

# **Interface Products (IF)**

## *Data Book*

Data Book

**Interface Products (IF)**

2000

*Analog and Mixed-Signal*

2000

On October 15, 1999, Texas Instruments strengthened its ability to provide you with truly premier Power Management solutions. We are proud to announce the acquisition of Power Management expert Unitrode and Battery Management expert Benchmarq.

As you may know, Unitrode has a 40-year history of designing and supplying Power Management components and subsystems. Benchmarq, based in Dallas and acquired by Unitrode last year, has won multiple awards for its industry-leading Battery Management solutions.

TI's commitment to the Power Management marketplace is already evident in its growing portfolio of industry-leading low dropout regulators, supply voltage supervisors, low-power DC-DC converters, power distribution switches and processor power products. Now, with the combination of TI's and Unitrode's high-performance products and TI's leading-edge process technologies and packaging expertise, we are positioned to provide you with easy-to-use, high-performance Power Management solutions.

Unitrode brings a family of products that complements TI's existing portfolio. TI's worldwide network of service and support increases access to and support for the Unitrode and Benchmarq portfolios. Most important, Unitrode brings to this union hundreds of experienced employees dedicated to the Power Management market.

What's in this for you? TI and Unitrode designers are working together right now to develop next-generation Power and Battery Management solutions. Maybe you're looking for easy-to-design-in, turn-key solutions. Or perhaps you need high-performance products, and complete systems and applications knowledge so you can put a power system together yourself. Either way, TI is dedicated to satisfying all of your Power Management needs today and in the future.

The combined TI and Unitrode Power Management offering comprises a rich portfolio that we intend to build upon together. To find out more, including ordering samples, you can visit our website at [www.ti.com/sc/powerleader](http://www.ti.com/sc/powerleader), complete the enclosed reply card, or call us for more information, using the TI contact information found on the back cover of this book.



## Using Unitrode Data Books

Data sheets and other information about Unitrode's products are organized, by business line, into four volumes: Interface (IF), Portable Power (PP), Power Supply Control (PP), and Nonvolatile SRAMs and Real-Time Clocks (NV).

Each book contains general information as well as sections devoted to the specific business line. Information in these books is referenced in several ways.

Information Source	Volume/ Page Location			
	IF	NV	PP	PS
Data Sheet Types	v	v	v	v
Table of Contents	vi	vi	vi	vi
Master Part Number Index	1-1	1-1	1-1	1-1
Master Application Note Index by Part Number	1-19	1-19	1-19	1-20
Master Application Note Index by Publication Number	1-24	1-24	1-24	1-25
Master Application Note Index by Subject	1-28	1-28	1-28	1-29
Unitrode Product Portfolio	7-1	10-1	6-1	10-1
Product Cross-Reference Tables (NV Book Only)	–	3-2 4-2 5-2	–	–
Ordering Information	2-1	2-1	2-1	2-1

### Reading the Indices

The master indices, contained in all four data books, list the location of all data sheets. Each entry is preceded by one of the following 2-letter abbreviations:

- **IF** Interface
- **NV** Nonvolatile SRAMs and Real-Time Clocks
- **PP** Portable Power
- **PS** Power Supply Control



### Unitrode's Products

Unitrode Corporation is a world leader in the design and manufacture of innovative, high-performance linear and mixed-signal ICs and modules. This data book introduces the Company's products designed for commercial, industrial, consumer, and military/aerospace applications.

Focused on power management, battery management, and high-speed data communications, products include:

- Off-line power management
- DC/DC power management
- Protection/supervisory circuits
- Portable power management
- Motion/motor controls
- High-speed interface
- Nonvolatile controllers and NVSRAMs
- Real-time clocks

Unitrode also offers an assortment of special function ICs, including fiber-to-curb ringers, CAN transceivers, IrDA transceivers, cellular power-management products and pager/PDA power controllers.

All Unitrode products are backed by design and applications teams that understand the interaction between the Company's products and rest of the power system/subsystem. Unitrode designs technically advanced products in response to customer needs and in anticipation of market trends.

Whatever the application—Power Management, Battery Management, or Ultrafast Data Communications—Unitrode is an innovative, dependable and customer-driven source for catalog, semi-custom, and custom linear/mixed-signal ICs and modules.





### ***Worldwide Service***

Unitrode serves its customers around the world from many locations:

- Design centers in New Hampshire, Texas, California, and North Carolina
- A facility in Dallas for assembly and manufacturing
- A facility in Singapore for testing, assembly subcontractor coordination, and customer service
- A worldwide network of manufacturers' representatives and distributors

### ***Process Capabilities***

Unitrode's bipolar process, optimized for both precision-analog and power functions, is constantly updated with the latest process options, such as:

- Operating-voltage ranges from 4–65V
- Schottky and integrated injection logic
- Ion implant
- Thin-film resistors for high accuracy
- Double-level metallization for high-density, high-current layouts and buried zener reference

The Company's BiCMOS process is ideal for high-density linear and mixed-mode designs, especially where speed and low power-consumption are of primary importance.

Options include:

- 3-, 2.5-, and 1-micron processes
- Up to 15V operation
- High-current, double-level metallization
- 125 fully isolated, vertical NPN transistors
- Thin-film resistors

This year, a new BCDMOS process offers all the options available with BiCMOS, as well as a lateral DMOS device with up to 35V operation for added power-handling capability.

### ***An ISO9001 and 9002 Firm***

Unitrode was one of the first U.S. linear/analog manufacturers to achieve IS/ISO 9001/EN29001 registration, and in 1998, the registrars completed recertification of the Merrimack and Singapore facilities and renewed the Company's registration to ISO 9001/9002-1994, respectively.

To be registered, the Company passed a rigorous examination of its quality systems—from product design through shipment. These registrations thus assure customers all over the world that Unitrode is adhering to very high, precisely defined standards.

### ***Listening To Customers***

To develop custom and semi-custom parts, Unitrode design engineers work very closely with customers, so all requirements are accurately understood, all possibilities are fully explored, and all products meet or exceed specified needs.

Unitrode also pays careful attention to customers and markets to help guide its development of catalog parts. Continuing close contact makes it possible to anticipate industry requirements, and to create devices that satisfy them.



### ***Important Notice***

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TI warrants performance of its semiconductor products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

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In order to minimize risks associated with the customer's applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

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## Product Production Status

The table below defines three types of data sheets issued at various stages of product development. Unitrode reserves the right to change products without notice to improve design performance, reliability, or manufacturability.

<b>CLASSIFICATION</b>	<b>PRODUCT STAGE</b>	<b>DESCRIPTION</b>
Advance Information Data Sheet	Formative or Design	This document contains the design specifications for product under development. Specifications may be changed in any manner without notice.
Preliminary Data Sheets	First Production	Supplementary data may be published at a later date. Unitrode reserves the right to make changes at any time without notice, in order to improve design and supply the best product possible.
No Classification Noted	Full Production	Product is in full production.



# Table of Contents



Using Unitrode Data Books .....	i
Unitrode Products .....	ii
Product Production Status .....	v

## Indices

**1**

Master Part Number Index .....	1-1
Master Application Note Index by Part Number .....	1-19
Master Application Note Index by Publication Number .....	1-24
Master Application Note Index by Subject .....	1-28

## General Information

**2**

Ordering Information .....	2-1
Quality .....	2-2
Die and Wafer .....	2-9
New Products .....	2-10

## SCSI

**3**

SCSI Selection Guides .....	3-1
UCC5510 Low Voltage Differential (LVD/SE) SCSI 9 Line Terminator .....	3-5
UC5601 SCSI Active Terminator .....	3-9
UC5602 SCSI Active Terminator .....	3-13
UC5603 9-Line SCSI Active Terminator .....	3-18
UC5604 9-Line Low Capacitance SCSI Active Terminator .....	3-22
UC5605 9-Line Low Capacitance SCSI Active Terminator .....	3-26
UCC5606 9-Line 3-5 Volt SCSI Active Terminator, Reverse Disconnect .....	3-30
UC5607 Plug and Play, 18-Line SCSI Active Terminator .....	3-34
UC5608 18-Line Low Capacitance SCSI Active Terminator .....	3-37
UC5609 18-Line Low Capacitance SCSI Active Terminator .....	3-40
UC5612 9-Line Low Capacitance SCSI Active Terminator .....	3-43
UC5613 9-Line Low Capacitance SCSI Active Terminator .....	3-47
UCC5614 9-Line 3-5 Volt Low Capacitance SCSI Active Terminator .....	3-51
UCC5617 18-Line SCSI Terminator (Reverse Disconnect) .....	3-55
UCC5618 18-Line SCSI Terminator .....	3-59
UCC5619 27-Line SCSI Terminator With Reverse Disconnect .....	3-63
UCC5620 27-Line SCSI Terminator .....	3-66
UCC5621 27-Line SCSI Terminator With Split Reverse Disconnect .....	3-70
UCC5622 27-Line SCSI Terminator With Split Disconnect .....	3-74
UCC5628 Multimode SCSI 14 Line Terminator .....	3-78
UCC5630 Low Voltage Differential (LVD/SE) SCSI 9 Line Terminator .....	3-83
UCC5630A Multimode SCSI 9 Line Terminator .....	3-87
UCC5632 Multimode (LVD/SE) SCSI 9 Line Terminator w/ 2.85V Regulator .....	3-93
UCC5638 Multimode SCSI 15 Line Terminator .....	3-94
UCC5639 Multimode SCSI 15 Line Terminator with Reverse Disconnect .....	3-99
UCC5640 Low Voltage Differential (LVD) SCSI 9 Line Terminator .....	3-104
UCC5641 Low Voltage Differential (LVD/SE) SCSI 9 Line Terminator Reverse Disconnect .....	3-108



UCC5646 27-Line SCSI Terminator .....	3-112
UC5661 Ethernet Coaxial Impedance Monitor .....	3-116
UCC5672 Multimode (LVD/SE) SCSI 9 Line Terminator .....	3-120
UCC5680 Low Voltage Differential (LVD) SCSI 9 Line Terminator .....	3-121
DN- 92 UCC5630 SCSI Multimode (LVD/SE) Evaluation Board and List of Materials .....	3-122

## **Bus Bias Generators 4**

Bus Bias Generators Selection Guides .....	4-1
UC560 27-Line SCSI Source/Sink Regulator .....	4-3
UC561 Low Voltage Differential SCSI (LVD) 27 Line Regulator Set .....	4-7
UC563 32 Line VME Bus Bias Generator .....	4-10

## **Hot Swap Power Manager™ ICs 5**

Hot Swap Power Manager Selection Guides .....	5-1
UCC3831 Universal Serial Bus Power Controller .....	5-3
UCC38531 Universal Serial Bus Power Controller .....	5-6
UCC3912 Programmable Hot Swap Power Manager .....	5-9
UCC3913 Negative Voltage Hot Swap Power Manager .....	5-15
UC3914 5V to 35V Hot Swap Power Manager .....	5-23
UCC3915 15V Programmable Hot Swap Power Manager .....	5-37
UCC39151 15V Programmable Hot Swap Power Manager .....	5-42
UCC3916 SCSI Termpower Manager .....	5-47
UCC39161 Low Current Hot Swap Power Manager .....	5-50
UCC3917 Positive Floating Hot Swap Power Manager .....	5-53
UCC3918 Low On Resistance Hot Swap Power Manager .....	5-61
UCC3919 3V to 8V Hot Swap Power Manager .....	5-68
UCC3921 Latchable Negative Floating Hot Swap Power Manager .....	5-78
UCC3981 Universal Serial Bus Hot Swap Power Controller .....	5-88
UCC39811 Universal Serial Bus Hot Swap Power Controller .....	5-91
UCC3985 Programmable CompactPCI Hot Swap Power Manager .....	5-94
UCC3995 Simple Single Channel External N-FET Hot Swap Manager .....	5-98
UCC3996 Dual Sequencing Hot Swap Power Manager .....	5-100
DN- 58 UCC3912 Programmable Hot Swap Power Manager - Performance Evaluation and Programming Information .....	5-102
DN- 67 UCC3913 Hot Swap Power Manager for Negative Voltage Applications Evaluation Kit List of Materials for a -48V/1A Test Circuit .....	5-105
DN- 68 UCC3831 USB Power Controller IC, Evaluation Board – Schematic and List of Materials .....	5-106
DN- 85 UCC3831 USB Power Controller IC, Evaluation Board – Schematic and List of Materials .....	5-110
DN- 87 UCC3918 Low On-Resistance Hot Swap Power Manager Performance Evaluation Kit – Schematic and List of Materials .....	5-113
DN- 95 UCC3919 Hot Swap Power Manager Evaluation Board and Bill of Materials .....	5-116



DN- 98 UCC3917 Positive Floating Hot Swap Power Manager Evaluation Kit, Schematic and Bill of Materials .....	5-120
U- 151 UCC3912 Integrated Hot Swap Power Manager IC for Hot-Swap and Power Management Applications .....	5-124

## **Drivers/Receiver Transceivers 6**

Drivers/Receiver Transceivers Selection Guides .....	6-1
UC5170C Octal Line Driver .....	6-3
UC5171 Octal Line Driver .....	6-7
UC5172 Octal Line Driver .....	6-11
UC5180C Octal Line Receiver .....	6-15
UC5181C Octal Line Receiver .....	6-18
UC5350 CAN Transceiver .....	6-21
UC5351 CAN Transceiver with Voltage Regulator .....	6-27

## **Unitrode Product Portfolio 7**

Interface Product Selection Guides .....	7-1
Nonvolatile and Real Time Clock Product Selection Guides .....	7-9
Portable Product Selection Guides .....	7-7
Power Supply Control Product Selection Guides .....	7-25

## **Military/Aerospace Products 8**

Capabilities .....	8-1
Standardized Military Drawings .....	8-2

## **Packaging Information 9**

Recommended Profile Limits .....	9-3
Device Temp Management .....	9-5
Package Thermal Resistance Data .....	9-9
Typical Materials Used for Assembly .....	9-14
Thermal Characteristics of Surface Mount Packages .....	9-15
Package Diagrams .....	9-19





# **Master Part Number and Application Indices**

1

**General Information**

2

**SCSI**

3

**Bus Bias Generators**

4

**Hot Swap Power Manager™ ICs**

5

**Drivers/Receivers Transceivers**

6

**Unitrode Product Portfolio**

7

**Military/Aerospace Products**

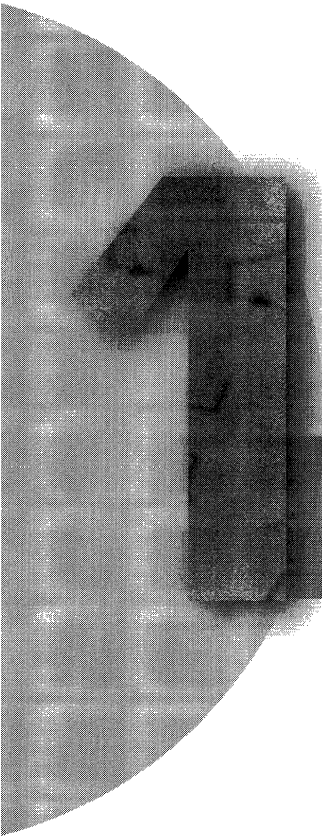
8

**Packaging Information**

9







# Master Part Number and Application Indices



# Numeric Master Part Index



Part No.	Description	Volume/Page
UC1517	Stepper Motor Drive Circuit . . . . .	PS/8-30
UC1524	Advanced Regulating Pulse Width Modulators . . . . .	PS/3-43
UC1524A	Advanced Regulating Pulse Width Modulators . . . . .	PS/3-48
UC1525A	Regulating Pulse Width Modulators . . . . .	PS/3-54
UC1525B	Regulating Pulse Width Modulators . . . . .	PS/3-61
UC1526	Regulating Pulse Width Modulator . . . . .	PS/3-68
UC1526A	Regulating Pulse Width Modulator . . . . .	PS/3-75
UC1527A	Regulating Pulse Width Modulators . . . . .	PS/3-54
UC1527B	Regulating Pulse Width Modulators . . . . .	PS/3-61
UC1543	Power Supply Supervisory Circuit . . . . .	PS/7-5
UC1544	Power Supply Supervisory Circuit . . . . .	PS/7-5
UC1548	Primary Side PWM Controller . . . . .	PS/3-83
UCC1570	Low Power Pulse Width Modulator . . . . .	PS/3-91
UCC15701	Advanced Voltage Mode Pulse Width Modulator . . . . .	PS/3-99
UC1572	Negative Output Flyback Pulse Width Modulator . . . . .	PS/3-108
UC1573	Buck Pulse Width Modulator Stepdown Voltage Regulator . . . . .	PS/3-112
UCC1580-1	Single Ended Active Clamp/Reset PWM . . . . .	PS/3-122
UCC1580-2	Single Ended Active Clamp/Reset PWM . . . . .	PS/3-122
UCC1580-3	Single Ended Active Clamp/Reset PWM . . . . .	PS/3-122
UCC1580-4	Single Ended Active Clamp/Reset PWM . . . . .	PS/3-122
UCC1581	Micropower Voltage Mode PWM . . . . .	PS/3-131
UCC1583	Switch Mode Secondary Side Post Regulator . . . . .	PS/3-139
UC1584	Secondary Side Synchronous Post Regulator . . . . .	PS/3-148
UCC1585	Low Voltage Synchronous Buck Controller . . . . .	PS/3-154
UCC1588	5-Bit Programmable Output BiCMOS Power Supply Controller . . . . .	PS/3-163
UC1610	Dual Schottky Diode Bridge . . . . .	PS/7-10
UC1611	Quad Schottky Diode Array . . . . .	PS/7-12
UC1612	Dual Schottky Diode . . . . .	PS/7-15
UC1625	Brushless DC Motor Controller . . . . .	PS/8-37
UC1633	Phase Locked Frequency Controller . . . . .	PS/8-63
UC1634	Phase Locked Frequency Controller . . . . .	PS/8-70
UC1635	Phase Locked Frequency Controller . . . . .	PS/8-74
UC1637	Switched Mode Controller for DC Motor Drive . . . . .	PS/8-78
UC1638	Advanced PWM Motor Controller . . . . .	PS/8-84
UC1702	Quad PWM Relay Driver . . . . .	PS/6-12
UC1705	High Speed Power Driver . . . . .	PS/6-16
UC1706	Dual Output Driver . . . . .	PS/6-19
UC1707	Dual Channel Power Driver . . . . .	PS/6-24
UC1708	Dual Non-Inverting Power Driver . . . . .	PS/6-31
UC1709	Dual High-Speed FET Driver . . . . .	PS/6-35
UC1710	High Current FET Driver . . . . .	PS/6-38
UC1711	Dual Ultra High-Speed FET Driver . . . . .	PS/6-41
UC17131	Smart Power Switch . . . . .	PS/9-13
UC17132	Smart Power Switch . . . . .	PS/9-13
UC17133	Smart Power Switch . . . . .	PS/9-13

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).  
Products included in this book are listed in **bold**.

# Numeric Master Part Index



Part No.	Description	Volume/Page
UC1714	Complementary Switch FET Drivers	PS/6-43
UC1715	Complementary Switch FET Drivers	PS/6-43
UC1717	Stepper Motor Drive Circuit	PS/8-92
UC1724	Isolated Drive Transmitter	PS/6-50
UC1725	Isolated High Side FET Driver	PS/6-53
UC1726	Isolated Drive Transmitter	PS/6-57
UC1727	Isolated High Side IGBT Driver	PS/6-62
UC1730	Thermal Monitor	PS/7-17
UCC17423	Dual 3A MOSFET Driver	PS/6-68
UCC17424	Dual 3A MOSFET Driver	PS/6-68
UCC17425	Dual 3A MOSFET Driver	PS/6-68
UCC17523	Dual 3A MOSFET Driver With Adaptive LEB	PS/6-73
UCC17524	Dual 3A MOSFET Driver With Adaptive LEB	PS/6-73
UCC17525	Dual 3A MOSFET Driver With Adaptive LEB	PS/6-73
UCC1776	Quad FET Driver	PS/6-79
UCC1800	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC1801	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC1802	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC1803	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC1804	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC1805	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC1806	Low Power, Dual Output, Current Mode PWM Controller	PS/3-180
UCC1807-1	Programmable Maximum Duty Cycle PWM Controller	PS/3-187
UCC1807-2	Programmable Maximum Duty Cycle PWM Controller	PS/3-187
UCC1807-3	Programmable Maximum Duty Cycle PWM Controller	PS/3-187
UCC1808-1	Low Power Current Mode Push-Pull PWM	PS/3-192
UCC1808-2	Low Power Current Mode Push-Pull PWM	PS/3-192
UCC1809-1	Economy Primary Side Controller	PS/3-198
UCC1809-2	Economy Primary Side Controller	PS/3-198
UCC1810	Dual Channel Synchronized Current Mode PWM	PS/3-205
UCC1817	BiCMOS Power Factor Preregulator	PS/4-5
UCC1818	BiCMOS Power Factor Preregulator	PS/4-5
UC182-1	Fast LDO Linear Regulator	PS/5-5
UC182-2	Fast LDO Linear Regulator	PS/5-5
UC1823	High Speed PWM Controller	PS/3-219
UC1823A	High Speed PWM Controller	PS/3-225
UC1823B	High Speed PWM Controller	PS/3-225
UC182-3	Fast LDO Linear Regulator	PS/5-5
UC1824	High Speed PWM Controller	PS/3-233
UC1825	High Speed PWM Controller	PS/3-240
UC1825A	High Speed PWM Controller	PS/3-225
UC1825B	High Speed PWM Controller	PS/3-225
UC1826	Secondary Side Average Current Mode Controller	PS/3-247
UC1827-1	Buck Current/Voltage Fed Push-Pull PWM Controllers	PS/3-257
UC1827-2	Buck Current/Voltage Fed Push-Pull PWM Controllers	PS/3-257

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).  
 Products included in this book are listed in **bold**.

# Numeric Master Part Index



Part No.	Description	Volume/Page
UC182-ADJ	Fast LDO Linear Regulator . . . . .	PS/5-5
UC1832	High Speed PWM Controller . . . . .	PS/5-11
UC1833	Precision Low Dropout Linear Controller . . . . .	PS/5-11
UC1834	High Efficiency Linear Regulator. . . . .	PS/5-18
UC1835	High Efficiency Regulator Controller. . . . .	PS/5-24
UC1836	High Efficiency Regulator Controller. . . . .	PS/5-24
UCC1837	8-Pin N-FET Linear Regulator Controller . . . . .	PS/5-28
UC1838A	Magnetic Amplifier Controller . . . . .	PS/3-272
UCC1839	Secondary Side Average Current Mode Controller . . . . .	PS/3-276
UC1841	Programmable, Off-Line, PWM Controller . . . . .	PS/3-281
UC1842	Current Mode PWM Controller . . . . .	PS/3-289
UC1842A	Current Mode PWM Controller . . . . .	PS/3-296
UC1843	Current Mode PWM Controller . . . . .	PS/3-289
UC1843A	Current Mode PWM Controller . . . . .	PS/3-296
UC1844	Current Mode PWM Controller . . . . .	PS/3-289
UC1844A	Current Mode PWM Controller . . . . .	PS/3-296
UC1845	Current Mode PWM Controller . . . . .	PS/3-289
UC1845A	Current Mode PWM Controller . . . . .	PS/3-296
UC1846	Current Mode PWM Controller . . . . .	PS/3-302
UC1847	Current Mode PWM Controller . . . . .	PS/3-302
UC1848	Average Current Mode PWM Controller . . . . .	PS/3-309
UC1849	Secondary Side Average Current Mode Controller. . . . .	PS/3-317
UCC18500	Combined PFC/PWM Controller . . . . .	PS/4-15
UCC18501	Combined PFC/PWM Controller . . . . .	PS/4-15
UCC18502	Combined PFC/PWM Controller . . . . .	PS/4-15
UCC18503	Combined PFC/PWM Controller . . . . .	PS/4-15
UC1851	Programmable, Off-Line, PWM Controller . . . . .	PS/3-327
<b>UC185-1</b>	<b>Fast LDO Linear Regulator . . . . .</b>	<b>IF/5-35</b>
UC1852	High Power-Factor Preregulator . . . . .	PS/4-22
<b>UC185-2</b>	<b>Fast LDO Linear Regulator . . . . .</b>	<b>IF/5-35</b>
UC1853	High Power Factor Preregulator . . . . .	PS/4-27
<b>UC185-3</b>	<b>Fast LDO Linear Regulator . . . . .</b>	<b>IF/5-35</b>
UC1854	High Power Factor Preregulator . . . . .	PS/4-32
UC1854A	Enhanced High Power Factor Preregulator . . . . .	PS/4-42
UC1854B	Enhanced High Power Factor Preregulator . . . . .	PS/4-42
UC1855A	High Performance Power Factor Preregulator . . . . .	PS/4-48
UC1855B	High Performance Power Factor Preregulator . . . . .	PS/4-48
UC1856	Improved Current Mode PWM Controller . . . . .	PS/3-333
UCC1857	Isolated Boost PFC Preregulator Controller. . . . .	PS/4-56
UCC1858	High Efficiency, High Power Factor Preregulator. . . . .	PS/4-65
<b>UC185-ADJ</b>	<b>Fast LDO Linear Regulator . . . . .</b>	<b>IF/5-35</b>
UC1860	Resonant Mode Power Supply Controller. . . . .	PS/3-341
UC1861	Resonant-Mode Power Supply Controllers. . . . .	PS/3-349
UC1862	Resonant-Mode Power Supply Controllers. . . . .	PS/3-349

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).

Products included in this book are listed in **bold**.

# Numeric Master Part Index



Part No.	Description	Volume/Page
UC1863	Resonant-Mode Power Supply Controllers	PS/3-349
UC1864	Resonant-Mode Power Supply Controllers	PS/3-349
UC1865	Resonant-Mode Power Supply Controllers	PS/3-349
UC1866	Resonant-Mode Power Supply Controllers	PS/3-349
UC1867	Resonant-Mode Power Supply Controllers	PS/3-349
UC1868	Resonant-Mode Power Supply Controllers	PS/3-349
UC1871	Resonant Fluorescent Lamp Driver	PP/8-2
UC1872	Resonant Lamp Ballast Controller	PP/8-8
UC1875	Phase Shift Resonant Controller	PS/3-357
UC1876	Phase Shift Resonant Controller	PS/3-357
UC1877	Phase Shift Resonant Controller	PS/3-357
UC1878	Phase Shift Resonant Controller	PS/3-357
UC1879	Phase Shift Resonant Controller	PS/3-367
UCC1884	Frequency Foldback Current Mode PWM Controller	PS/3-393
UC1886	Average Current Mode PWM Controller IC	PS/3-400
UCC1888	Off-line Power Supply Controller	PS/3-407
UCC1889	Off-line Power Supply Controller	PS/3-412
UCC1890	Off-Line Battery Charger Circuit	PS/3-418
UCC1895	BiCMOS Advanced Phase Shift PWM Controller	PS/3-425
UC1901	Isolated Feedback Generator	PS/7-21
UC1902	Load Share Controller	PS/7-27
UC1903	Quad Supply and Line Monitor	PS/7-32
UC1904	Precision Quad Supply and Line Monitor	PS/7-39
UC1907	Load Share Controller	PS/7-44
UC1910	4-Bit DAC and Voltage Monitor	PS/3-437
<b>UCC1913</b>	<b>Negative Voltage Hot Swap Power Manager</b>	<b>IF/5-15</b>
<b>UC1914</b>	<b>5V to 35V Hot Swap Power Manager</b>	<b>IF/5-23</b>
<b>UCC1919</b>	<b>3V to 8V Hot Swap Power Manager</b>	<b>IF/5-68</b>
<b>UCC1921</b>	<b>Latchable Negative Floating Hot Swap Power Manager</b>	<b>IF/5-78</b>
UCC1926	±20A Integrated Current Sensor	PS/9-43
UCC19411	Low Power Synchronous Boost Converter	PP/7-58
UCC19412	Low Power Synchronous Boost Converter	PP/7-58
UCC19413	Low Power Synchronous Boost Converter	PP/7-58
UC19431	Precision Adjustable Shunt Regulator	PS/7-50
UC19432	Precision Analog Controller	PS/7-56
UCC1946	Microprocessor Supervisor with Watchdog Timer	PP/7-88
UCC1960	Primary-Side Startup Controller	PS/3-442
UCC1961	Advanced Primary-Side Startup Controller	PS/3-450
UC1965	Precision Reference with Low Offset Error Amplifier	PS/7-60
UC1972	BiCMOS Cold Cathode Fluorescent Lamp Driver Controller	PP/8-13
bq2000	Programmable Multi-Chemistry Fast-Charge-Management IC	PP/3-7
DV2000S1	Multi-Chemistry Switching Charger Development System	PP/3-33
bq2000T	Programmable Multi-Chemistry Fast-Charge Management IC	PP/3-20
bq2002/F	Fast-Charge ICs	PP/3-35

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).  
 Products included in this book are listed in **bold**.



# Numeric Master Part Index



Part No.	Description	Volume/Page
bq2002C	Fast-Charge IC	PP/3-43
bq2002D/T	Fast-Charge ICs	PP/3-51
bq2002E/G	Fast-Charge ICs	PP/3-61
DV2002L2/TL2	Fast-Charge Development Systems	PP/3-70
bq2003	Fast-Charge IC	PP/3-73
DV2003L1	Fast-Charge Development System	PP/3-85
DV2003S1	Fast-Charge Development System	PP/3-87
DV2003S2	Fast-Charge Development System	PP/3-89
bq2004	Fast-Charge IC	PP/3-91
bq2004E/H	Fast-Charge ICs	PP/3-105
DV2004L1	Fast-Charge Development System	PP/3-103
DV2004S1/ES1/HS1	Fast-Charge Development Systems	PP/3-117
bq2005	Fast-Charge IC for Dual-Battery Packs	PP/3-119
DV2005L1	Fast-Charge Development System	PP/3-131
DV2005S1	Fast-Charge Development System	PP/3-134
bq2007	Fast-Charge IC	PP/3-137
DV2007S1	Fast-Charge Development System	PP/3-151
bq2010	Gas Gauge IC	PP/4-3
EV2010	bq2010 Evaluation System	PP/4-21
bq2011	Gas Gauge IC for High Discharge Rates	PP/4-24
EV2011	bq2011 Evaluation System	PP/4-42
bq2011J	Gas Gauge IC for High Discharge Rates	PP/4-45
bq2011K	Gas Gauge IC for High Discharge Rates	PP/4-63
bq2012	Gas Gauge with Slow-Charge Control	PP/4-81
EV2012	bq2012 Evaluation System	PP/4-100
bq2013H	Gas Gauge IC for Power-Assist Applications	PP/4-103
bq2014	Gas Gauge IC with External Charge Control	PP/4-123
EV2014	bq2014 Evaluation Board	PP/4-142
bq2014H	Gas Gauge IC with External Charge Control	PP/4-149
EV2014x	Gas-Gauge and Fast-Charge Evaluation System	PP/4-145
bq2018	Power Minder IC	PP/4-170
bq2031	Lead-Acid Fast-Charge IC	PP/3-154
DV2031S2	Lead-Acid Charger Development System	PP/3-168
bq2040	Gas-Gauge IC with SMBus Interface	PP/4-185
bq2050	Li-Ion Power Gauge IC	PP/4-215
EV2050	Power Gauge Evaluation Board	PP/4-234
bq2050H	Low-Cost Li-Ion Power Gauge IC	PP/4-237
bq2052	Gas Gauge IC for Lithium Primary Cells	PP/4-259
bq2054	Li-Ion Fast-Charge IC	PP/3-170
DV2054S2	Li-Ion Charger Development System	PP/3-184
bq2056/T/V	Low-Dropout Li-Ion Fast-Charge ICs	PP/3-186
bq2058	Li-Ion Pack Supervisor for 3- and 4-Cell Packs	PP/6-2
bq2058T	Li-Ion Pack Supervisor for 2-Cell Packs	PP/6-14
bq2060	SBS v1.1-Compliant Gas-Gauge IC	PP/4-276
bq2092	Gas Gauge IC with SMBus-Like Interface	PP/4-314

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).  
 Products included in this book are listed in **bold**.

# Numeric Master Part Index



Part No.	Description	Volume/Page
bq2110	NiCd or NiMH Gas Gauge Module	PP/5-2
bq2111L	NiCd Gas Gauge Module with LEDs for High Discharge Rates	PP/5-8
bq2112	NiCd or NiMH Gas Gauge Module with Slow-Charge Control	PP/5-14
bq2113H	Gas Gauge Module for Power Assist Applications	PP/5-20
bq2114	NiCd or NiMH Gas-Gauge Module with Charge-Control Output	PP/5-24
bq2118	Power Minder Mini-Board	PP/5-30
bq2145	Smart Battery Module with LEDs	PP/5-34
bq2148	Smart Battery Module with LEDs and Pack Supervisor	PP/5-40
bq2150	Li-Ion Power Gauge Module	PP/5-47
bq2150H	Li-Ion Power Gauge Module	PP/5-53
bq2158	3 or 4 Series Cell Li-Ion Pack Supervisor Module	PP/5-57
bq2158T	Two Series Cell Li-Ion Pack Supervisor Module	PP/5-64
bq2164	NiCd or NiMH Gas Gauge Module with Fast-Charge Control	PP/5-71
bq2167	Li-Ion Power Gauge Module with Pack Supervisor	PP/5-77
bq2168	Li-Ion Power Gauge Module with Pack Supervisor	PP/5-85
bq219XL	Smart Battery Module with LEDs	PP/5-93
EV2200	EV2200 PC Interface Board for Gas Gauge Evaluation	PP/4-370
bq2201	Nonvolatile Controller (by one)	NV/3-3
bq2202	SRAM Nonvolatile Controller with Reset	NV/3-11
bq2203A	Nonvolatile Controller with Battery Monitor	NV/3-19
bq2204A	Nonvolatile Controller (by four)	NV/3-27
UCC2305	HID Lamp Controller	PS/9-1
bq2502	Integrated Backup Unit	NV/3-35
UC2524	Advanced Regulating Pulse Width Modulators	PS/3-43
UC2524A	Advanced Regulating Pulse Width Modulators	PS/3-48
UC2525A	Regulating Pulse Width Modulators	PS/3-54
UC2525B	Regulating Pulse Width Modulators	PS/3-61
UC2526	Regulating Pulse Width Modulator	PS/3-68
UC2526A	Regulating Pulse Width Modulator	PS/3-75
UC2527A	Regulating Pulse Width Modulators	PS/3-54
UC2527B	Regulating Pulse Width Modulators	PS/3-61
UC2543	Power Supply Supervisory Circuit	PS/7-5
UC2544	Power Supply Supervisory Circuit	PS/7-5
UC2548	Primary Side PWM Controller	PS/3-83
UCC2570	Low Power Pulse Width Modulator	PS/3-91
UCC25701	Advanced Voltage Mode Pulse Width Modulator	PS/3-99
UC2572	Negative Output Flyback Pulse Width Modulator	PS/3-108
UC2573	Buck Pulse Width Modulator Stepdown Voltage Regulator	PS/3-112
UC2577-12	Simple Step-Up Fixed Voltage Regulators	PS/3-31
UC2577-13	Simple Step-Up Fixed Voltage Regulators	PS/3-31
UC2577-14	Simple Step-Up Fixed Voltage Regulators	PS/3-31
UC2577-15	Simple Step-Up Fixed Voltage Regulators	PS/3-31
UC2577-ADJ	Simple Step-Up Voltage Regulator	PS/3-36
UC2578	Buck Pulse Width Modulator Stepdown Voltage Regulator	PS/3-116
UCC2580-1	Single Ended Active Clamp/Reset PWM	PS/3-122

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).  
 Products included in this book are listed in **bold**.

# Numeric Master Part Index



Part No.	Description	Volume/Page
UCC2580-2	Single Ended Active Clamp/Reset PWM	PS/3-122
UCC2580-3	Single Ended Active Clamp/Reset PWM	PS/3-122
UCC2580-4	Single Ended Active Clamp/Reset PWM	PS/3-122
UCC2581	Micropower Voltage Mode PWM	PS/3-131
UCC2583	Switch Mode Secondary Side Post Regulator	PS/3-139
UC2584	Secondary Side Synchronous Post Regulator	PS/3-148
UCC2585	Low Voltage Synchronous Buck Controller	PS/3-154
UCC2588	5-Bit Programmable Output BiCMOS Power Supply Controller	PS/3-163
UC2610	Dual Schottky Diode Bridge	PS/7-10
UC2625	Brushless DC Motor Controller	PS/8-37
UCC2626	Brushless DC Motor Controller	PS/8-50
UC2633	Phase Locked Frequency Controller	PS/8-63
UC2634	Phase Locked Frequency Controller	PS/8-70
UC2635	Phase Locked Frequency Controller	PS/8-74
UC2637	Switched Mode Controller for DC Motor Drive	PS/8-78
UC2638	Advanced PWM Motor Controller	PS/8-84
UC2702	Quad PWM Relay Driver	PS/6-12
UC2705	High Speed Power Driver	PS/6-16
UC2706	Dual Output Driver	PS/6-19
UC2707	Dual Channel Power Driver	PS/6-24
UC2708	Dual Non-Inverting Power Driver	PS/6-31
UC2709	Dual High-Speed FET Driver	PS/6-35
UC2710	High Current FET Driver	PS/6-38
UC2717	Stepper Motor Drive Circuit	PS/8-92
UC27131	Smart Power Switch	PS/9-13
UC27132	Smart Power Switch	PS/9-13
UC27133	Smart Power Switch	PS/9-13
UC2714	Complementary Switch FET Drivers	PS/6-43
UC3717	Stepper Motor Drive Circuit	PS/8-92
UC3715	Complementary Switch FET Drivers	PS/6-43
UC2724	Isolated Drive Transmitter	PS/6-50
UC2725	Isolated High Side FET Driver	PS/6-53
UC2726	Isolated Drive Transmitter	PS/6-57
UC2727	Isolated High Side IGBT Driver	PS/6-62
UC2730	Thermal Monitor	PS/7-17
UCC27423	Dual 3A MOSFET Driver	PS/6-68
UCC27424	Dual 3A MOSFET Driver	PS/6-68
UCC27425	Dual 3A MOSFET Driver	PS/6-68
UCC2750	Source Ringer Controller	PS/9-22
UCC2751	Single Line Ring Generator Controller	PS/9-32
UCC2752	Resonant Ring Generator Controller	PS/9-38
UCC27523	Dual 3A MOSFET Driver With Adaptive LEB	PS/6-73
UCC27524	Dual 3A MOSFET Driver With Adaptive LEB	PS/6-73
UCC27525	Dual 3A MOSFET Driver With Adaptive LEB	PS/6-73
UCC2776	Quad FET Driver	PS/6-79

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).  
 Products included in this book are listed in **bold**.

# Numeric Master Part Index



Part No.	Description	Volume/Page
UCC2800	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC2801	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC2802	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC2803	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC2804	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC2805	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC2806	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC2806	Low Power, Dual Output, Current Mode PWM Controller	PS/3-180
UCC2807-1	Programmable Maximum Duty Cycle PWM Controller	PS/3-187
UCC2807-2	Programmable Maximum Duty Cycle PWM Controller	PS/3-187
UCC2807-3	Programmable Maximum Duty Cycle PWM Controller	PS/3-187
UCC2808-1	Low Power Current Mode Push-Pull PWM	PS/3-192
UCC2808-2	Low Power Current Mode Push-Pull PWM	PS/3-192
UCC2809-1	Economy Primary Side Controller	PS/3-198
UCC2809-2	Economy Primary Side Controller	PS/3-198
UCC2810	Dual Channel Synchronized Current Mode PWM	PS/3-205
UCC281-3	Low Dropout 1 Ampere Linear Regulator Family	PP/7-5
UCC2813-0	Low Power Economy BiCMOS Current Mode PWM	PS/3-212
UCC2813-1	Low Power Economy BiCMOS Current Mode PWM	PS/3-212
UCC2813-2	Low Power Economy BiCMOS Current Mode PWM	PS/3-212
UCC2813-3	Low Power Economy BiCMOS Current Mode PWM	PS/3-212
UCC2813-4	Low Power Economy BiCMOS Current Mode PWM	PS/3-212
UCC2813-5	Low Power Economy BiCMOS Current Mode PWM	PS/3-212
UCC281-5	Low Dropout 1 Ampere Linear Regulator Family	PP/7-5
UCC2817	BiCMOS Power Factor Preregulator	PS/4-5
UCC2818	BiCMOS Power Factor Preregulator	PS/4-5
UCC281-ADJ	Low Dropout 1 Ampere Linear Regulator Family	PP/7-5
UC282-1	Fast LDO Linear Regulator	PS/5-5
UC282-2	Fast LDO Linear Regulator	PS/5-5
UC2823	High Speed PWM Controller	PS/3-219
UC282-3	Fast LDO Linear Regulator	PS/5-5
UC2823A	High Speed PWM Controller	PS/3-225
UC2823B	High Speed PWM Controller	PS/3-225
UC2824	High Speed PWM Controller	PS/3-233
UC2825	High Speed PWM Controller	PS/3-240
UC2825A	High Speed PWM Controller	PS/3-225
UC2825B	High Speed PWM Controller	PS/3-225
UC2826	Secondary Side Average Current Mode Controller	PS/3-247
UC2827-1	Buck Current/Voltage Fed Push-Pull PWM Controllers	PS/3-257
UC2827-2	Buck Current/Voltage Fed Push-Pull PWM Controllers	PS/3-257
UC282-ADJ	Fast LDO Linear Regulator	PS/5-5
UC2832	Precision Low Dropout Linear Controllers	PS/5-11
UC2833	Precision Low Dropout Linear Controllers	PS/5-11
UCC283-3	Low Dropout 3 Ampere Linear Regulator Family	PP/7-12
UC2834	High Efficiency Linear Regulator	PS/5-18

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).  
 Products included in this book are listed in **bold**.

# Numeric Master Part Index



Part No.	Description	Volume/Page
UC2835	High Efficiency Regulator Controller . . . . .	PS/5-24
UCC283-5	Low Dropout 3 Ampere Linear Regulator Family . . . . .	PP/7-12
UC2836	High Efficiency Regulator Controller . . . . .	PS/5-24
UCC2837	8-Pin N-FET Linear Regulator Controller . . . . .	PS/5-28
UC2838A	Magnetic Amplifier Controller . . . . .	PS/3-272
UCC2839	Secondary Side Average Current Mode Controller . . . . .	PS/3-276
UCC283-ADJ	Low Dropout 3 Ampere Linear Regulator Family . . . . .	PP/7-12
UC2841	Programmable, Off-Line, PWM Controller . . . . .	PS/3-281
UCC284-12	Low Dropout 0.5A Negative Linear Regulator. . . . .	PP/7-19
UC2842	Current Mode PWM Controller . . . . .	PS/3-289
UC2842A	Current Mode PWM Controller . . . . .	PS/3-296
UC2843	Current Mode PWM Controller . . . . .	PS/3-289
UC2843A	Current Mode PWM Controller . . . . .	PS/3-296
UC2844	Current Mode PWM Controller . . . . .	PS/3-289
UC2844A	Current Mode PWM Controller . . . . .	PS/3-296
UC2845	Current Mode PWM Controller . . . . .	PS/3-289
UCC284-5	Low Dropout 0.5A Negative Linear Regulator. . . . .	PP/7-19
UC2845A	Current Mode PWM Controller . . . . .	PS/3-296
UC2846	Current Mode PWM Controller . . . . .	PS/3-302
UC2847	Current Mode PWM Controller . . . . .	PS/3-302
UC2848	Average Current Mode PWM Controller . . . . .	PS/3-309
UC2849	Secondary Side Average Current Mode Controller. . . . .	PS/3-317
UCC284-ADJ	Low Dropout 0.5A Negative Linear Regulator . . . . .	PP/7-19
UCC28500	Combined PFC/PWM Controller . . . . .	PS/4-15
UCC28501	Combined PFC/PWM Controller . . . . .	PS/4-15
UCC28502	Combined PFC/PWM Controller . . . . .	PS/4-15
UCC28503	Combined PFC/PWM Controller . . . . .	PS/4-15
UC2851	Programmable, Off-Line, PWM Controller . . . . .	PS/3-327
<b>UC285-1</b>	<b>Fast LDO Linear Regulator . . . . .</b>	<b>IF/5-35</b>
UC2852	High Power-Factor Preregulator . . . . .	PS/4-22
<b>UC285-2</b>	<b>Fast LDO Linear Regulator . . . . .</b>	<b>IF/5-35</b>
UC2853	High Power Factor Preregulator . . . . .	PS/4-27
<b>UC285-3</b>	<b>Fast LDO Linear Regulator . . . . .</b>	<b>IF/5-35</b>
UC2854	High Power Factor Preregulator . . . . .	PS/4-32
UC2854A	Enhanced High Power Factor Preregulator . . . . .	PS/4-42
UC2854B	Enhanced High Power Factor Preregulator . . . . .	PS/4-42
UC2855A	High Performance Power Factor Preregulator . . . . .	PS/4-48
UC2855B	High Performance Power Factor Preregulator . . . . .	PS/4-48
UC2856	Improved Current Mode PWM Controller . . . . .	PS/3-333
UCC2857	Isolated Boost PFC Preregulator Controller. . . . .	PS/4-56
UCC2858	High Efficiency, High Power Factor Preregulator . . . . .	PS/4-65
<b>UC285-ADJ</b>	<b>Fast LDO Linear Regulator . . . . .</b>	<b>IF/5-35</b>
UCC286	Low Dropout 200mA Linear Regulator . . . . .	PP/7-29
UC2860	Resonant Mode Power Supply Controller. . . . .	PS/3-341

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).  
 Products included in this book are listed in **bold**.

# Numeric Master Part Index



Part No.	Description	Volume/Page
UC2861	Resonant-Mode Power Supply Controllers	PS/3-349
UC2862	Resonant-Mode Power Supply Controllers	PS/3-349
UC2863	Resonant-Mode Power Supply Controllers	PS/3-349
UC2864	Resonant-Mode Power Supply Controllers	PS/3-349
UC2865	Resonant-Mode Power Supply Controllers	PS/3-349
UC2866	Resonant-Mode Power Supply Controllers	PS/3-349
UC2867	Resonant-Mode Power Supply Controllers	PS/3-349
UC2868	Resonant-Mode Power Supply Controllers	PS/3-349
UCC287	Low Dropout 200mA Linear Regulator	PP/7-29
UC2871	Resonant Fluorescent Lamp Driver	PP/8-2
UC2872	Resonant Lamp Ballast Controller	PP/8-8
UC2875	Phase Shift Resonant Controller	PS/3-357
UC2876	Phase Shift Resonant Controller	PS/3-357
UC2877	Phase Shift Resonant Controller	PS/3-357
UC2878	Phase Shift Resonant Controller	PS/3-357
UC2879	Phase Shift Resonant Controller	PS/3-367
UCC288	Low Dropout 200mA Linear Regulator	PP/7-29
UCC2880-4	Pentium® Pro Controller	PS/3-373
UCC2880-5	Pentium® Pro Controller	PS/3-373
UCC2880-6	Pentium® Pro Controller	PS/3-373
UCC2882-1	Average Current Mode Synchronous Controller with 5-Bit DAC	PS/3-380
UCC2884	Frequency Foldback Current Mode PWM Controller	PS/3-393
UC2886	Average Current Mode PWM Controller IC	PS/3-400
UCC2888	Off-line Power Supply Controller	PS/3-407
UCC2889	Off-line Power Supply Controller	PS/3-412
UCC2890	Off-Line Battery Charger Circuit	PS/3-418
UCC2895	BiCMOS Advanced Phase Shift PWM Controller	PS/3-425
UC2901	Isolated Feedback Generator	PS/7-21
UC2902	Load Share Controller	PS/7-27
bq2902	Rechargeable Alkaline Charge/Discharge Controller IC	PP/3-194
DV2902	Rechargeable Alkaline Development System	PP/3-202
UC2903	Quad Supply and Line Monitor	PS/7-32
bq2903	Rechargeable Alkaline Charge/Discharge Controller IC	PP/3-204
EV2903	bq2903 Evaluation System	PP/3-214
UC2904	Precision Quad Supply and Line Monitor	PS/7-39
UC2906	Sealed Lead-Acid Battery Charger	PP/3-237
UC2907	Load Share Controller	PS/7-44
UC2909	Switchmode Lead-Acid Battery Charger	PP/3-244
UC2910	4-Bit DAC and Voltage Monitor	PS/3-437
<b>UCC2913</b>	<b>Negative Voltage Hot Swap Power Manager</b>	<b>IF/5-15</b>
<b>UC2914</b>	<b>5V to 35V Hot Swap Power Manager</b>	<b>IF/5-23</b>
<b>UCC2915</b>	<b>15V Programmable Hot Swap Power Manager</b>	<b>IF/5-37</b>
<b>UCC2918</b>	<b>Low On Resistance Hot Swap Power Manager</b>	<b>IF/5-61</b>
<b>UCC2919</b>	<b>3V to 8V Hot Swap Power Manager</b>	<b>IF/5-68</b>

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).  
 Products included in this book are listed in **bold**.

# Numeric Master Part Index



Part No.	Description	Volume/Page
<b>UCC2921</b>	<b>Latchable Negative Floating Hot Swap Power Manager</b>	<b>IF/5-78</b>
UCC2926	±20A Integrated Current Sensor	PS/9-43
L293/D	Push-Pull Four Channel Driver	PS/6-5
UCC29401	Advanced Low Voltage Boost Controller	PP/7-34
UCC29411	Low Power Synchronous Boost Converter	PP/7-58
UCC29412	Low Power Synchronous Boost Converter	PP/7-58
UCC29413	Low Power Synchronous Boost Converter	PP/7-58
UCC29421	High Power Synchronous Boost Controller	PP/7-66
UCC29422	High Power Synchronous Boost Controller	PP/7-66
UC29431	Precision Adjustable Shunt Regulator	PS/7-50
UC29432	Precision Analog Controller	PS/7-56
bq2945	Gas Gauge IC with SMBus-Like Interface	PP/4-340
UCC2946	Microprocessor Supervisor with Watchdog Timer	PP/7-88
UC2950	Half-Bridge Bipolar Switch	PS/6-10
bq2954	Li-Ion Fast-Charge IC	PP/3-217
DV2954S1H	Li-Ion Charger Development System	PP/3-235
DV2954S1L	Li-Ion Charger Development System	PP/3-233
UCC2956	Switch Mode Lithium-Ion Battery Charger Controller	PP/3-253
UCC2960	Primary-Side Startup Controller	PS/3-442
UCC2961	Advanced Primary-Side Startup Controller	PS/3-450
UC2965	Precision Reference with Low Offset Error Amplifier	PS/7-60
UCC2972	BiCMOS Cold Cathode Fluorescent Lamp Driver Controller	PP/8-13
UC3173A	Full Bridge Power Amplifier	PS/8-5
UC3175B	Full Bridge Power Amplifier	PS/8-16
UC3176	Full Bridge Power Amplifier	PS/8-21
UC3177	Full Bridge Power Amplifier	PS/8-21
UC3178	Full Bridge Power Amplifier	PS/8-25
bq3285	Real-Time Clock IC (RTC)	NV/4-3
bq3285E/L	Real-Time Clock ICs (RTC)	NV/4-22
bq3285EC/LC	Real-Time Clock ICs (RTC)	NV/4-46
bq3285ED/LD	Real-Time Clock ICs (RTC)	NV/4-69
bq3285LF	ACPI-Compliant Real-Time Clock IC	NV/4-92
bq3287/bq3287A	Real-Time Clock Module	NV/4-111
bq3287E/bq3287EA	Real-Time Clock Module	NV/4-115
bq3287LD	Real-Time Clock Module	NV/4-119
UCC3305	HID Lamp Controller	PS/9-5
UC3517	Stepper Motor Drive Circuit	PS/8-30
UC3524	Advanced Regulating Pulse Width Modulators	PS/3-43
UC3524A	Advanced Regulating Pulse Width Modulators	PS/3-48
UC3525A	Regulating Pulse Width Modulators	PS/3-54
UC3525B	Regulating Pulse Width Modulators	PS/3-61
UC3526	Regulating Pulse Width Modulator	PS/3-68
UC3526A	Regulating Pulse Width Modulator	PS/3-75
UC3527A	Regulating Pulse Width Modulators	PS/3-54
UC3527B	Regulating Pulse Width Modulators	PS/3-61

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# Numeric Master Part Index



Part No.	Description	Volume/Page
UC3543	Power Supply Supervisory Circuit . . . . .	PS/7-5
UC3544	Power Supply Supervisory Circuit . . . . .	PS/7-5
UC3548	Primary Side PWM Controller . . . . .	PS/3-83
UCC3570	Low Power Pulse Width Modulator . . . . .	PS/3-91
UCC35701	Advanced Voltage Mode Pulse Width Modulator . . . . .	PS/3-99
UC3572	Negative Output Flyback Pulse Width Modulator . . . . .	PS/3-108
UC3573	Buck Pulse Width Modulator Stepdown Voltage Regulator . . . . .	PS/3-112
UC3578	Buck Pulse Width Modulator Stepdown Voltage Regulator . . . . .	PS/3-116
UCC3580-1	Single Ended Active Clamp/Reset PWM . . . . .	PS/3-122
UCC3580-2	Single Ended Active Clamp/Reset PWM . . . . .	PS/3-122
UCC3580-3	Single Ended Active Clamp/Reset PWM . . . . .	PS/3-122
UCC3580-4	Single Ended Active Clamp/Reset PWM . . . . .	PS/3-122
UCC3581	Micropower Voltage Mode PWM . . . . .	PS/3-131
UC3583	Switch Mode Secondary Side Post Regulator . . . . .	PS/3-139
UC3584	Secondary Side Synchronous Post Regulator . . . . .	PS/3-148
UCC3585	Low Voltage Synchronous Buck Controller . . . . .	PS/3-154
UCC3588	5-Bit Programmable Output BiCMOS Power Supply Controller . . . . .	PS/3-163
UC3610	Dual Schottky Diode Bridge . . . . .	PS/7-10
UC3611	Quad Schottky Diode Array . . . . .	PS/7-12
UC3612	Dual Schottky Diode . . . . .	PS/7-15
UC3625	Brushless DC Motor Controller . . . . .	PS/8-37
UCC3626	Brushless DC Motor Controller . . . . .	PS/8-50
UC3633	Phase Locked Frequency Controller . . . . .	PS/8-63
UC3634	Phase Locked Frequency Controller . . . . .	PS/8-70
UC3635	Phase Locked Frequency Controller . . . . .	PS/8-74
UC3637	Switched Mode Controller for DC Motor Drive . . . . .	PS/8-78
UC3638	Advanced PWM Motor Controller . . . . .	PS/8-84
UC3702	Quad PWM Relay Driver . . . . .	PS/6-12
UC3705	High Speed Power Driver . . . . .	PS/6-16
UC3706	Dual Output Driver . . . . .	PS/6-19
UC3707	Dual Channel Power Driver . . . . .	PS/6-24
UC3708	Dual Non-Inverting Power Driver . . . . .	PS/6-31
UC3709	Dual High-Speed FET Driver . . . . .	PS/6-35
UC3710	High Current FET Driver . . . . .	PS/6-38
UC3711	Dual Ultra High-Speed FET Driver . . . . .	PS/6-41
UC37131	Smart Power Switch . . . . .	PS/9-13
UC37132	Smart Power Switch . . . . .	PS/9-13
UC37133	Smart Power Switch . . . . .	PS/9-13
UC3714	Complementary Switch FET Drivers . . . . .	PS/6-43
UC3715	Complementary Switch FET Drivers . . . . .	PS/6-43
UC3717	Stepper Motor Drive Circuit . . . . .	PS/8-92
UC3717A	Stepper Motor Drive Circuit . . . . .	PS/8-100
UC3724	Isolated Drive Transmitter . . . . .	PS/6-50
UC3725	Isolated High Side FET Driver . . . . .	PS/6-53
UC3726	Isolated Drive Transmitter . . . . .	PS/6-57

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).  
 Products included in this book are listed in **bold**.



# Numeric Master Part Index



Part No.	Description	Volume/Page
UC3727	Isolated High Side IGBT Driver	PS/6-62
UC3730	Thermal Monitor	PS/7-17
UCC37423	Dual 3A MOSFET Driver	PS/6-68
UCC37424	Dual 3A MOSFET Driver	PS/6-68
UCC37425	Dual 3A MOSFET Driver	PS/6-68
UCC3750	Source Ringer Controller	PS/9-22
UCC3751	Single Line Ring Generator Controller	PS/9-32
UCC3752	Resonant Ring Generator Controller	PS/9-38
UCC37523	Dual 3A MOSFET Driver With Adaptive LEB	PS/6-73
UCC37524	Dual 3A MOSFET Driver With Adaptive LEB	PS/6-73
UCC37525	Dual 3A MOSFET Driver With Adaptive LEB	PS/6-73
UC3770A	High Performance Stepper Motor Drive Circuit	PS/8-108
UC3770B	High Performance Stepper Motor Drive Circuit	PS/8-108
UCC3776	Quad FET Driver	PS/6-79
UCC3800	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC3801	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC3802	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC3803	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC3804	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC3805	Low-Power BiCMOS Current-Mode PWM	PS/3-173
UCC3806	Low Power, Dual Output, Current Mode PWM Controller	PS/3-180
UCC3807-1	Programmable Maximum Duty Cycle PWM Controller	PS/3-187
UCC3807-2	Programmable Maximum Duty Cycle PWM Controller	PS/3-187
UCC3807-3	Programmable Maximum Duty Cycle PWM Controller	PS/3-187
UCC3808-1	Low Power Current Mode Push-Pull PWM	PS/3-192
UCC3808-2	Low Power Current Mode Push-Pull PWM	PS/3-192
UCC3809-1	Economy Primary Side Controller	PS/3-198
UCC3809-2	Economy Primary Side Controller	PS/3-198
UCC3810	Dual Channel Synchronized Current Mode PWM	PS/3-205
UCC381-3	Low Dropout 1 Ampere Linear Regulator Family	PP/7-5
UCC3813-0	Low Power Economy BiCMOS Current Mode PWM	PS/3-212
UCC3813-1	Low Power Economy BiCMOS Current Mode PWM	PS/3-212
UCC3813-2	Low Power Economy BiCMOS Current Mode PWM	PS/3-212
UCC3813-3	Low Power Economy BiCMOS Current Mode PWM	PS/3-212
UCC3813-4	Low Power Economy BiCMOS Current Mode PWM	PS/3-212
UCC3813-5	Low Power Economy BiCMOS Current Mode PWM	PS/3-212
UCC381-5	Low Dropout 1 Ampere Linear Regulator Family	PP/7-5
UCC3817	BiCMOS Power Factor Preregulator	PS/4-5
UCC3818	BiCMOS Power Factor Preregulator	PS/4-5
UCC381-ADJ	Low Dropout 1 Ampere Linear Regulator Family	PP/7-5
UC382-1	Fast LDO Linear Regulator	PS/5-5
UC382-2	Fast LDO Linear Regulator	PS/5-5
UC3823	High Speed PWM Controller	PS/3-219
UC382-3	Fast LDO Linear Regulator	PS/5-5
UC3823A	High Speed PWM Controller	PS/3-225

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).  
 Products included in this book are listed in **bold**.

# Numeric Master Part Index



Part No.	Description	Volume/Page
UC3823B	High Speed PWM Controller .....	PS/3-225
UC3824	High Speed PWM Controller .....	PS/3-233
UC3825	High Speed PWM Controller .....	PS/3-240
UC3825A	High Speed PWM Controller .....	PS/3-225
UC3825B	High Speed PWM Controller .....	PS/3-225
UC3826	Secondary Side Average Current Mode Controller .....	PS/3-247
UC3827-1	Buck Current/Voltage Fed Push-Pull PWM Controllers .....	PS/3-257
UC3827-2	Buck Current/Voltage Fed Push-Pull PWM Controllers .....	PS/3-257
UC382-ADJ	Fast LDO Linear Regulator .....	PS/5-5
UCC3830-4	5-Bit Microprocessor Power Supply Controller .....	PS/3-263
UCC3830-5	5-Bit Microprocessor Power Supply Controller .....	PS/3-263
UCC3830-6	5-Bit Microprocessor Power Supply Controller .....	PS/3-263
<b>UCC3831</b>	<b>Universal Serial Bus Power Controller .....</b>	<b>IF/5-3</b>
UC3832	Precision Low Dropout Linear Controllers .....	PS/5-11
UC3833	Precision Low Dropout Linear Controllers .....	PS/5-11
UCC383-3	Low Dropout 3 Ampere Linear Regulator Family .....	PP/7-12
UC3834	High Efficiency Linear Regulator .....	PS/5-18
UC3835	High Efficiency Regulator Controller .....	PS/5-24
UCC383-5	Low Dropout 3 Ampere Linear Regulator Family .....	PP/7-12
UC3836	High Efficiency Regulator Controller .....	PS/5-24
UCC3837	8-Pin N-FET Linear Regulator Controller .....	PS/5-28
UC3838A	Magnetic Amplifier Controller .....	PS/3-272
UCC3839	Secondary Side Average Current Mode Controller .....	PS/3-276
UCC383-ADJ	Low Dropout 3 Ampere Linear Regulator Family .....	PP/7-12
UC3841	Programmable, Off-Line, PWM Controller .....	PS/3-281
UCC384-12	Low Dropout 0.5A Negative Linear Regulator .....	PP/7-19
UC3842	Current Mode PWM Controller .....	PS/3-289
UC3842A	Current Mode PWM Controller .....	PS/3-296
UC3843	Current Mode PWM Controller .....	PS/3-289
UC3843A	Current Mode PWM Controller .....	PS/3-296
UC3844	Current Mode PWM Controller .....	PS/3-289
UC3844A	Current Mode PWM Controller .....	PS/3-296
UC3845	Current Mode PWM Controller .....	PS/3-289
UCC384-5	Low Dropout 0.5A Negative Linear Regulator .....	PP/7-19
UC3845A	Current Mode PWM Controller .....	PS/3-296
UC3846	Current Mode PWM Controller .....	PS/3-302
UC3847	Current Mode PWM Controller .....	PS/3-302
UC3848	Average Current Mode PWM Controller .....	PS/3-309
UC3849	Secondary Side Average Current Mode Controller .....	PS/3-317
UCC384-ADJ	Low Dropout 0.5A Negative Linear Regulator .....	PP/7-19
UCC38500	Combined PFC/PWM Controller .....	PS/4-15
UCC38501	Combined PFC/PWM Controller .....	PS/4-15
UCC38502	Combined PFC/PWM Controller .....	PS/4-15
UCC38503	Combined PFC/PWM Controller .....	PS/4-15
UC3851	Programmable, Off-Line, PWM Controller .....	PS/3-327

*Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).  
Products included in this book are listed in **bold**.*

# Numeric Master Part Index



Part No.	Description	Volume/Page
<b>UC385-1</b>	<b>Fast LDO Linear Regulator</b> . . . . .	<b>IF/5-35</b>
UC3852	High Power-Factor Preregulator . . . . .	PS/4-22
<b>UC385-2</b>	<b>Fast LDO Linear Regulator</b> . . . . .	<b>IF/5-35</b>
UC3853	High Power Factor Preregulator . . . . .	PS/4-27
<b>UC385-3</b>	<b>Fast LDO Linear Regulator</b> . . . . .	<b>IF/5-35</b>
<b>UCC38531</b>	<b>Universal Serial Bus Power Controller</b> . . . . .	<b>IF/5-6</b>
UC3854	High Power Factor Preregulator . . . . .	PS/4-32
UC3854A	Enhanced High Power Factor Preregulator . . . . .	PS/4-42
UC3854B	Enhanced High Power Factor Preregulator . . . . .	PS/4-42
UC3855A	High Performance Power Factor Preregulator . . . . .	PS/4-48
UC3855B	High Performance Power Factor Preregulator . . . . .	PS/4-48
UC3856	Improved Current Mode PWM Controller . . . . .	PS/3-333
UCC3857	Isolated Boost PFC Preregulator Controller . . . . .	PS/4-56
UCC3858	High Efficiency, High Power Factor Preregulator . . . . .	PS/4-65
<b>UC385-ADJ</b>	<b>Fast LDO Linear Regulator</b> . . . . .	<b>IF/5-35</b>
UCC386	Low Dropout 200mA Linear Regulator . . . . .	PP/7-29
UC3860	Resonant Mode Power Supply Controller . . . . .	PS/3-341
UC3861	Resonant-Mode Power Supply Controllers . . . . .	PS/3-349
UC3862	Resonant-Mode Power Supply Controllers . . . . .	PS/3-349
UC3863	Resonant-Mode Power Supply Controllers . . . . .	PS/3-349
UC3864	Resonant-Mode Power Supply Controllers . . . . .	PS/3-349
UC3865	Resonant-Mode Power Supply Controllers . . . . .	PS/3-349
UC3866	Resonant-Mode Power Supply Controllers . . . . .	PS/3-349
UC3867	Resonant-Mode Power Supply Controllers . . . . .	PS/3-349
UC3868	Resonant-Mode Power Supply Controllers . . . . .	PS/3-349
UCC387	Low Dropout 200mA Linear Regulator . . . . .	PP/7-29
UC3871	Resonant Fluorescent Lamp Driver . . . . .	PP/8-2
UC3872	Resonant Lamp Ballast Controller . . . . .	PP/8-8
UC3875	Phase Shift Resonant Controller . . . . .	PS/3-357
UC3876	Phase Shift Resonant Controller . . . . .	PS/3-357
UC3877	Phase Shift Resonant Controller . . . . .	PS/3-357
UC3878	Phase Shift Resonant Controller . . . . .	PS/3-357
UC3879	Phase Shift Resonant Controller . . . . .	PS/3-367
UCC388	Low Dropout 200mA Linear Regulator . . . . .	PP/7-29
UCC3880-4	Pentium® Pro Controller . . . . .	PS/3-373
UCC3880-5	Pentium® Pro Controller . . . . .	PS/3-373
UCC3880-6	Pentium® Pro Controller . . . . .	PS/3-373
UCC3882-1	Average Current Mode Synchronous Controller with 5-Bit DAC . . . . .	PS/3-380
UCC3884	Frequency Foldback Current Mode PWM Controller . . . . .	PS/3-393
UC3886	Average Current Mode PWM Controller IC . . . . .	PS/3-400
UCC3888	Off-line Power Supply Controller . . . . .	PS/3-407
UCC3889	Off-line Power Supply Controller . . . . .	PS/3-412
UCC3890	Off-Line Battery Charger Circuit . . . . .	PS/3-418
UCC3895	BiCMOS Advanced Phase Shift PWM Controller . . . . .	PS/3-425

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).  
 Products included in this book are listed in **bold**.

# Numeric Master Part Index



Part No.	Description	Volume/Page
UC3901	Isolated Feedback Generator	PS/7-21
UC3902	Load Share Controller	PS/7-27
UC3903	Quad Supply and Line Monitor	PS/7-32
UC3904	Precision Quad Supply and Line Monitor	PS/7-39
UC3906	Sealed Lead-Acid Battery Charger	PP/3-237
UC3907	Load Share Controller	PS/7-44
UC3909	Switchmode Lead-Acid Battery Charger	PP/3-244
UCC391	5-Bit Programmable Output BiCMOS Precision Voltage Reference	PS/3-434
UC3910	4-Bit DAC and Voltage Monitor	PS/3-437
UCC3911	Lithium-Ion Battery Protector	PP/6-26
<b>UCC3912</b>	<b>Programmable Hot Swap Power Manager</b>	<b>IF/5-9</b>
<b>UCC3913</b>	<b>Negative Voltage Hot Swap Power Manager</b>	<b>IF/5-15</b>
<b>UC3914</b>	<b>5V to 35V Hot Swap Power Manager</b>	<b>IF/5-23</b>
<b>UCC3915</b>	<b>15V Programmable Hot Swap Power Manager</b>	<b>IF/5-37</b>
<b>UCC39151</b>	<b>15V Programmable Hot Swap Power Manager</b>	<b>IF/5-42</b>
<b>UCC3916</b>	<b>SCSI Termpower Manager</b>	<b>IF/5-47</b>
<b>UCC39161</b>	<b>Low Current Hot Swap Power Manager</b>	<b>IF/5-50</b>
<b>UCC3917</b>	<b>Positive Floating Hot Swap Power Manager</b>	<b>IF/5-53</b>
<b>UCC3918</b>	<b>Low On Resistance Hot Swap Power Manager</b>	<b>IF/5-61</b>
<b>UCC3919</b>	<b>3V to 8V Hot Swap Power Manager</b>	<b>IF/5-68</b>
<b>UCC3921</b>	<b>Latchable Negative Floating Hot Swap Power Manager</b>	<b>IF/5-78</b>
UCC3926	±20A Integrated Current Sensor	PS/9-43
UCC39401	Advanced Low Voltage Boost Controller	PP/7-34
UCC39411	Low Power Synchronous Boost Converter	PP/7-58
UCC39412	Low Power Synchronous Boost Converter	PP/7-58
UCC39413	Low Power Synchronous Boost Converter	PP/7-58
UCC3941-3	1V Synchronous Boost Converter	PP/7-48
UCC3941-5	1V Synchronous Boost Converter	PP/7-48
UCC3941-ADJ	1V Synchronous Boost Converter	PP/7-48
UCC39421	High Power Synchronous Boost Controller	PP/7-66
UCC39422	High Power Synchronous Boost Controller	PP/7-66
UC39431	Precision Adjustable Shunt Regulator	PS/7-50
UC39431B	Precision Adjustable Shunt Regulator	PS/7-50
UC39432	Precision Analog Controller	PS/7-56
UC39432B	Precision Analog Controller	PS/7-56
UCC3946	Microprocessor Supervisor with Watchdog Timer	PP/7-88
UCC3952-1	Enhanced Single Cell Lithium-Ion Battery Protection IC	PP/6-32
UCC3952-2	Enhanced Single Cell Lithium-Ion Battery Protection IC	PP/6-32
UCC3952-3	Enhanced Single Cell Lithium-Ion Battery Protection IC	PP/6-32
UCC3952-4	Enhanced Single Cell Lithium-Ion Battery Protection IC	PP/6-32
UCC3954	Single Cell Lithium-Ion to +3.3V Converter	PP/7-93
UCC3956	Switch Mode Lithium-Ion Battery Charger Controller	PP/3-253
UCC3957-1	Three - Four Cell Lithium-Ion Protector Circuit	PP/6-37
UCC3957-2	Three - Four Cell Lithium-Ion Protector Circuit	PP/6-37

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).

Products included in this book are listed in **bold**.

# Numeric Master Part Index



Part No.	Description	Volume/Page
UCC3957-3	Three - Four Cell Lithium-Ion Protector Circuit	PP/6-37
UCC3957-4	Three - Four Cell Lithium-Ion Protector Circuit	PP/6-37
UCC3958-1	Single Cell Lithium-Ion Battery Protection IC	PP/6-44
UCC3958-2	Single Cell Lithium-Ion Battery Protection IC	PP/6-44
UCC3958-3	Single Cell Lithium-Ion Battery Protection IC	PP/6-44
UCC3958-4	Single Cell Lithium-Ion Battery Protection IC	PP/6-44
UCC3960	Primary-Side Startup Controller	PS/3-442
UCC3961	Advanced Primary-Side Startup Controller	PS/3-450
UC3965	Precision Reference with Low Offset Error Amplifier	PS/7-60
UCC3972	BiCMOS Cold Cathode Fluorescent Lamp Driver Controller	PP/8-13
<b>UCC3981</b>	<b>Universal Serial Bus Hot Swap Power Controller</b>	<b>IF/5-88</b>
<b>UCC39811</b>	<b>Universal Serial Bus Hot Swap Power Controller</b>	<b>IF/5-91</b>
<b>UCC3985</b>	<b>Programmable CompactPCI Hot Swap Power Manager</b>	<b>IF/5-94</b>
<b>UCC3995</b>	<b>Simple Single Channel External N-FET Hot Swap Power Manager</b>	<b>IF/5-98</b>
<b>UCC3996</b>	<b>Dual Sequencing Hot Swap Power Manager</b>	<b>IF/5-100</b>
bq4010/Y	8Kx8 Nonvolatile SRAM	NV/5-3
bq4011/Y	32Kx8 Nonvolatile SRAM	NV/5-13
bq4013/Y	128Kx8 Nonvolatile SRAM	NV/5-23
bq4014/Y	256Kx8 Nonvolatile SRAM	NV/5-33
bq4015/Y	512Kx8 Nonvolatile SRAM	NV/5-42
bq4016/Y	1024Kx8 Nonvolatile SRAM	NV/5-52
bq4017/Y	2048Kx8 Nonvolatile SRAM	NV/5-61
bq4285	Real-Time Clock Module with NVRAM Control	NV/4-123
bq4285E/L	Enhanced RTC Module with NVRAM Control	NV/4-143
bq4287	Real-Time Clock Module with NVRAM Control	NV/4-168
bq4310/Y	8Kx8 ZEROPOWER Nonvolatile SRAM	NV/5-70
bq4311Y/L	32Kx8 ZEROPOWER Nonvolatile SRAM	NV/5-81
bq4802	Y2K-Compliant Parallel RTC with CPU Supervisor	NV/4-174
bq4822Y	RTC Module with 8Kx8 NVSRAM	NV/4-176
bq4823Y	TIMEKEEPER Module with 8Kx8 NVSRAM	NV/4-191
bq4830Y	RTC Module with 32Kx8 NVSRAM	NV/4-205
bq4832Y	RTC Module with 32Kx8 NVSRAM	NV/4-218
bq4833Y	TIMEKEEPER Module with 32Kx8 NVSRAM	NV/4-233
bq4842Y	RTC Module with 128Kx8 NVSRAM	NV/4-247
bq4845/Y	Parallel RTC Module with CPU Supervisor	NV/4-262
bq4847/Y	RTC Module with CPU Supervisor	NV/4-279
bq4850Y	RTC Module with 512Kx8 NVSRAM	NV/4-282
bq4852Y	RTC Module with 512Kx8 NVSRAM	NV/4-295
UC494A/AC	Advanced Regulating Pulse Width Modulators	PS/3-460
UC495A/AC	Advanced Regulating Pulse Width Modulators	PS/3-460
<b>UC5170A</b>	<b>Octal Line Driver</b>	<b>IF/6-2</b>
<b>UC5171</b>	<b>Octal Line Driver</b>	<b>IF/6-6</b>
<b>UC5172</b>	<b>Octal Line Driver</b>	<b>IF/6-10</b>
<b>UC5180C</b>	<b>Octal Line Receiver</b>	<b>IF/6-14</b>

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).  
 Products included in this book are listed in **bold**.

# Numeric Master Part Index



Part No. Description	Volume/Page
<b>UC5181C</b> Octal Line Receiver .....	IF/6-17
UCC5341 IrDA 2.4kbps to 115.2kbps Receiver .....	PP/9-2
UCC5342 IrDA 2.4kbps to 115.2kbps Transceiver .....	PP/9-6
UCC5343 IrDA Transceiver with Encoder/Decoder .....	PP/9-10
<b>UC5350</b> CAN Transceiver .....	IF/6-20
<b>UC5351</b> CAN Transceiver with Voltage Regulator .....	IF/6-26
<b>UCC5510</b> Low Voltage Differential (LVD/SE) SCSI 9 Line Terminator .....	IF/3-5
<b>UC560</b> 27-Line SCSI Source/Sink Regulator .....	IF/4-3
<b>UC5601</b> SCSI Active Terminator .....	IF/3-9
<b>UC5602</b> SCSI Active Terminator .....	IF/3-13
<b>UC5603</b> 9-Line SCSI Active Terminator .....	IF/3-18
<b>UC5604</b> 9-Line Low Capacitance SCSI Active Terminator .....	IF/3-22
<b>UC5605</b> 9-Line Low Capacitance SCSI Active Terminator .....	IF/3-26
<b>UCC5606</b> 9-Line 3-5 Volt SCSI Active Terminator, Reverse Disconnect .....	IF/3-30
<b>UC5607</b> Plug and Play, 18-Line SCSI Active Terminator .....	IF/3-34
<b>UC5608</b> 18-Line Low Capacitance SCSI Active Terminator .....	IF/3-40
<b>UC5609</b> 18-Line Low Capacitance SCSI Active Terminator .....	IF/3-40
<b>UCC561</b> Low Voltage Differential SCSI (LVD) 27 Line Regulator Set .....	IF/4-7
<b>UC5612</b> 9-Line Low Capacitance SCSI Active Terminator .....	IF/3-43
<b>UC5613</b> 9-Line Low Capacitance SCSI Active Terminator .....	IF/3-47
<b>UCC5614</b> 9-Line 3-5 Volt Low Capacitance SCSI Active Terminator .....	IF/3-51
<b>UCC5617</b> 18-Line SCSI Terminator With Reverse Disconnect .....	IF/3-55
<b>UCC5618</b> 18-Line SCSI Terminator .....	IF/3-59
<b>UCC5619</b> 27-Line SCSI Terminator With Reverse Disconnect .....	IF/3-63
<b>UCC5620</b> 27-Line SCSI Terminator .....	IF/3-66
<b>UCC5621</b> 27-Line SCSI Terminator With Split Reverse Disconnect .....	IF/3-70
<b>UCC5622</b> 27-Line SCSI Terminator With Split Disconnect .....	IF/3-74
<b>UCC5628</b> Multimode SCSI 14 Line Terminator .....	IF/3-78
<b>UCC563</b> 32 Line VME Bus Bias Generator .....	IF/4-10
<b>UCC5630</b> Low Voltage Differential (LVD/SE) SCSI 9 Line Terminator .....	IF/3-83
<b>UCC5630A</b> Multimode SCSI 9 Line Terminator .....	IF/3-87
<b>UCC5632</b> Multimode (LVD/SE) SCSI 9 Line Terminator w/ 2.85V Regulator .....	IF/3-93
<b>UCC5638</b> Multimode SCSI 15 Line Terminator .....	IF/3-94
<b>UCC5639</b> Multimode SCSI 15 Line Terminator with Reverse Disconnect .....	IF/3-99
<b>UCC5640</b> Low Voltage Differential (LVD) SCSI 9 Line Terminator .....	IF/3-104
<b>UCC5641</b> Low Voltage Differential (LVD) SCSI 9 Line Terminator Reverse Disconnect .....	IF/3-108
<b>UCC5646</b> 27-Line SCSI Terminator .....	IF/3-112
<b>UCC5647</b> 27-Line SCSI Terminator .....	IF/3-112
<b>UC5661</b> Ethernet Coaxial Impedance Monitor .....	IF/3-116
<b>UCC5672</b> Multimode (LVD/SE) SCSI 9 Line Terminator .....	IF/3-120
<b>UCC5680</b> Low Voltage Differential (LVD) SCSI 9 Line Terminator .....	IF/3-121
<b>UCC5950</b> 10-Bit Serial D/A Converter .....	PS/9-48

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).  
 Products included in this book are listed in **bold**.

# Application/Design Notes by Part Number



1

IC Featured	Pub. Title	Volume/Page
bq2000/T	U-504 Using the bq2000/T to Control Fast Charge . . . . .	PP/3-262
bq2003	U-505 Using the bq2003 to Control Fast Charge . . . . .	PP/3-273
bq2003	U-506 Step-Down Switching Current Regulation Using the bq2003 Fast-Charge IC . . . . .	PP/3-291
bq2005	U-507 Using the bq2005 to Control Fast Charge . . . . .	PP/3-309
bq2007	U-508 Using the bq2007 Display Mode Options . . . . .	PP/3-327
bq2007	U-509 Using the bq2007 Enhanced Features for Fast Charge . . . . .	PP/3-332
bq2010	U-514 Using the bq2010: A Tutorial for Gas Gauging . . . . .	PP/4-390
bq2031	U-510 Using the bq2031 to Charge Lead-Acid Batteries . . . . .	PP/3-346
bq2031	U-511 Switch-Mode Power Conversion Using the bq2031 . . . . .	PP/3-360
bq2040	U-513 Using the bq2040: Smart Battery System Gas Gauge IC . . . . .	PP/4-372
UC2577	DN-49 Easy Switcher Controls SEPIC Converter for Automotive Applications. . . . .	PP/3-487
bq2902/3	U-512 Using the bq2902/3 Rechargeable Alkaline ICs. . . . .	PP/3-376
bq3285/7E	U-503 Using the bq3285/7E in a Green or Portable Environment . . . . .	NV/4-331
bq3285/bq3287	DN-501 Using RAM Clear Function with bq3285/bq3287A RTCs . . . . .	NV/4-321
UCC3305	DN-72 Lamp Ignitor Circuit . . . . .	PS/9-52
UCC3305	U-161 Powering a 35W DC Metal Halide High Intensity Discharge (HID) Lamp using the UCC3305 HID Lamp Controller . . . . .	PS/9-61
UC3525A/27A	DN-36 UC1525B/1527B Devices - Comparison Summary to UC1525A/1527A Devices. . . . .	PS/3-470
UCC3570	U-150 Applying the UCC3570 Voltage-Mode PWM Controller to Both Off-Line and DC/DC Converter Designs . . . . .	PS/3-696
UCC35701	DN-62 Switching Power Supply Topology: Voltage Mode vs. Current Mode . . . . .	PS/3-496
UC3573	DN-70 UC3573 Buck Regulator PWM Control IC . . . . .	PS/3-508
UC3578	U-167 UC3578 Telecom Buck Converter Evaluation Board . . . . .	PS/3-818
UCC3583	DN-64 Inductorless Bias Supply for Synchronous Rectification and High Side Drive Applications . . . . .	PS/3-502
UC3584	DN-83 UC3584 DW Secondary Side Post Regulator, Evaluation Board, Schematic, and List of Materials . . . . .	PS/3-511
UC3625	DN-50 Simple Techniques for Isolating and Correcting Common Application Problems with UC3625 Brushless DC Motor Drives . . . . .	PS/8-111
UC3625	U-115 New Integrated Circuit Produces Robust, Noise Immune System for Brushless DC Motors . . . . .	PS/8-155
UC3625	U-130 Dedicated ICs Simplify Brushless DC Servo Amplifier Design. . . . .	PS/8-166
UC3634	U-113 Design Notes on Precision Phase Locked Speed Control for DC Motors . . . . .	PS/8-145
UC3637	DN-53A Design Considerations for Synchronizing Multiple UC3637 PWMs . . . . .	PS/8-115
UC3637	U-102 UC1637/2637/3637 Switched Mode Controller for DC Motor Drive . . . . .	PS/8-126
UC3637	U-112 A High Precision PWM Transconductance Amplifier for Microstepping using Unitrode's UC3637. . . . .	PS/8-137
UC3638	DN-76 Closed Loop Temperature Regulation Using the UC3638 H-Bridge Motor Controller and a Thermoelectric Cooler. . . . .	PS/8-118
UC3638	U-120 A Simplified Approach to DC Motor Modeling for Dynamic Stability Analysis . . . . .	PS/8-162
UC3708	DN-35 IGBT Drive Using MOSFET Gate Drivers . . . . .	PS/6-85
UC3709	U-111 Practical Considerations in Current Mode Power Supplies . . . . .	PS/3-558
UC3709	U-118 New Driver ICs Optimize High Speed Power MOSFET Switching Characteristics. . . . .	PS/6-92
UC3709	U-137 Practical Considerations in High Performance MOSFET, IGBT & MCT Gate Drive Circuits . . . . .	PS/6-122
UC3717	U-99 UC3717 and L-C Filter Reduce EMI and Chopping Losses in Step Motor . . . . .	PS/8-118

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).

Publications included in this book are listed in **bold**.

# Application/Design Notes by Part Number



IC Featured	Pub. Title	Volume/Page
UC3725	U-127 Unique Chip Pair Simplifies High Side Switch Drive	PS/6-107
UC3726	DN-57 Power Dissipation Considerations for the UC3726N/UC3727N IGBT Driver Pair	PS/6-87
UC3726	DN-60 UC3726/UC3727 IGBT Driver Pair Evaluation Kit Testing Procedure	PS/6-90
UC3727	U-143C New Chip Pair Provides Isolated Drive for High Voltage IGBTs	PS/6-137
UCC3750	DN-79 UCC3750 Demonstration Board Operating Guidelines	PS/9-55
UCC3750	U-169 The New UCC3750 Source Ringer Controller Provides A Complete Control Solution for a Four-Quadrant Flyback Converter	PS/9-76
UCC3800/1-5	DN-42A Design Considerations for Transitioning from UC3842 to the New UCC3802 Family	PS/3-476
UCC3800/1-5	DN-43 Simple Techniques to Generate a Negative Voltage Bias Supply from a Positive Input Voltage	PS/3-479
UCC3800/1-5	DN-56A Single Switch Flyback Circuit Converts +5VDC to +/-12VDC for RS-232 and RS-422 Applications	PS/3-492
UCC3800/1-5	U-133A UCC3800/1/2/3/4/5 BiCMOS Current Mode Control ICs	PS/3-594
UCC3806	DN-45 UC3846, UC3856 and UCC3806 Push-Pull PWM Current Mode Control ICs	PS/3-480
UCC3806	DN-51 Programming the UCC3806 Features	PS/3-489
UCC3806	U-144 UCC3806 BiCMOS Current Mode Control IC	PS/3-678
UCC3807	DN-48 Versatile Low Power SEPIC Converter Accepts Wide Input Voltage Range	PS/3-484
UCC3809-1,-2	DN-65 Considerations in Powering BiCMOS ICs	PS/3-505
UCC3809-1,-2	U-168 Implementing an Off-Line Lithium-Ion Charger Using the UCC3809 Primary Side Controller and the UCC3956 Battery Charger Controller	PS/3-455
UCC3813	DN-46 Highly Efficient Low Power DC to DC Inverter Converts +5V Input to -3V Output	PS/3-482
UCC3813	DN-48 Versatile Low Power SEPIC Converter Accepts Wide Input Voltage Range	PS/3-484
UCC3813	DN-54 Innovative Buck Regulator Uses High Side N-Channel Switch without Complex Gate Drive	PS/3-492
UCC3813	U-97 Modeling, Analysis and Compensation of the Current Mode Converter	PS/3-526
UC3823A,B/ UC3825A,B	U-128 The UC3823A,B & UC3825A,B Enhanced Generation of PWM Controllers	PS/3-585
UC3825	U-110 1.5MHz Current Mode IC Controlled 50W Power Supply	PS/3-546
UCC3831	<b>DN-85</b> UCC3831 USB Power Controller IC, Evaluation Board – Schematic and List of Materials	IF/5-106
UC3832/3	DN-32 Optocoupler Feedback Drive Techniques	PS/5-41
UC3832/3	DN-61 A High Performance Linear Regulator for Low Dropout Applications	PS/5-42
UC3832/3	U-152 A High Performance Linear Regulator for Low Dropout Applications	PS/5-71
UC3834	U-95 Versatile UC1834 Optimizes Linear Regulator Efficiency	PS/5-49
UC3841	DN-28 UC3840/UC3841/UC3851 PWM Controllers - Summary of Functional Differences	PS/3-467
UC3842/3/4/5	DN-27 UC1842/UC1842A Summary of Functional Differences	PS/3-466
UC3842/3/4/5	DN-40 The Effects of Oscillator Discharge Current Variations on Maximum Duty Cycle and Frequency in UC3842 and UC3842A PWM ICs	PS/3-473
UC3842/3/4/5	DN-89 Comparing the UC3842, UCC3802, and UCC3809 Primary-Side PWM Controllers	PS/3-514
UC3842/3/4/5	U-100A UC3842/3/4/5 Provides Low-Cost Current-Mode Control	PS/3-532
UC3842A/3A/4A/5A	DN-26 UC3842A - Low Cost Startup and Fault Protection Circuit	PS/3-464
UC3842A/3A/4A/5A	DN-29 UC3842A Family Frequency Foldback Technique Provides Protection	PS/3-468
UC3842A/3A/4A/5A	DN-30 Programmable Electronic Circuit Breaker	PS/3-469
UC3846/7	U-93 A New Integrated Circuit for Current Mode Control	PS/3-518

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).

Publications included in this book are listed in **bold**.



# Application/Design Notes by Part Number



IC Featured	Pub. Title	Volume/Page
UC3848	U-135 The UC3848 Average Current Mode Controller Squeezes Maximum Performance from Single Switch Converters . . . . .	PS/3-612
UC3849	U-140 Average Current Mode Control of Switching Power Supplies. . . . .	PS/3-664
UC3852	U-132 Power Factor Correction Using the UC3852 Controlled ON-Time Zero Current Switching Technique . . . . .	PS/4-98
UC3853	DN-77 Overcurrent Shutdown with the UC3853 . . . . .	PS/4-91
UC3853	DN-78 High Power Factor Preregulator IC, Evaluation Board, Schematic and List of Materials . . . . .	PS/4-92
UC3853	U-159 Boost Power Factor Corrector Design with the UC3853 . . . . .	PS/4-154
UC3854	DN-41 Extend Current Transformer Range . . . . .	PS/4-81
UC3854	U-134 UC3854 Controlled Power Factor Correction Circuit Design . . . . .	PS/4-114
UC3854A/B	DN-44 UC3854A and UC3854B Advanced Power Factor Correction Control ICs . .	PS/4-83
UC3854A/B	DN-66 Unitrode - UC3854A/B and UC3855A/B Provide Power Limiting with Sinusoidal Input Current for PFC Front Ends. . . . .	PS/4-86
UC3855A/B	U-153 UC3855A/B High Performance Power Factor Preregulator . . . . .	PS/4-134
UC3856	DN-45 UC3846, UC3856 and UCC3806 Push-Pull PWM Current Mode Control ICs . . . . .	PS/3-480
UCC3857	DN-39E Optimizing Performance in UC3854 Power Factor Correction Applications . . . . .	PS/4-76
UCC3858	DN-90 UCC3858 "Energy Star" PFC Evaluation Board, Schematic and List of Materials. . . . .	PS/4-94
UC3861-8	U-122 A New Family of Integrated Circuits Controls Resonant Mode Power Converters . . . . .	PS/3-576
UC3861-8	U-138 Zero Voltage Switching Resonant Power Conversion . . . . .	PS/3-637
UC3871	U-141 Resonant Fluorescent Lamp Converter Provides Efficient and Compact Solution . . . . .	PP/8-27
UC3871	U-148 Dimmable Cold-Cathode Fluorescent Lamp Ballast Design Using the UC3871 . . . . .	PP/8-35
UC3872	DN-75 Using the UC3871 and UC3872 Resonant Fluorescent Lamp Drivers in Floating Lamp Applications . . . . .	PP/8-50
UC3875/6/7/8	DN-63 The Current-Doubler Rectifier: An Alternative Rectification Technique for Push-Pull and Bridge Converters. . . . .	PS/3-499
UC3875/6/7/8	U-136A Phase Shifted, Zero Voltage Transition Design Considerations and the UC3875 PWM Controller . . . . .	PS/3-623
UC3879	U-154 The New UC3879 Phase Shifted PWM Controller Simplifies the Design of Zero Voltage Transition Full-Bridge Converters . . . . .	PS/3-709
UCC3884	U-164 The UCC3884 Frequency Foldback Pulse Width Modulator . . . . .	PS/3-783
UC3886	U-156 The UC3886 PWM Controller Uses Average Current Mode Control to Meet the Transient Regulation Performance of High End Processors . . . . .	PS/3-717
UC3886	U-157 Fueling the Megaprocessor - A DC/DC Converter Design Review Featuring the UC3886 and UC3910. . . . .	PS/3-741
UCC3888	DN-59A UCC3889 Bias Supply Controller Evaluation Kit - Schematic and Lists of Materials . . . . .	PS/3-494
UCC3888	U-149A Simple Off-Line Bias Supply for Very Low Power Applications . . . . .	PS/3-685
UC3901	DN-19 A Simple Isolation Amplifier using the UC1901 . . . . .	PS/7-64
UC3901	U-94 The UC1901 Simplifies the Problem of Isolated Feedback in Switching Regulators . . . . .	PS/7-72
UC3902	U-163 The UC3902 Load Share Controller and Its Performance in Distributed Power Systems . . . . .	PS/7-100
UC3903	DN-33 Optocoupler Feedback Drive Techniques Using the UC3901 and UC3903 .	PS/7-65

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).

Publications included in this book are listed in **bold**.

# Application/Design Notes by Part Number



IC Featured	Pub. Title	Volume/Page
UC3906	U-104 Improved Charging Methods for Lead-Acid Batteries using the UC3906 . . .	PP/3-388
UC3906	U-131 Simple Switchmode Lead-Acid Battery Charger . . . . .	PP/3-417
UC3907	U-129 UC3907 Load Share IC Simplifies Parallels Power Supply Design . . . . .	PS/7-84
UC3909	U-155 Implementing Multi-State Charge Algorithm with the UC3909 Switchmode Lead-Acid Battery Charger Controller . . . . .	PP/3-426
UC3909	U-166 An Off-Line Lead-Acid Charger Based on the UC3909 . . . . .	PP/3-399
UC3910	U-158 The UC3910 Combines Programmability, Accuracy and Integrated Functions to Control and Monitor High End Processor Power Supplies . . . . .	PS/3-771
UCC3911	DN-81 UCC3911 Demo Board Information. . . . .	PP/6-51
UCC3912	<b>DN-58</b> UCC3912 Programmable Electronic Circuit Breaker - Performance Evaluation and Programming Information . . . . .	IF/5-102
UCC3912	<b>DN-68</b> Parelling UCC3912 Electronic Circuit Breaker Ics. . . . .	IF/5-106
UCC3912	<b>U-151</b> UCC3912 Integrated Hot Swap Power Managerr IC for Hot-Swap and Power Management Applications . . . . .	IF/5-124
UCC3913	<b>DN-67</b> UCC3913 Electronic Circuit Breaker for Negative Voltage Applications Evaluation Kit List of Materials for a -48V/1A Test Circuit . . . . .	IF/5-105
UCC3917	<b>DN-98</b> UCC3917 Positive Floating Hot Swap Power Manager Evaluation Kit, Schematic and Bill of Materials . . . . .	IF/5-120
UCC3918	<b>DN-87</b> UCC3918 Low On-Resistance Hot Swap Power Manager Performance Evaluation Kit , Schematic and List of Materials . . . . .	IF/5-113
UCC3919	<b>DN-95</b> UCC3919 Hot Swap Power Manager Evaluation Circuit Board and Bill of Materials . . . . .	IF/5-116
UCC3926	DN-91 UCC3926DS ± 20A Integrated Current Sensor Evaluation Board – Schematic and List of Materials . . . . .	PS/9-58
UCC39411/2/3	DN-97 UCC39411 Low Power Synchronous Boost Converter Evaluation Kit, Schematic and Bill of Materials . . . . .	PP/7-106
UCC3941-3/5/ADJ	DN-73 UCC3941 One Volt Boost Converter Demonstration Kit - Schematic and List of Materials. . . . .	PP/7-101
UC39432	DN-52 Adjustable Electronic Load for Low Voltage DC Applications . . . . .	PS/7-76
UCC3952	DN-96 UCC3952 Evaluation Board and List of Materials . . . . .	PP/6-61
UCC3954	DN-86 UCC3954 Single Cell Lithium-Ion to +3.3V Converter Performance Evaluation Kit – Schematic and List of Materials . . . . .	PP/7-103
UCC3956	DN-84 UCC3956 Switch Mode Lithium-Ion Battery Charger Controller Evaluation Board, Schematic and List of Materials . . . . .	PP/3-413
UCC3957	DN-93 UCC3957, Three - Four Cell Lithium-Ion Protector Circuit, Evaluation Board and List of Materials . . . . .	PP/6-57
UCC3958	DN-82 UCC3958 Demonstration Board Schematic and Bill of Materials . . . . .	PP/6-55
UCC3961	DN-99 Pulse Edge Transmission (PET) circuit . . . . .	PS/8-102
UC3965	U-165 Design Review: Isolated 50W Flyback with the UCC3809 Primary Side Controller and the UC3965 Precision Reference and Error Amplifier . . . . .	PS/3-800
bq4845	U-500 Using the bq4845 for a Low-Cost RTC/NVSRAM Subsystem . . . . .	NV/4-310
UC494/5A&C	DN-38 Unique Converter for Low Power Bias Supplies . . . . .	PS/3-471
UCC5342	DN-88 UCC5342 IrDA 115.2kbps Transceiver Performance Evaluation Board – Schematic and List of Materials . . . . .	PP/9-15
UCC5343	DN-94 UCC5343, IrDA Transceiver with Encoder/Decoder, Evaluation Board and List of Materials . . . . .	PP/9-19
UCC5630	<b>DN-92</b> UCC5630 SCSI Multimode (LVD/SE) Evaluation Board and List of Materials . . . . .	IF/3-122
General	DN-502 High-Side Current Sensing with Benchmarq Portable Power Fast-Charge Control IC . . . . .	PP/3-307

Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).  
Publications included in this book are listed in **bold**.

# Application/Design Notes by Part Number



IC Featured	Pub. Title	Volume/Page
General	U-502 Time-Base Oscillator for RTC ICs .....	NV/4-322

*Part numbers are listed numerically, not by prefix (bq, DV, EV, UC, UCC).  
Publications included in this book are listed in **bold**.*

# Application/Design Notes by Publication Number



Pub.	Title	IC Featured	Volume/Page
DN-19	A Simple Isolation Amplifier using the UC1901	UC3901	PS/7-64
DN-26	UC3842A - Low Cost Startup and Fault Protection Circuit	UC3842A/3A/4A/5A	PS/3-464
DN-27	UC1842/UC1842A Summary of Functional Differences	UC3842/3/4/5	PS/3-466
DN-28	UC3840/UC3841/UC3851 PWM Controllers - Summary of Functional Differences	UC3841	PS/3-467
DN-29	UC3842A Family Frequency Foldback Technique Provides Protection	UC3842A/3A/4A/5A	PS/3-468
DN-30	Programmable Electronic Circuit Breaker	UC3842A/3A/4A/5A	PS/3-469
DN-32	Optocoupler Feedback Drive Techniques	UC3832/3	PS/5-41
DN-33	Optocoupler Feedback Drive Techniques Using the UC3901 and UC3903	UC3903	PS/7-65
DN-35	IGBT Drive Using MOSFET Gate Drivers	UC3708	PS/6-85
DN-36	UC1525B/1527B Devices - Comparison Summary to UC1525A/1527A Devices	UC3525A/27A	PS/3-470
DN-38	Unique Converter for Low Power Bias Supplies	UC494/5A&C	PS/3-471
DN-39E	Optimizing Performance in UC3854 Power Factor Correction Applications	UCC3857	PS/4-76
DN-40	The Effects of Oscillator Discharge Current Variations on Maximum Duty Cycle and Frequency in UC3842 and UC3842A PWM ICs	UC3842/3/4/5	PS/3-473
DN-41	Extend Current Transformer Range	UC3854	PS/4-81
DN-42A	Design Considerations for Transitioning from UC3842 to the New UCC3802 Family	UCC3800/1/2/3/4/5	PS/3-476
DN-43	Simple Techniques to Generate a Negative Voltage Bias Supply from a Positive Input Voltage	UCC3800/1/2/3/4/5	PS/3-479
DN-44	UC3854A and UC3854B Advanced Power Factor Correction Control ICs	UC3854A/B	PS/4-83
DN-45	UC3846, UC3856 and UCC3806 Push-Pull PWM Current Mode Control ICs	UCC3806	PS/3-480
DN-45	UC3846, UC3856 and UCC3806 Push-Pull PWM Current Mode Control ICs	UC3856	PS/3-480
DN-46	Highly Efficient Low Power DC to DC Inverter Converts +5V Input to -3V Output	UCC3813	PS/3-482
DN-48	Versatile Low Power SEPIC Converter Accepts Wide Input Voltage Range	UCC3813	PS/3-484
DN-49	Easy Switcher Controls SEPIC Converter for Automotive Applications	UC2577	PS/3-487
DN-50	Simple Techniques for Isolating and Correcting Common Application Problems with UC3625 Brushless DC Motor Drives	UC3625	PS/8-111
DN-51	Programming the UCC3806 Features	UCC3806	PS/3-489
DN-52	Adjustable Electronic Load for Low Voltage DC Applications	UC39432	PS/7-76
DN-53A	Design Considerations for Synchronizing Multiple UC3637 PWMs	UC3637	PS/8-115
DN-54	Innovative Buck Regulator Uses High Side N-Channel Switch without Complex Gate Drive	UCC3813	PS/3-492
DN-56A	Single Switch Flyback Circuit Converts +5VDC to +/-12VDC for RS-232 and RS-422 Applications	UCC3800/1/2/3/4/5	PS/3-492
DN-57	Power Dissipation Considerations for the UC3726N/UC3727N IGBT Driver Pair	UC3726	PS/6-87
<b>DN-58</b>	<b>UCC3912 Programmable Electronic Circuit Breaker - Performance Evaluation and Programming Information</b>	<b>UCC3912</b>	<b>IF/5-102</b>
DN-59A	UCC3889 Bias Supply Controller Evaluation Kit - Schematic and List of Materials	UCC3888	PS/3-494
DN-60	UC3726/UC3727 IGBT Driver Pair Evaluation Kit Testing Procedure	UC3726	PS/6-90
DN-61	A High Performance Linear Regulator for Low Dropout Applications	UC3832/3	PS/5-42
DN-62	Switching Power Supply Topology: Voltage Mode vs. Current Mode	UCC35701	PS/3-496
DN-63	The Current-Doubler Rectifier: An Alternative Rectification Technique for Push-Pull and Bridge Converters	UC3875/6/7/8	PS/3-499

*Publications included in this book are listed in bold.*

# Application/Design Notes by Publication Number



Pub.	Title	IC Featured	Volume/Page
DN-64	Inductorless Bias Supply for Synchronous Rectification and High Side Drive Applications	UCC3583	PS/3-502
DN-65	Considerations in Powering BiCMOS ICs	UCC3809-1,-2	PS/3-505
DN-66	Unitorde - UC3854A/B and UC3855A/B Provide Power Limiting with Sinusoidal Input Current for PFC Front Ends	UC3854A/B	PS/4-86
<b>DN-67</b>	UCC3913 Electronic Circuit Breaker for Negative Voltage Applications		
	Evaluation Kit List of Materials for a -48V/1A Test Circuit	UCC3913	IF/5-105
<b>DN-68</b>	Parrelling UCC3912 Electronic Circuit Breaker ICs	UCC3912	IF/5-106
DN-70	UC3573 Buck Regulator PWM Control IC	UC3573	PS/3-508
DN-72	Lamp Ignitor Circuit	UCC3305	PS/9-52
DN-73	UCC3941 One Volt Boost Converter Demonstration Kit - Schematic and List of Materials	UCC3941-3/5/ADJ	PP/7-101
DN-75	Using the UC3871 and UC3872 Resonant Fluorescent Lamp Drivers in Floating Lamp Applications	UC3872	PP/8-50
DN-76	Closed Loop Temperature Regulation Using the UC3638 H-Bridge Motor Controller and a Thermoelectric Cooler	UC3638	PS/8-118
DN-77	Overcurrent Shutdown with the UC3853	UC3853	PS/4-91
DN-78	High Power Factor Preregulator IC, Evaluation Board, Schematic and List of Materials	UC3853	PS/4-92
DN-79	UCC3750 Demonstration Board Operating Guidelines	UCC3750	PS/9-55
DN-81	UCC3911 Demo Board Information	UCC3911	PP/6-51
DN-82	UCC3958 Demonstration Board Schematic and Bill of Materials	UCC3958	PP/6-55
DN-83	UC3584 DW Secondary Side Post Regulator, Evaluation Board, Schematic, and List of Materials	UC3584	PS/3-511
DN-84	UCC3956 Switch Mode Lithium-Ion Battery Charger Controller Evaluation Board, Schematic and List of Materials	UCC3956	PP/3-413
<b>DN-85</b>	UCC3831 USB Power Controller IC, Evaluation Board – Schematic and List of Materials	UCC3831	IF/5-106
DN-86	UCC3954 Single Cell Lithium-Ion to +3.3V Converter Performance Evaluation Kit – Schematic and List of Materials	UCC3954	PP/7-103
<b>DN-87</b>	UCC3918 Low On-Resistance Hot Swap Power Manager Performance Evaluation Kit , Schematic and List of Materials	UCC3918	IF/5-113
DN-88	UCC5342 IrDA 115.2kbps Transceiver Performance Evaluation Board – Schematic and List of Materials	UCC5342	PP/9-15
DN-89	Comparing the UC3842, UCC3802, and UCC3809 Primary-Side PWM Controllers	UC3842/3/4/5	PS/3-514
DN-90	UCC3858 “Energy Star” PFC Evaluation Board, Schematic and List of Materials	UCC3858	PS/4-94
DN-91	UCC3926DS ±20A Integrated Current Sensor Evaluation Board – Schematic and List of Materials	UCC3926	PS/9-58
<b>DN-92</b>	UCC5630 SCSI Multimode (LVD/SE) Evaluation Board and List of Materials	UCC5630	IF/3-122
DN-93	UCC3957, Three - Four Cell Lithium-Ion Protector Circuit, Evaluation Board and List of Materials	UCC3957	PP/6-57
DN-94	UCC5343, IrDA Transceiver with Encoder/Decoder, Evaluation Board and List of Materials	UCC5343	PP/9-19
<b>DN-95</b>	UCC3919 Hot Swap Power Manager Evaluation Circuit Board and Bill of Materials	UCC3919	IF/5-116
DN-96	UCC3952 Evaluation Board and List of Materials	UCC3952	PP/6-61

Publications included in this book are listed in **bold**.

# Application/Design Notes by Publication Number



Pub.	Title	IC Featured	Volume/Page
DN-97	UCC39411 Low Power Synchronous Boost Converter Evaluation Kit, Schematic and Bill of Materials	UCC39411/2/3	PP/7-106
<b>DN-98</b>	<b>UCC3917 Positive Floating Hot Swap Power Manager Evaluation Kit, Schematic and Bill of Materials</b>	<b>UCC3917</b>	<b>IF/5-120</b>
DN-99	Pulse Edge Transmission (PET) circuit	UCC3961	PS/8-102
DN-501	Using RAM Clear Function with bq3285/bq3287A RTCs	bq3285/bq3287	NV/4-321
DN-502	High-Side Current Sensing with Benchmarq Portable Power Fast-Charge Control IC		PP/3-307
U-100A	UC3842/3/4/5 Provides Low-Cost Current-Mode Control	UC3842/3/4/5	PS/3-532
U-102	UC1637/2637/3637 Switched Mode Controller for DC Motor Drive	UC3637	PS/8-126
U-104	Improved Charging Methods for Lead-Acid Batteries using the UC3906	UC3906	PP/3-388
U-110	1.5MHz Current Mode IC Controlled 50W Power Supply	UC3825	PS/3-546
U-111	Practical Considerations in Current Mode Power Supplies	UC3709	PS/3-558
U-112	A High Precision PWM Transconductance Amplifier for Microstepping using Unitrode's UC3637	UC3637	PS/8-137
U-113	Design Notes on Precision Phase Locked Speed Control for DC Motors	UC3634	PS/8-145
U-115	New Integrated Circuit Produces Robust, Noise Immune System for Brushless DC Motors	UC3625	PS/8-155
U-118	New Driver ICs Optimize High Speed Power MOSFET Switching Characteristics	UC3709	PS/6-92
U-120	A Simplified Approach to DC Motor Modeling for Dynamic Stability Analysis	UC3638	PS/8-162
U-122	A New Family of Integrated Circuits Controls Resonant Mode Power Converters	UC3861-8	PS/3-576
U-127	Unique Chip Pair Simplifies High Side Switch Drive	UC3725	PS/6-107
U-128	The UC3823A,B & UC3825A,B Enhanced Generation of PWM Controllers	UC3823/5A/B/3	PS/3-585
U-129	UC3907 Load Share IC Simplifies Parallels Power Supply Design	UC3907	PS/7-84
U-130	Dedicated ICs Simplify Brushless DC Servo Amplifier Design	UC3625	PS/8-166
U-131	Simple Switchmode Lead-Acid Battery Charger	UC3906	PP/3-417
U-132	Power Factor Correction Using the UC3852 Controlled ON-Time Zero Current Switching Technique	UC3852	PS/4-98
U-133A	UCC3800/1/2/3/4/5 BiCMOS Current Mode Control ICs	UCC3800/1/2/3/4/5	PS/3-594
U-134	UC3854 Controlled Power Factor Correction Circuit Design	UC3854	PS/4-114
U-135	The UC3848 Average Current Mode Controller Squeezes Maximum Performance from Single Switch Converters	UC3848	PS/3-612
U-136A	Phase Shifted, Zero Voltage Transition Design Considerations and the UC3875 PWM Controller	UC3875/6/7/8	PS/3-623
U-137	Practical Considerations in High Performance MOSFET, IGBT & MCT Gate Drive Circuits	UC3709	PS/6-122
U-138	Zero Voltage Switching Resonant Power Conversion	UC3861-8	PS/3-637
U-140	Average Current Mode Control of Switching Power Supplies	UC3849	PS/3-664
U-141	Resonant Fluorescent Lamp Converter Provides Efficient and Compact Solution	UC3871	PP/8-27
U-143C	New Chip Pair Provides Isolated Drive for High Voltage IGBTs	UC3727	PS/6-137
U-144	UCC3806 BiCMOS Current Mode Control IC	UCC3806	PS/3-678
U-148	Dimmable Cold-Cathode Fluorescent Lamp Ballast Design Using the UC3871	UC3871	PP/8-35
U-149A	Simple Off-Line Bias Supply for Very Low Power Applications	UCC3888	PS/3-685

Publications included in this book are listed in **bold**.

# Application/Design Notes by Publication Number



Pub.	Title	IC Featured	Volume/Page
U-150	Applying the UCC3570 Voltage-Mode PWM Controller to Both Off-Line and DC/DC Converter Designs . . . . .	UCC3570 . . . . .	PS/3-696
<b>U-151</b>	<b>UCC3912 Integrated Hot Swap Power Manager™ IC for Hot-Swap and Power Management Applications . . . . .</b>	<b>UCC3912 . . . . .</b>	<b>IF/5-124</b>
U-152	A High Performance Linear Regulator for Low Dropout Applications . . . . .	UC3832/3 . . . . .	PS/5-71
U-153	UC3855A/B High Performance Power Factor Preregulator . . . . .	UC3855A/B . . . . .	PS/4-134
U-154	The New UC3879 Phase Shifted PWM Controller Simplifies the Design of Zero Voltage Transition Full-Bridge Converters . . . . .	UC3879 . . . . .	PS/3-709
U-155	Implementing Multi-State Charge Algorithm with the UC3909 Switchmode Lead-Acid Battery Charger Controller . . . . .	UC3909 . . . . .	PP/3-426
U-156	The UC3886 PWM Controller Uses Average Current Mode Control to Meet the Transient Regulation Performance of High End Processors. . . . .	UC3886 . . . . .	PS/3-717
U-157	Fueling the Megaprocessor - A DC/DC Converter Design Review Featuring the UC3886 and UC3910 . . . . .	UC3886 . . . . .	PS/3-741
U-158	The UC3910 Combines Programmability, Accuracy and Integrated Functions to Control and Monitor High End Processor Power Supplies . . . . .	UC3910 . . . . .	PS/3-771
U-159	Boost Power Factor Corrector Design with the UC3853 . . . . .	UC3853 . . . . .	PS/4-154
U-161	Powering a 35W DC Metal Halide High Intensity Discharge (HID) Lamp using the UCC3305 HID Lamp Controller . . . . .	UCC3305 . . . . .	PS/9-61
U-163	The UC3902 Load Share Controller and Its Performance in Distributed Power Systems . . . . .	UC3902 . . . . .	PS/7-100
U-164	The UCC3884 Frequency Foldback Pulse Width Modulator . . . . .	UCC3884 . . . . .	PS/3-783
U-165	Design Review: Isolated 50W Flyback with the UCC3809 Primary Side Controller and the UC3965 Precision Reference and Error Amplifier . . . . .	UC3965 . . . . .	PS/3-800
U-166	An Off-Line Lead-Acid Charger Based on the UC3909. . . . .	UC3909 . . . . .	PP/3-399
U-167	UC3578 Telecom Buck Converter Evaluation Board . . . . .	UC3578 . . . . .	PS/3-818
U-168	Implementing an Off-Line Lithium-Ion Charger Using the UCC3809 Primary Side Controller and the UCC3956 Battery Charger Controller . . . . .	UCC3809-1,-2 . . . . .	PS/3-455
U-169	The New UCC3750 Source Ringer Controller Provides A Complete Control Solution for a Four-Quadrant Fluback Converter . . . . .	UCC3750 . . . . .	PS/9-76
U-500	Using the bq4845 for a Low-Cost RTC/NVSRAM Subsystem. . . . .	bq4845 . . . . .	NV/4-310
U-502	Time-Base Oscillator for RTC ICs . . . . .		NV/4-322
U-503	Using the bq3285/7E in a Green or Portable Environment . . . . .	bq3285/7E . . . . .	NV/4-331
U-504	Using the bq2000/T to Control Fast Charge . . . . .	bq2000/T . . . . .	PP/3-262
U-505	Using the bq2003 to Control Fast Charge . . . . .	bq2003 . . . . .	PP/3-273
U-506	Step-Down Switching Current Regulation Using the bq2003 Fast-Charge IC . . . . .	bq2003 . . . . .	PP/3-291
U-507	Using the bq2005 to Control Fast Charge . . . . .	bq2005 . . . . .	PP/3-309
U-508	Using the bq2007 Display Mode Options . . . . .	bq2007 . . . . .	PP/3-327
U-509	Using the bq2007 Enhanced Features for Fast Charge . . . . .	bq2007 . . . . .	PP/3-332
U-510	Using the bq2031 to Charge Lead-Acid Batteries . . . . .	bq2031 . . . . .	PP/3-346
U-511	Switch-Mode Power Conversion Using the bq2031 . . . . .	bq2031 . . . . .	PP/3-360
U-512	Using the bq2902/3 Rechargeable Alkaline ICs . . . . .	bq2902/3 . . . . .	PP/3-376
U-513	Using the bq2040: Smart Battery System Gas Gauge IC . . . . .	bq2040 . . . . .	PP/4-372
U-514	Using the bq2010: A Tutorial for Gas Gauging . . . . .	bq2010 . . . . .	PP/4-390
U-93	A New Integrated Circuit for Current Mode Control . . . . .	UC3846/7 . . . . .	PS/3-518
U-94	The UC1901 Simplifies the Problem of Isolated Feedback in Switching Regulators . . . . .	UC3901 . . . . .	PS/7-72
U-95	Versatile UC1834 Optimizes Linear Regulator Efficiency . . . . .	UC3834 . . . . .	PS/5-49
U-97	Modeling, Analysis and Compensation of the Current Mode Converter . . . . .	UCC3813 . . . . .	PS/3-526
U-99	UC3717 and L-C Filter Reduce EMI and Chopping Losses in Step Motor . . . . .	UC3717 . . . . .	PS/8-118

Publications included in this book are listed in **bold**.



## INTERFACE (IF)

### Hot Swap Power Managers

Discrete Electronic Hot Swap Power Manager Design .....	<b>DN-30</b>
Hot Swap Protection .....	<b>U-151</b>
Integrated Hot Swap Power Manager .....	<b>U-151</b>
Paralleling Multiple UCC3912s .....	<b>DN-68</b>
UCC3912 Programming and Demo Kit .....	<b>DN-58</b>
UCC3913/21 Negative Floating Hot Swap Power Manager Evaluation Kit, Schematic and List of Materials .....	<b>DN-67</b>
UCC3917 Positive Floating Hot Swap Power Manager Evaluation Kit, Schematic and Bill of Materials .....	<b>DN-98</b>
UCC3918 Low On-Resistance Hot Swap Power Manager Demo Board .....	<b>DN-87</b>
UCC3919 Hot Swap Power Manager Evaluation Circuit and List of Materials ..	<b>DN-95</b>

## SCSI

UCC5630 SCSI Multimode (LVD/SE) Evaluation Board and List of Materials ..	<b>DN-92</b>
---	--------------

## NONVOLATILE SRAMs AND REAL-TIME CLOCKS (NV)

### Real-Time Clocks

Low-Cost RTC/NVSRAM Subsystem .....	<b>U-500</b>
Typical PC Hookups for Real-Time Clocks .....	<b>U-501</b>
Time-Base Oscillator for Real-Time Clock ICs .....	<b>U-502</b>
Real-Time Clocks in a Green Environment .....	<b>U-503</b>
Using the RAM Clear Function .....	<b>DN-501</b>

## PORTABLE POWER (PP)

### Battery Charging

Battery Charger Basics .....	<b>U-155</b>
Current Sense Considerations .....	<b>U-155</b>
Lead Acid Battery Charger .....	<b>U-104, U-131, U-510</b>
Lead Acid Charging Algorithms .....	<b>U-131</b>
Switchmode Lead-Acid Battery Charger .....	<b>U-131, U-155</b>
Off-Line Lead Acid Battery Charger .....	<b>U-166</b>
Off-Line Lithium Ion Battery Charger .....	<b>DN-84, U-168</b>
High-Side Current Sensing with Fast-Charge ICs .....	<b>DN-502</b>
NiMH and NiCd Switch-Mode Battery Charger .....	<b>U-506</b>
NiMH and NiCd Battery Charger with $\Delta T/\Delta t$ and $-\Delta V$ Termination .....	<b>U-505, U-507</b>
Fast-Charge IC with LCD and LED and Other Advanced Features .....	<b>U-508, U-509</b>
Fast-Charge IC for Switch-Mode Power Conversion .....	<b>U-511</b>





Rechargeable Alkaline Battery Charger . . . . . U-512  
 Multi-Chemistry Battery Charger . . . . . U-504

## **Battery Capacity Monitoring**

Smart Battery System Gas Gauge . . . . . U-513  
 Tutorial for Gas Gauging . . . . . U-514

## **Cold Cathode Fluorescent Lamp Driver (CCFL)**

ZVS Resonant Converter Drive . . . . . U-141  
 CCFL and LCD Bias Circuit . . . . . U-148  
 Floating Lamp Driver . . . . . DN-75

## **Lighting Circuits**

CCFL and LCD Bias Circuit . . . . . U-148

## **Reference Designs**

### ***CCFL Drives***

ZVS Converters . . . . . U-141, U-148

### ***Battery Protection***

2-Cell Lithium Ion Battery Protection . . . . . DN-81  
 Single Cell Lithium Ion Battery Protection . . . . . DN-82  
 3 or 4 Cell Lithium Ion Battery Protection . . . . . DN-93  
 Enhanced Single Cell Lithium Ion Battery Protection . . . . . DN-96

### ***Battery Charging***

Lead Acid Battery Charger . . . . . U-131  
 Off-Line Lead Acid Battery Charger . . . . . U-166  
 Off-Line Lithium Ion Battery Charger . . . . . DN-84, U-168

## **POWER SUPPLY CONTROL (PS)**

### **Bias Supplies**

Buck-Boost Supply . . . . . DN-38  
 High Efficiency Startup / Bootstrap Circuits . . . . . U-111 (fig. 38, 39)  
 Inductorless Bias Supply . . . . . DN-64  
 Negative Bias Supply . . . . . DN-43  
 Novel Regulated Bias Supply for PFC Applications . . . . . DN-39E (fig. 5)  
 Self-Generating High Side Gate Bias Supply . . . . . DN-54  
 Simple Off-Line Bias Supply . . . . . DN-65, U-149A  
 UCC3889 Demo Kit . . . . . DN-59A

### **Bootstrap Circuits**

High Efficiency Startup / Bootstrap Circuits . . . . . U-111 (figs. 38, 39)  
 Startup / Bootstrapping . . . . . U-128, U-133A

*Publications included in this book are listed in bold.*



## Charge Pumps

Inverting Charge Pump .....	U-100A
Non-Inverting Charge Pump .....	U-100A
Simple Inverting and Non-Inverting Circuits .....	U-133A (fig. 26)

## Class-D Amplifiers

Class-D Amplifier for Thermoelectric Devices .....	DN-76
--	-------

## Control Techniques

Current / Voltage Mode Tradeoffs .....	DN-62
--	-------

### **Average Current Mode**

Average Current Control .....	U-131, U-135, U-140, U-156, U-157, U-159
Average Current Sensing .....	U-140, DN-41

### **Peak Current Mode**

BiMOS Controller Advantages .....	DN-42A
Comparison of Economy Primary Side Controllers .....	DN-89
Frequency Foldback .....	DN-29, U-164
Low Power Controller .....	U-144
Peak Current Mode Control ...	U-93, U-100A, U-133A, U-144, U-164, U-165, U-170
Practical Considerations .....	U-111, U133A
Programming the UCC3806 .....	DN-51
Slope Compensation .....	U-97, U-110, U-111
Soft Start .....	U-133
Using Current Mode ICs in Voltage Mode Applications .....	U-111

### **Voltage Mode**

Primary Side Controller .....	U-150, U-167
Voltage Feedforward .....	U-150
Using Current Mode ICs in Voltage Mode Applications .....	U-111

## Current Sensing

Average Current Sensing .....	U-135, U-140, U-156, U-157
Current Sense Amplifiers .....	U-156, U-157
Using PCB Traces to Sense Current .....	DN-71
UCC3926 +/- 20 Amp Integrated Circuit for Current Sensing .....	DN-91

## Distributed Power

Load Sharing .....	U-129, U-163
--------------------	--------------

## Electronic Loads

Adjustable Load for Low Voltage DC Applications .....	DN-52
---	-------

## Feedback Techniques

Average Current Sensing .....	U-135, U-140
Optocoupler Feedback .....	DN-32, DN-33, U-160, U-165
Transformer Isolation .....	U-94, DN-41

*Publications included in this book are listed in **bold**.*



## Frequency Foldback

Simple Frequency Foldback Circuit . . . . .	DN-29
UCC3884 Frequency Foldback PWM . . . . .	U-164

## Gate Drives

Gate Drive Considerations . . . . .	U-137
Gate Drive Pulse Transformer Design . . . . .	U-127
General Gate Drive Information . . . . .	U-111
Integrated Drivers . . . . .	U-143C, DN-35
UC3726 / UC3727 Demo Kit Testing . . . . .	DN-60
UC3726 / UC3727 Power Considerations . . . . .	DN-57

## Isolation Amplifier

Discrete Iso-Amp Design . . . . .	DN-19
-----------------------------------	-------

## Leading Edge Blanking

Current Sense Noise . . . . .	U-128
LEB Implementation . . . . .	U-128, U-133A

## Lighting Circuits

Driving Floating Fluorescent Lamps . . . . .	DN-75
HID Lamp Controller . . . . .	U-161
Lamp Ignitor Circuits . . . . .	DN-72
ZVS Resonant Converter Drive . . . . .	U-141

## Linear Voltage Regulators

External Power Device Configurations . . . . .	U-95, U-104
Linear Regulator Controllers . . . . .	U-95, U-116, U-152
Loadsharing . . . . .	U-129
Microprocessor Regulator Design . . . . .	U-152, DN-61
Multiple LDO Regulator Demo Kit . . . . .	DN-74
Small Signal Analysis . . . . .	U-95, U-152

## Load Sharing

Application Circuits . . . . .	U-129, U-163
Load Sharing Control Techniques . . . . .	U-129, U-163
Startup Considerations . . . . .	U-129

## Magnetics Design

1.5MHz Forward Converter Main Transformer . . . . .	U-110
225KHz Off-Line Transformer . . . . .	U-150
Gate Drive Pulse Transformer Design . . . . .	U-127
SEPIC Converter Inductor Design . . . . .	U-161

Publications included in this book are listed in **bold**.



## Microprocessor Voltage Regulators

### **Linear Regulators**

High Performance LDO Controller . . . . . U-152, DN-61

### **Switching Regulators**

4Bit DAC and Voltage Monitor for Pentium®Pro . . . . . U-158

Average I-Mode Controller for Pentium®Pro . . . . . U-156

Fueling the MegaProcessor - A DC/DC Converter Design Review . . . . . U-157

## Motor Control

### **Brush DC Motors**

PWM DC Motor Controller . . . . . U-102

Synchronizing Multiple UC3637 Oscillators . . . . . DN-53A

### **Brushless DC Motors**

3-Phase Controller . . . . . U-115, U-130

Current Loop Design . . . . . U-130

Four Quadrant Control . . . . . U-130

Fixed Off-Time Modulation . . . . . U-106

Integrated 3-Phase Control / Driver . . . . . U-106

Power Supply Bus Clamp . . . . . U-130

Trouble Shooting UC3625 Applications . . . . . DN-50

### **Phase Locked Loops**

Loop Filter Design . . . . . U-113

Small Signal Analysis . . . . . U-113

### **Power H-Bridge Design**

H-Bridge Power Amplifier . . . . . U-102, U-112

### **Small Signal Modeling**

Current Loop, Small Signal Analysis . . . . . U-112

Motor Modeling . . . . . U-102, U-113, U-120

Velocity Loop, Small Signal Analysis . . . . . U-102, U-113

### **Stepper Motors**

Microstepping Transconductance Amplifier . . . . . U-112

Reducing EMI in Stepper Motor Drives . . . . . U-99

## Optocoupler Isolation

Optocoupler Feedback Drive Techniques . . . . . DN-32, DN-33

Simple Circuit Modifications Enhance Optocoupler Performance . . . . . U-160

## Post Regulation

UC3584 Evaluation Board . . . . . DN-83

## Power Device Drivers

Calculating Average Gate Drive Current . . . . . U-156

Determining Gate Charge . . . . . U-118, U-137

Direct Coupled Drivers . . . . . U-118, U-137

*Publications included in this book are listed in bold.*



Gate Drive Considerations	U-137, U143C
General Gate Drive Information	U-111
Isolated High Side Switch Drive	U-127
Modeling the Power MOSFET	U-118
Power Dissipation Analysis	U-137
Transformer Coupled Drivers	U-118
UC3726 / UC3727 Power Considerations	DN-57

## Power Factor Correction

Active Power Factor Correction Description	U-134, U-159
Controlled On-Time, Zero Current Switched PFC	U-132
Controlled On-Time, Zero Current Switching	U-132
Current Sensing	U-134, U-153
Current Synthesizer	U-153
Distortion Sources	U-134
Effects of Discharge Current on Maximum Duty Cycle	DN-40
Fault Protection Circuits	DN-77
Novel Regulated Bias Supply for PFC Applications	DN-39E (fig. 5)
Optimizing Circuit Performance	DN-39E
Power Limiting Features	DN-66
UC3853 Evaluation Board	DN-78
UC3854 Demo Board	DN-44
UC3855 Design Example	U-153
UCC3858 Evaluation Board	DN-90
Voltage Feedforward Circuitry	U-132, U-134
ZVT Techniques	U-153

## PWM Oscillators

Noise Sensitivity	U-100A
Universal Synchronization Techniques	U-100A, U-111, U-133A
Voltage Feedforward Oscillators	U-94

## Rectification

Alternative Full-Wave Rectifier Topology	DN-63
--	-------

## Resonant Converters

Resonant Tank Considerations	U-136
Transformer Coupled Equations	U-138
Zero-Voltage Switching	U-122, U-136
Zero-Current Switching	U-122

## Ring Generator Controllers

Design Procedure and Circuit Analysis	U-169
UCC3750 Demo Board	DN-79

Publications included in this book are listed in **bold**.



## Secondary Side Regulation

Secondary Side Regulator .....	U-139
UC3584 Switching Post Regulator Evaluation Board .....	DN-83

## Small Signal Analysis

Average Current Mode .....	U-135, U-140, U-157
Average Current Mode PFC .....	U-134, U-153, U-159
Buck Regulator .....	U-97
CCFL Ballast .....	U-148
Error Amplifier Response .....	U-95, U-100A
Load Models .....	U-95
Push-Pull Forward Converter .....	U-110

## Subharmonic Oscillation

Slope Compensation .....	U-95, U-110
--------------------------	-------------

## Supervisory Functions

Overvoltage Protection .....	U-158
Startup and Fault Protection .....	DN-26

## Switching Regulators - Reference Designs

### **Flyback Converters**

1W, 5VIN, +/-12VOUT, RS-232 / RS-422 Converter .....	DN-56A
25W, Off-Line, 5V, +/-12VOUT, Flyback .....	U-100A
50W, -48VIN, 5V, Flyback .....	U-165
60W, Off-Line, 5V, 12VOUT, Flyback .....	U-94

### **Forward Converters**

20W, 48VIN, 5VOUT Voltage Mode Forward Converter .....	U-150
50W, 18-26VIN, 5VOUT, ZVS Forward Converter .....	U-138
50W, Off-Line, 12VOUT, Voltage Mode Converter .....	U-150
200W, Off-Line, 5V, +/-15VOUT, Average I-Mode Forward Converter .....	U-135

### **Non-Isolated Buck, Boost, Flyback and SEPIC Converters**

5VIN, 3.3VOUT, Buck Regulator .....	DN-54
200mW, 5VIN, -3VOUT, Flyback Converter .....	DN-46
500mW, 1VIN, Adjustable Output Voltage, Boost .....	DN-73
5W, 12VIN, 5VOUT, Buck Regulator .....	DN-70
35W, +48VIN, 5VOUT, Buck .....	U-167
HID Lamp Controller, SEPIC .....	U-161
Low Power Synchronous Boost Converter Evaluation Kit .....	DN-97
Peak Current Mode, Buck / Boost Designs .....	U-133A
Pentium®Pro Converter with Adjustable Output, Buck .....	U-157
Single Cell Lithium Ion to +3.3V Converter Evaluation Kit .....	DN-86
Versatile Low Power SEPIC Converter .....	DN-48

## **Push-Pull Converters**

50W, -48VIN, 5VOUT, 1.5MHz Peak I Mode .....	U-110
75W, 48VIN, 5VOUT, Isolated Push-Pull .....	U-170
500W, -48 VIN, 5VOUT Push-Pull .....	U-100A
Push-Pull Forward Converter .....	U-93

## **Full Bridge**

500W, 400VIN, 48VOUT, ZVT Converter .....	U-136
---	-------

## **Post Regulation**

150KHz, 3.3VOUT, Switching Post Regulator .....	DN-83
---	-------

## **Power Factor Correction**

85W, 350VOUT, Zero Current Switched PFC .....	U-132
250W, 400VOUT, Average Current Mode PFC .....	U-134
250W, 385VOUT, Average I-Mode PFC .....	DN-44
100W, 75KHz, 385VOUT, Average Current Mode PFC .....	DN-78
250W, 385VOUT, Average Current Mode PFC .....	DN-90
500W, 410VOUT, Average Current Mode, ZVT, PFC .....	U-153
Controlled, On-Time, Zero Current Switched PFC .....	U-132

## **Soft Switching ZVT Converters**

500W, 400VIN, 48VOUT, ZVT Converter .....	U-136
---	-------

## **Ring Generator Controllers**

85V, 15 REN, Ring Generator .....	DN-79, U-169
-----------------------------------	--------------

## **Synchronization**

Universal Synchronization Techniques .....	U-100A, U-111, U-133A
--	-----------------------

## **Thermoelectric Drivers**

Class-D Amplifier for Thermoelectric Devices .....	DN-76
--	-------

## **Zero Current Switching**

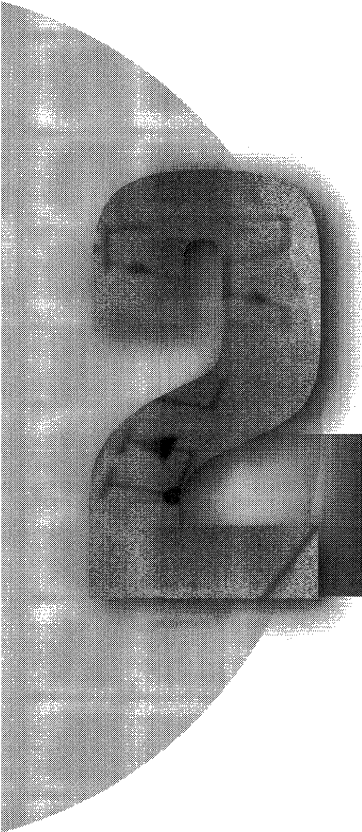
Controlled, On-Time, Zero Current Switched PFC .....	U-132
Resonant Mode Control .....	U-122

## **Zero Voltage Switching**

Design Examples .....	U-138
Phase Shifted Full-Bridge Controller .....	U-154
Resonant Mode ZVS .....	U-122, U-136, U-138
Transformer Coupled Design Equations .....	U-138
ZVS Topologies .....	U-138







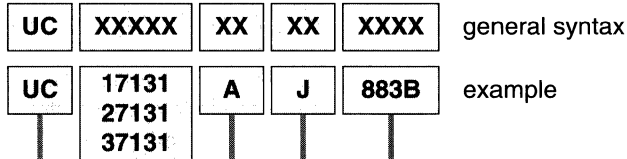
# General Information



# Ordering Information



(see Benchmark ordering information page for "bq" prefix products)



**PREFIX**  
 "UC" ~ Linear Integrated Circuits  
 "UCC" ~ BiCMOS

**PART NUMBER**  
 First digit "1" ~ Military Temperature Range\*  
 First digit "2" ~ Industrial Temperature Range\*  
 First digit "3" ~ Commercial Temperature Range\*  
 (\*consult individual data sheets for specific temperature ranges on each part)

**SCREEN/PROCESSING OPTIONS**  
 "883" ~ MIL-STD-883  
 Class Q of MIL-PRF-38535

**PACKAGE OPTIONS**

**OPTIONAL GRADES**  
 A or B ~ Improved Version

Letter Designator	Package Type
D	Plastic Narrow Body (150 mil) SOIC
DW	Plastic Wide Body (300 mil) SOIC
DP	Plastic Narrow Body Power SOIC
DS	Plastic Narrow Body (150 mil) SOIC with Shunt Current Sense
DWP	Plastic Wide Body Power SOIC
FP	Power Plastic Metric Quad Flatpack (MQFP)
FQ	Power Low Profile Quad Flatpack (LQFP)
FQP	Power Plastic Low Profile Quad Flatpack (LQFP)
J	Ceramic Dual-in-Line (300 mil and 600 mil)
L	Ceramic Leadless Chip Carrier
LP	Power LCC
M	Quasi Shrink Small Outline (150 mil body, 0.635mm pitch)
MWP	Power Quasi Shrink Small Outline (300 mil body, 0.88mm pitch)
N	Plastic Dual-in-Line (300mil and 600 mil)
P	Mini SOIC
PW	Thin Shrink Small Outline (TSSOP)
PWP	Power TSSOP
Q	Plastic Leadless Chip Carrier (PLCC)
QP	Power (PLCC)
SP	Power Ceramic Dual-in-Line
T	Plastic TO-220
TD	Plastic TO-263 Power Surface Mount
Z	Zig-Zag In-Line Power Package



Quality and innovation characterize our products!

Our commitment begins with our Quality Assurance System. In October 1992, Unitrode Corporation became one of the first in our industry to achieve IS/ISO 9001/EN 29001 Registration. Currently, Unitrode's quality-assurance system exceeds the rigorous requirements of ISO 9001-1994 and MIL-PRF-38535. Quality Management Institute (QMI) has awarded Unitrode a Certificate of Registration (Number 003889) indicating compliance with ISO 9001, for the design and manufacture of analog integrated circuits. For its Singapore branch, Unitrode also holds an ISO 9002 Certificate of Registration (Number 93-2-0148) from the Singapore Productivity and Standards Board, for semiconductor IC manufacturing, factory inspection and testing, and wafer-probe testing.

In August 1996, the Defense Supply Center-Columbus (DSCC) granted Unitrode full Q-Level certification to MIL-PRF-38535 for listing on the Qualified Manufacturers List (QML). In addition, DSCC continued Unitrode's laboratory suitability by certifying that our test methods accord with MIL-STD-883.

All Unitrode products and manufacturing processes meet extensive qualification requirements. Qualification ensures that

- Customer and/or design requirements are translated efficiently into manufacturing requirements
- All groups are integrated, coordinated, and capable
- Our processes are manufacturable
- Our products meet or exceed the reliability requirements of our customers

### ***Process Qualification***

When a process qualification is required, Quality Assurance organizes a cross-functional team that prepares and completes a formal qualification plan according to QP 2515. Key requirements for major processes include

- Documented design rules and process specifications; process and device simulation with full SPICE models
- Completed process control plan with identified critical, significant, and non-critical characteristics
- Implemented process-control charts
- Demonstrated Cp, and Cpk for significant and critical characteristics
- Documented out-of-control action plans (OCAPs)
- Completed quality audit
- Process-acceptance criteria
- Gage R&R studies
- Construction analyses



## ***Reliability Testing***

Our extensive reliability requirements ensure that our new processes demonstrate, for commercial products under typical use conditions, a 200 FIT rate or better (failures in time calculated at 70°C, 0.7eV activation energy, 60% confidence) at the time of qualification, using a minimum of three wafer lots. Figure 1, on page 2-6, lists typical reliability tests performed for new major processes.

## ***Package Qualification***

Whenever a new package is introduced, in addition to qualifying the manufacturing process using requirements appropriate to assembly processing, Unitrode performs a complete battery of reliability tests.

Figure 2, on page 2-7, depicts typical requirements for plastic packages. Figure 3, on page 2-8, presents the requirements for hermetic packages.

## ***Product Qualification***

New products must be manufactured using qualified processes and packages. Unitrode's new product qualification consists of 2 major milestones: Release For Introduction (RFI) and Release to Production (RTP).

RFI is the term Unitrode uses to describe devices that

- Are built on a qualified process
- Meet the preliminary data sheet over the specified temperature range
- Demonstrate no infant mortality
- Have been verified in the appropriate application
- Have had ESD measured and classified
- Have a released preliminary test program

Devices that achieve RTP meet all the RFI requirements (plus additional requirements) and complete Unitrode's product qualification. Typical RTP requirements include

- Bench and temperature characterization
- Demonstrated compliance to all data-sheet parameters
- Cp, Cpk targets met for all untrimmed parameters in data sheet
- Test program complete and released to production
- Machine capability less than 5% of the device specification range
- Test schematic(s), test program(s), bonding diagram(s), and burn-in diagrams approved and released
- ESD measured and classified (human body model)
- Passed latch-up and HTOL test to 1000 hours
- Final data sheet approved and released.



### **Results**

As a result of our comprehensive qualification procedures, we are able to report long-term device reliability of 4.0 FIT or lower for combined functional families. This figure is estimated from millions of hours of life-testing at accelerated temperatures.

### **Failure Analysis**

If we do experience a failure during pre-production qualification, we have an extensive failure-analysis lab to determine and fix the root cause before the products reach our customers. We begin by verifying the failure to published specifications. We provide written failure-verification to our customers within 72 hours.

This notification is followed by failure-mode identification through laboratory analyses such as electrical measurements, optical and electron microscopy, radiography, device deprocessing, microsectioning, spectrometry, and cholesteric liquid-crystal analysis. Unitrode maintains a ten-day cycle to identify moderately complex failures from receipt of failed units.

If needed, closed-loop corrective action is managed through our Corrective Action Continuous Improvement Team using the 8D approach.

### **Customer Notification**

Our continuous improvement requires an occasional product or process change. Unitrode notifies the customer (a 90-day notification whenever possible) when

- A waiver to a customer's or Unitrode's specification is required before shipment of material deemed suitable by Unitrode or our customer
- Any product, process or mask change requires a change to Unitrode's data sheet, SCD, purchase order, or customer specification
- Any product, process or mask change reduces ESD rating
- A change occurs in manufacturing location, including wafer fabrication, assembly, and test
- There is a change in wafer starting material, dielectric, passivation or metalization materials and certain assembly materials
- A major change occurs in manufacturing process on a critical or significant characteristic, according to our process control plan(s)
- A manufacturing process changes a characteristic that is a reliability concern
- Unitrode's operating procedures or quality systems change significantly



### ***Total Business Excellence***

Unitrode's policy of Total Business Excellence (TBE) goes well beyond the scope of Quality Assurance. A company demonstrating Total Business Excellence must have more rigorous business practices than industry standards and a supporting culture to enable and improve these practices.

TBE requires continuous improvement. It is a never-ending search for ways to improve everything we do, and a pledge to ultimately translate improvements into better products and services for our customers.

Our goals include improved designs that meet the broadest spectrum of application needs, improved translation of customer requirements into actual product performance characteristics, improved understanding of process capabilities to improve the product introduction process, higher productivity, less scrap and rework, and lower production costs.

For example, Unitrode internal qualification procedures now include rigorous qualification of our suppliers, subcontractors, and the wafer fabrication (both major new processes and unit processes). Each qualification is managed by a cross-functional quality team. Qualification requirements include detailed and advanced process control plans, out-of-control action plans (OCAPs), demonstrated process-capability, advanced statistical process-control techniques, and Gage R&R studies.

We've improved many of our internal practices: for example, shop floor control, document management, customer notification, and corrective action. We've replaced our old hardcopy system with electronically based systems using the best software systems and relational databases.

Total Business Excellence affects every department, activity, and product, from initial concept to end-user installation and operation.

For all of these reasons we deliver high-quality, reliable products. Our continuing quest to improve everything we do yields better and more reliable products and services for our customers. That is what earns customer loyalty!



Figure 1. Typical Reliability Tests for New Processes

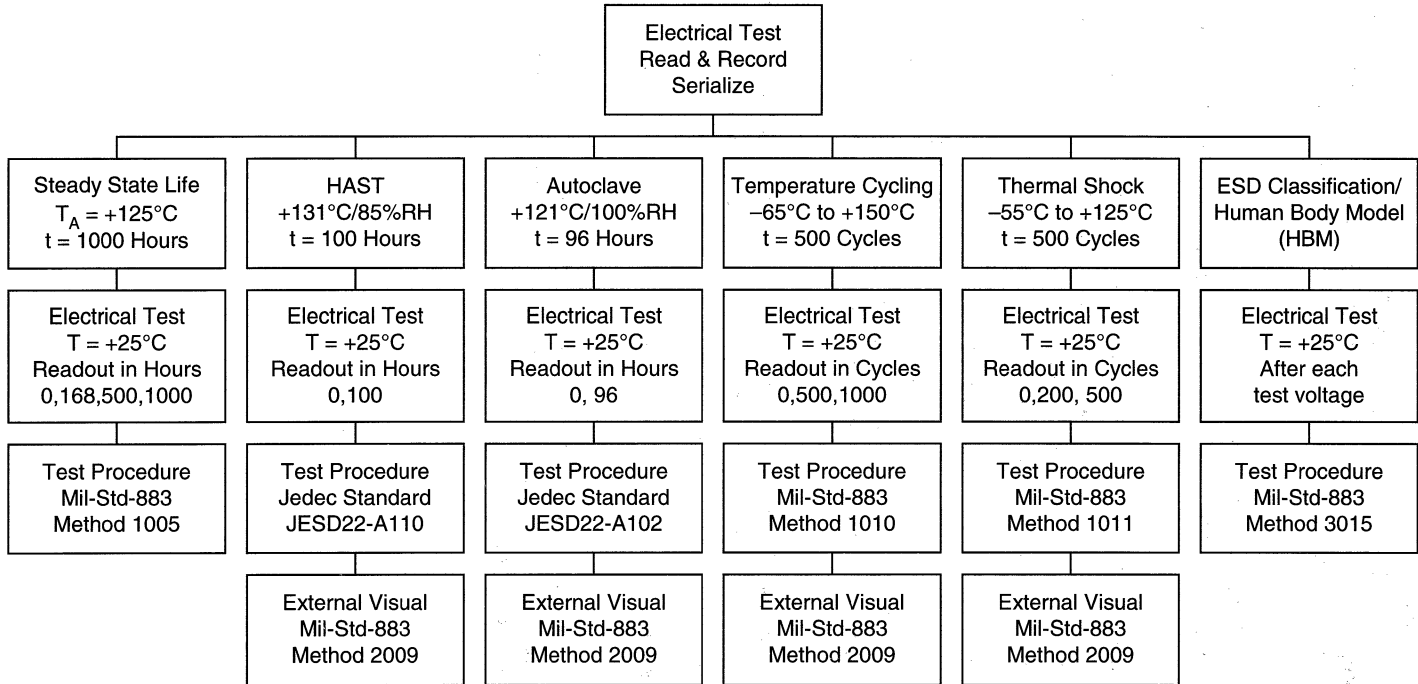




Figure 2. Typical Reliability Requirements for Plastic Packages

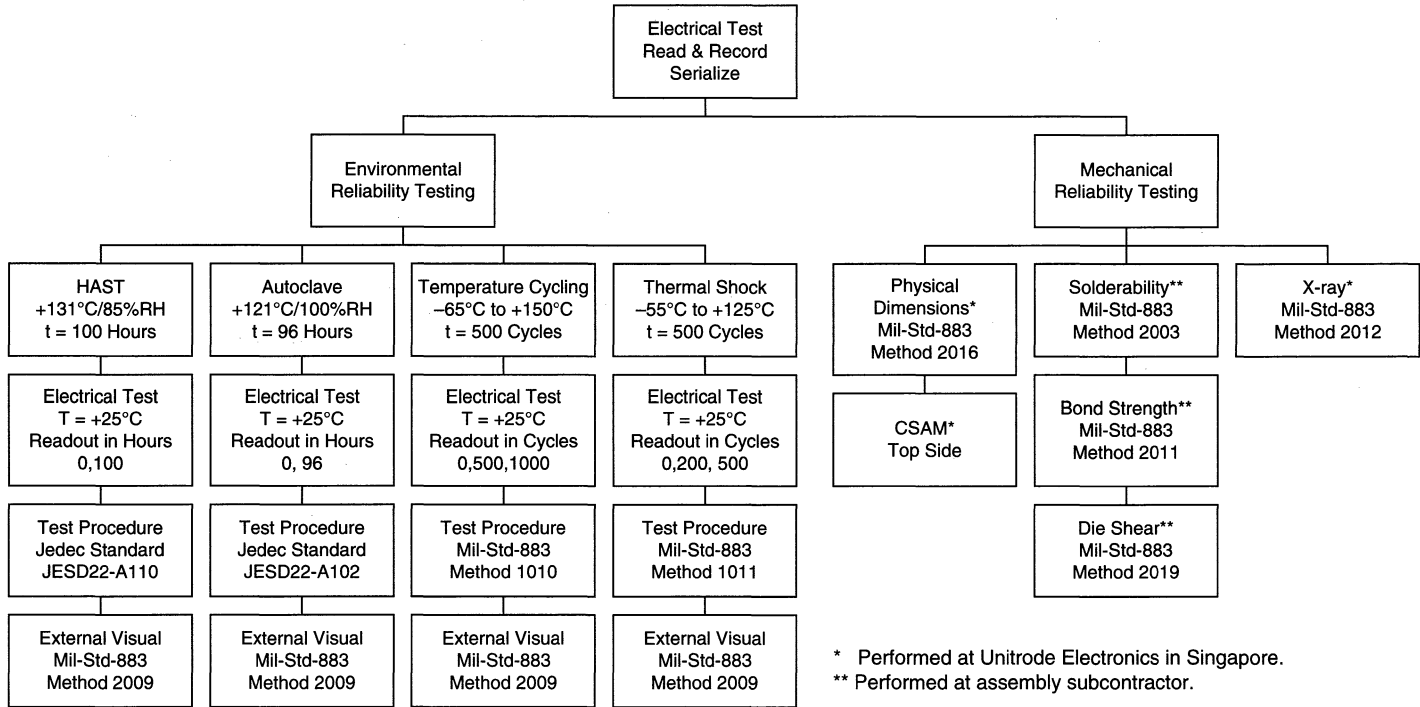
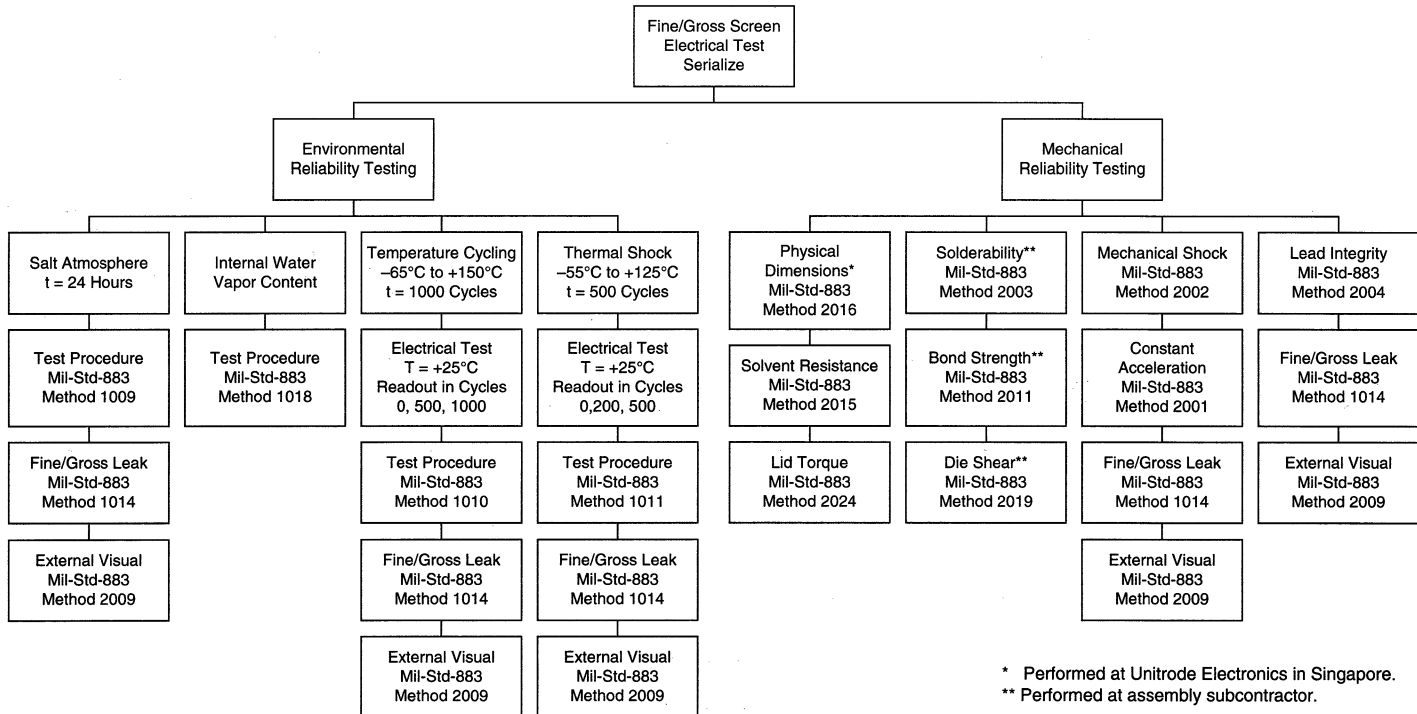


Figure 3. Typical Reliability Requirements for Hermetic Packages



## **Description**

Unitrode offers most of our products in die and/or wafer form through our die distributors. Unitrode's die utilize either linear bipolar or BiCMOS process technology featuring tight beta controls and resistor matching techniques. Die thickness is either 12 mils or 15 mils, +/- 1 mil. Interconnects are an alloy of copper and aluminum (to reduce the possibility of electromigration). Most product's backside material is pure silicon.

## **Testing**

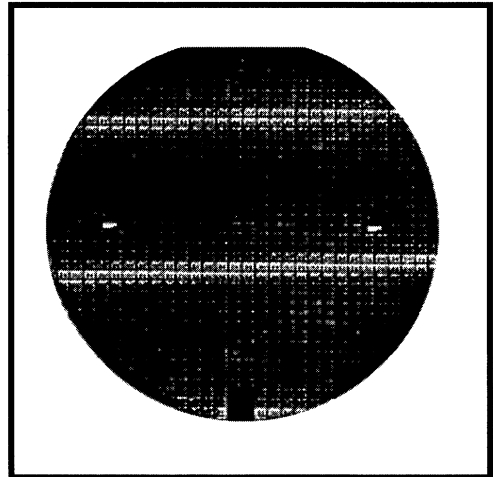
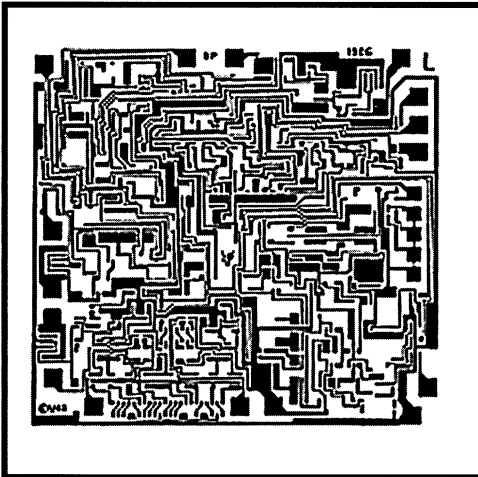
All products are tested at two separate points: (1) wafer process parameter in-line probing and (2) ambient electrical test probing. Die are tested to full data sheet specifications, with the exception of some high power or high speed devices where production probe equipment limit the test environment.

## **Inspection**

Unitrode performs visual inspections on military grade die to MIL-STD-883, Method 2010, conditions A or B, or to individual customer specifications. Die is supplied in "waffle pack" or single wafer form. Standard wafers are 100 mils, generic 4- or 6-inch diameter.

## **Ordering**

Product is available from Unitrode's authorized die distributors, and part numbers end with the suffix "c" for chip form or "chipwfr" for wafer form.





**Small Computer Systems Interface (SCSI)**

UCC5510 Low Voltage Differential (LVD/SE) SCSI 9 Line Terminator . . . . . 3-5  
UCC5628 Multimode SCSI 14 Line Terminator . . . . . 3-78  
UCC5638 Multimode SCSI 15 Line Terminator . . . . . 3-94  
UCC5639 Multimode SCSI 15 Line Terminator with Reverse Disconnect . . . . . 3-99  
UCC5640 Low Voltage Differential (LVD) SCSI 9 Line Terminator . . . . . 3-104  
UCC5641 Low Voltage Differential (LVD/SE) SCSI 9 Line Terminator Reverse Disconnect . . . . . 3-108  
UCC5672 Multi-mode (LVD/SE) SCSI 9 Line Terminator . . . . . 3-120

**Bus Bias Generators**

UC561 Low Voltage Differential SCSI (LVD) 27 Line Regulator Set . . . . . 4-7  
UC563 32 Line VME Bus Bias Generator . . . . . 4-10

**Hot Swap Power Manager™ ICs**

UCC3917 Positive Floating Hot Swap Power Manager . . . . . 5-53  
UCC3981 Universal Serial Bus Hot Swap Power Controller . . . . . 5-88  
UCC39811 Universal Serial Bus Hot Swap Power Controller . . . . . 5-91  
UCC3985 Programmable CompactPCI Hot Swap Power Manager . . . . . 5-94  
UCC3995 Simple Single Channel External N-FET Hot Swap Power Manager . . . 5-98  
UCC3996 Dual Sequencing Hot Swap Power Manager . . . . . 5-100

**Drivers/Receiver Transceivers**

UC5351 CAN Transceiver with Voltage Regulator . . . . . 6-27



**SCSI**



# Selection Guides ~ SCSI



## SCSI

Multimode/ LVD SCSI Active Terminators	UNITRODE PART NUMBER				
	UCC5628+	UCC5630	UCC5632	UCC5638+	UCC5639+
<b>Channels</b>	14	9	9	15	15
<b>Channel Capacitance</b>	4	4	4	4	4
<b>Termination Impedance</b>	Single110, Differential 105, Common Mode 150	Single110, Differential 105, Common Mode 150	Single 110, Differential 105, Common Mode 150	Single 110, Differential 105, Common Mode 150	Single 110, Differential 105, Common Mode 150
<b>Disconnect High or Low</b>	H	H	H	H	L
<b>TempwrVoltage Range</b>	2.7 - 5.25	2.7 - 5.25	2.7 - 5.25	2.7 - 5.25	2.7 - 5.25
<b>Supports Active Negation</b>	Y	Y	Y	Y	Y
<b>SCSI Hot Plug Current</b>	<10nA	<10nA	<10nA	<10nA	<10nA
<b>Type LVD or SE /LVD</b>	LVD / SE	LVD / SE	LVD / SE	LVD / SE	LVD / SE
<b>Page Number</b>	IF/3-78	IF/3-83	IF/3-93	IF/3-94	IF/3-99

Multimode/ LVD SCSI Active Terminators	UNITRODE PART NUMBER		
	UCC5640+	UCC5641+	UCC5646
<b>Channels</b>	9	9	27
<b>Channel Capacitance</b>	3	3	3
<b>Termination Impedance</b>	Differential 105, Common Mode 150	Differential 105, Common Mode 150	Differential 105, Common Mode 150
<b>Disconnect High or Low</b>	H	L	H
<b>TempwrVoltage Range</b>	2.7 - 5.25	2.7 - 5.25	2.7 - 5.25
<b>SCSI Hot Plug Current</b>	<10nA	<10nA	<10nA
<b>Type LVD or SE /LVD</b>	LVD	LVD	LVD
<b>Page Number</b>	IF/3-104	IF/3-108	IF/3-112

+ New Product



# Selection Guides ~ SCSI



## SCSI (cont.)

Multimode LVD SCSI Active Terminators	UNITRODE PART NUMBER			
	UCC5510+	UCC5630A	UCC5672+	UCC5680
Channels	9	9	9	9
Channel Capacitance	4	4	4	4
Termination Impedance	Single110, Differential 105, Common Mode 150	Single110, Differential 105, Common Mode 150	Single110, Differential 105, Common Mode 150	Single 110, Differential 105, Common Mode 150
Diff B input filter	N	N	Y	Y
Disconnect High or Low	N/A	H	H	H
TempwrVoltage Range	2.7 - 5.25	2.7 - 5.25	2.7 - 5.25	2.7 - 5.25
Supports Active Negation	Y	Y	Y	Y
SCSI Hot Plug Current	<10nA	<10nA	<10nA	<10nA
Type LVD or SE / LVD	LVD / SE	LVD / SE	LVD / SE	LVD
Page Number	IF/3-5	IF/3-87	IF/3-120	IF/3-121

Single Ended SCSI Active Terminators	UNITRODE PART NUMBER				
	UC5601	UC5602	UC5603	UC5604	UC5605
Channels	18	18	9	9	9
Channel Capacitance	10	11	6	9	4
Termination Impedance	110	110	110	110	110
Disconnect High or Low	H	H	H	H	L
TempwrVoltage Range	4 - 5.25	4 - 5.25	4 - 5.25	4 - 5.25	4 - 5.25
Supports Active Negation	N	N	Y	N	Y
SCSI Hot Plug Current	<10nA	<10nA	<10nA	<10nA	<10nA
Type SE, LVD or SE / LVD	SE	SE	SE	SE	SE
Page Number	IF/3-9	IF/3-13	IF/3-18	IF/3-22	IF/3-26

+ New Product





## SCSI (cont.)

Single Ended SCSI Active Terminators	UNITRODE PART NUMBER				
	UCC5606	UC5607	UC5608	UC5609	UC5612
Channels	9	18	18	18	9
Channel Capacitance	1.8	8	6	6	4
Termination Impedance	110 & 2500	110	110	110	110
Disconnect High or Low	L	2L	H	L	H
TempwrVoltage Range	2.7 - 5.25	4 - 5.25	4 - 5.25	4 - 5.25	4 - 5.25
Supports Active Negation	Y	Y	Y	Y	Y
SCSI Hot Plug Current	<10nA	<10nA	<10nA	<10nA	<10nA
Type SE, LVD or SE / LVD	SE	SE	SE	SE	SE
Page Number	IF/3-30	IF/3-34	IF/3-37	IF/3-40	IF/3-43

Single Ended SCSI Active Terminators	UNITRODE PART NUMBER				
	UC5613	UCC5614	UCC5617	UCC5618	UCC5619
Channels	9	9	18	18	27
Channel Capacitance	3	1.8	2.5	2.5	3
Termination Impedance	110	110 & 2500	110	110	110
Disconnect High or Low	H	H	L	H	L
TempwrVoltage Range	4 - 5.25	2.7 - 5.25	4 - 5.25	4 - 5.25	4 - 5.25
Supports Active Negation	Y	Y	Y	Y	Y
SCSI Hot Plug Current	<10nA	<10nA	<10nA	<10nA	<10nA
Type SE, LVD or SE / LVD	SE	SE	SE	SE	SE
Page Number	IF/3-47	IF/3-51	IF/3-55	IF/3-59	IF/3-63

+ New Product



# Selection Guides ~ SCSI



## SCSI (cont.)

Single Ended SCSI Active Terminators	UNITRODE PART NUMBER		
	UCC5620	UCC5621	UCC5622
Channels	27	27	27
Channel Capacitance	3	3	3
Termination Impedance	110	110	110
Disconnect High or Low	H	Split Low	Split High
TempwrVoltage Range	4 - 5.25	4 - 5.25	4 - 5.25
Supports Active Negation	Y	Y	Y
SCSI Hot Plug Current	<10nA	<10nA	<10nA
Type SE, LVD or SE / LVD	SE	SE	SE
Page Number	IF/3-66	IF/3-70	IF/3-74

Special Functions Circuit	UNITRODE PART NUMBER		
	UCC5661		
Part Name	Ethernet Coaxial Impedance Monitor		
Description	Contains all the Functions Required to Monitor Ethernet Coaxial Systems and is Compatible with IEEE 802.3, 10Base5, 10Base2, and 10BaseT		
Page Number	IF/3-112		

+ *New Product*

# Low Voltage Differential (LVD/SE) SCSI 9 Line Terminator

## FEATURES

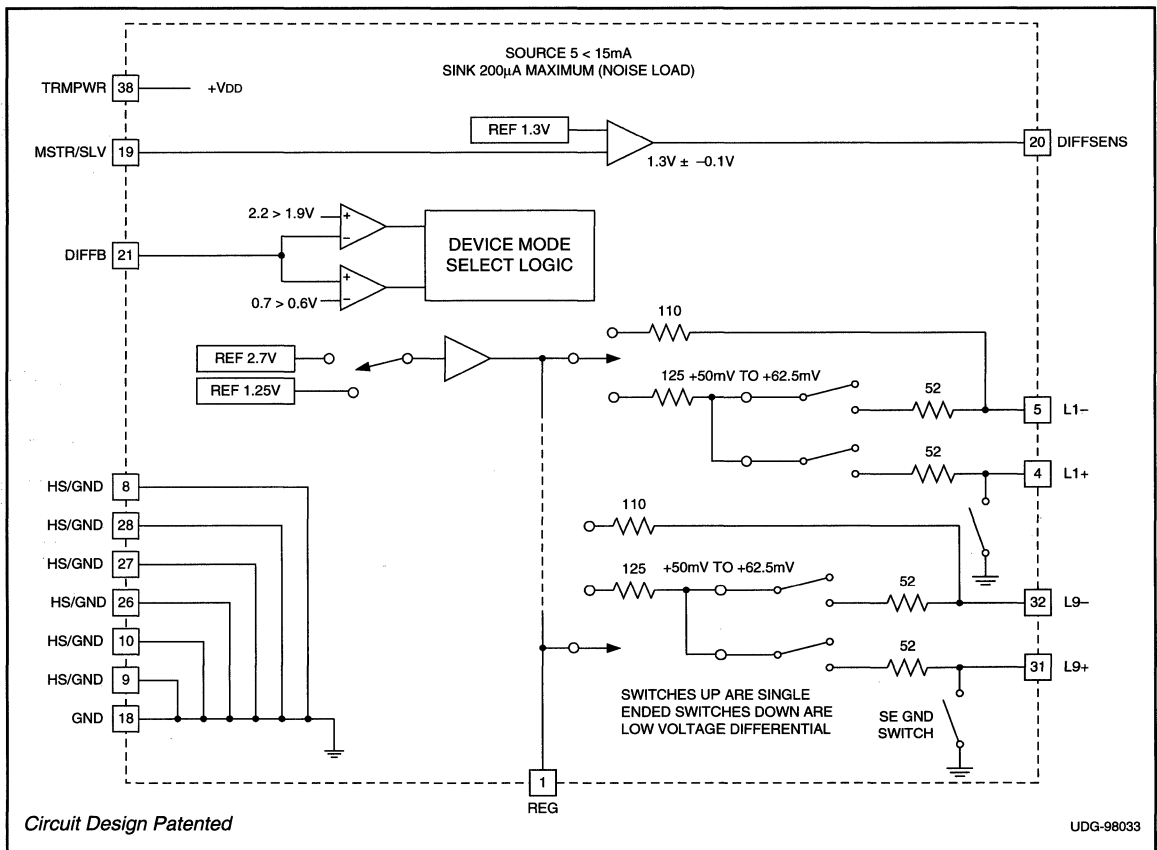
- Auto Selection Multi-Mode Single Ended or Low Voltage Differential Termination
- 3.0V to 5.25V Operation
- Differential Failsafe Bias
- Thermal Packaging for Low Junction Temperature and Better MTBF
- Master/Slave Inputs
- Supports Active Negation
- 3pF Channel Capacitance

## DESCRIPTION

The UCC5510 Multi-Mode Low Voltage Differential and Single Ended Terminator is specially designed for automatic termination of Single-Ended or Low Voltage Differential SCSI Bus. The Multi-Mode operation of this device allows for a transition system design for the next generation SCSI Parallel Interface (SPI-2). Compliant with SPI-2, with SPI and Fast-20 the UCC5510 incorporates all the functions necessary to properly terminate the SCSI Bus and has internal thermal shut down and short circuit limiting.



## BLOCK DIAGRAM



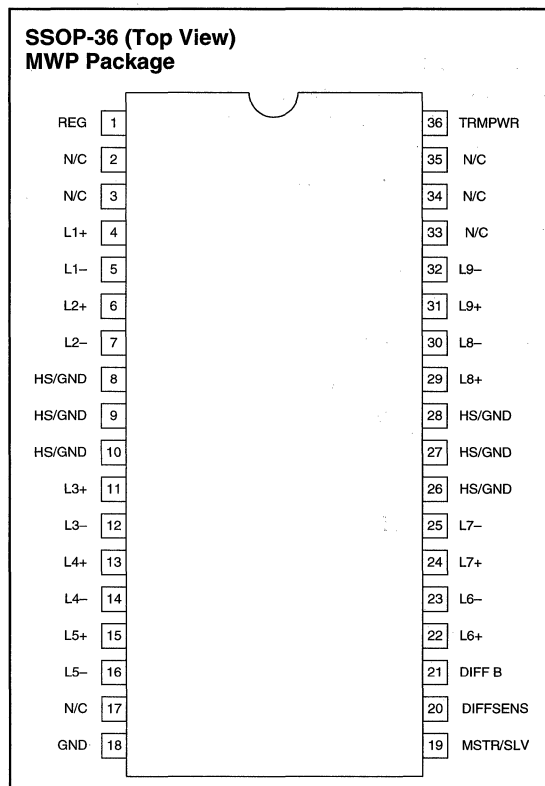
**ABSOLUTE MAXIMUM RATINGS**

TRMPWR Voltage	6V
Signal Line Voltage	0V to TRMPWR
Package Power Dissipation	2W
Storage Temperature	-65°C to +150°C
Junction Temperature	-55°C to +150°C
Lead Temperature (Soldering, 10sec.)	+300°C

**RECOMMENDED OPERATING CONDITIONS**

TRMPWR Voltage	3.0V TO 5.25V
----------------	---------------

All voltages are with respect to pin 1. Currents are positive into, negative out of the specified terminal. Consult Packaging Section of the Databook for thermal limitations and considerations of packages.

**CONNECTION DIAGRAM**

**ELECTRICAL CHARACTERISTICS:** Unless otherwise specified,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ , TRMPWR = 3.3V.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>TRMPWR Supply Current Section</b>					
TRMPWR Supply Current				20	mA
	Disable Terminator, in DISCNCT mode.			35	$\mu\text{A}$
<b>Regulator Section</b>					
1.25V Regulator	LVD Mode	1.15	1.25	1.35	V
1.25V Regulator Source Current	LVD Mode, Differential Sense Floating	-80	-100		mA
1.25V Regulator Sink Current	LVD Mode, Differential Sense Floating	80	100		mA
1.3V Regulator	DIFFSENS	1.2	1.3	1.4	V
1.3V Regulator Source Current	DIFFSENS	-5		-15	mA
1.3V Regulator Sink Current	DIFFSENS	50		200	$\mu\text{A}$
2.7V Regulator	Single Ended Mode	2.5	2.7	3	V
2.7V Regulator Source Current	Single Ended Mode	-200	-400	-800	mA
2.7V Regulator Sink Current	Single Ended Mode	100	200	400	mA
2.7V Regulator Dropout Voltage	$V_{\text{TRMPWR}} - (V_{\text{REG}} - 3.0 \text{ Min})$			200	mV

**ELECTRICAL CHARACTERISTICS:** Unless otherwise specified, TA = 0°C to 70°C, TRMPWR = 3.3V.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Differential Termination Section</b>					
Differential Impedance		100	105	110	Ω
Common Mode Impedance		110	125	165	Ω
Differential Bias Voltage	Drivers Tri-stated	100		125	mV
Common Mode Bias			1.25		V
Output Capacitance	Single Ended Measurement to Ground (Note 1)			3	pF
<b>Single Ended Termination Section</b>					
Impedance		102.3	110	117.7	Ω
Termination Current	Signal Level 0.2V	-21	-23	-24	mA
	Signal Level 0.5V			-22.4	mA
Output Leakage	Disabled, TRMPWR = 0V to 5.25V			400	nA
Output Capacitance	Single Ended Measurement to Ground (Note 1)			3	pF
Single Ended GND SW Impedance				60	Ω
<b>Differential Sense (DIFF B) Input Sections</b>					
DIFFB Single Ended Threshold		0.6		0.7	V
DIFFB Sense LVD Threshold		1.9		2.2	V
DIFFB Input Current	V <sub>DIFFB</sub> = 0V and 3.3V	-10		10	μA
<b>Master/Slave (MSTR/SLV) Input Section</b>					
MSTR/SLV Threshold		0.8		2	V
MSTR/SLV Input Current		-30		30	μA

Note 1: Guaranteed by design. Not 100% tested in production.

## PIN DESCRIPTIONS

**DIFFB:** DIFF SENSE filter pin should be connected to a 0.1μF capacitor to GND and 20k resistor to SCSI/Bus DIFF SENSE Line.

**DIFFSENS:** The SCSI bus DIFF SENSE line is driven to 1.3V to detect what type of devices are connected to the SCSI bus.

**HS/GND:** Heat Sink GND. Connect to large area PC board traces to increase power dissipation capability.

**GND:** Power Supply Return.

**L1– thru L9–:** Signal line/active line for single ended or

negative line in differential applications for the SCSI bus.

**L1+ thru L9+:** Ground line for single ended or positive line for differential applications for the SCSI bus.

**MSTR/SLV:** Mode select for the non-controlling terminator. MSTR enables the 1.3V regulator, when the terminator is enabled. **Note:** This function will be removed on further generations of the multimode terminators.

**REG:** Regulator bypass, must be connected to a 4.7μF capacitor.

**TRMPWR:** V<sub>IN</sub> 3.0V to 5.25V supply.

## APPLICATION INFORMATION

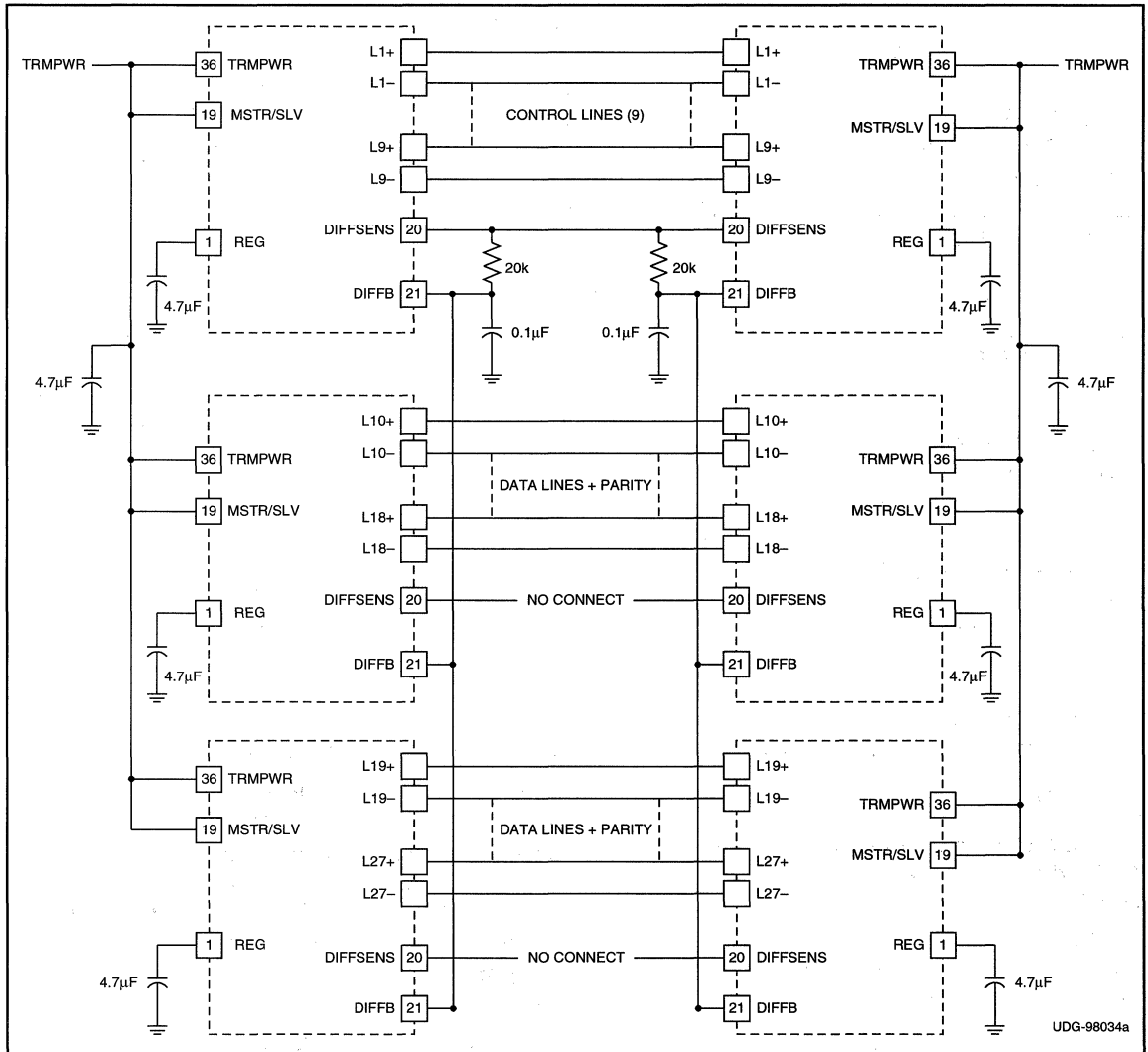


Figure 1. Application Drawing

The master is selected by placing TRMPWR on MSTR/SLV and enabling the 1.3V regulator. The master is the only terminator connected directly to the DIFFSENS bus line. All the other terminators receive a mode signal by connecting the DIFFFB pins together.

The balancing capacitor is very important during high speed operation. The typical capacitor balance between the positive (+) and negative (-) signals is 0.1pF, except

in the MWP package where between L8 and L9 the balance is 0.23pF and 0.4pF respectively. The negative (-) signal line has a higher capacitance than the positive (+) signal line. The FQP package has typically 0.2pF less capacitance than the MWP package, where the typical balance is 0.1pF except for L8 and L3, where the balance is 0.4pF.

*Note: The master/slave function will not be included in future Unitorde terminators.*

# SCSI Active Terminator

## FEATURES

- Complies with SCSI, SCSI-2 Standards
- 10pF Channel Capacitance During Disconnect
- Active Termination for 18 Lines
- Logic Command Disconnects all Termination Lines
- Low Supply Current in Disconnect Mode
- Trimmed Regulator for Accurate Termination Current
- Current Limit and Thermal Shutdown Protection
- 110 Ohm Termination
- Meets SCSI Hot Plugging

## DESCRIPTION

The UC5601 provides precision resistive pull-up to a 2.9V reference for all 18 lines in a Small Computer Systems Interface (SCSI) bus cable. The SCSI-2 standard recommends active termination at both ends of every cable segment utilizing single ended drivers and receivers.

Internal circuit trimming is utilized, first to reduce resistor tolerances to  $\pm 3\%$  and then to adjust the regulator's output voltage to insure termination current accuracy of  $\pm 3\%$ .

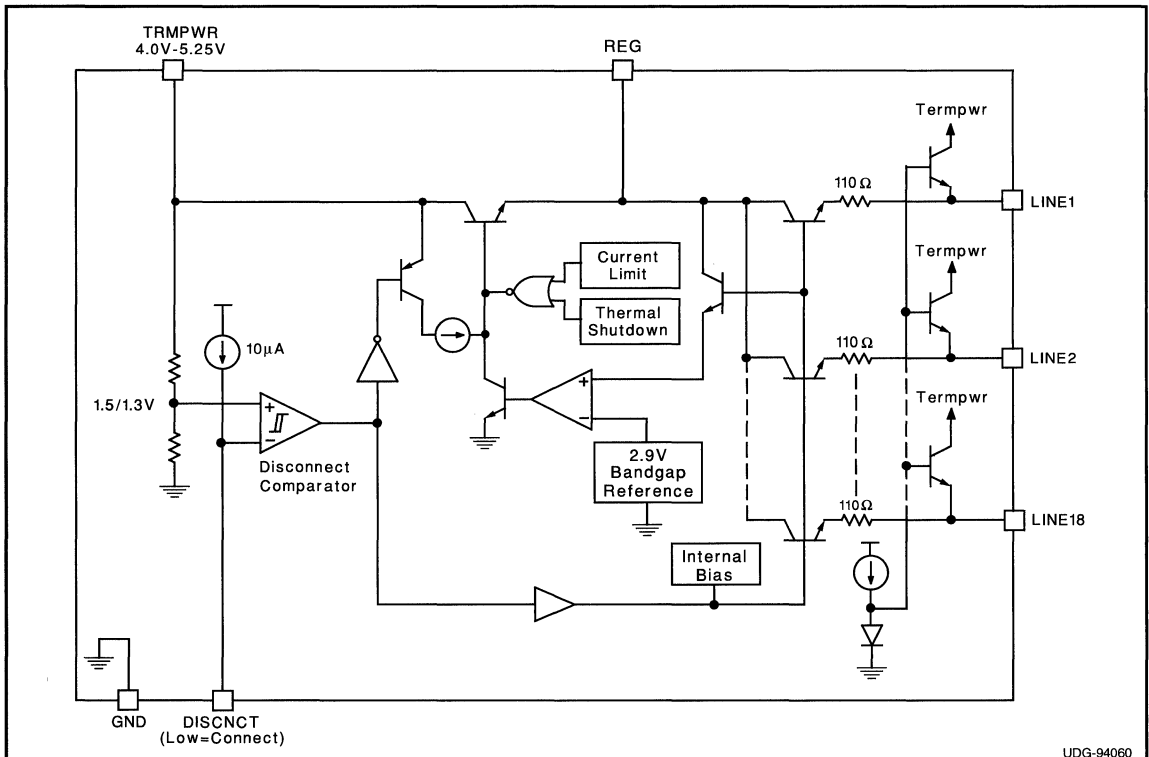
The UC5601 provides a disconnect feature which, upon a logic command, disconnects all terminating resistors, and turns off the regulator; greatly reducing standby power.

Other features include negative clamping on all signal lines, 20mA of active negation sink current capability, regulator current limiting, and thermal shut-down protection.

This device is offered in low thermal resistance versions of the industry standard 28 pin wide body SOIC and PLCC, as well as a 24 pin DIL plastic package.



## BLOCK DIAGRAM



Circuit Design Patented

**ABSOLUTE MAXIMUM RATINGS**

Tempwr Voltage .....	+7V
Signal Line Voltage .....	0V to +7V
Regulator Output Current .....	1A
Storage Temperature .....	-65°C to +150°C
Operating Temperature .....	-55°C to +150°C
Lead Temperature (Soldering, 10 Sec.) .....	+300°C

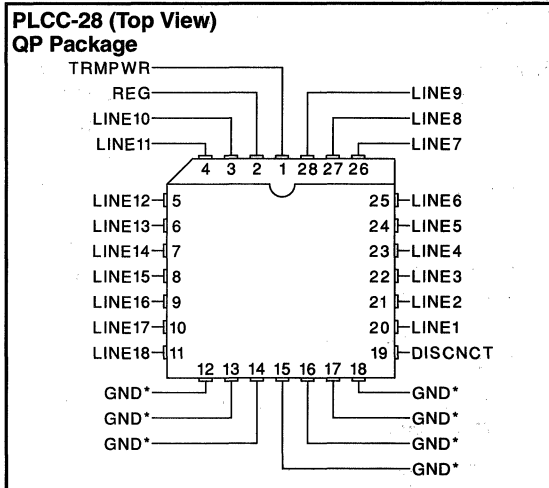
Unless otherwise specified all voltages are with respect to Ground. Currents are positive into, negative out of the specified terminal.

Consult Packaging Section of Unitrode Integrated Circuits datobook for thermal limitations and considerations of packages.

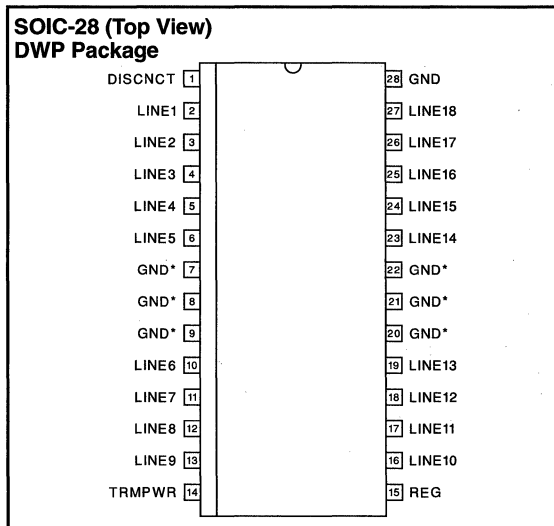
**RECOMMENDED OPERATING CONDITIONS**

Tempwr Voltage .....	4.0V to 5.25V
Signal Line Voltage .....	0V to +3V
Disconnect Input Voltage .....	0V to Tempwr

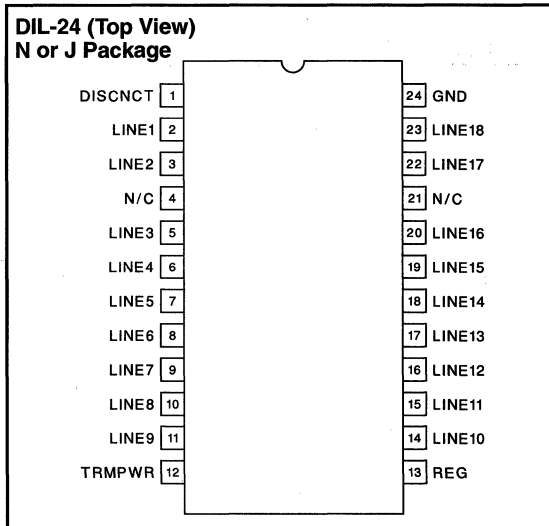
**CONNECTION DIAGRAMS**



\* QP package pins 12 - 18 serve as both heatsink and signal ground.



\* DWP package pin 28 serves as signal ground; pins 7, 8, 9, 20, 21, 22 serve as heatsink/ground.



Note: Drawings are not to scale.



**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ .  
TRMPWR = 4.75V, DISCNCT = 0V.  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS	
<b>Supply Current Section</b>						
Tempwr Supply Current	All termination lines = Open		17	25	mA	
	All termination lines = 0.5V		400	430	mA	
Power Down Mode	DISCNCT = Open		100	150	$\mu\text{A}$	
<b>Output Section (Termination Lines)</b>						
Termination Impedance	$\Delta\text{LINE} = -5\text{mA}$ to $-15\text{mA}$	107	110	113	$\Omega$	
Output High Voltage	$V_{\text{TRMPWR}} = 4\text{V}$ (Note 1)	2.65	2.9		V	
Max Output Current	$V_{\text{LINE}} = 0.5\text{V}$	-21.1	-21.7	-22.4	mA	
	$V_{\text{LINE}} = 0.5\text{V}$ , TRMPWR = 4V (Note 1)	-19.8	-21.7	-22.4	mA	
Output Clamp Level	$I_{\text{LINE}} = -30\text{mA}$	-0.2	-0.05	0.1	V	
Output Leakage	DISCNCT = 4V	TRMPWR = 0V to 5.25V REG = 0V	$V_{\text{LINE}} = 0$ to 4V	10	400	nA
			$V_{\text{LINE}} = 5.25\text{V}$		100	$\mu\text{A}$
		TRMPWR = 0V to 5.25V, REG = Open $V_{\text{LINE}} = 0\text{V}$ to 5.25V		10	400	nA
Output Capacitance	DISCNCT = Open (Note 2)		10	12	pF	
<b>Regulator Section</b>						
Regulator Output Voltage		2.8	2.9	3.0	V	
Line Regulation	TRMPWR = 4V to 6V		10	20	mV	
Load Regulation	$I_{\text{REG}} = 0$ to $-400\text{mA}$		20	50	mV	
Drop Out Voltage	All Termination Lines = 0.5V		1.0	1.2	V	
Short Circuit Current	$V_{\text{REG}} = 0\text{V}$	-450	-650	-850	mA	
Current Sink Capability	$V_{\text{REG}} = 3.5\text{V}$	8	20	25	mA	
Thermal Shutdown			170		$^\circ\text{C}$	
<b>Disconnect Section</b>						
Disconnect Threshold		1.3	1.5	1.7	V	
Threshold Hysteresis		100	160	250	mV	
Input Current	DISCNCT = 0V		10	15	$\mu\text{A}$	

Note 1: Measuring each termination line while other 17 are low (0.5V).

Note 2: Guaranteed by design. Not 100% tested in production.

## THERMAL DATA

QP package: (see packaging section of UICC data book for more details on thermal performance)

Thermal Resistance Junction to Leads,  $\theta_{jL}$  .....  $15^\circ\text{C/W}$

Thermal Resistance Junction to Ambient,  $\theta_{ja}$  .....  $30^\circ\text{--}40^\circ\text{C/W}$

DWP package:

Thermal Resistance Junction to Leads,  $\theta_{jL}$  .....  $18^\circ\text{C/W}$

Thermal Resistance Junction to Ambient,  $\theta_{ja}$  .....  $33^\circ\text{--}43^\circ\text{C/W}$

J package:

Thermal Resistance Junction to Leads,  $\theta_{jL}$  .....  $40^\circ\text{C/W}$

Thermal Resistance Junction to Ambient,  $\theta_{ja}$  .....  $75^\circ\text{--}85^\circ\text{C/W}$

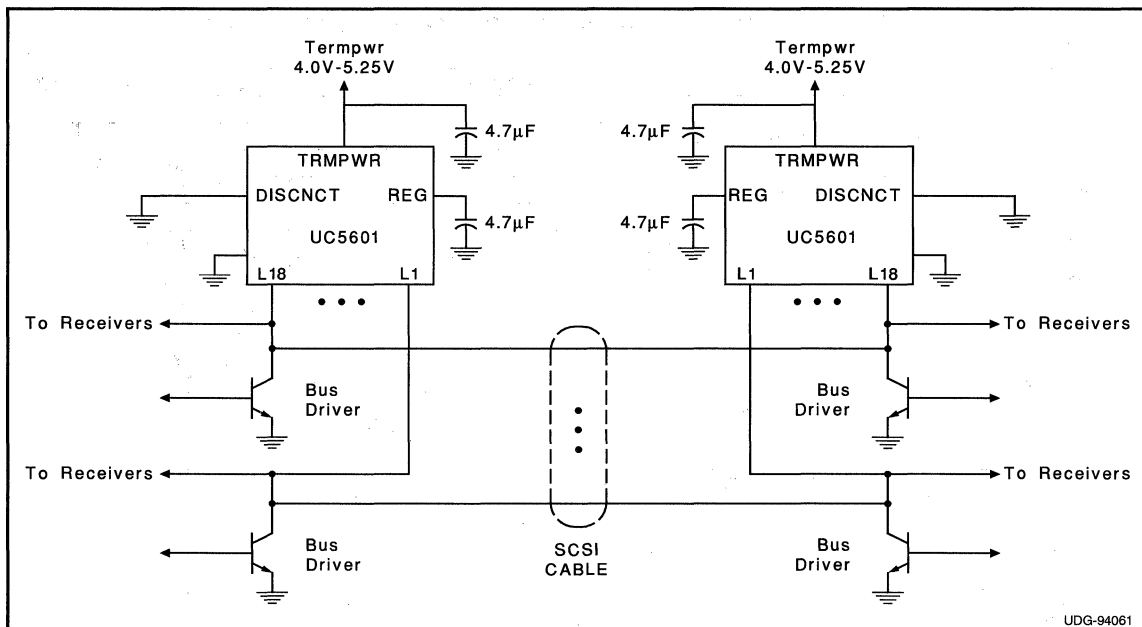
N package:

Thermal Resistance Junction to Leads,  $\theta_{jL}$  .....  $50^\circ\text{C/W}$

Thermal Resistance Junction to Ambient,  $\theta_{ja}$  .....  $95^\circ\text{--}105^\circ\text{C/W}$

Note: The above numbers for  $\theta_{jL}$  are maximums for the limiting thermal resistance of the package in a standard mounting configuration. The  $\theta_{ja}$  numbers are meant to be guidelines for the thermal performance of the device/pc-board system. All of the above numbers assume no ambient airflow.





Typical SCSI Bus Configuration Using the UC5601

### A Look at the Response of a SCSI-2 Cable

Figure 1 shows a single line of a SCSI cable. The driver is an open collector type which when asserted pulls low, and when negated the termination resistance serves as the pull-up.

Figure 2 shows a worst case scenario of mid cable deassertion with a close proximity receiver. The voltage  $V_{STEP}$  is defined as:

$$V_{STEP} = V_{OL} + I_O Z_0$$

$V_{OL}$  = Driver Output Low Voltage

$I_O$  = Current from Receiving Terminator

$Z_0$  = Cable Characteristic Impedance

$$I_O = \frac{V_{REG} - V_{OL}}{110}$$

In the pursuit of higher data rates, sampling could occur during this step portion, therefore it is important to ensure that the step is as high as possible to get the most noise margin. For this reason the UC5601 is trimmed so that the output current ( $I_O$ ) is as close as possible to the SCSI max current spec of 22.4mA. The Termination impedance is initially trimmed on the IC to 110 ohms typical, then the regulator voltage is trimmed for the highest output current to within 22.4mA.

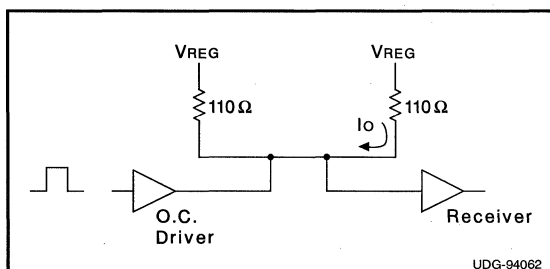


Figure 1. A Single Line of a SCSI Cable

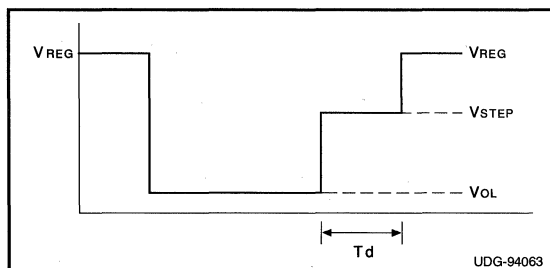


Figure 2. A Typical Response of a SCSI Cable

# SCSI Active Terminator

## FEATURES

- Complies with SCSI, SCSI-2 Standards
- 10pF Channel Capacitance During Disconnect
- Active Termination for 18 Lines
- Logic Command Disconnects all Termination Lines
- Low Supply Current in Disconnect Mode
- Trimmed Regulator for Accurate Termination Current
- Current Limit and Thermal Shutdown Protection
- 110 Ohm Termination
- Meets SCSI Hot Plugging

## DESCRIPTION

The UC5602 is a pin compatible version of its predecessor, the UC5601, and is targeted for high volume applications which require active termination, but not the high performance of the UC5601. The major differences are relaxed output current and termination tolerances, and the absence of low side clamps.

The UC5602 provides 18 lines of active termination for a SCSI (Small Computer Systems Interface) parallel bus. The SCSI-2 standard recommends active termination at both ends of the cable segment, and SCSI-3 will make it a requirement.

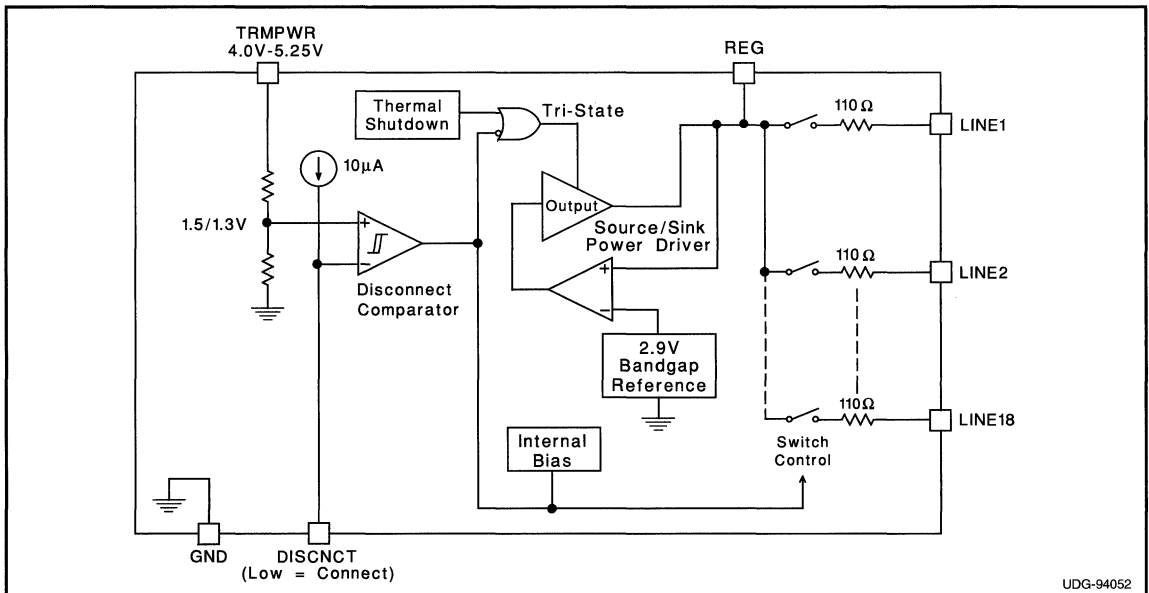
The UC5602 provides a disconnect feature which, when opened or driven high, will disconnect all terminating resistors, and disables the regulator; greatly reducing standby power. The output channels remain high impedance even without Tempwr applied.

Internal circuit trimming is utilized, first to trim the impedance to a 7% tolerance; and then most importantly, to trim the output current 7% tolerance, as close to the max SCSI as possible, which maximizes noise margin in fast SCSI operation.

Other features include thermal shutdown, current limit, and 40mA of active negation sink current capability.

This device is offered in low thermal resistance versions of the industry standard 28 pin wide body SOIC and PLCC, as well as a 24 pin DIL plastic package.

## BLOCK DIAGRAM



**ABSOLUTE MAXIMUM RATINGS**

Tempwr Voltage .....	+7V
Signal Line Voltage .....	0V to +7V
Regulator Output Current .....	0.5A
Storage Temperature .....	-65°C to +150°C
Operating Temperature .....	-55°C to +150°C
Lead Temperature (Soldering, 10 Sec.) .....	+300°C

Unless otherwise specified all voltages are with respect to Ground. Currents are positive into, negative out of the specified terminal.

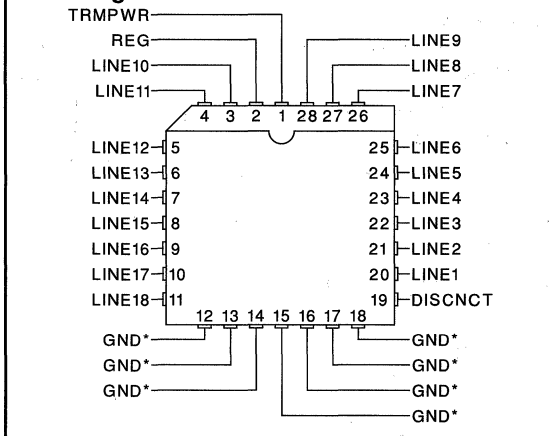
Consult Packaging Section of Unirode Integrated Circuits datobook for thermal limitations and considerations of packages.

**RECOMMENDED OPERATING CONDITIONS**

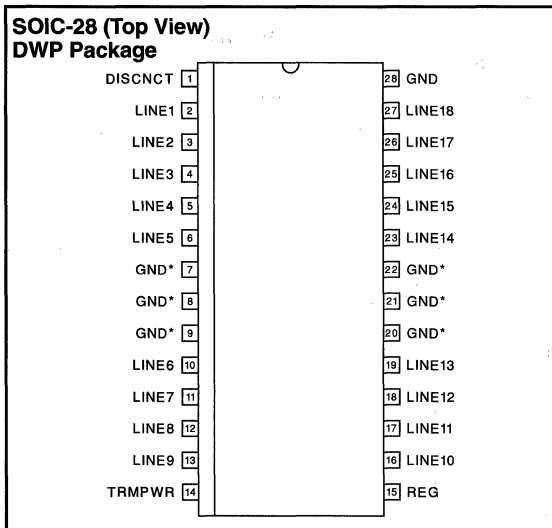
Tempwr Voltage .....	4.0V to 5.25V
Signal Line Voltage .....	0V to +3V
Disconnect Input Voltage .....	0V to Tempwr

**CONNECTION DIAGRAMS**

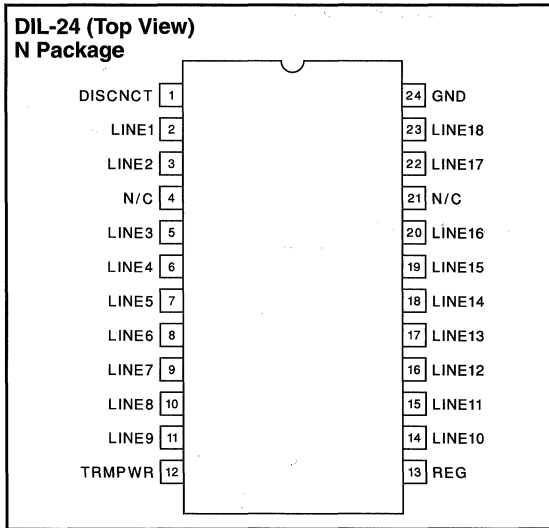
**PLCC-28 (Top View)  
QP Package**



\*QP package pins 12 - 18 serve as both heatsink and signal ground.



\*DWP package pin 28 serves as signal ground; pins 7, 8, 9, 20, 21, 22 serve as heatsink/ground.



Note: Drawings are not to scale.

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ .  
TRMPWR = 4.75V, DISCNCT = 0V.  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNITS	
<b>Supply Current Section</b>							
Termpwr Supply Current	All termination lines = Open			20	29	mA	
	All termination lines = 0.5V			400	435	mA	
Power Down Mode	DISCNCT = Open			100	150	$\mu\text{A}$	
<b>Output Section (Termination Lines)</b>							
Termination Impedance	$\Delta\text{LINE} = -5\text{mA}$ to $-15\text{mA}$		$T_J = 25^\circ\text{C}$	102	110	118	$\Omega$
			$0^\circ\text{C} < T_J < 70^\circ\text{C}$	97		129	$\Omega$
Output High Voltage	$V_{\text{TRMPWR}} = 4\text{V}$ (Note 1)		$T_J = 25^\circ\text{C}$	2.6	2.9	3.1	V
			$0^\circ\text{C} < T_J < 70^\circ\text{C}$	2.55		3.2	V
Max Output Current	$V_{\text{LINE}} = 0.5\text{V}$		$T_J = 25^\circ\text{C}$	-19.5	-21.4	-22.4	mA
			$0^\circ\text{C} < T_J < 70^\circ\text{C}$	-18.5		-22.4	mA
Max Output Current	$V_{\text{LINE}} = 0.5\text{V}$ , TRMPWR = 4V (Note 1)		$T_J = 25^\circ\text{C}$	-18.0	-21.5	-22.4	mA
			$0^\circ\text{C} < T_J < 70^\circ\text{C}$	-17.0		-22.4	mA
Output Leakage	DISCNCT = 4V	TRMPWR = 0V to 5.25V REG = 0V	$V_{\text{LINE}} = 0$ to 4V		10	400	nA
		TRMPWR = 0V to 5.25V, REG = Open $V_{\text{LINE}} = 0\text{V}$ to 5.25V	$V_{\text{LINE}} = 5.25\text{V}$		10	400	nA
Output Capacitance	DISCNCT = Open (Note 2)			10	13	pF	
<b>Regulator Section</b>							
Regulator Output Voltage			$T_J = 25^\circ\text{C}$	2.7	2.9	3.1	V
			$0^\circ\text{C} < T_J < 70^\circ\text{C}$	2.55		3.2	V
Line Regulation	TRMPWR = 4V to 6V			10	20	mV	
Load Regulation	IREG = 0 to -400mA			20	50	mV	
Drop Out Voltage	All Termination Lines = 0.5V			1.0	1.2	V	
Short Circuit Current	$V_{\text{REG}} = 0\text{V}$			-450	-650	-850	mA
Sinking Current Capability	$V_{\text{REG}} = 3.5\text{V}$			20	40	mA	
Thermal Shutdown					170	$^\circ\text{C}$	
<b>Disconnect Section</b>							
Disconnect Threshold			1.1	1.4	1.7	V	
Threshold Hysteresis				100		mV	
Input Current	DISCNCT = 0V			150	200	$\mu\text{A}$	

Note 1: Measuring each termination line while other 17 are low (0.5V).

Note 2: Guaranteed by design. Not 100% tested in production.

## THERMAL DATA

DWP package: (see packaging section of UICC data book for more details on thermal performance)

Thermal Resistance Junction to Leads,  $\theta_{jL}$  ..... 18 $^\circ\text{C}/\text{W}$

Thermal Resistance Junction to Ambient,  $\theta_{ja}$  ..... 33 $^\circ\text{C}$ -43 $^\circ\text{C}/\text{W}$

N package:

Thermal Resistance Junction to Leads,  $\theta_{jL}$  ..... 50 $^\circ\text{C}/\text{W}$

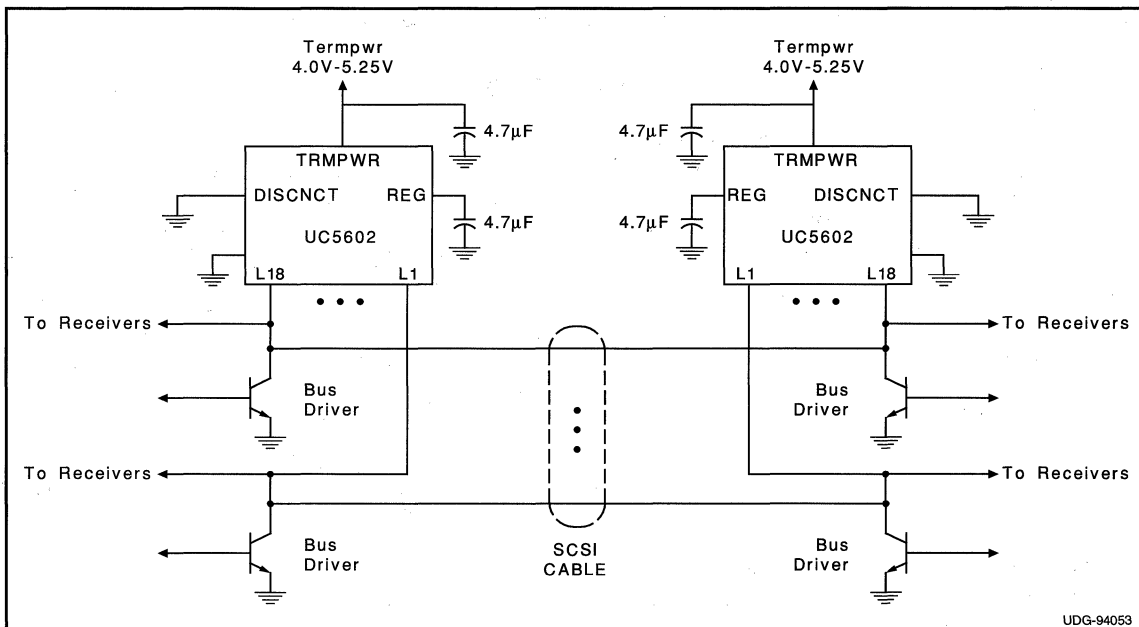
Thermal Resistance Junction to Ambient,  $\theta_{ja}$  ..... 95 $^\circ\text{C}$ -105 $^\circ\text{C}/\text{W}$

QP package:

Thermal Resistance Junction to Leads,  $\theta_{jL}$  ..... 15 $^\circ\text{C}/\text{W}$

Thermal Resistance Junction to Ambient,  $\theta_{ja}$  ..... 30 $^\circ\text{C}$ -40 $^\circ\text{C}/\text{W}$

Note: The above numbers for  $\theta_{jL}$  are maximums for the limiting thermal resistance of the package in a standard mounting configuration. The  $\theta_{ja}$  numbers are meant to be guidelines for the thermal performance of the device/pc-board system. All of the above numbers assume no ambient airflow.



Typical SCSI Bus Configuration Using the UC5602

UDG-94053

### A Look at the Response of a SCSI-2 Cable

Figure 1 shows a single line of a SCSI cable. The driver is an open collector type which when asserted pulls low, and when negated the termination resistance serves as the pull-up.

Figure 2 shows a worst case scenario of mid cable deassertion with a close proximity receiver. The voltage  $V_{STEP}$  is defined as:

$$V_{STEP} = V_{OL} + I_O Z_0$$

- $V_{OL}$  = Driver Output Low Voltage
- $I_O$  = Current from Receiving Terminator
- $Z_0$  = Cable Characteristic Impedance

$$I_O = \frac{V_{REG} - V_{OL}}{110}$$

In the pursuit of higher data rates, sampling could occur during this step portion, therefore it is important to ensure that the step is as high as possible to get the most noise margin. For this reason the UC5602 is trimmed so that the output current ( $I_O$ ) is as close as possible to the SCSI max current spec of 22.4mA. The Termination impedance is initially trimmed on the IC to 110 ohms typical, then the regulator voltage is trimmed for the highest output current to within 22.4mA.

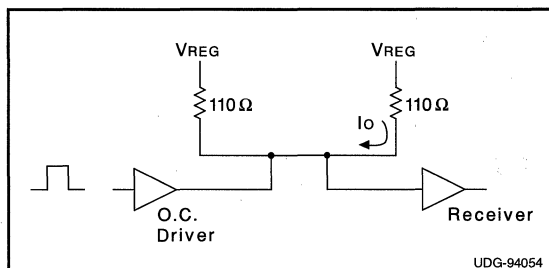


Figure 1. A Single Line of a SCSI Cable

UDG-94054

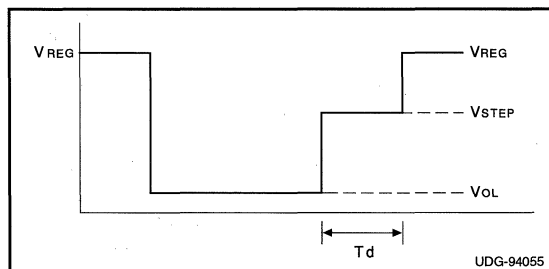
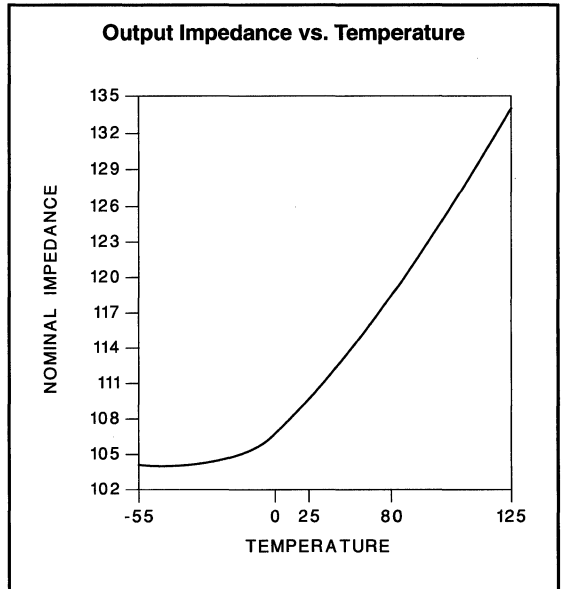
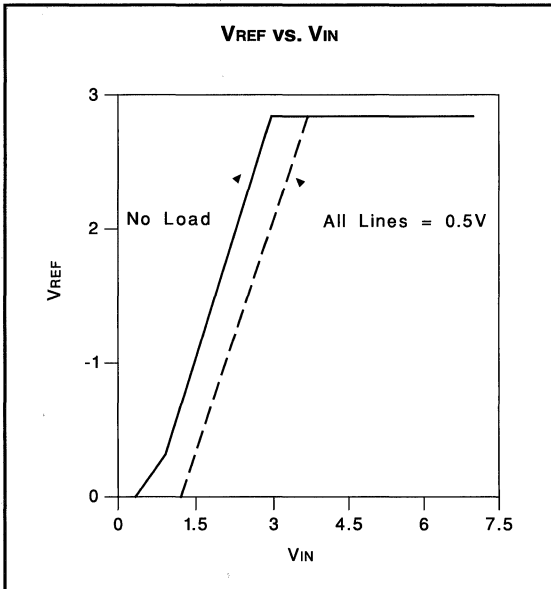
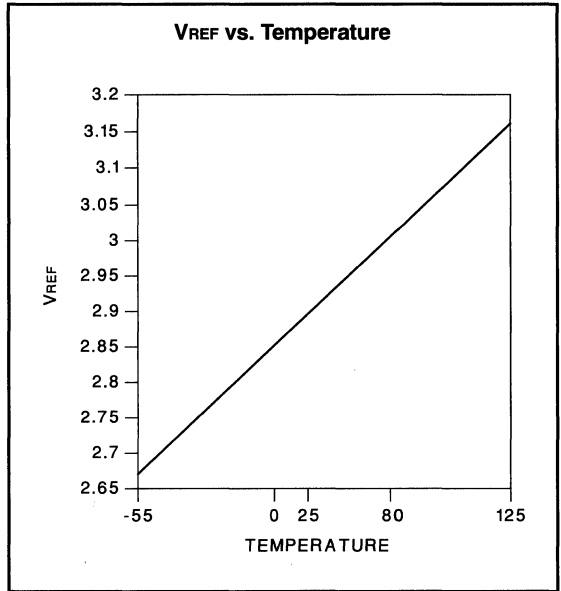
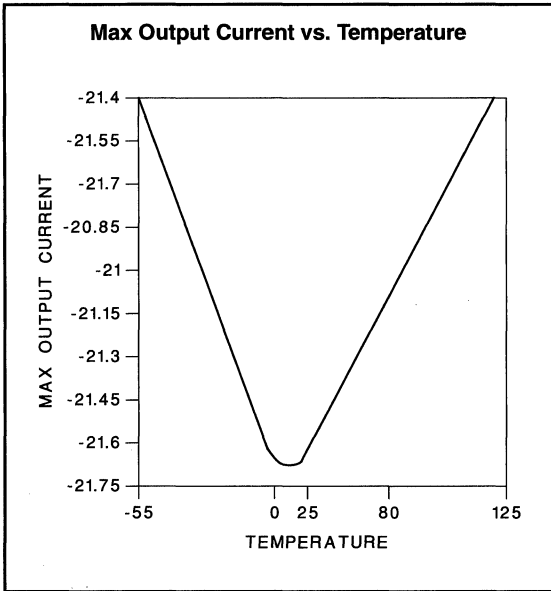


Figure 2. A Typical Response of a SCSI Cable

UDG-94055



# 9-Line SCSI Active Terminator

## FEATURES

- Complies with SCSI, SCSI-2 and SPI-2 Standards
- 6pF Channel Capacitance during Disconnect
- 100µA Supply Current in Disconnect Mode
- Meets SCSI Hot Plugging
- -400mA Sourcing Current for Termination
- +400mA Sinking Current for Active Negation Drivers
- Logic Command Disconnects all Termination Lines
- Trimmed Termination Current to 3%
- Trimmed Impedance to 3%
- Negative Clamping on all Signal Lines
- Current Limit and Thermal Shutdown Protection

## DESCRIPTION

The UC5603 provides 9 lines of active termination for a SCSI (Small Computers Systems Interface) parallel bus. The SCSI standard recommends active termination at both ends of the cable segment.

The UC5603 provides a disconnect feature which, when opened or driven high, will disconnect all terminating resistors, and disables the regulator; greatly reducing standby power. The output channels remain high impedance even without Tempwr applied. A low channel capacitance of 6pF allows units at interim points of the bus to have little to no effect on the signal integrity.

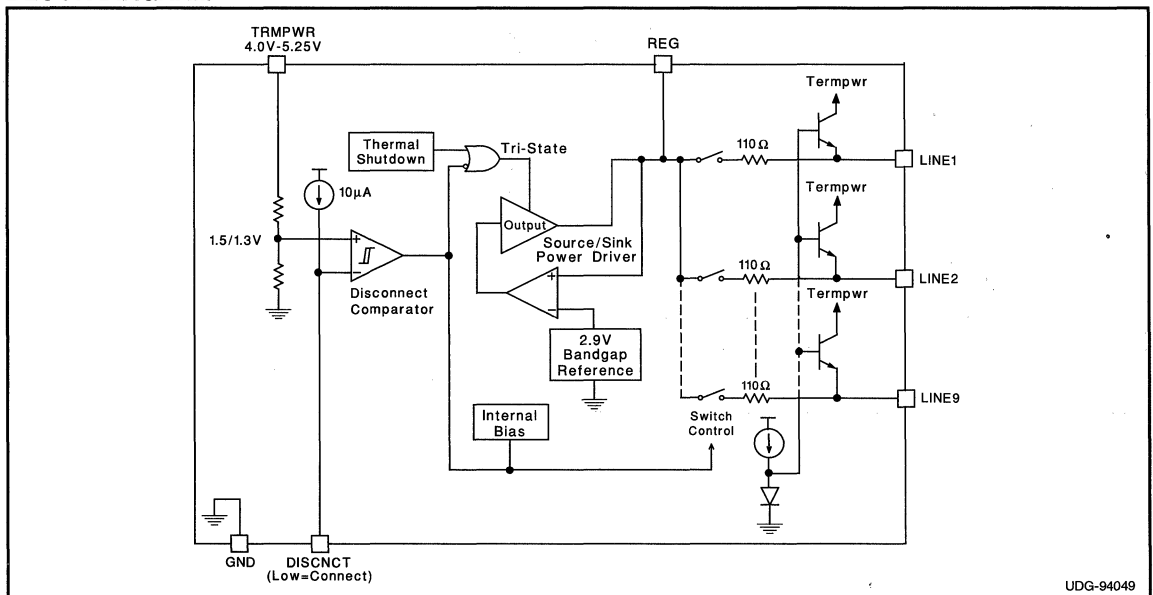
Functionally the UC5603 is similar to its predecessor, the UC5601 - 18 line Active Terminator. Several electrical enhancements were incorporated in the UC5603, such as a sink/source regulator output stage to accommodate all signal lines at +5V, while the regulator remains at its nominal value, reduced channel capacitance to 6pF typical, and as with the UC5601, custom power packages are utilized to allow normal operation at full power conditions (1.2 watts).

Internal circuit trimming is utilized, first to trim the impedance to a 3% tolerance, and then most importantly, to trim the output current to a 3% tolerance, as close to the max SCSI spec as possible, which maximizes noise margin in fast SCSI operation.

Other features include negative clamping on all signal lines to protect external circuitry from latch-up, thermal shutdown and current limit.

This device is offered in low thermal resistance versions of the industry standard 16 pin narrow body SOIC, 16 pin ZIP (zig-zag in line package) and 24 pin TSSOP.

## BLOCK DIAGRAM



UDG-94049



**ABSOLUTE MAXIMUM RATINGS**

Tempwr Voltage .....	+7V
Signal Line Voltage .....	0V to +7V
Regulator Output Current .....	0.5A
Storage Temperature .....	-65°C to +150°C
Operating Temperature .....	-55°C to +150°C
Lead Temperature (Soldering, 10 Sec.) .....	+300°C

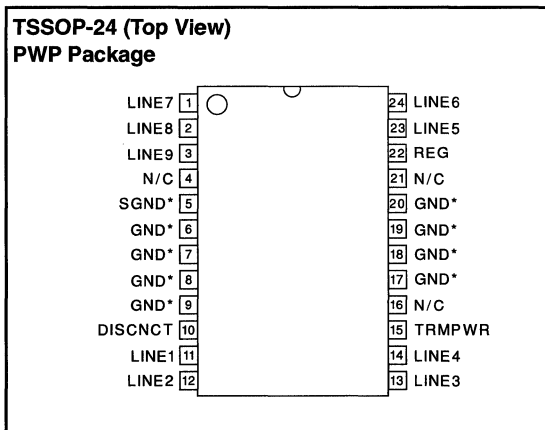
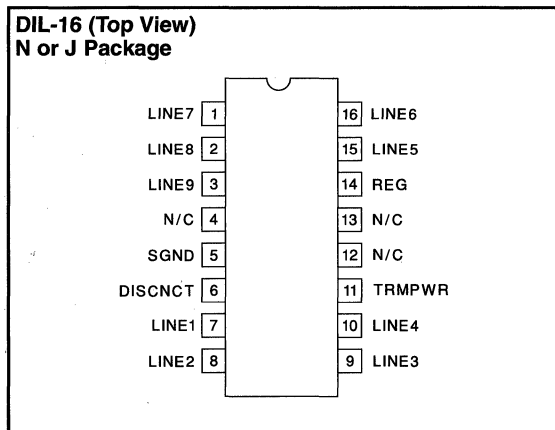
Unless otherwise specified all voltages are with respect to Ground. Currents are positive into, negative out of the specified terminal.

Consult Packaging Section of Unirode Integrated Circuits databook for thermal limitations and considerations of packages.

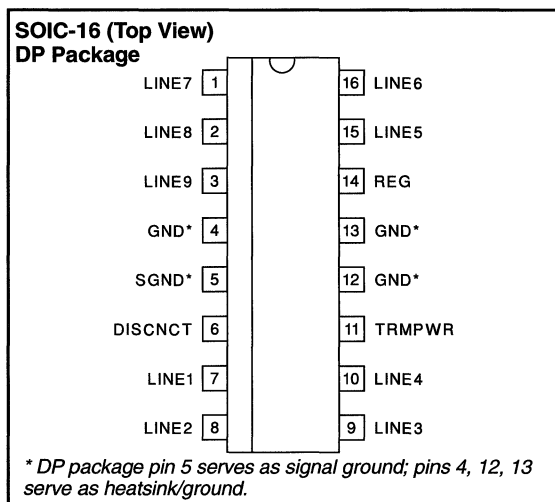
**RECOMMENDED OPERATING CONDITIONS**

Tempwr Voltage .....	3.8V to 5.25V
Signal Line Voltage .....	0V to +5V
Disconnect Input Voltage .....	0V to Tempwr

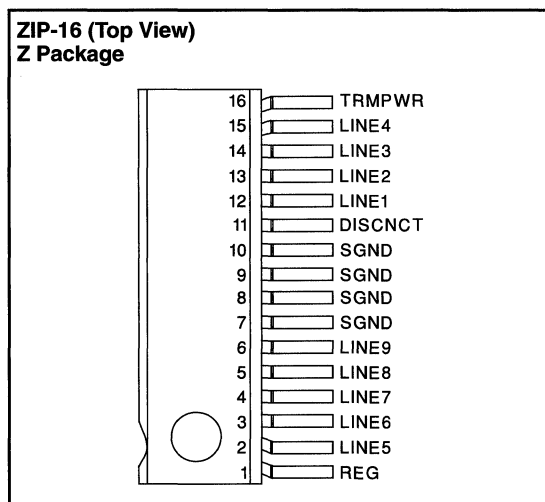
**CONNECTION DIAGRAMS**



\* PWP package pin 5 serves as signal ground; pins 6, 7, 8, 9, 17, 18, 19, and 20 serve as heatsink/ground.



\* DP package pin 5 serves as signal ground; pins 4, 12, 13 serve as heatsink/ground.



Note: Drawings are not to scale.



**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ .  
 TRMPWR = 4.75V DISCNCT = 0V.  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS	
<b>Supply Current Section</b>						
Tempwr Supply Current	All termination lines = Open		12	18	mA	
	All termination lines = 0.5V		200	220	mA	
Power Down Mode	DISCNCT = Open		100	150	$\mu\text{A}$	
<b>Output Section (Terminator Lines)</b>						
Terminator Impedance	$\Delta I_{\text{LINE}} = -5\text{mA}$ to $-15\text{mA}$	107	110	113	Ohms	
Output High Voltage	$V_{\text{TRMPWR}} = 4\text{V}$ (Note 1)	2.7	2.9		V	
Max Output Current	$V_{\text{LINE}} = 0.5\text{V}$	$T_J = 25^\circ\text{C}$	-21.1	-21.9	-22.4	mA
		$0^\circ\text{C} < T_J < 70^\circ\text{C}$	-20.5	-21.9	-22.4	mA
Max Output Current	$V_{\text{LINE}} = 0.5\text{V}$ , TRMPWR = 4V (Note 1)	$T_J = 25^\circ\text{C}$	-20.3	-21.9	-22.4	mA
		$0^\circ\text{C} < T_J < 70^\circ\text{C}$	-19.8	-21.9	-22.4	mA
	$V_{\text{LINE}} = 0.2\text{V}$ , TRMPWR = 4.0V to 5.25V	$0^\circ\text{C} < T_J < 70^\circ\text{C}$	-22.0	-24.0	-25.4	mA
Output Clamp Level	$I_{\text{LINE}} = -30\text{mA}$	-0.2	-0.05	0.1	V	
Output Leakage	DISCNCT = 4V	TRMPWR = 0V to 5.25V REG = 0V	$V_{\text{LINE}} = 0$ to 4V $V_{\text{LINE}} = 5.25\text{V}$	10	400	nA
		TRMPWR = 0V to 5.25V, REG = Open $V_{\text{LINE}} = 0\text{V}$ to 5.25V		10	400	nA
		Output Capacitance	DISCNCT = Open (Note 2) (DP Package)		6	8
<b>Regulator Section</b>						
Regulator Output Voltage		2.8	2.9	3	V	
Regulator Output Voltage	All Termination Lines = 5V	2.8	2.9	3	V	
Line Regulation	TRMPWR = 4V to 6V		10	20	mV	
Load Regulation	$I_{\text{REG}} = +100\text{mA}$ to $-100\text{mA}$		20	50	mV	
Drop Out Voltage	All Termination Lines = 0.5V		0.7	1	V	
Short Circuit Current	$V_{\text{REG}} = 0\text{V}$	-200	-400	-600	mA	
Sinking Current Capability	$V_{\text{REG}} = 3.5\text{V}$	200	400	600	mA	
Thermal Shutdown			170		$^\circ\text{C}$	
Thermal Shutdown Hysteresis			10		$^\circ\text{C}$	
<b>Disconnect Section</b>						
Disconnect Threshold		1.3	1.5	1.7	V	
Threshold Hysteresis		100	160	250	mV	

Note 1: Measuring each termination line while other 8 are low (0.5V).

Note 2: Guaranteed by design. Not 100% tested in production.

APPLICATION INFORMATION

3

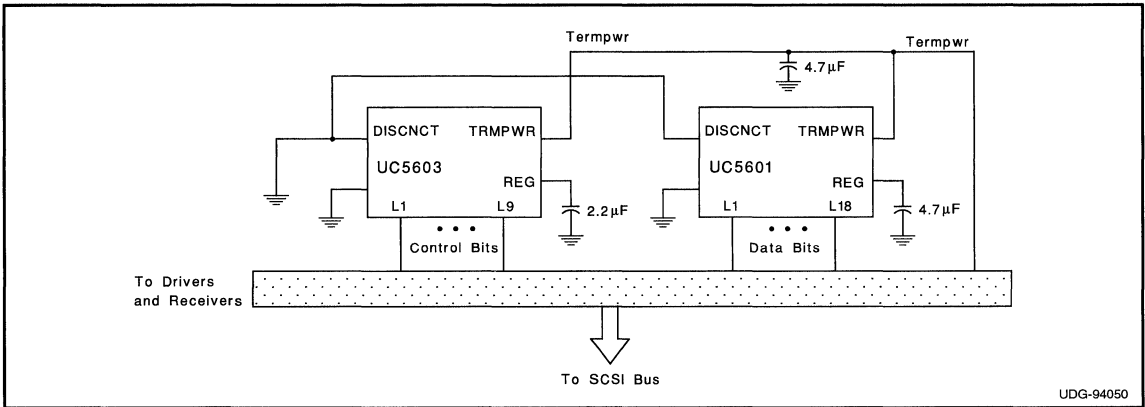


Figure 1: Typical Wide SCSI Bus Configurations Utilizing 1 UC5601 and 1 UC5603 Device

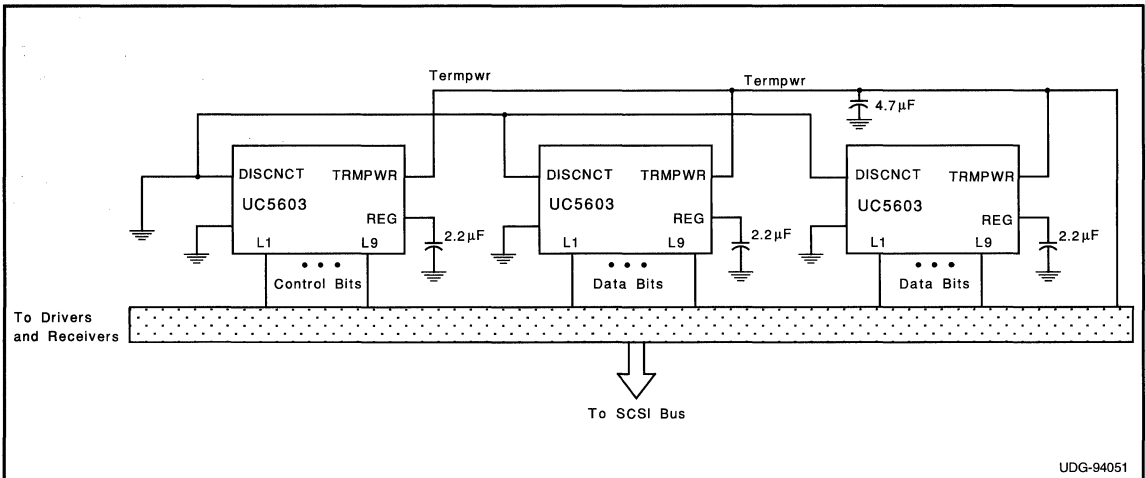


Figure 2: Typical Wide SCSI Bus Configurations Utilizing 3 UC5603 Devices.

# 9-Line Low Capacitance SCSI Active Terminator

## FEATURES

- Complies with SCSI, SCSI-2 Standards
- 9pF Channel Capacitance during Disconnect
- 100µA Supply Current in Disconnect Mode
- Meets SCSI Hot Plugging Capability
- -300mA Sourcing Current for Termination
- +40mA Sinking Current for Active Negation
- Logic Command Disconnects all Termination Lines
- Trimmed Termination Current to 7%
- Trimmed Impedance to 7%
- Current Limit and Thermal Shutdown Protection

## DESCRIPTION

The UC5604 provides 9 lines of active termination for a SCSI (Small Computer Systems Interface) parallel bus. The SCSI standard recommends active termination at both ends of the cable segment.

The UC5604 provides a disconnect feature which, when opened or driven high, will disconnect all terminating resistors and disable the regulator, greatly reducing standby power. The output channels remain high impedance even without Termpwr applied.

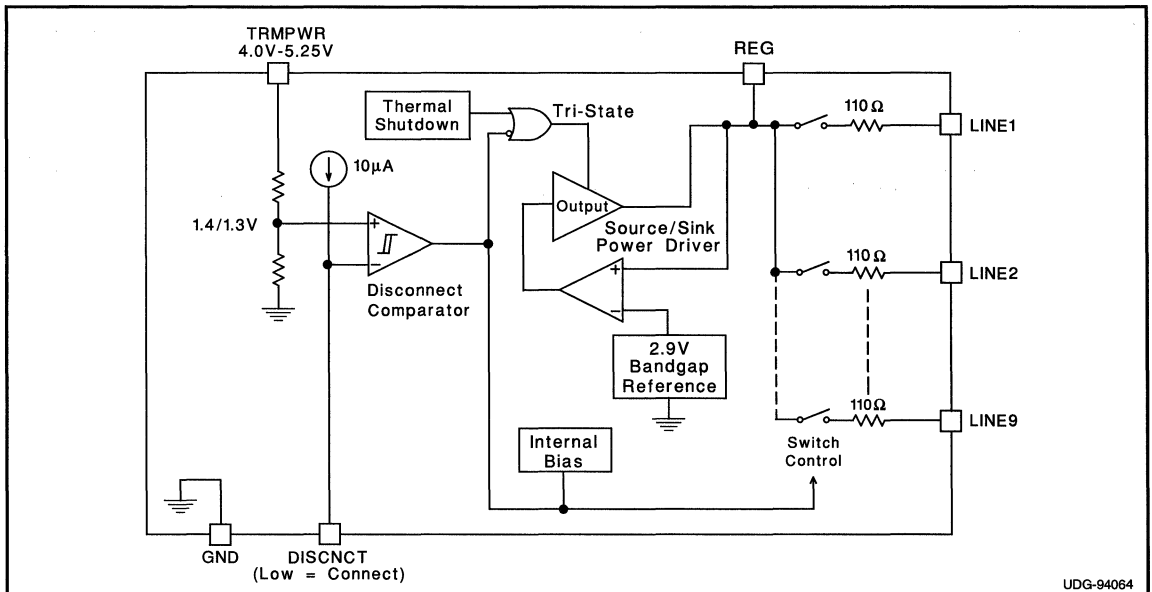
The UC5604 is pin-for-pin compatible with its predecessor, the UC5603 - 9 line Active Terminator. The only functional difference between the UC5604 and UC5603 is the absence of the negative clamps. Parametrically, the UC5604 has a 7% tolerance on impedance and current compared to a 3% tolerance on the UC5603 and the sink current is reduced from 300mA to 40mA. Custom power packages are utilized to allow normal operation at full power conditions (1.2 watts).

Internal circuit trimming is utilized, first to trim the impedance to a 7% tolerance, and then most importantly, to trim the output current to a 7% tolerance, as close to the max SCSI spec as possible, which maximizes noise margin in fast SCSI operation.

Other features include thermal shutdown and current limit.

This device is offered in low thermal resistance versions of the industry standard 16 pin narrow body SOIC, 16 pin ZIP (zig-zag in line package) and 24 pin TSSOP.

## BLOCK DIAGRAM



Circuit Design Patented

### ABSOLUTE MAXIMUM RATINGS

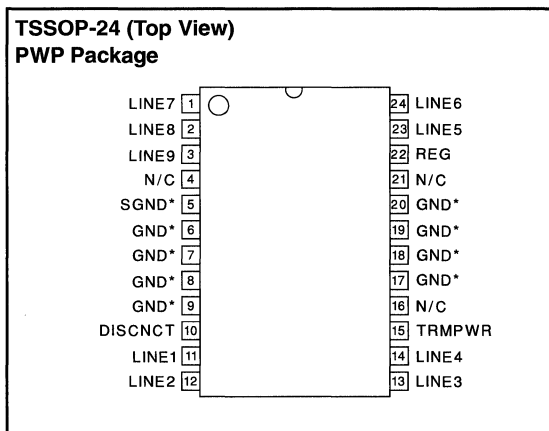
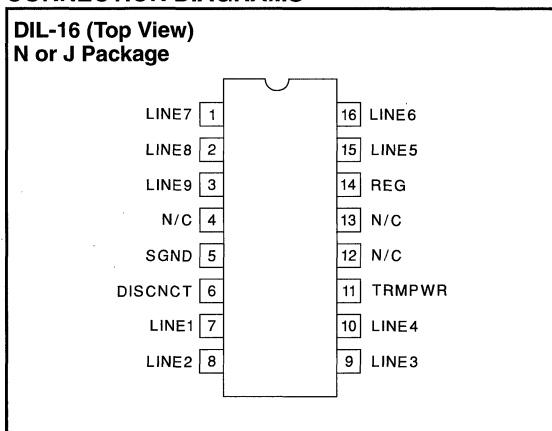
Tempwr Voltage	..... +7V
Signal Line Voltage	..... 0V to +7V
Regulator Output Current	..... 0.5A
Storage Temperature	..... -65°C to +150°C
Operating Temperature	..... -55°C to +150°C
Lead Temperature (Soldering, 10 Sec.)	..... +300°C

Unless otherwise specified all voltages are with respect to Ground. Currents are positive into, negative out of the specified terminal.  
Consult Packaging Section of Unitorde Integrated Circuits databook for thermal limitations and considerations of packages.

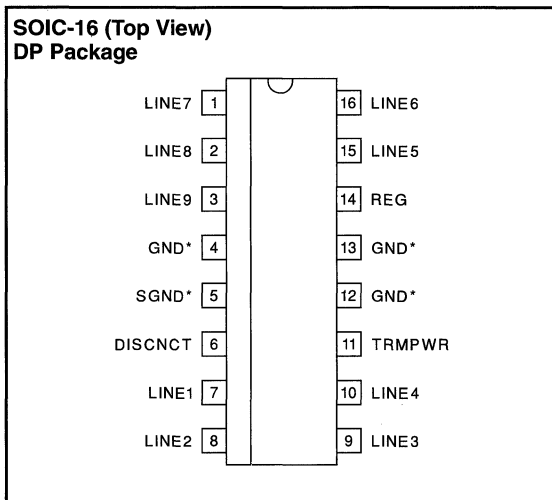
### RECOMMENDED OPERATING CONDITIONS

Tempwr Voltage	..... 3.8V to 5.25V
Signal Line Voltage	..... 0V to +5V
Disconnect Input Voltage	..... 0V to Tempwr

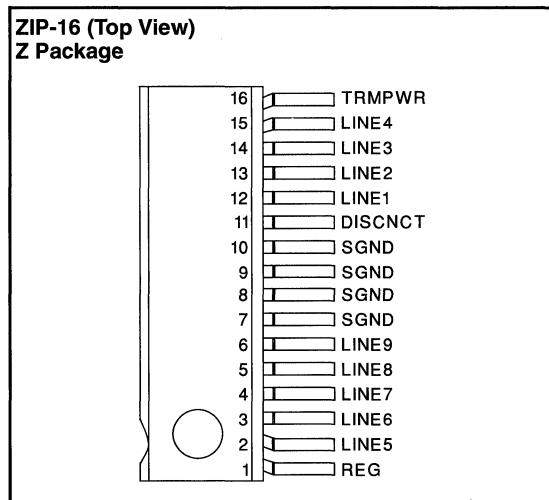
### CONNECTION DIAGRAMS



\* PWP package pin 5 serves as signal ground; pins 6, 7, 8, 9, 17, 18, 19, and 20 serve as heatsink/ground.



\* DP package pin 5 serves as signal ground; pins 4, 12, 13 serve as heatsink/ground.



Note: Drawings are not to scale.



**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ .  
 TRMPWR = 4.75V, DISCNCT = 0V.  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNITS	
<b>Supply Current Section</b>							
Tempwr Supply Current	All termination lines = Open			14	20	mA	
	All termination lines = 0.5V			200	220	mA	
Power Down Mode	DISCNCT = Open			100	150	$\mu\text{A}$	
<b>Output Section (Terminator Lines)</b>							
Terminator Impedance	$\Delta\text{LINE} = -5\text{mA}$ to $-15\text{mA}$		97	110	129	Ohms	
Output High Voltage	TRMPWR = 4V (Note 1)	$0^\circ\text{C} < T_J < 70^\circ\text{C}$	2.55		3.2	V	
		$T_J = 25^\circ\text{C}$	2.6	2.9	3.1	V	
Max Output Current	$V_{\text{LINE}} = 0.5\text{V}$	$T_J = 25^\circ\text{C}$	-19.5	-21.9	-22.4	mA	
		$0^\circ\text{C} < T_J < 70^\circ\text{C}$	-18.5	-21.9	-22.4	mA	
Max Output Current	$V_{\text{LINE}} = 0.5\text{V}$ , TRMPWR = 4V (Note 1)	$T_J = 25^\circ\text{C}$	-18.0	-21.9	-22.4	mA	
		$0^\circ\text{C} < T_J < 70^\circ\text{C}$	-17.0	-21.9	-22.4	mA	
Output Clamp Level	$I_{\text{LINE}} = -30\text{mA}$		-0.2	-0.05	0.1	V	
Output Leakage	DISCNCT = 4V	TRMPWR = 0V to 5.25V REG = 0V	$V_{\text{LINE}} = 0$ to 4V		10	400	nA
			$V_{\text{LINE}} = 5.25\text{V}$			100	$\mu\text{A}$
		TRMPWR = 0V to 5.25V, REG = Open $V_{\text{LINE}} = 0\text{V}$ to 5.25V		10	400	nA	
Output Capacitance	DISCNCT = Open (Note 2)			9	12	pF	
<b>Regulator Section</b>							
Regulator Output Voltage			2.5	2.9	3.2	V	
Regulator Output Voltage	All Termination Lines = 5V		2.55	2.9	3.1	V	
Line Regulation	TRMPWR = 4V to 6V			10	20	mV	
Load Regulation	$I_{\text{REG}} = +100\text{mA}$ to $-100\text{mA}$			20	50	mV	
Drop Out Voltage	All Termination Lines = 0.5V			1.0	1.2	V	
Short Circuit Current	$V_{\text{REG}} = 0\text{V}$		-200	-400	-600	mA	
Sinking Current Capability	$V_{\text{REG}} = 3.5\text{V}$		20	40		mA	
Thermal Shutdown				170		$^\circ\text{C}$	
Thermal Shutdown Hysteresis				10		$^\circ\text{C}$	
<b>Disconnect Section</b>							
Disconnect Threshold			1.1	1.4	1.7	V	
Threshold Hysteresis				100		mV	
Input Current	DISCNCT = 0V			150	200	$\mu\text{A}$	

Note 1: Measuring each termination line while other 8 are low (0.5V).

Note 2: Guaranteed by design. Not 100% tested in production.

## APPLICATION INFORMATION

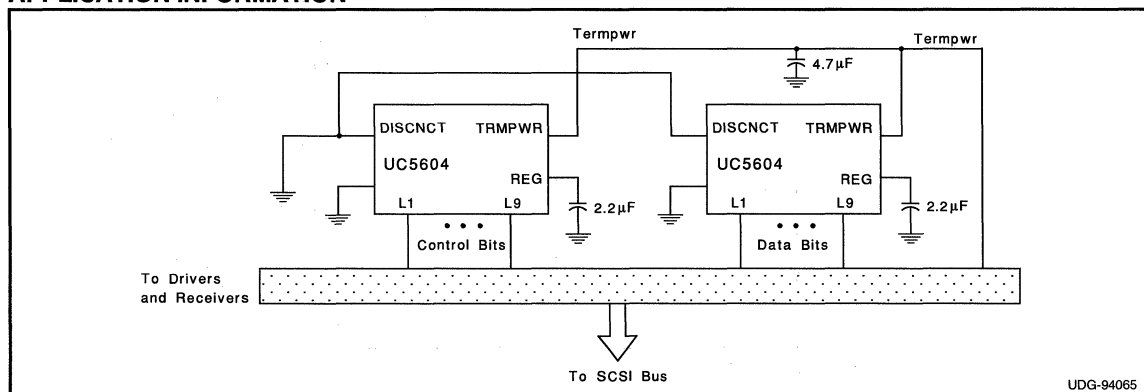


Figure 1: Typical SCSI Bus Configurations Utilizing 2 UC5604 Devices

APPLICATION INFORMATION (cont.)

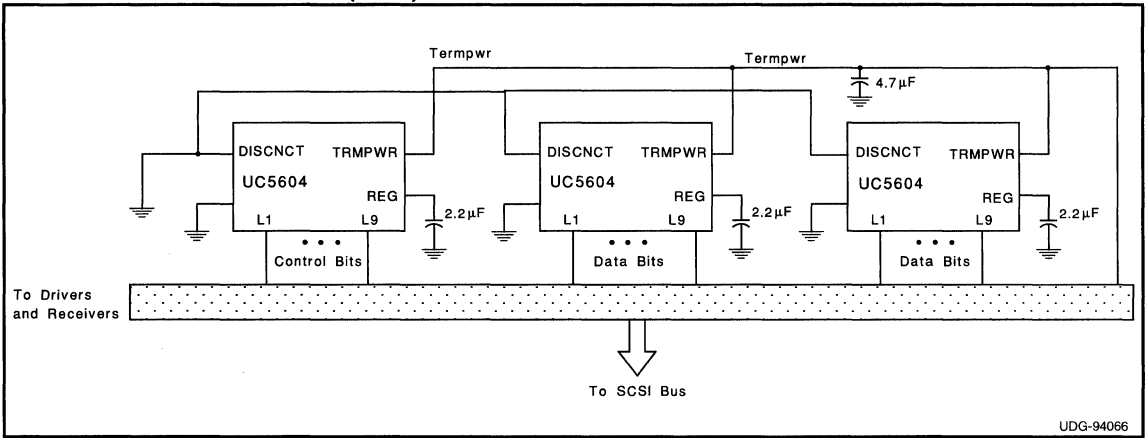


Figure 2: Typical Wide SCSI Bus Configurations Utilizing 3 UC5604 Devices.



# 9-Line Low Capacitance SCSI Active Terminator

## FEATURES

- Reverse Disconnect
- Complies with SCSI, SCSI-2 and SPI-2 Standards
- 5pF Channel Capacitance during Disconnect
- Hot Plugging Capability
- -400mA Sourcing Current for Termination
- +100mA Sinking Current for Active Negation
- 1V Dropout Voltage Regulator
- 100µA Supply Current in Disconnect Mode
- Trimmed Termination Current to 5%
- Trimmed Impedance to 5%
- Low Thermal Resistance Surface Mount Packages

## DESCRIPTION

The UC5605 provides 9 lines of active termination for a SCSI (Small Computer Systems Interface) parallel bus. The SCSI standard recommends active termination at both ends of the cable segment.

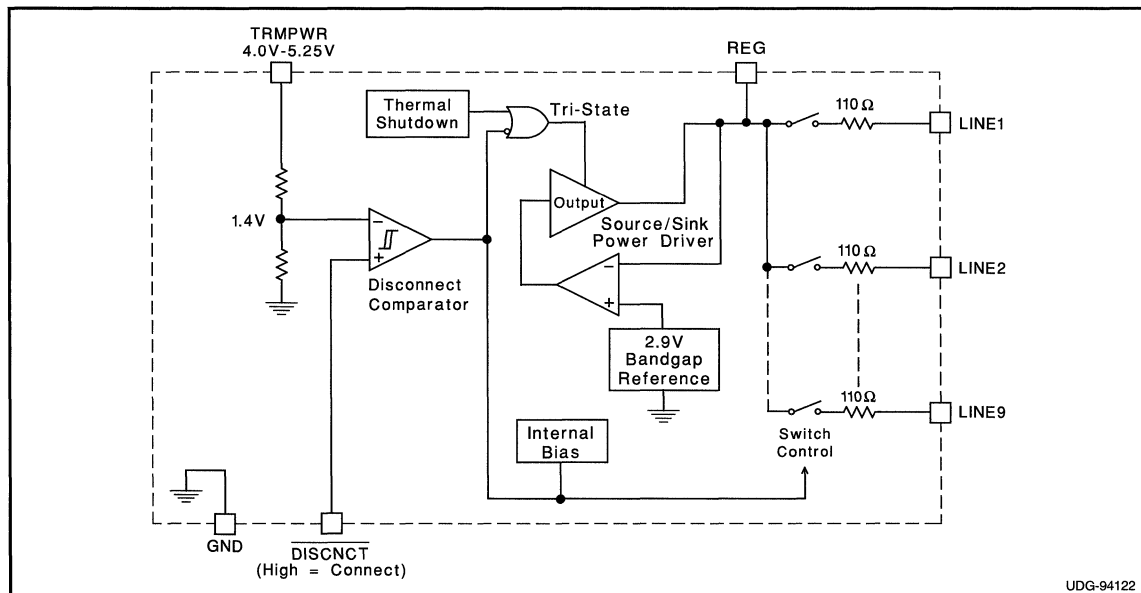
The only functional differences between the UC5603 and UC5605 is the absence of the negative clamps on the output lines and the disconnect input must be at a logic-low for the terminating resistors to be disconnected. Parametrically, the UC5605 has a 5% tolerance on impedance and current compared to a 3% tolerance on the UC5603. Custom power packages are utilized to allow normal operation at full power (2 Watts).

The UC5605 provides a disconnect feature which, when driven low, disconnects all terminating resistors, disables the regulator and greatly reduces standby power consumption. The output channels remain high impedance even without Tempwvr applied. A low channel capacitance of 5pF allows interim points of the bus to have little to no effect on the signal integrity.

Internal circuit trimming is utilized, first to trim the impedance to a 5% tolerance, and then most importantly, to trim the output current to a 5% tolerance, as close to the maximum SCSI specification as possible. This maximizes the noise margin in fast SCSI operation. Other features include thermal shutdown and current limit.

This device is offered in low thermal resistance versions of the industry standard 16 pin narrow body SOIC, 16 pin ZIP (zig-zag in line package) and 24 pin TSSOP.

## BLOCK DIAGRAM



Circuit Design Patented

UDG-94122



**ABSOLUTE MAXIMUM RATINGS**

Tempwr Voltage .....	+7V
Signal Line Voltage .....	0V to +7V
Regulator Output Current .....	0.6A
Storage Temperature .....	-65°C to +150°C
Operating Temperature .....	-55°C to +150°C
Lead Temperature (Soldering, 10 Sec.) .....	+300°C

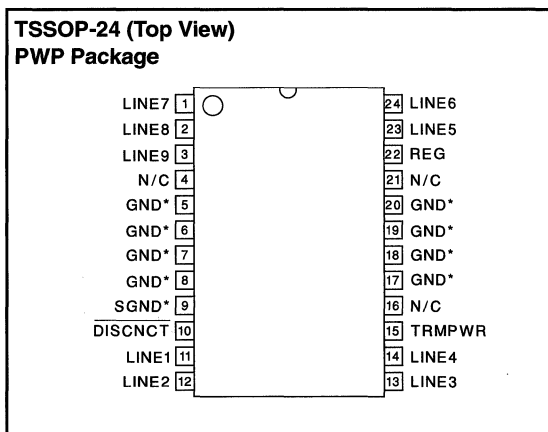
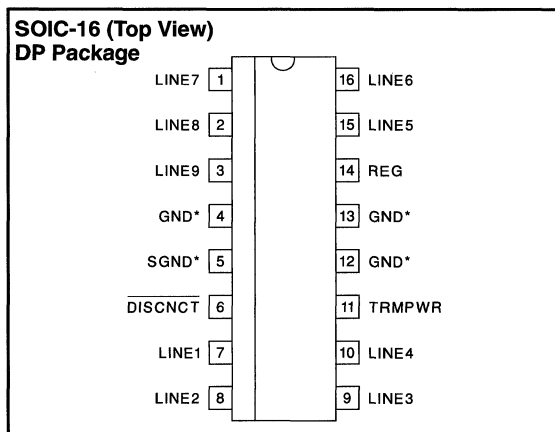
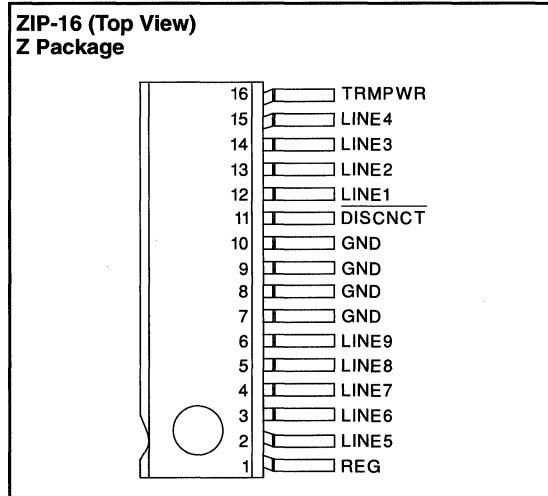
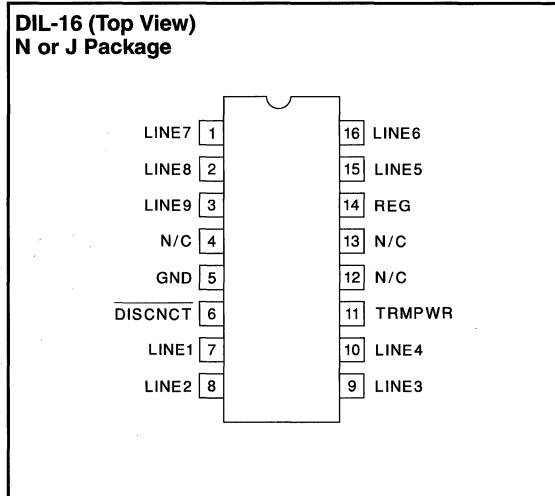
Unless otherwise specified all voltages are with respect to Ground. Currents are positive into, negative out of the specified terminal.  
Consult Packaging Section of Unitrode Integrated Circuits data-book for thermal limitations and considerations of packages.

**RECOMMENDED OPERATING CONDITIONS**

Tempwr Voltage .....	3.8V to 5.25V
Signal Line Voltage .....	0V to +5V
Disconnect Input Voltage .....	0V to Tempwr



**CONNECTION DIAGRAMS**



\* DP package pin 5 serves as signal ground; pins 4, 12, 13 serve as heatsink/ground.

\* PWP package pin 9 serves as signal ground; pins 5, 6, 7, 8, 17, 18, 19, and 20 serve as heatsink/ground.

Note: Drawings are not to scale.

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ .  
 TRMPWR = 4.75V, DISCNCT = 2.4V,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS	
<b>Supply Current Section</b>						
Tempwr Supply Current	All termination lines = Open		17	23	mA	
	All termination lines = 0.5V		200	225	mA	
Power Down Mode	DISCNCT = 0V		100	150	$\mu\text{A}$	
<b>Output Section (Termination Lines)</b>						
Terminator Impedance	$\Delta\text{LINE} = -5\text{mA}$ to $-15\text{mA}$	104.5	110	115.5	Ohms	
Output High Voltage	TRMPWR = 4V	2.65	2.9	3.1	V	
Max Output Current	VLINE = 0.5V	TJ = 25°C	-20.3	-21.5	-22.4	mA
		0°C < TJ < 70°C	-19.8	-21.5	-22.4	mA
Max Output Current	VLINE = 0.5V, TRMPWR = 4V (Note 1)	TJ = 25°C	-19.5	-21.5	-22.4	mA
		0°C < TJ < 70°C	-19.0	-21.5	-22.4	mA
	VLINE = 0.2V, TRMPWR = 4.0V to 5.25V	0°C < TJ < 70°C	-21.6	-24.0	-25.4	mA
Output Leakage	DISCNCT = 0V TRMPWR = 0V to 5.25V	REG = 0V		10	400	nA
					100	$\mu\text{A}$
	REG = Open		10	400	nA	
Output Capacitance	DISCNCT = 0V (Note 2) (DP Package)		5	6	pF	
<b>Regulator Section</b>						
Regulator Output Voltage		2.7	2.9	3.1	V	
	All Termination Lines = 4V	2.7	2.9	3.1	V	
Line Regulation	TRMPWR = 4V to 6V		10	20	mV	
Drop Out Voltage	All Termination Lines = 0.5V		1.0	1.2	V	
Short Circuit Current	REG = 0V	-200	-400	-600	mA	
Sinking Current Capability	REG = 3.5V	75	100	400	mA	
Thermal Shutdown			170		°C	
Thermal Shutdown Hysteresis			10		°C	
<b>Disconnect Section</b>						
Disconnect Threshold		1.1	1.4	1.7	V	

Note 1: Measuring each termination line while other 8 are low.

Note 2: Guaranteed by design. Not 100% tested in production.

## APPLICATION INFORMATION

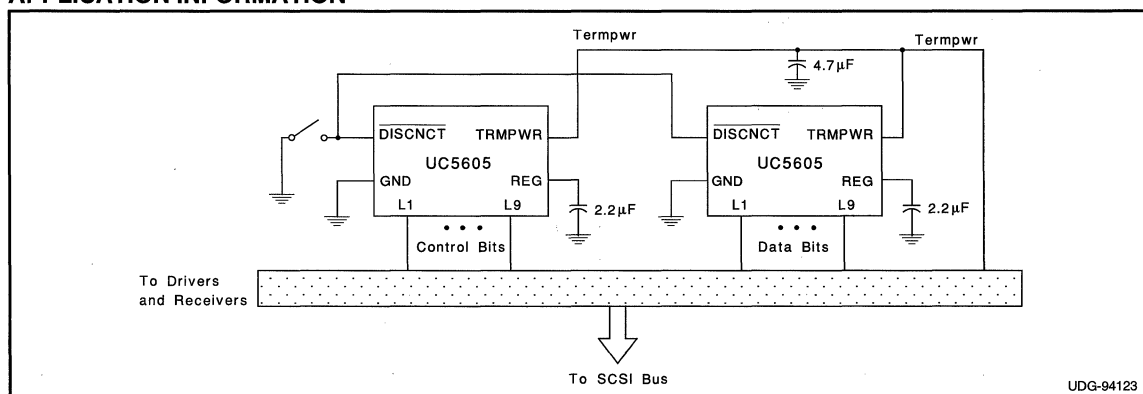


Figure 1: Typical SCSI Bus Configurations Utilizing 2 UC5605 Devices

APPLICATION INFORMATION (cont.)

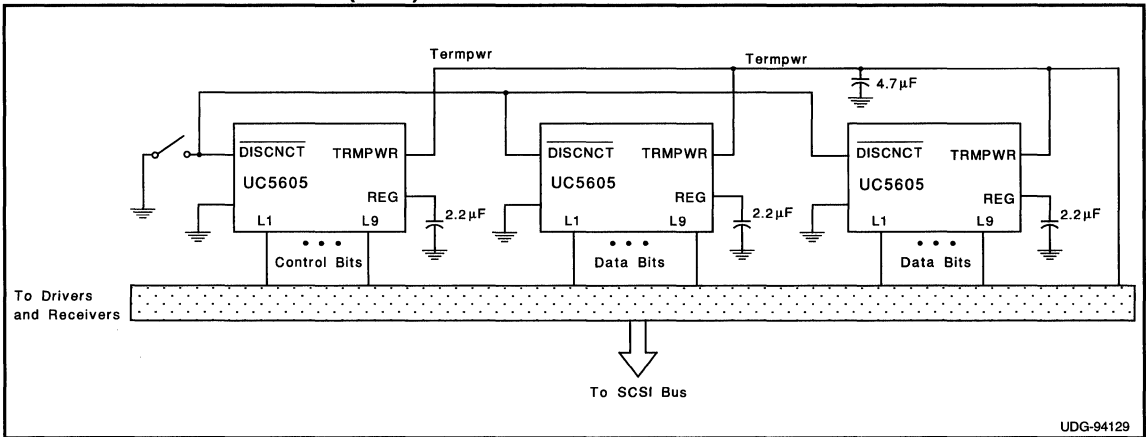


Figure 2: Typical Wide SCSI Bus Configurations Utilizing 3 UC5605 Devices.

3

# 9-Line 3-5 Volt SCSI Active Terminator, Reverse Disconnect

## FEATURES

- Complies with SCSI, SCSI-2 and SCSI-3 Standards
- 2.7V to 7V Operation
- 1.8pF Channel Capacitance during Disconnect
- 1µA Supply Current in Disconnect Mode
- 110 Ohm/2.5k Programmable Termination
- Completely Meets SCSI Hot Plugging
- -400mA Sourcing Current for Termination
- +400mA Sinking Current for Active Negation Drivers
- Trimmed Termination Current to 4%
- Trimmed Impedance to 7%
- Current Limit and Thermal Shutdown Protection

## DESCRIPTION

The UCC5606 provides 9 lines of active termination for a SCSI (Small Computer Systems Interface) parallel bus. The SCSI standard recommends active termination at both ends of the cable segment.

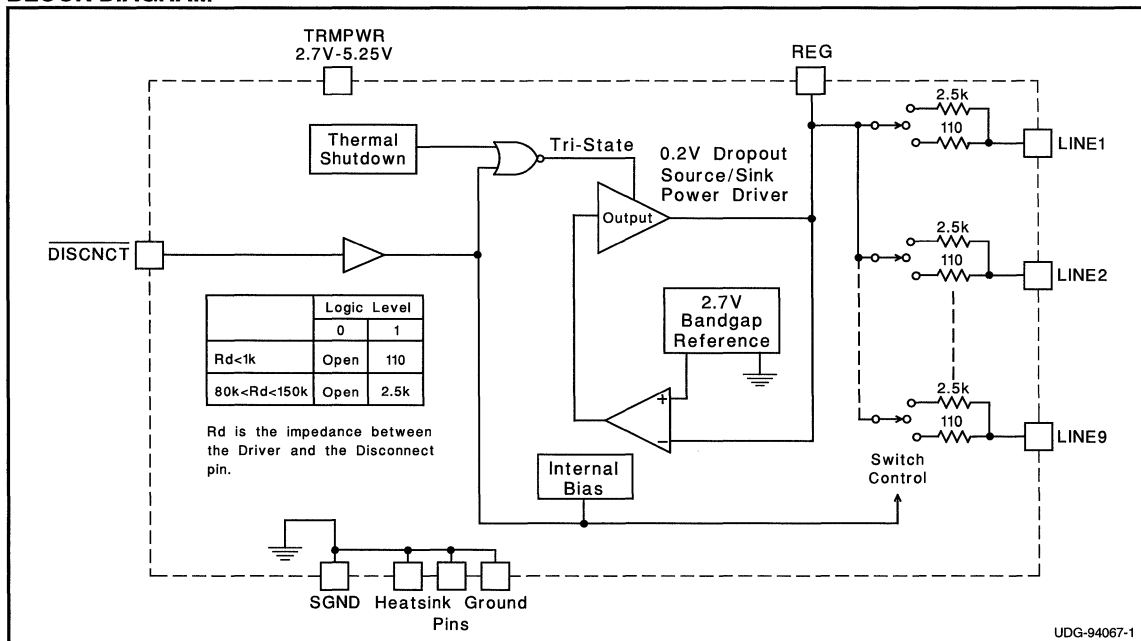
The UCC5606 is ideal for high performance 3.3V SCSI systems. The key features contributing to such low operating voltage are the 0.1V drop out regulator and the 2.7V reference. The reduced reference voltage was necessary to accommodate the lower termination current dictated in the SCSI-3 specification. During disconnect the supply current is typically only 1µA, which makes the IC attractive for battery powered systems.

The UCC5606 is designed with an ultra low channel capacitance of 1.8pF, which eliminates effects on signal integrity from disconnected terminators at interim points on the bus.

The UCC5606 can be programmed for either a 110 ohm or 2.5k ohm termination. The 110 ohm termination is used for standard SCSI bus lengths and the 2.5k ohm termination is typically used in short bus applications. When driving the TTL compatible DISCNCT pin directly, the 110 ohm termination is connected when the DISCNCT pin is driven high, and disconnected when low. When the DISCNCT pin is driven through an impedance between 80k and 150k, the 2.5k ohm termination is connected when the DISCNCT pin is driven high, and disconnected when driven low.

**continued**

## BLOCK DIAGRAM



UDG-94067-1

Circuit Design Patented

**Description Continued**

The power amplifier output stage allows the UCC5606 to source full termination current and sink active negation current when all termination lines are actively negated.

The UCC5606 is pin for pin compatible with Unitrode's other 9 line SCSI terminators, except that DISCNCT is now active low, allowing lower capacitance and lower voltage upgrades to existing systems. The UCC5606, as with all Unitrode terminators, is completely hot pluggable and appears as high impedance at the terminating channels with VTRMPWR = 0V or open.

Internal circuit trimming is utilized, first to trim the 110 ohm termination impedance to a 7% tolerance, and then most importantly, to trim the output current to a 4% tolerance, as close to the max SCSI-3 spec as possible, which maximizes noise margin in fast SCSI operation.

Other features include thermal shutdown and current limit.

This device is offered in low thermal resistance versions of the industry standard 16 pin narrow body SOIC, 16 pin ZIP (Zig-Zag In Line package), 24 pin TSSOP and 28 pin PLCC.

**ABSOLUTE MAXIMUM RATINGS**

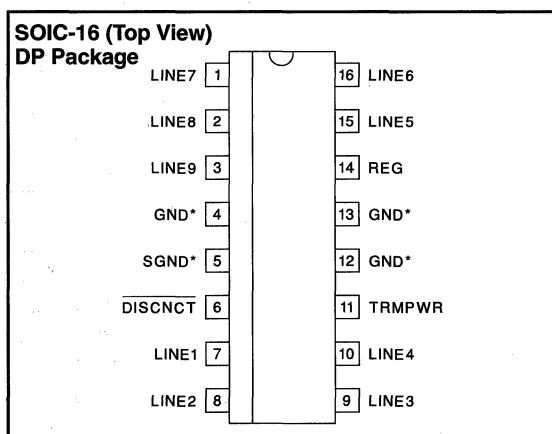
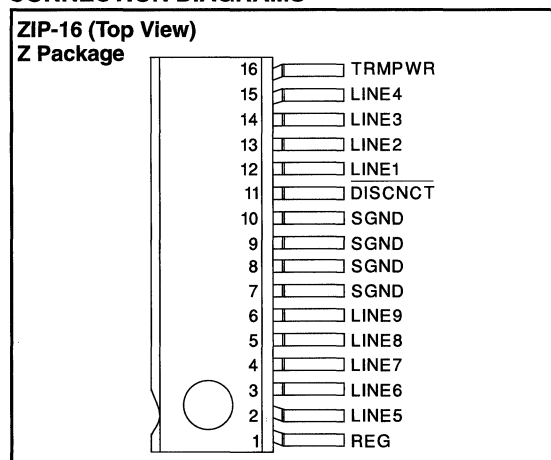
Tempwr Voltage	.....+7V
Signal Line Voltage	..... 0V to +7V
Regulator Output Current	..... 0.6A
Storage Temperature	..... -65°C to +150°C
Operating Temperature	..... -55°C to +150°C
Lead Temperature (Soldering, 10 Sec.)	..... +300°C

*Unless otherwise specified all voltages are with respect to Ground. Currents are positive into, negative out of the specified terminal.  
Consult Packaging Section of Unitrode Integrated Circuits data-book for thermal limitations and considerations of packages.*

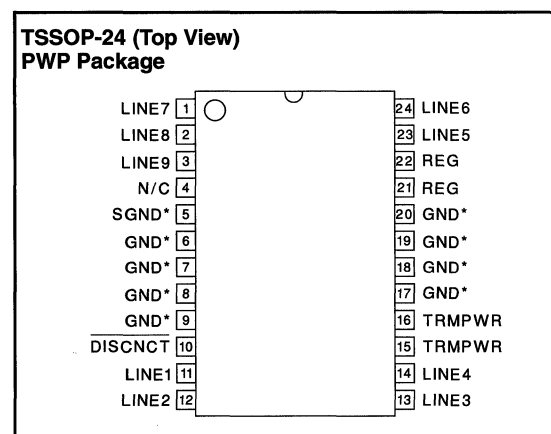
**RECOMMENDED OPERATING CONDITIONS**

Tempwr Voltage	..... 2.7V to 5.25V
Signal Line Voltage	..... 0V to +5V
Disconnect Input Voltage	..... 0V to Tempwr

**CONNECTION DIAGRAMS**



\* DP package pin 5 serves as signal ground; pins 4, 12, 13 serve as heatsink/ground.

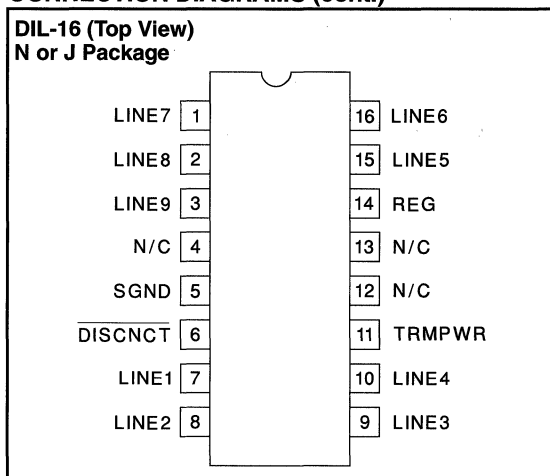


\* PWP package pin 5 serves as signal ground; pins 6, 7, 8, 9, 17, 18, 19, and 20 serve as heatsink/ground.

Note: Drawings are not to scale.



## CONNECTION DIAGRAMS (cont.)



Note: Drawings are not to scale.

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ .  
 $\text{TRMPWR} = 3.3\text{V}$ ,  $\text{DISCNCT} = 3.3\text{V}$ ,  $\text{R}_{\text{DISCNCT}} = 0$  ohms.  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Supply Current Section</b>					
Tempwr Supply Current	All termination lines = Open		1	2	mA
	All termination lines = 0.2V		210	218	mA
Power Down Mode	$\text{DISCNCT} = 0\text{V}$		0.5	5	$\mu\text{A}$
<b>Output Section (110 ohms - Terminator Lines)</b>					
Terminator Impedance		102.3	110	117.7	Ohms
Output High Voltage	$\text{TRMPWR} = 3\text{V}$ (Note 1)	2.5	2.7	3.0	V
Max Output Current	$V_{\text{LINE}} = 0.2\text{V}$ , $T_J = 25^\circ\text{C}$	-22.1	-23	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$	-21	-23	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$ , $\text{TRMPWR} = 3\text{V}$ , $T_J = 25^\circ\text{C}$ (Note 1)	-20.2	-23	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$ , $\text{TRMPWR} = 3\text{V}$ (Note 1)	-19	-23	-24	mA
	$V_{\text{LINE}} = 0.5\text{V}$			-22.4	mA
Output Leakage	$\text{DISCNCT} = 0\text{V}$ , $\text{TRMPWR} = 0\text{V}$ to $5.25\text{V}$		10	400	nA
Output Capacitance	$\text{DISCNCT} = 0\text{V}$ , DP Package (Note 2)		1.8	2.5	pF
<b>Output Section (2.5k ohms - Terminator Lines) (<math>\text{R}_{\text{DISCNCT}} = 80\text{k}</math> ohms)</b>					
Terminator Impedance		2	2.5	3	k $\Omega$
Output High Voltage	$\text{TRMPWR} = 3\text{V}$ (Note 1)	2.5	2.7	3.0	V
Max Output Current	$V_{\text{LINE}} = 0.2\text{V}$	-0.7	-1	-1.4	mA
	$V_{\text{LINE}} = 0.2\text{V}$ , $\text{TRMPWR} = 3\text{V}$ (Note 1)	-0.6	-1	-1.5	mA
Output Leakage	$\text{DISCNCT} = 0\text{V}$ , $\text{TRMPWR} = 0$ to $5.25\text{V}$		10	400	nA
Output Capacitance	$\text{DISCNCT} = 0\text{V}$ , DP Package (Note 2)		1.8	2.5	pF
<b>Regulator Section</b>					
Regulator Output Voltage	$5.25\text{V} > \text{TRMPWR} > 3\text{V}$	2.5	2.7	3.0	V
Drop Out Voltage	All Termination Lines = 0.2V		0.1	0.2	V

**ELECTRICAL CHARACTERISTICS (cont.)** Unless otherwise stated, these specifications apply for  $T_A=0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .  
 $\text{TRMPWR} = 3.3\text{V}$ ,  $\text{DISCNCNT} = 3.3\text{V}$ ,  $\text{RDISCNCNT} = 0$  ohms.  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Regulator Section (cont.)</b>					
Short Circuit Current	$V_{\text{REG}} = 0\text{V}$	-200	-400	-800	mA
Sinking Current Capability	$V_{\text{REG}} = 3\text{V}$	200	400	800	mA
Thermal Shutdown	(Note 2)		170		$^{\circ}\text{C}$
Thermal Shutdown Hysteresis	(Note 2)		10		$^{\circ}\text{C}$
<b>Disconnect Section</b>					
Disconnect Threshold	$\text{RDISCNCNT} = 0$ & $80\text{k}$	0.8	1.5	2.0	V
Input Current	$\text{DISCNCNT} = 3.3\text{V}$		30	50	$\mu\text{A}$

Note 1: Measuring each termination line while other 8 are low (0.2V).  
 Note 2: Guaranteed by design. Not 100% tested in production.

**APPLICATION INFORMATION**

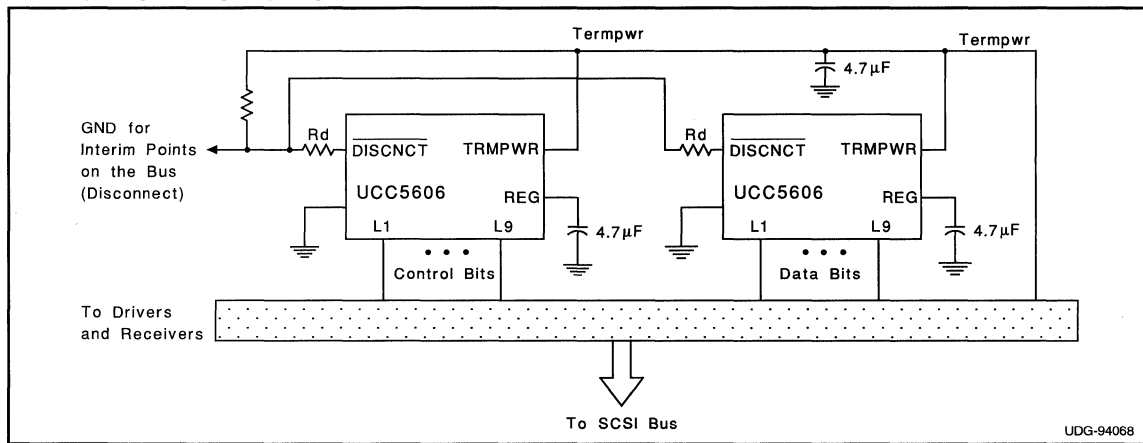


Figure 1: Typical SCSI Bus Configurations Utilizing 2 UCC5606 Devices

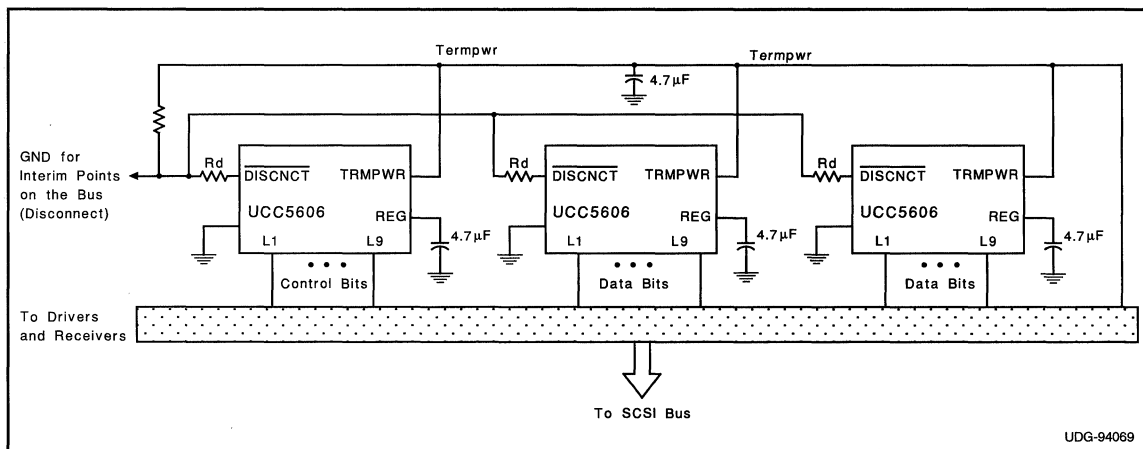


Figure 2: Typical Wide SCSI Bus Configurations Utilizing 3 UCC5606 Devices.



# Plug and Play, 18-Line SCSI Active Terminator

## FEATURES

- Complies with SCSI and SCSI-2 Standards
- 8pF Channel Capacitance during Disconnect
- SCSI Plug and Play, Dual Low Disconnect, Logic Low Command Disconnects All Termination Lines
- Meets SCSI Hot Plugging Capability
- -650mA Sourcing Current for Termination
- +200mA Sinking Current for Active Negation
- 200µA Supply Current in Disconnect Mode
- Trimmed Termination Current to 7%
- Trimmed Impedance to 7%
- Provides Active Termination for 18 Lines

## DESCRIPTION

The UC5607 provides 18 lines of active termination for a SCSI (Small Computer Systems Interface) parallel bus. The SCSI standard recommends active termination at both ends of the cable segment.

The UC5607 provides a low disconnect feature which will disconnect all terminating resistors, and will disable the regulator, greatly reducing standby power. The output channels remain high impedance even without Tempwr applied.

The UC5607 terminator is specially designed with two disconnect pins for full SCSI Plug and Play (PnP) applications.

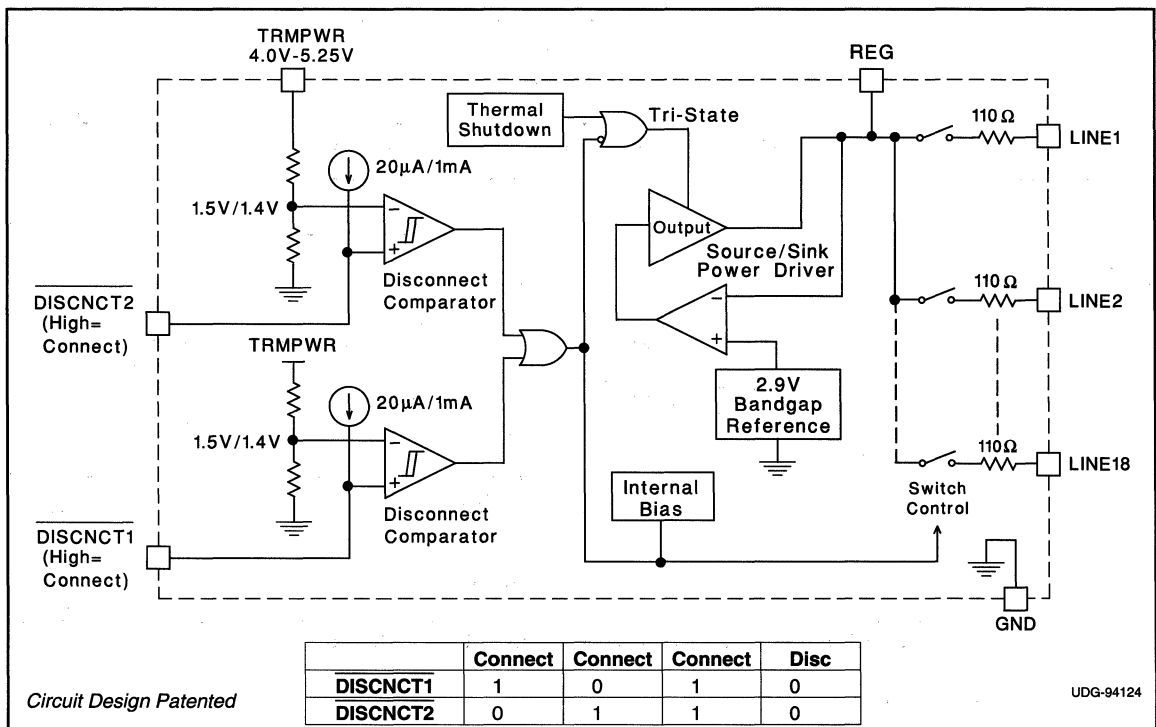
Custom power packages are utilized to allow normal operation at full power conditions (2 Watts).

Internal circuit trimming is utilized, first to trim the impedance to a 7% tolerance, and then most importantly, to trim the output current to a 7% tolerance, as close to the max SCSI spec as possible, which maximizes noise margin in fast SCSI operation.

Other features include thermal shutdown and current limit.

This device is offered in low thermal resistance versions of the industry standard 28 pin wide body SOIC, and 28 pin PLCC, as well as 24 pin DIP.

## BLOCK DIAGRAM





### ABSOLUTE MAXIMUM RATINGS

Tempwr Voltage	..... +7V
Signal Line Voltage	..... 0V to +7V
Regulator Output Current	..... 1A
Storage Temperature	..... -65°C to +150°C
Operating Temperature	..... -55°C to +150°C
Lead Temperature (Soldering, 10 Sec.)	..... +300°C

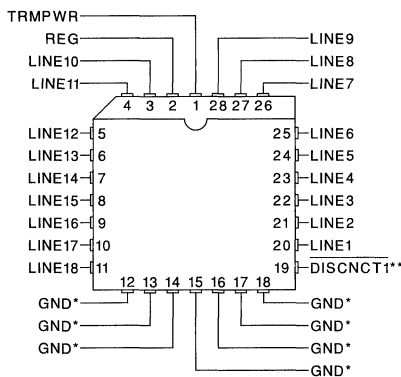
Unless otherwise specified all voltages are with respect to Ground. Currents are positive into, negative out of the specified terminal. Consult Packaging Section of Unitrode Integrated Circuits databook for thermal limitations and considerations of packages.

### RECOMMENDED OPERATING CONDITIONS

Tempwr Voltage	..... 3.8V to 5.25V
Signal Line Voltage	..... 0V to +5V
Disconnect Input Voltage	..... 0V to Tempwr

### CONNECTION DIAGRAMS

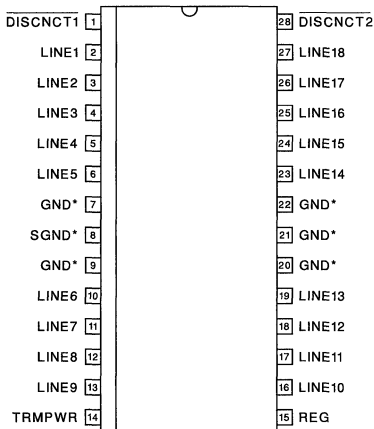
**PLCC-28 (Top View)  
QP Package**



\* QP package pins 12 - 18 serve as both heatsink and signal ground.

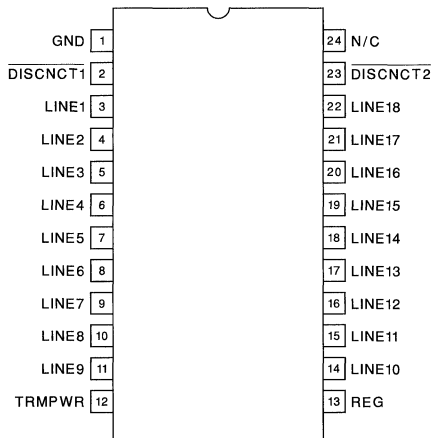
\*\* DISCNCT2 is internally tied to ground.

**SOIC-28 (Top View)  
DWP Package**



\* DWP package pin 8 serves as signal ground; pins 7, 8, 9, 20, 21, 22 serve as heatsink/ground.

**DIL-24 (Top View)  
N or J Package**



Note: Drawings are not to scale.



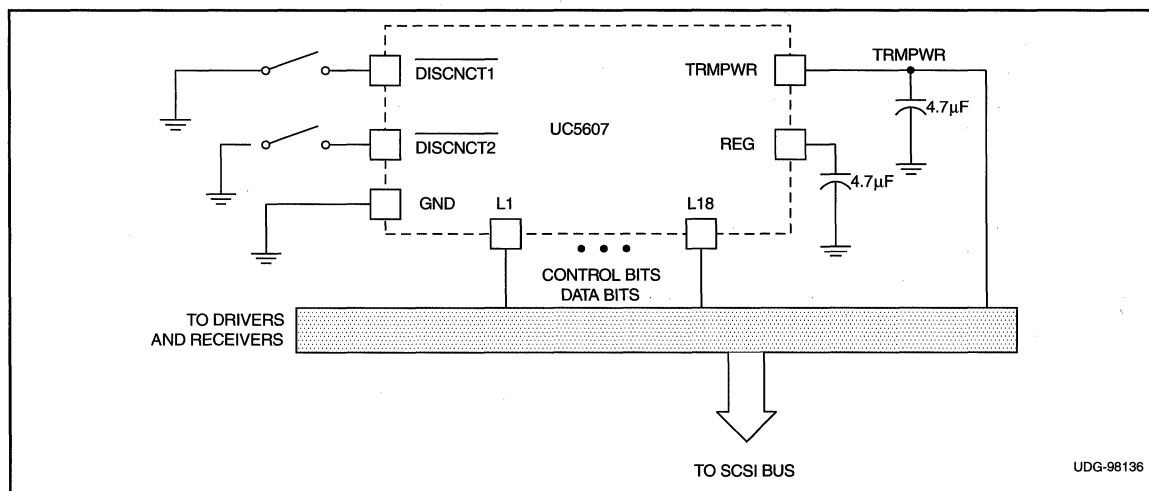
**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ .  
 $\text{TRMPWR} = 4.75\text{V}$ ,  $\text{DISCNCT1} = \text{DISCNCT2} = 2.2\text{V}$ ,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	
<b>Supply Current Section</b>						
Tempwr Supply Current	All termination lines = Open		30	45	mA	
	All termination lines = 0.5V		420	470	mA	
Power Down Mode	$\text{DISCNCT1} = \text{DISCNCT2} = 0\text{V}$		300	500	$\mu\text{A}$	
<b>Output Section (Terminator Lines)</b>						
Terminator Impedance	$\Delta I_{\text{LINE}} = -5\text{mA}$ to $-15\text{mA}$	$T_J = 25^\circ\text{C}$	102	110	118	Ohms
		$0^\circ\text{C} < T_J < 70^\circ\text{C}$	97	110	129	Ohms
Output High Voltage	$V_{\text{TRMPWR}} = 4\text{V}$ (Note 1)	$T_J = 25^\circ\text{C}$	2.6	2.9	3.1	V
		$0^\circ\text{C} < T_J < 70^\circ\text{C}$	2.55	2.9	3.2	V
Max Output Current	$V_{\text{LINE}} = 0.5\text{V}$	$T_J = 25^\circ\text{C}$	-19.5	-21.9	-22.4	mA
		$0^\circ\text{C} < T_J < 70^\circ\text{C}$	-18.5	-21.9	-22.4	mA
Max Output Current	$V_{\text{LINE}} = 0.5\text{V}$ , $\text{TRMPWR} = 4\text{V}$ (Note 1)	$T_J = 25^\circ\text{C}$	-18.0	-21.9	-22.4	mA
		$0^\circ\text{C} < T_J < 70^\circ\text{C}$	-17.0	-21.9	-22.4	mA
Output Leakage	$\text{DISCNCT1} = \text{DISCNCT2} = 0\text{V}$ , $\text{TRMPWR} = 0\text{V}$ to $5.25\text{V}$		10	400	nA	
Output Capacitance	$\text{DISCNCT1} = \text{DISCNCT2} = 0\text{V}$ (Note 2)		8	10	pF	
<b>Regulator Section</b>						
Regulator Output Voltage	All Termination Lines = 5V	$T_J = 25^\circ\text{C}$	2.7	2.9	3.1	V
		$0^\circ\text{C} < T_J < 70^\circ\text{C}$	2.55	2.9	3.2	V
Line Regulation	$\text{TRMPWR} = 4\text{V}$ to $6\text{V}$		10	20	mV	
Load Regulation	$I_{\text{REG}} = +100\text{mA}$ to $-100\text{mA}$		20	50	mV	

Note 1: Measuring each termination line while other 17 are low (0.5V).

Note 2: Guaranteed by design. Not 100% tested in production.

## APPLICATION INFORMATION



UDG-98136

Figure 1: Typical SCSI Bus Configuration Utilizing UC5607 Device

# 18-Line Low Capacitance SCSI Active Terminator

## FEATURES

- Complies with SCSI, SCSI-2 and SPI-2 Standards
- 6pF Channel Capacitance during Disconnect
- 100µA Supply Current in Disconnect Mode
- Meets SCSI Hot Plugging Capability
- -650mA Sourcing Current for Termination
- +200mA Sinking Current for Active Negation
- Provides Active Termination for 18 Lines
- Logic Command Disconnects all Termination Lines
- Trimmed Termination Current to 5%
- Trimmed Impedance to 5%
- Current Limit and Thermal Shutdown Protection

## DESCRIPTION

The UC5608 provides 18 lines of active termination for a SCSI (Small Computer Systems Interface) parallel bus. The SCSI standard recommends active termination at both ends of the bus cable.

The UC5608 is pin-for-pin compatible with its predecessors, the UC5601 and UC5602 - 18 Line Active Terminator. Parametrically the UC5608 has a 5% tolerance on impedance and current compared to a 3% tolerance on the UC5601 and the sink current is increased from 20 to 200mA. The low side clamps have been removed. Custom power packages are utilized to allow normal operation at full power conditions (2 Watts).

When in disconnect mode the terminator will disconnect all terminating resistors and disable the regulator, greatly reducing standby power. The output channels remain high impedance even without Tempwr applied.

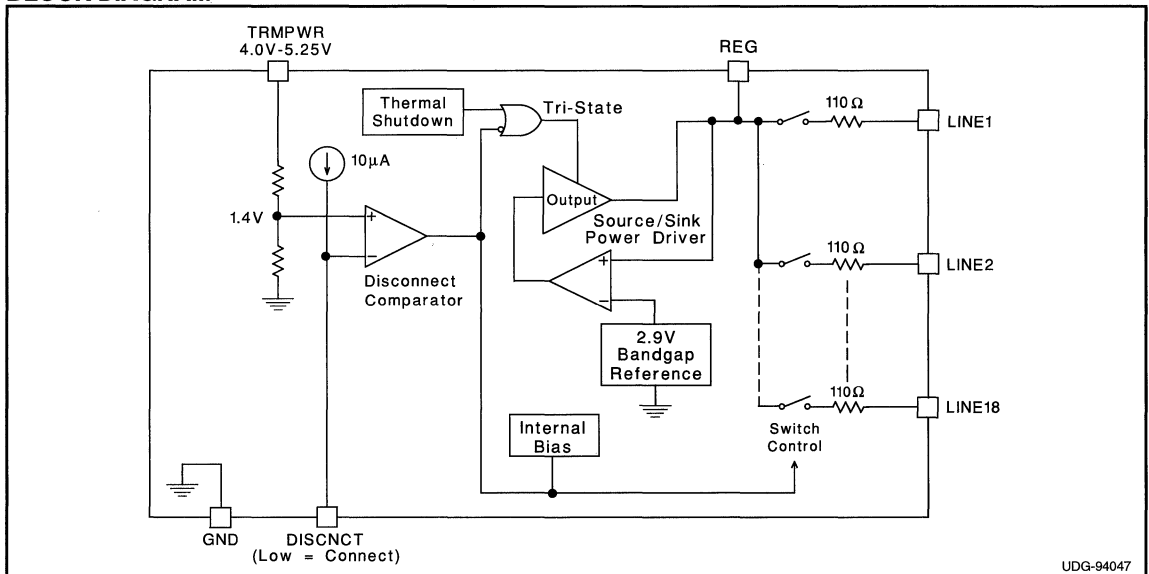
Internal circuit trimming is utilized to trim the impedance to a 5% tolerance and, most importantly, to trim the output current to a 5% tolerance, as close to the max SCSI spec as possible, which maximizes noise margin in fast SCSI operation.

Other features include 4.0 to 5.25V Tempwr, thermal shutdown and current limit.

This device is offered in low thermal resistance versions of the industry standard 28 pin wide body SOIC, 28 pin wide body TSSOP, and 28 pin PLCC, as well as 24 pin DIP.



## BLOCK DIAGRAM



UDG-94047

Circuit Design Patented

**ABSOLUTE MAXIMUM RATINGS**

Tempwr Voltage .....	+7V
Signal Line Voltage .....	0V to +7V
Regulator Output Current .....	1A
Storage Temperature .....	-65°C to +150°C
Operating Temperature .....	-55°C to +150°C
Lead Temperature (Soldering, 10 Sec.) .....	+300°C

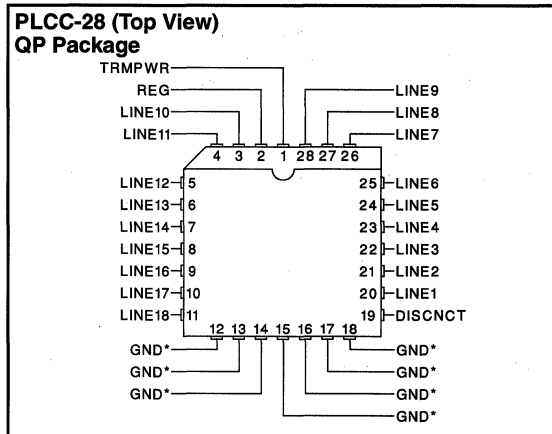
*Unless otherwise specified all voltages are with respect to Ground. Currents are positive into, negative out of the specified terminal.*

*Consult Packaging Section of Unitrode Integrated Circuits databook for thermal limitations and considerations of packages.*

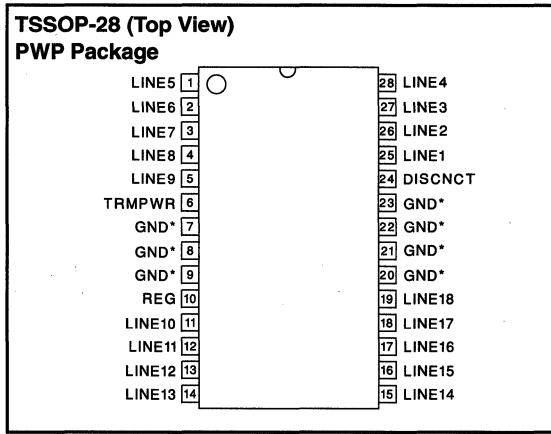
**RECOMMENDED OPERATING CONDITIONS**

Tempwr Voltage .....	3.8V to 5.25V
Signal Line Voltage .....	0V to +5V
Disconnect Input Voltage .....	0V to Tempwr

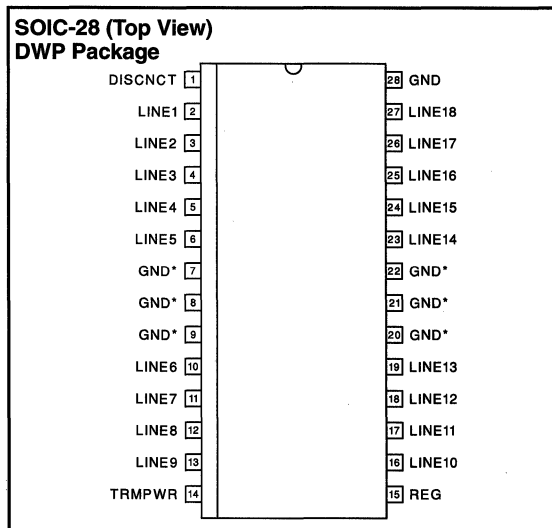
**CONNECTION DIAGRAMS**



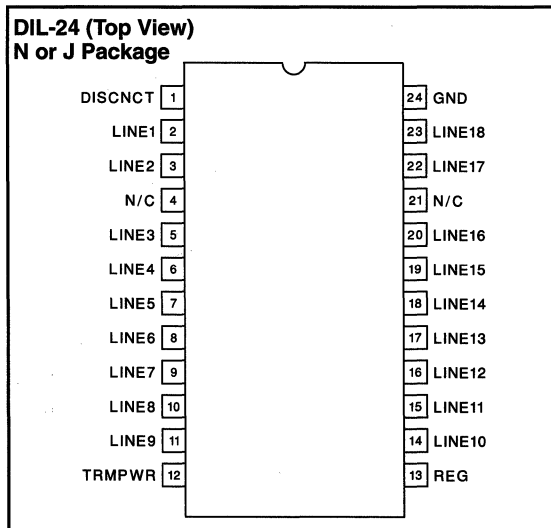
\* QP package pins 12 - 18 serve as both heatsink and signal ground.



\* PWP package pin 23 serves as signal ground; pins 7, 8, 9, 20, 21 and 22 serve as heatsink/ground.



\* DWP package pin 28 serves as signal ground; pins 7, 8, 9, 20, 21, 22 serve as heatsink/ground.



Note: Drawings are not to scale.

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ . TRMPWR = 4.75V, DISCNCT = Ground.  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS	
<b>Supply Current Section</b>						
Termpwr Supply Current	All termination lines = Open		17	25	mA	
	All termination lines = 0.5V		400	430	mA	
Power Down Mode	DISCNCT = Open		100	150	$\mu\text{A}$	
<b>Output Section (Terminator Lines)</b>						
Terminator Impedance	$\Delta\text{LINE} = -5\text{mA}$ to $-15\text{mA}$	104.5	110	115.5	Ohms	
Output High Voltage	$V_{\text{TRMPWR}} = 4\text{V}$ (Note 1)	2.65	2.9	3.0	V	
Max Output Current	$V_{\text{LINE}} = 0.5\text{V}$	$T_J = 25^\circ\text{C}$	-20.3	-21.5	-22.4	mA
		$0^\circ\text{C} < T_J < 70^\circ\text{C}$	-19.8	-21.5	-22.4	mA
Max Output Current	$V_{\text{LINE}} = 0.5\text{V}$ , TRMPWR = 4V (Note 1)	$T_J = 25^\circ\text{C}$	-19.5	-21.5	-22.4	mA
		$0^\circ\text{C} < T_J < 70^\circ\text{C}$	-19.0	-21.5	-22.4	mA
Output Leakage	DISCNCT = 4V	TRMPWR = 0V to 5.25V, REG = 0V	$V_{\text{LINE}} = 0$ to 4V	10	400	nA
			$V_{\text{LINE}} = 5.25\text{V}$		100	$\mu\text{A}$
		TRMPWR = 0V to 5.25V, REG = Open	$V_{\text{LINE}} = 0\text{V}$ to 5.25V	10	400	nA
Output Capacitance	DISCNCT = Open (Note 2)		6	7	pF	
<b>Regulator Section</b>						
Regulator Output Voltage		2.8	2.9	3	V	
Regulator Output Voltage	All Termination Lines = 4V	2.8	2.9	3	V	
Line Regulation	TRMPWR = 4V to 6V		10	20	mV	
Drop Out Voltage	All Termination Lines = 0.5V		1.0	1.2	V	
Short Circuit Current	$V_{\text{REG}} = 0\text{V}$	-450	-650	-950	mA	
Sinking Current Capability	$V_{\text{REG}} = 3.5\text{V}$	100	200	500	mA	
Thermal Shutdown			170		$^\circ\text{C}$	
Thermal Shutdown Hysteresis			10		$^\circ\text{C}$	
<b>Disconnect Section</b>						
Disconnect Threshold		1.1	1.4	1.7	V	

Note 1: Measuring each termination line while other 17 are low (0.5V).

Note 2: Guaranteed by design. Not 100% tested in production.

**APPLICATION INFORMATION**

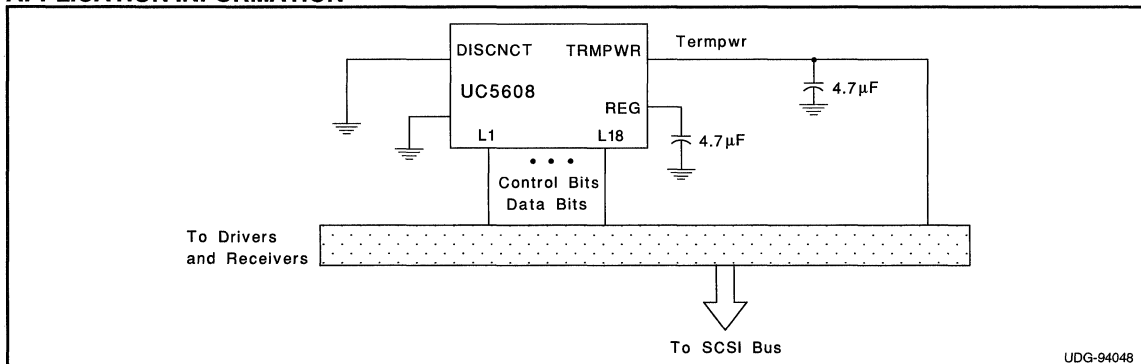


Figure 1: Typical SCSI Bus Configuration

# 18-Line Low Capacitance SCSI Active Terminator

## FEATURES

- Reverse Disconnect
- Complies with SCSI, SCSI-2 and SPI-2 Standards
- 6pF Channel Capacitance during Disconnect
- 100µA Supply Current in Disconnect Mode
- Meets SCSI Hot Plugging Capability
- -650mA Sourcing Current for Termination
- +200mA Sinking Current for Active Negation
- Provides Active Termination for 18 Lines
- Logic Command Disconnects all Termination Lines
- Trimmed Termination Current to 5%
- Trimmed Impedance to 5%
- Current Limit and Thermal Shutdown Protection

## DESCRIPTION

The UC5609 provides 18 lines of active termination for a SCSI (Small Computer Systems Interface) parallel bus. The SCSI standard recommends active termination at both ends of the bus cable.

The UC5609 is pin-for-pin compatible with its predecessors, the UC5601, UC5602 and UC5608 - 18 Line Active Terminators, except for the reverse disconnect sense. Parametrically the UC5609 has a 5% tolerance on impedance and current compared to a 3% tolerance on the UC5601 and the sink current is increased from 20 to 200mA. The low side clamps have been removed. Custom power packages are utilized to allow normal operation at full power conditions (2 Watts).

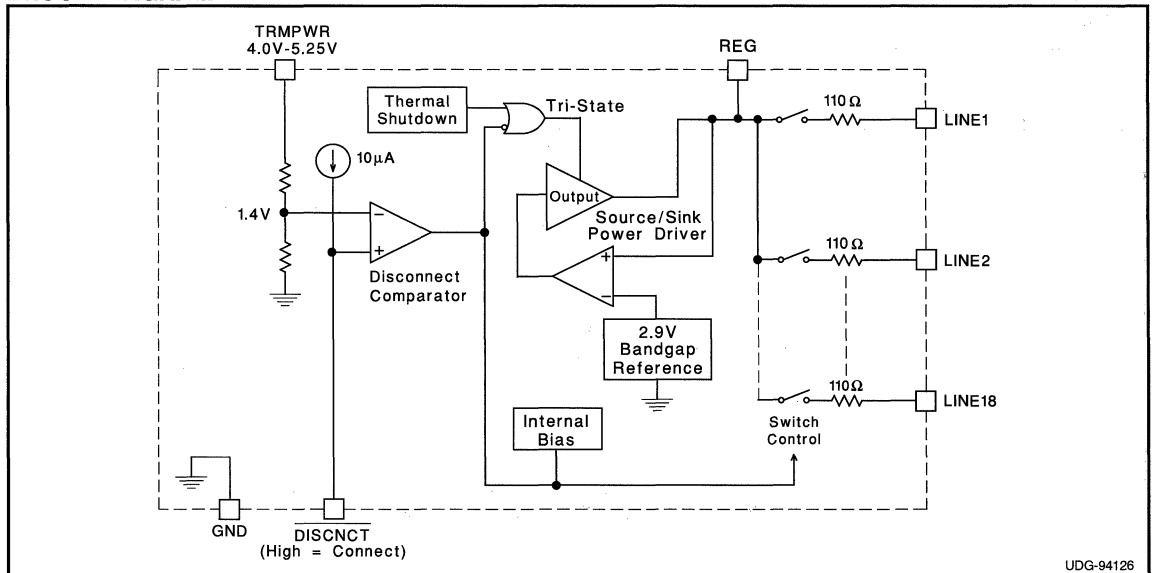
When in disconnect mode the terminator will disconnect all terminating resistors and disable the regulator, greatly reducing standby power. The output channels remain high impedance even without Tempwr applied.

Internal circuit trimming is utilized to trim the impedance to a 5% tolerance and, most importantly, to trim the output current to a 5% tolerance, as close to the max SCSI spec as possible, which maximizes noise margin in fast SCSI operation.

Other features include 4.0 to 5.25V Tempwr, thermal shutdown and current limit.

This device is offered in low thermal resistance versions of the industry standard 28 pin wide body SOIC, 28 pin wide body TSSOP, and 28 pin PLCC, as well as 24 pin DIP.

## BLOCK DIAGRAM



Circuit Design Patented

UDG-94126



### ABSOLUTE MAXIMUM RATINGS

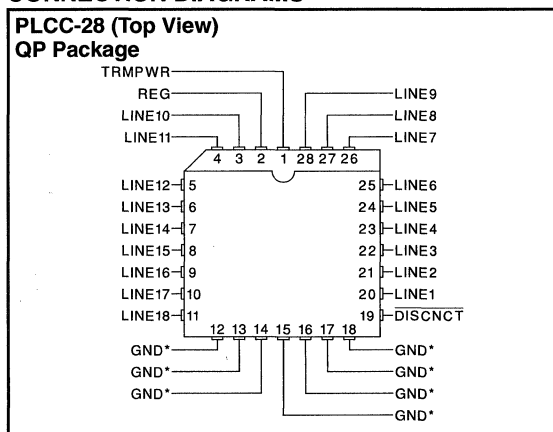
Tempwr Voltage	..... +7V
Signal Line Voltage	..... 0V to +7V
Regulator Output Current	..... 1A
Storage Temperature	..... -65°C to +150°C
Operating Temperature	..... -55°C to +150°C
Lead Temperature (Soldering, 10 Sec.)	..... +300°C

Unless otherwise specified all voltages are with respect to Ground. Currents are positive into, negative out of the specified terminal.  
Consult Packaging Section of Unitrode Integrated Circuits databook for thermal limitations and considerations of packages.

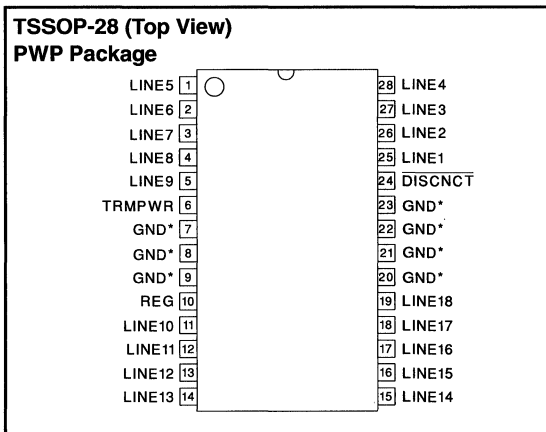
### RECOMMENDED OPERATING CONDITIONS

Tempwr Voltage	..... 3.8V to 5.25V
Signal Line Voltage	..... 0V to +5V
Disconnect Input Voltage	..... 0V to Tempwr

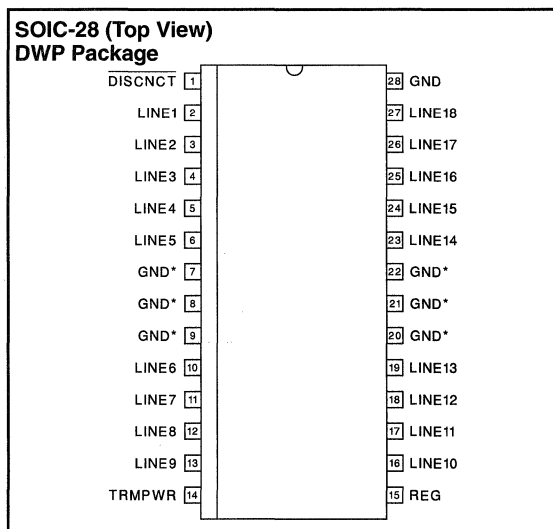
### CONNECTION DIAGRAMS



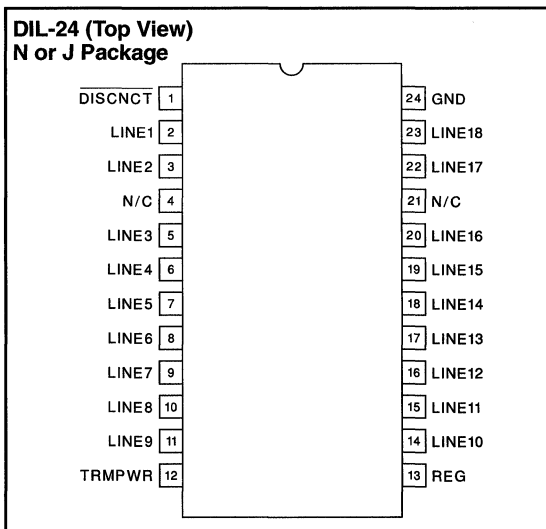
\* QP package pins 12 - 18 serve as both heatsink and signal ground.



\* PWP package pin 23 serves as signal ground; pins 7, 8, 9, 20, 21 and 22 serve as heatsink/ground.



\* DWP package pin 28 serves as signal ground; pins 7, 8, 9, 20, 21, 22 serve as heatsink/ground.



Note: Drawings are not to scale.

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ .  $\text{TRMPWR} = 4.75\text{V}$ ,  $\text{DISCNCNT} = 2.4\text{V}$ .  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS		
<b>Supply Current Section</b>							
Tempwr Supply Current	All termination lines = Open		17	25	mA		
	All termination lines = 0.5V		400	430	mA		
Power Down Mode	DISCNCNT = GND		100	150	$\mu\text{A}$		
<b>Output Section (Terminator Lines)</b>							
Terminator Impedance	$\Delta\text{LINE} = -5\text{mA}$ to $-15\text{mA}$	104.5	110	115.5	$\Omega$		
Output High Voltage	$V_{\text{TRMPWR}} = 4\text{V}$ (Note 1)	2.65	2.9	3.0	V		
Max Output Current	$V_{\text{LINE}} = 0.5\text{V}$	$T_J = 25^\circ\text{C}$	-20.3	-21.5	-22.4	mA	
		$0^\circ\text{C} < T_J < 70^\circ\text{C}$	-19.8	-21.5	-22.4	mA	
Max Output Current	$V_{\text{LINE}} = 0.5\text{V}$ , $\text{TRMPWR} = 4\text{V}$ (Note 1)	$T_J = 25^\circ\text{C}$	-19.5	-21.5	-22.4	mA	
		$0^\circ\text{C} < T_J < 70^\circ\text{C}$	-19.0	-21.5	-22.4	mA	
Output Leakage	$\text{DISCNCNT} = \text{GND}$	$\text{TRMPWR} = 0\text{V}$ to $5.25\text{V}$ $\text{REG} = 0\text{V}$	$V_{\text{LINE}} = 0$ to $4\text{V}$		10	400	nA
			$V_{\text{LINE}} = 5.25\text{V}$			100	$\mu\text{A}$
Output Leakage	$\text{DISCNCNT} = \text{GND}$	$\text{TRMPWR} = 0\text{V}$ to $5.25\text{V}$ , $\text{REG} = \text{Open}$ $V_{\text{LINE}} = 0\text{V}$ to $5.25\text{V}$			10	400	nA
Output Capacitance	$\text{DISCNCNT} = \text{GND}$ (Note 2)		6	7	pF		
<b>Regulator Section</b>							
Regulator Output Voltage		2.8	2.9	3	V		
Regulator Output Voltage	All Termination Lines = 4V	2.8	2.9	3	V		
Line Regulation	$\text{TRMPWR} = 4\text{V}$ to $6\text{V}$		10	20	mV		
Drop Out Voltage	All Termination Lines = 0.5V		1.0	1.2	V		
Short Circuit Current	$V_{\text{REG}} = 0\text{V}$	-450	-650	-950	mA		
Sinking Current Capability	$V_{\text{REG}} = 3.5\text{V}$	100	200	500	mA		
Thermal Shutdown			170		$^\circ\text{C}$		
Thermal Shutdown Hysteresis			10		$^\circ\text{C}$		
<b>Disconnect Section</b>							
Disconnect Threshold		1.1	1.4	1.7	V		

Note 1: Measuring each termination line while other 17 are low (0.5V).

Note 2: Guaranteed by design. Not 100% tested in production.

## APPLICATION INFORMATION

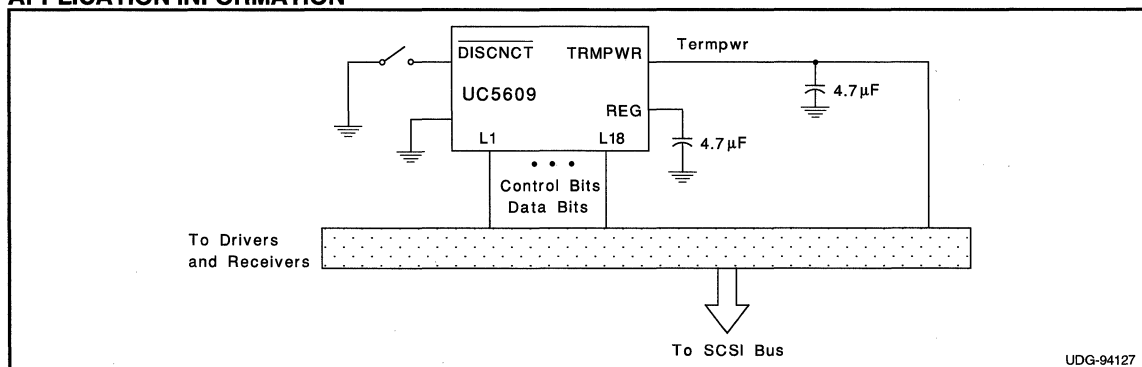


Figure 1: Typical SCSI Bus Configuration



# 9-Line Low Capacitance SCSI Active Terminator

## FEATURES

- Complies with SCSI, SCSI-2 and SPI-2 Standards
- 5pF Channel Capacitance during Disconnect
- Meets SCSI Hot Plugging
- -400mA Sourcing Current for Termination
- +100mA Sinking Current for Active Negation
- 1V Dropout Voltage Regulator
- Logic High Command Disconnects all Termination Lines
- 100µA Supply Current in Disconnect Mode
- Trimmed Termination Current to 5%
- Trimmed Impedance to 5%
- Low Thermal Resistance Surface Mount Packages

## DESCRIPTION

The UC5612 provides 9 lines of active termination for a SCSI (Small Computer Systems Interface) parallel bus. The SCSI standard recommends active termination at both ends of the cable segment.

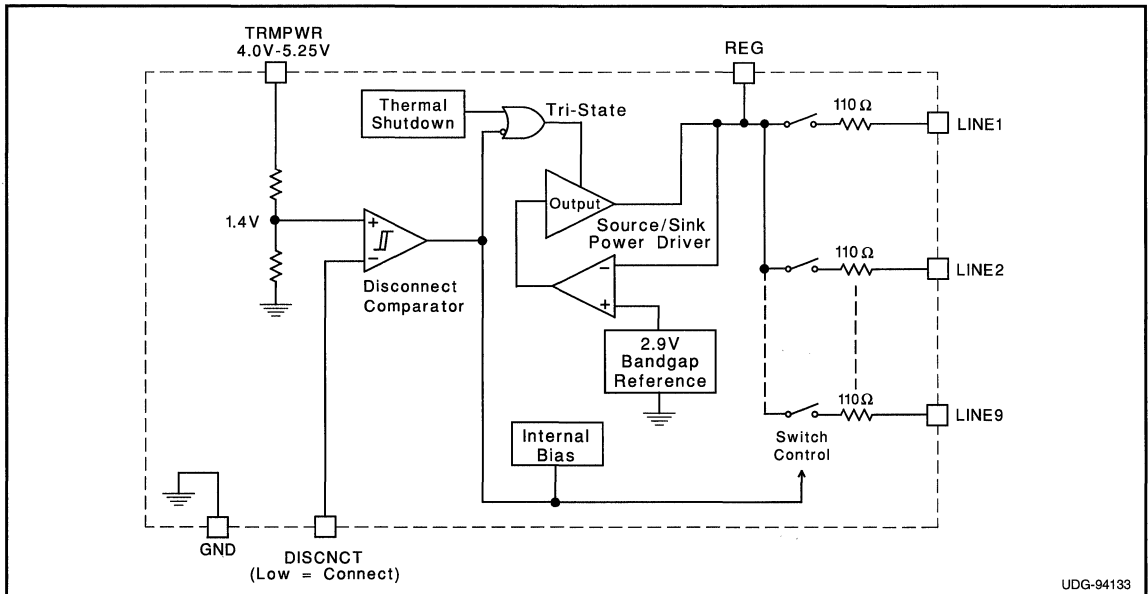
The only functional differences between the UC5603 and UC5612 is the absence of the negative clamps on the output lines. Parametrically, the UC5612 has a 5% tolerance on impedance and current compared to a 3% tolerance on the UC5603. Custom power packages are utilized to allow normal operation at full power (2 Watts).

The UC5612 provides a disconnect feature which, when opened or driven high, disconnects all terminating resistors, disables the regulator and greatly reduces standby power consumption. The output channels remain high impedance even without Tempwr applied. A low channel capacitance of 5pF allows interim points of the bus to have little to no effect on the signal integrity.

Internal circuit trimming is utilized, first to trim the impedance to a 5% tolerance, and then most importantly, to trim the output current to a 5% tolerance, as close to the maximum SCSI specification as possible. This maximizes the noise margin in fast SCSI operation. Other features include thermal shutdown and current limit.

This device is offered in low thermal resistance versions of the industry standard 16 pin narrow body SOIC, 16 pin ZIP (zig-zag in line package) and 24 pin TSSOP.

## BLOCK DIAGRAM



Circuit Design Patented

UDG-94133



**ABSOLUTE MAXIMUM RATINGS**

Tempwr Voltage .....	+7V
Signal Line Voltage .....	0V to +7V
Regulator Output Current .....	0.6A
Storage Temperature .....	-65°C to +150°C
Operating Temperature .....	-55°C to +150°C
Lead Temperature (Soldering, 10 Sec.) .....	+300°C

Unless otherwise specified all voltages are with respect to Ground. Currents are positive into, negative out of the specified terminal.

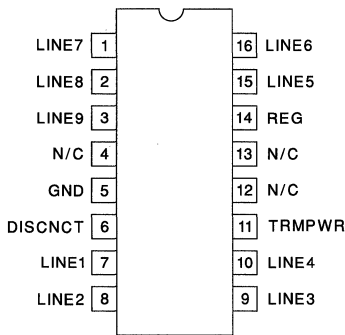
Consult Packaging Section of Unirode Integrated Circuits databook for thermal limitations and considerations of packages.

**RECOMMENDED OPERATING CONDITIONS**

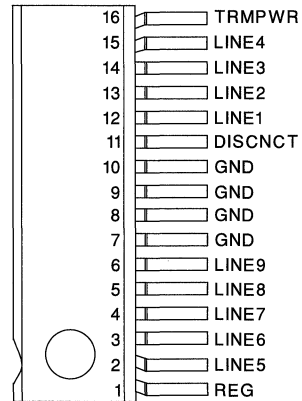
Tempwr Voltage .....	3.8V to 5.25V
Signal Line Voltage .....	0V to +5V
Disconnect Input Voltage .....	0V to Tempwr

**CONNECTION DIAGRAMS**

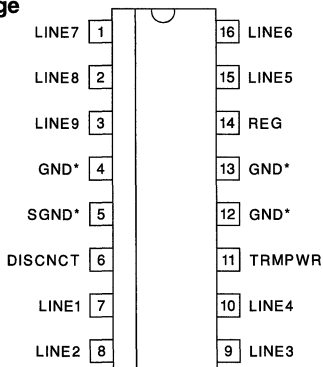
**DIL-16 (Top View)**  
N or J Package



**ZIP-16 (Top View)**  
Z Package

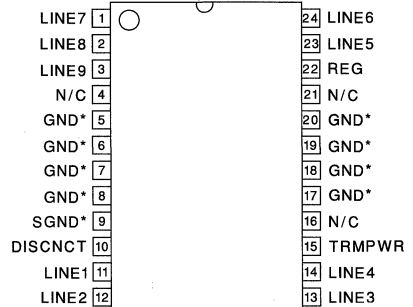


**SOIC-16 (Top View)**  
DP Package



\* DP package pin 5 serves as signal ground; pins 4, 12, 13 serve as heatsink/ground.

**TSSOP-24 (Top View)**  
PWP Package



\* PWP package pin 9 serves as signal ground; pins 5, 6, 7, 8, 17, 18, 19, and 20 serve as heatsink/ground.

Note: Drawings are not to scale.

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for TA = 0°C to 70°C.  
 TRMPWR = 4.75V, DISCNCT = 0V, TA = TJ.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS	
<b>Supply Current Section</b>						
Tempwr Supply Current	All termination lines = Open		17	23	mA	
	All termination lines = 0.5V		200	225	mA	
Power Down Mode	DISCNCT = Open		100	150	μA	
<b>Output Section (Termination Lines)</b>						
Terminator Impedance	ΔLINE = -5mA to -15mA	104.5	110	115.5	Ohms	
Output High Voltage		2.65	2.9	3.1	V	
Max Output Current	VLINE = 0.5V	TJ = 25°C	-20.3	-21.5	-22.4	mA
		0°C < TJ < 70°C	-19.8	-21.5	-22.4	mA
Max Output Current	VLINE = 0.5V, TRMPWR = 4V (Note 1)	TJ = 25°C	-19.5	-21.5	-22.4	mA
		0°C < TJ < 70°C	-19.0	-21.5	-22.4	mA
	VLINE = 0.2V, TRMPWR = 4V to 5.25V	0°C < TJ < 70°C	-21.6	-24.0	-25.4	mA
Output Leakage	DISCNCT = 4V TRMPWR = 0V to 5.25V	REG = 0V	VLINE = 0 to 4V	10	400	nA
			VLINE = 5.25V		100	μA
	REG = Open	VLINE = 0V to 5.25V	10	400	nA	
Output Capacitance	DISCNCT = Open (Note 2) (DP Package)		5	6	pF	
<b>Regulator Section</b>						
Regulator Output Voltage		2.7	2.9	3.1	V	
	All Termination Lines = 4V	2.7	2.9	3.1	V	
Line Regulation	TRMPWR = 4V to 6V		10	20	mV	
Drop Out Voltage	All Termination Lines = 0.5V		1.0	1.2	V	
Short Circuit Current	REG = 0V	-200	-400	-600	mA	
Sinking Current Capability	REG = 3.5V	75	100	400	mA	
Thermal Shutdown			170		°C	
Thermal Shutdown Hysteresis			10		°C	
<b>Disconnect Section</b>						
Disconnect Threshold		1.1	1.4	1.7	V	

Note 1: Measuring each termination line while other 8 are low.  
 Note 2: Guaranteed by design. Not 100% tested in production.

**APPLICATION INFORMATION**

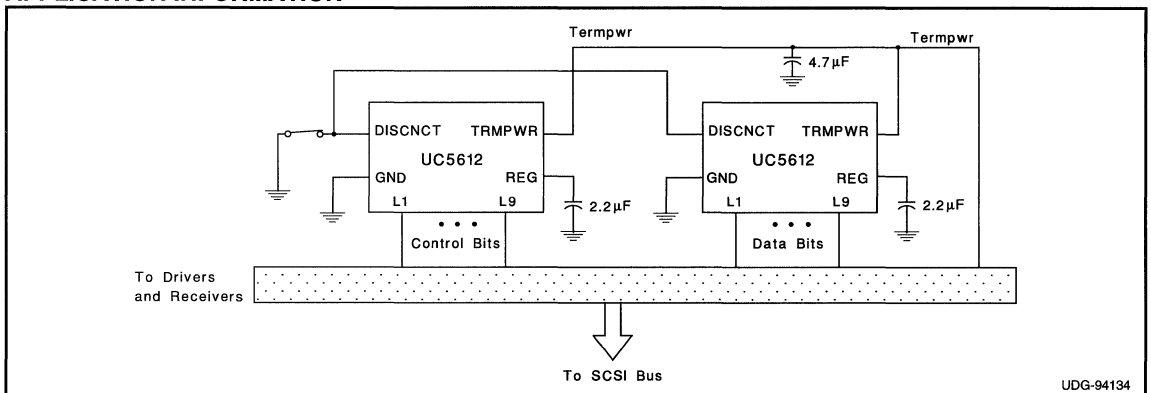


Figure 1: Typical SCSI Bus Configurations Utilizing 2 UC5612 Devices

APPLICATION INFORMATION (cont.)

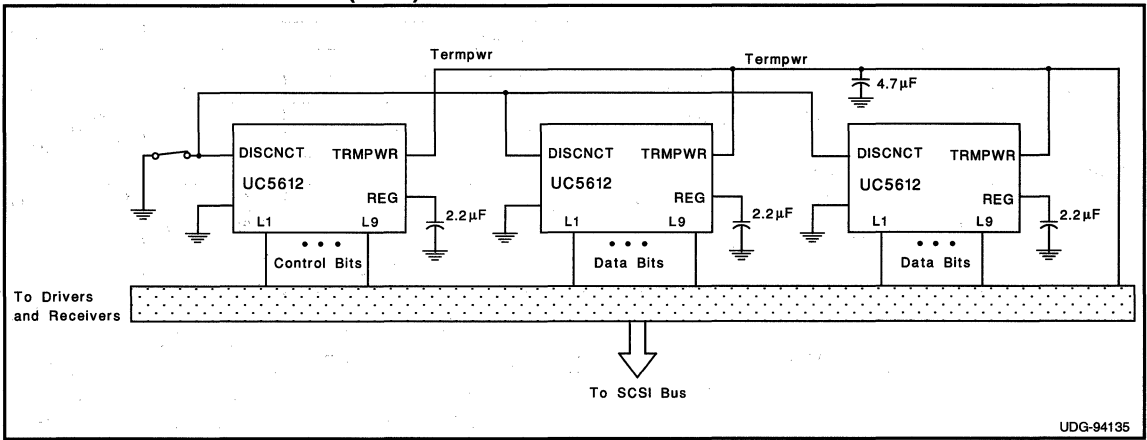


Figure 2: Typical Wide SCSI Bus Configurations Utilizing 3 UC5612 Devices.

UDG-94135

# 9-Line Low Capacitance SCSI Active Terminator

## FEATURES

- Complies with SCSI, SCSI-2 and SPI-2 Standards
- 3pF Channel Capacitance during Disconnect
- 100µA Supply Current in Disconnect Mode
- Meets SCSI Hot Plugging Capability
- -400mA Sourcing Current for Termination
- +400mA Sinking Current for Active Negation
- Logic Command Disconnects all Termination Lines
- Trimmed Termination Current to 5%
- Trimmed Impedance to 5%
- Current Limit and Thermal Shutdown Protection

## DESCRIPTION

The UC5613 provides 9 lines of active termination for a SCSI (Small Computer Systems Interface) parallel bus. The SCSI standard recommends active termination at both ends of the cable segment.

The UC5613 provides a disconnect feature which, when opened or driven high, disconnects all terminating resistors and disables the regulator greatly reducing standby power. The output channels remain high impedance even without *Tempwr* applied. A low channel capacitance of 3pF allows units at interim points of the bus to have little or no effect on the signal integrity.

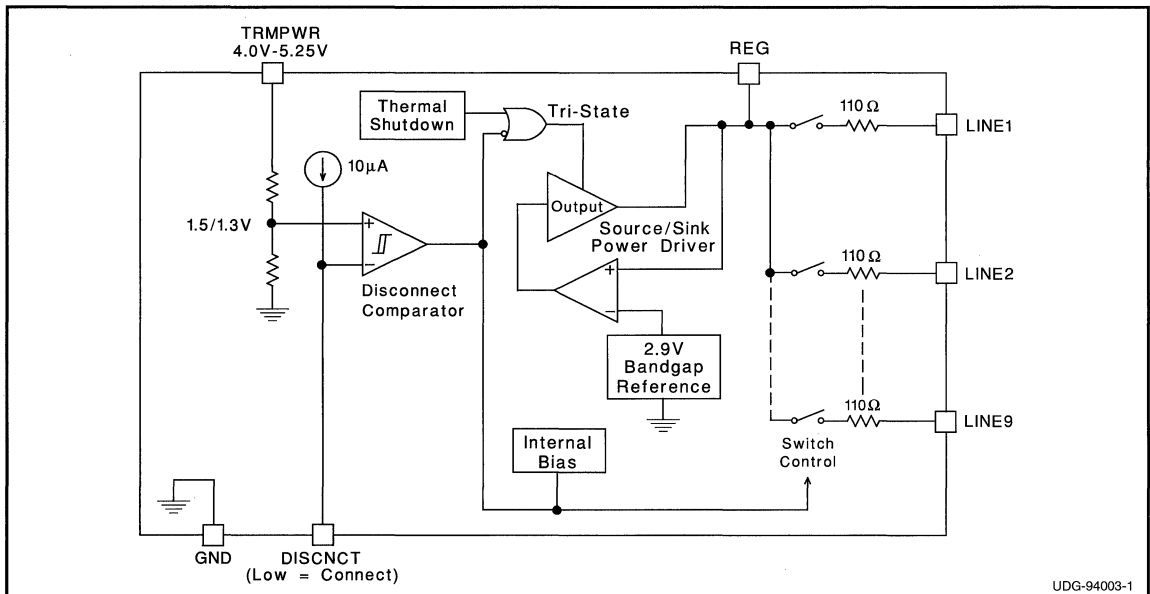
The UC5613 is pin-for-pin compatible with its predecessor, the UC5603 - 9 line Active Terminator. The only functional difference between the UC5613 and UC5603 is the absence of the negative clamps. Parametrically, the UC5613 has a 5% tolerance on impedance and current compared to a 3% tolerance on the UC5603. Custom power packages are utilized to allow normal operation at full power (1.2 watts).

Internal circuit trimming is utilized, first to trim the impedance to a 5% tolerance; then, the output current is trimmed to a 5% tolerance. The output current trim is set as close as possible to the maximum value of the SCSI specification which maximizes the noise margin for fast SCSI operation.

Other features include thermal shutdown and current limit.

This device is offered in low thermal resistance versions of the industry standard 16 pin narrow body SOIC, 16 pin ZIP (zig-zag in line package), and 24 pin TSSOP.

## BLOCK DIAGRAM



Circuit Design Patented

UDG-94003-1

**ABSOLUTE MAXIMUM RATINGS**

Tempwr Voltage .....	+7V
Signal Line Voltage.....	0V to +7V
Regulator Output Current .....	0.5A
Storage Temperature .....	-65°C to +150°C
Operating Temperature .....	-55°C to +150°C
Lead Temperature (Soldering, 10 Sec.).....	+300°C

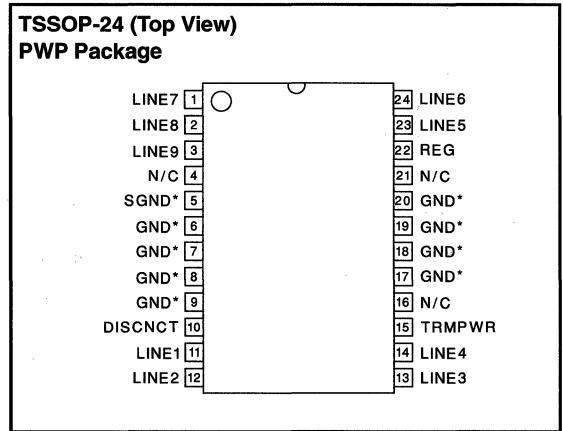
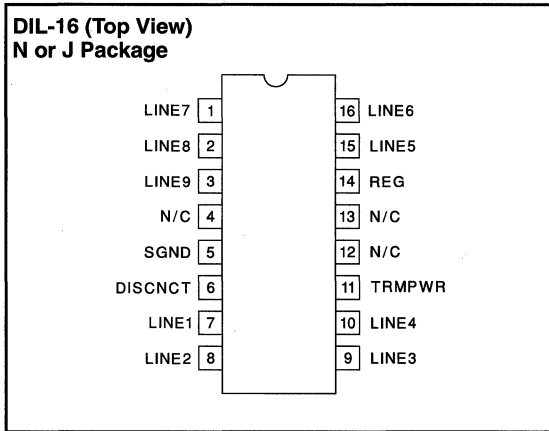
Unless otherwise specified all voltages are with respect to Ground. Currents are positive into, negative out of the specified terminal.

Consult Packaging Section of Unirode Integrated Circuits databook for thermal limitations and considerations of packages.

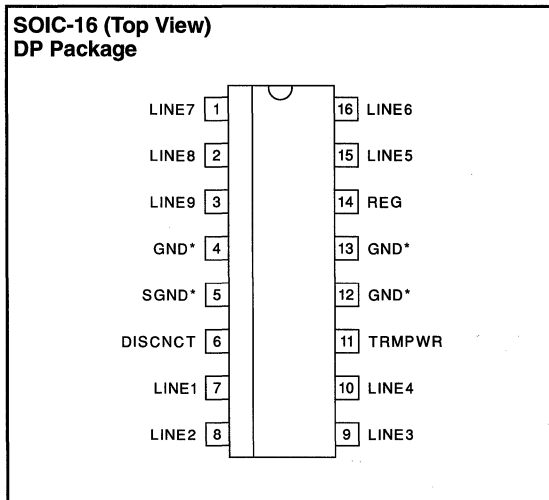
**RECOMMENDED OPERATING CONDITIONS**

Tempwr Voltage .....	3.8V to 5.25V
Signal Line Voltage.....	0V to +5V
Disconnect Input Voltage .....	0V to Tempwr

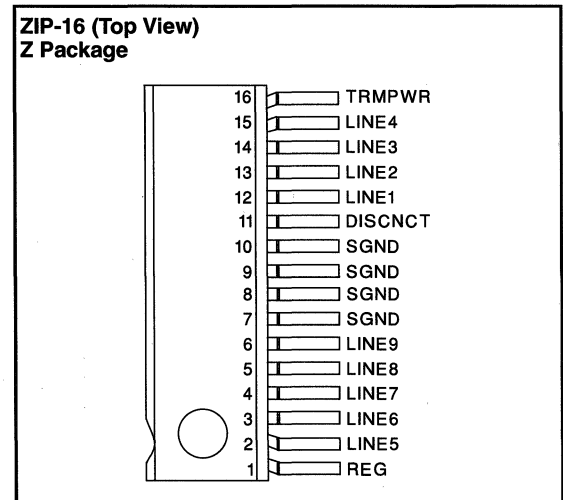
**CONNECTION DIAGRAMS**



\* PWP package pin 5 serves as signal ground; pins 6, 7, 8, 9, 17, 18, 19, and 20 serve as heatsink/ground.



\* DP package pin 5 serves as signal ground; pins 4, 12, 13 serve as heatsink/ground.



Note: Drawings are not to scale.

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ .  
TRMPWR = 4.75V, DISCNECT = 0V.  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS	
<b>Supply Current Section</b>						
Tempwr Supply Current	All termination lines = Open		17	23	mA	
	All termination lines = 0.5V		200	225	mA	
Power Down Mode	DISCNECT = Open		100	150	$\mu\text{A}$	
<b>Output Section (Terminator Lines)</b>						
Terminator Impedance	$\Delta\text{LINE} = -5\text{mA}$ to $-15\text{mA}$	104.5	110	115.5	Ohms	
Output High Voltage	TRMPWR = 4V (Note 1)	2.7	2.9		V	
Max Output Current	$V_{\text{LINE}} = 0.5\text{V}$	$T_J = 25^\circ\text{C}$	-20.3	-21.5	-22.4	mA
		$0^\circ\text{C} < T_J < 70^\circ\text{C}$	-19.8	-21.5	-22.4	mA
Max Output Current	$V_{\text{LINE}} = 0.5\text{V}$ , TRMPWR = 4V (Note 1)	$T_J = 25^\circ\text{C}$	-19.5	-21.5	-22.4	mA
		$0^\circ\text{C} < T_J < 70^\circ\text{C}$	-19.0	-21.5	-22.4	mA
		$0^\circ\text{C} < T_J < 70^\circ\text{C}$	-21.6	-24.0	-25.4	mA
Output Leakage	DISCNECT = 4V	TRMPWR = 0V to 5.25V REG = 0V	$V_{\text{LINE}} = 0$ to 4V	10	400	nA
			$V_{\text{LINE}} = 5.25\text{V}$		100	$\mu\text{A}$
		TRMPWR = 0V to 5.25V, REG = Open $V_{\text{LINE}} = 0\text{V}$ to 5.25V	10	400	nA	
Output Capacitance	DISCNECT = Open, DP Package (Note 2)		3	4.5	pF	
<b>Regulator Section</b>						
Regulator Output Voltage		2.8	2.9	3	V	
Regulator Output Voltage	All Termination Lines = 5V	2.8	2.9	3	V	
Line Regulation	TRMPWR = 4V to 6V		10	20	mV	
Load Regulation	$I_{\text{REG}} = +100\text{mA}$ to $-100\text{mA}$		20	50	mV	
Drop Out Voltage	All Termination Lines = 0.5V		0.7	1	V	
Short Circuit Current	$V_{\text{REG}} = 0\text{V}$	-200	-400	-600	mA	
Sinking Current Capability	$V_{\text{REG}} = 3.5\text{V}$	200	400	600	mA	
Thermal Shutdown			170		$^\circ\text{C}$	
Thermal Shutdown Hysteresis			10		$^\circ\text{C}$	
<b>Disconnect Section</b>						
Disconnect Threshold		1.3	1.5	1.7	V	
Threshold Hysteresis		100	160	250	mV	

Note 1: Measuring each termination line while other 8 are low (0.5V).

Note 2: Guaranteed by design. Not 100% tested in production.

## APPLICATION INFORMATION

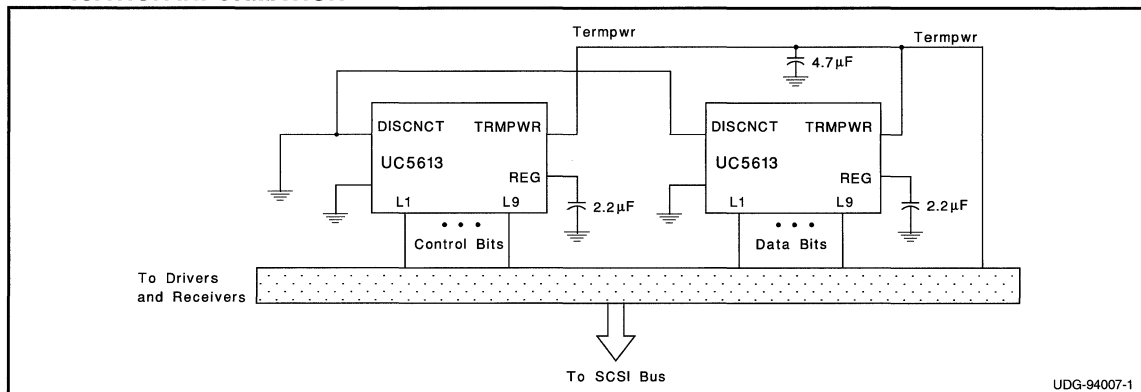


Figure 1: Typical SCSI Bus Configurations Utilizing 2 UC5613 Devices

APPLICATION INFORMATION (cont.)

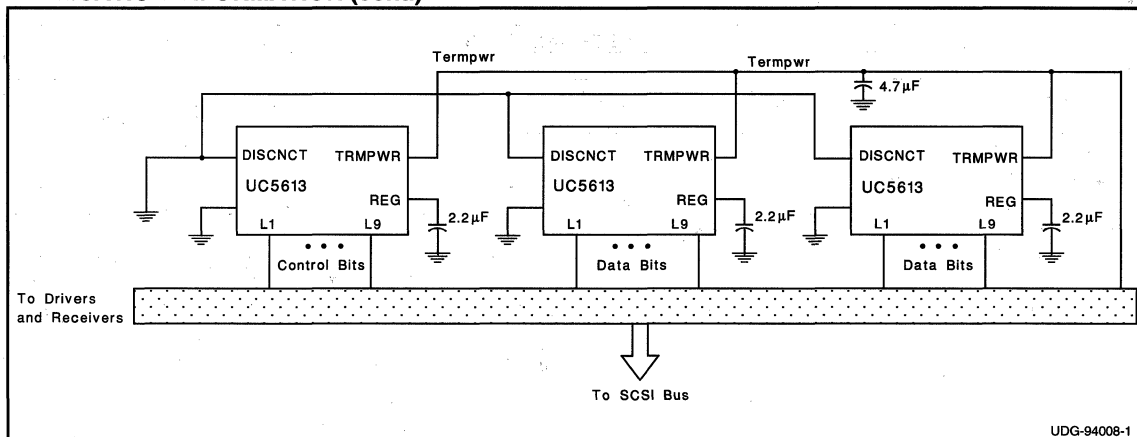


Figure 2: Typical Wide SCSI Bus Configurations Utilizing 3 UC5613 Devices.

UDG-94008-1



# 9-Line 3-5 Volt Low Capacitance SCSI Active Terminator

## FEATURES

- Complies with SCSI, SCSI-2 and SCSI-3 Standards
- 2.7V to 7V Operation
- 1.8pF Channel Capacitance during Disconnect
- 0.5µA Supply Current in Disconnect Mode
- 110 Ohm/2.5k Programmable Termination
- Completely Meets SCSI Hot Plugging
- -400mA Sourcing Current for Termination
- +400mA Sinking Current for Active Negation Drivers
- Trimmed Termination Current to 4%
- Trimmed Impedance to 7%
- Current Limit and Thermal Shutdown Protection

## DESCRIPTION

The UCC5614 provides 9 lines of active termination for a SCSI (Small Computer Systems Interface) parallel bus. The SCSI standard recommends active termination at both ends of the cable.

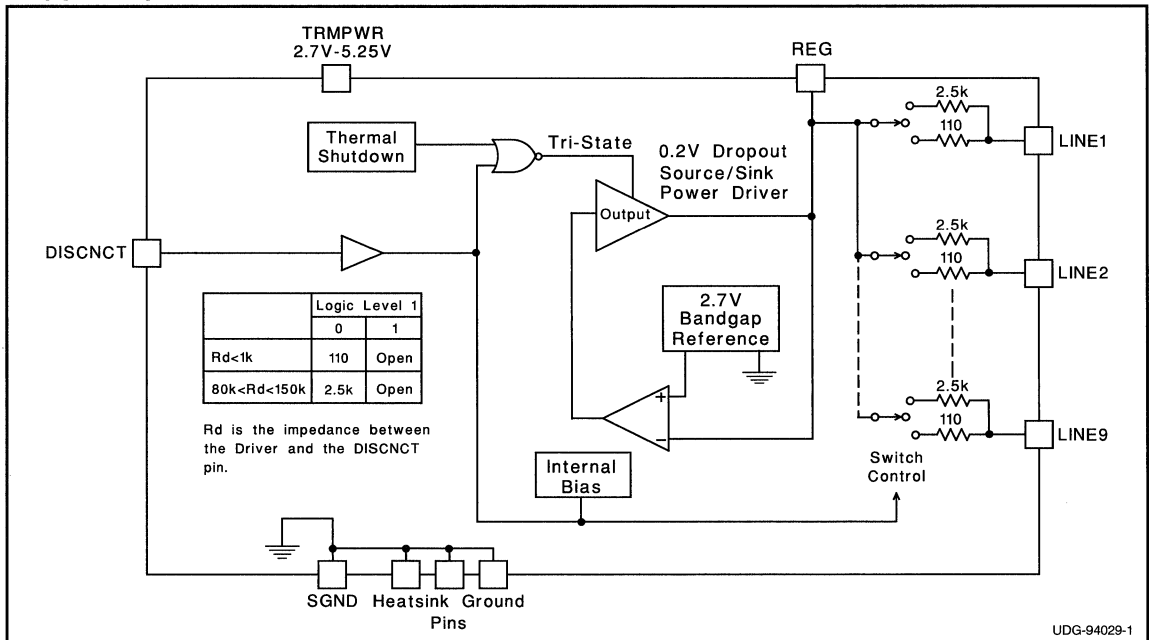
The UCC5614 is ideal for high performance 3.3V SCSI systems. The key features contributing to such low operating voltage are the 0.1V drop out regulator and the 2.7V reference. The reduced reference voltage was necessary to accommodate the lower termination current dictated in the SCSI-3 specification. During disconnect the supply current is typically only 0.5µA, which makes the IC attractive for battery powered systems.

The UCC5614 is designed with an ultra low channel capacitance of 1.8pF, which eliminates effects on signal integrity from disconnected terminators at interim points on the bus.

The UCC5614 can be programmed for either a 110 ohm or 2.5k ohm termination. The 110 ohm termination is used for standard SCSI bus lengths and the 2.5k ohm termination is typically used in short bus applications. When driving the TTL compatible DISCNCT pin directly, the 110 ohm termination is connected when the DISCNCT pin is driven low, and disconnected when driven high. When the DISCNCT pin is driven through an impedance between 80k and 150k, the 2.5k ohm termination is connected when the DISCNCT pin is driven low, and disconnected when driven high.

**continued**

## BLOCK DIAGRAM



UDG-94029-1

Circuit Design Patented

**Description Continued**

The power amplifier output stage allows the UCC5614 to source full termination current and sink active negation current when all termination lines are actively negated.

The UCC5614 is pin for pin compatible with Unitrode's other 9 line SCSI terminators, allowing lower capacitance and lower voltage upgrades to existing systems. The UCC5614, as with all Unitrode terminators, is completely hot pluggable and appears as high impedance at the terminating channels with VTRMPWR = 0V or open.

Internal circuit trimming is utilized, first to trim the 110 ohm termination impedance to a 7% tolerance, and then

most importantly, to trim the output current to a 4% tolerance, as close to the max SCSI-3 spec as possible, which maximizes noise margin in fast SCSI operation.

Other features include thermal shutdown and current limit.

This device is offered in low thermal resistance versions of the industry standard 16 pin narrow body SOIC, 16 pin ZIP (Zig-Zag In Line package), 24 pin TSSOP and 28 pin PLCC.

**ABSOLUTE MAXIMUM RATINGS**

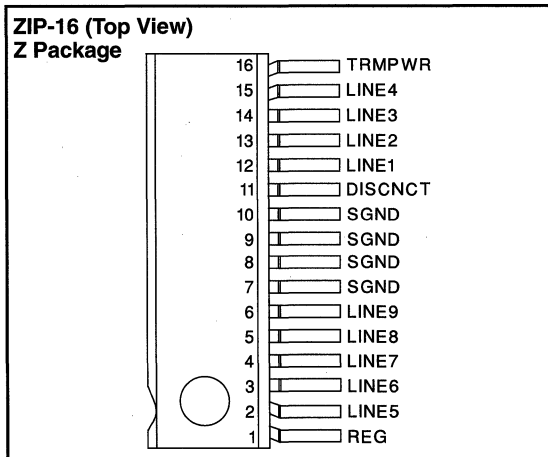
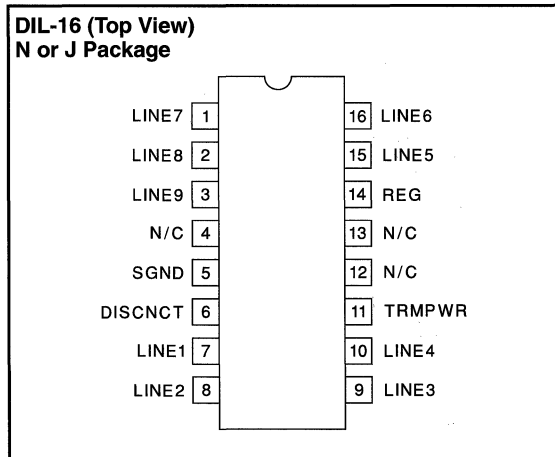
Tempwr Voltage .....	+7V
Signal Line Voltage.....	0V to +7V
Regulator Output Current .....	0.6A
Storage Temperature .....	-65°C to +150°C
Operating Temperature .....	-55°C to +150°C
Lead Temperature (Soldering, 10 Sec.).....	+300°C

*Unless otherwise specified all voltages are with respect to Ground. Currents are positive into, negative out of the specified terminal.  
Consult Packaging Section of Unitrode Integrated Circuits databook for thermal limitations and considerations of packages.*

**RECOMMENDED OPERATING CONDITIONS**

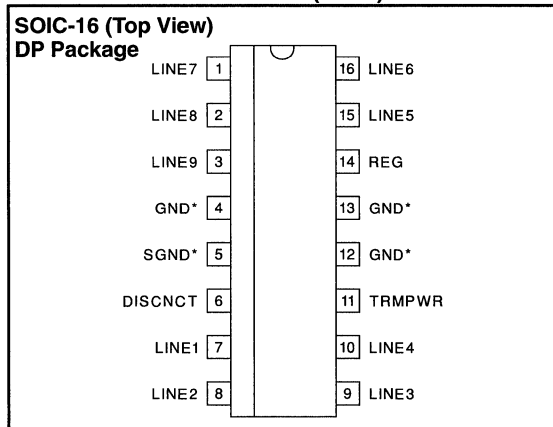
Tempwr Voltage .....	2.7V to 5.25V
Signal Line Voltage.....	0V to +5V
Disconnect Input Voltage .....	0V to Tempwr

**CONNECTION DIAGRAMS**



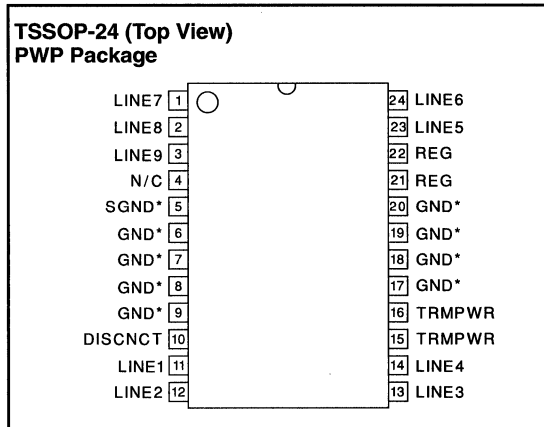
Note: Drawings are not to scale.

**CONNECTION DIAGRAMS (cont.)**



\* DP package pin 5 serves as signal ground; pins 4, 12, 13 serve as heatsink/ground.

Note: Drawings are not to scale.



\* PWP package pin 5 serves as signal ground; pins 6, 7, 8, 9, 17, 18, 19, and 20 serve as heatsink/ground.

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ .  
 TRMPWR = 3.3V, DISCNCT = 0V, R<sub>DISCNCT</sub> = 0 ohms.  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Supply Current Section</b>					
Tempwr Supply Current	All termination lines = Open		1	2	mA
	All termination lines = 0.2V		210	218	mA
Power Down Mode	DISCNCT = Tempwr		0.5	5	μA
<b>Output Section (110 ohms - Terminator Lines)</b>					
Terminator Impedance		102.3	110	117.7	Ohms
Output High Voltage	(Note 1)	2.5	2.7	3.0	V
Max Output Current	V <sub>LINE</sub> = 0.2V T <sub>J</sub> = 25°C	-22.1	-23	-24	mA
	V <sub>LINE</sub> = 0.2V	-21	-23	-24	mA
	V <sub>LINE</sub> = 0.2V, TRMPWR = 3V T <sub>J</sub> = 25°C (Note 1)	-20.2	-23	-24	mA
	V <sub>LINE</sub> = 0.2V, TRMPWR = 3V (Note 1)	-19	-23	-24	mA
	V <sub>LINE</sub> = 0.5V			-22.4	mA
Output Leakage	DISCNCT = 2.4V, TRMPWR = 0V to 5.25V		10	400	nA
Output Capacitance	DISCNCT = 2.4V (Note 2) (DP Package)		1.8	2.5	pF
<b>Output Section (2.5k ohms - Terminator Lines) (R<sub>DISCNCT</sub> = 80k ohms)</b>					
Terminator Impedance		2	2.5	3	kΩ
Output High Voltage	TRMPWR = 3V (Note 1)	2.5	2.7	3.0	V
Max Output Current	V <sub>LINE</sub> = 0.2V	-0.7	-1	-1.4	mA
	V <sub>LINE</sub> = 0.2V, TRMPWR = 3V (Note 1)	-0.6	-1	-1.5	mA
Output Leakage	DISCNCT = 2.4V, TRMPWR = 0 to 5.25V		10	400	nA
Output Capacitance	DISCNCT = 2.4V (Note 2) (DP Package)		1.8	2.5	pF
<b>Regulator Section</b>					
Regulator Output Voltage	5.25V > TRMPWR > 3V	2.5	2.7	3.0	V
Drop Out Voltage	All Termination Lines = 0.2V		0.1	0.2	V
Short Circuit Current	V <sub>REG</sub> = 0V	-200	-400	-800	mA

**ELECTRICAL CHARACTERISTICS (cont.)** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ .  
 $\text{TRMPWR} = 3.3\text{V}$ ,  $\text{DISCNCT} = 0\text{V}$ ,  $\text{RDISCNCT} = 0$  ohms.  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Regulator Section (cont.)</b>					
Sinking Current Capability	$V_{\text{REG}} = 3\text{V}$	200	400	800	mA
Thermal Shutdown	(Note 2)		170		$^\circ\text{C}$
Thermal Shutdown Hysteresis	(Note 2)		10		$^\circ\text{C}$
<b>Disconnect Section</b>					
Disconnect Threshold	$\text{RDISCNCT} = 0$ & $80\text{k}$	0.8	1.5	2.0	V
Input Current	$\text{DISCNCT} = 0\text{V}$		30	50	$\mu\text{A}$

Note 1: Measuring each termination line while other 8 are low (0.2V).

Note 2: Guaranteed by design. Not 100% tested in production.

**APPLICATION INFORMATION**

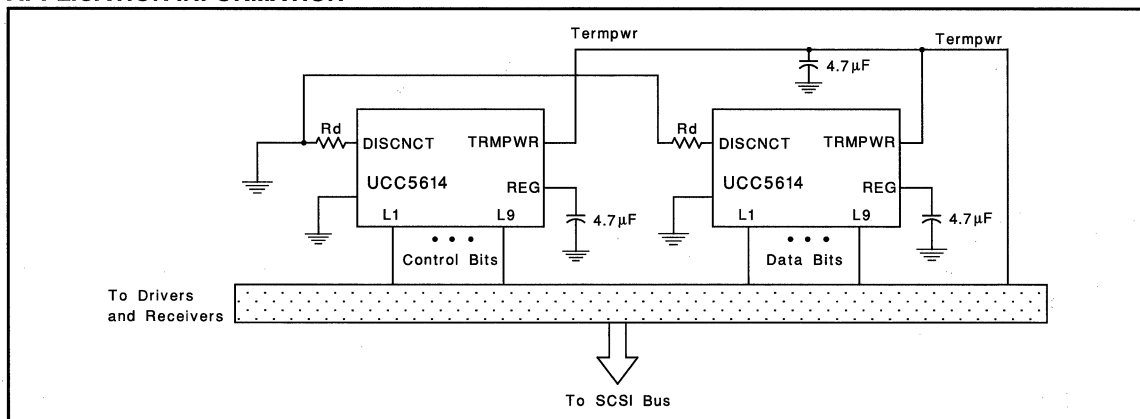


Figure 1: Typical SCSI Bus Configurations Utilizing 2 UCC5614 Devices

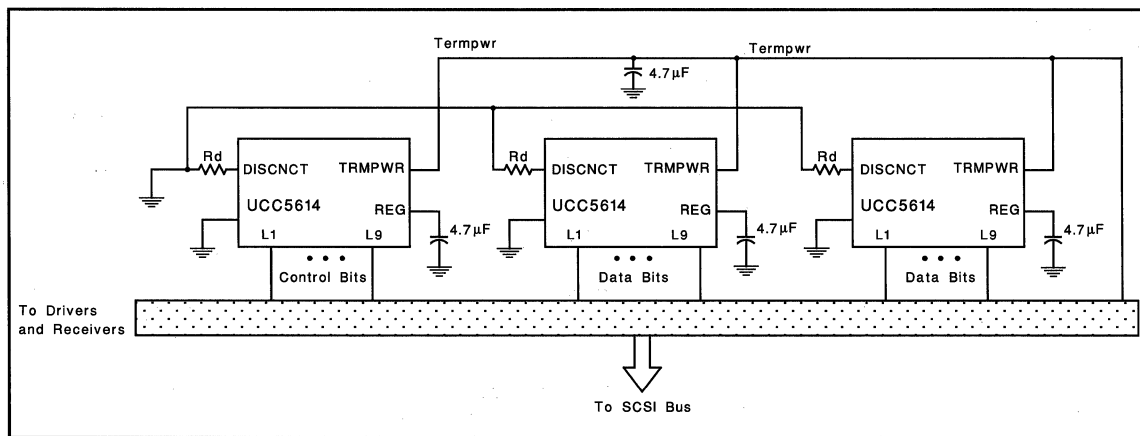


Figure 2: Typical Wide SCSI Bus Configurations Utilizing 3 UCC5614 Devices.

# 18-Line SCSI Terminator (Reverse Disconnect)

## FEATURES

- Complies with SCSI, SCSI-2, SCSI-3, SPI and FAST-20 Standards
- 2pF Channel Capacitance During Disconnect
- 50mA Supply Current in Disconnect Mode
- 110Ω Termination
- SCSI Hot Plugging Compliant, 10nA Typical
- +400mA Sinking Current for Active Negation
- -650mA Sourcing Current for Termination
- Trimmed Impedance to 5%
- Thermal Shutdown
- Current Limit

## DESCRIPTION

The UCC5617 provides 18 lines of active termination for a SCSI (Small Computers Systems Interface) parallel bus. The SCSI standard recommends and Fast-20 (Ultra) requires active termination at both ends of the cable.

Pin for pin compatible with the UC5609, the UCC5617 is ideal for high performance 5V SCSI systems, Tempwr 4.0-5.25V. During disconnect the supply current is only 50μA typical, which makes the IC attractive for lower powered systems.

The UCC5617 is designed with a low channel capacitance of 2pF, which eliminates effects on signal integrity from disconnected terminators at inter-termin points on the bus.

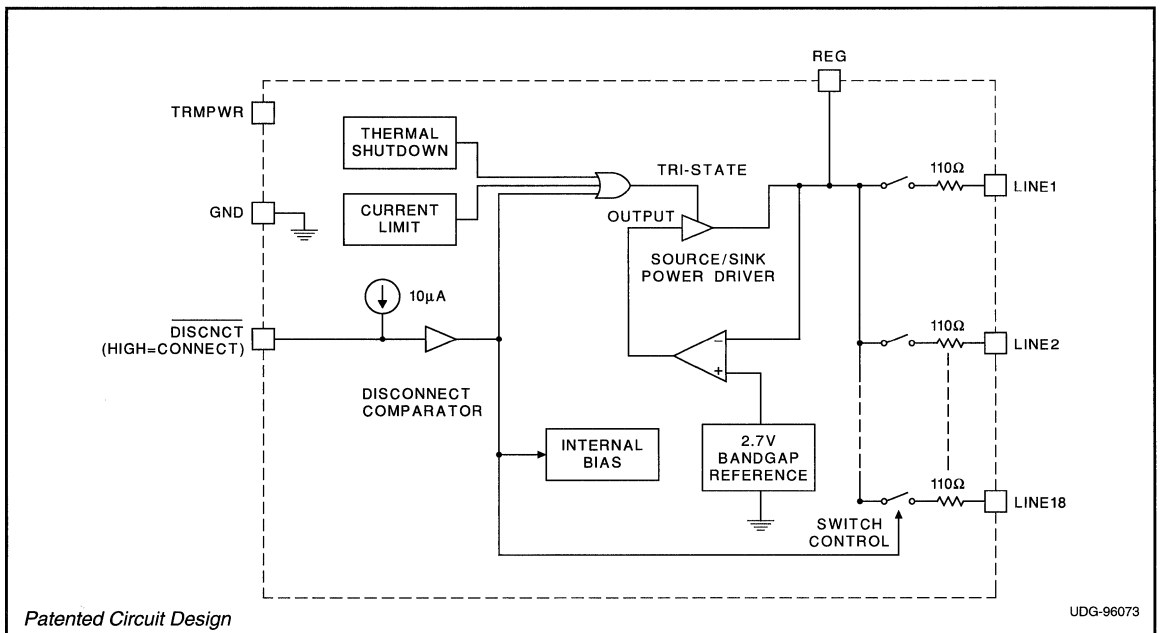
The power amplifier output stage allows the UCC5617 to source full termination current and sink active negation current when all termination lines are actively negated.

The UCC5617, as with all Unitrode terminators, is completely hot pluggable and appears as high impedance at the terminating channels with TRMPWR=0V or open.

Internal circuit trimming is utilized, first to trim the 110Ω impedance, and then most importantly, to trim the output current as close to the maximum SCSI-3 specification as possible, which maximizes noise margin in fast SCSI operation.

This device is offered in low thermal resistance versions of the industry standard 28 pin wide body SOIC, TSSOP and PLCC.

## BLOCK DIAGRAM

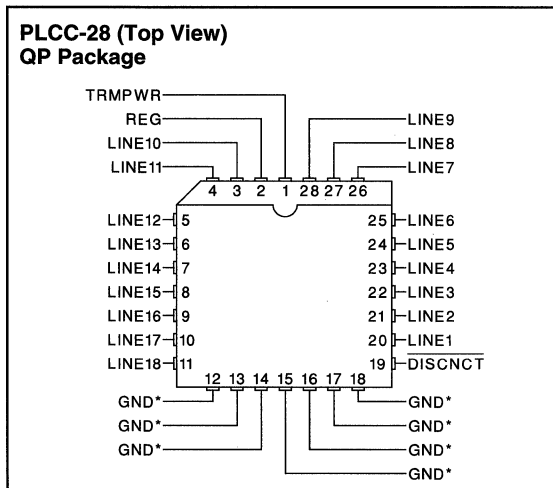


### ABSOLUTE MAXIMUM RATINGS

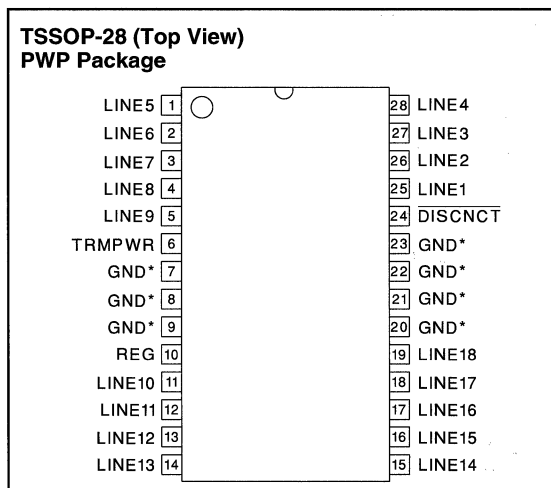
TRMPWR	.....	+7V
Signal Line Voltage	.....	0V to +7V
Regulator Output Current	.....	1A
Storage Temperature	.....	-65°C to +150°C
Operating Junction Temperature	.....	-55°C to +150°C
Lead Temperature (Soldering, 10 Seconds)	.....	300°C

All currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages.

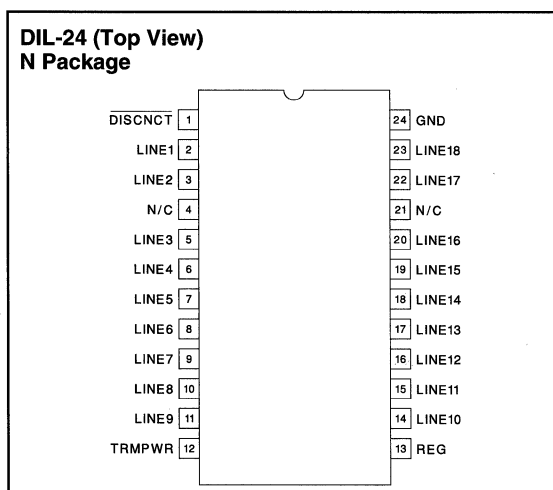
### CONNECTION DIAGRAMS



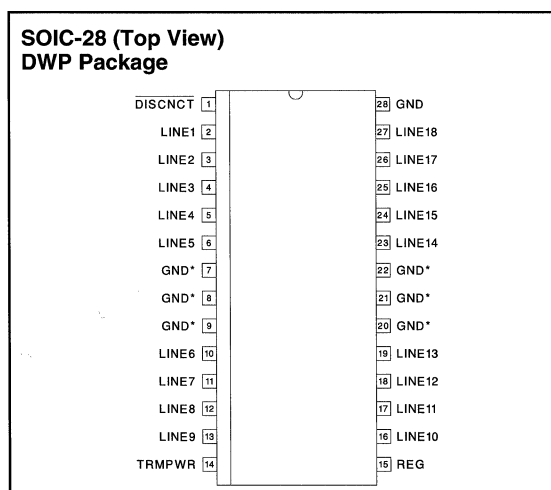
\* DWP package pins 12 - 18 serve as both heatsink and signal ground.



\* PWP package pin 23 serves as signal ground; pins 7, 8, 9, 20, 21, and 22 serve as heatsink ground.



Note: Drawings are not to scale.



**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ ,  $\text{TRMPWR} = 4.75\text{V}$ ,  $\text{DISCNCT} = 0\text{V}$ ,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Supply Current Section</b>					
TERMPWR Supply Current	All Termination Lines = Open		1	2	mA
	All Termination Lines = 0.2V		420	440	mA
Power Down Mode	$\overline{\text{DISCNCT}} = 0\text{V}$		50	100	$\mu\text{A}$
<b>Output Section (Termination Lines)</b>					
Termination Impedance	(Note 3)	104.5	110	115.5	$\Omega$
Output High Voltage	$V_{\text{TRMPWR}} = 4\text{V}$ (Note 1)	2.6	2.8	3	V
Max Output Current	$V_{\text{LINE}} = 0.2\text{V}$ , $T_J = 25^\circ\text{C}$	-22.1	-23.3	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$	-20.7	-23.3	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$ , $\text{TERMPWR} = 4\text{V}$ , $T_J = 25^\circ\text{C}$ (Note 1)	-21	-23.3	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$ , $\text{TRMPWR} = 4\text{V}$ (Note 1)	-20	-23	-24	mA
	$V_{\text{LINE}} = 0.5\text{V}$			-22.4	mA
Output Leakage	$\text{DISCNCT} = 2.4\text{V}$ , $\text{TRMPWR} = 0\text{V}$ to $5.25\text{V}$ , $\text{REG} = 0.2\text{V}$ , $V_{\text{LINE}} = 5.25\text{V}$		10	400	nA
Output Capacitance	$\text{DISCNCT} = 2.4\text{V}$ (Note 2)		2	3.5	pF
<b>Regulator Section</b>					
Regulator Output Voltage		2.6	2.8	3	V
Drop Out Voltage	All Termination Lines = 0.2V		0.4	0.8	V
Short Circuit Current	$V_{\text{REG}} = 0\text{V}$	-475	-650	-850	mA
Sinking Current Capability	$V_{\text{REG}} = 3.5\text{V}$	200	400	800	mA
Thermal Shutdown			170		$^\circ\text{C}$
Thermal Shutdown Hysteresis			10		$^\circ\text{C}$
<b>Disconnect Section</b>					
Disconnect Threshold		0.8	1.5	2	V
Input Current	$\text{DISCNCT} = 0\text{V}$		-10	-30	$\mu\text{A}$

Note 1: Measuring each termination line while other 17 are low (0.2V).

Note 2: Guaranteed by design. Not 100% tested in production.

Note 3: Tested by measuring  $I_{\text{OUT}}$  with  $V_{\text{OUT}} = 0.2\text{V}$  and  $V_{\text{OUT}}$  with no load, then calculating:  $Z = \frac{V_{\text{OUT N.L.}} - 0.2\text{V}}{I_{\text{OUT at 0.2V}}}$

## PIN DESCRIPTIONS

**DISCNCT:** Taking this pin low causes the 18 channels to become high impedance and the chip to go into low-power mode; a high or open state allows the channels to provide normal termination.

**GND:** Ground reference for the IC.

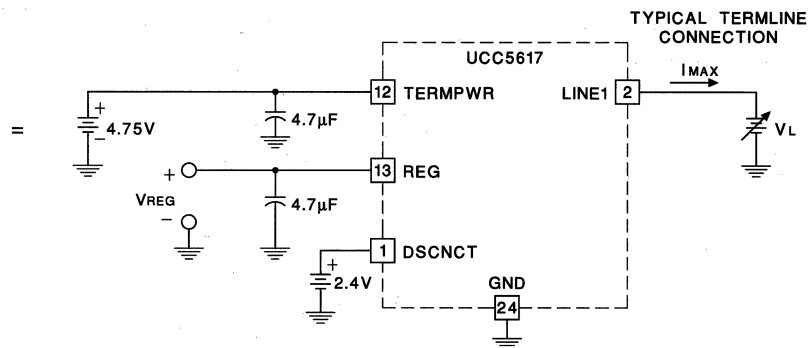
**LINE1–LINE18:** 110 $\Omega$  termination channels.

**REG:** Output of the internal 2.8V regulator.

**TRMPWR:** Power for the IC.

Procedure:

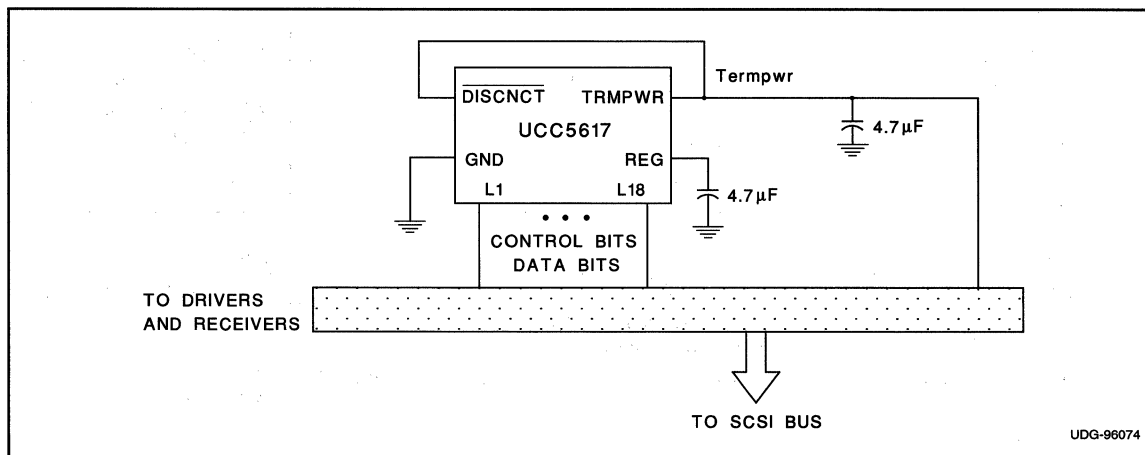
- 1) Measure  $V_{REG}$  N.L.
  - 2) Set  $V_L = 0.2V$
  - 3) Measure  $I_{MAX}$  at 0.2V
  - 4) Impedance
- $$\frac{V_{REG} N.L. - 0.2V}{I_{MAX}}$$



UDG-96108

Figure 1. Termline Impedance Measurement Circuit

APPLICATION INFORMATION



UDG-96074



# 18-Line SCSI Terminator

## FEATURES

- Complies with SCSI, SCSI-2, SCSI-3, SPI and FAST-20 Standards
- 2pF Channel Capacitance During Disconnect
- 50µA Supply Current in Disconnect Mode
- 110Ω Termination
- SCSI Hot Plugging Compliant, 10nA Typical
- +400mA Sinking Current for Active Negation
- -650mA Sourcing Current for Termination
- Trimmed Impedance to 5%
- Thermal Shutdown
- Current Limit

## DESCRIPTION

The UCC5618 provides 18 lines of active termination for a SCSI (Small Computers Systems Interface) parallel bus. The SCSI standard recommends and Fast-20 (Ultra) requires active termination at both ends of the cable.

Pin for pin compatible with the UC5601 and UC5608, the UCC5618 is ideal for high performance 5V SCSI systems, Tempwr 4.0-5.25V. During disconnect the supply current is only 50µA typical, which makes the IC attractive for lower powered systems.

The UCC5618 is designed with a low channel capacitance of 2pF, which eliminates effects on signal integrity from disconnected terminators at interim points on the bus.

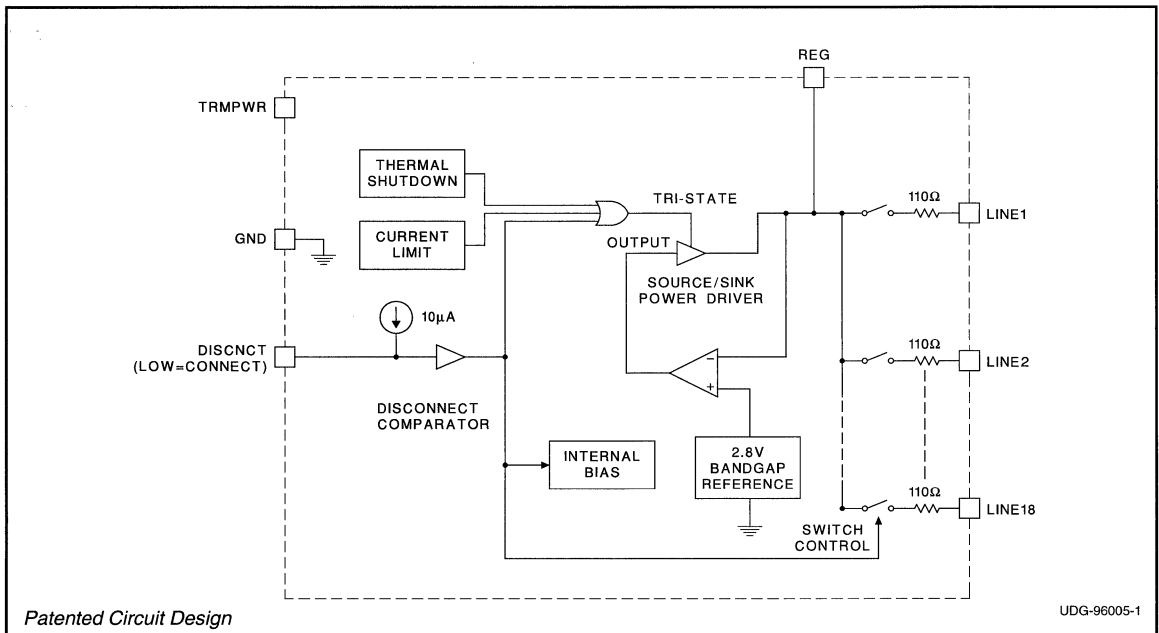
The power amplifier output stage allows the UCC5618 to source full termination current and sink active negation current when all termination lines are actively negated.

The UCC5618, as with all Unitrode terminators, is completely hot pluggable and appears as high impedance at the terminating channels with TRMPWR=0V or open.

Internal circuit trimming is utilized, first to trim the 110Ω impedance, and then most importantly, to trim the output current as close to the max SCSI-3 spec as possible, which maximizes noise margin in fast SCSI operation.

This device is offered in low thermal resistance versions of the industry standard 28 pin wide body SOIC, TSSOP and PLCC.

## BLOCK DIAGRAM

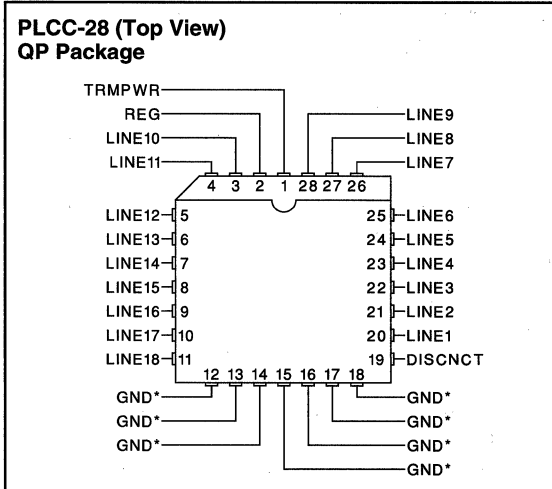


**ABSOLUTE MAXIMUM RATINGS**

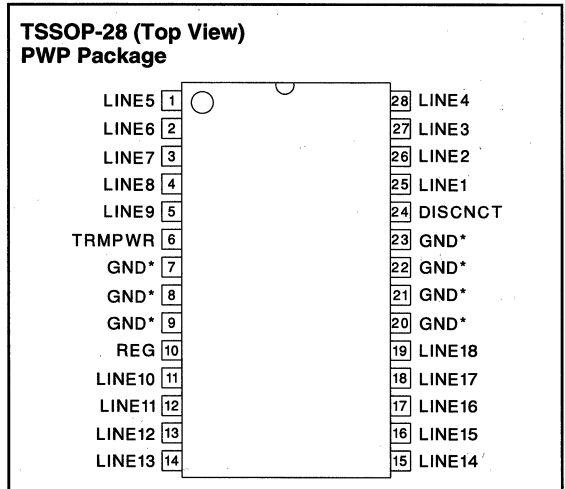
TEMPWR	.....	+7V
Signal Line Voltage	.....	0V to +7V
Regulator Output Current	.....	1A
Storage Temperature	.....	-65°C to +150°C
Operating Junction Temperature	.....	-55°C to +150°C
Lead Temperature (Soldering, 10 Seconds)	.....	300°C

All currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages.

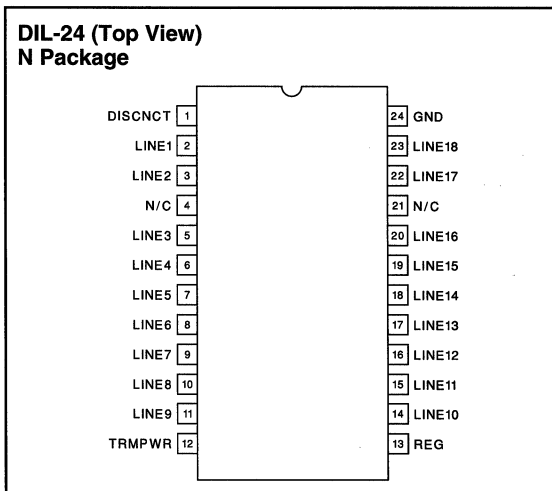
**CONNECTION DIAGRAMS**



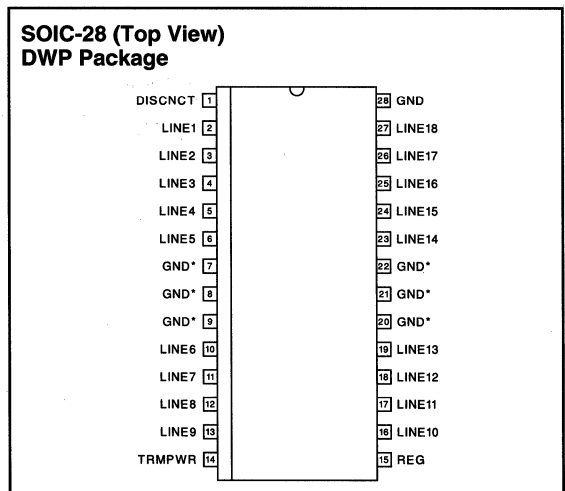
\* DWP package pins 12-18 serve as both heatsink and signal ground.



\* PWP package pin 23 serves as signal ground; pins 7, 8, 9, 20, 21, and 22 serve as heatsink ground.



Note: Drawings are not to scale.



\* DWP package pin 28 serves as signal ground; pins 7, 8, 9, 20, 21, 22 serve as heatsink/ground.

**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated these specifications apply for  $T_A = 0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ ,  $\text{TRMPWR} = 4.75\text{V}$ ,  $\text{DISCNCT} = 0\text{V}$ ,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Supply Current Section</b>					
TERMPWR Supply Current	All Termination Lines = Open		1	2	mA
	All Termination Lines = 0.2V		420	440	mA
Power Down Mode	DISCNCT = TRMPWR		50	100	$\mu\text{A}$
<b>Output Section (Termination Lines)</b>					
Termination Impedance	See Figure 1	104.5	110	115.5	$\Omega$
Output High Voltage	$V_{\text{TRMPWR}} = 4\text{V}$ (Note 1)	2.6	2.8	3	V
Max Output Current	$V_{\text{LINE}} = 0.2\text{V}$ , $T_J = 25^{\circ}\text{C}$	-22.1	-23.3	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$	-20.7	-23.3	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$ , $\text{TRMPWR} = 4\text{V}$ , $T_J = 25^{\circ}\text{C}$ (Note 1)	-21	-23.3	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$ , $\text{TRMPWR} = 4\text{V}$ (Note 1)	-20	-23	-24	mA
	$V_{\text{LINE}} = 0.5\text{V}$			-22.4	mA
Output Leakage	DISCNCT = 2.4V, $\text{TRMPWR} = 0\text{V}$ to 5.25V, $\text{REG} = 0.2\text{V}$ , $V_{\text{LINE}} = 5.25\text{V}$		10	400	nA
Output Capacitance	DISCNCT = 2.4V (Note 2)		2	3.5	pF
<b>Regulator Section</b>					
Regulator Output Voltage		2.6	2.8	3	V
Drop Out Voltage	All Termination Lines = 0.2V		0.4	0.8	V
Short Circuit Current	$V_{\text{REG}} = 0\text{V}$	-475	-650	-950	mA
Sinking Current Capability	$V_{\text{REG}} = 3.5\text{V}$	200	400	800	mA
Thermal Shutdown			170		$^{\circ}\text{C}$
Thermal Shutdown Hysteresis			10		$^{\circ}\text{C}$
<b>Disconnect Section</b>					
Disconnect Threshold		0.8	1.5	2	V
Input Current	DISCNCT = 0V		-10	-30	$\mu\text{A}$

Note 1: Measuring each termination line while other 17 are low (0.2V).

Note 2: Guaranteed by design. Not 100% tested in production.

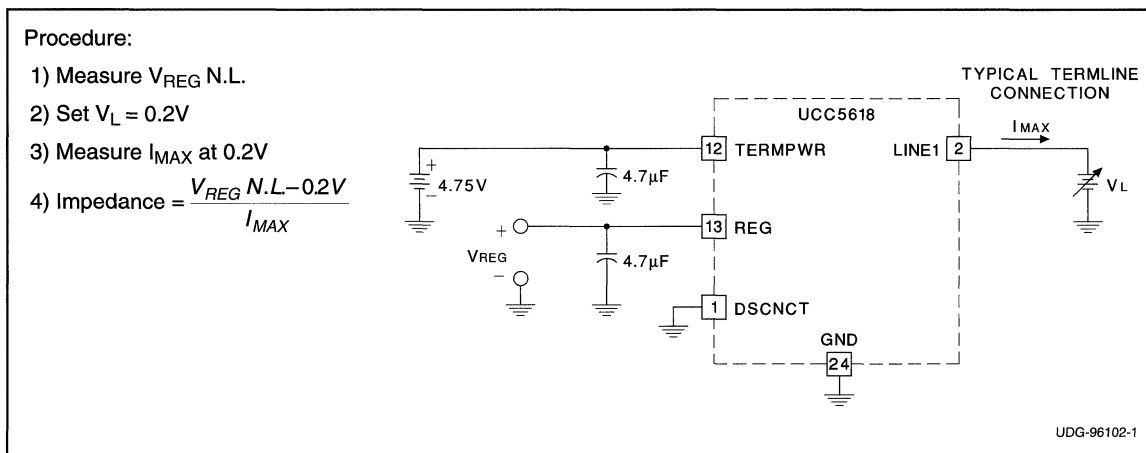


Figure 1. Termline Impedance Measurement Circuit



**PIN DESCRIPTIONS**

**DISCNET:** Taking this pin high or leaving it open causes the 18 channels to become high impedance and the chip to go into low-power mode; a low state allows the channels to provide normal termination.

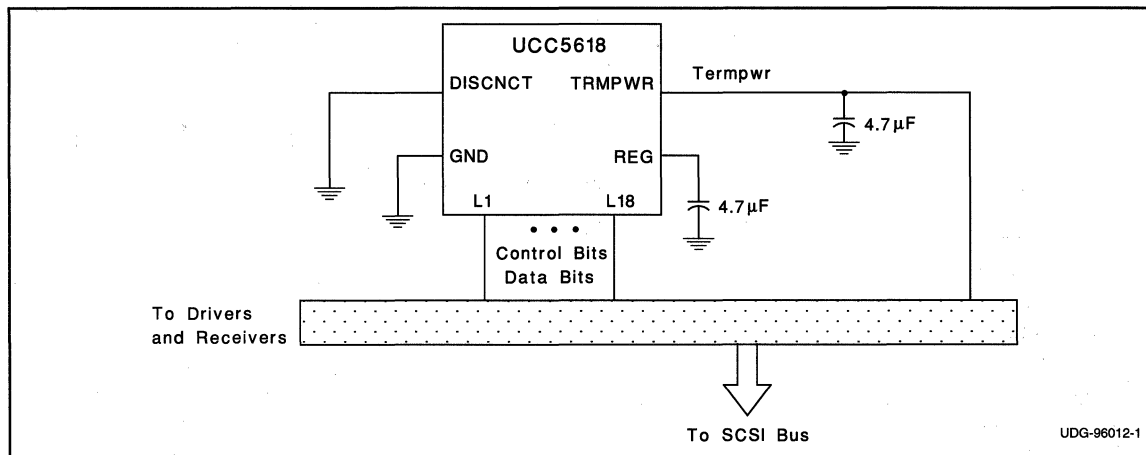
**GND:** Ground reference for the IC.

**LINE1–LINE18:** 110Ω termination channels.

**REG:** Output of the internal 2.8V regulator.

**TRMPWR:** Power for the IC.

**APPLICATION INFORMATION**



# 27-Line SCSI Terminator With Reverse Disconnect

## FEATURES

- Complies with SCSI, SCSI-2, SCSI-3, SPI and FAST-20 (Ultra) Standards
- 2.5pF Channel Capacitance during Disconnect
- 100µA Supply Current in Disconnect Mode
- 4V To 7V Operation
- 110Ω Termination
- Completely Meets SCSI Hot Plugging
- -900mA Sourcing Current for Termination
- +500mA Sinking Current for Active Negation
- Logic Command Disconnects all Termination Lines
- Trimmed Impedance to 5%
- Current Limit and Thermal Shutdown Protection

## DESCRIPTION

UCC5619 provides 27 lines of active termination for a SCSI (Small Computer Systems Interface) parallel bus. The SCSI standard recommends active termination at both ends of the cable.

The UCC5619 is ideal for high performance 5V SCSI systems. During disconnect the supply current is typically only 100µA, which makes the IC attractive for lower powered systems.

The UCC5619 is designed with a low channel capacitance of 2.5pF, which eliminates effects on signal integrity from disconnected terminators at interim points on the bus.

The power amplifier output stage allows the UCC5619 to source full termination current and sink active negation current when all termination lines are actively negated.

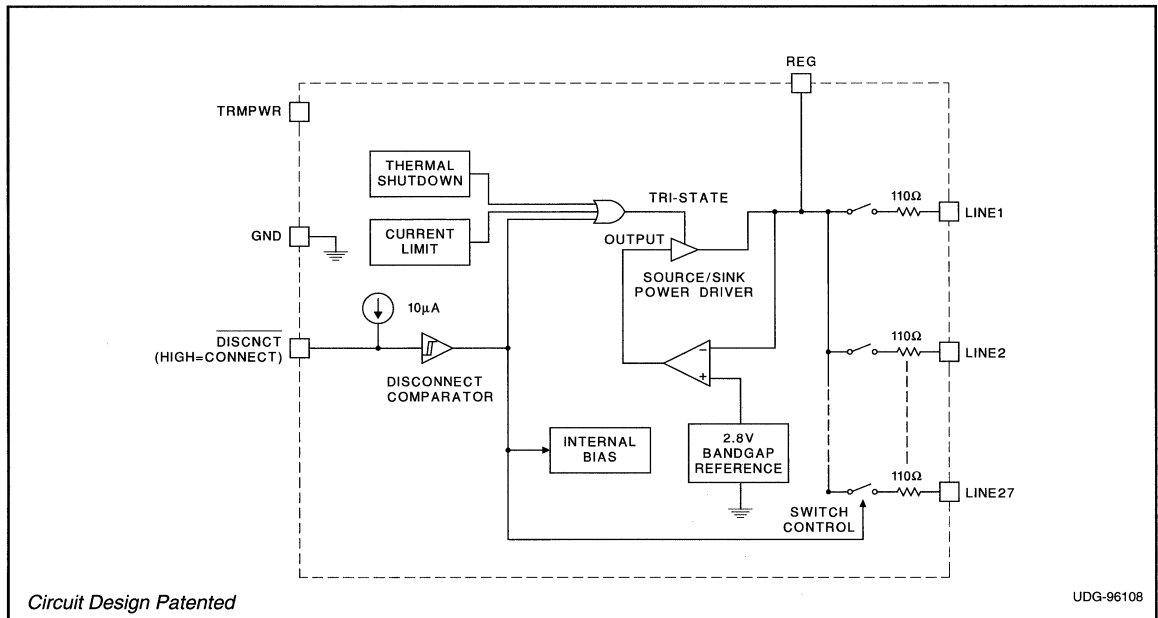
The UCC5619, as with all Unitrode terminators, is completely hot pluggable and appears as high impedance at the terminating channels with VTRMPWR = 0V or open.

Internal circuit trimming is utilized, first to trim the 110Ω impedance, and then most importantly, to trim the output current as close to the maximum SCSI-3 specification as possible, which maximizes noise margin in fast SCSI operation.

Other features include thermal shutdown and current limit. This device is offered in low thermal resistance versions of the industry standard 36 pin wide body QSSOP (MWP) and 48 pin LQFP (FQP).

Consult SSOP-36 (MWP QSSOP-36) and FQP-48 Packaging Diagram for exact dimensions.

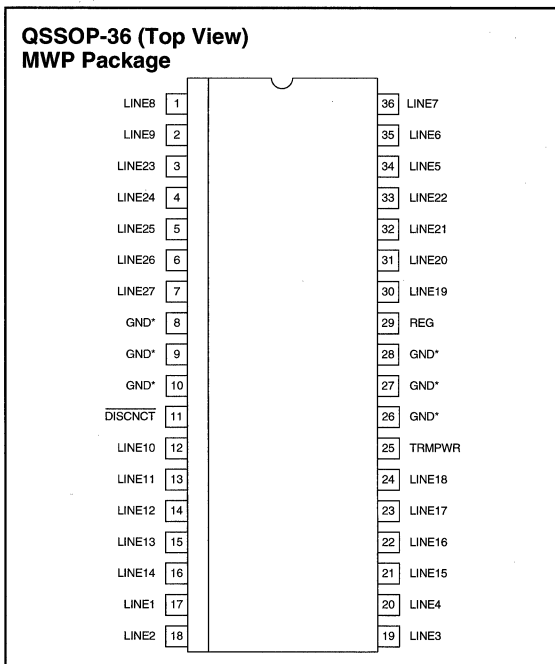
## BLOCK DIAGRAM



**ABSOLUTE MAXIMUM RATINGS**

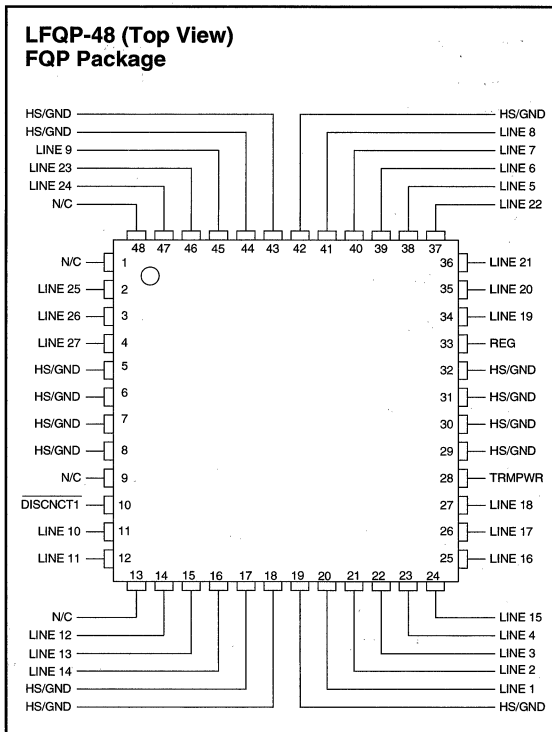
TRMPWR Voltage	+7V
Signal Line Voltage	0V to +7V
Regulator Output Current	1.5A
Storage Temperature	-65°C to +150°C
Junction Temperature	-55°C to +150°C
Lead Temperature (Soldering, 10 Sec.)	+300°C

Currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages.



\* MWP package pins 8 - 10 and 26 - 28 serve as heatsink/ground.

**CONNECTION DIAGRAM**



**ELECTRICAL CHARACTERISTICS**

Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ , TRMPWR = 4.75V, DISCNCT = 4.75V,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Supply Current Section</b>					
TRMPWR Supply Current	All Termination Lines = Open		1	2	mA
	All Termination Lines = 0.2V		630	650	mA
Power Down Mode	DISCNCT = 0V		100	200	$\mu\text{A}$
<b>Output Section (Termination Lines)</b>					
Termination Impedance	(Note 3)	104.5	110	115.5	$\Omega$
Output High Voltage	(Note 1)	2.6	2.8	3.0	V
Max Output Current	$V_{\text{LINE}} = 0.2\text{V}$ , $T_J = 25^\circ\text{C}$	-22.1	-23.3	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$	-20.7	-23.3	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$ , TRMPWR = 4V, $T_J = 25^\circ\text{C}$ (Note 1)	-21	-23	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$ , TRMPWR = 4V (Note 1)	-20	-23	-24	mA

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ ,  $\text{TRMPWR} = 4.75\text{V}$ ,  $\text{DISCNCT} = 4.75\text{V}$ ,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Output Section (CONT.)</b>					
	$V_{\text{LINE}} = 0.5\text{V}$			22.4	mA
Output Leakage	$\text{DISCNCT} = 0\text{V}$ , $\text{TRMPWR} = 0\text{V}$ to $5.25\text{V}$		10	400	nA
Output Capacitance	$\text{DISCNCT} = 0\text{V}$ (Note 2)		2.5	4	pF
<b>Regulator Section</b>					
Regulator Output Voltage		2.6	2.8	3.0	V
Drop Out Voltage	All Termination Lines = $0.2\text{V}$		0.4	0.8	V
Short Circuit Current	$V_{\text{REG}} = 0\text{V}$	-650	-900	-1300	mA
Sinking Current Capability	$V_{\text{REG}} = 3.5\text{V}$	300	500	900	mA
Thermal Shutdown			170		$^\circ\text{C}$
Thermal Shutdown Hysteresis			10		$^\circ\text{C}$
<b>Disconnect Section</b>					
Disconnect Threshold		0.8	1.5	2.0	V
Input Current	$\text{DISCNCT} = 0\text{V}$		-20	-60	$\mu\text{A}$



**PIN DESCRIPTIONS**

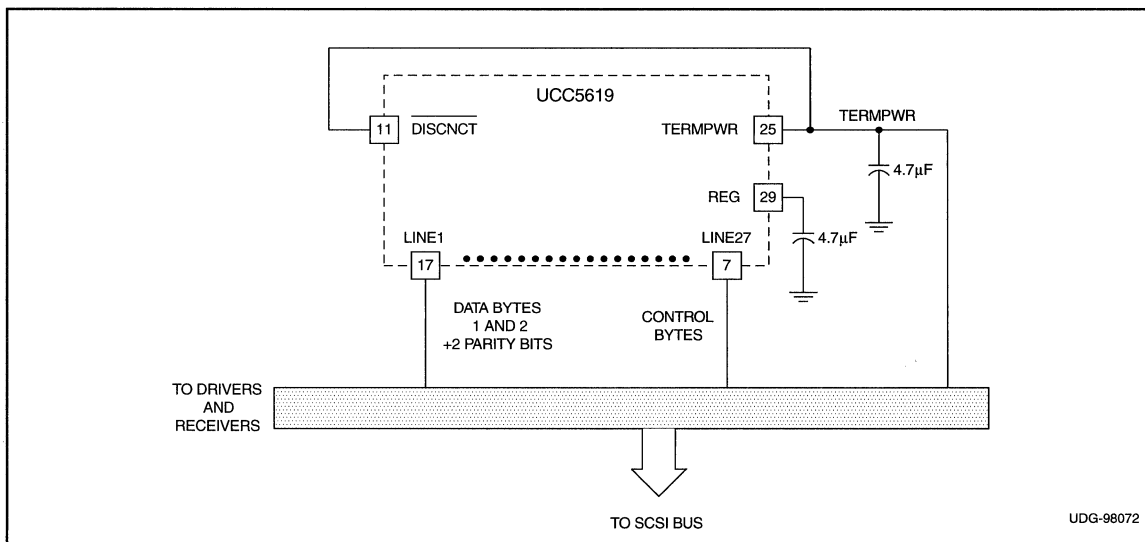
**DISCNCT:** Taking this pin low causes all channels to become high impedance, and the chip to go into low-power mode; a high state or leaving it open allows the channels to provide normal termination.

**GND:** Ground reference for the IC.

**LINE1 - LINE27:**  $110\Omega$  termination channels.

**REG:** Output of the internal  $2.7\text{V}$  regulator; bypass with a  $4.7\mu\text{F}$  capacitor to GND.

**TRMPWR:** Power for the IC; bypass with a  $4.7\mu\text{F}$  capacitor to GND.



**Figure 1. Typical wide SCSI bus configuration using the UCC5619**

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## 27-Line SCSI Terminator

### FEATURES

- Complies with SCSI, SCSI-2, SCSI-3, SPI and FAST-20 (Ultra) Standards
- 2.5pF Channel Capacitance during Disconnect
- 100mA Supply Current in Disconnect Mode
- 4V To 7V Operation
- 110Ω Termination
- Completely Meets SCSI Hot Plugging
- -900mA Sourcing Current for Termination
- +500mA Sinking Current for Active Negation
- Logic Command Disconnects all Termination Lines
- Trimmed Impedance to 5%
- Current Limit and Thermal Shutdown Protection

### DESCRIPTION

UCC5620 provides 27 lines of active termination for a SCSI (Small Computer Systems Interface) parallel bus. The SCSI standard recommends active termination at both ends of the cable.

The UCC5620 is ideal for high performance 5V SCSI systems. During disconnect the supply current is typically only 100μA, which makes the IC attractive for lower powered systems.

The UCC5620 is designed with a low channel capacitance of 2.5pF, which eliminates effects on signal integrity from disconnected terminators at interim points on the bus.

The power amplifier output stage allows the UCC5620 to source full termination current and sink active negation current when all termination lines are actively negated.

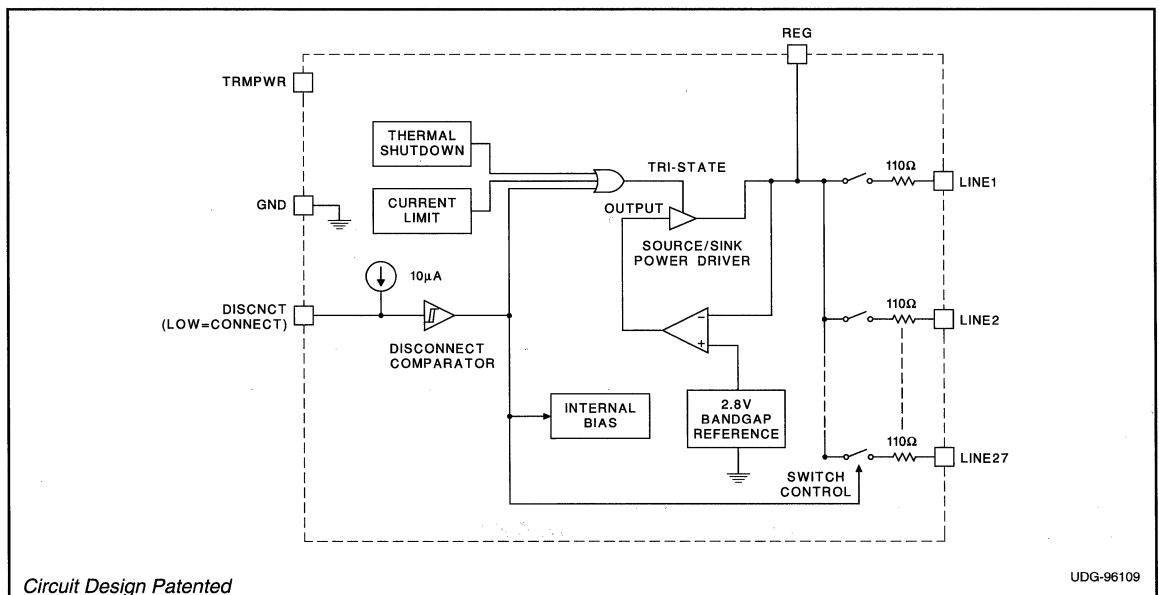
The UCC5620, as with all Unitrode terminators, is completely hot pluggable and appears as high impedance at the terminating channels with  $V_{TRMPWR} = 0V$  or open.

Internal circuit trimming is utilized, first to trim the 110Ω impedance, and then most importantly, to trim the output current as close to the maximum SCSI-3 specification as possible, which maximizes noise margin in fast SCSI operation.

Other features include thermal shutdown and current limit. This device is offered in low thermal resistance versions of the industry standard 36-Pin Wide Body QSOP (MWP) and 48-Pin LQFP (FQP).

Consult QSOP-36 or LQFP-48 packaging diagram for exact dimensions.

### BLOCK DIAGRAM





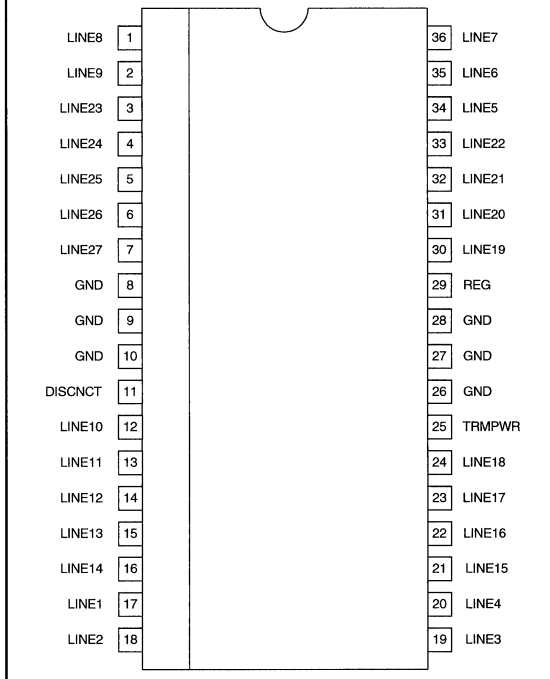
**ABSOLUTE MAXIMUM RATINGS**

Tempwr Voltage	..... +7V
Signal Line Voltage	..... 0V to +7V
Regulator Output Current	..... 1.5A
Storage Temperature	..... -65°C to +150°C
Junction Temperature	..... -55°C to +150°C
Lead Temperature (Soldering, 10 Sec.)	..... +300°C

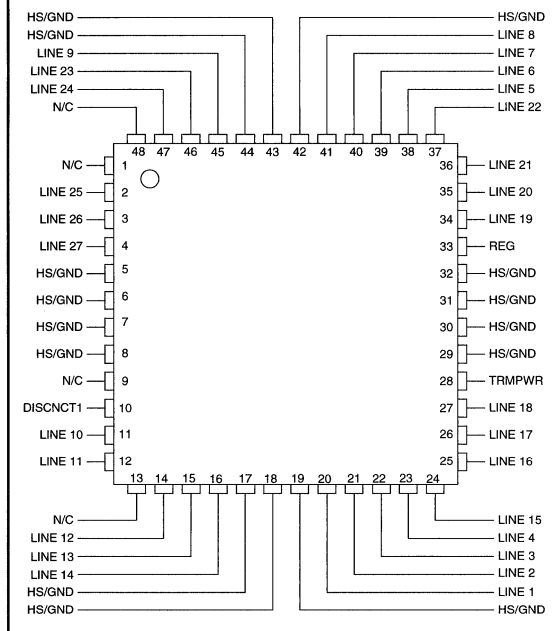
*Currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages.*

**CONNECTION DIAGRAM**

**SSOP-36 (Top View)  
MWP Package**



**LFQP-48 (Top View)  
FQP Package**



**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ , TRMPWR = 4.75V, DISCNCT = 0V,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Supply Current Section</b>					
TRMPWR Supply Current	All Termination Lines = Open		1	2	mA
	All Termination Lines = 0.2V		630	650	mA
Power Down Mode	DISCNCT = TRMPWR		100	200	$\mu\text{A}$

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ , TRMPWR = 4.75V, DISCNCT = 0V,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Output Section (Termination Lines)</b>					
Termination Impedance	(Note 3)	104.5	110	115.5	$\Omega$
Output High Voltage	(Note 1)	2.6	2.8	3.0	V
Max Output Current	$V_{\text{LINE}} = 0.2\text{V}$ , $T_J = 25^\circ\text{C}$	-22.1	-23.3	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$	-20.7	-23.3	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$ , TRMPWR = 4V, $T_J = 25^\circ\text{C}$ (Note 1)	-21	-23	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$ , TRMPWR = 4V (Note 1)	-20	-23	-24	mA
	$V_{\text{LINE}} = 0.5\text{V}$			-22.4	mA
Output Leakage	DISCNCT = 2.4V, TRMPWR = 0V to 5.25V		10	400	nA
Output Capacitance	DISCNCT = 2.4V (Note 2)		2.5	4	pF
<b>Regulator Section</b>					
Regulator Output Voltage		2.6	2.8	3.0	V
Drop Out Voltage	All Termination Lines = 0.2V		0.4	0.8	V
Short Circuit Current	$V_{\text{REG}} = 0\text{V}$	-650	-900	-1300	mA
Sinking Current Capability	$V_{\text{REG}} = 3.5\text{V}$	300	500	900	mA
Thermal Shutdown			170		$^\circ\text{C}$
Thermal Shutdown Hysteresis			10		$^\circ\text{C}$
<b>Disconnect Section</b>					
Disconnect Threshold		0.8	1.5	2.0	V
Input Current	DISCNCT = 0V		-20	-60	$\mu\text{A}$

**Note 1:** Measuring each termination line while other 26 are low (0.2V).

**Note 2:** Guaranteed by design. Not 100% tested in production.

**Note 3:** Tested by measuring  $I_{\text{OUT}}$  with  $V_{\text{OUT}} = 0.2\text{V}$  and  $V_{\text{OUT}}$  with no load, then calculate:  $Z = \frac{(V_{\text{OUT}} N.L. - 0.2\text{V})}{I_{\text{OUT}} \text{ at } 0.2\text{V}}$

## PIN DESCRIPTIONS

**DISCNCT:** Taking this pin high or leaving it open causes all channels to become high impedance, and the chip to go into low-power mode; a low state allows the channels to provide normal termination.

**GND:** Ground reference for the IC.

**LINE1 - LINE27:** 110 $\Omega$  termination channels.

**REG:** Output of the internal 2.7V regulator.

**TRMPWR:** Power for the IC.

APPLICATION INFORMATION

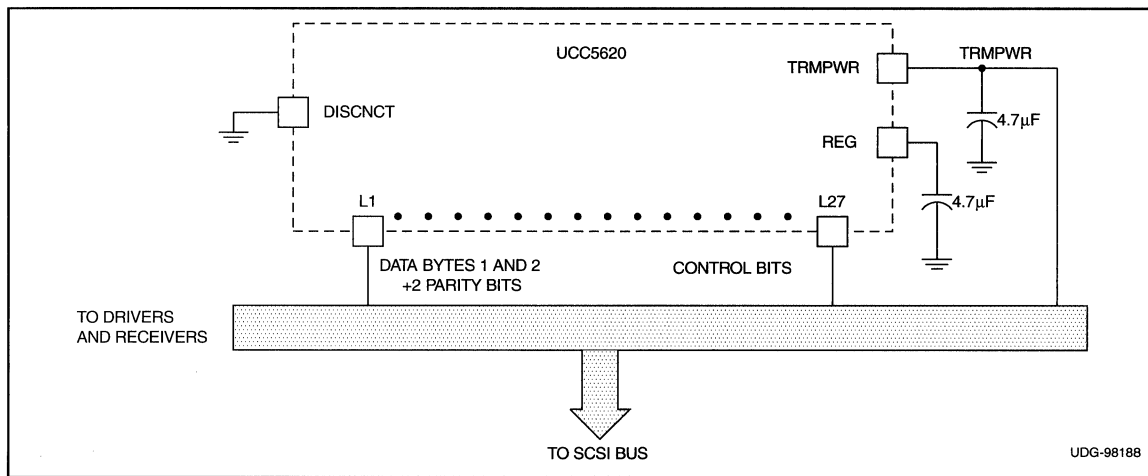


Figure 1. Typical Wide SCSI Bus Configuration Using the UCC5620





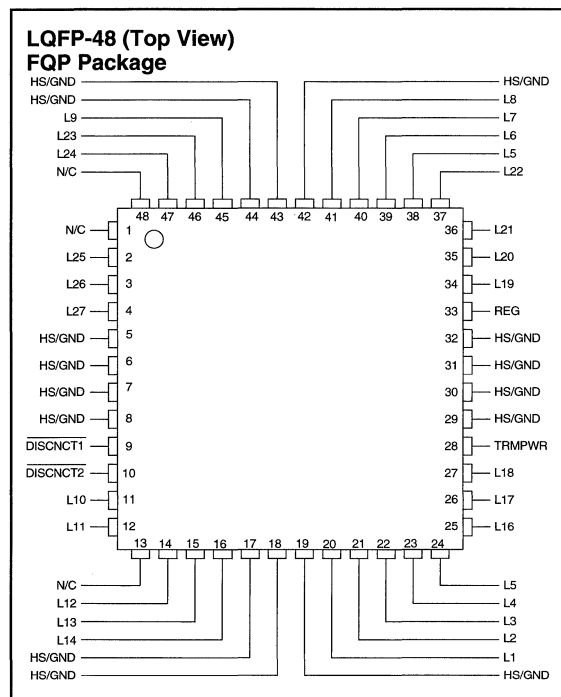
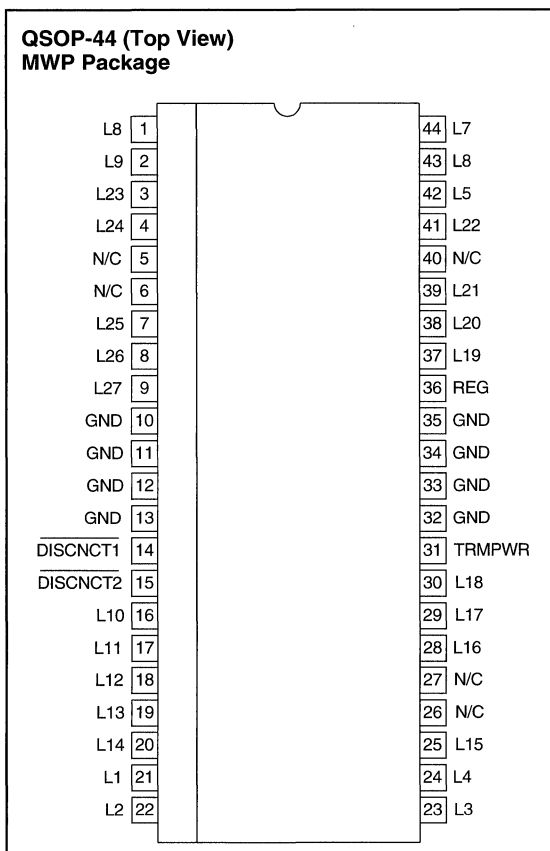
### ABSOLUTE MAXIMUM RATINGS

TRMPWR Voltage	+7V
Signal Line Voltage	0V to +7V
Regulator Output Current	1.5A
Storage Temperature	-65°C to +150°C
Junction Temperature	-55°C to +150°C
Lead Temperature (Soldering, 10 Sec.)	+300°C

Currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages.

### CONNECTION DIAGRAM

**QSOP-44 (Top View)  
MWP Package**



### DESCRIPTION (cont.)

Other features include thermal shutdown and current limit. This device is offered in low thermal resistance versions of the industry standard 44 pin wide body QSOP (MWP) and 48 pin LQFP. Consult QSOP-44 and FQP-48 Packaging Diagrams for exact dimensions.

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ , TRMPWR = 4.75V, DISCNCT1 = DSCNCT2 = 4.75V,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Supply Current Section</b>					
TRMPWR Supply Current	All Termination Lines = Open		1	2	mA
	All Termination Lines = 0.2V		630	650	mA
Power Down Mode	DISCNCT1 = DSCNCT2 = 0V		100	200	$\mu\text{A}$

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ , TRMPWR = 4.75V, DISCNCT1 = DISCNCT2 = 4.75V,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Output Section (Termination Lines)</b>					
Termination Impedance	(Note 3)	104.5	110	115.5	$\Omega$
Output High Voltage	(Note 1)	2.6	2.8	3.0	V
Max Output Current	$V_{\text{LINE}} = 0.2\text{V}$ , $T_J = 25^\circ\text{C}$	-22.1	-23.3	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$	-20.7	-23.3	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$ , TRMPWR = 4V, $T_J = 25^\circ\text{C}$ (Note 1)	-21	-23	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$ , TRMPWR = 4V (Note 1)	-20	-23	-24	mA
	$V_{\text{LINE}} = 0.5\text{V}$			-22.4	mA
Output Leakage	DISCNCT1 = DISCNCT2 = 0V, TRMPWR = 0V to 5.25V		10	400	nA
Output Capacitance	DISCNCT1 = DISCNCT2 = 0V (Note 2)		2.5	4	pF
<b>Regulator Section</b>					
Regulator Output Voltage		2.6	2.8	3.0	V
Drop Out Voltage	All Termination Lines = 0.2V		0.4	0.8	V
Short Circuit Current	$V_{\text{REG}} = 0\text{V}$	-650	-900	-1300	mA
Sinking Current Capability	$V_{\text{REG}} = 3.5\text{V}$	300	500	900	mA
Thermal Shutdown			170		$^\circ\text{C}$
Thermal Shutdown Hysteresis			10		$^\circ\text{C}$
<b>Disconnect Section</b>					
Disconnect Threshold DISCNCT1	Controls Lines 10 to 27	0.8	1.5	2.0	V
Input Current DISCNCT1	DISCNCT1 = 0V		-10	-30	$\mu\text{A}$
Disconnect Threshold DISCNCT2	Controls Lines 1 to 9	0.8	1.5	2	V
Input Current DISCNCT2	DISCNCT2 = 0V		-10	-30	$\mu\text{A}$

Note 1: Measuring each termination line while other 26 are low (0.2V).

Note 2: Guaranteed by design. Not 100% tested in production.

Note 3: Tested by measuring  $I_{\text{OUT}}$  with  $V_{\text{OUT}} = 0.2\text{V}$  and  $V_{\text{OUT}}$  with no load, then calculate:

$$Z = \frac{V_{\text{OUT}} N \cdot L - 0.2\text{V}}{I_{\text{OUT}} \text{ at } 0.2\text{V}}$$

## PIN DESCRIPTIONS

**DISCNCT1:** Disconnect one controls termination lines L10 – L27. Taking this pin low causes termination lines L10 – L27 to become high impedance, taking this pin high or leaving it open allows the channels to provide normal termination.

**DISCNCT2 :** Disconnect two controls termination lines L1 – L9. Taking this pin low causes termination lines L1 – L9 to become high impedance. Taking this pin high or leaving it open allows the channels to provide normal termination. Taking both disconnect pins low will put the chip in to sleep mode where it will be in low-power mode.

**GND:** Ground reference for the IC.

**L1 - L27:** 110 $\Omega$  termination channels.

**REG:** Output of the internal 2.7V regulator.

**TRMPWR:** Power for the IC.

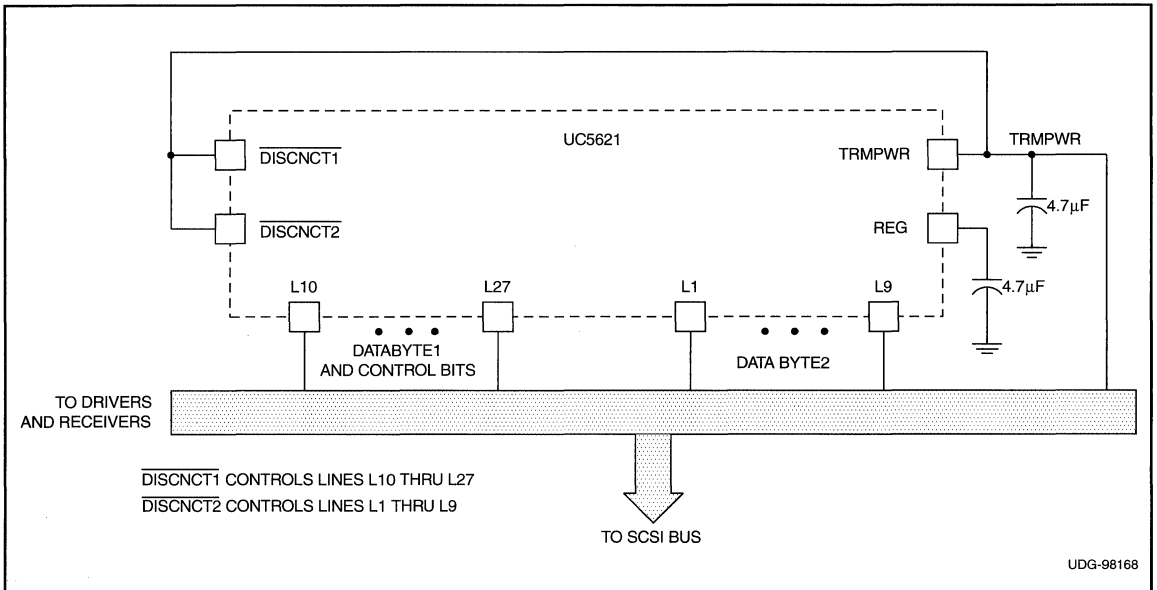


Figure 1. Typical Wide SCSI Bus Configuration Using the UCC5621



## 27 - Line SCSI Terminator With Split Disconnect

### FEATURES

- Complies with SCSI, SCSI-2, SCSI-3, SPI and FAST-20 (Ultra) Standards
- 2.5pF Channel Capacitance During Disconnect
- 100µA Supply Current in Disconnect Mode
- 4V To 7V Operation
- 110Ω Termination
- Completely Meets SCSI Hot Plugging
- -900mA Sourcing Current for Termination
- +500mA Sinking Current for Active Negation
- Logic Command Disconnects all Termination Lines
- Split Disconnect Controls Lines 1 to 9 and 10 to 27 Separately
- Trimmed Impedance to 5%
- Current Limit and Thermal Shutdown Protection

### DESCRIPTION

The UCC5622 provides 27 lines of active termination for a SCSI (Small Computer Systems Interface) parallel bus. The SCSI standard recommends active termination at both ends of the cable.

The UCC5622 is ideal for high performance 5V SCSI systems. During disconnect the supply current is typically only 100µA, which makes the IC attractive for lower powered systems.

The UCC5622 features a split disconnect allowing the user to control termination lines 10 to 27 with disconnect one, DISCNCT1, and control termination lines 1 to 9 with disconnect two, DISCNCT2.

The UCC5622 is designed with a low channel capacitance of 2.5pF, which eliminates effects on signal integrity from disconnected terminators at interim points on the bus.

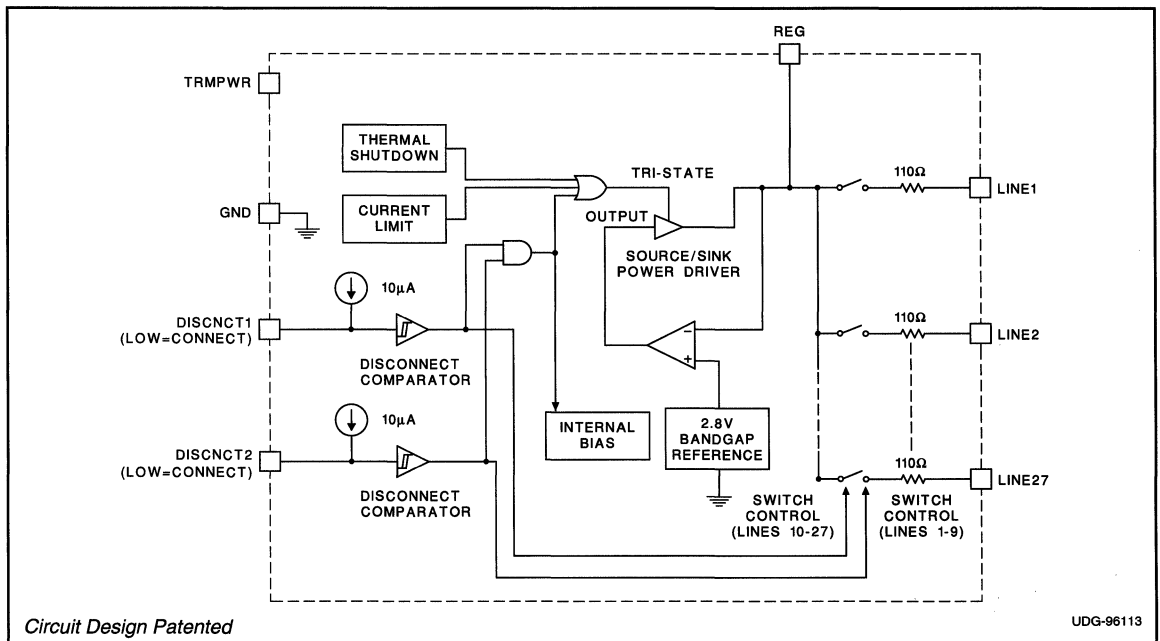
The power amplifier output stage allows the UCC5622 to source full termination current and sink active negation current when all termination lines are actively negated.

The UCC5622, as with all Unitrode terminators, is completely hot pluggable and appears as high impedance at the terminating channels with  $V_{TRMPWR} = 0V$  or open.

Internal circuit trimming is utilized, first to trim the 110Ω impedance, and then most importantly, to trim the output current as close to the maximum SCSI-3 specification as possible, which maximizes noise margin in FAST-20 SCSI operation.

(continued)

### BLOCK DIAGRAM



Circuit Design Patented

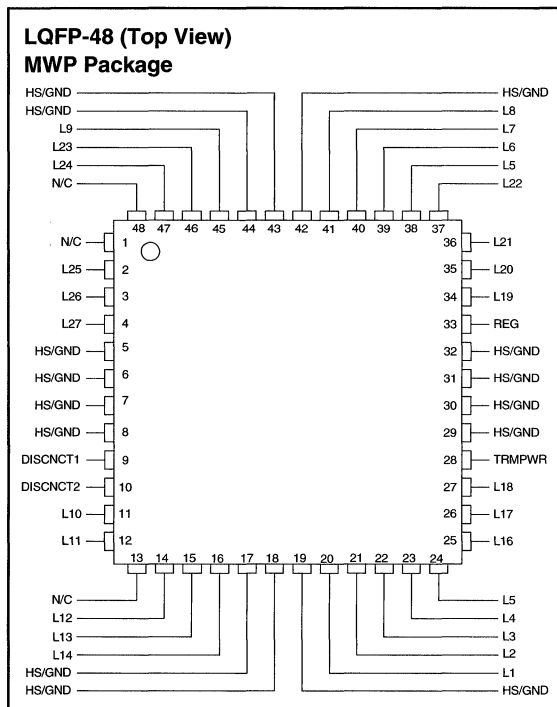
UDG-96113



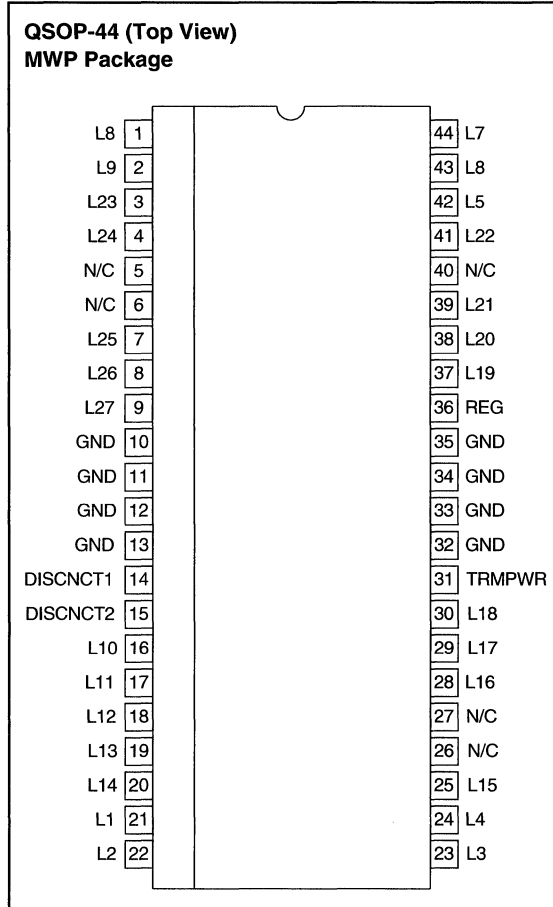
**ABSOLUTE MAXIMUM RATINGS**

TRMPWR Voltage	+7V
Signal Line Voltage	0V to +7V
Regulator Output Current	1.5A
Storage Temperature	-65°C to +150°C
Junction Temperature	-55°C to +150°C
Lead Temperature (Soldering, 10 Sec.)	+300°C

Currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages.



**CONNECTION DIAGRAM**



**DESCRIPTION (cont.)**

Other features include thermal shutdown and current limit. This device is offered in low thermal resistance versions of the industry standard 44 pin wide body QSOP (MWP) and 48 pin LQFP (FQP). Consult QSOP-44 and LQFP-48 Packaging Diagram for exact dimensions.

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ , TRMPWR = 4.75V, DISCNCT1 = DISCNCT2 = 0V,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Supply Current Section</b>					
TRMPWR Supply Current	All Termination Lines = Open		1	2	mA
	All Termination Lines = 0.2V		630	650	mA
Power Down Mode	DISCNCT1 = DISCNCT2 = TRMPWR		100	200	$\mu\text{A}$

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ ,  $\text{TRMPWR} = 4.75\text{V}$ ,  $\text{DISCNCT1} = \text{DISCNCT2} = 0\text{V}$ ,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Output Section (Termination Lines)</b>					
Termination Impedance	(Note 3)	104.5	110	115.5	$\Omega$
Output High Voltage	(Note 1)	2.6	2.8	3.0	V
Max Output Current	$V_{\text{LINE}} = 0.2\text{V}$ , $T_J = 25^\circ\text{C}$	-22.1	-23.3	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$	-20.7	-23.3	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$ , $\text{TRMPWR} = 4\text{V}$ , $T_J = 25^\circ\text{C}$ (Note 1)	-21	-23	-24	mA
	$V_{\text{LINE}} = 0.2\text{V}$ , $\text{TRMPWR} = 4\text{V}$ (Note 1)	-20	-23	-24	mA
	$V_{\text{LINE}} = 0.5\text{V}$			-22.4	mA
Output Leakage	$\text{DISCNCT1} = \text{DISCNCT2} = 2.4\text{V}$ , $\text{TRMPWR} = 0\text{V}$ to $5.25\text{V}$		10	400	nA
Output Capacitance	$\text{DISCNCT1} = \text{DISCNCT2} = 2.4\text{V}$ (Note 2)		2.5	4	pF
<b>Regulator Section</b>					
Regulator Output Voltage		2.6	2.8	3.0	V
Drop Out Voltage	All Termination Lines = $0.2\text{V}$		0.4	0.8	V
Short Circuit Current	$V_{\text{REG}} = 0\text{V}$	-650	-900	-1300	mA
Sinking Current Capability	$V_{\text{REG}} = 3.5\text{V}$	300	500	900	mA
Thermal Shutdown			170		$^\circ\text{C}$
Thermal Shutdown Hysteresis			10		$^\circ\text{C}$
<b>Disconnect Section</b>					
Disconnect Threshold DISCNCT1	Controls Lines 10 to 27	0.8	1.5	2.0	V
Input Current DISCNCT1	$\text{DISCNCT1} = 0\text{V}$		-10	-30	$\mu\text{A}$
Disconnect Threshold DISCNCT2	Controls Lines 1 to 9	0.8	1.5	2	V
Input Current DISCNCT2	$\text{DISCNCT2} = 0\text{V}$		-10	-30	$\mu\text{A}$

Note 1: Measuring each termination line while other 26 are low ( $0.2\text{V}$ ).

Note 2: Guaranteed by design. Not 100% tested in production.

Note 3: Tested by measuring  $I_{\text{OUT}}$  with  $V_{\text{OUT}} = 0.2\text{V}$  and  $V_{\text{OUT}}$  with no load, then calculate:

$$Z = \frac{V_{\text{OUT}} \text{ N.L.} - 0.2\text{V}}{I_{\text{OUT}} \text{ at } 2.0\text{V}}$$

## PIN DESCRIPTIONS

**DISCNCT1:** Disconnect one controls termination lines 10 – 27. Taking this pin high or leaving it open causes termination lines 10 - 27 to become high impedance, taking this pin low allows the channels to provide normal termination.

**DISCNCT2:** Disconnect two controls termination lines 1 – 9. Taking this pin high or leaving it open causes termination lines 1 - 9 to become high impedance. Taking this pin low allows the channels to provide normal termination. Taking both disconnect pins high or leaving

them open will put the chip in to sleep mode where it will be in low-power mode.

**GND:** Ground reference for the IC.

**L1 – L27:**  $110\Omega$  termination channels.

**REG:** Output of the internal  $2.7\text{V}$  regulator.

**TRMPWR:** Power for the IC.

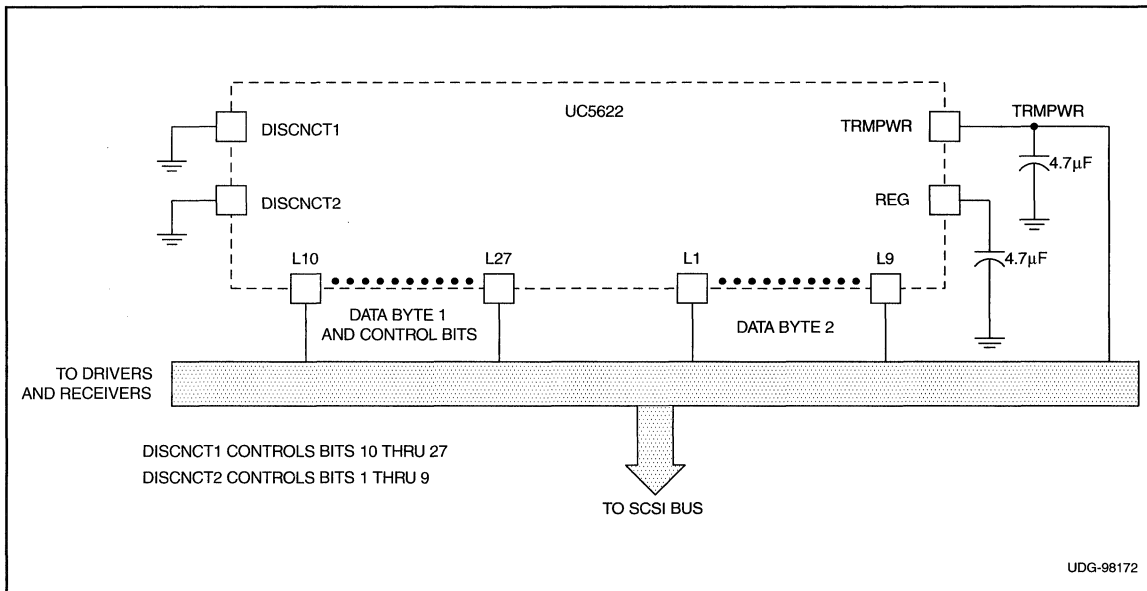


Figure 1. Typical Wide SCSI Bus Configuration Using the UCC5622

# Multimode SCSI 14 Line Terminator

## FEATURES

- Auto Selection Single Ended (SE) or Low Voltage Differential (LVD) Termination
- Meets SCSI-1, SCSI-2, SCSI-3, SPI, Ultra (Fast-20), Ultra2 (SPI-2 LVD) and Ultra3 Standards
- 2.7V to 5.25V Operation
- Differential Failsafe Bias
- Thermal packaging for low junction temperature and better MTBF.

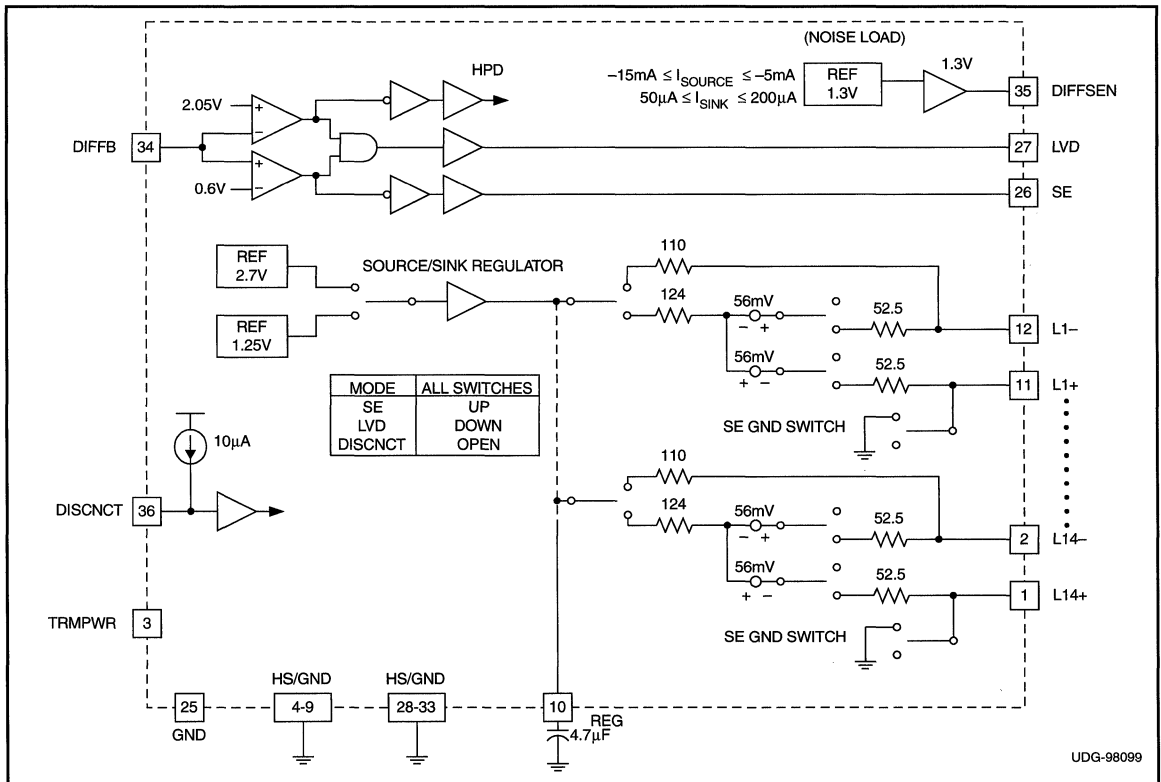
## DESCRIPTION

The UCC5628 Multimode SCSI Terminator provides a smooth transition into the next generation of the SCSI Parallel Interface (SPI-2). It automatically senses the bus, via DIFFB, and switches the termination to either single ended (SE) or low voltage differential (LVD) SCSI, dependent on which type of devices are connected to the bus. The UCC5628 can not be used on a HVD, EIA485, differential SCSI bus. If the UCC5628 detects a HVD SCSI device, it switches to a high impedance state.

The Multimode terminator contains all functions required to terminate and auto detect and switch modes for SPI-2 bus architectures. Single Ended and Differential impedances and currents are trimmed for maximum effectiveness. Fail Safe biasing is provided to insure signal integrity. Device/Bus type detection circuitry is integrated into the terminator to provide automatic switching of termination between single ended and LVD SCSI and a high impedance for HVD SCSI. The multimode function provides all the performance analog functions necessary to implement SPI-2 termination in a single monolithic device.

The UCC5628 is offered in a 48 pin LQFP package for a temperature range of 0°C to 70°C.

## BLOCK DIAGRAM



**ABSOLUTE MAXIMUM RATINGS**

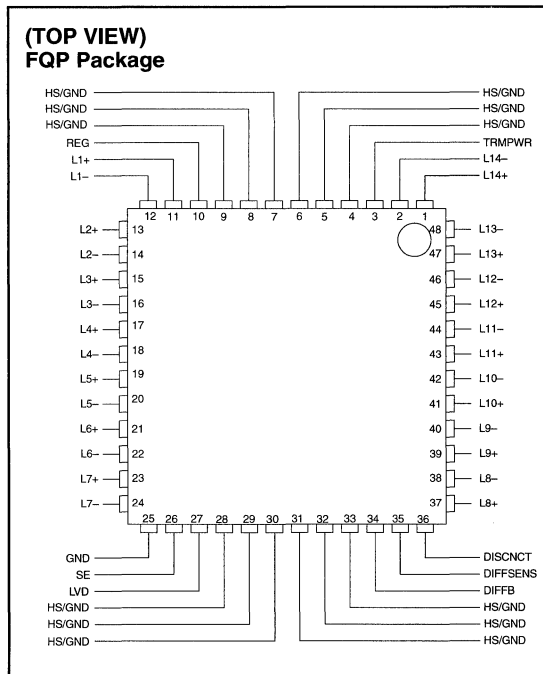
TRMPWR Voltage	+6V
Signal Line Voltage	0V to TRMPWR
Package Dissipation	2W
Storage Temperature	-65°C to +150°C
Junction Temperature	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.)	+300°C
Recommended Operating Conditions	2.7V to 5.25V

Currents are positive into negative out of the specified terminal.  
 Note: Consult Packaging Section of Databook for thermal limitations and considerations of package.

**RECOMMENDED OPERATING CONDITIONS**

TRMPWR Voltage	2.7V to 5.25V
Temperature Ranges	0°C to +70°C

**CONNECTION DIAGRAMS**



**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = T_J = 0^\circ\text{C}$  to  $70^\circ\text{C}$ , TRMPWR = 3.3V.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>TRMPWR Supply Current Section</b>					
TRMPWR Supply Current	LVD Mode		20	25	mA
	SE Mode		1.6	10	mA
	Disabled Terminator		250	400	$\mu\text{A}$
<b>Regulator Section</b>					
1.25V Regulator	LVD Mode	1.15	1.25	1.35	V
1.25V Regulator Source Current	$V_{\text{REG}} = 0\text{V}$	-375	-700	-1000	mA
1.25V Regulator Sink Current	$V_{\text{REG}} = 3.3\text{V}$	170	300	700	mA
1.3V Regulator	Diff Sense	1.2	1.3	1.4	V
1.3V Regulator Source Current	$V_{\text{REG}} = 0\text{V}$	-15		-5	mA
1.3V Regulator Sink Current	$V_{\text{REG}} = 3.3\text{V}$	50		200	$\mu\text{A}$
2.7V Regulator	SE Mode	2.5	2.7	3.0	V
2.7V Regulator Source Current	$V_{\text{REG}} = 0\text{V}$	-375	-700	-1000	mA
2.7V Regulator Sink Current	$V_{\text{REG}} = 3.3\text{V}$	170	300	700	mA
<b>Differential Termination Section</b>					
Differential Impedance		100	105	110	$\Omega$
Common Mode Impedance	(Note 2)	110	150	165	$\Omega$
Differential Bias Voltage		100		125	mV
Common Mode Bias		1.15	1.25	1.35	V
Output Capacitance	Single Ended Measurement to Ground (Note 1)			3	pF

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = T_J = 0^\circ\text{C}$  to  $70^\circ\text{C}$ ,  $\text{TRMPWR} = 3.3\text{V}$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Single Ended Termination Section</b>					
Impedance	$Z = (V_{LX} - 0.2\text{V}) / I_{LX}$ , (Note 3)	102.3	110	117.7	$\Omega$
Termination Current	Signal Level 0.2V, All Lines Low	-21	-24	-25.4	mA
	Signal Level 0.5V	-18		-22.4	mA
Output Leakage				400	nA
Output Capacitance	Single Ended Measurement to Ground (Note 1)			3	pF
Single Ended GND SE Impedance	I = 10mA		20	60	$\Omega$
<b>Disconnect and Diff Buffer Input Section</b>					
DISCNCT Threshold		0.8		2.0	V
DISCNCT Input Current			10	30	$\mu\text{A}$
Diff Buffer Single Ended to LVD Threshold		0.5		0.7	V
Diff Buffer LVD to HPD Threshold		1.9		2.2	V
DIFFB Input Current		-10		10	$\mu\text{A}$
<b>Status Bits (SE, LVD) Output Section</b>					
I <sub>SOURCE</sub>	V <sub>LOAD</sub> = 2.4V	-4	-6		mA
I <sub>SINK</sub>	V <sub>LOAD</sub> = 0.4V	2	5		mA

**Note 1:** Guaranteed by design. Not 100% tested in production.

**Note 2:**  $Z_{CM} = \frac{1.2\text{V}}{[I_{(V_{CM}+0.6\text{V})} - I_{(V_{CM}-0.6\text{V})}]}$  where VCM=voltage measured with L+ tied to L- and zero current applied

**Note 3:**  $V_{LX}$  = Output voltage for each terminator minus output pin (L1- through L14-) with each pin unloaded.  
 $I_{LX}$  = Output current for each terminator minus output pin (L1- through L14-) with the minus output pin forced to 0.2V.

## PIN DESCRIPTIONS

**DIFFB:** Diff sense filter pin should be connected at a 0.1 $\mu\text{F}$  capacitor.

**DIFFSENS:** The SCSI bus Diff Sense line to detect what types of devices are connected to the SCSI bus.

**DISCNCT:** Disconnect pin shuts down the terminator when it is not at the end of the bus. The disconnect pin low enables the terminator.

**LINE $n$ -:** Signal line active line for single ended or negative line in differential applications for the SCSI bus.

**LINE $n$ +**: Ground line for single ended or positive line for differential applications for the SCSI bus.

**LVD:** TTL Compatible status bit indicating that the device has detected the bus in LVD mode. If the terminator is connected it is in LVD mode.

**REG:** Regulator bypass pin, must be connected to a 4.7 $\mu\text{F}$  capacitor.

**SE:** TTL Compatible status bit indicating that the device has detected the bus in single ended mode. If the terminator is connected it is in single ended mode.

**TRMPWR:** V<sub>IN</sub> 2.7V to 5.25V supply.

## APPLICATION INFORMATION

The UCC5628 is a Multi-mode active terminator with selectable single ended (SE) and low voltage differential (LVD) SCSI termination integrated into a monolithic component. Mode selection is accomplished with the "diff sense" signal.

The diff sense signal is a three level signal, which is driven at each end of the bus by one active terminator. A LVD or multi-mode terminator drives the diff sense line to 1.3 V. If diff sense is at 1.3 V, then bus is in LVD mode. If a single ended SCSI device is plugged into the bus, the diff sense line is shorted to ground. With diff sense shorted to ground, the terminator changes to single ended mode to accommodate the SE device. If a HVD device is plugged in to the bus, the diff sense line is pulled high and the terminator shuts down.

The diff sense line is driven and monitored by the terminator through a 50Hz noise filter at the DIFFB input pin. A set of comparators, that allow for ground shifts, determine the bus status as follows. Any diff sense signal below 0.5V is single ended, between 0.7V and 1.9V is LVD and above 2.2V is HVD.

In the single ended mode, a multi-mode terminator has a 110 $\Omega$  terminating resistor connected to a 2.7V termination voltage regulator. The 2.7V regulator is used on all Unitrode terminators designed for 3.3V systems. This requires the terminator to operate in specification down to 2.7V TRMPWR voltage to allow for the 3.3V supply tolerance, an unidirectional fusing device and cable drop. At each L+ pin, a ground driver drives the pin to ground, while in single ended mode. The ground driver is specially designed so it will not effect the capacitive balance of the bus when the device is in LVD or disconnect mode. The device requirements call for 1.5pF balance on the lines of a differential pair. The terminator capacitance has to be a small part of the capacitance imbalance.

Layout is very critical for Ultra2 and Ultra3 systems. Multi-layer boards need to adhere to the 120 $\Omega$  impedance standard, including connector and feed-through. This is normally done on the outer layers with 4 mil etch

and 4 mil spacing between the runs within a pair, and a minimum of 8 mil spacing to the next pair. This spacing between the pairs reduces potential crosstalk. Beware of feed-throughs and each through hole connection adds a lot of capacitance. Standard power and ground plane spacing yields about 1pF to each plane. Each feed-through will add about 2.5pF to 3.5pF. Enlarging the clearance holes on both power and ground planes can reduce the capacitance and opening up the power and ground planes under the connector can reduce the capacitance for through hole connector applications. Microstrip technology is normally too low of impedance and should not be used. It is designed for 50 $\Omega$  rather than 120 $\Omega$  differential systems.

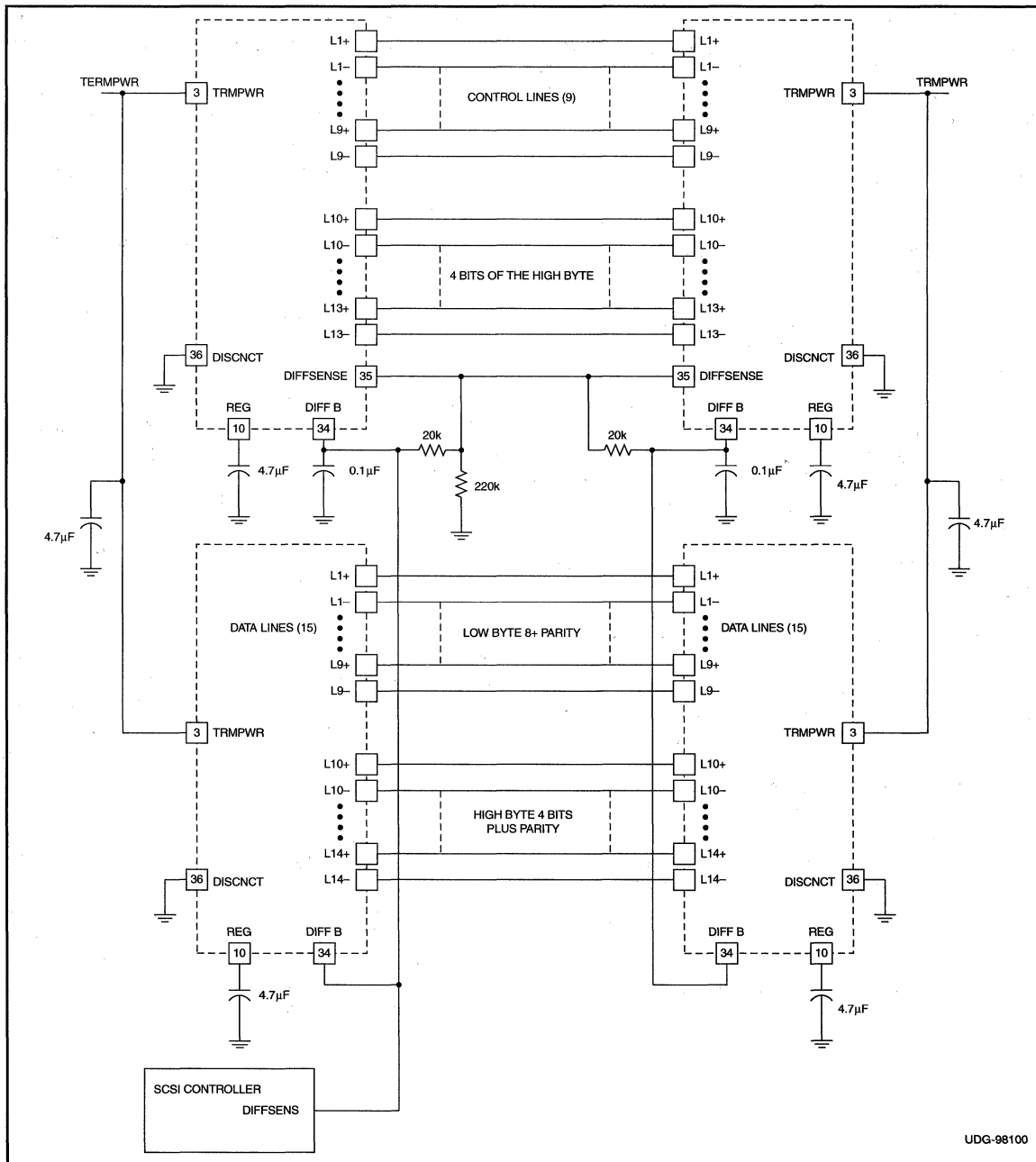
Capacitance balance is critical for Ultra2 and Ultra3. The balance capacitance standard is 0.5pF per line with the balance between pairs of 2pF. The components are designed with very tight balance, typically 0.1pF between pins in a pair and 0.3pF between pairs. Layout balance is critical, feed-throughs and etch length must be balanced, preferably no feed-throughs would be used. Capacitance for devices should be measured in the typical application, material and components above and below the circuit board effect the capacitance.

Multi-mode terminators need to consider power dissipation; the UCC5628 is offered in a power package with heat sink ground pins. These heat sink/ground pins are directly connected to the die mount paddle under the die and conduct heat from the die to reduce the junction temperature. These pins need to be connected to etch area or a feed-through per pin connecting to the ground plane layer on a multi-layer board.

In 3.3V TRMPWR systems, the UCC3912 should be used to replace the fuse and diode. This reduces the voltage drop, allowing for cable drop to the far end terminator. 3.3V battery systems normally have a 10% tolerance. The UCC3912 is 150mV drop under LVD loads, allowing 150mV drop in the cable system. All Unitrode LVD and multi-mode terminators are designed for 3.3V systems, operating down to 2.7V.



TYPICAL APPLICATION



UDG-98100

**Note:** A 220k resistor is added to ground to insure the transceivers will come up in single-ended mode when no terminator is enabled. The controller DIFFSENS ties to the DIFFB pin on the terminators, only one RC network should be on a device.



# Low Voltage Differential (LVD/SE) SCSI 9 Line Terminator

## FEATURES

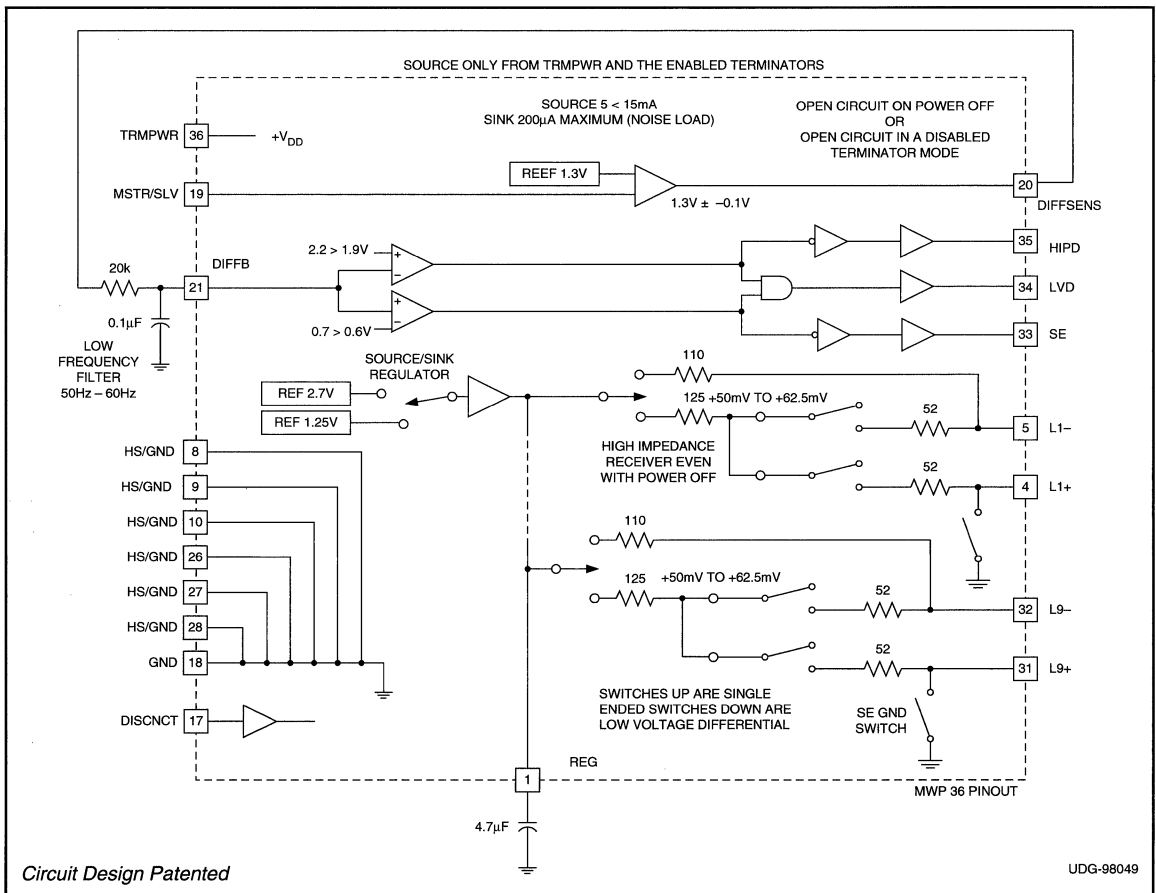
- Auto Selection Multi-Mode Single Ended or Low Voltage Differential Termination
- 2.7V to 5.25V Operation
- Differential Failsafe Bias
- Thermal Packaging for Low Junction Temperature and Better MTBF
- Master/Slave Inputs
- Supports Active Negation
- Standby (Disable Mode) 5 $\mu$ A
- 3pF Channel Capacitance

## DESCRIPTION

The UCC5630 Multi-Mode Low Voltage Differential and Single Ended Terminator is both a single ended terminator and a low voltage differential terminator for the transition to the next generation SCSI Parallel Interface (SPI-2). The low voltage differential is a requirement for the higher speeds at a reasonable cost and is the only way to have adequate skew budgets. The transceivers can be incorporated into the controller, unlike SCSI high power differential (EIA485) which requires external transceivers. Low Voltage differential is specified for Fast-40 and Fast-80, but has the potential of speeds up to Fast-320. The UCC5630 is SPI-2, SPI and Fast-20 compliant. Consult QSOP-36 and LQFP-48 Package Diagram for exact dimensions.

The UCC5630 can not be used with SCSI high voltage differential (HVD) EIA485. It will shut down when it sees high power differential to protect the bus. The pinning for high power differential is not the same as LVD or single ended and the bias voltage, current and power are also different for EIA485 differential.

## BLOCK DIAGRAM



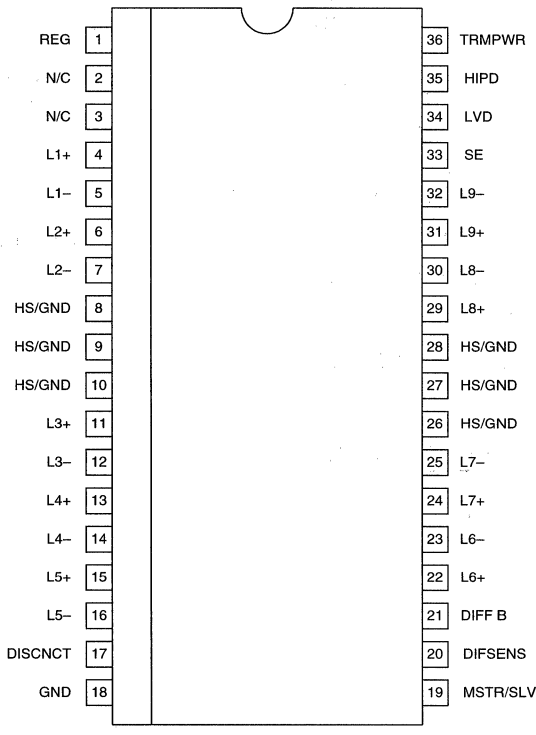
**ABSOLUTE MAXIMUM RATINGS**

TRMPWR Voltage .....	6V
Signal Line Voltage .....	0V to TRMPWR
Package Power Dissipation .....	2W
Storage Temperature .....	-65°C to +150°C
Junction Temperature .....	-55°C to +150°C
Lead Temperature (Soldering, 10sec.) .....	+300°C

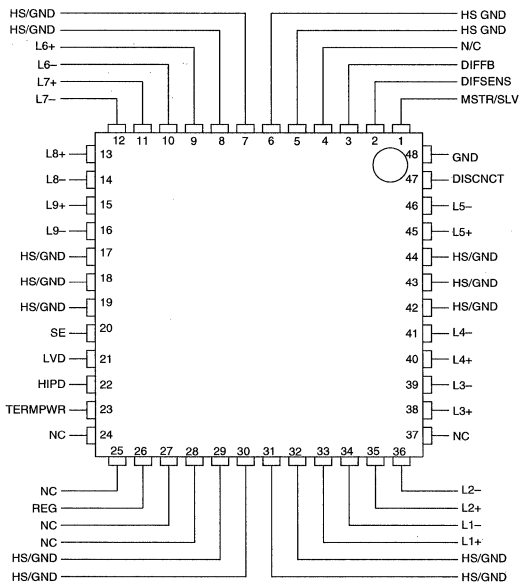
All voltages are with respect to PIN1. Currents are positive into, negative out of the specified terminal. Consult Packaging Section of the Databook for thermal limitations and considerations of packages.

**CONNECTION DIAGRAM**

**QSOP-36 (Top View)  
MWP Package**



**LQFP-48 (Top View)  
FQP Package**



**RECOMMENDED OPERATING CONDITIONS**

TRMPWR Voltage ..... 2.7V TO 5.25V

**ELECTRICAL CHARACTERISTICS:** Unless otherwise specified,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ , TRMPWR = 3.3V.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>TRMPWR Supply Current Section</b>					
TRMPWR Supply Current				20	mA
	Disable Terminator, in DISCNCT mode.			35	$\mu\text{A}$
<b>Regulator Section</b>					
1.25V Regulator	LVD Mode	1.15	1.25	1.35	V
1.25V Regulator Source Current	LVD Mode, Differential Sense Floating	-80	-100		mA
1.25V Regulator Sink Current	LVD Mode, Differential Sense Floating	80	100		mA
1.3V Regulator	DIFSENS	1.2	1.3	1.4	V
1.3V Regulator Source Current	DIFSENS	-5		-15	mA
1.3V Regulator Sink Current	DIFSENS	50		200	$\mu\text{A}$

**ELECTRICAL CHARACTERISTICS:** Unless otherwise specified,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ ,  $\text{TRMPWR} = 3.3\text{V}$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
2.7V Regulator	Single Ended Mode	2.5	2.7	3	V
2.7V Regulator Source Current	Single Ended Mode	-200	-400	-800	mA
2.7V Regulator Sink Current	Single Ended Mode	100	200	400	mA
2.7V Regulator Dropout Voltage	$V_{\text{TRMPWR}} - (V_{\text{REG}} - 2.7 \text{ Min})$			200	mV
<b>Differential Termination Section</b>					
Differential Impedance		100	105	110	$\Omega$
Common Mode Impedance		110	125	165	$\Omega$
Differential Bias Voltage	Drivers Tri-stated	100		125	mV
Common Mode Bias			1.25		V
Output Capacitance	Single Ended Measurement to Ground (Note 1)			3.5	pF
<b>Single Ended Termination Section</b>					
Impedance		102.3	110	117.7	$\Omega$
Termination Current	Signal Level 0.2V	-21	-23	-25.4	mA
	Signal Level 0.5V			-22.4	mA
Output Leakage	Disabled, $\text{TRMPWR} = 0\text{V}$ to $5.25\text{V}$			400	nA
Output Capacitance	Single Ended Measurement to Ground (Note 1)			3	pF
Single Ended GND SW Impedance				60	$\Omega$
<b>Disconnect (DISCNECT) Input Section</b>					
DISCNECT Threshold		0.8		2.0	V
DISCNECT Input Current	$V_{\text{DISCNECT}} = 0\text{V}$ and $3.3\text{V}$	-30		30	$\mu\text{A}$
<b>Differential Sense (DIFFB) Input Sections</b>					
DIFFB Single Ended Threshold		0.6		0.7	V
DIFFB Sense LVDS Threshold		1.9		2.2	V
DIFFB Input Current	$V_{\text{DIFFB}} = 0\text{V}$ and $3.3\text{V}$	-30		30	$\mu\text{A}$
<b>Master/Slave (MSTR/SLV) Input Section</b>					
MSTR/SLV Threshold		0.8		2	V
MSTR/SLV Input Current		-30		30	$\mu\text{A}$
<b>Status Bits (SE, LVD, HIPD) Output Section</b>					
$I_{\text{SOURCE}}$	$V_{\text{LOAD}} = 2.4\text{V}$	-4	-8.7		mA
$I_{\text{SINK}}$	$V_{\text{LOAD}} = 0.5\text{V}$	3	6		mA
	$V_{\text{LOAD}} = 0.4\text{V}$	2	5		mA

Note 1: Guaranteed by design. Not 100% tested in production.

**PIN DESCRIPTIONS**

**DIFFB:** DIFSENS filter pin should be connected to a  $0.1\mu\text{F}$  capacitor to GND and 20k resistor to SCSI/Bus DIFSENS Line.

**DIFSENS:** The SCSI bus DIFSENS line is driven to 1.3V to detect what type of devices are connected to the SCSI bus.

**DISCNECT:** Disconnect shuts down the terminator when it is not at the ended of the bus. The disconnect pin low enables the terminator.

**HIPD:** TTL compatible status bit indicating high voltage differential has been detected on DIFFB. The terminator

is in shutdown. (Not valid in disconnect mode.)

**HS/GND:** Heat Sink GND. Connect to large area PC board traces to increase power dissipation capability.

**GND:** Power Supply Return.

**L1- thru L9-:** Signal line/active line for single ended or negative line in differential applications for the SCSI bus.

**L1+ thru L9+:** Ground line for single ended or positive line for differential applications for the SCSI bus.

**LVD:** TTL compatible status bit indicating low voltage differential level on DIFFB. The terminator is in LVD mode.(Not valid in disconnect mode.)

**PIN DESCRIPTIONS (cont.)**

**MSTR/SLV:** Mode select for the non-controlling terminator. MSTR enables the 1.3V regulator, when the terminator is enabled. Note: This function will be removed on further generations of the multimode terminators.

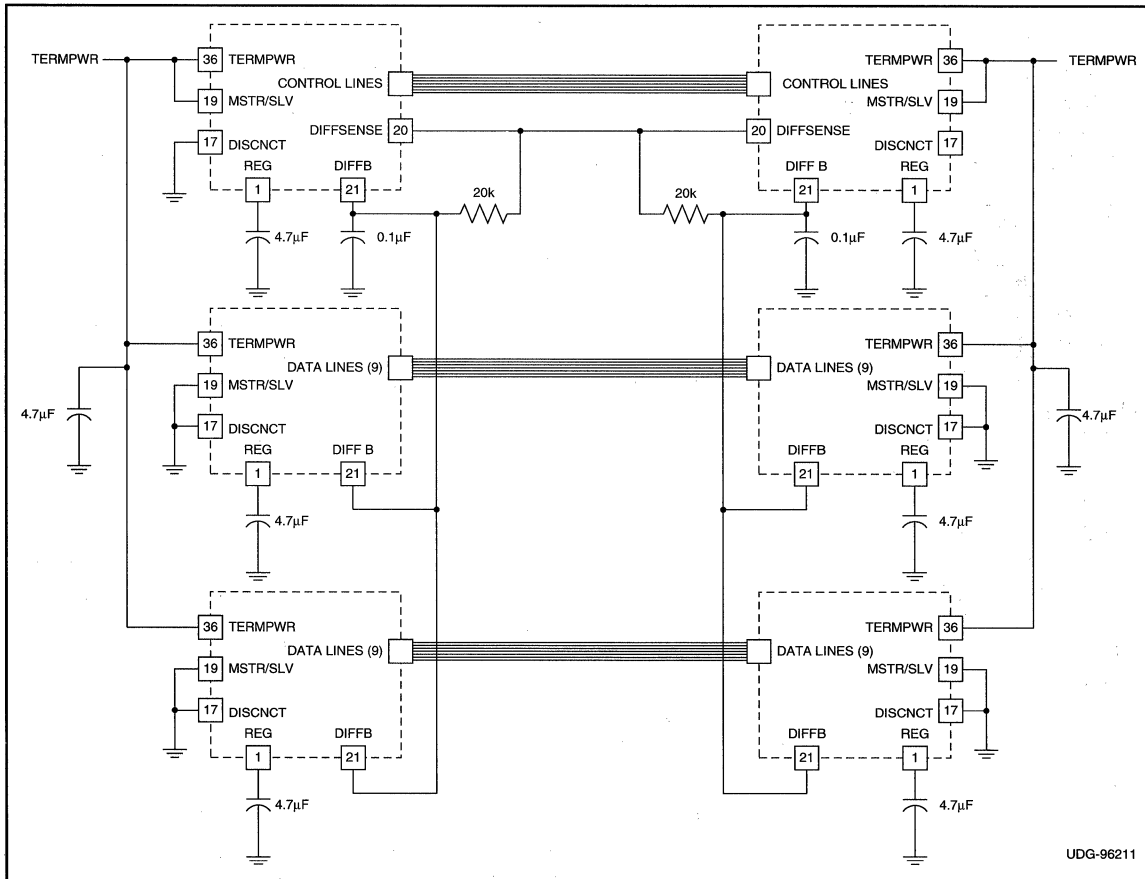
**REG:** Regulator bypass, must be connected to a 4.7μF

capacitor.

**SE:** TTL compatible status bit indicating single ended device has been detected on DIFFB. The terminator is in single ended mode.

**TRMPWR:** V<sub>IN</sub> 2.7V to 5.25V supply.

**APPLICATION INFORMATION**



Balancing capacitor is very important in high speed operation. The typical balance between the positive (+) and negative (-) signals is 0.1pF except for L8 and L9, 0.23pF and 0.4pF respectively on the MWP package. The negative (-) signal has higher capacitance than the positive (+) signal. The FQP package is typically 0.2pF less than the MWP. Typical balance is 0.1pF except for L8 and L3, where it is 0.4pF.

The master is selected by placing TRMPWR on MSTR/SLV and the terminator enabled by grounding DISCNCT, enabling the 1.3V regulator. The master is the only terminator connected directly to DIFSENS bus line, all the other terminators receive the mode signal by connecting the DIFFB pins together.

*Note: The Master/Slave function will not be on future terminators.*

# Multimode SCSI 9 Line Terminator

## FEATURES

- Auto Selection Single Ended (SE) or Low Voltage Differential (LVD) Termination
- Meets SCSI-1, SCSI-2, SCSI-3, SPI, Ultra (Fast-20), Ultra2 (SPI-2 LVD) and Ultra3 Standards
- 2.7V to 5.25V Operation
- Differential Failsafe Bias
- Thermal packaging for low junction temperature and better MTBF
- Master/Slave Input
- Supports Active Negation
- 3pF Channel Capacitance

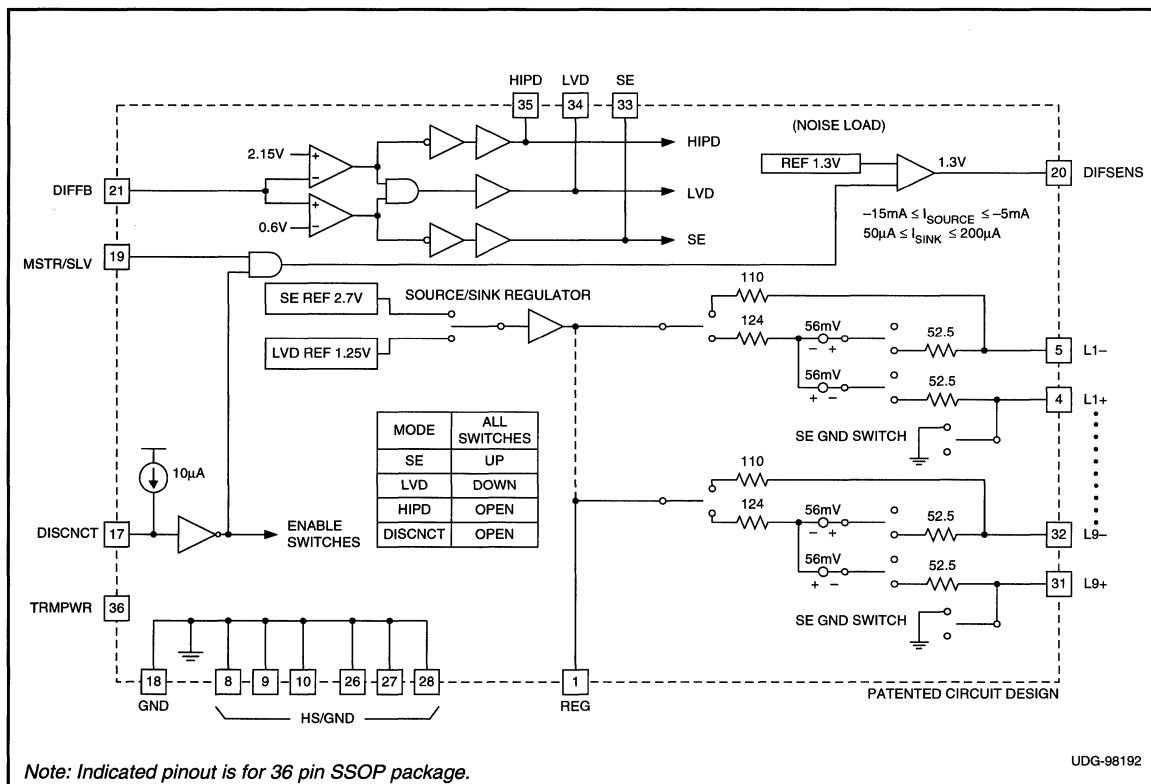
## DESCRIPTION

The UCC5630A Multimode SCSI Terminator provides a smooth transition into the next generation of the SCSI Parallel Interface (SPI-2). It automatically senses the bus, via DIFFB, and switches the termination to either single ended (SE) or low voltage differential (LVD) SCSI, dependent on which type of devices are connected to the bus. The UCC5630A can not be used on a HVD, EIA485, differential SCSI bus. If the UCC5630A detects a HVD SCSI device, it switches to a high impedance state.

The Multimode terminator contains all functions required to terminate and auto detect and switch modes for SPI-2 bus architectures. Single Ended and Differential impedances and currents are trimmed for maximum effectiveness. Fail Safe biasing is provided to insure signal integrity. Device/Bus type detection circuitry is integrated into the terminator to provide automatic switching of termination between single ended and LVD SCSI and a high impedance for HVD SCSI. The multimode function provides all the performance analog functions necessary to implement SPI-2 termination in a single monolithic device.

The UCC5630A is offered in a 36 pin SSOP package, as well as a 48 pin LQFP package for a temperature range of 0°C to 70°C.

## BLOCK DIAGRAM



**ABSOLUTE MAXIMUM RATINGS**

TRMPWR Voltage	6V
Signal Line Voltage	0V to TRMPWR
Package Power Dissipation	2W
Storage Temperature	-65°C to +150°C
Junction Temperature	-55°C to +150°C
Lead Temperature (Soldering, 10sec.)	+300°C

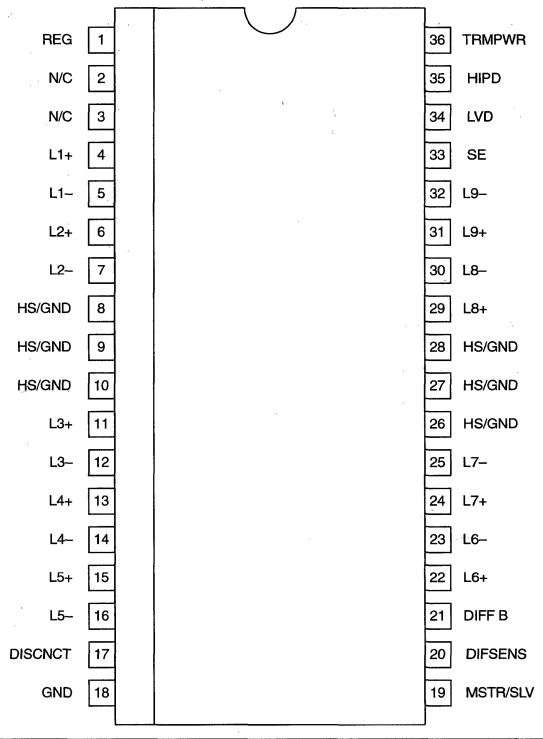
All voltages are with respect to pin 18. Currents are positive into, negative out of the specified terminal. Consult Packaging Section of the Databook for thermal limitations and considerations of packages.

**RECOMMENDED OPERATING CONDITIONS**

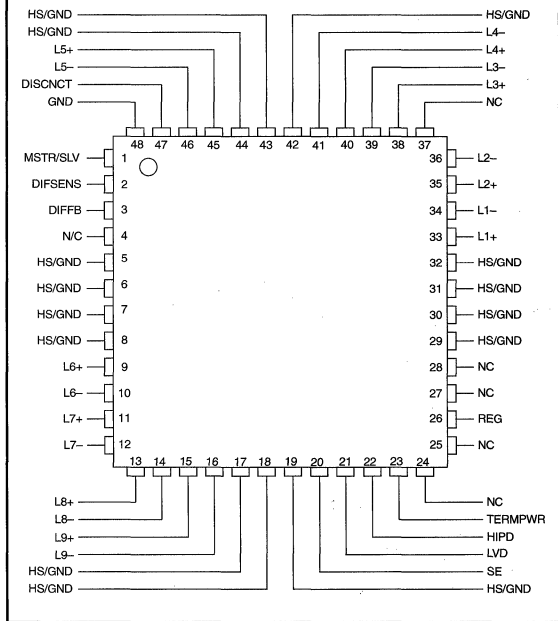
TRMPWR Voltage	2.7V to 5.25V
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**CONNECTION DIAGRAM**

**QSOP-36 (Top View)  
MWP Package**



**LQFP-48 (Top View)  
FQP Package**



**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = T_J = 0^\circ\text{C}$  to  $70^\circ\text{C}$ ,  
TRMPWR = 3.3V.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>TRMPWR Supply Current Section</b>					
TRMPWR Supply Current	LVD Mode		13	20	mA
	SE Mode		1.6	10	mA
	Disabled Terminator		250	400	$\mu\text{A}$
<b>Regulator Section</b>					
1.25V Regulator	LVD Mode	1.15	1.25	1.35	V
1.25V Regulator Source Current	$V_{\text{REG}} = 0\text{V}$	-600	-420	-225	mA
1.25V Regulator Sink Current	$V_{\text{REG}} = 3.3\text{V}$	100	180	420	mA
2.7V Regulator	SE Mode	2.5	2.7	3.0	V
2.7V Regulator Source Current	$V_{\text{REG}} = 0\text{V}$	-600	-420	-225	mA
2.7V Regulator Sink Current	$V_{\text{REG}} = 3.3\text{V}$	100	180	420	$\mu\text{A}$
<b>Diff Sense Driver (DIFSENS) Section</b>					
1.3V DIFSENS Output	DIFSENS	1.2	1.3	1.4	V
1.3V DIFSENS Source Current	$V_{\text{DIFSENS}} = 0\text{V}$	-15		-5	mA
1.3V DIFSENS Sink Current	$V_{\text{DIFSENS}} = 2.75\text{V}$	50		200	mA
<b>Differential Termination Section</b>					
Differential Impedance		100	105	110	$\Omega$
Common Mode Impedance	(Note 2)	110	150	165	$\Omega$
Differential Bias Voltage		100		125	mV
Common Mode Bias		1.15	1.25	1.35	V
Output Capacitance	Single Ended Measurement to Ground (Note 1)			3	pF
<b>Single Ended Termination Section</b>					
Impedance	$Z = (V_{LX} - 0.2\text{V}) / I_{LX}$ , (Note 3)	102.3	110	117.7	$\Omega$
Termination Current	Signal Level 0.2V, All Lines Low	-25.4	-24	-21	mA
	Signal Level 0.5V	-22.4		-18	mA
Output Leakage				400	nA
Output Capacitance	Single Ended Measurement to Ground (Note 1)			3	pF
Single Ended GND SE Impedance	$I = 10\text{mA}$		20	60	$\Omega$
<b>Disconnect (DISCNCT) and Diff Buffer (DIFFB) Input Section</b>					
DISCNCT Threshold		0.8		2.0	V
DISCNCT Input Current		-30	10		$\mu\text{A}$
DIFFB Single Ended to LVD Threshold		0.5		0.7	V
DIFFB LVD to HPD Threshold		1.9		2.4	V
DIFFB Input Current		-10		10	$\mu\text{A}$

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = T_J = 0^\circ\text{C}$  to  $70^\circ\text{C}$ ,  $\text{TRMPWR} = 3.3\text{V}$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Master/Slave (MSTR/SLV) Input Section</b>					
MSTR/SLV Threshold		0.8		2	V
MSTR/SLV Input Current		-30		30	$\mu\text{A}$
<b>Status Bits (SE, LVD, HIPD) Output Section</b>					
$I_{\text{SOURCE}}$	$V_{\text{LOAD}} = 2.4\text{V}$		-8.7	-4	$\text{mA}$
$I_{\text{SINK}}$	$V_{\text{LOAD}} = 0.5\text{V}$	3	6		$\text{mA}$
	$V_{\text{LOAD}} = 0.4\text{V}$	2	5		$\text{mA}$

**Note 1:** Guaranteed by design. Not 100% tested in production.

**Note 2:**  $Z_{\text{CM}} = \frac{1.2\text{V}}{I_{(V_{\text{CM}}+0.6\text{V})} - I_{(V_{\text{CM}}-0.6\text{V})}}$ ;

Where  $V_{\text{CM}}$  = Voltage measured with  $L+$  tied to  $L-$  and zero current applied;

**Note 3:**  $V_{L_x}$  = Output voltage for each terminator minus output pin ( $L1-$  through  $L9-$ ) with each pin unloaded.  
 $I_{L_x}$  = Output current for each terminator minus output pin ( $L1-$  through  $L9-$ ) with the minus output pin forced to 0.2V.

## PIN DESCRIPTIONS

**DIFFB:** Input pin for the comparators that select SE, LVD, or HIPD modes of operation. This pin should be decoupled with a  $0.1\mu\text{F}$  capacitor to ground and then coupled to the DIFSENS pin through a  $20\text{k}\Omega$  resistor.

**DIFSENS:** Connects to the Diff Sense line of the SCSI bus. The bus mode is controlled by the voltage level on this pin.

**DISCNCT:** Input pin used to shut down the terminator if the terminator is not connected at the end of the bus. Connect this pin to ground to activate the terminator or open pin to disable the terminator.

**HIPD:** TTL compatible status bit. This output pin is high when a high voltage differential device is detected on the bus.

**HS/GND:** Heat sink ground pins. These should be connected to large area PC board traces to increase the power dissipation capability.

**GND:** Power Supply return.

**L1- thru L9-:** Termination lines. These are the active lines in SE mode and are the negative lines for LVD mode. In HIPD mode, these lines are high impedance.

**L1+ thru L9+:** Termination lines. These lines switch to ground in SE mode and are the positive lines for LVD mode. In HIPD mode, these lines are high impedance.

**MSTR/SLV:** If the terminator is enabled, this input pin enables / disables the DIFSENS driver, when connected to TRMPWR or ground respectively. When the terminator is disabled, the DIFSENS driver is off, independent of this input.

**LVD:** TTL compatible status bit. This output pin is high when the SCSI bus is in LVD mode.

**REG:** Regulator output bypass pin. This pin must be connected to a  $4.7\mu\text{F}$  capacitor to ground.

**SE:** TTL compatible status bit. This output pin is high when the SCSI bus is in SE mode.

**TRMPWR:** 2.7V to 5.25V power input pin.



## APPLICATION INFORMATION

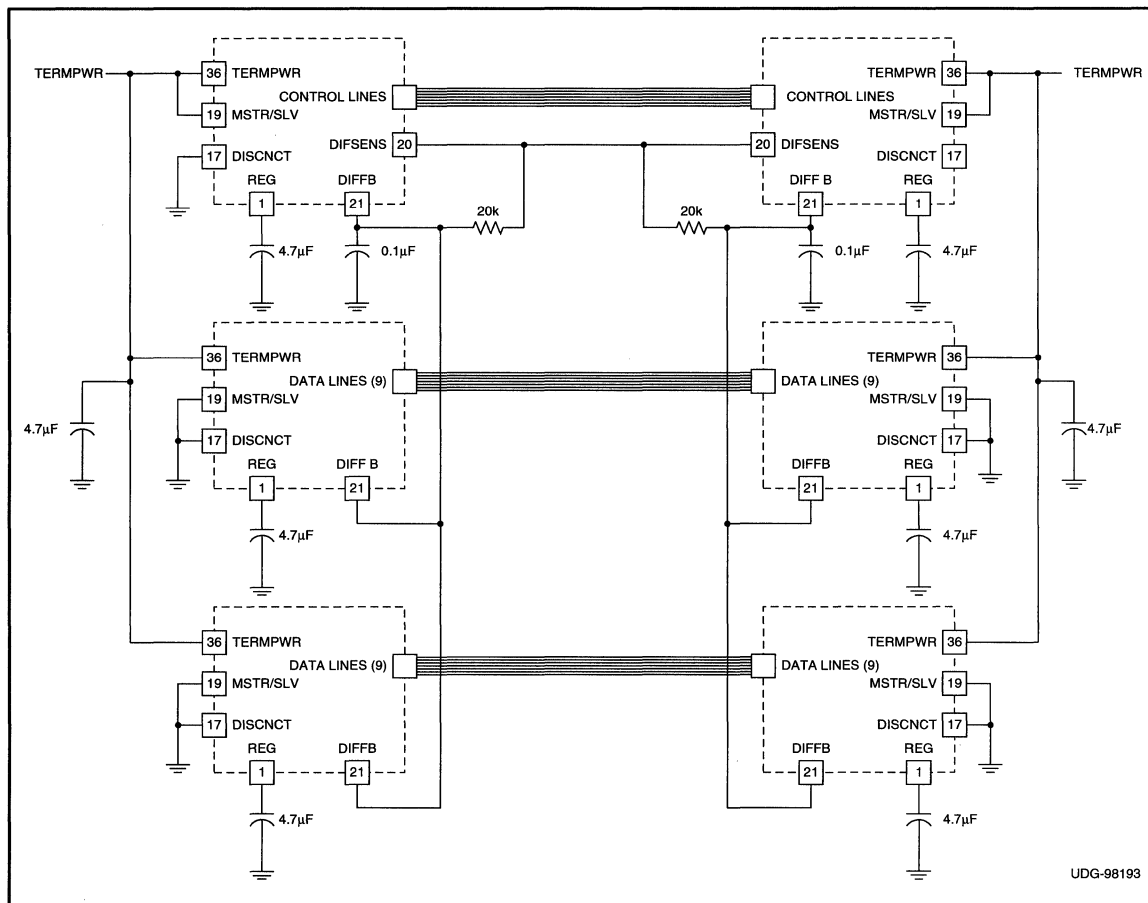


Figure 2. Application diagram.

All SCSI buses require a termination network at each end to function properly. Specific termination requirements differ, depending on which types of SCSI devices are present on the bus.

The UCC5630A is used in multi-mode active termination applications, where single ended (SE) and low voltage differential (LVD) devices might coexist. The UCC5630A has both SE and LVD termination networks integrated into a single monolithic component. The correct termination network is automatically determined by the SCSI bus "DIFSENS" signal.

The SCSI bus DIFSENS signal line is used to identify which types of SCSI devices are present on the bus. On power-up, the UCC5630A DIFSENS drivers will try to deliver 1.3V to the DIFSENS line. If only LVD devices are present, the DIFSENS line will be successfully driven to 1.3V and the terminators will configure for LVD operation. If any single ended devices are present, they will present a short to ground on the DIFSENS line, signaling the UCC5630A(s) to configure into the SE mode, accommodating the SE devices. Or, if any high voltage differential (HVD) devices are present, the DIFSENS line is pulled high and the terminator will enter a high impedance state, effectively disconnecting from the bus.

## APPLICATION INFORMATION (cont.)

The DIFSENS line is monitored by each terminator through a 50Hz noise filter at the DIFFB input pin. A set of comparators detect and select the appropriate termination for the bus as follows. If the DIFSENS signal is below 0.5V, the termination network is SE. Between 0.7V and 1.9V, the termination network switches to LVD, and above 2.4V is HVD, causing the terminators to disconnect from the bus. The thresholds accommodate differences in ground potential that can occur with long lines.

Three UCC5630A multi-mode parts are required at each end of the bus to terminate 27 (18 data, plus 9 control) lines. Each part includes a DIFSENS driver, but only one is necessary to drive the line. A MSTR/SLV input pin is provided to disable the other two. The "master" part must have its' MSTR/SLV pin connected to TRMPWR and the two "slave" parts must have the MSTR/SLV inputs grounded. Only the "master" is connected directly to the SCSI bus DIFSENS line. The DIFFB inputs on all three parts are connected together, allowing them to share the same 50Hz noise filter. This multi-mode terminator operates in full specification down to 2.7V TRMPWR voltage. This accommodates 3.3V systems, with allowance for the 3.3V supply tolerance (+/- 10%), a unidirectional fusing device and cable drop. In 3.3V TRMPWR systems, the UCC3916 is recommended in place of the fuse and diode. The UCC3916's lower voltage drop allows additional margin over the fuse and diode, for the far end terminator.

Layout is critical for Ultra2 and Ultra3 systems. The SPI-2 standard for capacitance loading is 10pF maximum from each positive and negative signal line to ground, and a maximum of 5pF between the positive and negative signal lines of each pair is allowed. These maximum capacitances apply to differential bus termination circuitry that is not part of a SCSI device, (e.g. a cable terminator). If the termination circuitry is included as part of a SCSI device, (e.g., a host adaptor, disk or tape drive), then the corresponding requirements are 30pF maximum from each positive and negative signal line to ground and 15pF maximum between the positive and negative signal lines of each pair.

The SPI-2 standard for capacitance balance of each pair and balance between pairs is more stringent. The standard is 0.75pF maximum difference from the positive and negative signal lines of each pair to ground. An addi-

tional requirement is a maximum difference of 2pF when comparing pair to pair. These requirements apply to differential bus termination circuitry that is not part of a SCSI device. If the termination circuitry is included as part of a device, then the corresponding balance requirements are 2.25pF maximum difference within a pair, and 3pF from pair to pair.

Feed-throughs, through-hole connections, and etch lengths need to be carefully balanced. Standard multi-layer power and ground plane spacing add about 1pF to each plane. Each feed-through will add about 2.5pF to 3.5pF. Enlarging the clearance holes on both power and ground planes will reduce the capacitance. Similarly, opening up the power and ground planes under the connector will reduce the capacitance for through-hole connector applications. Capacitance will also be affected by components, in close proximity, above and below the circuit board.

Unitrode multi-mode terminators are designed with very tight balance, typically 0.1pF between pins in a pair and 0.3pF between pairs. At each L+ pin, a ground driver drives the pin to ground, while in single ended mode. The ground driver is specially designed to not effect the capacitive balance of the bus when the device is in LVD or disconnect mode.

Multi-layer boards need to adhere to the 120Ω impedance standard, including the connectors and feed-throughs. This is normally done on the outer layers with 4 mil etch and 4 mil spacing between runs within a pair, and a minimum of 8 mil spacing to the adjacent pairs to reduce crosstalk. Microstrip technology is normally too low of impedance and should not be used. It is designed for 50Ω rather than 120Ω differential systems. Careful consideration must be given to the issue of heat management. A multi-mode terminator, operating in SE mode, will dissipate as much as 130mW of instantaneous power per active line with TRMPWR = 5.25V. The UCC5630A is offered in a 36 pin SSOP and a 48 lead LFQP. Both packages include heat sink ground pins. These heat sink/ground pins are directly connected to the die mount paddle under the die and conduct heat from the die to reduce the junction temperature. All of the HS/GND pins need to be connected to etch area or a feed-through per pin connecting to the ground plane layer on a multi-layer board.

# Multi-mode (LVD/SE) SCSI 9 Line Terminator w/ 2.85V Regulator

## FEATURES

- Auto Selection Single Ended (SE) or Low Voltage Differential (LVD) Termination
- Meets SCSI-1, SCSI-2, SCSI-3 SPI, Ultra Fast-20, Ultra-2 (SPI-2 LVD) and Ultra 3 Standards
- 2.7V to 5.25V Tempwr Operation
- Differential Failsafe Bias
- Thermal Packaging for Low Junction Temperature and

## DESCRIPTION

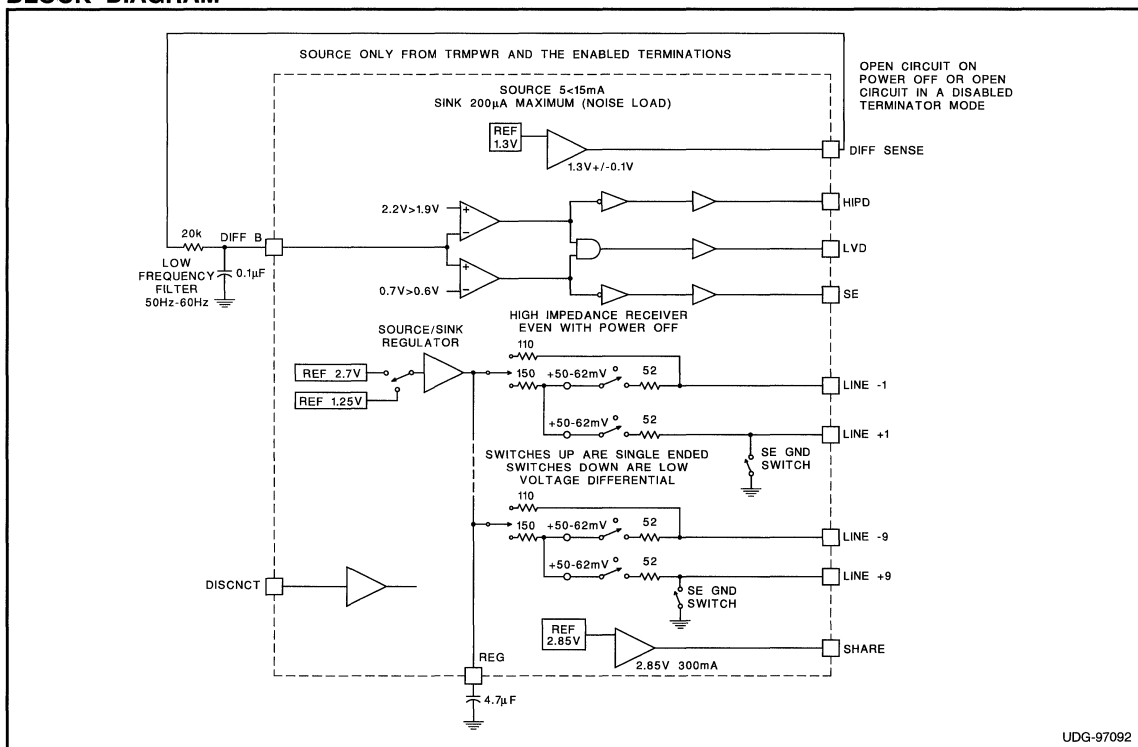
The UCC5632 Multi-mode SCSI Terminator, both Low Voltage Differential and Single Ended Terminator is both a single ended terminator and a low voltage differential terminator for the transition to the next generation SCSI Parallel Interface (SPI-2). The low voltage differential is a requirement for the higher speeds at a reasonable cost and is the only way to have adequate skew budgets. The transceivers can be incorporated into the controller, unlike SCSI high power differential (EIA485) which requires external transceivers. Low Voltage differential is specified for Ultra-2 (Fast-40) and Ultra-3 (Fast-80), but has the potential of speeds up to Fast-320.

The UCC5630 cannot be used with SCSI differential EIA485, it will shutdown when it sees high power differential to protect the bus. The pinning for high power differential is not the same as LVD SCSI or single ended and the bias voltage, current and power are also different for EIA485 differential.

## ABSOLUTE MAXIMUM RATINGS

TERMPWR Voltage	+6V	Junction Temperature	-55°C to +150°C
Signal Line Voltage	0V to TERMPWR	Lead Temperature (Soldering, 10 sec.)	+300°C
Package Power Dissipation	2W	<b>RECOMMENDED OPERATING CONDITIONS</b>	
Storage Temperature	-65°C to +150°C	TERMPWR Voltage	2.7V to 5.25V

## BLOCK DIAGRAM



UDG-97092

Circuit Design Patented

# Multimode SCSI 15 Line Terminator

## FEATURES

- Auto Selection Single Ended (SE) or Low Voltage Differential (LVD) Termination
- Meets SCSI-1, SCSI-2, SCSI-3, SPI, Ultra (Fast-20), Ultra 2 (SPI-2 LVD) and Ultra 3 Standards
- 2.7V to 5.25V Operation
- Differential Failsafe Bias
- Thermal packaging for low junction temperature and better MTBF.

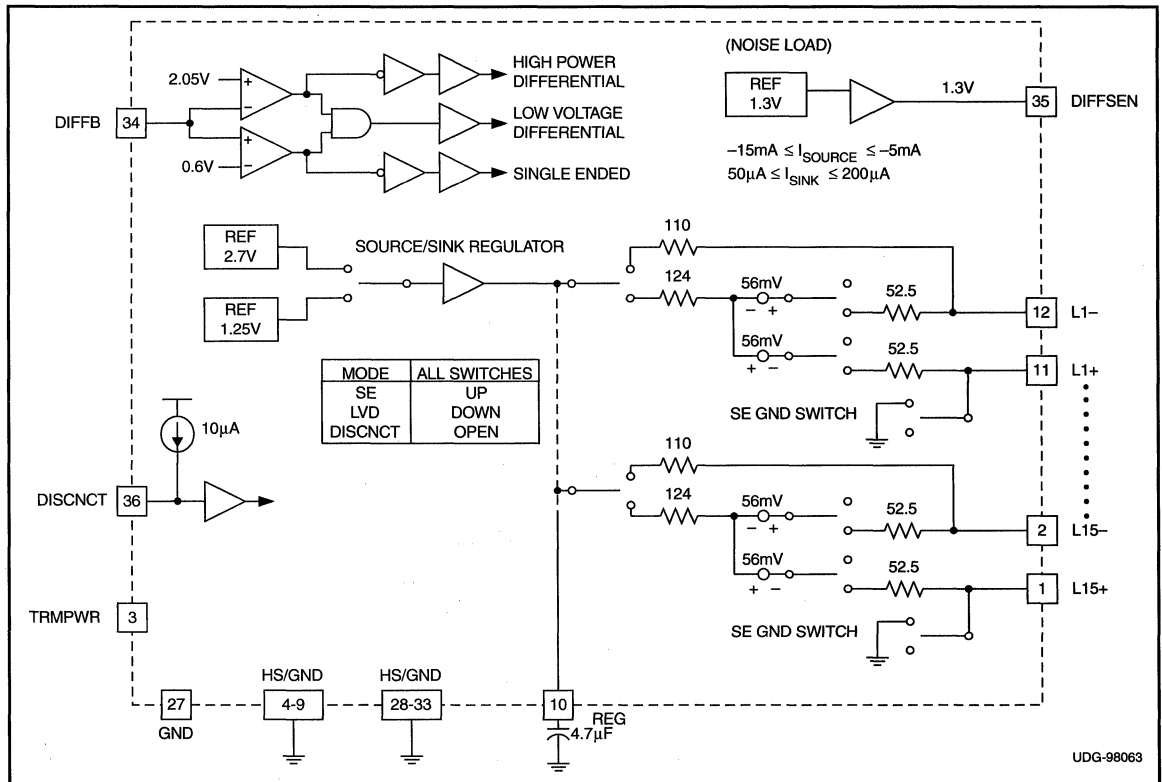
## DESCRIPTION

The UCC5638 Multimode SCSI Terminator provides a smooth transition into the next generation of the SCSI Parallel Interface (SPI-2). It automatically senses the bus, via DIFFB, and switches the termination to either single ended (SE) or low voltage differential (LVD) SCSI, dependent on which type of devices are connected to the bus. The UCC5638 can not be used on a HVD, EIA485, differential SCSI bus. If the UCC5638 detects a HVD SCSI device, it switches to a high impedance state.

The Multimode terminator contains all functions required to terminate and auto detect and switch modes for SPI-2 bus architectures. Single Ended and Differential impedances and currents are trimmed for maximum effectiveness. Fail Safe biasing is provided to insure signal integrity. Device/Bus type detection circuitry is integrated into the terminator to provide automatic switching of termination between single ended and LVD SCSI and a high impedance for HVD SCSI. The multimode function provides all the performance analog functions necessary to implement SPI-2 termination in a single monolithic device.

The UCC5638 is offered in a 48 pin LQFP package for a temperature range of 0°C to 70°C.

## BLOCK DIAGRAM



UDG-98063

**ABSOLUTE MAXIMUM RATINGS**

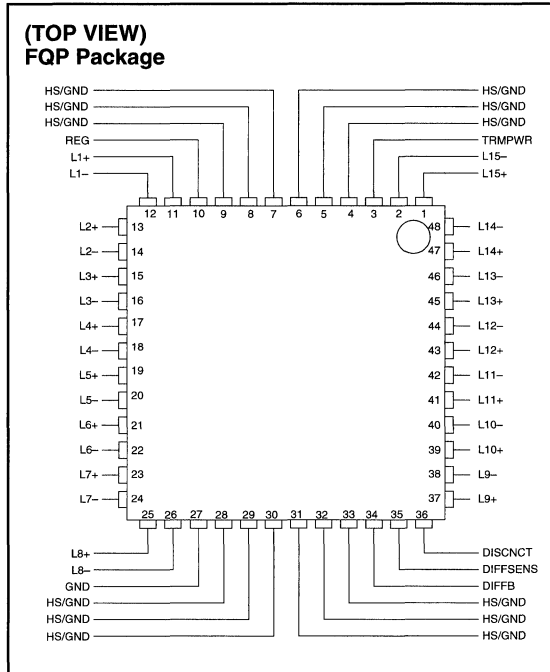
TRMPWR Voltage	+6V
Signal Line Voltage	0V to TRMPWR
Package Dissipation	2W
Storage Temperature	-65°C to +150°C
Junction Temperature	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.)	+300°C
Recommended Operating Conditions	2.7V to 5.25V

Currents are positive into negative out of the specified terminal.  
 Note: Consult Packaging Section of Databook for thermal limitations and considerations of package.

**RECOMMENDED OPERATING CONDITIONS**

TRMPWR Voltage	2.7V to 5.25V
Temperature Ranges	0°C to +70°C

**CONNECTION DIAGRAMS**



**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = T_J = 0^\circ\text{C}$  to  $70^\circ\text{C}$ , TRMPWR = 3.3V.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>TRMPWR Supply Current Section</b>					
TRMPWR Supply Current	LVD Mode		20	25	mA
	SE Mode		1.6	10	mA
	Disabled Terminator		250	400	$\mu\text{A}$
<b>Regulator Section</b>					
1.25V Regulator	LVD Mode	1.15	1.25	1.35	V
1.25V Regulator Source Current	$V_{\text{REG}} = 0\text{V}$	-375	-700	-1000	mA
1.25V Regulator Sink Current	$V_{\text{REG}} = 3.3\text{V}$	170	300	700	mA
1.3V Regulator	Diff Sense	1.2	1.3	1.4	V
1.3V Regulator Source Current	$V_{\text{REG}} = 0\text{V}$	-15		-5	mA
1.3V Regulator Sink Current	$V_{\text{REG}} = 3.3\text{V}$	50		200	$\mu\text{A}$
2.7V Regulator	SE Mode	2.5	2.7	3.0	V
2.7V Regulator Source Current	$V_{\text{REG}} = 0\text{V}$	-375	-700	-1000	mA
2.7V Regulator Sink Current	$V_{\text{REG}} = 3.3\text{V}$	170	300	700	mA
<b>Differential Termination Section</b>					
Differential Impedance		100	105	110	$\Omega$
Common Mode Impedance	(Note 2)	110	150	165	$\Omega$
Differential Bias Voltage		100		125	mV
Common Mode Bias		1.15	1.25	1.35	V
Output Capacitance	Single Ended Measurement to Ground (Note 1)			3	pF

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = T_J = 0^\circ\text{C}$  to  $70^\circ\text{C}$ , TRMPWR = 3.3V.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Single Ended Termination Section</b>					
Impedance	$Z = (V_{Lx} - 0.2V) / I_{Lx}$ , (Note 3)	102.3	110	117.7	$\Omega$
Termination Current	Signal Level 0.2V, All Lines Low	-21	-24	-25.4	mA
	Signal Level 0.5V	-18		-22.4	mA
Output Leakage				400	nA
Output Capacitance	Single Ended Measurement to Ground (Note 1)			3	pF
Single Ended GND SE Impedance	I = 10mA		20	60	$\Omega$
<b>Disconnect and Diff Buffer Input Section</b>					
DISCNCT Threshold		0.8		2.0	V
DISCNCT Input Current			10	30	$\mu\text{A}$
Diff Buffer Single Ended to LVD Threshold		0.5		0.7	V
Diff Buffer LVD to HPD Threshold		1.9		2.2	V
DIFFB Input Current		-10		10	$\mu\text{A}$

**Note 1:** Guaranteed by design. Not 100% tested in production.

**Note 2:** Line+ (positive) tied to Line- (negative);  $\frac{I_{(VCMmax)} - I_{(VCMmin)}}{1.2V}$

**Note 3:**  $V_{Lx}$  = Output voltage for each terminator minus output pin (L1- through L15-) with each pin unloaded.  
 $I_{Lx}$  = Output current for each terminator minus output pin (L1- through L15-) with the minus output pin forced to 0.2V.

## PIN DESCRIPTIONS

**DIFFB:** Diff sense filter pin should be connected at a 0.1 $\mu\text{F}$  capacitor.

**DIFSENS:** The SCSI bus Diff Sense line to detect what types of devices are connected to the SCSI bus.

**DISCNCT:** Disconnect pin shuts down the terminator when it is not at the end of the bus. The disconnect pin low enables the terminator.

**LINE-:** Signal line active line for single ended or negative line in differential applications for the SCSI bus.

**LINE+:** Ground line for single ended or positive line for differential applications for the SCSI bus.

**REG:** Regulator bypass pin, must be connected to a 4.7 $\mu\text{F}$  capacitor.

**TRMPWR:**  $V_{IN}$  2.7V to 5.25V supply.

**Note:** In Disconnect Mode, the comparator set powers down for low idle current.

## APPLICATION INFORMATION

The UCC5638 is a Multi-mode active terminator with selectable single ended (SE) and low voltage differential (LVD) SCSI termination integrated into a monolithic component. Mode selection is accomplished with the "diff sense" signal.

The diff sense signal is a three level signal, which is driven at each end of the bus by one active terminator. A LVD or multi-mode terminator drives the diff sense line to 1.3 V. If diff sense is at 1.3 V, then bus is in LVD mode. If a single ended SCSI device is plugged into the bus, the diff sense line is shorted to ground. With diff sense shorted to ground, the terminator changes to single ended mode to accommodate the SE device. If a HVD device is plugged in to the bus, the diff sense line is pulled high and the terminator shuts down.

The diff sense line is driven and monitored by the terminator through a 50Hz noise filter at the DIFFB input pin. A set of comparators, that allow for ground shifts, determine the bus status as follows. Any diff sense signal below 0.5V is single ended, between 0.7V and 1.9V is LVD and above 2.2V is HVD.

In the single ended mode, a multi-mode terminator has a 110 $\Omega$  terminating resistor connected to a 2.7V termination voltage regulator. The 2.7V regulator is used on all Unitrode terminators designed for 3.3V systems. This requires the terminator to operate in specification down to 2.7V TRMPWR voltage to allow for the 3.3V supply tolerance, an unidirectional fusing device and cable drop. At each L+ pin, a ground driver drives the pin to ground, while in single ended mode. The ground driver is specially designed so it will not effect the capacitive balance of the bus when the device is in LVD or disconnect mode. The device requirements call for 0.5pF balance on the lines of a differential pair. The terminator capacitance has to be a small part of the capacitance imbalance.

Layout is very critical for Ultra 2 and Ultra 3 systems. Multi-layer boards need to adhere to the 120 $\Omega$  impedance standard, including connector and feed-through. This is normally done on the outer layers with 4 mil etch

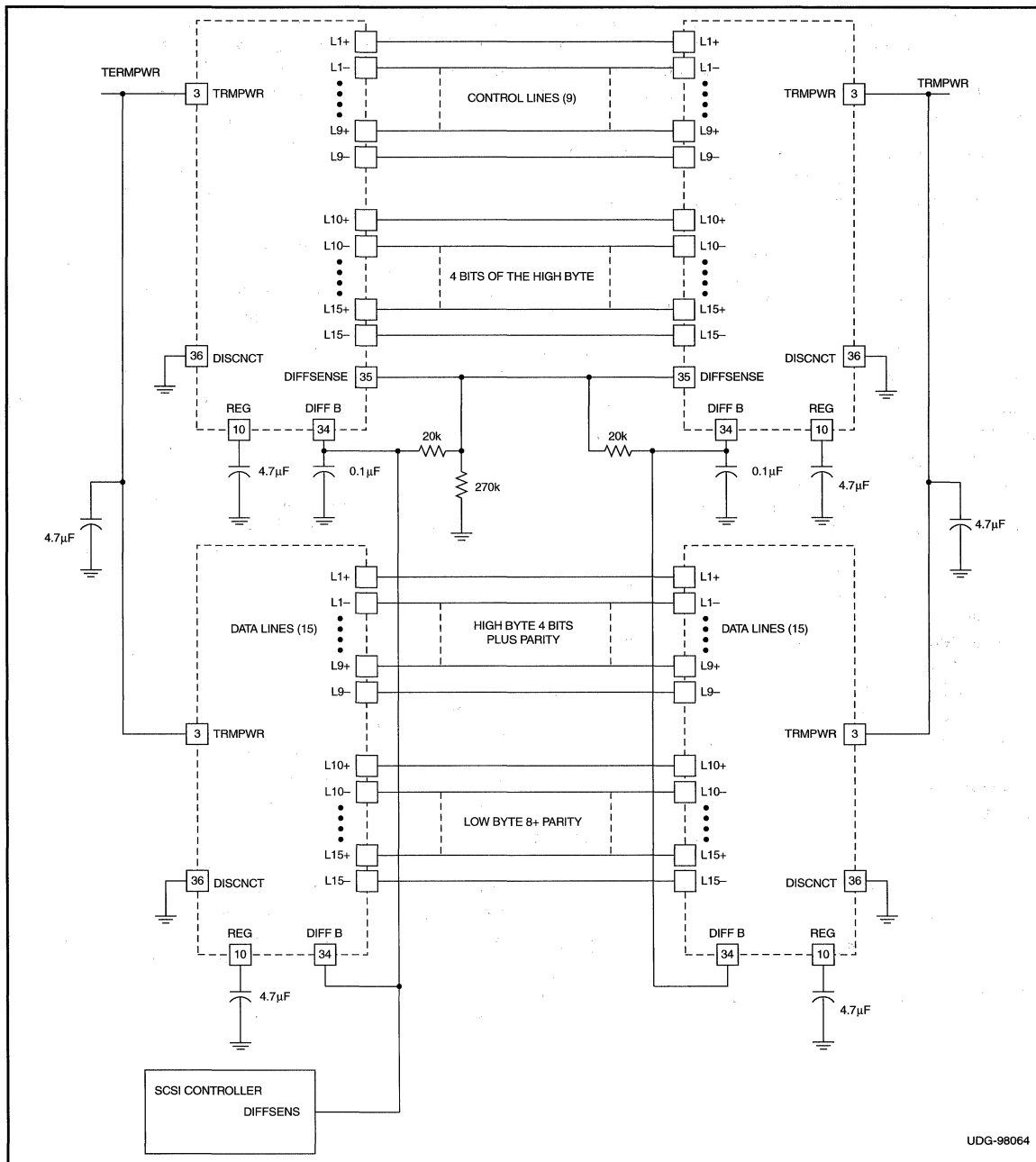
and 4 mil spacing between the runs within a pair, and a minimum of 8 mil spacing to the next pair. This spacing between the pairs reduces potential crosstalk. Beware of feed-throughs and each through hole connection adds a lot of capacitance. Standard power and ground plane spacing yields about 1pF to each plane. Each feed-through will add about 2.5pF to 3.5pF. Enlarging the clearance holes on both power and ground planes can reduce the capacitance and opening up the power and ground planes under the connector can reduce the capacitance for through hole connector applications. Microstrip technology is normally too low of impedance and should not be used. It is designed for 50 $\Omega$  rather than 120 $\Omega$  differential systems.

Capacitance balance is critical for Ultra 2 and Ultra 3. The balance capacitance standard is 0.5pF per line with the balance between pairs of 2pF. The components are designed with very tight balance, typically 0.1pF between pins in a pair and 0.3pF between pairs. Layout balance is critical, feed-throughs and etch length must be balanced, preferably no feed-throughs would be used. Capacitance for devices should be measured in the typical application, material and components above and below the circuit board effect the capacitance.

Multi-mode terminators need to consider power dissipation; the UCC5638 is offered in a power package with heat sink ground pins. These heat sink/ground pins are directly connected to the die mount paddle under the die and conduct heat from the die to reduce the junction temperature. These pins need to be connected to etch area or a feed-through per pin connecting to the ground plane layer on a multi-layer board.

In 3.3V TRMPWR systems, the UCC3912 should be used to replace the fuse and diode. This reduces the voltage drop, allowing for cable drop to the far end terminator. 3.3V battery systems normally have a 10% tolerance. The UCC3912 is 150mV drop under LVD loads, allowing 150mV drop in the cable system. All Unitrode LVD and multi-mode terminators are designed for 3.3V systems, operating down to 2.7V.

TYPICAL APPLICATION



UDG-98064

**Note:** A 220k resistor is added to ground to insure the transceivers will come up in single-ended mode when no terminator is enabled. The controller DIFFSENS ties to the DIFFB pin on the terminators, only one RC network should be on a device.



# Multimode SCSI 15 Line Terminator with Reverse Disconnect

## FEATURES

- Auto Selection Single Ended (SE) or Low Voltage Differential (LVD) Termination
- Meets SCSI-1, SCSI-2, SCSI-3, SPI, Ultra (Fast-20), Ultra2 (SPI-2 LVD) and Ultra3 Standards
- 2.7V to 5.25V Operation
- Differential Failsafe Bias
- Thermal packaging for low junction temperature and better MTBF.

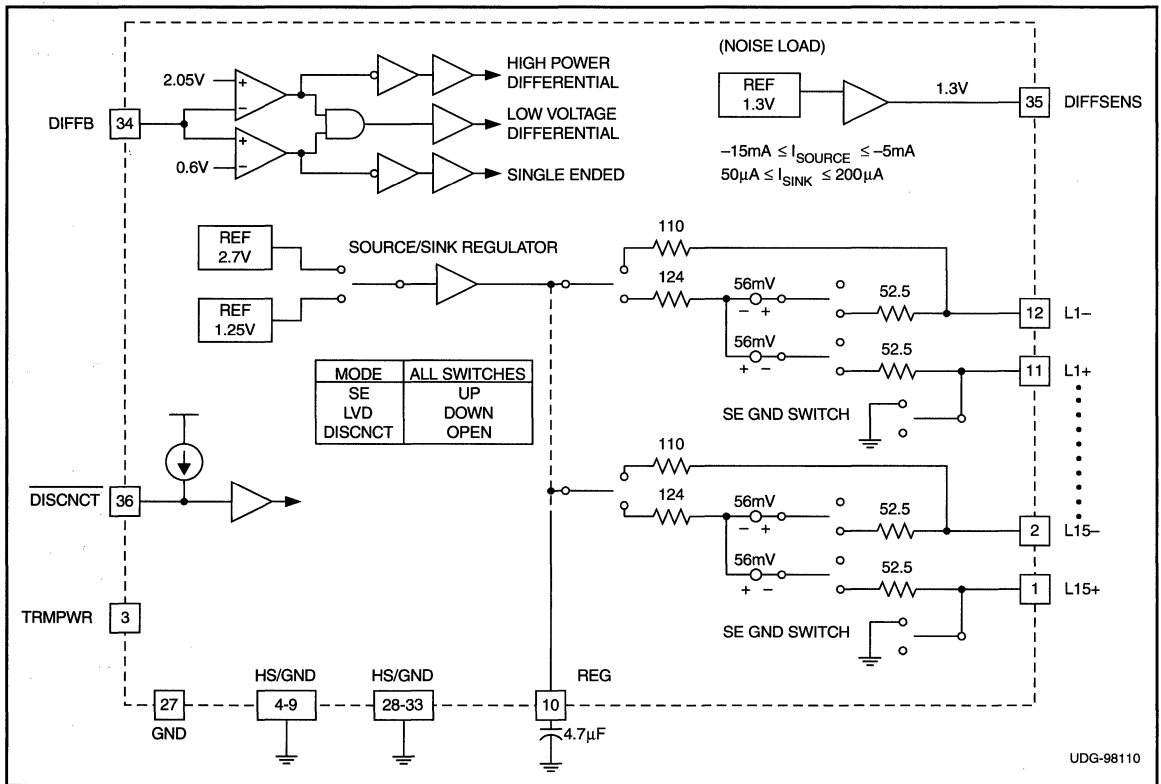
## DESCRIPTION

The UCC5639 Multimode SCSI Terminator provides a smooth transition into the next generation of the SCSI Parallel Interface (SPI-2). It automatically senses the bus, via DIFFB, and switches the termination to either single ended (SE) or low voltage differential (LVD) SCSI, dependent on which type of devices are connected to the bus. The UCC5639 can not be used on a HVD, EIA485, differential SCSI bus. If the UCC5639 detects a HVD SCSI device, it switches to a high impedance state.

The Multimode terminator contains all functions required to terminate and auto detect and switch modes for SPI-2 bus architectures. Single Ended and Differential impedances and currents are trimmed for maximum effectiveness. Fail Safe biasing is provided to insure signal integrity. Device/Bus type detection circuitry is integrated into the terminator to provide automatic switching of termination between single ended and LVD SCSI and a high impedance for HVD SCSI. The multimode function provides all the performance analog functions necessary to implement SPI-2 termination in a single monolithic device.

The UCC5639 is offered in a 48 pin LQFP package for a temperature range of 0°C to 70°C.

## BLOCK DIAGRAM



**ABSOLUTE MAXIMUM RATINGS**

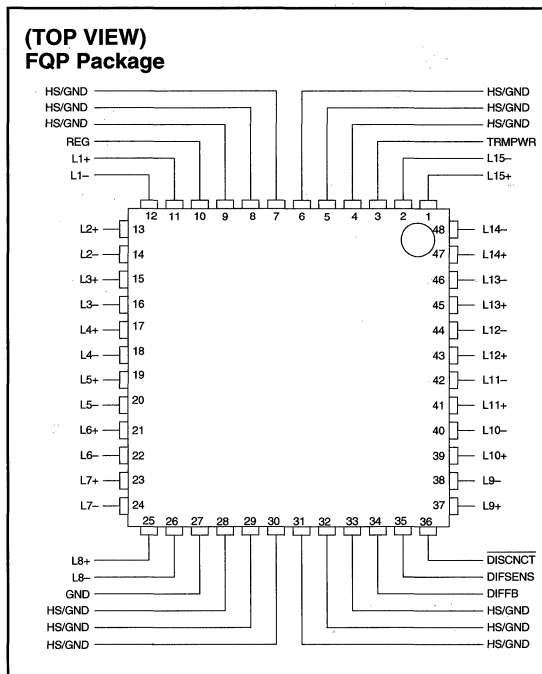
TRMPWR Voltage	+6V
Signal Line Voltage	0V to TRMPWR
Package Dissipation	2W
Storage Temperature	-65°C to +150°C
Junction Temperature	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.)	+300°C
Recommended Operating Conditions	2.7V to 5.25V

Currents are positive into negative out of the specified terminal.  
 Note: Consult Packaging Section of Databook for thermal limitations and considerations of package.

**RECOMMENDED OPERATING CONDITIONS**

TRMPWR Voltage	2.7V to 5.25V
Temperature Ranges	0°C to +70°C

**CONNECTION DIAGRAMS**



**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = T_J = 0^\circ\text{C}$  to  $70^\circ\text{C}$ , TRMPWR = 3.3V.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>TRMPWR Supply Current Section</b>					
TRMPWR Supply Current	LVD Mode		20	25	mA
	SE Mode		1.6	10	mA
	Disabled Terminator		250	400	$\mu\text{A}$
<b>Regulator Section</b>					
1.25V Regulator	LVD Mode	1.15	1.25	1.35	V
1.25V Regulator Source Current	$V_{\text{REG}} = 0\text{V}$	-375	-700	-1000	mA
1.25V Regulator Sink Current	$V_{\text{REG}} = 3.3\text{V}$	170	300	700	mA
1.3V Regulator	DIFSENS	1.2	1.3	1.4	V
1.3V Regulator Source Current	$V_{\text{REG}} = 0\text{V}$	-15		-5	mA
1.3V Regulator Sink Current	$V_{\text{REG}} = 3.3\text{V}$	50		200	$\mu\text{A}$
2.7V Regulator	SE Mode	2.5	2.7	3.0	V
2.7V Regulator Source Current	$V_{\text{REG}} = 0\text{V}$	-375	-700	-1000	mA
2.7V Regulator Sink Current	$V_{\text{REG}} = 3.3\text{V}$	170	300	700	mA
<b>Differential Termination Section</b>					
Differential Impedance		100	105	110	$\Omega$
Common Mode Impedance	(Note 2)	110	150	165	$\Omega$
Differential Bias Voltage		100		125	mV
Common Mode Bias		1.15	1.25	1.35	V
Output Capacitance	Single Ended Measurement to Ground (Note 1)			3	pF

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = T_J = 0^\circ\text{C}$  to  $70^\circ\text{C}$ , TRMPWR = 3.3V.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Single Ended Termination Section</b>					
Impedance	$Z = (V_{LX} - 0.2V) / I_{LX}$ , (Note 3)	102.3	110	117.7	$\Omega$
Termination Current	Signal Level 0.2V, All Lines Low	-21	-24	-25.4	mA
	Signal Level 0.5V	-18		-22.4	mA
Output Leakage				400	nA
Output Capacitance	Single Ended Measurement to Ground (Note 1)			3	pF
Single Ended GND SE Impedance	$I = 10\text{mA}$		20	60	$\Omega$
<b>Disconnect and Diff Buffer Input Section</b>					
DISCNCT Threshold		0.8		2.0	V
DISCNCT Input Current			10	30	$\mu\text{A}$
Diff Buffer Single Ended to LVD Threshold		0.5		0.7	V
Diff Buffer LVD to HPD Threshold		1.9		2.2	V
DIFFB Input Current		-10		10	$\mu\text{A}$

**Note 1:** Guaranteed by design. Not 100% tested in production.

**Note 2:**  $Z_{CM} = \frac{1.2V}{[I_{(V_{CM}+0.6V)} - I_{(V_{CM}-0.6V)}]}$  where  $V_{CM}$ =voltage measured with  $L+$  tied to  $L-$  and zero current applied

**Note 3:**  $V_{LX}$ = Output voltage for each terminator minus output pin ( $L1-$  through  $L15-$ ) with each pin unloaded.  
 $I_{LX}$ = Output current for each terminator minus output pin ( $L1-$  through  $L15-$ ) with the minus output pin forced to 0.2V.

## PIN DESCRIPTIONS

**DIFFB:** Diff sense filter pin should be connected at a  $0.1\mu\text{F}$  capacitor.

**DIFSENS:** The SCSI bus Diff Sense line to detect what types of devices are connected to the SCSI bus.

**DISCNCT:** Disconnect pin shuts down the terminator when it is not at the end of the bus. The disconnect pin high enables the terminator.

**LINE $n-$ :** Signal line active line for single ended or negative line in differential applications for the SCSI bus.

**LINE $n+$ :** Ground line for single ended or positive line for differential applications for the SCSI bus.

**REG:** Regulator bypass pin, must be connected to a  $4.7\mu\text{F}$  capacitor.

**TRMPWR:**  $V_{IN}$  2.7V to 5.25V supply.

## APPLICATION INFORMATION

The UCC5639 is a Multi-mode active terminator with selectable single ended (SE) and low voltage differential (LVD) SCSI termination integrated into a monolithic component. Mode selection is accomplished with the "diff sense" signal.

The diff sense signal is a three level signal, which is driven at each end of the bus by one active terminator. A LVD or multi-mode terminator drives the diff sense line to 1.3 V. If diff sense is at 1.3 V, then bus is in LVD mode. If a single ended SCSI device is plugged into the bus, the diff sense line is shorted to ground. With diff sense shorted to ground, the terminator changes to single ended mode to accommodate the SE device. If a HVD device is plugged in to the bus, the diff sense line is pulled high and the terminator shuts down.

The diff sense line is driven and monitored by the terminator through a 50Hz noise filter at the DIFFB input pin. A set of comparators, that allow for ground shifts, determine the bus status as follows. Any diff sense signal below 0.5V is single ended, between 0.7V and 1.9V is LVD and above 2.2V is HVD.

In the single ended mode, a multi-mode terminator has a 110 $\Omega$  terminating resistor connected to a 2.7V termination voltage regulator. The 2.7V regulator is used on all Unitorde terminators designed for 3.3V systems. This requires the terminator to operate in specification down to 2.7V TRMPWR voltage to allow for the 3.3V supply tolerance, an unidirectional fusing device and cable drop. At each L+ pin, a ground driver drives the pin to ground, while in single ended mode. The ground driver is specially designed so it will not effect the capacitive balance of the bus when the device is in LVD or disconnect mode. The device requirements call for 0.5pF balance on the lines of a differential pair. The terminator capacitance has to be a small part of the capacitance imbalance.

Layout is very critical for Ultra2 and Ultra3 systems. Multi-layer boards need to adhere to the 120 $\Omega$  impedance standard, including connector and feed-through. This is normally done on the outer layers with 4 mil etch

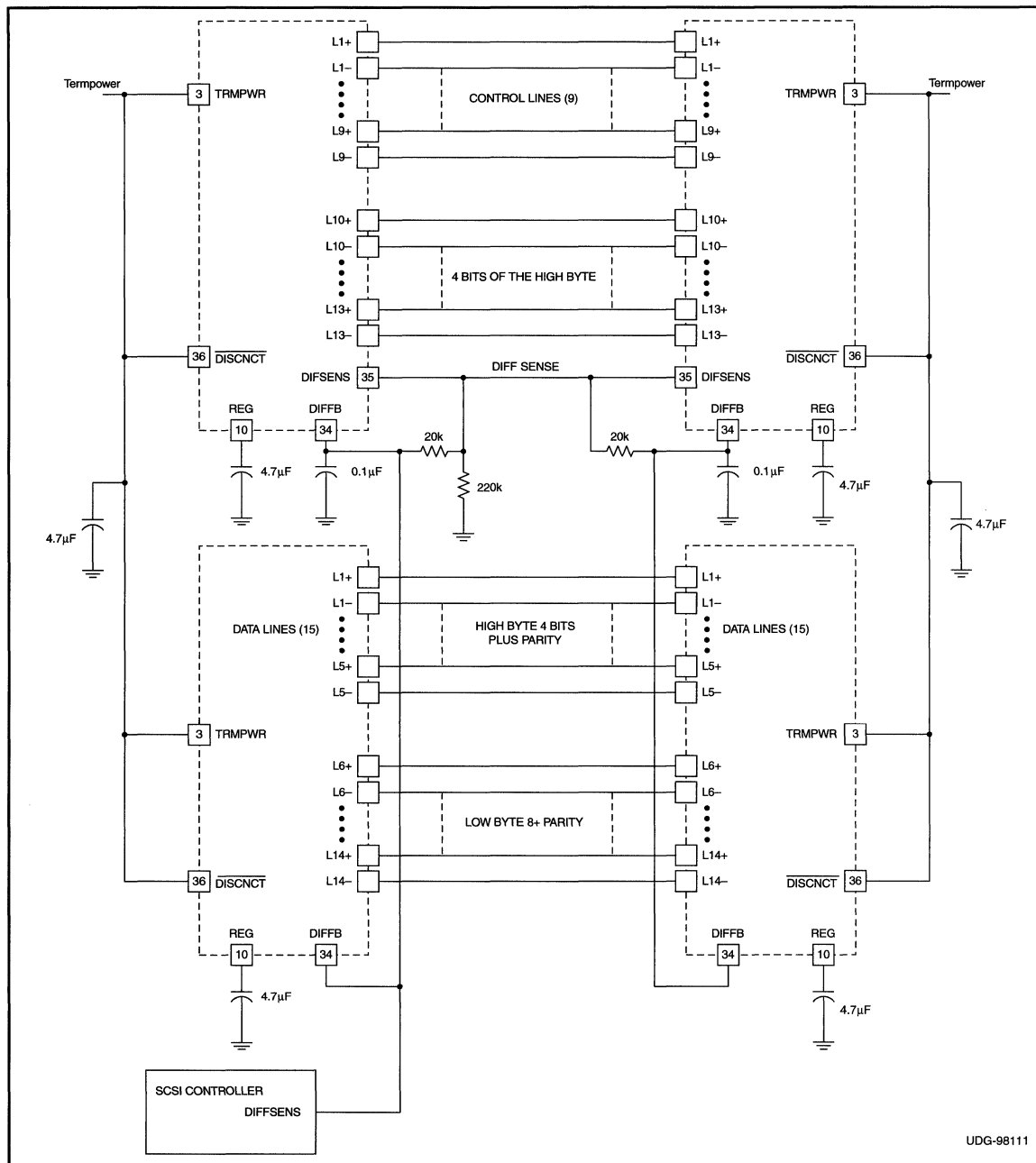
and 4 mil spacing between the runs within a pair, and a minimum of 8 mil spacing to the next pair. This spacing between the pairs reduces potential crosstalk. Beware of feed-throughs and each through hole connection adds a lot of capacitance. Standard power and ground plane spacing yields about 1pF to each plane. Each feed-through will add about 2.5pF to 3.5pF. Enlarging the clearance holes on both power and ground planes can reduce the capacitance and opening up the power and ground planes under the connector can reduce the capacitance for through hole connector applications. Microstrip technology is normally too low of impedance and should not be used. It is designed for 50 $\Omega$  rather than 120 $\Omega$  differential systems.

Capacitance balance is critical for Ultra2 and Ultra3. The balance capacitance standard is 0.5pF per line with the balance between pairs of 2pF. The components are designed with very tight balance, typically 0.1pF between pins in a pair and 0.3pF between pairs. Layout balance is critical, feed-throughs and etch length must be balanced, preferably no feed-throughs would be used. Capacitance for devices should be measured in the typical application, material and components above and below the circuit board effect the capacitance.

Multi-mode terminators need to consider power dissipation; the UCC5639 is offered in a power package with heat sink ground pins. These heat sink/ground pins are directly connected to the die mount paddle under the die and conduct heat from the die to reduce the junction temperature. These pins need to be connected to etch area or a feed-through per pin connecting to the ground plane layer on a multi-layer board.

In 3.3V TRMPWR systems, the UCC3912 should be used to replace the fuse and diode. This reduces the voltage drop, allowing for cable drop to the far end terminator. 3.3V battery systems normally have a 10% tolerance. The UCC3912 is 150mV drop under LVD loads, allowing 150mV drop in the cable system. All Unitorde LVD and multi-mode terminators are designed for 3.3V systems, operating down to 2.7V.

TYPICAL APPLICATION

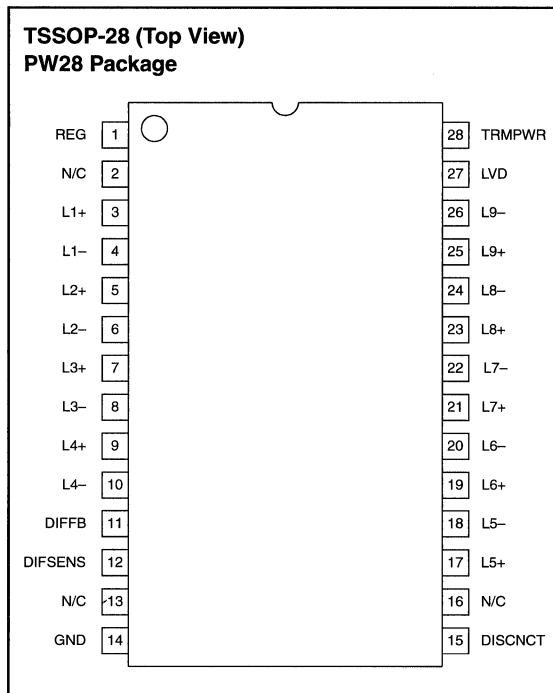
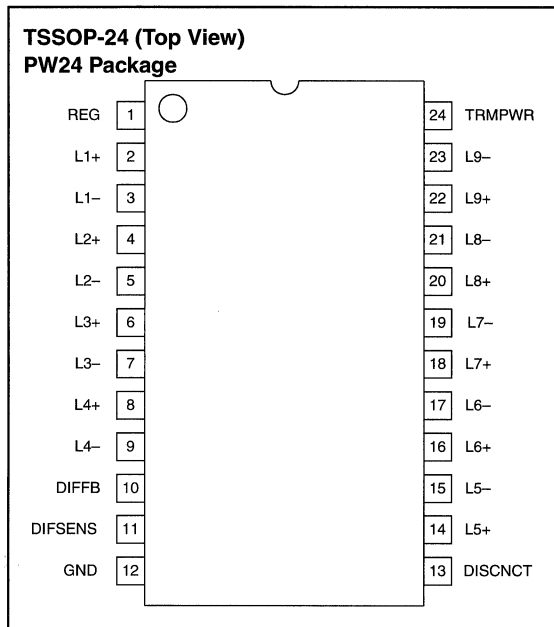


**Note:** A 220k resistor is added to ground to insure the transceivers will come up in single-ended mode when no terminator is enabled. The controller DIFFSENS ties to the DIFFB pin on the terminators, only one RC network should be on a device.





CONNECTION DIAGRAMS



**ABSOLUTE MAXIMUM RATINGS**

TRMPWR Voltage . . . . . +6V  
 Signal Line Voltage . . . . . 0V to 3.6V  
 Package Dissipation . . . . . 1W  
 Storage Temperature . . . . . -65°C to +150°C  
 Junction Temperature . . . . . -55°C to +150°C  
 Lead Temperature (Soldering, 10 sec.) . . . . . +300°C

*Currents are positive into negative out of the specified terminal. consult Packaging Section of Databook for thermal limitations and considerations of package.*

**RECOMMENDED OPERATING CONDITIONS**

TRMPWR Voltage . . . . . 2.7V to 5.25V

**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ , TRMPWR = 3.3V.  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>TRMPWR Supply Current Section</b>					
TRMPWR Supply Current	No Load			25	mA
	Disabled Terminator			400	$\mu\text{A}$
TRMPWR Voltage		2.7		5.25	V

**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ ,  
 TRMPWR = 3.3V.  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Regulator Section</b>					
1.25V Regulator	DIFSENS connected to DIFFB	1.15	1.25	1.35	V
1.25V Regulator Source Current	DIFSENS connected to DIFFB		-100	-80	mA
1.25V Regulator Sink Current	DIFSENS connected to DIFFB	80	100		mA
1.3V Regulator	DIFFB connected to GND	1.2	1.3	1.4	V
1.3V Regulator Source Current	DIFSENS to GND	-15		-5	mA
1.3V Sink Current	DIFSENS to 3.3V	50		200	$\mu\text{A}$
<b>Differential Termination Section</b>					
Differential Impedance	-2.5mA to 4.5mA	100	105	110	$\Omega$
Common Mode Impedance	L+ connected to L-	110	150	165	$\Omega$
Differential Bias Voltage	No load, L+ or L-	100		125	mV
Common Mode Bias		1.15	1.25	1.35	V
Output Leakage, Disconnect	DISCNCT, TRMPWR = 0 to 5.25V, $V_{\text{LINE}} = 0.2$ to 5.25V		10	400	nA
Output Capacitance	Single ended measurement to ground (Note 1)			3	pF
<b>Low Voltage Differential (LVD) Status Bit Section</b>					
ISOURCE	$V_{\text{LOAD}} = 2.4\text{V}$		-6	-4	mA
ISINK	$V_{\text{LOAD}} = 0.4\text{V}$	2	5		mA
<b>Disconnect &amp; Differential Sense Input Section</b>					
DISCNCT Threshold		0.8		2	V
Input Current	At 0V and 3.3V	-30	-10		$\mu\text{A}$
Differential Sense Signal Ended to LVD Threshold		0.5		0.7	V
Differential Sense LVD to HPD Threshold		1.9		2.4	V

Note 1: Guaranteed by design. Not 100% tested in production.

## PIN DESCRIPTION

**DIFFB:** Differential sense filter pin should be connected to a  $0.1\mu\text{F}$  capacitor and  $20\text{k}\Omega$  resistor to Diff Sense.

**DIFSENS:** The SCSI bus differential sense line to detect what type of devices are connected to the SCSI Bus.

**DISCNCT:** Disconnect pin shuts down the terminator when it is not at the end of the bus.

**GND:** Ground.

**Ln -:** Signal active line for single ended or negative line

in differential applications for the SCSI Bus.

**Ln +:** Ground line for single ended or positive line for differential applications for the SCSI Bus.

**LVD:** (28 pin package only) Indicates that the bus is in LVD mode.

**REG:** Regulator bypass; must be connected to a  $4.7\mu\text{F}$  capacitor to ground.

**TRMPWR:**  $V_{\text{IN}}$  2.7V to 5.25V supply.







**ABSOLUTE MAXIMUM RATINGS**

TRMPWR Voltage . . . . . +6V  
 Signal Line Voltage . . . . . 0V to TRMPWR  
 Package Dissipation . . . . . 1W  
 Storage Temperature . . . . . -65°C to +150°C  
 Junction Temperature . . . . . -55°C to +150°C  
 Lead Temperature (Soldering, 10 sec.) . . . . . +300°C

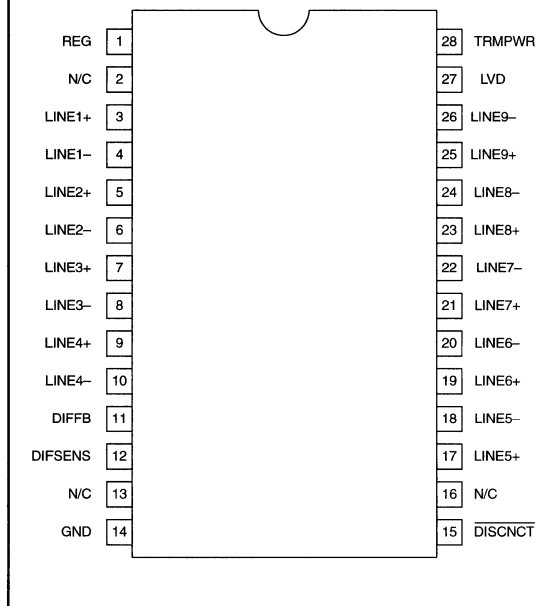
**RECOMMENDED OPERATING CONDITIONS**

TERMPWR Voltage . . . . . 2.7V to 5.25V

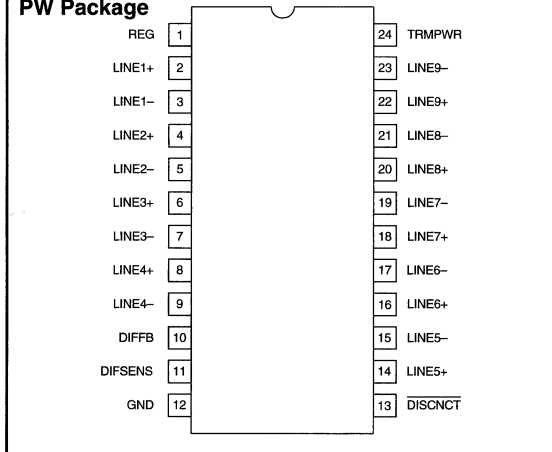
*Currents are positive into negative out of the specified terminal. consult Packaging Section of Databook for thermal limitations and considerations of package.*

**CONNECTION DIAGRAMS**

**TSSOP-28 (Top View)  
PW Package**



**TSSOP-24 (Top View)  
PW Package**



**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ , TRMPWR = 3.3V,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>TRMPWR Supply Current Section</b>					
TRMPWR Supply Current	No Load			25	mA
	Disabled Terminator			200	$\mu\text{A}$
TRMPWR Voltage		2.7		5.25	V
<b>Regulator Section</b>					
1.25V Regulator	DIFSENS connected to DIFFB	1.15	1.25	1.35	V
1.25V Regulator Source Current	DIFSENS connected to DIFFB	-80	-100		mA
1.25V Regulator Sink Current	DIFSENS connected to DIFFB	80	100		mA
1.25V Current Limit	DIFSENS connected to DIFFB	300			mA
1.3V Regulator	DIFFB connected to GND	1.2	1.3	1.4	V
1.3V Regulator Source Current	DIFFB to GND	-5		-15	mA
1.3V Sink Current	DIFFB to GND	50		200	$\mu\text{A}$

**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ ,  $\text{TRMPWR} = 3.3\text{V}$ .  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Differential Termination Section</b>					
Differential Impedance	-2.5mA to 4.5mA	100	105	110	$\Omega$
Common Mode Impedance	LINE+ connected to LINE-	110	150	165	$\Omega$
Differential Bias Voltage	Drivers Tristated	100		125	mV
Common Mode Bias			1.25		V
Output Leakage, Disconnect	DISCNECT, $\text{TRMPWR} = 0$ to $5.25\text{V}$ , $V_{\text{LINE}} = 0.2$ to $2.5\text{V}$		10	400	nA
Output Capacitance	Single ended measurement to ground (Note 1)			3	pF
<b>Disconnect &amp; Differential Sense Input Section</b>					
DISCNECT Threshold		0.8		2	V
Input Current	At 0V and 3.3V		10	30	$\mu\text{A}$
Differential Sense Signal Ended Threshold		0.6		0.7	V
Differential Sense LVD Threshold		1.9		2.2	V
Differential HP Differential Threshold		2.2			V

Note 1: Guaranteed by design. Not 100% tested in production.

**TRMPWR:**  $V_{\text{IN}}$  2.7 to 5.25 Volts supply.

**DIFSENS:** The SCSI bus diff sense line to detect what type of devices are connected to the SCSI bus.

**DISCNECT:** Disconnect pin shuts down the terminator when it is not at the end of the bus.

**DIFFB:** Diff Sense filter pin should be connected to a  $0.1\mu\text{F}$  Capacitor.

**REG:** Regulator bypass pin, must be connected to a

$4.7\mu\text{F}$  Capacitor.

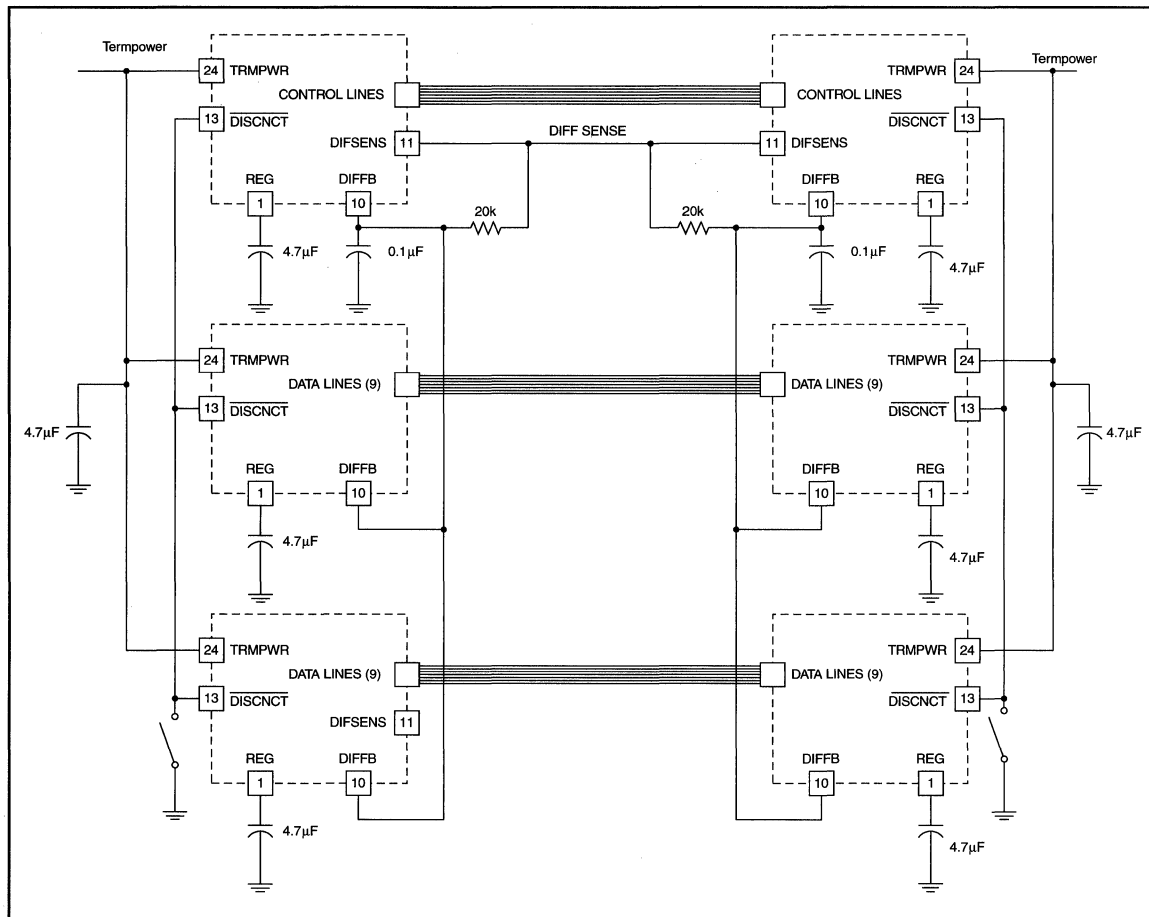
**LINE-:** Signal line Active line for single ended or negative line in differential applications for the SCSI Bus.

**LINE+:** Ground line for single ended or positive line for differential applications for the SCSI Bus.

**LVD:** Indicates that the bus is in LVD mode regardless of the terminator's connection mode.

**APPLICATION INFORMATION**

Diff Sense is driven by only one terminator at each end of the bus. All other terminators receive the mode signal by connecting the DIFFB pins together.



**Figure 1. Application Diagram**

UDG-97181



# 27 Line LVD SCSI Terminator

**ADVANCE INFORMATION**

**FEATURES**

- SCSI SPI-2, SPI-3, 160m Compliance
- Smallest Footprint
- Lowest Channel Capacitance, 2pF
- Less than 0.5pF Capacitance Differential Between Pairs
- 2.7V to 5.25V Operation
- Differential Failsafe Bias
- 64 Pin LQFP

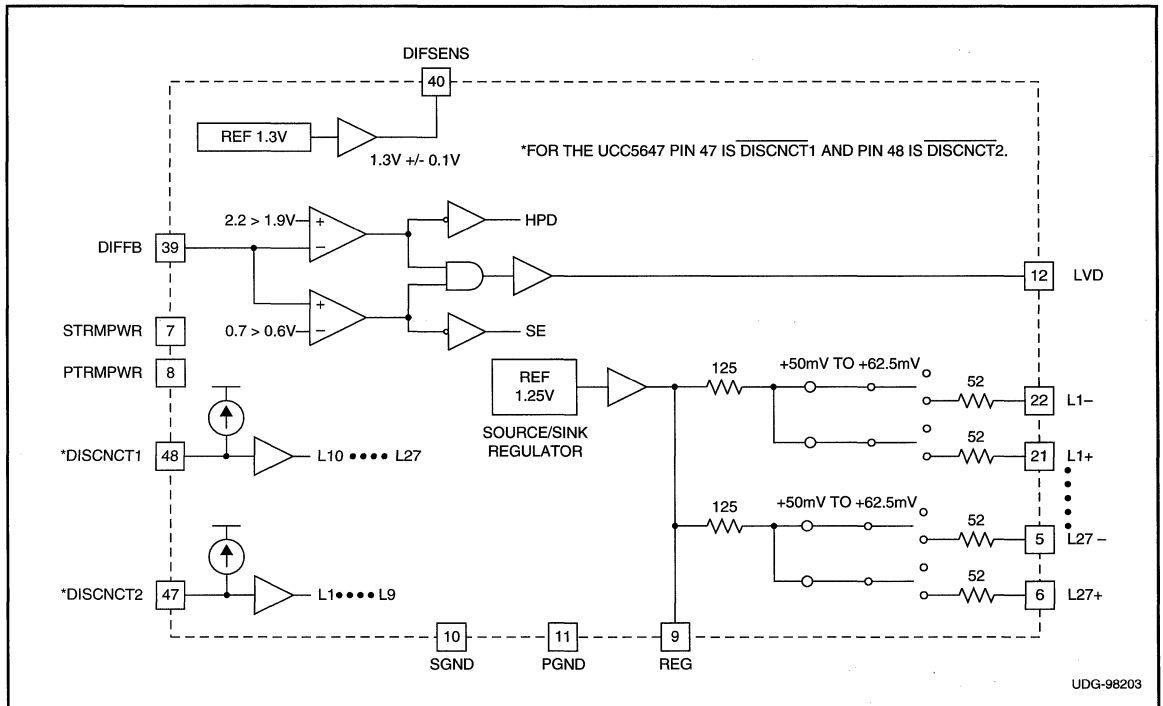
**DESCRIPTION**

The UCC5646 is a twenty-seven line active terminator for Low Voltage Differential (LVD) SCSI networks. This LVD SCSI only design allows the user to reach peak bus performance, while reducing system cost. The device is designed as an active Y-terminator to improve the frequency response of the LVD SCSI Bus. Designed with a 2pF typical channel capacitance, the UCC5646 allows for minimal bus loading for a maximum number of peripherals. With the UCC5646, the designer will be able to comply with the Ultra2 and Ultra3, 160m specifications. The UCC5646 also provides a much-needed system migration path for the ever improving SCSI system standards.

This device is available in the 64 pin LQF package for ease of layout use.

The UCC5646 is not designed for single ended or high volume differential systems.

**BLOCK DIAGRAM**





**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated these specifications are for TRMPWR = 2.7V to 5.25V, T<sub>A</sub> = 0°C to +70°C, DISCNCT1 = DISCNCT2 = 0V for UCC5646 DISCNCT1 = DISCNCT2 = open for UCC5647, T<sub>A</sub> = T<sub>J</sub>.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Differential Termination Section (Applies to each line pair 1-27)</b>					
Differential Bias Voltage		100		125	V
I <sub>DIFFB(max)</sub>	V <sub>DIFFB</sub> = +1V; T <sub>A</sub> = 25°C (Note1)	7.955		9	mA
I <sub>DIFFB(min)</sub>	V <sub>DIFFB</sub> = -1V; T <sub>A</sub> = 25°C (Note1)	-10		-11.25	mA
Differential Impedance	$Z_{DIFF} = \left( \frac{V_{DIFF1} - V_{DIFF2}}{7mA} \right)$	100	105	110	Ω
Common Mode Bias Voltage	L+ and L- shorted together	1.15	1.25	1.35	V
ICM(max)	VCM = 2V (Note 3)	2.083		8.75	mA
ICM(min)	VCM = 0.5V (Note 3)	-2.083		-8.75	mA
Common Mode Impedance	$ICM = \frac{1.5V}{(ICM(max) - ICM(min))}$	110	140	165	Ω
Output Leakage in Disconnect	TRMPWR = 0V to 5.25V, V <sub>LINE</sub> = 0.2V to 2.5V		10	400	nA
Output Capacitance	Single Ended measurement to GND (Note 1)			3	pF
Single Ended GND SE Impedance	I = 10mA		20	60	Ω
<b>Disconnect Control (DISCNCT1) or (DISCNT2) Section</b>					
DISCNCT Threshold		0.8	1.5	2.0	V
DISCNCT Input Current		-10		-30	μA
<b>DIFFB Input Section</b>					
DIFFB SE to LVD Threshold		0.5	0.6	0.7	V
DIFFB LVD Range		0.7		1.9	V
DIFFB LVD to HPD Threshold		1.9	2.05	2.2	V
DIFFB Input Current		-10		10	μA

Note 1: I<sub>DIFF</sub> = Current into L-, with V<sub>DIFF</sub> applied to L-with respect to L+.

Note 2: V<sub>DIFF1</sub> = (VL-) - (VL+) with 2.5mA current sourced applied across L- and L+ (current into L-.)

V<sub>DIFF2</sub> = (VL-) - (VL+) with 4.5mA current sourced applied across L+ and L- (current into L+.)

Note 3: ICM = Sum of currents into L+ and L-, with VCM applied to both terminals with respect to ground.

Note 4: Guaranteed by design. Not 100% tested in production.

## PIN DESCRIPTIONS

**STRMPWR:** 2.7 to 5.25 Volts power supply for all circuitry except the 1.25V regulator.

**SGND:** Ground reference for all circuitry except the 1.25V regulator.

**PTRMPWR:** 2.7 to 5.25 Volts power supply for the 1.25V regulator.

**PGND:** Ground reference for the 1.25V regulator.

**REG:** Output of the internal 1.25V regulator; must be connected to a 4.7μF bypass capacitor.

**DIFSENS:** Drives the SCSI bus DIFF SENSE line to 1.3V to detect what types of devices are tied to the bus.

**DIFFB:** DIFF SENSE filter pin. Should be connected to a 0.1μF capacitor to GND and to a 20k resistor to the SCSI bus DIFF SENSE line.

**DISCNCT1:** Disconnect one controls termination lines 10-27 (control and low byte.)

**DISCNCT2:** Disconnect two controls termination lines 1-9 (high byte.)

**LVD:** TTL compatible status bit indicating when Low Voltage Differential voltage is present on DIFFB.

**L1- thru L27-:** Negative lines for the SCSI bus.

**L1+ thru L27+:** Positive lines for the SCSI bus.



APPLICATION INFORMATION

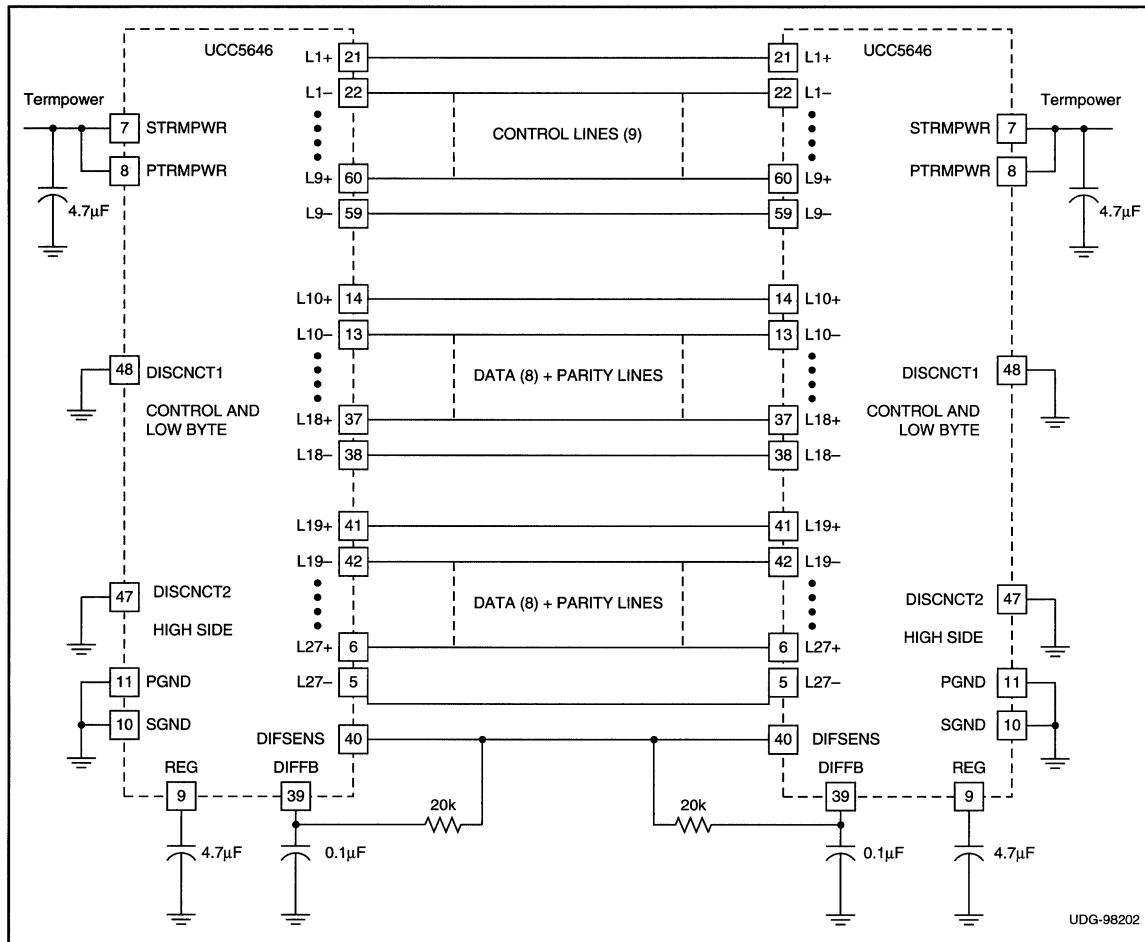


Figure 1. Application drawing.

# Ethernet Coaxial Impedance Monitor

## FEATURES

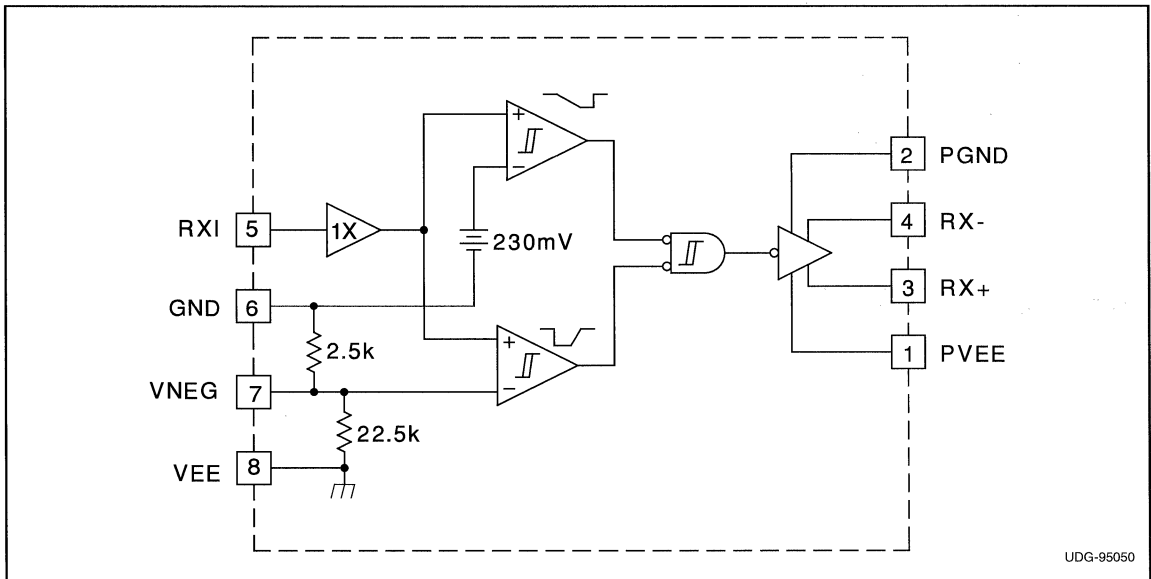
- Compatible with IEEE 802.3 10Base5, 10Base2, and 10BaseT
- Preset and Adjustable Data Thresholds
- Protects DTE from Spurious Data
- Prevents Erroneous Transmission Through Repeaters
- Detects Cable Termination Errors
- Detects Cable Impedance Errors

## DESCRIPTION

The UC5661 is a monolithic integrated circuit which functions as an Ethernet Coaxial Impedance Monitor (CIM). This IC is intended to augment the receive (RX) function of IEEE 802.3 Coaxial Transceiver Interface (CTI) circuits. The UC5661 implements a hardware algorithm to detect reflections on the Ethernet coaxial cable or twisted pair which are caused by improper network termination or physical medium damage. If a physical problem is detected, the UC5661, whose receiver outputs operate in parallel with the CTI, immediately squelches the receive data, preventing the propagation of invalid network packets. During ordinary operation, the CIM RX outputs enable at the beginning of the data packet preamble, making it transparent to normal CTI functions. The valid data threshold, although preset for thick and thin-wire Ethernets, may be adjusted with the addition of one or two external resistors to meet 10BaseT requirements.

A secondary system design feature is provided by the UC5661. At the completion of a normal data transmission, the CIM Squelch activates much faster than typical transceiver ICs. The receiver outputs of the UC5661 have been designed to properly terminate the data packet, even with RX data transformers as small as 16 $\mu$ H, possibly allowing for smaller and less expensive system implementations. In these cases, end-of-packet squelch overshoot will be held to less than 100mV.

## BLOCK DIAGRAM

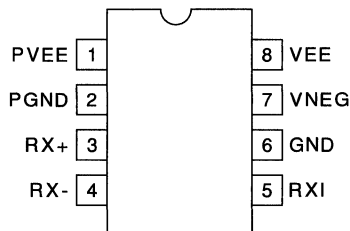


**ABSOLUTE MAXIMUM RATINGS**

Supply Voltage (PVEE, VEE)	-15V
Input Voltage (RXI)	+2V to -10V
Operating Temperature Range	0°C to +70°C
Junction Temperature (Note 1)	+125°C
Storage Temperature Range	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.)	+300°C

All currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages.

Note 1: The devices are guaranteed by design to be functional up to the absolute maximum junction temperature.

**CONNECTION DIAGRAMS****DIL-8, (Top View)  
J or N, Package**

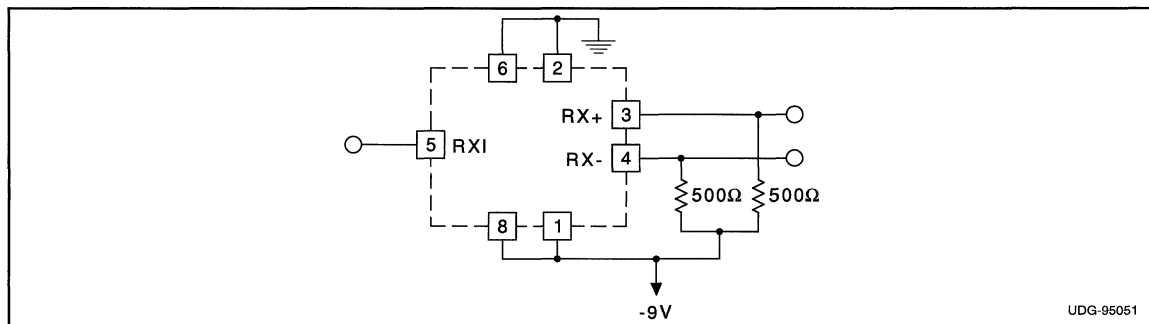
**DC ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ ,  $V_{EE} = PVEE = -9.0\text{V}$ , and  $R_L = 500\text{ ohms}$ ,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Supply Current	Outputs Locked or Unlocked, Unloaded		10	20	mA
Input Bias Current	$RXI = 0\text{V}$		2	5	$\mu\text{A}$
Input Shunt Resistance	$RXI = -2\text{V}$ to $0\text{V}$	0.200	45		$\text{M}\Omega$
Input Shunt Capacitance	(Note 1)		3	4	pF
VNEG (Valid Data Reference)	VNEG = open	-980	-900	-830	mV
RX Output Voltage High (Squelch)		-1.2	-0.9	0	V
RX Output Voltage Low (Enable)		-6	-3.7	-3.2	V
Output Short Circuit	$RX+ = RX- = 9\text{V}$	-150			mA
Valid Data Threshold		-980	-900	-830	mV
Data Reflection Threshold		200	230	300	mV

Note 1: Guaranteed by design. Not 100% tested in production.

**AC ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ ,  $V_{EE} = PVEE = -9.0\text{V}$ , and  $R_L = 500\text{ ohms}$ ,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
$T_{EN}$ RX Enable Delay	See Figures 1, 2		100	400	ns
$T_{DIS}$ RX Disable Delay	See Figures 1, 2	250	340	475	ns
$T_{FS}$ RX+ to RX- Falling Edge Skew	See Figures 1, 2		5	20	ns
$T_{FR}$ RX+ to RX- Rising Edge Skew	See Figures 1, 2		5	20	ns
$T_{SQL}$ RX Squelch Delay	See Figures 1, 3		230	2000	ns
$T_{REL}$ RX Release Delay	See Figures 1, 3	500	1150	1500	ns

**Figure 1. Switching Test Circuit**

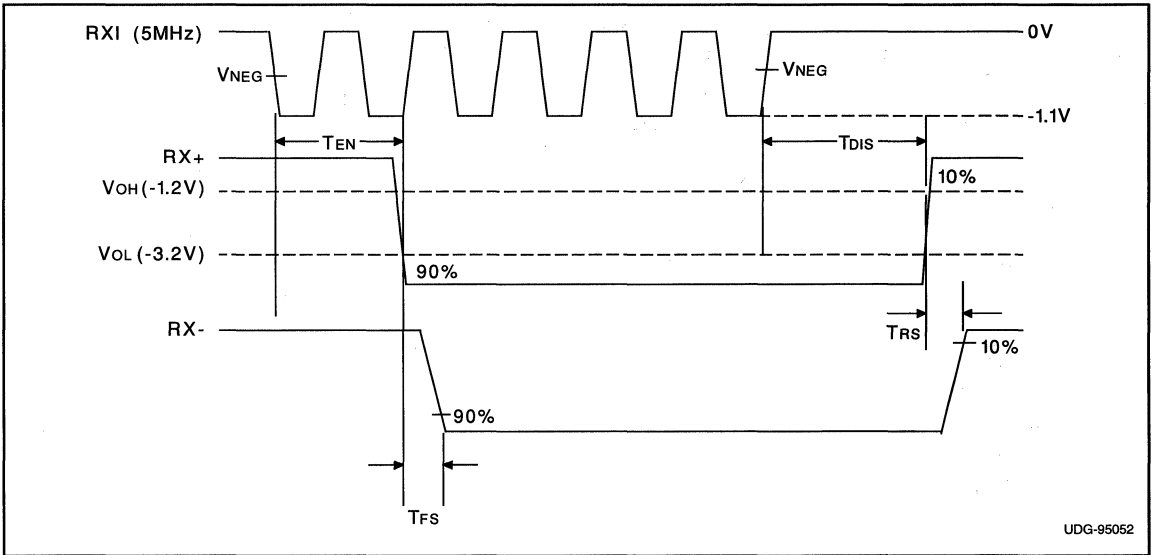


Figure 2. Input/Output Timing Diagram

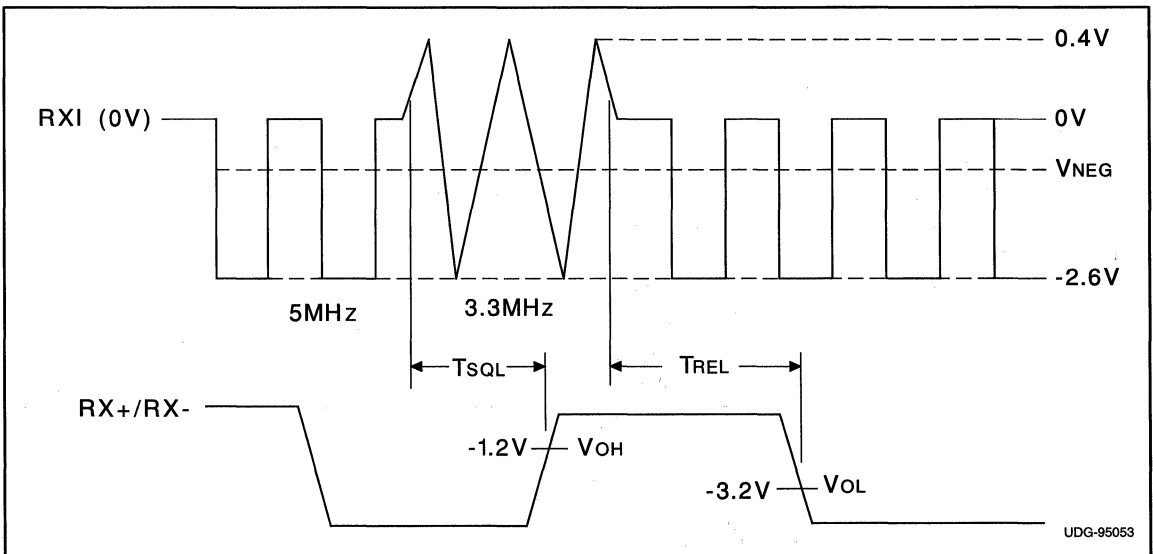
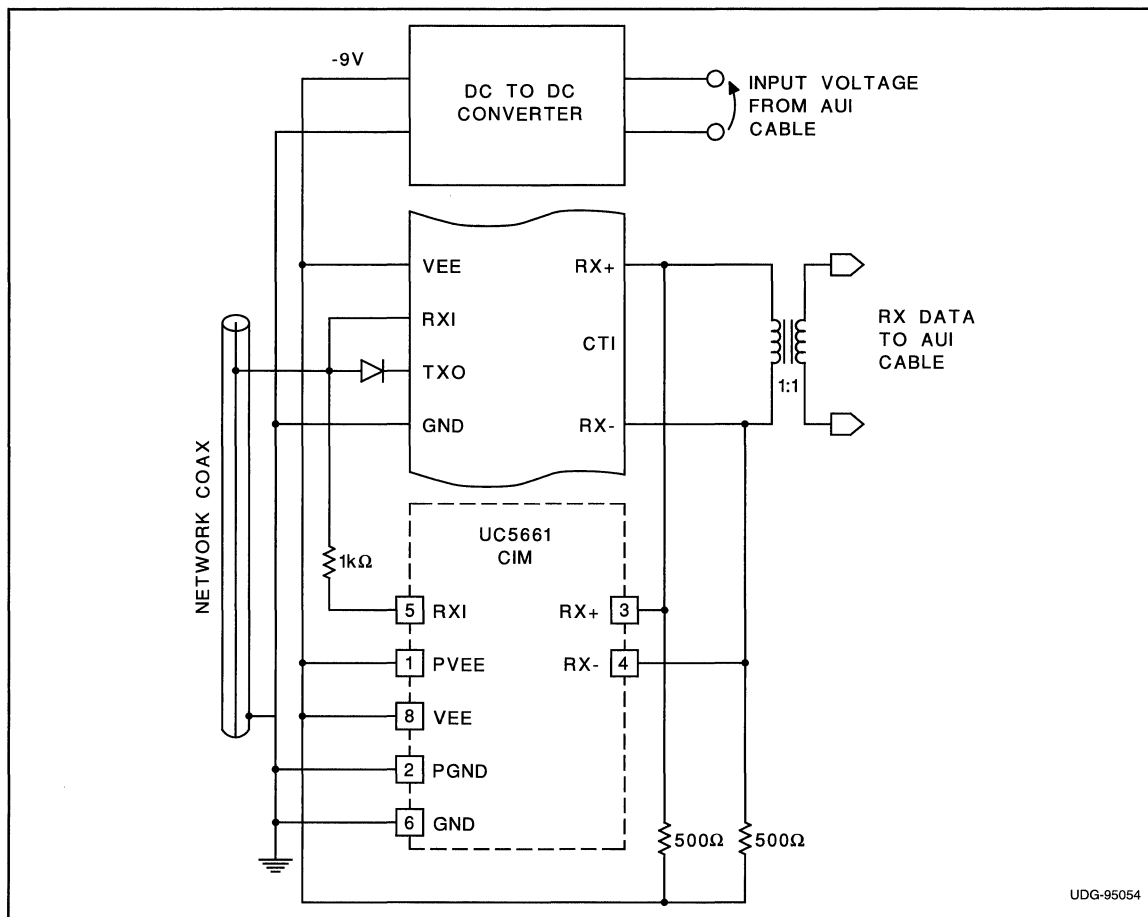


Figure 3. Short Detect Timing Diagram



**Figure 4. Typical Application**

Figure 4 shows the UC5661 (SDI) being used with a Coaxial Transceiver Interface (CTI) device. The primary function of the SDI is to detect LAN cable shorts (or other impedance matching problems) and appropriately squelch the RX outputs of the CTI device to prevent the transmission of corrupted network data. The secondary function of the SDI is to provide improved RX squelching at the completion of a normal data transmission.

To perform the two functions, SDI uses two threshold voltages, Data Reflection Threshold (DRT), and the Valid

Data Threshold (VDT). During transmission SDI looks for signal activity above ground and below ground. In the event that the magnitude of the input voltage exceeds DRT the outputs will be locked within  $2\mu\text{s}$  and will remain locked for 0.5 to  $1.5\mu\text{s}$  after the last edge below DRT (see Figure 3). During signal activity below ground when the signal goes below VDT the outputs will unlock within 400ns. While unlocked, if the input exceeds VDT the outputs will lock within 250 to 475ns relative to the last positive going edge (Figure 2).

# Multimode (LVD/SE) SCSI 9 Line Terminator

## FEATURES

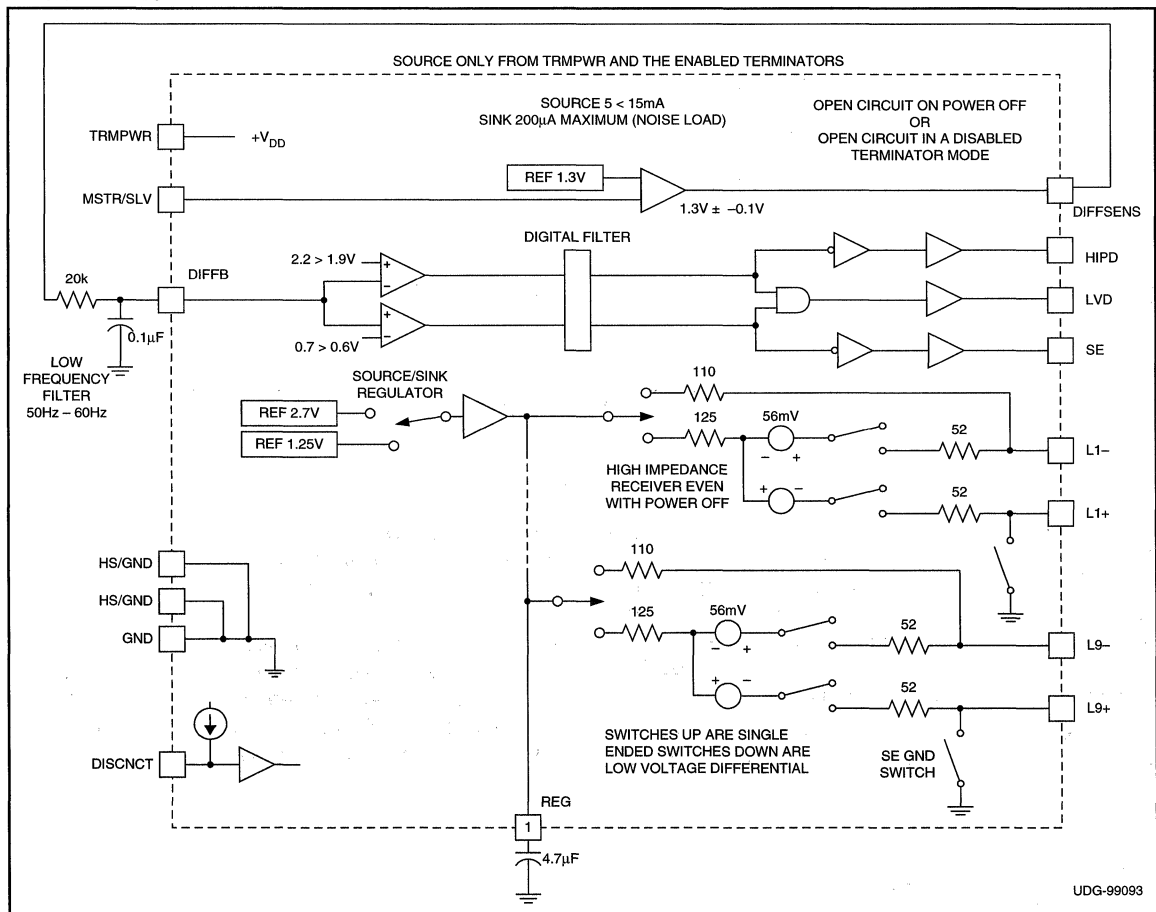
- Auto Selection Multi-Mode Single Ended or Low Voltage Differential Termination
- 2.7V to 5.25V Operation
- Differential Failsafe Bias
- Built-in SPI-3 Mode Change Filter Delay
- Master/Slave Inputs
- Supports Active Negation
- Standby (Disable Mode) 5 $\mu$ A
- 3pF Channel Capacitance

## DESCRIPTION

The UCC5672 Multi-Mode Low Voltage Differential and Single Ended Terminator is both a single ended terminator and a low voltage differential terminator for the transition to the next generation SCSI Parallel Interface (SPI-3). The low voltage differential is a requirement for the higher speeds at a reasonable cost and is the only way to have adequate skew budgets.

The UCC5672 is SPI-3, SPI-2, SPI and Fast-20 compliant. This device comes in a TSSOP package to minimize the footprint.

## BLOCK DIAGRAM



# Low Voltage Differential (LVD) SCSI 9 Line Terminator

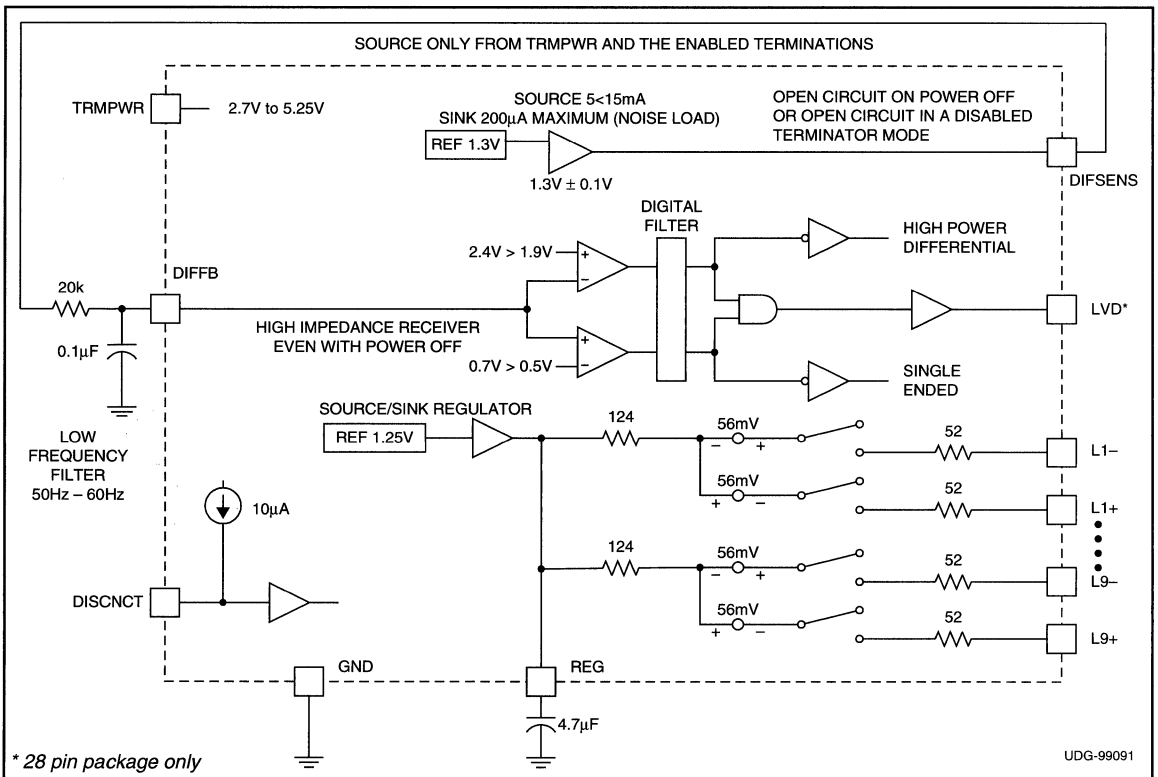
**FEATURES**

- Low Voltage Differential Termination
- 2.7V to 5.25V Operation
- Differential Failsafe Bias
- Built-in SPI-3 Mode Change Filter Delay
- Supports Active Negation
- Standby (Disable Mode) 5 $\mu$ A
- 3pF Channel Capacitance

**DESCRIPTION**

The UCC5680 Low Voltage Differential Terminator is a low voltage differential terminator for the next generation SCSI Parallel Interface (SPI-3). The low voltage differential is a requirement for the higher speeds at a reasonable cost and is the only way to have adequate skew budgets. The UCC5680 is backwards compliant with SPI-2 (Ultra2) and compliant with SPI-3 (Ultra3), (Ultra160/m).

This device comes in a TSSOP package to minimize the footprint and with a unique pin out that eliminate feed through requirements.

**BLOCK DIAGRAM**


**Design Note**
**UCC5630 SCSI Multimode (LVD/SE) Evaluation Board and List of Materials**

By Paul Aloisi

The UCC5630 is a high performance 9 line Multimode terminator designed to provide the lowest capacitance and the lowest possible temperature drift. It is designed for 3.3V or 5V systems and will operate over the range of 2.7V to 5.25V.

The demo board should be used at the end of the bus, between the last device and the cable or as a plug terminator at the end of the cable. Active terminators should be used at both ends of the cable. Generally, they will be used between the controller and the cable and the last device and the cable. If they are used as a plug terminator, the second connector becomes a stub effecting the capacitance load on the bus. The termination can be disabled on the demo card allowing the demo board to be part of the bus path.

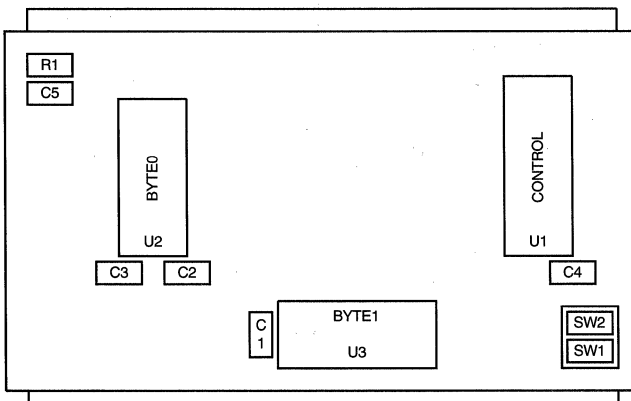
The demo board can be used to test the Unitrode terminator versus drive or controller termination. The demo board demonstrates how Unitrode termination can clean up problems on the bus.

The demo board layout below shows the UCC5630 9 line multimode SCSI termination with a separate disconnect for the high byte (Switch 2) and the control lines and the low byte (Switch 1). Termination should be disabled on all devices but the device at the ends of the cable.

The multimode terminators automatically detect the bus mode by placing 1.3V on the diff sense line, then monitoring the diff sense line through an R-C filter, (R1) 20k and (C5) 0.1 $\mu$ F, to filter out noise down to 50Hz on the bus. If the diff sense line is below 0.5V, the terminators are in single ended mode (SE). If the diff sense line is between 0.7V and 1.9V, the terminators are in Low voltage differential (LVD) mode. If the diff sense line is above 2.1V, the terminator is in high impedance mode. The demo board can not be used on a high voltage differential (HVD) system. The terminator mode can be monitored on pin 33 for single ended mode, pin 34 for low voltage differential mode, and pin 35 for when high impedance high voltage differential devices are detected. The outputs are not valid when the terminators are in disconnect mode.

The connector pinning is defined in **SCSI-3 SPI-2 P** cable LVD.

The layout of the demo board is an attempt to match the length and loading of the lines. Every line has a feedthrough connection to the terminator, but the surface mount connector requires a feedthrough on one side of every line. This is not as critical on this 2 sided board since there is no inner layer capacitance on the feedthroughs. On a



SWITCH 2	SWITCH 1
HIGH BYTE AND PARITY	LOW BYTE AND CONTROL
OFF DISCONNECT	OFF DISCONNECT
TERMINATION ENABLED	TERMINATION ENABLED

**Figure 1. Demonstration board layout**



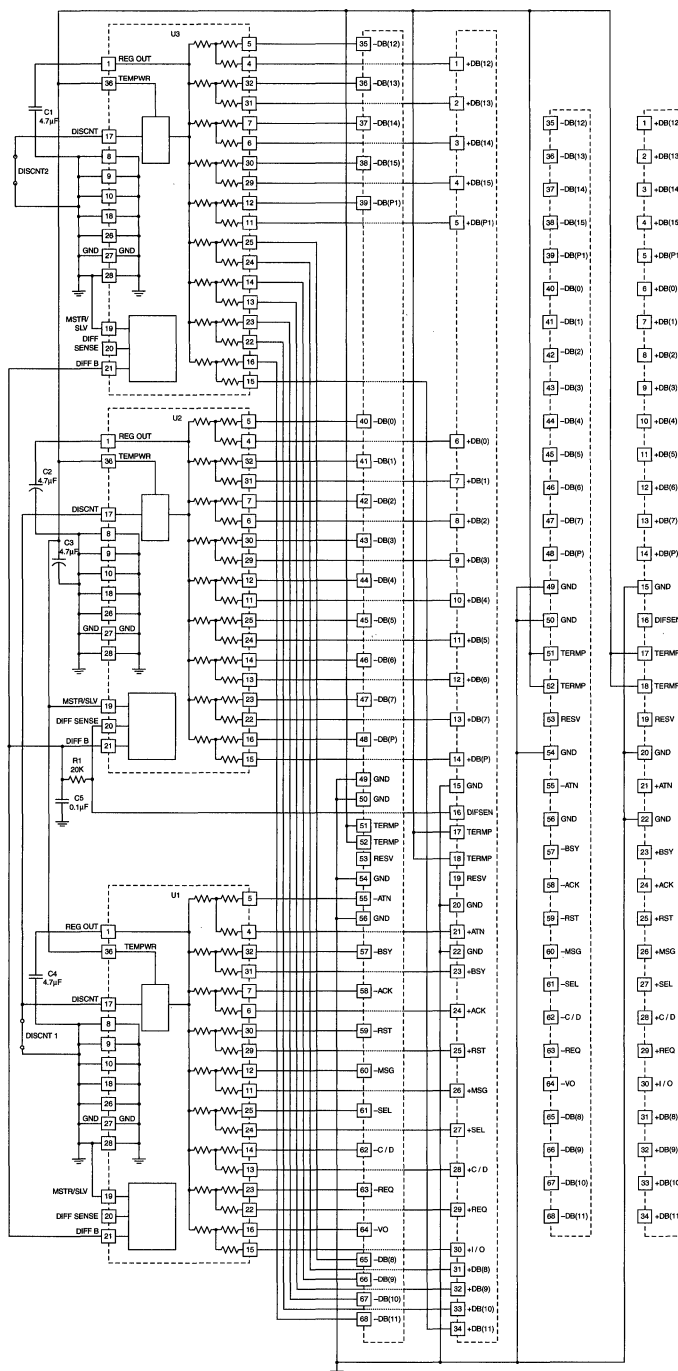


Figure 1. UCC5630 Evaluation Board Schematic

multilayer board, one extra feedthrough is more capacitance imbalance than allowed unless the clearance holes on the inner layers are enlarged. Note the heat sink area for the UCC5630 terminators to dissipate heat. If a multilayer layout is used, one feedthrough from each heat sink pin should be connected to the ground plane instead of the heat sink area on the outside layer.

The key indicators of signal integrity are the rising and falling edges of the signals. The REQ and ACK signals are the highest speed signals until Fast-80DT. Reflections on lower speed signals up to Fast-40 normally occur within the bit time. LVD Fast-40 and beyond reflections can be 4 or more bit times from the switch point.

For single ended signals, the rising edge should be over 2.0V on the first step to guarantee data integrity and high speed operation or the bus should be shortened to allow the reflected wave within the set up time. If the falling edge of a signal overshoots and returns to a higher level this is normally a sign that the frequency response of the terminator is not fast enough. This is typical of a problem seen on current mode terminators or terminators with the

disconnect switch in the wrong position. Some terminators look good when the signal is observed at the end of the cable, but in the center of the bus the signals can have serious problems.

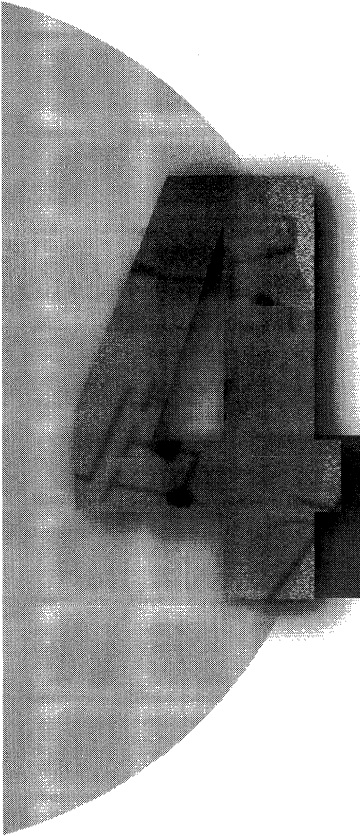
LVD signals must transition at least 60mV beyond the zero crossing, some receivers will require at least ¼ the signal in the opposite polarity to switch at high speeds. If the signals do not reach the correct amplitude check the system impedance, it should be above 85Ω differential when all the devices are installed on the bus.

Reflections can be isolated by the reflection time. Signal round trip time is normally 10 nanoseconds per meter on cables with standard PVC insulation. Reflections from older devices or bad cables can cause major problems, older designs paid little attention to capacitance and balancing stub lengths. The long stubs and high capacitance will cause reflection problems.

*For more information refer to the Unitrode LVD Design Guide or the Single Ended Active Termination Design Guide. Additional support help is available from Unitrode local applications or 408-246-3100 extension 41 or 603-429-8687.*

**Table 1. UCC5630 Evaluation Board List of Materials**

Reference Designator	Description	Manufacturer	Part Number
C1, C2, C3, C4	Tantalum Capacitor 4.7μF	Panasonic	ECS-TICY4755
C5	Ceramic Capacitor 0.1μF	Panasonic	ECJ-3YFIA106Z
R1	20.0K small Resistor	Panasonic	ERJ-8ENF2002
SW1	2 position dip switch	C+K Comp.	SD02HOSK
U1, U2, U3	IC	Unitrode	UCC5630MWP



# Bus Bias Generators





## Bus Bias Generators

Special Functions	UNITRODE PART NUMBER				
	UC382	UC385	UC560	UCC561+	UC563+
<b>Bus Standard</b>	GTL / BTL	GTL / BTL	SCSI-1,2,3	SPI-2,3	VME / VME64
<b>Sink / Source Current</b>	Pgm / 3A	Pgm / 5A	300mA / -750mA	200mA / -200mA	475mA / -575mA
<b>Page Number</b>	PS/5-5	PS/5-35	IF/4-3	IF/4-7	IF/4-10

+ *New Product*





## 27-Line SCSI Source/Sink Regulator

### FEATURES

- Complies with SCSI, SCSI-2, SCSI-3 SPI and Ultra SCSI (Fast-20)
- 2.85V Regulated Output Voltage With 1.4% Tolerance
- Provides Current for up to 27 Lines of Active Termination for SCSI Buses
- -750mA Sourcing Current for Termination
- +300mA Sinking Current for Active Negation Drivers
- 0.9V Dropout Voltage Regulator at 750mA and 2.75V Output
- 100 $\mu$ A Supply Current in Disconnect Mode
- Current Limit and Thermal Shutdown Protection
- Low Thermal Resistance Surface Mount Packages

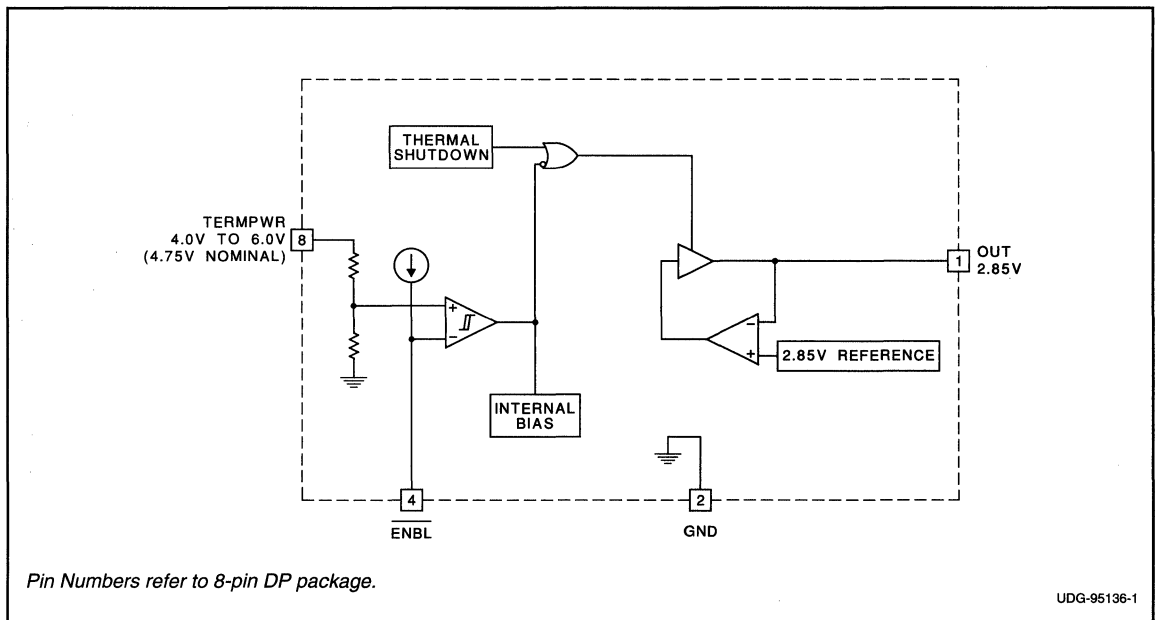
### DESCRIPTION

The UC560 provides current for up to 27 lines of active termination for a SCSI (Small Computers Systems Interface) parallel bus. The SCSI standard requires active termination at both ends of the cable. The UC560 is based on the UC5603 and UC5613 SCSI Active Terminators. It uses the voltage regulator and internal logic circuits of those parts, but has no termination circuits. The UC560 provides greater source current drive capability compared to the UC5603 and UC5613.

The UC560 sink current maintains regulation with all active-negation drivers negated. It provides a disconnect feature which disables the regulator to greatly reduce standby power. Internal circuit trimming is utilized for a 1.4% tolerance output voltage. Other features include thermal shutdown and current limit for short circuit conditions.

The UC560 is available in low thermal resistance versions of the industry standard 8-pin power SOIC, 5-pin TO-220 and 5-pin TO-263.

### BLOCK DIAGRAM



UDG-95136-1

**ABSOLUTE MAXIMUM RATINGS**

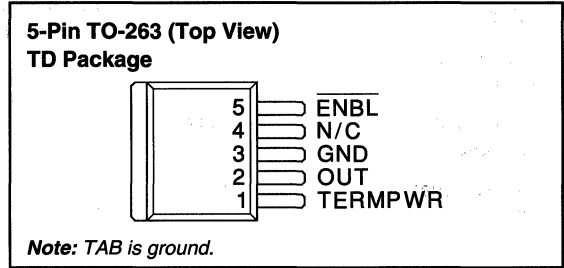
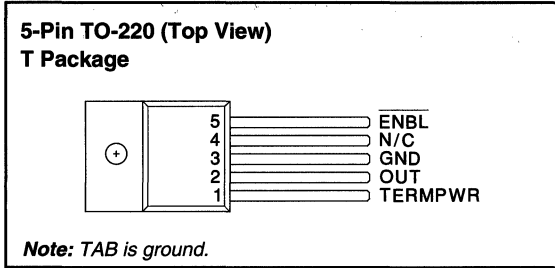
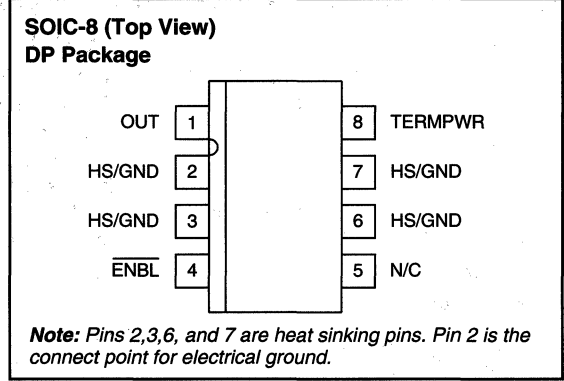
TERMPWR Voltage	7V
ENBL Voltage	-0.3V to TERMPWR + 0.3V
Regulator Output Current	1.4A
Power Dissipation	2.5W
Storage Temperature	-65°C to +150°C
Junction Temperature	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.)	+300°C

Currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages.

**RECOMMENDED OPERATING CONDITIONS**

TERMPWR Voltage	4.0V to 6.0V
ENBL Voltage	0V to TERMPWR

**CONNECTION DIAGRAMS**



**ELECTRICAL CHARACTERISTICS** Unless otherwise specified,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ ,  $\overline{\text{ENBL}} = 0\text{V}$ ,  $C_{\text{OUT}} = 4.7\mu\text{F}$ ,  $C_{\text{TERMPWR}} = 4.7\mu\text{F}$ ,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Supply Current Section</b>					
TERMPWR Supply Current	No Load		16	22	mA
	$I_{\text{OUT}} = -700\text{mA}$		710	750	mA
Power Down Mode	$\overline{\text{ENBL}} = 2.0\text{V}$		100	140	$\mu\text{A}$
<b>Regulator Section</b>					
Regulator Output Voltage	$25^\circ\text{C}$ , No Load	2.81	2.85	2.89	V
Load Regulation	$I_{\text{OUT}} = 300\text{mA}$ to $-750\text{mA}$ (Note 2)		25	30	mV
Line Regulation	$\text{TERMPWR} = 4.0\text{V}$ to $6.0\text{V}$ , No Load (Note 2)		10	20	mV
Dropout Voltage	$I_{\text{OUT}} = -750\text{mA}$ , $V_{\text{OUT}} = 2.75\text{V}$		0.9	1.2	V
Short Circuit Current	$V_{\text{OUT}} = 0.0\text{V}$	-0.85	-1.3		A
Sinking Current	$V_{\text{OUT}} = 3.5\text{V}$		500	600	mA
	$\overline{\text{ENBL}} = 2.0\text{V}$ , $V_{\text{OUT}} = 3.0\text{V}$		1	2	mA
Thermal Shutdown	(Note 1)		170		$^\circ\text{C}$
Thermal Shutdown Hysteresis	(Note 1)		10		$^\circ\text{C}$
<b>Shutdown Section</b>					
ENBL Threshold		1.1	1.4	1.7	V
Threshold Hysteresis			100		mV
ENBL Output Current			-10	-15	$\mu\text{A}$

Note 1: Guaranteed by design. Not 100% tested in production.  
 Note 2: Tested at a constant junction temperature by low duty cycle pulse testing.



**PIN DESCRIPTIONS**

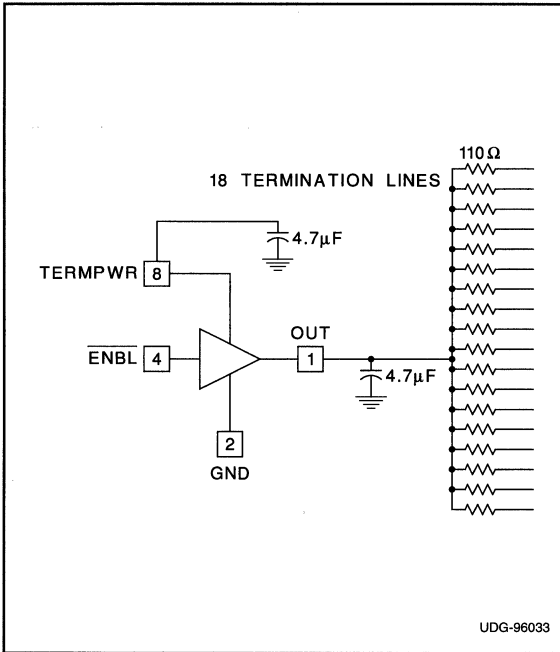
**ENBL:** Enable Bar pin. The  $\overline{\text{ENBL}}$  function is active low, and the pin will source  $10\mu\text{A}$  typically when at ground and  $\text{TERMPWR}$  is between 4V and 6V. The part will go into disable mode if  $\overline{\text{ENBL}}$  is above 1.4V typical, and will turn back on when  $\overline{\text{ENBL}}$  drops below 1.3V typical. The part also greatly reduces  $\text{TERMPWR}$  current when disabled ( $100\mu\text{A}$  typical).

**GND:** Ground pin.

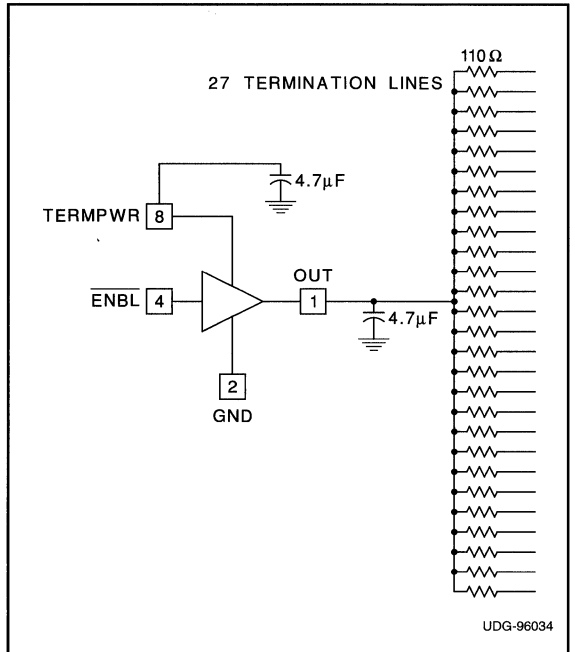
**OUT:** 2.85V regulated output voltage pin. The part is internally current limited for both sinking and sourcing current to prevent damage. When the part is in disabled mode ( $\overline{\text{ENBL}} \geq 1.4\text{V}$  typical), the output goes to 0V with no external supply source on OUT. The part will sink current, though, if there is an external supply voltage applied to OUT when in disabled mode. For best performance, a  $4.7\mu\text{F}$  low ESR capacitor is recommended.

**TERMPWR:** Supply voltage pin. The pin should be decoupled with at least a  $2.2\mu\text{F}$  low ESR output capacitor. For best performance, a  $4.7\mu\text{F}$  low ESR capacitor is recommended. Lead lengths should be kept at a minimum.

**APPLICATIONS INFORMATION**



**Figure 1. Typical SCSI Bus Configuration Utilizing UC560 Device**



**Figure 2. Typical Wide SCSI Bus Configuration Utilizing UC560 Device**

TYPICAL CHARACTERISTICS

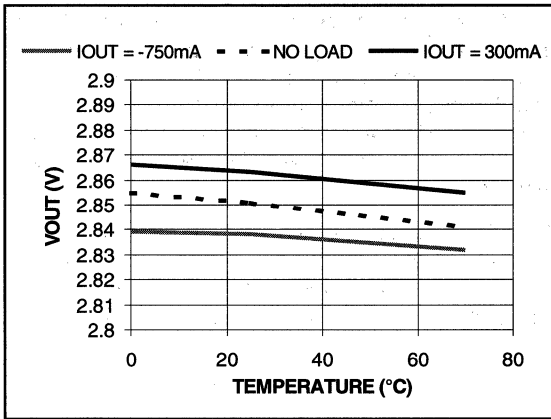


Figure 3. V<sub>OUT</sub> vs Temperature

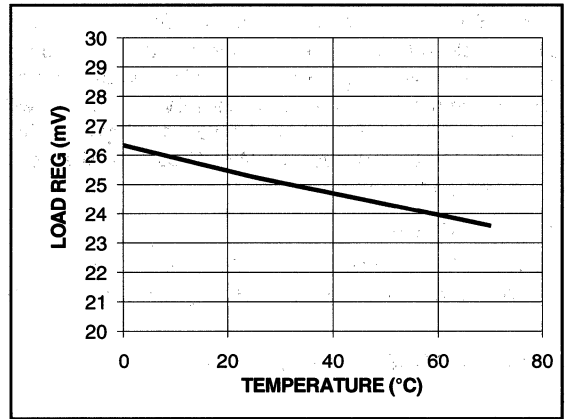


Figure 5. Load Regulation vs. Temperature  
(I<sub>OUT</sub> = 300mA to -750mA)

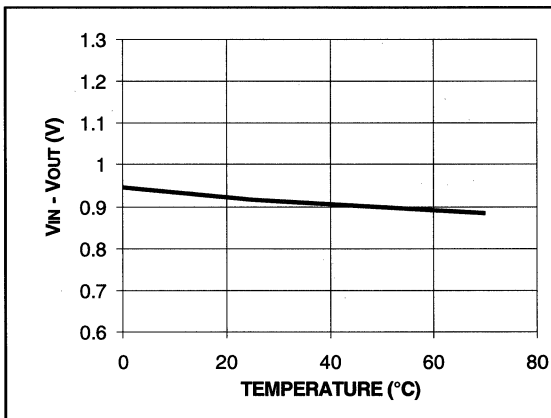


Figure 4. Dropout Voltage vs. Temperature  
(I<sub>OUT</sub> = -750mA, V<sub>OUT</sub> = 2.75V)

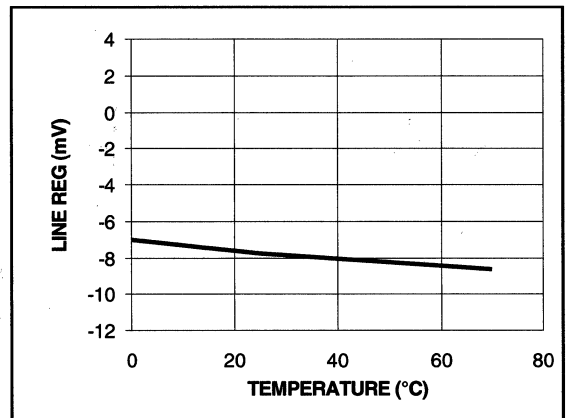


Figure 6. Line Regulation vs Temperature  
(TEMPWR = 4.0V to 6.0V)

# Low Voltage Differential SCSI (LVD) 27 Line Regulator Set

## FEATURES

- SCSI SPI-2 LVD SCSI 27 Line Low Voltage Differential Regulator
- 2.7V to 5.25V Operation
- Integrated Regulator Set for LVD SCSI
- Differential Failsafe Bias

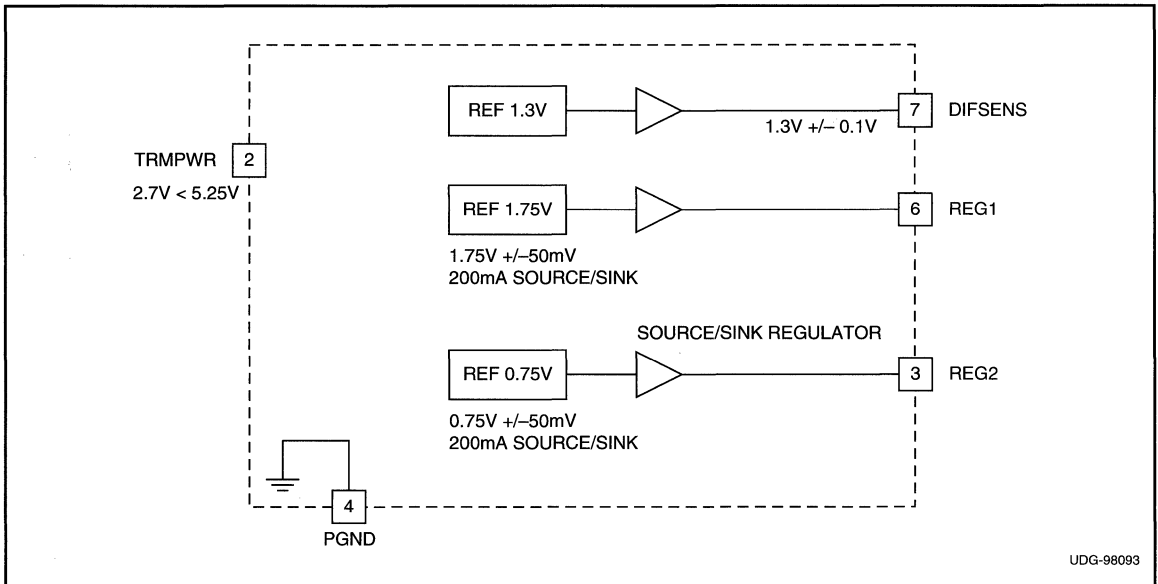
## DESCRIPTION

The UCC561 LVD Regulator set is designed to provide the correct references voltages and bias currents for LVD termination resistor networks (475Ω, 121Ω, and 475Ω). The device also provides a 1.3V output for Diff Sense signaling. With the proper resistor network, the UCC561 solution will meet the common mode bias impedance, differential bias, and termination impedance requirements of SPI-2 (Ultra2) and SPI-3 (Ultra3).

This device incorporates into a single monolith, two sink/source reference voltage regulators, a 1.3V buffered output and protection features. The protection features include thermal shut down and active current limiting circuitry. The UCC561 is offered in 16-pin SOIC(DP) package.



## BLOCK DIAGRAM



UDG-98093

**ABSOLUTE MAXIMUM RATINGS**

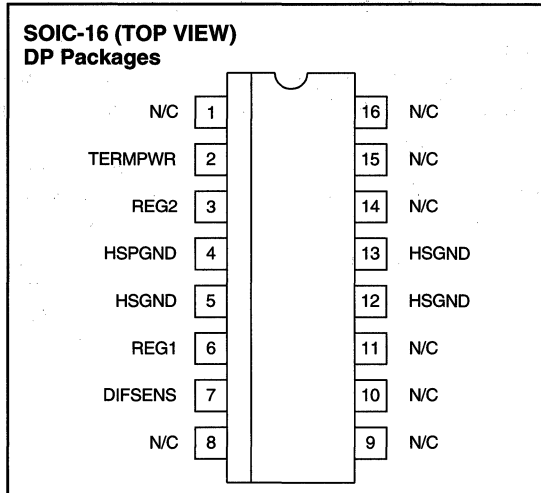
TERMPWR .....	+6V
Package Dissipation .....	1.2W
Junction Temperature .....	-55°C to +150°C
Storage Temperature .....	-65°C to +150°C

Currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages.

**RECOMMENDED OPERATING CONDITIONS**

TERMPWR Voltage .....	2.7V to 5.25V
-----------------------	---------------

**CONNECTION DIAGRAMS**



**ELECTRICAL CHARACTERISTICS:** Unless otherwise specified these specifications apply for TA = 0°C to 70°C, TERMPWR = 3.3V.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>TERMPWR Supply Current Section</b>					
TERMPWR Supply Current	No Load			40.0	mA
TERMPWR Voltage		2.7		5.25	V
<b>Regulator Section</b>					
1.75 Volt Regulator	REG1 (± 125mA)	1.7	1.75	1.8	V
1.3 Volt Regulator	DIFSENS, No Load	1.2	1.3	1.4	V
0.75 Volt Regulator	REG2 (± 125mA)	0.7	0.75	0.8	V
1.75 Volt Regulator Source Current	VO = 1.25			-200	mA
1.75 Volt Regulator Sink Current	VO = 2.25	200			mA
1.75 Volt Sink Current Limit				700	mA
1.75 Volt Source Current Limit		-700			mA
1.3 Volt Regulator Source Current	DIFSENS, GND	-5		-15	mA
1.3 Volt Regulator Sink Current	DIFSENS, 2.4V	50		200	µA
0.75 Volt Regulator Source Current	VO = 0.25			-200	mA
0.75 Volt Regulator Sink Current	VO = 1.25	200			mA
0.75 Source Current Limit				700	mA
0.75 Sink Current Limit		-700			mA

Note 1: Guaranteed by design. Not 100% tested in production.

APPLICATION INFORMATION

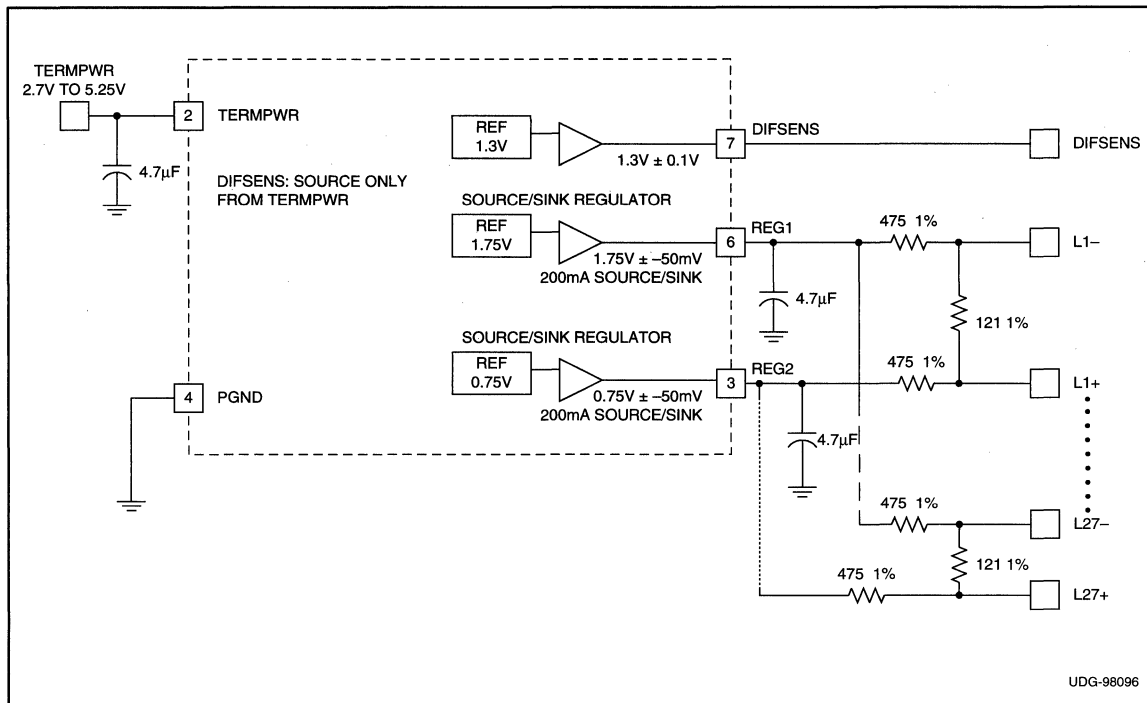


Figure 1. LVD SCSI discrete resistor stack.

Table I. Resistor stack vs. standard.

Outputs	Specification
107.3Ω Diff	100Ω to 110Ω
112.9mV Diff Bias	100mV to 125mV
237Ω Common Mode	100Ω to 300Ω
1.25V Common Mode	1.2V to 1.30V

Application Note: The resistor stack with the 1.75V and 0.75V reference will give the correct differential impedance, bias voltage, common mode differential impedance and common mode voltage as show in Table 1.

# 32 Line VME Bus Bias Generator

## FEATURES

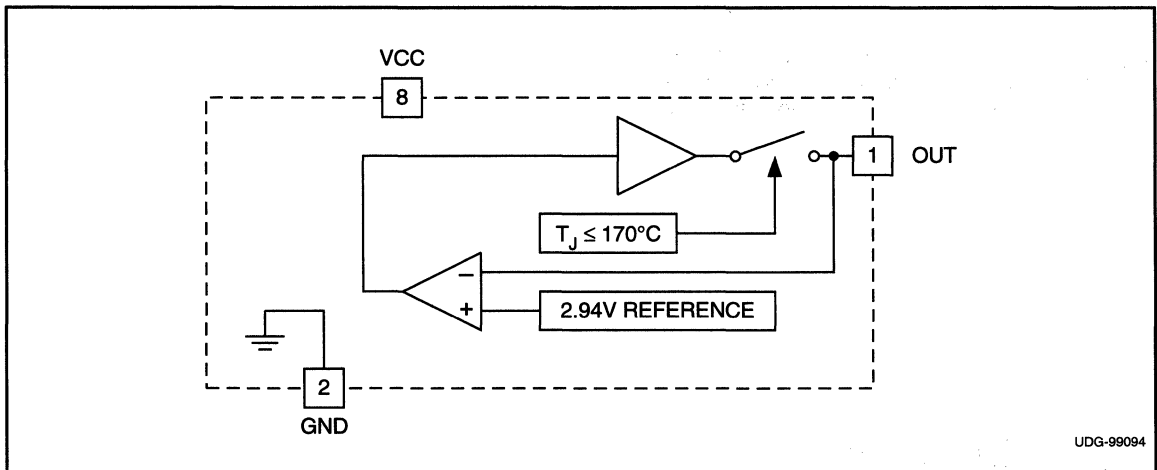
- Complies with VME64 Standard
- 2.94V Regulated Output Voltage With 1% Tolerance at 25°C
- Provides Bias for up to 32 Lines of Active Termination for VME busses
- -575mA Sourcing Current for Termination
- +475mA Sinking Current for Active Negation Drivers
- Current Limit and Thermal Shutdown Protection
- Low Thermal Resistance Surface Mount Packages

## DESCRIPTION

The VME bus bias generator provides current for up to 32 lines of active termination for a VME64 parallel bus. The VME standards require termination at both ends of the bus. The voltage regulator and internal logic circuits of these parts provide all the functionality and performance necessary to bias termination resistors for the VME Bus. The VME bus bias generator sink current maintains regulation with all active negation drivers negated. Internal circuit trimming is used to trim the output voltage to a 1% tolerance. Other features include thermal shutdown and current limit for short circuit conditions. This device is available in low thermal resistance versions of the industry standard 8-pin power SOIC, 3 pin TO-220 and 3 pin TO-263.

Termination is a VME requirement but passive is also an option.

## BLOCK DIAGRAM



UDG-99094

**ABSOLUTE MAXIMUM RATINGS**

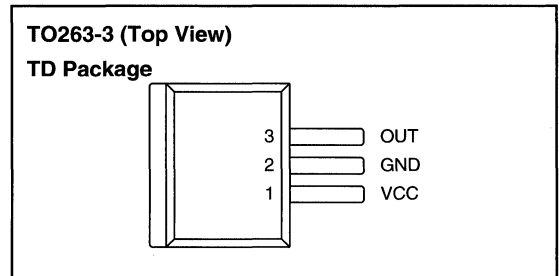
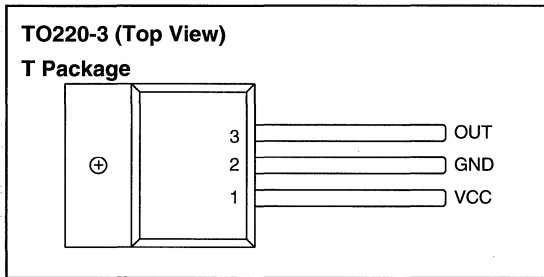
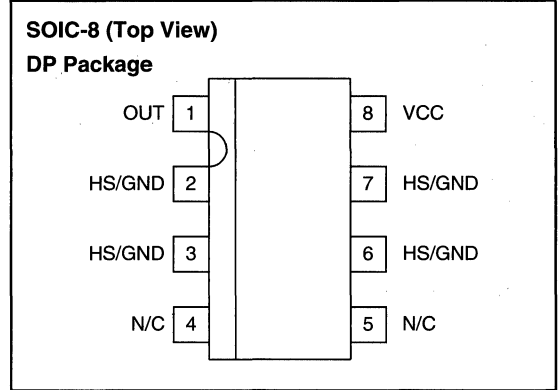
VCC	.....	+7V
Regulator Output Current	.....	600mA
Storage Temperature	.....	-65°C to +150°C
Junction Temperature	.....	-55°C to +150°C
Lead Temperature (Soldering, 10 secretary.)	.....	+300°C

Currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages. All voltages are referenced to ground.

**RECOMMENDED OPERATING CONDITIONS**

VCC Voltage	.....	4.875V to 5.25V
-------------	-------	-----------------

**CONNECTION DIAGRAMS**



**ELECTRICAL CHARACTERISTICS:** Unless otherwise specified,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$ ,  $V_{CC} = 5.00\text{V}$ ;  $C_{OUT} = 4.7\mu\text{F}$ ;  $T_A = T_J$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Supply Current Section</b>					
Supply Current	No load		25		mA
	$I_{OUT} = -600\text{mA}$		602	650	mA
<b>Regulator Section</b>					
Output Voltage	25°C, No load	2.793	2.94	3.087	V
Load Regulation	$-575\text{mA} \leq I_{OUT} \leq 475\text{mA}$ (Note 1)		25	30	mV
Line Regulation	$4.875\text{V} \leq V_{CC} \leq 5.25\text{V}$ , No load		10	20	mV
Short Circuit Current	$V_{OUT} = 0\text{V}$			-600	mA
	$V_{OUT} = 3.5\text{V}$	500			
Thermal Shutdown	(Note 2)		170		°C
Thermal Shutdown Hysteresis	(Note 2)		10		°C

Note 1: Tested at a constant junction temperature by low duty cycle pulse testing.

Note 2: Guaranteed by design. Not 100% tested in production.

## PIN DESCRIPTIONS

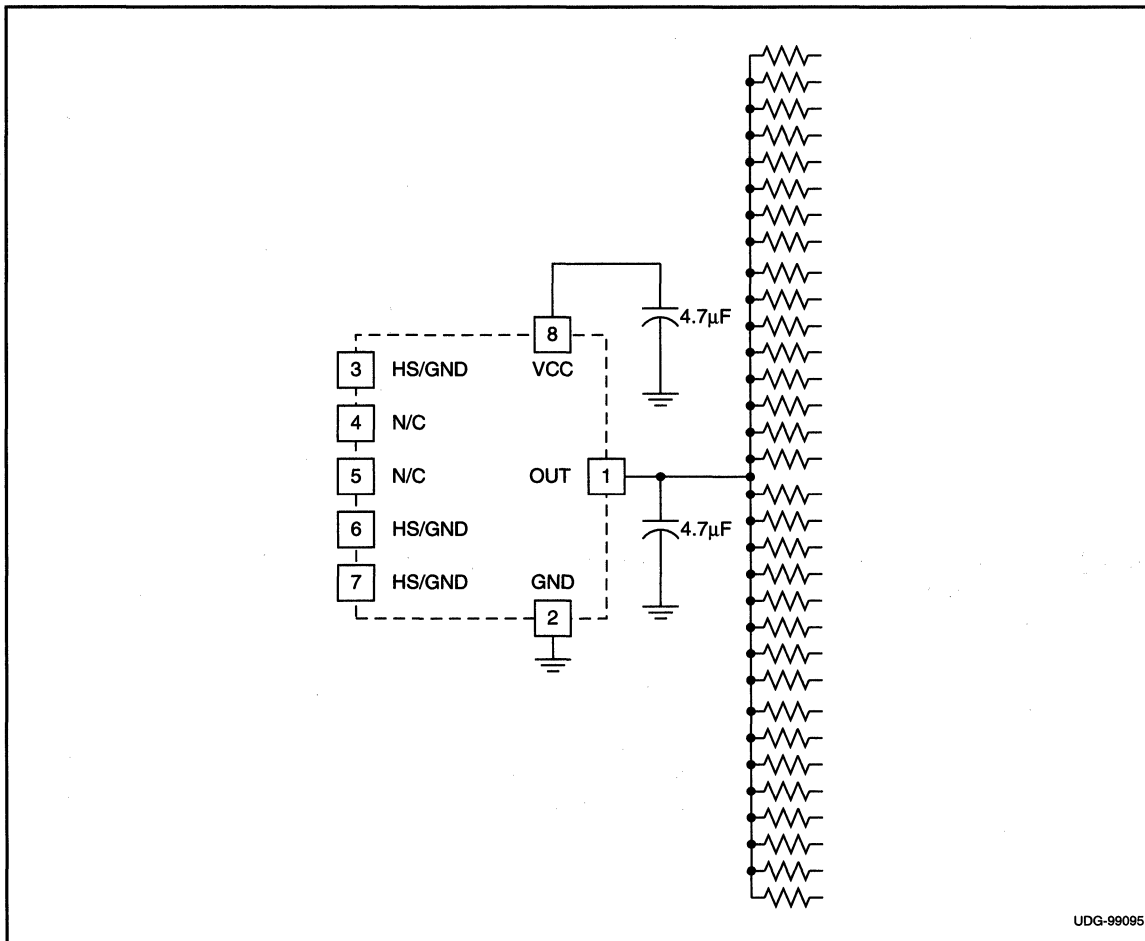
**GND:** Ground pin.

**HS/GND:** Heat sink GND. Connect to large area PC board traces to increase power dissipation capability.

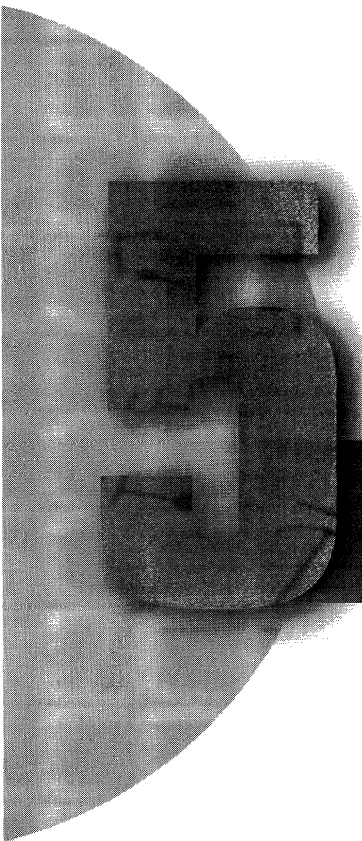
**OUT:** 2.94V regulated output voltage pin. The part is internally current limited for both sinking and sourcing current to prevent damage. For best performance, a 4.7 $\mu$ F low ESR capacitor is recommended.

**VCC:** Supply voltage pin. The pin should be de-coupled with at least a 2.2 $\mu$ F low ESR capacitor. For best performance, a 4.7 $\mu$ F low ESR capacitor is recommended. Lead lengths should be kept at a minimum.

## TYPICAL APPLICATION







# Hot Swap Power Manager™ ICs



# Selection Guides ~ Hot Swap Power Manager™ ICs



## Hot Swap Power Managers

Hot Swap Power Managers	UNITRODE PART NUMBER				
	UCC3912	UCC3913	UC3914	UCC3915	UCC39151
<b>Voltage Range</b>	3V to 8V	-10.5V to External Limitation	5V to 35V	7V to 15V	7V to 15V
<b>Current Range</b>	0A to 3A	Externally Limited	Externally Limited	0A to 3A	0A to 3A
<b>Integrated Power FET</b>	Y	N	N	Y	Y
<b>RDSon</b>	150mΩ	N/A	N/A	150mΩ	150mΩ
<b>Programmable Fault Threshold</b>	Y	Y	Y	Y	Y
<b>Programmable Time Delay</b>	Y	Y	Y	Y	Y
<b>Latched Fault Mode</b>	N	Y	Y	N	N
<b>Average Power Limiting</b>	N/A	Y	Y	N/A	N/A
<b>Application / Design Note</b>	DN-58, DN-68, U-151	DN-67		DN-58, DN-68, U-151	DN-58, DN-68, U-151
<b>Available Package</b>	TSSOP, SOIC or PDIP	SOIC or PDIP	SOIC or PDIP	TSSOP, SOIC or PDIP	TSSOP, SOIC or PDIP
<b>Page Number</b>	IF/5-9	IF/5-15	IF/5-23	IF/5-37	IF/5-42

Hot Swap Power Managers	UNITRODE PART NUMBER				
	UCC3916	UCC39161	UCC3917+	UCC3918	UCC3919
<b>Voltage Range</b>	4V to 6V	4V to 6V	10V to External Limitation	3V to 6V	3V to 8V
<b>Current Range</b>	-1.8A to -1.5A	-1A to -0.7A	Externally Limited	0A to 4A	Externally Limited
<b>Integrated Power FET</b>	Y	Y	N	Y	N
<b>RDSon</b>	220mΩ	220mΩ	N/A	60mΩ	N/A
<b>Programmable Fault Threshold</b>	N	N	Y	Y	Y
<b>Programmable Time Delays</b>	Y	Y	Y	Y	Y
<b>Latched Fault Mode</b>	N	N	Y	N	Y
<b>Average Power Limiting</b>	N/A	N/A	Y	N/A	Y
<b>Application / Design Note</b>			DN-98	DN-87	DN-95
<b>Available Package</b>	SOIC or PDIP	SOIC or PDIP	SOIC or PDIP	SOIC or PDIP	SOIC or PDIP
<b>Page Number</b>	IF/5-47	IF/5-50	IF/5-53	IF/5-61	IF/5-68

+ New Product

# Selection Guides ~ Hot Swap Power Manager™ ICs



## Hot Swap Power Managers (cont.)

Hot Swap Power Managers	UNITRODE PART NUMBER		
	UCC3921	UCC3995+	UCC3996+
<b>Voltage Range</b>	-10.5V to External Limitation	2.75V to 5.5V	2.75V to 13.6V Two Supplies Sequenced
<b>Current Range</b>	Externally Limited	Externally Limited	Externally Limited
<b>Integrated Power FET</b>	N	N	N
<b>RDSon</b>	N/A	N/A	N/A
<b>Programmable Fault Threshold</b>	Y	Y	Y
<b>Programmable Time Delay</b>	Y	Y	Y
<b>Latched Fault Mode</b>	Y	N	Y
<b>Average Power Limiting</b>	Y	Y	Y
<b>Application / Design Note</b>			
<b>Available Package</b>	SOIC or PDIP	TSSOP or SOIC	TSSOP, SOIC or PDIP
<b>Page Number</b>	IF/5-78	IF/5-98	IF/5-100

Special Functions	UNITRODE PART NUMBER				
	UCC3831	UCC38531	UCC3981+	UCC39811+	UCC3985+
<b>Part Name</b>	Universal Serial Bus Power Controller	Universal Serial Bus Power Controller	Universal Serial Bus Power Controller	Universal Serial Bus Power Controller	CompactPCI Hot Swap Power Manager
<b>Description</b>	Powers Four 5V Peripherals and One 3.3V USB Controller	Powers Four 5V Peripherals and One 3.3V USB Controller	Powers Four 5V Peripherals and One 3.3V USB Controller	Powers Four 5V Peripherals and One 3.3V USB Controller	Fully CompactPCI Compliant. Four Channels for Individual Control of Four Supplies 12V, -12V, 5V, and 3.3V
<b>Application / Design Note</b>					
<b>Available Package</b>	SOIC or PDIP	SOIC or PDIP	SOIC or PDIP	SOIC or PDIP	TSSOP, SOIC or PDIP
<b>Page Number</b>	IF/5-3	IF/5-6	IF/5-88	IF/5-91	IF/5-94

+ New Product

# Universal Serial Bus Power Controller

## FEATURES

- Fully USB Compliant
- Support Four 5V Peripherals and One USB 3.3V Controller
- Separate Power Enables
- 500mA Current Limiting per Channel
- Separate Open Drain Fault Indicator for Each Channel
- 3.3V Output for USB Controller
- Available in 28 Pin Wide Surface Mount and DIP

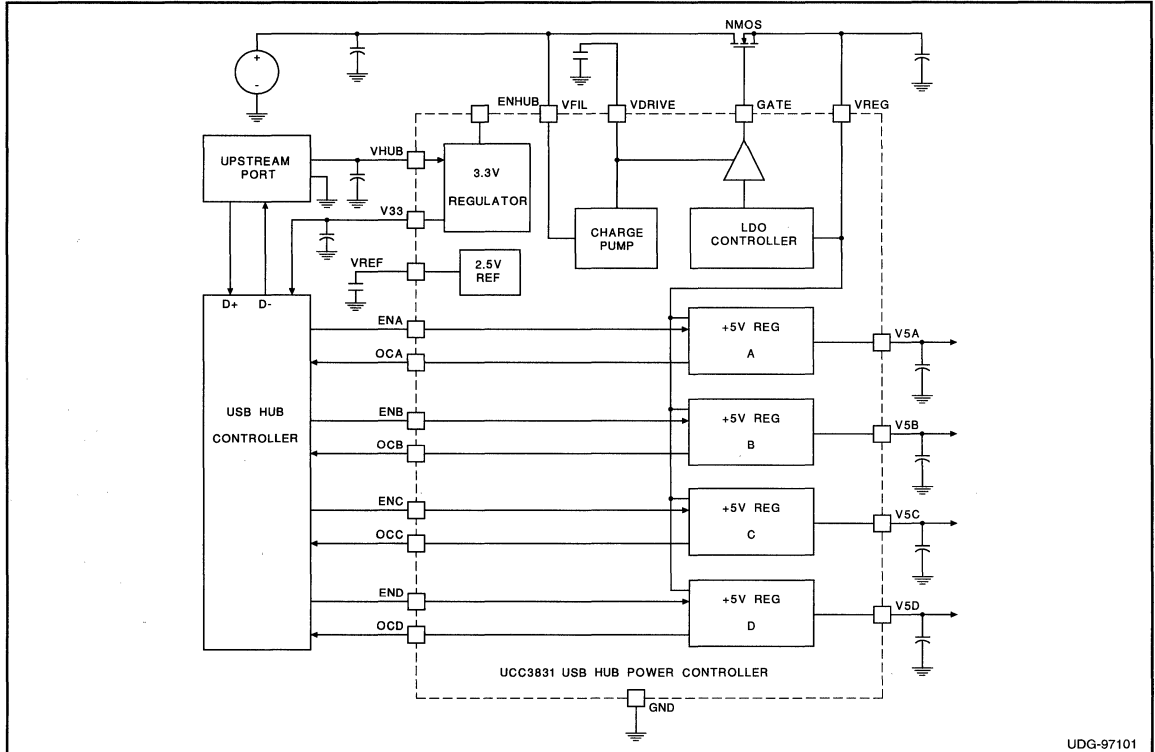
## DESCRIPTION

The UCC3831 Power Controller is designed to provide a self powered USB hub with a local 3.3V regulated voltage and four 5V regulated voltages for USB ports. Each of the 5V output ports is individually enabled for optimal port control. Each port also provides an overcurrent fault signal indicating that the port has exceeded a 500mA current limit. The 3.3V linear regulator is used to power the local USB microcontroller. This regulator is protected with a 100mA current limit and has a logic level enable input.

The UCC3831 can be configured to provide USB port power from a loosely regulated voltage such as a Filament voltage internal to a monitor. Pre-regulation is provided by an internal linear regulator controller and one external logic level N-channel MOSFET. The UCC3831 can also be configured without using the pre-regulator stage by connecting the VREG pins to a regulated 5.5V 2A source.

The UCC3831 comes in a 28-pin wide SOIC power package optimized for power dissipation, and is protected by internal over-temperature shutdown mechanism, which disables the outputs should the internal junction temperature exceed 150°C.

## APPLICATION AND BLOCK DIAGRAM

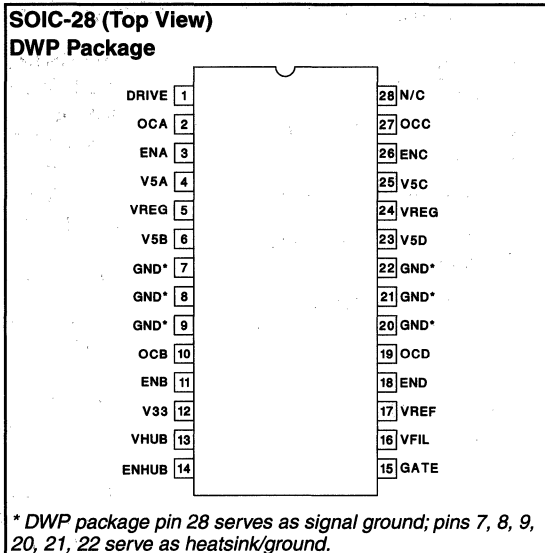


**ABSOLUTE MAXIMUM RATINGS**

VFIL	9V
VCON Supply Voltage	9V
Logic Inputs (ENA-D, ENHUB)	
Maximum Forced Voltage	-0.3V to 7V
Maximum Forced Current	±1mA
V33	
Maximum Forced Voltage	5V
Maximum Current	200mA
V5A-D	
Maximum Voltage	9V
Maximum Current	750mA
Storage Temperature	-65°C to +150°C
Junction Temperature	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.)	+300°C

*Unless otherwise indicated, voltages are reference to ground.  
Pulsed is defined as a less than 10% duty cycle with a maximum duration of 500µs. Currents are positive into, negative out of the specified terminal. All voltages are with respect to ground. Consult Packaging Section of Databook for thermal limitations and considerations of packages.*

**CONNECTION DIAGRAM**



**ELECTRICAL CHARACTERISTICS** Unless otherwise specified, T<sub>J</sub> = 0°C to 125°C for the UCC3831. VFIL = 6.5V, VHUB = 5V. TA = T<sub>J</sub>.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Input Supply Currents</b>					
VHUB Supply Current	No External Load on V33		1	3	mA
VFIL Supply Current			1	3	mA
<b>Reference</b>					
VREF Voltage	Over Temperature	2.35	2.5	2.65	V
Line Regulation	VHUB = 4.5V to 9V		3	10	mV
3.3V Regulator					
V33 Voltage	T <sub>J</sub> = 25°C, I <sub>LOAD</sub> = 10mA	3.2	3.3	3.4	V
	0mA to 100mA, 0°C to 125°C, VHUB = 4.5V to 9V	3.165	3.3	3.435	V
Short Circuit Current Limit	VHUB = 6V, Output shorted to Ground	100	120	150	mA
<b>Pre-Regulator</b>					
VREG Voltage	0A to 2A, 0°C to 125°C, VFIL = 6V to 9V	5.25	5.5	5.7	V
<b>5V Regulator</b>					
V5A-D Voltage	T <sub>J</sub> = 25°C, I <sub>LOAD</sub> = 250mA, VREG = 5.5V	4.85	5	5.15	V
	0mA to 500mA, 0°C to 125°C	4.8	5	5.2	V
Short Circuit Current Limit	VREG = 5.5V, Output Shorted to Ground	500	600	750	mA
<b>Charge Pump</b>					
Quiescent Output Voltage	T <sub>J</sub> = 25°C, VFIL = 6V, ENA-D = 5V, ENHUB = 5V	11	11.45	12	V
	0°C to 125°C, VFIL = 6V	10.5	11.45	12	V
Output Impedance			9	15	kΩ
<b>Enable Inputs</b>					
ENA-D Inputs - Guaranteed Low				0.7	V
ENA-D Inputs - Guaranteed High		3			V
<b>Enable Inputs (cont.)</b>					
ENHUB Input - Guaranteed Low				0.7	V

**ELECTRICAL CHARACTERISTICS** Unless otherwise specified,  $T_J = 0^\circ\text{C}$  to  $125^\circ\text{C}$  for the UCC3831.  $V_{FIL} = 6.5\text{V}$ ,  $V_{HUB} = 5\text{V}$ .  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
ENHUB Input - Guaranteed High		3			V
<b>Overcurrent Signals</b>					
Active Sink Current	$I_{OCX} = 100\mu\text{A}$		140	500	mV

## PIN DESCRIPTIONS

**ENA-D:** Separate enables pins for each of the four 5V supplies.

**ENHUB:** Enables the 3.3V output V33. Pulling this pin low disables V33.

**GATE:** Gate drive for an external NMOS used to regulate the 5.5V VREG supply. Minimum available drive is 11V.

**GND:** All 6 GND pins must be tied to the system ground. In addition to serving as electrical conductors, these 6 pins are heat sinks. Refer to the Packaging Device Temperature Management guide in the Packaging section of the Unitorde Databook.

**OCA-D:** Open drain overcurrent indicator. OCA-D can be wire OR'ed by the user to create a single overcurrent indicator.

**V5A-D:** 5V regulated output with enable, 500mA (mini-

mum) current limit, and overcurrent indicator.

**V33:** 3.3V regulator output. Enable when ENHUB is high. Current limit is 100mA minimum.

**VDRIVE:** Internal charge pump voltage is brought out for external decoupling. Nominal voltage is between 11V and 13V. No external loading permitting. Decouple with at least  $0.001\mu\text{F}$  capacitor.

**VFIL:** Bias supply for all four of the 5V regulators. VFIL voltage must be between 6V and 9V.

**VHUB:** Supply for the 3.3V USB controller power supply and bandgap reference.

**VREF:** Internal 2.5V reference is brought out for external decoupling only. Decouple with  $0.01\mu\text{F}$  capacitor.

**VREG:** Regulated to 5.5V by means of an external NMOS. 2 pins supply up to a total of 2.5A to the four 5V bus voltages (V5A, V5B, V5C, V5D).

# Universal Serial Bus Power Controller

## FEATURES

- Fully USB Compliant
- Support Four 5V Peripherals and One USB 3.3V Controller
- Separate Power Enables
- 500mA Current Limiting per Channel
- Separate Open Drain Fault Indicator for Each Channel
- 3.3V Output for USB Controller
- Available in 20 Pin DIP

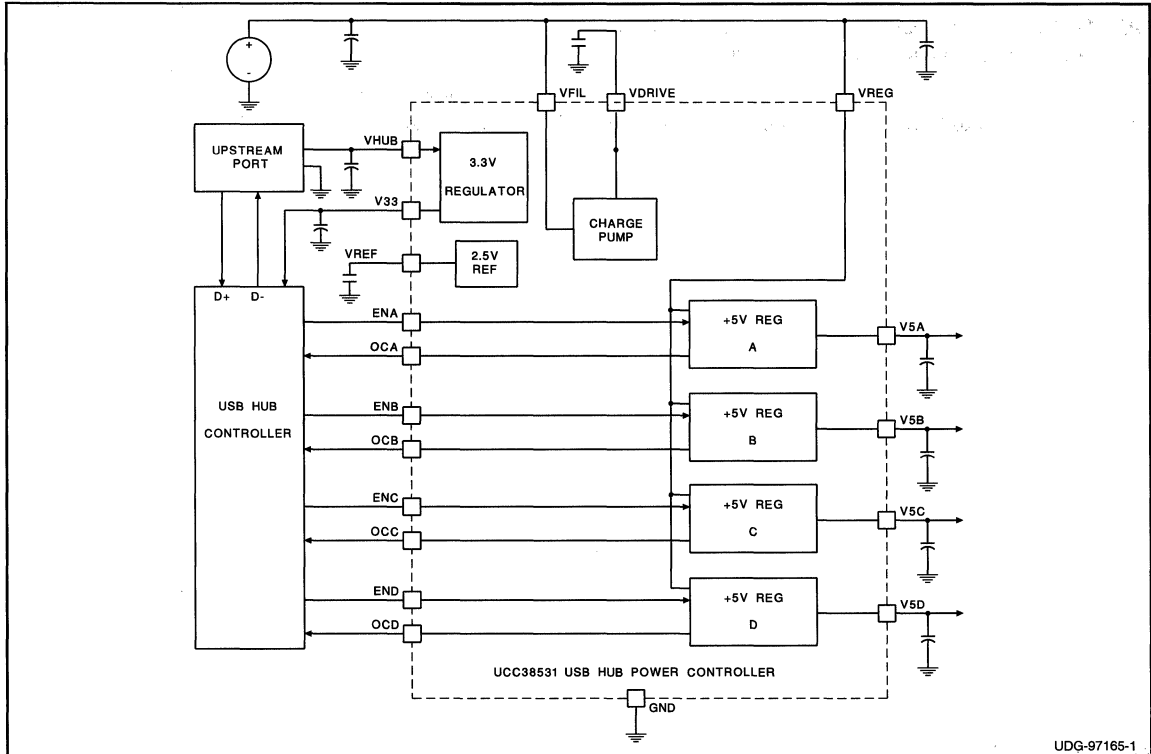
## DESCRIPTION

The UCC38531 Power Controller is designed to provide a self powered USB hub with a local 3.3V regulated voltage and four 5V regulated voltages for USB ports. Each of the 5V output ports is individually enabled for optimal port control. Each port also provides an overcurrent fault signal indicating that the port has exceeded a 500mA current limit. The 3.3V linear regulator is used to power the local USB microcontroller. This regulator is protected with a 100mA current limit.

The UCC38531 is configured by connecting the VREG to a regulated 5.5V 2A source.

The 20-pin DIP package is protected by internal over-temperature shut-down mechanism, which disables the outputs should the internal junction temperature exceed 150°C.

## APPLICATION AND BLOCK DIAGRAM



UDG-97165-1

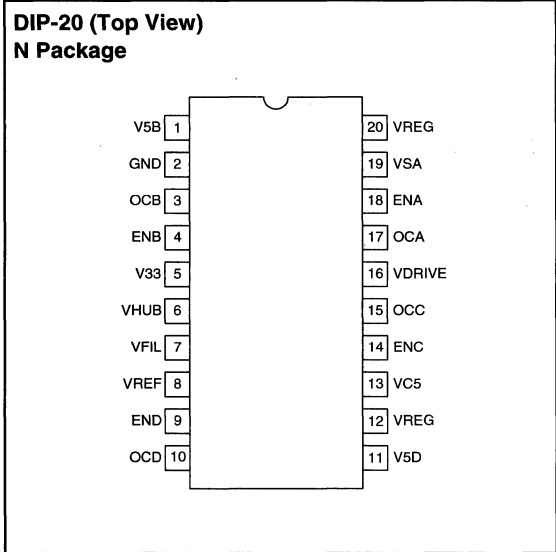


**ABSOLUTE MAXIMUM RATINGS**

VFIL	9V
VCON Supply Voltage	9V
Logic Inputs (ENA-D)	
Maximum Forced Voltage	-0.3V to 7V
Maximum Forced Current	1mA
V33	
Maximum Forced Voltage	5V
Maximum Current	200mA
V5A-D	
Maximum Voltage	9V
Maximum Current	750mA
Storage Temperature	65°C to +150°C
Junction Temperature	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.)	+300°C

*Unless otherwise indicated, voltages are reference to ground. Pulsed is defined as a less than 10% duty cycle with a maximum duration of 500µs. Currents are positive into, negative out of the specified terminal. All voltages are with respect to ground. Consult Packaging Section of Databook for thermal limitations and considerations of packages.*

**CONNECTION DIAGRAM**



**ELECTRICAL CHARACTERISTICS** Unless otherwise specified, T<sub>J</sub> = 0°C to 125°C for the UCC38531. VFIL = 6.5V, VHUB = 5V. T<sub>A</sub> = T<sub>J</sub>.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Input Supply Currents</b>					
VHUB Supply Current	No External Load on V33		1	3	mA
VFIL Supply Current			1	3	mA
<b>Reference</b>					
VREF Voltage	Over Temperature	2.35	2.5	2.65	V
Line Regulation	VHUB = 4.5V to 9V		3	10	mV
3.3V Regulator					
V33 Voltage	T <sub>J</sub> = 25°C, I <sub>LOAD</sub> = 10mA	3.2	3.3	3.4	V
	0mA to 100mA, 0°C to 125°C, VHUB = 4.5V to 9V	3.165	3.3	3.435	V
Short Circuit Current Limit	VHUB = 6V, Output shorted to Ground	100	120	150	mA
<b>5V Regulator</b>					
V5A-D Voltage	T <sub>J</sub> = 25°C, I <sub>LOAD</sub> = 250mA, V <sub>REG</sub> = 5.5V	4.85	5	5.15	V
	0mA to 500mA, 0°C to 125°C	4.8	5	5.2	V
Short Circuit Current Limit	V <sub>REG</sub> = 5.5V, Output Shorted to Ground	500	600	750	mA
<b>Charge Pump</b>					
Quiescent Output Voltage	T <sub>J</sub> = 25°C, VFIL = 6V, ENA-D = 5V, ENHUB = 5V	11	11.45	12	V
	0°C to 125°C, VFIL = 6V	10.5	11.45	12	V
Output Impedance			9	15	k
<b>Enable Inputs</b>					
ENA-D Inputs - Guaranteed Low				0.7	V
ENA-D Inputs - Guaranteed High		3			V
<b>Overcurrent Signals</b>					
Active Sink Current	I <sub>OCX</sub> = 100µA		140	500	mV

**PIN DESCRIPTIONS**

**ENA-D:** Separate enables pins for each of the four 5V supplies.

**GND:** All voltages are measured with respect to this pin. Bypass capacitors should be connected to GND as close to this pin as possible.

**OCA-D:** Open drain overcurrent indicator. OCA-D can be wire OR'ed by the user to create a single overcurrent indicator.

**V5A-D:** 5V regulated output with enable, 500mA (minimum) current limit, and overcurrent indicator.

**V33:** 3.3V regulator output. Current limit is 100mA minimum.

**VDRIVE:** Internal charge pump voltage is brought out for external decoupling. Nominal voltage is between 11V and 13V. No external loading permitting. Decouple with at least 0.001 $\mu$ F capacitor.

**VFIL:** Bias supply for all four of the 5V regulators. VFIL voltage must be between 6V and 9V.

**VHUB:** Supply for the 3.3V USB controller power supply and bandgap reference.

**VREF:** Internal 2.5V reference is brought out for external decoupling only. Decouple with 0.01 $\mu$ F capacitor.

**VREG:** Input supply for all four 5V regulators. 2 pins supply up to a total of 2.5A to the four 5V bus voltages (V5A, V5B, V5C, V5D). Can be tied directly to VFIL.

# Programmable Hot Swap Power Manager

## FEATURES

- Integrated 0.15Ω Power MOSFET
- 3V to 8V Operation
- Digital Programmable Current Limit from 0 to 3A
- Electronic Circuit Breaker Function
- 1μA I<sub>CC</sub> when Disabled
- Programmable on Time
- Programmable Start Delay
- Fixed 3% Duty Cycle
- Uni-Directional Switch
- Thermal Shutdown
- Fault Output Indicator
- Maximum Output Current can be set to 1A above the Programmed Fault Level or to a full 4A
- Power SOIC, Low Thermal Resistance Packaging

## DESCRIPTION

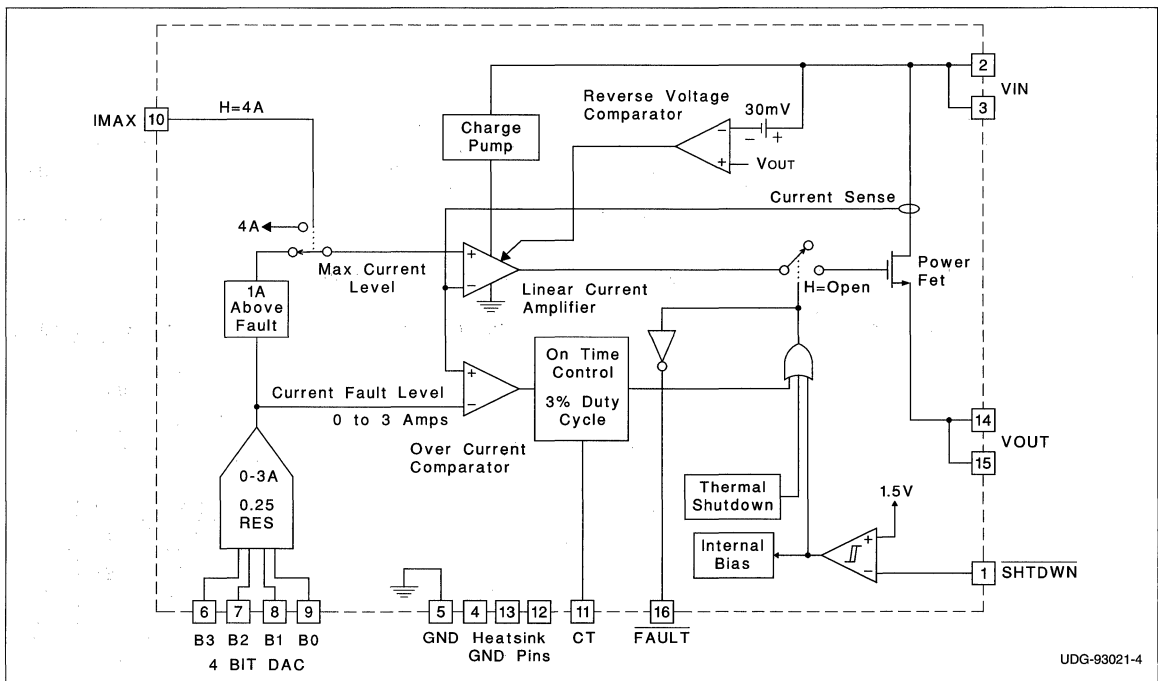
The UCC3912 Hot Swap Power Manager provides complete power management, hot swap capability, and circuit breaker functions. The only component required to operate the device, other than supply bypassing, is the fault timing capacitor, C<sub>T</sub>. All control and housekeeping functions are integrated, and externally programmable. These include the fault current level, maximum output sourcing current, maximum fault time, and start-up delay. In the event of a constant fault, the Internal fixed 3% duty cycle ratio limits average output power.

The internal 4 bit DAC allows programming of the fault level current from 0 to 3A with 0.25A resolution. The IMAX control pin sets the maximum sourcing current to 1A above the fault level when driven low, and to a full 4A when driven high for applications which require fast output capacitor charging.

When the output current is below the fault level, the output MOSFET is switched on with a nominal on resistance of 0.15Ω. When the output current exceeds the fault level, but is less than the maximum sourcing level, the output remains switched on, but the fault timer starts charging C<sub>T</sub>. Once C<sub>T</sub> charges to a preset threshold, the switch is turned off, and remains off for 30 times the programmed fault time. When the output current reaches the maximum sourcing level, the MOSFET transitions from a switch to a constant current source.

(continued)

## BLOCK DIAGRAM



**DESCRIPTION (cont.)**

The UCC3912 is designed for unidirectional current flow, emulating an ideal diode in series with the power switch. This feature is particularly attractive in applications where many devices are powering a common bus, such as with SCSI Tempwr.

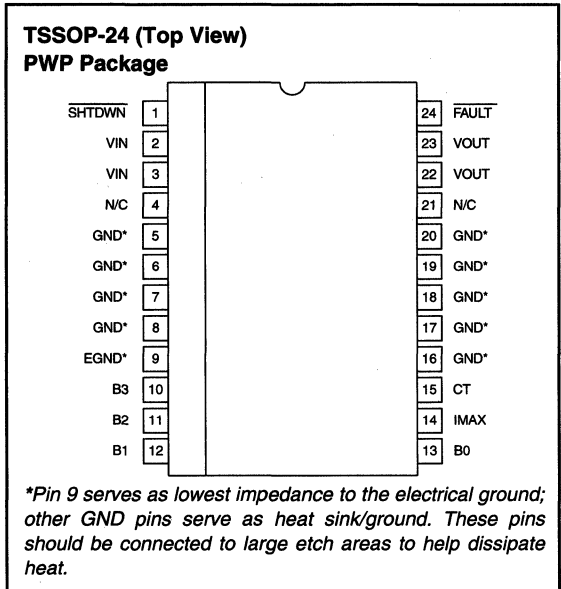
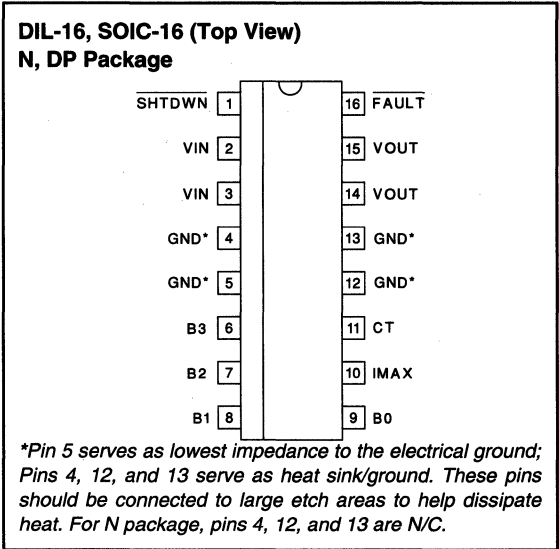
The UCC3912 can be put into sleep mode drawing only 1µA of supply current. The SHTDWN pin has a preset threshold hysteresis which allows the user the ability to set a time delay upon start-up to achieve sequencing of power. Other features include an open drain Fault output indicator, Thermal Shutdown, Under Voltage Lockout, and a low thermal resistance Small outline package.

**ABSOLUTE MAXIMUM RATINGS**

VIN	.....	+8 V
FAULT Sink Current	.....	50mA
FAULT Voltage	.....	-0.3 to VIN
Output Current	.....	Self Limiting
TTL Input Voltage	.....	-0.3 to VIN
Storage Temperature	.....	-65°C to +150°C
Junction Temperature	.....	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.)	.....	+300°C

*Currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages.*

**CONNECTION DIAGRAMS**



**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, these specifications apply for T<sub>J</sub> = 0°C to 70°C, VIN = 5V, IMAX = 0.4V, SHTDWN = 2.4V.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Supply Section</b>					
Voltage Input Range		3.0		8.0	V
Supply Current			1.0	2.0	mA
Sleep Mode Current	SHTDWN = 0.2V		0.5	5.0	µA
<b>Output Section</b>					
Voltage Drop	I <sub>OUT</sub> = 1A		0.15	0.22	V
	I <sub>OUT</sub> = 2A		0.3	0.45	V
	I <sub>OUT</sub> = 3A		0.45	0.68	V
	I <sub>OUT</sub> = 1A, VIN = 3V		0.17	0.27	V
	I <sub>OUT</sub> = 2A, VIN = 3V		0.35	0.56	V
	I <sub>OUT</sub> = 3A, VIN = 3V		0.5	0.8	V

**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, these specifications apply for  $T_J = 0^\circ\text{C}$  to  $70^\circ\text{C}$ ,  $V_{IN} = 5\text{V}$ ,  $I_{MAX} = 0.4\text{V}$ ,  $SHTDWN = 2.4\text{V}$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Output Section (cont.)</b>					
Reverse Leakage	$V_{IN} < V_{OUT}$ , $V_{OUT} = 5\text{V}$		5	20	$\mu\text{A}$
Initial Start-up Time	(Note 2)		100		$\mu\text{s}$
Short Circuit Response	(Note 2)		100		ns
Thermal Shutdown	(Note 2)		170		$^\circ\text{C}$
Thermal Hysteresis	(Note 2)		10		$^\circ\text{C}$
<b>DAC Section</b>					
Output Leakage	Code = 0000-0011		0	20	$\mu\text{A}$
Trip Current	Code = 0100	0.1	0.25	0.45	A
	Code = 0101	0.25	0.50	0.75	A
	Code = 0110	0.5	0.75	1.0	A
	Code = 0111	0.75	1.00	1.25	A
	Code = 1000	1.0	1.25	1.5	A
	Code = 1001	1.25	1.50	1.75	A
Trip Current	Code = 1010	1.5	1.75	2.0	A
	Code = 1011	1.7	2.00	2.3	A
	Code = 1100	1.9	2.25	2.58	A
Trip Current	Code = 1101	2.1	2.50	2.9	A
	Code = 1110	2.3	2.75	3.2	A
	Code = 1111	2.5	3.0	3.5	A
Max Output Current	Code = 0000 to 0011			0.02	mA
Max Output Current Over Trip (Current Source Mode)	Code = 0100 to 1111, $I_{MAX} = 0\text{V}$	0.5	1.0	1.8	A
Max Output Current (Current Source Mode)	Code = 0100 to 1111, $I_{MAX} = 2.4\text{V}$	3.0	4.0	5.2	A
<b>Timer Section</b>					
CT Charge Current	$V_{CT} = 1.0\text{V}$	-45.0	-36.0	-22.0	$\mu\text{A}$
CT Discharge Current	$V_{CT} = 1.0\text{V}$	0.72	1.2	1.5	$\mu\text{A}$
Output Duty Cycle	$V_{OUT} = 0\text{V}$	2.0	3.0	6.0	%
CT Fault Threshold		1.3	1.5	1.7	V
CT Reset Threshold		0.4	0.5	0.6	V
<b>Shutdown Section</b>					
Shutdown Threshold		1.1	1.5	1.9	V
Shutdown Hysteresis			100		mV
Input Current	$SHTDWN = 1\text{V}$		100	500	nA
<b>Fault Output Section</b>					
Output Leakage Current				500	nA
Low Level Output Voltage	$I_{OUT} = 10\text{mA}$		0.4	0.8	V
<b>TTL Input DC Characteristics Section</b>					
TTL Input Voltage High	(can be connected to $V_{IN}$ )	2.0			V
TTL Input Voltage Low				0.8	V
TTL Input High Current	$V_{IH} = 2.4\text{V}$		3	10	$\mu\text{A}$
TTL Input Low Current	$V_{IL} = 0.4\text{V}$			1	$\mu\text{A}$

**Note 1:** All voltages are with respect to Ground. Current is positive into and negative out of the specified terminal.

**Note 2:** Guaranteed by design. Not 100% tested in production.

**PIN DESCRIPTIONS**

**B0 - B3:** These pins provide digital input to the DAC which sets the fault current threshold. They can be used to provide a digital soft-start, adaptive current limiting.

**CT:** A capacitor connected to ground sets the maximum fault time. The maximum fault time must be more than the time to charge the external capacitance in one cycle. The maximum fault time is defined as  $FAULT = 27.8 \cdot 10^3 \cdot CT$ . Once the fault time is reached the output will shut-down for a time given by:  $T_{SD} = 833 \cdot 10^3 \cdot CT$ , this equates to a 3% duty cycle.

**FAULT:** Open drain output which pulls low upon any condition which causes the output to open: Fault, Thermal Shutdown, or Shutdown.

**IMAX:** When this pin is set to logic low the maximum sourcing current will always be 1A above the pro-

grammed fault level. When set to logic high, the maximum sourcing current will be a constant 4A for applications which require fast charging of load capacitance.

**SHTDWN:** When this pin is brought to a logic low, the IC is put into a sleep mode drawing typically less than  $1\mu A$  of ICC. The input threshold is hysteretic, allowing the user to program a start-up delay with an external RC circuit.

**VIN:** Input voltage to the UCC3912. The recommended voltage range is 3 to 8 volts. Both VIN pins should be connected together and to the power source.

**VOUT:** Output voltage from the UCC3912. When switched the output voltage will be approximately  $V_{IN} - (0.15\Omega \cdot I_{OUT})$ . Both VOUT pins should be connected together and to the load.

**APPLICATION INFORMATION**

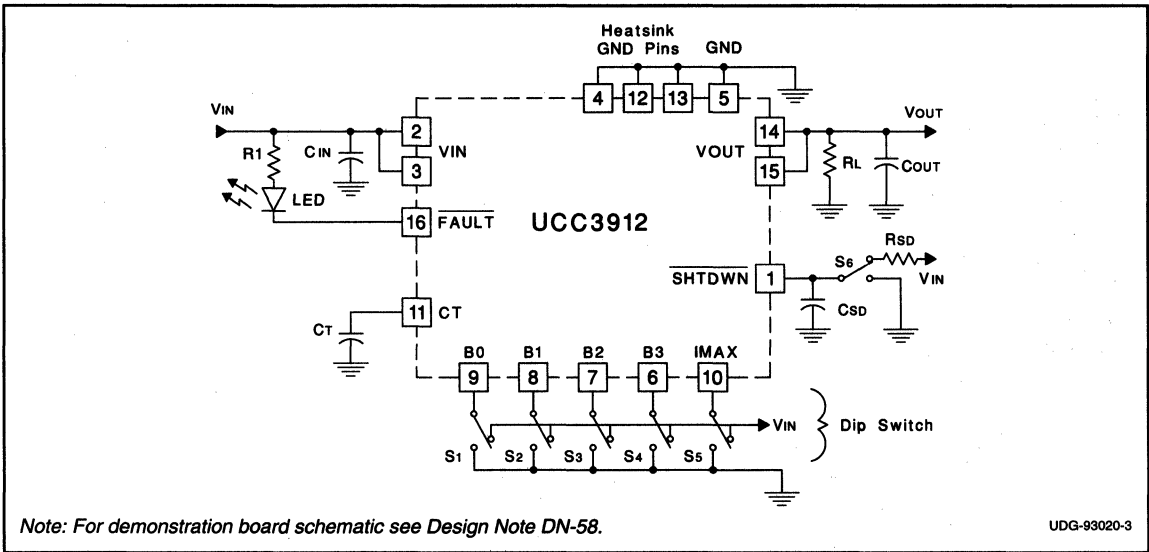


Figure 1. Evaluation circuit.

APPLICATION INFORMATION (cont.)

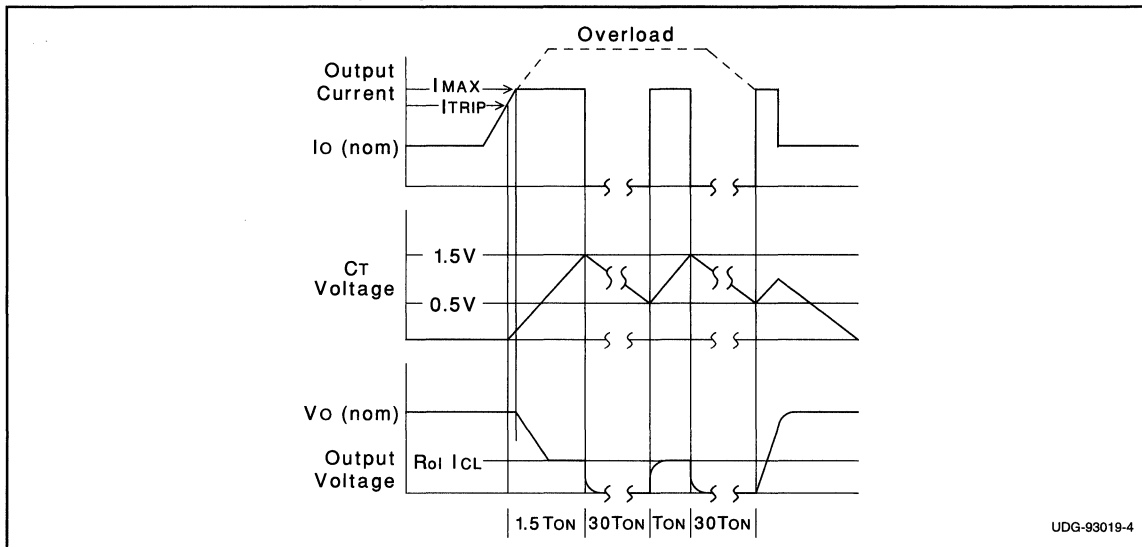


Figure 2. Load current, timing capacitor voltage, and output voltage of the UCC3912 under Fault conditions.

Estimating Maximum Load Capacitance

For hot swap applications, the rate at which the total output capacitance can be charged depends on the maximum output current available and the nature of the load. For a constant-current current-limited controller, the output will come up if the load asks for less than the maximum available short-circuit current.

To guarantee recovery of a duty-cycle from a short-circuited load condition, there is a maximum total output capacitance which can be charged for a given unit ON time (Fault time). The design value of ON or Fault time can be adjusted by changing the timing capacitor  $C_T$ .

For worst-case constant-current load of value just less than the trip limit;  $C_{OUT(max)}$  can be estimated from:

$$C_{OUT(max)} \approx (I_{MAX} - I_{LOAD}) \cdot \left( \frac{28 \cdot 10^3 \cdot C_T}{V_{OUT}} \right)$$

where  $V_{OUT}$  is the output voltage.

For a resistive load of value  $R_L$ , the value of  $C_{OUT(max)}$  can be estimated from:

$$C_{OUT(max)} \approx \left( \frac{28 \cdot 10^3 \cdot C_T}{R_L \cdot \ln \left( \frac{1}{1 - \left( \frac{V_{OUT}}{I_{MAX} \cdot R_L} \right)} \right)} \right)$$



**APPLICATION INFORMATION (cont.)**

The overcurrent comparator senses both the DAC output and a representation of the output current. When the output current exceeds the programmed level the timing capacitor  $C_T$  charges with  $36\mu\text{A}$  of current. If the fault occurs for the time it takes for  $C_T$  to charge up to 1.5V, the fault latch is set and the output switch is opened. The output remains opened until  $C_T$  discharges to 0.5V with a

$1.2\mu\text{A}$  current source. Once the 0.5V is reached the output is enabled and will either appear as a switch, if the fault is removed, or a current source if the fault remains. If the over current condition is still present then  $C_T$  will begin charging, starting the cycle over, resulting in approximately a 3% on time.

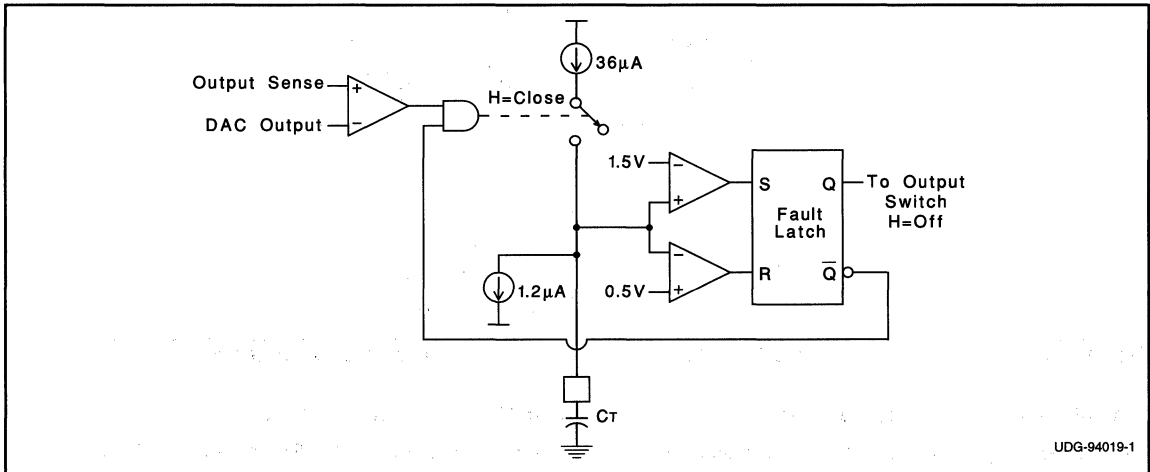


Figure 3. UCC3912 on time control circuitry.

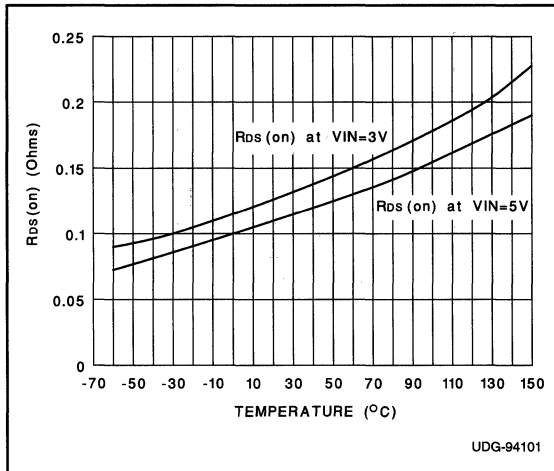


Figure 4. RDS(on) vs temperature at 2A load current.

**SAFETY RECOMMENDATIONS**

Although the UCC3912 is designed to provide system protection for all fault conditions, all integrated circuits can ultimately fail short. For this reason, if the UCC3912 is intended for use in safety critical applications where UL or some other safety rating is required, a redundant safety device such as a fuse should be placed in series with the device. The UCC3912 will prevent the fuse from blowing virtually all fault conditions, increasing system reliability and reducing maintenance cost, in addition to providing the hot swap benefits of the device.



# Negative Voltage Hot Swap Power Manager

## FEATURES

- Precision Fault Threshold
- Programmable Average Power Limiting
- Programmable Linear Current Control
- Programmable
- Overcurrent Limit
- Programmable Fault Time
- Fault Output Indication
- Shutdown Control
- Undervoltage Lockout
- 8-Pin SOIC

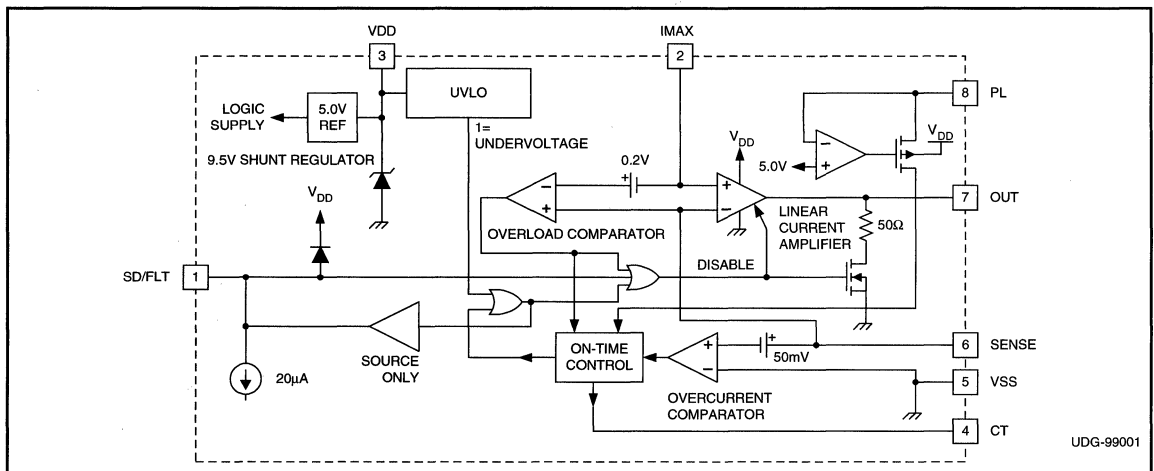
## DESCRIPTION

The UCC1913 family of negative voltage circuit breakers provides complete power management, hot swap, and fault handling capability. The IC is referenced to the negative input voltage and is driven through an external resistor connected to ground, which is essentially a current drive as opposed to the traditional voltage drive. The on-board 10V shunt regulator protects the IC from excess voltage and serves as a reference for programming the maximum allowable output sourcing current during a fault. All control and housekeeping functions are integrated, and externally programmable. These include the fault current level, maximum output sourcing current, maximum fault time, soft start time, and average power limiting. In the event of a constant fault, the internal timer will limit the on-time from less than 0.1% to a maximum of 3%. The duty cycle modulates depending on the current into the PL pin, which is a function of the voltage across the FET, and will limit average power dissipation in the FET. The fault level is fixed at 50mV across the current sense amplifier to minimize total dropout. The fault current level is set with an external current sense resistor. The maximum allowable sourcing current is programmed with a voltage divider from VDD to generate a fixed voltage on the IMAX pin. The current level, when the output appears as a current source, is equal to  $V_{IMAX}/R_{SENSE}$ . If desired, a controlled current startup can be programmed with a capacitor on the IMAX pin.

When the output current is below the fault level, the output device is switched on. When the output current exceeds the fault level, but is less than the maximum sourcing level programmed by the IMAX pin, the output remains switched on, and the fault timer starts charging CT. Once CT charges to 2.5V, the output device is turned off and performs a retry some time later. When the output current reaches the maximum sourcing current level, the output appears as a current source, limiting the output current to the set value defined by IMAX.

Other features of the UCC1913 family include undervoltage lockout, and 8-pin small outline (SOIC) and Dual-In-Line (DIL) packages.

## BLOCK DIAGRAM

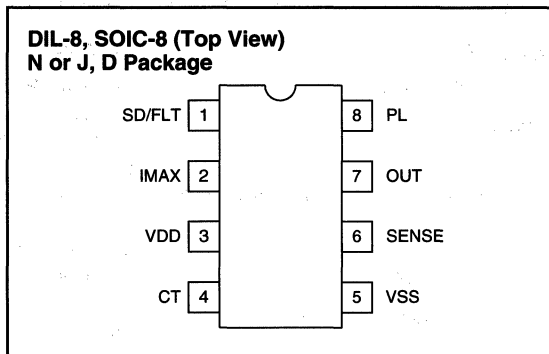


### ABSOLUTE MAXIMUM RATINGS

I <sub>vcc</sub> .....	50mA
SHUTDOWN Current.....	10mA
PL Current.....	10mA
IMAX Input Voltage.....	VCC
Storage Temperature.....	-65°C to +150°C
Junction Temperature.....	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.).....	+300°C

All voltages are with respect to VSS (The most negative voltage). All currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages.

### CONNECTION DIAGRAMS



**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated these specifications apply for T<sub>A</sub> = -55°C to +125°C for UCC1913; -40°C to +85°C for UCC2913; 0°C to +70°C for UCC3913; I<sub>VDD</sub> = 2mA, C<sub>T</sub> = 4.7pF, T<sub>A</sub> = T<sub>J</sub>

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>VDD Section</b>					
IDD			1.0	2.0	mA
Regulator Voltage	I <sub>SOURCE</sub> = 2mA to 10mA	8.5	9.5	10.5	V
UVLO Off Voltage		6	7	8	V
<b>Fault Timing Section</b>					
Overcurrent Threshold	T <sub>J</sub> = 25°C	47.5	50	53	mV
	Over Operating Temperature	46	50	53.5	mV
Overcurrent Input Bias			50	500	nA
CT Charge Current	V <sub>CT</sub> = 1.0V, I <sub>PL</sub> = 0	-50	-36	-22	μA
	Overload Condition, V <sub>SENSE</sub> - V <sub>IMAX</sub> = 300mV	-1.7	-1.2	-0.7	mA
CT Discharge Current	V <sub>CT</sub> = 1.0V, I <sub>PL</sub> = 0	0.6	1	1.5	μA
CT Fault Threshold		2.2	2.4	2.6	V
CT Reset Threshold		0.32	0.5	0.62	V
Output Duty Cycle	Fault Condition, I <sub>PL</sub> = 0	1.7	2.7	3.7	%
<b>Output Section</b>					
Output High Voltage	I <sub>OUT</sub> = 0A	8.5	10		V
	I <sub>OUT</sub> = -1mA	6	8		V
Output Low Voltage	I <sub>OUT</sub> = 0A; V <sub>SENSE</sub> - V <sub>IMAX</sub> = 100mV		0	0.01	V
	I <sub>OUT</sub> = 2mA; V <sub>SENSE</sub> - V <sub>IMAX</sub> = 100mV		0.2	0.6	V
<b>Linear Amplifier Section</b>					
Sense Control Voltage	IMAX = 100mV	85	100	115	mV
	IMAX = 400mV	370	400	430	mV
Input Bias			50	500	nA
<b>Shutdown/Fault Section</b>					
Shutdown Threshold		1.4	1.7	2.0	V
Input Current	Shutdown = 5V	15	25	45	μA
Fault Output High		6	7.5	9	V
Fault Output Low			0	0.01	V
Delay to Output	(Note 1)		150	300	ns

**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated these specifications apply for  $T_A = -55^\circ\text{C}$  to  $+125^\circ\text{C}$  for UCC1913;  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$  for UCC2913;  $0^\circ\text{C}$  to  $+70^\circ\text{C}$  for UCC3913;  $I_{VDD} = 2\text{mA}$ ,  $C_T = 4.7\text{pF}$ ,  $T_A = T_J$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Power Limiting Section</b>					
$V_{\text{SENSE}}$ Regulator Voltage	$I_{\text{PL}} = 64\mu\text{A}$	4.35	4.85	5.35	V
Duty Cycle Control	$I_{\text{PL}} = 64\mu\text{A}$	0.6	1.2	1.7	%
	$I_{\text{PL}} = 1\text{mA}$	0.045	0.1	0.17	%
<b>Overload Section</b>					
Delay to Output	(Note 1)		300	500	ns
Output Sink Current	$V_{\text{SENSE}} = V_{\text{IMAX}} = 300\text{mV}$	40	100		mA
Threshold	Relative to IMAX	140	200	260	mV

Note 1: Guaranteed by design. Not 100% tested in production.

## PIN DESCRIPTIONS

**CT:** A capacitor is connected to this pin in order to set the maximum fault time. The maximum fault time must be more than the time to charge external load capacitance. The maximum fault time is defined as:

$$T_{\text{FAULT}} = \frac{(2 \cdot CT)}{I_{\text{CH}}}$$

where

$$I_{\text{CH}} = 36\mu\text{A} + I_{\text{PL}}$$

and  $I_{\text{PL}}$  is the current into the power limit pin. Once the fault time is reached the output will shutdown for a time given by:

$$T_{\text{SD}} = 2 \cdot 106 \cdot CT$$

**IMAX:** This pin programs the maximum allowable sourcing current. Since VDD is a regulated voltage, a voltage divider can be derived from VDD to generate the program level for the IMAX pin. The current level at which the output appears as a current source is equal to the voltage on the IMAX pin over the current sense resistor. If desired, a controlled current startup can be programmed with a capacitor on the imax pin, and a programmed start delay can be achieved by driving the shutdown with an open collector/drain device into an RC network.

**OUT:** Output drive to the MOSFET pass element.

**PL:** This feature ensures that the average MOSFET power dissipation is controlled. A resistor is connected

from this pin to the drain of the NMOS pass element. When the voltage across the NMOS exceeds 5V, current will flow into the PL pin which adds to the fault timer charge current, reducing the duty cycle from the 3% level. When  $I_{\text{PL}} \gg 36\mu\text{A}$  then the average MOSFET power dissipation is given by:

$$P_{\text{FET(avg)}} = \text{IMAX} \cdot 1 \cdot 10^{-6} \cdot R_{\text{PL}}$$

**SENSE:** Input voltage from the current sense resistor. When there is greater than 50mV across this pin with respect to VSS, then a fault is sensed, and CT starts to charge.

**SD/FLT:** This pin provides fault output indication and shutdown control. Interface into and out of this pin is usually performed through level shift transistors. When  $20\mu\text{A}$  is sourced into this pin, shutdown drives high causing the output to disable the NMOS pass device. When opened, and under a non-fault condition, the SD/FLT pin will pull to a low state. When a fault is detected by the fault timer, or undervoltage lockout, this pin will drive to a high state, indicating the output FET is off.

**VDD:** Current driven with a resistor to a voltage at least 10V more positive than VSS. Typically a resistor is connected to ground. The 10V shunt regulator clamps VDD at 10V above the VSS pin, and is also used as an output reference to program the maximum allowable sourcing current.

**VSS:** Ground reference for the IC and the most negative voltage available.

APPLICATION INFORMATION

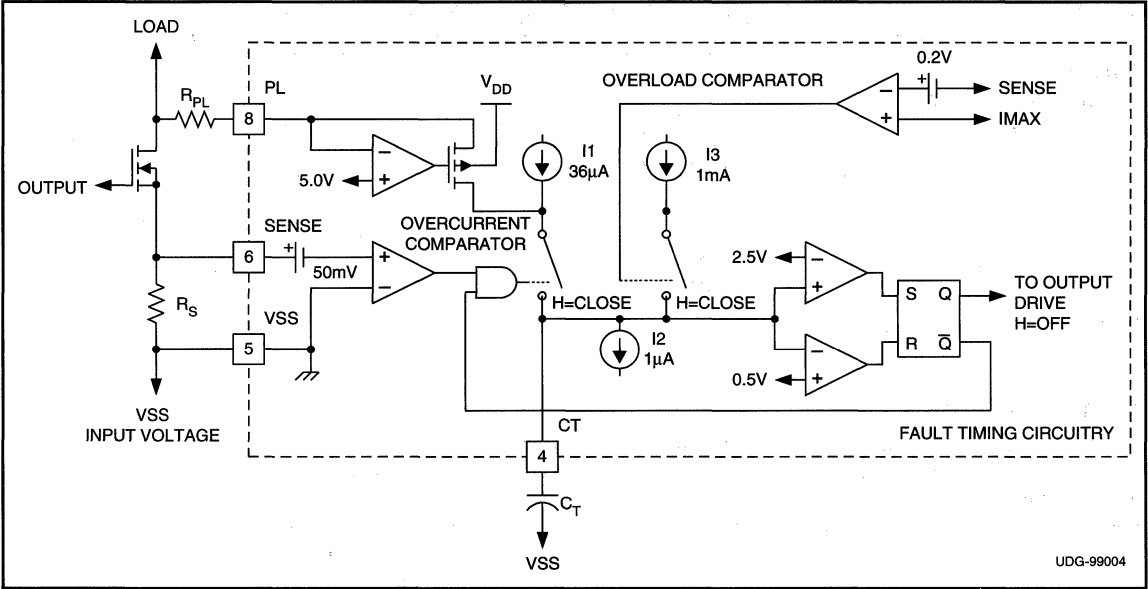


Figure 1. Fault timing circuitry for the UCC1913, including power limit overload.

Figure 1 shows the detailed circuitry for the fault timing function of the UCC1913. For the time being, we will discuss a typical fault mode, therefore, the overload comparator, and current source I3 does not work into the operation. Once the voltage across the current sense resistor, R<sub>S</sub>, exceeds 50mV, a fault has occurred. This causes the timing capacitor to charge with a combination of 36µA plus the current from the power limiting amplifier. The PL amplifier is designed to only source current into the CT pin and to begin sourcing current once the voltage across the output FET exceeds 5V. The current I<sub>PL</sub> is related to the voltage across the FET with the following expression:

$$I_{PL} = \frac{V_{FET} - 5V}{R_{PL}}$$

Where V<sub>FET</sub> is the voltage across the NMOS pass device.

Later it will be shown how this feature will limit average power dissipation in the pass device. Note that under a condition where the output current is more than the fault level, but less than the max level, V<sub>OUT</sub> ~ VSS (input voltage), I<sub>PL</sub> = 0, the CT charging current is 36µA.

During a fault, CT will charge at a rate determined by the internal charging current and the external timing capacitor. Once CT charges to 2.5V, the fault comparator switches and sets the fault latch. Setting of the fault latch causes both the output to switch off and the charging switch to open. CT must now discharge with the 1µA current source, I2, until 0.5V is reached. Once the voltage at CT reaches 0.5V, the fault latch resets, which re-enables the output and allows the fault circuitry to regain control of the charging switch. If a fault is still present, the fault comparator will close the charging switch causing the cycle to begin. Under a constant fault, the duty cycle is given by:

$$Duty\ Cycle = \frac{1\mu A}{I_{PL} + 36\mu A}$$

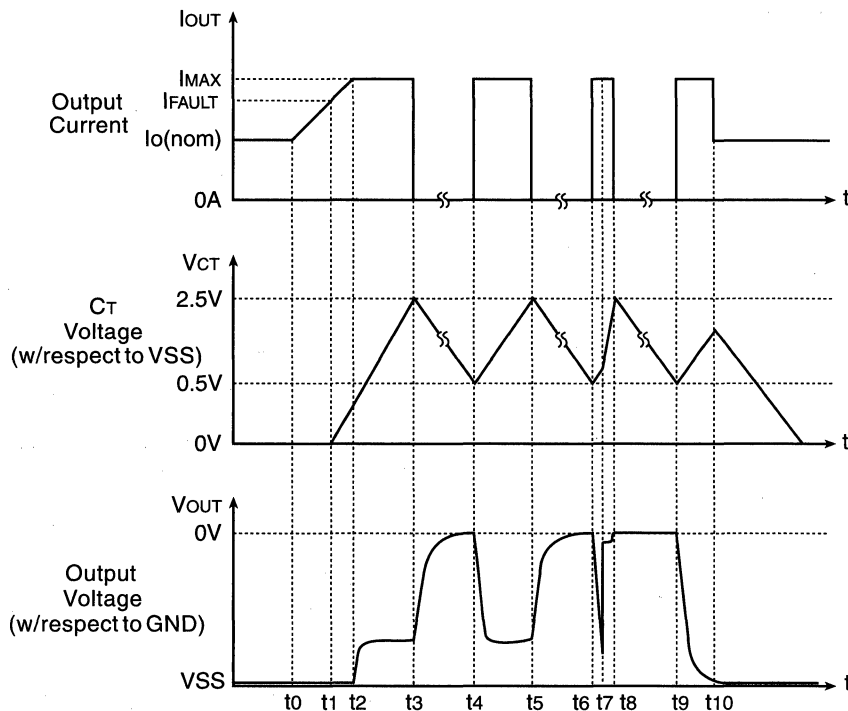
Average power dissipation in the pass element is given by:

$$P_{FET(avg)} = V_{FET} \cdot I_{MAX} \cdot \frac{1\mu A}{I_{PL} + 36\mu A}$$

where V<sub>FET</sub> >> 5V I<sub>PL</sub> can be approximated as :  $\frac{V_{FET}}{R_{PL}}$

and where I<sub>PL</sub> >> 36µA, the duty cycle can be approximated as :

APPLICATION INFORMATION (cont.)



- |  |   |
|--|---|
| <p>t<sub>0</sub>: safe condition – output current is nominal, output voltage is at the negative rail, V<sub>SS</sub>.</p> <p>t<sub>1</sub>: fault control reached – output current rises above the programmed fault value, C<sub>T</sub> begins to charge at <math>\cong 36\mu\text{A}</math>.</p> <p>t<sub>2</sub>: max current reached – output current reaches the programmed maximum level and becomes a constant current with value I<sub>MAX</sub>.</p> <p>t<sub>3</sub>: fault occurs – C<sub>T</sub> has charged to 2.5V, fault output goes high, the FET turns off allowing no output current to flow, V<sub>OUT</sub> floats up to ground.</p> <p>t<sub>4</sub>: retry – C<sub>T</sub> has discharged to 0.5V, but fault current is still exceeded, C<sub>T</sub> begins charging again, FET is on, V<sub>OUT</sub> pulled down to V<sub>SS</sub>.</p> | <p>t<sub>5</sub>: t<sub>5</sub> = t<sub>3</sub>: illustrates 3% duty cycle.</p> <p>t<sub>6</sub>: t<sub>6</sub> = t<sub>4</sub></p> <p>t<sub>7</sub>: output short circuit - if V<sub>OUT</sub> is short circuited to ground, C<sub>T</sub> charges at a higher rate depending upon the values for V<sub>SS</sub> and R<sub>P</sub>L.</p> <p>t<sub>8</sub>: fault occurs – output is still short circuited, but the occurrence of a fault turns the FET off so no current is conducted.</p> <p>t<sub>9</sub>: t<sub>9</sub> = t<sub>4</sub>; output short circuit released, still in fault mode.</p> <p>t<sub>10</sub>: t<sub>10</sub> = t<sub>0</sub>; fault released, safe condition – return to normal operation of the circuit breaker.</p> |
|--|---|

Figure 2. Typical timing diagram.

APPLICATION INFORMATION (cont.)

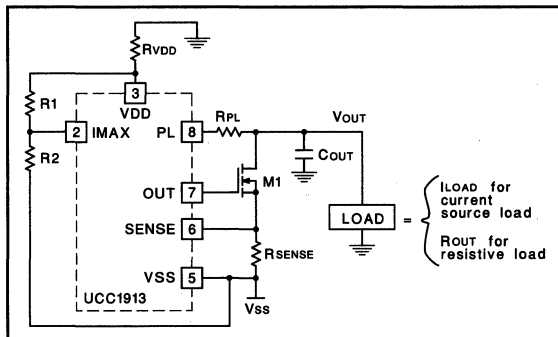


Figure 3.

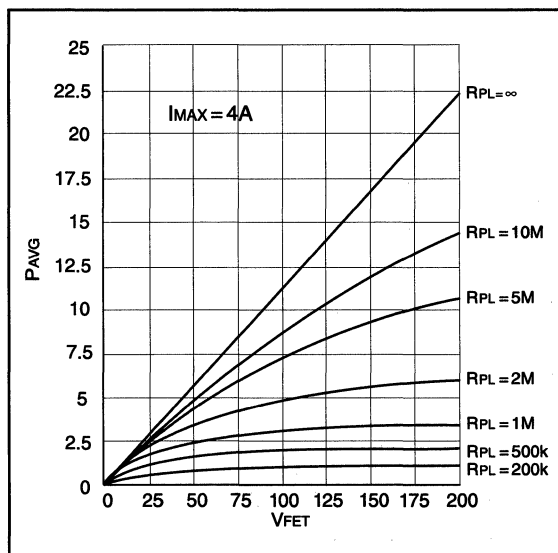


Figure 4. Plot average power vs. FET voltage for increasing values of  $R_{PL}$ .

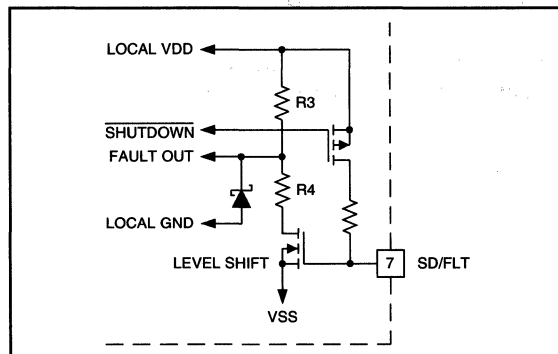


Figure 5. Possible level shift circuitry to interface to the UCC1913.

$$\frac{1\mu A \cdot R_{PL}}{V_{FET}}$$

Therefore, the maximum average power dissipation in the MOSFET can be approximated by:

$$P_{FET(avg)} =$$

$$V_{FET} \cdot I_{MAX} \cdot \frac{1\mu A \cdot R_{PL}}{V_{FET}} = I_{MAX} \cdot 1\mu A \cdot R_{PL}$$

Notice that in the approximation,  $V_{FET}$  cancels. therefore, average power dissipation is limited in the NMOS pass element.

Overload Comparator

The linear amplifier in the UCC1913 ensures that the output NMOS does not pass more than  $I_{MAX}$  (which is  $V_{IMAX}/R_S$ ). In the event the output current exceeds the programmed  $I_{MAX}$  by  $0.2V/R_S$ , which can only occur if the output FET is not responding to a command from the IC, the CT pin will begin charging with I3, 1mA, and continue to charge to approximately 8V. This allows a constant fault to show up on the SD/FLT pin, and also since the voltage on CT will only charge past 2.5V in an overload fault mode, it can be used for detection of output FET failure or to build in redundancy in the system.

Determining External Component Values

Referring now to Figure 3. To set  $R_{VDD}$  the following must be achieved:

$$\frac{V_{IN(min)}}{R_{VDD}} > \frac{10V}{(R1 + R2)} + 2mA$$

In order to estimate the minimum timing capacitor,  $C_T$ , several things must be taken into account. For example, given the schematic below as a possible (and at this point, a standard) application, certain external component values must be known in order to estimate  $C_{T(min)}$ .

Now, given the values of  $C_{OUT}$ , Load,  $R_{SENSE}$ ,  $V_{SS}$ , and the resistors determining the voltage on the IMAX pin, the user can calculate the approximate startup time of the node  $V_{OUT}$ . This startup time must be faster than the time it takes for  $C_T$  to charge to 2.5V (relative to  $V_{SS}$ ), and is the basis for estimating the minimum value of  $C_T$ . In order to determine the value of the sense resistor,  $R_{SENSE}$ , assuming the user has determined the fault current,  $R_{SENSE}$  can be calculated by:

$$R_{SENSE} = \frac{50mV}{I_{FAULT}}$$

**APPLICATION INFORMATION (cont.)**

Next, the variable  $I_{MAX}$  must be calculated.  $I_{MAX}$  is the maximum current that the UCC1913 will allow through the transistor, M1, and it can be shown that during startup with an output capacitor the power MOSFET, M1, can be modeled as a constant current source of value  $I_{MAX}$  where:

$$I_{MAX} = \frac{V_{IMAX}}{R_{SENSE}}$$

where  $V_{IMAX}$  = voltage on pin IMAX.

Given this information, calculation of the startup time is now possible via the following:

Current Source Load:

$$T_{START} = \frac{C_{OUT} \cdot |VSS|}{I_{MAX} - I_{LOAD}}$$

Resistive Load:

$$T_{START} = C_{OUT} \cdot R_{OUT} \cdot \ln \left( \frac{I_{MAX} \cdot R_{OUT}}{I_{MAX} \cdot R_{OUT} - |VSS|} \right)$$

Once  $T_{START}$  is calculated, the power limit feature of the UCC1913 must be addressed and component values derived. Assuming the user chooses to limit the maximum allowable average power that will be associated with the circuit breaker, the power limiting resistor,  $R_{PL}$ , can be easily determined by the following:

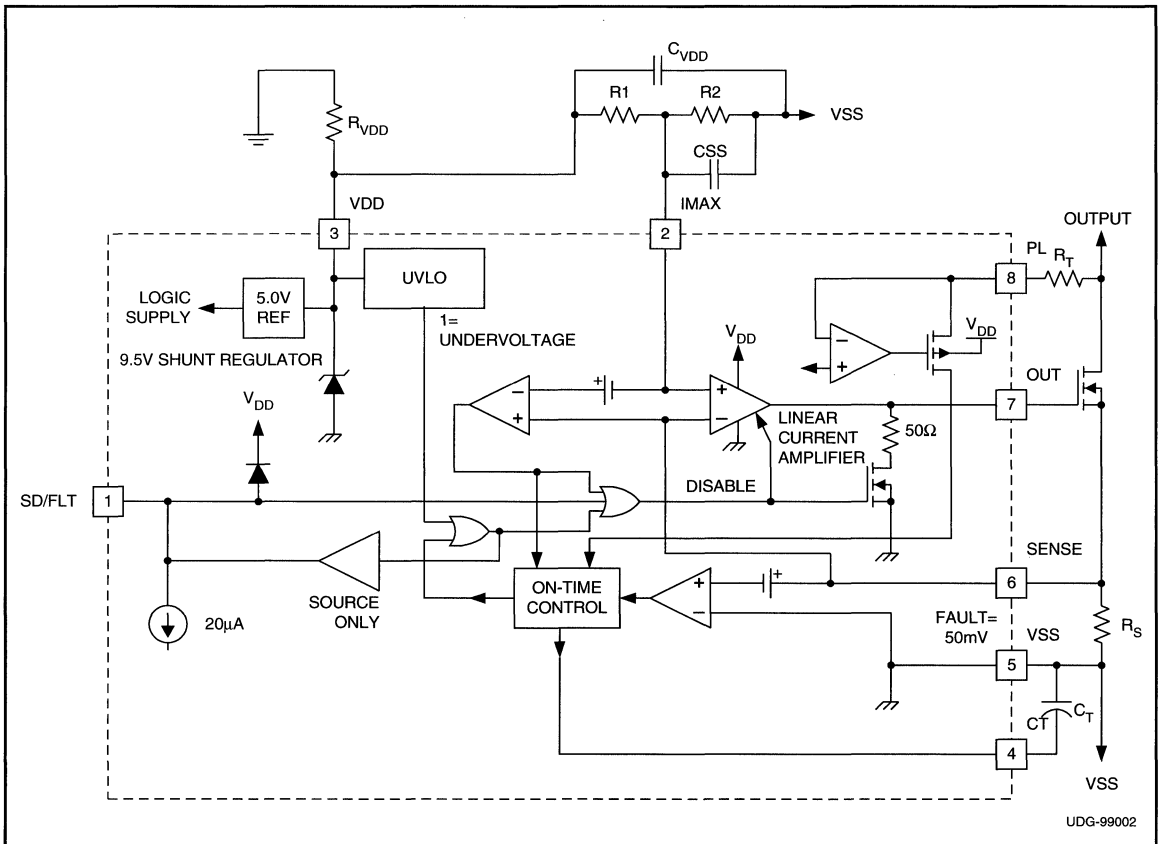


Figure 6. Typical application diagram.

**APPLICATION INFORMATION (cont.)**

$$R_{PL} = \frac{P_{FET(avg)}}{1\mu A \cdot I_{MAX}}$$

where a minimum  $R_{PL}$  exists defined by  $R_{PL(min)} = \frac{|VSS|}{5mA}$

Finally, after computing the aforementioned variables, the minimum timing capacitor can be derived as such:

Current Source Load:

$$C_{T(min)} = \frac{(3 \cdot T_{START} \cdot 62\mu A \cdot R_{PL} + |VSS| - 10V)}{10 \cdot R_{PL}}$$

Resistive Load:

$$C_{T(min)} =$$

$$\frac{3 \cdot T_{START} (31\mu A \cdot R_{PL} + |VSS| - 5V - I_{MAX} \cdot R_{OUT})}{5 \cdot R_{PL}} +$$

$$\frac{3 \cdot R_{OUT} \cdot |VSS| \cdot C_{OUT}}{5 \cdot R_{PL}}$$

**SAFETY RECOMENDATION**

Although the UCC3913 is designed to provide system protection for all fault conditions, all integrated circuits can ultimately fail short. For this reason, if the UCC3913 is intended for use in safety critical applications where UL or some other safety rating is required, a redundant

safety device such as a fuse should be placed in series with the device. The UCC3913 will prevent the fuse from blowing for virtually all fault conditions, increasing system reliability and reducing maintenance cost, in addition to providing the hot swap benefits of the device.



# 5V to 35V Hot Swap Power Manager

## FEATURES

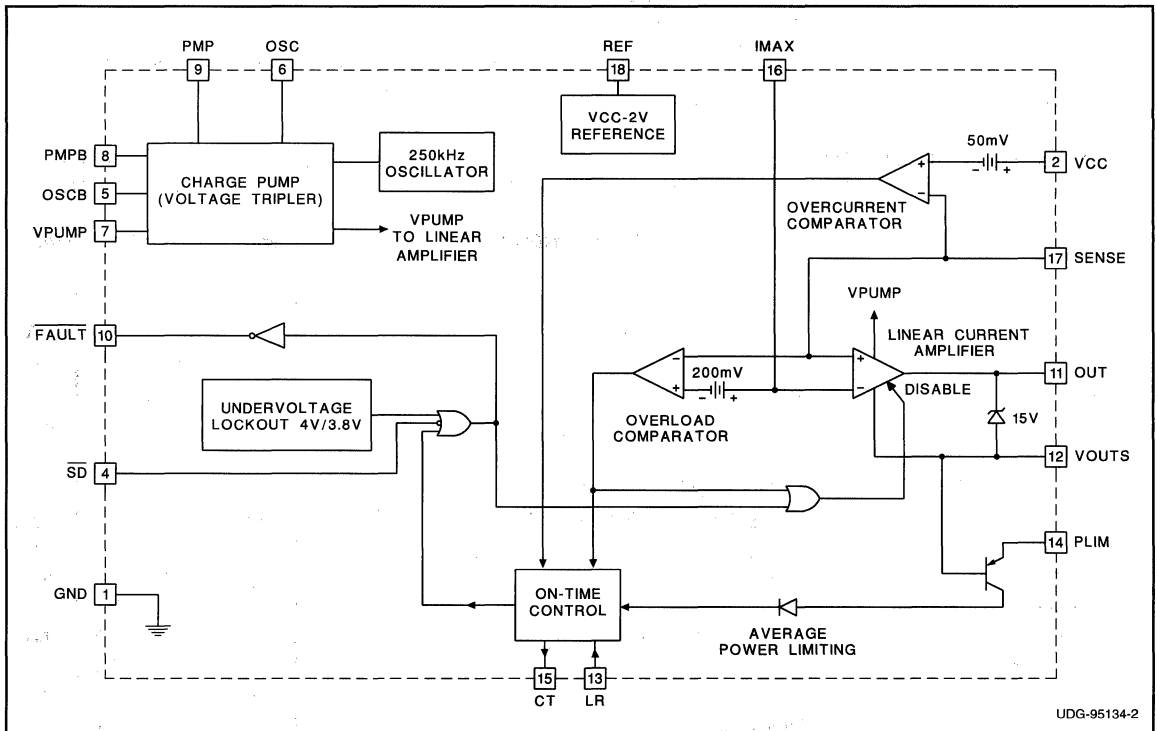
- 5V to 35V Operation
- Precision Maximum Current Control
- Precision Fault Threshold
- Programmable Average Power Limiting
- Programmable Overcurrent Limit
- Shutdown Control
- Charge Pump for Low RDSON High-Side Drive
- Latch Reset Function Available
- Output Drive Vgs Clamping
- Fault Output Indication
- 18 Pin DIL and SOIC Packages

## DESCRIPTION

The UC3914 family of Hot Swap Power Managers provides complete power management, hot swap and fault handling capability. Integrating this part and a few external components, allows a board to be swapped in or out upon failure or system modification without removing power to the hardware, while maintaining the integrity of the powered system. Complementary output drivers and diodes have been integrated for use with external capacitors as a charge pump to ensure sufficient gate drive to the external NMOS transistor for low  $R_{DS(ON)}$ . All control and housekeeping functions are integrated and externally programmable and include the fault current level, maximum output sourcing current, maximum fault time and average power limiting of the external FET. The UC3914 features a duty ratio current limiting technique, which provides peak load capability while limiting the average power dissipation of the external pass transistor during fault conditions. The fault level is fixed at 50mV with respect to VCC to minimize total dropout. The fault current level is set with an external current sense resistor. The maximum allowable sourcing current is programmed by using a resistor divider from VCC to REF to set the voltage on IMAX. The maximum current level, when the output appears as a current source is  $(V_{CC} - V_{IMAX})/R_{SENSE}$ .

(continued)

## BLOCK DIAGRAM

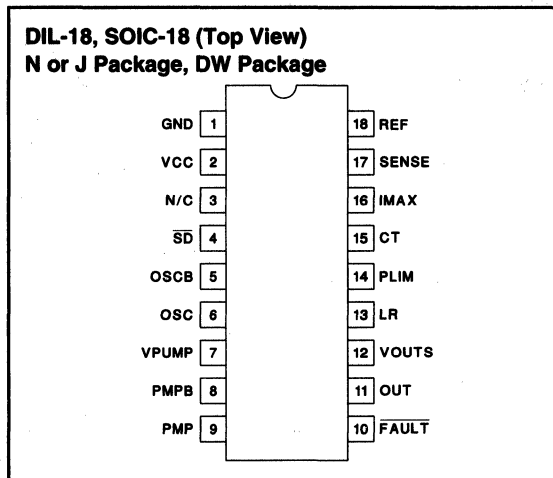


### ABSOLUTE MAXIMUM RATINGS

Input Supply Voltage, VCC	40V
Maximum Forced Voltage	
SD	12V
IMAX	VCC
LR	12V
Maximum Current	
FAULT	20mA
PLIM	10mA
Maximum Voltage, FAULT	40V
Reference Output Current	Internally Limited
Storage Temperature	-65°C to +150°C
Junction Temperature	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.)	+300°C

Unless otherwise indicated, voltages are referenced to ground. Currents are positive into, negative out of specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of package.

### CONNECTION DIAGRAM



### DESCRIPTION (cont.)

When the output current is less than the fault level, the external output transistor remains switched on. When the output current exceeds the fault level, but is less than the maximum sourcing level programmed by IMAX, the output remains switched on, and the fault timer starts to charge  $C_T$ , a timing capacitor. Once  $C_T$  charges to 2.5V, the output device is turned off and  $C_T$  is slowly discharged. Once  $C_T$  is discharged to 0.5V, the IC performs a retry and the output transistor is switched on again. The UC3914 offers two distinct reset modes. In one

mode with LR left floating or held low, the IC will repeatedly try to reset itself if a fault occurs as described above. In the second mode with LR held high, once a fault occurs, the output is latched off until either LR is toggled low, the part is shutdown then re-enabled using SD, or the power to the part is turned off and then on again.

This part is offered in both 18 pin DW Wide-Body (SOIC) and Dual-In-Line (DIL) packages.

**ELECTRICAL CHARACTERISTICS:** Unless otherwise specified,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$  for the UC3914,  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for the UC2914, and  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for the UC1914. VCC = 12V,  $V_{PUMP} = V_{PUMP(max)}$ , SD = 5V,  $CP1 = CP2 = C_{PUMP} = 0.01\mu\text{F}$ .  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>VCC Section</b>					
I <sub>CC</sub>	(Note 2)		8	15	mA
	VCC = 35V, (Note 2)		12	20	mA
Shutdown I <sub>CC</sub>	$\overline{SD} = 0V$		500	900	$\mu\text{A}$
UVLO	Turn on threshold		4	4.4	V
UVLO Hysteresis		100	200	350	mV
<b>Fault Timing Section</b>					
Overcurrent Threshold	$T_J = 25^\circ\text{C}$ , with respect to VCC	-55	-50	-45	mV
	Over operating temperature, with respect to VCC	-57	-50	-42	mV
IMAX Input Bias			1	3	$\mu\text{A}$
CT Charge Current	CT = 1V	-140	-100	-60	$\mu\text{A}$
CT Discharge Current	CT = 1V	2	3	4.5	$\mu\text{A}$
CT Charge Current	CT = 1V, Overload condition	-6	-3	-1.5	mA
CT Fault Threshold		2.25	2.5	2.75	V
CT Reset Threshold		0.45	0.5	0.55	V
Output Duty Cycle	Fault condition, I <sub>PL</sub> = 0	1.5	3	4.5	%

**ELECTRICAL CHARACTERISTICS:** Unless otherwise specified,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$  for the UC3914,  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for the UC2914, and  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for the UC1914.  $V_{CC} = 12\text{V}$ ,  $V_{PUMP} = V_{PUMP(max)}$ ,  $\overline{SD} = 5\text{V}$ ,  $CP1 = CP2 = C_{PUMP} = 0.01\mu\text{F}$ .

$T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Output Section</b>					
OUT High Voltage	$V_{OUTS} = V_{CC}$ , $V_{PUMP} = V_{PUMP max}$ , with respect to $V_{PUMP}$	-1.5	-1		V
OUT High Voltage	$V_{OUTS} = V_{CC}$ , $V_{PUMP} = V_{PUMP max}$ , $I_{OUT} = -2\text{mA}$ , with respect to $V_{PUMP}$	-2	-1.5		V
OUT Low Voltage	$I_{OUT} = 0$		0.8	1.3	V
	$I_{OUT} = 5\text{mA}$		1	2	V
	$I_{OUT} = 25\text{mA}$ , Overload Condition, $V_{OUTS} = 0\text{V}$		1.2	1.8	V
OUT Clamp Voltage	$V_{OUTS} = 0\text{V}$	11.5	13	14.5	V
Rise Time	$C_{OUT} = 1\text{nF}$ (Note 1)		750	1250	ns
Fall Time	$C_{OUT} = 1\text{nF}$ (Note 1)		250	500	ns
<b>Charge Pump Section</b>					
OSC, OSCB Frequency		60	150	250	kHz
OSC, OSCB Output High	$I_{OSC} = -5\text{mA}$	10	11	11.6	V
OSC, OSCB Output Low	$I_{OSC} = 5\text{mA}$		0.2	0.5	V
OSC, OSCB Output Clamp Voltage	$V_{CC} = 25$	18.5	20.5	22.5	V
OSC, OSCB Output Current Limit	High Side Only	-20	-10	-3	mA
Pump Diode Voltage Drop	$I_{DIODE} = 10\text{mA}$ , Measured from PMP to PMPB, PMPB to $V_{PUMP}$	0.5	0.9	1.3	V
PMP Clamp Voltage	$V_{CC} = 25$	18.5	20.5	22.5	V
VPUMP Maximum Voltage	$V_{CC} = 12$ , $V_{OUTS} = V_{CC}$ , Voltage Where Charge Pump Disabled	20	22	24	V
	$V_{CC} = 35\text{V}$ , $V_{OUTS} = V_{CC}$ , Voltage Where Charge Pump Disabled	42	45	48	V
VPUMP Hysteresis	$V_{CC} = 12$ , $V_{OUTS} = V_{CC}$ , Voltage Where Charge Pump Re-enabled	0.3	0.7	1.4	V
	$V_{CC} = 35\text{V}$ , $V_{OUTS} = V_{CC}$ , Charge Pump Re-enabled	0.25	0.7	1.4	V
<b>Linear Current Section</b>					
Input Offset Voltage		-15	0	15	mV
Voltage Gain		60	80		dB
IMAX Control Voltage	$IMAX = OUT$ , $SENSE = V_{CC}$ , with respect to $V_{CC}$	-20	0	20	mV
	$IMAX = OUT$ , $SENSE = REF$ , with respect to $REF$	-20	0	20	mV
SENSE Input Bias			1.5	3.5	$\mu\text{A}$
<b>Reference Section</b>					
REF Output Voltage	With respect to $V_{CC}$	-2.25	-2	-1.75	V
REF Current Limit		12.5	20	50	mA
Load Regulation	$I_{VREF} = 1\text{mA}$ to $5\text{mA}$		25	60	mV
Line Regulation	$V_{CC} = 5\text{V}$ to $35\text{V}$		25	100	mV
<b>Shutdown Section</b>					
Shutdown Threshold		0.6	1.5	2	V
Input Current	$\overline{SD} = 5\text{V}$		150	300	$\mu\text{A}$
Delay to Output	(Note 1)		0.5	2	$\mu\text{s}$
<b>Fault Section</b>					
Fault Output Low	$I_{FAULT} = 1\text{mA}$		100	200	mV
Fault Output Leakage	$V_{FAULT} = 35\text{V}$		10	500	nA

**ELECTRICAL CHARACTERISTICS:** Unless otherwise specified,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$  for the UC3914,  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for the UC2914, and  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for the UC1914.  $V_{CC} = 12\text{V}$ ,  $V_{PUMP} = V_{PUMP}(\text{MAX})$ ,  $SD = 5\text{V}$ ,  $CP1 = CP2 = C_{PUMP} = 0.01\mu\text{F}$ .

$T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Latch Section</b>					
LR Threshold	High to Low	0.6	1.4	2	V
Input Current	LR = 5V		500	750	$\mu\text{A}$
<b>Power Limiting Section</b>					
Duty Cycle Control	In Fault, $I_{PLIM} = 200\mu\text{A}$	0.6	1.3	2.0	%
	In Fault, $I_{PLIM} = 3\text{mA}$	0.05	0.12	0.2	%
<b>Overload Section</b>					
Delay to Output	(Note 1)		500	1250	ns
Threshold	Respect to IMAX	-250	-200	-150	mV

Note 1: Guaranteed by design. Not 100% tested in production.

Note 2: A mathematical averaging is used to determine this value. See Application Section for more information.

## PIN DESCRIPTIONS

**CT:** A capacitor is connected to this pin in order to set the maximum fault time. The minimum fault time must be more than the time to charge external load capacitance. The fault time is defined as:

$$T_{FAULT} = \frac{2 \cdot CT}{I_{CH}}$$

where  $I_{CH} = 100\mu\text{A} + I_{PL}$ , where  $I_{PL}$  is the current into the power limit pin. Once the fault time is reached the output will shutdown for a time given by:

$$T_{SD} = \frac{2 \cdot CT}{I_{DIS}}$$

where  $I_{DIS}$  is nominally  $3\mu\text{A}$ .

**FAULT:** Open collector output which pulls low upon any of the following conditions: Timer fault, Shutdown, UVLO. This pin **MUST** be pulled up to VCC or another supply through a suitable impedance.

**GND:** Ground reference for the IC.

**IMAX:** This pin programs the maximum allowable sourcing current. Since REF is a  $-2\text{V}$  reference (with respect to VCC), a voltage divider can be derived from VCC to REF in order to generate the program level for the IMAX pin. The current level at which the output appears as a current source is equal to the voltage on the IMAX pin, with respect to VCC, divided by the current sense resistor. If desired, a controlled current startup can be programmed with a capacitor on IMAX to VCC.

**LR:** If this pin is held high and a fault occurs, the timer will be prevented from resetting the fault latch when CT is discharged below the reset comparator threshold. The part will not retry until this pin is brought to a logic low or

a power-on-reset occurs. Pulling this pin low before the reset time is reached will not clear the fault until the reset time is reached. Floating or holding this pin low will result in the part repeatedly trying to reset itself if a fault occurs.

**OUT:** Output drive to the MOSFET pass element. Internal clamping ensures that the maximum VGS drive is 15V.

**OSC, OSCB:** Complementary output drivers for intermediate charge pump stages. A  $0.01\mu\text{F}$  capacitor should be placed between OSC and PMP, and OSCB and PMPB.

**PLIM:** This feature ensures that the average MOSFET power dissipation is controlled. A resistor is connected from this pin to VCC. Current will flow into PLIM which adds to the fault timer charge current, reducing the duty cycle from the typical 3% level. When  $I_{PL} \gg 100\mu\text{A}$  then the average MOSFET power dissipation is given by:  $P_{FET\_AVG} = IMAX \cdot 3 \cdot 10^{-6} \cdot R_{PL}$ .

**PMP, PMPB:** Complementary pins which couple charge pump capacitors to internal diodes and are used to provide charge to the reservoir capacitor tied to VPUMP. Typical capacitor values used are  $0.01\mu\text{F}$ .

**REF:**  $-2\text{V}$  reference with respect to VCC used to program the IMAX pin voltage. A  $0.1\mu\text{F}$  ceramic or tantalum capacitor **MUST** be tied between this pin and VCC to ensure proper operation of the chip.

**SD:** When this TTL compatible input is brought to a logic low, the output of the linear amplifier is driven low, FAULT is pulled low and the IC is put into a low power mode. The **ABSOLUTE** maximum voltage that can be placed on this pin is 12V.

**PIN DESCRIPTIONS (cont.)**

**SENSE:** Input voltage from current sense resistor. When there is greater than 50mV across this pin with respect to VCC, a fault is sensed and  $C_T$  begins to charge.

**VCC:** Input voltage to the IC. Typical voltages are 4.5V to 35V. The minimum input voltage required for operation is 4.5V.

**VOULTS:** Source connection of external N-channel MOSFET and sensed output voltage of load.

**VPUMP:** Charge pump output voltage. A capacitor should be tied between this pin and VOULTS with a typical value being 0.01 $\mu$ F.

**TYPICAL CHARACTERISTIC CURVES**

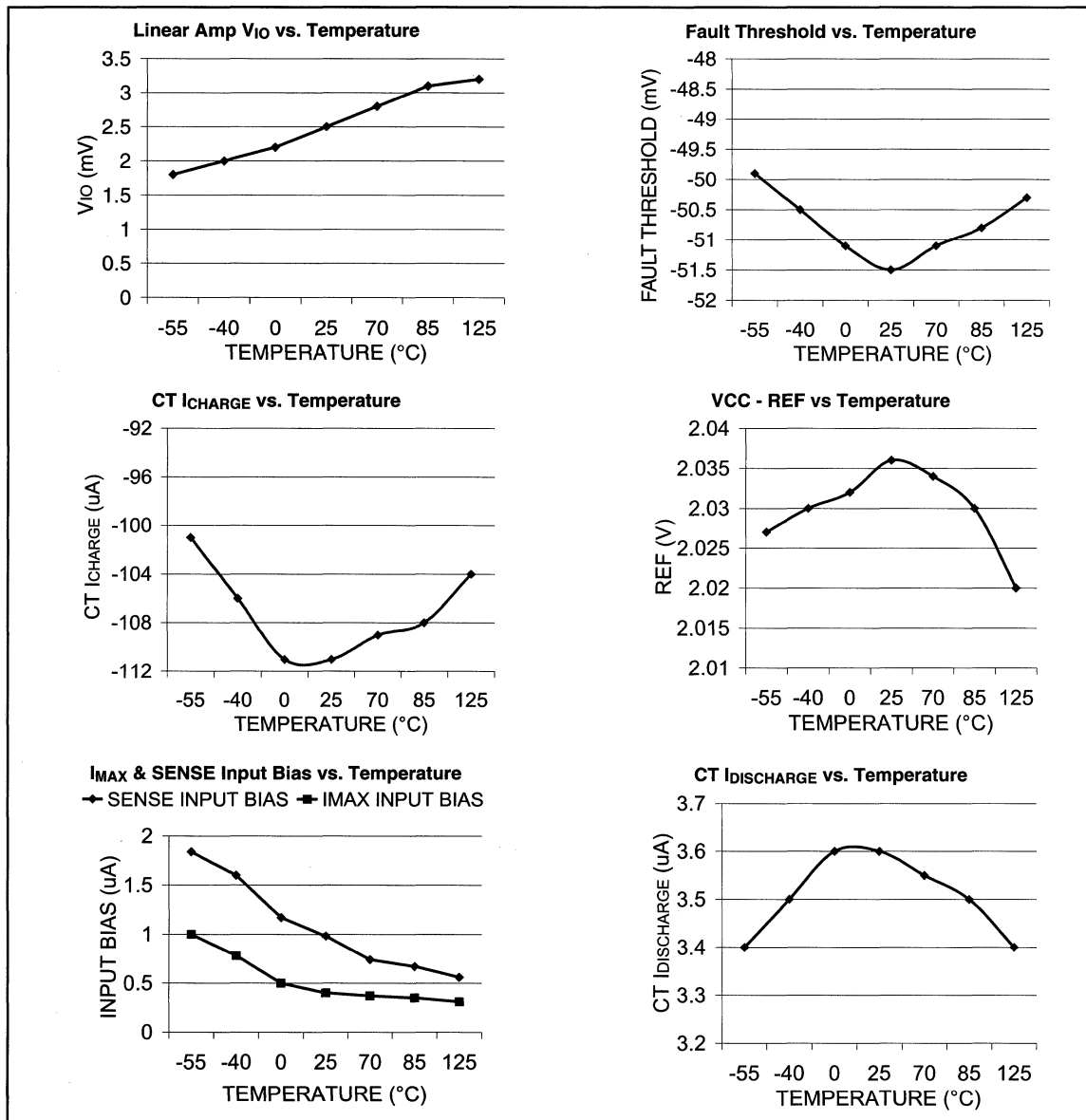


Figure 1. Typical characteristic curves.

### APPLICATION INFORMATION

The UC3914 is to be used in conjunction with external passive components and an N-channel MOSFET (NMOS) to facilitate hot swap capability of application modules. A typical application set-up is given in Figure 9. The term hot swap refers to the system requirement that submodules be swapped in or out upon failure or system modification without removing power to the operating hardware. The integrity of the power bus must not be compromised due to the addition of an unpowered module. Significant power bus glitches can occur due to the substantial initial charging current of on-board module bypass capacitance and other load conditions (for more information on hot swapping and power management applications, see Application Note U-151). The UC3914 provides protection by monitoring and controlling the output current of an external NMOS to charge this capacitance and provide load current. The addition of the NMOS, a sense resistor,  $R_{SENSE}$ , and two other resistors,  $R1$  and  $R2$ , sets the programmed maximum current level the NMOS can source to charge the load in a controlled manner. The equation for this current,  $I_{MAX}$ , is:

$$I_{MAX} = \frac{V_{CC} - V_{IMAX}}{R_{SENSE}}$$

where  $V_{IMAX}$  is the voltage generated at the IMAX pin.

Analysis of the application circuit shows that  $V_{IMAX}$  (with respect to GND) can be defined as:

$$V_{IMAX} = V_{REF} + \frac{(V_{CC} - V_{REF}) \cdot R1}{R1 + R2} = \frac{2V \cdot R1}{R1 + R2} + V_{REF}$$

where  $V_{REF}$  is the voltage on the REF pin and whose internally generated potential is two volts below  $V_{CC}$ . The UC3914 also has an internal overcurrent comparator which monitors the voltage between SENSE and  $V_{CC}$ . If this voltage exceeds 50mV, the comparator determines that a fault has occurred, and a timing capacitor,  $C_T$ , will begin to charge. This can be rewritten as a current which causes a fault,  $I_{FAULT}$ :

$$I_{FAULT} = \frac{50mV}{R_{SENSE}}$$

### Fault Timing

Figure 2 shows the circuitry associated with the fault timing function of the UC3914. A typical fault mode, where the overload comparator and current source I3 do not factor into operation (switch S2 is open), will first be considered. Once the voltage across  $R_{SENSE}$  exceeds 50mV, a fault has occurred. This causes the timing capacitor,  $C_T$ , to charge with a combination of 100 $\mu$ A (I1) plus the current from the power limiting circuitry (IPL).

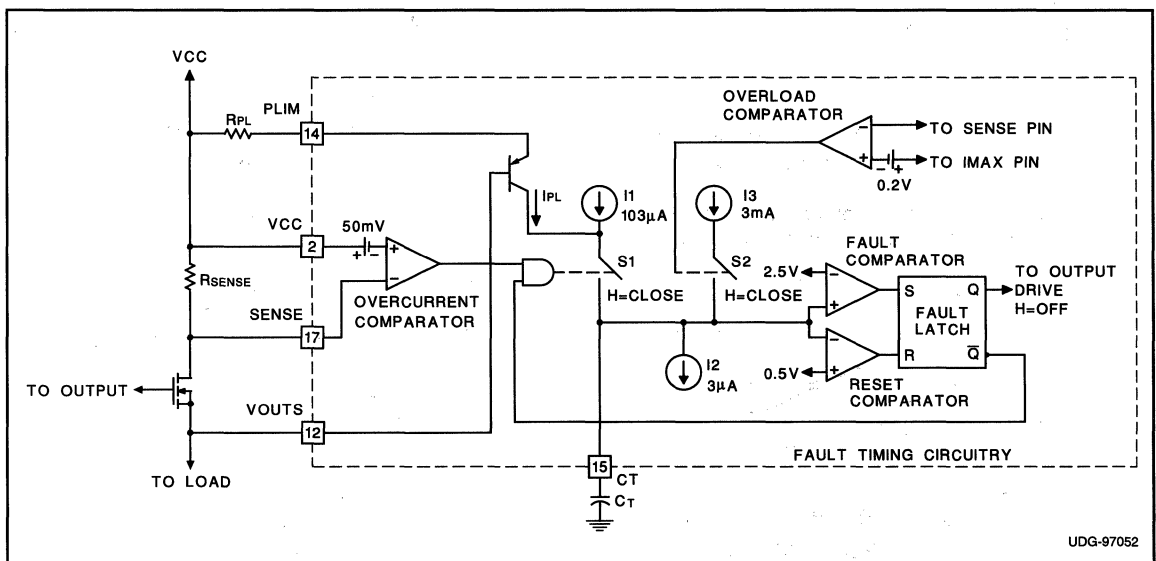
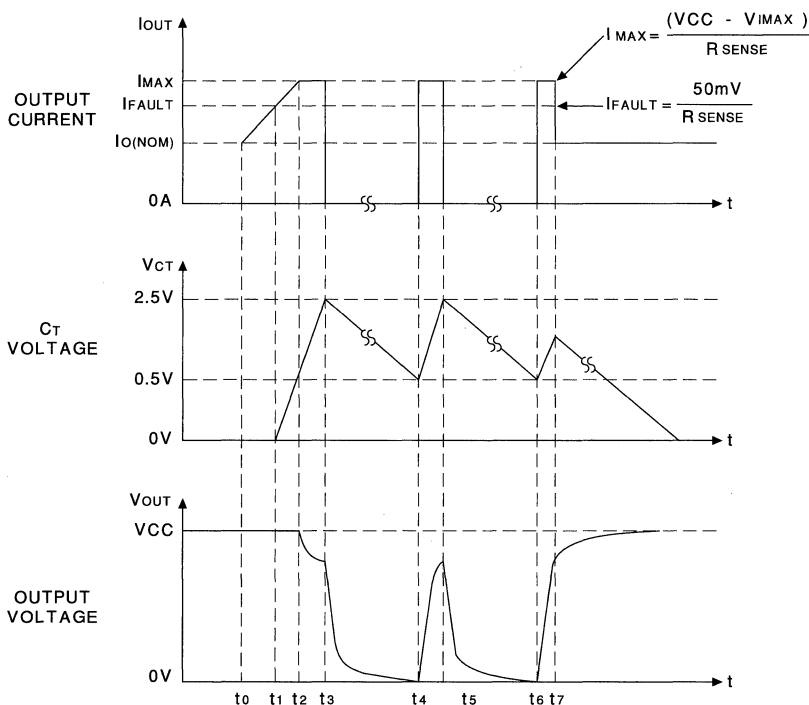


Figure 2. Fault timing circuitry for the UC3914, including power limit and overcurrent.

**APPLICATION INFORMATION (cont.)**

Figure 3a shows typical fault timing waveforms for the external NMOS output current, the voltage on the CT pin, and the output load voltage,  $V_{OUT}$ , with LR left floating or grounded. The output voltage waveforms have assumed an RC characteristic load and time constants will vary depending upon the component values. Prior to time  $t_0$ , the load is fully charged to almost VCC and the NMOS is supplying the current,  $I_O$ , to the load. At  $t_0$ , the current begins to ramp up due to a change in the load conditions until, at  $t_1$ , the fault current level,  $I_{FAULT}$ , has been reached to cause switch S1 to close. This results in CT

being charged with the current sources  $I_1$  and  $I_{PL}$ . During this time,  $V_{OUT}$  is still almost equal to VCC except for small losses from voltage drops across the sense resistor and the NMOS. The output current reaches the programmed maximum level,  $I_{MAX}$ , at  $t_2$ . The  $C_T$  voltage continues to rise since  $I_{MAX}$  is still greater than  $I_{FAULT}$ . The load output voltage drops because the current load requirements have become greater than the controlled maximum sourcing current. The  $C_T$  voltage reaches the upper comparator threshold (Figure 2) of 2.5V at  $t_3$ , which promptly shuts off the gate drive to the NMOS (not



- t0:** Normal conditions - output current is nominal, output voltage is at positive rail, VCC
- t1:** Fault control reached - output current rises above the programmed fault value,  $C_T$  begins to charge with  $\cong 100\mu A + I_{PL}$ .
- t2:** Maximum current reached - output current reaches the programmed maximum level and becomes a constant current with value  $I_{MAX}$ .
- t3:** Fault occurs -  $C_T$  has charged to 2.5V, fault output

- goes low, the FET turns off allowing no output current to flow,  $V_{OUT}$  discharge to GND.
- t4:** Retry -  $C_T$  has discharged to 0.5V, but fault current is still exceeded,  $C_T$  begins charging again, FET is on,  $V_{OUT}$  increases.
- t5 = t3:** Illustrates <3% duty cycle depending upon  $R_{PL}$  selected.
- t6 = t4**
- t7 = t0:** Fault released, normal condition - return to normal operation of the hot swap power manager.

**Figure 3a: Typical timing diagram.**

## APPLICATION INFORMATION (cont.)

shown but can be inferred from the fact that no output current is provided to the load), latches in the fault and opens switch S1 disconnecting the charging currents I1 and I<sub>PL</sub> from C<sub>T</sub>. Since no output current is supplied, the load voltage decays at a rate determined by the load characteristics and the capacitance. The 3μA current source, I2, discharges C<sub>T</sub> to the 0.5V reset comparator threshold. This time is significantly longer than the charging time and is the basis for the duty cycle current limiting technique. When the C<sub>T</sub> voltage reaches 0.5V at t4, the part performs a retry, allowing the NMOS to again source current to the load and cause V<sub>OUT</sub> to rise. In this particular example, I<sub>MAX</sub> is still sourced by the NMOS at each attempted retry and the fault timing sequence is repeated until time t7 when the load requirements change to I<sub>O</sub>. Since I<sub>O</sub> is less than the fault current level at this time, switch S1 is opened, I2 discharges C<sub>T</sub> and V<sub>OUT</sub> rises to almost VCC.

Figure 3b shows fault timing waveforms similar to those depicted in Figure 3a except that the latch reset (LR) function is utilized. Operation is the same as described above until t4 when the voltage on C<sub>T</sub> reaches the reset threshold. Holding LR high prevents the latch from being reset, preventing the IC from performing a retry (sourcing current to the load). The UC3914 is latched off until either LR is pulled to a logic low, or the chip is forced into an under voltage lockout (UVLO) condition and back out of UVLO causing the latch to automatically perform a power on reset. Figure 3b illustrates LR being toggled low at t5, causing the part to perform a retry. Time t6 again illustrates what happens when a fault is detected. The LR pin is toggled low and back high at time t7, prior to the voltage on the C<sub>T</sub> pin hitting the reset threshold. This information tells the UC3914 to allow the part to perform a retry when the lower reset threshold is reached, which occurs at t8. Time t9 corresponds to when load conditions change to where a fault is not present as described for Figure 3a.

### Power Limiting

The power limiting circuitry is designed to only source current into the C<sub>T</sub> pin. To implement this feature, a resistor, R<sub>PL</sub>, should be placed between VCC and PLIM. The current, I<sub>PL</sub> (shown in Figure 2) is given by the following expression:

$$I_{PL} = \frac{V_{CC} - V_{OUTS}}{R_{PL}}, \text{ for } V_{OUTS} > 1V + V_{CT}$$

where V<sub>CT</sub> is the voltage on the C<sub>T</sub> pin. For V<sub>OUTS</sub> < 1V + V<sub>CT</sub> the common mode range of the power limiting cir-

cuitry causes I<sub>PL</sub> = 0 leaving only the 100μA current source to charge C<sub>T</sub>. V<sub>CC</sub> - V<sub>OUTS</sub> represents the voltage across the NMOS pass device.

Later it will be shown how this feature will limit average power dissipation in the pass device. Note that under a fault condition where the output current is just above the fault level, but less than the maximum level, V<sub>OUTS</sub> ~ VCC, I<sub>PL</sub> = 0 and the C<sub>T</sub> charging current is 100μA.

During a fault, the C<sub>T</sub> pin will charge at a rate determined by the internal charging current and the external timing capacitor, C<sub>T</sub>. Once C<sub>T</sub> charges to 2.5V, the fault comparator trips and sets the fault latch. When this occurs, OUT is pulled down to V<sub>OUTS</sub>, causing the external NMOS to shut off and the charging switch, S1, to open. C<sub>T</sub> will be discharged with I2 until the C<sub>T</sub> potential reaches 0.5V. Once this occurs, the fault latch will reset (unless LR is being held high, whereby a fault can only be cleared by pulling this pin low or going through a power-on-reset cycle), which re-enables the output of the linear amplifier and allows the fault circuitry to regain control of the charging switch. If a fault is still present, the overcurrent comparator will close the charging switch causing the cycle to repeat. Under a constant fault the duty cycle is given by:

$$\text{Duty Cycle} = \frac{3\mu A}{I_{PL} + 100\mu A}$$

Average power dissipation can be limited using the PLIM pin. Average power dissipation in the pass element is given by:

$$\begin{aligned} PFET_{avg} &= (V_{CC} - V_{OUTS}) \cdot I_{MAX} \cdot \text{Duty Cycle} \\ &= (V_{CC} - V_{OUTS}) \cdot I_{MAX} \cdot \frac{3\mu A}{I_{PL} + 100\mu A} \end{aligned}$$

VCC - V<sub>OUTS</sub> is the drain to source voltage across the FET. When I<sub>PL</sub> >> 100μA, the duty cycle equation given above can be rewritten as:

$$\text{Duty Cycle} = \frac{R_{PL} + 3\mu A}{(V_{CC} - V_{OUTS})}$$

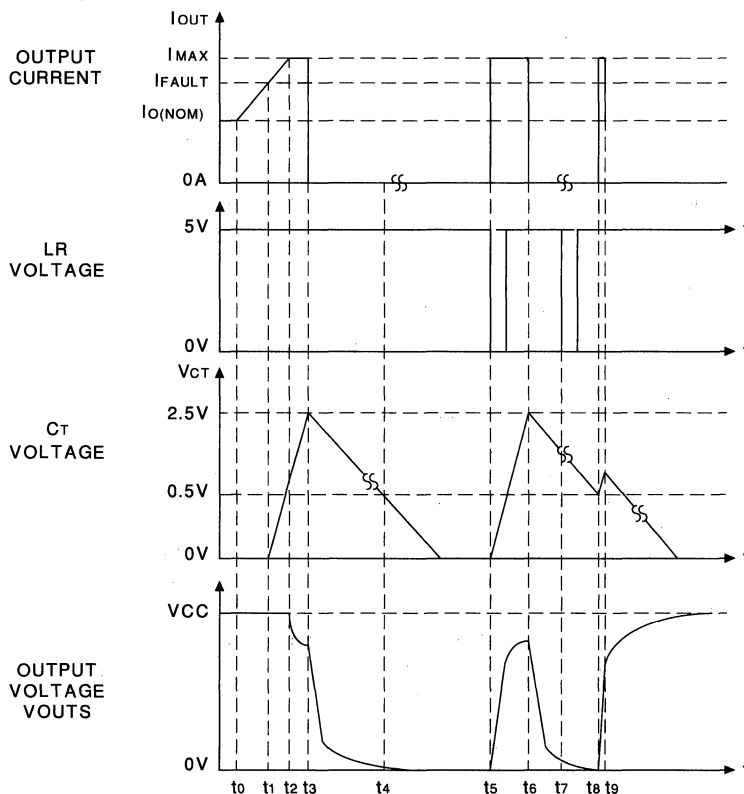
and the average power dissipation of the MOSFET is given by:

$$\begin{aligned} PFET_{avg} &= (V_{CC} - V_{OUTS}) \cdot I_{MAX} \cdot \frac{R_{PL} + 3\mu A}{(V_{CC} - V_{OUTS})} \\ &= I_{MAX} \cdot R_{PL} \cdot 3\mu A \end{aligned}$$

The average power is limited by the programmed I<sub>MAX</sub> current and the appropriate value for R<sub>PL</sub>.



APPLICATION INFORMATION (cont.)



UDG-97055

**t<sub>0</sub>:** Normal conditions - output current is nominal, output voltage is at positive rail, VCC

**t<sub>1</sub>:** Fault control reached - output current rises above the programmed fault value, C<sub>T</sub> begins to charge with  $\cong 100\mu\text{A} + \text{IPL}$ .

**t<sub>2</sub>:** Maximum current reached - output current reaches the programmed maximum level and becomes a constant current with value I<sub>MAX</sub>.

**t<sub>3</sub>:** Fault occurs - C<sub>T</sub> has charged to 2.5V, fault output goes low, the FET turns off allowing no output current to flow, V<sub>OUT</sub> discharge to GND.

**t<sub>4</sub>:** Reset comparator threshold reached but no retry since LR pin held high.

**t<sub>5</sub>:** LR toggled low, NMOS turned on and sources current to load.

**t<sub>6</sub> = t<sub>3</sub>**

**t<sub>7</sub>:** LR toggled low before V<sub>CT</sub> reaches reset comparator threshold, causing retry.

**t<sub>8</sub>:** Since LR toggled low during present cycle, NMOS turned on and sources current to load.

**t<sub>9</sub> = t<sub>0</sub>:** Fault released, normal condition - return to normal operation of the hot swap power manager.

Figure 3b. Typical timing diagram utilizing LR (Latch Reset) function.

## APPLICATION INFORMATION (cont.)

### Overload Comparator

The linear amplifier in the UC3914 ensures that the external NMOS does not source more than the current  $I_{MAX}$ , defined above as:

$$I_{MAX} = \frac{VCC - V_{IMAX}}{R_{SENSE}}$$

In the event that output current exceeds the programmed  $I_{MAX}$  by more than  $200mV/R_{SENSE}$ , the output of the linear amplifier will immediately be pulled low (with respect to  $V_{OUTS}$ ) providing no gate drive to the NMOS, and preventing current from being delivered to the load. This situation could occur if the external NMOS is not responding to a command from the IC or output load conditions change quickly to cause an overload condition before the linear amplifier can respond. For example, if the NMOS is sourcing current into a load and the load suddenly becomes short circuited, an overload condition may occur. The short circuit will cause the  $V_{GS}$  of the NMOS to immediately increase, resulting in increased load current and voltage drop across  $R_{SENSE}$ . If this drop exceeds the overload comparator threshold, the amplifier output will be quickly pulled low. It will also cause the CT pin to begin charging with I3, a 3mA current source (refer to Figure 2) and continue to charge until approximately one volt below  $VCC$ , where it is clamped. This allows a constant fault to show up on  $FAULT$  and since the voltage on CT will only charge past 2.5V in an overload fault condition, it can be used for detection of output NMOS failure or to build redundancy into the system.

### Estimating Minimum Timing Capacitance

The startup time of the IC may not exceed the fault time for the application. Since the timing capacitor,  $C_T$ , determines the fault time, its minimum value can be determined by calculating the startup time of the IC. The startup time is dependent upon several external components. A load capacitor,  $C_{LOAD}$ , should be tied between  $V_{OUTS}$  and GND. Its value should be greater than that of  $C_{PUMP}$ , the reservoir capacitor tied from  $V_{PUMP}$  to  $V_{OUTS}$  (see Figure 4). Given values of  $C_{LOAD}$ , Load,  $R_{SENSE}$ ,  $VCC$  and the resistors determining the voltage on  $I_{MAX}$ , the user can calculate the approximate startup time of the node  $V_{OUT}$ . This time must be less than the time it takes for  $C_T$  to charge to 2.5V. Assuming the user has determined the fault current,  $R_{SENSE}$  can be calculated by:

$$R_{SENSE} = \frac{50mV}{I_{FAULT}}$$

$I_{MAX}$  is the maximum current the UC3914 will allow through the transistor M1. During startup with an output

capacitor, M1 can be modeled as a constant current source of value  $I_{MAX}$  where:

$$I_{MAX} = \frac{VCC - V_{IMAX}}{R_{SENSE}}$$

Given this information, calculation of startup time is now possible via the following:

Current Source Load:

$$T_{START} = \frac{C_{LOAD} \cdot VCC}{I_{MAX} - I_{LOAD}}$$

Resistive Load:

$$T_{START} = -R_{LOAD} \cdot C_{LOAD} \cdot \ln \cdot \left( 1 - \frac{VCC}{I_{MAX} \cdot R_{LOAD}} \right)$$

The only remaining external component which may affect the minimum timing capacitor is the optional power limiting resistor,  $R_{PL}$ . If the addition of  $R_{PL}$  is desirable, its value can be determined from the "Fault Timing" section above. The minimum timing capacitor values are now given by

Current Source Load:

$$CT \text{ min} = 2 \cdot T_{START} \cdot \left( \frac{10^{-4} \cdot R_{PL} + \frac{VCC}{2}}{2 \cdot R_{PL}} \right)$$

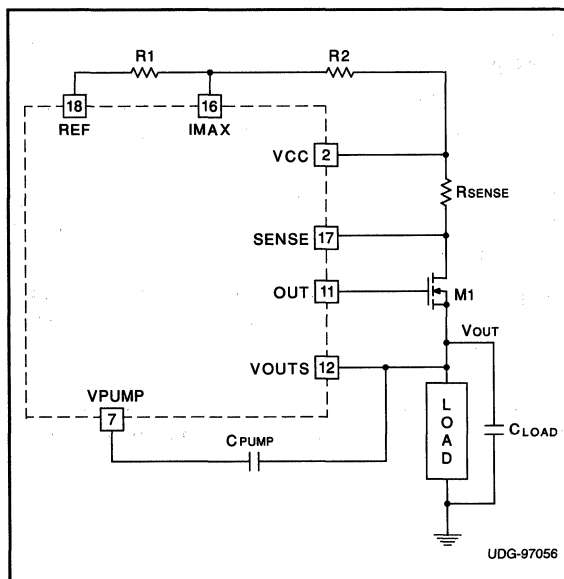


Figure 4. Estimating minimum timing capacitor.

### APPLICATION INFORMATION (cont.)

Resistive Load:

$CT_{min} =$

$$\frac{(10^{-4} \cdot R_{PL} + V_{CC} - (I_{MAX} \cdot R_{LOAD})) \cdot T_{START}}{2 \cdot R_{PL}} + \frac{I_{MAX} \cdot (R_{LOAD})^2 \cdot C_{LOAD}}{2 \cdot R_{PL}} \cdot \left[ 1 - e^{\frac{-T_{START}}{R_{LOAD} \cdot C_{LOAD}}} \right]$$

### Output Current Softstart

The external MOSFET output current can be increased at a user-defined rate to ensure that the output voltage comes up in a controlled fashion by adding capacitor  $C_{SS}$ , as shown in Figure 5. The chip does place one constraint on the soft start time and that is that the charge pump time constant has to be much less than the soft-start time constant to ensure proper soft start operation. The time constant determining the startup time of the charge pump is given by:

$$\tau_{CP} = R_{OUT} \cdot C_{PUMP}$$

$R_{OUT}$  is the output impedance of the charge pump given by:

$$R_{OUT} = \frac{1}{f_{PUMP} \cdot CP}$$

where  $f_{PUMP}$  is the charge pump frequency (125kHz) and  $CP = CP1 = CP2$  are the charge pump flying capacitors. For typical values of  $CP1$ ,  $CP2$  and  $C_{PUMP}$  (0.01 $\mu$ F) and a switching frequency of 125kHz, the output impedance is 800 $\Omega$  and the charge pump time constant is 8 $\mu$ s. The charge pump should be close to being fully charged in 3 time constants or 24 $\mu$ s. By placing a capacitor from  $V_{CC}$  to  $IMAX$ , the voltage at  $IMAX$ , which sets the maximum

output current of the FET, will exponentially decay from  $V_{CC}$  to the desired value set by  $R1$  and  $R2$ . The output current of the MOSFET will be controlled via soft start as long as the soft start time constant ( $\tau_{SS}$ ) is much greater than the charge pump time constant  $\tau_{CP}$ , given by

$$\tau_{SS} = (R1 \parallel R2) \cdot C_{SS}$$

### Minimizing Total Dropout Under Low Voltage Operation

In a typical application, the UC3914 will be used to control the output current of an external NMOS during hot swapping situations. Once the load has been fully charged, the desired output voltage on the load,  $V_{OUT}$ , will be required to be as close to  $V_{CC}$  as possible to minimize total dropout. For a resistive load,  $R_{LOAD}$ , the output voltage is given by:

$$V_{OUT} = \frac{R_{LOAD}}{R_{LOAD} + R_{SENSE} + R_{dsON}} \cdot V_{CC}$$

$R_{SENSE}$  was picked to set the fault current,  $I_{FAULT}$ .  $R_{dsON}$ , the on-resistance of the NMOS, should be made as small as possible to ensure  $V_{OUT}$  is as close to  $V_{CC}$  as possible. For a given NMOS, the manufacturer will specify the  $R_{dsON}$  for a certain  $V_{GS}$  (maybe 7V to 10V). The source potential of the NMOS is  $V_{OUT}$ . In order to ensure sufficient  $V_{GS}$ , this requires the gate of the NMOS, which is the output of the linear amplifier, to be many volts higher than  $V_{CC}$ . The UC3914 provides the capability to generate this voltage through the addition of 3 capacitors,  $CP1$ ,  $CP2$  and  $C_{PUMP}$  as shown in Figure 6. These capacitors should be used in conjunction with the complementary output drivers and internal diodes included on-chip to create a charge pump or voltage

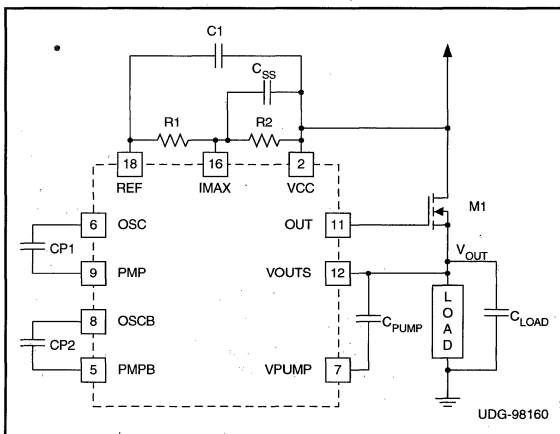


Figure 5. MOSFET soft start diagram.

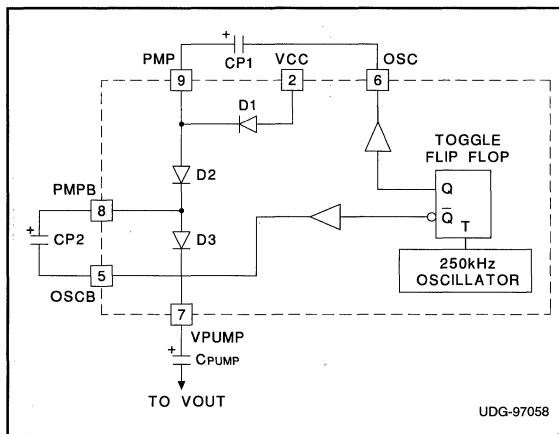


Figure 6. Charge pump block diagram.

### APPLICATION INFORMATION (cont.)

tripler. The circuit boosts VCC by utilizing capacitors CP1, CP2 and CPUMP in such a way that the voltage at VPUMP approximately equals  $(3 \cdot V_{CC}) - (5 \cdot V_{DIODE})$ , almost tripling the input supply voltage to the chip.

On each complete cycle, CP1 is charged to approximately  $V_{CC} - V_{DIODE}$  (unless VCC is greater than 15V causing internal clamping to limit this charging voltage to about 13V) when the output Q of the toggle flip flop is low. When Q is transitioned low (and Q correspondingly is brought high), the negative side of CP2 is pulled to ground, and CP1 charges CP2 up to about  $(2 \cdot V_{CC} - 3 \cdot V_{DIODE})$ . When Q is toggled high, the negative side of CP2 is brought to  $(V_{CC} - V_{DIODE})$ . Since the voltage across a capacitor cannot change instantaneously with time, the positive side of the capacitor swings up to  $(3 \cdot V_{CC} - 4 \cdot V_{DIODE})$ . This charges CPUMP up to  $(3 \cdot V_{CC} - 5 \cdot V_{DIODE})$ .

The maximum output voltage of the linear amplifier is actually less than this because of the ability of the amplifier to swing to within approximately 1V of VPUMP. Due to inefficiencies of the charge pump, the UC3914 may not have sufficient gate drive to fully enhance a standard power MOSFET when operating at input voltages below 7V. Logic Level MOSFETs could be used depending on the application but are limited by their lower current capability. For applications requiring operation below 7V there are two ways to increase the charge pump output volt-

age. Figure 7 shows the typical tripler of figure 6 enhanced with three external schottky diodes. Placing the schottky diodes in parallel with the internal charge pump diodes decreases the voltage drop across each diode thereby increasing the overall efficiency and output voltage of the charge pump.

Figure 8 shows a way to use the existing drivers with external diodes (or Schottky diodes for even higher pump voltages but with additional cost) and capacitors to make a voltage quadrupler. The additional charge pump stage will provide a sufficient pump voltage  $(V_{PUMP} = 4 \cdot V_{CC} - 7 \cdot V_{DIODE})$  to generate the maximum VGS. Operation is similar to the case described above. This additional circuitry is not necessary for higher input voltages because the UC3914 has internal clamping which only allows VPUMP to be 10V greater than VOUTs.

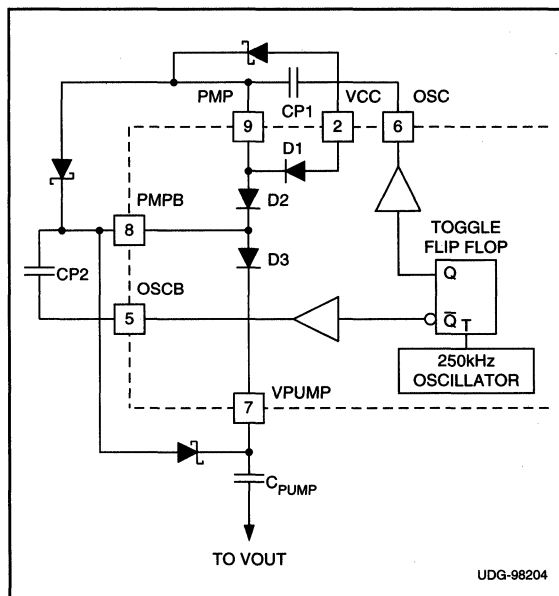


Figure 7. Charge pump block diagram.

Input Voltage (VCC)	Internal Diodes (Vgs)	External Schottky Diodes (Vgs)	Quadrupler (Vgs)
4.5	4.57	6.8	8.7
5	5.8	7.9	8.8
5.5	6.6	8.6	8.9
6	7.6	8.8	9
6.5	8.7	8.8	9
7	8.8	9	9
9	9.2	9.4	9.1
10	9.3	9.4	9.3

Table 1. UC3914 charge pump characteristics.

Table 1 characterizes the UC3914 charge pump in its standard configuration, with external schottky diodes, and configured as a voltage quadrupler. Please note: The voltage quadrupler is unnecessary for input voltages above 7.0V due the internal clamping action.

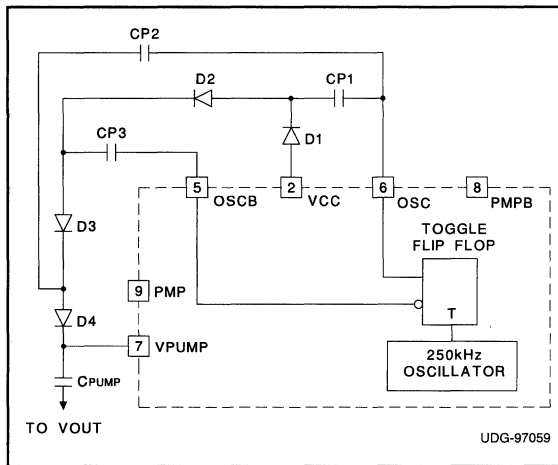
### ICC Specification

The ICC operating measurement is actually a mathematical calculation. The charge pump voltage is constantly being monitored with respect to both VCC and VOUTs to determine whether the pump requires servicing. If there is insufficient voltage on this pin, the charge pump drivers are alternately switched to raise the voltage of the pump (see Fig. 9). Once the voltage on the pump is high enough, the drivers and other charge pump related circuitry are shutdown to conserve current. The pump voltage will decay due to internal loading until it reaches a low enough level to turn the drivers back on. The chip requires significantly different amounts of current during these two modes of operation and the following mathematical calculation is used to figure out the average current:

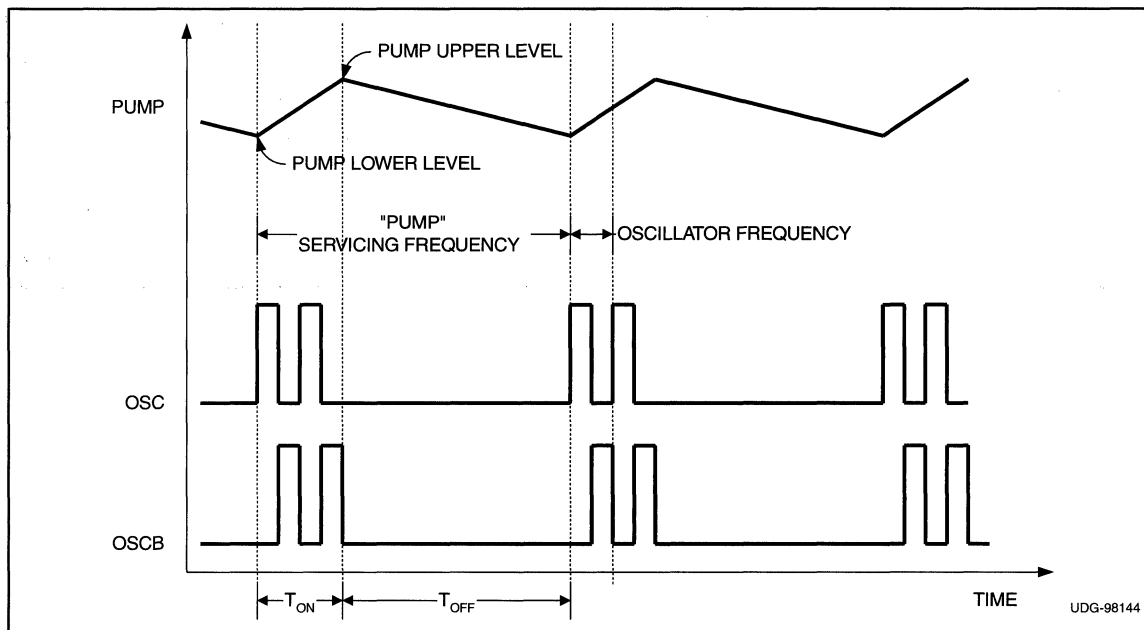
**APPLICATION INFORMATION (cont.)**

$$I_{CC} = \frac{I_{CC_{DRIVERS(on)}} \cdot T_{ON} + I_{CC_{DRIVERS(off)}} \cdot T_{OFF}}{T_{ON} + T_{OFF}}$$

Since the charge pump does not always require servicing, the user may think that the charge pump frequency is much less than the datasheet specification. This is not the case as the free-running frequency is guaranteed to be within the datasheet limits. The charge pump servicing frequency can make it appear as though the drivers are operating at a much lower frequency.



**Figure 8. Low voltage operation to produce higher pump voltage**



**Figure 9. Charge pump waveforms.**

**SAFETY RECOMMENDATIONS**

Although the UC3914 is designed to provide system protection for all fault conditions, all integrated circuits can ultimately fail short. For this reason, if the UC3914 is intended for use in safety critical applications where UL or some other safety rating is required, a redundant safety

device such as a fuse should be placed in series with the device. The UC3914 will prevent the fuse from blowing in virtually all fault conditions, increasing system reliability and reducing maintenance cost, in addition to providing the hot swap benefits of the device.

APPLICATION INFORMATION (cont.)

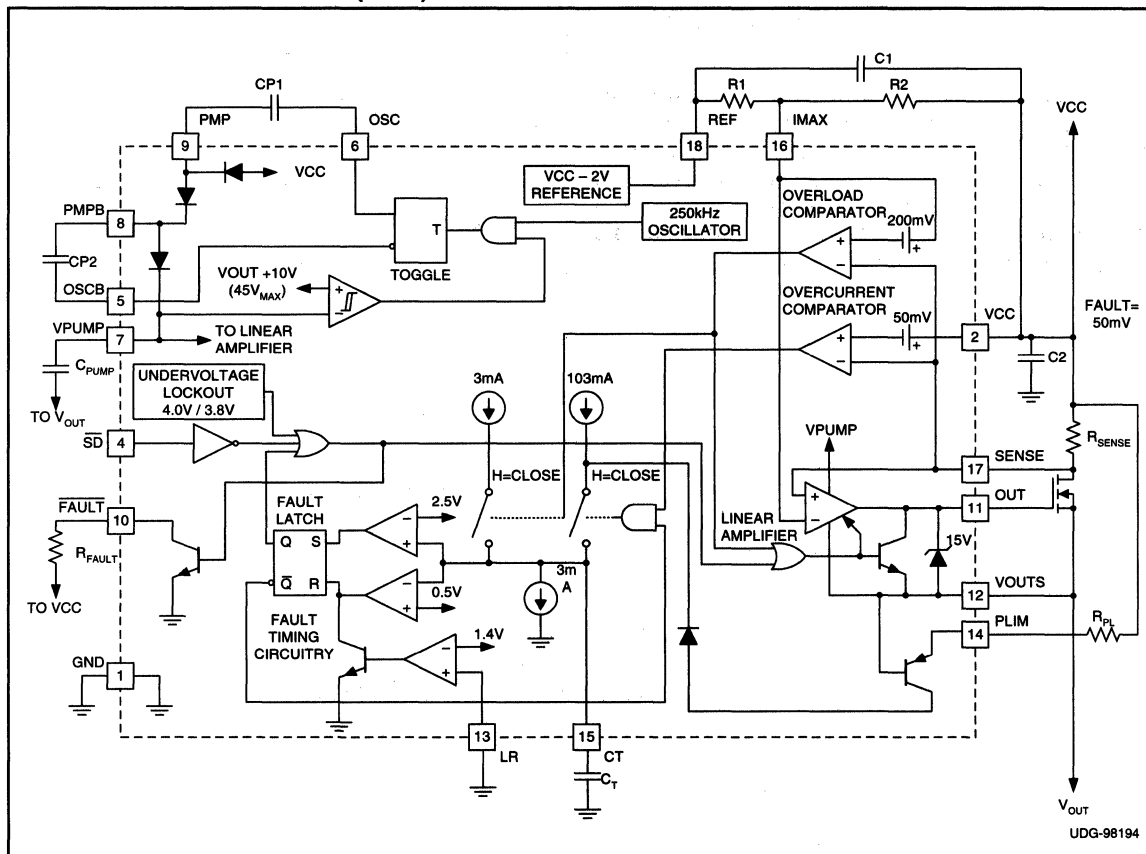


Figure 10. Typical application.

# 15V Programmable Hot Swap Power Manager

**PRELIMINARY**

## FEATURES

- Integrated 0.15 Ohm Power MOSFET
- 7V to 15V Operation
- Digital Programmable Current Limit from 0A to 3A
- 100 $\mu$ A  $I_{CC}$  when Disabled
- Programmable ON Time
- Programmable Start Delay
- Fixed 2% Duty Cycle
- Thermal Shutdown
- Fault Output Indicator
- Maximum Output Current can be set to 1A above the Programmed Fault Level or to a full 4A
- Power SOIC and TSSOP, Low Thermal Resistance Packaging

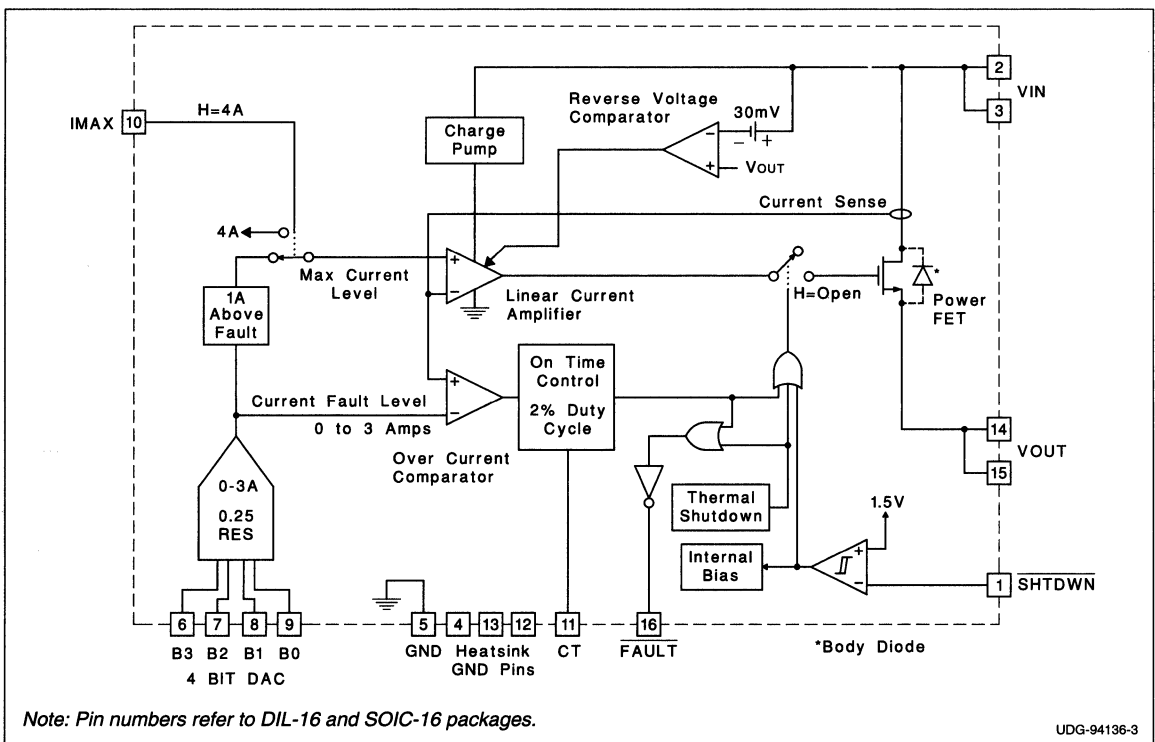
## DESCRIPTION

The UCC3915 Programmable Hot Swap Power Manager provides complete power management, hot swap capability, and circuit breaker functions. The only external component required to operate the device, other than power supply bypassing, is the fault timing capacitor,  $C_T$ . All control and housekeeping functions are integrated, and externally programmable. These include the fault current level, maximum output sourcing current, maximum fault time, and startup delay. In the event of a constant fault, the internal fixed 2% duty cycle ratio limits average output power.

The internal 4 bit DAC allows programming of the fault level current from 0 to 3A with 0.25A resolution. The IMAX control pin sets the maximum sourcing current to 1A above the trip level or to a full 4A of output current for fast output capacitor charging.

When the output current is below the fault level, the output MOSFET is switched ON with a nominal ON resistance of 0.15 $\Omega$ . When the output current exceeds the fault level, but is less than the maximum sourcing level, the output remains switched ON, but the fault timer starts, charging  $C_T$ . Once  $C_T$  charges to a preset threshold, the switch is turned OFF, and remains OFF for 50 times the programmed fault time. When the output current reaches the maximum sourcing level, the MOSFET transitions from a switch to a constant current source.

## BLOCK DIAGRAM



UDG-94136-3

(continued)

**ABSOLUTE MAXIMUM RATINGS**

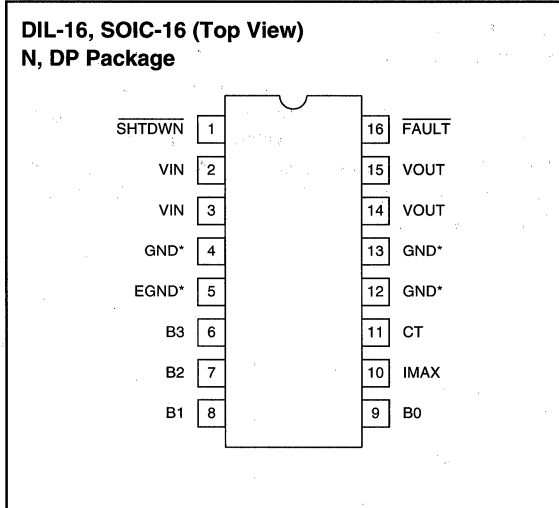
V <sub>IN</sub> .....	+15.5 Volts
V <sub>OUT</sub> – V <sub>IN</sub> .....	–0.3V
FAULT Sink Current .....	50mA
FAULT Voltage .....	–0.3 to 8V
Output Current .....	Self Limiting
TTL Input Voltage .....	–0.3 to V <sub>IN</sub>
Storage Temperature .....	–65°C to +150°C
Junction Temperature .....	–55°C to +150°C
Lead Temperature (Soldering, 10 sec.) .....	+300°C

Currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages.

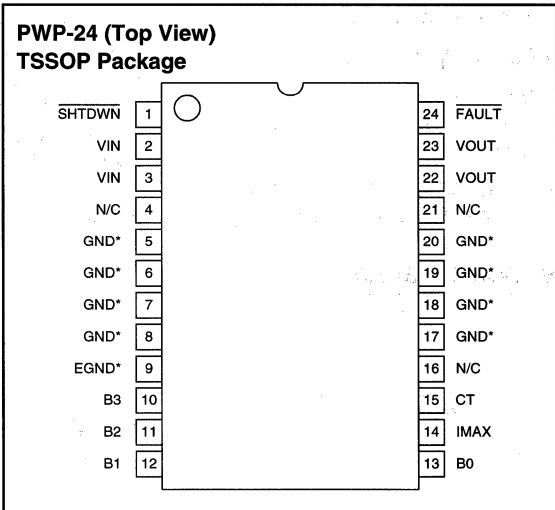
**DESCRIPTION (cont.)**

The UCC3915 can be put into sleep mode, drawing only 100µA of supply current. Other features include an open drain Fault Output Indicator, Thermal Shutdown, Under-

**CONNECTION DIAGRAMS**



\*Pin 5 serves as lowest impedance to the electrical ground; Pins 4, 12, and 13 serve as heat sink/ground. These pins should be connected to large etch areas to help dissipate heat. For N Package, pins 4, 12, and 13 are N/C.



\*Pin 9 serves as lowest impedance to the electrical ground; other GND pins serve as heat sink/ground. These pins should be connected to large etch areas to help dissipate heat.

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for T<sub>A</sub> = –40°C to +85°C for the UCC2915 and 0°C to 70°C for the UCC3915, V<sub>IN</sub> = 12V, I<sub>MAX</sub> = 0.4V, SHTDWN = 2.4V, T<sub>A</sub> = T<sub>J</sub>.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Supply Section</b>					
Voltage Input Range		7.0		15.0	V
Supply Current			1.0	2.0	mA
Sleep Mode Current	SHTDWN = 0.2V, No load		100	150	µA
Output Leakage	SHTDWN = 0.2V			20	µA
<b>Output Section</b>					
Voltage Drop	I <sub>OUT</sub> = 1A (10V to 12V)		0.15	0.3	V
	I <sub>OUT</sub> = 2A (10V to 12V)		0.3	0.6	V
	I <sub>OUT</sub> = 3A (10V to 12V)		0.45	0.9	V



**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = -40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  for the UCC2915 and  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$  for the UCC3915,  $V_{IN} = 12\text{V}$ ,  $I_{MAX} = 0.4\text{V}$ ,  $SHTDWN = 2.4\text{V}$ ,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Output Section (cont.)</b>					
Voltage Drop (cont.)	$I_{OUT} = 1\text{A}$ , $V_{IN} = 7\text{V}$ and $15\text{V}$		0.2	0.4	V
	$I_{OUT} = 2\text{A}$ , $V_{IN} = 7\text{V}$ and $15\text{V}$		0.4	0.8	V
	$I_{OUT} = 3\text{A}$ , $V_{IN} = 7\text{V}$ , $12\text{V}$ Max.		0.6	1.2	V
Initial Startup Time	Note 2		100		$\mu\text{s}$
Short Circuit Response	Note 2		100		ns
Thermal Shutdown	Note 2		165		$^{\circ}\text{C}$
Thermal Hysteresis	Note 2		10		$^{\circ}\text{C}$
<b>DAC Section</b>					
Trip Current	Code = 0000-0011 (Device Off)				
	Code = 0100	0.07	0.25	0.45	A
	Code = 0101	0.32	0.50	0.70	A
	Code = 0110	0.50	0.75	0.98	A
	Code = 0111	0.75	1.00	1.3	A
	Code = 1000	1.0	1.25	1.6	A
	Code = 1001	1.25	1.50	1.85	A
	Code = 1010	1.5	1.75	2.15	A
	Code = 1011	1.70	2.00	2.4	A
	Code = 1100	1.90	2.25	2.7	A
	Code = 1101	2.1	2.50	2.95	A
	Code = 1110	2.30	2.75	3.25	A
	Code = 1111	2.50	3.0	3.50	A
Max Output Current Over Trip (Current Source Mode)	Code = 0100 to 1111, $I_{MAX} = 0\text{V}$	0.35	1.0	1.65	A
Max Output Current (Current Source Mode)	Code = 0100 to 1111, $I_{MAX} = 2.4\text{V}$	3.0	4.0	5.2	A
<b>Fault Output Section</b>					
CT Charge Current	$V_{CT} = 1.0\text{V}$	-83	-62	-47	$\mu\text{A}$
CT Discharge Current	$V_{CT} = 1.0\text{V}$	0.8	1.2	1.8	$\mu\text{A}$
Output Duty Cycle	$V_{OUT} = 0\text{V}$	1.0	1.9	3.3	%
CT Fault Threshold		1.2	1.5	1.7	V
CT Reset Threshold		0.4	0.5	0.6	V
<b>Shutdown Section</b>					
Shutdown Threshold		1.1	1.5	1.9	V
Shutdown Hysteresis			150		mV
Input Current			100	500	nA
<b>Open Drain Output Section</b>					
High Level Output Current	$\overline{\text{FAULT}} = 5\text{V}$			250	$\mu\text{A}$
Low Level Output Voltage	$I_{OUT} = 5\text{mA}$		0.2	0.8	V
<b>TTL Input DC Characteristics Section</b>					
TTL Input Voltage High		2.0			V
TTL Input Voltage Low				0.8	V
TTL Input High Current	$V_{IH} = 2.4\text{V}$		3	10	$\mu\text{A}$
TTL Input Low Current	$V_{IL} = 0.4\text{V}$			1	$\mu\text{A}$

Note 1: All voltages are with respect to GND. Current is positive into and negative out of the specified terminal.

Note 2: Guaranteed by design. Not 100% tested in production.

**PIN DESCRIPTIONS**

**SB0 - B3:** These pins provide digital input to the DAC, which sets the fault current threshold. They can be used to provide a digital soft-start and adaptive current limiting.

**CT:** A capacitor connected to ground sets the maximum fault time. The maximum fault time must be more than the time required to charge the external capacitance in one cycle. The maximum fault time is defined as  $T_{FAULT} = 16.1 \cdot 10^3 \cdot CT$ . Once the fault time is reached the output will shutdown for a time given by  $T_{SD} = 833 \cdot 10^3 \cdot CT$ , this equates to a 1.9% duty cycle.

**FAULT:** Open drain output, which pulls low upon any fault or interrupt condition, Fault, or Thermal Shutdown.

**IMAX:** When this pin is set to a logic low, the maximum sourcing current will always be 1A above the programmed fault level. When set to a logic high, the maximum sourcing current will be a constant 4A for applications which require fast charging of load capacitance.

**SHTDWN:** When this pin is brought to a logic low, the IC is put into a sleep mode drawing typically less than  $100\mu A$  of  $I_{CC}$ . The input threshold is hysteretic, allowing the user to program a startup delay with an external RC circuit.

**VIN:** Input voltage to the UCC3915. The recommended voltage range is 7 to 15 volts. Both VIN pins should be connected together and connected to power source.

**VOUT:** Output voltage from the UCC3915. Both VOUT pins should be connected together and connected to the load. When switched the output voltage will be approximately  $V_{IN} - (0.15\Omega \cdot I_{OUT})$ . VOUT must not exceed  $V_{IN}$  by greater than 0.3V.

**APPLICATIONS INFORMATION**

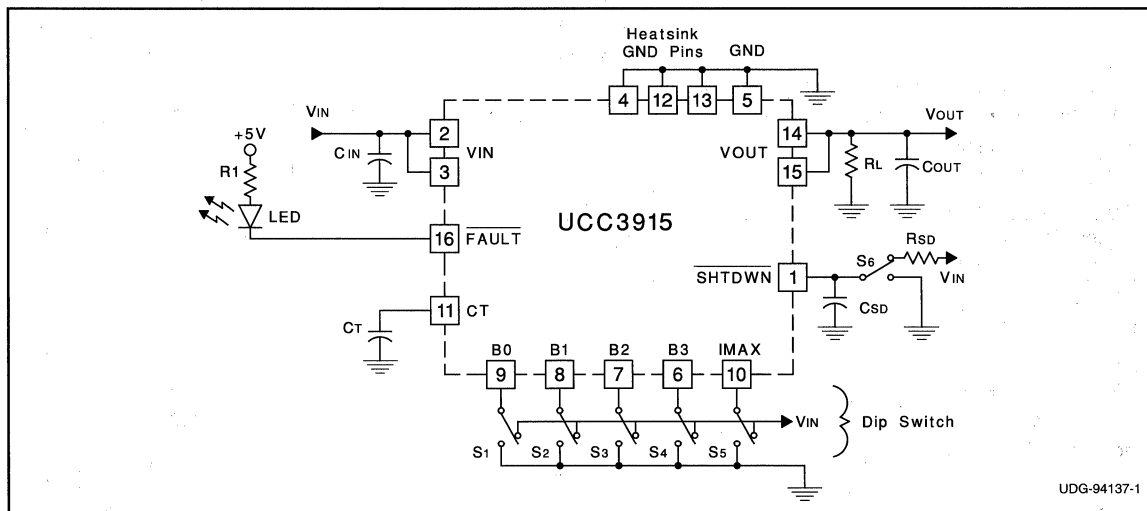
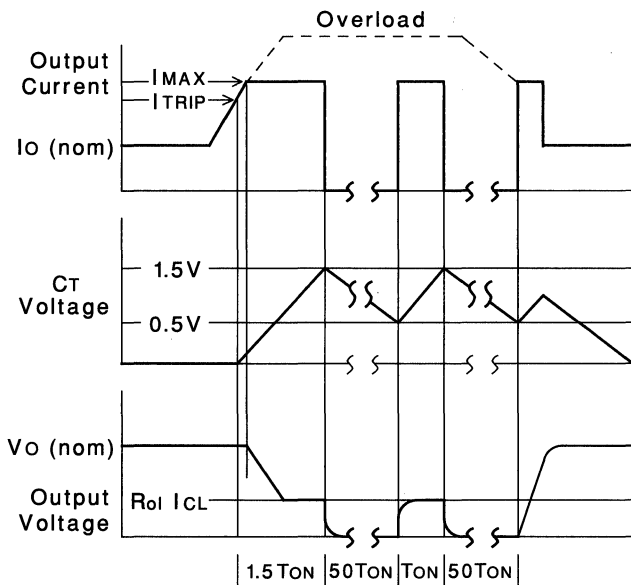


Figure 1. Evaluation circuit

APPLICATION INFORMATION (cont.)



UDG-94138

**Estimating Maximum Load Capacitance**

For hot swap applications, the rate at which the total output capacitance can be charged depends on the maximum output current available and the nature of the load. For a constant-current, current-limited application, the output will come up if the load asks for less than the maximum available short-circuit current.

To guarantee recovery of a duty-cycle from a short-circuited load condition, there is a maximum total output capacitance which can be charged for a given unit ON time (Fault time). The design value of ON or Fault time can be adjusted by changing the timing capacitor  $C_T$ .

For worst-case constant-current load of value just less than the trip limit;  $C_{OUT(max)}$  can be estimated from:

$$C_{OUT(max)} = (I_{MAX} - I_{LOAD}) \cdot \frac{16.1 \cdot 10^3 \cdot C_T}{V_{OUT}}$$

Where  $V_{OUT}$  is the output voltage.

For a resistive load of value  $R_L$ , the value of  $C_{OUT(max)}$  can be estimated from:

$$C_{OUT(max)} = \frac{16.1 \cdot 10^3 \cdot C_T}{R_L \cdot \ln \frac{1}{1 - \frac{V_{OUT}}{I_{MAX} \cdot R_L}}}$$

Figure 2. Load current, timing capacitor voltage, and output voltage of the UCC3915 under fault conditions.

**SAFETY RECOMMENDATIONS**

Although the UCC3915 is designed to provide system protection for all fault conditions, all integrated circuits can ultimately fail short. For this reason, if the UCC3915 is intended for use in safety critical applications where UL or some other safety rating is required, a redundant

safety device such as a fuse should be placed in series with the device. The UCC3915 will prevent the fuse from blowing for virtually all fault conditions, increasing system reliability and reducing maintenance cost, in addition to providing the hot swap benefits of the device.

# 15V Programmable Hot Swap Power Manager

## FEATURES

- Integrated 0.15Ω Power MOSFET
- 7V to 15V Operation
- Digital Programmable Current Limit from 0A to 3A
- Programmable ON Time
- Programmable Start Delay
- Fixed 2% Duty Cycle
- Thermal Shutdown
- Fault Output Indicator
- Maximum Output Current can be set to 1A above the Programmed Fault Level or to a full 4A
- Power SOIC and TSSOP, Low Thermal Resistance Packaging

## DESCRIPTION

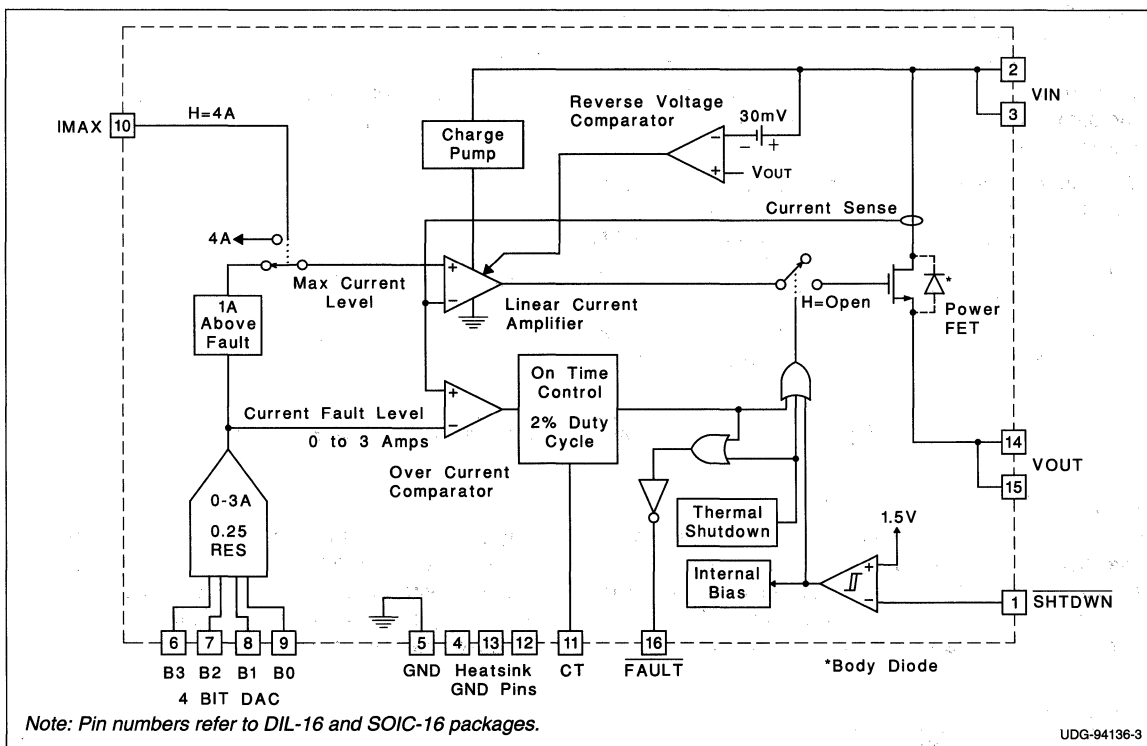
The UCC39151 Programmable Hot Swap Power Manager provides complete power management, hot swap capability, and circuit breaker functions. The only external component required to operate the device, other than power supply bypassing, is the fault timing capacitor,  $C_T$ . All control and housekeeping functions are integrated, and externally programmable. These include the fault current level, maximum output sourcing current, maximum fault time, and startup delay. In the event of a constant fault, the Internal fixed 2% duty cycle ratio limits average output power.

The internal 4 bit DAC allows programming of the fault level current from 0A to 3A with 0.25A resolution. The IMAX control pin sets the maximum sourcing current to 1A above the trip level or to a full 4A of output current for fast output capacitor charging.

When the output current is below the fault level, the output MOSFET is switched ON with a nominal ON resistance of 0.15Ω. When the output current exceeds the fault level, but is less than the maximum sourcing level, the output remains switched ON, but the fault timer starts, charging  $C_T$ . Once  $C_T$  charges to a preset threshold, the switch is turned OFF, and remains OFF for 50 times the programmed fault time. When the output current reaches the maximum sourcing level, the MOSFET transitions from a switch to a constant current source.

## BLOCK DIAGRAM

(continued)



**ABSOLUTE MAXIMUM RATINGS**

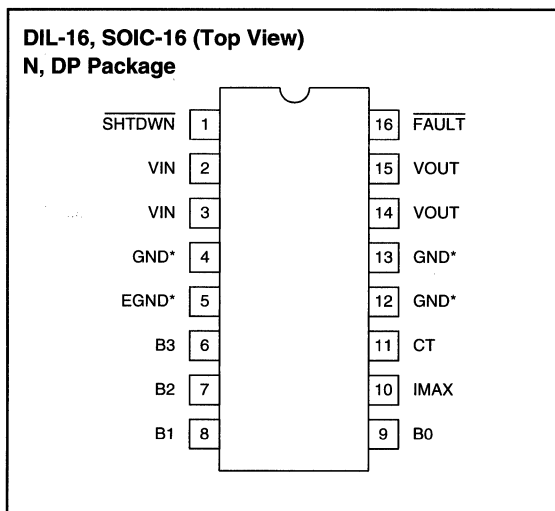
V <sub>IN</sub> .....	+15.5 Volts
V <sub>OUT</sub> – V <sub>IN</sub> .....	0.3V
FAULT Sink Current .....	50mA
FAULT Voltage .....	–0.3 to 8V
Output Current .....	Self Limiting
TTL Input Voltage .....	–0.3 to V <sub>IN</sub>
Storage Temperature .....	–65°C to +150°C
Junction Temperature .....	–55°C to +150°C
Lead Temperature (Soldering, 10 sec.) .....	+300°C

Currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages.

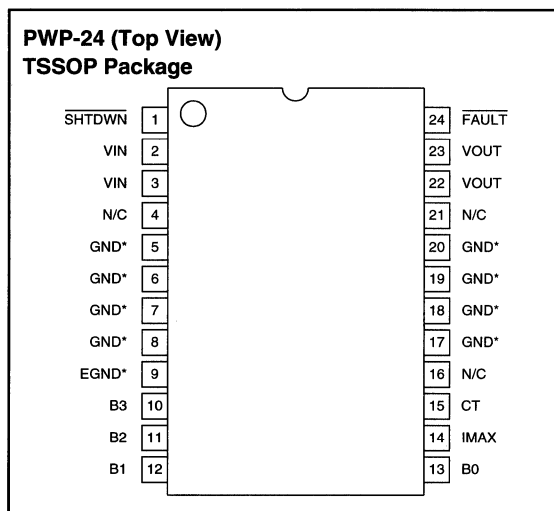
**DESCRIPTION (cont.)**

The UCC39151 can be put into sleep mode, drawing only 20mA of supply current. Other features include an open drain Fault Output Indicator, Thermal Shutdown, Undervoltage Lockout, 7V to 15V operation, and low thermal resistance SOIC and TSSOP Power Packages.

**CONNECTION DIAGRAMS**



\*Pin 5 serves as lowest impedance to the electrical ground; Pins 4, 12, and 13 serve as heat sink/ground. These pins should be connected to large etch areas to help dissipate heat. For N Package, pins 4, 12, and 13 are N/C.



\*Pin 9 serves as lowest impedance to the electrical ground; other GND pins serve as heat sink/ground. These pins should be connected to large etch areas to help dissipate heat.

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for T<sub>A</sub> = 0°C to 70°C for the UCC39151, V<sub>IN</sub> = 12V, I<sub>MAX</sub> = 0.4V, SHTDWN = 2.4V, T<sub>A</sub> = T<sub>J</sub>.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Supply Section</b>					
Voltage Input Range		7.0		15.0	V
Supply Current			1.0	2.0	mA
Sleep Mode Current	SHTDWN = 0.2V, No load		100	150	μA
Output Leakage	SHTDWN = 0.2V			20	mA
<b>Output Section</b>					
Voltage Drop	I <sub>OUT</sub> = 1A (10V to 12V)		0.15	0.3	V
	I <sub>OUT</sub> = 2A (10V to 12V)		0.3	0.6	V
	I <sub>OUT</sub> = 3A (10V to 12V)		0.45	0.9	V
	I <sub>OUT</sub> = 1A, V <sub>IN</sub> = 7V and 15V		0.2	0.4	V
	I <sub>OUT</sub> = 2A, V <sub>IN</sub> = 7V and 15V		0.4	0.8	V
	I <sub>OUT</sub> = 3A, V <sub>IN</sub> = 7V, 12V Max.		0.6	1.2	V

**ELECTRICAL CHARACTERISTICS** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$  for the UCC39151,  $V_{IN} = 12\text{V}$ ,  $I_{MAX} = 0.4\text{V}$ ,  $SHTDWN = 2.4\text{V}$ ,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Output Section (continued)</b>					
Initial Startup Time	(Note 2)		100		$\mu\text{s}$
Short Circuit Response	(Note 2)		100		ns
<b>DAC Section</b>					
Trip Current	Code = 0000-0011 (Device Off)				
	Code = 0100	0.07	0.25	0.45	A
	Code = 0101	0.32	0.50	0.7	A
	Code = 0110	0.50	0.75	0.98	A
	Code = 0111	0.75	1.00	1.3	A
	Code = 1000	1.0	1.25	1.6	A
	Code = 1001	1.25	1.50	1.85	A
	Code = 1010	1.5	1.75	2.15	A
	Code = 1011	1.70	2.00	2.4	A
	Code = 1100	1.90	2.25	2.7	A
	Code = 1101	2.1	2.50	2.95	A
	Code = 1110	2.30	2.75	3.25	A
	Code = 1111	2.50	3.0	3.5	A
Max Output Current Over Trip (Current Source Mode)	Code = 0100 to 1111, $I_{MAX} = 0\text{V}$	0.35	1.0	1.65	A
Max Output Current (Current Source Mode)	Code = 0100 to 1111, $I_{MAX} = 2.4\text{V}$	3.0	4.0	5.2	A
<b>Fault Output Section</b>					
CT Charge Current	$V_{CT} = 1.0\text{V}$	-83	-62	-47	$\mu\text{A}$
CT Discharge Current	$V_{CT} = 1.0\text{V}$	0.8	1.2	1.8	$\mu\text{A}$
Output Duty Cycle	$V_{OUT} = 0\text{V}$	1.0	1.9	3.3	%
CT Fault Threshold		1.2	1.5	1.7	V
CT Reset Threshold		0.4	0.5	0.6	V
<b>Shutdown Section</b>					
Shutdown Threshold		1.1	1.5	1.9	V
Shutdown Hysteresis			150		mV
Input Current			100	500	nA
<b>Open Drain Output Section</b>					
High Level Output Current	$\overline{\text{FAULT}} = 5\text{V}$			250	$\mu\text{A}$
Low Level Output Voltage	$I_{OUT} = 5\text{mA}$		0.2	0.8	V
<b>TTL Input DC Characteristics Section</b>					
TTL Input Voltage High		2.0			V
TTL Input Voltage Low				0.8	V
TTL Input High Current	$V_{IH} = 2.4\text{V}$		3	10	$\mu\text{A}$
TTL Input Low Current	$V_{IL} = 0.4\text{V}$			1	$\mu\text{A}$

Note 1: All voltages are with respect to Ground. Current is positive into and negative out of the specified terminal.

Note 2: Guaranteed by design. Not 100% tested in production.

**PIN DESCRIPTIONS**

**B0, B1, B2, B3:** These pins provide digital input to the DAC, which sets the fault current threshold. They can be used to provide a digital soft-start and adaptive current limiting.

**CT:** A capacitor connected to ground sets the maximum fault time. The maximum fault time must be more than the time required to charge the external capacitance in one cycle. The maximum fault time is defined as:

$$T_{FAULT} = 16.1 \cdot 10^3 \cdot C_T$$

Once the fault time is reached the output will shutdown for a time given by:

$$T_{SD} = 833 \cdot 10^3 \cdot C_T$$

this equates to a 1.9% duty cycle.

**FAULT:** Open drain output, which pulls low upon any fault or interrupt condition, Fault, or Thermal Shutdown.

**IMAX:** When this pin is set to a logic low, the maximum sourcing current will always be 1A above the programmed fault level. When set to a logic high, the maximum sourcing current will be a constant 4A for applications which require fast charging of load capacitance.

**SHTDWN:** When this pin is brought to a logic low, the IC is put into a sleep mode drawing typically less than 100µA of I<sub>CC</sub> (with V<sub>OUT</sub> unloaded). The input threshold is hysteretic, allowing the user to program a startup delay with an external RC circuit.

**VIN:** Input voltage to the UCC39151. The recommended voltage range is 7V to 15V. Both VIN pins should be connected together and connected to power source.

**VOUT:** Output voltage from the UCC39151. Both VOUT pins should be connected together and connected to the load. When switched:

$$V_{OUT} \approx V_{IN} - (0.15 \Omega \cdot I_{OUT})$$

V<sub>OUT</sub> must not exceed V<sub>IN</sub> by more than 0.3V.

**APPLICATIONS INFORMATION**

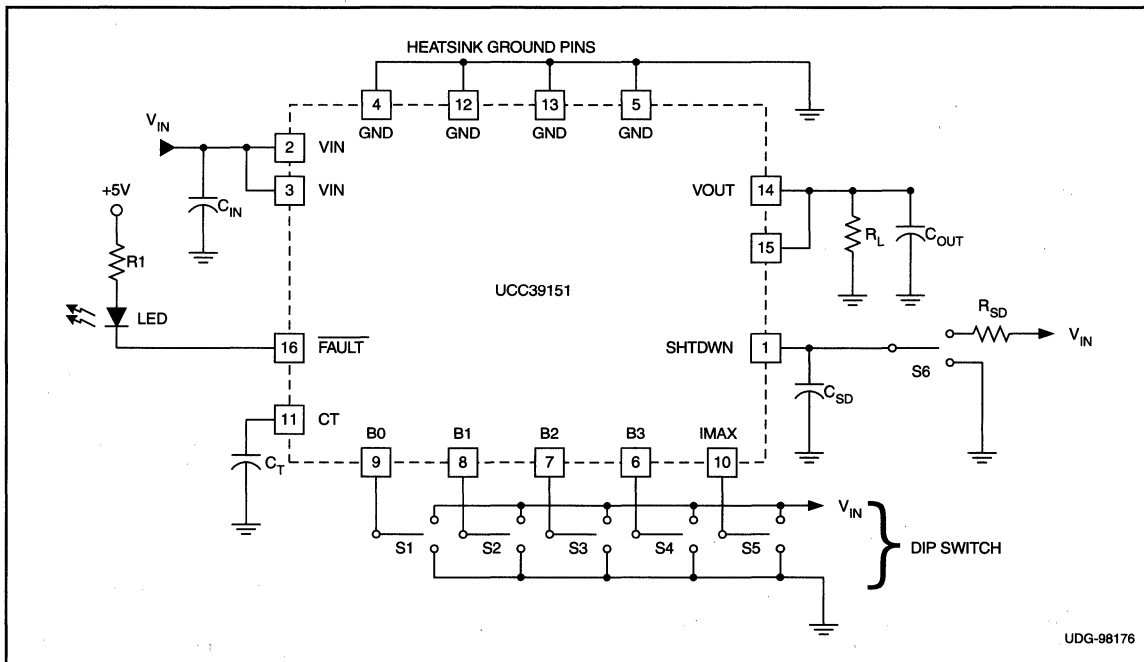
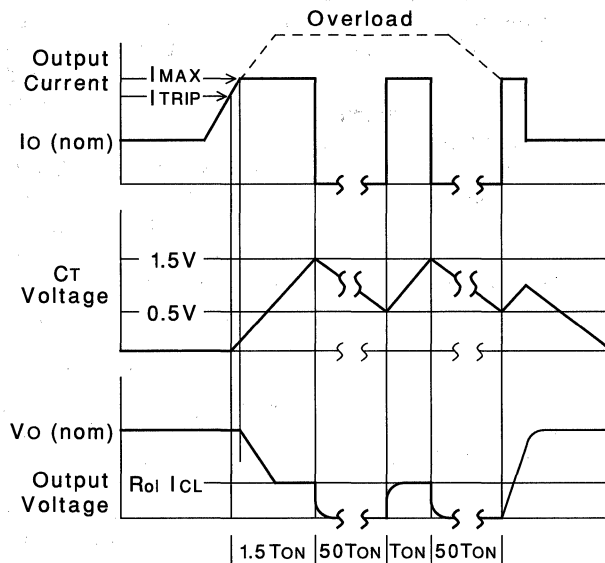


Figure 1. Evaluation circuit.

APPLICATION INFORMATION (cont.)



UDG-94138

Estimating Maximum Load Capacitance

For hot swap applications, the rate at which the total output capacitance can be charged depends on the maximum output current available and the nature of the load. For a constant-current, current-limited application, the output will come up if the load asks for less than the maximum available short-circuit current.

To guarantee recovery of a duty-cycle from a short-circuited load condition, there is a maximum total output capacitance which can be charged for a given unit ON time (Fault time). The design value of ON or Fault time can be adjusted by changing the timing capacitor  $C_T$ .

For worst-case constant-current load of value just less than the trip limit;  $C_{OUT(max)}$  can be estimated from:

$$C_{OUT(max)} \approx (I_{MAX} - I_{LOAD}) \cdot \left( \frac{16.1 \cdot 10^3 \cdot C_T}{V_{OUT}} \right)$$

Where  $V_{OUT}$  is the output voltage.

For a resistive load of value  $R_L$ , the value of  $C_{OUT(max)}$  can be estimated from:

$$C_{OUT(max)} \approx \left( \frac{16.1 \cdot 10^3 \cdot C_T}{R_L \cdot \ell n \left[ \frac{1}{1 - \frac{V_{OUT}}{I_{MAX} \cdot R_L}} \right]} \right)$$

Long  $C_T$  times must consider the maximum temperature. Thermal shutdown protection may be the limiting Fault time.

Figure 2. Load current, timing capacitor voltage, and output voltage of the UCC39151 under fault conditions.

SAFETY RECOMMENDATIONS

Although the UCC39151 is designed to provide system protection for all fault conditions, all integrated circuits can ultimately fail short. For this reason, if the UCC39151 is intended for use in safety critical applications where UL or some other safety rating is required, a redundant safety device such as a fuse should be placed

in series with the device. The UCC39151 will prevent the fuse from blowing for virtually all fault conditions, increasing system reliability and reducing maintenance cost, in addition to providing the hot swap benefits of the device.



# SCSI Termpower Manager

## FEATURES

- Integrated Circuit Breaker Function
- Integrated 0.2Ω Power FET
- SCSI, SCSI-2, SCSI-3 Compliant
- 1μA ICC When Disabled
- Programmable On Time
- Accurate 1.65A Trip Current/  
2.1A Max Current
- Fixed 3% Duty Cycle
- Uni-Directional Switch
- Thermal Shutdown

## DESCRIPTION

The UCC3916 SCSI termpower manager provides complete power management, hot swap capability, and circuit breaker functions with minimal external components. For most applications, the only external component required to operate the device, other than supply bypassing, is a timing capacitor which sets the fault time.

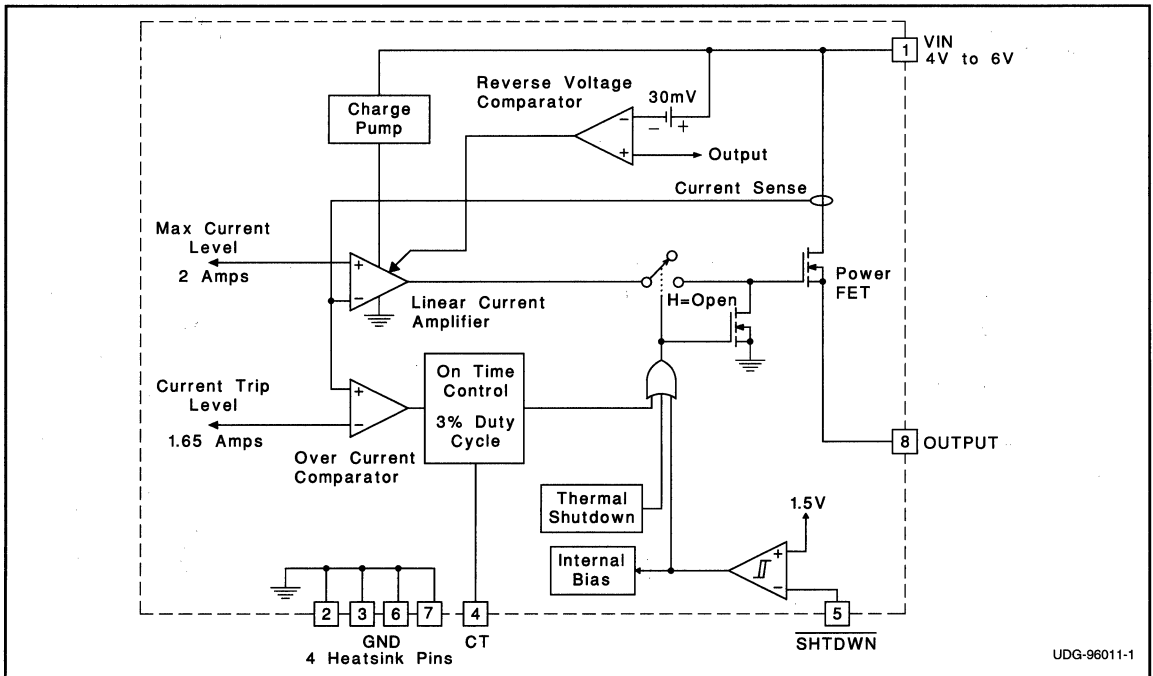
The current trip level is internally set at 1.65A, and the maximum current level is also internally programmed for 2A. While the output current is below the trip level of 1.65A, the internal power MOSFET is switched on at a nominal 220mΩ. When the output current exceeds the trip level but remains less than the maximum current level, the MOSFET remains switched on, but the fault timer starts charging CT. Once the fault time is reached, the circuit will shut off for a time which equates to a 3% duty cycle. Finally, when the output current reaches the maximum current level, the MOSFET transitions from a switch to a constant current source.

The UCC3916 is designed for uni-directional current flow, emulating a diode in series with the power MOSFET.

The UCC3916 can be put in a sleep mode, drawing only 1μA of supply current.

Other features include thermal shutdown and low thermal resistance Small Outline Power package.

## BLOCK DIAGRAM

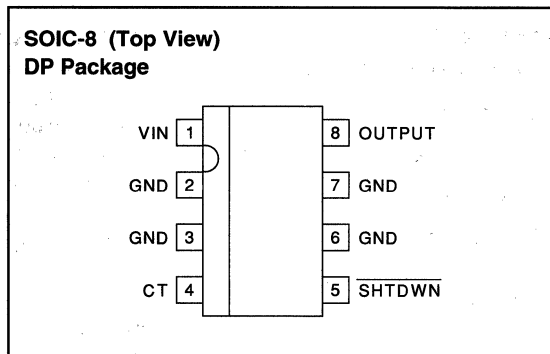


**ABSOLUTE MAXIMUM RATINGS**

VIN .....	+6V
Output Current	
DC .....	Self Limiting
Pulse (Less than 100ns) .....	20A
Storage Temperature .....	-65°C to +150°C
Junction Temperature .....	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.) .....	+300°C

Currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages.

**CONNECTION DIAGRAM**



**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, these parameters apply for  $T_J = 0^\circ\text{C}$  to  $+70^\circ\text{C}$ ;  $V_{IN} = 5\text{V}$ ,  $SHTDWN = 2.4\text{V}$ ,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Supply Current Section</b>					
ICC			1.00	2.00	mA
ICC - Sleep Mode	SHTDWN = 0.2V		0.50	5	$\mu\text{A}$
<b>Output Section</b>					
Voltage Drop	$I_{OUT} = 1\text{A}$		0.22	0.33	V
	$I_{OUT} = 1.5\text{A}$		0.33	0.50	V
	$I_{OUT} = 1.8\text{A}$		0.40	0.60	V
Trip Current		-1.8	-1.65	-1.5	A
Max Current		-2.4	-2	-1.8	A
Reverse Leakage	$V_{IN} = 4.5\text{V}, V_{OUT} = 5\text{V}$		6	20	$\mu\text{A}$
	$V_{IN} = 0\text{V}, V_{OUT} = 5\text{V}$		0.50	9	$\mu\text{A}$
Soft Start Time	Initial Startup		50		$\mu\text{s}$
Short Circuit Response			100		ns
<b>Fault Section</b>					
CT Charge Current	$V_{CT} = 1.0\text{V}$	-45	-36.0	-27	$\mu\text{A}$
CT Discharge Current	$V_{CT} = 1.0\text{V}$	0.90	1.0	1.50	$\mu\text{A}$
Output Duty Cycle	$V_{OUT} = 0\text{V}$	2.00	3.00	6.00	%
CT Charge Threshold		0.4	0.5	0.6	V
CT Discharge Threshold		1.2	1.4	1.8	V
Thermal Shutdown			170		$^\circ\text{C}$
Thermal Hysteresis			10		$^\circ\text{C}$
<b>Shutdown Section</b>					
Shutdown Threshold			1.5	3.0	V
Shutdown Hysteresis			150	300	mV
Shutdown Bias Current	SHTDWN = 1.0V		100	500	nA

Note 1: All voltages are with respect to ground.

**PIN DESCRIPTIONS**

**CT:** A capacitor is applied between this pin and ground to set the maximum fault time. The maximum fault time must be more than the time to charge external capacitance. The maximum fault time is defined as:

$$T_{FAULT} = 28 \cdot 10^3 \cdot CT.$$

Once the fault time is reached the output will shutdown for a time given by:

$$T_{SD} = 1 \cdot 10^6 \cdot CT$$

this results in a 3% duty cycle. 0.1μF is recommended for SCSI applications to achieve the normal maximum capacitance on the Tempwr line.

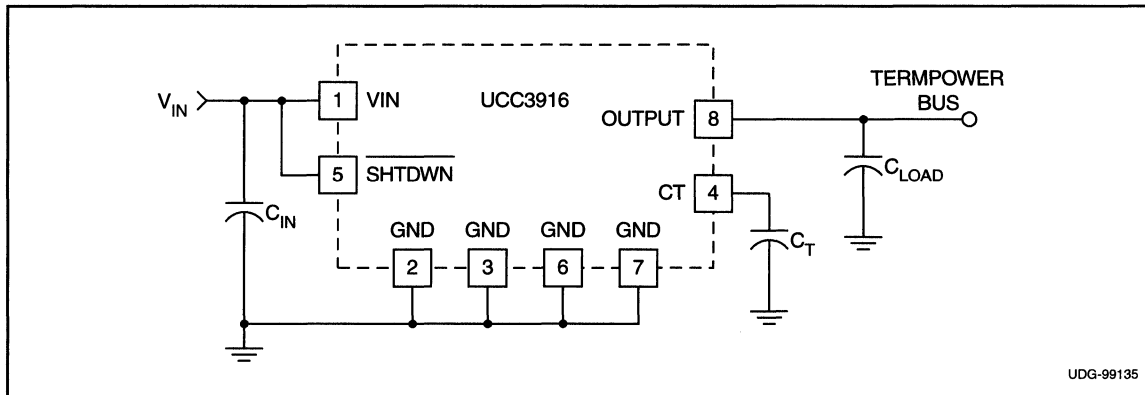
**SHTDWN:** The IC enters a low-power sleep mode when this pin is low and exits the sleep mode when this pin is high.

**VIN:** Input voltage to the circuit breaker, ranging from 4V to 6V.

**VOUT:** Output voltage of the circuit breaker. When switched, the output voltage is approximately:

$$V_{OUT} = V_{IN} - (220m\Omega) \cdot I_{OUT}.$$

**TYPICAL APPLICATION**



**SAFETY RECOMMENDATIONS**

Although the UCC3916 is designed to provide system protection for all fault conditions, all integrated circuits can ultimately fail short. For this reason, if the UCC3916 is intended for use in safety critical applications where UL or some other safety rating is required, a redundant

safety device such as a fuse should be placed in series with the device. The UCC3916 will prevent the fuse from blowing virtually all fault conditions, increasing system reliability and reducing maintenance cost, in addition to providing the hot swap benefits of the device.

# Low Current Hot Swap Power Manager

## FEATURES

- Integrated Circuit Breaker Function
- Integrated  $0.2\Omega$  Power FET
- $1\mu\text{A}$  ICC When Disabled
- Programmable On Time
- Accurate 0.8A Max Current
- Fixed 3% Duty Cycle
- Uni-Directional Switch
- Thermal Shutdown

## DESCRIPTION

The UCC39161 low current hot swap power manager provides complete power management, hot swap capability, and circuit breaker functions with minimal external components. For most applications, the only external component required to operate the device, other than supply bypassing, is a timing capacitor which sets the fault time.

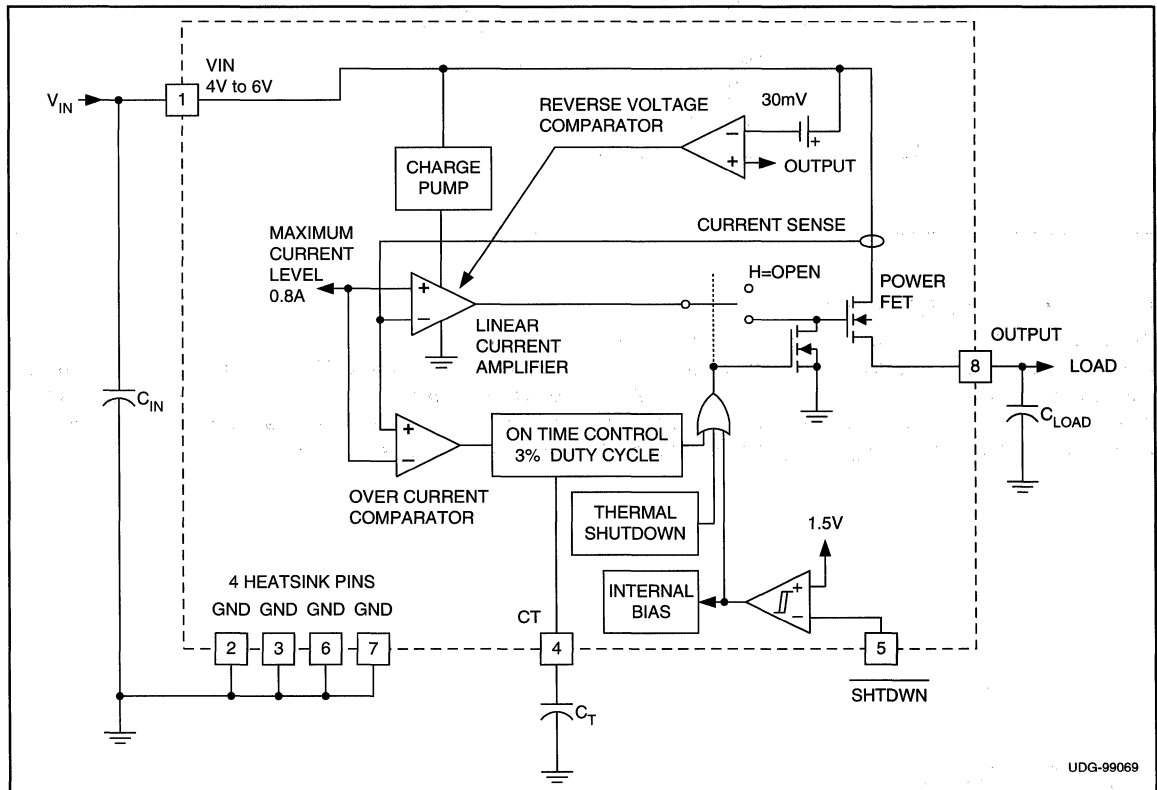
The maximum current level is internally programmed for 0.8A. While the output current is below 0.8A, the internal power MOSTFET is switched on at a nominal  $220\text{m}\Omega$ . When the output current exceeds 0.8A, the MOSFET transitions from a switch to a constant current source and the fault timer starts charging CT. Once the fault time is reached, the current will shut off for a time, which equates to a 3% duty cycle.

The UCC39161 also provides unidirectional current flow, emulating a diode in series with the power MOSFET.

The UCC39161 can be put into sleep mode by grounding the SHTDWN pin. In sleep mode, the UCC39161 draws under  $5\mu\text{A}$  of supply current.

Other features include thermal shutdown and a low thermal resistance Small Outline Power package.

## BLOCK DIAGRAM AND TYPICAL APPLICATION

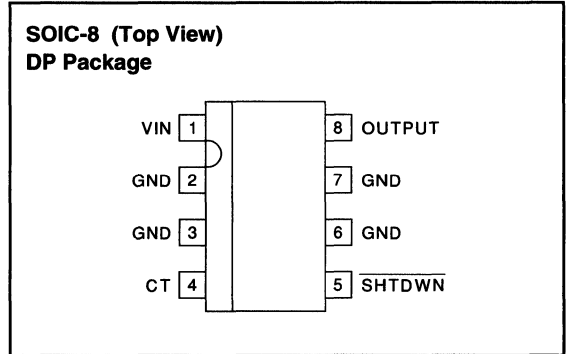


**ABSOLUTE MAXIMUM RATINGS**

VIN .....	+6V
Output Current	
DC .....	Self Limiting
Pulse (Less than 100ns) .....	20A
Storage Temperature .....	-65°C to +150°C
Junction Temperature .....	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.) .....	+300°C

Currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages.

**CONNECTION DIAGRAM**



**ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, these parameters apply for  $T_J = 0^\circ\text{C}$  to  $+70^\circ\text{C}$ ;  $V_{IN} = 5\text{V}$ ,  $SHTDWN = 2.4\text{V}$ ,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Supply Current Section</b>					
ICC			1.00	2.00	mA
ICC - Sleep Mode	SHTDWN = 0.2V		0.50	5	$\mu\text{A}$
<b>Output Section</b>					
Voltage Drop	$I_{OUT} = 0.5\text{A}$		0.10	0.16	V
Max Current		-1.0	-0.8	-0.6	A
Reverse Leakage	$V_{IN} = 4.5\text{V}$ , $V_{OUT} = 5\text{V}$		6	20	$\mu\text{A}$
	$V_{IN} = 0\text{V}$ , $V_{OUT} = 5\text{V}$		0.50	9	$\mu\text{A}$
Soft Start Time	Initial Startup		50		$\mu\text{s}$
Short Circuit Response			100		ns
<b>Fault Section</b>					
CT Charge Current	$V_{CT} = 1.0\text{V}$	-45	-36.0	-27	$\mu\text{A}$
CT Discharge Current	$V_{CT} = 1.0\text{V}$	0.90	1.0	1.50	$\mu\text{A}$
Output Duty Cycle	$V_{OUT} = 0\text{V}$	2.00	3.00	6.00	%
CT Charge Threshold		0.4	0.5	0.6	V
CT Discharge Threshold		1.2	1.4	1.8	V
Thermal Shutdown			170		$^\circ\text{C}$
Thermal Hysteresis			10		$^\circ\text{C}$
<b>Shutdown Section</b>					
Shutdown Threshold			1.5	3.0	V
Shutdown Hysteresis			150	300	mV
Shutdown Bias Current	SHTDWN = 1.0V		100	500	nA

Note 1: All voltages are with respect to ground.

**PIN DESCRIPTIONS**

**CT:** A capacitor is applied between this pin and ground to set the maximum fault time. The maximum fault time must be more than the time to charge external capacitance. The maximum fault time is defined as:

$$T_{FAULT} = 28 \cdot 10^3 \cdot CT.$$

Once the fault time is reached the output will shutdown for a time given by:

$$T_{SD} = 1 \cdot 10^6 \cdot CT$$

this results in a 3% duty cycle.

**SHTDWN:** The IC enters a low-power sleep mode when this pin is low and exits the sleep mode when this pin is high.

**VIN:** Input voltage to the circuit breaker, ranging from 4V to 6V.

**VOU:** Output voltage of the circuit breaker. When switched, the output voltage is approximately:

$$V_{OUT} = V_{IN} - 220m\Omega \cdot I_{OUT}.$$

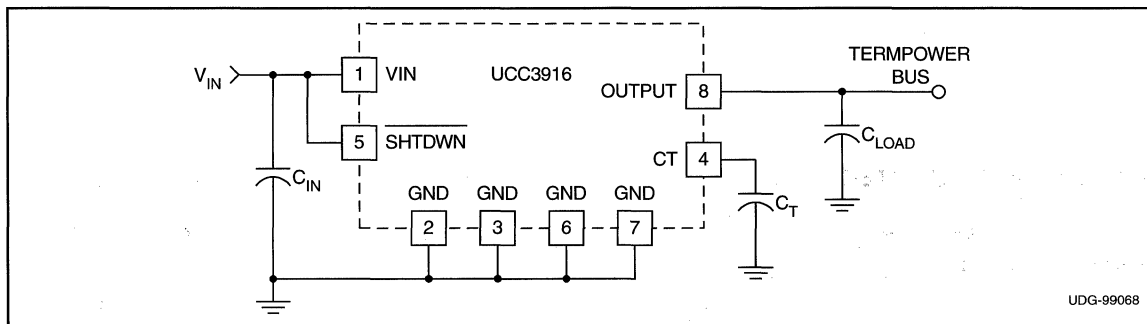


Figure 1. Typical application.

**SAFETY RECOMMENDATIONS**

Although the UCC39161 is designed to provide system protection for all fault conditions, all integrated circuits can ultimately fail short. For this reason, if the UCC39161 is intended for use in safety critical applications where UL or some other safety rating is required, a

redundant safety device such as a fuse should be placed in series with the device. The UCC39161 will prevent the fuse from blowing virtually all fault conditions, increasing system reliability and reducing maintenance cost, in addition to providing the hot swap benefits of the device.

# Positive Floating Hot Swap Power Manager

## FEATURES

- Manages Hot Swap of 15V and Above
- Precision Fault Threshold
- Programmable Average Power Limiting
- Programmable Linear Current Control
- Programmable Overcurrent Limit
- Programmable Fault Time
- Internal Charge Pump to Control External NMOS Device
- Fault Output and Catastrophic Fault Indication
- Fault Mode Programmable to Latch or Retry
- Shutdown Control
- Undervoltage Lockout

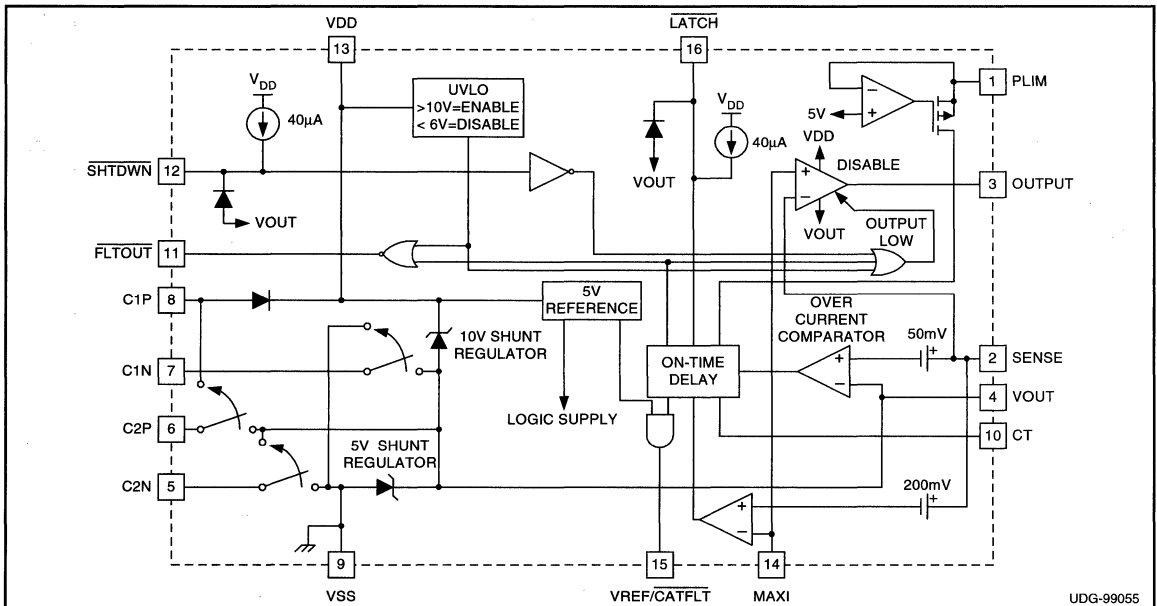
## DESCRIPTION

The UCC3917 family of positive floating hot swap managers provides complete power management, hot swap, and fault handling capability. The voltage limitation of the application is only restricted by the external component voltage limitations. The IC provides its own supply voltage via a charge pump off of VOUT. The onboard 10V shunt regulator protects the IC from excess voltage. The IC also has catastrophic fault indication to alert the user that the ability to shut off the output NMOS has been bypassed. All control and housekeeping functions are integrated and externally programmable. These include the fault current level, maximum output sourcing current, maximum fault time, soft start time, and average NMOS power limiting.

The fault level across the current sense amplifier is fixed at 50mV to minimize total drop out. Once 50mV is exceeded across the current sense resistor, the fault timer will start. The maximum allowable sourcing current is programmed with a voltage divider from the VREF/CATFLT pin to generate a fixed voltage on the MAXI pin. The current level at which the output appears as a current source is equal to VMAXI divided by the current sense resistor. If desired, a controlled current startup can be programmed with a capacitor on MAXI.

When the output current is below the fault level, the output device is switched on with full gate drive. When the output current exceeds the fault level, but is less than maximum allowable sourcing level programmed by MAXI, the output remains switched on, and the fault timer starts charging CT. Once CT charges to 2.5V, the output device is turned off and attempts either a retry sometime later or waits for the state on the LATCH pin to change if in latch mode. When the output current reaches the maximum sourcing current level, the output device appears as a current source.

## BLOCK DIAGRAM

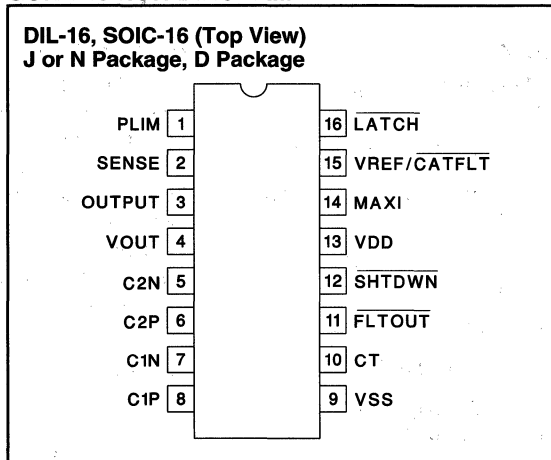


### ABSOLUTE MAXIMUM RATINGS

IDD	20mA
SHTDWN Current	-500 $\mu$ A
LATCH Current	-500 $\mu$ A
VREF Current	-500 $\mu$ A
PLIM Current	10mA
MAXI Input Voltage	VDD + 0.3V
Storage Temperature	-65°C to +150°C
Junction Temperature	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.)	+300°C

*Currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of package.*

### CONNECTION DIAGRAM



**ELECTRICAL CHARACTERISTICS:** Unless otherwise specified,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$  for the UCC3917,  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for the UCC2917 and  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for the UCC1917,  $C_T = 4.7\text{nF}$ ,  $T_A = T_J$ . All voltages are with respect to VOUT. Current is positive into and negative out of the specified terminal.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>VDD Section</b>					
IDD	From VOUT (Note 2)	3.0	5	11	mA
UVLO Turn On Threshold		8	9	10	V
UVLO Off Voltage		5.5	6.5	7.5	V
VSS Regulator Voltage		-6	-5	-4	V
<b>Fault Timing Section</b>					
Overcurrent Threshold	$T_A = 25^\circ\text{C}$	47.5	50	53	mV
	Over Operating Temperature	46	50	54	mV
Overcurrent Input Bias			50	500	nA
CT Charge Current	$V_{CT} = 1\text{V}$	-70	-50	-36	$\mu\text{A}$
CT Discharge Current	$V_{CT} = 1\text{V}$	0.9	1.5	2.1	$\mu\text{A}$
CT Fault Threshold		2.25	2.5	2.75	V
CT Reset Threshold		0.32	0.5	0.62	V
Output Duty Cycle	Fault Condition	1.7	2.7	3.7	%
<b>Output Section</b>					
Output High Voltage	$I_{OUT} = 0$	6	8	10	V
	$I_{OUT} = -500\mu\text{A}$	5	7	9	V
Output Low Voltage	$I_{OUT} = 0$		0	0.05	V
	$I_{OUT} = 500\mu\text{A}$		0.1	0.5	V
	$I_{OUT} = 1\text{mA}$		0.5	0.9	V
<b>Linear Current Section</b>					
Sense Control Voltage	MAXI = 100mV	85	100	115	mV
	MAXI = 400mV	370	400	430	mV
Input Bias	MAXI = 200mV		50	500	nA
<b>SHUTDOWN Section</b>					
Shutdown Threshold		2.0	2.4	2.8	V
Input Current	SHTDWN = 0V	24	40	60	$\mu\text{A}$
Shutdown Delay			100	500	ns



**ELECTRICAL CHARACTERISTICS:** Unless otherwise specified,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$  for the UCC3917,  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for the UCC2917 and  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for the UCC1917,  $C_T = 4.7\text{nF}$ .  $T_A = T_J$ . All voltages are with respect to VOUT. Current is positive into and negative out of the specified terminal.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>LATCH Section</b>					
Latch Threshold		1.7	2	2.3	V
Input Current	LATCH = 0V	24	40	60	$\mu\text{A}$
<b>Fault Out Section</b>					
Fault Output High		6	8	10	V
Fault Output Low			0.01	0.05	V
<b>Power Limiting Section</b>					
VSENSE Regulator Voltage	IPLIMIT = $64\mu\text{A}$	4.5	5	5.5	V
Duty Cycle Control	IPLIMIT = $64\mu\text{A}$	0.6	1.2	1.7	%
	IPLIMIT = 1mA	0.045	0.1	0.2	%
<b>VREF/CATFLT Section</b>					
VREF Regulator Voltage		4.5	5	5.5	V
Fault Output Low			0.01	0.05	V
Output Sink Current	$V_{CT} = 5\text{V}$	2	5	8	$\text{mA}$
Overload Comparator Threshold	Relative to MAXI	140	200	260	$\text{mV}$

Note 2: Set by user with Rss.

## PIN DESCRIPTIONS

**C1N:** Negative side of the upper charge pump capacitor.

**C1P:** Positive side of the upper charge pump capacitor.

**C2N:** Negative side of the lower charge pump capacitor.

**C2P:** Positive side of lower charge pump capacitor.

**CT:** A capacitor is connected to this pin to set the fault time. The fault time must be more than the time to charge the external load capacitance (see Application Information).

**FLTOUT:** This pin provides fault output indication. Interface to this pin is usually performed through level shift transistors. Under a non-fault condition, FLTOUT will pull to a high state. When a fault is detected by the fault timer or the under voltage lockout, this pin will drive to a low state, indicating the output NMOS is in the off state.

**LATCH:** Pulling this pin low causes a fault to latch until this pin is brought high or a power on reset is attempted. However, pulling this pin high before the reset time is reached will not clear the fault until the reset time is reached. Keeping LATCH high will result in normal operation of the fault timer. Users should note there will be an RC delay dependent upon the external capacitor at this pin.

**MAXI:** This pin programs the maximum allowable sourcing current. Since VREF/CATFLT is a regulated voltage, a voltage divider can be derived to generate the program level for MAXI. The current level at which the output appears as a current source is equal to the voltage on MAXI divided by the current sense resistor. If de-

sired, a controlled current start up can be programmed with a capacitor on MAXI (to VOUT), and a programmed start delay can be achieved by driving the shutdown with an open collector/drain device into an RC network.

**OUTPUT:** Gate drive to the NMOS pass element.

**PLIM:** This feature ensures that the average external NMOS power dissipation is controlled. A resistor is connected from this pin to the drain of the external NMOS pass element. When the voltage across the NMOS exceeds 5V, current will flow into PLIM which adds to the fault timer charge current, reducing the duty cycle from the 3% level.

**SENSE:** Input voltage from the current sense resistor. When there is greater than 50mV across this pin with respect to VOUT, a fault is sensed, and CT starts to charge.

**SHTDWN:** This pin provides shutdown control. Interface to this pin is usually performed through level shift transistors. When shutdown is driven low, the output disables the NMOS pass device.

**VDD:** Power to the I.C. Is supplied by an external current limiting resistor on initial power-up or if the load is shorted. As the load voltages rises (VOUT), a small amount of power is drawn from VOUT by an internal charge pump. The charge pump's input voltage is regulated by an on-chip 5V zener. Power to VDD is supplied by the charge pump under normal operation (i.e., external FET is on).

## PIN DESCRIPTIONS (cont.)

**VOUT:** Ground reference for the IC.

**VREF/CATFLT:** This pin primarily provides an output reference for the programming of MAXI. Secondly, it provides catastrophic fault output indication. Under a catastrophic fault, when the IC is unsuccessfully attempting to shutdown the NMOS pass device, this pin will pull to a low state. In an application, this pin could be con-

nected to a second NMOS transistor in series with the main NMOS for redundancy. Due to the primary function of this pin, full gate drive would not be available to the second NMOS.

**VSS:** Negative reference out of the chip. Normally current fed via a resistor to ground.

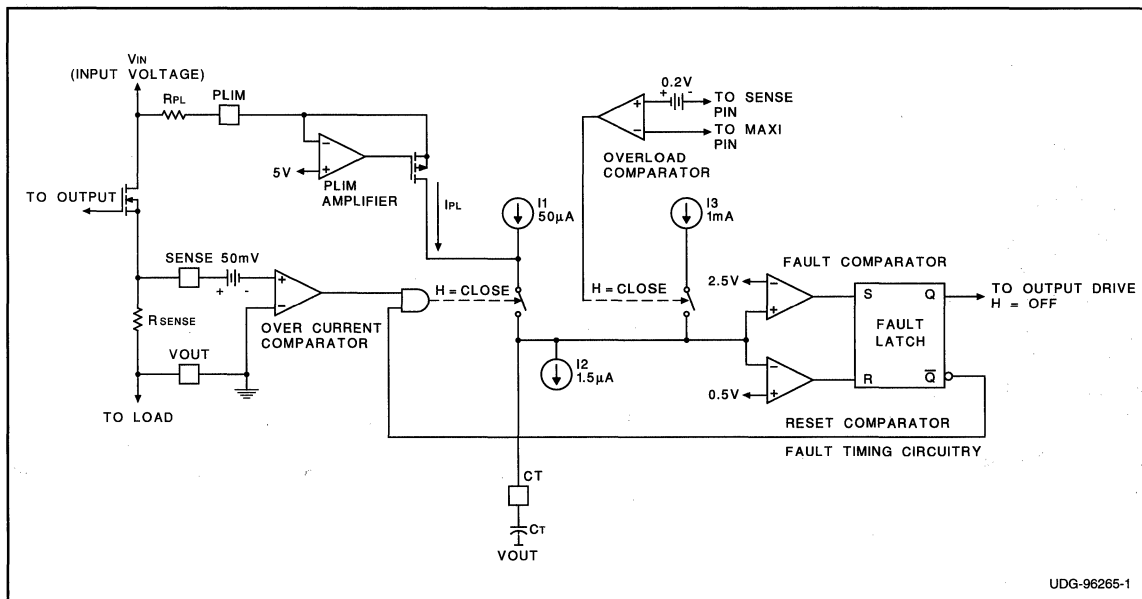


Figure 1. Fault timing circuitry for the UCC3917, including power limit and overload.

## APPLICATION INFORMATION

### Fault Timing

Fig. 1 shows the detailed circuitry for the fault timing function of the UCC3917. For simplicity, we first consider a typical fault mode where the overload comparator and the current source I3 do not come into play. A typical fault occurs once the voltage across the current sense resistor,  $R_S$ , exceeds 50mV. This causes the over current comparator to trip and the timing capacitor to charge with current source I1 plus the current from the power limiting amplifier, or PLIM amplifier. The PLIM amplifier is designed to only source current into the CT pin once the voltage across the output FET exceeds 5V. The current  $I_{PL}$  is related to the voltage across the FET with the following expression:

$$I_{PL} = \frac{(V_{IN} - V_{OUT}) - 5V}{R_{PL}}$$

Note that under normal fault conditions where the output current is just above the fault level,  $V_{OUT} \cong V_{IN}$ ,  $I_{PL} = 0$ , and the  $C_T$  charging current is just I1.

During a fault,  $C_T$  will charge at a rate determined by the internal charging current and the external timing capacitor,  $C_T$ . Once  $C_T$  charges to 2.5V, the fault comparator switches and sets the fault latch. Setting the fault latch causes both the output to switch off and the charging switch to open.  $C_T$  must now discharge with current source I2 until 0.5V is reached. Once the voltage at  $C_T$  reaches 0.5V, the fault latch resets (assuming LATCH is high, otherwise the fault latch will not reset until the LATCH pin is brought high or a power-on reset occurs) which re-enables the output and allows the fault circuitry to regain control of the charging switch. If a fault is still present, the overcurrent comparator will close the charging switch causing the cycle to repeat. Under a constant fault the duty cycle is given by:

$$\text{Duty Cycle} = \frac{I_2}{I_{PL} + I_1} \cong \frac{1.5\mu A}{I_{PL} + 50\mu A}$$

### APPLICATION INFORMATION (cont.)

where  $I_{PL}$  is  $0\mu\text{A}$  under normal operations (see Fig. 2).

However, under large transients, average power dissipation can be limited using the PLIM pin. A proof follows, average dissipation in the pass element is given by:

$$P_{FET\ AVG} = (V_{IN} - V_{OUT}) \cdot I_{MAX} \cdot \text{Duty Cycle}$$

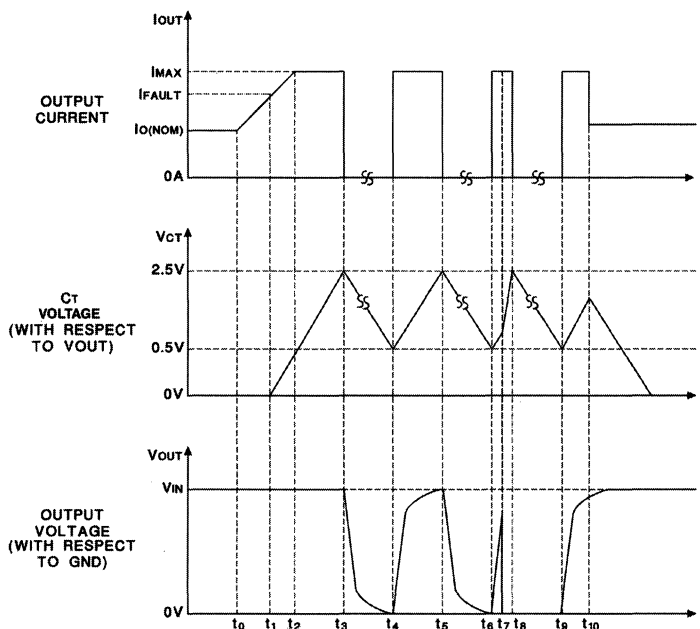
$$= (V_{IN} - V_{OUT}) \cdot I_{MAX} \cdot \frac{1.5\mu\text{A}}{I_{PL} + 50\mu\text{A}}$$

Where  $(V_{IN} - V_{OUT}) \gg 5V$ ,

$$I_{PL} \cong \frac{V_{IN} - V_{OUT}}{R_{PL}}$$

and where  $I_{PL} \gg 50\mu\text{A}$ , the duty cycle can be approximated as:

$$\frac{1.5\mu\text{A} \cdot R_{PL}}{V_{IN} - V_{OUT}}$$



UDG-96266

**t0:** Safe condition - output current is nominal, output voltage is at the positive rail,  $V_{IN}$ .

**t1:** Fault control reached - output current rises above the programmed fault value, CT begins to charge with  $\cong 50\mu\text{A}$ .

**t2:** Maximum current reached - output current reaches the programmed maximum level and becomes a constant current with value  $I_{MAX}$ .

**t3:** Fault occurs - CT has charged to 2.5V, fault output goes low, the FET turns off allowing no output current to flow, VOUT discharges to ground.

**t4:** Retry - CT has discharged to 0.5V, but fault current is still exceeded, CT begins charging again, FET is on, VOUT rises to  $V_{IN}$ .

**t5 = t3:** Illustrates 3% duty cycle.

**t6 = t4:**

**t7:** Output short circuit - if VOUT is short circuited to ground, CT charges at a higher rate depending upon the values for  $V_{IN}$  and  $R_{PL}$ .

**t8:** Fault occurs - output is still short circuited, but the occurrence of a fault turns the FET off so no current is conducted.

**t9 = t4:** Output short circuit released, still in fault mode.

**t10 = t0:** Fault released, safe condition - return to normal operation of the circuit breaker.

Note that  $t6 - t5 \cong 36 \cdot (t5 - t4)$ .

Figure 2. Nominal timing diagram.

### APPLICATION INFORMATION (cont.)

Therefore the average power dissipation in the MOSFET can be approximated by:

$$P_{FET\ AVG} = (V_{IN} - V_{OUT}) \cdot I_{MAX} \cdot \frac{1.5\mu A \cdot R_{PL}}{V_{IN} - V_{OUT}}$$

$$= I_{MAX} \cdot 1.5\mu A \cdot R_{PL}$$

Notice that since  $(V_{IN} - V_{OUT})$  cancels, average power dissipation is limited in the NMOS pass element (see Fig. 3). Also, a value for  $R_{PL}$  can be roughly determined from this approximation.

$$R_{PL} = \frac{P_{FET\ AVG}}{I_{MAX} \cdot 1.5\mu A}$$

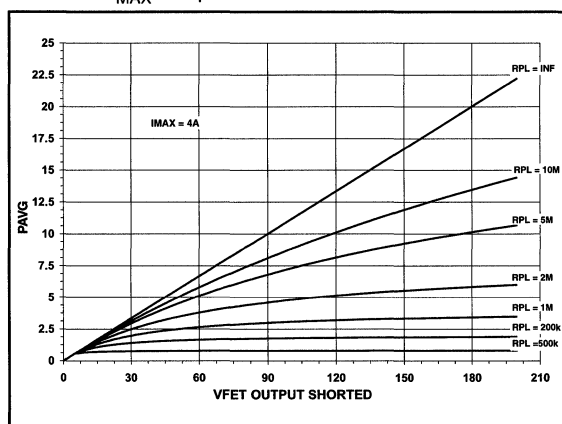


Figure 3. Plot of average power vs. FET voltage for increasing values of  $R_{PL}$ .

### Overload Comparator

The overload comparator provides protection against a shorted load during normal operation when the external N-channel FET is fully enhanced. Once the FET is fully enhanced the linear current amplifier essentially saturates and the system is in effect operating open loop. Once the FET is fully enhanced the linear current amplifier requires a finite amount of time to respond to a shorted output possibly destroying the external FET. The overload comparator is provided to quickly shutdown the external MOSFET in the case of a shorted output (if the FET is fully enhanced). During an output short CT is charged by I3 at ~ 1mA. The current threshold for the overload comparator is a function of  $I_{MAX}$  and a fixed offset and is defined as:

$$I_{OVERLOAD} = I_{MAX} + 200mV / R_S$$

Once the overcurrent comparator trips the UCC3917 will enter programmed fault mode (hiccup or latched). It should be noted that on subsequent retries during Hiccup

mode or if a short should occur when the UCC3917 is actively limiting the current, the output current will not exceed  $I_{MAX}$ . In the event that the external FET does not respond during a fault the UCC3917 will set the VREF/CATFLT pin low to indicate a catastrophic failure.

### Selecting the Minimum Timing Capacitance

To ensure that the IC will startup correctly the designer must ensure that the fault time programmed by CT exceeds the startup time of the load. The startup time ( $T_{START}$ ) is a function of several components; load resistance and load capacitance, soft start components R1, R2 and  $C_{SS}$ , the power limit current contribution determined by  $R_{PL}$ , and  $C_{IN}$ . The equation for  $T_{START}$  will depend on whether the load is resistive or constant current in nature.

For a constant current load: (1)

$$T_{START} = \frac{C_{LOAD} \cdot V_{IN}}{I_{MAX} - I_{LOAD}}$$

For a resistive load :

$$T_{START} = -R_{LOAD} \cdot C_{LOAD} \cdot \ln \left[ 1 - \frac{V_{OUT}}{I_{MAX} \cdot R_{LOAD}} \right] \quad (2)$$

If the power limit function is not be used then CT(min) can be easily found:

$$CT(\min) = \frac{I_{CH} \cdot T_{START}}{dV_{CT}} \quad (3)$$

where  $dV_{CT}$  is the hysteresis on the fault detection circuitry. During operation in the latched fault mode configuration  $dV_{CT} = 2.5V$ . When the UCC3917 is configured for the hiccup or retry mode of fault operation  $dV_{CT} = 2.0V$ .

If the power limit function is used the CT charging current becomes a function of  $I_{CH} + I_{PL}$ . And CT(min) is found from:

$$CT(\min) \equiv \left[ I_{CH} + \frac{V_{IN} - I_{MAX} \cdot R_{LOAD} \cdot \left( 1 - e^{-\frac{-t}{R_{LOAD} \cdot C_{LOAD}}} \right)}{R_{PL}} \right] \cdot \frac{dt}{dV_{CT}} \quad (4)$$

### APPLICATION INFORMATION (cont.)

Since  $I_{PL}$  is a function of the output voltage,  $V_{OUT}$ , which varies over time, equation 4 must be integrated to solve for  $CT(\min)$ . However equation 4 can be easily approximated if the output voltage slews. If the output voltage slews linearly then the CT charge current contribution from the power limit circuitry is shown to be at a peak when  $V_{OUT} = 0V$  and at  $0A$  when  $V_{OUT}=VIN-V_{PL}$ , where  $V_{PL}$  is the power limit voltage threshold.  $I_{PL}$  is shown in Fig. 4 below.

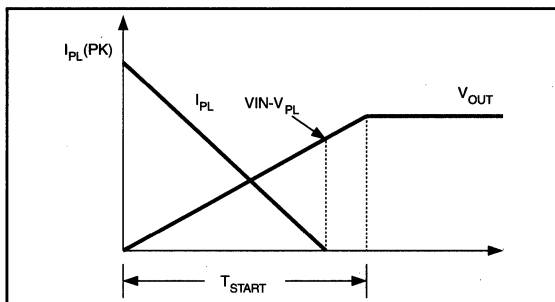


Figure 4. Relationship between  $I_{PL}$ ,  $V_{OUT}$  and  $T_{START}$ .

Where  $I_{PL}$  is defined as:

$$I_{PL} \equiv \frac{(VIN - V_{OUT} - V_{PL})}{R_{PL}} \quad (5)$$

The average  $I_{PL}$  current for the interval  $(0, T_{START})$  from Fig. 4 is defined as:

$$I_{PL}(AVG) \equiv \frac{(VIN - V_{PL})^2}{2 \cdot R_{PL} \cdot VIN} \quad (6)$$

Equation 4 can now be simplified to:

$$CT(\min) \equiv \frac{I_{CH} + I_{PL}(AVG)}{dV_{CT}} \cdot T_{START} \quad (7)$$

Please note that the actual on-time in hiccup mode when operating into a short is defined by:

$$T(on) = \frac{CT \cdot dV_{CT}}{I_{CH} + I_{PL}(PK)} \text{ seconds} \quad (8)$$

where  $dV_{CT} \sim 2.0V$  and

$$I_{PL}(PK) = \frac{VIN}{R_{PL}} \text{ A} \quad (9)$$

### Selecting Other External Components

Other external components are necessary for correct operation of the IC. Referring to the application diagram at the back of the data sheet, resistors  $R_{SENSE}$ ,  $R_{SS}$ ,  $R1$ ,  $R2$  and  $R3$  are required and follow certain equations with a brief description following where applicable:

$$R_{SENSE} = \frac{50mV}{I_{FAULT}} \text{ (Sense Resistor)}$$

$$R_{SS} = \frac{VIN - 5V}{5mA} \text{ (Connected between VSS and GND)}$$

$$R3 = \frac{VIN - 10}{5mA} \text{ (Used in series with a diode to connect VIN to VDD)}$$

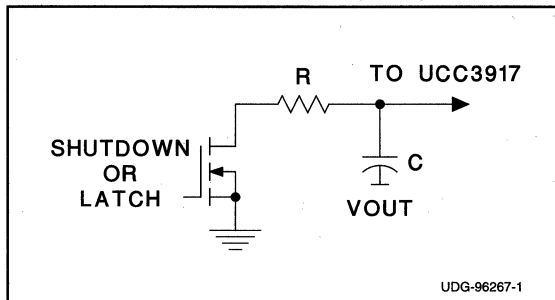
$$(R1 + R2) > 20k\Omega \text{ (Current limit out of VREF)}$$

Lastly, the external capacitors used for the charge pump are required and need to equal  $0.1\mu F$ , i.e.  $C_{IN} = C_H = C1 = C2 = 0.1\mu F$ .

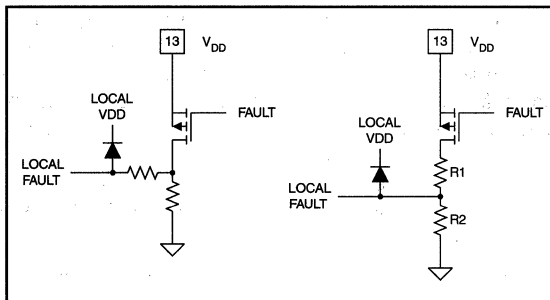
### LEVEL Shift Circuitry (Optional)

The level shift circuitry shown in Fig. 5 and Fig.6 represents a way of interfacing to LATCH, SHTDWN, and FLTOUT. These pins provide functionality that is not necessary for normal operation of the IC but may prove useful to the application. The resistor,  $R$ , shown in both figures is used for the current limiting and follows  $R_{MAX} = V_{SD}/I_{SD}$ . The capacitor,  $C$ , shown in both figures is operational to the level shift circuitry and keeps spurious signals from occurring during transients. It's recommended value is  $C_{MIN} = 0.1nF$ . It should be noted that the use of the capacitor,  $C$ , will cause delays into and out of these pins.

**APPLICATION INFORMATION (cont.)**



**Figure 5. Potential level shift circuitry to interface to LATCH and SHTDWN on the UCC3917.**

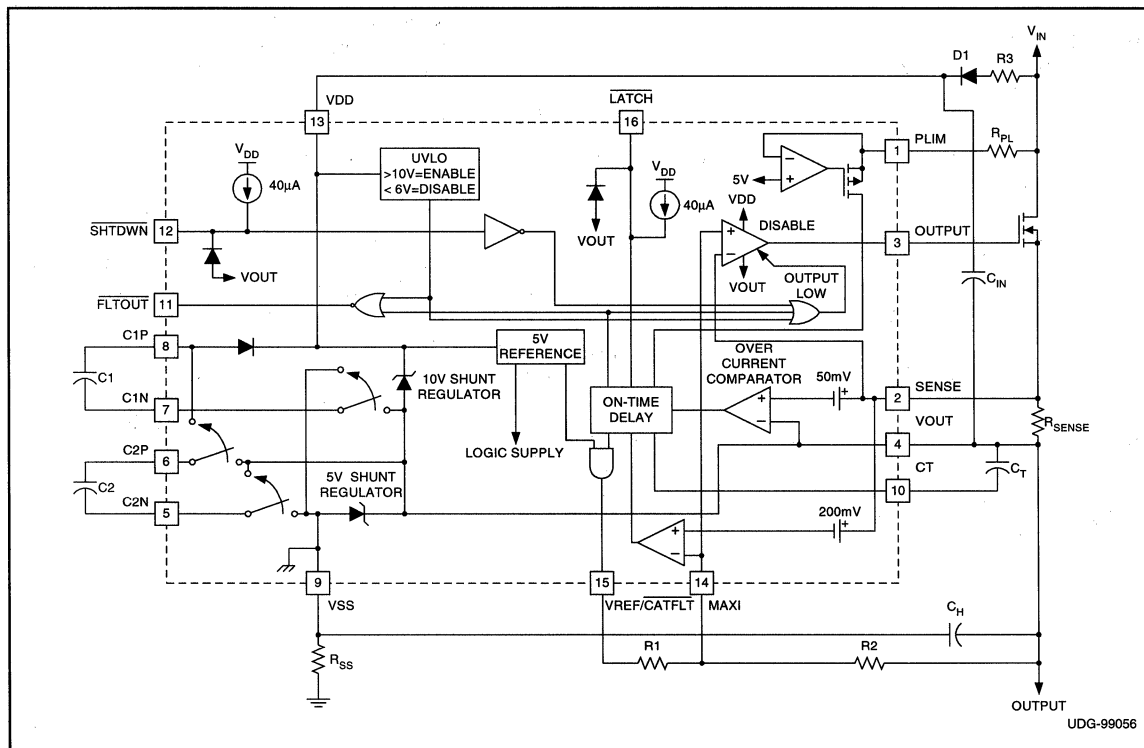


**Figure 6. Potential level shift circuitry to interface to FLTOUT on the UCC3917.**

**SAFETY RECOMMENDATIONS**

Although the UCC3917 is designed to provide system protection for all fault conditions, all integrated circuits can ultimately fail short. For this reason, if the UCC3917 is intended for use in safety critical applications where UL or some other safety rating is required, a redundant safety

device such as a fuse should be placed in series with the power device. The UCC3917 will prevent the fuse from blowing for virtually all fault conditions, increasing system reliability and reducing maintenance cost, in addition to providing the hot swap benefits of the device.



**Figure 7. Positive floating hot swap power manager UCC1917, UCC2917 and UCC3917.**

# Low On Resistance Hot Swap Power Manager

## FEATURES

- Integrated 0.06Ω Power MOSFET
- 3V to 6V Operation
- External Analog control of Fault Current from 0A to 4A
- Independent Analog Control of Current Limit up to 5A
- Fast Overload Protection
- Minimal External Components
- 1μA I<sub>CC</sub> when Disabled
- Programmable On Time
- Programmable Start Delay
- Fixed 3% Duty Cycle

## DESCRIPTION

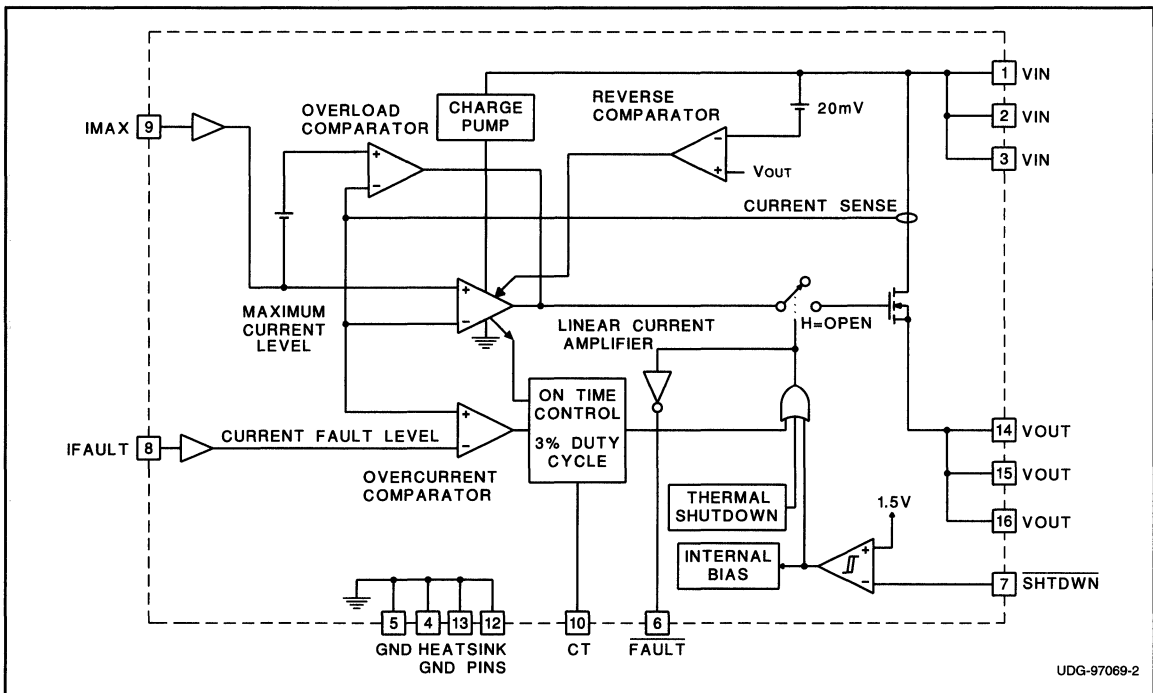
The UCC3918 Low on Resistance Hot Swap Power Manager provides complete power management, hot swap capability, and circuit breaker functions. The only components needed to operate the device, other than supply bypassing, are a timing capacitor, and 2 programming resistors. All control and housekeeping functions are integrated, and externally programmable. These include the fault current level, maximum output sourcing current, maximum fault time, and startup delay. In the event of a constant fault, the internal fixed 3% duty cycle ratio limits the average output power. The IFAULT pin allows linear programming of the fault level current from 0A to 4A.

Fast overload protection is accomplished by an additional overload comparator. Its threshold is internally set above the maximum sourcing current limit setting. In the event of a short circuit or extreme current condition, this comparator is tripped, shutting down the output. This function is needed since the maximum sourcing current limit loop has a finite bandwidth.

When the output current is below the fault level, the output MOSFET is switched on with a nominal resistance of 0.06Ω. When the output current exceeds the fault level or the maximum sourcing level, the output remains on, but the fault timer starts charging CT. Once CT charges to a preset threshold, the switch is turned off, and remains off for 30 times the programmed fault time. When the output current reaches the maximum sourcing level, the MOSFET transitions from a switch to a constant current source.

## BLOCK DIAGRAM

(continued)



### DESCRIPTION (continued)

The UCC3918 is designed for unidirectional current flow, emulating an ideal diode in series with the power switch. This feature is particularly attractive in applications where many devices are powering a common bus, such as with SCSI Termpwr. The UCC3918 can also be put into the sleep mode, drawing only 1µA of supply current.

Other features include an open drain fault output indicator, thermal shutdown, undervoltage lockout, 3V to 6V operation, and a low thermal resistance small outline power package.

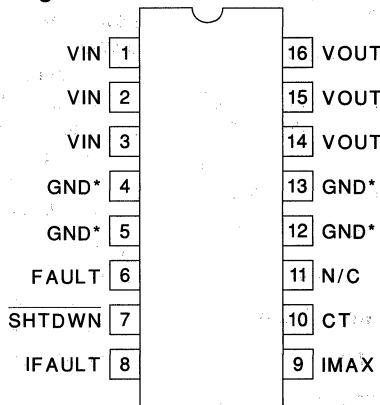
### ABSOLUTE MAXIMUM RATINGS

Input Supply Voltage (VIN) .....	8V
SOIC Power Dissipation .....	2.5W
Fault Output Sink Current .....	50mA
Fault Output Voltage .....	VIN
Output Current (DC) .....	Internally Limited
TTL Input Voltage .....	-0.3V to VIN
Storage Temperature .....	-65°C to +150°C
Junction Temperature .....	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.) .....	+300°C

*Unless otherwise indicated, voltages are reference to ground and currents are positive into, negative out of the specified terminal. Pulsed is defined as a less than 10% duty cycle with a maximum duration of 500µs. Consult Packaging Section of Databook for thermal limitations and considerations of package.*

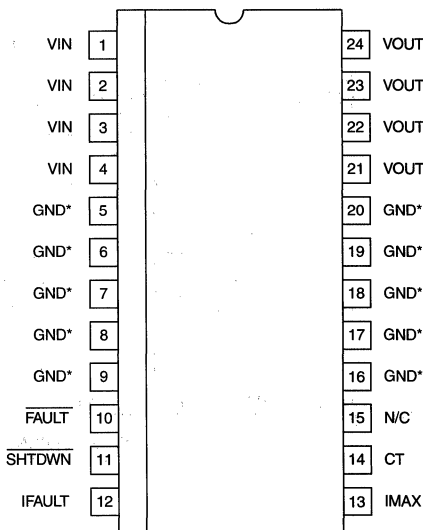
### CONNECTION DIAGRAM

**DIL-16, SOIC-16 (Top View)  
N Package, DP Package  
Q,L Packages**



\* Pin 5 serves as the lowest impedance to the electrical ground. Pins 4, 12, and 13 serve as heat sink/ground. These pins should be connected to large etch PCB areas to help dissipate heat. For N Package, pins 4, 12, and 13 are N/C.

**TSSOP-24 (Top View)  
PWP Package**



\* Pin 9 serves as the lowest impedance to the electrical ground. Pins 5, 6, 7, 8, 16, 17, 18, 19 and 20 serve as heat sink/ground.



**ELECTRICAL CHARACTERISTICS:** Unless otherwise specified,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$  for the UCC3918,  $-40^\circ\text{C}$  to  $85^\circ$  for the UCC2918,  $V_{IN} = 5\text{V}$ ,  $R_{I\text{MAX}} = 42.2\text{k}$ ,  $R_{I\text{FAULT}} = 52.3\text{k}$ ,  $S\text{HTDWN} = 2.4$ ,  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Supply Section</b>					
Voltage Input Range, $V_{IN}$		3	5	6	V
$V_{DD}$ Supply Current	No Load		1	2	mA
Sleep Mode Current	SHTDWN = 0.2V		0.5	5	$\mu\text{A}$
<b>Output Section</b>					
$R_{DS\text{ON}}$	$I_{\text{OUT}} = 1\text{A to }4\text{A}$ , $V_{IN} = 5\text{V}$ , $T_A = 25^\circ\text{C}$		0.075	0.095	$\Omega$
	$I_{\text{OUT}} = 1\text{A to }4\text{A}$ , $V_{IN} = 3\text{V}$ , $T_A = 25^\circ\text{C}$		0.09	0.116	$\Omega$
	$I_{\text{OUT}} = 1\text{A to }4\text{A}$ , $V_{IN} = 5\text{V}$		0.75	0.125	$\Omega$
	$I_{\text{OUT}} = 1\text{A to }4\text{A}$ , $V_{IN} = 3\text{V}$		0.09	0.154	$\Omega$
Initial Startup Time	(Note 1)		100		$\mu\text{s}$
Thermal Shutdown	(Note 1)		170		DEG
<b>Output Section (cont)</b>					
Thermal Hysteresis	(Note 1)		10		DEG
Output Leakage	SHTDWN = 0.2V			20	$\mu\text{A}$
Trip Current	$R_{I\text{FAULT}} = 105\text{k}$	0.75	1	1.25	A
	$R_{I\text{FAULT}} = 52.3\text{k}$	1.7	2	2.3	A
	$R_{I\text{FAULT}} = 34.8\text{k}$	2.5	3	3.5	A
	$R_{I\text{FAULT}} = 25.5\text{k}$	3.3	4	4.7	A
Maximum Output Current	$R_{I\text{MAX}} = 118\text{k}$	0.3	1	1.7	A
	$R_{I\text{MAX}} = 60.4\text{k}$	1	2	3	A
	$R_{I\text{MAX}} = 42.2\text{k}$	2	3	4	A
	$R_{I\text{MAX}} = 33.2\text{k}$	2.5	3.8	5.1	A
	$R_{I\text{MAX}} = 27.4\text{k}$	3.0	4.6	6.2	A
<b>Fault Section</b>					
$C_T$ Charge Current	$V_{CT} = 1\text{V}$	-50	-36	-22	$\mu\text{A}$
$C_T$ Discharge Current	$V_{CT} = 1\text{V}$	0.5	1.2	2.0	$\mu\text{A}$
<b>Fault Section (cont.)</b>					
Output Duty Cycle	$V_{\text{OUT}} = 0\text{V}$	1.5	3	6	%
$C_T$ Fault Threshold		0.8	1.3	1.8	V
$C_T$ Reset Threshold		0.25	0.5	0.75	V
<b>Shutdown Section</b>					
Shutdown Threshold		1.1	1.5	2.0	V
Shutdown Hysteresis			100		mV
Input Low Current	SHTDWN = 0V	-500	0	500	nA
Input High Current	SHTDWN = 2V	-2	-1	-0.5	$\mu\text{A}$
<b>Open Drain Fault Output</b>					
High Level Output Current				1	$\mu\text{A}$
Low Level Output Voltage	$I_{\text{OUT}} = 1\text{mA}$		0.4	0.9	V

Note 1: Guaranteed by design. Not 100% tested in production.

**PIN DESCRIPTIONS**

**CT:** A capacitor connected to this pin sets the maximum fault time. The maximum must be more than the time to charge external load capacitance. The maximum fault time is defined as

$$T_{FAULT} = 27.8 \cdot 10^3 \cdot C_T$$

Once the fault time is reached the output will shutdown for a time given by

$$T_{SD} = 0.833 \cdot 10^6 \cdot C_T,$$

this equates to a 3% duty cycle.

**FAULT:** Open drain output, which pulls low upon any condition which causes the output to open; Fault, Thermal Shutdown, Shutdown, and maximum sourcing current greater than the fault time.

**GND:** This is the most negative voltage in the circuit. All 4 ground pins should be used, and properly heat sunk on the PCB.

**IFAULT:** A resistor connected from this pin to ground sets the fault threshold. The resistor vs fault current is set by the formula

$$R_{FAULT} = \frac{105k}{I_{TRIP}}$$

**IMAX:** A resistor connected from this pin to ground sets the maximum sourcing current. The resistor vs the output sourcing current is set by the formula,

$$R_{FAULT} = \frac{126k}{\text{Maximum Sourcing Current}}$$

**SHTDWN:** When this pin is brought low, the IC is put into sleep mode. The input threshold is hysteric, allowing the user to program a startup delay with an external RC circuit.

**VIN:** This is the input voltage to the UCC3918. The recommended operating voltage range is 3V to 6V. All VIN pins should be connected together and to the power source.

**VOUT:** Output voltage for the circuit breaker. When switched the output voltage will be approximately  $V_{IN} - 0.06\Omega \cdot I_{OUT}$ . All VOUT pins should be connected together and to the load.

**APPLICATION INFORMATION**

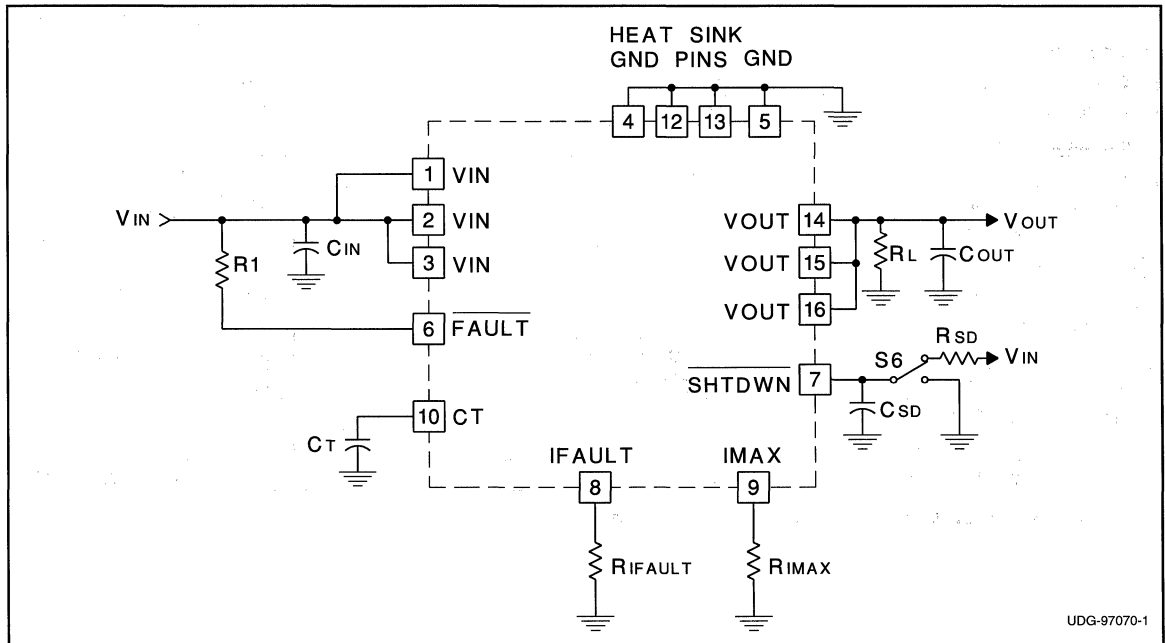
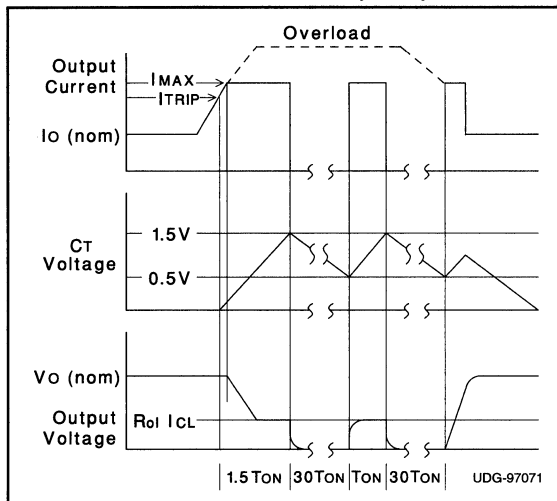


Figure 1. Evaluation Circuit

**APPLICATION INFORMATION (cont.)**



**Figure 2. Load Current, Timing Capacitor Voltage and Output Voltage of the UCC3918 Under Fault**

**Estimating Maximum Load Capacitance**

For circuit breaker applications, the rate at which the total output capacitance can be charged depends on the maximum output current available and the nature of the load. For a constant-current current-limited circuit breaker, the output will come up if the load asks for less

than the maximum available short-circuit current.

To guarantee recovery of a duty-cycle of the current-limited circuit breaker from a short-circuited load condition, there is a maximum total output capacitance which can be charged for a given unit ON time (Fault time). The design value of ON or Fault time can be adjusted by changing the timing capacitor  $C_T$ .

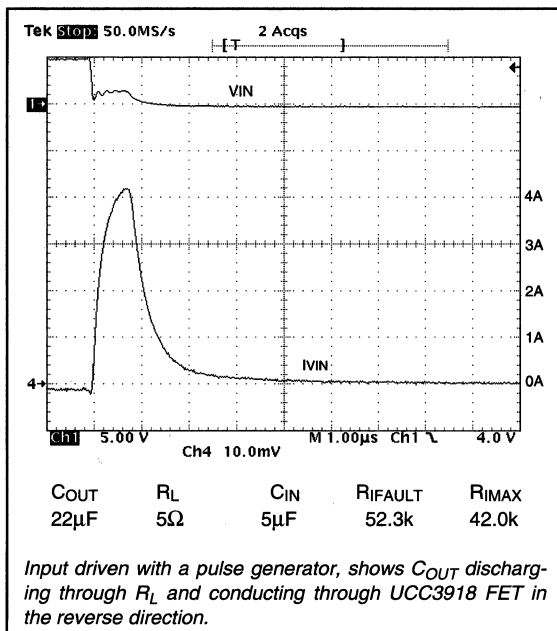
For worst-case constant-current load of value just less than the trip limit;  $C_{OUT(max)}$  can be estimated from:

$$C_{OUT(max)} \approx (I_{MAX} - I_{LOAD}) \left( \frac{28 \cdot 10^3 \cdot C_T}{V_{OUT}} \right)$$

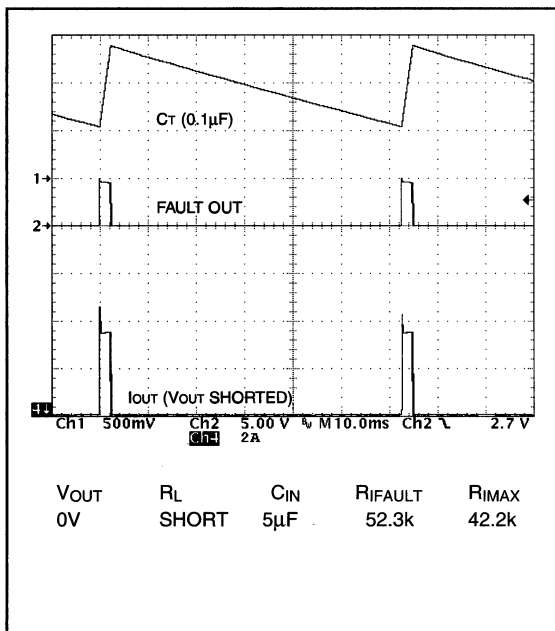
Where  $V_{OUT}$  is the output voltage and  $I_{MAX}$  is the maximum, sourcing current.

For a resistive load of value  $R_L$ , the value of  $C_{OUT(max)}$  can be estimated from:

$$C_{OUT(max)} \approx \frac{28 \cdot 10^3 \cdot C_T}{R_L \cdot \ln \left[ \frac{1}{1 - \frac{V_{OUT}}{I_{MAX} \cdot R_L}} \right]}$$



**Figure 3.**



**Figure 4. UCC3918 in Shorted Condition**

APPLICATION INFORMATION

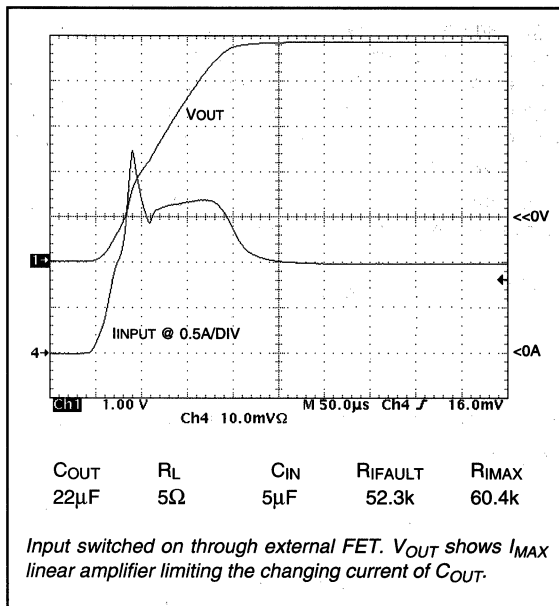


Figure 5. Input Hot Swap

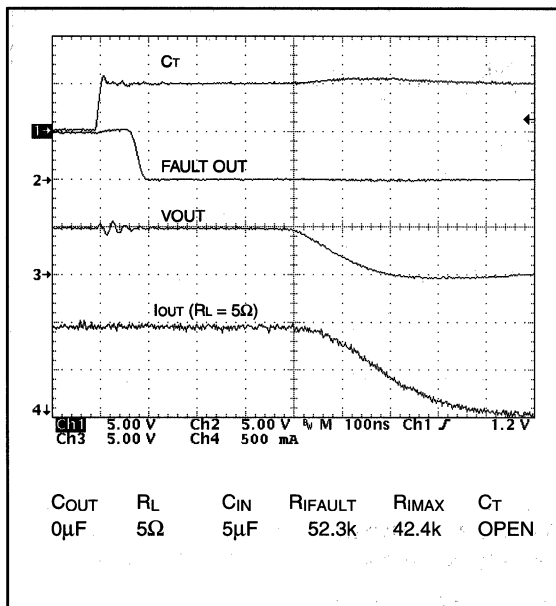


Figure 6. C<sub>T</sub> to V<sub>OUT</sub> Delay (Fault Condition)

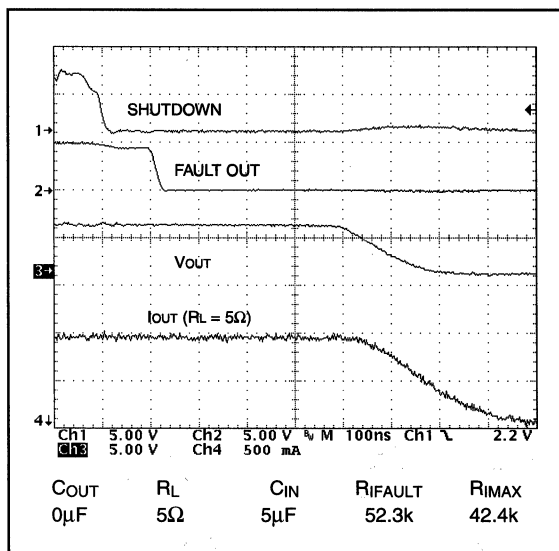


Figure 7. Shutdown Delay to V<sub>OUT</sub> Off

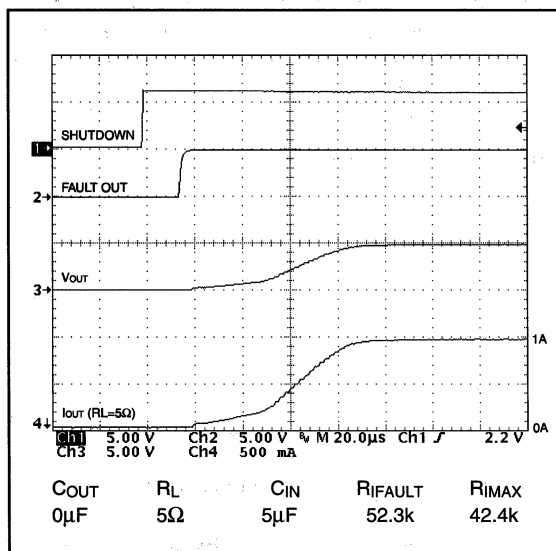


Figure 8. Shutdown Delay to V<sub>OUT</sub> On

**APPLICATION INFORMATION**

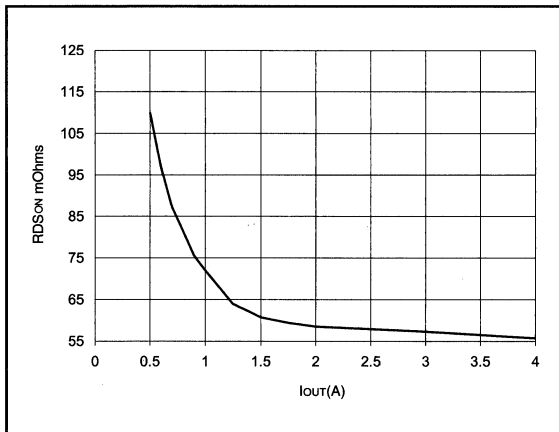


Figure 9.  $R_{DS(ON)}$  vs  $I_{OUT}$

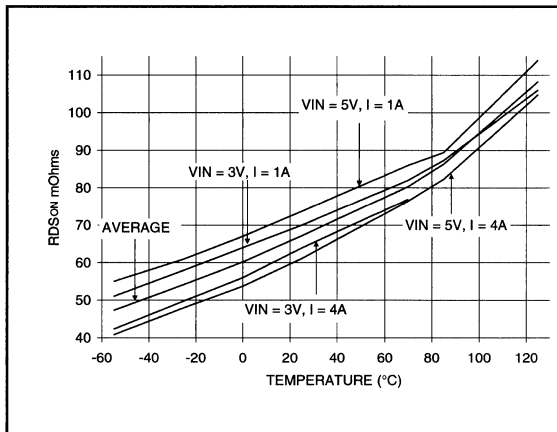


Figure 10.  $R_{DS(ON)}$  vs Temperature

**SAFETY RECOMMENDATIONS**

Although the UCC3918 is designed to provide system protection for all fault conditions, all integrated circuits can ultimately fail short. For this reason, if the UCC3918 is intended for use in safety critical applications where UL or some other safety rating is required,

a redundant safety device such as a fuse should be placed in series with the power device. The UCC3918 will prevent the fuse from blowing for virtually all fault conditions, increasing system reliability and reducing maintenance cost, in addition to providing the hot swap benefits of the device.



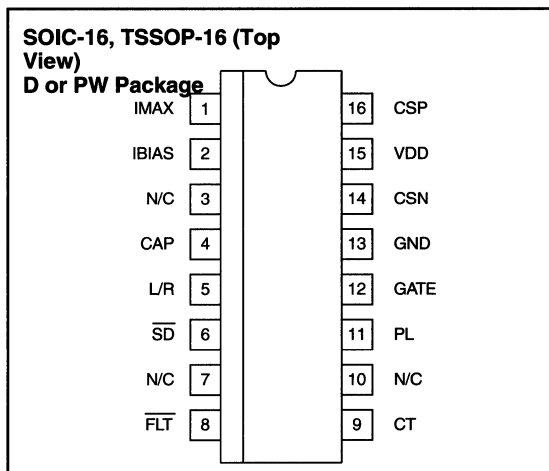
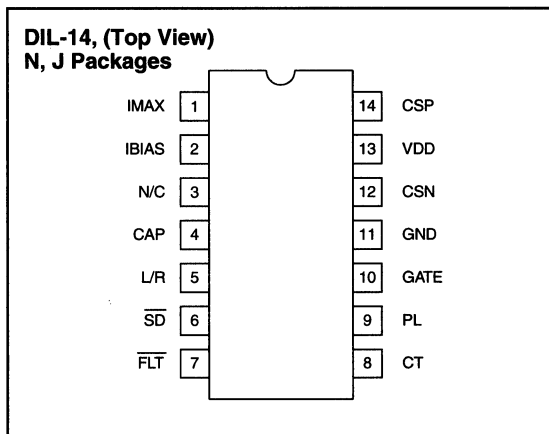


**ABSOLUTE MAXIMUM RATINGS**

VDD	.....	-0.3V to 10V
Pin Voltage (All pins except CAP and GATE)	.....	-0.3V to VDD + 0.3V
Pin Voltage (CAP and GATE)	.....	-0.3V to 15V
PL Current	.....	0.5mA to -10mA
IBIAS Current	.....	0mA to 3mA
Storage Temperature	.....	-65°C to +150°C
Junction Temperature	.....	-55°C to +150°C
Lead Temperature (Soldering, 10sec.)	.....	+300°C

*Currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of package.*

**CONNECTION DIAGRAMS**



**ELECTRICAL CHARACTERISTICS:** Unless otherwise specified, VDD = 5V, TA = 0°C to 70°C for the UCC3919, -40°C to 85° for the UCC2919 and -55°C to 125°C for the UCC1919. All voltages are with respect to GND. TA = TJ.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Input Supply</b>					
Supply Current	VDD = 3V		0.5	1	mA
	VDD = 8V		1	1.5	mA
Shutdown Current	SD = 0.2V		1	5	μA
<b>Undervoltage Lockout</b>					
Minimum Voltage to Start		2.5	2.75	3	V
Minimum Voltage after Start		2	2.25	2.5	V
Hysteresis		0.25	0.5	0.75	V
<b>IBIAS</b>					
Output Voltage, (0μA < IOUT < 15μA)	25°C, referred to CSP	1.47	1.5	1.53	V
	Over Temperature Range, referred to CSP	1.44	1.5	1.56	V
Maximum Output Current		1	2		mA

**ELECTRICAL CHARACTERISTICS:** Unless otherwise specified, VDD = 5V, TA = 0°C to 70°C for the UCC3919, -40°C to 85°C for the UCC2919 and -55°C to 125°C for the UCC1919. All voltages are with respect to GND. TA = TJ.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Current Sense</b>					
Over Current Comparator Offset	Referred to CSP, $3V \leq VDD \leq 8V$	-55	-50	-45	mV
Linear Current Amplifier Offset	$V_{IMAX} = 100mV$ , Referred to CSP, $3V \leq VDD \leq 8V$	-110	-100	-90	mV
	$V_{IMAX} = 400mV$ , Referred to CSP, $3V \leq VDD \leq 8V$	-410	-400	-390	mV
Overload Comparator Offset	$V_{IMAX} = 100mV$ , Referred to CSP, $3V \leq VDD \leq 8V$	-360	-300	-240	mV
CSN Input Common Mode Voltage Range	Referred to VDD, $3V \leq VDD \leq 8V$ , (Note 1)	-1.5		0.2	V
CSP Input Common Mode Voltage Range	Referred to VDD, $3V \leq VDD \leq 8V$ , (Note 1)	0		0.2	V
Input Bias Current CSN			1	5	$\mu A$
Input Bias Current CSP			100	200	$\mu A$
<b>Current Fault Timer</b>					
CT Charge Current	$V_{CT} = 1V$	-56	-35	-16	$\mu A$
CT Discharge Current	$V_{CT} = 1V$	0.5	1.2	1.9	$\mu A$
On Time Duty Cycle in Fault	$I_{PL} = 0$	1.5	3	6	%
CT Fault Threshold		1.0	1.5	1.7	V
CT Reset Threshold		0.25	0.5	0.75	V
<b>IMAX</b>					
Input Bias Current	$V_{IMAX} = 100mV$ , Referred to CSP	-1	0	1	$\mu A$
<b>Power Limiting Section</b>					
Voltage on PL	$I_{PL} = -250\mu A$ , Referred to VDD	-1.0	-1.4	-1.9	V
	$I_{PL} = -1.5mA$ , Referred to VDD	-0.5	-1.8	-2.2	V
On Time Duty Cycle in Fault	$I_{PL} = -250\mu A$	0.25	0.5	1	%
	$I_{PL} = -1.5mA$	0.05	0.1	0.2	%
<b>SD and L/R Inputs</b>					
Input Voltage Low				0.8	V
Input Voltage High		2			V
L/R Input Current		1	3	6	mA
SD Internal Pulldown Impedance		100	270	500	k $\Omega$
<b>FLT Output</b>					
Output Leakage Current	VDD = 5V			10	$\mu A$
Output Low Voltage	$I_{OUT} = 10mA$			1	V
<b>FET GATE Driver and Charge Pump</b>					
Peak Output Current	$V_{CAP} = +15V$ , $V_{GATE} = 10V$	-3	-1	-0.25	mA
Peak Sink Current	$V_{GATE} = 5V$		20		mA
Fault Delay			100	300	nS
Maximum Output Voltage	VDD = 3V, Average $I_{OUT} = 1\mu A$	8	10	12	V
	VDD = 8V, Average $I_{OUT} = 1\mu A$	12	14	16	V
Charge Pump UVLO Minimum Voltage to Start	VDD = 3V	6.5	7.5		V
	VDD = 8V	6.5	8		V
Charge Pump Source Impedance	VDD = 5V, Average $I_{OUT} = 1\mu A$	50	100	150	k $\Omega$

**Note 1:** Guaranteed by design. Not 100% tested in production.



## PIN DESCRIPTIONS

**CAP:** A capacitor is placed from this pin to ground to filter the output of the on board charge pump. A .01 $\mu$ F to 0.1 $\mu$ F capacitor is recommended .

**CSN:** The negative current sense input signal.

**CSP:** The positive current sense input signal.

**CT:** Input to the duty cycle timer. A capacitor is connected from this pin to ground, setting the off time and the maximum on time of the overcurrent protection circuits.

**FLT:** Fault indicator. This open drain output will pull low under any fault condition where the output driver is disabled. This output is disabled when the IC is in low current standby mode.

**GATE:** The output of the linear current amplifier. This pin drives the gate of an external N-channel MOSFET pass transistor. The linear current amplifier control loop is internally compensated, and guaranteed stable for output load (gate) capacitance between 100pF and .01 $\mu$ F. In applications where the GATE voltage (or charge pump voltage) exceeds the maximum Gate-to-Source voltage ratings ( $V_{GS}$ ) for the external N-channel MOSFET, a Zener clamp may be added to the gate of the MOSFET. No additional series resistance is required since the internal charge pump has a finite output impedance of 100k $\Omega$  typical.

**GND:** The ground reference for the device.

**IBIAS:** Output of the on board bias generator internally regulated to 1.5V below CSP. A resistor divider between this pin and CSP can be used to generate the IMAX voltage. The bias circuit is internally compensated, and requires no bypass capacitance. If an external bypass is required due to a noisy environment, the circuit will be

stable with up to .001 $\mu$ F of capacitance. The bypass must be to CSP, since the bias voltage is generated with respect to CSP. Resistor R2 (Figure 4) should be greater than 50k $\Omega$  to minimize the effect of the finite input impedance of the IBIAS pin on the IMAX threshold.

**IMAX:** Used to program the maximum allowable sourcing current. The voltage on this pin is with respect to CSP. If the voltage across the shunt resistor exceeds this voltage the linear current amplifier lowers the voltage at GATE to limit the output current to this level. If the voltage across the shunt resistor goes more than 200mV beyond this voltage, the gate drive pin GATE is immediately driven low and kept low for one full off time interval.

**L/R:** Latch/Reset. This pin sets the reset mode. If L/R is low and a fault occurs the device will begin duty ratio current limiting. If L/R is high and a fault occurs, GATE will go low and stay low until L/R is set low. This pin is internally pulled low by a 3 $\mu$ A nominal pulldown.

**PL:** Power Limit. This pin is used to control average power dissipation in the external MOSFET. If a resistor is connected from this pin to the source of the external MOSFET, the current in the resistor will be roughly proportional to the voltage across the FET. As the voltage across the FET increases, this current is added to the fault timer charge current, reducing the on time duty cycle from its nominal value of 3% and limiting the average power dissipation in the FET.

**SD:** Shutdown pin. If this pin is taken low, GATE will go low, and the IC will go into a low current standby mode and CT will be discharged. This TTL compatible input must be driven high to turn on.

**VDD:** The power connection for the device.

## APPLICATION INFORMATION

The UCC3919 monitors the voltage drop across a high side sense resistor and compares it against three different voltage thresholds. These are discussed below. Figure 1 shows the UCC3919 waveforms under fault conditions.

### Fault Threshold

The first threshold is fixed at 50mV. If the current is high enough such that the voltage on CSN is 50mV below CSP, the timing capacitor CT begins to charge at about 35 $\mu$ A if the PL pin is open. (Power limiting will be discussed later). If this threshold is exceeded long enough for CT to charge to 1.5V, a fault is declared and the ex-

ternal MOSFET will be turned off. It will either be latched off (until the power to the circuit is cycled, the L/R pin is taken low, or the SD pin is toggled), or will retry after a fixed off time (when CT has discharged to 0.5V), depending on whether the L/R pin is set high or low by the user. The equation for this current threshold is simply:

$$I_{FAULT} = \frac{0.05}{R_{SENSE}} \quad (1)$$

The first time a fault occurs, CT is at ground, and must charge 1.5V. Therefore:

$$t_{FAULT} = t_{ON}(\text{sec}) = \frac{C_T(\mu\text{F}) \cdot 1.5}{35} \quad (2)$$



**APPLICATION INFORMATION**

In the retry mode, the timing capacitor will already be charged to 0.5V at the end of the off time, so all subsequent cycles will have a shorter ton time, given by:

$$t_{FAULT} \cong t_{ON}(sec) = \frac{C_T(\mu F)}{35} \quad (3)$$

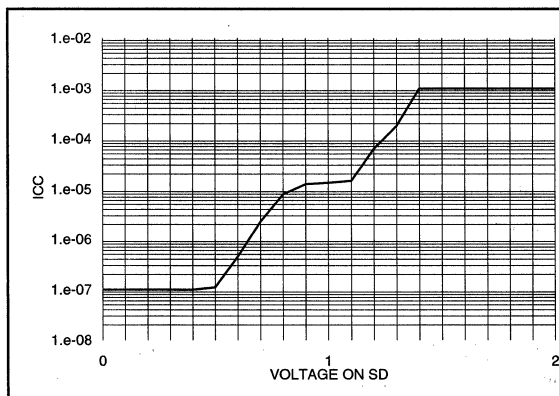
Note that these equations for ton are without the power limiting feature (RPL pin open). The effects of power limiting on ton will be discussed later.

The off time in the retry mode is set by CT and an internal 1.2µA sink current. It is the time it takes CT to discharge from 1.5V to 0.5V. The equation for the off time is therefore:

$$t_{OFF}(sec) = \frac{C_T \mu F}{1.2} \quad (4)$$

**Shutdown Characteristics**

When the SD pin is set to TTL high (above 2V) the UCC3919 is guaranteed to be enabled. When SD is set to a low TTL (below 0.8V) the UCC3919 is guaranteed to be disabled, but may not be in ultra low current sleep mode. When SD is set to 0.2V or less, the UCC3919 is guaranteed to be disabled and in ultra low current sleep mode. See Fig. 1.



**Figure 1. Typical Shutdown Current**

**IMAX Threshold**

The second threshold is programmed by the voltage on IMAX (measured with respect to the CSP pin). This controls the maximum current, IMAX, that the UCC3919 will allow to flow into the load during the MOSFET on time. A resistive divider connected between IBIAS and CSP generates the programming voltage. When the drop across the sense resistor reaches this voltage, a linear amplifier

reduces the voltage on GATE to control the external MOSFET in a constant current mode.

During this time CT is charging, as described above. If this condition lasts long enough for CT to charge to 1.5V, a fault will be declared and the MOSFET will be turned off. The IMAX current is calculated as follows:

$$I_{MAX} = \frac{V_{CSP} - V_{IMAX}}{R_{SENSE}} \quad (5)$$

Note that if the voltage on the IMAX pin is programmed to be less than 50mV below CSP, then the UC3919 will control the MOSFET in a constant current mode all the time. No fault will be declared and the MOSFET will remain on because IMAX is less than IFAULT.

**Overload Threshold**

There is a third threshold which, if exceeded, will declare a fault and shutdown the external MOSFET immediately, without waiting for CT to charge. This "Overload" threshold is 200mV greater than the IMAX threshold (again, this is with respect to CSP). This feature protects the circuit in the event that the external MOSFET is on, with a load current below IMAX, and a short is quickly applied across the output. This allows hot-swapping in cases where the UCC3919 is already powered up (on the backplane) and capacitors are added across the output bus. In this case, the load current could rise too quickly for the linear amplifier to reduce the voltage on GATE and limit the current to IMAX. If the overload threshold is reached, the MOSFET will be turned off quickly and a fault declared. A latch is set so that CT can be charged, guaranteeing that the MOSFET will remain off for the same period as defined above before retrying. The overload current is:

$$I_{OVERLOAD} = \frac{V_{CSP} - V_{IMAX} + 0.2}{R_{SENSE}} = I_{MAX} + \frac{0.2}{R_{SENSE}} \quad (6)$$

Note that IOVERLOAD may be much greater than IMAX, depending on the value of RSENSE.

**Power Limiting**

A power limiting feature is included which allows the power dissipated in the external MOSFET to be held relatively constant during a short, for different values of input voltage. This is accomplished by connecting a resistor from the output (source of the external MOSFET) to PL. When the output voltage drops due to a short or overload, an internal bias current is generated which is equal to:

$$I_{PL} \cong \frac{(V_{IN} - V_{OUT} - V_{PL})}{R_{PL}} \quad (7)$$

## APPLICATION INFORMATION (cont.)

This current is used to help charge the timing capacitor in the event that the load current exceeds  $I_{FAULT}$ . (A simplified schematic of the circuit internal to the UCC3919 is shown in Figure 2.) The result is that the on time of the MOSFET during current limit is reduced as the input voltage is increased. This reduces the effective duty cycle, holding the average power dissipated constant.

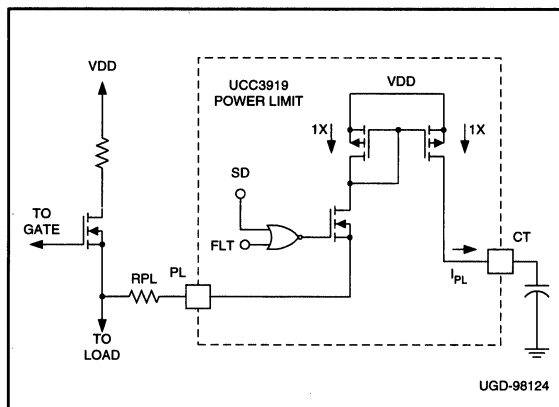


Figure 2. Power limiting circuit.

It can be seen that power limiting will only occur when  $I_{PL}$  is  $> 0$  (it cannot be negative). For power limiting to begin to occur, the voltage drop across the MOSFET must be greater than  $V_{DD} - V_{PL}$  or 1.4V(typ).

$$V_{IN} - V_{OUT} \geq 1.4V \quad (8)$$

The on time using  $R_{PL}$  is defined as:

$$t_{ON} = \frac{C_T \cdot \Delta V}{I_{PL} + 35 \cdot 10^{-6}} \quad \text{where } \Delta V = 1V \quad (9)$$

The graph in Figure 4 illustrates the effect of  $R_{PL}$  on the average MOSFET power dissipation into a short. The equation for the average power dissipation during a short is:

$$P_{DISS} = \frac{I_{MAX} \cdot V_{IN} \cdot 1.2 \cdot 10^{-6}}{I_{PL} + 35 \cdot 10^{-6}}, \text{ or} \quad (10)$$

$$P_{DISS} = \frac{I_{MAX} \cdot V_{IN} \cdot t_{ON}}{t_{ON} + t_{OFF}}$$

If  $PL$  is left unconnected, the power limiting feature will not be exercised. In the retry mode, the duty cycle during a fault will be nominally 3%, independent of input voltage. The average power dissipation in the external MOSFET with a shorted output will be proportional to input voltage, as shown by the equation:

$$P_{DISS} = I_{MAX} \cdot V_{IN} \cdot 0.033 \quad (11)$$

### Calculating $C_T(\text{min})$ for a Given Load Capacitance without Power Limiting

To guarantee recovery from an overload when operating in the retry mode, there is a maximum total output capacitance which can be charged for a given  $t_{ON}$  (fault time) before causing a fault. For a worst case situation of a constant current load below the fault threshold,  $C_T(\text{min})$  for a given output load capacitance (without power limiting) can be calculated from:

$$C_T(\text{min}) = \frac{V_{IN} \cdot C_{OUT} \cdot 35 \cdot 10^{-6}}{I_{MAX} - I_{LOAD}} \quad (12)$$

A larger load capacitance or a smaller  $C_T$  will cause a fault when recovering from an overload, causing the circuit to get stuck in a continuous hiccup mode. To handle larger capacitive loads, increase the value of  $C_T$ . The equation can be easily re-written, if desired, to solve for  $C_{OUT}(\text{max})$  for a given value of  $C_T$ .

For a resistive load of value  $R_L$  and an output cap  $C_{OUT}$ ,  $C_T(\text{min})$  can be smaller than in the constant current case, and can be estimated from:

$$C_T(\text{min}) = \frac{-C_{OUT} \cdot R_L \cdot \ln \left( 1 - \frac{V_{IN}}{I_{MAX} \cdot R_L} \right)}{28 \cdot 10^3} \quad (13)$$

Note that in the latch mode (or when first turning on in the retry mode), since the timing capacitor is not recovering from a previous fault, it is charging from 0V rather than 0.5V. This allows up to 50% more load capacitance without causing a fault.

### Estimating $C_T(\text{min})$ When Using Power Limiting

If power limiting is used, the calculation of  $C_T(\text{min})$  for a given  $C_{OUT}$  becomes considerably more complex, especially with a resistive load. This is because the  $C_T$  charge current becomes a function of  $V_{OUT}$ , which is changing with time. The amount of capacitance that can be charged (without causing a fault) when using power limiting will be significantly reduced for the same value  $C_T$ , due to the shorter  $t_{on}$  time.

The charge current contribution from the power limiting circuit is defined as:

$$I_{PL} \cong \frac{(V_{IN} - V_{OUT} - V_{PL})}{R_{PL}} \quad (14)$$

APPLICATION INFORMATION (cont.)

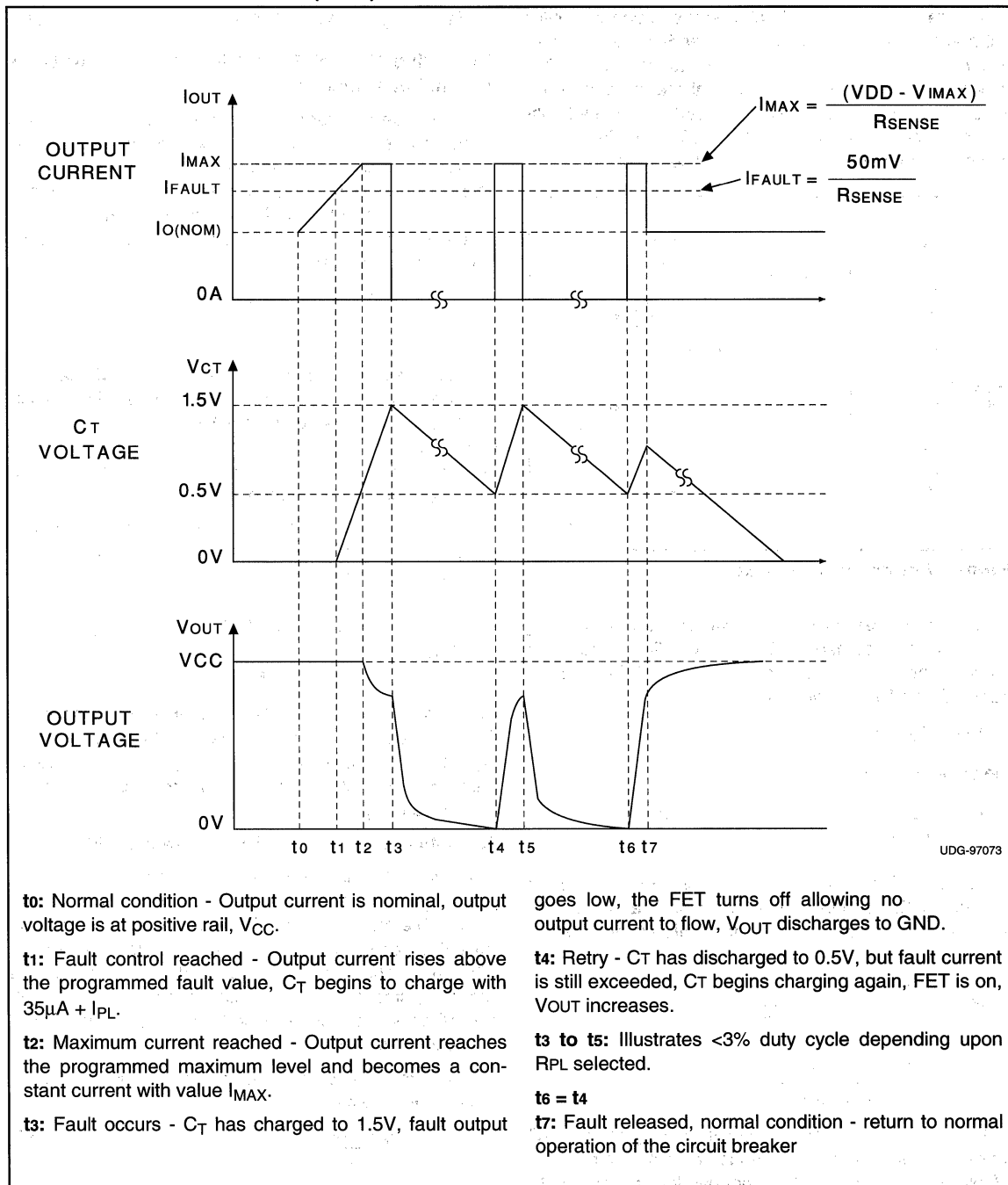


Figure 3. Typical Timing Diagram

### APPLICATION INFORMATION (cont.)

#### Constant Current Load

For a constant current load, the output capacitor will charge linearly. During that time:

$$I_{PL} (avg) \cong \frac{(V_{IN} - V_{PL})^2}{2 \cdot R_{PL} \cdot V_{IN}} \quad (15)$$

Modifying equation (12) yields:

$$C_T (min) \cong \frac{V_{IN} \cdot C_{OUT} \cdot \left[ \frac{(V_{IN} - V_{PL})^2}{2 \cdot R_{PL} \cdot V_{IN}} + 35 \cdot 10^{-6} \right]}{I_{MAX} - I_{LOAD}} \quad (16)$$

#### Resistive Load

Determining  $C_T(min)$  for a resistive load is more complex. First, the expression for the output voltage as a function of time is:

$$V_{OUT}(t) = I_{MAX} \cdot R_{LOAD} \left( 1 - e^{-\frac{T_{START}}{R_{LOAD} \cdot C_{OUT}}} \right) \quad (17)$$

Solving for  $T_{START}$  when  $V_{OUT} = V_{IN}$  yields:

$$T_{START} = -R_{LOAD} \cdot C_{OUT} \cdot \ln \left( 1 - \left( \frac{V_{IN}}{I_{MAX} \cdot R_{LOAD}} \right) \right) \quad (18)$$

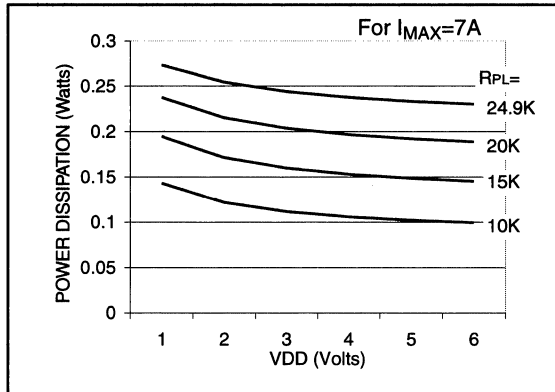


Figure 4. MOSFET average short circuit power dissipation vs.  $V_{IN}$  for values of  $R_{PL}$ .

Assuming that the device is operating in the retry mode, where  $C_T$  is charging from 0.5V to just below 1.5V in time  $t$ ,  $C_T$  is defined as:

$$C_T = \frac{I_{CT} \cdot dt}{dV} = I_{CT} \cdot dt \quad \text{Where} \quad (19)$$

$$I_{CT} = (I_{PL} + 35 \cdot 10^{-6})$$

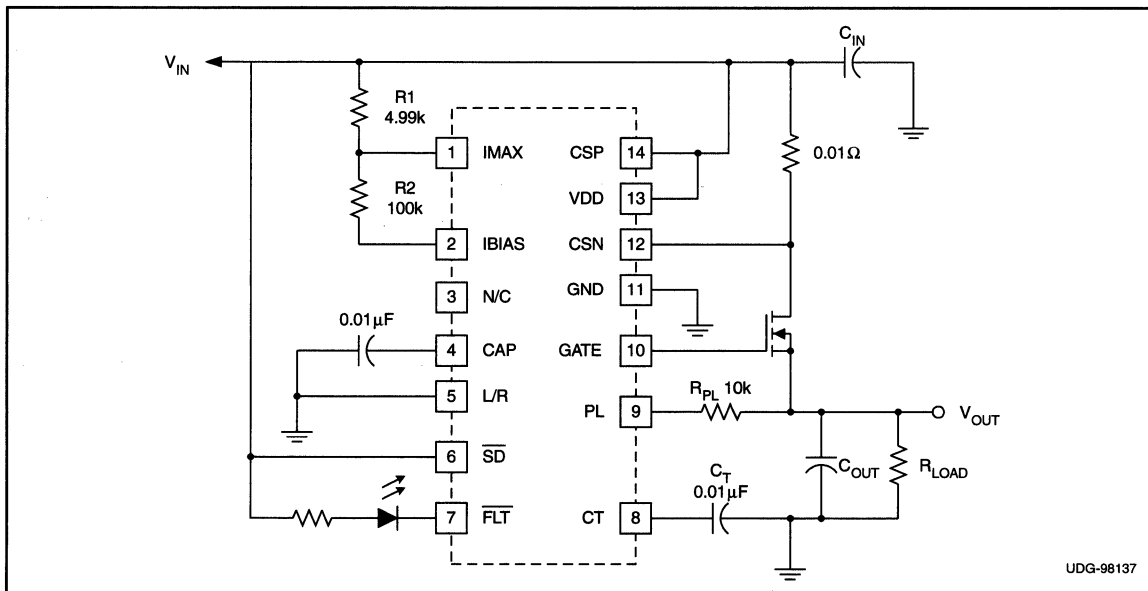


Figure 5. Application Circuit

## APPLICATION INFORMATION (cont.)

Substituting equation (15) into (19) yields:

$$C_T(\min) = \left( \frac{(V_{IN} - V_{PL})^2}{2 \cdot R_{PL} \cdot V_{IN}} + 35 \cdot 10^{-6} \right) \cdot dt \quad (20)$$

This yields the following expression for  $C_T(\min)$  for a resistive load with power limiting. By substituting the value calculated for  $T_{START}$  in equation (18) for  $dt$ ,  $C_T(\min)$  is determined.

$$C_T(\min) = \left[ \frac{(V_{IN} \cdot V_{PL})^2}{2 \cdot R_{PL} \cdot V_{IN}} + 35 \cdot 10^{-6} \right] \cdot T_{START} \quad (21)$$

### Example

The example in Figure 5 shows the UCC3919 in a typical application. A low value sense resistor and N-channel MOSFET minimize losses. With the values shown for  $R_1$ ,  $R_2$ , and  $R_S$ , the overcurrent fault will be 5A nominal. Linear current limiting ( $I_{MAX}$ ) will occur at 7.14A and the overload comparator will trip at 27A. The calculations are shown below.

$$I_{FAULT} = \frac{0.05}{R_S} = \frac{0.05}{0.01} = 5A \quad (22)$$

$$I_{MAX} = \frac{V_{CSP} - V_{IMAX}}{R_S} = \frac{1.5 \cdot R_1}{(R_1 + R_2) \cdot R_S} = 7.14A \quad (23)$$

$$I_{OVERLOAD} = I_{MAX} + \frac{0.2}{R_S} = 7.14A + \frac{0.2}{0.01} = 27.14A \quad (24)$$

$$T_{OFF}(\text{sec}) = \frac{C_T \mu F}{1.2} = \frac{0.01}{1.2} = 8.33 \text{ ms} \quad (25)$$

With the value shown for  $R_{PL}$ :

$$I_{PL(\text{typ})}(\text{output shorted}) = \quad (26)$$

$$\left( \frac{V_{IN} - V_{PL}}{R_{PL}} \right) = \left( \frac{5 - 1.6}{10K} \right) = 340 \mu A$$

$$t_{ON}(\text{shorted}) = \quad (27)$$

$$\frac{C_T}{I_{PL} + 35 \cdot 10^{-6}} = \frac{0.01 \cdot 10^{-6}}{375 \mu A} = 27 \mu s$$

$$P_{DISS}(\text{shorted}) = \frac{I_{MAX} \cdot V_{IN} \cdot t_{ON}}{t_{ON} + t_{OFF}} \quad (28)$$

$$= \frac{7.14 \cdot 5 \cdot 27 \mu s}{27 \mu s + 8.33 \cdot 10^{-3}} = 0.12W$$

For a worst case 1Ω resistive load:  $C_{OUT}(\max) \cong 47 \mu F$ .

For a worst case 5A constant current load:  $C_{OUT}(\max) \cong 27 \mu F$ .

With L/R grounded, the part will operate in the retry or "hiccup" mode. The values shown for  $C_T$  and  $R_{PL}$  will yield a nominal duty cycle of 0.32% and an off time of 8.3ms. With a shorted output, the average steady state power dissipation in Q1 will be less than 100mW over the full input voltage range.

If power limiting is disabled by opening  $R_{PL}$ , then:

$$t_{FAULT} = t_{ON} \text{ sec} = \frac{C_T \mu F \cdot 1}{35} = 287 \mu s \quad (29)$$

$$P_{DISS}(\text{shorted}) = \frac{I_{MAX} \cdot V_{IN} \cdot t_{ON}}{t_{OFF} + t_{ON}} \quad (30)$$

$$= \frac{7.14 \cdot 5 \cdot 287 \cdot 10^{-6}}{287 \cdot 10^{-6} + 8.33 \cdot 10^{-3}} = 1.2W \text{ (with } V_{IN} = 5V)$$

For a worst case 1Ω resistive load:  $C_{OUT}(\max) \cong 220 \mu F$ .

For a worst case 5A constant current load:  $C_{OUT}(\max) \cong 120 \mu F$ .

## THERMAL CONSIDERATIONS

### Steady State Conditions

In normal operation, with a steady state load current below  $I_{FAULT}$ , the power dissipation in the external MOSFET will be:

$$P_{DISS} = RDS_{ON} \cdot I_{LOAD}^2 \quad (31)$$

The junction temperature of the MOSFET can be calculated from:

$$T_J = T_A + (P_{DISS} \cdot \theta_{JA}) \quad (32)$$

Where  $T_A$  is the ambient temperature and  $\theta_{JA}$  is the MOSFET's thermal resistance from junction to ambient. If the device is on a heatsink, then the following equation:

$$\theta_{JA} + \theta_{JC} + \theta_{CS} + \theta_{SA} \quad (33)$$

Where  $\theta_{JC}$  is the MOSFET's thermal resistance from junction to case,  $\theta_{CS}$  is the thermal resistance from case to sink, and  $\theta_{SA}$  is the thermal resistance of the heatsink to ambient.

The calculated  $T_J$  must be lower than the MOSFET's maximum junction temperature rating, therefore:

$$\theta_{JA} < \frac{T_J(\max) - T_A}{P_{DISS}} \quad (34)$$

## APPLICATION INFORMATION

### Transient Thermal Impedance

During a fault condition in the retry mode, the average MOSFET power dissipation will generally be quite low due to the low duty cycle, as defined by:

$$P_{DISS} (avg) = \frac{I_{MAX} \cdot V_{IN} \cdot t_{ON}}{t_{ON} + t_{OFF}} \quad (\text{w/output shorted}) \quad (35)$$

(In the latch mode,  $t_{OFF}$  will be the time between a fault and the time the device is reset.)

However, the pulse power in the MOSFET during  $t_{ON}$ , with the output shorted, is:

$$P_{DISS} (pulse) = I_{MAX} \cdot V_{IN} \quad (\text{w/output shorted}) \quad (36)$$

In choosing  $t_{ON}$  for a given  $V_{IN}$ ,  $I_{MAX}$ , and duty cycle it is important to consult the manufacturer's transient thermal impedance curves for the MOSFET to make sure the device is within its safe operating area. These curves provide the user with the effective thermal impedance of the device for a given time duration pulse and duty cycle. Note that some of the impedance curves are normalized to one, in which case the transient impedance values must be multiplied by the DC (steady state) thermal resistance,  $\theta_{JC}$ .

For duty cycles not shown in the manufacturer's curves, the transient thermal impedance for any duty cycle and ton time (given a square pulse) can be estimated from [1]:

$$\theta_{JC} (trans) = (D \cdot \theta_{JC}) + (1 - D) \cdot \theta_{SP} \quad (37)$$

where D is the duty cycle:  $\frac{t_{ON}}{t_{ON} + t_{OFF}}$ .

and  $\theta_{SP}$  is the single pulse thermal impedance given in the transient thermal impedance curves for the time duration of interest ( $t_{ON}$ ). Note that these are absolute numbers, not normalized. If the given single pulse impedance

is normalized, it must first be multiplied by  $\theta_{JC}$  before using in the equation above.

This effective transient thermal impedance, when multiplied by the pulse power, will give the transient temperature rise of the die. To keep the junction temperature below the maximum rating, the following must be true:

$$\theta_{JC} (trans) = \frac{T_J (\max) - T_C}{P_{DISS} (pulse)} \quad (38)$$

If necessary, the junction temperature rise can be reduced by reducing  $t_{on}$  (using a smaller value for  $C_T$ ), or by reducing the duty cycle using the power limiting feature already discussed. Note that in either case, the amount of load capacitance,  $C_{OUT}$ , that can be charged before causing a fault, will also be reduced.

### Safety Recommendations

Although the UCC3919 is designed to provide system protection for all fault conditions, all integrated circuits can ultimately fail short. For this reason, if the UCC3919 is intended for use in safety critical applications where UL or some other safety rating is required, a redundant safety device such as a fuse should be placed in series with the device. The UCC3919 will prevent the fuse from blowing for virtually all fault conditions, increasing system reliability and reducing maintenance cost, in addition to providing the hot swap benefits of the device.

### References

- [1] International Rectifier, HEXFET Power MOSFET Designer's Manual, Application Note 949B, *Current Ratings, Safe Operating Area, and High Frequency Switching Performance of Power HEXFETs*, pp.1553-1565, September 1993.

# Latchable Negative Floating Hot Swap Power Manager

## FEATURES

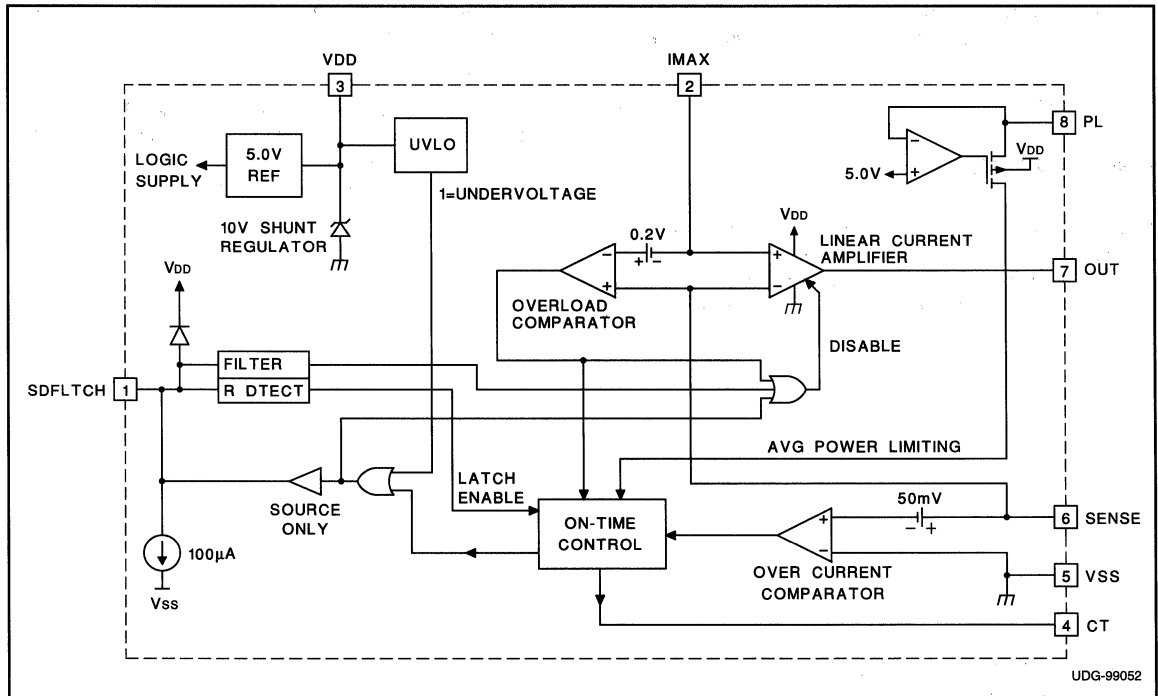
- Precision Fault Threshold
- Programmable: Average Power Limiting, Linear Current Control, Overcurrent Limit and Fault Time
- Fault Output Indication Signal
- Automatic Retry Mode or Latched Operation Mode
- Shutdown Control
- Undervoltage Lockout
- 250 $\mu$ s Glitch Filter on the SDFLTCH pin
- 8-Pin DIL and SOIC

## DESCRIPTION

The UCC3921 family of negative floating hot swap power managers provides complete power management, hot swap, and fault handling capability. The IC is referenced to the negative input voltage and is powered through an external resistor connected to ground, which is essentially a current drive as opposed to the traditional voltage drive. The onboard 10V shunt regulator protects the IC from excess voltage and serves as a reference for programming the maximum allowable output sourcing current during a fault. All control and housekeeping functions are integrated and externally programmable. These include the fault current level, maximum output sourcing current, maximum fault time, selection of Retry or Latched mode, soft start time, and average power limiting. In the event of a constant fault, the internal timer will limit the on time from less than 0.1% to a maximum of 3% duty cycle. The duty cycle modulation depends on the current into PL, which is a function of the voltage across the FET, thus limiting average power dissipation in the FET. The fault level is fixed at 50mV across the current sense amplifier to minimize total

(continued)

## BLOCK DIAGRAM





## DESCRIPTION (continued)

dropout. The fault current level is set with an external current sense resistor, while the maximum allowable sourcing current is programmed with a voltage divider from VDD to generate a fixed voltage on IMAX. The current level, when the output acts as a current source, is equal to  $V_{IMAX}/R_{SENSE}$ . If desired, a controlled current start up can be programmed with a capacitor on IMAX.

When the output current is below the fault level, the output device is switched on. When the output current exceeds the fault level, but is less than the maximum sourcing level programmed by IMAX, the output remains switched on, and the fault timer starts charging CT. Once

CT charges to 2.5V, the output device is turned off and performs a retry some time later (provided that the selected mode of operation is Automatic Retry Mode). When the output current reaches the maximum sourcing current level, the output acts as a current source, limiting the output current to the set value defined by IMAX.

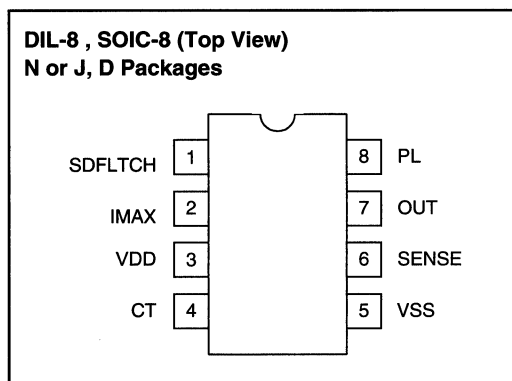
Other features of the UCC3921 include undervoltage lockout, 8-pin Small Outline (SOIC) and Dual-In-Line (DIL) packages, and a Latched Operation Mode option, in which the output is latched off once CT charges to 2.5V and stays off until either SDFLTCH is toggled (for greater than 1ms) or the IC is powered down and then back up.

## ABSOLUTE MAXIMUM RATINGS

I <sub>VDD</sub> .....	50mA
SDFLTCH Current .....	10mA
PL Current .....	10mA
IMAX Input Voltage .....	VDD
Storage Temperature .....	-65°C to +150°C
Junction Temperature .....	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.) .....	+300°C

All voltages are with respect to V<sub>SS</sub> (the most negative voltage). Currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages.

## CONNECTION DIAGRAM



**ELECTRICAL CHARACTERISTICS** Unless otherwise specified, T<sub>A</sub> = 0°C to 70°C for the UCC3921 and -40°C to 85°C for the UCC2921, and -55°C to 125°C for the UCC1921; I<sub>VDD</sub> = 2mA, C<sub>T</sub> = 1nF (the minimum allowable value), there is no resistor connected between the SDFLTCH and VSS pins. T<sub>A</sub> = T<sub>J</sub>.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>VDD Section</b>					
ID <sub>D</sub>			1	2	mA
Regulator Voltage	I <sub>SOURCE</sub> = 2mA	9	9.5	10.0	V
	I <sub>SOURCE</sub> = 10mA	9.15	9.6	10.15	V
UVLO Off Voltage		6	7	8	V
<b>Fault Timing Section</b>					
Overcurrent Threshold	T <sub>J</sub> = 25°C	47.5	50	53.5	mV
	Over Operating Temperature	46	50	53.5	mV
Overcurrent Input Bias			50	500	nA
CT Charge Current	V <sub>CT</sub> = 1V, I <sub>PL</sub> = 0	-50	-36	-22	μA
	Overload Condition, V <sub>SENSE</sub> - V <sub>IMAX</sub> = 300mV	-1.7	-1.2	-0.7	mA
CT Discharge Current	V <sub>CT</sub> = 1V, I <sub>PL</sub> = 0	0.6	1	1.5	μA
CT Fault Threshold		2.2	2.45	2.6	V
CT Reset Threshold		0.41	0.49	0.57	V
Output Duty Cycle	Fault Condition, I <sub>PL</sub> = 0	1.7	2.7	3.7	%

**ELECTRICAL CHARACTERISTICS** Unless otherwise specified,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$  for the UCC3921 and  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for the UCC2921, and  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for the UCC1921;  $I_{VDD} = 2\text{mA}$ ,  $C_T = 1\text{nF}$  (the minimum allowable value), there is no resistor connected between the SDFLTCH and VSS pins.  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Output Section</b>					
Output High Voltage	$I_{OUT} = 0\text{mA}$	8.5	10		V
	$I_{OUT} = -1\text{mA}$	6	8		V
Output Low Voltage	$I_{OUT} = 0\text{mA}$ , $V_{SENSE} - V_{IMAX} = 100\text{mV}$		0	10	mV
	$I_{OUT} = 2\text{mA}$ , $V_{SENSE} - V_{IMAX} = 100\text{mV}$		200	600	mV
<b>Linear Amplifier Section</b>					
Sense Control Voltage	$V_{IMAX} = 100\text{mV}$	85	100	115	mV
	$V_{IMAX} = 400\text{mV}$	370	400	430	mV
Input Bias			50	500	nA
<b>Power Limiting Section</b>					
VSENSE Regulator Voltage	$I_{PL} = 64\mu\text{A}$	4.35	4.85	5.35	V
Duty Cycle Control	$I_{PL} = 64\mu\text{A}$	0.6	1.2	1.7	%
	$I_{PL} = 1\text{mA}$	0.045	0.1	0.17	%
<b>Overload Section</b>					
Delay to Output	Note 1		300	500	ns
Output Sink Current	$V_{SENSE} - V_{IMAX} = 300\text{mV}$	40	100		mA
Threshold	Relative to IMAX	140	200	260	mV
<b>Shutdown/Fault/Latch Section</b>					
Shutdown Threshold		3	5	VDD+1	V
Input Current	$V_{SDFLTCH} = 5\text{V}$	50	110	250	$\mu\text{A}$
Filter Delay Time (Delay to Output)		250	500	1000	$\mu\text{s}$
Fault Output High		6	9.5		V
	$I_{SDFLTCH} = -100\mu\text{A}$	5	8.5		V
Fault Output Low			0	10	mV
Output Duty Cycle	Fault Condition, $I_{PL} = 0$	1.7	2.7	3.7	%
	$I_{SDFLTCH} = -100\mu\text{A}$ , Fault Condition, $I_{PL} = 0$			0	%

Note 1: Guaranteed by design. Not 100% tested in production.

## PIN DESCRIPTIONS

**CT:** A capacitor is connected to this pin in order to set the fault time. The fault time must be longer than the time to charge external load capacitance. The fault time is defined as:

$$T_{FAULT} = \frac{2 \cdot C_T}{I_{CH}}$$

where  $I_{CH} = 36\mu\text{A} + I_{PL}$ , and  $I_{PL}$  is the current into the power limit pin. Once the maximum fault time is reached the output will shutdown for a time given by:

$$T_{SD} = 2 \cdot 10^6 \cdot C_T$$

**IMAX:** This pin programs the maximum allowable sourcing current. Since VDD is a regulated voltage, a voltage divider can be derived from VDD to generate the program level for IMAX. The current level at which the output appears as a current source is equal to the

voltage on IMAX over the current sense resistor. If desired, a controlled current start up can be programmed with a capacitor on IMAX, and a programmed start delay can be achieved by driving the shutdown with an open collector/drain device into an RC network.

**OUT:** This pin provides gate output drive to the MOSFET pass element.

**PL:** This feature ensures that the average MOSFET power dissipation is controlled. A resistor is connected from this pin to the drain of the NMOS pass element. When the voltage across the NMOS exceeds 5V, current will flow into the PL pin which adds to the fault timer charge current, reducing the duty cycle from the 3% level. When  $I_{PL} \gg 36\mu\text{A}$ , then the average MOSFET power dissipation is given by:

$$P_{MOSFET\ avg} = IMAX \cdot 1 \cdot 10^{-6} \cdot R_{PL}$$

**PIN DESCRIPTIONS (continued)**

**SENSE:** Input voltage from the current sense resistor. When there is greater than 50mV across this pin with respect to VSS, then a fault is sensed, and  $C_T$  starts to charge.

**SDFLTCH:** This pin provides fault output indication, shutdown control, and operating mode selection. Interface into and out of this pin is usually performed through level shift transistors. When open, and under a non-fault condition, this pin pulls to a low state with respect to VSS. When a fault is detected by the fault timer, or undervoltage lockout, this pin will drive to a high state with respect to VSS, indicating the NMOS pass element is OFF. When  $> 250\mu\text{A}$  is sourced into this pin for  $> 1\text{ms}$ , it drives high causing the output to disable the NMOS pass device.

If an  $5\text{k} < R_{\text{LATCH}} < 250\text{k}\Omega$  resistor is placed from this pin to VSS, then the latched operating mode will be invoked. Upon the occurrence of a fault, under the latched mode of operation, once the  $C_T$  capacitor charges up to 2.5V the NMOS pass element latches off. A retry will not periodically occur. To reset the latched off device, either SDFLTCH is toggled high for a duration greater than 1ms or the IC is powered down and then up.

**VDD:** Current driven with a resistor to a voltage approximately 10V more positive than VSS. Typically a resistor is connected to ground. The 10V shunt regulator clamps VDD approximately 10V above VSS, and is also used as an output reference to program the maximum allowable sourcing current.

**VSS:** Ground reference for the IC and the most negative voltage available.

**APPLICATION INFORMATION**

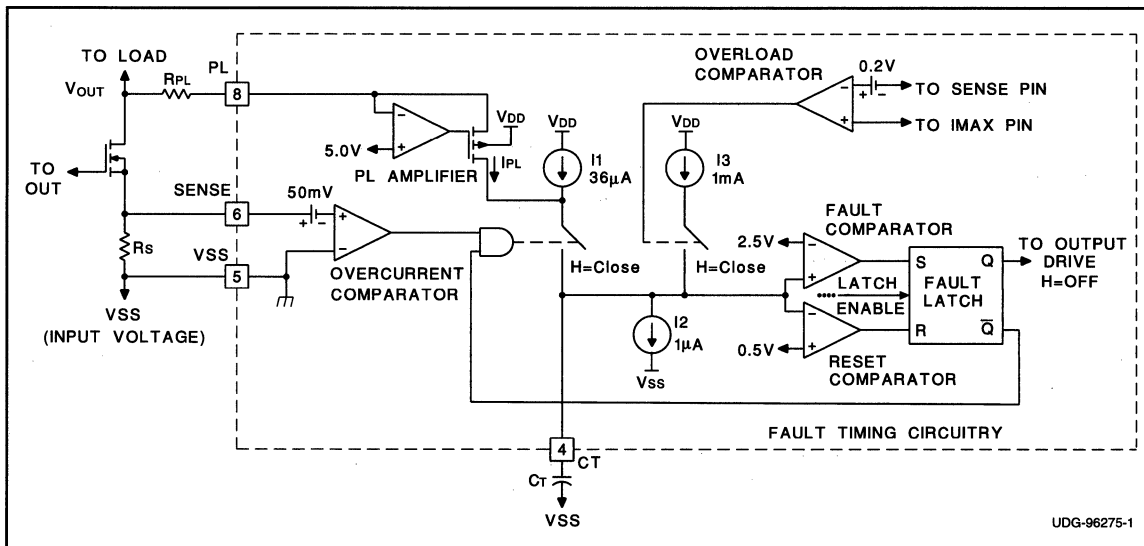


Figure 1. Fault Timing Circuitry for the UCC3921, Including Power Limit Overload



## APPLICATION INFORMATION (continued)

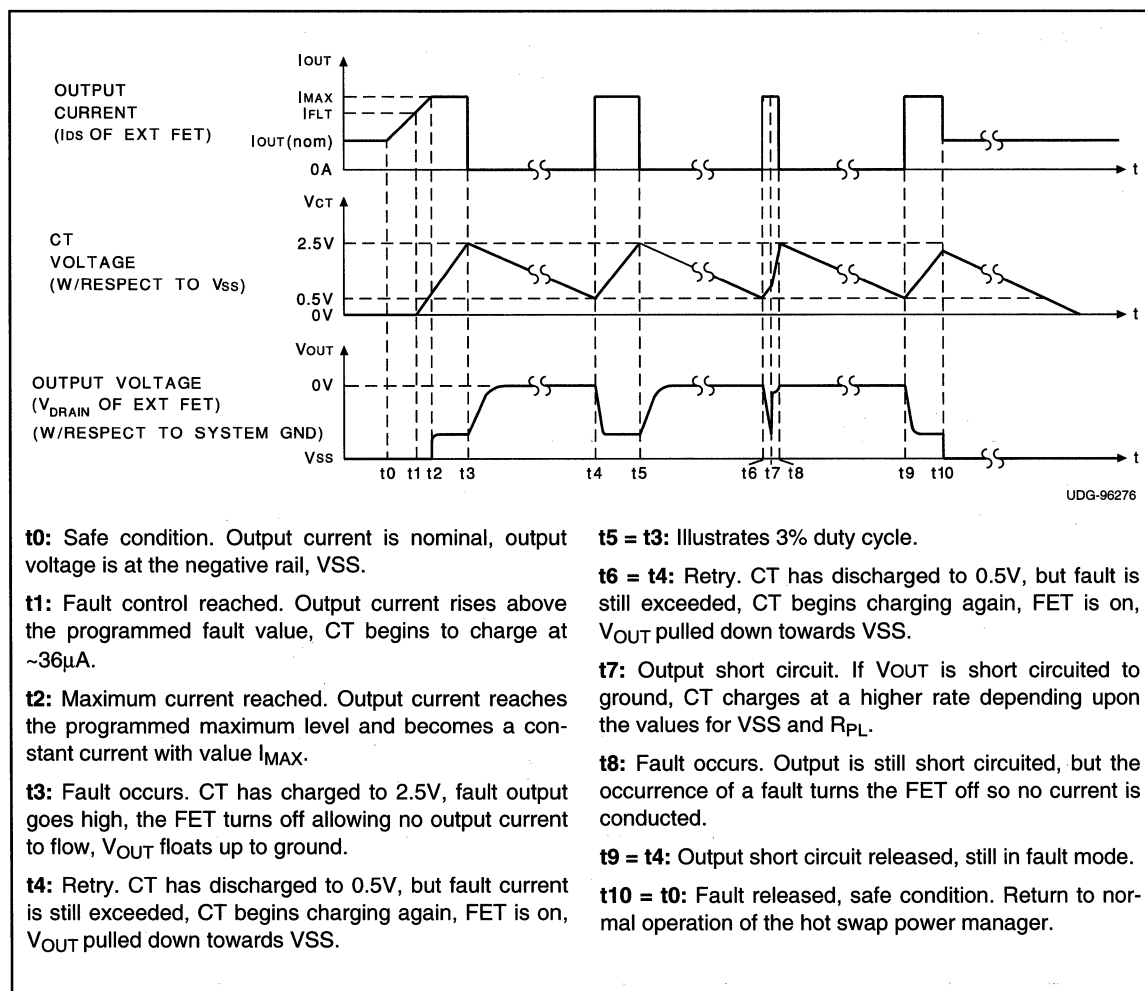
Figure 1 shows the detailed circuitry for the fault timing function of the UCC3921. For the time being, we will discuss a typical fault mode, therefore, the overload comparator, and current source I3 does not work into the operation. Once the voltage across the current sense resistor,  $R_s$ , exceeds 50mV, a fault has occurred. This causes the timing capacitor to charge with a combination of 36 $\mu$ A plus the current from the power limiting amplifier. The PL amplifier is designed to only source current into the CT pin and to begin sourcing current once the voltage across the output FET exceeds 5V. The current  $I_{PL}$  is related to the voltage across the FET with the following

expression:

$$I_{PL} = \frac{V_{FET} - 5V}{R_{PL}}$$

where  $V_{FET}$  is the voltage across the NMOS pass device. Later it will be shown how this feature will limit average power dissipation in the pass device. Note that under a condition where the output current is more than the fault level, but less than the max level,  $V_{OUT} \approx V_{SS}$  (input voltage),  $I_{PL} = 0$ , the CT charging current is 36 $\mu$ A.

During a fault, CT will charge at a rate determined by the



**t<sub>0</sub>**: Safe condition. Output current is nominal, output voltage is at the negative rail, V<sub>SS</sub>.

**t<sub>1</sub>**: Fault control reached. Output current rises above the programmed fault value, CT begins to charge at ~36 $\mu$ A.

**t<sub>2</sub>**: Maximum current reached. Output current reaches the programmed maximum level and becomes a constant current with value  $I_{MAX}$ .

**t<sub>3</sub>**: Fault occurs. CT has charged to 2.5V, fault output goes high, the FET turns off allowing no output current to flow,  $V_{OUT}$  floats up to ground.

**t<sub>4</sub>**: Retry. CT has discharged to 0.5V, but fault current is still exceeded, CT begins charging again, FET is on,  $V_{OUT}$  pulled down towards V<sub>SS</sub>.

**t<sub>5</sub> = t<sub>3</sub>**: Illustrates 3% duty cycle.

**t<sub>6</sub> = t<sub>4</sub>**: Retry. CT has discharged to 0.5V, but fault is still exceeded, CT begins charging again, FET is on,  $V_{OUT}$  pulled down towards V<sub>SS</sub>.

**t<sub>7</sub>**: Output short circuit. If  $V_{OUT}$  is short circuited to ground, CT charges at a higher rate depending upon the values for V<sub>SS</sub> and  $R_{PL}$ .

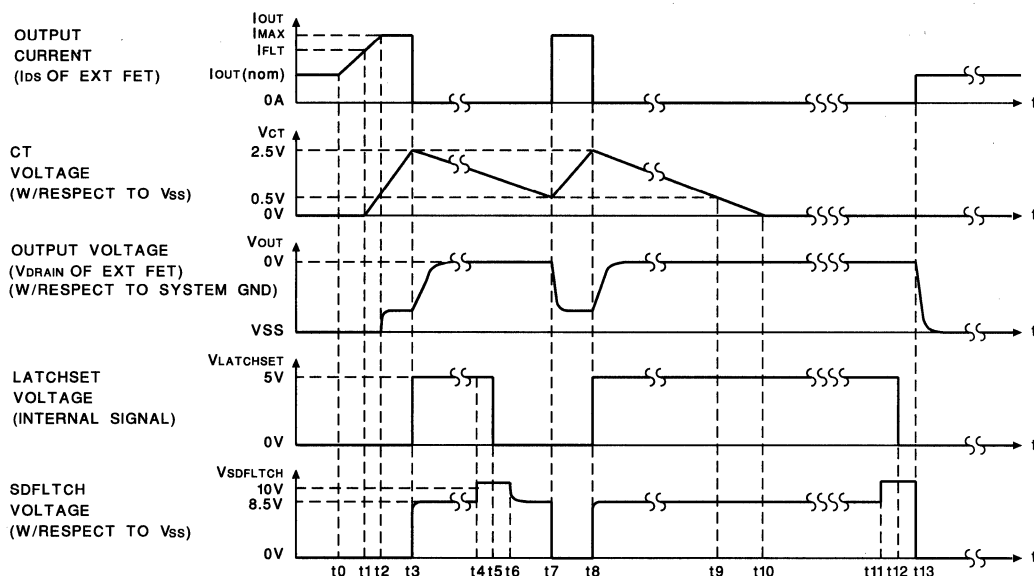
**t<sub>8</sub>**: Fault occurs. Output is still short circuited, but the occurrence of a fault turns the FET off so no current is conducted.

**t<sub>9</sub> = t<sub>4</sub>**: Output short circuit released, still in fault mode.

**t<sub>10</sub> = t<sub>0</sub>**: Fault released, safe condition. Return to normal operation of the hot swap power manager.

Figure 2. Retry Operation Mode

APPLICATION INFORMATION (cont.)



UDG-96277

**t<sub>0</sub>**: Safe condition. Output current is nominal, output voltage is at the negative rail, V<sub>SS</sub>.

**t<sub>1</sub>**: Fault control reached. Output current rises above the programmed fault value, CT begins to charge at ~36μA.

**t<sub>2</sub>**: Maximum current reached. Output current reaches the programmed maximum level and becomes a constant current with value I<sub>MAX</sub>.

**t<sub>3</sub>**: Fault occurs. CT has charged to 2.5V, fault output goes high as indicated by the SDFLTCH voltage. The FET turns off allowing no output current to flow, V<sub>OUT</sub> floats up to ground, and since there is an 82kΩ resistor from the SDFLTCH pin to V<sub>SS</sub>, the internal latchset signal goes high.

**t<sub>4</sub>**: Since the user does not want the chip to LATCH off during this cycle, he toggles SDFLTCH high for greater than 1ms {t<sub>6</sub> - t<sub>4</sub> > 1ms}.

**t<sub>5</sub>**: The latchset signal is reset.

**t<sub>6</sub>**: Forcing of SDFLTCH is released after having been applied for > 1ms.

**t<sub>7</sub>**: Retry (since the latchset signal has been reset to its' low state) - CT has discharged to 0.5V, but fault current is still exceeded, CT begins charging again, FET is on,

V<sub>OUT</sub> pulled down towards V<sub>SS</sub>.

**t<sub>8</sub> = t<sub>3</sub>**: Fault occurs. CT has charged to 2.5V, fault output goes high as indicated by the SDFLTCH voltage, the FET turns off allowing no output current to flow, V<sub>OUT</sub> floats up to ground, and since there is an 82kΩ resistor from SDFLTCH to V<sub>SS</sub>, the internal latchset signal goes high.

**t<sub>9</sub>**: Output is latched off. Even though CT has discharged to 0.5V, there will not be a retry since the latchset signal was allowed to remain high.

**t<sub>10</sub>**: Output remains latched off. CT has discharged all the way to 0V.

**t<sub>11</sub>**: The output has been latched off for quite some time. The user now wishes to reset the latched off output, thus toggling SDFLTCH high for greater than 1ms {t<sub>13</sub> - t<sub>11</sub>}.

**t<sub>12</sub> = t<sub>5</sub>**: The latchset signal is reset.

**t<sub>13</sub>**: Forcing of SDFLTCH is released after having been applied for > 1ms. The fault had also been released during the time the output was latched off, safe condition, return to normal operation of the hot swap power manager.

Figure 3. Latched Operation Mode: R<sub>LATCH</sub> = 82k

## APPLICATION INFORMATION (continued)

internal charging current and the external timing capacitor. Once CT charges to 2.5V, the fault comparator switches and sets the fault latch. Setting of the fault latch causes both the output to switch off and the charging switch to open. CT must now discharge with the 1μA current source, I2, until 0.5V is reached. Once the voltage at CT reaches 0.5V, the fault latch resets, which re-enables the output and allows the fault circuitry to regain control of the charging switch. If a fault is still present, the fault comparator will close the charging switch causing the cycle to repeat. Under a constant fault, the duty cycle is given by:

$$\text{Duty Cycle} = \frac{1\mu\text{A}}{I_{PL} + 36\mu\text{A}}$$

Average power dissipation in the pass element is given by:

$$P_{FET\text{AVG}} = V_{FET} \cdot I_{MAX} \cdot \frac{1\mu\text{A}}{I_{PL} + 36\mu\text{A}}$$

Where  $V_{FET} \gg 5V$   $I_{PL}$  can be approximated as:

$$\frac{V_{FET}}{R_{PL}}$$

and where  $I_{PL} \gg 36\mu\text{A}$ , the duty cycle can be approximated as:

$$\frac{1\mu\text{A} \cdot R_{PL}}{V_{FET}}$$

Therefore, the maximum average power dissipation in the MOSFET can be approximated by:

$$\begin{aligned} P_{FET\text{AVG}} &= V_{FET} \cdot I_{MAX} \cdot \frac{1\mu\text{A} \cdot R_{PL}}{V_{FET}} \\ &= I_{MAX} \cdot 1\mu\text{A} \cdot R_{PL} \end{aligned}$$

Notice that in the approximation,  $V_{FET}$  cancels, thereby limiting the average power dissipation in the NMOS pass element.

### Overload Comparator

The linear amplifier in the UCC3921 ensures that the output NMOS does not pass more than  $I_{MAX}$  (which is  $V_{IMAX}/R_{SENSE}$ ). In the event the output current exceeds the programmed  $I_{MAX}$  by  $0.2V/R_{SENSE}$ , which can only occur if the output FET is not responding to a command from the IC, CT will begin charging with I3, 1mA, and continue to charge to approximately 8V. This allows a constant fault to show up on the SDFLTCH pin, and also since the voltage on CT will continue charging past 2.5V in an overload fault mode, it can be used for detection of output FET failure or to build redundancy into the sys-

tem.

### Determining External Component Values

To set  $R_{VDD}$  (see Fig. 4) the following must be achieved:

$$\frac{V_{IN\text{min}}}{R_{VDD}} > \frac{10V}{R1 + R2} + 2mA$$

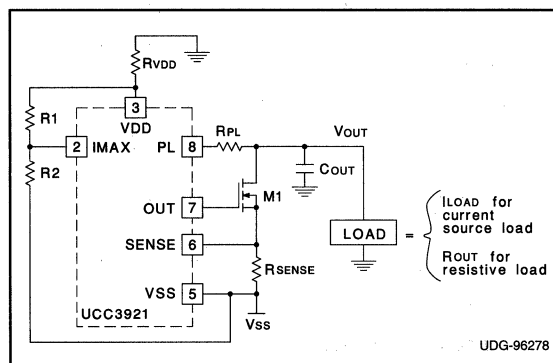


Figure 4.

In order to estimate the minimum timing capacitor,  $C_T$ , several things must be taken into account. For example, given the schematic in Figure 4 as a possible (and at this point, a standard) application, certain external component values must be known in order to estimate  $C_{TMIN}$ . Now, given the values of  $C_{OUT}$ , Load,  $R_{SENSE}$ ,  $V_{SS}$ , and the resistors determining the voltage on the IMAX pin, the user can calculate the approximate startup time of the node  $V_{OUT}$ . This startup time must be faster than the time it takes for  $C_T$  to charge to 2.5V (relative to  $V_{SS}$ ), and is the basis for estimating the minimum value of  $C_T$ . In order to determine the value of the sense resistor,  $R_{SENSE}$ , assuming the user has determined the fault current,  $R_{SENSE}$  can be calculated by:

$$R_{SENSE} = \frac{50mV}{I_{FAULT}}$$

Next, the variable  $I_{MAX}$  must be calculated.  $I_{MAX}$  is the maximum current that the UCC3921 will allow through the transistor, M1, and it can be shown that during startup with an output capacitor the power MOSFET, M1, can be modeled as a constant current source of value  $I_{MAX}$  where

$$I_{MAX} = \frac{V_{IMAX}}{R_{SENSE}} \text{ where } V_{IMAX} = \text{voltage on pin IMAX.}$$

Given this information, calculation of the startup time is now possible via the following:

## APPLICATION INFORMATION (continued)

Current Source Load:

$$T_{START} = \frac{C_{OUT} \cdot |V_{SS}|}{I_{MAX} - I_{LOAD}}$$

Resistive Load:

$$T_{START} = \frac{C_{OUT} \cdot R_{OUT} \cdot \ln\left(\frac{I_{MAX} \cdot R_{OUT}}{I_{MAX} \cdot R_{OUT} - |V_{SS}|}\right)}{1}$$

Once  $T_{START}$  is calculated, the power limit feature of the UCC3921 must be addressed and component values derived. Assuming the user chooses to limit the maximum

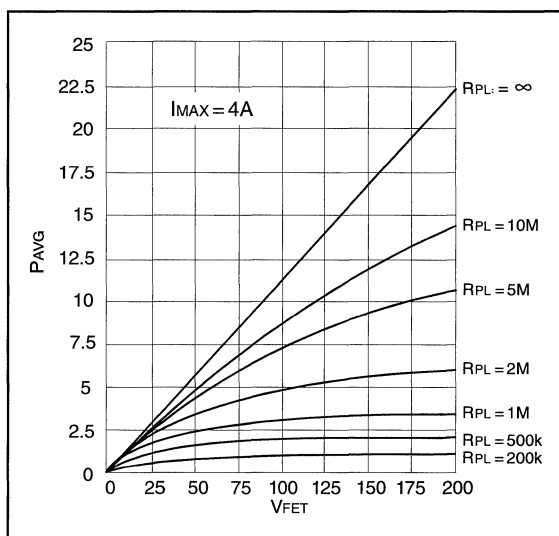


Figure 5. Plot Average Power vs FET Voltage for Increasing Values of  $R_{PL}$

allowable average power that will be associated with the hot swap power manager, the power limiting resistor,  $R_{PL}$ , can be easily determined by the following:

$$R_{PL} = \frac{P_{FET\ avg}}{1\mu A \cdot I_{MAX}} \text{ where a minimum } R_{PL} \text{ exists}$$

$$\text{defined by } R_{PL\ min} = \frac{|V_{SS}|}{5\ mA} \text{ (Refer to Figure 5).}$$

Finally, after computing the aforementioned variables, the minimum timing capacitor can be derived as such:

Current Source Load:

$C_T\ min =$

$$\frac{3 \cdot T_{START} \cdot (72\mu A \cdot R_{PL} + |V_{SS}| - 10V)}{10 \cdot R_{PL}}$$

Resistive Load:

$C_T\ min =$

$$\frac{3 \cdot T_{START} \cdot (36\mu A \cdot R_{PL} + |V_{SS}| - 5V - I_{MAX} \cdot R_{OUT})}{5 \cdot R_{PL}} + \frac{3 \cdot R_{OUT} \cdot |V_{SS}| \cdot C_{OUT}}{5 \cdot R_{PL}}$$

### Level Shift Circuitry to Interface with SDFLTCH

Some type of circuit is needed to interface with the UCC3921 via SDFLTCH, such as opto-couplers or level shift circuitry. Figure 6 depicts one implementation of level shift circuitry that could be used, showing component values selected for a typical  $-48V$  telecommunication application. There are three communication conditions which could occur; two of which are Hot Swap Power Manager (HSPM) state output indications, and the third being an External Shutdown.

- 1) When open, and under a non-fault condition, SDFLTCH is pulled to a low state. In Figure 6, the N-channel level shift transistor is off, and the FAULT OUT signal is pulled to LOCAL VDD through R3. This indicates that the HSPM is not faulted.
- 2) When a fault is detected by the fault timer or under-voltage lockout, this pin will drive to a high state, indicating that the external power FET is off. In Figure 6, the N-channel level shift transistor will conduct, and the FAULT OUT signal will be pulled to a Schottky Diode voltage drop below LOCAL GND. This indi-

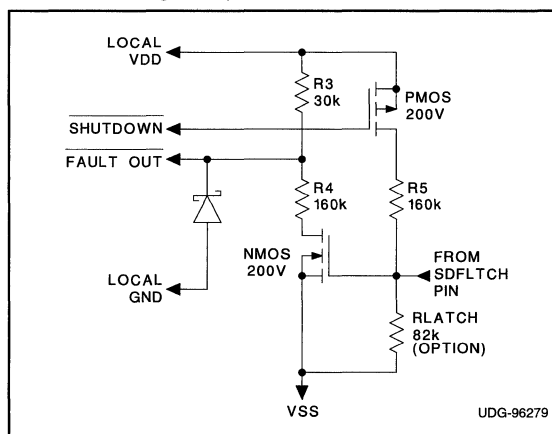


Figure 6. Possible Level Shift Circuitry to Interface to the UCC3921, showing component values selected for a typical telecom application.

**APPLICATION INFORMATION (continued)**

icates that the HSPM is faulted. The Schottky Diode is necessary to ensure that the FAULT OUT signal does not traverse too far below LOCAL GND, making fault detection difficult.

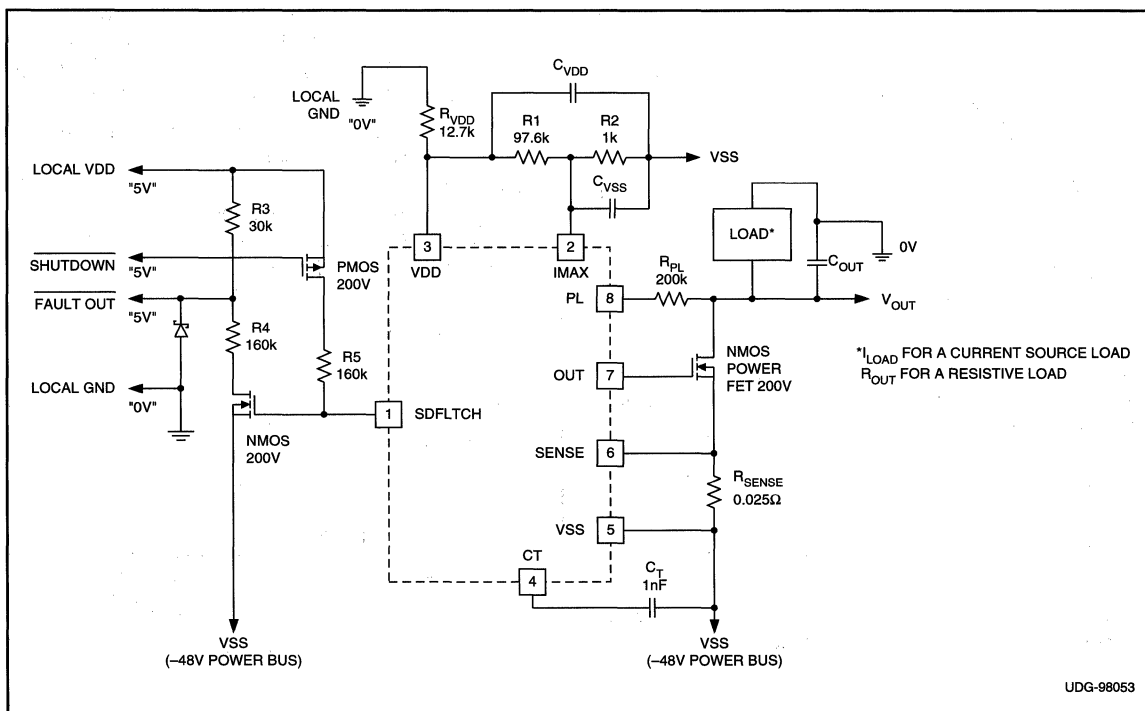
If a  $5k < R_{LATCH} < 250k\Omega$  resistor is tied between SDFLTCH & VSS, as optionally shown in Figure 6, then the latched operating mode (described earlier) will be invoked upon the occurrence of a fault.

- 3) To externally shutdown the HSPM, the SHUTDOWN signal (typically held at LOCAL VDD) must be pulled to LOCAL GND. Assuming SHUTDOWN is tied to LOCAL GND, the P-channel level shift transistor will conduct, driving SDFLTCH high (to roughly VDD plus a diode). By sourcing  $> 250\mu A$  into SDFLTCH for  $> 1ms$  the output to the external power FET will

be disabled. The current sourced into SDFLTCH must be limited to 10mA or less:  $ISDFLTCHMAX < 10mA$ .

**SAFETY RECOMMENDATIONS**

Although the UCC3921 is designed to provide system protection for all fault conditions, all integrated circuits can ultimately fail short. For this reason, if the UCC3921 is intended for use in safety critical applications where UL® or some other safety rating is required, a redundant safety device such as a fuse should be placed in series with the external power FET. The UCC3921 will prevent the fuse from blowing for virtually all fault conditions, increasing system reliability and reducing maintenance cost, in addition to providing the hot swap benefits of the device.



**Figure 7. Typical Telecommunications Application**

*(The "Negative Magnitude-Side" of the Supply is Switched in)*



APPLICATION INFORMATION (continued)

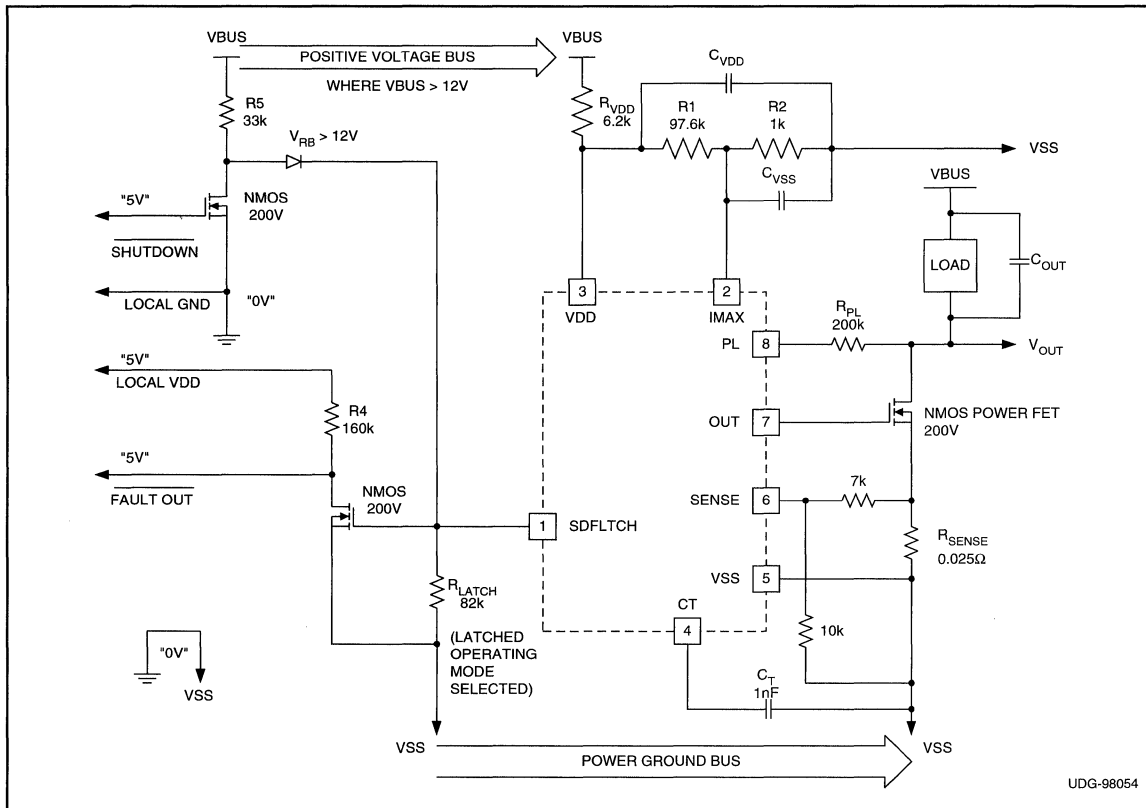


Figure 8. Floating Positive Application

The "Ground-side" of the Supply is Switched In

# Universal Serial Bus Hot Swap Power Controller

## FEATURES

- Fully USB Compliant
- Support Four 5V Peripherals and One USB 3.3V Controller
- Separate Power Enables
- 500mA Current Limiting per Channel
- Separate Open Drain Fault Indicator for Each Channel
- 3.3V Output for USB Controller
- Available in 28 Pin Wide Surface Mount and DIP

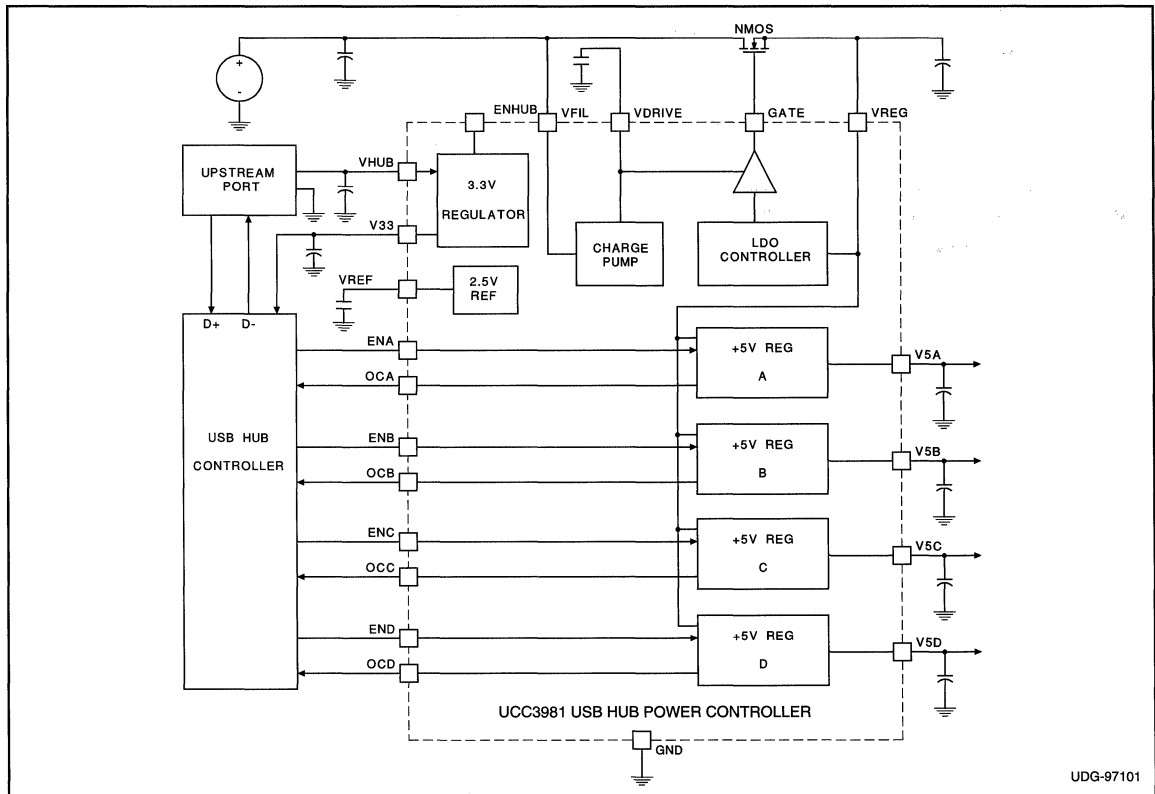
## DESCRIPTION

The UCC3981 Hot Swap Power Controller is designed to provide a self powered USB hub with a local 3.3V regulated voltage and four 5V regulated voltages for USB ports. Each of the 5V output ports is individually enabled for optimal port control. Each port also provides an overcurrent fault signal indicating that the port has exceeded a 500mA current limit. The 3.3V linear regulator is used to power the local USB microcontroller. This regulator is protected with a 100mA current limit and has a logic level enable input.

The UCC3981 can be configured to provide USB port power from a loosely regulated voltage such as a Filament voltage internal to a monitor. Pre-regulation is provided by an internal linear regulator controller and one external logic level N-channel MOSFET. The UCC3981 can also be configured without using the pre-regulator stage by connecting the VREG pins to a regulated 5.5V 2A source.

The UCC3981 comes in a 28-pin wide SOIC power package optimized for power dissipation, and is protected by internal over-temperature shut-down mechanism, which disables the outputs should the internal junction temperature exceed 150°C.

## APPLICATION AND BLOCK DIAGRAM



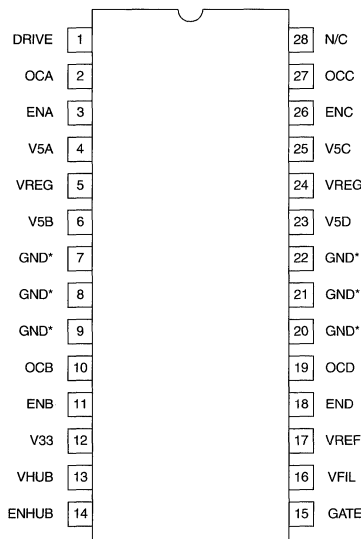
**ABSOLUTE MAXIMUM RATINGS**

VFIL	9V
VCON Supply Voltage	9V
Logic Inputs (ENA-D, ENHUB)	
Maximum Forced Voltage	-0.3V to 7V
Maximum Forced Current	±1mA
V33	
Maximum Forced Voltage	5V
Maximum Current	200mA
V5A-D	
Maximum Voltage	9V
Maximum Current	750mA
Storage Temperature	-65°C to +150°C
Junction Temperature	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.)	+300°C

Unless otherwise indicated, voltages are reference to ground. Pulsed is defined as a less than 10% duty cycle with a maximum duration of 500µs. Currents are positive into, negative out of the specified terminal. All voltages are with respect to ground. Consult Packaging Section of Databook for thermal limitations and considerations of packages.

**CONNECTION DIAGRAM**

**SOIC-28 (Top View)  
DWP Package**



\* DWP package pin 28 serves as signal ground; Pins 7, 8, 9, 20, 21, 22 serve as heatsink/ground.

**ELECTRICAL CHARACTERISTICS** Unless otherwise specified, T<sub>J</sub> = 0°C to 125°C for the UCC3981. VFIL = 6.5V, VHUB = 5V. T<sub>A</sub> = T<sub>J</sub>.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Input Supply Currents</b>					
VHUB Supply Current	No External Load on V33		1	3	mA
VFIL Supply Current			1	3	mA
<b>Reference</b>					
VREF Voltage	Over Temperature	2.35	2.5	2.65	V
Line Regulation	VHUB = 4.5V to 9V		3	10	mV
3.3V Regulator					
V33 Voltage	T <sub>J</sub> = 25°C, I <sub>LOAD</sub> = 10mA	3.2	3.3	3.4	V
	0mA to 100mA, 0°C to 125°C, VHUB = 4.5V to 9V	3.165	3.3	3.435	V
Short Circuit Current Limit	VHUB = 6V, Output shorted to Ground	100	120	150	mA
<b>Pre-Regulator</b>					
VREG Voltage	0A to 2A, 0°C to 125°C, VFIL = 6V to 9V	5.25	5.5	5.7	V
<b>5V Regulator</b>					
V5A-D Voltage	T <sub>J</sub> = 25°C, I <sub>LOAD</sub> = 250mA, VREG = 5.5V	4.85	5	5.15	V
	0mA to 500mA, 0°C to 125°C	4.8	5	5.2	V
Short Circuit Current Limit	VREG = 5.5V, Output Shorted to Ground	500	600	750	mA
<b>Charge Pump</b>					
Quiescent Output Voltage	T <sub>J</sub> = 25°C, VFIL = 6V, ENA-D = 5V, ENHUB = 5V	11	11.45	12	V
	0°C to 125°C, VFIL = 6V	10.5	11.45	12	V
Output Impedance			9	15	kΩ

**ELECTRICAL CHARACTERISTICS** Unless otherwise specified,  $T_J = 0^\circ\text{C}$  to  $125^\circ\text{C}$  for the UCC3981.  $V_{FIL} = 6.5\text{V}$ ,  $V_{HUB} = 5\text{V}$ .  $T_A = T_J$ .

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Enable Inputs</b>					
ENA-D Inputs - Guaranteed Low				0.7	V
ENA-D Inputs - Guaranteed High		3			V
ENHUB Input - Guaranteed Low				0.7	V
ENHUB Input - Guaranteed High		3			V
<b>Overcurrent Signals</b>					
Active Sink Current	$I_{OCX} = 100\mu\text{A}$		140	500	mV

## PIN DESCRIPTIONS

**ENA-D:** Separate enables pins for each of the four 5V supplies.

**ENHUB:** Enables the 3.3V output V33. Pulling this pin low disables V33.

**GATE:** Gate drive for an external NMOS used to regulate the 5.5V VREG supply. Minimum available drive is 11V.

**GND:** All 6 GND pins must be tied to the system ground. In addition to serving as electrical conductors, these 6 pins are heat sinks. Refer to the Packaging Device Temperature Management guide in the Packaging section of the Unitrode Databook.

**OCA-D:** Open drain overcurrent indicator. OCA-D can be wire OR'ed by the user to create a single overcurrent indicator.

**V5A-D:** 5V regulated output with enable, 500mA (mini-

um) current limit, and overcurrent indicator.

**V33:** 3.3V regulator output. Enable when ENHUB is high. Current limit is 100mA minimum.

**VDRIVE:** Internal charge pump voltage is brought out for external decoupling. Nominal voltage is between 11V and 13V. No external loading permitting. Decouple with at least 0.001 $\mu\text{F}$  capacitor.

**VFIL:** Bias supply for all four of the 5V regulators. VFIL voltage must be between 6V and 9V.

**VHUB:** Supply for the 3.3V USB controller power supply and bandgap reference.

**VREF:** Internal 2.5V reference is brought out for external decoupling only. Decouple with 0.01 $\mu\text{F}$  capacitor.

**VREG:** Regulated to 5.5V by means of an external NMOS. Two pins supply up to a total of 2.5A to the four 5V bus voltages (V5A, V5B, V5C, V5D).

# Universal Serial Bus Hot Swap Power Controller

## FEATURES

- Support Four 5V Peripherals and One USB 3.3V Controller
- Separate Power Enables
- 650mA Current Limiting per Channel
- Separate Open Drain Fault Indicator for Each Channel
- 3.3V Output for USB Controller
- Available in 20 Pin DIP

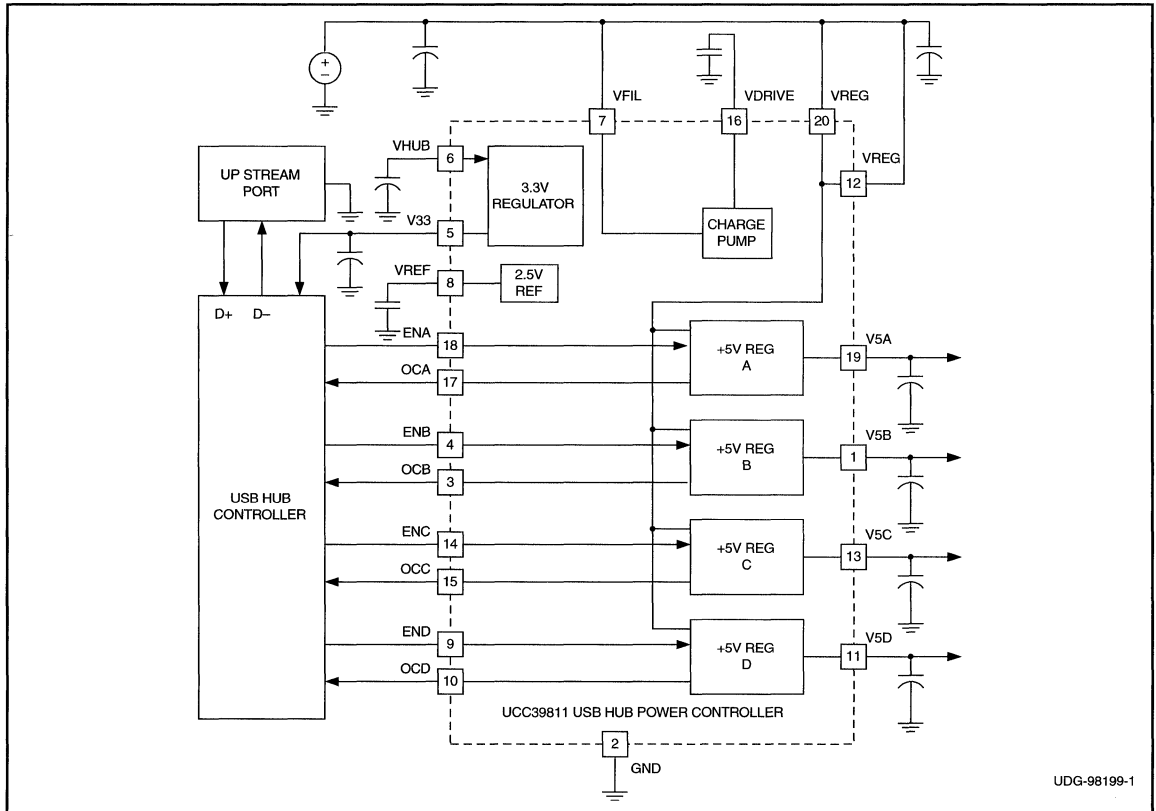
## DESCRIPTION

The UCC39811 Hot Swap Power Controller is designed to provide a self powered USB hub with a local 3.3V regulated voltage and four 5V regulated voltages for USB ports. Each of the 5V output ports is individually enabled for optimal port control. Each port also provides an overcurrent fault signal indicating that the port has exceeded a 650mA current limit. The 3.3V linear regulator is used to power the local USB microcontroller. This regulator is protected with a 100mA current limit and has a logic level enable input.

The UCC39811 can be configured to provide USB port power from a loosely regulated voltage such as a Filament voltage internal to a monitor. Pre-regulation is provided by an internal linear regulator controller and one external logic level N-channel MOSFET. The UCC39811 can also be configured without using the pre-regulator stage by connecting the VREG pins to a regulated 5.5V 2A source.

The UCC39811 comes in a 20-pin DIP package and is protected by internal over-temperature shutdown mechanism, which disables the outputs should the internal junction temperature exceed 150°C.

## APPLICATION AND BLOCK DIAGRAM

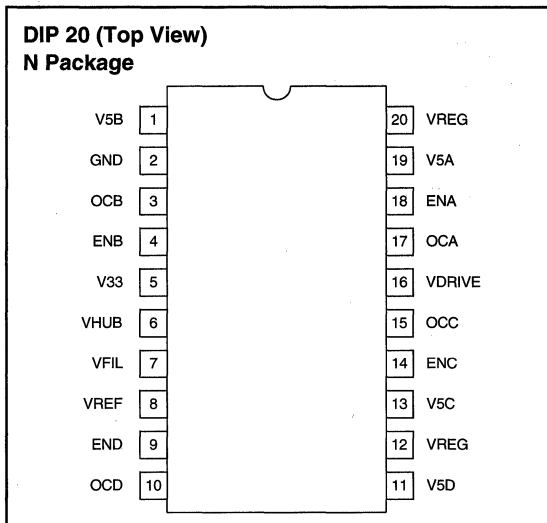


**ABSOLUTE MAXIMUM RATINGS**

VFIL	9V
VHUB Supply Voltage	9V
Logic Inputs (ENA-D, ENHUB)	
Maximum Forced Voltage	-0.3V to 7V
Maximum Forced Current	1mA
V33	
Maximum Forced Voltage	5V
Maximum Current	200mA
V5A-D	
Maximum Voltage	9V
Maximum Current	900mA
Storage Temperature	65°C to +150°C
Junction Temperature	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.)	+300°C

Unless otherwise indicated, voltages are reference to ground. Pulsed is defined as a less than 10% duty cycle with a maximum duration of 500µS. Currents are positive into, negative out of the specified terminal. All voltages are with respect to ground. Consult Packaging Section of Databook for thermal limitations and considerations of packages.

**CONNECTION DIAGRAM**



**ELECTRICAL CHARACTERISTICS** Unless otherwise specified, T<sub>J</sub> = 0°C to 125°C for the UCC39811. VFIL = 6.5V, VHUB = 5V. T<sub>A</sub> = T<sub>J</sub>.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Input Supply Currents</b>					
VHUB Supply Current	No External Load on V33		1	3	mA
VFIL Supply Current			1	3	mA
<b>Reference</b>					
VREF Voltage	Over Temperature	2.35	2.5	2.65	V
Line Regulation	VHUB = 4.5V to 9V		3	10	mV
3.3V Regulator					
V33 Voltage	T <sub>J</sub> = 25°C, I <sub>LOAD</sub> = 10mA	3.2	3.3	3.4	V
	0mA to 100mA, 0°C to 125°C, VHUB = 4.5V to 9V	3.165	3.3	3.435	V
Short Circuit Current Limit	VHUB = 6V, Output shorted to Ground	100	120	150	mA
<b>Pre-Regulator</b>					
VREG Voltage	0A to 2A, 0°C to 125°C, VFIL = 6V to 9V	5.25	5.5	5.7	V
<b>5V Regulator</b>					
V5A-D Voltage	T <sub>J</sub> = 25°C, I <sub>LOAD</sub> = 250mA, V <sub>REG</sub> = 5.5V	4.85	5	5.15	V
	0mA to 500mA, 0°C to 125°C	4.8	5	5.2	V
Short Circuit Current Limit	VREG = 5.5V, Output Shorted to Ground	650	750	900	mA
<b>Charge Pump</b>					
Quiescent Output Voltage	T <sub>J</sub> = 25°C, VFIL = 6V, ENA-D = 5V, ENHUB = 5V	11	11.45	12	V
	0°C to 125°C, VFIL = 6V	10.5	11.45	12	V
Output Impedance			9	15	k
<b>Enable Inputs</b>					
ENA-D Inputs - Guaranteed Low				0.7	V
ENA-D Inputs - Guaranteed High		3			V
ENHUB Input - Guaranteed Low				0.7	V
ENHUB Input - Guaranteed High		3			V
<b>Overcurrent Signals</b>					
Active Sink Current	I <sub>OCX</sub> = 100µA		140	500	mV

## PIN DESCRIPTIONS

**ENA-D:** Separate enables pins for each of the four 5V supplies.

**ENHUB:** Enables the 3.3V output V33. Pulling this pin low disables V33.

**GATE:** Gate drive for an external NMOS used to regulate the 5.5V VREG supply. Minimum available drive is 11V.

**GND:** All 6 GND pins must be tied to the system ground. In addition to serving as electrical conductors, these 6 pins are heat sinks. Refer to the Packaging Device Temperature Management guide in the Packaging section of the Unitrode Databook.

**OCA-D:** Open drain overcurrent indicator. OCA-D can be wire OR'ed by the user to create a single overcurrent indicator.

**V5A-D:** 5V regulated output with enable, 500mA (mini-

um) current limit, and overcurrent indicator.

**V33:** 3.3V regulator output. Enable when ENHUB is high. Current limit is 100mA minimum.

**VDRIVE:** Internal charge pump voltage is brought out for external decoupling. Nominal voltage is between 11V and 13V. No external loading permitting. Decouple with at least 0.001 $\mu$ F capacitor.

**VFIL:** Bias supply for all four of the 5V regulators. VFIL voltage must be between 5.5V and 9V Can be tied to VRE.

**VHUB:** Supply for the 3.3V USB controller power supply and bandgap reference.

**VREF:** Internal 2.5V reference is brought out for external decoupling only. Decouple with 0.01 $\mu$ F capacitor.

**VREG:** Regulated to 5.5V by means of an external NMOS. Two pins supply up to a total of 2.5A to the four 5V bus voltages (V5A, V5B, V5C, V5D).

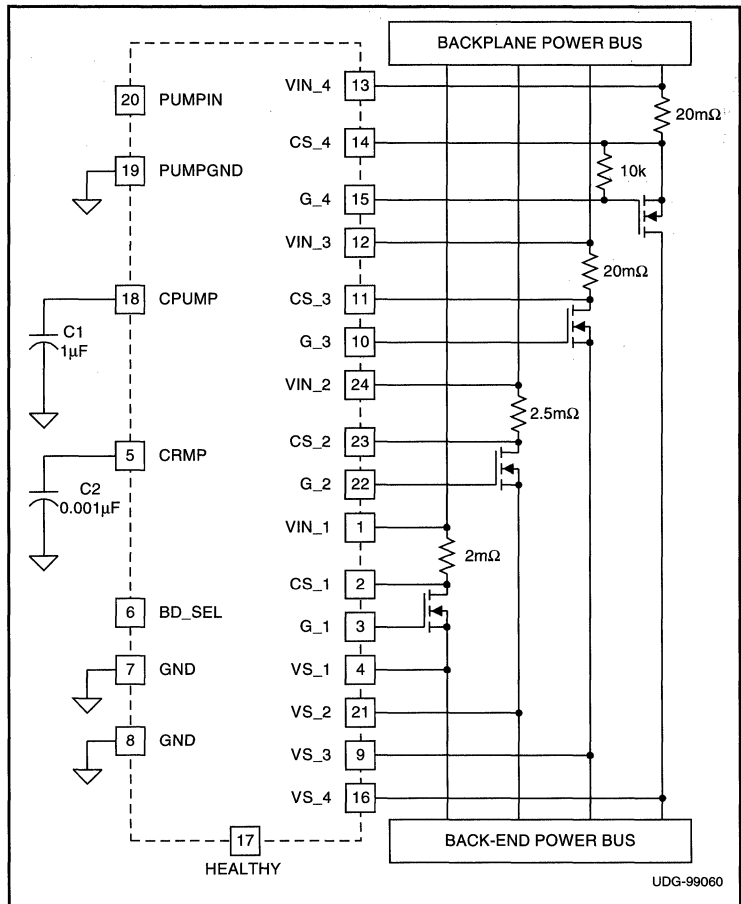


# Programmable CompactPCI™ Hot Swap Manager

## FEATURES

- Fully CompactPCI™ compliant
- Features and ranges programmable using internal non-volatile memory
- Four Channels for individual control of 4 supplies
- Minimal external parts count
- Precise Linear Current Amplifier for controlled current ramping
- True ramp-up and ramp-down current slew control
- Precision 2X over-current detection
- High voltage charge pump permits design with lower cost external NFET devices
- Shutdown control with low sleep mode quiescent current
- Input under-voltage lockout (UVLO)
- Wide input operating range: -15V to 15V
- Easily programmable for other applications
- Windows 95/98 programming interface and utilities
- 24 Pin SOIC and TSSOP package

## TYPICAL APPLICATION



## DESCRIPTION

The UCC3985 family of Compact PCI Hot Swap Power Managers (HSPM) provides fully programmable supply management using an absolute minimum of external support components. The UCC3985 provides full management of 3 positive supplies and 1 negative power rail. The UCC3985 is the first HSPM to offer on-chip non-volatile memory, which allows the user to customize the performance of the part to the application. This feature enables interactive programming during the circuit development phase, leading to rapid product deployment. Programming during development is supported with an easy to use PC parallel port interface and a Windows 95/98 based Graphical User Interface (GUI). UCC3985 high volume delivery can be pre-programmed to the customer requirements at the factory. The programmable features of the UCC3985 include:

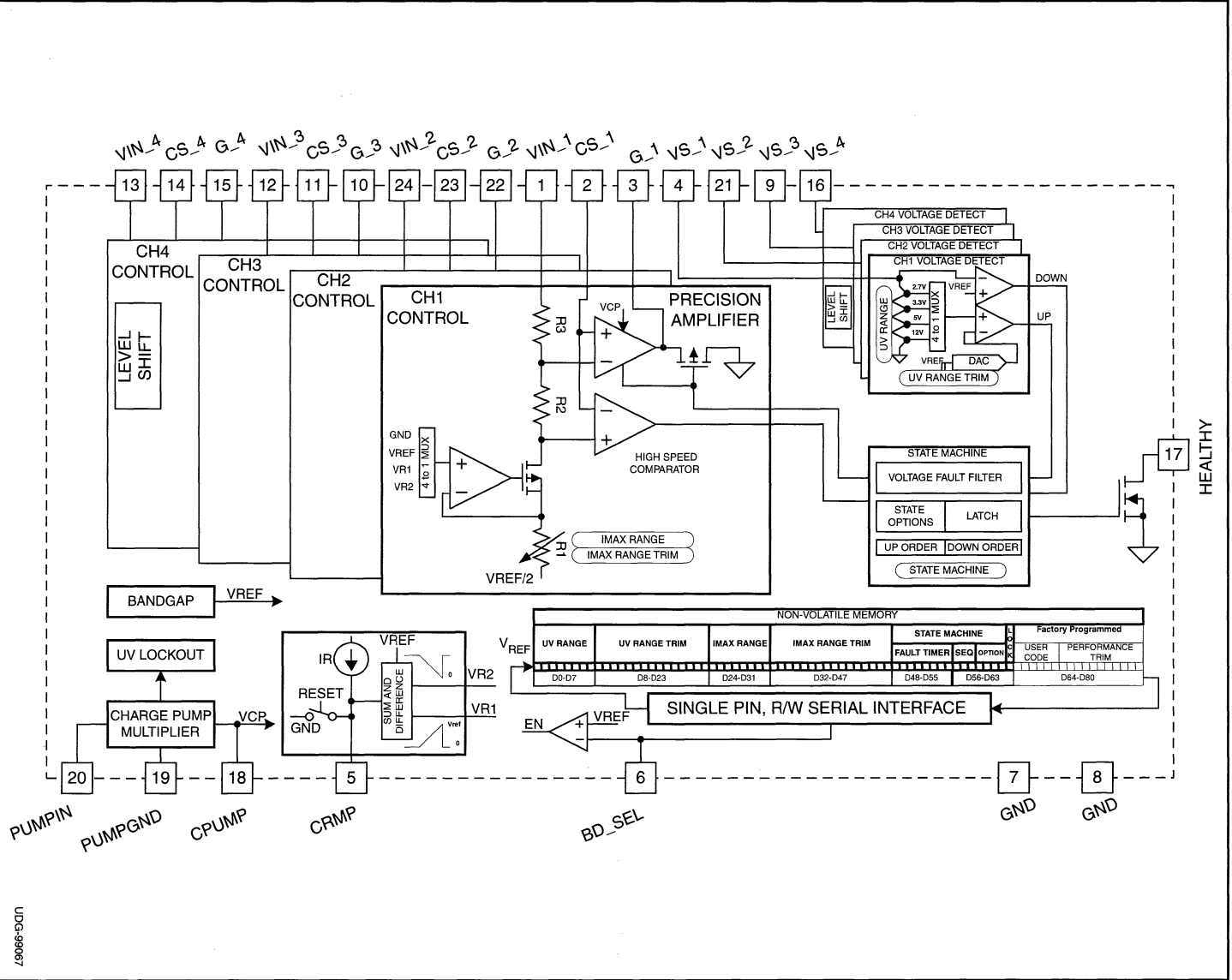
- Independent Linear Current Limit and Under-voltage detection
- Supply sequencing order
- Fault event behavior
- Common Voltage fault filter time

Like other Unitrode Hot Swap Power Managers the UCC3985 utilizes a Linear Current Amplifier (LCA) in each of its 4 channels to provide closed loop control of the inrush current profile during start-up. The LCA concept allows the designer to program the startup current slew rate and steady state level. The  $<1mV$  input offset voltage of the LCA allows for low value sense resistors, minimizing insertion loss across the hot swap interface, while not compromising performance in low current appli-



Figure 1. Block diagram.

5-95



UCC-99067

UCC3985

## DESCRIPTION (cont.)

cautions. Current limit range and fine adjust for each channel are fully programmable to allow for an easy match of desired current limit and standard, low value, current sense resistors. Low input offset and set-point voltages make board copper trace resistors feasible for high current applications.

A versatile programmable state machine defines how the supplies are sequenced and how the device responds to a fault or over-current condition. A programmable Voltage Fault Delay Filter can be set to enable compatibility with the longer voltage ramps associated with large bus filter capacitance. To protect the host system power bus, the UCC3985 can provide fault protection in the form of an electronic circuit breaker with a programmable

over-current threshold set to precisely 2 times the programmed current limit value. Detection of an over-current condition on any rail(s) can be set to cause the corresponding external N-channel MOSFET(s) device(s) to be latched off immediately with the remaining supplies being ramped down per the pre-programmed schedule.

The UCC3985 is designed to work with supplies ranging from -15V to +15V. A 24V onboard charge pump multiplier ensures maximum external N-channel MOSFET gate overdrive offering the use of lower cost devices for the equivalent insertion loss. A separate PUMPIN pin allows for pump connection to the highest input supply for maximum pump efficiency.

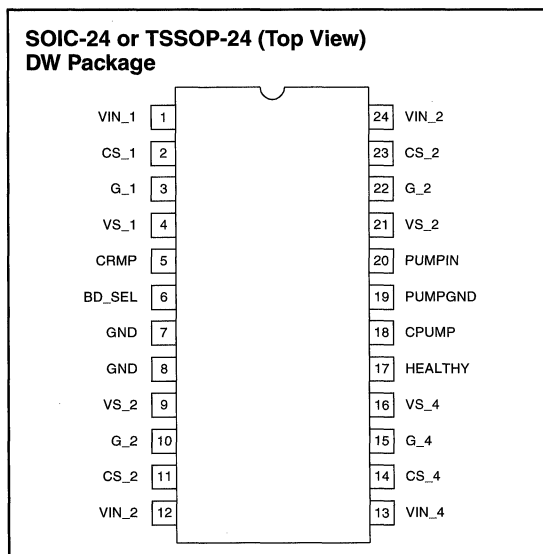
The UCC3985 is available in 24 pin SOIC (DW) and 24 pin TSSOP packages.

## ABSOLUTE MAXIMUM RATINGS

VIN_1, VIN_2, VIN_3	0.3V to 15V
VS_1, VS_2, VS_3	-0.3 to VIN (corresponding channel)
CS_1, CS_2, CS_3	-0.3 to VIN (corresponding channel)
VIN_4, VS_4	-15 to 0.3V
BD_SEL	-0.3 to 20V
PUMPIN	-0.3 to 15V
HEALTHY	-0.3 to 12V
Storage Temperature	-65°C to 150°C
Junction Temperature	-55°C to 150°C
Lead Temperature (Soldering, 10 seconds)	300°C

*Currents are positive into, negative out of the specified terminal. Consult Packaging Section of Databook for thermal limitations and considerations of packages. All voltages are referenced to GND.*

## CONNECTION DIAGRAM



## PIN DESCRIPTIONS

**BD\_SEL:** A logic low on this pin enables the UCC3985 to supply power to the Back-End Bus. The logic threshold for this pin is 1.5 Volts. When disabled, the UCC3985 enters a low current sleep mode. This pin also serves as the input to the UCC3985 serial interface to read and write memory data. This unique interface employs multi-threshold voltage/current mode methods to enable simultaneous Data In, Data Out and Clock on a single pin.

**CRMP:** A capacitor tied to this pin sets the linear ramp up/down of the LCA current limit for each supply during supply sequencing.

**CS\_1, CS\_2, CS\_3:** These pins tie to the low end of the external current sense resistor and are used along with the VIN\_1-3 pins as the input to the LCA.

**CS\_4:** This pin ties to the more positive end of the current sense resistor of the negative supply rail. It is used with VIN\_4 as the input to the LCA.

**G\_1, G\_2, G\_3:** The Gate drive for the external NFETs for the positive rail switches. The gate drive is controlled as a function of sequencing and current to a value between 0 and 24 volts. The LCA is internally compensated and guaranteed stable for a wide range of gate capacitance.

## PIN DESCRIPTIONS

**G\_4:** Gate drive for the negative rail switch. This pin is driven in response to sequencing and load current to a voltage between VIN\_4 and ground. An external pull-down resistor should be used between G\_4 and CS\_4.

**GND:** Analog grounds for the device.

**HEALTHY:** In the *CompactPCI*<sup>TM</sup> application, this pin is driven low to indicate the board's suitability to be connected to the bus. This is an open drain output which is driven false if the Back End power is not within the tolerances programmed into the under-voltage comparators, the result of an over-current on either supply controller or a fault time-out on either supply during linear ramp-up.

**PUMPC:** Charge Pump output. A 1 $\mu$ F capacitor should be connected from this pin to ground. This capacitor provides charge storage to drive the gate of the external NFET device for each channel.

**PUMPGND:** Ground for internal charge pump multiplier.

**PUMPIN:** This is the input to the charge pump multiplier. It should be connected to the highest input supply voltage to ensure sufficient gate overdrive for the NFET of the highest supply rail. It is recommended to place a 0.1 $\mu$ F de-coupling capacitor from this pin to PUMPGND to minimize board level noise due to internal charge pump switching.

**VIN\_1, VIN\_2, VIN\_3:** These pins tie to the positive backplane supplies.

**VIN\_4:** This pin ties to the negative backplane supply.

**VS\_1, VS\_2, VS\_3:** These are the voltage sense pins for the positive Back-End power bus.

**VS\_4:** This is the voltage sense pin for the negative Back-End power bus.

## APPLICATION INFORMATION

### Programmability:

The UCC3985 has 64 bits of user settable non-volatile memory. These bits are programmed through the BD\_SEL pin and the self-clocking, multilevel, read-able and writ-able serial interface of the UCC3985. The UCC3985 PC Parallel Port Interface Kit and Windows 95/98 Drivers provides the user with a quick and easy means to customize the UCC3985 to the specific application. A "LOCK" bit can be set to disable the serial interface and prevent any future modification of memory contents. Once the customization is developed, high volume delivery can be fully preprogrammed at the factory.

### Non-Volatile Memory Bits:

**D0-D7, UV RANGE:** These bits (2 per channel) set the coarse range of the under-voltage detection comparators. The positive and negative supplies can be individually set to 2.7V, 3.3V, 5.0V or 12V. The "UP" and "DOWN" comparison information is used to detect an output fault or to determine the completion of an individual supply ramp sequence.

**D8-D23, UV RANGE TRIM:** These bit positions provide additional resolution in the trim of the UV RANGE of each channel.

**D24-D31, IMAX RANGE:** The coarse range of the IMAX current limit can be set with 2 bits of resolution per channel. These bits allow a range adjustment of the equivalent voltage drop across the external current sense resistor while in closed loop linear current control. This value can be set from 10mV to 80mV.

**D32-D47, IMAX RANGE TRIM:** The current limit range set by IMAX RANGE can be fine tuned with an additional 4 bits of resolution per channel with these bits.

**D48-D62, STATE MACHINE:** Bits 48-55 set the amount of time that the UCC3985 is allowed to operate in the constant current mode during supply sequencing. This time can be set from 0 and 150 mSec and is common to all 4 channels. Bits 56-58 set the supply up/down sequence. Bits 59-63 determine how the state machine responds to a fault condition.

**D63, LOCK:** Once set, this bit permanently disables the serial interface and disconnects it from the BD\_SEL pin, preventing any further change of memory contents.

**D64-D80, FACTORY PRETRIM:** These readable positions are permanently written at the factory. They contain customer specific and product version information as well as parametric pre-trim information.

# Simple Single Channel External N-FET Hot Swap Manager

## FEATURES

- Precise Linear Current Amplifier for precision inrush current profile programming
- Programmable over-current detection threshold
- Internal Charge Pump for control of external NMOS devices
- Shutdown Control with low sleep mode quiescent current
- Input undervoltage lockout (UVLO)
- Input operating range: 2.75V to 5.5V
- Simple 8-pin part

## DESCRIPTION

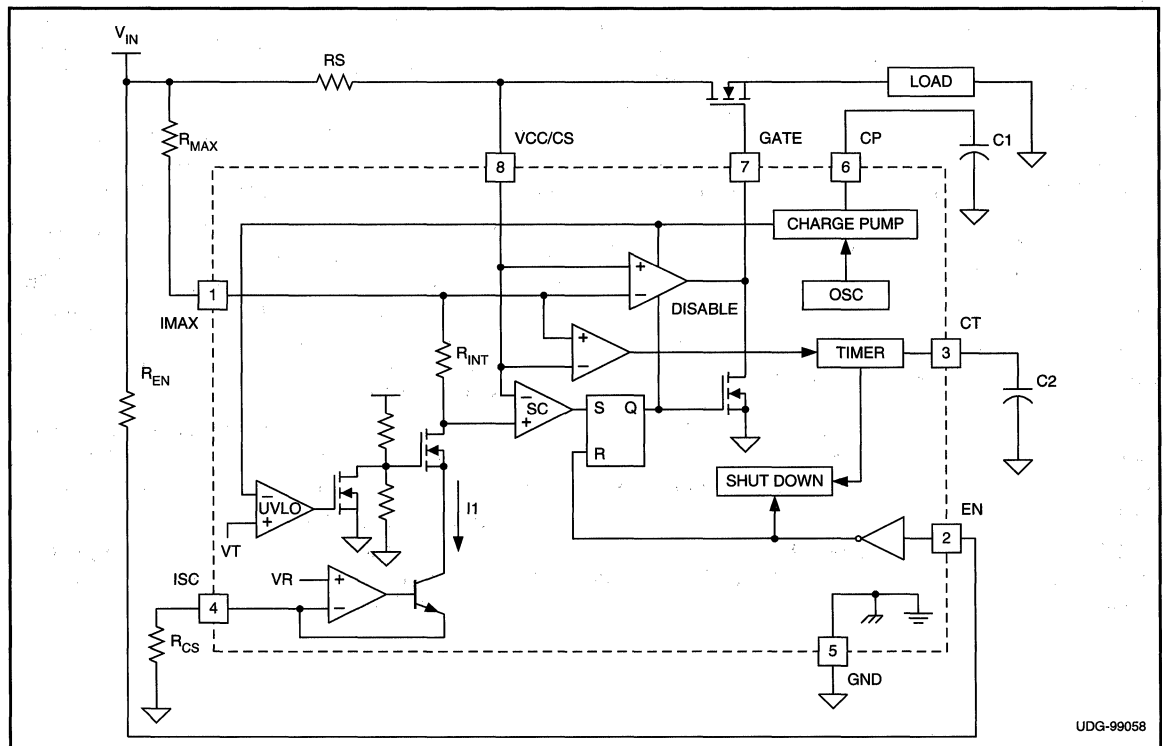
The UCC3995 family of Hot Swap Power Managers provides the most functions available in the industry in a simple 8 pin package requiring minimal external parts count. The UCC3995 needs few external components to operate, producing the lowest total system cost.

Like other Unitrode Hot Swap Power Managers (HSPM) the UCC3995 utilizes a Linear Current Amplifier (LCA) to provide closed loop control and direct programming of the inrush current profile during start-up. The LCA allows the designer to program the maximum inrush current level and the slew rate of the inrush current. In addition, the  $<1\text{mV}$  input offset voltage of the LCA allows for low value sense resistors while not compromising low current applications and minimizing insertion loss across the hot swap interface.

To maintain the integrity of the host system power bus, the UCC3995 provides fault protection in the form of an electronic circuit breaker with a programmable over-current threshold. Detection of an over-current condition will result in the external NMOS device being immediately latched off.

The UCC3995 allows the designer to program how long the HSPM can operate in the current control mode to satisfy system specific load current requirements.

## BLOCK AND SIMPLIFIED APPLICATION DIAGRAM



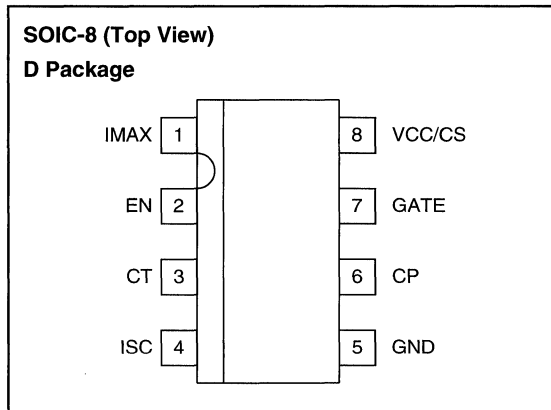
UDG-99058

### ABSOLUTE MAXIMUM RATINGS

V <sub>CC</sub> /CS .....	-0.3V to 7V
Pin Voltage ( Except CP Gate) .....	-0.3V to V <sub>CC</sub> +0.3V
Pin Voltage ( CP and Gate) .....	-0.3V to 24V
I <sub>SET</sub> current .....	0mA to 1mA
Storage Temperature .....	-65°C to 150°C
Junction Temperature .....	-55°C to 150°C
Lead Temperature .....	300°C

Currents are positive into, negative out of the specified terminal. Consult packaging section of Databook for thermal limitations and package considerations.

### CONNECTION DIAGRAMS



### PIN DESCRIPTIONS

**IMAX:** This pin programs the constant current threshold level. The voltage across the resistor (R<sub>IMAX</sub> connected between IMAX and the input voltage rail) will be equal to the voltage across R<sub>S</sub> in constant current mode. The current sink on IMAX is determined by the resistor connected from the ISET pin to ground. The inrush current slew rate can be controlled by placing a capacitor in parallel with R<sub>IMAX</sub>.

$$I_{MAX} = \frac{(V_R \cdot R_{MAX})}{(R_S \cdot R_{CS})}$$

$$I_{SC} = V_R \cdot \frac{(R_{MAX} + R_{INT})}{R_S \cdot R_{CS}}$$

$$I_{SC} = I_{MAX} \cdot \frac{(1 + R_{INT})}{R_{MAX}}$$

**ISET:** Output used to set the precision current sink on the IMAX pin as well as the Over-current threshold. A resistor should be connected from ISET to ground.

**GND:** Ground connection for the IC.

**GATE:** Output of the Linear Current Amplifier. This pin is used to drive the gate of the external NMOS device.

**VCC/CS:** This dual function pin is used for input power to the chip as well as current sense input for the LCA. The VCC current should have little effect on the accuracy of the constant current threshold due to the small valued sense resistor and the low supply current demands.

**HI/EN:** Pulling this pin below 0.8V will disable the external NMOS device and put the IC in sleep mode. Allowing this pin to float or driving to VIN will enable the UCC3995.



# Dual Sequencing Hot Swap Power Manager

## FEATURES

- Precise Linear Current Amplifier for high efficiency and low voltage drop
- Controls inrush current and supply voltage ramp; ramp up sequence and slope and ramp down sequence
- Easily expandable to three or more supplies
- Programmable over-current detection threshold
- High voltage charge pump to drive low cost external NMOS devices
- Programmable soft start capability and fault timer
- Fault output indicator
- Shutdown Control with low sleep mode current (<math><1\mu\text{A}</math>)
- Input undervoltage lockout
- Wide input operating range: 2.75V to 13.6V
- 16 pin SOIC and DIP packages

## DESCRIPTION

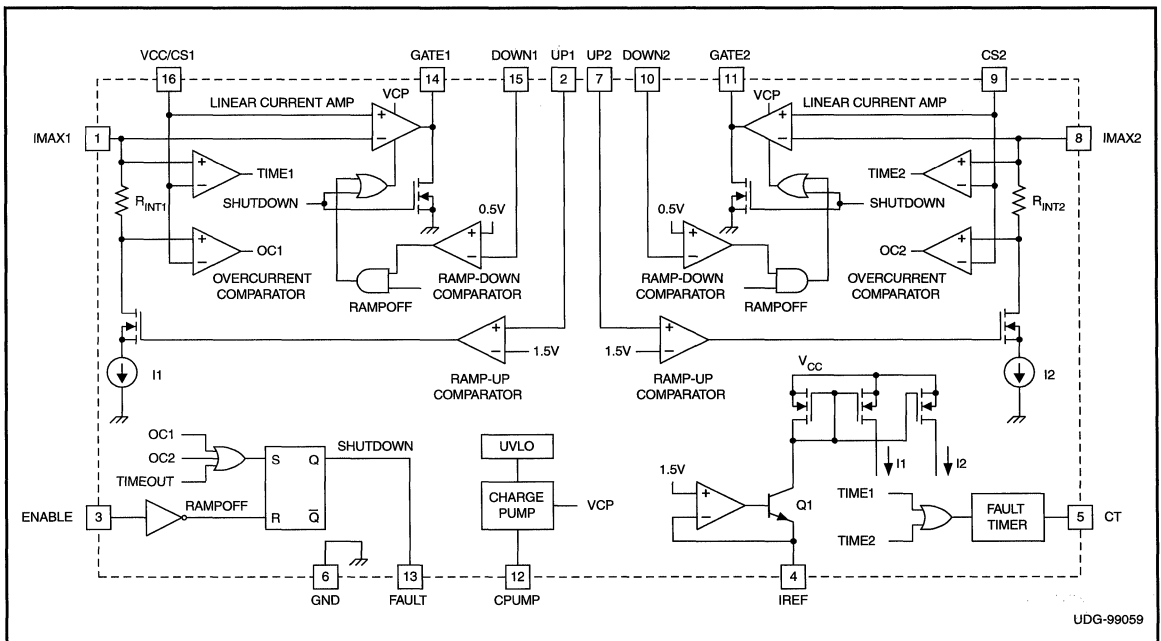
The UCC3996 family of Hot Swap Power Managers provides hot swap control, fault handling and power supply sequencing of two positive supplies. The UCC3996 operates over a wide supply range allowing single part inventory for a variety of output voltages.

Like other Unitrode Hot Swap Power Managers the UCC3996 utilizes a Linear Current Amplifier (LCA) to provide closed loop control and direct programming of the inrush current profile during start-up. The LCA allows the designer to program the maximum inrush current level and the slew rate of the inrush current. In addition, the <math><1\text{mV}</math> input offset voltage of the LCA allows for low value sense resistors while not compromising low current applications and minimizing insertion loss across the hot swap interface.

To maintain the integrity of the host system power bus, the UCC3996 provides fault protection in the form of an electronic circuit breaker with a programmable overcurrent threshold. Detection of an overcurrent condition will result in the external NMOS device being immediately latched off.

The UCC3996 allows the designer to program how the HSPM can operate in the current control mode to satisfy system specific load requirements.

## BLOCK DIAGRAM



**ABSOLUTE MAXIMUM RATINGS**

V <sub>CC</sub> /CS1	−0.3V to 15V
Pin Voltage	
(Except V <sub>CC</sub> /CS1, CP Gate1, Gate2)	−0.3V to V <sub>CC</sub> +0.3V
I <sub>REF</sub> Current	0 to −1mA
Storage Temperature	−65°C to 150°C
Junction Temperature	−55°C to 150°C
Lead Temperature	300°C

Currents are positive into, negative out of the specified terminal. Consult packaging section of databook for thermal limitations and package considerations.

**PIN DESCRIPTIONS**

**CPUMP:** Charge pump output. A 0.1μF capacitor should be connected from this pin to ground. The capacitor provides charge storage to drive the gate of the external NMOS devices.

**CS2:** Current sense input 2. This pin is used as the current sense for the LCA on the second supply controller. This must be connected to the sense resistor on the input supply with the lowest voltage.

**CT:** Fault timer capacitor. A capacitor connected from this pin to ground determines the amount of time that the UCC3996 is allowed to operate in the constant current mode. The capacitance value must be selected to ensure that the load capacitance has adequate time to charge.

*Note:* Connecting a scope probe or other metering device will alter the fault time.

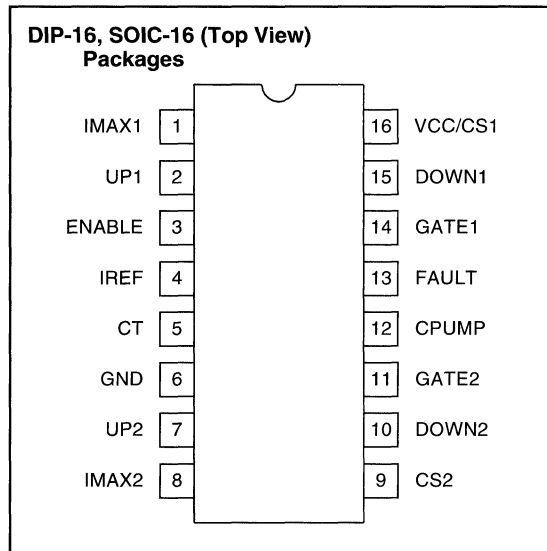
**DOWN1, DOWN2:** Ramp-down comparator inputs 1 and 2. These inputs are used to sequence the turn-off of the two supplies. The supply will start its turn-off when the voltage on the DOWN1, DOWN2 input pin falls below 0.5V.

**ENABLE:** Device enable input. Pulling this pin below 0.8V will disable both external NMOS devices and put the IC in sleep mode. Allowing this pin to float above 0.8V or driving to VIN will enable the UCC3996.

**FAULT:** Fault output. This pin will be active high when a latched fault occurs. The fault can be the result of an overcurrent on either supply controller or a fault time-out on either supply during linear ramp-up.

**GATE1, GATE2:** Outputs of the Linear Current Amplifiers. These pins are used to drive the gates of the external NMOS devices. The LCA is internally compensated and guaranteed stable for gate capacitance between TBD and TBD.

**CONNECTION DIAGRAMS**



**GND:** Ground connection for the IC.

**IMAX1, IMAX2:** Maximum source current. These pins program the constant current threshold level. The voltage across the resistor (R<sub>IMAX</sub> connected between IMAX1, IMAX2 and the input voltage rail) will be equal to the voltage across R<sub>SENSE</sub> in constant current mode. The current sink on IMAX1, IMAX2 is determined by the resistor connected from the IREF pin to ground. Placing a capacitor in parallel with R<sub>IMAX</sub> controls the inrush current slew rate.

**IREF:** Reference current. This pin sets the precision current sink on the IMAX1, IMAX2 pins as well as the Overcurrent threshold. A resistor should be connected from IREF to ground.

**UP1, UP2:** Ramp-up comparator inputs 1 and 2. These inputs are used to sequence the ramp-up of the two supplies. The supply will ramp-up when the voltage on the UP1/UP2 input pin exceeds 1.5V.

**VCC/CS1:** Supply input and current sense1. This dual function pin is used for input power to the chip as well as current sense input for the LCA. VCC must be connected to the sense resistor on the input supply with the highest voltage. The VCC current should have little effect on the accuracy of the constant current threshold due to the small valued sense resistor and the low supply current demands.

**UCC3912 Programmable Electronic Circuit Breaker  
– Performance Evaluation and Programming Information**

by Bill Andreyca

The UCC3912 Demonstration Kit will enable designers to evaluate the performance of The UCC3912 Electronic Circuit Breaker in a typical application circuit. This kit features a number of programming options which include : individual "Hot Swap" of input and output connections, maximum current, Fault cur-

rent level, and Shutdown. Each of these is programmed via switches located on the board. An LED indicates when the Current Fault Level comparator has been triggered and the device is in a low duty cycle mode.

**List of switches, connections and functions:**

SWITCH	CONNECTION (IC pin #)	FUNCTION
SW1	VIN (2,3)	"Hot Swapping" of the input supply
SW2	VOUT (14,15)	"Hot Swapping" of the output supply
SW3-1	IMAX (10)	Sets maximum current level
SW3-3	B3 (6)	Current Limit DAC Bit#3 input
SW3-4	B2 (7)	Current Limit DAC Bit#2 input
SW3-5	B1 (8)	Current Limit DAC Bit#1 input
SW3-6	B0 (9)	Current Limit DAC Bit#0 input
SW3-8	Shutdown (1)	Shutdown input to disable IC

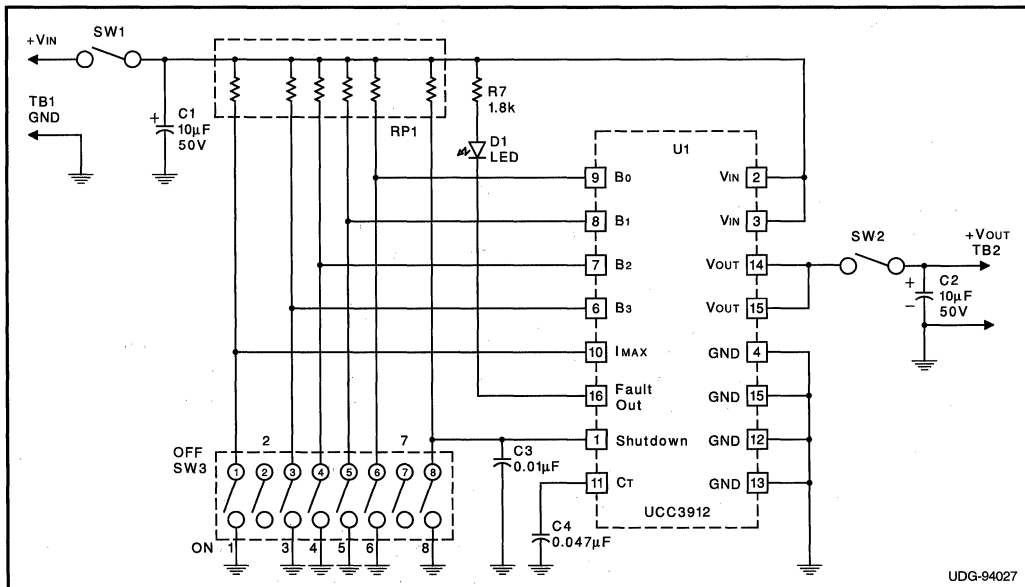


Figure 1. UCC3912 Demo Circuit Schematic



**Programming the switches :** Switch SW3 is a standard eight position DIP switch, but only six of these provide programming functions. The two switches located at positions 2 and 7 (SW3-2, SW3-7) are not used. Moving the switches toward the corresponding switch position number, or the "ON" direction GROUNDS the input and provides a digital "low", or zero. A digital "high" input is provided when the switches are in the "OFF" position, or facing towards switches SW1 and SW2.

**Timing functions :** The UCC3912 Demo Kit incorporates a 0.047 microfarad timing capacitor to provide fault protection. Using the equations found in the device's datasheet, the actual timing intervals can be determined by:

$$FAULT = CT \cdot 28 \cdot 10^3 = 1.3 \text{ milliseconds}$$

$$T_{SHUTDOWN} = CT \cdot 10^6 = 47 \text{ milliseconds}$$

The exact duty cycle during a fault condition is :

$$duty \ cycle = \frac{FAULT}{T_{SHUTDOWN}} = \frac{1.3ms}{47ms} = 2.8\% \text{ (typical)}$$

**Maximum load capacitance :** The maximum load capacitance can also be calculated using the equations found in the UCC3912 datasheet. Since a wide range of maximum load currents, output voltages and timing capacitors can be used, the maximum load capacitance value will vary with each application. Note that the Demo Kit uses a 10µF electrolytic capacitor on the output (VOUT) connection which must be taken into account to determine the maximum capacitive load.

**Supplying power :** The Demo Kit has two terminal blocks for electrical connections to the input voltage

supply and the output load. Terminal block TB1 is used for the input supply (VIN) and TB2 is used to connect the kit to an appropriate load. Observe the correct polarity (+/-) of the connections as indicated on the printed circuit board, or damage could result.

**Input voltage range :** 3 volts minimum to 8 volts maximum

**Output load :** An adjustable electronic load can be used to draw varying amplitudes of current through the UCC3912 Demo Kit. This type of load is much easier to use than fixed value power resistors to determine the exact current limiting threshold. One example of an adjustable electronic load is shown in Unirode Design Note #DN-52 which can sink over 5 amps of DC current and dissipate over 35 Watts of heat without a fan. This design is adequate for comprehensive testing of the UCC3912 Demo Kit.

**Output current range :** 0 to 4 amps, 0 to 32 watts (approximate)

"Hot swap" testing should be performed using power resistors and/or capacitors to draw the specific load current and characteristics required. These should be placed across the Demo Kit output connections and testing performed by switching SW2 on and off while monitoring the load current and voltage. DO NOT USE AN ELECTRONIC LOAD unless it has been characterized for this "hot swap" application. Many electronic loads will attempt to draw very high current with a rapid application of input voltage and could falsely cause tripping of the UCC3912 Fault circuitry.

**Other Applications :** While primarily intended for "hot swap" data communications power supply applications, the UCC3912 also lends itself to any low

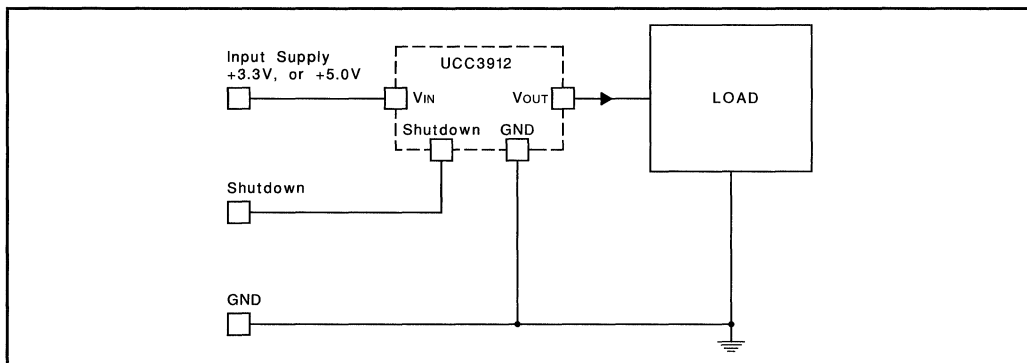


Figure 2. UCC3912 Used as a Low Current Standby (<5µA) Power Switch

voltage circuit breaker or protection application below 4 amps. Some of these include battery powered tools and equipment, PCMCIA card power switching and many 3.0V, 3.3V and 5.0 volt power supplies.

able maximum current protection for a wide variety of power applications including : data communications, computer, battery powered and portable equipment, PCMCIA card power, industrial controls and many low voltage power supplies.

**Summary:** The features of the UCC3912 Electronic Circuit Breaker offer design flexibility and program-

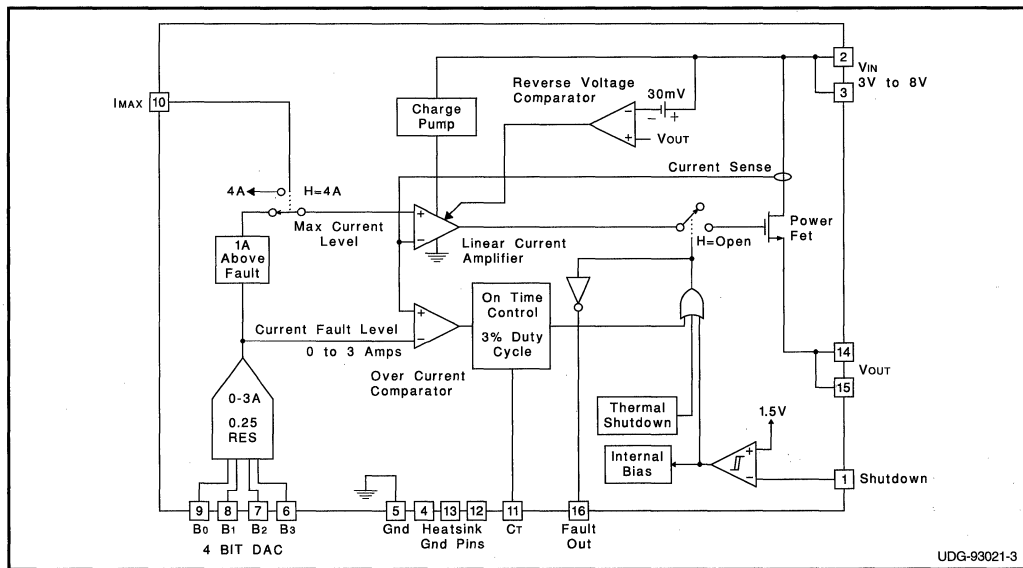


Figure 3. UCC3912 Block Diagram



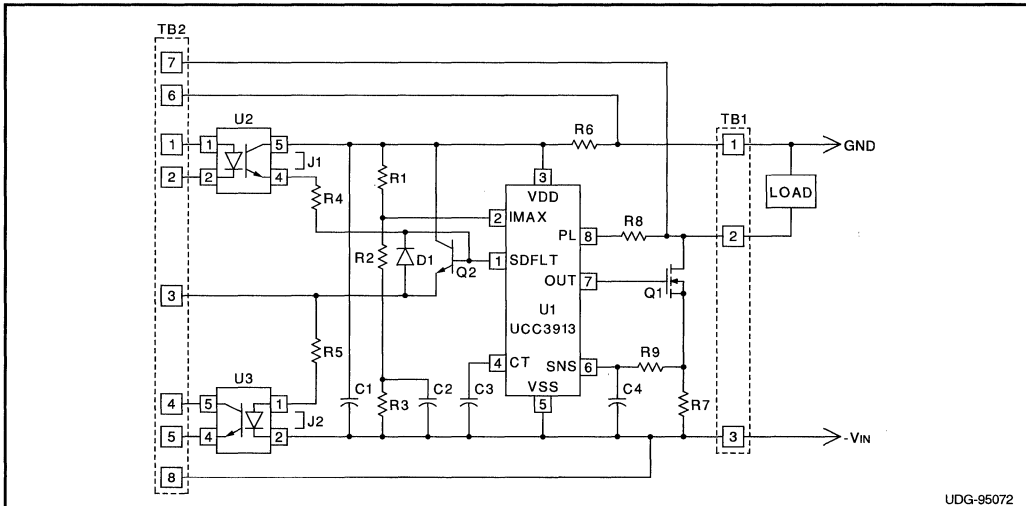
**Design Note**

**UCC3913 Electronic Circuit Breaker for Negative Voltage Applications  
Evaluation Kit List of Materials for a -48V/1A Test Circuit**

**by Bill Andreycak**

Many battery powered and Telecommunications power supplies use some form of protection to prevent high currents from flowing during a short circuit or overload condition. This function is often performed by a self-resetting circuit breaker -as opposed to a fuse, which would require manual replacement whenever triggered. Circuit breakers can be implemented in a number of different ways, but the most popular approach is use a MOSFET transistor which can be switched on and off as required. Load current is typically sensed with a low value resistor and

compared to a reference level to determine when an overcurrent condition exists. This function can be achieved with discrete circuitry or with a fully integrated solution, such as the UCC3913 Negative Voltage Circuit Breaker. This Design Note highlights the UCC3913 Evaluation Board in a typical -48VDC, 1A application circuit. Complete details for programming the various features of the device can be obtained from the UCC3913 Datasheet, found in the Unitrode Product and Applications Handbook.



**Figure 1. UCC3913 Evaluation Kit Schematic**

**List of Materials :**

- C1 1μF/16VDC Ceramic
- C2 not used - open circuit
- C3 1.5nF/16VDC
- C4 not used - open circuit
- D1 1N4148 Diode
- Q1 IRF630 200V/5A MOSFET
- Q2 2N2222 NPN
- R1 24k, 1/4W
- R2 510 ohms, 1/4W
- R3 JUMPER - use AWG 22 wire
- R4 47k, 1/4W

- R5 1k, 1/4W
- R6 3.3k, 1/4W or Qty (4) 13kΩ  
1/8W SMT resistors in parallel
- R7 50 milliohm shunt
- R8 510k, 1/4W
- R9 JUMPER - use AWG 22 wire
- U1 UCC3913 IC
- U2,3 4N29 Optocoupler

**Test Equipment :**

- Power supply : 48VDC / 1.5ADC
- Programmable electronic load to sink 1.5A at 48VDC



**Paralleling UCC3912 Electronic Circuit Breaker ICs**

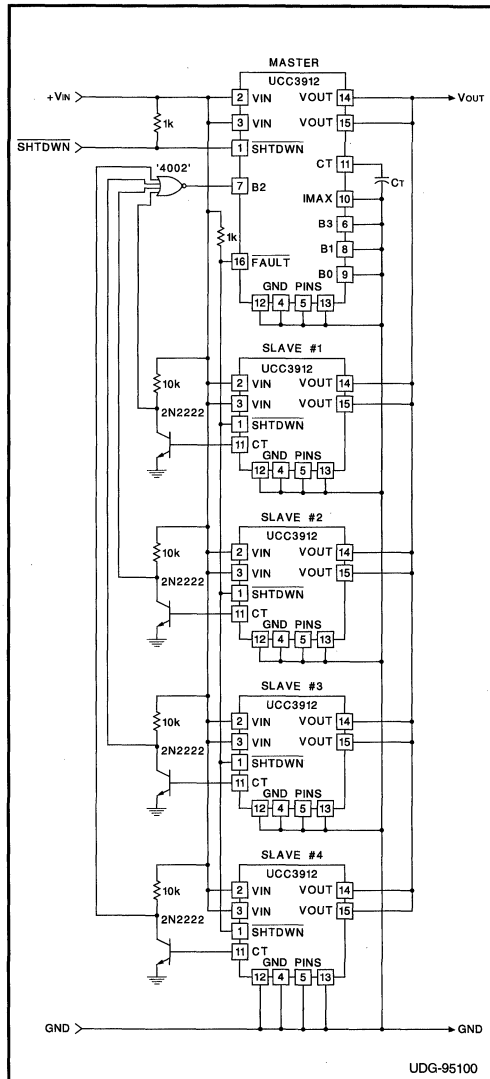
By Paul Aloisi and Bill Andreycak

The UCC3912 IC is an integrated 3 Amp electronic circuit breaker which includes programmable overcurrent protection and retry timing following a fault. Other common uses for this function are in higher current (12A) and low "headroom" applications where a lower voltage drop is required. Each of these can be addressed by paralleling UCC3912 devices as shown in Figure 1.

To provide the circuit breaker function, the UCC3912 uses an internal FET switch having a typical on resistance of 0.150 ohms and 3 Amp continuous current rating. The positive temperature characteristics of MOS devices are beneficial in parallel applications to help divide the total load current evenly amongst all of the devices used. The UCC3912 with the lowest on resistance will pass slightly more of the current than the others, but its forward voltage drop will increase accordingly. This causes the load current to steer towards the other devices (in parallel) which were previously passing less current. With this configuration, equilibrium will be reached quickly as the total load current is distributed amongst all of the slaves.

One feature of the UCC3912 is its digitally programmable threshold for overcurrent limiting. When this current level is reached, the UCC3912 control circuitry regulates current to the programmed IMAX amplitude. To facilitate this, the gate drive to its internal MOS pass device is reduced, causing its on resistance and corresponding voltage drop to increase. As in the previous example for paralleled devices, this steers current to the other UCC3912s in parallel, forcing load sharing.

The duration of this allowable overcurrent condition is also programmable by selecting the appropriate timing capacitor value to the IC's fault timing (CT) pin. When the overcurrent condition is detected, two protection functions begin operation. First, the UCC3912 goes into a constant current mode to regulate current to the pro-



**Figure 1. Paralleling UCC3912 Electronic Circuit Breakers**

grammed value of IMAX. Simultaneously, the device begins charging the fault timing capacitor and provides a digital indication at the open collector FAULT pin of the IC. The overcurrent duration concludes when the timing capacitor charges to a preset voltage and the MOS pass transistor is turned off. The off time is internally controlled to thirty times the programmed fault duration ( $t_{OFF} = 30 \cdot t_{FAULT}$ ), resulting in an approximate three percent (3%) effective duty cycle to safely limit power dissipation into a short circuit. Note that the UCC3912 also features internal overtemperature shutdown protection should the timer be incorrectly programmed for too long of a fault duration or inadequate heatsinking provided. Consult the UCC3912 datasheet for complete details of the timing and fault protection circuitry operation into single and repetitive overcurrent conditions.

### Circuit Operation

In this paralleled application of UCC3912 devices, a master/slave arrangement will be incorporated and the fault timing control will be governed entirely by the master. Slave devices are configured to give a digital representation of the overcurrent condition, and their individual CT outputs are "NOR"ed together as an input to the master. A generic CMOS '4002 digital IC is used for its low current and 3V operational characteristics. Note that each input requires a 2N2222 NPN signal level transistor with a 10k ohm pull up resistor from the input supply ( $V_{IN}$ ) to its collector to complete the interface. This arrangement is necessary to achieve the proper digital inputs to the NOR gate while clamping the UCC3912 CT pin voltages to just a base-emitter diode drop ( $V_{BE}$ ) above ground. This will override the internal timing circuits of the individual slaves which are being controlled by the master's fault timer.

In normal operation (prior to any overcurrent condition) the CT pin of each slave UCC3912 is low and the corresponding NPN transistor is off. The 10k ohm collector resistors place a digital high on the NOR gate's four inputs, and the output of this gate is low. When any of the slave UCC3912 devices goes into overcurrent protec-

tion its CT pin is pulled high by an internal current source. Normally, this would start charging the fault timing capacitor, but in this paralleled application, it forward biases the base-emitter junction of the respective 2N2222 transistor. This turns on the NPN device and forces a digital low input to the NOR gate. When all four of the NOR inputs go low, the output of the NOR gate goes high. This indicates that all four of the slaves are limiting current to their programmed maximum level and that an overcurrent condition exists.

The output of this NOR gate is used to digitally program one bit (BIT2) of the master UCC3912's overcurrent limit. The master was previously "off", not providing any load current since its four overcurrent inputs (BITS 0 through 3) were all low. Any digital input below "0100" programs its output current to zero by turning off the power switch. But triggered by the overcurrent conditions of the slaves, the NOR gate output switches BIT2 of the master high. This turns the master on and programs its output current to 0.25A by the "0100" code at BITS 0 through 3. The master now allows 0.25 amps in addition to the slaves 12 amps to the load for a system total of 12.25A. This is the sum of the master (0.25A) and the four slave overcurrent programming thresholds of three amps each ( $4 \cdot 3.0A$ ). Provided that the demanded load current is in excess of 12.25 amps, as would be the case with a short circuited load, the master then provides two functions. First, it regulates the current through the master to the programmed 0.25 amp level. Additionally, it begins a fault timing sequence, the duration of which is programmed by the value of the fault timing capacitor, CT. This capacitor charges during the overcurrent condition until it reaches the internal 1.5 volt fault threshold. Once triggered, the fault latch turns off the UCC3912's internal MOSFET switch (to provide the circuit breaker function) while also indicating the fault condition by providing a "low" on the IC's FAULT pin. Note that the master's FAULT output is connected to the slaved UCC3912s' SHTDWN pin which turns off all of the slaved devices at the same time that the master turns off.



The duration of the overcurrent event is programmed entirely by the master's CT timing capacitor value according to the UCC3912 datasheet information and design equations. The timing circuitry will deliver a current limited, pulsed mode fault protection and retry with a three percent (3%) duty cycle. While the timing capacitor is charging, each IC regulates and compares its load current to the programmed fault overcurrent level. Providing that the fault condition does exist, all UCC3912 ICs are turned off for the remaining ninety-seven percent (97%) of the programmed fault timing period. The resulting three percent duty cycle fault mode facilitates safe operation into a continuous overload or short circuited condition. It safely limits input power consumption and power dissipation in the circuit breaker switches. Additionally, no costly system downtime or manual replacement of a fuse or resetting of a circuit breaker is required.

Once the abnormal load condition has been removed, the circuit goes back into normal operation. The master's FAULT output returns to a "high" along with each of the slaves' SHTDWN inputs. If the load has not been removed, the master is retriggered by the NOR gate once each slave has detected an overcurrent condition, and the system goes back to the three percent duty cycle protection mode.

Note that the entire system is nominally triggered at 12.25A which is programmed by the four UCC3912 slaves' individual 3A thresholds and the 0.25A contribution of the master. However, this is unlikely to occur in a typical application because of two of the device's other ratings. First, is the maximum specified "trip" current of 3.5A for each slave switch and 0.45A for the master with the programmed overcurrent inputs (Bits 0 - 3). This would raise the highest trigger threshold to 14.45A. However, the more dominant factor is the high current capability of the UCC3912's switch which - is rated at four amps (4A) typical. In fact, each device can safely provide 5.2A (worst case) over all rated temperature and manufacturing conditions. One possible scenario should be reviewed using an instantaneous short circuit on the outputs. Even though all of

the slaves properly triggered their internal fault logic at 3.5A (worst case), all four of the slaves could be delivering as much as 5.2 amps maximum (within the device's ratings) to the load. This would correspond to a maximum load current of 21.25 amps. And while unlikely to repetitively occur in a typical application, it does represent the worst case sum of the four slaves' ( $4 \cdot 5.2A$ ) plus the master's (0.45A) maximum current ratings. However, it's advised to evaluate this figure to that of other fault protection and overcurrent techniques, for example fuses, which can be significantly higher for short durations. More specific details and comparisons can be found in Unitorde Application Note U-151.

### Other Applications

This design example utilized the UCC3912 device's rated current capability of 3A, but can be scaled for other applications with higher or lower requirements. Each slave can be individually programmed for a maximum current between 0.25A and 3A in 0.25A increments using the 4 bit digital inputs to the fault circuitry. This is beneficial in many low voltage supply applications which require a low headroom or dropout voltage (the voltage drop between the input and output connections of the circuit breaker) to meet the load's power supply specifications. In these, the UCC3912's could be paralleled to minimize the series voltage drop - and not to obtain the higher current capability of the system. This is one application where it is desirable to program the slave's overcurrent thresholds to a lower value than 3A each.

The 0.25A example of additional load current provided by the master can also be raised to deliver higher total system current to accommodate a transient load condition. Examples of this can be found in many battery powered energy management systems where only the required active circuitry is enabled and all others are switched off. When supplying power to these types of loads, often high inrush currents are needed to quickly charge up any local bypassing and filtering capacitors. This brief condition can be accommodated by programming the master UCC3912's overcurrent bits accordingly.

Although switching of only the master UCC3912's BIT2 is shown, its BIT3 input can also be switched for higher current capability. Additionally, BIT0 and BIT1 are shown grounded in the example circuit but can be programmed or switched with digital "1"s as well. Active digital programming of the master and all slave overcurrent BITs is also possible for the more demanding overcurrent protection applications. Each UCC3912 Electronic Circuit Breaker IC also features internal overtemperature protection with shutdown for complete system protection.

**Additional Reference Material:**

- [1] UCC3912 Data Sheet
- [2] Application Note U-151: "UCC3912 Programmable Electronic Circuit Breaker – Performance Evaluation and Programming Information"
- [3] UCC3912 Evaluation Kit
- [4] Design Note DN-58: "UCC3912 Programmable Electronic Circuit Breaker – Performance Evaluation and Programming Information"



## Design Note

### UCC3981 USB Power Controller IC, Evaluation Board, Schematic, and List of Materials

By Chuck Melchin

#### Introduction

The UCC3981 Power Controller is designed to provide a self powered USB hub with a local 3.3V regulated voltage as well as four 5V regulated voltages for USB ports. The 3.3V linear regulator is used to provide power to a local USB microcontroller. The 5V outputs are current limited to 500mA and the 3.3V output to 100mA in full compliance with USB specifications.

This demonstration kit provides all the circuitry necessary to evaluate the performance of the UCC3981 in a typical application. Each of the 5V outputs, as well as the 3.3V microcontroller voltage, can be individually enabled for optimal port control. Output enable is accomplished by the use of a five-position dipswitch and overcurrent signals are pulled up to the input voltage through 10K $\Omega$  resistors. Both enable and overcurrent signals are available at a 10 position in line SIP for easy scope probe access. The demo kit utilizes an external NMOS switch in a low dropout linear regulator for pre-regulating a rough DC voltage, such as a filament voltage, to provide the 5.5V input to the four 5V linear regulators.

This kit can also provide a valid means of evaluating the UCC3981 in a typical application circuit. The UCC3981 is intended to perform the same tasks as the UCC3981 with the exception of providing the gate drive and control circuitry for the 5.5V preregulator. The preregulator function can be bypassed by providing 5.5V externally at VREG, removing Q1 and replacing C09 with a 0.1 $\mu$ F ceramic capacitor. In this case VFIL and VHUB should also be connected to the 5.5V supply providing DC bias for the 3.3V regulator and the gate drive for the internal 5V regulators.

#### TESTING PROCEDURE

1. Set all enable switches to the "off" position. SW1 switches 1-4 correspond to outputs ENA-D respectively. Switch 5 controls ENHUB.
2. Supply a minimum of 6V, maximum of 9V, from a 2A minimum supply to the VFIL banana jack. Apply a 5V, 500mA supply to the VHUB banana

jack. Connect grounds for both supplies to the demonstration kit ground. Ensure the maximum voltage of 9V is not exceeded on either the VFIL or VHUB pins.

3. Connect a voltmeter to the VREG output. The voltage should read approximately 5.5V.
4. Connect the voltmeter to the V5A output. The output voltage should read approximately 0V.
5. Set the enable switch (ENA) for V5A to the "on" position. The output voltage should read approximately 5V. The corresponding enable pin of the 10 position SIP should transition from a low to a high.
6. Repeat steps 4 and 5 for outputs V5B – V5D and the 3.3V output.
7. Apply variable resistive loads to all outputs. Increase the loads sequentially to approximately 500mA on the 5V outputs, and 100mA on the 3.3V output. The appropriate overcurrent flags on the 10 position SIP should transition from a high to a low as each output reaches its overcurrent condition. Reset each load to its nominal value after observing each output's overcurrent flag to prevent thermal problems with the device. The overcurrent flags would normally signal the USB controller of the overcurrent condition and the controller would shut down the appropriate output in an actual application. The overcurrent flags should return to a logic high once the load is reset to its nominal value.
8. Reset the enable switch for each output. The corresponding output voltages should read approximately 0V.
9. Power down the input supplies.

If the testing procedure is successfully completed the demonstration kit is verified to be functional and is ready for more rigorous and application specific evaluation to be performed.

*For more complete information, pin descriptions and specifications for the UCC3981 USB power controller IC, please refer to the UCC3981 data sheet or contact your Unitrode Field Applications Engineer.*





## Notes:

- 1) Absolute Maximum voltage for VHUB is 9.0V
- 2) Absolute Maximum voltage for VFIL is 9.0V
- 3) VHUB and VFIL can be connected together
- 4) Pregulator can be bypassed by providing 5.5V at VREG and VFIL, removing Q1 and replacing C09 with a 0.1 $\mu$ F Ceramic capacitor.

- 5) ENABLE and OVERCURRENT signals are pulled up to VHUB. 0 $\Omega$  jumpers R10 and R11 can be removed to wire pullups to a different voltage
- 6) Capacitors C04 through C10 can be replaced with size "D" Tantalum SMD capacitors.
- 7) Capacitor C01 can be replaced with size "B" Tantalum SMD capacitors.

Reference Designator	Description	Manufacturer	Part Number
R01-R09	10k, 5%, 1/8W, Metal Film Resistor		
R10, R11	0.0W, 5%, Jumper, Metal Film Resistor		
TB1	Pin Header, 10 position	Mill-Max	ED7210
SW1	DIP Switch, 5 Position, SPST	AMP	A5205
C01	4.7 $\mu$ F, 10V, Tantalum Capacitor		
C02, C03	0.01 $\mu$ F, Z5U, Ceramic Capacitor		
C04-C08	150 $\mu$ F, 6.3V, Electrolytic Capacitor		
C09, C10	100 $\mu$ F, 10V, Electrolytic Capacitor		
J01-J10	Binding Post		
U1	USB Power Controller IC	Unitrode	UCC3981
Q1	60V, 17A, N-Channel MOSFET	International Rectifier	IRFZ24

**Table 1. UCC3981 evaluation board list of materials.**

Note: UCC3981 is also the UCC3831. UCC39811 was formerly UCC38531.

**Design Note**
**UCC3918 “Low On-Resistance Hot Swap Power Manager”, Evaluation Board, Schematic, and List of Materials**
**By Dave Olson**
**INTRODUCTION**

The UCC3918 evaluation kit allows the designer to evaluate the performance of the UCC3918 Low On-Resistance Hot Swap Power Manager in a typical application circuit. The schematic for the evaluation kit is shown in Figure 1.

**FEATURES**

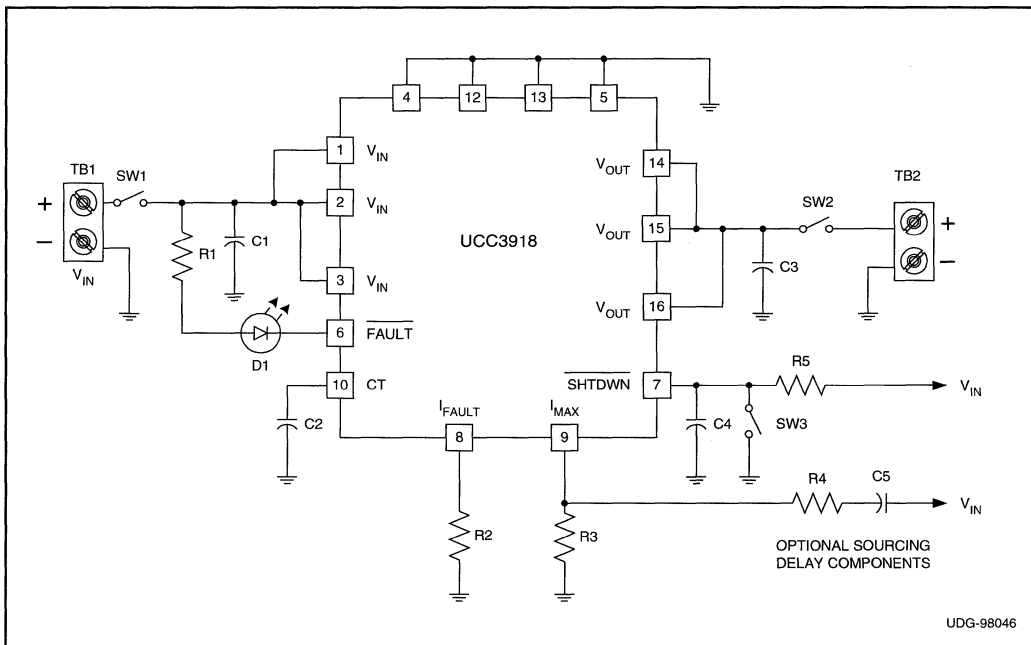
- Integrated 0.06Ω Power MOSFET
- 3V to 6V Operation
- External Analog Control of Fault Current  
0A to 4A
- Independent Analog Control of Current Limit  
up to 5A
- Overload Protection
- 1μA ICC when Disabled
- Programmable On Time
- Programmable Start Delay
- Fixed 3% Duty Cycle During Fault Conditions

**ABSOLUTE MAXIMUM RATINGS**

Input Supply Voltage	8V
SOIC Power Dissipation	2.5W
Fault Output Sink Current	50mA
Fault Output Voltage	$V_{IN}$
Output Current (DC)	Internally Limited
TTL Input Voltage	-0.3V to $V_{IN}$

**Functions of SW1, SW2 and SW3**

SW1 and SW2 provide the designer with the flexibility of evaluating the performance of the UCC3918 when residing on either the system backplane or on an adapter card. Closing SW1 after SW2 simulates an application where the UCC3918 resides on a plug-in adapter card. Closing SW1 prior to SW2 simulates an application where the UCC3918 resides on the system backplane. SW3 provides a shutdown input to disable the IC.


**Figure 1. UCC3918 Evaluation Board Schematic**

### Calculating Maximum Sourcing Current (I<sub>MAX</sub>)

The maximum sourcing current is programmed by selection of R3, connected from pin 9 (I<sub>MAX</sub>) to GND. R3 can be calculated as:

$$R3 = \frac{126k}{I_{MAX}} \Omega \quad (1)$$

For the UCC3918 evaluation kit R3 is set to 42.2kΩ for I<sub>MAX</sub> = 3A typical. Please refer to the UCC3918 data sheet for further discussion of I<sub>MAX</sub>.

### Calculating the Fault Current (I<sub>FAULT</sub>)

The I<sub>FAULT</sub> pin allows linear programming of the fault level current from 0 to 5A. When operating below the fault current the internal FET will be fully enhanced providing low on resistance. When output currents exceed I<sub>FAULT</sub> the output remains on but the fault timer starts charging CT. R2 sets the current fault level. R2 can be calculated as:

$$R2 = \frac{105k}{I_{FAULT}} \Omega \quad (2)$$

For the UCC3918 evaluation kit R2 is set to 52.3kΩ for I<sub>FAULT</sub> = 2A typical.

### Calculating the Fault and Shutdown Times

The UCC3918 evaluation kit incorporates a 0.1μF timing capacitor, C2 (CT) to set the fault time. The fault and shutdown times can be found by using the following equations.

$$T_{FAULT} = 27.8k \cdot C2 \quad (3)$$

$$T_{SHUTDOWN} = 0.833 \times 10^6 \cdot C2 \quad (4)$$

Where C2 is in Farads and T is in Seconds.

For the evaluation board T<sub>FAULT</sub> = 2.78mSec and T<sub>SHUTDOWN</sub> = 83.3mSec.

### Estimating Maximum Load Capacitance

The maximum load capacitance that can be charged depends on several factors; the nature of the load (constant current or resistive), the maximum sourcing current, and the allowed fault time.

For a constant current load, the maximum capacitance can be estimated from:

$$C_{OUT} = (I_{MAX} - I_{LOAD}) \cdot \left[ \frac{27.8 \times 10^3 \cdot C2}{V_{OUT}} \right] \text{ Farads} \quad (5)$$

For a resistive load of value RL, C<sub>OUT</sub> can be estimated from:

$$C_{OUT} = \frac{27.8 \times 10^3 \cdot C2}{RL \cdot \ln \left[ \frac{1}{1 - \frac{V_{OUT}}{I_{MAX} \cdot RL}} \right]} \text{ Farads} \quad (6)$$

## SAFETY RECOMMENDATIONS

Although the UCC3918 is designed to provide system protection for all fault conditions, all integrated circuits can ultimately fail short. For this reason, if the UCC3918 is intended for use in safety critical applications where UL or some other safety agency rating is required, a redundant safety device such as a fuse should be placed in series with the power MOSFET device. The UCC3918 will prevent the fuse from blowing for virtually all fault conditions, increasing system reliability and reducing maintenance cost, in addition to providing the hot swap benefits of the device.

**Note:** Capacitor C1 is located on the component side of the input switch and will contribute to the inrush current.

For more complete information, pin descriptions and specifications for the UCC3918 Low On-Resistance Hot Swap Power Manager, please refer to the UCC3918 data sheet or contact your Unitrode Field Applications Engineer at (603) 424-2410.

Reference Designator	Description	Manufacturer	Part Number
C1	22 $\mu$ F, 25V Tantalum Capacitor	Sprague	199D226X0025DA1
C2	0.1 $\mu$ F, 50V Ceramic Capacitor		
C3	22 $\mu$ F, 25V Tantalum Capacitor	Sprague	199D226X0025DA1
C4	Not Populated		
C5	Not Populated		
D1	LED		
R1	300 $\Omega$ , 0.25W Resistor		
R2	52.3k $\Omega$ , 0.25W Resistor		
R3	42.2k $\Omega$ , 0.25W Resistor		
R4	Not Populated		
R5	10k $\Omega$ , 0.25W Resistor		
SW1	Slide Switch		
SW2	Slide Switch		
SW3	Dip Switch		
TB1	Terminal Block		
TB2	Terminal Block		
U1	Low On-Resistance Hot Swap Power Manager	Unitrode	UCC3918

**Table 1. UCC3918 Evaluation board list of materials.**



# Design Note

## UCC3919 Hot Swap Power Manager Evaluation Circuit and List of Materials

By Robert B. Diener

### INTRODUCTION

The UCC3919 evaluation board is designed to allow the user to fully test the capabilities of the UCC3919 Hot Swap Power Manager. Over-current protection circuitry can be added to either a plug in adapter card that is being hot swapped or to the backplane circuit itself. This circuit can be used to test the capabilities of the UCC3919 Hot Swap Power Manager for either application.

### EVALUATION BOARD FEATURES

- 3V to 8V operation
- Fault current threshold of 5A
- Maximum output current of 7A during fault
- Overload shutdown (Electronic Circuit Breaker)
- On-board fault indicator
- On-board N-channel MOSFET with 0.011Ω  $R_{DS(on)}$

- On-board 0.01Ω, 1W sense resistor
- Choice of manual or automatic reset modes
- Choice of 3% duty cycle current limiting or average power limiting during fault
- Shutdown function
- Optional provision for soft-start delay

### CONTROL SWITCHES

The UCC3919 Hot Swap Power Manager Evaluation Circuit has several switches enabling the user to evaluate its operation in different configurations.

SW1 and SW2 can be used to mimic the connections between a back plane and a plug in adapter card. The order of operation for these switches will determine whether the protection circuitry is located on the plug in adapter card or on the backplane. By closing SW1 prior to SW2, the circuit will

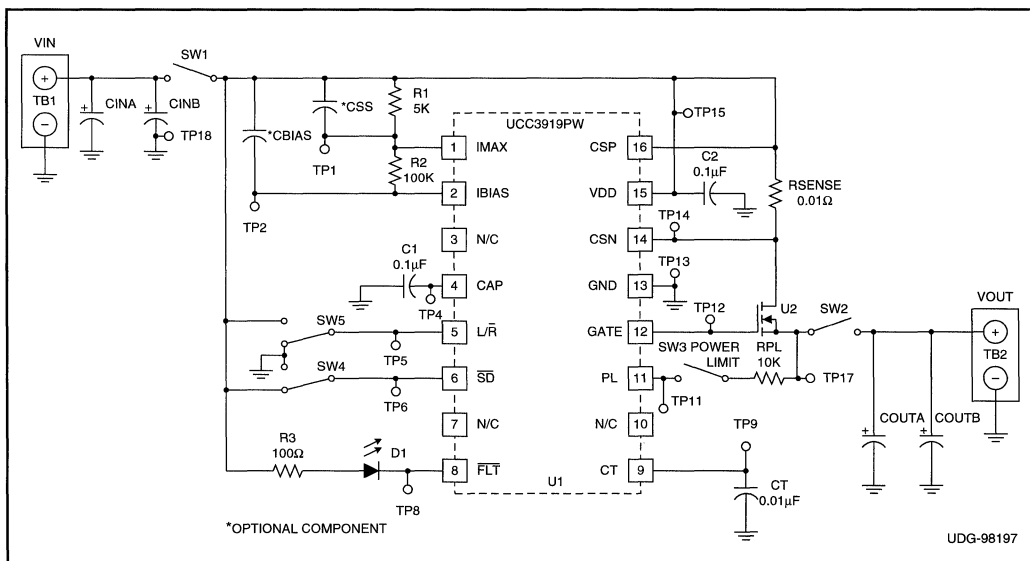


Figure 1. Schematic diagram.

simulate a situation where the protection circuitry is located on the back plane. Closing SW2 prior to SW1 simulates a situation where the protection circuitry is located on the adapter card that is being hot swapped.

SW3 controls the Power Limit function. In the PLIM position, the PL pin is connected to the output via a 10k resistor. During a fault condition, as the input voltage is increased the duty cycle will decrease and the average power will be held relatively constant. In the HCCP position, a fault condition will cause the output to be limited to a 3% duty cycle independent of input voltage.

SW4 controls the shutdown pin. In the SD position the UCC3919 will be put into a low current standby mode and the external MOSFET will be turned off.

SW5 controls the L/R pin. While in the LATCH position, a detection of a fault condition will cause the external MOSFET to be turned off and remain off until SW5 is set to the RESET position or the power is cycled. With SW5 in the RESET position, a fault condition will cause the circuit to be in hiccup mode until the output current falls below  $I_{FAULT}$ .

## CURRENT THRESHOLDS

$I_{FAULT}$  is the output current threshold that starts the fault timer. For this circuit,  $I_{FAULT}$  has been set to 5A. The fault timer will run until either the output current falls below  $I_{FAULT}$  or until it times out. If the fault timer times out, the external MOSFET will turn off and the circuit will enter a fault condition.

$I_{MAX}$  is the maximum output current the circuit will supply. For this circuit  $I_{MAX}$  has been set to 7A. During a fault, if SW5 is in RESET mode the output will be duty cycle limited and the current supplied during  $T_{ON}$  will be limited to  $I_{MAX}$ . If  $I_{MAX}$  is set below  $I_{FAULT}$ , the external MOSFET will be in a high power dissipation mode limiting the output current to  $I_{MAX}$  and the circuit will never enter a fault condition.

$I_{OVERLOAD}$  is the threshold that will activate the circuit breaker function. For this circuit  $I_{OVERLOAD}$  has been set to 27A. This threshold could be reached if the circuit is already powered up and a heavy load or a direct short is applied to the output. In this case the overload comparator will take over, the external MOSFET will turn off immediately, and the fault timer will be started.

## OPERATION

### Fault Timer

During normal operation the external MOSFET is fully on and current is supplied to the output. If the output current rises above  $I_{FAULT}$ , the fault timer will be started.  $I_{FAULT}$  is calculated as:

$$I_{FAULT} = \frac{0.05V}{R_{SENSE}} \quad (1)$$

The fault timer is controlled by the CT capacitor. When the fault timer is started, the CT capacitor will charge up to 1.5V as long as the output current is above  $I_{FAULT}$ . If the voltage across CT reaches 1.5V the external MOSFET will turn off and the circuit will enter a fault condition. The time required for CT to charge from 0V to 1.5V is referred to as  $T_{ON(INIT)}$ . With SW3 in the HCCP position,  $T_{ON(INIT)}$  for this circuit is approximately 430 $\mu$ s.  $T_{ON(INIT)}$  is calculated as:

$$T_{ON(INIT)}(\text{sec}) = \frac{CT(\mu F) \cdot 1.5}{35\mu A + I_{PL}} \quad (2)$$

If SW5 is in the LATCH position, the output will stay off until switched back to RESET or the power is cycled. If SW5 is in the RESET position the CT capacitor will then discharge to 0.5V at which point the external MOSFET will turn back on. If the output current is above  $I_{FAULT}$ , the process will repeat with the external MOSFET on during the charge time of the CT capacitor and the external MOSFET off during the discharge time of the CT capacitor. The charge and discharge times are referred to as  $T_{ON}$  and  $T_{OFF}$  respectively. With SW3 in the HCCP position,  $T_{ON}$  and  $T_{OFF}$  are calculated as:

$$T_{ON}(\text{sec}) = \frac{CT(\mu F)}{35\mu A + I_{PL}} \quad (3)$$

$$T_{OFF}(\text{sec}) = \frac{CT(\mu F)}{1.2\mu A} \quad (4)$$

$I_{PL}$  will be zero if SW3 is set to HCCP. If the circuit enters a fault condition with SW3 set to HCCP, the output current will be duty cycle limited to 3%. For this circuit,  $T_{ON} = 280\mu$ s and  $T_{OFF} = 8.3$ ms.

If the circuit is in fault and SW3 is set to PLIM the circuit will be in the power limit mode. In this mode  $I_{PL}$  is calculated as:

$$I_{PL} = \frac{V_{IN} - V_{OUT} - V_{PL}}{R_{PL}} \quad (5)$$



$V_{PL}$  is measured with respect to the CSP pin as listed in the UCC3919 data sheet.

While in power limit mode, as the input voltage is increased, the duty cycle of the output will decrease, thus keeping the power dissipation relatively constant. For this circuit, with  $V_{IN}=5V$  and the output shorted,  $I_{PL}$  will be approximately  $320\mu A$ . The circuit will have  $T_{ON}=25\mu s$  for an average power dissipation of approximately  $68mW$ . If the input voltage is raised to  $8V$ ,  $T_{ON}$  will decrease to  $14\mu s$  and the average power dissipation will be approximately  $57mW$ .  $T_{OFF}$  will remain the same independent of SW3.

### Timing Capacitor

The CT capacitor must be selected to ensure that the UCC3919 will not enter fault mode during the initial start-up or when recovering from a fault in the hiccup mode. The selection of CT is dependent upon the type of load and the size of the load capacitor. If CT is too small or  $C_{OUT}$  is too large, the CT capacitor will charge up to  $1.5V$  and the circuit will enter a fault mode before  $C_{OUT}$  is allowed to fully charge. Refer to the UCC3919 data sheet when changing the value of the CT capacitor.

For this circuit, the CT capacitor has been selected to be  $0.01\mu F$ . When operating in the hiccup mode with a duty cycle of 3%,  $C_{OUT} (MAX)$  is shown in Equation (6).

where  $I_{CH}$ , the charging current of the CT capacitor is approximately  $35\mu A$ . With  $V_{IN}=5V$  and an output current of  $3.3A$ , the maximum value for  $C_{OUT}$  is approximately  $290\mu F$ .

When operating in the power limit mode, the maximum value for  $C_{OUT}$  can be calculated in Equation (7).

With  $V_{IN}=5V$  and an output current of  $3.3A$ , the maximum value of  $C_{OUT}$  is approximately  $71\mu F$ .

### $I_{MAX}$

Once the output current has risen above  $I_{FAULT}$ , the internal linear amplifier will limit this current to a maximum of  $I_{MAX}$ .  $I_{MAX}$  is determined as:

$$I_{MAX} = \frac{1.5V \cdot R1}{(R1 + R2) \cdot R_{SENSE}} \quad (8)$$

If  $I_{MAX}$  is set to a level lower than  $I_{FAULT}$ , the UCC3919 will limit the output current to a maximum of  $I_{MAX}$ , while never entering a fault condition. This leaves the external MOSFET in a high power dissipation region.

### $I_{OVERLOAD}$

With the circuit powered up, a heavy load or a direct short suddenly applied to the output will cause the output current to spike. If this current reaches  $I_{OVERLOAD}$ , the external MOSFET will immediately turn off and the fault timer will start.  $I_{OVERLOAD}$  is calculated as:

$$I_{OVERLOAD} = I_{MAX} + \frac{0.2V}{R_{SENSE}} \quad (9)$$

This condition occurs only if SW2 is closed after SW1. For cases where SW2 is closed before SW1, an optional capacitor, CSS can be added to the circuit to provide for a soft start. In this case CSS will limit the slew rate of the output current.

If the circuit is operating in a noisy environment, an optional capacitor, CBIAS can be added to bypass the internal  $1.5V$  bias generator. CBIAS should be limited to a maximum of  $0.001\mu F$ .

$$C_{OUT} (MAX) = \frac{CT}{I_{CH} \cdot RL \cdot \ell \eta \left( 1 - \frac{V_{IN}}{I_{MAX} \cdot RL} \right)} \quad (6)$$

$$C_{OUT} (MAX) = \frac{CT}{\left[ \frac{(V_{IN} - V_{PL})^2}{2 \cdot R_{PL} \cdot V_{IN}} + I_{CH} \right] \cdot \left[ -RL \cdot \ell \eta \left( 1 - \frac{V_{IN}}{I_{MAX} \cdot RL} \right) \right]} \quad (7)$$



Table I: List of Materials

Designator	Description	Manufacturer/Dist.	Part Number
C1, C2	0.1 $\mu$ F, Ceramic capacitor, 1206 SMD	Digikey	PCC104BCT-ND
CBIAS	*optional		
CINA, CINB	100 $\mu$ F, 16V, Tantalum capacitor, 7343 SMD	AVX	TAJD107M016
COUTA	10 $\mu$ F, 20V, Tantalum capacitor, 3528 SMD	AVX	TAJB106K020
COUtb	*optional		
CSS	*optional		
CT	0.01 $\mu$ F, Ceramic capacitor, 1206 SMD	Digikey	PCC103BCT-ND
D1	LED, red, 1206 SMD	Digikey	LU60351CT-ND
R1	5k, Metal film resistor, 1206 SMD	Digikey	P4.99KFCT-ND
R2	100k, Metal film resistor, 1206 SMD	Digikey	P100KFCT-ND
R3	150 $\Omega$ , Metal film resistor, 1206 SMD	Digikey	P150FCT-ND
RPL	10k, Metal film resistor, 1206 SMD	Digikey	P10.0KFCT-ND
RSense	0.01 $\Omega$ , 1W, Metal film resistor, 2512 SMD	IRC	LR2512-01-FTR
SW1, SW2	Right. angle, SPDT slide switch	Digikey	CKN5006
SW3, SW4, SW5	Miniature SPDT slide switch	Newark	52F516 switch
TB1, TB2	Terminal block	Mouser	506-2SV-02
U1	Hot Swap Power Manager	Unitrode	UCC3919PW
U2	N-channel MOSFET	International Rectifier	IRF7413

## SAFETY RECOMMENDATIONS

The UCC3919 is designed to provide protection against over current situations, but since semiconductors can ultimately fail short, this circuit may require a fuse or electro-mechanical circuit breaker in series as back-up protection.

For complete details about the operation of the UCC3919 Hot Swap Power Manager, please refer to the UCC3919 Data Sheet and UCC3919 Hot Swap Power Manager Application Note.



Design Note

**UCC3917 Positive Floating Hot Swap Power Manager Evaluation Kit, Schematic and List of Materials**

By Dave Olson

**INTRODUCTION**

The UCC3917 evaluation kit allows the designer to evaluate the performance of the UCC3917 Positive Floating Hot Swap Power Manager (HSPM) in a typical application setting. Component selection for the UCC3917 Evaluation Kit is for operation at 28Vdc, 1A. Operation at other voltages/currents may be accomplished by proper component selection and replacement. The schematic for the evaluation kit is shown in Fig. 1. The Bill of Materials with component ratings is specified in Table 1.

**UCC3917 Features**

- Programmable Linear Current Control
- Programmable Overcurrent Limit
- Precision Fault Threshold
- Internal Charge Pump for Driving External NMOS Device
- Programmable Average Power Limiting
- Fault Output
- Programmable Fault Mode - Latch or Retry
- Programmable Fault Timer
- Shutdown Control
- Undervoltage Lockout
- No maximum voltage limitation

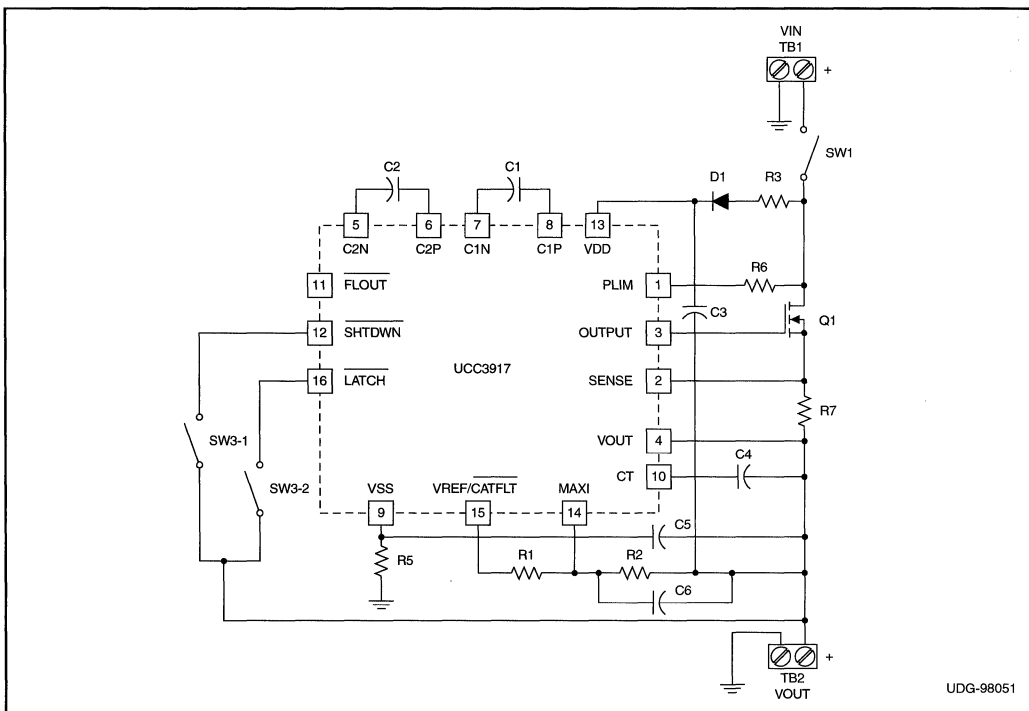


Figure 1. UCC3917 evaluation kit schematic 28V/1A.

### Switch Functions

**SW1:** Switch SW1 allows the designer to evaluate the performance of the UCC3917 when residing on an adapter card. Closing SW1 after input power is applied to the board simulates hot insertion into a backplane.

**SW2:** Omitted

**SW3:** Switch SW3-1 controls the SHTDWN pin of the UCC3917. In the OFF position, the switch pulls the SHTDWN pin to VOUT. In the ON position, the SHTDWN pin is left open. SW3-2 is used to program the fault-handling mode of the UCC3917. In the OFF position, the LATCH pin will be pulled low to VOUT, placing the UCC3917 in the latch mode of operation during a fault. In the ON position, SW3-2 allows LATCH to float high, thus putting the UCC3917 in the hiccup mode during a fault condition.

### Programming the Maximum Sourcing Current Pin, MAXI

The maximum sourcing current level, the current level at which the output looks like a constant current source, is equal to the voltage at the MAXI pin divided by the sense resistor R7. MAXI is derived using a voltage divider from the internally regulated voltage  $V_{REF}/CATFLT$  to VOUT. If desired, placing a capacitor on MAXI with respect to VOUT can program a controlled current slew rate (soft start). The evaluation kit is designed for a maximum sourcing current of 2A. Please see the Bill of Materials for respective resistor values. There is also a spare footprint for an optional soft start capacitor. The maximum sourcing capability is defined by:

$$I_{MAX} = \frac{V_{MAXI}}{R7} \quad (1)$$

where

$I_{MAX}$  = maximum sourcing current desired (A)

R7 = sense resistor ( $\Omega$ )

$V_{MAXI}$  = voltage at MAXI with respect to VOUT (V)

The voltage at MAXI with respect to VOUT is defined by:

$$V_{MAXI} = \frac{R2}{R2 + R1} \cdot V_{REF} \quad (2)$$

where

$V_{REF}$  = Regulated voltage at  $V_{REF}/CATFLT$  (V)

R1 = Resistance from  $V_{REF}/CATFLT$  to MAXI ( $\Omega$ )

R2 = Resistance from MAXI to VOUT ( $\Omega$ )

### Programming the Fault Timer

The fault timer starts when the load current increases beyond the fault current,  $I_{FAULT}$ , threshold. The  $I_{FAULT}$  threshold is defined as:

$$I_{FAULT} = \frac{50mV}{R7} \quad (3)$$

where

$I_{FAULT}$  = The fault current threshold (A)

R7 = The sense resistor value ( $\Omega$ )

The fault current threshold for the UCC3917 evaluation board is set for 1A (R7 = 0.05 $\Omega$ ). Once the load current increases beyond the fault current threshold, the fault timer starts. The fault timer consists of an internal constant current source charging an external cap C4. Once the voltage on C4 reaches the 2.5V, an internal comparator trips and signals a fault condition. The gate drive to the external FET is disabled and the IC either latches off or enters its hiccup mode of operation (refer to the Switch Functions section for more details on programming latch mode versus hiccup mode). The internal current source charges C4 at a nominal rate of 50 $\mu$ A. C4 must be selected to allow enough time for the output capacitance to charge. The fault time, the time required to charge C4 to the fault comparator's threshold, is defined as:

$$T_{FAULT} = \frac{C4 \cdot \Delta V}{I_{CH}} \quad (4)$$

where

$T_{FAULT}$  = time required to charge C4 to the fault threshold (sec)

C4 = the external capacitor on the CT pin (F)

$\Delta V$  = the fault comparator threshold (2.5V for latch mode; 2.0V for hiccup mode)

$I_{CH}$  = internal charge current (A)



The rate at which the total output capacitance can be charged is dependent on the maximum output current available and the nature of the load. The fault time,  $T_{FAULT}$ , must be greater than the time required to charge any load capacitance. Please refer to the UCC3917 data sheet, *Selecting Minimum Timing Capacitance*, for more detailed information.

### **Programming the Average Power Dissipation of the External FET, PLIM**

During the hiccup mode of operation, mentioned in the previous section on programming the fault timer, it is necessary to limit the average power dissipated in the external MOSFET. The hiccup mode of operation typically retries the output at a 3% duty cycle. The MOSFET will be turned on for the duration of the programmed fault time and if the fault is still present will shut down for an extended period of time. The duty cycle is defined as:

$$DutyCycle = \frac{1.5\mu A}{I_{PL} + 50\mu A} \quad (5)$$

where,

$50\mu A$  = CT charging current

$1.5\mu A$  = CT discharge current

$I_{PL}$  = charge current provided by R6 (A)

Under normal operation  $I_{PL}=0$ , however, even operation at 3% duty cycle can result in substantial power dissipation in the external MOSFET. The power dissipated in the MOSFET is defined as:

$$P_{DISS} = V_{FET} \cdot I_{MAX} \cdot DutyCycle \quad W \quad (6)$$

where

$V_{FET}$  = the voltage across the FET, VINV-OUT, (V)

$I_{MAX}$  = the maximum sourcing current (A)

DutyCycle = operating duty cycle

The average power dissipation in the FET when incorporating the power limit function is defined as:

$$P_{FET(avg)} = I_{MAX} \cdot 1.5\mu A \cdot R6 \quad W \quad (7)$$

or solving for R6,

$$R6 = \frac{P_{FET(avg)}}{I_{MAX} \cdot 1.5\mu A} \quad \Omega \quad (8)$$

The UCC3917 evaluation board is populated with  $R6=200K$ . The average power dissipated in the FET,  $P_{FET(avg)}$ , during a fault condition should be  $\sim 0.3W$ . Please refer to the UCC3917 for more detailed information on R6 and controlling  $P_{FET(avg)}$ .

### **Selection Criteria for Other External Components**

Because the UCC3917 derives its own operating voltage through a charge pump supplied by  $IDD$ , it is necessary for  $IDD$  to provide  $\sim 5mA$  of current to keep the charge pump operating. During startup, this current will be provided by input ( $V_{IN}$ ) through R3, but once the IC is up and running on its own,  $IDD$  is supplied by the output ( $V_{OUT}$ ). The current is returned through R5. Therefore, R3 and R5 can be determined by:

$$R3 = \frac{V_{IN} - 10V}{5mA} \quad \Omega \quad (9)$$

$$R5 = \frac{V_{IN} - 5V}{5mA} \quad \Omega \quad (10)$$

For applications that require wide input ranges it may be difficult to size R3 and R5 to provide adequate current over the whole operating range. For the wide input ranges, R3 and R5 can be replaced with constant current regulator diodes (1N5314).

**Please Note:  $IDD$  should not be allowed to exceed 10mA.**

**External Input Capacitors:** Excess source impedance may adversely affect operation of the Linear Current Amplifier control loop, resulting in oscillation when operating at the maximum sourcing current. Decoupling the evaluation board's input from the source impedance using low ESR tantalum or aluminum electrolytic capacitors can eliminate this oscillation. The capacitors should be placed at the input connector of the board.

**Table 1. UCC3917 evaluation kit bill of materials.**

Designator	Description	Part Value	Manufacturer	Part Number
C1, C2, C3, C5	X7R, Ceramic, 1206	0.1 $\mu$ F	Panasonic/Digi-Key	PCC104BCT-ND
C4	Tantalum, 50V, Case E/1206	1.0 $\mu$ F	Sprague	194D105X0050E2
C6	Case E/1206 Dual Footprint			Provisional
D1	100V, 1A, Rectifier		Digi-Key	DL4002DICT-ND
Q1	IRF530NS		IR/Newark	IRF530NS
R1	0.1W, 1%, 0805	100k $\Omega$	Panasonic/Digi-key	P100KDCT-ND
R2	0.1W, 1%, 0805	2.0k $\Omega$	Panasonic/Digi-key	P2.0KDCT-ND
R3	0.25W, 5%, 1210	3.6k $\Omega$	Panasonic/Digi-key	P3.6KVCT-ND
R5	0.25W, 5%, 1210	4.7k $\Omega$	Panasonic/Digi-key	P4.7KVCT-ND
R6	0.1W, 1%, 0805	200k $\Omega$	Panasonic/Digi-key	P200KDCT-ND
R7	1W, 1%, 2512	0.05 $\Omega$	Dale/Newark	01F1551
SW1	Slide Switch	28Vdc, 3A	C&K/Digi-key	CKN5006-ND
SW3	Dip Switch, 2 pos		C&K/Digi-key	CKN3001-ND
TB1,TB2	Terminal Block, 2 pole		AUGAT/RDI /Mouser	506-2SV-02
U1	HSPM, SOIC-16		Unitrode	UCC3917D

### **Safety Considerations**

Although the UCC3917 is designed to provide system protection for all fault conditions, all integrated circuits can ultimately fail short. For this reason, if the UCC3917 is intended for use in safety critical applications where UL or some other safety agency requires a redundant safety device such as

a fuse, it should be placed in series with the power MOSFET device. In addition to providing the hot swap benefits of the device, the UCC3917 will prevent the fuse from blowing for virtually all fault conditions increasing system reliability and reducing maintenance cost.

For further information, consult the UCC3917 Data Sheet or contact a local Unitrode Representative or Field Applications Engineer at (603) 424-2410.

**UCC3912 INTEGRATED ELECTRONIC CIRCUIT BREAKER IC FOR HOT-SWAP AND POWER MANAGEMENT APPLICATIONS**

by Dave Zendzian  
Applications Engineer

**ABSTRACT**

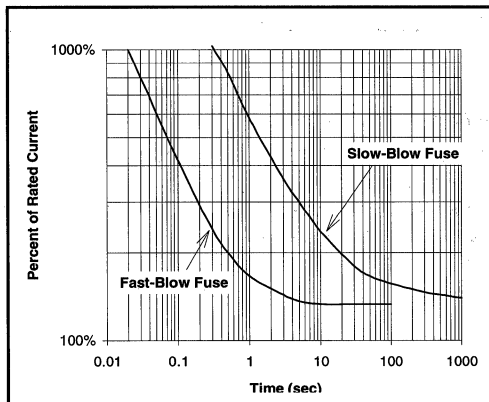
*This application note describes the design and performance characteristics of the UCC3912 Electronic Circuit Breaker. The practical aspects of applying the circuit breaker are discussed as well as its performance compared to existing technologies. The UCC3912 integrates a power MOSFET with all of the necessary control and housekeeping functions including current limiting, short circuit protection, and auto recovery capabilities. The performance of the circuit breaker is compared to PolySwitches® and conventional fuses in both hot swap and short circuit applications.*

**INTRODUCTION**

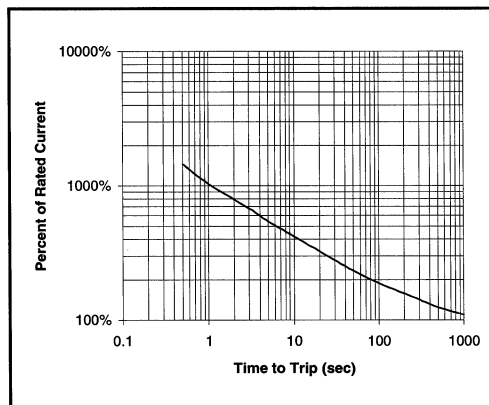
Today's design engineers are faced with a variety of choices when selecting protection devices to meet their circuit or system's design requirements. Fuses, positive temperature coefficient (PTC) resistors, and electromechanical circuit breakers represent only a sampling of the technologies available to meet their needs. Each of these devices provides a different degree of security, ranging from simple short circuit protection to devices which offer active current limiting and remotely resettable operation.

Fuses, while providing an inexpensive solution, fall short of many of the protection requirements imposed on modern electronic equipment. Figure 1 illustrates the protection capability of two general fuse categories; fast-acting and slow-blow. Although both devices provide gross short circuit protection, even the fastest devices react on the order of milliseconds, passing currents up to 500% of their rated value. In addition, fuses, by their very nature, have to be physically replaced following an overload condition. This increases the equipment's down time along with the chance of an incorrect device being installed, thereby reducing overall system reliability.

PTC resistors, on the other hand, eliminate the need for human intervention by providing resettable overcurrent protection. However, because they are actuated by the heating effect of an overcurrent load, their reaction time is limited to several milliseconds. This results in output currents several times their steady state rating. Figure 2 illustrates typical "time to trip" data for polymeric PTC resistors.



**Figure 1.** Relation of Percent of Rated Current to Fuse Blowing Time.



**Figure 2.** Relation of Percent of Rated Current to Blowing Time.

The UCC3912 Electronic Circuit Breaker offers a new, integrated solution to the problem of circuit protection and power management. Each of the drawbacks associated with existing technologies are addressed in the UCC3912 design. In addition, the UCC3912 provides logic level load control for power management applications. This note describes the features and performance of the UCC3912 as compared to other available protection techniques. In particular, hot swap, power management, and short circuit protection applications are addressed in detail.

**HOT SWAPPING**

The term hot swap refers to the system requirement that submodules be swapped out upon failure or system modification without removing power to the hardware. Design of modern computer systems, disk arrays, network hubs and communication switches require modules to be hot swapped while maintaining the integrity of the powered and operating system. This requirement allows the hardware to maintain operation, increasing the system's performance and reliability.

Implementing the hot swap requirement imposes several design constraints upon the equipment's power system. In order for the hardware to maintain error free operation during the installation or removal of a submodule, the 5 volt power bus must not drop below a minimum voltage of 4.5V. Voltages below 4.5V can disrupt logic levels, causing an indeterminate number of failures including data corruption and logic lockups. This ultimately reduces system reliability and data integrity.

The potential for glitching the power bus exists whenever an unpowered module is inserted into an operational system. Virtually all modules possess some amount of onboard bus capacitance which serves to filter and maintain power quality once the board becomes operational. However, these very same capacitors require an initial charging current in order to bring their voltage up to the same level as the system's power supply. The only factors limiting the magnitude of this current is the equivalent series resistance (ESR) of the capacitors themselves and the impedance of the interconnect between the module and the rest of the system. Unfortunately, the better the capacitors are at serving their purpose of filtering the bus, the lower their ESR. As a result, the initial inrush current during the hot swap can become excessively high.

Figure 3 illustrates the inrush current and corresponding voltage glitch when a load of 2A and 120µF is switched onto a 5V power bus. The 120µF of load capacitance consisted of a solid tantalum, surface mount style capacitor (Sprague #595D127X9020R2T) with a typical ESR of 0.25Ω at 100kHz. The power bus was bypassed with 240µF of the same style capacitor. As the figure illustrates, the inrush current reaches a maximum value of approximately 27A, resulting in a 1V glitch on the power bus. This exceeds the 4.5V limit by 500mV causing the supply to drop to 4.0V! In addition to causing the voltage glitch, the excessive inrush current can also result in arcing between connector pins and excessive heating of the load capacitance. Each of these effects shortens the life of the component, ultimately reducing system reliability.

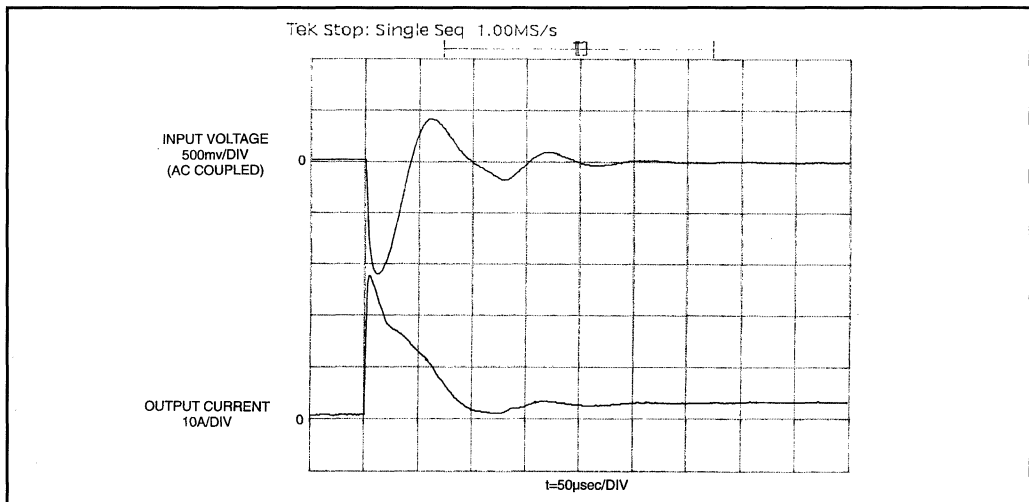


Figure 3. Inrush Current and Corresponding Voltage Glitch for a 2A, 120µF Load.

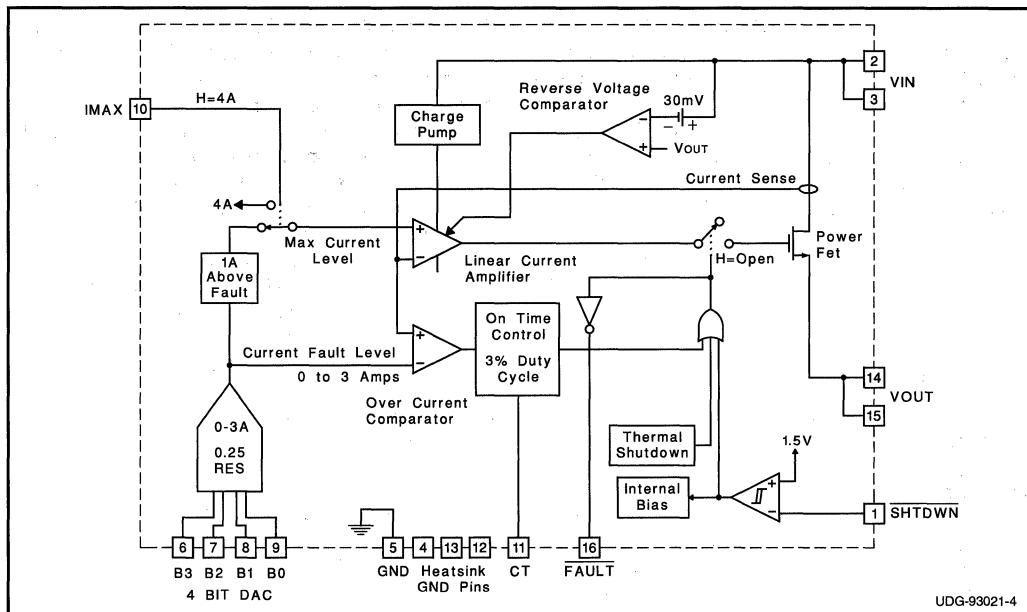


Figure 4. UCC3912 Electronic Circuit Breaker Block Diagram

### THE UCC3912 ELECTRONIC CIRCUIT BREAKER

In its most rudimentary form, a circuit breaker, whether electromechanical or electronic, protects a circuit from excessive current flow. Electromechanical devices accomplish this by opening a set of contacts when the current exceeds a specified level. These types of breakers usually latch off during a fault and therefore need to be manually reset once the current falls below a reasonable value. An electronic circuit breaker, on the other hand, provides protection through the use of a power transistor. By monitoring the output current through a current shunt, the transistor can be biased "on" or "off" based upon whether or not a predetermined trip current has been exceeded.

The UCC3912 is an electronic circuit breaker IC designed to provide power management and hot swap capability in addition to its basic circuit breaker function. Performance features of the UCC3912 include:

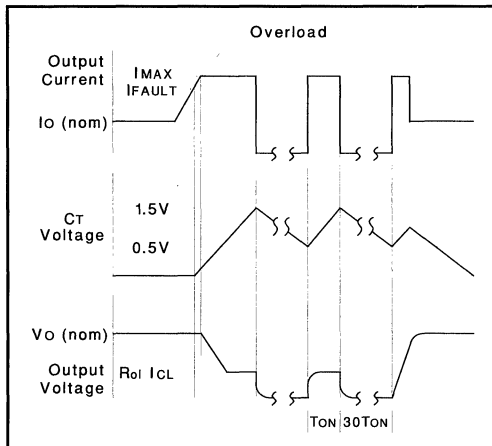
- Integrated 0.15Ω power MOSFET
- Switchmode short circuit protection
- Automatic short circuit recovery
- Digitally programmable 4-bit maximum current limit
- Unidirectional current flow
- SMT power package
- Fault indicator output

- Low power "sleep" mode
- Thermal shutdown
- Low part count implementation

The block diagram of the UCC3912 is shown in Figure 4. Under normal operating conditions the integrated N-channel MOSFET is biased "on" using the internal charge pump to drive the gate. Output current is sensed using a mirrored MOSFET and is compared to an adjustable trip level set by the 4-bit DAC input. When the output current exceeds the trip level, the fault timer begins to charge the timing capacitor, CT, with a current of 36μA. If the output current does not fall below the trip level by the time the capacitor charges to 1.5V, the output is switched off and the capacitor is discharged with a current of 1.2μA. Once the capacitor's voltage has reached 500mV, the circuit breaker attempts to return power to the load. At this point the timer cycle will repeat as long as the fault is present, resulting in an output duty cycle of 3%.

Figure 5 illustrates the cyclical retry of the UCC3912 under fault conditions. Note that the initial fault time is longer than subsequent cycles due to the fact that the capacitor is completely discharged and must initially charge to the reset threshold of 0.5V. If at any time the output current reaches IMAX, the MOSFET transitions into linear mode, providing constant output current until the fault time expires. The discrete IMAX input is used to set the maximum output current to either a fixed





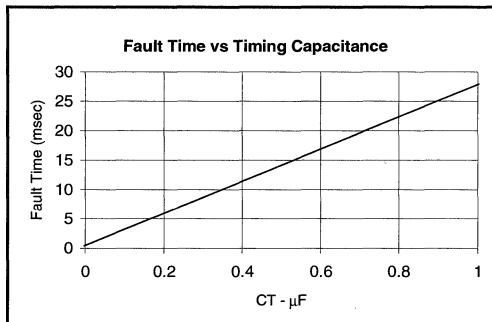
**Figure 5.** Load Current, Timing Capacitor Voltage and Output Voltage of the UCC3912 under Fault Conditions.

value of 4A, (logic level high), or to a value 1A above the trip current as set by the DAC inputs, (logic level low). The 4 bit DAC allows the fault current level to be programmed from 0 to 3A in 250mA increments.

Fault time duration is controlled by the value of the timing capacitor, CT, according to the following equation:

$$(1) \quad t_{\text{FAULT}} = CT \cdot \frac{\Delta v}{I} = CT \cdot \frac{1.5 - 0.5}{36E - 6} = 27.8E3 \cdot CT$$

Figure 6 provides a plot of fault time vs timing capacitance. The fault time duration is set based upon the load capacitance, load current, and the maximum output current. *The "on" or fault time must be of sufficient duration to charge the load capacitance during a normal startup sequence or when recovering from a fault.* If not, the charge accumulated on the output capacitance will be depleted by the load during the "off" time. The cycle



**Figure 6.** Fault Time vs Timing Capacitance

will then repeat, preventing the output from turning on.

To determine the minimum fault time, assume a maximum load current just less than the trip limit. This leaves the difference between the I<sub>MAX</sub> and I<sub>TRIP</sub> values as the current available to charge the output capacitance. The minimum required fault time can then be calculated as follows:

$$(2) \quad t_{\text{FAULTmin}} = \frac{C_{\text{OUT}} \cdot V_{\text{OUT}}}{I_{\text{MAX}} - I_{\text{TRIP}}}$$

The minimum timing capacitor can be calculated by substituting equation (1) for t<sub>FAULT</sub> in equation (2) and solving for CT.

$$(3) \quad C_{\text{Tmin}} = \frac{C_{\text{OUT}} \cdot V_{\text{OUT}}}{27.8E3 \cdot (I_{\text{MAX}} - I_{\text{TRIP}})}$$

In addition to the I<sub>MAX</sub> and DAC inputs, the UCC3912 provides a fault indicator output and shutdown command. The FAULT signal is an open drain output which is active low under any condition which turns the output MOSFET "off". These conditions include under voltage lockout (UVLO), over current faults, thermal shutdown, and active shutdown as commanded by the SHTDWN input. Note that FAULT is asserted (low) during power up while the UCC3912 is in a UVLO state.

The SHTDWN command is an active low input which turns the MOSFET "off" and puts the IC into sleep mode, reducing the quiescent current to less than 5μA. The shutdown command can be used to extend the life of battery powered systems by powering down subsystems when not in use.

Unidirectional current flow is another attractive feature of UCC3912. The reverse voltage comparator senses the output voltage and turns the MOSFET "off" whenever the output voltage is less than 30mV below the input. Under light loads, the UCC3912 regulates the voltage drop until

$$(4) \quad (I_{\text{OUT}}) \cdot (R_{\text{DSon}}) \geq 30\text{mV},$$

thus preventing false shutdowns. This effectively prevents current flow from output to input, eliminating the need for series diode protection and the associated voltage drop and power losses incurred with its use.

**PRACTICAL CONSIDERATIONS**

The UCC3912 is supplied in 16-pin power surface mount packages. Four ground leads are provided in order to effectively transfer heat out of the package. These pins should always be terminated to as large an area of copper as possible. Although the 3% duty cycle switchmode protection drastically minimizes power dissipation, thermal analysis

should still be performed in order to insure reliable circuit operation.

When interfacing with larger values of load capacitance, the UCC3912 fault time must be increased accordingly. While the average power remains low due to the 3% duty cycle, the power dissipation during the fault time will result in a junction temperature rise based on the thermal time constant of the system. A simplified thermal model of the system is comprised of the die, leadframe and PC board. However, for fault times less than 30msec, the effect of the leadframe and PC board can be considered negligible as their thermal time constants are on the order of 2 and 300sec respectively. A rough estimate of the transient junction temperature can then be calculated based on the following equation:

$$(5) \quad T_j(t) = P_{DISS} \left[ \Theta_{DIE} \left( 1 - e^{-t/\tau} \right) \right] + T_L$$

- Where  $P_{DISS}$  = transient power dissipation
- $\Theta_{DIE}$  = thermal resistivity between die and leadframe  $\approx 4^\circ/W$
- $t$  = fault time
- $\tau$  = thermal time constant of the die  $\approx 30msec$
- $T_L$  = steady state lead temperature

As the fault time is increased beyond 30msec, a more thorough transient thermal analysis is required. For additional information regarding thermal analysis and transient response, the reader is directed to reference (1).

In applications requiring minimum voltage losses, it is important to take the effects of PCB trace resistance into account. When passing two to three amps of current, minimum trace widths can result in enough  $I \cdot R$  voltage drop to effect system performance. By increasing either the trace width or copper weight, these effects can be made negligible. Table I provides resistance/inch values for various trace widths of 1, 1.5, and 2 oz. copper.

Table I PCB Trace Resistance (mΩ/inch)						
Copper Wt.	Trace Width (inches)					
	0.01	0.02	0.03	0.05	0.07	0.1
1.0 oz.	48.5	24.23	16.2	9.7	6.9	4.9
1.5 oz.	38.8	19.4	12.9	7.8	5.5	3.9
2.0 oz.	24	12	8	4.8	3.4	2.4

**A TYPICAL APPLICATION**

In order to evaluate the performance of the UCC3912, consider a typical application consisting of a 2A maximum load current in parallel with 120μF of load capacitance. The 2A output current

is accommodated by setting the UCC3912 trip current to 2.25A, using the DAC inputs. Bits B0 and B1 are grounded while bits B2 and B3 are tied to VIN. The maximum output current is configured to 1A above the trip current (3.25A) by grounding the I<sub>MAX</sub> input. The timing capacitor value must then be selected to accommodate the 120μF load capacitance:

$$(6) \quad C_{Tmin} = \frac{C_{OUT} \cdot V_{OUT}}{27.8E3 \cdot (I_{MAX} - I_{TRIP})}$$

$$= \frac{120E - 6 \cdot 5}{27.8E3 \cdot (3.25 - 2.25)} = 21.6nF$$

A 47nF capacitor was chosen in order to provide adequate margin for component and parameter tolerances. Lastly, the SHTDWN input to the UCC3912 is connected to VIN since it is not used in this example.

In actual hot swap applications, the circuit breaker function may reside on the system's backplane servicing one or more submodules, or be distributed throughout the individual submodules depending on system requirements. In order to test both of these application scenarios, a MOSFET was used to simulate a hot swap on the input and output of the UCC3912. A test load was constructed using a 120μF low ESR tantalum capacitor in parallel with a carbon power resistor, while 240μF was used to simulate the system's input bus capacitance. Output current was monitored using a noninductive 10mΩ current shunt in series with the load. Figure 7 illustrates the test setup including the UCC3912 circuit configuration.

**HOT SWAP PERFORMANCE**

Figure 8 illustrates the load current and input voltage waveforms, measured at points A and B in Figure 7, with and without the UCC3912. In Figure 8(a), transistor Q2 was used to perform the hot swap on the output of the UCC3912, simulating an application with the circuit breaker resident on the system backplane. In this situation the UCC3912 limits the load current to approximately 4A as compared to the 24A peak seen without the breaker! Consequently, the voltage glitch seen at the input bus capacitor is reduced from approximately 1V to less than 150mV!

Figure 8(b) illustrates the results when Q2 is used to simulate the hot swap on the input of the UCC3912. Again, the output current is controlled as both the circuit breaker and submodule receive power, providing very similar results to those of Figure 8(a).

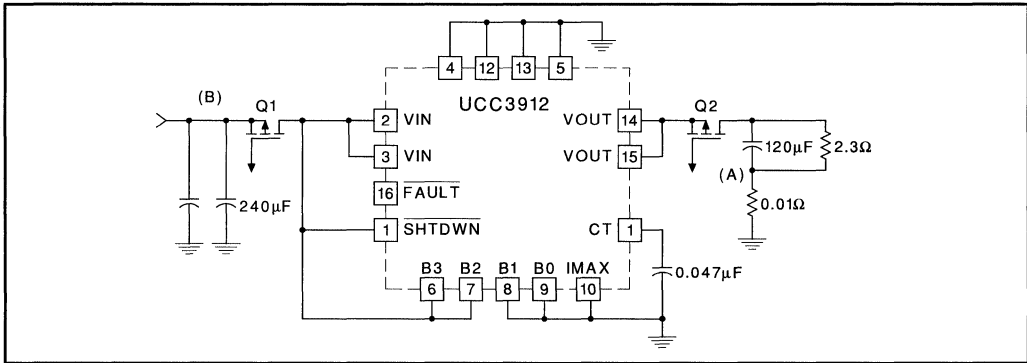


Figure 7. Typical UCC3912 Configuration and Hot Swap Test Circuit Setup.

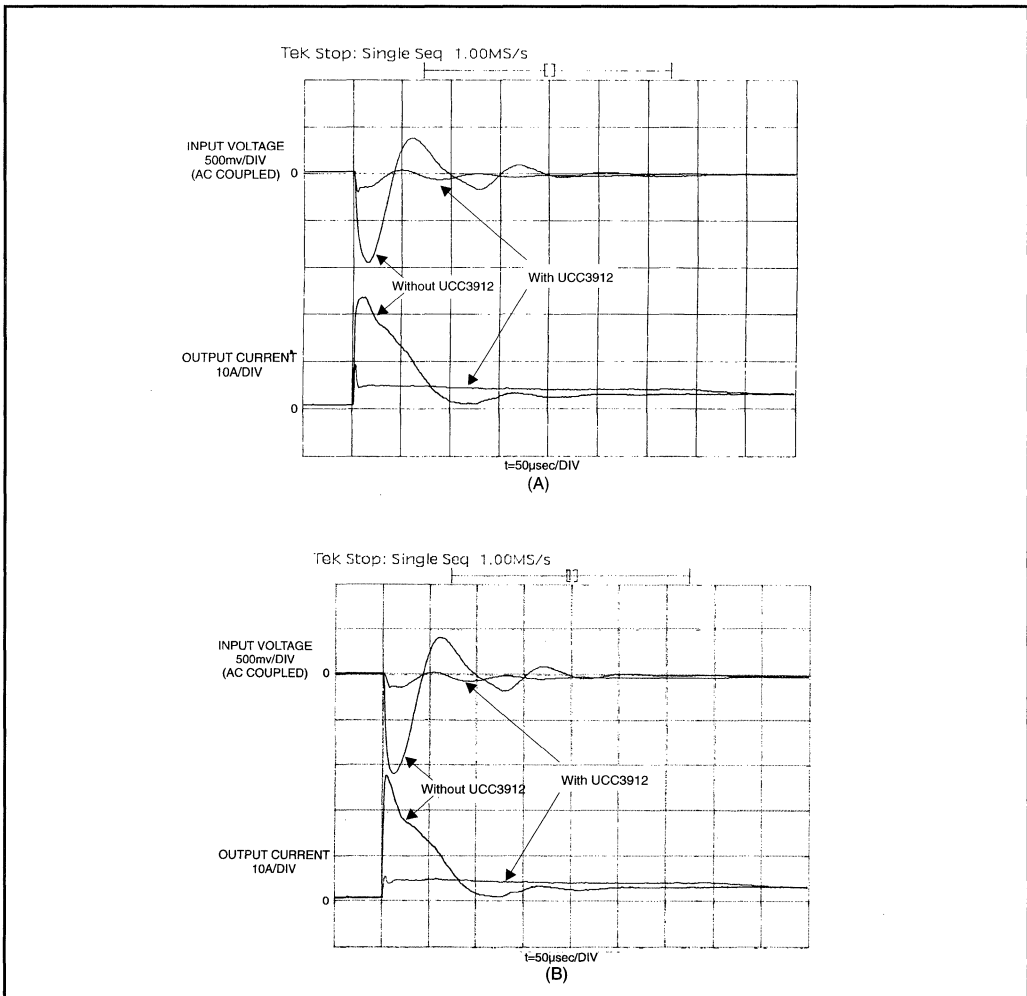


Figure 8. Hot Swap Results With and Without the UCC3912 Circuit Breaker. A) Hot Swap Performed on UCC3912 Output. B) Hot Swap Performed on UCC3912 Input.

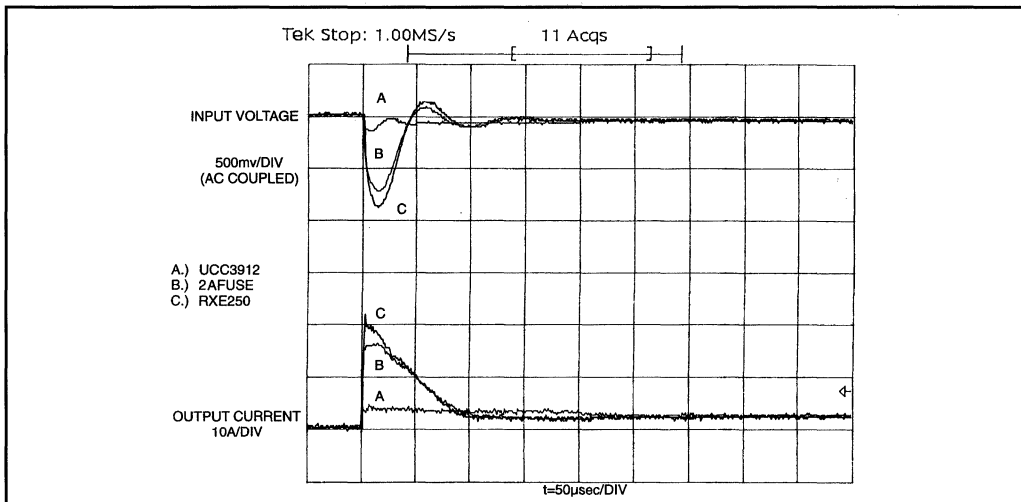


Figure 9. Hot Swap Performance Comparison Between a Fuse, PolySwitch® and the UCC3912.

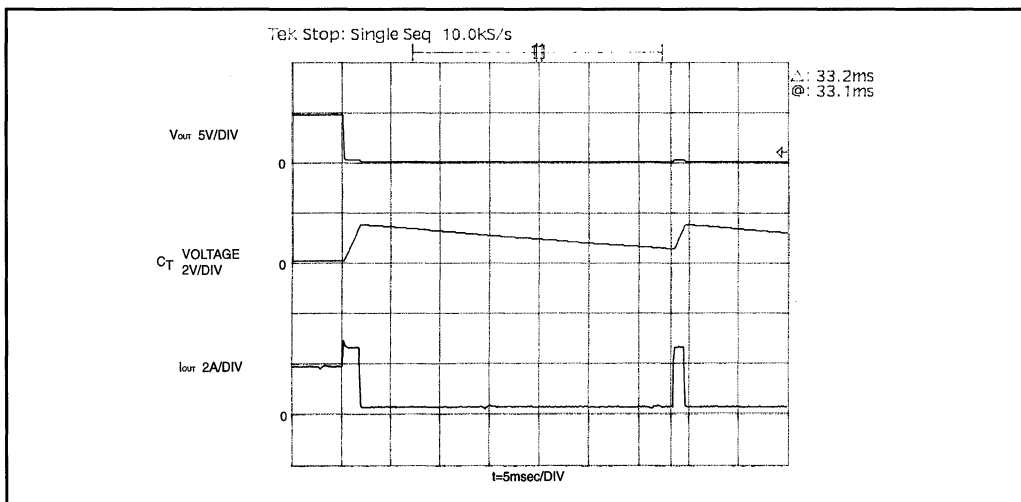


Figure 10. Short Circuit Performance of the UCC3912 Illustrating the 3% Duty Cycle Protection Technique.

Not shown in this figure is a delay of approximately 100µsec as the internal charge pump builds up gate charge for the MOSFET.

The hot swap performance of the UCC3912 was also compared to that of a fuse and PolySwitch®, two industry standard protection devices. A 2.5A PolySwitch® (RXE250) and a 2A slow-blow fuse (Littelfuse 313.002) were each substituted for the UCC3912 during a hot swap test. Figure 9 illustrates the results using the three different protection devices. Comparing the results of Figures 8 and 9, it is evident that both the fuse and PolySwitch® offer virtually no protection for tran-

sients of this speed; the current magnitudes are very close to those seen without any protection device at all. The circuit breaker, on the other hand, provides a fast transient response, keeping the current and the associated voltage transient within specification.

**SHORT CIRCUIT PROTECTION**

As previously described, the UCC3912 provides overcurrent and short circuit protection by modulating the output at a 3% duty cycle. During the "on" time, output current is limited to the value set by the IMAX and DAC inputs. Figure 10 illustrates the performance of the UCC3912 test circuit when a

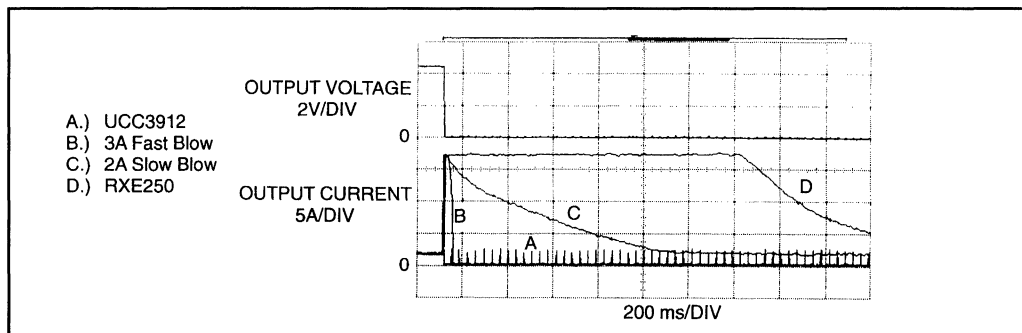


Figure 11. Short Circuit Performance Comparison of a Fuse, PolySwitch® and the UCC3912.

short-circuit is applied in place of the load. The bottom trace is the output current, modulated at a 3% duty cycle, while the center trace is the voltage across the timing capacitor. Note that the first current pulse is approximately 50% longer than subsequent pulses due to the timing capacitor initially charging from 0V.

The short circuit test was also conducted on the 2.5A PolySwitch®, 2A slow-blow fuse, and a 3A fast-acting fuse (Littelfuse 312.003). Figure 11 compares the performance of the 4 different protection techniques. The peak currents incurred with each of the fuses and the PolySwitch® reach approximately 17.5A and are limited only by the output capability of the 5V power supply. The PolySwitch® takes approximately 1.25sec before it begins to limit the current and eventually latches into high impedance mode. At this point it will remain in a high impedance state due to a sustained self heating current and will only reset after it has cooled and the fault condition has been corrected. As a result, the device requires that the input voltage be removed from the system in order to insure a circuit reset. The fuses on the other hand, respond faster than the PolySwitch®, but once blown require manual replacement before the hardware can resume operation. Table II compares the I • T and peak current characteristics of the four techniques.

Table II		
Protection Device	Peak Current (Amps)	I • T (Amp-sec)
PolySwitch® RXE250	17.5	17.5
Fuse 312.003	17.5	9.75
Fuse 313.002	17.5	0.875
UCC3912	3.25	0.098

Note: 1) Peak currents are limited by power supply.  
 2) I • T estimated for first second of short circuit.

When compared to any of the other commonly used technologies, the performance of the UCC3912 is superior. The electronic circuit breaker responds almost immediately to a short circuit, limiting the current to 3.25A before turning off the output. The breaker then attempts to reapply power at a 3% duty cycle until the fault has been corrected. The low duty cycle, coupled with the current limiting feature keeps the power dissipation at a reasonable level, eliminating the need for extensive heating sinking. In this example the UCC3912 dissipates only  $5V \cdot 3.25A \cdot 3\% = 488mW$  of power during the short circuit.

POWER MANAGEMENT APPLICATIONS

In an effort to save energy, the federal government is working to impose regulations that will require electronic equipment and appliances to operate more efficiently. As an example, consider the personal computer (PC). PCs typically dissipate 100 to 200W, with an additional 150 to 350W consumed by the monitor. In order to limit the power dissipation to a recommended 30W during periods of nonusage, circuitry must be added to shutdown key components such as the monitor, high powered cache circuits and bus interfaces. The UCC3912 offers a simple solution to these types of power management applications.

The UCC3912 can be configured as a low current (<5µA) standby power switch, as shown in Figure 12. The shutdown input, SHTDWN, is utilized to turn off the internal MOSFET, removing power from the load and reducing the UCC3912 quiescent current to <5µA. When reactivated by the logic command, the current limiting features of the UCC3912 allow the load circuits to resume operation without disrupting the rest of the system.

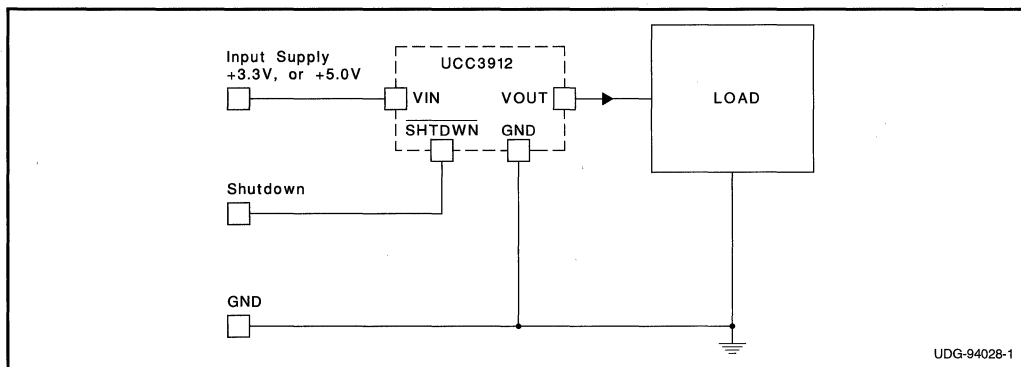


Figure 12. Low Current Standby Power Switch

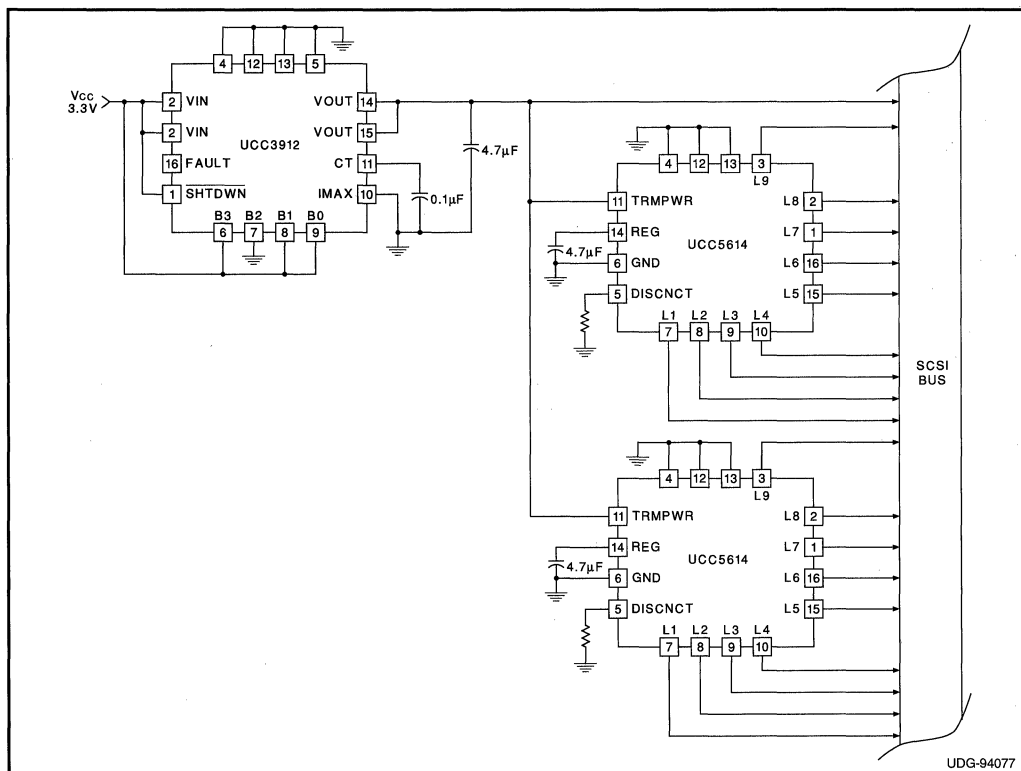


Figure 13. Typical 3.3V SCSI Application

**APPLICATION CIRCUITS**

The 3.3V power bus has quickly become the standard for laptop computers and other battery operated equipment. Unfortunately, SCSI standards specify an active termination voltage of 2.7V. In addition, standards require that the Termpwr source be fused and provide for unidirectional current flow. These requirements have typically forced designers to include a 5V supply in 3.3V systems - a 5%,

3.3V bus leaves only 130mV of headroom for a diode, fuse, and regulator overhead. Replacing the diode and fuse with the UCC3912 limits the voltage drop to less than 60mV while still meeting SCSI requirements. Combining the UCC3912 with a low dropout active terminator such as the UCC5614 results in a complete design. Figure 13 illustrates a typical 3.3V SCSI application.

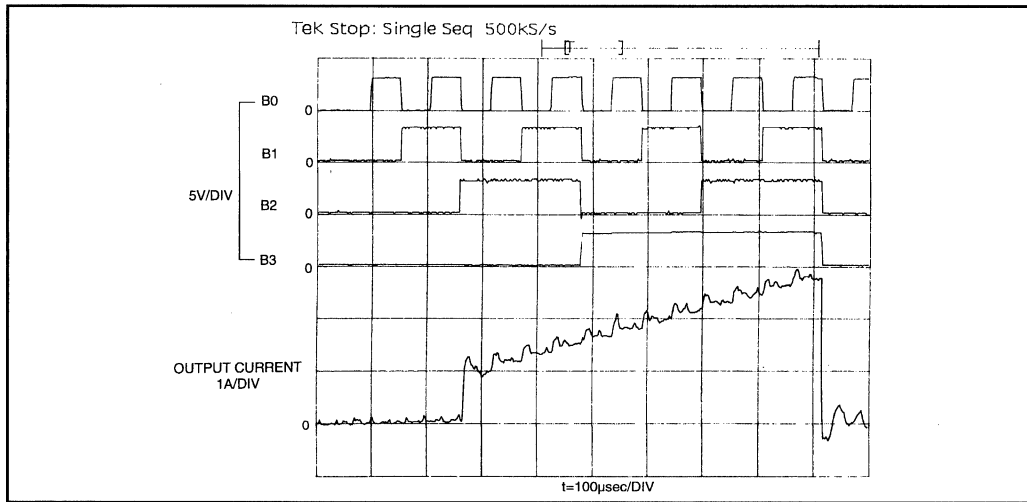


Figure 14. Controlled Current Slew Rate Using the UCC3912 4-Bit DAC.

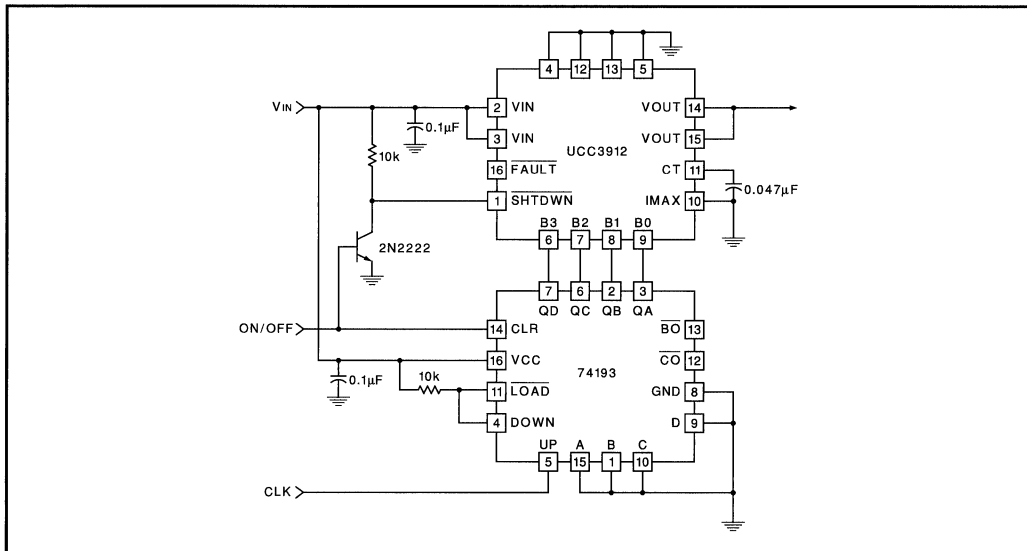


Figure 15. UCC3912 Current Control Circuit Implementation.

The UCC3912 lends itself well to more sophisticated current limiting schemes through the use of the DAC inputs. Greater control of output current slew rate can be obtained by stepping the DAC through a series of its input codes. Figure 14 illustrates the output current as the DAC inputs are controlled using the output of a 4-bit counter as shown in Figure 15. Similarly, loads such as motors often require inrush currents several times their normal running value. By using the counter in Figure 15 to count down rather than up, the motor can be quickly accelerated to speed using maximum

current and then closely protected against overload.

The duty cycle protection capability of the UCC3912 can be disabled by grounding the timing capacitor input, CT. This causes the UCC3912 to remain in constant current mode during a fault condition. When operating in this manner the UCC3912 is in linear mode and will dissipate power as function of the maximum output current and differential input/output voltage. It is extremely important that adequate heatsinking is provided when operating in this configuration.

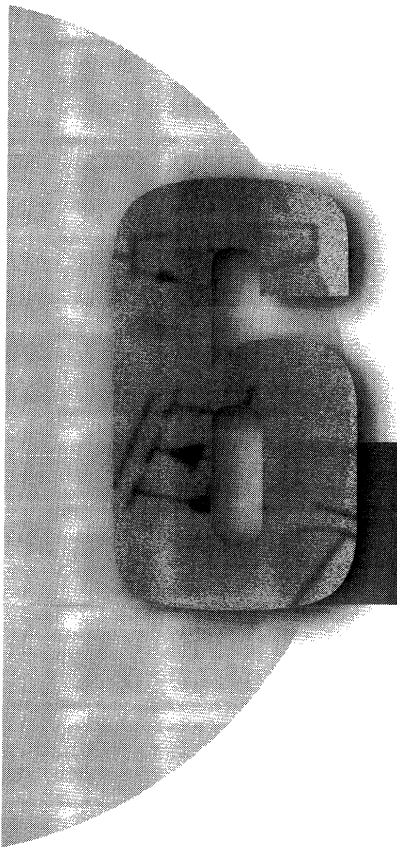
**SUMMARY**

As demonstrated throughout this application note, the UCC3912 provides a level of protection far superior to that offered by existing technologies. Integrating a high speed, programmable current amplifier, power MOSFET, and charge pump allows for precise control of both inrush and short circuit currents. Fast, accurate transient control helps to maintain power supply tolerance, enabling reliable hot swap implementation. In addition, preventing destructive current transients during connector mating prolongs the life of the hardware. By integrating each of these features, the UCC3912 electronic circuit breaker offers a new and complete solution to power management, hot swap, and short circuit requirements.

**REFERENCES**

- [ 1 ] J. O'Connor, "Thermal Characteristics of Surface Mount Packages", Unitrode Product and Applications Handbook, 1993-94.
- [ 2 ] Raychem, PolySwitch® R-Line Circuit Protectors, RXE Product Family, Manufacturers Data Sheet, Raychem Corporation, Menlo Park, CA, 1993.
- [ 3 ] Littelfuse, Electromechanical Devices and Circuit Protection Components, Manufacturers Catalog No. 20, Littelfuse Tracor, Des Plaines, IL, 1985.





# Drivers/Receivers Transceivers



# Selection Guides ~ Drivers / Receivers / Transceivers



## Drivers / Receivers / Transceivers

Interface Drivers, Receivers	UNITRODE PART NUMBER				
	UC5170C	UC5171	UC5172	UC5180C	UC5181C
<b>Drivers</b>	8	8	8		
<b>Receivers</b>				8	8
<b>Power</b>	±10V	±10V	±10V	+5V	+5V
<b>EIA232 / V.28</b>	Y	Y	Y	Y	Y
<b>EIA423 / V.10</b>	Y	Y	Y	Y	Y
<b>EIA422 / V.11</b>	N	N	N	Y	Y
<b>V.35</b>	N	N	N	Y	Y
<b>Appletalk</b>	N	N	N	N	Y
<b>Page Number</b>	IF/6-3	IF/6-7	IF/6-11	IF/6-15	IF/6-18

Interface Transceivers	UNITRODE PART NUMBER				
	UC5350	UC5351+			
<b>Drivers</b>	1	1			
<b>Receivers</b>	1	1			
<b>Power</b>	+5V	+5V to 24V			
<b>Control Area Network</b>	Y	Y			
<b>Device Net</b>	Y	Y			
<b>SDS</b>	Y	Y			
<b>Page Number</b>	IF/6-21	IF/6-27			

+ New Product





# Octal Line Driver

## FEATURES

- Eight Single Ended Line Drivers in One Package
- Meets EIA Standards EIA232E/V.28, EIA423A and CCITT V.10/X.26
- Single External Resistor Controls Slew Rate
- Wide Supply Voltage Range
- Tri-State Outputs
- Output Short-Circuit Protection

## DESCRIPTION

The UC5170C is a single-ended octal line driver designed to meet both standard modem control applications (EIA232E/V.28), and long line drive applications (EIA423A/V.10/X.26). The slew rate for all eight drivers is controlled by a single external resistor. The slew rate and output levels in Low Mode are independent of the power variations.

Mode selection is easily accomplished by taking the select pins (MS+ and MS-) to ground for low output mode (EIA232E/V.28 and EIA423A/V.10) or to their respective supplies for high mode (EIA232E/V.28). High mode should only be used to drive adapters that take power from the control lines, or applications using high threshold receivers.

## ABSOLUTE MAXIMUM RATINGS (Note 1)

V+ (Pin 20) .....	15V
V- (Pin 11) .....	-15V
PLCC Power Dissipation, TA = 25°C (Note 2) .....	1000 mW
DIP Power Dissipation, TA = 25°C (Note 2) .....	1250 mW
Input Voltage .....	-1.5V to +7V
Output Voltage .....	-12V to +12V
Slew Rate Resistor .....	2k to 10kΩ
Storage Temperature .....	-65°C to +150°C

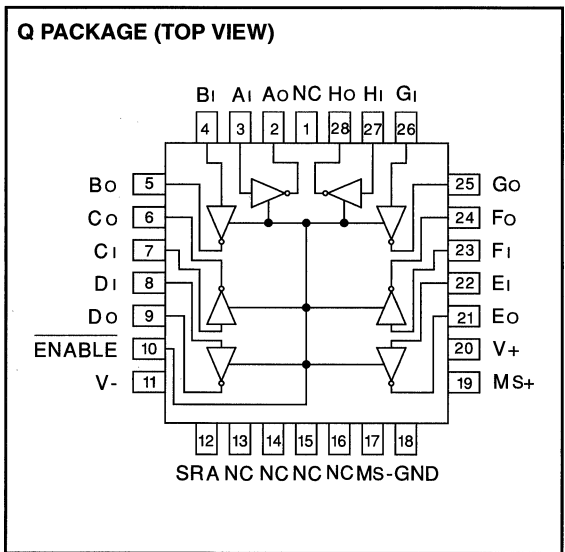
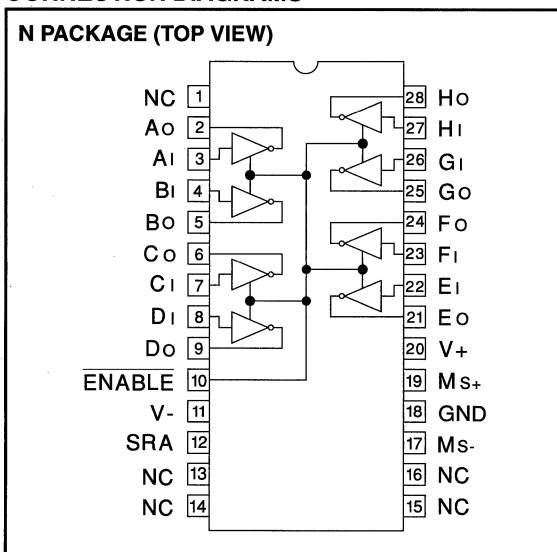
Note 1: All voltages are with respect to ground, pin 18.  
 Note 2: Consult Packaging Section of Databook for thermal limitations and considerations of packages.

## FUNCTIONAL TABLE

INPUTS		OUTPUTS	
EN	DATA	HIGH	LOW
		EIA-232E <sup>(2)</sup>	EIA423A+EIA232E
0	0	(V+)-3V	5V to 6V
0	1	(V-)-3V	-5V to -6V
1	X	High Z	High Z

Note 2: Minimum output swings.

## CONNECTION DIAGRAMS



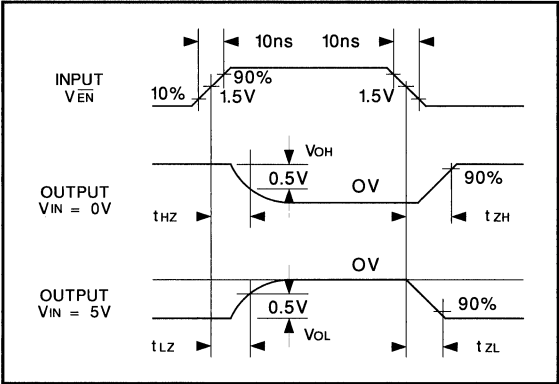
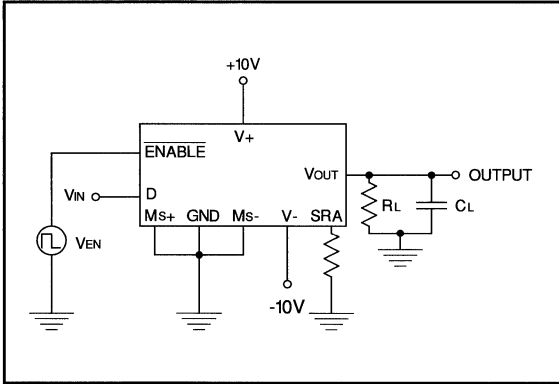
**DC ELECTRICAL CHARACTERISTICS:** Unless otherwise stated these specifications hold for  $|V_+| = |V_-| = 10V$ ,  
 $0 < T_A < +70^\circ C$ ,  $M_{S+} = M_{S-} = 0V$ ,  $R_{SRA} = +10k$ ,  $T_A = T_J$ .

PARAMETERS	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>POWER SUPPLY REQUIREMENTS</b>						
V+ Range			9		15	V
V- Range			-9		-15	V
V+ Supply Current	I+	$R_L = \text{Infinite}$ $\overline{E_n} = 0V$		25	42	mA
V- Supply Current	I-	$R_L = \text{Infinite}$ $\overline{E_n} = 0V$		-23	-42	mA
<b>INPUTS</b>						
High Level Input Voltage	V <sub>IH</sub>		2.0			V
Low Level Input Voltage	V <sub>IL</sub>				0.8	V
Input Clamp Voltage	V <sub>IK</sub>	I <sub>I</sub> = -15 mA		-1.1	-1.8	V
High Level Input Current	I <sub>IH</sub>	V <sub>IH</sub> = 2.4V		0.25	40	μA
Low Level Input Current	I <sub>IL</sub>	V <sub>IL</sub> = 0.4V	-200	-8.0		μA
<b>OUTPUTS</b>						
High Level (Low Mode) Output Voltage (EIA423A/V.10, EIA232E/V.28)	V <sub>OH</sub>	$V_{IN} = 0.8V$ $R_L = \text{Inf.}$	5.0	5.3	6.0	V
		$\overline{E_n} = 0.8V$ $R_L = 3k$	5.0	5.3	6.0	V
		$R_L = 450$	4.5	5.2	6.0	V
Low Level (Low Mode) Output Voltage (EIA423A/V.10, EIA232E/V.28)	V <sub>OL</sub>	$V_{IN} = 2.0V$ $R_L = \text{Inf.}$	-5.0	-5.3	-6.0	V
		$\overline{E_n} = 0.8V$ $R_L = 3k$	-5.0	-5.3	-6.0	V
		$R_L = 450$	-4.5	-5.2	-6.0	V
Output Balance (EIA423A/V.10)	V <sub>BAL</sub>	$R_L = 450$ $V_{OH} - V_{OL} = V_{BAL}$		0.2	0.4	V
High Level (High Mode) Output Voltage (EIA232E/V.28)	V <sub>OH</sub>	$V_{IN} = 0.8V$ $R_L = \text{Inf.}$ , $M_{S+} = V_+$ , $M_{S-} = V_-$	7.0	7.6	10	V
		$\overline{E_n} = 0.8V$ $R_L = 3k$ , $M_{S+} = V_+$ , $M_{S-} = V_-$	7.0	7.6	10	V
Low Level (High Mode) Output Voltage (EIA232E, V.28)	V <sub>OL</sub>	$V_{IN} = 2.0V$ $R_L = \text{Inf.}$ , $M_{S+} = V_+$ , $M_{S-} = V_-$	-7.0	-7.7	-10	V
		$\overline{E_n} = 0.8V$ $R_L = 3k$ , $M_{S+} = V_+$ , $M_{S-} = V_-$	-7.0	-7.7	-10	V
Off-State Output Current	I <sub>oz</sub>	$\overline{E_n} = 2.0V$ , $V_o = \pm 6V$ , $V_+ = 15V$ , $V_- = -15V$	-100		100	μA
Short-Circuit Current	I <sub>os</sub>	$V_{IN} = 0V$ , $\overline{E_n} = 0V$	25	50		mA
		$V_{IN} = 5V$ , $\overline{E_n} = 0V$	25	40		mA

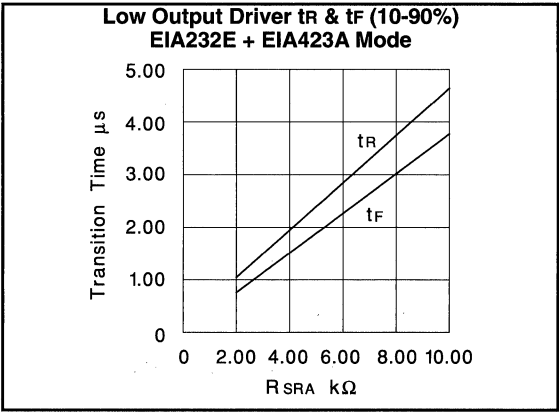
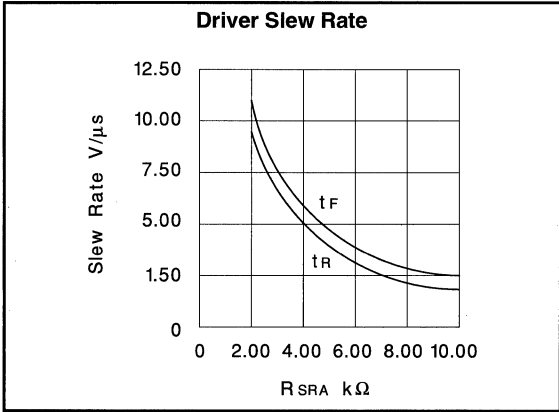
**AC ELECTRICAL CHARACTERISTICS:** at  $|V_+| = |V_-| = 10V$ ,  $0 < T_A < +70^\circ C$ ,  $M_{S+} = M_{S-} = 0V$ ,  $T_A = T_J$ .

PARAMETERS	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Output Slew Rate	t <sub>R</sub>	$R_{SRA} = 2k$	6.65	9.5	12.3	V/μs
	t <sub>F</sub>	$R_L = 450$ , $C_L = 50pF$	6.65	10	12.3	V/μs
Output Slew Rate	t <sub>R</sub>	$R_{SRA} = 10k$	1.33	1.9	2.45	V/μs
	t <sub>F</sub>	$R_L = 450$ , $C_L = 50pF$	1.33	2.2	2.45	V/μs
Propagation Output to High Impedance	t <sub>Hz</sub>	$R_{SRA} = 10k$		0.3	1.0	μs
	t <sub>Lz</sub>	$R_L = 450$ , $C_L = 50pF$		0.5	1.0	μs
Propagation High Impedance to Output	t <sub>zH</sub>	$R_{SRA} = 10k$		6.0	15	μs
	t <sub>zL</sub>	$R_L = 450$ , $C_L = 50pF$		7.0	15	μs

**AC PARAMETER TEST CIRCUIT AND WAVEFORMS**



**AC CHARACTERISTICS**



**APPLICATION INFORMATION**

**Slew Rate Programming**

Slew rate for the UC5170C is set up by a single external resistor connected between the SRA pin and ground. Slew rate adjustments can be approximated by using the following formula:

$$V/\mu s = \frac{20}{R_{SRA}} \quad (R_{SRA} \text{ in } k\Omega)$$

The slew rate resistor can vary between 2k and 10k which allows slew rates between 10 to 2.2V/μs, respectively. The relationship between slew rate and RSRA is shown in the typical characteristics.

Waveshaping of the output lets the user control the level of interference (near-end crosstalk) that may be coupled to adjacent circuits in an interconnection. The recommended output characteristics for cable length and data rates can be found in EIA standard EIA423A +V.10. Approximations of these standards are given by the following equations:

*Max. Data Rate = 300/t (For data rates 1k to 100k bit/s)*

*Max. Cable Length (feet) = 100 x t (Max. length 4000 feet)*

where t is the transition time from 10% to 90% of the output swing in microseconds. For data rates below 1k bit/s t may be up to 300 microseconds.

**Output Voltage Programming**

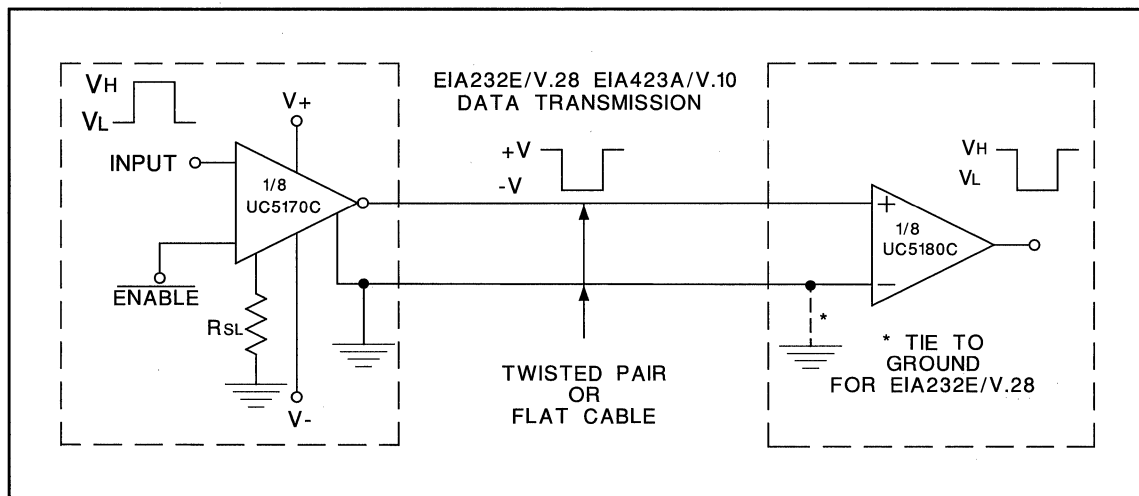
The UC5170C has two programmable output modes, either a low voltage mode which meets EIA423A, EIA232E/V.28/V.10 specifications, or the high output mode which meets the EIA232E, V.28 specifications.

The high output mode provides greater output swings, minimum of 3V below and supply rails for driving higher, attenuated lines. This mode is selected by connecting the mode select pins to their respected supplies, MS+ to V+ and MS- to V-.

The low output mode provides a controlled output swing and is accomplished by connecting both mode select pins to ground.



## APPLICATIONS



## SPECIFIC LAYOUT NOTES

The UC5170C layout must have bulk bypassing close to the device. Peak slew current is greater than 500mA when all eight drivers slew at once in the same direction. Some applications mount the UC5170C on a bulkhead or isolated plane for RFI/FCC/VDE reasons. If bulk bypassing is not used, the -10V supply may go above -8.5 volts, causing the slew rate control circuit to become unstable.

The UC5170C can have output oscillation at 100kHz if the +10V supply is applied before the -10V supply. This has been a problem in some terminal designs where the +10V was developed from the flyback, which can result in a 500ms difference in the application of the supplies at power up.

## GENERAL LAYOUT NOTES

The drivers and receivers should be mounted close to the system common ground point, with the ground reference tied to the common point to reduce RFI/EMI.

Filter connectors or transzorb should be used to reduce the RFI/EMI, protecting the system from static (ESD), and electrical overstress (EOS). A filter connector or capacitor will reduce the ESD pulse by 90% typically. A cable dragged across a carpet and connected to a system can easily be charged to over 25,00 volts. This is a metal to metal contact when the cable is connected to the system (no resistance), currents exceed 80 amps with less than a nanosecond rise time. A transzorb provides two functions, the device capacitance inherently acts as a filter capacitor, and the device clamps the ESD and EOS pulses which would pass through the capacitor and destroy the devices. The recommended transzorb for the UC5170C is P6KEI0CA.

\*Transzorb is a trademark of General Semiconductor Industries.



# Octal Line Driver

## FEATURES

- Eight Single-Ended Line Drivers in One Package
- Digital Selection of High Mode EIA232E/CCITT V.28 only, and Low Mode EIA232E/V.28 & EIA423A/CCITT V.10/X.26
- Single External Resistor Controls Slew Rate
- Wide Supply Voltage Range
- Tri-State Outputs
- Output Short-Circuit Protection
- Low Power Consumption
- 2kV ESD Protection on all Pins

## DESCRIPTION

The UC5171 is a single-ended octal line driver designed to meet both standard modem control applications (EIA232E/V.28), and long line drive applications (EIA423A/V.10/X.26). The slew rate for all 8 drivers is controlled by a single external resistor. The slew rate and output levels in Low Mode are independent of the power variations.

Mode selection is accomplished by the select pin Ms logic "low" for low output mode (EIA232E/V.28 & EIA423A/V.10) or pin Ms logic "high" for high mode (EIA232E/V.28). High mode should only be used to drive adapters that take power from the control lines, or applications using high threshold receivers.

## ABSOLUTE MAXIMUM RATINGS (Note 1)

V+ (Pin 20)	15V
V- (Pin 11)	-15V
PLCC Power Dissipation, TA = 25°C (Note 2)	1000 mW
DIP Power Dissipation, TA = 25°C (Note 2)	1250 mW
Input Voltage	-1.5V to +7V
Output Voltage	-12V to +12V
Slew Rate Resistor	2k to 10kΩ
Storage Temperature	-65°C to +150°C

Note 1: All voltages are with respect to ground, pin 18.

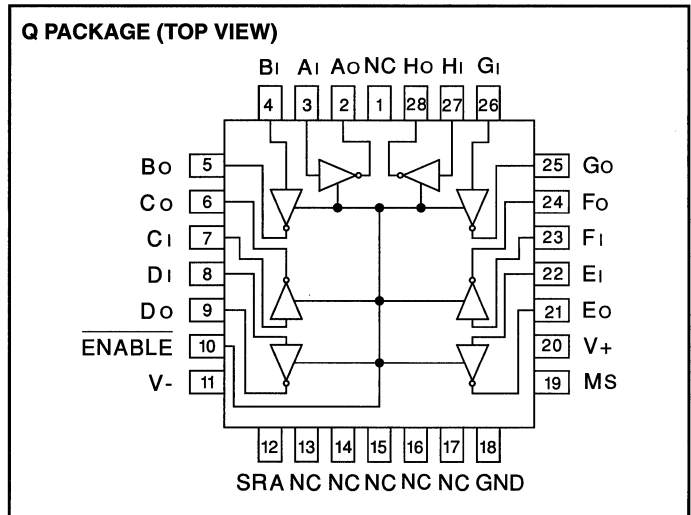
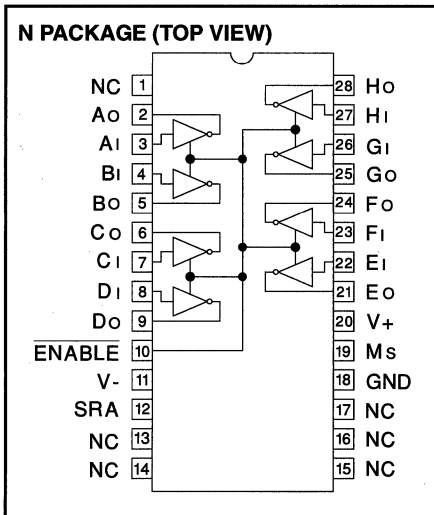
Note 2: Consult Packaging section of Databook for thermal limitations and considerations of package.

## FUNCTIONAL TABLE

INPUTS		OUTPUTS	
EN	DATA	EIA-232E(3)	EIA-232E/EIA-423A
0	0	(V+)-3V	5V to 6V
0	1	(V-)+3V	-5V to -6V
1	X	High Z	High Z

Note 3: Minimum output swings.

## CONNECTION DIAGRAMS



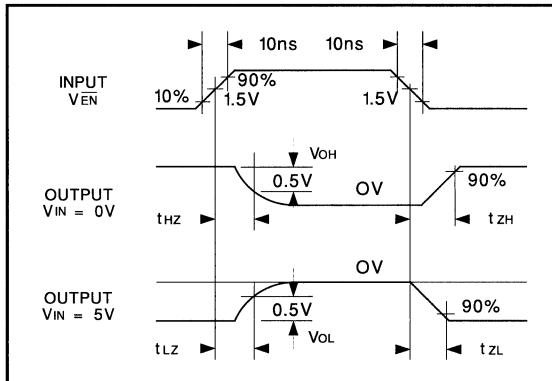
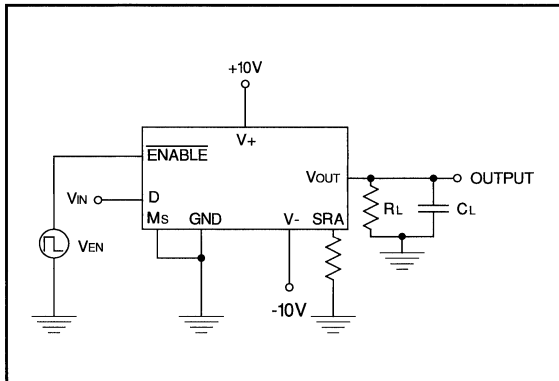
**DC ELECTRICAL CHARACTERISTICS:** Unless otherwise stated these specifications hold for  $|V_+| = |V_-| = +10V$ ,  $0 < T_A < +70^\circ C$ ,  $M_s \leq 0.8V$ ,  $R_{SRA} = +10k$ ,  $T_A = T_J$ .

PARAMETERS	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNITS	
<b>POWER SUPPLY REQUIREMENTS</b>							
V+ Range			9		15	V	
V- Range			-15		-9	V	
V+ Supply Current	I+	$R_L = \text{Infinite}$ $\overline{E_n} = 0V$		25	42	mA	
V- Supply Current	I-	$R_L = \text{Infinite}$ $\overline{E_n} = 0V$	-42	-23		mA	
<b>INPUTS</b>							
High Level Input Voltage	V <sub>IH</sub>		2.0			V	
Low Level Input Voltage	V <sub>IL</sub>				0.8	V	
Input Clamp Voltage	V <sub>IK</sub>	$I_i = -15 \text{ mA}$	-1.8	-1.1		V	
High Level Input Current	I <sub>IH</sub>	V <sub>IH</sub> = 2.4V		0.25	40	$\mu A$	
Low Level Input Current	I <sub>IL</sub>	V <sub>IL</sub> = 0.4V	-200	-8.0		$\mu A$	
<b>OUTPUTS</b>							
High Level Output Voltage EIA232E (EIA423A)	V <sub>OH</sub>	V <sub>IN</sub> = 0.8V $\overline{E_n} = 0.8V$	R <sub>L</sub> = Inf. R <sub>L</sub> = 3k R <sub>L</sub> = 450	5.0 5.0 4.5	5.3 5.3 5.2	6.0 6.0 6.0	V V V
Low Level Output Voltage EIA232E (EIA423A)	V <sub>OL</sub>	V <sub>IN</sub> = 2.0V $\overline{E_n} = 0.8V$	R <sub>L</sub> = Inf. R <sub>L</sub> = 3k R <sub>L</sub> = 450	-6.0 -6.0 -6.0	-5.3 -5.3 -5.2	-5.0 -5.0 -4.5	V V V
Output Balance (EIA423A)	V <sub>BAL</sub>	R <sub>L</sub> = 450	V <sub>OH</sub> + V <sub>OL</sub> = V <sub>BAL</sub>		0.2	0.4	V
High Level Output Voltage (EIA232E)	V <sub>OH</sub>	V <sub>IN</sub> = 0.8V, M <sub>s</sub> = 2.0V $\overline{E_n} = 0.8V$	R <sub>L</sub> = Inf. R <sub>L</sub> = 3k	7.0 7.0	7.6 7.6	10 10	V V
Low Level Output Voltage (EIA232E)	V <sub>OL</sub>	V <sub>IN</sub> = 2.0V, M <sub>s</sub> = 2.0V $\overline{E_n} = 0.8V$	R <sub>L</sub> = Inf. R <sub>L</sub> = 3k	-10 -10	-7.7 -7.7	-7.0 -7.0	V V
Off-State Output Current	I <sub>oz</sub>	$\overline{E_n} = 2.0V$ , V <sub>o</sub> = $\pm 6V$ , M <sub>s</sub> = 2.0V		-100		100	$\mu A$
Short-Circuit Current	I <sub>os</sub>	$\overline{E_n} = 0V$	V <sub>IN</sub> = 0V V <sub>IN</sub> = 5V	25 25	50 40		mA mA

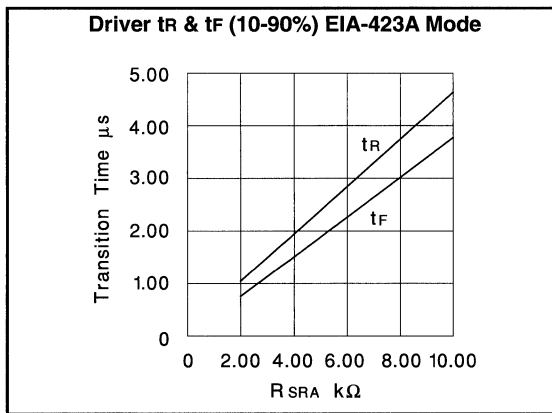
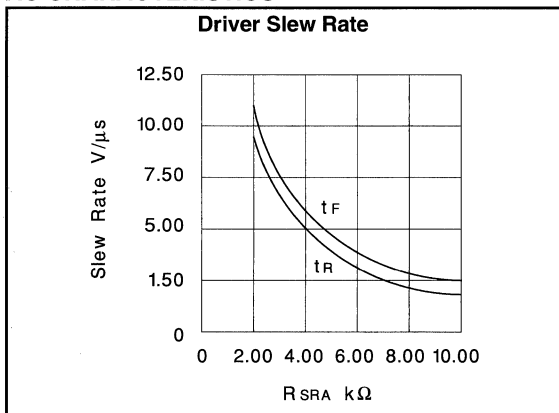
**AC ELECTRICAL CHARACTERISTICS:** at  $|V_+| = |V_-| = +10V$ ,  $0 < T_A < +70^\circ C$ ,  $M_s \leq 0.8V$ ,  $T_A = T_J$ .

PARAMETERS	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Output Slew Rate	t <sub>R</sub>	R <sub>SRA</sub> = 2k	6.65	9.5	12.3	V/ $\mu s$
	t <sub>F</sub>	R <sub>L</sub> = 450, C <sub>L</sub> = 50pF	6.65	10	12.3	V/ $\mu s$
Output Slew Rate	t <sub>R</sub>	R <sub>SRA</sub> = 10k	1.33	1.9	2.45	V/ $\mu s$
	t <sub>F</sub>	R <sub>L</sub> = 450, C <sub>L</sub> = 50pF	1.33	2.2	2.45	V/ $\mu s$
Propagation Output to High Impedance	t <sub>HZ</sub>	R <sub>SRA</sub> = 10k		0.3	1.0	$\mu s$
	t <sub>LZ</sub>	R <sub>L</sub> = 450, C <sub>L</sub> = 50pF		0.5	1.0	$\mu s$
Propagation High Impedance to Output	t <sub>ZH</sub>	R <sub>SRA</sub> = 10k		6.0	15	$\mu s$
	t <sub>ZL</sub>	R <sub>L</sub> = 450, C <sub>L</sub> = 50pF		7.0	15	$\mu s$

**AC PARAMETER TEST CIRCUIT AND WAVEFORMS**



**AC CHARACTERISTICS**



**APPLICATIONS INFORMATION**

**Slew Rate Programming**

Slew rate for the UC5171 is set up by a single external resistor connected between the SRA pin and ground. Slew rate adjustments can be approximated by using the following formula:

$$V_{\mu s} = \frac{20}{R_{SRA}} (R_{SRA} \text{ in } k\Omega)$$

The slew rate resistor can vary between 2k and 10kΩ which allows slew rates between 10 to 2.2V/μs, respectively. The relationship between slew rate and R<sub>SRA</sub> is shown in the typical characteristics.

Waveshaping of the output lets the user control the level of interference (near-end crosstalk) that may be coupled to adjacent circuits in an interconnection. The recommended output characteristics for cable length and data rates can be found in EIA standard EIA-423A. Approximations of these standards are given by the following equations:

- Max. Data Rate=300/t (For data rates 1k to 100k bit/s)
- Max. Cable Length (feet)=100 x t (Max. length 4000 feet)

where t is the transition time from 10% to 90% of the output swing in microseconds. For data rates below 1k bit/s, t may be up to 300 microseconds.

**Output Voltage Programming**

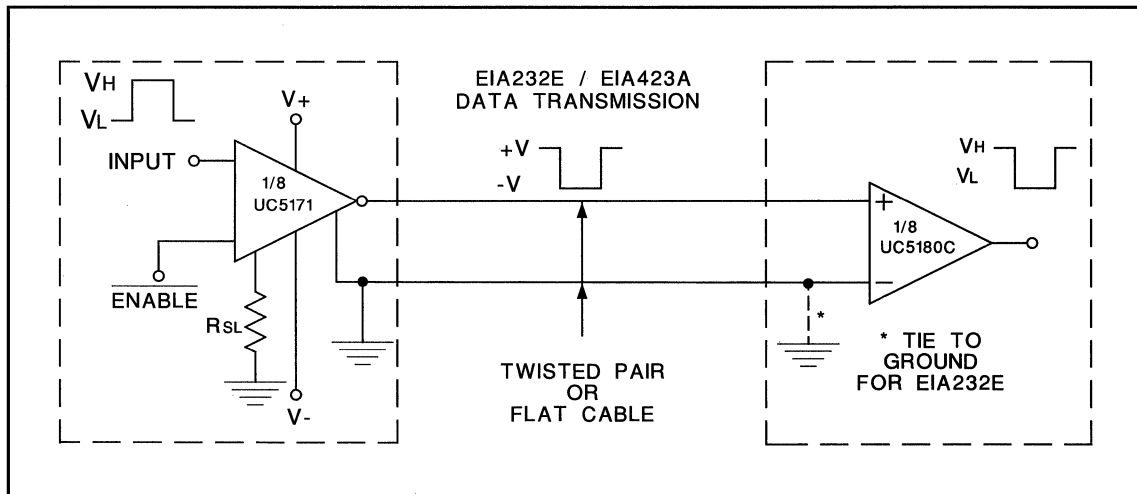
The UC5171 has two programmable output modes, either a low voltage mode which meets EIA-423A operational specifications, or the high output voltage mode which meets the EIA-232E specifications.

The high output mode provides greater output swings, minimum of 3V below the supply rails, for driving higher, attenuated lines. This mode is selected by connecting the modes select pin, (MS), to a TTL “high” level. The low output mode provides a controlled output swing and is accomplished by connecting the mode select pin, (MS), to a TTL “low level.”

**EIA Standards**

The UC5171 meets or exceeds the EIA Standards for EIA-232E and EIA-423A modes of operation except under power down conditions. When powered down with the output attached to an active buss, the UC5171 has the potential to load the bus under transient conditions.

## APPLICATIONS

**UC5171 Specific Layout Notes**

The UC5171 layout must have bulk bypassing close to the device. Peak slew current is greater than 500mA when all eight drivers slew at once in the same direction. Some applications mount the UC5171 on a bulkhead or isolated plane for RFI/FCC/VDE reasons. If bulk bypassing is not used, the -10V supply may go above -8.5 volts, causing the slew rate control circuit to become unstable.

The UC5171 can have output oscillation at 100kHz if the +10V supply is applied before the -10V supply. This has been a problem in some terminal designs where the +10V was developed from the flyback, which can result in a 500ms difference in the application of the supplies at power up.

**General Layout Notes**

The drivers and receivers should be mounted close to the system common ground point, with the ground reference tied to the common point to reduce RFI/EMI.

Filter connectors or transzorb should be used to reduce the RFI/EMI, protecting the system from static (ESD), and electrical overstress (EOS). A filter connector or capacitor will reduce the ESD pulse by 90% typically. A cable dragged across a carpet and connected to a system can easily be charged to over 25,000 volts. This is a metal-to-metal contact when the cable is connected to the system (no resistance), currents exceed 80 amps with less than a nanosecond rise time. A transzorb provides two functions, the device capacitance inherently acts as a filter capacitor, and the device clamps the ESD and EOS pulses which would pass through the capacitor and destroy the devices. The recommended transzorb for the UC5171 is P6KEIOCA

\*Transzorb is a trademark of General Semiconductor Industries.

# Octal Line Driver

## FEATURES

- Eight Single-Ended Line Drivers in One Package
- Meets Standards EIA232E/CCITT V.28, and EIA423A/CCITT V.10/X.26
- Single External Resistor Controls Slew Rate
- Wide Supply Voltage Range
- Tri-State Outputs
- Output Short-Circuit Protection
- Low Power Consumption
- 2kV ESD Protection on all Pins
- EOS on all Output Pins 35V under all Output Conditions
- High Current Output for Long Line Drive, Exceeds Standards

## DESCRIPTION

The UC5172 is a single-ended octal line driver designed to meet both standard modem control applications (EIA232E/V.28), and long line drive applications (EIA423A/V.10/X.26). The slew rate for all 8 drivers is controlled by a single external resistor. The slew rate and output levels are independent of the power variations.

The UC5172 has high output current, and current balance for long line drive applications. EOS - Output parasitic SCRs powered on and off are 35V, well above signal levels, allowing protection devices to work.

Inputs are compatible TTL+MOS logic families and are diode protected against negative transients.

## FUNCTIONAL TABLE

INPUTS		OUTPUT
$\overline{\text{EN}}$	DATA	EIA232E/EIA423A
0	0	5V to 6V
0	1	-5V to -6V
1	X	High Z

Note 2: Minimum output swings.

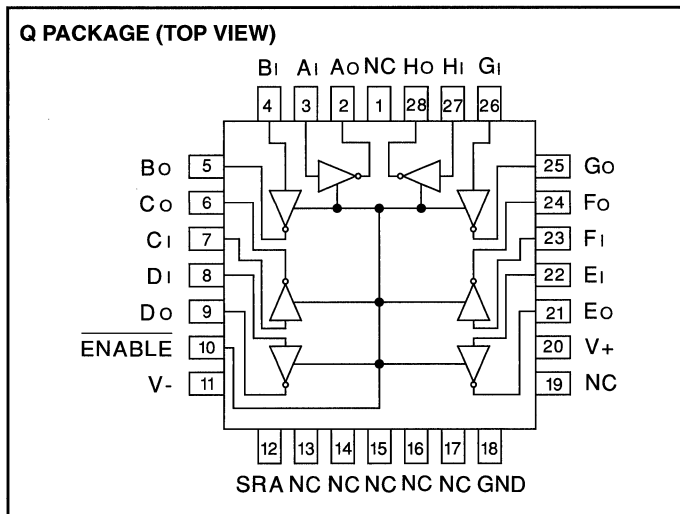
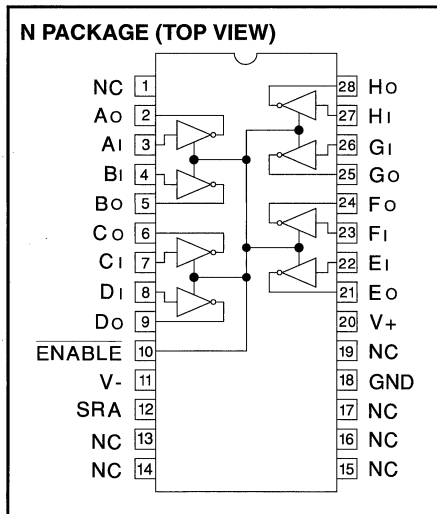
## ABSOLUTE MAXIMUM RATINGS (Note 1)

- V+ (Pin 20) ..... 15V
- V- (Pin 11) ..... -15V
- PLCC Power Dissipation, TA=25°C (Note 3) ..... 1000 mW
- DIP Power Dissipation, TA=25°C (Note 3) ..... 1250 mW
- Input Voltage ..... -1.5V to +7V
- Output Voltage ..... -6V to +6V
- Slew Rate Resistor ..... 2k to 10kΩ
- Storage Temperature ..... -65°C to +150°C

Note 1: All voltages are with respect to ground, pin 18.

Note 3: Consult Packaging section of Databook for thermal limitations and considerations of package.

## CONNECTION DIAGRAMS



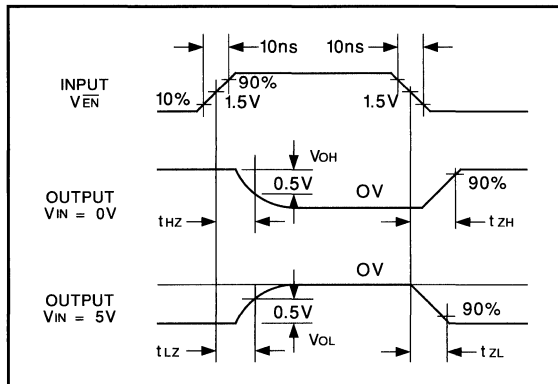
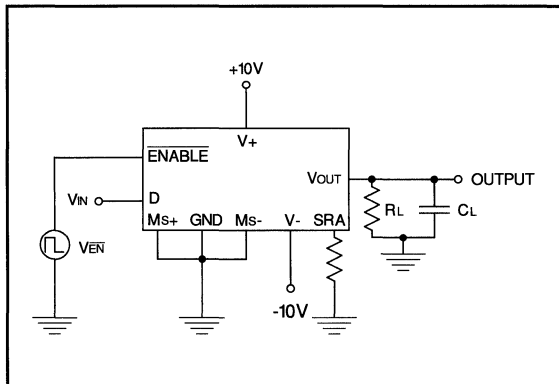
**DC ELECTRICAL CHARACTERISTICS:** Unless otherwise stated these specifications hold for  $I_{V+} = I_{V-} = 10V$ ,  
 $0^{\circ}C < T_A < +70^{\circ}C$ ,  $R_{SRA} = +10k$ ,  $T_A = T_J$ .

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>POWER SUPPLY REQUIREMENTS</b>						
V+ Range			9		15	V
V- Range			-9		-15	V
V+ Supply Current	I+	$R_L = \text{Infinite}$ $\overline{E_n} = 0V$		15	25	mA
V- Supply Current	I-	$R_L = \text{Infinite}$ $\overline{E_n} = 0V$		-17	-25	mA
<b>INPUTS</b>						
High-Level Input Voltage	$V_{IH}$		2.0			V
Low-Level Input Voltage	$V_{IL}$				0.8	V
Input Clamp Voltage	$V_{IK}$	$I_i = -15 \text{ mA}$		-1.1	-18	V
High Level Input Current	$I_{IH}$	$V_{IH} = 2.4V$	-2	0.25	40	$\mu A$
Low Level Input Current	$I_{IL}$	$V_{IL} = 0.4V$	-200	-8.0		$\mu A$
<b>OUTPUTS</b>						
High Level Output Voltage	$V_{OH}$	$V_{IN} = 0.8V$ $R_L = \text{Inf.}$	5.0	5.3	6.0	V
EIA232E		$\overline{E_n} = 0.8V$ $R_L = 3k$	5.0	5.3	6.0	V
(EIA-423A)		$R_L = 450$	4.5	5.2	6.0	V
Low Level Output Voltage	$V_{OL}$	$V_{IN} = 2.0V$ $R_L = \text{Inf.}$	-5.0	-5.3	-6.0	V
EIA232E		$\overline{E_n} = 0.8V$ $R_L = 3k$	-5.0	-5.6	-6.0	V
(EIA-423A)		$R_L = 450$	-4.5	-5.4	-6.0	V
Output Balance (EIA-423A)	$V_{BAL}$	$R_L = 450$ , $V_{OH} - V_{OL} = V_{BAL}$		0.2	0.4	V
Off-State Output Current	$I_{OZ}$	$\overline{E_n} = 2.0V$ , $V_O = \pm 6V$ , $V_+ = 15V$ , $V_- = -15V$	-100		100	$\mu A$
Short-Circuit Current	$I_{OS}$	$\overline{E_n} = 0V$ $V_{IN} = 0V$	25	65		mA
		$V_{IN} = 5V$	25	70		mA
Power Off Output Current	$I_{PO}$	$V_O = \pm 6V$ , $V_+ = V_- = 0V$	-100		100	mA

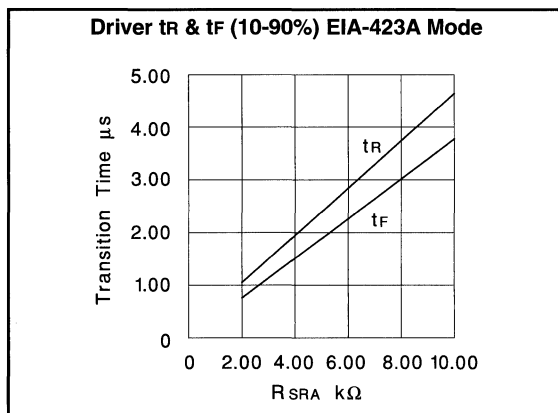
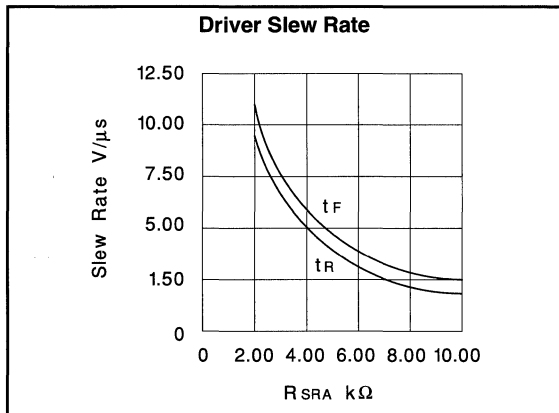
**AC ELECTRICAL CHARACTERISTICS:** at  $I_{V+} = I_{V-} = +10V$ ,  $0^{\circ}C < T_A < +70^{\circ}C$ ,  $T_A = T_J$ .

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Output Slew Rate	$t_R$	$R_{SRA} = 2k$	7.6	8.5	9.4	V/ $\mu s$
	$t_F$	$R_L = 450$ , $C_L = 50pF$	7.6	8.5	9.4	V/ $\mu s$
Output Slew Rate	$t_R$	$R_{SRA} = 10k$	1.5	1.7	1.9	V/ $\mu s$
	$t_F$	$R_L = 450$ , $C_L = 50pF$	1.5	1.7	1.9	V/ $\mu s$
Propagation Output to High Impedance	$t_{Hz}$	$R_{SRA} = 10k$		0.8	2.0	$\mu s$
	$t_{Lz}$	$R_L = 450$ , $C_L = 50pF$		0.5	2.0	$\mu s$
Propagation High Impedance to Output	$t_{zH}$	$R_{SRA} = 10k$		2.0	7.0	ms
	$t_{zL}$	$R_L = 450$ , $C_L = 50pF$		1.0	7.0	$\mu s$

**AC PARAMETER TEST CIRCUIT AND WAVEFORMS**



**AC CHARACTERISTICS**



**APPLICATIONS**

**Slew Rate Programming**

Slew rate for the UC5172 is set up by a single external resistor connected between the SRA pin and ground. Slew rate adjustments can be approximated by using the following formula:

$$V/\mu s = \frac{20}{RSRA} \text{ (RSRA in } k\Omega \text{)}$$

The slew rate resistor can vary between 2k and 10kΩ which allows slew rates between 10 to 2.2V/μs, respectively. The relationship between slew rate and RSRA is shown in the typical characteristics.

Waveshaping of the output lets the user control the level of interference (near-end crosstalk) that may be coupled

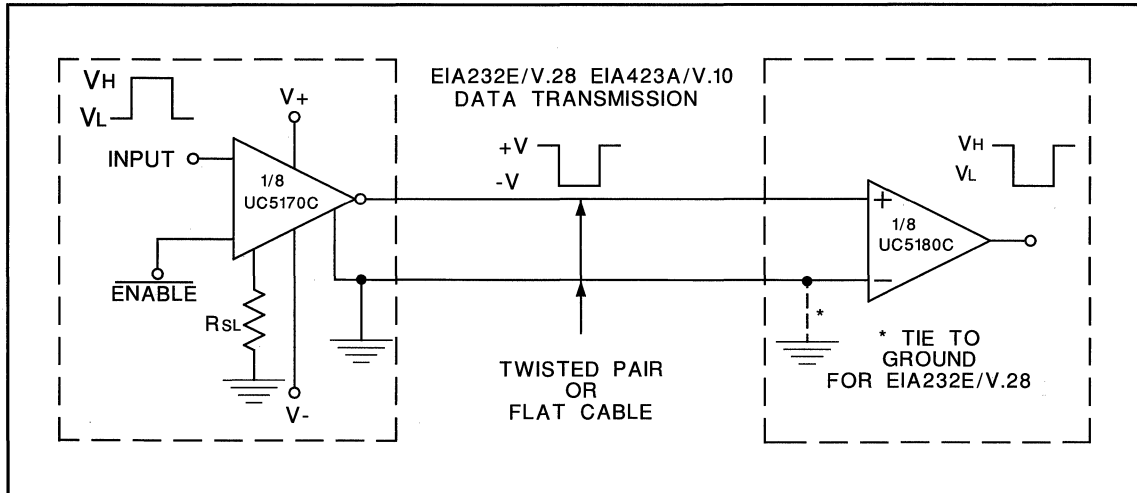
to adjacent circuits in an interconnection. The recommended output characteristics for cable length and data rates can be found in EIA standard EIA-423A. Approximations of these standards are given by the following equations:

Max. Data Rate = 300/t (For data rates 1k to 100k bit/s)  
 Max. Cable Length (feet) = 100 x t (Max. length 4000 feet)

where t is the transition time from 10% to 90% of the output swing in microseconds. For data rates below 1k bit/s, t may be up to 300 microseconds.

The UC5172 has been used in applications up to 460KBPS.

## APPLICATIONS



## Specific Layout Notes

The UC5172 layout must have bulk bypassing close to the device. Peak slew current is greater than 500mA when all eight drivers slew at once in the same direction. Some applications mount the UC5172 on a bulkhead or isolated plane for RFI/FCC/VDE reasons. If bulk bypassing is not used, the -10V supply may go above -8.5 volts, causing the slew rate control circuit to become unstable.

The UC5172 can have output oscillation at 100kHz if the +10V supply is applied before the -10V supply. This has been a problem in some terminal designs where the +10V was developed from the flyback, which can result in a 500ms difference in the application of the supplies at power up.

## General Layout Notes

The drivers and receivers should be mounted close to the system common ground point, with the ground reference tied to the common point to reduce RFI/EMI.

Filter connectors or transzorb should be used to reduce the RFI/EMI, protecting the system from static (ESD), and electrical overstress (EOS). A filter connector or capacitor will reduce the ESD pulse by 90% typically. A cable dragged across a carpet and connected to a system can easily be charged to over 25,000 volts. This is a metal to metal contact when the cable is connected to the system (no resistance), currents exceed 80 amps with less than a nanosecond rise time. A transzorb provides two functions, the device capacitance inherently acts as a filter capacitor, and the device clamps the ESD and EOS pulses which would pass through the capacitor and destroy the devices. The recommended transzorb for the UC5172 is P6KEIOCA.

\*Transzorb is a trademark of General Semiconductor Industries.



# Octal Line Receiver

## FEATURES

- Meets EIA 232E/423A/422A and CCITT V.10, V.11, V.28, X.26, X.27
- Single +5V Supply--TTL Compatible Outputs
- Differential Inputs Withstand  $\pm 25V$
- Low Open Circuit Voltage for Improved Failsafe Characteristic
- Reduced Supply Current--35 mA Max
- Input Noise Filter
- Internal Hysteresis

## DESCRIPTION

The UC5180C is an octal line receiver designed to meet a wide range of digital communications requirements as outlined in EIA standards EIA232E, EIA423A, EIA422A, and CCITT V.10, V.11, V.28, X.26, and X.27. The UC5180C includes an input noise filter and is intended for applications employing data rates up to 200 KBPS. A failsafe function allows these devices to "fail" to a known state under a wide variety of fault conditions at the inputs.

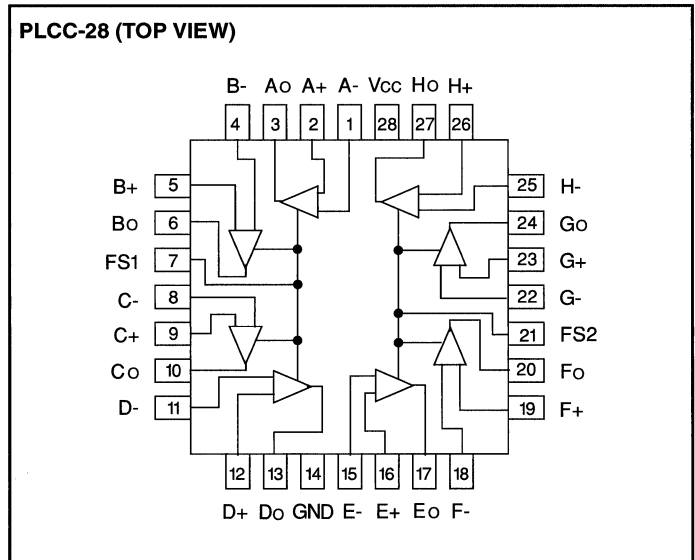
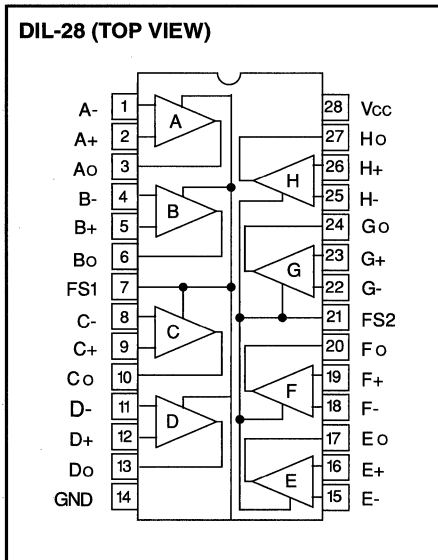
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage, Vcc	7V
Output Sink Current	50 mA
Output Short Circuit Time	1 Sec
Common Mode Input Range	15V
Differential Input Range	25V
Failsafe Voltage	-0.3 to Vcc
PLCC Power Dissipation, TA = 25°C (Note 2)	1000 mW
DIP Power Dissipation, TA = 25°C (Note 2)	1200 mW
Storage Temperature Range	-65°C to +150°C
Lead Temperature (Soldering, 10 Seconds)	-300°C

Note 1: All voltages are with respect to ground, pin 14. Currents are positive into, negative out of the specified terminal

Note 2: Consult Packaging Section of Databook for thermal limitations and considerations of package.

## CONNECTION DIAGRAMS



**DC ELECTRICAL CHARACTERISTICS:** Unless otherwise stated these specifications apply for  $T_A = 0^\circ\text{C}$  to  $+70^\circ\text{C}$ ,  $V_{CC} = 5\text{V} \pm 5\%$ , Input Common Mode Range  $\pm 7\text{V}$ ,  $T_A = T_J$

PARAMETERS	SYMBOL	TEST CONDITIONS	UC5180C		UNITS	
			MIN	MAX		
DC Input Resistance	$R_{IN}$	$3\text{V} \leq  V_{IN}  \leq 25\text{V}$	3	7	$k\Omega$	
Failsafe Output Voltage	$V_{OFS}$	Inputs Open or Shorted Together, or One Input Open and One Grounded	$0 \leq I_{OUT} \leq 8\text{mA}$ , $V_{FAILSAFE} = 0\text{V}$		0.45	V
			$0 \geq I_{OUT} \geq -400\mu\text{A}$ , $V_{FAILSAFE} = V_{CC}$	2.7		
Differential Input High Threshold	$V_{TH}$	$V_{OUT} = 2.7\text{V}$ , $I_{OUT} = 440\mu\text{A}$ (See Figure 1)	$R_S = 0$ (Note 2)	50	200	mV
			$R_S = 500$ (Note 2)		400	
Differential Input Low Threshold	$V_{TL}$	$V_{OUT} = 0.45\text{V}$ , $I_{OUT} = 440\text{mA}$ (See Figure 1)	$R_S = 0$ (Note 2)	-200	-50	mV
			$R_S = 500$ (Note 2)	-400		
Hysteresis	$V_H$	$F_S = 0\text{V}$ or $V_{CC}$ (See Figure 1)	50	140	mV	
Open Circuit Input Voltage	$V_{ICC}$			75	mV	
Input Capacitance	$C_I$			20	pF	
High Level Output Voltage	$V_{CH}$	$V_{ID} = 1\text{V}$ , $I_{OUT} = -440\mu\text{A}$	2.7		V	
Low Level Output Voltage	$V_{OL}$	$V_{ID} = -1\text{V}$ (Note 3)	$I_{OUT} = 4\text{mA}$		0.4	V
			$I_{OUT} = 8\text{mA}$		0.45	
Short Circuit Output Current	$I_{OS}$	Note 4	20	100	mA	
Supply Current	$I_{CC}$	$4.75\text{V} \leq V_{CC} \leq 5.25\text{V}$		35	mA	
Input Current	$I_{IN}$	Other Inputs Grounded	$V_{IN} = +10\text{V}$		3.25	mA
			$V_{IN} = -10\text{V}$	-3.25		

Note 2:  $R_S$  is a resistor in series with each input.

Note 3: Measured after 100ms warm up (at  $0^\circ\text{C}$ )

Note 4: Only 1 output may be shorted at one time and then only for a maximum of 1 sec.

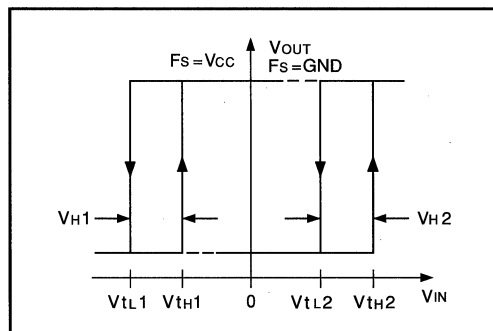


Figure 1.  $V_{tL}$ ,  $V_{tH}$ ,  $V_H$  Definition

**AC ELECTRICAL CHARACTERISTICS:**  $V_{CC} = 5\text{V} \pm 5\%$ ,  $T_A = 0^\circ\text{C}$  to  $+70^\circ\text{C}$ , Figure 2,  $T_A = T_J$ .

PARAMETERS	SYMBOL	TEST CONDITIONS	UC5180C		UNITS
			MIN	MAX	
Propagation Delay - Low to High	$t_{PLH}$	$C_L = 50\text{pF}$ , $V_{IN} = \pm 500\text{mV}$		550	ns
Propagation Delay - High to Low	$t_{PHL}$	$C_L = 50\text{pF}$ , $V_{IN} = \pm 500\text{mV}$		550	ns
Acceptance Input Frequency	$f_A$	Unused Input Grounded, $V_{IN} = \pm 200\text{mV}$		0.1	MHz
Rejectable Input Frequency	$f_R$	Unused Input Grounded, $V_{IN} = \pm 500\text{mV}$	5.5		MHz

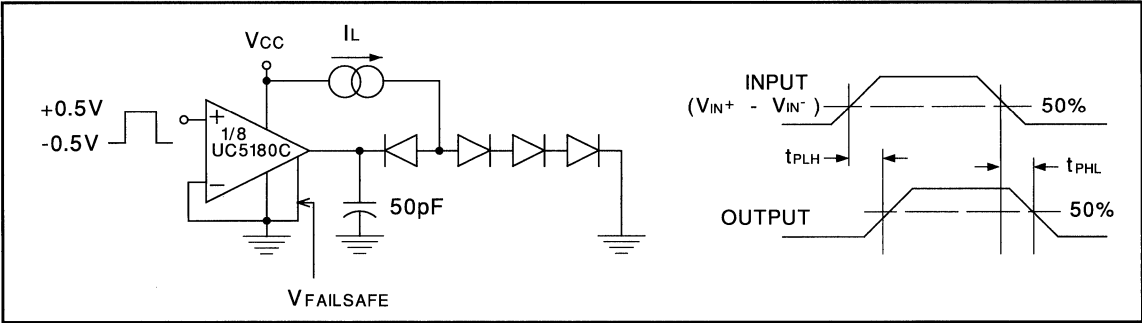


Figure 2. AC Test Circuit

**APPLICATIONS INFORMATION**

**Failsafe Operation**

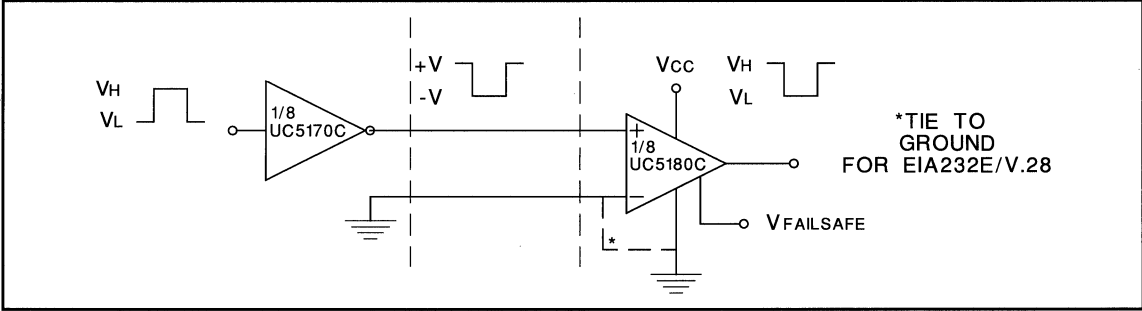
These devices provide a failsafe operating mode to guard against input fault conditions as defined in EIA422A and EIA423A standards. These fault conditions are (1) drive in power-off condition, (2) receiver not interconnected with driver, (3) open-circuited interconnecting cable, and (4) short-circuited interconnecting cable. If one of these four fault conditions occurs at the inputs of a receiver, then the output of that receiver is driven to a known logic level. The receiver is programmed by connecting the failsafe input to VCC or ground. A connection to VCC provides a logic "1" output

under fault conditions, while a connection to ground provides a logic "0". There are two failsafe pins (FS1 and FS2) on the UC5180C where each provides common failsafe control for four receivers.

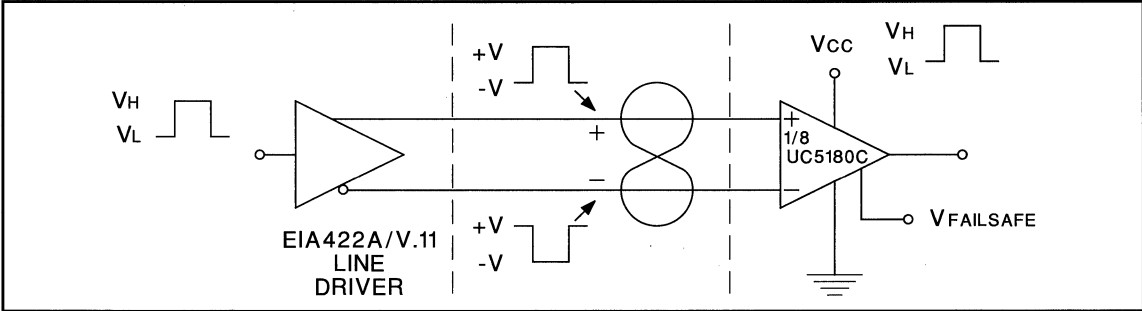
**Input Filtering (UC5180C)**

The UC5180C has input filtering for additional noise rejection. This filtering is a function of both signal level and frequency. For the specified input (5.5 MHz at ±500 mV) the input stage filter attenuates the signal such that the output stage threshold levels are not exceeded and no change of state occurs at the output.

**EIA232E/V.28 / EIA423A/V.10 DATA TRANSMISSION**



**EIA422A/V.11 DATA TRANSMISSION**



UNITRODE CORPORATION  
 7 CONTINENTAL BLVD. • MERRIMACK, NH 03054  
 TEL. (603) 424-2410 • FAX (603) 424-3460

# Octal Line Receiver

## FEATURES

- Meets EIA232E/423A/422A and CCITT V.10, V.11, V.28, X.26, X.27
- Single +5V Supply—TTL Compatible Outputs
- Differential Inputs withstand  $\pm 25V$
- Low Open Circuit Voltage for Improved Failsafe Characteristic
- Reduced Supply Current—35mA Max
- Internal Hysteresis

## DESCRIPTION

The UC5181C is an octal line receiver designed to meet a wide range of digital communications requirements as outlined in EIA standards EIA232E, EIA422A, EIA423A and CCITT V.10, V.11, V.28, X.26, and X.27. The UC5181C is similar to the UC5180C, but without the input filtering. Thus, it covers the entire range of data rates up to 10MBPS. A failsafe function allows these devices to "fail" to a known state under a wide variety of fault conditions at the inputs.

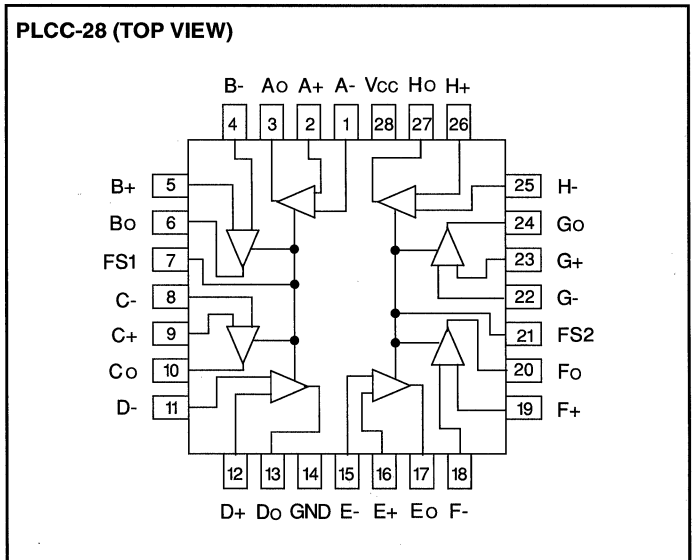
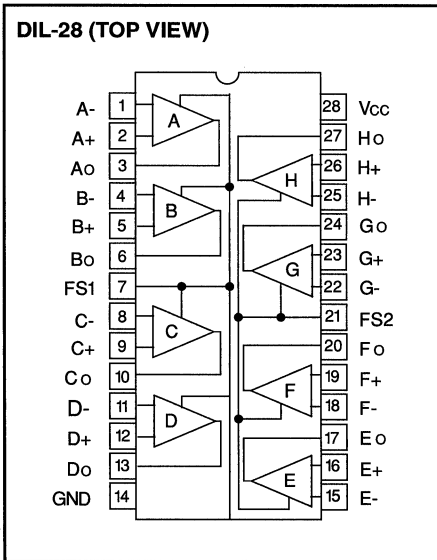
## ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage, $V_{CC}$ .....	7V
Output Sink Current .....	50mA
Output Short Circuit Time .....	1 Sec
Common Mode Input Range .....	15V
Differential Input Range .....	25V
Failsafe Voltage .....	-0.3 to $V_{CC}$
PLCC Power Dissipation, $T_A=25^\circ C$ (Note 2) .....	1000 mW
DIP Power Dissipation, $T_A=25^\circ C$ (Note 2) .....	1200 mW
Storage Temperature Range .....	-65° C to +150° C
Lead Temperature (Soldering, 10 seconds) .....	-300° C

*Note 1: All voltages are with respect to ground, pin 14. Currents are positive in, negative out of the specified terminal.*

*Note 2: Consult packaging section of Databook for thermal limitations and considerations of package.*

## CONNECTION DIAGRAMS



**DC ELECTRICAL CHARACTERISTICS:** Unless otherwise stated, these specifications apply for  $T_A = 0^\circ\text{C}$  to  $+70^\circ\text{C}$ ;  $V_{CC} = 5\text{V} \pm 5\%$ , Input Common Mode Range  $\pm 7\text{V}$ ,  $T_A = T_J$ .

PARAMETER	SYMBOL	TEST CONDITIONS	UC5181C		UNITS	
			MIN	MAX		
DC Input Resistance	$R_{IN}$	$3\text{V} \leq  V_{IN}  \leq 25\text{V}$	3	7	$\text{k}\Omega$	
Failsafe Output Voltage	$V_{OFS}$	Inputs Open or Shorted Together, or One Input Open and One Grounded	$0 \geq I_{OUT} \leq 8\text{mA}$ , $V_{FAILSAFE} = 0\text{V}$	0.45	V	
			$0 \geq I_{OUT} \geq -400\mu\text{A}$ , $V_{FAILSAFE} = V_{CC}$	2.7		
Differential Input High Threshold	$V_{TL}$	$V_{OUT} = 0.45\text{V}$ , $I_{OUT} = -440\mu\text{A}$ (See Figure 1)	$R_s = 0$ (Note 3)	50	200	mV
			$R_s = 500$ (Note 3)		400	
Differential Input Low Threshold	$V_{TL}$	$V_{OUT} = 0.45\text{V}$ , $I_{OUT} = 8\text{mA}$ (See Figure 1)	$R_s = 0$ (Note 3)	-200	-50	mV
			$R_s = 500$ (Note 3)	-400		
Hysteresis	$V_H$	$F_s = 0\text{V}$ or $V_{CC}$ (See Figure 1)	45	140	mV	
Open Circuit Input Voltage	$V_{IOC}$			75	mV	
Input Capacitance	$C_I$			20	pF	
High Level Output Voltage	$V_{OH}$	$V_{ID} = 1\text{V}$ , $I_{OUT} = -440\mu\text{A}$	2.7		V	
Low Level Output Voltage	$V_{OL}$	$V_{ID} = -1\text{V}$ (Note 4)	$I_{OUT} = 4\text{mA}$		0.4	V
			$I_{OUT} = 8\text{mA}$		0.45	
Short Circuit Output Current	$I_{OS}$	Note 5	20	100	mA	
Supply current	$I_{CC}$	$4.75\text{V} \leq V_{CC} \leq 5.25\text{V}$		35	mA	
Input Current	$I_{IN}$	Other Inputs Grounded	$V_{IN} = +10\text{V}$		3.25	mA
			$V_{IN} = -10\text{V}$	-3.25		

- Note 3:  $R_s$  is a resistor in series with each input.
- Note 4: Measure after 100 ms warm up (at  $0^\circ\text{C}$ ).
- Note 5: Only 1 output may be shorted at a time and then only for a maximum of 1 sec.
- Note 6: The delays, either  $t_{PLH}$  or  $t_{PHL}$ , shall not vary from receiver to receiver by more than 35ns.

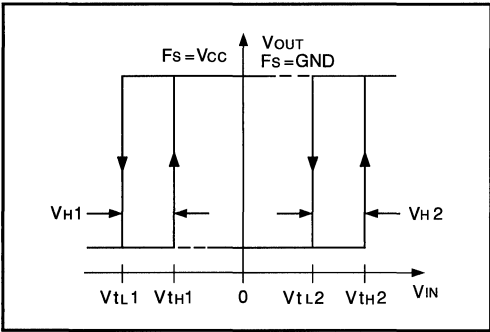


Figure 1.  $V_{TL}$ ,  $V_{TH}$ ,  $V_H$  Definition

**AC ELECTRICAL CHARACTERISTICS:**  $V_{CC} = 5\text{V} \pm 5\%$ ,  $T_A = 0^\circ\text{C}$  to  $+70^\circ\text{C}$ , Figure 2  $T_A = T_J$ .

PARAMETER	SYMBOL	TEST CONDITIONS	UC5181C		UNITS
			MIN	MAX	
Propagation Delay—Low to High	$t_{PLH}$	$C_L = 50\text{pF}$ , $V_{IN} = \pm 500\text{mV}$ (Note 6)		120	ns
Propagation Delay—High to Low	$t_{PHL}$	$C_L = 50\text{pF}$ , $V_{IN} = \pm 500\text{mV}$ (Note 6)		120	ns
Acceptable Input frequency	$f_A$	Unused Input Grounded, $V_{IN} = \pm 200\text{mV}$		5.0	MHz

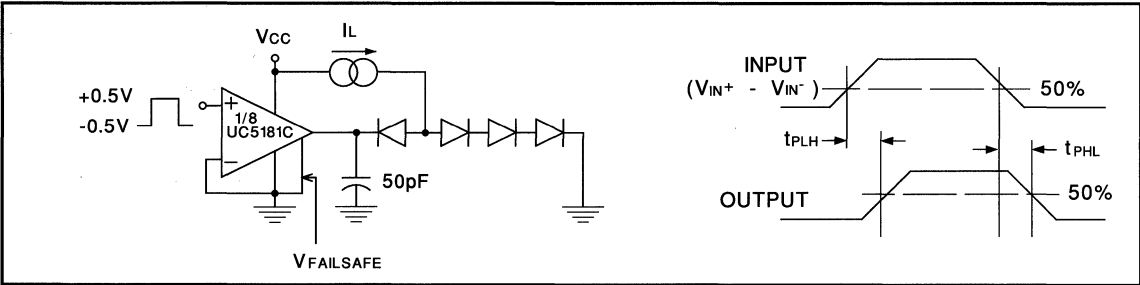


Figure 2. AC Test Circuit

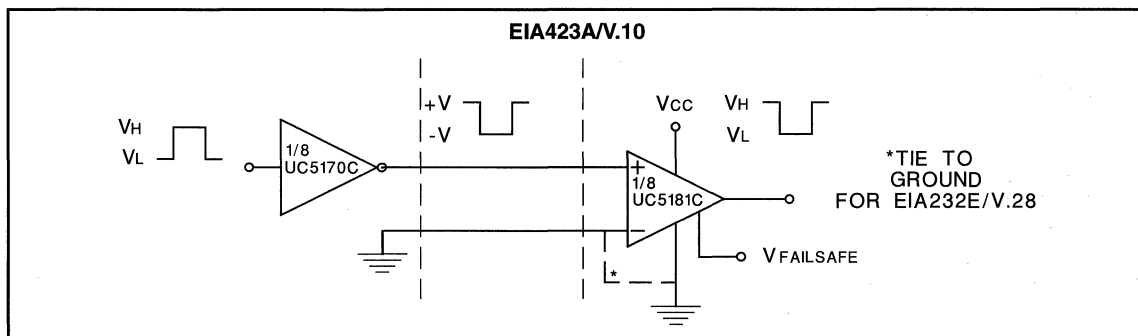
## APPLICATIONS INFORMATION

### Failsafe Operation

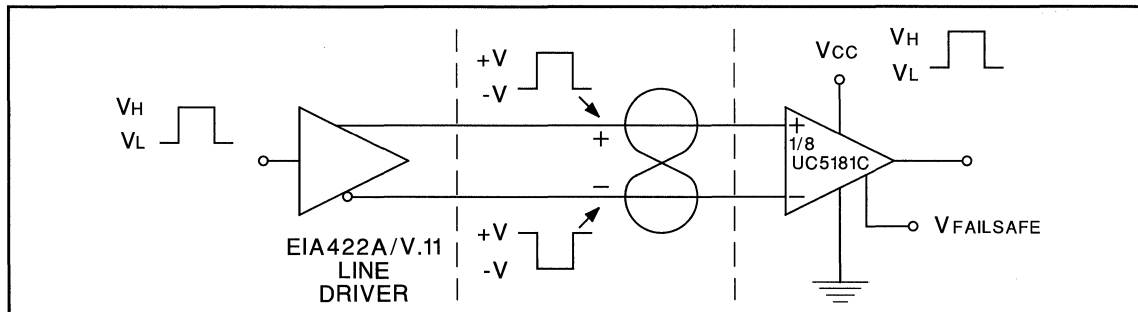
These devices provide a failsafe operating mode to guard against input fault conditions as defined in EIA422A and EIA423A standards. These fault conditions are (1) driver in power-off condition, (2) receiver not interconnected with driver, (3) open-circuited interconnecting cable, and (4) short-circuited interconnecting cable. If one of these four fault conditions occurs at the inputs of a receiver,

then the output of that receiver is driven to a known logic level. The receiver is programmed by connecting the failsafe input to VCC or ground. A connection to VCC provides a logic "1" output under fault conditions, while a connection to ground provides a logic "0". There are two failsafe pins (Fs1 and Fs2) on the UC5181C where each provides common failsafe control for four receivers.

### EIA232E/V.28 / EIA423A/V.10 DATA TRANSMISSION



### EIA422A/V.11 DATA TRANSMISSION



## GENERAL LAYOUT NOTES

The drivers and receivers should be mounted close to the system common ground point, with the ground reference tied to the common point to reduce RFI/EMI.

Filter connectors or transzorbz should be used to reduce the RFI/EMI, and protecting the system from static (ESD), and electrical overstress (EOS). A filter connector or capacitor will reduce the ESD pulse by 90% typically. A cable dragged across a carpet and connected to a system can easily be charged to over 25,000 volts. This is a metal to metal contact when the cable is connected to the

system (no resistance), currents exceed 80 amps with less than a nanosecond rise time. A transzorb provides two functions, the device capacitance inherently acts as a filter capacitor, and the device clamps the ESD and EOS pulses which would pass through the capacitor and destroy the devices. The recommended transzorb for the UC5180C and the UC5181C is P6KE22CA.

\* Transzorb is a trademark of General Semiconductor Industries.

# CAN Transceiver

## FEATURES

- Pin Compatible with PCA82C250 and DeviceNet, SDS, ISO11898 Compatible
- High Speed, up to 1Mbps
- Differential Transmit to the Bus and Receive from the Bus to the CAN Controller
- At Least 110 Nodes Can Be Connected
- 100V Transient Protection on the Transmit Output
- 24V Supply Cross Wire Protection on CANH and CANL
- No Bus Loading When Powered Down
- Operates over  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$
- Unitrode DeviceNet ID#107

## DESCRIPTION

The UC5350 Control Area Network Transceiver is designed for industrial applications employing the CAN serial communications physical layer per ISO 11898 standard. The device is a high speed transceiver designed for use up to 1Mbps. Especially designed for hostile environments, this device features cross wire, loss of ground, over voltage, and over temperature protections well as a wide common mode range.

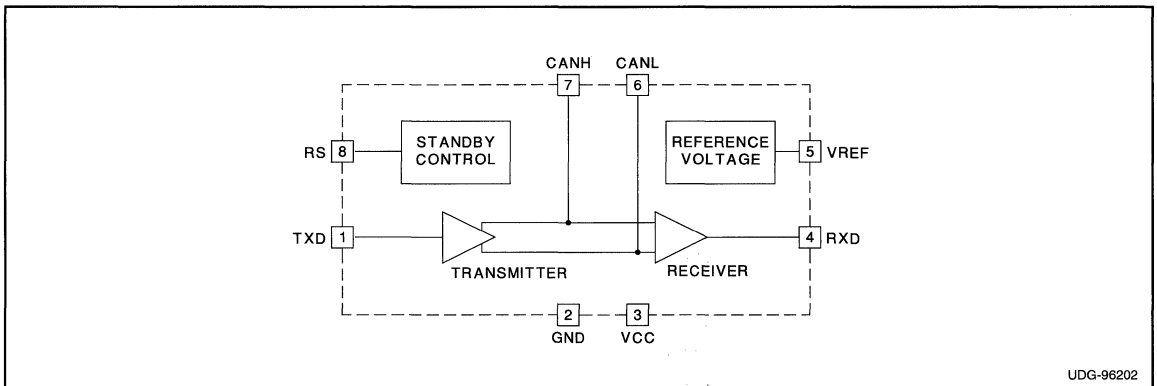
The transceiver interfaces the single ended CAN controller with the differential CAN bus found in industrial and automotive applications. It operates over the  $-7\text{V}$  to  $+12\text{V}$  common mode range of the bus and will withstand common mode transients of  $-25\text{V}$  to  $+18\text{V}$  as well as Schaffner tests. Performance features include high differential input impedance, a symmetrical differential signal driver and very low propagation delay that improves bus bandwidth and length by reducing reflection and distortion.

The transceiver operates over a wide temperature range,  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  and is available in 8-pin SOIC and Dual-in-Line packages.

## FUNCTIONAL TABLE (VCC = 4.5V to 5.5V)

Inputs		System Mode	Output Mode	Outputs	
TXD	RS			VCANH - VCANL	RXD
0	0	High Speed	Dominant	1.5V to 3V	0
1	0	High Speed	Recessive	$-120\text{mV}$ to $+12\text{mV}$	1
High Z	0	High Speed	Recessive	$-120\text{mV}$ to $+12\text{mV}$	1
X	1	Standby		High Z	0 at Bus = Dominant 1 at Bus = Recessive

## BLOCK DIAGRAM



UDG-96202



**ABSOLUTE MAXIMUM RATINGS**

Supply Voltage	-0.3V to 9V
TXD, RXD, VREF, RS	-0.3V to VCC + 0.3V
CANL, CANH	
0V < VCC < 5.5V	-8V to +36V
Non-Destructive, Non-Operative	-8V to +32V
Transient, Schaffner Test (Fig. 1)	-150 to +100V
Operating Temperature	-40°C to +125°C
Storage Temperature	-65°C to +150°C
Junction Temperature	-55°C to +150°C
Lead Temperature (Soldering, 10 sec.)	+300°C
Crosswire Protection Maximum VBUS	30V
Bus Differential Voltage*	30V
Cross Wire Protection TA	-40°C to 125°C

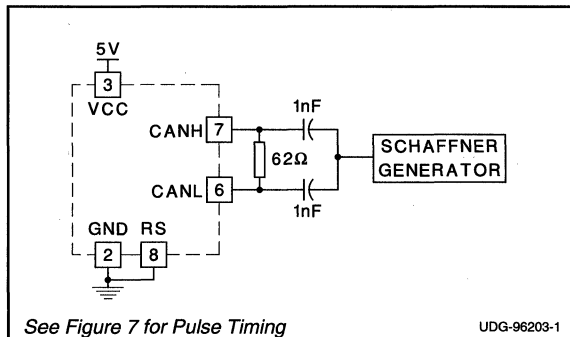
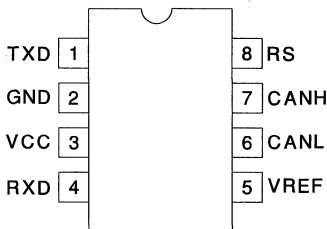
Currents are positive into, negative out of the specified terminal.

Consult Packaging Section of the Databook for thermal limitations and considerations of packages.

\*Refers to Figures 9, 10, 11, 12 and 13.

**CONNECTION DIAGRAM**

**DIL-8, SOIC-8 (Top View)  
N, D Package**



See Figure 7 for Pulse Timing

UDG-96203-1

**Figure 1. Schaffner Test**

**ELECTRICAL CHARACTERISTICS (Total Device)** Unless otherwise stated, the device is disconnected from the bus line; VCC = 4.5V to 5.5V; 60Ω in parallel with 100pF load between CANH and CANL; TA = -40°C to +125°C, TA = TJ

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Supply Voltage		4.5		5.5	V
Supply Current	Dominant, TXD = 1V			70	mA
	Recessive, TXD = 4V		9	13	mA
	Standby, RS = 4V		1	1.5	mA
RS Input Current		-10		5	μA
RS Voltage Input = Logic 1	Standby	0.75VCC			V
RS Voltage Input = Logic 0	High Speed			0.3VCC	V
Transmitter Voltage Input = Logic 1	Transmitter Output Recessive	0.7VCC			V
Transmitter Voltage Input = Logic 0	Transmitter Output Dominant			0.3VCC	V
Transmitter Current Input at Logic 1	TXD = 4V			30	μA
Transmitter Current Input at Logic 0	TXD = 1V	-30		30	μA
Receiver Voltage Output = Logic 1	RXD = -100μA, TXD = 4V	VCC - 1.0			V
Receiver Voltage Output = Logic 0	RXD = 1mA, TXD = 1V		0.75	1.0	V
	RXD = 10mA, TXD = 1V		1.2	1.5	V
CANH, CANL Input Resistance	No Load, TXD = 4V	30	43	54	kΩ
Differential Input Resistance	No Load, TXD = 4V	60	86	108	kΩ
CANH, CANL Input Capacitance	(Note 1)			20	pF
Differential Input Capacitance	(Note 1)			10	pF
Reference Output Voltage	VREF = ±50μA	0.45VCC		0.55VCC	V

Note 1: Guaranteed by design. Not 100% tested in production.



**ELECTRICAL CHARACTERISTICS (DC Parameters For Recessive State)** Unless otherwise stated, the device is disconnected from the bus line; 60Ω in parallel with 100pF load between CANH and CANL.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
V <sub>CANH</sub> , V <sub>CANL</sub>	No Load, TXD = 4V (Figure 2)	2	2.5	3	V
Differential Output Transmitter (V <sub>CANH</sub> - V <sub>CANL</sub> )	No Load, TXD = 4V (Figure 2)	-500	0	50	mV
Differential Input Receiver	Common Mode Range = -7V to +12V, TXD = 4V, CANH, CANL Externally Driven (Figure 3)	-1		0.40	V
Differential Input Resistance	No Load	60			kΩ
CANH, CANL Input Resistance		15		50	kΩ

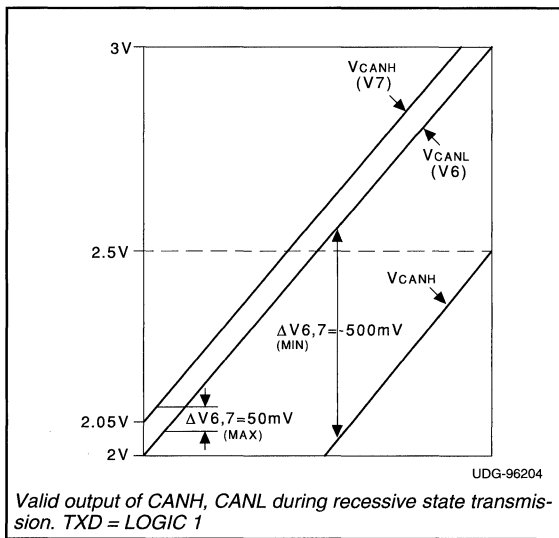


Figure 2. Recessive State Voltage Diagram

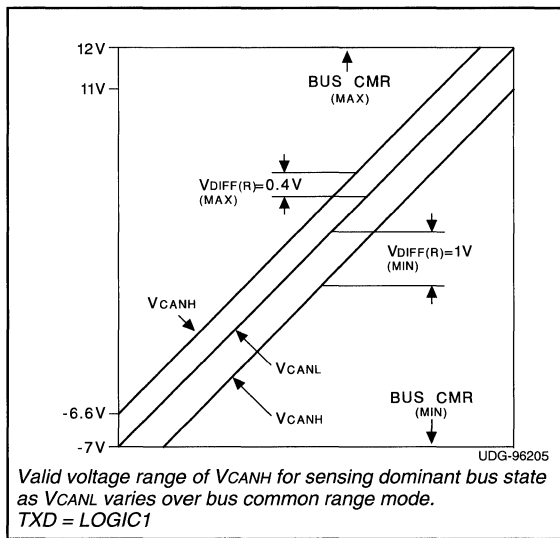
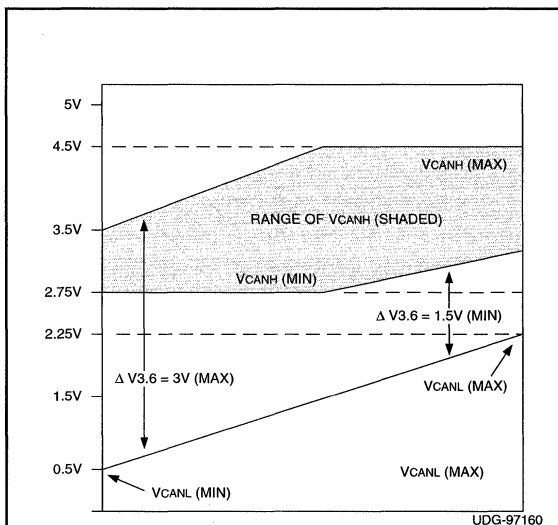


Figure 3. Recessive State Voltage Diagram

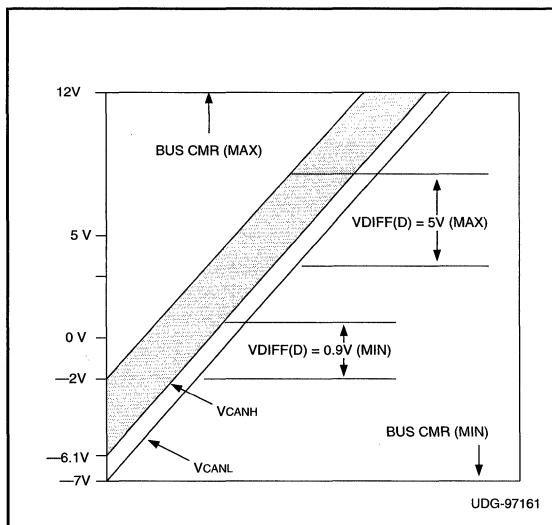
**ELECTRICAL CHARACTERISTICS (DC Parameters For Dominant State)** Unless otherwise stated, the device is disconnected from the bus line; 60Ω in parallel with 100pF load between CANH and CANL. VCC = 4.75V to 5.5V

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
CANH Output Voltage (V <sub>CANH</sub> )	TXD = 1V (Figure 4)	2.75		4.5	V
CANL Output Voltage (V <sub>CANL</sub> )	TXD = 1V (Figure 4)	0.50	1.1	2.25	V
Differential Output Transmitter (V <sub>CANH</sub> - V <sub>CANL</sub> )	TXD = 1V (Figure 4)	1.5	2	3	V
Differential Input Receiver (V <sub>DIFF(D)</sub> )	Common Mode Range = -2 to +7V, TXD = 4V, CANH, CANL Externally Driven (Figure 5)	0.9		5	V
	Common Mode Range = -7 to +12V, TXD = 4V, CANH, CANL Externally Driven (Figure 5)	1.0		5	V



Valid voltage range of V<sub>CANH</sub> for sensing recessive bus state as V<sub>CANL</sub> varies over bus common mode range. TXD = LOGIC 1

**Figure 4. Dominant State Voltage Diagram**



Valid voltage range of V<sub>CANH</sub> for sensing dominant bus state as V<sub>CANL</sub> varies over bus common range mode. TDX = LOGIC 0

**Figure 5. Dominant State Voltage Diagram**

**TRANSMITTER CHARACTERISTICS**

Unless otherwise stated, the device is disconnected from the bus line; 60Ω in parallel with 100pF load between CANH and CANL.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Differential Output Transmitter (VCANH - VCANL)	Dominant Mode	1.5	2	3	V
	Recessive Mode	-500		50	mV
Delay From TXD to Bus Active TON (TXD)	(Figure 6)		45	65	ns
Delay From TXD to Bus Inactive TOFF (TXD)	60Ω Across CANH and CANL (Figure 6)		40	80	ns

**RECEIVER CHARACTERISTICS**

Unless otherwise stated, the device is disconnected from the bus line; 60Ω in parallel with 100pF load between CANH and CANL.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Differential Input Receiver (VCANH - VCANL)	Dominant Mode, TXD = 4V	0.9			V
	Recessive Mode, TXD = 4V			0.4	V
Differential Input Hysteresis	TXD = 4V		150		mV
Delay From Bus to RXD (TON)	Inactive to Active Bus (Figure 6)			55	ns
Delay From Bus to RXD (TOFF)	Active to Inactive Bus, 60Ω Across CANH and CANL (Figure 6)			145	ns
Delay From Bus to RXD (TOFF)	TA = -25°C to 85°C Active to Inactive Bus, 60Ω Across CANH and CANL (Figure 6)			75	ns

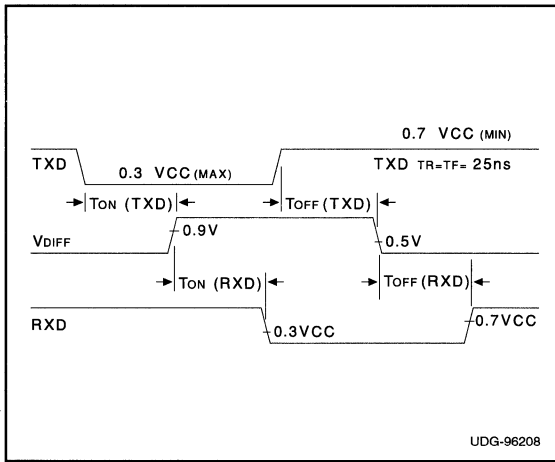


Figure 6. Transceiver AC Response

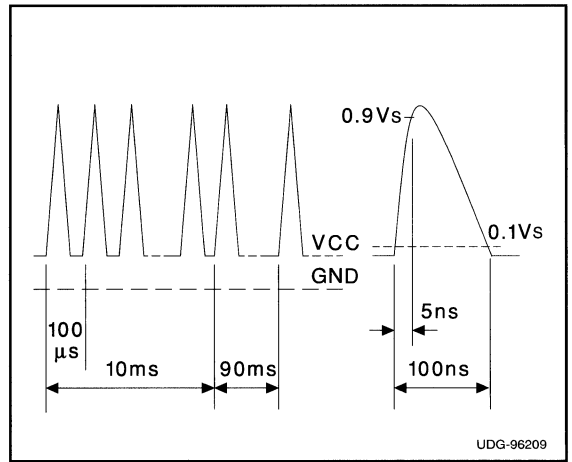


Figure 7. Timing Diagram for Schaffner Tests

**Magnitude Specifications for Vs**

ISO	DIN 40839-1	Schaffner
DP7637/1	(Draft)	NSG500C/506C
Up to 150V	Up to 150V	40V to 200V

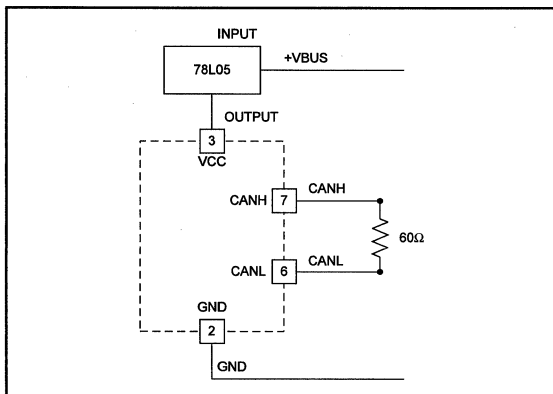


Figure 8. Normal Connection

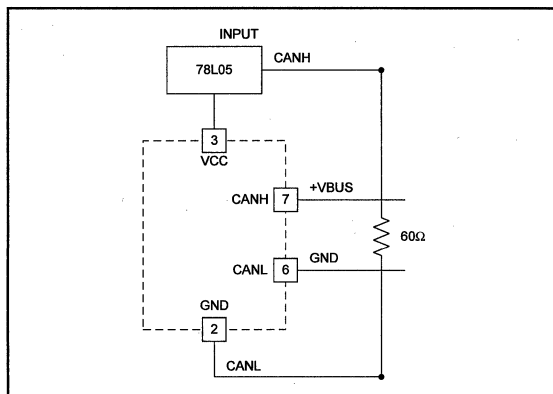


Figure 9. Crosswire No. 1

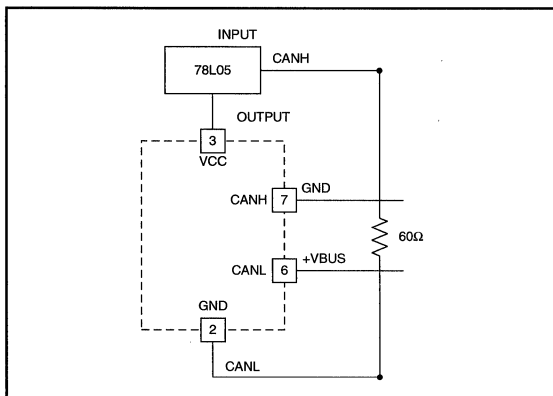


Figure 10. Crosswire No. 2

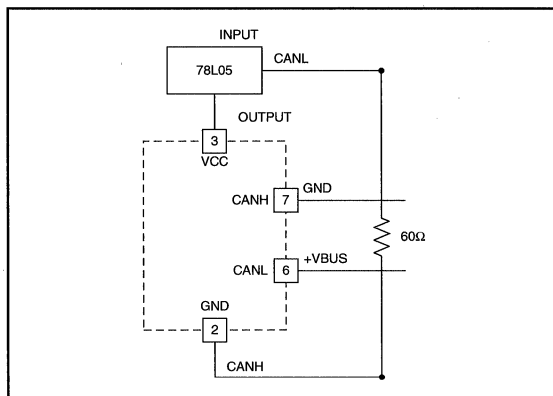


Figure 11. Crosswire No. 3

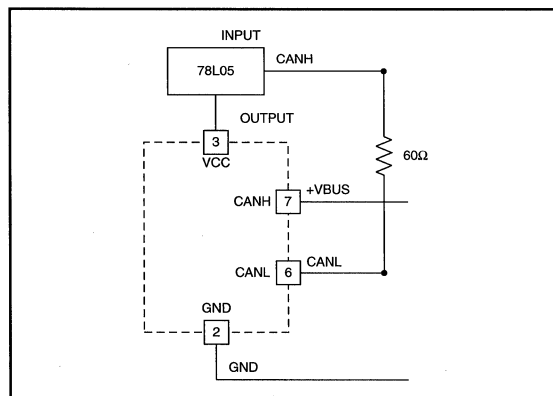


Figure 12. Crosswire No. 4

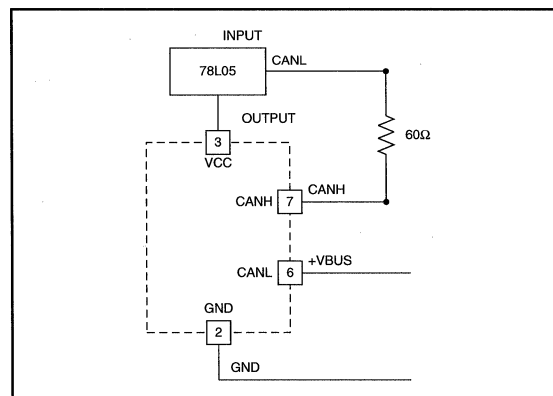


Figure 13. Crosswire No. 5

# CAN Transceiver with Voltage Regulator

## FEATURES

- DeviceNet, SDS, ISO 11898 Compatible
- High Speed, up to 1Mbps
- Differential Transmitter and Receiver bus interface
- -25V to +18V Protection on CANH and CANL
- Loss of Ground Protection
- High Differential Input Impedance
- Supports 110 nodes or more
- Operates over -25°C to +85°C
- Unitrode DeviceNet ID#107

## DESCRIPTION

The UC5351 Control Area Network (CAN) Transceiver is designed for industrial applications employing the CAN serial communications physical layer per the ISO 11898 standard. The device is a high speed transceiver plus voltage regulator designed for use up to 1Mbps. Especially designed for hostile environments, this device features cross-wire and over voltage protection, thermal shutdown, a wide common mode range, and loss of ground protection.

The UC5351 CAN Transceiver interfaces the single ended CAN Controller with the differential CAN Bus found in industrial and automotive applications. Performance features include high input impedance, a symmetrical differential signal driver, and low propagation delay that improve bus bandwidth and length, while reducing reflection and distortion. Reduced reflection and distortion results in increases of effective bus length and bandwidth.

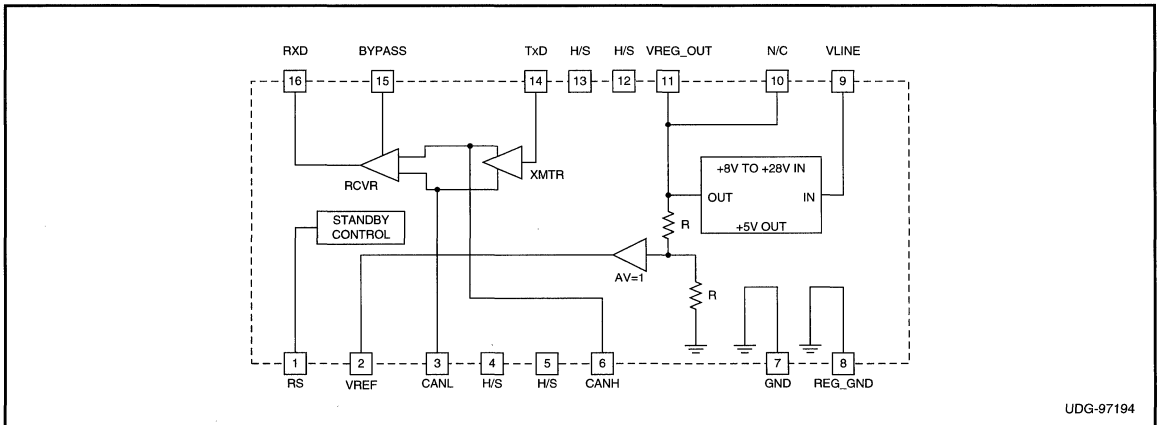
The on-board regulator permits direct connection to a +8V to 24V power bus and supply power to the transceiver with 40mA of reserve output current to power external components.

The transceiver operates over a wide temperature range, -25°C to 85°C, and is available in a 16-pin power SOIC package.

FUNCTIONAL TABLE (VLINE = 8V TO 28V)					
Inputs		System Mode	Output Mode	Outputs	
TxD	Rs			V <sub>CANH</sub> - V <sub>CANL</sub>	RxD
0	0	High Speed	Dominant	1.5V to 3V	0
1	0	High Speed	Recessive	-120mV to +12mV	1
High Z	0	High Speed	Recessive	-120mV to +12mV	1
X	1	Standby		high Z	A & "0" @ Bus = Dominant A & "0" @ Bus = Recessive



## BLOCK DIAGRAM

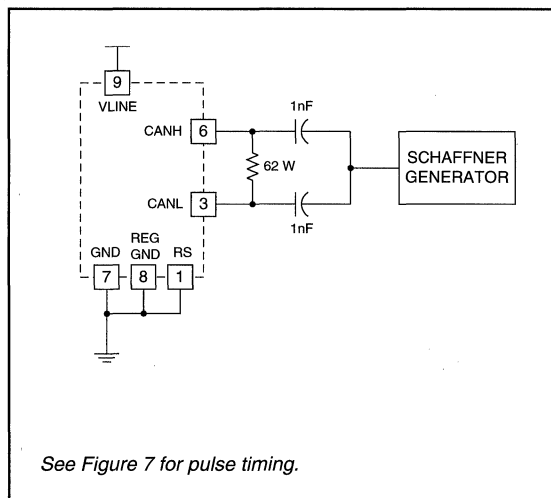
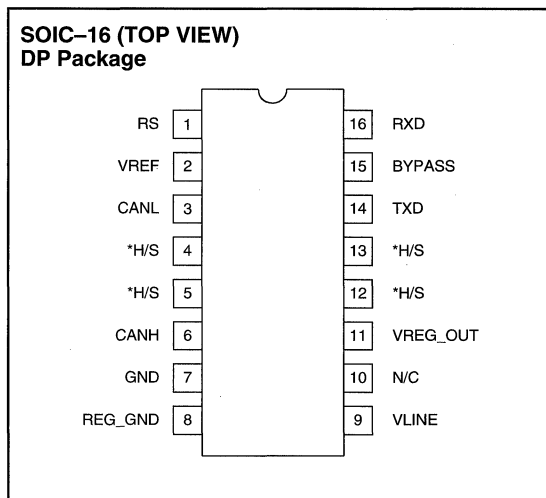


UDG-97194

## ABSOLUTE MAXIMUM RATINGS

Supply Voltage . . . . . -0.3V to +36V  
 TXD, RXD, VREF, RS . . . . . -0.3V to VCC +0.3V  
 CANL, CANH 8V < VLINE < 28V . . . . . -8V to +36V  
 Non-Destructive, Non-Operative . . . . . -8V to +32V  
 Transient, Schaffner Test (Figure 1) . . . . . -150V to +100V  
 Operating Temperature . . . . . -25°C to +85°C  
 Storage Temperature . . . . . -65°C to +150°C  
 Junction Temperature . . . . . -55°C to +150°C  
 Lead Temperature (Soldering, 10 sec) . . . . . +300°C  
*Currents are positive into, negative out of the specified terminal.  
 Consult Packaging Section of the Databook for thermal limitations and consideration of packages.*

## CONNECTION DIAGRAM



*\*Warning: H/S pins are connected to the substrate which must float, attach all four pins to at least 0.5 square inch of etch.  
**DO NOT ATTACH TO GROUND!***

**ELECTRICAL CHARACTERISTICS (Total Device)** Unless otherwise stated, the device is disconnected from the bus line; VLINE = 10V; I<sub>o</sub>(VREG\_OUT) = -40mA; C<sub>VLINE</sub>=0.33μF; C<sub>VREG\_OUT</sub> = 0.1μF; C<sub>BYPASS</sub> = 0.1μF; 60Ω in parallel with 100pF between CANH and CANL; T<sub>J</sub> = -25°C to +150°C. V<sub>R</sub> = VREG\_OUT Voltage.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
<b>Section</b>					
Supply Voltage (VLINE)		8		28	V
Supply Current (VLINE)	Dominant, TXD = 1V; I <sub>o</sub> (VREG_OUT) = 0			75	mA
	Recessive, TXD = 4V; I <sub>o</sub> (VREG_OUT) = 0		12	17	mA
	Standby, RS = 4V; I <sub>o</sub> (VREG_OUT) = 0		6.5	9	mA
Output Voltage (VREG_OUT)	T <sub>J</sub> = 25°C	4.8	5	5.2	V
	1mA < I <sub>o</sub> (VREG_OUT) < 40mA; 8V < VLINE < 28V	4.75		5.25	V
Line Regulation (VREG_OUT)	T <sub>J</sub> = 25°C, 8V < VLINE < 28V			90	mV
Load Regulation (VREG_OUT)	T <sub>J</sub> = 25°C, 1mA < I <sub>o</sub> (VREG_OUT) < 40mA			60	mV
Ripple Rejection (VREG_OUT)	f=120Hz, 8V < VLINE < 16V	47			dB
RS Input Current		-5		5	μA
RS Input Voltage = Logic 1	Standby	(0.75)•V <sub>R</sub>			V
RS Input Voltage = Logic 0	High Speed			(0.3)•V <sub>R</sub>	V

**ELECTRICAL CHARACTERISTICS (Total Device)** Unless otherwise stated, the device is disconnected from the bus line;  $V_{LINE} = 10V$ ;  $I_o(V_{REG\_OUT}) = -40mA$ ;  $C_{VLINE} = 0.33\mu F$ ;  $C_{VREG\_OUT} = 0.1\mu F$ ;  $C_{BPASS} = 0.1\mu F$ ;  $60\Omega$  in parallel with  $100pF$  between CANH and CANL;  $T_J = -25^\circ C$  to  $+150^\circ C$ .  $V_R = V_{REG\_OUT}$  Voltage.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Transmitter Voltage Input = Logic 1	Transmitter Output Recessive	$(0.7) \cdot V_R$			V
Transmitter Voltage Input = Logic 0	Transmitter Output Dominant			0.3	V
Transmitter Current Input at Logic 1	TXD = 4V			30	$\mu A$
Transmitter Current Input at Logic 0	TXD = 1V	-30		30	$\mu A$
Receiver Voltage Output = Logic 1	RXD = $-100\mu A$	$(0.8) \cdot V_R$			V
Receiver Voltage Output = Logic 0	RXD = 1mA			$(0.2) \cdot V_R$	V
	RXD = 10mA			1.5	V
CANH, CANL Input Resistance	No Load	34	43	54	$k\Omega$
Differential Input Resistance	No Load	68	86	108	$k\Omega$
CANH, CANL Input Capacitance	(Note 1)			20	pF
Differential Input Capacitance	(Note 1)			10	pF
Reference Output Voltage	I (VREF) = $\pm 50\mu A$	$(0.45) \cdot V_R$		$(0.55) \cdot V_R$	V

Note: Guaranteed by design. Not 100% tested in production.

**ELECTRICAL CHARACTERISTICS (DC Parameters for Recessive State)** Unless otherwise stated, the device is disconnected from the bus line;  $60\Omega$  in parallel with  $100pF$  load between CANH and CANL.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
$V_{CANH}$ , $V_{CANL}$	No Load, TXD = 4V (Figure 2)	2	2.5	3	V
Differential Output Transmitter ( $V_{CANH}$ , $V_{CANL}$ )	No Load, TXD = 4V (Figure 2)	-500	0	50	mV
Differential Input Receiver		-1		0.4	V
Differential Input Resistance	No Load	68		108	$k\Omega$
Differential Input Receiver	Common Mode Range = $-7V$ to $+12V$ , TXD = 4V, CANH, CANL Externally Driven (Figure 3)	-1		0.40	V
Differential Input Resistance	No Load	68		108	$k\Omega$

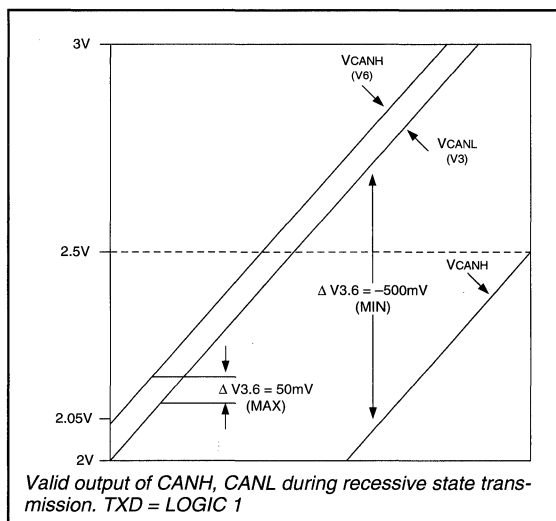


Figure 2. Recessive State Voltage Diagram

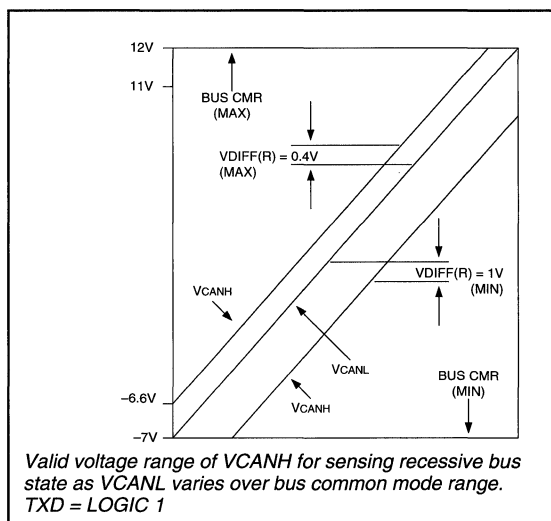


Figure 3. Recessive State Voltage Diagram

**ELECTRICAL CHARACTERISTICS  
(DC Parameters for Dominant State)**

Unless otherwise stated, the device is disconnected from the bus line; 60Ω in parallel with 100pF load between CANH and CANL.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
CANH Output Voltage (V <sub>CANH</sub> )	TXD = 1V (Figure 4)	2.75	3.5	4.5	V
CANL Output Voltage (V <sub>CANL</sub> )	TXD = 1V (Figure 4)	0.5	1.5	2.25	V
Differential Output Transmitter (V <sub>CANH</sub> – V <sub>CANL</sub> )	TXD = 1V (Figure 4)	1.5	2	3	V
Differential Input Transmitter (V <sub>DIFF(D)</sub> )	Common Mode Range = –7V to +12V; TXD = 4V, CANH, CANL Externally Driven (Figure 5)	0.9		5	V

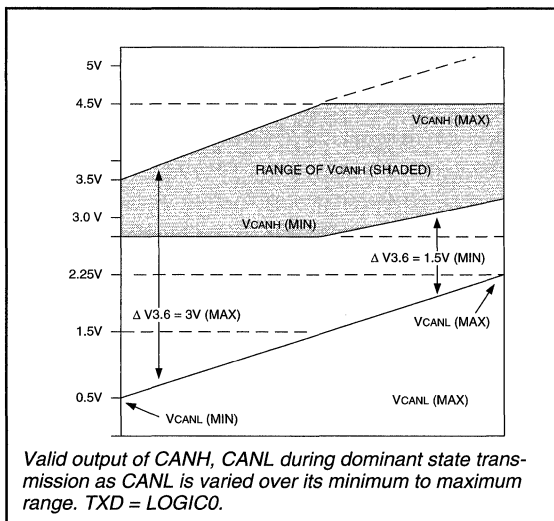


Figure 4. Dominant State Voltage Diagram

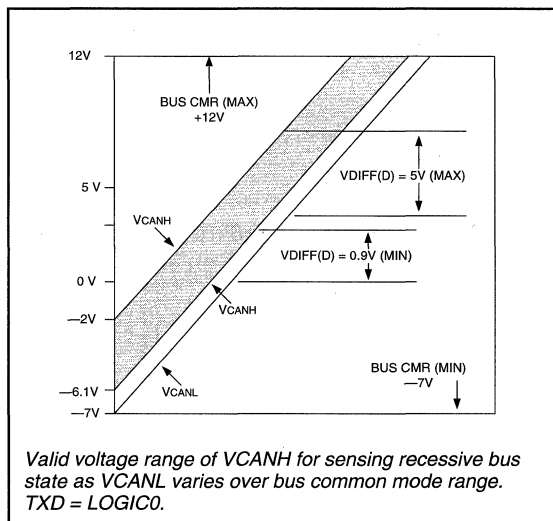


Figure 5. Dominant State Voltage Diagram

**TRANSMITTER CHARACTERISTICS**

Unless otherwise stated, the device is disconnected from the bus line; 60Ω in parallel with 100pF load between CANH and CANL.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Differential Output Transmitter (V <sub>CANH</sub> – V <sub>CANL</sub> )	Dominant Mode	1.5	2	3	V
	Recessive Mode	– 500		50	mV
Delay From TXD to Bus Active T <sub>ON</sub> (TXD)	(Figure 6)			75	nS
Delay From TXD to Bus Active T <sub>OFF</sub> (TXD)	60Ω Across CANH and CANL (Figure 6)			75	nS

**RECEIVER CHARACTERISTICS**

Unless otherwise stated, the device is disconnected from the bus line; 60Ω in parallel with 100pF load between CANH and CANL.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Differential Input Transmitter (V <sub>CANH</sub> – V <sub>CANL</sub> )	Dominant Mode, TXD = 4V	0.9			V
	Recessive Mode, TXD = 4V		150		mV
Differential Input Hysteresis	TXD = 4V		150		mV
Delay from Bus to RXD (T <sub>ON</sub> )	Inactive to Active Bus (Figure 6)			150	nS
Delay from Bus to RXD (T <sub>OFF</sub> )	Active to Inactive Bus; 60Ω Across CANH and CANL (Figure 6)			150	nS



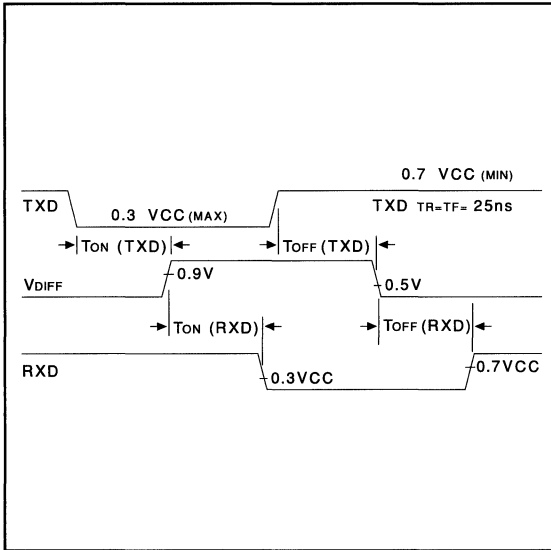


Figure 6. Tranceiver AC Response

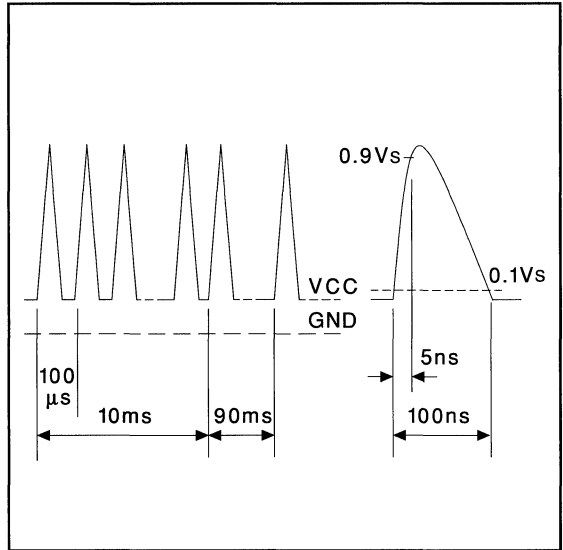
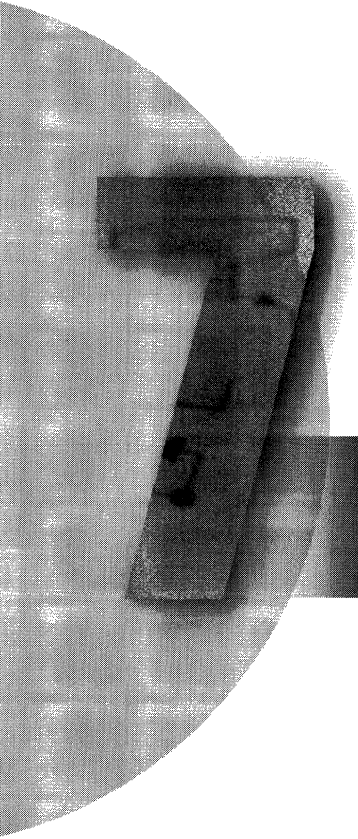


Figure 7. Timing Diagram for Schaffner Tests

Magnitude Specifications for $V_s$		
ISO	DIN-40839-1	Schaffner
DP7637/1	(Draft)	NSG500C/506C
Up to 150V	Up to 150V	40V to 200V







# Unitrode Product Portfolio







## **Interface Products**

### ***SCSI***

Multimode / LVD SCSI Active Terminators .....	7-3
Single Ended SCSI Active Terminators .....	7-4
Special Functions Circuit .....	7-6

### ***Bus Bias Generators***

Special Functions .....	7-6
-------------------------	-----

### ***Hot Swap Power Manager***

Hot Swap Power Managers .....	7-7
Special Functions .....	7-8

### ***Drivers / Receivers***

Interface Drivers, Receivers .....	7-10
------------------------------------	------

### ***Transceivers***

Interface Transceivers .....	7-10
------------------------------	------

## **Nonvolatile Products**

Static-RAM Nonvolatile Controllers .....	7-11
Real-Time Clocks .....	7-12
Real-Time Clock Cross-Reference .....	7-13
Nonvolatile Static RAM .....	7-14
Nonvolatile Static RAM Cross Reference .....	7-15

## **Portable Power Products**

Battery Charge Management .....	7-16
bq2002 Family .....	7-18
bq2004 Family .....	7-20
Li-Ion PWM Charge IC .....	7-21
Battery Capacity-Monitoring .....	7-22
bq2011 Family .....	7-23
Battery Management Modules .....	7-24
Pack-Protection and Supervisory .....	7-25
Power Management .....	7-26
Linear Regulation .....	7-27
Back-Light Controller .....	7-30
IrDA .....	7-31





## Power Supply Control Products

### ***PWM Control***

Current Mode Controllers .....	7-31
Dedicated DC/DC Controllers .....	7-43
Power Controllers .....	7-46
Power Support .....	7-48
Post Regulation Controllers .....	7-49
Secondary Side Control .....	7-50
Soft Switching Controllers .....	7-51
Voltage Mode Controllers .....	7-55

### ***Power Factor Correction***

Power Factor Correction Products .....	7-61
--	------

### ***Linear Regulation***

Linear Controllers .....	7-64
Low Dropout Linear Regulators .....	7-65
Special Function .....	7-66

### ***Power Drivers***

Power and FET Drivers .....	7-67
-----------------------------	------

### ***Power Supply Support***

Feedback Signal Generators .....	7-70
Load Share Controllers .....	7-71
Diode Array/Bridges .....	7-71
Supervisory and Monitor Circuits .....	7-72

### ***Motion Control***

Motor Products .....	7-73
DC Motor Controllers .....	7-73
Linear Power Amplifier Products .....	7-74
Phase Locked Frequency Controllers .....	7-74
Stepper Motor Controllers .....	7-75

### ***Special Functions***

Current Sensors .....	7-76
Lighting Controllers .....	7-76
Ring Generator Controllers .....	7-77
Sensor Drivers .....	7-78
Serial DACs .....	7-78

# Interface (IF) Selection Guides



## SCSI

Multimode / LVD SCSI Active Terminators	UNITRODE PART NUMBER				
	UCC5628+	UCC5630	UCC5632	UCC5638+	UCC5639+
Channels	14	9	9	15	15
Channel Capacitance	4	4	4	4	4
Termination Impedance	Single110, Differential 105, Common Mode 150	Single110, Differential 105, Common Mode 150	Single 110, Differential 105, Common Mode 150	Single 110, Differential 105, Common Mode 150	Single 110, Differential 105, Common Mode 150
Disconnect High or Low	H	H	H	H	L
Tempwr Voltage Range	2.7 - 5.25	2.7 - 5.25	2.7 - 5.25	2.7 - 5.25	2.7 - 5.25
Supports Active Negation	Y	Y	Y	Y	Y
SCSI Hot Plug Current	<10nA	<10nA	<10nA	<10nA	<10nA
Type LVD or SE / LVD	LVD / SE	LVD / SE	LVD / SE	LVD / SE	LVD / SE
Page Number	IF/3-78	IF/3-83	IF/3-93	IF/3-94	IF/3-99

Multimode / LVD SCSI Active Terminators	UNITRODE PART NUMBER		
	UCC5640+	UCC5641+	UCC5646
Channels	9	9	27
Channel Capacitance	3	3	3
Termination Impedance	Differential 105, Common Mode 150	Differential 105, Common Mode 150	Differential 105, Common Mode 150
Disconnect High or Low	H	L	H
Tempwr Voltage Range	2.7 - 5.25	2.7 - 5.25	2.7 - 5.25
SCSI Hot Plug Current	<10nA	<10nA	<10nA
Type LVD or SE / LVD	LVD	LVD	LVD
Page Number	IF/3-104	IF/3-108	IF/3-112

+ New Product



# Interface (IF) Selection Guides



## SCSI (cont.)

Multimode / LVD SCSI Active Terminators	UNITRODE PART NUMBER			
	UCC5510+	UCC5630A	UCC5672+	UCC5680
<b>Channels</b>	9	9	9	9
<b>Channel Capacitance</b>	4	4	4	4
<b>Termination Impedance</b>	Single110, Differential 105, Common Mode 150	Single110, Differential 105, Common Mode 150	Single110, Differential 105, Common Mode 150	Single 110, Differential 105, Common Mode 150
<b>Diff B input filter</b>	N	N	Y	Y
<b>Disconnect High or Low</b>	N/A	H	H	H
<b>Tempwr Voltage Range</b>	2.7 - 5.25	2.7 - 5.25	2.7 - 5.25	2.7 - 5.25
<b>Supports Active Negation</b>	Y	Y	Y	Y
<b>SCSI Hot Plug Current</b>	<10nA	<10nA	<10nA	<10nA
<b>Type LVD or SE / LVD</b>	LVD / SE	LVD / SE	LVD / SE	LVD
<b>Page Number</b>	IF/3-5	IF/3-87	IF/3-120	IF/3-121

Single Ended SCSI Active Terminators	UNITRODE PART NUMBER				
	UC5601	UC5602	UC5603	UC5604	UC5605
<b>Channels</b>	18	18	9	9	9
<b>Channel Capacitance</b>	10	11	6	9	4
<b>Termination Impedance</b>	110	110	110	110	110
<b>Disconnect High or Low</b>	H	H	H	H	L
<b>Tempwr Voltage Range</b>	4 - 5.25	4 - 5.25	4 - 5.25	4 - 5.25	4 - 5.25
<b>Supports Active Negation</b>	N	N	Y	N	Y
<b>SCSI Hot Plug Current</b>	<10nA	<10nA	<10nA	<10nA	<10nA
<b>Type SE, LVD or SE / LVD</b>	SE	SE	SE	SE	SE
<b>Page Number</b>	IF/3-9	IF/3-13	IF/3-18	IF/3-22	IF/3-26

+ New Product



## Interface (IF) Selection Guides



### SCSI (cont.)

Single Ended SCSI Active Terminators	UNITRODE PART NUMBER				
	UCC5606	UC5607	UC5608	UC5609	UC5612
Channels	9	18	18	18	9
Channel Capacitance	1.8	8	6	6	4
Termination Impedance	110 & 2500	110	110	110	110
Disconnect High or Low	L	2L	H	L	H
Tempwr Voltage Range	2.7 - 5.25	4 - 5.25	4 - 5.25	4 - 5.25	4 - 5.25
Supports Active Negation	Y	Y	Y	Y	Y
SCSI Hot Plug Current	<10nA	<10nA	<10nA	<10nA	<10nA
Type SE, LVD or SE / LVD	SE	SE	SE	SE	SE
Page Number	IF/3-30	IF/3-34	IF/3-37	IF/3-40	IF/3-43

Single Ended SCSI Active Terminators	UNITRODE PART NUMBER				
	UC5613	UCC5614	UCC5617	UCC5618	UCC5619
Channels	9	9	18	18	27
Channel Capacitance	3	1.8	2.5	2.5	3
Termination Impedance	110	110 & 2500	110	110	110
Disconnect High or Low	H	H	L	H	L
Tempwr Voltage Range	4 - 5.25	2.7 - 5.25	4 - 5.25	4 - 5.25	4 - 5.25
Supports Active Negation	Y	Y	Y	Y	Y
SCSI Hot Plug Current	<10nA	<10nA	<10nA	<10nA	<10nA
Type SE, LVD or SE / LVD	SE	SE	SE	SE	SE
Page Number	IF/3-47	IF/3-51	IF/3-55	IF/3-59	IF/3-63

+ New Product



## Interface (IF) Selection Guides



### SCSI (cont.)

Single Ended SCSI Active Terminators	UNITRODE PART NUMBER		
	UCC5620	UCC5621	UCC5622
Channels	27	27	27
Channel Capacitance	3	3	3
Termination Impedance	110	110	110
Disconnect High or Low	H	Split Low	Split High
Tempwr Voltage Range	4 - 5.25	4 - 5.25	4 - 5.25
Supports Active Negation	Y	Y	Y
SCSI Hot Plug Current	<10nA	<10nA	<10nA
Type SE, LVD or SE / LVD	SE	SE	SE
Page Number	IF/3-66	IF/3-70	IF/3-74

Special Functions Circuit	UNITRODE PART NUMBER		
	UCC5661		
Part Name	Ethernet Coaxial Impedance Monitor		
Description	Contains all the Functions Required to Monitor Ethernet Coaxial Systems and is Compatible with IEEE 802.3, 10Base5, 10Base2, and 10BaseT		
Page Number	IF/3-112		

+ New Product

### Bus Bias Generators

Special Functions	UNITRODE PART NUMBER				
	UC382	UC385	UC560	UCC561+	UC563+
Bus Standard	GTL / BTL	GTL / BTL	SCSI-1,2,3	SPI-2,3	VME / VME64
Sink / Source Current	Pgm / 3A	Pgm / 5A	300mA / -750mA	200mA / -200mA	475mA / -575mA
Page Number	PS/4-2	PS/4-8	IF/4-3	IF/4-7	IF/4-10

+ New Product

# Interface (IF) Selection Guides



## Hot Swap Power Managers

Hot Swap Power Managers	UNITRODE PART NUMBER				
	UCC3912	UCC3913	UC3914	UCC3915	UCC39151
<b>Voltage Range</b>	3V to 8V	-10.5V to External Limitation	5V to 35V	7V to 15V	7V to 15V
<b>Current Range</b>	0A to 3A	Externally Limited	Externally Limited	0A to 3A	0A to 3A
<b>Integrated Power FET</b>	Y	N	N	Y	Y
<b>RDSon</b>	150mΩ	N/A	N/A	150mΩ	150mΩ
<b>Programmable Fault Threshold</b>	Y	Y	Y	Y	Y
<b>Programmable Time Delay</b>	Y	Y	Y	Y	Y
<b>Latched Fault Mode</b>	N	Y	Y	N	N
<b>Average Power Limiting</b>	N/A	Y	Y	N/A	N/A
<b>Application / Design Note</b>	DN-58, DN-68, U-151	DN-67		DN-58, DN-68, U-151	DN-58, DN-68, U-151
<b>Available Package</b>	TSSOP, SOIC or PDIP	SOIC or PDIP	SOIC or PDIP	TSSOP, SOIC or PDIP	TSSOP, SOIC or PDIP
<b>Page Number</b>	IF/5-9	IF/5-15	IF/5-23	IF/5-37	IF/5-42

Hot Swap Power Managers	UNITRODE PART NUMBER				
	UCC3916	UCC39161	UCC3917+	UCC3918	UCC3919
<b>Voltage Range</b>	4V to 6V	4V to 6V	10V to External Limitation	3V to 6V	3V to 8V
<b>Current Range</b>	-1.8A to -1.5A	-1A to -0.7A	Externally Limited	0A to 4A	Externally Limited
<b>Integrated Power FET</b>	Y	Y	N	Y	N
<b>RDSon</b>	220mΩ	220mΩ	N/A	60mΩ	N/A
<b>Programmable Fault Threshold</b>	N	N	Y	Y	Y
<b>Programmable Time Delays</b>	Y	Y	Y	Y	Y
<b>Latched Fault Mode</b>	N	N	Y	N	Y
<b>Average Power Limiting</b>	N/A	N/A	Y	N/A	Y
<b>Application / Design Note</b>			DN-98	DN-87	DN-95
<b>Available Package</b>	SOIC or PDIP	SOIC or PDIP	SOIC or PDIP	SOIC or PDIP	SOIC or PDIP
<b>Page Number</b>	IF/5-47	IF/5-50	IF/5-53	IF/5-61	IF/5-68

+ New Product



# Interface (IF) Selection Guides



## Hot Swap Power Managers (cont.)

Hot Swap Power Managers	UNITRODE PART NUMBER				
	UCC3921	UCC3995+	UCC3996+		
Voltage Range	-10.5V to External Limitation	2.75V to 5.5V	2.75V to 13.6V Two Supplies Sequenced		
Current Range	Externally Limited	Externally Limited	Externally Limited		
Integrated Power FET	N	N	N		
RDSon	N/A	N/A	N/A		
Programmable Fault Threshold	Y	Y	Y		
Programmable Time Delay	Y	Y	Y		
Latched Fault Mode	Y	N	Y		
Average Power Limiting	Y	Y	Y		
Application / Design Note					
Available Package	SOIC or PDIP	TSSOP or SOIC	TSSOP, SOIC or PDIP		
Page Number	IF/5-78	IF/5-98	IF/5-100		

Special Functions	UNITRODE PART NUMBER				
	UCC3831	UCC38531	UCC3981+	UCC39811+	UCC3985+
Part Name	Universal Serial Bus Power Controller	Universal Serial Bus Power Controller	Universal Serial Bus Power Controller	Universal Serial Bus Power Controller	CompactPCI Hot Swap Power Manager
Description	Powers Four 5V Peripherals and One 3.3V USB Controller	Powers Four 5V Peripherals and One 3.3V USB Controller	Powers Four 5V Peripherals and One 3.3V USB Controller	Powers Four 5V Peripherals and One 3.3V USB Controller	Fully CompactPCI Compliant. Four Channels for Individual Control of Four Supplies 12V, -12V, 5V, and 3.3V
Application / Design Note					
Available Package	SOIC or PDIP	SOIC or PDIP	SOIC or PDIP	SOIC or PDIP	TSSOP, SOIC or PDIP
Page Number	IF/5-3	IF/5-6	IF/5-88	IF/5-91	IF/5-94

+ New Product

# Interface (IF) Selection Guides



## Drivers / Receivers Transceivers

Interface Drivers, Receivers	UNITRODE PART NUMBER				
	UC5170C	UC5171	UC5172	UC5180C	UC5181C
<b>Drivers</b>	8	8	8		
<b>Receivers</b>				8	8
<b>Power</b>	±10V	±10V	±10V	+5V	+5V
<b>EIA232 / V.28</b>	Y	Y	Y	Y	Y
<b>EIA423 / V.10</b>	Y	Y	Y	Y	Y
<b>EIA422 / V.11</b>	N	N	N	Y	Y
<b>V.35</b>	N	N	N	Y	Y
<b>Appletalk</b>	N	N	N	N	Y
<b>Page Number</b>	IF/6-3	IF/6-7	IF/6-11	IF/6-15	IF/6-18

+ New Product

Interface Transceivers	UNITRODE PART NUMBER			
	UC5350	UC5351+		
<b>Drivers</b>	1	1		
<b>Receivers</b>	1	1		
<b>Power</b>	+5V	+5V to 24V		
<b>Control Area Network</b>	Y	Y		
<b>Device Net</b>	Y	Y		
<b>SDS</b>	Y	Y		
<b>Page Number</b>	IF/6-21	IF/6-27		

+ New Product



## Nonvolatile SRAMs and RTCs (NV) Selection Guides



Unitrode nonvolatile controllers provide power monitoring, write-protection, and supply switching to convert standard SRAM and a backup battery into a reliable, predictable nonvolatile memory. The nonvolatile controller modules are complete battery-backup solutions including an encapsulated 130mAh lithium cell that is isolated until power is applied.

- Power monitoring and switching for 3V battery-backup applications
- 5V  $V_{CC}$  operation
- Automatic write-protection during power-up/power-down cycles
- Automatic switching from  $V_{CC}$  to first backup battery and from first backup battery to second backup battery
- Battery internally isolated until power is first supplied
- Industrial temperature range available

### Static-RAM Nonvolatile Controller Selection Guide

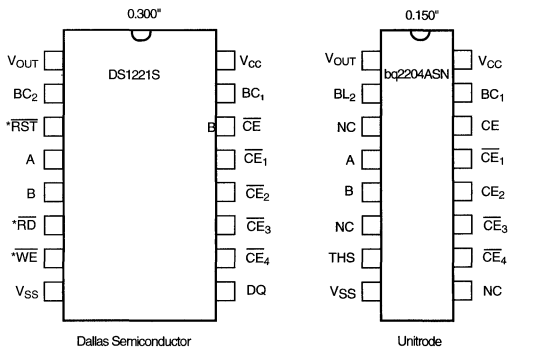
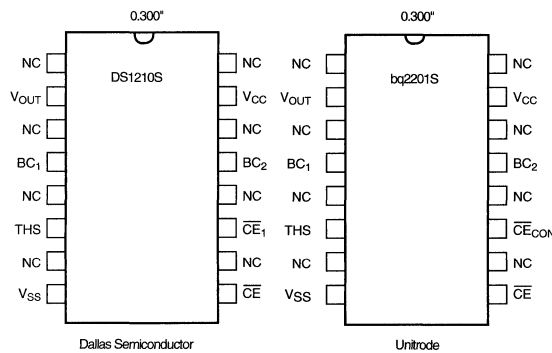
SRAM Banks Controlled	Battery Monitor Outputs	Reset Output	$I_{OUT}$ (Typ.)	Pins / Package	Part Number	Page Number
1			160 mA	8 / NDIP, NSOIC 16 / NSOIC	bq2201	NV/3-3
2		✓	160 mA	16 / NDIP, NSOIC	bq2202	NV/3-11
2	✓	✓	160 mA	16 / NDIP, NSOIC	bq2203A	NV/3-19
4			160 mA	16 / NDIP, NSOIC	bq2204A	NV/3-27
2		✓	160 mA	12 / DIP module	bq2502	NV/3-35



## Static-RAM Nonvolatile Controller Cross-Reference

Dallas Semiconductor	Unitrode
DS1210	bq2201PN <sup>1,2</sup>
DS1210S	bq2201S <sup>1,2</sup>
DS1218	bq2201PN <sup>1,2</sup>
DS1218S	bq2201SN <sup>1,2</sup>
DS1221	bq2204APN <sup>1,3</sup>
DS1221S	bq2204ASN <sup>1,3,4</sup>

- Notes:**
1. Unitrode's bq2201 and bq2204A do not incorporate a "check battery status" function.
  2. Unitrode's bq2201 pins THS and BC<sub>2</sub> should be tied to V<sub>SS</sub>.
  3. Optional "security feature" DS1221 pins are no-connect on the bq2204A.
  4. Unitrode's bq2204ASN is a small 16-pin, 150-mil SOIC, compared to the DS1221S, which is a 16-pin, 300-mil SOIC.



\*These pairs must be connected to ground if the security option is not used.



# Nonvolatile SRAMs and RTCs (NV) Selection Guides



Unitrode's NVSRAMs integrate extremely low standby power SRAM, nonvolatile control circuitry, and a long-life lithium cell in either a single DIP package or a two-piece LIFETIME LITHIUM SMT module. The NVSRAMs combine secure long-term nonvolatility (more than 10 years without power) with standard SRAM pinouts and fast, unlimited read/write operation.

- Data retention without power
- Automatic write-protection during power-up/power-down cycles
- Industry-standard pinout
- Conventional SRAM operation; unlimited write cycles
- 10 or 5 years minimum data retention in the absence of power
- Battery internally isolated until power is first supplied
- Industrial temperature range available

## Nonvolatile Static RAM Selection Guide

Density	Configuration	Access Time (ns)	Minimum Data-Retention Time	Pins / Package	Part Number <sup>1</sup>	Page Number
64Kb	8Kb x 8	70, 85 <sup>2</sup> , 150 <sup>2</sup> , 200	10 years	28 / DIP	bq4010/Y	NV/5-3
256Kb	32Kb x 8	70 <sup>2</sup> , 100, 150 <sup>2</sup> , 200	10 years	28 / DIP	bq4011/Y	NV/5-13
1Mb	128Kb x 8	70 <sup>2</sup> , 85 <sup>2</sup> , 120	10 years	32 / DIP 32 / SMT	bq4013/Y	NV/5-23
2Mb	256Kb x 8	85, 120	10 years	32 / DIP	bq4014/Y	NV/5-33
4Mb	512Kb x 8	70, 85, 120	10 years	32 / DIP 32 / SMT	bq4015/Y	NV/5-42
8Mb	1024Kb x 8	70	10 years	36 / DIP	bq4016/Y	NV/5-52
16Mb	2048Kb x 8	70	5 years	36 / DIP	bq4017/Y	NV/5-61
64Kb	8kB x 8	70	10 years	28 / SNAPHAT	bq4310/Y+	NV/5-70
256Kb	32kB x 8	70 <sup>3</sup> , 100 <sup>5</sup>	10 years	28 / SNAPHAT	bq4311Y/L <sup>4</sup> +	NV/5-81

- Notes:**
1. "Y" version denotes 10%  $V_{CC}$  tolerance.
  2. "Y" version available in -40°C to +85°C industrial temperature range.
  3. "Y" version only.
  4. "L" version denotes 3.2V typical  $V_{CC}$  operation.
  5. "L" version only.

+ New Product





## Nonvolatile Static RAM Cross-Reference

Density	Dallas Semiconductor	STMicroelectronics	Unitrode
64Kb	DS1225AB	M48Z08	bq4010
	DS1225AD	M48Z18	bq4010Y
	-	M48Z58	bq4010/4823Y
	DS1225Y	M48Z58Y	bq4010Y
256Kb	DS1230AB	M48Z35	bq4011
	DS1230Y	M48Z35Y	bq4011Y/4833Y
1M	DS1245AB	M48Z128	bq4013
	DS1245Y	M48128Y	bq4013Y
2M	DS1258AB	-	bq4014
	DS1258Y	-	bq4014Y
4M	DS1250AB	M48Z512A	bq4015
	DS1250Y	M48Z512AY	bq4015Y
8M	DS1265AB	-	bq4016
	DS1265Y	-	bq4016Y
16M	DS1270AB	M48Z2M1	bq4017
	DS1270Y	M48Z2M1Y	bq4017Y



## Nonvolatile SRAMs and RTCs (NV) Selection Guides



Unitorde's real-time clocks (RTCs) provide highly integrated clock/calendar solutions for microcomputer-based designs. Each *module* is a completely self-contained unit, including IC, crystal, and a battery ensuring operation for 10 years in the absence of power. The very compact, low-power ICs need only a battery and a crystal for operation. NVSRAM controller versions allow users to make inexpensive SRAM nonvolatile for data and configuration storage in computers, portable equipment, office machines, and other applications.

- Clock/calendar counts seconds through years with daylight savings and leap-year adjustments
- IBM PC AT-compatible clocks include:
  - 5- or 3-Volt operation
  - 114, 240, or 242 bytes of user nonvolatile RAM storage
- 32kHz output for power management
- Nonvolatile control for an external SRAM
- SRAM-based clocks feature:
  - SRAM interface
  - Up to 512 kilobytes of NVSRAM
  - CPU supervisor
- One minute per month clock accuracy in modules
- IC versions require only a crystal and battery

### Real-Time Clock Selection Guide

Onboard RAM (bytes)	NVRAM Control	Bus Interface	Voltage	32kHz Output	CPU Supervisor	Pins / Package	Part Number	Page Number
114		Muxed	5V			24 / DIP, SOIC	bq3285	NV/4-3
242		Muxed	5V	✓		24 / DIP, SOIC, SSOP	bq3285E	NV/4-22
242		Muxed	5V	✓		24 / SSOP	bq3285EC/ED	NV/4-46, NV/4-69
242		Muxed	3V	✓		24 / DIP, SOIC, SSOP	bq3285L	NV/4-22
242		Muxed	3V	✓		24 / SSOP	bq3285LC/LD	NV/4-46, NV/4-69
240		Muxed	3V			24 / SSOP	bq3285LF+	NV/4-92
114		Muxed	5V			24 / DIP module	bq3287/A	NV/4-111
242		Muxed	5V	✓		24 / DIP module	bq3287E/EA	NV/4-115
242		Muxed	3V			24 / DIP Module	bq3287LD+	NV/4-119
114	✓	Muxed	5V			24 / DIP, SOIC	bq4285	NV/4-123
114	✓	Muxed	5V	✓		24 / DIP, SOIC, SSOP,	bq4285E	NV/4-143
114	✓	Muxed	3V	✓		24 / DIP, SOIC, SSOP	bq4285L	NV/4-143
114	✓	Muxed	5V			24 / DIP module	bq4287	NV/4-168
0		SRAM	3V		✓	28 / DIP, SOIC 28 / SNAPHAT	bq4802+	NV/4-174
8K	✓	SRAM	5V		✓	28 / DIP module	bq4822Y	NV/4-176
8K		SRAM	5V			28 / SNAPHAT	bq4823Y+	NV/4-191

+ New Product



## Real-Time Clock Selection Guide (Continued)

Onboard RAM (bytes)	NVRAM Control	Bus Interface	Voltage	CPU Supervisor	Pins / Package	Part Number	Page Number
32K		SRAM	5V		28 / DIP module	bq4830Y	NV/4-205
32K		SRAM	5V	✓	32 / DIP module	bq4832Y	NV/4-218
32K		SRAM	5V		28 / SNAPHAT	bq4833Y+	NV/4-233
128K		SRAM	5V	✓	32 / DIP module	bq4842Y	NV/4-247
0	✓	SRAM	5V	✓	28 / DIP, SOIC	bq4845/Y	NV/4-262
0	✓	SRAM	5V	✓	28 / DIP module	bq4847/Y	NV/4-279
512K		SRAM	5V	✓	32 / DIP module	bq4850Y	NV/4-282
512K		SRAM	5V	✓	36 / DIP module	bq4852Y	NV/4-295

+ New Product

## Real-Time Clock Cross-Reference

Dallas Semiconductor	STMicroelectronics	Unitrode
DS1285/885	-	bq3285P
DS1285S/885S	-	bq3285S
DS1287/887	-	bq3287MT
DS1287A/887A	M48T86	bq3287A
DS14285	-	bq4285
DS14285	-	bq4285P
DS14285S	-	bq4285S
DS14287	-	bq4287
DS1643	M48T08/T18 M48T58Y/59Y	bq4822Y
DS1644	M48T35	bq4830Y <sup>1</sup>
DS1646	-	bq4842Y <sup>2</sup>

- Notes:**
1. Memory upgrade.
  2. Additional bq4842 features: microprocessor reset, watchdog monitor, clock alarm, and periodic interrupt.

## Portable Power (PP) Selection Guides



Unitrode battery charge-management ICs provide full-function, safe charge control for all types of rechargeable chemistries. Functions include pre-charge qualification and conditioning, charge regulation, and termination.

- Fast charging and conditioning of nickel cadmium, nickel metal hydride, lead acid, lithium ion, or rechargeable alkaline batteries
- Flexible charge regulation support:
  - Linear
  - Switch-mode
  - Gating control (external regulator)
- Easily integrated into systems or as a stand-alone charger
- Direct LED outputs display battery and charge status
- Fast, safe, and reliable chemistry-specific charge-termination methods, including rate of temperature rise ( $\Delta T/\Delta t$ ), negative delta voltage ( $-\Delta V$ ), peak voltage detect (PVD), minimum current, maximum temperature, maximum voltage, and maximum time
- Optional top-off and maintenance charging
- Discharge-before-charge option for NiCd
- Complete set of development tools available for quick product-design

### Battery Charge-Management Selection Guide

Battery Technology	Key Features	Fast-Charge Termination Method	Pins / Package	Part Number	Page Number
Multi-Chemistry	Complete charge management with integrated switching controller	PVD, minimum current, maximum temperature, maximum time	8/0.300" DIP, 8/0.150" SOIC	bq2000+	PP/3-7
		$\Delta T/\Delta t$ , minimum current, maximum temperature, maximum time	8/0.300" DIP, 8/0.150" SOIC	bq2000T+	PP/3-20
NiMH, NiCd	Gating control of an external regulator	$-\Delta V$ , PVD, maximum temperature, maximum time	8/0.300" DIP, 8/0.150" SOIC	bq2002/C/E/F/G	PP/3-3
		$\Delta T/\Delta t$ , maximum temperature, maximum time	8/0.300" DIP, 8/0.150" SOIC	bq2002D/T	PP/3-3
	PWM Controller	$-\Delta V$ , $\Delta T/\Delta t$ , maximum temperature, maximum time	16/0.300" DIP, 16/0.300" SOIC	bq2003	PP/3-73
	PWM controller, enhanced display mode	$-\Delta V$ , PVD, $\Delta T/\Delta t$ , maximum temperature, maximum time	16/0.300" DIP, 16/0.150" SOIC	bq2004/E/H	PP/3-5
	Dual sequential charge-controller for 2-bay chargers	$-\Delta V$ , $\Delta T/\Delta t$ , maximum temperature, maximum time	20/0.300" DIP, 20/0.300" SOIC	bq2005	PP/3-119
Lithium Ion	PWM controller	Minimum current, maximum time	16/0.300" DIP, 16/0.150" SOIC	bq2054	PP/3-6
	Low-dropout linear with AutoComp™ feature	-	8/0.150" SOIC	bq2056/T/V	PP/3-186
	PWM controller, enhanced display mode	Minimum current, maximum time	16/0.300" DIP, 16/0.150" SOIC	bq2954+	PP/3-6
	PWM controller, differential current sense	Minimum current, maximum time	20/0.300" DIP, 20/0.300" SOIC	UCC3956	PP/3-6

+ New Product

Continued on next page



## Battery Charge-Management Selection Guide (Continued)

Battery Technology	Key Features	Fast-Charge Termination Method	Pins/Package	Part Number	Page Number
Lead Acid	PWM controller, 3 charge algorithms	Maximum voltage, $-\Delta^2V$ , minimum current, maximum time	16/0.300" DIP, 16/0.150" SOIC	bq2031	PP/3-154
	Linear controller	Maximum voltage, minimum current	16/0.300" DIP, 16/0.300"SOIC	UC3906	PP/3-237
	PWM controller, differential current sense	Maximum voltage, minimum current	20/0.300" DIP, 20/0.300"SOIC	UC3909	PP/3-244
Rechargeable Alkaline	2-cell charging	Maximum voltage	8/0.300"DIP, 8/0.150" SOIC	bq2902	PP/3-194
	3- or 4-cell charging	Maximum voltage	14/0.300" DIP, 14/0.150" SOIC	bq2903	PP/3-204



## Portable Power (PP) Selection Guides



The bq2002 fast-charge control ICs are low-cost CMOS battery charge-control ICs providing reliable charge termination for both NiCd and NiMH battery applications. Controlling a current-limited or constant-current supply allows the ICs to be the basis for a cost-effective stand-alone or system-integrated charger. The bq2002 family includes options that integrate fast charge, top-off, and pulse-trickle charge control in a single IC for charging one or more NiCd or NiMH batteries.

A new charge cycle is started by the application of a charging supply or by replacement of the battery. For safety, fast charge is inhibited if the battery voltage or temperature is outside of configured limits. Fast charge may be inhibited using the INH input. In some versions, this input may be used to synchronize voltage sampling. A low-power standby mode reduces system power consumption.

- Fast-charge control of nickel cadmium or nickel-metal hydride batteries
- Fast-charge terminations available:
  - $-\Delta V$
  - Peak Voltage Detection (PVD)
  - $\Delta T/\Delta t$
- Direct LED output displays charge status
- Backup safety termination on maximum voltage, maximum temperature, and maximum time
- Top-off and pulse-trickle charge rates available
- Synchronized voltage sampling available
- Low-power mode
- 8-pin 300-mil DIP or 150-mil SOIC packaging

### bq2002 Family Selection Guide

Feature	Part Number						
	$-\Delta V$ or PVD Termination					$\Delta T/\Delta t$ Termination	
	bq2002	bq2002F	bq2002C	bq2002E	bq2002G	bq2002T	bq2002D
Fast charge time limit options (minutes)	160/80/40	160/100/40	160/80/40	200/80/40	160/80/40	320/80/40	440/110/55
Hold-off period options (seconds)	600/300/10	600/300/10	300/150/75	300/150/75	300/150/75	none	none
Top-off options	C/32,C/16,0	C/32,C/16,0	none	C/16,0	C/16,0	C/64,C/16,0	none
Top-off period	4.6ms	4.6ms	n/a	1.17s	1.17s	4.6ms	n/a
Pulse-trickle options	C/64,C/32	C/64,C/32	C/32	C/32	C/32	C/256,C/128	none
Pulse-trickle period	9 or 18ms	9 or 18ms	1.17s	1.17s	1.17s	18 or 73ms	n/a
Synchronized voltage sampling	no	no	yes	yes	yes	no	no
Minimum voltage pre-charge qualification	no	no	yes	yes	yes	no	no

Continued on next page



## bq2002 Family Selection Guide (Continued)

Feature	Part Number						
	- $\Delta V$ or PVD Termination					$\Delta T/\Delta t$ Termination	
	bq2002	bq2002F	bq2002C	bq2002E	bq2002G	bq2002T	bq2002D
Hysteresis on high-temperature cut-off	no	no	no	no	no	yes	yes
LED in "charge pending" phase	n/a	n/a	flashes	flashes	flashes	on	off
Page number	PP/3-35	PP/3-35	PP/3-43	PP/3-61	PP/3-61	PP/3-51	PP/3-51



## Portable Power (PP) Selection Guides



The bq2004 fast-charge control ICs are low-cost CMOS battery charge control ICs providing reliable charge termination for both NiCd and NiMH battery applications. Integration of PWM current control circuitry allows the ICs to be the basis for a cost-effective stand-alone or system-integrated charger. The bq2004 family includes options that integrate fast charge, top-off, and pulse-trickle charge control in a single IC for charging one or more NiCd or NiMH batteries.

A new charge cycle is started by the application of a charging supply, replacement of the battery, or a logic-level pulse. For safety, fast charge is inhibited if the battery voltage or temperature is outside of configured limits. Fast charge may be inhibited using the INH input, which also puts the IC into a low-power standby mode, reducing system power consumption.

- Fast-charge control of nickel cadmium or nickel-metal hydride batteries
- Integrated PWM closed-loop current control
- Configurable, direct LED output displays charge status
- Low-power mode
- Top-off and pulse-trickle charging available
- Fast-charge terminations available:
  - $-\Delta V$
  - Peak Voltage Detection (PVD)
  - $\Delta T/\Delta t$
- Backup safety termination on maximum voltage, maximum temperature, and maximum time
- 16-pin 300-mil DIP or 150-mil SOIC packaging

### bq2004 Family Selection Guide

Feature	Part Number		
	bq2004	bq2004E	bq2004H
Maximum time-out selections (minutes)	360/180/90/45/23	325/154/77/39/19	650/325/154/77/39
Hold-off period selections (seconds)	137/820/410/200/100	137/546/273/137/68	273/546/546/273/137
Charge rate during hold-off period	full fast-charge rate	1/8*fast-charge rate	1/8*fast-charge rate
Top-off options	C/2,C/4,C/8,C/16,0	C/2,C/4,C/8,C/16,0	C/4,C/8,C/16,C/32,0
Top-off pulse width/period (seconds)	260/2080	260/2080	260/2080
Top-off duration	MTO	0.235*MTO	0.235*MTO
Pulse-trickle selections	C/32,C/64,0	C/512,0	C/512,0
Pulse-trickle period (ms)	4.17/8.3/16.7/33.3/66.7	66.7/133/267/532	33.3/66.7/133/267
Pulse-trickle pulse width (seconds)	260	260	260
DSEL floating disables pulse-trickle	no	yes	yes
VSEL high disables low-temperature fault threshold	yes	no	no
High-temperature fault threshold	1/4LTF + 3/4 TCO	1/3LTF + 2/3 TCO	1/3LTF + 2/3 TCO
Page number	PP/3-91	PP/3-105	PP/3-105



# Portable Power (PP) Selection Guides



## Li-Ion PWM Charge IC Selection Guide

Feature	Part Number		
	bq2054	bq2954	UCC3956
Charge algorithm	During pre-qualification, the bq2054 charges using a low trickle current if the battery voltage is low. Then it charges using constant current followed by constant voltage. After fast-charge termination, charge is re-initiated by resetting the power to the IC or by inserting a new battery.	Performs similar to the bq2054, but the bq2954 also re-initiates a recharge if the battery voltage falls below a threshold level. This allows the bq2954 to maintain a full charge in the battery at all times.	Uses a 4-step charge algorithm: low-current trickle charge (when the cell voltage is below a user-programmable level); high-current bulk charge; constant-voltage overcharge; optional top-off with user-programmable timer
Current-sensing technique	Low-side current sensing	Low-side and high-side current sensing	Fully differential high-side current sensing can be used up to 20V common mode without the need for external level shifting.
Charge initiation	Application of power or detection of battery insertion	Application of power or detection of battery insertion	One-shot charge initiates charging, or a simple comparator initiates charging on battery insertion.
Detection of deeply discharged (bad) cells	Minimum cell voltage required for fast charge: 2V/cell Trickle-charge period: 1 * MTO	Minimum cell voltage required for fast charge: 3V/cell Trickle-charge period: 0.25 * MTO (for faster detection of bad cells)	User-programmable threshold limits charge current when battery cells are deeply discharged and provides short-circuit protection.
Charge termination based on minimum current	User-programmable minimum current is a ratio of the charging current: 1/10, 1/20, 1/30. A safety charge timer is also available.	User-programmable minimum current is a ratio of the charging current: 1/10, 1/15, 1/20. A safety charge timer is also available.	User-programmable minimum current or user-programmable overcharge timer
Temperature monitoring	Measured using an external thermistor. Fast charge is inhibited if the battery temperature is outside user-configured limits.	Measured using an external thermistor. Fast charge is inhibited if the battery temperature is outside user-configured limits.	No
Status display	3 LEDs for state of charge	2 LEDs or one bi-color LED optimize state of charge	2 LEDs for state of charge including end of charge
Full-charge indication	LEDs indicate full charge after charge termination	LEDs indicate full charge just before charge termination	LEDs indicate full charge on charge termination
Input voltage range	4.5V to 5.5V	4.5V to 5.5V	6.5V to 20V
Typical supply current	2mA	2mA	5mA
Voltage regulation accuracy	±1% at 25°C	±1% at 25°C	±1% at 25°C
Wakeup feature for battery pack protectors	No	Yes	No
Integrated PWM controller	Yes	Yes	Yes
Pins/package	16-pin narrow PDIP or SOIC	16-pin narrow PDIP or SOIC	20-pin SOIC or DIP
Page number	PP/3-170	PP/3-217	PP/3-253

## Portable Power (PP) Selection Guides



Unitrode's Gas Gauge ICs measure the available charge, calculate self-discharge, and communicate the available charge of a battery pack over a serial port or by directly driving an LED display.

- Accurate measurement of available charge for nickel cadmium, nickel metal-hydride, lithium ion, lead-acid batteries, and primary lithium
- Serial port or direct LED display for remaining battery capacity indication
- Designed for battery-pack integration
- Available capacity is compensated for charge/discharge rate and temperature
- 150 $\mu$ A or less typical operating current
- Accurately measures across a wide range of currents

### Battery Capacity-Monitoring ICs Selection Guide

Battery Technology	Approximate Pack Capacity (mAh)	Communication Interface	Additional Key Features	Pins / Package	Part Number	Page Number
NiCd/NiMH	800-5000	1-wire DQ	5 or 6 LED outputs	16 /SOIC	bq2010	PP/4-3
			Slow-charge control	16 /SOIC	bq2012	PP/4-81
		External charge-control support	16 /SOIC	bq2014	PP/4-123	
		1-wire HDQ	Register-compatible with bq2050H	16 /SOIC	bq2014H+	PP/4-149
NiCd	800-2000	1-wire DQ	See bq2011 Family Selection Guide	16 /SOIC	bq2011 bq2011J bq2011K	PP/4-24, PP/4-45, PP/4-63
NiCd/NiMH/ Lead Acid	2000- 10,000	1-wire HDQ	Programmable offset and load compensation	16 /SOIC	bq2013H	PP/4-103
Li-Ion	800-5000	1-wire DQ	Remaining power (Wh) indication	16 /SOIC	bq2050	PP/4-215
		1-wire HDQ	Register-compatible with bq2014H	16 /SOIC	bq2050H	PP/4-237
Primary Lithium	800- 15,000	1-wire HDQ	Programmable discharge efficiency compensation	16 /SOIC	bq2052+	PP/4-259
NiCd/NiMH Lead Acid/ Li-Ion	800- 10,000	2-wire SMBus	SBS rev. 1.0-compliant	16 /SOIC	bq2040	PP/4-185
			SBS rev. 0.95-compliant	16 /SOIC	bq2092	PP/4-314
			SBS rev. 1.0-compliant with 5 LEDs	16 /SOIC	bq2945	PP/4-340
		2-wire SMBus or 1-wire HDQ16	SBS rev. 1.1-compliant	28 / SSOP	bq2060+	PP/4-276
Any	Any	1-wire HDQ	Analog peripheral for $\mu$ C	8 / SOIC or TSSOP	bq2018	PP/4-170

+ New Product

## Portable Power (PP) Selection Guides



The bq2011 Gas Gauge ICs provide accurate capacity monitoring of rechargeable batteries in high discharge rate environments. The ICs can monitor a wide range of charge/discharge currents using the onboard V-to-F converter and a low-value sense resistor. The ICs track remaining capacity (NAC) and compensate it for battery self-discharge, charge/discharge rate, and temperature. Five LEDs can communicate remaining capacity in 20% increments. A serial port allows a host microcontroller to access the nonvolatile memory registers containing battery capacity, voltage, temperature, and other critical parameters.

- Accurate measurement of available charge in rechargeable batteries
- Designed for NiCd high discharge rate applications
- Drives 5 LEDs for capacity indication
- Automatic charge self-discharge and discharge compensation
- Low operating current
- 16-pin narrow SOIC

### bq2011 Family Selection Guide

Feature	Part Number		
	bq2011	bq2011J	bq2011K
Display	Relative or absolute	Absolute	Absolute
Programmed Full Count (PFC) range	4.5–10.5mVh	2.21–3.81mVh	2.21–3.81mVh
Nominal Available Capacity (NAC) on reset	NAC = 0	NAC = PFC or 0	NAC = PFC or 0
Self-discharge rate	NAC/80	NAC/80 or disabled	NAC/80 or disabled
Charge compensation	75–95% based on rate and temperature	65–95% based on rate and temperature	70–95% based on rate and temperature
Discharge compensation	75–100% plus temperature compensation	75–100% plus temperature compensation	100%
End-of-discharge voltage	0.9V/cell	0.9V/cell	0.96–1.16V/cell
Page number	PP/4-24	PP/4-45	PP/4-63



## Portable Power (PP) Selection Guides



Unitrode's battery management module products provide true turn-key solutions for capacity monitoring and charge control of NiCd, NiMH, Li-Ion, or Rechargeable Alkaline battery packs. Designed for battery pack integration, the small boards contain all necessary components to easily implement intelligent or smart battery packs in a portable system. The wide selection of boards offers battery monitoring, capacity tracking, charge control, and remaining capacity communication to the host system or user. The boards are fully tested and provide direct cell connections for simple battery packs.

- Turnkey solutions for intelligent or smart batteries for portable equipment
  - Computers, cellular phones, and camcorders
  - Handheld terminals
  - Communication radios
  - Medical and test equipment
  - Power tools
- Capacity monitoring and charge control
  - Pushbutton-activated LED capacity indication
  - Designed for battery pack integration
    - Small size
    - Low power
    - Direct cell connections

### Battery-Management Modules Selection Guide

Battery Technology	Key Features	Part Number	Page Number
NiCd/NiMH	Capacity monitoring, LED indication, serial communications port	bq2110	PP/5-2
	Capacity monitoring, slow-charge control, LED indication, serial communications port	bq2112	PP/5-14
	Capacity monitoring, charge control output, LED indication, serial communications port	bq2114	PP/5-24
	Capacity monitoring and fast charge control	bq2164	PP/5-71
NiCd	Capacity monitoring for high discharge rates, LED indication	bq2111L	PP/5-8
NiCd/NiMH, Lead Acid	Capacity monitoring, LED indication, single-wire serial communications port	bq2113H+	PP/5-20
Li-Ion	Capacity monitoring, Smart Battery data set and interface, LED indication, pack supervision, 4-segment LED indication	bq2148	PP/5-40
	Capacity monitoring, LED indication, serial communications port	bq2150 bq2150/H	PP/5-47 PP/5-53
	Pack supervision: overvoltage, undervoltage, and overcurrent control	bq2158 bq2158T	PP/5-57 PP/5-64
	Capacity monitoring, 3- or 4-cell pack supervision, and LED indication	bq2167+ bq2168+	PP/5-77 PP/5-85
NiCd/NiMH/ Lead Acid/ Li-Ion	Capacity monitoring, Smart Battery data set and interface, 5-segment LED indication	bq2145	PP/5-34
	Capacity monitoring, Smart Battery data set and interface, 4-segment LED indication	bq219XL	PP/5-93
Any	Charge and discharge counting, serial communication port, single-wire interface	bq2118	PP/5-30

+ New Product

## Portable Power (PP) Selection Guides



Unitrode Lithium Ion Pack-Protection ICs provide reversible overvoltage, undervoltage, and overcurrent protection for lithium ion battery packs.

- Protects one to four Lithium Ion series cells from overvoltage, undervoltage, and overcurrent
- User-selectable thresholds mask-programmable by Unitrode
- Designed for battery-pack integration
  - Small outline package, minimal external components and space, and low cost

### Pack-Protection and Supervisory ICs Selection Guide

Battery Technology	Number of Cells Protected	Protection Types	Key Features	Pins / Package	Part Number	Page Number
Lithium Ion	3 or 4	Overvoltage, overcurrent, and undervoltage	Very low power	16/0.150" SOIC	bq2058	PP/6-2
	2				bq2058T	PP/6-14
		1	Overcharge, overdischarge, overcurrent	Internal MOSFET (80mΩ total)	16/0.150" TSSOP	UCC3911
	UCC3952+					PP/6-32
	3 or 4	Overvoltage, undervoltage, overcurrent	Smart-discharge circuitry	16/0.150" SSOP	UCC3957	PP/6-37
	1	Overcharge, overdischarge, overcurrent	Internal MOSFETS (50mΩ total)	16/0.150" SOIC	UCC3958	PP/6-44

+ New Product



# Portable Power (PP) Selection Guides



## Power-Management ICs Selection Guide

Features	Part Number			
	UCC3581	UCC3809 -1/2	UCC3800/ 1/2/3/4/5	UCC3813- 0/1/2/3/4/5
Topology	Forward, flyback	Forward, flyback, buck, boost	Forward, flyback, buck, boost	Forward, flyback, buck, boost
Input voltage	Off-line AC	Off-line AC	Off-line AC, battery	Off-line AC, battery
Output voltage	NA	NA	NA	NA
Operating mode	Fixed/variable frequency	Fixed frequency (1MHz maximum)	Fixed frequency (1MHz maximum)	Fixed frequency (1MHz maximum)
Output	1A FET drives	0.8A FET drives	1A FET drives	1A FET drives
Output power	N / A	N / A	N / A	N / A
Supply current	300µA	500µA	500µA	500µA
Power limit	Yes	No	Yes	Yes
Application/design note	DN-48, DN-65	DN-65, DN-89, U-165, U-168	DN-42A, DN-43, DN-46, DN-48, DN-54, DN-56A, DN-65, DN-89, U-133A, U-97	DN-42A, DN-43, DN-46, DN-48, DN-54, DN-56A, DN-65, DN-89, U-133A, U-97
Pin count ♦	14	8	8	8
Page number	PS/8-128	PS/8-192	PS/8-169	PS/8-206

♦ The smallest available pin count for thru-hole and surface-mount packages.

## Power-Management ICs Selection Guide (Continued)

Features	Part Number					
	UCC39401	UCC3941 -3/-5/-ADJ	UCC39411 /2/3+	UCC39421/2+	UCC3946	UCC3954
Topology	Boost / battery charger	Boost	Boost	Boost/SEPIC/flyback	Watchdog/reset	Flyback
Input voltage	0.8V to ( $V_{OUT} + 0.5V$ )	0.8V to ( $V_{OUT} + 0.5V$ )	1.1V to ( $V_{OUT} + 0.5V$ )	1.8V–8V	2.1V–5.5V	2.5V–4.2V
Output voltage	ADJ to 5.0V	3.3V, 5V, ADJ	3.3V, 5V, ADJ	ADJ	$V_{IN} - 0.3V$	3.3V
Operating mode	Variable frequency	Variable frequency	Variable	Fixed/variable frequency	Watchdog/reset	Fixed frequency (200kHz)
Output	Internal power FETs	Internal power FETs	Internal power FETs	FET Drives	NA	Internal power FETs
Output power	200mW	500mW (1 cell) 1W (2 cells)	200mW	NA	NA	2W
Supply current	55µA	80µA	48µA	635µA	10µA	1mA
Power limit	Yes	Yes	Yes	Yes	NA	Yes
Application/design note	-	DN-73	DN-97	-	-	DN-86
Pin count ♦	20	8	8	16/20	8	8
Page number	PP/7-34	PP/7-48	PP/7-58	PP/7-66	PP/7-88	PP/7-93

+ New Product

♦ The smallest available pin count for thru-hole and surface-mount packages.



## Linear Controller ICs Selection Guide

Features	Part Number					
	UC3832	UC3833	UC3834	UC3835	UC3836	UCC3837
Type of output	Positive adjustable	Positive adjustable	Positive/negative adjustable	5V fixed	Positive adjustable	Positive adjustable
Maximum input voltage	36V	36V	40V	40V	40V	12V
Minimum output voltage	2.0V	2.0V	+1.5V / -2.0V		2.5V	1.5V
Output drive	300mA	300mA	350mA	500mA	500mA	1.5mA
Type of short circuit limit	Duty cycle	Duty cycle	Foldback	Foldback	Foldback	Duty cycle
Reference voltage accuracy	2%	2%	3% / 4%	2%	2%	2%
Special features	Multiple pins accessible	-	-	Built-in Rsense	Built-in Rsense	Internal charge pump; Direct N-FET drive
Application/design note	DN-32, DN-61, U-152	DN-32, DN-61, U-152	U-95			-
Pin count ♦	14, 16	8, 16	16	8, 16	8, 16	8
Page number	PS/3-11	PS/3-11	PS/3-18	PS/3-24	PS/3-24	PS/3-28

♦The smallest available pin count for thru-hole and surface-mount packages.

## Low-Dropout Linear Regulator ICs Selection Guide

Features	Part Number				
	UCC381	UC382-1	UC382-2	UC382-3	UC382-ADJ
Output voltage	3.3V, 5V, ADJ	1.5V	2.1V	2.5V	1.2V/adjustable
Dropout voltage	0.5V at 1A	450mV at 3A	450mV at 3A	450mV at 3A	450mV at 3A
Output voltage accuracy	2.5%	1%	1%	1%	1%
Maximum input voltage	9V	7.5V	7.5V	7.5V	7.5V
Shutdown current	10µA	-	-	-	-
Operating current	400µA	-	-	-	-
Line regulation	0.01% / V	-	-	-	-
Load regulation	0.1%, I <sub>OUT</sub> = 0 to 1A	-	-	-	-
Special features	Power limit	Fast transient response	Fast transient response	Fast transient response	Fast transient response
Pin count ♦	8	5	5	5	5
Page number	PP/7-5	PS/3-5	PS/3-5	PS/3-5	PS/3-5

♦The smallest available pin count for thru-hole and surface-mount packages.





## Low-Dropout Linear Regulator ICs Selection Guide (Continued)

Features	Part Number				
	UCC383	UCC384	UC385-1	UC385-2	UC385-3
Output voltage	3.3V, 5V, ADJ	5V, 12V, ADJ	1.5V	2.1V	2.5V
Dropout voltage	0.45V at 3A	0.2V at 500mA	450mV at 5A	450mV at 5A	450mV at 5A
Output voltage accuracy	2.5%	2.5%	1%	1%	1%
Maximum input voltage	9V	-16V	7.5V	7.5V	7.5V
Shutdown current	40μA	17μA	-		
Operating current	400μA	240μA	-		
Line regulation	0.01% / V	0.01% / V	-		
Load regulation	0.1%, I <sub>OUT</sub> = 0 to 1A	0.1%, I <sub>OUT</sub> = 0 to 500mA	-		
Special features	Power limit	Power limit	Fast transient response	Fast transient response	Fast transient response
Pin count ♦	3	8	5	5	5
Page number	PP/7-12	PP/7-19	PS/3-35	PS/3-35	PS/3-35

♦The smallest available pin count for thru-hole and surface-mount packages.

## Low-Dropout Linear Regulator ICs Selection Guide (Continued)

Features	Part Number			
	UC385-ADJ	UC386+	UC387+	UC388+
Output voltage	1.2V/adjustable	3.3V	5V	Adjustable down to 1.25V
Dropout voltage	450mV at 5A	0.2V at 200mA	0.2V at 200mA	0.2V at 200mA
Output voltage accuracy	1%	1.5%	1.5%	1.5%
Maximum input voltage	7.5V	9V	9V	9V
Shutdown current	-	2μA	2μA	2μA
Operating current	-	10μA	10μA	10μA
Line regulation	-	25mV max	25mV max	25mV max
Load regulation	-	10mV max	10mV max	10mV max
Special features	Fast transient response	TSSOP	TSSOP	TSSOP
Pin count ♦	5	8	8	8
Page number	PS/3-35	PP/7-29	PP/7-29	PP/7-29

♦The smallest available pin count for thru-hole and surface-mount packages.

+ New product.





## Special Function Linear Regulation ICs Selection Guide

Features	Part number		
	UC560	UCC561+	UC563+
Type of output	Positive	Positive	Positive
Application	Source/sink regulator for the 18- and 27-line SCSI termination	LVD SCSI regulator for the 18- and 27-line termination	32-line VME bus bias generator
Input voltage	4V-6V	2.7V- 5.25V	4.875V-5.25V
Output voltage	2.85V	1.3V, 1.75V, 0.75V	2.94V
Dropout voltage	0.9V at 750mA	-	-
Bus standard	SCSI-1,2,3	SPI-2, 3	VME / VME64
Sink/source current	300mA / -750mA	200mA / -200mA	475mA / -575mA
Application/design note	-	-	-
Pin count ❖	5, 8	16	3, 8
Page number	IF/4-3	IF/4-7	IF/4-10

❖The smallest available pin count for thru-hole and surface-mount packages.

+ New product.





## Back-Light Controller ICs Selection Guide

Features	Part Number		
	UC3871	UC3872	UCC3972+
Application	Fluorescent lamp driver with LCD Bias	Fluorescent lamp driver	Fluorescent lamp driver
Voltage range	4.5V–20V	4.5V–24V	4.5V–25V
Reference tolerance	1.2%	1.2	NA
Open lamp detect	Yes	Yes	Yes
PWM synchronization	Yes	Yes	Yes
PWM frequency	Programmable	Programmable	80kHz–160kHz
Analog dimming	Yes	Yes	Yes
Low-frequency dimming	Yes	Yes	Yes
Operating current	8mA	6mA	1mA
Package	18-pin SOIC	16-pin SSOP	8-pin TSSOP
Application/design note	U-141, U-148	DN-75, U-141, U-148	-
Page number	PP/8-2	PP/8-8	PP/8-13

+ New Product



## IrDA Selection Guide

Device Type	Supply Voltage	Data Rate	Dynamic Range	Quiescent Current	Encoder/ Decoder	IrDA Compliant	LED Driver	Part Number	Page Number
Receiver	3.3V or 5V	2.4kbps 115.2kbps	150nA 100mA	250μA	N	Y	N/A	UCC5341	PP/9-2
Transceiver	3.3V or 5V	2.4kbps 115.2kbps	150nA 100m A	250μA	N	Y	500mA	UCC5342	PP/9-6
Transceiver	3.3V or 5V	2.4kbps 115.2kbps	150nA 100mA	280μA	Y	Y	500mA	UCC5343	PP/9-10





## PWM Control

Current Mode Controllers .....	7-32
Dedicated DC/DC Controllers .....	7-44
MicroProcessor Power Controllers .....	7-47
MicroProcessor Power Support .....	7-49
Post Regulation Controllers .....	7-50
Secondary Side PWM Control .....	7-51
Soft Switching Controllers .....	7-52
Voltage Mode Controllers .....	7-56

## PWM Control

Current Mode Controllers	UNITRODE PART NUMBER				
	UCC3800	UCC3801	UCC3802	UCC3803	UCC3804
Application	DC-DC and Battery	DC-DC and Battery	Off-line	DC-DC and Battery	Off-line
Topology	Buck, Boost	Buck, Boost	Forward, Flyback	Buck, Boost	Forward, Flyback
Voltage Reference Tolerance	1.5%	1.5%	1.5%	1.5%	1.5%
Peak Output Current	1A	1A	1A	1A	1A
Under Voltage Lockout	7.2V / 6.9V	9.4V / 7.4V	12.5V / 8.3V	4.1V / 3.6V	12.5V / 8.3V
Maximum Practical Operating Frequency	1MHz	1MHz	1MHz	1MHz	1MHz
Outputs	Single, Totem Pole	Single, Totem Pole	Single, Totem Pole	Single, Totem Pole	Single, Totem Pole
Startup Current	100µA	100µA	100µA	100µA	100µA
Leading Edge Blanking	Y	Y	Y	Y	Y
Soft Start	Y	Y	Y	Y	Y
Maximum Duty Cycle	100%	50%	100%	100%	50%
Separate Oscillator / Synchronization Terminal					
Application / Design Note	DN-42A, DN-48, DN-54, DN-65, DN-89, U-97, U-133A	DN-42A, DN-48, DN-54, DN-65, DN-89, U-97, U-133A	DN-42A, DN-48, DN-54, DN-65, DN-89, U-97, U-133A	DN-42A, DN-43, DN-46, DN-48, DN-54, DN-56A, DN-65, DN-89, U-97, U-133A	DN-42A, DN-48, DN-54, DN-65, DN-89, U-97, U-133A
Pin Count ❖	8	8	8	8	8
Page Number	PS/3-173	PS/3-173	PS/3-173	PS/3-173	PS/3-173

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

❖ The smallest available pin count for thru-hole and surface mount packages.

+ New Product

# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Current Mode Controllers	UNITRODE PART NUMBER				
	UCC3805	UCC3806	UCC3807-1	UCC3807-2	UCC3807-3
Application	DC-DC and Battery	Isolated Output, Push-pull Controller	DC-DC	Off-line	DC-DC and Battery
Topology	Forward, Flyback	Push-pull, Full Bridge, Half Bridge	Forward, Flyback Buck, Boost	Forward, Flyback Buck, Boost	Forward, Flyback Buck, Boost
Voltage Reference Tolerance	1.5%	1%	1.5%	1.5%	1.5%
Peak Output Current	1A	0.5A	1A	1A	1A
Under Voltage Lockout	4.1V / 3.6V	7.5V / 6.75V	7.2V / 6.9V	12.5V / 8.3V	4.3V / 4.1V
Maximum Practical Operating Frequency	1MHz	1MHz	1MHz	1MHz	1MHz
Outputs	Single, Totem Pole	Dual Alternating, Totem Pole	Single, Totem Pole	Single, Totem Pole	Single, Totem Pole
Startup Current	100µA	100µA	100µA	100µA	100µA
Leading Edge Blanking	Y		Y	Y	Y
Soft Start	Y	Y	Y	Y	Y
Maximum Duty Cycle	50%	50% / 50%	Programmable	Programmable	Programmable
Separate Oscillator / Synchronization Terminal		Y			
Application / Design Note	DN-42A, DN-43, DN-46, DN-48, DN-54, DN-56A, DN-65, DN-89, U-97, U-133A	DN-45, DN-51, DN-65, U-97, U-110, U-144	DN-48, DN-65, U-97, U-133A	DN-48, DN-65, U-97, U-133A	DN-48, DN-65, U-97, U-133A
Pin Count ❖	8	16	8	8	8
Page Number	PS/3-173	PS/3-180	PS/3-187	PS/3-187	PS/3-187

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

❖ The smallest available pin count for thru-hole and surface mount packages.

+ New Product



# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Current Mode Controllers	UNITRODE PART NUMBER				
	UCC3808-1	UCC3808-2	UCC3809-1	UCC3809-2	UCC3810
Application	Off-line	DC-DC and Battery	DC-DC	Off-line	Dual PWM Controller, Off-line, DC-DC
Topology	Push-pull, Full Bridge, Half Bridge	Push-pull, Full Bridge, Half Bridge	Forward, Flyback, Buck, Boost	Forward, Flyback, Buck, Boost	Forward, Flyback Buck, Boost
Voltage Reference Tolerance	2%	2%	5%	5%	1.5%
Peak Output Current	0.5A Source, 1A Sink	0.5A Source, 1A Sink	0.4A Source, 0.8A Sink	0.4A Source, 0.8A Sink	1A
Under Voltage Lockout	12.5V / 8.3V	4.3V / 4.1V	10V / 8V	15V / 8V	11.3V / 8.3V
Maximum Practical Operating Frequency	1MHz	1MHz	1MHz	1MHz	1MHz
Outputs	Dual Alternating, Totem Pole	Dual Alternating, Totem Pole	Single, Totem Pole	Single, Totem Pole	Dual, Totem Pole
Startup Current	130µA	130µA	100µA	100µA	150µA
Leading Edge Blanking					Y
Soft Start	Y	Y	Y	Y	
Maximum Duty Cycle	50% / 50%	50% / 50%	90%	90%	50%
Separate Oscillator / Synchronization Terminal			N/A	N/A	Y
Application / Design Note	DN-65, U-97, U-110, U-170	DN-65, U-97, U-110, U-170	DN-65, DN-89, U-165, U-168	DN-65, DN-89, U-165, U-168	DN-65, U-97, U-110, U-133A
Pin Count ❖	8	8	8	8	16
Page Number	PS/3-192	PS/3-192	PS/3-198	PS/3-198	PS/3-205

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

❖ The smallest available pin count for thru-hole and surface mount packages.

+ New Product

# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Current Mode Controllers	UNITRODE PART NUMBER				
	UCC3813-0	UCC3813-1	UCC3813-2	UCC3813-3	UCC3813-4
<b>Application</b>	DC-DC and Battery	DC-DC and Battery	Off-line	DC-DC and Battery	Off-line
<b>Topology</b>	Buck, Boost	Buck, Boost	Forward, Flyback	Buck, Boost	Forward, Flyback
<b>Voltage Reference Tolerance</b>	1.5%	1.5%	1.5%	1.5%	1.5%
<b>Peak Output Current</b>	1A	1A	1A	1A	1A
<b>Under Voltage Lockout</b>	7.2V / 6.9V	9.4V / 7.4V	12.5V / 8.3V	4.1V / 3.6V	12.5V / 8.3V
<b>Maximum Practical Operating Frequency</b>	1MHz	1MHz	1MHz	1MHz	1MHz
<b>Outputs</b>	Single, Totem Pole	Single, Totem Pole	Single, Totem Pole	Single, Totem Pole	Single, Totem Pole
<b>Startup Current</b>	100µA	100µA	100µA	100µA	100µA
<b>Leading Edge Blanking</b>	Y	Y	Y	Y	Y
<b>Soft Start</b>	Y	Y	Y	Y	Y
<b>Maximum Duty Cycle</b>	100%	50%	100%	100%	50%
<b>Separate Oscillator / Synchronization Terminal</b>					
<b>Application / Design Note</b>	DN-42A, DN-48, DN-54, DN-65, DN-89, U-97, U-133A	DN-42A, DN-48, DN-54, DN-65, DN-89, U-97, U-133A	DN-42A, DN-48, DN-54, DN-65, DN-89, U-97, U-133A	DN-42A, DN-43, DN-46, DN-48, DN-54, DN-56A, DN-65, DN-89, U-97, U-133A	DN-42A, DN-48, DN-54, DN-65, DN-89, U-97, U-133A
<b>Pin Count</b> ✧	8	8	8	8	8
<b>Page Number</b>	PS/3-212	PS/3-212	PS/3-212	PS/3-212	PS/3-212

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

✧ The smallest available pin count for thru-hole and surface mount packages.

+ New Product



# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Current Mode Controllers	UNITRODE PART NUMBER				
	UCC3813-5	UC3823	UC3823A	UC3823B	UC3824
<b>Application</b>	DC-DC and Battery	DC-DC	DC-DC	Off-line	Synchronous Rectifier, Forward Converter
<b>Topology</b>	Forward, Flyback	Buck, Boost	Buck, Boost	Buck, Boost	Forward, Flyback
<b>Voltage Reference Tolerance</b>	1.5%	1%	1%	1%	1%
<b>Peak Output Current</b>	1A	1.5A	2A	2A	1.5A
<b>Under Voltage Lockout</b>	4.1V / 3.6V	9.2V / 8.4V	9.2V / 8.4V	16V / 10V	9.2V / 8.4V
<b>Maximum Practical Operating Frequency</b>	1MHz	1MHz	1MHz	1MHz	1MHz
<b>Outputs</b>	Single, Totem Pole	Single, Totem Pole	Single, Totem Pole	Single, Totem Pole	Dual Complementary, Totem Pole
<b>Startup Current</b>	100µA	1.1mA	0.1mA	0.1mA	1.1mA
<b>Leading Edge Blanking</b>	Y		Y	Y	
<b>Soft Start</b>	Y	Y	Y	Y	Y
<b>Maximum Duty Cycle</b>	50%	100%	Programmable, <100%	Programmable, <100%	100%
<b>Separate Oscillator / Synchronization Terminal</b>		Y	Y	Y	Y
<b>Application / Design Note</b>	DN-42A, DN-43, DN-46, DN-48, DN-54, DN-56A, DN-65, DN-89, U-97, U-133A	U-97, U-111, U-131	U-97, U-110, U-111, U-128, U-131	U-97, U-110, U-111, U-128, U-131	U-111
<b>Pin Count ✧</b>	8	16	16	16	16
<b>Page Number</b>	PS/3-212	PS/3-219	PS/3-225	PS/3-225	PS/3-233

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

✧ The smallest available pin count for thru-hole and surface mount packages.

+ New Product



# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Current Mode Controllers	UNITRODE PART NUMBER				
	UC3825	UC3825A	UC3825B	UC3826	UC3827-1
<b>Application</b>	DC-DC	DC-DC	Off-line	Secondary Side, Average Current Mode	Multiple Output or High Voltage Output DC-DC Converters
<b>Topology</b>	Push-pull, Full Bridge, Half Bridge	Push-pull, Full Bridge, Half Bridge	Push-pull, Full Bridge, Half Bridge	Forward, Flyback, Buck, Boost	Buck Current Fed Push-pull
<b>Voltage Reference Tolerance</b>	1%	1%	1%	1%	4%
<b>Peak Output Current</b>	1.5A	2A	2A	0.25A	Floating 1A for Buck Stage, 0.8A for Push-pull Drivers
<b>Under Voltage Lockout</b>	9.2V / 8.4V	9.2V / 8.4V	16V / 10V	8.4V / 8.0V	9V / 8.4V
<b>Maximum Practical Operating Frequency</b>	1MHz	1MHz	1MHz	1MHz	500kHz
<b>Outputs</b>	Dual Alternating, Totem Pole	Dual Alternating, Totem Pole	Dual Alternating, Totem Pole	Single, Totem Pole	Floating Buck, Push-pull
<b>Startup Current</b>	1.1mA	0.1mA	0.1mA		1mA
<b>Leading Edge Blanking</b>		Y	Y	N/A	
<b>Soft Start</b>	Y	Y	Y	Y	Y
<b>Maximum Duty Cycle</b>	50% / 50%	Programmable	Programmable, <50%	Programmable, <50%	90% for Buck Stage, 50% / 50% for Push-pull Stage
<b>Separate Oscillator / Synchronization Terminal</b>	Y	Y	Y	Y	Y
<b>Application / Design Note</b>	U-97, U-110, U-111	U-97, U-110, U-111, U-128, U-131	U-97, U-110, U-111, U-128, U-131	U-135, U-140	
<b>Pin Count</b> ✧	16	16	16	24	24
<b>Page Number</b>	PS/3-240	PS/3-225	PS/3-225	PS/3-247	PS/3-257

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

✧ The smallest available pin count for thru-hole and surface mount packages.

○ Pulse-by-Pulse Current Limiting Not Applicable.

+ New Product



# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Current Mode Controllers	UNITRODE PART NUMBER				
	UC3827-2	UCC3830-4	UCC3830-5	UCC3830-6	UCC3839 >
Application	Multiple Output or High Voltage Output DC-DC Converters	Microprocessor Power	Microprocessor Power	Microprocessor Power	Secondary Side, Average Current Mode Control
Topology	Buck Voltage Fed Push-pull	Buck	Buck	Buck	Any Topology
Voltage Reference Tolerance	4%	1%*	1%*	1%*	1%
Peak Output Current	Floating 1A for Buck Stage, 0.8A for Push-pull Drivers	1.5A	1.5A	1.5A	10mA to Drive Opto-coupler
Under Voltage Lockout	9V / 8.4V	10.5V / 10V	10.5V / 10V	10.5V / 10V	
Maximum Practical Operating Frequency	500kHz	100kHz	200kHz	400kHz	1MHz
Outputs	Floating Buck, Push-pull	Single	Single	Single	Opto-coupler Drive
Startup Current	1mA				
Leading Edge Blanking					
Soft Start	Y				
Maximum Duty Cycle	90% for Buck Stage, 50% / 50% for Push-pull Stage	95%	95%	95%	
Separate Oscillator / Synchronization Terminal	Y				
Application / Design Note					U-140
Pin Count ❖	24	20	20	20	14
Page Number	PS/3-257	PS/3-263	PS/3-263	PS/3-263	PS/3-276

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

❖ The smallest available pin count for thru-hole and surface mount packages.

\* Combined Reference, DAC, and Error Amplifier Tolerance.

○ Pulse-by-Pulse Current Limiting Not Applicable.

+ New Product

# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Current Mode Controllers	UNITRODE PART NUMBER				
	UC3841	UC3842	UC3842A	UC3843	UC3843A
<b>Application</b>	Primary Side, Programmable, Off-line, DC-DC	Off-line	Off-line	DC-DC	DC-DC
<b>Topology</b>	Forward, Flyback, Buck, Boost	Forward, Flyback, Buck, Boost	Forward, Flyback, Buck, Boost	Forward, Flyback Buck, Boost	Forward, Flyback Buck, Boost
<b>Voltage Reference Tolerance</b>	1%	1%	1%	1%	1%
<b>Peak Output Current</b>	1A	1A	1A	1A	1A
<b>Under Voltage Lockout</b>		16V / 10V	16V / 10V	8.4V / 7.6V	8.5V / 7.9V
<b>Maximum Practical Operating Frequency</b>	500kHz	500kHz	500kHz	500kHz	500kHz
<b>Outputs</b>	Single, Open Collector	Single, Totem Pole	Single, Totem Pole	Single, Totem Pole	Single, Totem Pole
<b>Startup Current</b>	4.5mA	1mA	0.5mA	1mA	0.5mA
<b>Leading Edge Blanking</b>					
<b>Soft Start</b>	Y				
<b>Maximum Duty Cycle</b>	Programmable	100%	100%	100%	100%
<b>Separate Oscillator / Synchronization Terminal</b>					
<b>Special Features</b>			Trimmed Oscillator Discharge Current		Trimmed Oscillator Discharge Current
<b>Application / Design Note</b>	DN-28	DN-27, DN-40, DN-89, U-100A, U-111	DN-26, DN-27, DN-29, DN-30, DN-40, DN-89, U-100A, U-111	DN-27, DN-40, DN-89, U-100A, U-111	DN-26, DN-27, DN-29, DN-30, DN-40, DN-89, U-100A, U-111
<b>Pin Count</b> ✧	18	8, 14	8, 14	8, 14	8, 14
<b>Page Number</b>	PS/3-281	PS/3-289	PS/3-296	PS/3-289	PS/3-296

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

✧ The smallest available pin count for thru-hole and surface mount packages.

+ New Product



# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Current Mode Controllers	UNITRODE PART NUMBER				
	UC3844	UC3844A	UC3845	UC3845A	UC3846
Application	Off-line	Off-line	DC-DC	DC-DC	Off-line, DC-DC
Topology	Forward, Flyback Buck, Boost	Forward, Flyback Buck, Boost	Forward, Flyback Buck, Boost	Forward, Flyback Buck, Boost	Push-pull, Full Bridge, Half Bridge
Voltage Reference Tolerance	1%	1%	1%	1%	1%
Peak Output Current	1A	1A	1A	1A	0.5A
Under Voltage Lockout	16V / 10V	16V / 10V	8.4V / 7.6V	8.5V / 7.9V	7.7V / 6.95V
Maximum Practical Operating Frequency	500kHz	500kHz	500kHz	500kHz	500kHz
Outputs	Single, Totem Pole	Single, Totem Pole	Single, Totem Pole	Single, Totem Pole	Dual Alternating, Totem Pole
Startup Current	1mA	0.5mA	1mA	0.5mA	
Leading Edge Blanking					
Soft Start					Y
Maximum Duty Cycle	50%	50%	50%	50%	50% / 50%
Separate Oscillator / Synchronization Terminal					Y
Special Features		Trimmed Oscillator Discharge Current		Trimmed Oscillator Discharge Current	
Application / Design Note	DN-27, DN-40, DN-89, U-100A, U-111	DN-26, DN-27, DN-29, DN-30, DN-40, DN-89, U-100A, U-111	DN-27, DN-40, DN-89, U-100A, U-111	DN-26, DN-27, DN-29, DN-30, DN-40, DN-89, U-100A, U-111	DN-45, U-93, U-97, U-100A, U-111
Pin Count ❖	8, 14	8, 14	8, 14	8, 14	16
Page Number	PS/3-289	PS/3-296	PS/3-289	PS/3-296	PS/3-302

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

❖ The smallest available pin count for thru-hole and surface mount packages.

+ New Product

# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Current Mode Controllers	UNITRODE PART NUMBER				
	UC3847	UC3848 )	UC3849 )	UC3851	UC3856
<b>Application</b>	Off-line, DC-DC	Average Current Mode, Off-line, DC-DC	Secondary Side, Average Current Mode	Off-line, Programmable, Primary Side Controller	Isolated Output, Push-pull Controller
<b>Topology</b>	Push-pull, Full Bridge, Half Bridge	Forward, Flyback	Forward, Flyback, Buck, Boost	Forward, Flyback, Buck, Boost	Push-pull, Full Bridge, Half Bridge
<b>Voltage Reference Tolerance</b>	1%	1%	1%	1%	1%
<b>Peak Output Current</b>	0.5A	2A	0.25A	0.2A	1.5A
<b>Under Voltage Lockout</b>	7.7V / 6.95V	13V / 10V	8.3V / 7.9V		7.7V / 7.0V
<b>Maximum Practical Operating Frequency</b>	500kHz	1MHz	1MHz	500kHz	1MHz
<b>Outputs</b>	Dual Alternating, Totem Pole	Single, Totem Pole	Single, Totem Pole	Single, Totem Pole	Dual Alternating, Totem Pole
<b>Startup Current</b>		500 $\mu$ A		4.5mA	
<b>Leading Edge Blanking</b>		N/A	N/A	Y	
<b>Soft Start</b>	Y		Y	Y	Y
<b>Maximum Duty Cycle</b>	50% / 50%	Programmable	Programmable	50%	50% / 50%
<b>Separate Oscillator / Synchronization Terminal</b>	Y		Y		Y
<b>Application / Design Note</b>	DN-45, U-93, U-97, U-100A, U-111	U-135, U-140	U-135, U-140	DN-28	DN-45, U-93, U-97, U-110
<b>Pin Count</b> ❖	16	16	24	18	16
<b>Page Number</b>	PS/3-302	PS/3-309	PS/3-317	PS/3-327	PS/3-333

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

❖ The smallest available pin count for thru-hole and surface mount packages.

○ Pulse-by-Pulse Current Limiting Not Applicable.

+ New Product



# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Current Mode Controllers	UNITRODE PART NUMBER				
	UCC3880-4	UCC3880-5	UCC3880-6	UCC3882	UCC3884
Application	Microprocessor Power	Microprocessor Power	Microprocessor Power	Microprocessor Power	Off-Line or DC-DC Frequency Foldback Controller
Topology	Buck	Buck	Buck	Synchronous Buck	Forward, Flyback, Buck, Boost
Voltage Reference Tolerance	1%*	1%*	1%*	1%*	2%
Peak Output Current	1.5A	1.5A	1.5A	1.5A	0.5A Source, 1A Sink
Under Voltage Lockout	10.5V / 10V	10.5V / 10V	10.5V / 10V	10.5V / 10V	8.9V / 8.3V
Maximum Practical Operating Frequency	100kHz	200kHz	400kHz	700kHz	750kHz
Outputs	Single	Single		Dual, N-FET Drive	Single
Startup Current					200µA
Leading Edge Blanking					
Average Current Mode	Y	Y		Y	
Foldback Current Limiting	Y	Y		Y	
Soft Start					Y
Maximum Duty Cycle	95%	95%		95%	80%
Separate Oscillator / Synchronization Terminal					Y
Special Features	4 Bit Programmable Output Voltage, UV/OV Monitor	4 Bit Programmable Output Voltage, UV/OV Monitor	4 Bit Programmable Output Voltage, UV/OV Monitor	5 Bit Programmable Output Voltage, UV/OV Monitor	
Application / Design Note	U-140	U-140	U-140	U-140	DN-65, U-164
Pin Count ⇄	24	18	16	28	16
Page Number	PS/3-373	PS/3-373	PS/3-373	PS/3-380	PS/3-393

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

⇄ The smallest available pin count for thru-hole and surface mount packages.

\* Combined Reference, DAC, and Error Amplifier Tolerance.

+ New Product

# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Current Mode Controllers		UNITRODE PART NUMBER			
UC3886					
Application	Microprocessor Power				
Topology	Buck				
Voltage Reference Tolerance	1.5%				
Peak Output Current	1.5A				
Under Voltage Lockout	10.3V / 10.05V				
Maximum Practical Operating Frequency	400kHz				
Outputs	Single				
Startup Current					
Leading Edge Blanking					
Average Current Mode					
Foldback Current Limiting					
Soft Start					
Maximum Duty Cycle	95%				
Separate Oscillator / Synchronization Terminal					
Special Features	External Reference Input, Use with UC3910				
Application / Design Note	U-140, U-156, U-157				
Pin Count ❖	16				
Page Number	PS/3-400				

*All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.*

*❖ The smallest available pin count for thru-hole and surface mount packages.*

*+ New Product*



# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Dedicated DC/DC Controllers	UNITRODE PART NUMBER		
	UC2577-12	UC2577-15	UC2577-ADJ
<b>Description</b>	Simple Step-up Voltage Regulator	Simple Step-up Voltage Regulator	Simple Step-up Voltage Regulator
<b>Application</b>	3A Step-up Switching Regulator for Boost, Flyback, and Forward Converter Applications	3A Step-up Switching Regulator for Boost, Flyback, and Forward Converter Applications	3A Step-up Switching Regulator for Boost, Flyback, and Forward Converter Applications
<b>Output Voltage</b>	12V	15V	Adjustable
<b>Special Features</b>	<ul style="list-style-type: none"> <li>• Circuit Requires Few External Components</li> <li>• NPN Output Switches 3A</li> <li>• Current Mode Operation for Improved Response</li> <li>• Fixed and Adjustable Output Versions Available</li> </ul>	<ul style="list-style-type: none"> <li>• Circuit Requires Few External Components</li> <li>• NPN Output Switches 3A</li> <li>• Current Mode Operation for Improved Response</li> <li>• Fixed and Adjustable Output Versions Available</li> </ul>	<ul style="list-style-type: none"> <li>• Circuit Requires Few External Components</li> <li>• NPN Output Switches 3A</li> <li>• Current Mode Operation for Improved Response</li> <li>• Fixed and Adjustable Output Versions Available</li> </ul>
<b>Application / Design Note</b>	DN-47, DN-49	DN-47, DN-49	DN-49
<b>Pin Count</b> ❖	5	5	5
<b>Page Number</b>	PS/3-31	PS/3-31	PS/3-36

*All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.*

*❖ The smallest available pin count for thru-hole and surface mount packages.*

*+ New Product*



# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Dedicated DC/DC Controllers	UNITRODE PART NUMBER			
	UC3572	UC3573	UC3578	UCC3585+
<b>Application</b>	Low Power, High Efficiency, Spot Regulator	Low Power, High Efficiency, Spot Regulator	DC-DC	Low Input Voltage Synchronous Buck Regulator with Output Voltage Tracking
<b>Topology</b>	Negative Output Flyback	Buck	Buck	Voltage Mode Synchronous Buck
<b>Voltage Reference Tolerance</b>	2%	2%	2%	1%
<b>Peak Output Current</b>	0.5A	0.5A	0.6A Source, 0.8A Sink	0.5A
<b>Maximum Practical Operating Frequency</b>	300kHz	300kHz	100kHz Internal Oscillator	700kHz
<b>Outputs</b>	Single, Totem Pole	Single, Totem Pole	Single, Floating Totem Pole	P FET/N FET Synchronous
<b>Startup Current</b>			N/A	2.3mA
<b>Voltage Feedforward</b>				N
<b>Soft Start</b>			Y	Y
<b>Maximum Duty Cycle</b>	100%	100%	90%	100%
<b>Separate Oscillator / Synchronization Terminal</b>				N
<b>Application / Design Note</b>		DN-70	U-167	
<b>Pin Count</b> ❖	8	8	16	16
<b>Page Number</b>	PS/3-108	PS/3-112	PS/3-116	PS/3-154

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

❖ The smallest available pin count for thru-hole and surface mount packages.

+ New Product



# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Dedicated DC/DC Controllers	UNITRODE PART NUMBER		
	UCC39401+	UCC3941	UCC39411/2/3+
<b>Description</b>	Low Voltage Boost Controller / Charger	1V Synchronous Boost Converter	1V Low Power Boost Controller
<b>Application</b>	Pager Power	High Efficiency Integrated Boost Converter	High Efficiency Low Power Synchronous Boost Conversion
<b>Special Features</b>	<ul style="list-style-type: none"> <li>• High Efficiency Boost</li> <li>• 1V Input</li> <li>• Battery Charger</li> <li>• Backup LDO</li> </ul>	<ul style="list-style-type: none"> <li>• Full Load Startup at 1V</li> <li>• Power Limit Control</li> <li>• Auxiliary 9V Supply</li> <li>• Output Disconnect</li> <li>• Shutdown Mode</li> </ul>	<ul style="list-style-type: none"> <li>• 200mW Output Power with Battery Voltages as low as 0.8V</li> <li>• Power Limit Control</li> <li>• Adaptive Current Mode Control</li> <li>• Auxiliary 7V Supply</li> <li>• Shutdown Mode</li> </ul>
<b>Application / Design Note</b>			
<b>Pin Count</b> ❖	20	8	8
<b>Page Number</b>	PP/7-34	PP/7-45	PP/7-58

Dedicated DC/DC Controllers	UNITRODE PART NUMBER	
	UCC39421/2+	UCC3954
<b>Description</b>	Multimode HF PWM Controller	Single Cell Lithium-Ion to 3.3V Converter
<b>Application</b>	High Efficiency Boost, Sepic Flyback Converter	High Efficiency Flyback Converter
<b>Special Features</b>	<ul style="list-style-type: none"> <li>• 2MHz Operation</li> <li>• 1.8V Input</li> <li>• Current Limit</li> <li>• Power-on Reset</li> <li>• Low Voltage Detect</li> </ul>	<ul style="list-style-type: none"> <li>• Fixed 3.3V Output</li> <li>• 750mA Output Current</li> <li>• Low Battery Warning</li> <li>• Low Battery Disconnect</li> <li>• Shutdown Mode</li> </ul>
<b>Application / Design Note</b>		
<b>Pin Count</b> ❖	16, 20	8
<b>Page Number</b>	PP/7-66	PP/7-93

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

❖ The smallest available pin count for thru-hole and surface mount packages.

+ New Product

# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

MicroProcessor Power Controllers	UNITRODE PART NUMBER				
	UCC3588+	UCC3830-4	UCC3830-5	UCC3830-6	UCC3880-4
<b>Application</b>	Synchronous Buck Regulator with 5 Bit DAC	Microprocessor Power	Microprocessor Power	Microprocessor Power	Microprocessor Power
<b>Topology</b>	Voltage Mode Synchronous Buck	Buck	Buck	Buck	Buck
<b>Voltage Reference Tolerance</b>	1%	1%*	1%*	1%*	1%*
<b>Peak Output Current</b>	1A	1.5A	1.5A	1.5A	1.5A
<b>Maximum Practical Operating Frequency</b>	700kHz	100kHz	200kHz	400kHz	100kHz
<b>Outputs</b>	Dual NFET Synchronous	Single	Single	Single	Single
<b>Soft Start</b>	Y				
<b>Average Current Mode</b>		Y	Y	Y	Y
<b>Foldback Current Limiting</b>		Y	Y	Y	Y
<b>Maximum Duty Cycle</b>	100%	95%	95%	95%	95%
<b>Special Features</b>		5 Bit Programmable Output Voltage, UV/OV Monitor	5 Bit Programmable Output Voltage, UV/OV Monitor	5 Bit Programmable Output Voltage, UV/OV Monitor	4 Bit Programmable Output Voltage, UV/OV Monitor
<b>Application / Design Note</b>					U-140
<b>Pin Count</b> ❖	16	20	20	20	20
<b>Page Number</b>	PS/3-163	PS/3-263	PS/3-263	PS/3-263	PS/3-373

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

❖ The smallest available pin count for thru-hole and surface mount packages.

\* Combined Reference, DAC, and Error Amplifier Tolerance.

+ New Product



# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

MicroProcessor Power Controllers	UNITRODE PART NUMBER				
	UCC3880-5	UCC3880-6	UCC3882		
Application	Microprocessor Power	Microprocessor Power	Microprocessor Power		
Topology	Buck	Buck	Synchronous Buck		
Voltage Reference Tolerance	1%*	1%*	1%*		
Peak Output Current	1.5A	1.5A	1.5A		
Maximum Practical Operating Frequency	200kHz	400kHz	700kHz		
Outputs	Single	Single	Dual, N-FET Drive		
Soft Start					
Average Current Mode	Y	Y	Y		
Foldback Current Limiting	Y	Y	Y		
Maximum Duty Cycle	95%	95%	95%		
Special Features	4 Bit Programmable Output Voltage, UV/OV Monitor	4 Bit Programmable Output Voltage, UV/OV Monitor	5 Bit Programmable Output Voltage, UV/OV Monitor		
Application / Design Note	U-140	U-140	U-140		
Pin Count ✧	20	20	28		
Page Number	PS/3-373	PS/3-373	PS/3-380		

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

✧ The smallest available pin count for thru-hole and surface mount packages.

\* Combined Reference, DAC, and Error Amplifier Tolerance.

+ New Product

# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

MicroProcessor Power Support	UNITRODE PART NUMBER		
	UCC391+	UC3910	UCC3946
<b>Description</b>	5-Bit DAC 5V Operation	Reference, 4-bit DAC and Fault Monitor	Microprocessor Supervisor with Watchdog Timer
<b>Application</b>	Sets Control Voltage for UC3886 and other Precision PWMs	Sets Control Voltage for UC3886, UC3870 and other Precision PWMS	Accurate Microprocessor Supervision
<b>Special Features</b>	<ul style="list-style-type: none"> <li>•5V Operation</li> <li>•1% Combined Reference and DAC Tolerance</li> <li>•Meets VID Code for Pentium II Processors</li> </ul>	<ul style="list-style-type: none"> <li>•4-bit DAC Sets Output Voltage of PWM, Meets Intel VID Code</li> <li>•1% Combined Reference and DAC Tolerance</li> <li>•Over and Under Voltage Monitoring and Protection</li> </ul>	<ul style="list-style-type: none"> <li>•Programmable Reset Period</li> <li>•Programmable Watchdog Period</li> <li>•1.5% Accurate Threshold</li> <li>•4mA IDD</li> </ul>
<b>Application / Design Note</b>		U-157, U-158	
<b>Pin Count</b> ✧	8	16	8
<b>Page Number</b>	PS/3-434	PS/3-437	PP/7-88

*All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.*

✧ *The smallest available pin count for thru-hole and surface mount packages.*

+ *New Product*



# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Post Regulation Controllers	UNITRODE PART NUMBER		
	UCC3583	UC3584	UC3838A
<b>Application</b>	Secondary Side Post Regulation	DC-DC Secondary Side Synchronous Post Regulator	Mag-Amp Controller
<b>Topology</b>	Buck	Buck	
<b>Voltage Reference Tolerance</b>	1.5%	1%	1%
<b>Peak Output Current</b>	1.5A Source, 0.5A Sink	1.5A Source and Sink	120mA Reset Current
<b>Maximum Practical Operating Frequency</b>	500kHz	1MHz	
<b>Undervoltage Lockout</b>	9.0V / 8.4V	10.5V / 8.8V	N/A
<b>Outputs</b>	Single, Totem Pole	Single, Totem Pole	
<b>Startup Current</b>	100 $\mu$ A	N/A	
<b>Voltage Feedforward</b>	N/A		
<b>Soft Start</b>	Y	Y	
<b>Maximum Duty Cycle</b>	95%	94%	
<b>Separate Oscillator / Synchronization Terminal</b>	Y	Y	
<b>Special Features</b>	<ul style="list-style-type: none"> <li>• For Both Single Ended and Center Tapped Secondary Circuits</li> <li>• Operation From Floating Supply Referenced to Output</li> </ul>	<ul style="list-style-type: none"> <li>• Can Use Existing Windings</li> <li>• Internally Regulated 15V Boost Supply Bias for Low Voltage Applications</li> <li>• Short Circuit Protection with Programmable Delay</li> </ul>	<ul style="list-style-type: none"> <li>• Dual Op-Amps</li> <li>• -120V Reset Driver</li> </ul>
<b>Application / Design Note</b>	DN-64	DN-64, DN-83	DN-47
<b>Pin Count</b> ❖	14	16	16, 20
<b>Page Number</b>	PS/3-139	PS/3-148	PS/3-272

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

❖ The smallest available pin count for thru-hole and surface mount packages.

+ New Product

# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Secondary Side PWM Control	UNITRODE PART NUMBER				
	UC3826	UCC3839 >	UC3849 >	UCC3960+	UCC3961+
Application	Secondary Side, Average Current Mode	Secondary Side, Average Current Mode Control	Secondary Side, Average Current Mode	Primary-Side Startup Control	Primary-Side Startup Control
Topology	Forward, Flyback, Buck, Boost	Any Topology	Forward, Flyback, Buck, Boost		
Voltage Reference Tolerance	1%	1%	1%	5%	5%
Peak Output Current	0.25A	10mA to Drive Opto-coupler	0.25A	1.5A	1.5A
Undervoltage Lockout	8.4V / 8V		8.3V / 7.9V	10V / 8V	10V / 8V
Maximum Practical Operating Frequency	1MHz	1MHz	1MHz	400kHz Synchronizable Switching Frequency	400kHz Synchronizable Switching Frequency
Outputs	Single, Totem Pole	Opto-coupler Drive	Single, Totem Pole	Single	Single
Startup Current				150µA	150µA
Leading Edge Blanking	N/A		N/A	N/A	N/A
Soft Start	Y		Y	Y	Y
Maximum Duty Cycle	Programmable		Programmable		Programable V-S Clamp
Separate Oscillator / Synchronization Terminal	Y		Y		
Special Features					<ul style="list-style-type: none"> <li>• Multimode OVC Protection,</li> <li>• Programable OV and UV,</li> <li>• Self Bias Regulation.</li> </ul>
Application / Design Note	U-135, U-140	U-140	U-135, U-140	DN-99	DN-99
Pin Count ✧	24	14	24	8	14
Page Number	PS/3-247	PS/3-276	PS/3-317	PS/3-442	PS/3-450

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

✧ The smallest available pin count for thru-hole and surface mount packages.

○ Pulse-by-Pulse Current Limiting Not Applicable.

+ New Product



# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Soft Switching Controllers	UNITRODE PART NUMBER				
	UCC3580-1★	UCC3580-2★	UCC3580-3★	UCC3580-4★	UC3860
Application	Active Clamp / Reset PWM	Active Clamp / Reset PWM	Active Clamp / Reset PWM	Active Clamp / Reset PWM	Off-line, DC-DC, Zero Current Switching
Topology	Forward, Flyback	Forward, Flyback	Forward, Flyback	Forward, Flyback	Half Bridge, Full Bridge
Voltage Reference Tolerance	1.5%	1.5%	1.5%	1.5%	1%
Peak Output Current	1A / 0.5A	1A / 0.5A	1A / 0.5A	1A / 0.5A	2A
Undervoltage Lockout	9V / 8.5V	15V / 8.5V	9V / 8.5V	15V / 8.5V	17.3V / 10.5V
Maximum Practical Operating Frequency	1MHz	1MHz	1MHz	1MHz	2MHz
Outputs	Dual Complementary, Totem Pole	Dual Complementary, Totem Pole	Dual Complementary, Totem Pole, Inverted Out2	Dual Complementary, Totem Pole, Inverted Out2	Dual Programmable, Totem Pole
Startup Current	50µA	50µA	50µA	50µA	300µA
Voltage Feedforward	Y	Y	Y	Y	
Soft Start	Y	Y	Y	Y	
Maximum Duty Cycle	Programmable	Programmable	Programmable	Programmable	Programmable
Separate Oscillator / Synchronization Terminal	Y	Y	Y	Y	Y
Application / Design Note	DN-65	DN-65	DN-65	DN-65	
Pin Count ❖	16	16	16	16	24, 28
Page Number	PS/3-122	PS/3-122	PS/3-122	PS/3-122	PS/3-341

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

❖ The smallest available pin count for thru-hole and surface mount packages.

★ Does Not Feature Current Limiting.

+ New Product



# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Soft Switching Controllers	UNITRODE PART NUMBER				
	UC3861	UC3862	UC3863	UC3864	UC3865
<b>Application</b>	Off-line, Zero Voltage Switching	DC-DC and Battery, Zero Voltage Switching	DC-DC and Battery, Zero Voltage Switching	DC-DC and Battery, Zero Voltage Switching	Off-line, Zero Current Switching
<b>Topology</b>	Half Bridge, Full Bridge	Forward, Flyback	Half Bridge, Full Bridge	Forward, Flyback	Half Bridge, Full Bridge
<b>Voltage Reference Tolerance</b>	1%	1%	1%	1%	1%
<b>Peak Output Current</b>	1A	1A	1A	1A	1A
<b>Undervoltage Lockout</b>	16.5V / 10.5V	16.5V / 10.5V	8V / 7V	8V / 7V	16.5V / 10.5V
<b>Maximum Practical Operating Frequency</b>	1MHz	1MHz	1MHz	1MHz	1MHz
<b>Outputs</b>	Dual Alternating, Totem Pole	Single, Totem Pole	Dual Alternating, Totem Pole	Single, Totem Pole	Dual Alternating, Totem Pole
<b>Startup Current</b>	150μA	150μA	150μA	150μA	150μA
<b>Voltage Feedforward</b>					
<b>Soft Start</b>					
<b>Maximum Duty Cycle</b>	50% / 50%	100%	50% / 50%	100%	50% / 50%
<b>Separate Oscillator / Synchronization Terminal</b>					
<b>Application / Design Note</b>	U-122, U-138	U-122, U-138	U-122, U-138	U-122, U-138	U-122, U-138
<b>Pin Count</b> ❖	16	16	16	16	16
<b>Page Number</b>	PS/3-349	PS/3-349	PS/3-349	PS/3-349	PS/3-349

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

❖ The smallest available pin count for thru-hole and surface mount packages.

+ New Product



# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Soft Switching Controllers	UNITRODE PART NUMBER				
	UC3866	UC3867	UC3868	UC3875	UC3876
<b>Application</b>	Off-line, Zero Current Switching	DC-DC and Battery, Zero Current Switching	DC-DC and Battery, Zero Current Switching	Zero Voltage Transition, Phase Shifted Bridge	Zero Voltage Transition, Phase Shifted Bridge
<b>Topology</b>	Forward, Flyback	Half Bridge, Full Bridge	Forward, Flyback	Full Bridge	Full Bridge
<b>Voltage Reference Tolerance</b>	1%	1%	1%	1%	1%
<b>Peak Output Current</b>	1A	1A	1A	2A	2A
<b>Undervoltage Lockout</b>	16.5V / 10.5V	8V / 7V	8V / 7V	10.75V / 9.5V	15.25V / 9.25V
<b>Maximum Practical Operating Frequency</b>	1MHz	1MHz	1MHz	1MHz	1MHz
<b>Outputs</b>	Single, Totem Pole	Dual Alternating, Totem Pole	Single, Totem Pole	Quad Phase Shifted, Totem Pole	Quad Phase Shifted, Totem Pole
<b>Startup Current</b>	150µA	150µA	150µA	150µA	150µA
<b>Soft Start</b>				Y	Y
<b>Maximum Duty Cycle</b>	100%	50% / 50%	100%	100%	100%
<b>Separate Oscillator / Synchronization Terminal</b>				Y	Y
<b>Application / Design Note</b>	U-122, U-138	U-122, U-138	U-122, U-138	DN-63, U-111, U-136A	DN-63, U-111, U-136A
<b>Pin Count</b> ❖	16	16	16	20, 28	20, 28
<b>Page Number</b>	PS/3-349	PS/3-349	PS/3-349	PS/3-357	PS/3-357

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

❖ The smallest available pin count for thru-hole and surface mount packages.

+ New Product

# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Soft Switching Controllers	UNITRODE PART NUMBER			
	UC3877	UC3878	UC3879	UCC3895+
<b>Application</b>	Zero Voltage Transition, Phase Shifted Bridge	Zero Voltage Transition, Phase Shifted Bridge	Zero Voltage Transition, Phase Shifted Bridge	Zero Voltage Transition, Phase, Shifted Bridge
<b>Topology</b>	Full Bridge	Full Bridge	Full Bridge	Full Bridge
<b>Voltage Reference Tolerance</b>	1%	1%	1%	1%
<b>Peak Output Current</b>	2A	2A	0.1A	0.1A
<b>Undervoltage Lockout</b>	10.75V / 9.5V	15.25V / 9.25V	Selectable 10.75V / 9.5V, 15.25V / 9.25V	11V / 9V
<b>Maximum Practical Operating Frequency</b>	1MHz	1MHz	300kHz	1MHz
<b>Outputs</b>	Quad, Phase Shifted, Totem Pole	Quad Phase Shifted, Totem Pole	Quad Phase Shifted, Totem Pole	Quad, Phase Shifted, Totem Pole
<b>Startup Current</b>	150µA	150µA	150µA	150µA
<b>Leading Edge Blanking</b>				
<b>Soft Start</b>	Y	Y	Y	Y
<b>Maximum Duty Cycle</b>	100%	100%	100%	100%
<b>Separate Oscillator / Synchronization Terminal</b>	Y	Y	Y	Y
<b>Application / Design Note</b>	DN-63, U-111, U-136A	DN-63, U-111, U-136A	DN-63, U-111, U-136A, U-154	DN-63, U-136A
<b>Pin Count</b> ✧	20, 28	20, 28	20	20
<b>Page Number</b>	PS/3-357	PS/3-357	PS/3-367	PS/3-425

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

✧ The smallest available pin count for thru-hole and surface mount packages.

+ New Product



# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Voltage Mode Controllers	UNITRODE PART NUMBER				
	UC3524❖	UC3524A	UC3525A	UC3525B	UC3526
Application	Fixed Frequency PWM, Off-line, DC-DC	Fixed Frequency PWM, Off-line, DC-DC	Fixed Frequency PWM, Off-line, DC-DC	Fixed Frequency PWM, Off-line, DC-DC	Fixed Frequency PWM, Off-line, DC-DC
Topology	Forward, Flyback, Buck, Boost	Forward, Flyback, Buck, Boost	Full Bridge, Half Bridge	Full Bridge, Half Bridge	Full Bridge, Half Bridge
Voltage Reference Tolerance	4%	1%	1%	0.75%	1%
Peak Output Current	100mA	200mA	400mA	200mA	100mA
Undervoltage Lockout		7.5V / 7V	7V	7V	Y
Maximum Practical Operating Frequency	300kHz	500kHz	500kHz	500kHz	400kHz
Outputs	Dual Alternating, Uncommitted	Dual Alternating, Uncommitted	Dual Alternating, Totem Pole	Dual Alternating, Totem Pole	Dual Alternating, Totem Pole
Startup Current		4mA			
Voltage Feedforward					
Soft Start			Y	Y	Y
Maximum Duty Cycle	50% / 50%	50% / 50%	50% / 50%	50% / 50%	50% / 50%
Separate Oscillator / Synchronization Terminal	Y	Y	Y	Y	Y
Application / Design Note			DN-36	DN-36	
Pin Count ❖	16	16	16	16	16
Page Number	PS/3-43	PS/3-48	PS/3-54	PS/3-61	PS/3-68

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

❖ The smallest available pin count for thru-hole and surface mount packages.

❖ Does Not Feature UVLO.

+ New Product

# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Voltage Mode Controllers	UNITRODE PART NUMBER				
	UC3526A	UC3527A	UC3527B	UC3548	UCC3570
<b>Application</b>	Fixed Frequency PWM Off-line, DC-DC	Fixed Frequency PWM, Off-line, DC-DC	Fixed Frequency PWM, Off-line, DC-DC	Off-line, DC-DC	Wide Range, Off-line
<b>Topology</b>	Full Bridge, Half Bridge	Full Bridge, Half Bridge	Full Bridge, Half Bridge	Flyback, Forward	Forward, Flyback, Buck, Boost
<b>Voltage Reference Tolerance</b>	1%	1%	0.75%	1%	1%
<b>Peak Output Current</b>	100mA	400mA	200mA	2A	500mA
<b>Undervoltage Lockout</b>	Y	7V	7V	13V / 10V	13V / 9V
<b>Maximum Practical Operating Frequency</b>	550kHz	500kHz	500kHz	1MHz	500kHz
<b>Outputs</b>	Dual Alternating, Totem Pole	Dual Alternating, Totem Pole	Dual Alternating, Totem Pole	Single, Totem Pole	Single, Totem Pole
<b>Startup Current</b>				500µA	85µA
<b>Voltage Feedforward</b>				Y	Y
<b>Soft Start</b>	Y	Y	Y	Y	Y
<b>Maximum Duty Cycle</b>	50% / 50%	50% / 50%	50% / 50%	Programmable	100%
<b>Separate Oscillator / Synchronization Terminal</b>	Y	Y	Y		
<b>Application / Design Note</b>		DN-36	DN-36		DN-48, DN-62, DN-65, U-150
<b>Pin Count</b> ❖	18	16	16	16	14
<b>Page Number</b>	PS/3-75	PS/3-54	PS/3-61	PS/3-83	PS/3-91

*All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.*

*❖ The smallest available pin count for thru-hole and surface mount packages.*

*+ New Product*



# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Voltage Mode Controllers	UNITRODE PART NUMBER				
	UCC35701+	UCC3580-1★	UCC3580-2★	UCC3580-3★	UCC3580-4★
<b>Application</b>	Wide Range DC-DC and Off-line	Active Clamp / Reset PWM	Active Clamp / Reset PWM	Active Clamp / Reset PWM	Active Clamp / Reset PWM
<b>Topology</b>	Forward, Flyback, Buck and Boost	Forward, Flyback	Forward, Flyback	Forward, Flyback	Forward, Flyback
<b>Voltage Reference Tolerance</b>	1%	1.5%	1.5%	1.5%	1.5%
<b>Peak Output Current</b>	1.2A	1A / 0.5A	1A / 0.5A	1A / 0.5A	1A / 0.5A
<b>Undervoltage Lockout</b>	13V / 9V	9V / 8.5V	15V / 8.5V	9V / 8.5V	15V / 8.5V
<b>Maximum Practical Operating Frequency</b>	700kHz	1MHz	1MHz	1MHz	1MHz
<b>Outputs</b>	Single, Totem Pole	Dual Complementary, Totem Pole	Dual Complementary, Totem Pole	Dual Complementary, Totem Pole, Inverted Out2	Dual Complementary, Totem Pole, Inverted Out2
<b>Startup Current</b>	130μA	50μA	50μA	50μA	50μA
<b>Voltage Feedforward</b>	Y	Y	Y	Y	Y
<b>Soft Start</b>	Y	Y	Y	Y	Y
<b>Maximum Duty Cycle</b>	100%	Programmable	Programmable	Programmable	Programmable
<b>Separate Oscillator / Synchronization Terminal</b>	Y	Y	Y	Y	Y
<b>Application / Design Note</b>	DN-48, DN-62, DN-65, U-150	DN-65	DN-65	DN-65	DN-65
<b>Pin Count</b> ❖	14	16	16	16	16
<b>Page Number</b>	PS/3-99	PS/3-122	PS/3-122	PS/3-122	PS/3-122

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

❖ The smallest available pin count for thru-hole and surface mount packages.

★ Does Not Feature Current Limiting.

+ New Product

# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Voltage Mode Controllers	UNITRODE PART NUMBER				
	UCC3581	UCC3588+	UCC3888	UCC3889	UCC3890
<b>Application</b>	Off-line, Primary Side PWM for ISDN Applications	Synchronous Buck Regulator with 5 Bit DAC	Off-line Power Supply Controller	Off-line Power Supply Controller	Off-line Battery Charge Controller
<b>Topology</b>	Forward, Flyback	Voltage Mode Synchronous Buck	Flyback	Flyback	Flyback
<b>Voltage Reference Tolerance</b>	1.5%	1%	3%	3%	4%
<b>Peak Output Current</b>	1A	1A	0.15A	0.15A	0.15A
<b>Undervoltage Lockout</b>	7.3V / 6.8V	10.5V / 10V	8.4V / 6.3V	8.4V / 6.3V	8.6V / 6.3V
<b>Maximum Practical Operating Frequency</b>	100kHz	700kHz	250kHz	250kHz	250kHz
<b>Outputs</b>	Single, Totem Pole	Dual NFET Synchronous	Single, Totem Pole	Single, Totem Pole	Single, Totem Pole
<b>Startup Current</b>	100µA		150µA	150µA	
<b>Voltage Feedforward</b>			Y	Y	Y
<b>Soft Start</b>	Y	Y			
<b>Maximum Duty Cycle</b>	Programmable	100%	55%	55%	N/A
<b>Separate Oscillator / Synchronization Terminal</b>	Y				
<b>Application / Design Note</b>	DN-48, DN65		DN-59A, U-149A	DN-59A, DN-65, U-149A	
<b>Pin Count</b> ❖	14	16	8	8	8
<b>Page Number</b>	PS/3-131	PS/3-163	PS/3-407	PS/3-412	PS/3-418

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

❖ The smallest available pin count for thru-hole and surface mount packages.

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# Power Supply Control (PS) Selection Guides



## PWM Control (cont.)

Voltage Mode Controllers	UNITRODE PART NUMBER			
	UC494A/AC	UC495A/AC		
Application	DC-DC	DC-DC		
Topology	Buck, Boost, Push-Pull, Half Bridge	Buck, Boost, Push-Pull, Half Bridge		
Voltage Reference Tolerance	1%	1%		
Peak Output Current	200mA	200mA		
Undervoltage Lockout	5V / 4.7V	5V / 4.7V		
Maximum Practical Operating Frequency				
Outputs	Dual Floating	Dual Floating		
Startup Current	6mA	6mA		
Voltage Feedforward				
Soft Start				
Maximum Duty Cycle				
Separate Oscillator / Synchronization Terminal				
Special Features		On Chip 39V Zener		
Application / Design Note	DN-38	DN-38		
Pin Count ✧	16	18		
Page Number	PS/3-460	PS/3-460		

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.

✧ The smallest available pin count for thru-hole and surface mount packages.

+ New Product





## Power Factor Correction

Power Factor Correction Products . . . . . 7-61

### Power Factor Correction

Power Factor Correction Products	UNITRODE PART NUMBER				
	UCC3817+	UCC3818+	UCC38500+	UCC38501+	UCC38502+
<b>Soft Switching</b>					
<b>Maximum Practical Operating Frequency</b>	250kHz	250kHz	250kHz	250kHz	250kHz
<b>Current Error Amplifier Bandwidth</b>	3MHz	3MHz	3MHz	3MHz	3MHz
<b>Average Current Mode</b>	Y	Y	Y	Y	Y
<b>Worldwide AC Input Voltage Operation</b>	Y	Y	Y	Y	Y
<b>Output Drive</b>	1A	1A	1A	1A	1A
<b>Startup Current</b>	0.1A	0.1A	0.1A	0.1A	0.1A
<b>Undervoltage Lockout</b>	16V / 10V	10.5V / 10V	16V / 10V	10.5V / 10V	16V / 10V
<b>UVLO 2 Hysteresis</b>			1.2V (300V Turn-off)	1.2V (300V Turn-off)	3V (200V Turn-off)
<b>Overvoltage Protection</b>	Y	Y	Y	Y	Y
<b>Enable Input</b>	Y (with OVP)	Y	Y	Y	Y
<b>Multiplier / Divider Feedforward</b>	Y (Simplified)	Y (Simplified)	Y (Simplified)	Y (Simplified)	Y (Simplified)
<b>Special Features</b>			DC / DC Controller Included	DC / DC Controller Included	DC / DC Controller Included
<b>Application / Design Note</b>	DN-39E	DN-39E	DN-39E		
<b>Pin Count</b> ❖	16	16	20	20	20
<b>Page Number</b>	PS/4-5	PS/4-5	PS/4-15	PS/4-15	PS/4-15

❖ *The smallest available pin count for thru-hole and surface mount packages.*  
 + *New Product*



# Power Supply Control (PS) Selection Guides



## Power Factor Correction (cont.)

Power Factor Correction Products	UNITRODE PART NUMBER				
	UC3854B	UC3855A	UC3855B	UCC3857	UCC3858
Soft Switching		ZVT	ZVT	ZCT	
Maximum Practical Operating Frequency	200kHz	500kHz	500kHz	500kHz	500kHz
Current Error Amplifier Bandwidth	5MHz	5MHz	5MHz	5MHz	5MHz
Average Current Mode	Y	Y	Y	Y	Y
Worldwide AC Input Voltage Operation	Y	Y	Y	Y	Y
Output Drive	1A	1.5A	1.5A	1A	0.5A
Startup Current	0.3mA	0.15mA	0.15mA	0.06mA	0.1mA
Undervoltage Lockout	10.5V / 10V	16V / 10V	10.5V / 10V	13.8V / 10V	13.8V / 10V
Overvoltage Protection		Y	Y		Y
Enable Input	Y	Y	Y		Y
Multiplier / Divider Feedforward	Y	Y	Y	Y (Faster Response)	Y (Faster Response)
Special Features		Current Synthesizer	Current Synthesizer	Single Stage Isolated Output	Improved Efficiency at Light Load
Application / Design Note	DN-39E, DN-44, DN-66	DN-39E, DN-66, U-153	DN-39E, DN-66, U-153	DN-39E	DN-39E, DN-90
Pin Count ❖	16	20	20	20	16
Page Number	PS/4-42	PS/4-48	PS/4-48	PS/4-56	PS/4-65

❖ The smallest available pin count for thru-hole and surface mount packages.  
 + New Product

# Power Supply Control (PS) Selection Guides



## Power Factor Correction (cont.)

Power Factor Correction Products	UNITRODE PART NUMBER				
	UC38503+	UC3852	UC3853	UC3854	UC3854A
Soft Switching		ZCT			
Maximum Practical Operating Frequency	250kHz	Variable	125kHz	200kHz	200kHz
Current Error Amplifier Bandwidth	3MHz	N/A	1MHz	800kHz	5MHz
Average Current Mode	Y		Y	Y	Y
Worldwide AC Input Voltage Operation	Y		Y	Y	Y
Output Drive	1A	0.5A	1A	1A	1A
Startup Current	0.1A	1mA	0.25mA	1.5mA	0.3mA
Undervoltage Lockout	10.5V / 10V	16.3V / 11.5V	11.5V / 9.5V	16V / 10V	16V / 10V
UVLO 2 Hysteresis	3V (200V Turn-off)				
Overvoltage Protection	Y		Y		
Enable Input	Y			Y	Y
Multiplier / Divider Feedforward	Y (Simplified)	N/A	Y	Y	Y
Special Features	DC / DC Controller Included				
Application / Design Note		DN-39E, U-132	DN-39E, DN-77, DN-78, U-159	DN-39E, DN-41, U-134	DN-39E, DN-44, DN-66
Pin Count ❖	20	8	8	16	16
Page Number	PS/4-15	PS/4-22	PS/4-27	PS/4-32	PS/4-42

❖ The smallest available pin count for thru-hole and surface mount packages.

+ New Product



# Power Supply Control (PS) Selection Guides



## Linear Regulation

Linear Controllers .....	7-64
Low Dropout Linear Regulators.....	7-65
Special Function .....	7-66

## Linear Regulation

Linear Controllers	UNITRODE PART NUMBER				
	UC3832	UC3833	UC3834	UC3835	UC3836
Type of Output	Positive Adjustable	Positive Adjustable	Positive / Negative Adjustable	5V Fixed	Positive Adjustable
Maximum Input Voltage	36V	36V	40V	40V	40V
Minimum Output Voltage	2.0V	2.0V	+1.5V / -2.0V		2.5V
Output Drive	300mA	300mA	350mA	500mA	500mA
Type of Short Circuit Limit	Duty Cycle	Duty Cycle	Foldback	Foldback	Foldback
Reference Voltage Accuracy	2%	2%	3% / 4%	2%	2%
Special Features	Multiple Pins Accessible	8 Pin Package		Built in Rsense	Built in Rsense
Application / Design Note	DN-32, DN-61, U-152	DN-32, DN-61, U-152	U-95		
Pin Count ❖	14, 16	8, 16	16	8, 16	8, 16
Page Number	PS/5-11	PS/5-11	PS/5-18	PS/5-24	PS/5-24

Linear Controllers	UNITRODE PART NUMBER				
	UCC3837				
Type of Output	Positive Adjustable				
Maximum Input Voltage	12V				
Minimum Output Voltage	1.5V				
Output Drive	1.5mA				
Type of Short Circuit Limit	Duty Cycle				
Reference Voltage Accuracy	2%				
Special Features	<ul style="list-style-type: none"> <li>• Internal Charge Pump</li> <li>• Direct N-FET Drive</li> </ul>				
Application / Design Note					
Pin Count ❖	8				
Page Number	PS/5-28				

❖ The smallest available pin count for thru-hole and surface mount packages.  
 + New Product



## Linear Regulation (cont.)

Low Dropout Linear Regulators	UNITRODE PART NUMBER				
	UC381	UC382-1	UC382-2	UC382-3	UC382-ADJ
Output Voltage	3.3V, 5V, ADJ	1.5V	2.1V	2.5V	1.2V / Adjustable
Dropout Voltage	0.5V at 1A	450mV at 3A	450mV at 3A	450mV at 3A	450mV at 3A
Output Voltage Accuracy	2.5%	1%	1%	1%	1%
Maximum Input Voltage	9V	7.5V	7.5V	7.5V	7.5V
Shutdown Current	10 $\mu$ A				
Operating Current	400 $\mu$ A				
Line Regulation	0.01% / V				
Load Regulation	0.1%, I <sub>OUT</sub> = 0 to 1A				
Special Features	Power Limit	Fast Transient Response	Fast Transient Response	Fast Transient Response	Fast Transient Response
Pin Count $\diamond$	8	5	5	5	5
Page Number	PP/7-5	PS/5-5	PS/5-5	PS/5-5	PS/5-5

Low Dropout Linear Regulators	UNITRODE PART NUMBER				
	UC383	UC384	UC385-1	UC385-2	UC385-3
Output Voltage	3.3V, 5V, ADJ	5V, 12V, ADJ	1.5V	2.1V	2.5V
Dropout Voltage	0.45V at 3A	0.2V at 500mA	450mV at 5A	450mV at 5A	450mV at 5A
Output Voltage Accuracy	2.5%	2.5%	1%	1%	1%
Maximum Input Voltage	9V	-16V	7.5V	7.5V	7.5V
Shutdown Current	40 $\mu$ A	17 $\mu$ A			
Operating Current	400 $\mu$ A	240 $\mu$ A			
Line Regulation	0.01% / V	0.01% / V			
Load Regulation	0.1%, I <sub>OUT</sub> = 0 to 1A	0.1%, I <sub>OUT</sub> = 0 to 500mA			
Special Features	Power Limit	Power Limit	Fast Transient Response	Fast Transient Response	Fast Transient Response
Pin Count $\diamond$	3	8	5	5	5
Page Number	PP/7-12	PP/7-19	PS/5-35	PS/5-35	PS/5-35

$\diamond$  The smallest available pin count for thru-hole and surface mount packages.

+ New Product



# Power Supply Control (PS) Selection Guides



## Linear Regulation (cont.)

Low Dropout Linear Regulators	UNITRODE PART NUMBER			
	UC385-ADJ	UC386+	UC387+	UC388+
Output Voltage	1.2V / Adjustable	3.3V	5V	Adjustable down to 1.25V
Dropout Voltage	450mV at 5A	0.2V at 200mA	0.2V at 200mA	0.2V at 200mA
Output Voltage Accuracy	1%	1.5%	1.5%	1.5%
Maximum Input Voltage	7.5V	9V	9V	9V
Shutdown Current		2 $\mu$ A	2 $\mu$ A	2 $\mu$ A
Operating Current		10 $\mu$ A	10 $\mu$ A	10 $\mu$ A
Line Regulation		25mV max	25mV max	25mV max
Load Regulation		10mV max	10mV max	10mV max
Special Features	Fast Transient Response	TSSOP	TSSOP	TSSOP
Pin Count $\diamond$	5	8	8	8
Page Number	PS/5-35	PP/7-29	PP/7-29	PP/7-29

Special Functions Linear Regulators	UNITRODE PART NUMBER		
	UC560	UCC561+	UC563+
Type of Output	Positive	Positive	Positive
Application	Source / Sink Regulator for the 18 and 27 Line SCSI Termination	LVD SCSI Regulator for the 18 and 27 Line Termination	32 Line VME Bus Bias Generator
Input Voltage	4V-6V	2.7V- 5.25V	4.875V-5.25V
Output Voltage	2.85V	1.3V, 1.75V, 0.75V	2.94V
Dropout Voltage	0.9V at 750mA		
Bus Standard	SCSI-1,2,3	SPI-2, 3	VME / VME64
Sink / Source Current	300mA / -750mA	200mA / -200mA	475mA / -575mA
Application / Design Note			
Pin Count $\diamond$	5, 8	16	3, 8
Page Number	IF/4-3	IF/4-7	IF/4-10

$\diamond$  The smallest available pin count for thru-hole and surface mount packages.

+ New Product

# Power Supply Control (PS) Selection Guides



## Power Drivers

Power and FET Drivers ..... 7-67

### Power Drivers

Power and FET Drivers	UNITRODE PART NUMBER				
	L293/D	UC2950	UC3702	UC3705	UC3706
Power Driver	Quad	Single		Single	Dual
FET Driver					
Isolated Driver Pairs					
Relay Drivers			Quad		
Output Configuration	Non-Inverting	Sink / Source TTL	Non-Inverting	Complementary	Complementary
Enable					
Inhibit	Y		Y		Y
Analog Stop					Y
Output Rise Time	250ns			60ns	60ns
Maximum Voltage	36V	35V	42.5V	40V	40V
Peak Output Current	2.0A / 1.2A	4.0A	50mA per Relay	1.5A	1.5A
Application / Design Note				U-111, U-118, U-137	U-111, U-118, U-137
Pin Count ✧	16, 28	5	16	5, 8	16
Page Number	PS/6-5	PS/6-10	PS/6-12	PS/6-16	PS/6-19

Power and FET Drivers	UNITRODE PART NUMBER				
	UC3707	UC3708	UC3709	UC3710	UC3711
Power Driver	Dual	Dual			
FET Driver			Single	Single	Dual
Isolated Driver Pairs					
Relay Drivers					
Output Configuration	Complementary	Non-Inverting	Non-Inverting	Complementary	Non-Inverting
Enable		Y			
Inhibit	Y				
Analog Stop	Y				
Output Rise Time	50ns	75ns	40ns	40ns	20ns
Maximum Voltage	40V	35V	40V	20V	40V
Peak Output Current	1.5A	3.0A	1.5A	6.0A	1.5A
Application / Design Note	U-111, U-118, U-137	DN-35, U-111, U-137	U-111, DN-118, U-137	U-111	U-111
Pin Count ✧	16	8, 16	8, 16	5, 8, 16	8
Page Number	PS/6-24	PS/6-31	PS/6-35	PS/6-38	PS/6-41

✧ The smallest available pin count for thru-hole and surface mount packages.

+ New Product



# Power Supply Control (PS) Selection Guides



## Power Drivers (cont.)

Power and FET Drivers	UNITRODE PART NUMBER				
	UC3714	UC3715	UC3724	UC3725	UC3726
Power Driver					Transmitter
FET Driver	Dual	Dual	Transmitter	Single	
Isolated Driver Pairs			FET Drv	FET Drv	IGBT Drv
Relay Drivers					
Output Configuration	Non-Inverting	One Inverting, One Non-Inverting	Non-Inverting	Non-Inverting	Non-Inverting
Enable	Y	Y			
Inhibit					
Analog Stop					
Output Rise Time	100ns / 50ns	100ns / 50ns	30ns	30ns	75ns
Maximum Voltage	20V	20V	40V	40V	40V
Peak Output Current	1.0A / 2.0A	1.0A / 2.0A	2.0A	2.0A	4.0A
Application / Design Note	U-111	U-111	DN-35, U-127	DN-35, U-127	DN-57, DN-60, U-143C
Pin Count ❖	8, 16	8, 16	8, 16	8, 16	16, 28
Page Number	PS/6-43	PS/6-43	PS/6-50	PS/6-53	PS/6-57

Power and FET Drivers	UNITRODE PART NUMBER				
	UC3727	UCC37423+	UCC37424+	UCC37425+	UCC37523+
Power Driver	Single				
FET Driver		Dual	Dual	Dual	Dual
Isolated Driver Pairs	IGBT Drv				
Relay Drivers					
Output Configuration	Non-Inverting	Inverting	Non-Inverting	One Inverting, One Non-Inverting	Inverting
Enable					Y
Inhibit					
Analog Stop					
Output Rise Time	75ns	20ns	20ns	20ns	20ns
Maximum Voltage	40V	20V	20V	20V	20V
Peak Output Current	4.0A	3.0A	3.0A	3.0A	3.0A
Special Features		UVLO	UVLO	UVLO	UVLO, Adaptive LEB
Application / Design Note	DN-57, DN-60, U-143C				
Pin Count ❖	20, 28	8, 16	8, 16	8, 16	8, 16
Page Number	PS/6-62	PS/6-68	PS/6-68	PS/6-68	PS/6-73

❖ The smallest available pin count for thru-hole and surface mount packages.

+ New Product



# Power Supply Control (PS) Selection Guides



## Power Drivers (cont.)

Power and FET Drivers	UNITRODE PART NUMBER		
	UCC37524+	UCC37525+	UCC3776
Power Driver			
FET Driver	Dual	Dual	Quad
Isolated Driver Pairs			
Relay Drivers			
Output Configuration	Non-Inverting	One Inverting, One Non-Inverting	Non-Inverting
Enable	Y	Y	Y
Inhibit			
Analog Stop			
Output Rise Time (ns)			
Maximum Voltage	20V	20V	18V
Peak Output Current	3.0A	3.0A	1.5A / 2.0A
Special Features	UVLO, Adaptive LEB	UVLO, Adaptive LEB	UVLO
Application / Design Note			
Pin Count ❖	8, 16	8, 16	16
Page Number	PS/6-73	PS/6-73	PS/6-79

❖ The smallest available pin count for thru-hole and surface mount packages.

+ New Product



# Power Supply Control (PS) Selection Guides



## Power Supply Support

Feedback Signal Generators.....	7-70
Load Share Controllers.....	7-71
Schottky Diode Array/Bridges.....	7-71
Supervisory and Monitor Circuits.....	7-72

## Power Supply Support

Feedback Signal Generators	UNITRODE PART NUMBER			
	UC3901	UC39431	UC39432	UC3965
<b>Description</b>	Isolated Feedback Generator	Precision Adjustable Shunt Regulator	Precision Analog Controller	Precision Reference with Low Offset Error Amplifier
<b>Application</b>	Amplitude Modulation System Used to Couple a Control Signal Across a Voltage Isolation Barrier	Adjustable 100mA Shunt Regulator, Voltage Reference, Optocoupler Driver, Voltage to Current Converter	Adjustable 100mA Shunt Regulator, Optocoupler Driver, Programmable Transconductance Voltage to Current Converter	Used for High Precision PWM Switching Regulators
<b>Key Features</b>	<ul style="list-style-type: none"> <li>•Transformer Couples Isolated Feedback Error Signal</li> <li>•Low Cost Alternative to Optical Couplers</li> <li>•5MHz Carrier Provides Fast Response Capability</li> <li>•Modulator Synchronizable to an External Clock</li> </ul>	<ul style="list-style-type: none"> <li>•Multiple On-chip Programmable Reference Voltages</li> <li>•2.2V to 36V Operating Supply Voltage and User Programmable Reference</li> <li>•Linear Transconductance for Optocoupler Feedback Applications</li> </ul>	<ul style="list-style-type: none"> <li>•Programmable, Linear Transconductance for Optimum Optocoupler Current Drive</li> <li>•Precision Reference and Error Amplifier Inputs Externally Available</li> <li>•2.2V to 36V Operating Supply Voltage and User Programmable Reference</li> </ul>	<ul style="list-style-type: none"> <li>•2.5V Precision Reference with 0.4% Accuracy</li> <li>•Low 1mV Offset Error Amplifier</li> <li>•2X Inverting Amplifier / Buffer Output</li> <li>•Drivers Optocoupler Diode for Isolated Applications</li> </ul>
<b>Application / Design Note</b>	DN-19, DN-33, U-94		DN-52	U-165
<b>Pin Count</b> ✧	14, 16	8	8	8
<b>Page Number</b>	PS/7-21	PS/7-50	PS/7-56	PS/7-60

✧ The smallest available pin count for thru-hole and surface mount packages.

+ New Product

# Power Supply Control (PS) Selection Guides



## Power Supply Support (cont.)

Load Share Controllers	UNITRODE PART NUMBER	
	UC3902	UC3907
<b>Description</b>	8-Pin Load Share Controller	Load Share Controller
<b>Application</b>	Allows Multiple Independent Power Supplies to be Paralleled so that Each Unit Supplies Only its Proportional Share of Total Load Current	Allows Multiple Independent Power Supplies to be Paralleled so that Each Unit Supplies Only its Proportional Share of Total Load Current
<b>Key Features</b>	<ul style="list-style-type: none"> <li>• Highly Tolerant of Voltage Differences Between Power Supply Return</li> <li>• 2.7V to 20V Operation</li> <li>• High Gain, Low Offset Current Sense Amplifier Permits Low Shunt Resistor Values</li> <li>• Single Capacitor Sets Load Share Filter Response</li> </ul>	<ul style="list-style-type: none"> <li>• Fully Differential High Impedance Voltage Sensing</li> <li>• Accurate Current Amplifier for Precise Load Sharing</li> <li>• Optocoupler Driving Capability</li> <li>• 4.5V to 35V Operation</li> </ul>
<b>Application / Design Note</b>	U-129, U-163	U-129, U-163
<b>Pin Count</b> ❖	8	16
<b>Page Number</b>	PS/7-27	PS/7-44

Schottky Diode Array / Bridges	UNITRODE PART NUMBER		
	UC3610	UC3611	UC3612
<b>Description</b>	Dual Schottky Diode Bridge	Quad Schottky Diode Array	Dual Schottky Diode
<b>Application</b>	Eight-diode Array for High Current, Low Duty Cycle Flyback Voltage Clamping for Inductive Loads	Four-diode Array for High Current Bridges and Voltage Clamps	Two-diode Array for High Current, Low Duty Cycle Flyback Voltage Clamping for Inductive Loads
<b>Key Features</b>	<ul style="list-style-type: none"> <li>• Monolithic Eight-diode Array</li> <li>• High Peak Current</li> <li>• Low Forward Voltage</li> <li>• Fast Recovery Time</li> </ul>	<ul style="list-style-type: none"> <li>• Matched, Four-diode Monolithic Array</li> <li>• High Peak Current</li> <li>• Low Forward Voltage</li> <li>• Parallelable for Higher Current or Lower Voltage Drop</li> </ul>	<ul style="list-style-type: none"> <li>• Monolithic Two-diode Array</li> <li>• High Peak Current</li> <li>• Low Forward Voltage</li> <li>• Fast Recovery Time</li> </ul>
<b>Application / Design Note</b>			DN-48
<b>Pin Count</b> ❖	8, 16	8, 16	8
<b>Page Number</b>	PS/7-10	PS/7-12	PS/7-15

❖ The smallest available pin count for thru-hole and surface mount packages.  
+ New Product

# Power Supply Control (PS) Selection Guides



## Power Supply Support (cont.)

Supervisory and Monitor Circuits	UNITRODE PART NUMBER				
	UC3543	UC3544	UC3730	UC3903	UC3904
Power Supply Monitor	Single	Single		Quad	Quad
Temperature Monitor			Y		
Description	Power Supply Supervisory with OV, UV and Current Sensing	Power Supply Supervisory with OV, UV and Current Sensing	Combines a Temperature Transducer, Precision Reference, and Temperature Comparator for Maximum System Flexibility	Quad Supply and Line Monitor	Quad Supply and Line Monitor
Voltage Clamp					
Voltage Range	5V to 35V	5V to 35V		8V to 40V	4.75V to 18V
Window Adjust	N	N		Y	Y
Current Range					
Current Limit	Y	Y		N	N
Programmable Threshold	Y	Y		Y	Y
Programmable Time Delay	Y	Y		Y	Y
Special Features		Uncommitted OV Inputs			
Application / Design Note				DN-33	
Pin Count ❖	16	18	5, 8, 20	18	18
Page Number	PS/7-5	PS/7-5	PS/7-17	PS/7-32	PS/7-39

Supervisory and Monitor Circuits	UNITRODE PART NUMBER		
	UCC3946		
Description	Microprocessor Supervisor with Watchdog Timer		
Application	Accurate Microprocessor Supervision		
Key Features	<ul style="list-style-type: none"> <li>• Programmable Reset Period</li> <li>• Programmable Watchdog Period</li> <li>• 1.5% Accurate Threshold</li> <li>• 4mA IDD</li> </ul>		
Pin Count ❖	8		
Page Number	PP/7-88		

All products feature Pulse-by-Pulse Current Limiting and UVLO unless otherwise noted.  
 ❖ The smallest available pin count for thru-hole and surface mount packages.  
 + New Product

# Power Supply Control (PS) Selection Guides



## Motion Control

Brushless Motor Products .....	7-73
DC Motor Controllers .....	7-73
Linear Power Amplifier Products .....	7-74
Phase Locked Frequency Controllers .....	7-74
Stepper Motor Controllers .....	7-75

## Motion Control

Brushless Motor Products	UNITRODE PART NUMBER				
	UC3625	UCC3626+			
Hall Logic	Y	Y			
Tachometer	Y	Y			
Output Current per Output	0.1A	0.01A			
Operating Voltage	10V - 18V	11V - 15V			
Differential Current Sense Amplifier	Y	Y			
Current Limit	Y				
Application / Design Note	DN-50, U-115, U-120, U-130	U-120			
Pin Count ❖	28	28			
Page Number	PS/8-37	PS/8-50			

DC Motor Controllers	UNITRODE PART NUMBER				
	UC3637	UC3638			
Output Clamp Diodes					
Output Current per Output	0.1A	0.1A / 0.05A			
Operating Voltage	5V - 36V	10V - 36V			
Differential Current Sense Amplifier		Y			
Thermal Shutdown					
Current Limit	Y	Y			
Application / Design Note	DN-53A, U-102, U-112, U-120	DN-76, U-120			
Pin Count ❖	18, 20	20			
Page Number	PS/8-78	PS/8-84			

❖ The smallest available pin count for thru-hole and surface mount packages.

+ New Product



# Power Supply Control (PS) Selection Guides



## Motion Control (cont.)

Linear Power Amplifier Products	UNITRODE PART NUMBER				
	UC3173A	UC3175B	UC3176	UC3177	UC3178
Output Clamp Diodes	Y	Y	Y	Y	Y
Output Current per Output	0.55A	0.8A	2A	2A	0.45A
Operating Voltage	4V - 15V	4V - 15V	3V - 35V	3V - 35V	3V - 15V
Differential Current Sense Amplifier	Y	Y	Y	Y	Y
Thermal Shutdown	Y	Y	Y	Y	Y
Current Limit	Y	Y	Y	Y	Y
Four Quadrant	Y	Y	Y	Y	Y
Number of Outputs	2	2	2	2	2
BW	2MHz	2MHz	1MHz	1MHz	2MHz
Special Features			B+ Input Pin	Supply OK Pin	
Pin Count ❖	24	24	28	28	28
Page Number	PS/8-5	PS/8-16	PS/8-21	PS/8-21	PS/8-25

Phase Locked Frequency Controllers	UNITRODE PART NUMBER		
	UC3633	UC3634	UC3635
Internal Oscillator	Y	Y	Y
Divider Output Provided			Y
External Phase Detector Inputs			Y
2 Phase Drive Logic		Y	Y
Divide Logic Select	4/5 & 2/4/8	2/4/8	2/4
Operating Voltage	8V - 15V	8V - 15V	8V - 15V
Maximum Frequency	10MHz	10MHz	10MHz
Application / Design Note	U-113	U-113	U-113
Pin Count ❖	16, 20	16, 20	16
Page Number	PS/8-63	PS/8-70	PS/8-74

❖ The smallest available pin count for thru-hole and surface mount packages.

+ New Product

# Power Supply Control (PS) Selection Guides



## Motion Control (cont.)

Stepper Motor Controllers	UNITRODE PART NUMBER				
	UC3517	UC3717	UC3717A	UC3770A	UC3770B
Output Clamp Diodes		Y	Y	Lower	Lower
Output Current per Output	0.35A	0.8A	1A	1.3A	1.3A
Operating Voltage	10V - 40V	10V - 45V	10V - 46V	10V - 50V	10V - 50V
Differential Current Sense Amplifier					
Thermal Shutdown		Y	Y	Y	Y
Current Limit		Y	Y	Y	Y
Current Sense Thresholds					Tailored for half stepping applications
Application / Design Note		U-99	U-99		
Pin Count ❖	16	16, 20	16, 20	16, 28	16, 28
Page Number	PS/8-30	PS/8-92	PS/8-100	PS/8-108	PS/8-108

❖ The smallest available pin count for thru-hole and surface mount packages.

+ New Product



# Power Supply Control (PS) Selection Guides



## Special Functions

Current Sensors .....	7-76
Lighting Controllers .....	7-76
Ring Generator Controllers .....	7-77
Sensor Drivers .....	7-78
Serial DACs .....	7-78

## Special Functions

Current Sensors		UNITRODE PART NUMBER			
		<b>UCC3926</b>			
Application	Current Sensing				
Maximum Current	± 20A				
Application / Design Note	DN-91				
Pin Count ❖	16				
Page Number	PS/9-43				

Lighting Controllers		UNITRODE PART NUMBER			
		<b>UCC3305❖+</b>			
Application	Constant Power HID Lamp Controller				
Topology	Boost, Flyback				
Outputs	3 - Single and Dual Alternating, Totem Pole				
Reference Tolerance	2%				
Open Lamp Detect	Y				
Soft Start	Y				
External Synchronization	Y				
Shutdown Current	N/A				
Maximum Frequency	500kHz				
Lamp Intensity Control	Y				
Application / Design Note	DN-72, U-161				
Pin Count ❖	28				
Page Number	PS/9-5				

❖ The smallest available pin count for thru-hole and surface mount packages.

❖ Does Not Feature UVLO.

+ New Product



# Power Supply Control (PS) Selection Guides



## Special Functions (cont.)

Ring Generator Controllers	UNITRODE PART NUMBER		
	UCC3750	UCC3751+	UCC3752+
<b>Description</b>	Source Ringer Controller	Single Line Ring Generator Controller	Mult-Line Ring Generator Controller
<b>Application</b>	4 Quadrant Flyback Controller Develops High Voltage AC Output	Controls Low Cost Circuit for Generating High Voltage AC Output with DC Offset	Controls Low Cost Circuit for Generating High Voltage AC Output with DC Offset
<b>Key Features</b>	<ul style="list-style-type: none"> <li>• On Chip Low THD Sinewave Reference, Pin Selectable 20Hz, 25Hz, and 50Hz</li> <li>• Programmable Output Amplitude and DC Offset</li> <li>• AC and DC Current Limiting With Short Circuit Protection</li> </ul>	<ul style="list-style-type: none"> <li>• Off-hook Detection With Automatic Transition to DC Operation</li> <li>• Pin Selectable 20Hz, 25Hz, and 50Hz Output Frequency</li> <li>• Operates From a Single 12V Supply</li> <li>• AC Current Limiting and Short Circuit Protection</li> </ul>	<ul style="list-style-type: none"> <li>• Off-hook Detection and Indication</li> <li>• Pin Selectable 20Hz, 25Hz, and 50Hz Output Frequency</li> <li>• Operates From a Single 12V Supply</li> <li>• AC Current Limiting and Short Circuit Protection</li> </ul>
<b>Application / Design Note</b>	DN-79, U-169		
<b>Pin Count</b> ❖	28	16	16
<b>Page Number</b>	PS/9-22	PS/9-32	PS/9-38

❖ *The smallest available pin count for thru-hole and surface mount packages.*  
 + *New Product*



# Power Supply Control (PS) Selection Guides



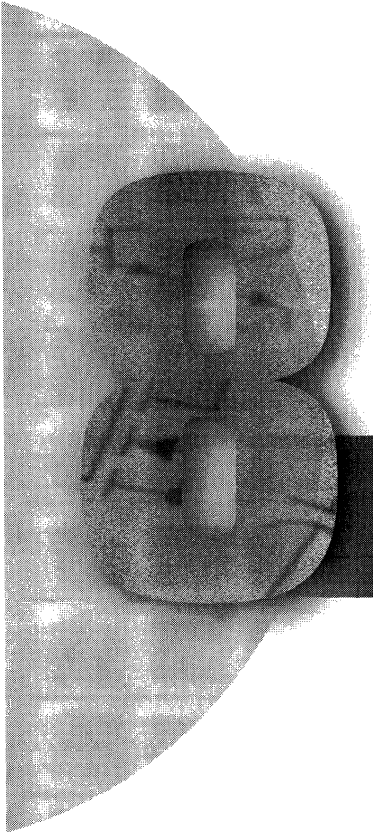
## Special Functions (cont.)

Sensor Drivers		UNITRODE PART NUMBER		
		UC37131+	UC37132+	UC37133+
<b>Part Name</b>	Smart Power Switch	Smart Power Switch	Smart Power Switch	
<b>Description</b>	65V Universal Low Side Driver with Current Limiting	65V Universal High or Low Side Driver with Current Limiting	65V Universal High Side Driver with Current Limiting	
<b>Pin Count</b> ❖	8	14, 16	8	
<b>Page Number</b>	PS/9-13	PS/9-13	PS/9-13	

Serial DACs		UNITRODE PART NUMBER		
		UCC5950		
<b>Part Name</b>	Digital to Analog Converter			
<b>Description</b>	10-Bit BiCMOS Digital to Analog Converter for Servo and Instrumentation Systems			
<b>Pin Count</b> ❖	8			
<b>Page Number</b>	PS/9-48			

❖ The smallest available pin count for thru-hole and surface mount packages.

+ New Product



# Military/Aerospace Products







## General Information

### **Die and Wafers**

Unitrode offers most of its products in die and/or wafer form through die distributors. Unitrode's die utilize either linear bipolar or BiCMOS process technology featuring tight beta controls and resistor matching techniques. Die thickness is either 12 mils or 15 mils,  $\pm 1$  mil. Interconnects are an alloy of copper and aluminum (to reduce the possibility of electromigration). Most product's backside material is pure silicon.

**Testing.** All products are tested at two separate points: (1) wafer process parameter in-line probing and (2) ambient electrical test probing. Die are tested to full data sheet specifications with the exception of some high power or high speed devices where production probe equipment limit the test environment.

**Inspection.** Unitrode performs visual inspections on military grade die to MIL-STD-883, Method 2010, conditions A or B, or to individual customer specifications. Die is supplied in "waffle pack" or single wafer form. Standard wafers are 100 mils, generic 4- or 6-inch diameter.

**Ordering.** Product is available from Unitrode's authorized die distributors, and part numbers end with the suffix "c" for chip form or "chipwfr" for wafer form.

## Military/Aerospace Products

Unitrode offers its innovative, quality products in military/aerospace and high reliability versions. Our certification to MIL-PRF-38535 demonstrates our commitment to our customer's requirements in this important market segment. Our product offering includes:

- **STANDARD MILITARY DRAWINGS (SMD)** ~ Conformance to Class Q performance requirements of MIL-PRF-38535, and individual SMD electrical parameters. Unitrode offers over 100 SMD products.
- **CLASS V** ~ Conformance to all Class V requirements of MIL-PRF-38535, or to individual customer source control documents.
- **SCD Class B** ~ Unitrode also accepts unique customer source control drawings for Class B, MIL-STD-883 type products.
- **Bare Die / Lot Acceptance Testing** ~ Tested to individual source control documents.

Unitrode has had DESC facility certification continuously since November 1985.

## Space Level Products

Unitrode is a leader in producing linear ICs to customers' Class S specifications and has many years of proven experience in this field. Our abilities in this area include all processing requirements of Class S (including MIL-PRF-38535, MIL-STD-883, and SCC9000), as well as an extensive library of radiation data on our most popular devices (see below). Our superior design support, years of experience, and flexibility to service our customers' unique requirements make us the best choice for Class S linear products.





## **Radiation Data Availability**

Unitrode has provided products screened to the S-level requirements of MIL-STD-883, MIL-PRF-38535, and the European specification SCC9000. Due to our participation in this market, we have collected a variety of radiation reports including SEU, total dose (including low dose rate), and neutron fluence, which are available upon customer request (see listing below). These reports are results of independent testing by our customers and do not represent guaranteed levels of radiation tolerance by Unitrode. The availability of this data is subject to change. Contact your local Unitrode sales representative.

Radiation data is available for the following Unitrode products: UC1625, UC1635, UC1710, UC1711, UCC1800, UCC1806, UC1823, UC1825/A, UC1832, UC1834, UC1838A, UC1843A, UC1845, UC1846, UC1856, UC1863, UC1875, UC1901, UC1907, UCC1912.

## **Standard Military Drawings (SMDs) Listing Unitrode as an Approved Supplier**

<b>SMD Number . . . . .</b>	<b>Unitrode Part Number</b>	<b>SMD Number . . . . .</b>	<b>Unitrode Part Number</b>
5962-8670401PA . . . . .	UC1842J/883B	5962-8768103XA . . . . .	UC1825BLP/883B
5962-8670401XA . . . . .	UC1842L/883B	5962-8774001EA . . . . .	UC1543J/883B
5962-8670402PA . . . . .	UC1843J/883B	5962-8774002EA . . . . .	UC1544J/883B
5962-8670402XA . . . . .	UC1843L/883B	5962-87742012A . . . . .	UC1834L/883B
5962-8670403PA . . . . .	UC1844J/883B	5962-8774201EA . . . . .	UC1834J/883B
5962-8670403XA . . . . .	UC1844L/883B	5962-88697012A . . . . .	UC1903L/883B
5962-8670404PA . . . . .	UC1845J/883B	5962-8869701VA . . . . .	UC1903J/883B
5962-8670404XA . . . . .	UC1845L/883B	5962-89441012A . . . . .	UC1901L/883B
5962-8670405PA . . . . .	UC1842AJ/883B	5962-8944101CA . . . . .	UC1901J/883B
5962-8670405XA . . . . .	UC1842AL/883B	5962-89511012A . . . . .	UC1525AL/DESC
5962-8670406PA . . . . .	UC1843AJ/883B	5962-8951101EA . . . . .	UC1525AJ/DESC
5962-8670406XA . . . . .	UC1843AL/883B	5962-89511032A . . . . .	UC1525AL/883B
5962-8670407PA . . . . .	UC1844AJ/883B	5962-8951103EA . . . . .	UC1525AJ/883B
5962-8670407XA . . . . .	UC1844AL/883B	5962-8951104EA . . . . .	UC1527AJ/883B
5962-8670408PA . . . . .	UC1845AJ/883B	5962-89611012A . . . . .	UC1706L/DESC
5962-8670408XA . . . . .	UC1845AL/883B	5962-8961101EA . . . . .	UC1706J/DESC
5962-86806012A . . . . .	UC1846L/883B	5962-89899012A . . . . .	UC1838AL/883B
5962-8680601EA . . . . .	UC1846J/883B	5962-8989901EA . . . . .	UC1838AJ/883B
5962-86806022A . . . . .	UC1847L/883B	5962-89905012A . . . . .	UC1823L/883B
5962-8680602EA . . . . .	UC1847J/883B	5962-8990501EA . . . . .	UC1823J/883B
5962-87619012A . . . . .	UC1707L/DESC	5962-89905022A . . . . .	UC1823AL/883B
5962-8761901EA . . . . .	UC1707J/DESC	5962-8990502EA . . . . .	UC1823AJ/883B
5962-8764502EA . . . . .	UC1524AJ/DESC	5962-89905032A . . . . .	UC1823BL/883B
5962-87681012A . . . . .	UC1825L/883B	5962-8990503EA . . . . .	UC1823BJ/883B
5962-8768101EA . . . . .	UC1825J/883B	5962-89920012A . . . . .	UC1840L/883B
5962-87681022A . . . . .	UC1825AL/883B	5962-8992001VA . . . . .	UC1840J/883B
5962-8768102EA . . . . .	UC1825AJ/883B	5962-89920022A . . . . .	UC1841L/883B
5962-8768102XA . . . . .	UC1825ALP/883B	5962-8992002VA . . . . .	UC1841J/883B
5962-87681032A . . . . .	UC1825BL/883B	5962-89957012A . . . . .	UC1637L/883B
5962-8768103EA . . . . .	UC1825BJ/883B	5962-8995701VA . . . . .	UC1637J/883B

# Standardized Military Drawings



## **SMD Number . . . . . Unitrode Part Number**

5962-90538012A . . . . UC1611L/883B  
5962-9053801PA . . . . UC1611J/883B  
5962-90650012A . . . . UC1835L/883B  
5962-9065001PA . . . . UC1835J/883B  
5962-9098701M2A . . . UC1633L/883B  
5962-9098701MEA . . . UC1633J/883B  
5962-9168901MXA . . . UC1625J/883B  
5962-9203101M2A . . . UC1864L/883B  
5962-9203101MEA . . . UC1864J/883B  
5962-9203102MEA . . . UC1865J/883B  
5962-9235001MXC . . . L293DSP/883B  
5962-9320601M2A . . . UC1907L/883B  
5962-9320601MEA . . . UC1907J/883B  
5962-9321501M2A . . . UC1517L/883B  
5962-9321501MEA . . . UC1517J/883B  
5962-9326101M2A . . . UC1854L/883B  
5962-9326101MEA . . . UC1854J/883B  
5962-9326102M2A . . . UC1854BL/883B  
5962-9326102MEA . . . UC1854BJ/883B  
5962-9326103M2A . . . UC1854AL/883B  
5962-9326103MEA . . . UC1854AJ/883B  
5962-9326501M2A . . . UC1832L/883B  
5962-9326501MCA . . . UC1832J/883B  
5962-9326502M2A . . . UC1833L/883B  
5962-9326502MPA . . . UC1833J/883B  
5962-9451301MPA . . . UCC1801J/883B  
5962-9451302MPA . . . UCC1802J/883B  
5962-9451303MPA . . . UCC1803J/883B  
5962-9451304MPA . . . UCC1804J/883B  
5962-9451305MPA . . . UCC1805J/883B

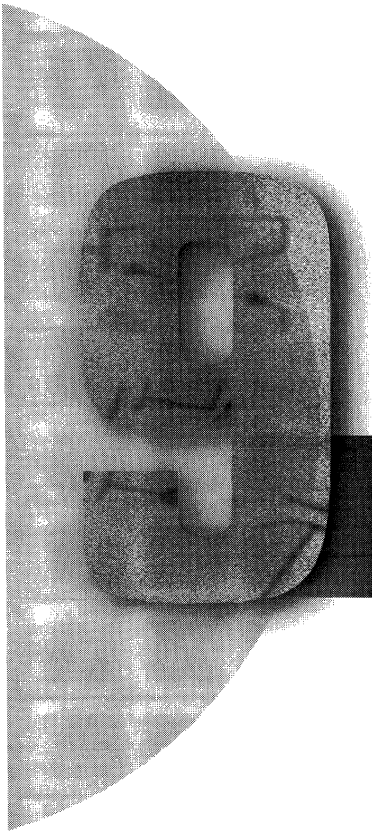
## **SMD Number . . . . . Unitrode Part Number**

5962-9453001M2A . . . UC1856L/883B  
5962-9453001MEA . . . UC1856J/883B  
5962-9455501M3A . . . UC1875L/883B  
5962-9455501MRA . . . UC1875J/883B  
5962-9455501MXA . . . UC1875LP/883B  
5962-9457501MEA . . . UCC1806J/883B  
5962-9462201M2A . . . UC1871L/883B  
5962-9462201MVA . . . UC1871J/883B  
5962-9474601M2A . . . UC1717L/883B  
5962-9474601MEA . . . UC1717J/883B  
5962-9554401MJC . . . UC1620SP/883B  
5962-9558601MVA . . . UC1851J/883B  
5962-9579801M2A . . . UC1705L/883B  
5962-9579801MPA . . . UC1705J/883B  
77034012A . . . . . UC117L/883B  
77034052A . . . . . UC117AL/DESC  
7802801EA . . . . . UC1524J/DESC  
85515012A . . . . . UC1526L/883B  
8551501VA . . . . . UC1526J/883B  
85515022A . . . . . UC1526AL/883B  
8551502VA . . . . . UC1526AJ/883B









# Packaging Information





<b>Recommended Profile Limits</b> .....	9-3
<b>Device Temp Management</b> .....	9-5
<b>Package Thermal Resistance Data</b> .....	9-8
<b>Typical Materials Used for Assembly</b> .....	9-14
<b>Thermal Characteristics of Surface Mount Packages</b> .....	9-15
<b>Package Diagrams</b>	
8-Pin Plastic DIP (N) .....	9-19
14-Pin Plastic DIP (N) .....	9-19
16-Pin Plastic DIP (N, NP) .....	9-20
18-Pin Plastic DIP (N) .....	9-20
20-Pin Plastic DIP (N) .....	9-21
24-Pin Plastic DIP (N) .....	9-21
28-Pin Plastic DIP (N) .....	9-22
20-Pin Plastic PLCC (Q) .....	9-22
28-Pin Plastic PLCC (Q, QP) .....	9-23
44-Pin Plastic PLCC (Q, QP) .....	9-23
8-Pin SOIC (D, DP) .....	9-24
14-Pin SOIC (D) .....	9-24
16-Pin SOIC (D, DP, DS) .....	9-25
16-Pin SOIC Wide Body (DW) .....	9-25
18-Pin SOIC Wide Body (DW) .....	9-26
20-Pin SOIC Wide Body (DW) .....	9-26
24-Pin SOIC Wide Body (DW) .....	9-27
28-Pin SOIC Wide Body (DW, DWP) .....	9-27
8-Pin Ceramic DIP (J) .....	9-28
14-Pin Ceramic DIP (J) .....	9-28
16-Pin Ceramic DIP (J) .....	9-29
18-Pin Ceramic DIP (J) .....	9-30
20-Pin Ceramic DIP (J) .....	9-31
24-Pin Ceramic DIP (J) .....	9-32
28-Pin Ceramic DIP (J) .....	9-33
3-Pin TO-220 Plastic (T) .....	9-34
5-Pin TO-220 Plastic (T) .....	9-35
20-Pin Ceramic Leadless (L) .....	9-35
28-Pin Ceramic Leadless (L) .....	9-36
28-Pin Power Ceramic Leadless (LP) .....	9-36
48-Pin LQFP (FQ, FQP) .....	9-37
64-Pin LQFP (FQ) .....	9-38
100-Pin LQFP (FQ) .....	9-39



16-Pin Power Ceramic Sidebrazed DIP (SP) .....	9-40
24-Pin Power Ceramic Sidebrazed DIP (SP) .....	9-41
16-Pin Zig-Zag (Z) .....	9-41
36-Pin QSOP (MWP) .....	9-42
44-Pin QSOP (MWP) .....	9-42
16-Pin QSOP (M) .....	9-43
20-Pin QSOP (M) .....	9-43
8-Pin TSSOP (PW) .....	9-44
14-Pin TSSOP (PW) .....	9-44
16-Pin TSSOP (PW) .....	9-45
20-Pin TSSOP (PW) .....	9-45
24-Pin TSSOP (PW, PWP) .....	9-46
28-Pin TSSOP (PWP) .....	9-47
3-Pin Plastic TO-263 Power Surface Mount (TD) .....	9-48
5-Pin Plastic TO-263 Power Surface Mount (TD) .....	9-48
8-Pin Mini SO (P) .....	9-49
10-Pin Mini SO (P) .....	9-49



### **Packaging Information**

The following are Unitrode's recommended profiles and limits for plastic package surface-mounting and de-soldering methods. To achieve and maintain the recommended conditions near the plastic package, time/temperature profiles of the surface-mount processing equipment may differ from those below, depending on board density, oven mass, exhaust rate, and other factors.

Unitrode uses a solder reflow pre-conditioning process with a 220° C peak temperature to determine moisture sensitivity ratings for plastic packaged components. The profiles shown are used with Unitrode's moisture-sensitivity ratings of the plastic packaged surface-mount components. Published moisture sensitivity ratings may not apply when a process with a more extreme peak temperature (such as wave solder) is used. If the temperatures or rates of temperature increase exceed those noted for IR reflow, then we recommend that the packaged component be either baked before surface-mount assembly or handled in consistence with the next lower moisture-sensitivity rating. (For example, handle a Level-2 rated part as Level 3.) For baking conditions and/or definitions of moisture-sensitivity level ratings, consult JEDEC J-STD-020A and J-STD-033.

For more than one soldering pass (e.g., on boards with components on top and bottom), time between the two soldering processes must be between 5 minutes and 48 hours. Between passes, if the environmental conditions of the plastic packaged component exceed 30° C/60% RH, then the component must be baked before the second pass.

### **Wave Solder** (Temperatures unless otherwise noted apply to the top-side of the component body.)

- Maximum rate of increase for pre-heat 6° C/s
- Pre-heat temperature range 100–150° C
- Total pre-heat time 60–120 seconds
- Maximum rate of increase to maximum solder temperature 3° C/s
- Solder temperature of first (turbulent) wave < 250° C (4 seconds maximum)
- Solder temperature of second (broad) wave < 240° C (10 seconds maximum, 2° C/s maximum rate of cooling from first wave)
- Maximum cooling to room temperature 4° C/s maximum
- Total time over 183° C < 90s
- Difference between the maximum pre-heat and maximum soldering temperatures  $\leq 100^{\circ}\text{C}$
- Maximum time from 25° C to peak temperature 6 minutes
- Minimum 5-minute cool-down time between cycles

**NOTE:** We **STRONGLY RECOMMEND** that the component's plastic body not contact the solder wave or bath during assembly. Contact can be prevented by shielding. If contact occurs, then do the following:

- Pre-bake parts within 4 hours before board-mount assembly (24 hours at 125° C or 192 hours at 40° C).
- Limit all rates of temperature change to 2.5° C/s.
- Limit total time over 183° C to less than 45s.

## Recommended Profile Limits (cont.)



**IR Reflow or Convection Reflow** (Temperatures unless otherwise noted apply to the top-side of the component body.)

- Maximum rate of increase for pre-heat 6° C/s
- Pre-heat temperature range 100–150° C
- Total pre-heat time 60–120s
- Maximum rate of increase to maximum solder temperature 3° C/s
- Maximum reflow temperature < 240° C (20s maximum with 5° C of peak temperature)
- Maximum rate of decrease to room temperature 6° C/s
- Maximum time over 210° C < 40s
- Maximum total time over 183° C < 150s
- Difference between the maximum pre-heat and maximum soldering temperatures  $\leq 100^{\circ}$  C
- Maximum time from 25° C to peak temperature 6 minutes
- Minimum 5-minute cool-down time between cycles

**Vapor Phase Reflow** (Temperatures unless otherwise noted apply to the top-side of the component body.)

- Maximum rate of increase for pre-heat 6° C/s
- Pre-heat temperature range 100–150° C
- Total pre-heat time 60–120s
- Maximum rate of increase to maximum solder temperature 10° C/s
- Maximum reflow temperature < 219° C (60s maximum with 5° C of peak temperature)
- Maximum rate of decrease to room temperature 10° C/s
- Maximum time over 183° C < 80s
- Difference between the maximum pre-heat and maximum soldering temperatures  $\leq 100^{\circ}$  C
- Minimum 5-minute cool-down time between cycles

**Rework** (Temperatures unless otherwise noted apply to the top-side of the component body.)

To preserve the integrity of the plastic packaged component (for further analysis), we suggest the following steps to minimize damage from component removal.

- Always keep the package body temperature below 200° C.
- Bake out moisture in packages rated JEDEC Level 2-6 or in packages exposed to uncontrolled ambient conditions since being assembled.
- For hand de-soldering (i.e., soldering iron), do not allow maximum temperature at the leads to exceed 300° C for more than 5s.

For forced-hot-air de-soldering, the following limits apply:

- Limit the rate of temperature increase to 25° C/s between ambient and 100° C.
- Limit the rate of temperature increase to 4° C/s maximum from 100° C to de-soldering temperature.
- Limit maximum de-soldering temperature at leads to less than 240° C (10s maximum).
- Carefully minimize the cooling rate after removing the part from the printed circuit board.



## Introduction

All operating circuit components dissipate power, causing their temperature to rise. Unitrode integrated circuits are designed to operate in a considerable range of temperatures, but there are limits. This note suggests ways to ensure that specified temperature limits for each part are not exceeded.

## Junction Temperature ( $T_j$ )

For reliability and long-term operating life of the device, the system designer must manage the power dissipated by the device in the system so junction temperature ( $T_j$ ) not only does not exceed specified limits, but also is kept as low as possible. This temperature control is necessary, because higher junction temperatures adversely affect the operating life of the device.

## Power Dissipation ( $P_d$ ) and Thermal Resistance ( $\theta$ )

With power off, all components of a given circuit approach (and in time reach) ambient temperature. With the power on, the components are warmed by their internal power dissipation until a new equilibrium is reached. Some electrical power is dissipated as heat by an integrated circuit ( $P_d$ ) during operation, thus raising the junction temperature. The effectiveness of the IC package and the system in dissipating this heat is "thermal resistance" ( $\theta$ ), a term analogous to electrical resistance in the sense that the materials of the IC, package, and system restrict the flow of heat from the higher junction temperature ( $T_j$ ) to the lower ambient temperature of the system ( $T_a$ ). Understanding the thermal resistance characteristics of the package and system facilitates management of the device junction temperature within desired limits.

The rate of heat flow depends on the temperature difference ( $\Delta T$ ) between the two endpoints ( $T_j$  and  $T_a$ ), and also on the thermal resistance,  $\theta$ , of the package and system. Heat is a form of energy, and if we choose the joule as the measuring unit we can specify the rate of heat flow in units of joules per second. Therefore,  $P_d$  [*joules per second*] =  $\frac{\Delta T}{\theta}$  and since one *joule per second* is the same as a watt ( $W$ ),

$$\text{we have } \theta = \frac{\Delta T}{P_d} \text{ (}^\circ\text{C / W)}$$

Thermal resistance is typically expressed in terms of resistance from junction-to-ambient ( $\theta_{ja}$ ), which incorporates not only the internal resistance of the IC package, but also the resistance of the system as well.  $\theta_{ja}$  can be broken down into the sum of these two different thermal resistances, from junction-to-case,  $\theta_{jc}$  (or in the case of power surface-mount packages, junction-to-lead,  $\theta_{jl}$ ) and case-to-ambient,  $\theta_{ca}$ . Therefore,  $\theta_{ja} = \frac{T_j - T_a}{P_d} = \theta_{jc} + \theta_{ca}$

## Variables Which Affect $\theta_{ja}$

The thermal resistance of the package is a function of many variables, such as the leadframe material and design configuration, the plastic encapsulant material, the silicon die area, the die attach material, and others. However, as previously indicated, the effectiveness of the system in removing heat from the package also has a significant impact on  $\theta_{ja}$ . These variables include the material and configuration of the circuit board on which the package is mounted, the type of cooling used (i.e., conduction or convection), the size of the traces on the circuit board, the use of heatsinks, etc. It is essential that the system designer understand these variables and how they affect  $\theta_{ja}$ .



## Unitrode Test Procedures

Table 1 shows thermal resistance values for Unitrode IC packages. Thermal resistance junction-to-case ( $\theta_{jc}$ ) is measured by mounting the device to an essentially infinite heat sink. Power leadframe surface-mount packages and the batwing DIP conduct most of the dissipated power through their leads rather than through the case. For these noted packages, the specified thermal resistance is junction-to-lead ( $\theta_{jl}$ ).

Junction-to-ambient ( $\theta_{ja}$ ) thermal resistance is measured on a 5.0-square-inch printed circuit board in 1 cubic foot of still air. For through-hole packages, single-side FR-4 boards with 1-ounce copper traces are used. (See Figure 1.) However, since surface-mount devices, including those without power leadframes, conduct a significant amount of heat through their leads to the pc-board, various types of surface-mount boards are measured. (See Figure 2.) To indicate the effect of the pc-board on  $\theta_{ja}$ , a range of values is given. The lower value is for a device mounted on a 5.0-square-inch, 0.062 inch thick aluminum pc-board. The highest value is for a device mounted on a 5.0-square-inch single-sided pc-board. These values are intended to give the system designer an indication of the best and worst case conditions. Some interpolation may be needed based on an individual application to arrive at an accurate estimate of the actual  $\theta_{ja}$ .

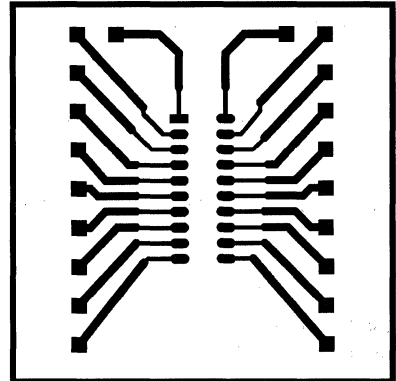


Figure 1. Typical through-hole pc-board design.

To determine the device  $\theta_{ja}$ , a measurement of the device junction temperature is made under the above conditions using a technique called the “temperature-sensitive parameter” method. This technique involves measuring the voltage drop of calibrated component, typically a diode, which then allows calculation of the device junction temperature. Since  $P_d$ ,  $T_j$ , and  $T_a$  are known,  $\theta_{ja}$  can be determined. For the case of power leadframe surface-mount packages,  $\theta_{jl}$  is determined by measuring the temperature of the pc-board at the device leads and then using this temperature in place of the ambient temperature in the calculation. For a more detailed discussion on surface-mount packages, refer to “Thermal Characteristics of Surface-Mount Packages,” found later in this section.

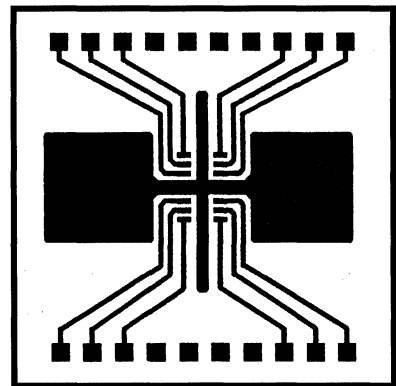


Figure 2. Typical surface mount pc-board design for power leadframe SOIC packages.

## Example

Estimate the junction temperature of a UC5601DWP 18-Line SCSI Active Terminator on a 4-layer 0.062 inch thick multilayer pc-board at 1.0 watt power dissipation in a still-air environment at 30°C.

1. *Determine  $\theta_{ja}$ .* Table 1 shows that the the DWP package is a power leadframe surface-mount device, so the use of thermal resistance junction-to-lead ( $\theta_{jl}$ ) is appropriate. For the DWP package,  $\theta_{jl} = 16^\circ\text{C}/\text{W}$ . From Figure 8 in “Thermal Characteristics of Surface-Mount Packages,” thermal resistance board-to-ambient ( $\theta_{ba}$ ) =  $19^\circ\text{C}/\text{W}$ . We know that for a power leadframe surface-mount package,  $\theta_{ja} = \theta_{jl} + \theta_{ba}$ , so,  $\theta_{ja} = 16^\circ\text{C}/\text{W} + 19^\circ\text{C}/\text{W} = 35^\circ\text{C}/\text{W}$ .





2. Calculate the junction temperature,  $T_j$ .

$$\begin{aligned}T_j &= (P_d \times \theta_{ja}) + T_a \\T_j &= (1.0 \text{ W} \times 35^\circ\text{C/W}) + 30^\circ\text{C} \\T_j &= 65^\circ\text{C}\end{aligned}$$

This is well below the maximum rated junction temperature of  $150^\circ\text{C}$  listed in the Absolute Maximum Ratings section of the UC5601 product data sheet, so the thermal dissipation is satisfactory.

### **System Design Considerations**

Through-hole devices such as dual in-line packages (DIPs) can be cooled by forcing airflow over the device in order to improve the convection cooling performance, or by conduction cooling of the package case to a heat sink such as the system chassis or cold-wall. Plastic DIPs are not particularly well suited to either of these techniques since the plastic encapsulant is a relatively poor thermal conductor. However, Unitrode offers several through-hole packages which have been optimized for conduction cooling techniques, namely the batwing DIP, the SP power ceramic DIP and the power leadframe Zig-Zag (ZIP) package. All of these packages provide low thermal resistance paths from the junction to the pc-board. Refer to Table 1 for the applicable ratings.

Surface-mount packages are well suited to conduction cooling since, as previously indicated, the package leads conduct a significant amount of heat to the pc-board. The pc-board itself can be utilized effectively as a heat sink when designed properly. For example, as seen in the discussion "Thermal Characteristics of Surface Mount Packages," when a power leadframe package is mounted on a multi-layer pc-board such that the heat-sink leads are thermally coupled to a ground plane in the board, or an area of copper fan-out on the board, then the overall thermal resistance is considerably lower than on a single-sided board with no heat-sinking. Additionally, Unitrode offers a power ceramic leadless chip carrier with a metallized thermal grid on the package case, which can be soldered directly to the board, thus greatly reducing its overall thermal resistance.

In general, the system designer should attempt to use larger traces on the pc-board where possible in order to spread the heat away from the device more effectively. Also, one should avoid grouping higher power devices tightly together on the board. A better approach would be to spread out the higher power devices to the cooler areas of the board. The choice of pc-board material will greatly affect the overall thermal performance of the system as well, although there are many factors involved when selecting the board material, such as cost, mechanical properties and environmental requirements.

### **Summary**

Thermal management has been shown to be an essential factor in the reliable use of Unitrode integrated circuits. Thermal characteristics of Unitrode packages have been provided to the system designer in order to ensure that the system design effectively dissipates the power generated by the integrated circuit during operation.

## Package Thermal Resistance Data



Package	Lead Count	Unitrode Package Code	Body Size (mils unless noted)	Die Paddle or Cavity Size (mils)	Die Size Tested (mils) (16)
Ceramic DIP	8	J	390x288x140	150x200	N/A
	14		760x248x140	110x140	N/A
	16		760x288x140	160x250	N/A
	18		890x288x140	160x250	N/A
	20		950x288x140	160x250	N/A
	24		1250x520x170	250x250	N/A
	28		1450x520x165	250x250	N/A
Ceramic LCC	20	L	350x350x80	194x194	N/A
	28		450x450x80	250x250	N/A
Ceramic LCC Power	28	LP	450x450x80	250x250	N/A
LQFP	48	FQ	7x7x1.4 mm	200x200x5	100x100x12
	64		10x10x1.4 mm	260x260x5	100x100x12
	100		14x14x1.4 mm	276x276x5	100x100x12
LQFP Power	48	FQP	7x7x1.4 mm	185x185x5	100x100x12
	48		7x7x1.4 mm	190x190x5	100x100x12
MSOP	8	P	3x3x0.86 mm	68x94x6	50x50x8
	10		3x3x0.86 mm	68x98x6	50x50x8
PDIP	8	N	360x253x137	140x150x10	N/A
	14		760x253x137	110x140x10	N/A
	16		760x253x137	140x170x10	N/A
	18		905x253x137	160x250x10	N/A
	20		1020x253x137	150x190x10	N/A
	24		1250x525x137	180x220x10	N/A
28		1425x525x137	200x200x10	N/A	
PDIP Power	16	NP	760x253x137	160x170x10	N/A
PLCC	20	Q	350x350x155	180x180x10	N/A
	28		450x450x155	230x230x10	N/A
	44		650x650x155	230x230x10	N/A
PLCC Power	28	QP	450x450x155	200x200x10	N/A
	44		650x650x155	300x300x10	N/A

\* = Estimated

N/A = Not Available

\*\* = Modeled Data. If value range given for  $\theta_{ja}$ , lower value is for 3x3 in. 1 oz. internal copper gnd plane, higher value is for 1x1 in. gnd plane. All model data assumes only one trace for each non-fused lead.

## Package Thermal Resistance Data



$\theta_{ja}$ (°C/W) (6)(15)	$\theta_{jc}$ (°C/W) (15)	Comments
125-160	28 (8)	
90-120	28 (8)	
80-120	28 (8)	
70-90	28 (8)	
70-85	28 (8)	
60-75	28 (8)	
50-65	28 (8)	
70-80	20 (8)	
60-70	20 (8)	
N/A	5-8*	$\theta_{jc}$ estimated for backside of device, through the metalized thermal conduction pads.
58-76**	15**	Modeled using .3 mm trace width
44-59**	12**	Modeled using .3 mm trace width
31-46**	11**	Modeled using .3 mm trace width
34 (9) 38-61**	8**	Leads 5,6,7,8,17, 18,19,29,30,31,32, 42,43 and 44 are fused to the die attach paddle. Modeled with 2 thermal vias to gnd plane per fused lead and .3 mm trace width.
35 (10) 43-65**	8**	Leads 4,5,6,7,8,9,28,29,30,31,32 and 33 are fused to the die attach paddle. Modeled with 2 thermal vias to gnd plane per fused lead and .3 mm trace width.
238-269** 312-373**(7)	41**	Modeled using .3 mm trace width.
210-241** 273-330**(7)	39**	Modeled using .3 mm trace width.
110 (3)	50	
90 (3)	45	
90 (3)	45	
85 (3)	40	
80 (3)	35	
60 (3)	30	
60 (3)	30	
25-50 (4)	12 (2)	Leads 4,5,12 and 13 are fused to the die attach paddle.
43-75 (3)	34	
40-65 (3)	30	
35-50 (3)	20	
28-50 (3)	14 (2)	Leads 12,13,14,15,16,17 and 18 are fused to the die attach paddle. Single layer board used 1.2 in <sup>2</sup> of 1 oz copper on top of PWB for heatsinking to fused leads.
24-38 (3)	12 (2)	Leads 6,7,17,29,39 and 40 are fused to the die attach paddle. Single layer board used 1.1 in <sup>2</sup> of 1 oz copper on top of PWB for heatsinking to fused leads.



# Package Thermal Resistance Data



Package	Lead Count	Unirode Package Code	Body Size (mils unless noted)	Die Paddle or Cavity Size (mils)	Die Size Tested (mils) (16)
QSOP	16	M	193x154x59	96x130x8	50x50x12
	20		340x154x59	96x140x8	50x50x12
	28		389x154x59	96x150x8	50x50x12
QSOP Wide Body Power	36	MWP	606x295x92	180x240x10	100x100x15 100x100x12**
	44		704x295x92	190x260x10	100x100x15 100x100x12**
SOIC Narrow Body	8	D	192x154x54	95x152x8	N/A
	14		340x154x54	83x142x8	N/A
	16		390x154x54	90x150x8	N/A
SOIC Narrow Power	8	DP	192x154x54	95x150x8	N/A
	16		390x154x54	95x165x8	N/A
SOIC Wide Body	16	DW	408x296x94	165x205x10	N/A
	18		458x296x94	145x190x10	100x100x12
	20		508x296x94	165x205x10	N/A
	24		602x296x94	165x205x10	100x100x12
	28		705x296x94	165x205x10	100x100x12
SOIC Wide Body Power	28	DWP	705x296x94	156x205x10	N/A
TO220	3	T, TH, TV	400x592x165	180x180x18	N/A
	5		400x605x165	180x180x18	N/A
TO263	3	TD	395x415x175	240x180x23	N/A
	5		395x415x175	240x180x23	N/A
TSSOP	8	PW	118x174x35	126x87x5	50x50x10
	14		197x174x35	118x150x5	100x100x10
	16		197x174x35	118x154x5	100x100x10
	20		255x174x35	118x165x5	100x100x10
	24		307x174x35	118x217x5	100x100x10
	28		382x174x35	118x217x5	100x100x10
TSSOP Power	24	PWP	307x174x35	118x217x5	100x100x10
	28		382x174x35	118x250x5	100x100x10
	28		382x174x35	118x250x5	100x100x10

\* = Estimated

N/A = Not Available

\*\* = Modeled Data. If value range given for  $\theta_{ja}$ , lower value is for 3x3 in. 1 oz internal copper gnd plane, higher value is for 1x1 in. gnd plane. All model data assumes only one trace for each non-fused lead.

## Package Thermal Resistance Data



$\theta_{ja}$ ( $^{\circ}\text{C}/\text{W}$ ) (6)(15)	$\theta_{jc}$ ( $^{\circ}\text{C}/\text{W}$ ) (15)	Comments
144-172**	38**	Modeled using .3 mm trace widths.
116-138**	36**	Modeled using .3 mm trace widths.
96-118**	33**	Modeled using .3 mm trace widths.
31 (11) 36-52**	8**	Leads 8,9,10,26,27 and 28 are fused to the die attach paddle. Modeled with 2 thermal vias to gnd plane per fused lead and .5 mm trace width.
29 (12) 32-46**	7**	Leads 10,11,12,13,32,33,34 and 35 are fused to the die attach paddle. Modeled with 2 thermal vias to gnd plane per fused lead and .5 mm trace width.
84-160 (3)	42	
50-120 (3)	35	
50-120 (3)	35	
40-70 (3)	22 (2)	Leads 2,3,6 and 7 are fused to the die attach paddle.
36-58 (3)	20 (2)	Leads 4,5,12 and 13 are fused to the die attach paddle. Single layer board used .68 in <sup>2</sup> of 1 oz copper on top of PWB for heatsinking to fused leads.
50-100 (3)	27	
89-102**	26**	Modeled using .3 mm trace widths.
45-95 (3)	25	
71-83**	24**	Modeled using .3 mm trace widths.
65-76**	21**	Modeled using .3 mm trace widths.
30-50 (3)	16 (2)	Leads 7,8,9,20,21 and 22 are fused to the die attach paddle. . Single layer board used 0.165 in <sup>2</sup> of 1 oz copper on top of PWB for heatsinking to fused leads.
83*	3*	
65-75*	3*	
50-87*	3	
65-75*	3	
232-257**	32**	Modeled using .3 mm trace widths.
132-158**	15**	Modeled using .3 mm trace widths.
123-147**	15**	Modeled using .3 mm trace widths.
102-125**	14**	Modeled using .3 mm trace widths.
150 (3) 88-109**	13**	Modeled using .3 mm trace widths.
77-96**	13**	Modeled using .3 mm trace widths.
30-70 (3) 63-87**	20 (2) 9**	Leads 5,6,7,8,17,18,19 and 20 are fused to the die attach paddle. Empirical tests used 1.1 in <sup>2</sup> of 1 oz top copper on top of PWB for heatsinking to fused leads. Modeled with 2 thermal vias to gnd plane per fused lead and .3 mm trace width.
33 (13) 61-80**	20 (2) 11**	Leads 8 and 21 are fused to the die attach paddle. Modeled with 2 thermal vias to gnd plane per fused lead gnd plane and .3 mm trace width.
30-70 (3) 57-79**	20 (2) 9**	Leads 7,8,9,20,21 and 22 are fused to the die attach paddle. Modeled with 2 thermal vias to gnd plane per fused lead and .3 mm trace width.

## Package Thermal Resistance Data



Databook numbers for thermal resistance are for reference in making relative package-to-package performance comparisons and are not a statement of absolute performance in a system application.

### Notes:

- 1) All data assumes testing with the long side of the die coinciding with the long side of the die attach mounting area.
- 2) Specified thermal resistance is  $j_l$  (junction to lead) where noted.
- 3) Specified  $\theta_{ja}$  (junction to ambient) is for devices mounted to 5 in<sup>2</sup> FR4 PC board with one ounce copper where noted. When resistance range is given, lower values are for 5 in<sup>2</sup> aluminum PC board. Test PWB was .062 in thick and typically used 0.635 mm trace widths for power pkgs and 1.3 mm trace widths for non-power pkgs with a 100x100 mil probe land area at the end of each trace - see *Thermal Characteristics of Surface Mounted Packages* by John O'Connor.
- 4) Lower value is for 5 in<sup>2</sup> multi-layer PC board. The multi layer PWB was .062 in. thick and typically used 0.635 mm trace widths for power pkgs, 1.3 mm trace widths for non-power pkgs with a 100x100 mil probe land area at the end of each trace. The backside of the PWB used 1.0 mm traces in the X and Y directions to simulate 20% coverage by multilayer traces. Thermal vias were not used to connect fused leads to backside traces. - see "Thermal Characteristics of Surface Mounted Packages" by John O'Connor.
- 5) Lower value is with a finned heatsink.
- 6)  $\theta_{ja}$  tests were performed in still air.  $\theta_{ja}$  results will vary depending on test conditions and setup. Airflow can lower the  $\theta_{ja}$  value stated by 15-30%, depending on air speed, package type and PWB configuration.
- 7) Modeled with no internal gnd plane. Lower value is for .5 mm trace widths, higher value for .3 mm trace widths.
- 8)  $\theta_{jc}$  data values stated were derived from MIL-STD-1835B. MIL-STD-1835B states that "*The baseline values shown are worst case (mean + 2s) for a 60x60 mil microcircuit device silicon die and applicable for devices with die sizes up to 14400 square mils. For device die sizes greater than 14400 square mils use the following values; dual-in-line, 11°C/W; flat pack, 10°C/W; pin grid array, 10°C/W.*"
- 9) Tested on multi layer 3x4.5x.062 in. PWB with (2) 1 oz copper internal planes, 10 mil trace widths and 2.43 in<sup>2</sup> of 1 oz. copper on top of PWB for heatsinking to fused leads. Thermal vias were not used to connect fused leads to inner copper planes.
- 10) Tested on multi layer 3x4.5x.062 in. PWB with (2) 1 oz. copper internal planes, 10 mil trace widths and 1.53 in<sup>2</sup> of 1 oz. copper on top of PWB for heatsinking to fused leads. Thermal vias were not used to connect fused leads to inner copper planes.
- 11) Tested on multi layer 3x4.5x.062 in. PWB with (2) 1 oz copper internal planes, 10 mil trace widths and 2.28 in<sup>2</sup> of 1 oz. copper on top of PWB for heatsinking to fused leads. Thermal vias were not used to connect fused leads to inner copper planes.
- 12) Tested on multi layer 3x4.5x.062 in. PWB with (2) 1 oz. copper internal planes, 10 mil trace widths and 2.74 in<sup>2</sup> of copper on top of PWB for heatsinking to fused leads. Thermal vias were not used to connect fused leads to inner copper planes.
- 13) Tested on multi layer 3x4.5x.062 in. PWB with (2) 1 oz copper internal planes, 10 mil trace widths and 2.2 in<sup>2</sup> of 1 oz. copper on top of PWB for heatsinking to fused leads. Thermal vias were not used to connect fused leads to inner copper planes.
- 14) Trace width for test PWBs is typically 10 mils.
- 15) Test conditions typically use a 110-125C junction temperature with an ambient temperature of 25-30°C.
- 16) Die size noted is for a thermal test die with a uniformly distributed heating area.

## Typical Materials Used for Assembly



Package	Unitrode Package Code	Die Thickness (mils)	Die Attach (2)	Leadframe Material Thermal Conductivity (1)	Molding Compound or Package Material
Ceramic DIP	J	15	Eutectic or Silver Glass	75	Alumina
Ceramic LCC	L	15	Eutectic or Silver Glass	N/A	Alumina
Ceramic LCC Power	LP	15	Eutectic or Silver Glass	N/A	Alumina
LQFP	FQ	12	Silver Filled Epoxy	85-110	Standard, non-thermally enhanced epoxy
LQFP Power	FQP	12	Silver Filled Epoxy	220	Standard, non-thermally enhanced epoxy
PDIP	N	12	Silver Filled Epoxy	150	Standard, non-thermally enhanced epoxy
MSOP	P	8	Silver Filled Epoxy	150	Standard, non-thermally enhanced epoxy
PDIP Power	NP	12	Silver Filled Epoxy	150	Standard, non-thermally enhanced epoxy
PLCC	Q	12	Silver Filled Epoxy	208	Standard, non-thermally enhanced epoxy
PLCC Power	QP	12	Silver Filled Epoxy	208	Standard, non-thermally enhanced epoxy
QSOP	M	12	Silver Filled Epoxy	150	Standard, non-thermally enhanced epoxy
QSOP Wide Body Power	MWP	12	Silver Filled Epoxy	208	Standard, non-thermally enhanced epoxy
SOIC Narrow Body	D	12	Silver Filled Epoxy	150	Standard, non-thermally enhanced epoxy
SOIC Narrow Power	DP	12	Silver Filled Epoxy	208	Standard, non-thermally enhanced epoxy
SOIC Wide Body	DW	12	Silver Filled Epoxy	150	Standard, non-thermally enhanced epoxy
SOIC Wide Body Power	DWP	12	Silver Filled Epoxy	208	Standard, non-thermally enhanced epoxy
TO220	T	12	Silver Filled Epoxy	150	Standard, non-thermally enhanced epoxy
TO263	TD	12	Silver Filled Epoxy	150	Standard, non-thermally enhanced epoxy
TSSOP	PW	10	Silver Filled Epoxy	85-110	Standard, non-thermally enhanced epoxy
TSSOP Power	PWP	10	Silver Filled Epoxy	85-110	Standard, non-thermally enhanced epoxy

Note (1):  $\frac{BTU \cdot in}{ft^2 \cdot hr \cdot ^\circ F}$

Leadframe downset is typically 8 to 15 mils. Leadframe thickness is typically 5-10 mils.

Note (2) :Die attach thickness is between 0.5-1.5 mils for plastic devices; 1.9-2.4 mils for ceramic.

**Table 1. Typical materials used for assembly.**



## THERMAL CHARACTERISTICS OF SURFACE MOUNT PACKAGES

John A. O'Connor

### Introduction

Surface mount packaging continues to expand market share, displacing dual in-line packages (DIPs) at an ever increasing rate. Smaller surface mount devices allow a significant increase in circuit density with a corresponding decrease in system size. Miniaturization is not without penalty however, as thermal management can quickly dominate system packaging design.

With the familiar DIP, the majority of heat is removed through the case. Typically, this is accomplished by convection air currents, although forced air or conduction cooling is often used in more demanding applications. Unlike the DIP however, the majority of heat is removed from surface mount packages through the leads. This means that the PC board design directly affects the thermal capability of surface mounted circuitry. For optimal thermal design, the integrated circuit, the package, and the PC board must be considered as a system.

Many designers use steady-state thermal behavior (thermal resistance) to predict IC junction temperature. While this approach certainly is valid for devices subjected to continuous power dissipation, it often results in an overly conservative design when dissipation varies over time. Generating a model which accounts for transient thermal behavior allows the designer to fully exploit the system's thermal mass. Instantaneous junction temperature can then be calculated, insuring reliability with minimal system size.

### Thermal Model

Figure 1 shows the basic model which is expanded for more complex situations. The power dissipated is represented by the current source. Resistance to heat flow is represented by the resistor, and the thermal mass is represented by the capacitor. The analogous thermal units for the current, thermal resis-

tance, and thermal capacitance are also shown in figure 1. Ground is ambient temperature, so all values are temperature rise above ambient. With more complex systems, it is usually easiest to initially convert to electrical units, analyze the circuit, then convert back to thermal units. This approach allows standard electrical circuit analysis tools and techniques to be used without unnecessary confusion.

A surface mounted device on a PC board can be modeled as in figure 2. Each R-C section roughly

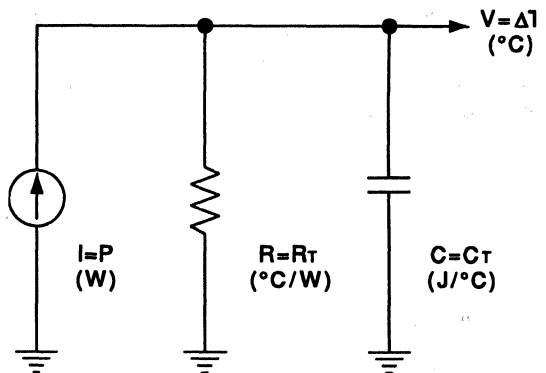


Figure 1. Basic Thermal Model

correlates to the physical system. The first R-C is the device die. The second is the lead frame and package, and the third is the PC board. Other parameters such as the junction to case and case to ambient thermal resistances, are lumped into the three R-C sections. This simplification does cause transient thermal response errors, although normally these errors are small. The additional elements can be broken out separately if greater accuracy is required. Although the physical correlation is far from perfect for the 3 R-C model, the thermal correlation can be very good.



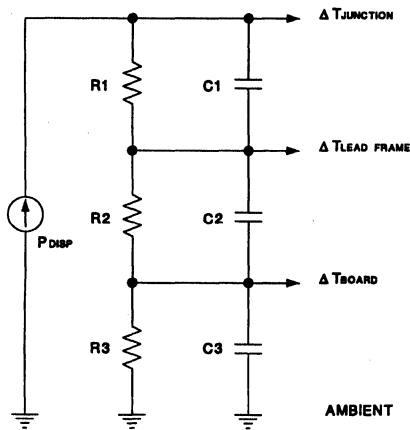


Figure 2. Surface Mounted Device on a PC Board Model

### Parameter Measurement

The circuit technique shown in figure 3 can be used to evaluate the thermal performance of almost any IC. Device power dissipation must be known and constant. This is achieved with resistive loading for devices such as voltage regulators or amplifiers. Other devices may require additional circuitry to insure constant dissipation.

The change in forward voltage of a diode is typically utilized for temperature measurement, although any temperature dependant parameter could also be used. Ideally, the diode should be close to the output transistors for maximum accuracy. In prac-

tice, this is not critical since the temperature drop across the die will only be a few degrees C in a surface mountable IC. During the test, the measurement diode must not have any current other than the fixed bias current. The bias current should be as small as possible to avoid self-heating the diode.

Many devices have a diode intended for forward biased operation in the actual application circuit such as an output stage clamping diode. If such a diode is not available it may be necessary to forward bias a parasitic diode for measurement. While this approach should be considered a last resort, it can yield acceptable data. If a parasitic diode is forward biased, erratic or unspecified behavior is likely, even with low bias currents. Evaluate the test circuit carefully, insuring that dissipation is constant over the measurement temperature range.

Kelvin all connections to avoid interconnect voltage drops. Every 2mV is approximately 1°C, so even small DC offsets can cause significant error. Without any power applied to the device other than the diode bias current, characterize the diode's forward voltage in an oven at several temperatures over the expected operating junction temperature range. The slope of a best-fit line gives the thermal coefficient ( $T_C$ ) which is used in subsequent calculations.

Thermocouples are used to sense PC board and ambient temperature. PC board temperature is measured as close to the device as possible.

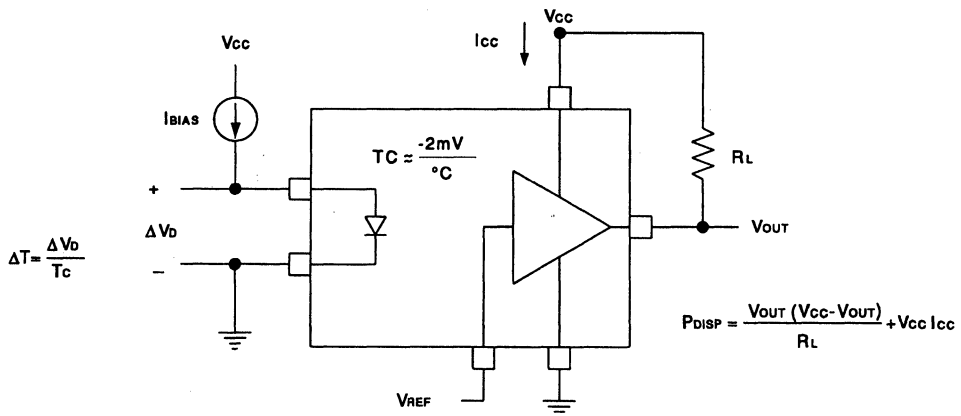


Figure 3. Typical Thermal Test Circuit





Some parameters are measured directly while others are derived by curve fitting. Junction to PC board, and PC board to ambient thermal resistance are measured by dissipating a constant power. Allow 15 minutes for the temperature to stabilize. The change in diode forward voltage and PC board temperature give the junction to ambient and board to ambient thermal resistance:

$$R_{(j-a)} = \Delta V_D / (T_C P_{DISP})$$

$$R_{(b-a)} = \Delta T_B / P_{DISP}$$

Note that these resistances are based on change in temperature - ambient is assumed constant for the duration of the test. These values correlate to R1, R2, and R3 by:

$$R1 + R2 = R_{(j-a)} - R_{(b-a)} \quad (1)$$

$$R3 = R_{(b-a)} \quad (2)$$

The thermal capacitance of the die is measured by applying a pulsed load and recording the junction temperature waveform. Varying the dissipation pulse width allows observation of each capacitance's effect, although only the die's thermal capacitance can be measured directly. A typical 10ms transient dissipation waveform is shown in figure 4. The thermal time constant of the die is on the order of 30ms. To minimize exponential decay error, the slope of the waveform is measured at (t) = 3ms. The die's thermal capacitance is then:

$$C1 = P_{DISP} \Delta t T_C / \Delta V_D \quad (3)$$

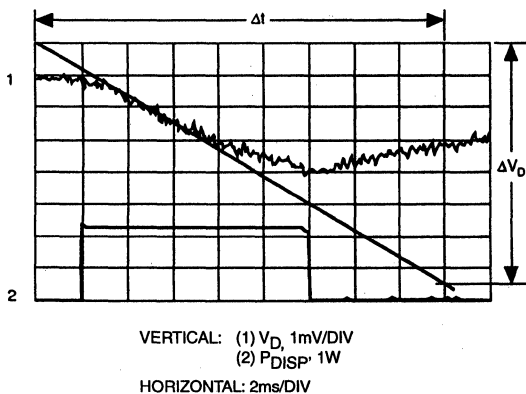


Figure 4: 10ms Transient Dissipation Waveform

Transient waveforms should also be taken for 100ms, 1s, and 10s dissipation intervals to generate an accurate temperature versus time curve. If tran-

sient thermal behavior is critical beyond 10 seconds then additional curves must be taken. The thermal time constant of the PC board can go out to several minutes, so a strip chart recorder or computer based data acquisition system will be required. For most systems, this additional data is unnecessary.

The remaining parameters are determined by curve fitting. Visual comparison of measured versus calculated curves is easily done with a spread sheet program. Measured junction temperature versus time data (4 points per decade is sufficient) is entered into the spread sheet. Junction temperature is then calculated at each point with estimated values for R2 and C2 and C3 using:

$$T(t) = P_{DISP} [R1(1-e^{-t/\tau1}) + R2(1-e^{-t/\tau2}) + R3(1-e^{-t/\tau3})] \quad (4)$$

Data presented in the following section will help in estimating initial values. This procedure is iterated until an acceptable curve fit is achieved. C3's value is iterated only if the measured curve goes out to several minutes. Figure 5 is a typical measured and calculated junction temperature versus time curve. A logarithmic time axis aids in curve fitting by spreading data points evenly.

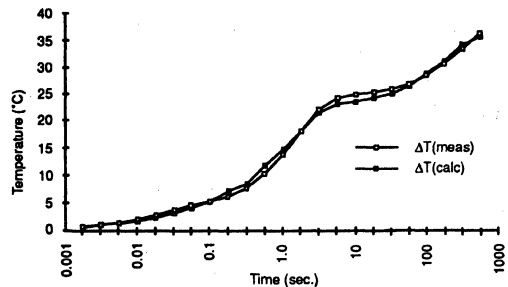


Figure 5: Junction Temperature versus Time for FQP48 Package Dissipating 1W.

## Typical Data

The preceding technique was used to characterize two devices in nine different packages. Five different PC board types were also tested to provide relative comparison. This information should be used to help initially determine package, PC board type, and layout. It must be stressed that this typical data should not substitute for a rigorous thermal analysis of the actual application.

# Thermal Characteristics of Surface Mount Packages



PACKAGE	R1 (°C/W)	C1 (J/°C)	$\tau_1$ (sec)	R2 (°C/W)	C2 (J/°C)	$\tau_2$ (sec)	R3 (°C/W)	C3 (J/°C)	$\tau_3$ (sec)	R(J-a) (°C/W)
D8	5	0.0035	0.02	64	0.030	1.9	15	24	360	84
D14	4	0.0045	0.02	45	0.035	1.6	16	24	384	65
DW16	4	0.0045	0.02	44	0.070	3.1	15	24	360	63
DW16	4	0.011	0.04	34	0.11	3.7	13	24	312	51
DWP28	2.5	0.008	0.02	13	0.13	1.7	15	24	360	30
Q20	3	0.010	0.02	26	0.12	3.1	14	24	336	43
Q28	2.5	0.008	0.02	25	0.12	2.9	13	24	312	40
QP28	2.5	0.009	0.02	12	0.25	3.0	14	24	336	28
FQ48	4	0.006	0.02	57	0.07	4.0	15	24	360	76
FQP48	4	0.005	0.02	21	0.08	1.7	14	25	350	39

Figure 6. Model Values Versus Package Type for 1W Dissipation on Aluminum PC Board.

Figure 6 shows model values and time constants versus package type, mounted on an aluminum PC board [1]. Junction to ambient thermal resistance is also shown to indicate overall steady state thermal performance. All data was taken with one watt dissipated. The values that were determined by curve fitting result in a fairly conservative model. Values were chosen which tended to predict higher temperature than actually measured where errors could not be eliminated. As indicated, two devices were used for testing. At 7,500 square mils, the UC3730 is representative of the smaller dies typically packaged in D8, D14, and DW16 packages. The UC3173 is 16,500 square mils, and is typical of the dies packaged in the other larger packages.

Both devices were packaged in the DW16 to isolate the effect of die size. The UC1730's smaller die increased R2 by about 30%. Interpolating between these two data points is difficult since the relationship between die size and thermal resistance is non-linear. Curves are available which account for this dimensional difference [2], although the actual conditions differ and are more complicated than the configuration used to generate the curves. Fortunately, the resulting error will be small in most applications. Conservatively estimating R2 will minimally impact system size, but if a more accurate value is required the actual device can be characterized on a test PC board.

Figure 7 illustrates the power lead frame's dramatic improvement in thermal performance over standard lead frames by comparing the junction to ambient thermal resistances of the QP28 to the Q28, and the FQP48 to the FQ48. Standard lead frames connect the die to the leads thermally through the epoxy molding compound. Power lead frame packages incorporate a single piece for die attachment and ground leads. This uninterrupted, high thermal conductivity path offers a significant improvement over standard lead frames. Occasionally a stiffer but less conductive alloy is used for standard lead frames. The FQ48's poorer thermal performance is partially caused by the lower conductivity alloy.

Printed circuit board design significantly affects the overall thermal performance of the system, particularly with the power lead frame packages. The UC3173 in the DWP28 package was used to

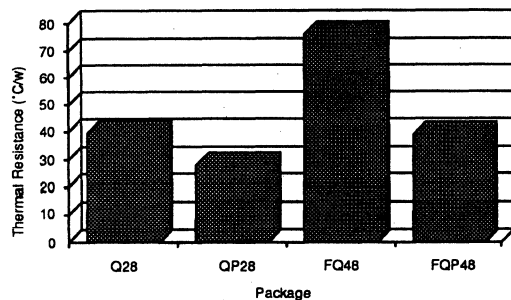


Figure 7. Power lead frames significantly reduce thermal resistance.



compare PC board thermal performance. Five different PC board types were evaluated with one watt dissipated:

1. Single side 1 oz. copper, 0.062 aluminum
2. Single side 1 oz. copper, 0.062 FR4 epoxy fiberglass
3. Single side 2 oz. copper, 0.062 FR4 epoxy fiberglass
4. Four layer (signal, ground, Vcc, signal) 1 oz. copper, 0.031 FR4 epoxy fiberglass
5. Four layer (signal, ground, Vcc, signal) 1 oz. copper, 0.062 FR4 epoxy fiberglass

PCB TYPE	R(b-a) (°C/W)	C(b-a) (J/°C)	$\tau$ (sec)
Aluminum	15	24	360
FR4-1oz	31	2.5	78
FR4-2oz	25	3	74
4 layer - 0.031	21	4	84
4 layer - 0.062	19	5	94

Figure 8. Board to ambient thermal resistance and capacitance versus PC board type for DWP28 package dissipating 1W.

The thermal resistance, capacitance, and time constants for the five PC boards are shown in figure 8. The PC board layouts used for testing are shown in figure 9. Only the component side is shown for the four layer boards. The back side, which has 10 mil traces on 50 mil centers to provide a typical amount of interconnect copper, and the Vcc plane were

unconnected. The inner ground plane is connected to the small component side ground plane through 16 feed-throughs.

As expected, the aluminum PC board's significantly higher specific heat results in nearly an order of magnitude increase in thermal capacitance. Surprisingly the four layer 0.062 board's thermal resistance is nearly as low as the aluminum board's, indicating good heat distribution through the inner planes. Note that although the Vcc plane is unconnected, it does help distribute the heat across the board. Conduction or forced air cooling is necessary to fully exploit the aluminum board's capability.

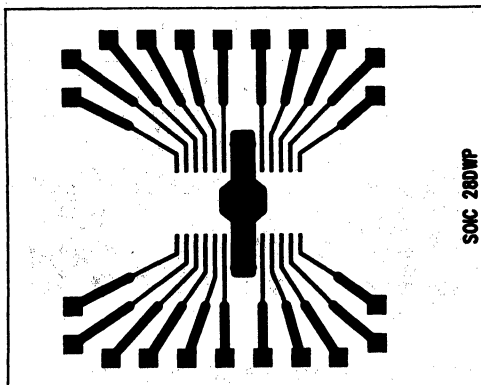
## Summary

A method for accurately modeling the thermal behavior of a surface mounted IC has been presented. The model relies on measured data, insuring excellent correlation to the physical system. Typical thermal behavior of nine different packages and five different PC boards were also presented, indicating relative thermal performance differences. Optimum thermal system design is achievable using the techniques and data presented.

## References

1. Thermal Clad insulated metal substrates, The Bergquist Company, 5300 Edina Industrial Blvd., Minneapolis, MN 55439, 612-835-2322
2. R. Tummala, E. Rymaszewski, "Microelectronics Packaging Handbook", Van Nostrand Reinhold, 1989, pp173-179

### 4 Layer-Component Side



### Single Sided

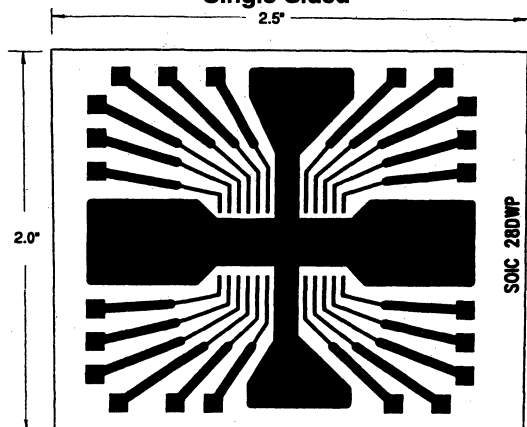
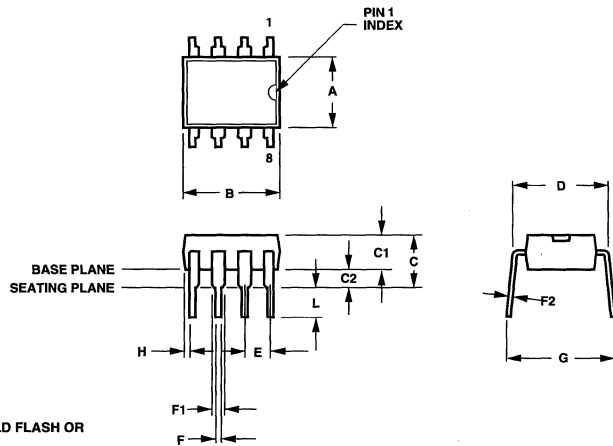


Figure 9. Test PC Board Layouts (SOIC 28DWP)



## 8-PIN PLASTIC DIP ~ N PACKAGE SUFFIX

	DIMENSIONS				NOTES
	INCHES		MILLIMETERS		
	MIN	MAX	MIN	MAX	
A	.245	.260	6.22	6.60	1
B	.320	.400	9.40	10.16	1
C	-	.210	-	5.33	
C1	.125	.150	3.18	3.81	
C2	.015	.055	0.38	1.40	2
D	.300	.325	7.62	8.26	3
E	.100 BSC		2.54 BSC		4
F	.014	.022	0.35	0.56	
F1	.045	.070	1.14	1.78	
F2	.008	.014	0.20	0.35	
G	.300	.400	7.62	10.16	5
H	.005	-	0.13	-	
L	.115	.160	2.92	4.06	

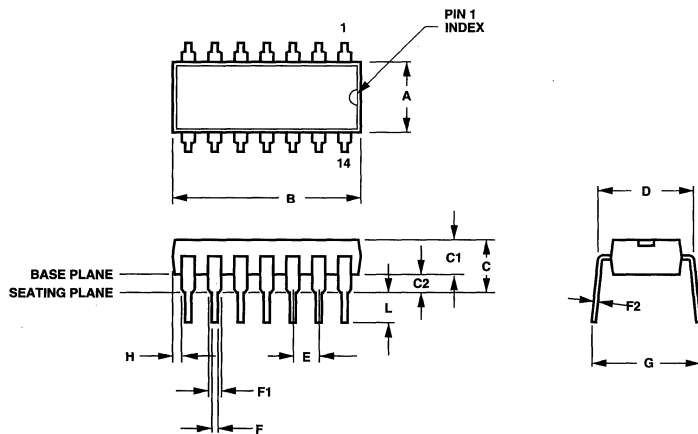


**NOTES:**

1. 'A' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
2. 'C2' SHALL BE MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
3. 'D' SHALL BE MEASURED WITH THE LEADS CONSTRAINED TO BE PERPENDICULAR TO THE BASE PLANE.
4. THE BASIC LEAD SPACING IS 0.100 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.010$  IN. OF ITS EXACT TRUE POSITION.
5. 'G' SHALL BE MEASURED AT THE LEAD TIPS WITH THE LEADS UNCONSTRAINED.
6. CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.

## 14-PIN PLASTIC DIP ~ N PACKAGE SUFFIX

	DIMENSIONS				NOTES
	INCHES		MILLIMETERS		
	MIN	MAX	MIN	MAX	
A	.245	.260	6.22	6.60	1
B	.745	.775	18.92	19.68	1
C	-	.210	-	5.33	
C1	.125	.150	3.18	3.81	
C2	.015	.055	0.38	1.40	2
D	.300	.325	7.62	8.26	3
E	.100 BSC		2.54 BSC		4
F	.014	.022	0.35	0.56	
F1	.045	.070	1.14	1.78	
F2	.008	.014	0.20	0.35	
G	.300	.400	7.62	10.16	5
H	.005	-	0.13	-	
L	.115	.160	2.92	4.06	



**NOTES:**

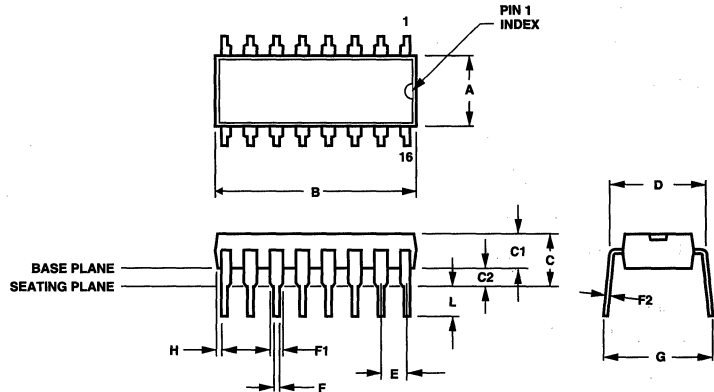
1. 'A' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
2. 'C2' SHALL BE MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
3. 'D' SHALL BE MEASURED WITH THE LEADS CONSTRAINED TO BE PERPENDICULAR TO THE BASE PLANE.
4. THE BASIC LEAD SPACING IS 0.100 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.010$  IN. OF ITS EXACT TRUE POSITION.
5. 'G' SHALL BE MEASURED AT THE LEAD TIPS WITH THE LEADS UNCONSTRAINED.
6. CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.





## 16-PIN PLASTIC DIP ~ N PACKAGE SUFFIX

	DIMENSIONS				NOTES
	INCHES		MILLIMETERS		
	MIN	MAX	MIN	MAX	
A	.245	.260	6.22	6.60	1
B	.745	.775	18.92	19.68	1
C	-	.210	-	5.33	
C1	.125	.150	3.18	3.81	
C2	.015	.055	0.38	1.40	2
D	.300	.325	7.62	8.26	3
E	.100 BSC		2.54 BSC		4
F	.014	.022	0.35	0.56	
F1	.045	.070	1.14	1.78	
F2	.008	.014	0.20	0.35	
G	.300	.400	7.62	10.16	5
H	.005	-	0.13	-	
L	.115	.160	2.92	4.06	

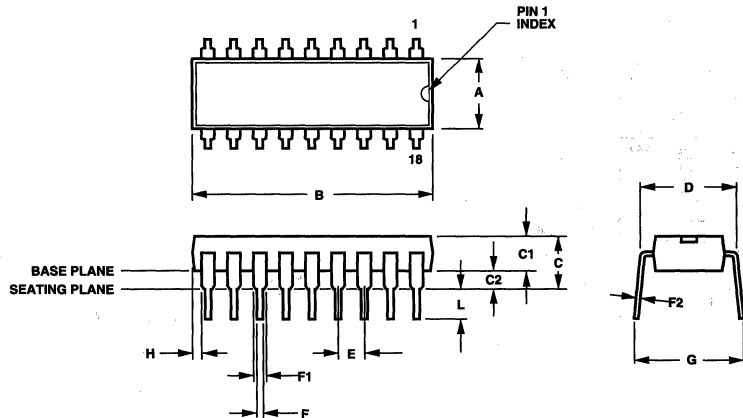


### NOTES:

- 'A' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
- 'C2' SHALL BE MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
- 'D' SHALL BE MEASURED WITH THE LEADS CONSTRAINED TO BE PERPENDICULAR TO THE BASE PLANE.
- THE BASIC LEAD SPACING IS 0.100 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.010$  IN. OF ITS EXACT TRUE POSITION.
- 'G' SHALL BE MEASURED AT THE LEAD TIPS WITH THE LEADS UNCONSTRAINED.
- CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.

## 18-PIN PLASTIC DIP ~ N PACKAGE SUFFIX

	DIMENSIONS				NOTES
	INCHES		MILLIMETERS		
	MIN	MAX	MIN	MAX	
A	.245	.260	6.22	6.60	1
B	.890	.920	22.61	23.39	1
C	-	.210	-	5.33	
C1	.125	.150	3.18	3.81	
C2	.015	.055	0.38	1.40	2
D	.300	.325	7.62	8.26	3
E	.100 BSC		2.54 BSC		4
F	.014	.022	0.35	0.56	
F1	.045	.070	1.14	1.78	
F2	.008	.014	0.20	0.35	
G	.300	.400	7.62	10.16	5
H	.005	-	0.13	-	
L	.115	.160	2.92	4.06	



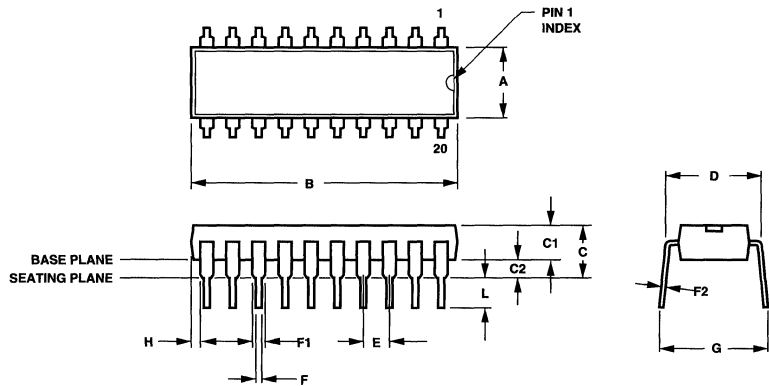
### NOTES:

- 'A' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
- 'C2' SHALL BE MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
- 'D' SHALL BE MEASURED WITH THE LEADS CONSTRAINED TO BE PERPENDICULAR TO THE BASE PLANE.
- THE BASIC LEAD SPACING IS 0.100 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.010$  IN. OF ITS EXACT TRUE POSITION.
- 'G' SHALL BE MEASURED AT THE LEAD TIPS WITH THE LEADS UNCONSTRAINED.
- CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.



## 20-PIN PLASTIC DIP ~ N PACKAGE SUFFIX

	DIMENSIONS				NOTES
	INCHES		MILLIMETERS		
	MIN	MAX	MIN	MAX	
A	.245	.260	6.22	6.60	1
B	1.010	1.030	25.65	26.16	1
C	—	.210	—	5.33	
C1	.125	.150	3.18	3.81	
C2	.015	.055	0.38	1.40	2
D	.300	.325	7.62	8.26	3
E	.100 BSC	—	2.54 BSC	—	4
F	.014	.022	0.35	0.56	
F1	.045	.070	1.14	1.78	
F2	.008	.014	0.20	0.35	
G	.300	.400	7.62	10.16	5
H	.005	—	0.13	—	
L	.115	.160	2.92	4.06	

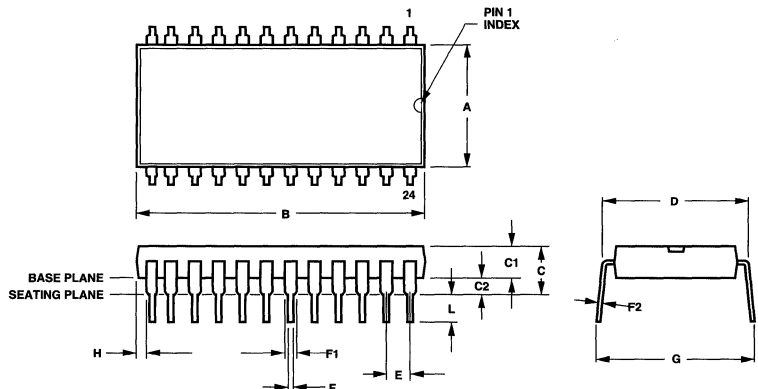


### NOTES:

- 'A' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
- 'C2' SHALL BE MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
- 'D' SHALL BE MEASURED WITH THE LEADS CONSTRAINED TO BE PERPENDICULAR TO THE BASE PLANE.
- THE BASIC LEAD SPACING IS 0.100 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.010$  IN. OF ITS EXACT TRUE POSITION.
- 'G' SHALL BE MEASURED AT THE LEAD TIPS WITH THE LEADS UNCONSTRAINED.
- CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.

## 24-PIN PLASTIC DIP ~ N PACKAGE SUFFIX

	DIMENSIONS				NOTES
	INCHES		MILLIMETERS		
	MIN	MAX	MIN	MAX	
A	.500	.550	12.70	13.97	1
B	1.230	1.270	31.24	32.26	1
C	—	.210	—	5.33	
C1	.125	.150	3.18	3.81	
C2	.015	.055	0.38	1.40	2
D	.600	.625	15.24	15.87	3
E	.100 BSC	—	2.54 BSC	—	4
F	.014	.022	0.35	0.56	
F1	.045	.070	1.14	1.78	
F2	.008	.014	0.20	0.35	
G	.600	.675	15.24	17.15	5
H	.005	—	0.13	—	
L	.115	.160	2.92	4.06	



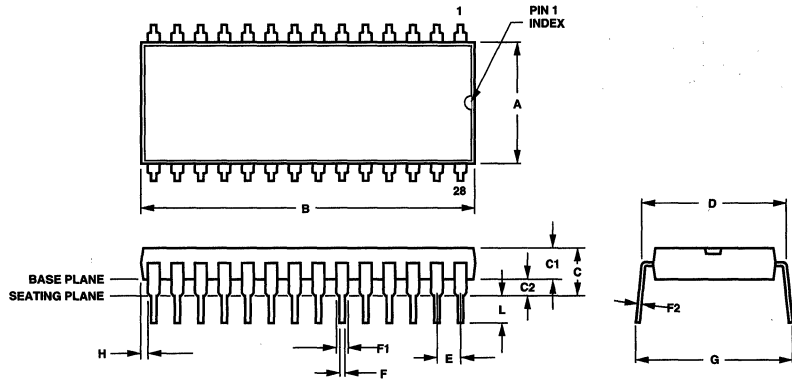
### NOTES:

- 'A' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
- 'C2' SHALL BE MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
- 'D' SHALL BE MEASURED WITH THE LEADS CONSTRAINED TO BE PERPENDICULAR TO THE BASE PLANE.
- THE BASIC LEAD SPACING IS 0.100 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.010$  IN. OF ITS EXACT TRUE POSITION.
- 'G' SHALL BE MEASURED AT THE LEAD TIPS WITH THE LEADS UNCONSTRAINED.
- CONTROLLING DIMENSIONS: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.



## 28-PIN PLASTIC DIP ~ N PACKAGE SUFFIX

	DIMENSIONS				NOTES
	INCHES		MILLIMETERS		
	MIN	MAX	MIN	MAX	
A	.500	.550	12.70	13.97	1
B	1.380	1.470	35.10	37.34	1
C	—	.210	—	5.33	
C1	.125	.150	3.18	3.81	
C2	.015	.055	0.38	1.40	2
D	.600	.825	15.24	15.87	3
E	.100 BSC	2.54 BSC			4
F	.014	.022	0.35	0.56	
F1	.045	.070	1.14	1.78	
G	.600	.875	15.24	17.15	5
H	.005	—	0.13	—	
L	.115	.160	2.92	4.06	

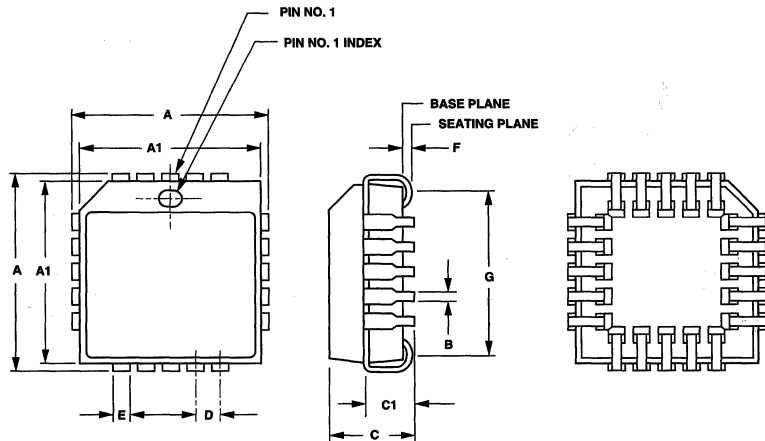


### NOTES:

- 'A' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
- 'C2' SHALL BE MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
- 'D' SHALL BE MEASURED WITH THE LEADS CONSTRAINED TO BE PERPENDICULAR TO THE BASE PLANE.
- THE BASIC LEAD SPACING IS 0.100 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.010$  IN. OF ITS EXACT TRUE POSITION.
- 'G' SHALL BE MEASURED AT THE LEAD TIPS WITH THE LEADS UNCONSTRAINED.
- CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.

## 20-PIN PLASTIC PLCC SURFACE MOUNT ~ Q PACKAGE SUFFIX

	DIMENSIONS				NOTES
	INCHES		MILLIMETERS		
	MIN	MAX	MIN	MAX	
A	.385	.395	9.78	10.03	
A1	.350	.356	8.89	9.04	1
B	.013	.021	0.33	0.53	
C	.170	.180	4.32	4.57	
C1	.100	.110	2.54	2.79	
D	.050 BSC	1.27 BSC			2
E	.026	.032	0.66	0.81	
F	.020	—	0.51	—	3, 4
G	.290	.330	7.37	8.38	



### NOTES:

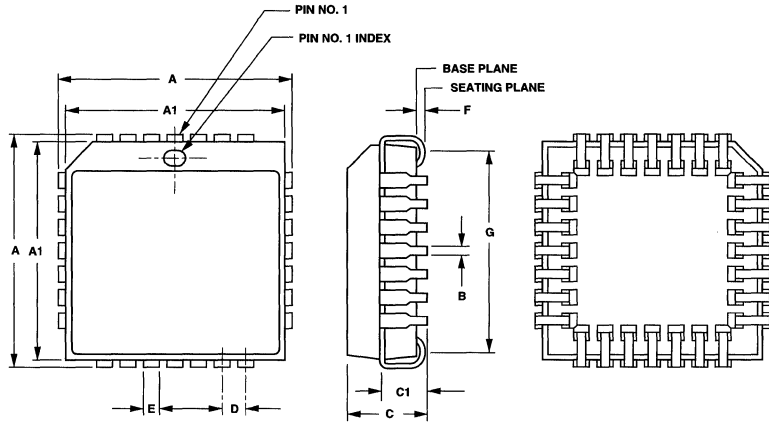
- 'A1' DOES NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
- THE BASIC LEAD SPACING IS 0.050 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.004$  IN. OF ITS EXACT TRUE POSITION.
- 'F' IS MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
- LEADS SHALL BE COPLANAR WITHIN 0.004 IN. AT THE SEATING PLANE.
- CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.





## 28-PIN PLASTIC PLCC SURFACE MOUNT ~ Q, QP PACKAGE SUFFIX

	DIMENSIONS				NOTES
	INCHES		MILLIMETERS		
	MIN	MAX	MIN	MAX	
A	.485	.495	12.32	12.57	
A1	.480	.456	11.43	11.58	1
B	.013	.021	0.33	0.53	
C	.170	.180	4.32	4.57	
C1	.100	.110	2.54	2.79	
D	.050 BSC		1.27 BSC		2
E	.026	.032	0.66	0.81	
F	.020	-	0.51	-	3, 4
G	.390	.430	9.91	10.92	

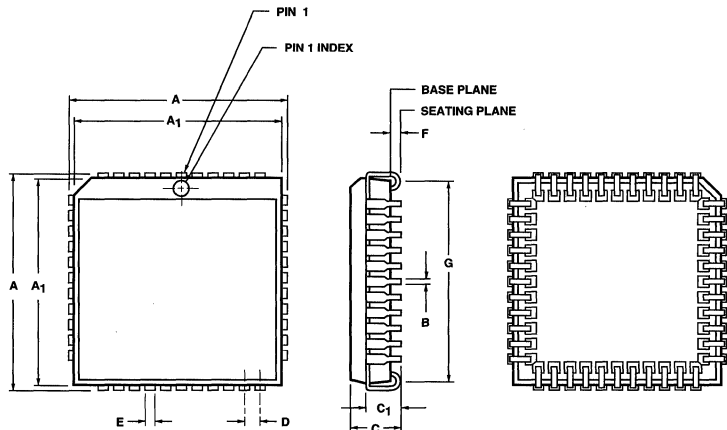


**NOTES:**

1. 'A1' DOES NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
2. THE BASIC LEAD SPACING IS 0.050 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.004$  IN. OF ITS EXACT TRUE POSITION.
3. 'F' IS MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
4. LEADS SHALL BE COPLANAR WITHIN 0.004 IN. AT THE SEATING PLANE.
5. CONTROLLING DIMENSION : INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.

## 44-PIN PLASTIC PLCC SURFACE MOUNT ~ Q, QP PACKAGE SUFFIX

	DIMENSIONS				NOTES
	INCHES		MILLIMETERS		
	MIN	MAX	MIN	MAX	
A	.685	.695	17.40	17.65	
A1	.650	.656	16.51	16.66	1
B	.013	.021	0.33	0.53	
C	.165	.180	4.19	4.57	
C1	.095	.110	2.41	2.79	
D	.050 BSC		1.27 BSC		2
E	.026	.032	0.66	0.81	
F	.020	-	0.51	-	3, 4
G	.590	.630	14.99	16.00	



**NOTES:**

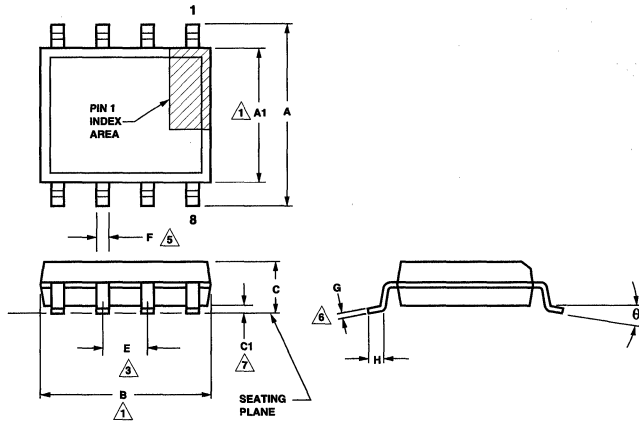
1. 'A1' DOES NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
2. THE BASIC LEAD SPACING IS 0.050 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.004$  IN. OF ITS EXACT TRUE POSITION.
3. 'F' IS MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
4. LEADS SHALL BE COPLANAR WITHIN 0.004 IN. AT THE SEATING PLANE.
5. CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.





## 8-PIN SOIC SURFACE MOUNT ~ D, DP PACKAGE SUFFIX

DIMENSIONS				
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.228	.244	5.80	6.20
A1	.150	.158	3.80	4.00
B	.189	.196	4.80	4.98
C	.053	.069	1.35	1.75
C1	.004	.009	0.10	0.23
E	.050 BSC		1.27 BSC	
F	.014	.019	0.35	0.48
G	.007	.010	0.19	0.25
H	.016	.035	0.41	0.89
θ	0°	8°	0°	8°

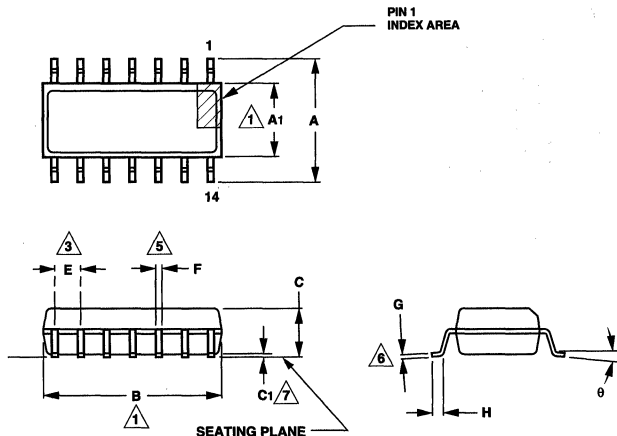


### NOTES:

1. 'A1' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
2. LEADS SHALL BE COPLANAR WITHIN 0.004 IN. AT THE SEATING PLANE.
3. THE BASIC LEAD SPACING IS 0.050 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.004 IN. OF ITS EXACT TRUE POSITION.
4. CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
5. DIMENSION 'F' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'F' MAXIMUM BY MORE THAN 0.003 IN. DAMBAR CAN NOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.004 IN. AND 0.010 IN. FROM THE LEAD TIP.
7. 'C1' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).

## 14-PIN SOIC SURFACE MOUNT ~ D PACKAGE SUFFIX

DIMENSIONS				
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.228	.244	5.80	6.20
A1	.150	.158	3.80	4.00
B	.336	.344	8.55	8.75
C	.053	.069	1.35	1.75
C1	.004	.009	0.10	0.22
E	.050 BSC		1.27 BSC	
F	.014	.019	0.36	0.48
G	.007	.010	0.19	0.25
H	.016	.035	0.41	0.89
θ	0°	8°	0°	8°



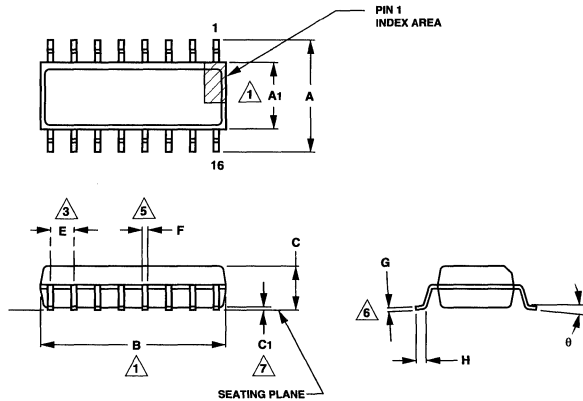
### NOTES:

1. 'A1' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
2. LEADS SHALL BE COPLANAR WITHIN 0.004 IN. AT THE SEATING PLANE.
3. THE BASIC LEAD SPACING IS 0.050 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.004 IN. OF ITS EXACT TRUE POSITION.
4. CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
5. DIMENSION 'F' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'F' MAXIMUM BY MORE THAN 0.003 IN. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.004 IN. AND 0.010 IN. FROM THE LEAD TIP.
7. 'C1' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).



## 16-PIN SOIC SURFACE MOUNT ~ D, DP, DS PACKAGE SUFFIX

DIMENSIONS				
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.228	.244	5.80	6.20
A1	.150	.158	3.80	4.00
B	.386	.393	9.80	9.98
C	.053	.069	1.35	1.75
C1	.004	.009	0.10	0.22
E	.050 BSC		1.27 BSC	
F	.014	.019	0.36	0.48
G	.007	.010	0.19	0.25
H	.016	.035	0.41	0.89
θ	0°	8°	0°	8°

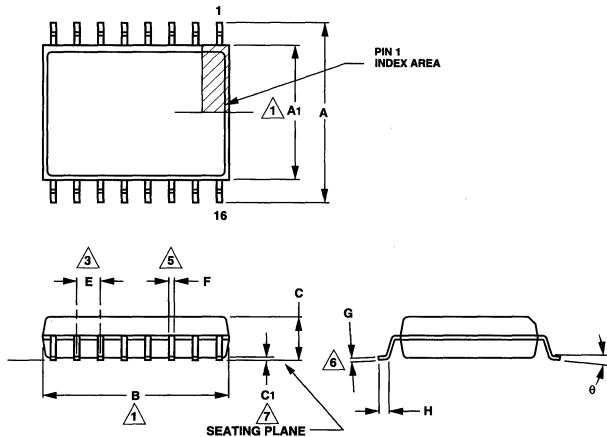


**NOTES:**

- 1 'A1' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
- 2 LEADS SHALL BE COPLANAR WITHIN 0.004 IN. AT THE SEATING PLANE.
- 3 THE BASIC LEAD SPACING IS 0.050 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.004 IN. OF ITS EXACT TRUE POSITION.
- 4 CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
- 5 DIMENSION 'F' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'F' MAXIMUM BY MORE THAN 0.003 IN. DAMBAR CAN NOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
- 6 THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.004 IN. AND 0.010 IN. FROM THE LEAD TIP.
- 7 'C1' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).

## 16-PIN SOIC SURFACE MOUNT ~ DW PACKAGE SUFFIX

DIMENSIONS				
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.394	.419	10.00	10.64
A1	.292	.299	7.42	7.59
B	.403	.413	10.24	10.49
C	.097	.104	2.46	2.64
C1	.004	.011	0.10	0.28
E	.050 BSC		1.27 BSC	
F	.014	.019	0.36	0.48
G	.009	.012	0.23	0.30
H	.018	.035	0.46	0.89
θ	0°	8°	0°	8°



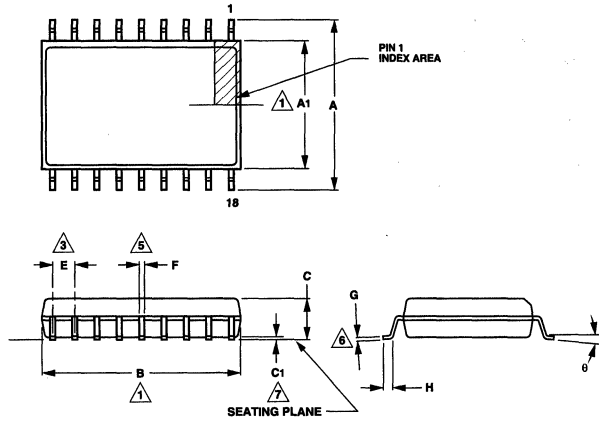
**NOTES:**

- 1 'A1' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
- 2 LEADS SHALL BE COPLANAR WITHIN 0.004 IN. AT THE SEATING PLANE.
- 3 THE BASIC LEAD SPACING IS 0.050 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.004 IN. OF ITS EXACT TRUE POSITION.
- 4 CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
- 5 DIMENSION 'F' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'F' MAXIMUM BY MORE THAN 0.003 IN. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
- 6 THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.004 IN. AND 0.010 IN. FROM THE LEAD TIP.
- 7 'C1' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).



## 18-PIN SOIC SURFACE MOUNT ~ DW PACKAGE SUFFIX

DIMENSIONS				
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.394	.419	10.00	10.64
A1	.292	.299	7.42	7.59
B	.453	.462	11.51	11.73
C	.097	.104	2.46	2.64
C1	.004	.011	0.10	0.28
E	.050 BSC		1.27 BSC	
F	.014	.019	0.36	0.48
G	.009	.012	0.23	0.30
H	.018	.035	0.46	0.89
θ	0°	8°	0°	8°

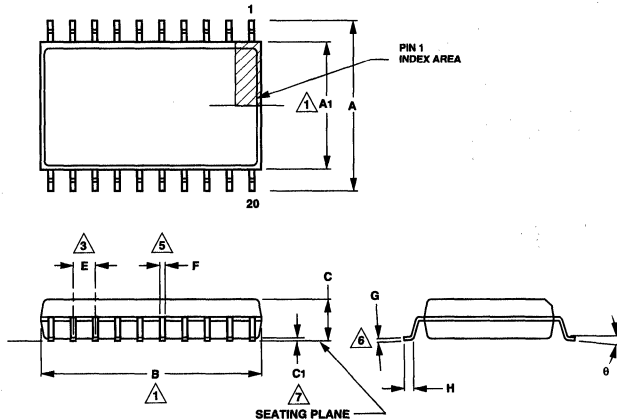


**NOTES:**

1. 'A1' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
2. LEADS SHALL BE COPLANAR WITHIN 0.004 IN. AT THE SEATING PLANE.
3. THE BASIC LEAD SPACING IS 0.050 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.004 IN. OF ITS EXACT TRUE POSITION.
4. CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
5. DIMENSION 'F' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'F' MAXIMUM BY MORE THAN 0.003 IN. DAMBAR CAN NOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.004 IN. AND 0.010 IN. FROM THE LEAD TIP.
7. 'C1' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).

## 20-PIN SOIC SURFACE MOUNT ~ DW PACKAGE SUFFIX

DIMENSIONS				
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.394	.419	10.00	10.64
A1	.292	.299	7.42	7.59
B	.504	.511	12.80	12.98
C	.097	.104	2.46	2.64
C1	.004	.011	0.10	0.28
E	.050 BSC		1.27 BSC	
F	.014	.019	0.36	0.48
G	.009	.012	0.23	0.30
H	.018	.035	0.46	0.89
θ	0°	8°	0°	8°



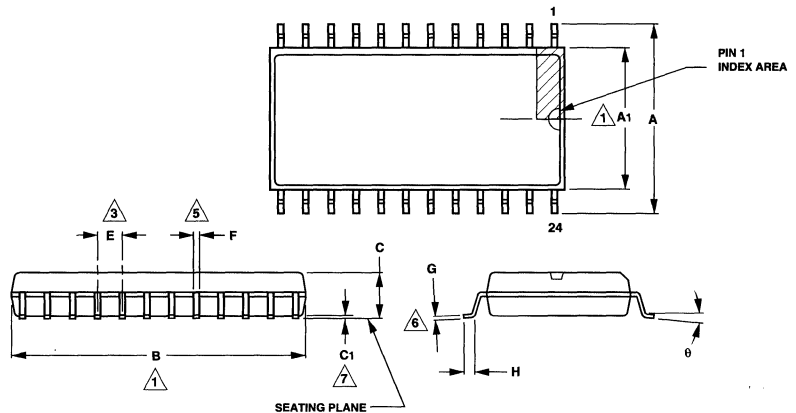
**NOTES:**

1. 'A1' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
2. LEADS SHALL BE COPLANAR WITHIN 0.004 IN. AT THE SEATING PLANE.
3. THE BASIC LEAD SPACING IS 0.050 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.004 IN. OF ITS EXACT TRUE POSITION.
4. CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
5. DIMENSION 'F' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'F' MAXIMUM BY MORE THAN 0.003 IN. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.004 IN. AND 0.010 IN. FROM THE LEAD TIP.
7. 'C1' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).



## 24-PIN SOIC SURFACE MOUNT ~ DW PACKAGE SUFFIX

DIMENSIONS				
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.394	.419	10.00	10.64
A1	.292	.299	7.42	7.59
B	.598	.606	15.20	15.40
C	.097	.104	2.46	2.64
C1	.004	.011	0.10	0.28
E	.050 BSC		1.27 BSC	
F	.014	.019	0.36	0.48
G	.009	.012	0.23	0.30
H	.019	.035	0.46	0.89
θ	0°	8°	0°	8°

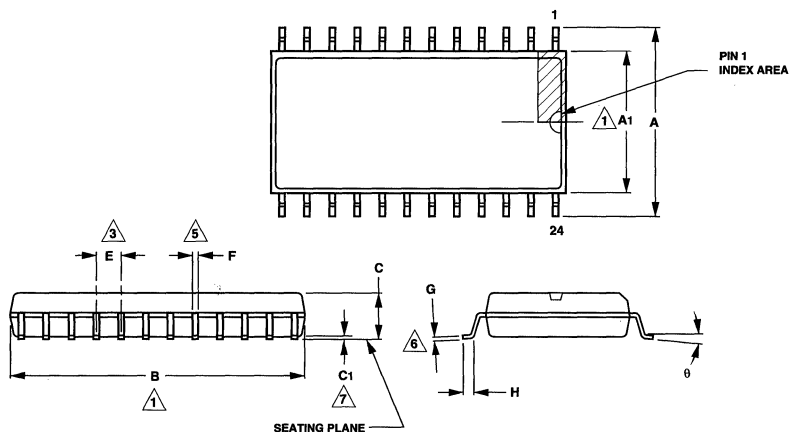


### NOTES:

1. 'A1' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
2. LEADS SHALL BE COPLANAR WITHIN 0.004 IN. AT THE SEATING PLANE.
3. THE BASIC LEAD SPACING IS 0.050 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.004 IN. OF ITS EXACT TRUE POSITION.
4. CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
5. DIMENSION 'F' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'F' MAXIMUM BY MORE THAN 0.003 IN. DAMBAR CAN NOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.004 IN. AND 0.010 IN. FROM THE LEAD TIP.
7. 'C1' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).

## 28-PIN SOIC SURFACE MOUNT ~ DW, DWP PACKAGE SUFFIX

DIMENSIONS				
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.394	.419	10.00	10.64
A1	.292	.299	7.42	7.59
B	.698	.712	17.73	18.08
C	.097	.104	2.46	2.64
C1	.004	.011	0.10	0.28
E	.050 BSC		1.27 BSC	
F	.014	.019	0.36	0.48
G	.009	.012	0.23	0.30
H	.018	.035	0.46	0.89
θ	0°	8°	0°	8°



### NOTES:

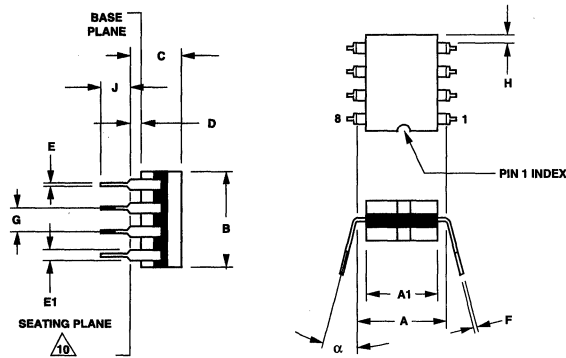
1. 'A1' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
2. LEADS SHALL BE COPLANAR WITHIN 0.004 IN. AT THE SEATING PLANE.
3. THE BASIC LEAD SPACING IS 0.050 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.004 IN. OF ITS EXACT TRUE POSITION.
4. CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
5. DIMENSION 'F' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'F' MAXIMUM BY MORE THAN 0.003 IN. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.004 IN. AND 0.010 IN. FROM THE LEAD TIP.
7. 'C1' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).





## 8-PIN CERAMIC DIP ~ J PACKAGE SUFFIX

	DIMENSIONS				NOTES
	INCHES		MILLIMETERS		
	MIN	MAX	MIN	MAX	
A	0.290	0.320	7.37	8.13	7
A1	0.220	0.310	5.59	7.87	4
B	—	0.405	—	10.29	4
C	—	0.200	—	5.08	
D	0.015	0.060	0.38	1.52	3
E	0.014	0.026	0.36	0.66	8
E1	0.045	0.065	1.14	1.65	2
F	0.008	0.018	0.20	0.46	8
G	0.100 BSC		2.54 BSC		5
H	0.005	—	0.13	—	6
J	0.125	0.200	3.18	5.08	
$\alpha$	0°	15°	0°	15°	

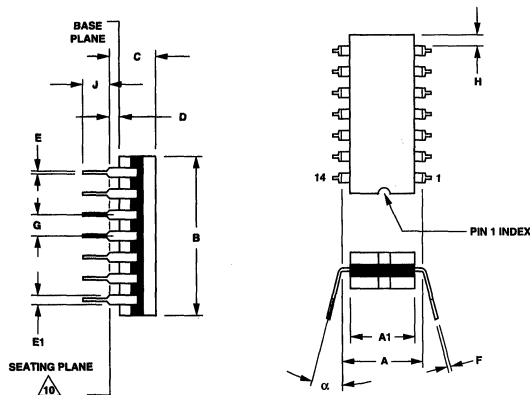


### NOTES:

- INDEX AREA: A NOTCH OR A PIN ONE IDENTIFICATION MARK SHALL BE LOCATED ADJACENT TO PIN ONE. THE MANUFACTURER'S IDENTIFICATION SHALL NOT BE USED AS A PIN ONE IDENTIFICATION MARK.
- THE MINIMUM LIMIT FOR DIMENSION "E1" MAY BE 0.023 (0.58mm) FOR LEADS NUMBER 1, 4, 5 AND 8 ONLY.
- DIMENSION "D" SHALL BE MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
- THIS DIMENSION ALLOWS FOR OFF-CENTER LID, MENISCUS AND GLASS OVERRUN.
- THE BASIC PIN SPACING IS 0.100 (2.54mm) BETWEEN CENTERLINES. EACH PIN CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.010$  (0.25mm) OF ITS EXACT TRUE POSITION.
- APPLIES TO ALL FOUR CORNERS (LEADS NUMBER 1, 4, 5 AND 8).
- DIMENSION "A" SHALL BE MEASURED AT THE CENTERLINE OF THE LEADS WHEN  $\alpha = 0^\circ$ .
- THE MAXIMUM LIMITS OF DIMENSIONS "E" AND "F" SHALL BE MEASURED AT THE CENTER OF THE FLAT WHEN SOLDER DIP IS APPLIED.
- CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
- THE SEATING PLANE IS LOCATED AT THE LOWEST POINT ON THE LEAD AT WHICH THE LEAD WIDTH EXCEEDS 0.040 (1.02mm) MINIMUM, EXCLUDING ANY HALF LEADS AT THE PACKAGE ENDS.

## 14-PIN CERAMIC DIP ~ J PACKAGE SUFFIX

	DIMENSIONS				NOTES
	INCHES		MILLIMETERS		
	MIN	MAX	MIN	MAX	
A	0.290	0.320	7.37	8.13	7
A1	0.220	0.310	5.59	7.87	4
B	—	0.785	—	19.94	4
C	—	0.200	—	5.08	
D	0.015	0.060	0.38	1.52	3
E	0.014	0.026	0.36	0.66	8
E1	0.045	0.065	1.14	1.65	2
F	0.008	0.018	0.20	0.46	8
G	0.100 BSC		2.54 BSC		5
H	0.005	—	0.13	—	6
J	0.125	0.200	3.18	5.08	
$\alpha$	0°	15°	0°	15°	



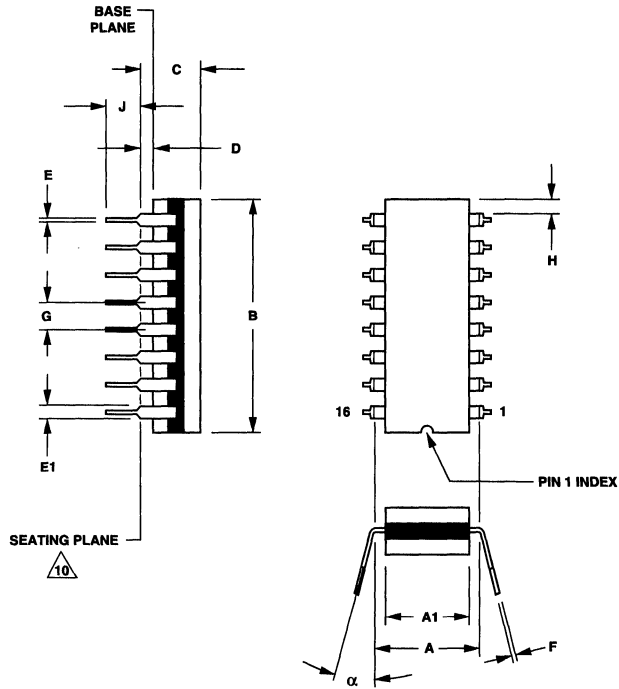
### NOTES:

- INDEX AREA: A NOTCH OR A PIN ONE IDENTIFICATION MARK SHALL BE LOCATED ADJACENT TO PIN ONE. THE MANUFACTURER'S IDENTIFICATION SHALL NOT BE USED AS A PIN ONE IDENTIFICATION MARK.
- THE MINIMUM LIMIT FOR DIMENSION "E1" MAY BE 0.023 (0.58mm) FOR LEADS NUMBER 1, 4, 5 AND 8 ONLY.
- DIMENSION "D" SHALL BE MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
- THIS DIMENSION ALLOWS FOR OFF-CENTER LID, MENISCUS AND GLASS OVERRUN.
- THE BASIC PIN SPACING IS 0.100 (2.54mm) BETWEEN CENTERLINES. EACH PIN CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.010$  (0.25mm) OF ITS EXACT TRUE POSITION.
- APPLIES TO ALL FOUR CORNERS (LEADS NUMBER 1, 4, 5 AND 8).
- DIMENSION "A" SHALL BE MEASURED AT THE CENTERLINE OF THE LEADS WHEN  $\alpha = 0^\circ$ .
- THE MAXIMUM LIMITS OF DIMENSIONS "E" AND "F" SHALL BE MEASURED AT THE CENTER OF THE FLAT WHEN SOLDER DIP IS APPLIED.
- CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
- THE SEATING PLANE IS LOCATED AT THE LOWEST POINT ON THE LEAD AT WHICH THE LEAD WIDTH EXCEEDS 0.040 (1.02mm) MINIMUM, EXCLUDING ANY HALF LEADS AT THE PACKAGE ENDS.



## 16-PIN CERAMIC DIP ~ J PACKAGE SUFFIX

	DIMENSIONS				NOTES
	INCHES		MILLIMETERS		
	MIN	MAX	MIN	MAX	
A	0.290	0.320	7.37	8.13	7
A1	0.220	0.310	5.59	7.87	4
B	—	0.840	—	21.34	4
C	—	0.200	—	5.08	
D	0.015	0.060	0.38	1.52	3
E	0.014	0.026	0.36	0.66	8
E1	0.045	0.065	1.14	1.65	2
F	0.008	0.018	0.20	0.46	8
G	0.100	BSC	2.54	BSC	5
H	0.005	—	0.13	—	6
J	0.125	0.200	3.18	5.08	
$\alpha$	0°	15°	0°	15°	



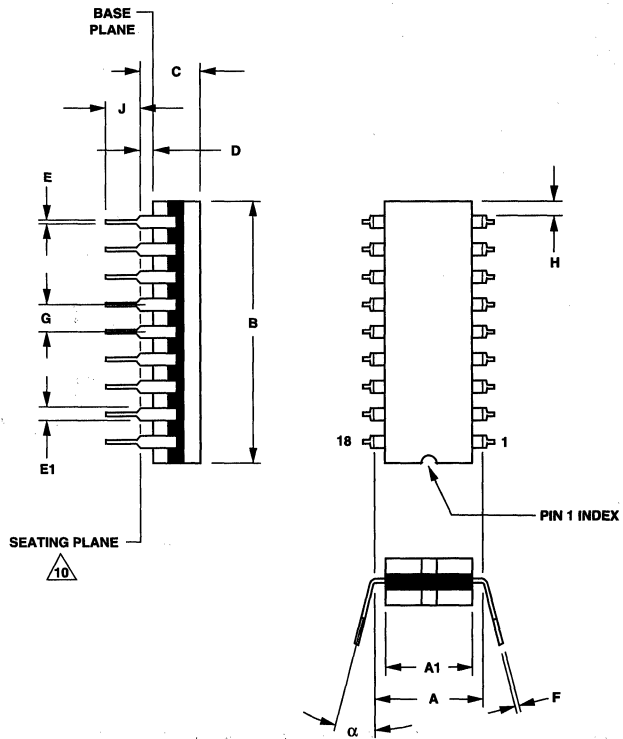
### NOTES:

- INDEX AREA: A NOTCH OR A PIN ONE IDENTIFICATION MARK SHALL BE LOCATED ADJACENT TO PIN ONE. THE MANUFACTURER'S IDENTIFICATION SHALL NOT BE USED AS A PIN ONE IDENTIFICATION MARK.
- THE MINIMUM LIMIT FOR DIMENSION "E1" MAY BE 0.023 (0.58mm) FOR LEADS NUMBER 1, 8, 9 AND 16 ONLY.
- DIMENSION "D" SHALL BE MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
- THIS DIMENSION ALLOWS FOR OFF-CENTER LID, MENISCUS AND GLASS OVERRUN.
- THE BASIC PIN SPACING IS 0.100 (2.54mm) BETWEEN CENTERLINES. EACH PIN CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.010$  (0.25mm) OF ITS EXACT TRUE POSITION.
- APPLIES TO ALL FOUR CORNERS (LEADS NUMBER 1, 8, 9 AND 16).
- DIMENSION "A" SHALL BE MEASURED AT THE CENTERLINE OF THE LEADS WHEN  $\alpha = 0^\circ$ .
- THE MAXIMUM LIMITS OF DIMENSIONS "E" AND "F" SHALL BE MEASURED AT THE CENTER OF THE FLAT WHEN SOLDER DIP IS APPLIED.
- CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
- THE SEATING PLANE IS LOCATED AT THE LOWEST POINT ON THE LEAD AT WHICH THE LEAD WIDTH EXCEEDS 0.040 (1.02mm) MINIMUM, EXCLUDING ANY HALF LEADS AT THE PACKAGE ENDS.



## 18-PIN CERAMIC DIP ~ J PACKAGE SUFFIX

DIMENSIONS					
	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.290	0.320	7.37	8.13	7
A1	0.220	0.310	5.59	7.87	4
B	—	0.980	—	24.38	4
C	—	0.200	—	5.08	
D	0.015	0.060	0.38	1.52	3
E	0.014	0.026	0.36	0.66	8
E1	0.045	0.065	1.14	1.65	2
F	0.008	0.018	0.20	0.46	8
G	0.100	BSC	2.54	BSC	5
H	0.005	—	0.13	—	6
J	0.125	0.200	3.18	5.08	
$\alpha$	0°	15°	0°	15°	



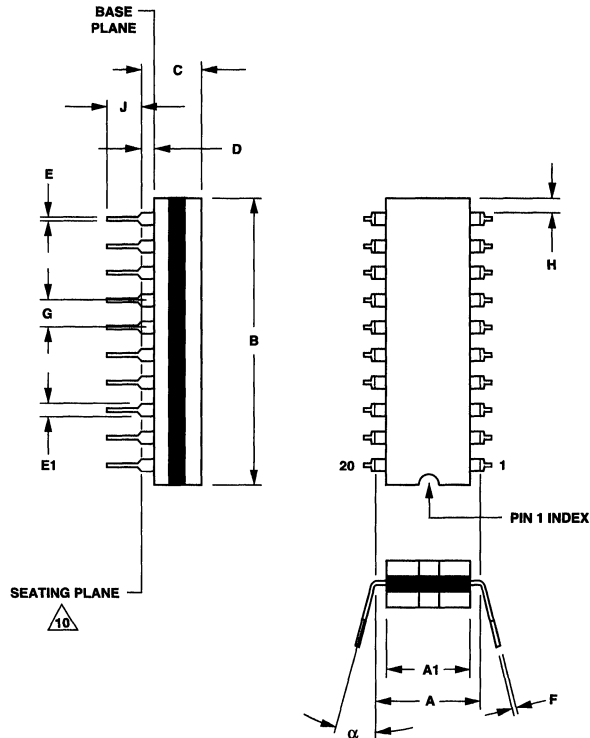
### NOTES:

- INDEX AREA: A NOTCH OR A PIN ONE IDENTIFICATION MARK SHALL BE LOCATED ADJACENT TO PIN ONE. THE MANUFACTURER'S IDENTIFICATION SHALL NOT BE USED AS A PIN ONE IDENTIFICATION MARK.
- THE MINIMUM LIMIT FOR DIMENSION "E1" MAY BE 0.023 (0.58mm) FOR LEADS NUMBER 1, 9, 10 AND 18 ONLY.
- DIMENSION "D" SHALL BE MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
- THIS DIMENSION ALLOWS FOR OFF-CENTER LID, MENISCUS AND GLASS OVERRUN.
- THE BASIC PIN SPACING IS 0.100 (2.54mm) BETWEEN CENTERLINES. EACH PIN CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.010$  (0.25mm) OF ITS EXACT TRUE POSITION.
- APPLIES TO ALL FOUR CORNERS (LEADS NUMBER 1, 9, 10 AND 18).
- DIMENSION "A" SHALL BE MEASURED AT THE CENTERLINE OF THE LEADS WHEN  $\alpha = 0^\circ$ .
- THE MAXIMUM LIMITS OF DIMENSIONS "E" AND "F" SHALL BE MEASURED AT THE CENTER OF THE FLAT WHEN SOLDER DIP IS APPLIED.
- CONTROLLING DIMENSION: INCHES, MILLIMETERS SHOWN FOR REFERENCE ONLY.
- THE SEATING PLANE IS LOCATED AT THE LOWEST POINT ON THE LEAD AT WHICH THE LEAD WIDTH EXCEEDS 0.040 (1.02mm) MINIMUM, EXCLUDING ANY HALF LEADS AT THE PACKAGE ENDS.



## 20-PIN CERAMIC DIP ~ J PACKAGE SUFFIX

	DIMENSIONS				NOTES
	INCHES		MILLIMETERS		
	MIN	MAX	MIN	MAX	
A	0.290	0.320	7.37	8.13	7
A1	0.220	0.310	5.59	7.87	4
B	—	1.080	—	26.92	4
C	—	0.200	—	5.08	
D	0.015	0.060	0.38	1.52	3
E	0.014	0.026	0.36	0.66	8
E1	0.045	0.065	1.14	1.65	2
F	0.008	0.018	0.20	0.46	8
G	0.100 BSC		2.54 BSC		5
H	0.005	—	0.13	—	6
J	0.125	0.200	3.18	5.08	
$\alpha$	0°	15°	0°	15°	



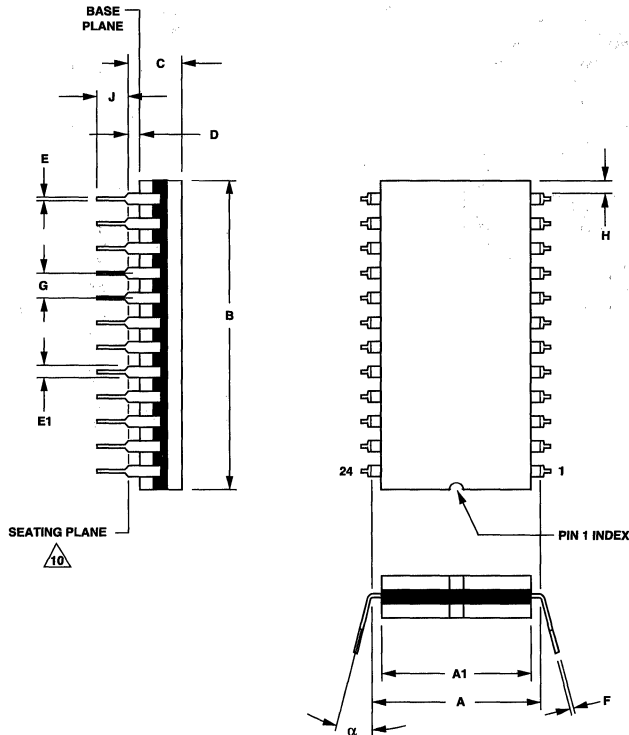
### NOTES:

- INDEX AREA: A NOTCH OR A PIN ONE IDENTIFICATION MARK SHALL BE LOCATED ADJACENT TO PIN ONE. THE MANUFACTURER'S IDENTIFICATION SHALL NOT BE USED AS A PIN ONE IDENTIFICATION MARK.
- THE MINIMUM LIMIT FOR DIMENSION "E1" MAY BE 0.023 (0.58mm) FOR LEADS NUMBER 1, 10, 11 AND 20 ONLY.
- DIMENSION "D" SHALL BE MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
- THIS DIMENSION ALLOWS FOR OFF-CENTER LID, MENISCUS AND GLASS OVERRUN.
- THE BASIC PIN SPACING IS 0.100 (2.54mm) BETWEEN CENTERLINES. EACH PIN CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.010$  (0.25mm) OF ITS EXACT TRUE POSITION.
- APPLIES TO ALL FOUR CORNERS (LEADS NUMBER 1, 10, 11 AND 20).
- DIMENSION "A" SHALL BE MEASURED AT THE CENTERLINE OF THE LEADS WHEN  $\alpha = 0^\circ$ .
- THE MAXIMUM LIMITS OF DIMENSIONS "E" AND "F" SHALL BE MEASURED AT THE CENTER OF THE FLAT WHEN SOLDER DIP IS APPLIED.
- CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
- THE SEATING PLANE IS LOCATED AT THE LOWEST POINT ON THE LEAD AT WHICH THE LEAD WIDTH EXCEEDS 0.040 (1.02mm) MINIMUM, EXCLUDING ANY HALF LEADS AT THE PACKAGE ENDS.



## 24-PIN CERAMIC DIP ~ J PACKAGE SUFFIX

DIMENSIONS					
	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.590	0.625	14.99	15.88	7
A1	0.515	0.605	13.08	15.37	4
B	1.180	1.260	29.97	32.00	4
C	—	0.225	—	5.72	
D	0.015	0.055	0.38	1.40	3
E	0.014	0.026	0.36	0.66	8
E1	0.045	0.065	1.14	1.65	2
F	0.008	0.018	0.20	0.46	8
G	0.100	BSC	2.54	BSC	5
H	0.005	0.065	0.127	1.65	6
J	0.125	0.200	3.18	5.08	
$\alpha$	0°	15°	0°	15°	



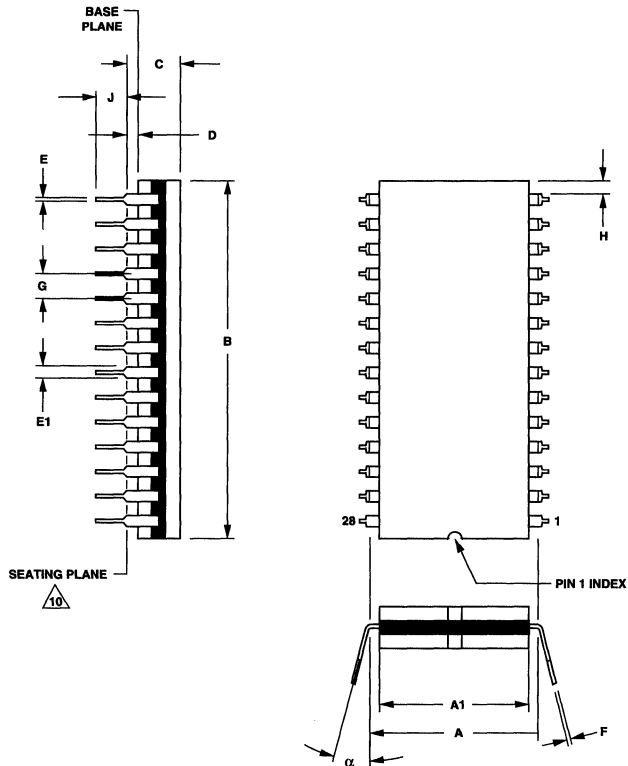
### NOTES:

- INDEX AREA: A NOTCH OR A PIN ONE IDENTIFICATION MARK SHALL BE LOCATED ADJACENT TO PIN ONE. THE MANUFACTURER'S IDENTIFICATION SHALL NOT BE USED AS A PIN ONE IDENTIFICATION MARK.
- THE MINIMUM LIMIT FOR DIMENSION "E1" MAY BE 0.023 (0.58mm) FOR LEADS NUMBER 1, 12, 13 AND 24 ONLY.
- DIMENSION "D" SHALL BE MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
- THIS DIMENSION ALLOWS FOR OFF-CENTER LID, MENISCUS AND GLASS OVERRUN.
- THE BASIC PIN SPACING IS 0.100 (2.54mm) BETWEEN CENTERLINES. EACH PIN CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.010$  (0.25mm) OF ITS EXACT TRUE POSITION.
- APPLIES TO ALL FOUR CORNERS (LEADS NUMBER 1, 12, 13 AND 24).
- DIMENSION "A" SHALL BE MEASURED AT THE CENTERLINE OF THE LEADS WHEN  $\alpha = 0^\circ$ .
- THE MAXIMUM LIMITS OF DIMENSIONS "E" AND "F" SHALL BE MEASURED AT THE CENTER OF THE FLAT WHEN SOLDER DIP IS APPLIED.
- CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
- THE SEATING PLANE IS LOCATED AT THE LOWEST POINT ON THE LEAD AT WHICH THE LEAD WIDTH EXCEEDS 0.040 (1.02mm) MINIMUM, EXCLUDING ANY HALF LEADS AT THE PACKAGE ENDS.



## 28-PIN CERAMIC DIP ~ J PACKAGE SUFFIX

DIMENSIONS					
	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.590	0.825	14.99	15.88	7
A1	0.570	0.605	14.48	15.37	4
B	1.380	1.460	35.05	37.08	4
C	—	0.225	—	5.72	
D	0.015	0.060	0.38	1.52	3
E	0.014	0.026	0.36	0.66	8
E1	0.045	0.065	1.14	1.65	2
F	0.008	0.018	0.20	0.46	8
G	0.100	BSC	2.54	BSC	5
H	0.005	—	0.127	—	6
J	0.125	0.200	3.18	5.08	
$\alpha$	0°	15°	0°	15°	



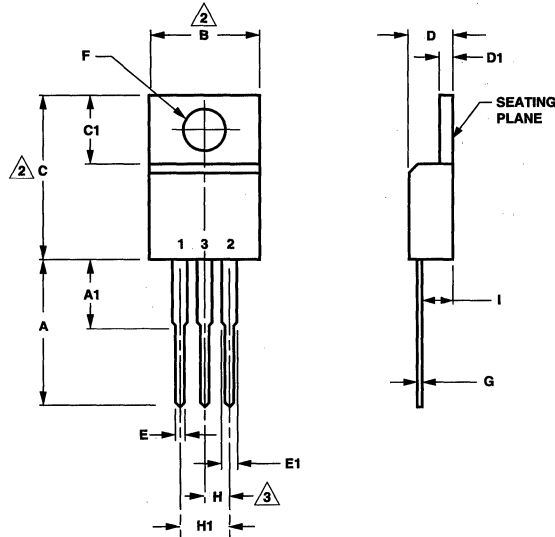
### NOTES:

- INDEX AREA: A NOTCH OR A PIN ONE IDENTIFICATION MARK SHALL BE LOCATED ADJACENT TO PIN ONE. THE MANUFACTURER'S IDENTIFICATION SHALL NOT BE USED AS A PIN ONE IDENTIFICATION MARK.
- THE MINIMUM LIMIT FOR DIMENSION "E1" MAY BE 0.023 (0.58mm) FOR LEADS NUMBER 1, 14, 15 AND 28 ONLY.
- DIMENSION "D" SHALL BE MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
- THIS DIMENSION ALLOWS FOR OFF-CENTER LID, MENISCUS AND GLASS OVERRUN.
- THE BASIC PIN SPACING IS 0.100 (2.54mm) BETWEEN CENTERLINES. EACH PIN CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.010$  (0.25mm) OF ITS EXACT TRUE POSITION.
- APPLIES TO ALL FOUR CORNERS (LEADS NUMBER 1, 14, 15 AND 28).
- DIMENSION "A" SHALL BE MEASURED AT THE CENTERLINE OF THE LEADS WHEN  $\alpha = 0^\circ$ .
- THE MAXIMUM LIMITS OF DIMENSIONS "E" AND "F" SHALL BE MEASURED AT THE CENTER OF THE FLAT WHEN SOLDER DIP IS APPLIED.
- CONTROLLING DIMENSION INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
- THE SEATING PLANE IS LOCATED AT THE LOWEST POINT ON THE LEAD AT WHICH THE LEAD WIDTH EXCEEDS 0.040 (1.02mm) MINIMUM, EXCLUDING ANY HALF LEADS AT THE PACKAGE ENDS.



## 3-PIN TO-220 PLASTIC ~ T PACKAGE SUFFIX

	DIMENSIONS			
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.500	.562	12.70	14.27
A1	—	.250	—	6.35
B	.380	.420	9.66	10.66
C	.580	.625	14.23	15.87
C1	.230	.270	5.85	6.85
D	.140	.190	3.56	4.82
D1	.045	.055	1.14	1.39
E	.020	.045	0.51	1.14
E1	.045	.070	1.14	1.77
F	.139	.161	3.53	4.09
G	.014	.022	0.36	0.56
H	.090	.110	2.29	2.79
H1	.190	.210	4.83	5.33
I	.080	.115	2.04	2.92



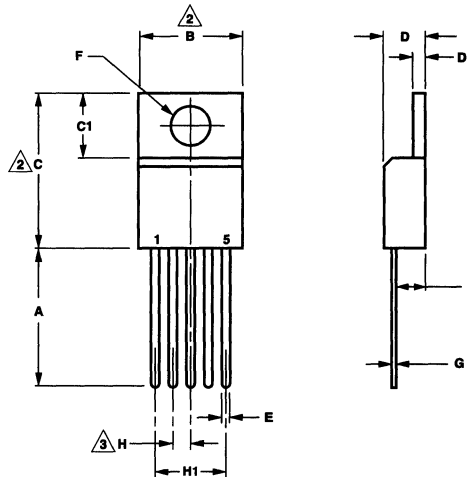
### NOTES:

1. CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
2. 'B' AND 'C' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
3. THE BASIC LEAD SPACING IS 0.100 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.010$  IN. OF ITS EXACT TRUE POSITION.



## 5-PIN TO-220 PLASTIC ~ T PACKAGE SUFFIX

	DIMENSIONS			
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.500	.580	12.70	14.73
B	.380	.420	9.65	10.67
C	.560	.650	14.22	16.51
C1	.230	.270	5.84	6.86
D	.140	.190	3.56	4.83
D1	.045	.055	1.14	1.40
E	.020	.045	0.51	1.14
F	.139	.161	3.53	4.09
G	.014	.022	0.36	0.56
H	.057	.077	1.45	1.96
H1	.258	.278	6.55	7.06
I	.080	.115	2.03	2.92

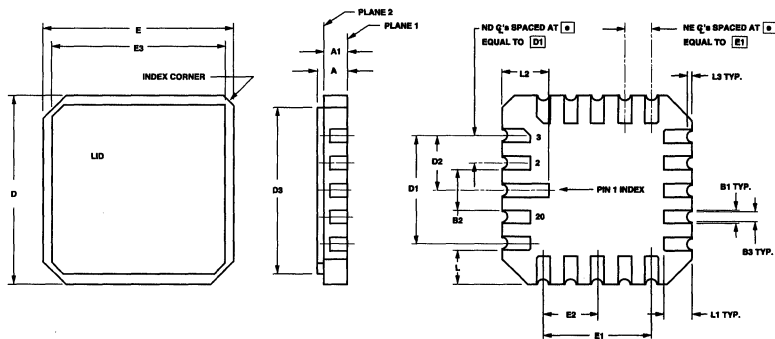


### NOTES:

- CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
- 'B' AND 'C' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
- THE BASIC LEAD SPACING IS 0.067 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.010$  IN. OF ITS EXACT TRUE POSITION.

## 20-PIN CERAMIC LEADLESS SURFACE MOUNT ~ L PACKAGE SUFFIX

	DIMENSIONS				NOTES
	INCHES		MILLIMETERS		
	MIN	MAX	MIN	MAX	
A	.080	.100	1.52	2.54	6
A1	.050	.088	1.27	2.24	
B1	.022	.028	0.56	0.71	1, 3
B2	.072 REF.		1.83 REF.		
B3	.006	.022	0.15	0.56	8
D/E	.342	.358	8.69	9.09	
D1/E1	.200 BSC		5.08 BSC		
D2/E2	.100 BSC		2.54 BSC		
D3/E3	-	.358	-	9.09	4
L	.045	.055	1.14	1.40	
L1	.045	.055	1.14	1.40	
L2	.075	.095	1.90	2.41	5
L3	.003	.015	0.08	0.38	
N	20		20		2
ND/NE	5		5		2
e	.050 BSC		1.27 BSC		10



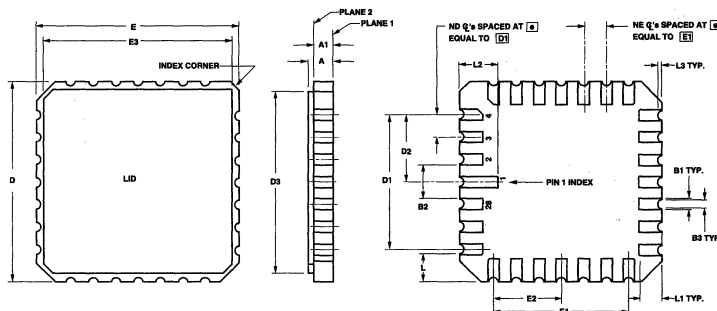
### NOTES:

- A MINIMUM CLEARANCE OF 0.015 INCH (0.38 mm) SHALL BE MAINTAINED BETWEEN ADJACENT TERMINALS.
- 'N' IS THE MAXIMUM QUANTITY OF TERMINAL POSITIONS. 'ND' AND 'NE' ARE THE NUMBERS OF TERMINALS ALONG THE SIDES OF LENGTH 'D' AND 'E' RESPECTIVELY.
- ELECTRICAL CONNECTION TERMINALS ARE REQUIRED ON PLANE 1 AND OPTIONAL ON PLANE 2. HOWEVER, IF PLANE 2 HAS SUCH TERMINALS THEY SHALL BE ELECTRICALLY CONNECTED TO OPPOSING TERMINALS ON PLANE 1.
- A MINIMUM CLEARANCE OR 0.015 INCH (0.38 mm) SHALL BE MAINTAINED BETWEEN A METAL LID AND OTHER METAL FEATURES (E.G., PLANE 2 TERMINALS, METALLIZED CASTELLATIONS, ETC.) THE LID SHALL NOT EXTEND BEYOND THE EDGES OF THE BODY.
- THE INDEX FEATURE FOR NUMBER 1 TERMINAL IDENTIFICATION, OPTIONAL ORIENTATION OR HANDLING PURPOSES SHALL BE WITHIN THE AREA DEFINED BY DIMENSIONS 'B2' AND 'L2' ON PLANE 1.
- DIMENSION 'A' CONTROLS THE OVERALL PACKAGE THICKNESS.
- CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
- CASTELLATIONS ARE REQUIRED ON BOTTOM TWO LAYERS. CASTELLATIONS IN THE TOP LAYER ARE OPTIONAL.
- WHEN SOLDER DIP LEAD FINISH APPLIES, SOLDER BUMP HEIGHT SHALL NOT EXCEED 0.007 INCHES AND SOLDER BUMP COPLANARITY SHALL NOT EXCEED 0.006 INCHES.
- THE BASIC TERMINAL SPACING IS 0.050 INCHES BETWEEN CENTERLINES. EACH TERMINAL CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.004$  INCHES OF ITS EXACT TRUE POSITION.



## 28-PIN CERAMIC LEADLESS SURFACE MOUNT ~ L PACKAGE SUFFIX

	DIMENSIONS				NOTES
	INCHES		MILLIMETERS		
	MIN	MAX	MIN	MAX	
A	.060	.100	1.52	2.54	6
A1	.050	.088	1.27	2.24	
B1	.022	.028	0.56	0.71	1, 3
B2	.072 REF.		1.83 REF.		
B3	.006	.022	0.15	0.56	8
D/E	.442	.460	11.23	11.68	
D1/E1	.300 BSC		7.62 BSC		
D2/E2	.150 BSC		3.81 BSC		
D3/E3	— .460		— 11.68		4
L	.045	.055	1.14	1.40	
L1	.045	.055	1.14	1.40	
L2	.075	.095	1.90	2.41	5
L3	.003	.015	0.08	0.38	
N	28		28		2
ND/NE	7		7		2
e	.050 BSC		1.27 BSC		10

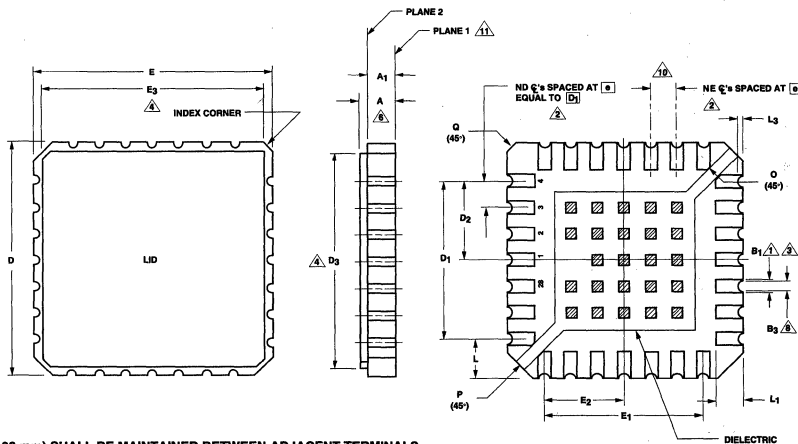


### NOTES:

1. A MINIMUM CLEARANCE OF 0.015 INCH (0.38 mm) SHALL BE MAINTAINED BETWEEN ADJACENT TERMINALS.
2. 'N' IS THE MAXIMUM QUANTITY OF TERMINAL POSITIONS. 'ND' AND 'NE' ARE THE NUMBERS OF TERMINALS ALONG THE SIDES OF LENGTH 'D' AND 'E' RESPECTIVELY.
3. ELECTRICAL CONNECTION TERMINALS ARE REQUIRED ON PLANE 1 AND OPTIONAL ON PLANE 2. HOWEVER, IF PLANE 2 HAS SUCH TERMINALS THEY SHALL BE ELECTRICALLY CONNECTED TO OPPOSING TERMINALS ON PLANE 1.
4. A MINIMUM CLEARANCE OR 0.015 INCH (0.38 mm) SHALL BE MAINTAINED BETWEEN A METAL LID AND OTHER METAL FEATURES (E.G., PLANE 2 TERMINALS, METALLIZED CASTELLATIONS, ETC.) THE LID SHALL NOT EXTEND BEYOND THE EDGES OF THE BODY.
5. THE INDEX FEATURE FOR NUMBER 1 TERMINAL IDENTIFICATION, OPTIONAL ORIENTATION OR HANDLING PURPOSES SHALL BE WITHIN THE AREA DEFINED BY DIMENSIONS 'B2' AND 'L2' ON PLANE 1.
6. DIMENSION 'A' CONTROLS THE OVERALL PACKAGE THICKNESS.
7. CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
8. CASTELLATIONS ARE REQUIRED ON BOTTOM TWO LAYERS. CASTELLATIONS IN THE TOP LAYER ARE OPTIONAL.
9. WHEN SOLDER DIP LEAD FINISH APPLIES, SOLDER BUMP HEIGHT SHALL NOT EXCEED 0.007 INCHES AND SOLDER BUMP COPLANARITY SHALL NOT EXCEED 0.006 INCHES.
10. THE BASIC TERMINAL SPACING IS 0.050 INCHES BETWEEN CENTERLINES. EACH TERMINAL CENTERLINE SHALL BE LOCATED WITHIN ±0.004 INCHES OF ITS EXACT TRUE POSITION.

## 28-PIN CERAMIC LEADLESS SURFACE MOUNT ~ LP PACKAGE SUFFIX

	DIMENSIONS			
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.060	.100	1.52	2.54
A1	.050	.088	1.27	2.24
B1	.022	.028	0.56	0.71
B3	.006	.022	0.15	0.56
D/E	.442	.458	11.23	11.63
D1/E1	.300 BSC		7.62 BSC	
D2/E2	.150 BSC		3.81 BSC	
D3/E3	— .460		— 11.68	
L	.075 REF		1.905 REF	
L1	.045	.055	1.14	1.40
L3	.003	.013	0.08	0.33
N	28		28	
ND/NE	7		7	
O	.006 REF		0.152 REF	
P	.040 REF		1.016 REF	
Q	.020 REF		0.508 REF	
e	.050 BSC		1.27 BSC	



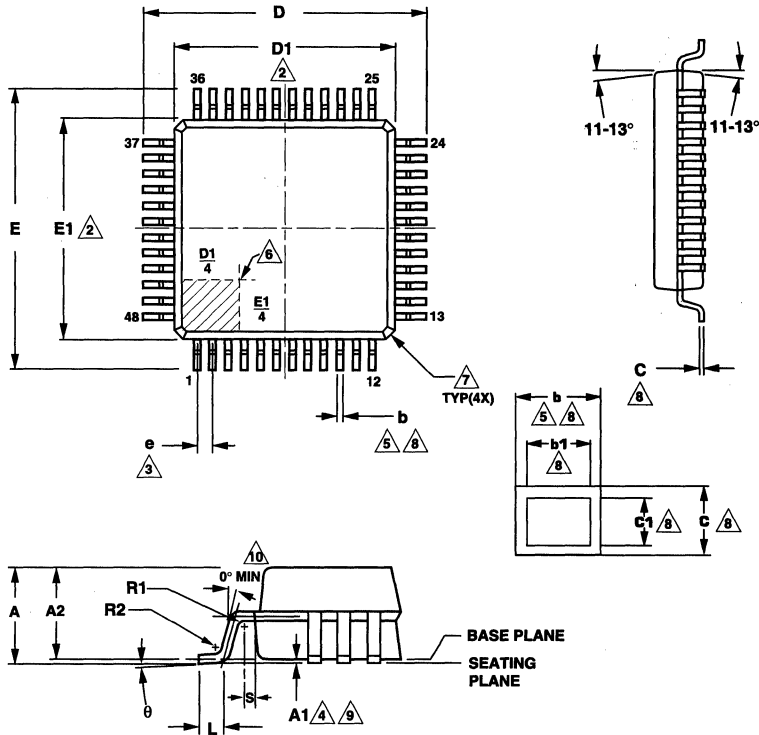
### NOTES:

1. A MINIMUM CLEARANCE OF 0.015 INCH (0.38 mm) SHALL BE MAINTAINED BETWEEN ADJACENT TERMINALS.
2. 'N' IS THE MAXIMUM QUANTITY OF TERMINAL POSITIONS. 'ND' AND 'NE' ARE THE NUMBERS OF TERMINALS ALONG THE SIDES OF LENGTH 'D' AND 'E' RESPECTIVELY.
3. ELECTRICAL CONNECTION TERMINALS ARE REQUIRED ON PLANE 1 AND OPTIONAL ON PLANE 2. HOWEVER, IF PLANE 2 HAS SUCH TERMINALS THEY SHALL BE ELECTRICALLY CONNECTED TO OPPOSING TERMINALS ON PLANE 1.
4. A MINIMUM CLEARANCE OR 0.015 INCH (0.38 mm) SHALL BE MAINTAINED BETWEEN A METAL LID AND OTHER METAL FEATURES (E.G., PLANE 2 TERMINALS, METALLIZED CASTELLATIONS, ETC.) THE LID SHALL NOT EXTEND BEYOND THE EDGES OF THE BODY.
5. THE INDEX FEATURE FOR NUMBER 1 TERMINAL IDENTIFICATION, OPTIONAL ORIENTATION OR HANDLING PURPOSES SHALL BE WITHIN THE AREA DEFINED BY DIMENSIONS 'B2' AND 'L2' ON PLANE 1.
6. DIMENSION 'A' CONTROLS THE OVERALL PACKAGE THICKNESS.
7. CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
8. CASTELLATIONS ARE REQUIRED ON BOTTOM TWO LAYERS. CASTELLATIONS IN THE TOP LAYER ARE OPTIONAL.
9. WHEN SOLDER DIP LEAD FINISH APPLIES, SOLDER BUMP HEIGHT SHALL NOT EXCEED 0.007 INCHES AND SOLDER BUMP COPLANARITY SHALL NOT EXCEED 0.006 INCHES.
10. THE BASIC TERMINAL SPACING IS 0.050 INCHES BETWEEN CENTERLINES. EACH TERMINAL CENTERLINE SHALL BE LOCATED WITHIN ±0.004 INCHES OF ITS EXACT TRUE POSITION.



## 48-PIN LQFP ~ FQ PACKAGE SUFFIX

DIMENSIONS				
	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	-	1.60	-	.063
A1	0.05	0.15	.002	.006
A2	1.35	1.45	.053	.057
b	0.17	0.27	.007	.011
b1	0.17	0.23	.007	.009
C	0.09	0.20	.003	.008
C1	0.09	0.16	.003	.006
D	9.00 BSC	.354 BSC		
D1	7.00 BSC	.276 BSC		
E	9.00 BSC	.354 BSC		
E1	7.00 BSC	.276 BSC		
e	0.50 BSC	.020 BSC		
L	0.45	0.75	.018	.030
R1	0.08	-	.003	-
R2	0.08	0.20	.003	.008
S	0.20	-	.008	-
θ	0°	7°	0°	7°



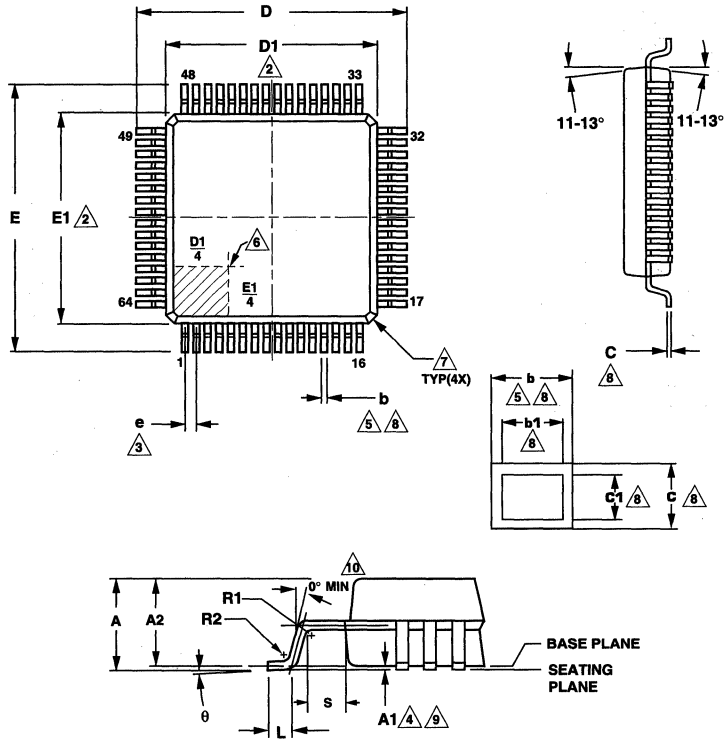
### NOTES:

- CONTROLLING DIMENSION: MILLIMETERS. INCHES SHOWN FOR REFERENCE ONLY.
- 'D1' AND 'E1' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.25mm PER SIDE. 'D1' AND 'E1' INCLUDE MOLD MISMATCH.
- THE BASIC LEAD SPACING IS 0.50mm BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.10mm OF ITS EXACT TRUE POSITION.
- LEADS SHALL BE COPLANAR WITHIN 0.08mm AT THE SEATING PLANE.
- DIMENSION 'b' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'b' MAXIMUM BY MORE THAN 0.08mm. DAMBAR CAN NOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT. MINIMUM SPACE BETWEEN PROTRUSION AND AN ADJACENT LEAD IS 0.07mm.
- DETAILS OF PIN1 IDENTIFIER ARE OPTIONAL BUT MUST BE LOCATED WITHIN THE ZONE INDICATED.
- EXACT SHAPE AND SIZE OF THIS FEATURE IS OPTIONAL.
- THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.10mm AND 0.25mm FROM THE LEAD TIP.
- 'A1' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).
- THE TOP PACKAGE BODY MAY BE SMALLER THAN THE BOTTOM PACKAGE BODY SIZE BY AS MUCH AS 0.15mm.



## 64-PIN LQFP ~ FQ PACKAGE SUFFIX

DIMENSIONS				
	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	1.40	1.60	0.055	0.063
A1	0.05	0.15	0.002	0.006
A2	1.35	1.45	0.53	0.57
b	0.17	0.27	0.007	0.011
b1	0.17	0.23	0.007	0.009
C	0.09	0.20	0.004	0.008
C1	0.09	0.16	0.004	0.006
D	12.00 BSC	0.472 BSC		
D1	10.00 BSC	0.393 BSC		
E	12.00 BSC	0.472 BSC		
E1	10.00 BSC	0.393 BSC		
e	0.50 BSC	0.020 BSC		
L	0.45	0.75	0.18	0.03
R1	0.08	-	0.003	-
R2	0.08	0.20	0.003	0.008
S	0.20	-	0.008	-
θ	0°	7°	0°	7°



### NOTES:

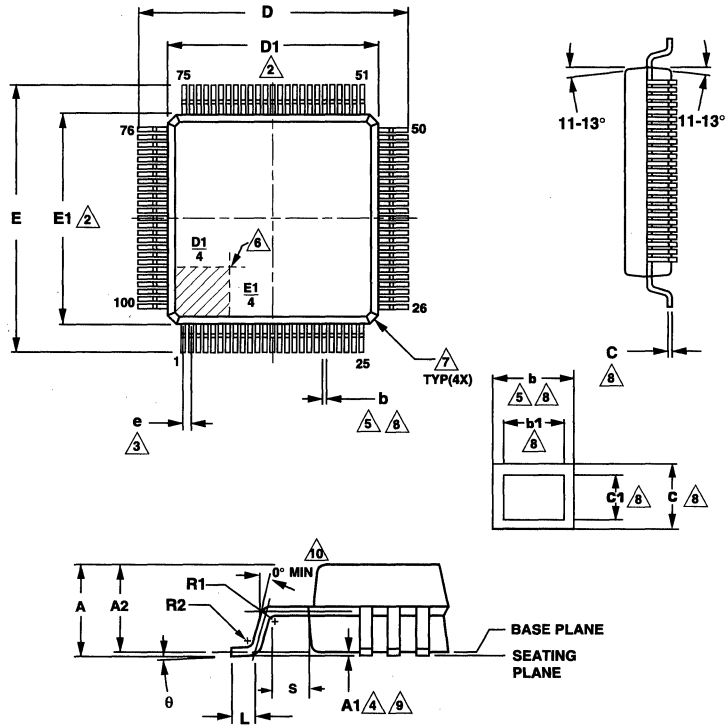
- CONTROLLING DIMENSION: MILLIMETERS. INCHES SHOWN FOR REFERENCE ONLY.
- 'D1' AND 'E1' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.25mm PER SIDE. 'D1' AND 'E1' INCLUDE MOLD MISMATCH.
- THE BASIC LEAD SPACING IS 0.50mm BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.10$ mm OF ITS EXACT TRUE POSITION.
- LEADS SHALL BE COPLANAR WITHIN 0.08mm AT THE SEATING PLANE.
- DIMENSION 'b' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'b' MAXIMUM BY MORE THAN 0.08mm. DAMBAR CAN NOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT. MINIMUM SPACE BETWEEN PROTRUSION AND AN ADJACENT LEAD IS 0.07mm.
- DETAILS OF PIN1 IDENTIFIER ARE OPTIONAL BUT MUST BE LOCATED WITHIN THE ZONE INDICATED.
- EXACT SHAPE AND SIZE OF THIS FEATURE IS OPTIONAL.
- THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.10mm AND 0.25mm FROM THE LEAD TIP.
- 'A1' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).
- THE TOP PACKAGE BODY MAY BE SMALLER THAN THE BOTTOM PACKAGE BODY SIZE BY AS MUCH AS 0.15mm.





## 100-PIN LQFP ~ FQ PACKAGE SUFFIX

	DIMENSIONS			
	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	1.40	1.60	0.055	0.063
A1	0.05	0.15	0.002	0.006
A2	1.35	1.45	0.53	0.57
b	0.17	0.27	0.007	0.011
b1	0.17	0.23	0.007	0.009
C	0.09	0.20	0.004	0.008
C1	0.09	0.16	0.004	0.006
D	16.00 BSC	0.630 BSC		
D1	14.00 BSC	0.551 BSC		
E	16.00 BSC	0.630 BSC		
E1	14.00 BSC	0.551 BSC		
e	0.50 BSC	0.020 BSC		
L	0.45	0.75	0.18	0.03
R1	0.08	-	0.003	-
R2	0.08	0.20	0.003	0.008
S	0.20	-	0.008	-
θ	0°	7°	0°	7°



### NOTES:

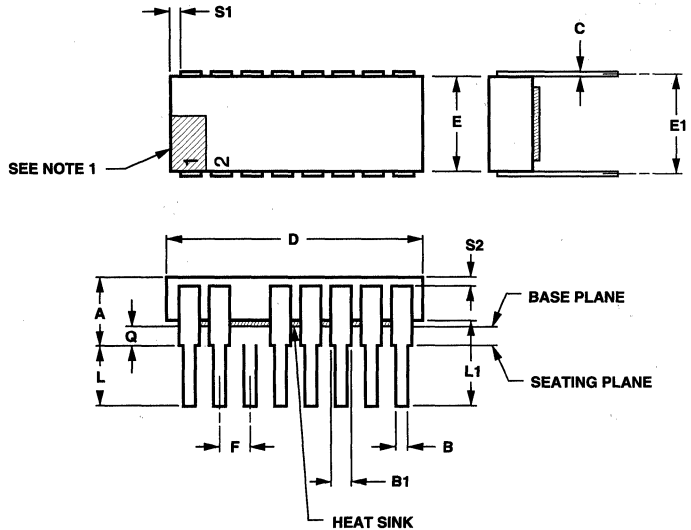
1. CONTROLLING DIMENSION: MILLIMETERS. INCHES SHOWN FOR REFERENCE ONLY.
2.  $\triangle$  'D1' AND 'E1' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.25mm PER SIDE. 'D1' AND 'E1' INCLUDE MOLD MISMATCH.
3.  $\triangle$  THE BASIC LEAD SPACING IS 0.50mm BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.10$ mm OF ITS EXACT TRUE POSITION.
4. LEADS SHALL BE COPLANAR WITHIN 0.08mm AT THE SEATING PLANE.
5.  $\triangle$  DIMENSION 'b' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'b' MAXIMUM BY MORE THAN 0.08mm. DAMBAR CAN NOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT. MINIMUM SPACE BETWEEN PROTRUSION AND AN ADJACENT LEAD IS 0.07mm.
6.  $\triangle$  DETAILS OF PIN1 IDENTIFIER ARE OPTIONAL BUT MUST BE LOCATED WITHIN THE ZONE INDICATED.
7.  $\triangle$  EXACT SHAPE AND SIZE OF THIS FEATURE IS OPTIONAL.
8.  $\triangle$  THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.10mm AND 0.25mm FROM THE LEAD TIP.
9.  $\triangle$  'A1' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).
10.  $\triangle$  THE TOP PACKAGE BODY MAY BE SMALLER THAN THE BOTTOM PACKAGE BODY SIZE BY AS MUCH AS 0.15mm.





## 16-PIN SIDEBRAZE DIP ~ SP PACKAGE SUFFIX

	DIMENSIONS				
	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	—	.200	—	5.08	
B	.014	.023	0.36	0.58	8
B <sub>1</sub>	.045	.065	1.14	1.65	2,8
C	.008	.015	0.20	0.38	8
D	—	.840	—	21.34	4
E	.220	.310	5.59	7.78	4
E <sub>1</sub>	.290	.320	7.37	8.13	7
F	.100 BSC		2.54 BSC		5,9
L	.125	.200	3.18	5.08	
L <sub>1</sub>	.150	—	3.81	—	
Q	.015	.060	0.38	1.52	3
S <sub>1</sub>	.005	—	0.13	—	6
S <sub>2</sub>	.005	—	0.13	—	



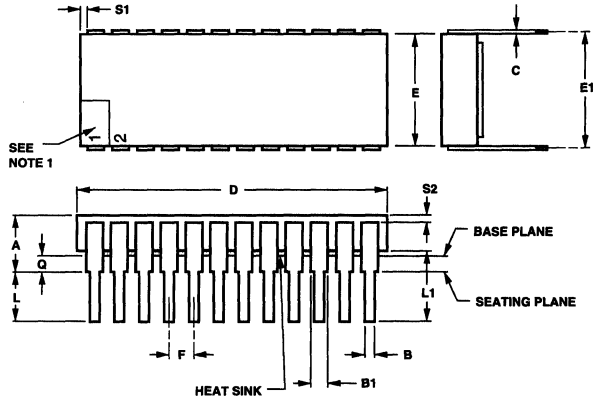
### NOTES:

- INDEX AREA: A NOTCH OR A PIN ONE IDENTIFICATION MARK SHALL BE LOCATED ADJACENT TO ONE AND SHALL BE LOCATED WITHIN THE SHADED AREA SHOWN. THE MANUFACTURER'S IDENTIFICATION SHALL NOT BE USED AS A PIN ONE IDENTIFICATION MARK.
- THE MINIMUM LIMIT FOR DIMENSION 'B1' MAY BE 0.023 IN. (0.58mm) FOR CORNER LEADS.
- DIMENSION 'Q' SHALL BE MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
- THIS DIMENSION ALLOWS FOR OFF-CENTER LID, MENISCUS, AND GLASS OVERRUN.
- THE BASIC LEAD SPACING IS 0.100 IN. (2.54mm) BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.010$  IN. (0.25mm) OF ITS EXACT TRUE POSITION.
- MEASURE ALL FOUR CORNERS.
- E<sub>1</sub> SHALL BE MEASURED AT THE CENTERLINE OF THE LEADS.
- ALL LEADS - INCREASE MAXIMUM LIMIT BY 0.003 IN. (0.08mm) MEASURED AT THE CENTER OF THE FLAT, WHEN SOLDER DIP IS APPLIED.
- 14 SPACES
- BRAZE FILLET SHALL BE CONCAVE.
- CONTROLLING DIMENSIONS: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.



## 24-PIN SIDEBRAZE DIP ~ SP PACKAGE SUFFIX

DIMENSIONS					
	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	—	.225	—	5.72	
B	.014	.023	0.36	0.58	8
B <sub>1</sub>	.045	.065	1.14	1.65	2,8
C	.008	.015	0.20	0.38	8
D	—	1.220	—	30.99	4
E	.580	.610	14.73	15.49	4
E <sub>1</sub>	.585	.615	14.86	15.62	7
F	.100 BSC	2.54 BSC			5,9
L	.125	.200	3.18	5.08	
L <sub>1</sub>	.150	—	3.81	—	
Q	.015	.060	0.38	1.52	3
S <sub>1</sub>	.005	—	0.13	—	6
S <sub>2</sub>	.005	—	0.13	—	

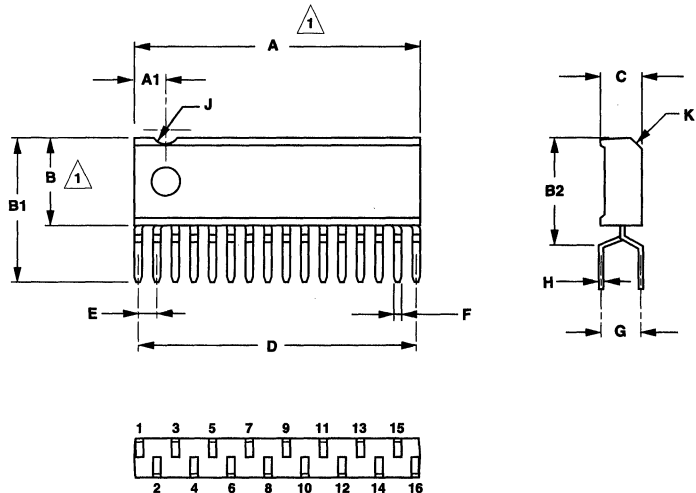


### NOTES:

- INDEX AREA; A NOTCH OR A PIN ONE IDENTIFICATION MARK SHALL BE LOCATED ADJACENT TO PIN ONE AND SHALL BE LOCATED WITHIN THE SHADED AREA SHOWN. THE MANUFACTURER'S IDENTIFICATION SHALL NOT BE USED AS A PIN ONE IDENTIFICATION MARK.
- THE MINIMUM LIMIT FOR DIMENSION 'B1' MAY BE 0.023 IN.(0.58mm) FOR CORNER LEADS.
- DIMENSION 'Q' SHALL BE MEASURED FROM THE SEATING PLANE TO THE BASE PLANE.
- THIS DIMENSION ALLOWS FOR OFF-CENTER LID, MENISCUS, AND GLASS OVERRUN.
- THE BASIC LEAD SPACING IS 0.100 IN.(2.54mm) BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.010 IN. (0.25mm) OF ITS EXACT TRUE POSITION.
- MEASURE ALL FOUR CORNERS.
- E<sub>1</sub> SHALL BE MEASURED AT THE CENTERLINE OF THE LEADS.
- ALL LEADS - INCREASE MAXIMUM LIMIT BY 0.003 IN. (0.08mm) MEASURED AT THE CENTER OF THE FLAT, WHEN SOLDER DIP IS APPLIED.
- 22 SPACES
- BRAZE FILLET SHALL BE CONCAVE.
- CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.

## 16-PIN ZIG-ZAG INLINE ~ Z PACKAGE SUFFIX

	DIMENSIONS				NOTES
	MILLIMETERS		INCHES		
	MIN	MAX	MIN	MAX	
A	19.40	19.60	.784	.772	
A <sub>1</sub>	—	2.00	—	.079	
B	5.70	5.90	.224	.232	
B <sub>1</sub>	9.40	10.40	.370	.409	
B <sub>2</sub>	6.50	7.50	.256	.295	
C	2.70	2.90	.106	.114	
D	18.75	19.35	.738	.762	
E	1.07	1.47	.042	.058	
F	0.45	0.65	.018	.026	
G	2.50	3.00	.098	.118	
H	0.23	0.35	.009	.014	
J	1.00 BSC	.039 BSC			RAD.
K	1.00 BSC	.039 BSC			CHAM.



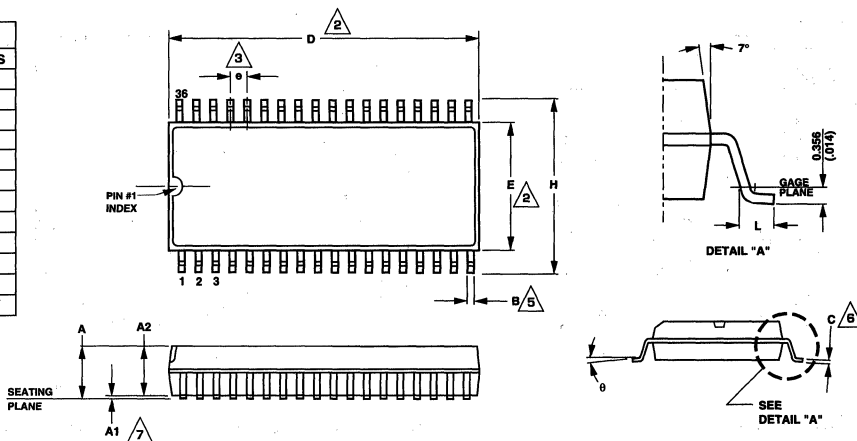
### NOTES:

- DOES NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.15mm (0.006 IN.) PER SIDE.



## 36-PIN QSOP ~ MWP PACKAGE SUFFIX

SYMBOL	DIMENSIONS			
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.093	.104	2.35	2.65
A1	.004	.012	0.10	0.30
A2	.092 TYP		2.34 TYP	
B	.011	.015	0.28	0.39
C	.006	.0125	0.15	0.32
D	.598	.614	15.20	15.60
E	.291	.299	7.40	7.60
e	.031 BSC		0.80 BSC	
H	.394	.419	10.00	10.65
L	.016	.050	0.40	1.27
θ	0°	8°	0°	8°

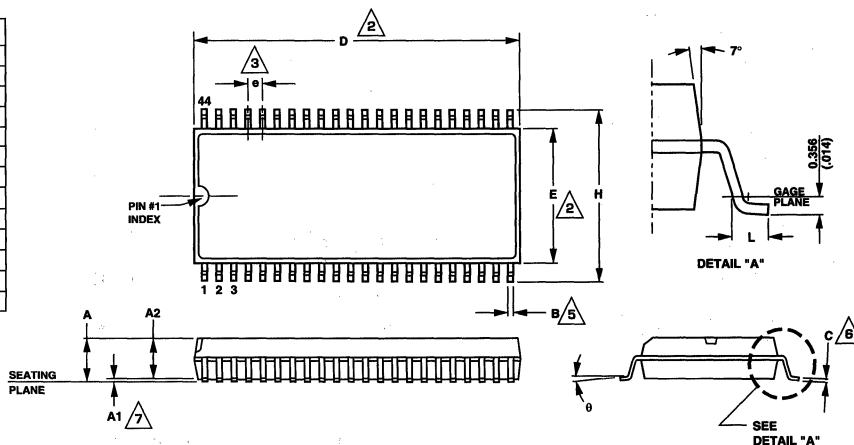


### NOTES:

1. CONTROLLING DIMENSION: INCHES. MILLIMETERS CONTROL LEAD PITCH ONLY.
2. 'D' AND 'E' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.15mm PER SIDE.
3. THE BASIC LEAD SPACING IS 0.80mm BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.10mm OF ITS EXACT TRUE POSITION.
4. LEADS SHALL BE COPLANAR WITHIN 0.10mm AT THE SEATING PLANE.
5. DIMENSION 'B' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'B' MAXIMUM BY MORE THAN 0.08mm. DAMBAR CAN NOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.10mm AND 0.25mm FROM THE LEAD TIP.
7. 'A1' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).

## 44-PIN QSOP ~ MWP PACKAGE SUFFIX

SYMBOL	DIMENSIONS			
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.093	.104	2.35	2.65
A1	.004	.012	0.10	0.30
A2	.092 TYP		2.34 TYP	
B	.011	.015	0.28	0.39
C	.006	.0125	0.15	0.32
D	.697	.712	17.70	18.10
E	.291	.299	7.40	7.60
e	.031 BSC		0.80 BSC	
H	.394	.419	10.00	10.65
L	.016	.050	0.40	1.27
θ	0°	8°	0°	8°



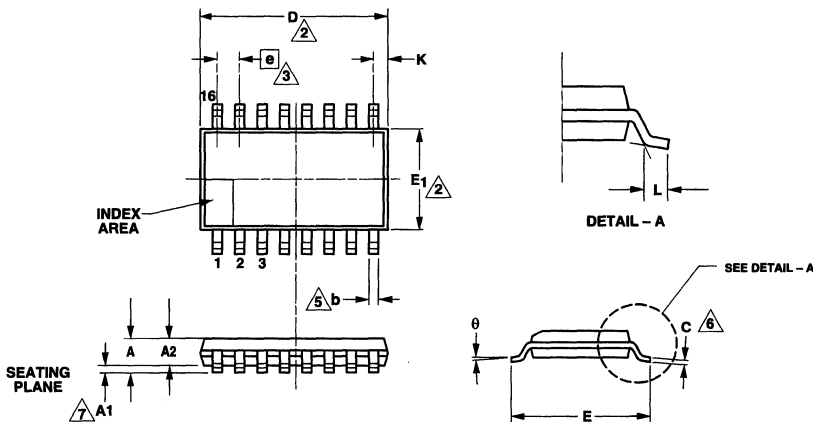
### NOTES:

1. CONTROLLING DIMENSION: INCHES. MILLIMETERS CONTROL LEAD PITCH ONLY.
2. 'D' AND 'E' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.15mm PER SIDE.
3. THE BASIC LEAD SPACING IS 0.80mm BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.10mm OF ITS EXACT TRUE POSITION.
4. LEADS SHALL BE COPLANAR WITHIN 0.10mm AT THE SEATING PLANE.
5. DIMENSION 'B' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'B' MAXIMUM BY MORE THAN 0.08mm. DAMBAR CAN NOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.10mm AND 0.25mm FROM THE LEAD TIP.
7. 'A1' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).



## 16-PIN QSOP ~ M PACKAGE SUFFIX

DIMENSIONS				
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.053	.069	1.35	1.75
A1	.004	.010	.10	.25
A2	—	.059	—	1.50
b	.008	.012	.20	.30
C	.007	.010	.18	.25
D	.189	.197	4.80	5.00
E	.228	.244	5.79	6.20
E1	.150	.157	3.81	3.99
e	.025 BSC		.635 BSC	
K	.009 REF		.23 REF	
L	.016	.050	.41	1.27
θ	0°	8°	0°	8°

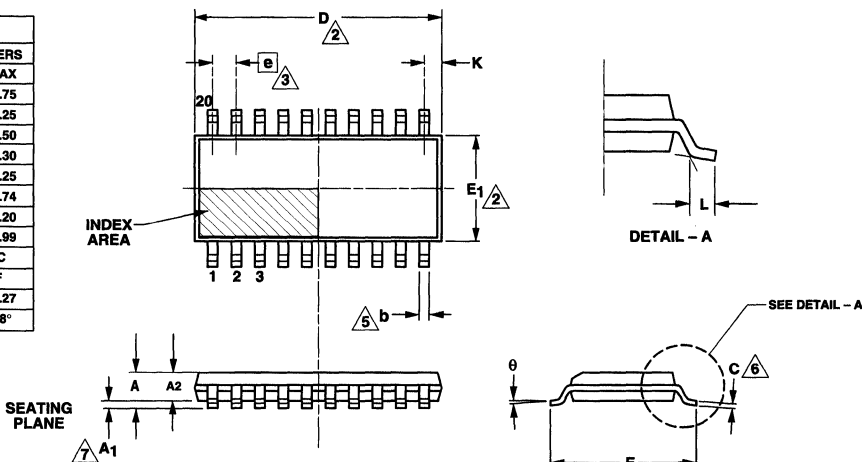


### NOTES:

1. CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
2. 'D' AND 'E1' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
3. THE BASIC LEAD SPACING IS 0.025 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.004$  IN. OF ITS EXACT TRUE POSITION.
4. LEADS SHALL BE COPLANAR WITHIN 0.004 IN. AT THE SEATING PLANE.
5. DIMENSION 'b' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'b' MAXIMUM BY MORE THAN 0.003 IN. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.004 IN. AND 0.010 IN. FROM THE LEAD TIP.
7. 'A1' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).

## 20-PIN QSOP ~ M PACKAGE SUFFIX

DIMENSIONS				
	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	.053	.069	1.35	1.75
A1	.004	.010	.10	.25
A2	—	.059	—	1.50
b	.008	.012	.20	.30
C	.007	.010	.18	.25
D	.337	.344	8.56	8.74
E	.228	.244	5.79	6.20
E1	.150	.157	3.81	3.99
e	.025 BSC		.635 BSC	
K	.058 REF		1.47 REF	
L	.016	.050	.41	1.27
θ	0°	8°	0°	8°



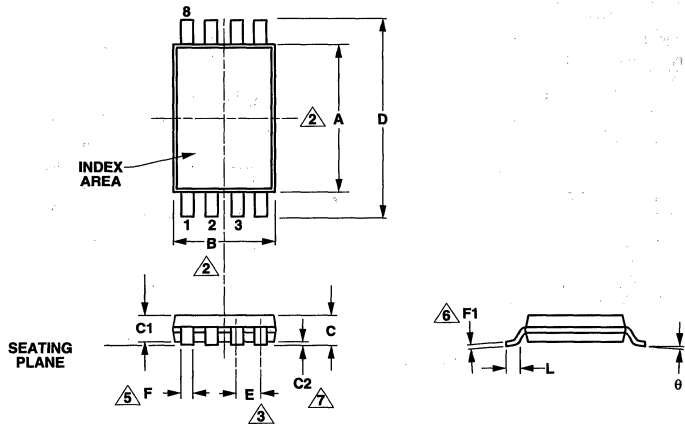
### NOTES:

1. CONTROLLING DIMENSION: INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
2. 'D' AND 'E1' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
3. THE BASIC LEAD SPACING IS 0.025 IN. BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.004$  IN. OF ITS EXACT TRUE POSITION.
4. LEADS SHALL BE COPLANAR WITHIN 0.004 IN. AT THE SEATING PLANE.
5. DIMENSION 'b' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED "b" MAXIMUM BY MORE THAN 0.003 IN. DAMBAR CAN NOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.004 IN. AND 0.010 IN. FROM THE LEAD TIP.
7. 'A1' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).



## 8-PIN TSSOP ~ PW PACKAGE SUFFIX

DIMENSIONS				
	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.3	4.5	0.170	0.177
B	2.9	3.1	0.114	0.122
C	-	1.10	-	0.043
C1	0.90 REF.		0.035 REF.	
C2	0.05	0.15	0.002	0.006
D	6.4 BSC		0.252 BSC	
E	0.65 BSC		0.0256 BSC	
F	0.18	0.30	0.007	0.012
F1	0.09	0.18	0.004	0.007
L	0.50	0.70	0.020	0.028
θ	0°	7°	0°	7°



### NOTES:

1. CONTROLLING DIMENSION: MILLIMETERS. INCHES SHOWN FOR REFERENCE ONLY.

2. 'A' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.15mm PER SIDE.

3. THE BASIC LEAD SPACING IS 0.65mm BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.10mm OF ITS EXACT TRUE POSITION.

4. LEADS SHALL BE COPLANAR WITHIN 0.08mm AT THE SEATING PLANE.

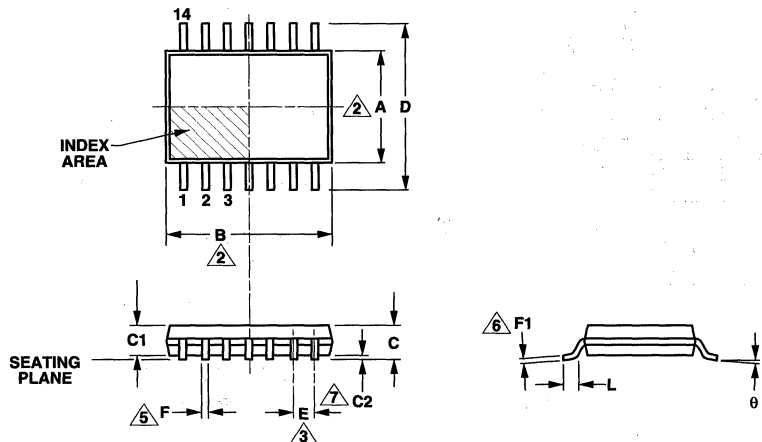
5. DIMENSION 'F' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'F' MAXIMUM BY MORE THAN 0.08mm. DAMBAR CAN NOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.

6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.10mm AND 0.25mm FROM THE LEAD TIP.

7. 'C2' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).

## 14-PIN TSSOP ~ PW PACKAGE SUFFIX

DIMENSIONS				
	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.3	4.5	0.170	0.177
B	4.9	5.1	0.193	0.200
C	-	1.10	-	0.043
C1	0.90 REF.		0.035 REF.	
C2	0.05	0.15	0.002	0.006
D	6.4 BSC		0.252 BSC	
E	0.65 BSC		0.0256 BSC	
F	0.18	0.30	0.007	0.012
F1	0.09	0.18	0.004	0.007
L	0.50	0.70	0.020	0.028
θ	0°	7°	0°	7°



### NOTES:

1. CONTROLLING DIMENSION: MILLIMETERS. INCHES SHOWN FOR REFERENCE ONLY.

2. 'A' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.15mm PER SIDE.

3. THE BASIC LEAD SPACING IS 0.65mm BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.10mm OF ITS EXACT TRUE POSITION.

4. LEADS SHALL BE COPLANAR WITHIN 0.08mm AT THE SEATING PLANE.

5. DIMENSION 'F' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'F' MAXIMUM BY MORE THAN 0.08mm. DAMBAR CAN NOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.

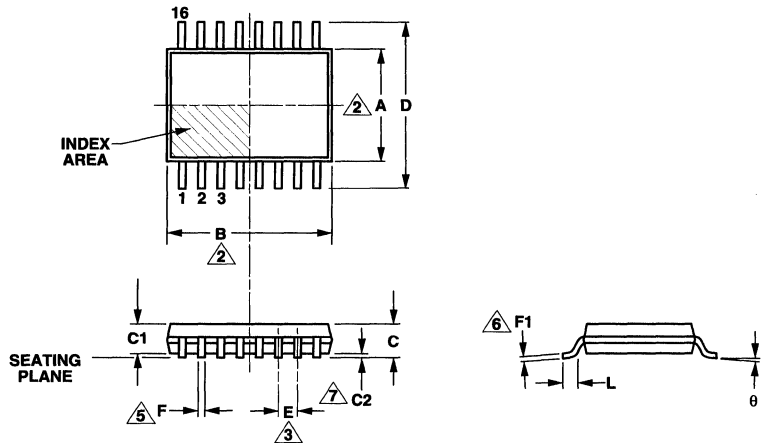
6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.10mm AND 0.25mm FROM THE LEAD TIP.

7. 'C2' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).



## 16-PIN TSSOP ~ PW PACKAGE SUFFIX

	DIMENSIONS			
	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.3	4.5	0.170	0.177
B	4.9	5.1	0.193	0.200
C	-	1.10	-	0.043
C1	0.90 REF.		0.035 REF.	
C2	0.05	0.15	0.002	0.006
D	6.4 BSC		0.252 BSC	
E	0.65 BSC		0.0256 BSC	
F	0.18	0.30	0.007	0.012
F1	0.09	0.18	0.004	0.007
L	0.50	0.70	0.020	0.028
θ	0°	7°	0°	7°

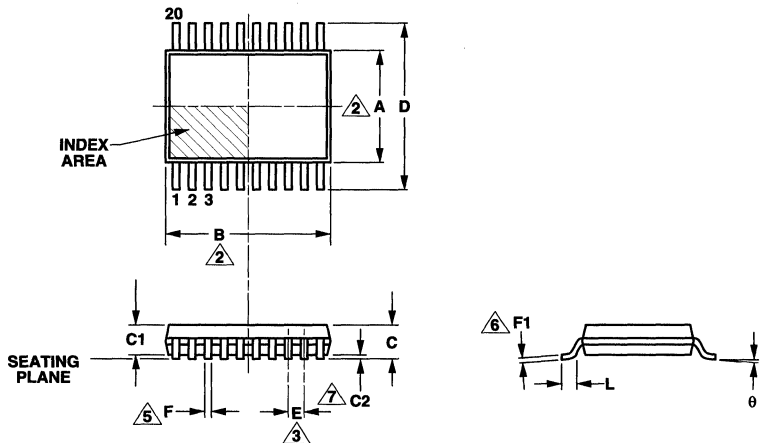


### NOTES:

1. CONTROLLING DIMENSION: MILLIMETERS. INCHES SHOWN FOR REFERENCE ONLY.
2. 'A' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.15mm PER SIDE.
3. THE BASIC LEAD SPACING IS 0.65mm BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.10$ mm OF ITS EXACT TRUE POSITION.
4. LEADS SHALL BE COPLANAR WITHIN 0.08mm AT THE SEATING PLANE.
5. DIMENSION 'F' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'F' MAXIMUM BY MORE THAN 0.08mm. DAMBAR CAN NOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.10mm AND 0.25mm FROM THE LEAD TIP.
7. 'C2' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).

## 20-PIN TSSOP ~ PW PACKAGE SUFFIX

	DIMENSIONS			
	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.30	4.48	.169	.176
B	6.40	6.60	.252	.260
C	-	1.10	-	.043
C1	.90 REF.		.0354 REF.	
C2	.05	.15	.002	.006
D	6.25	6.50	.246	.256
E	.65 BSC		.0256 BSC	
F	.18	.30	.007	.012
F1	.09	.18	.003	.007
L	.50	.70	.020	.028
θ	0°	8°	0°	8°



### NOTES:

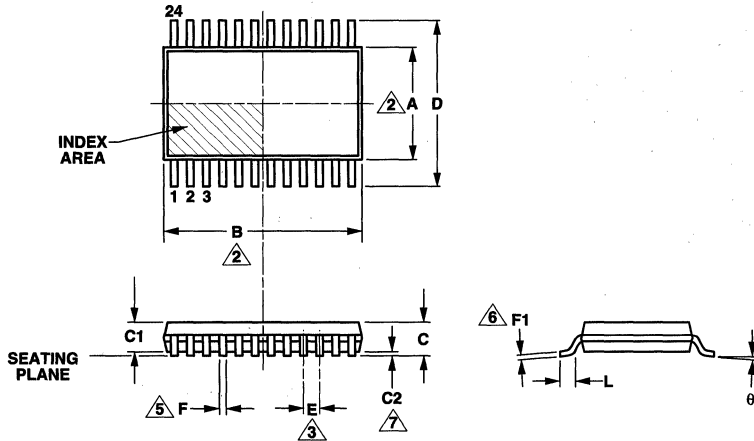
1. CONTROLLING DIMENSION: MILLIMETERS. INCHES SHOWN FOR REFERENCE ONLY.
2. 'A' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.15mm PER SIDE.
3. THE BASIC LEAD SPACING IS 0.65mm BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.10$ mm OF ITS EXACT TRUE POSITION.
4. LEADS SHALL BE COPLANAR WITHIN 0.08mm AT THE SEATING PLANE.
5. DIMENSION 'F' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'F' MAXIMUM BY MORE THAN 0.08mm. DAMBAR CAN NOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.10mm AND 0.25mm FROM THE LEAD TIP.
7. 'C2' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).





## 24-PIN TSSOP ~ PW, PWP PACKAGE SUFFIX

DIMENSIONS				
	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.30	4.48	.169	.176
B	7.70	7.90	.303	.311
C	-	1.10	-	.043
C1	.90 REF.		.0354 REF.	
C2	.05	.15	.002	.006
D	6.25	6.50	.246	.256
E	.65 BSC		.0256 BSC	
F	.18	.30	.007	.012
F1	.09	.18	.003	.007
L	.50	.70	.020	.028
θ	0°	8°	0°	8°



### NOTES:

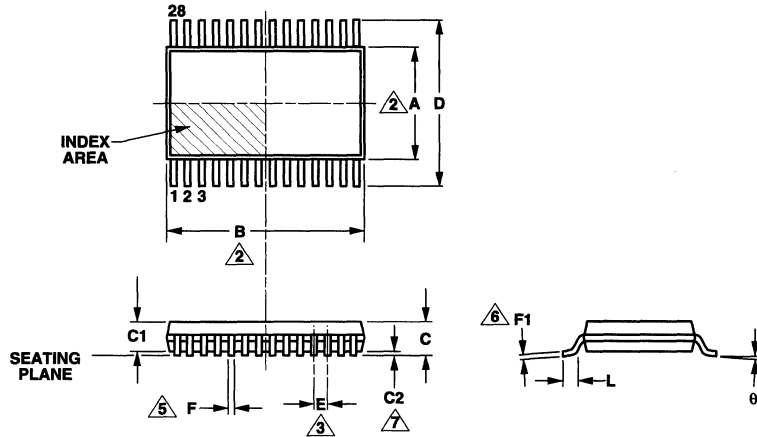
1. CONTROLLING DIMENSION : MILLIMETERS. INCHES SHOWN FOR REFERENCE ONLY.
2. 'A' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.15mm PER SIDE.
3. THE BASIC LEAD SPACING IS 0.65 MM BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.10mm OF ITS EXACT TRUE POSITION.
4. LEADS SHALL BE COPLANAR WITHIN 0.08mm AT THE SEATING PLANE
5. DIMENSION 'F' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'F' MAXIMUM BY MORE THAN 0.08mm. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.10mm AND 0.25mm FROM THE LEAD TIP.
7. 'C2' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).





## 28-PIN TSSOP - PWP PACKAGE SUFFIX

	DIMENSIONS			
	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.30	4.48	.169	.176
B	9.60	9.80	.378	.386
C	-	1.10	-	.043
C1	.90 REF.		.0354 REF.	
C2	.05	.15	.002	.006
D	6.25	6.50	.246	.256
E	.65 BSC		.0256 BSC	
F	.18	.30	.007	.012
F1	.09	.18	.003	.007
L	.50	.70	.020	.028
θ	0°	8°	0°	8°



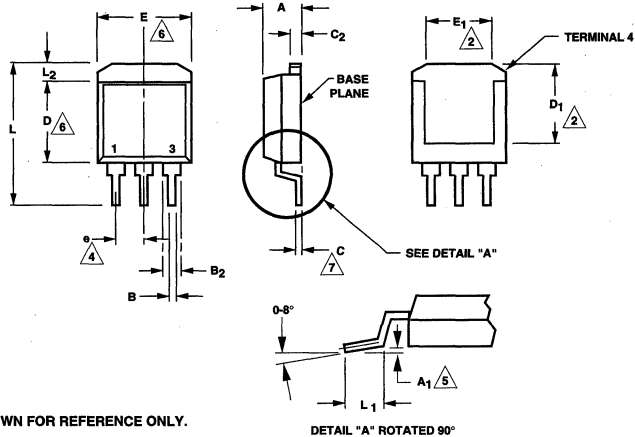
### NOTES:

1. CONTROLLING DIMENSION : MILLIMETERS. INCHES SHOWN FOR REFERENCE ONLY.
2. 'A' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.15mm PER SIDE.
3. THE BASIC LEAD SPACING IS 0.65 MM BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.10mm OF ITS EXACT TRUE POSITION.
4. LEADS SHALL BE COPLANAR WITHIN 0.08mm AT THE SEATING PLANE.
5. DIMENSION 'F' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'F' MAXIMUM BY MORE THAN 0.08mm. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.10mm AND 0.25mm FROM THE LEAD TIP.
7. 'C2' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).



## 3-PIN PLASTIC TO-263 POWER SURFACE MOUNT ~ TD PACKAGE SUFFIX

DIMENSIONS						
	INCHES			MILLIMETERS		
	MIN	NOM	MAX	MIN	NOM	MAX
A	.170	.175	.180	4.31	4.44	4.57
A <sub>1</sub>	.000	—	.010	0.00	—	0.25
B	.020	.032	.039	0.51	0.81	0.99
B <sub>2</sub>	.045	.050	.055	1.14	1.27	1.40
C	.018	—	.029	0.46	—	0.74
C <sub>2</sub>	.045	.050	.055	1.14	1.27	1.40
D	.326	.331	.336	8.28	8.41	8.53
D <sub>1</sub>	.305 REF.			7.75 REF.		
E	.396	.401	.405	10.05	10.18	10.31
E <sub>1</sub>	.256 REF.			6.50 REF.		
e	.100 BSC			2.54 BSC		
L	.580	.600	.620	14.73	15.24	15.75
L <sub>1</sub>	.090	.100	.110	2.29	2.54	2.79
L <sub>2</sub>	.055	.061	.066	1.40	1.54	1.68

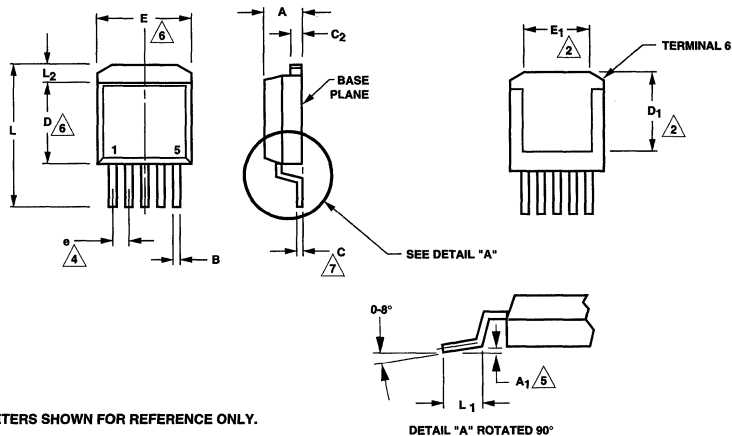


**NOTES:**

1. CONTROLLING DIMENSION : INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
2. D<sub>1</sub> AND E<sub>1</sub> ESTABLISH A MINIMUM MOUNTING SURFACE FOR TERMINAL 4.
3. TAB CONTOUR OPTIONAL WITHIN DIMENSION E AND ZONE L<sub>2</sub>.
4. THE BASIC LEAD SPACING IS 0.100 INCHES BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.010 INCHES OF ITS EXACT TRUE POSITION.
5. A<sub>1</sub> IS MEASURED FROM THE LEAD TIP TO THE BASE PLANE.
6. D AND E DO NOT INCLUDE MOLD FLASH ON PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
7. LEAD TIPS SHALL BE COPLANAR WITHIN 0.004 INCHES.

## 5-PIN PLASTIC TO-263 POWER SURFACE MOUNT ~ TD PACKAGE SUFFIX

DIMENSIONS						
	INCHES			MILLIMETERS		
	MIN	NOM	MAX	MIN	NOM	MAX
A	.170	.175	.180	4.31	4.44	4.57
A <sub>1</sub>	.000	—	.010	0.00	—	0.25
B	.020	.032	.039	0.51	0.81	0.99
C	.018	—	.029	0.46	—	0.74
C <sub>2</sub>	.045	.050	.055	1.14	1.27	1.40
D	.326	.331	.336	8.28	8.41	8.53
D <sub>1</sub>	.305 REF.			7.75 REF.		
E	.396	.401	.405	10.05	10.18	10.31
E <sub>1</sub>	.256 REF.			6.50 REF.		
e	.067 BSC			1.70 BSC		
L	.580	.600	.620	14.73	15.24	15.75
L <sub>1</sub>	.090	.100	.110	2.29	2.54	2.79
L <sub>2</sub>	.055	.061	.066	1.40	1.54	1.68



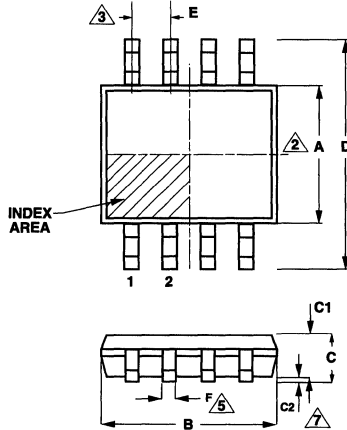
**NOTES:**

1. CONTROLLING DIMENSION : INCHES. MILLIMETERS SHOWN FOR REFERENCE ONLY.
2. D<sub>1</sub> AND E<sub>1</sub> ESTABLISH A MINIMUM MOUNTING SURFACE FOR TERMINAL 6.
3. TAB CONTOUR OPTIONAL WITHIN DIMENSION E AND ZONE L<sub>2</sub>.
4. THE BASIC LEAD SPACING IS 0.067 INCHES BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN ±0.010 INCHES OF ITS EXACT TRUE POSITION.
5. A<sub>1</sub> IS MEASURED FROM THE LEAD TIP TO THE BASE PLANE.
6. D AND E DO NOT INCLUDE MOLD FLASH ON PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 IN. PER SIDE.
7. LEAD TIPS SHALL BE COPLANAR WITHIN 0.004 INCHES.

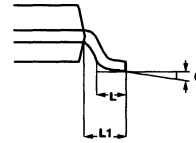


## 8-PIN MINI SO ~ P PACKAGE SUFFIX

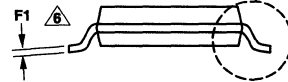
	DIMENSIONS			
	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	2.84	3.15	.112	.124
B	2.84	3.15	.112	.124
C	-	1.10	-	0.043
C1	0.90 REF.		0.035 REF.	
C2	0.05	0.15	0.002	0.006
D	4.9 BSC		0.193 BSC	
E	0.65 BSC		0.0256 BSC	
F	0.20	0.46	0.008	0.018
F1	0.08	0.28	0.003	0.011
L	0.41	0.71	0.016	0.028
L1	0.94 REF.		0.037 REF.	
θ	0°	6°	0°	6°



DETAIL - A



SEE DETAIL - A

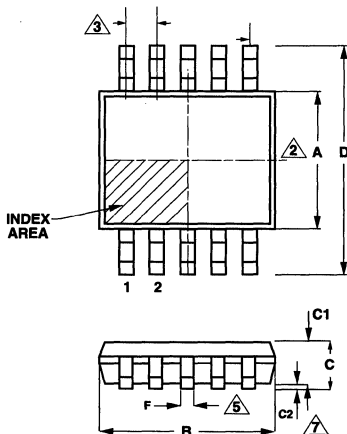


**NOTES:**

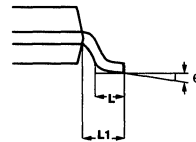
1. CONTROLLING DIMENSION: MILLIMETERS. INCHES SHOWN FOR REFERENCE ONLY.
2. 'A' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.20mm PER SIDE.
3. THE BASIC LEAD SPACING IS 0.65mm BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.10$ mm OF ITS EXACT TRUE POSITION.
4. LEADS SHALL BE COPLANAR WITHIN 0.08mm AT THE SEATING PLANE.
5. DIMENSION 'F' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'F' MAXIMUM BY MORE THAN 0.08mm. DAMBAR CAN NOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.10mm AND 0.25mm FROM THE LEAD TIP.
7. 'C2' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).

## 10-PIN MINI SO ~ P PACKAGE SUFFIX

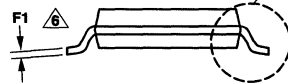
	DIMENSIONS			
	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	2.84	3.15	.112	.124
B	2.84	3.15	.112	.124
C	-	1.10	-	0.043
C1	0.90 REF.		0.035 REF.	
C2	0.05	0.15	0.002	0.006
D	4.9 BSC		0.193 BSC	
E	0.50 BSC		0.0197 BSC	
F	0.15	0.41	0.006	0.016
F1	0.08	0.28	0.003	0.011
L	0.41	0.71	0.016	0.028
L1	0.94 REF.		0.037 REF.	
θ	0°	6°	0°	6°



DETAIL - A



SEE DETAIL - A



**NOTES:**

1. CONTROLLING DIMENSION: MILLIMETERS. INCHES SHOWN FOR REFERENCE ONLY.
2. 'A' AND 'B' DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.20mm PER SIDE.
3. THE BASIC LEAD SPACING IS 0.50mm BETWEEN CENTERLINES. EACH LEAD CENTERLINE SHALL BE LOCATED WITHIN  $\pm 0.10$ mm OF ITS EXACT TRUE POSITION.
4. LEADS SHALL BE COPLANAR WITHIN 0.08mm AT THE SEATING PLANE.
5. DIMENSION 'F' DOES NOT INCLUDE DAMBAR PROTRUSION. THE DAMBAR PROTRUSION(S) SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED 'F' MAXIMUM BY MORE THAN 0.08mm. DAMBAR CAN NOT BE LOCATED ON THE LOWER RADIUS OR THE LEAD FOOT.
6. THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.10mm AND 0.25mm FROM THE LEAD TIP.
7. 'C2' IS DEFINED AS THE DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT OF THE PACKAGE BODY (BASE PLANE).



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## NOTES

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**NOTES**

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## NOTES

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## NOTES



