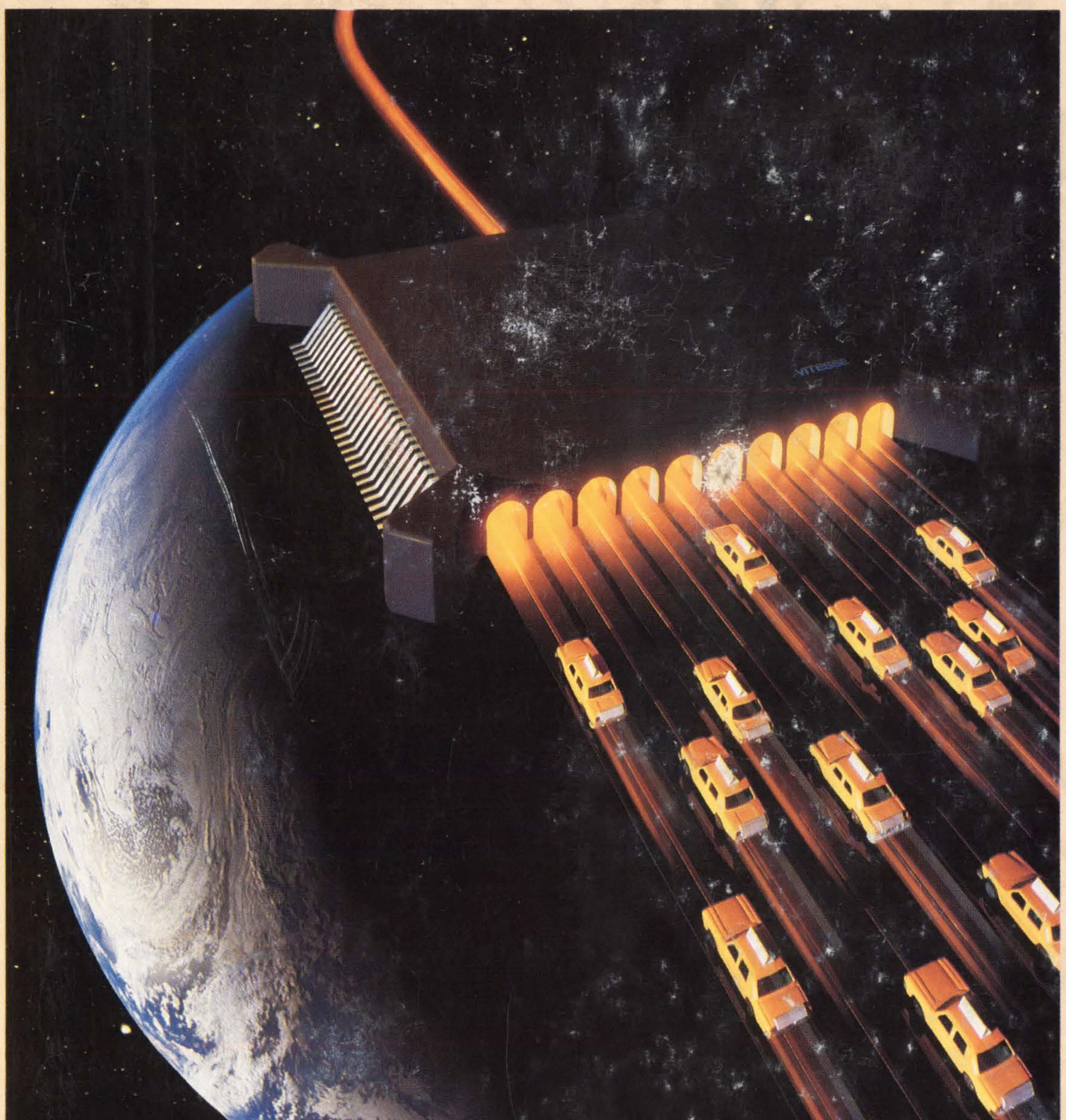
PROCESSOR UPDATES PG 119

EDN

A CAHNERS PUBLICATION
May 7, 1992

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS WORLDWIDE



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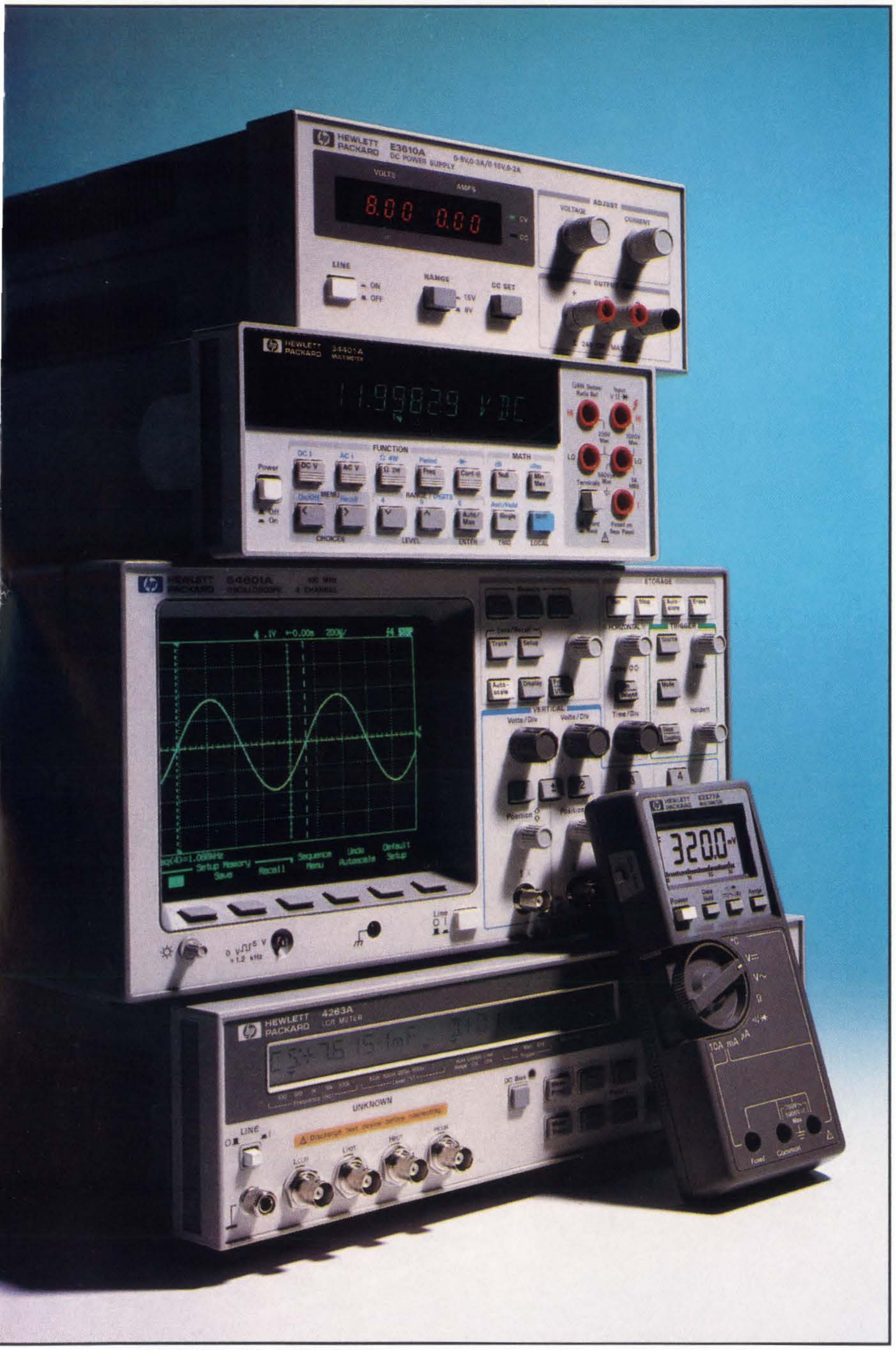

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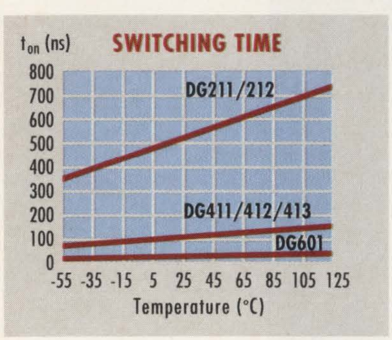

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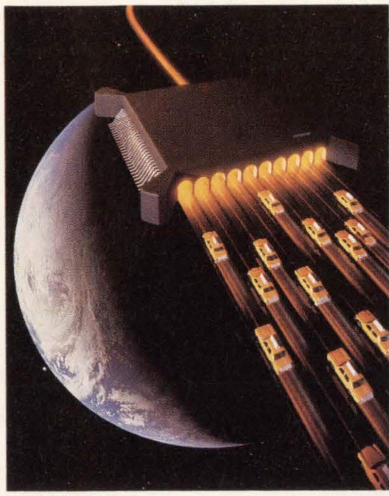
MAGAZINE EDITION

MAY 7, 1992 VOLUME 37, NUMBER 10

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS WORLDWIDE

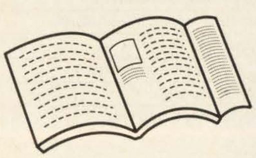


On the cover: New data-communications schemes are merging high performance and low cost to provide the data rates your high-end PCs and faster systems require. (Photo courtesy Vitesse Semiconductor) . . . . **PAGE 134**

Continued on page 7

Foldout contents

Turn to the last information-retrieval service card in the back of this magazine and you'll find a foldout table of contents. Now, instead of flipping back and forth from this table of contents to the articles you want to read, you can have the convenient foldout open at all times while you're reading EDN. Use the foldout contents to mark off articles you'd like your colleagues to read or to remind yourself to copy stories for your files.



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And thanks to the Fluke 79's proprietary new integrated circuit technology, that's only the beginning. When it comes to zeroing in on tough electrical problems, the Fluke 79 leaves the competition behind:

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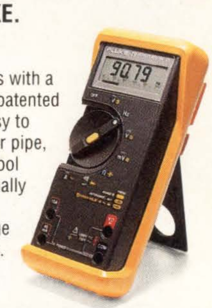

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MAY 7, 1992

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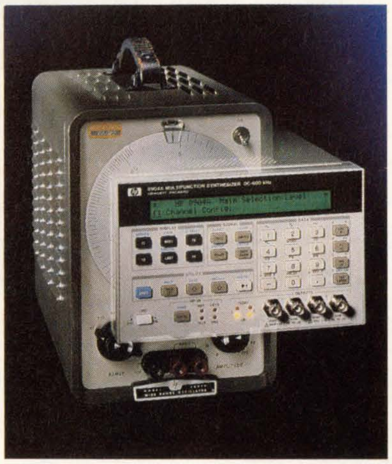

Through such techniques as using function libraries, instruments based on the technology of first-generation arbitrary-waveform generators now make obtaining basic waveforms simple. . . **PAGE 65**

TECHNOLOGY UPDATES

PRODUCT UPDATES

PROCESSOR UPDATES

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275 Washington St, Newton, MA 02158
EDN Bulletin Board: (617) 558-4241
MCI: EDNBOS
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Brian Kerridge, *Technical Editor*
22 Mill Rd, Loddon
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MAY 7, 1992

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EDITORIAL

DESIGN IDEAS

PROFESSIONAL ISSUES

NEW PRODUCTS

DEPARTMENTS

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Registers	5.2ns	5.5ns	5.0ns
Latches	4.2ns	5.5ns	5.0ns

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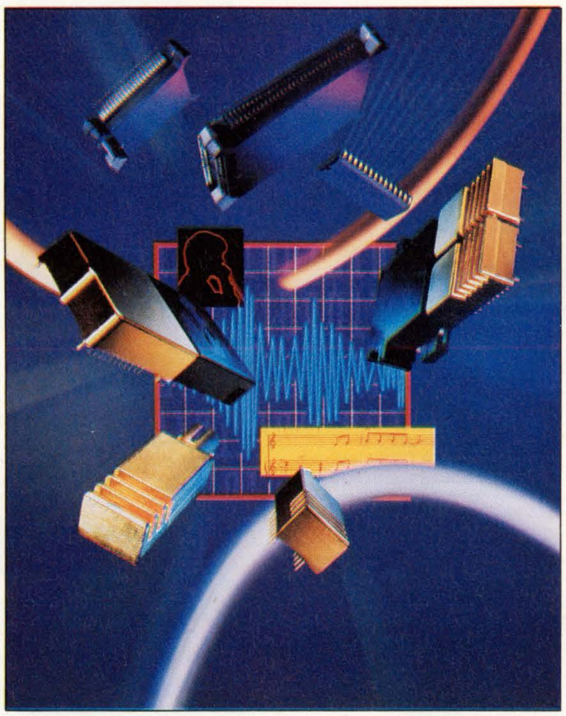
CIRCLE NO. 7

INSIDE EDN

A summary and analysis of articles in this issue

We dedicate all of the articles in EDN to making your job easier, but in this issue we've gone at that task with a vengeance. Do you need a customized power supply quickly? Would you like to create complex waveforms in the lab with little effort? Perhaps you'd like help breaking through one of the last great bottlenecks of computer system design: networks. You'll find help on all of these topics in this issue.

In his Special Report, Technical Editor Maury Wright looks at the large throughput gains we're about to experience in LANs. The 100-Mbps FDDI LAN has been far too costly for conventional LANs, but Maury explains why that situation is about to end. See his sidebar on low-cost FDDI for more information. If you can't wait for the imminent drop in FDDI prices, you should look at some of the alternative proprietary LAN protocols discussed in this article.



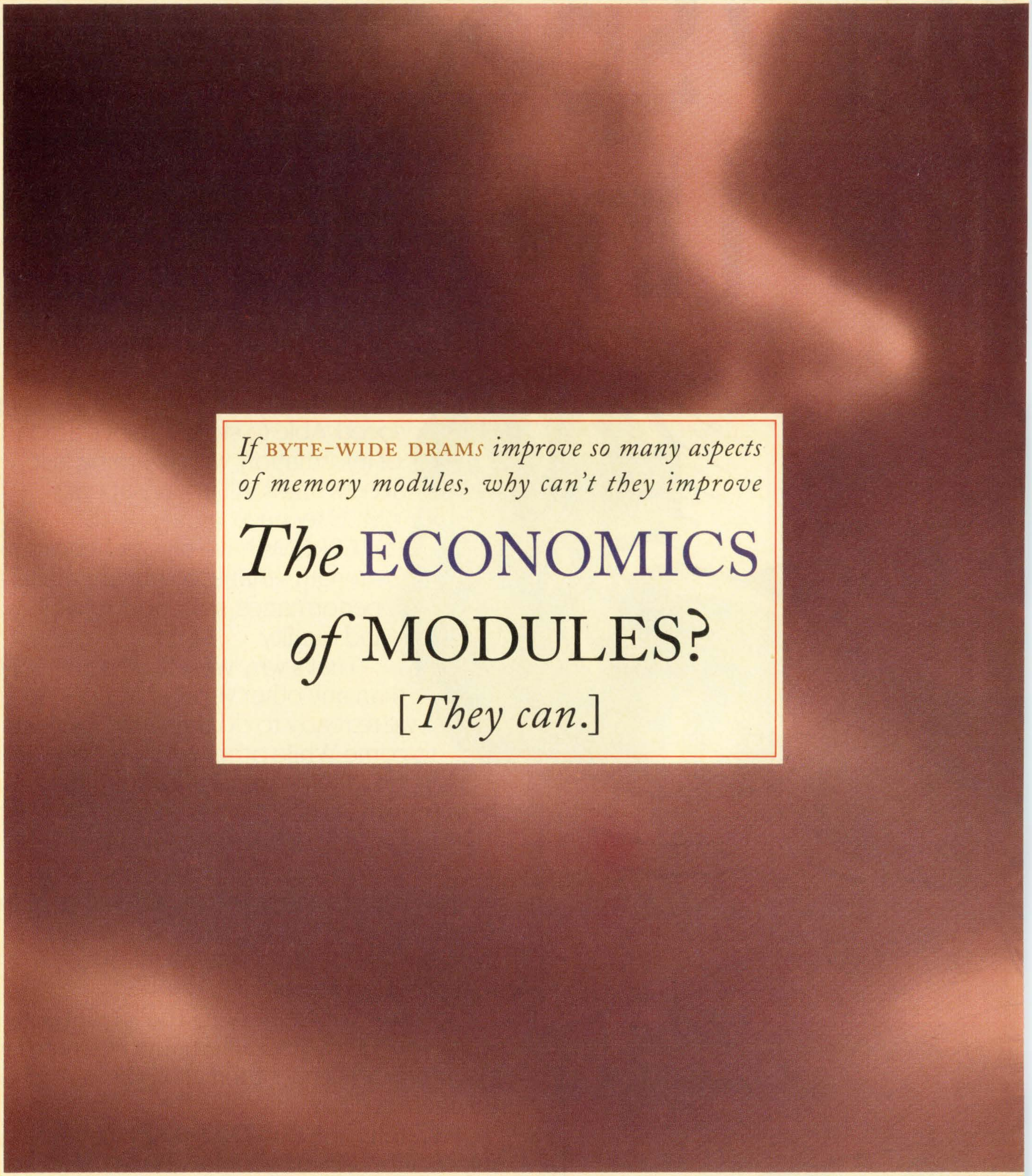
This issue's Special Report covers data communications.

Even if the products you design don't employ LANs, it's a good bet they incorporate power supplies. Although you've been able to order custom power supplies for many years, decreasing product design cycles make it tougher than ever to wait for a custom supply to be designed and built. Worse, decreasing product life cycles ensure that your power supply requirements will change often. Modular power supplies, the topic of Technical Editor Brian Kerridge's Technology Update, can alleviate both of these problems. Using modular components, vendors can provide built-to-order power supplies in a few days. Brian tells you who these vendors are and what types of products you can get.

The same short product design and life cycles put real pressure on you to test your initial designs as quickly as possible. And you often need to test parts of a system before other sections are ready. Arbitrary-waveform generators (ARBs) can simulate parts of a system not yet built. For complex signals, it sometimes feels as though it's almost as hard to generate the waveform as it is to get the missing system components built. The latest batch of ARBs, which Technical Editor Dan Strassberg discusses in his Technology Update, makes this task much easier through the inclusion of function libraries and algorithmic waveform storage. At the same time, vendors are experimenting with several different user interfaces, which Dan summarizes.

Steven H Leibson
Executive Editor

It Takes Some Characteristics To



Byte-wide DRAMs in memory modules. When you compare a 4-meg byte-wide with the normal combination of 1-megs and 256K's, you find that one chip can replace six.

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KM418C256	256Kx18	70, 80, 100 ns
KM48C512*	512Kx8	70, 80, 100 ns
KM49C512	512Kx9	70, 80, 100 ns

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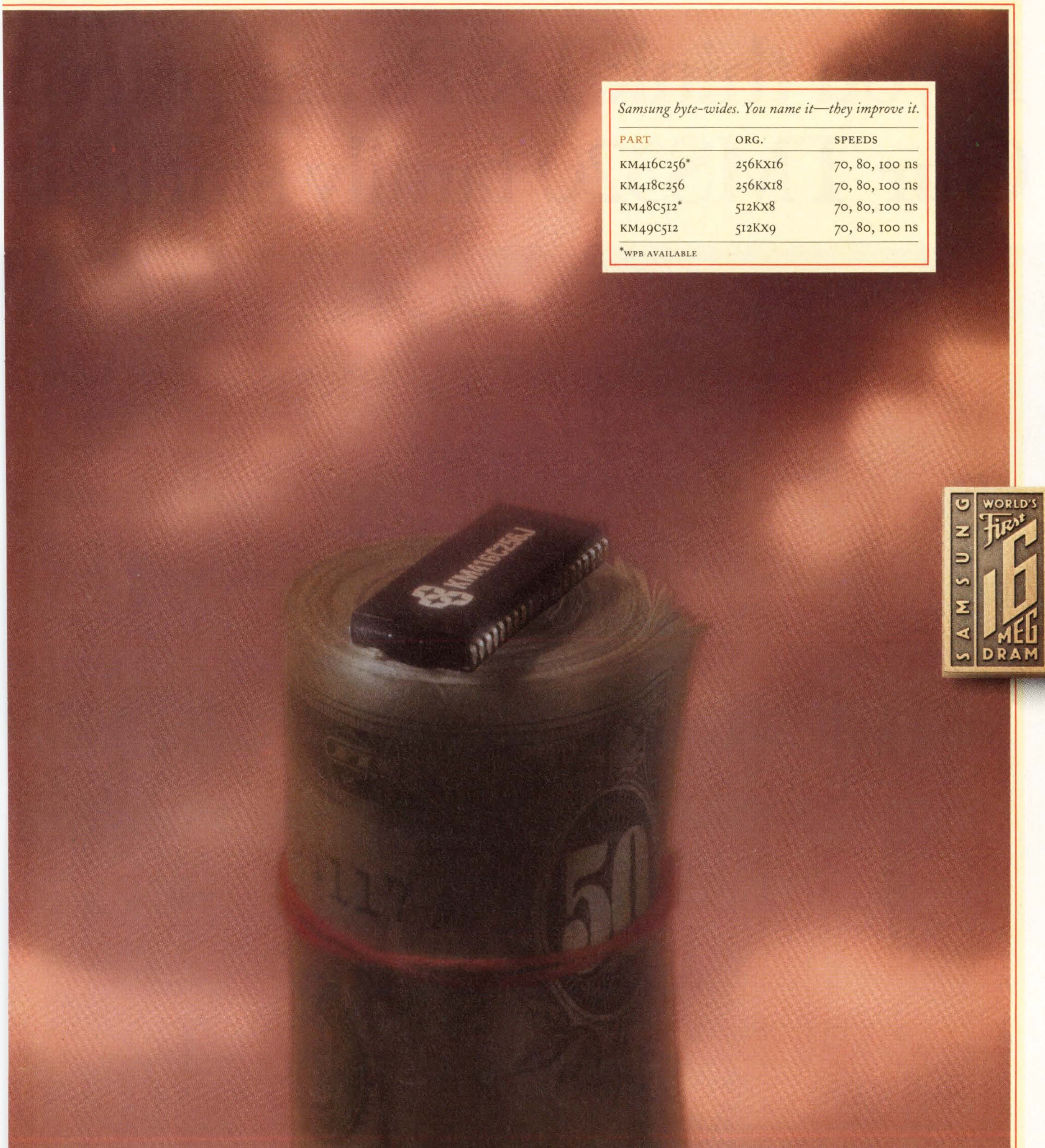

And also because board assembly is less expensive.

So if you've been wishing you could exploit the design advantages of byte-wides but have been holding off for cost reasons, hold off no more—the future is here.

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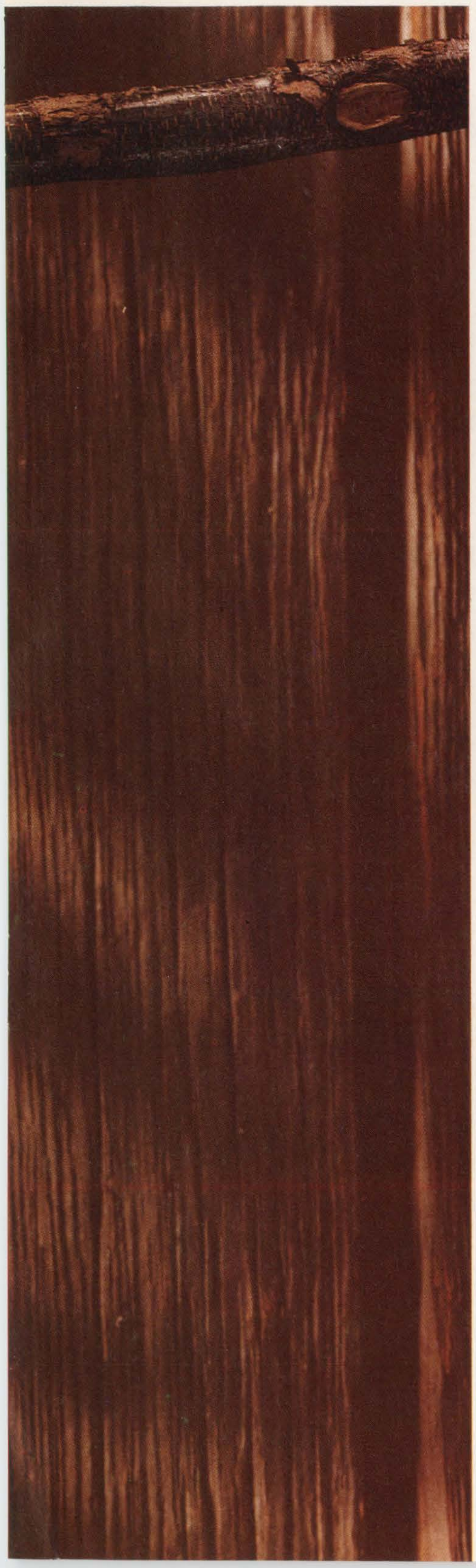

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TEXAS INSTRUMENTS

 08-12081

CIRCLE NO. 21

EDITED BY SUSAN ROSE

Tools help find mixed-signal-IC test problems

The $80,000 Dantes (design and test engineering system) software tools from Cadence speed the development of analog and mixed-signal-IC tests that will run in production on large-scale automatic test systems. Currently, more than 50% of the time required to develop analog and mixed-signal ICs is spent developing and debugging the test programs, and in some cases, the specialized hardware required to make the programs run. For the most part, test development for these ICs takes place after silicon is available. Because test development takes so much time and takes place in series with the rest of the IC-design process, test development has a major impact on an IC's development cost and time to market. With the software, IC manufacturers will now be able to run simulated production tests on models of devices under development so that they can learn how to modify the device designs and the test methodology to maximize throughput and yield.

The software provides tools for describing the attributes of mixed-signal ATE; determining whether a proposed test methodology can be implemented on a particular tester; determining what specialized hardware is not part of the test system—and therefore must be placed on a "load board" that's unique to an IC or IC family; generating a load-board layout; sequencing the tests so that tests most likely to fail run first; and, sequencing the tests so that ones that leave the tester or device in states critical to proper operation of subsequent tests run in the proper order. The software will be available by the third quarter of 1992. Description files for testers from Hewlett-Packard, LTX, Teradyne, and Yokogawa will be available from the ATE suppliers. Cadence Design Systems Inc, San Jose, CA, (408) 943-1234, FAX (408) 943-0513.

—Dan Strassberg

Electrical rules drive place-and-route tool

If your high-performance-circuit schematic designs need reams of paper to tell the board-design specialist the do's and don'ts of laying out the board, you might want to consider a product that lets you integrate the rules into your design. Board Station 500 from Mentor Graphics accommodates network topology control, signal path lengths, matched path lengths, stub lengths, layer restrictions, via limits, balanced pair routing, parallelism control, and shielding generation.

A circuit designer uses the software to work with parameters such as time delays and timing skew limits. The integrated transmission-line analysis tools from Quad Design (Camarillo, CA) translates the timing parameters into physical design rules—such as line lengths, widths, and length matching—that the board designer needs to complete the pc-board or multichip-module design. The $125,000 software is available on HP-Apollo, HP Series 700, and Sun SPARCstations. Mentor Graphics Corp, Wilsonville, OR, (800) 547-3000 Dept 107, FAX (503) 685-8001.

—Doug Conner

Dual-port SRAMs offer semaphores

The CY7B13X and CY7B14X family dual-port static RAMs from Cypress Semiconductor provide on-chip logic that helps simplify memory-access arbitration in multiprocessor systems. The logic includes interrupts, Busy signals, and semaphores, which help processors on each port communicate their use of shared memory. The devices are also fast enough to support 50-MHz systems; family members offer access times as fast as 15 nsec. They come in 4k×8-bit and 8k×9-bit configurations, with differing sets of arbitration signals. Prices range from $42.10 to $84.20. Cypress Semiconductor, San Jose, CA, (408) 943-2600.

—Richard A Quinnell

Develop DSP systems under Windows

DSPworks Version 2.0 operates under Windows, letting you develop and test DSP systems on a personal computer. Functions let you acquire and process data and then display it, save it to a file, or put it out to a DSP board. The software supports DSP boards from a variety of suppliers, including Ariel, Data Translation, Spectrum Signal Processing, and Sonitech. In addition to acquiring data, you can use the software to generate and process test signals to test and debug your DSP applications. Additional tools from the company let you develop filters and produce code for commercial DSP chips. Momentum Data Systems, Costa Mesa, CA, (714) 557-6884, FAX (714) 557-6969.—Jon Titus

DSP µP boosts digital-cellular applications

The power, size, and processing requirements of digital-cellular telephones are extremely stringent. AT&T Microelectronics has addressed all three issues with a single DSP1616 DSP µP programmed to perform the VSELP speech compression and speech error-correction function required in IS-54 digital-cellular terminals. (VSELP is the type of

Text continued on pg 20

Mass-storage chip set offers programmability

Hard-disk-drive designs typically require custom analog circuits to handle data and servo functions, but that may change with a 3-chip set from AT&T Microelectronics. The chip set uses a combination of programmable analog- and digital-signal-processing techniques to provide designers with the necessary flexibility in a standard product. The three chips are the Search1 servo-channel device, the Reach2 read-channel device, and the Spin1 servo-processor interface. All three are implemented in 0.9-μm CMOS and collectively dissipate <1W when active.

A main feature of the chip set is its programmability, supporting multizone, constant-density recording at data rates from 6.67 to 40 Mbps. Factors such as pulse-detector qualification thresholds, analog-filter corner frequencies, data precompensation, and data-synchronizer window shift combine with a programmable timing generator and DSP to give you control of virtually all of the operating parameters and qualification levels in your disk drive.

A development kit is available to help speed your system design effort using the Search1 chip set. The kit includes an evaluation board, source code for actuator and servo-spindle control, DSP and microcontroller assemblers, and application notes. You can use the board with any 80C31 emulator for debugging control software. The board also includes a prototyping area. Sample prices are approximately $10 for the Search1 and Reach2 chips and $4 for the Spin1. The devices come in shrink quad flatpacks. AT&T Microelectronics, Allentown, PA, (800) 372-2447, ext 829, FAX (215) 778-4106.—Richard A Quinnell

Text continued from pg 19

speech coder specified for the IS-54 digital-cellular standard.) To ensure high speech quality, the DSP1616 VSELP engine ($37 (10,000)) has an S/N ratio of 34 dB, which is 12 dB higher than required by the standard. To lengthen talk times and reduce the weight of the telephone, the device consumes less than 60 mA of current from a 5V battery when driven with a 20-MHz clock. The device comes in a 100-pin shrunken quad flatpack that stands less than 1.5 mm high and measures 14×14 mm^2. The device includes a selectable spectral post filter, a selectable loopback function for testing, and flexible host and codec interfaces. The company provides a set of hardware- and software-development tools for the DSP, which together cost approximately $7500.

The company also announced a partnership with Mitsui Co Ltd (Tokyo, Japan; in the US, Mitsui Comtek Corp, Saratoga, CA), and Teknekron Communications (Berkeley, CA) to market the chip globally. The VSELP device is the first product from the development effort, and it's just one piece of the digital-telephone subsystem. Mitsui is primarily serving a distribution function, but Teknekron Communications is a software company that provides expertise in algorithm design, DSP software, and system integration. An entire chip set for the subsystem will be available early next year. AT&T Microelectronics, (800) 372-2447; in Canada, (800) 553-2448.

—Anne Watson Swager

Math routines in C simplify DSP tasks

If you're developing software for Texas Instrument's (Dallas, TX) TMS320C30, C31, and C40 DSP ICs and writing programs in C, you may be able to speed up your software's math operations. A series of math routines in the Fastar library developed by Tartan Inc (Monroeville, PA) can reduce C-code execution times for math operations by an average of 40%. To apply the routines, you replace existing math routines in Texas Instrument's C compiler with those supplied by Tartan. The company also defines 14 new math routines such as cot, asinh, and invsqrt (inverse of the square root). The math routines cost $495 and are available from Spectrum Signal Processing Inc, Burnaby, BC, Canada, (604) 438-3046, FAX (604) 438-3046.—Jon Titus

It's not too late to buy Heathkits

In March, the New York Times *reported that Heath (Benton Harbor, MI) was closing out the last of its electronics kits to concentrate on home-improvement products and educational materials. However, the company doesn't expect to run out of kits until the end of the year. Heath's latest catalog has 14 pages of kits ranging from laptop computers to logic analyzers to surround-sound processors. The 10 beginners' kits include electronic dice, an infrared motion detector, a wireless microphone, and a digital clock. Phone (800) 253-0570 for a catalog.*

—Julie Anne Schofield

EEPROM packs more speed in smaller package

Seeq Technology Inc has shrunk its 28C010 1-Mbit (128k × 8-bit) EEPROM, reducing the die area by 44%. The smaller device now fits into a 32-pin leadless chip carrier, offering a board density improvement over the device's original 44-pin pack-

Text continued on pg 22

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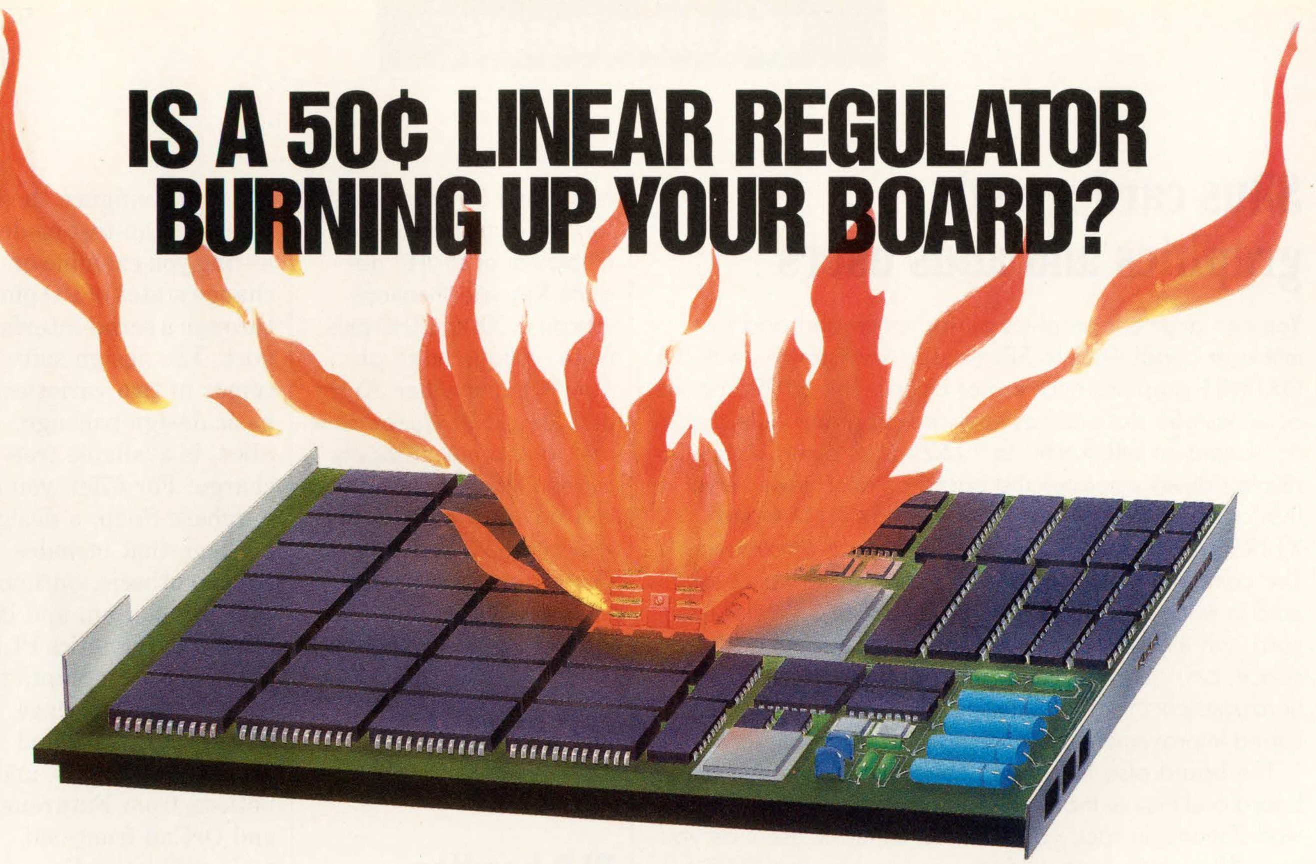

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CIRCLE NO. 70

SBus card speeds graphics and adds users

You can augment graphics performance and add fast multiuser capabilities to SBus-based workstations with the GXTRA/1 graphics-accelerator board. The $1995 board occupies one slot and has software-programmable display resolutions of 640×480 to 1152×900 pixels. A SunOS display driver operates the board as an XNews server that accepts OpenWindows, X-Window X11R4 and X11R5, and Sunview display commands, all simultaneously. The company claims that the graphics performance of this card is twice that of Sun Microsystems' GX accelerator card, yet the card consumes only 4 Mbytes of address space, one quarter of that consumed by the GX card. A hardware cursor on the card is responsible for part of the speed improvement, and it eliminates cursor flicker.

The board also has a port for a Sun-compatible keyboard and mouse that lets you add a user to SPARC-based workstations. In fact, you can add as many users as you have SBus slots. Each added user requires one GXTRA/1 card, a keyboard, and a mouse (additional $298), as well as a color display monitor. The company says that the total cost of these parts is less than $2900 per user, but it also recommends that you add memory for each new user. The GXTRA/1 is a cost-reduced version of the company's $2500 GXTRA/W series, which can operate displays with resolutions to 1600 × 1280 pixels but lacks the programmable-resolution ability. Tech-Source Inc, Altamonte Springs, FL, (407) 830-8301, FAX (407) 339-2554.

—Steven H Leibson

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age. It is also the same size as 256-kbit EEPROMs. The smaller die brings a performance boost to the part. The device's access time has dropped from 120 to 90 nsec and its write cycle from 5 to 3 msec. As with the larger version, the smaller 28C010 offers on-chip error correction and software write protection. The device costs $354 (100); a MIL-STD-883 version costs $510. Samples will be available in May. Seeq Technology, San Jose, CA, (408) 432-5801, FAX (408) 432-1640.

—Richard A Quinnell

Mix JFET and bipolar with amp input stage

Analog Device's OP-275 dual op amp uses a newly patented input architecture (named the Butler architecture for the IC's designer). This architecture combines bipolar- and JFET-transistor design techniques to provide the accuracy and low-noise performance of bipolar designs with the speed and dynamic range of JFET op amps. The OP-275 ($0.99 (100)) saves power and board space and increases speed, voltage-noise, and distortion performance compared with all-bipolar or all-JFET designs. Key specifications include 0.0006% THD plus noise, voltage noise of 6 nV/$\sqrt{Hz}$ at either 30 Hz or 1 kHz, a 25V/μsec slew rate, and 5 mA of supply current. Input offset voltage is a maximum of 1 mV and typically is 200 μV. The device comes in an 8-pin surface-mount package. Analog Devices Inc, Precision Monolithics Div, Santa Clara, CA, (408) 562-7456.

—Anne Watson Swager

PLD handles 32-bit-wide bus structures

The PML2852 PLD from Signetics provides enough I/O capacity to handle two 32-bit buses, offering 29 dedicated input pins, 16 dedicated output pins, and 24 bidirectional pins. It also offers a flexible internal logic structure. The device's core includes 96 258-input NAND gates and 20 buried J-K flip-flops. The output pins of the gates and flip-flops fold back into the array, enabling you to cascade logic without sacrificing I/O pins. The device has a 35-nsec propagation delay and comes in 84-pin plastic leaded chip carriers ($24) or J-leaded ceramic quad packages ($70 (1000)). It is also available in a 50-nsec speed grade.

Signetics supports the device with test hardware on chip and design software. The test hardware lets you configure the device in a scan-test mode, letting you examine or change states of I/O pins through a serial-interface port. The design software comes in two varieties. A basic design package, Slice, is available free of charge. For $750, you can purchase Snap, a design package that includes logic synthesis, optimization, simulation, and layout for all Signetics PLDs. The software accepts the Abel design language, schematics, state and Boolean equations, and netlists from Futurenet and OrCad front-end tools. Signetics Co, Sunnyvale, CA, (408) 991-2321, contact Paul Sasaki.

—Richard A Quinnell

Flash memory reaches 8-Mbit density

Intel Corp released a 1M×8-bit flash EEPROM device organized as 16 independently erasable 64-kbyte blocks with 100,000-cycle endurance. The 28F008SA ($29.90 (10,000)) offers self-completing write and erase cycles, enabling you to access the device much like a static RAM. Because writing or erasing an EEPROM location requires 10 μsec, the device also offers a ready/busy status pin to signal the system that it is not yet available for another write command. The device, however, does let you read from one block while another is being

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Neural system incorporates versatile hardware unit

Neural Technologies' NT5000 neural-networking system consists of software and hardware to let you set up, train, and investigate performance of a neural network in a range of applications. The PC-based, mouse-supported software lets you develop a network of 4000 neurons, 32,000 connections, and a user-specified number of hidden layers. Using a graphical user interface, you also use the software to define and set up a hardware configuration from a selection of modules in the processing unit. You then download data via RS-232C from the PC to the processing unit and proceed to train the network with data from live signal inputs.

The processing unit contains I/O modules that include a 16-bit bidirectional digital interface, a dc to 150-kHz analog input, audio amplifier, and optional CCIR video interface. Other integrated hardware includes an internal loudspeaker, a 5-channel multiplexer, filters, an 8-bit DAC, and an LCD. The processing unit is portable, measures 275 × 280 × 85 mm, and operates from an external 9V supply, which is provided with the package. Once you have set up, downloaded, and trained your network, you can disconnect the processing unit from the PC and transport it to your application.

Extensive facilities exist for network editing during and after the training phase of operation. For example, you can either prune out or add whole layers to the network, or progressively remove low-effect interconnections to speed up operation. While training, you receive visible feedback of the network's performance from actual and rms error plots, and a weighted histogram indicates overall effectiveness. At any time you can halt operation, edit the network, and continue training from the same point or restart. In addition, you can import entire networks to NT5000 from other neural software, such as California Scientific Software's Brainmaker and Neuralware's Neuralworks.

The system comes in basic, turbo, or video versions. The basic configuration includes software and a processing unit for 630 neurons, 4500 connections, 2k-interconnects/sec, and 5-kHz analog signals ($7500). Turbo version extends capacity to 4000 neurons, 32,000 connections, 2M interconnects/sec, and includes 32-bit digital I/O ($9900). Video version adds CCIR interface and video monitor, and includes image processing (due third quarter of 1992). Neural Technologies Ltd, Petersfield, UK, 730-260256, FAX 730-260466. In US, California Scientific Software, Nevada City, CA, (916) 478-9040, FAX (916) 478-9041.

—Brian Kerridge

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erased. You can read data as fast as 85 nsec.

The company has used the device to build its Series 2 Flash Memory Cards on the PCMCIA 2.0 card standard. The series offers densities of 4, 10, and 20 Mbytes and will be available in 5 and 3.3V versions. The 4-, 10-, and 20-Mbyte cards cost $163.50, $331.50, and $611.50, respectively, (1000). Intel Corp, call or fax your local office.—Richard A Quinnell

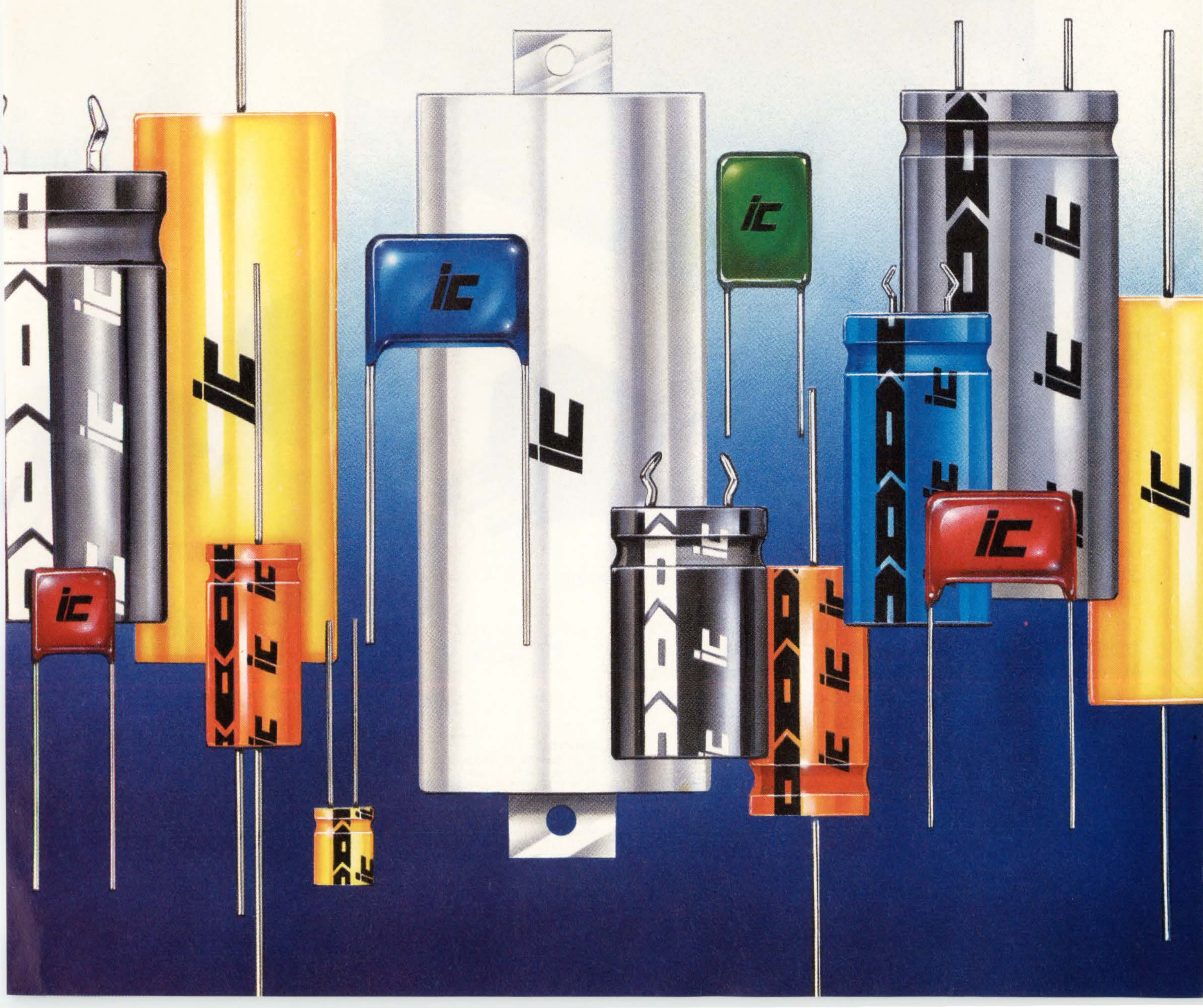
ASIC family offers 600,000 gates three ways

LSI Logic is accepting designs for its 300K family of ASICs based on a 0.6-μm (drawn) CMOS process. You can obtain devices as large as 600,000 used gates with more than 800 I/O pins. If you're after the lowest design cost, use the LCA300K compacted-array series. The series is a sea-of-gates design that has ECL-like I/O buffers and built-in termination resistors. For the highest density, the LCB300K series uses standard-cell design and features libraries with both SPARC and Mips processors. Striking a balance between the two is the LEA300K series, which you design by using a combination of standard cells and gate arrays. You can then begin wafer fabrication before your design has been fully tested by using the gate-array portion to make last-minute corrections. Nonrecurring engineering charges for the family start at $30,000, and production shipments begin by the fourth quarter of 1992. LSI Logic, Milpitas, CA, (408) 433-8000.—Richard A Quinnell

Perform time-domain analysis in Windows

Snap-Master Analysis lets you analyze, display, store, and retrieve time-domain data while working in the Microsoft Windows 3.0 or 3.1. This $495 program includes arithmetic, trigonometric, logarithmic, and statistical functions. It also provides auto- and cross-correlation, smoothing, three types of differentiation, and five types of integration. A tabular format defines and stores constants, equations, and algorithms. You create an analysis procedure by dragging icons from the program's on-screen toolbox. You can define data flow by using data pipes to connect icons.

You view data using y-time, y-x, and trip-chart emulations. Disk I/O elements let you store and replay both the equation definitions and the resultant data in your files. You can read more than one data file at a time and analyze multiple data files simultaneously. You can use the software with a $995 Snap-Master Data Acquisition program that also operates within. HEM Data Corp, Southfield, MI, (313) 559-5607.—J D Mosley



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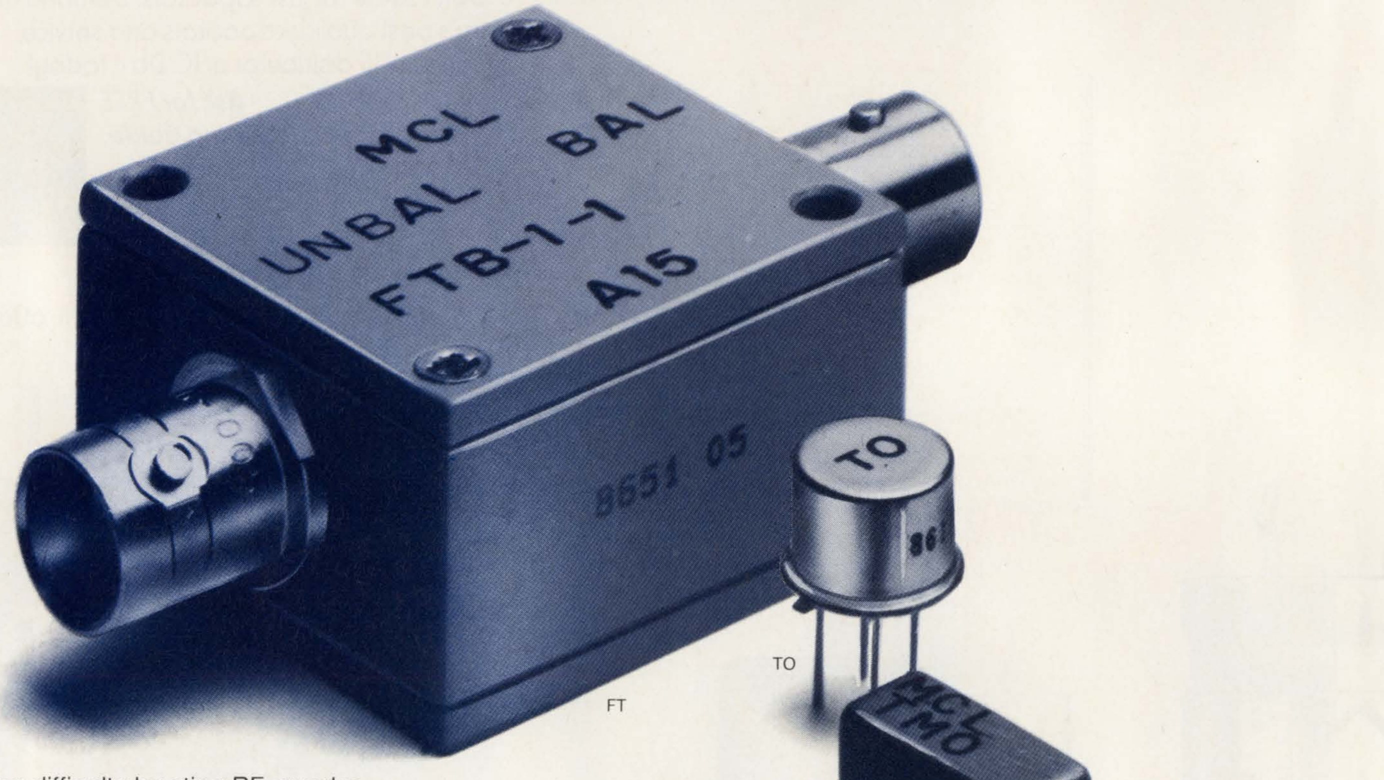

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FTB1-6	5950-01-225-8773	TMO2.5-6	5950-01-215-4038
T1-1	5950-10-128-3745	TMO2.5-6T	5950-01-215-8697
T1-1T	5950-01-153-0668	TMO3-1T	5950-01-168-7512
T2-1	5950-01-106-1218	TMO4-1	5950-01-067-1012
T3-1T	5950-01-153-0298	TMO4-2	5950-01-091-3553
T4-1	5950-01-024-7626	TMO4-6	5950-01-132-8102
T9-1	5950-01-105-8153	TMO5-1T	5950-01-183-0779
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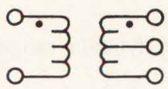
A*	T	T1-1T	1	.05-200	.05-200	.08-150	.2-80	4.45
PRI  SEC		T1-6T	1	.003-300	.003-300	.01-150	.02-50	6.95
		T2-1T	2	.07-200	.07-200	.1-100	.5-50	4.95
		T2.5-6T	2.5	.01-100	.01-100	.02-50	.50-20	4.95
		T3-1T	3	.05-250	.05-200	.1-200	.5-70	4.95
		T4-1	4	.2-350	.2-350	.35-300	2-100	3.25
		T4-6T	4	.02-250	.02-250	.05-150	0.1-100	4.45
		T5-1T	5	.3-300	.3-300	.6-200	.5-100	4.95
		T8-1T	8	.03-140	.03-140	.10-90	1-60	7.95
		T13-1T	13	.3-120	.3-120	.7-80	5-20	4.95
		T16-6T	16	.03-75	.03-75	.06-30	.1-20	5.65
	TH	T4-1H	4	10-350	10-350	15-300	25-200	5.95
	TMO	TMO1-1T	1	05-200	.05-200	.08-150	.2-80	7.95
		TMO2-1T	2	.07-200	.07-200	.1-100	.5-50	8.45
		†TMO2.5-6T	2.5	.01-100	.01-100	.02-50	.05-20	8.45
		†TMO3-1T	3	.05-250	.05-250	.1-200	.5-70	7.95
		TMO4-1	4	.2-350	.2-350	.35-300	2-100	6.25
		TMO5-1T	5	.3-300	.3-300	.6-200	5-100	8.45
		TMO13-1T	13	.3-120	.3-120	.7-80	5-20	8.45
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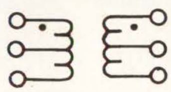
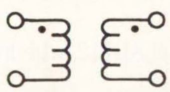
PRI  SEC		TT1.5-1	1.5	.075-500	.075-500	.2-100	1-50	5.95
		TT2.5-6	2.5	.01-50	.01-50	.025-25	.05-10	6.45
		TT4-1	3	.05-200	.2-50	.2-50	1-30	5.95
		TT4-1A	4	0.1-300	0.1-300	0.2-250	0.3-180	6.95
		TT25-1	25	.02-30	.02-30	.05-20	.1-10	9.95
	TTMO	TTMO25-1	25	.02-30	.02-30	.05-20	.1-10	11.95
		TTMO1-1	1	.005-100	.005-100	.01-75	.05-40	11.45
		TTMO4-1A	4	0.1-300	0.1-300	0.2-250	0.3-180	13.95
C	T	T1-1	1	.15-400	.15-400	.35-200	2-50	3.25
PRI  SEC		T1.18-3	1.18	0.01-250	0.01-250	0.02-200	0.03-50	5.65
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		T1.5-1	1.5	.1-300	.1-300	.2-150	.5-80	4.45
		T1.5-6	1.5	.02-100	.02-100	.05-50	0.1-25	5.65
		T2.5-6	2.5	.01-100	.01-100	.02-50	.05-20	4.45
		T4-6	4	.02-200	.02-200	.05-150	.1-100	4.45
		T9-1	9	.15-200	.15-200	.3-150	2-40	3.95
		T16-1	16	.3-120	.3-120	.7-80	5-20	4.45
		T36-1	36	.03-20	.03-20	.05-10	.1-5	6.95
	TO	TO-75	1	10-500	—	10-500	40-250	6.95
	TH	T1-1H	1	8-300	8-300	10-200	25-100	5.95
		T9-1H	9	2-90	2-90	3-75	6-50	6.45
		T16-H	16	7-85	7-85	10-65	15-40	6.45
	TMO	TMO1-02	1	1-800	1-800	2-500	—	9.45
		TMO1-1	1	.15-400	.15-400	.35-200	2-50	6.25
		TMO1.5-1	1.5	.1-300	.1-300	.2-150	.5-8	8.45
		†TMO2.5-6	2.5	.01-100	.01-100	.02-50	.05-20	7.95
		†TMO4-6	4	.02-200	.02-200	.05-150	.1-100	7.95
		TMO6-1	6	.3-200	.3-200	.5-150	5-50	7.95
		TMO9-1	9	.15-200	.15-200	.3-150	2-40	7.95
		TMO16-1	16	.3-120	.3-120	.7-80	5-20	7.95
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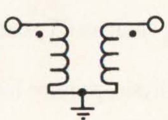
PRI  SEC		T3-1	3	.5-800	.5-800	2-400	—	4.45
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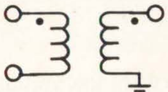
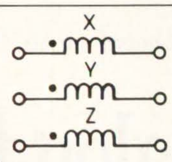
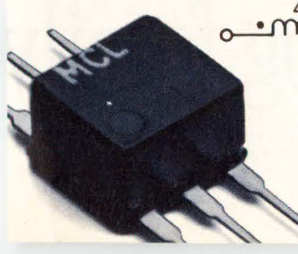
		T14-1	14	.2-150	.2-150	.5-100	2-50	4.95
	TMO	TMO2-1	2	.050-600	.050-600	.1-400	.5-200	7.95
		TMO3-1	3	.5-800	.5-800	2-400	—	8.45
		TMO4-2	4	.2-600	.2-600	.5-500	2-250	7.95
		TMO8-1	8	.15-250	.15-250	.25-200	2-100	7.95
		TMO14-1	14	.2-150	.2-150	.5-100	2-50	8.45
	FT	FT1.22-1	1.22	.005-100	.005-100	.01-50	.05-25	35.95
		FT1.5-1	1.5	.1-400	.1-400	5-200	1-100	35.95
E PRI  SEC	FTB	FTB-1	1	.2-500	.2-500	.5-300	1-100	36.95
		FTB1-6	1	.01-125	.01-125	.05-50	.1-25	36.95
		■FTB-1-75	1	.5-500	.5-500	5-300	10-100	36.95
F	T	T-622	1	0.1-200	0.1-200	0.5-100	5-80	3.25
		T626	1	0.01-10	0.01-10	0.2-5	.04-2	3.95



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ormance of your entire system.

higher speed AD745 offer the best combination of specs — 3.2 nV/$\sqrt{\text{Hz}}$ and 6.9 fA/$\sqrt{\text{Hz}}$. If your emphasis is vice versa, then the AD645 has the specs you want — 0.6 fA/$\sqrt{\text{Hz}}$ for current noise, and 9 nV/$\sqrt{\text{Hz}}$ for voltage noise.

OP AMPS THAT ARE INSTRUMENTAL FOR INSTRUMENTATION.

If you're working in instrumentation applications, our op amps could prove to be instrumental in your design.

The world's lowest current noise (0.11 fA/$\sqrt{\text{Hz}}$) monolithic op amp, the AD549, has 60 fA of input bias current — which is ideal for interfacing with very high

Model	Voltage Noise nV/√Hz @1 kHz typ	Current Noise fA/√Hz @1 kHz typ	Vos mV max	Supply Current mA typ	Input Bias Current max	SR V/µs typ
AD829	2.0	1.5	0.5	5	7 µA	230
OP-27/OP-37	3.0	400	.025	3	40 nA	2.8/17
AD743/745	3.2	6.9	0.5	8	250 pA	2.8/12.5
OP-275 (dual)	6	1500	1	4	350 nA	22
AD645	9	0.6	0.25	3	1.5 pA	2.0
AD712 (dual)	18	0.01	0.7	5	75 pA	20
AD548/648 (dual)	30	1.8	0.25/0.3	.34	10 pA	1.8
AD549	35	0.11	0.5	.60	60 fA	3

impedance sources. The AD548 (single) and AD648 (dual) deliver low bias current (10 pA), extremely low current noise (1.8 fA/$\sqrt{\text{Hz}}$) and low power consumption at a highly attractive price. And the industry-standard OP-27 and OP-37 offer ultralow noise (3 nV/$\sqrt{\text{Hz}}$ at 1 kHz) and precision dc performance.

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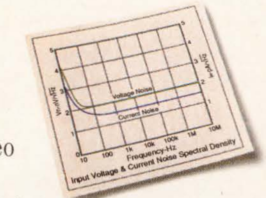

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Or for more information on our low noise op amps, write to Analog Devices, P.O. Box 9106, Norwood, MA 02062-9106.

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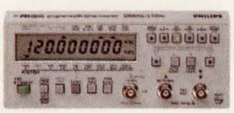

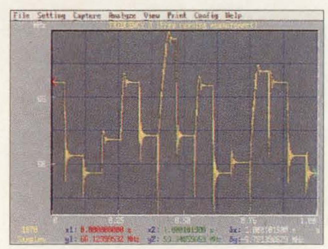

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CIRCLE NO. 30

Why manufacturing facilities are crumbling

Dan Strassberg's editorial (EDN, February 17, 1992, pg 55) raises the question, Why . . . is our infrastructure . . . crumbling?

It's easy to blame management for taking a short-term view of business. Quarterly profits seem to be more important than long-term success. Although management may be partially at fault, we, the stockholders of public corporations, are really to blame by demanding short-term performance. When a company takes a strategic write-down, investors dump the stock so that they can invest in one promising better, more immediate profits. Management is forced to respond to stockholder demands, reasonable or not.

We gas consumers are really responsible for the Exxon Valdez accident. By shopping around for the cheapest possible gas, we force Exxon to buy cheap, single-hulled tankers. If the company went out on a limb to be "environmentally responsible" and added an extra charge to pay for this, it would quickly go out of business.

One of the wonderful things about privately held companies [as opposed to public corporations] is that they can work toward long-term goals. Making a profit this quarter or this year is often not important.

High-tech companies suffer in comparison with, say, the real-estate market. Bankers just cannot understand what the information revolution is all about. They can put a lien on a piece of property, but high tech's real assets are intellectual. For example, if my business lost every desk and chair, every computer and scope, we would easily survive. If we lost our files (CAD, programs, database, and related information), we would be out of business instantly. The value of technology lies not so much in "stuff" as it does in information.

I think the one profound strategic advantage held by the Japanese is the availability of low-cost capital. Their government makes cheap, long-term loans to small businesses.

Jack G Ganssle, President
Softaid Inc
Columbia, MD

Computerized "thinking"

[In response to Charles Small's article, "Innovation software stimulates engineering creativity"(EDN, February 3, 1992, pg 59),] using a computer program isn't going to enhance *your* thinking abilities. So why not learn to think more creatively? People like Edward de Bono and Tony Buzan have been saying this for years, and I've found their techniques very useful.

Thinking, of whatever kind, doesn't come naturally. Creative thinking is particularly difficult for people with scientific training, such as professional engineers, who have been taught to reason rationally and deductively. Indeed, society at large favors this approach above irrational [sic] processes.

At least Small gave a suitably skeptical review for Active Life, the software that offers to schedule every minute of your day. With items on the screen like "4:45p Call Kim to arrange lunch [:15]," all that was missing was an entry or ten for using the program itself.

Whoops, I have to go. I have an appointment with the coffee machine in two minutes.

Mike Lavocah
Cabletime Ltd
Newbury, Berkshire, England

Free enterprise needs self-regulating economy

In response to Dan Strassberg's editorial, "Where have all the investments gone?" (EDN, February 17, 1992, pg 55), a self-regulating economy is in effect an automatic-gain-control (AGC) system. The only serious problem in designing an AGC system is to keep time delays short enough so that phase shifts in the control loop don't cause "motorboating," thus rendering the feedback positive.

In the construction cycle for commercial real estate, there are several delays that contribute to overshooting:

1. Market study to verify that a perceived need is real enough and large enough to justify investment.
2. Deciding exactly what to build and where to put it to best fulfill the need.
3. Acquisition of land and municipal code approval, which are often inter-dependent.
4. Design and design approval.
5. Securing financing.
6. Bidding and letting contracts.
7. Subletting contracts.
8. Actual construction, including contractors' intervals in procurement.
9. Final inspection and occupancy.

It's customary to press for reduced intervals by running these steps concurrently and even slighting one or more of them sometimes. The principal incentive for speed is the desire for an early return on capital. But the system does "motorboat," so there's obviously a need to reduce delays still more.

The first two steps are probably the longest, but the hardest to shorten. To guard against possible competition until the project must finally be made public, each entrepreneur proceeds in secrecy. And each commits himself to a project with scant and inaccurate knowledge of what else is being committed. Shortening later steps increases the risk of tying up money unwisely and losing it.

Real-estate operators may find fault with this analysis. (I have seen mostly municipal planning and approval.) But they cannot deny that too many operators start and finish too many developments too late, so the market is overbuilt. Better communication in the early stages might remedy [this situation].

Any enterprise process involves delays, which are the greatest peril to ultimate success. But freedom is too precious to submit to imposed control systems. Control is necessary, as part of the responsibility that freedom entails, in a system of free enterprise as elsewhere. But it must be collaborative, not dictatorial, or it will destroy that freedom.

Donald H Rogers
Warminster, PA

HAVE YOUR SAY

EDN's Signals & Noise column provides a forum for readers to express their opinions on issues raised in the magazine's articles or on any topic that affects the engineering industry. Send your letters to Signals & Noise Editor, EDN Magazine, 275 Washington St, Newton, MA 02158.

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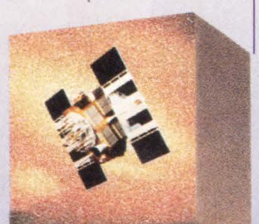

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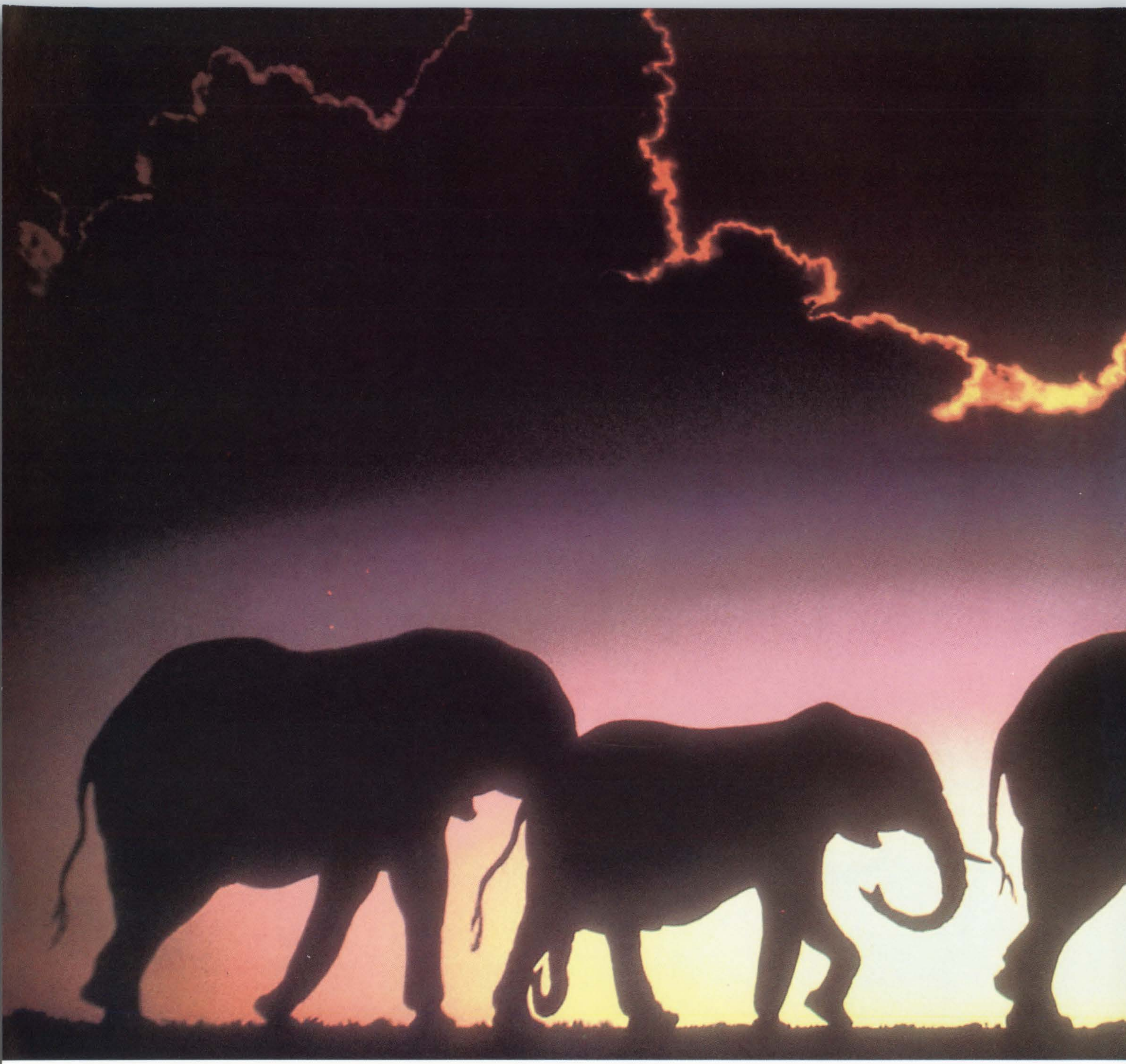
NOW WHO'S LEADING THE HERD IN DRAMs?



GOLDSTAR ELECTRON DRAMS. .

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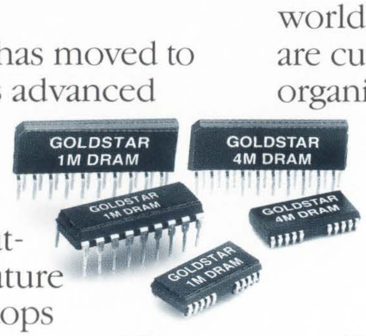
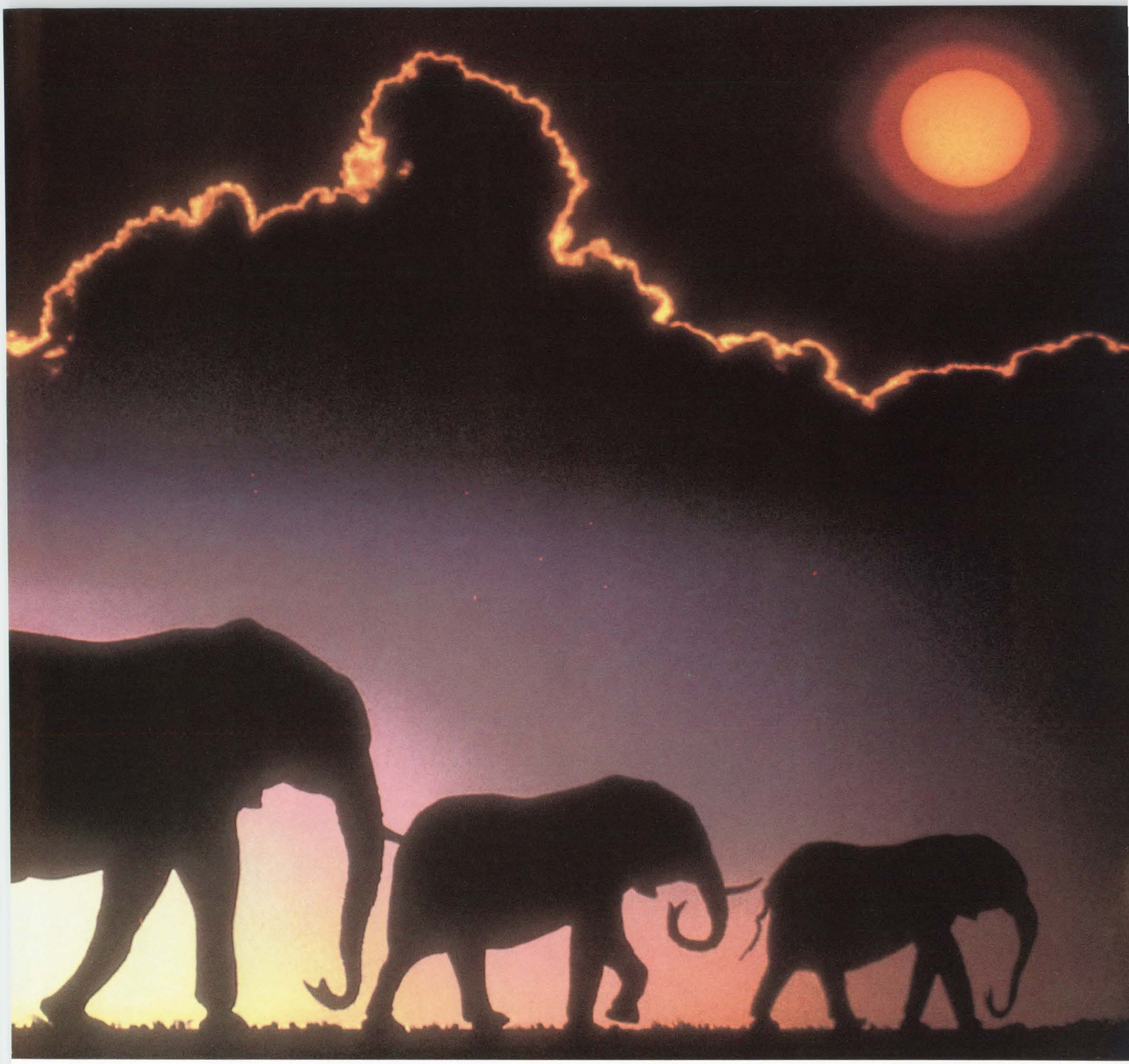
Now Goldstar Electron has moved to the head of the herd with its advanced second generation family of 4M DRAMs. The new chips have access times as fast as 60ns, and standby current ratings as low as 200 μA—a feature of special importance in laptops and other battery-powered systems. The products are manufactured on two of the world's finest submicron lines, and they are currently offered in both x1 and x4 organizations in industry-standard 300-mil surface-mount SOJs and 400-mil ZIPs. Designs for other multi-bit organizations such as x8/9 and x16/18 are also in development.



1M DRAMs

If you're not ready yet for the crossover to 4M DRAMs, Goldstar Electron will



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ELECTRON AMERICA INC.

THE GOLDSTAR DRAM FAMILY

CMOS DYNAMIC RAMs

ORG	TYPE NO.	MAX ACCESS TIME (ns)	CURRENT (mA) ACTIVE	CURRENT (mA) S/B (CMOS)	FEATURE	PACKAGE (MIL)
4M x 1	GM71C4100A - 60 70 80	60 70 80	110 100 90	1	FAST PAGE MODE	20 SOJ (300) 20 ZIP (400)
	GM71C4100AL - 60 70 80	60 70 80	110 100 90	0.2	FAST PAGE MODE/ L-POWER	20 SOJ (300) 20 ZIP (400)
1M x 4	GM71C4400A - 60 70 80	60 70 80	110 100 90	1	FAST PAGE MODE	20 SOJ (300) 20 ZIP (400)
	GM71C4400AL - 60 70 80	60 70 80	110 100 90	0.2	FAST PAGE MODE/ L-POWER	20 SOJ (300) 20 ZIP (400)
1M x 1	GM71C1000 - 60 70 80	60 70 80	90 80 70	1	FAST PAGE MODE	20 SOJ, 18 DIP (300) (300) 20 ZIP (400)
	GM71C1000L - 60 70 80	60 70 80	90 80 70	0.2	FAST PAGE MODE/ POWER	20 SOJ, 18 DIP (300) (300) 20 ZIP (400)
256K x 4	GM71C4256A - 60 70 80	60 70 80	90 80 70	1	FAST PAGE MODE	20 SOJ, 20 DIP (300) (300) 20 ZIP (400)
	GM71C4256AL - 60 70 80	60 70 80	90 80 70	0.2	FAST PAGE MODE/ L-POWER	20 SOJ, 20 DIP (300) (300) 20 ZIP (400)
*512K x 8	GM71C4800/L - 60 70 80	60 70 80	TBD		FAST PAGE MODE L-POWER	28 SOJ (400)
*512K x 9	GM71C4900/L - 60 70 80	60 70 80	TBD		FAST PAGE MODE L-POWER	28 SOJ (400)

*Available 2nd Half '92.

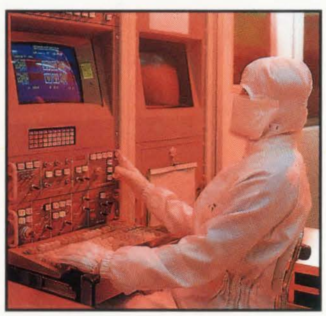
DRAM MODULES

ORG	TYPE NO.	MAX ACCESS TIME (ns)	CURRENT (mA) ACTIVE	CURRENT (mA) S/B (CMOS)	FEATURE	PACKAGE (MIL)
1M x 8	GMM78100NS - 60 70 80	60 70 80	220 200 180	2	FAST PAGE MODE	30 PIN SOCKET
1M x 9	GMM791000NS - 60 70 80	60 70 80	310 280 250	3	FAST PAGE MODE	30 PIN SOCKET
4M x 8	GMM784000S - 60 70 80	60 70 80	880 800 720	8	FAST PAGE MODE	30 PIN SOCKET
4M x 9	GMM794000S - 60 70 80	60 70 80	990 900 810	9	FAST PAGE MODE	30 PIN SOCKET
1M x 36	GMM7361000SG - 60 70 80	60 70 80	1240 1120 1000	12	FAST PAGE MODE	72 PIN SOCKET
256K x 36	GMM736256SG - 70 80	70 80	920 800	20	FAST PAGE MODE	72 PIN SOCKET
512K x 36	GMM736512SG - 70 80	70 80	950 830	40	FAST PAGE MODE	72 PIN SOCKET
2M x 36	GMM7362000SG - 60 70 80	60 70 80	TBD		FAST PAGE MODE	72 PIN SOCKET

The combination of high performance with high density in Goldstar's 1M and 4M devices has been achieved by the use of sub-micron design rules, an advanced triple-poly, double-metal CMOS process technology, and the use of state-of-the-art manufacturing equipment and facilities. For complete product specs, send for data sheets.

A WORD ABOUT GOLDSTAR QUALITY

Goldstar's Quality Assurance System and Reliability Testing covers all phases of design and manufacturing. In the development stage, we *design* reliability into our products. During manufacturing, we *build* reliability into our products. And in the test stages, our quality assurance inspection *verifies* that the required quality and reliability have been achieved.



Our stringent standards have resulted in an Acceptable Outgoing Quality Level (AOQL) of 50 PPM or better on all DRAMs shipped by Goldstar Electron. To further ensure quality, all DRAMs are burned-in under high voltage stress. Other key features implemented by Goldstar Electron in its Quality Program are in-process inspection gates, assembly process gates, 100% electrical inspection, redundant QA testing, on-going reliability and process monitoring, and use of real-time Statistical Process Control. That's how we produce some of the world's finest DRAMs in our state-of-the-art facility at Chung Ju, Korea.

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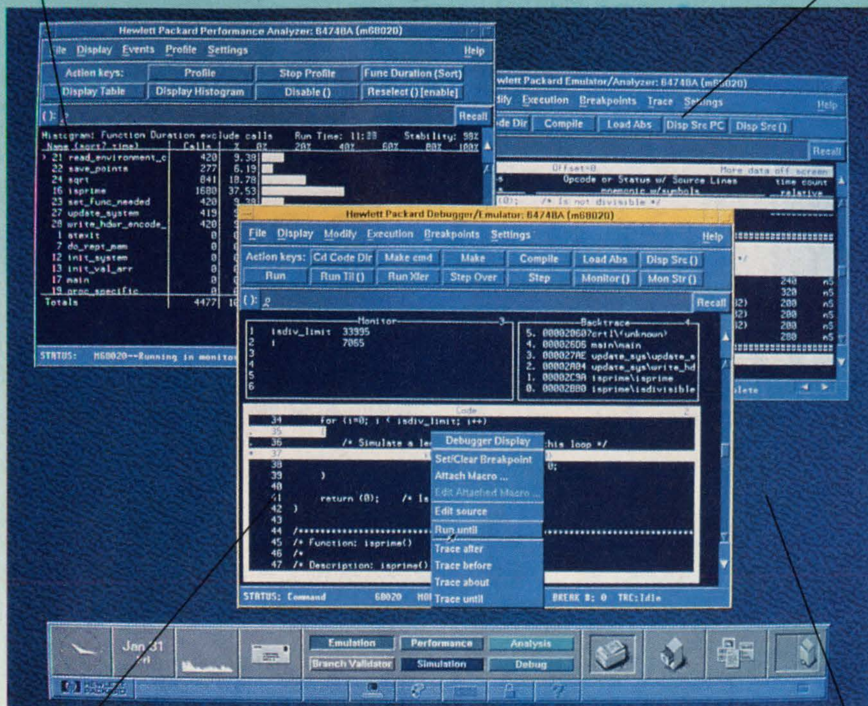

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EDITED BY JULIE ANNE SCHOFIELD

Reader looking for discontinued parts

Like many of the readers in your forum, I'm looking for a key-component replacement part. In my case, the part needed is a Texas Instruments SN76477 or SN76488 sound-generator chip.

The parts are discontinued components, and I have been unable to find them in any quantity. If anyone has or knows of a comparable component, we would be glad to buy any amount.
Ariel Spivakovsky
Biofeedtrack Inc
Brooklyn, NY

By using the Computer Aided Product Selection (CAPS) system, which is available from Cahners Technical Information Service, we found that those parts are indeed discontinued and that there are no pin-for-pin replacements or upgrades. If any reader has SN76477s or SN76488s, please contact Ask EDN.

Electronic glove can interface to PC

A while ago I bought a Mattel Power Glove. The glove connects to Mattel and Nintendo entertainment systems as a hand-tracking device. I wanted the Power Glove to work with my personal computer. Following an article published in the July, 1990, issue of *Byte* magazine, I built a small microcomputer interface. A small machine program residing in an EPROM reads the glove's orientation and button status and passes it to my PC. From the view of the PC, the glove and microcomputer behave like a nonproportional pointing device similar to a joystick.

Recently I heard that the Power Glove is also equipped with a proportional mode, so the glove and microcomputer interface could be made to appear to my PC like a pointing device similar to a mouse. Unluckily, the article from *Byte* did not provide any information on the proportional mode. Do you know where I could obtain information on the proportional mode?
Christian Pfarrherr
Hannover, Germany

Scott Fullam, an engineer with Abrams/Gentile Entertainment Inc (New York, NY), responds:

The Power Glove was developed by my company in 1988 and was manufactured and sold by Mattel beginning in 1989. The glove is equipped with a high-resolution mode for special games. A special interface box is required to activate this mode. This box decodes the raw data from the glove and formats it as a serial-data stream running at 9600 bps. In this high-resolution mode, the glove provides x, y, and z special data; 12-position roll data; 2 bits of flex data for the thumb, index, and middle fingers; and all keypad information. This box is available from Dave Richers of Syracuse University. Please write to him for details.

Dave Richers
Advanced Graphics Lab
Syracuse University
820 Comstock Ave
Syracuse, NY 13244

Compilers available for Z80

Can you tell me where I can purchase or otherwise get a C compiler that produces Z80 code?
Yves Ephraim
Cable and Wireless
Antigua, West Indies

All the cross-compiler companies, such as Boston Systems Office and Intermetrics, have cross compilers for the old Z80. Your Zilog field engineers should have a list. Also check out Z-World, which has a tricky combination of a turbo-C-like compiler/debugger that compiles into a ROM emulator. You write your code, press the go button, and it's running in your target system.

Boston Systems Office
411 Waverly Oaks Rd
Waltham, MA 02254
(617) 894-7800

Intermetrics Inc
733 Concord Ave
Cambridge, MA 02138
(617) 661-0072

Z-World
1340 Covell, Suite 101
Davis, CA 95616
(916) 753-3722

SCPI standard is yours for the asking

How or where can I get the SCPI (Standard Commands for Programmable Instruments) standard details so that I can develop SCPI protocols for my instruments?
Alan Rasmussen
Larson Davis Labs
Provo, UT

You can get SCPI information and copies of the standard from
Fred Bode
SCPI Consortium
8380 Hercules Dr
La Mesa, CA 92042.

Thrifty reader seeks 8051 real-time kernel

Does anybody know where to find a cheap 8051 real-time kernel? I'm working on some home-control projects and would like to try them out in a real-time environment. I am aware that these kernels can be achieved for about $1000, but my private budget will not allow me to spend that amount.
Claus Dahm
Copenhagen, Denmark

Several 8051 kernels written in C are on the /util Special Interest Group on the EDN bulletin-board system (BBS) and are free for the downloading. However, the 8051 is a pretty poor match for the underlying hardware that C assumes (a DEC PCP-11), so a kernel written in C might not work that well when compiled for the 8051.

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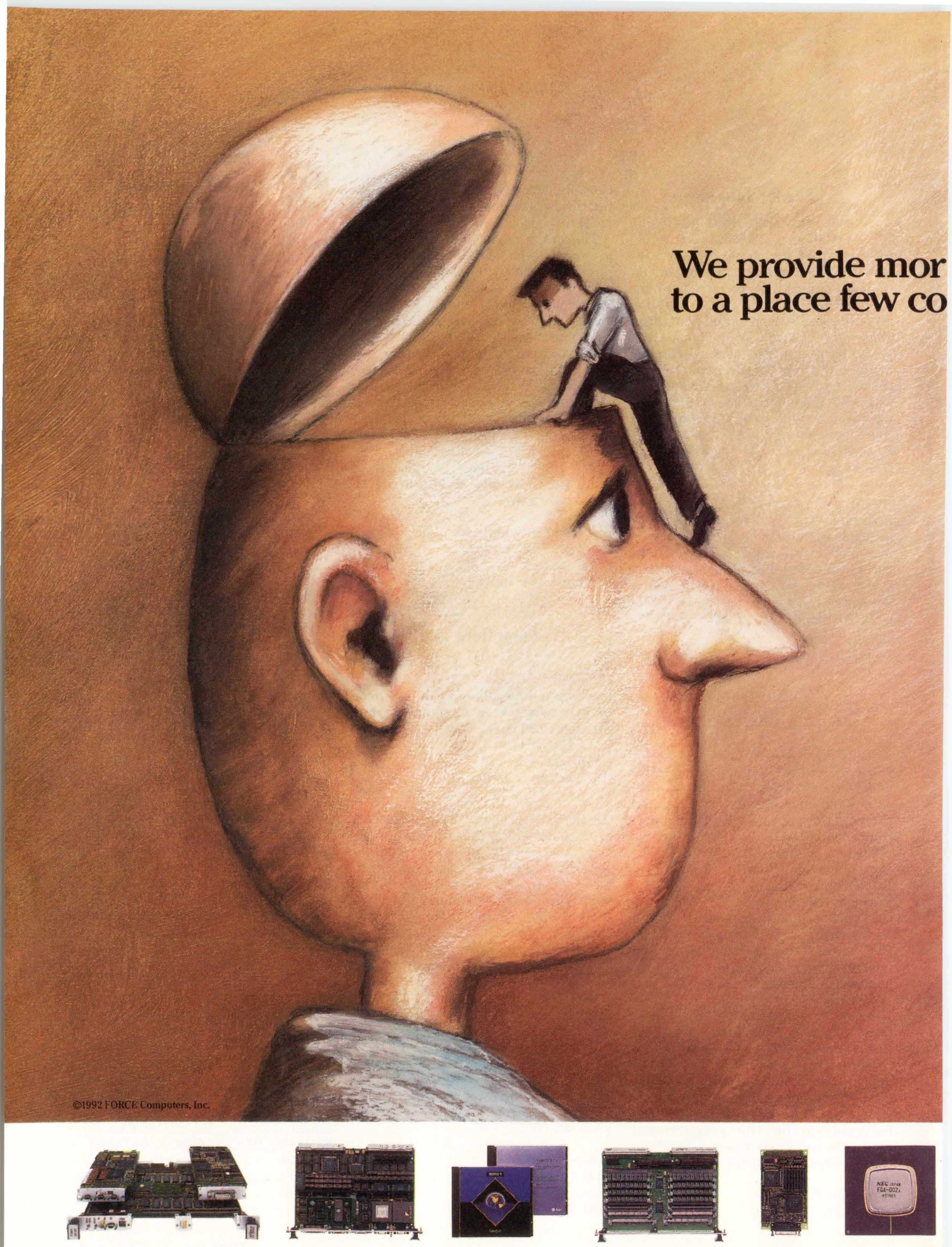

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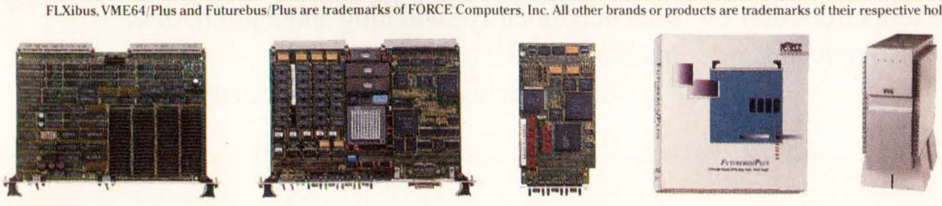

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Electronic Components & Technology Conference, San Diego, CA. Jim Bruorton, Publicity Chair, Kemet Electronics Corp, Box 5928, Greenville, SC 29606. Phone (803) 963-6621. May 18 to 20.

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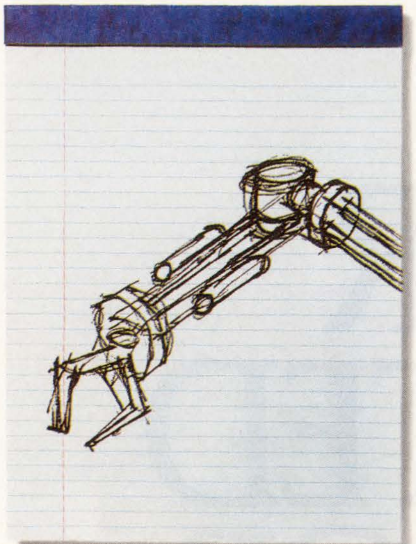

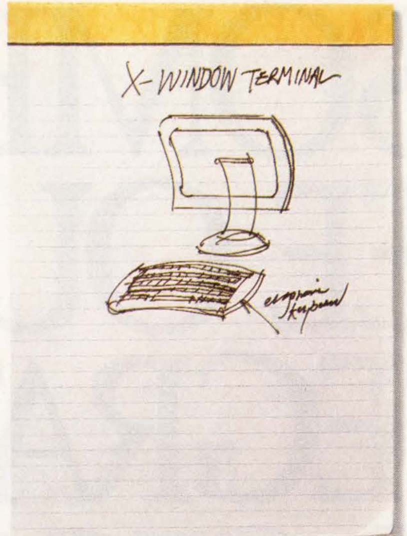
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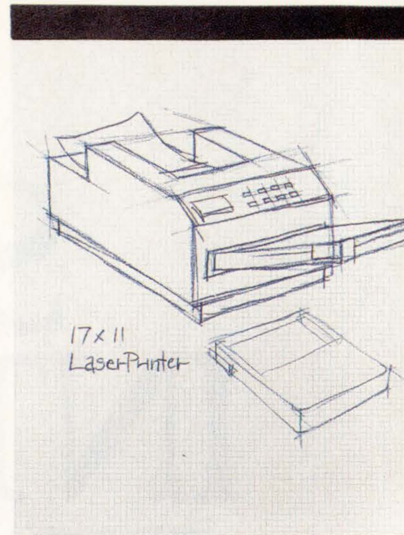
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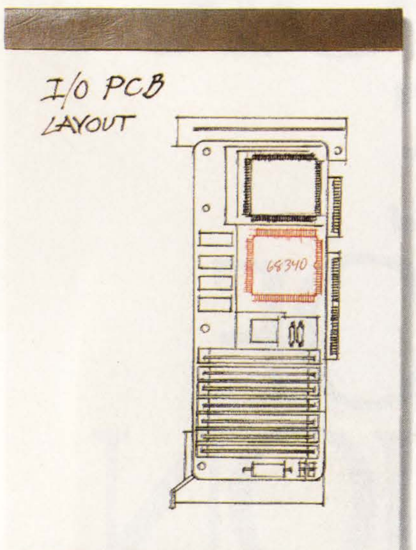
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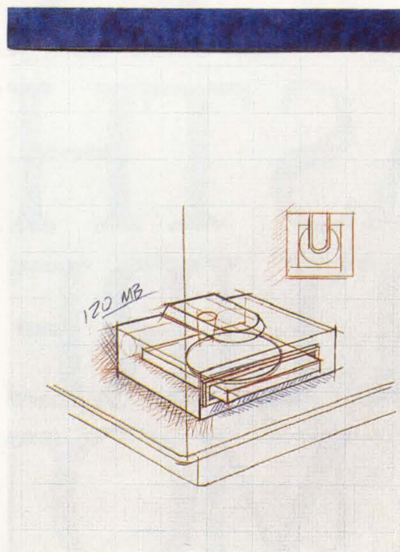
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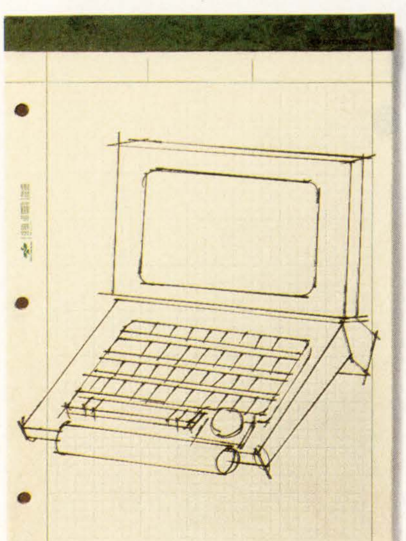

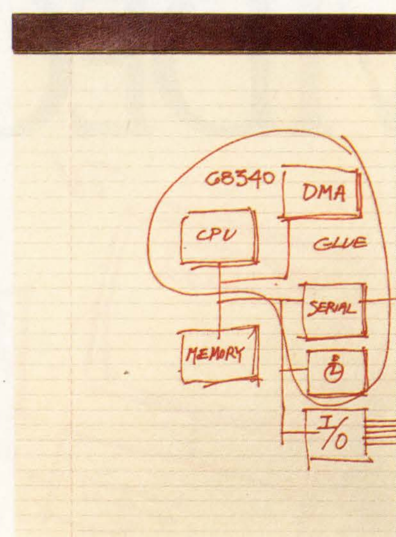
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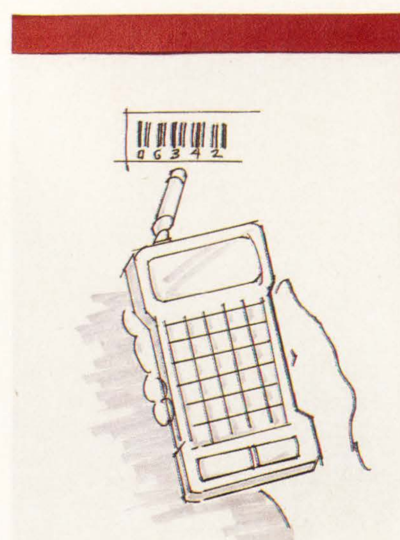
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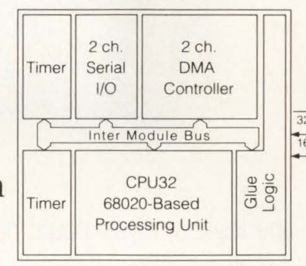

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Although digital signal processors or DSP chips have only been available for a decade, they're being used in more and more applications. To many engineers, DSP is still black magic. For example, at first glance it's difficult to understand how a series of multiplication and addition instructions can be made to "filter" or transform a signal.

While the IEEE has been sponsoring the International Conference on Acoustics, Speech, and Signal Processing (ICASSP) for many years, there hasn't been a good forum for those designers who wanted to know more about the practical aspects of signal processing. Luckily, the DSP scene is changing. EDN, in conjunction with Reed Exhibitions (a part of our parent company), has been putting together a DSP conference meant for potential DSP users and designers who have just started to use DSP products. In short, the conference concentrates on the practical aspects of DSP. You'll learn more about what's going on in DSP, about new products, and about how others have solved the DSP-related problems you may be facing.

Although the conference goes by a long-winded name, The International Conference on Digital Signal Processing Applications and Technology, we've nicknamed it DSPx. It's set for October 14 to 16, 1992, in the San Jose Convention Center in San Jose, CA. The technical sessions will explore how DSP is being used in fields of computers, communications, consumer and automotive products, industrial and medical areas, and in military and aerospace projects. You'll get more than an overview. Speakers will tell you about their applications, what they did, and how they did it. You'll get details that will help you design DSP-based circuits, software, and products.

In addition, you'll have the opportunity to meet and talk with representatives from most DSP-related companies. Whether they supply chips, boards, systems, or software, companies will exhibit their wares at DSPx. We're also setting aside time for short manufacturer presentations on new products and technologies. If you're a designer or a manager who is using, or who anticipates using DSP, make plans to be in San Jose in October for the DSPx gathering.

I am actively soliciting papers for all the sessions. The conference committee has appointed session administrators, and I'll forward your proposals to them. The main point is that papers can't be product pitches or descriptions. Instead, they must talk about DSP applications, and they must give attendees information they can use. If you're interested in presenting a 20-minute talk or in attending, you can drop me a note by FAX or by MCI (EDNTITUS), and I'll send you information. You can also send requests to DSPx, Reed Exhibitions, 999 Summer St, Stamford, CT 06905 USA. Phone (203) 352-8367, FAX (203) 964-0176. If you're interested in introducing a new DSP-related product, I'd like to hear from you, too. You should submit entries by June 1, 1992.

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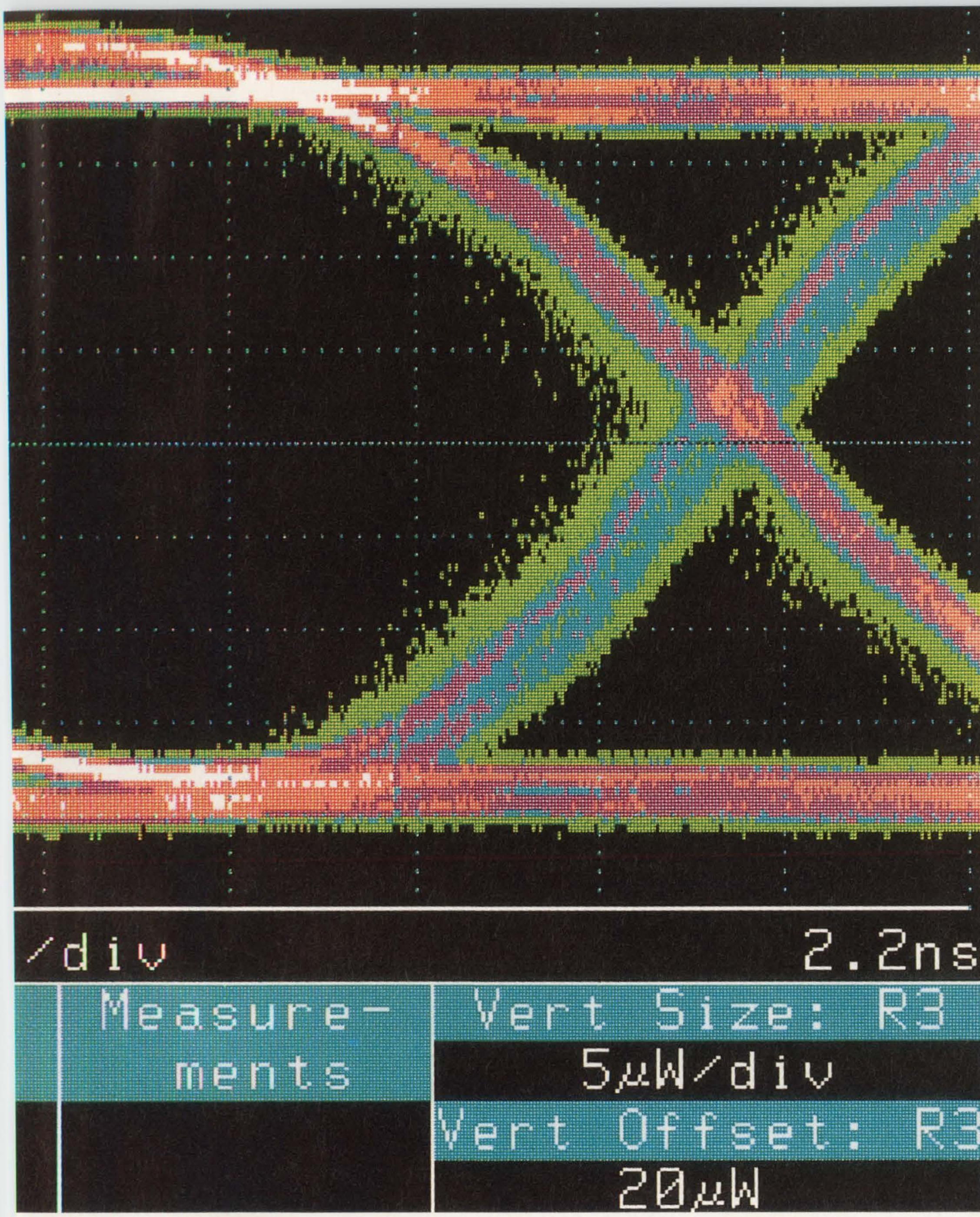
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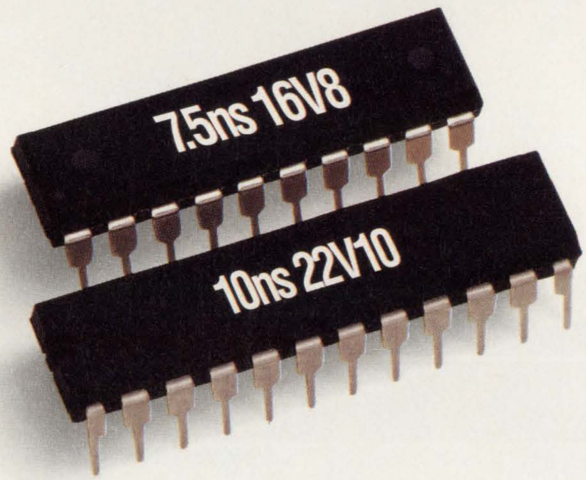

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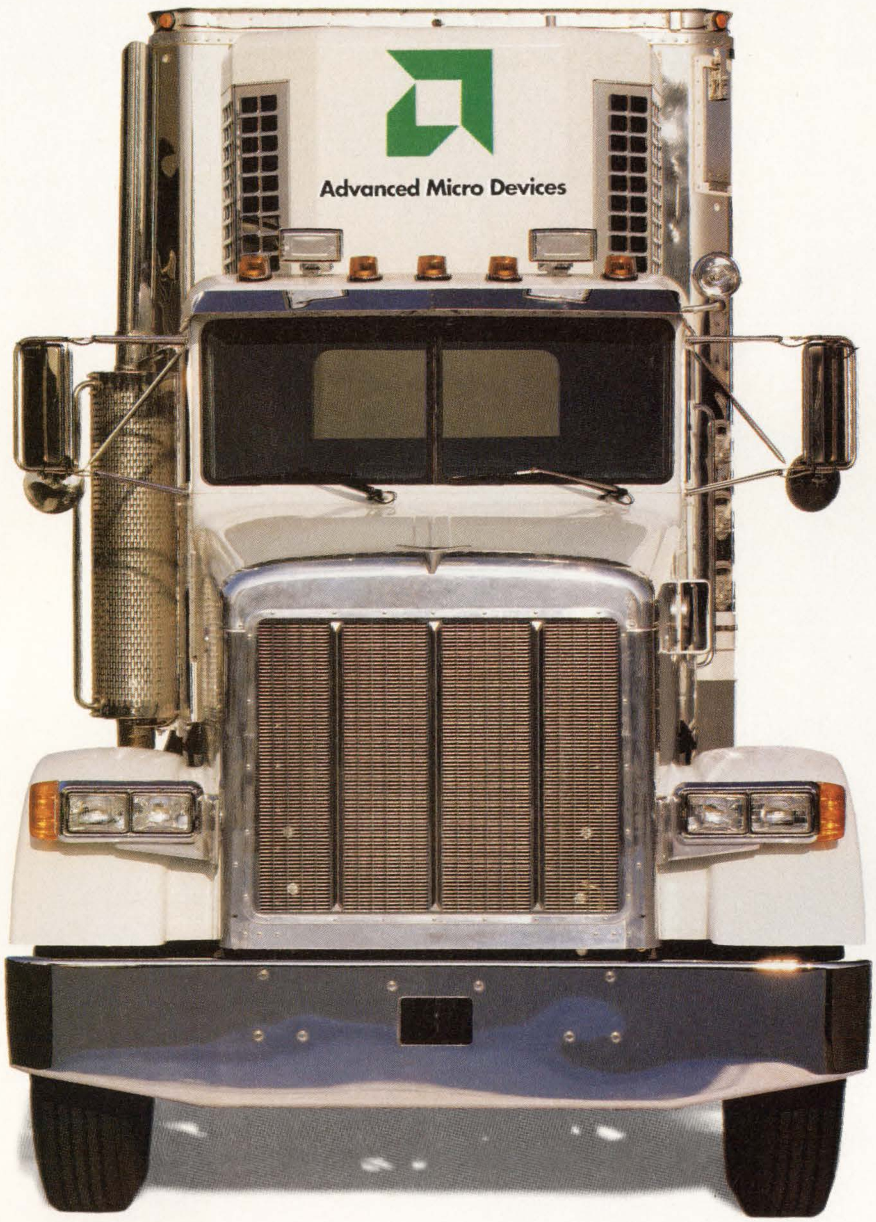

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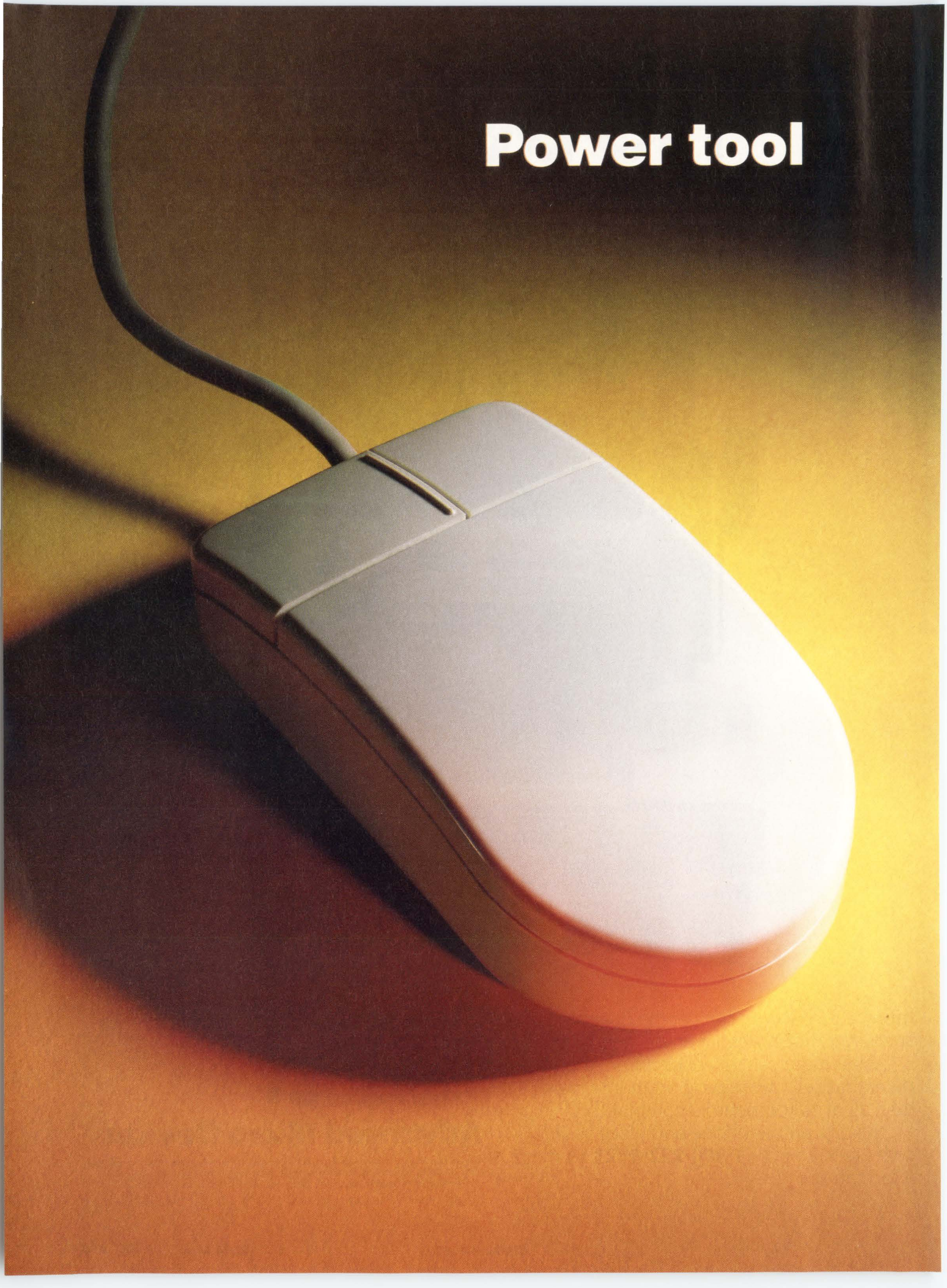

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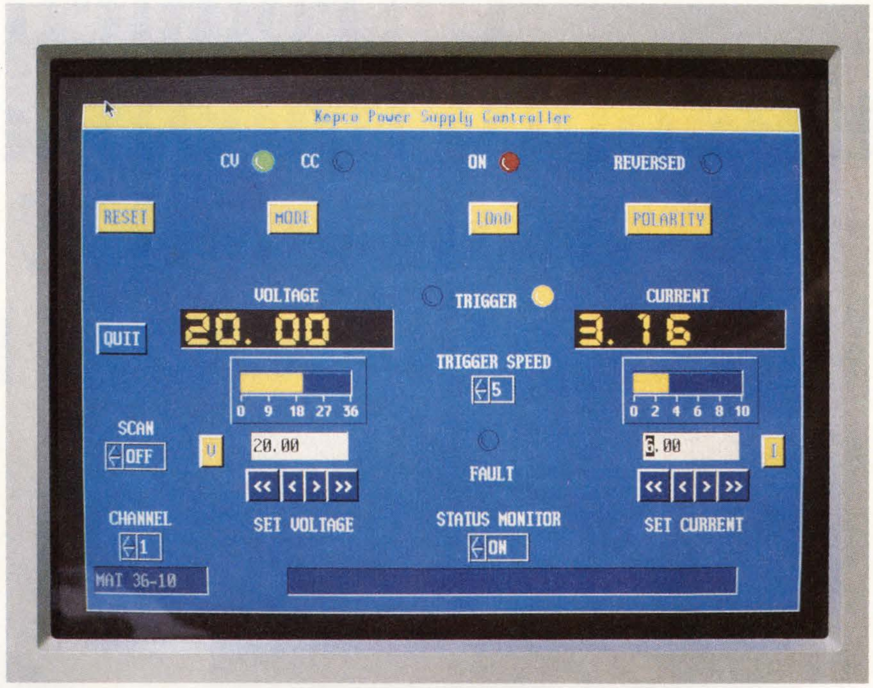

Other power supplies have knobs or keypads. Kepco's "MAT" lets you use your mouse...
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Kepco's MAT power supplies implement LabWindows.(1) The interactive screen lets you use your mouse to set voltage and current and even open and close load and polarity relays. Kepco's MAT power supplies report back their actual voltage, current and status.

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(1) LabWindows © National Instruments

Three 360W Power Modules shown in RA 50 Housing

LabWindows runs on 386 DOS-based computers with a VGA display and, of course, a mouse. We have drivers for all of the **SN** digital interfaces, type **MAT** power supplies and the low-voltage **BOP** series bipolar power supplies. The PC can drive the power supplies via the IEEE-488 bus using Kepco's model **TMA 488-27** interface to fan out from one GPIB address to as many as 27 power supplies, or the PC can drive the power supplies directly via an internal half-card called **TMA PC-27.** The **BOP** require the plug-in interface card, **BIT TMA-27.**

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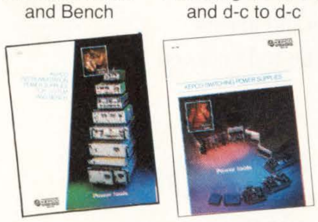

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CIRCLE NO. 53

Generators take the hassle out of defining waveforms

DAN STRASSBERG, Technical Editor

A signal source that uses digital technology and includes libraries of predefined functions can make short work of specifying waveforms.

Signal sources that produce predefined as well as user-defined functions are making waves in the once-stodgy waveform-generation field. These instruments are a step beyond first-generation arbitrary-waveform generators (ARBs). First-generation ARBs sometimes aren't especially easy to use. But by now they're old hat to many EEs, and most of them do provide nearly all of the flexibility you ever could want. They use D/A-converter technology, but they're not just DACs under another name. (See **box** "You need more than a DAC to build an ARB.")

The problem that many users had with first-generation ARBs was getting the instruments to produce common signals (waveforms) without having to go through the time-consuming step of waveform definition. Regardless of how cleverly vendors designed the waveform-definition software used with ARBs, or how well ARBs' built-in waveform-generation features worked, users who merely wanted common signals balked at getting involved with any process more complex than pushing a few buttons or setting a few switches.

Through such techniques as using function libraries, instruments based on ARB technology now make obtaining basic waveforms simple. In most cases, they achieve this simplicity without sacrificing the ability to produce user-defined and customized waveforms. In several cases, the generators use local intelligence—even DSP μPs—to synthesize the waveforms from data stored as algorithms. Algorithmic storage uses much less memory than point-by-point storage.

Compared with classic analog function generators, units based on digital technology are more flexible: the repertoires of most go well beyond analog generators' standard menu of sine, square, ramp, triangle, and sawtooth waves. With most digital units, you can combine library waveforms to create custom signals, instead of having to define them

Emphasizing the importance of waveform generation's long tradition is this montage of the panel of Hewlett-Packard's 8904A overlaying a photo of the company's venerable 200CD. The 200CD, a sine-wave oscillator, is a close descendent of Bill Hewlett's 1939 original 200A.

from scratch. Also, the digital units' outputs are more stable and predictable than those of typical analog generators. Most analog generators derive their timebases from RC oscillators, whereas most digital units have crystal timebases. Some digital units develop their output frequencies from the timebase via direct digital (frequency) synthesis (DDS).

DDS helps to make waves

Direct digital synthesis is at the heart of several instruments listed in **Table 1**. Some vendors refer to these DDS-based generators as function synthesizers. Although some function synthesizers lack the custom-waveform-generation capabilities of ARB-based units, DDS provides a long list of benefits, including the abilities to set frequencies with many digits of precision; change frequencies rapidly; and provide phase continuity when the frequency changes. (That is, the generators introduce no discontinuities in supposedly continuous waveforms.)

In this era of ASICs, companies that use DDS see little, if any, downside in the technology. Stanford Research Systems' Dave Kruse says flatly that in a very short time, all waveform generators, except possibly some low-cost models used in education and field-service, will use DDS.

Stanford's original DS345 prototype, built from discrete components, occupied a densely packed 11×14-in. pc board. However, in less than a year, the firm reduced the design to one CMOS ASIC that consumes a small fraction of the discrete design's power and space and runs at higher frequencies. Implementing DDS via ASIC technology

You need more than a DAC to build an ARB

Any D/A converter can generate a signal that is an arbitrary function of time; all you have to do is supply the DAC with the correct data at periodic intervals. Indeed, if you are designing a product whose operation depends on synthesizing waveforms, but whose main purpose is something else, a single DAC will probably generate the waveforms quite satisfactorily. But function-generator instruments must serve a range of applications; the simplest possible implementations can't meet the expectations of many users.

A general-purpose generator needs several features not found in straightforward DACs. General-purpose generators must produce waveforms of varying amplitude. To be sure, a generator can vary the amplitude of a DAC's output by scaling the DAC's digital inputs, but at low-output amplitudes this approach uses only a small portion of the DAC's dynamic range. The result is that the DAC's fixed quantization error of ½ LSB (the least-significant-bit weight) becomes a large percentage of the output-signal amplitude, and the signal-to-noise ratio deteriorates. One solution is to add a second DAC—a multiplying DAC—to scale the output.

Adding such a multiplying DAC (or gain DAC) also provides a convenient place to introduce a signal that modulates the amplitude of the output waveform. Some generators assign the gain-control and amplitude-modulation functions to separate multiplying DACs, however. Note that if a multiplying DAC performs the modulation, the generator won't accept externally generated modulating signals in analog form. Moreover, to see the modulating waveform as something other than the envelope of a modulated carrier, you must set the main DAC to produce dc.

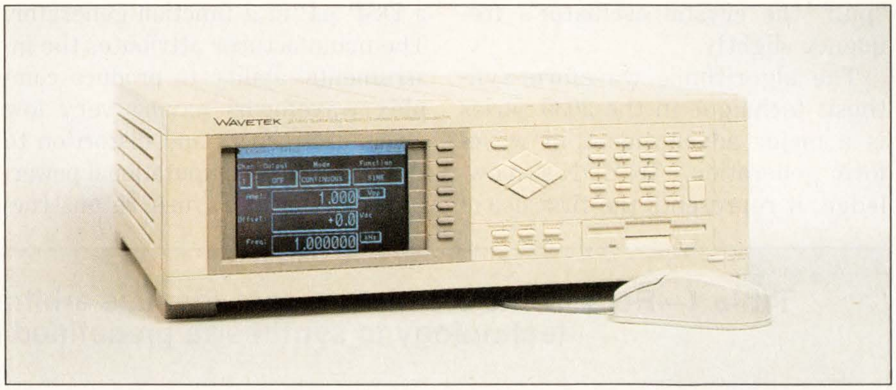
If the output waveform must ride on a programmable dc baseline level, single-DAC designs can experience a dynamic-range problem similar to the one found in generators that use one DAC for both waveform synthesis and gain control. The values that represent the waveform at the DAC input can include a quantity corresponding to the baseline. However, such numeric offsets reduce the portion of the DAC's dynamic range usable for representing the waveform. A more flexible approach uses an offset DAC whose output sums with the output of the waveform DAC (or the output of the waveform DAC multiplied by a scale factor set by the gain DAC).

Here a DAC, there a DAC, everywhere a DAC

So a single-channel waveform generator can include four DACs, one for generating the output waveform, one to perform amplitude modulation, and one each to control the gain and to provide a dc offset. But the number of DACs doesn't tell the whole story about signal generators' DAC requirements. Obtaining artifact-free waveforms requires special care, particularly to remove glitches from the outputs of the DACs that generate the output waveform and that introduce modulation. The sources of these glitches or transients include time skew among the DACs' several bit inputs and coupling of logic-level signals through the capacitance of the DACs' bit switches. The remedies range from using double-rank registers for correcting time skew among the DACs' digital inputs to using specialized sample-and-hold circuits (deglitchers) to smooth the DAC output transitions.

Unlike the majority of component-level DACs, most general-purpose waveform generators can drive reasonably heavy loads. Typical specifications are ±5V permits small size, low cost, and low power that are very attractive for waveform generators. Kruse says the question now is not *whether* competing companies that aren't using DDS will make the switch, but *when* they will do so.

Analogic, which also uses DDS, in its 2030 and 2030A, has found some ways to refine the already elegant DDS technique. At high frequencies, close to the clock frequency, DDS runs into limitations on the resolution of frequency adjustments. To overcome these limitations, the Analogic generators



Attractive styling, relatively simple panels, and displays with graphics capability characterize the look of many of today's waveform generators. This one is Wavetek's 295, a unit with a 50-MHz data rate and as many as four channels. The generator stores waveform definitions in nonvolatile memory.

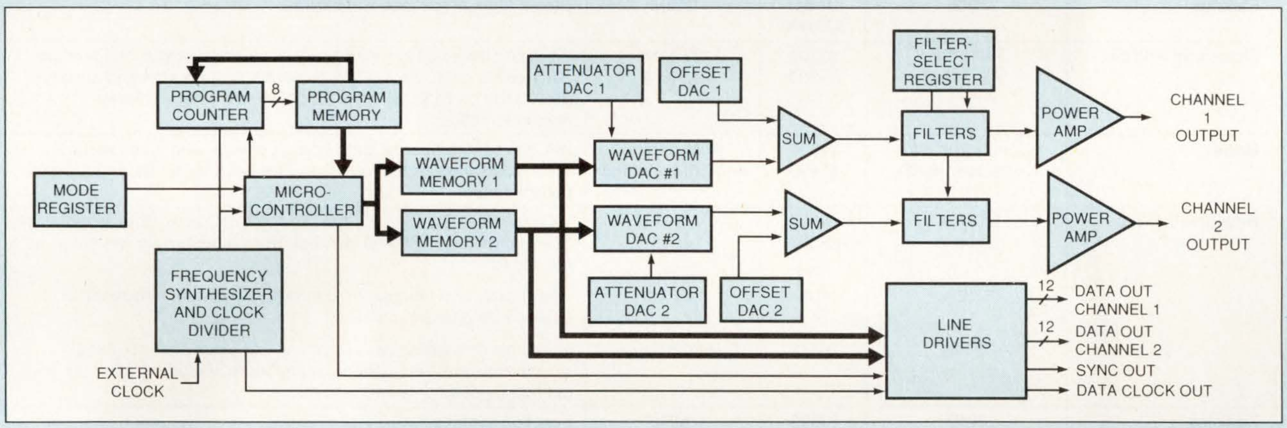


Fig A—This 2-channel generator, Signatec's AWG502, fits on a single ISA bus board. Note the use of waveform, attenuation, and offset DACs for each channel. Also note the programmable-cut-off-frequency lowpass filters and power amplifiers for each channel.

into 50Ω and ±10V into an open circuit. Those specifications translate to a maximum output current of 100 mA. Therefore, in addition to all of the other components that make up the instrument—the several DACs mentioned already; the memory; the oscillator; the microprocessor(s) and other digital circuits; the power supply; the front panel; and the panel interface—a general-purpose function generator includes one or more output amplifiers. And each of these amplifiers can have its own gain and offset DACs.

Fig A shows the block diagram of the Signatec AWG502, 2-channel ISA bus waveform generator board, a commercial product that uses most of the techniques discussed in this box. (The AWG 502 has no modulation DAC.) Don't assume, however, that all of the generators in **Table 1** have basically similar architectures—they don't; the products use many different circuit approaches.

Note the AWG502's switchable-frequency lowpass filters. Although these 3-pole filters may prove inadequate for converting square waves into high-quality sine waves, some vendors (Stanford Research, for example) produce low-distortion sinusoids by using automatically tuned high-order lowpass filters to remove square-wave harmonics. Because a square wave's digital representation requires a minimal-length sequence—just 2 samples/cycle—many generators can produce square waves at half their clock rate; waveforms whose representations require more samples have lower maximum frequencies. Thus, at a given clock frequency, a generator that creates sine waves by lowpass-filtering square waves can produce higher-frequency sine waves than a generator that uses longer data sequences and little or no filtering.

WAVEFORM GENERATORS

"pull" the crystal oscillator's frequency slightly.

The algorithmic waveform-synthesis technique in the 2030 series is a major advancement in waveform generation. To EDN's knowledge, it represents the first use of a DSP μP in a function generator. The manufacturer attributes the instruments' ability to produce complex waveforms having very low levels of artifacts and distortion to the DSP chip's computational power.

The generators use reconstruction filters to attenuate artifacts inherent in synthesizing waveforms from a finite number of sampled data points. Unavoidably, the reconstruction filters introduce distortion of their own. However, this distortion is predictable; to mini-

Table 1—Representative instruments that use arbitrary-waveform-generation technology to synthesize predefined functions

Vendor	Model	Base US list price	Maximum data rate (samples/sec)	Comments
Analogic	2030 2030A	$2995 $3995	50M 50M	Compared with the 2030, the 2030A adds extensive waveform libraries and arbitrary-waveform capabilities. Other models have rates to 8000 Msamples/sec.
Flexstar	7000	Under $20,000	250M	Stores eight predefined waveforms.
Fluke and Philips	PM 5138 PM 5139	$3700 $4300	20.48M 20.48M	Specified data rate is for arbitrary waveforms, which can contain 1024 points each. Standard waveforms include sine and squares (to 10 MHz on 5138; 20 MHz on 5139) and others at lower maximum rates.
Gage	Compugen 840 Compugen 840A	$1900 $1400	40M (8 bits) and 20M (12 bits)	ISA bus plug-in boards. Both boards offer 8- and 12-bit resolutions. Load waveforms from disk. The 840A lacks the 840's digital pattern output.
Hewlett-Packard	E1340A E1445A	$2500 $8000	42M 42M	VXI modules: E1340A is B size; E1445A is C size. Both respond to SCPI commands. E1445A can hop from waveform to waveform at full speed.
	8770A	$26,000	125M	Offers extensive modulation capability. Changes frequency in 8 nsec with phase continuity.
	8904A	$3175	600 kHz[1]	Multifunction-synthesizer — not an ARB. Produces six fixed waveforms (and, with options, many more, including complex ones defined by deep data sequences).
Keithley	3910 3930A 3940	$1695 $3590 $5390	1 MHz[1] 1.2 MHz[1] 20 MHz[1]	Function synthesizer. Adds sweep and burst over full range. Adds arbitrary-waveform and dual-synthesizer capability.
LeCroy	9101 9112	$10,900 $15,900	200M 50M	1 channel, 8 bits, 64-kbyte memory. 2 channels, 12 bits, 64k-words/channel. Other models at intermediate prices.
Pragmatic	2201A 2202A 2205A 2411A	$9985 $2495 $10,985 $2495	2M 20M 50M 2M	3 channels, 16 bits, 64k-words/channel. 1 channel, 12 bits, 32k-word memory. 2 channels, 12 bits, 256k-words/channel. 1 channel, 16 bits, 64k-word memory.
Rapid Systems	R4010	$2995	10M	PC-based unit. With vendor's R4 software ($995), recalls predefined waves, lets you define and edit waveforms.
	R4350 R4300	$1495 $995	5M (pulse)[2] or 300 kHz[2] (other waveforms)	ISA bus direct-digital-synthesis function generators. Sine, triangle, noise, sawtooth built in. 12 bits. 8k-word arbitrary-function memory. R4300 lacks R4350's high-speed pulse capability.
Signatec	AWG502	$3500	50M	Plugs into 16-bit ISA bus. Has two independent 12-bit channels. Uses either or both as 12-bit digital word generator. 64k-word waveform memory for each channel. Loop/branch capability lets you define very long waveforms. Ten lowpass filters per channel.
Stanford Research	DS345	$1895	40M	Direct-digital-synthesis generator, 1-μHz frequency resolution. 16k-word arbitrary-waveform memory. 12-bit amplitude resolution. Built-in sine, ramp square, triangle, and noise waveforms.
Wavetek	75A	$1695	5M	Nine waveforms stored in nonvolatile memory. Arbitrary waves to 8192 points.
	295	$5995	50M	Allows one to four channels; outputs can be summed. Stores waveforms in nonvolatile memory and on optional floppy disk.

Notes:
[1]Maximum sine frequency
[2]Output frequency

WAVEFORM GENERATORS

mize it, the generators intentionally correct the numeric data they send to their DACs. This correction is the inverse of the filter's distortion. A second correction term compensates for the sin(x)/x sampling roll-off. Each time you adjust the generator's output, the DSP μP reconvolves the sampled data with the inverse of the filter and sampling-roll-off functions and modifies the waveform memory's contents accordingly.

Producing accurate waveforms is only part of the challenge waveform-generator designers face. Making the instruments easy to use is another big challenge. Generator designers have invested considerable effort and creativity in designing the controls and displays you use to define arbitrary or custom waveforms on their equipment. The importance that vendors attach to this human interface is entirely appropriate; the interface has a profound effect on users' productivity and, therefore, on users' reactions to a product.

Some vendors take the position that the best way to define waveforms is to run a specialized software package on your PC. According to this argument, cluttered lab benches and cramped instrument panels just aren't conducive to doing a good job of waveform definition; you'll do the job best while you are seated in front of the PC, with its large screen, full keyboard, and mouse or trackball.

But a quick look at the brochures for the instruments in **Table 1** reveals that using PCs to define waveforms is far from universal. Several vendors have devoted much effort to building waveform-definition features into their instruments and to making the use of those functions natural and intuitive.

One such firm is Pragmatic Instruments. Pragmatic's generators work with a mouse or a trackball and connect to virtually any analog or digital oscilloscope. The scope display allows you to watch the results as you define and edit arbitrary waveforms or combine and customize predefined ones. By using algorithmic waveform storage, the firm's 2202A and 2411A each store 20 predefined signals that you can make part of custom waves. Unlike the Analogic 2030 series, though, the Pragmatic generators don't use DSP μP's. Instead, the units' main μPs translate the mathematical signal definitions into point-by-point waveform replicas. Because the generators include RS-232C interfaces and offer IEEE-488 ports, users who prefer to define waveforms on a PC have the option of doing so.

User interfaces run the gamut

For combining and customizing the waveforms in its repertoire, the Analogic 2030A relies on displaying block diagrams of mathematical operations on a backlit LCD screen. This scheme portrays the manipulations you request the generator to perform in a way that mirrors how you probably think about the operations. Like the Pragmatic generators, this unit offers users the freedom to download waveforms via RS-232C or IEEE-488 ports.

You don't get the precision, ver-

For more information . . .

For more information on the waveform generators discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you read about their products in EDN.

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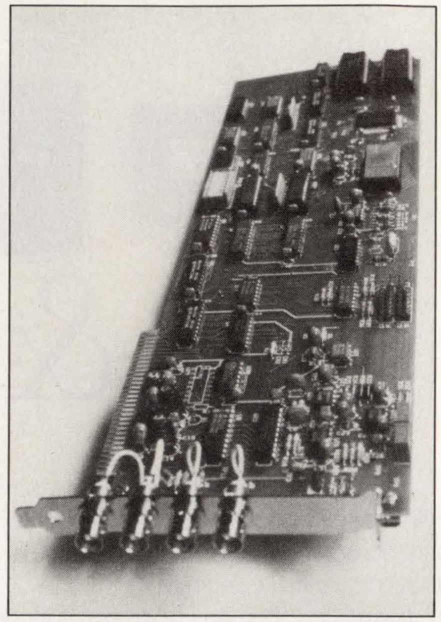
WAVEFORM GENERATORS



Waveform generators come in a variety of shapes and sizes. This unit, the R4300 from Rapid Systems, plugs into the ISA bus. At $995, it is the least expensive unit in Table 1.

satility, and repeatability of these digital generators for free. The price range of the units in **Table 1** is $995 to $26,000, excluding options (⅔ of the units have prices below $5000). On the other hand, a good-quality basic analog generator whose maximum output frequency is several MHz costs just a few hundred dollars. So, like analog oscilloscopes, analog function generators are not destined to disappear any time soon. But, like digital scopes, function generators based on digital technology will appear on the lab benches of more and more EEs whose applications allow little room for performance compromises. EDN

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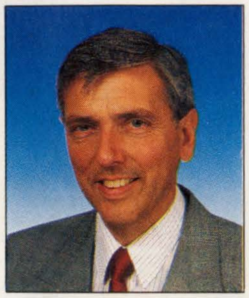
HIGH-POWER MODULAR SWITCHING POWER SUPPLIES

Custom-configured supplies promote design flexibility

BRIAN KERRIDGE, Technical Editor



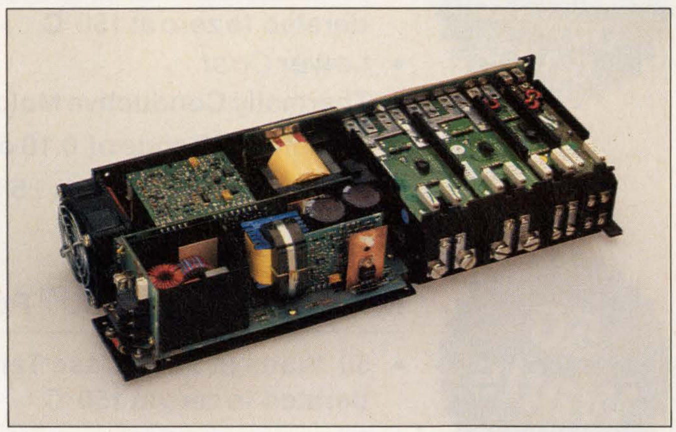
Power supplies made up of submodules let vendors satisfy wide-ranging power and voltage demands at lightning speed and without an engineering charge.

Predicting power-supply requirements before a design is complete is a headache familiar to all designers of electronic products. When the product consumes power in the 200 to 2000W range and has multiple voltage rails, the headache intensifies.

Some modular-power-supply vendors offer relief from this burden by offering a class of custom-configured supplies that employ submodule construction. Essentially, within the same modular enclosure the vendor can mix and match submodules to adapt a power supply to meet your product's specific output requirements. What's more, vendors have fine-tuned their manufacturing process to the point where a delivery time of 10 days or less is the norm.

Such flexibility allows you some freedom to make design changes or offer product upgrades without being constrained by a fixed-design power source. You can make these changes with minimal delay to your own development schedule. Some modular supplies accept as many as eight submodules, which gives you enough margin to introduce a new voltage rail to your design if necessary or boost current capability on an existing rail with a parallel module. Conversely, if you've been overly conservative in power budgeting at the outset of a design, you can reduce the margin and pass lower line-power requirements to your customers.

For the majority of power supplies in this class, the internal power-supply configuration for each design is fixed by the vendor at manufacture. Generally, the submodules are soldered to an internal subframe mother board. Philips and Vicor recently introduced modular power supplies that let users change around the submodules; that is, the supplies are field configurable. The submodules use plug and socket connectors, and you can remove submodules after releasing a few fixing screws. This facility offers the possibility of shipping extra power-supply submodules to customers as part of a product upgrade kit—for example, when adding a floppy drive or extra plug-in cards to a system.



Taking the cover off a Coutant-Lambda 600W MML series switcher shows a snug fit for as many as six output submodules. Fan cooling, power-factor correction, and a single input range of 85 to 265V ac are standard features. The company guarantees 10-day delivery for this series.

Although configurable power supplies bring considerable benefits to the user, the original motivation for using submodules came from manufacturers

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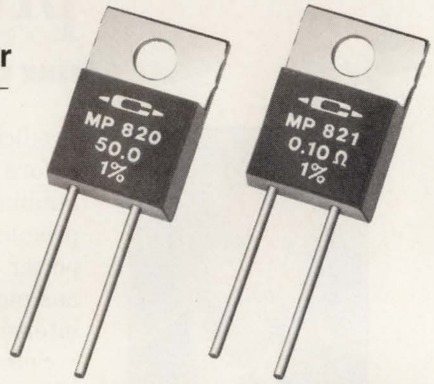

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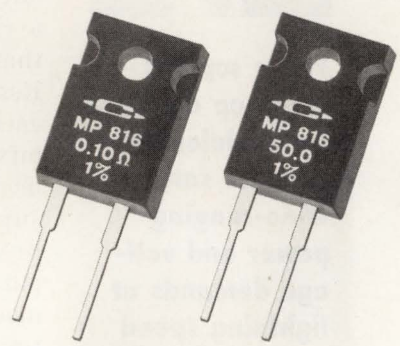

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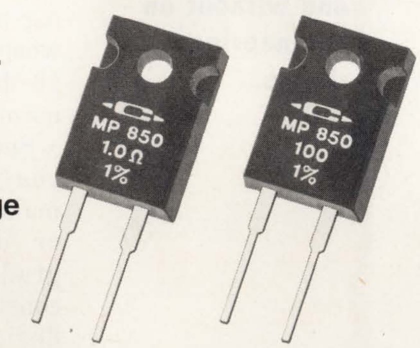
- Resistance Range of 1.0 ohm to 10K
- Tolerance ±1%, ±2%, ±5% or ±10%



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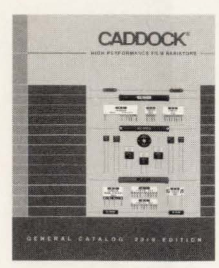

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themselves. Submodules let vendors offer products with a range of voltage-level and power-output combinations while minimizing the number of subassembly variants passing along their production lines. Naturally, this approach has a cost penalty. But set against the design flexibility and rapid delivery that results, it's a penalty users find acceptable.

Table 1 shows specifications for a selection of power supplies that use submodule construction for fast-delivery custom products.

Lack of standardization exists between models from different vendors, and this variation can be both a weakness and a strength in your choice of model. Physical constraints will lock you to one vendor because, although the external dimensions column shows similar overall sizes for different models, the fan position and input-output connectors are quite different. But conversely, because submodules' maximum output power also differs among vendors, your requirements may form a better match with one vendor's submodule power capacity than with another's.

Regarding overall power-handling capacity, one important point to note is the maximum operating temperature at which the supply will deliver its full power. Different vendors choose to specify this temperature as 40, 50, or 55°C. The power-derating figure for a modular supply in this class is typically 2.5%/°C. This figure indicates that if a supply's full power limit is specified as 50°C, then at 70°C the power-output capability will have already dropped by half. Rather obvious, but worth pointing out, is that in some models a full set of sub-

Table 1—Representative custom-configurable modular power supplies

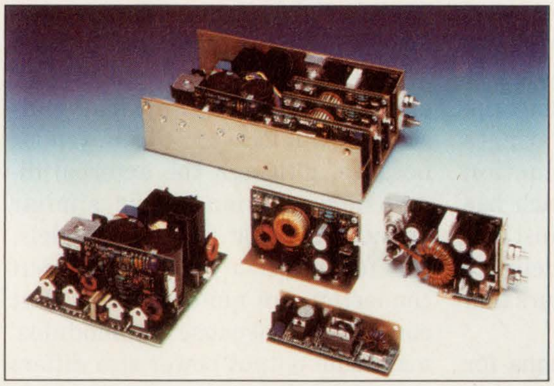
Manufacturer	Model	Standard output voltages (V)	Maximum total power (W)	Maximum operating temperature before derating (°C)	Maximum submodule power (W)	Maximum number of output submodules	Enclosure dimensions (in.)	Comments	Price* (25+)
Astec Standard Power	Spectrum-VS	2,3.3,12,15,24, 28,36, or 48	1200	50	240	4	5.0×5.0×11.0	Single input range of 85 to 264V ac; holdover storage 30 msec; due second quarter of 1992, prices provisional.	$1975
			2000	50	240	4	5.0×8.0×11.0		$3150
Coutant-Lambda	Omega	5,12,24, or 48	600	50	60	6	2.5×5.0×13.75	Power-factor correction standard; single input range of 85 to 265V ac; meets VDE 0871 Curve B.	f447
		5,12,24, or 48	1500	50	200	5	5.0×8.0×11.0		f861
Deltron	Moduflex-M	2,3.3,5,12,15 18,24,36, or 48	750	50	150	7	2.5×5.2×9.6	DM series accepts dc input; power-factor correction and fan cooling optional.	$875
Philips Industrial	300 Family	5,12,24, or 48	800	55	800	2	4.0×5.0×12.0	Field configurable; power-factor-correction standard.	$1100
		5,12,24, or 48	1600	55	800	2	8.0×5.0×12.0		$1800
Power-One	SMP/SPF series	2,3.3,5,8,10, 12,15,24,28,36, or 48	1500	50	1250	5	5.0×8.0×11.0	Dual- and triple-output modules available; optional power-factor-correction submodule takes up one slot.	$1200
Qualidyne Systems	21 to 36 series	4,5,12,24, dual 24, or 48	2000	50	1500	5	5.0×8.0×13.75	Wide output adjustment; for example, 5V nominal adjustable 2 to 56V.	$1695
Unipower	U-series	2,3.3,5,12,15, 24, or 48	800	50	240	7	3.75×8.0×11.0	Similar P-series with low-profile enclosure.	$1520
	H-series	2,3.3,5,12, 15,24, or 48	1200	50	624	6	5.0×8.0×11.0	Power-factor correction standard.	$1269
Vicor	Flatpac	5,12,15,24,28, or 48	600	40	200	3	1.37×7.4×8.6	Similar Compac family accepts 24 or 48V dc inputs; power-factor correction planned.	$575
	Mini Stakpac	2,3.3,5,12,15, 24, 28, or 48	600	40	200	4	1.9×5.5×12.0	Power-factor correction not available	$963
	Stakpac	2,3.3,5,12,15, 24,28, or 48	1200	40	200	8	3.2×5.5×11.5	Power-factor correction to 0.75 optional; adds approximately 10% to the price.	$1634
	Megapac	2,3.3,5,12,15, 24,28,48, or 96	1200	40	200	8	3.4×6.0×11.7	Field configurable; power-factor correction planned.	$1436

*Assumes maximum power capability and maximum number of submodules.

modules running at their individual full power would exceed the maximum power rating of the supply overall.

Another power-limiting factor to observe concerns the voltage-trimming adjustment found on all models. The maximum-output-power specification for a submodule determines an output-current maximum assuming nominal output voltage. If you adjust the voltage down, the specified current maximum remains the same; therefore, the total output-power capability falls. On several models the adjustment range is approximately ±10%, so the corresponding drop in power is probably within your design margin. On other models, such as members of Coutant-Lambda's Omega series, the voltage-adjustment range extends from +20% to −60% of the nominal output. In this case, you need to identify clearly the consequent drop in power when the supply is running at well below the nominal voltage.

You should also consider other current-limiting factors when selecting a power supply. In particular, transient currents in your design can cause temporary overload that may reflect back into the supply and reappear as glitches on other voltage outputs. Start-up currents can easily double average running levels, particularly when motors are involved. A submodular custom-configured power supply's transient current is typically 50% overload for 500 msec.



The submodular design of Deltron's 750W Moduflex M switching power supply includes optional power-factor correction circuitry, fan cooling, and as many as seven output modules.

Switchers neutralize notoriety

Switching power supplies have the reputation of being rogue products when it comes to generating EMI and distorting the line supply. The trend by power-supply manufacturers to adopt EMC (electromagnetic-compatibility) specification VDE 0871 and line-disturbance specification IEC (International Electrotechnical Commission) 555 effectively counters this infamy, but many switchers in use have yet to conform.

The German VDE specification is the most stringent of the EMC requirements, and a few manufacturers choose to comply with its more demanding Curve-B limits (**Fig 1**). Many products that use switching power supplies, such as computing equipment, do not have to meet such strict EMC requirements themselves. But using a VDE-compliant switcher builds in extra margin.

Equally attractive is a switcher

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For more information on the power-supply products discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you read about their products in EDN.

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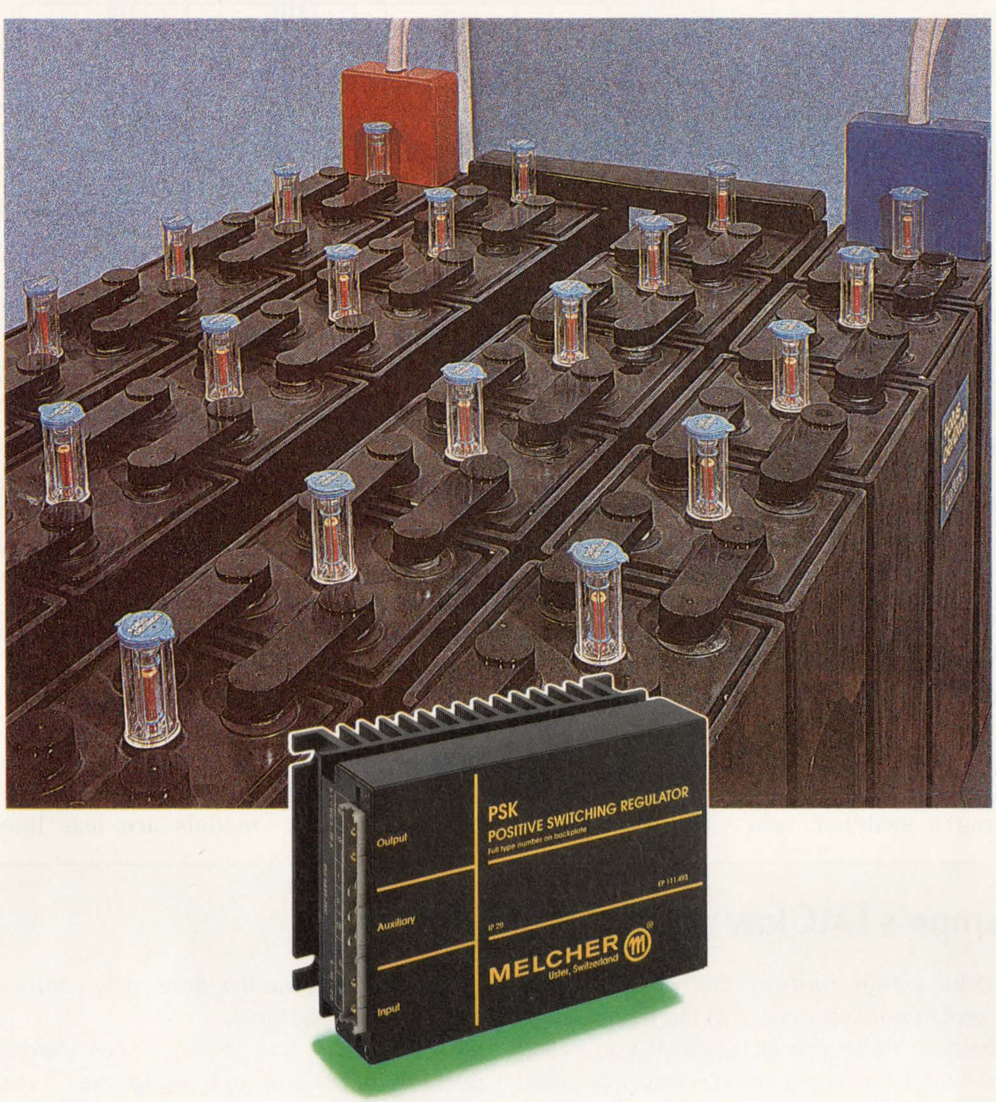

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that observes IEC 555 Section 2, which applies to the harmonic distortion of the line supply. High-power switchers have been a major cause of gross distortion in line supplies **(Ref 1)**. The effect results from the single short shot of line current drawn each time the line voltage passes its peak value.

IEC 555-compatible designs include control circuitry that ensures that many line-current pulses are drawn over one half cycle of the line voltage instead of one cycle. In addition, the density of the current pulses tracks the magnitude of the line-voltage waveform. The mean current and voltage waveforms are therefore of the same shape and in phase; ideally, the result is unity power factor. In practice, the technique achieves a power factor of approximately 0.99. An added bonus of supplies that use this technique is a single ac input-voltage range, which manufacturers generally specify as 85 to 265V.

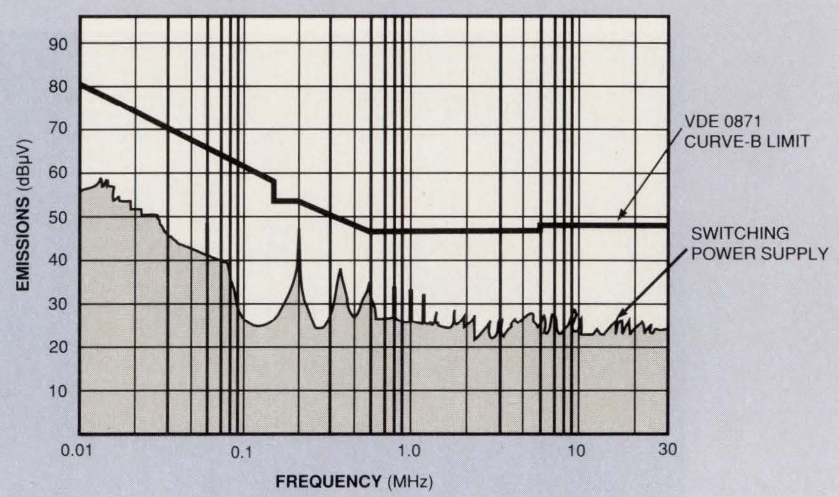

Fig 1—Power-factor-correction techniques alone still leave excessive levels of switching-frequency ripple current on the line supply. Additional internal ripple-current-cancellation techniques can make switching power supplies meet the tough Curve-B limits of the VDE 0871 specification by a comfortable margin. (Figure courtesy Coutant-Lambda)

When selecting a switcher, you need to check carefully how the product includes power-factor correction. Some vendors—notably Astec, Coutant-Lambda, and Philips—include the feature as standard. Other vendors offer power-factor correction as an option that may require an additional bolt-on unit. Generally, lower-power models are less likely than high-

Facing Europe's EMC law

Users of modular power supplies are well aware of potential EMI problems associated with the high-voltage switching techniques these products use. If you intend to incorporate a modular supply into a product destined for the European market, be aware that in the future your product will need to conform to EMC (electromagnetic compatibility) regulations by law.

The two specifications likely to apply to your product are European Standard EN 55022, which concerns emissions from information-technology equipment, and EN 60555, which is equivalent to IEC 555 and concerns line disturbances.

Although the EMC law was supposed to be in place throughout Europe January 1, 1992 **(Ref 2)**, legislation has yet to reach the statute books in most European Community countries. Because of this delay and the wide-ranging commercial implications of the law, EC authorities have set up a transition period during which manufacturers can opt to conform to existing national regulations or to meet the terms of the new EMC law straightaway. The transition period will end on December 31, 1995. After this date, only conformance to the law will be acceptable.

The difficulty now facing manufacturers is as much deciding if the law applies to their product as it is deciding how to get the product approved. Recently, the Commission of European Communities, in an effort to clarify its position, classified products into the broad categories of components, apparatus, systems, and installations. Their overall objective is to reduce the amount of duplicated test work. So, for example, components do not need to comply to the EMC law because they will be built into products that fall into the apparatus category, which must comply.

Strictly speaking, modular power supplies that are part of a larger product do not need to comply. In practice, however, switcher manufacturers accept that the law changes little for them. Their customers already expect conformance to EMC regulations and are now starting to expect power-factor correction as well. Europe's new EMC law only serves to reinforce those user demands.

MODULAR POWER SUPPLIES

power supplies to include this feature as standard. In Europe, compliance will soon become mandatory for power levels greater than 300W. The **box,** "Facing Europe's EMC law," briefly explains the law's background. EDN

References

1. Strassberg, Dan, "Power-factor-corrected switching power supplies," *EDN*, April 11, 1991, pg 90.
2. Kerridge, Brian, "Europe lays down EMC law," *EDN*, September 16, 1991, pg 57.

Brian Kerridge, Technical Editor, can be reached in the UK at (508) 28435; FAX (508) 28430.

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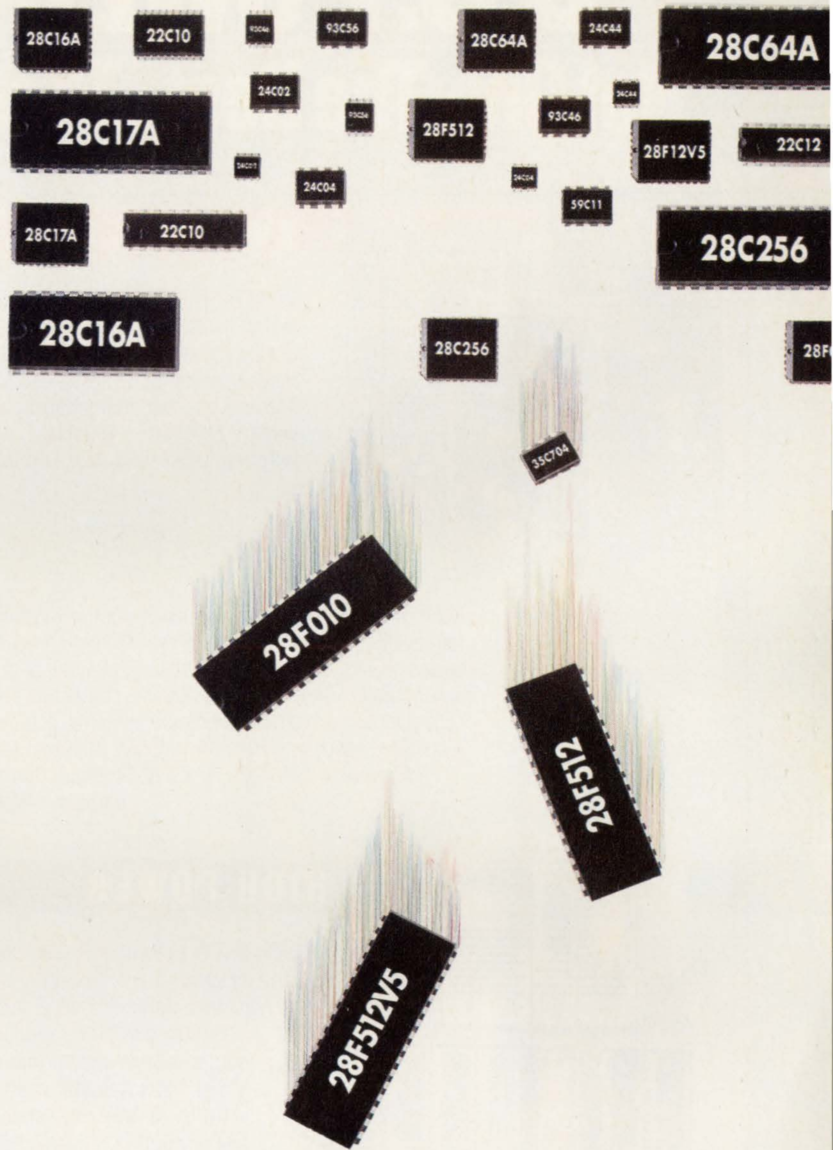

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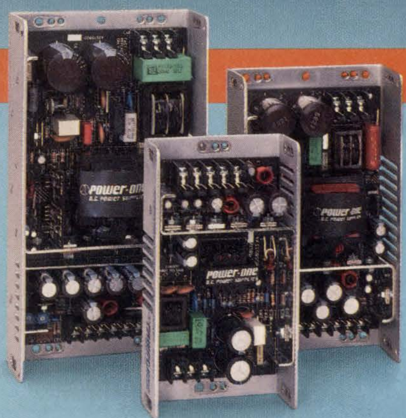

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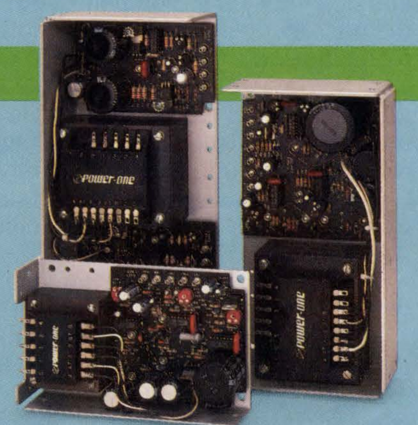

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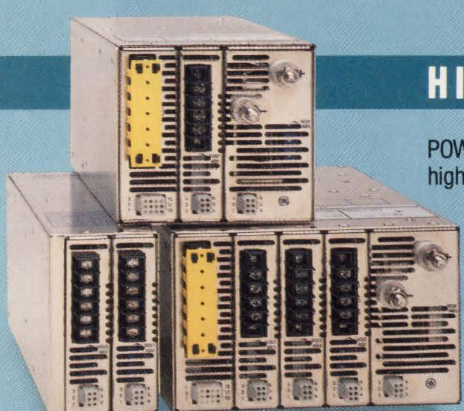

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CIRCLE NO. 65

Crystal oscillators provide precision in high-speed systems

TOM ORMOND, Senior Technical Editor

As system operating speeds increase, the need for high-precision clock sources gains importance. Crystal oscillators can provide the necessary precision and can do so without exacting any cost or packing-density penalties.

High speed and high density seem to be the two major design goals for today's system designers. When you look to provide a timing source for such systems, the crystal oscillator can fill the bill on both counts.

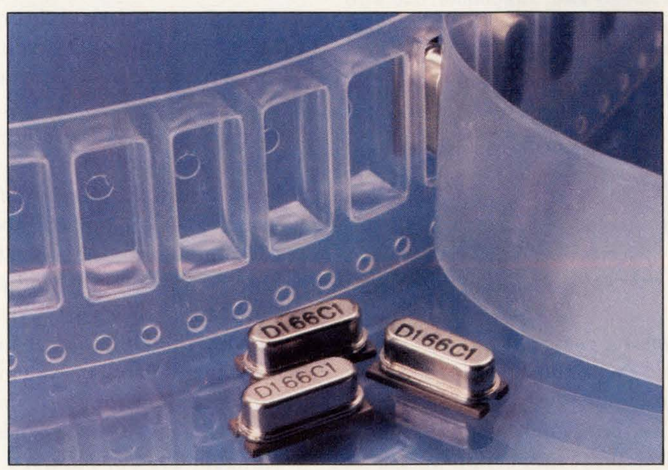
Crystal oscillators with output frequencies in the hundreds-of-megahertz range are readily available today. These devices have accuracies on the order of 0.01%. When it comes to density considerations, many of today's oscillators are housed in low-profile DIPs, and a good number of crystal oscillators are starting to appear in surface-mount packages.

Crystal oscillators offer designers another positive feature—flexibility. When you go looking for a clock source, you'll find it quite easy to select only as much oscillator as you need for the job at hand. There's no need to buy an oscillator with all the bells and whistles when you have no need for them. Oscillators are available that use a number of technologies that let you pretty much match your needs with the standpoint of frequency, stability, size, and cost that you want.

The most basic design is an uncompensated crystal oscillator (XO). In an XO, the overall frequency stability of the output relies solely on the capability of the internal crystal. Basically, the XO contains the crystal and buffer circuitry to develop logic-level outputs. Commonly available with outputs ranging from 1 to 150 MHz, today's XOs feature stabilities ranging to ±100 ppm over an operating range of 0 to 70°C. Units that provide lower or higher frequencies are also available. These oscillators typically use frequency dividers or multipliers, or they utilize a harmonic (overtone) of the basic quartz-crystal frequency.

The prime advantages of the XO are low cost and small size. On the negative side, XOs have relatively poor stability. However, designers will find that the simple XO is a good choice as a clock source in digital systems where environmental conditions are not too severe.

AVX/Kyocera, Champion, CTS, KDS America, M-tron, and Pletronics all offer basic crystal oscillators (**Table 1**). Available output frequencies range from 156 kHz to 120 MHz—certainly a good spectrum. All of these XOs come in DIP-style packages to accommodate high-density applications. Frequency stabili-



Housed in a 0.45×0.2×0.18-in. package, DSO-49 oscillators from KDS America are designed for high-density applications. They have outputs ranging from 0.156 to 50 MHz and feature a 50- to 100-ppm stability from −10 to +70°C.

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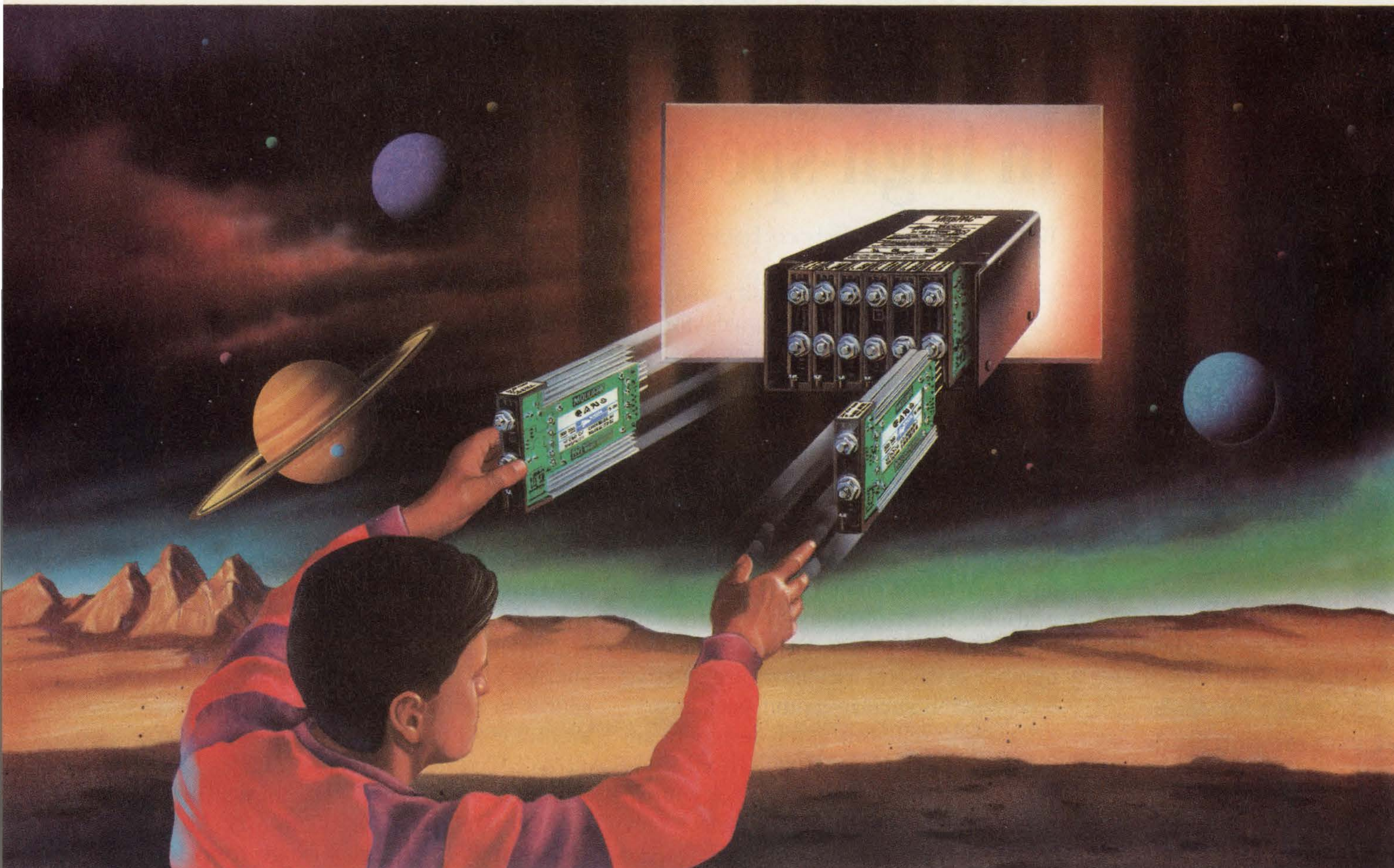

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ties range to 100 ppm and quantity pricing goes as low as $2.

The XO establishes a baseline for gauging crystal oscillator capability. At the other end of the stability spectrum is the oven-controlled crystal oscillator (OCXO). The OCXO represents the practical limit in commercial output-frequency stability. OCXOs are used as the main clock in large telecommunications systems, earth station networks, military applications, and other critical applications. Output frequency stability can be in the 0.001-ppm range.

In an OCXO, a temperature-controlled module houses the crystal and associated electronics. This module maintains the crystal at a stabilized temperature that is slightly higher than the highest ambient in which the oscillator is expected to operate. The OCXO is unmatched when it comes to output frequency stability—over a −55 to +85°C range, stability figures of 0.001 ppm are not uncommon. Over a narrower operating range, frequency stability figures will be even better.

Featuring a 100- to 170-MHz output capability, the M2100 from MF Electronics uses the system µP to let users program the output in 1-kHz increments. The oscillator output is ECL compatible and features a frequency stability of ±50 ppm.

Unfortunately, you have to pay for this performance. OCXOs draw considerably more power than other crystal oscillator designs. The OCXOs also require more pc-board space, take time to warm up to operating status, and are expensive.

Two factors affect power consumption—the amount of oven insulation used in the design and the temperature differential between the oven temperature and the ambient temperature. Warm-up time defines the time it takes for the oscillator to reach the operating temperature required to stabilize its output frequency. For the most part, warm-up time depends on the amount of power available and the thermal mass of the oven. Warm-up time can range into tens of minutes.

It is possible to use a single supply to power an OCXO, but it is much wiser to use one supply for the oscillator and one for the oven. For powering the oscillator, the supply must have the same regulation and noise characteristic as the supply being used to power system-logic circuitry. You really don't need a well-regulated supply to power the oven.

Bliley, Genwave, and Vectron all offer classical oven-controlled crystal oscillators. These manufacturers offer products that cover a 1-kHz

Table 1—Representative crystal oscillators

Manufacturer	Model	Type[1]	Frequency (MHz)	Stability (ppm)	Operating range (°C)[2]	Size (in.)	Price
AT&T Microelectronics	154	VCXO	10 to 55	50	−40 to +85	0.825×0.5×0.3	$10 to $30
AVX/Kyocera	KXO-01	XO	4 to 50	100	0 to 70	0.83×0.5×0.2	$2 (1000)
Bliley Electric	N26S	OCXO	0.001 to 20	0.005	0 to 70	2×2×1	$205.70 (100)
Champion Technologies	K11041	XO	40 to 70	100	0 to 70	0.8×0.5×0.3	$26.03 (100)
Connor-Winfield Corp	EV535-100	VCXO	25 to 80	50	0 to 70	0.8×0.5×0.26	From $65 (10)
CTS Corp	EX075	XO	250 to 400	100 to 1000	0 to 70	0.8×0.5×0.39	$175 (100)
Genwave Corp	250-0502	OCXO	10	0.015	−30 to +70	2×2×1	$355
KDS America	DSO-49S	XO	0.156 to 50	50 to 100	−10 to +70	0.45×0.2×0.18	$2.10 (1000)
MF Electronics	M2100	MCXO	100 to 170	50	0 to 85	0.825×0.5×0.2	$35 (1000)
M-tron Industries	MEH	XO	40 to 200	50	0 to 70	0.52×0.52×0.24	$14 (1000)
Murata Erie	DC2210 AH	DCXO	10 to 25	1	−40 to +85	0.79×0.79×0.45	$75 (1000)
Pletronics	SM1100	XO	1 to 120	25 to 500	0 to 70	0.485×0.39×0.185	$4 to $10 (10,000)
Q-Tech Corp	QT 2010	MCXO	10	0.03	−55 to +85	2×4×1	$780 (100)
Raltron	TF-65010-B	OCXO	1 to 20	0.2	−20 to +70	1.38×1.06×1.0	$65 (10,000)
TEW North America	TXS-1134M	VCTCXO	12.8 to 26	2.5	−30 to +70	0.45×0.45×0.18	$21 (OEM qty)
Vectron Labs	CO724	OCXO	25 to 140	0.005	0 to 50	2×2×1	$282 (100)

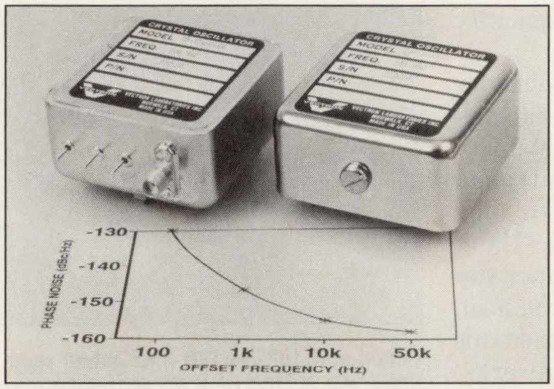
Notes:

[1]XO, uncompensated crystal oscillator; TCXO, temperature-compensated crystal oscillator; DCXO, digitally compensated crystal oscillator; MCXO, microcomputer-compensated crystal oscillator; VCXO, voltage-controlled crystal oscillator; TCVCXO, temperature-compensated, voltage-controlled crystal oscillator; OCXO, oven-controlled crystal oscillator.

[2]Operating range for specified stability.

CRYSTAL OSCILLATORS

to 140-MHz frequency spectrum. And with figures of 0.005 to 0.015 ppm, the improvement in output stability is obvious. Just as obvious, however, are the price and space penalties. All the OCXOs listed in **Table 1** are housed in packages measuring 4 in.[3], and prices are now in the $200 to $300 range. Even though the data is not included in **Table 1**, the OCXOs listed have typical power requirements of 4 to 6W during turn on and warm up, and continuous power requirements ranging from 1.7 to 2W.



Offering output frequencies ranging to 140 MHz, Vectron's C0724 OCXOs have a ±0.005-ppm frequency stability from 0 to 50°C and provide an HCMOS-compatible output.

Where's the oven?

Raltron is also listed as a supplier of OCXOs. However, their oscillator is somewhat different and deserves a closer look.

Raltron's Model TF-65010-B utilizes oven-like compensation techniques to achieve its stability of 0.22 ppm over −20 to +70°C. In addition, the oscillator reaches this stability level in 2 minutes, drawing 3W, which is far less power consumption than the typical oven-controlled oscillator would require. Such performance opens up a number of high-stability applications that you would have previously avoided because of the cost.

Because the unit does not use classical oven control for compensation, it reacts to temperature variations in real time, and it has no hysteresis characteristics. Phase noise at 10 kHz is specified at −140 dBc. Because you can adjust the output frequency over a maximum range of ±6 ppm, you can compensate for more than 10 years of aging. The oscillator operates from supply voltages of 5 to 12V.

In a classical oven-controlled crystal oscillator, a resistance-wire heater controls the temperature of

For more information . . .

For more information on the crystal oscillators discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you read about their products in EDN.

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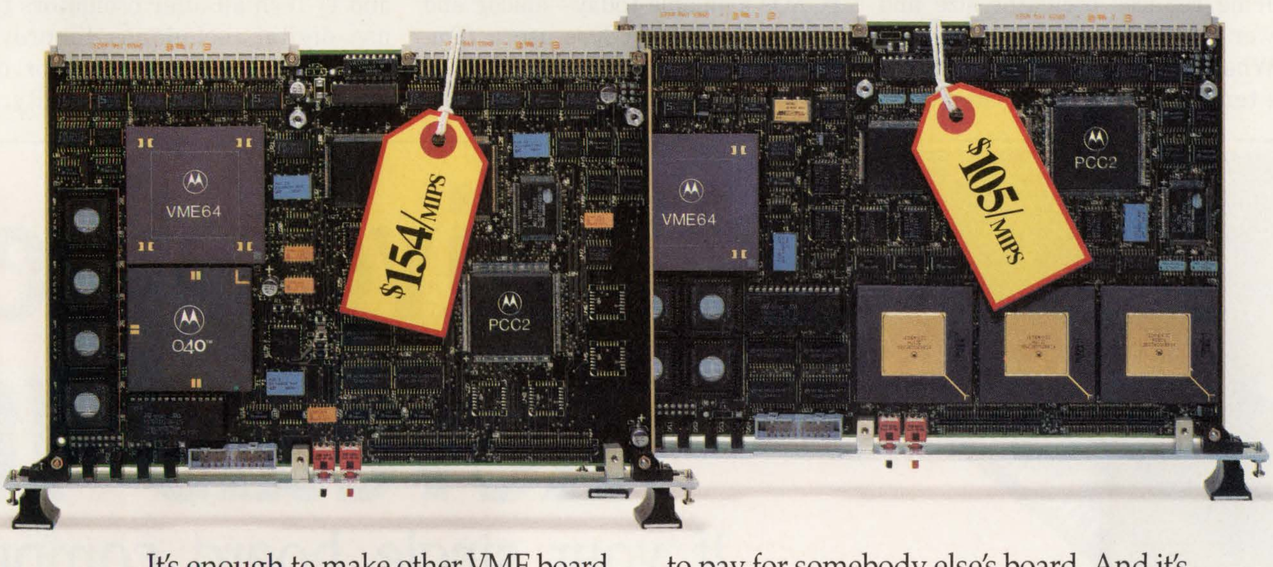

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an oven that houses the crystal and associated electronics. The combined thermal mass of the oven and the crystal retards crystal heating, and it can take as long as 10 minutes to stabilize an oven-controlled crystal oscillator. Model TF-65010-B's design lets the oscillator heat the crystal directly by positioning the temperature sensor inside the crystal case and in direct contact with the crystal. This scheme provides an accurate and real measurement of crystal temperature and significantly shortens warm-up time.

Because the resistance heating element acts directly on the Model TF-65010-B's crystal, the unit has no power requirements for oven heating. Thus, the direct heating scheme reduces oscillator size and power consumption.

When it comes to performance, the temperature-compensated crystal oscillator (TCXO) falls between the XO and the OCXO. The TCXO's low noise and output frequency range from 1 Hz to 100 MHz. TCXOs suit applications involving thermal stress because they feature some degree of external-frequency control. Over an operating range of −40 to +85°C, frequency-stability figures will be in the 1-ppm range.

Although they can't match the stability performance of OCXOs, TCXOs do have some advantages. Warm up time for the TCXO is significantly shorter (in the microsecond range) and power consumption for TCXOs is measured in milliwatts. TCXOs are also smaller and less expensive than OCXOs.

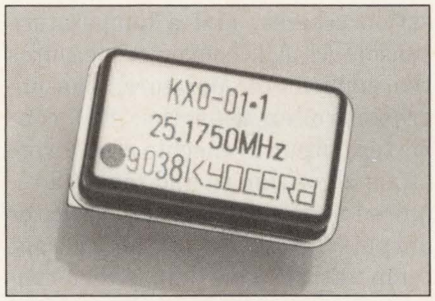
There are actually two types of TCXOs available today—analog and digital. Analog TCXOs use a temperature-sensitive, custom-tailored compensation network to tune the oscillator just enough to offset the uncompensated frequency change with temperature. As is the case with the OCXO, the performance of a TCXO will be better over narrower operating ranges. But unlike the case with the OCXO, you can power a TCXO with a single supply without running into problems.

Today, you can also find crystal oscillator designs that use digital techniques for compensation and/or increased flexibility. These digital devices are somewhat larger than the analog TCXO, and they are somewhat more expensive. However, they offer better stability over wider operating ranges than the analog TCXOs.

MF Electronics, Murata Erie, and Q-Tech all offer oscillators that use digital techniques to provide temperature compensation or output frequency programmability.

MF Electronics uses microprocessor control to provide a variable frequency capability (rather than temperature compensation) for the M2100 ECL-compatible oscillator. The unit will output any frequency in the 100- to 170-MHz range with a resolution of ±1 kHz. The design makes it unnecessary to specify a particular frequency output in advance. You can simply program the oscillator output under software control. Because the M2100 is crystal based, the output has an overall tolerance of ±100 ppm.

The programmable oscillator offers users two key benefits. First, the M2100 can replace several oscillators in applications where only one frequency is needed at any given time. In many video applications, for example, you may have to generate several frequencies for different presentations or to match frequencies of various monitors. Instead of having to use a specific oscillator for each frequency, you can use one programmable M2100.



Housed in all-metal DIPs, KXO-01 crystal oscillators from AVX/Kyocera output frequencies of 4 to 50 MHz. They meet FCC EMI specifications and feature a ±100-ppm stability from 0 to 70°C.

The second benefit involves design-time considerations. By using the M2100 programmable oscillator, you can optimize the operating frequency during the time you're producing the board—there's no need to go through an extensive calculation in advance to order a specific frequency value. The result is a faster time to market, which saves on the lead time required to order optimized oscillators.

In their Model DC2210 AH, Murata Erie uses an ASIC to provide digital temperature compensation. The ASIC integrates the majority of oscillator and compensation functions associated with high-stability crystal oscillators on a single chip, replacing more than seven discrete ICs that are normally required. Contained in a 28-pin plastic leaded chip carrier, the ASIC is based on 1.5-μm CMOS technology.

The ASIC implements a self-contained adaptive measurement and control system. Also included on the chip is an amplifier that serves as the gain stage for compen-

CRYSTAL OSCILLATORS

sation scheme, and a temperature sensor. An A/D converter measures the ambient temperature. The microcontroller uses the A/D converter output to execute an interpolation algorithm to find the data required to compensate the oscillator output frequency at the current temperature. This data is then converted to an analog voltage by a 10-bit D/A converter and fed back to the oscillator.

A nonvolatile EEPROM on the ASIC stores the required compensation data and certain calibration constants. Other on-chip memory includes a ROM that contains the system operating software and some RAM for temporary storage.

Q-Tech's QT 2010 microcomputer compensated crystal oscillator (MCXO) uses hybrid crystal-oscillator circuits combined with an ASIC and a microcontroller. The unit provides frequency and time accuracies of 0.030 ppm over an operating range of −55 to +85°C with negligible warm-up time and power consumption.

The ASIC contains the signal mixers, divider chains, counters, phase comparators, digital-control logic, and a direct-digital synthesizer (DDS). Two oscillators operating from a single 10-MHz crystal resonator drive the system. One oscillator excites the third overtone C-mode (F_O), while the second excites the fundamental C-mode (F_F). The difference frequency, F_B, is a nearly linear function of temperature and provides a precision measurement of the actual temperature of the quartz crystal.

F_B is measured in a counter, which outputs a numerical value, N1, that corresponds to temperature. The microcomputer, or memory unit, solves an equation (unique to a particular crystal) that relates the correction frequency, F_D, to each value of N1. The DDS generates F_D and a PLL synchronizes the 10-MHz VCXO to the sum of F_O and F_D.

In the frequency mode, dividers from the 10-MHz output drive the timing outputs of the QT 2010. In the Clock mode, F_F drives the DDS to generate the timing outputs directly. In the Clock mode, the PLL and portions of the digital circuitry are turned off to save power.

Rounding out the field

The voltage-controlled crystal oscillator (VCXO) rounds out the selection of crystal oscillators. VCXOs offer a little more capability than the simple XO. The VCXO has an input terminal that lets you apply a control voltage and pull the oscillator output frequency in either direction. VCXOs are 100 times more sensitive to external voltage control than a TCXO.

VCXOs are used extensively in applications involving PLLs. You can construct a PLL with a lowpass filter, a phase shifter, and a VCXO. Currently, VCXOs have sensitivities ranging to ±100 ppm/V. Frequency outputs for VCXOs are approaching the 100-MHz range.

Actually the VCXO is not a distinctly separate type of oscillator. You can apply voltage control to any of the basic oscillator technologies. TEW North America uses voltage control in the TCXO units, and AT&T and Connor-Winfield feature voltage control in basic XO designs. EDN

Article Interest Quotient
(Circle One)
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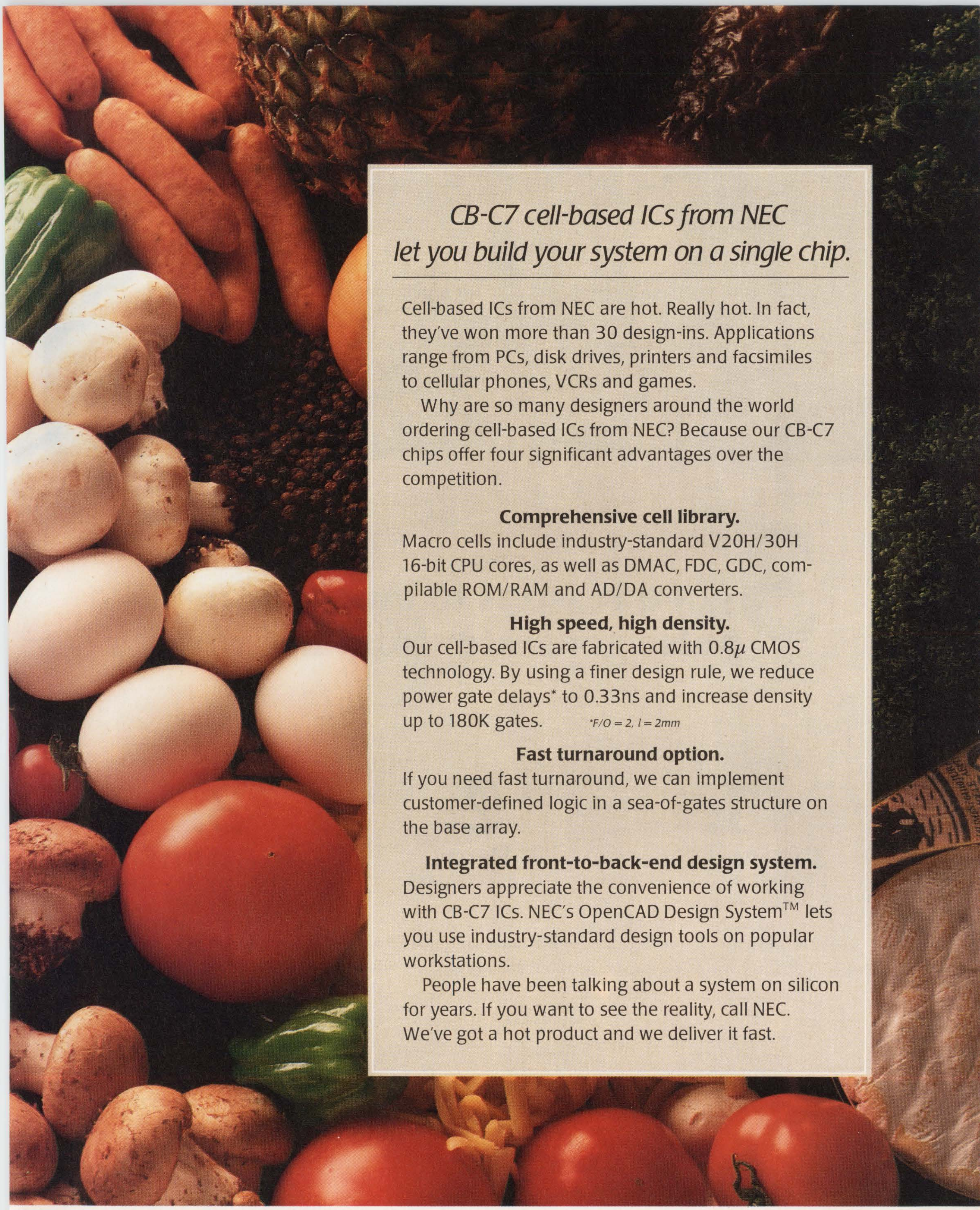

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CIRCLE NO. 74

Programmable-connection IC promises quick and easy prototypes

Now that you're accustomed to programmable memories and logic, prepare yourself for programmable interconnect, a technology that promises to reshape the way you design, prototype, and build hardware. Never before have you had the option of working with programmable connections in one component on the scale made possible by the AX1024 field-programmable interconnection component. It's a CMOS IC that can create a resistive circuit path between any two of its 940 I/O pins. Coupled with some innovative prototyping hardware and associated development software being introduced along with the chips, programmable-interconnect technology may soon make cut-and-jump prototyping methods seem intolerably slow and archaic.

The interconnection IC employs a RAM-based programming scheme so you can reprogram its connections on the fly. You send programming instructions to the chip through a serial port. A programmed connection employs a pass transistor to electrically join two of the I/O pins with a typical resistance of 150Ω. Once activated, the pass transistor in one of these connections remains on, so the connection's bandwidth is independent of the transistor's switching speed. High-speed connections experience 5 to 10 nsec of delay through the device. Because the base fabrication technology is 5V CMOS, signals sent through the chip must stay between 0 and 5V, but they need not conform to any logic levels and can, in fact, be analog signals.

Initially, the company is offering the chip in two versions. The $2938 AX1024D provides 64 diagnostic pins on an attached flex cable in addition to its 940 interconnect pins. You can connect these diagnostic pins to test equipment, thus gaining access to any part of your design that's routed through the IC without having to use probes. This device employs an exotic package having spring-loaded connecting pins and is intended for prototype troubleshooting (the "D" suffix means "development").

The $1105 AX1024R lacks the 64 diagnostic pins and is packaged in a slightly more conventional surface-mountable pin-grid array (it has stubby pins). The "R" suffix stands for "reprogrammable," although both devices are actually reprogrammable. Both parts connect to a pc board using a 32×32-pad array on 40-mil centers. Less expensive, one-time programmable devices are planned but aren't part of the initial product introduction.

The two AX1024 versions are nearly pin compatible, but one has the mirror-image pinout of the other. That's not an accident. The mirror imaging allows you to attach one of each device to the same set of circuit pads by placing one on either side of the pc board. Consequently, you can solder an AX1024R permanently to a board and use the AX1024D as a probe by clamping it to the opposite side of your board. In this configuration, both parts will link the same pad sets when programmed with the same configuration information.

Because these are field-programmable devices, you need software to make them do anything useful. The initial release of the development software runs on SPARCstations and costs $15,000. The company plans to announce PC software shortly. The company also offers two prototyping boards, which it has dubbed "field-programmable circuit boards" or "FPCBs," to help you use the AX1024 chips. The field-programmable characteristic of these board products stems from

Chip, board, and software products together provide field-programmable interconnections for circuit boards. Prototype construction may never be the same.

the linkage between every hole in the FPCB to one of the AX1024 I/O pins. In addition, the AX1024s have global connections between them. Consequently, no IC connects to any other IC on these boards except through one or more interconnection chips. There's no need to make hard signal connections, although you can if you wish. Power connections and supply bypassing are simple, using a set of power and ground pads located next to each hole. For power connections, you use a surface-mountable shunt or a very short wire. For bypassing, the pads accept an SMT bypass capacitor.

The $1538 FPCB-AT accepts three AX1024s and plugs into the ISA bus. The $1154 FPCB-GP2 accepts two AX1024s and conforms to no particular form-factor standard. These prices do not include the programmable-interconnect ICs. Special hole patterns on both boards accept a variety of IC packages. You can plug in through-hole DIPs of all widths. In addition, the hole patterns accept existing SMT package adapters from various third-party sources, so you can plug just about any device into an FPCB. Alternatively, the company offers a $15,000 FPCB compiler for custom designs.

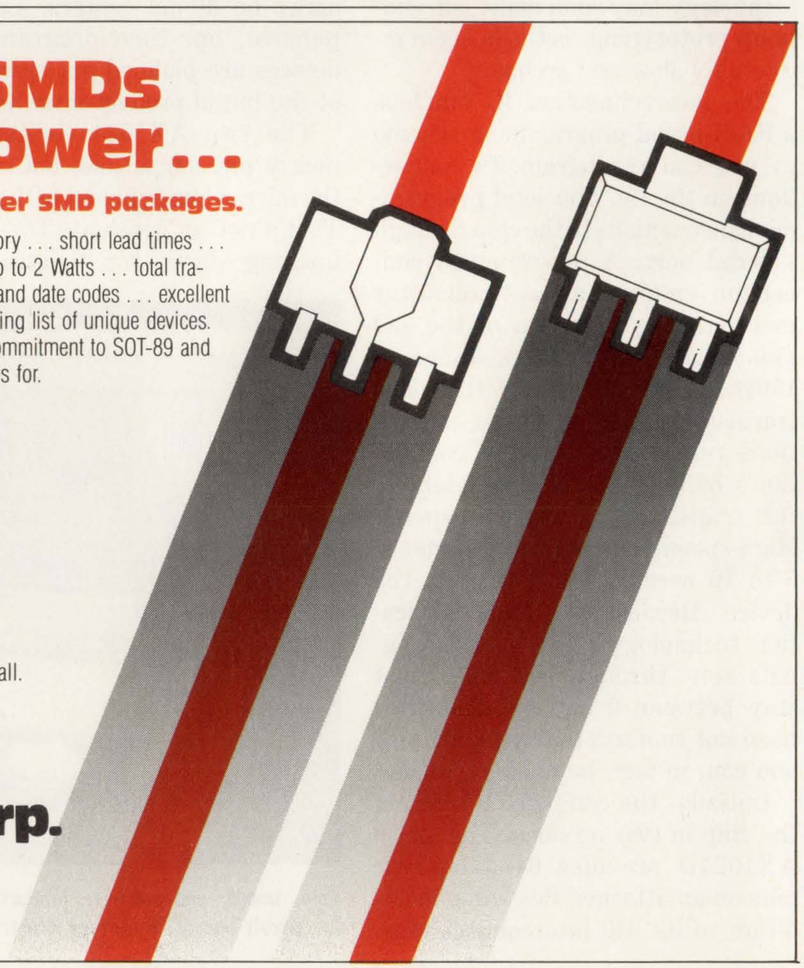
For design troubleshooting, you can pick either a $5000 diagnostic software package or a $7500 package geared specifically for the Hewlett-Packard 16500 and 1650 logic-analyzer families. The spiffier software package communicates directly with the logic analyzer over an RS-232C or IEEE-488 connection and configures the signal names in the analyzer directly from your schematic. With the less expensive diagnostic software, you have to configure the logic analyzer manually. You have to set up trigger conditions manually with either package. If you purchase the HP-specific package, you'll probably want the $769 interface pod, which provides some signal conditioning and simplifies the connection between the AX1024D's flex cable and the logic analyzer.

At first glance, the component costs for reprogrammable interconnect technology look high. However, for prototyping, you can easily recoup that money if you avoid a few pc-board revisions and save a few weeks in your development cycle. While many production-volume applications of field-programmable interconnections will await lower-cost (perhaps one-time-programmable) devices, some applications requiring fast rerouting of large numbers of signals will find this technology's cost and speed superior to existing alternatives.

—Steven H Leibson

Aptix Corp, 225 Charcot Ave, San Jose, CA 95131, Phone (408) 428-6200. FAX (408) 944-0646.

Circle No. 740



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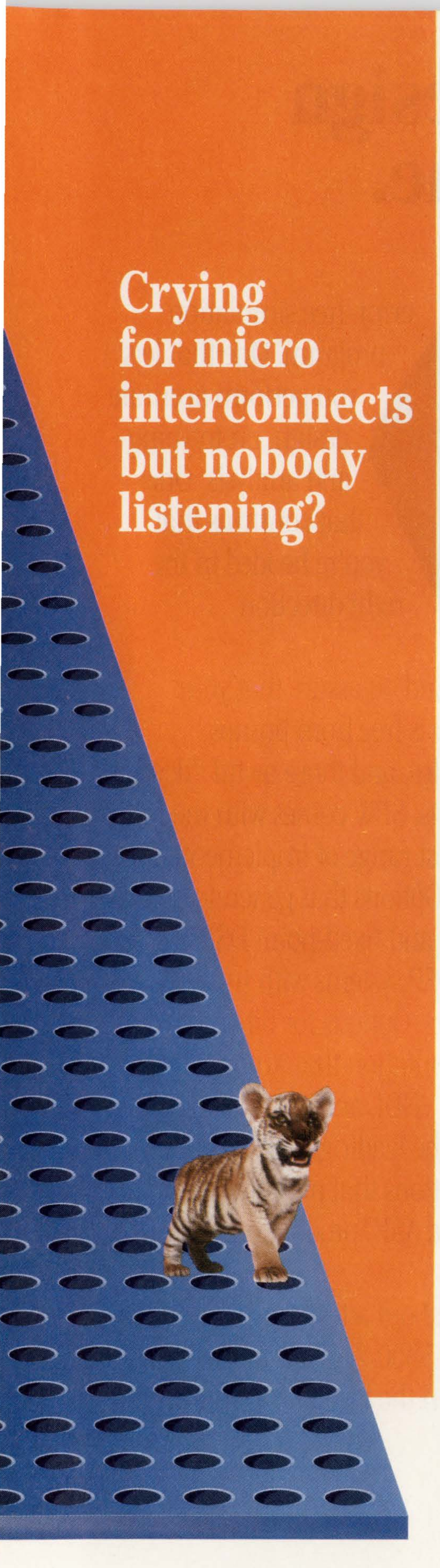


CPU boards use SPARC to handle embedded uses

A pair of CPU boards that target embedded and real-time applications perform the function of a complete SPARCstation-2-compatible computer. The CPU-2E is a VMEbus-compatible board, and the CPU-2S is a board that does not include a system bus. Both boards fit VMEbus 6U single slots. The CPU-2S uses VMEbus connectors only for power and ground.

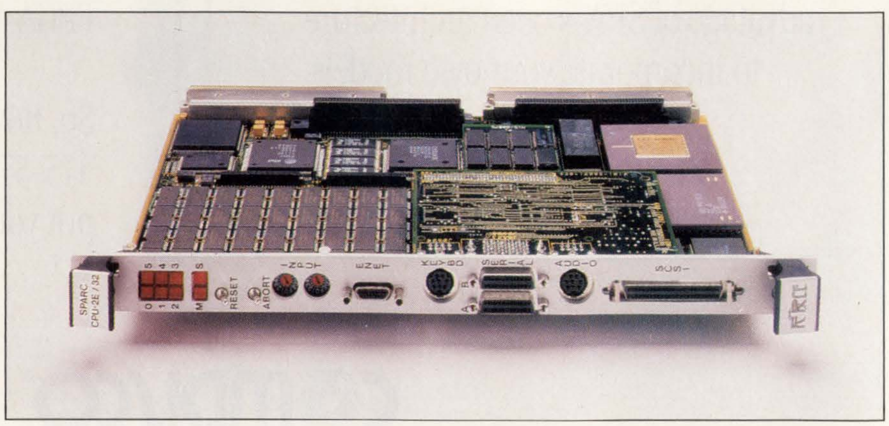
The boards share a number of features. Both include two SBus-compatible expansion connectors. The boards can accommodate as much as 32 Mbytes of memory each, and you can add another 32 Mbytes with daughter cards. They each include two serial ports, a keyboard/mouse interface, an audio port, an Ethernet port, and a SCSI-2 port, all of which are accessible from the front panel. You can run the SunOS Unix-based operating system and any Sun application programs on the boards, as well as real-time operating systems.

The CPU-2E also includes Open Boot firmware, which supports dynamic reconfiguration of the system resources and is currently in the IEEE standardization process. Open Boot lets a variety of peripherals operate with the system by loading appropriate operating-system drivers on boot up. The Open Boot firmware also includes a Forth monitor and debugger.

The CPU-2E board uses a 64-bit VMEbus implementation, called VME64, and also supports the proposed IEEE P1014R SSBLT (source-synchronous-block-transfer method) protocol. SSBLT increases the maximum VME64 data-transfer rate from 80 to 160 Mbytes/sec. The CPU-2E includes an additional SCSI-2 port, a floppy-disk controller, and a speaker that you can access via the VMEbus P2 connector.

The company plans to ship production units of the CPU-2E by July. The board costs \$7995, \$9495, or \$12,490 for 16-, 32-, and 64-Mbyte, respectively, memory configurations. You can buy the CPU-2S now, and the price ranges from \$7495 to \$11,990, based on memory configuration.—**Maury Wright**

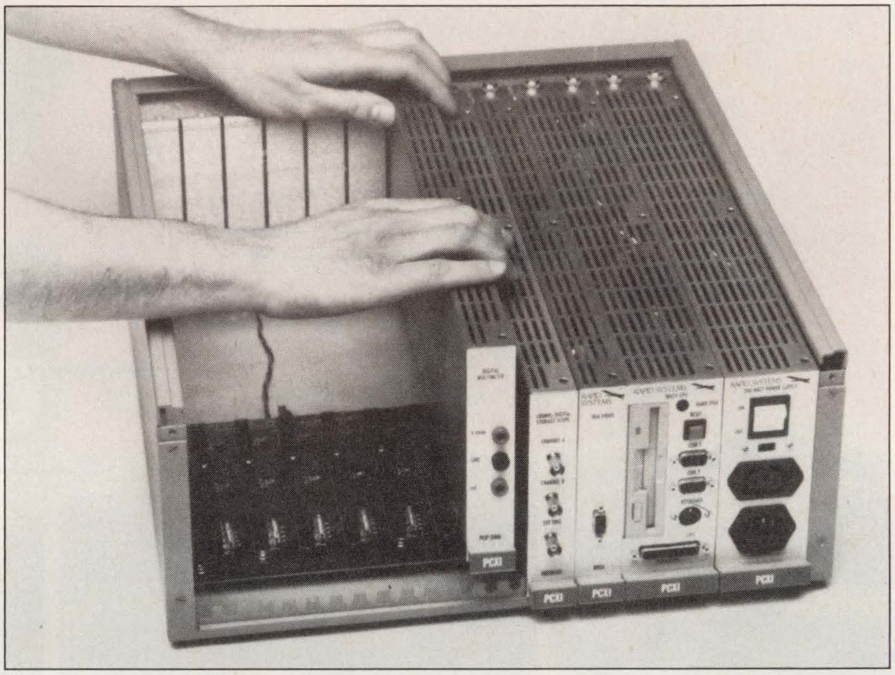
Force Computers Inc, 3165 Winchester Blvd, Campbell, CA 95008. Phone (408) 370-6300. FAX (408) 374-1146. **Circle No. 741**



The CPU-2E combines a SPARCstation-2-compatible design with 64-bit VMEbus compatibility and support for the new 160-Mbyte/sec SSBLT protocol.

Low-cost modular-instrumentation standard uses passive EISA backplane

Some people view the PCXI (PCs extended for industry) system originated by Rapid Systems as competitive with VXI (VME extensions for instrumentation) systems. Others view the two modular-instrumentation standards as complementary. Whichever way you look at PCXI, you have to agree that the standard offers designers of PC-based instrumentation systems, particularly those produced in small to moderate quantities, a low-cost alternative to IEEE-488 and VXI as well as less well-known standards, such as NIM and CAMAC. Now, a version of the PCXI standard based on the EISA bus (the 32-bit extended industry-standard architecture) lets PCXI systems offer high performance as well as economy.



When you lift the hood of a PCXI chassis, you see how simple reconfiguring and replacing modules is. Note the system power supply in a double-width module at the far right. Next to it is a double-width module that houses the system CPU with its floppy-disk drive. The adjacent single-width module is the video controller.

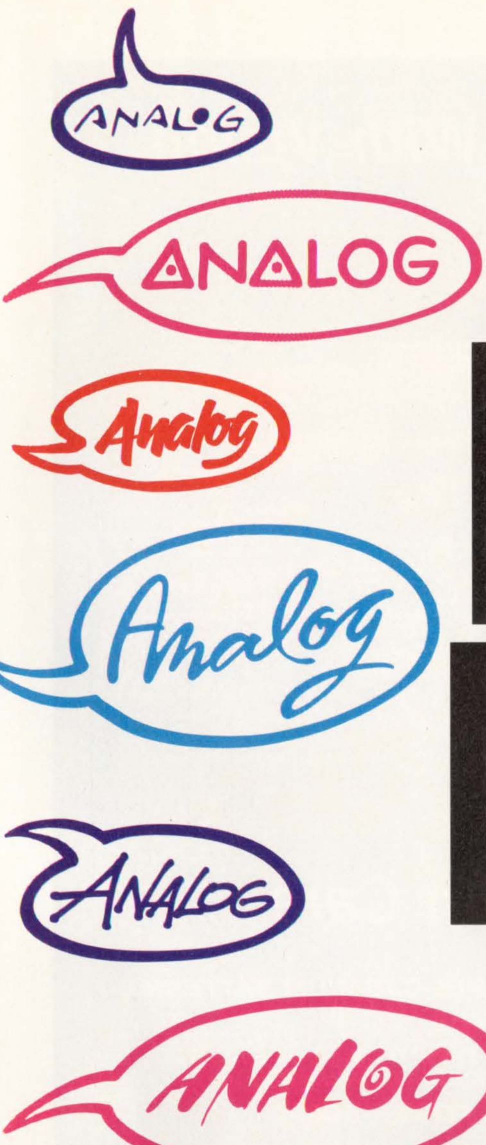
Although Rapid Systems, the Seattle-based vendor of test-and-measurement products for PCs, is the driving force behind PCXI, the PCXI consortium has 16 members, all of which are suppliers of instruments and related products for PCs. Several of these firms expect to announce EISA bus PCXI products in coming months; Rapid has already announced several EISA PCXI modules. Of course, one of the beauties of a system based on EISA is that it can also use cards designed for the 8- and 16-bit ISA buses.

Despite a strong software component, PCXI is first and foremost a packaging scheme. A PCXI mainframe incorporates a passive backplane; the system designers deemed the mother-board concept of most PCs to be inappropriate for industrial use. In the event of a failure, replacing a standard mother board takes too much time. By keeping the backplane passive and placing the system CPU and memory in plug-in modules, replacing a failed CPU is much easier as is upgrading to system controllers based on new and more powerful μPs.

For several reasons, the system architects also decided that, for industrial applications, the modules had to be enclosed instead of having an open-board construction. First, without the mechanical shielding provided by a cover, modules not installed in a backplane would be vulnerable to damage unless handled with care. Second, ambient electrical noise is a problem in industrial environments. A metal cover that provides mechanical shielding can also provide electrical shielding. Third, a shield that reduces the effects of noise that originates outside the system enclosure will have a similar effect on noise generated by neighboring modules. Hence, modules that handle low-level signals become practical.

To accommodate the shield, PCXI modules mount on 1.2-in. centers instead of the 0.8-in. centers used by standard ISA and EISA bus cards. To use a standard ISA or EISA card in a PCXI system, you remove the card's standard front panel and replace it with a new and slightly wider panel that mounts a bit further ($\sim 1\frac{3}{4}$ in.) from the end of the card than the standard panel does. Connectors that were attached to the original card remain attached; cables lead to new connectors on the wider panel. This arrangement permits attaching module covers.

When the EISA bus was first engineered, its designers did not envision a passive-backplane version.



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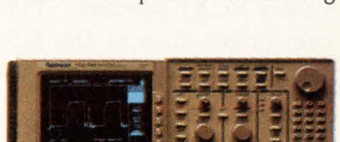

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CIRCLE NO. 78

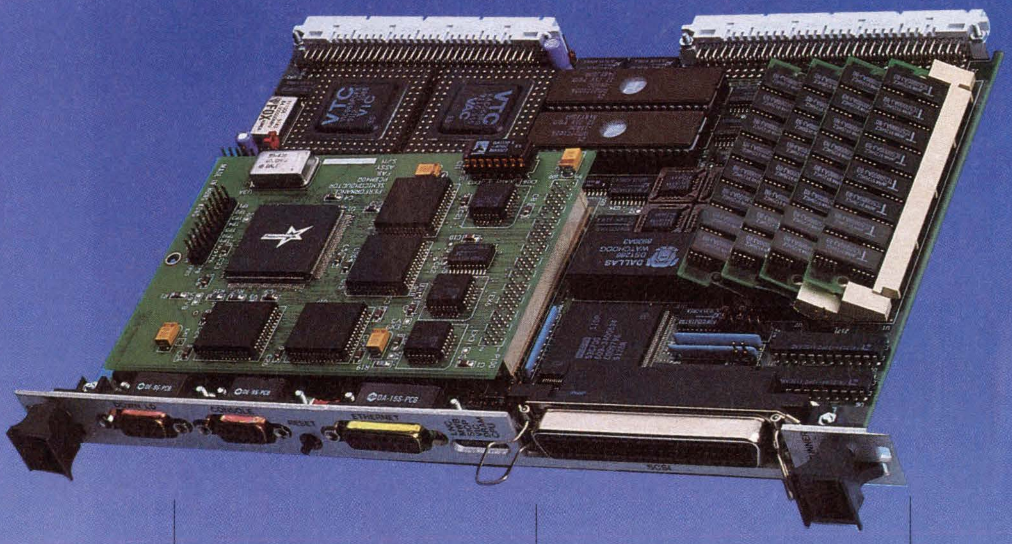
They did foresee automatic system configuration at power-up—a feature the EISA bus shares with the VXIbus. To let a CPU poll each backplane slot to determine its contents, EISA bus systems have lines that separately link each I/O slot with the CPU. To accommodate daughter-board-mounted CPUs, the passive-backplane EISA standard had to let the CPU slot access the slot-specific signals for all of a system's I/O slots. An extra connector on the CPU slot performs this function.

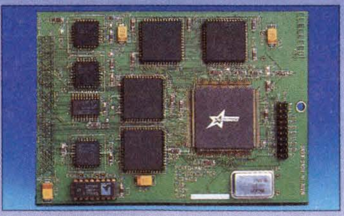
In the area of software, PCXI advocates claim superiority over VXI. You must be the judge of how true those claims will be for you. Often, you can deal with message-based VXI modules as if they were IEEE-488 instruments. System developers who are familiar with IEEE-488 require little or no time to learn how to program such VXI units. On the other hand, several virtual-instrument software packages do away with conventional programming for controlling and gathering data from PC-based instruments, including PCXI modules. With such software, the PCXI learning curve is not a problem, even for developers unfamiliar with IEEE-488. Such software can offer higher throughput than can message-based IEEE-488 communication.

More than 175 PCXI modules are available, so a comprehensive treatment of prices would look like a vendor price list, especially when you include the long list of ISA bus products compatible with EISA-based PCXI systems. Typical system prices such as the following illustrate PCXI's economy: A system that includes a 20-MHz, 2-channel DSO; a 4½-digit DMM; a 100-channel matrix switch; and a 5-Msample/sec arbitrary-waveform generator costs approximately $15,000.

—Dan Strassberg

Rapid Systems Inc, 433 N 34th St, Seattle, WA 98103. Phone (206) 547-8311. FAX (206) 548-0322. TLX 265017. **Circle No. 739**





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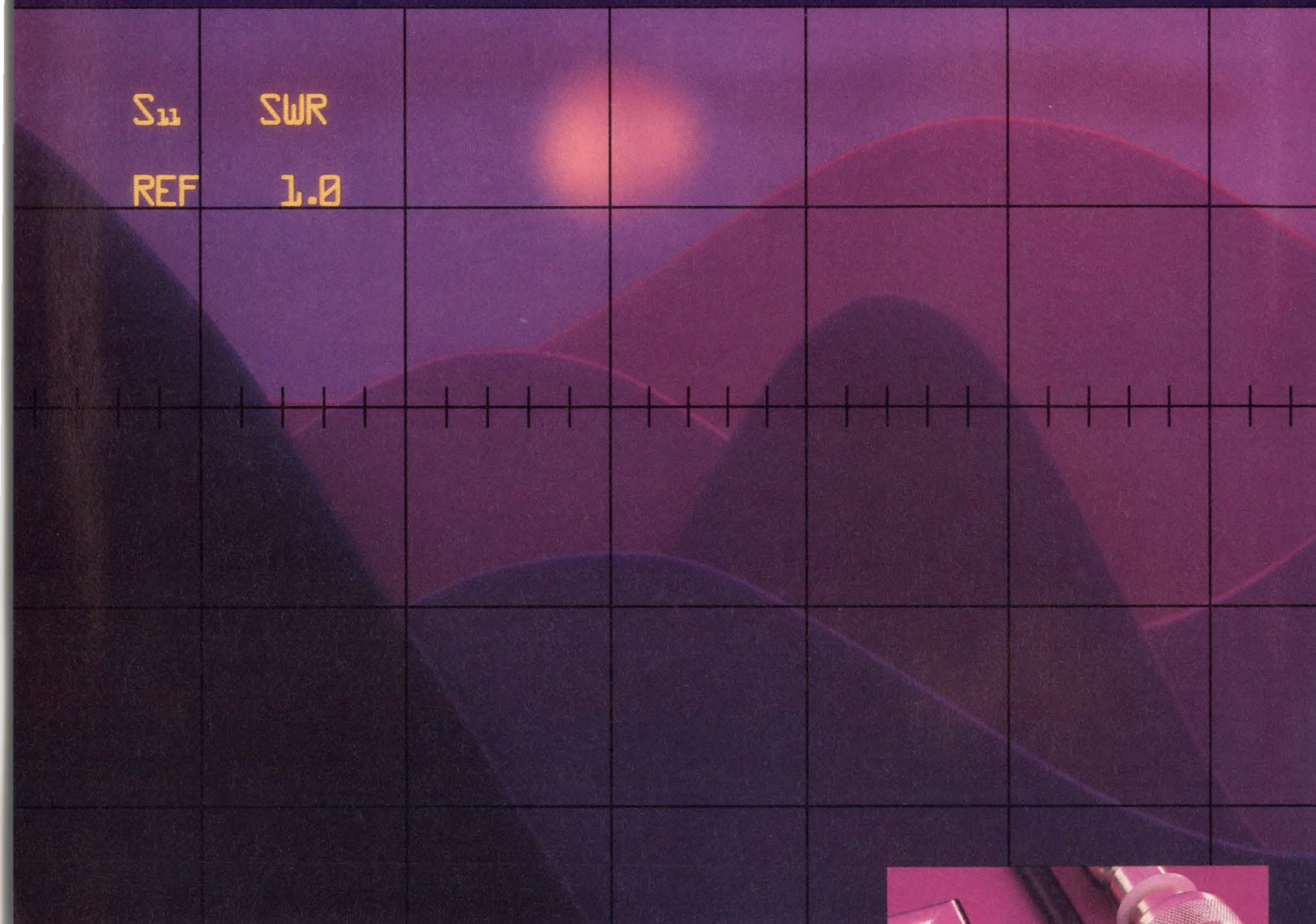

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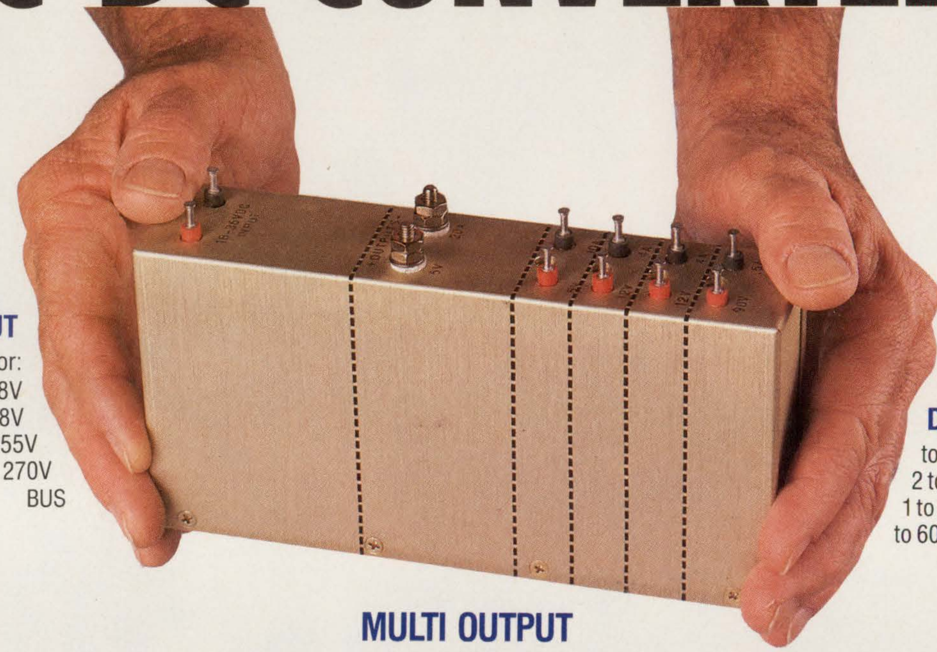

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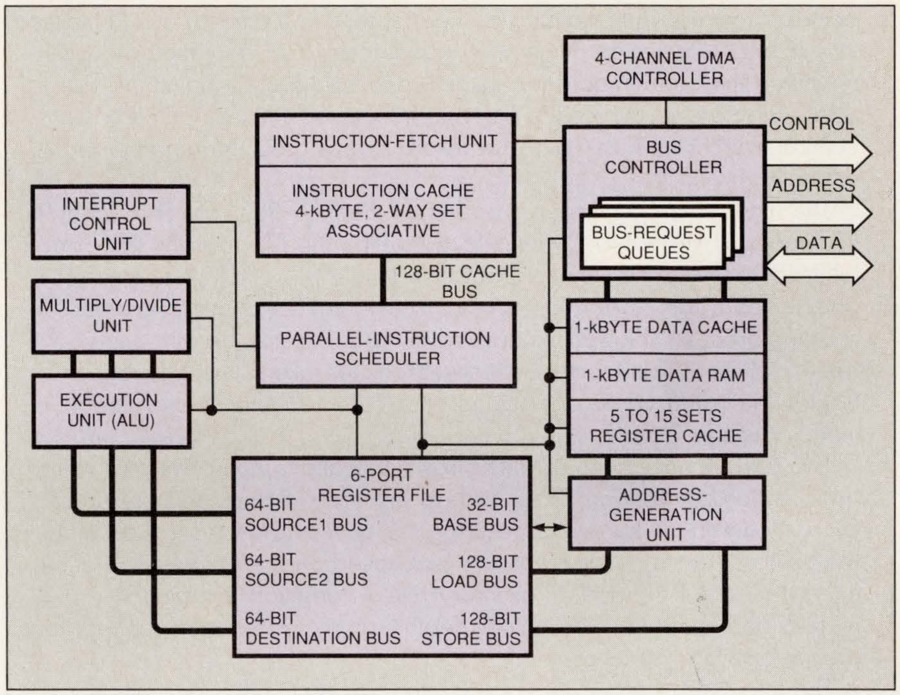
CIRCLE NO. 82

RISC µP enlarges instruction cache and adds data cache

Embedded systems place additional demands on RISC processors: Users need high performance coupled with cost-effective memory and deterministic performance. Intel kicked up the performance of its superscalar i960CA, a 32-bit superscalar RISC (reduced-instruction-set-computer) processor, by as much as 60% in some applications. This µP employs a larger, 4-kbyte instruction cache and a 1-kbyte data cache, as well as an optimizing compiler.

Currently, the i960 is one of the major RISC architectures for embedded applications, especially in laser printers and emerging X-terminals. In addition, the i960 is penetrating the high-end networking world, showing up in network routers, bridges, and servers. This move is aided by the i960's sophisticated external bus controller, which supports as many as four DMA channels. In addition, the JIAWG (Joint Integrated Avionics Working Group) selected the i960 MX as an acceptable 32-bit Instruction Set Architecture.



The i960 has a superscalar architecture; it can issue as many as 3 instructions/clock cycle.

The Intel i960CF

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- MPY, DIV instructions: MPY (32-/16-bit; 4/2 clocks)
- 6-port register file (32 × 32 bit); 128- or 64-bit paths
- 4-kbyte instruction cache, 2-way set associative 1-kbyte direct-mapped data cache write-through, 1-kbyte RAM/(register set cache)
- 32-bit pipelined, external memory interface with multiple memory regions, burst mode
- 3-stage pipeline (2-stage branch)
- 4 functional units: MPY/DIV, instruction/fetch, integer, address generation; no FPU
- Branch-prediction bit; out-of-order branch execution
- Pipelined store (3-deep buffer)
- 4 DMA channels; sophisticated bus controller
- 196-pin PQFP, 168-pin PGA (33 MHz)
- 16-MHz version, $105.80 (10,000); 33-MHz version, $165.30 (sample qty); production qty by fourth quarter 1992

The first RISC designed for embedded applications, the i960 comprises a family of embedded RISC processors, ranging from the i960SA, which costs less than $20, to the massive i960MM, which suits military applications.

The new addition to the family, the i960CF, extends the high-end i960CA processor's performance. Designers enlarged the CPU's instruction cache from 1 kbyte to 4 kbytes. Holding as much as 1k 32-bit instructions, the instruction cache is big enough to cache the repetitive inner-processing loops for many embedded applications. The cache is 2-way set associative, with a 4-instruction-word line size. Similar to that of the earlier i960CA, the cache can be locked (1/2 of the cache at a time), enabling programmers to lock key interrupt service routines or application inner-loop code into the cache. Locking ensures that time will not be lost while fetching key service code.

To raise processor throughput further, the µP has a 1-kbyte data cache to hold key data values for on-chip processing. Previous designs relied on on-chip data RAM, which held register sets and data. Now, with this data cache, the compiler and programmers have the option of relying on caching for on-chip data values as well as holding key values in the dedicated RAM. The RAM also acts as an effective buffer for DMA and other I/O transfers.

The i960's architecture supports as many as 15 register sets—each with 16 active, 32-bit registers. Using register sets, context switches take 750 nsec, which is the time to swap register sets (this speed is a result of the µP's 128-bit-wide internal buses.) Register sets, like

Profile-driven compilation

Traditionally, software tools such as compilers were decoupled from the actual hardware. Compilation was independent of the hardware; compiler optimization did not automatically change based on how the hardware executed the code in question. RISC processors are changing this because they are far more dependent on compiler efficiency than earlier computer architectures—a bad software mapping can trigger large processing inefficiency.

The Intel GNU C compiler is based on the Free Software Foundation's (Cambridge, MA) GNU C compiler. Targeting the i960 family, the compiler closes the link between the RISC hardware and compilation, gaining an additional 20% performance. For critical code, compilation becomes a 2-step process. The working application code is compiled with built-in trace facilities to track code efficiency: branches taken, function usage (for later in-lining), cache operations, code block placement, and global memory usage.

This performance data, profiling the application, then drives a second optimization compilation. Thus, code is optimized based on its previous interaction with the hardware, resulting in higher efficiencies. For example, the compiler sets branch prediction bits based on the actual application execution rather than on an arbitrary rule. In addition, the compiler reviews and optimizes function call depths, source and destination register usage, and load/store performance.

The Intel GNU C compiler is available now. A PC platform costs $350, and a Unix platform costs $400. The DOS version is object code only; the Unix version includes source code. Software support is also available on a yearly basis: $6000 (full software support) or $2500 (software assistance by phone). Profile-driven compilation will also be available on Intel 960 compilers at some time later this year.

register windows, are effective for small applications or if use is tightly controlled. Using a register window for each function called can be a real-time disaster in a complex-function application: Once all the register sets are used, an overflow will make processing indeterminate. Thus, register sets must be used with care.

Processor throughput is enhanced via the μP's superscalar architecture. Unlike a standard RISC, the CA/CF is superscalar: as many as three instructions can be issued simultaneously and executed in parallel if there are no outstanding data dependencies. The processor picks up and decodes as many as four instructions at a time. Intel claims a sustained processing rate of 2 instructions/instruction clock cycle. In contrast, a standard RISC processor can, by definition, execute 1 instruction/instruction clock cycle at most.

The enlarged instruction cache and additional data cache help raise processor performance by providing a larger store for instructions and data. The on-chip caches buffer processing from the chip's 32-bit bus interface. CPU processing rates will fall for processing that is dependent on sustained access to external memory. The external 32-bit bus is no match for the 128-bit internal buses; however, this problem can be solved with a desktop-type wide external bus, even though it's costly for many embedded applications.

Intel engineers took an alternative approach to the bus architecture of the i960MM, which has two external buses, a slower, multiplexed 32-bit system bus, and a fast 64-bit local bus for high-throughput processing.—**Ray Weiss**

Intel Corp, Embedded Processor Group, 5000 W Chandler Ave, Chandler, AZ 85226. Phone (602) 554-2388. **Circle No. 742**

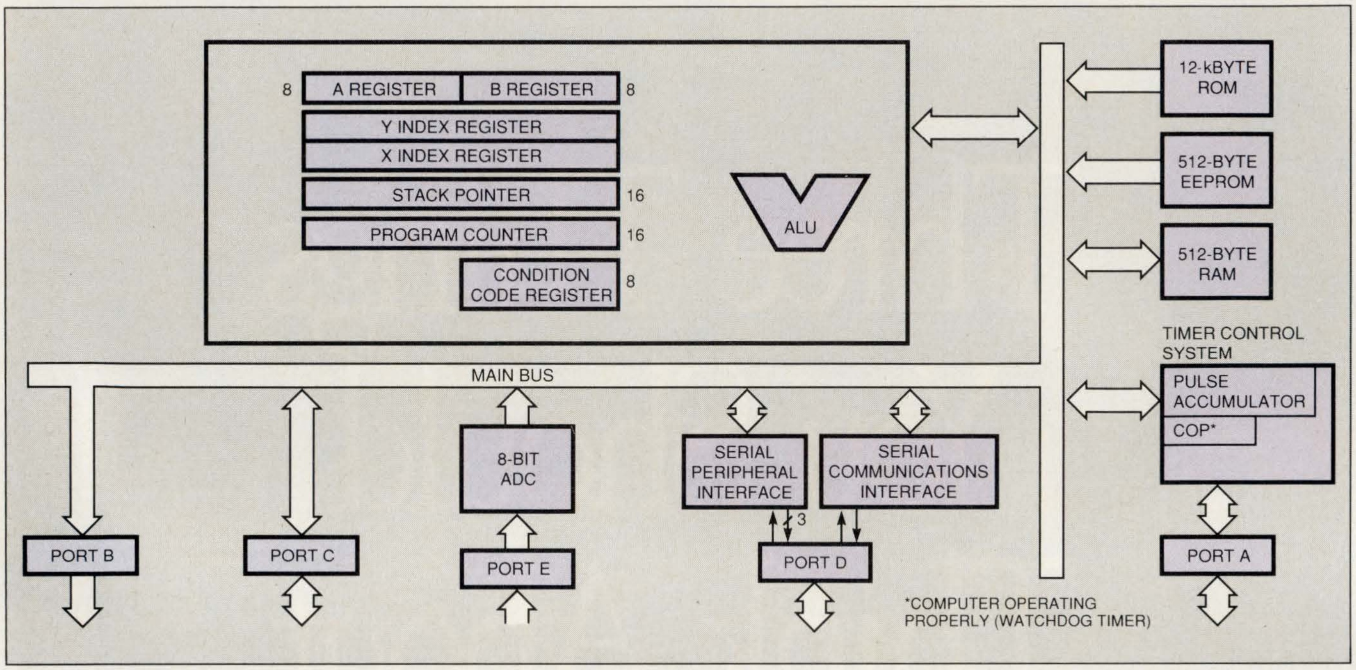
68HC11 adapts to 3.3V designs

For 3V designs, engineers working with the Motorola 68HC11 will no longer be left out of the low-power arena. With the Motorola 3.3V 68HC11E9 and 68HC11L6 (3 to 6V range, ±10%), designers can decrease power consumption significantly and keep the same processor design in place.

At 3.3V, the parts run with a 1.05-MHz clock rate. Typically, 68HC11 microcontroller (μC) clock rates run from 2 to 4 MHz max. Power dissipation for the 3.3V 68HC11E9 is 12.6 mW in Single

The Motorola 68HC11E9

- 1.05-MHz bus clock (4.20 MHz external); 1-μsec cycle
- ADD (direct) 3 cycles; NOP 2 cycles
- Two 8-bit accumulators; 16-bit: 2 index, 1 stack pointer, index, program-counter registers
- Single 64-kbyte address space
- 12-kbyte ROM program memory (one-time-programmable EPROM version, the 68HC711E9, available for prototyping); 512-byte EEPROM data/program; 512-byte data RAM
- 5 I/O ports with 38 I/O pins
- 2 serial ports: SPI, SCI
- 16-bit timer with 5 input compare and 3 output capture registers and prescaler, watchdog timers
- 14-bit PWM function
- 8-bit A/D (32-clock conversion)
- 1 external interrupt; 18 interrupt sources
- 3 to 6V (±10%) operation
- 52-pin PLCC; 64-pin quad flatpack
- $9.15 (10,000) (sample qty); same pricing for 68HC11L6



The 68HC11 is an accumulator-based architecture with a highly structured instruction set.

Chip Mode (uses on-chip memory only) and 18 mW in Expanded Multiplexed Mode (uses off-chip memory). Power dissipation decreases further by the μCs' dropping into one of two power-saving modes, Wait or Stop. In Wait Mode—with all peripheral functions shut down except the timer—the total supply current is 1.5 mA, and 2.5 mA for Expanded Mode. In Stop Mode—all peripherals, including the timer are stopped—total supply current drops to 2.0 mA.

Motorola's 68HC11 is a major μC architecture. A descendant of the early 6800/01, the 68HC11 is an 8-bit μC aimed at mid- to high-end, 8-bit applications. The μC operates as a single-chip solution, with as much as 32 kbytes of program ROM and 1 kbyte of data RAM. The chip can be used stand-alone or with external memory. It services as much as 64 kbytes (less on-chip memory) of external memory.

The 68HC11 instruction set is relatively clean and easy to use. The CPU architecture is accumulator based, with two 8-bit accumulators, supplemented by 16-bit index registers, a stack pointer, and a program counter. The μCs support a range of peripherals, including an 8-bit A/D converter, timers, serial I/O, and complex timer functions.

The 68HC11E9 μC features 12 kbytes of program ROM, 512 bytes of both RAM and EEPROM, and a peripheral set that includes an 8-bit A/D converter, a 16-bit timer, two serial ports, and 38 I/Os. The 68HC11L6 has a larger ROM (16 kbytes) and more I/Os (46 pins).

—**Ray Weiss**

Motorola Inc, Advanced Microcontroller Div, 6501 William Cannon Dr W, Austin, TX 78735. Phone (512) 891-3465. FAX (512) 891-2652. **Circle No. 743**

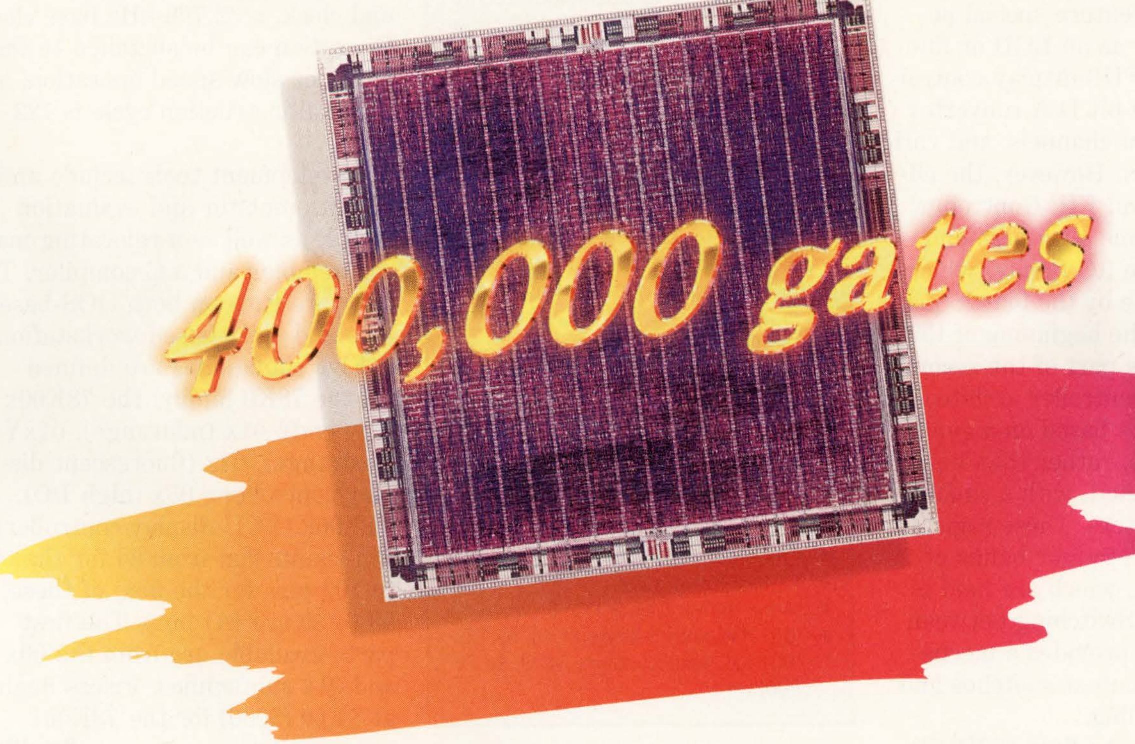
μC combines 4-bit peripherals with 8-bit CPU

Cost-conscious embedded-system designers have had to choose between 4-bit microcontrollers (μCs), which have peripherals, and 8-bit μCs, which have processing power. That choice may no longer be your only option, as 4-bit peripherals migrate to the 8-bit world. Taking advantage of 4-bit μCs, NEC's 8-bit line integrates peripherals from its 4-bit 75xxx family with the 8-bit 78K2 line of μCs. The 78K0 series targets low- to midrange embedded applications, delivering 4-bit peripherals backed by an 8-bit processor.

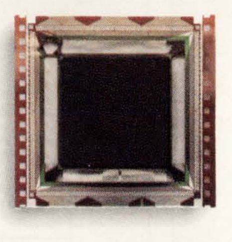
The 78K0 builds around a stripped-down 78K2; the sophisticated automatic-peripheral-handling feature is gone, and the minimal instruction cycle (1-byte instruction) is 480 nsec, up from the K2's 330-nsec cycle. The 78K0 is, however, code compatible with the older version, enabling engineers to use existing code, as well as providing an upward migration path.

Basically, the 78K0 is a midrange 8-bit μC, with 64-, 80-, and 100-pin versions. It supports a set of stan-

Think Performance.



Think Mitsubishi Gate Arrays.



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CIRCLE NO. 84

dard peripherals, including an 8-bit A/D converter, 16- and 8-bit timers, and watchdog timers. Other family members will feature special peripherals, such as an LCD or fluorescent-tube (FIP) display controller/driver, an 8-bit D/A converter with two output channels, and variable clock rates. However, the advanced LCD and FIP Controller/Drivers will come with high-end members of the μC family, which will be available by the fourth quarter of 1992 or the beginning of 1993.

The K2/K0 is part of the second wave of microcontroller architectures; this μC is based on a general set of registers, rather than being accumulator based, with a small set of special registers. These registers are organized into four banks of eight registers, which are held in on-chip RAM. Switching between register banks provides a mechanism for fast context switches and interrupt handling.

This 78K0 is the first of NEC's 8-bit μCs to use the variable clocking scheme in the 75xxx family. A static design, the chip clock rate can be dynamically changed to meet application conditions. Using a 10-MHz main clock, the clock can be divided by 8, 16, 32, and 64 for reduced execution speeds and power savings. The μC also supplies a second clock, a 32.768-kHz base clock. Operation can be switched to this clock for slow speed operation: a minimal instruction cycle is 122 μsec.

Development tools include an in-circuit emulator and evaluation board, as well as a relocating macroassembler and a C compiler. The software runs on both DOS-based PCs and Unix-based workstations.

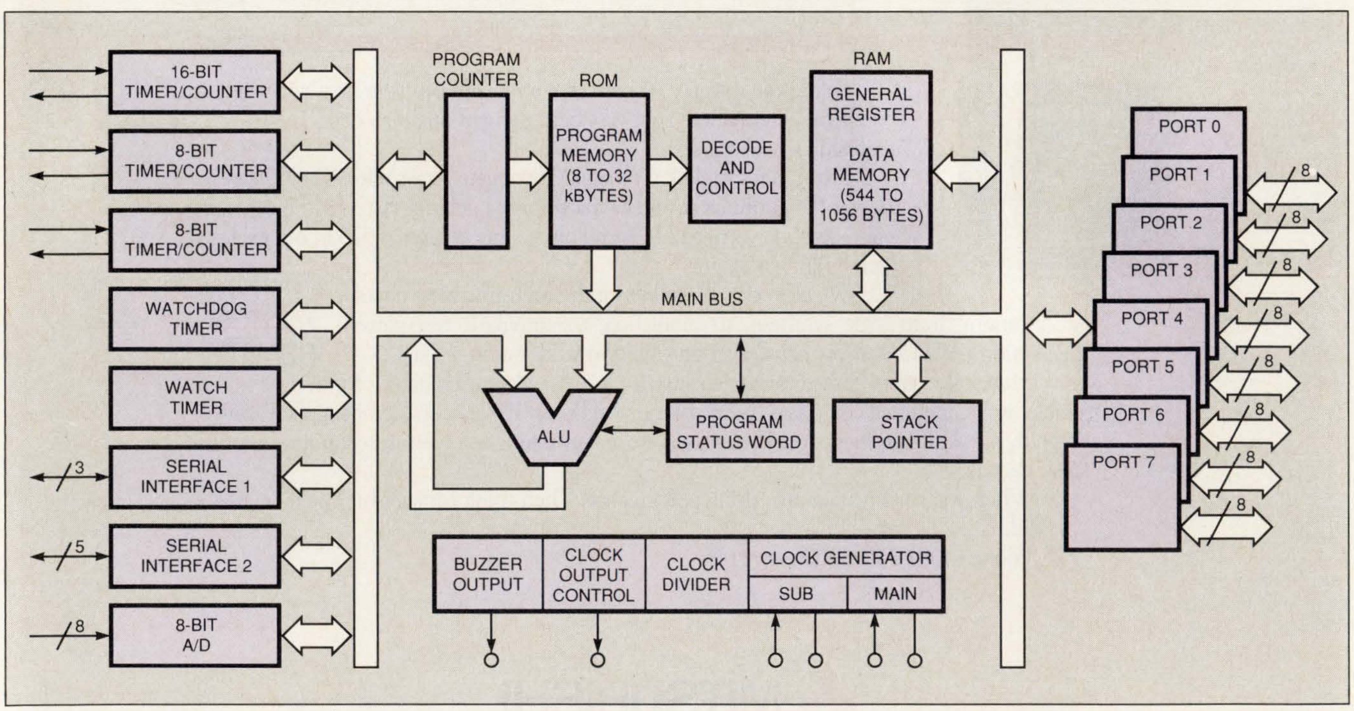
Five subfamilies are defined for the 78K0 family: the 78K00x (low end), 01x (midrange), 01xY (midrange), 04x (fluorescent display/controller), 05x (high I/O), and 06x (LCD display/controller). Pin counts run from 64 for the 00x to 100 pins for the 06x; of these, 53 to 89 are I/O pins. The first parts available are from the 00x and 01x subfamilies. Prices begin at $4.50 (5000) for the 78K001.

—**Ray Weiss**

NEC Electronics, Box 7241, Mountain View, CA 94039. Phone (415) 960-6000. **Circle No. 744**

The NEC K0 μPD7801x

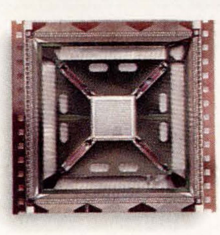
- 10-MHz external clock (480-nsec instruction cycle); also a 32.8-kHz subsystem clock
- Can dynamically change clock speed divide by 8, 16, 32, 64
- ADD (direct) 3 cycles; NOP 2 cycles
- Four RAM-based register banks; eight 8-bit registers/bank
- Single 64-kbyte address space
- 8-, 16-, 24-, 32-kbyte program ROM (32-kbyte one-time-programmable/EPROM prototype); 544/1056-byte data RAM
- 53 I/O pins
- 2 clocked serial ports (1 with automatic data transfer)
- 5 timers: 16-bit timer/counter clock timer; two 8-bit timer/counters, watchdog timer
- 8-bit A/D (8 channels)
- Buzzer output (2, 4, 8 kHz)
- 4 external interrupts
- 2.7 to 6V operation
- 64-pin shrink DIP or PQFP
- 78011GC with 8-kbyte ROM, $5.15; 78014GC with 16-kbyte ROM, $6.25 (5000)



This 8-bit μC combines an 8-bit architecture with 4-bit peripherals. The clock rate is dynamically adjustable.

Think Low Power.

Think Mitsubishi Gate Arrays.



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Add to all of this 400,000 gates, 512 I/Os, and Mitsubishi's exclusive µ Pitch TAB™ packaging with pin counts as high as 576.

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CIRCLE NO. 85

Static chip runs at 20 MHz and reduces EMI

The Zilog Z8S180 doubles its internal clock speed to 20 MHz and is built around a power-saving static core. This new core is more efficient than its predecessor, reducing instruction cycle time by an average of 20%.

The chip is pin compatible with the earlier—and slower—dynamic Z80180 μCs. With the Z8S180, you can upgrade existing Z80180 designs, needing only faster memory to kick up the processor throughput rates. Zilog engineers also built in EMI suppression to cope with higher clock rates. You can program the power levels of the chip-output pins, significantly reducing EMI by as much as 75% (see **Fig 1**).

The Z8S180 and Z80180 are high-end 8-bit μPs built around the 8-bit Z80 processor. Both chips have an enhanced Z80 design that's based on a Hitachi implementation (64180), which features an on-chip memory-management unit (MMU). Thus, the Z8S180 can handle large application programs. It supports as much as 1 Mbyte of external memory and bank switches between 64-kbyte local-address spaces. Memory design is easy for the Z8S180; the chip has a programmable wait-state generator, which allows for adjusting to varying memory implementations.

The chip features four power-management levels: Run, Sleep, System Stop, and Standby. In Sleep mode the CPU is stopped while on-chip I/O continues to run; in System Stop mode the CPU and peripherals are stopped, decreasing power consumption further. The Z8S180 adds another mode, called Standby. In Standby mode, the clock and internal clock and external oscillators are also stopped,

The Zilog Z8S180

- 16- or 20-MHz clock (divide by 1 internal clock)
- ADD (to register) 9 cycles; NOP 6 cycles (300 nsec at 20 MHz)
- 2 register sets (eight 8-bit registers): 1 special register set with two 16-bit index, stack pointer, and program counter
- 64-kbyte local-address space; MMU extends space to 1 Mbyte off-chip memory
- 2 DMA channels
- Programmable wait-state generator
- Programmable low EMI/power output
- One clocked serial port; two asynchronous serial channels
- Two 16-bit timers
- Four external interrupts
- 68-pin PLCC; 80-pin quad flatpack
- \$14.29 for 16-MHz version; \$17.86 for 20-MHz version (10,000)

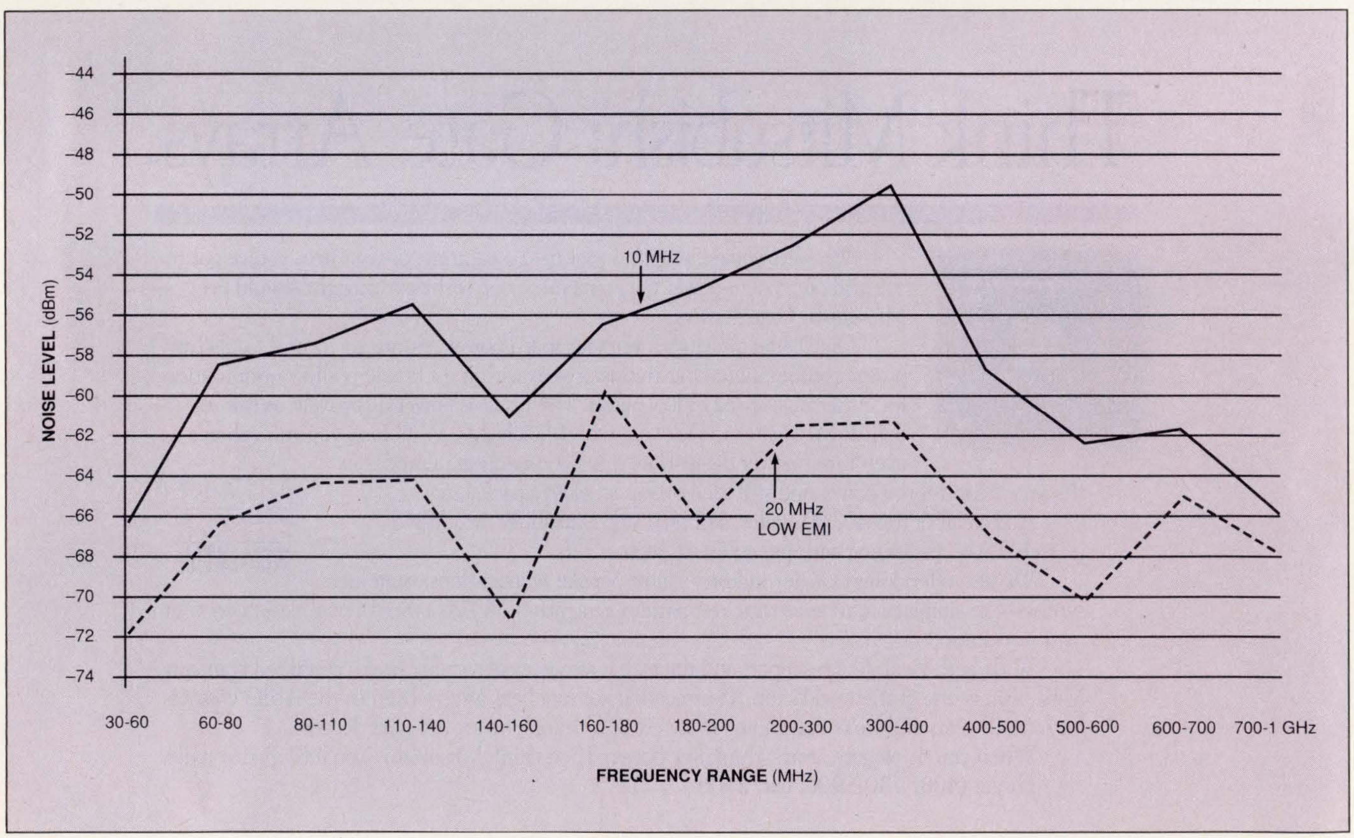

Fig 1—The Z8S180 doubles the Z80181 CPU clock rate but minimizes EMI increases by reducing output pin current. This reduction is programmable.

Think Packaging.

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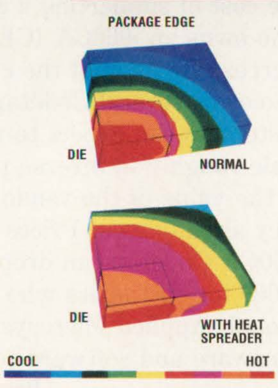

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Mitsubishi also offers power-cooling packages for higher reliability in fast, gate-intensive arrays. Available in both μ Pitch TAB and QFP, power packaging features an aluminum heat spreader that transfers heat from the die across the entire package. The result is a much cooler die and higher reliability.

We also give you over 100 packaging options, including plastic and ceramic QFPs and PGAs.

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dropping power consumption to less than 10 μA.

Huntsville Microsystems, Softaid, and Sophia Systems all supply in-circuit emulators for the Z8S180. The chip is code compatible with the Z80/Z80180 and can be programmed with existing assemblers and C compilers. Zilog also offers a $175 20-MHz evaluation board for the chip.—**Ray Weiss**

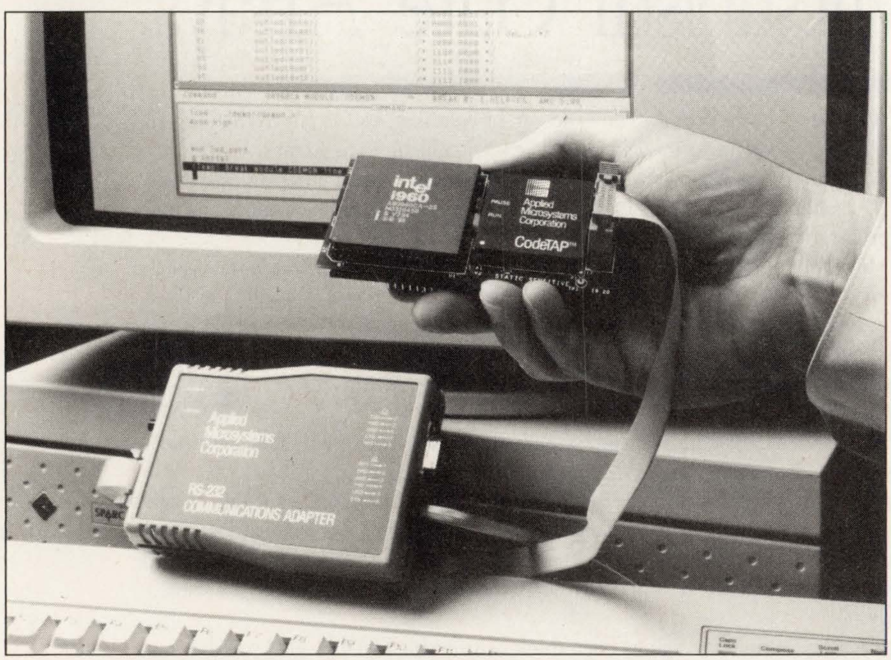
Zilog Inc, 210 Hacienda Ave, Campbell, CA 95008. Phone (408) 370-8092. FAX (408) 370-8092.

Circle No. 745

Low-cost debug tool ups system developers' productivity

Intel's i960CA is fast and powerful. Embedded systems based on the μP are big, and the teams that develop the necessary system software can include more than two dozen members. Ultimately, debugging the code for such systems requires expensive tools; prices of i960CA in-circuit emulators (ICEs) start in the mid-$20,000 area and can go much higher. This cost leads companies to limit the number of such instruments teams can buy. Yet if a software engineer sits idle for an hour waiting to use an ICE, the cost to the company can approach $100. At that rate, if tool availability costs each member of a 25-person team just one day during a development project, the lost time would pay for another ICE.

Recognizing that large teams need many debugging setups, Applied Microsystems is offering a hardware and software-based tool called a Codetap that costs much less than an ICE. Though the tool doesn't obviate a full-fledged ICE, it lets developers do much more complete debugging than they can with software-only tools. It is aimed at the middle of the debugging process—after the logical flaws have been excised, but before the final system integration (which requires an ICE). Last year, the company introduced Codetaps for the 80386 and 80186. Now it is announcing a Codetap for the i960CA. The superscalar μP is the most complex chip for which the firm has announced a Codetap tool.



Consisting of a target-access probe, based on emulator technology, and a communications adapter, the Codetap 960CA is a much lower-cost tool than an in-circuit emulator for debugging embedded systems based on the i960CA superscalar μP. At the same time, it is a much more powerful tool than a software debugger.

The i960CA Codetap hardware consists of a target-access probe and a communications adapter. The adapter plugs into the RS-232C port of the host Sun workstation or PC. The unit provides visibility and control of code execution by the target at the CPU's full clock speed—without necessitating code modifications, without adding wait states, and without usurping target memory, interrupts, or I/O ports. The Codetap includes the vendor's Validate/XEL symbolic source-level debugger for C and assembly-language code.

For the price of one i960CA ICE, a company can purchase at least three (and in some cases, six or more) Codetaps. This pricing strategy recognizes two facts: customer support represents a substantial portion of the cost of supplying debugging tools for embedded systems based on complex μPs, and the cost of supporting a customer who owns an i960CA ICE will not increase by much if the customer also owns several Codetaps. Hence, customers can expect to pay on a scale roughly in inverse proportion to the value of the vendor's tools they already own. Prices for the i960CA Codetap can drop nearly $4000 for customers who own enough Applied Microsystems hardware and software tools.

—**Dan Strassberg**

Applied Microsystems Inc, Box 97002, Redmond, WA 98073. Phone (800) 426-3925; (206) 882-2000. FAX (206) 883-3049. TLX 185196.

Circle No. 746

Recent advances in several areas of data communications will give you increased network performance at prices you can afford. (Photo courtesy AT&T; concept and design by Bessen Tully & Lee; photography by Clayton Price)

Data COMMUNICATIONS

High-speed schemes, such as copper FDDI and Fiber Channel, promise to allow engineers to design systems that take advantage of LANs' utility without reducing system performance or breaking the bank.

Maury Wright, Technical Editor

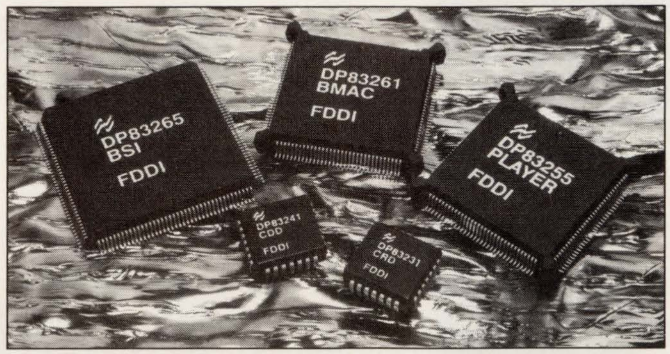
Designers have substantially improved all areas of computer-system performance in recent years, except for network performance. But you can expect a number of data-communications developments soon that will drown the performance drought. ANSI workgroups will shortly adopt low-cost alternatives to standard FDDI (fiber distributed-data interface), and semiconductor companies have compliant ICs waiting in the wings. Other companies, tired of waiting for the standards effort, already offer proprietary high-speed LANs (local-area networks). But coming higher-integration FDDI chip sets should offer lower prices for standard FDDI connections. And, finally, manufacturers have just introduced the first chips for the new Fiber Channel scheme, which can speed data communications an order of magnitude faster than FDDI.

In the past, only computer users that could afford the several-thousand dollars per system for FDDI attachments could gain suitable network performance. Ethernet and Token Ring LANs simply don't offer the bandwidth high-end PCs and faster systems require. In addition, LANs haven't kept up with other system resources. You need only look at the numbers to understand the performance discrepancy between a LAN connection and the rest of a computer system.

Disk drives for PCs, for example, now offer data-transfer rates as fast as 4 Mbytes/sec, and even low-end drives typically attain 2-Mbyte/sec rates. Drives targeted at other system architectures transfer data even faster. Yet Token Ring offers a 16-Mbps (2-Mbyte/sec) maximum transfer rate, and most Token Ring LANs operate at only 4 Mbps. Ethernet operates at a maximum rate of only 10 Mbps. In addition, each system can access only a portion of a network's bandwidth. Because many systems can share a LAN, any given system may have to wait some period of time to gain access to the network. Furthermore, protocol software such as TCP/IP (transmission-control protocol/internet protocol) for Unix-based LANs adds substantial overhead to data transfers on a network. A workstation typically realizes data transfers at 30 to 50% of the network maximum.

Yet LANs are necessary. Consider situations that range from an engineering team using CAE tools over a network to design a product to a business office sharing a mailing list. Managers and users demand LANs despite the sluggish performance most LANs offer. System administrators like the LAN concept also. The administrators cringed when the barrage of users with distributed PCs revolted against multiuser minicomputers. They feared that key data might be lost or mismanaged. Furthermore, administrators of a legion of PCs faced major headaches anytime maintenance or software updates were required. The LAN concept allows administrators to manage key data and handle software updates on a network server. In fact, most administrators would prefer to assign users diskless workstations.

Today, most LANs store shared data and some programs on a server. But users of performance-hungry programs typically demand local storage. For example, most engineers store frequently used CAE programs locally. Likewise, a power PC user would be reluctant to load Windows or Windows' applications over a network. The next generation of LANs and other data-communications links may make local storage unnecessary.



Station-management features such as group-address matching and source routing are handled by National Semiconductor's DP83200 family of FDDI chips.

Proponents have long championed FDDI as the LAN that solves the performance bottleneck. The ANSI X3T9.5 standard specifies a network that offers 100-Mbps data rates using a dual counter-rotating ring topology. **Fig 1** depicts the FDDI topology (see **Refs 1, 2,** and 3 for more background information). FDDI's high bandwidth and token-passing scheme can serve PCs, workstations, and even larger systems well, despite overhead added by network software protocols. But the cost of implementing FDDI has remained at least $2000 more expensive per node than Ethernet and Token Ring, and, therefore, the faster LAN has largely been delegated to serving as a backbone that connects lower-speed departmental LANs. The fiber optics, the connectors, and the optical transceiver modules required for FDDI keep the cost high. Furthermore, vendors of FDDI chips have been unable to cut costs substantially because production volumes have remained low.

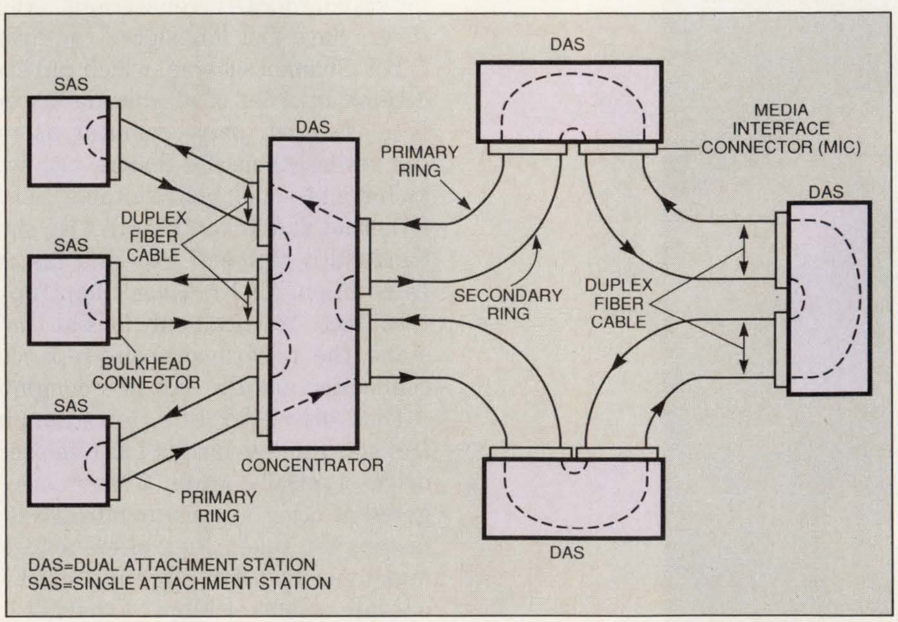


Fig 1—The FDDI LAN employs a Token Ring architecture, includes dual counter-rotating rings for reliability, and allows you to use concentrators to reduce the cost of node adapters for individual workstations.

You should consider adding FDDI or an alternative to your new system designs in spite of present high prices. Users are nearing the point of demanding faster networks, and a number of developments promise to relieve the price hurdles that have kept FDDI from the desktop. Working groups within the ANSI X3T9.5 committee have been busily attempting to standardize on two lower-cost media that can handle FDDI's speed and data encoding (see **box**, "Low-cost FDDI").

This month, expect the committee to endorse a

Low-cost FDDI

The relatively high cost of FDDI has kept the 100-Mbps LAN from challenging Ethernet or Token Ring for the PC and workstation marketplace. Primarily, the fiber-optic medium, the connector, and the optical transceiver required to meet the FDDI spec boost the cost. High cost has thus far relegated FDDI to use as a high-speed backbone network that connects multiple departmental or subnetworks that use Ethernet or other less expensive LAN technologies. However, two ANSI X3T9.5 committee working groups have been developing alternatives to standard FDDI that should lower costs.

The FDDI spec defines a dual-ring topology that ensures reliability. But the spec also describes a multiport concentrator that can be used to connect stations that have a single-ring interface to the dual-ring main network. (**Fig 1** (main text) depicts a concentrator on an FDDI network.) The concentrator handles network reliability and includes circuitry that can wrap and self-heal the network when connected single-ring stations or nodes on the dual ring fail. Concentrators are expensive—ranging from \$5000 to more than \$50,000 based on the number of ports included.

The groups working on low-cost alternatives intend to lower the cost of both concentrators and the node controllers for individual stations. One of the groups has concentrated on developing a lower-cost fiber-optic implementation. Meanwhile, the second group has been working on a way to attain 100-Mbps transmissions on copper wire.

Bob Fink, head of communications and network resources at Lawrence Berkeley Labs, chairs the low-cost-fiber working group. Fink reports that the low-cost-fiber proposal is in draft format and is in the ANSI review process. Therefore you can assume the specification is fairly solid. It defines a fiber-optic LAN that can only stretch 500m between nodes compared with 2 km for standard FDDI. The low-cost-fiber version uses the same fiber medium as standard FDDI but should require substantially less expensive optical transceivers to drive the shorter cable lengths.

Defining copper standards

The group working on the copper-wire alternative is not as far along but has certainly been in the news more often recently. The effort to define a standard copper-wire alternative to FDDI is almost two years old. The effort has centered on achieving 100-Mbps transfers on three types of wire: shielded twisted pair, data-grade unshielded twisted pair, and voice-grade unshielded twisted pair. Furthermore, the group would like communication to be reliable at distances of at least 100m.

A number of companies have made presentations to the working group on data-encoding methods that achieve the desired speed on copper. Recently, the working group made two key decisions. The group decided that no proposed encoding scheme would work reliably at 100m on voice-grade unshielded twisted pair. The group therefore decided to concentrate its efforts on a scheme that would work for the other two types of wire, despite the fact that much of the installed wire for 10Base-T Ethernet is voice-grade unshielded twisted pair.

The working group also decided to concentrate on two proposed encoding schemes. The MLT-3 (multilevel transitional) code backed by Crescendo Communications and AT&T is one of the schemes. National Semiconductor backs the other scheme, which it has trademarked 100Base-T and which is also known as preemphasized NRZI (non return to zero inverted). Currently, Hewlett-Packard, with help from other interested parties, is performing unbiased test of the two technologies to determine whether the two proposals meet the working group's goals. The encoding schemes also must be able to meet FCC RFI requirements.

Bill Cronin, principle engineer at Digital Equipment Corp, chairs the working group for copper FDDI alternatives. Cronin hopes to decide on a copper FDDI scheme in meetings this month. He expects Hewlett-Packard to report on the test, and, after discussion among the group, he expects to hold a vote on the two proposals. The working group can then move forward with completing the standards process. But, more importantly, companies can proceed to build products that will meet the standard. For more details on the history of the copper FDDI effort, see **Ref 3**.

method for running FDDI data over shielded twisted-pair wire and data-grade unshielded twisted-pair wire. Such a method will allow many to run FDDI over existing network wiring. Furthermore, the committee is already reviewing a standard that specifies a lower-cost fiber-optic medium that covers shorter distances.

The new media don't require complete new FDDI chip sets either. They only affect chips that implement the PMD (physical medium dependent) sublayer of the FDDI spec. Designers can therefore use a single FDDI implementation to serve all types of FDDI media. You simply customize the board- or system-level implementation with a daughter card—or even an external plug-in module—that handles the physical interface.

The FDDI architecture will allow you to mix and match different media using concentrators. Therefore, you can match FDDI to your needs. The type of medium that you have previously installed can also affect your choice of FDDI medium because cable-installation cost can exceed the cost of new hardware. A small office that needs short cable runs can stick strictly with the lowest cost choice—copper wire. Larger installations can use a main dual ring that uses standard FDDI and concentrators that connect to the dual ring can provide low-cost loops to individual stations. Stations that connect using copper wire can be 100m from the concentrator, whereas low-cost-fiber stations can stretch as far as 500m away. Bob Fink, chairman of the low-cost-fiber working group believes a low-cost-fiber node will cost about $15 more than a copper node.

You should be able to buy the ICs that you'll need to implement all types of FDDI soon. Currently, Advanced Micro Devices (AMD), Motorola, and National Semiconductor all offer complete FDDI chip sets. AT&T has a chip that handles strictly the physical layer of the standard. Expect either National or AT&T to have a PMD chip for FDDI on copper by mid-year at the latest. Which company will be the first to market will depend on the decision that the working group makes on which encoding method to use with copper wire. Regardless, expect the first PMD chip out to work with FDDI chip sets from all three vendors. And other vendors will follow the first with their own PMD chips shortly after. Each company has committed to following the standard adopted by the committee. Apparently, you can use existing PMD chips to implement

Manufacturers of data-communications products

For more information on data-communications products such as those described in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you saw their products in EDN.

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low-cost fiber already, although down the road the companies may choose to create new chips specifically for the new standard.

Choosing among the available FDDI chip sets to implement your design probably will require you to match the architecture of your design to the available ICs. You may find that one of the chip sets mates to your choice of controlling μP more easily than the rest. But the key to your choice will most likely center on the chip set that offers the best performance in your design.

Just two to three years ago, the trend in LAN-adapter designs was to use a dedicated μP to control network operations and possibly even off-load the task of executing the network protocol from the host. Such an architecture still works fine, but it proves too costly for most desktop applications. In many cases, the CPU in a PC or workstation has to wait for the network to move data anyway. Therefore, you may as well let the CPU perform the network-protocol task.

So the key to performance in your design may be

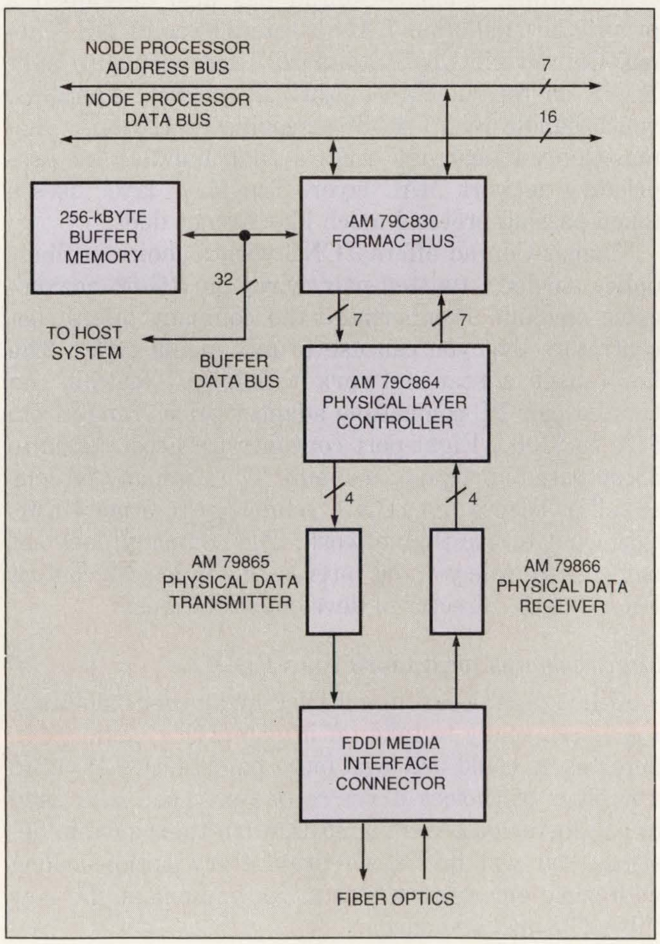
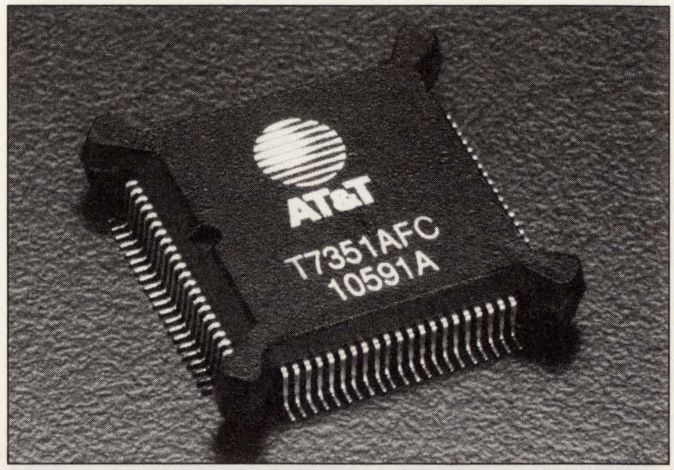


Fig 2—The MAC, PHY, and PMD sublayers defined by the FDDI specification map directly to ICs in AMD's Supernet 2 family of chips.



The T7351A PHY chip from AT&T includes a dedicated 8-bit station-management bus and dissipates less than 800 mW of power.

how well the FDDI chip set can take data directly from main memory and send it down the network medium with no latency. AMD, Motorola, and National all claim direct memory transfers to be among the key performance features of their chips. Their chips purportedly minimize latency by eliminating memory-to-memory transfers.

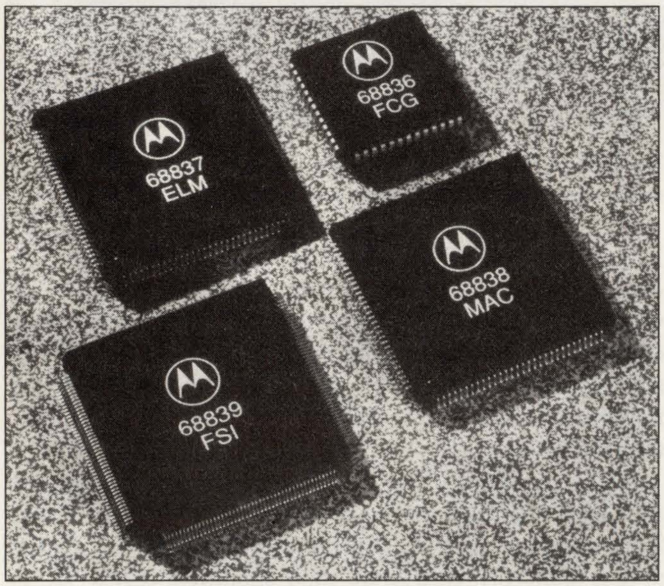
AMD pioneered the FDDI chip business with its Supernet 1 family and now offers the 4-chip Supernet 2 set shown in **Fig 2**. The set includes a MAC (media-access control) chip that also includes the system-interface circuitry. The Am79C864 PLC (physical layer controller) IC performs the PHY (physical) sublayer of the FDDI spec and handles the connection-management portion of the FDDI station-management requirements. Separate ICs handle the send and receive PMD tasks. The Supernet 2 set adds a tag-mode feature that allows the ICs to transfer data directly to and from main memory. The Supernet 2 chip set costs $159.75 (1000).

Motorola's chip set includes a dedicated IC that handles the system interface—the MC68839 FDDI System Interface. The IC uses a 128-bit-wide internal bus and has dual 32-bit I/O ports. The set also includes a MAC IC (the MC 68838), the MC68837 elasticity buffer and link manager, which handles connection management and portions of the physical layer, and the MC68836 FDDI clock generator, which connects to external driver and receiver chips. This chip set costs $186 (1000).

IC handles station management

National's DP83200 family of chips is partitioned similarly to Motorola's, except the National family uses a fifth chip to do clock distribution. Key features of National's set include the ability to automatically sort incoming low- and high-priority frames. The ICs also perform station-management group-address matchings, and the PHY chip includes a multiplexer for concentrator applications. Finally, the chip set includes a bus-master interface for SBus systems such as Sun SPARCstations. The chip set costs $190 (1000).

AT&T currently offers only an IC that handles the PHY sublayer. The company's T7351A performs the 4B/5B encoding and the NRZI (nonreturn-to-zero-inverted) data recovery specified by the FDDI standard. The PHY chip costs $50 (1000). AT&T marketing



The MC68800 chip set from Motorola includes two 32-bit I/O ports and uses a 128-bit-wide internal bus to move data at the 100-Mbps FDDI speed.

manager Juan Figueroa states that the company wants to offer a single-chip FDDI implementation rather than a chip set. And Figueroa believes that AT&T will offer such a chip next year.

FDDI chip-set prices seem reasonable now but have yet to experience a drop caused by high-volume demand. Standard FDDI transceiver modules can still cost $500 or more, and you need two for a dual-ring connection. (**Ref** 4 contains more information on FDDI transceivers.) The new low-cost fiber and copper standards should remove the transceiver-cost obstacle.

Proprietary LANs are here now

But if you can't wait, a couple of companies already offer other ways to add 100-Mbps communications to a system. The proprietary schemes don't offer compatibility with a standard such as FDDI, but they can be bridged to any standard network. Furthermore, you can realize even lower-cost designs than you will be able to with low-cost FDDI.

PC-Office, for example, designed a proprietary LAN that can operate at 50 or 100 Mbps, depending on cable length and the type of wire used. The LAN uses cable that includes six twisted pairs, so it most likely will not operate over existing wiring. But John Costello, company president, points out that the 6-pair cable costs only $0.06 per ft. The PC-Office LAN uses a collision-detection scheme similar to Ethernet, and you bus the cable from system to system. Without concentrators or signal repeaters, the network operates over a total cable length of 800 ft.

The best feature of the PC-Office LAN is its price, however. A 16-bit ISA bus card (model T100) costs only $295. Furthermore, the company sells the 6100 IC, which drives the network, for less than $90. The 6100 includes a 16-bit host interface. The company also plans to offer a 2-chip set with a 32-bit host interface for less than $180. Although the PC-Office LAN doesn't have FDDI's dual-ring topology to ensure reliability, or offer the cable length FDDI does, it can serve departmental needs well. And you can still bridge the departmental LAN to a main network.

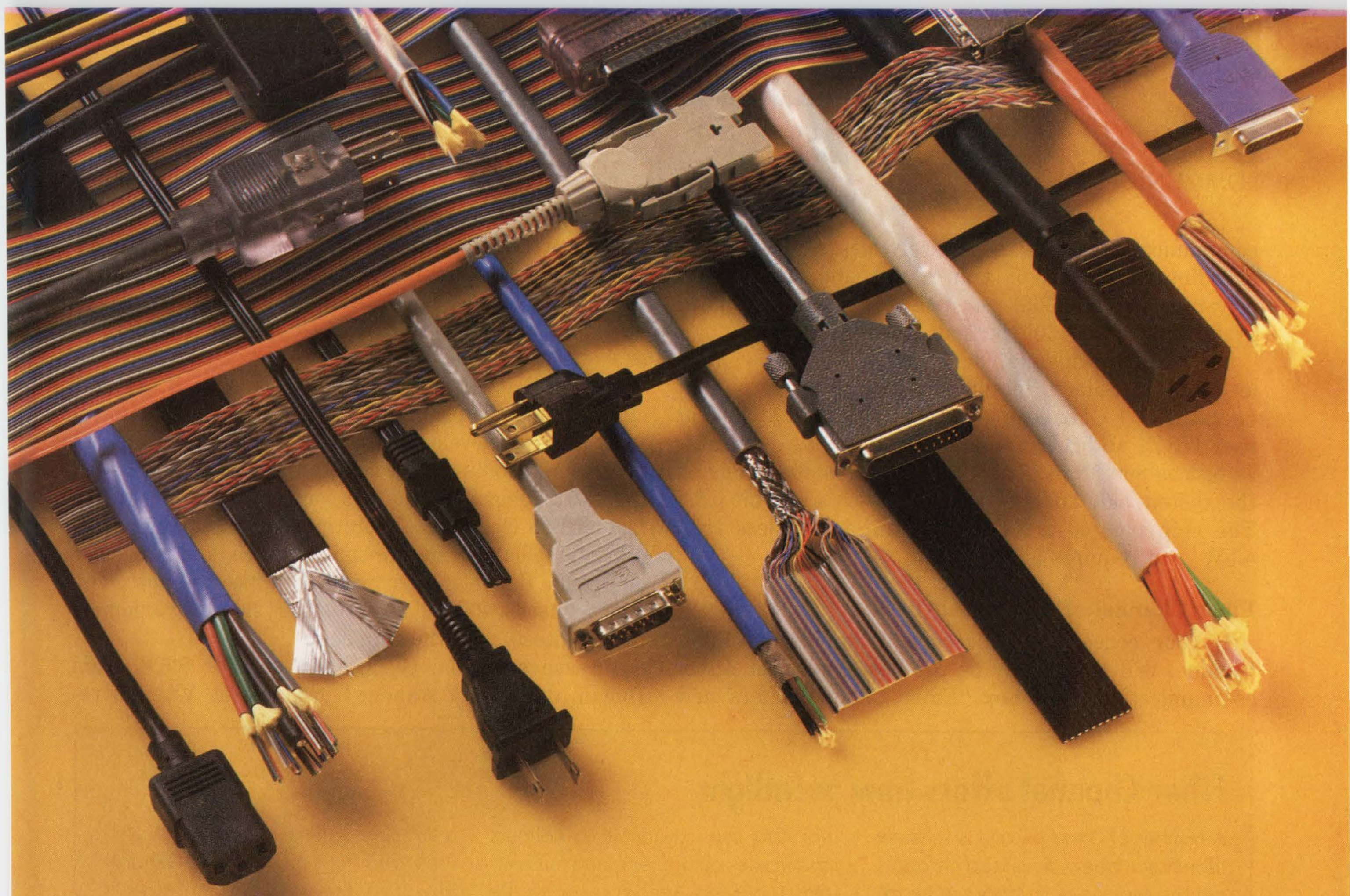
Meanwhile, Thomas-Conrad has also developed a proprietary 100-Mbps LAN it refers to as TCNS (Thomas-Conrad Network Standard). The company built TCNS on top of AMD's Am7968/Am7969 Taxichips, which handle NRZI 4B/5B encoding at 100 bps. Thomas-Conrad designed ASICs that handle the proprietary network MAC layer. The MAC layer uses a token-passing protocol much like Arcnet does.

Thomas-Conrad offers TCNS with a choice of fiber-optic, shielded twisted-pair wire, or RG-62 coaxial-cable medium. Furthermore the company offers concentrators that you can use to mix media types. The LAN uses a star network topology. Coaxial and twisted-pair PC-compatible adapter prices range from $595 to $1000. Eight-port concentrators cost $2000 to $3000 based on type of medium. The company intends to sell or license the TCNS technology to other OEMs that want to use the network. The company does not have ICs for sale yet, but interested parties can contact Peter Rauch, director of developer relations.

Many systems need more than FDDI

Although it looks like FDDI and other 100-Mbps LANs are ready to take off in popularity, many computer users could use even more bandwidth. You have a number of choices if you're one of those who need to add faster data communications to their system designs. You will find some proprietary options along with some emerging ICs that can implement the new Fiber Channel standard.

AMD's Taxichip mentioned previously, for example, has been available for some time in 125- and 175-MHz speed grades. The grades support 100- and 140-Mbps



communications rates, respectively, using NRZI 4B/5B encoding. The Am7968 transmitter and Am7969 receiver cost $36 (1000) per pair for the lower-speed grade and $44.75 (1000) per pair for the faster ICs.

Triquint, meanwhile, has used its GaAs (gallium arsenide) manufacturing process to produce an IC that operates at 1 GHz. The company's Hot Rod 2-chip set uses NRZI 4B/5B encoding and can realize data rates as fast as 800 Mbps. The chip set uses a 40-bit bus on the system side and is compatible with all 32-bit μPs. The chip pair costs $440 (100), dissipates less than 4.5W, and requires a 5V supply.

Fiber Channel offers 100 Mbytes/sec

If your concern is adherence to standards, Fiber Channel will most likely be the best choice for faster communications (see **box** "Fiber Channel offers new paradigm"). Fiber Channel defines 100-Mbyte/sec point-to-point communications channels and a matrix of switches called a fabric that can perform a network-like function. The standard also specifies operations at slower speeds such as 25 and 50 Mbytes/sec.

Vitesse Semiconductor recently introduced the first chip set capable of handling Fiber Channel communications. Vitesse developed the 4-chip set using its GaAs process and architectural assistance from AMD. Called the G-Taxichip set, the ICs can actually operate as fast as 1.25 Gbits/sec. A multiplexer chip and a transmitter chip handle the transmit function, and a receiver chip and a demultiplexer bring data into the host. The chip set uses a 40-bit bus on the host side. **Fig 3** depicts the architecture of the chip set.

Vitesse sells the G-Taxichip set for $900. Tom Dugan, director of standard products at Vitesse, re-

Fiber Channel offers new paradigm

A number of communications schemes that have been discussed throughout the industry can boost network-communications speeds past the 100-Mbps FDDI rate. Fiber Channel currently appears to be the most practical in the short term.

The point-to-point data-communications scheme offers a maximum 100-Mbyte/sec data-transfer rate but can also operate at ½, ¼, or ⅛ of maximum speed. The fiber-optic communications channel can connect two devices over a distance of 4 to 10 km based on the type of fiber optic used. It uses an 8B/10B data-encoding scheme.

You may wonder why a point-to-point communications standard is relevant in a discussion about LANs. It's certainly relevant here because FDDI is actually no more than a network made up of point-to-point links. You could also make a fast network with Fiber Channel links. However, the Fiber Channel standard being shepherded by the ANSI X3T9.3 committee defines a new paradigm for communications that may transcend LANs.

Fiber Channel defines a communications channel in the same sense that IBM uses channels to connect mainframe computers and subsystems together. And, in a sense, the Fiber Channel physical interface resembles a mass-storage interface because it doesn't rely on software protocols to ensure reliable data transfers.

The fabric of fiber

Fiber Channel depends on dedicated hardware to control communications. The standard requires no network protocol and handles errors in hardware. The standard defines a set of switches, called a fabric, that performs a function similar to that of a large telephone-system switch. Each computer system or peripheral attaches to the fabric with dedicated send and receive lines. And the switch can route any incoming signal to any output port.

The fabric, at first glance, doesn't look like a network. In reality, however, the fabric is similar to many LAN installations, most of which use a star-wired topology that requires a cable from each system to route into a central wiring closet. Network administrators demand such a topology to ensure reliability against single-point failures and to simplify troubleshooting. The Fiber Channel fabric's switches actually form temporary direct links between systems. But the hardware can change connections so quickly that Fiber Channel can perform the same functions as a LAN, only far more efficiently.

Fiber Channel fabrics require you to add switches if you want to add systems to a network, whereas typical LANs require you to add multiport concentrators to add network stations. Adding to a Fiber Channel fabric, however, adds to the total bandwidth of the network because the fabric supports multiple point-to-point communications channels simultaneously. In contrast, adding nodes to a LAN actually reduces the bandwidth for each station.

Also realize that 100-Mbyte/sec Fiber Channel links deliver data at that rate. The standard actually uses a 1.0625-Gbps communications rate that includes error detection data. The 100-Mbyte/sec rate is a realizable rate and is not partially wasted by network protocols.

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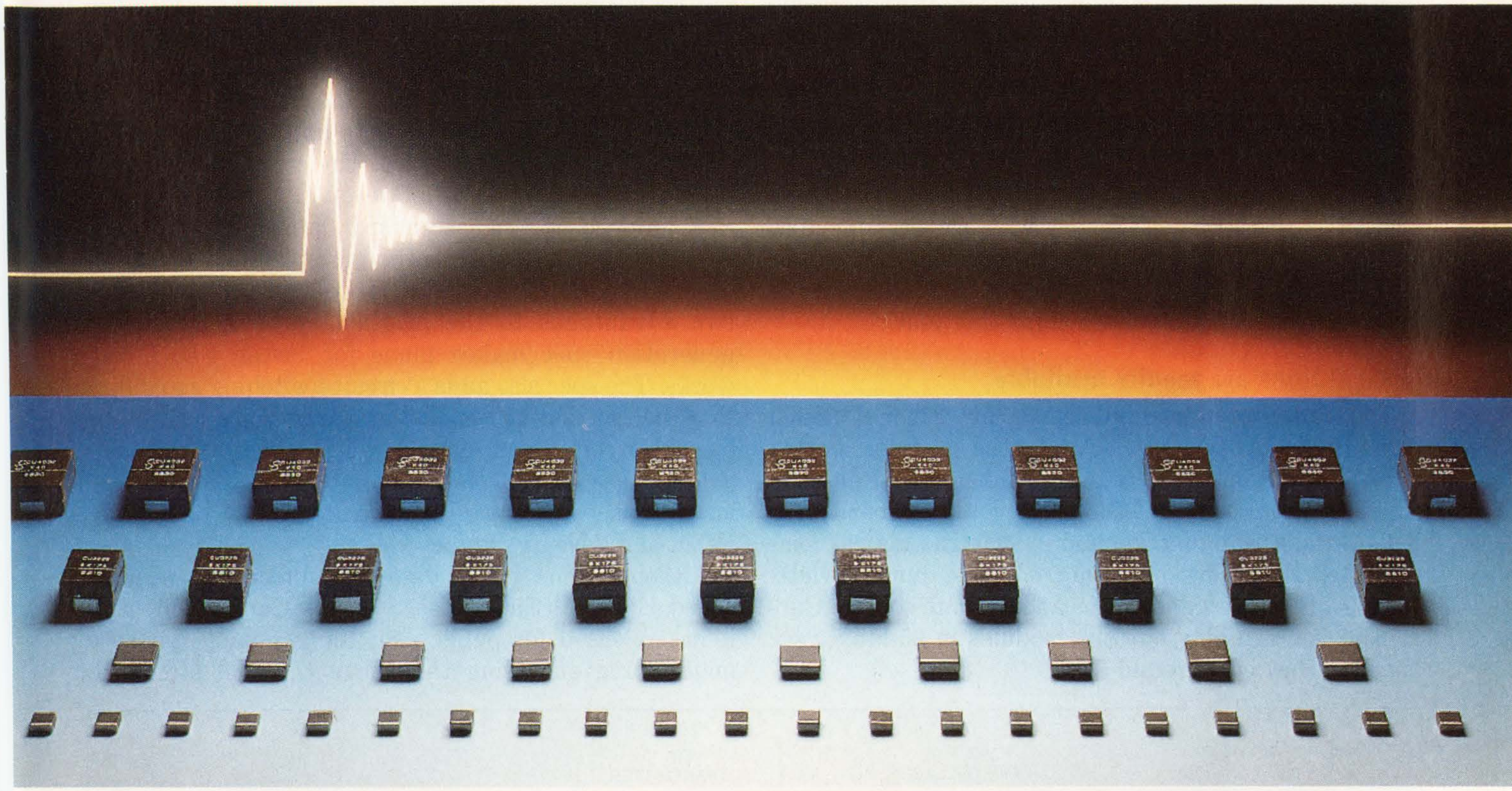

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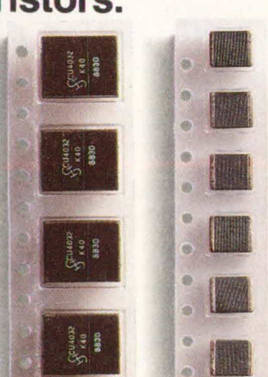

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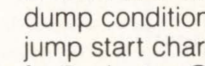

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ports that customers have shown interest in using the chip set in applications ranging from LAN backbones to parallel bus serialization to video distribution. AMD also has the right to sell the G-Taxichip set but has chosen not to at this time. AMD did just introduce its own Fiber Channel-compatible version of its Taxichip line. The Am79168/Am79169 offer 25-Mbyte/sec Fiber Channel communication using 8B/10B encoding. The companies' other Taxichips use 4B/5B encoding. The new chips cost about $55 (1000) per pair.

You can expect a few other companies to offer Fiber Channel chips shortly. AMCC has described a 2-chip set at ANSI meetings that they will formally announce this quarter. The company will build the 100-Mbyte/sec chips using its ECL process. Cypress Semiconductor is also expected to introduce chips this year.

Optical links are readily available

You can buy optical-link cards for Fiber Channel from IBM and Hewlett-Packard. The modules include a 10-bit-wide interface to a transmitter/receiver pair. The cards, dubbed OLC 266, perform the Fiber Channel's serialization function and include the optical components. IBM developed the modules, but Hewlett-Packard recently signed on as an alternate source. Currently, you can only buy the modules in 25-Mbyte/sec speeds. They cost around $500.

Ancor Communications plans to offer a fabric shortly that will use the OLC 266 module. The Ancor fabric will feature a modular architecture that users can expand in 16-port increments. Ancor also had to develop an ASIC to handle the Fiber Channel coding and framing requirements not handled on the OLC 266. The company is considering selling the ASIC, although it expects fabrics to be its primary product for Fiber Channel. Canstar also plans to offer a fabric, and, like Ancor, is working on an ASIC to handle higher layers of the Fiber Channel standard. The company currently has no plans to sell an IC however.

A number of other standard data-communications efforts may merit your continuing attention for future use. The FDDI-II standard is well defined and adds two advantages to the original spec. The second-generation spec makes plans for faster FDDI networks. The spec also adds a circuit-switching capability to FDDI so that the LAN can carry voice as well as data. No companies offer FDDI-II chips as yet, but you may see an IC from AT&T later this year. Several large Japanese companies are rumored to be testing FDDI-II LANs already as well.

Although IBM has a data-communications scheme called ESCON (Enterprise Systems Connection) that it has released for public use, the company is also a major force endorsing the Fiber Channel standard.

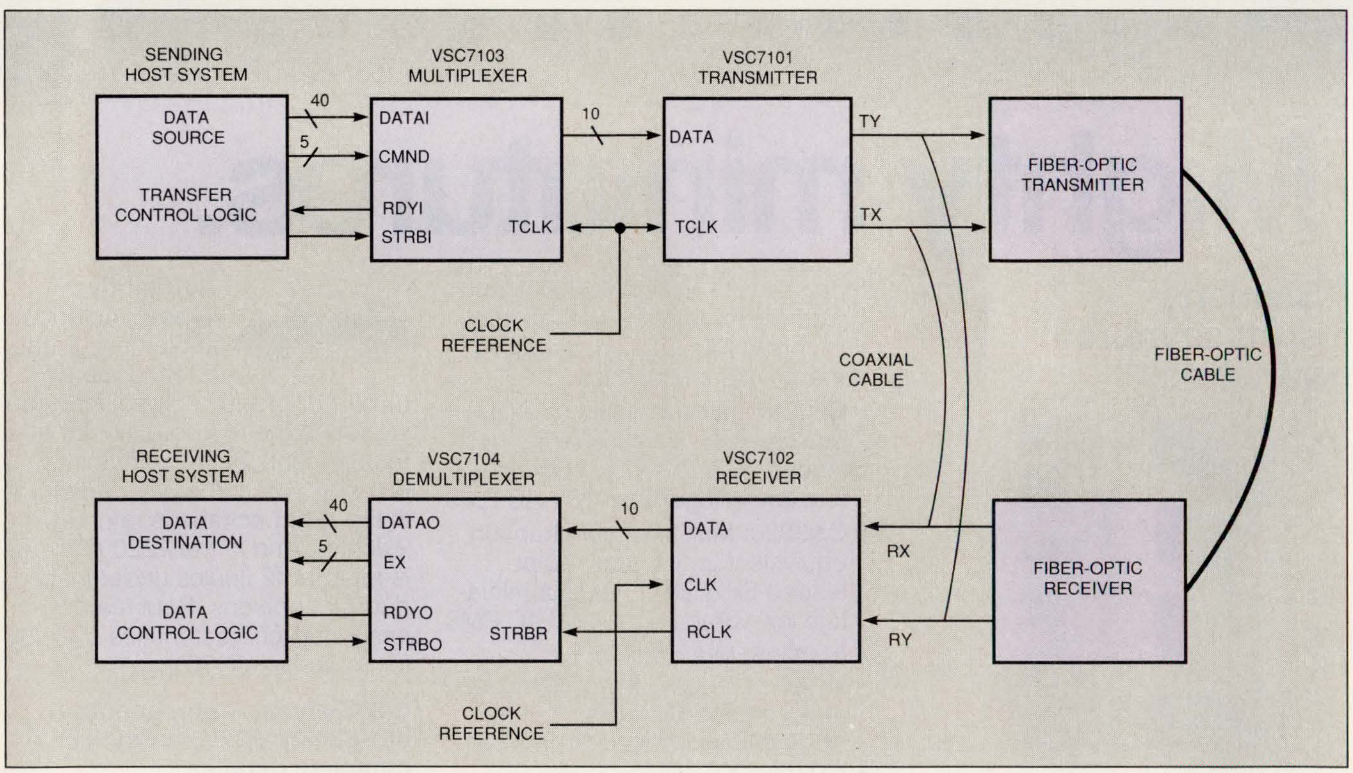

Fig 3—You can design Fiber Channel point-to-point links that operate at 100 Mbytes/sec using the G-Taxichip set from Vitesse Semiconductor.

Data
COMMUNICATIONS

While they wait for Fiber Channel's 100 Mbytes/sec, the company is using ESCON at lower speeds. The communications scheme operates as fast as 200 Mbps, and IBM uses it for computer-to-computer and computer-to-subsystem links. You can use AMD's newest Taxichip set and the OLC 266 optical links from IBM and Hewlett-Packard to build an ESCON interface.

Further down the road, some people see SONET (synchronous optical network) as the do-all end-all for data communications. SONET was designed as a replacement for T1 telecommunications links and initially will be used exclusively for telecommunications. Looking ahead, manufacturers could combine it with a data-communications standard called asynchronous transfer mode to bring 1-Gbit/sec connections that have the convenience of a LAN to every desktop worldwide. EDN

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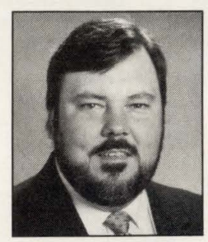

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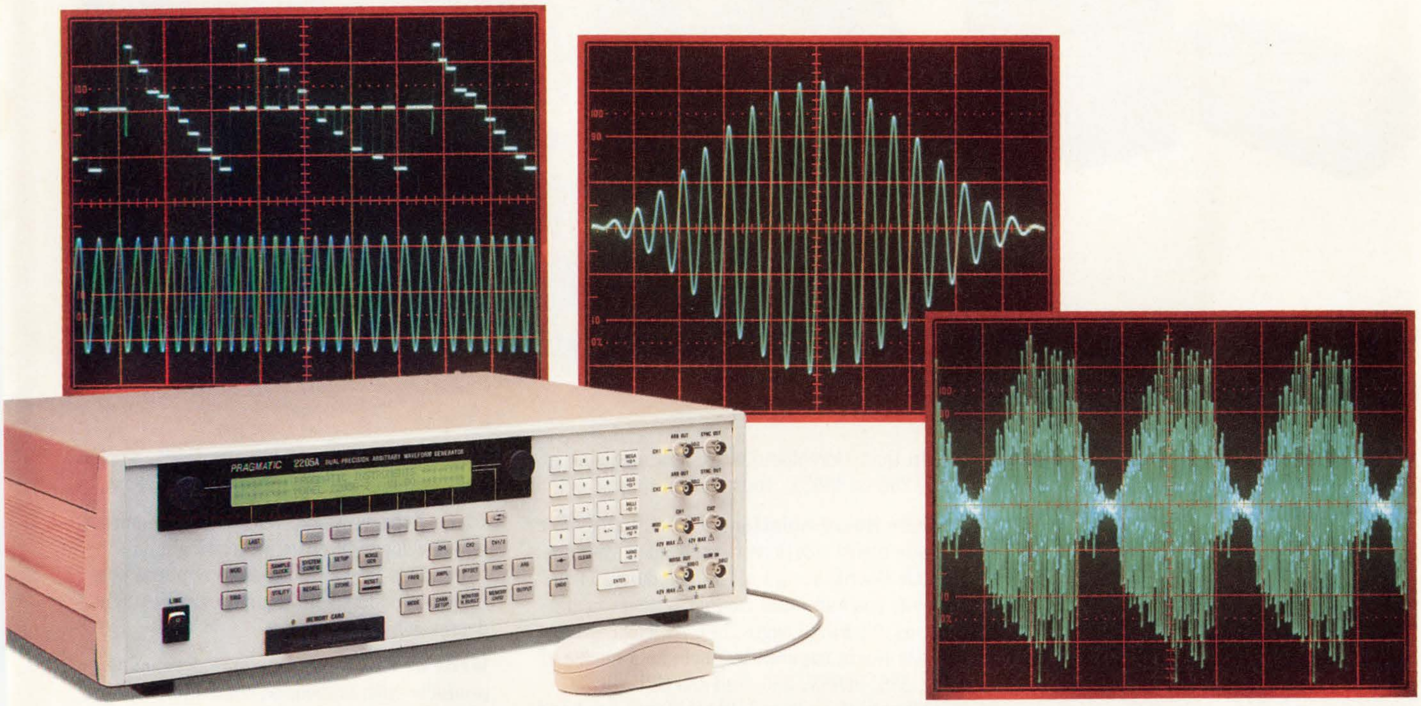

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In fact, they're ideal for any design that craves the low power of the LMC6082 (900µA) or the ultra-low power of the LMC6062 (32µA). All while slewing at 1.5V/µs and 0.035V/µs, respectively.

FEATURES

- 350µV offset voltage*
- 1µV/°C offset voltage drift
- 10fA input bias current
- 85dB CMRR
- 85dB + PSRR/94dB - PSRR
- Rail-to-rail output swing
  LMC6082: 4.98V-0.02V (100kΩ)*
  4.50V-0.40V (600Ω)*
  LMC6062: 4.99V-0.01V (100kΩ)*
  4.975V-0.02V (25kΩ)*
- Free SPICE model

*guaranteed max/min specs

Single-supply operation with rail-to-rail output swing.

The LMC6082/6062 guarantees maximum signal range thanks to its rail-to-rail output swing — a feature that's especially critical in single-supply systems where every millivolt matters.

What's more, its input common-mode range includes ground. Which means you can zero in on even the lowest signals.

So now you can count on unparalleled, single-supply precision. Wherever you happen to be.

Go for it.

For your *free* sample kit and SPICE model, call: 1-800-NAT-SEMI, Ext. 183. Or, fax: 1-800-888-5113.

National Semiconductor

NORTH AMERICA: P.O. Box 7643, Mt. Prospect, IL 60056-7643 (Tel: 1 800 628 7364, ext. 183; Fax: 1 800 888 5113); **EUROPE**: Industriestraße 10, D-8080 Fürstenfeldbruck, Germany (Tel: 49 8141 103 0; Fax: 49 8141 103 515); **HONG KONG**: 15th Floor, Straight Block, Ocean Center, 5 Canton Rd., Tsimshatsui, Hong Kong (Tel: 852 737 1654; Fax: 852 736 9921); **JAPAN**: Sanseido Building 5F, 4-15-3, Nishi-shinjuku, Shinjuku-ku, Tokyo, Japan 160 (Tel: 81 3 3299 7001; Fax: 81 3 3299 7000).

CIRCLE NO. 94

ELECTRO '92
BOSTON

Focusing on the needs of design engineers, Electro/92 will offer more than 60 technical sessions and 800 exhibits. Technical courses and management seminars round out the program.

Dave Pryce, Technical Editor

THE CITY OF BOSTON, noted for its cultural and historical attractions, will host Electro/92 on May 12, 13, and 14. This year, all Electro events will be held at the Hynes Convention Center, which is located on Boylston Street adjacent to the Prudential Center in downtown Boston.

The theme of Electro/92 is "New Directions in High-Tech Innovation." In keeping with this theme, and in response to the increasing significance of software innovation, this year's show will feature several sessions on software in engineering. You'll be exposed to the most current software programs and methods, and be able to meet the experts at the forefront of software development.

Helping to kick off Electro/92 will be Jim P. Manzi, president and CEO of Lotus Development Corp. Manzi will deliver the keynote address, entitled "Networks and Mobile Users: Personal Computing in the 90s." The keynote program will take place at a luncheon at noon, Tuesday, May 12, in the Hynes Convention Center. Tickets are $25.

Following the keynote luncheon, IEEE life members are invited to attend the seminar on

Photography by Kevin Bryan

"The Father of Radio: E H Armstrong." Professor William Siebert, Ford Professor of Engineering at MIT, will deliver the talk at 2:30 pm in the Hynes Convention Center.

In addition to the focus on software engineering, Electro/92 includes more than 50 other technical sessions (see **table**). The categories for these sessions are

- Concurrent-engineering methodologies
- Concurrent-engineering technology
- Semiconductor-device technology
- Manufacturing, quality, and reliability
- Engineering and technical education
- Going international
- Current topics.

Complementing the technical sessions are several conferences, technical short courses, and management seminars. An all-industry

Electro/92 technical-session schedule

Day/time	Concurrent-engineering methodologies	Concurrent-engineering technologies	Semiconductor device technology	Manufacturing, quality, and reliability	Software engineering	Engineering and technical education
Tuesday May 12, 1992 9:15 am to 11 am		**Session 1** New trends and techniques in system-level verification	**Session 2** Model availability and how we achieve it	**Session 3** Total-quality-management trends	**Session 4** A re-engineering process for large software systems	**Session 5** Competitive engineering methodology
1 pm to 2:45 pm	**Session 8** Expert-system development and application	**Session 9** TCAD for total quality control	**Session 10** Modern solid-state microwave design	**Session 11** Customer-driven product design	**Session 12** Software-engineering process trends and overviews	**Session 13** Restructuring the engineering resource for the 21st century
3:15 pm to 5 pm	**Session 16** Knowledge-based engineering/expert systems	**Session 17** Impact of integrated-component information management	**Session 18** Building design-for-test into your ASICs	**Session 19** Supportability-assessment systems and model-development environments	**Session 20** Software reliability engineering	**Session 21** Systems for keeping world-class engineers up to date
Wednesday May 13, 1992 9:15 am to 11 am	**Session 24** Product data sharing using STEP	**Session 25** Innovations in CAD for electromechanical design	**Session 26** FPGAs—Where is the industry going?	**Session 27** Design-to-cost	**Session 28** Object-oriented design	**Session 29** Education for total quality management
1 pm to 2:45 pm	**Session 32** ECAD frameworks: standardization in the marketplace	**Session 33** PC-board technology trends	**Session 34** FPGA design technology enhances design productivity	**Session 35** SMT processing	**Session 36** Software development and applications using object-oriented and other technologies	**Session 37** Software education for open systems
3:15 pm to 5 pm	**Session 40** Improving the design process—the best of theory and practice	**Session 41** Computer-aided-design tools for solid-state-device development	**Session 42** Programmable architectures	**Session 43** An approach to building distributed applications on the plant floor	**Session 44** Software re-use issues	**Session 45** Career planning for the 1990s
Thursday May 14, 1992 9:15 am to 11 am	**Session 48** Managing concept-to-commercialization cycle time: opportunities and expectations	**Session 49** Concurrent engineering in ASIC design	**Session 50** Multichip modules			
1 pm to 2:45 pm	**Session 53** Concurrent engineering	**Session 54** Current issues in thermal management	**Session 55** Cache-memory design: what's new?			
3:15 pm to 5 pm			**Session 58** Specialty memory: applications and innovations			

Admission to technical sessions and exhibits is complimentary.

*Sessions 7 and 39 require special registration.

conference, titled "How the Northeast Can Grow in the World Marketplace," will be held Tuesday, May 12, from 9:15 to 11:00 am. Tickets are $20. A purchasing conference, titled "Teambuilding: The Ultimate Vendor," will be held Wednesday, May 13, from 1:00 to 2:45 pm. Again, tickets are $20.

The technical short courses include full-day seminars on such topics as programming with the X-Window system, the Demeter method for object-oriented design, surface-mount technology, use of Spice for modern analog simulation, and concurrent engineering. The cost of these technical courses ranges from $300 to $400.

The management seminars feature idea-generating topics such as project management, doing business with the Japanese, and preparing and delivering effective presentations. These seminars cost $300 each. The technical short courses and the management seminars will be held on Monday, May 11, from 9 am to 5 pm.

Exhibits abound

Engineers attend Electro as much for the diverse exhibits as for the technical sessions and other programs. Perhaps nowhere else can an engineer gain as much knowledge of available products as in the aisles of these exhibits.

Going international	Current topics
Session 6 Global engineering	**Session 7*** All-industry conference
Session 14 Government support to international trade	**Session 15** Super glue: high-speed logic for the 1990s
Session 22 European perspective: overview of Europe on becoming a single market	**Session 23** Current topics in medical electronics
Session 30 Avoiding legal landmines in global marketing strategies	**Session 31** Getting started: the right steps in starting and growing your own high-tech company
Session 38 Third-world manufacturing	**Session 39*** Purchasing conference
Session 46 International finance	**Session 47** Marketing in Asia
Session 51 Specs and standards go international	**Session 52** Recent developments in high-performance storage batteries
Session 56 Forming international relationships	**Session 57** Energy management from utility to customer
Session 59 The use of on-line resources for scientific, technical, and marketing research	

Traveling to Electro

The site of this year's Electro show is the Hynes Convention Center, located at 900 Boylston Street adjacent to the Prudential Center in the Back Bay section of Boston.

From the west, you can reach the Convention Center by taking the Massachusetts Turnpike (Route 90) to the Prudential Center exit.

From Logan Airport and points north, take Route 93, which runs north and south through Boston, to the Storrow Dr exit at Copley Square. Turn right on Beacon St, left on Massachusetts Ave, and left on Boylston St.

From the south or east, take the Southeast Expressway (Route 93/3) to the Massachusetts Ave exit. Continue on Massachusetts Ave to Boylston St.

Park 'n ride locations

To avoid the rush-hour traffic and to address the limited parking available in downtown Boston, four park-and-ride locations will operate Tuesday through Thursday, May 12 to 14. You can park in one of three suburban locations and take the free Electro shuttle to the Hynes Convention Center.

The shuttle location for the north is the Showcase Cinema in Woburn; for the west, Shoppers World in Framingham; and for the south, the Showcase Cinema in Dedham.

Shuttle buses will leave at 20-minute intervals from 7:40 to 9:00 am and return from the Convention Center from 4:00 to 5:30 pm on Tuesday and Wednesday and 3:00 to 4:30 pm on Thursday.

Bayside parking

"In-town" parking will be available at the Bayside Expo Center in Boston. The cost to park will be $5. Shuttle service to the Hynes Convention Center will run from 8:30 am to 5:30 pm and will operate at 20-minute intervals most of the day.

You can reach Bayside from the north or south by taking exit 15 from Route 93/3. From the west, take the Massachusetts Turnpike east until it merges with the Fitzgerald Expressway and Route 93 in Boston; follow the signs to Route 93 South.

Electro/92

Nearly 400 manufacturers will display products ranging from components, hardware, and semiconductors to CAD/CAE tools, test equipment, power supplies, and production equipment.

Exhibits will be open from 9 am to 5 pm on Tuesday and Wednesday (May 12 and 13), and from 9 am to 4 pm on Thursday, May 14. Registration at the door is $5 for IEEE members and $10 for nonmembers. However, if you bring a complimentary registration form with you to Electro, you'll receive free admission to the show. Registration will be located on the second floor of the Hynes Convention Center.

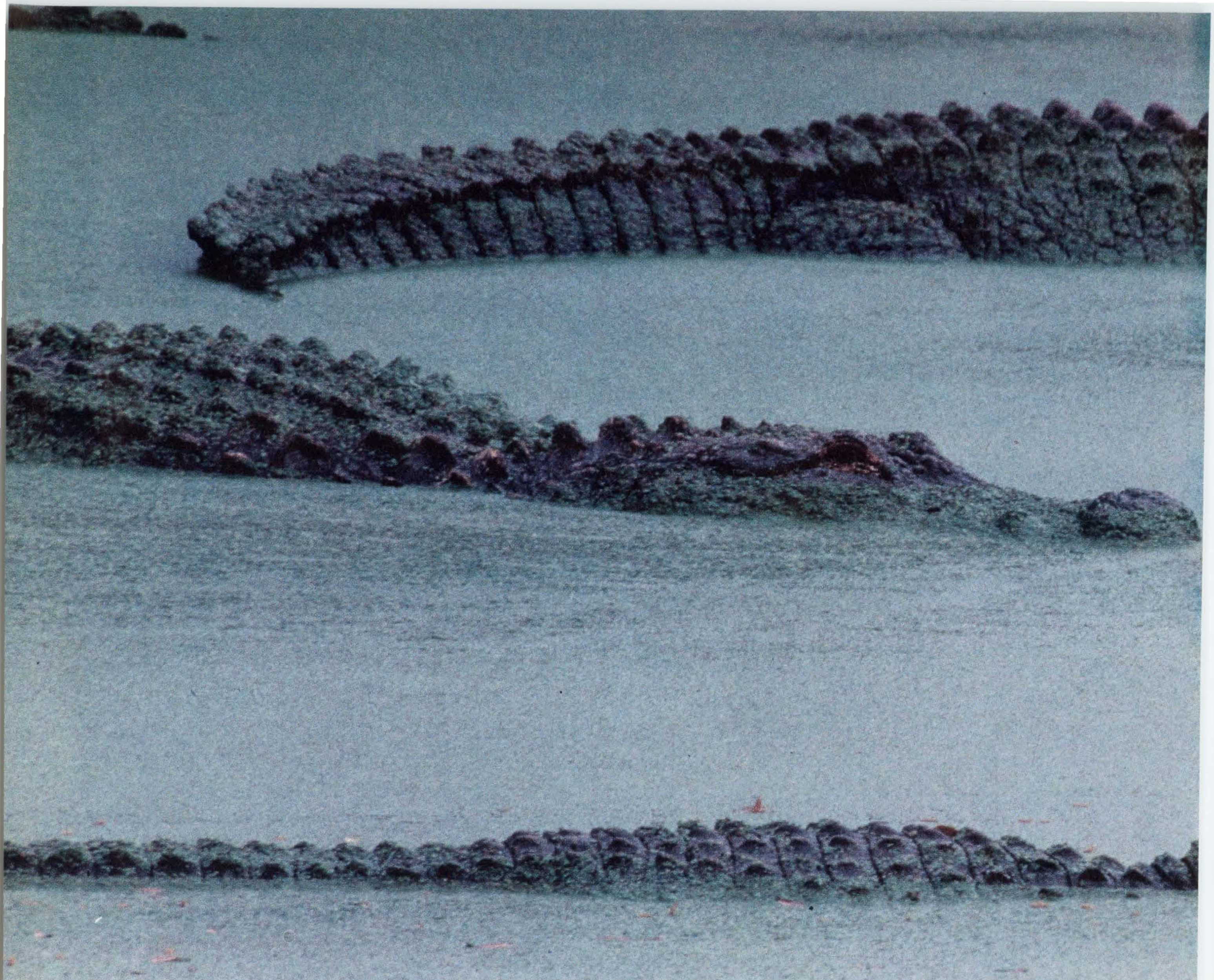
Digital Equipment Corp has invited Electro/92 attendees to DECWorld '92, which is being held at Boston's World Trade Center from April 27 through May 15. DECWorld will present a line-up of personal computing and supercomputing products. The exhibits will highlight new services and business practices and will feature advanced business applications available from DEC and hundreds of its business partners.

Electro attendees will be able to register for specially scheduled tours at the DECWorld booth in the Hynes Convention Center. Bus transportation will be available between the Hynes Center and the World Trade Center.

With its wealth of historical attractions and its notably good food and entertainment, Boston is always a favorite spot for Electro visitors. After a full day of attending technical sessions and visiting the exhibits, you can relax and enjoy the best that the city has to offer. EDN

Dave Pryce, Technical Editor, can be reached at (617) 558-4326; FAX (617) 558-4470.

Article Interest Quotient
(Circle One)
High 470 Medium 471 Low 472



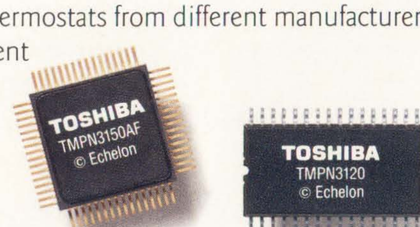
Your friends would tell you if they were using a LONBUILDER 2 Developer's Workbench to develop new products, wouldn't they?

Not if they're also your competitors, they won't.

Because using a LONBUILDER™ 2 Developer's Workbench and LONWORKS™ technology gives them a tremendous advantage.

They can develop and produce intelligent distributed control applications very quickly and inexpensively. And market new products that can interoperate and perform more functions, more efficiently.

For example: In an office environment, switches, lights, security sensors, and thermostats from different manufacturers can work together to maximize efficiency and productivity. On a factory floor, equipment can be tied into the building automation system to maximize control and conserve energy. The applications are endless, and the companies that develop them first will reap the benefits.

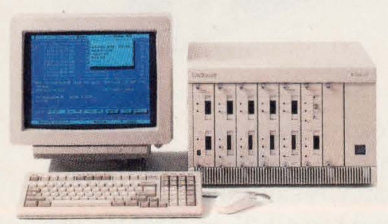


At the heart of this competitive advantage is LONWORKS control network technology, developed by Echelon.® LONWORKS networks are made up of a series of interoperating "nodes." Each node contains a NEURON® CHIP, made by Toshiba, the first company to ship them in production quantity. There are two types: the NEURON 3120™ CHIP for applications where size and cost are most critical; and the NEURON 3150™ CHIP with external memory support for more complex applications.

Each node also contains an interface that allows NEURON CHIPS to communicate over a wide variety of common media, using the common LONTALK™ protocol.

There are a host of LONWORKS products available, including control modules, bridges and routers, network management tools, and the LONBUILDER 2 Developer's Workbench.

Really 3 tools in 1, the Developer's Workbench is: a multi-node system for developing and debugging LONWORKS nodes; a network manager for installing and debugging the integrated network; and a protocol analyzer for network monitoring and testing. An easy to use interface called LON® Navigator takes you through the process, then compiles, links, loads and configures your applications with a single command.



All of which makes LONWORKS technology the first low cost, off the shelf solution to your distributed control application needs. More than 200 companies have already recognized its potential and are using LONBUILDER 2 Workbenches to develop their next generation of products.

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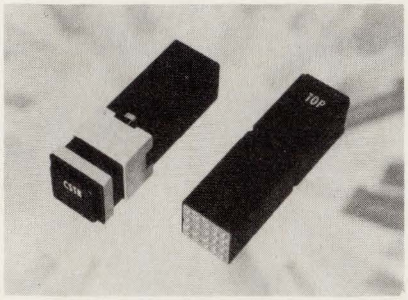
For more information and the location of the Toshiba Demonstration Office nearest you, call the LONWORKS Hotline at **1-800-879-7566**. Or fax **1-415-856-6154**. (From outside the U.S., please fax.) Or write to Echelon Corporation, 4015 Miranda Avenue, Palo Alto, CA 94304.

ECHELON

CIRCLE NO. 97



Lighted Pushbutton Switches

The Series 584 lighted pushbutton switches includes an extended-capsule model that provides a 75° cone of vision. Other models are a rod-mount model that permits gang-mounting into small panel openings and a termination system that permits easy assembly and disassembly of wires. The ⅝-in. switches and indicators have an 8A rating. Matrix-mount switches accept poke-home terminals conforming to the MIL-C-39029/57-354 standard. Options include RFI/EMI protection, drip- or slash-proof seals, switch guards, and spacers for light-plate thicknesses. \$95 to \$285 (1000).

Eaton Corp, Aerospace and Commercial Controls Div, 4201 N 27th St, Milwaukee, WI 53216. Phone (414) 449-7326. Booths 2233 and 2235. **Circle No. 400**

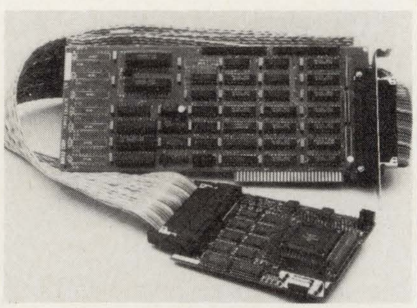
Fine-Pitch Sockets

The Socket/Adapter System lets you temporarily surface mount a quad flatpack (QFP) on a pc board. The lower portion of the socket surface mounts to a footprint pattern of the QFP via a gull-wing lead frame. The upper portion of the socket, which houses the QFP device, connects to the lower assembly. When the QFP device no longer requires a socket, you can surface mount the device directly to the board without redesign costs. The unit accepts any QFP having lead pitches of 0.025 in. or less. Units are available for 100-, 128-, 132-, 164-, 196-, and 208-pin devices. 100-pin unit, \$272.

Advanced Interconnections Corp, 5 Energy Way, West Warwick, RI 02893. Phone (401) 823-5200. FAX (401) 823-8723. Booths 3412 and 3414. **Circle No. 401**

In-Circuit Emulator

The Emul16/300-PC is an in-circuit emulator for Motorola's 16-bit 68HC16 and 32-bit 68300 μCs. The emulator consists of an ISA bus plug-in board, a 5-ft twisted-pair ribbon cable, a pod board, and an optional trace board. The software runs under Windows 3.0, which lets



you monitor several functions at the same time. For example, you could link the contents of a shadow-RAM to an Excel cell while the emulator is running at full speed. The emulator provides real-time emulation at 16.78 MHz. The pod board has 256 kbytes of emulation RAM, and the ISA bus board has 1 Mbyte of shadow RAM that writes to both external and internal memory at full speed. \$1995.

Nohau Corp, 51 E Campbell Ave, Campbell, CA 95008. Phone (408) 866-1820. FAX (408) 378-7869. Booths 5403 and 5405. **Circle No. 402**

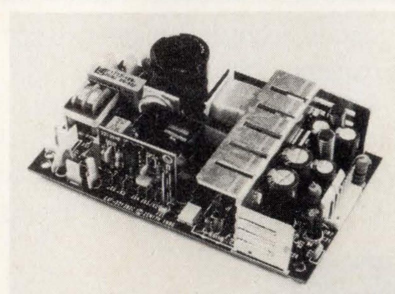
Universal Programmer

You can use the BP-1200 universal programmer to program EPROMs, EEPROMs, bipolar PROMs, PLDs, and all microcontrollers. The unit can change the voltage on any pin, which eliminates the need for DACs. The programmer weighs less than 6 lbs and measures $9.56 \times 6.75 \times 3$ in. You can choose among versions with 32-, 40-, or 48-pin driver cards; all versions come with a 48-pin ZIF DIP IC socket. The universal SMT-84 surface-mount socket accepts 20- to 84-pin plastic leaded chip carriers and small-outline packages. BP-1200/32, \$2500; BP-1200/40, \$3000; BP-1200/48, \$3500. SMT-84 surface-mount socket, \$750; individual plastic-leaded-chip-carrier sockets, \$90.

BP Microsystems Inc, 10681 Haddington Dr, Houston, TX 77043. Phone (800) 225-2102; (713) 461-9430. Booth 1106. **Circle No. 403**

Switching Power Supply

The ZPS-45 switching power supply operates with a single-phase 85 to 265V ac or 120 to 364V dc input voltage. The unit provides 40W max using convection cooling and 45W max using air-flow cooling. The triple-output unit supplies 5V dc at 5A; 12V dc at 2A; and −12V dc at 0.7A. The 5V output has a



±3% load regulation. The ±12V outputs have ±5% load regulation. The supply resides on a 3×5-in. pc board and has a 1.25-in. profile. The supply meets FCC Part 15J Class B and VDE 0871/B EMI emission standards and has a 100,000 MTBF. \$55.

Zenith Magnetics, 1000 Milwaukee Ave, Glenview, IL 60025. Phone (708) 391-8510. FAX (708) 391-7078. Booths 1101 to 1105. **Circle No. 404**

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Our DIP switches are compatible with today's demanding assembly methods. We audit *every* production lot of sealed DIP switches with the 85°C Flourinert 60-second immersion test for proven seal integrity. We apply this same care to our entire line of DIP switches to guarantee the highest quality standards. High quality at a competitive price. Broadline variety – surface mount, low profile, right angle, side actuated and our new .050 pitch miniature make C&K your primary DIP switch source. For free catalog and engineering samples – Call (800)635-5936 or Fax (617)527-3062.

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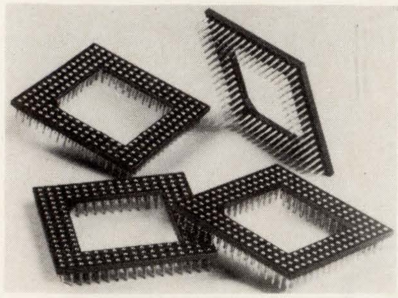


PGA Sockets

The Series MD cold-formed pin-grid-array (PGA) sockets come in five grid sizes ranging from 11×11 to 17×17 pins. The sockets have 68 to 168 pins. Seamless BeCu contacts require a typical insertion force of 1.5 oz. Molded standoffs and a liquid-crystal-polymer insulator allow vapor-phase or IR soldering. A cold-form sleeve prevents solder wicks from forming in the contact area. Features include 10-mΩ contact resistance, 3A contact rating, 2-pF contact-to-contact capacitance, 1×10^6-MΩ insulation resistance, 1000V ac (rms) dielectric withstanding voltage, and a −55 to +125°C operating temperature range. $0.01 to $0.018 (OEM).

Marc Eyelet Inc, 63 Wakelee Rd, Wolcott, CT 06716. Phone (203) 756-8847. FAX (203) 755-9410. Booth 4318. **Circle No. 405**

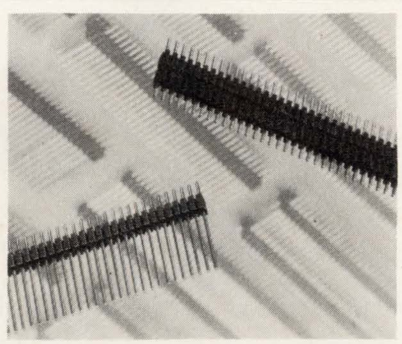
CAD Software

The HiWire II Version 2.2 electronic CAD package lets you do schematic capture and circuit-board design. A menu-driven executive program automatically organizes projects and files. A graphical editor uses a single pull-down menu, which contains frequently used commands. You can draw schematics and circuit-board drawings having as many as 200 ICs within the 640-kbyte MS-DOS limit. In addition, the editor supports 32 Mbytes of expanded memory and 15 Mbytes of extended memory for more complex designs. The drawing grid can be in inch or millimeter scales. A utility for rubber bands and rats nests simplifies both editing and placement. Two autorouters feature 1-mil resolution and support buried and through-hole vias. From $995 to $2395.

Wintek Corp, 1801 South St, Lafayette, IN 47904. Phone (800) 742-6809; (317) 742-8428. FAX (317) 448-4823. TLX 709079. Booth 1216. **Circle No. 406**

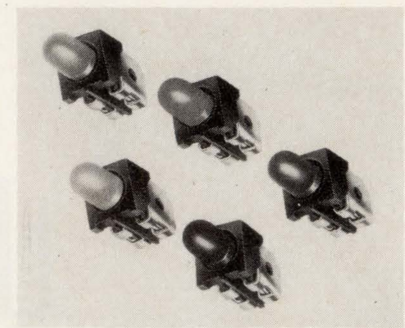
Terminal Strips

The company has expanded its line of 0.05-in. microconnectors to include headers having variable post and body heights. The MTMS Series lets you order custom post heights without long lead times or minimum orders. The 0.05×0.10-in. centerline terminal strip is available with post heights ranging from 0.10 to 0.605 in. in 0.005-in. increments. The terminal strips come in single or double rows having as many as 50 positions/row. The DWM Series provides flexibility in board stacking. The 0.05×0.10-in. terminals permit board spacings of 0.38 to



0.92 in. when they mate with the company's SLM and SMS Series socket strips. Plating options and a variety of lead styles are available for both series. MTMS and DWM Series, from $0.028 and $0.031 per pin, respectively.

Samtec Inc, Box 1147, New Albany, IN 47151. Phone (800) 726-8329. FAX (812) 948-5047. Booth 3322. **Circle No. 407**



Surface-Mount LEDs

The SMT LEDs are a line of T-1 and T-1 3/4 surface-mount LEDs. The LEDs are available in five colors—red, green, amber, yellow, and blue. Bicolor (red/green) LEDs are also available. The units withstand IR and vapor-phase mounting and have standoffs to ease cleaning solder flux. The LEDs mount at right angles to the board and have built-in resistors for 5 or 12V operation. A black-molded housing meets the UL 94V-0 rating. Solder-coated terminals employ a self-aligning 6-point attachment to ensure electrical and mechanical integrity. The units come in antistatic tape and reel packages that conform to EIA 481 specifications. From $0.78 (1000).

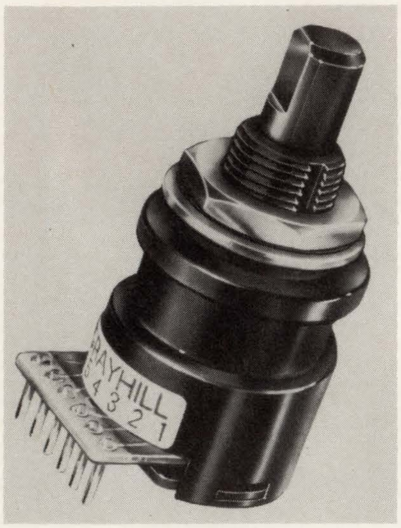
Industrial Devices Inc, 260 Railroad Ave, Hackensack, NJ 07601. Phone (201) 489-8989. FAX (201) 489-6911. Booth 1430. **Circle No. 408**

Arc Suppression Networks

The Type LNEM metalized-polyester suppression network suits arc-suppression and snubber applications. The network provides a series-connected capacitor and resistor in a single component. Laser-produced patterns create 60 to 1000Ω resistors that dissipate 0.5 to 2W. Capacitance is 0.1 or 0.5 μF (±20%), rated for 600V dc or 250V ac. The unit has been tested to withstand one billion 330V peak-to-peak pulses. The axial-lead networks are available in bulk quanti-

ties or tape and reel packages for automatic insertion. 0.1 μF, 600V dc, 100Ω, 0.5W unit; $0.58 (1000).

Aerovox, 742 Belleville Ave, New Bedford, MA 02745. Phone (508) 999-1000. FAX (508) 990-8696. Booth 2221. **Circle No. 409**



Optical Rotary Encoder

The Series 61 optically coupled rotary-encoder switch provides two quadrature encoded output signals. The switch produces the output signals by interrupting a light beam or allowing light to fall on a pair of phototransistors. Because there are no metal-to-metal contacts, the switch's rated lifetime is one million cycles of operation. An integral pushbutton switch lets you set the 2-bit output code for a desired setting. $10.50 (100).

Grayhill Inc, 561 Hillgrove Ave, LaGrange, IL 60525. Phone (708) 354-1040. FAX (708) 354-2820. Booths 3504 and 3506. **Circle No. 410**

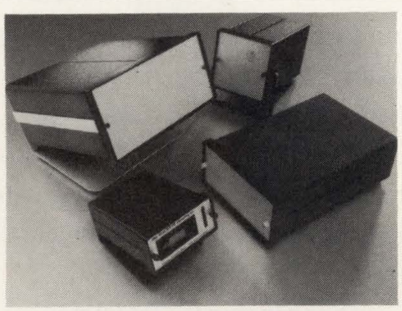
Switching Power Supplies

The MSC Series includes 350, 400, and 750W triple-output and a 400W dual-output switching power supplies. The supplies power multiple synchronous disk-drive systems. Each supply can maintain 1% regulation on the 12V line when powering as many as 16 disk drives. The 350 and 400W triple-output units deliver 35A from a primary 5V output and 26A peak from secondary ±12V outputs. The 750W unit delivers 120A from 5V, 27A from 12V, and 6A from −12V. The 400W dual-output unit has input and output connectors instead of standard barrier strips. The dual-output unit delivers 20A at 5V and 25A from 12V. An autorange option automatically selects a 115 or 230V ac range. $300 to $500.

Todd Products Corp, 50 Emjay Blvd, Brentwood, NY 11717. Phone (800) 223-8633; (516) 231-3366. FAX (516) 231-3473. Booths 5308 and 5310. **Circle No. 411**

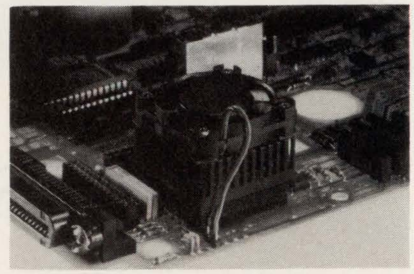
DIN Enclosures

The E Series DIN-standard enclosures are available in a black wrinkle-finish powder coat. The enclosures are made from extruded aluminum shapes that lock together to create rectangular or square enclosures of any length. Standard units are 6- or 8-in. deep and have integral grooves that are 0.08-in. wide on



0.2-in. centers. The spacing lets you mount boards vertically or horizontally. Side bars lock the units in place when you mount them in a panel. The enclosures have a PVC vinyl-coated tilt handle. A 44×91-mm, 6-in.-deep case, $16.05 (25).

Buckeye Stamping, 555 Marion Rd, Columbus, OH 43207. Phone (614) 445-8433. Booths 4404 and 4406. **Circle No. 412**



PGA Cooling Modules

The Thermalloy Cooling Modules consist of a pin-fin heat sink and a brushless dc fan. The five standard modules cool Intel's i486, i860, i960, Advanced Micro Devices' Am29000, and Motorola's 68040 μPs. The units also fit on pin-grid arrays (PGAs) having 15×15, 17×17, 18×18, or 21×21 pins. You can select a 5 or 12V fan for the module. Cooling with a 5V fan is 5 to 9 times more efficient than natural convection cooling and 2.7 times more efficient than forced-air convection at a 400 ft/min (fpm) linear airflow. For example, a module for a 17×17-pin PGA has a thermal resistance of 1.4°C/W as compared with 10°C/W for natural convection cooling and 3.9°C/W for 400-fpm forced-air cooling. $13.24 (500).

Thermalloy Inc, Box 810839, Dallas, TX 75381. Phone (214) 243-4321. FAX (214) 241-4656. TLX 203965. Booth 5136. **Circle No. 413**

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The TG and TXG Series impact printers come in an injection-molded housing having a 7.8×6-in. footprint. The nine models provide a range of 24 to 42 print columns and have an RS-232C, RS-422, or Centronics parallel port. The 24-column model prints 144 dots/line; the 42-column model prints 252 dots/line. An input buffer and bit-image graphics are standard on all models. The TXG Series has a 6912-character input buffer, and the TG Series has a 2048-character input buffer. The units operate from a

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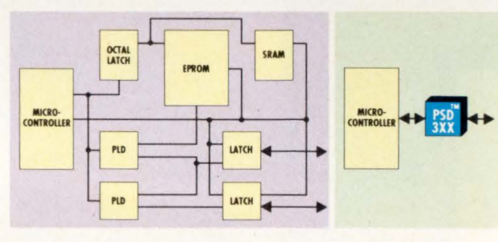

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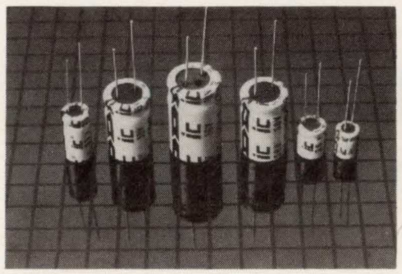
Telpar Inc, Box 796, Addison, TX 75001. Phone (214) 233-6631. FAX (214) 233-8947. Booth 2308. **Circle No. 414**



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A line of low-leakage, radial-lead, aluminum capacitors offers an alternative to tantalum capacitors. The devices feature a 0.1- to 1000-μF capacitance range, a working voltage range of 10 to 50V dc, a minimum leakage current of 0.4 μA; an operating temperature range of −40°C to +85°C; and a storage temperature range of −55°C to +85°C. Standard capacitance tolerance is ±20%; ±10% tolerance is optional. From \$0.04 (1000).

Illinois Capacitor Inc, 3757 W Touhy Ave, Lincolnwood, IL 60645. Phone (708) 675-1760. FAX (708) 673-2850. TLX 724361. Booth 4514. **Circle No. 415**

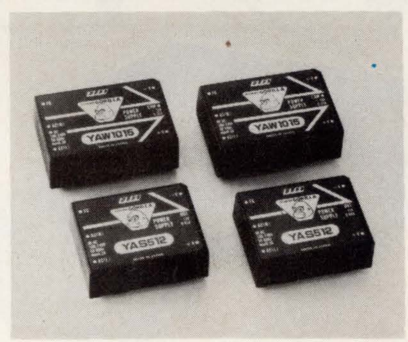
Digital Voltmeter

AP-501 Series digital voltmeters have a 3½-digit LED display and a measurement accuracy of 0.1% of the reading or 1 digit at room temperature. The four meters in the series span the measurement range from 200 mV to 200V. The two low-voltage models have a differential input, and the two high-voltage models have a single-ended input. Other features include automatic zero and decimal-point adjustment. When an input signal exceeds the display range, the meter displays an overrange indicator. The meters measure 48×96×12.2 mm and weigh 50 grams. The meter's conversion rate is 2.5 sec. \$71.

Delco Products Co, 7580 Stage Rd, Buena Park, CA 90621. Phone (800) 257-3526; (714) 521-8673. FAX (714) 739-1507. Booth 4305. **Circle No. 416**

PC-Board AC/DC Converters

The YAS and YAW series 5 and 10W ac/dc converters have single and dual outputs, respectively. The units mount to a pc board and have autoranging inputs that handle 100 to 240V ac. The 5W units measure 58×45×19.5 mm, and the 10W units measure 65×45×21 mm. Both series come in 5V, ±12V, or ±15V output models. Other features include 20-msec holding time,

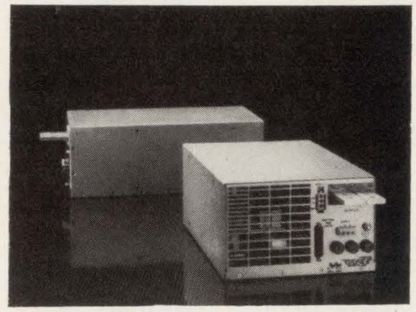


47- to 440-Hz frequency range, typical inrush current of 20A for 100V ac inputs and 40A for 200V ac inputs, and automatic recovery from overcurrent operation. The units operate from 0 to 55°C. They can withstand 10g vibration from 10 to 55 Hz and an impact of 50g for 11 msec. \$41 to \$48 (100).

US Elco Inc, 2930 Scott Blvd, Santa Clara, CA 95054. Phone (800) 888-3526. FAX (408) 980-9754. Booth 1405. **Circle No. 417**

Power Supply

The M series 3500W power supply comes in a 5×8×11.5-in. package. Models in the series have 2 to 6V dc outputs. Because the 100-kHz switcher has a current-controlled MOSFET H-bridge, you can connect as many as eight supplies in a parallel current-sharing configuration. The supply has overvoltage, overcurrent, and over-temperature protection. The supply accepts a 3-phase, 47- to 63-Hz, 220V ac input or a 230V dc input. An input power-fail flag indicates when the input power drops below the minimum line voltage. Other features are 0.1% line regulation, 0.2% load

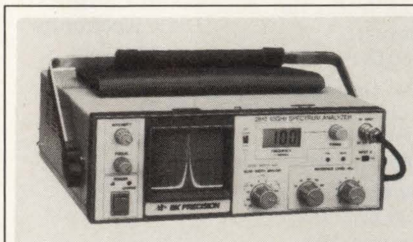


regulation, and a maximum inrush current of 30A peak. The unit weighs 22 lbs. $2495.

Opt Industries Inc, 300 Red School Lane, Phillipsburg, NJ 08865. Phone (908) 454-2600. FAX (908) 454-3742. Booths 5128 and 5130. **Circle No. 418**

Spectrum Analyzer

The Model 2610 portable RF spectrum analyzer can operate at 1.0 GHz. The 4.5×11.8×13.4-in. unit weighs 20 lbs and runs from ac or battery power. For communications measurements, you can select a fixed RF bandwidth of 1 MHz regardless of the scan-width setting. The analyzer has a rechargeable battery and battery charger as well as a 100-MHz, 80-dBμV calibration signal. The unit has a switch-selectable input impedance that

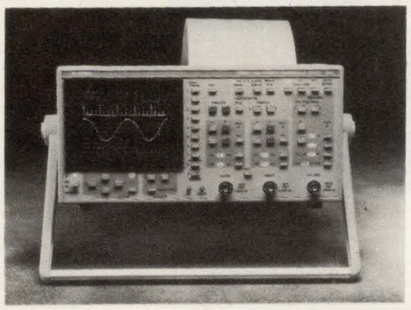


matches either 50 or 75Ω cable. The analyzer comes with a 75Ω input cable, BNC-to-F connector adapter, CRT hood, adjustment tool, spare fuses, and a manual. $2995.

B+K Precision, 6770 W Cortland Ave, IL 60635. Phone (312) 889-1448. FAX (312) 794-9740. Booth 2132. **Circle No. 419**

Portable Digital Oscilloscope

The 465 portable digital oscilloscope can simultaneously sample two channels at 200 Msamples/sec, thus providing a 100-MHz signal bandwidth for both channels. The unit has a 2-Gsample/sec equivalent time-sampling rate for repetitive signals. Other features include 8-bit resolution for all input sensitivities,



three nonvolatile waveform memories, 400V input protection, and a battery option for field-service applications. The scope conforms to the IEEE-488.2 Standard Commands for Programmable Instruments (SCPI) standard. On-screen cursors facilitate voltage and time measurements, and the automatic setup feature evaluates a signal to optimize scope settings. $3490.

Gould Inc, Test and Measurement Group, 8333 Rockside Rd, Valley View, OH 44125. Phone (216) 328-7263. FAX (216) 328-7400. Booth 2303. **Circle No. 420**

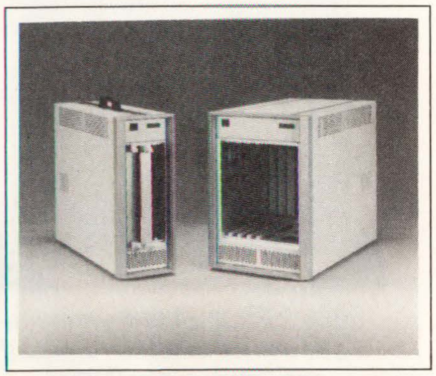
Vertical Enclosures

Models in the Frugal Frame line of vertical enclosures incorporate top and base cowlings as part of the frame. The enclosures accept most of the company's accessories, including cooling devices, mounting channels, hardware, shelves, power strips, drawers, writing surfaces, panels, and doors. The enclosures are available in 21- to 78-in. panel heights having 19-in. widths. Depths of 25½ or 30 in. are optional. The enclosures have a textured finish, and panels, doors, and tops are available in a variety of standard colors. A modular design permits series-mounted and multibay configurations. Typical cost for a 61 × 19 × 25½-in. console is $450 including frame, top panel, side panels, and rear door.

Amco Engineering Co, 3801 N Rose St, Schiller Park, IL 60176. Phone (800) 833-3156; (708) 671-6670. FAX (708) 671-9469. Booths 1415 and 1417. **Circle No. 421**

Futurebus + Products

A line of Futurebus + floor-standing tower chassis meets Profile A, B, and F specifications. The multi-



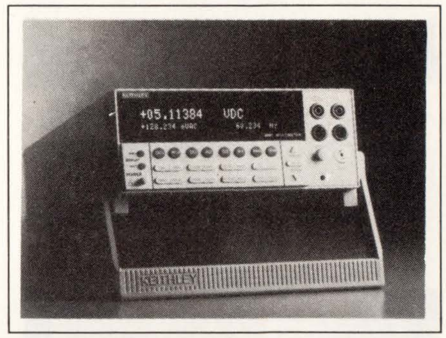
layer 64-bit, 192-pin backplane has three I/O slots. The chassis feature RFI/EMI shielding and come with a fan and power supply. A line of backplanes that meet Profile A, B, and F specifications is also available. The multilayer, impedance-controlled backplanes have 3 to 14 slots and 192 I/O pins for 64-bit data transfers. The backplanes feature surface-mount terminators, distributed and central arbitration, and 2-mm metric connectors. Chassis, from $3000. Backplanes, from $850 for a 3-slot version; $2150 for a 14-slot version.

Schroff Inc, 170 Commerce Dr, Warwick, RI 02886. Phone (800) 451-8755; (401) 732-3770. FAX (401) 738-7988. Booth 5424.

Circle No. 422

Digital Multimeter

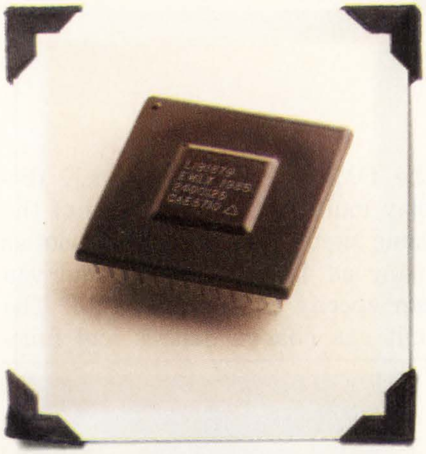
The Model 2001 digital multimeter (DMM) has a resolution range of 4½ to 7½ digits. Other features include 18-ppm dc voltage accuracy (90 days); 0.05% ac voltage accuracy; average, rms, and peak ac measurements; frequency measurement to 15 MHz; a 1100V input rating; and a resistance resolution of 1Ω. You can program the DMM's 10-channel scanner to measure different functions on each channel. In addition, the DMM can simultaneously display multiple measurements of the same signal. The DMM can take as many as 45 readings/sec, and you can specify the reading rate. The unit can change ranges and func-



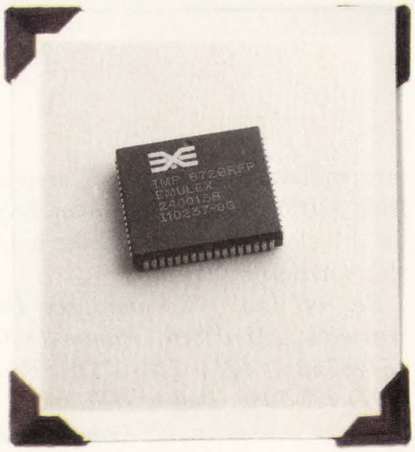
tions in 20 to 150 msec, and the trigger delay is 20 μsec. $2695.

Keithley Instruments Inc, 28775 Aurora Rd, Cleveland, OH 44139. Phone (800) 552-1115; (216) 248-0400. FAX (216) 248-6168. Booth 2418.

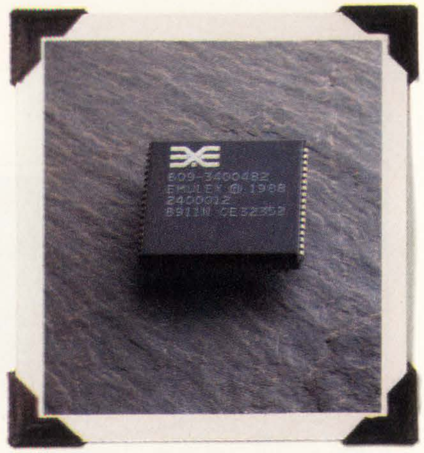
Circle No. 423



1986-MAC100. We introduce a combined disk formatter and buffer controller in a single disk controller chip.



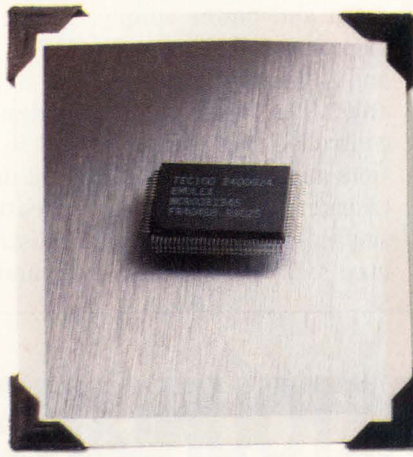
1987-ESP100. The industry's first high-performance SCSI chip is born at Emulex.



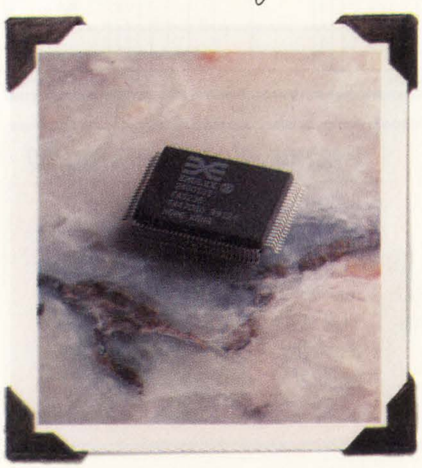
1988-ESP200. Second-generation SCSI arrives with SCSI-2 support and parity pass-through.

1988-MAC200. Our advanced merged architecture controller is the first to include an automated Data Flow feature for faster data handling.

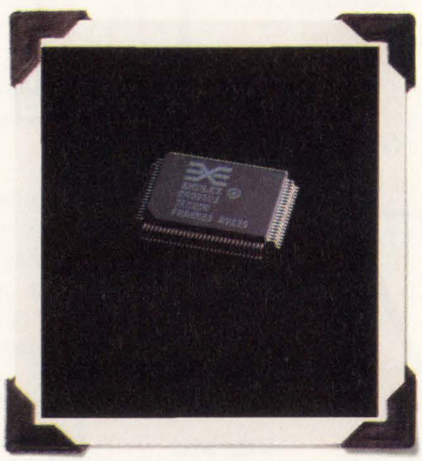
1989-BC200. A dynamic 4-port DMA controller for DRAMs is created.



1989-TEC100. EMD combines disk, buffer, and SCSI controllers in a single chip.



1990-FAS236. We deliver the first Fast SCSI chips with a 16-bit DMA port.

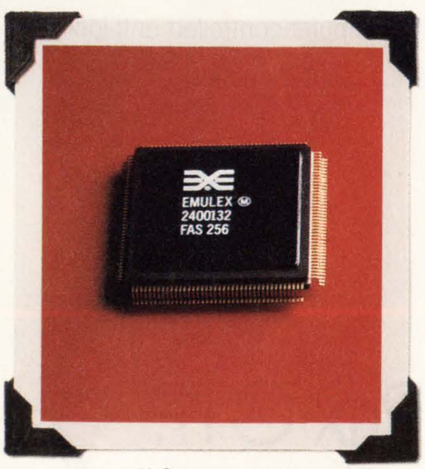


1991-TEC200. Our second-generation TEC becomes the industry's first Fast single-chip disk controller.

1991-TEC256. The first Fast and Wide SCSI disk controller also boasts the fastest disk data rate and highest system bandwidth.

1988-ESP2X6. We give SCSI a 16-bit split-bus architecture for greater efficiency and throughput.

1990-TEC 100A. Mid-to-low capacity SCSI drives get a reduced-price version of the TEC100.



1991-FAS256. 16-Bit Fast and Wide SCSI brings SCSI-2 support to host adapters and peripherals including drive array applications.

1992-Emulex Chips. A whole new generation of firsts is due.

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CIRCLE NO. 105

CIRCLE NO. 106

Phase compensation optimizes photodiode bandwidth

Jerald Graeme, Burr-Brown Corp

There is a trick to compensating photodiode amplifiers for stable operation and maximum bandwidth. Classical analysis is more likely to confuse you than to help you, but an intuitive understanding of the circuits' operation can quickly lead to selecting the best compensation.

Photodiodes' large capacitance severely restricts the bandwidth of basic photodiode circuits. An op amp connected as a current-to-voltage converter greatly improves the bandwidth by isolating the capacitance from the signal voltage. Removing the signal voltage from the photodiode prevents the diode's capacitance from shunting the signal away from the load. However, the current-to-voltage converter's interaction with the photodiode capacitance complicates calculating the stability conditions, the phase compensation, and the resulting bandwidth. Even so, by examining the circuit behavior, you can develop a simple, intuitive approach to each of these calculations.

When operated with a direct resistor load, as in **Fig 1a**, a photodiode exhibits a bandwidth limited mainly by its internal capacitance. In **Fig 1b**, which models the bandwidth limit, the photodiode acts primarily as a current source. A large resistance, R_D, and the capacitance of the diode junction, C_D, shunt this source. The capacitance ranges from 2 to 20,000 pF depending for the most part on the diode area. In parallel with the shunt is the monitor amplifier's input capacitance, C_{IA}. With the monitor amplifier shown, $C_{IA}=C_{ICM}$, the common-mode input capacitance of the op amp.

In practice, load resistances are small compared with R_D, so you can usually ignore the diode resistance. Similarly, the input resistance of the op amp is so high that the amplifier exhibits little shunting effect on R_L. The net input-circuit capacitance and R_L then deter-

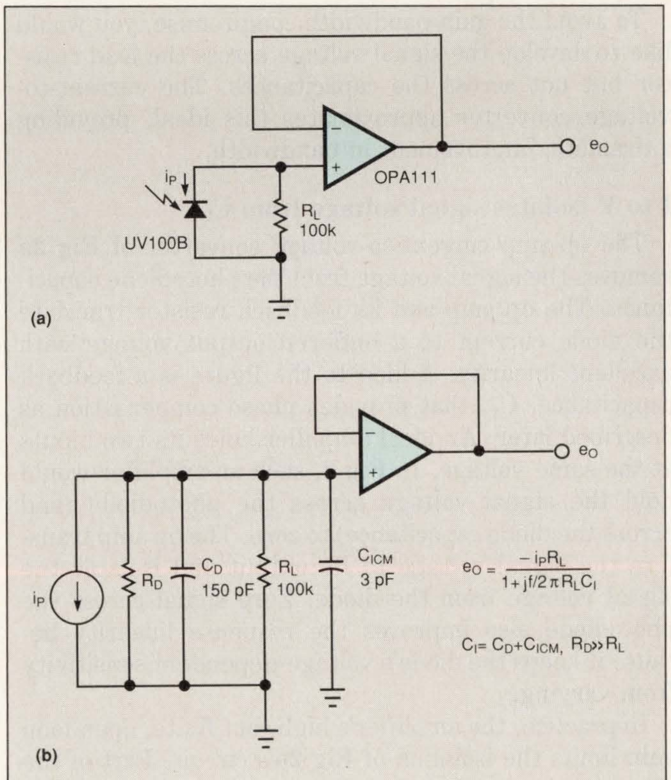

Fig 1—Load-voltage swing across the diode capacitance limits the basic photodiode bandwidth.

mine the input circuit's response rolloff. The resulting input circuit response has a break frequency, f_I. For **Fig 1** the response is

$$\frac{e_O}{i_P}=\frac{-R_L}{(1+jf/f_I)},$$

where, $f_I=1/2\pi R_L C_I$,
and $C_I=C_D+C_{ICM}$.

For this single-pole response, the circuit's −3-dB bandwidth equals the pole frequency and the typical components of the **Fig 1** circuit set $BW=f_I=10$ kHz.

The above expression reflects a typical gain-vs-bandwidth compromise. Increasing R_L gives greater gain but reduces f_I. From a circuit perspective, this compromise results from impressing the signal voltage on the circuit capacitances. The signal voltage in **Fig 1b** appears across C_D and C_{ICM}. The resulting capacitive currents shunt a portion of i_P, the signal current, away from the load resistor. Increasing R_L to raise the gain also increases the signal voltage on the capacitances and increases the portion of the signal current that the capacitances shunt away from the load. Such changes move the −3-dB response point of the circuit to a lower frequency.

To avoid the gain-bandwidth compromise, you would like to develop the signal voltage across the load resistor but not across the capacitances. The current-to-voltage converter approximates this ideal, providing a dramatic improvement in bandwidth.

I to V isolates signal voltage from C_D

The op-amp current-to-voltage converter of **Fig 2a** removes the signal voltage from the photodiode capacitance. The op amp and its feedback resistor translate the diode current to a buffered output voltage with excellent linearity. Added to the figure is a feedback capacitance, C_L, that provides phase compensation as described later. An ideal amplifier holds its two inputs at the same voltage. In **Fig 2**, such an amplifier would hold the signal voltage across the photodiode (and across the diode capacitance) to zero. The op amp transfers the signal voltage to its output and isolates the signal voltage from the diode. Zero signal across the photodiode also improves the response linearity because it keeps the diode's voltage-dependent sensitivity from varying.

In practice, the amplifier's high, but finite, open-loop gain limits the isolation of **Fig 2a**'s circuit. Part of the circuit's output voltage remains on the photodiode and produces a new bandwidth limit. Determining this new bandwidth limit is more difficult than determining the bandwidth of **Fig 1**'s circuit. Despite **Fig 2a**'s simplicity, the current-to-voltage converter exhibits complex ac performance as analyzed below. As a result of an input circuit that appears as an inductance and capacitance in parallel, this circuit has a 2-pole—rather than a single-pole—response. Feedback resistances above some maximum cause the circuit to resonate and oscillate. A direct mathematical analysis of this ac behavior is complex, but a more intuitive analysis results in simple design equations.

To ensure that a current-to-voltage converter is stable, you must usually supply phase compensation. Because phase compensation and bandwidth are related, you must consider them together. This discussion develops a bandwidth and phase-compensation background that extends to other photodiode amplifiers. This background also applies to other op-amp applications that present source capacitance to the amplifier. Also, this background applies to any op-amp circuit in which high feedback resistance reacts with the amplifier's input capacitance.

To find the bandwidth of the current-to-voltage converter, you first determine the locations of the circuit's

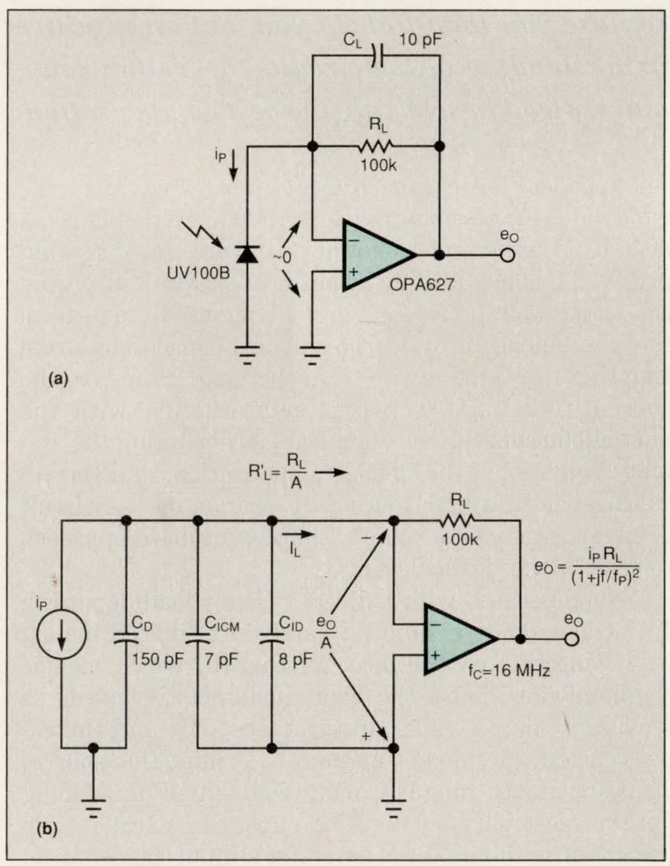

Fig 2—The simple current-to-voltage converter isolates the load voltage swing from the photodiode capacitance.

response poles. Then, you design the phase compensation, which defines the overall bandwidth. **Fig 2b** models the circuit for these analyses. Here, a current source and a capacitance, C_D, replace the photodiode. Also, the op-amp input capacitance is separate from the amplifier. The remainder of the amplifier replaces **Fig 1**'s R_L with an effective load resistance R_L'. For the first step of locating the poles, **Fig 2b** excludes **Fig 2a**'s phase-compensation capacitor, C_L, as well as the negligible, high resistances of the reverse-biased diode and the op-amp input.

The input break frequency controls the response of **Fig 2b**'s circuit. At the op-amp summing junction, this circuit faces the impedance R_L'. By definition, R_L' equals the voltage across this impedance divided by the current, i_L, supplied to the impedance. The relevant voltage is that from the op amp's inverting input to ground—simply the amplifier's gain-error signal, e_O/A. Because of the amplifier's finite open-loop gain, A, this signal must exist between the amplifier inputs to support the output voltage, e_O.

The output voltage is $e_O = i_L R_L$, so the voltage across R_L' becomes $i_L R_L/A$. Dividing this voltage by the current, i_L, defines $R_L' = R_L/A$. This resistance breaks with the capacitance of **Fig 2b**'s input circuit at

$$f_P = \frac{A}{2\pi R_L C_I} \approx Af_I,$$

where $C_I = C_D + C_{ID} + C_{ICM}$.

Above, the break frequency of the input circuit increases from f_I of **Fig 1** by a factor approximating the open-loop gain, A.

This factor is approximate because the input capacitance C_I is actually smaller for **Fig 1**. There, C_I is the diode capacitance plus the C_{ICM} presented by the voltage follower. In **Fig 2**, however, the amplifier adds its differential input capacitance, C_{ID}, to the total input-circuit capacitance, so $C_I = C_D + C_{ICM} + C_{ID}$. For most photodiodes $C_D \gg C_{ID}$, and the C_{ID} difference between the two circuits is not significant. Therefore, the current-to-voltage converter increases the response-pole frequency by a factor essentially equal to the gain, A.

However, this gain varies with frequency, so the actual improvement factor isn't immediately obvious. To calculate the actual pole location, you must determine the relevant ac value of A. This value is the open-loop gain at f_P. To find this gain, consider an approximation to the op amp's open-loop response. In all practical cases, f_P occurs where the gain of the amplifier exhibits a single-pole roll-off. There, you can approximate the amplifier's gain magnitude as $|A| = f_C/f$, where f_C is the amplifier's unity-gain crossover frequency. At f_P, $|A| = f_C/f_P$. For **Fig 2**'s circuit, substituting this expression for A in the f_P equation yields a pole location of

$$f_P = \sqrt{(f_I f_C)},$$

where $f_I = 1/2\pi R_L C_I$,
and $C_I = C_D + C_{ID} + C_{ICM}$.

In this new f_P expression, the pole location is the geometric mean of the old pole frequency, f_I, and the op-amp crossover frequency, f_C. Thus, as long as $f_C > f_I$, the current-to-voltage converter increases the response speed. A typical increase is a factor of 10 to 100, as seen from evaluating $f_P/f_I = \sqrt{(f_C/f_I)}$. With the high-speed OPA627 and the other components of **Fig 2**, the improvement factor is 38:1, and the pole is at 380 kHz. In the rare cases where $f_C < f_I$, the current-to-voltage converter reduces the bandwidth. Even then, however, the current-to-voltage converter provides the improved response linearity mentioned before.

Input circuit forms an L-C tank

Once you have found f_P, you can determine the required phase compensation. Further analysis shows f_P to result from a double—rather than a single pole. Consequently, you must pay careful attention to bandwidth and stability. With the simple, resistive load of **Fig 1**, a single pole controls the response, and the −3-dB frequency, f_I, coincides with the pole location. Capacitive shunting of a resistive load defines this simple pole. **Fig 2** exhibits similar shunting, but of a frequency-dependent load rather than a purely resistive one. As shown above, R_L' varies with frequency and is an impedance, Z_L', not a resistance.

In **Fig 2**, as the frequency increases and the gain, A, declines, the load of $Z_L' = R_L/A$ rises. A load impedance that rises with frequency is inductive. Confirming the inductive character of R_L/A is the phase shift of the gain, A. Over most of the amplifier's useful frequency range, A has a phase lag of 90°. The 180° phase inversion of the basic amplifier gain converts this lag to a 90° phase lead. You can see this effect by including phase information in the previous approximation for A, where $|A| = f_C/f$ for most of the amplifier frequency range. If you include phase in this approximation, $A = 2\pi f_C/s$. Then, the load impedance is $R_L/A = R_L s/2\pi f_C$. With s in the numerator, this impedance appears inductive.

This inductive load resonates with the capacitance of the input circuit at a frequency equal to f_P above. If the resonance occurs at a low enough frequency, it produces oscillation in the current-to-voltage converter. Oscillation occurs if the amplifier's open-loop gain is above unity at the resonant frequency, f_P. Above the unity-gain crossover frequency, the amplifier lacks the gain needed to sustain oscillation. In most cases, $f_P<f_C$, which meets the condition for oscillation.

In L-C tank circuits that can oscillate, you can introduce degeneration by adding resistance in series with either the capacitor or the inductor. For **Fig 2**, this solution would add resistance in the input path of the photodiode-signal current. Signal voltage developed on this added resistance would appear across the photodiode and would degrade the response bandwidth and linearity. In **Fig 2a**, capacitor C_L degenerates the inductive $Z_L'=R_Ls/2\pi f_C$. Adding C_L in parallel with R_L converts the resistive load to $R_L/(1+R_LC_Ls)$. Then, $Z_L'=R_Ls/2\pi f_C(1+R_LC_Ls)$, which adds an s term to the denominator of the impedance. This denominator s term counteracts the numerator's s term to degenerate the L-C tank circuit.

Feedback analysis quantifies stability

The feedback analysis that guides the selection of the degeneration capacitor, C_L, quantifies the component's effect. Plotted comparisons of the amplifier and feedback characteristics illustrate how this phase compensation controls the frequency stability. A plot of both the op-amp open-loop gain and the feedback demand for that gain indicates the net conditions for a stable feedback loop. **Fig 3** shows this graphical analysis for the uncompensated current-to-voltage converter of **Fig 2b**. This figure combines the amplifier's open-loop gain response with the reciprocal of the feedback factor, $1/\beta$. Superimposed on the plot is the resulting current-to-voltage frequency response. As expected from the previous discussion, this response reveals a resonant peak at f_P.

Fig 3's $1/\beta$ curve represents the feedback demand, which arises from the feedback factor, β—the fraction of the output fed back to the amplifier input. The voltage-divider action of the feedback network determines β. In **Fig 3**, the voltage divider formed by R_L and C_I produces $\beta=1/(1+R_LC_Is)=1/(1+s/2\pi f_I)$. Here, C_I is the total input-circuit capacitance or $C_I=C_D+C_{ID}+C_{ICM}$. The feedback factor reflects the pole at f_I introduced into the feedback path by the input circuit. The pole attenuates the feedback signal supplied to the amplifier input. The attenuated input signal requires the amplifier gain to increase at higher frequencies to sustain the amplifier output. The rise in the $1/\beta$ curve, which begins with the response zero of the expression $1/\beta=(1+s/2\pi f_I)$, reflects this greater gain demand.

Within the limit of its open-loop gain response, the amplifier meets the feedback demand. At low frequencies, the $1/\beta$ curve is flat at unity as expected from simple resistor feedback around an op amp. At f_I, in response to the attenuated feedback signal, the $1/\beta$ curve begins its rise. Initially, the curve remains below the open-loop gain curve and the vertical distance between the two curves represents the excess gain available, that is, the loop gain. As the frequency increases, the rising $1/\beta$ increases the gain demand. Moreover, the op amp's gain curve drops simultaneously.

Where the two curves meet, the required gain equals the total available gain so that there can be no further frequency increase. This meeting point is the critical intercept fundamental to feedback stability analysis. At frequencies beyond the intercept, the amplifier gain is insufficient to support the feedback demand and the response rolls off. Thus, the intercept defines the frequency of the response poles. Graphical analysis of the curves (**Ref 2**) confirms that $f_P=\sqrt{(f_If_C)}$, as indicated above.

The slopes of the $1/\beta$ and gain curves predict the frequency stability conditions through the two curves' rate of closure. For stability analysis, the rate of clo-

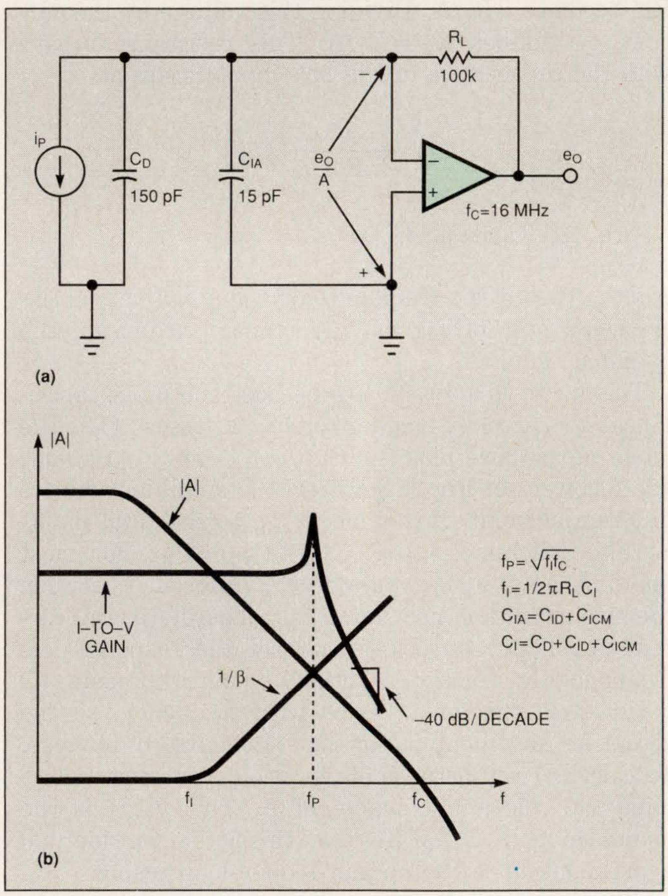

Fig 3—Capacitance at the input of the current-to-voltage converter causes the 1/β curve to rise and results in a resonant response peak.

sure is the difference between the slopes of the two curves at their intercept. Oscillation can occur where the rate of closure is 40 dB/decade. Each 20 dB/decade of slope corresponds to 90° of phase shift, so the 40 dB/decade of the criterion corresponds to 180° (**Ref 2**). Added to this is the 180° phase shift of the op-amp gain inversion, producing a net feedback phase shift of 360°. At the intercept, the loop gain is unity. If the phase shift is 360° at the unity-gain frequency, the feedback signal becomes self-sustaining; that is, the circuit oscillates.

For **Fig 3**, both the 1/β rise and the op-amp roll-off are the result of a single zero or pole, so each has a 20-dB/decade slope. The difference in slopes at the intercept is the critical 40 dB/decade, as anticipated from the earlier resonance discussion. The current-to-voltage response curve of the figure reflects this resonance with a high, sharp peak at f_P, where oscillation will probably occur. Even if oscillation doesn't actually occur, the stability will be poor, with excessive overshoot and ringing. Such stability problems are familiar to everyone who has used high feedback resistances with op amps. With large feedback resistors, the phase shift introduced by the input capacitance alone disturbs the circuit response.

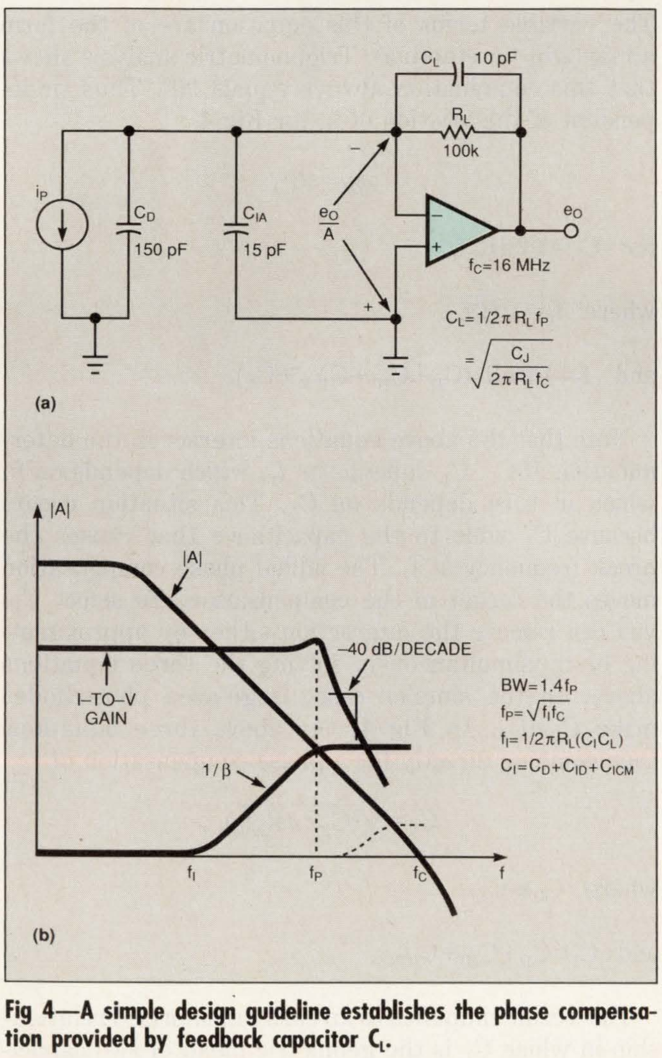

Fig 4—A simple design guideline establishes the phase compensation provided by feedback capacitor C_L.

Phase compensation levels 1/β

In **Fig 4**, to restore stability, place phase-compensation capacitor C_L across feedback resistor R_L. This compensation was added in **Fig 2a** and removed in **Fig 2b** for determining the phase-compensation requirements. Capacitor C_L bypasses R_L at high frequencies to boost the feedback signal at the amplifier input. C_L produces a response zero in the feedback factor and counteracts the pole created by capacitance of the input circuit. Then, for **Fig 4**,

$$\beta=\frac{1+s/2\pi f_L}{1+s/2\pi f_I},$$

where $f_L=1/2\pi R_L C_L$,
and $f_I=1/2\pi R_L(C_D+C_{ID}+C_{ICM}+C_L)$.

The response zero added to β at f_L is a pole of the inverse function, 1/β. In **Fig 4**, the pole levels off 1/β and reduces the rate of closure for improved stability. To increase the bandwidth, you must sacrifice some stability. Choosing a large C_L could easily make the rate of closure a simple 20 dB/decade, which would yield uncompromised stability. However, this choice would unnecessarily limit the bandwidth. Although the bypass action of C_L counteracts a feedback pole, it degrades the circuit's ability to convert current to voltage at high frequencies. To produce an output signal, the current-to-voltage converter depends on the voltage developed across R_L. Bypassing that resistor to re-establish frequency stability also shunts the output signal and limits the bandwidth.

To optimize the ±3-dB bandwidth, use a simple guideline to choose a compromise that provides 45° of phase margin. This guideline holds for all practical circuit cases. The phase margin is the difference between the critical 360°, which produces oscillation, and the actual phase shift of the feedback loop. This phase difference is important only at the intercept of the 1/β and gain-magnitude curves (**Ref 2**). For basic feedback stability, the op amp, because of its gain inversion, starts by injecting 180° of phase shift. The phase margin is thus 180° minus the added phase shifts through the op amp and the feedback network.

The following analyses determine the phase margin of the current-to-voltage converter under two conditions. The relative proximity of f_P to the other circuit-response singularities differentiates these cases. In the simpler case, f_P is more than a decade away from any of the circuit's other response poles or zeros. In that case, any pole or zero at a frequency lower than f_P develops essentially a full 90° of phase difference at the intercept frequency. Similarly, any pole or zero at a frequency higher than f_P contributes essentially zero phase shift at the intercept. For **Fig 3**, this simple case results in 90° of added phase shift from both the first op-amp pole and the $1/\beta$ zero. For this case, the far-removed poles around f_C cause no phase shift at f_P. Therefore, the amplifier and feedback loop add a net phase shift of 180°, leaving a phase margin of zero and ensuring oscillation.

To restore the phase margin in **Fig 4**, add C_L to reduce the phase shift from the $1/\beta$ curve. For 45° of phase margin, choose C_L to break with R_L right at the intercept frequency, f_P. At its break frequency, a response singularity's phase effect is exactly 45°. Therefore, placing the f_L break frequency at f_P reduces the $1/\beta$ phase shift at the intercept from 90° to 45° and boosts the phase margin from zero to 45°.

Fortunately, this simple guideline remains accurate even as f_P approaches f_C, as often occurs in practice. In this second case, the frequency difference between f_P and the other singularities is less than a decade. Hence the phase contribution of these singularities differs from the simple 90° of the first analysis. This condition occurs with smaller photodiode capacitances, which move the input break frequency f_I to the right in **Fig 4**. A dashed curve in **Fig 4** represents $1/\beta$ for this second condition, in which f_P moves down the open-loop gain curve toward f_C, and the phase shift at the new f_P enters the higher-frequency poles' range of influence around f_C. However, frequency f_I simultaneously moves to the right (the dashed curve in **Fig 4**). This movement compresses the distance between the new f_I and the corresponding new f_P. This compression reduces the phase effect of the lower-frequency singularity at f_I.

For first-order analyses, these two phase adjustments cancel, leaving the choice of C_L unchanged. To demonstrate this effect, consider the op-amp response to be essentially 2-pole in nature with the second pole occurring at the unity-gain crossover frequency, f_C. Although this situation is not the actual one, it accurately portrays the op-amp phase response at frequencies as high as f_C. This simple model shows that the amplifier phase shift increases with frequency and produces 135° of phase shift at f_C. Such phase shift is a conservative model of the performance of most op amps. Beyond f_C, the exact phase response of the amplifier is not usually important. At these frequencies, the loop gain is below unity and will not support oscillation.

With the 2-pole amplifier model, four response singularities determine the net phase margin. Two of these singularities follow from the first case: the first amplifier pole and the break frequency of C_L. As before, this amplifier pole decreases the phase margin from 180 to 90° and the $1/\beta$ leveling provided by C_L restores 45°. In the second analysis, the closer proximity of f_P to f_I and f_C alters the phase from the initial 135°. No longer does f_I introduce a complete 90° of phase shift nor is the influence of f_C zero.

To find the actual effects on the phase margin in **Fig 4**, the following equations express the influences of f_I and f_C with higher resolution:

$$\phi_M = 135° - \arctan(f_P/f_I) - \arctan(f_P/f_C).$$

From before, $f_P = \sqrt{(f_I f_C)}$. Substituting this expression in the above equation produces:

$$\phi_M = 135° - \arctan\sqrt{(f_L/f_I)} - \arctan\sqrt{(f_I/f_L)}.$$

The variable terms of this equation are of the form $\arctan(a/b) + \arctan(b/a)$. Trigonometric analysis shows that this combination always equals 90°. Thus, independent of the location of f_I, for **Fig 4**

$$\phi_M = 45°,$$

for $C_L = 1/2\pi R_L f_P$,

where $f_P = \sqrt{(f_I f_C)}$,

and $f_I = 1/2\pi R_L(C_D + C_{ID} + C_{ICM} + C_L)$.

Note that the above equations interact in the determination of C_L. C_L depends on f_P, which depends on f_I, which in turn depends on C_L. This situation occurs because C_L adds to the capacitance that causes the break frequency at f_I. The added phase compensation moves the target of the compensation. To select C_L, you can remove the interaction either by approximating or by simultaneously solving the three equations above. In the simpler case, large-area photodiodes make $C_D \gg C_L$. In **Fig 4**, the above three equations then combine directly for a phase compensation of

$$C_L = \sqrt{(C_I/2\pi R_L f_C)},$$

where $C_D \gg C_L$

and $C_I = C_D + C_{ID} + C_{ICM}$.

This result simplifies to an easily memorized relationship in which C_L is the geometric mean of two capacitances. Defining an artificial capacitance, $C_C=1/2\pi R_L f_C$, relates f_C to R_L just as the resistance relates to f_I and f_L. The above result simplifies to the geometric mean $C_L=\sqrt{(C_I C_C)}$. The phase compensation capacitor C_L equals the geometric mean of the input circuit's total capacitance and the capacitance that represents f_C. This result parallels the expression $f_P=\sqrt{(f_I f_C)}$ in which f_P is the geometric mean of the analogous frequencies. For C_L, one of these capacitances, C_I, is real and the other simply represents the op-amp bandwidth, f_C. For the typical current-to-voltage photodiode amplifier, set the phase compensation at

$$C_L=\sqrt{(C_I C_C)},$$

for $C_D \gg C_L$

where $C_I=C_D+C_{ID}+C_{ICM}$, and $C_C=1/2\pi R_L f_C$, and where f_C is the unity-gain crossover frequency of the op amp.

In the more comprehensive case, select C_L to accommodate even small photodiode capacitances. Don't use the previous approximation. Instead, solve the preceding simultaneous equations for $\phi_M=45°$. For **Fig 4**, this approach yields

$$C_L=(C_C/2)(1+\sqrt{1+4C_I/C_C}),$$

where $C_C=1/2\pi R_L f_C$,

and $C_I=C_D+C_{ID}+C_{ICM}$.

You need this more exact expression where there are lower circuit capacitances that are more sensitive to parasitic capacitances. Depending on where they occur, these parasitics can alter the value of C_L in either direction. Some board parasitics add to the C_I term but others supplement C_L. A final tuning adjusts for these unknowns empirically.

Two features benefit bandwidth

When you set the phase compensation by choosing C_L, you determine the bandwidth of the current-to-voltage converter. This circuit's 2-pole response is actually advantageous because gain peaking extends the bandwidth. Excessive damping is inherent in the single-pole response of **Fig 1**; this damping fixes the 3-dB bandwidth at the pole location. The 2-pole case of **Fig 4** permits an underdamped response and extends the bandwidth beyond the pole frequency. Just how much the bandwidth increases depends on the required response accuracy. Where you can accept the traditional ±3-dB deviation, the damping factors and the resulting responses (**Ref 3**) show a factor of 1.4 increase for a 45° phase margin. Gain peaking is then just +3 dB followed by the final bandwidth limit at the −3-dB point. Thus, for the current-to-voltage converter of **Fig 4**, with C_L breaking at f_P,

$$BW=1.4f_P=1.4\sqrt{(f_I f_C)},$$

where $f_I=1/2\pi R_L(C_D+C_{ID}+C_{ICM}+C_L)$.

For the components shown in **Fig 4**, $f_I=9.1$ kHz and $f_C=16$ MHz for BW=534 kHz. This represents a 53:1 bandwidth improvement over the 10-kHz limit of the basic circuit in **Fig 1**.

The above expression displays an advantageous gain-bandwidth relationship because of the square-root function. The R_L in the expression for f_I is the element that sets the current-to-voltage converter's transresistance or gain. Increasing R_L for greater gain reduces the bandwidth, but by less than you might expect. Normally, in voltage-amplifier applications, an increase in gain causes an equal reduction in bandwidth. For the current-to-voltage converter, the gain-bandwidth product is R_L(BW). Substituting BW from its equation above shows this product to be $1.4\sqrt{(R_L f_C/2\pi C_I)}$—proportional to $\sqrt{(R_L)}$. Thus, the maximum practical value of R_L yields the maximum gain-bandwidth product. Above a certain R_L value, parasitic capacitance rolls off the gain that this resistor provides.

The Bode plots of **Fig 4** explain this reduced gain-bandwidth sensitivity. Consider what happens when you start with the dashed curve and move back to the solid 1/β curve. Increasing R_L moves f_I down in frequency and shifts the 1/β curve in direct proportion, lowering the bandwidth-defining intercept of 1/β with the amplifier gain-magnitude curve—but not in direct proportion. Because the gain-magnitude curve rises as the frequency decreases, the intercept recedes more slowly. The equal slopes of the gain and 1/β curves make this bandwidth decrease one-half that of $\log(f_I)$, and the log scale converts this fraction to a square root.

An alternate approach to increasing the gain-bandwidth product enjoys the same square-root benefit. By using larger area photodiodes, you increase the overall circuit response to the light source at a rate greater than the accompanying bandwidth decline. Both the photodiode's capacitance and its responsiveness to light are directly proportional to the diode area, A_D. Increasing A_D produces a directly proportional increase in the light-to-voltage gain of the circuit. However, the bandwidth, described by the previous equation, declines only by the square-root of C_D. Thus, gain-bandwidth product for the current-to-voltage converter is proportional to $\sqrt{(A_D)}$. The maximum gain-bandwidth product results from a photodiode area that covers as much of the area illuminated by the light source as is practical.

PHOTODIODE-AMPLIFIER PHASE COMPENSATION

To maximize the bandwidth instead of the gain-bandwidth product, choose R_L to take advantage of the full amplifier bandwidth. In **Fig 4**, making R_L smaller moves f_I to the right—to the limit imposed by f_C. Beyond f_C, the amplifier lacks the bandwidth required for further extension of the current-to-voltage converter response. To maximize the bandwidth, select R_L to place the intercept frequency, f_P, at the amplifier's unity-gain crossover frequency, f_C. This choice moves the $1/\beta$ curve to the right, compressing its rise to zero and making the three response-defining frequencies coincide; $f_I = f_P = f_C$. Given this condition, the expression for f_I sets the feedback resistor in **Fig 4** to

$R_L = 1/2\pi f_C(C_D + C_{ID} + C_{ICM})$, for maximum bandwidth.

Any further increase in bandwidth must come from using a higher speed op amp that moves the f_C limit to a higher frequency. Once again, a square-root relationship determines the improvement, because f_P is proportional to $\sqrt{(f_C)}$. **Fig 4** shows the wideband OPA627 instead of **Fig 1**'s slower OPA111. This change increases f_C from 2 to 16 MHz for a $\sqrt{(8)}$ increase in current-to-voltage-converter bandwidth. In **Fig 1**, changing amplifiers would offer no benefit because the photodiode in front of the op amp limits the bandwidth. EDN

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Author's biography

Jerry Graeme, a prolific contributor to EDN, is one of the very few EEs who have worked for a single employer for a quarter century. Jerry manages instrument-components design for Burr-Brown Corp in Tucson, AZ. At Burr-Brown, he has personally designed many analog ICs. He holds a BSEE from the University of Arizona and an MSEE from Stanford. He lists his hobbies as scuba diving, photography, and woodworking.

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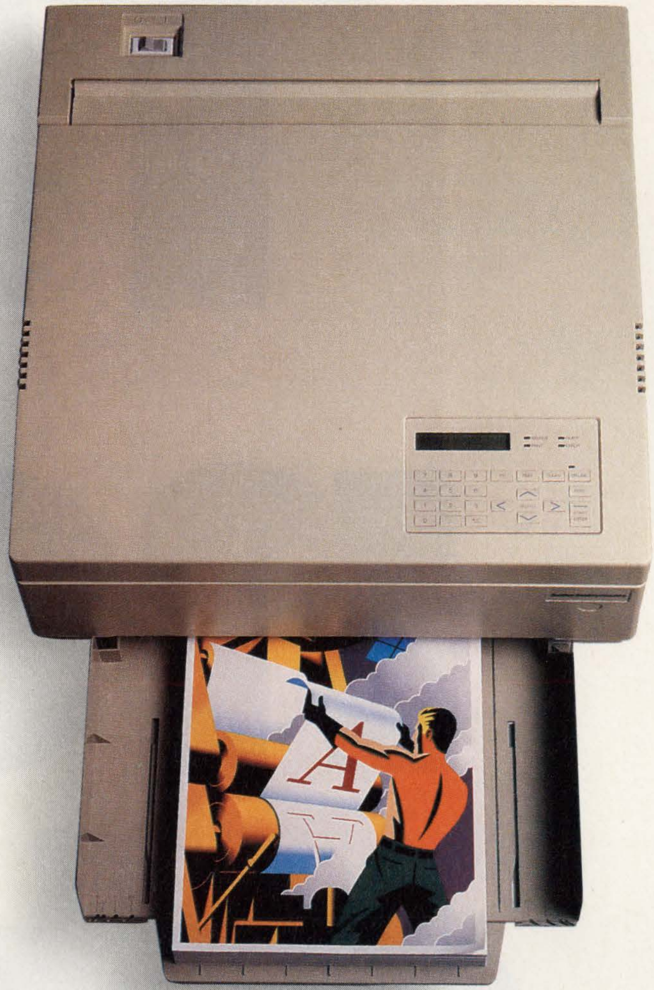

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Concurrent engineering speeds development time, lowers costs

Jon Turino, Logical Solutions Technology Inc

To be competitive in the 1990s, your company must embrace concurrent-engineering philosophies. Implementing these philosophies requires that everyone in your organization understands the basics of the product-development cycle—the frequency of activity in each phase and where the costs associated with each phase are actually determined.

Today's shorter product life cycles and increased pressure for shorter time to market make it imperative to replace the "redo it until it's right" philosophy with the "do it right the first time" philosophy—concurrent engineering. Using concurrent engineering, you can determine design tradeoffs for the overall success of the product (and the business) given the specific customer requirements, business capabilities, and competitive environment from the onset.

For example, a change in the silicon for an ASIC may cost weeks (or even months) in terms of time to market. Seemingly unimportant or simple things can cause design changes: a lack of communication between the ASIC designer and the system designer; neglecting to simulate the overall product; redesigning the part to include boundary scan so that manufacturing can test the product containing the part; or inadequate input from product marketing.

There are many causes, and even more excuses, for product designs going over time and budget. There is only one prevention—concurrent engineering. Even though its practice won't prevent all of the problems all of the time, you have a much better chance to improve your "hit ratio" when you use it properly.

The overall product cycle in a business moves in the direction of design, manufacture, test, and finally, service. The design activity is a nonrecurring cost—or at least it is supposed to be. Products are designed once per product type. They are built once per product, as you duplicate the design in manufacturing. They are tested at many levels, and must often be serviced in the field.

The objective of concurrent engineering is to make the right decisions during the nonrecurring activity. By making good decisions early, you maximize productivity during the recurring activities—activities that may last for years. Making good up-front decisions is referred to as creating maximum leverage. Not maximum leverage in banker's terms, but in terms of investing a little time and money during product design to reap larger profits over the life of the product.

You cannot attain maximum leverage by redoing a design once you discover that the original is difficult, time consuming, and expensive to produce. You can attain some leverage by improving the design in the review stage, but this may still require a redesign either on paper or in software.

Time and money

Reduced design cost is not the only benefit of concurrent engineering. Design engineers are under intense pressure to bring products to market as quickly as possible. One of the most frequent complaints heard from design engineers is that of unrealistic design schedules imposed by management. And one of the most frequent excuses from management for not using concurrent engineering is that there is no time—they need to get the product designed as quickly as possible.

That kind of narrow and short-term attitude needs significant adjustment, because time to market is not just design time. Time to market is the time it takes to get a product into your customer's hands at a competitive price. If you must redesign the product to lower manufacturing and test costs, or to fix glitches because of inadequate design verification, you've negated the advantage of rushing a design through.

Concurrent engineering helps speed the product's actual time to market, even if that means spending a little more time making sure the design is flawless in its performance and making sure you can manufacture, test, and service the product.

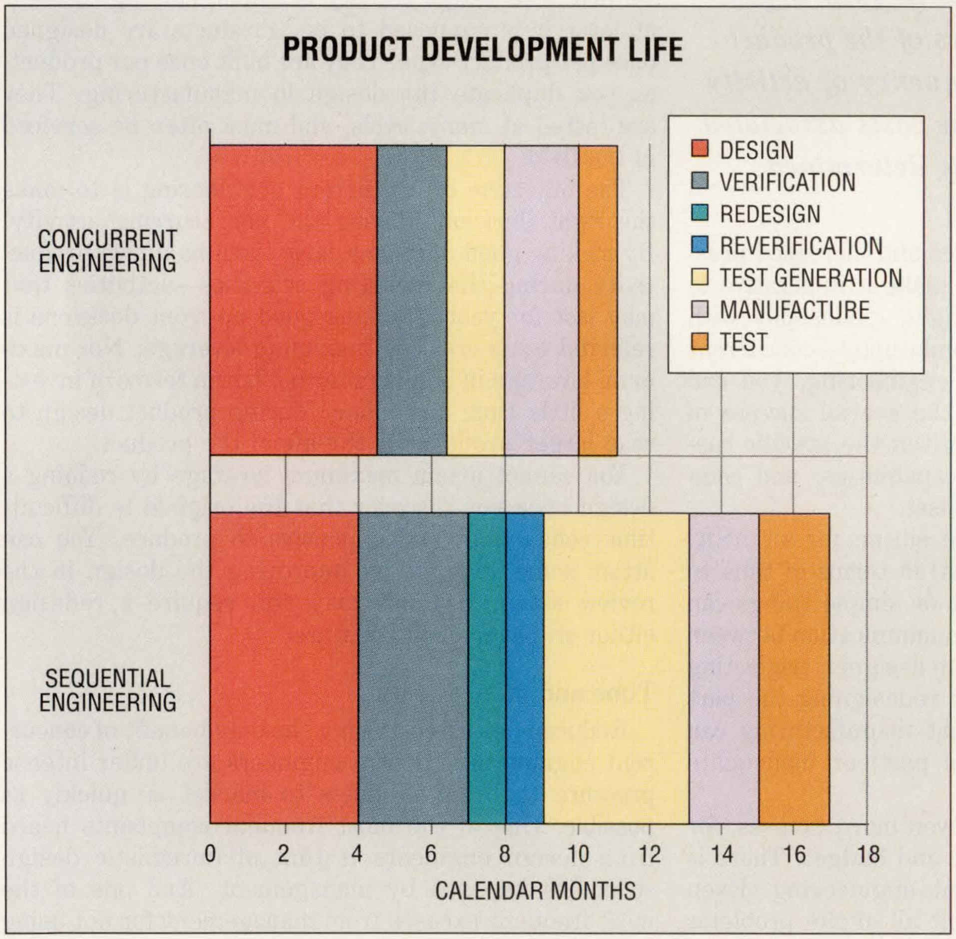
Burr-Brown used concurrent engineering in the design of D/A and A/D converters for DSP applications with excellent results. The personal interaction among design team members yielded better and more manufacturable designs. The process started when design, test, and manufacturing input was encouraged during the final revisions of product proposals from marketing, rather than during final revisions of the product designs themselves. Input continued during design, test development, characterization, prototype production, and device qualification.

Each team member was not only encouraged, but also expected, to ask questions, make suggestions, and offer alternatives. The primary team consisted of members from design, test, manufacturing, and marketing, led by a product manager.

Personnel with additional expertise—purchasing, production, etc—were called upon as needed during the product design. Weekly meetings kept team members in communication to discuss reallocation of funds or other issues. The result was that time to market was cut by six to nine months.

Studies show that somewhere between 60 and 95% of overall product cost is determined during the design phase. Product parts, assembly, test, and service costs are dictated far more often by the product's design than by the actual manufacturing, testing, or servicing. The earlier design decisions are made, the larger their impact.

Concurrent engineering helps you make early design decisions that minimize costs over the life of the prod-



Not only will you eliminate redesign and reverification costs using concurrent engineering, you will save time in design verification, test generation, and test because of the efficiency early in the design. The savings in time to market typically amount to between 10 and 25% and result in a better product.

uct. For example, designing the product to fit into an existing manufacturing process, rather than requiring a new process (and new capital equipment), can have a big impact on cost. By being included in the initial design decisions, manufacturing can propose this cost-effective suggestion, whereas alone (sequential engineering), the designers may not take the extra costs of buying new capital equipment into consideration. Taking some extra design time to ensure error-free assembly by using a minimal number of assembly operations can also significantly lower overall product costs.

The five most important design-for-performance issues faced by designers are product size, weight, speed of operation, human factors, and product-reliability goals. Overall design guidelines often require tradeoffs in these factors. All too often, those decisions are made without considering all the factors, such as in the case of using an existing manufacturing process. Concurrent engineering takes all of these factors into consideration from the beginning.

Reaping the benefits

Hewlett-Packard (HP) used the concurrent-engineering philosophy of total quality control to improve not only its manufacturing performance, but also its administrative and engineering performance. The elements of HP's program include management commitment, customer focus, statistical control, systematic problem solving, and total participation.

Top management's commitment in the form of learning, understanding, and leading the quality-control efforts with a well-communicated, unwavering purpose, including ongoing management involvement, was critical. The results for HP were scrap and rework costs cut 80 to 95%, manufacturing costs reduced by as much as 42%, parts inventories cut by 70%, manufacturing cycle times reduced by 95%, and overall product development time cut by 35%.

You can switch to concurrent engineering in mid-project and still see cost benefits. Texas Instruments (TI) had tremendous results with the redesign of a complex infrared sight (**Fig 1**). By redesigning the sight (and without reinventing the factory that produced it), TI achieved some impressive reductions in the number of parts and assembly steps and, therefore, the overall assembly time.

Experience shows that many product design decisions in organizations that practice sequential engineering are made based on opinions, not facts. Concurrent engineering changes that and simplifies your designs in the process. Complexity for complexity's sake is counterproductive. After all, how many of the features of most of your sophisticated electronic products do you (or your customers) actually use on a regular basis? Sometimes simplifying the product makes it more marketable. That's why you need accurate input from all of the business elements when making design decisions.

	Serial Engineering	Concurrent Engineering	Reduction (%)
Assembly Time (months)	129	20	85
Total Number of Parts	47	12	75
Total Number of Steps	56	13	71

Fig 1—By creating more efficient designs through concurrent engineering, you can reduce the number of parts you need and reduce the number of steps in manufacturing. Texas Instruments cut the assembly time of their infrared sight by 85%.

Getting closer to customers—with one-on-one meetings between potential product users and the actual product-design team—is one way of gathering the facts regarding which design features and parameters are most important to customers. Partnering with customers and suppliers can also help the product birthing team come up with the kinds of quantitative information that they need to make truly informed design decisions.

People in manufacturing, test, quality, and service often have large amounts of data regarding the overall time and cost associated with bringing certain products to market (and their on-going production and warranty/service costs). You should take these facts into account when designing new products. You can learn from what you've done right (or wrong) before.

A word to the wise to those in manufacturing, test, quality, and service: The facts you bring forward must be timely, accurate, and presented in the proper manner. The data you hold gives you power. Use it wisely—for improvement, not punishment of other organizations (or, worse yet, specific people in other groups).

The types and granularity of time and cost data required for good concurrent-engineering design decisions are illustrated in **Fig 2**, which shows detailed breakdowns of each of the major cost elements associated with each major business activity. The design and design-verification cost are the nonrecurring cost elements in the product development, manufacturing, and service cycle. Depending upon the exact nature of your organization and your products, you may need to expand the list. Note that these costs need to be estimated for each type of device, board, subassembly, or complete product.

Usually a very small increase in design cost will result in a moderate decrease in design-verification cost, and a large decrease in fault-simulation and test-generation costs. Concurrent design also provides the opportunity to eliminate the redesign cost.

Fig 2 also details the cost elements that make up the actual material cost of a product. Here again, depending upon product configuration, you may need to expand the list and, as before, develop the data for the entire product. For example, there are occasions when you can use ASICs to replace glue logic (and, conversely, when developing an ASIC is simply not justified). There may be occasions when an increase in the cost of a part (for improved testing characteristics) will be offset by a decrease in board, subsystem or system test, and troubleshooting costs. Sometimes breaking a large board into two smaller (and simpler) boards makes sense. The decreased cost for the individual bare boards can offset the extra connector cost (reducing the number of layers required, for example).

Assembly cost is another significant element in the cost of a product, depending again upon its size and complexity, and the methods used to manufacture it. The costs estimated should include not only the recurring costs at each level of integration, but also the nonrecurring cost for capital equipment, machine programming, and the like (amortized over the total estimated number of products of each type to be built).

The recurring test and diagnosis costs for each element of the overall product also need to be ascertained or estimated. Then you can estimate the deltas to determine whether design changes for testability are warranted and, if so, just how much testability is affordable based on potential increased costs for components.

Design improvements may not make a large difference in go/no-go testing costs but they can make a big difference in troubleshooting times and costs. The test cost list in **Fig 2** is for recurring test costs—you should also estimate the cost for capital equipment, test programs, and test fixtures for the total number of items you are building to come up with a per item cost that you can use during design to make tradeoffs.

Quality costs are another significant element in the overall product cost equation. It might actually be more appropriate to term the costs identified in **Fig 2** as the cost of not quality, since products that you can produce perfectly every time do not require inspection, rework, or scrap costs. Escape cost refers to the premium paid when a defect escapes a test (say at board level) and must be detected, diagnosed, and repaired at a later stage (say at system test) at a much higher cost.

It is also necessary to have yield (or failure rate)

DESIGN-COST DATA FOR DEVICES, BARE BOARDS, LOADED BOARDS, AND SYSTEMS

- DESIGN VERIFICATION $ ______
- DESIGN-VERIFICATION COST $ ______
- FAULT-SIMULATION COST $ ______
- TEST-GENERATION COST $ ______
- ITERATION COST $ ______

PARTS COST

- GLUE LOGIC $ ______
- DISCRETES $ ______
- ASICs $ ______
- BARE BOARDS $ ______
- CAGES/BACKPLANES $ ______

ASSEMBLY COST

- BOARD ASSEMBLY $ ______
- SUBSYSTEM ASSEMBLY $ ______
- SYSTEM ASSEMBLY $ ______

TEST COST, CAPITAL, PROGRAMS, FIXTURES PLUS:

- DEVICE TEST $ ______
- BOARD TEST $ ______
- BOARD DIAGNOSIS $ ______
- SYSTEM TEST $ ______
- SYSTEM DIAGNOSIS $ ______

QUALITY COST AT EACH LEVEL

- INSPECTION COST $ ______
- REWORK COST $ ______
- ESCAPE COST $ ______
- SCRAP COST $ ______

SERVICE COST

- FIELD SERVICE CALL $ ______
- DEPOT REPAIR $ ______
- NO FAULT FOUND $ ______
- SPARES INVENTORY $ ______

Fig 2—Every design has a variety of cost considerations. Depending on the nature of your products, you may need to expand the list.

and fault distribution figures for each testing and/or inspection step in order to calculate quality costs. Gathering this data, however, can also help in identifying areas where the manufacturing operation itself, without affecting product designs, can be improved to reduce costs and raise quality levels.

Finally, there is service cost data. The list of service cost data identifies the major categories of costs you should estimate over the service life of a product with the predicted failure rate factored in to come up with a per item service cost.

You should take these estimates, along with all of the other elements shown in **Fig 2**, into account during the concurrent-engineering design phase. Only when all of the factors are considered, and all of the proper engineering expertise applied, is it possible to develop the best product at the lowest cost in the shortest time.

You must plan out product goals, strategies, and tactics as early as possible in the product development cycle—preferably right at the beginning when the product is specified. Those of you in functions that are currently downstream from design engineering must take it upon yourselves to get involved in the product design process if you are going to be a source of solutions.

If customer requirements dictate a design approach outside the scope of current company capabilities, everyone needs to know about it so that you can develop plans to cope with it. If you can modify the design approach to fit into current company capabilities, so much the better.

Concurrent engineering can reduce the time and cost of test generation, while simultaneously helping to increase fault coverage. Reductions of as much as 50% in test-program generation and fault-simulation times, while still achieving 99.9% fault-coverage levels, are typical.

You can also reduce service costs in several ways. The cost of a field service call continues to rise due to heightened customer expectations and increased product complexity, personnel costs, spare inventory costs, and travel expenses. If you can diagnose systems remotely, you can send boards (instead of people with boards) to the customer. Proper design for serviceability, as part of the concurrent-engineering discipline, can significantly cut service costs.

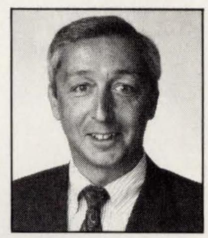
NCR Worldwide Service, for example, actually supplies NCR manufacturing with funds for service connectors and EEPROMs that are put on certain products. The savings in service costs more than pays for the added parts costs (which, because they are paid for by the service organization, do not impact the accounting department's interpretation of manufacturing costs).

There are many more creative ways to save time and money in areas other than manufacturing, test, and service. Shortened cycle time, for example, can help reduce inventory levels, thus saving interest costs and freeing up working capital. The bottom line, then, is that the proper application of concurrent engineering can increase profits and make an organization more competitive. Implementing concurrent engineering is not easy and cannot be done instantly. But it can be done.

Yes, it takes investment—nothing comes for free. Yes, it takes commitment—nothing happens overnight. Yes, it takes culture change—the barriers must come down. It may take time and significant educational efforts to realize the benefits of concurrent engineering. But it can, and indeed must, be done if your organization is to be competitive in the 1990s. EDN

Adapted from Concurrent Engineering by John Turino, Logical Solutions Technology Inc, Campbell, CA, 1991. ISBN 0-912253-09-6.

Author's biography



Jon Turino is President and CEO of Logical Solutions Technology Inc, a consulting firm in Campbell, CA. Jon has more than 20 years of experience in the engineering field and has been a full-time consultant for more than 12 years. He studied engineering and management at West Coast University (Orange, CA) and El Camino College (Via Torrance, CA).

Article Interest Quotient (Circle One)
High 488 Medium 489 Low 490

Bridge drive simplifies classic design

Malcolm Watts, Wellington Polytechnic, Wellington, New Zealand

The circuit in **Fig 1** is a simplified version of the classic H bridge for controlling dc motors or driving an inverter stage. Unlike the classic bridge drive, **Fig 1**'s circuit has less control circuitry and does not require p-channel MOSFETs. Yet the MOSFET transistors in the lower branches of the bridge mean that you can excite the circuit directly from low-drive outputs such as μP output ports.

Calculate the value of the base resistors for the pnp transistors from the following equation:

$$R_B = (V^+ - 0.9V)/I_C) \times h_{FE}.$$

The two R_P gate resistors protect the MOSFETs' gates when the inputs are disconnected. You may or may not need the R_I resistors to prevent parasitic oscillations. **EDN BBS /DI_SIG #1104**

To Vote For This Design, Circle No. 665

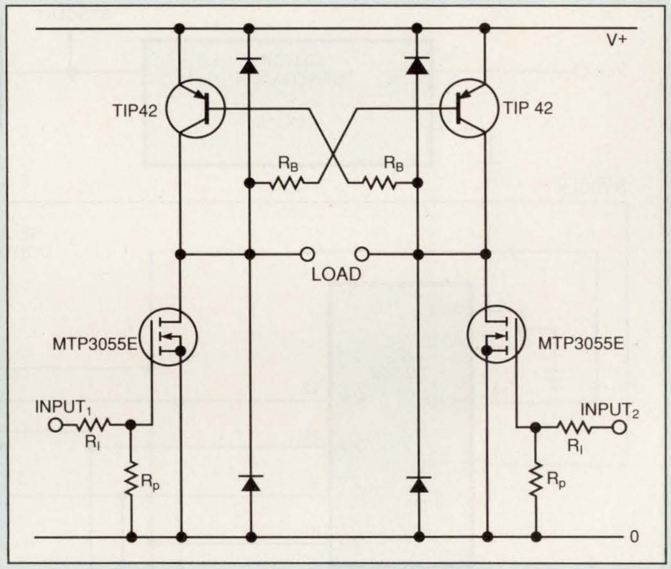


Fig 1—This variation on the classic H bridge features reduced component count and relaxed drive-control specifications.

Digital synthesizer tests servo systems

Dmitrii Loukianov, CONECO Ltd, Moscow, Russia

The direct digital synthesizer in **Fig 1** is computer controlled and programmable. The synthesizer uses the phase-accumulation principle to generate waveforms at various frequencies **(Ref 1)**. **Fig 1**'s output addresses the waveform-storage memory **(Fig 2)**. The waveform memory's output passes through a D/A converter.

The circuit's 12×12-bit waveform map yields 60-dB spectral purity at a frequency resolution of 0.000194 Hz (32-bit phase) for carriers whose frequencies are less than 1 kHz. The frequency stability of the generated signal is the same as that of the circuit's crystal oscillator.

The circuit stores current phase and frequency values in AM129705 dual-port register-file RAMs, IC_{15} and IC_{16}. Four bits from these RAMs determine phase, and four bits determine the frequency step.

In **Fig 1**, 8-bit full adder IC_9 and IC_{10}, carry latch IC_7, edge-triggered dual-port operand registers IC_{11} and IC_{12}, and bus buffer IC_{13} form an accumulator. The dual-port register and buffer provide a bidirectional data bus to register-file RAMs IC_{15} and IC_{16}.

The accumulator section accesses the register-file RAMs via port B to get or store phase and frequency values. The accumulator's port A lets the controlling computer access these values. Thus, the computer can load new values, interrogate the present values, and start or stop synthesis.

The length of the calculation algorithm depends on word size; for a 32-bit word, the calculation takes 12 clock cycles.

In operation, assuming that the carry bit in IC_7 is cleared, the addition algorithm begins with fetching the LSB of the phase value into IC_{11}'s and IC_{12}'s port 1 from register-file RAM address A_0 to $A_3=0$. When the data byte loads, it appears at the port B inputs of the adder. In the next clock period, the RAM address switches to FA_0 to $FA_3=4_{HEX}$, and the data appear at the A inputs of the adder. Because the clock period is slightly greater than the setup time, the result of the addition is written into IC_{11} and IC_{12} on the rising edge of SYSCLK, and IC_7 stores the carry bit. In the next clock period, IC_{13} transmits data to the RAM bus while the circuit generates write pulse WRF. Thus, the current-phase byte overwrites the previous value.

The algorithm repeats the same triad of operations four times with two exceptions. On the last cycle of the third addition, the circuit generates the $\overline{\text{LW}}$ pulse

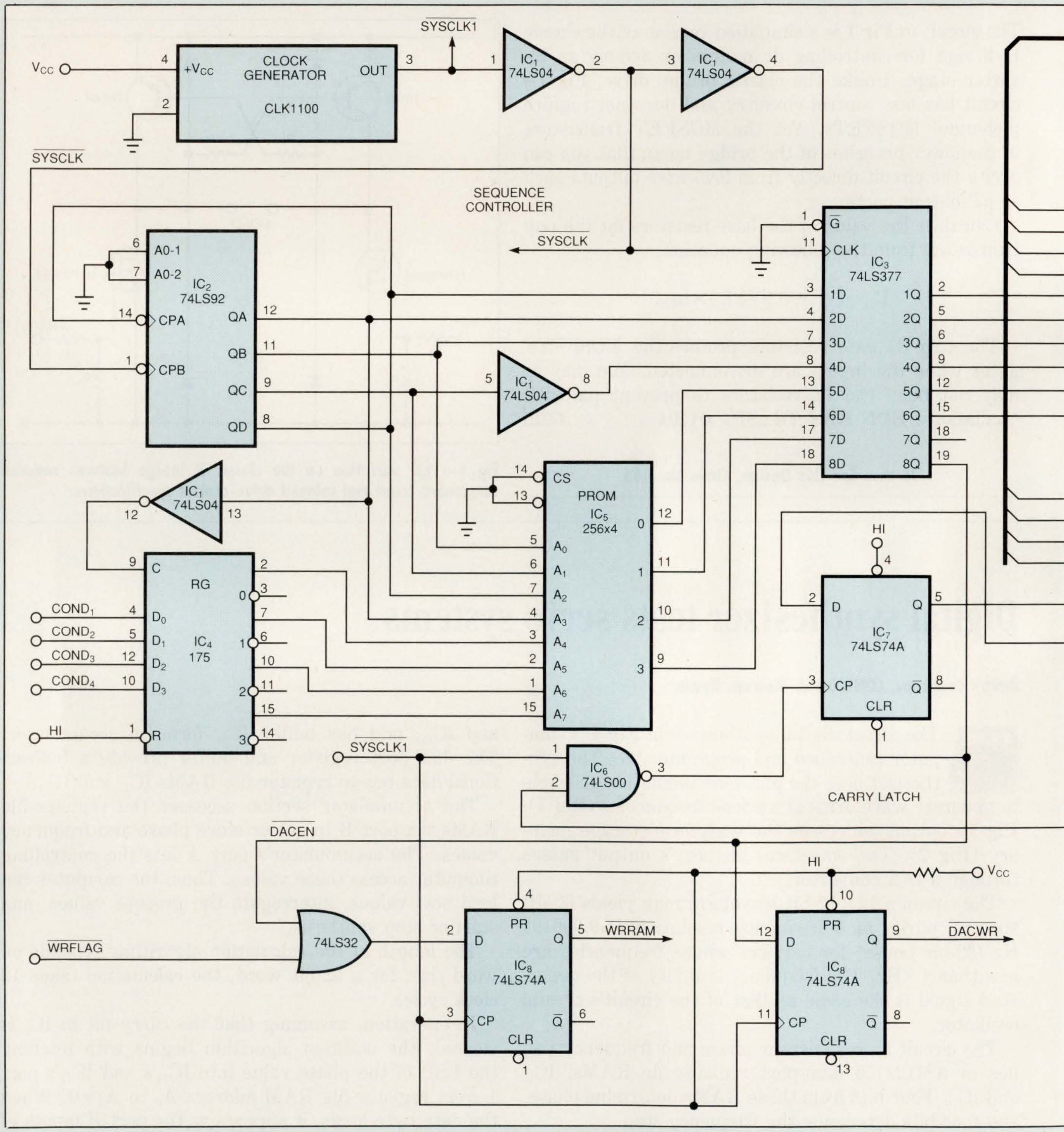
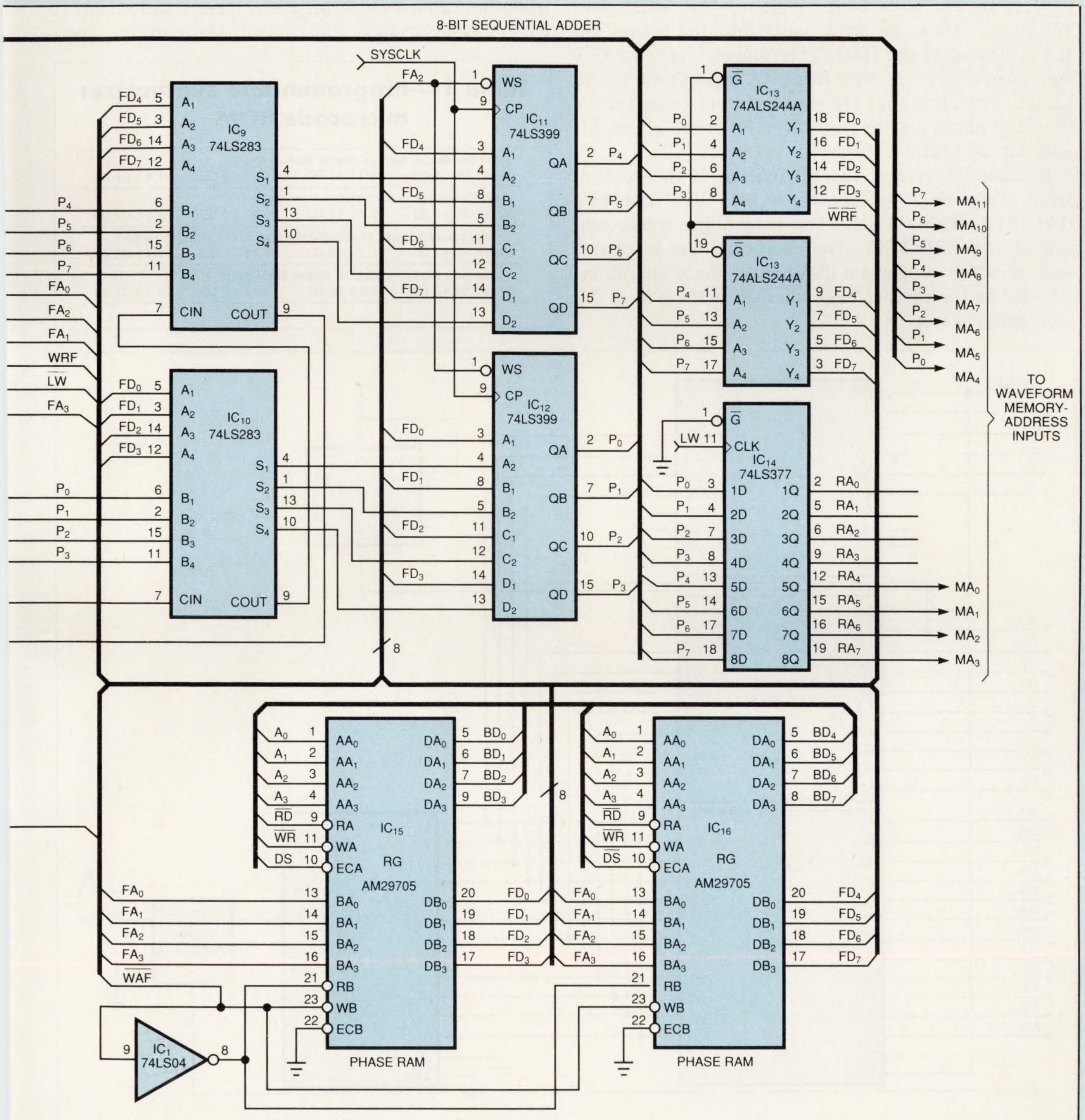


Fig 1—This digital synthesizer yields 60-dB spectral purity at a frequency resolution of 0.000194 Hz (32-bit phase) for carriers whose frequencies are less than 1 kHz.

to write the low-order byte of the waveform memory's address into IC_{14}. On the last cycle of the fourth addition, the circuit generates the DACWR strobe and clears carry-flag register IC_7.

The phase value at the outputs of IC_{11} and IC_{12} is stable within two clock periods, so even slow static RAMs, such as the 6164, are suitable for waveform-table storage.

The control computer accesses the current phase and frequency through the standard A_0 to A_3, $RD/\overline{WR}$,



CA, and BD_0 to BD_8 I/O interfaces of an IBM PC. The computer loads the waveform RAM in a different manner. First, it sets the frequency to zero and the phase to point at the desired memory location. Second, the computer writes waveform data to the 74LS374 registers (**Fig 2**), LSB first. Writing the MSB sets WRFLAG, thus the data loads into the waveform RAM instead of the DAC. The computer repeats this sequence for each waveform-RAM location to be loaded, providing that the writes do not come earlier than the phase-update loop takes to finish (about 1.2 μsec for a 10-MHz clock).

IC_2 and IC_5 control the sequencing of the synthesizer. You could replace these two ICs with one GAL16V8. **Table 1** lists the controlling microcode loaded into PROM IC_5. The microcode has 16 pages, each of which supports a different mode of operation. IC_4 latches the current page number at the end of the accumulation loop.

Note that the AM29705 phase RAMs, IC_{15} and IC_{16}, actually hold 16 words, but the synthesizer uses 8 words at a time for 32-bit phase accumulation. The different sequencer modes treat the phase RAMs as having upper and lower 8-bit banks. Page 0 (normal mode) in **Table 1** performs the sequence described. If page 1 (sync mode) is in control, the current phase

Table 1—Programmable synthesizer microcode ROM

normal mode, access phase RAM page 0			
00: 15 11 11 00	11 11 11 00	11 11 10 00	11 11 01 00
sync requested, take phase from page 1			
20: 17 11 11 00	13 11 11 00	13 11 10 00	13 11 01 00
halt requested, use phase RAM page 0, but write to page 1			
40: 15 11 13 00	11 11 13 00	11 11 12 00	11 11 03 00
alternate signal=switch to phase RAM page 1			
60: 17 13 13 00	13 13 13 00	13 13 12 00	13 13 03 00

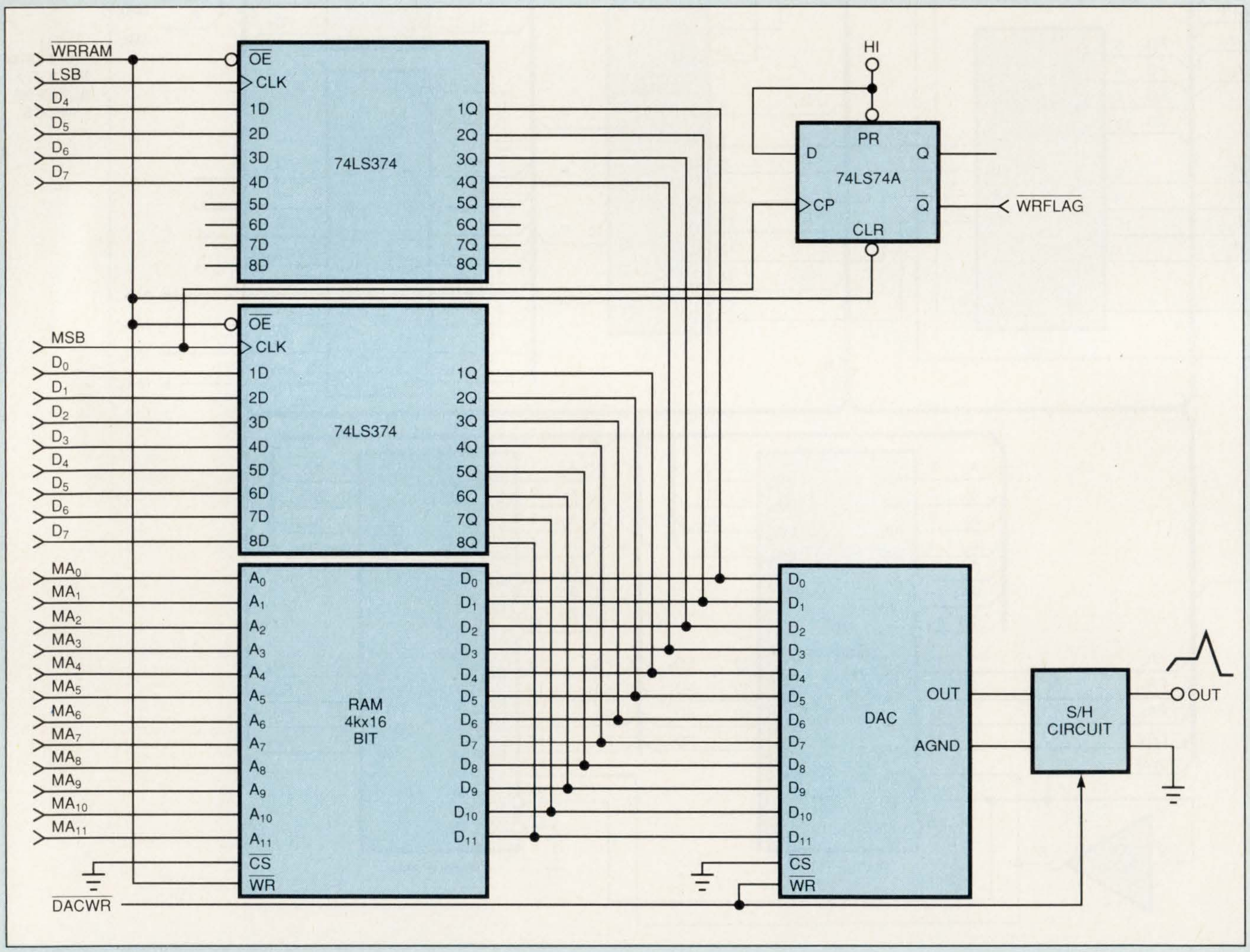


Fig 2—The synthesizer in Fig 1 accesses various locations in the programmable waveform memory. A D/A converter develops an analog output from the waveform memory's output data.

comes from the upper page and gets written into the corresponding page in the lower bank. Thus, the phase is "preset" to the value written into the upper bank. In page 2 (halt mode), writes to the phase RAM's lower bank are disabled, so the waveform suspends at the current phase value until the lower bank is re-enabled. In page 3 (alternate-signal mode), the synthesizer operates like Page 0, except that it uses the upper phase-RAM bank, so the waveform immediately switches to a second phase and frequency.

You can control which ROM sequencer page is in control via software or through the COND1 to COND4 inputs. These same inputs implement the waveform-burst mode. You can get copies of the documentation, sequencer-ROM program, and a P-CAD version of the schematics from the EDN BBS.

EDN BBS /DI_SIG #1105

To Vote For This Design, Circle No. 666

Reference

1. McCune, E, "Create signals having optimum resolution, response, and noise," *EDN*, March 14, 1991, pg 95.

Buffer tree multiplies dc supply voltages

Ian M Wiles, IPR Technology, Basingstoke, Hants, UK

The "buffer tree" in **Fig 1** can multiply a dc supply voltage by any whole number. The circuit successively adds the supply voltage to itself using a cascadable circuit element. The circuit element comprises two capacitors and paralleled HEX inverters configured as a noninverting buffer. The circuit relies on the bidirectional properties of MOSFETs.

Fig 2 shows the complete circuit for the first two stages of the buffer tree. The oscillator in **Fig 2** produces a 50-kHz clock drive. Lowering this frequency increases efficiency at the expense of lessening the output current. The efficiency of a breadboarded circuit was 90% for a 5-mA output from a 3-stage circuit (multiplier of 4) and dropped to 75% for a 15-mA output.

You can realize an inverting multiplier by treating the positive supply rail as a common and rearranging the circuit accordingly. **EDN BBS /DI_SIG #1103**

To Vote For This Design, Circle No. 667

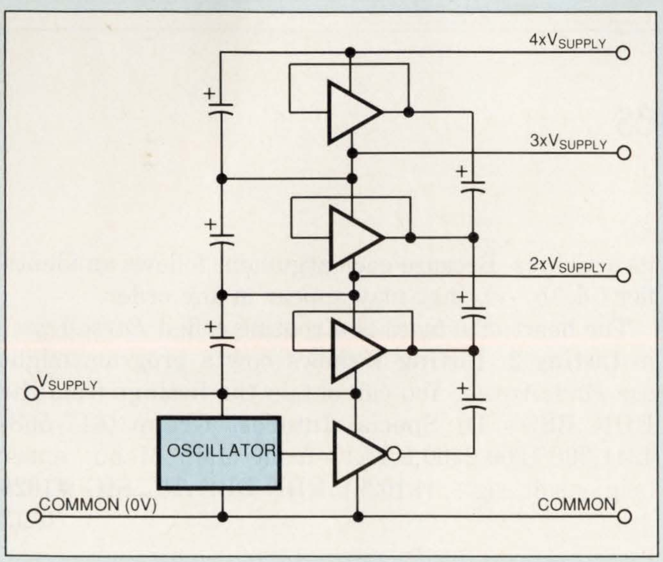


Fig 1—You can cascade buffer elements to multiply a supply voltage by any whole number.

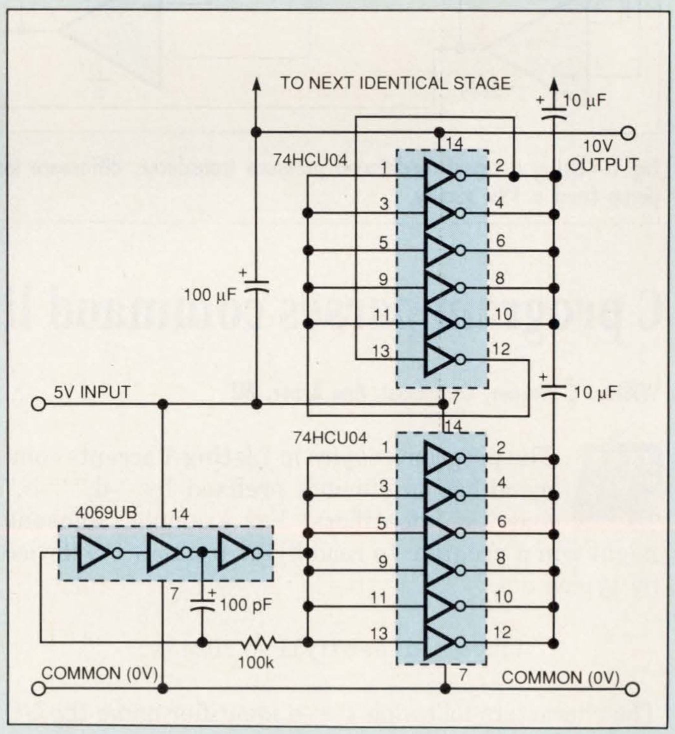


Fig 2—Expanding on Fig 1, this diagram shows the first two stages of a buffer tree. Note that each HEX inverter's configuration makes it a noninverting buffer.

Motor controller powers peristaltic pump

T G Barnett and M J George, Queen Mary and Westfield College, London, England

The circuit in **Fig 1** is a simple, low-cost motor controller, initially designed to control a peristaltic pump. These pumps often require input-drive voltages of 30V. Also, any steady-state error in the pump's proportional control system may not be acceptable. The circuit monitors pressure using a signal-conditioned pressure transducer suited for the required operating range. The typical output voltage of the pressure transducer will be between 1 and 5V. The output of the transducer drives a voltage follower, IC_{1A}. The potentiometer sets the reference voltage, which is obtained from a ZNREF050 diode of a second follower, IC_{1B}. The outputs of each of these followers form the inputs to a Norton-type current-differencing amplifier, IC_2. The circuit configures this amplifier as a difference integrator. The exact value of C_{INT} depends on the particular application. A dc/dc converter provides IC_2 with a supply of 30V. The overall circuit operates from a 12V supply. You can easily modify this circuit. For example, you can use additional LM324 op amps, which come in quad packages, to provide offset voltages for fine adjustment and to amplify or attenuate sensor and reference voltages. **EDN BBS /DI_SIG #1052** EDN

To Vote For This Design, Circle No. 668

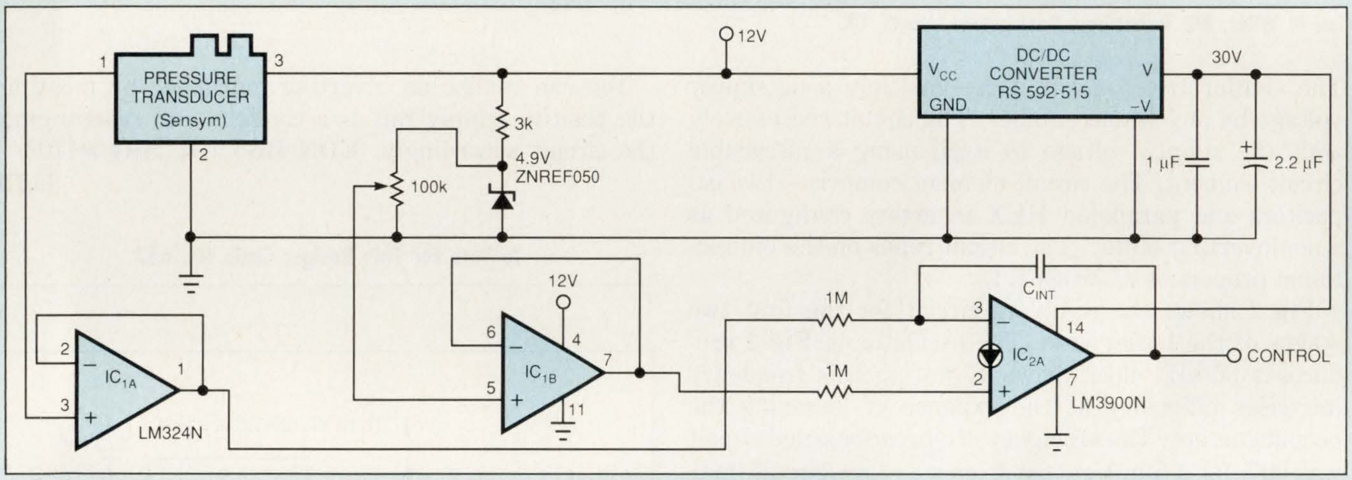


Fig 1—Using a signal-conditioned pressure transducer, difference integrator, and dc/dc converter, this motor controller drives a peristaltic pump from a 12V supply.

C program parses command lines

William C Warner, Consultant, Ann Arbor, MI

BBS The program *inbytes* in **Listing 1** accepts command-line arguments prefixed by "-d," "-b," and "-v" identifiers. For example, someone might run a program to read bytes from an I/O device by typing

inbytes -d /dev/tty11 -b 1024 -v.

The characters following the -d identifier name the I/O device. The number after -b is the maximum number of bytes to read from the device. The -v, if present, stands for "verbose," which tells the program to report its activities. Because each argument follows an identifier (-d, -b, -v), they may appear in any order.

The heart of *inbytes* is a routine called *ParseArgs()* in **Listing 2. Listing 1** shows how a program might use *ParseArgs()*. You can obtain the **listings** from the EDN BBS's DI Special Interest Group (617-558-4241,300/1200/2400,8,N,1—from Main Menu, enter (s)ig, <s/di_sig>, rk1026). **EDN BBS /DI_SIG #1026** EDN

To Vote For This Design, Circle No. 669

Listing 1—Command-line-argument parsing program

```
#include <stdio.h>
#include <fcntl.h>
#include <errno.h>

/* OS global error number */
extern int errno;

/* calling sequence for a routine to parse cmd line args */
int ParseArgs(char *pArgv[], int nArgc, char *pIdent, char *pFmt, void
*pValue);


/*
** Program:  inbytes
**
** Invoked as follows:
**
**      inbytes -d <device name> -b <bytes>  [-v]
**
**      where   <device name> names an I/O device
**              <bytes> is the max number of bytes to read from the device
**              -v, if present, has the program report its activities
**
** Like all C programs, this program accepts two arguments from the
** operating system.  "argc" is a count of the command line strings.
** "argv" is the address of an array of pointers to the command line
** strings.
*/

main( argc, argv )
int argc;                   /* number of command line strings           */
char *argv[];               /* argv[] holds pntrs to cmd line strings   */
{
    int fVerbose;           /* flag: true to report activities          */
    int nCnt;               /* max number of bytes to read from device */
    char szDevName[40];     /* name of device                           */
    static char buf[1024];  /* buffer for characters read               */
    int rd, fd;

    /* establish defaults */
    strcpy( szDevName, "" );
    nCnt = sizeof( buf);
    fVerbose = 0;

    /*
    ** Call ParseArgs() to possibly override defaults with values
    ** from command line
    */
    ParseArgs( argv, argc, "-d", "%s", szDevName );
    ParseArgs( argv, argc, "-b", "%d", &nCnt      );
    fVerbose = ParseArgs( argv, argc, "-v", "%d", NULL );

/*
** Passed here, szDevName[] holds the name of a device, nCnt
** holds a count value, and fVerbose is TRUE if the program
** should report its activities
*/

/*
** Check arguments: must have device name, bytes must
** not overflow buf[]
*/
if ( strcmp( szDevName, "") == 0 )
{
    printf( "inbytes: bad device name\n" );
    exit();
}
if ( nCnt > sizeof( buf) )
{
    printf( "inbytes: byte count too big (max: %d)\n", sizeof( buf) );
    exit();
}

if ( fVerbose )
    printf( "inbytes: opening device '%s'\n", szDevName );

/* open device */
fd = open( szDevName, O_RDONLY );
if ( fd < 0 )
{
    printf( "inbytes: failed to open device '%s' (errno: %d)\n",
    szDevName, errno );
    exit();
}

if ( fVerbose )
    printf( "inbytes: reading up to %d bytes\n", nCnt );

/* read in nCnt bytes */
rd = read( fd, buf, nCnt );
if ( rd < 0 )
{
    printf( "inbytes: failed to read device (errno: %d)\n", errno );
    exit();
}

if ( fVerbose )
{
    printf( "inbytes: %d bytes read\n", rd );
    printf( "inbytes: first byte: 0x%02x\n", ((int) buf[0]) & 0xff );
}
    close (fd);
    exit();
}
```

Listing 1—Command-line-argument parsing subroutine

```
/*
** ParseArgs()
**
** Parse command-line arguments.
**
** C call:       int ParseArgs( pArgv, nArgc, pIdent, pFmt, pValue )
**
** Parameters:   char *pArgv[]
**                  Address of array of pointers of command line strings
**
**               int nArgc
**                  Number of command line strings
**
**               char *pIdent
**                  String used to identify a certain cmd line arg (i.e., "-
v")
**
**               char *pFmt
**                  Format string for scanning argument value (i.e., "%d" )
**
**               void *pValue
**                  Pointer to storage for the argument value, if any.
**                  This parameter can be NULL if no value is expected.
**
** Retuned:      1 if match found for "pIdent"; or
**               0 if not
**
** This routine searches the cmd line strings for a match to pIdent.  If
** found and pValue is NULL, this routine returns 1 to signify that the
** cmd line argument was present.  If found and pValue not NULL, this
** routine scans the value following the identifying characters according
** to the format string *pFmt and into storage at *pValue.
*/

int ParseArgs( pArgv, nArgc, pIdent, pFmt, pValue )
char *pArgv[];
int  nArgc;
char *pIdent;
char *pFmt;
void *pValue;
{
    int i, ret = 0;
    char *pScan = NULL;
/*
** Check all cmd line arguments for a match to pIdent
*/
for (i = 0; i < nArgc; i++)
{
    /* check one arg for match with pIdent */
if ( strncmp( pArgv[i], pIdent, strlen( pIdent)) )
    continue;  /* no match */

/* got match */

/* return now if don't need value */
if ( pValue == NULL )
{
    ret = 1;
    break;
}

/* check for value following ident with no space or after space */
if ( strlen( pArgv[i]) != strlen( pIdent) )
{
    /* value following with no space */
    pScan = &( pArgv[i][ strlen( pIdent)] );
}
else if ( (i+1) < nArgc )
{
    /* value following after space - scan next cmd line string */
    pScan = pArgv[i + 1];
}

/* scan the value and return 1 if value scans */
if ( pScan != NULL )
{
    ret = (sscanf( pScan, pFmt, pValue) == 1) ? 1 : ret;
    break;
}
}

return (ret);
}
```

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Polynomial linearizes thermocouple

Robert S Villanucci, Wentworth Institute, Boston, MA

By combining a second-order-polynomial curve-fitting circuit and a scaling amplifier having the proper offset, you can reduce thermocouple-linearization costs. Yet, you can still achieve a worst-case system response—over an extended temperature range—of less than 4°C. A low-cost analog-multiplier IC provides the squared term of the second-order polynomial.

The circuit in **Fig 1** uses a chromel-constantan (type-E) thermocouple, sensing temperature from 0 to 650°C. Adding a series-opposing correction voltage, V_C, to the sensor cancels the cold-junction error voltage, V_R. IC_1, a cold-junction compensator, tracks the ambient temperature, T_A, and produces this temperature-dependent V_C. V_C has the same sensitivity (60.0 μV/°C) as the cold-junction thermocouple junctions.

IC_2 amplifies the thermocouple's low-level signal with a gain of 100 and applies the amplified signal, V_T, to the curve-fitting and scaling circuitry. The output voltage of the curve-fitting and scaling circuitry yields an overall sensitivity of 10 mV/°C.

Fig 2, a plot of V_O vs V_T, shows that the thermocouple's response is linear above 350°C and nonlinear below this transition temperature. You scale the section above 350°C (where $V_T = 2.4961V$) for a 10-mV/°C sensitivity with the linear expression

$$V_O = (1.24V_T + 0.399V) \times \mu(V_T - 2.4961V)$$

where μ is a step function added to indicate that this linear equation is valid only for temperatures above 350°C. You set the required gain of 1.24 in **Fig 1**'s circuit with feedback resistor R_1 and input-resistance network $R_2 \parallel R_3$. IC_{3D} generates the 0.399V offset. Comparator IC_5 combines with analog switch IC_6 to

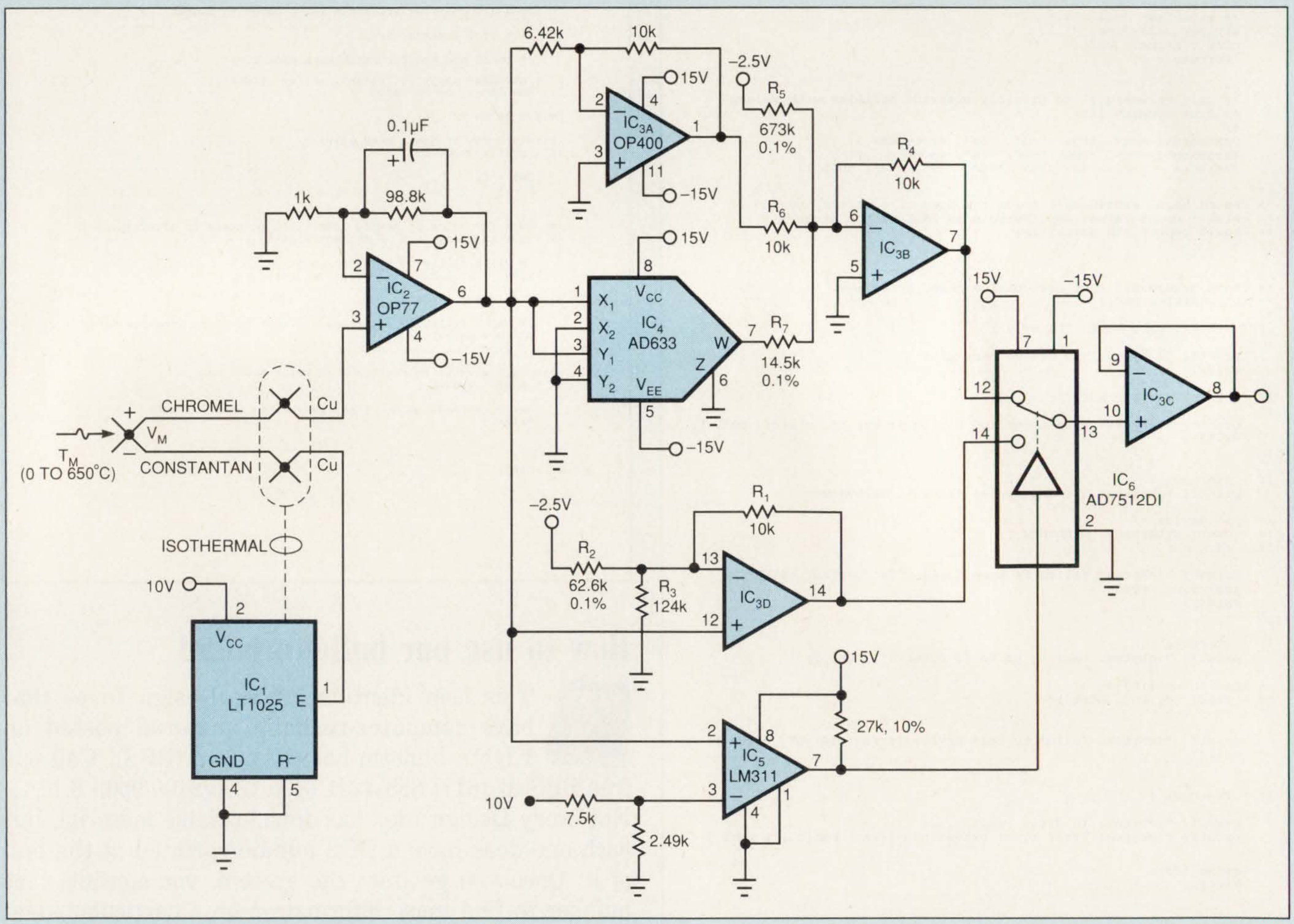

Fig 1—Switching in circuitry having a second-order-polynomial response, at the proper point in the thermocouple's response curve, linearizes the output of a type-E thermocouple.

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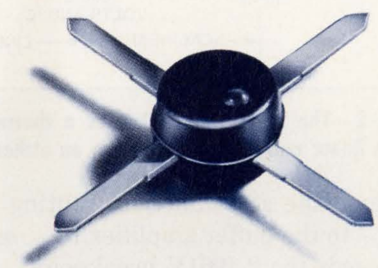


dc to 2000 MHz amplifier series

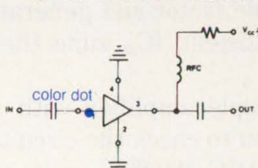
SPECIFICATIONS

MODEL	FREQ. MHz	GAIN, dB 100 MHz	1000 MHz	2000 MHz	Min. (note)	•MAX. PWR. dBm	NF dB	PRICE $ Ea.	Qty.
MAR-1	DC-1000	18.5	15.5	—	13.0	0	5.0	0.99	(100)
MAR-2	DC-2000	13	12.5	11	8.5	+3	6.5	1.35	(25)
MAR-3	DC-2000	13	12.5	10.5	8.0	+8□	6.0	1.45	(25)
MAR-4	DC-1000	8.2	8.0	—	7.0	+11	7.0	1.55	(25)
MAR-6	DC-2000	20	16	11	9	0	2.8	1.29	(25)
MAR-7	DC-2000	13.5	12.5	10.5	8.5	+3	5.0	1.75	(25)
MAR-8	DC-1000	33	23	—	19	+10	3.5	1.70	(25)

NOTE: Minimum gain at highest frequency point and over full temperature range.
• 1dB Gain Compression
□ +4dBm 1 to 2 GHz

designers amplifier kit, DAK-2

5 of each model, total 35 amplifiers
only $59.95



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*MAR-8, Input/Output Impedance is not 50ohms, see data sheet. Stable for source/load impedance VSWR less than 3:1

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Size (mils)	Tolerance	Temperature Characteristic	Value
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80 × 50	10%	X7R	2200, 4700, 6800, 10,000 pf
120 × 60	10%	X7R	.022, .047, .068, .1µf

† Minimum Order 50 per Value
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C113-Rev. D

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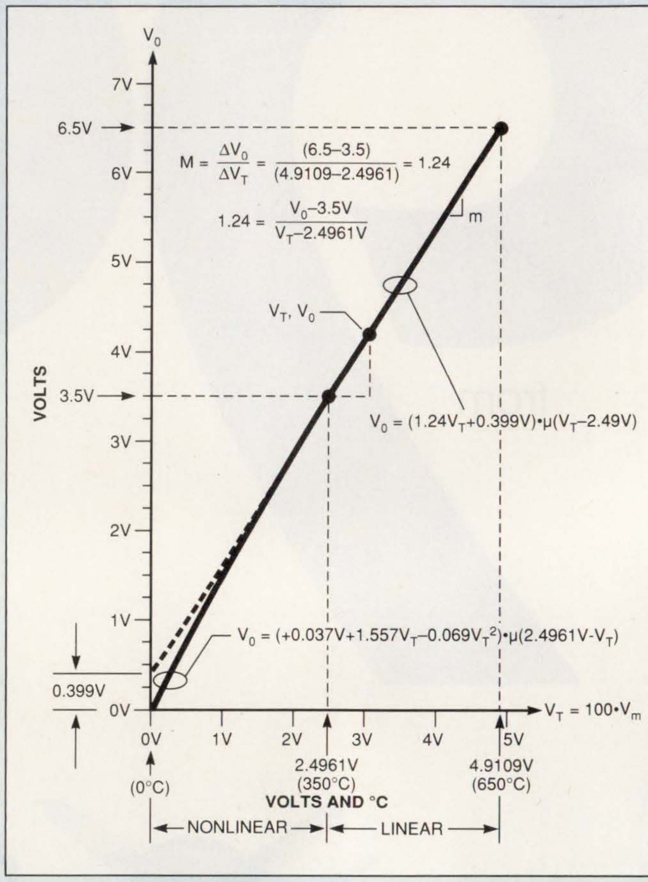


Fig 2—The circuit in Fig 1 uses a thermocouple whose response has linear and nonlinear regions on either side of 350°C.

create the step function, routing the linear output of IC_{3D} to the buffer amplifier IC_{3C}, only when the voltage exceeds the 2.4961V breakpoint.

For temperatures below 350°C, the output of comparator IC_5 goes low, switching IC_{3B}'s output through the analog switch IC_6 to the output-buffer amplifier IC_{3C}. The method of least squares yields the second-order polynomial,

$$V_O = (0.037V + 1.557V_T - 0.069V_T^2) \times \mu(2.4961V - V_T).$$

In **Fig 1**, the attenuation of R_4 and R_5 creates the positive 0.037V offset from the −2.5V reference. R_4 and R_6 set IC_{3A}'s gain to −1.557. IC_4 creates the squared term, and the combination of R_4 and R_7 removes the device's 10V scale factor and generates the squared term's −0.069 coefficient. IC_{3B} sums the terms of the polynomial.

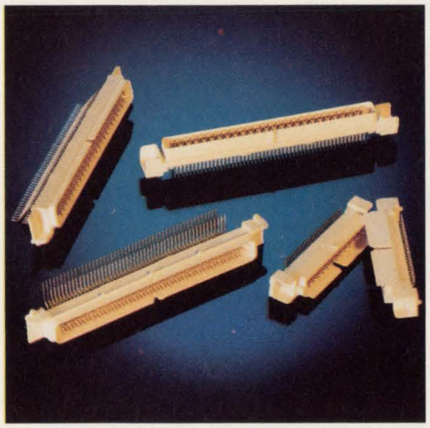
Replacing the thermocouple amplifier with a low-impedance source allows you to check the circuit's performance. **EDN BBS /DI_DIG #1092** EDN

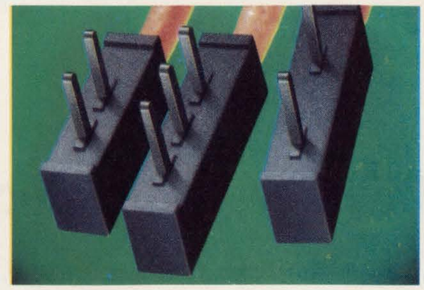
To Vote For This Design, Circle No. 670

High Density Hermaphroditic Connectors

- *Identical contacts on mating halves*
- *Close pitch .050″ centers*

Meritec 50 ohm, impedance matched Hermaphroditic Connectors feature .050″ centers, with board spacing as close as .394″ (10 mm), making them ideal for dense package applications. Two, three and four row connectors are available, in straight or right angle versions, with through hole or SMT contact tails. Precision, high strength molded terminations are reliable in the most critical applications. The connectors are designed to meet IR or vapor phase reflow requirements.





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- *Low profile*

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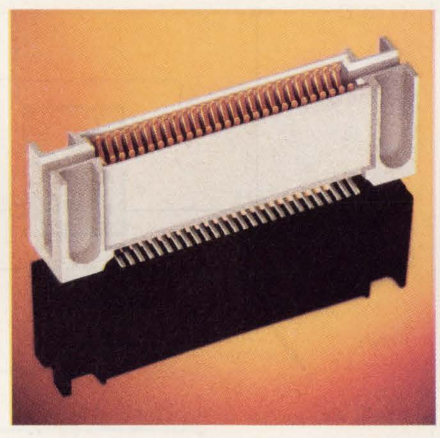

Close Pitch Card Edge Connectors

- *.050″ centers*
- *50 Ω impedance matched*

Meritec's high density Card Edge Connectors are designed with .050″ centers to minimize board space requirements. The 50 Ω, impedance matched connectors are ideal for high density board-to-board applications. The connectors are designed to meet IR or vapor phase reflow requirements. Through hole and SMT contact tail configurations are available. Precision, high strength molded terminations provide reliability in critical applications.

Dual-frequency clock's outputs have low skew

Louis Pandula, Pandula Consulting, Sunnyvale, CA

The clock circuit in **Fig 1** produces both a reference clock and a half-frequency clock. The circuit's multiplexer-based logic exhibits low skew between the two outputs. If you use 74ACT or 74F logic to implement this circuit, the skew can be less than 1 nsec.

In the circuit, flip-flop IC_1 divides the input clock by two. Flip-flop IC_2 mirrors the state of IC_1, delayed by half a clock cycle. Multiplexer IC_4 selects the output of IC_1 during the low clock state and the output of IC_2 during the high clock state. Thus IC_4 generates a divide-by-two clock that changes state one propagation delay after the input clock.

Multiplexer IC_3 simply develops the inverse of the input clock, again adding a delay. As long as the two multiplexers reside in the same IC, their delays will match closely, and the resulting skew between the two output clocks will be very low.

EDN BBS /DI_SIG #1082

To Vote For This Design, Circle No. 671

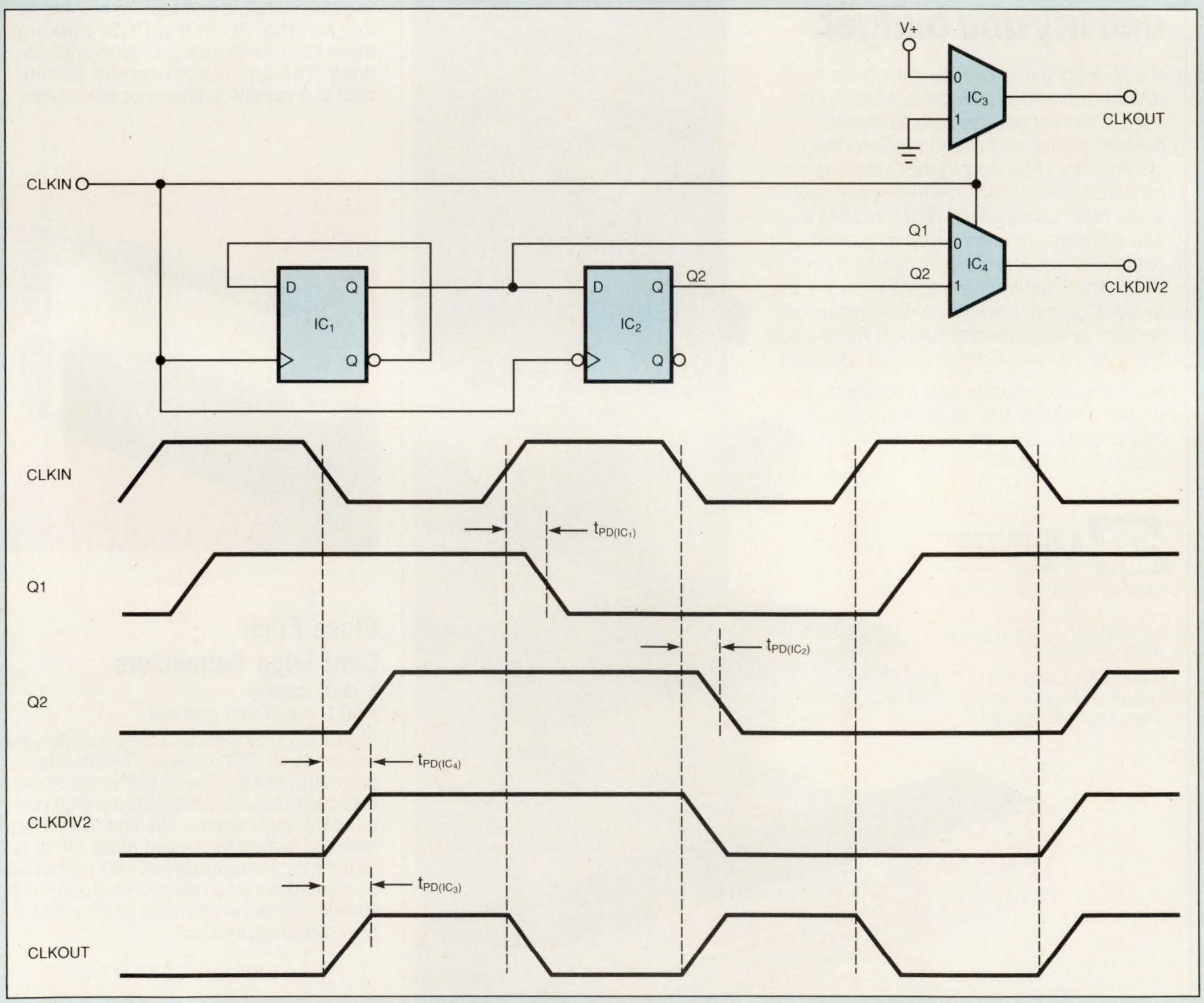

Fig 1—Clever use of multiplexer logic produces a pair of in-phase clock signals. One clock runs at half the speed of the other.

Digitally controlled amplifier takes 1-dB steps

Mark Williamsen, Ansan Industries Ltd, Rockford, IL

Fig 1 shows a 2-stage digitally controlled amplifier that features accurate logarithmic gain steps and has excellent linearity and headroom at all gain settings. The circuit is well suited for audio, ultrasonic, and instrumentation applications. The circuit connects resistor-divider networks to two analog multiplexers. Under digital control, the multiplexers switch various taps of the resistor chain to the inverting inputs of two JFET-input op amps, thereby changing the gain. The resistor divider chains are set up so that each digital input bit corresponds to a binary-weighted gain change of 1, 2, 4 dB, and so on. Cascading the two stages allows adding together the dB gain for the stages. Thus, you can connect the digital control lines to 6 bits of an output register in a μC, for instance, to provide instantaneous switching to any gain from 0 dB to 63 dB in 1-dB increments.

Every element of the circuit operates optimally. Each gain stage drives a constant and linear resistive load. A low-impedance, constant voltage source drives each feedback divider chain. The divider chains are loaded only by the high-impedance input of an op amp through the analog multiplexer. The analog multiplexer operates in a voltage mode instead of the more common current mode. Switching the op amp's inverting input from one tap to the next has essentially no effect on signals present in the divider, aside from the desired gain change. Analog voltages present at the selected tap are immediately carried through to the multiplexer's common output terminal. Since essentially no current flows through the selected multiplexer channel, there is no voltage drop and therefore virtually no nonlinearity in the circuit over the full bipolar range of output voltages.

Note that digital controls D_0, D_1, and D_5 connect to one multiplexer and D_2, D_3, and D_4 connect to a second multiplexer. This digital control allows the two stages to balance the required gains. In the circuit shown, the 32-dB bit (D_5) is combined with the 1-dB (D_0) and 2-dB bits (D_1), so that the worst-case gain for the second stage is 35 dB. The first stage then receives the control bits for 4-dB (D_2), 8-dB (D_3), and 16-dB (D_4) gain changes. The total gain for the first stage is 28 dB.

Industry-standard 4051 analog multiplexers are recommended because of their built-in decoders and level shifters. These provide an extra measure of isolation between the digital control inputs (which are likely to carry an assortment of hash, noise, and spikes) and the analog signal path. The separate V_{EE} pin connects to a negative power supply to allow handling of bipolar analog signals while maintaining standard ground-referenced logic levels.

No bias resistor is needed for the op amp's inverting input, since it's always biased by the op-amp output through the analog multiplexer and divider chain. The multiplexer's inhibit input is tied low to ensure that the op amp remains biased at all times. While this portion of the circuit should be dc coupled, blocking

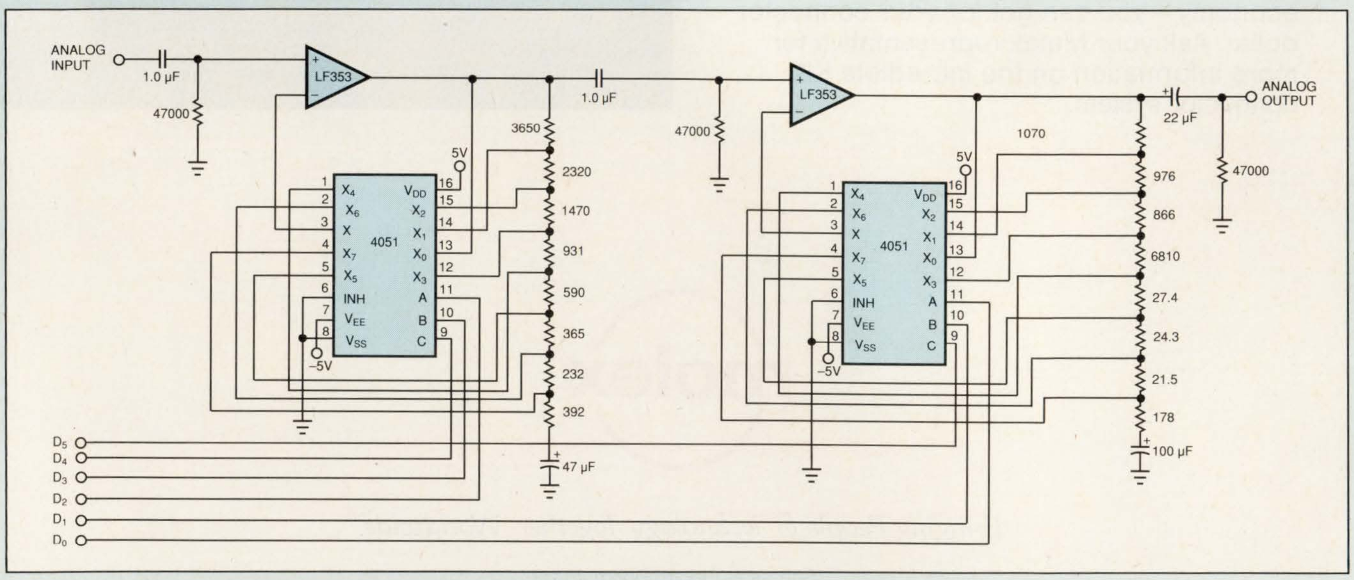

Fig 1—This 2-stage, digitally controlled amplifier balances the gain between the two stages and uses carefully selected resistor values to achieve a dynamic range of 63 dB, which digital inputs can change in 1-dB increments.

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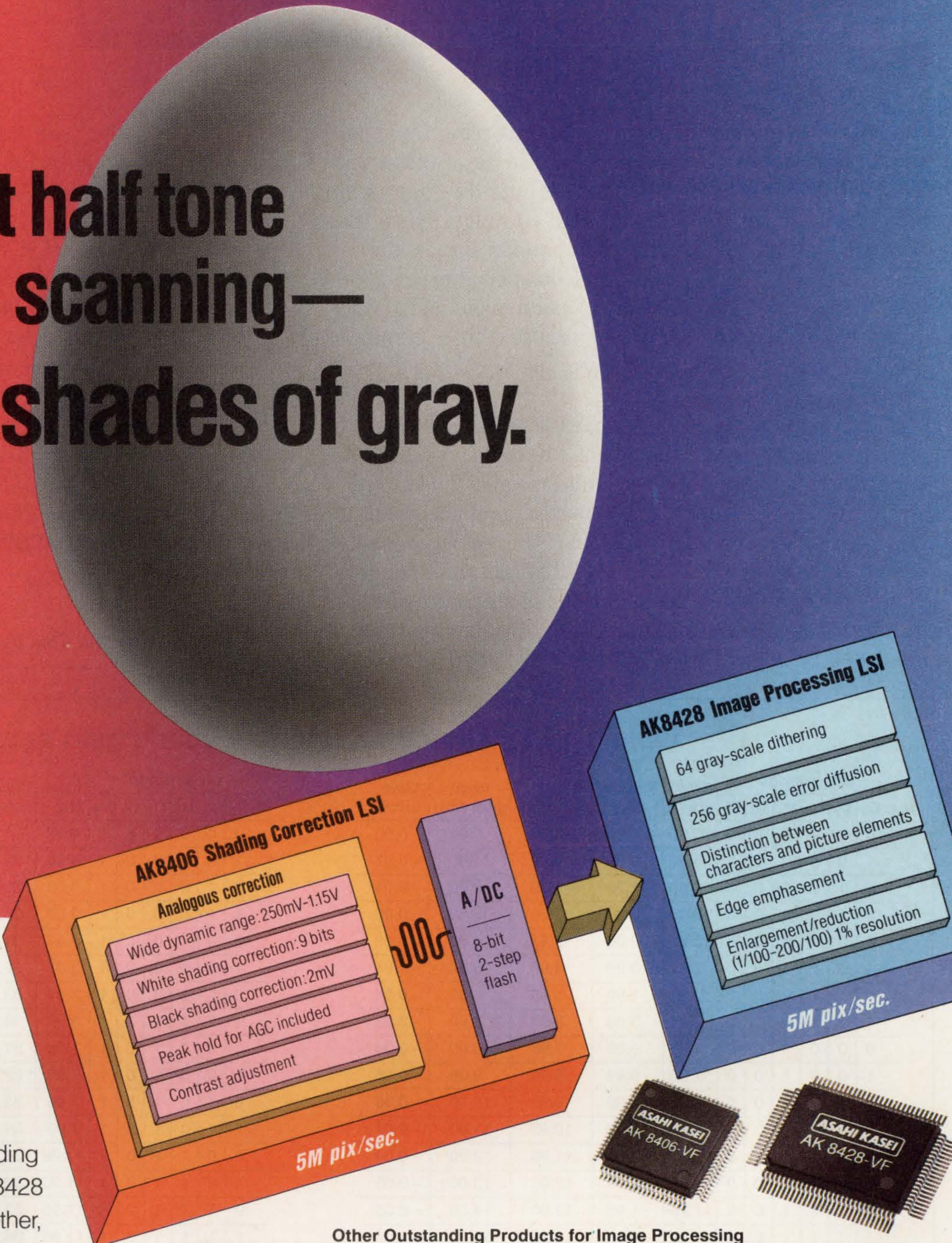

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CIRCLE NO. 116

capacitors may be added at the noninverting input and at the low end of the divider chain in ac applications. This will eliminate any spurious outputs due to op-amp offset voltage by reducing dc gain to unity. Note that because the multiplexer handles bipolar signals and all signals are referenced to ground, no special precautions are needed in dc applications, aside from using low-offset or adjustable-offset op amps whose common-mode input range includes any expected analog input signals.

Fig 1 includes blocking capacitors that will remove any dc offsets from the output. Frequency response is flat from subaudio to ultrasound ranges. The circuit's accuracy is limited only by the precision of the resistors in the divider chains. Note that the resistor values shown are standard 1% values. The actual calculated values needed for precise logarithmic steps are slightly different, as shown in **Table 1**. Note also that steps need not be logarithmic, nor do they need to be uniform. For instance, you can set up step sizes of 2, 5, and 10 for instrumentation applications.

Although the circuit responds instantly to gain changes with no audible ticks or pops of its own, any sudden gain changes that occur when the output level is nonzero will result in a step function at the output. This is true for any step attenuator or amplifier. You can minimize this effect by waiting for a zero-crossing, or by making a number of small gain changes in sequence instead of one large change. If a zero-crossing detector is used, you must carefully isolate its output from the analog signal path. The choice of 64 steps of 1 dB resulted from consideration of the desired dynamic range. You can calculate other step sizes for different applications. **EDN BBS /DI_SIG #1114**

EDN

To Vote For This Design, Circle No. 672

Table 1—Digitally controlled amplifier's gain settings

Bit settings*						First	Second	Actual	Ideal	Gain
D_0	D_1	D_2	D_3	D_4	D_5	stage	stage	gain (dB)	gain (dB)	error
0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00
1	0	0	0	0	0	0.00	0.99	0.99	1.00	−0.01
0	1	0	0	0	0	0.00	1.99	1.99	2.00	−0.01
1	1	0	0	0	0	0.00	3.00	3.00	3.00	0.00
0	0	1	0	0	0	3.97	0.00	3.97	4.00	−0.03
1	0	1	0	0	0	3.97	0.99	4.96	5.00	−0.04
0	1	1	0	0	0	3.97	1.99	5.96	6.00	−0.04
1	1	1	0	0	0	3.97	3.00	6.97	7.00	−0.03
0	0	0	1	0	0	7.96	0.00	7.96	8.00	−0.04
1	0	0	1	0	0	7.96	0.99	8.95	9.00	−0.05
0	1	0	1	0	0	7.96	1.99	9.95	10.00	−0.05
1	1	0	1	0	0	7.96	3.00	10.96	11.00	−0.04
0	0	1	1	0	0	11.96	0.00	11.96	12.00	−0.04
1	0	1	1	0	0	11.96	0.99	12.95	13.00	−0.05
0	1	1	1	0	0	11.96	1.99	13.95	14.00	−0.05
1	1	1	1	0	0	11.96	3.00	14.96	15.00	−0.04
0	0	0	0	1	0	15.99	0.00	15.99	16.00	−0.01
1	0	0	0	1	0	15.99	0.99	16.98	17.00	−0.02
0	1	0	0	1	0	15.99	1.99	17.98	18.00	−0.02
1	1	0	0	1	0	15.99	3.00	18.99	19.00	−0.01
0	0	1	0	1	0	20.05	0.00	20.05	20.00	0.05
1	0	1	0	1	0	20.05	0.99	21.04	21.00	0.04
0	1	1	0	1	0	20.05	1.99	22.04	22.00	0.04
1	1	1	0	1	0	20.05	3.00	23.05	23.00	0.05
0	0	0	1	1	0	24.05	0.00	24.05	24.00	0.05
1	0	0	1	1	0	24.05	0.99	25.04	25.00	0.04
0	1	0	1	1	0	24.05	1.99	26.04	26.00	0.04
1	1	0	1	1	0	24.05	3.00	27.05	27.00	0.05
0	0	1	1	1	0	28.09	0.00	28.09	28.00	0.09
1	0	1	1	1	0	28.09	0.99	29.08	29.00	0.08
0	1	1	1	1	0	28.09	1.99	30.08	30.00	0.08
1	1	1	1	1	0	28.09	3.00	31.09	31.00	0.09
0	0	0	0	0	1	0.00	31.98	31.98	32.00	−0.02
1	0	0	0	0	1	0.00	32.98	32.98	33.00	−0.02
0	1	0	0	0	1	0.00	33.98	33.98	34.00	−0.02
1	1	0	0	0	1	0.00	34.97	34.97	35.00	−0.03
0	0	1	0	0	1	3.97	31.98	35.95	36.00	−0.05
1	0	1	0	0	1	3.97	32.98	36.95	37.00	−0.05
0	1	1	0	0	1	3.97	33.98	37.95	38.00	−0.05
1	1	1	0	0	1	3.97	34.97	38.94	39.00	−0.06
0	0	0	1	0	1	7.96	31.98	39.94	40.00	−0.06
1	0	0	1	0	1	7.96	32.98	40.94	41.00	−0.06
0	1	0	1	0	1	7.96	33.98	41.94	42.00	−0.06
1	1	0	1	0	1	7.96	34.97	42.93	43.00	−0.07
0	0	1	1	0	1	11.96	31.98	43.94	44.00	−0.06
1	0	1	1	0	1	11.96	32.98	44.94	45.00	−0.06
0	1	1	1	0	1	11.96	33.98	45.94	46.00	−0.06
1	1	1	1	0	1	11.96	34.97	46.93	47.00	−0.07
0	0	0	0	1	1	15.99	31.98	47.97	48.00	−0.03
1	0	0	0	1	1	15.99	32.98	48.97	49.00	−0.03
0	1	0	0	1	1	15.99	33.98	49.97	50.00	−0.03
1	1	0	0	1	1	15.99	34.97	50.96	51.00	−0.04
0	0	1	0	1	1	20.05	31.98	52.03	52.00	0.03
1	0	1	0	1	1	20.05	32.98	53.03	53.00	0.03
0	1	1	0	1	1	20.05	33.98	54.03	54.00	0.03
1	1	1	0	1	1	20.05	34.97	55.02	55.00	0.02
0	0	0	1	1	1	24.05	31.98	56.03	56.00	0.03
1	0	0	1	1	1	24.05	32.98	57.03	57.00	0.03
0	1	0	1	1	1	24.05	33.98	58.03	58.00	0.03
1	1	0	1	1	1	24.05	34.97	59.02	59.00	0.02
0	0	1	1	1	1	28.09	31.98	60.07	60.00	0.07
1	0	1	1	1	1	28.09	32.98	61.07	61.00	0.07
0	1	1	1	1	1	28.09	33.98	62.07	62.00	0.07
1	1	1	1	1	1	28.09	34.97	63.06	63.00	0.06

Notes:

*Bit weight for D_0=1 dB; D_1=2 dB; D_2=4 dB; D_3=8 dB; D_4=16 dB; D_5=32 dB.

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CIRCLE NO. 117

Registers build FIFO memory for ASICs

Michael Fitzsimmons, Interphase, Dallas, TX

If your ASIC vendor's library contains no FIFO (first-in, first-out) memories and the library's RAM cells are too troublesome to use, building a FIFO out of simple registers may be the best solution. Using registers instead of RAM to build a FIFO memory eliminates read/write pointers and data multiplexing.

The 16-word × 32-bit FIFO memory in **Fig 1**'s block diagram requires 512 registers for the memory plus some associated control logic and clock buffers. You can adapt the design to FIFO memories of other sizes as well.

In **Fig 1**, the column labeled "ELEVATOR CONTROL" controls the stack. The "elevator" goes up on writes and down on reads. The highest logical 1 in the elevator points to the next empty location in the stack of data registers. The elevator always has "floor" 0 set to 1 because you read data out from floor 0. You can bring out elevator-control bits Q_7 and Q_{15} as flags for half-full and full conditions, respectively.

Fig 2 is a sketch of the FIFO data registers; **Figs** 3 and 4 show the control logic for shifting data from floor to floor during read and write cycles.

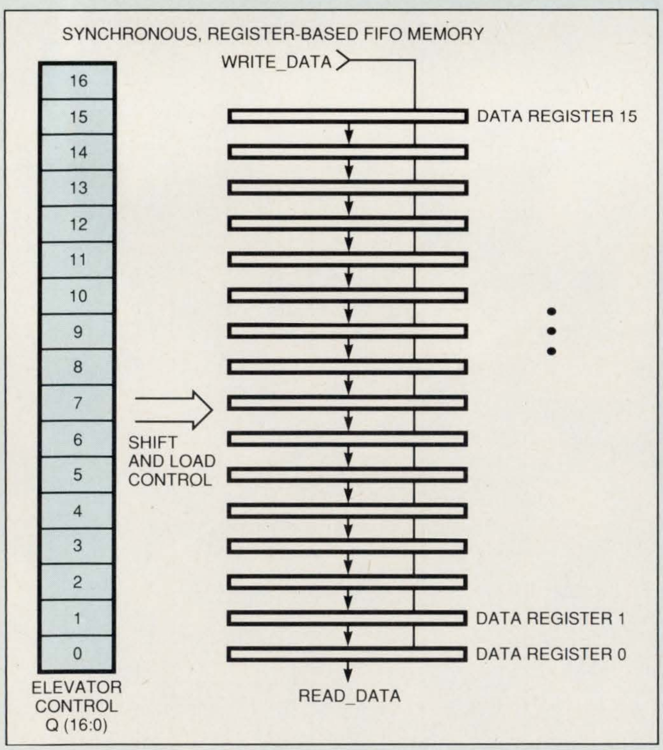

Fig 1—This block diagram serves as a conceptual model for a small FIFO memory you can implement in ASICs by using load/shift registers.

After you write your first word into FIFO register 0 by asserting WRITE (and therefore LD(0)), elevator bit Q_1 will go high, pointing to register 1 for the next write. Subsequent writes will raise the elevator one floor for each write. A simultaneous read and write

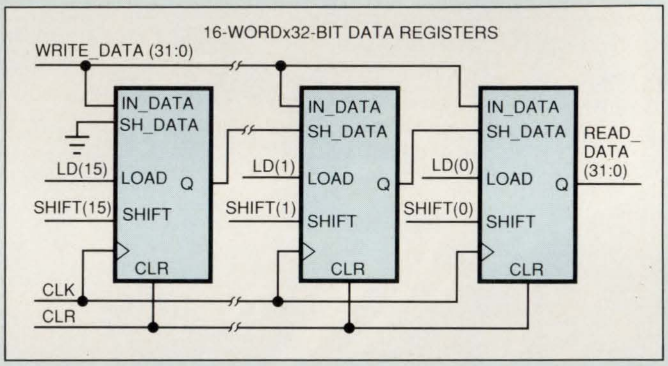

Fig 2—This chain of registers, under the control of the load/shift logic in Figs 3 and 4, moves one bit of each word stored in the FIFO memory up and down the stack in response to read and write commands.

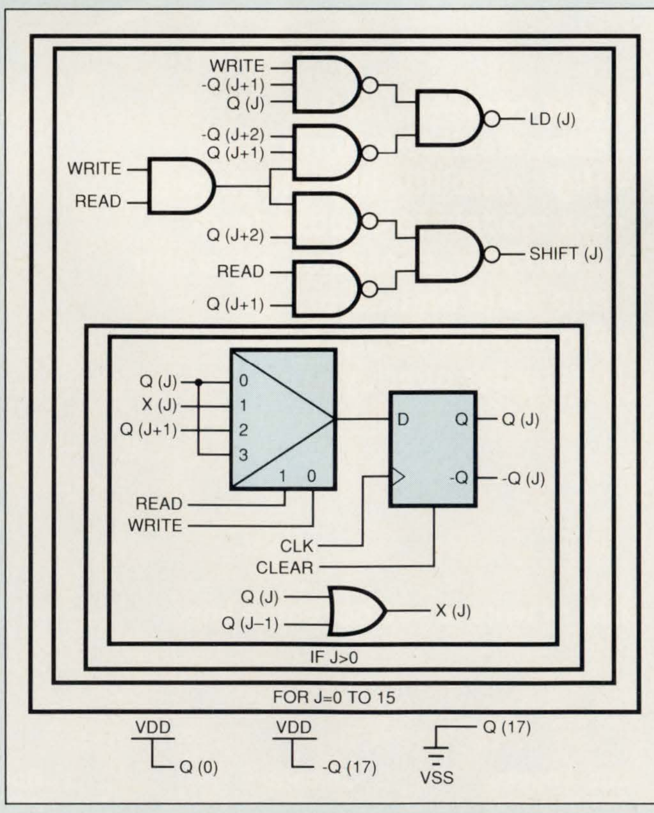

Fig 3—This ASCII macro will generate load/shift logic for each of the vertical strings of bit registers in the FIFO memory.

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CIRCLE NO. 118

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Entry blank must accompany all entries. Design entered must be submitted exclusively to EDN, must not be patented, and must have no patent pending. Design must be original with author(s), must not have been previously published (limited-distribution house organs excepted), and must have been constructed and tested. Fully annotate all circuit diagrams. Please submit software listings and all other computer-readable documentation on a 5¼-in. IBM PC disk in plain ASCII.

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Date ____________________

ISSUE WINNER

The winning Design Idea for the February 3, 1992, issue is entitled "Circular RAM buffer generates long delays," submitted by Yongping Xia of West Virginia University (Morgantown, WV).

Your vote determines this issue's winner. All designs published win $100 cash. All issue winners receive an additional $100 and become eligible for the annual $1500 Grand Prize. **Vote now,** by circling the appropriate number on the reader inquiry card.

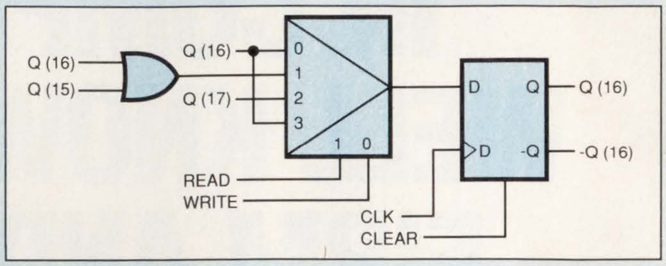

Fig 4—The last location in the FIFO memory needs "top-floor" control logic.

will have no effect on the elevator bits. Read operations always cycle out the word from register 0 and shift all the other stored words down one floor.

Note that this FIFO memory is synchronous and runs on one clock signal. Setup times for the SHIFT and LOAD signals going to the registers limit the circuit's performance. You must optimize the read and write control signals for both minimal gates and fanout. **EDN BBS /DI_SIG #1102** EDN

To Vote For This Design, Circle No. 673

Design Ideas are continued on pg 218

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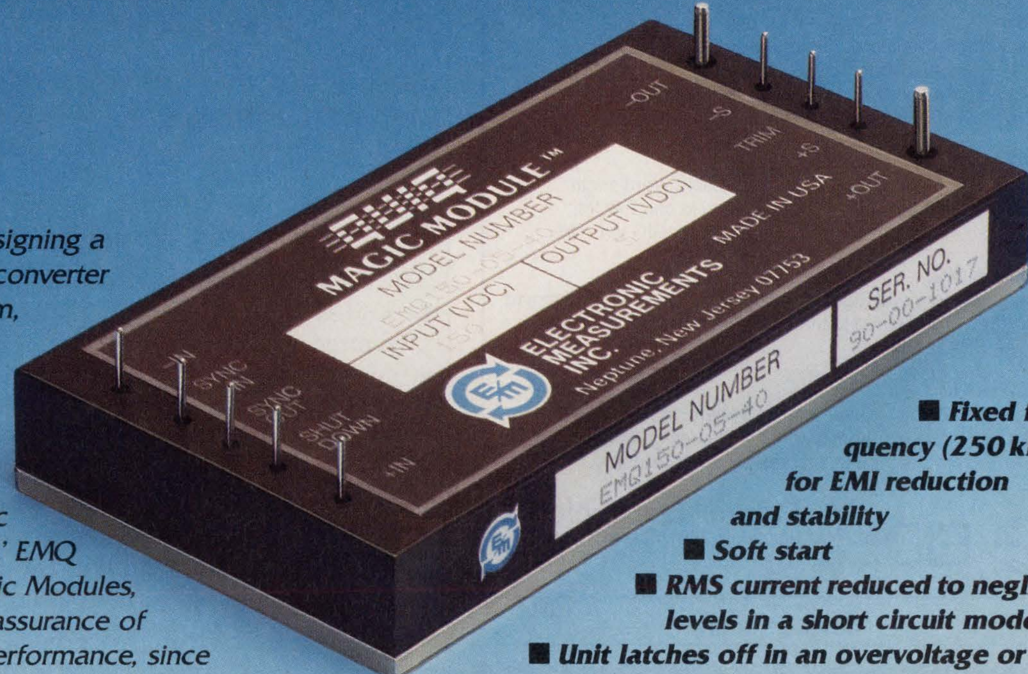

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CIRCLE NO. 120

Satisfied customer

Thank you very much for deciding to publish my Design Idea #1030 "High-frequency VCOs top 100 MHz." I was very, very happy when I received your letter. Please extend my thanks to everyone on your staff involved in the decision.

Di Paolo Franco
Ericsson-Fatme
Dept: XT/TT Via Anagina, 203
00040 Roma, Italy

Reader suggests corrections

The description of DI #999 (EDN, August 19, 1991, pg 156) probably should say that the circuit generates a 68-msec positive-going pulse on power-up. On loss of power, the signal diode must discharge C_1. If the power supply has a low impedance, or its output crowbars, the discharge current will probably destroy the signal diode. Also, the "instant reset" provided by the resistor network on power-down may not be very "instant." The IC may not recognize a low transition until its pin 1 drops to around 0.9V or less, meaning that the power supply has already dropped to about 1.5V. That's a little late to attempt an orderly shutdown of a system. An absolute threshold, not a ratio, needs to be sensed. Everything works against you in this circuit: the 1.67:1 sensing ratio and the fact that the negative-going transition threshold of IC_1 decreases with decreasing V_{CC}.

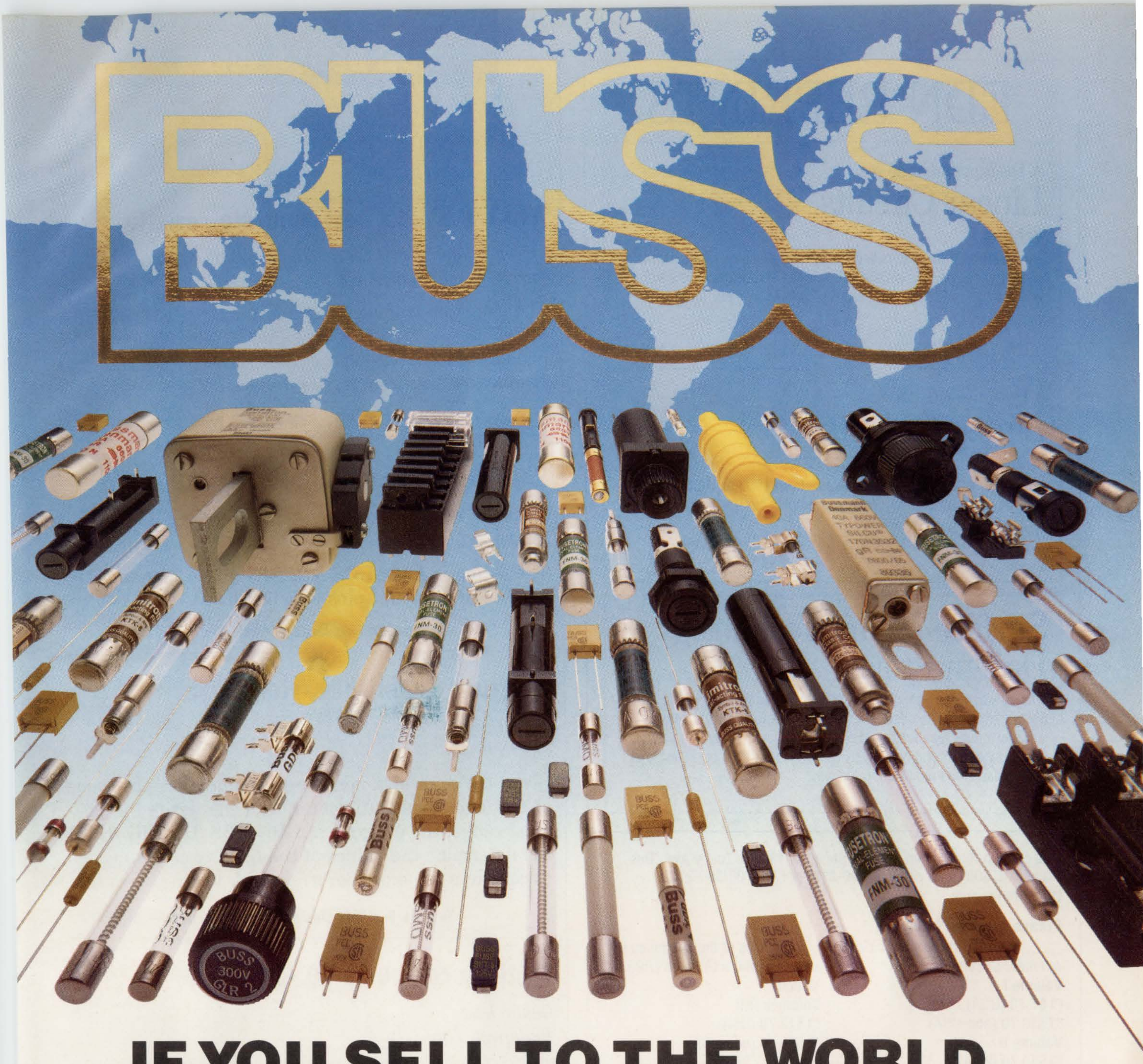
William N Schroeder, Hardware Engineering Mgr
Intecom Inc
601 Intecom Dr
Allen, TX 75002
(214) 727-9141

Errata

The Design Idea "Backup time-out saves battery," on page 174 of the October 24, 1991 issue of EDN, contains an error. The connection between pin 8 of IC_1 and ground should be through a 10-kΩ resistor, and not directly to ground as incorrectly drawn.

Anne Watson Swager
Design Ideas Editor

The schematic for the Design Idea "8051 μC converses with dual-port RAM" in the June 6, 1991 issue of EDN, pg 176, contains two potentially misleading typos. The signal $\overline{\text{XDAT\_AC}}$ should *not* have a bar over it as this signal is active high, and the signals XDAT_RD and DPR_WR *should* have overbars as they are active low. These are errors in name only—the circuit diagram itself is correct.


BUSS

AT&T DSP32Cs communicate serially

Steven J Roome and Steven Denny, Data Sciences Ltd
Farnborough, Hants, UK

The simple assembler program in **EDN BBS /DI_SIG #1106** sets up two AT&T SDP32C DSP μPs for interprocess communication via their serial ports. The program saves you from having to use DMA.

To Vote For This Design, Circle No. 674

Routine adds 68302 interrupt pins

Robert W O'Dell, Motorola
Austin, TX

The listing in **EDN BBS /DI_SIG #1107** increases the number of interrupt pins on a 680302 μC from 7 to 19.

To Vote For This Design, Circle No. 675

Program establishes trim range

John Dunn
Merrick, NY

Given the gain of a noninverting amplifier, the value of a trimming potentiometer, and the desired adjustment range, the program in **EDN BBS /DI_SIG #1111** can determine the values of the fixed resistors needed to complete the amplifier's feedback loop.

To Vote For This Design, Circle No. 676

C utility computes 10 CRCs

Gábor Kiss
Budapest, Hungary

The C program in **EDN BBS /DI_SIG #1110** computes CRCs (cyclic redundancy checks) 10 different ways. Use it as a check against other CRC routines. As a bonus, the package contains a program for converting Gregorian dates to Julian dates, and vice versa.

To Vote For This Design, Circle No. 677

Spice models a solar array

Steven C Hageman, Calex Mfg Co Inc
Pleasant Hill, CA

Along with complete documentation, the Spice program in **EDN BBS /DI_SIG #1109** models solar arrays so that you can simulate solar-powered equipment.

To Vote For This Design, Circle No. 678

Software Shorts

Computer reads DMM chip

Yongping Xia, West Virginia University
Morgantown, WV

The C++ program and circuit diagram in **EDN BBS /DI_SIG #1094** allow you to read an ICL7106 DMM chip's 7-segment LCD outputs with a computer.

To Vote For This Design, Circle No. 679

Switcher syncs with slow peripherals

Gregor Said Jackson, Azad International,
Hamburg, Germany

The complete design package in **EDN BBS /DI_SIG #1062** details a pair of high-speed PAL-device designs that allow a Mips R3000 RISC μP to synchronize with slow peripherals by switching clock sources. Circuit diagrams are Postscript files.

To Vote For This Design, Circle No. 680

22V10 detects hung 680xx

Dave Splitz, Stratus Computer,
Marlboro, MA

The Abel file attached to **EDN BBS /DI_SIG #1064** produces a 22V10 that will detect when a 680xx μP is hung and will return an error signal. Thus your system will not hang as long as the current bus master asserts AS* and can detect the bus-error signal.

To Vote For This Design, Circle No. 681

Modular 8051 routine converts bases

Kenneth W Arnold, Compaq Computer Corp,
Houston, TX

Using a modular approach, the 8051 routines in **EDN BBS /DI_SIG #1065** convert n-digit BCD numbers to m-byte binary numbers. The routines execute as fast as earlier, specialized base-conversion routines.

To Vote For This Design, Circle No. 682

These Software Shorts listings are too long to reproduce here. You can obtain the listings from the Design Idea Special Interest Group on EDN's bulletin-board system (BBS): (617) 558-4241, 300/1200/2400/9600 8,N,1. From Main Menu, enter ss/DI_SIG, then rk*nnnn*, where *nnnn* is the number referenced above.

LINEAR TECHNOLOGY DESIGN NOTES

A Simple, Surface Mount Flash Memory Vpp Generator – Design Note 58

Steve Pietkiewicz
Jim Williams

"Flash" type memories add electrical chip-erasure and reprogramming to established EPROM technology. These features make them a cost effective and reliable alternative for updatable non-volatile memory. Utilizing the electrical program-erase capability requires linear circuitry techniques. Intel flash memory, built on the ETOX™ process, specifies programming operation with 12V amplitude pulses. These "Vpp" amplitudes must fall within tight tolerances, and excursions beyond 14.0V will damage the device.

ETOX is a trademark of Intel Corporation.

Providing the Vpp pulse requires generating and controlling high voltages within the tightly specified limits. Figure 1's circuit does this. When the Vpp command pulse goes high (trace A, Figure 2) the LT1109 switching regulator drives L1, producing high voltage. DC feedback occurs via the regulator's sense pin. The result is a smoothly rising Vpp pulse (trace B) which settles to the required value. Trace C, a time and amplitude expanded version of trace B, details the desired settling to 12V. Artifacts of the switching regulator's action are discernible, although no overshoot or poor dynamics are displayed.

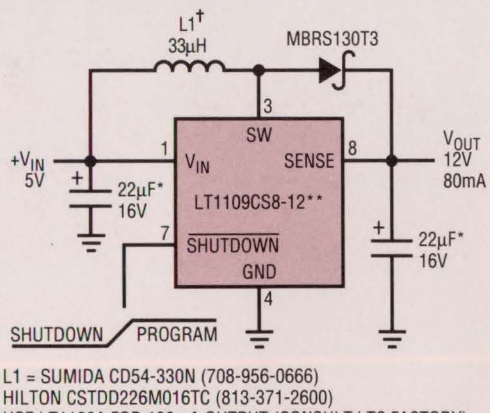


Figure 1. All Surface Mount Flash Memory Vpp Generator

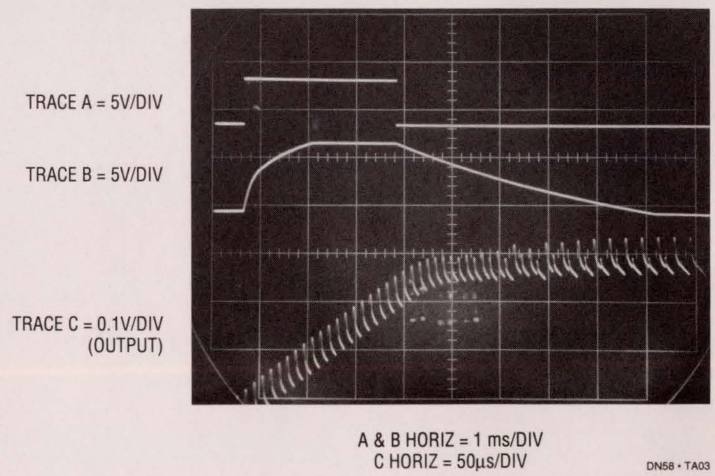


Figure 2. Waveforms for the Flash Memory Pulser Show No Overshoot

This circuit is well suited for providing Vpp power to flash memory. All associated components, including the inductor, are surface mount devices. As such, the complete circuit occupies very little space (see Figure 3). In the shutdown mode the circuit pulls only 300µA. Output voltage goes to V_{CC} minus a diode drop when the converter is in shutdown mode. This is an acceptable and specified condition for flash memories and does not harm the memory. A 0V output is possible by placing a 5.6V Zener diode in series with the output rectifier (Figure 4A). An alternative configuration, suggested by J. Dutra of LTC, AC couples the output to achieve a 0V output (Figure 4B). Both of these methods add component count, decrease efficiency and slightly limit available output current. They are unnecessary unless the user desires a 0V output on the Vpp line.

A good question might be; "Why not set the switching regulator output voltage at the desired Vpp level and use a simple low resistance FET or bipolar switch?" This is a potentially dangerous approach. Figure 5 shows the clean output of a low resistance switch operating directly at the Vpp supply. The PC trace run to the memory chip looks like a transmission line with ill-defined termination characteristics. As such, Figure 5's clean pulse degrades and rings badly (Figure 6) at the memory IC's pins. Overshoot exceeds 20V, well beyond the 14V destruction level. The controlled edge times of the circuit discussed eliminate this problem. Further discussion of this and other circuits appears in LTC Application Note 31, "Linear Circuits for Digital Systems" and LTC Demo Manual DC019, "Flash Memory Vpp Generator."

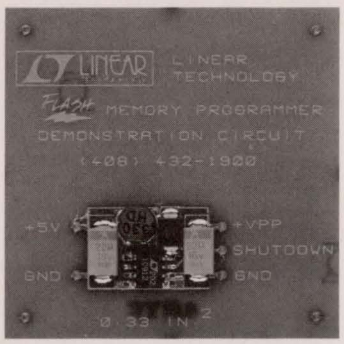


Figure 3. Simple Flash Memory Pulser Uses All Surface Mount Components

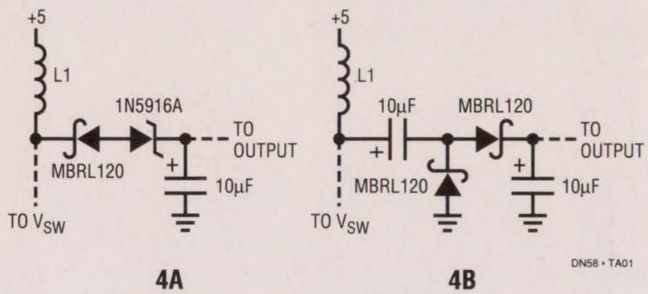
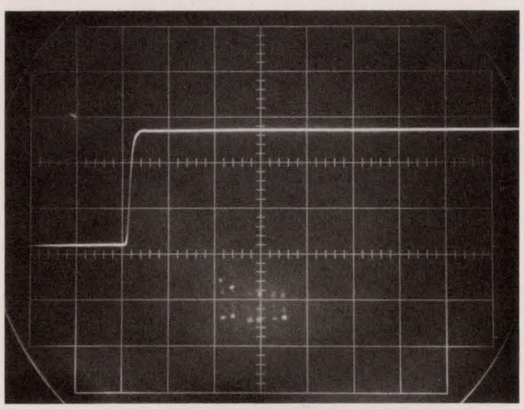


Figure 4. Two Arrangements for Obtaining a 0V Output

A = 5V/DIV

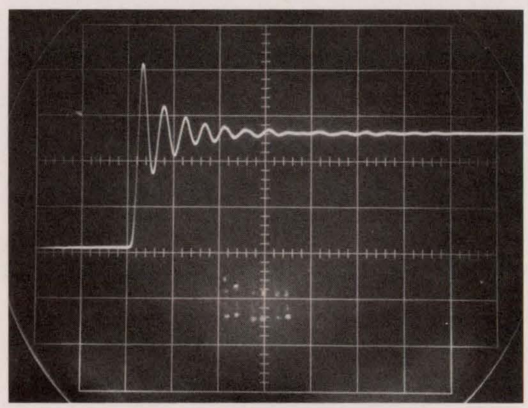


HORIZ = 100ns/DIV

DN57 • TA04

Figure 5. An "Ideal" Flash EPROM Vpp Pulse

A = 5V/DIV



HORIZ = 100ns/DIV

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Figure 6. Rings at Destructive Voltages After a PC Trace Run

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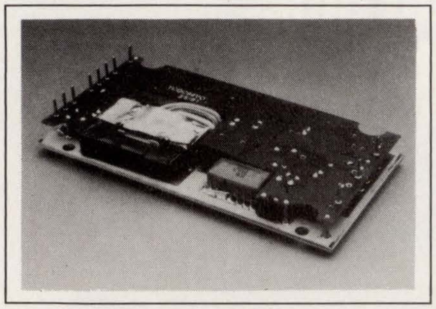
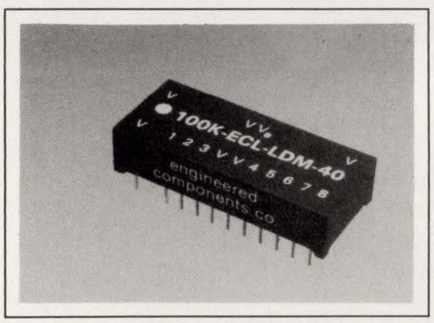


DC/DC converter. HFS 200 dc/dc converters feature single outputs of 3 to 48V (200W power capability) and accept inputs of 18 to 36, 36 to 72, and 200 to 400V. The converters operate at 700 kHz to minimize the size of magnetic components. Line and load regulations equal ±0.5%, and efficiency figures range from 81 to 88%. The converters feature overvoltage and overtemperature protection and meet VDE 0871A conducted EMI standards. The inductor of the integral filter is integrated with the main transformer and magnetically coupled to cancel ripple current in the output. The converters include a limiter circuit that limits current at 115% of rated current. $250. **Computer Products,** 7 Elkins St, South Boston, MA 02127. Phone (617) 268-1170. FAX (617) 268-0300. **Circle No. 351**



Logic delay lines. 100K ECL LDM logic-delay modules provide tapped delays with required driving and pick-off circuitry compatible with ECL 100K circuits. Housed in a 24-pin DIP, the modules provide delays ranging from 9 to 80 nsec. Each module includes taps at 12.5% increments of total delay. Each delay module will drive as many as 70 ECL dc loads on a single tap. The hybrid construction employs integrated circuitry and passive RLC networks. The modules accept either logic 1 or 0 inputs and reproduce the logic at the selected output tap without inversion. $30 (100). **Engineered Components Co,** Box 8121, San Luis Obispo, CA 93403. Phone (800) 235-4144; (805) 544-3800. FAX (805) 544-8091. **Circle No. 352**

Varistor. This high-capacitance varistor protects sensitive automotive circuitry from overvoltages while suppressing EMI from dc motors. It's designed for operating voltages as high as 26V, therefore it's compatible with the 12 and 24V systems standard in the automotive industry. The units are available with four capacitance values ranging from 0.47 to 1.5 μF. The devices can absorb spikes of 1J. $0.65 (5000). **Siemens Components Inc,** 186 Wood Ave S, Iselin, NJ 08830. Phone (800) 222-2203; (201) 321-3900. **Circle No. 353**

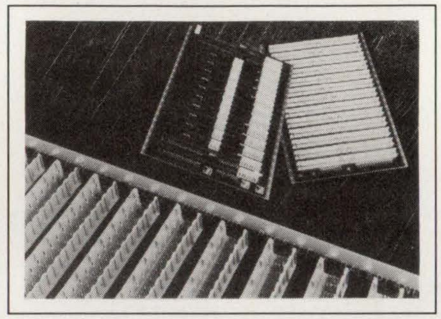
Power resistors. V3PR precision foil resistors are available in two sizes. HI-OHM Model 300589 is a standard 1-in.-square plate, which can be trimmed to any value between 10Ω and 5 kΩ. Tolerance is ±0.005%. The LO-OHM family features resistance values of 0.25 to 2Ω. Model 300589 versions, $38.09 (100). **Vishay Resistors,** 63 Lincoln Hwy, Malvern, PA 19355. Phone (215) 644-1300. FAX (215) 640-9081. **Circle No. 354**

Transient protectors. Series 160 devices limit transient level at the input to electronic equipment. The 161 operates on 120V ac single-phase service, and the 162 protects 120/208V ac single-phase, 3-wire service. The 163 protects 120/208V ac, 3-phase, 4-wire lines. LEDs mounted on the front panel indicate protection status. From $141. **MCG Electronics Inc,** 12 Burt Dr, Deer Park, NY 11729. Phone (800) 851-1508; (516) 586-5125. FAX (516) 586-5120. **Circle No. 355**

Subminiature fans. These pc-board-mountable subminiature dc fans are designed for applications where density is a prime problem. The line includes a 23×20×20-mm model, which operates from 4V. The line also includes models that measure 25×25×10 mm and 40×40×10 mm. $8 (1000). Delivery, stock to eight weeks ARO. **Evox-Rifa Inc,** 100 Tri-State International, Suite 290, Lincolnshire, IL 60069. Phone (708) 948-9511. FAX (708) 948-9320. **Circle No. 356**

Conformal-coated inductors. Series 9130 molded inductors have values ranging from 0.1 to 1000 μH. The devices are constructed to be compatible with automatic-insertion equipment and meet all the requirements of MIL-C-15305. From $0.15 (OEM qty). **J W Miller Division,** 306 E Alondra Blvd, Gardena, CA 90247. Phone (310) 515-1720. FAX (310) 515-1962. **Circle No. 357**

Terminal blocks. These bidirectional terminal blocks come in 36-position versions with a 5-mm contact pitch. The plug portion mounts on a pc board, and the mating portion plugs in either horizontally or vertically. The brass terminals are rated for 10A, and the insulators meet UL 94V-0 standards. Mated pair, $19.16. **E-Mark Inc,** 4 Daniels Farm Rd, Suite 328, Trumbull, CT 06611. Phone (203) 452-1003. **Circle No. 358**



Backplane. This Profile F Futurebus+ backplane is a 13-slot, 16-layer design. The unit is 12SU high and supports 265×288-mm daughter boards. Surface-mount resistors and capacitors are arranged to match the length of each signal trace exactly and minimize signal skew. Power for all supply rails is supplied via a low-impedance connector. $2000. **Bicc-Vero Electronics Inc,** 1000 Sherman Ave, Hamden, CT 06514. Phone (203) 288-8001. FAX (203) 287-0062. **Circle No. 359**

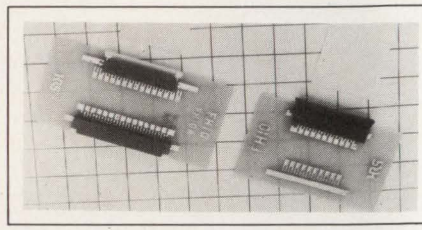
Computer battery. The TA-4511 alkaline battery is a direct replacement for the Rayovac Model 844 battery. It is rated at 4.5V dc and 1.25 Ahr and will last approximately five years in normal service. The battery comes with leads, a 4-pin, gold-contact connector, and a hook-and-loop fastener with woven-mat polyolefin with adhesive backing for easy mounting. $10.95. **Tauber Electronics Inc,** 4901 Morena Blvd, Suite 314, San Diego, CA 92117. Phone (619) 274-7242. FAX (619) 274-2220. **Circle No. 360**

Pin-grid-array socket. These PGA sockets conform to Intel's specification for their i80486DX. The socket insulator

is molded of PPS thermoplastic, which carries a UL 94V-0 rating. A variety of contacts and platings are available including very low insertion force and ultra low insertion force options. Part #169H008B5-1780R gold-plated, ultra-low-insertion-force contact option, $4.25 (1000). **McKenzie Technology,** 44370 Old Warm Springs Blvd, Fremont, CA 94538. Phone (510) 651-2700. FAX (510) 651-1020. TWX 910-240-6355.

Circle No. 361

Surface-mount connectors. FH10A Series surface-mount connectors are designed for flat flexible-cable and flexible printed circuitry. They provide from 6 to 30 pins spaced on a 1-mm pitch. The connectors will accept cable or flex-circuit thicknesses ranging from 0.25 to 0.31 mm. PPS insulators carry a UL 94V-0 rating and accommodate high-temperature and harsh-solvent applications. Connector contacts are rated for 0.5A, and resistance equals 20 mΩ. Insulation resistance is $5\times10^{8}\Omega$ at 100V dc, and withstanding voltage rating is 150V ac. $1.14 for a 20-pin model. **Hirose Electric Inc,** 2685-C Park Center Dr, Simi Valley, CA 93065. Phone (805) 522-7958. FAX (805) 522-3217.



Circle No. 362

Surface-mount inductors. RL2515 Series inductors are compatible with automatic-insertion equipment. The 35 values cover an inductance range of 0.15 to 100 μH with a dc current rating of 70 to 610 mA. The units operate over a −25 to +80°C range and can be supplied in bulk or on tape and reel. $0.25 (2500). Delivery, stock to eight weeks ARO. **Renco Electronics Inc,** 60 Jefryn Blvd East, Deer Park, NY 11729. Phone (516) 586-5566. **Circle No. 363**

Coaxial adapter. The model PE9206 is a type N female to type BNC female adapter. The unit has a brass, nickel-plated body, utilizes PTFE insulation, has a gold-plated contact, and operates over a −65 to +165°C range. The adapters meet the interface requirements of MIL-39012. $12.95. **Pasternack Enterprises,** Box 16759, Irvine, CA 92713. Phone (714) 261-1920. FAX (714) 261-7451. **Circle No. 364**

Terminal strip. Model 8142 is available in marked or unmarked versions. Units with 5-mm contact spacings are available in 2- to 24-contact sizes; models with 10-mm spacings come in 2- to 12-contact versions. Ratings for 5- and 10-mm units equal 300V at 15A and 600V at 5A, respectively. All units accept #12 through #22 AWG wire. 2-position model, from $0.7375 (100). **Wieland Inc,** 466 Main St, New Rochelle, NY 10801. Phone (914) 633-0222, ext 229.

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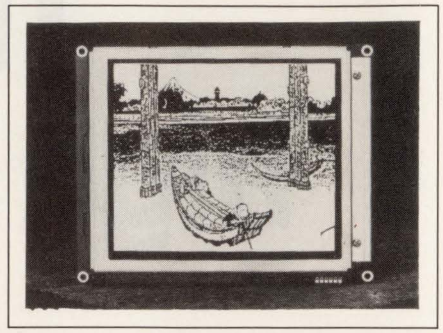
factor correction, N+1 redundancy, and automatic current sharing. \$0.60/W (OEM qty). **Technology Dynamics Inc,** 100 School St, Bergenfield, NJ 07621. Phone (201) 385-0500. FAX (201) 385-0702. **Circle No. 366**

Hermetically sealed resistors. The SMH MELF resistor line includes two models—the SMH55 rated for 200 mW at 70°C, and the SMH60 rated for 250 mW at 70°C. Minimum resistance value is 10Ω for both models. Maximum resistance value is 1.21 MΩ and 2.49 MΩ for SMH55 and SMH60 versions, respectively. All units are available with ±0.05 to ±1% tolerances. SMH55, 10 kΩ, 1% unit, \$2.22 (300). Delivery, 10 to 12 weeks ARO. **Angstrohm Precision Inc,** c/o Dale Electronics Inc, Box 609, Columbus, NE 68602. Phone (301) 739-8722. FAX (301) 797-6852. **Circle No. 367**



LCD module. This Series G321D LCD module incorporates cathode-fluorescent, edge-lighting and film-supertwist technology. Display brightness measures 100 cd/m, and the module measures just 166×134×15.1 mm. The module has a 70° viewing angle and operates from 5V and −24V supplies. G321D black-and-white module with controller chip, \$238; blue version without controller, \$210. **Seiko Instruments USA Inc,** 2990 W Lomita Blvd, Torrance, CA 90505 Phone (213) 517-7770. FAX (213) 517-7792. **Circle No. 368**

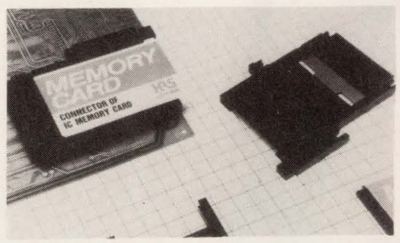
Panel meter. Model 2152 is a dual-meter model designed to meet MIL-M-10304 and MIL-M-16034 requirements. Units can be stacked vertically or horizontally without limitation. Magnetic interaction is nil bacause the moving coil movement is self-shielded. The sealed waterproof case is also an effective magnetic shield. From \$850. **International Instruments,** Box 185, North Branford, CT 06471. Phone (203) 481-5721. FAX (203) 481-8937. **Circle No. 369**

Switching regulator. Model 78SRI33HC features a 90-W/in.^{3} power density, 85% min efficiency, a self-contained inductor, and internal short-circuit and overtemperature protection. The regulator is available in vertical- or horizontal-mount packages, which measure 0.88×0.92×0.3 in. Less than \$10 (OEM qty). **Power Trends Inc,** 1101 N Raddant Rd, Batavia, IL 60510. Phone (708) 406-0900. FAX (708) 406-0901. **Circle No. 370**

Snap-acting switches. These snap-acting switches are available with 20A and 25A ratings in either spdt or spst versions. Units have a variety of actuators, including standard-pin plungers, wide-pin plungers, levers, lever rollers, and simulated rollers. Termination styles include solder terminals, standard quick-connect, offset quick-connect, and screw terminals. From \$1.50

(OEM qty). Delivery, eight weeks ARO. **Unimax,** Box 152, Wallingford, CT 06492. Phone (800) 624-4308; (203) 269-8701. FAX (203) 265-5398.

Circle No. 371



Memory card connectors. IC1FB memory card connectors have a 0.5A/pin current rating and will handle 125V ac. The connectors are available in 68-pin versions with contacts spaced on 0.05-in. spacings. The brass contacts are selectively gold plated. The connectors conform to Version 4 of the JEIDA specification and PCMCIA Release 2.0. $10.10. **Hirose Electric Inc,** 2685-C Park Center Dr, Simi Valley, CA 93065. Phone (805) 522-7958. FAX (805) 522-3217. **Circle No. 372**

Crystal oscillator. The model OC2541DT is a 10-MHz, oven-compensated crystal oscillator. It has a stability of ±0.02 ppm from 0 to 50°C. Operating current is 90 mA at 25°C. $200 (1000). **Murata Erie North America,** 2200 Lake Park Dr, Smyrna, GA 30080. Phone (800) 831-9172. **Circle No. 373**

Power supplies. These 1000W supplies accept inputs of 90 to 264V ac. The line includes single- and triple-output models. The supplies feature floating outputs, overvoltage protection on the main output, and remote sense on all outputs. Output ripple and noise is limited to less than 1%. Single-output model, $800 (OEM qty). **Acme Electric Corp,** 20 Water St, Cuba, NY 14727 Phone (716) 968-2400. **Circle No. 374**

Surge protectors. DLP-10, DLP-20, and DLP-30 surge protectors protect 2- to 8-wire configurations for RS-232C, RS-422, RS-423, and 20-mA loop interfaces. Clamp voltage ratings range from ±6 to ±200V. Series resistance equals 15Ω, and energy-handling capability measures 50J/line. From $58. **MCG Electronics,** 12 Burt Dr, Deer Park, NY 11729. Phone (800) 851-1508; (516) 586-5125. FAX (516) 586-5120. **Circle No. 375**

CAE & Software Development Tools

Visual Basic tool kit. The Professional Toolkit for Visual Basic lets you program the latest features in Windows—including multimedia, handwriting recognition, and object linking and embedding. The package includes new controls for user-interface components; a compiler for creating Windows help files; an application-programming interface (API) on-line reference; and a setup kit for creating installation programs. $299; $495 with Visual Basic. **Microsoft Corp,** 1 Microsoft Way, Redmond, WA 98052. Phone (206) 882-8080. FAX (206) 936-7329. TLX 160520. **Circle No. 376**

Integrated design system. Board Station 500 helps you design the physical representation of printed-circuit boards and multichip modules. It combines place-and-route algorithms (with timing constraints) and analysis capabilities. The combination lets you control and analyze physical effects and maintain signal integrity. The product is a component of the company's Concurrent Design Environment and is available on HP Apollo, HP Series 700, and Sun SPARCstations. $125,000. **Mentor Graphics Corp,** 8005 SW Boeckman Rd, Wilsonville, OR 97070. Phone (408) 436-1500. **Circle No. 377**

High/low-level 8051 debugger. Chip View 51 is available in two versions for 8051 C compilers: as a simulator/debugger and as a front end for Nohau's EMUL51-PC emulator. It is keystroke-compatible with Borland's Turbo Debugger. Features include point-and-click data browsing of C structures and linked lists, plus context-sensitive hypertext help. Simulator version, $795; emulator version, $595; combination, $995. **Chip Tools,** 1232 Stavebank Rd, Mississauga, ON L5G 2V2, Canada. Phone (416) 274-6244. FAX (416) 891-2715. **Circle No. 378**

Ada text editor. Amacs, an Ada implementation of the Emacs programmer's editor, can be made to emulate nearly any other editor. It requires MS-DOS 2.0 or higher and any combination of hard- and floppy-disk drives. $150. **Xadax Inc,** 34-32 57th St, Woodside, NY 11377. Phone (718) 672-6500. FAX (718) 397-0972. **Circle No. 379**

Autorouters for Unix workstations. Pads-Force Routers use gridless technology and a shape-based data structure. Force Router I has a set of tools for SMD, PTH, and high-density designs. Force Router II adds a set of tools that let you set trace pairs, balanced signals, signal-length matching, and layer restrictions. Both versions run on Sun SPARCstations. Force I, $25,000; Force II, $39,000. **Pads Software Inc,** 119 Russell St, Suite 6, Littleton, MA 01460. Phone (508) 486-9521. FAX (508) 486-8217. **Circle No. 380**

Data-acquisition configuration tool. DAQ Designer helps you configure data-acquisition systems for PC/XT-, PC/AT-, EISA-, and Micro Channel Architecture-based computers. The tool asks questions about system requirements and recommends specific data-acquisition boards, signal-conditioning products, cable assemblies, and software packages. You can save your selected configuration to disk or print it with a word processor or a spreadsheet program. Free of charge. **National Instruments,** 6504 Bridge Point Pkwy, Austin, TX 78730. Phone in US and Canada, (800) 433-3488; (512) 794-0100. FAX (512) 794-8411. TLX 75637. **Circle No. 381**

General-purpose simulation program. Tutsim Version 7 lets you model systems, equations, or hypotheses. If you change a block, a parameter, or a concept, the software will show a changed result. The software accommodates both linear and nonlinear functions. Professional version, $695; personal version (not for corporate or government use), $149. **Tutsim Products,** 200 California Ave, Suite 212, Palo Alto, CA 94306. Phone (415) 325-4800. FAX (415) 325-4801. **Circle No. 382**

Parallel-computer Fortran. The DECmpp Fortran compiler automatically optimizes programs to run on computers with massively parallel processor architectures. The compiler runs on the DECmpp 12000 Series computer under the Ultrix operating system. License, $11,800. **Digital Equipment Corp,** Maynard, MA 01754. Phone (508) 493-6767. **Circle No. 383**

Command shell for OS-9. Mshell, a command shell for the OS-9 real-time operating system, provides functions common to popular Unix shells. It is compatible with existing Microware shells at the command-line and script-file levels. It can be installed on any OS-9 system running OS-9/680x0 version 2.3 or later. $300 (1); $90 (100). **Microware Systems Corp,** 1900 NW 114th St, Des Moines, IA 50325. Phone (515) 224-1929. FAX (515) 224-1352. **Circle No. 384**

Test-pattern generator for ICs. Testgen automatically creates programs for testing ICs. It supports a variety of circuit types: combinatorial and sequential logic; synchronous and asynchronous circuits; ASICs and full-custom ICs; and chips with sophisticated embedded functions. The product provides high fault coverage and minimizes the need for scan circuitry. Custom version, $160,000; ASIC version, $95,000. **Sunrise Test Systems,** 1095 E Duane Ave, Suite 207, Sunnyvale, CA 94086. Phone (408) 739-4000. FAX (408) 739-4081. **Circle No. 385**

Debug monitor. XVME-991 is an implementation of the Probe+ debug monitor from Software Components Group. This particular implementation is compatible with the supplier's XVME-630, a 68EC030 VMEbus processor module. Enhancements to standard Probe+ include power-up diagnostics, real-time-clock access routines, serial-port configuration, user-accessible memory test, and console I/O support. $500. **Xycom Inc,** 750 N Maple Rd, Saline, MI 48176. Phone (800) 289-9266; (313) 429-4971. FAX (313) 429-1010. **Circle No. 386**

Test-vector generator for ASICs. TDX-130 is a low-cost workstation version of the supplier's Test Design Expert. It generates test vectors for ASIC designs having as many as 25,000 2-input gate equivalents from behavioral and structural circuit descriptions. The software runs on Sun SPARCstations. From $95,000. **Expertest Inc,** 810 E Middlefield Rd, Mountain View, CA 94043. Phone (415) 965-2000. FAX (415) 969-3932. **Circle No. 387**

Vocoder software. The Self-Excited Vocoder (SEV) and new versions of the Subband Coder (SBC) are algorithms that compress digital representations of speech signals to minimize the number of bits. Applications for SEV include mobile radio, cellular telephony, secure voice systems, and satellite-based communications; SBC suits answering ma-

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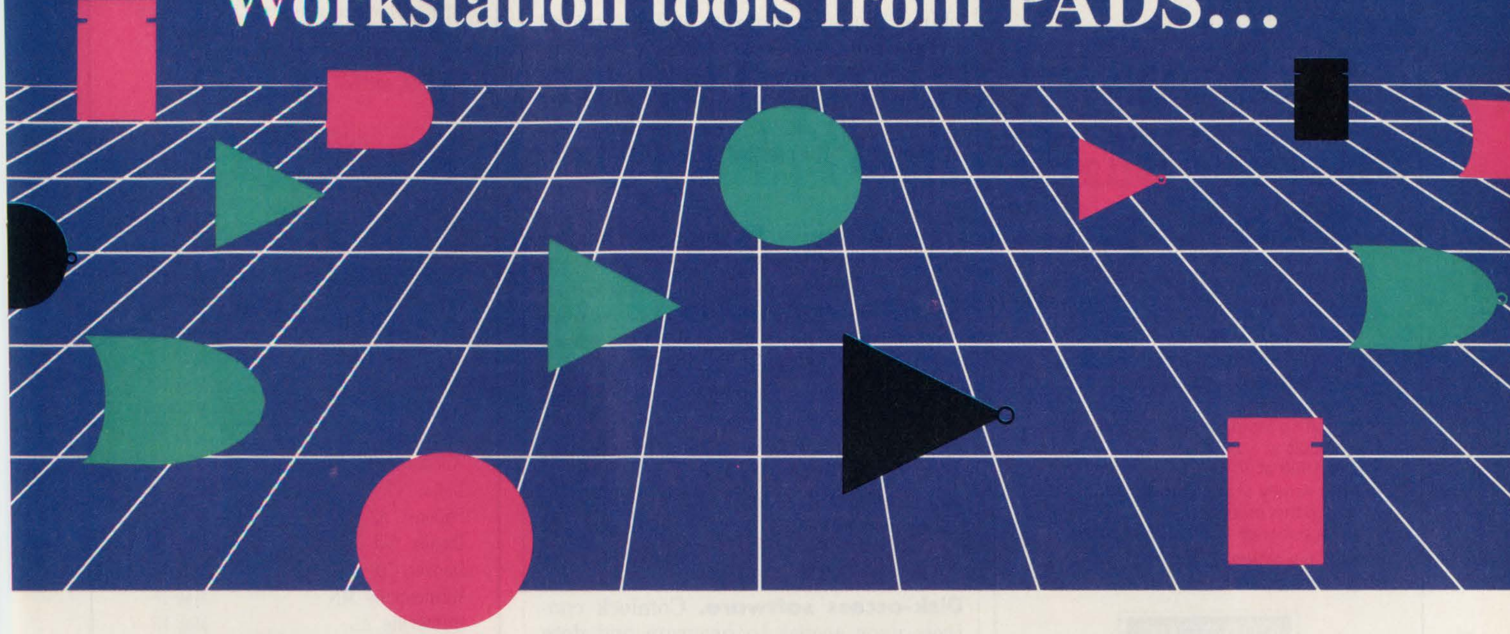

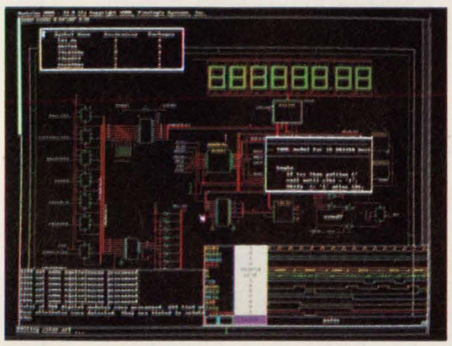

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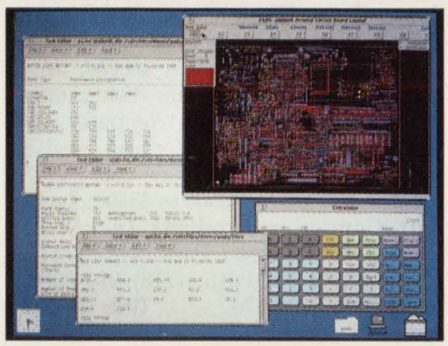

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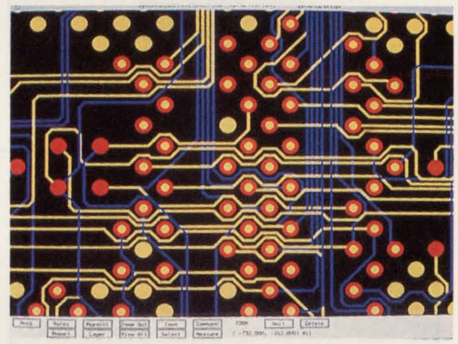

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C++ graphics library. Objectgraphics extends Borland's C++ with Application Frameworks and Turbo C++ for Windows to create graphics in Windows applications. It masks the graphics "engine" of Windows and allows you to use a simple set of graphics objects, rather than many primitive function calls. $195. **The Whitewater Group,** 1800 Ridge Ave, Evanston, IL 60201. Phone (708) 328-3800. FAX (708) 328-9386. **Circle No. 389**

Disk-access software. Comlock controls user access to program and data floppy disks. Users of the software can designate disks as either "group" or "nongroup" for selective access. Any disk copied from a group disk cannot be read by a nongroup computer, although a group computer can read a nongroup disk. Single-user copy, $125 to $275; 100 users, $2500 to $5500. **Techmar Computer Products Inc,** 98-11 Queens Blvd, Rego Park, NY 11374. Phone (800) 922-0015; (718) 997-6666. FAX (718) 520-0170. **Circle No. 390**

PLD-design software. PLDshell Plus, an expanded PLD-design software package, has been expanded to support the development of all Intel PLDs. The software package adds simulation capability and logic minimization features and supports features of the 5AC312 and 5AC324 PLDs. Free of charge. **Intel Corp,** Literature Packet #IP-91, Box 7641, Mt Prospect, IL 60056. In US and Canada, phone (800) 548-4725. **Circle No. 391**

LAN-based CASE system. Pose 4.3 is a multiuser, multiproject, front-end CASE tool that lets you run a suite of modular Pose (Picture Oriented Software Engineering) tools on any NetBIOS-compatible LAN. In addition to facilitating multiple users and projects, this version includes more than 20 enhancements. $1195 to $2995. **Computer Systems Advisers Inc,** 50 Tice Blvd, Woodcliff Lake, NJ 07675. Phone (201) 391-6500. FAX (201) 391-2210. **Circle No. 392**

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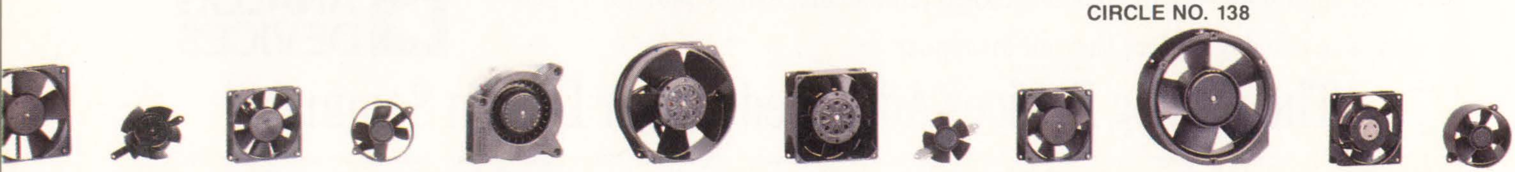
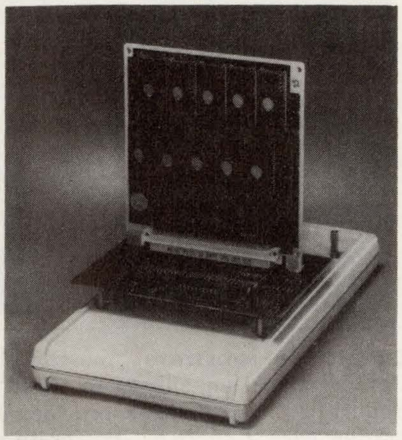


◄ For More Information on Lambda Circle No. 59



In-circuit programmer. The T-2000 in-circuit programmer programs EPROMs, EEPROMs, and microcontrollers already mounted on pc boards. The hardware consists of an ISA bus coprocessor board, a connecting cable, a programming head, and a universal adapter. The programmer works with boards that have 8- or 16-bit-wide data buses and contain as many as 32 programmable ICs. You can set up the programmer to handle devices using nonstandard supply voltages and programming algorithms. You configure the programmer via fill-in-the-blanks software that creates configuration files. The vendor supplies three styles of pc-board adapters. Both the configuration files and the adapters work with the vendor's production in-circuit programmers that simultaneously program multiple boards. T-2000, $3500; adapters, $450 to $750. **Sunrise Electronics Inc,** 524 S Vermont Ave, Glendora, CA 91740. Phone (818) 914-1926. FAX (818) 914-1583.

Circle No. 425

RF counter/timer for PCXI bus. The PX2235, which plugs into the PCs extended for industry (PCXI) bus, provides 10-digit resolution from 10 Hz to 2.4 GHz and counts directly to 150 MHz. It uses reciprocal counting for low-frequency measurements and provides 10-mV sensitivity to 1.6 GHz. $839. **Rapid Systems Inc,** 403 N 34th St, Seattle, WA 98103. Phone (206) 547-8311. FAX (206) 548-0322. TLX 265017.

Circle No. 426

Test-generation software for Xilinx PLDs. You use LCA2ICT to develop pin-level tests for Xilinx logic-cell arrays. The software exploits the devices' reprogrammability by loading a simple design that checks for board-level assembly faults and also verifies that the device can load a configuration and can drive and sense its pins. The software reads the original design and creates a test design that uses the same pins. $3000 to $4500 if added to the vendor's existing products; from $14,000 otherwise. **Acugen Software Inc,** 427-3 Amherst St, Suite 391, Nashua, NH 03063. Phone (603) 881-8821.

Circle No. 427

Background-mode emulator for 68300 series. The Series 300 Performance Plus background-mode emulator works with the MC 68300, 68331, 68332, 68333, 68340, and 68HC16. The instrument, which can have 512 kbytes of simulation memory and 256 kbytes of ROM-overlay memory, lets you boot your system from RAM and use the μPs' background-mode debugging ports to conduct software performance analysis. For testing μP-based boards in production, the emulator includes a facility for writing custom diagnostics in C. These diagnostics run from simulation memory and make calls to the target board via the background-mode port. Performance Plus model, $3050; field unit upgradable to Performance Plus version, $2450. **Embedded Support Tools Corp,** 10 Elmwood St, Canton, MA 02021. Phone (617) 828-5588. FAX (617) 828-7941. **Circle No. 428**

Function generator and frequency counter. The OscPC version B4.0 device includes an analog output with 16-bit resolution and 0.005% error. The frequency counter detects pulses as narrow as 12 nsec at frequencies to 12 MHz, which it measures with an error of 1 Hz or 5 ppm. You can program both the rate (to 2 MHz) and the width of the output pulses; pulse-width increments are 1/6 μsec. $180 to $200. **StarPC Instruments,** Box 64418, Sunnyvale, CA 94086. Phone (408) 739-5117.

Circle No. 429

Calibrated light meter. The Cal-light measures ambient illumination. The vendor calibrates each unit against nationally accepted standards. The unit's spectral sensitivity matches that of the human eye. The unit produces readings in user-selectable units—either foot-candles (fc) or lux. Maximum readout is 400,000 fc. $345. **Cooke Corp,** Box 209, Buffalo, NY 14216. Phone (716) 833-8274. FAX (716) 836-2927.

Circle No. 430

25- and 54-kHz digital phase-angle voltmeters. You can use the TMI 4001C-1 (10 Hz to 25 kHz) and 4001C-2 (autoranging 26 Hz to 54 kHz) phase-angle voltmeters for synchro/resolver testing; in-phase and quadrature voltage measurement; amplifier gain and phase testing; and impedance-angle measurement. They have isolated reference and signal inputs and indicate results on 4½-digit LED displays. The units require no calibration or frequency locking. The 4001C-1's phase error is $< \pm 0.5°$; its voltage error is $< \pm 2\%$ of full scale across its bandwidth. The 4001C-2's phase error is $\pm 0.25°$. The unit's voltage error depends on its mode but when measuring in-phase or quadrature signals to 1.5 kHz, it can be as low as $\pm 0.05\%$ of full scale 0.07% of reading. 4001C-1, $4190; 4001C-2, $9800. Delivery, 12 weeks ARO. **Transmagnetics Inc,** 210 Adams Blvd, Farmingdale, NY 11735. Phone (516) 293-3100. FAX (516) 293-3793. TWX 510-224-6420. **Circle No. 431**

Optical attenuation and return-loss test set. The FOT-150 series measures at wavelengths of 1300 and 1550 nm. It has a dynamic range of +10 to −75 dB in the attenuation mode and −8 to −70 dB in the return-loss mode. Its resolution is 0.01 dB. An IEEE-488 interface is optional. $2800 to $11,000. **Exfo EO Engineering Inc,** 465 Godin, Vanier, QC G1M 3G7, Canada. Phone (418) 683-0211. FAX (418) 683-2170.

Circle No. 432

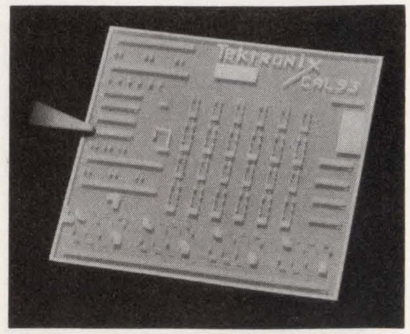
Digital megohmmeters. The ST700201 meter measures resistance to 2000 MΩ and ac voltage to 600V. The ST700200 meter is similar but offers higher sensitivity at the expense of reduced ability to measure high resistances (100 MΩ max). Each unit, $748. **Davis Instrument Mfg Co Inc,** 4701 Mt Hope Dr, Baltimore, MD 21215. Phone (800) 368-2516. FAX (410) 358-0252. **Circle No. 433**

Turbo C++ support for IEEE-488 interfaces. Turbo C++ Software is available separately for $95 or at no cost as part of the library the vendor supplies with its IEEE-488 interfaces. The interfaces support IEEE-488.2. The library supports most dialects of Basic, C, Pascal, and Fortran from Borland and Microsoft, as well as assembly language and high-level-language dialects from a few other vendors. **Capital Equipment Corp,** 76 Blanchard Rd, Burlington, MA 01803. Phone (617) 273-1818. FAX (617) 273-9057. **Circle No. 434**

Instrument-control software. Total Control for Windows allows developers to design MS-Windows-based applications that control robots, read barcoded data, and work with programmable logic controllers. A network module is compatible with Novell, IBM, and DEC networks. Development kit, $1995; licenses for each unit sold by a developer, $200. **Hudson Control Group Inc,** 44 Commerce St, Springfield, NJ 07081. Phone (201) 376-7400. FAX (201) 376-8265. **Circle No. 435**

Burn-in board tester and X-Y table. The BTS-2000 tester makes 2- and 4-wire resistance measurements and uses a driven guard. Adding cards lets you upgrade the 256-channel system to 1024 channels. The system tests boards from their edge connectors and also connects to individual devices mounted on boards. The system computer, an MS-DOS PC, provides full-color graphics displays that highlight failing-component locations. From $22,000. Delivery, 8 to 12 weeks ARO. **Aehr Test Systems,** 1667 Plymouth St, Mountain View, CA 94043. Phone (415) 691-9400. FAX (415) 641-9300. TWX 415-691-0938. **Circle No. 436**

IEEE-488 interface for Silicon Graphics workstations. The GPIB-SG-S kit lets you control as many as 14 IEEE-488 instruments from the SCSI (small-computer systems interface) port of an Iris Indigo RISC-based workstation. The kit uses a SCSI-to-IEEE-488 converter that mounts outside the workstation. $1695. **National Instruments Corp,** 6504 Bridge Point Pkwy, Austin, TX 78730. Phone in US and Canada, (800) 433-3488; (512) 794-0100. FAX (512) 794-8411. TLX 756737. **Circle No. 437**



Calibration substrate. You use the Cal93 calibration substrate with 2-contact probing systems to provide calibration from 1 to 26.5 GHz, or to dc with a low-band load. A metrology-grade sapphire substrate and laser trimming produce low-inductance resistors with >30-dB of return loss. $995. **Tektronix Inc,** Box 1520, Pittsfield, MA 01202. Phone (800) 426-2200. **Circle No. 438**

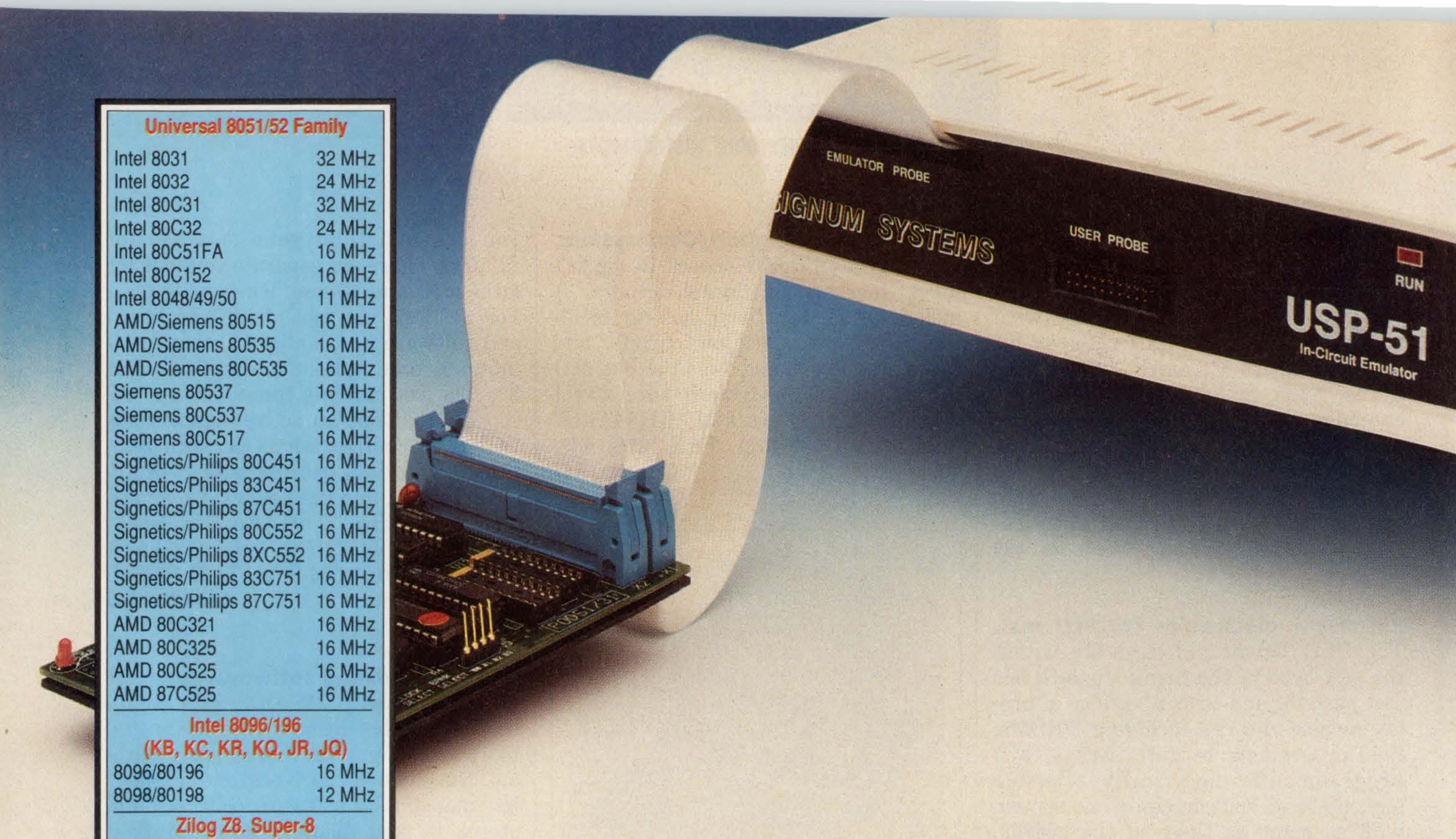
IEEE-488.2 driver software for MS-DOS PCs. Versions of NI-488.2 V2.0 work with MS-DOS memory extenders from Rational systems and Phar Lap. A new MS-Windows driver also incorporates standard dynamic-link-library entry points. Driver software with IEEE-488 interface kits for the 16-bit ISA and Micro Channel Architecture buses, \$395 to \$495; DOS memory-extender-compliant versions of the drivers, \$200. **National Instruments Corp,** 6504 Bridge Point Pkwy, Austin, TX 78730. Phone in US and Canada, (800) 433-3488; (512) 794-0100. FAX (512) 794-8411. TLX 756737. **Circle No. 439**

Pin-driver electronics for PLD test. The PLD Driver pin card fits within the test head of the firm's Vista Series test systems and tests a variety of programmable devices including PROMs, field-programmable gate arrays, and programmable electrically erasable logic devices. You can equip one system with as many as three of the boards, thus enabling the system to produce high programming voltages on 24 channels. \$10,000/board. **Credence Systems Corp,** 47211 Bayside Pkwy, Fremont, CA 94538. Phone (510) 657-7400. FAX (510) 623-2560. **Circle No. 440**

IEEE-488-based digital I/O subsystem. The Digital488HS/32 houses 16 digital-input lines and 16 digital outputs. It includes complete handshaking facilities, provides a trigger output, and transfers data to and from the bus at 1 Mbyte/sec. \$795. **IOtech Inc,** 25971 Cannon Rd, Cleveland, OH 44146. Phone (216) 439-4091. FAX (216) 439-4093. **Circle No. 441**

Ethernet and Token Ring protocol analyzers. The Interview 80 series uses an interface board and software that you can install in your own PC for \$12,000. There are separate versions for Ethernet and Token Ring networks. For \$19,995, you can obtain the board and software in a laptop PC that has a monochrome plasma display. For \$24,995, you can buy the items in a laptop PC that has an active-matrix color LCD. All configurations perform real-time monitoring, data recording, protocol decoding, and performance analysis. **Telenex Corp,** 7401 Boston Blvd, Springfield, VA 22153. Phone (703) 644-9000. FAX (703) 644-9011. TLX 197733. **Circle No. 442**

Automatic-testing software. AutoCAT V3.0 works with MS-DOS PCs. It directly controls instruments connected to RS-232C and IEEE-488 ports without the need for drivers or high-level languages. The software collects data, stores it, and displays it or prints it out. Use of the software does not require a knowledge of programming. \$495. **Neos Technologies Inc,** 4451B Enterprise Ct, Melbourne, FL 32934. Phone (407) 259-2090. FAX (407) 255-0274. **Circle No. 443**



Universal 8051/52 Family	
Intel 8031	32 MHz
Intel 8032	24 MHz
Intel 80C31	32 MHz
Intel 80C32	24 MHz
Intel 80C51FA	16 MHz
Intel 80C152	16 MHz
Intel 8048/49/50	11 MHz
AMD/Siemens 80515	16 MHz
AMD/Siemens 80535	16 MHz
AMD/Siemens 80C535	16 MHz
Siemens 80537	16 MHz
Siemens 80C537	12 MHz
Siemens 80C517	16 MHz
Signetics/Philips 80C451	16 MHz
Signetics/Philips 83C451	16 MHz
Signetics/Philips 87C451	16 MHz
Signetics/Philips 80C552	16 MHz
Signetics/Philips 8XC552	16 MHz
Signetics/Philips 83C751	16 MHz
Signetics/Philips 87C751	16 MHz
AMD 80C321	16 MHz
AMD 80C325	16 MHz
AMD 80C525	16 MHz
AMD 87C525	16 MHz
Intel 8096/196 (KB, KC, KR, KQ, JR, JQ)	
8096/80196	16 MHz
8098/80198	12 MHz
Zilog Z8, Super-8	
Z8	20 MHz
86C94	30 MHz
Super-8	20 MHz
Texas Instruments DSP's	
320C10/15	33 MHz
320C16	35 MHz
320C17	20 MHz

Let's talk real 8051 8096/196 in-circuit emulation. . . . and DSP's too!

Signum Systems' in-circuit emulators offer more standard features than you'd expect, and some you wouldn't.

Features You'd Expect

- Windowed/mouse interface
- Flash download 115 k-baud
- Debug in C and PL/M
- Non-intrusive to target or PC
- Full speed emulation

Signum Extras

- C-51 and C-96 HLL debugger with locals support
- Full bank switching support
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- 32K x 80 real-time trace
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  - All emulation RAM contents
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  - 8 level sequencer
  - Trace and execution displays
  - 256K address breakpoints
  - 2 16-bit event counters
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- Unlimited user support

Performance . . .
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* System capable of 32 MHz; actual emulation speeds limited by currrent device speeds.

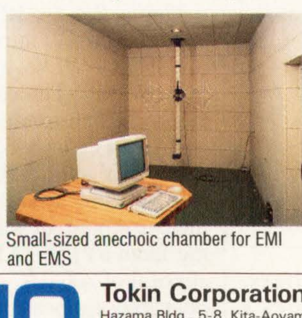
CIRCLE NO. 140

As easy as building blocks

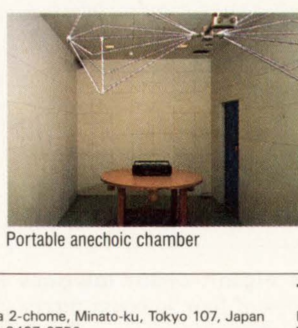
New easy-to-assemble anechoic chambers from Tokin

- Small-sized hexahedronal
- FCC Filing and 10 m regulations
- Portable chambers

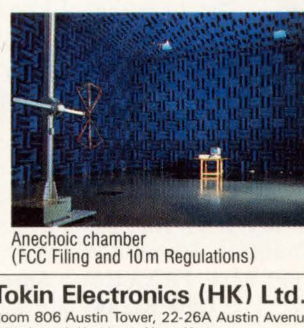
The more you need anechoic chambers, the more you'll appreciate Tokin.
Why?
Because Tokin's new assembly method makes building them as easy as child's play.
Look.
With Tokin, panels (120 cm × 120 cm) come with ferrite tiles already attached. You don't have to waste time—or money—attaching 10 cm tiles, piece by piece, yourself. Then, Tokin's panels are lightweight, and put together with a hanging bar—simplicity itself.
But assembly ease is not their only strong point. Tokin's chambers are designed by computer simulation using the most reliable testing and advanced EMC technology. So whatever your needs are for diversified EMI counter measurement, Tokin skillfully meets them.
If you're in the business of measuring noise immunity and EMI, you'll find it worthwhile to look into these new Tokin chambers.
They're the basic building blocks of your new success.



Small-sized anechoic chamber for EMI and EMS



Portable anechoic chamber



Anechoic chamber (FCC Filing and 10 m Regulations)

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Phone: 03-3402-6166 Fax: 03-3497-9756

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Daechi-Dong, Kangnam-gu, Seoul, Korea
Phone: (2) 569-2582~5 Fax: (2) 544-7087

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Phone: 408-432-8020 Fax: 408-434-0375
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Phone: 708-215-8802 Fax: 708-215-8804
Boston Branch
945 Concord Street, Framingham, Massachusetts 01701, U.S.A.
Phone: 508-875-0389 Fax: 508-875-1479

Tokin Electronics (HK) Ltd.
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Phone: 367-9157 Fax: 739-5950
Taiwan Liaison Office
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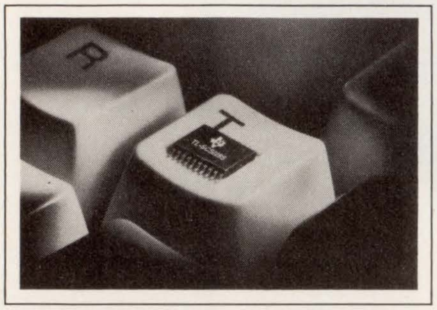
Phone: (02) 7728852 Fax: (02) 7114260
Singapore Branch
140 Cecil Street, No.13-01 PIL Bldg., Singapore
Phone: 2237076 Fax: 2236093, 2278772

Tokin Europe GmbH
Knorrstr. 142, 8000 München 45, Germany
Phone: 089-311 10 66 Fax: 089-311 35 84 Telex: 5 24 537 tokin d

CIRCLE NO. 141

Integrated Circuits



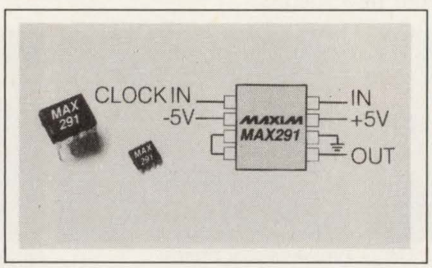
Voltage regulator for active SCSI termination. The TL-SCSI285 voltage regulator allows designers to use the high-speed Small Computer Systems Interface (SCSI) standard in desktop and battery-powered computers. The regulator exceeds the SCSI specification for active termination. For example, the device allows the input voltage to drop as low as 3.45V while maintaining an output voltage of 2.85V. This maximum drop-out of 0.6V satisfies both the 1V drop-out requirement of desktop computers and the 0.6V drop-out requirement of battery-operated laptop and notebook computers. The TL-SCSI285 comes in DIPs, TO-220 packages, and to accommodate space-restricted systems, TSSOP, (thin-scaled small-outline package) that are 0.040 in. thick, from \$1.60 to \$1.70 (1000). **Texas Instruments Inc,** Semiconductor Group (SC-92001), Box 809066, Dallas, TX 75380. Phone (800) 336-5236, ext 3990; (214) 995-6611, ext 3990. **Circle No. 444**

Graphics chip. The TVGA8900CX increases resolution, speeds Windows applications, and offers 24-bit color support. The chip interfaces with ISA, MCA, and Local buses. The Local bus interface bypasses the 8-MHz bottleneck of the ISA bus and allows the chip to communicate with 386 and 486 processors. Operating at a 108-MHz dot-clock rate, the chip supports resolutions to 1280×1024 pixels and 256 colors. In 160-pin plastic quad flatpack, \$20 (1000). **Trident Microsystems Inc,** 205 Ravendale Dr, Mountain View, CA 94043. Phone (415) 691-9211. FAX (415) 691-9260. **Circle No. 445**

Crosspoint switch. The TQ8016 16×16 digital crosspoint switch operates at data rates to 1.3 Gbps. The differential switch suits high-speed telecom and datacom applications such as SONET at 1.244 Gbps, FDDI from 100 Mbps to 1.3 Gbps, and Fiber Channel at 266 Mbps and 1 Gbps. Propagation delay is 1.2 nsec, and the delay match from any input to any output is ±200 psec. TQ8016, \$157 (1000). **Triquint Semiconductor Inc,** 3625A Murray Blvd, Beaverton, OR 97005. Phone (503) 644-3535. FAX (503) 644-3198. **Circle No. 446**

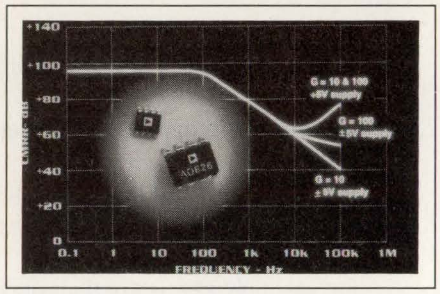
Read/write preamplifier. Accommodating the low-power needs of portable computers, the XR-9010 read/write preamplifier operates from a 5V supply. The IC consumes 1 mW in idle mode and 125 mW in read mode. Featuring read/write control for four channels, the chip provides read-mode amplification, write-current control, and head selection. The 9010R option provides internal 750Ω damping resistors. The read preamplifier has a 60-MHz bandwidth, and the write drive supports 50 mA of write current. XR-9010/9010R, less than \$3 (OEM qty). **Exar Corp,** 2222 Qume Dr, San Jose, CA 95161. Phone (408) 434-6400. FAX (408) 943-8245. TWX 910-339-9233. **Circle No. 447**

DRAM/SRAM chip. The M5M44409TP integrates a 1M×4-bit dynamic RAM (DRAM) with a 4k×4-bit static RAM (SRAM). The combination device attains 100-MHz cache-hit performance, and you can couple it directly to the CPU without buffers. The device is available with cache access times of 10, 15, or 20 nsec. M5M44409TP, in a 44-pin thin SO package, from \$15 to \$16.20 (100). **Mitsubishi Electronics America Inc,** 1050 E Arques Ave, Sunnyvale, CA 94086. Phone (408) 730-5900. **Circle No. 448**



Small eighth-order lowpass filters. A series of four lowpass filters offers a choice of two responses. The MAX291/MAX295 provide a Butterworth response; the MAX292/MAX296 provide a Bessel response. The filters' corner frequency is set by the frequency of a clock signal. The clock-to-corner-frequency ratio for the MAX291/MAX292 is 100:1 with a 0.1-Hz to 25-kHz corner-frequency range. The frequency ratio for the MAX295/MAX296 is 50:1 with a 0.1-Hz to 50-kHz corner-frequency range. You can drive the clock with an external CMOS-level signal or with the internal oscillator's utilizing an external capacitor to set its frequency. All of the filters operate from 5 or ±5V supplies. In 8-pin DIPs and 8- or 16-pin SOIC packages, from \$2.95 (1000). **Maxim Integrated Products,** 120 San Gabriel Dr, Sunnyvale, CA 94086. Phone (408) 737-7600. **Circle No. 449**

Compression chip. Featuring 30-Mbyte/sec performance, the 9706 data-compression chip offers direct connection to a microprocessor's high-speed local bus. You can configure the chip for 16- or 32-bit data transfers. A sleep mode reduces current drain to 300 μA as soon as compression tasks are completed. \$19.90 (OEM qty) (50,000). **Stac Electronics,** 5993 Avenida Encinas, Carlsbad, CA 92008. Phone (619) 431-7474. FAX (619) 431-0880. **Circle No. 450**



Monolithic, single-supply difference amplifier. Using a single AD626, you can replace traditional difference or instrumentation amplifiers that normally require several discrete op amps. The monolithic device can operate from a single 2.4 to 12V supply or a dual ±1.2 to ±6V supply. Output swings are from $-V_S$ to within 300 mV of the positive rail. The common-mode voltage range, which exceeds the supply range, is 0 to 24V for a 5V supply and ±24V for a ±5V supply. Common-mode rejection is typically 90 dB, enabling the measurement of small signals. Operating from 5V, the AD626 has a quiescent current of 230 μA, suiting it for battery-operated applications. In 8-pin miniDIP and SOIC packages, from \$2.85 (1000). **Analog Devices,** 804 Woburn St, Wilmington, MA 01887. Phone (617) 937-2507. **Circle No. 451**

Synchronous SRAM. The MCM62110 synchronous static RAM (SRAM) integrates a 32k × 9-bit SRAM core with address registers, two sets of input data

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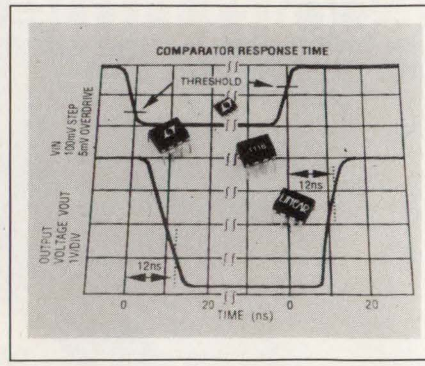
CIRCLE NO. 142

registers, two sets of output latches, active-high and active-low chip enables, and a parity checker. The dual I/O allows isolation of the processor bus from the memory bus, reducing capacitive loading on the local bus. MCM62110, in a 52-pin plastic leaded chip carrier, comes in 17- and 20-nsec speed ratings; $32.60 and $30.50, respectively, (1000). **Motorola Inc,** MOS Memory Products Div, Box 6000, Austin, TX 78762. Phone (512) 928-7726. **Circle No. 452**

Ground-sensing comparator. Featuring a response time of 12 nsec, the LT1116 comparator can sense signals near the negative supply rail while operating from a single 5V supply. The comparator's common-mode input range extends from 2.5V below the positive rail to the negative rail. Complementary outputs interface directly to TTL logic. Unlike other fast comparators, the LT1116 remains stable for slow transitions through the active region, with no minimum slew-rate requirement. In 8-pin DIP and SO packages, $3.50 and $3.75, respectively, (100). **Linear Technology Corp,** 1630 McCarthy Blvd, Milpitas, CA 95035. Phone (800) 637-5545; (408) 432-1900. FAX (408) 434-0507. **Circle No. 453**



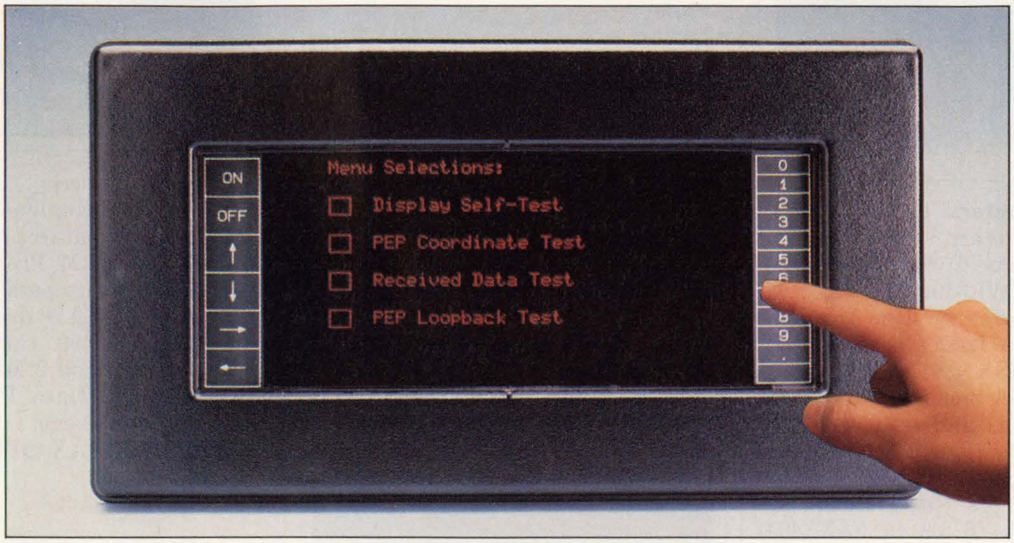
Quad audio switch. The SSM-2404 fits four spst bilateral switches in a single 20-pin DIP or SOIC package. The switches have a maximum on-resistance of 45Ω (25Ω typ). With a 2V 1-kHz signal, THD is only 0.0065% into a 10-kΩ load, and off-isolation and crosstalk are −100 and −94 dB, respectively. The SSM-2404 operates from single 12 to 24V or dual ±5.5 to ±12V supplies. $3.45 (100). **Analog Devices Inc,** Precision Monolithics Div, 1500 Space Park Dr, Santa Clara, CA 95052. Phone (408) 562-7513. **Circle No. 454**

3V submicron ASICs. Capable of operating over a supply range of 2.7 to 5.5V, the MSM10S0000 sea-of-gates family comes in seven sizes, from 11k to 225k total gates. Using a 3V supply, these high-density ASICS can operate to 50 MHz. Typical gate delays are less than 300 psec, and flip-flop toggle rates extend to 500 MHz. **Oki Semiconductor,** 785 N Mary Ave, Sunnyvale, CA 94086. Phone (408) 720-1900. FAX (408) 720-1918. **Circle No. 455**

Motor-control IC. The SSI 32H6810 features low-resistance drivers that support 5V, 0.7A drive capability for voice-coil motors and sensorless spindle motors. A power-down mode and low-voltage head retraction aid the design of 1.8- and 2.5-in. drives. A low-voltage condition or an external command can initiate head retraction or delayed spindle braking. $5 (OEM qty). **Silicon Systems,** 14351 Myford Rd, Tustin, CA 92680. Phone (714) 731-7110. FAX (714) 669-8814. **Circle No. 456**

 CIRCLE NO. 143

Take This Opportunity To Meet Our Distinguished Panel



The PEP™ 4286 Interactive Flat Panel Display

Ideal for Menu-Driven Applications

The PEP™ 4286 interactive flat panel display provides you with a complete touchscreen man-machine interface that is ideal for menu driven applications. PEP 4286 combines a full-dot DC gas plasma display with a highly reliable infrared touchscreen switch matrix.

Exceptional LAB-6™ Brightness... Even in Sunlight!

The display's LAB-6™ cathode coating provides a brightness level of 200fL before filtering, and unsurpassed contrast. PEP 4286 can be used in high ambient light applications. This coating also allows the display to be used over a wide −20 to +75°C temperature range.

A Complete Touchscreen Sub-system

As a complete touchscreen subsystem, the module includes a drip proof, polycarbonate bezel which seals to your front panel, a circular polarized filter which has two side areas for fixed function switch legends, and a rear chassis cover. 14K bytes of battery backed CMOS RAM is built-in for canned messages.

Ergonomically Distinguished

- User friendly touchscreen input
- Minimize training time and errors with menu driven input choices
- Bell output for touch confirmation
- 200fL brightness is software-dimmable in 6 steps for comfortable long term viewing
- IR switch matrix means a clear, sharp display without distorting overlays
- Dedicated fixed function switch areas for most commonly used functions

Economically Distinguished

- Complete subsystem simplifies your design process and minimizes your time-to-market
- Replace banks of switches and dials with soft keys
- Display and touchscreen self-test speeds up QA and in-field diagnostics
- Compact flat panel is only 3″ deep—fits where CRTs can't
- Battery backed canned message RAM reduces host memory overhead

Display Features

- 240×120 accessible dots form a 12 line by 40 character display, using a nominal 5×7 dot matrix character
- 96-character U.S. ASCII character set in regular height-width, double height, double width, double height-width; all in regular and reverse video
- 96-character ISA Graphics character set
- 14.10×7.85×3.00″ (W×H×D)

Operation

- Requires only +5.0VDC TTL supply and an unregulated 11-29VDC panel supply
- Serial I/O RS-232-C (with CTS and DTR) and RS-422 interfaces at 1200 or 9600 baud
- ANSI-standard VT100 compatible control codes

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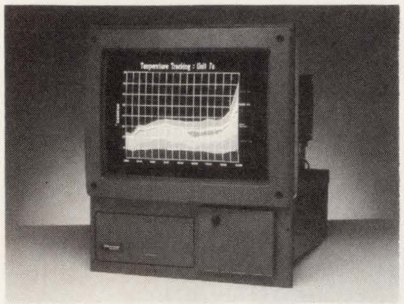
Computers & Peripherals

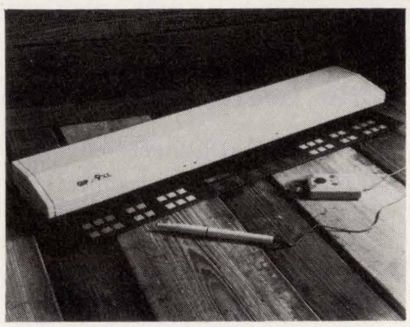


Industrial computers. The WS3002-20P and WS3002-20R are stand-alone and rackmount industrial workstations, respectively. The WR3102-00R workrack is a small footprint version. The computers contain a 12-slot passive backplane, an 80386SX µP, a VGA board and a 20-in. VGA monitor, a 52-Mbyte hard-disk drive, and a 1.44-Mbyte floppy-disk drive. Workstations, from $7495; workrack, from $4995. **Intecolor,** 2150 Boggs Rd, Duluth, GA 30136. Phone (404) 623-9145. FAX (404) 623-9163. **Circle No. 682**

V.32bis fax modems. The PM14400 FXSA and PM14400FX are stand-alone and half-card versions, respectively, of a V.32bis fax modem. The data-transfer rate is 14,400 bps. The units provide V.42 error correction and V.42bis data compression. Detecting credit-card "bong" tones, the modems can assist phone credit-card dialing. The units can also translate alphanumeric phone numbers to their numerical equivalent. PM14400FXSA, $549; PM14400FX, $499. **Practical Peripherals,** 31245 La Baya Dr, Westlake Village, CA 91362. Phone (818) 706-0333. FAX (818) 706-2474. **Circle No. 683**

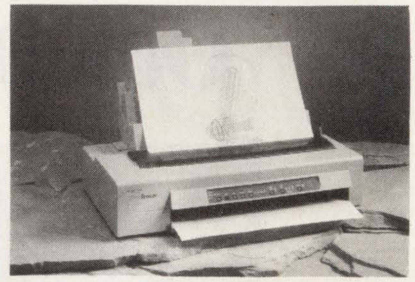
Embedded control modules. The Lonworks twisted-pair control modules are miniature circuit cards for the company's Lonworks embedded-control networks. They contain the company's Neuron chip, a PROM socket, and a communications transceiver. As many as 32,000 modules can communicate on the network using a common twisted-pair cable. Distributed modules intelligently control and supervise sensors and output devices, such as triacs and relays, on the Lonworks network. Two versions communicate at 78 kbps using Manchester-encoded data or an RS-485 protocol. A third version communicates at 1.25 Mbps using Manchester-encoding. A programmable, event-driven program lets you tailor the modules to particular applications. RS-485 module, from $35 (OEM qty). **Echelon Corp,** 4015 Miranda Ave, Palo Alto, CA 94304. Phone (415) 855-7400. FAX (415) 856-6153. **Circle No. 684**

20-in. color monitor. The ECM 2000 is a series of 20-in. monitors that automatically adjust to horizontal scan rates from 15 to 38 kHz and vertical scan rates from 45 to 120 Hz. A digital-memory-sizing feature lets you store scan rates in memory to eliminate resizing an image when the scan rate changes. The units have a 0.31-mm dot pitch and support CGA through VGA, Super VGA, XGA, 8514A, and MAC II resolutions. Approximately $3195. **Electrohome Ltd,** 809 Wellington St, North Kitchener, ON N2G 4J6, Canada. Phone (519) 744-7111. **Circle No. 685**



Nontablet digitizer. The GP-9-XL digitizer doesn't require a tablet or work surface. It uses the company's sonic-digitizing technology to digitize an area of 40×60 in. The portable unit measures 7×26×2.5 in. and digitizes drawings, maps, x-rays, and projected images on a flat surface. Input devices include a stylus or 4-button cursor. $2495. **Science Accessories Corp,** 200 Watson Blvd, Stratford, CT 06497. Phone (203) 386-9978. FAX (203) 381-9270. TLX 964300. **Circle No. 686**

Monochrome inkjet plotter. The Protracer monochrome inkjet plotter produces C-size drawings in less than 5 minutes. It also produces B-size drawings in 2.5 minutes and A-size drawings in 1.5 minutes. An Intel i960 RISC (reduced-instruction-set-computer) controller produces 360-dpi resolution and solid-area fills with no banding or streaking. The plotter prints on plain, bond, or plotter paper as well as vellum. Two optional sheet feeders automatically feed A- and B-size cut-sheet paper and business-size envelopes. In addi-



tion, the plotter accepts cut-sheet paper 17 in. wide and continuous feed fanfold paper. Other features include Epson LQ-1050 and IBM Proprinter emulations, a Centronics parallel and a serial port, an AutoCAD driver, and 512-kbyte RAM. $1499. Unit with HP-GL emulation card and 2 Mbytes of RAM, $1999. **Pacific Data Products,** 9125 Rehco Rd, San Diego, CA 92121. Phone (619) 552-0880. FAX (619) 552-0889. **Circle No. 687**

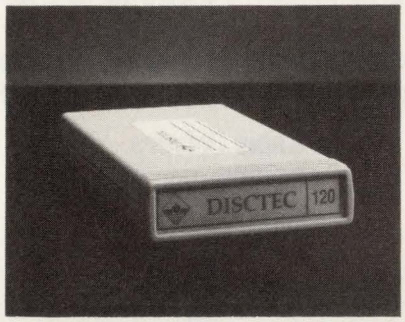
Graphics controller board. This board contains three of the company's ASICs—a GUIEngine/ALG2101 video-graphics chip with built-in GUI (graphical user interface) and Super VGA functions; an ImgDAC/ALG1101 IBM XGA chip having RAMDAC to display 64k simultaneous colors; and an ALG3102 clock-generator chip. You can also work with the company to incorporate the three ASICs in customized graphics designs. $56 (2000). **Avance Logic Inc,** 46750 Fremont Blvd, Suite 105, Fremont, CA 94538. Phone (510) 226-9555. FAX (510) 226-8039. **Circle No. 688**

SPARCstations. These five workstations use SPARC CPUs. The Station 1, Station 2, and Station 2 GX have three Sbus expansion slots and either a 25- or 40-MHz CPU. The Station VME and Station 2 VME use a 33- or a 40-MHz CPU and have six 6U VMEbus expansion slots. From $6900 to $11,800. **DTK Computer Inc,** 17700 Castleton St, Suite 300, City Of Industry, CA 91748. Phone (818) 810-8880. FAX (818) 810-5233. **Circle No. 689**

Video display board. The model IMH-1210 is a graphics display board for the ISA bus, VMEbus, or EISA bus. It uses a TMS34020 and 8 Mbytes of dual-port video RAM to drive four independent displays. Each display can have a resolution of 2048×1024×8 bits. In addition, the board has 4 Mbytes of overlay RAM and hardware zoom, pan,

and scroll. The board supports the TIGA graphics standard. $2000/display driver. Delivery, 90 days ARO. **Imagraph,** 11 Elizabeth Dr, Chelmsford, MA 01824. Phone (508) 256-4624. FAX (508) 250-9155. TLX 4946300.

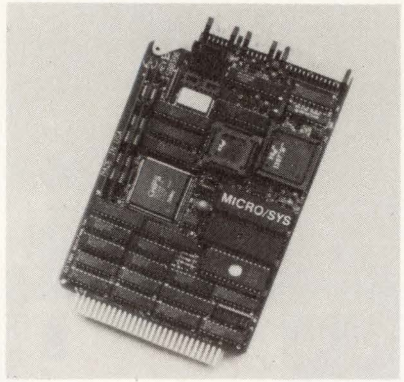
Circle No. 690



Removable hard-disk drives. The RHD 120 removable hard-disk drive provides 120 Mbytes of storage. The palm-sized unit measures $3 \times 5 \times 0.81$ in. and weighs less than 7 oz. Its Docking Bracket installs in standard 5¼-in. half-height or 3½ × 1-in. bays for notebook, laptop, and desktop computers having an IDE interface. The access time is 15 msec, the track-to-track seek time is 3 msec, and the maximum data-transfer rate is 10 Mbps. The unit can withstand an operating shock of 10g and a nonoperating shock of 100g. Because the drive is compatible with the company's 20-, 60-, and 80-Mbyte drives, you don't have to reboot the computer to access data on the lower-capacity drives after using the RHD 120. $1295. **Disk Technology Corp,** 925 S Semoran Blvd, Suite 114, Winter Park, FL 32792. Phone (800) 553-0337; (407) 671-5500. FAX (407) 671-6606. **Circle No. 691**

Disk mirror. The SCSI Disk Mirroring system implements Raid 1 technology for fault redundancy. The company offers the system as an option for its Smartcache Plus SCSI controllers. The hardware system offloads mirror overhead from the CPU and provides an alternative for operating systems that don't offer a software mirror. **Distributed Processing Technology,** 140 Candace Dr, Maitland, FL 32751. Phone (407) 830-5522. FAX (407) 260-5366.

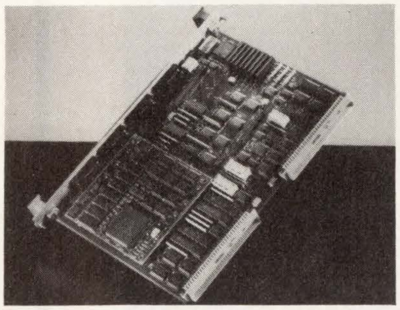
Circle No. 692



80386SX STD-Bus SBC. The SB8386 STD Bus single-board computer (SBC) uses a 16- or 20-MHz 80386SX μP. It also has as much as 8 Mbytes of RAM and sockets for as much as 1.8 Mbytes of EPROM, flash EPROM, static RAM (SRAM), or battery-backed SRAM. Other features include COM1 and COM2 serial ports, an LPT1 printer port, a real-time clock, a keyboard port, and a floppy-disk controller. $995. **Micro/sys Inc,** 1011 Grand Central Ave, Glendale, CA 91201. Phone (818) 244-4600. FAX (818) 244-4246. **Circle No. 693**

Stepper-motor controller. The Optistep system consists of an ISA bus motion-control card, a 2- or 3-axis driver board, and a power supply. The system has optoisolation on all control-signal and I/O lines. Software routines include linear and circular interpolation and programmable velocity and acceleration. 2-axis system, $758. **Microkinetics Corp,** 1220 Kennestone Circle, Suite J, Marietta, GA 30066. Phone (404) 422-7845. FAX (404) 422-7854.
Circle No. 694

4- and 8-mm tape backup. The DR600 is a series of 4-mm digital-audio-tape (DAT) and 8-mm helical-scan backup subsystems. They operate with Digital's Digital Storage Systems Interconnect (DSSI) VAXcluster computers. The DAT provides as much as 32 Gbytes of storage, and the helical-scan devices have as much as 10 Gbytes of storage. Both products connect to the host's DSSI port. DATs, $7900 to $17,500; helical-scan subsystems, $11,000 to $16,800. **Emulex Corp,** Box 6725, Costa Mesa, CA 92626. Phone (800) 854-7112; (714) 662-5600. **Circle No. 695**



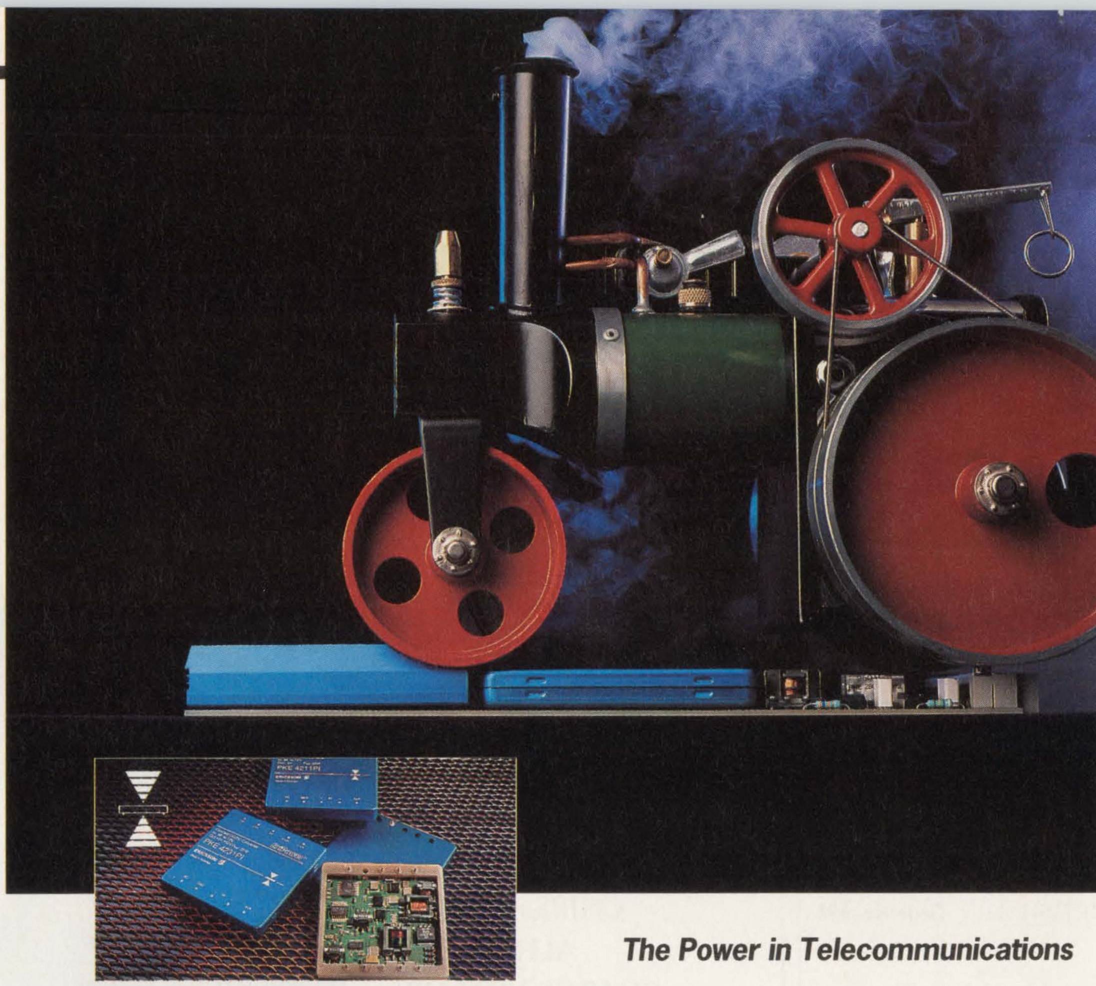
VMEbus DSP board. The ZPB3400 board provides the option of using one or two AT&T DSP32C or TI TMS320C31 chips. The DSP chips mount on separate daughter boards, which plug into the VMEbus board. Each DSP chip has a dedicated high-speed serial port and 256 kbytes of static RAM. The VMEbus board has 1 or 4 Mbytes of triple-port dynamic RAM. $4495. **Burr-Brown Corp,** Box 11400, Tucson, AZ 85734. Phone (800) 548-6132; (602) 746-1111. **Circle No. 696**

Quadra removable drive. The Bernoulli Macinsider 90 is a removable storage device for Macintosh Quadra 900 computers. It provides 90 Mbytes of storage per removable disk. A Mactools Deluxe utility from Central Point Software provides data compression. A 32-kbyte cache delivers a 19-msec effective access time and 20-Mbps transfer rate. $999. **Iomega Corp,** 1821 West-4000 S, Roy, UT 84067. Phone (800) 777-6179; (801) 778-3345. FAX (801) 778-3450. **Circle No. 697**

VMEbus 10Base-T. The ENET-1T Ethernet controller board for the VMEbus conforms to twisted-pair 10Base-T networks. It uses AMD's Am7990 Local Area Network Controller (LANCE) chip. The board also implements the company's T-Stream protocol suite, which consists of TCP/IP, address-resolution protocol, Ethernet link-level access, and serial-line internet protocol. $2195. **Radstone Technology,** 20 Craig Rd, Montvale, NJ 07645. Phone (800) 368-2738; (201) 391-2700. FAX (201) 391-2899. **Circle No. 698**

386SX single-board computer. The 5.75×7.75-in. SBC-SX board uses a 16-MHz 80386SX µP. It has 4 Mbytes of dynamic RAM, two COM ports, a printer port, a battery-backed real-time clock, and hard- and floppy-disk-drive interfaces. The board consumes 4.3W and drives CRTs and flat-panel displays. A licensed BIOS lets you run MS-DOS from a floppy-disk, hard-disk, or onboard ROM-disk drive. $971 (100). **Computer Dynamics,** 107 S Main St, Greer, SC 29650. Phone (803) 877-8700. FAX (803) 879-2030. **Circle No. 699**

Real-time imaging module. The model PX3013 is a module for the PCs Extended for Industry (PCXI) architecture. The module digitizes images as fast as 60 MHz. A 1-Mbyte image buffer provides 1024×1024-pixel resolution, a programmable line length as long as 65,536 pixels, and simultaneous read and write operations. The module accepts 8-bit digital and analog inputs with separate sync signals. $7495. **Rapid Systems Inc,** 433 N 34th St, Seattle, WA 98103. Phone (206) 547-8311. FAX (206) 548-0322. TLX 265017. **Circle No. 748**



The Power in Telecommunications

The squeeze is on

Slimming is an obsession in the electronics industry as engineers face the task of making thinner cards to fit even more functions into standard racks. Once again Ericsson can help.

The new PKE is a 25-30 W DC/DC converter squeezed into a slim package little more than half the height of its predecessor, the internationally acclaimed PKA converter. The PKE is only 10.7 mm (0.42") high and has the same 3"x3" industry-standard footprint and pin out.

Having set the standard for DC/DC converters in 1983, Ericsson's new series represents a remarkable leap forward in power supply technology. The PKE needs no power derating over its entire ambient temperature range of -45 to +85 °C. Quite simply, no one else achieves this in so little space. And you can choose from versions with one, two or three regulated outputs.

Perhaps most surprisingly, performance is in no way compromised by the size reduction. In fact, the PKE is even better than the PKA. A wide input voltage of 38 to 72 VDC is complemented by 1500 VDC isolation, 80-85% typical efficiency and two million hours MTBF at +45 °C ambient.

The PKE converter from Ericsson - slim, compact and beautifully formed. Squeeze in the time to call us for more information.

Please send me your latest information EDN 5-7-92

Name

Company

Job Title

Address

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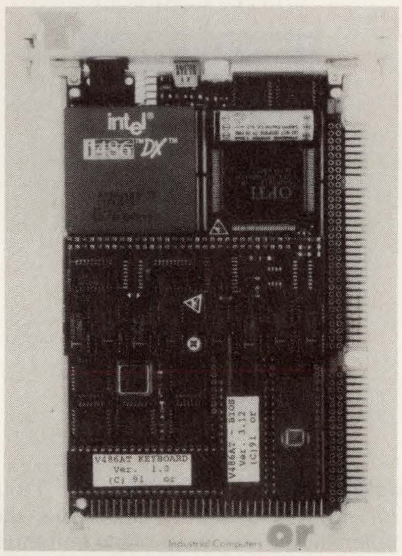
Germany:	**Ericsson Components Europe,** Neu-Isenburg, Tel: +49-6102-200 50 Fax: +33-6102-20 05 33
Great Britain:	**Ericsson Components Europe,** Coventry, Tel: +44-203-55 36 47 Fax: +44-203-22 58 30
Hong Kong:	**Ericsson Components,** East Asia, Wanchai, Tel: +852-5-75 66 40 Fax: +852-834 53 69
Italy:	**Ericsson Components Europe,** Milano, Tel: +39-2-33 20 06 35 Fax: +39-2-33 20 06 41
Norway:	**Ericsson Components A/S,** Oslo, Tel: +47-2-65 01 90 Fax: +47-2-64 41 38
Sweden:	**Ericsson Components AB,** Stockholm, Tel: +46-8-757 43 84 Fax: +46-8-757 44 21
United States:	**Ericsson Components Inc,** Richardson, TX, Tel: +1-214-997-6561 Fax: +1-214-680-1059

ERICSSON

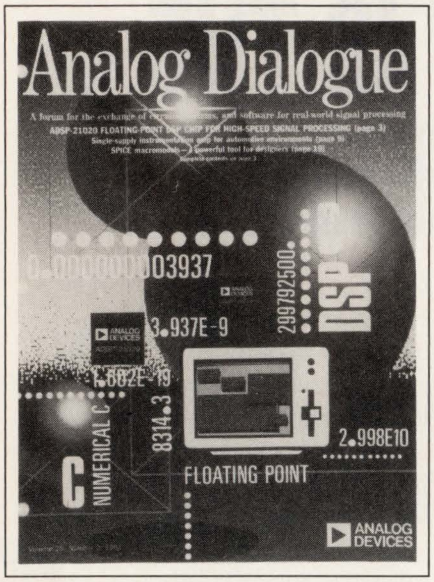
CIRCLE NO. 152

Operator interface module. The Qterm-III user-configurable interface module communicates with a host via an RS-232C port. It drives any LCD module having 1 row×8 characters to 4 rows×40 characters and 9 digital devices. You can select and input a keypad having from 1 to 48 keys. You can assign a shifted or unshifted string or a repeat code to any code. $122 (25) **QSI Corp,** 2212 SW Temple, #46, Salt Lake City, UT 84115. Phone (801) 466-8770. FAX (801) 466-8792. **Circle No. 749**



VMEbus industrial PC. The 486-SX/DX DOS-compatible VMEbus module contains a 20-MHz 80486SX or a 33-MHz 80486DX μP. It provides a real-time clock, keyboard interface, DMA and interrupt controllers, and 1, 2, 4, or 8 Mbytes of dynamic RAM. The BIOS can access a 1-Mbyte flash ROM as a solid-state disk. The module contains a 16-bit ISA bus and a VMEbus connector. $2564 (OEM qty). **Dynatem,** 15795 Rockfield Blvd, Suite G, Irvine, CA 92718. Phone (714) 855-3235. FAX (714) 770-3481. **Circle No. 750**

DAT drives. The Turbo SL family Digital-Audio-Tape (DAT) drives store 5 Gbytes on 4-mm tape. The half-height 5¼-in. drives can back up Netware software at 300 kbytes/sec. One family member, the Server DAT, resides at a filesaver and the other member, the LANDAT, resides at a workstation. Flash memory lets you upgrade firmware in less than 90 sec. **Gigatrend Inc,** 2234 Rutherford Rd, Carlsbad, CA 92008. Phone (619) 931-9122. FAX (619) 931-9959. **Circle No. 801**

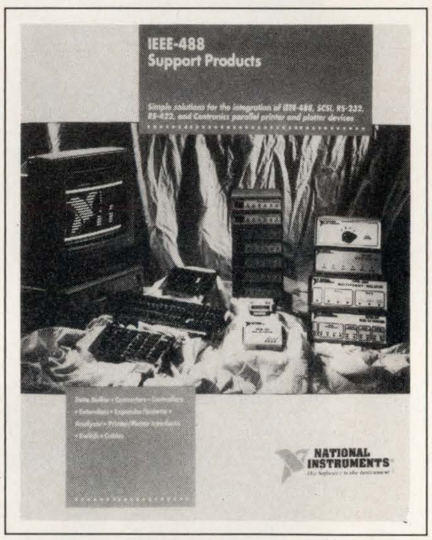


Technical journal on circuits, systems, and software. Vol 25, No. 2 of *Analogue Dialogue* focuses on the IEEE-compatible floating-point ADSP-2100 for high-speed signal processing. Related articles follow, including "Numerical C Speeds Code Development and Execution," and "Development Tools and Third-Party Support for Floating-Point DSP." The *Ask the Applications Engineer* column answers the question, "When is a wire not a wire?" **Analog Devices,** Literature Center, 70 Shawmut Rd, Canton, MA 02021. FAX (617) 821-4273. **Circle No. 457**

Paperback on DOS.5. *Voodoo DOS, Tips & Tricks With an Attitude* explains shortcuts, notes, and tips for using DOS version 5.0. It contains 10 main sections: getting started—upgrading and setup; the secret of the Shell; working with programs; command-line sleight-of-hand; disks and hard drives; formulas in DOS 5.0; organizing batch files; getting the most from Doskey; understanding arcane commands; and managing DOS memory. $19.95. **Ventana Press,** Box 2468, Chapel Hill, NC 27515. Phone (919) 942-0220. FAX (919) 942-1140.
INQUIRE DIRECT

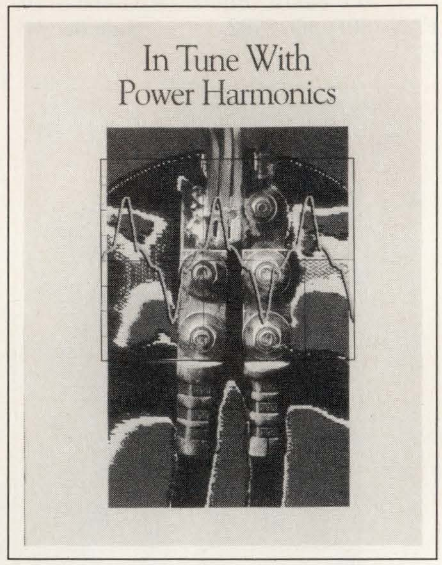
Products for the IEEE-488 bus. The 1992 Catalog of IEEE-488-bus products is divided into sections dealing with the bus's use for IBM PCs, workstations, Macintosh computers, data acquisition, support, and serial devices. Two other sections cover accessories and ordering information. Each section begins with a selection guide and an overview of the products. The 142-pg publication specifies, describes, illustrates, and provides command summaries for the products. **IOtech Inc,** 25971 Cannon Rd, Cleveland, OH 44146. Phone (216) 439-4091. FAX (216) 439-4093.
Circle No. 458

Electrical equipment/HVAC-R service equipment. The 1992 Electrical/HVAC-R (heating, ventilation, air-conditioning-refrigeration) Service Equipment catalog describes the Series 10 DMMs and Series 30 Current Masters clamp meters. It also presents the problem of harmonics in office buildings and factories. The 18-pg publication features a compatibility and selection chart and discusses current clamps, multimeters, thermometers, and accessories for the electrical service industry. **John Fluke Mfg Co Inc,** Box 9090, Everett, WA 98206. Phone (800) 873-5853; (206) 347-6100. FAX (206) 356-5116. TLX 185102. **Circle No. 459**



Foldout of IEEE-488 support products. This 6-pg foldout brochure describes more than 16 support products and how to use them to integrate IEEE-488, SCSI, RS-232C, RS0422, and Centronics parallel devices for engineering and scientific applications. It explains the functions of data buffers, converters, controllers, extenders, an expander/isolator, a bus analyzer/monitor, printer and plotter interfaces, a switch box, and several cables. Application diagrams show how to connect the products to each other and to PCs and workstations. **National Instruments Corp,** 6504 Bridge Point Pkwy, Austin, TX 78730. Phone in US and Canada, (800) 433-3488; (512) 794-0100. FAX (512) 794-8411. **Circle No. 460**

"Diskless demo" of ICEs. Destined for disk-inundated engineers, this 30-pg booklet describes 80188, 80186, 68000, and Z180 in-circuit emulators. It illustrates a typical C-language debugging session. The booklet allows you to read at leisure, without needing a computer. **Softaid Inc,** 8300 Guilford Rd, Columbia, MD 21046. Phone (800) 433-8812; (301) 290-7760. **Circle No. 461**



Booklet about harmonics. *In Tune With Power Harmonics* addresses the problem of harmonics in office buildings and factories. The booklet deals with sources of harmonics, the effects of harmonic currents, how to find harmonics, the troubleshooting tools needed, and how to solve the problem. Tools described in the booklet include the 30 Series Current Masters clamp meters and the 87 DMM. **John Fluke Mfg Co Inc,** Box 9090, M/S 250-E, Everett, WA 98206. Phone (800) 873-5853; (206) 347-6100. FAX (206) 356-5116. TWX 910-445-2943. **Circle No. 462**

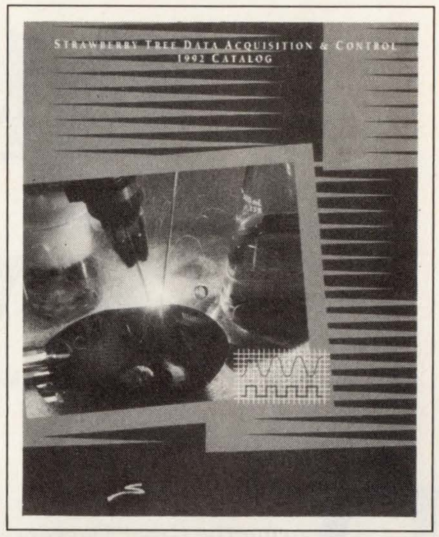
Data book on multiprocessing computers. The 350-pg *Technical Data Book* deals with multiprocessing computers for test and control applications and includes STD 32 offerings and other new products. Guides to product features, an index, and a low-power/extended temperature directory allows a quick overview of the products. Other features include an STD-80 Bus Specification and a 12-pg overview of STD 32 with illustrations from its specification. The publication also mentions two services provided by the vendor: a systems-engineering course and an electronic bulletin board. The data book provides

a list of application notes and technical briefs. **Ziatech Corp,** 3433 Roberto Ct, San Luis Obispo, CA 93401. Phone (805) 541-0488. **Circle No. 463**

Brochures on cable assembly and microwave designs. A 4-pg brochure lists custom RF and microwave cable assemblies. It deals with flex and semirigid assemblies. Another 4-pg booklet lists custom services for RF and microwave-design engineers, such as low-cost commercial and military-specification design, turnkey and contract manufacturing, and parts-screening and device selection, including environmental testing. **Penstock Inc,** 520 Mercury Dr, Sunnyvale, CA 94086. Phone (408) 730-0300. FAX (408) 730-4782. **Circle No. 464**

Temperature-measurement handbook. This handbook contains technical specifications and pricing for more than 10,000 temperature-measurement and control products. It describes thermocouple, RTD, and thermistor probes. The 270-pg publication also lists temperature-indicating, -controlling, and -recording devices. It also features 50 pages of technical notes, as well as application data and test results for temperature measurement of plastics processing, heat-treating, glass manufacturing, and aerospace applications. **Nanmac Corp,** 9-11 Mayhew St, Framingham Centre, MA 01701. Phone (508) 872-4811. TWX 710-321-0075. **Circle No. 465**

Publication on fast-pulse generators. Catalog No. 8S1 discusses high-speed pulse generators and laser-diode drivers that are not included in the General Catalog No. 8. It emphasizes 10- and 50-MHz general-purpose laboratory pulse generators, 40 and 100A laser-diode drivers, and 800 to 900V pulse generators. **Avtech Electrosystems Ltd,** Box 265, Ogdensburg, NY 13669. Phone (315) 472-5270. FAX (613) 226-2802. **Circle No. 466**



Data-acquisition and control products. This 1992 catalog features plug-in boards and software for applications such as precision-temperature measurement, weighing, and chromatography, and it also includes IEEE-488 instrumentation. The catalog highlights WorkbenchPC and WorkbenchMac, which use icon-based software for measuring, analyzing, and responding to data with no programming. **Strawberry Tree Inc,** 160 S Wolfe Rd, Sunnyvale, CA 94086. Phone (408) 736-8800. FAX (408) 736-1041. **Circle No. 467**

Take control of your time

JAY FRASER, Associate Editor

> **You won't have to work long hours if you manage your time better.**

During the Great Depression, Charles Schwab was the president of Bethlehem Steel Company. One day he was talking to a management consultant named Ivy Lee about how he wanted to accomplish more with his time.

Lee suggested a simple method. In the evening, take a blank piece of paper and write down the six most important tasks you have to do the next day. Number them in order of priority and put the paper in your pocket. Next morning, take out the list and begin on task number one. Work on it until you finish it, then start on task number two, and so on. Don't worry if you only complete one or two tasks each day, because they will be the most important ones. After you go home, tear up the piece of paper and write out a new list for the following morning.

Schwab asked Lee what fee he wanted for the advice. Lee replied that Schwab should try the method for as long as he wanted, then send him a check for whatever he thought it was worth.

One month later, Schwab mailed Lee a check for $25,000—a huge sum during the Depression—and said that it was worth every penny because finally he and his executives were getting first things done first. Schwab went on to make Bethlehem Steel the largest independent steel producer in the world and amass a personal fortune of more than $100 million.

Managing your time effectively can pay big dividends, those dividends can arrive quickly, and time-management methods can be straightforward and easy to implement.

Time is your most precious resource, and it's nonrenewable. Each of us spends time at exactly the same rate, yet some people accomplish more with it than others. You'd probably like to get more done on your job, but maybe you just don't seem able to do it. You may even have worked extra hours sometimes, but it didn't help much. Working extra hours isn't the answer. Achieving better control of your time is.

The well-known management consultant E B Osborn once said, "If your aim is control, it must be self-control first. If your aim is management, it must be self-management first. Beside the task of acquiring the ability to organize a day's work, all else you will ever learn about management is but child's play."

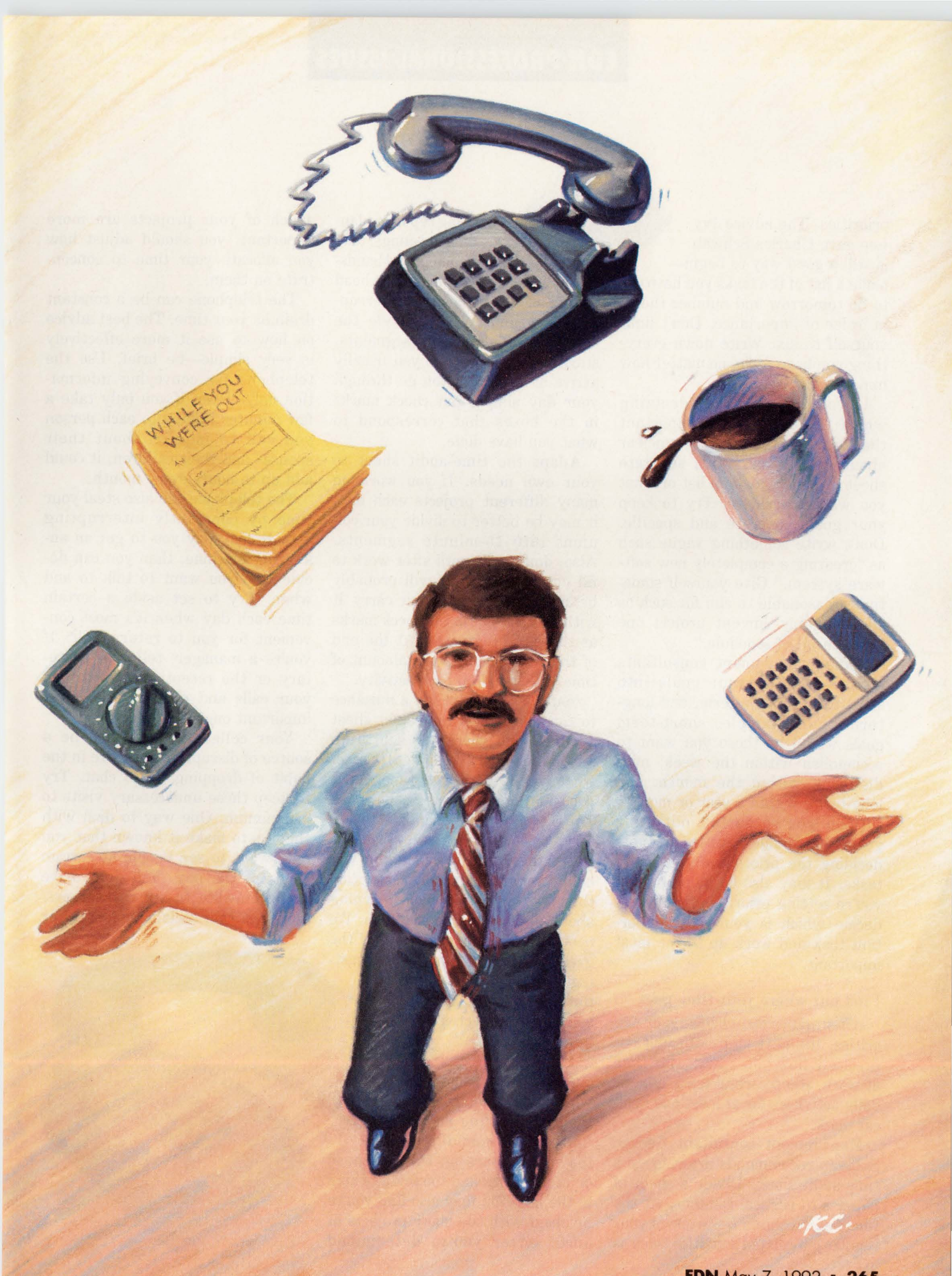
Take the time to plan well

The greatest time-waster is lack of planning. Many people don't devote sufficient time to planning because they don't understand the benefits it brings. Engineers, especially, tend to want to get into the lab, get their hands on the equipment, and see what it will do. That may be satisfying, but it usually isn't the best use of time.

Not taking the time to plan thoroughly may put you in a Catch-22. If you don't plan well, you may spend more time than is necessary on your work, and if you spend more time than is necessary on your work, you won't have time to plan well. If you're a manager, insufficient planning may cause emergencies to keep cropping up. If your days are taken up dealing with emergency after emergency, you may not have the time to plan sufficiently. It's true that good planning takes time, but it's also true that in the long run, good planning saves more time than it takes.

The first step in effective time management is to establish your

Illustration by Ken Condon


WHILE YOU WERE OUT
KC

priorities. The advice Ivy Lee gave Charles Schwab is still a good way to begin—make a list of the tasks you have to do tomorrow and number them in order of importance. Don't limit yourself to six. Write down everything you have to do, no matter how minor it may seem.

If you have trouble deciding which tasks are more important than others, you may be unclear about your goals. On a separate sheet of paper, make a list of what you want to achieve. Try to keep your goals concrete and specific. Don't write something vague such as "creating a completely new software system." Give yourself something reasonable to aim for such as "finishing my current project one week ahead of schedule."

Some management consultants advise dividing your goals into short-term, middle-term, and long-term. For example, short-term goals would be those you want to accomplish within the week; middle-term, within the month; and long-term, within a year or more.

Once you've sorted out your goals, you should have less trouble deciding the priority of your daily tasks. It may also be helpful when you're setting priorities if you first decide which is your least important task and work up to the most important.

Find out where your time goes

After you've established your priorities, the next step is to find out precisely how you spend your time at work. Keep careful track of your daily activities for at least one typical week.

Management consultant George Sullivan recommends drawing up a time-audit sheet. Divide a sheet of paper into vertical columns. At the top of each column write one of your regular job-related activities, such as writing reports, planning, meetings, telephoning, and hands-on work. Also head one column "interruptions." Then divide the columns into half-hour segments, starting with the time you usually arrive at work. As you go through your day simply put check marks in the boxes that correspond to what you have done.

Adapt the time-audit sheet to your own needs. If you work on many different projects each day, it may be better to divide your columns into 15-minute segments. Also, don't wait until after work to fill out the sheet. It will probably be more accurate if you carry it with you and put in the check marks as the day progresses. At the end of the week, add up the amount of time you spend on each activity.

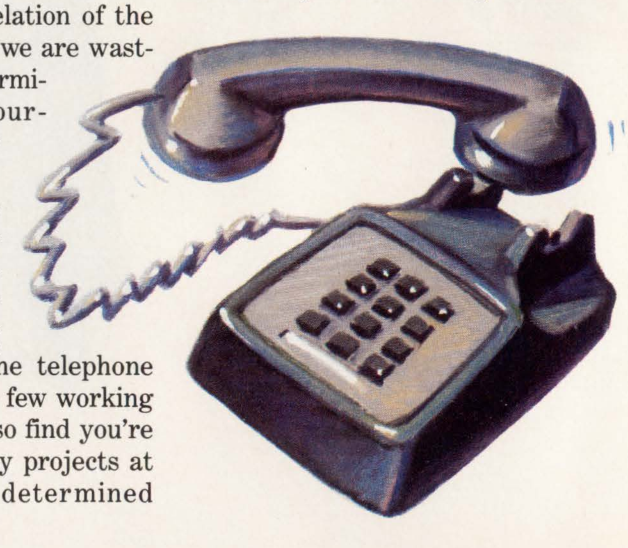
You may feel that it's a nuisance to carry around a time-audit sheet all week, but there's no substitute for meticulously keeping track of what you do with your time. As R Alec Mackenzie wrote in his book *The Time Trap*, "The time inventory, or log, is necessary because the painful task of changing our habits requires far more conviction than we can build from learning about the experience of others. We need the amazing revelation of the great portions of time we are wasting to provide the determination to manage ourselves more effectively in this respect."

Many people are surprised to discover where their time is actually going. You may find you're spending too many hours on the telephone or in meetings and too few working in the lab. You may also find you're involved with too many projects at once. After you've determined which of your projects are more important, you should adjust how you allocate your time to concentrate on them.

The telephone can be a constant drain on your time. The best advice on how to use it more effectively is very simple—be brief. Use the telephone for conveying information only. Even if you only take a few minutes talking to each person you call to inquire about their spouses and their children, it could add up to hours every month.

The telephone can also steal your time by constantly interrupting you. It may pay you to get an answering machine, then you can decide who you want to talk to and when. Try to set aside a certain time each day when it's most convenient for you to return calls. If you're a manager, tell your secretary or the receptionist to screen your calls and put only the most important ones through to you.

Your colleagues can also be a source of disruption if they're in the habit of dropping by to chat. Try to keep these unnecessary visits to a minimum. One way to deal with them is to make it known that you only want to see people at certain times of the day. You don't have to be impolite to your coworkers. Just save your socializing until after



work. Your company may have an open-door policy, but you will be better off if you close yours sometimes.

If you have to meet with someone

who has a tendency to rattle on, set a time limit on the meeting. Also, try to meet in his or her office. That makes it much easier for you to leave when you want.

Another way to safeguard your time is to find some quiet place you can retreat to, from time to time, to work without interruption. It may be your company's library or an empty conference room or the office of an absent coworker. If your job allows it, you could also try working at home once in a while.

Keep firm control of meetings

Poorly planned and poorly run meetings are another serious waste of time. Many organizations hold meetings at the same time each week. Sometimes their original purpose changes or disappears altogether, but the meetings continue out of habit. If you find yourself involved in such meetings, suggest that their purpose be re-examined.

If you're in a position to plan and conduct a meeting, you can do yourself and others a big favor by making sure it has a well-defined purpose and a firm agenda. When you're running a meeting, don't let the participants' minds wander away from the business at hand. Your meeting should have a goal, and everyone in the meeting should work toward it until it's accomplished. Also, make sure your meeting starts and ends on time.

If you're a manager, you have an advantage because you can delegate some work to others. Delegation isn't really an option. It's a necessity. As Ross Webber, professor of Management at the Wharton School, University of Pennsylvania (Philadelphia, PA) has said, "You can't do everything yourself and live very long. You must delegate."

There are two basic methods of delegation. In the first, you determine which of your tasks are routine and repetitive and you give them to your subordinates. That leaves you free to concentrate on more important or unique work and on any emergencies that may arise. This is termed management by exception.

The other common method is to delegate those tasks that you don't like or do especially well to others and keep the ones that you do best. If one of your subordinates can handle a job more easily and quickly than you can, you should give it to him or her. If no one who works with you has any expertise in a certain area, don't be afraid to call in a specialist from outside.

The most important aspect of delegating is to make sure your subordinates understand what they are supposed to do. Give them clear instructions and explain what the goal of each project is. Also, remember that delegating will give you more time, but it won't give you less responsibility. You can pass work on to others, but the ultimate responsibility remains with you.

After you have determined your goals, established the priority of the tasks you have to do, and tracked and evaluated how you spend your time, the final step is to create a new schedule.

Draw up a schedule for one full week. Use whatever you feel most comfortable with—a wall chart, a desk calendar, a pocket notebook, or just a plain piece of paper. Give yourself goals that you can accomplish in a reasonable amount of time. If a large project is looming ahead for you, try to break it down into a series of smaller, easier-to-handle tasks. Be flexible. Don't fill up every minute of the day. Leave time for the unexpected to occur—because it probably will. Nothing ever goes exactly as planned.

Try to stick to your new schedule as closely as possible, even though you may find it difficult. At the end of the week, evaluate what you've done. Then write out another schedule for the following week, making any adjustments you feel are necessary. At the end of just one week you should feel you have better control of your time, your job, and your life. EDN

Jay Fraser, Associate Editor, can be reached at (617) 558-4561, FAX (617) 558-4471.

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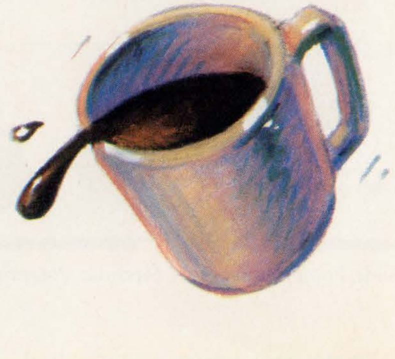

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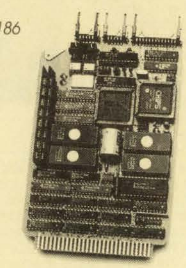

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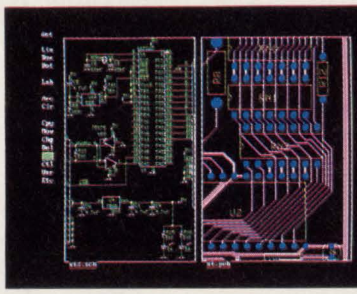

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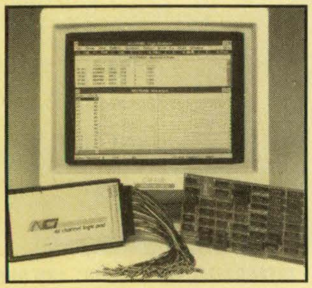

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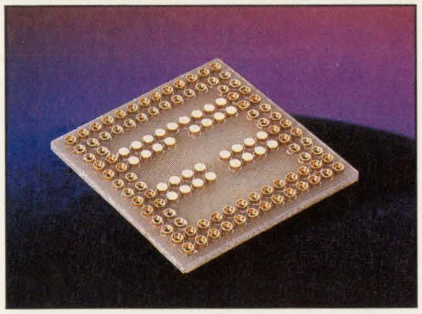

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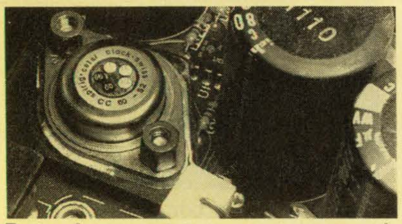

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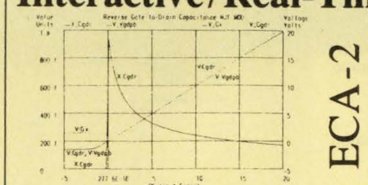

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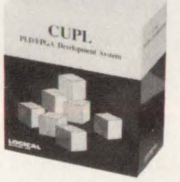

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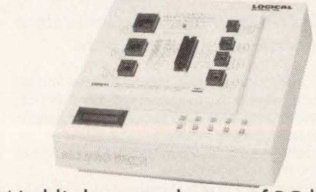

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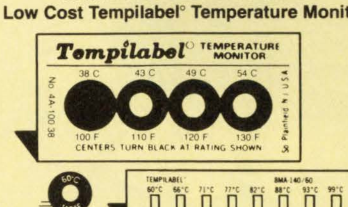

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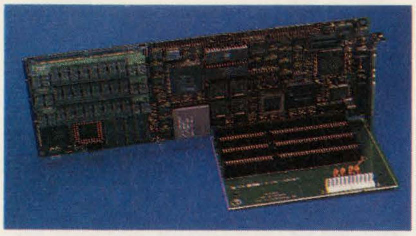

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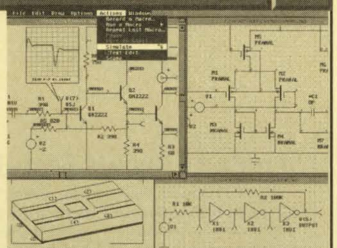

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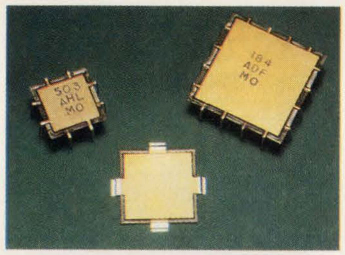

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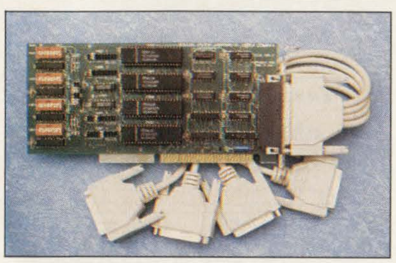

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Issue	Issue Date	Ad Deadline	Editorial Emphasis
News Edition	May 28	May 14	Communication ICs • CAE Software • Regional Profile: Texas, Oklahoma, Kansas
Magazine Edition	June 4	May 14	ASICs/PLDs • DSP Software • CAE/Software/Interoperability • Digital ICs & Semiconductors
News Edition	June 8	May 21	CAE SPECIAL ISSUE • EDA/CASE Supplement • DAC Hot Products • Software Engineering • Diversity Special Series
Magazine Edition	June 18	May 28	Microprocessors • Electromechanical Devices • ICs & Semiconductors
SOFTWARE ISSUE	June 18	May 28	SOFTWARE ENGINEERING SPECIAL ISSUE (To be polybagged with the June 18th Magazine Edition issue)
News Edition	June 25	June 11	MILITARY ELECTRONICS SPECIAL ISSUE • DSP Hardware • Military Electronics • Regional Profile: Florida, Alabama
Magazine Edition	July 6	June 11	INTERNATIONAL PRODUCT SHOWCASE—Vol. I • Hardware & Interconnect • Software • ICs & Semiconductors • Power Sources
Magazine Edition	July 20	June 25	INTERNATIONAL PRODUCT SHOWCASE—Vol. II • Computers & Peripherals • Components • CAE • Test & Measurement
News Edition	July 23	July 9	Engineering PCs & Workstations • CAE Software • SIGGRAPH Hot Products • Graphics Technology • Engineering Management Special Series • Regional Profile: Arizona, New Mexico
Magazine Edition	Aug. 6	July 16	Microprocessor Development Tools • ICs & Semiconductors • Technical Article Database Index • EDN's "Innovation Crusade"—Finalists Coverage • Reader Vote Contest: All advertisers in the issue qualify
News Edition	Aug. 13	July 30	DSP ICs • EDN's "Innovation Crusade"—Finalists Coverage • Telecom Software • Engineering Management Special Series
Magazine Edition	Aug. 20	July 30	MILITARY ELECTRONICS SPECIAL ISSUE • Military Computers Design • Test & Measurement • Memory Technology • Components
News Edition	Aug. 27	Aug. 13	Embedded Software • Software • Regional Profile: Washington DC, Maryland, Virginia
Magazine Edition	Sept. 3	Aug. 13	ASICs SPECIAL ISSUE • CAE Tools & Techniques • Computer Peripherals • Computer Buses • Sensors & Transducers • Buscon Show Coverage
News Edition	Sept. 10	Aug. 27	CAE • Test & Measurement • Diversity Special Series
Magazine Edition	Sept. 17	Aug. 27	Field-Programmable Gate Arrays • DSP Directory • Embedded Computers • CAE
SOFTWARE ISSUE	Sept. 17	Aug. 27	SOFTWARE ENGINEERING SPECIAL ISSUE (To be polybagged with the Sept. 17th Magazine Edition issue)
News Edition	Sept. 24	Sept. 10	Automotive Electronics • Sensors • Computers & Peripherals • Regional Profile: Oregon, Washington
Magazine Edition	Oct. 1	Sept. 10	TEST & MEASUREMENT SPECIAL ISSUE • European Technology Update • Data Acquisition Software • Superconductors • How to Design it Right the 1st Time Series—Part I • PLD/FPGA Directory
News Edition	Oct. 8	Sept. 24	CAE • PC/Workstation Design • Engineering Management Special Series
Magazine Edition	Oct. 15	Sept. 24	Disk Drives • Portable-Computer Design • Switching Power Supplies • Design it Right Series—Part II
News Edition	Oct. 22	Oct. 8	Data Storage Technology • Communications Technology • Regional Profile: Michigan, Illinois, Missouri
Magazine Edition	Oct. 29	Oct. 8	ELECTRONICA SHOW ISSUE • Object-oriented Programming • Chipsets for PCs • Design it Right Series—Part III • Wescon Preview Issue
News Edition	Nov. 5	Oct. 22	COMDEX/WESCON SPECIAL ISSUE • Special Supplement: Design for Portability • Microprocessors • Wescon/Comdex Hot Products • CAE Software • Diversity Special Series
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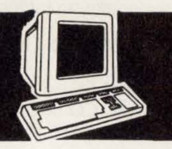

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Business/Publishing Headquarters
275 Washington St
Newton, MA 02158
Fax: (617) 558-4470

VP/Publishing Director
Peter D Coley
(617) 558-4673
Ora Dunbar, Sales Coordinator

VP/Publisher
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199 Wells Ave
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Tel: (617) 964-3730
Fax: (617) 332-7128

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249 W 17th St
New York, NY 10011
Tel: (212) 463-6419
Fax: (212) 463-6404

SOUTHEAST CORRIDOR/PA
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487 Devon Park Dr
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IL, IN, KY, MI, OH, TN
Greg Anastos
Cahners Plaza
1350 E Touhy Ave, Box 5080
Des Plaines, IL 60018
Tel: (708) 635-8800
Fax: (708) 635-0929

IL, MN, NE, IA, KS, ND, SD, WI, MO, AL, AR, OK, CANADA
Jack Johnson
Cahners Plaza
1350 E Touhy Ave, Box 5080
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Tel: (708) 635-8800
Fax: (708) 635-0929

ARIZONA
John Huff
44 Cook St
Denver, CO 80206
Tel: (303) 388-4511
Fax: (303) 394-4709

COLORADO
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44 Cook St
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Hanauer Landstrasse 294
D-6000 Frankfurt/Main 1
Germany; Tel: 4969 42 2951
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Fax: 65-738-2108

AUSTRALIA
Alexandra Harris-Pearson
World Media Network Pty Ltd
Level 2, 285 Clarence Street
Sydney, NSW 2000 Australia
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Fax: 61-2-283-2035

TAIWAN
Parson Lee
Acteam International Marketing Corp
Box 82153, Taipei, Taiwan ROC
Tel: 886-2-7114833
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PRODUCT MART
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the fast FFT spectrum analyzer

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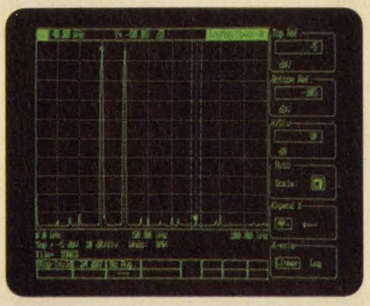
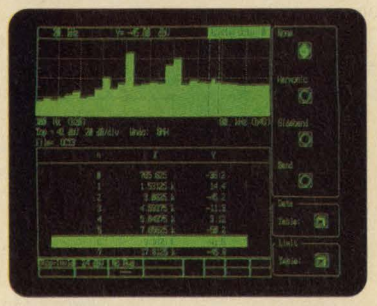


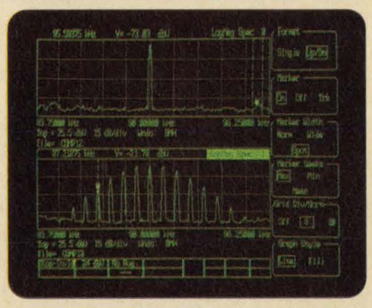
Analysis Capabilities

Easy to use analysis functions are included. Data tables monitor up to 200 frequencies.



Spectral Comparisons

Menu selected math operations can be used to measure spectral differences.



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SR760.......$4350 (U.S. list)

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- 100 kHz real-time bandwidth
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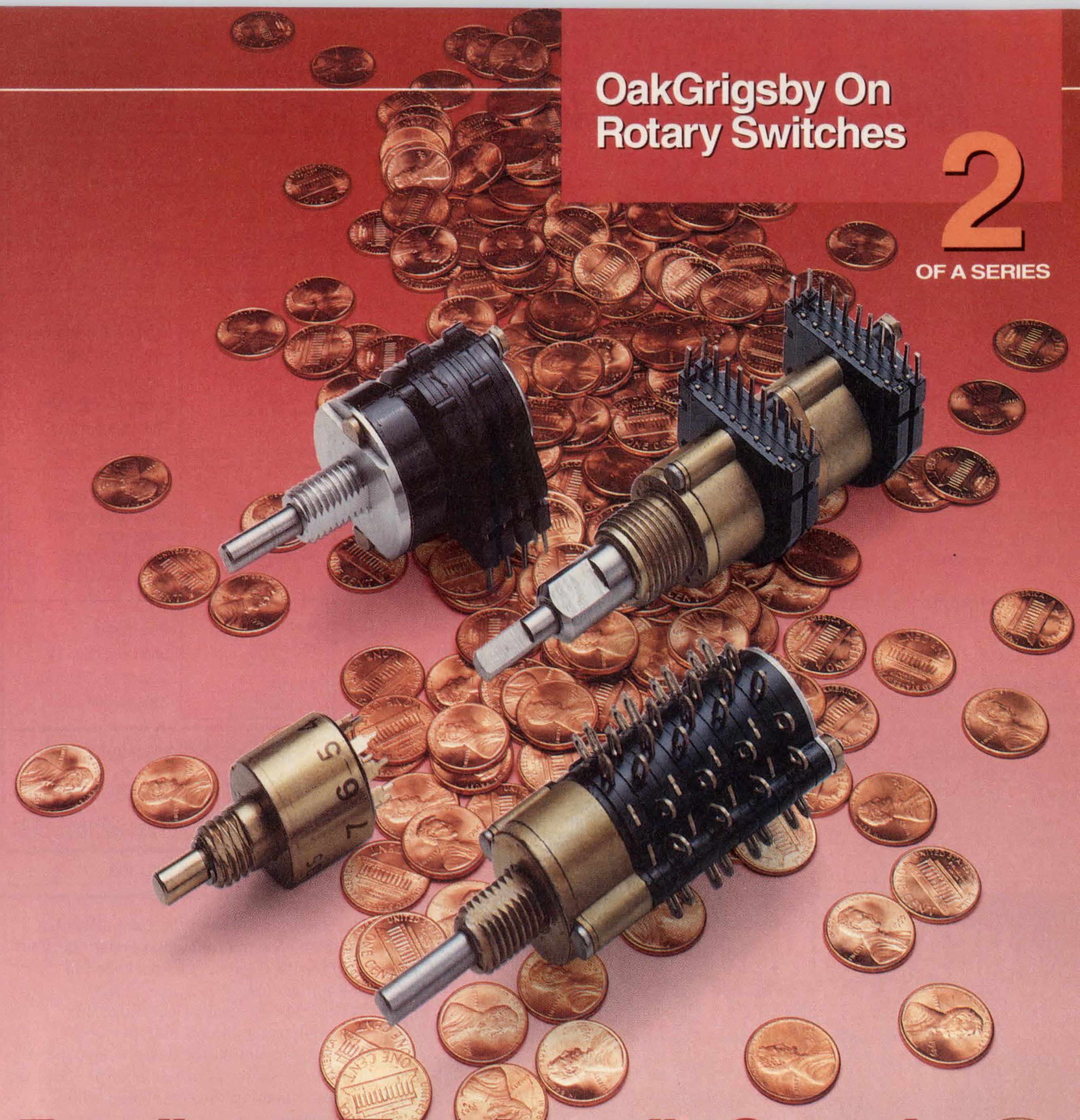
OakGrigsby On Rotary Switches

2 OF A SERIES



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EDN-ACRONYMS & ABBREVIATIONS

A/D—analog to digital
ANSI—American National Standards Institute
ARB—arbitrary-waveform generator
ASIC—application-specific integrated circuit
CAE—computer-aided engineering
CMOS—complementary metal-oxide semiconductor
CPU—central processing unit
D/A—digital to analog
DAC—digital-to-analog converter
DCXO—digitally compensated crystal oscillator
DDS—direct digital (frequency) synthesis
DIP—dual in-line package
DSP—digital signal processing
EC—European Community
ECL—emitter-coupled logic
EEPROM—electrically erasable programmable read-only memory
8B/10B—a data-encoding scheme used in Fiber Channel that can encode eight data bits in ten clock cycles
EMC—electromagnetic compatibility
EMI—electromagnetic interference
ESCON—Enterprise Systems Connection; a fiber-optic-based data-communication scheme developed by IBM
FCC—Federal Communications Commission
FDDI—Fiber Distributed Data Interface
4B/5B—a data-encoding scheme used in FDDI that can encode four data bits in five clock cycles
GaAs—gallium arsenide; an alternative to silicon used as a substrate in ICs
IC—integrated circuit
IEC—International Electrotechnical Commission
IEEE-488—The Institute of Electrical and Electronics Engineers' standard for communication with instruments
I/O—input-output
ISA—Industry Standard Architecture; the I/O bus of most MS-DOS PCs
ISO—International Standards Organization
LAN—local-area network
MAC—media access control; a layer in a communication-protocol stack that handles network bandwidth allocation
MCXO—microcomputer-compensated crystal oscillator
MLT-3—multilevel transitional; a proposed encoding scheme that allows 100-Mbps communications on twisted-pair wire
NRZI—nonreturn to zero inverted; a data-encoding scheme used in data-storage and network applications
OCXO—oven-controlled crystal oscillator
OEM—original equipment manufacturer
100Base-T—a proposed encoding scheme that allows 100-Mbps communications on twisted-pair wire
OSI—Open Systems Interconnect; the 7-layer communication model defined by the ISO
pc board—printed-circuit board
PC—personal computer
PHY—physical, an FDDI sublayer that corresponds to the upper half of the physical layer defined in the OSI 7-layer stack
PLL—phase-locked loop
PMD—physical medium dependent; an FDDI sublayer that corresponds to the lower half of the physical layer defined in the OSI 7-layer stack
ppm—parts per million
RFI—radio-frequency interference
RS-232C—an Electronic Industries Association standard for serial communication popular in PCs
SBus—an expansion bus used in workstations made by Sun Microsystems
SCSI—Small Computer System Interface
SMT—station management; a part of the FDDI standard that lies outside the bounds of the 7-layer OSI model
SONET—synchronous optical network; a telecommunication standard conceived to replace T1
TCNS—Thomas-Conrad Network Standard; a proprietary 100-Mbps LAN designed by Thomas Conrad Corp
TCP/IP—transmission control protocol/internet protocol; a standard set of network protocols typically used with the Unix operating system
TCXO—temperature-compensated crystal oscillator
10Base-T—a type of Ethernet that operates on twisted-pair wire
VCXO—voltage-controlled crystal oscillator
VDE—German National Standards Institution (from its title in German)
XO—crystal oscillator

This list includes acronyms and abbreviations found in EDN's Special Report, Technology Updates, and feature articles.

Vendor designs demo package, creates $50 data-acquisition unit

What Dataq had in mind was demonstrating its Codas computer-based oscillograph and data-acquisition system more effectively than a simple demo disk could. In its full-priced version, Codas embodies—besides software—hardware for the 16-bit ISA bus or the Micro Channel Architecture bus. Although a disk containing demo software and files of previously acquired waveforms can provide a decent idea of what interacting with the real product is like, a demo that could let you acquire actual waveforms in real time would provide an even better simulation. So Dataq's engineers designed a minimum-cost hardware module that you can easily connect to any PC.

The RS-232C-interfaced ADC module in Dataq's Codas Demo version isn't very big. You can see it attached to the extension cable at the bottom of the photo.

The resulting $49.95 package includes the $2 \times 2 \times 0.75$-in. DI-100 module. The module plugs into a PC's COM1 RS-232C port and draws all of its operating power from the port. It contains a 1-channel, 10-bit, 5-ksample/sec ADC, a digital-input port, and an oscillator that you can use as a signal source. You can use the module, as we did, simply to observe the oscillator's output waveform. But you can also apply signals of your own, digitize the data, store it on disk, and recall it for subsequent analysis. That analysis can include not just measurements of maximum and minimum values, but also DSP functions such as spectrum analysis and filtering.

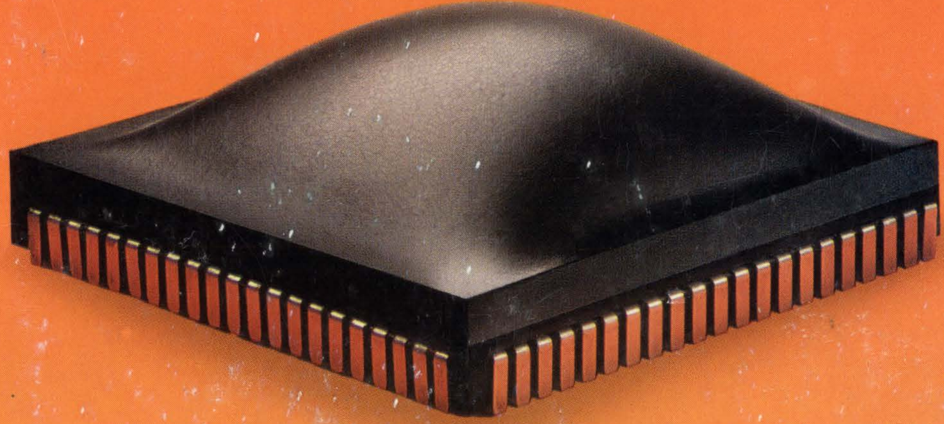
Besides the module and data sheets, the package that EDN received from Dataq included an extension cable terminated in 9-pin D-subminiature connectors. There was also a 9-pin male to 25-pin female D-subminiature adapter. You make your input-signal connections to a 4-position screw-terminal block on the module.

Also in the package were $5\frac{1}{4}$-in., 1.2-Mbyte and $3\frac{1}{2}$-in., 1.44-Mbyte disks containing the demo software and data files. The files are in packed form; running the Install program places them on your hard disk, where they occupy 1.5 Mbytes. Your PC must have 480 kbytes of free RAM. The demo disk contains data files that simulate the ADC output; therefore, if you obtain a copy of the disk from a friend (something that Dataq encourages) but you don't get the ADC module, you can still run the demo software.

The data sheet and the disk label indicate the need for a 640×480-pixel VGA display. Neither one states that a color display is needed, and, indeed, the monochrome display of our Toshiba T2000 laptop seemed quite adequate; there was no need to modify the display's mapping of colors to shades of gray. Several times, though, the speed of the laptop's LCD proved frustratingly slow; to obtain an acceptable waveform display, we had to try different effective sweep speeds. Were it not for the demo's promotional messages (complete with high-resolution graphics), a display with resolution lower than 640×480 pixels probably would work acceptably—if the software included appropriate drivers; it doesn't.

If your data-acquisition requirements are modest and involve only one channel, Dataq's $49.95 demo package is a real bargain. Version 5.3 of the full-scale AT/MCA Codas product, including a data-acquisition board, sells for $2790. Owners of earlier versions of the software can upgrade to Advanced Codas V3.1 for $595.—**Dan Strassberg**

Dataq Instruments Inc, 825 Sweitzer Ave, Akron, OH 44311. Phone (800) 553-9006; (216) 434-4284.



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