Am29368

1 Megabit Dynamic Memory Controller (DMC)

PRELIMINARY

DISTINCTIVE CHARACTERISTICS

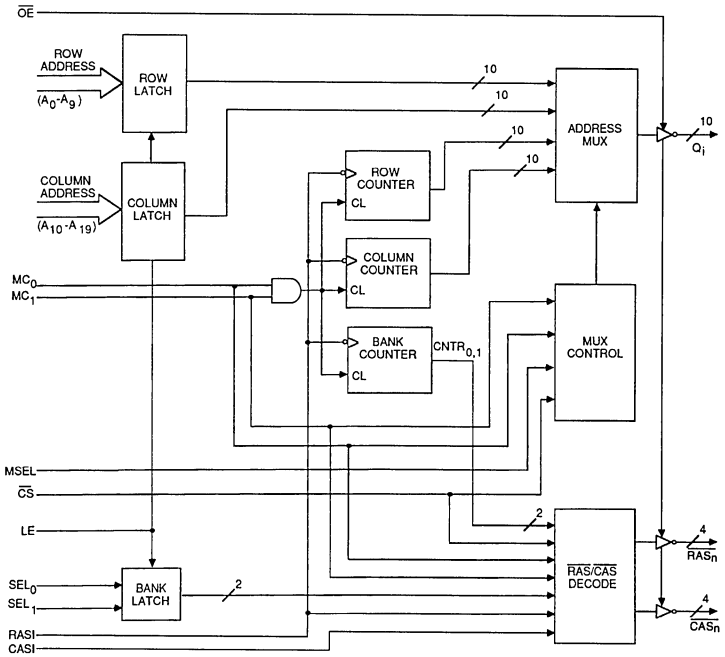
- Provides control for 16K, 64K, and 256K and 1-megabit dynamic RAMs
- Outputs directly drive up to 88 DRAMs, with a guaranteed worst-case limit on the undershoot
- Highest-order two address bits select one of four banks of RAMs
- Separate output enable for multi-channel access to memory
- Supports scrubbing operations and other specialty access modes
- Upgradable from Am2968A 256K DRAM

GENERAL DESCRIPTION

The Am29368 Dynamic Memory Controller (DMC) is intended to be used with today's high performance memory systems. The DMC acts as the address controller between any processor and dynamic memory array, using its two 10-bit address latches to hold the Row and Column addresses for any DRAM up to 1 megabit. These latches, and the two Row/Column refresh address counters, feed into a 10-bit, 4-input MUX for output to the dynamic RAM address lines. A 2-bit bank select latch for the two high-order address bits is provided to select one each of the four $\overline{RAS}_n$ and $\overline{CAS}_n$ outputs.

The Am29368 has two basic modes of operation, read/write and refresh. In refresh mode, the two counters cycle through the refresh addresses. If memory scrubbing is not being implemented, only the Row Counter is used, generating up to 1024 addresses to refresh a 1024-cycle-refresh 1-megabit DRAM. When memory scrubbing is being performed, both the Row and Column counters are used to perform read-modify-write cycles. In this mode all $\overline{RAS}_n$ outputs will be active while only one $\overline{CAS}_n$ is active at a time.

BLOCK DIAGRAM



BD007001

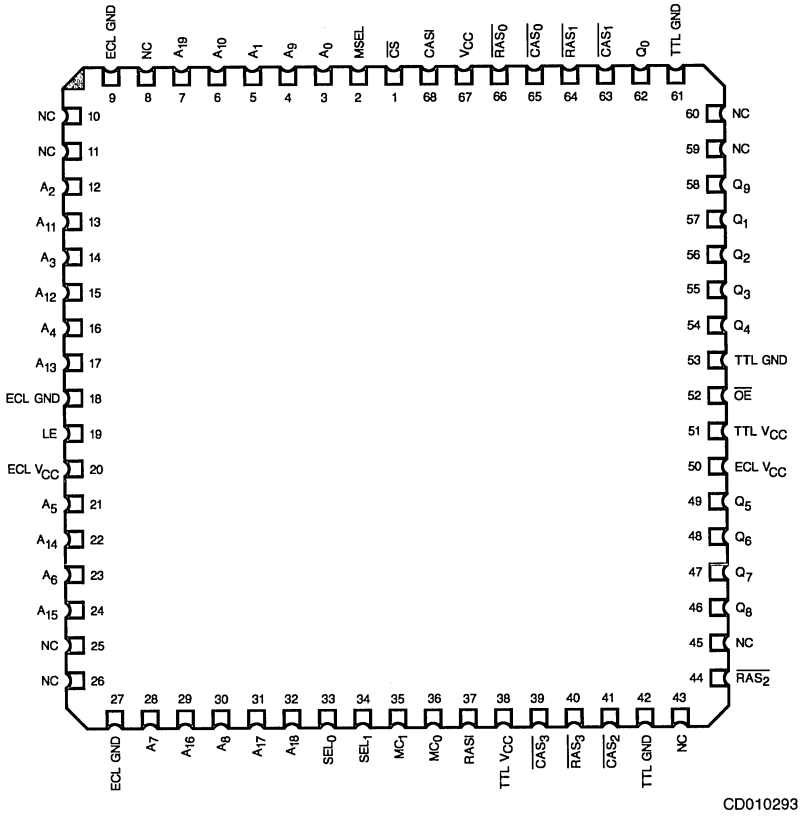
Publication # 05712 | Rev. B | Amendment /0
Issue Date: July 1987

RELATED AMD PRODUCTS

Part No.	Description
Am2960A	16-Bit Error Detection and Correction Unit
Am29C60	16-Bit CMOS EDC
Am2961	EDC Bus Buffer (Inverting)
Am2962	EDC Bus Buffer (Non-Inverting)
Am2968A	256K Dynamic Memory Controller
Am2969	Memory Timing Controller with EDC Control
Am2970	Memory Timing Controller
Am2971	Programmable Event Generator
Am29827/28	High-Performance Buffers with Three-State Outputs (Non-Inverting)
Am29845	Octal High-Performance Bus Interface Latch (Inverting)
Am29846	Octal High-Performance Bus Interface Latch

CONNECTIONS DIAGRAMS
Top View

LCC*

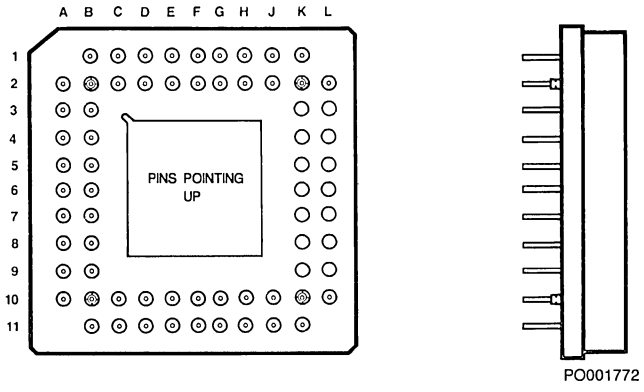


CD010293

*Also available in 68-Pin PLCC. Pinout identical to LCC package.

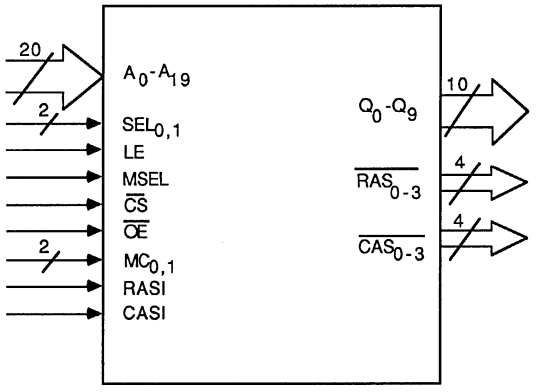
CONNECTIONS DIAGRAMS (Cont'd.)

PGA



PIN DESIGNATIONS							
(SORTED BY PIN NAME)				(SORTED BY PIN NUMBER)			
PIN NAME	PIN NO.	PIN NAME	PIN NO.	PIN NO.	PIN NAME	PIN NO.	PIN NAME
A_0	E-2	NC	A-10	A-2	GND	G-1	V_{CC}
A_1	D-1	NC	B-2	A-3	A_2	G-2	$\overline{RAS_0}$
A_2	A-3	NC	B-3	A-4	A_3	G-10	SEL_1
A_3	A-4	NC	B-10	A-5	A_4	G-11	SEL_0
A_4	A-5	NC	B-11	A-6	GND	H-1	$\overline{CAS_0}$
A_5	A-8	NC	C-1	A-7	LE	H-2	$\overline{RAS_1}$
A_6	A-9	NC	C-11	A-8	A_5	H-10	MC_0
A_7	D-10	NC	D-11	A-9	A_6	H-11	MC_1
A_8	E-11	NC	K-2	A-10	NC	J-1	$\overline{CAS_1}$
A_9	D-1	$\overline{OE}$	K-5	B-1	A_{19}	J-2	Q_0
A_{10}	C-2	Q_0	J-2	B-2	NC	J-10	V_{CC}
A_{11}	B-4	Q_1	K-3	B-3	NC	J-11	RASI
A_{12}	B-5	Q_2	L-3	B-4	A_{11}	K-1	GND
A_{13}	B-6	Q_3	K-4	B-5	A_{12}	K-2	NC
A_{14}	B-8	Q_4	L-4	B-6	A_{13}	K-3	Q_1
A_{15}	B-9	Q_5	L-7	B-7	V_{CC}	K-4	Q_3
A_{16}	E-10	Q_6	K-7	B-8	A_{14}	K-5	$\overline{OE}$
A_{17}	F-11	Q_7	L-8	B-9	A_{15}	K-6	V_{CC}
A_{18}	F-10	Q_8	K-8	B-10	NC	K-7	Q_6
A_{19}	B-1	Q_9	L-2	B-11	NC	K-8	Q_8
CASI	F-1	RASI	J-11	C-1	NC	K-9	GND
$\overline{CAS_0}$	H-1	$\overline{RAS_0}$	G-2	C-2	A_{10}	K-10	$\overline{RAS_3}$
$\overline{CAS_1}$	J-1	$\overline{RAS_1}$	H-2	C-10	GND	K-11	$\overline{CAS_3}$
$\overline{CAS_2}$	L-10	$\overline{RAS_2}$	L-9	C-11	NC	L-2	Q_9
$\overline{CAS_3}$	K-11	$\overline{RAS_3}$	K-10	D-1	A_9	L-3	Q_2
CS	F-2	SEL_0	G-11	D-2	A_1	L-4	Q_4
GND	A-2	SEL_1	G-10	D-10	A_7	L-5	GND
GND	A-6	V_{CC}	L-6	D-11	NC	L-6	V_{CC}
GND	C-10	V_{CC}	B-7	E-1	MSEL	L-7	Q_5
GND	K-1	V_{CC}	J-10	E-2	A_0	L-8	Q_7
GND	L-5	V_{CC}	G-1	E-10	A_{16}	L-9	$\overline{RAS_2}$
GND	K-9	V_{CC}	K-6	E-11	A_8	L-10	$\overline{CAS_2}$
LE	A-7			F-1	CASI		
MC_0	H-10			F-2	CS		
MC_1	H-11			F-10	A_{18}		
MSEL	E-1			F-11	A_{17}		

LOGIC DIAGRAM



LS002881

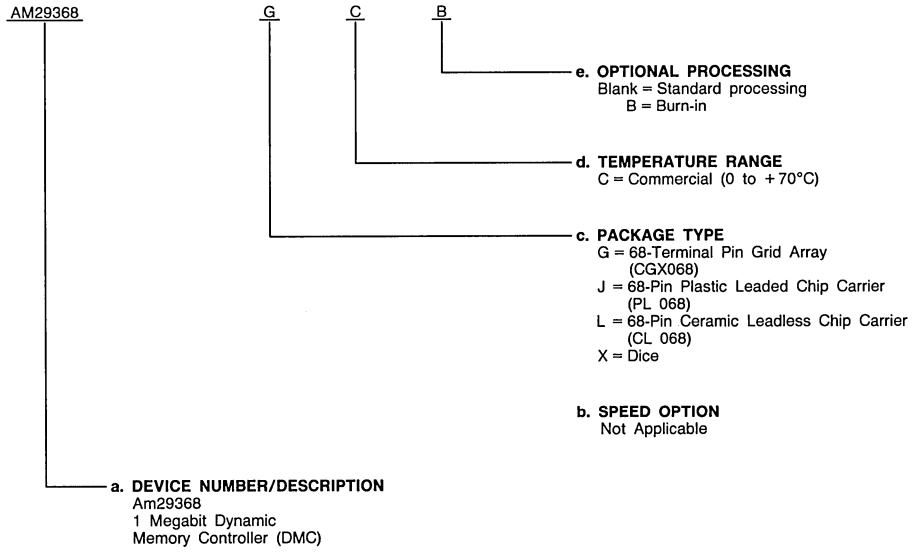
Die Size: 0.205″ x 0.256″ Gate Count: 325

Parameter	PGA	LCC	PLCC	Units
θ_{JA}	34	31	35	°C/Watt
θ_{JC}	N/A	6	N/A	

ORDERING INFORMATION

Standard Products

AMD standard products are available in several packages and operating ranges. The order number (Valid Combination) is formed by a combination of: **a. Device Number**
b. Speed Option (if applicable)
c. Package Type
d. Temperature Range
e. Optional Processing



Valid Combinations	
AM29368	GC, GCB, GE, GEB, JC, JCB, LC, LCB, LEB, XC

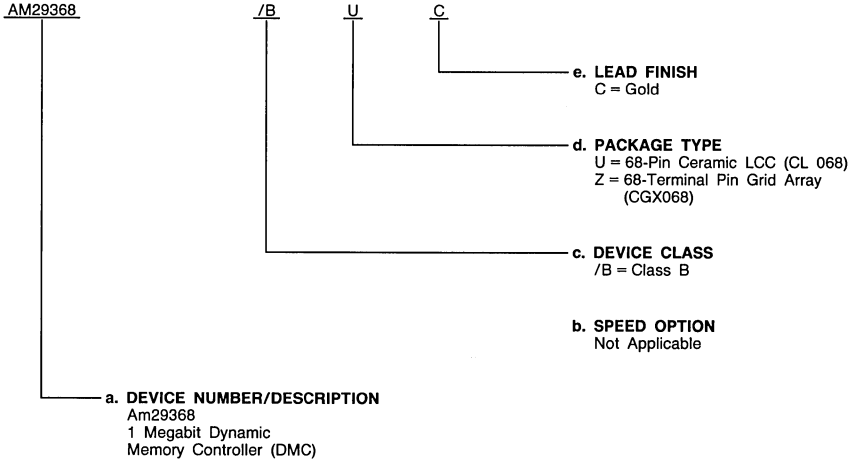
Valid Combinations

Valid Combinations list configurations planned to be supported in volume for this device. Consult the local AMD sales office to confirm availability of specific valid combinations, to check on newly released combinations, and to obtain additional data on AMD's standard military grade products.

ORDERING INFORMATION (Cont'd.)

APL Products

AMD products for Aerospace and Defense applications are available in several packages and operating ranges. APL (Approved Products List) products are fully compliant with MIL-STD-883C requirements.The order number (Valid Combination) for APL products is formed by a combination of: **a. Device Number**
b. Speed Option (if applicable)
c. Device Class
d. Package Type
e. Lead Finish



Valid Combinations	
AM29368	/BUC, /BZC

Valid Combinations

Valid Combinations list configurations planned to be supported in volume for this device. Consult the local AMD sales office to confirm availability of specific valid combinations or to check for newly released valid combinations.

Group A Tests

Group A tests consist of 1, 2, 3, 7, 8, 9, 10, 11

PIN DESCRIPTION

$A_0 - A_{19}$ Address Inputs (Input (20))
$A_0 - A_9$ are latched in as the 10-bit Row Address for the RAM. These inputs drive $Q_0 - Q_9$ when the Am29368 is in the Read/Write mode and MSEL is LOW. $A_{10} - A_{19}$ are latched in as the Column Address, and will drive $Q_0 - Q_9$ when MSEL is HIGH and the DMC is in the Read/Write mode. The addresses are latched with the Latch Enable (LE) signal.

$\overline{CAS}_{0-3}$ Column Address Strobe (Output (4))
During normal Read/Write cycles the two select bits (SEL_0, SEL_1) determine which $\overline{CAS}_n$ output will go active following CASI going HIGH. When memory scrubbing is performed, only the $\overline{CAS}_n$ signal selected by $CNTR_0$ and $CNTR_1$ will be active (see $\overline{CAS}$ Output Function Table). For non-scrubbing cycles, all four $\overline{CAS}_n$ outputs remain HIGH.

CASI Column Address Strobe (Input (1))
This input going active will cause the selected $\overline{CAS}_n$ output to be forced LOW.

$\overline{CS}$ Chip Select (Input (1))
This active-LOW input is used to select the DMC. When $\overline{CS}$ is active, the Am29368 operates normally in all four modes. When $\overline{CS}$ goes HIGH, the device will not enter the Read/Write mode. This allows more than one Am29368 DMC to control multiple memory banks, thus providing an easy method for expanding the memory size.

LE Latch Enable (Input (1))
This active-HIGH input causes the Row, Column, and Bank Select latches to become transparent, allowing the latches to accept new input data. A LOW input on LE latches the input data, assuming it meets the setup and hold time requirements.

MC_{0-1} Mode Control (Input (2))
These inputs are used to specify which of the four operating modes the DMC should be using. The description of the four operating modes is given in Table 1.

MSEL Multiplexer Select (Input (1))
This input determines whether the Row or Column Address will be sent to the memory address inputs. When MSEL is HIGH the Column Address is selected, while the Row Address is selected when MSEL is LOW. The address may come from either the address latch or refresh address counter depending on $MC_{0,1}$.

$\overline{OE}$ Output Enable (Input (1))
This active-LOW input enables/disables the output signals. When $\overline{OE}$ is HIGH, the outputs of the DMC enter the high-impedance state.

Q_{0-9} Address Outputs (Outputs (10))
These address outputs will feed the DRAM address inputs, and provide drive for memory systems up to 500 picofarads in capacitance.

$\overline{RAS}_{0-3}$ Row Address Strobe (Output (4))
Each one of the Row Address Strobe outputs provides a $\overline{RAS}_n$ signal to one of the four banks of dynamic memory. Each will go LOW only when selected by SEL_0 and SEL_1 and only after RASI goes HIGH. All four go LOW in response to RASI in either of the Refresh modes.

RASI Row Address Strobe (Input (1))
During normal memory cycles, the decoded $\overline{RAS}_n$ output ($\overline{RAS}_0$, $\overline{RAS}_1$, $\overline{RAS}_2$, or $\overline{RAS}_3$) is forced LOW after receipt of RASI. In either Refresh mode, all four $\overline{RAS}_n$ outputs will go LOW following RASI going HIGH.

SEL_{0-1} Bank Select (Input (2))
These two inputs are normally the two higher-order address bits, and are used in the Read/Write mode to select which bank of memory will be receiving the $\overline{RAS}_n$ and $\overline{CAS}_n$ signals after RASI and CASI go HIGH.

FUNCTIONAL DESCRIPTION

Architecture

The Am29368 provides all the required data and refresh addresses needed by the dynamic RAM memory. In normal operation, the Row and Column addresses are multiplexed to the dynamic RAM by using MSEL, with the corresponding $\overline{RAS}_n$ and $\overline{CAS}_n$ signals activated to strobe the addresses into the RAM. High capacitance drivers on the outputs allow the DMC to drive four banks of 16-bit words, including a 6-bit checkword, for a total of 88 DRAMs.

TABLE 1. MODE CONTROL FUNCTION TABLE

MC_1	MC_0	Operating Mode
0	0	Refresh without Scrubbing. Refresh cycles are performed with only the Row Counter being used to generate addresses. In this mode, all four $\overline{RAS}_n$ outputs are active while the four $\overline{CAS}_n$ signals are kept HIGH.
0	1	Refresh with Scrubbing/Initialize. During this mode, refresh cycles are done with both the Row and Column counters generating the addresses. MSEL is used to select between the Row and Column counter. All four $\overline{RAS}_n$ go active in response to RASI, while only one $\overline{CAS}_n$ output goes LOW in response to CASI. The Bank Counter keeps track of which $\overline{CAS}_n$ output will go active. This mode is also used on system power-up so that the memory can be written with a known data pattern.
1	0	Read/Write. This mode is used to perform Read/Write cycles. Both the Row and Column addresses are latched and multiplexed to the address output lines using MSEL. SEL_0 and SEL_1 are decoded to determine which $\overline{RAS}_n$ and $\overline{CAS}_n$ will be active.
1	1	Clear Refresh Counter. This mode will clear the three refresh counters (Row, Column, and Bank) on the HIGH-to-LOW transition of RASI, putting them at the start of the refresh sequence. In this mode, all four $\overline{RAS}_n$ are driven LOW upon receipt of RASI so that DRAM wake-up cycles may be performed.

TABLE 2. ADDRESS OUTPUT FUNCTION TABLE

$\overline{CS}$	MC_1	MC_0	MSEL	Mode	MUX Output
0	0	0	X	Refresh without Scrubbing	Row Counter Address
	0	1	1	Refresh with Scrubbing	Column Counter Address
			0		Row Counter Address
	1	0	1	Read/Write	Column Address Latch
			0		Row Address Latch
	1	1	X	Clear Refresh Counter	Zero
1	0	0	X	Refresh without Scrubbing	Row Counter Address
	0	1	1	Refresh with Scrubbing	Column Counter Address
			0		Row Counter Address
	1	0	X	Read/Write	Zero
	1	1	X	Clear Refresh Counter	Zero

TABLE 3. $\overline{RAS}$ OUTPUT FUNCTION TABLE

RASI	$\overline{CS}$	MC_1	MC_0	SEL_1	SEL_0	Mode	$\overline{RAS_0}$	$\overline{RAS_1}$	$\overline{RAS_2}$	$\overline{RAS_3}$
0	X	X	X	X	X	X	1	1	1	1
1	0	0	0	X	X	Refresh without Scrubbing	0	0	0	0
		0	1	X	X	Refresh with Scrubbing	0	0	0	0
		1	0	0	0	Read/Write	0	1	1	1
				0	1		1	0	1	1
				1	0		1	1	0	1
				1	1		1	1	1	0
		1	1	X	X	Clear Refresh Counter	0	0	0	0
	1	0	0	X	X	Refresh without Scrubbing	0	0	0	0
		0	1			Refresh with Scrubbing	0	0	0	0
		1	0			Read/Write	1	1	1	1
		1	1			Clear Refresh Counter	0	0	0	0

TABLE 4. $\overline{CAS}$ OUTPUT FUNCTION TABLE

Inputs						Internal		Outputs			
CASI	$\overline{CS}$	MC_1	MC_0	SEL_1	SEL_0	$CNTR_1$	$CNTR_0$	$\overline{CAS_0}$	$\overline{CAS_1}$	$\overline{CAS_2}$	$\overline{CAS_3}$
1	0	0	0	X	X	X	X	1	1	1	1
		0	1	X	X	0	0	0	1	1	1
						0	1	1	0	1	1
						1	0	1	1	0	1
						1	1	1	1	1	0
		1	0	0	0	X	X	0	1	1	1
				0	1			1	0	1	1
				1	0			1	1	0	1
				1	1			1	1	1	0
		1	1	X	X	X	X	1	1	1	1
	1	0	0	X	X	X	X	1	1	1	1
		0	1	X	X	0	0	0	1	1	1
						0	1	1	0	1	1
						1	0	1	1	0	1
						1	1	1	1	1	0
		1	0	X	X	X	X	1	1	1	1
		1	1								
0	X	X	X	X	X	X	X	1	1	1	1

Input Latches

For those systems where addresses and data are multiplexed onto a single bus, the DMC has latches to hold the address information. The twenty input latches (Row, Column, and Bank Select) are transparent when Latch Enable (LE) is HIGH and will latch the input data meeting setup and hold time requirements when LE goes LOW. For systems where the processor has separate address and data buses, LE may be permanently enabled HIGH.

Refresh Counters

The two 10-bit refresh counters make it possible to support 128, 256, and 512, and 1024 line refresh. External control over which type of refresh is to be performed allows the user maximum flexibility when choosing the refreshing scheme. Transparent (hidden), burst, synchronous or asynchronous refresh modes are all possible.

The refresh counters are advanced at the HIGH-to-LOW transition of RASI. This assures a stable counter output for the next refresh cycle.

Refresh with Error Correction

The Am29368 makes it possible to correct single-bit errors in parallel with performing dynamic RAM refresh cycles. This "scrubbing" of memory can be done periodically as a background routine when the memory is not being used by the processor. In a memory scrubbing cycle ($MC_{1,0} = 01$), the Row Address is strobed into all four banks with all four $\overline{RAS}_n$ outputs going LOW.

The Column Address is strobed into a single bank with the activated $\overline{CAS}_n$ output being selected by the Bank Counter. This type of cycle is used to simultaneously refresh the addressed row in all banks and read and correct (if necessary) one word in memory; thereby reducing the overhead associated with Error Detection and Correction. When doing refresh with memory scrubbing, both the Row and Column counters are multiplexed to the dynamic RAM address lines by using MSEL. Using the Refresh with Memory Scrubbing mode implies the presence of an error correcting facility such as the Am2960A EDC unit. When doing refresh without scrubbing, all four $\overline{RAS}_n$ still go LOW but the $\overline{CAS}_n$ outputs are all driven HIGH so as not to activate the output lines of the memory.

Decoupling

Due to the high switching speeds and high drive capability of the Am29368, it is necessary to decouple the device for proper operation. 1μF multilayer ceramic capacitors are recommended for decoupling (see Figures 1.1 & 1.2). It is important to mount the capacitors as close as possible to the power pins (V_{CC}, GND) to minimize lead inductance and noise. A ground plane is recommended.

It is strongly recommended that the Am29368 be directly surface mounted whenever possible. Should a PLCC, LCC, or PGA socket be required, a one-time-insertion-only socket with minimal lead lengths is necessary for proper device functioning.

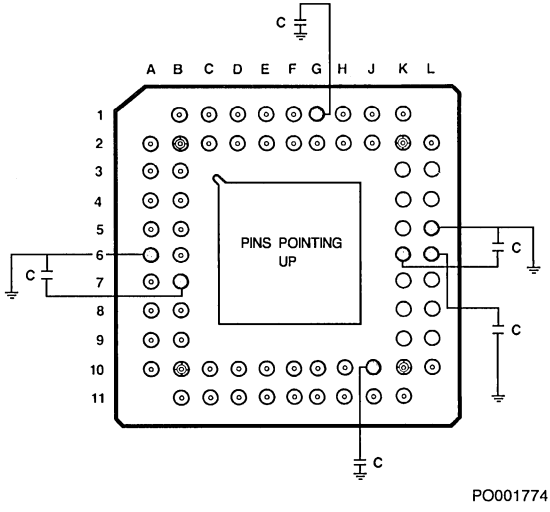


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Figure 1.1. PGA Decoupling Connection Diagram

Note: PGA package has a different footprint from LCC or PLCC in a socket.

PGA Hook-Ups

V_{CC}	GND
K6	L5
L6	GP
G1	GP
J10	GP
B7	A6

GP = Ground Plane

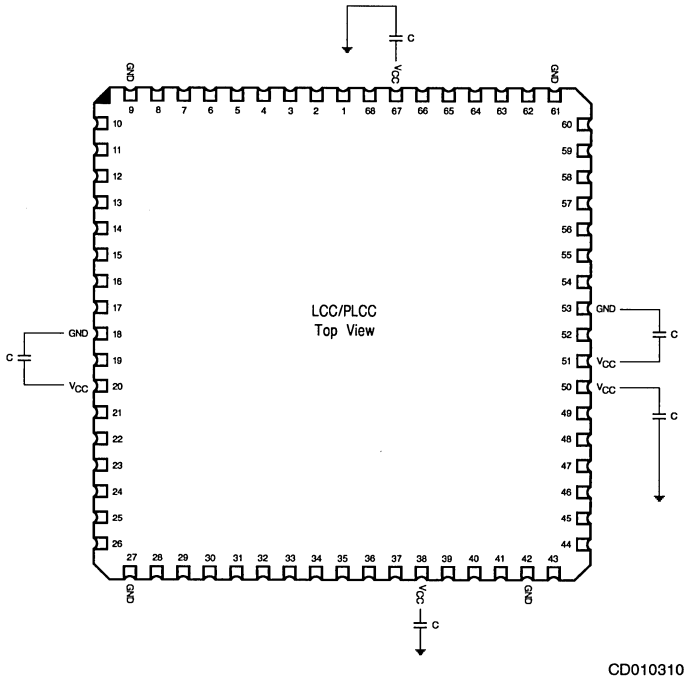


Figure 1.2. LCC/PLCC Decoupling Connection Diagram

V_{ONP}

The guaranteed maximum undershoot voltage of the Am29368 is −1.5 volts. V_{ONP} is measured with respect to ground (see Figure 1.3). Note that the ground of the capacitive load must be the same as for the V_{CC} pin(s). As loading increases, V_{ONP} will approach zero.

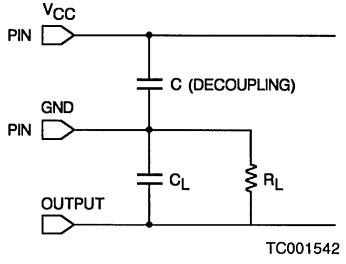
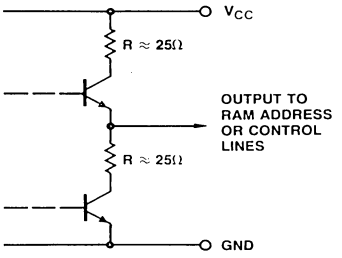


Figure 1.3. V_{ONP} with Respect to Ground

The RAM Driver symmetrical output design offers significant improvement over a standard Schottky output by providing a balanced drive output impedance (≈25 Ω both HIGH and LOW), and by pulling up to MOS V_{OH} levels. External resistors, not required with the RAM Driver, protect standard Schottky drivers from error causing undershoot but also slow the output rise by adding to the internal R.

The RAM Driver is optimized to drive LOW at maximum speed based on safe undershoot control and to drive HIGH with a symmetrical speed characteristic. This is an optimum approach because the dominant RAM loading characteristic is input capacitance.

TYPICAL OUTPUT DRIVER



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APPLICATIONS

Timing Control

To obtain optimum performance and maximum design flexibility, the timing and control logic for the memory system has been kept a separate function. For systems implementing Error Detection and Correction, the Am2969 Memory Timing Controller (MTC) provides all the necessary control signals for the Am29368, Am2961/62 EDC Bus Buffers, and the Am2960A EDC unit (See Figure 2.1). Systems not using EDC, can use the Am2970 MTC to provide the control for the Am29368 (See Figure 2.2). Both the Am2969 and Am2970 Memory Timing Controllers use an Am2971 PEG or delay lines to provide the most accurate timing reference from which the control signals are derived.

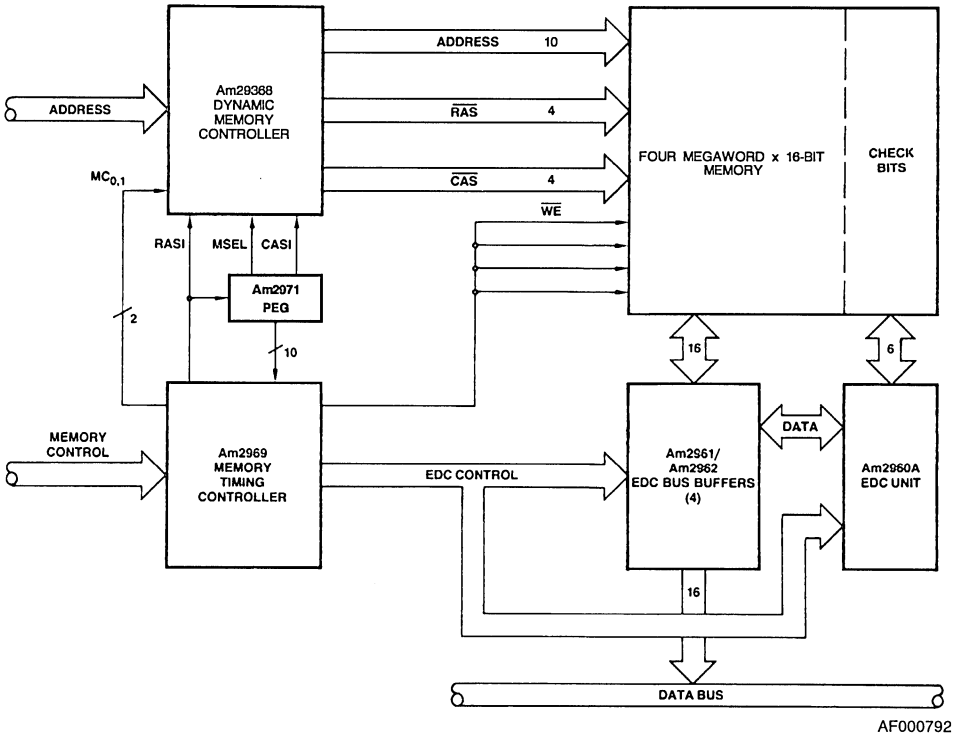

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Figure 2.1. Four Megaword Dynamic Memory with Error Detection and Correction

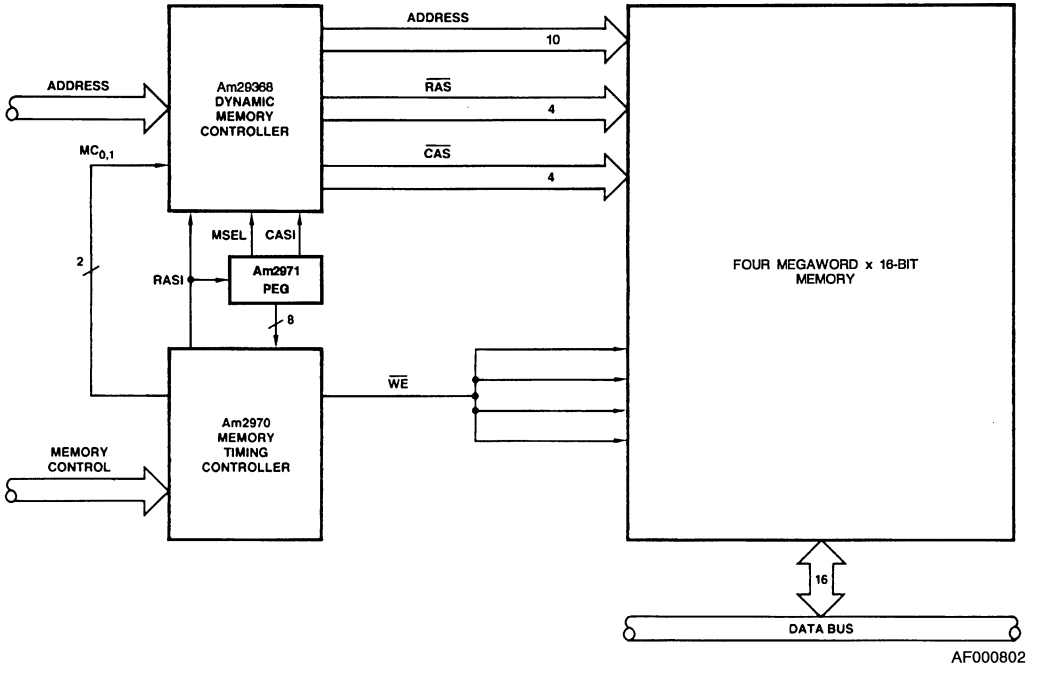


Figure 2.2. Four Megaword Dynamic Memory

Memory Expansion

With a 10-bit address path, the Am29368 can control up to a four megaword memory when using 1M dynamic RAMs. If a larger memory size is desired, the DMC's chip select ($\overline{CS}$) makes it easy to double the memory size by using two Am29368s. Memory can be increased in four megaword increments by adding another DMC unit. A sixteen-megaword memory system implementing EDC is shown in Figure 3.

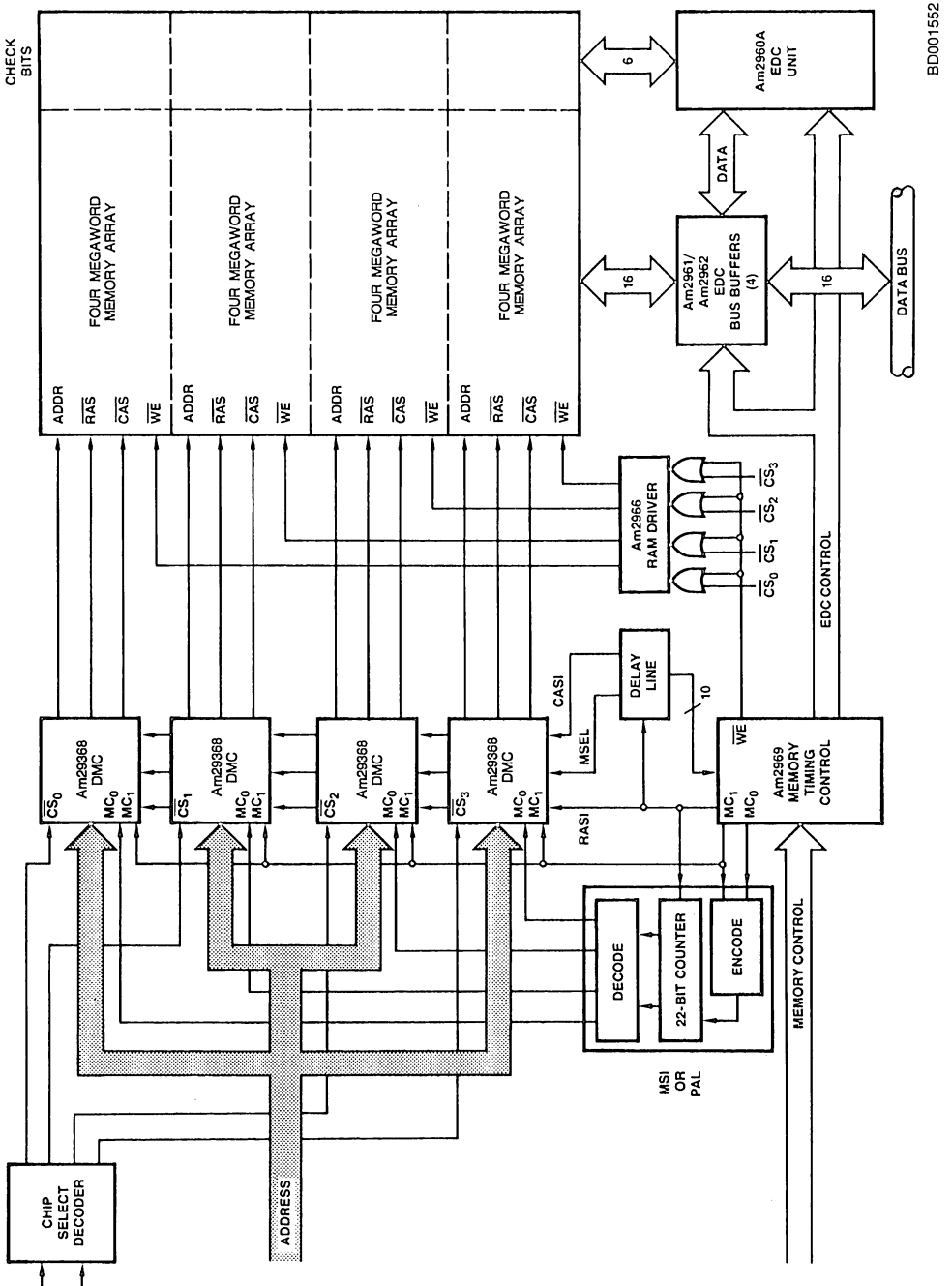


Figure 3. Sixteen Megaword Error Correcting Memory

ABSOLUTE MAXIMUM RATINGS

Storage Temperature ..... −65°C to +150°C
Ambient Temperature with
Power Applied ..... −55°C to +125°C
Supply Voltage to Ground Potential
Continuous ..... −0.5 V to +7.0 V
DC Voltage Applied to Outputs For
High Output State ..... −0.5 V to +V_{CC} max
DC Input Voltage ..... −0.5 V to +5.5 V
DC Input Current ..... −30 mA to +5.0 mA

Stresses above those listed under ABSOLUTE MAXIMUM RATINGS may cause permanent device failure. Functionality at or above these limits is not implied. Exposure to absolute maximum ratings for extended periods may affect device reliability.

OPERATING RANGES

Commercial (C) Devices
T_A (Ambient) ..... 0 to +70°C
V_{CC} ..... 5.0 V ±10%
Min ..... 4.50 V
Max ..... 5.50 V

Military* (M) Devices or Extended Commercial (E) Devices
T_C (Case) ..... −55 to +125°C
V_{CC} ..... 5.0 V ±10%
Min ..... 4.50 V
Max ..... 5.50 V

Operating ranges define those limits between which the functionality of the device is guaranteed.

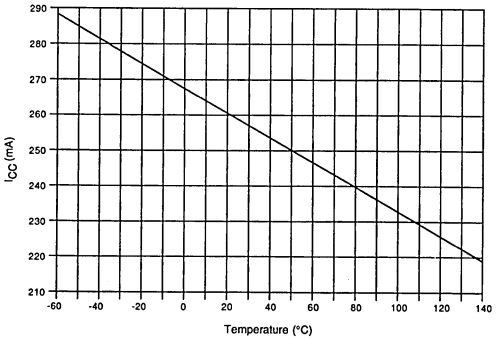
*Military Product 100% tested at T_C = +25°C, +125°C, and −55°C.

DC CHARACTERISTICS over operating ranges unless otherwise specified; Included in Group A, Subgroup 1, 2, 3 tests unless otherwise noted.

Parameters	Descriptions	Test Conditions (Note 1)		Min.	Typ.	Max.	Units
V_{OH}	Output HIGH Voltage	V_{CC} = Min., V_{IN} = V_{IH} or V_{IL}, I_{OH} = −1 mA	COMM	2.7			Volts
			MIL	2.5			
V_{OL}	Output LOW Voltage	V_{CC} = Min., V_{IN} = V_{IH} or V_{IL}	I_{OL} = 1 mA			0.5	Volts
			I_{OL} = 12 mA			0.8	
V_{IH}	Input HIGH Level	Guaranteed input logical-HIGH voltage for all inputs		2.0			Volts
V_{IL}	Input LOW Level	Guaranteed input logical-LOW voltage for all inputs				0.8	Volts
V_I	Input Clamp Voltage	V_{CC} = Min., I_{IN} = −18 mA				−1.2	Volts
I_{IL}	Input LOW Current	V_{CC} = Max., V_{IN} = 0.4 V				−400	μA
I_{IH}	Input HIGH Current	V_{CC} = Max., V_{IN} = 2.4 V				20	μA
I_I	Input HIGH Current	V_{CC} = Max., V_{IN} = 5.5 V				100	μA
I_{OZH}	Off-State Current	V_O = 2.4 V				50	μA
I_{OZL}	Off-State Current	V_O = 0.4 V				−50	μA
I_{OL}	Output Sink Current	V_{OL} = 2.0 V		45			mA
I_{SC}	Output Short-Circuit Current	V_{CC} = Max. (Note 2)		−60	−95	−275	mA
I_{CC}	Power Supply Current	V_{CC} = Max.	25°C, 5 V		260		mA
			0°C to +70°C			375	
			−55°C to 125°C			415	

Notes: 1. For conditions shown as Min or Max, use the appropriate value specified under Operating Range for the applicable device type.
2. Not more than one output should be shorted at a time. Duration of the short-circuit test should not exceed one second.

TYPICAL I_{CC} Change with Temperature



OP002590

SWITCHING CHARACTERISTICS over operating range unless otherwise specified

Light Capacitive Loading (Small System)

No.	Parameter Symbol	Parameter Description	Test Conditions		Min.	Max.	Units
ADDRESS/RASI/CASI/LE LINES (Note 1)							
1	t_{PD}	A_n to Q_n	C_L = 50 pF		3	20	ns
2	t_{PD}	MSEL to Q_n	C_L = 50 pF		3	20	ns
3	t_{PD}	MC_n to Q_n	C_L = 50 pF		5	24	ns
4	t_{PD}	LE to Q_n	C_L = 50 pF		5	25	ns
5	t_{PD}	$\overline{CS}$ to Q_n	C_L = 50 pF			23	ns
6	t_S	A_n/SEL_n to LE (Note 2)	C_L = 50 pF		5		ns
7	t_H	A_n/SEL_n to LE (Note 2)	C_L = 50 pF		5		ns
8	t_H	MC_1 to RASI	C_L = 50 pF		5		ns
9	t_S	$\overline{CS}$ to RASI	C_L = 50 pF		5		ns
10	t_S	SEL_n to RASI	C_L = 50 pF		5		ns
11	t_{PWL}	RASI, CASI	C_L = 50 pF		20		ns
12	t_{PWH}	RASI, CASI	C_L = 50 pF		20		ns
$\overline{RAS_n}/\overline{CAS_n}$ LINES (Notes 1 and 3)							
13	t_{PD}	RASI to $\overline{RAS_n}$	C_L = 50 pF		3	18	ns
14	t_{PD}	CASI to $\overline{CAS_n}$	C_L = 50 pF		3	17	ns
15	t_{PD}	LE to $\overline{RAS_n}$	C_L = 50 pF			25	ns
16	t_{PD}	LE to $\overline{CAS_n}$	C_L = 50 pF			24	ns
17	t_{PD}	MC_n to $\overline{RAS_n}$	C_L = 50 pF		3	21	ns
18	t_{PD}	MC_n to $\overline{CAS_n}$	C_L = 50 pF		3	19	ns
19	t_{PD}	$\overline{CS}$ to $\overline{RAS_n}$	C_L = 50 pF			20	ns
20	t_{PD}	$\overline{CS}$ to $\overline{CAS_n}$	C_L = 50 pF			19	ns
21	t_{PD}	SEL_n to $\overline{RAS_n}$	C_L = 50 pF			20	ns
22	t_{PD}	SEL_n to $\overline{CAS_n}$	C_L = 50 pF			18	ns
23	t_{SKEW}	[t_{PD} (RASI to $\overline{RAS_n}$) – t_{PD} (A_n to Q_n)] (MC_n = 10)	C_L = 200 pF		–4	11	ns
			C_L = 350 pF		2	11	
24	t_{SKEW}	[t_{PD} (RASI to $\overline{RAS_n}$) – t_{PD} (MC_n to Q_n)] (MC_n = 00, 01)	C_L = 200 pF		–5	11	ns
			C_L = 350 pF		0	11	
25	t_{SKEW}	[t_{PD} (MSEL to $\overline{Q_n}$) – t_{PD} (RASI to $\overline{RAS_n}$)]	C_L = 200 pF		– 15	– 2	ns
			C_L = 350 pF		– 15	– 8	
26	t_{SKEW}	[t_{PD} (CASI to $\overline{CAS_n}$) – (MSEL to Q_n)]	C_L = 200 pF		– 3	11	ns
			C_L = 350 pF		2	11	
THREE-STATE OUTPUTS/UNDERSHOOT (Note 4)							
27	t_{PLZ}	Output Disable Time from LOW, HIGH	C_L = 50 pF	S = 1		22	ns
28	t_{PHZ}			S = 2		20	
29	t_{PZL}	Output Enable Time from LOW, HIGH	C_L = 50 pF	S = 1		19	ns
30	t_{PZH}			S = 2		21	
31	V_{ONP}	Output Undershoot Voltage (Note 5)	C_L = 50 pF			– 1.5	V

Notes: See notes following the Heavy Capacitive Loading Switching Characteristics table.

SWITCHING CHARACTERISTICS (Cont'd.)

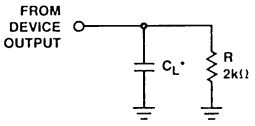
Heavy Capacitive Loading (Large Systems)

No.	Parameter Symbol	Parameter Description	Test Conditions	Min.	Max.	Units
ADDRESS/RASI/CASI/LE LINES (Note 1)						
1	t_{PD}	A_n to Q_n	C_L = 500 pF	12	40	ns
2	t_{PD}	MSEL to Q_n	C_L = 500 pF	12	42	ns
3	t_{PD}	MC_n to Q_n	C_L = 500 pF	12	44	ns
4	t_{PD}	LE to Q_n	C_L = 500 pF	12	46	ns
5	t_{PD}	$\overline{CS}$ to Q_n	C_L = 500 pF		45	ns
6	t_S	A_n/SEL_n to LE	C_L = 500 pF	5		ns
7	t_H	A_n/SEL_n to LE (Note 2)	C_L = 500 pF	5		ns
8	t_H	MC_1 to RASI (Note 2)	C_L = 500 pF	5		ns
9	t_S	$\overline{CS}$ to RASI	C_L = 500 pF	5		ns
10	t_S	SEL_n to RASI	C_L = 500 pF	5		ns
11	t_{PWL}	RASI, CASI	C_L = 500 pF	20		ns
12	t_{PWH}	RASI, CASI	C_L = 500 pF	20		ns
$\overline{RAS_n}/\overline{CAS_n}$ LINES (Notes 1 and 3)						
13	t_{PD}	RASI to $\overline{RAS_n}$	C_L = 200 pF	10	25	ns
			C_L = 350 pF	11	33	
14	t_{PD}	CASI to $\overline{CAS_n}$	C_L = 200 pF	10	24	ns
			C_L = 350 pF	11	31	
15	t_{PD}	LE to $\overline{RAS_n}$	C_L = 200 pF		31	ns
			C_L = 350 pF		38	
16	t_{PD}	LE to $\overline{CAS_n}$	C_L = 200 pF		30	ns
			C_L = 350 pF		37	
17	t_{PD}	MC_n to $\overline{RAS_n}$	C_L = 200 pF	10	27	ns
			C_L = 350 pF	11	34	
18	t_{PD}	MC_n to $\overline{CAS_n}$	C_L = 200 pF	10	29	ns
			C_L = 350 pF	11	37	
19	t_{PD}	$\overline{CS}$ to $\overline{RAS_n}$	C_L = 200 pF		25	ns
			C_L = 350 pF		32	
20	t_{PD}	$\overline{CS}$ to $\overline{CAS_n}$	C_L = 200 pF		24	ns
			C_L = 350 pF		31	
21	t_{PD}	SEL_n to $\overline{RAS_n}$	C_L = 200 pF		26	ns
			C_L = 350 pF		34	
22	t_{PD}	SEL_n to $\overline{CAS_n}$	C_L = 200 pF		25	ns
			C_L = 350 pF		33	
23	t_{SKEW}	[t_{PD} (RASI to $\overline{RAS_n}$) – t_{PD} (A_n to Q_n)] (MC_n = 10)	C_L = 200 pF	– 17	– 3	ns
			C_L = 350 pF	– 13	– 3	
24	t_{SKEW}	[t_{PD} (RASI to $\overline{RAS_n}$) – t_{PD} (MC_n to Q_n)] (MC_n = 00, 01)	C_L = 200 pF	– 16	– 1	ns
			C_L = 350 pF	– 16	– 1	
25	t_{SKEW}	[t_{PD} (MSEL to $\overline{Q_n}$) – t_{PD} (RASI to $\overline{RAS_n}$)]	C_L = 200 pF	– 6	11	ns
			C_L = 350 pF	– 6	6	
26	t_{SKEW}	[t_{PD} (CASI to $\overline{CAS_n}$) – (MSEL to Q_n)]	C_L = 200 pF	– 18	– 5	ns
			C_L = 350 pF	– 13	– 5	

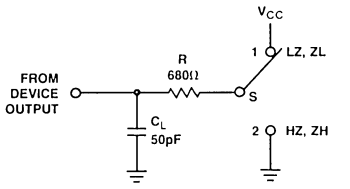
Notes:

1. Reference Figures A and C apply to all parameters except Parameters 8, 9, and 10.
2. Hold times are not tested, but are guaranteed by characterization data. Not included in Group A testing.
3. C_L = 200 pF loading corresponds to 4 banks, 22 bits (16 data bits + 6 check bits).
   C_L = 350 pF loading corresponds to 4 banks, 39 bits (32 data bits + 7 check bits). For additional loading information or to calculate t_{PD} between specified loads, see section labled "NANOSECONDS VERSUS PICOFARADS" following the Switching Waveforms. All parameters with a 200 pF load are not tested but are guaranteed by characterization data. Not included in Group A testing.
4. Not included in Group A testing. Reference Figures B and D apply.
5. V_{ONP} is not production tested but is guaranteed by characterization data. Limit specified is for all outputs switching simultaneously with minimum specified loading. As loading increases, V_{ONP} will approach zero.

SWITCHING TEST CIRCUITS



TC000490



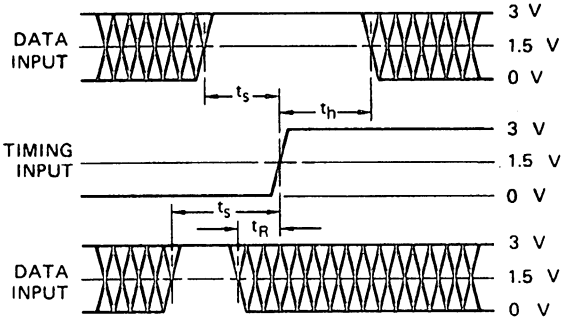
TC000510

*t_{pd} specified at C_L = 50 and 500 pF for Q_n
C_L = 50 and 350 pF for $\overline{RAS_n}$, $\overline{CAS_n}$

A. Capacitive Load Switching

B. Three-State Enable/Disable

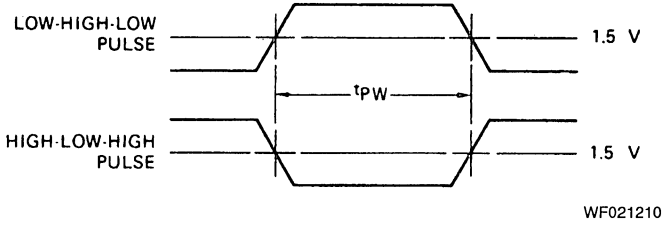
SWITCHING TEST WAVEFORMS



WF021190

A. Setup, Hold, and Release Times

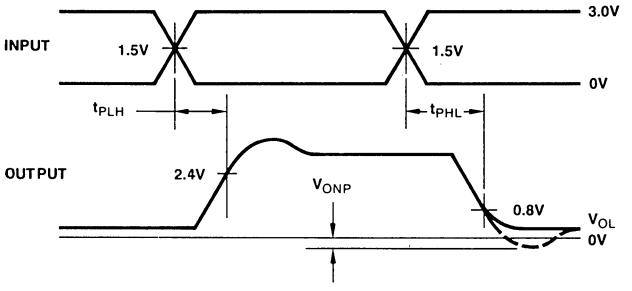
Notes: 1. Diagram shown for HIGH data only. Output transition may be opposite sense.
2. Cross-hatched are "don't care" condition.



WF021210

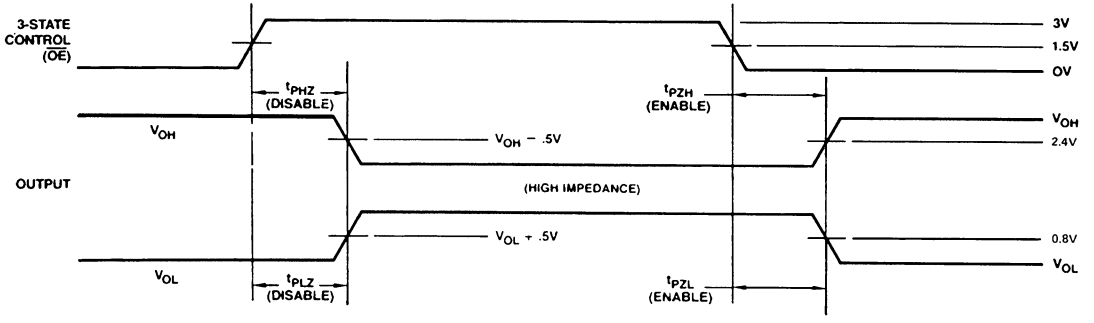
B. Pulse Width

SWITCHING TEST WAVEFORMS (Cont'd.)



WF002122

C. Output Drivers Levels



WFR02941

Note: Decoupling is needed for all AC tests

D. Three-State Control Levels

General Test Notes

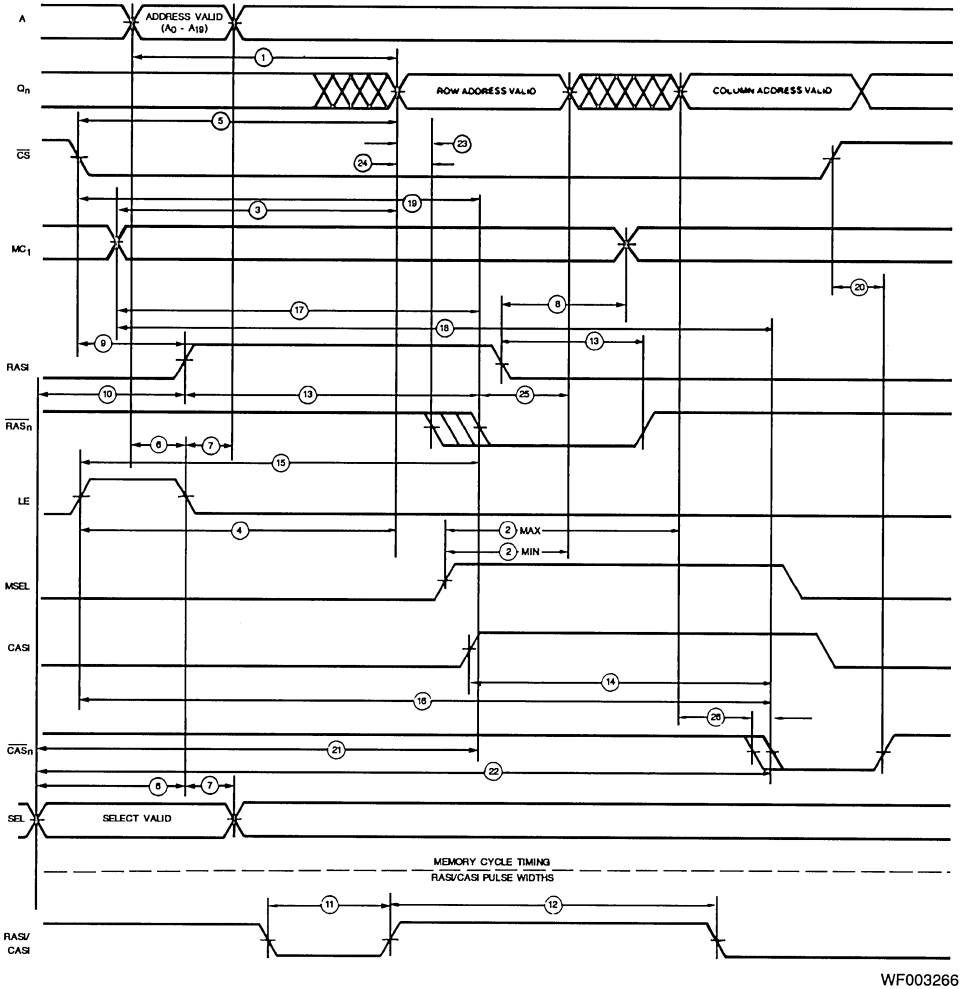
Incoming test procedures on this device should be carefully planned, taking into account the complexity and power levels of the part. The following notes may be useful.

1. Insure the part is adequately decoupled at the test head. Large changes in V_{CC} current as the device switches may cause erroneous function failures due to V_{CC} changes.
2. Do not leave inputs floating during any tests, as they may start to oscillate at high frequency.
3. Do not attempt to perform threshold tests at high speed. Following an input transition, ground current may change by as much as 400 mA in 5-8 ns. Inductance in the ground cable may allow the ground pin at the device to rise by 100's of millivolts momentarily.
4. Use extreme care in defining input levels for AC tests. Many inputs may be changed at once, so there will be significant noise at the device pins and they may not actually reach V_{IL} or V_{IH} until the noise has settled. AMD recommends using $V_{IL} \leqslant 0$ V and $V_{IH} \geqslant 4$ V for AC tests.
5. To simplify failure analysis, programs should be designed to perform DC, Function, and AC tests as three distinct groups of tests.
6. Automatic tester hardware and handler add additional round trip A.C. delay to test measurements. Actual propagation delay testing may incorporate a correlation factor to negate the additional delay.

SWITCHING WAVEFORMS
KEY TO SWITCHING WAVEFORMS

WAVEFORM	INPUTS	OUTPUTS
———	MUST BE STEADY	WILL BE STEADY
⋀⋀⋀	MAY CHANGE FROM H TO L	WILL BE CHANGING FROM H TO L
⋁⋁⋁	MAY CHANGE FROM L TO H	WILL BE CHANGING FROM L TO H
⋈⋈⋈	DON'T CARE; ANY CHANGE PERMITTED	CHANGING; STATE UNKNOWN
⋈⋈⋈	DOES NOT APPLY	CENTER LINE IS HIGH IMPEDANCE "OFF" STATE

KS000010



WF003266

Am29368 Dynamic Memory Controller Timing

Memory Cycle Timing

The relationship between DMC specifications and system timing requirements are shown in Figure 4. T_1, T_2 and T_3 represent the minimum timing requirements at the DMC inputs to guarantee that RAM timing requirements are met and that maximum system performance is achieved.

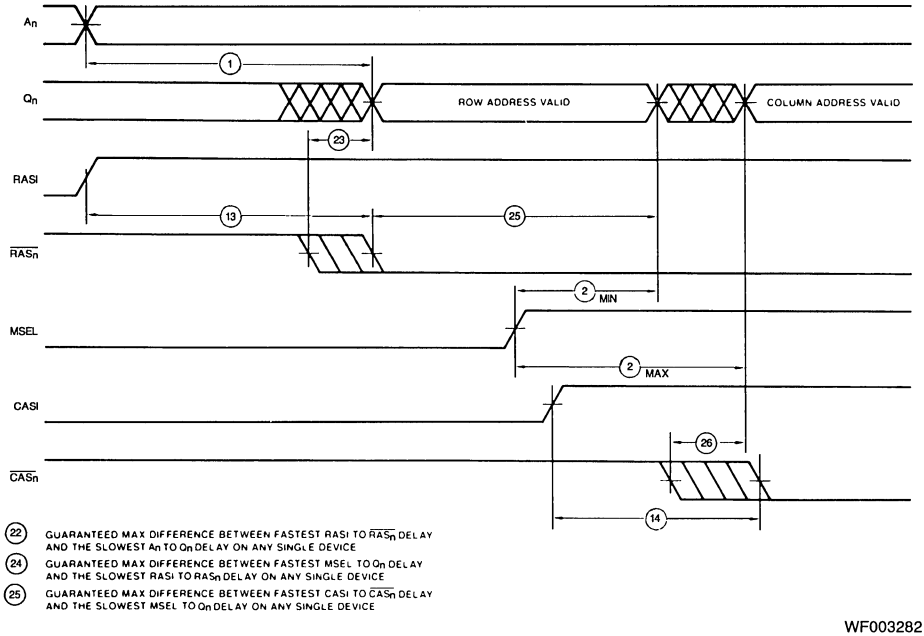
The minimum requirement for T_1, T_2 and T_3 are as follows:

T_1 Min. = $t_{ASR} + t_{23}$
T_2 Min. = $t_{RAH} + t_{25}$
T_3 Min. = $T_2 + t_{26} + t_{ASC}$

See RAM data sheet for applicable values for t_{RAH}, t_{ASC} and t_{ASR}.

Figure 4. Memory Cycle Timing

a. Specifications Applicable to Memory Cycle Timimg (MC_n = 1, 0)



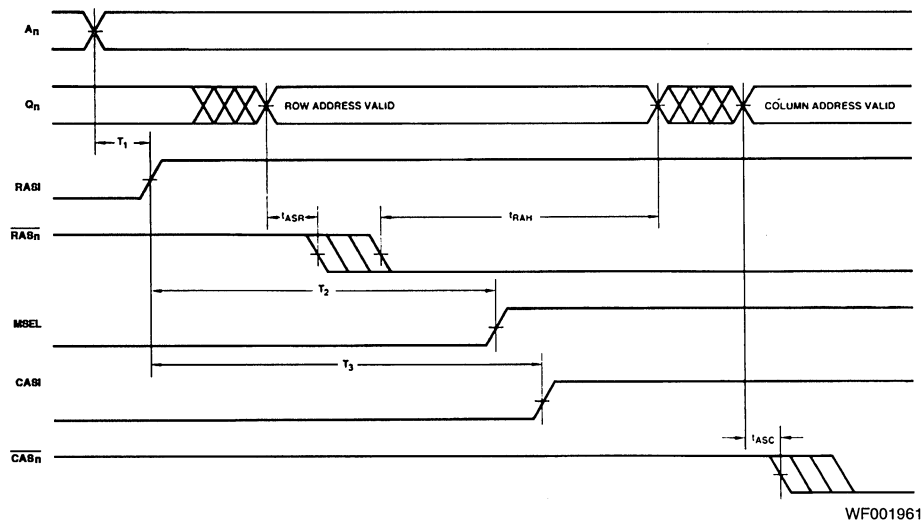
(22) GUARANTEED MAX DIFFERENCE BETWEEN FASTEST RASI TO $\overline{RAS_n}$ DELAY AND THE SLOWEST A_n TO Q_n DELAY ON ANY SINGLE DEVICE

(24) GUARANTEED MAX DIFFERENCE BETWEEN FASTEST MSEL TO Q_n DELAY AND THE SLOWEST RASI TO RAS_n DELAY ON ANY SINGLE DEVICE

(25) GUARANTEED MAX DIFFERENCE BETWEEN FASTEST CASI TO $\overline{CAS_n}$ DELAY AND THE SLOWEST MSEL TO Q_n DELAY ON ANY SINGLE DEVICE

WF003282

b. Desired System Timing



WF001961

Refresh Cycle Timing

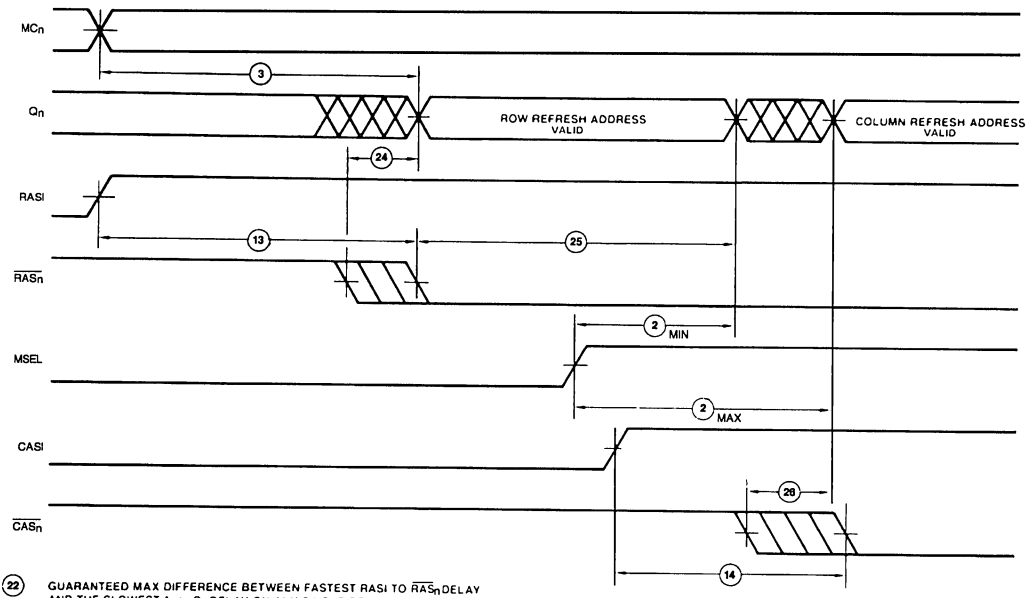
The timing relationships for refresh are shown in Figure 5.

T_4 minimum is calculated as follows:

T_4 Min. = $t_{ASR} + t_{24}$

Figure 5. Refresh Cycle Timing

a. Specifications Applicable to Refresh Cycle Timing (MC_n = 00, 01)



(22) GUARANTEED MAX DIFFERENCE BETWEEN FASTEST RASI TO $\overline{RAS}_n$ DELAY AND THE SLOWEST A_n to Q_n DELAY ON ANY SINGLE DEVICE

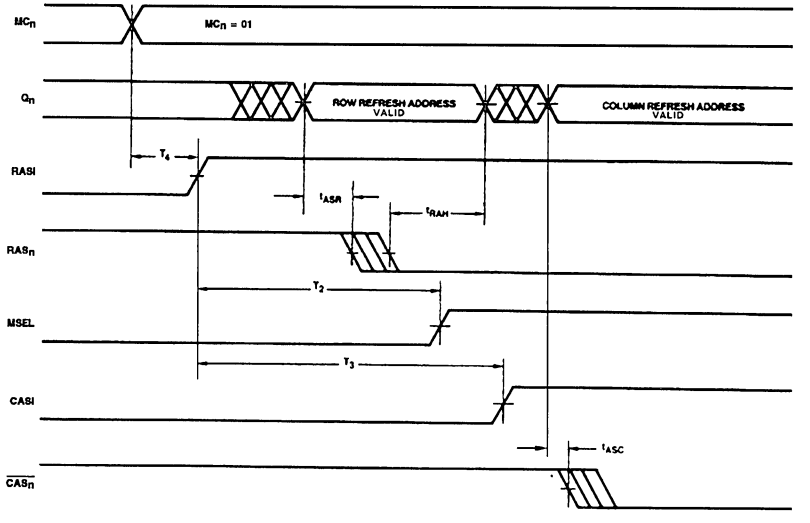
(23) GUARANTEED MAX DIFFERENCE BETWEEN FASTEST RASI TO $\overline{RAS}_n$ DELAY AND THE SLOWEST MC_n TO Q_n DELAY ON ANY SINGLE DEVICE

(24) GUARANTEED MAX DIFFERENCE BETWEEN FASTEST MSEL TO Q_n DELAY AND THE SLOWEST RASI TO $\overline{RAS}_n$ DELAY ON ANY SINGLE DEVICE

(25) GUARANTEED MAX DIFFERENCE BETWEEN FASTEST CASI TO CAS_n DELAY AND THE SLOWEST MSEL TO Q_n DELAY ON ANY SINGLE DEVICE

WF003272

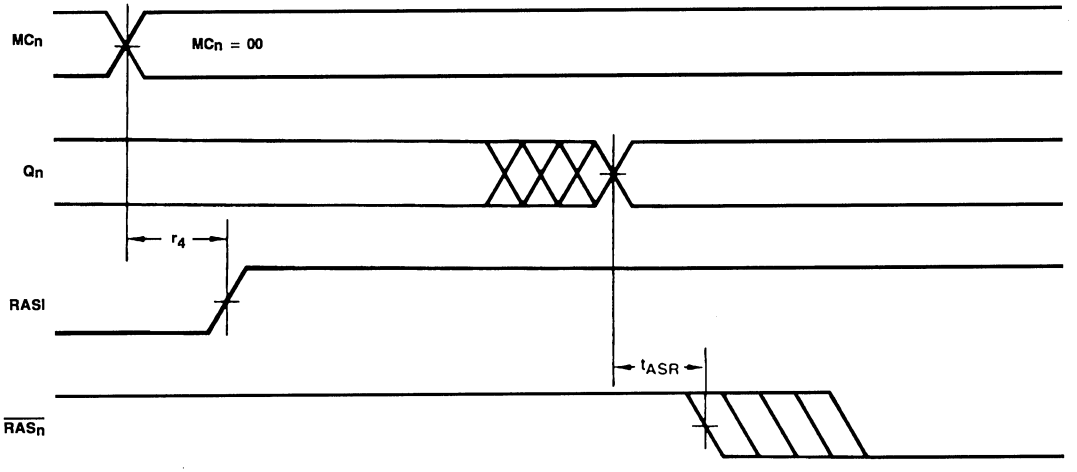
b. Desired Timing: Refresh with Scrubbing



WF001982

Figure 5. Refresh Cycle Timing (Cont'd.)

c. Desired Timing: Refresh without Scrubbing



WF003252

TYPICAL PERFORMANCE CURVES

NANOSECONDS VERSUS PICOFARADS

The Switching Characteristics Tables specify the minimum and maximum propagation delays for effective capacitive loads of 50 pF and 500 pF on Address Lines and 50 pF, 200 pF, and 350 pF on $\overline{RAS_n}$ and $\overline{CAS_n}$ Lines. The upper limits represent the maximum calculated load for the following conditions:

Address Lines: 500 pF = 16 data bits + 6 check bits, four banks

500 pF = 32 data bits + 7 check bits, two banks

$\overline{RAS_n}/\overline{CAS_n}$: 200 pF = 16 data bits + 6 check bits, four banks

350 pF = 32 data bits + 7 check bits, four banks

A more comprehensive analysis of loading is given in the table below.

16-Bit Systems (plus 6 Check Bits for Error Detection and Correction)

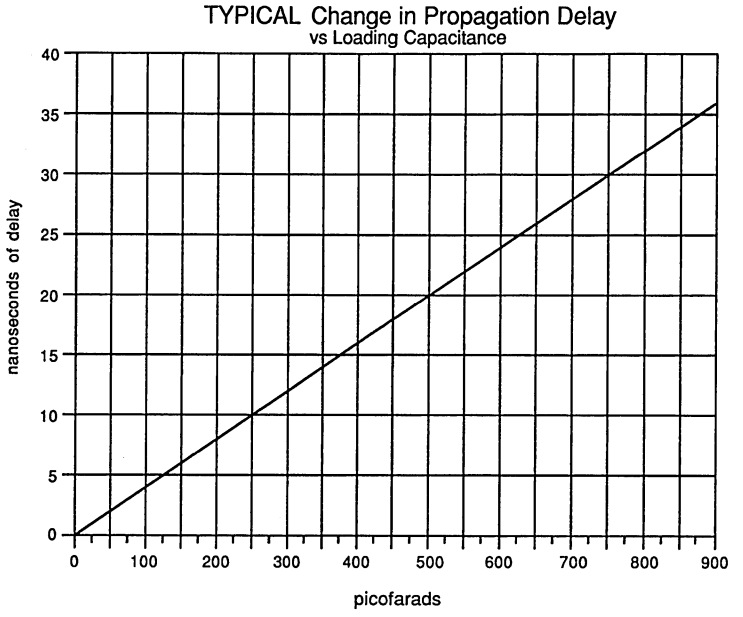
DMC Output	No. of DRAMS	Line Drive	Total Required Drive for Indicated Banks			Specified Data Sheet Load
			1	2	4	
Q_n (Address)	16 + 6 = 22	5 pF	100 pF	220 pF	440 pF	500 pF
$\overline{RAS_n}$		8 pF	176 pF	176 pF	176 pF	200 pF
$\overline{CAS_n}$		8 pF	176 pF	176 pF	176 pF	200 pF

32-Bit Systems (plus 7 Check Bits for Error Detection and Correction)

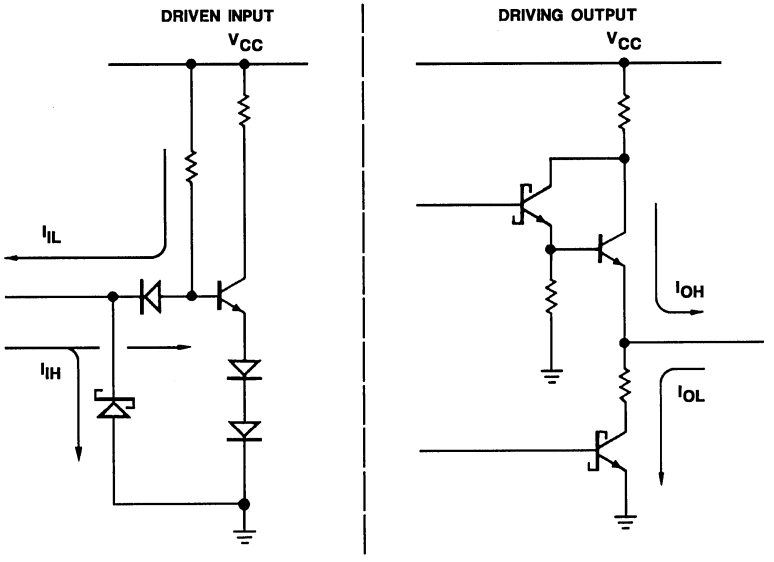
DMC Output	No. of DRAMS	Line Drive	Total Required Drive for Indicated Banks			Specified Data Sheet Load
			1	2	4	
Q_n (Address)	32 + 7 = 39	5 pF	195 pF	390 pF	780 pF	500 pF
$\overline{RAS_n}$		8 pF	312 pF	312 pF	312 pF	350 pF
$\overline{CAS_n}$		8 pF	312 pF	312 pF	312 pF	350 pF

To calculate propagation delays at loads other than those which are specified, the following graph has been provided. For example, to calculate a system capacitive load of 275 pF, add the delay associated with 75 pF from the graph to the 200 pF $\overline{RAS_n}/\overline{CAS_n}$ delay as specified in the Switching Characteristics Tables. Likewise, add the delay associated with 225 pF from the graph to the 50 pF Q_n (Address) delay in the same AC Tables. This provides a 275 pF load for $\overline{RAS_n}$, $\overline{CAS_n}$, and Q_n lines.

For 32-bit systems using four banks, the Address line delays can be adjusted in a similar fashion to compensate for loads exceeding the 500 pF specified. The specified 350 pF load is sufficient to drive four 32-bit banks $\overline{RAS_n}/\overline{CAS_n}$ without additional delay.



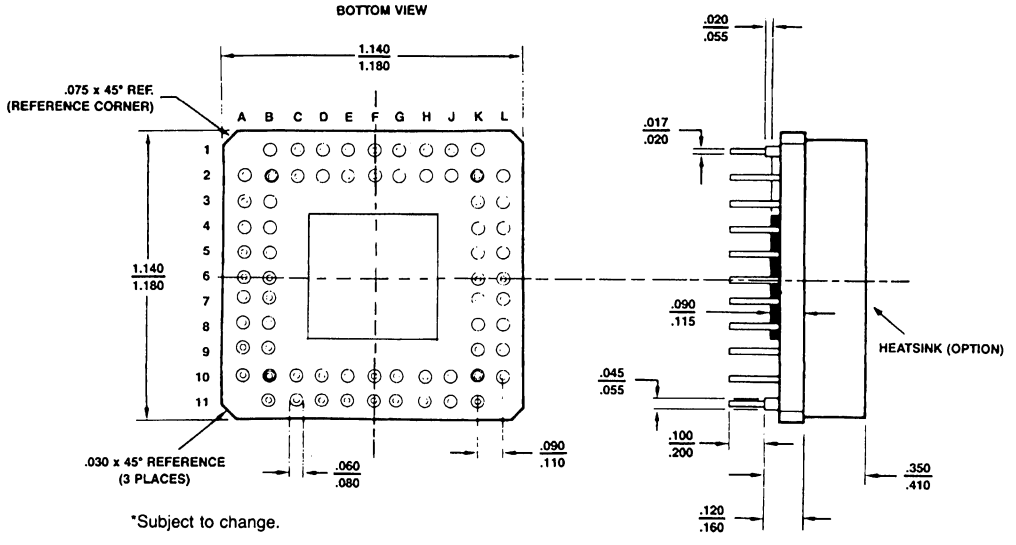
INPUT/OUTPUT CIRCUIT DIAGRAM



IC000791

PHYSICAL DIMENSIONS*

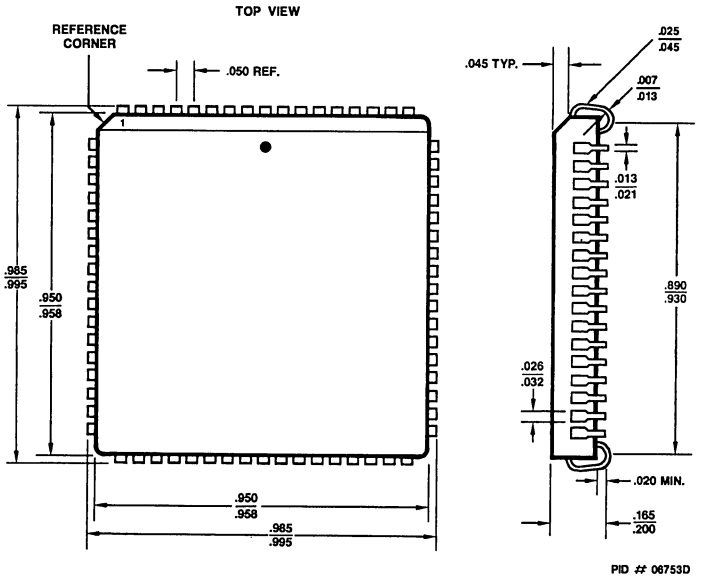
CGX068



*Subject to change.

PID # 07547A

PL 068

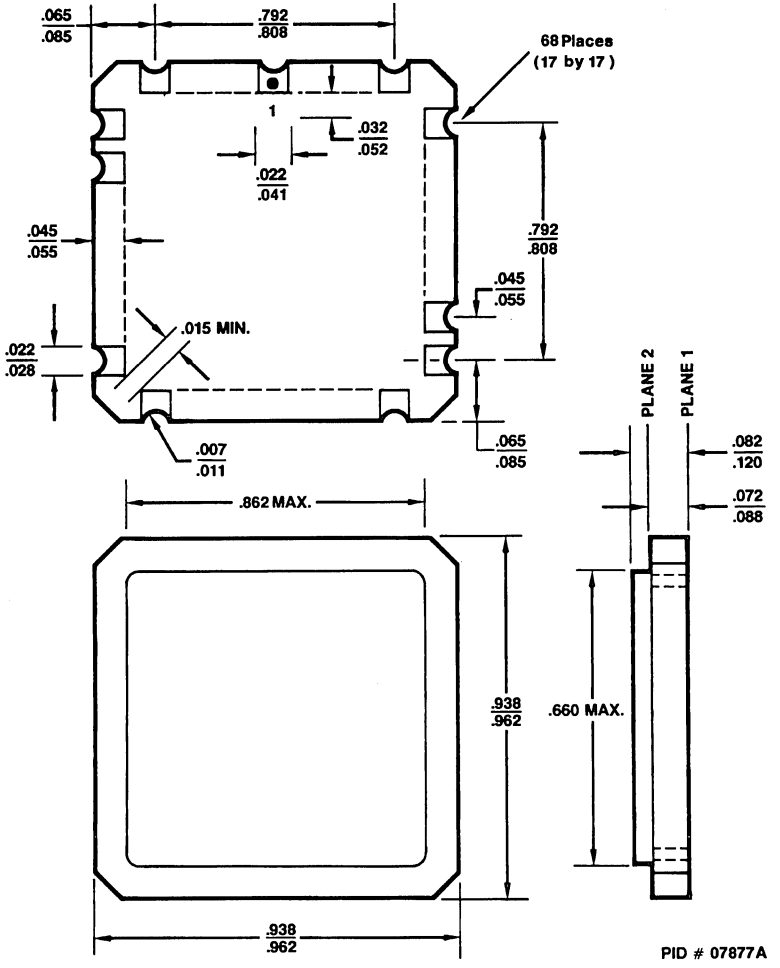


PID # 06753D

*For reference only.

PHYSICAL DIMENSIONS (Cont'd.)

CL 068



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