3

Advance Information
1M x 4 CMOS Dynamic RAM
Fast Page Mode

The MCM44400 is a 0.8μ CMOS high-speed dynamic random access memory. It is organized as 1,048,576 four-bit words and fabricated with CMOS silicon-gate process technology. Advanced circuit design and fine line processing provide high performance, improved reliability, and low cost.

The MCM44400 requires only 10 address lines; row and column address inputs are multiplexed. The device is packaged in a standard 300 mil J-lead small outline package, and a 100 mil zig-zag in-line package (ZIP).

- Three-State Data Output
- Fast Page Mode
- Test Mode
- TTL-Compatible Inputs and Outputs
- $\overline{RAS}$-Only Refresh
- $\overline{CAS}$ Before $\overline{RAS}$ Refresh
- Hidden Refresh
- 1024 Cycle Refresh:
  MCM44400 = 16 ms
  MCM4L4400 = 128 ms
- Fast Access Time (t_{RAC}):
  MCM44400-60 and MCM4L4400-60 = 60 ns (Max)
  MCM44400-70 and MCM4L4400-70 = 70 ns (Max)
  MCM44400-80 and MCM4L4400-80 = 80 ns (Max)
- Low Active Power Dissipation:
  MCM44400-60 and MCM4L4400-60 = 605 mW (Max)
  MCM44400-70 and MCM4L4400-70 = 550 mW (Max)
  MCM44400-80 and MCM4L4400-80 = 495 mW (Max)
- Low Standby Power Dissipation:
  MCM44400 and MCM4L4400 = 11 mW (Max, TTL Levels)
  MCM44400 = 5.5 mW (Max, CMOS Levels)
  MCM4L4400 = 1.1 mW (Max, CMOS Levels)

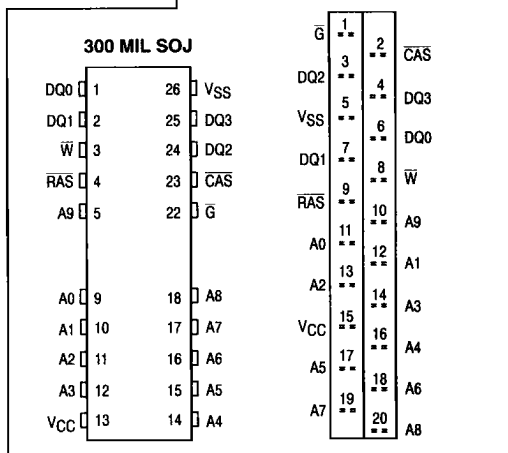

MCM44400
MCM4L4400

N PACKAGE
300 MIL SOJ
CASE 822B-01

Z PACKAGE
PLASTIC
ZIG-ZAG IN-LINE
CASE 836A-01

PIN NAMES

A0 – A9	Address Inputs
DQ0 – DQ3	Data Input/Output
$\overline{G}$	Output Enable
$\overline{W}$	Read/Write Enable
$\overline{RAS}$	Row Address Strobe
$\overline{CAS}$	Column Address Strobe
V_{CC}	Power Supply (+ 5 V)
V_{SS}	Ground

PIN ASSIGNMENTS

300 MIL SOJ

DQ0	1	26	V_{SS}
DQ1	2	25	DQ3
$\overline{W}$	3	24	DQ2
$\overline{RAS}$	4	23	$\overline{CAS}$
A9	5	22	$\overline{G}$
A0	9	18	A8
A1	10	17	A7
A2	11	16	A6
A3	12	15	A5
V_{CC}	13	14	A4

100 MIL ZIP

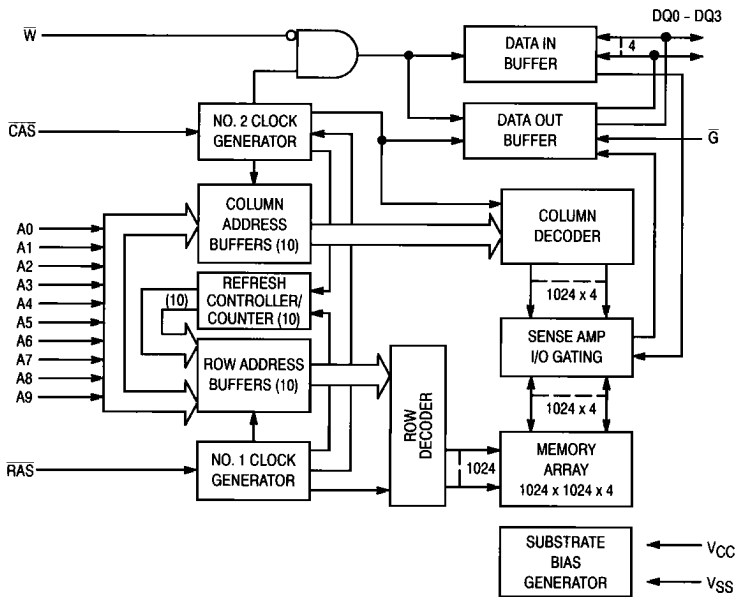|			
$\overline{G}$	1	2	$\overline{CAS}$
DQ2	3	4	DQ3
V_{SS}	5	6	DQ0
DQ1	7	8	$\overline{W}$
$\overline{RAS}$	9	10	A9
A0	11	12	A1
A2	13	14	A3
V_{CC}	15	16	A4
A5	17	18	A6
A7	19	20	A8

This document contains information on a new product. Specifications and information herein are subject to change without notice.

MOTOD010

BLOCK DIAGRAM

ABSOLUTE MAXIMUM RATINGS (See Note)

Rating	Symbol	Value	Unit
Power Supply Voltage	V_{CC}	-1 to $+7$	V
Voltage Relative to V_{SS} for Any Pin Except V_{CC}	V_{in}, V_{out}	-1 to $+7$	V
Data Out Current	I_{out}	50	mA
Power Dissipation	P_D	1	W
Operating Temperature Range	T_A	0 to $+70$	°C
Storage Temperature Range	T_{stg}	-55 to $+125$	°C

NOTE: Permanent device damage may occur if ABSOLUTE MAXIMUM RATINGS are exceeded. Functional operation should be restricted to RECOMMENDED OPERATING CONDITIONS. Exposure to higher than recommended voltages for extended periods of time could affect device reliability.

This device contains circuitry to protect the inputs against damage due to high static voltages or electric fields; however, it is advised that normal precautions be taken to avoid application of any voltage higher than maximum rated voltages to these high-impedance circuits.

MOTOD010

DC OPERATING CONDITIONS AND CHARACTERISTICS

(V_{CC} = 5.0 V ± 10%, T_A = 0 to 70°C, Unless Otherwise Noted)

RECOMMENDED OPERATING CONDITIONS (All voltages referenced to V_{SS})

Parameter	Symbol	Min	Typ	Max	Unit
Supply Voltage (Operating Voltage Range)	V_{CC}	4.5	5.0	5.5	V
	V_{SS}	0	0	0	
Logic High Voltage, All Inputs	V_{IH}	2.4	—	6.5	V
Logic Low Voltage, All Inputs	V_{IL}	– 1.0	—	0.8	V

DC CHARACTERISTICS AND SUPPLY CURRENTS

Characteristic	Symbol	Min	Max	Unit	Notes
V_{CC} Power Supply Current MCM44400-60 and MCM4L4400-60, t_{RC} = 110 ns MCM44400-70 and MCM4L4400-70, t_{RC} = 130 ns MCM44400-80 and MCM4L4400-80, t_{RC} = 150 ns	I_{CC1}	 — — —	 110 100 90	mA	1, 2
V_{CC} Power Supply Current (Standby) ($\overline{RAS}$ = $\overline{CAS}$ = V_{IH})	I_{CC2}	—	2.0	mA	
V_{CC} Power Supply Current During $\overline{RAS}$-Only Refresh Cycles ($\overline{CAS}$ = V_{IH}) MCM44400-60 and MCM4L4400-60, t_{RC} = 110 ns MCM44400-70 and MCM4L4400-70, t_{RC} = 130 ns MCM44400-80 and MCM4L4400-80, t_{RC} = 150 ns	I_{CC3}	 — — —	 110 100 90	mA	1, 2
V_{CC} Power Supply Current During Fast Page Mode Cycle ($\overline{RAS}$ = V_{IL}) MCM44400-60 and MCM4L4400-60, t_{PC} = 45 ns MCM44400-70 and MCM4L4400-70, t_{PC} = 45 ns MCM44400-80 and MCM4L4400-80, t_{PC} = 50 ns	I_{CC4}	 — — —	 110 100 90	mA	1, 3
V_{CC} Power Supply Current (Standby) ($\overline{RAS}$ = $\overline{CAS}$ = V_{CC} – 0.2 V) MCM44400 MCM4L4400	I_{CC5}	 — —	 1.0 200	 mA µA	
V_{CC} Power Supply Current During $\overline{CAS}$ Before $\overline{RAS}$ Refresh Cycle MCM44400-60 and MCM4L4400-60, t_{RC} = 110 ns MCM44400-70 and MCM4L4400-70, t_{RC} = 130 ns MCM44400-80 and MCM4L4400-80, t_{RC} = 150 ns	I_{CC6}	 — — —	 110 100 90	mA	1
V_{CC} Power Supply Current, Battery Backup Mode — MCM4L4400 Only (t_{RC} = 125 µs; $\overline{CAS}$ = $\overline{CAS}$ Before $\overline{RAS}$ Cycling or 0.2 V; $\overline{G}$, $\overline{W}$ = V_{CC} – 0.2 V; A0 – A9 = V_{CC} – 0.2 V or 0.2 V; DQ0 – DQ3 = V_{CC} – 0.2 V or 0.2 V or OPEN; t_{RAS} = Min to 1 µs)	I_{CC7}	—	300	µA	1, 4
Standby Current $\quad\quad\quad\quad\quad\quad\quad\overline{RAS}$ = V_{IH} $\overline{CAS}$ = V_{IL} Q = Enable	I_{CC8}	—	5	mA	1
Input Leakage Current (0 V ≤ V_{in} ≤ 6.5 V)	$I_{lkg(I)}$	– 10	10	µA	
Output Leakage Current ($\overline{CAS}$ = V_{IH}, 0 V ≤ V_{out} ≤ 5.5 V)	$I_{lkg(O)}$	– 10	10	µA	
Output High Voltage (I_{OH} = – 5 mA)	V_{OH}	2.4	V_{CC}	V	
Output Low Voltage (I_{OL} = 4.2 mA)	V_{OL}	0	0.4	V	

NOTES:
1. Current is a function of cycle rate and output loading; maximum currents are specified cycle time (minimum) with the output open.
2. Column address can be changed once or less while $\overline{RAS}$ = V_{IL}.
3. Column address can be changed once or less while $\overline{CAS}$ = V_{IH}.
4. t_{RAS} (max) = 1 µs is only applied to refresh of battery-back up. t_{RAS} (max) = 10 µs is applied to functional operating.

CAPACITANCE (f = 1.0 MHz, T_A = 25°C, V_{CC} = 5 V, Periodically Sampled Rather Than 100% Tested)

Parameter	Symbol	Max	Unit
Input Capacitance $\quad\quad\quad\quad\quad\quad\quad\quad\quad$ A0 – A9	C_{in}	5	pF
$\overline{G}$, $\overline{RAS}$, $\overline{CAS}$, $\overline{W}$		7	
I/O Capacitance ($\overline{CAS}$ = V_{IH} to Disable Output) $\quad$ DQ0 – DQ3	$C_{I/O}$	7	pF

NOTE: Capacitance measured with a Boonton Meter or effective capacitance calculated from the equation: C = I $\Delta t/\Delta V$.

MOTOD010

AC OPERATING CONDITIONS AND CHARACTERISTICS

(V_{CC} = 5.0 V ± 10%, T_A = 0 to 70°C, Unless Otherwise Noted)

READ, WRITE, AND READ-WRITE CYCLES (See Notes 1, 2, 3, 4, and 5)

Parameter	Symbol		MCM44400-60 MCM4L4400-60		MCM44400-70 MCM4L4400-70		MCM44400-80 MCM4L4400-80		Unit	Notes
	Std	Alt	Min	Max	Min	Max	Min	Max		
Random Read or Write Cycle Time	t_{RELREL}	t_{RC}	110	—	130	—	150	—	ns	6
Read-Write Cycle Time	t_{RELREL}	t_{RWC}	150	—	180	—	200	—	ns	6
Fast Page Mode Cycle Time	t_{CELCEL}	t_{PC}	40	—	45	—	50	—	ns	
Fast Page Mode Read-Write Cycle Time	t_{CELCEL}	t_{PRWC}	80	—	95	—	100	—	ns	
Access Time from $\overline{RAS}$	t_{RELQV}	t_{RAC}	—	60	—	70	—	80	ns	7,8,9
Access Time from $\overline{CAS}$	t_{CELQV}	t_{CAC}	—	15	—	20	—	20	ns	7,9,10,11
Access Time from Column Address	t_{AVQV}	t_{AA}	—	30	—	35	—	40	ns	7,9,11,12
Access Time from Precharge $\overline{CAS}$	t_{CEHQV}	t_{CPA}	—	35	—	40	—	45	ns	7,9,11
Output Buffer and Turn-Off Delay	t_{CEHQZ}	t_{OFF}	0	15	0	20	0	20	ns	13
Transition Time (Rise and Fall)	t_T	t_T	3	50	3	50	3	50	ns	1
$\overline{RAS}$ Precharge Time	t_{REHREL}	t_{RP}	40	—	50	—	60	—	ns	
$\overline{RAS}$ Pulse Width	t_{RELREH}	t_{RAS}	60	10 k	70	10 k	80	10 k	ns	
$\overline{RAS}$ Pulse Width (Fast Page Mode)	t_{RELREH}	t_{RASP}	—	100 k	—	100 k	—	100 k	ns	
$\overline{RAS}$ Hold Time	t_{CELREH}	t_{RSH}	15	—	20	—	20	—	ns	
$\overline{CAS}$ Hold Time	t_{RELCEH}	t_{CSH}	60	—	70	—	80	—	ns	
$\overline{CAS}$ Precharge to $\overline{RAS}$ Hold Time	t_{CEHREH}	t_{RHCP}	35	—	40	—	45	—	ns	
$\overline{CAS}$ Pulse Width	t_{CELCEH}	t_{CAS}	15	10 k	20	10 k	20	10 k	ns	
$\overline{RAS}$ to $\overline{CAS}$ Delay Time	t_{RELCEL}	t_{RCD}	20	45	20	50	20	60	ns	14
$\overline{RAS}$ to Column Address Delay Time	t_{RELAV}	t_{RAD}	15	30	15	35	15	40	ns	15
$\overline{CAS}$ to $\overline{RAS}$ Precharge Time	t_{CEHREL}	t_{CRP}	10	—	10	—	10	—	ns	
$\overline{CAS}$ Precharge Time	t_{CEHCEL}	t_{CP}	10	—	10	—	10	—	ns	
Row Address Setup Time	t_{AVREL}	t_{ASR}	0	—	0	—	0	—	ns	
Row Address Hold Time	t_{RELAX}	t_{RAH}	10	—	10	—	10	—	ns	
Column Address Setup Time	t_{AVCEL}	t_{ASC}	0	—	0	—	0	—	ns	

NOTES: (continued)

1. V_{IH} (min) and V_{IL} (max) are reference levels for measuring timing of input signals. Transition times are measured between V_{IH} and V_{IL}.
2. An initial pause of 100 μs is required after power-up followed by 8 initialization cycles ($\overline{RAS}$ only refresh cycle or $\overline{CAS}$ before $\overline{RAS}$ refresh cycle) before proper device operation is guaranteed.
3. The transition time specification applies for all input signals. In addition to meeting the transition rate specification, all input signals must transition between V_{IH} and V_{IL} (or between V_{IL} and V_{IH}) in a monotonic manner.
4. AC measurements assume t_T = 5.0 ns.
5. In delayed write or read modify write cycles, must disable output buffer prior to applying data to the device.
6. The specifications for t_{RC} (min) and t_{RWC} (min) are used only to indicate cycle time at which proper operation over the full temperature range is ensured.
7. Measured with a current load equivalent to 2 TTL (– 200 μA, + 4 mA) loads and 100 pF with the data output trip points set at V_{OH} = 2.0 V and V_{OL} = 0.8 V.
8. Assumes that $t_{RCD} \le t_{RCD}$ (max) and $t_{RAD} \le t_{RAD}$ (max). If t_{RCD} or t_{RAD} is greater than the maximum recommended value shown in this table, t_{RAC} exceeds the value shown.
9. In a test mode read cycle, the value of t_{RAC}, t_{AA}, t_{CAC}, and t_{CPA} is delayed for 2 ns to 5 ns for the specified value. These parameters should be in the test mode cycles by adding the above value to the specified value in the data sheet.
10. Assumes that $t_{RCD} \ge t_{RCD}$ (max) and $t_{RAD} \le t_{RAD}$ (max).
11. Access time is determined by the longer of t_{AA} or t_{CAC} or t_{CPA}.
12. Assumes that $t_{RCD} \le t_{RCD}$ (max) and $t_{RAD} \ge t_{RAD}$ (max).
13. t_{OFF} (max) defines the time at which the output achieves the open circuit condition and is not referenced to output voltage levels.
14. Operation within the t_{RCD} (max) limit ensures that t_{RAC} (max) can be met. t_{RCD} (max) is specified as a reference point only; if t_{RCD} is greater than the specified t_{RCD} (max) limit, then access time is controlled exclusively by t_{CAC}.
15. Operation within the t_{RAD} (max) limit ensures that t_{RAC} (max) can be met. t_{RAD} (max) is specified as a reference point only; if t_{RAD} is greater than the specified t_{RAD} (max) limit, then access time is controlled exclusively by t_{AA}.
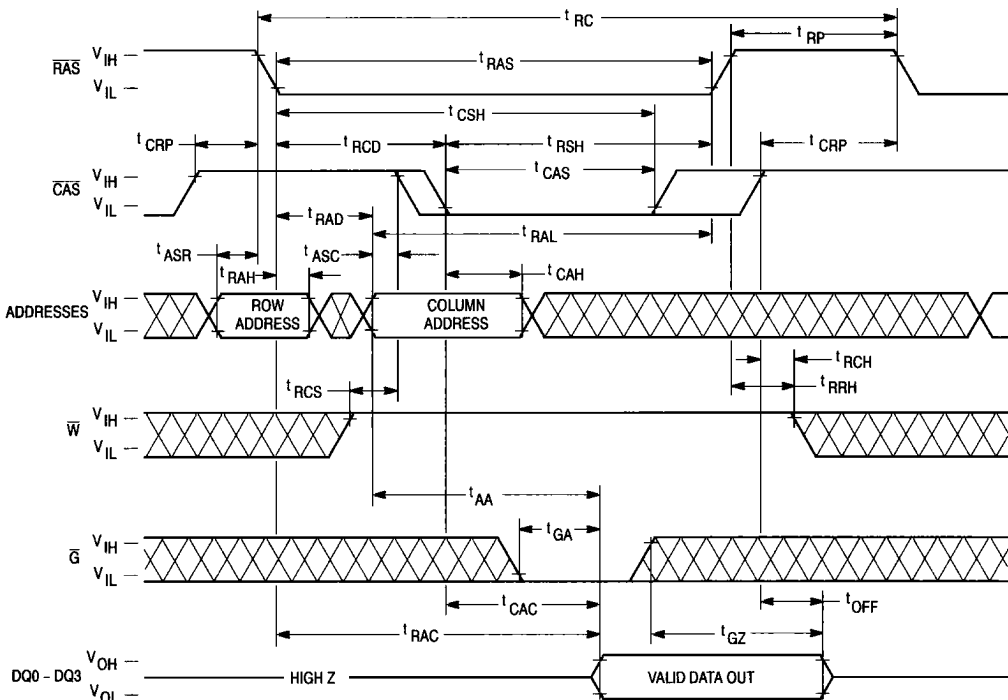
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MOTOD010

READ, WRITE, AND READ-WRITE CYCLES (Continued)

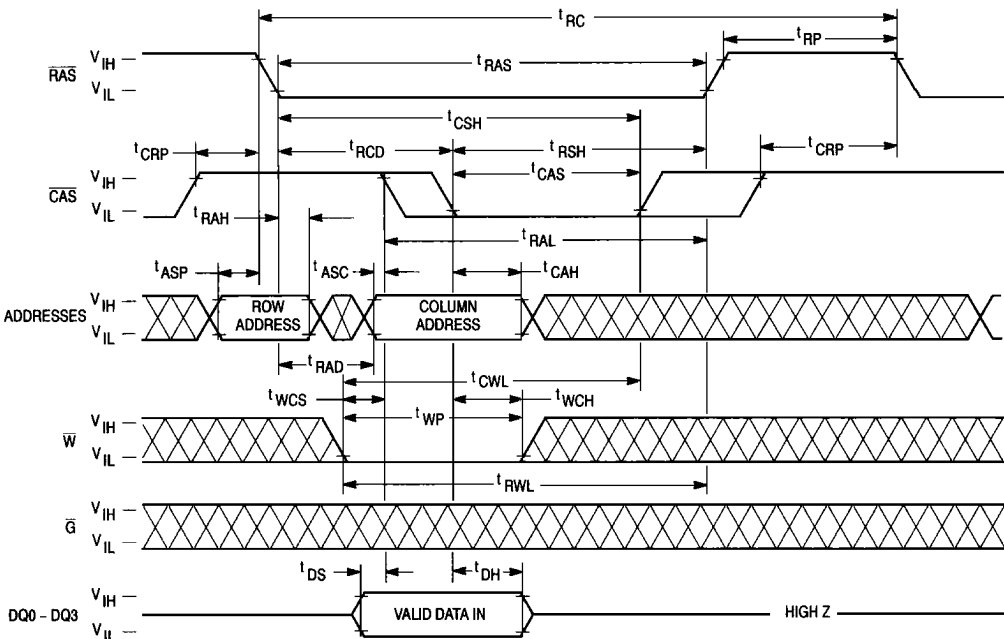| Parameter	Symbol Std	Alt	MCM44400-60 MCM4L4400-60 Min	Max	MCM44400-70 MCM4L4400-70 Min	Max	MCM44400-80 MCM4L4400-80 Min	Max	Unit	Notes
Column Address Hold Time	t_{CELAX}	t_{CAH}	15	—	15	—	15	—	ns	
Column Address to $\overline{RAS}$ Lead Time	t_{AVREH}	t_{RAL}	30	—	35	—	40	—	ns	
Read Command Setup Time	t_{WHCEL}	t_{RCS}	0	—	0	—	0	—	ns	
Read Command Hold Time Referenced to $\overline{CAS}$	t_{CEHWX}	t_{RCH}	0	—	0	—	0	—	ns	16
Read Command Hold Time Referenced to $\overline{RAS}$	t_{REHWX}	t_{RRH}	0	—	0	—	0	—	ns	16
Write Command Hold Time Referenced to $\overline{CAS}$	t_{CELWH}	t_{WCH}	15	—	15	—	15	—	ns	
Write Command Pulse Width	t_{WLWH}	t_{WP}	10	—	10	—	10	—	ns	
Write Command to $\overline{RAS}$ Lead Time	t_{WLREH}	t_{RWL}	15	—	20	—	20	—	ns	
Write Command to $\overline{CAS}$ Lead Time	t_{WLCEH}	t_{CWL}	15	—	20	—	20	—	ns	
Data in Setup Time	t_{DVCEL}	t_{DS}	0	—	0	—	0	—	ns	17
Data in Hold Time	t_{CELDX}	t_{DH}	15	—	15	—	15	—	ns	17
Refresh Period MCM44400 MCM4L4400	t_{RVRV}	t_{RFSH}	— —	16 128	— —	16 128	— —	16 128	ms	
Write Command Setup Time	t_{WLCEL}	t_{WCS}	0	—	0	—	0	—	ns	18
$\overline{CAS}$ to Write Delay	t_{CELWL}	t_{CWD}	35	—	45	—	45	—	ns	18
$\overline{RAS}$ to Write Delay	t_{RELWL}	t_{RWD}	80	—	95	—	105	—	ns	18
Column Address to Write Delay Time	t_{AVWL}	t_{AWD}	50	—	60	—	65	—	ns	18
$\overline{CAS}$ Precharge to Write Delay Time (Page Mode)	t_{CEHWL}	t_{CPWD}	55	—	65	—	70	—	ns	18
$\overline{CAS}$ Setup Time for $\overline{CAS}$ Before $\overline{RAS}$ Refresh	t_{RELCEL}	t_{CSR}	10	—	10	—	10	—	ns	
$\overline{CAS}$ Hold Time for $\overline{CAS}$ Before $\overline{RAS}$ Refresh	t_{RELCEH}	t_{CHR}	10	—	10	—	10	—	ns	
$\overline{RAS}$ Precharge to $\overline{CAS}$ Active Time	t_{REHCEL}	t_{RPC}	10	—	10	—	10	—	ns	
$\overline{CAS}$ Precharge Time for $\overline{CAS}$ Before $\overline{RAS}$ Counter Time	t_{CEHCEL}	t_{CPT}	40	—	40	—	40	—	ns	
$\overline{G}$ Access Time	t_{GLQV}	t_{GA}	—	15	—	20	—	20	ns	7
$\overline{G}$ to Data Delay	t_{GLHDX}	t_{GD}	15	—	20	—	20	—	ns	
Output Buffer Turn-Off Delay Time from $\overline{G}$	t_{GHQZ}	t_{GZ}	0	15	0	20	0	20	ns	13
$\overline{G}$ Command Hold Time	t_{WLGL}	t_{GH}	15	—	20	—	20	—	ns	
Write Command Setup Time (Test Mode)	t_{WLREL}	t_{WTS}	0	—	0	—	0	—	ns	
Write Command Hold Time (Test Mode)	t_{RELWH}	t_{WTH}	10	—	10	—	10	—	ns	
Write to $\overline{RAS}$ Precharge Time ($\overline{CAS}$ Before $\overline{RAS}$ Refresh)	t_{WHREL}	t_{WRP}	0	—	0	—	0	—	ns	
Write to $\overline{RAS}$ Hold Time ($\overline{CAS}$ Before $\overline{RAS}$ Refresh)	t_{RELWL}	t_{WRH}	10	—	10	—	10	—	ns	

16. Either t_{RRH} or t_{RCH} must be satisfied for a read cycle.
17. These parameters are referenced to $\overline{CAS}$ leading edge in early write cycles and to $\overline{W}$ leading edge in read-write cycles.
18. t_{WCS}, t_{RWD}, t_{CWD}, t_{AWD}, and t_{CPWD} are not restrictive operating parameters. They are included in the data sheet as electrical characteristics only; if $t_{WCS} \geq t_{WCS}$ (min), the cycle is an early write cycle and the data out pin will remain open circuit (high impedance) throughout the entire cycle; if $t_{CWD} \geq t_{CWD}$ (min), $t_{RWD} \geq t_{RWD}$ (min), $t_{AWD} \geq t_{AWD}$ (min), and $t_{CPWD} \geq t_{CPWD}$ (min) (page mode), the cycle is a read-write cycle and the data out will contain data read from the selected cell. If neither of these sets of conditions is satisfied, the condition of the data out (at access time) is indeterminate.
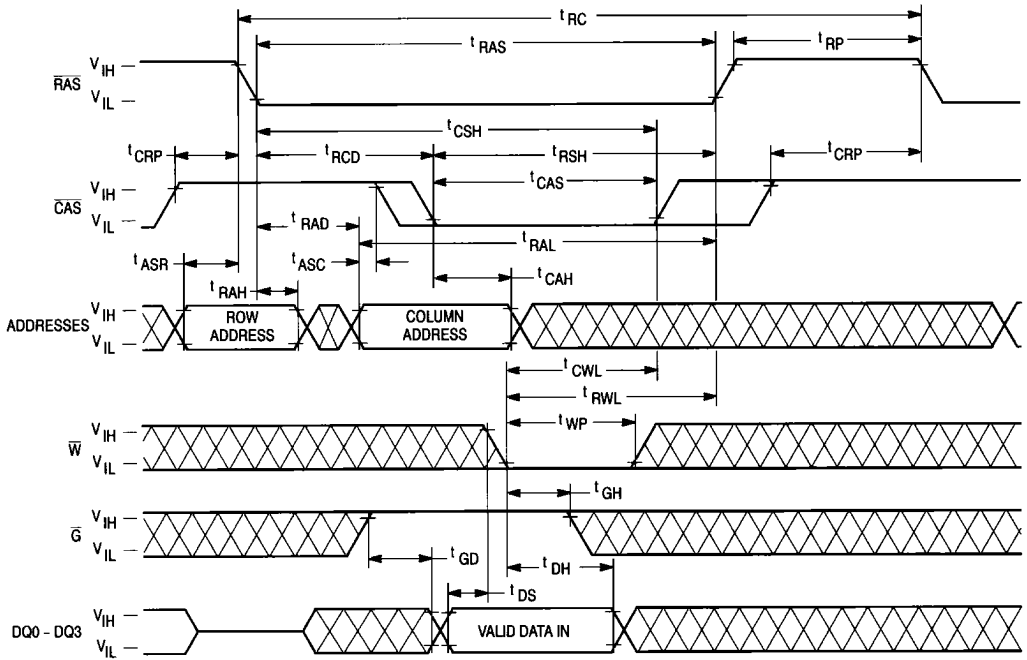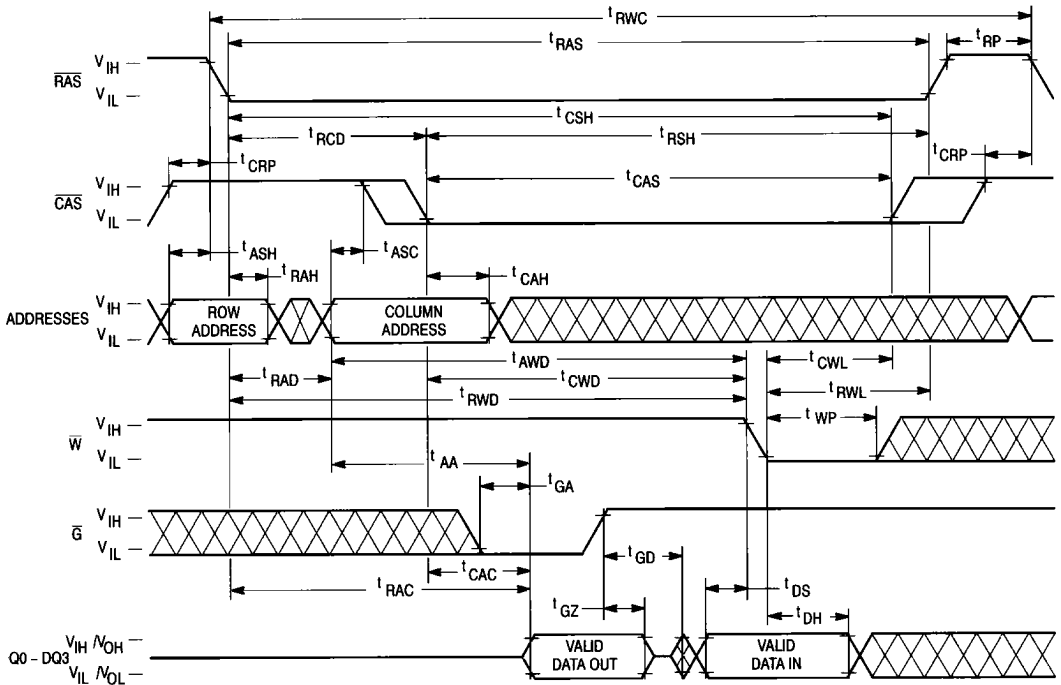
MOTOD010

READ CYCLE

t_{RC}

$\overline{RAS}$ V_{IH} V_{IL}

t_{RAS} t_{RP}

t_{CSH}

t_{CRP} t_{RCD} t_{RSH} t_{CRP}

t_{CAS}

$\overline{CAS}$ V_{IH} V_{IL}

t_{RAD}

t_{RAL}

t_{ASR} t_{ASC}

t_{RAH} t_{CAH}

ADDRESSES V_{IH} V_{IL} ROW ADDRESS COLUMN ADDRESS

t_{RCS} t_{RCH}

t_{RRH}

$\overline{W}$ V_{IH} V_{IL}

t_{AA}

t_{GA}

$\overline{G}$ V_{IH} V_{IL}

t_{CAC} t_{OFF}

t_{RAC} t_{GZ}

DQ0 – DQ3 V_{OH} V_{OL} HIGH Z VALID DATA OUT

EARLY WRITE CYCLE

t_{RC}

$\overline{RAS}$ V_{IH} V_{IL}

t_{RAS} t_{RP}

t_{CSH}

t_{CRP} t_{RCD} t_{RSH} t_{CRP}

t_{CAS}

$\overline{CAS}$ V_{IH} V_{IL}

t_{RAH}

t_{RAL}

t_{ASP} t_{ASC} t_{CAH}

ADDRESSES V_{IH} V_{IL} ROW ADDRESS COLUMN ADDRESS

t_{RAD}

t_{CWL}

t_{WCS} t_{WCH}

t_{WP}

$\overline{W}$ V_{IH} V_{IL}

t_{RWL}

$\overline{G}$ V_{IH} V_{IL}

t_{DS} t_{DH}

DQ0 – DQ3 V_{IH} V_{IL} VALID DATA IN HIGH Z

3

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$\overline{G}$ CONTROLLED WRITE CYCLE

READ-WRITE CYCLE

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FAST PAGE MODE READ CYCLE

FAST PAGE MODE EARLY WRITE CYCLE

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FAST PAGE MODE READ-WRITE CYCLE

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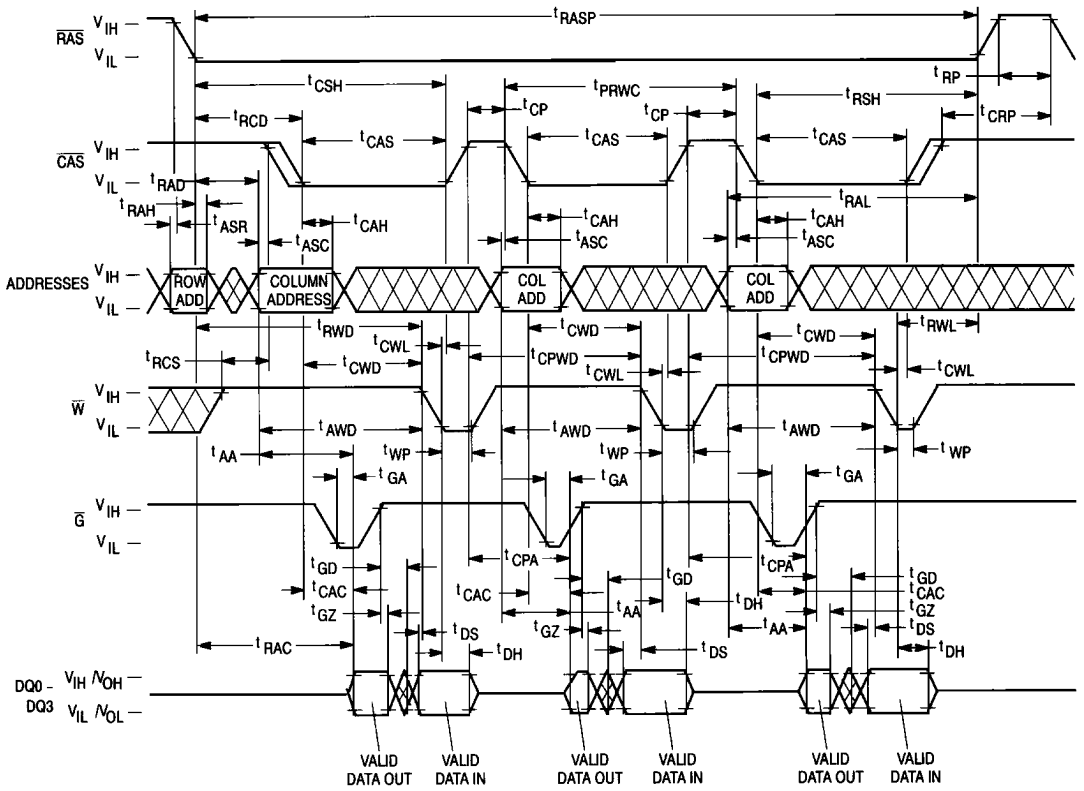
RAS-ONLY REFRESH CYCLE
(W̄ and Ḡ are Don't Care)
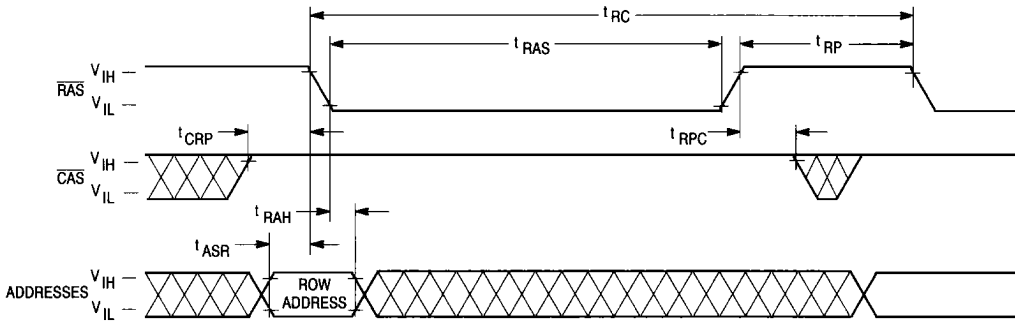
CAS BEFORE RAS REFRESH CYCLE
(Ḡ and A0 – A9 are Don't Care)

MOTOD010
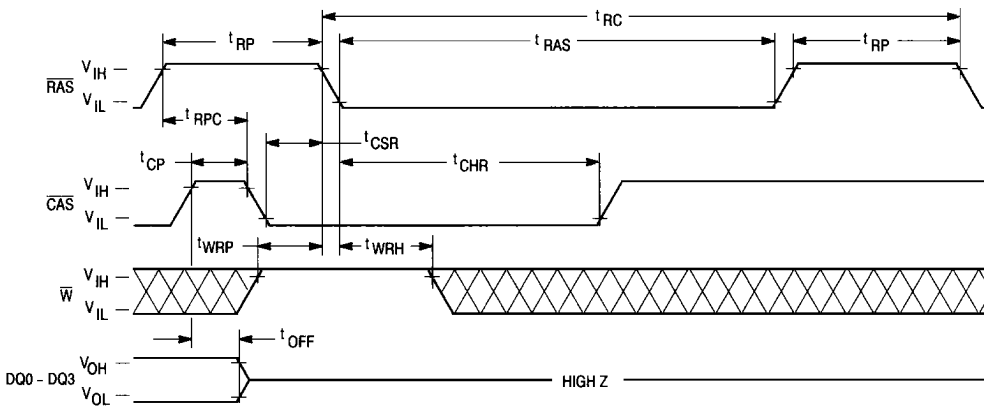
HIDDEN REFRESH CYCLE (READ)
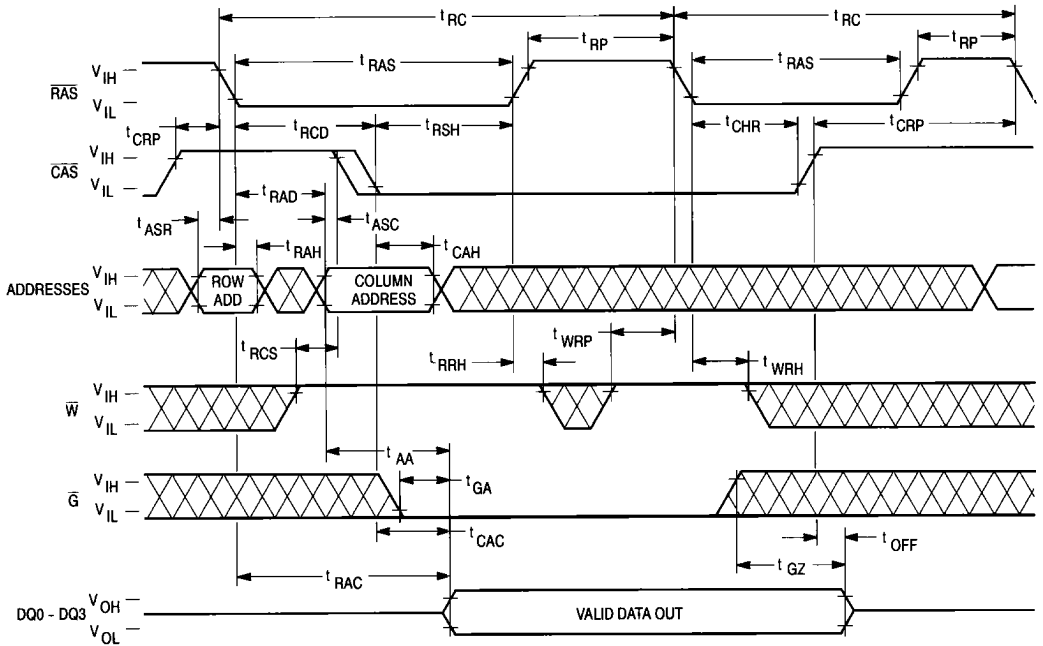
HIDDEN REFRESH CYCLE (EARLY WRITE)

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$\overline{\text{CAS}}$ BEFORE $\overline{\text{RAS}}$ REFRESH COUNTER TEST CYCLE

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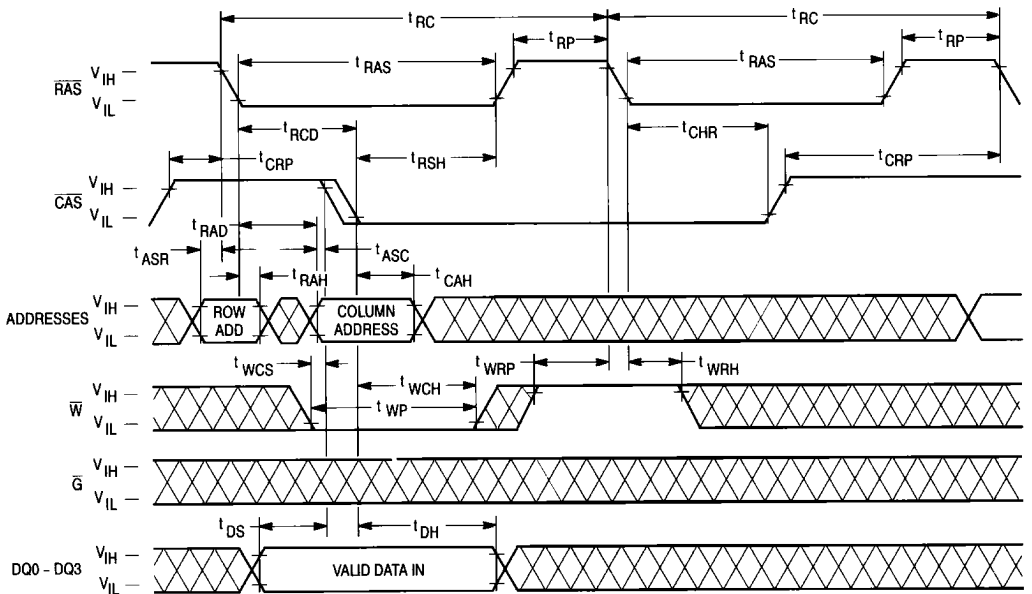
DEVICE INITIALIZATION

On power-up, an initial pause of 100 microseconds is required for the internal substrate generator to establish the correct bias voltage. This must be followed by a minimum of eight active cycles of the row address strobe (clock) to initialize all dynamic nodes within the RAM. During an extended inactive state (greater than 16 milliseconds or 128 milliseconds in case of low power device with the device powered up), a wakeup sequence of eight active cycles is necessary to ensure proper operation.

ADDRESSING THE RAM

The ten address pins on the device are time multiplexed at the beginning of a memory cycle by two clocks, row address strobe ($\overline{RAS}$) and column address strobe ($\overline{CAS}$), into two separate 10-bit address fields. A total of twenty address bits, ten rows and ten columns, will decode one of the 1,048,576 bit locations in the device. $\overline{RAS}$ active transition is followed by $\overline{CAS}$ active transition (active = V_{IL}, t_{RCD} minimum) for all read or write cycles. The delay between $\overline{RAS}$ and $\overline{CAS}$ active transitions, referred to as the **multiplex window**, gives a system designer flexibility in setting up the external addresses into the RAM.

The external $\overline{CAS}$ signal is ignored until an internal $\overline{RAS}$ signal is available. This "gate" feature on the external $\overline{CAS}$ clock enables the internal $\overline{CAS}$ line as soon as the row address hold time (t_{RAH}) specification is met (and defines t_{RCD} minimum). The multiplex window can be used to absorb skew delays in switching the address bus from row to column addresses and in generating the $\overline{CAS}$ clock.

There are three other variations in addressing the 1M x 4 RAM: **$\overline{RAS}$-only refresh cycle, $\overline{CAS}$ before $\overline{RAS}$ refresh cycle,** and **page mode**. All three are discussed in separate sections that follow.

READ CYCLE

The DRAM may be read with four different cycles: "normal" random read cycle, page mode read cycle, read-write cycle, and page mode read-write cycle. The normal read cycle is outlined here, while the other cycles are discussed in separate sections.

The normal read cycle begins as described in **ADDRESSING THE RAM**, with $\overline{RAS}$ and $\overline{CAS}$ active transitions latching the desired bit location. The write ($\overline{W}$) input level must be high (V_{IH}), t_{RCS} (minimum) before the $\overline{CAS}$ active transition, to enable read mode.

Both the $\overline{RAS}$ and $\overline{CAS}$ clocks trigger a sequence of events that are controlled by several delayed internal clocks. The internal clocks are linked in such a manner that the read access time of the device is independent of the address multiplex window. Both $\overline{CAS}$ and output enable ($\overline{G}$) control read access time: $\overline{CAS}$ must be active before or at t_{RCD} maximum and $\overline{G}$ must be active $t_{RAC} - t_{GA}$ (both minimum) after $\overline{RAS}$ active transition to guarantee valid data out (Q) at t_{RAC} (access time from $\overline{RAS}$ active transition). If the t_{RCD} maximum is exceeded and/or $\overline{G}$ active transition does not occur in time, read access time is determined by either the $\overline{CAS}$ or $\overline{G}$ clock active transition (t_{CAC} or t_{GA}).

The $\overline{RAS}$ and $\overline{CAS}$ clocks must remain active for minimum times of t_{RAS} and t_{CAS}, respectively, to complete the read cycle. $\overline{W}$ must remain high throughout the cycle, and for time t_{RRH} or t_{RCH} after $\overline{RAS}$ or $\overline{CAS}$ inactive transition,

respectively, to maintain the data at that bit location. Once $\overline{RAS}$ transitions to inactive, it must remain inactive for a minimum time of t_{RP} to precharge the internal device circuitry for the next active cycle. Q is valid, but not latched, as long as the $\overline{CAS}$ and $\overline{G}$ clocks are active. When either the $\overline{CAS}$ or $\overline{G}$ clock transitions to inactive, the output will switch to High Z (three-state) t_{OFF} or t_{GZ} after the inactive transition.

WRITE CYCLE

The user can write to the DRAM with any of four cycles: early write, late write, page mode early write, and page mode read-write. Early and late write modes are discussed here, while page mode write operations are covered in a separate section.

A write cycle begins as described in **ADDRESSING THE RAM**. Write mode is enabled by the transition of $\overline{W}$ to active (V_{IL}). Early and late write modes are distinguished by the active transition of $\overline{W}$, with respect to $\overline{CAS}$. Minimum active time t_{RAS} and t_{CAS}, and precharge time t_{RP} apply to write mode, as in the read mode.

An early write cycle is characterized by $\overline{W}$ active transition at minimum time t_{WCS} before $\overline{CAS}$ active transition. Data in (D) is referenced to $\overline{CAS}$ in an early write cycle. $\overline{RAS}$ and $\overline{CAS}$ clocks must stay active for t_{RWL} and t_{CWL}, respectively, after the start of the early write operation to complete the cycle.

Q remains in three-state condition throughout an early write cycle because $\overline{W}$ active transition precedes or coincides with $\overline{CAS}$ active transition, keeping data-out buffers and $\overline{G}$ disabled.

A late write cycle (referred to as $\overline{G}$-controlled write) occurs when $\overline{W}$ active transition is made after $\overline{CAS}$ active transition. $\overline{W}$ active transition could be delayed for almost 10 microseconds after $\overline{CAS}$ active transition, ($t_{RCD} + t_{CWD} + t_{RWL} + 2t_T$) ≤ t_{RAS}, if other timing minimums (t_{RCD}, t_{RWL}, and t_T) are maintained. D is referenced to $\overline{W}$ active transition in a late write cycle. Output buffers are enabled by $\overline{CAS}$ active transition but outputs are switched off by $\overline{G}$ inactive transition, which is required to write to the device. Q may be indeterminate (see note 18 of the AC Operating Conditions table). $\overline{RAS}$ and $\overline{CAS}$ must remain active for t_{RWL} and t_{CWL}, respectively, after $\overline{W}$ active transition to complete the write cycle. $\overline{G}$ must remain inactive for t_{GH} after $\overline{W}$ active transition to complete the write cycle.

READ-WRITE CYCLE

A read-write cycle performs a read and then a write at the same address, during the same cycle. This cycle is basically a late write cycle, as discussed in the **WRITE CYCLE** section, except $\overline{W}$ must remain high for t_{CWD} minimum after $\overline{CAS}$ active transition, to guarantee valid Q before writing the bit.

PAGE MODE CYCLES

Page mode allows fast successive data operations at all 1024 column locations on a selected row of the 1M x 4 dynamic RAM. Read access time in page mode (t_{CAC}) is typically half the regular $\overline{RAS}$ clock access time, t_{RAC}. Page mode operation consists of keeping $\overline{RAS}$ active while toggling $\overline{CAS}$ between V_{IH} and V_{IL}. The row is latched by $\overline{RAS}$ active transition, while each $\overline{CAS}$ active transition allows selection of a new column location on the row.

A page mode cycle is initiated by a normal read, write, or read-write cycle, as described in prior sections. Once the timing requirements for the first cycle are met, $\overline{CAS}$ transitions to inactive for minimum t_{CP}, while $\overline{RAS}$ remains low (V_{IL}). The second $\overline{CAS}$ active transition while $\overline{RAS}$ is low initiates the first page mode cycle (t_{PC} or t_{PRWC}). Either a read, write, or read-write operation can be performed in a page mode cycle, subject to the same conditions as in normal operation (previously described). These operations can be intermixed in consecutive page mode cycles and performed in any order. The maximum number of consecutive page mode cycles is limited by t_{RASP}. Page mode operation is ended when $\overline{RAS}$ transitions to inactive, coincident with or following $\overline{CAS}$ inactive transition.

REFRESH CYCLES

The dynamic RAM design is based on capacitor charge storage for each bit in the array. This charge will tend to degrade with time and temperature. Each bit must be periodically **refreshed** (recharged) to maintain the correct bit state. Bits in the MCM44400 require refresh every 16 milliseconds, while refresh time for the MCM4L4400 is 128 milliseconds.

This is accomplished by cycling through the 1024 row addresses in sequence within the specified refresh time. All the bits on a row are refreshed simultaneously when the row is addressed. Distributed refresh implies a row refresh every 15.6 microseconds for the MCM44400, and 124.8 microseconds for the MCM4L4400. Burst refresh, a refresh of all 1024 rows consecutively, must be performed every 16 milliseconds on the MCM44400 and 128 milliseconds on the MCM4L4400.

A normal read, write, or read-write operation to the RAM will refresh all the bits (4096) associated with the particular row decodes. Three other methods of refresh, $\overline{RAS}$-**only refresh**, $\overline{CAS}$ **before** $\overline{RAS}$ **refresh,** and **hidden refresh** are available on this device for greater system flexibility.

$\overline{RAS}$-Only Refresh

$\overline{RAS}$-only refresh consists of $\overline{RAS}$ transition to active, latching the row address to be refreshed, while $\overline{CAS}$ remains high (V_{IH}) throughout the cycle. An external counter is employed to ensure all rows are refreshed within the specified limit.

$\overline{CAS}$ Before $\overline{RAS}$ Refresh

$\overline{CAS}$ before $\overline{RAS}$ refresh is enabled by bringing $\overline{CAS}$ active before $\overline{RAS}$. This clock order activates an internal refresh counter that generates the row address to be refreshed. External address lines are ignored during the automatic refresh cycle. The output buffer remains at the same state it was in during the previous cycle (hidden refresh). $\overline{W}$ must be inactive for time t_{WRP} before and time t_{WRH} after $\overline{RAS}$ active transition to prevent switching the device into a **test mode cycle**.

Hidden Refresh

Hidden refresh allows refresh cycles to occur while maintaining valid data at the output pin. Holding $\overline{CAS}$ active at the end of a read or write cycle, while $\overline{RAS}$ cycles inactive for t_{RP} and back to active, starts the hidden refresh. This is essentially the execution of a $\overline{CAS}$ before $\overline{RAS}$ refresh from a cycle in progress (see Figure 1). $\overline{W}$ is subject to the same conditions with respect to $\overline{RAS}$ active transition (to prevent test mode entry) as in $\overline{CAS}$ before $\overline{RAS}$ refresh.

$\overline{CAS}$ BEFORE $\overline{RAS}$ REFRESH COUNTER TEST

The internal refresh counter of this device can be tested with a $\overline{CAS}$ **before** $\overline{RAS}$ **refresh counter test**. This test is performed with a read-write operation. During the test, the internal refresh counter generates the row address, while the external address supplies the column address. The entire array is refreshed after 1024 cycles, as indicated by the check data written in each row. See $\overline{CAS}$ **before** $\overline{RAS}$ **refresh counter test cycle** timing diagram.

The test can be performed after a minimum of eight $\overline{CAS}$ **before** $\overline{RAS}$ initialization cycles. Test procedure:

1. Write "0"s into all memory cells with normal write mode.
2. Select a column address, read "0" out and write "1" into the cell by performing the $\overline{CAS}$ **before** $\overline{RAS}$ **refresh counter test, read-write cycle**. Repeat this operation 1024 times.
3. Read the "1"s which were written in step 2 in normal read mode.
4. Using the same starting column address as in step 2, read "1" out and write "0" into the cell by performing the $\overline{CAS}$ **before** $\overline{RAS}$ **refresh counter test, read-write cycle**. Repeat this operation 1024 times.
5. Read "0"s which were written in step 4 in normal read mode.
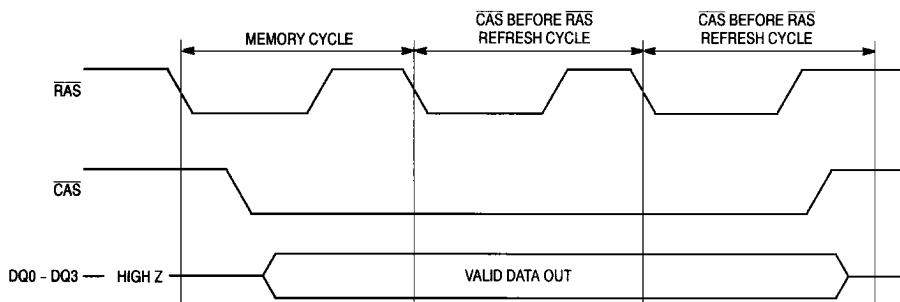6. Repeat steps 1 to 5 using complement data.

Figure 1. Hidden Refresh Cycle

MOTOD010

TEST MODE

The internal organization of this device (512K x 8) allows it to be tested as if it were a 512K x 4 DRAM. Nineteen of the twenty addresses are used when operating the device in test mode. Column address A0 is ignored by the device in test mode. A test mode cycle reads and/or writes data to a bit in each of eight 512K blocks (B0 – B7) in parallel. External data out is determined by the internal test mode logic of the device. See following truth table and test mode block diagram.
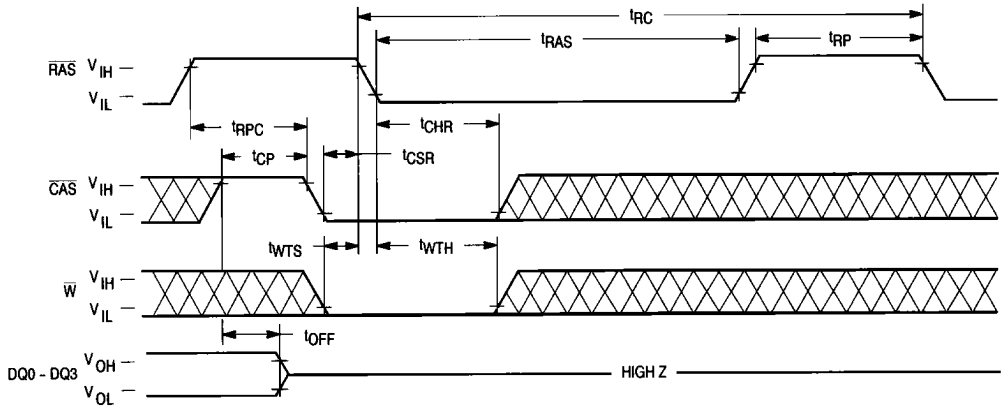
$\overline{W}$, $\overline{CAS}$ before $\overline{RAS}$ timing puts the device in **Test Mode** as shown in the test mode timing diagram. A $\overline{CAS}$ **before** $\overline{RAS}$ or a $\overline{RAS}$**-only refresh cycle** puts the device back into normal mode. Refresh is performed in test mode by using a $\overline{W}$, $\overline{CAS}$ **before** $\overline{RAS}$ **refresh cycle** which uses internal refresh address counter.

TEST MODE TRUTH TABLE

D	B0, B1	B2, B3	B4, B5	B6, B7	Q
0	0	0	0	0	1
1	1	1	1	1	1
—	Any Other				0

$\overline{W}$, $\overline{CAS}$ BEFORE $\overline{RAS}$ REFRESH CYCLE (TEST MODE ENTRY)
($\overline{G}$ and A0 – A9 are Don't Care)

MOTOD010

TEST MODE — READ CYCLE

t_{RC}

t_{RAS}

t_{RP}

$\overline{RAS}$ V_{IH} V_{IL}

t_{CSH}

t_{CRP} t_{RCD} t_{RSH} t_{CRP}

t_{CAS}

$\overline{CAS}$ V_{IH} V_{IL}

t_{RAD} t_{RAL}

t_{ASR} t_{ASC} t_{CAH}

t_{RAH}

ADDRESSES V_{IH} V_{IL}

ROW ADDRESS COLUMN ADDRESS

t_{RCH}

t_{RRH}

t_{RCS}

$\overline{W}$ V_{IH} V_{IL}

t_{AA}

t_{CAC}

t_{OFF}

t_{RAC}

DQ0 - DQ3 V_{OH} V_{OL}

HIGH Z VALID DATA OUT

3

TEST MODE — EARLY WRITE CYCLE

t_{RC}

t_{RAS}

t_{RP}

$\overline{RAS}$ V_{IH} V_{IL}

t_{CSH}

t_{CRP} t_{RCD} t_{RSH} t_{CRP}

t_{CAS}

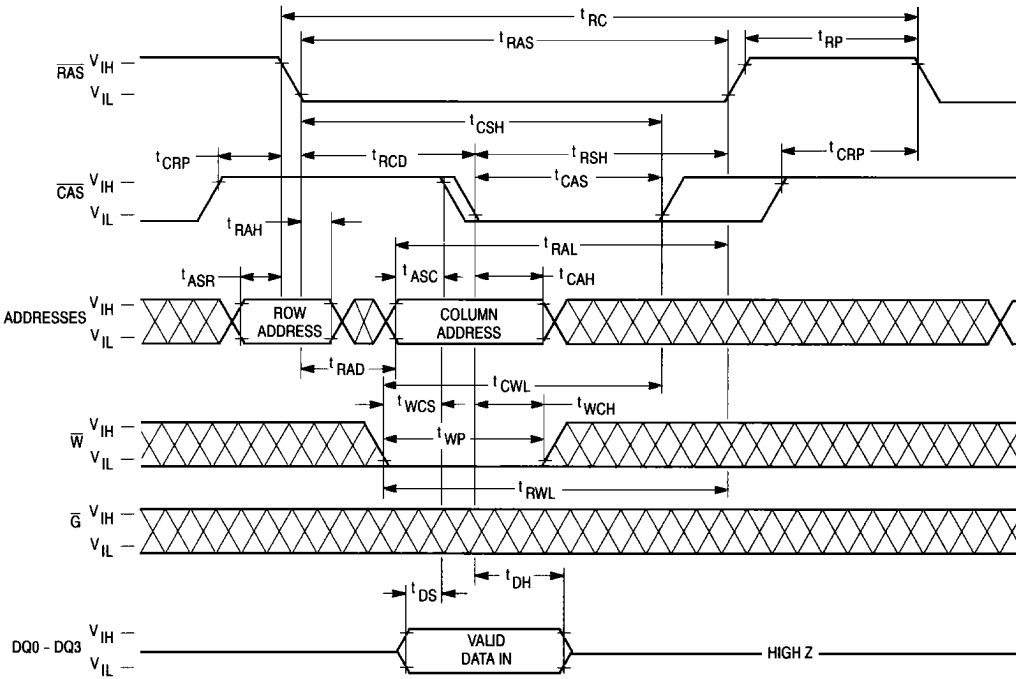$\overline{CAS}$ V_{IH} V_{IL}

t_{RAH}

t_{RAL}

t_{ASR} t_{ASC} t_{CAH}

ADDRESSES V_{IH} V_{IL}

ROW ADDRESS COLUMN ADDRESS

t_{RAD} t_{CWL}

t_{WCS} t_{WCH}

$\overline{W}$ V_{IH} V_{IL}

t_{WP}

t_{RWL}

$\overline{G}$ V_{IH} V_{IL}

t_{DS} t_{DH}

DQ0 - DQ3 V_{IH} V_{IL}

VALID DATA IN HIGH Z

MOTOROLA DRAM DATA

MCM44400•MCM4L4400

3-35

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MOTOD010

TEST MODE — FAST PAGE MODE READ CYCLE
($\overline{G}$ = Low)

TEST MODE — FAST PAGE MODE EARLY WRITE CYCLE

MOTOD010

ORDERING INFORMATION
(Order by Full Part Number)

MCM   44400 or 4L4400   X   XX   XX

Motorola Memory Prefix

Part Number

Shipping Method (R2 = Tape and Reel, Blank = Rails)

Speed (60 = 60 ns, 70 = 70 ns, 80 = 80 ns)

Package (N = 300 mil SOJ, Z = 100 mil Plastic ZIP)
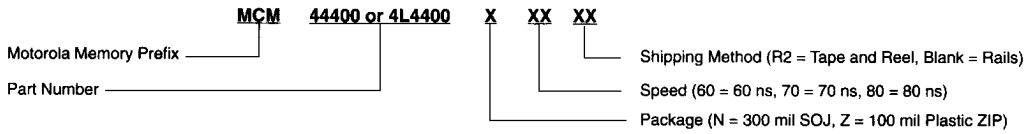
Full Part Numbers — MCM44400N60   MCM44400N60R2   MCM44400Z60
MCM44400N70   MCM44400N70R2   MCM44400Z70
MCM44400N80   MCM44400N80R2   MCM44400Z80

MCM4L4400N60   MCM4L4400N60R2   MCM4L4400Z60
MCM4L4400N70   MCM4L4400N70R2   MCM4L4400Z70
MCM4L4400N80   MCM4L4400N80R2   MCM4L4400Z80

NOTE: For mechanical data, please see Chapter 10.

3

MOTOD010