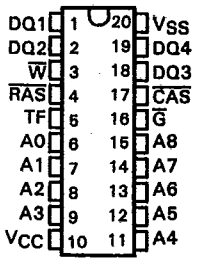
T-46-23-17

- 262,144 × 4 Organization
- Single 5-V Supply (10% Tolerance)
- Performance Ranges:

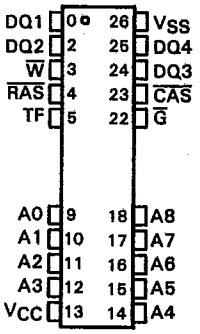
	ACCESS TIME $t_{a(R)}$ (t_{RAC}) (MAX)	ACCESS TIME $t_{a(C)}$ (t_{CAC}) (MAX)	ACCESS TIME $t_{a(CA)}$ (t_{CAA}) (MAX)	READ OR WRITE CYCLE (MIN)
TMS44C25_-10	100 ns	25 ns	45 ns	190 ns
TMS44C25_-12	120 ns	30 ns	55 ns	220 ns
TMS44C25_-15	150 ns	40 ns	70 ns	260 ns

- TMS44C256 – Enhanced Page Mode Operation with $\overline{CAS}$-Before-$\overline{RAS}$ Refresh
- TMS44C257 – Static Column Decode Mode Operation with $\overline{CAS}$-Before-$\overline{RAS}$ Refresh
- Long Refresh Period . . . 512-Cycle Refresh in 8 ms (Max)
- 3-State Unlatched Output
- Lower Power Dissipation
- Texas Instruments EPIC™ CMOS Process
- All Inputs and Clocks Are TTL Compatible
- High-Reliability Plastic 20-Pin 300-Mil-Wide DIP or 20/26-Lead Surface Mount (SOJ) Package
- Operation of TI's Megabit CMOS DRAMs Can Be Controlled by TI's SN74ALS6301 and SN74ALS6302 Dynamic RAM Controllers
- Operating Free-Air Temperature . . . 0°C to 70°C

N PACKAGE
(TOP VIEW)



DJ PACKAGE†
(TOP VIEW)



†The packages shown here are for pinout reference only. The DJ package is actually 75% of the length of the N package.

PIN NOMENCLATURE	
A0-A8	Address Inputs
$\overline{CAS}$	Column-Address Strobe
DQ1-DQ4	Data In/Data Out
$\overline{G}$	Data-Output Enable
$\overline{RAS}$	Row-Address Strobe
TF	Test Function
$\overline{W}$	Write Enable
V_{CC}	5-V Supply
V_{SS}	Ground

description

The TMS44C256 and TMS44C257 series are high-speed, 1,048,576-bit Dynamic Random-Access Memories organized as 262,144 words of four bits each. They employ state-of-the-art EPIC™ (Enhanced Process Implanted CMOS) technology for high performance, reliability, and low power at a low cost.

operation

enhanced page mode (TMS44C256)

Page-mode operation allows faster memory access by keeping the same row address while selecting random column addresses. The time for row-address setup and hold and address multiplex is thus eliminated. The maximum number of columns that may be accessed is determined by the maximum $\overline{RAS}$ low time and

EPIC is a trademark of Texas Instruments Incorporated.

the $\overline{CAS}$ page-mode cycle time used. With minimum $\overline{CAS}$ page cycle time, all 512 columns specified by column addresses A0 through A8 can be accessed without intervening $\overline{RAS}$ cycles.

Unlike conventional page-mode DRAMs, the column-address buffers in this device are activated on the falling edge of $\overline{RAS}$. The buffers act as transparent or flow-through latches while $\overline{CAS}$ is high. The falling edge of $\overline{CAS}$ latches the column addresses. This feature allows the TMS44C256 to operate at a higher data bandwidth than conventional page-mode parts, since data retrieval begins as soon as column address is valid rather than when $\overline{CAS}$ transitions low. This performance improvement is referred to as "enhanced page mode." Valid column address may be presented immediately after $t_{h(RA)}$ (row address hold time) has been satisfied, usually well in advance of the falling edge of $\overline{CAS}$. In this case, data is obtained after $t_{a(C)}$ max (access time from $\overline{CAS}$ low), if $t_{a(CA)}$ max (access time from column address) has been satisfied. In the event that column addresses for the next page cycle are valid at the time $\overline{CAS}$ goes high, access time for the next cycle is determined by the later occurrence of $t_{a(C)}$ or $t_{a(CP)}$ (access time from rising edge of $\overline{CAS}$).

static column decode mode (TMS44C257)

The static column decode mode of operation allows high-speed read, write, or read-modify-write by reducing the number of required signal setup, hold, and transition timings. This is achieved by first addressing the row and column in the normal manner, but after the first access maintain $\overline{CAS}$ low. Subsequently changing the column address produces valid data at the $t_{a(CA)}$. The first bit is accessed in the normal manner with read data coming out at $t_{a(C)}$ time. Similarly, write or read-modify-write cycle times can be achieved with appropriate toggling of $\overline{W}$. The addresses are latched during the write operation, but at the completion of the internal write operation the addresses are unlatched.

address (A0 through A8)

Eighteen address bits are required to decode 1 of 262,144 storage cell locations. Nine row-address bits are set up on pins A0 through A8 and latched onto the chip by the row-address strobe ($\overline{RAS}$). Then nine column-address bits are set up on pins A0 through A8 and latched onto the chip by the column-address strobe ($\overline{CAS}$). All addresses must be stable on or before the falling edges of $\overline{RAS}$ and $\overline{CAS}$. $\overline{RAS}$ is similar to a chip enable in that it activates the sense amplifiers as well as the row decoder. The TMS44C256 $\overline{CAS}$ is used as a chip select activating the output buffer, as well as latching the address bits into the column-address buffers. The TMS44C257 column addresses are latched only on write cycles with the later of the $\overline{CAS}$ or $\overline{W}$ falling edge.

write enable ($\overline{W}$)

The read or write mode is selected through the write-enable ($\overline{W}$) input. A logic high on the $\overline{W}$ input selects the read mode and a logic low selects the write mode. The write-enable terminal can be driven from standard TTL circuits without a pull-up resistor. The data input is disabled when the read mode is selected. When $\overline{W}$ goes low prior to $\overline{CAS}$ (early write), data out will remain in the high-impedance state for the entire cycle permitting a write operation with $\overline{G}$ grounded. The TMS44C257 latches the column addresses on write cycles with the later of $\overline{CAS}$ or $\overline{W}$ falling edge.

data in (DQ1-DQ4)

Data is written during a write or read-modify-write cycle. Depending on the mode of operation, the falling edge of $\overline{CAS}$ or $\overline{W}$ strobes data into the on-chip data latch. In an early write cycle, $\overline{W}$ is brought low prior to $\overline{CAS}$ and the data is strobed in by $\overline{CAS}$ with setup and hold times referenced to this signal. In a delayed write or read-modify-write cycle, $\overline{CAS}$ will already be low, thus the data will be strobed in by $\overline{W}$ with setup and hold times referenced to this signal. In a delayed or read-modify-write cycle, $\overline{G}$ must be high to bring the output buffers to high impedance prior to impressing data on the I/O lines.

TEXAS INSTRUMENTS
POST OFFICE BOX 1443 • HOUSTON, TEXAS 77001

data out (DQ1-DQ4)

The three-state output buffer provides direct TTL compatibility (no pull-up resistor required) with a fanout of two Series 74 TTL loads. Data out is the same polarity as data in. The output is in the high-impedance (floating) state until $\overline{CAS}$ and $\overline{G}$ are brought low. In a read cycle the output becomes valid after the access time interval $t_{a(C)}$ that begins with the negative transition of $\overline{CAS}$ as long as $t_{a(R)}$ and $t_{a(CA)}$ are satisfied. The output becomes valid after the access time has elapsed and remains valid while $\overline{CAS}$ and $\overline{G}$ are low. $\overline{CAS}$ or $\overline{G}$ going high returns it to a high-impedance state. This is accomplished by bringing $\overline{G}$ high prior to applying data, thus satisfying $t_{d(GHD)}$.

output enable ($\overline{G}$)

$\overline{G}$ controls the impedance of the output buffers. When $\overline{G}$ is high, the buffers will remain in the high-impedance state. Bringing $\overline{G}$ low during a normal cycle will activate the output buffers putting them in the low-impedance state. It is necessary for both $\overline{RAS}$ and $\overline{CAS}$ to be brought low for the output buffers to go into the low-impedance state. Once in the low-impedance state, they will remain in the low-impedance state until either $\overline{G}$ or $\overline{CAS}$ is brought high.

refresh

A refresh operation must be performed at least once every eight milliseconds to retain data. This can be achieved by strobing each of the 512 rows (A0-A8). A normal read or write cycle will refresh all bits in each row that is selected. A $\overline{RAS}$-only operation can be used by holding $\overline{CAS}$ at the high (inactive) level, thus conserving power as the output buffer remains in the high-impedance state. Externally generated addresses must be used for a $\overline{RAS}$-only refresh. Hidden refresh may be performed while maintaining valid data at the output pin. This is accomplished by holding $\overline{CAS}$ at V_{IL} after a read operation and cycling $\overline{RAS}$ after a specified precharge period, similar to a $\overline{RAS}$-only refresh cycle.

$\overline{CAS}$-before-$\overline{RAS}$ refresh

$\overline{CAS}$-before-$\overline{RAS}$ refresh is utilized by bringing $\overline{CAS}$ low earlier than $\overline{RAS}$ [see parameter $t_{d(CLRL)R}$] and holding it low after $\overline{RAS}$ falls [see parameter $t_{d(RLCH)R}$]. For successive $\overline{CAS}$-before-$\overline{RAS}$ refresh cycles, $\overline{CAS}$ can remain low while cycling $\overline{RAS}$. The external address is ignored and the refresh address is generated internally. The external address is also ignored during the hidden refresh option.

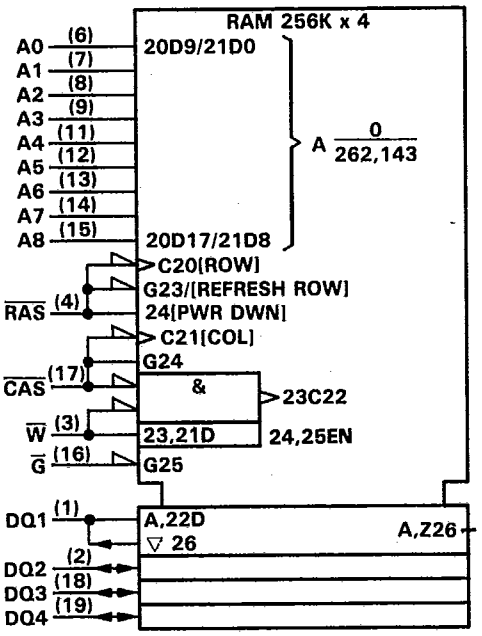
power up

To achieve proper device operation, an initial pause of 200 μs followed by a minimum of eight initialization cycles is required after power up to the full V_{CC} level.

test function pin

During normal device operation, the TF pin must be either disconnected or biased at a voltage less than or equal to V_{CC}.

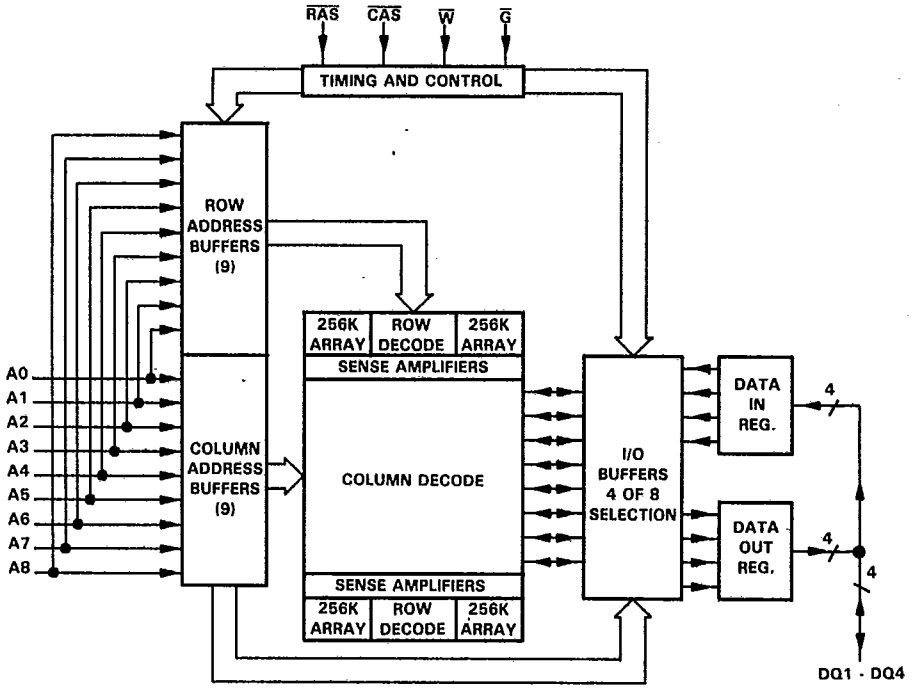
logic symbol†



†This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.

TEXAS INSTRUMENTS
POST OFFICE BOX 1443 • HOUSTON, TEXAS 77001

functional block diagram



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Voltage range on any pin (see Note 1) . . . . . −1 V to 7 V
Voltage range on V_{CC} . . . . . 0 V to 7 V
Short circuit output current . . . . . 50 mA
Power dissipation . . . . . 1 W
Operating free-air temperature range . . . . . 0°C to 70°C
Storage temperature range . . . . . −65°C to 150°C

†Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions beyond those indicated in the "Recommended Operating Conditions" section of this specification is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTE 1: All voltage values in this data sheet are with respect to V_{SS}.

recommended operating conditions

		MIN	NOM	MAX	UNIT
V_{CC}	Supply voltage	4.5	5	5.5	V
V_{SS}	Supply voltage		0		V
V_{IH}	High-level input voltage	2.4		6.5	V
V_{IL}	Low-level input voltage (see Note 2)	−1		0.8	V
T_A	Operating free-air temperature	0		70	°C

NOTE 2: The algebraic convention, where the more negative (less positive) limit is designated as minimum, is used in this data sheet for logic voltage levels only.

electrical characteristics over full ranges of recommended operating conditions (unless otherwise noted)

PARAMETER		TEST CONDITIONS	TMS44C25_-10		TMS44C25_-12		TMS44C25_-15		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
V_{OH}	High-level output voltage	I_{OH} = −5 mA	2.4		2.4		2.4		V
V_{OL}	Low-level output voltage	I_{OL} = 4.2 mA		0.4		0.4		0.4	V
I_I	Input current (leakage)	V_I = 0 V to 5.8 V, V_{CC} = 5 V, All other pins = 0 V to V_{CC}		±10		±10		±10	μA
I_O	Output current (leakage)	V_O = 0 V to V_{CC}, V_{CC} = 5.5 V, $\overline{CAS}$ high		±10		±10		±10	μA
I_{CC1}	Read/write cycle current	$t_{c(rdW)}$ = minimum, V_{CC} = 5.5 V		70		60		55	mA
I_{CC2}	Standby current	After 1 memory cycle, $\overline{RAS}$ and $\overline{CAS}$ high, V_{IH} = 2.4 V		3		3		3	mA
I_{CC3}	Average refresh current	$t_{c(rdW)}$ = minimum, V_{CC} = 5.5 V, $\overline{RAS}$ cycling, $\overline{CAS}$ high		65		55		50	mA
I_{CC4}	Average page current	$t_{c(P)}$ = minimum, V_{CC} = 5.5 V, $\overline{RAS}$ low, $\overline{CAS}$ cycling		45		35		30	mA
I_{CC6}	Average static column decode current	$t_{c(rdW)}$ = minimum, V_{CC} = 5.5 V, $\overline{RAS}$ low, $\overline{CAS}$ cycling		45		35		30	mA

TEXAS INSTRUMENTS
POST OFFICE BOX 1443 • HOUSTON, TEXAS 77001

capacitance over recommended supply voltage range and operating free-air temperature range, f = 1 MHz (see Note 3)

PARAMETER		MIN	MAX	UNIT
$C_{i(A)}$	Input capacitance, address inputs		6	pF
$C_{i(RC)}$	Input capacitance, strobe inputs		7	pF
$C_{i(W)}$	Input capacitance, write-enable input		7	pF
C_o	Output capacitance		7	pF

NOTE 3: V_{CC} equal to 5.0 V ± 0.5 V and the bias on pins under test is 0.0 V.

switching characteristics over recommended supply voltage range and operating free-air temperature range (see Figure 1)

PARAMETER		ALT. SYMBOL	TMS44C25_-10		TMS44C25_-12		TMS44C25_-15		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$t_{a(C)}$	Access time from $\overline{CAS}$ low	t_{CAC}		25		30		40	ns
$t_{a(CA)}$	Access time from column address	t_{CAA}		45		55		70	ns
$t_{a(R)}$	Access time from $\overline{RAS}$ low	t_{RAC}		100		120		150	ns
$t_{a(G)}$	Access time from $\overline{G}$ low	t_{GAC}		25		30		40	ns
$t_{a(CP)}$	Access time from column precharge (TMS44C256 only)	t_{CAP}		50		60		75	ns
$t_{a(WHQ)}$	Access time from $\overline{W}$ high, Static column decode mode (see Note 4) (TMS44C257 only)	t_{WRA}		30		35		40	ns
$t_{a(WLQ)}$	Access time from $\overline{W}$ low, Static column decode mode (see Note 4) (TMS44C257 only)	t_{ALW}		95		115		120	ns
$t_{dis(CH)}$	Output disable time after $\overline{CAS}$ high (see Note 5)	t_{OFF}	0	25	0	30	0	35	ns
$t_{dis(G)}$	Output disable time after $\overline{G}$ high (see Note 5)	t_{GOFF}	0	25	0	30	0	35	ns

NOTES: 4. Read-modify-write operation only.
5. $t_{dis(CH)}$ and $t_{dis(G)}$ are specified when the output is no longer driven.

timing requirements over recommended supply voltage range and operating free-air temperature range

		ALT. SYMBOL	TMS44C256-10		TMS44C256-12		TMS44C256-15		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$t_{c(rd)}$	Read cycle time (see Note 7)	t_{RC}	190		220		260		ns
$t_{c(W)}$	Write cycle time	t_{WC}	190		220		260		ns
$t_{c(rdW)}$	Read-write/read-modify-write cycle time	t_{RWC}	220		255		305		ns
$t_{c(P)}$	Page-mode read or write cycle time (see Note 8)	t_{PC}	55		65		80		ns
$t_{c(PM)}$	Page-mode read-modify-write cycle time	t_{PCM}	85		100		125		ns
$t_{w(CH)}$	Pulse duration, $\overline{CAS}$ high	t_{CP}	10		15		25		ns
$t_{w(CL)}$	Pulse duration, $\overline{CAS}$ low (see Note 9)	t_{CAS}	25	10,000	30	10,000	40	10,000	ns
$t_{w(RH)}$	Pulse duration $\overline{RAS}$ high (precharge)	t_{RP}	80		90		100		ns
$t_{w(RL)}$	Non-page-mode pulse duration, $\overline{RAS}$ low (see Note 10)	t_{RAS}	100	10,000	120	10,000	150	10,000	ns
$t_{w(RL)P}$	Page-mode pulse duration, $\overline{RAS}$ low (see Note 10)	t_{RASP}	100	100,000	120	100,000	150	100,000	ns
$t_{w(WL)}$	Write pulse duration	t_{WP}	15		20		25		ns
$t_{su(CA)}$	Column-address setup time before $\overline{CAS}$ low	t_{ASC}	0		0		0		ns
$t_{su(RA)}$	Row-address setup time before $\overline{RAS}$ low	t_{ASR}	0		0		0		ns
$t_{su(D)}$	Data setup time before $\overline{W}$ low (see Note 11)	t_{DS}	0		0		0		ns
$t_{su(rd)}$	Read setup time before $\overline{CAS}$ low	t_{RCS}	0		0		0		ns
$t_{su(WCL)}$	$\overline{W}$-low setup time before $\overline{CAS}$ low (see Note 12)	t_{WCS}	0		0		0		ns
$t_{su(WCH)}$	$\overline{W}$-low setup time before $\overline{CAS}$ high	t_{CWL}	25		30		40		ns
$t_{su(WRH)}$	$\overline{W}$-low setup time before $\overline{RAS}$ high	t_{RWL}	25		30		40		ns
$t_{h(CA)}$	Column-address hold time after $\overline{CAS}$ low (see Note 11)	t_{CAH}	20		20		25		ns
$t_{h(RA)}$	Row-address hold time after $\overline{RAS}$ low	t_{RAH}	15		15		20		ns

Continued next page.

NOTES: 6. Timing measurements are referenced to V_{IL} max and V_{IH} min.
7. All cycle times assume t_t = 5 ns.
8. $t_{c(P)} > t_{w(CH)}$ min + $t_{w(CL)}$ min + $2t_t$.
9. In a read-modify-write cycle, $t_{d(CLWL)}$ and $t_{su(WCH)}$ must be observed. Depending on the user's transition times, this may require additional $\overline{CAS}$ low time [$t_{w(CL)}$].
10. In a read-modify-write cycle, $t_{d(RLWL)}$ and $t_{su(WRH)}$ must be observed. Depending on the user's transition times, this may require additional $\overline{RAS}$ low time [$t_{w(RL)}$].
11. Later of $\overline{CAS}$ or $\overline{W}$ in write operations.
12. Early write operation only.

TEXAS INSTRUMENTS
POST OFFICE BOX 1443 • HOUSTON, TEXAS 77001

timing requirements over recommended supply voltage range and operating free-air temperature range (continued)

		ALT. SYMBOL	TMS44C256-10		TMS44C256-12		TMS44C256-15		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$t_{h(RLCA)}$	Column-address hold time after $\overline{RAS}$ low (see Note 13)	t_{AR}	70		80		100		ns
$t_{h(D)}$	Data hold time after $\overline{CAS}$ low (see Note 11)	t_{DH}	20		25		30		ns
$t_{h(RLD)}$	Data hold time after $\overline{RAS}$ low (see Note 13)	t_{DHR}	70		85		110		ns
$t_{h(CHrd)}$	Read hold time after $\overline{CAS}$ high (see Note 15)	t_{RCH}	0		0		0		ns
$t_{h(RHrd)}$	Read hold time after $\overline{RAS}$ high (see Note 15)	t_{RRH}	10		10		10		ns
$t_{h(CLW)}$	Write hold time after $\overline{CAS}$ low (see Note 12)	t_{WCH}	20		25		30		ns
$t_{h(RLW)}$	Write hold time after $\overline{RAS}$ low (see Note 13)	t_{WCR}	70		85		100		ns
$t_{d(RLCH)}$	Delay time, $\overline{RAS}$ low to $\overline{CAS}$ high	t_{CSH}	100		120		150		ns
$t_{d(CHRL)}$	Delay time, $\overline{CAS}$ high to $\overline{RAS}$ low	t_{CRP}	0		0		0		ns
$t_{d(CLRH)}$	Delay time, $\overline{CAS}$ low to $\overline{RAS}$ high	t_{RSH}	25		30		40		ns
$t_{d(CLWL)}$	Delay time, $\overline{CAS}$ low to $\overline{W}$ low (see Note 4)	t_{CWD}	50		60		70		ns
$t_{d(RLCL)}$	Delay time, $\overline{RAS}$ low to $\overline{CAS}$ low (see Note 14)	t_{RCD}	25	75	25	90	30	110	ns
$t_{d(RLCA)}$	Delay time, $\overline{RAS}$ low to column address (see Note 14)	t_{RAD}	20	55	20	65	25	80	ns
$t_{d(CARH)}$	Delay time, column address to $\overline{RAS}$ high	t_{RAL}	45		55		70		ns
$t_{d(CACH)}$	Delay time, column address to $\overline{CAS}$ high	t_{CAL}	45		55		70		ns
$t_{d(RLWL)}$	Delay time, $\overline{RAS}$ low to $\overline{W}$ low (see Note 4)	t_{RWD}	100		120		150		ns
$t_{d(CAWL)}$	Delay time, column address to $\overline{W}$ low (see Note 4)	t_{AWD}	45		55		70		ns
$t_{d(GHD)}$	Delay time, $\overline{G}$ high before data at DQ	t_{GDD}	25		30		40		ns
$t_{d(GLRH)}$	Delay time, $\overline{G}$ low to $\overline{RAS}$ high	t_{GSR}	20		25		35		ns

Continued next page.

NOTES: 4. Read-modify-write operation only.
11. Later of $\overline{CAS}$ or $\overline{W}$ in write operations.
12. Early write operation only.
13. The minimum value is measured when $t_{d(RLCL)}$ is set to $t_{d(RLCL)}$ min as a reference.
14. Maximum value specified only to guarantee access time.
15. Either $t_{h(RHrd)}$ or $t_{h(CHrd)}$ must be satisfied for a read cycle.

timing requirements over recommended supply voltage range and operating free-air temperature range (concluded)

		ALT. SYMBOL	TMS44C256-10		TMS44C256-12		TMS44C256-15		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$t_{d(RLCH)R}$	Delay time, $\overline{RAS}$ low to $\overline{CAS}$ high (see Note 16)	t_{CHR}	25		25		30		ns
$t_{d(CLRL)R}$	Delay time, $\overline{CAS}$ low to $\overline{RAS}$ low (see Note 16)	t_{CSR}	10		10		15		ns
$t_{d(RHCL)R}$	Delay time, $\overline{RAS}$ high to $\overline{CAS}$ low (see Note 16)	t_{RPC}	0		0		0		ns
t_{rf}	Refresh time interval	t_{REF}		8		8		8	ms
t_t	Transition time	t_T	3	50	3	50	3	50	ns

NOTE 16: $\overline{CAS}$-before-$\overline{RAS}$ refresh only.

TEXAS INSTRUMENTS
POST OFFICE BOX 1443 • HOUSTON, TEXAS 77001

timing requirements over recommended supply voltage range and operating free-air temperature range

		ALT. SYMBOL	TMS44C257-10		TMS44C257-12		TMS44C257-15		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$t_{c(rd)}$	Read cycle time (see Note 7)	t_{RC}	190		220		260		ns
$t_{c(W)}$	Write cycle time	t_{WC}	190		220		260		ns
$t_{c(rdW)}$	Read-write/read-modify-write cycle time	t_{RWC}	220		255		305		ns
$t_{c(rd)SC}$	Static column decode mode read-only cycle time	t_{SCR}	50		60		90		ns
$t_{c(W)SC}$	Static column decode mode write-only cycle time	t_{CSW}	50		60		90		ns
$t_{c(rdW)SC}$	Static column decode mode read-modify-write cycle time	t_{SCRDW}	100		120		150		ns
$t_{w(CH)}$	Pulse duration, $\overline{CAS}$ high	t_{CP}	10		15		25		ns
$t_{w(CL)}$	Pulse duration, $\overline{CAS}$ low (see Note 9)	t_{CAS}	20	10,000	25	10,000	35	10,000	ns
$t_{w(RH)}$	Pulse duration, $\overline{RAS}$ high (precharge)	t_{RP}	80		90		100		ns
$t_{w(RL)}$	Non-static column decode mode pulse duration, $\overline{RAS}$ low (see Note 10)	t_{RAS}	100	10,000	120	10,000	150	10,000	ns
$t_{w(RL)P}$	Static column decode mode pulse duration, $\overline{RAS}$ low (see Note 10)	t_{RASP}	100	100,000	120	100,000	150	100,000	ns
$t_{w(WL)}$	Write pulse duration	t_{WP}	15		20		25		ns
$t_{w(CA)}$	Static column decode mode column address pulse duration	t_{ADP}	45		55		70		ns
$t_{w(WH)}$	Static column decode mode $\overline{W}$ high pulse duration	t_{WI}	10		15		25		ns
$t_{su(CA)}$	Column-address setup times before $\overline{CAS}$ low or $\overline{W}$ low (see Note 11)	t_{ASC}	0		0		0		ns
$t_{su(RA)}$	Row address setup time before $\overline{RAS}$ low	t_{ASR}	0		0		0		ns
$t_{su(D)}$	Data setup time before $\overline{W}$ low (see Note 11)	t_{DS}	0		0		0		ns
$t_{su(rd)}$	Read setup time before $\overline{CAS}$ low	t_{RCS}	0		0		0		ns
$t_{su(WCL)}$	$\overline{W}$-low setup time before $\overline{CAS}$ low (see Note 12)	t_{WCS}	0		0		0		ns
$t_{su(WCH)}$	$\overline{W}$-low setup time before $\overline{CAS}$ high	t_{CWL}	25		30		40		ns
$t_{su(WHCH)}$	$\overline{W}$-high setup time before $\overline{CAS}$ high (see Note 12)	t_{WHCH}	0		0		0		ns

Continued next page.

NOTES: 6. Timing measurements are referenced to V_{IL} max and V_{IH} min.

7. All cycle times assume t_t = 5 ns.

9. In a read-modify-write cycle, $t_{d(CLWL)}$ and $t_{su(WCH)}$ must be observed. Depending on the user's transition times, this may require additional $\overline{CAS}$ low time [$t_{w(CL)}$].

10. In a read-modify-write cycle, $t_{d(RLWL)}$ and $t_{su(WRH)}$ must be observed. Depending on the user's transition times, this may require additional $\overline{RAS}$ low time [$t_{w(RL)}$].

11. Later of $\overline{CAS}$ or $\overline{W}$ in write operations.

12. Early write operation only.

timing requirements over recommended supply voltage range and operating free-air temperature range (continued)

		ALT. SYMBOL	TMS44C257-10		TMS44C257-12		TMS44C257-15		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$t_{su(WRH)}$	$\overline{W}$-low setup time before $\overline{RAS}$ high	t_{RWL}	25		30		40		ns
$t_{su(RLrd)}$	Read-command setup time before $\overline{RAS}$ low	t_{WRP}	0		0		0		ns
$t_{su(CAR)}$	Column-address setup time before $\overline{RAS}$ high	t_{CAR}	50		60		75		ns
$t_{h(CA)}$	Column-address hold time after $\overline{CAS}$ low, $\overline{W}$ low (see Note 11)	t_{CAH}	20		20		25		ns
$t_{h(RA)}$	Row-address hold time after $\overline{RAS}$ low	t_{RAH}	15		15		20		ns
$t_{h(RLCA)}$	Column-address hold time after $\overline{RAS}$ low (see Note 17)	t_{AR}	100		120		150		ns
$t_{h(D)}$	Data hold time after $\overline{CAS}$ low (see Note 11)	t_{DH}	20		25		30		ns
$t_{h(RLD)}$	Data hold time after $\overline{RAS}$ low (see Note 17)	t_{DHR}	70		85		110		ns
$t_{h(CHrd)}$	Read hold time after $\overline{CAS}$ high (see Note 15)	t_{RCH}	0		0		0		ns
$t_{h(RHrd)}$	Read hold time after $\overline{RAS}$ high (see Note 15)	t_{RRH}	10		10		10		ns
$t_{h(CLW)}$	Write hold time after $\overline{CAS}$ low	t_{WCH}	20		25		30		ns
$t_{h(RLW)}$	Write hold time after $\overline{RAS}$ low (see Note 17)	t_{WCR}	70		85		100		ns
$t_{h(RHCA)}$	Column-address hold time after $\overline{RAS}$ high	t_{AH}	10		15		15		ns
$t_{h(CAQ)}$	Output hold time after address change	t_{OH}	5		5		5		ns
$t_{d(RLCH)}$	Delay time, $\overline{RAS}$ low to $\overline{CAS}$ high	t_{CSH}	100		120		150		ns
$t_{d(CHRL)}$	Delay time, $\overline{CAS}$ high to $\overline{RAS}$ low	t_{CRP}	0		0		0		ns
$t_{d(CLRH)}$	Delay time, $\overline{CAS}$ low to $\overline{RAS}$ high	t_{RSH}	25		30		40		ns
$t_{d(CLWL)}$	Delay time, $\overline{CAS}$ low to $\overline{W}$ low (see Note 4)	t_{CWD}	25		30		40		ns

Continued next page.

NOTES: 4. Read-modify-write operation only.
11. Later of $\overline{CAS}$ or $\overline{W}$ in write operations.
15. Either $t_{h(RHrd)}$ or $t_{h(CHrd)}$ must be satisfied for a read cycle.
17. The minimum value is measured when $t_{d(RLCA)}$ is set to $t_{d(RLCA)}$ min as a reference.

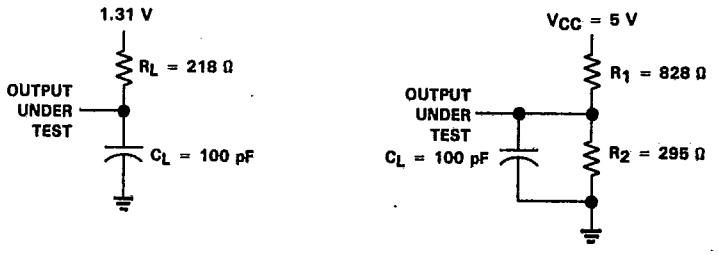
TEXAS INSTRUMENTS
POST OFFICE BOX 1443 • HOUSTON, TEXAS 77001

timing requirements over recommended supply voltage range and operating free-air temperature range (concluded)

		ALT. SYMBOL	TMS44C257-10		TMS44C257-12		TMS44C257-15		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
$t_{d(RLCL)}$	Delay time, $\overline{RAS}$ low to $\overline{CAS}$ low (see Note 14)	t_{RCD}	25	75	25	90	30	110	ns
$t_{d(RLCA)}$	Delay time, $\overline{RAS}$ low to column address (see Note 14)	t_{RAD}	20	55	20	65	25	80	ns
$t_{d(CARH)}$	Delay time, column address to $\overline{RAS}$ high	t_{RAL}	45		55		70		ns
$t_{d(CACH)}$	Delay time, column address to $\overline{CAS}$ high	t_{CAL}	45		55		70		ns
$t_{d(RLWL)}$	Delay time, $\overline{RAS}$ low to $\overline{W}$ low (see Note 4)	t_{RWD}	100		120		150		ns
$t_{d(CAWL)}$	Delay time, column address to $\overline{W}$ low (see Note 4)	t_{AWD}	45		55		70		ns
$t_{d(GHD)}$	Delay time, $\overline{G}$ high before data at DQ	t_{GDD}	25		30		40		ns
$t_{d(GLRH)}$	Delay time, $\overline{G}$ low to $\overline{RAS}$ high	t_{GSR}	20		25		35		ns
$t_{d(WQ)}$	Delay time, $\overline{W}$ high to output transition from high impedance to active	t_{OW}	0		0		0		ns
$t_{d(RLCH)R}$	Delay time, $\overline{RAS}$ low to $\overline{CAS}$ high (see Note 16)	t_{CHR}	25		25		30		ns
$t_{d(CLRL)R}$	Delay time, $\overline{CAS}$ low to $\overline{RAS}$ low (see Note 16)	t_{CSR}	10		10		15		ns
$t_{d(RHCL)R}$	Delay time $\overline{RAS}$ high to $\overline{CAS}$ low (see Note 16)	t_{RPC}	0		0		0		ns
t_{rf}	Refresh time interval	t_{REF}		8		8		8	ms
t_t	Transition time	t_T	3	50	3	50	3	50	ns

NOTES: 4. Read-modify-write operation only.
14. Maximum value specified only to guarantee access time.
16. $\overline{CAS}$-before-$\overline{RAS}$ refresh only.

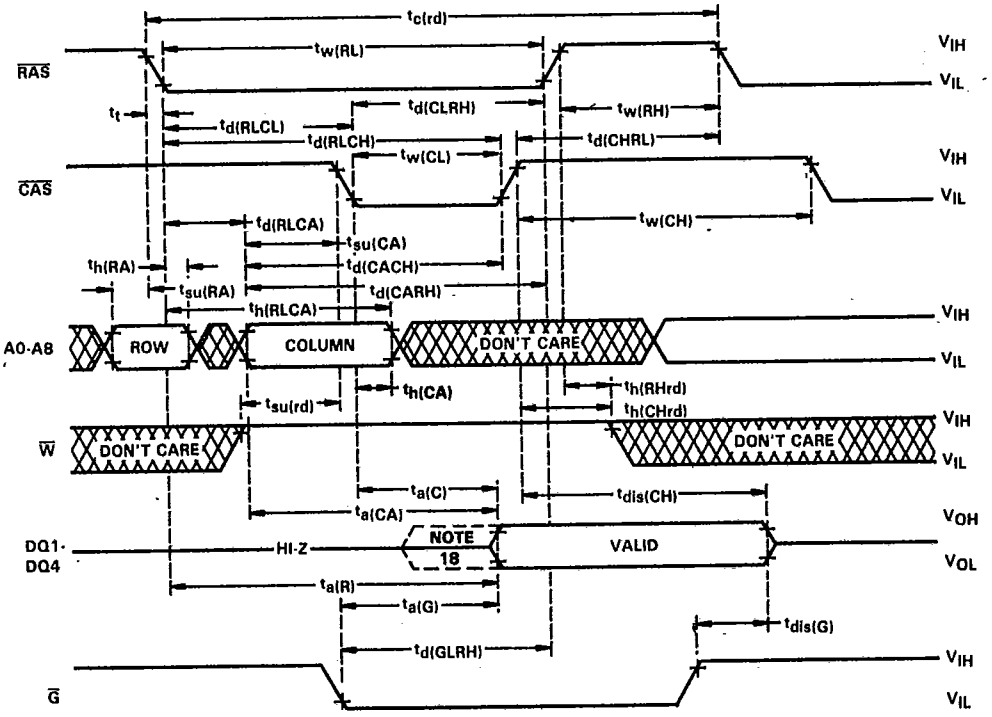
PARAMETER MEASUREMENT INFORMATION



(a) LOAD CIRCUIT (b) ALTERNATE LOAD CIRCUIT

FIGURE 1. LOAD CIRCUITS FOR TIMING PARAMETERS

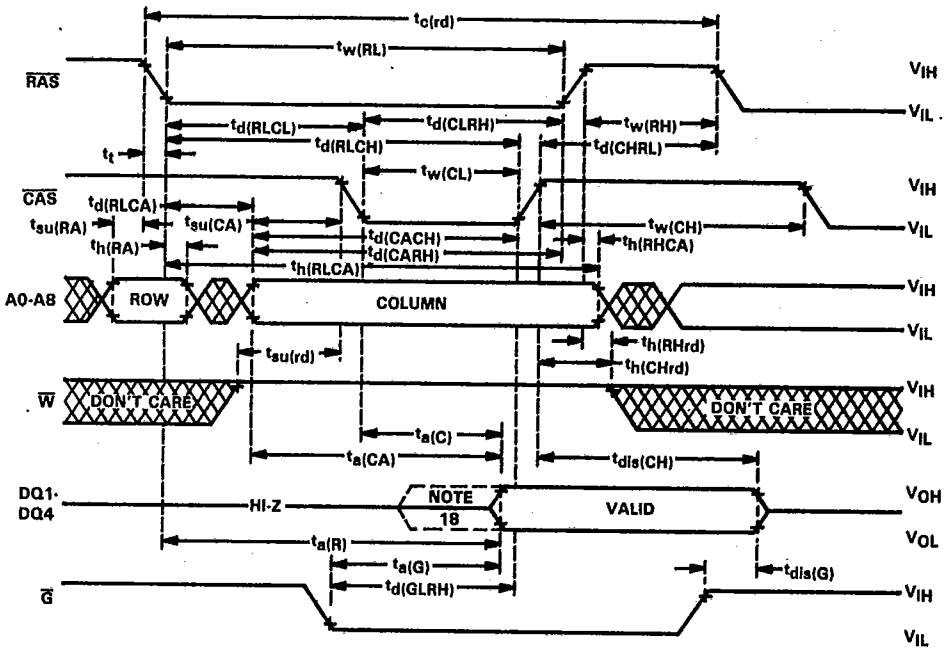
read cycle timing



NOTE 18: Output may go from high impedance to an invalid data state prior to the specified access time.

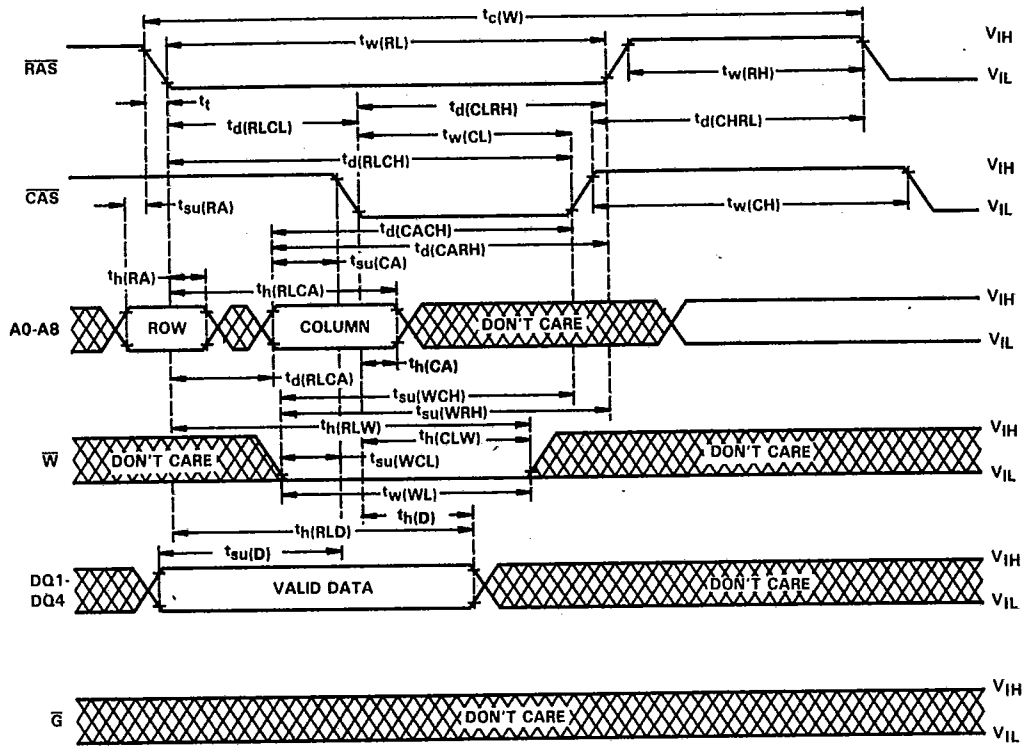
TEXAS INSTRUMENTS
POST OFFICE BOX 1443 • HOUSTON, TEXAS 77001

read cycle timing



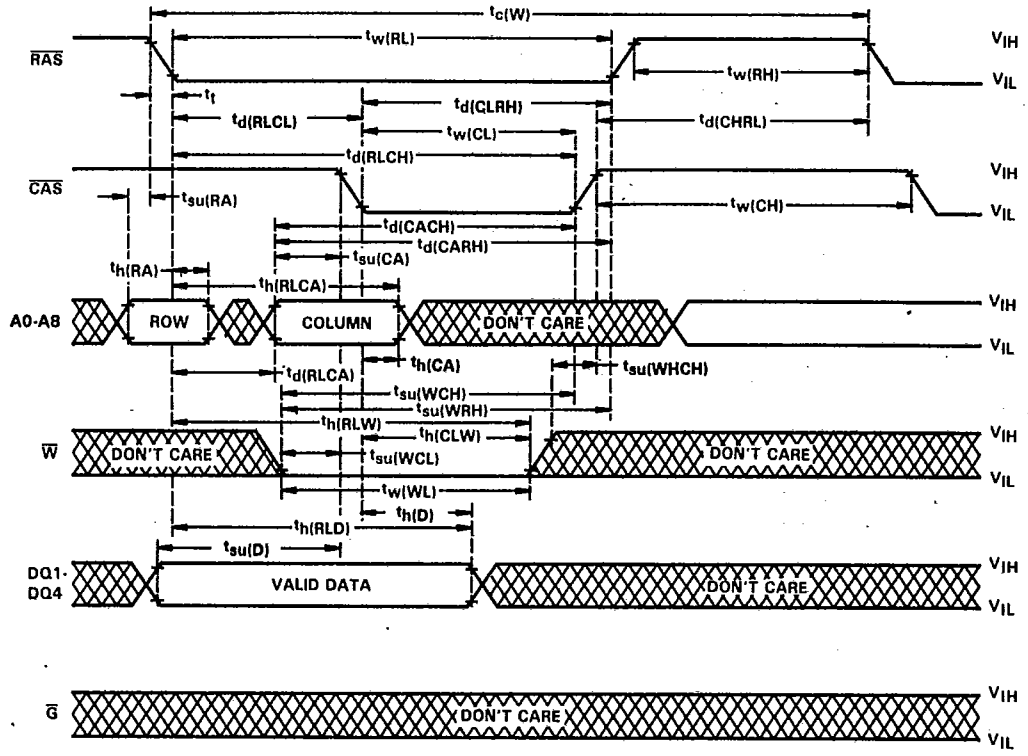
NOTE 18: Output may go from high impedance to an invalid data state prior to the specified access time.

early write cycle timing

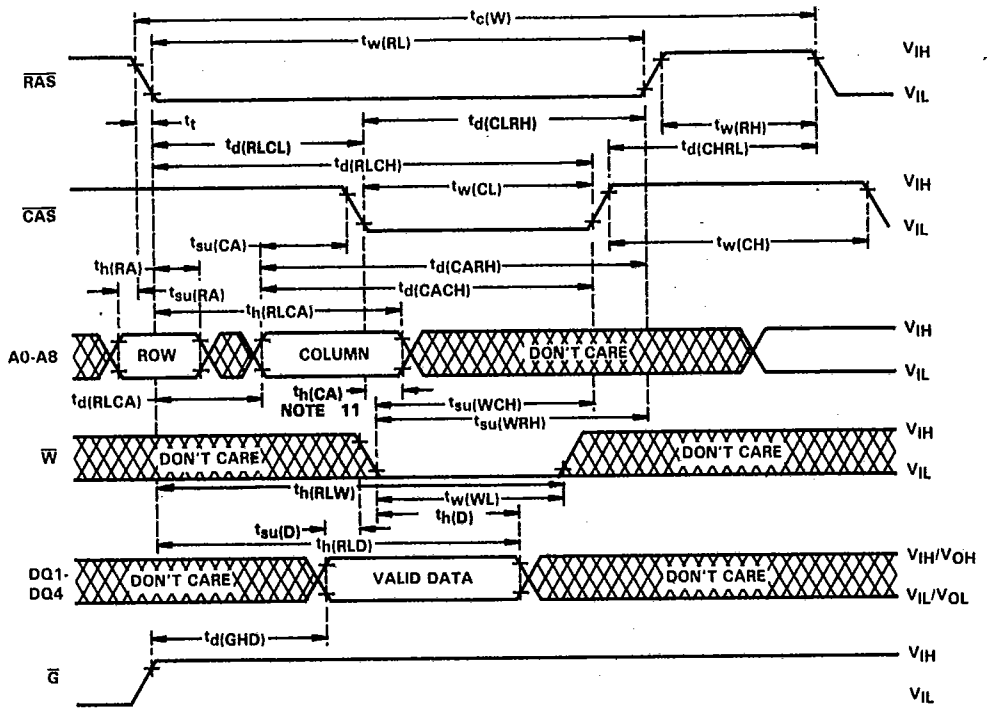


TEXAS INSTRUMENTS
POST OFFICE BOX 1443 • HOUSTON, TEXAS 77001

early write cycle timing



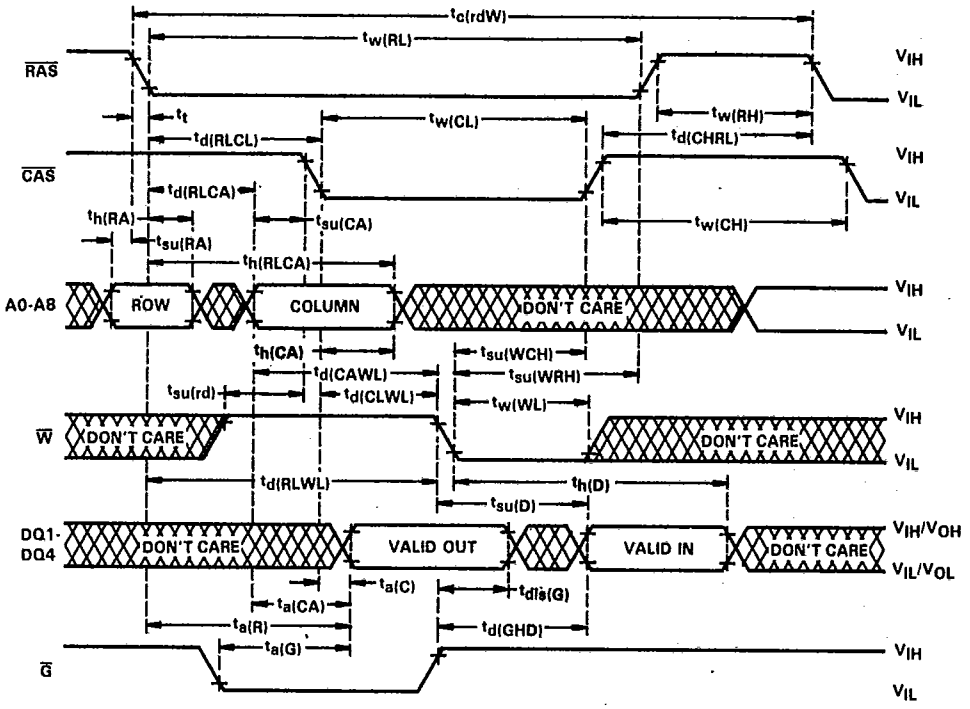
write cycle timing



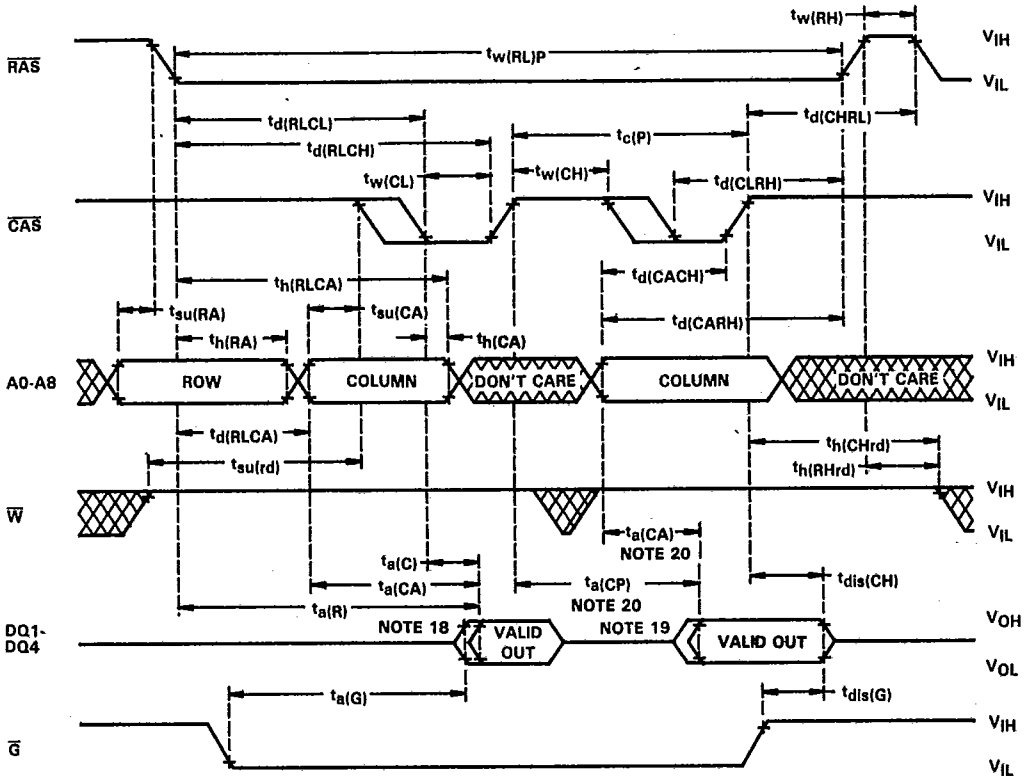
NOTE 11: Later of $\overline{CAS}$ or $\overline{W}$ in write operation.

TEXAS INSTRUMENTS
POST OFFICE BOX 1443 • HOUSTON, TEXAS 77001

read-write/read-modify-write cycle timing



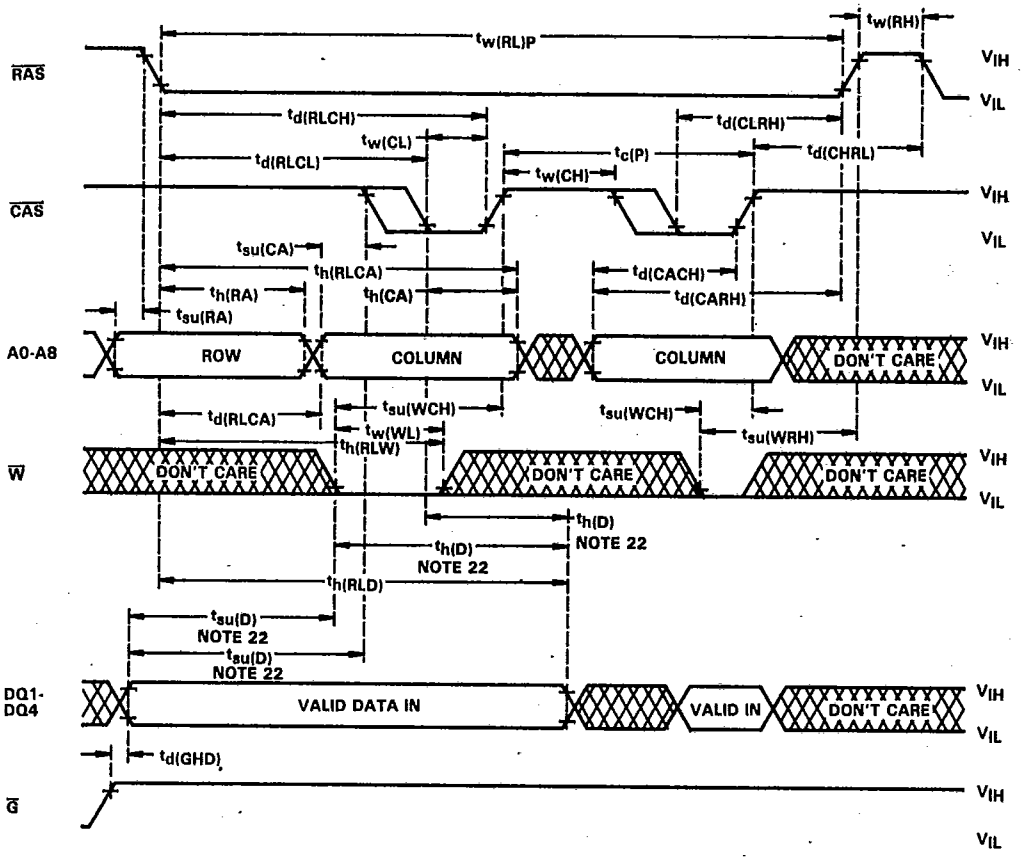
enhanced page-mode read cycle timing



NOTES: 18. Output may go from high impedance to an invalid data state prior to the specified access time.
19. A write cycle or read-modify-write cycle can be mixed with the read cycles as long as the write and read-modify-write timing specifications are not violated.
20. Access time is $t_{a(CP)}$ or $t_{a(CA)}$ dependent.

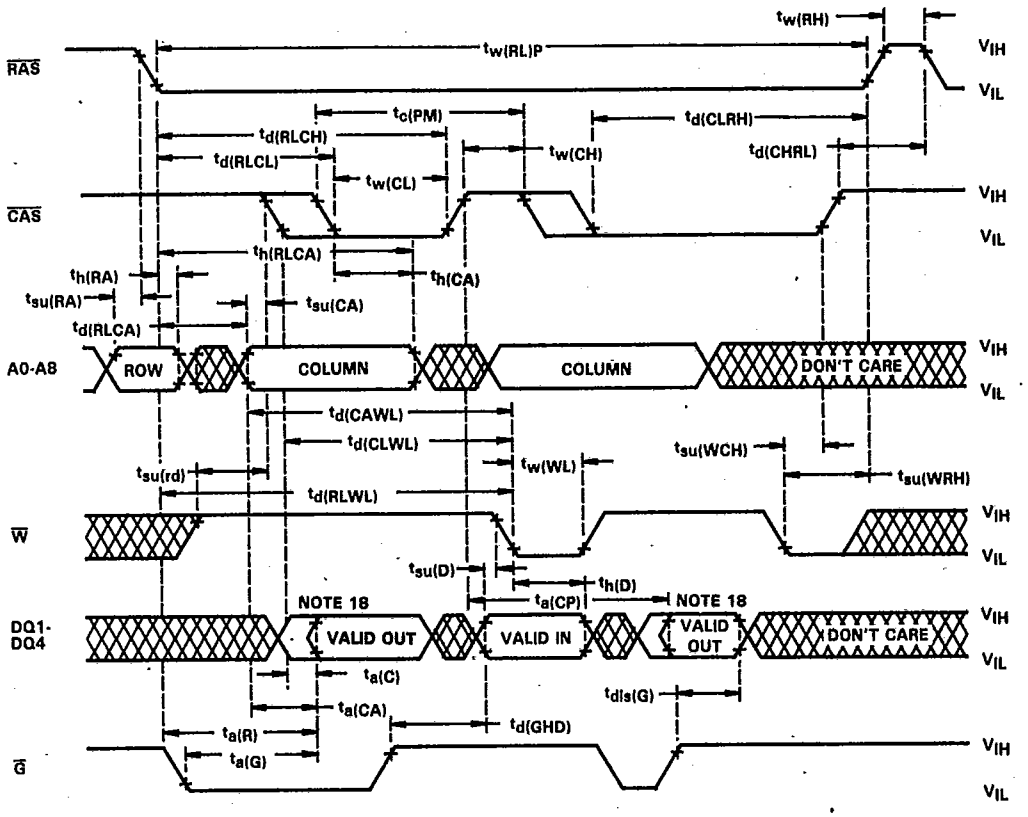
TEXAS INSTRUMENTS
POST OFFICE BOX 1443 • HOUSTON, TEXAS 77001

enhanced page-mode write cycle timing



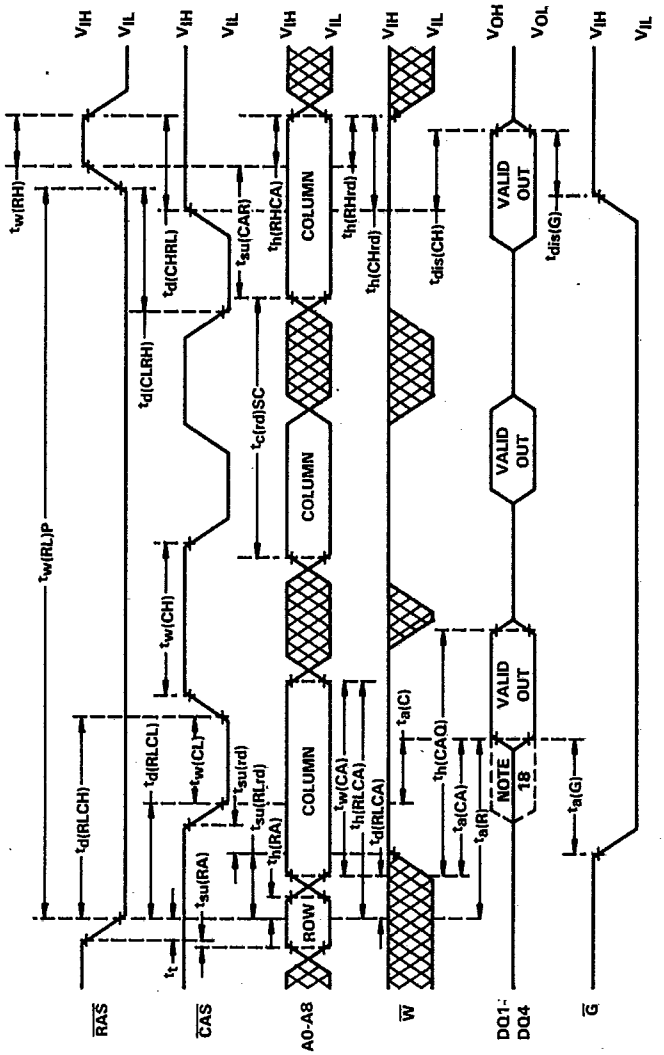
NOTES: 21. A read cycle or a read-modify-write cycle can be intermixed with the write cycles as long as the read and read-modify-write timing specifications are not violated.
22. Referenced to $\overline{CAS}$ or $\overline{W}$, whichever occurs last.

enhanced page-mode read-modify-write cycle timing



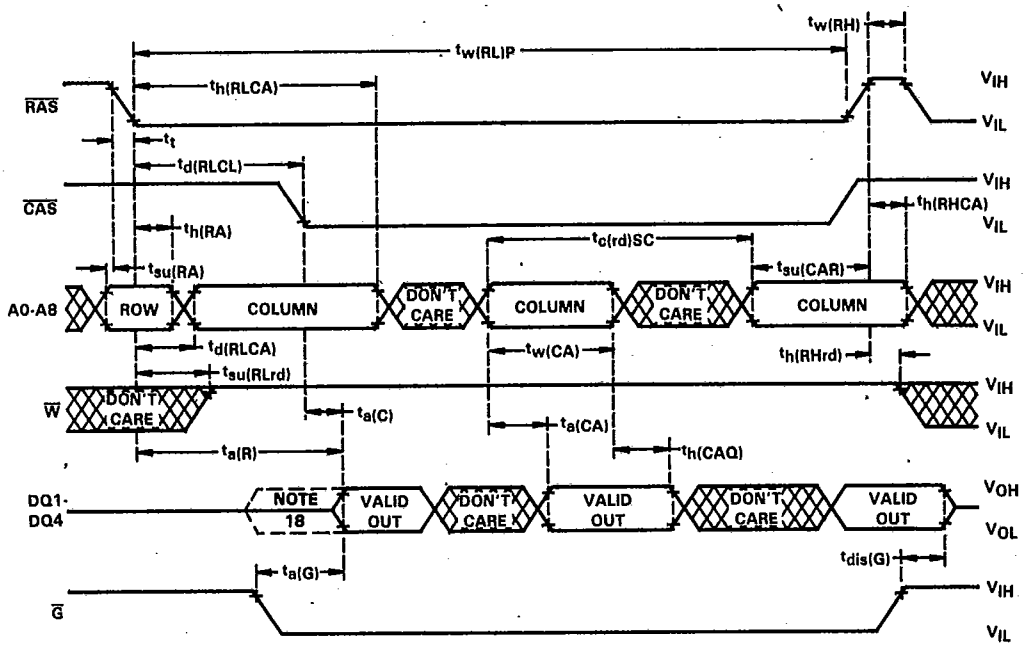
NOTES: 18. Output may go from high-impedance to an invalid data state prior to the specified access time.
23. A read or a write cycle can be intermixed with read-modify-write cycles as long as the read and write cycle timing specifications are not violated.

static column decode mode read timing with $\overline{CAS}$ cycling



NOTE 18: Output may go from high impedance to an invalid data state prior to the specified access time.

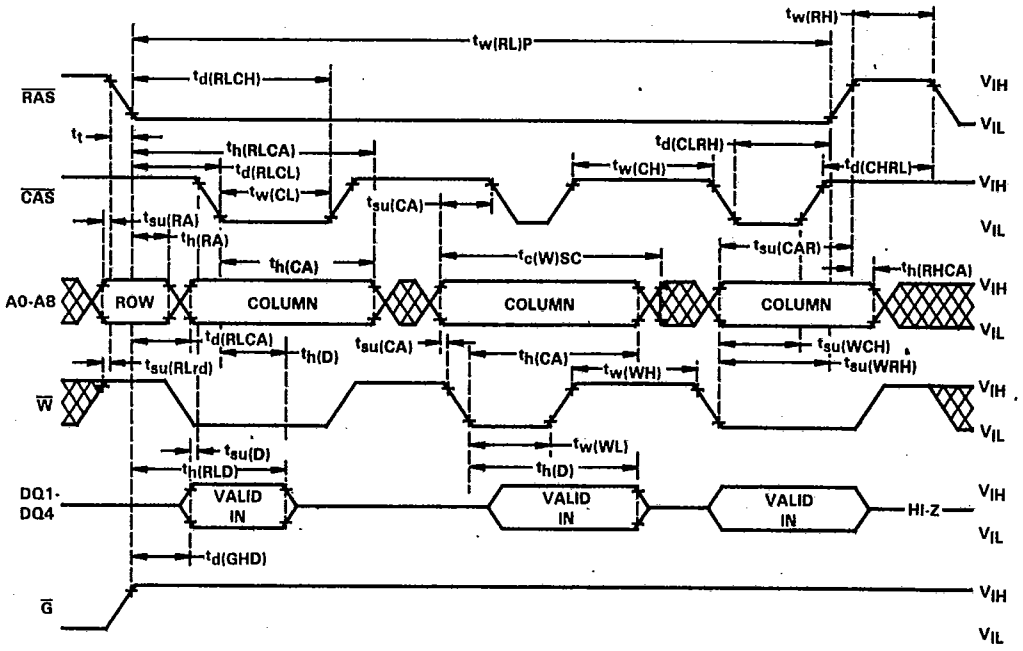
static column decode mode read cycle timing



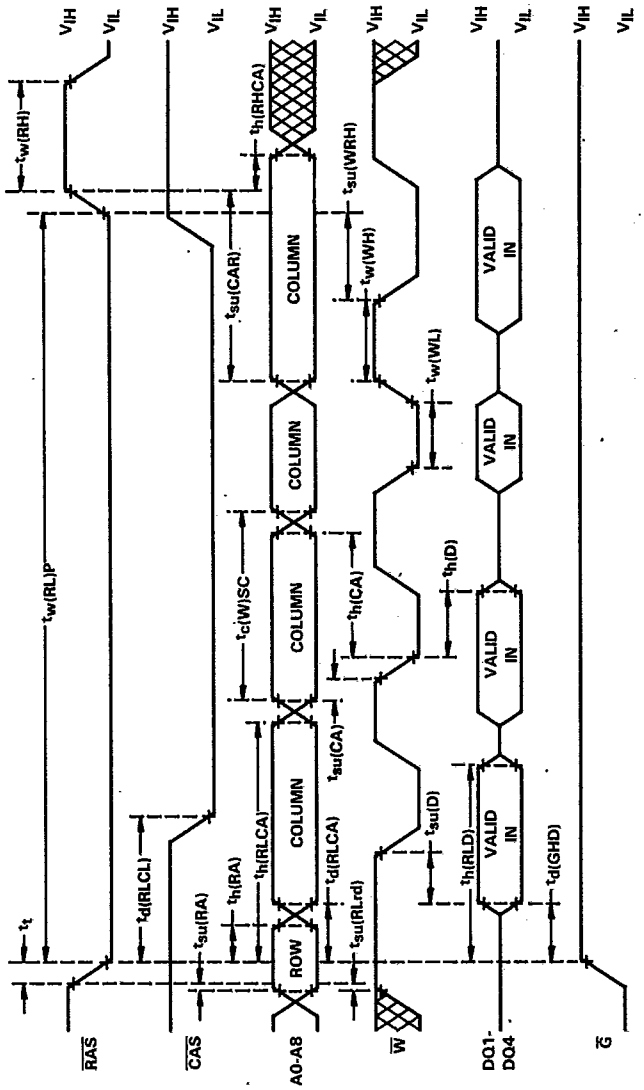
NOTE 18: Output may go from high impedance to an invalid data state prior to the specified access time.

TEXAS INSTRUMENTS
POST OFFICE BOX 1443 • HOUSTON, TEXAS 77001

static column decode mode early write cycle timing

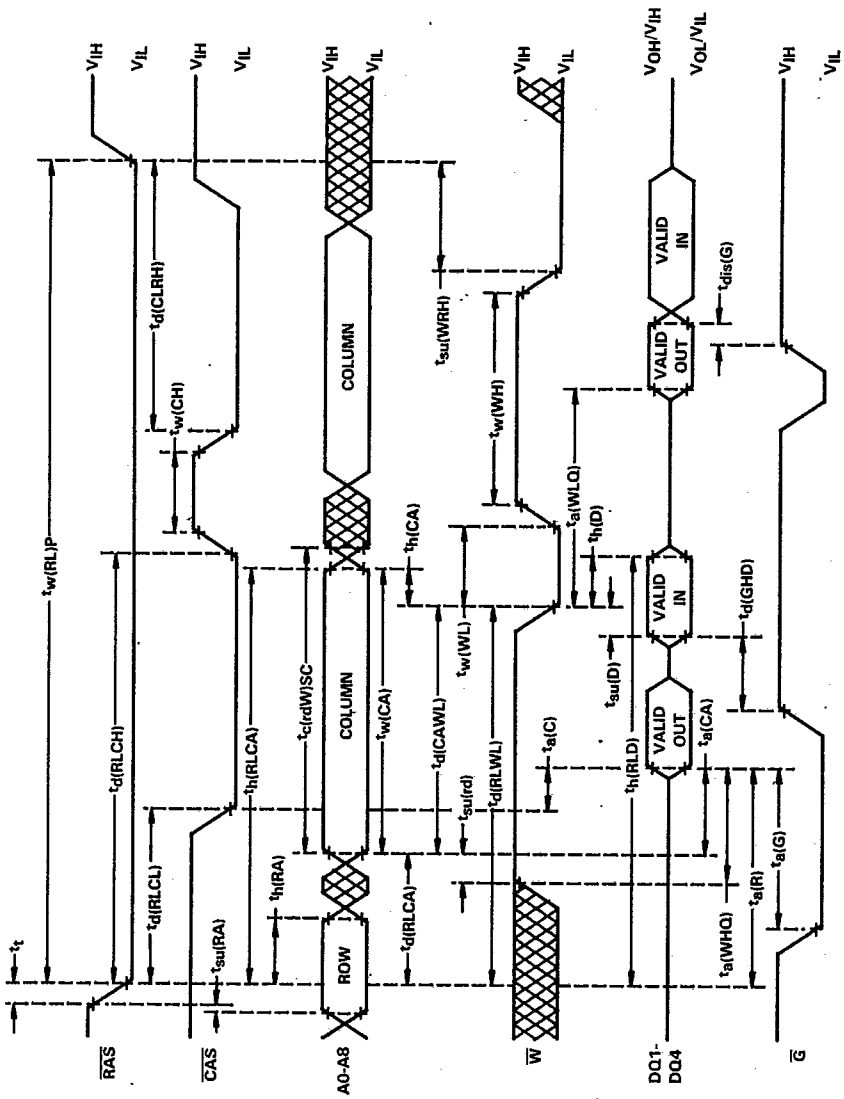


static column decode mode write cycle timing

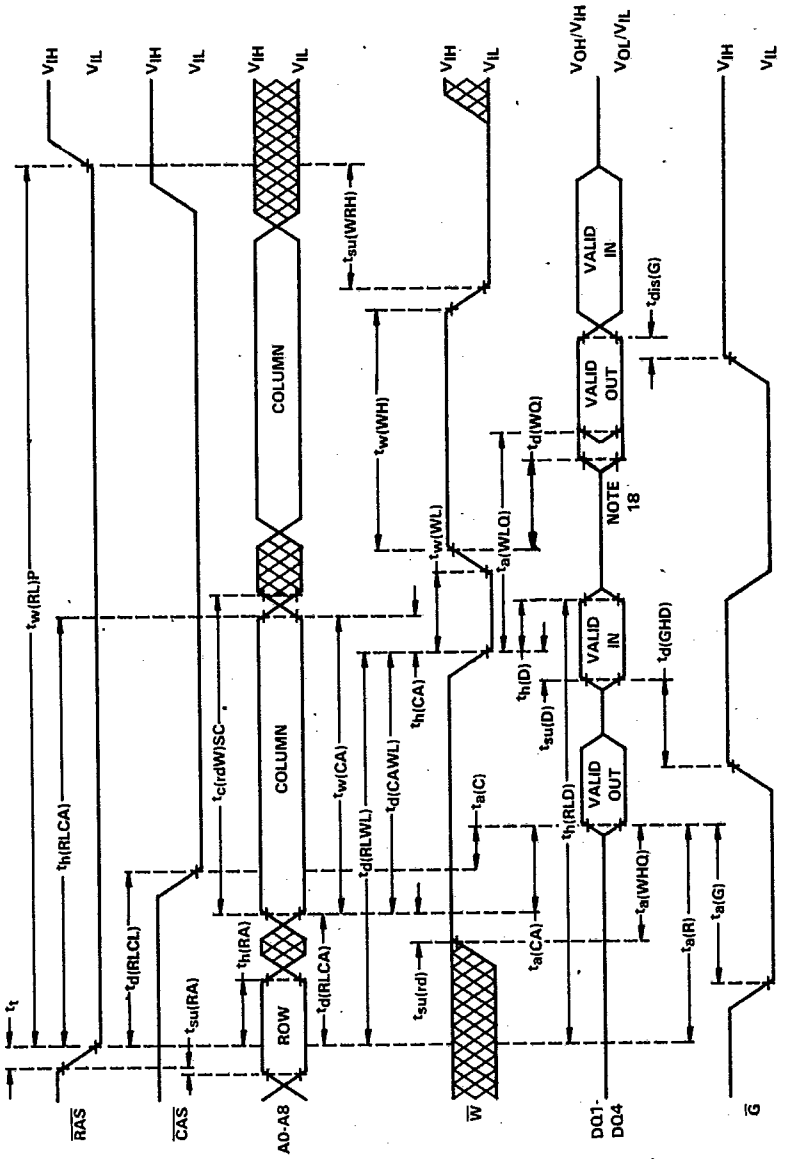


TEXAS INSTRUMENTS
POST OFFICE BOX 1443 • HOUSTON, TEXAS 77001

static column decode mode read-modify-write cycle timing with $\overline{CAS}$ cycling



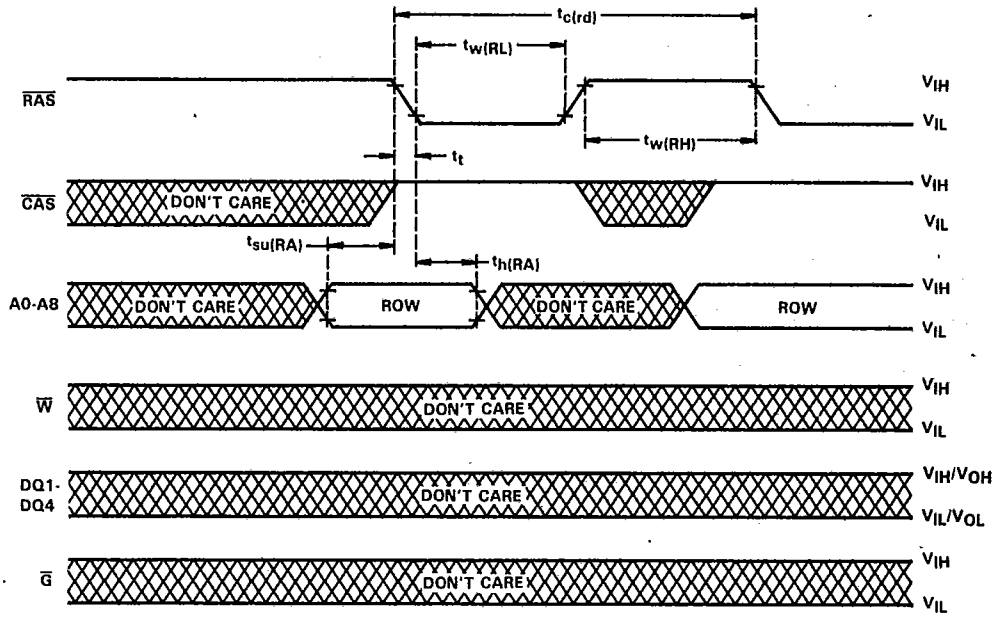
static column decode mode read-modify-write cycle timing



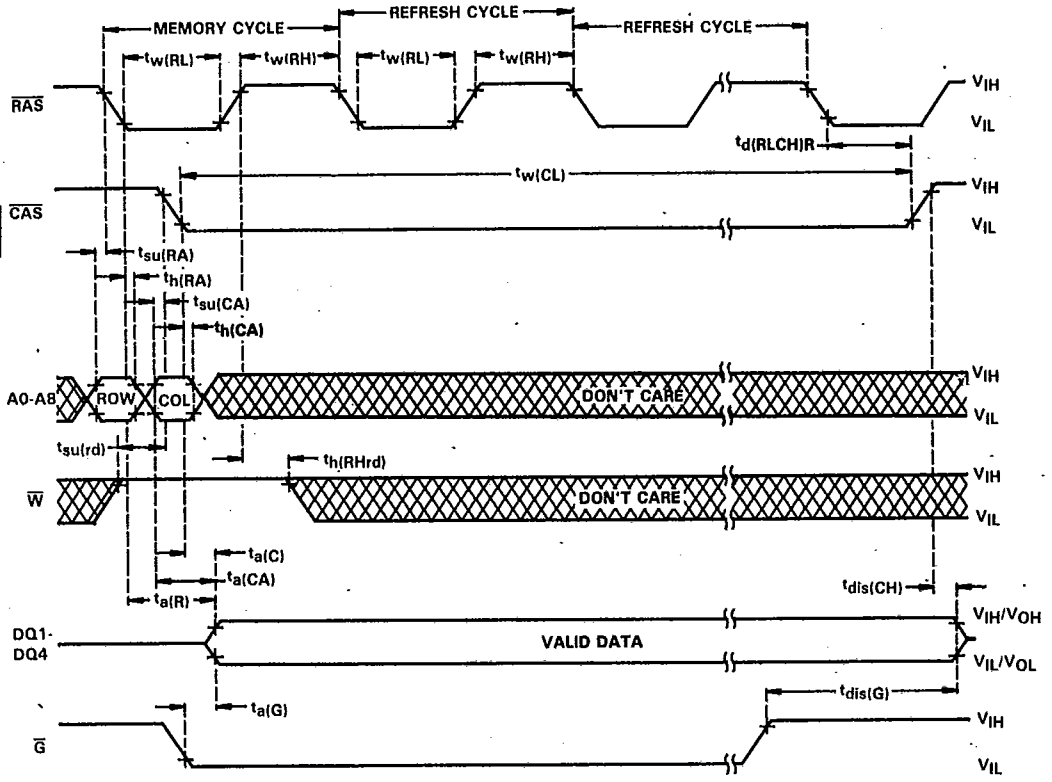
NOTE 18: Output may go from high impedance to an invalid data state prior to the specified access time.

TEXAS INSTRUMENTS
POST OFFICE BOX 1443 • HOUSTON, TEXAS 77001

$\overline{RAS}$-only refresh timing

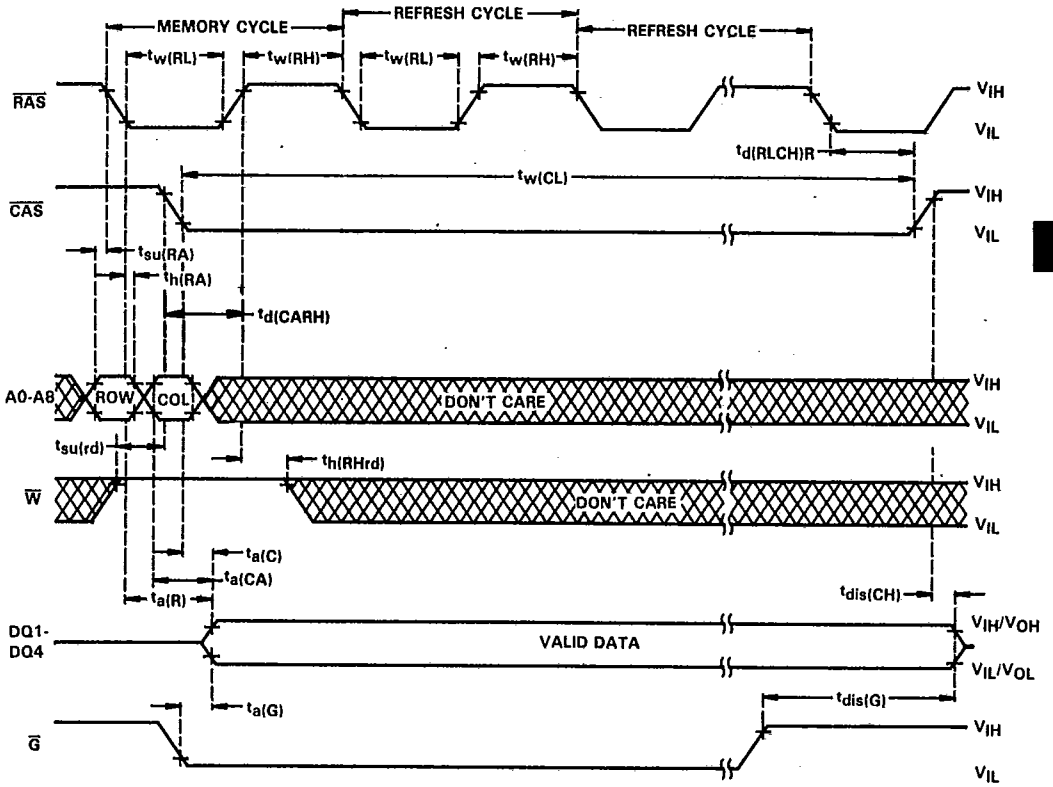


hidden refresh cycle (enhanced page mode)

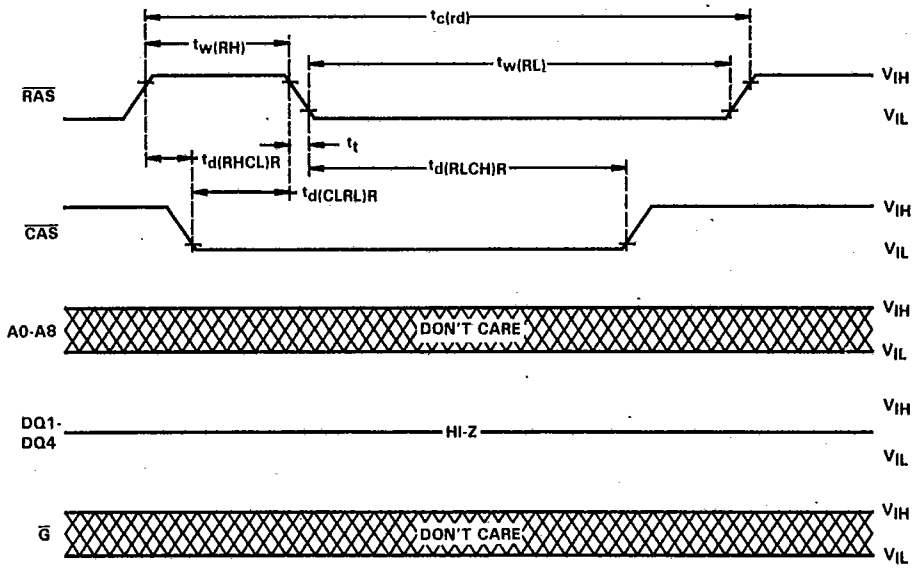


TEXAS INSTRUMENTS
POST OFFICE BOX 1443 • HOUSTON, TEXAS 77001

hidden refresh cycle (static column decode mode)



automatic ($\overline{CAS}$-before-$\overline{RAS}$) refresh cycle timing



TEXAS INSTRUMENTS
POST OFFICE BOX 1443 • HOUSTON, TEXAS 77001

Designing and Manufacturing Surface Mount Assemblies

T-90-20

Elizabeth Gunther, Charles Hutchins, and Paul Peterson

The competitive nature of the semiconductor industry has driven vendors to minimize the size of electronic components, so that more functions can be achieved in a given volume. In addition, improved electrical performance, decreased mass, and the potential for lower system cost are all by-products of compacted packaging and circuitry which hold interest to component manufacturers and users alike.

Surface Mount Technology (SMT) offers an excellent method of reducing component size. A typical memory array can be reduced to 50 percent of its original PWB size with single-sided mounting, and 25 to 30 percent with double-sided mounting. Logic designs cannot achieve the same dramatic reduction, but decreases up to 40 to 60 percent can be achieved for single-sided and double-sided assemblies respectively.

The key design and manufacturing process issues must be understood in order to fully reap the benefits of Surface Mount Technology. This article gives a general overview of the key aspects of design, process, and manufacturing of surface mounted assemblies, and offers surface mount as an opportunity to lower a system's cost without sacrificing reliability.

Components

Most surface mount components are at least one-third the size of the comparable through-hole mounted device (Figure 1). The 68-pin chip carrier is approxmiately one square inch, while the 64-pin DIP is approximately three square inches. The 20-pin chip carrier is slightly larger than 0.1 square inch, while the 20-pin DIP is 0.3 square inch. Similarly, other IC packages are reduced to approximately one-third the size of comparable lead count packages. The passive components occupy approximately one-tenth the board area, and this is why they have been used in most small consumer products built in the last couple of years.

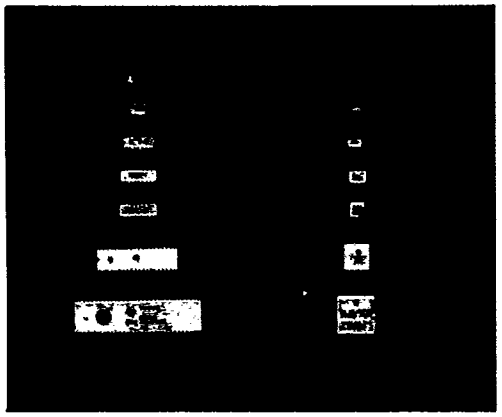


Figure 1. Component Site Reduction

There were many references in the recent past to problems with component availability, cost, and standardization. This area of SMT has probably received more attention than any other. Several recent magazine articles now state that significantly more components (particularly actives) are now available and that cost parity has been achieved on most of them. The effort by various industry committees on standardization has also been effective.

Thus, although more needs to be accomplished in these areas, a designer can begin a project with confidence that there will be no insurmountable barriers in this area. There are several consultants and subcontract assembly companies to assist in this effort. It is strongly recommended that all new designs utilize some form of SMT, particularly when space is an important consideration.

Process

The process to manufacture a surface mount assembly (SMA) is very simple. It consists of four basic steps, as shown in Figure 2. First, the solder paste is screened on the PWB. Then the component is placed on the board, with due care to get it positioned correctly. Typical geometries require placement accuracy of less than plus/minus 4 mils. Next the solder is reflowed with either a vapor phase or infrared system. Finally, the assembly is cleaned and is now ready for test. This process, although simple in concept, relies on board and component planarity and solderability. These are easily achievable with the chip carriers and memory modules we will discuss later.

Texas Instruments has installed a Surface Mount Technology Center at its plant in Houston, Texas. At this center, we have a complete and flexible engineering line to assist our customers in converting to Surface Mount Technology.

The engineering line is equipped with a screen printer, pick and place system, vapor phase reflow, and clean-up station that will easily handle PWBs up to 9″ × 10″. Larger boards up to 14″ × 16″ can be processed with some additional care. TI uses this engineering line to produce its prototype and demo boards. It is also available to any of TI's customers, free of charge, for use in building test or prototype boards.

The effectiveness of the assembly process can be characterized by the number of unacceptable solder joints formed during the process. Unacceptable joints are defined by their electrical and mechanical (strength and reliability) characteristics. The major problem is open solder joints, followed by bridging and misregistration.

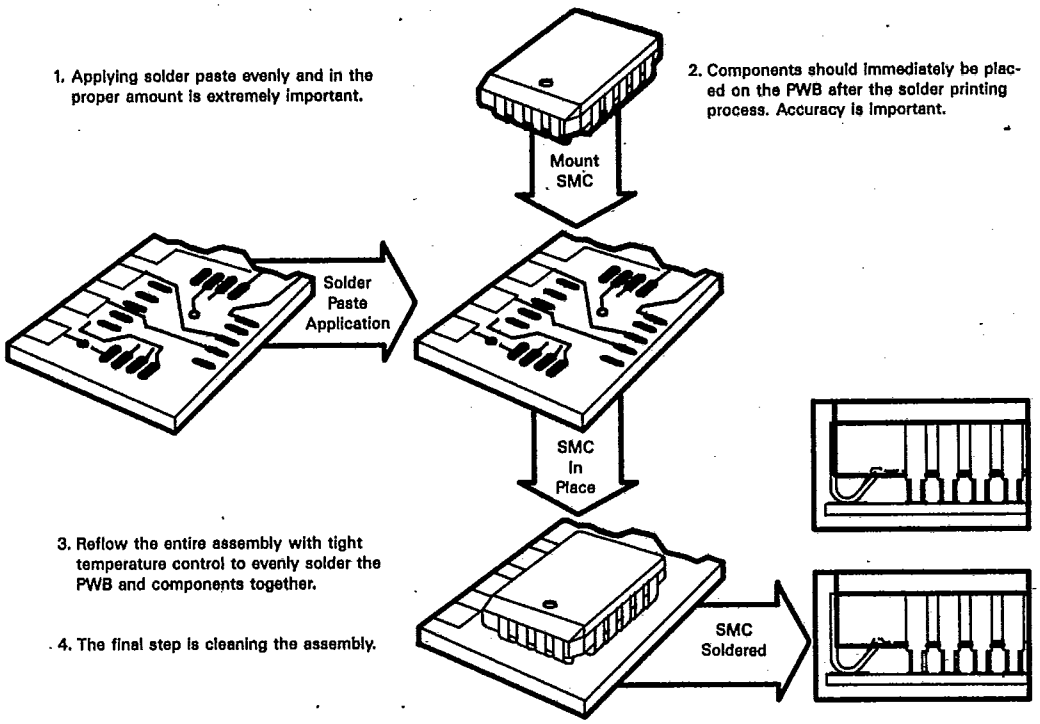


Figure 2. Basic Process Steps

Open circuits are detected at electrical test and are the first defects detected after soldering. At Texas Instruments, 10 PPM or less is the desirable defect level. Several factors that contribute to open solder joints were identified during production start-up. Lead tip planarity of the J-leaded plastic chip carriers is the most important factor in obtaining acceptable process yields. Lead position, lead finish, solder paste composition, and PWB solderability affect process yield as well.

Experiments in which lead tip planarity was confined to specific limits between 1 to 7 mils indicate that a 2 mil planarity requirement produces acceptable results with the process currently in use. Little gain in yield was noted at a 1 mil planarity requirement.

Another interesting result showed that silver in the process, either as a lead finish or in the solder paste, improves yields significantly. One explanation may have to do with the dynamics of the solder during the reflow process as they are affected by the different surface forces acting in the silver and non-silver process.

Design

The design of the PWB, in addition to providing the component interconnections, will provide the proper amount and correct placement of solder paste for a strong fillet formation. The wave soldering process, by comparison, provides a semi-infinite amount of solder, whereas the SMT process will provide only a predetermined amount. Thus, the component connection pad must be correctly placed and be of the proper size.

Further, consideration must be given for inspection, testing, and rework. The density achievable can lead to severe problems at these points if understanding and due care are not exercised in the design. The project team should include members from manufacturing, testing, QA, and purchasing, in addition to the design engineers, from the start. The design and processing of test boards is strongly recommended to provide experience and direction for the major project.

A very practical set of design guidelines is given in Figure 3. These have been used on a number of SMT designs and have given good results. With proper manufacturing techniques as described later, a high yield can be achieved. Component spacings should be approximately equal to the height of the tallest component. This allows an angle of 45 degrees for visual inspection of test probes.

Figure 4 shows the standard footprint for all Small Outline (SO) packages. The larger and more important fillet of an SO package is on the inside of the gull-wing lead. The solder pad, or land, should therefore be designed to extend slightly under the body of the package in order to optimize this fillet. From Table 1 we can see all packages have 50 mil centers with 25 mil spacings between lands. This allows the designer enough space to put traces between pads, and also reduces the occurrence of solder bridging of adjacent lands. Table 1 also summarizes the suggested land lengths and placement, depending on the terminal count of the SO. While not an absolute solution, these land sizes offer a conservative design solution that will meet most vendors' specifications and provide a mechanically and electrically sound solder joint.

● Geometries	
• Trace Width/Space	8/8 MIL Min., 10/10 MIL Typ.
• IC Lead Solder Pad Size	25 ± 5 MIL × 70 ± 10 MIL
• Via Hole Size	20 MIL DIA
• Via Pad Size	40 MIL DIA
• Cap/Resistor Pad Size	W = MAX Dimensions of Component L = 20 MIL Beyond Metallization 10 MIL Inside Metallization
• Solder Mask	5 MIL Larger than IC/Component Pad

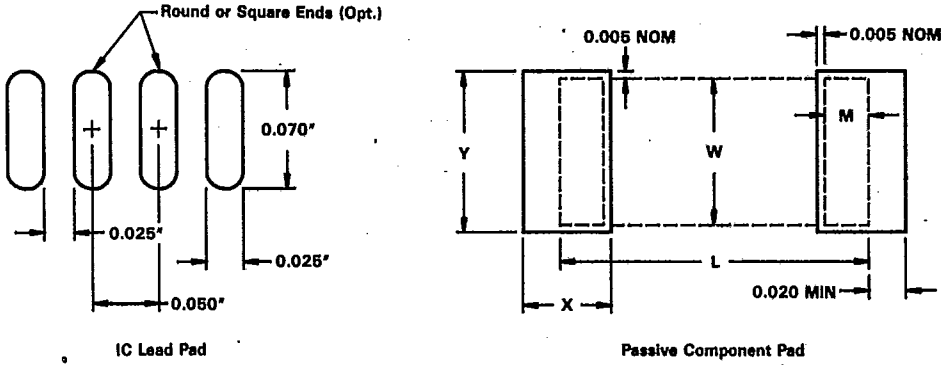


Figure 3. PWB Design Guidelines

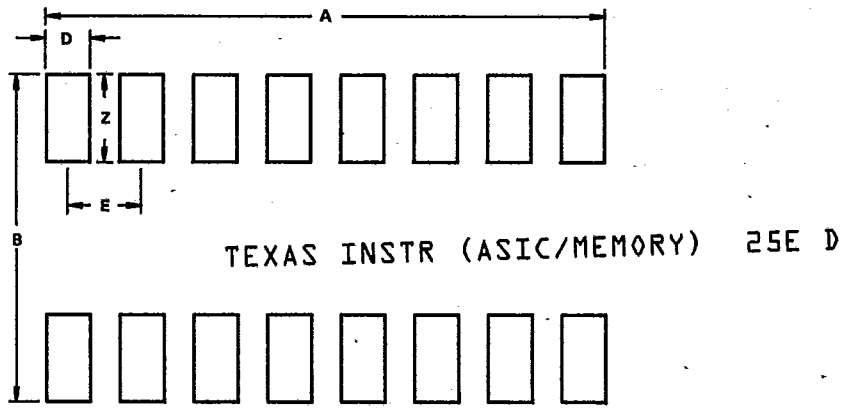


Figure 4. Standard SOIC Footprint

Table 1. SOIC Footprint Dimensions

No. of Terminals	A	B	Z	D	E
8	.175	.250	.050	.025	.050
14	.325	.250	.050	.025	.050
16	.375	.250	.050	.025	.050
20	.475	.430	.070	.025	.050
24	.575	.430	.070	.025	.050

Test	4164A PLCC	4164 DIP	Units
Life Test, 125°C	42	64	Fits*—60% UCL
85°C/85% RH	0.17	0.37	%/1000 Hours
Autoclave	0.17	0.96	%/240 Hours
T/C—65/150	0.52	1.44	%/1000 Cycles
T/C 0/125	0.0	0.0	%/2000 Cycles

*Derated to 55°C Assuming 0.5EV Activation Energy

Figure 5. Failure Rate Comparison 4164A PLCC VS DIP

Manufacturing

The SMT manufacturing area must have the following basic equipment:

- Solder Paste Printer
- Component Pick and Place Machine
- Solder Paste Reflow Machine
- Clean-up System
- Inspection/Process Control Aids
- Electrical Test

The criteria for choosing the above is determined mainly by the size(s) and quantity of PWBs per month, the gross number of components per PWB, and the number of different components per PWB.

The size of the largest PWB is an important criterion in the choice of all of the major items. The printer, pick and place, reflow, and clean-up must all be able to handle it with no difficulty or process nonuniformity. The number and size of the various PWBs that may be produced will secondarily be considered for ease of set up and changeover in the printer and pick and place. The pick and place machine(s) will probably be the most expensive item in the list above and therefore, should get the most attention.

The gross number of components and PWBs will provide data for choosing the pick and place. Component per hour placement speed should be checked in actual operation, as the interrelationship may affect ultimate speed. The number of different components per board will determine how many feeders and what types of feeders will be required. This is a very key issue, as well as the accuracy of placement.

Reflow

The solder reflow is easily achieved with any of the commercially available equipment. Subtle differences between vapor phase, either batch or in-line, and infrared are overshadowed by the choice of solder paste and the solderability/planarity issue. A batch vapor phase is extremely flexible for different sizes of boards with different component counts. The in-line vapor phase is a good choice for a more automated processing line with standard or similar sized boards. The infrared has the advantage of being less expensive to operate, but requires more alteration to set up the time-temperature profile for a different size PWB. This would be a minimal problem on a manufacturing line building high volumes of the same board.

Clean-up

The most popular flux for SMT is the mildly activated rosin flux (RMA). This was developed in the days of vacuum tube assembly when clean-up was next to impossible. It is noncorrosive but provides sufficient fluxing action for good quality components and PWBs. Thus it is the preferred choice for SMAs with small spacings under most passives and SOICs, where complete cleaning is difficult. A mild solvent, such as Freon TMS, is generally sufficient to achieve a good visual cleanup, and there are several systems available that provide hot vapor, spray, or ultrasonic de-fluxing.

Reliability

With the smaller surface mount packages, there is some concern about component reliability. Texas Instruments addressed the overall DRAM reliability issue several years ago. Through an extensive task force effort, the major problems of the life test, humidity performance, and temperature cycle were identified. The best solutions to these problems required several changes in the design and process of the silicon chip. In doing so, the reliability of the DRAM chip became independent of the package used. Thus, the 64K DRAM in the plastic chip carrier package performs equivalently to the same chip in a DIP as shown in Figure 5. Similar data is available on most semiconductor ICs.

An additional reliability concern originates in the surface mount solder reflow process, which submits components to higher reflow temperatures more suddenly than the wave-soldering methods of DIP components, with oftentimes repeated reflow cycles for rework and repair.

The best method for resolving this issue involves comparing the temperature-time differential of the vapor phase or infrared solder reflow process to the standard temperature

cycling reliability tests to which surface mount components are routinely submitted. Figures 6 and 7 show temperature profiles of the vapor phase and infrared solder reflow processes. In the vapor phase process, the maximum temperature change with time is:

$$\frac{215°C - 25°C}{45 \text{ sec}} = \frac{190°C}{45 \text{ sec}}$$

equaling approximately 4°C/sec. The infrared solder reflow method submits the ICs to a similar, yet less severe temperature over time change of 3°C/second. Comparing these temperature profile ramp-ups to that which a surface mount component undergoes in a temperature cycling reliability test proves that there should be no concern over damage to the component during reflow. In the temp cycling test, the surface mount components were submitted to 1000 cycles of sudden cycling from 150°C to −65°C within three seconds. This represents a temperature-time differential of:

$$\frac{150°C-(-65°C)}{3} = \frac{215°C}{3 \text{ sec}} = \frac{70°C}{\text{sec}}$$

with less than 0.5 percent failures.

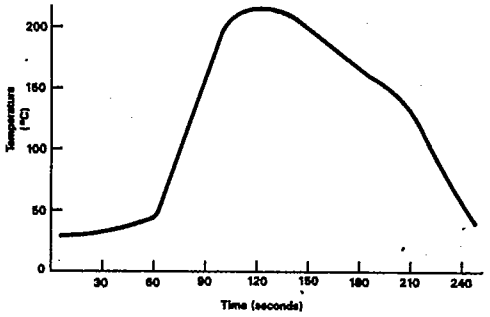


Figure 6. Typical Temperature Profile for In-Line Vapor Phase Reflow

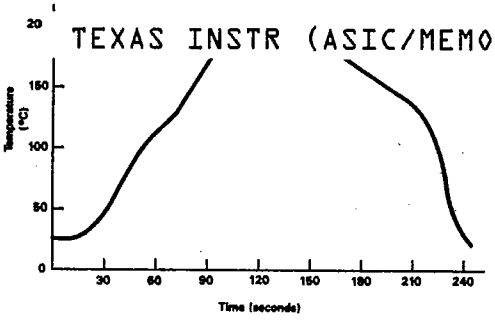


Figure 7. Typical IR Reflow System Profile

Since the surface mounted components were able to withstand a 70°C/second temperature change of 1000 cycles, they should be able to withstand the less severe conditions of a 4°C/second damage during reflow without reliability degradation.

Another concern in the solder reflow processing of surface mount components is the dwell time in reflow temperatures of 215°C or above. The dwell time for a small PWB populated with surface mount devices is about 20 seconds. For a larger board of about 10"×12" up to 50 seconds is needed for reflow. A generalized component degradation curve, relating accumulated time and temperature, can be assumed to exist. The shape of the curve for this discussion is assumed to be a decaying parabolic for simplicity and conservatism. There are two generally known points of this curve. The flame retardant mold compound (FRMC) of a plastic package starts to break down at 300°C in two to three seconds. Also, the molding and curing of a surface mount device is performed over several hours at 175°C. These two points are shown on the generalized curve shown in Figure 8, with the "safe" region being the area under the curve. Two points that fall within this region are the industry standard practice of solder dipping leads of several types of ICs, and of the soldering plastic devices on the bottom with Type III surface mount assembly, each submerges the component for three to four seconds in a solder wave.

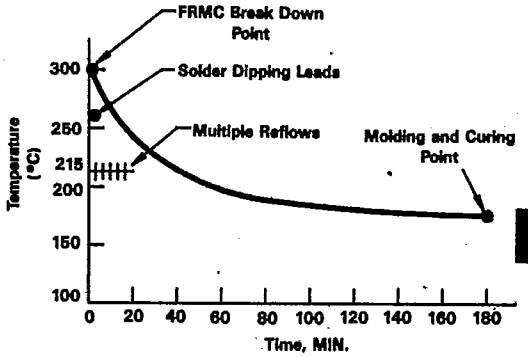


Figure 8. General Plastic Degradation Curve

Summary

Surface mount assembly techniques provide a significant advantage in cost, volume, and reliability over the current "thru-hole" technology. These are well documented, and the manufacturing equipment and related products are becoming readily available to support new production lines. Also, as experience grows, improved products and ideas are developed from the cooperative efforts of vendors and users in standardization organizations and in problem-solving sessions. The broad selection of package types and product technologies available now are sufficient to begin conversion of existing electronic system products for size reduction or feature enhancement. Definitely, new products should be designed with surface mount technology.