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TMS416160, TMS416160P, TMS418160, TMS418160P
TMS426160, TMS426160P, TMS428160, TMS428160P
1048576-WORD BY 16-BIT HIGH-SPEED DRAMS

SMKS160C – MAY 1995 – REVISED NOVEMBER 1995

- Organization . . . 1048576 × 16
- Single Power Supply (5 V or 3.3 V)
- Performance Ranges:

	ACCESS TIME	ACCESS TIME	ACCESS TIME	READ OR WRITE CYCLE MIN
	t _{RAC} MAX	t _{CAC} MAX	t _{AA} MAX	
'4xx160/P-60	60 ns	15 ns	30 ns	110 ns
'4xx160/P-70	70 ns	18 ns	35 ns	130 ns
'4xx160/P-80	80 ns	20 ns	40 ns	150 ns

- Enhanced Page-Mode Operation With CAS-Before-RAS (CBR) Refresh
- Long Refresh Period and Self-Refresh Option (TMS4xx160P)
- 3-State Unlatched Output
- Low Power Dissipation
- High-Reliability Plastic 42-Lead (DZ Suffix) 400-Mil-Wide Surface-Mount (SOJ) Package and 44/50-Lead (DGE Suffix) Surface-Mount Thin Small-Outline Package (TSOP)
- Operating Free-Air Temperature Range 0°C to 70°C
- Fabricated Using the Texas Instruments Enhanced Performance Implanted CMOS (EPIC™) Technology

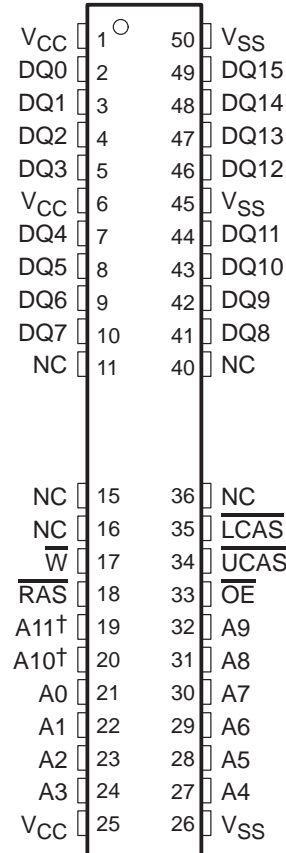
AVAILABLE OPTIONS

DEVICE	POWER SUPPLY	SELF REFRESH, BATTERY BACKUP	REFRESH CYCLES
TMS416160	5 V	—	4096 in 64 ms
TMS416160P	5 V	Yes	4096 in 128 ms
TMS418160	5 V	—	1024 in 16 ms
TMS418160P	5 V	Yes	1024 in 128 ms
TMS426160	3.3 V	—	4096 in 64 ms
TMS426160P	3.3 V	Yes	4096 in 128 ms
TMS428160	3.3 V	—	1024 in 16 ms
TMS428160P	3.3 V	Yes	1024 in 128 ms

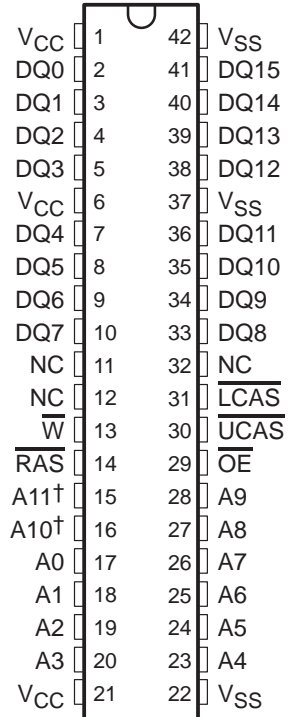
description

The TMS4xx160 series is a set of high-speed, 16777216-bit dynamic random-access memories (DRAMs) organized as 1048576 words of 16 bits each. The TMS4xx160P series is a similar set of high-speed, low-power, self-refresh, 16777216-bit DRAMs organized as 1048576 words of 16 bits each. Both sets employ state-of-the-art enhanced performance implanted CMOS (EPIC™) technology for high performance, reliability, and low power at low cost.

DGE PACKAGE
(TOP VIEW)



DZ PACKAGE
(TOP VIEW)



† A10 and A11 are NC for TMS4x8160 and TMS4x8160P.

PIN NOMENCLATURE

A0–A11	Address Inputs
DQ0–DQ15	Data In/Data Out
LCAS	Lower Column-Address Strobe
UCAS	Upper Column-Address Strobe
NC	No Internal Connection
OE	Output Enable
RAS	Row-Address Strobe
VCC	5-V or 3.3-V Supply†
VSS	Ground
W	Write Enable

‡ See Available Options Table.



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description (continued)

These devices feature maximum $\overline{\text{RAS}}$ access times of 60 ns, 70 ns, and 80 ns. All addresses and data-in lines are latched on chip to simplify system design. Data out is unlatched to allow greater system flexibility.

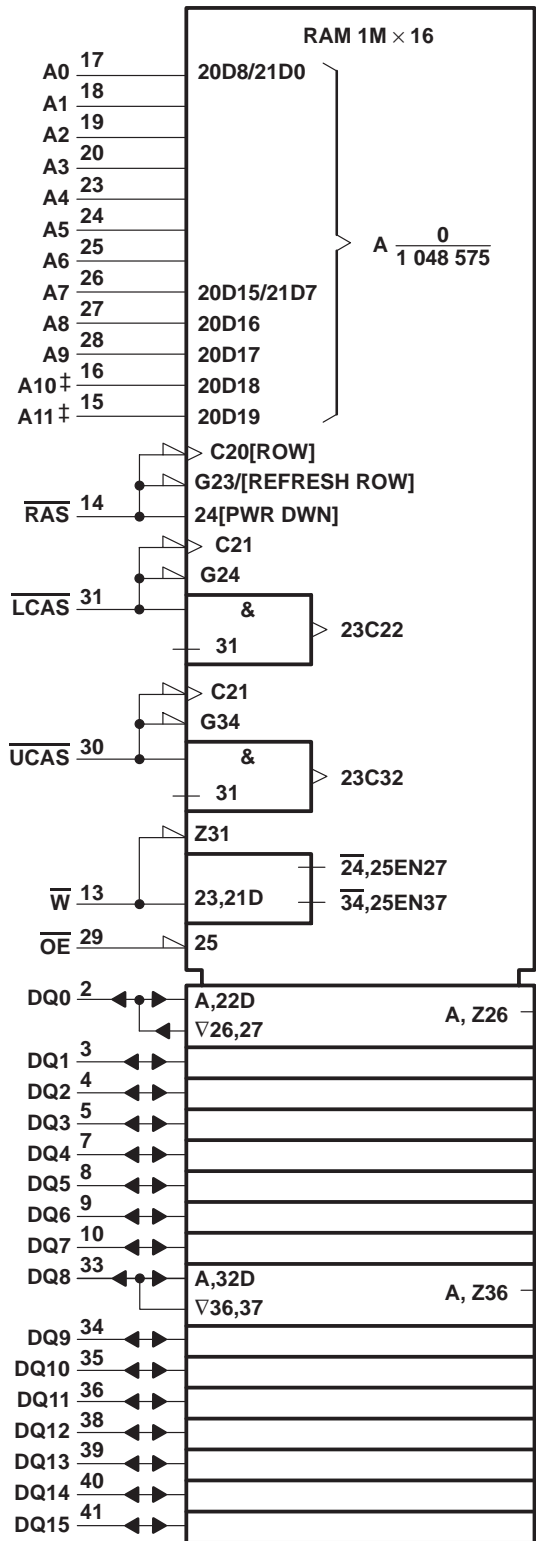
The TMS4xx160 and TMS4xx160P are offered in a 44/50-lead plastic surface-mount TSOP (DGE suffix) and a 42-lead plastic surface-mount SOJ (DZ suffix) package. These packages are characterized for operation from 0°C to 70°C.



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logic symbol†



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

The pin numbers shown correspond to the DZ package.

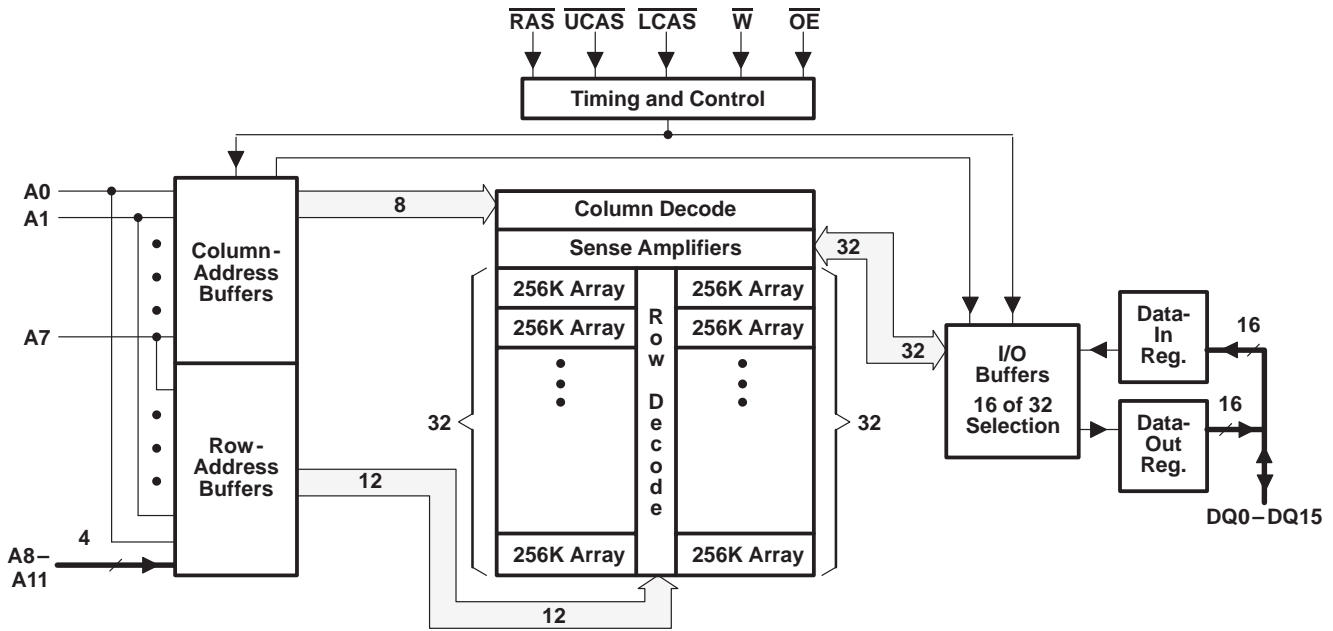
‡ A10 and A11 are NC for TMS4x8160 and TMS4x8160P.



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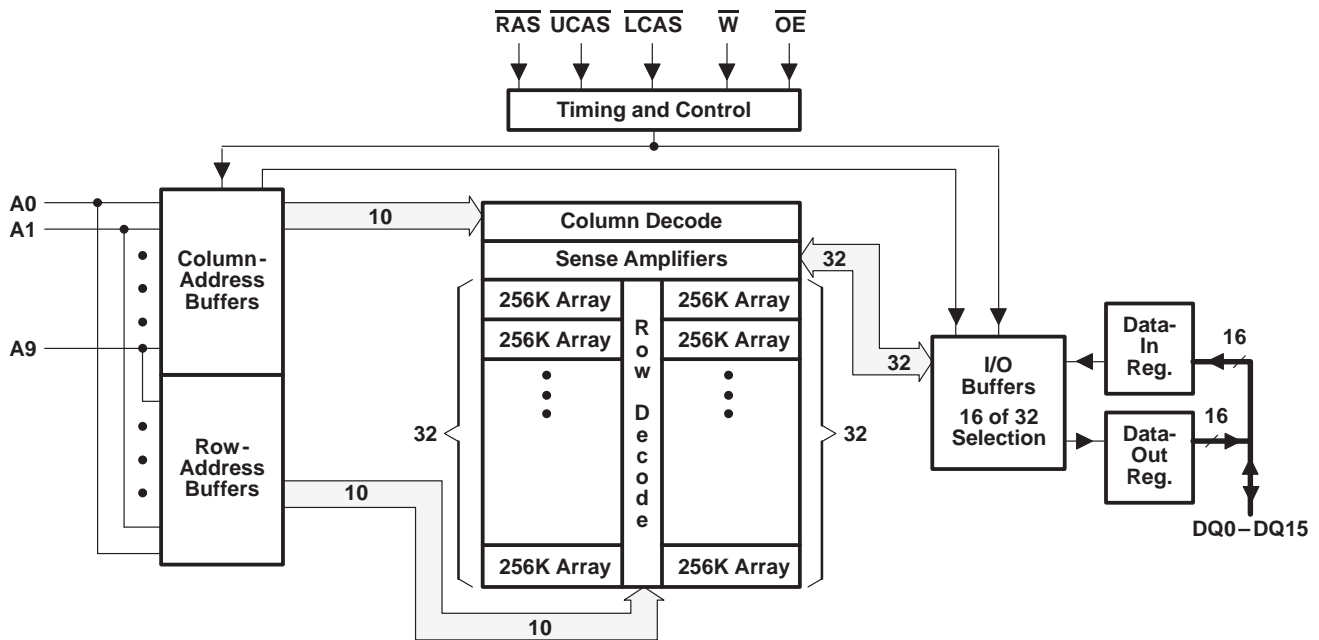
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functional block diagrams (TMS4x6160/P)



(a) TMS4x6160, TMS4x6160P

functional block diagram (TMS4x8160/P)



(b) TMS4x8160, TMS4x8160P



operation

dual $\overline{\text{CAS}}$

Two $\overline{\text{CAS}}$ pins ($\overline{\text{LCAS}}$ and $\overline{\text{UCAS}}$) are provided to give independent control of the 16 data-I/O pins (DQ0–DQ15), with $\overline{\text{LCAS}}$ corresponding to DQ0–DQ7 and $\overline{\text{UCAS}}$ corresponding to DQ8–DQ15. For read or write cycles, the column address is latched on the first $\overline{\text{xCAS}}$ falling edge. Each $\overline{\text{xCAS}}$ going low enables its corresponding DQx pin with data associated with the column address latched on the first falling $\overline{\text{xCAS}}$ edge. All address setup and hold parameters are referenced to the first falling $\overline{\text{xCAS}}$ edge. The delay time from $\overline{\text{xCAS}}$ low to valid data out (see parameter t_{CAC}) is measured from each individual $\overline{\text{xCAS}}$ to its corresponding DQx pin.

In order to latch in a new column address, both $\overline{\text{xCAS}}$ pins must be brought high. The column-precharge time (see parameter t_{CP}) is measured from the last $\overline{\text{xCAS}}$ rising edge to the first $\overline{\text{xCAS}}$ falling edge of the new cycle. Keeping a column address valid while toggling $\overline{\text{xCAS}}$ requires a minimum setup time, t_{CLCH} . During t_{CLCH} , at least one $\overline{\text{xCAS}}$ must be brought low before the other $\overline{\text{xCAS}}$ is taken high.

For early-write cycles, the data is latched on the first $\overline{\text{xCAS}}$ falling edge. Only the DQs that have the corresponding $\overline{\text{xCAS}}$ low are written into. Each $\overline{\text{xCAS}}$ must meet t_{CAS} minimum in order to ensure writing into the storage cell. To latch a new address and new data, all $\overline{\text{xCAS}}$ pins must be high and meet t_{CP} .

enhanced page mode

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 eliminated. The maximum number of columns that can be accessed is determined by the maximum $\overline{\text{RAS}}$ low time and the $\overline{\text{xCAS}}$ page-mode cycle time used. With minimum $\overline{\text{xCAS}}$ page-cycle time, all columns can be accessed without intervening $\overline{\text{RAS}}$ cycles.

Unlike conventional page-mode DRAMs, the column-address buffers in this device are activated on the falling edge of $\overline{\text{RAS}}$. The buffers act as transparent or flow-through latches while $\overline{\text{xCAS}}$ is high. The falling edge of the first $\overline{\text{xCAS}}$ latches the column addresses. This feature allows the devices to operate at a higher data bandwidth than conventional page-mode parts because data retrieval begins as soon as the column address is valid rather than when $\overline{\text{xCAS}}$ transitions low. This performance improvement is referred to as enhanced page mode. A valid column address may be presented immediately after t_{RAH} (row-address hold time) has been satisfied, usually well in advance of the falling edge of $\overline{\text{xCAS}}$. In this case, data is obtained after t_{CAC} maximum (access time from $\overline{\text{xCAS}}$ low) if t_{AA} maximum (access time from column address) has been satisfied. In the event that column addresses for the next page cycle are valid at the time $\overline{\text{xCAS}}$ goes high, minimum access time for the next cycle is determined by t_{CPA} (access time from rising edge of the last $\overline{\text{xCAS}}$).

address: A0–A11 (TMS4x6160, TMS4x6160P) and A0–A9 (TMS4x8160, TMS4x8160P)

Twenty address bits are required to decode 1 of 1048576 storage cell locations. For the TMS4x6160 and TMS4x6160P, 12 row-address bits are set up on A0 through A11 and latched onto the chip by $\overline{\text{RAS}}$. Eight column-address bits are set up on A0 through A7 and latched onto the chip by the first $\overline{\text{xCAS}}$. For the TMS4x8160 and TMS4x8160P, 10 row-address bits are set up on A0–A9 and latched onto the chip by $\overline{\text{RAS}}$. Ten column-address bits are set up on A0–A9 and latched onto the chip by the first $\overline{\text{xCAS}}$. All addresses must be stable on or before the falling edge of $\overline{\text{RAS}}$ and $\overline{\text{xCAS}}$. $\overline{\text{RAS}}$ is similar to a chip enable in that it activates the sense amplifiers as well as the row decoder. $\overline{\text{xCAS}}$ is used as a chip select, activating its corresponding output buffer and latching the address bits into the column-address buffers.

write enable ($\overline{\text{W}}$)

The read or write mode is selected through $\overline{\text{W}}$. A logic high on $\overline{\text{W}}$ selects the read mode and a logic low selects the write mode. The data inputs are disabled when the read mode is selected. When $\overline{\text{W}}$ goes low prior to $\overline{\text{xCAS}}$ (early write), data out remains in the high-impedance state for the entire cycle, permitting a write operation with $\overline{\text{OE}}$ grounded.

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data in (DQ0–DQ15)

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

data out (DQ0–DQ15)

Data out is the same polarity as data in. The output is in the high-impedance (floating) state until \overline{xCAS} and \overline{OE} are brought low. In a read cycle, the output becomes valid after the access time interval t_{CAC} (which begins with the negative transition of \overline{xCAS}) as long as t_{RAC} and t_{AA} are satisfied.

output enable (\overline{OE})

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

\overline{RAS} -only refresh

TMS4x6160, TMS4x6160P

A refresh operation must be performed at least once every 64 ms (128 ms for TMS4x6160P) to retain data. This can be achieved by strobing each of the 4096 rows (A0–A11). A normal read or write cycle refreshes all bits in each row that is selected. A \overline{RAS} -only operation can be used by holding both \overline{xCAS} at the high (inactive) level, conserving power as the output buffers remain in the high-impedance state. Externally generated addresses must be used for a \overline{RAS} -only refresh.

TMS4x8160, TMS4x8160P

A refresh operation must be performed at least once every 16 ms (128 ms for TMS4x8160P) to retain data. This can be achieved by strobing each of the 1024 rows (A0–A9). A normal read or write cycle refreshes all bits in each row that is selected. A \overline{RAS} -only operation can be used by holding both \overline{xCAS} at the high (inactive) level, conserving power as the output buffers remain in the high-impedance state. Externally generated addresses must be used for a \overline{RAS} -only refresh.

hidden refresh

Hidden refresh can be performed while maintaining valid data at the output pin. This is accomplished by holding \overline{xCAS} at V_{IL} after a read operation and cycling \overline{RAS} after a specified precharge period, similar to a \overline{RAS} -only refresh cycle. The external address is ignored and the refresh address is generated internally.

\overline{xCAS} -before- \overline{RAS} (xCBR) refresh

\overline{xCBR} refresh is utilized by bringing at least one \overline{xCAS} low earlier than \overline{RAS} (see parameter t_{CSR}) and holding it low after \overline{RAS} falls (see parameter t_{CHR}). For successive \overline{xCBR} refresh cycles, \overline{xCAS} can remain low while cycling \overline{RAS} . The external address is ignored and the refresh address is generated internally.

battery-backup refresh

TMS4x6160P

A low-power battery-backup refresh mode that requires less than $600\ \mu\text{A}$ (5 V) or $350\ \mu\text{A}$ (3.3 V) refresh current is available on the TMS4x6160P. Data integrity is maintained using \overline{xCBR} refresh with a period of $31.25\ \mu\text{s}$ while holding \overline{RAS} low for less than 300 ns. To minimize current consumption, all input levels must be at CMOS levels ($V_{IL} < 0.2\ \text{V}$, $V_{IH} > V_{CC} - 0.2\ \text{V}$).



TMS4x8160P

A low-power battery-backup refresh mode that requires less than 600 μ A (5 V) or 350 μ A (3.3 V) refresh current is available on the TMS4x8160P. Data integrity is maintained using xCBR refresh with a period of 125 μ s while holding $\overline{\text{RAS}}$ low for less than 300 ns. To minimize current consumption, all input levels must be at CMOS levels ($V_{\text{IL}} < 0.2 \text{ V}$, $V_{\text{IH}} > V_{\text{CC}} - 0.2 \text{ V}$).

self refresh (TMS4xx160P)

The self-refresh mode is entered by dropping $\overline{\text{xCAS}}$ low prior to $\overline{\text{RAS}}$ going low. Then $\overline{\text{xCAS}}$ and $\overline{\text{RAS}}$ are both held low for a minimum of 100 μ s. The chip is then refreshed internally by an on-board oscillator. No external address is required because the CBR counter is used to keep track of the address. To exit the self-refresh mode, both $\overline{\text{RAS}}$ and $\overline{\text{xCAS}}$ are brought high to satisfy t_{CHS} . Upon exiting self-refresh mode, a burst refresh (refresh a full set of row addresses) must be executed before continuing with normal operation. The burst refresh ensures the DRAM is fully refreshed.

power up

To achieve proper device operation, an initial pause of 200 μ s followed by a minimum of eight initialization cycles is required after power up to the full V_{CC} level. These eight initialization cycles must include at least one refresh ($\overline{\text{RAS}}$ -only or $\overline{\text{xCBR}}$) cycle.

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

Supply voltage range, V_{CC} :	TMS41x160, TMS41x160P	- 1 V to 7 V
	TMS42x160, TMS42x160P	- 0.5 V to 4.6 V
Voltage range on any pin (see Note 1):	TMS41x160, TMS41x160P	- 1 V to 7 V
	TMS42x160, TMS42x160P	- 0.5 V to 4.6 V
Short-circuit output current		50 mA
Power dissipation		1 W
Operating free-air temperature range, T_{A}		0°C to 70°C
Storage temperature range, T_{stg}		- 55°C to 125°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTE 1: All voltage values are with respect to V_{SS} .

recommended operating conditions

	TMS41x160			TMS42x160			UNIT
	MIN	NOM	MAX	MIN	NOM	MAX	
V_{CC} Supply voltage	4.5	5	5.5	3	3.3	3.6	V
V_{SS} Supply voltage	0			0			V
V_{IH} High-level input voltage	2.4		6.5	2	$V_{\text{CC}} + 0.3$		V
V_{IL} Low-level input voltage (see Note 2)	- 1		0.8	- 0.3		0.8	V
T_{A} Operating free-air temperature	0		70	0		70	°C

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



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TMS416160/P

electrical characteristics over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	'416160-60 '416160P-60		'416160-70 '416160P-70		'416160-80 '416160P-80		UNIT	
		MIN	MAX	MIN	MAX	MIN	MAX		
		V_{OH}	High-level output voltage	$I_{OH} = -5 \text{ mA}$		2.4			2.4
V_{OL}	Low-level output voltage	$I_{OL} = 4.2 \text{ mA}$		0.4		0.4		V	
I_I	Input current (leakage)	$V_{CC} = 5.5 \text{ V}, V_I = 0 \text{ V to } 6.5 \text{ V},$ All others = $0 \text{ V to } V_{CC}$		± 10		± 10		μA	
I_O	Output current (leakage)	$V_{CC} = 5.5 \text{ V}, V_O = 0 \text{ V to } V_{CC},$ $\overline{\text{xCAS}}$ high		± 10		± 10		μA	
$I_{CC1} \ddagger$	Read- or write-cycle current	$V_{CC} = 5.5 \text{ V},$ Minimum cycle		90		80		70	mA
I_{CC2}	Standby current	$V_{IH} = 2.4 \text{ V (TTL),}$ After 1 memory cycle, RAS and $\overline{\text{xCAS}}$ high		2		2		2	mA
		$V_{IH} = V_{CC} - 0.2 \text{ V (CMOS),}$ After 1 memory cycle, RAS and $\overline{\text{xCAS}}$ high	'416160	1		1		1	mA
			'416160P	500		500		500	μA
$I_{CC3} \S$	Average refresh current (RAS-only refresh or CBR)	$V_{CC} = 5.5 \text{ V},$ Minimum cycle, RAS cycling, $\overline{\text{xCAS}}$ high (RAS only), RAS low after $\overline{\text{xCAS}}$ low (CBR)		90		80		70	mA
$I_{CC4} \ddagger \parallel$	Average page current	$V_{CC} = 5.5 \text{ V},$ $\overline{\text{RAS}}$ low, $t_{PC} = \text{MIN},$ $\overline{\text{xCAS}}$ cycling		90		80		70	mA
$I_{CC6} \#$	Self-refresh current	$\overline{\text{xCAS}} < 0.2 \text{ V},$ $\overline{\text{RAS}} < 0.2 \text{ V},$ Measured after $t_{RASS} \text{ min}$		500		500		500	μA
$I_{CC10} \#$	Battery back-up operating current (equivalent refresh time is 128 ms); CBR only	$t_{RC} = 31.25 \mu\text{s},$ $t_{RAS} \leq 300 \text{ ns},$ $V_{CC} - 0.2 \text{ V} \leq V_{IH} \leq 6.5 \text{ V},$ $0 \text{ V} \leq V_{IL} \leq 0.2 \text{ V},$ $\overline{\text{W}}$ and $\overline{\text{OE}} = V_{IH},$ Address and data stable		600		600		600	μA

† For conditions shown as MIN/MAX, use the appropriate value specified in the timing requirements.

‡ Measured with outputs open

§ Measured with a maximum of one address change while $\overline{\text{RAS}} = V_{IL}$

¶ Measured with a maximum of one address change while $\overline{\text{xCAS}} = V_{IH}$

For TMS416160P only



TMS418160/P

electrical characteristics over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted) (continued)

PARAMETER	TEST CONDITION†	'418160-60 '418160P-60		'418160-70 '418160P-70		'418160-80 '418160P-80		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 _{CC} = 5.5 V, V _I = 0 V to 6.5 V, All others = 0 V to V _{CC}	± 10		± 10		± 10		µA	
I _O	Output current (leakage) V _{CC} = 5.5 V, V _O = 0 V to V _{CC} , xCAS high	± 10		± 10		± 10		µA	
I _{CC1} ‡§	Read- or write-cycle current V _{CC} = 5.5 V, Minimum cycle	190		180		170		mA	
I _{CC2}	Standby current V _{IH} = 2.4 V (TTL), After 1 memory cycle, RAS and xCAS high	2		2		2		mA	
		V _{IH} = V _{CC} - 0.2 V (CMOS), After 1 memory cycle, RAS and xCAS high	'418160	1		1		1	mA
			'418160P	500		500		500	µA
I _{CC3} §	Average refresh current (RAS-only refresh or CBR) V _{CC} = 5.5 V, Minimum cycle, RAS cycling, xCAS high (RAS only), RAS low after xCAS low (CBR)	190		180		170		mA	
I _{CC4} ¶	Average page current V _{CC} = 5.5 V, t _{PC} = MIN, RAS low, xCAS cycling	100		90		80		mA	
I _{CC6} #	Self-refresh current xCAS < 0.2 V, RAS < 0.2 V, Measured after t _{RASS} min	500		500		500		µA	
I _{CC10} #	Battery back-up operating current (equivalent refresh time is 128 ms); CBR only t _{RC} = 125 µs, t _{RAS} ≤ 300 ns, V _{CC} - 0.2 V ≤ V _{IH} ≤ 6.5 V, 0 V ≤ V _{IL} ≤ 0.2 V, W and OE = V _{IH} , Address and data stable	600		600		600		µA	

† For conditions shown as MIN/MAX, use the appropriate value specified in the timing requirements.

‡ Measured with outputs open

§ Measured with a maximum of one address change while RAS = V_{IL}

¶ Measured with a maximum of one address change while xCAS = V_{IH}

For TMS418160P only

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TMS426160/P

electrical characteristics over recommended ranges of supply voltage and operating free-air conditions (unless otherwise noted) (continued)

PARAMETER	TEST CONDITIONST	'426160-60 '426160P-60		'426160-70 '426160P-70		'426160-80 '426160P-80		UNIT	
		MIN	MAX	MIN	MAX	MIN	MAX		
V _{OH}	High-level output voltage	I _{OH} = -2 mA	LVTTL	2.4		2.4		2.4	V
		I _{OH} = -100 μA	LVC MOS	V _{CC} -0.2		V _{CC} -0.2		V _{CC} -0.2	
V _{OL}	Low-level output voltage	I _{OL} = 2 mA	LVTTL		0.4		0.4	0.4	V
		I _{OL} = 100 μA	LVC MOS		0.2		0.2	0.2	
I _I	Input current (leakage)	V _{CC} = 3.6 V, V _I = 0 V to 3.9 V, All others = 0 V to V _{CC}			± 10		± 10	± 10	μA
I _O	Output current (leakage)	V _{CC} = 3.6 V, V _O = 0 V to V _{CC} , xCAS high			± 10		± 10	± 10	μA
I _{CC1} ‡§	Read- or write-cycle current	V _{CC} = 3.6 V, Minimum cycle			90		80	70	mA
I _{CC2}	Standby current	V _{IH} = 2 V (LVTTL), After 1 memory cycle, RAS and xCAS high			1		1	1	mA
		V _{IH} = V _{CC} - 0.2 V (LVC MOS), After 1 memory cycle, RAS and xCAS high	'426160		500		500	500	μA
			'426160P		200		200	200	μA
I _{CC3} §	Average refresh current (RAS-only refresh or CBR)	V _{CC} = 3.6 V, Minimum cycle, RAS cycling, xCAS high (RAS-only refresh) RAS low after xCAS low (CBR)			90		80	70	mA
I _{CC4} ‡¶	Average page current	V _{CC} = 3.6 V, RAS low, t _{PC} = MIN, xCAS cycling			90		80	70	mA
I _{CC6} #	Self-refresh current	xCAS < 0.2 V, RAS < 0.2 V, Measured after t _{RASS} min			250		250	250	μA
I _{CC10} #	Battery back-up operating current (equivalent refresh time is 128 ms), CBR only	t _{RC} = 31.25 μs, t _{RAS} ≤ 300 ns, V _{CC} - 0.2 V ≤ V _{IH} ≤ 3.9 V, 0 V ≤ V _{IL} ≤ 0.2 V, W and OE = V _{IH} , Address and data stable			350		350	350	μA

† For conditions shown as MIN/MAX, use the appropriate value specified in the timing requirements.

‡ Measured with outputs open

§ Measured with a maximum of one address change while RAS = V_{IL}

¶ Measured with a maximum of one address change while xCAS = V_{IH}

For TMS426160P only



TMS428160/P

electrical characteristics over recommended ranges of supply voltage and operating free-air conditions (unless otherwise noted) (continued)

PARAMETER	TEST CONDITIONS†		'428160-60 '428160P-60		'428160-70 '428160P-70		'428160-80 '428160P-80		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	
V _{OH} High-level output voltage	I _{OH} = -2 mA	LVTTL	2.4		2.4		2.4		V
	I _{OH} = -100 μA	LVC MOS	V _{CC} -0.2		V _{CC} -0.2		V _{CC} -0.2		
V _{OL} Low-level output voltage	I _{OL} = 2 mA	LVTTL	0.4		0.4		0.4		V
	I _{OL} = 100 μA	LVC MOS	0.2		0.2		0.2		
I _I Input current (leakage)	V _{CC} = 3.6 V, V _I = 0 V to 3.9 V, All others = 0 V to V _{CC}		± 10		± 10		± 10		μA
I _O Output current (leakage)	V _{CC} = 3.6 V, V _O = 0 V to V _{CC} , xCAS high		± 10		± 10		± 10		μA
I _{CC1} ‡§ Read- or write-cycle current	V _{CC} = 3.6 V, Minimum cycle		190		180		170		mA
I _{CC2} Standby current	V _{IH} = 2 V (LVTTL), After 1 memory cycle, RAS and xCAS high		1		1		1		mA
	V _{IH} = V _{CC} - 0.2 V (LVC MOS), After 1 memory cycle, RAS and xCAS high	'428160	500		500		500		μA
		'428160P	200		200		200		μA
I _{CC3} § Average refresh current (RAS-only refresh or CBR)	V _{CC} = 3.6 V, Minimum cycle, RAS cycling, xCAS high (RAS-only refresh) RAS low after xCAS low (CBR)		190		180		170		mA
I _{CC4} ‡¶ Average page current	V _{CC} = 3.6 V, RAS low, t _{PC} = MIN, xCAS cycling		100		90		80		mA
I _{CC6} # Self-refresh current	xCAS < 0.2 V, RAS < 0.2 V, Measured after t _{RASS} min		250		250		250		μA
I _{CC10} # Battery back-up operating current (equivalent refresh time is 128 ms), CBR only	t _{RC} = 125 μs, t _{RAS} ≤ 300 ns, V _{CC} - 0.2 V ≤ V _{IH} ≤ 3.9 V, 0 V ≤ V _{IL} ≤ 0.2 V, W and OE = V _{IH} , Address and data stable		350		350		350		μA

† For conditions shown as MIN/MAX, use the appropriate value specified in the timing requirements.

‡ Measured with outputs open

§ Measured with a maximum of one address change while RAS = V_{IL}

¶ Measured with a maximum of one address change while xCAS = V_{IH}

For TMS428160P only

**TMS416160, TMS416160P, TMS418160, TMS418160P
TMS426160, TMS426160P, TMS428160, TMS428160P
1048576-WORD BY 16-BIT HIGH-SPEED DRAMS**

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

PARAMETER		MIN	MAX	UNIT
C _{i(A)}	Input capacitance, A0–A11		5	pF
C _{i(OE)}	Input capacitance, \overline{OE}		7	pF
C _{i(RC)}	Input capacitance, \overline{xCAS} and \overline{RAS}		7	pF
C _{i(W)}	Input capacitance, \overline{W}		7	pF
C _O	Output capacitance		7	pF

NOTE 3: V_{CC} = 5 V ± 0.5 V or 3.3 V ± 0.3 V (see Table 1), and the bias on pins under test is 0 V.

switching characteristics over recommended ranges of supply voltage and operating free-air temperature

PARAMETER	'4xx160-60 '4xx160P-60		'4xx160-70 '4xx160P-70		'4xx160-80 '4xx160P-80		UNIT		
	MIN	MAX	MIN	MAX	MIN	MAX			
t _{AA}	Access time from column address (see Note 4)		30		35		40	ns	
t _{CAC}	Access time from \overline{xCAS} low (see Note 4)		15		18		20	ns	
t _{CPA}	Access time from column precharge (see Note 4)		35		40		45	ns	
t _{RAC}	Access time from \overline{RAS} low (see Note 4)		60		70		80	ns	
t _{OEa}	Access time from \overline{OE} low (see Note 4)		15		18		20	ns	
t _{CLZ}	Delay time, \overline{xCAS} low to output in low-impedance state		0		0		0	ns	
t _{OH}	Output data hold time (from \overline{xCAS})		3		3		3	ns	
t _{OHO}	Output data hold time (from \overline{OE})		3		3		3	ns	
t _{OFF}	Output disable time after \overline{xCAS} high (see Note 5)		0	15	0	18	0	20	ns
t _{OEZ}	Output disable time after \overline{OE} high (see Note 5)		0	15	0	18	0	20	ns

NOTES: 4. Access times for TMS42x160 are measured with output reference levels of V_{OH} = 2 V and V_{OL} = 0.8 V.

5. t_{OFF} and t_{OEZ} are specified when the output is no longer driven.



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

		'4xx160-60 '4xx160P-60		'4xx160-70 '4xx160P-70		'4xx160-80 '4xx160P-80		UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	
t _{RC}	Cycle time, read (see Note 6)	110		130		150		ns
t _{WC}	Cycle time, write (see Note 6)	110		130		150		ns
t _{RWC}	Cycle time, read-write (see Note 6)	155		181		205		ns
t _{PC}	Cycle time, page-mode read or write (see Notes 6 and 7)	40		45		50		ns
t _{PRWC}	Cycle time, page-mode read-write (see Note 6)	85		96		105		ns
t _{RASP}	Pulse duration, $\overline{\text{RAS}}$ low, page mode (see Note 8)	60	100 000	70	100 000	80	100 000	ns
t _{RAS}	Pulse duration, $\overline{\text{RAS}}$ low, nonpage mode (see Note 8)	60	10 000	70	10 000	80	10 000	ns
t _{CAS}	Pulse duration, $\overline{\text{xCAS}}$ low (see Note 9)	15	10 000	18	10 000	20	10 000	ns
t _{RP}	Pulse duration, $\overline{\text{RAS}}$ high (precharge)	40		50		60		ns
t _{WP}	Pulse duration, $\overline{\text{W}}$ low	10		10		10		ns
t _{ASC}	Setup time, column address before $\overline{\text{xCAS}}$ low	0		0		0		ns
t _{ASR}	Setup time, row address before $\overline{\text{RAS}}$ low	0		0		0		ns
t _{DS}	Setup time, data (see Note 9)	0		0		0		ns
t _{RCS}	Setup time, $\overline{\text{W}}$ high before $\overline{\text{xCAS}}$ low	0		0		0		ns
t _{CWL}	Setup time, $\overline{\text{W}}$ low before $\overline{\text{xCAS}}$ high	15		18		20		ns
t _{RWL}	Setup time, $\overline{\text{W}}$ low before $\overline{\text{RAS}}$ high	15		18		20		ns
t _{WCS}	Setup time, $\overline{\text{W}}$ low before $\overline{\text{xCAS}}$ low (early-write operation only)	0		0		0		ns
t _{CAH}	Hold time, column address after $\overline{\text{xCAS}}$ low	10		15		15		ns
t _{DH}	Hold time, data (see Note 10)	10		15		15		ns
t _{RAH}	Hold time, row address after $\overline{\text{RAS}}$ low	10		10		10		ns
t _{RCH}	Hold time, $\overline{\text{W}}$ high after $\overline{\text{xCAS}}$ high (see Note 11)	0		0		0		ns
t _{RRH}	Hold time, $\overline{\text{W}}$ high after $\overline{\text{RAS}}$ high (see Note 11)	0		0		0		ns
t _{WCH}	Hold time, $\overline{\text{W}}$ low after $\overline{\text{xCAS}}$ low (early-write operation only)	10		15		15		ns
t _{CLCH}	Hold time, $\overline{\text{xCAS}}$ low to $\overline{\text{xCAS}}$ high	5		5		5		ns
t _{RHCP}	Hold time, $\overline{\text{RAS}}$ high from $\overline{\text{xCAS}}$ precharge	35		40		45		ns
t _{OEH}	Hold time, $\overline{\text{OE}}$ command	15		18		20		ns
t _{ROH}	Hold time, $\overline{\text{RAS}}$ referenced to $\overline{\text{OE}}$	10		10		10		ns
t _{CHS}	Hold time, $\overline{\text{xCAS}}$ low after $\overline{\text{RAS}}$ high (self refresh)	- 50		- 50		- 50		ns
t _{CP}	Delay time, $\overline{\text{xCAS}}$ high (precharge)	10		10		10		ns
t _{AWD}	Delay time, column address to $\overline{\text{W}}$ low (read-write operation only)	55		63		70		ns
t _{CHR}	Delay time, $\overline{\text{RAS}}$ low to $\overline{\text{xCAS}}$ high (xCBR refresh only)	10		10		10		ns
t _{CRP}	Delay time, $\overline{\text{xCAS}}$ high to $\overline{\text{RAS}}$ low	5		5		5		ns
t _{CSH}	Delay time, $\overline{\text{RAS}}$ low to $\overline{\text{xCAS}}$ high	60		70		80		ns
t _{CSR}	Delay time, $\overline{\text{xCAS}}$ low to $\overline{\text{RAS}}$ low (xCBR refresh only)	5		5		5		ns
t _{CWD}	Delay time, $\overline{\text{xCAS}}$ low to $\overline{\text{W}}$ low (read-write operation only)	40		46		50		ns
t _{OED}	Delay time, $\overline{\text{OE}}$ to data	15		18		20		ns

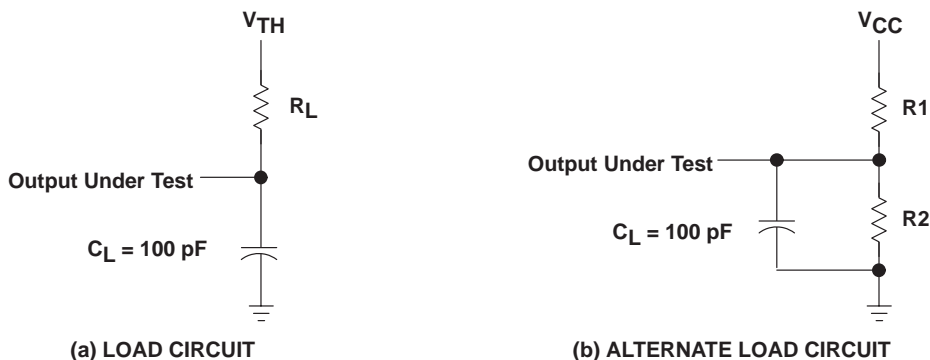
- NOTES: 6. All cycle times assume $t_T = 5$ ns.
7. To assure t_{PC} min, t_{ASC} should be $\geq t_{CP}$.
8. In a read-write cycle, t_{RWD} and t_{RWL} must be observed.
9. In a read-write cycle, t_{CWD} and t_{CWL} must be observed.
10. Referenced to the later of $\overline{\text{xCAS}}$ or $\overline{\text{W}}$ in write operations
11. Either t_{RRH} or t_{RCH} must be satisfied for a read cycle.

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

		'4xx160-60 '4xx160P-60		'4xx160-70 '4xx160P-70		'4xx160-80 '4xx160P-80		UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	
t _{RAD}	Delay time, $\overline{\text{RAS}}$ low to column address (see Note 12)	15	30	15	35	15	40	ns
t _{RAL}	Delay time, column address to $\overline{\text{RAS}}$ high	30		35		40		ns
t _{CAL}	Delay time, column address to $\overline{\text{xCAS}}$ high	30		35		40		ns
t _{RCD}	Delay time, $\overline{\text{RAS}}$ low to $\overline{\text{xCAS}}$ low (see Note 12)	20	45	20	52	20	60	ns
t _{RPC}	Delay time, $\overline{\text{RAS}}$ high to $\overline{\text{xCAS}}$ low	0		0		0		ns
t _{RSH}	Delay time, $\overline{\text{xCAS}}$ low to $\overline{\text{RAS}}$ high	15		18		20		ns
t _{RWD}	Delay time, $\overline{\text{RAS}}$ low to $\overline{\text{W}}$ low (read-write operation only)	85		98		110		ns
t _{CPW}	Delay time, $\overline{\text{W}}$ low after $\overline{\text{xCAS}}$ precharge (read-write operation only)	60		68		75		ns
t _{RASS}	Pulse duration, self-refresh entry from $\overline{\text{RAS}}$ low	100		100		100		μs
t _{RPS}	Pulse duration, $\overline{\text{RAS}}$ precharge after self refresh	110		130		150		ns
t _{REF}	Refresh time interval	'4x6160	64		64		64	ms
		'4x6160P	128		128		128	
		'4x8160	16		16		16	ms
		'4x8160P	128		128		128	
t _T	Transition time	3	30	3	30	3	30	ns

NOTE 12: The maximum value is specified only to assure access time.

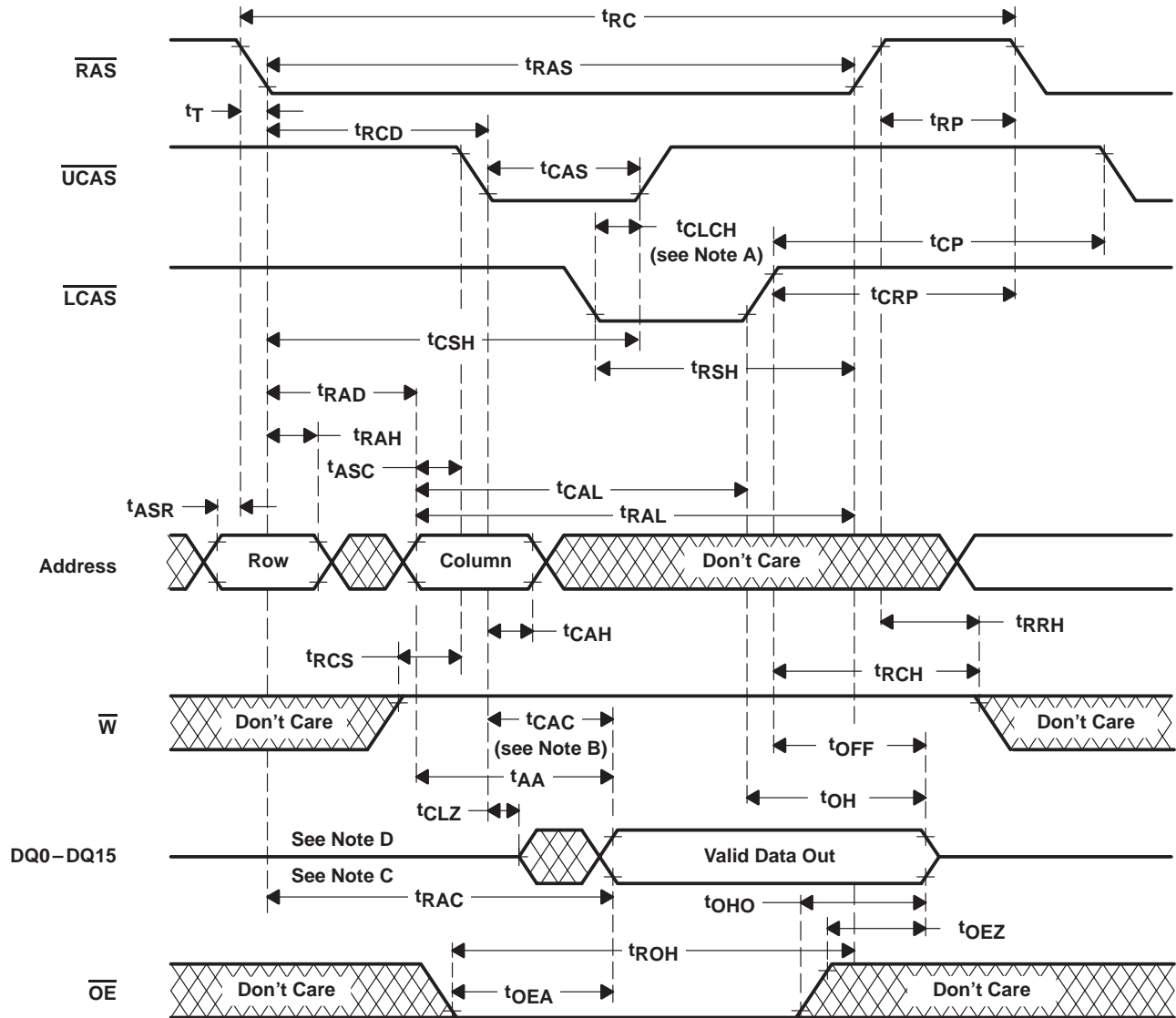
PARAMETER MEASUREMENT INFORMATION



DEVICE	V _{CC} (V)	R ₁ (Ω)	R ₂ (Ω)	V _{TH} (V)	R _L (Ω)
41x160/P	5	828	295	1.31	218
42x160/P	3.3	1178	868	1.4	500

Figure 1. Load Circuits for Timing Parameters

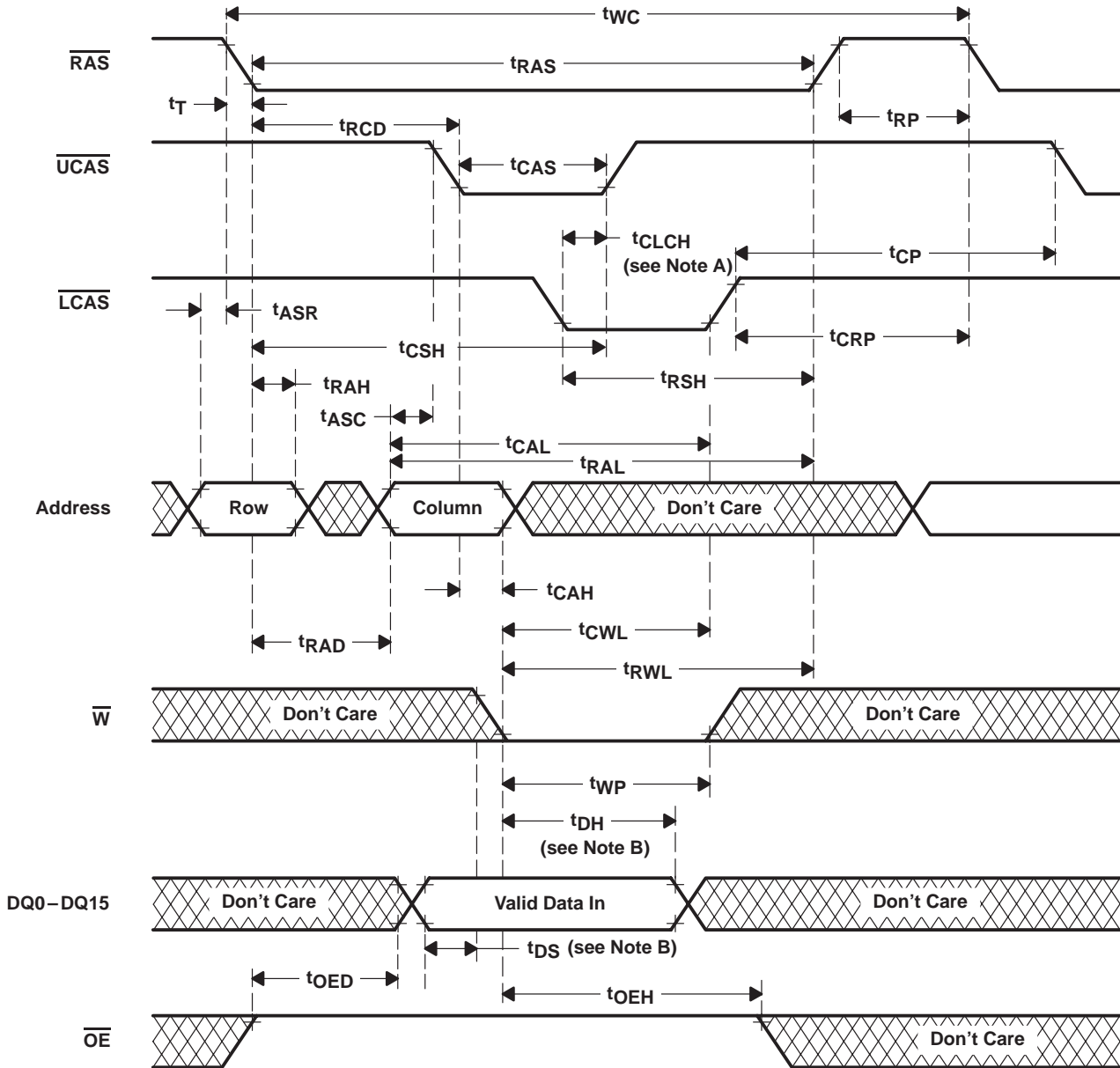
PARAMETER MEASUREMENT INFORMATION



- NOTES: A. To hold the address latched by the first xCAS going low, the parameter t_{CLCH} must be met.
 B. t_{CAC} is measured from xCAS to its corresponding DQx.
 C. Output can go from the high-impedance state to an invalid-data state prior to the specified access time.
 D. xCAS order is arbitrary.

Figure 2. Read-Cycle Timing

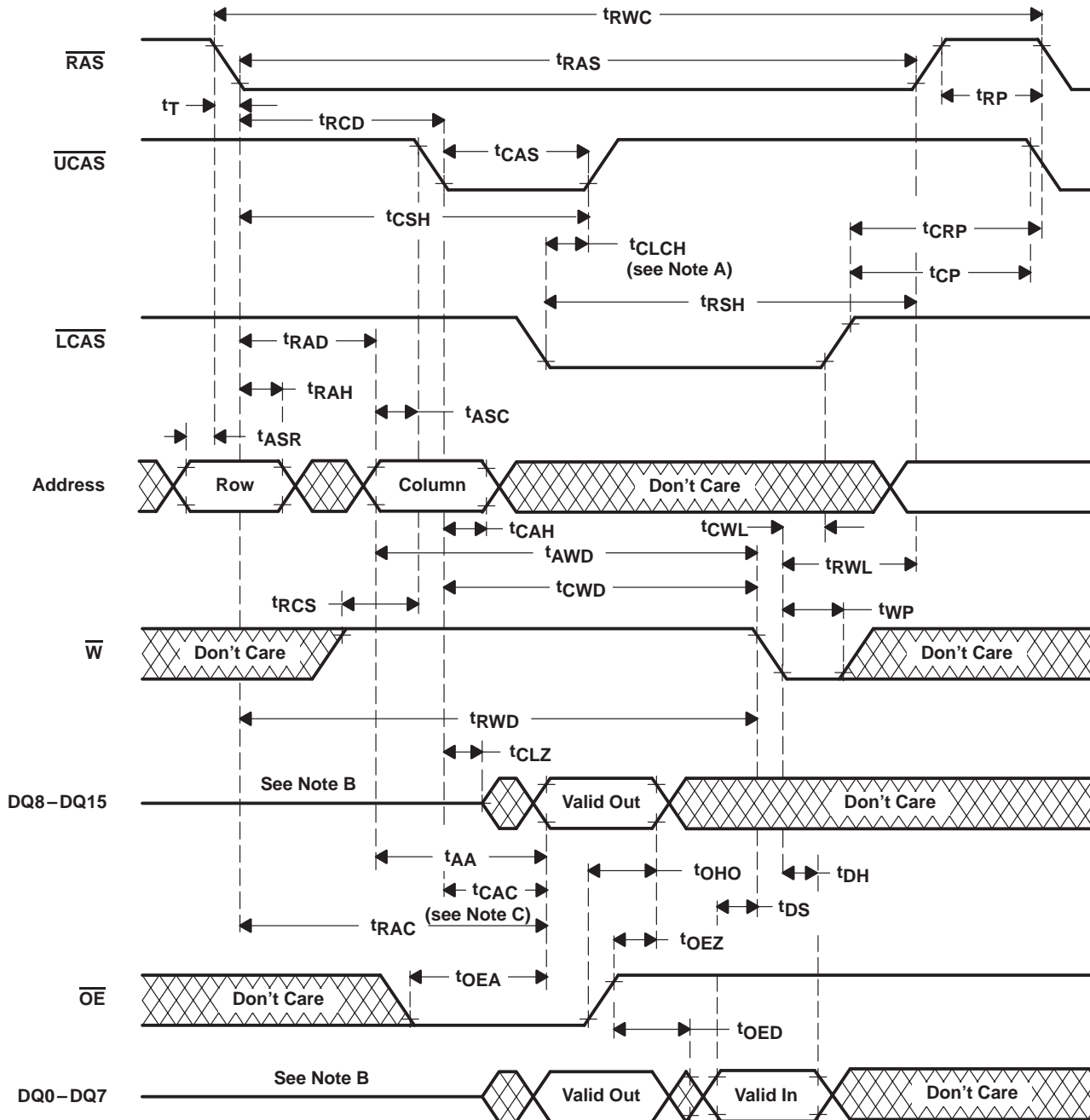
PARAMETER MEASUREMENT INFORMATION



- NOTES: A. To hold the address latched by the first xCAS going low, the parameter t_{CLCH} must be met.
 B. Referenced to the first xCAS or \overline{W} , whichever occurs last
 C. xCAS order is arbitrary.

Figure 3. Write-Cycle Timing

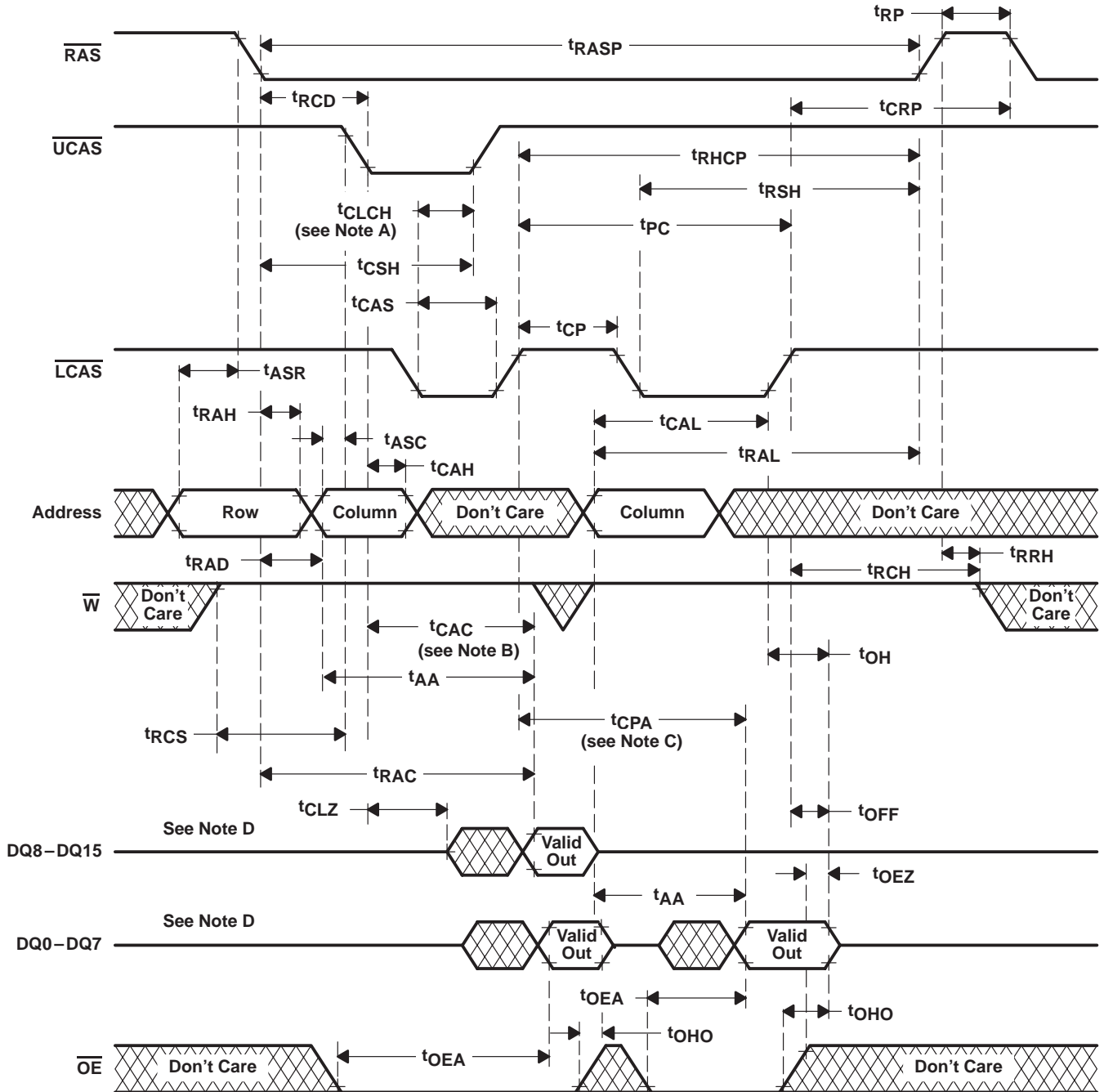
PARAMETER MEASUREMENT INFORMATION



- NOTES: A. To hold the address latched by the first $\overline{x}CAS$ going low, the parameter t_{CLCH} must be met.
 B. Output can go from a high-impedance state to an invalid-data state prior to the specified access time.
 C. t_{CAC} is measured from $\overline{x}CAS$ to its corresponding DQx.
 D. $\overline{x}CAS$ order is arbitrary.

Figure 5. Read-Modify-Write-Cycle Timing

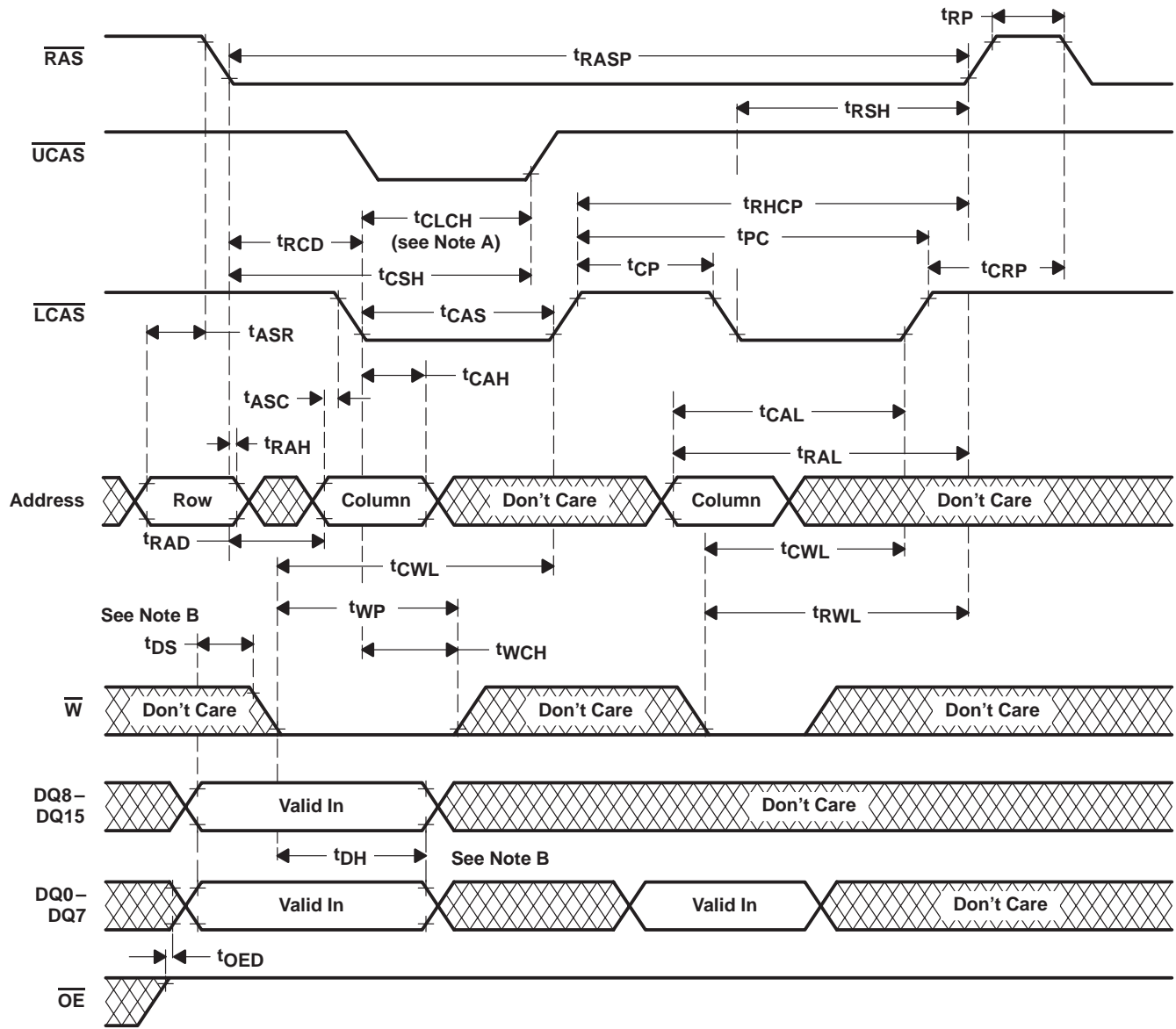
PARAMETER MEASUREMENT INFORMATION



- NOTES: A. To hold the address latched by the first xCAS going low, the parameter t_{CLCH} must be met.
 B. t_{CAC} is measured from xCAS to its corresponding DQx.
 C. Access time is t_{CPA} or t_{AA} dependent.
 D. Output can go from the high-impedance state to an invalid-data state prior to the specified access time.
 E. 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.
 F. xCAS order is arbitrary.

Figure 6. Enhanced-Page-Mode Read-Cycle Timing

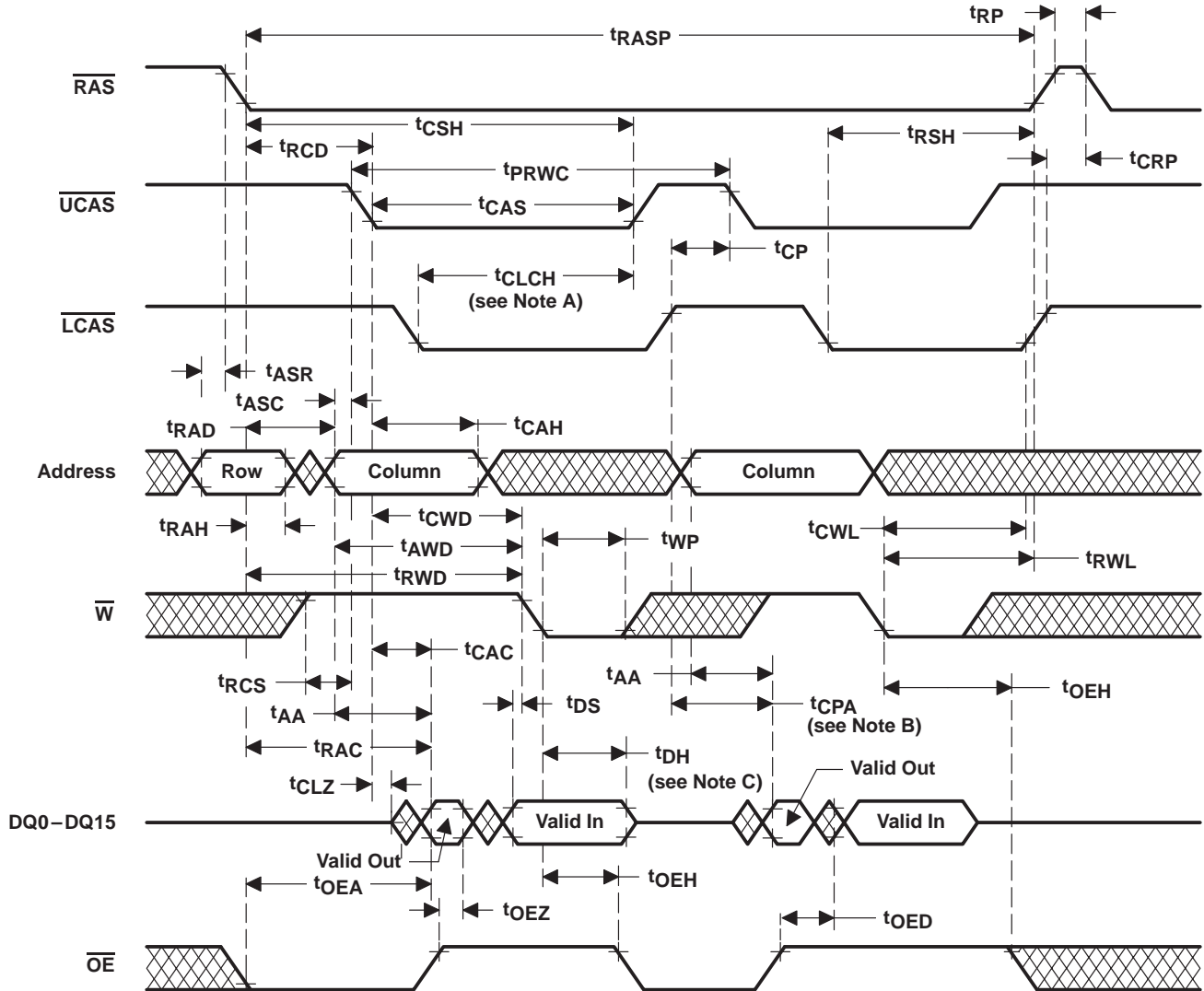
PARAMETER MEASUREMENT INFORMATION



- NOTES: A. To hold the address latched by the first xCAS going low, the parameter t_{CLCH} must be met.
 B. Referenced to the first xCAS or W, whichever occurs last
 C. A read cycle or read-modify-write cycle can be mixed with the write cycles as long as the read- and read-modify-write-timing specifications are not violated.
 D. xCAS order is arbitrary.

Figure 7. Enhanced-Page-Mode Write-Cycle Timing

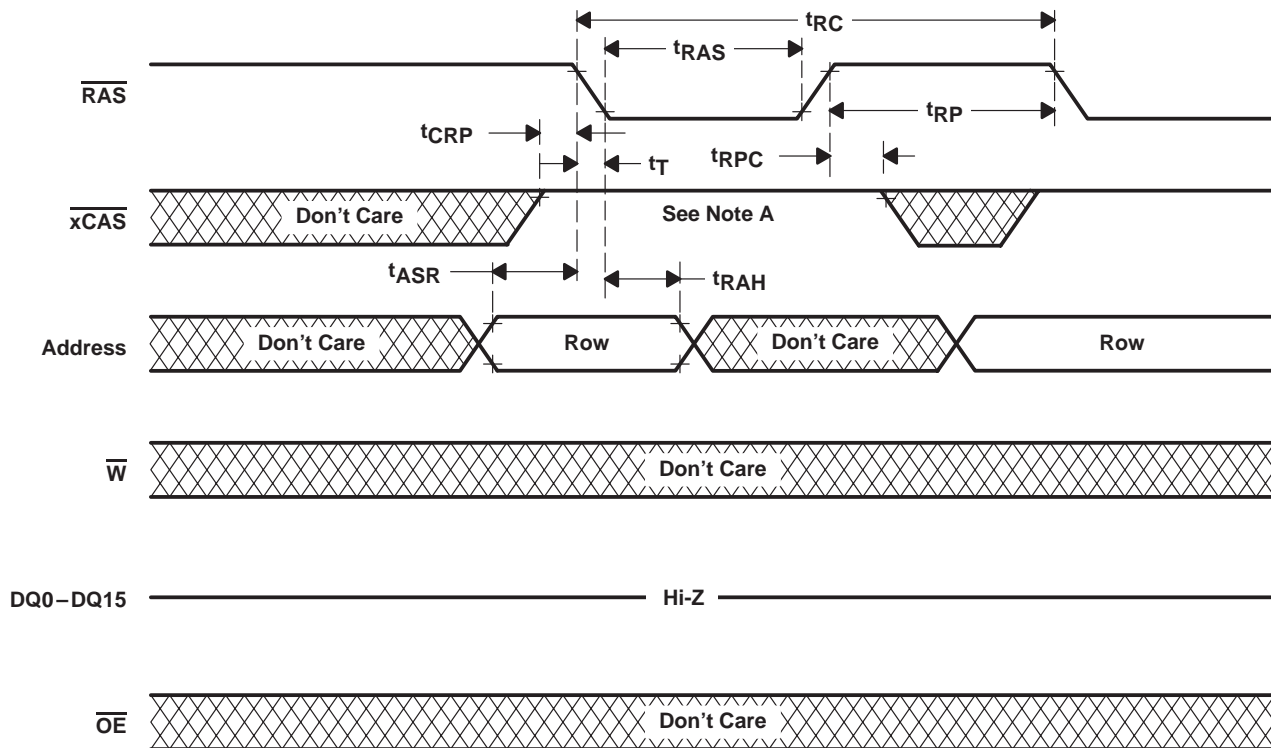
PARAMETER MEASUREMENT INFORMATION



- NOTES:
- To hold the address latched by the first $\overline{x}CAS$ going low, the parameter t_{CLCH} must be met.
 - Access time is t_{CPA} or t_{AA} dependent.
 - Output can go from the high-impedance state to an invalid-data state prior to the specified access time.
 - $\overline{x}CAS$ order is arbitrary.
 - A read or write cycle can be intermixed with read-modify-write cycles as long as the read- and write-cycle timing specifications are not violated.
 - t_{CAC} is measured from $\overline{x}CAS$ to its corresponding DQx.

Figure 8. Enhanced-Page-Mode Read-Modify-Write Cycle Timing

PARAMETER MEASUREMENT INFORMATION



NOTE A: All xCAS must be high.

Figure 9. RAS-Only Refresh-Cycle Timing

PARAMETER MEASUREMENT INFORMATION

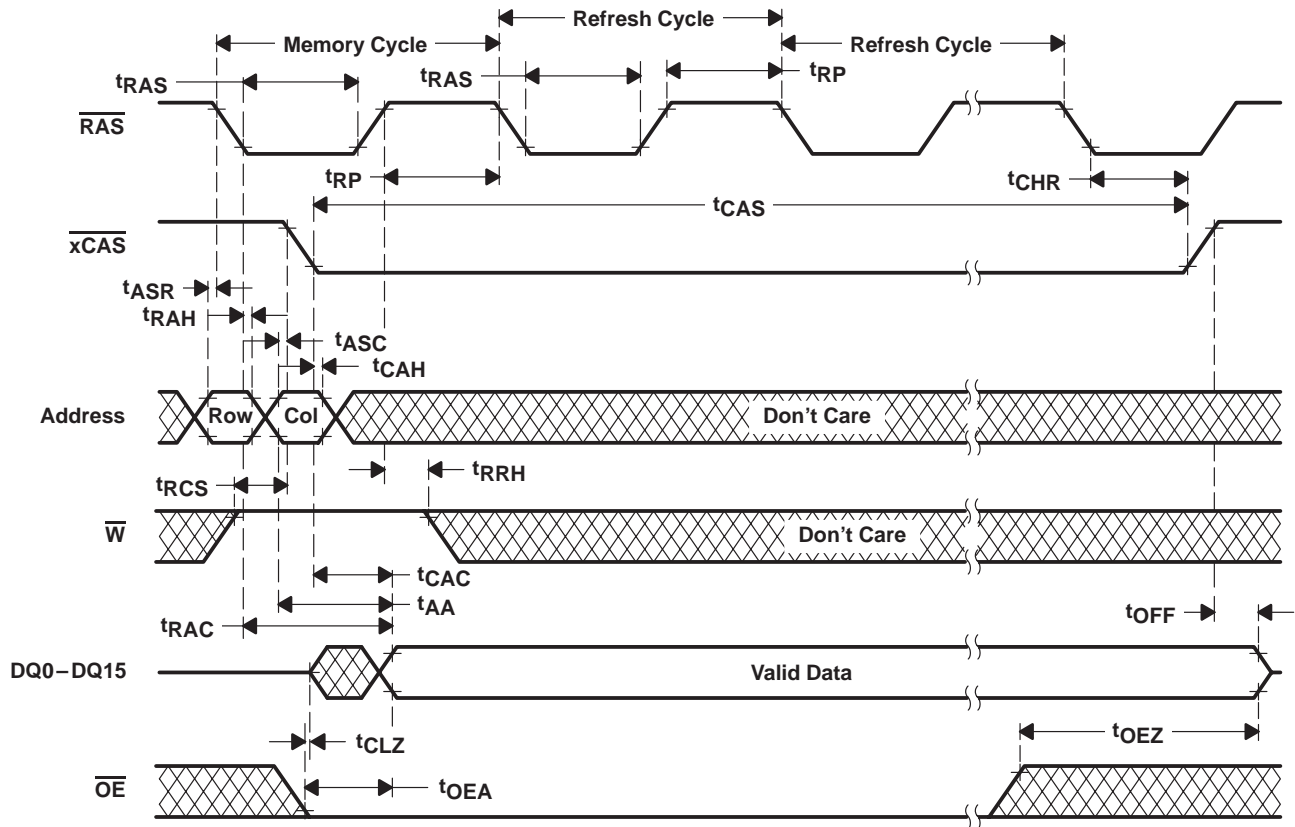
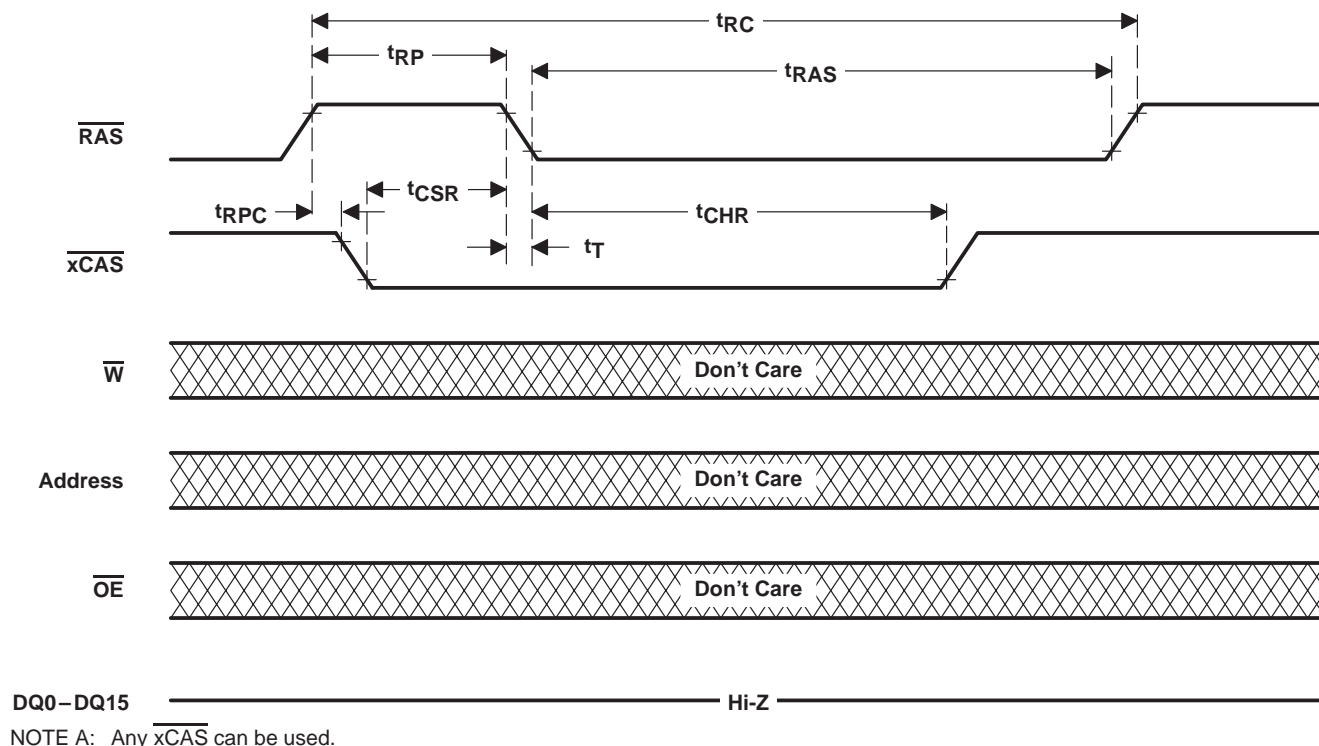


Figure 10. Hidden-Refresh-Cycle Timing

PARAMETER MEASUREMENT INFORMATION



NOTE A: Any xCAS can be used.

Figure 11. Automatic-CBR-Refresh-Cycle Timing

PARAMETER MEASUREMENT INFORMATION

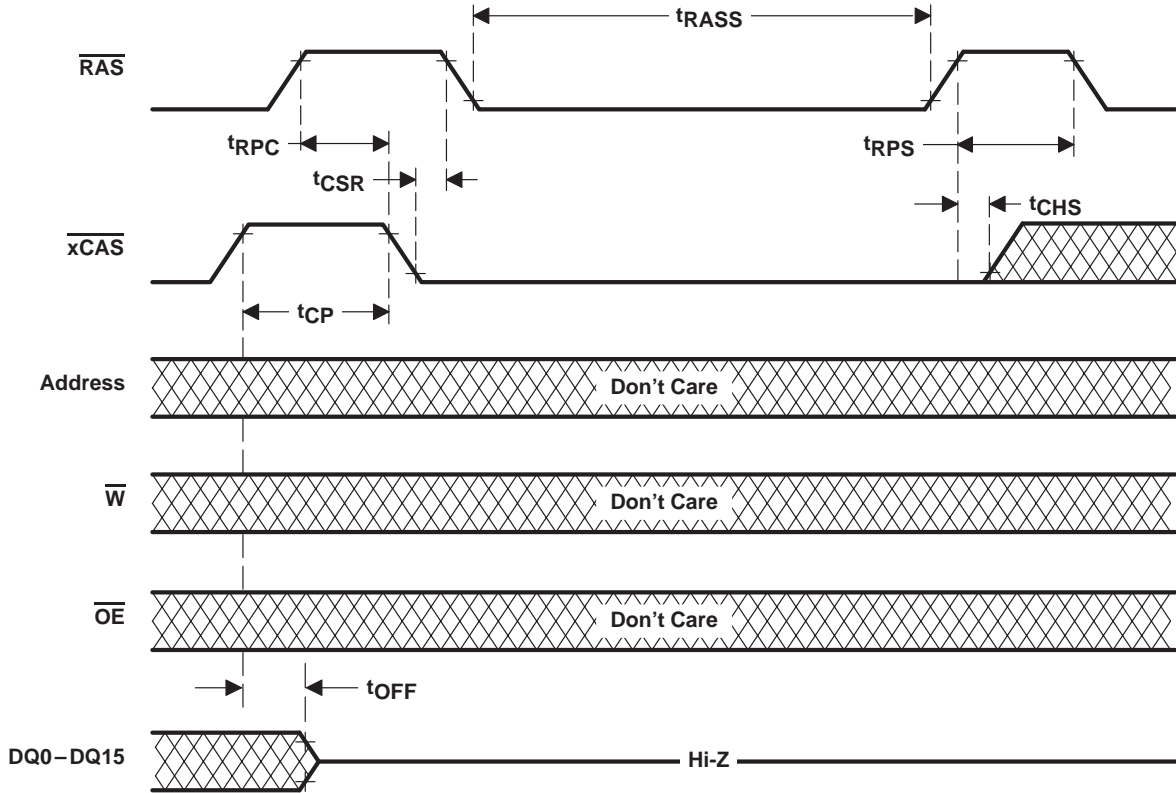


Figure 12. Self-Refresh-Cycle Timing

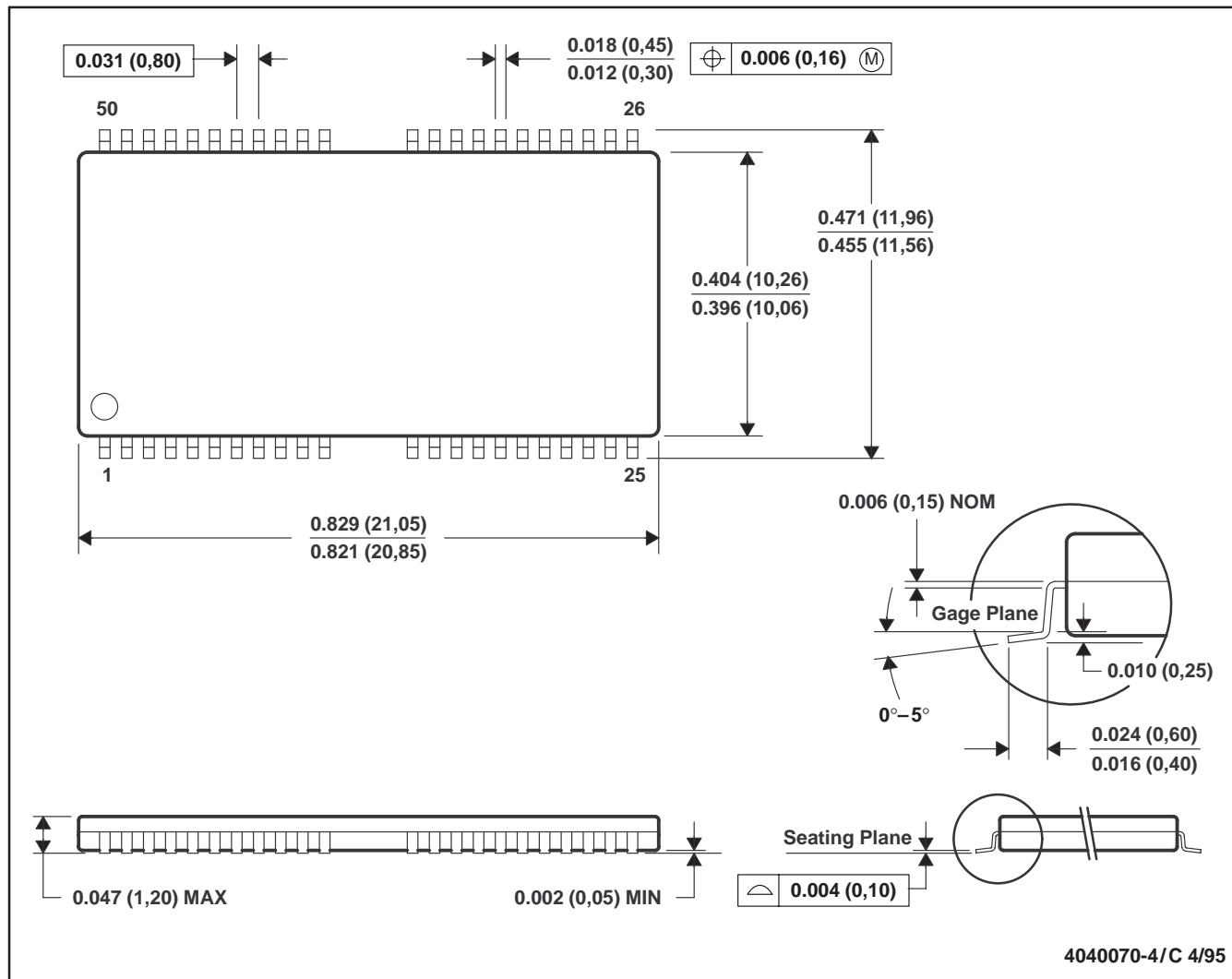
TMS416160, TMS416160P, TMS418160, TMS418160P
 TMS426160, TMS426160P, TMS428160, TMS428160P
 1048576-WORD BY 16-BIT HIGH-SPEED DRAMS

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MECHANICAL DATA

DGE (R-PDSO-G44/50)

PLASTIC SMALL-OUTLINE PACKAGE

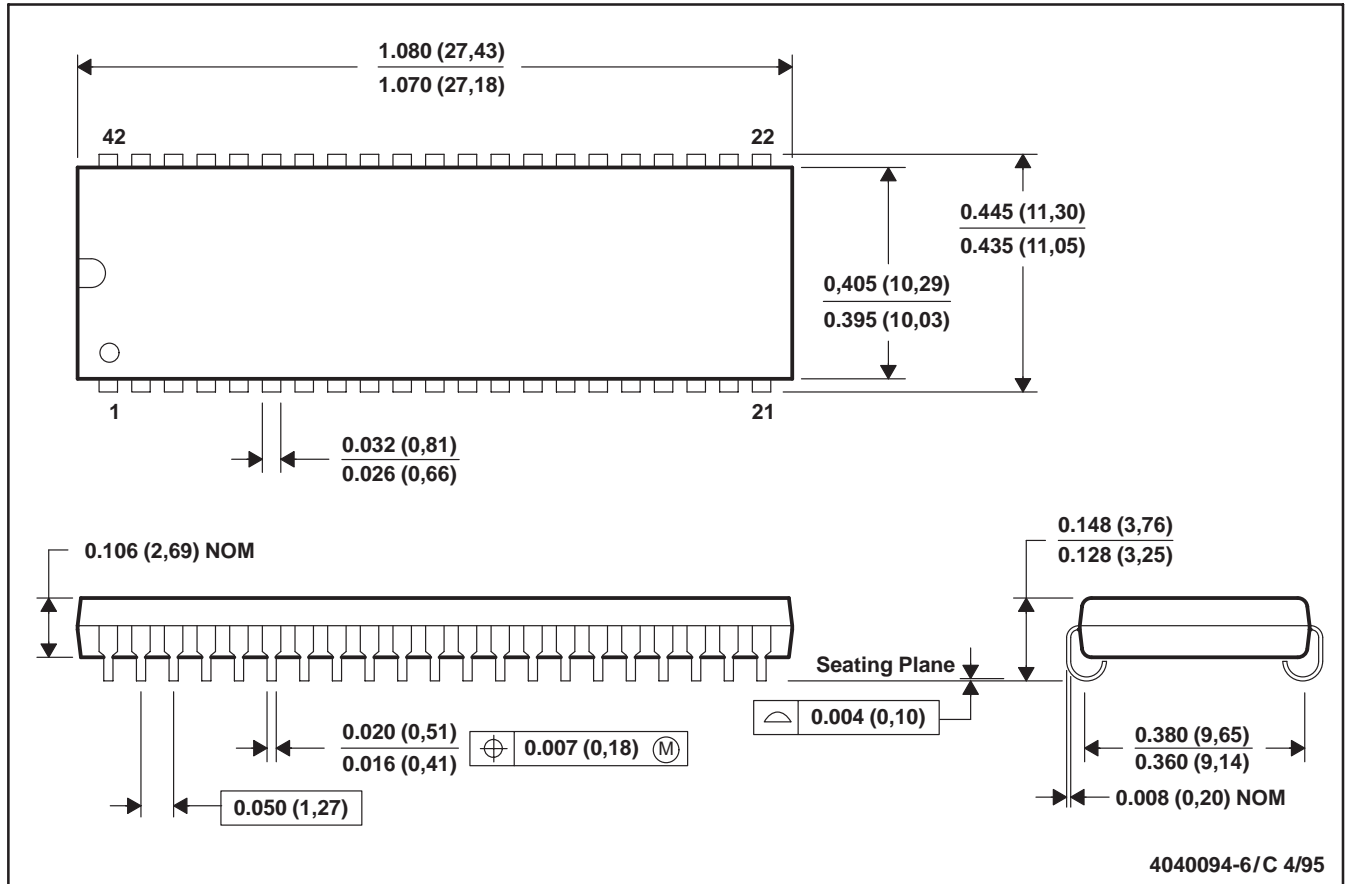


- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. Body dimensions do not include mold flash or protrusion.

MECHANICAL DATA

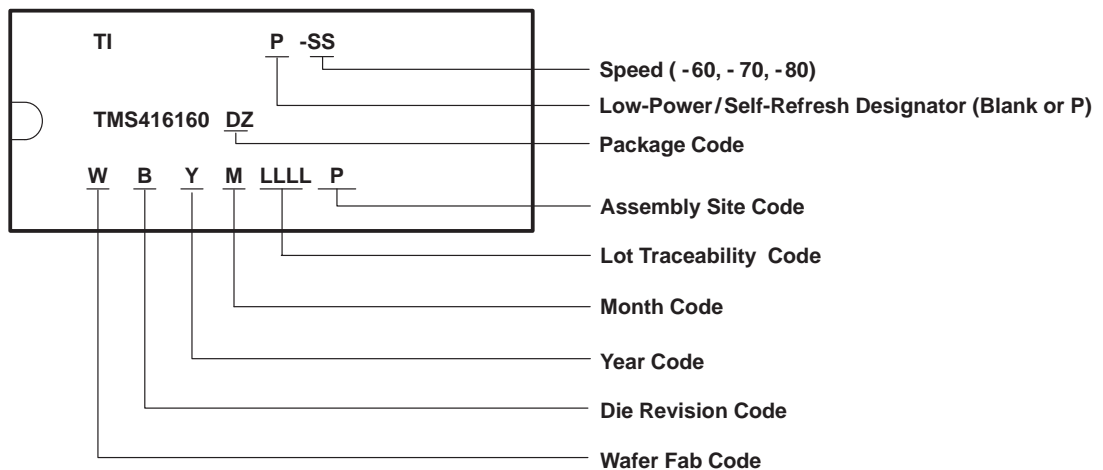
DZ (R-PDSO-J42)

PLASTIC SMALL-OUTLINE J-LEAD PACKAGE



- NOTES: A. All linear dimensions are in inches (millimeters).
 B. This drawing is subject to change without notice.
 C. Plastic body dimensions do not include mold protrusion. Maximum mold protrusion is 0.005 (0,125).

device symbolization (TMS416160P illustrated)



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