

HM538121 Series

Preliminary

131,072 x 8-Bit Multiport CMOS Video Random Access Memory

DESCRIPTION

The HM538121 is a 1-Mbit multiport video RAM equipped with a 128k-word x 8-bit dynamic RAM and a 256-word x 8-bit SAM (serial access memory). Its RAM and SAM operate independently and asynchronously. It can transfer data between RAM and SAM and has a write mask function. It is suitable for a graphic processing buffer memory.

FEATURES

- Multiport Organization
 - Asynchronous and Simultaneous Operation of RAM and SAM Capability
 - RAM: 128k-word x 8-bit and SAM: 256-word x 8-bit
- Access Time
 - RAM 100 ns/100 ns/120 ns/150 ns (max)
 - SAM 30 ns/35 ns/40 ns/50 ns (max)
- Cycle Time
 - RAM 190 ns/190 ns/220 ns/260 ns (min)
 - SAM 30 ns/40 ns/40 ns/60 ns (min)
- Low Power
 - Active
 - RAM 495 mW (max)
 - SAM 468 mW (max)
 - Standby 40 mW (max)
- High-Speed Page Mode Capability
- Mask Write Mode Capability
- Bidirectional Data Transfer Cycle between RAM and SAM Capability
- Real Time Read Transfer Capability
- 3 Variations of Refresh (8 ms/512 Cycles)
 - RAS Only Refresh
 - CAS Before RAS Refresh
 - Hidden Refresh
- TTL Compatible

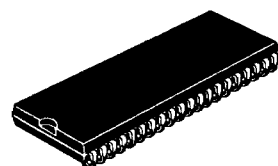
ORDERING INFORMATION

Part No.	Access Time		Package
	RAM	SAM	
HM538121JP-10	100 ns	30 ns	400 mil
HM538121JP-11	100 ns	35 ns	40-pin
HM538121JP-12	120 ns	40 ns	Plastic SOJ
HM538121JP-15	150 ns	50 ns	(CP-40D)

PIN DESCRIPTION

Pin Name	Function
A ₀ -A ₈	Address Inputs
I/O ₀ -I/O ₇	RAM Port Data Inputs/Outputs
SI/O ₀ -SI/O ₇	SAM Port Data Inputs/Outputs
RAS	Row Address Strobe
CAS	Column Address Strobe
WE	Write Enable
DT/OE	Data Transfer/Output Enable
SC	Serial Clock
SE	SAM Port Enable
V _{CC}	Power Supply
V _{SS}	Ground
NC	Non Connection

HM538121JP Series

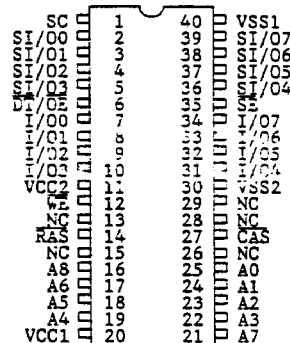


3DCP400

(CP-40D)

PIN OUT

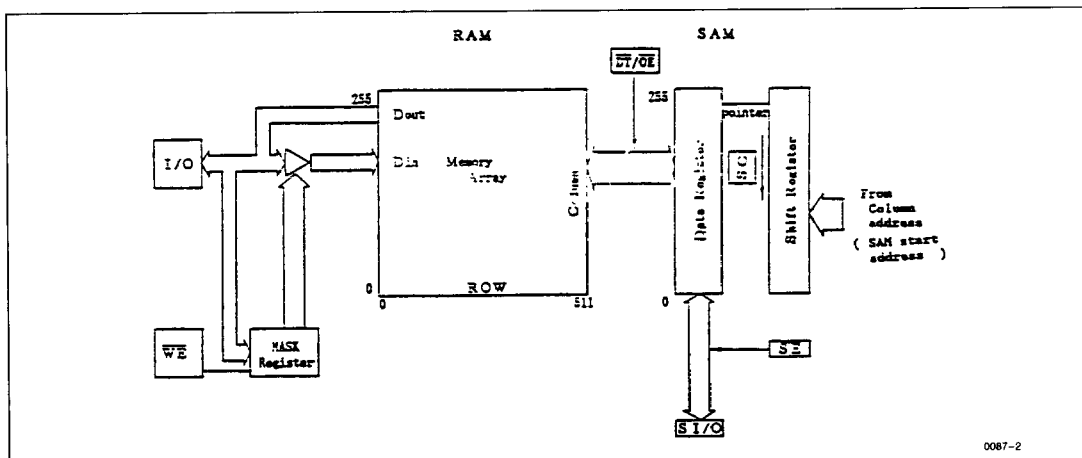
HM538121JP Series



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(Top View)

■ BLOCK DIAGRAM



■ PIN FUNCTION

RAS (input pin): $\overline{\text{RAS}}$ is a basic RAM signal. It is active in low level and standby in high level. Row address and signals as shown in Table 1 are input at the falling edge of $\overline{\text{RAS}}$. The input level of those signals determine the operation cycle of the HM538121.

• Table 1. Operation Cycles of the HM538121

Input Level at the Falling Edge of $\overline{\text{RAS}}$				Operation Cycle
$\overline{\text{CAS}}$	$\overline{\text{DT/OE}}$	$\overline{\text{WE}}$	$\overline{\text{SE}}$	
H	H	H	X	RAM Read/Write
H	H	L	X	Mask Write
H	L	H	X	Read Transfer
H	L	L	H	Pseudo Transfer
H	L	L	L	Write Transfer
L	X	X	X	CBR Refresh

Note: X: Don't care.

$\overline{\text{CAS}}$ (input pin): Column address is put into chip at the falling edge of $\overline{\text{CAS}}$. $\overline{\text{CAS}}$ controls output impedance of I/O in RAM.

$\text{A}_0\text{--}\text{A}_8$ (input pins): Row address is determined by $\text{A}_0\text{--}\text{A}_8$ level at the falling edge of $\overline{\text{RAS}}$. Column address is determined by $\text{A}_0\text{--}\text{A}_7$ level at the falling edge of $\overline{\text{CAS}}$. In transfer cycles, row address is the address on the word line which transfers data with SAM data register, and column address is the SAM start address after transfer.

$\overline{\text{WE}}$ (input pin): $\overline{\text{WE}}$ pin has two functions at the falling edge of $\overline{\text{RAS}}$ and after. When $\overline{\text{WE}}$ is low at the falling edge of $\overline{\text{RAS}}$, the HM538121 turns to mask write mode. According to the I/O level at the time, write on each I/O can be masked. ($\overline{\text{WE}}$ level at the falling edge of $\overline{\text{RAS}}$ is don't care in read

cycle.) When $\overline{\text{WE}}$ is high at the falling edge of $\overline{\text{RAS}}$, a normal write cycle is executed. After that, $\overline{\text{WE}}$ switches read/write cycles as in a standard DRAM. In a transfer cycle, the direction of transfer is determined by $\overline{\text{WE}}$ level at the falling edge of $\overline{\text{RAS}}$. When $\overline{\text{WE}}$ is low, data is transferred from SAM to RAM (data is written into RAM), and when $\overline{\text{WE}}$ is high, data is transferred from RAM to SAM (data is read from RAM).

$\text{I/O}_0\text{--}\text{I/O}_7$ (input/output pins): I/O pins function as mask data at the falling edge of $\overline{\text{RAS}}$ (in mask write mode). Data is written only on high I/O pins. Data on low I/O pins are masked and internal data are retained. After that, they function as input/output pins as those of a standard DRAM.

$\overline{\text{DT/OE}}$ (input pin): $\overline{\text{DT/OE}}$ pin functions as $\overline{\text{DT}}$ (data transfer) pin at the falling edge of $\overline{\text{RAS}}$ and as $\overline{\text{OE}}$ (output enable) pin after that. When $\overline{\text{DT}}$ is low at the falling edge of $\overline{\text{RAS}}$, this cycle becomes a transfer cycle. When $\overline{\text{DT}}$ is high at the falling edge of $\overline{\text{RAS}}$, RAM and SAM operate independently.

SC (input pin): SC is a basic SAM clock. In a serial read cycle, data is output from an SI/O pin synchronously with the rising edge of SC. In a serial write cycle, data on an SI/O pin at the rising edge of SC is put into the SAM data register.

$\overline{\text{SE}}$ (input pin): $\overline{\text{SE}}$ pin activates SAM. When $\overline{\text{SE}}$ is high, SI/O is in the high impedance state in serial read cycle and data on SI/O is not put into the SAM data register in serial write cycle. $\overline{\text{SE}}$ can be used as a mask for serial write because internal pointer is incremented at the rising edge of SC.

$\text{SI/O}_0\text{--}\text{SI/O}_7$ (input/output pins): SI/O s are input/output pins in SAM. Direction of input/output is determined by the previous transfer cycle. When it was a read transfer cycle, SI/O outputs data. When it was a pseudo transfer cycle or write transfer cycle, SI/O inputs data.

■ OPERATION OF HM538121

• Operation of RAM Port

RAM Read Cycle ($\overline{DT}/\overline{OE}$ high, \overline{CAS} high, at the falling edge of \overline{RAS})

Row address is entered at the \overline{RAS} falling edge and column address at the \overline{CAS} falling edge to the device as in standard DRAM. Then, when \overline{WE} is high and $\overline{DT}/\overline{OE}$ is low while \overline{CAS} is low, the selected address data is output through I/O pin. At the falling edge of \overline{RAS} , $\overline{DT}/\overline{OE}$ and \overline{CAS} become high to distinguish RAM read cycle from transfer cycle and CBR refresh cycle. Address access time (t_{AA}) and \overline{RAS} to column address delay time (t_{RAD}) specifications are added to enable high-speed page mode.

RAM Write Cycle (Early Write, Delayed Write, Read-Modify-Write) ($\overline{DT}/\overline{OE}$ high, \overline{CAS} high at the falling edge of \overline{RAS})

- Normal Mode Write Cycle (\overline{WE} high at the falling edge of \overline{RAS})

When \overline{CAS} and \overline{WE} are set low after \overline{RAS} is set low, a write cycle is executed and I/O data is written at the selected addresses. When all 8 I/Os are written, \overline{WE} should be high at the falling edge of \overline{RAS} to distinguish normal mode from mask write mode.

If \overline{WE} is set low before the \overline{CAS} falling edge, this cycle becomes an early write cycle and I/O becomes high impedance. Data is entered at the \overline{CAS} falling edge.

If \overline{WE} is set low after the \overline{CAS} falling edge, this cycle becomes a delayed write cycle. Data is input at the \overline{WE} falling edge. I/O does not become high impedance in this cycle, so data should be entered with \overline{OE} in high.

If \overline{WE} is set low after t_{CWD} (min) and t_{AWD} (min) after the \overline{CAS} falling edge, this cycle becomes a read-modify-write cycle and enables write after read to execute in the same address cycle. In this cycle also, to avoid I/O contention, data should be input after reading data and setting \overline{OE} high.

- Mask Write Mode (\overline{WE} low at the falling edge of \overline{RAS})

If \overline{WE} is set low at the falling edge of \overline{RAS} , the cycle becomes a mask write mode cycle which writes only to selected I/O. Whether or not an I/O is written depends on I/O level (mask data) at the falling edge of \overline{RAS} . Then the data is written in high I/O pins and masked in low ones and internal data is preserved. This mask data is effective during the \overline{RAS} cycle. So, in high-speed page mode cycle, the mask data is preserved during the page access.

High-Speed Page Mode Cycle ($\overline{DT}/\overline{OE}$ high, \overline{CAS} high at the falling edge of \overline{RAS})

High-speed page mode cycle reads/writes the data of the same row address at high speed by toggling \overline{CAS} while \overline{RAS} is low. Its cycle time is one third of the random read/write cycle and is higher than the standard page mode cycle by 70–80%. This product is based on static column mode, therefore, address access time (t_{AA}), \overline{RAS} to column address delay time (t_{RAD}), and access time from \overline{CAS} pre-charge (t_{ACP}) are added. In one \overline{RAS} cycle, 256-word memory cells of the same row address can be accessed. It is necessary to specify access frequency within t_{RASP} max (100 μ s).

• Transfer Operation

HM538121 provides the read transfer cycle, pseudo transfer cycle, and write transfer cycle as data transfer cycles. These transfer cycles are set by driving $\overline{DT}/\overline{OE}$ low at the falling edge of \overline{RAS} .

They have the following functions:

- (1) Transfer data between row address and SAM data register (except for pseudo transfer cycle)
- (2) Determine direction of data transfer
 - (a) Read transfer cycle: RAM \rightarrow SAM
 - (b) Write transfer cycle: RAM \leftarrow SAM
- (3) Determine input or output of SAM I/O pin (SI/O)

Read transfer cycle: SI/O output

Pseudo transfer cycle, write transfer cycle: SI/O input
- (4) Determine first SAM address to access (SAM start address) after transferring at column address.

Read Transfer Cycle (\overline{CAS} high, $\overline{DT}/\overline{OE}$ low, \overline{WE} high at the falling edge of \overline{RAS})

This cycle becomes read transfer cycle by setting $\overline{DT}/\overline{OE}$ low and \overline{WE} high at the falling edge of \overline{RAS} . The row address data (256 x 8-bit) determined by this cycle is transferred synchronously at the rising of $\overline{DT}/\overline{OE}$. After the rising edge of $\overline{DT}/\overline{OE}$, the new address data outputs from SAM start address decided by column address.

This cycle can execute SAM access serially even during transfer (real time read transfer). In this case, the timing t_{SD} (min) is specified between the last SAM access before transfer and $\overline{DT}/\overline{OE}$ rising edge, and t_{SPH} (min) between the first SAM access and $\overline{DT}/\overline{OE}$ rising edge (see Figure 1).

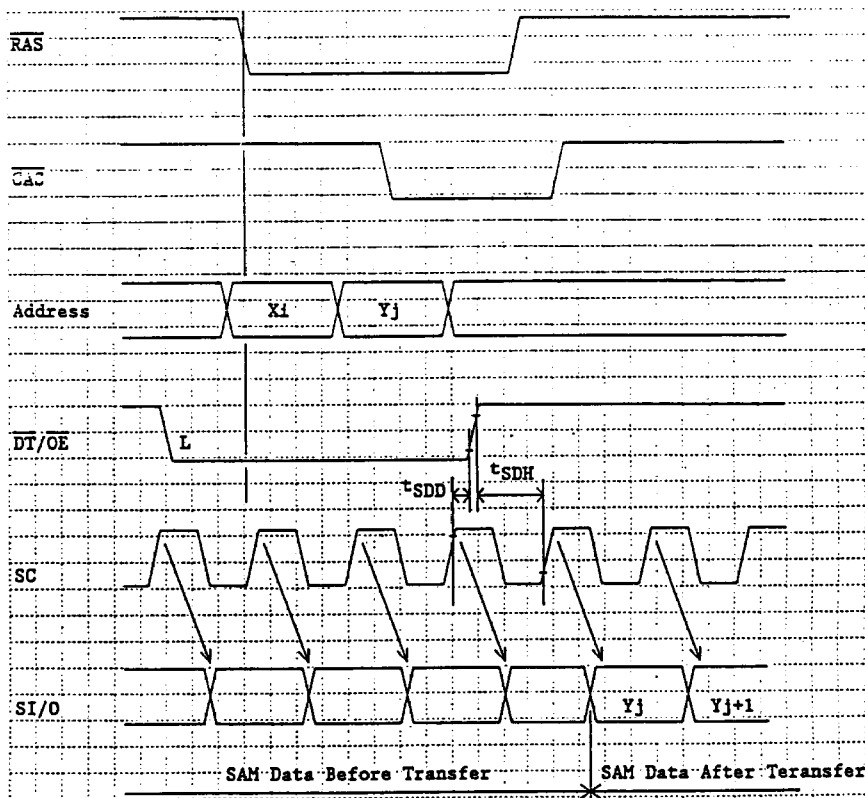
If read transfer cycle is executed, SI/O becomes output state. When the previous transfer cycle is either pseudo transfer cycle or write transfer cycle and SI/O is in input state, uncertain data is output after t_{PLZ} (min) after the \overline{RAS} falling edge. Before that, input should be set high impedance to avoid data contention.

Pseudo Transfer Cycle (\overline{CAS} high, $\overline{DT}/\overline{OE}$ low, \overline{WE} low, and \overline{SE} high at the falling edge of \overline{RAS})

Pseudo transfer cycle is available for switching SI/O from output state to input state because data in RAM isn't rewritten. This cycle starts when \overline{CAS} is high, $\overline{DT}/\overline{OE}$ low, \overline{WE} low, and \overline{SE} high, at the falling edge of \overline{RAS} . The output buffer in SI/O becomes high impedance within t_{SRZ} (max) from the \overline{RAS} falling edge. Data should be input to SI/O later than t_{SPD} (min) to avoid data contention. SAM access becomes enabled after t_{SRD} (min) after \overline{RAS} becomes high. In this cycle, SAM access is inhibited during \overline{RAS} low, therefore, SC should not be raised.

Write Transfer Cycle (\overline{CAS} high, $\overline{DT}/\overline{OE}$ low, \overline{WE} low, and \overline{SE} low at the falling edge of \overline{RAS})

Write transfer cycle can transfer a row of data input by serial write cycle to RAM. The row address of data transferred into RAM is determined by the address at the falling edge of \overline{RAS} . The column address is specified as the first address to serial write after terminating this cycle. Also in this cycle, SAM access becomes enabled after t_{SRD} (min) after \overline{RAS} becomes high. SAM access is inhibited during \overline{RAS} low. In this period, SC should not be raised.



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Figure 1. Real Time Read Transfer

• SAM Port Operation Serial Read Cycle

SAM port is in read mode when the previous data transfer cycle is read transfer cycle. Access is synchronized with SC rising, and SAM data is output from SI/O. If \overline{SE} is set high SI/O becomes high impedance and internal pointer is incremented at the SC rising edge.

Serial Write Cycle

If previous data transfer cycle is pseudo transfer cycle or write transfer cycle, SAM port goes into write mode. In this cycle, SI/O data is programmed into data register at the SC rising edge like in the serial read cycle. If \overline{SE} is high, SI/O data isn't input into data register. Internal pointer is incremented according to the SC rising edge, so \overline{SE} high can mask data for SAM.

• Refresh RAM Refresh

RAM, which is composed of dynamic circuits, requires refresh to retain data. Refresh is performed by accessing all 512 row addresses every 8 ms. There are three refresh cycles: (1) \overline{RAS} only refresh cycle, (2) \overline{CAS} before \overline{RAS} (CBR)

refresh cycle, and (3) Hidden refresh cycle. Besides them, the cycles which activate \overline{RAS} such as read/write cycles or transfer cycles can refresh the row address. Therefore, no refresh cycle is required for accessing all row addresses every 8 ms.

\overline{RAS} Only Refresh Cycle: \overline{RAS} only refresh cycle is performed by activating only \overline{RAS} cycle with \overline{CAS} fixed to high by inputting the row address (= refresh address) from external circuits. To distinguish this cycle from data transfer cycle, $\overline{DT/OE}$ should be high at the falling edge of \overline{RAS} .

CBR Refresh Cycle: CBR refresh cycle is set by activating \overline{CAS} before \overline{RAS} . In this cycle, refresh address need not to be input through external circuits because it is input through an internal refresh counter. In this cycle, output is in high impedance and power dissipation is lowered because \overline{CAS} circuits don't operate.

Hidden Refresh Cycle: Hidden refresh cycle performs refresh by reactivating \overline{RAS} when $\overline{DT/OE}$ and \overline{CAS} keep low in normal RAM read cycles.

SAM Refresh

SAM parts (data register, shift register, selector), organized as fully static circuitry, don't require refresh.

■ ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Value	Unit	Note
Terminal Voltage	V_T	-1.0 to +7.0	V	1
Power Supply Voltage	V_{CC}	-0.5 to +7.0	V	1
Power Dissipation	P_T	1.0	W	
Operating Temperature	T_{opr}	0 to +70	°C	
Storage Temperature	T_{stg}	-55 to +125	°C	

Note: 1. Relative to V_{SS} .

■ ELECTRICAL CHARACTERISTICS

• Recommended DC Operating Conditions ($T_A = 0$ to +70°C)

Parameter	Symbol	Min	Typ	Max	Unit	Note
Supply Voltage	V_{CC}	4.5	5.0	5.5	V	1
Input High Voltage	V_{IH}	2.4	—	6.5	V	1
Input Low Voltage	V_{IL}	-0.5	—	0.8	V	1, 2

Notes: 1. All voltages referenced to V_{SS} .
 2. -3.0V for pulse width ≤ 10 ns.

• DC Electrical Characteristics ($T_A = 0$ to +70°C, $V_{CC} = 5V \pm 10\%$, $V_{SS} = 0V$)

Parameter	Symbol	HM538121-10		HM538121-11		HM538121-12		HM538121-15		Unit	Test Conditions		Note
		Min	Max	Min	Max	Min	Max	Min	Max		RAM Port	SAM Port	
Operating Current	I_{CC1}	—	90	—	90	—	80	—	70	mA	\overline{RAS} , \overline{CAS} Cycling $t_{RC} = \text{Min}$	$\overline{SE} = V_{IH}$, $SC = V_{IL}$ $\overline{SE} = V_{IL}$, SC Cycling $t_{SCC} = \text{Min}$	1
	I_{CC7}	—	160	—	160	—	140	—	120	mA			
Standby Current	I_{CC2}	—	7	—	7	—	7	—	7	mA	\overline{RAS} , $\overline{CAS} = V_{IH}$	$\overline{SE} = V_{IH}$, $SC = V_{IL}$ $\overline{SE} = V_{IL}$, SC Cycling $t_{SCC} = \text{Min}$	1
	I_{CC8}	—	85	—	70	—	70	—	55	mA			
\overline{RAS} Only Refresh Current	I_{CC3}	—	90	—	90	—	80	—	70	mA	\overline{RAS} Cycling $CAS = V_{IH}$ $t_{RC} = \text{Min}$	$\overline{SE} = V_{IH}$, $SC = V_{IL}$ $\overline{SE} = V_{IL}$, SC Cycling $t_{SCC} = \text{Min}$	1
	I_{CC9}	—	150	—	150	—	130	—	110	mA			
Page Mode Current	I_{CC4}	—	115	—	115	—	105	—	95	mA	\overline{CAS} Cycling $RAS = V_{IL}$ $t_{PC} = \text{Min}$	$\overline{SE} = V_{IH}$, $SC = V_{IL}$ $\overline{SE} = V_{IL}$, SC Cycling $t_{SCC} = \text{Min}$	1
	I_{CC10}	—	185	—	185	—	160	—	140	mA			
\overline{CAS} Before \overline{RAS} Refresh Current	I_{CC5}	—	80	—	80	—	70	—	60	mA	\overline{RAS} Cycling $t_{RC} = \text{Min}$	$\overline{SE} = V_{IH}$, $SC = V_{IL}$ $\overline{SE} = V_{IL}$, SC Cycling $t_{SCC} = \text{Min}$	1
	I_{CC11}	—	130	—	130	—	110	—	90	mA			
Data Transfer Current	I_{CC6}	—	115	—	115	—	110	—	100	mA	\overline{RAS} , \overline{CAS} Cycling $t_{RC} = \text{Min}$	$\overline{SE} = V_{IH}$, $SC = V_{IL}$ $\overline{SE} = V_{IL}$, SC Cycling $t_{SCC} = \text{Min}$	1
	I_{CC12}	—	185	—	185	—	160	—	140	mA			
Input Leakage Current	I_{LI}	-10	10	-10	10	-10	10	-10	10	μA			
Output Leakage Current	I_{LO}	-10	10	-10	10	-10	10	-10	10	μA			
Output High Voltage	V_{OH}	2.4	—	2.4	—	2.4	—	2.4	—	V	$I_{OH} = -2$ mA		
Output Low Voltage	V_{OL}	—	0.4	—	0.4	—	0.4	—	0.4	V	$I_{OL} = 4.2$ mA		

Notes: 1. I_{CC} depends on output loading condition when the device is selected. I_{CC} max is specified at the output open condition ($I_{LO} = I_{SI/O} = 0$ mA).
 2. Address can be changed less than three times in one \overline{RAS} cycle.
 3. Address can be changed once or less while $\overline{CAS} = V_{IH}$.
 4. Address must be fixed.

- **Capacitance** ($T_A = 25^\circ\text{C}$, $V_{CC} = 5\text{V}$, $f = 1\text{MHz}$, Bias: Clock, I/O = V_{CC} , Address = V_{SS})

Parameter	Symbol	Min	Typ	Max	Unit
Address	C_{I1}	—	—	5	pF
Clocks	C_{I2}	—	—	5	pF
I/O, SI/O	$C_{I/O}$	—	—	7	pF

- **AC Characteristics** ($T_A = 0\text{ to } +70^\circ\text{C}$, $V_{CC} = 5\text{V} \pm 10\%$, $V_{SS} = 0\text{V}$)^{1, 11}

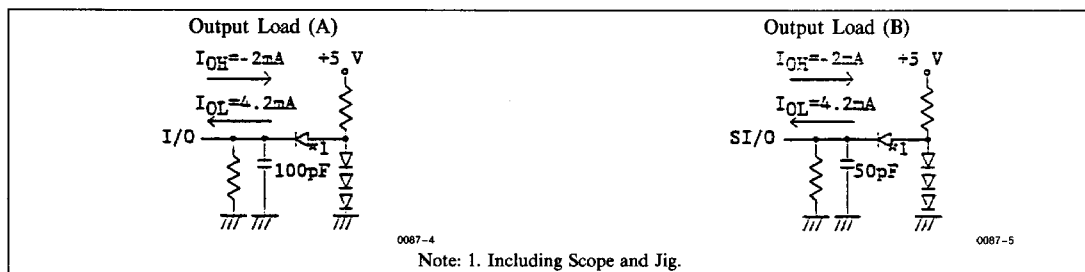
Test Conditions

Input Rise and Fall Time 5 ns

Output Load See Figures

Input Timing Reference Levels 0.8V, 2.4V

Output Timing Reference Levels 0.4V, 2.4V



Common Parameters

Parameter	Symbol	HM538121-10		HM538121-11		HM538121-12		HM538121-15		Unit	Note
		Min	Max	Min	Max	Min	Max	Min	Max		
Random Read or Write Cycle Time	t_{RC}	190	—	190	—	220	—	260	—	ns	
RAS Precharge Time	t_{RP}	80	—	80	—	90	—	100	—	ns	
RAS Pulse Width	t_{RAS}	100	10000	100	10000	120	10000	150	10000	ns	
CAS Pulse Width	t_{CAS}	30	10000	30	10000	35	10000	40	10000	ns	
Row Address Setup Time	t_{ASR}	0	—	0	—	0	—	0	—	ns	
Row Address Hold Time	t_{RAH}	15	—	15	—	15	—	20	—	ns	
Column Address Setup Time	t_{ASC}	0	—	0	—	0	—	0	—	ns	
Column Address Hold Time	t_{CAH}	20	—	20	—	20	—	25	—	ns	
RAS to CAS Delay Time	t_{RCD}	25	70	25	70	25	85	30	110	ns	5, 6
RAS Hold Time	t_{RSH}	30	—	30	—	35	—	40	—	ns	
CAS Hold Time	t_{CSH}	100	—	100	—	120	—	150	—	ns	
CAS to RAS Pre-charge Time	t_{CRP}	10	—	10	—	10	—	10	—	ns	
Transition Time (Rise to Fall)	t_T	3	50	3	50	3	50	3	50	ns	8
Refresh Period	t_{REF}	—	8	—	8	—	8	—	8	ms	



Common Parameters (continued)

Parameter	Symbol	HM538121-10		HM538121-11		HM538121-12		HM538121-15		Unit	Note
		Min	Max	Min	Max	Min	Max	Min	Max		
DT to RAS Setup Time	t _{DTS}	0	—	0	—	0	—	0	—	ns	
DT to RAS Hold Time	t _{DTH}	15	—	15	—	15	—	20	—	ns	
Data-in to OE Delay Time	t _{DZO}	0	—	0	—	0	—	0	—	ns	
Data-in to CAS Delay Time	t _{DZC}	0	—	0	—	0	—	0	—	ns	

Read Cycle (RAM), Page Mode Read Cycle

Parameter	Symbol	HM538121-10		HM538121-11		HM538121-12		HM538121-15		Unit	Note
		Min	Max	Min	Max	Min	Max	Min	Max		
Access Time from RAS	t _{RAC}	—	100	—	100	—	120	—	150	ns	2, 3
Access Time from CAS	t _{CAC}	—	30	—	30	—	35	—	40	ns	3, 5
Access Time from OE	t _{OAC}	—	30	—	30	—	35	—	40	ns	3
Address Access Time	t _{AA}	—	45	—	45	—	55	—	70	ns	3, 6
Output Buffer Turn-off Delay Referenced to CAS	t _{OFF1}	—	25	—	25	—	30	—	40	ns	7
Output Buffer Turn-off Delay Referenced to OE	t _{OFF2}	—	25	—	25	—	30	—	40	ns	7
Read Command Setup Time	t _{RCS}	0	—	0	—	0	—	0	—	ns	
Read Command Hold Time	t _{RCH}	0	—	0	—	0	—	0	—	ns	12
Read Command Hold Time Referenced to RAS	t _{RRH}	10	—	10	—	10	—	10	—	ns	12
RAS to Column Address Delay Time	t _{RAD}	20	55	20	55	20	65	25	80	ns	5, 6
Page Mode Cycle Time	t _{PC}	55	—	55	—	65	—	80	—	ns	
CAS Precharge Time	t _{CP}	10	—	10	—	15	—	20	—	ns	
Access Time from CAS Precharge	t _{ACP}	—	50	—	50	—	60	—	75	ns	
RAS Pulse Width in Page Mode	t _{RASP}	0.1	100	0.1	100	0.12	100	0.15	100	μs	



Write Cycle (RAM), Page Mode Write Cycle

Parameter	Symbol	HM538121-10		HM538121-11		HM538121-12		HM538121-15		Unit	Note
		Min	Max	Min	Max	Min	Max	Min	Max		
Write Command Setup Time	tWCS	0	—	0	—	0	—	0	—	ns	9
Write Command Hold Time	tWCH	25	—	25	—	25	—	30	—	ns	
Write Command Pulse Width	tWP	15	—	15	—	20	—	25	—	ns	
Write Command to RAS Lead Time	tRWL	30	—	30	—	35	—	40	—	ns	
Write Command to CAS Lead Time	tCWL	30	—	30	—	35	—	40	—	ns	
Data-in Setup Time	tDS	0	—	0	—	0	—	0	—	ns	10
Data-in Hold Time	tDH	25	—	25	—	25	—	30	—	ns	10
WE to RAS Setup Time	tWS	0	—	0	—	0	—	0	—	ns	
WE to RAS Hold Time	tWH	15	—	15	—	15	—	20	—	ns	
Mask Data to RAS Setup Time	tMS	0	—	0	—	0	—	0	—	ns	
Mask Data to RAS Hold Time	tMH	15	—	15	—	15	—	20	—	ns	
OE Hold Time Referenced to WE	tOEH	10	—	10	—	15	—	20	—	ns	
Page Mode Cycle Time	tPC	55	—	55	—	65	—	80	—	ns	
CAS Precharge Time	tCP	10	—	10	—	15	—	20	—	ns	
RAS Pulse Width in Page Mode	tRASP	0.1	100	0.1	100	0.12	100	0.15	100	μs	

Read-Modify-Write Cycle

Parameter	Symbol	HM538121-10		HM538121-11		HM538121-12		HM538121-15		Unit	Note
		Min	Max	Min	Max	Min	Max	Min	Max		
Read-Modify-Write Cycle Time	tRWC	255	—	255	—	295	—	350	—	ns	
RAS Pulse Width	tRWS	165	10000	165	10000	195	10000	240	10000	ns	
CAS to WE Delay	tCWD	65	—	65	—	75	—	90	—	ns	9
Column Address to WE Delay	tAWD	80	—	80	—	95	—	120	—	ns	9
OE to Data-in Delay Time	tODD	25	—	25	—	30	—	40	—	ns	
Access Time from RAS	tRAC	—	100	—	100	—	120	—	150	ns	2, 3
Access Time from CAS	tCAC	—	30	—	30	—	35	—	40	ns	3, 5
Access Time from OE	tOAC	—	30	—	30	—	35	—	40	ns	3
Address Access Time	tAA	—	45	—	45	—	55	—	70	ns	3, 6



Read-Modify-Write Cycle (continued)

Parameter	Symbol	HM538121-10		HM538121-11		HM538121-12		HM538121-15		Unit	Note
		Min	Max	Min	Max	Min	Max	Min	Max		
RAS to Column Address Delay	t _{RAD}	20	55	20	55	20	65	25	80	ns	5, 6
Output Buffer Turn-off Delay Referenced to OE	t _{OFF2}	—	25	—	25	—	30	—	40	ns	
Read Command Setup Time	t _{RCS}	0	—	0	—	0	—	0	—	ns	
Write Command to RAS Lead Time	t _{RWL}	30	—	30	—	35	—	40	—	ns	
Write Command to CAS Lead Time	t _{CWL}	30	—	30	—	35	—	40	—	ns	
Write Command Pulse Width	t _{WP}	15	—	15	—	20	—	25	—	ns	
Data-in Setup Time	t _{DS}	0	—	0	—	0	—	0	—	ns	10
Data-in Hold Time	t _{DH}	25	—	25	—	25	—	30	—	ns	10
WE to RAS Setup Time	t _{WS}	0	—	0	—	0	—	0	—	ns	
WE to RAS Hold Time	t _{WH}	15	—	15	—	15	—	20	—	ns	
Mask Data to RAS Setup Time	t _{MS}	0	—	0	—	0	—	0	—	ns	
Mask Data to RAS Hold Time	t _{MH}	15	—	15	—	15	—	20	—	ns	
OE Hold Time Referenced to WE	t _{OEH}	10	—	10	—	15	—	20	—	ns	

Refresh Cycle

Parameter	Symbol	HM538121-10		HM538121-11		HM538121-12		HM538121-15		Unit	Note
		Min	Max	Min	Max	Min	Max	Min	Max		
CAS Setup Time (CAS Before RAS Refresh)	t _{CSR}	10	—	10	—	10	—	10	—	ns	
CAS Hold Time (CAS Before RAS Refresh)	t _{CHR}	20	—	20	—	25	—	30	—	ns	
RAS Precharge to CAS Hold Time	t _{RPC}	10	—	10	—	10	—	10	—	ns	

Transfer Cycle

Parameter	Symbol	HM538121-10		HM538121-11		HM538121-12		HM538121-15		Unit	Note
		Min	Max	Min	Max	Min	Max	Min	Max		
WE to RAS Setup Time	t _{WS}	0	—	0	—	0	—	0	—	ns	
WE to RAS Hold Time	t _{WH}	15	—	15	—	15	—	20	—	ns	
SE to RAS Setup Time	t _{ES}	0	—	0	—	0	—	0	—	ns	
SE to RAS Hold Time	t _{EH}	15	—	15	—	15	—	20	—	ns	
RAS to SC Delay Time	t _{SRD}	25	—	30	—	30	—	35	—	ns	



Transfer Cycle (continued)

Parameter	Symbol	HM538121-10		HM538121-11		HM538121-12		HM538121-15		Unit	Note
		Min	Max	Min	Max	Min	Max	Min	Max		
SC to RAS Setup Time	t _{SRS}	30	—	40	—	40	—	45	—	ns	
DT Hold Time from RAS	t _{RDH}	80	—	90	—	90	—	110	—	ns	
DT Hold Time from CAS	t _{CDH}	20	—	30	—	30	—	45	—	ns	
Last SC to DT Delay Time	t _{SDD}	5	—	5	—	5	—	10	—	ns	
First SC to DT Hold Time	t _{SDH}	20	—	25	—	25	—	30	—	ns	
DT to RAS Lead Time	t _{DTL}	50	—	50	—	50	—	50	—	ns	
DT Hold Time Referenced to RAS High	t _{DTHH}	20	—	25	—	25	—	30	—	ns	
DT Precharge Time	t _{DTP}	30	—	35	—	35	—	40	—	ns	
Serial Data Input Delay Time from RAS	t _{SID}	50	—	60	—	60	—	75	—	ns	
Serial Data Input to RAS Delay Time	t _{SZR}	—	10	—	10	—	10	—	10	ns	
Serial Output Buffer Turn-off Delay from RAS	t _{SRZ}	10	50	10	60	10	60	10	75	ns	7
RAS to S _{out} (Low-Z) Delay Time	t _{RLZ}	5	—	10	—	10	—	10	—	ns	
Serial Clock Cycle Time	t _{SCC}	30	—	40	—	40	—	60	—	ns	
Serial Clock Cycle Time	t _{SCC2}	40	—	40	—	40	—	60	—	ns	13
Access Time from SC	t _{SCA}	—	30	—	35	—	40	—	50	ns	4
Serial Data-out Hold Time	t _{SOH}	7	—	7	—	7	—	7	—	ns	4
SC Pulse Width	t _{SC}	10	—	10	—	10	—	10	—	ns	
SC Precharge Width	t _{SCP}	10	—	10	—	10	—	10	—	ns	
Serial Data-in Setup Time	t _{SIS}	0	—	0	—	0	—	0	—	ns	
Serial Data-in Hold Time	t _{SIH}	15	—	20	—	20	—	25	—	ns	

Serial Read Cycle

Parameter	Symbol	HM538121-10		HM538121-11		HM538121-12		HM538121-15		Unit	Note
		Min	Max	Min	Max	Min	Max	Min	Max		
Serial Clock Cycle Time	t_{SCC}	30	—	40	—	40	—	60	—	ns	
Access Time from SC	t_{SCA}	—	30	—	35	—	40	—	50	ns	4
Access Time from \overline{SE}	t_{SEA}	—	25	—	30	—	30	—	40	ns	4
Serial Data-out Hold Time	t_{SOH}	7	—	7	—	7	—	7	—	ns	4
SC Pulse Width	t_{SC}	10	—	10	—	10	—	10	—	ns	
SC Precharge Width	t_{SCP}	10	—	10	—	10	—	10	—	ns	
Serial Output Buffer Turn-off Delay from \overline{SE}	t_{SEZ}	—	25	—	25	—	25	—	30	ns	7

Serial Write Cycle

Parameter	Symbol	HM538121-10		HM538121-11		HM538121-12		HM538121-15		Unit	Note
		Min	Max	Min	Max	Min	Max	Min	Max		
Serial Clock Cycle Time	t_{SCC}	30	—	40	—	40	—	60	—	ns	
SC Pulse Width	t_{SC}	10	—	10	—	10	—	10	—	ns	
SC Precharge Width	t_{SCP}	10	—	10	—	10	—	10	—	ns	
Serial Data-in Setup Time	t_{SIS}	0	—	0	—	0	—	0	—	ns	
Serial Data-in Hold Time	t_{SIH}	15	—	20	—	20	—	25	—	ns	
Serial Write Enable Setup Time	t_{SWS}	0	—	0	—	0	—	0	—	ns	
Serial Write Enable Hold Time	t_{SWH}	30	—	35	—	35	—	50	—	ns	
Serial Write Disable Setup Time	t_{SWIS}	0	—	0	—	0	—	0	—	ns	
Serial Write Disable Hold Time	t_{SWIH}	30	—	35	—	35	—	50	—	ns	

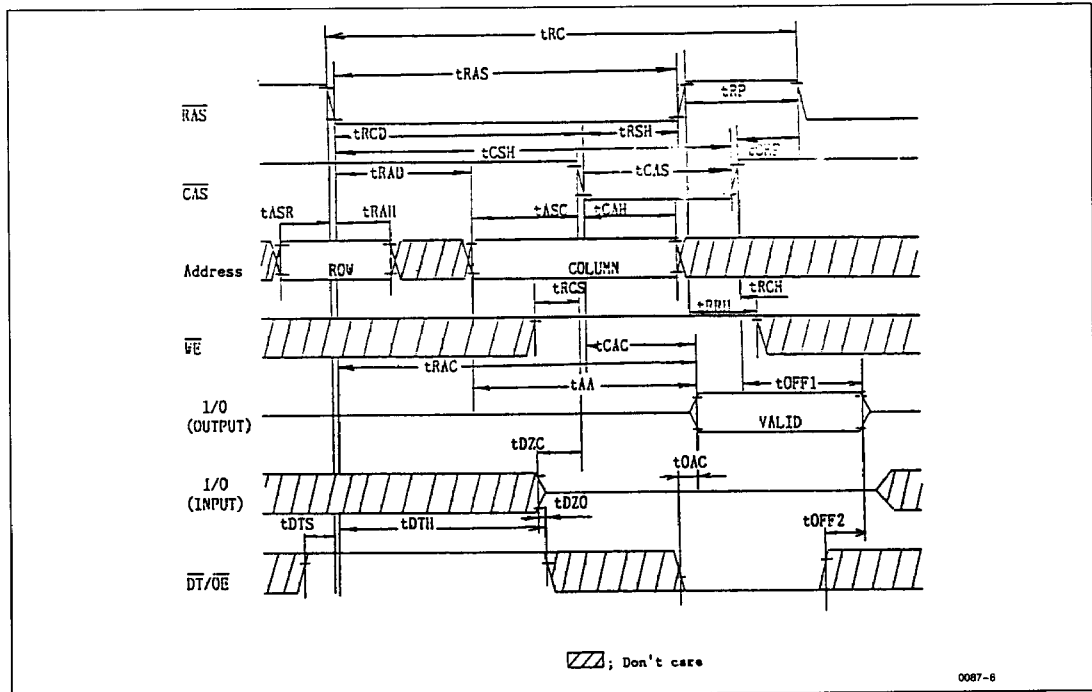
Notes: 1. AC measurements assume $t_T = 5$ ns.

- Assumes that $t_{RCD} \leq t_{RCD}(\max)$ and $t_{RAD} \leq t_{RAD}(\max)$. If t_{RCD} or t_{RAD} is greater than the maximum recommended value shown in this table, t_{RAC} exceeds the value shown.
- Measured with a load circuit equivalent to 2 TTL loads and 100 pF.
- Measured with a load circuit equivalent to 2 TTL loads and 50 pF.
- When $t_{RCD} \geq t_{RCD}(\max)$ and $t_{RAD} \leq t_{RAD}(\max)$, access time is specified by t_{CAC} .
- When $t_{RCD} \leq t_{RCD}(\max)$ and $t_{RAD} \geq t_{RAD}(\max)$, access time is specified by t_{AA} .
- $t_{OFF}(\max)$ is defined as the time at which the output achieves the open circuit condition ($V_{OH} - 200$ mV, $V_{OL} + 200$ mV).
- $V_{IH}(\min)$ and $V_{IL}(\max)$ are reference levels for measuring timing of input signals. Transition times are measured between V_{IH} and V_{IL} .
- When $t_{WCS} \geq t_{WCS}(\min)$, the cycle is an early write cycle, and I/O pins remain in an open circuit (high impedance) condition. When $t_{AWD} \geq t_{AWD}(\min)$ and $t_{CWD} \geq t_{CWD}(\min)$, the cycle is a read-modify-write cycle; the data of the selected address is read out from a data output pin and input data is written into the selected address. In this case, impedance on I/O pins is controlled by \overline{OE} .
- These parameters are referenced to \overline{CAS} falling edge in early write cycles or to \overline{WE} falling edge in delayed write or a read-modify-write cycles.
- After power-up, pause for 100 μ s or more and execute at least 8 initialization cycles (normal memory cycles or refresh cycles), then start operation.
- If either t_{RCH} or t_{RRH} is satisfied, operation is guaranteed.
- t_{CC2} is defined as the last SAM cycle time before read transfer in read transfer cycle (I).
- When I/O or SI/O is in the output state, data input signals must not be applied to I/O or SI/O.
- When \overline{SE} is low after power on, SI/O is in the output state. Data input signals must not be applied to SI/O in this time.
- When \overline{CAS} and $\overline{DT}/\overline{OE}$ are both low after power on, it is possible that I/O is in the output state. Data input signals must not be applied to I/O in this time.

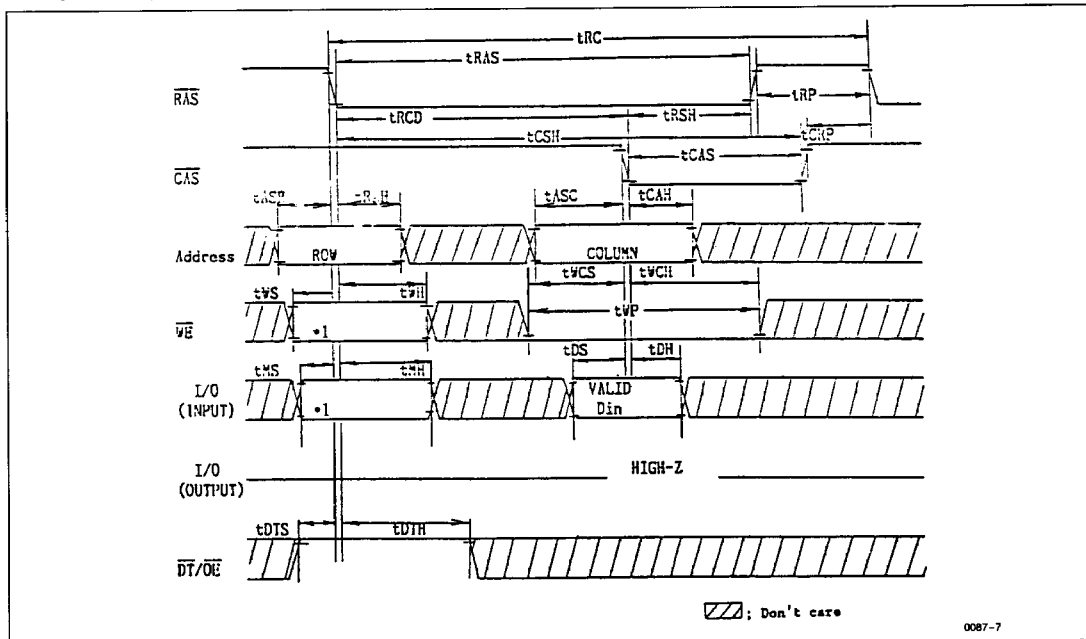


TIMING WAVEFORMS

Read Cycle



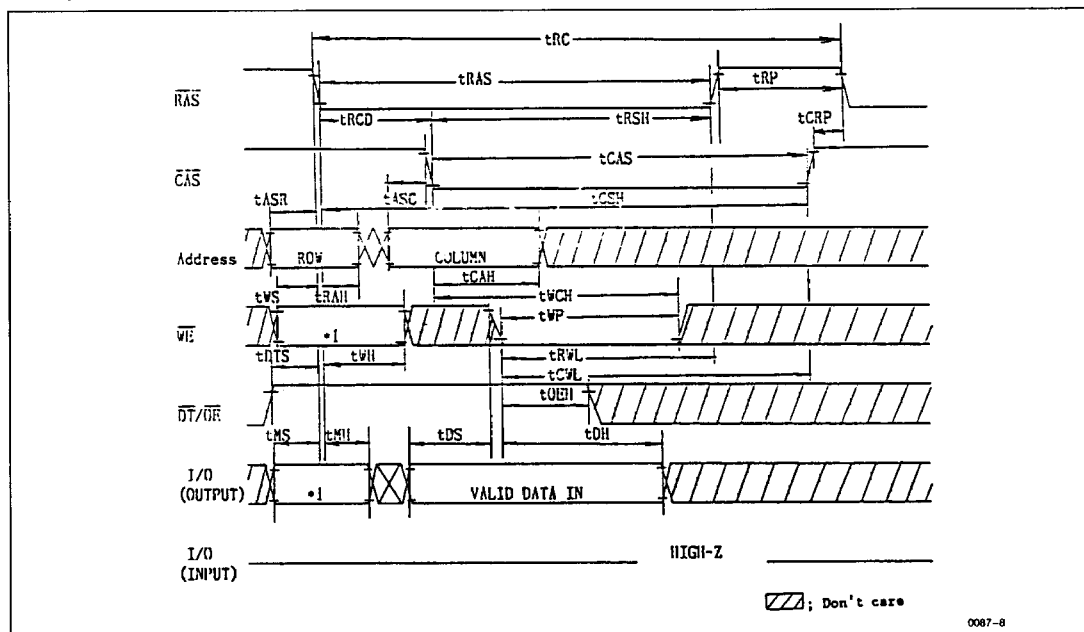
Early Write Cycle



Note: *1. When \overline{WE} is high level, all the data on I/Os can be written into the memory cell. When \overline{WE} is low level, the data on I/Os are not written except for the case that the I/O is high at the falling edge of RAS.



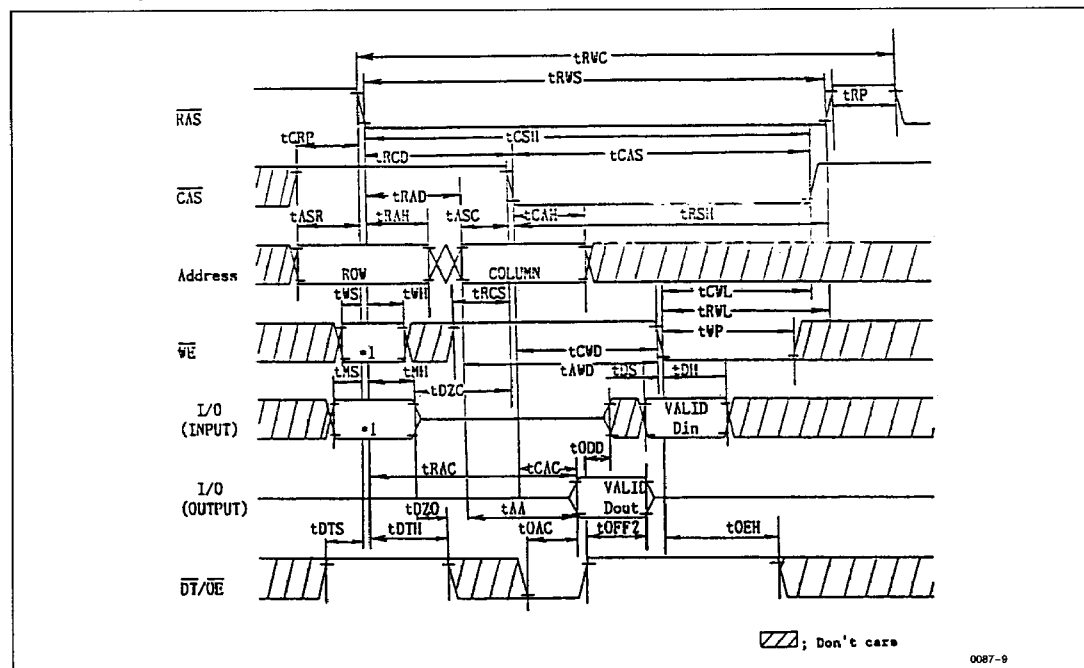
• Delayed Write Cycle



0087-8

Note: *1. When \overline{WE} is high level, all the data on I/Os can be written into the memory cell. When \overline{WE} is low level, the data on I/Os are not written except for the case that the I/O is high at the falling edge of \overline{RAS} .

• Read-Modify-Write Cycle

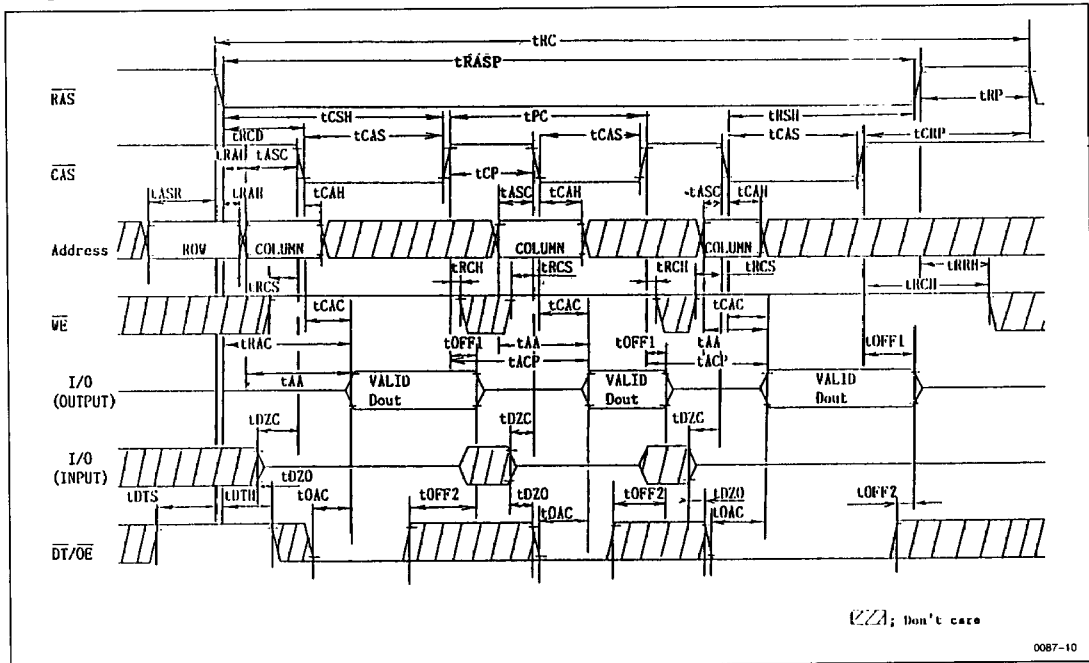


0087-9

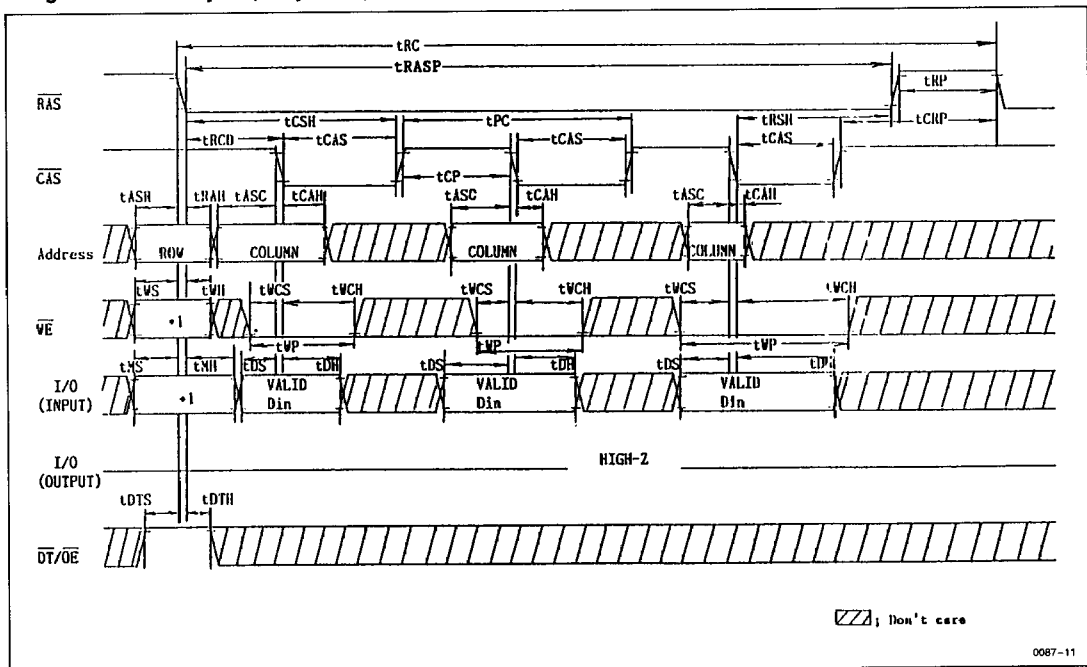
Note: *1. When \overline{WE} is high level, all the data on I/Os can be written into the memory cell. When \overline{WE} is low level, the data on I/Os are not written except for the case that the I/O is high at the falling edge of \overline{RAS} .



• Page Mode Read Cycle

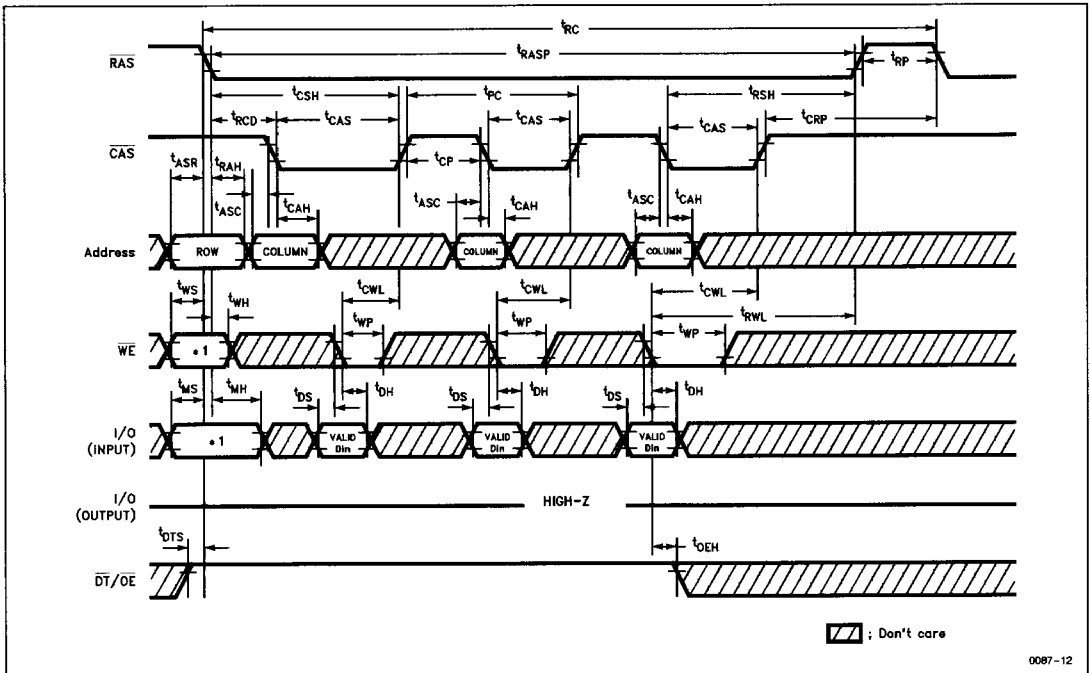


• Page Mode Write Cycle (Early Write)



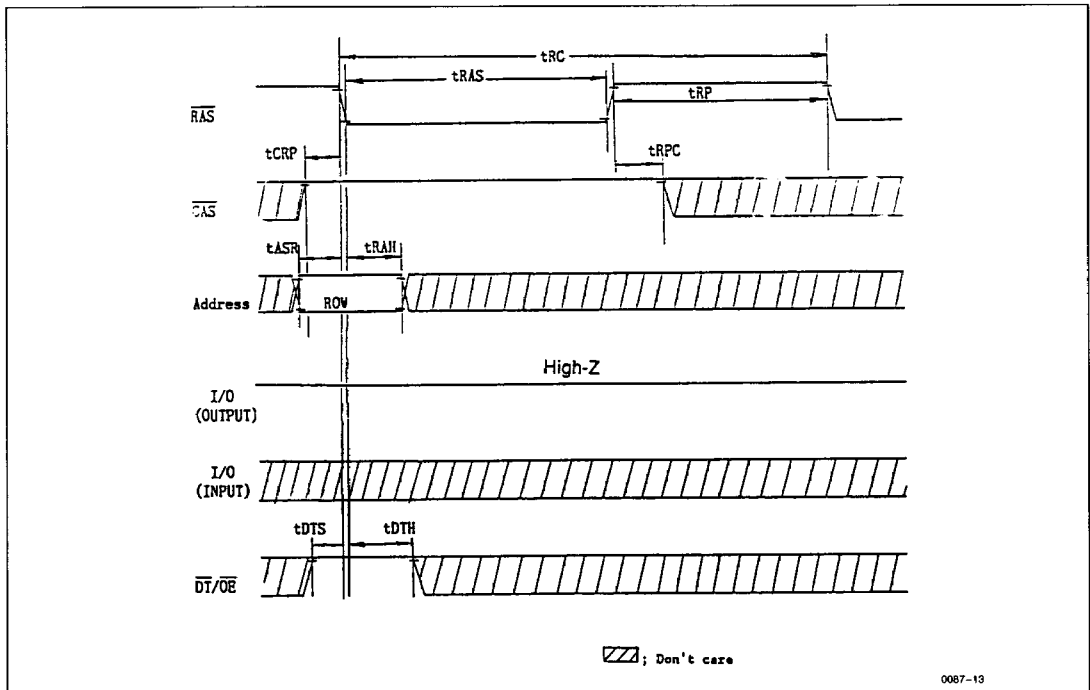
Note: *1. When \overline{WE} is high level, all the data on I/Os can be written into the memory cell. When \overline{WE} is low level, the data on I/Os are not written except for the case that the I/O is high at the falling edge of RAS.

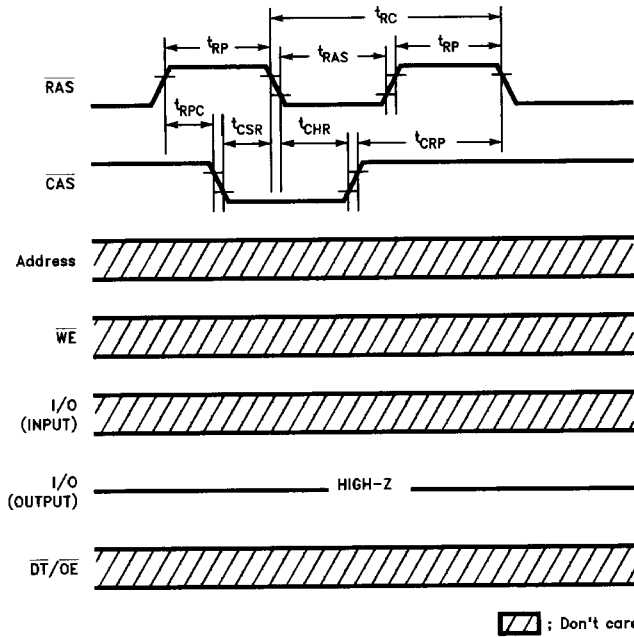
• Page Mode Write Cycle (Delayed Write)



Note: *1. When \overline{WE} is high level, all the data on I/Os can be written into the memory cell. When \overline{WE} is low level, the data on I/Os are not written except for the case that the I/O is high at the falling edge of RAS.

• RAS Only Refresh Cycle

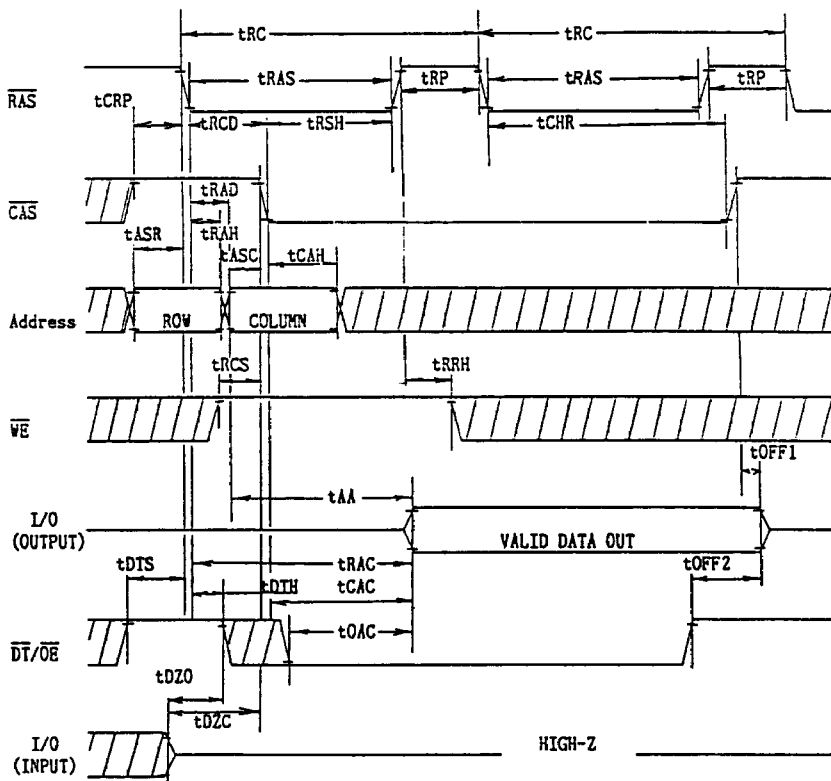


• $\overline{\text{CAS}}$ Before $\overline{\text{RAS}}$ Refresh Cycle

0067-14



• Hidden Refresh Cycle

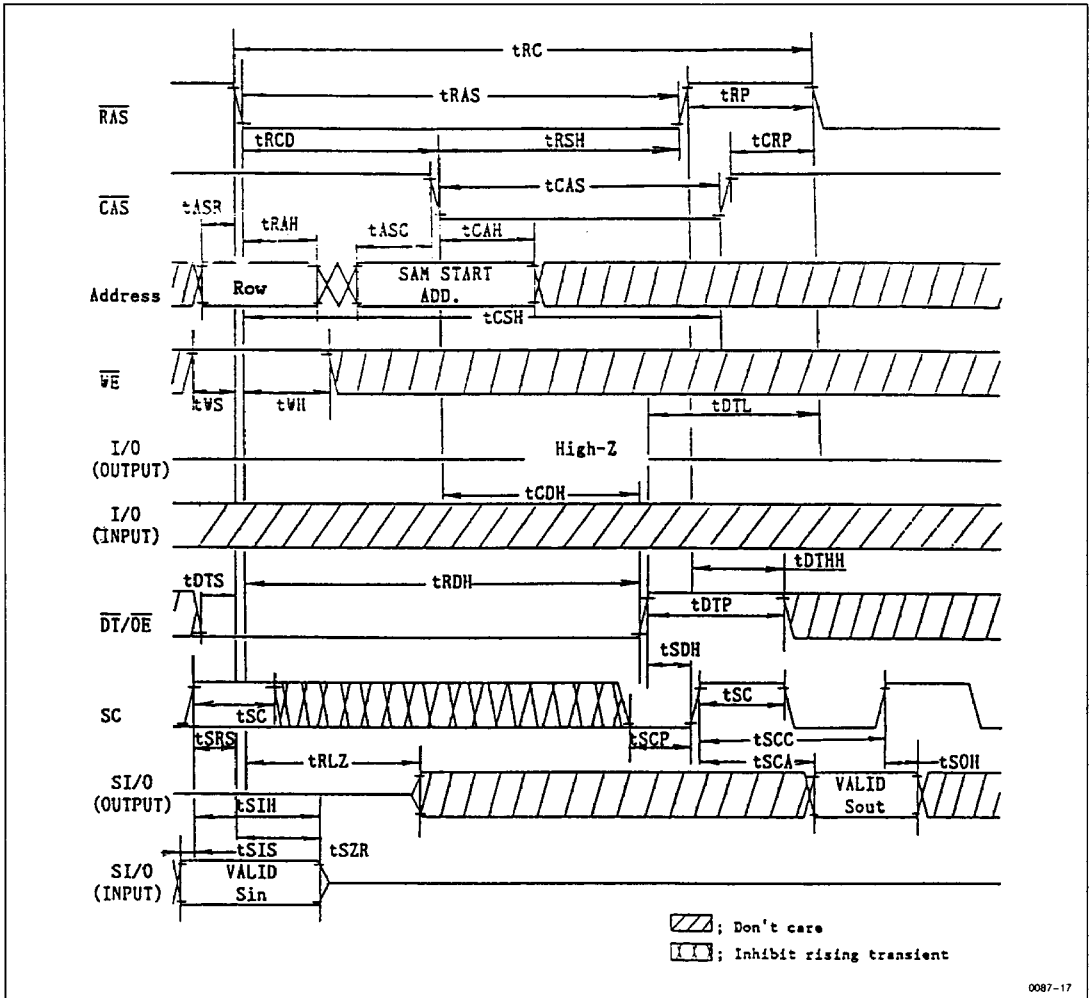


0087-15



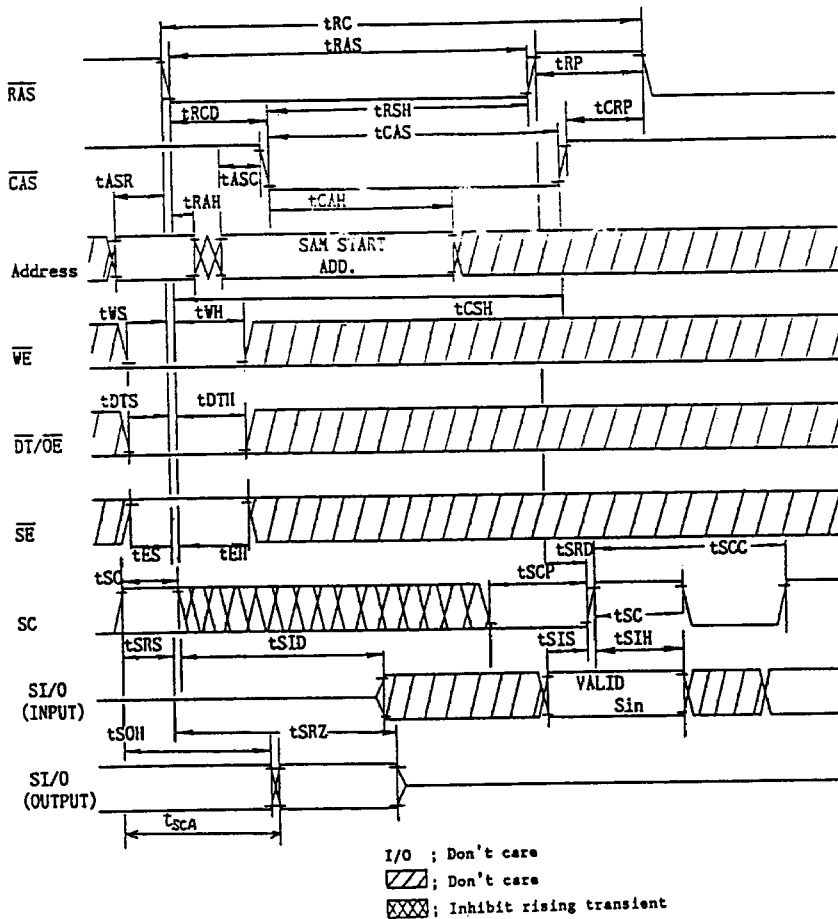
Notes: 1. When the previous data transfer cycle is a read transfer cycle, it is defined as read transfer cycle (1).
2. \overline{SE} is in low level. (When \overline{SE} is high, SI/O becomes high impedance.)

• Read Transfer Cycle (2) 1, 2



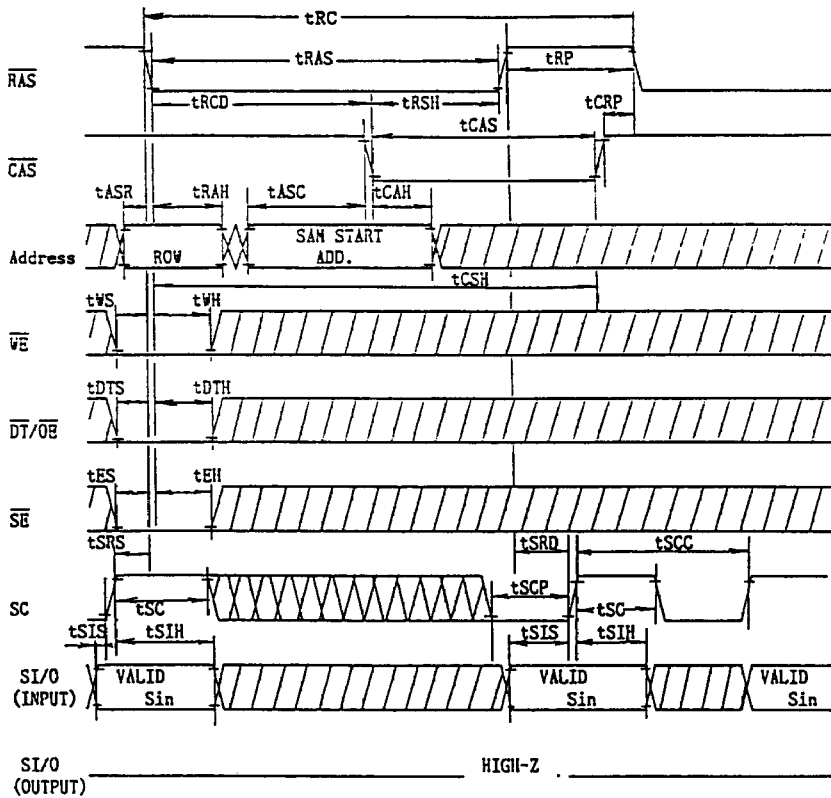
- Notes:
1. When the previous data transfer cycle is a write or pseudo transfer cycle, it is defined as read transfer cycle (2).
 2. \overline{SE} is in low level. (When \overline{SE} is high, SI/O becomes high impedance.)

• Pseudo Transfer Cycle



0087-18

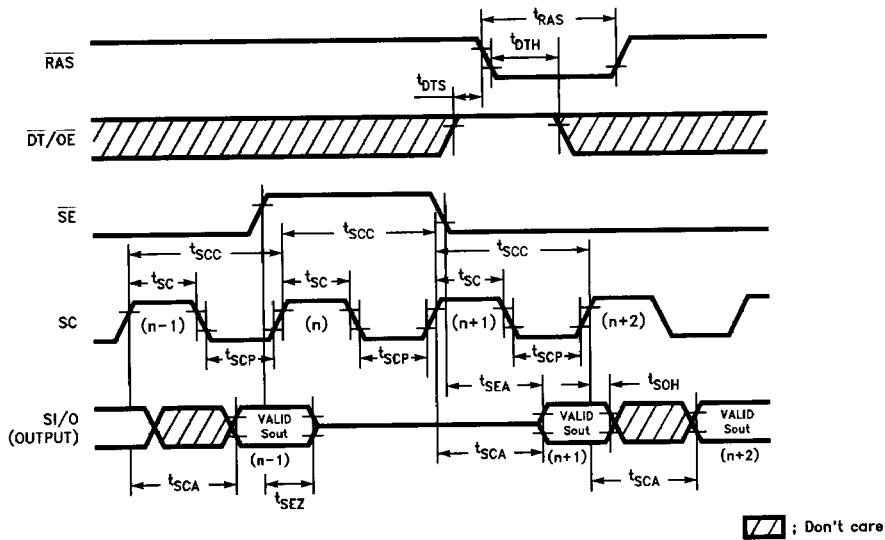
• Write Transfer Cycle



▨; Don't care
 XXX; Inhibit rising transient

0087-19

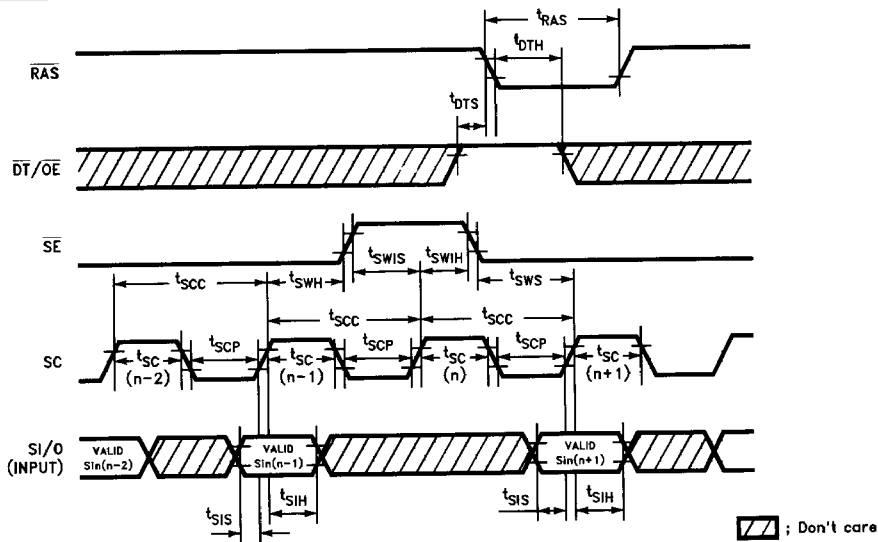
• Serial Read Cycle



0087-20

Note: 1. Address 0 is accessed next to address 255.

• Serial Write Cycle



0087-21

- Note: 1. When $\overline{\text{SE}}$ is high level in a serial write cycle, data is not written into SAM, however, the pointer is incremented.
 2. Address 0 is accessed next to address 255.

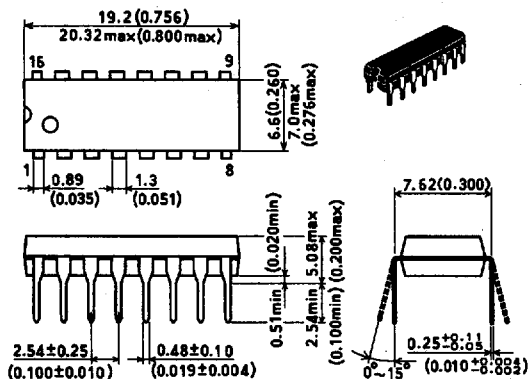


T-90-20

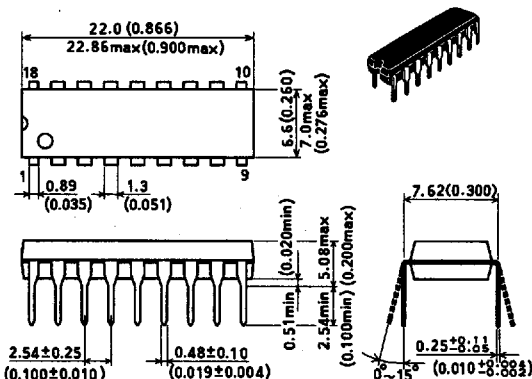
Unit: mm (inch) Scale 3/2

• Dual-in-line Plastic

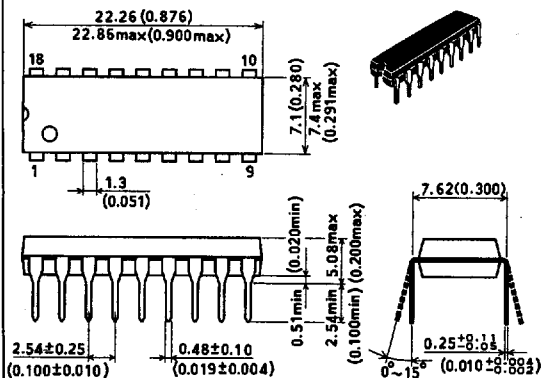
• DP-16B



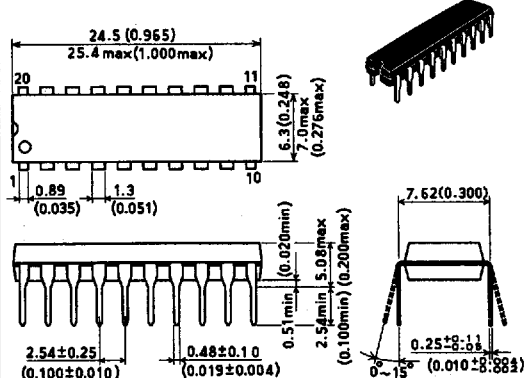
• DP-18B



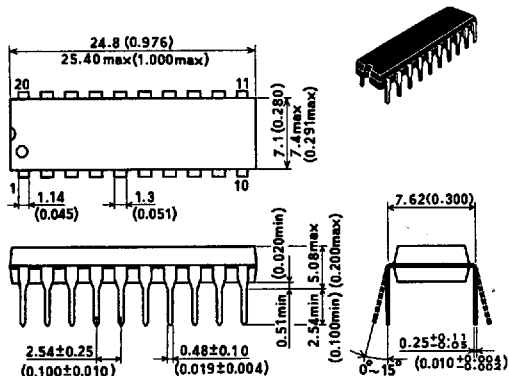
• DP-18C



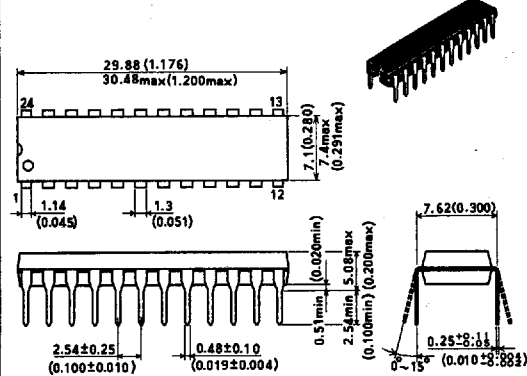
• DP-20N



• DP-20NA



• DP-20NC

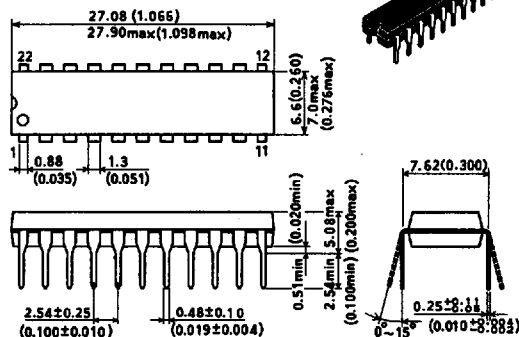


• Dual-In-line Plastic

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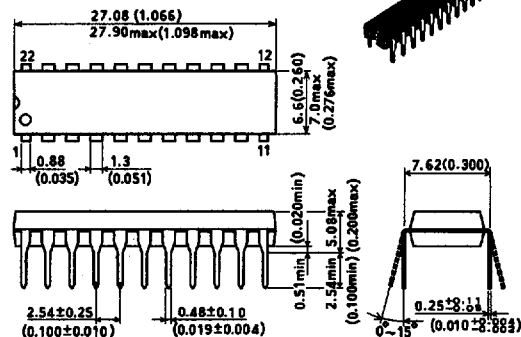
Unit: mm (inch) Scale 3/2

• DP-22N

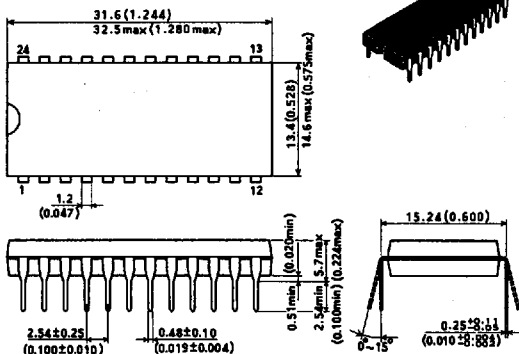


• DP-22NB

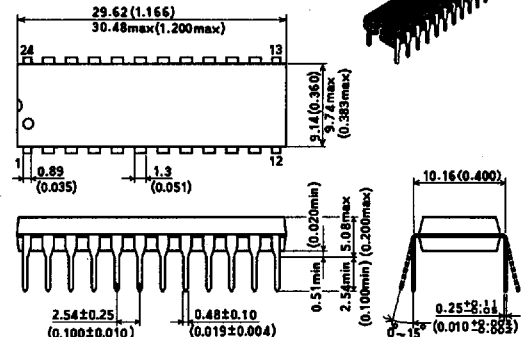
T-90-20



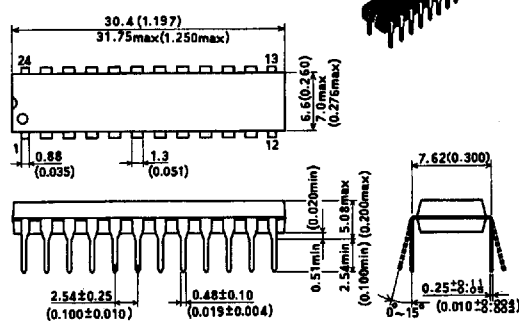
• DP-24



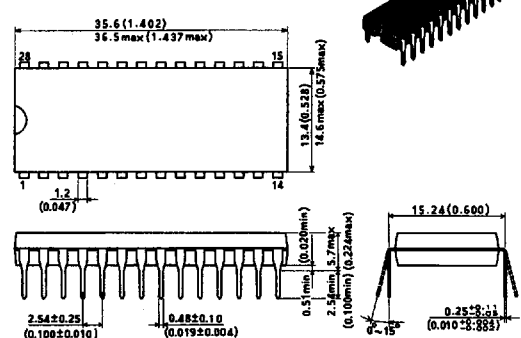
• DP-24A



• DP-24N



• DP-28

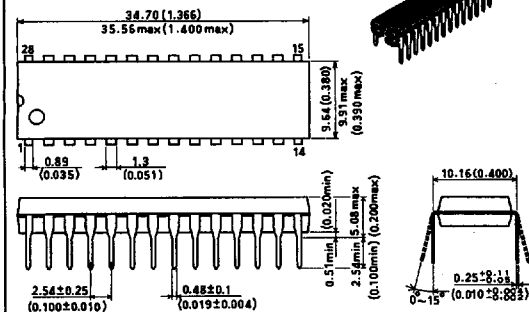


• Dual-in-line Plastic

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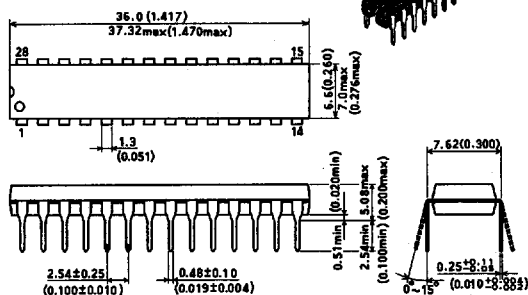
Unit: mm (inch) Scale 3/2

• DP-28C

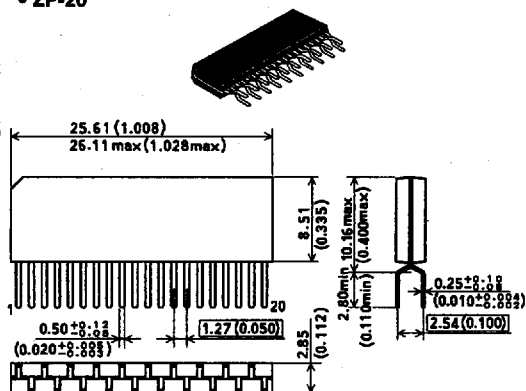


• DP-28N

T-90-20

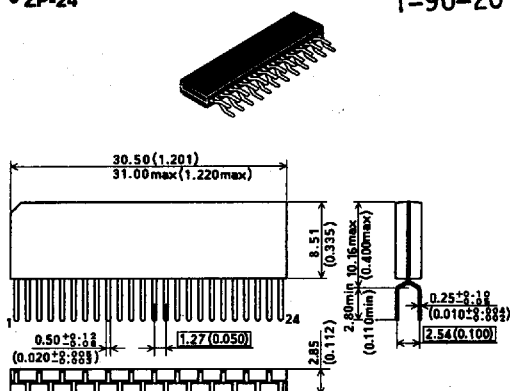


• ZP-20

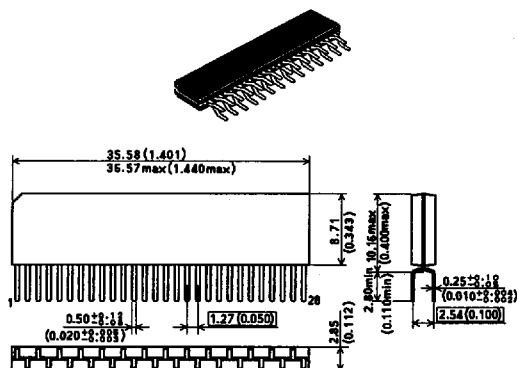


• ZP-24

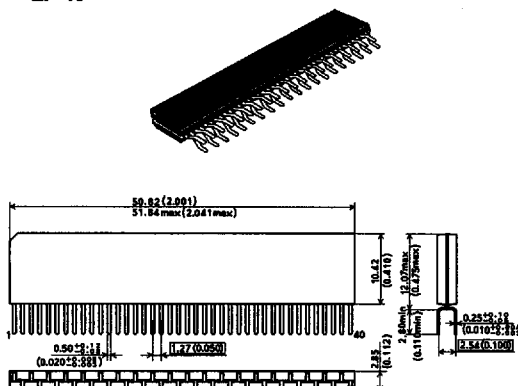
T-90-20



• ZP-28



• ZP-40



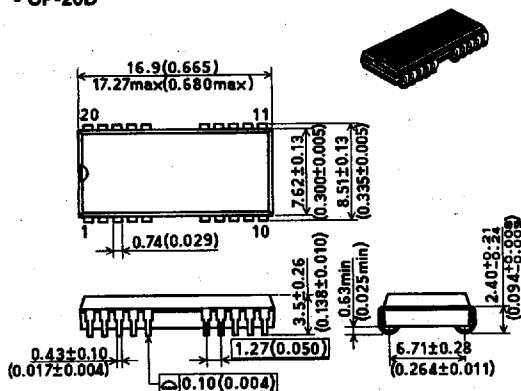
• Flat Package (J-bend Leads)

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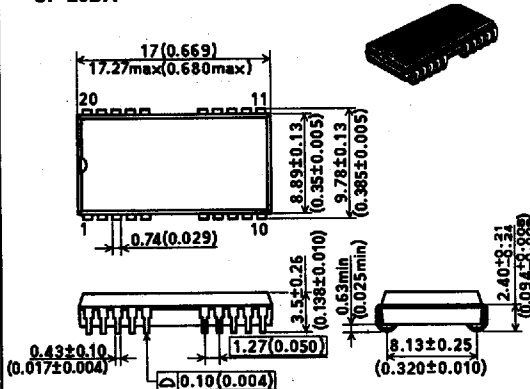
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T-90-20

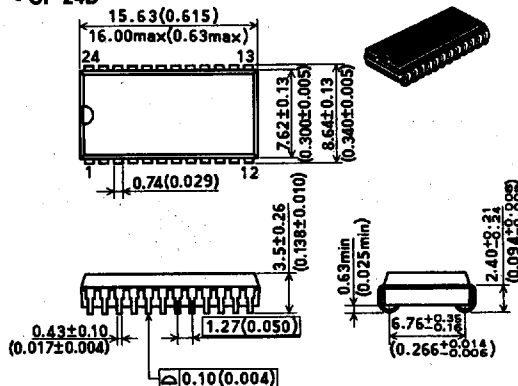
• CP-20D



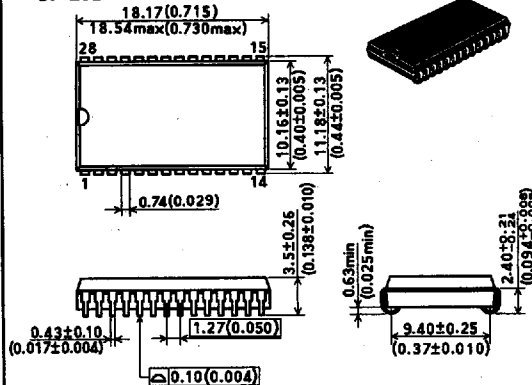
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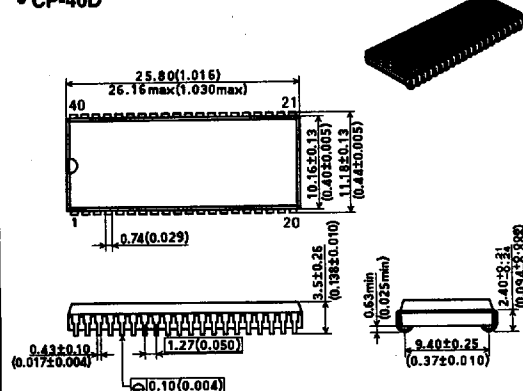
• CP-24D



• CP-28D



• CP-40D

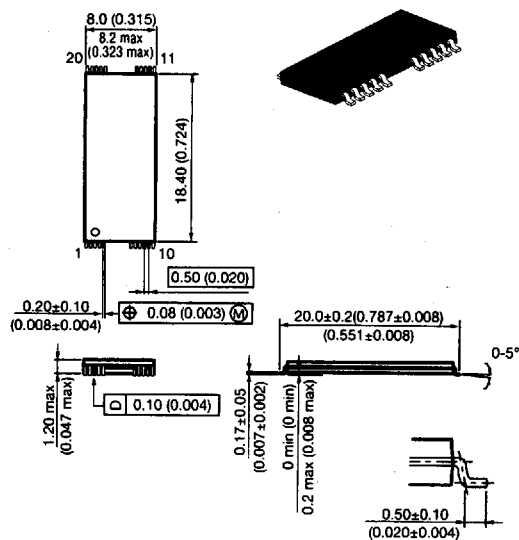


• TSOP (Thin Small Outline Package)

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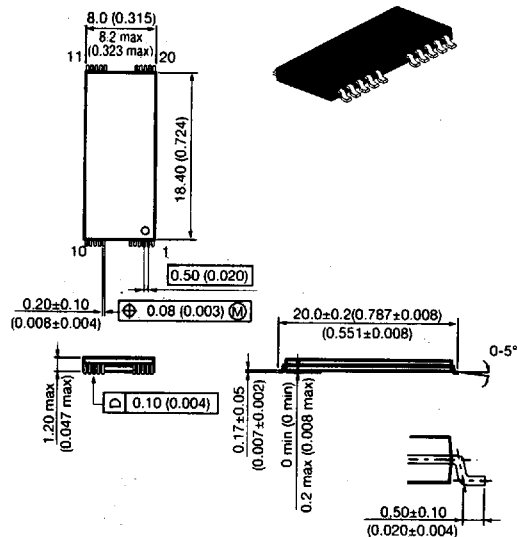
Unit: mm (inch) Scale 3/2

• TFP-20DA

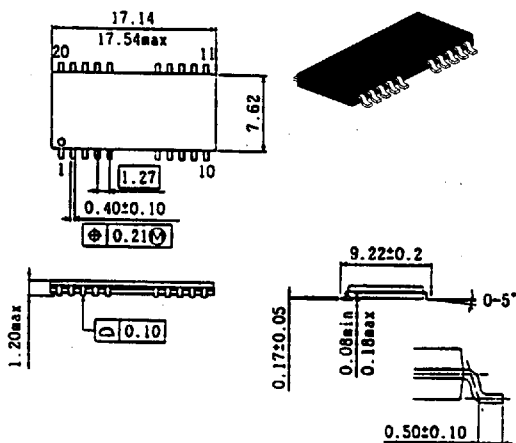


• TFP-20DAR

T-90-20



• TTP-20D



• TTP-20DR

