HM5316123 Series
HM5316124 Series

131,072-word × 16-bit Multiport CMOS Video RAM

HITACHI

The HM5316123/HM5316124 is a 2-Mbit multiport video RAM equipped with a 128-kword × 16-bit dynamic RAM and a 256-word × 16-bit SAM (full-sized SAM). Its RAM and SAM operate independently and asynchronously. The HM5316123/HM5316124 is basically upward-compatible with the HM534253A/HM538123A. However, the pseudo-write-transfer cycle is replaced with masked-write-transfer cycle, which has been approved by JEDEC.

Furthermore, several new features are added to the HM5316123/HM5316124 without conflict with the conventional features. The stopping column feature adds flexibility to the length of the split SAM register. The HM5316123/HM5316124 also has a persistent mask feature, according to the TMS34020. Byte-write-control is useful for connecting × 16 organization memory to 8-bit bus systems. The HM5316124 has Hyper page mode which enables fast page cycle.

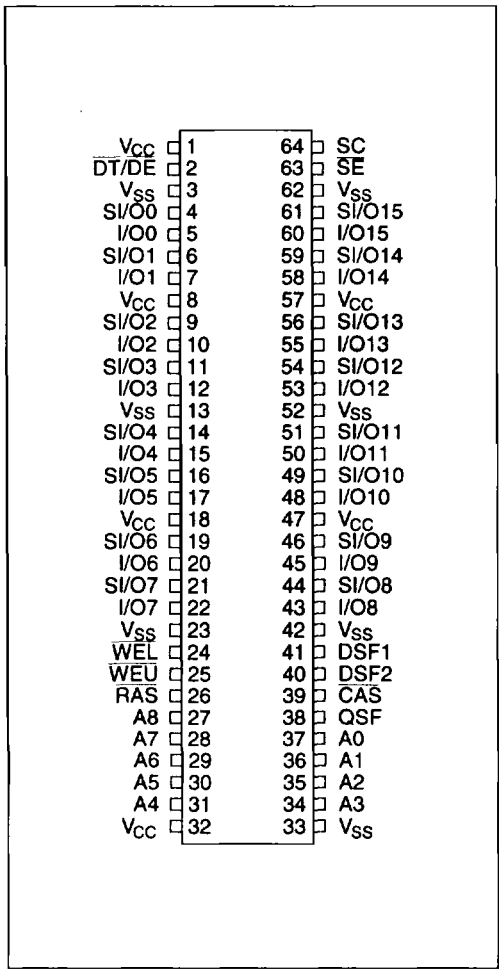
Ordering Information

Type No.	Access time	Package
HM5316123F-7	70 ns	64-pin plastic shrink SOP (FP-64DS)
HM5316123F-8	80 ns	
HM5316123F-10	100 ns	
HM5316124F-7	70 ns	
HM5316124F-8	80 ns	
HM5316124F-10	100 ns	

Features

- Multiport organization
  - — Asynchronous and simultaneous operation of RAM and SAM capability
    - RAM: 128 kword × 16 bit
    - SAM: 256 word × 16 bit
- Access time
  - — RAM: 70 ns/80 ns/100 ns max
  - — SAM: 20 ns/23 ns/25 ns max
- Cycle time
  - — RAM: 130 ns/150 ns/180 ns min
  - — SAM: 25 ns/28 ns/30 ns min
- Low power
  - — Active RAM: 660 mW/605 mW/550 mW
    SAM: 468 mW/413 mW/385 mW
  - — Standby 38.5 mW max
- Masked-write-transfer cycle capability
- Stopping column feature capability
- Persistent mask capability
- Byte write control capability: 2 $\overline{WE}$ control
- Fast page mode capability (HM5316123)
  - — Cycle time: 45 ns/50 ns/55 ns
  - — Power RAM: 688 mW/660 mW/633 mW
- Hyper page mode capability (HM5316124)
  - — Cycle time: 35 ns/40 ns/45 ns
  - — Power RAM: 743 mW/715 mW/688 mW
- Mask write mode capability
- Bidirectional data transfer cycle between RAM and SAM capability
- Split transfer cycle capability
- Block write mode capability
- Flash write mode capability
- 3 variations of refresh (8 ms/512 cycles)
  - — $\overline{RAS}$-only refresh
  - — $\overline{CAS}$-before-$\overline{RAS}$ refresh
  - — Hidden refresh
- TTL compatible

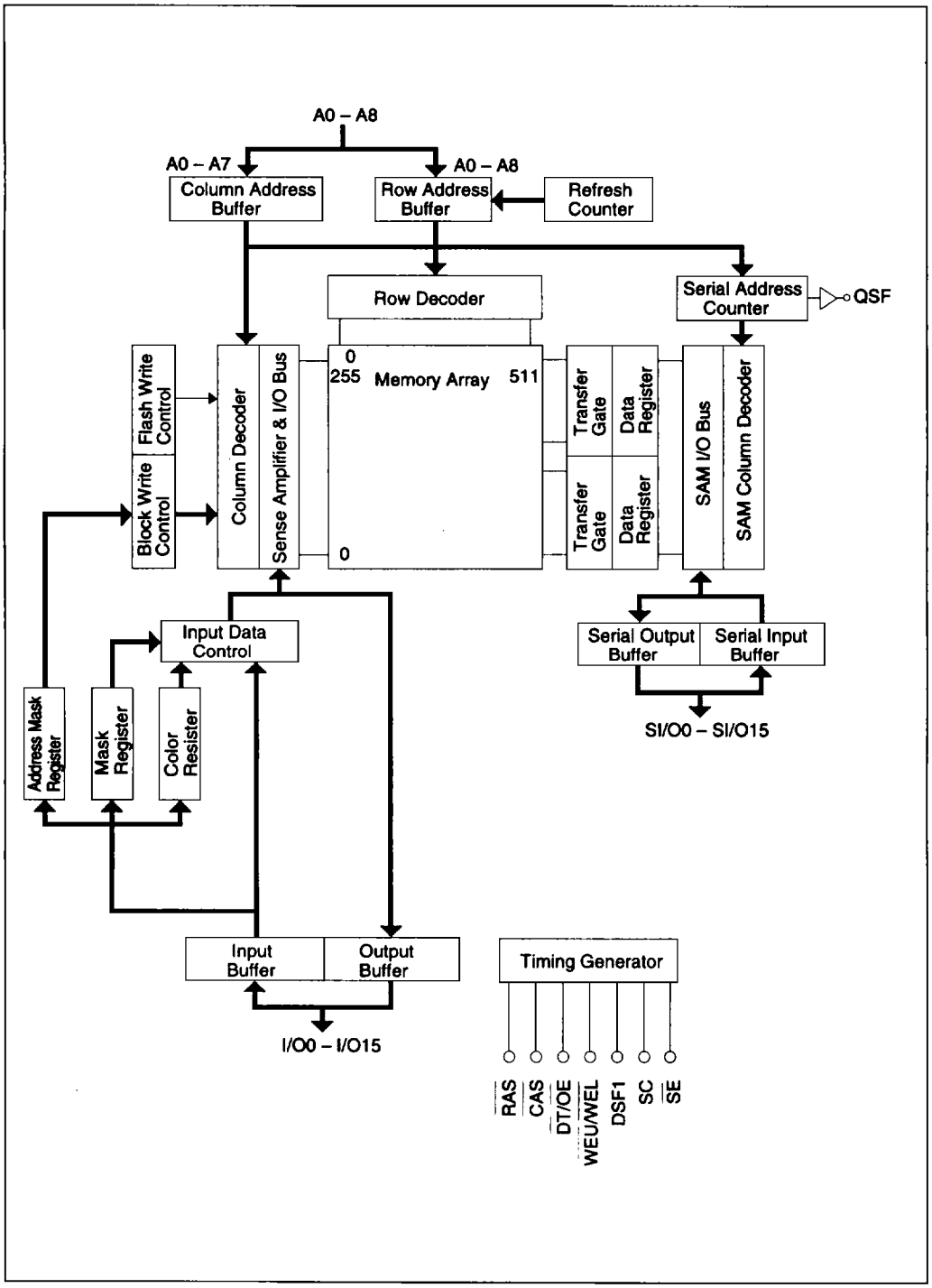
Pin Arrangement



Pin Description

Pin name	Function
A0–A8	Address inputs
I/O0–I/O15	RAM port data inputs/outputs
SI/O0–SI/O15	SAM port data inputs/outputs
$\overline{RAS}$	Row address strobe
$\overline{CAS}$	Column address strobe
$\overline{WEU}$, $\overline{WEL}$	Write enable
$\overline{DT/OE}$	Data transfer/output enable
SC	Serial clock
$\overline{SE}$	SAM port enable
DSF1, DSF2	Special function input flag
QSF	Special function output flag
V_{CC}	Power supply
V_{SS}	Ground

Block Diagram



Pin Functions

$\overline{RAS}$ (input pin): $\overline{RAS}$ is a basic RAM signal. It is active low and high in standby mode. Row address and signals as shown in table 1 are input at the falling edge of $\overline{RAS}$. The input level of these signals determine the operation cycle of the HM5316123/HM5316124.

$\overline{CAS}$ (input pin): Column address and DSF1 signals are fetched into the chip at the falling edge of $\overline{CAS}$, which determines the operation mode of the HM5316123/HM5316124.

A0–A8 (input pins): Row address (AX0–AX8) is determined by A0–A8 level at the falling edge of $\overline{RAS}$. Column address (AY0–AY7) is determined by A0–A7 level at the falling edge of $\overline{CAS}$. In transfer cycles, row address is the address on the word line that transfers data with SAM data register. Column address is the SAM start address after transfer.

$\overline{WEU}$ and $\overline{WEL}$ (input pins): $\overline{WEU}$ and $\overline{WEL}$ pins have two functions, at the falling edge of $\overline{RAS}$ and after. When either $\overline{WEU}$ or $\overline{WEL}$ is low at the falling edge of $\overline{RAS}$, the HM5316123/HM5316124 goes into mask write mode. Depending on the I/O level at the time, write on each I/O can be masked. ($\overline{WEU}$ and $\overline{WEL}$ levels at the falling edge of $\overline{RAS}$ are don't care in read cycle.) When both $\overline{WEU}$ and $\overline{WEL}$ are high at the falling edge of $\overline{RAS}$, a no-mask write cycle is executed. After that, $\overline{WEU}$ and $\overline{WEL}$ switch read/write cycles. Both $\overline{WEU}$ and $\overline{WEL}$ must be held high in a read cycle. In a

Table 1 Operation Cycles of the HM5316123/HM5316124

Mnemonic	$\overline{RAS}$					$\overline{CAS}$		Address		I/On Input	
Code	$\overline{CAS}$	DT/$\overline{OE}$	$\overline{WE}$	DSF1	DSF2	DSF1	DSF2	$\overline{RAS}$	$\overline{CAS}$	$\overline{RAS}$	$\overline{CAS}$/$\overline{WE}$
CBRS	0	–	0	1	0	–	0	Stop	–	–	–
CBRR	0	–	1	0	0	–	0	–	–	–	–
CBRN	0	–	1	1	0	–	0	–	–	–	–
MWT	1	0	0	0	0	–	0	Row	TAP	WM	–
MSWT	1	0	0	1	0	–	0	Row	TAP	WM	–
RT	1	0	1	0	0	–	0	Row	TAP	–	–
SRT	1	0	1	1	0	–	0	Row	TAP	–	–
RWM	1	1	0	0	0	0	0	Row	Column	WM	Input data
BWM	1	1	0	0	0	1	0	Row	Column	WM	Column Mask
RW (No)	1	1	1	0	0	0	0	Row	Column	–	Input Data
BW (No)	1	1	1	0	0	1	0	Row	Column	–	Column Mask
FWM	1	1	0	1	0	–	0	Row	–	WM	–
LMR and Old Mask Set	1	1	1	1	0	0	0	(Row)	–	–	Mask Data
LCR	1	1	1	1	0	1	0	(Row)	–	–	Color
Option	0	0	0	0	0	–	0	Mode	–	Data	–

transfer cycle, the direction of transfer is determined by $\overline{WEU}$ and $\overline{WEL}$ levels at the falling edge of $\overline{RAS}$. When either $\overline{WEU}$ or $\overline{WEL}$ is low, data is transferred from SAM to RAM (data is written into RAM). When both $\overline{WEU}$ and $\overline{WEL}$ are high, data is transferred from RAM to SAM (data is read from RAM).

I/O0–I/O15 (input/output pins): I/O pins function as mask data at the falling edge of $\overline{RAS}$ (in mask write mode). Data is written only to 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. In block write cycle, they function as column mask data at the falling edges of $\overline{CAS}$, and $\overline{WEU}$ or $\overline{WEL}$.

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

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

Mnemonic Code	Write Mask	Pers W.M.	Register WM	Register Color	No.of Bndry	Function
CBRS	–	–	–	–	Set	CBR refresh with stop resister set
CBRR	–	Reset	Reset	–	Reset	CBR refresh with register reset
CBRN	–	–	–	–	–	CBR refresh (no reset)
MWT	Yes	No Yes	Load/use Use	–	–	Masked write transfer (new/old mask)
MSWT	Yes	No Yes	Load/use Use	–	Use	Masked split write transfer (new/old mask)
RT	–	–	–	–	–	Read transfer
SRT	–	–	–	–	Use	Split read transfer
RWM	Yes	No Yes	Load/use Use	–	–	Read/write (new/old mask)
BWM	Yes	No Yes	Load/use Use	Use	–	Block write (new/old mask)
RW (No)	No	No	–	–	–	Read/write (no mask)
BW (No)	No	No	–	Use	–	Block write (no mask)
FWM	Yes	No Yes	Load/use Use	Use	–	Masked flash write (new/old mask)
LMR and Old Mask Set	–	Set	Load	–	–	Load mask register and old mask set
LCR	–	–	–	Load	–	Load color resister set
Option	–	–	–	–	–	–

Notes: 1. With CBRS, all SAM operations use stop register.
2. After LMR, RWM, BWM, FWM, MWT, and MSWT, use old mask which can be reset by CBRR.
3. DSF2 is fixed low in all operations (for the future addition of operation modes)

SI/O0–SI/O15 (input/output pins): SI/Os are input/output pins of the 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 masked write transfer cycle, SI/O inputs data.

DSF1 (input pin): DSF1 is a special function data input flag pin. It is set to high at the falling edge of $\overline{RAS}$ when new functions such as color register and mask register read/write, split transfer, and flash write, are used.

DSF2 (input pin): DSF2 is also a special function data input flag pin. This pin is fixed low in all operations of the HM5316123/HM5316124.

QSF (output pin): QSF outputs data of address A7 in SAM. QSF is switched from low to high by accessing address 127 in SAM and from high to low by accessing 255 address in SAM.

RAM Port Operation

RAM Read Cycle ($\overline{DT/OE}$ high, $\overline{CAS}$ high and DSF1 low at the falling edge of $\overline{RAS}$, DSF1 low at the falling edge of $\overline{CAS}$): 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 $\overline{WEU}$ or $\overline{WEL}$ is high and $\overline{DT/OE}$ is low while $\overline{CAS}$ is low, the selected address data outputs through I/O pin. At the falling edge of $\overline{RAS}$, $\overline{DT/OE}$ and $\overline{CAS}$ become high to distinguish RAM read cycle from transfer cycle and $\overline{CBR}$ refresh cycle. Address access time (t_{AA}) and $\overline{RAS}$ to column address delay time (t_{RAD}) specifications are added to enable fast page mode/hyper page mode.

RAM Write Cycle (Early Write, Delayed Write, Read-Modify-Write) ($\overline{DT/OE}$ high, $\overline{CAS}$ high and DSF1 low at the falling edge of $\overline{RAS}$, DSF1 low at the falling edge of $\overline{CAS}$)

No-Mask Write Cycle ($\overline{WEU}$ and $\overline{WEL}$ high at the falling edge of $\overline{RAS}$): When $\overline{CAS}$ is set low and either $\overline{WEU}$ or $\overline{WEL}$ is set low after $\overline{RAS}$ low, a write cycle is executed.

If either $\overline{WEU}$ or $\overline{WEL}$ is set low before the $\overline{CAS}$ falling edge, this cycle becomes an early write cycle and all I/O become in high impedance. All 16 data signals are latched on the falling edge of $\overline{CAS}$. If only one of $\overline{WEU}$ and $\overline{WEL}$ is low when $\overline{CAS}$ falls, the write will affect only those corresponding 8 bits. If the other of $\overline{WEU}$ and $\overline{WEL}$ falls at the same time in the cycle, those 8 bits will then be written with the latched data.

If both $\overline{WEU}$ and $\overline{WEL}$ are set low after the $\overline{CAS}$ falling edge, this cycle becomes a delayed write cycle and all 16 data bits are latched on the falling edge of $\overline{WEU}$ or $\overline{WEL}$. Byte write occurs if only one of $\overline{WEU}$ or $\overline{WEL}$ falls during the cycle. 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 read/write at the same address in one cycle. In this cycle also, to avoid I/O contention, data should be input after reading data and driving $\overline{OE}$ high.

Mask Write Mode ($\overline{WEU}$ or $\overline{WEL}$ low at the falling edge of $\overline{RAS}$): If $\overline{WEU}$ or $\overline{WEL}$ is set low at the falling edge of $\overline{RAS}$, two modes of mask write cycle are possible.

In new mask mode, mask data is loaded from I/O pin and used. Whether or not an I/O is written depends on the I/O level at the falling edge of $\overline{RAS}$. The data is written to high level I/Os, and the data is masked and retained in low level I/Os. This mask data is effective during the $\overline{RAS}$ cycle. So in page mode cycles, the mask data is retained during the page access.

If a load mask register cycle (LMR) has been performed, Mask write cycle (RAM write cycle, flash write cycle, block write cycle, masked write transfer cycle and masked sprit write transfer cycle) become all persistent mask mode. The mask data is not loaded from I/O pins. The persistent mask data stored in the mask registers are used. This operation known as persistent write mask, is reset by CBRR cycle, and become a new mask mode.

Fast Page Mode Cycle (HM5316123) ($\overline{DT/OE}$ high, $\overline{CAS}$ high and DSF1 low at the falling edge of $\overline{RAS}$): Fast 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. In this cycle, read, write, and block write cycles can be mixed. Note that address access time (t_{AA}), $\overline{RAS}$ to column address delay time (t_{RAD}), and access time from $\overline{CAS}$ precharge (t_{ACP}) are added. In one $\overline{RAS}$ cycle, 256-word memory cells with the same row address can be accessed. It is necessary to specify access frequency within t_{RASP} max (100 μs).

Hyper Page Mode Cycle (HM5316124) ($\overline{DT/OE}$ high, $\overline{CAS}$ high and DSF1 low at the falling edge of $\overline{RAS}$): Hyper 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 forth of the random read/write cycle. In this cycle, read, write, and block write cycles can be mixed. Note that address access time (t_{AA}), $\overline{RAS}$ to column address delay time (t_{RAD}), and access time from $\overline{CAS}$ precharge (t_{ACP}) are added. Column address is latched by $\overline{CAS}$ low edge trigger, access time from $\overline{CAS}$ is determined by t_{CAC} (t_{AA} from Column address, t_{ACP} from $\overline{CAS}$ high edge). Dout data is held during $\overline{CAS}$ high and is sustained until next Dout. Data output enable/disable is controlled by $\overline{DT/OE}$ and when both $\overline{RAS}$ and $\overline{CAS}$ become high, Data output become High-Z. In one $\overline{RAS}$ cycle, 512-word memory cells of the same row address can be accessed. It is necessary to specify access frequency within t_{RASP} max (100 μs).

Color Register Set/Read Cycle ($\overline{CAS}$ high, $\overline{DT/OE}$ high, $\overline{WEU}$ and $\overline{WEL}$ high and DSF1 high at the falling edge of $\overline{RAS}$: Mnemonic Code; LCR) In a color register set cycle, color data is set to the internal color register used in flash write cycle or block write cycle. 16 bits of internal color register are provided at each I/O. This register is composed of static circuits, so once it is set, it retains the data until reset. Since a color register set cycle is just as same as the usual read and write cycle, so read, early write and delayed write cycles can be executed. In this cycle, the HM5316123/HM5316124 refreshes the row address fetched at the falling edge of $\overline{RAS}$.

Mask Register Set/Read Cycle ($\overline{CAS}$ high, $\overline{DT/OE}$ high, $\overline{WEU}$ and $\overline{WEL}$ high, and DSF1 low at the falling edge of $\overline{RAS}$: Mnemonic Code; LMR) In this cycle, persistent mask data is set to the internal mask register used in mask write cycle, block write cycle, flash write cycle, masked write transfer, and masked split write transfer. 16 bits of internal mask register are provided at each I/O. This mask register is composed of static circuits, so once it is set, it retains the data until reset or reselect. Since the mask register set cycle is just as same as the usual read and write cycle, read, so early and delayed write cycles, and read cycles can be executed.

Flash Write Cycle ($\overline{CAS}$ high, $\overline{DT/OE}$ high, $\overline{WEU}$ or $\overline{WEL}$ low, and DSF1 high at the falling edge of $\overline{RAS}$: Mnemonic Code; FW) In a flash write cycle, a row of data (256 word × 16 bit) is cleared to 0 or 1 at each I/O according to the data of color register mentioned previously. It is also necessary to mask I/O in this cycle. This cycle starts when $\overline{CAS}$ and $\overline{DT/OE}$ are set high, $\overline{WEU}$ or $\overline{WEL}$ is low, and DSF1 is high at the falling edge of $\overline{RAS}$. Then, the row address to be cleared is set for the row address. Mask data is as same as that of a RAM write cycle. Cycle time is the same as those of RAM read/write cycles, so all bits can be cleared in 1/256 of the usual cycle time. (See figure 1.)

Block Write Cycle ($\overline{CAS}$ high, $\overline{DT/OE}$ high and DSF1 low at the falling edge of $\overline{RAS}$, DSF1 high and $\overline{WEU}$, $\overline{WEL}$ low at the falling edge of $\overline{CAS}$: Mnemonic Code; BW) In a block write cycle, 4 columns of data (4 column × 16 bit) are cleared to 0 or 1 at each I/O according to the data of color register. Column addresses A0 and A1 are disregarded. The mask data on I/Os and the mask data on column address can be determined independently. I/O level at the falling edge of $\overline{CAS}$ determines the address to be cleared. (See figure 2.) The block write cycle is as the same as the usual write cycle, so early and delayed write, read-modify-write, and page mode write cycles can be executed.

No-Mask Mode Block Write Cycle ($\overline{WEU}$ and $\overline{WEL}$ high at the falling edge of $\overline{RAS}$): The data on all 16 I/Os are cleared when $\overline{WEU}$ and $\overline{WEL}$ are high at the falling edge of $\overline{RAS}$.

Mask Block Write Cycle ($\overline{WEU}$ or $\overline{WEL}$ low at the falling edge of $\overline{RAS}$): When either $\overline{WEU}$ or $\overline{WEL}$ is low at the falling edge of $\overline{RAS}$, the HM5316123/HM5316124 starts mask block write cycle to clear the data on an optional I/O. The mask data is the same as that of a RAM write

cycle. High I/O is cleared, low I/O is not cleared and the internal data is retained. In new mask mode, the mask data is available in the $\overline{RAS}$ cycle. Inpersistent mask mode, I/O don't care about mask mode.

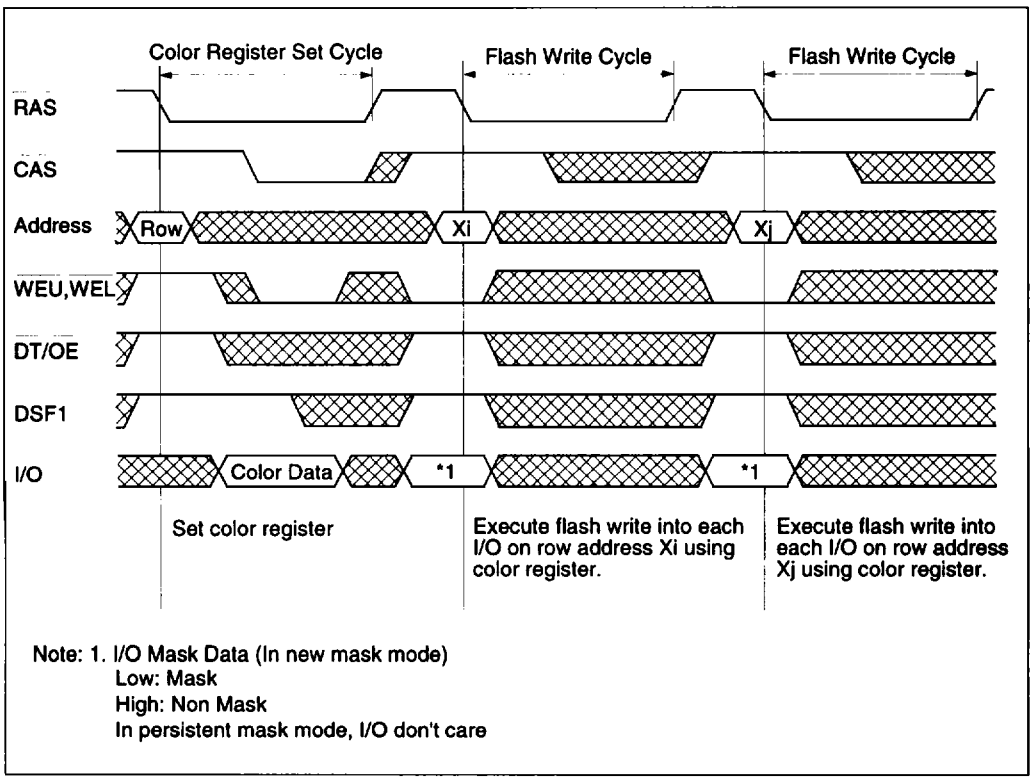
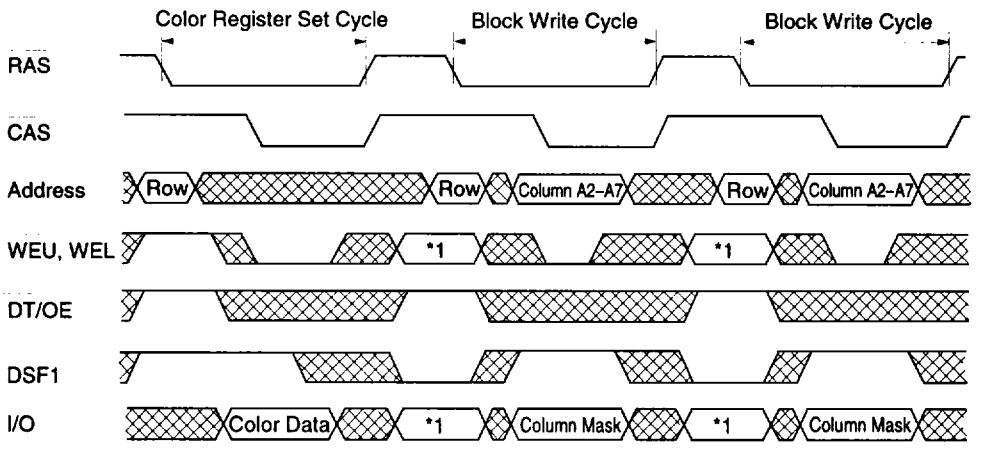


Figure 1 Use of Flash Write



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WEU, WEL	Mode	I/O data/RAS
Low	New mask mode	Mask
	Persistent mask mode	Don't care (mask register used)
High	No mask	Don't care

I/O Mask Data (In new mask mode)

Low: Mask

High: Non Mask

In persistent mask mode, I/O don't care

Column Mask Data

I/O0	Column0 (A0 = 0, A1 = 0) Mask Data	
I/O1	Column1 (A0 = 1, A1 = 0) Mask Data	Low: Mask
I/O2	Column2 (A0 = 0, A1 = 1) Mask Data	
I/O3	Column3 (A0 = 1, A1 = 1) Mask Data	High: Non Mask

Figure 2 Use of Block Write

Transfer Operation

The HM5316123 provides the read transfer cycle, split read transfer cycle, masked write transfer cycle and masked split write transfer cycle as data transfer cycles. These transfer cycles are set by driving $\overline{CAS}$ high and $\overline{DT/OE}$ low at the falling edge of $\overline{RAS}$. They have following functions:

- Transfer data between row address and SAM data register
  - — Read transfer cycle and split read transfer cycle: RAM to SAM
  - — Masked write transfer cycle and masked split write transfer cycle: SAM to RAM
- Determine SI/O state (except for split read transfer and masked split write transfer cycle)
  - — Read transfer cycle: SI/O output
  - — Masked write transfer cycle: SI/O input
- Determine first SAM address to access after transferring at column address (SAM start address).
  - — SAM start address must be determined by read transfer cycle or masked write transfer cycle (split transfer cycle isn't available) before SAM access, after power on, and for each transfer cycle.
- Use the stopping columns (boundaries) in the serial shift register. If the stopping columns have been set, split transfer cycles use the stopping columns, but no boundaries can be set as the start address.
- Load/use mask data in masked write transfer cycle and masked split write transfer cycle.

Read Transfer Cycle ($\overline{CAS}$ high, $\overline{DT/OE}$ low, $\overline{WEU}$ and $\overline{WEL}$ high and DSF1 low at the falling edge of $\overline{RAS}$: Mnemonic Code; RT) Start read transfer cycle by driving $\overline{DT/OE}$ low, $\overline{WEU}$ and $\overline{WEL}$ high and DSF1 low at the falling edge of $\overline{RAS}$. The row address data (256 × 16 bits) determined by this cycle is transferred to the SAM data register synchronously at the rising edge of $\overline{DT/OE}$. After the rising edge of $\overline{DT/OE}$, the new address data outputs from the SAM start address determined by the column address. In a read transfer cycle, $\overline{DT/OE}$ must be high to transfer data from RAM to SAM.

This cycle can access SAM even during transfer (real-time read transfer). In this case, the timing t_{SDD} (min) specified between the last SAM access before transfer and $\overline{DT/OE}$ rising edge, and t_{SDH} (min) specified between the first SAM access and $\overline{DT/OE}$ rising edge must be satisfied. (See figure 3.)

When a read transfer cycle is executed, SI/O reaches output state by first SAM access. Input

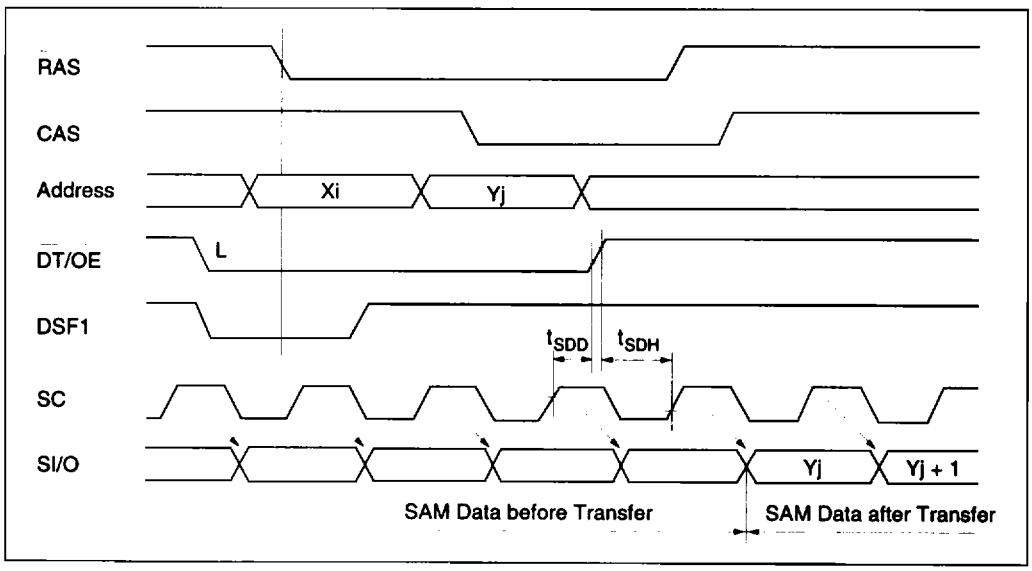


Figure 3 Real-Time Read Transfer

must be set high impedance before t_{SZS} (min) of the first SAM access to avoid data contention.

Masked Write Transfer Cycle ($\overline{CAS}$ high, $\overline{DT/OE}$ low, $\overline{WEU}$ or $\overline{WEL}$ low, and DSF1 low at the falling edge of $\overline{RAS}$: Mnemonic Code; MWT) Masked write transfer cycle can transfer only selected I/O data in a row of data input by a serial write cycle to RAM. Whether an I/O data is transferred or not depends on the corresponding I/O level (mask data) at the falling edge of $\overline{RAS}$. When SI/O change input mode. Set MWT with masked all I/O to protect RAM data. This mask transfer operation is the same as the mask write operation in RAM cycles, so the persistent mode is supported.

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 for serial write after terminating this cycle.

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 must not rise. Data transferred to SAM by read transfer cycle or split read transfer cycle can be written to other addreses in RAM by a write transfer cycle. However, the data write adddress must be the same as that of the read transfer cycle or the split read transfer cycle (row address AX8)

Split Read Transfer Cycle ($\overline{CAS}$ high, $\overline{DT/OE}$ low, $\overline{WEU}$ and $\overline{WEL}$ high and DSF1 high at the falling edge of $\overline{RAS}$: Mnemonic Code; SRT) To execute a continuous serial read by real-time read transfer, the HM5316123/HM5316124 must satisfy SC and $\overline{DT/OE}$ timing. It requires an external circuit to detect the last SAM address. The split read transfer cycle makes it possible to execute a continuous serial read without the above timing limitation.

The HM5316123/HM5316124 supports two types of split register operation. One is the normal split register operation, which splits the data register into two halves. The other is the boundary split register operation using stopping columns described later.

Figure 4 shows the block diagram for the normal split register operation. The SAM data register (DR) consists of 2 split buffers, whose organizations are 128 words × 16 bits each. Suppose that data is read from upper data register DR1. (The row address AX8 is 0 and SAM address A7 is 1.) When a split read transfer is executed

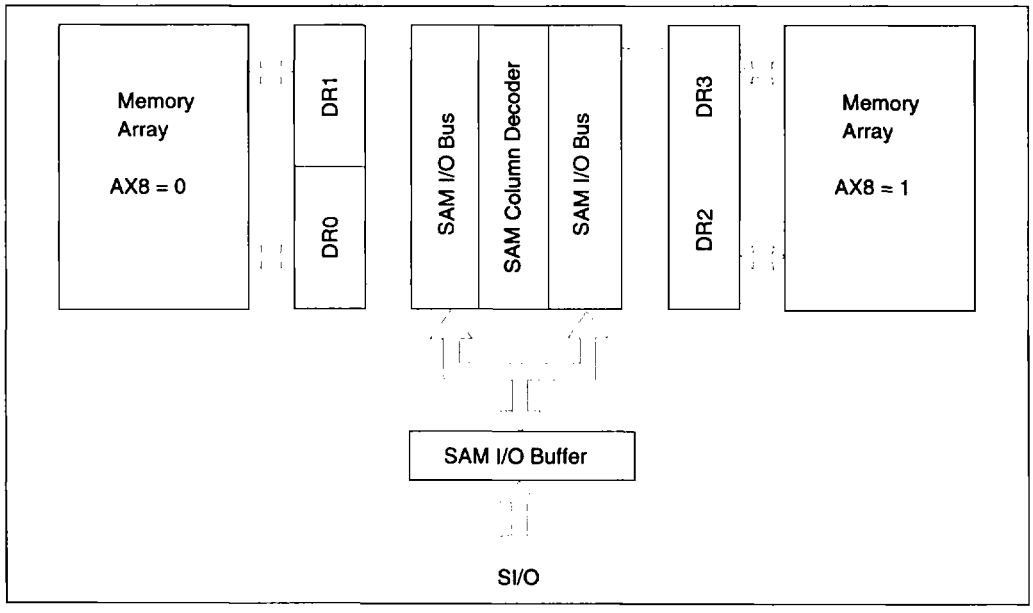


Figure 4 Split Transfer Block Diagram

setting row address AX8 to 0 and SAM start addresses A0 to A6, 128-word × 16-bit data are transferred from RAM to the lower data register DR0 (SAM address A7 is 0) automatically. After data is read from data register DR1, data read begins from SAM start addresses of data register DR0. If the next split read transfer isn't executed while data is being read from data register DR0, data start to be read from SAM start address 0 of DR1 after data is read from data register DR0.

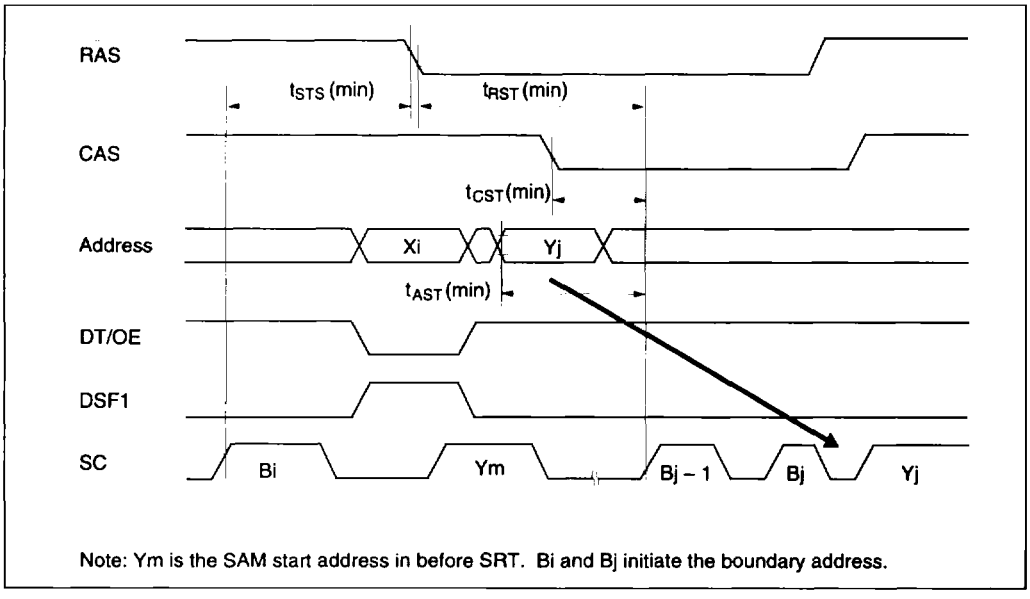
If split read transfer is executed with row address AX8 set to 1 and SAM start addresses A0 to A6 while data are read from data register DR1, 128-word × 16-bit data are transferred to data register DR2. After data are read from data register DR1, data read begins from SAM start addresses of data register DR2. If the next split read transfer isn't executed while data is read from data register DR2, data read begins from SAM start address 0 of data register DR1 after data are read from data register DR2. In split read data transfer, the SAM start address A7 is automatically set in the data register which isn't used.

The data on SAM address A7, which will be accessed next, is output to QSF. QSF is switched from low to high by accessing the last SAM address, 127, and from high to low by accessing address 255.

Split read transfer cycle is set when $\overline{CAS}$ is high, $\overline{DT/OE}$ is low, $\overline{WEU}$ and $\overline{WEL}$ is high and DSF1 is high at the falling edge of $\overline{RAS}$. The cycle can be executed asyncronously with SC. However, HM5316123/HM5316124 must satisfy t_{STS} (min) timing specified between SC rising (boundary address) and $\overline{RAS}$ falling. In split transfer cycle, the HM5316123/HM5316124 must satisfy t_{RST} (min), t_{CST} (min) and t_{AST} (min) timings specified between $\overline{RAS}$ or $\overline{CAS}$ falling and column address. (See figure 5.)

In split read transfer, SI/O isn't switched to output state. Therefore, read transfer must be executed to switch SI/O to output state when the previous transfer cycle is masked write transfer cycle or masked split write transfer cycle.

Masked Split Write Transfer Cycle ($\overline{CAS}$ high, $\overline{DT/OE}$ low, $\overline{WEU}$ or $\overline{WEL}$ low and DSF1 high at the falling edge of $\overline{RAS}$: Mnemonic Code; MSWT) A continuous serial write cannot be executed because accessing SAM is inhibited during $\overline{RAS}$ low in write transfer. Masked split write transfer cycle makes it possible. In this cycle, t_{STS} (min),



Note: Ym is the SAM start address in before SRT. Bi and Bj initiate the boundary address.

Figure 5 Split Transfer Limitation

t_{RST} (min), t_{CST} (min) and t_{AST} (min) timings must be satisfied as in split read transfer cycle. It is impossible to switch SI/O to input state in this cycle. If SI/O is in output state, masked write transfer cycle should be executed to switch SI/O into input state. Data transferred to SAM by read transfer cycle or split read transfer cycle can be written to other addresses of RAM by masked split write transfer cycle. However masked write transfer cycle must be executed before masked split write transfer cycle. And, in this masked split write transfer cycle, the MSB of the row address (AX8) for write data must be the same as that of the read transfer cycle or the split read transfer cycle. In this cycle, the boundary split register operation using stopping columns is possible as split read transfer cycle.

Stopping Column in Split Transfer Cycle: The HM5316123/HM5316124 boundary split register operation uses stopping columns. If a CBRS cycle has been performed, split transfer cycle performs the boundary operation. Figure 6 shows an example of boundary split register. (Boundary code is B6.)

First, a read data transfer cycle is executed, and SAM start addresses A0 to A7 are set. The RAM data are transferred to the SAM, and SAM serial read starts from the start address (Y1) on the lower SAM. After that, a split read transfer cycle is executed, and the next start address (Y2) is set. The RAM data are transferred to the upper SAM. When the serial read data arrive at the first boundary after the split read transfer cycle, the next read jumps to the start address (Y2) on the upper SAM (jump 1) and continues. Then the second split read transfer cycle is executed, and another start address (Y3) is set. The RAM data are transferred to the lower SAM. When the serial read arrive at the other boundary again, the next read jumps to the start address (Y3) on the lower SAM. In stopping column, split transfer is needed for jump operation between lower SAM and upper SAM.

Stopping Column Set Cycle (CBRS): Start a stopping column set cycle by driving $\overline{CAS}$ low, $\overline{WEU}$ or $\overline{WEL}$ low, DSF1 high at the falling edge of $\overline{RAS}$. Stopping column data (boundaries) are latched from address inputs on the falling edge of $\overline{RAS}$. Use A2 to A6 to determine the boundary. A0, A1, and A7 don't care. In the HM5316123 /HM5316124, six types of boundary (B2 to B7) can be set including the default case. (See table 1.) If A2 to A5 are set to high and A6 is set to low, the boundaries (B6) are selected. Figure 6 shows the example. Once a CBRS is executed, next sprit transfer cycle data becomes stopping columm data. Stopping columm is reset by CBBR.

Register Reset Cycle (CBRR): Start a register

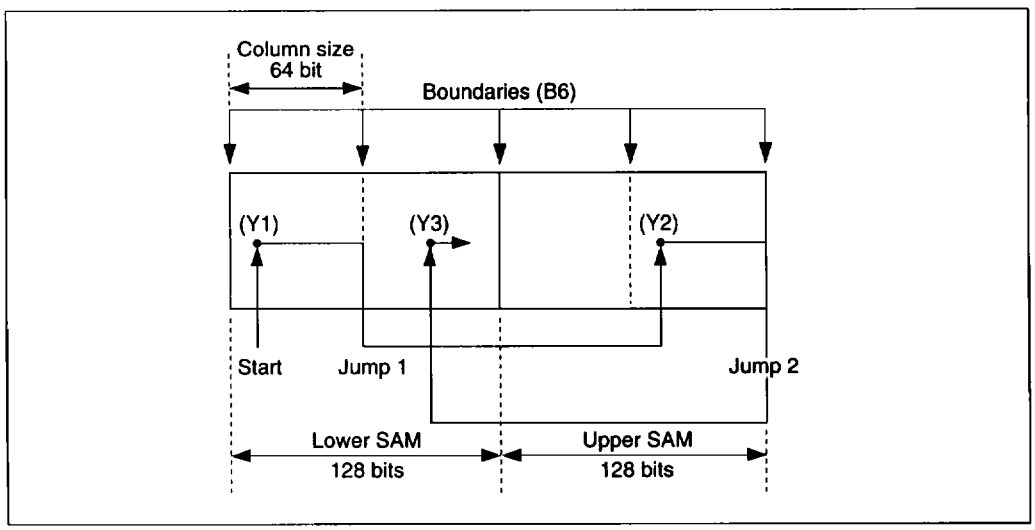


Figure 6 Boundary Split Register Example

Table 1 Stopping Column Boundary Table

Boundary Code	Column Size	Stop Address A2	A3	A4	A5	A6
B2	4	0	*	*	*	*
B3	8	1	0	*	*	*
B4	16	1	1	0	*	*
B5	32	1	1	1	0	*
B6	64	1	1	1	1	0
B7	128	1	1	1	1	1

Notes: 1. A0, A1, and A7: Don't care
2. *: Don't care

reset cycle (CBRR) by driving $\overline{CAS}$ low, $\overline{WEU}$ and $\overline{WEL}$ high, and DSF1 low at the falling edge of $\overline{RAS}$. A CBRR can reset the persistent mask operation and stopping column operation, so the HM5316123/HM5316124 becomes the new mask operation and boundary code B8. When a CBRR is executed for stopping column operation reset and split transfer operation, it must safisfy t_{STS} (min) and t_{RST} (min) between $\overline{RAS}$ falling and SC rising.

No Reset CBR Cycle (CBRN): This cycle becomes no reset CBR cycle (CBRN) by driving $\overline{CAS}$ low, $\overline{WE}$ high and DSF1 high at the falling edge of $\overline{RAS}$. The CBRN can only execute the refresh operation.

Byte Control ($\overline{WEU}$, $\overline{WEL}$): In a write cycle, when $\overline{WEL}$ set low and $\overline{WEU}$ set high, I/O0 to I/O7 become write mode and I/O8 to I/O15 become no write mode, and when $\overline{WEL}$ set high and $\overline{WEU}$ set low, I/O0 to I/O7 become no write mode and I/O8 to I/O15 become write mode. The write cycle that byte control is capable are RAM write cycle, block write cycle, load write mask register cycle and load color register cycle. The byte control write cycle is capable to execute early write, delay write, read-modify-write and page mode. But write mask in new mask mode, flash write, transfer and refresh cycle can not execute byte control.

SAM Port Operation

Serial Read Cycle

SAM port is in read mode when the previous data transfer cycle is a read transfer cycle. Access is synchronized with SC rising, and SAM data is output from SI/O. When $\overline{SE}$ is set high, SI/O becomes high impedance, and the internal pointer is incremented by the SC rising edge. After indicating the last address (address 255), the internal pointer indicates address 0 at the next access.

Serial Write Cycle

If the previous data transfer cycle is a masked write transfer cycle, SAM port goes into write mode. In this cycle, SI/O data is fetched into data register at the SC rising edge as in the serial read cycle. If $\overline{SE}$ is high, SI/O data isn't fetched into the data register. The internal pointer is incremented by the SC rising edge, so $\overline{SE}$ high can be used as mask data for SAM. After indicating the last address (address 255), the internal pointer indicates address 0 at the next access.

Refresh

RAM Refresh

RAM, which is composed of dynamic circuits, requires refresh to retain data. Refresh is executed by accessing all 512 row addresses within 8 ms. There are three refresh cycles: (1) $\overline{RAS}$-only

refresh, (2) $\overline{CAS}$-before-$\overline{RAS}$ (CBRN, CBRS, and CBRR) refresh, and (3) Hidden refresh. Besides these, cycles that activate $\overline{RAS}$ such as read/write cycles or transfer cycles can refresh the row address. Therefore, no refresh cycle is required when all row addresses are accessed within 8 ms.

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

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

Hidden Refresh Cycle: Hidden refresh cycle executes CBR refresh with the data output 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 resister and selector), are organized as fully static circuitry, require no refresh.

Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Voltage on any pin relative to V_{SS}	V_T	–1.0 to +7.0	V
Supply voltage relative to V_{SS}	V_{CC}	–0.5 to +7.0	V
Short circuit output current	Iout	50	mA
Power dissipation	P_T	1.0	W
Operating temperature	Topr	0 to +70	°C
Storage temperature	Tstg	-55 to +125	°C

Recommended DC Operating Conditions (Ta = 0 to +70°C)

Parameter	Symbol	Min	Typ	Max	Unit	Notes
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 (Note 2)	—	0.8	V	1

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

DC Characteristics (Ta = 0 to +70°C, V_{CC} = 5 V ± 10%, V_{SS} = 0 V)

		HM5316123/HM5316124								
		-7		-8		-10				
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Unit	Test conditions	
Operating current	I_{CC1}	—	120	—	110	—	100	mA	$\overline{RAS}$, $\overline{CAS}$ cycling t_{RC} = min	SC = V_{IL}, $\overline{SE}$ = V_{IH}
	I_{CC7}	—	195	—	175	—	160	mA		$\overline{SE}$ = V_{IL}, SC cycling t_{SCC} = min
Block write current	I_{CC1BW}	—	125	—	115	—	100	mA	$\overline{RAS}$, $\overline{CAS}$ cycling t_{RC} = min	SC = V_{IL}, $\overline{SE}$ = V_{IH}
	I_{CC7BW}	—	200	—	180	—	165	mA		$\overline{SE}$ = V_{IL}, SC cycling t_{SCC} = min
Standby current	I_{CC2}	—	7	—	7	—	7	mA	$\overline{RAS}$, $\overline{CAS}$ = V_{IH}	SC = V_{IL}, $\overline{SE}$ = V_{IH}
	I_{CC8}	—	85	—	75	—	70	mA		$\overline{SE}$ = V_{IL}, SC cycling t_{SCC} = min
$\overline{RAS}$-only refresh current	I_{CC3}	—	115	—	105	—	90	mA	$\overline{RAS}$ cycling $\overline{CAS}$ = V_{IH} t_{RC} = min	SC = V_{IL}, $\overline{SE}$ = V_{IH}
	I_{CC9}	—	185	—	165	—	150	mA		$\overline{SE}$ = V_{IL}, SC cycling t_{SCC} = min
Fast page mode current (HM5316123) *3	I_{CC4}	—	125	—	120	—	115	mA	$\overline{CAS}$ cycling $\overline{RAS}$ = V_{IL} t_{PC} = min	SC = V_{IL}, $\overline{SE}$ = V_{IH}
	I_{CC10}	—	200	—	185	—	175	mA		$\overline{SE}$ = V_{IL}, SC cycling t_{SCC} = min
Fast page mode block write current *3	I_{CC4BW}	—	145	—	135	—	130	mA	$\overline{CAS}$ cycling $\overline{RAS}$ = V_{IL} t_{PC} = min	SC = V_{IL}, $\overline{SE}$ = V_{IH}
	I_{CC10BW}	—	220	—	205	—	195	mA		$\overline{SE}$ = V_{IL}, SC cycling t_{SCC} = min
Hyper page mode current (HM5316124) *3	I_{CC4}	—	135	—	130	—	125	mA	$\overline{CAS}$ cycling $\overline{RAS}$ = V_{IL} t_{PC} = min	SC = V_{IL}, $\overline{SE}$ = V_{IH}
	I_{CC10}	—	210	—	200	—	190	mA		$\overline{SE}$ = V_{IL}, SC cycling t_{SCC} = min
Hyper page mode block write current *3	I_{CC4BW}	—	165	—	160	—	150	mA	$\overline{CAS}$ cycling $\overline{RAS}$ = V_{IL} t_{PC} = min	SC = V_{IL}, $\overline{SE}$ = V_{IH}
	I_{CC10BW}	—	240	—	225	—	210	mA		$\overline{SE}$ = V_{IL}, SC cycling t_{SCC} = min
$\overline{CAS}$-before-$\overline{RAS}$ refresh current	I_{CC5}	—	85	—	75	—	65	mA	$\overline{RAS}$ cycling t_{RC} = min	SC = V_{IL}, $\overline{SE}$ = V_{IH}
	I_{CC11}	—	155	—	140	—	125	mA		$\overline{SE}$ = V_{IL}, SC cycling t_{SCC} = min
Data transfer current	I_{CC6}	—	130	—	120	—	110	mA	$\overline{RAS}$, $\overline{CAS}$ cycling t_{RC} = min	SC = V_{IL}, $\overline{SE}$ = V_{IH}
	I_{CC12}	—	205	—	185	—	165	mA		$\overline{SE}$ = V_{IL}, SC cycling t_{SCC} = min

DC Characteristics (Ta = 0 to +70°C, V_{CC} = 5 V ± 10%, V_{SS} = 0 V) (cont)

		HM5316123/HM5316124							
		-7		-8		-10			
Parameter	**Symbol**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Unit**	**Test conditions**
Input leakage current	I_{LI}	−10	10	−10	10	−10	10	µA	
Output leakage current	I_{LO}	−10	10	−10	10	−10	10	µA	
Output high voltage	V_{OH}	2.4	—	2.4	—	2.4	—	V	I_{OH} = −1 mA
Output low voltage	V_{OL}	—	0.4	—	0.4	—	0.4	V	I_{OL} = 2.1 mA

Notes: 1. I_{CC} depends on output load condition when the device is selected. I_{CC} max is specified at the output open condition.
2. Address can be changed once while $\overline{RAS}$ is low and $\overline{CAS}$ is high.
3. Address can be changed once in 1 page cycle (tpc).

Capacitance (Ta = 25°C, V_{CC} = 5 ± 10%, f = 1 MHz, Bias: Clock, I/O = V_{CC}, Address = V_{SS})

Parameter	**Symbol**	**Typ**	**Max**	**Unit**	**Note**
Input capacitance (Address)	C_{I1}	—	5	pF	1
Input capacitance (Clocks)	C_{I2}	—	5	pF	1
Output capacitance (I/O, SI/O, QSF)	$C_{I/O}$	—	7	pF	1

Notes: 1. This parameter is sampled and not 100% tested.

AC Characteristics (Ta = 0 to +70°C, V_{CC} = 5 V ± 10%, V_{SS} = 0 V) *1, *16

Test Conditions

- Input rise and fall times: 5 ns
- Input pulse levels: V_{SS} to 3.0 V
- Input timing reference levels: 0.8 V, 2.4 V
- Output timing reference levels: 0.8 V, 2.0 V
- Output load:
  — RAM: 1 TTL + C_L (50 pF)
  — SAM, QSF: 1 TTL + C_L (30 pF)
  (Including scope and jig)

Common Parameter

		HM5316123/HM5316124							
		-7		-8		-10			
Parameter	**Symbol**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Unit**	**Notes**
Random read or write cycle time	t_{RC}	130	—	150	—	180	—	ns	
$\overline{RAS}$ precharge time	t_{RP}	50	—	60	—	70	—	ns	
$\overline{RAS}$ pulse width	t_{RAS}	70	10000	80	10000	100	10000	ns	
$\overline{CAS}$ pulse width	t_{CAS}	20	—	20	—	25	—	ns	
Row address setup time	t_{ASR}	0	—	0	—	0	—	ns	
Row address hold time	t_{RAH}	10	—	10	—	10	—	ns	
Column address setup time	t_{ASC}	0	—	0	—	0	—	ns	
Column address hold time	t_{CAH}	12	—	15	—	15	—	ns	
$\overline{RAS}$ to $\overline{CAS}$ delay time	t_{RCD}	20	50	20	60	20	75	ns	2
$\overline{RAS}$ hold time referenced to $\overline{CAS}$	t_{RSH}	20	—	20	—	25	—	ns	
$\overline{CAS}$ hold time referenced to $\overline{RAS}$	t_{CSH}	70	—	80	—	100	—	ns	
$\overline{CAS}$ to $\overline{RAS}$ precharge time	t_{CRP}	10	—	10	—	10	—	ns	
Transition time (rise to fall)	t_T	3	50	3	50	3	50	ns	3
Refresh period	t_{REF}	—	8	—	8	—	8	ms	
$\overline{DT}$ to $\overline{RAS}$ setup time	t_{DTS}	0	—	0	—	0	—	ns	
$\overline{DT}$ to $\overline{RAS}$ hold time	t_{DTH}	10	—	10	—	10	—	ns	
DSF1 to $\overline{RAS}$ setup time	t_{FSR}	0	—	0	—	0	—	ns	
DSF1 to $\overline{RAS}$ hold time	t_{RFH}	10	—	10	—	10	—	ns	
DSF1 to $\overline{CAS}$ setup time	t_{FSC}	0	—	0	—	0	—	ns	
DSF1 to $\overline{CAS}$ hold time	t_{CFH}	12	—	15	—	15	—	ns	
Data-in to $\overline{CAS}$ delay time	t_{DZC}	0	—	0	—	0	—	ns	4
Data-in to $\overline{OE}$ delay time	t_{DZO}	0	—	0	—	0	—	ns	4
Output buffer turn-off delay referenced to $\overline{CAS}$	t_{OFF1}	—	15	—	20	—	20	ns	5
Output buffer turn-off delay referenced to $\overline{OE}$	t_{OFF2}	—	15	—	20	—	20	ns	5

Read Cycle (RAM), Page Mode Read Cycle

		HM5316123/HM5316124							
		-7		-8		-10			
Parameter	**Symbol**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Unit**	**Notes**
Access time from $\overline{RAS}$	t_{RAC}	—	70	—	80	—	100	ns	6, 7
Access time from $\overline{CAS}$	t_{CAC}	—	20	—	20	—	25	ns	7, 8
Access time from $\overline{OE}$	t_{OAC}	—	20	—	20	—	25	ns	7
Address access time	t_{AA}	—	35	—	40	—	45	ns	7, 9
Read command setup time	t_{RCS}	0	—	0	—	0	—	ns	
Read command hold time	t_{RCH}	0	—	0	—	0	—	ns	10
Read command hold time referenced to $\overline{RAS}$	t_{RRH}	0	—	5	—	10	—	ns	10
$\overline{RAS}$ to column address delay time	t_{RAD}	15	35	15	40	15	55	ns	2
Column address to $\overline{RAS}$ lead time	t_{RAL}	35	—	40	—	45	—	ns	
Column address to $\overline{CAS}$ lead time	t_{CAL}	35	—	40	—	45	—	ns	
Page mode cycle time	t_{PC}	45	—	50	—	55	—	ns	
$\overline{CAS}$ precharge time	t_{CP}	7	—	10	—	10	—	ns	
Access time from $\overline{CAS}$ precharge	t_{ACP}	—	40	—	45	—	50	ns	
Page mode $\overline{RAS}$ pulse width	t_{RASP}	70	100000	80	100000	100	100000	ns	

Write Cycle (RAM), Page Mode Write Cycle, Color Register Set Cycle

		HM5316123/HM5316124							
		-7		-8		-10			
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Unit	Notes
Write command setup time	t_{WCS}	0	—	0	—	0	—	ns	11
Write command hold time	t_{WCH}	12	—	15	—	15	—	ns	
Write command pulse width	t_{WP}	12	—	15	—	15	—	ns	
Write command to $\overline{RAS}$ lead time	t_{RWL}	20	—	20	—	20	—	ns	
Write command to $\overline{CAS}$ lead time	t_{CWL}	20	—	20	—	20	—	ns	
Data-in setup time	t_{DS}	0	—	0	—	0	—	ns	12
Data-in hold time	t_{DH}	12	—	15	—	15	—	ns	12
$\overline{WE}$ to $\overline{RAS}$ setup time	t_{WS}	0	—	0	—	0	—	ns	
$\overline{WE}$ to $\overline{RAS}$ hold time	t_{WH}	10	—	10	—	10	—	ns	
Mask data to $\overline{RAS}$ setup time	t_{MS}	0	—	0	—	0	—	ns	
Mask data to $\overline{RAS}$ hold time	t_{MH}	10	—	10	—	10	—	ns	
$\overline{OE}$ hold time referenced to $\overline{WE}$	t_{OEH}	15	—	20	—	20	—	ns	
Page mode cycle time	t_{PC}	45	—	50	—	55	—	ns	
$\overline{CAS}$ precharge time	t_{CP}	7	—	10	—	10	—	ns	
$\overline{CAS}$ to data-in delay time	t_{CDD}	15	—	20	—	20	—	ns	13
Page mode $\overline{RAS}$ pulse width	t_{RASP}	70	100000	80	100000	100	100000	ns	

Read-Modify-Write Cycle

		HM5316123/HM5316124							
		-7		-8		-10			
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Unit	Notes
Read-modify-write cycle time	t_{RWC}	180	—	200	—	230	—	ns	
$\overline{RAS}$ pulse width (read-modify-write cycle)	t_{RWS}	120	10000	130	10000	150	10000	ns	
$\overline{CAS}$ to $\overline{WE}$ delay time	t_{CWD}	40	—	45	—	50	—	ns	14
Column address to $\overline{WE}$ delay time	t_{AWD}	60	—	65	—	70	—	ns	14
$\overline{OE}$ to data-in delay time	t_{ODD}	15	—	20	—	20	—	ns	12
Access time from $\overline{RAS}$	t_{RAC}	—	70	—	80	—	100	ns	6, 7
Access time from $\overline{CAS}$	t_{CAC}	—	20	—	20	—	25	ns	7, 8
Access time from $\overline{OE}$	t_{OAC}	—	20	—	20	—	25	ns	7
Address access time	t_{AA}	—	35	—	40	—	45	ns	7, 9
$\overline{RAS}$ to column address delay time	t_{RAD}	15	35	15	40	15	55	ns	
Read command setup time	t_{RCS}	0	—	0	—	0	—	ns	
Write command to $\overline{RAS}$ lead time	t_{RWL}	20	—	20	—	20	—	ns	
Write command to $\overline{CAS}$ lead time	t_{CWL}	20	—	20	—	20	—	ns	
Write command pulse width	t_{WP}	12	—	15	—	15	—	ns	
Data-in setup time	t_{DS}	0	—	0	—	0	—	ns	12
Data-in hold time	t_{DH}	12	—	15	—	15	—	ns	12
$\overline{OE}$ hold time referenced to $\overline{WE}$	t_{OEH}	15	—	20	—	20	—	ns	

Refresh Cycle

		HM5316123/HM5316124							
		-7		-8		-10			
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Unit	Notes
$\overline{CAS}$ setup time ($\overline{CAS}$-before-$\overline{RAS}$ refresh)	t_{CSR}	10	—	10	—	10	—	ns	
$\overline{CAS}$ hold time ($\overline{CAS}$-before-$\overline{RAS}$ refresh)	t_{CHR}	10	—	10	—	10	—	ns	
$\overline{RAS}$ precharge to $\overline{CAS}$ hold time	t_{RPC}	10	—	10	—	10	—	ns	

Flash Write Cycle, Block Write Cycle, and Register Read Cycle

		HM5316123/HM5316124							
		-7		-8		-10			
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Unit	Notes
$\overline{CAS}$ to data-in delay time	t_{CDD}	15	—	20	—	20	—	ns	13
$\overline{OE}$ to data-in delay time	t_{ODD}	15	—	20	—	20	—	ns	13

CBR Refresh with Register Reset

		HM5316123/HM5316124							
		-7		-8		-10			
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Unit	Notes
Split transfer setup time	t_{STS}	20	—	20	—	25	—	ns	
Split transfer hold time referenced to $\overline{RAS}$	t_{RST}	70	—	80	—	100	—	ns	

Hyper Page Mode Cycle (HM5316124)

		HM5316124							
		-7		-8		-10			
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Unit	Notes
Column address to $\overline{CAS}$ lead time	t_{CAL}	25	—	30	—	35	—	ns	
Hyper page mode cycle time	t_{PC}	35	—	40	—	45	—	ns	
Hyper page $\overline{CAS}$ precharge time	t_{CP}	5	—	10	—	10	—	ns	
Hyper page data out hold time	t_{DOH}	4	—	5	—	5	—	ns	
Data-out buffer turn-off time ($\overline{RAS}$)	t_{RHZ}	—	15	—	20	—	20	ns	5
Data-out buffer turn-off time ($\overline{CAS}$)	t_{CHZ}	—	15	—	20	—	20	ns	5
$\overline{RAS}$ to data-in delay time	t_{RDD}	20	—	20	—	20	—	ns	13

Read Transfer Cycle

		HM5316123/HM5316124							
		-7		-8		-10			
Parameter	**Symbol**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Unit**	**Notes**
$\overline{DT}$ hold time referenced to $\overline{RAS}$	t_{RDH}	60	10000	65	10000	80	10000	ns	
$\overline{DT}$ hold time referenced to $\overline{CAS}$	t_{CDH}	20	—	20	—	25	—	ns	
$\overline{DT}$ hold time referenced to column address	t_{ADH}	25	—	30	—	30	—	ns	
$\overline{DT}$ precharge time	t_{DTP}	20	—	20	—	30	—	ns	
$\overline{DT}$ to $\overline{RAS}$ delay time	t_{DRD}	60	—	70	—	80	—	ns	
SC to $\overline{RAS}$ setup time	t_{SRS}	15	—	20	—	30	—	ns	
1st SC to $\overline{RAS}$ hold time	t_{SRH}	70	—	80	—	100	—	ns	
1st SC to $\overline{CAS}$ hold time	t_{SCH}	25	—	25	—	25	—	ns	
1st SC to column address hold time	t_{SAH}	40	—	45	—	50	—	ns	
Last SC to $\overline{DT}$ delay time	t_{SDD}	5	—	5	—	5	—	ns	
1st SC to $\overline{DT}$ hold time	t_{SDH}	10	—	13	—	15	—	ns	
$\overline{DT}$ to QSF delay time	t_{DQD}	—	30	—	35	—	35	ns	15
QSF hold time referenced to $\overline{DT}$	t_{DQH}	5	—	5	—	5	—	ns	
Serial data-in to 1st SC delay time	t_{SZS}	0	—	0	—	0	—	ns	
Serial clock cycle time	t_{SCC}	25	—	28	—	30	—	ns	
SC pulse width	t_{SC}	5	—	10	—	10	—	ns	
SC precharge time	t_{SCP}	10	—	10	—	10	—	ns	
SC access time	t_{SCA}	—	20	—	23	—	25	ns	15
Serial data-out hold time	t_{SOH}	5	—	5	—	5	—	ns	
Serial data-in setup time	t_{SIS}	0	—	0	—	0	—	ns	
Serial data-in hold time	t_{SIH}	15	—	15	—	15	—	ns	
$\overline{RAS}$ to column address delay time	t_{RAD}	15	35	15	40	15	55	ns	
Column address to $\overline{RAS}$ lead time	t_{RAL}	35	—	40	—	45	—	ns	
$\overline{RAS}$ to QSF delay time	t_{RQD}	—	70	—	75	—	85	ns	15
$\overline{CAS}$ to QSF delay time	t_{CQD}	—	35	—	35	—	35	ns	15
QSF hold time referenced to$\overline{RAS}$	t_{RQH}	20	—	20	—	25	—	ns	
QSF hold time referenced to $\overline{CAS}$	t_{CQH}	5	—	5	—	5	—	ns	

Masked Write Transfer Cycle

		HM5316123/HM5316124							
		-7		-8		-10			
Parameter	**Symbol**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Unit**	**Notes**
SC setup time referenced to $\overline{RAS}$	t_{SRS}	15	—	20	—	30	—	ns	
$\overline{RAS}$ to SC delay time	t_{SRD}	20	—	25	—	25	—	ns	
Serial output buffer turn-off time referenced to $\overline{RAS}$	t_{SRZ}	10	30	10	35	10	50	ns	
$\overline{RAS}$ to serial data-in delay time	t_{SID}	30	—	35	—	50	—	ns	
$\overline{RAS}$ to QSF delay time	t_{RQD}	—	70	—	75	—	85	ns	15
$\overline{CAS}$ to QSF delay time	t_{CQD}	—	35	—	35	—	35	ns	15
QSF hold time referenced to $\overline{RAS}$	t_{RQH}	20	—	20	—	25	—	ns	
QSF hold time referenced to $\overline{CAS}$	t_{CQH}	5	—	5	—	5	—	ns	
Serial clock cycle time	t_{SCC}	25	—	28	—	30	—	ns	
SC pulse width	t_{SC}	5	—	10	—	10	—	ns	
SC precharge time	t_{SCP}	10	—	10	—	10	—	ns	
SC access time	t_{SCA}	—	20	—	23	—	25	ns	15
Serial data-out hold time	t_{SOH}	5	—	5	—	5	—	ns	
Serial data-in setup time	t_{SIS}	0	—	0	—	0	—	ns	
Serial data-in hold time	t_{SIH}	15	—	15	—	15	—	ns	

Split Read Transfer Cycle, Masked Split Write Transfer Cycle

		HM5316123/HM5316124							
		-7		-8		-10			
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Unit	Notes
Split transfer setup time	t_{STS}	20	—	20	—	25	—	ns	
Split transfer hold time referenced to $\overline{RAS}$	t_{RST}	70	—	80	—	100	—	ns	
Split transfer hold time referenced to $\overline{CAS}$	t_{CST}	20	—	20	—	25	—	ns	
Split transfer hold time referenced to column address	t_{AST}	35	—	40	—	45	—	ns	
SC to QSF delay time	t_{SQD}	—	30	—	30	—	30	ns	15
QSF hold time referenced to SC	t_{SQH}	5	—	5	—	5	—	ns	
Serial clock cycle time	t_{SCC}	25	—	28	—	30	—	ns	
SC pulse width	t_{SC}	5	—	10	—	10	—	ns	
SC precharge time	t_{SCP}	10	—	10	—	10	—	ns	
SC access time	t_{SCA}	—	20	—	23	—	25	ns	15
Serial data-out hold time	t_{SOH}	5	—	5	—	5	—	ns	
Serial data-in setup time	t_{SIS}	0	—	0	—	0	—	ns	
Serial data-in hold time	t_{SIH}	15	—	15	—	15	—	ns	
$\overline{RAS}$ to column address delay time	t_{RAD}	15	35	15	40	15	55	ns	
Column address to $\overline{RAS}$ lead time	t_{RAL}	35	—	40	—	45	—	ns	

Serial Read Cycle, Serial Write Cycle

		HM5316123/HM5316124							
		-7		-8		-10			
Parameter	Symbol	Min	Max	Min	Max	Min	Max	Unit	Notes
Serial clock cycle time	t_{SCC}	25	—	28	—	30	—	ns	
SC pulse width	t_{SC}	5	—	10	—	10	—	ns	
SC precharge width	t_{SCP}	10	—	10	—	10	—	ns	
Access time from SC	t_{SCA}	—	20	—	23	—	25	ns	15
Access time from $\overline{SE}$	t_{SEA}	—	17	—	20	—	25	ns	15
Serial data-out hold time	t_{SOH}	5	—	5	—	5	—	ns	
Serial output buffer turn-off time referenced to $\overline{SE}$	t_{SHZ}	—	15	—	20	—	20	ns	5, 17
$\overline{SE}$ to serial output in low-Z	t_{SLZ}	0	—	0	—	0	—	ns	5, 17
Serial data-in setup time	t_{SIS}	0	—	0	—	0	—	ns	
Serial data-in hold time	t_{SIH}	15	—	15	—	15	—	ns	

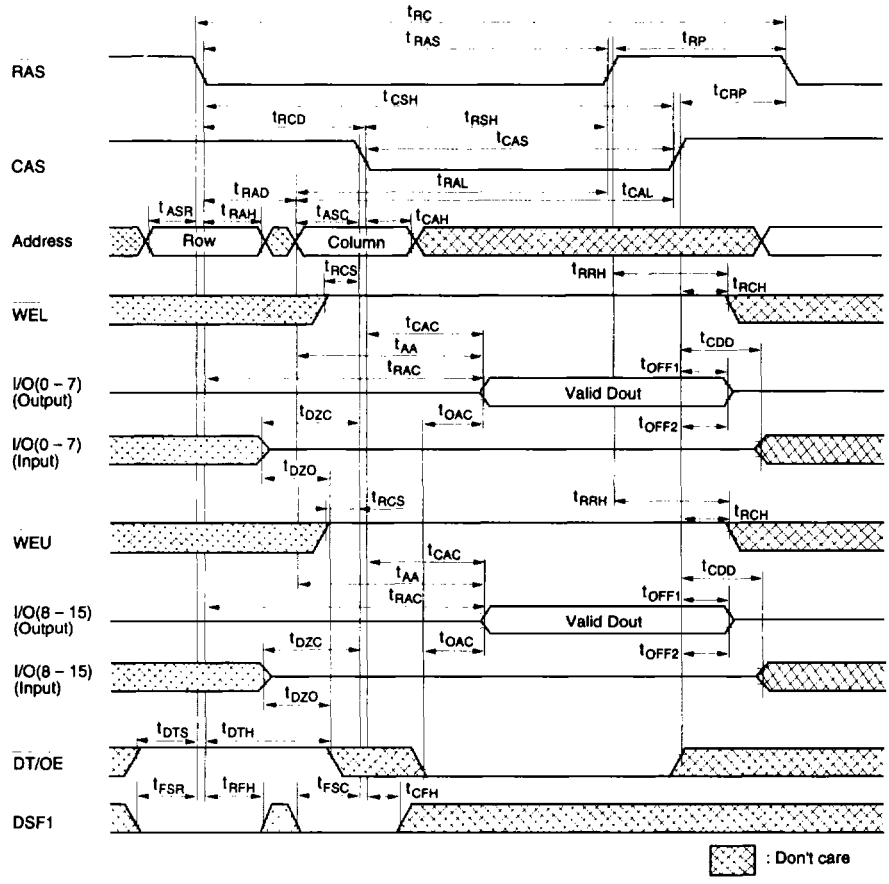
Serial Read Cycle, Serial Write Cycle (cont)

		HM5316123/HM5316124							
		-7		-8		-10			
Parameter	**Symbol**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Unit**	**Notes**
Serial write enable setup time	t_{SWS}	0	—	0	—	0	—	ns	
Serial wrtie enable hold time	t_{SWH}	15	—	15	—	15	—	ns	
Serial write disable setup time	t_{SWIS}	0	—	0	—	0	—	ns	
Serial write disable hold time	t_{SWIH}	15	—	15	—	15	—	ns	

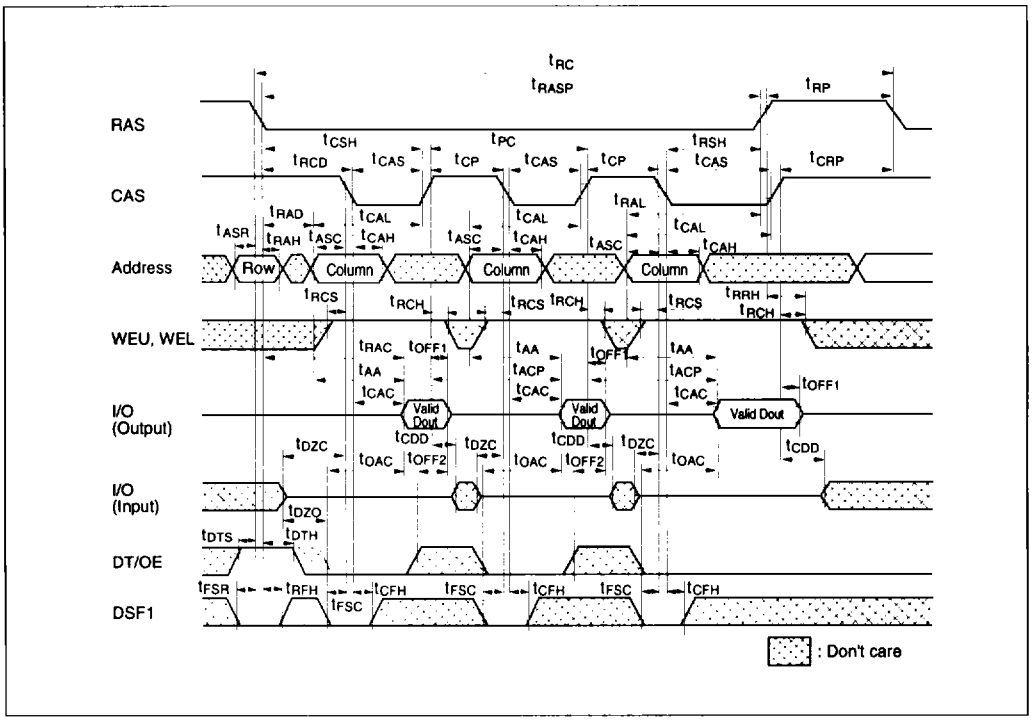
Notes:
1. AC measurements assume t_T = 5 ns.
2. When $t_{RCD} > t_{RCD}$ (max) and $t_{RAD} > t_{RAD}$ (max), access time is specified by t_{CAC} or t_{AA}.
3. V_{IH} (min) and V_{IL} (max) are reference levels for measuring timing of input signals. Transition time t_T is measured between V_{IH} and V_{IL}.
4. Data input must be floating before output buffer is turned on. In read cycle, read-modify-write cycle and delayed write cycle, either t_{DZC} (min) or t_{DZO} (min) must be satisfied.
5. t_{RHZ} (max), t_{CHZ} (max), t_{OFF1} (max), t_{OFF2} (max), t_{SHZ} (max) and t_{SLZ} (min) are defined as the time at which the output acheives the open circuit condition (V_{OH} – 100 mV, V_{OL} + 100 mV). This parameter is sampled and not 100% tested.
6. Assume 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.
7. Measured with a load circuit equivalent to 1 TTL loads and 50 pF.
8. When $t_{RCD} \geq t_{RCD}$ (max) and $t_{RAD} \leq t_{RAD}$ (max), access time is specified by t_{CAC}.
9. When $t_{RCD} \leq t_{RCD}$ (max) and $t_{RAD} \geq t_{RAD}$ (max), access time is specified by t_{AA}.
10. If either t_{RCH} or t_{RRH} is satisfied, operation is guaranteed. (HM5316123)
    If both t_{RCH} and t_{RRH} are satisfied, operation is guaranteed. (HM5316124)
11. 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.
12. These parameters are specified by the later falling edge of $\overline{CAS}$ or $\overline{WEU}$ and $\overline{WEL}$.
13. Either t_{CDD} (min) or t_{ODD} (min) must be satisfied because the output buffer must be turned off by $\overline{CAS}$ or $\overline{OE}$ before data is applied to the device when the output buffer is on. (HM5316123)
    Either t_{CDD} (min), t_{ODD} (min) or t_{RDD} (min) must be satisfied because the output buffer must be turn off by $\overline{CAS}$, $\overline{OE}$ or $\overline{RAS}$ prior to applying data to the device when output buffer is on. (HM5316124)
14. When $t_{AWD} \geq t_{AWD}$ (min) and $t_{CWD} \geq t_{CWD}$ (min) in read-modify-write cycle, the data of the selected address outputs to an I/O pin and input data is written into the selected address. t_{ODD} (min) must be satisfied because output buffer must be turned off by $\overline{OE}$ prior to applying data to the device.
15. Measured with a load circuit equivalent to 1 TTL loads and 30 pF.
16. After power-up, pause for 100 µs or more and execute at least 8 initialization cycles (normal memory cycle or refresh cycle), then start operation. Hitachi recommends that 8 initialization cycle is CBRR for internal register reset.
17. When t_{SHZ} and t_{SLZ} are measured in the same V_{CC} and Ta conditions and tr and tf of $\overline{SE}$ are less than 5 ns, $t_{SHZ} \leq t_{SLZ}$ + 5 ns.
18. When both $\overline{WEU}$ and $\overline{WEL}$ go low at the same time, all 16 bits of data are written into the device. $\overline{WEU}$ and $\overline{WEL}$ cannot be staggered within the same write cycle.
19. After power-up, QSF output may be High-Z, so 1 SC cycle is needed to be Low-Z it.
20. DSF2 pin is open pin, but Hitachi recommends it is fixed low in all operation for the addition mode in future.

Timing Waveforms

Read Cycle (HM5316123)



Fast page Mode Read Cycle (HM5316123)



Write Cycle

Table 2, the write cycle state table, applies to early write, delayed write, page mode write, and read-modify write.

Table 2 Write Cycle State

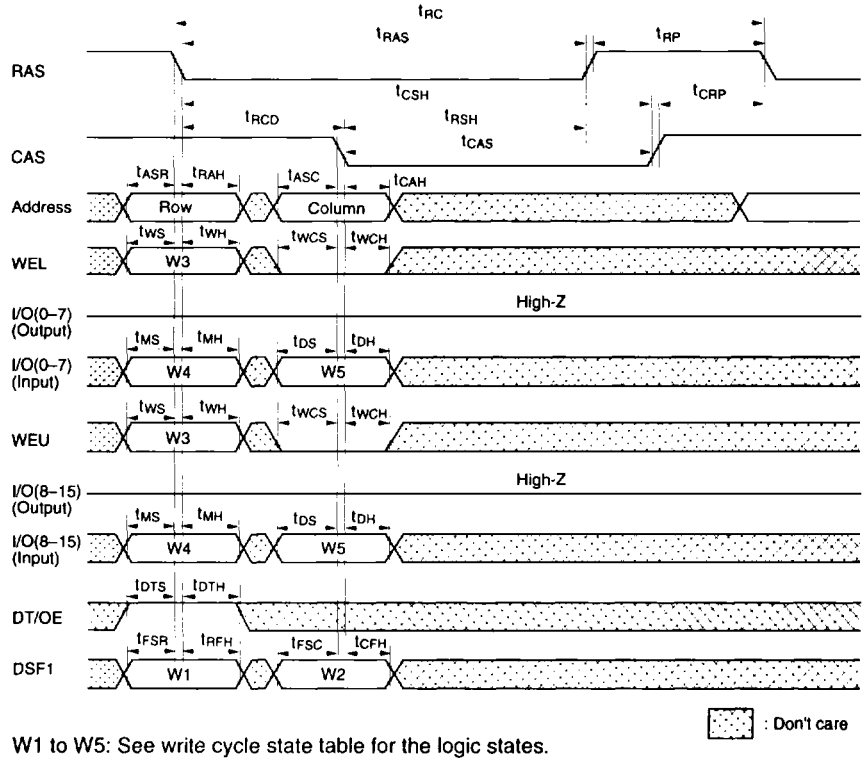
		$\overline{RAS}$	$\overline{CAS}$	$\overline{RAS}$	$\overline{RAS}$	$\overline{CAS}$
		DSF1	DSF1	$\overline{WEU}$, $\overline{WEL}$	I/O	I/O
MNEU	Cycle	W1	W2	W3	W4	W5
RWM	Write mask (new/old) Write DQs to I/Os	0	0	0	Write mask (Note 1)	Valid data
BWM	Write mask (new/old) Block write	0	1	0	Write mask (Note 2)	Column mask (Note 2)
RW	Normal write (no mask)	0	0	1	Don't care (Note 1)	Valid data
BW	Block write (no mask)	0	1	1	Don't care (Note 2)	Column mask (Note 2)
LMR (Note 4)	Load write mask resister	1	0	1	Don't care	Write mask data (Note 3)
LCR (Note 4)	Load color resister	1	1	1	Don't care	Color data

Notes: 1. I/O mask data (in new mask mode)
Low: Masked
High: Non masked
In persistent mask mode, I/O don't care.

$\overline{WEU}$, $\overline{WEL}$	Mode	I/O Data/$\overline{RAS}$
Either low	New mask mode	Mask
	Persistent mask mode	Don't care (mask register used)
Both high	No mask	Don't care

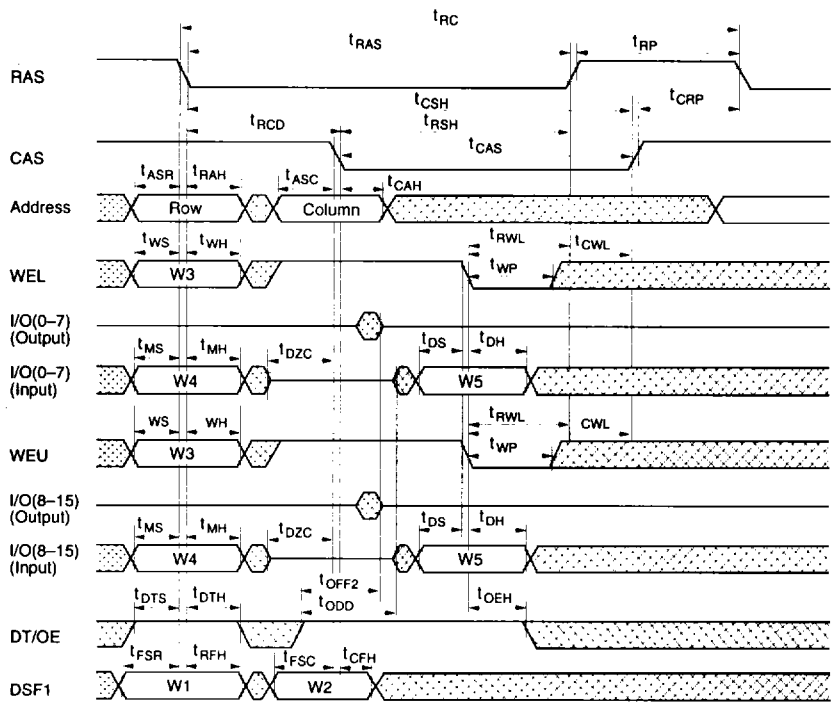
2. See figure 2, use of Block Write
3. I/O write mask data
Low: Masked
High: Non masked
4. Column address: Don't care

Early Write Cycle



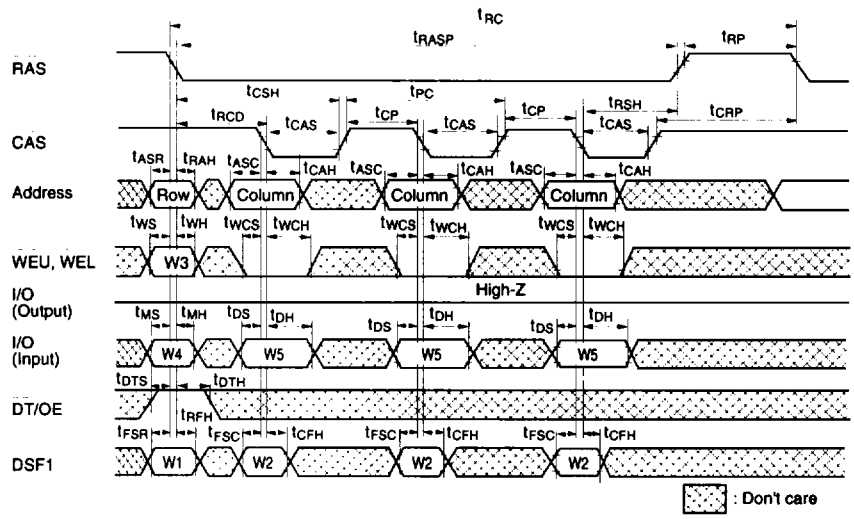
W1 to W5: See write cycle state table for the logic states.

Delayed Write Cycle



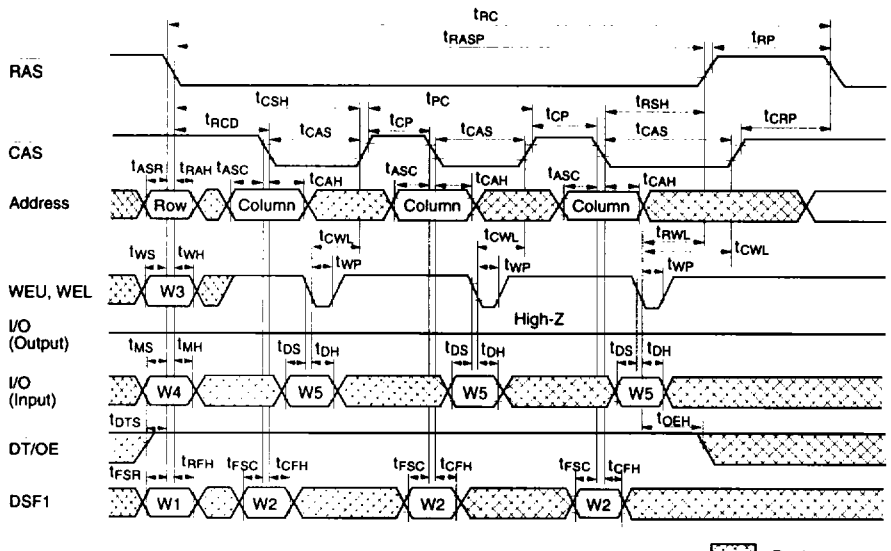
W1 to W5: See write cycle state table for the logic states

Fast/Hyper Page Mode Write Cycle (Early Write)



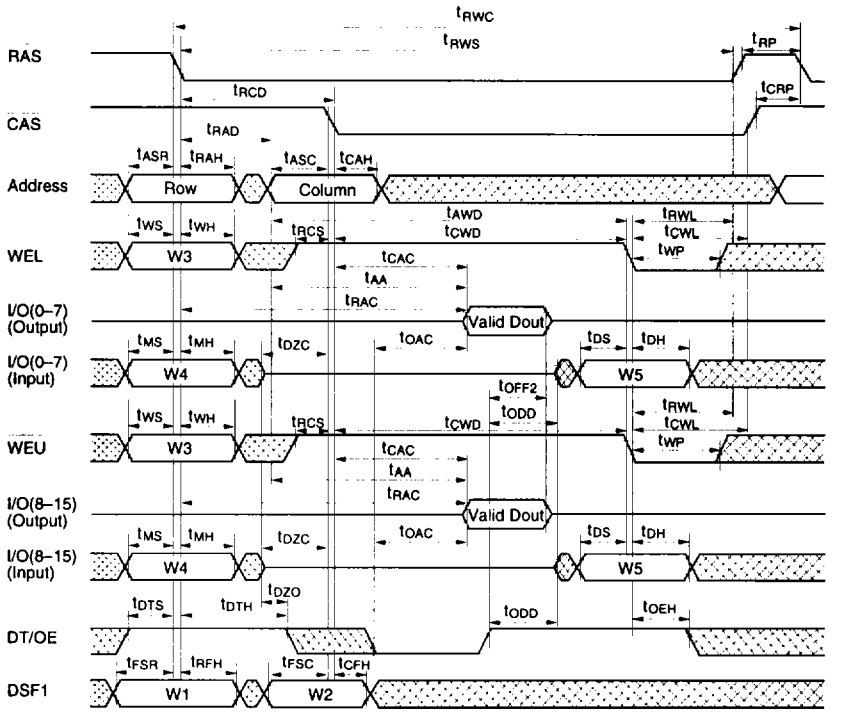
W1 to W5: See write cycle state table for the logic states

Fast/Hyper Page Mode Write Cycle (Delayed Write)



W1 to W5: See write cycle state table for the logic states

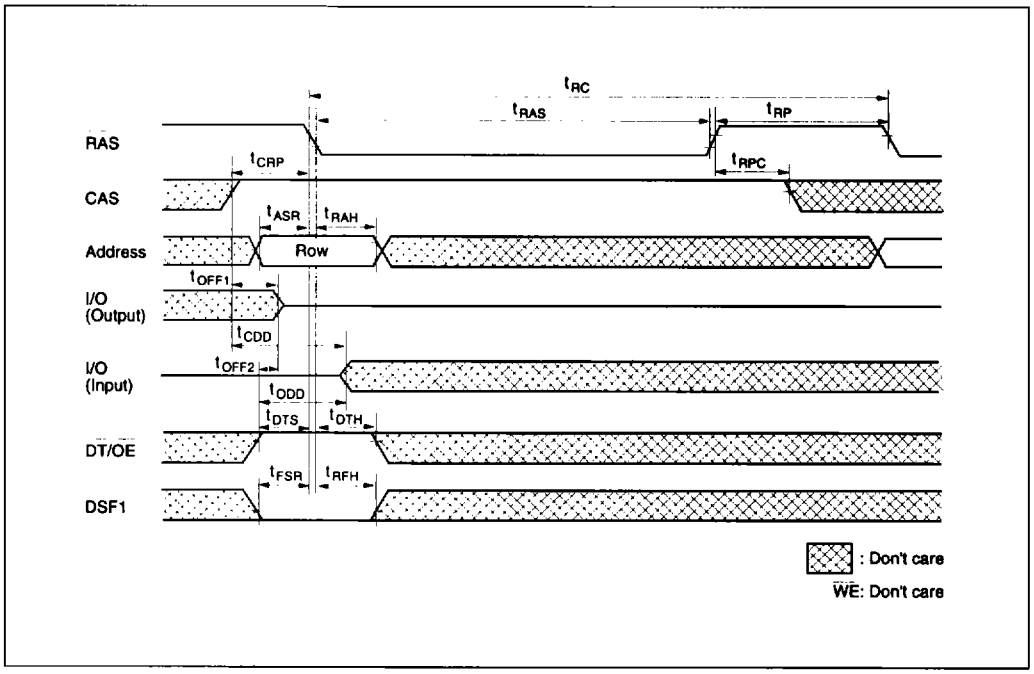
Read-Modify-Write Cycle



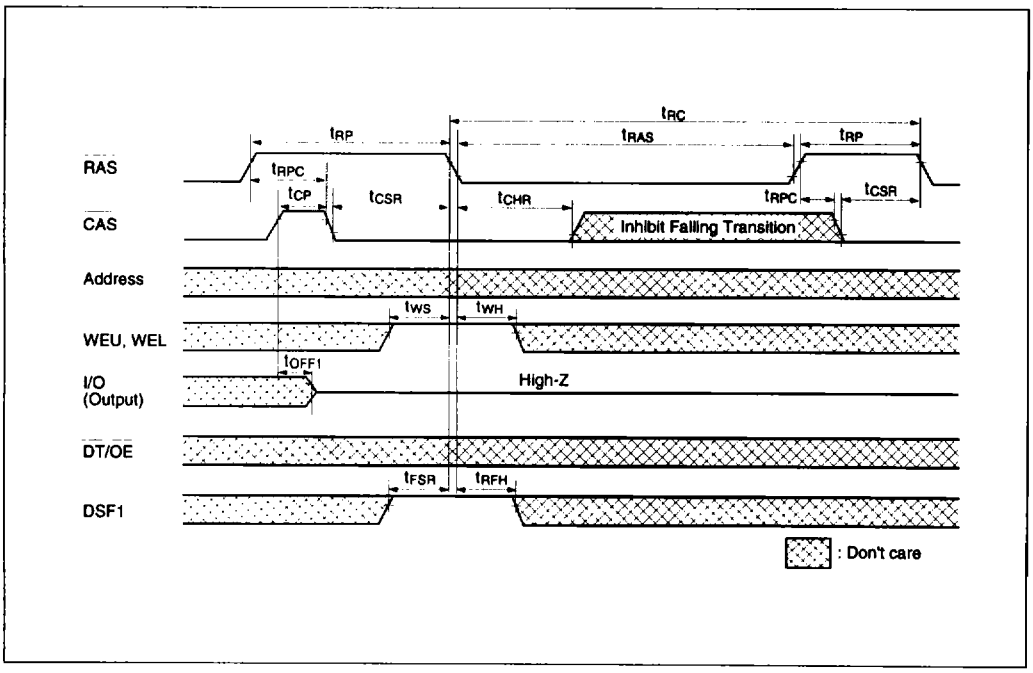
W1 to W5: See write cycle state table for the logic states

: Don't care

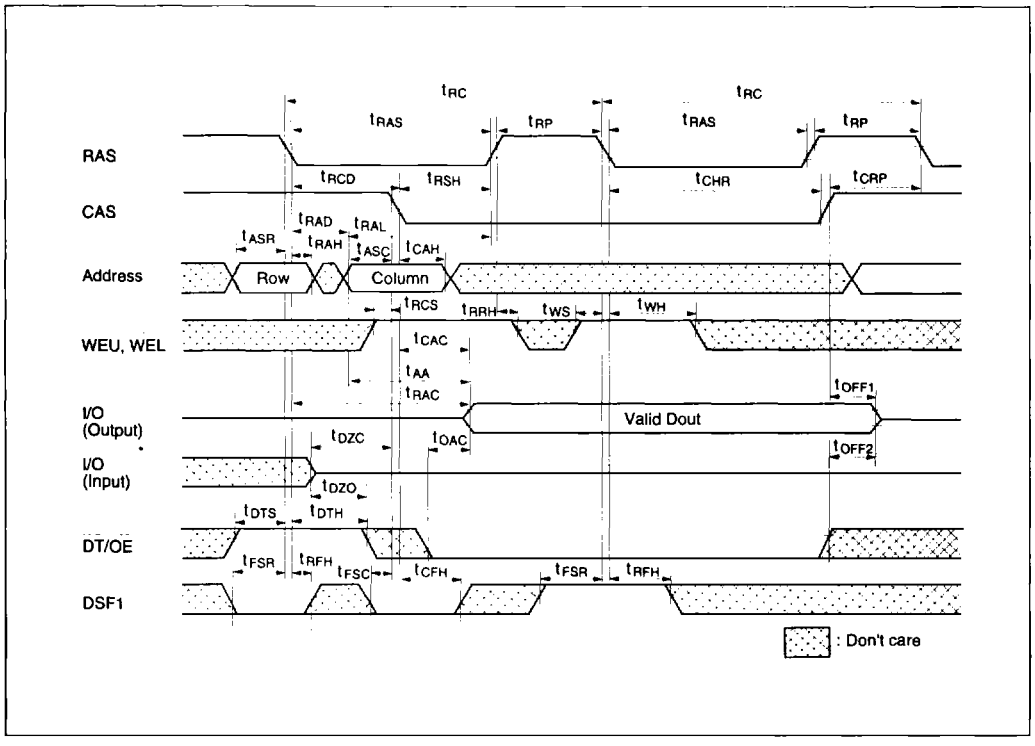
$\overline{\text{RAS}}$-Only Refresh Cycle (HM5316123)



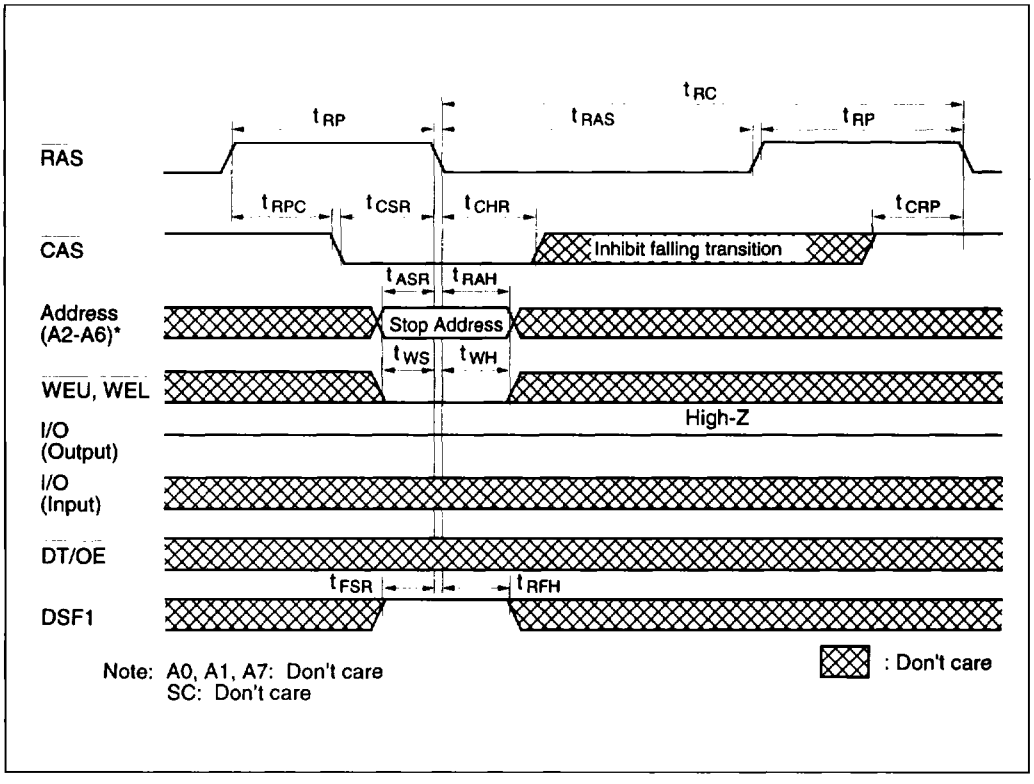
$\overline{\text{CAS}}$-Before-$\overline{\text{RAS}}$ Refresh Cycle (CBRN) (HM5316123)



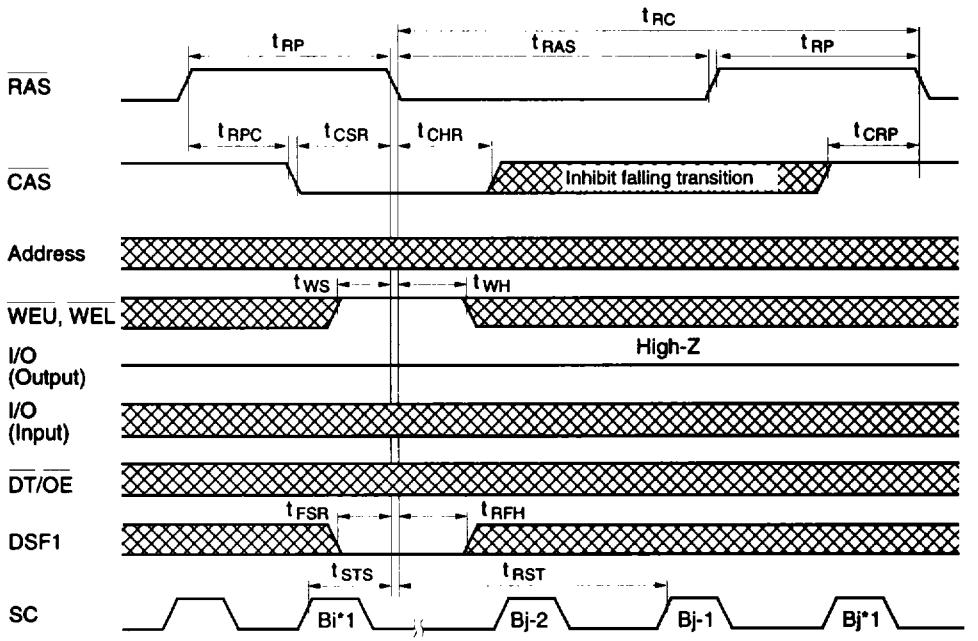
Hidden Refresh Cycle (HM5316123)



$\overline{\text{CAS}}$-Before-$\overline{\text{RAS}}$ Set Cycle (CBRS)



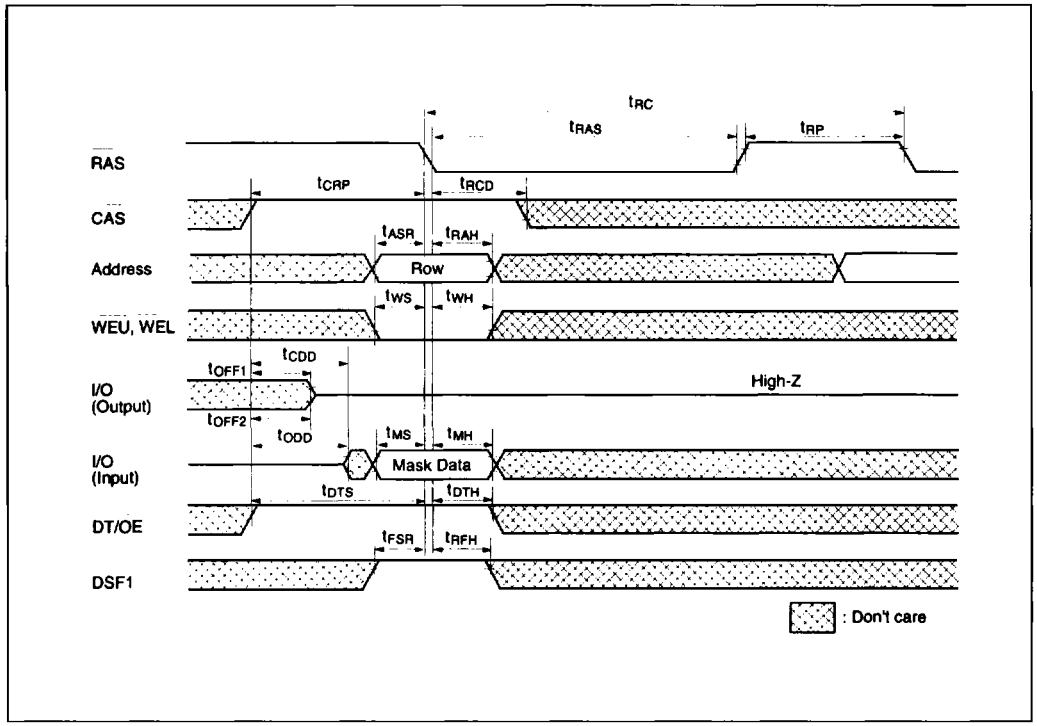
$\overline{\text{CAS}}$-Before-$\overline{\text{RAS}}$ Reset Cycle (CBRR)



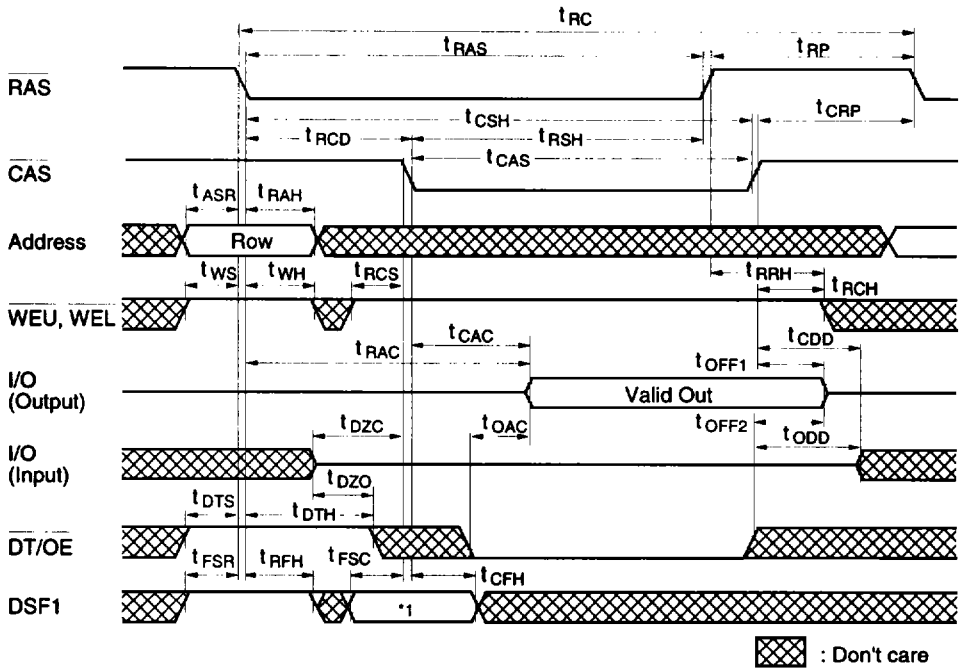
Note: 1. Bi, Bj initiate the boundary addresses.

: Don't care

Flash Write Cycle (HM5316123)



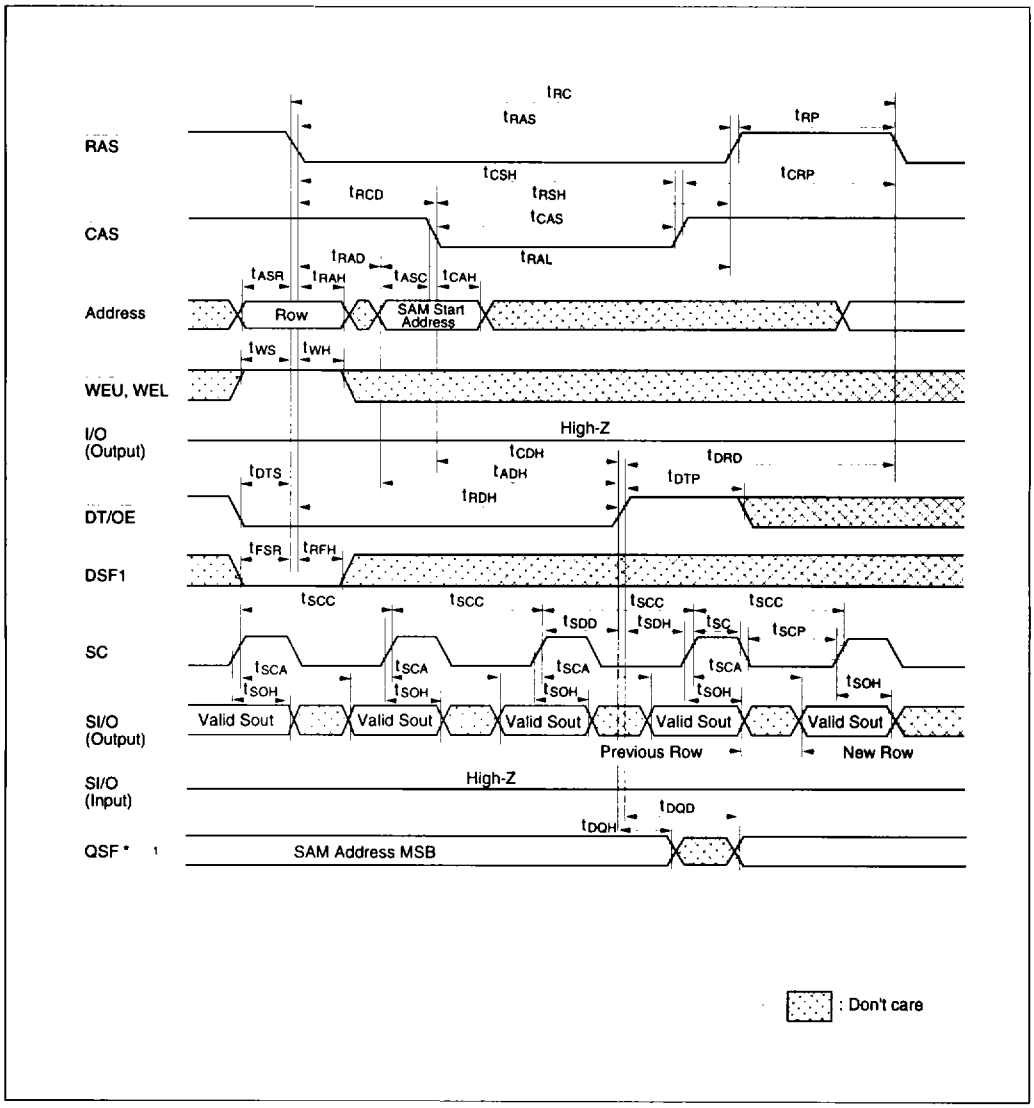
Register Read Cycle (Mask Data, Color Data) (HM5316123)



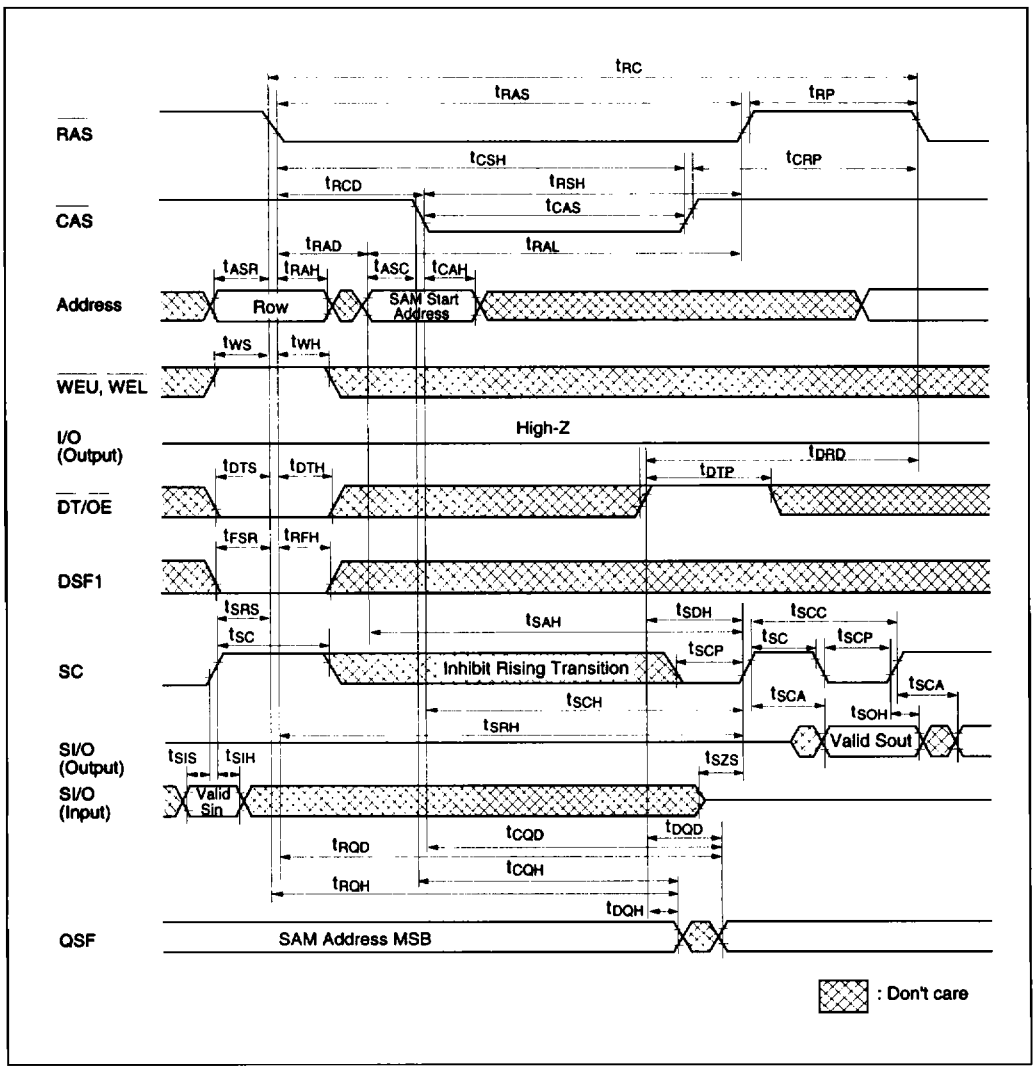
Note: 1. State of DSF1 at falling edge of $\overline{CAS}$

State	0	1
Accessed data	Mask data (LMR)	Color data (LCR)

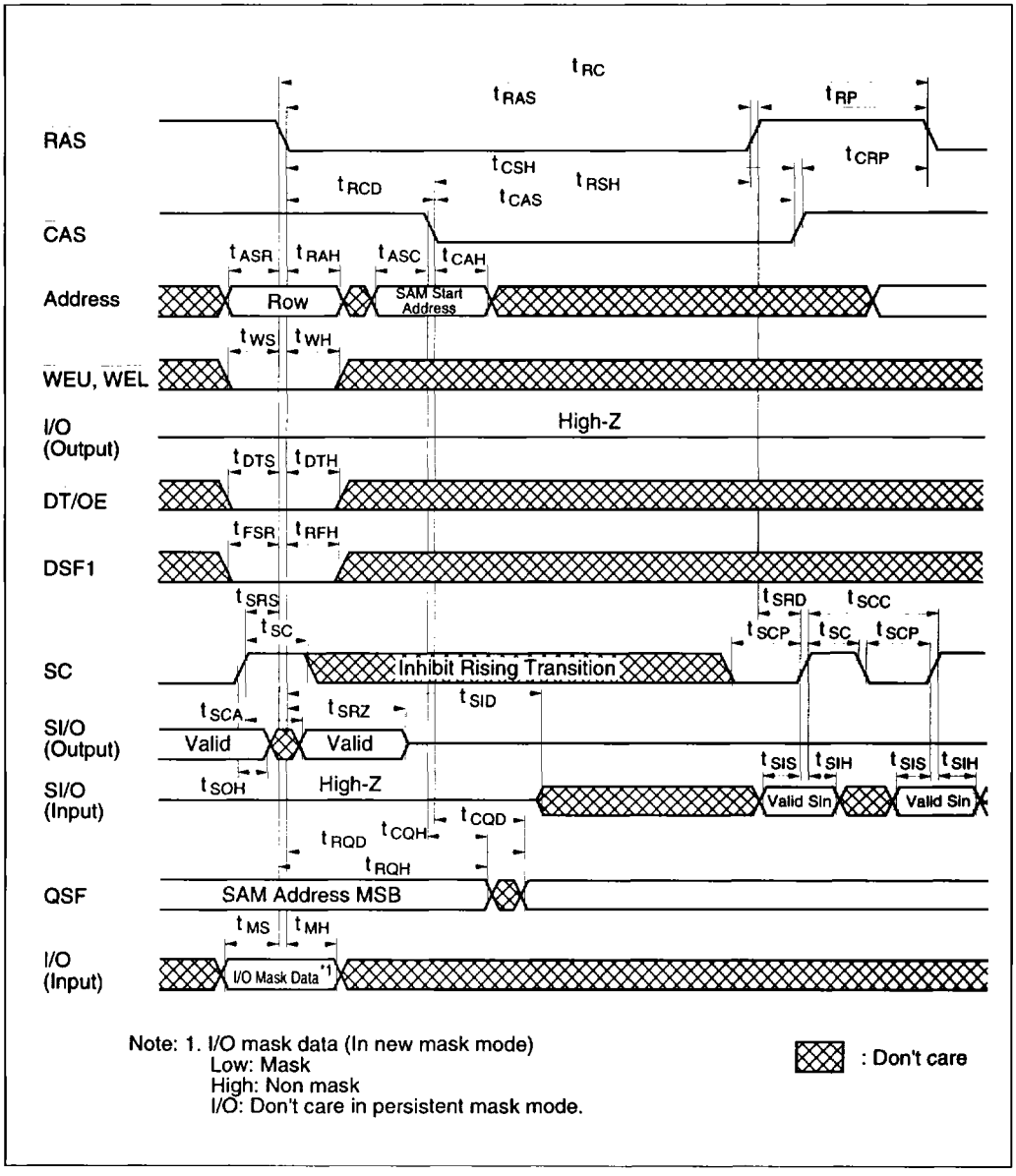
Read Transfer Cycle 1



Read Transfer Cycle 2



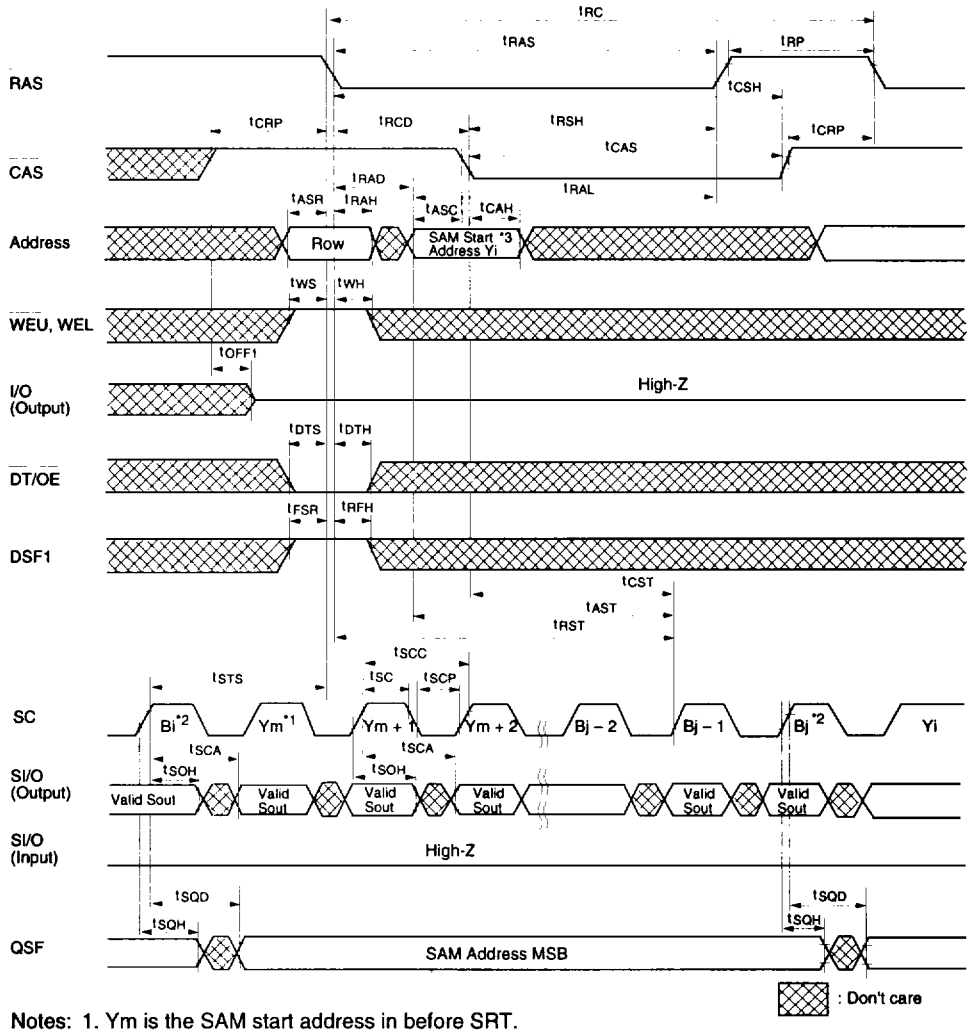
Masked Write Transfer Cycle



Note: 1. I/O mask data (In new mask mode)
Low: Mask
High: Non mask
I/O: Don't care in persistent mask mode.

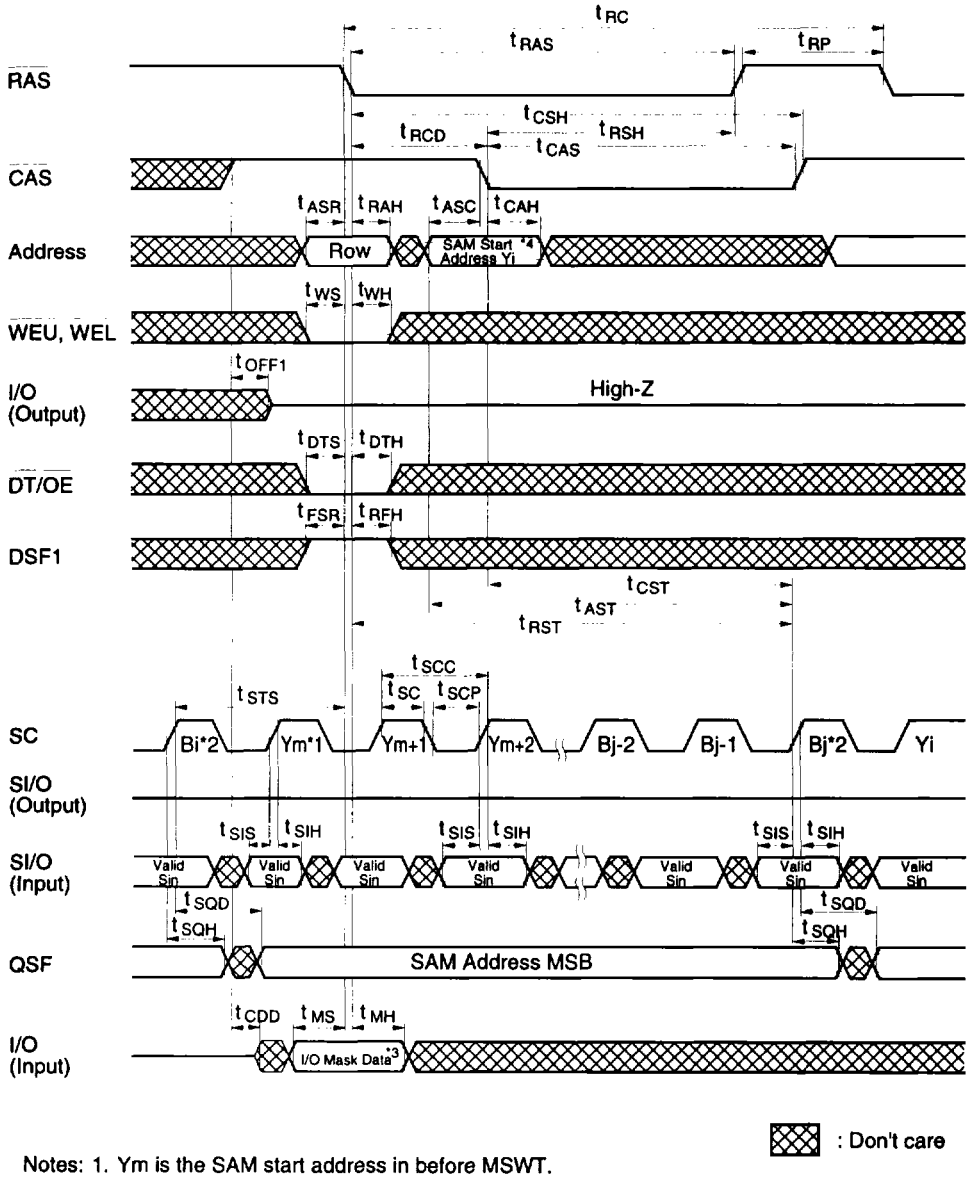
: Don't care

Split Read Transfer Cycle (HM5316123)



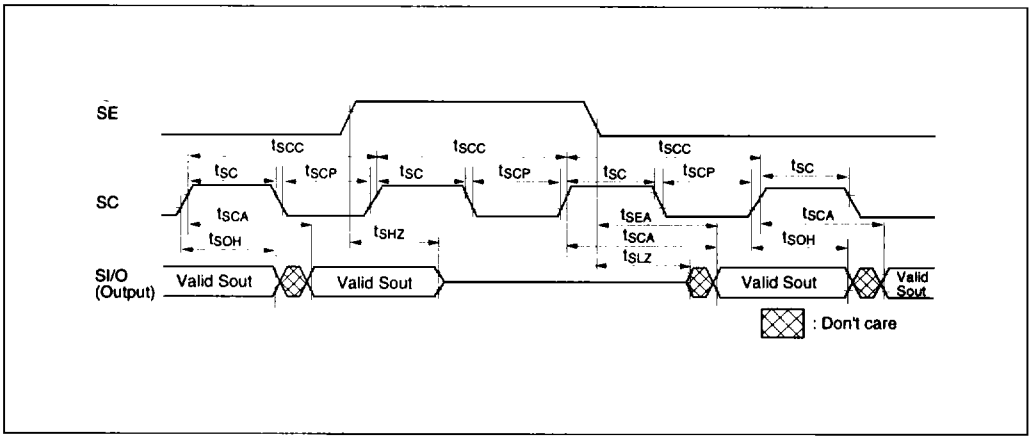
Notes: 1. Ym is the SAM start address in before SRT.
2. Bi, Bj initiate the boundary address.
3. A7: Don't care.

Masked Split Write Transfer Cycle (HM5316123)

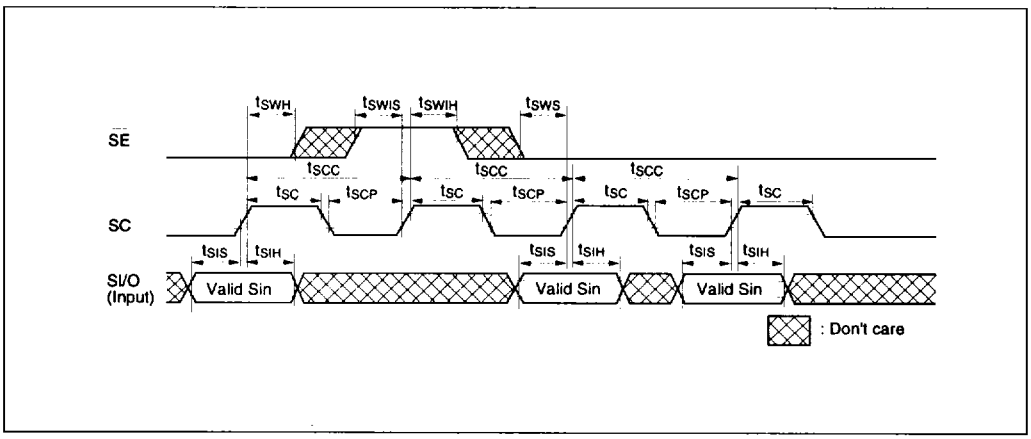


Notes: 1. Ym is the SAM start address in before MSWT.
2. Bi, Bj initiate the boundary address.
3. I/O Mask data (In new mask mode)
Low: Mask
High: Non mask
I/O: Don't care in persistent mask mode.
4. A7: Don't care.

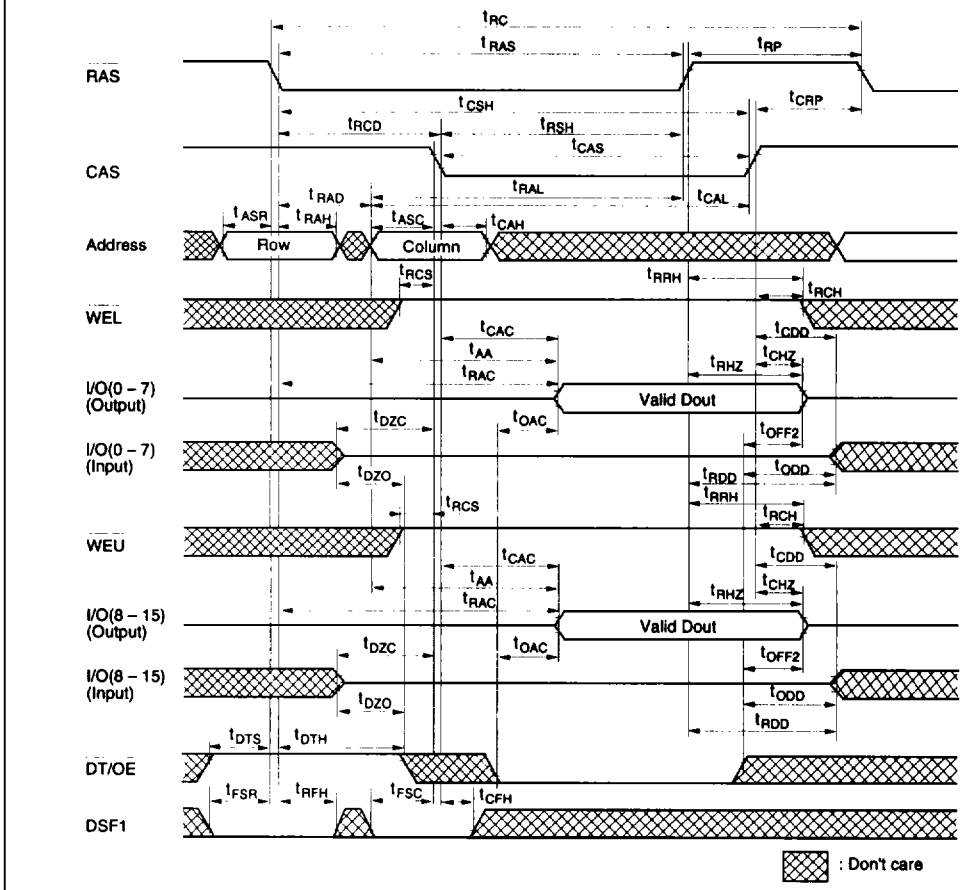
Serial Read Cycle



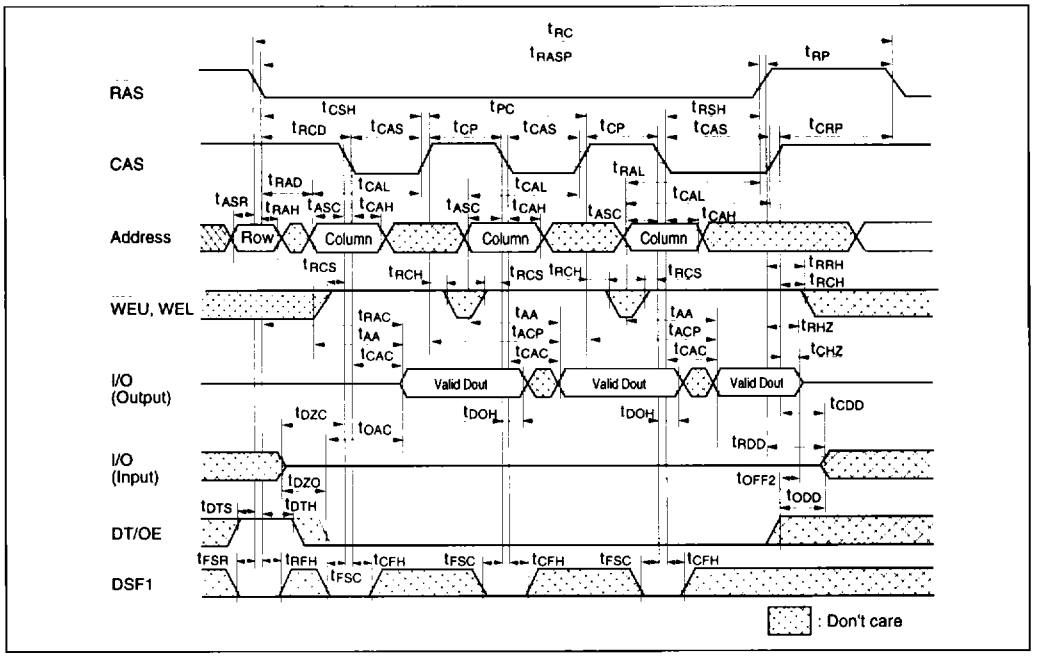
Serial Write Cycle



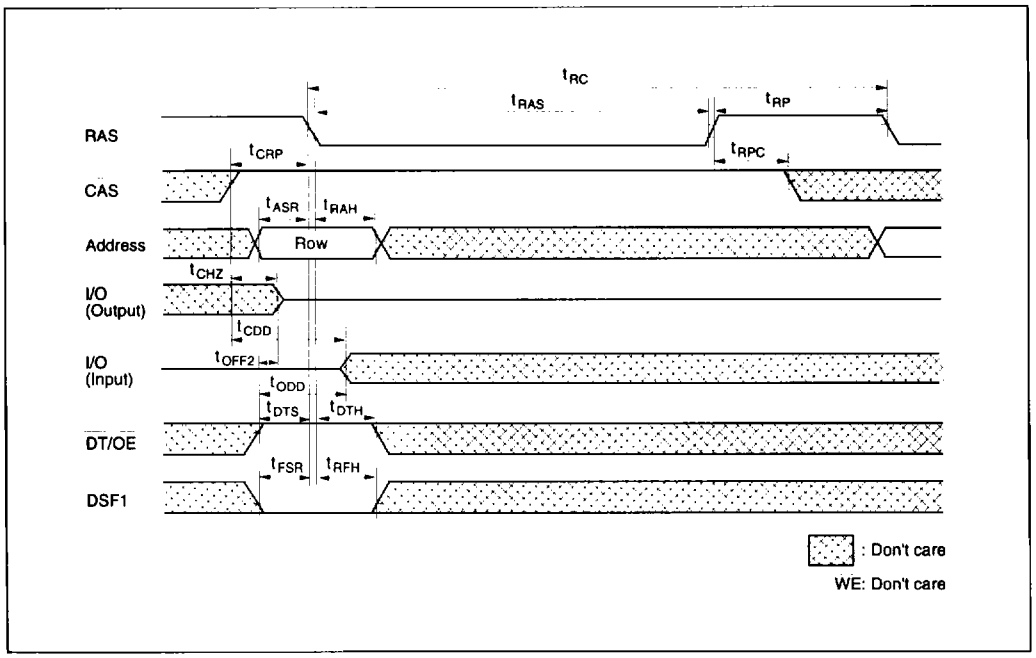
Read Cycle (HM5316124)



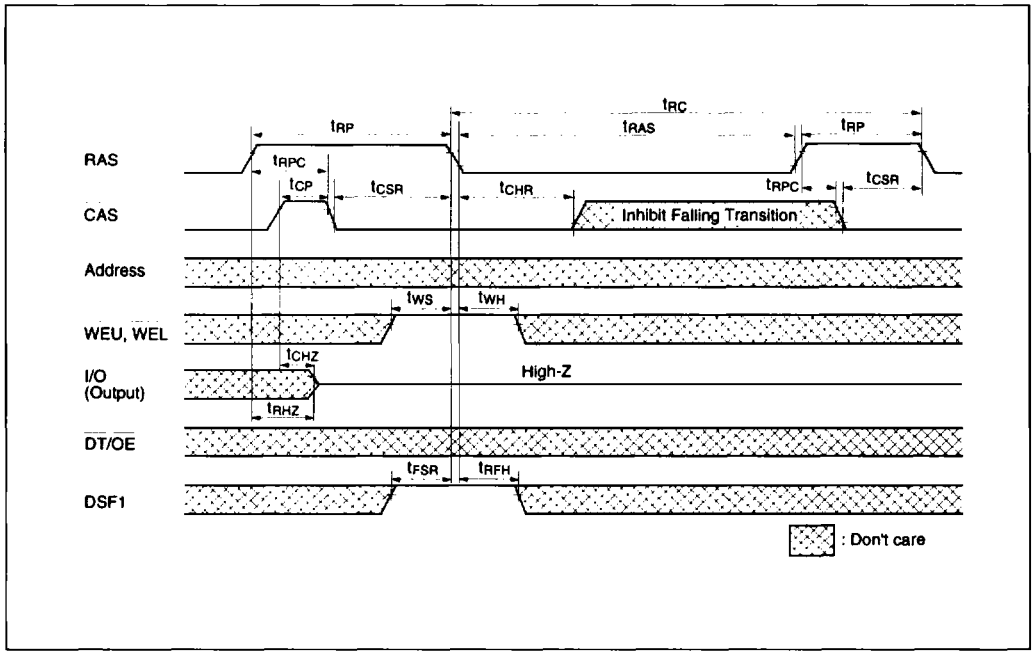
Hyper Page Mode Read Cycle (HM5316124)



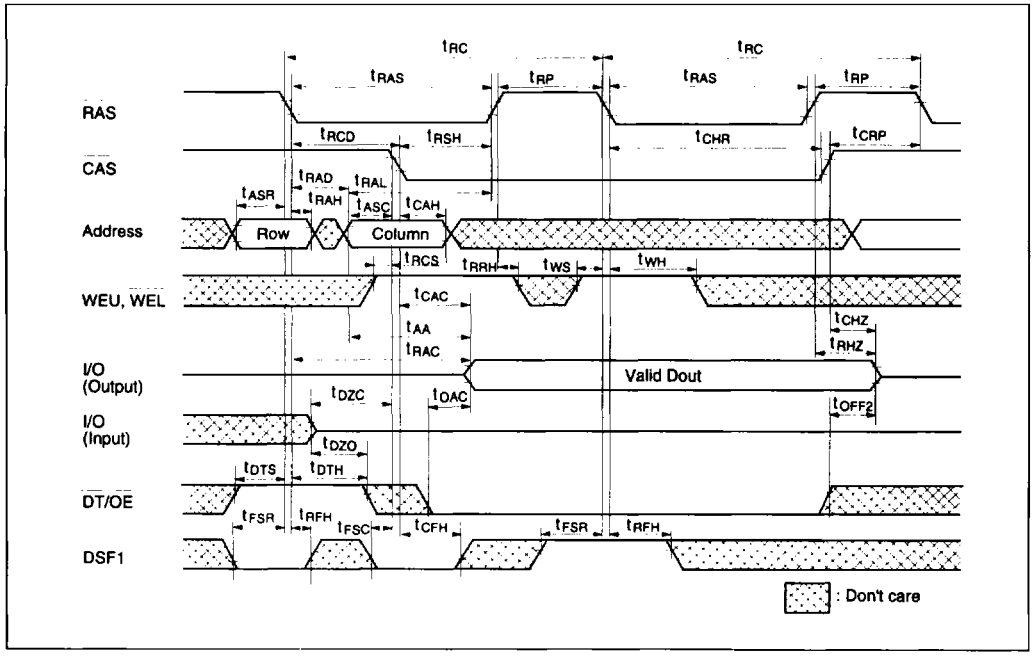
$\overline{\text{RAS}}$-Only Refresh Cycle (HM5316124)



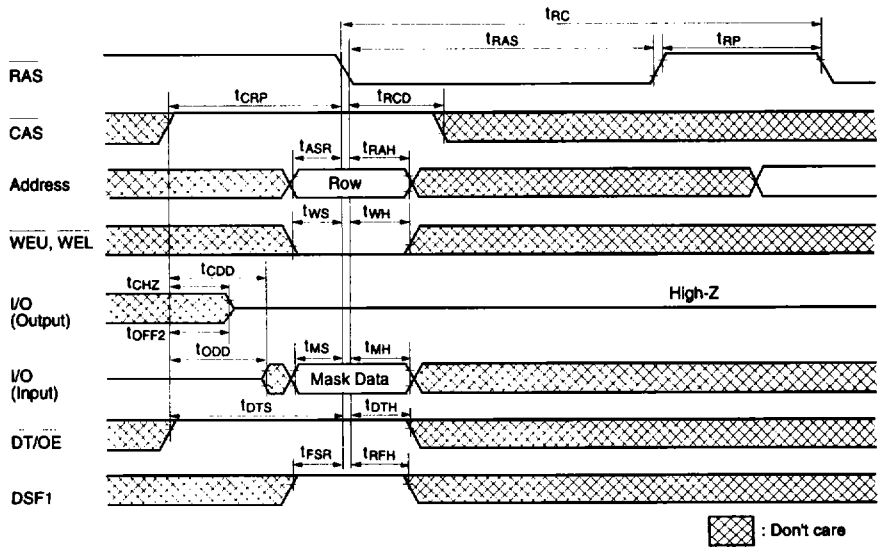
$\overline{\text{CAS}}$-Before-$\overline{\text{RAS}}$ Refresh Cycle (CBRN) (HM5316124)



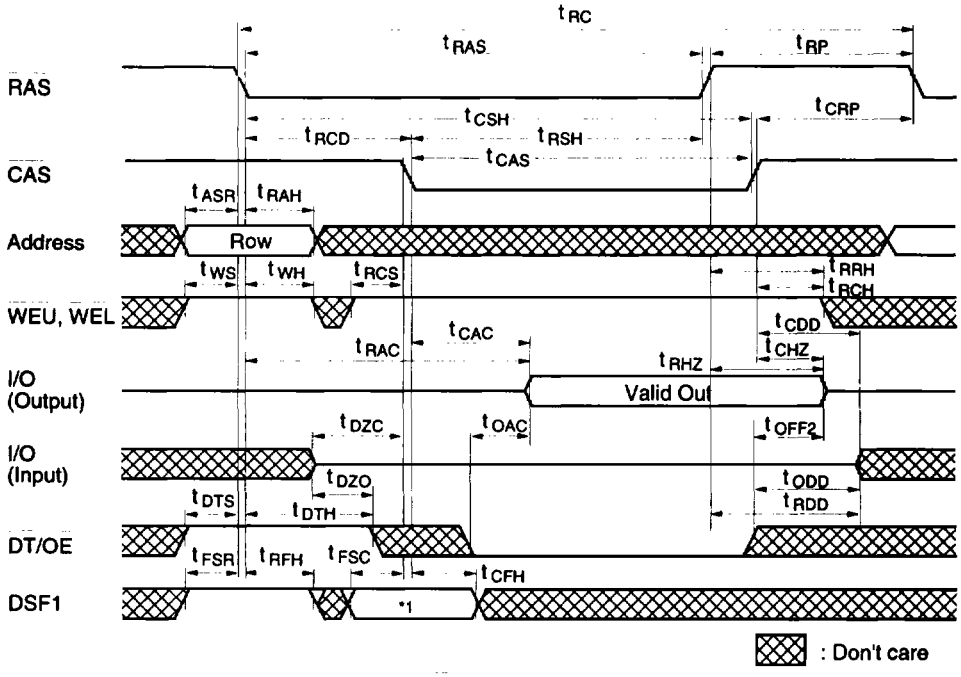
Hidden Refresh Cycle (HM5316124)



Flash Write Cycle (HM5316124)



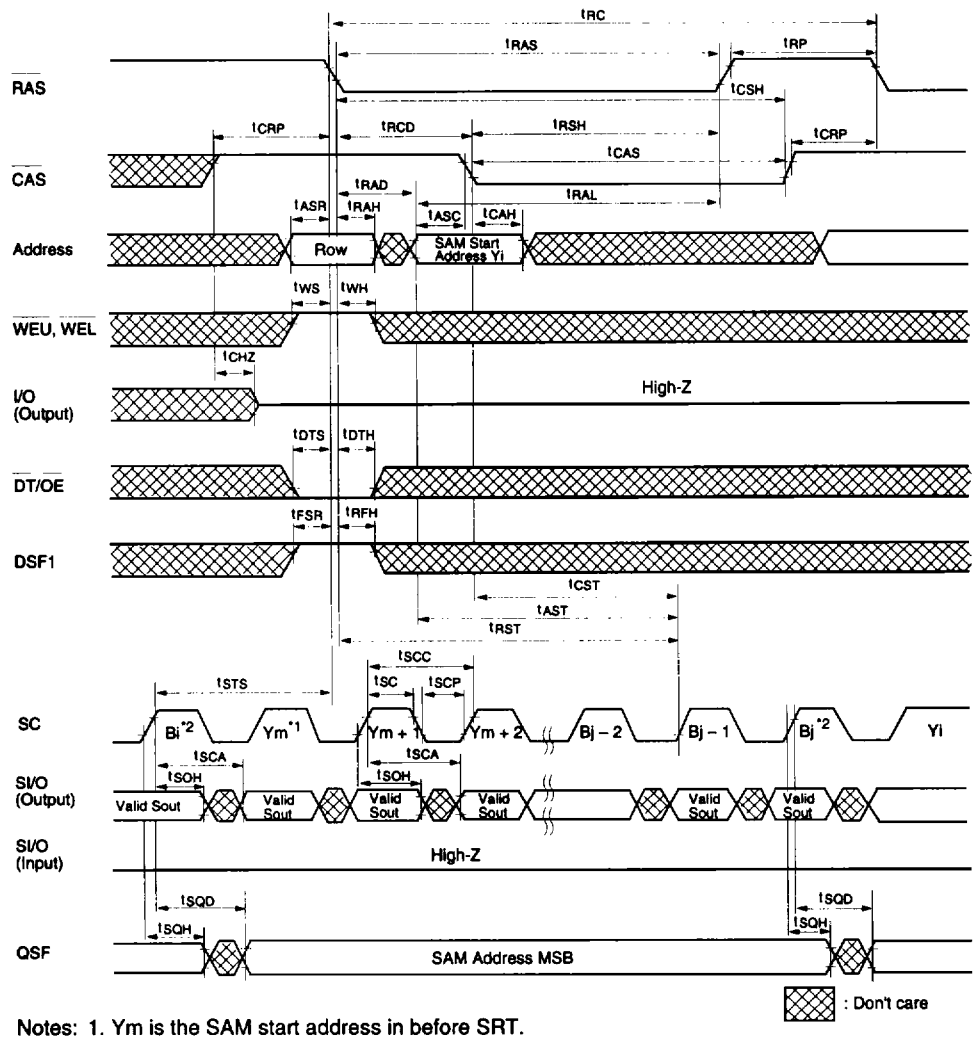
Register Read Cycle (Mask data, Color data) (HM5316124)



Note: 1. State of DSF1 at falling edge of CAS

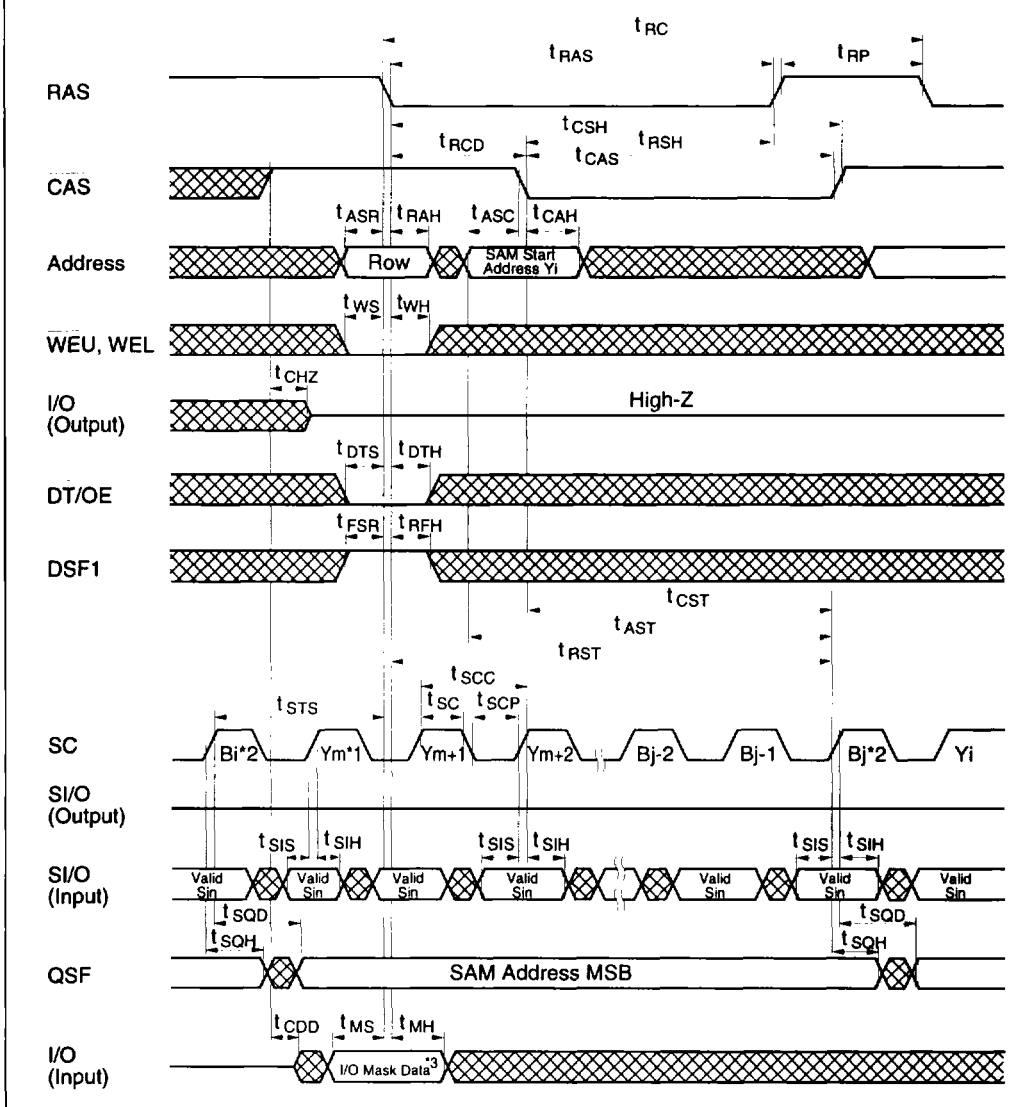
State	0	1
Accessed data	Mask data (LMR)	Color data (LCR)

Split Read Transfer Cycle (HM5316124)



Notes: 1. Ym is the SAM start address in before SRT.
2. Bi, Bj initiate the boundary address.

Masked Split Write Transfer Cycle (HM5316124)



Notes: 1. Ym is the SAM start address in before MSWT.
2. Bi, Bj initiate the boundary address.
3. I/O Mask data (In new mask mode)
Low: Mask
High: Non mask
I/O: Don't care in persistent mask mode.