# FM1608
## *64Kb Bytewide F-RAM Memory*

## Features

**64K bit Ferroelectric Nonvolatile RAM**
- Organized as 8,192 x 8 bits
- High Endurance 1 Trillion ($10^{12}$) Read/Writes
- 45 year Data Retention
- NoDelay™ Writes
- Advanced High-Reliability Ferroelectric Process

**Superior to BBSRAM Modules**
- No battery concerns
- Monolithic reliability
- True surface mount solution, no rework steps
- Superior for moisture, shock, and vibration
- Resistant to negative voltage undershoots

**SRAM & EEPROM Compatible**
- JEDEC 8Kx8 SRAM & EEPROM pinout
- 120 ns Access Time
- 180 ns Cycle Time

**Low Power Operation**
- 15 mA Active Current
- 20 µA Standby Current

**Industry Standard Configuration**
- Industrial Temperature -40° C to +85° C
- 28-pin SOIC or DIP
- "Green"/RoHS Packaging



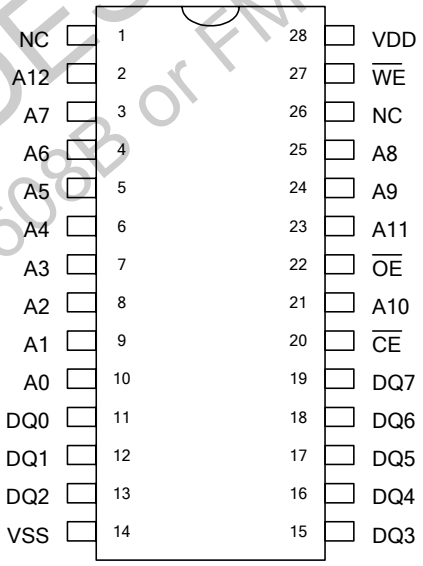
## Description

The FM1608 is a 64-kilobit nonvolatile memory employing an advanced ferroelectric process. A ferroelectric random access memory or F-RAM is nonvolatile but operates in other respects as a RAM. It provides data retention for 45 years while eliminating the reliability concerns, functional disadvantages and system design complexities of battery-backed SRAM. Its fast write and high write endurance make it superior to other types of nonvolatile memory.

In-system operation of the FM1608 is very similar to other RAM based devices. Minimum read- and write-cycle times are equal. The F-RAM memory, however, is nonvolatile due to its unique ferroelectric memory process. Unlike BBSRAM, the FM1608 is a truly monolithic nonvolatile memory. It provides the same functional benefits of a fast write without the serious disadvantages associated with modules and batteries or hybrid memory solutions.

These capabilities make the FM1608 ideal for nonvolatile memory applications requiring frequent or rapid writes in a bytewide environment. The availability of a true surface-mount package improves the manufacturability of new designs, while the DIP package facilitates simple design retrofits. The FM1608 offers guaranteed operation over an industrial temperature range of -40°C to +85°C.

**Pin Configuration**




| Ordering Information | |
|---|---|
| FM1608-120-PG | 120 ns access, 28-pin "Green" DIP |
| FM1608-120-SG | 120 ns access, 28-pin "Green" SOIC |

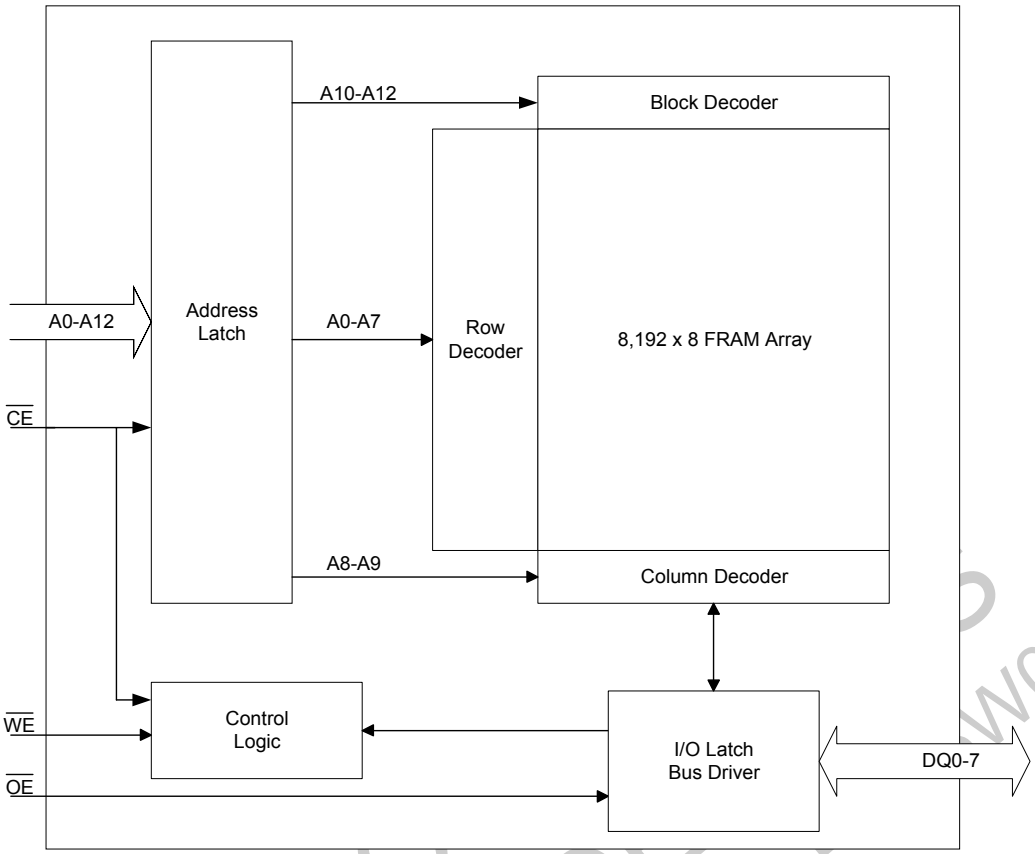



**Figure 1. Block Diagram**

**Pin Description**

| Pin Name | I/O | Pin Description |
|---|---|---|
| A0-A12 | Input | Address: The 13 address inputs select one of 8,192 bytes in the F-RAM array. The address value will be latched on the falling edge of /CE. |
| DQ0-7 | I/O | Data: 8-bit bi-directional data bus for accessing the F-RAM array. |
| /CE | Input | Chip Enable: /CE selects the device when low. Asserting /CE low causes the address to be latched internally. Address changes that occur after /CE goes low will be ignored until the next falling edge occurs. |
| /OE | Input | Output Enable: Asserting /OE low causes the FM1608 to drive the data bus when valid data is available. Deasserting /OE high causes the DQ pins to be tri-stated. |
| /WE | Input | Write Enable: Asserting /WE low causes the FM1608 to write the contents of the data bus to the address location latched by the falling edge of /CE. |
| VDD | Supply | Supply Voltage: 5V |
| VSS | Supply | Ground. |

**Functional Truth Table**

| /CE | /WE | Function |
|---|---|---|
| H | X | Standby/Precharge |
| ↓ | X | Latch Address (and Begin Write if /WE=low) |
| L | H | Read |
| L | ↓ | Write |

Note: The /OE pin controls only the DQ output buffers.

## Overview

The FM1608 is a bytewide F-RAM memory. The memory array is logically organized as 8,192 x 8 and is accessed using an industry standard parallel interface. The FM1608 is inherently nonvolatile via its unique ferroelectric process. All data written to the part is immediately nonvolatile with no delay. Functional operation of the F-RAM memory is the same as SRAM type devices, except the FM1608 requires a falling edge of /CE to start each memory cycle.

## Memory Architecture

Users access 8,192 memory locations each with 8 data bits through a parallel interface. The 13-bit address specifies each of the 8,192 bytes uniquely. Internally, the memory array is organized into 8 blocks of 1Kb each. The 3 most-significant address inputs decode one of 8 blocks. This block segmentation has no effect on operation, however the user may wish to group data into blocks by its endurance requirements as explained in a later section.

The cycle time is the same for read and write memory operations. This simplifies memory controller logic and timing circuits. Likewise the access time is the same for read and write memory operations. When /CE is deasserted high, a precharge operation begins, and is required of every memory cycle. Thus unlike SRAM, the access and cycle times are not equal. Writes occur immediately at the end of the access with no delay. Unlike an EEPROM, it is not necessary to poll the device for a ready condition since writes occur at bus speed.

Note that the FM1608 has no special power-down demands. It will not block user access, and it contains no power-management circuits other than a simple internal power-on reset. It is the user's responsibility to ensure that VDD is within datasheet tolerances and to ensure the proper voltage level and timing relationship between VDD and /CE in power-up and power-down events to prevent incorrect operation.

## Memory Operation

The FM1608 is designed to operate in a manner very similar to other bytewide memory products. For users familiar with BBSRAM, the performance is comparable but the bytewide interface operates in a slightly different manner as described below. For users familiar with EEPROM, the obvious differences result from the higher write performance of F-RAM technology including NoDelay writes and much higher write endurance.

### Read Operation

A read operation begins on the falling edge of /CE. At this time, the address bits are latched and a memory cycle is initiated. Once started, a complete memory cycle must be completed internally regardless of the state of /CE. Data becomes available on the bus after the access time has been satisfied.

After the address has been latched, the address value may change upon satisfying the hold time parameter. Unlike an SRAM, changing address values will have no effect on the memory operation after the address is latched.

The FM1608 will drive the data bus when /OE is asserted low. If /OE is asserted after the memory access time has been satisfied, the data bus will be driven with valid data. If /OE is asserted prior to completion of the memory access, the data bus will not be driven until valid data is available. This feature minimizes supply current in the system by eliminating transients caused by invalid data being driven onto the bus. When /OE is inactive the data bus will remain tri-stated.

### Write Operation

Writes occur in the FM1608 within the same time interval as reads. The FM1608 supports both /CE- and /WE-controlled write cycles. In both cases, the address is latched on the falling edge of /CE.

In a /CE-controlled write, the /WE signal is asserted prior to beginning the memory cycle. That is, /WE is low when /CE falls. In this case, the part begins the memory cycle as a write. The FM1608 will not drive the data bus regardless of the state of /OE.

In a /WE-controlled write, the memory cycle begins on the falling edge of /CE. The /WE signal falls after the falling edge of /CE. Therefore the memory cycle begins as a read. The data bus will be driven according to the state of /OE until /WE falls. The timing of both /CE- and /WE-controlled write cycles is shown in the Electrical Specifications section.

Write access to the array begins asynchronously after the memory cycle is initiated. The write access terminates on the rising edge of /WE or /CE, whichever is first. Data set-up time, as shown in the electrical specifications, indicates the interval during which data cannot change prior to the end of the write access.

Unlike other truly nonvolatile memory technologies, there is no write delay with F-RAM. Since the read and write access times of the underlying memory are the same, the user experiences no delay through the bus. The entire memory operation occurs in a single bus cycle. Therefore, any operation including read or write can occur immediately following a write. Data polling, a technique used with EEPROMs to determine if a write is complete, is unnecessary.

**Precharge Operation**

The precharge operation is an internal condition that prepares the memory for a new access. All memory cycles consist of a memory access and a precharge. The precharge is initiated by deasserting the /CE pin high. It must remain high for at least the minimum precharge time $t_{PC}$.

The user dictates the beginning of this operation since a precharge will not begin until /CE rises. However the device has a maximum /CE low time specification that must be satisfied.

## Endurance

The FM1608 internally operates with a read and restore mechanism. Therefore, each read and write cycle involves a change of state. The memory architecture is based on an array of rows and columns. Each read or write access causes an endurance cycle for an entire row. In the FM1608, a row is 32 bits wide. Every 4-byte boundary marks the beginning of a new row. Endurance can be optimized by ensuring frequently accessed data is located in different rows. Regardless, F-RAM offers substantially higher write endurance than other nonvolatile memories. The rated endurance limit of $10^{12}$ cycles will allow 3000 accesses per second to the same row for 10 years.

## F-RAM Design Considerations

When designing with F-RAM for the first time, users of SRAM will recognize a few minor differences. First, bytewide F-RAM memories latch each address on the falling edge of chip enable. This allows the address bus to change after starting the memory access. Since every access latches the memory address on the falling edge of /CE, users cannot ground it as they might with SRAM.

Users who are modifying existing designs to use F-RAM should examine the memory controller for timing compatibility of address and control pins. Each memory access must be qualified with a low transition of /CE. In many cases, this is the only change required. An example of the signal relationships is shown in Figure 2 below. Also shown is a common SRAM signal relationship that will not work for the FM1608.

The reason for /CE to strobe for each address is two-fold: it latches the new address and creates the necessary precharge period while /CE is high.

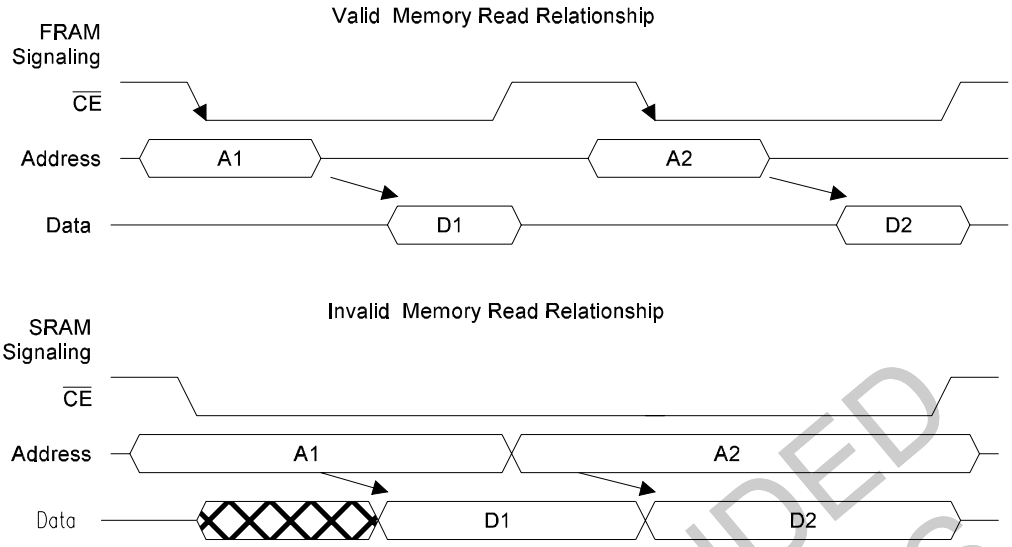



**Figure 2. Memory Address and /CE Relationships**

A second design consideration relates to the level of $V_{DD}$ during operation. Battery-backed SRAMs are designed to monitor $V_{DD}$ in order to switch to battery backup. They typically block user access below a certain $V_{DD}$ level in order to minimize battery drain from an otherwise active SRAM. The user can be abruptly cut off from access to the memory in a power down situation without warning.

F-RAM memories do not need this system overhead. The memory will not block access at any $V_{DD}$ level. The user, however, should prevent the processor from accessing memory when $V_{DD}$ is out-of-tolerance. The common design practice of holding a processor in reset during powerdown may be sufficient. It is recommended that Chip Enable is pulled high and allowed to track $V_{DD}$ during powerup and powerdown cycles. It is the user's responsibility to ensure that chip enable is high to prevent accesses below $V_{DD}$ min. (4.5V). Figure 3 shows a pullup resistor on /CE which will keep the pin high during power cycles assuming the MCU/MPU pin tri-states during the reset condition. The pullup resistor value should be chosen to ensure the /CE pin tracks $V_{DD}$ yet a high enough value that the current drawn when /CE is low is not an issue.

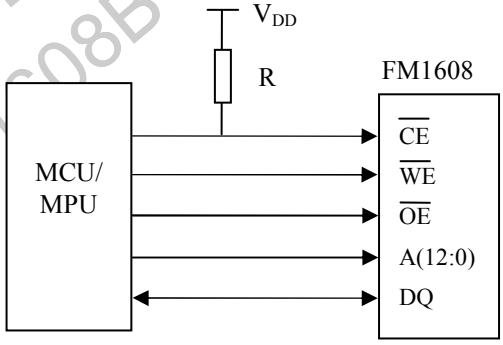



**Figure 3. Use of Pullup Resistor on /CE**

## Electrical Specifications

### Absolute Maximum Ratings

| Symbol | Description | Ratings |
|---|---|---|
| $V_{DD}$ | Power Supply Voltage with respect to $V_{SS}$ | -1.0V to +7.0V |
| $V_{IN}$ | Voltage on any pin with respect to $V_{SS}$ | -1.0V to +7.0V<br>and $V_{IN} < V_{DD}$+1.0V |
| $T_{STG}$ | Storage Temperature | -55°C to + 125°C |
| $T_{LEAD}$ | Lead temperature (Soldering, 10 seconds) | 300° C |
| $V_{ESD}$ | Electrostatic Discharge Voltage<br>- Human Body Model (JEDEC Std JESD22-A114-B)<br>- Machine Model (JEDEC Std JESD22-A115-A) | <br>4kV<br>300V |
| | Package Moisture Sensitivity Level | MSL-1 (-SG)[1]<br>MSL-2 (-SG)[2] |

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only, and the functional operation of the device at these or any other conditions above those listed in the operational section of this specification is not implied. Exposure to absolute maximum ratings conditions for extended periods may affect device reliability.

1. Applies to devices marked with date code 0627 and higher.
2. Applies to devices marked with date code prior to 0627.

### DC Operating Conditions ($T_A$ = -40° C to + 85° C, $V_{DD}$ = 4.5V to 5.5V unless otherwise specified)

| Symbol | Parameter | Min | Typ | Max | Units | Notes |
|---|---|---|---|---|---|---|
| $V_{DD}$ | Power Supply | 4.5 | 5.0 | 5.5 | V | |
| $I_{DD1}$ | VDD Supply Current – Active | | 5 | 15 | mA | 1 |
| $I_{SB1}$ | Standby Current – TTL | | | 400 | µA | 2 |
| $I_{SB2}$ | Standby Current – CMOS | | 7 | 20 | µA | 3 |
| $I_{LI}$ | Input Leakage Current | | | 10 | µA | 4 |
| $I_{LO}$ | Output Leakage Current | | | 10 | µA | 4 |
| $V_{IH}$ | Input High Voltage | 2.0 | | $V_{DD}$ + 0.3 | V | |
| $V_{IL}$ | Input Low Voltage | -0.3 | | 0.8 | V | |
| $V_{OH}$ | Output High Voltage ($I_{OH}$ = -2.0 mA) | 2.4 | | - | V | |
| $V_{OL}$ | Output Low Voltage ($I_{OL}$ = -4.2 mA) | - | | 0.4 | V | |

**Notes**

1. $V_{DD}$ = 5.5V, /CE cycling at minimum cycle time. All inputs at CMOS levels, all outputs unloaded.
2. $V_{DD}$ = 5.5V, /CE at $V_{IH}$, All other pins at TTL levels.
3. $V_{DD}$ = 5.5V, /CE at $V_{IH}$, All other pins at CMOS levels.
4. $V_{IN}$, $V_{OUT}$ between $V_{DD}$ and $V_{SS}$.

### Data Retention ($V_{DD}$ = 4.5V to 5.5V unless otherwise specified)

| Parameter | Min | Units | Notes |
|---|---|---|---|
| Data Retention | 45 | Years | |

**Read Cycle AC Parameters** ($T_A$ = -40° C to + 85° C, $V_{DD}$ = 4.5V to 5.5V unless otherwise specified)

| Symbol | Parameter | Min | Max | Units | Notes |
|---|---|---|---|---|---|
| $t_{CE}$ | Chip Enable Access Time ( to data valid) | | 120 | ns | |
| $t_{CA}$ | Chip Enable Active Time | 120 | 2,000 | ns | |
| $t_{RC}$ | Read Cycle Time | 180 | | ns | |
| $t_{PC}$ | Precharge Time | 60 | | ns | |
| $t_{AS}$ | Address Setup Time | 0 | | ns | |
| $t_{AH}$ | Address Hold Time | 10 | | ns | |
| $t_{OE}$ | Output Enable Access Time | | 10 | ns | |
| $t_{HZ}$ | Chip Enable to Output High-Z | | 15 | ns | 1 |
| $t_{OHZ}$ | Output Enable to Output High-Z | | 15 | ns | 1 |

**Write Cycle AC Parameters** ($T_A$ = -40° C to + 85° C, $V_{DD}$ = 4.5V to 5.5V unless otherwise specified)

| Symbol | Parameter | Min | Max | Units | Notes |
|---|---|---|---|---|---|
| $t_{CA}$ | Chip Enable Active Time | 120 | 2,000 | ns | |
| $t_{CW}$ | Chip Enable to Write High | 120 | | ns | |
| $t_{WC}$ | Write Cycle Time | 180 | | ns | |
| $t_{PC}$ | Precharge Time | 60 | | ns | |
| $t_{AS}$ | Address Setup Time | 0 | | ns | |
| $t_{AH}$ | Address Hold Time | 10 | | ns | |
| $t_{WP}$ | Write Enable Pulse Width | 40 | | ns | |
| $t_{DS}$ | Data Setup | 40 | | ns | |
| $t_{DH}$ | Data Hold | 0 | | ns | |
| $t_{WZ}$ | Write Enable Low to Output High Z | | 15 | ns | 1 |
| $t_{WX}$ | Write Enable High to Output Driven | 10 | | ns | 1 |
| $t_{HZ}$ | Chip Enable to Output High-Z | | 15 | ns | 1 |
| $t_{WS}$ | Write Setup | 0 | | ns | 2 |
| $t_{WH}$ | Write Hold | 0 | | ns | 2 |

**Notes**

1 This parameter is periodically sampled and not 100% tested.

2 The relationship between /CE and /WE determines if a /CE- or /WE-controlled write occurs. There is no timing specification associated with this relationship.

**Power Cycle Timing** ($T_A$ = -40° C to + 85° C, $V_{DD}$ = 4.5V to 5.5V unless otherwise specified)

| Symbol | Parameter | Min | Max | Units | Notes |
|---|---|---|---|---|---|
| $t_{PU}$ | $V_{DD}$(min) to First Access Start | 1 | - | µS | |
| $t_{PD}$ | Last Access Complete to $V_{DD}$(min) | 0 | - | µS | |

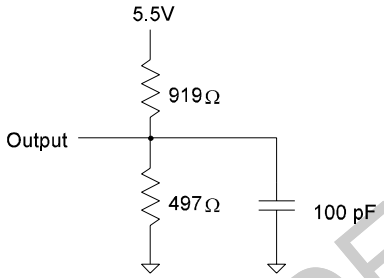
**Capacitance** ($T_A$ = 25° C , f=1.0 MHz, $V_{DD}$ = 5V)

| Symbol | Parameter | Max | Units | Notes |
|---|---|---|---|---|
| $C_{I/O}$ | Input/Output Capacitance (DQ) | 8 | pF | |
| $C_{IN}$ | Input Capacitance | 6 | pF | |

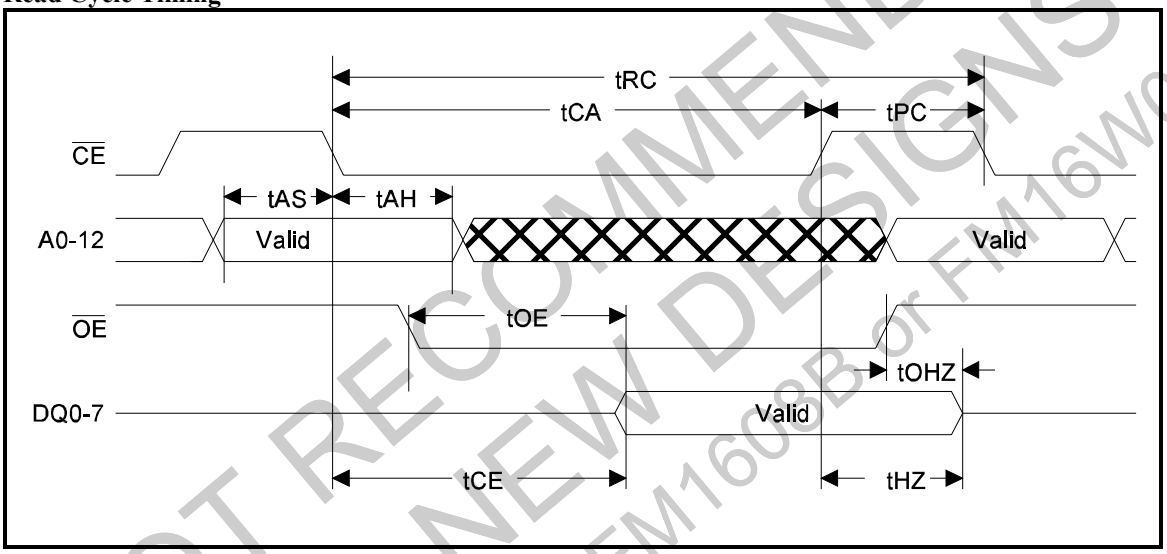
**AC Test Conditions**

| | |
|---|---|
| Input Pulse Levels | 0 to 3V |
| Input rise and fall times | 10 ns |
| Input and output timing levels | 1.5V |

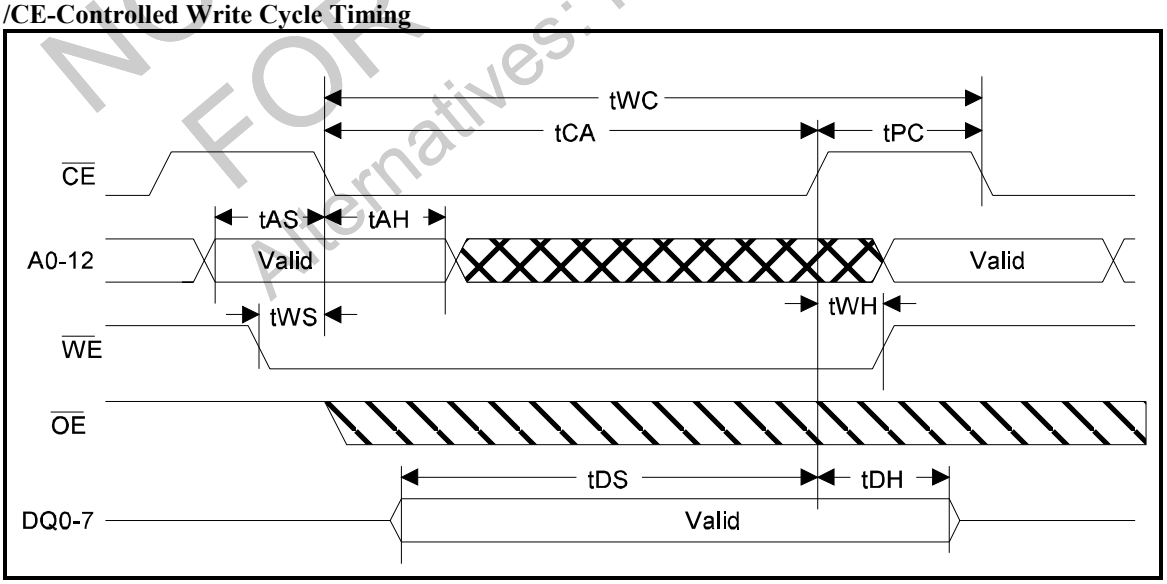
**Equivalent AC Load Circuit**



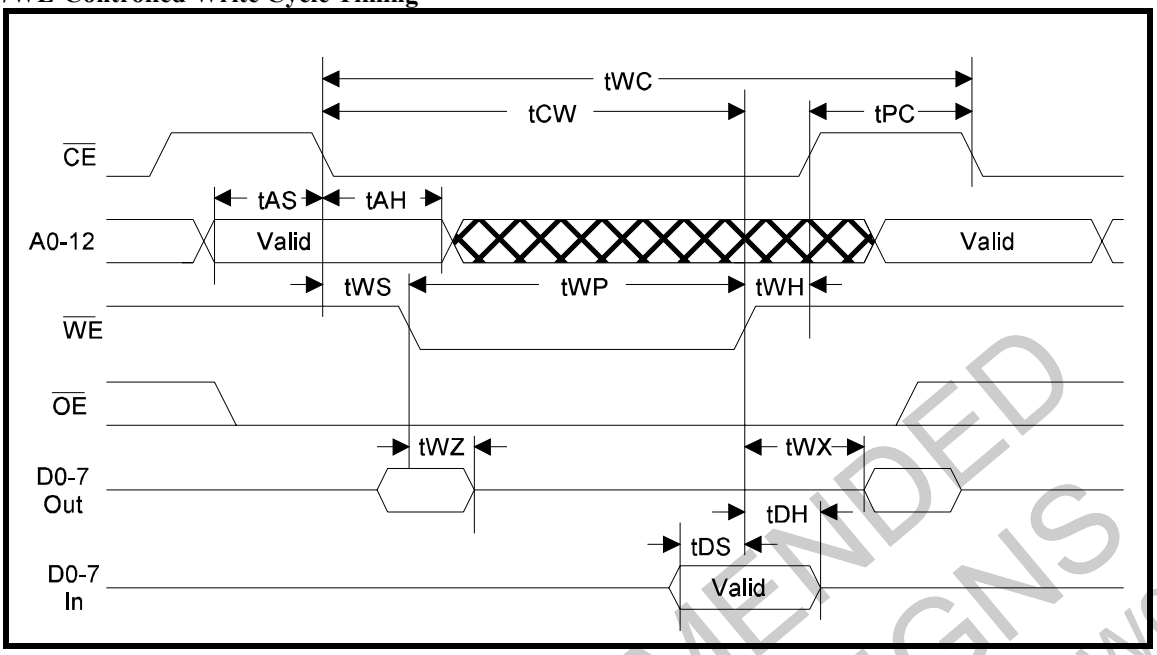

**Read Cycle Timing**



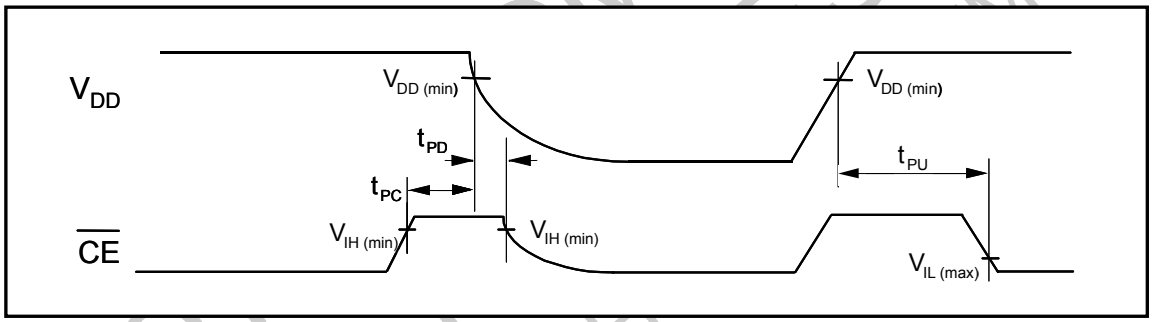

**/CE-Controlled Write Cycle Timing**



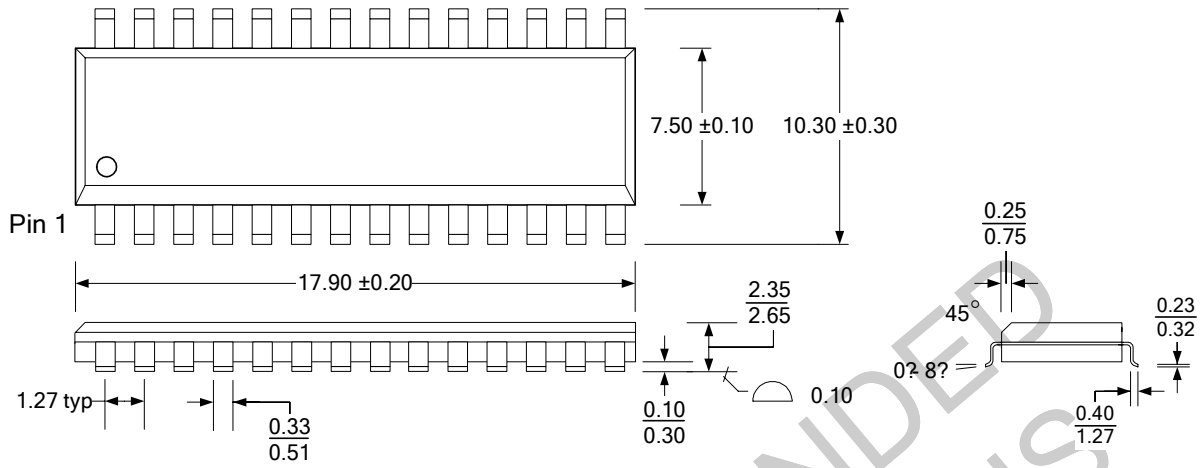
**/WE-Controlled Write Cycle Timing**



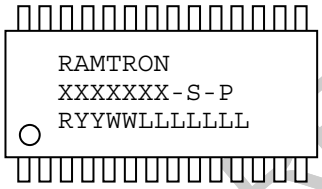

**Power Cycle Timing**



**28-pin SOIC (JEDEC MS-013 variation AE)**
*All dimensions in millimeters*




## SOIC Package Marking Scheme

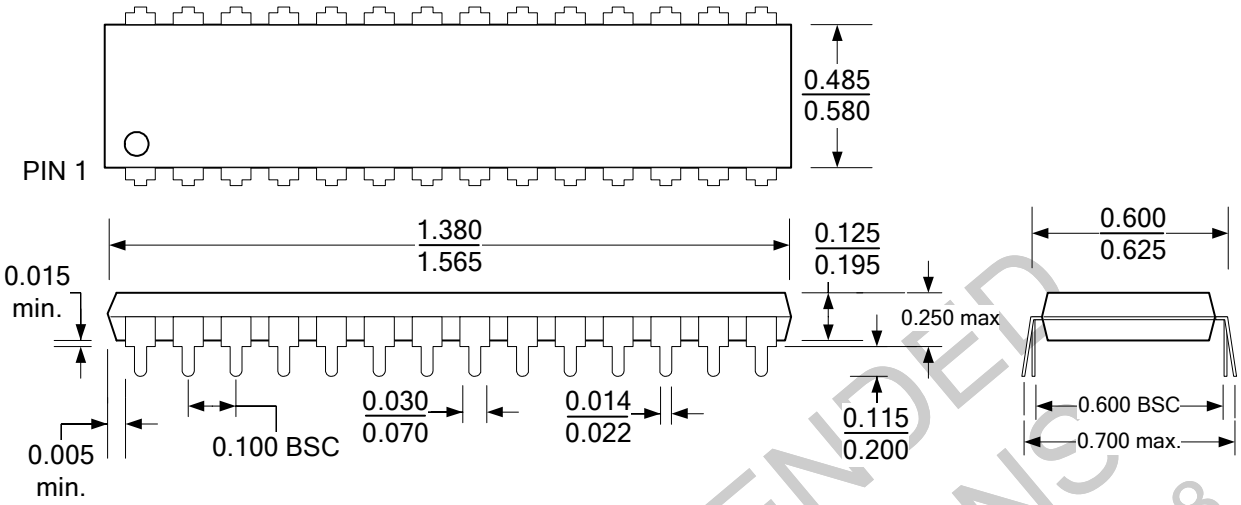



Legend:
XXXX= part number, S=speed (-120), P= package type (-PG, -SG)
R=rev code, YY=year, WW=work week, LLLLLL= lot code

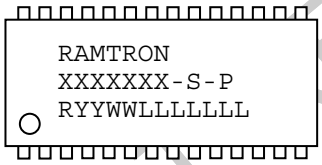
Example: FM1608, 120ns speed, "Green"/RoHS SOIC package,
M die rev., Year 2007, Work Week 11, Lot code 70085G

RAMTRON
FM1608-120-SG
M071170085G

**28-pin DIP (JEDEC MS-011)**
*All dimensions in inches*




## DIP Package Marking Scheme




Legend:
XXXX= part number, S=speed (-120), P= package type (-PG, -SG)
R=rev code, YY=year, WW=work week, LLLLLL= lot code

Example: FM1608, 120ns speed, "Green"/RoHS DIP package,
M rev., Year 2007, Work Week 11, Lot code 70085G

RAMTRON
FM1608-120-PG
M071170085G

## Revision History

| Revision | Date | Summary |
|---|---|---|
| 3.0 | 11/16/2004 | Removed Power Down Sequence diagram and associated timing parameters. Date codes 0435 and later are not affected by brownout conditions. Updated footer to comply with new Datasheet Change Procedure. Removed applications section. |
| 3.1 | 10/3/2006 | Removed -P and -S packaging options which are Not Recommended for New Designs. Extended data retention to 45 years. Added ESD and MSL ratings. Added recommendation on CE pin during power cycles. |
| 3.2 | 5/30/2007 | Redraw package outlines, added marking scheme. |
| 3.3 | 12/18/2007 | Updated MSL ratings. |
| 3.4 | 11/22/2010 | Not Recommended for New Designs. Alternative devices: FM1608B, FM16W08. |