

# FM21L16

## 2Mbit F-RAM Memory



### Features

#### 2Mbit Ferroelectric Nonvolatile RAM

- Organized as 128Kx16
- Configurable as 256Kx8 Using /UB, /LB
- $10^{14}$  Read/Write Cycles
- NoDelay™ Writes
- Page Mode Operation to 33MHz
- Advanced High-Reliability Ferroelectric Process

#### SRAM Compatible

- Industry Std. 128Kx16 SRAM Pinout
- 60 ns Access Time, 110 ns Cycle Time

#### Advanced Features

- Software Programmable Block Write Protect

#### Superior to Battery-backed SRAM Modules

- No Battery Concerns
- Monolithic Reliability
- True Surface Mount Solution, No Rework Steps
- Superior for Moisture, Shock, and Vibration

#### Low Power Operation

- 2.7V – 3.6V Power Supply
- Low Current Mode (5 $\mu$ A) using ZZ pin
- Low Active Current (8 mA typ.)

#### Industry Standard Configuration

- Industrial Temperature -40° C to +85° C
- 44-pin “Green”/RoHS TSOP-II package

### Description

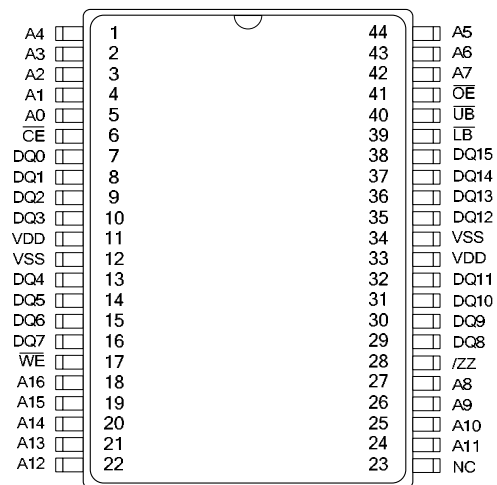
The FM21L16 is a 128Kx16 nonvolatile memory that reads and writes like a standard SRAM. A ferroelectric random access memory or F-RAM is nonvolatile, which means that data is retained after power is removed. It provides data retention for over 10 years while eliminating the reliability concerns, functional disadvantages, and system design complexities of battery-backed SRAM (BBSRAM). Fast write timing and high write endurance make the F-RAM superior to other types of memory.

In-system operation of the FM21L16 is very similar to other RAM devices and can be used as a drop-in replacement for standard SRAM. Read and write cycles may be triggered by /CE or simply by changing the address. The F-RAM memory is nonvolatile due to its unique ferroelectric memory process. These features make the FM21L16 ideal for nonvolatile memory applications requiring frequent or rapid writes in the form of an SRAM.

The FM21L16 includes a low voltage monitor that blocks access to the memory array when  $V_{DD}$  drops below  $V_{DD}$  min. The memory is protected against an inadvertent access and data corruption under this condition. The device also features software-controlled write protection. The memory array is divided into 8 uniform blocks, each of which can be individually write protected.

The device is available in a 400 mil 44-pin TSOP-II surface mount package. Device specifications are guaranteed over industrial temperature range -40°C to +85°C.

#### Pin Configuration



#### Ordering Information

|                 |                                                              |
|-----------------|--------------------------------------------------------------|
| FM21L16-60-TG   | 60 ns access, 44-pin<br>“Green”/RoHS TSOP-II                 |
| FM21L16-60-TGTR | 60 ns access, 44-pin<br>“Green”/RoHS TSOP-II,<br>Tape & Reel |

This is a product in the pre-production phase of development. Device characterization is complete and Ramtron does not expect to change the specifications. Ramtron will issue a Product Change Notice if any specification changes are made.

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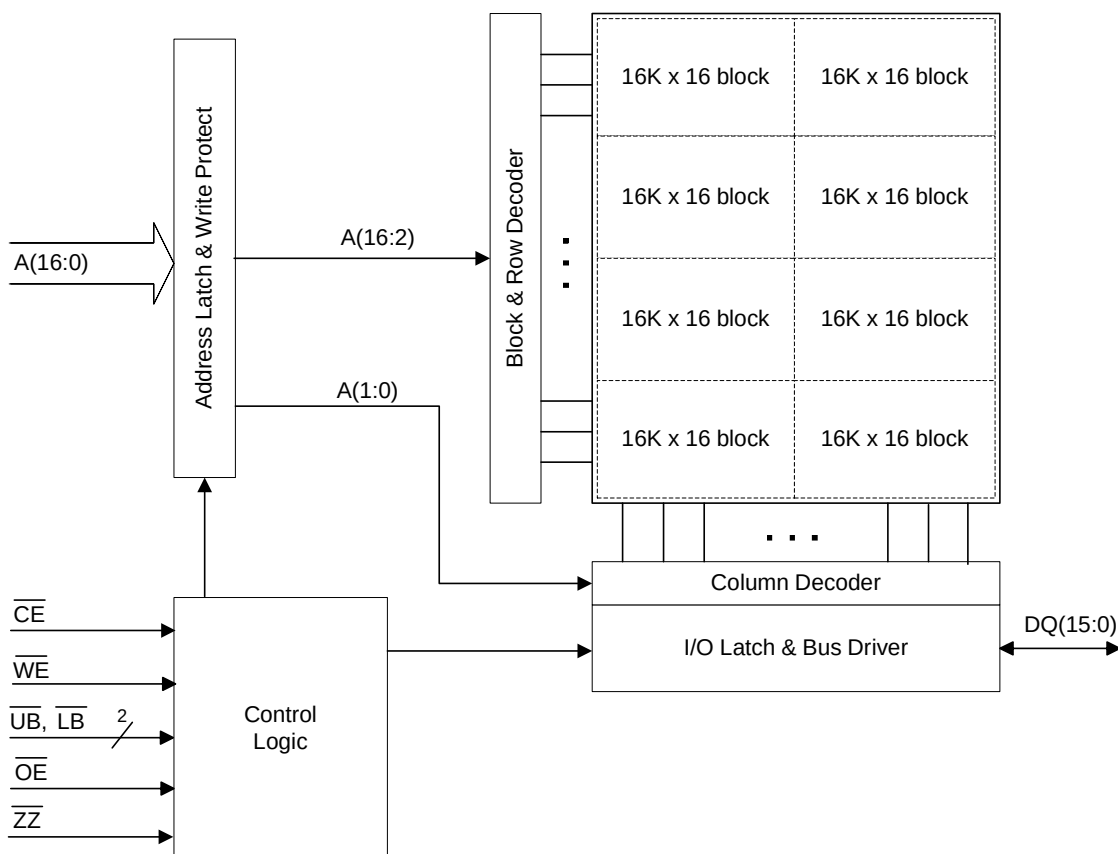


Figure 1. Block Diagram

#### Pin Description

| Pin Name | Type   | Pin Description                                                                                                                                                                                                                                                           |
|----------|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A(16:0)  | Input  | Address inputs: The 17 address lines select one of 131,072 words in the F-RAM array. The lowest two address lines A(1:0) may be used for page mode read and write operations.                                                                                             |
| /CE      | Input  | Chip Enable input: The device is selected and a new memory access begins when /CE is low and /ZZ is high. The entire address is latched internally on the falling edge of /CE. Subsequent changes to the A(1:0) address inputs allow page mode operation when /CE is low. |
| /WE      | Input  | Write Enable: A write cycle begins when /WE is asserted. The rising edge causes the FM21L16 to write the data on the DQ bus to the F-RAM array. The falling edge of /WE latches a new column address for page mode write cycles.                                          |
| /OE      | Input  | Output Enable: When /OE is low, the FM21L16 drives the data bus when valid read data is available. Deasserting /OE high tri-states the DQ pins.                                                                                                                           |
| /ZZ      | Input  | Sleep: When /ZZ is low, the device enters a low power sleep mode for the lowest supply current condition. Since this input is logically AND'd with /CE, /ZZ must be high for normal read/write operation. If unused, tie /ZZ to V <sub>DD</sub> .                         |
| DQ(15:0) | I/O    | Data: 16-bit bi-directional data bus for accessing the F-RAM array.                                                                                                                                                                                                       |
| /UB      | Input  | Upper Byte Select: Enables DQ(15:8) pins during reads and writes. These pins are hi-Z if /UB is high. If the user does not perform byte writes and the device is not configured as a 256Kx8, the /UB and /LB pins may be tied to ground.                                  |
| /LB      | Input  | Lower Byte Select: Enables DQ(7:0) pins during reads and writes. These pins are hi-Z if /LB is high. If the user does not perform byte writes and the device is not configured as a 256Kx8, the /UB and /LB pins may be tied to ground.                                   |
| VDD      | Supply | Supply Voltage                                                                                                                                                                                                                                                            |
| VSS      | Supply | Ground                                                                                                                                                                                                                                                                    |

**Functional Truth Table**<sup>1,2</sup>

| /CE | /WE | A(16:2)   | A(1:0) | /ZZ | Operation                         |
|-----|-----|-----------|--------|-----|-----------------------------------|
| X   | X   | X         | X      | L   | Sleep Mode                        |
| H   | X   | X         | X      | H   | Standby/Idle                      |
| ↓   | H   | V         | V      | H   | Read                              |
| L   | H   | No Change | Change | H   | Page Mode Read                    |
| L   | H   | Change    | V      | H   | Random Read                       |
| ↓   | L   | V         | V      | H   | /CE-Controlled Write              |
| L   | ↓   | V         | V      | H   | /WE-Controlled Write <sup>2</sup> |
| L   | ↓   | No Change | V      | H   | Page Mode Write <sup>3</sup>      |
| ↑   | X   | X         | X      | H   | Starts Precharge                  |

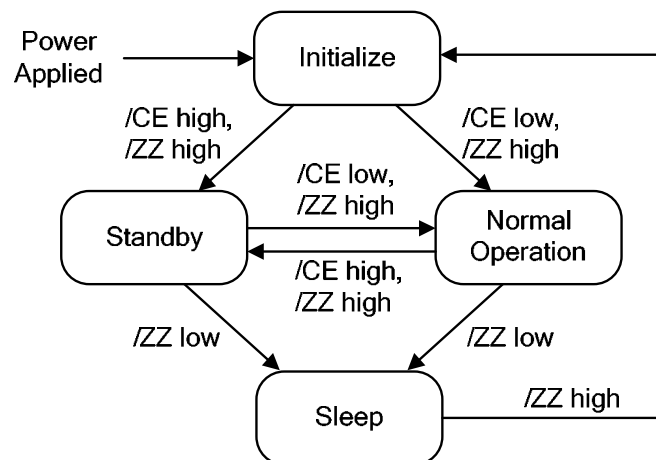
Notes:

- 1) H=Logic High, L=Logic Low, V=Valid Data, X=Don't Care.
- 2) /WE-controlled write cycle begins as a Read cycle and A(16:2) is latched then.
- 3) Addresses A(1:0) must remain stable for at least 10 ns during page mode operation.
- 4) For write cycles, data-in is latched on the rising edge of /CE or /WE, whichever comes first.

**Byte Select Truth Table**

| /WE | /OE | /LB | /UB | Operation                         |
|-----|-----|-----|-----|-----------------------------------|
| H   | H   | X   | X   | Read; Outputs Disabled            |
|     | X   | H   | H   |                                   |
| H   | L   | H   | L   | Read upper byte; Hi-Z lower byte  |
|     |     | L   | H   | Read lower byte; Hi-Z upper byte  |
|     |     | L   | L   | Read both bytes                   |
| L   | X   | H   | L   | Write upper byte; Mask lower byte |
|     |     | L   | H   | Write lower byte; Mask upper byte |
|     |     | L   | L   | Write both bytes                  |

Note: Assumes /CE is low and /ZZ is high for all cases. The /UB and /LB pins may be grounded if 1) the system does not perform byte writes and 2) the device is not configured as a 256Kx8.

**Figure 2. Simplified Sleep/Standby State Diagram**

## Overview

The FM21L16 is a wordwide F-RAM memory logically organized as 131,072 x 16 and accessed using an industry standard parallel interface. All data written to the part is immediately nonvolatile with no delay. The device offers page mode operation which provides higher speed access to addresses within a page (row). An access to a different page requires that either /CE transitions low or the upper address A(16:2) changes.

## Memory Operation

Users access 131,072 memory locations, each with 16 data bits through a parallel interface. The F-RAM array is organized as 8 blocks each having 4096 rows. Each row has 4 column locations, which allows fast access in page mode operation. Once an initial address has been latched by the falling edge of /CE, subsequent column locations may be accessed without the need to toggle /CE. When /CE is deasserted high, a precharge operation begins. Writes occur immediately at the end of the access with no delay. The /WE pin must be toggled for each write operation. The write data is stored in the nonvolatile memory array immediately, which is a feature unique to F-RAM called NoDelay™ writes.

## Read Operation

A read operation begins on the falling edge of /CE. The falling edge of /CE causes the address to be latched and starts a memory read cycle if /WE is high. Data becomes available on the bus after the access time has been satisfied. Once the address has been latched and the access completed, a new access to a random location (different row) may begin while /CE is still low. The minimum cycle time for random addresses is  $t_{RC}$ . Note that unlike SRAMs, the FM21L16's /CE-initiated access time is faster than the address cycle time.

The FM21L16 will drive the data bus when /OE and at least one of the byte enables (/UB, /LB) is asserted low. The upper data byte is driven when /UB is low, and the lower data byte is driven when /LB is 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 deasserted high, the data bus will remain in a high-Z state.

## Write Operation

Writes occur in the FM21L16 in the same time interval as reads. The FM21L16 supports both /CE-

and /WE-controlled write cycles. In both cases, the address A(16:2) 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 device begins the memory cycle as a write. The FM21L16 will not drive the data bus regardless of the state of /OE as long as /WE is low. Input data must be valid when /CE is deasserted high. In a /WE-controlled write, the memory cycle begins on the falling edge of /CE. The /WE signal falls some time later. Therefore, the memory cycle begins as a read. The data bus will be driven if /OE is low, however it will hi-Z once /WE is asserted low. The /CE- and /WE-controlled write timing cases are shown in the Electrical Specifications section.

Write access to the array begins on the falling edge of /WE after the memory cycle is initiated. The write access terminates on the rising edge of /WE or /CE, whichever comes first. A valid write operation requires the user to meet the access time specification prior to deasserting /WE or /CE. Data setup time indicates the interval during which data cannot change prior to the end of the write access (rising edge of /WE or /CE).

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. Data polling, a technique used with EEPROMs to determine if a write is complete, is unnecessary.

## Page Mode Operation

The F-RAM array is organized as 8 blocks each having 4096 rows. Each row has 4 column address locations. Address inputs A(1:0) define the column address to be accessed. An access can start on any column address, and other column locations may be accessed without the need to toggle the /CE pin. For fast access reads, once the first data byte is driven onto the bus, the column address inputs A(1:0) may be changed to a new value. A new data byte is then driven to the DQ pins no later than  $t_{AAP}$ , which is less than half the initial read access time. For fast access writes, the first write pulse defines the first write access. While /CE is low, a subsequent write pulse along with a new column address provides a page mode write access.

### Precharge Operation

The precharge operation is an internal condition in which the state of the memory is being prepared for a new access. Precharge is user-initiated by driving the /CE signal high. It must remain high for at least the minimum precharge time  $t_{PC}$ .

Precharge is also activated by changing the upper address A(16:2). The current row is first closed prior to accessing the new row. The device automatically detects an upper order address change which starts a precharge operation, the new address is latched, and the new read data is valid within the  $t_{AA}$  address access time. Refer to the *Read Cycle Timing 1* diagram on page 10. Likewise a similar sequence occurs for write cycles. Refer to the *Write Cycle Timing 3* diagram on page 12. The rate at which random addresses can be issued is  $t_{RC}$  and  $t_{WC}$ , respectively.

### Sleep Mode

The device incorporates a sleep mode of operation which allows the user to achieve the lowest power supply current condition. It enters a low power sleep mode by asserting the /ZZ pin low. Read and write operations must complete prior to the /ZZ pin going low. Once /ZZ is low, all pins are ignored except the /ZZ pin. When /ZZ is deasserted high, there is some time delay ( $t_{ZZEX}$ ) before the user can access the device.

If Sleep Mode is not used, the /ZZ pin should be tied to  $V_{DD}$ .

### Software Write Protection

The 128Kx16 address space is divided into 8 sectors (blocks) of 16Kx16 each. Each sector can be individually software write-protected and the settings are nonvolatile. A unique address and command sequence invokes the write protection mode.

To modify write protection, the system host must issue six read commands, three write commands, and a final read command. The specific sequence of read addresses must be provided in order to access to the write protect mode. Following the read address sequence, the host must write a data byte that specifies the desired protection state of each sector. For confirmation, the system must then write the complement of the protection byte immediately following the protection byte. Any error that occurs including read addresses in the wrong order, issuing a seventh read address, or failing to complement the protection value will leave the write protection unchanged.

The write protect state machine monitors all addresses, taking no action until this particular read/write sequence occurs. During the address sequence, each read will occur as a valid operation and data from the corresponding addresses will be driven onto the data bus. Any address that occurs out of sequence will cause the software protection state machine to start over. After the address sequence is completed, the next operation must be a write cycle. The data byte contains the write-protect settings. This value will not be written to the memory array, so the address is a don't-care. Rather it will be held pending the next cycle, which must be a write of the data complement to the protection settings. If the complement is correct, the write protect settings will be adjusted. If not, the process is aborted and the address sequence starts over. The data value written after the correct six addresses will not be entered into memory.

The protection data byte consists of 8-bits, each associated with the write protect state of a sector. The data byte must be driven to the lower 8-bits of the data bus, DQ(7:0). Setting a bit to 1 write protects the corresponding sector; a 0 enables writes for that sector. The following table shows the write-protect sectors with the corresponding bit that controls the write-protect setting.

#### Write Protect Sectors – 16K x16 blocks

|          |                 |
|----------|-----------------|
| Sector 7 | 1FFFFh – 1C000h |
| Sector 6 | 1BFFFh – 18000h |
| Sector 5 | 17FFFh – 14000h |
| Sector 4 | 13FFFh – 10000h |
| Sector 3 | 0FFFFh – 0C000h |
| Sector 2 | 0BFFFh – 08000h |
| Sector 1 | 07FFFh – 04000h |
| Sector 0 | 03FFFh – 00000h |

The write-protect read address sequence follows:

1. 12555h \*
2. 1DAAAh
3. 01333h
4. 0ECCCh
5. 000FFh
6. 1FF00h
7. 1DAAAh
8. 0ECCCh
9. 0FF00h
10. 00000h

\* If /CE is low entering the sequence, then an address of 00000h must precede 12555h.

The address sequence provides a very secure way of modifying the protection. The write-protect sequence has a 1 in  $3 \times 10^{32}$  chance of randomly accessing exactly the 1<sup>st</sup> six addresses. The odds are further

reduced by requiring three more write cycles, one that requires an exact inversion of the data byte. A flow chart of the entire write protect operation is shown in

Figure 3. The write-protect settings are nonvolatile. The factory default: all blocks are unprotected.

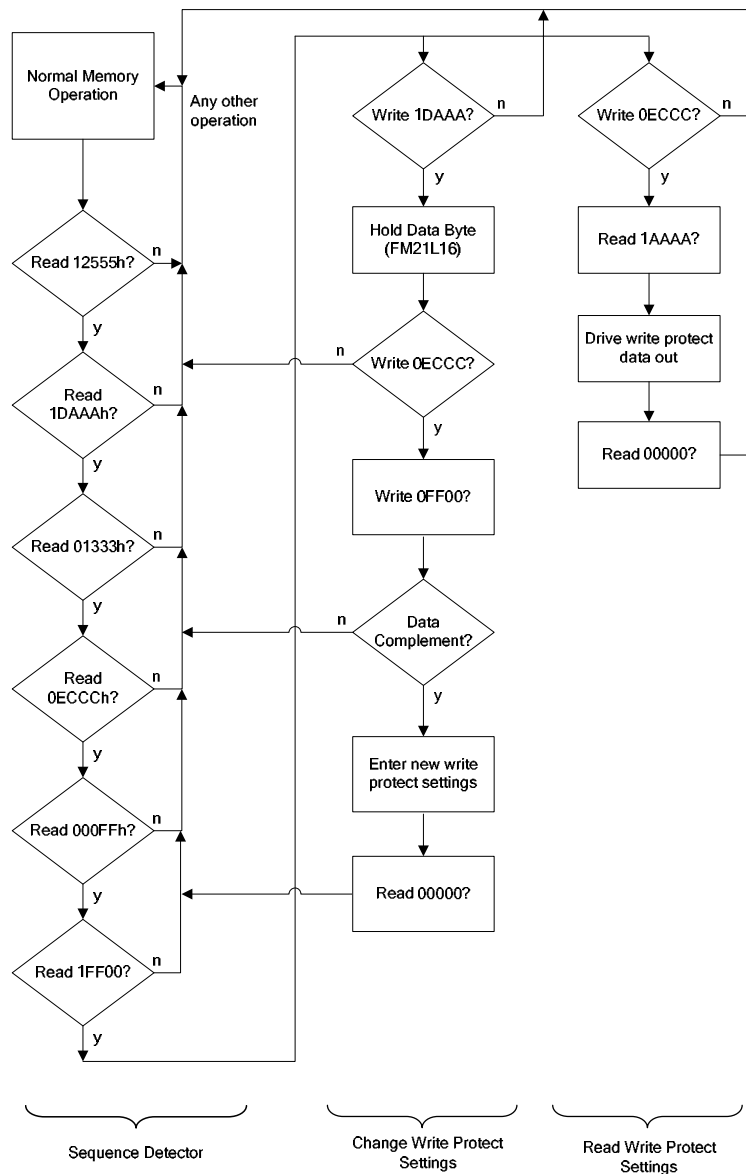
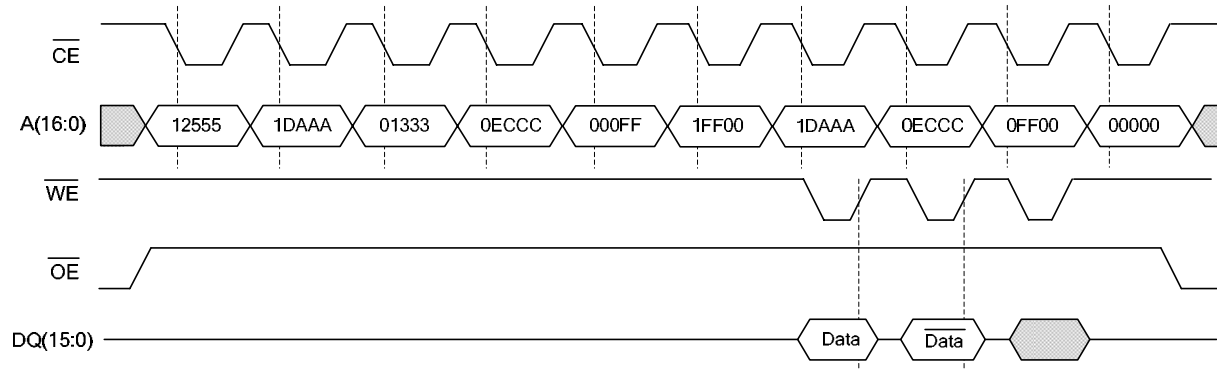


Figure 3. Write-Protect State Machine

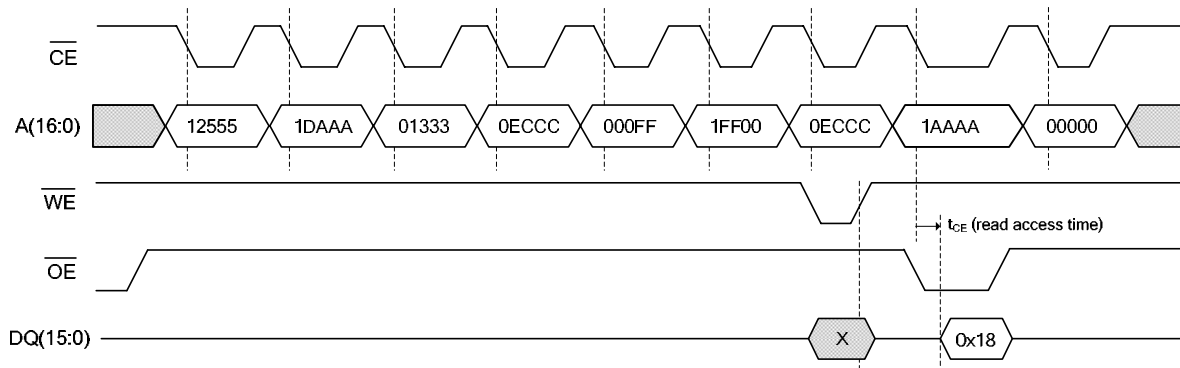
For example, the following sequence write-protects addresses from 0C000h to 13FFFh (sectors 3 & 4):

|       | Address | Data |                              |
|-------|---------|------|------------------------------|
| Read  | 12555h  | -    |                              |
| Read  | 1DAAAh  | -    |                              |
| Read  | 01333h  | -    |                              |
| Read  | 0ECCCh  | -    |                              |
| Read  | 000FFh  | -    |                              |
| Read  | 1FF00h  | -    |                              |
| Write | 1DAAAh  | 18h  | ; bits 3 & 4 = 1             |
| Write | 0ECCCh  | E7h  | ; complement of 18h          |
| Write | 0FF00h  | -    | ; Data is don't care         |
| Read  | 00000h  | -    | ; return to Normal Operation |



**Figure 4. Sequence to Set Write-Protect Blocks**

Note: This sequence requires  $t_{AS} \geq 10\text{ns}$  and address must be stable while  $\overline{CE}$  is low.



**Figure 5. Sequence to Read Write-Protect Settings**

Note: This sequence requires  $t_{AS} \geq 10\text{ns}$  and address must be stable while  $\overline{CE}$  is low.

## SRAM Drop-In Replacement

The FM21L16 has been designed to be a drop-in replacement for standard asynchronous SRAMs. The device does not require /CE to toggle for each new address. /CE may remain low for as long as 10 $\mu$ s. While /CE is low, the device automatically detects address changes and a new access is begun. It also allows page mode operation at speeds up to 33MHz. **The user must be sure /CE is not low at powerup or powerdown events. If /CE and /WE are both low during power cycles, data corruption will occur. Figure 6 shows a pullup resistor on /CE which will keep the pin high during power cycles assuming the MCU/MPU pin is tri-stated during the system reset. 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. A 10K ohm resistor draws 330 $\mu$ A when /CE is low and  $V_{DD}$ =3.3V.**

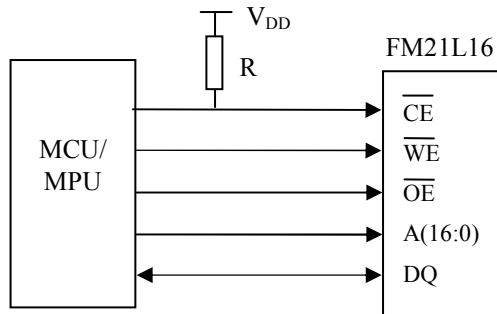


Figure 6. Use of Pullup Resistor on /CE

For applications that require the lowest power consumption, the /CE signal should be active (low)

only during memory accesses. The FM21L16 draws supply current while /CE is low, even if addresses and control signals are static. While /CE is high, the device draws no more than the maximum standby current  $I_{SB}$ .

The FM21L16 is backward compatible with the 1Mbit FM20L08 and 256Kbit FM18L08 devices. That is, operating the FM21L16 with /CE toggling low on every address is perfectly acceptable.

The /UB and /LB byte select pins are active for both read and write cycles. They may be used to allow the device to be wired as a 256Kx8 memory. The upper and lower data bytes can be tied together and controlled with the byte selects. Individual byte enables or the next higher address line A(17) may be available from the system processor.

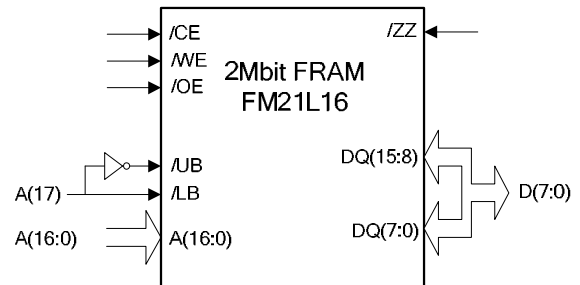


Figure 7. FM21L16 Wired as 256Kx8



## Electrical Specifications

### Absolute Maximum Ratings

| Symbol     | Description                                                                                                                                                                      | Ratings                                      |
|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| $V_{DD}$   | Power Supply Voltage with respect to $V_{SS}$                                                                                                                                    | -1.0V to +4.5V                               |
| $V_{IN}$   | Voltage on any signal pin with respect to $V_{SS}$                                                                                                                               | -1.0V to +4.5V and<br>$V_{IN} < V_{DD} + 1V$ |
| $T_{STG}$  | Storage Temperature                                                                                                                                                              | -55°C to +125°C                              |
| $T_{LEAD}$ | Lead Temperature (Soldering, 10 seconds)                                                                                                                                         | 260° C                                       |
| $V_{ESD}$  | Electrostatic Discharge Voltage<br>- Human Body Model (JEDEC Std JESD22-A114-F)<br>- Charged Device Model (JEDEC Std JESD22-C101-D)<br>- Machine Model (JEDEC Std JESD22-A115-A) | 2.5kV<br>800V<br>200V                        |
|            | Package Moisture Sensitivity Level                                                                                                                                               | MSL-3                                        |

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.

### DC Operating Conditions ( $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$ , $V_{DD} = 2.7V$ to $3.6V$ unless otherwise specified)

| Symbol    | Parameter                                                                      | Min            | Typ     | Max            | Units                          | Notes |
|-----------|--------------------------------------------------------------------------------|----------------|---------|----------------|--------------------------------|-------|
| $V_{DD}$  | Power Supply                                                                   | 2.7            | 3.3     | 3.6            | V                              |       |
| $I_{DD}$  | Power Supply Current                                                           |                | 8       | 12             | mA                             | 1     |
| $I_{SB}$  | Standby Current<br>@ $T_A = 25^\circ\text{C}$<br>@ $T_A = 85^\circ\text{C}$    |                | 90<br>- | 150<br>270     | $\mu\text{A}$<br>$\mu\text{A}$ | 2     |
| $I_{ZZ}$  | Sleep Mode Current<br>@ $T_A = 25^\circ\text{C}$<br>@ $T_A = 85^\circ\text{C}$ |                | -<br>-  | 5<br>8         | $\mu\text{A}$<br>$\mu\text{A}$ | 3     |
| $I_{LI}$  | Input Leakage Current                                                          |                |         | $\pm 1$        | $\mu\text{A}$                  | 4     |
| $I_{LO}$  | Output Leakage Current                                                         |                |         | $\pm 1$        | $\mu\text{A}$                  | 4     |
| $V_{IH}$  | Input High Voltage                                                             | 2.2            |         | $V_{DD} + 0.3$ | V                              |       |
| $V_{IL}$  | Input Low Voltage                                                              | -0.3           |         | 0.6            | V                              |       |
| $V_{OH1}$ | Output High Voltage ( $I_{OH} = -1.0\text{ mA}$ )                              | 2.4            |         |                | V                              |       |
| $V_{OH2}$ | Output High Voltage ( $I_{OH} = -100\text{ }\mu\text{A}$ )                     | $V_{DD} - 0.2$ |         |                | V                              |       |
| $V_{OL1}$ | Output Low Voltage ( $I_{OL} = 2.1\text{ mA}$ )                                |                |         | 0.4            | V                              |       |
| $V_{OL2}$ | Output Low Voltage ( $I_{OL} = 100\text{ }\mu\text{A}$ )                       |                |         | 0.2            | V                              |       |

### Notes

- $V_{DD} = 3.6V$ , /CE cycling at min. cycle time. All inputs toggling at CMOS levels (0.2V or  $V_{DD} - 0.2V$ ), all DQ pins unloaded.
- $V_{DD} = 3.6V$ , /CE at  $V_{DD}$ , All other pins are static and at CMOS levels (0.2V or  $V_{DD} - 0.2V$ ), /ZZ is high.
- $V_{DD} = 3.6V$ , /ZZ is low, all other inputs at CMOS levels (0.2V or  $V_{DD} - 0.2V$ ).
- $V_{IN}$ ,  $V_{OUT}$  between  $V_{DD}$  and  $V_{SS}$ .

**Read Cycle AC Parameters** ( $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ ,  $V_{DD} = 2.7\text{V}$  to  $3.6\text{V}$  unless otherwise specified)

| Symbol    | Parameter                           | Min | Max    | Units | Notes |
|-----------|-------------------------------------|-----|--------|-------|-------|
| $t_{RC}$  | Read Cycle Time                     | 110 | -      | ns    |       |
| $t_{CE}$  | Chip Enable Access Time             | -   | 60     | ns    |       |
| $t_{AA}$  | Address Access Time                 | -   | 110    | ns    |       |
| $t_{OH}$  | Output Hold Time                    | 20  | -      | ns    |       |
| $t_{AAP}$ | Page Mode Address Access Time       | -   | 25     | ns    |       |
| $t_{OHP}$ | Page Mode Output Hold Time          | 5   | -      | ns    |       |
| $t_{CA}$  | Chip Enable Active Time             | 60  | 10,000 | ns    |       |
| $t_{PC}$  | Precharge Time                      | 50  | -      | ns    |       |
| $t_{BA}$  | /UB, /LB Access Time                | -   | 20     | ns    |       |
| $t_{AS}$  | Address Setup Time (to /CE low)     | 0   | -      | ns    |       |
| $t_{AH}$  | Address Hold Time (/CE-controlled)  | 60  | -      | ns    |       |
| $t_{OE}$  | Output Enable Access Time           | -   | 15     | ns    |       |
| $t_{HZ}$  | Chip Enable to Output High-Z        | -   | 10     | ns    | 1     |
| $t_{OHZ}$ | Output Enable High to Output High-Z | -   | 10     | ns    | 1     |
| $t_{BHZ}$ | /UB, /LB High to Output High-Z      | -   | 10     | ns    | 1     |

**Write Cycle AC Parameters** ( $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ ,  $V_{DD} = 2.7\text{V}$  to  $3.6\text{V}$  unless otherwise specified)

| Symbol    | Parameter                                 | Min | Max    | Units | Notes |
|-----------|-------------------------------------------|-----|--------|-------|-------|
| $t_{WC}$  | Write Cycle Time                          | 110 | -      | ns    |       |
| $t_{CA}$  | Chip Enable Active Time                   | 60  | 10,000 | ns    |       |
| $t_{CW}$  | Chip Enable to Write Enable High          | 60  | -      | ns    |       |
| $t_{PC}$  | Precharge Time                            | 50  | -      | ns    |       |
| $t_{PWC}$ | Page Mode Write Enable Cycle Time         | 25  | -      | ns    |       |
| $t_{WP}$  | Write Enable Pulse Width                  | 16  | -      | ns    |       |
| $t_{AS}$  | Address Setup Time (to /CE low)           | 0   | -      | ns    |       |
| $t_{ASP}$ | Page Mode Address Setup Time (to /WE low) | 8   | -      | ns    |       |
| $t_{AHP}$ | Page Mode Address Hold Time (to /WE low)  | 15  | -      | ns    |       |
| $t_{WLC}$ | Write Enable Low to /CE High              | 25  | -      | ns    |       |
| $t_{BLC}$ | /UB, /LB Low to /CE High                  | 25  | -      | ns    |       |
| $t_{WLA}$ | Write Enable Low to A(16:2) Change        | 25  | -      | ns    |       |
| $t_{AWH}$ | A(16:2) Change to Write Enable High       | 110 | -      | ns    |       |
| $t_{DS}$  | Data Input Setup Time                     | 14  | -      | ns    |       |
| $t_{DH}$  | Data Input Hold Time                      | 0   | -      | ns    |       |
| $t_{WZ}$  | Write Enable Low to Output High Z         | -   | 10     | ns    | 1     |
| $t_{WX}$  | Write Enable High to Output Driven        | 10  | -      | ns    | 1     |
| $t_{WS}$  | Write Enable to /CE Low Setup Time        | 0   | -      | ns    | 2     |
| $t_{WH}$  | Write Enable to /CE High Hold Time        | 0   | -      | ns    | 2     |

**Notes**

1. This parameter is characterized but not 100% tested.
2. The relationship between /CE and /WE determines if a /CE- or /WE-controlled write occurs. The parameters  $t_{WS}$  and  $t_{WH}$  are not tested.

**Capacitance** ( $T_A = 25^\circ\text{C}$ ,  $f = 1\text{ MHz}$ ,  $V_{DD} = 3.3\text{V}$ )

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

**Power Cycle and Sleep Mode Timing** ( $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ ,  $V_{DD} = 2.7\text{V}$  to  $3.6\text{V}$  unless otherwise specified)

| Symbol     | Parameter                                                              | Min | Max | Units           | Notes |
|------------|------------------------------------------------------------------------|-----|-----|-----------------|-------|
| $t_{PU}$   | Power Up (after $V_{DD}$ min. is reached) to First Access Time         | 450 | -   | $\mu\text{s}$   |       |
| $t_{PD}$   | Last Write (/WE high) to Power Down Time                               | 0   | -   | $\mu\text{s}$   |       |
| $t_{VR}$   | $V_{DD}$ Rise Time                                                     | 50  | -   | $\mu\text{s/V}$ | 1,2   |
| $t_{VF}$   | $V_{DD}$ Fall Time                                                     | 100 | -   | $\mu\text{s/V}$ | 1,2   |
| $t_{ZZH}$  | /ZZ Active to DQ Hi-Z Time                                             | -   | 20  | ns              |       |
| $t_{WEZZ}$ | Last Write to Sleep Mode Entry Time                                    | 0   | -   | $\mu\text{s}$   |       |
| $t_{ZZL}$  | /ZZ Active Low Time                                                    | 1   | -   | $\mu\text{s}$   |       |
| $t_{ZZEN}$ | Sleep Mode Entry Time (/ZZ low to /CE don't care)                      | -   | 0   | $\mu\text{s}$   |       |
| $t_{ZZEX}$ | Sleep Mode Exit Time (/ZZ high to 1 <sup>st</sup> access after wakeup) | -   | 450 | $\mu\text{s}$   |       |

**Notes**

- Slope measured at any point on  $V_{DD}$  waveform.
- Ramtron cannot test or characterize all  $V_{DD}$  power ramp profiles. The behavior of the internal circuits is difficult to predict when  $V_{DD}$  is below the level of a transistor threshold voltage. Ramtron strongly recommends that  $V_{DD}$  power up faster than 100ms through the range of 0.4V to 1.0V.

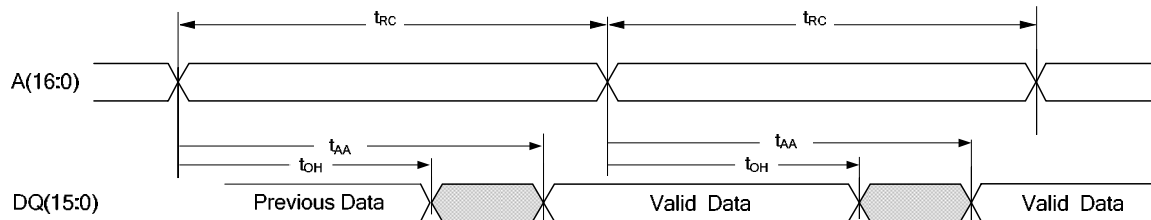
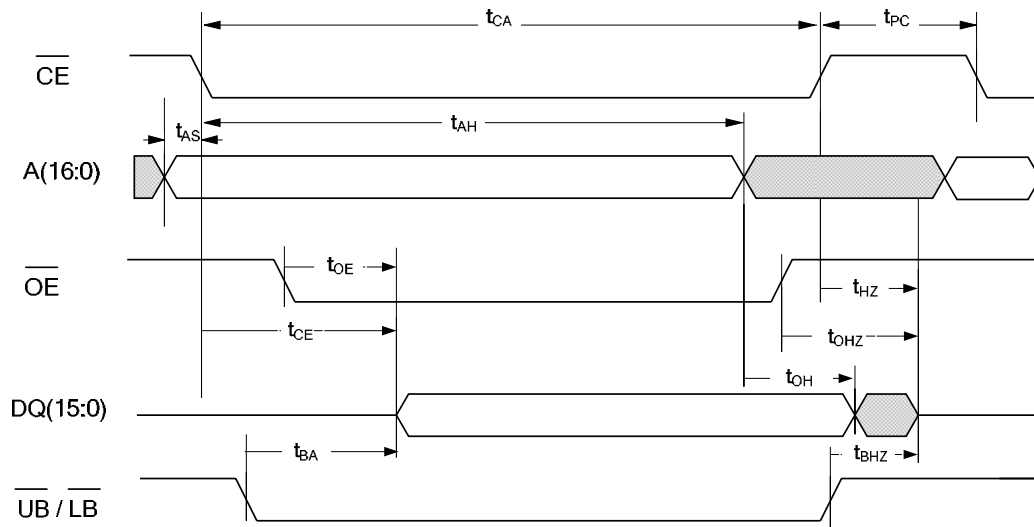
**Data Retention** ( $V_{DD} = 2.7\text{V}$  to  $3.6\text{V}$ )

| Parameter      | Min | Units | Notes |
|----------------|-----|-------|-------|
| Data Retention | 10  | Years |       |

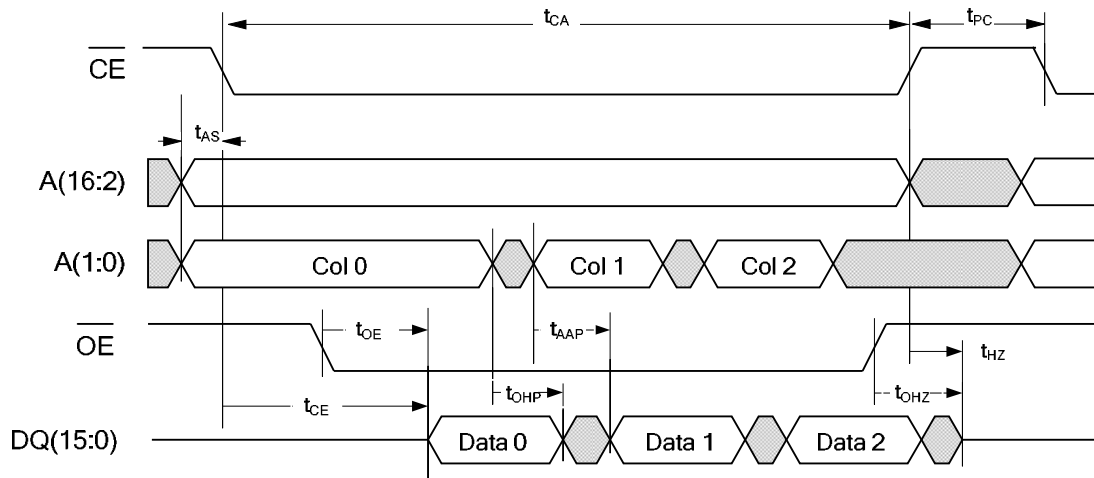
**AC Test Conditions**

Input Pulse Levels 0 to 3V  
Input Rise and Fall Times 3 ns

Input and Output Timing Levels 1.5V  
Output Load Capacitance 30pF

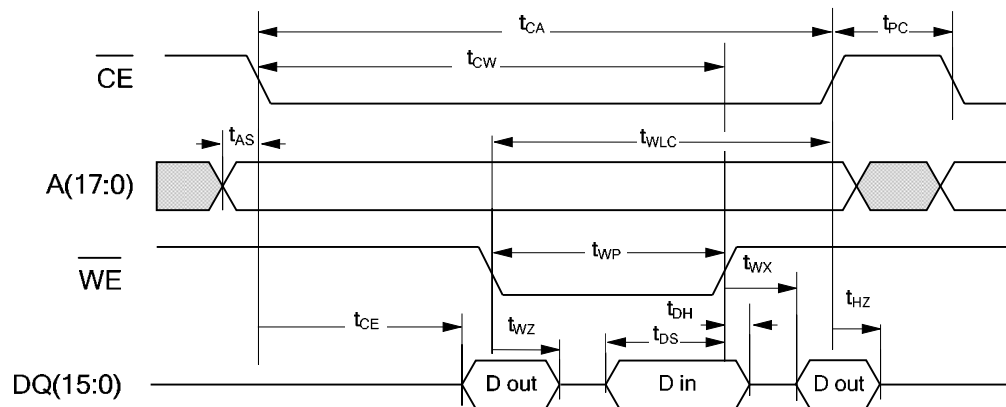
**Read Cycle Timing 1** (/CE low, /OE low)

**Read Cycle Timing 2** (/CE-controlled)


# Page Mode Read Cycle Timing

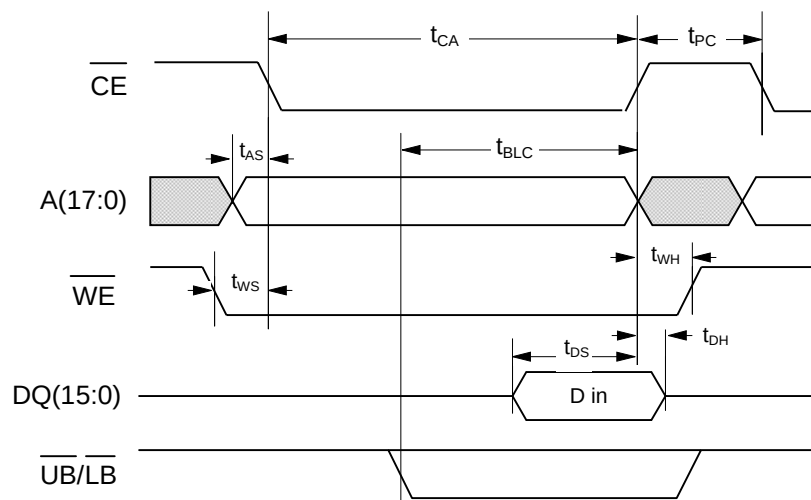


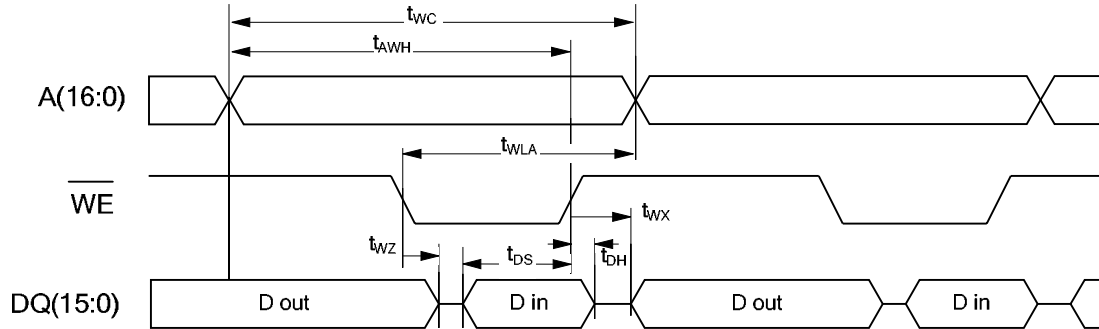
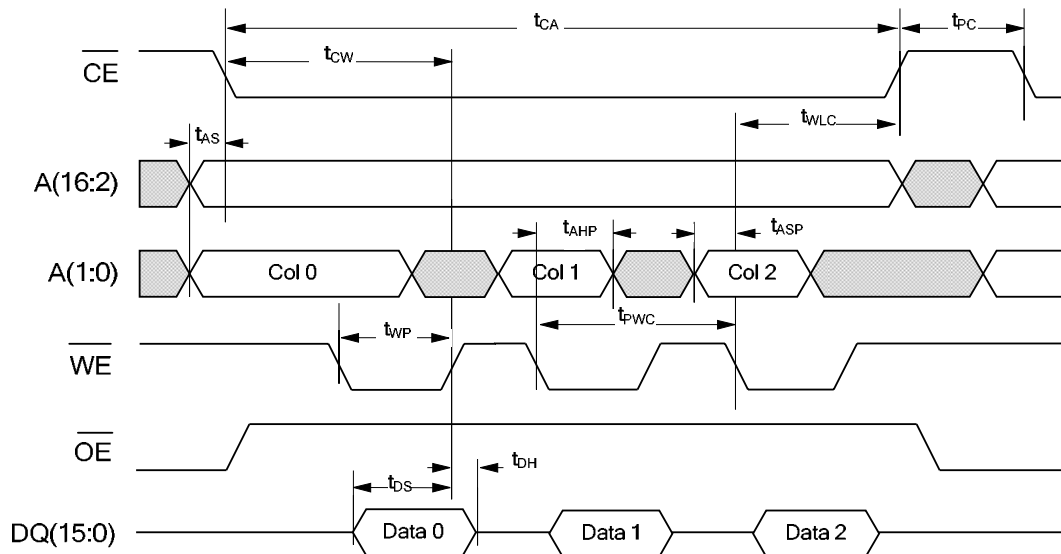
Although sequential column addressing is shown, it is not required.

## Write Cycle Timing 1 (/WE-Controlled) Note: /OE (not shown) is low only to show effect of /WE on DQ pins

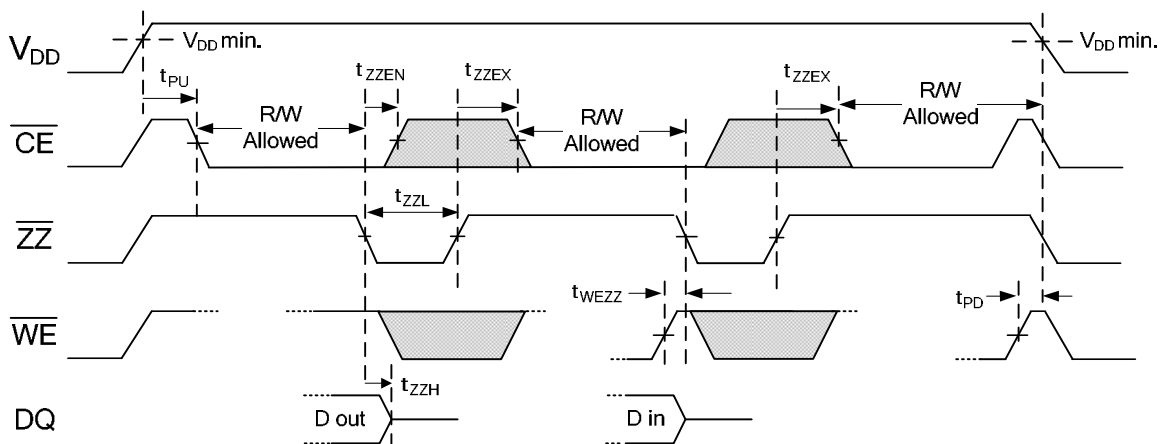


## Write Cycle Timing 2 (/CE-Controlled)



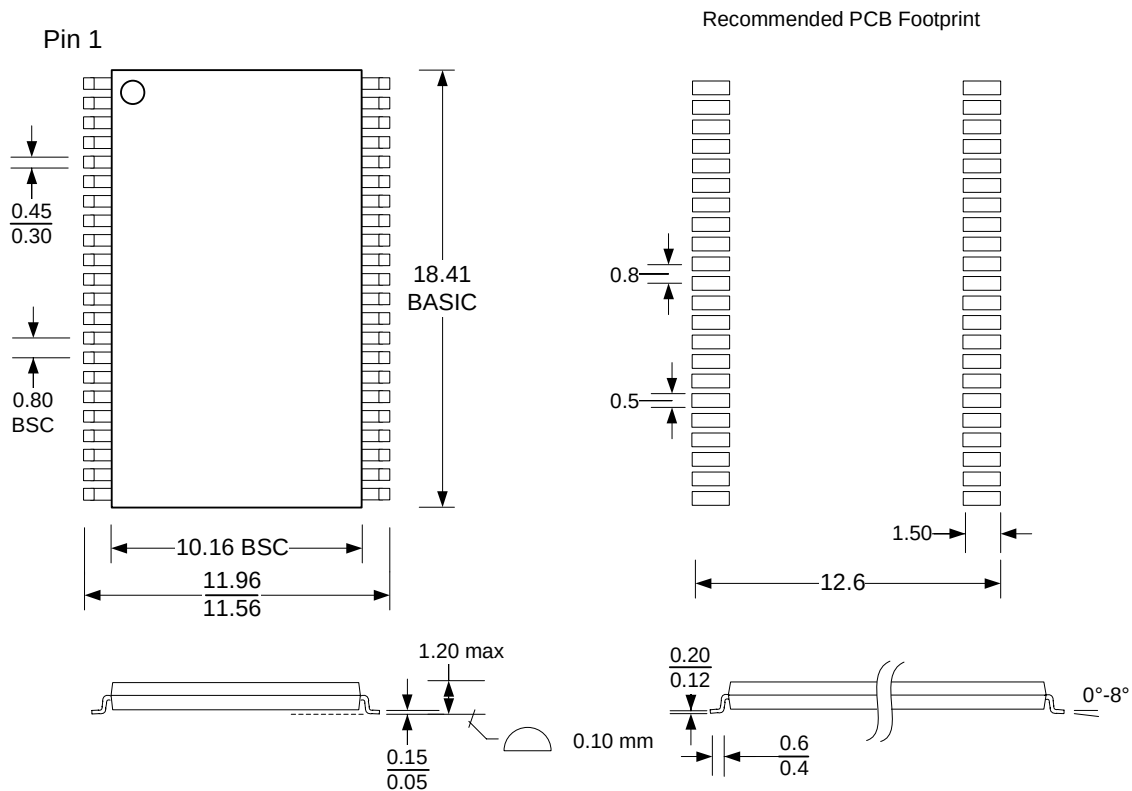
**Write Cycle Timing 3** (/CE low) Note: /OE (not shown) is low only to show effect of /WE on DQ pins

**Page Mode Write Cycle Timing**


Although sequential column addressing is shown, it is not required.

**Power Cycle and Sleep Mode Enter/Exit Timing**


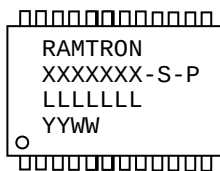
## Mechanical Drawing

### 44-pin TSOP-II (Complies with JEDEC Standard MS-024g Var. AC)



Note: All dimensions in millimeters.

### TSOP-II Package Marking Scheme



#### Legend:

XXXXXX= part number, S= speed, P=package  
 LLLLLL= lot code, YY=year, WW=work week

Examples: FM21L16, 60ns access time, "Green"/RoHS TSOP-II package,  
 Lot 6340282, Year 2007, Work Week 31

RAMTRON  
 FM21L16-60-TG  
 6340282  
 0731

**Revision History**

| Revision | Date       | Summary                                                                                                                                                                                                                                                                             |
|----------|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.0      | 9/24/2007  | Initial release.                                                                                                                                                                                                                                                                    |
| 1.1      | 12/12/2007 | Added package MSL rating and placeholder for ESD ratings.                                                                                                                                                                                                                           |
| 1.2      | 12/22/2009 | Lowered I <sub>DD</sub> limit. Added UB/LB signals to timing diagrams and added timing parameters to AC table. Expanded explanation of precharge operation. Updated lead temperature rating in Abs Max table. Removed V <sub>TP</sub> spec. Added tape & reel ordering information. |
| 2.0      | 4/4/2011   | Pre-Production status. Added ESD ratings. Modified write-protect flow diagram and added read sequence diagram. Made clarifications to Byte Select truth table. Added max. CE active time.                                                                                           |