



复旦微电子

FM29F02I3/FM29LF02I3 ***3.3V/1.8V 2G-BIT NAND FLASH*** ***MEMORY***

Datasheet

May. 2024



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Features Summary

- **Single-level cell(SLC) technology**
- **ONFI 1.0 Compliant**
- **Voltage Supply**
 - 2.7V ~ 3.6V
 - 1.7V ~ 1.95V
- **Memory Cell Organization**
 - Page Size:
X8: 2K+128 bytes
 - Block Size: 64 Pages
X8: 256K+16K bytes
 - Plane Size: 2048 Blocks
 - 1 Device: 1 Plane
- **Page Read / Program Time**
 - Random Read Time:
3.3V Device: 25us(Max.)
1.8V Device: 40us(Max.)
 - Sequential Access time:
3.3V Device: 25ns
1.8V Device: 30ns
- **Program/Erase/Read Speed**
 - Page Program time : 400us(Typ.)
 - BLOCK ERASE time : 4ms (Typ.)
- **Command/Address/Data Multiplexed I/O Port**
- **Hardware Data Protection**
 - Program/Erase Lockout during Power Transitions
- **Reliability**
 - Endurance : 80,000 Program/Erase Cycles
 - Data retention: 10 years
- **ECC Requirement**
 - 8bit/512 byte
- **Command Driven Operation**
- **Package**
 - TSOP48 (12X20mm)
 - FBGA63 (9X11mm)
 - All Packages are RoHS Compliant and Halogen-free

Summary Description

FM29F02I3/FM29LF02I3 is a **256M**x8bit with spare **16M**x8(x8) bit capacity.

The device is offered in 3.3/1.8 Vcc Power Supply, and with x8 I/O interface.

The memory is divided into blocks that can be erased independently so it is possible to preserve valid data while old data is erased.

The device contains **2048** blocks, composed by 64 pages consisting in two NAND structures of 32 series connected Flash cells.

Program operation allows the **2176**-byte page writing in typical 400us and an erase operation can be performed in typical 4ms on a **128K**-byte block.

Data in the page can be read out at 20ns cycle time per byte (3.3V version), and at 30ns cycle time per byte (1.8V version). The I/O pins serves as the ports for address and data input/output as well as command input. This interface allows a reduced pin count and easy migration towards different densities, without any rearrangement of footprint.

Commands, Data and Addresses are synchronously introduced using CE#, WE#, ALE and CLE input pin.

The on-chip Program/Erase controller automates all program and erase functions including pulse repetition, where required, and internal verification and margining of data. The modify operations can be locked using WP# input pin.

This device supports ONFI 1.0 specification.

The output pin R/B# (open drain) signals the status of the device during program/erase/read operation. In a system with multiple memories the R/B# pins can be connected all together to provide a global status signal.

The FM29F02I3/FM29LF02I3 is available in the following packages: 48-TSOP 12X20 mm package and FBGA63 9X11mm.

Product List

| Part Number | Organization | Vcc range | Package |
|-------------|--------------|-------------|---------------|
| FM29F02I3 | X8 | 2.7V ~ 3.6V | TSOP48, BGA63 |
| FM29LF02I3 | X8 | 1.7 - 1.95V | TSOP48, BGA63 |

Package

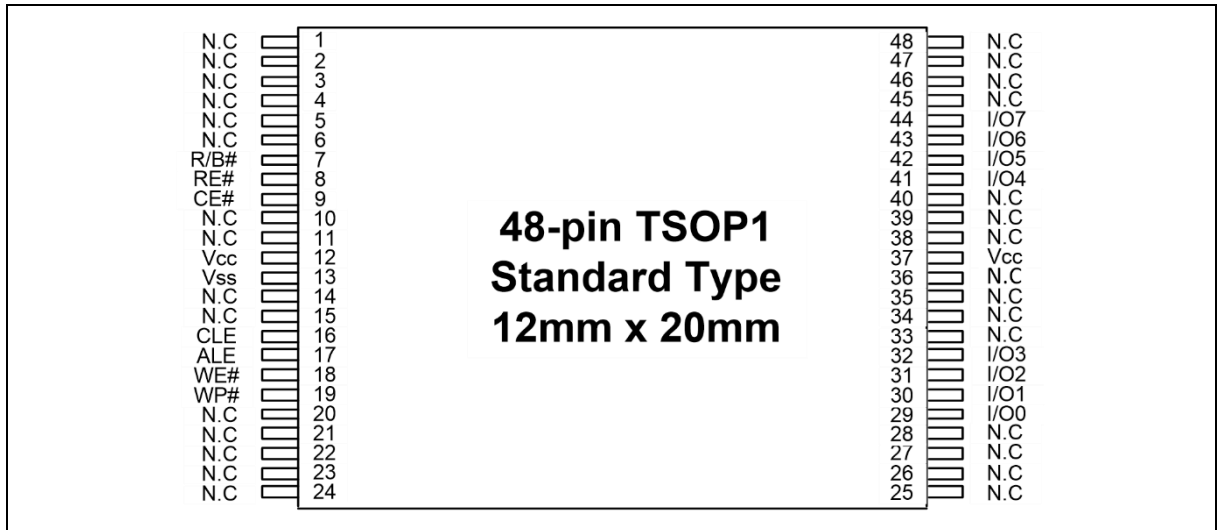


Figure 1 FM29F02I3/FM29LF02I3 pad assignments, TSOP48

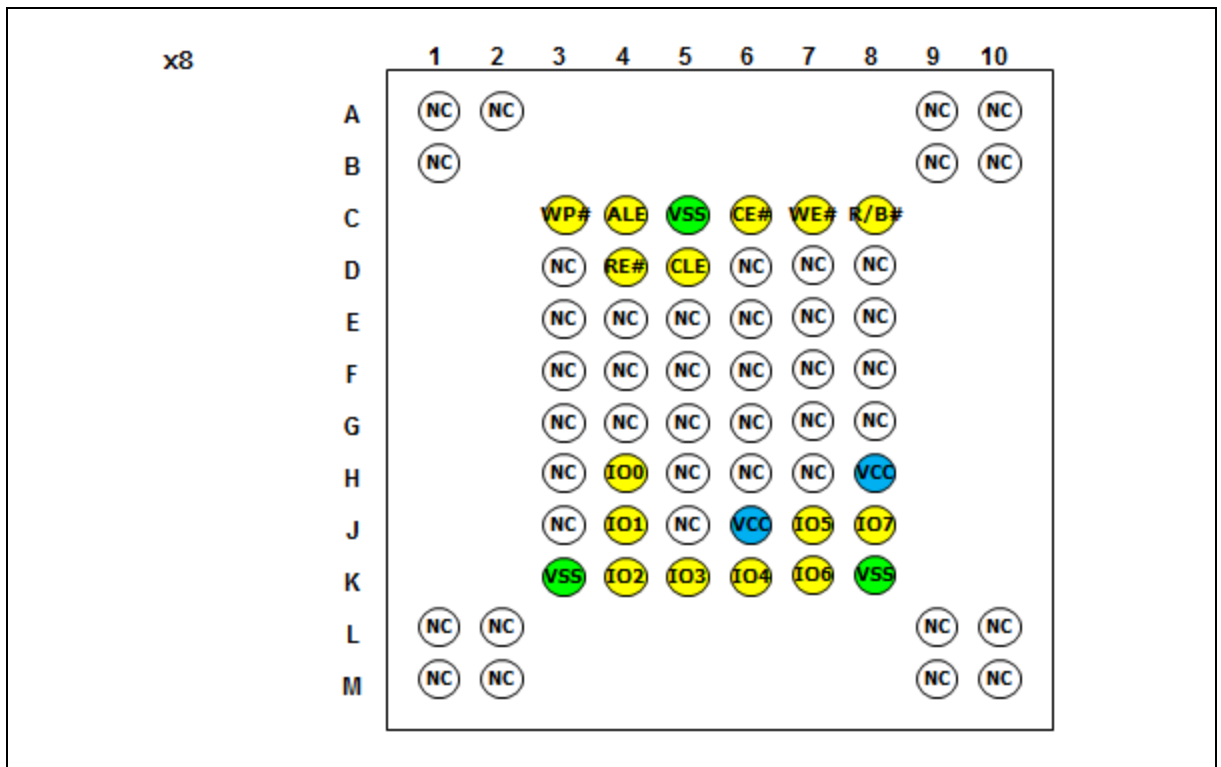


Figure 2 FM29F02I3/FM29LF02I3 ball assignments, FBGA63

Pin Description

| Pin Name | FUNCTION |
|-----------|---|
| I/O0~I/O7 | Data Inputs/Outputs The I/O pins are used to input command, address and data, and to output data during read operations. The I/O pins float to high-z when the chip is deselected or when the outputs are disabled. |
| CLE | Command Latch Enable The CLE input controls the activating path for commands sent to the command register. When active high, commands are latched into the command register through the I/O ports on the rising edge of the WE# signal. |
| ALE | Address Latch Enable The ALE input controls the activating path for address to the internal address register. Addresses are latched on the rising edge of WE# with ALE high. |
| CE# | Chip Enable The CE# input is the device selection control. When the device is in the Busy State, CE# high is ignored, and the device does not return to standby mode in program or erase operation. |
| RE# | Read Enable The RE# input is the serial data-out control, and when active drives the data onto the I/O bus. Data is valid t_{REA} after the falling edge of RE# which also increments the internal column address counter by one. |
| WE# | Write Enable The WE# input controls writes to the I/O port. Commands, address and data are latched on the rising edge of the WE# pulse. |
| WP# | Write Protect The WP# pin provides inadvertent program/erase protection during power transitions. The internal high voltage generator is reset when the WP# pin is active low. |
| R/B# | Ready/Busy Output The R/B# output indicates the status of the device operation. When low, it indicates that a program, erase or random read operation is in process and returns to high state upon completion. It is an open drain output and does not float to high-z condition when the chip is deselected or when outputs are disabled. |
| Vcc | Power Vcc is the power supply for device. |
| Vss | Ground |
| N.C | No connection Lead is not internally connected. |

Note:

1. A 0.1uF capacitor should be connected between the VCC supply Voltage pin and the VSS Ground pin to decouple the current surges from the power supply. The PCB tracks widths must be sufficient to carry the currents required during program and erase operations.

Block Diagram

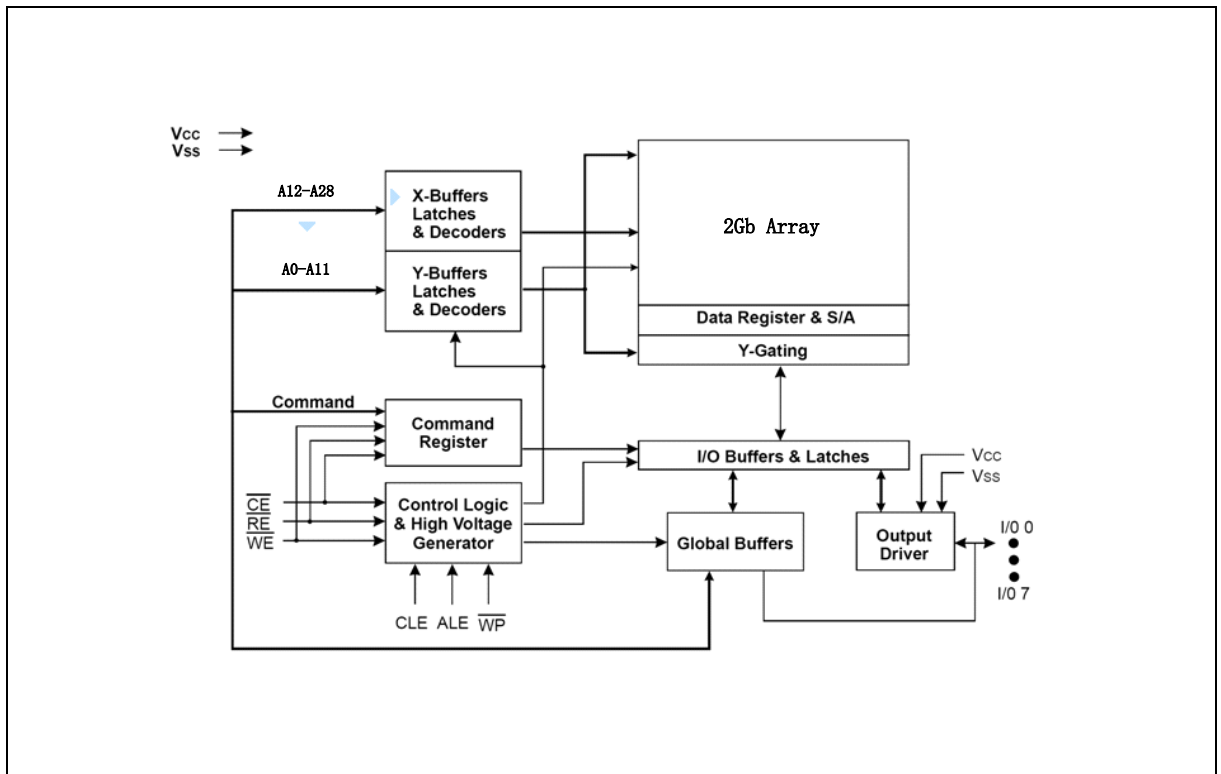


Figure 3 FM29F02I3/FM29LF02I3 NAND Flash Memory Block Diagram

Memory Mapping

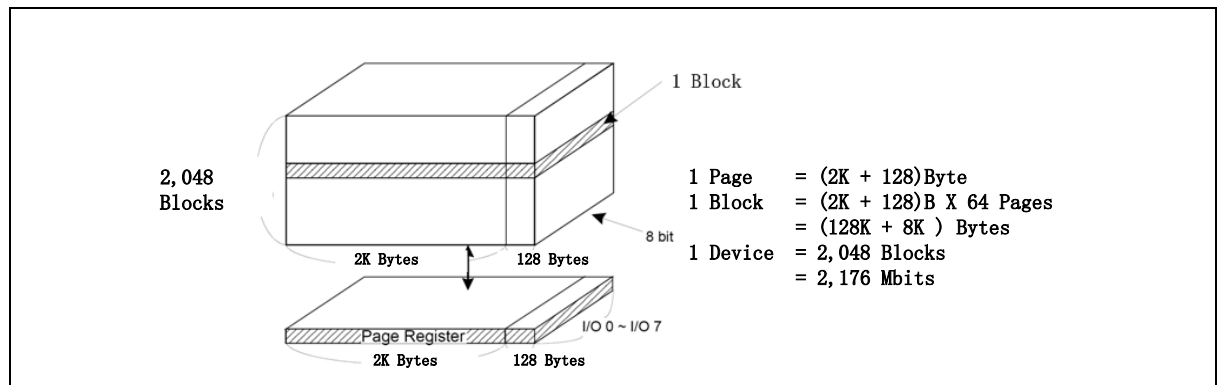


Figure 4 FM29F02I3/FM29LF02I3 Memory Map

Address role

| | DQ0 | DQ1 | DQ2 | DQ3 | DQ4 | DQ5 | DQ6 | DQ7 |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|
| 1st Cycle | A0 | A1 | A2 | A3 | A4 | A5 | A6 | A7 |
| 2nd Cycle | A8 | A9 | A10 | A11 | 0 | 0 | 0 | 0 |
| 3rd Cycle | A12 | A13 | A14 | A15 | A16 | A17 | A18 | A19 |
| 4th Cycle | A20 | A21 | A22 | A23 | A24 | A25 | A26 | A27 |
| 5th Cycle | A28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

NOTE:

A0 - A11 : byte (column) address in the page

A12 - A17 : page address in the block

A18 – A28: block address

Command Set

| Function | 1 st Cycle | 2 nd Cycle | 3 rd Cycle | 4 th Cycle | Accept Command during Busy |
|-----------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|----------------------------|
| Read | 00h | 30h | - | - | |
| Read for copy back | 00h | 35h | - | - | |
| Read ID | 90h | - | - | - | |
| Reset | FFh | - | - | - | Yes |
| Page PGM | 80h | 10h | - | - | |
| Copy-Back Program | 85h | 10h | - | - | |
| Block Erase | 60h | D0h | - | - | |
| Read Status | 70h | - | - | - | Yes |
| Random Data Input ⁽¹⁾ | 85h | - | - | - | |
| Random Data Output ⁽¹⁾ | 05h | E0h | - | - | |
| Read Parameter Page | ECh | - | - | - | |
| Read Unique ID | EDh | - | - | - | |

Table 1 Command Sets

NOTE:

1. Random Data Input/Output can be executed in a page.

Caution: Any undefined command inputs are prohibited except for above command set of Table 1.

Bus Operation

The bus on the device is multiplexed. Data IO, addresses and commands all share the same pins.

The command sequence typically consists of a COMMAND LATCH cycle, address input cycles, and one or more data cycles, either READ or WRITE.

There are serial standard bus operations that control the device. These are Command Input, Address Input, Data Input, Data Output, Write Protect, and Standby.

| Mode | | CLE | ALE | CE# | WE# | RE# | WP# |
|-----------------------|---------------|------------------|-----|-----|--------|---------|-----------------------------------|
| Read Mode | Command Input | H | L | L | Rising | H | X |
| | Address Input | L | H | L | | H | X |
| Write Mode | Command Input | H | L | L | | H | H |
| | Address Input | L | H | L | | H | H |
| Data Input | | L | L | L | | H | H |
| Data Output | | L | L | L | H | Falling | X |
| During Read (Busy) | | X | X | X | X | H | X |
| During Program (Busy) | | X | X | X | X | X | H |
| During Erase (Busy) | | X | X | X | X | X | H |
| Write Protect | | X ⁽¹⁾ | X | X | X | X | L |
| Stand-by | | X | X | H | X | X | 0V/V _{CC} ⁽²⁾ |

NOTE:

1. X can be VIL or VIH.
2. WP# should be biased to CMOS high or CMOS low for standby.

Command Latch Cycle

Command Input bus operation is used to give a command to the memory device. Command are accepted with Chip Enable low, Command Latch Enable High, Address Latch Enable low and Read Enable High and latched on the rising edge of Write Enable. Moreover, for commands that starts a modify operation (write/erase) the Write Protection pin must high.

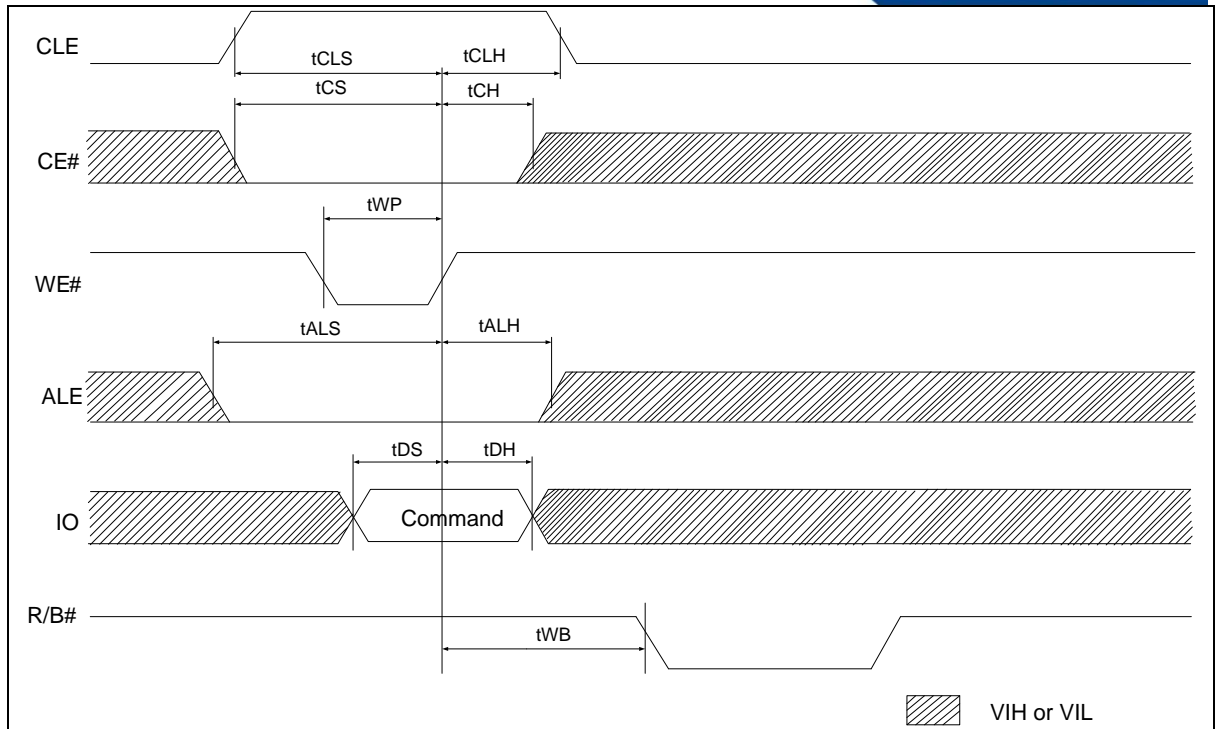


Figure 5 Command Latch timing

Address Latch Cycle

Address Input bus operation allows the insertion of the memory address. Addresses are accepted with Chip Enable low, Address Latch Enable High, Command Latch Enable low and Read Enable High and latched on the rising edge of Write Enable.

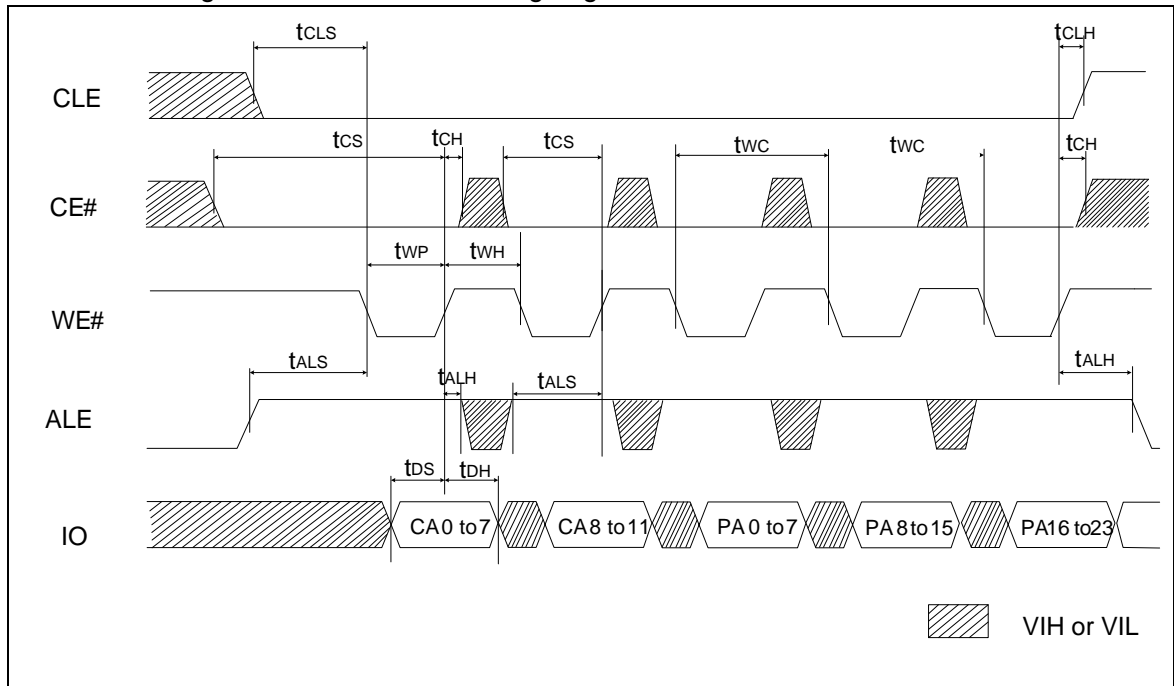


Figure 6 Address Latch timing

Input Data Latch Cycle

Data Input bus operation allows to feed to the device the data to be programmed. The data insertion is serially and timed by the Write Enable cycles. Data are accepted only with Chip Enable low, Address Latch Enable low, Command Latch Enable low and Read Enable High, and Write Protect High and latched on the rising edge of Write Enable.

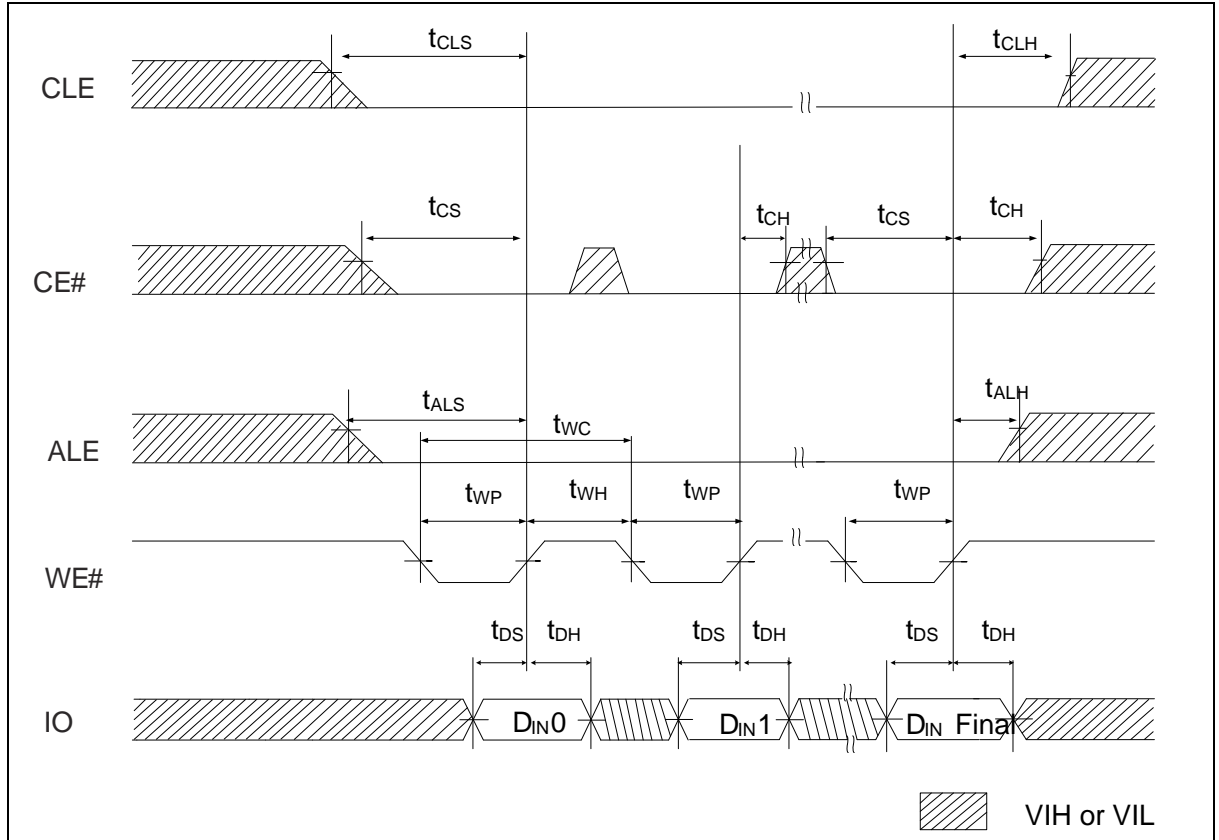
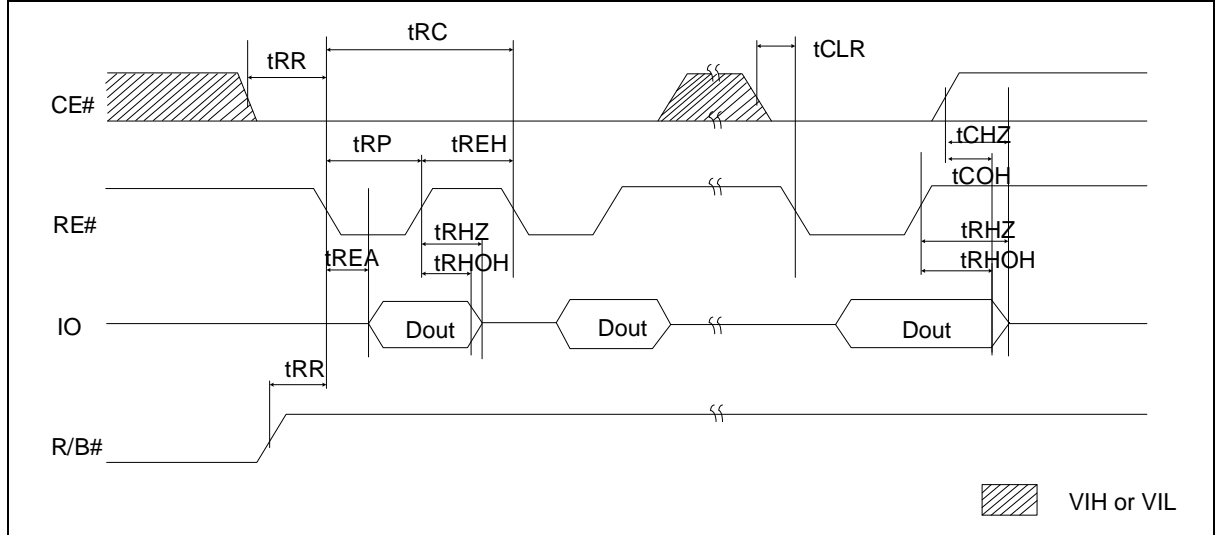


Figure 7 Input Data Latch timing

Serial Access Cycle after Read (CLE=L, WE#=H, ALE=L)

Data Output bus operation allows to output data from the device. The data output cycle is serially and timed by the Read Enable cycles. Data output may be used with CE# don't care. However, if CE# don't care is used t_{CEA} and t_{COH} timing requirements shall be met by the host.



NOTES:

1. Transition is measured at $\pm 200\text{mV}$ from steady state voltage with load.
2. This parameter is sampled and not 100% tested.
3. t_{RLOH} is valid when frequency is higher than 33MHz.
4. t_{RHOH} starts to be valid when frequency is lower than 33MHz.

Figure 8 Serial Read timing

Serial Access Cycle after Read (EDO Type, CLE=L, WE#=H, ALE=L)

If the host uses a sequential access time (t_{RC}) of less than 30ns, the data can be latched on the next falling edge of RE# as the waveform of EDO mode.

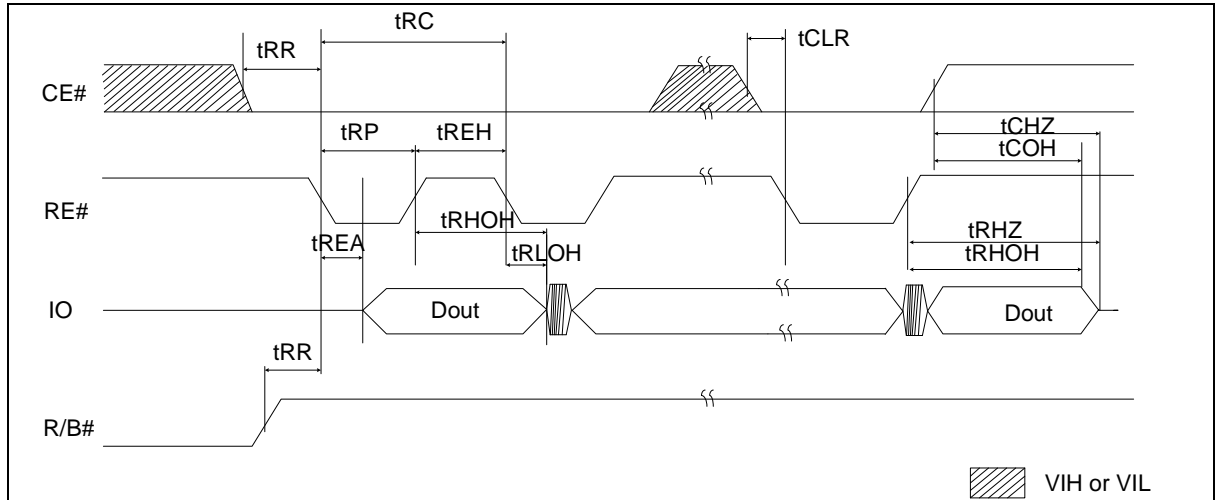


Figure 9 Serial Read timing with EDO mode

NOTES:

1. Transition is measured at $\pm 200\text{mV}$ from steady state voltage with load.
2. This parameter is sampled and not 100% tested.
3. t_{RLOH} is valid when frequency is higher than 33MHz.
4. t_{RHOH} starts to be valid when frequency is lower than 33MHz.

Write Protect

The Program and Erase Operations are automatically reset when WP# goes low. The operations are disabled and enabled as follows.

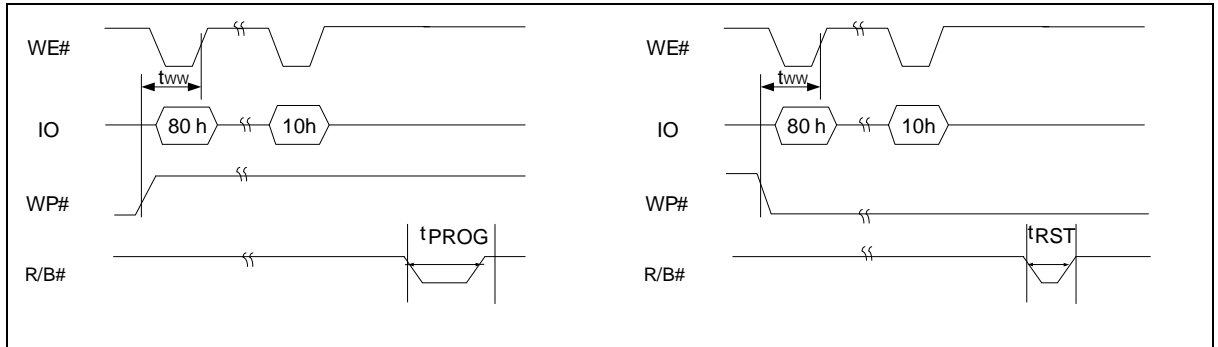


Figure 10 Write Protect Disable VS Enable with Program

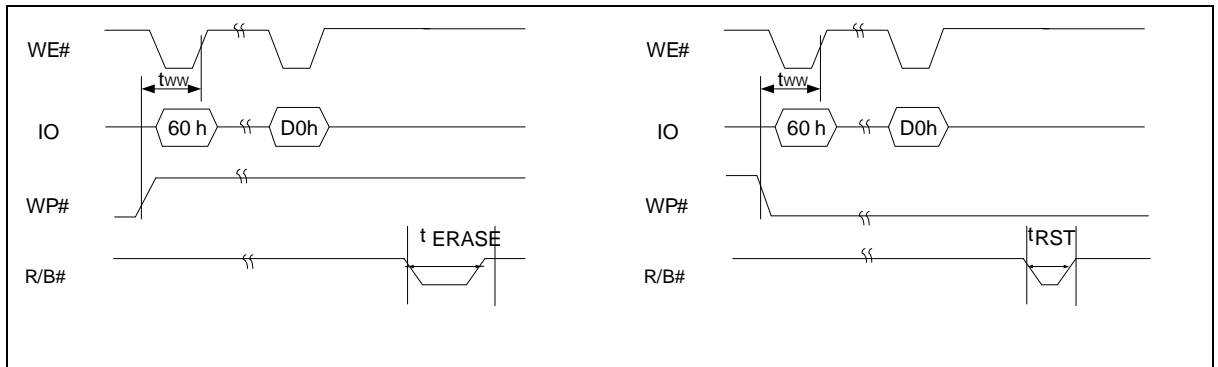


Figure 11 Write Protect Disable VS Enable with Erase

Device Operations

Page Read Operation

Common Page Read (00H-30H)

Page read is initiated by writing 00h-30h to the command register along with five address cycles. The 2,176 bytes of data within the selected page are transferred to the cache registers in less than $40\mu\text{s}(t_R)$.

The system controller can detect the completion of his data transfer(t_R) by analyzing the output of R/B# pin or read status. Once the data in a page is loaded into the cache registers, they may be read out in t_{RC} cycle time by sequentially pulsing RE#. The repetitive high to low transitions of the RE# clock make the device output the data starting from the selected column address up to the last column address.

After power up, device is in read mode so 00h command cycle is not necessary to start a read operation. Any operation other than read or random data output causes device to exit read mode. After the last data has been read out, CE# may be pulled up for some time to end the read operation, while during the RE# toggle cycle, CE# may be don't care when RE# is high. The CE# Don't care feature may simplify the system interface, which allows controller to directly download the code from flash device, and the CE# transitions will not stop the read operation during the latency time.

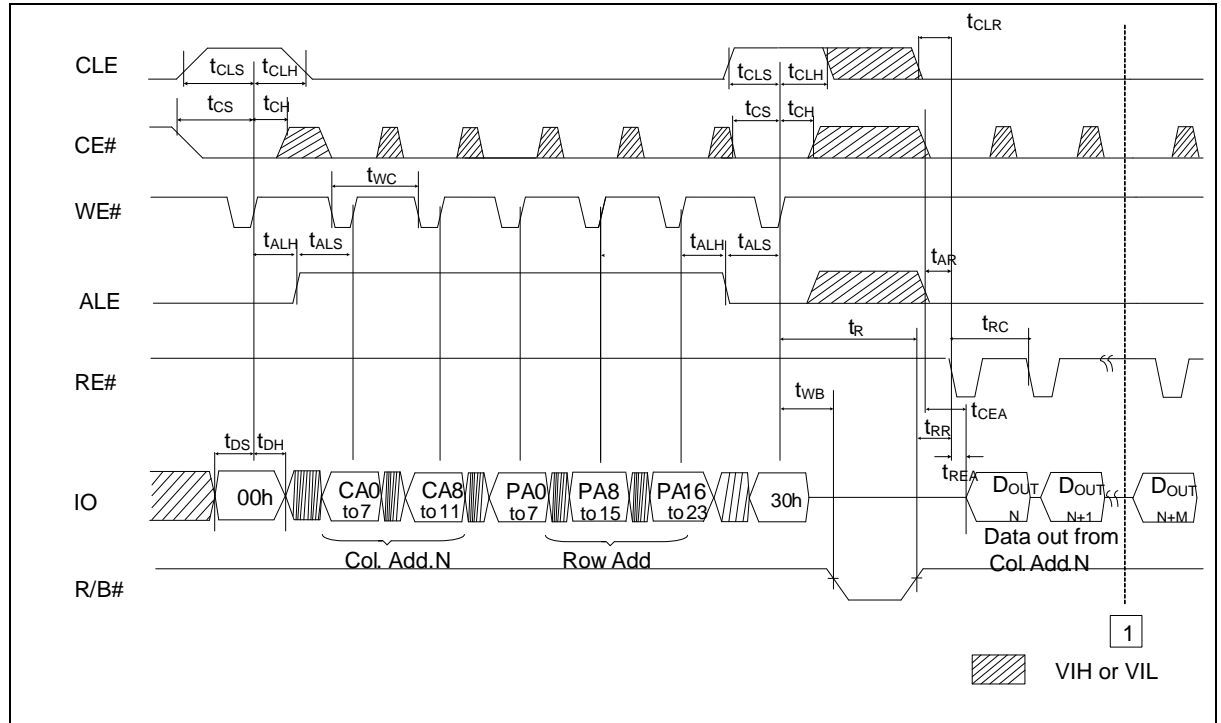


Figure 12 Read Operation

Random Data Output (05H-E0H)

The device may output random data in a page instead of the consecutive data by writing random data output command (05h-E0h). The column address of next data, which is going to be out, may be changed to the address which follows random data output command. Random data output can be operated multiple times regardless of how many times it is done in a page. Random data output shall be issued when the device is in a read idle condition.

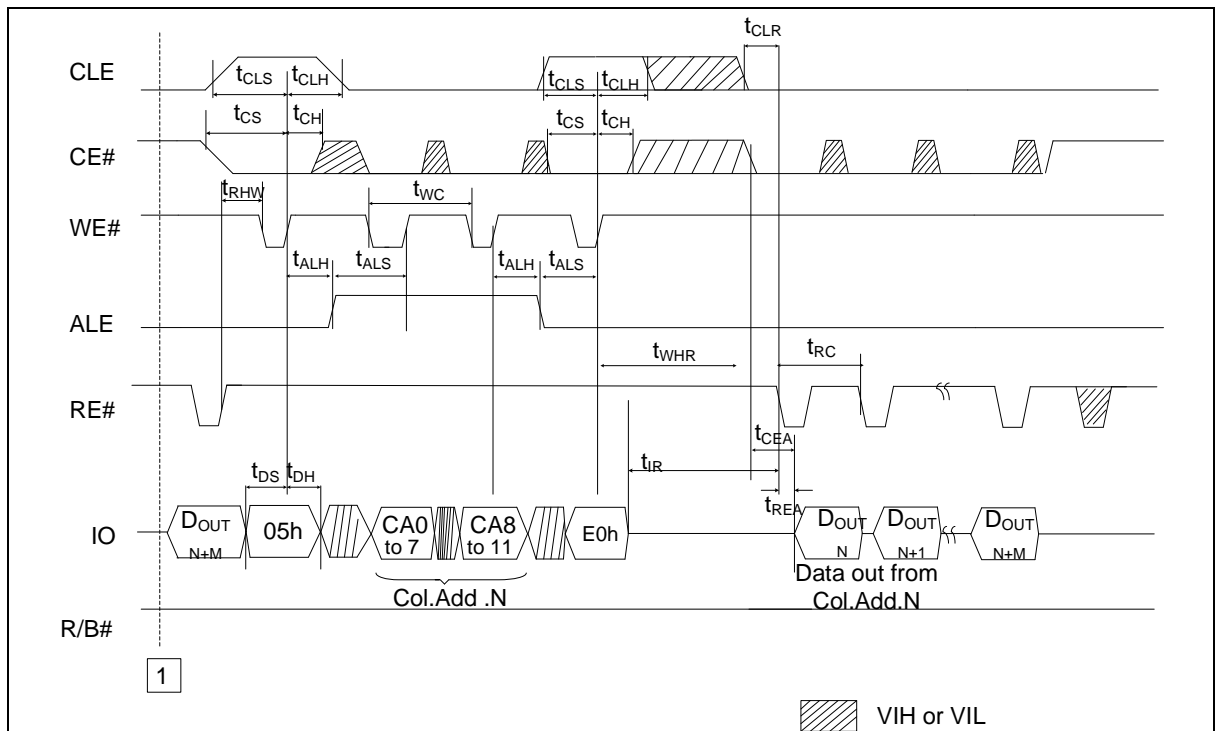


Figure 13 Random Data Output In a Page

Read for copy back(00h-35h)

The Copy-Back Read is configured to efficiently rewrite data stored in a page without data reloading when no error within the page is found. The data is read out only at page buffer for copy-back program.

Though it is not required, it is recommended that the host read the data out of the device to verify the data prior to issuing the Copy-Back Program (85h-10h) command to prevent the propagation of data errors.

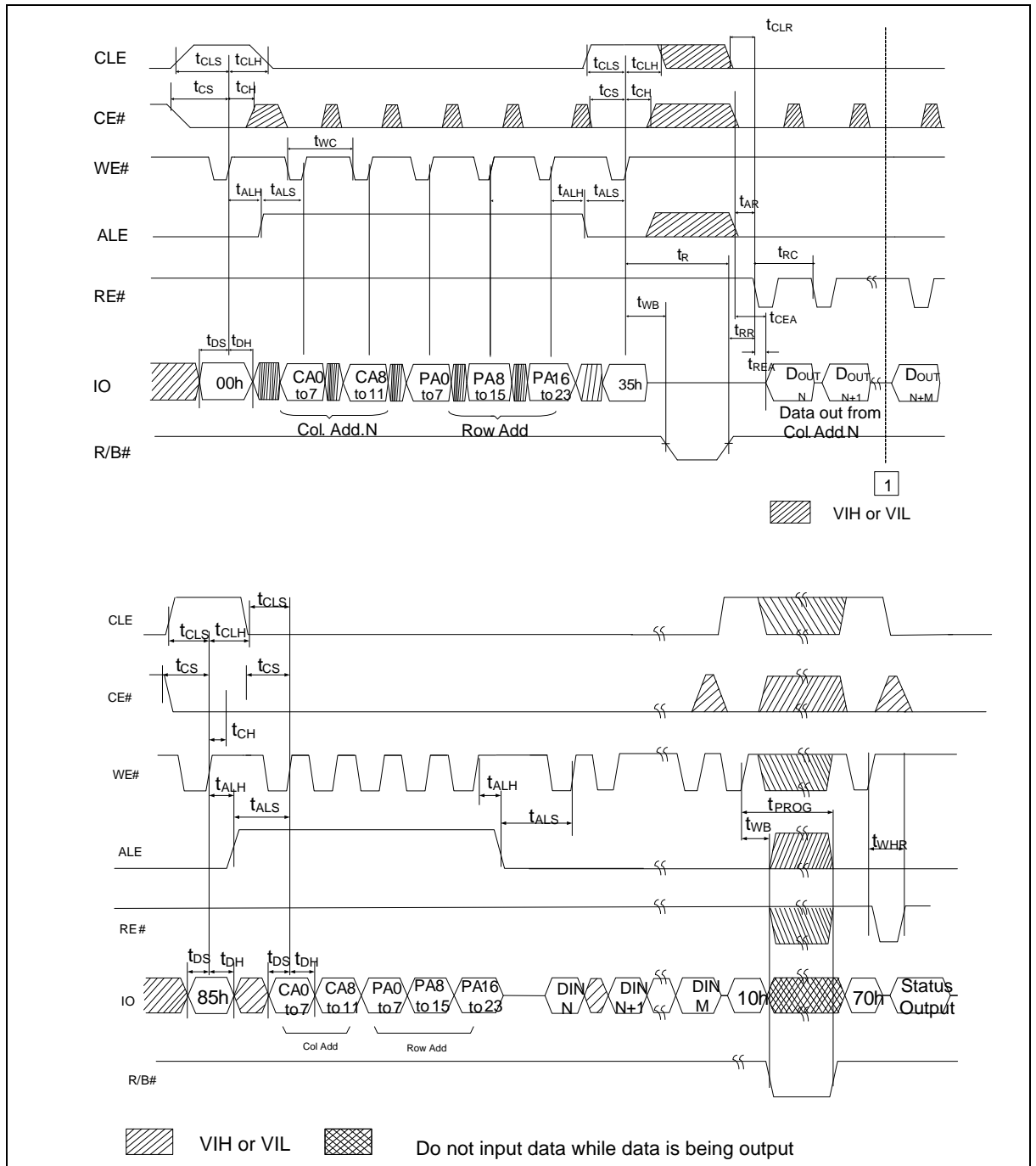


Figure 14 Copy-Back Program operation

Page Program Operation

Common Page Program(80h-10h)

The device is programmed basically on a page basis, but it does allow multiple partial page programming of a word or consecutive bytes up to 2,176, in a single page program cycle. The number of consecutive partial page programming operation within the same page without an intervening erase operation must not exceed 4 times for a single page. The addressing should be done in sequential order in a block.

A page program cycle consists of a serial data loading period in which up to 2,176bytes of data may be loaded into the cache register, followed by a non-volatile programming period where the loaded data is programmed into the appropriate cell.

The serial data loading period begins by inputting the Serial Data Input command(80h), followed by the five cycle address inputs and then serial data loading. The words other than those to be programmed do not need to be loaded.

The Page Program confirm command(10h) initiates the programming process. Writing 10h alone without previously entering the serial data will not initiate the programming process. The internal write state controller automatically executes the algorithms and timings necessary for program and verify, thereby freeing the system controller for other tasks. Once the program process starts, the Read Status Register command may be issued to read the status register.

The system controller can detect the completion of a program cycle by monitoring the R/B# output, or the Status bit(IO6) of the Status Register. Only the Read Status command and Reset command are valid while programming is in progress. When the Page Program is complete, the Write Status Bit(IO0) may be checked. The internal write verify detects only errors for "1"s that are not successfully programmed to "0"s. The command register remains in Read Status command mode until another valid command is written to the command register.

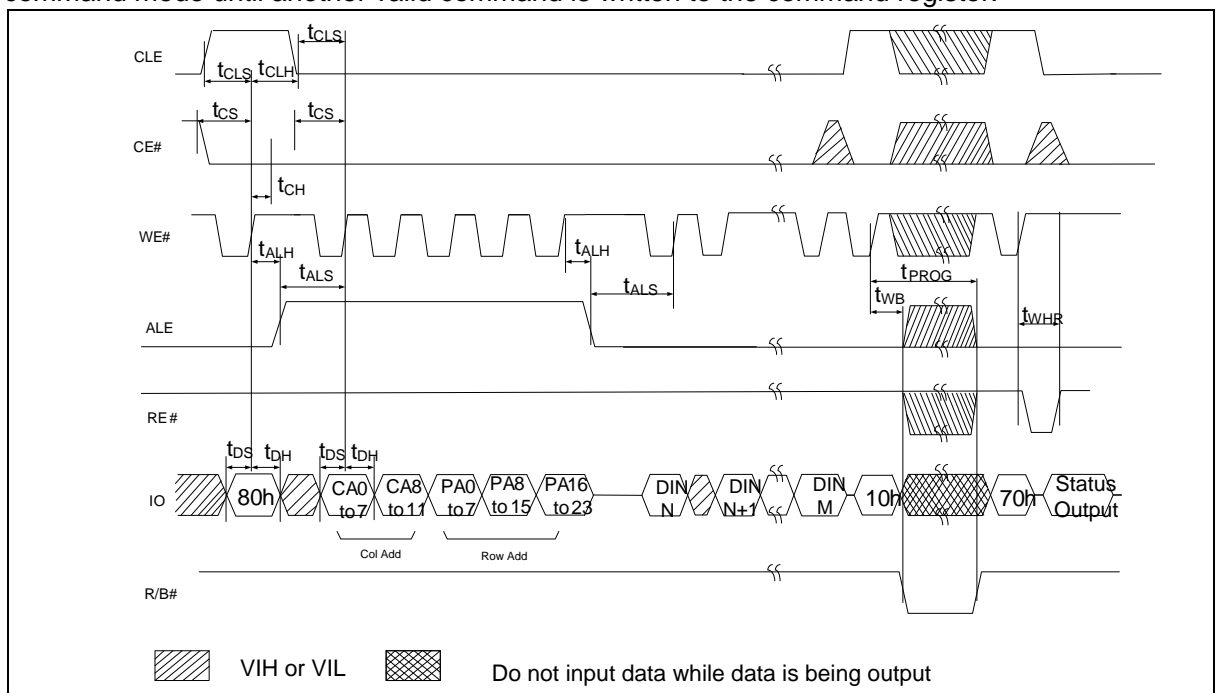


Figure 15 Program & Read Status Operation

Page Program Operation with Random Data Input(85h-10h)

The device supports random data input in a page. The column address for the next data, which will be entered, may be changed to the address which follows random data input command(85h). Random data input may be operated multiple times regardless of how many times it is done in a page.

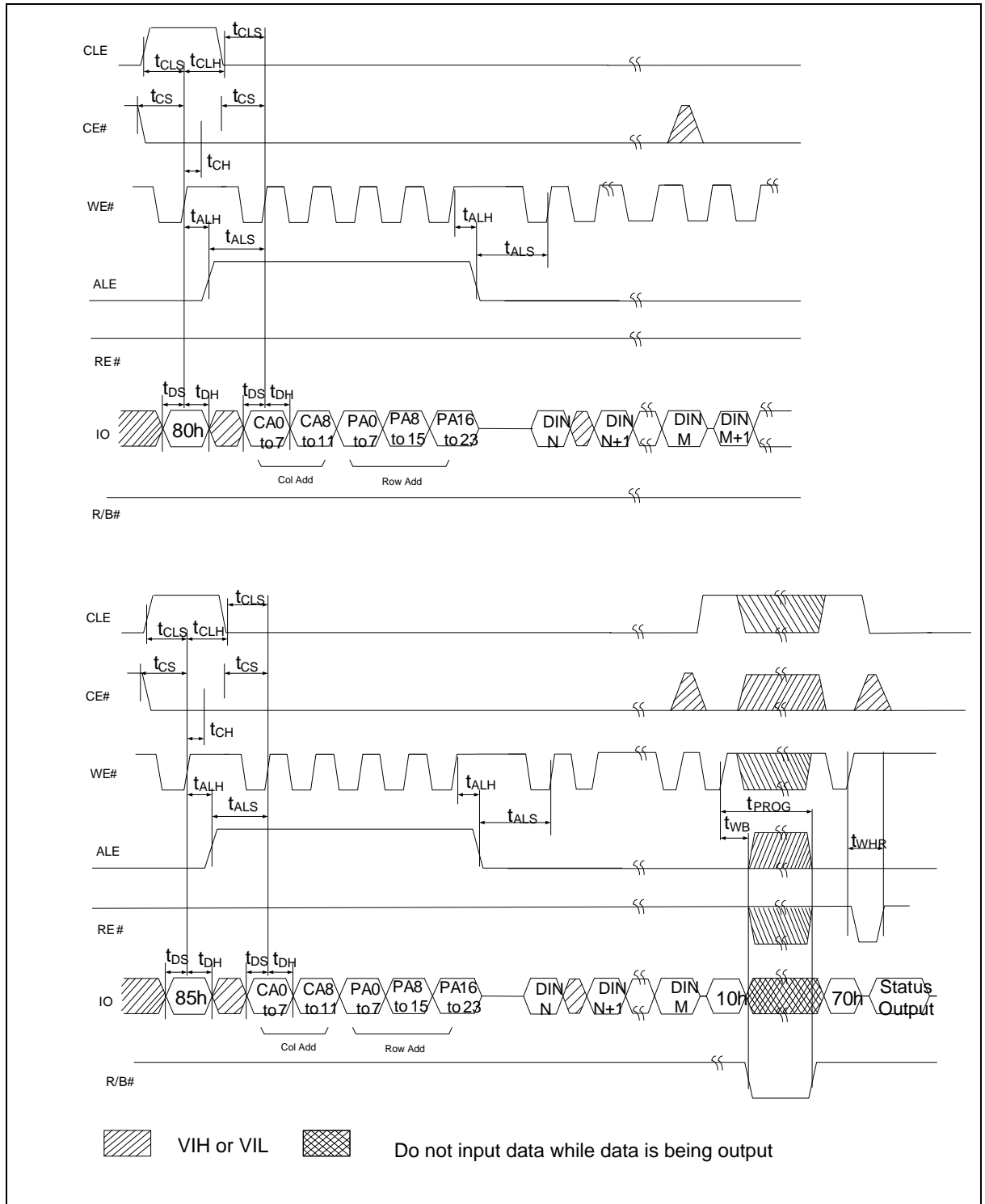


Figure 16 Random Data Input In a Page

Copy-Back Program with Random Data Input(85h-10h)

The Copy-Back program is configured to quickly and efficiently rewrite data stored in one page without utilizing an external memory. Since the time-consuming cycles of serial access and re-loading cycles are removed, the system performance is improved.

The benefit is especially obvious when a part of a block is updated and the rest of the blocks also needs to be copied to the newly assigned free block.

The operation for performing a copy-back program is a sequential execution of page-read without serial access and copying-program with the address of destination page. A read operation with "35h" command and the address of the source page moves the whole 2,176-byte data into the internal cache register. As soon as the device returns to Ready state, optional data read-out is allowed by toggling RE#, or CopyBack command (85h) with the address cycles of destination page followed may be written. The Program Confirm command (10h) is required to actually begin the programming operation. Data input cycle for modifying a portion or multiple distant portions of the source page is allowed. When there is a program-failure at Copy-Back operation, error is reported by pass/fail status.

Once the program process starts, the Read Status Register command (70h) may be entered to read the status register. The system controller can detect the completion of a program cycle by monitoring the R/B# output, or the Status bit(IO 6) of the Status Register.

When the Copy-Back Program is complete, the Write Status Bit(IO 0) may be checked. The internal write verification detects only errors for "1"s that are not successfully programmed to "0"s. The command register remains in Read Status command mode until another valid command is written to the command register.

During copy-back program, data modification is possible using random data input command (85h).

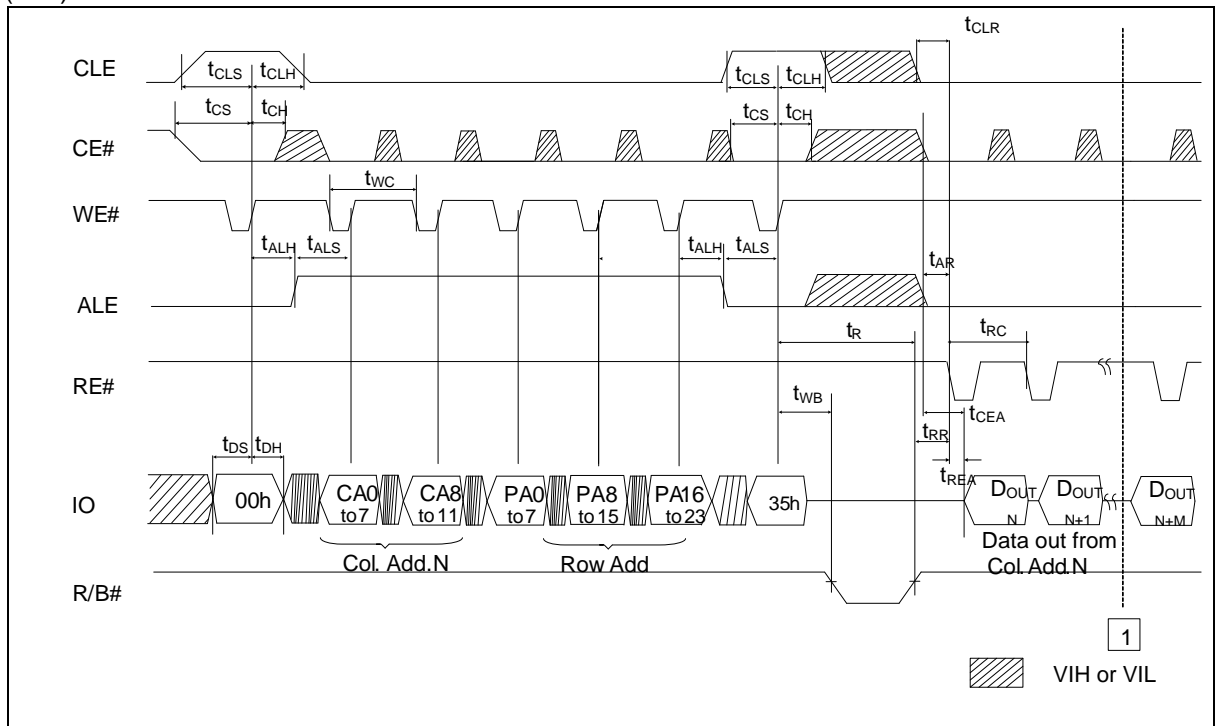


Figure 17 Page Copy-Back Program Operation

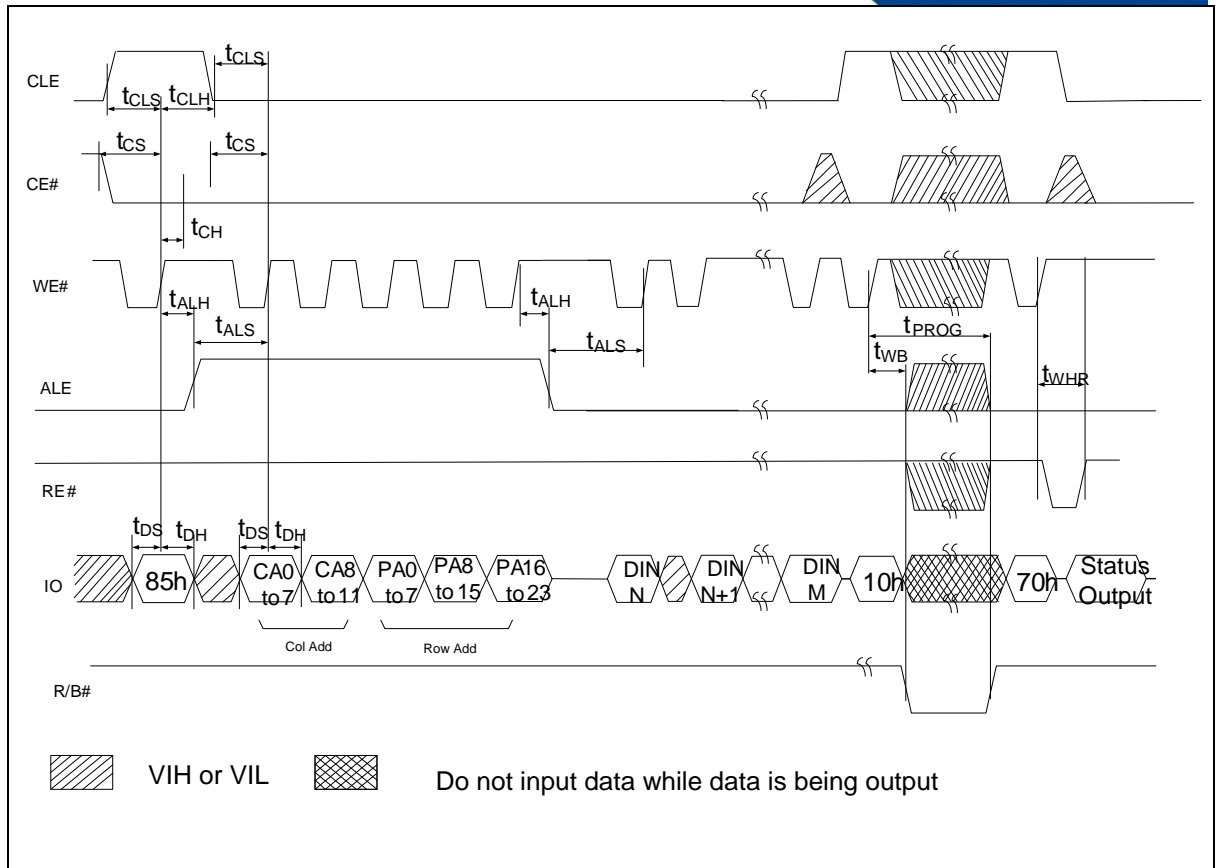


Figure 18 Page Copy-Back Program Operation with random data in

Block Erase Operation

Common Block Erase Operation(60h-D0h)

The Erase operation is done on a block basis. Block address loading is accomplished in three cycles initiated by an Erase Setup command(60h). Only address PA6 to PA17 is valid while PA0 to PA5 is ignored. The Erase Confirm command(D0h) following the block address loading initiates the internal erasing process. This two-step sequence of setup followed by execution command ensures that memory contents are not accidentally erased due to external noise conditions.

At the rising edge of WE# after the erase confirm command input, the internal write controller handles erase and erase-verify. Once the erase process starts, the Read Status Register command may be entered to read the status register. The system controller can detect the completion of an erase by monitoring the R/B# output, or the status bit IO6 of the Status Register. Only the Read Status command and Reset command are valid while erasing in progress. When the erase operation is completed, the Write Status Bit(IO 0) may be checked.

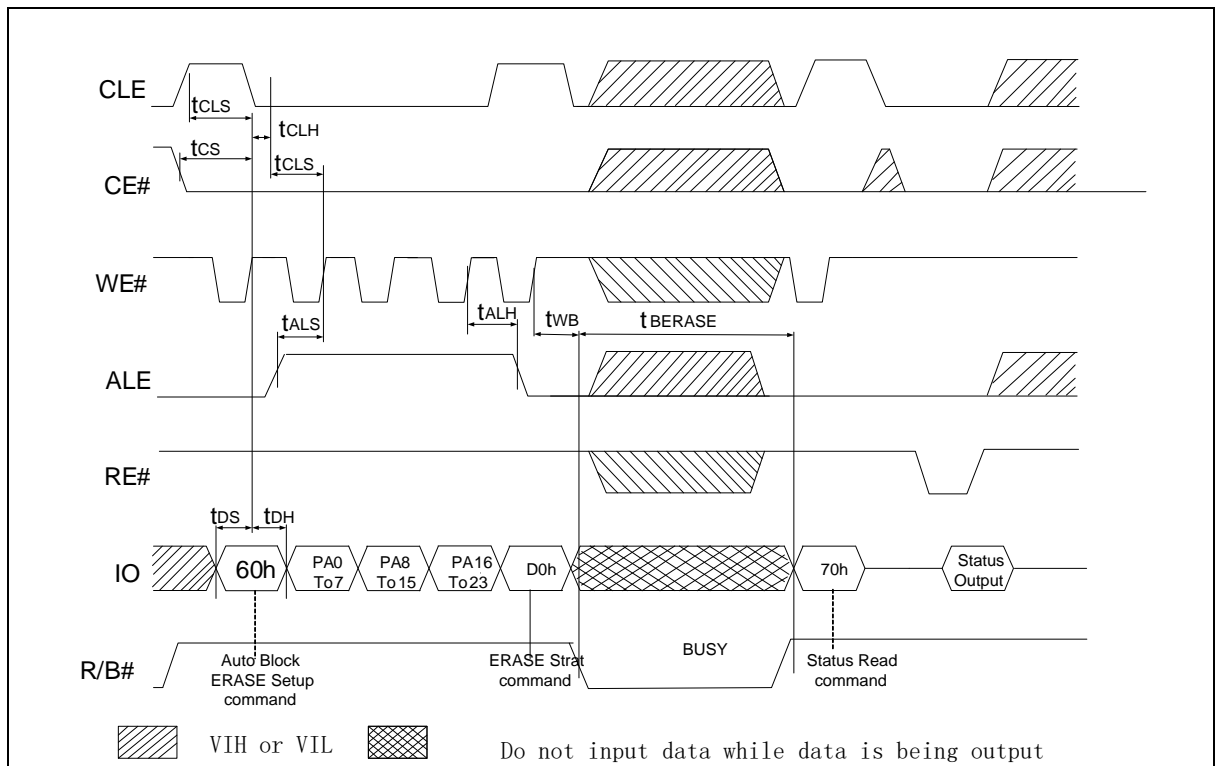


Figure 19 Block Erase Operation

Reset(FFh)

The device offers a reset feature, executed by writing FFh to the command register. When the device is in Busy state during random read, program or erase mode, the reset operation will abort these operations. The contents of memory cells being altered are no longer valid, as the data will be partially programmed or erased. The command register is cleared to wait for the next command, and the Status Register is cleared to value E0h when R/B# is high. If the device is already in ready state a new reset command will be accepted by the command register. The R/B# pin changes to low for t_{RST} after the Reset command is written.

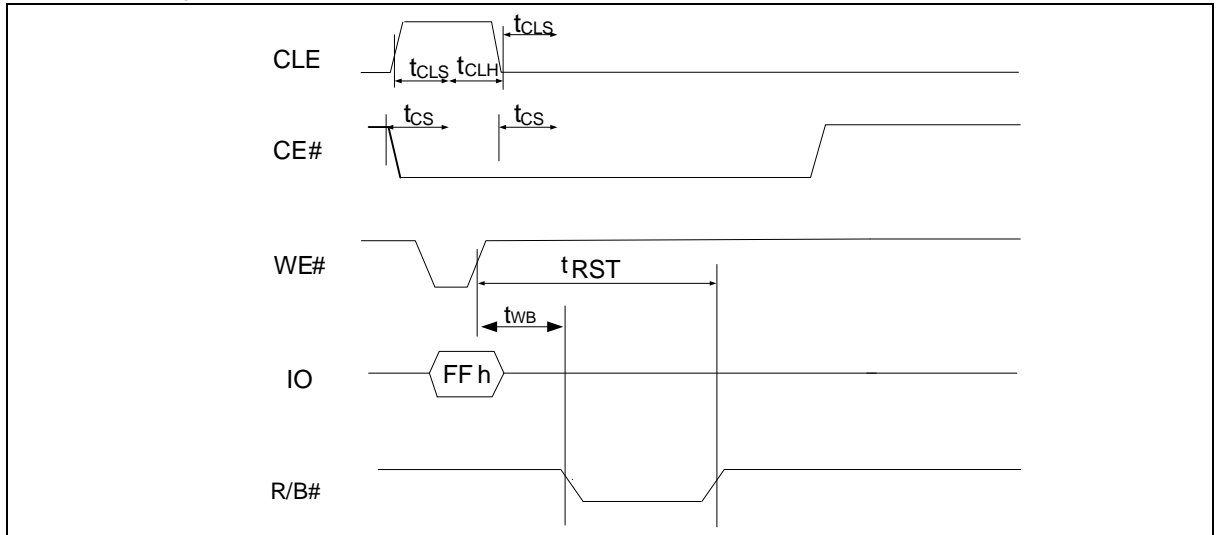


Figure 20 Reset Operation

Read Device information

Read ID and ONFI Signature (90h)

The device contains a product identification mode, initiated by writing 90h to the command register, followed by an address input of 00h. Five read cycles sequentially output the manufacturer code(A1h), and the device code and 3rd, 4th, 5th cycle ID respectively. The command register remains in Read ID mode until further commands are issued to it. Figure 21 shows the operation sequence.

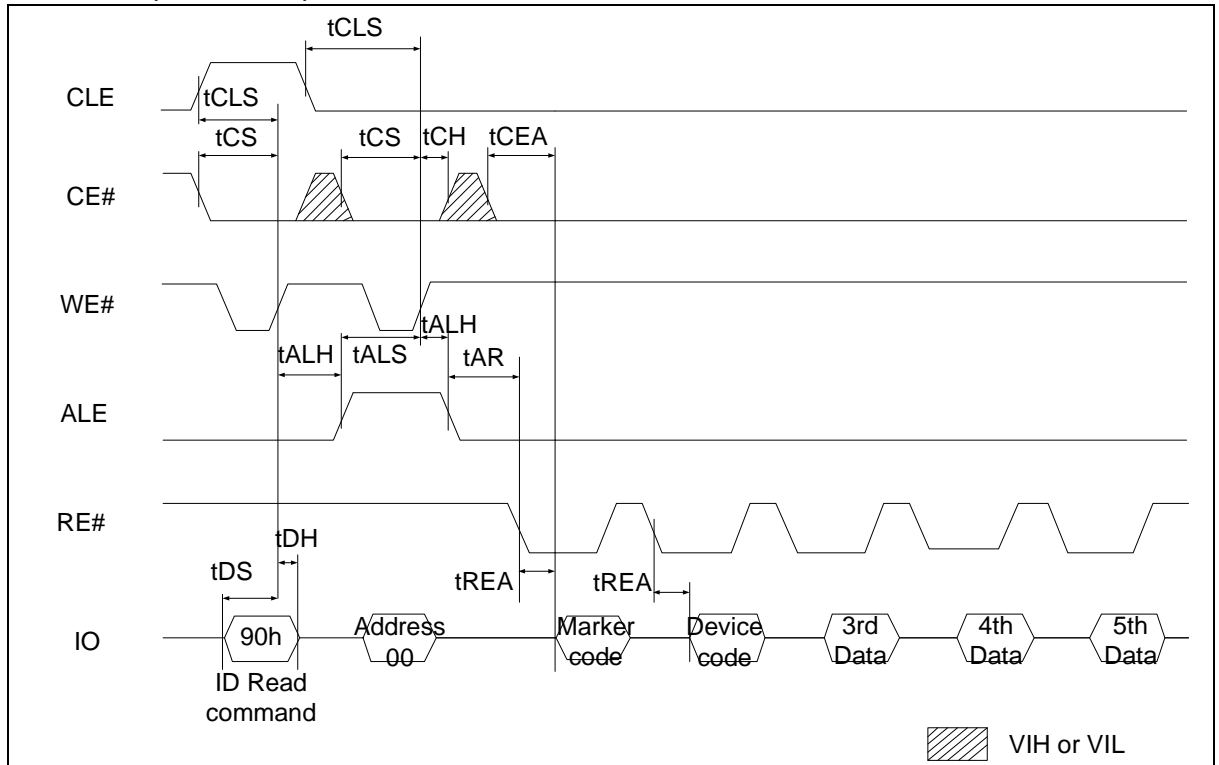


Figure 21 Read ID Operation

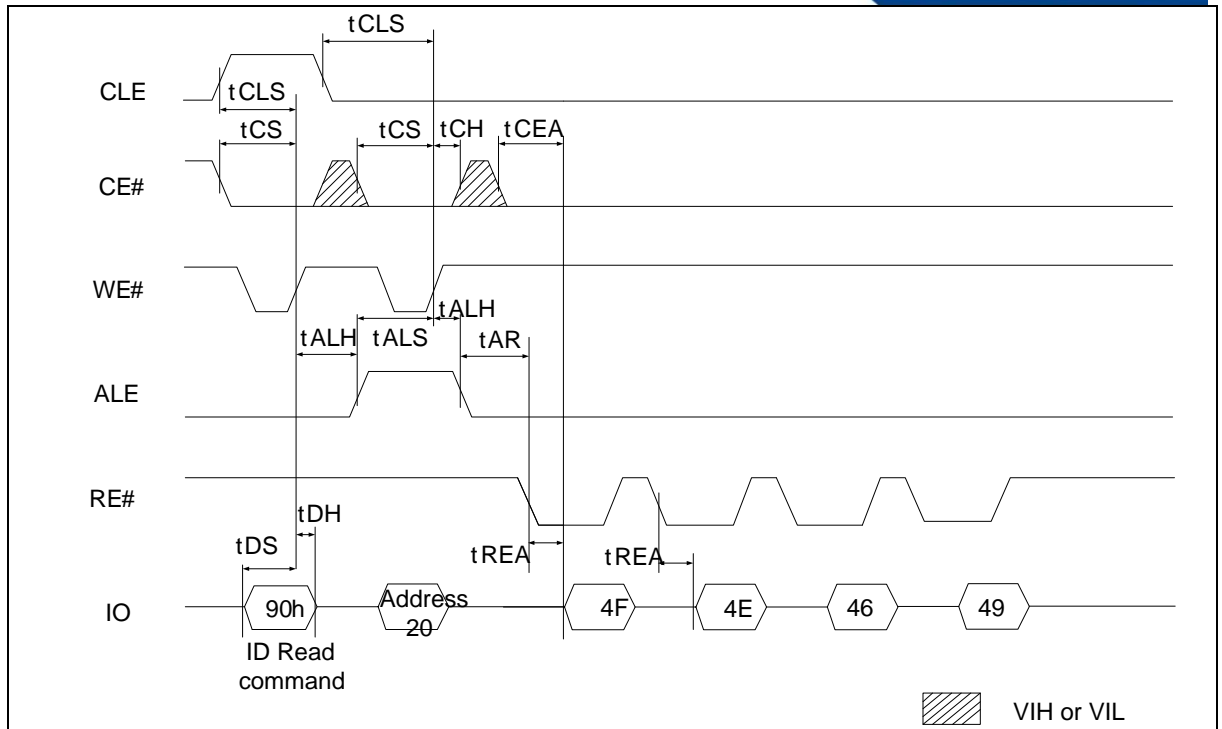


Figure 22 Read Signature

| Device | Maker Code | Device Code | 3rd Cycle | 4th Cycle | 5th Cycle |
|------------|------------|-------------|-----------|-----------|-----------|
| FM29F02I3 | A1h | A6h | 00h | 15h | 53h |
| FM29LF02I3 | A1h | A5h | 00h | 15h | 53h |

Read ID Definition Table

3rd ID Data

| | Description | IO7 | IO6 | IO5 | IO4 | IO3 | IO2 | IO1 | IO0 |
|---|---------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Internal Chip Number | 1 | | | | | | | 0 | 0 |
| | 2 | | | | | | | 0 | 1 |
| | 4 | | | | | | | 1 | 0 |
| | 8 | | | | | | | 1 | 1 |
| Cell Type | 2 Level Cell | | | | | 0 | 0 | | |
| | 4 Level Cell | | | | | 0 | 1 | | |
| | 8 Level Cell | | | | | 1 | 0 | | |
| | 16 Level Cell | | | | | 1 | 1 | | |
| Number of Simultaneously Programmed Pages | 1 | | | 0 | 0 | | | | |
| | 2 | | | 0 | 1 | | | | |
| | 4 | | | 1 | 0 | | | | |
| | 8 | | | 1 | 1 | | | | |
| Interleave Program Between multiple chips | Not support | | 0 | | | | | | |
| | Support | | 1 | | | | | | |
| Cache program | Not Support | 0 | | | | | | | |
| | Support | 1 | | | | | | | |

**4rd ID Data**

| | Description | IO7 | IO6 | IO5 | IO4 | IO3 | IO2 | IO1 | IO0 |
|------------------------------------|-------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Page Size (w/o redundant area) | 1KB | | | | | | | 0 | 0 |
| | 2KB | | | | | | | 0 | 1 |
| | 4KB | | | | | | | 1 | 0 |
| | 8KB | | | | | | | 1 | 1 |
| Block Size (w/o redundant area) | 64KB | | | 0 | 0 | | | | |
| | 128KB | | | 0 | 1 | | | | |
| | 256KB | | | 1 | 0 | | | | |
| | 512KB | | | 1 | 1 | | | | |
| Spare Area Size (byte/512 Byte) | 16 | | | | | | 0 | | |
| | 32 | | | | | | 1 | | |
| IO Organization | X8 | | 0 | | | | | | |
| | X16 | | 1 | | | | | | |
| Serial Access Minimum | 45ns/30ns | 0 | | | | 0 | | | |
| | 20ns | 1 | | | | 0 | | | |
| | Reserved | 0 | | | | 1 | | | |
| | Reserved | 1 | | | | 1 | | | |

5rd ID Data

| | Description | IO7 | IO6 | IO5 | IO4 | IO3 | IO2 | IO1 | IO0 |
|-----------------------------------|----------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Plane Number | 1 | | | | | 0 | 0 | | |
| | 2 | | | | | 0 | 1 | | |
| | 4 | | | | | 1 | 0 | | |
| | 8 | | | | | 1 | 1 | | |
| Plane Size(w/o redundant Area) | 64Mb | | 0 | 0 | 0 | | | | |
| | 128Mb | | 0 | 0 | 1 | | | | |
| | 256Mb | | 0 | 1 | 0 | | | | |
| | 512Mb | | 0 | 1 | 1 | | | | |
| | 1Gb | | 1 | 0 | 0 | | | | |
| | 2Gb | | 1 | 0 | 1 | | | | |
| | 4Gb | | 1 | 1 | 0 | | | | |
| | 8Gb | | 1 | 1 | 1 | | | | |
| ECC Level | 1 bit/512 Byte | | | | | | | 0 | 1 |
| | 2 bit/512 Byte | | | | | | | 1 | 0 |
| | 4 bit/512 Byte | | | | | | | 0 | 0 |
| | 8 bit/512 Byte | | | | | | | 1 | 1 |
| Internal ECC | ECC disable | 0 | | | | | | | |
| | ECC enable | 1 | | | | | | | |

To retrieve the ONFI signature, the command 90h together with an address of 20h shall be entered. The ONFI signature is the ASCII encoding of 'ONFI' where 'O' = 4Fh, 'N' = 4Eh, 'F' = 46h, and 'I' = 49h. Reading beyond four bytes yields indeterminate values. Figure 31 shows the operation sequence.

Read Unique ID(EDh)

The Read Unique ID function is used to retrieve the 16 byte unique ID (UID) for the device. The unique ID when combined with the device manufacturer shall be unique.

The UID data may be stored within the Flash array. To allow the host to determine if the UID is without bit errors, the UID is returned with its complement. If the XOR of the UID and its bit-wise complement is all ones, then the UID is valid. To accommodate robust retrieval of the UID in the case of bit errors, sixteen copies of the UID and the corresponding complement shall be stored by the target. For example, reading bytes 32-63 returns to the host another copy of the UID and its complement.

To change the data output location, it is recommended to use the Random Data Out command set (05H-E0H). The Status Read command (70H) can be used to check the completion. To continue the read operation, a following read command (00h) to re-enable the data out is necessary.

| Bytes | Value |
|-------|--------------------------|
| 0-15 | UID |
| 16-31 | UID complement(bit-wise) |

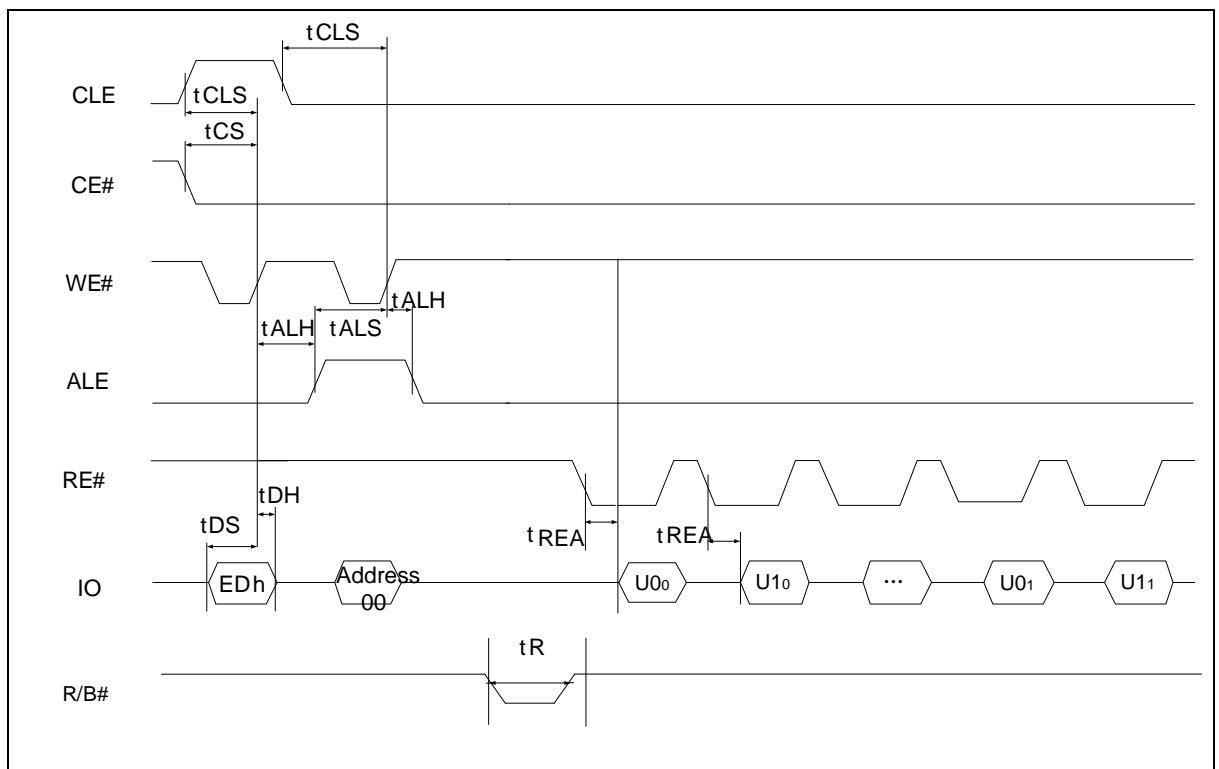


Figure 23 Read Unique ID Operation

Read Parameter Page(ECh)

The Read Parameter Page function retrieves the data structure that describes the chip's organization, features, timing and other behavioral parameters. This data structure enables the host processor to automatically recognize the NAND Flash configuration of a device. A minimum of three copies of the parameter page are stored in the device. The Read Status command (70H) may be used to check the status of read parameter page during execution. After completion of the Read Status command, 00H is issued by the host on the command line to continue with the data output flow for the Read Parameter Page command.

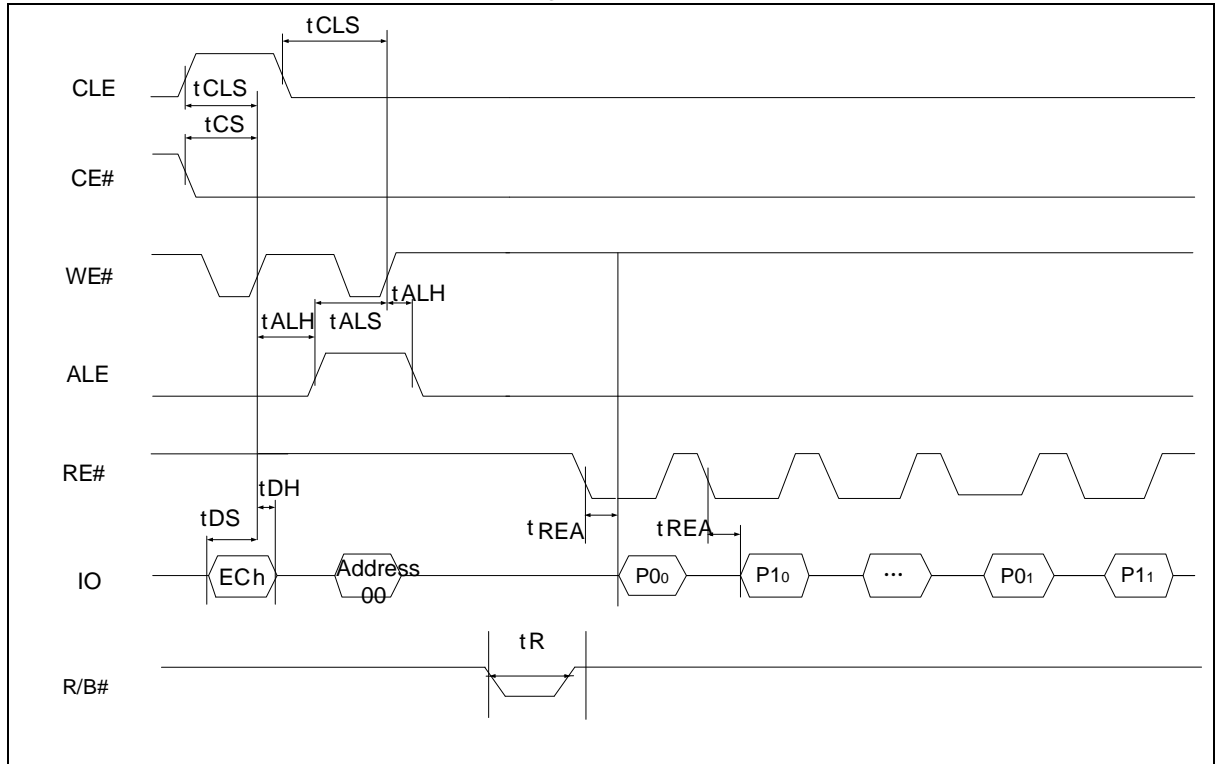


Figure 24 Read Parameter ID Operation

| Byte Number | O/M | Descriptions | Values |
|-------------|-----|--|--------------------|
| 0~3 | M | Parameter Page signature Byte 0: 4Fh, "O" Byte 1: 4Eh, "N" Byte 2: 46h, "F" Byte 3: 49h, "I" | 4Fh, 4Eh, 46h, 49h |
| 4~5 | M | Revision number 2-15 Reserved(0) 1 1=supports ONFI version 1.0 0 reserved (0) | 02h,00h |
| 6~7 | M | Feature supported 6-15 reserved (0) 5 1 = supports source synchronous 4 1 = supports odd to even page | 10h,00h |



| Byte Number | O/M | Descriptions | | Values |
|-------------|-----|---|--------------|--|
| | | Copyback 3 1 = supports interleaved operations 2 1 = supports non-sequential page programming 1 1 = supports multiple LUN operations 0 1 = supports 16-bit data bus width | | |
| 8~9 | M | Optional command supported 6-15 Reserved (0) 5 1 = supports Read Unique ID 4 1 = supports Copyback 3 1 = supports Read Status Enhanced 2 1 = supports Get Features and Set Features 1 1 = supports Read Cache commands 0 1 = supports Page Cache Program command | | 30h,00h |
| 10~31 | | Reserved | | All 00h |
| 32~43 | M | Device manufacture(12 characters)"FUDANMICRO " | ASCII | 46h,55h,44h,41h, 4eh,4dh,49h,43h, 52h,4fh, 20h, 20h |
| 44~63 | M | Device model (20 ASCII characters) | "FM29F02I3" | 46h,4dh,32h,39h, 46h,30h,32h, 49h, 33h,20h, 20h, 20h, 20h, 20h, 20h, 20h, 20h, 20h, 20h,20h |
| | | | "FM29LF02I3" | 46h,4dh,32h,39h, 4Ch,46h,30h, 32h, 49h,33h, 20h, 20h, 20h, 20h, 20h, 20h, 20h, 20h, 20h,20h |
| 64 | M | Manufacture ID | | A1h |
| 65~66 | O | Date code | | 00h,00h |
| 67~79 | | Reserved | | All 00h |
| 80~83 | M | Number of data bytes per page | | 00h, 08h, 00h, 00h |
| 84~85 | M | Number of spare bytes per page | | 80h, 00h |
| 86~89 | M | Number of data bytes per partial page | | 00h, 02h, 00h, 00h |
| 90~91 | M | Number of spare bytes per partial page | | 20h,00h |
| 92~95 | M | Number of pages per block | | 40h, 00h, 00h, 00h |
| 96~99 | M | Number of blocks per block unit | | 00h, 08h, 00h, 00h |
| 100 | M | Number of logic units | | 01h |
| 101 | M | Number of address bytes | | 23h |
| 102 | M | Number of bits per cell | | 01h |
| 103~104 | M | Bad blocks maximum per LUN | | 28h, 00h |
| 105~106 | M | Block endurance | | 08h,04h |
| 107 | M | Guaranteed valid blocks at beginning of target | | 01h |
| 108~109 | M | Block endurance for guaranteed valid blocks | | 01h,03h |
| 110 | M | Number of programs per page | | 04h |



| Byte Number | O/M | Descriptions | Values |
|-------------|-----|--|--------------------------------|
| 111 | M | Partial programming attributes 5-7 Reserved 4 1 = partial page layout is partial page data followed by partial page spare 1-3 Reserved 0 1 = partial page programming has constraints | 00h |
| 112 | M | Number of ECC bits | 08h |
| 113 | M | Interleaved addressing 4-7 Reserved (0) 0-3 Number of interleaved address bits | 00h |
| 114 | O | Interleaved operation attribute 4-7 Reserved (0) 3 Address restrictions for program cache 2 1 = program cache supported 1 1 = no block address restrictions 0 Overlapped / concurrent interleaving support | 00h |
| 115~127 | | Reserved | All 00h |
| 128 | M | I/O pin capacitance, maximum | 0Ah |
| 129~130 | M | Timing mode support 6-15 Reserved (0) 5 1 = supports timing mode 5 4 1 = supports timing mode 4 3 1 = supports timing mode 3 2 1 = supports timing mode 2 1 1 = supports timing mode 1 0 1 = supports timing mode 0, shall be 1 | 1Fh,00h(3.3V) 0Fh,00h(1.8V) |
| 131~132 | O | Program cache timing | 00H |
| 133~134 | M | Maximum page program time (μs) | 84h,03h |
| 135~136 | M | Maximum block erase time (μs) | 10h,27h |
| 137~138 | M | Maximum page read time (μs) | 1Eh,00h |
| 139~163 | | Reserved | All 00h |
| 164~165 | M | Vendor specified revision number | 00h,00h |
| 166~253 | | Vendor specific | All 00h |
| 254~255 | M | Integrity CRC | Set at test |
| 256~511 | M | Value of bytes 0~255 | |
| 512~767 | M | Value of bytes 0~255 | |
| 768+ | O | Reserved | |

Notes:

1. "O" Stands for Optional, "M" for Mandatory
2. The Integrity CRC (Cycling Redundancy Check) field is used to verify that the contents of the parameters page were transferred correctly to the host. Please refer to ONFI 1.0 specifications

for details.

The CRC shall be calculated using the following 16-bit generator polynomial: $G(X) = X^{16} + X^{15} + X^2 + 1$

| Part Number | Organization | Vcc range | CRC value Byte254-255 |
|-------------|--------------|-------------|--------------------------|
| FM29F02I3 | X8 | 2.7 –3.6V | 2EH、ECH |
| FM29LF02I3 | X8 | 1.7 - 1.95V | A5H、50H |

Read Status(70h)

The device contains a Status Register which may be read to find out whether program or erase operation is completed, and whether the program or erase operation is completed successfully. After writing 70h command to the command register, a read cycle outputs the content of the Status Register to the I/O pins on the falling edge of CE# or RE#, whichever occurs last. This allows the system to poll the progress of each device in multiple memory connections even when R/B# pins are common-wired. RE# or CE# does not need to be toggled for updated status. The command register remains in Status Read mode until further commands are issued to it. Therefore, if the status register is read during a random read cycle, the read command(00h) should be given before starting read cycles.

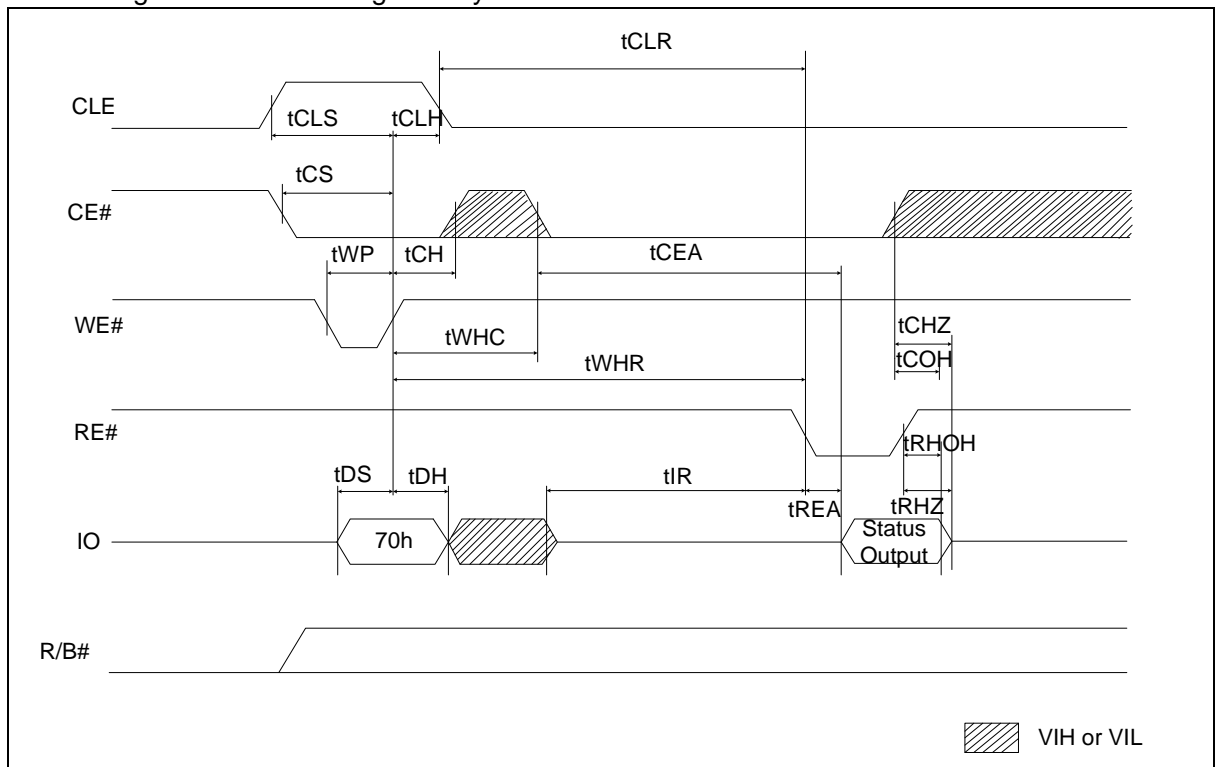


Figure 25 Status Read timing



| I/O | Page Program | Block Erase | Page Read | Definition |
|-------|-----------------|---------------------|---------------------|----------------------------------|
| I/O 0 | Pass/Fail | Pass/Fail | Not use | FAIL Pass: 0 Fail: 1 |
| I/O 1 | Not use | Not use | Not use | Not use |
| I/O 2 | Not use | Not use | Not use | Not use |
| I/O 3 | Not use | Not use | Not use | Don't Care |
| I/O 4 | Not use | Not use | Not use | Don't Care |
| I/O 5 | Read/Busy(ARDY) | Read/Busy (ARDY) | Read/Busy (ARDY) | Busy : 0 Ready: 1 |
| I/O 6 | Read/Busy | Read/Busy | Read/Busy | Busy : 0 Ready: 1 |
| I/O 7 | Write Protect | Write Protect | Write Protect | Protected: 0 Not Protected: 1 |

Table 2 Status Register Definition for 70h Command

Notes:

1. I/O0: This bit is only valid for Program and Erase operations.
2. I/O5: If set to high, then there is no array operation in progress. If cleared to 0, then there is a command being processed (I/O6 is cleared to low) or an array operation in progress.
3. I/O7: the bit indicates if the block is protected, which include WP# protection and other protection.

Ready/Busy

The device has a R/B# output that provides a hardware method of indicating the completion of a page program, erase and random read completion. The R/B# pin is normally high but transitions to low after program or erase command is written to the command register or random read is started after address loading. It returns to high when the internal controller has finished the operation. The pin is an open-drain driver thereby allowing two or more R/B# outputs to be Or-tied. Because pull-up resistor value is related to $t_r(R/B\#)$ and current drain during busy(i_{busy}), an appropriate value can be obtained with the following reference chart. Its value can be determined by the following guidance.

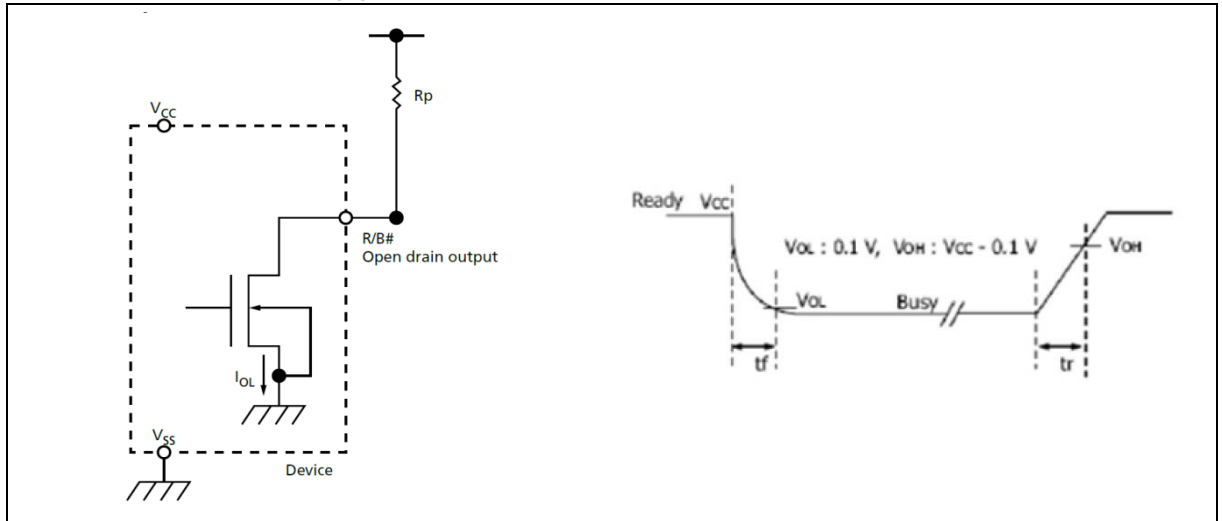
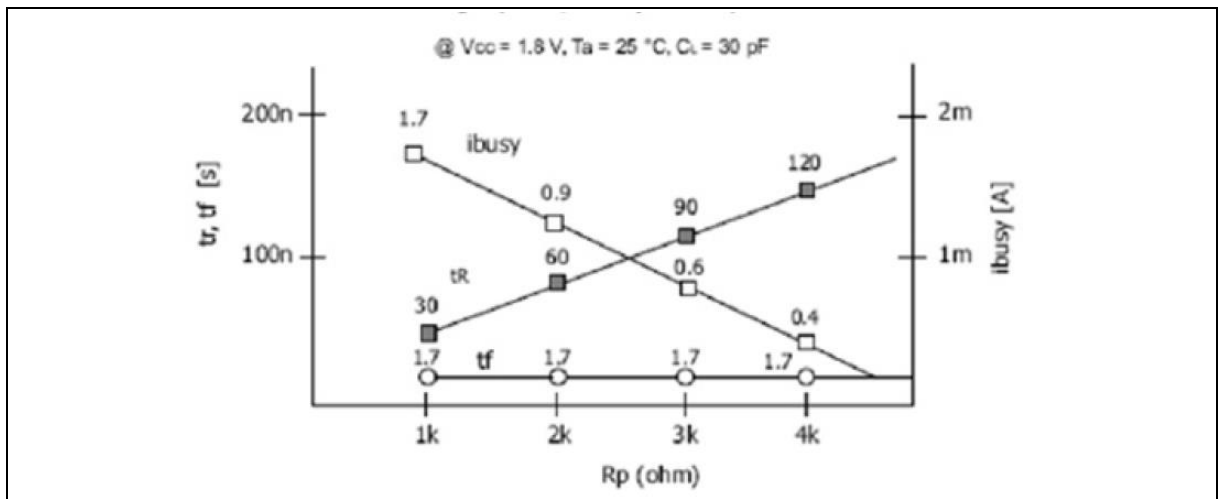


Figure 26 $R_p V_{str}, t_f \& R_p v_{sibusy}$



R_p value guidance

$$R_p (\min) = \frac{V_{CC} (\text{Max.}) - V_{OL} (\text{Max.})}{I_{OL} + \sum I_L} = \frac{1.85 \text{ V}}{3 \text{ mA} + \sum I_L}$$

where I_L is the sum of the input currents of all devices tied to the R/B# pin.

$R_p(\text{max})$ is determined by maximum permissible limit of t_r

Data Protection & Power up sequence

The device is designed to offer protection from any involuntary program/erase during power-transitions. An internal voltage detector disables all functions whenever V_{CC} is below about V_{th} . $WP\#$ pin provides hardware protection and is recommended to be kept at V_{IL} during power-up and power-down. A recovery time of minimum 2ms is required before internal circuit gets ready for any command sequences as shown in Figure 27.

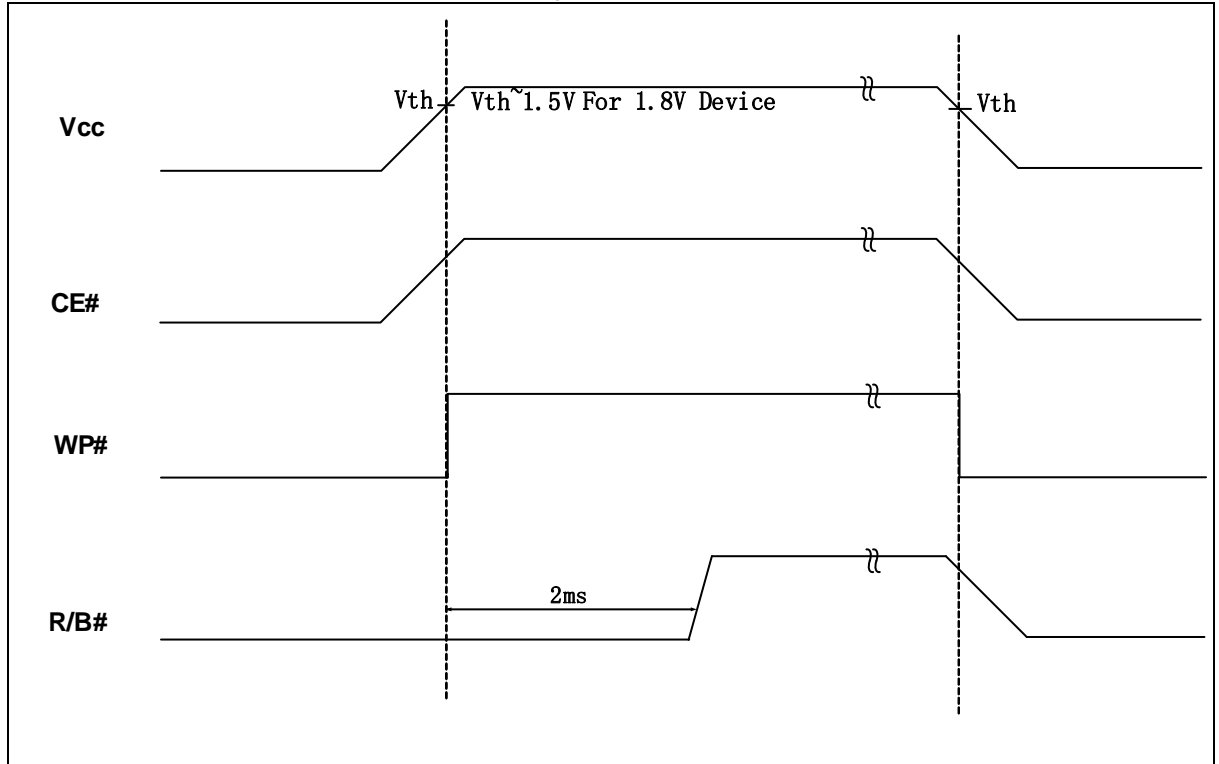


Figure 27 Data protection and power on/off

Electrical Characteristics

Valid Block

| Parameter | Symbol | Min | Typ | Max | Unit |
|----------------------|----------|-------|-----|-------|-------|
| FM29F02I3/FM29LF02I3 | N_{VB} | 2,008 | — | 2,048 | Block |

NOTE:

1. The device may include initial invalid blocks when first shipped. Additional invalid blocks may develop while being used. The number of valid blocks is presented with both cases of invalid blocks considered. Invalid blocks are defined as blocks that contain one or more bad bits. Do not erase or program factory-marked bad blocks. Refer to the attached technical notes for appropriate management of invalid blocks.
2. The 1st block, which is placed on 00h block address, is guaranteed to be a valid block up to 1K program/erase cycles with 8bit/512Byte ECC.
3. Each FM29F02I3/FM29LF02I3 chip has Maximum 40 invalid blocks.

Absolute Maximum Ratings

| Parameter | Symbol | Rating | Unit |
|------------------------------------|------------|----------------------|------|
| Voltage on any pin relative to Vss | V_{CC} | -0.6 to $V_{CC}+0.4$ | V |
| | V_{IN} | -0.6 to $V_{CC}+0.4$ | |
| | V_{IO} | -0.6 to $V_{CC}+0.4$ | |
| Temperature Under Bias | T_{BIAS} | -50 to +125 | °C |
| Storage Temperature | T_{STG} | -65 to +150 | °C |

NOTE:

1. Minimum DC voltage is -0.6V on input/output pins. During transitions, this level may undershoot to -2.0V for periods <30ns.
Maximum DC voltage on input/output pins is $V_{CC}+0.3V$ which, during transitions, may overshoot to $V_{CC}+2.0V$ for periods <20ns.
2. Permanent device damage may occur if ABSOLUTE MAXIMUM RATINGS are exceeded. Functional operation should be restricted to the conditions as detailed in the operational sections of this data sheet. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

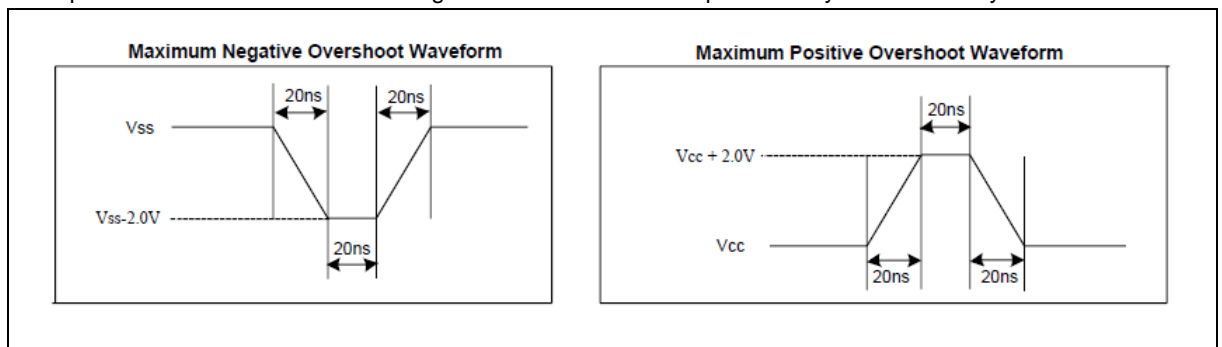


Figure 28 Input Test Waveform and Measurement Level

Recommended Operation Conditions

(Voltage reference to GND, FM29F02I3/FM29LF02I3: $T_A = -40^{\circ}\text{C} \sim 85^{\circ}\text{C}$)

| Parameter | Symbol | Min | Typ | Max | Unit |
|---------------------|-----------------|-----|-----|------|------|
| 1.8V Supply Voltage | V _{CC} | 1.7 | 1.8 | 1.95 | V |
| 3.3V Supply Voltage | V _{CC} | 2.7 | 3.3 | 3.6 | V |
| Supply Voltage | V _{SS} | 0 | 0 | 0 | V |

DC And Operating Characteristics

| Parameter | | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---------------------------|------------------------------|---------------------------|---|----------------------|-----|----------------------|------|
| Operating Current | Page Read with Serial Access | I _{CC1} | t _{RC} =25ns, CE#=V _I L I _{OUT} =0mA | — | 15 | 20 | mA |
| | Program | I _{CC2} | — | | | | |
| | Erase | I _{CC3} | — | | | | |
| Standby Current(CMOS) | | I _{SB2} | CE#=V _{CC} -0.2, WP#=0V/V _{CC} | — | 10 | 50 | uA |
| Input Leakage Current | | I _{LI} | V _{IN} =0 to V _{CC} (max) | — | — | ±10 | |
| Output Leakage Current | | I _{LO} | V _{OUT} =0 to V _{CC} (max) | — | — | ±10 | |
| Input High voltage | | V _{IH} | — | 0.8×V _{CC} | — | V _{CC} +0.3 | V |
| Input Low voltage | | V _{IL} | — | -0.3 | — | 0.2×V _{CC} | |
| Output High voltage Level | | V _{OH} | I _{OH} =-400uA | V _{CC} -0.1 | — | — | |
| Output Low voltage Level | | V _{OL} | I _{OL} =2.1mA | — | — | 0.4 | |
| Output Low Current(R/B#) | | I _{OL} (R/B#) | V _{OL} =0.4V | 8 | 10 | — | mA |

NOTE:

1. V_{IL} can undershoot to -0.4V and V_{IH} can overshoot to V_{CC} +0.4V for duration of 20ns or less.

AC Test Condition

Test Condition

($T_A = -40 \sim 85^{\circ}\text{C}$)

| Parameter | Value |
|--------------------------------|------------------------|
| Input Pulse Levels | 0V to V _{CC} |
| Input Rise and Fall Times | <5ns |
| Input and Output Timing Levels | V _{CC} /2 |
| Output Load | 1 TTL GATE and CL=30pF |

Capacitance

(TA=25°C, f=1.0MHz)

| Parameter | Symbol | Test Condition | Min | Max | Unit |
|--------------------------|------------------|---------------------|-----|-----|------|
| Input/Output Capacitance | C _{I/O} | V _{IL} =0V | — | 10 | pF |
| Input Capacitance | C _{IN} | V _{IL} =0V | — | 10 | pF |

Note: Capacitance is periodically sampled and not 100% tested.

Program/Erase Characteristics

| Parameter | Symbol | Test Condition | Typ | Max | Unit |
|----------------------------------|-------------------|----------------|-----|-----|-------|
| Program Time | t _{PROG} | — | 400 | 900 | us |
| Number of Partial Program Cycles | N _{OP} | — | — | 4 | Cycle |
| Block Erase Time | t _{BERS} | — | 4 | 10 | ms |

NOTE:

1. Typical value is measured at V_{cc}=3.3V, TA=25°C. Not 100% tested.
2. Typical program time is defined as the time within which more than 50% of the whole pages are programmed at 3.3V V_{cc} and 25°C temperature.

AC timing Characteristics for Command/Address/Data Input

| Parameter | Symbol | 3.3V | | 1.8V | | Unit |
|--------------------------------|---------------------------------|------|-----|------|-----|------|
| | | Min | Max | Min | Max | |
| CLE Setup Time | t _{CLS} ⁽¹⁾ | 10 | - | 10 | - | ns |
| CLE Hold Time | t _{CLH} | 5 | - | 5 | - | ns |
| CE# Setup Time | t _{CS} | 15 | - | 25 | - | ns |
| CE# Hold Time | t _{CH} | 5 | - | 5 | - | ns |
| WE# Pulse Width | t _{WP} | 10 | - | 15 | - | ns |
| ALE Setup Time | t _{ALS} | 10 | - | 10 | - | ns |
| ALE Hold Time | t _{ALH} | 5 | - | 5 | - | ns |
| Data Setup Time | t _{DS} | 7 | - | 10 | - | ns |
| Data Hold Time | t _{DH} | 5 | - | 5 | - | ns |
| Write Cycle Time | t _{WC} | 20 | - | 30 | - | ns |
| WE# High Hold Time | t _{WH} | 7 | - | 10 | - | ns |
| Address to Data Loading Timing | t _{ADL} ⁽²⁾ | 70 | - | 100 | - | ns |

NOTE:

1. The transition of the corresponding control pins must occur only once while WE# is held low
2. t_{ADL} is the time from the WE# rising edge of final address cycle to the WE# rising edge of first data cycle

AC Characteristics for Operation

| Parameter | Symbol | 3.3V | | 1.8V | | Unit |
|--|-----------------|------|--------------|------|--------------|------|
| | | Min | Max | Min | Max | |
| Data Transfer From Cell to Register | t_R | - | 25 | - | 40 | us |
| ALE to RE# Delay | t_{AR} | 10 | - | 10 | - | ns |
| CLE to RE# Delay | t_{CLR} | 10 | - | 10 | - | ns |
| Ready to RE# Low | t_{RR} | 20 | - | 20 | - | ns |
| RE# Pulse Width | t_{RP} | 10 | - | 15 | - | ns |
| WE# High to Busy | t_{WB} | - | 100 | - | 100 | ns |
| Read Cycle Time | t_{RC} | 20 | - | 30 | - | ns |
| RE# Access Time | t_{REA} | - | 20 | - | 30 | ns |
| CE# Access Time | t_{CEA} | - | 25 | - | 45 | ns |
| RE# High to Output Hi-Z | t_{RHZ} | - | 100 | - | 100 | ns |
| CE# High to Output Hi-Z | t_{CHZ} | - | 30 | - | 30 | ns |
| CE# High to ALE or CLE Don't care | t_{CSD} | 10 | | 10 | | ns |
| RE# High to Output Hold | t_{RHOH} | 15 | - | 15 | - | ns |
| RE# Low to Output Hold | t_{RLOH} | 5 | - | 5 | - | ns |
| CE# High to Output Hold | t_{COH} | 15 | - | 15 | - | ns |
| RE# High time | t_{REH} | 7 | - | 10 | - | ns |
| Output Hi-Z to RE# Low | t_{IR} | 0 | - | 0 | - | ns |
| RE# High to WE# Low | t_{RHW} | 100 | - | 100 | - | ns |
| WE# High to RE# Low | t_{WHR} | 60 | - | 60 | - | ns |
| Device Reset Time (Read/Program/Erase) | $t_{RST}^{(1)}$ | - | 5/10/50 0 | - | 5/10/50 0 | us |
| Write protection time | t_{WW} | 100 | | 100 | | ns |

NOTE:

1. If reset command(FFh) is written at Ready state, the device goes into Busy for maximum 7μs.



Ordering Information

| | FM | 29F | 02I3 | -XXX | -C | -H | M |
|---|----|-----|------|------|----|----|---|
| Company Prefix | | | | | | | |
| FM = Fudan Microelectronics Group Co.,Ltd | | | | | | | |
| Product Family | | | | | | | |
| 29F = 3.3V PPI NAND Flash | | | | | | | |
| Product Density&Version | | | | | | | |
| 02 = 2G-bit (Page Size 2K+128 bytes) | | | | | | | |
| Package Type | | | | | | | |
| TP = TSOP48 (12x20mm) BGA = BGA63 (9x11mm) | | | | | | | |
| Product Carrier | | | | | | | |
| A = Tray | | | | | | | |
| HSF ID Code | | | | | | | |
| G = RoHS Compliant, Halogen-free, Antimony-free | | | | | | | |
| MSL Level | | | | | | | |
| 3= MSL3 | | | | | | | |



| FM | 29LF | 02I3 | -XXX | -C | -H | M |
|----|------|------|------|----|----|---|
|----|------|------|------|----|----|---|

Company Prefix

FM = Fudan Microelectronics Group Co.,Ltd

Product Family

29LF = 1.8V PPI NAND Flash

Product Density&Version

02 = 2G-bit (Page Size 2K+128 bytes)

Package Type

TP = TSOP48 (12x20mm)
BGA = BGA63 (9x11mm)

Product Carrier

A = Tray

HSF ID Code

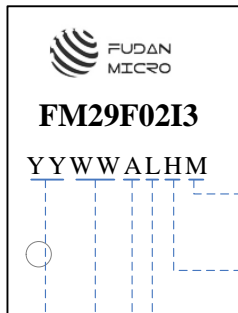
G = RoHS Compliant, Halogen-free, Antimony-free

MSL Level

3= MSL3

Part Marking Scheme

TSOP48 12x20mm



Moisture Sensitivity Level

Blank=MSL3

HSF ID Code

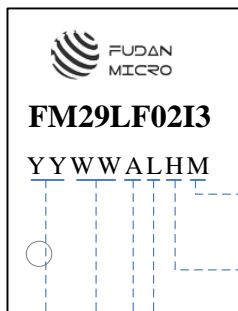
G = RoHS Compliant, Halogen-free, Antimony-free

Lot Number (just with 0~9、A~Z)

Assembly's Code

Work week during which the product was molded (eg..week 12)

The last two digits of the year In which the product was sealed / molded.



Moisture Sensitivity Level

Blank=MSL3

HSF ID Code

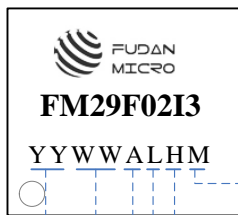
G = RoHS Compliant, Halogen-free, Antimony-free

Lot Number (just with 0~9、A~Z)

Assembly's Code

Work week during which the product was molded (eg..week 12)

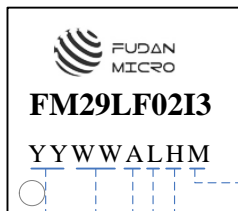
The last two digits of the year In which the product was sealed / molded.

BGA63 9x11mm**Moisture Sensitivity Level**

Blank=MSL3

HSF ID Code

G = RoHS Compliant, Halogen-free, Antimony-free

Lot Number (just with 0~9、A~Z)**Assembly's Code****Work week during which the product was molded (eg..week 12)****The last two digits of the year In which the product was sealed / molded.****Moisture Sensitivity Level**

Blank=MSL3

HSF ID Code

G = RoHS Compliant, Halogen-free, Antimony-free

Lot Number (just with 0~9、A~Z)**Assembly's Code****Work week during which the product was molded (eg..week 12)****The last two digits of the year In which the product was sealed / molded.**

Package Information

Pin configuration(TSOP48)

FM29F02I3/FM29LF02I3 is offered in 48-pin TSOP package as shown in Figure 29. Package diagram and dimension are illustrated in Figure 30.

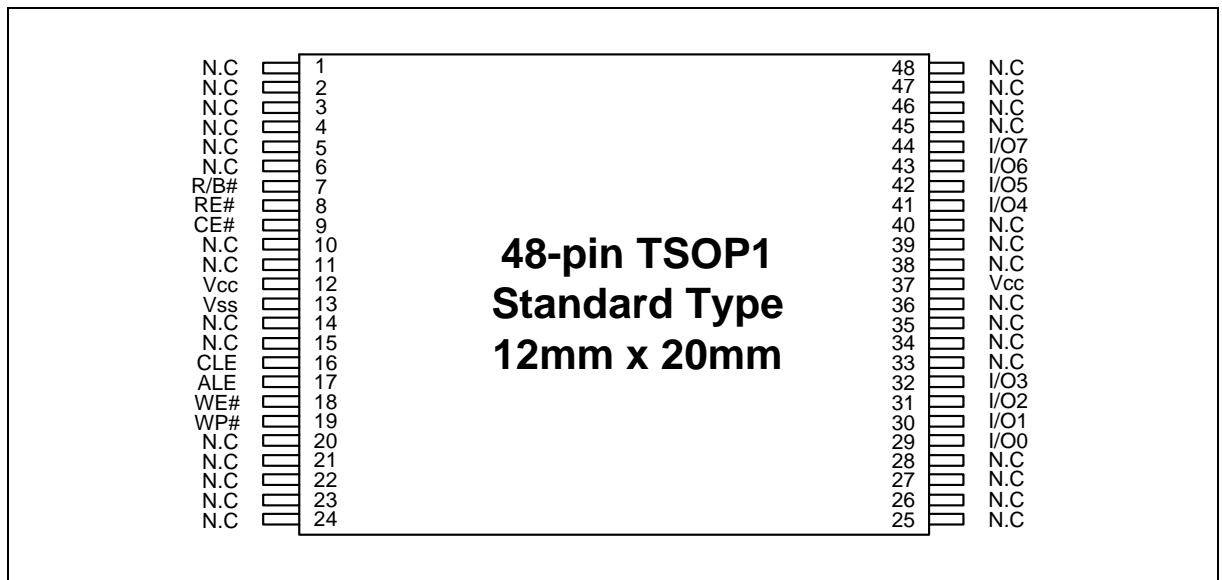
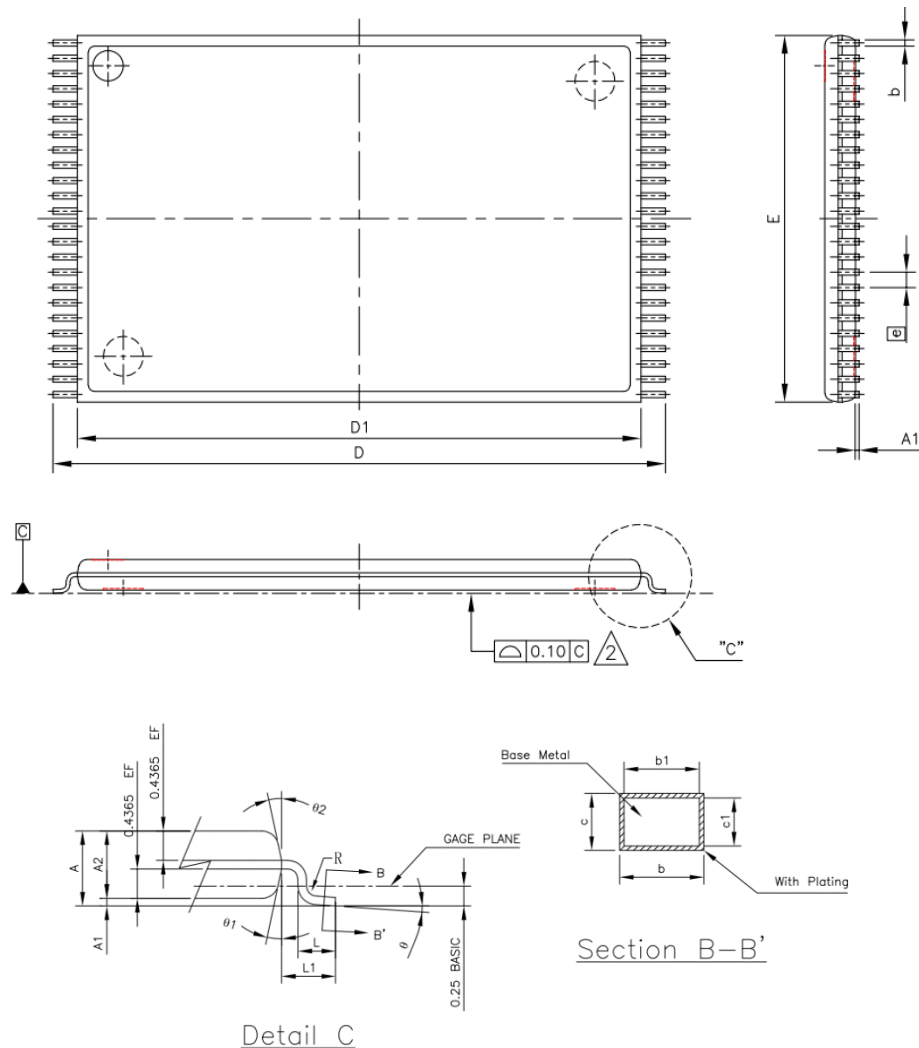


Figure 29 FM29F02I3/FM29LF02I3 pad assignments, TSOP48

Package Dimensions(TSOP48)



| Symbol | MIN | NOM | MAX |
|----------|------------|--------|--------|
| A | - | - | 1.200 |
| A1 | 0.050 | - | - |
| A2 | 0.950 | 1.000 | 1.050 |
| b | 0.170 | 0.220 | 0.270 |
| c | 0.090 | 0.150 | 0.210 |
| e | 0.500(BSC) | | |
| D | 19.800 | 20.000 | 20.200 |
| D1 | 18.200 | 18.400 | 18.600 |
| E | - | - | 12.400 |
| L | 0.450 | 0.600 | 0.750 |
| θ | 0° | 4° | 8° |

NOTE:

Dimensions are in Millimeters.

Figure 30 TSOP48 Package Dimensions

Ball Assignment: 63-Ball FBGA(Balls Down, Top View)

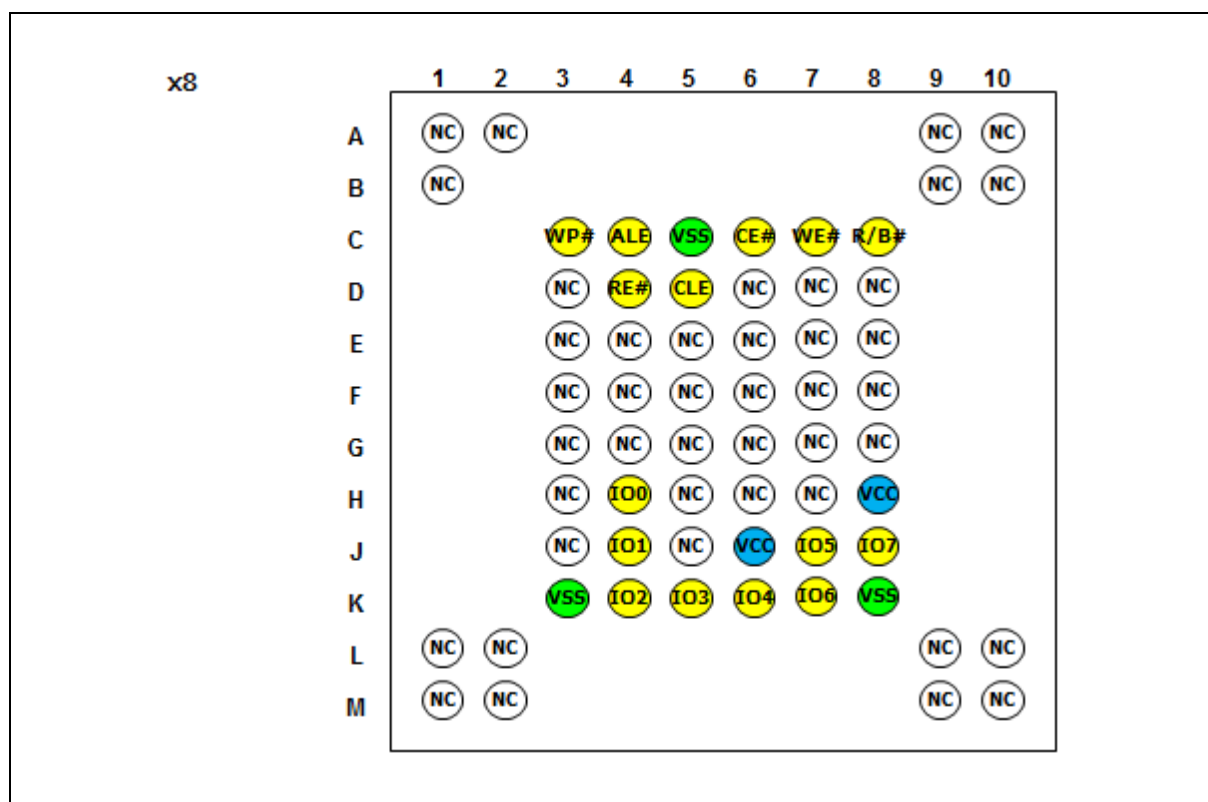


Figure 31 FM29F02I3/FM29LF02I3 ball assignments, FBGA63

Package Dimensions:63-Ball FBGA(Balls Down, Top View)

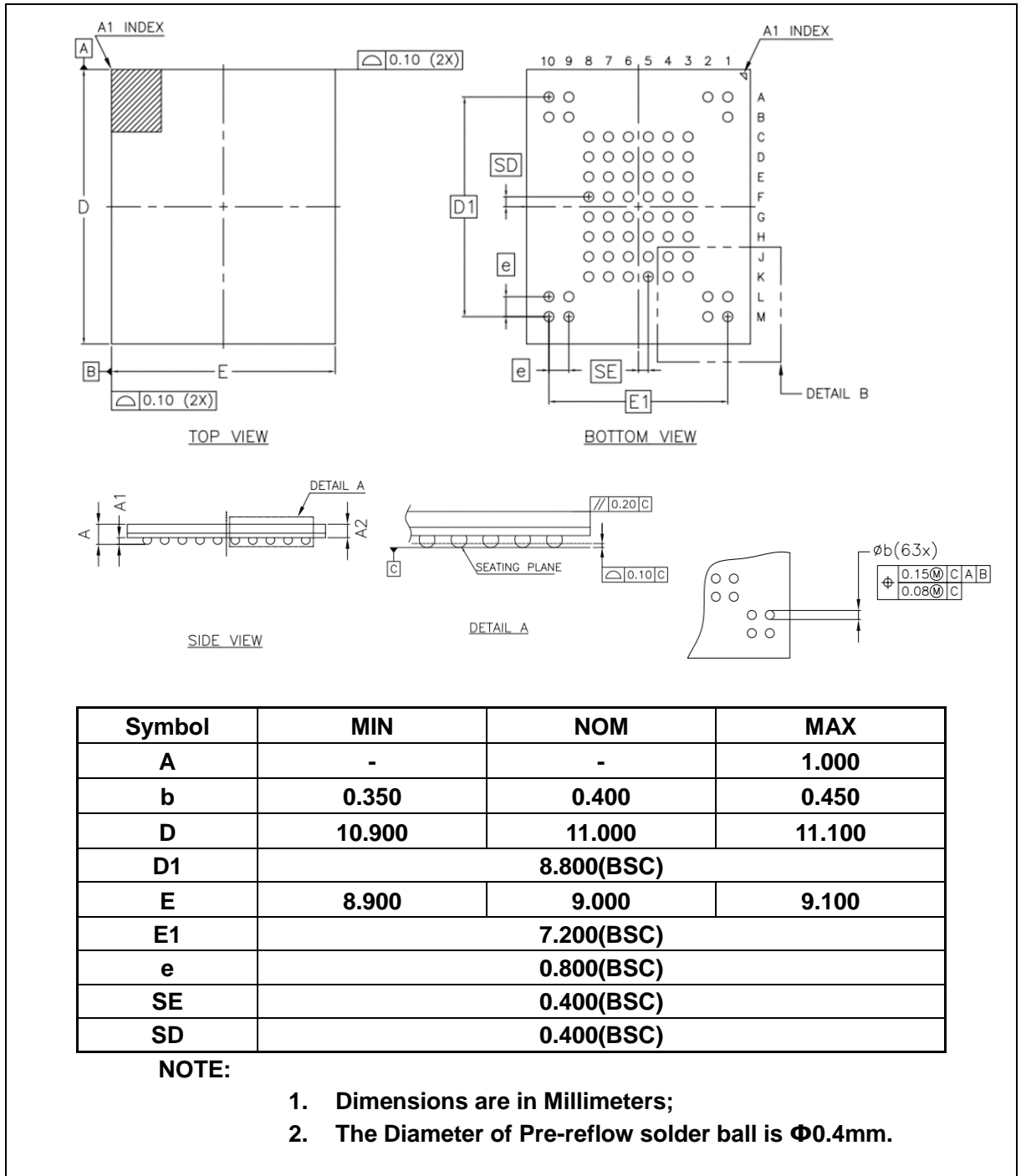


Figure 32BGA63 Package Dimensions

NAND Flash Technical Notes

Initial Invalid Block(s)

Initial invalid blocks are defined as blocks that contain one or more initial invalid bits whose reliability is not guaranteed. The information regarding the initial invalid block(s) is called the initial invalid block information. Devices with initial invalid block(s) have the same quality level as devices with all valid blocks and have the same AC and DC characteristics. An initial invalid block(s) does not affect the performance of valid block(s) because it is isolated from the bit line and the common source line by a select transistor. The system design must be able to mask out the initial invalid block(s) via address mapping. The 1st block, which is placed on 00h block address, is guaranteed to be a valid block up to 1K program/erase cycles with 8it/512Byte ECC.

Identifying Initial Invalid Block(s)

All device locations are erased(FFh) except locations where the initial invalid block(s) information is written prior to shipping. The initial invalid block(s) status is defined by the 1st byte in the spare area. FM29F02I3/FM29LF02I3 makes sure that either the 1st or 2nd page of every initial invalid block has non-FFh data at the column address of 2048. Since the initial invalid block information is also erasable in most cases, it is impossible to recover the information once it has been erased. Therefore, the system must be able to recognize the initial invalid block(s) based on the original initial invalid block information and create the initial invalid block table via the following suggested flow chart. Any intentional erasure of the original initial invalid block information is prohibited.

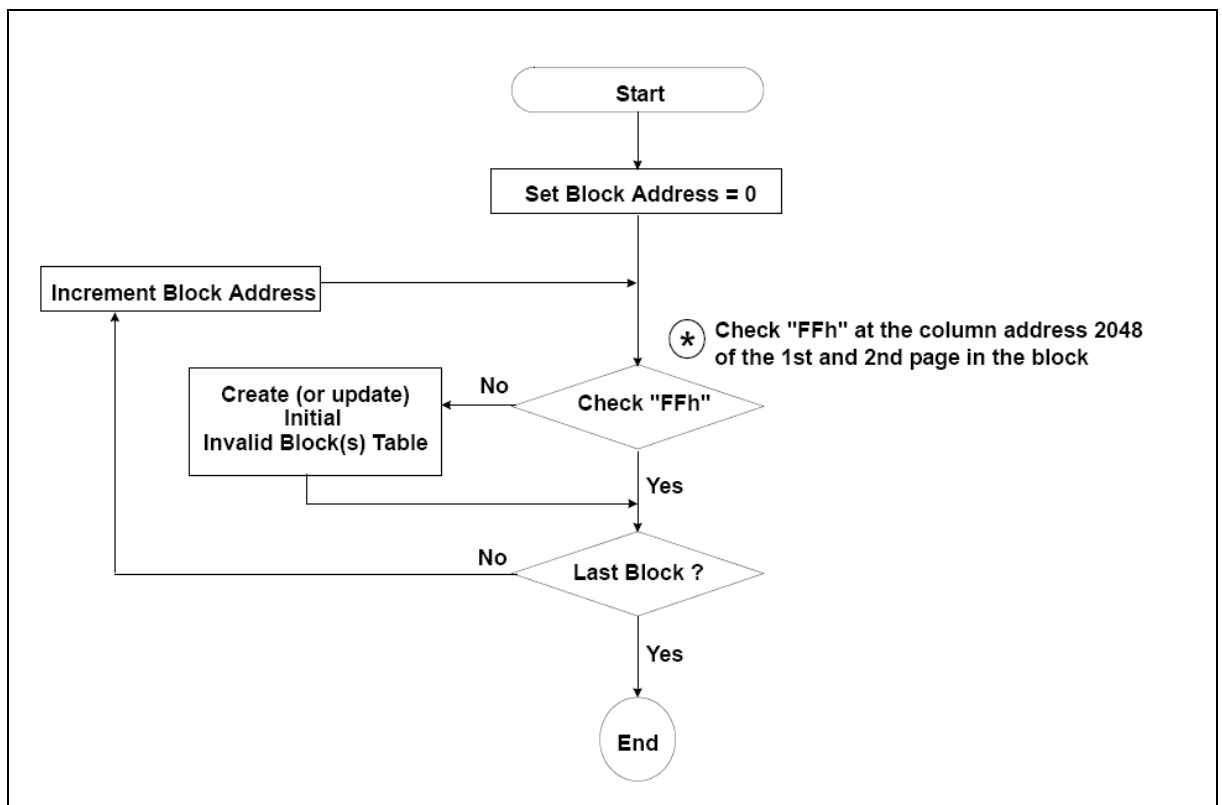


Figure 33 Flow Chart to create initial invalid block table

NAND Flash Technical Notes(Continued)

Error in write or read operation

Within its life time, additional invalid blocks may develop with NAND Flash memory. Refer to the qualification report for the actual data. The following possible failure modes should be considered to implement a highly reliable system. In the case of status read failure after erase or program, block replacement should be done. Because program status fail during a page program does not affect the data of the other pages in the same block, block replacement can be executed with a page-sized buffer by finding an erased empty block and reprogramming the current target data and copying the rest of the replaced block. In case of Read, ECC must be employed. To improve the efficiency of memory space, it is recommended that the read or verification failure due to single bit error be reclaimed by ECC without any block replacement. The said additional block failure rate does not include those reclaimed blocks.

| Failure Mode | | Detection and Countermeasure sequence |
|--------------|--------------------|---|
| Write | Erase Failure | Status Read after Erase-> Block Replacement |
| | Program Failure | Status Read after Program-> Block Replacement |
| Read | Single Bit Failure | Verify ECC -> ECC Correction |

Program Flow Chart

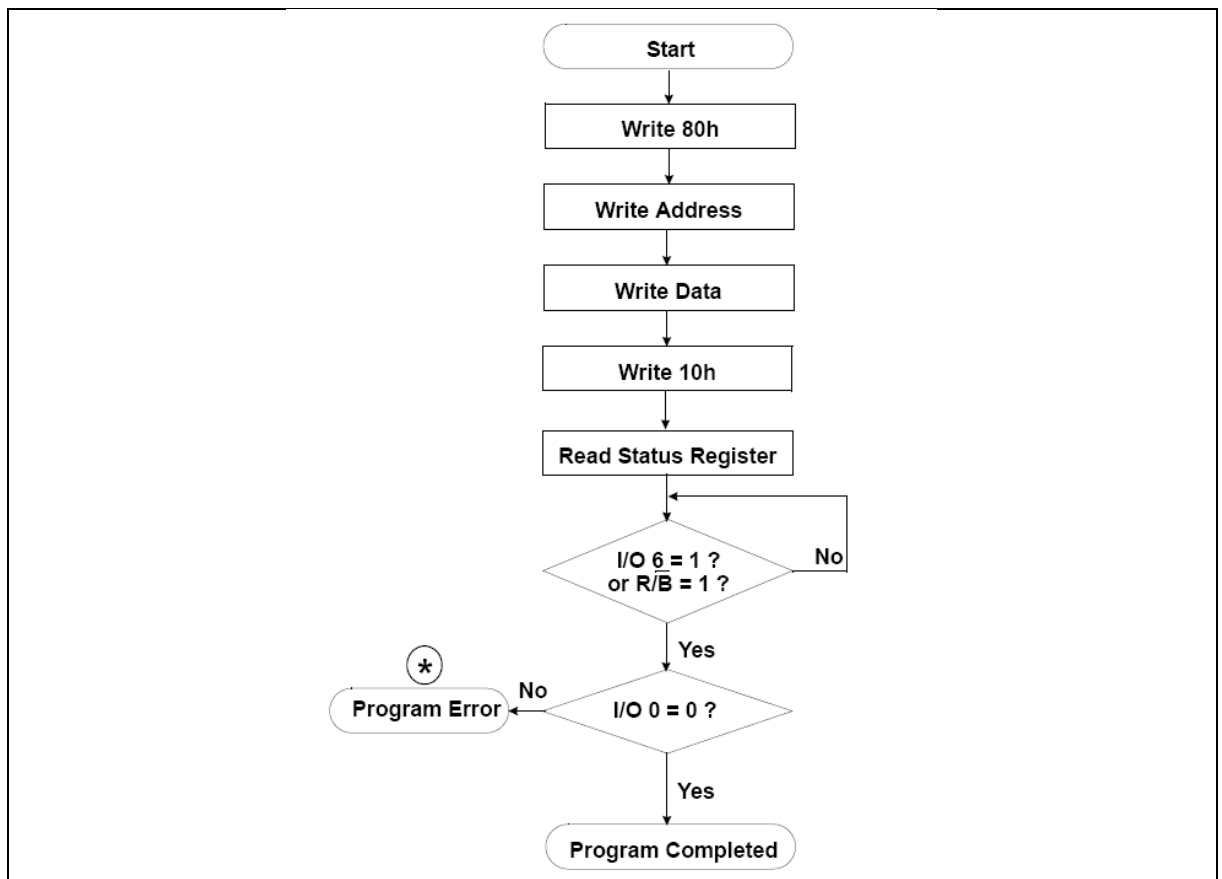
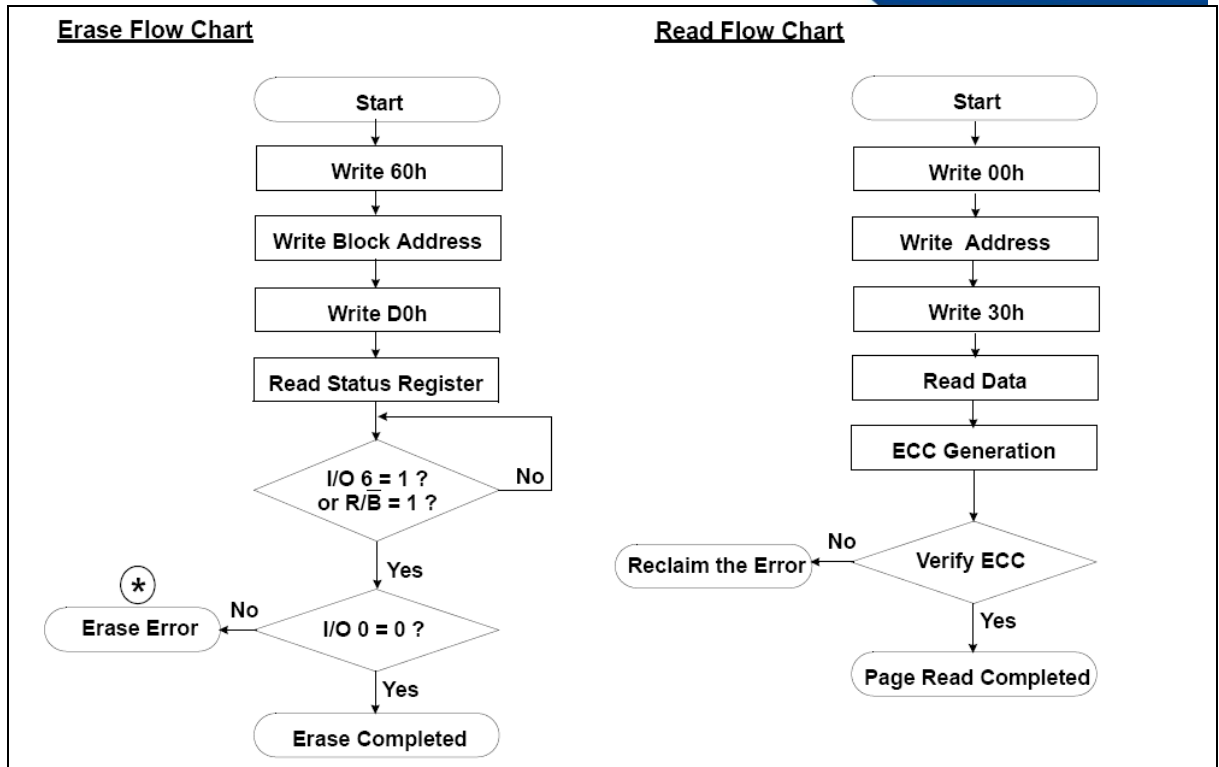


Figure 34 Program Flow Chart

* If program operation results in an error, map out the block including the page in error and copy the target data to another block.



* If erase operation results in an error, map out the failing block and replace it with another block.

Figure 35 Erase and Read Flow Chart

Block Replacement

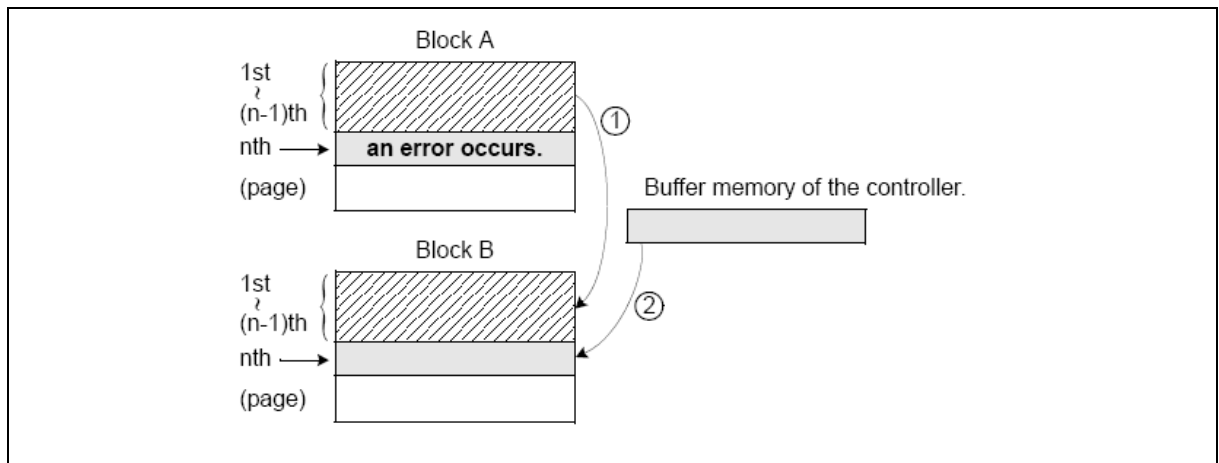


Figure 36 Block Replacement

*Step 1

When an error happens in the nth page of Block A during erase or program operation.

*Step 2

Copy the data in the 1st~(n-1)th page to the same location of another free block (Block B)

*Step 3

Then, copy the nth page data of the Block A in the buffer memory to the nth page of the Block B

*Step 4

Do not erase or program to Block A by creating an invalid block table or other appropriate scheme



Revision History

| Version | Publication date | Pages | Paragraph or Illustration | Revise Description |
|---------|------------------|-------|---------------------------|---------------------------|
| 1.0 | May 2024 | 51 | | Initial document Release. |
| | | | | |
| | | | | |



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Datasheet

51