



NAND Flash Memory

**MT29F1G08ABAEAWP, MT29F1G08ABAEAH4, MT29F1G08ABBEAH4
MT29F1G16ABBEAH4, MT29F1G08ABBEAHC, MT29F1G16ABBEAHC**

Features

- Open NAND Flash Interface (ONFI) 1.0-compliant¹
- Single-level cell (SLC) technology
- Organization
 - Page size x8: 2112 bytes (2048 + 64 bytes)
 - Page size x16: 1056 words (1024 + 32 words)
 - Block size: 64 pages (128K + 4K bytes)
 - Device size: 1Gb: 1024 blocks
- Asynchronous I/O performance
 - ^tRC/^tWC: 20ns (3.3V), 25ns (1.8V)
- Array performance
 - Read page: 25μs
 - Program page: 200μs (TYP, 3.3V and 1.8V)
 - Erase block: 700μs (TYP)
- Command set: ONFI NAND Flash Protocol
- Advanced command set
 - Program page cache mode
 - Read page cache mode
 - One-time programmable (OTP) mode
 - Read unique ID
 - Internal data move
 - Block lock (1.8V only)
- Operation status byte provides software method for detecting
 - Operation completion
 - Pass/fail condition
 - Write-protect status
- Internal data move operations supported within the device from which data is read
- Ready/busy# (R/B#) signal provides a hardware method for detecting operation completion
- WP# signal: write protect entire device
- First block (block address 00h) is valid when shipped from factory with ECC. For minimum required ECC, see Error Management.
- Block 0 requires 1-bit ECC if PROGRAM/ERASE cycles are less than 1000
- RESET (FFh) required as first command after power-on
- Alternate method of device initialization (Nand_Init) after power up³ (contact factory)
- Quality and reliability
 - Data retention: JESD47 compliant; see qualification report
 - Endurance: 100,000 PROGRAM/ERASE cycles
- Operating Voltage Range
 - V_{CC}: 2.7–3.6V
 - V_{CC}: 1.7–1.95V
- Operating temperature:
 - Commercial (CT): –0°C to +70°C
 - Industrial (IT): –40°C to +85°C
- Package
 - 48-pin TSOP Type 1, CPL²

- Notes: 1. The ONFI 1.0 specification is available at www.onfi.org.
2. CPL = Center parting line.
3. Available only in the 1.8V VFBGA package.

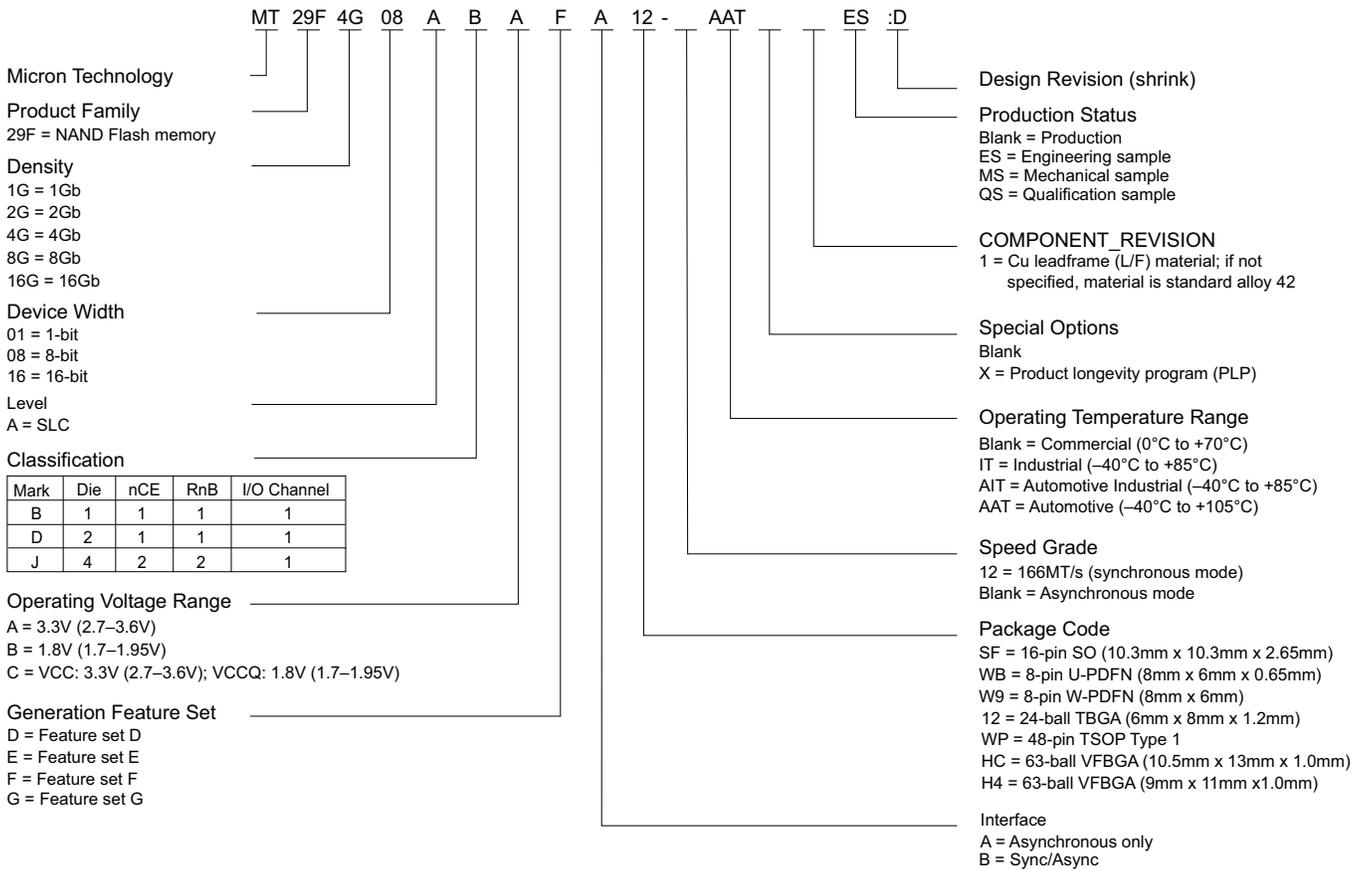


1Gb x8, x16: NAND Flash Memory Features

Part Numbering Information

Micron NAND Flash devices are available in different configurations and densities. Verify valid part numbers by using Micron’s part catalog search at www.micron.com. To compare features and specifications by device type, visit www.micron.com/products. Contact the factory for devices not found.

Figure 1: Marketing Part Number Chart





Contents

Important Notes and Warnings	8
General Description	9
Signal Descriptions and Assignments	9
Signal Assignments	10
Package Dimensions	13
Architecture	16
Device and Array Organization	17
Asynchronous Interface Bus Operation	19
Asynchronous Enable/Standby	19
Asynchronous Commands	19
Asynchronous Addresses	21
Asynchronous Data Input	22
Asynchronous Data Output	23
Write Protect#	24
Ready/Busy#	24
Device Initialization	29
Command Definitions	30
Reset Operations	33
RESET (FFh)	33
Identification Operations	34
READ ID (90h)	34
READ ID Parameter Tables	35
READ PARAMETER PAGE (ECh)	37
Parameter Page Data Structure Tables	38
READ UNIQUE ID (EDh)	41
Feature Operations	42
SET FEATURES (EFh)	42
GET FEATURES (EEh)	43
Status Operations	46
READ STATUS (70h)	46
READ STATUS ENHANCED (78h)	47
Column Address Operations	48
RANDOM DATA READ (05h-E0h)	48
RANDOM DATA READ TWO-PLANE (06h-E0h)	49
RANDOM DATA INPUT (85h)	50
PROGRAM FOR INTERNAL DATA INPUT (85h)	51
Read Operations	52
READ MODE (00h)	54
READ PAGE (00h-30h)	54
READ PAGE CACHE SEQUENTIAL (31h)	55
READ PAGE CACHE RANDOM (00h-31h)	56
READ PAGE CACHE LAST (3Fh)	58
READ PAGE TWO-PLANE 00h-00h-30h	59
Program Operations	61
PROGRAM PAGE (80h-10h)	61
PROGRAM PAGE CACHE (80h-15h)	62
PROGRAM PAGE TWO-PLANE (80h-11h)	65
Erase Operations	67
ERASE BLOCK (60h-D0h)	67
ERASE BLOCK TWO-PLANE (60h-D1h)	67
Internal Data Move Operations	69



READ FOR INTERNAL DATA MOVE (00h-35h)	69
PROGRAM FOR INTERNAL DATA MOVE (85h-10h)	71
Block Lock Feature	72
WP# and Block Lock	72
UNLOCK (23h-24h)	72
LOCK (2Ah)	75
LOCK TIGHT (2Ch)	76
BLOCK LOCK READ STATUS (7Ah)	77
One-Time Programmable (OTP) Operations	79
OTP DATA PROGRAM (80h-10h)	80
RANDOM DATA INPUT (85h)	81
OTP DATA PROTECT (80h-10)	82
OTP DATA READ (00h-30h)	84
Error Management	86
Output Drive Impedance	87
AC Overshoot/Undershoot Specifications	90
Output Slew Rate	91
Electrical Specifications	92
Electrical Specifications – AC Characteristics and Operating Conditions	94
Electrical Specifications – DC Characteristics and Operating Conditions	98
Electrical Specifications – Program/Erase Characteristics	100
Asynchronous Interface Timing Diagrams	101
Revision History	111
Rev. O – 04/2023	111
Rev. N – 02/2018	111
Rev. M – 01/2018	111
Rev. L – 02/2015	111
Rev. K – 10/2014	111
Rev. J – 04/2014	111
Rev. I – 08/2013	111
Rev. H – 02/2013	111
Rev. G – 11/2012	111
Rev. F – 08/2012	111
Rev. E – 07/2012	111
Rev. D – 02/2012	111
Rev. C – 02/2012	111
Rev. B – 11/2011	112
Rev. A – 08/2011	112



List of Figures

Figure 1: Marketing Part Number Chart	2
Figure 2: 48-Pin TSOP – Type 1, CPL (Top View)	10
Figure 3: 63-Ball VFBGA, x8 (Balls Down, Top View)	11
Figure 4: 63-Ball VFBGA, x16 (Balls Down, Top View)	12
Figure 5: 48-Pin TSOP – Type 1, CPL	13
Figure 6: 63-Ball VFBGA (HC) 10.5mm x 13mm	14
Figure 7: 63-Ball VFBGA (H4) 9mm x 11mm	15
Figure 8: NAND Flash Die (LUN) Functional Block Diagram	16
Figure 9: Device Organization for Single-Die Package (TSOP/BGA)	17
Figure 10: Array Organization – x8	17
Figure 11: Array Organization – x16	18
Figure 12: Asynchronous Command Latch Cycle	20
Figure 13: Asynchronous Address Latch Cycle	21
Figure 14: Asynchronous Data Input Cycles	22
Figure 15: Asynchronous Data Output Cycles	23
Figure 16: Asynchronous Data Output Cycles (EDO Mode)	24
Figure 17: READ/BUSY# Open Drain	25
Figure 18: t_{Fall} and t_{Rise} (3.3V V_{CC})	26
Figure 19: t_{Fall} and t_{Rise} (1.8V V_{CC})	26
Figure 20: I_{OL} vs. R_p ($V_{\text{CC}} = 3.3V$ V_{CC})	27
Figure 21: I_{OL} vs. R_p (1.8V V_{CC})	27
Figure 22: TC vs. R_p	28
Figure 23: R/B# Power-On Behavior	29
Figure 24: RESET (FFh) Operation	33
Figure 25: READ ID (90h) with 00h Address Operation	34
Figure 26: READ ID (90h) with 20h Address Operation	34
Figure 27: READ PARAMETER (ECh) Operation	37
Figure 28: READ UNIQUE ID (EDh) Operation	41
Figure 29: SET FEATURES (EFh) Operation	43
Figure 30: GET FEATURES (EEh) Operation	43
Figure 31: READ STATUS (70h) Operation	47
Figure 32: READ STATUS ENHANCED (78h) Operation	47
Figure 33: RANDOM DATA READ (05h-E0h) Operation	48
Figure 34: RANDOM DATA READ TWO-PLANE (06h-E0h) Operation	49
Figure 35: RANDOM DATA INPUT (85h) Operation	50
Figure 36: PROGRAM FOR INTERNAL DATA INPUT (85h) Operation	51
Figure 37: READ PAGE (00h-30h) Operation	54
Figure 38: READ PAGE CACHE SEQUENTIAL (31h) Operation	56
Figure 39: READ PAGE CACHE RANDOM (00h-31h) Operation	57
Figure 40: READ PAGE CACHE LAST (3Fh) Operation	58
Figure 41: READ PAGE TWO-PLANE (00h-00h-30h) Operation	60
Figure 42: PROGRAM PAGE (80h-10h) Operation	62
Figure 43: PROGRAM PAGE CACHE (80h-15h) Operation (Start)	64
Figure 44: PROGRAM PAGE CACHE (80h-15h) Operation (End)	64
Figure 45: PROGRAM PAGE TWO-PLANE (80h-11h) Operation	66
Figure 46: ERASE BLOCK (60h-D0h) Operation	67
Figure 47: ERASE BLOCK TWO-PLANE (60h-D1h) Operation	68
Figure 48: READ FOR INTERNAL DATA MOVE (00h-35h) Operation	70
Figure 49: READ FOR INTERNAL DATA MOVE (00h-35h) with RANDOM DATA READ (05h-E0h)	70
Figure 50: PROGRAM FOR INTERNAL DATA MOVE (85h-10h)	71
Figure 51: PROGRAM FOR INTERNAL DATA MOVE (85h-10h) with RANDOM DATA INPUT (85h)	71



Figure 52: Flash Array Protected: Invert Area Bit = 0	73
Figure 53: Flash Array Protected: Invert Area Bit = 1	73
Figure 54: UNLOCK Operation	74
Figure 55: LOCK Operation	75
Figure 56: LOCK TIGHT Operation	76
Figure 57: PROGRAM/ERASE Issued to Locked Block	77
Figure 58: BLOCK LOCK READ STATUS	77
Figure 59: BLOCK LOCK Flowchart	78
Figure 60: OTP DATA PROGRAM (After Entering OTP Operation Mode)	81
Figure 61: OTP DATA PROGRAM Operation with RANDOM DATA INPUT (After Entering OTP Operation Mode)	82
Figure 62: OTP DATA PROTECT Operation (After Entering OTP Protect Mode)	83
Figure 63: OTP DATA READ	84
Figure 64: OTP DATA READ with RANDOM DATA READ Operation	85
Figure 65: Overshoot	90
Figure 66: Undershoot	90
Figure 67: RESET Operation	101
Figure 68: READ STATUS Cycle	101
Figure 69: READ STATUS ENHANCED Cycle	102
Figure 70: READ PARAMETER PAGE	102
Figure 71: READ PAGE	103
Figure 72: READ PAGE Operation with CE# "Don't Care"	104
Figure 73: RANDOM DATA READ	104
Figure 74: READ PAGE CACHE SEQUENTIAL	105
Figure 75: READ PAGE CACHE RANDOM	106
Figure 76: READ ID Operation	107
Figure 77: PROGRAM PAGE Operation	107
Figure 78: PROGRAM PAGE Operation with CE# "Don't Care"	108
Figure 79: PROGRAM PAGE Operation with RANDOM DATA INPUT	108
Figure 80: PROGRAM PAGE CACHE	109
Figure 81: PROGRAM PAGE CACHE Ending on 15h	109
Figure 82: INTERNAL DATA MOVE	110
Figure 83: ERASE BLOCK Operation	110



List of Tables

Table 1: Asynchronous Signal Definitions	9
Table 2: Array Addressing (x8)	17
Table 3: Array Addressing (x16)	18
Table 4: Asynchronous Interface Mode Selection	19
Table 5: Command Set	30
Table 6: Two-Plane Command Set	32
Table 7: READ ID Parameters for Address 00h	35
Table 8: READ ID Parameters for Address 20h	36
Table 9: Parameter Page Data Structure	38
Table 10: Feature Address Definitions	42
Table 11: Feature Address 90h – Array Operation Mode	42
Table 12: Feature Addresses 01h: Timing Mode	43
Table 13: Feature Addresses 80h: Programmable I/O Drive Strength	45
Table 14: Feature Addresses 81h: Programmable R/B# Pull-Down Strength	45
Table 15: Status Register Definition	46
Table 16: Block Lock Address Cycle Assignments	74
Table 17: Block Lock Status Register Bit Definitions	77
Table 18: Error Management Details	86
Table 19: Output Drive Strength Conditions ($V_{CCQ} = 1.7\text{--}1.95\text{V}$)	87
Table 20: Output Drive Strength Impedance Values ($V_{CCQ} = 1.7\text{--}1.95\text{V}$)	87
Table 21: Output Drive Strength Conditions ($V_{CCQ} = 2.7\text{--}3.6\text{V}$)	88
Table 22: Output Drive Strength Impedance Values ($V_{CCQ} = 2.7\text{--}3.6\text{V}$)	88
Table 23: Pull-Up and Pull-Down Output Impedance Mismatch	89
Table 24: Asynchronous Overshoot/Undershoot Parameters	90
Table 25: Test Conditions for Output Slew Rate	91
Table 26: Output Slew Rate ($V_{CCQ} = 1.7\text{--}1.95\text{V}$)	91
Table 27: Output Slew Rate ($V_{CCQ} = 2.7\text{--}3.6\text{V}$)	91
Table 28: Absolute Maximum Ratings	92
Table 29: Recommended Operating Conditions	92
Table 30: Valid Blocks	92
Table 31: Capacitance	93
Table 32: Test Conditions	93
Table 33: AC Characteristics: Command, Data, and Address Input (3.3V)	94
Table 34: AC Characteristics: Command, Data, and Address Input (1.8V)	94
Table 35: AC Characteristics: Normal Operation (3.3V)	96
Table 36: AC Characteristics: Normal Operation (1.8V)	96
Table 37: DC Characteristics and Operating Conditions (3.3V)	98
Table 38: DC Characteristics and Operating Conditions (1.8V)	99
Table 39: ProgramErase Characteristics	100



Important Notes and Warnings

Micron Technology, Inc. ("Micron") reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions. This document supersedes and replaces all information supplied prior to the publication hereof. You may not rely on any information set forth in this document if you obtain the product described herein from any unauthorized distributor or other source not authorized by Micron.

Automotive Applications. Products are not designed or intended for use in automotive applications unless specifically designated by Micron as automotive-grade by their respective data sheets. Distributor and customer/distributor shall assume the sole risk and liability for and shall indemnify and hold Micron harmless against all claims, costs, damages, and expenses and reasonable attorneys' fees arising out of, directly or indirectly, any claim of product liability, personal injury, death, or property damage resulting directly or indirectly from any use of non-automotive-grade products in automotive applications. Customer/distributor shall ensure that the terms and conditions of sale between customer/distributor and any customer of distributor/customer (1) state that Micron products are not designed or intended for use in automotive applications unless specifically designated by Micron as automotive-grade by their respective data sheets and (2) require such customer of distributor/customer to indemnify and hold Micron harmless against all claims, costs, damages, and expenses and reasonable attorneys' fees arising out of, directly or indirectly, any claim of product liability, personal injury, death, or property damage resulting from any use of non-automotive-grade products in automotive applications.

Critical Applications. Products are not authorized for use in applications in which failure of the Micron component could result, directly or indirectly in death, personal injury, or severe property or environmental damage ("Critical Applications"). Customer must protect against death, personal injury, and severe property and environmental damage by incorporating safety design measures into customer's applications to ensure that failure of the Micron component will not result in such harms. Should customer or distributor purchase, use, or sell any Micron component for any critical application, customer and distributor shall indemnify and hold harmless Micron and its subsidiaries, subcontractors, and affiliates and the directors, officers, and employees of each against all claims, costs, damages, and expenses and reasonable attorneys' fees arising out of, directly or indirectly, any claim of product liability, personal injury, or death arising in any way out of such critical application, whether or not Micron or its subsidiaries, subcontractors, or affiliates were negligent in the design, manufacture, or warning of the Micron product.

Customer Responsibility. Customers are responsible for the design, manufacture, and operation of their systems, applications, and products using Micron products. ALL SEMICONDUCTOR PRODUCTS HAVE INHERENT FAILURE RATES AND LIMITED USEFUL LIVES. IT IS THE CUSTOMER'S SOLE RESPONSIBILITY TO DETERMINE WHETHER THE MICRON PRODUCT IS SUITABLE AND FIT FOR THE CUSTOMER'S SYSTEM, APPLICATION, OR PRODUCT. Customers must ensure that adequate design, manufacturing, and operating safeguards are included in customer's applications and products to eliminate the risk that personal injury, death, or severe property or environmental damages will result from failure of any semiconductor component.

Limited Warranty. In no event shall Micron be liable for any indirect, incidental, punitive, special or consequential damages (including without limitation lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort, warranty, breach of contract or other legal theory, unless explicitly stated in a written agreement executed by Micron's duly authorized representative.



General Description

Micron NAND Flash devices include an asynchronous data interface for high-performance I/O operations. These devices use a highly multiplexed 8-bit bus (I/Ox) to transfer commands, address, and data. There are five control signals used to implement the asynchronous data interface: CE#, CLE, ALE, WE#, and RE#. Additional signals control hardware write protection and monitor device status (R/B#).

This hardware interface creates a low pin-count device with a standard pinout that remains the same from one density to another, enabling future upgrades to higher densities with no board redesign.

A target is the unit of memory accessed by a chip enable signal. A target contains one or more NAND Flash die. A NAND Flash die is the minimum unit that can independently execute commands and report status. A NAND Flash die, in the ONFI specification, is referred to as a logical unit (LUN). There is at least one NAND Flash die per chip enable signal. For further details, see Device and Array Organization.

Signal Descriptions and Assignments

Table 1: Asynchronous Signal Definitions

Signal ¹	Type	Description ²
ALE	Input	Address latch enable: Loads an address from I/O[7:0] into the address register.
CE#	Input	Chip enable: Enables or disables one or more die (LUNs) in a target.
CLE	Input	Command latch enable: Loads a command from I/O[7:0] into the command register.
RE#	Input	Read enable: Transfers serial data from the NAND Flash to the host system.
WE#	Input	Write enable: Transfers commands, addresses, and serial data from the host system to the NAND Flash.
WP#	Input	Write protect: Enables or disables array PROGRAM and ERASE operations.
LOCK	Input	Lock: Enables the BLOCK LOCK function when LOCK is HIGH during power up. To disable BLOCK LOCK, connect LOCK to V _{SS} during power up or leave it disconnected (internal pull-down).
I/O[7:0] (x8) I/O[15:0] (x16)	I/O	Data inputs/outputs: The bidirectional I/Os transfer address, data, and command information.
R/B#	Output	Ready/busy: An open-drain, active-low output that requires an external pull-up resistor. This signal indicates target array activity.
V _{CC}	Supply	V_{CC}: Core power supply
V _{SS}	Supply	V_{SS}: Core ground connection
NC	–	No connect: NCs are not internally connected. They can be driven or left unconnected.
DNU	–	Do not use: DNUs must be left unconnected.

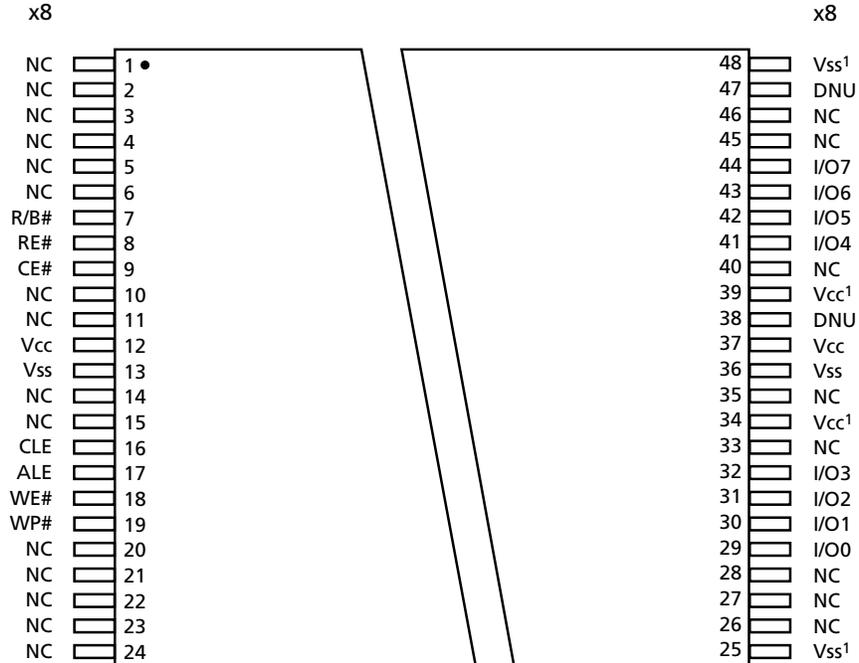
Notes: 1. See Device and Array Organization for detailed signal connections.

2. See Asynchronous Interface Bus Operation for detailed asynchronous interface signal descriptions.



Signal Assignments

Figure 2: 48-Pin TSOP – Type 1, CPL (Top View)

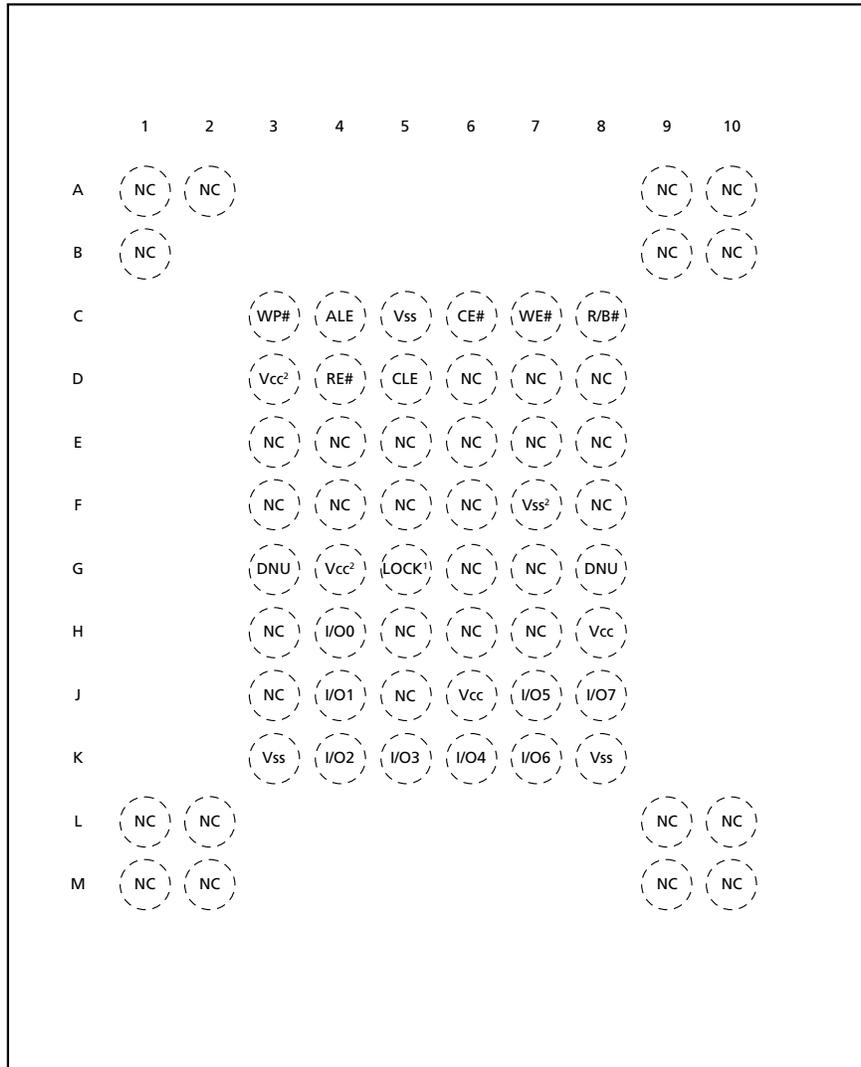


- Notes: 1. These pins might not be bonded in the package; however, Micron recommends that the customer connect these pins to the designated external sources for ONFI compatibility.
 2. For the 3V device, pin 38 is DNU. For the 1.8V device, pin 38 is LOCK.



**1Gb x8, x16: NAND Flash Memory
Signal Assignments**

Figure 3: 63-Ball VFBGA, x8 (Balls Down, Top View)

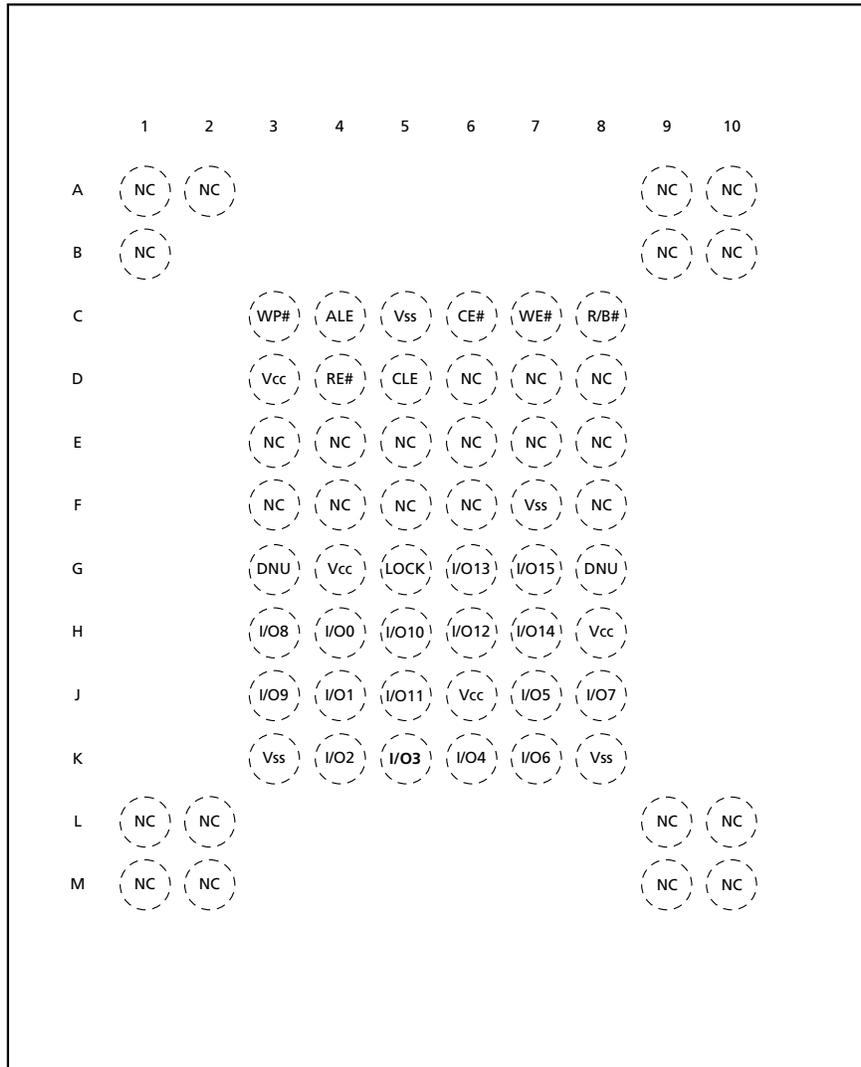


- Notes: 1. For the 3V device, G5 changes to DNU. NO LOCK function is available on the 3.3V device.
 2. These pins might not be bonded in the package; however, Micron recommends that the customer connect these pins to the designated external sources for ONFI compatibility.



**1Gb x8, x16: NAND Flash Memory
Signal Assignments**

Figure 4: 63-Ball VFBGA, x16 (Balls Down, Top View)



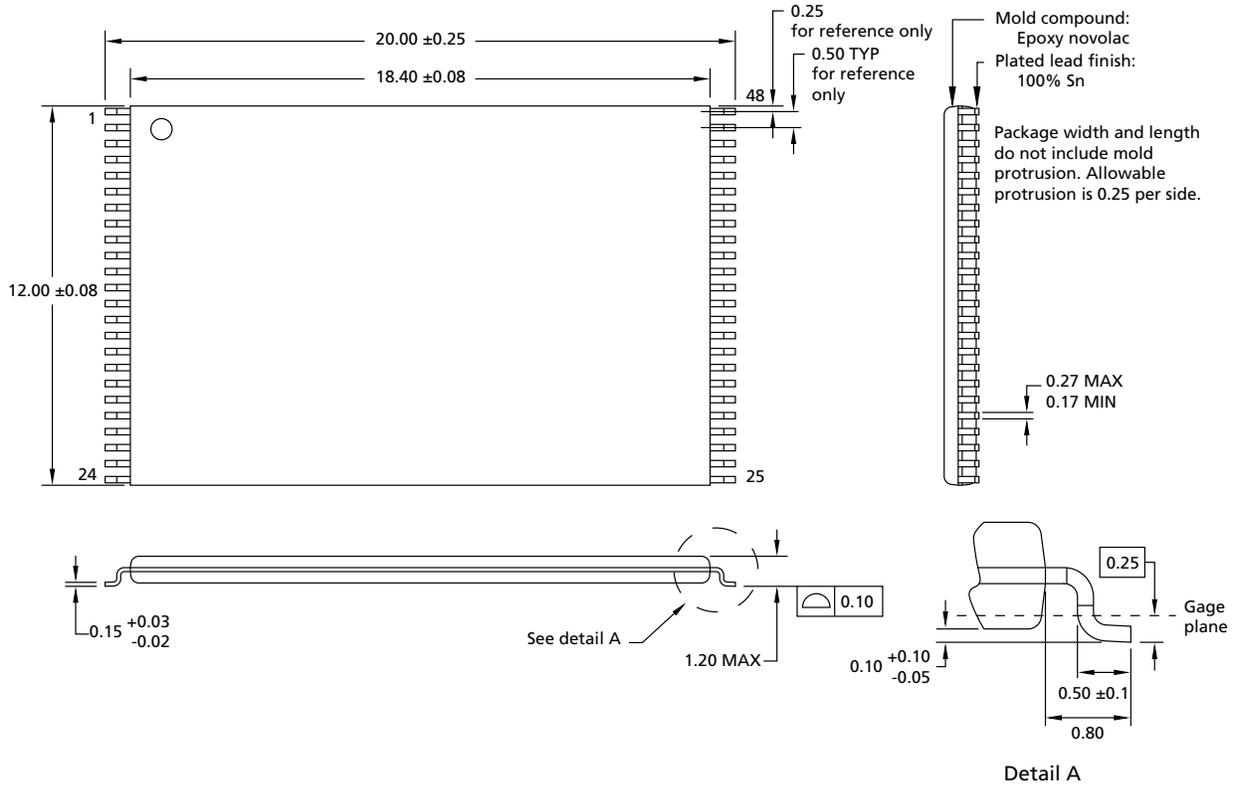
- Notes: 1. For the 3V device, G5 changes to DNU. NO LOCK function is available on the 3.3V device.
 2. These pins might not be bonded in the package; however, Micron recommends that the customer connect these pins to the designated external sources for ONFI compatibility.



**1Gb x8, x16: NAND Flash Memory
Package Dimensions**

Package Dimensions

Figure 5: 48-Pin TSOP – Type 1, CPL

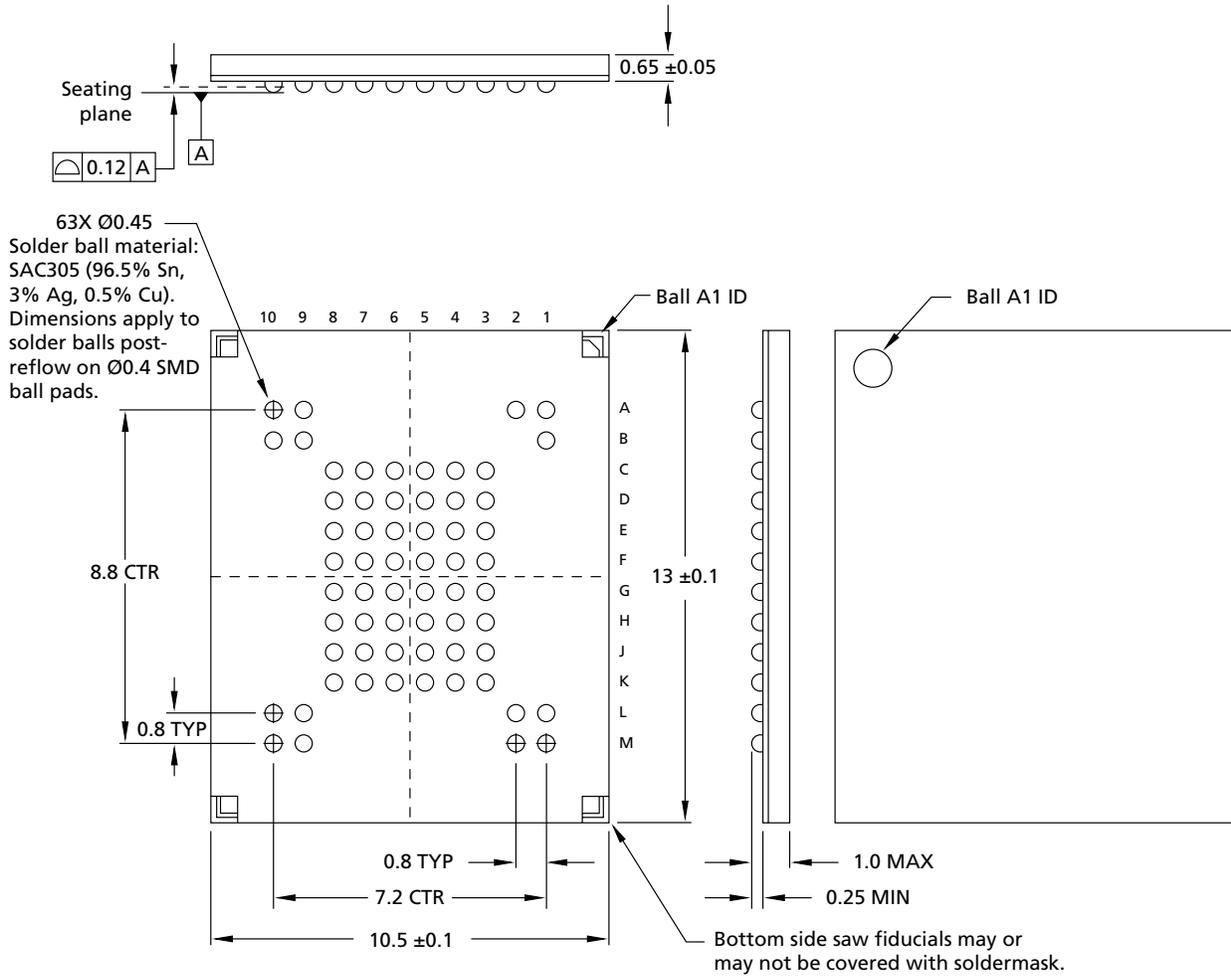


Note: 1. All dimensions are in millimeters.



**1Gb x8, x16: NAND Flash Memory
Package Dimensions**

Figure 6: 63-Ball VFBGA (HC) 10.5mm x 13mm

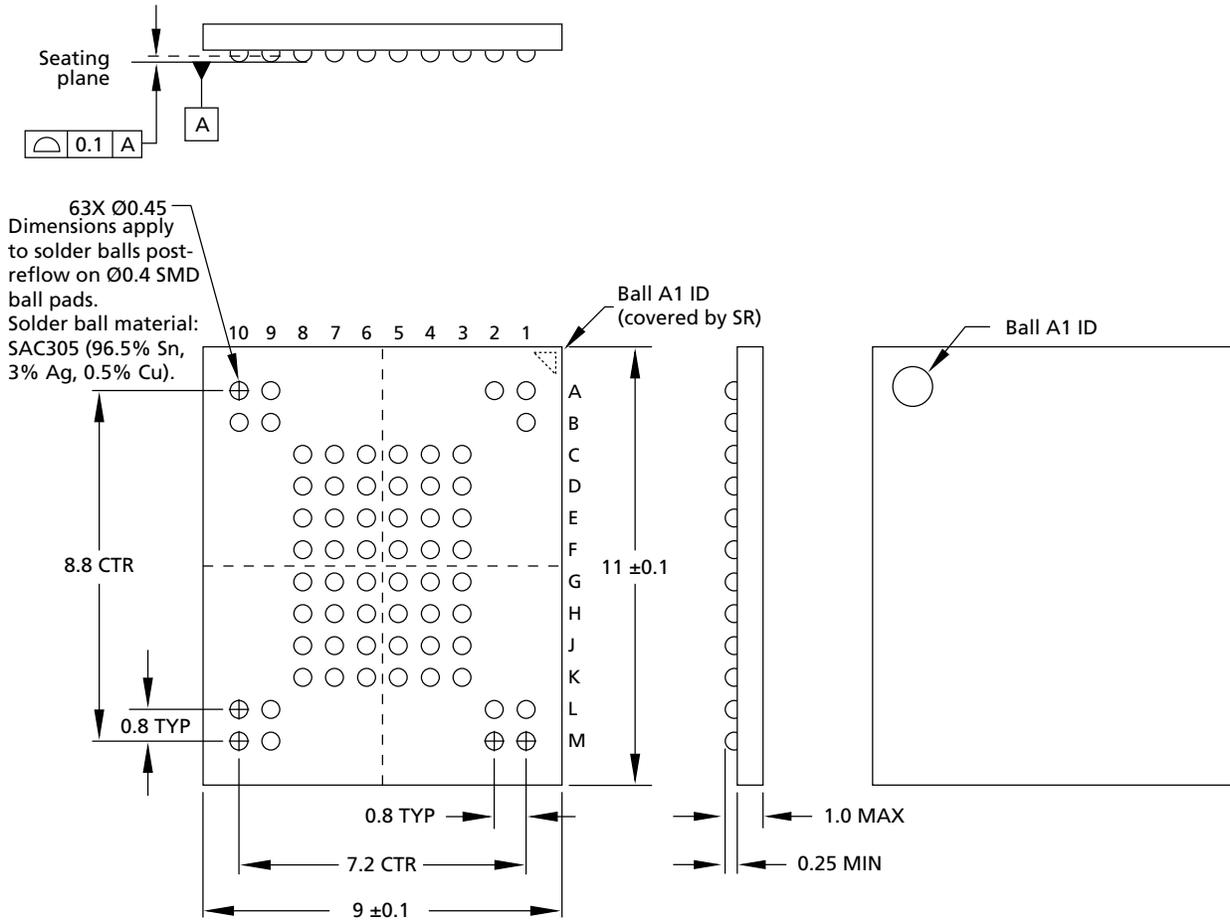


Note: 1. All dimensions are in millimeters.



1Gb x8, x16: NAND Flash Memory Package Dimensions

Figure 7: 63-Ball VFBGA (H4) 9mm x 11mm



Note: 1. All dimensions are in millimeters.



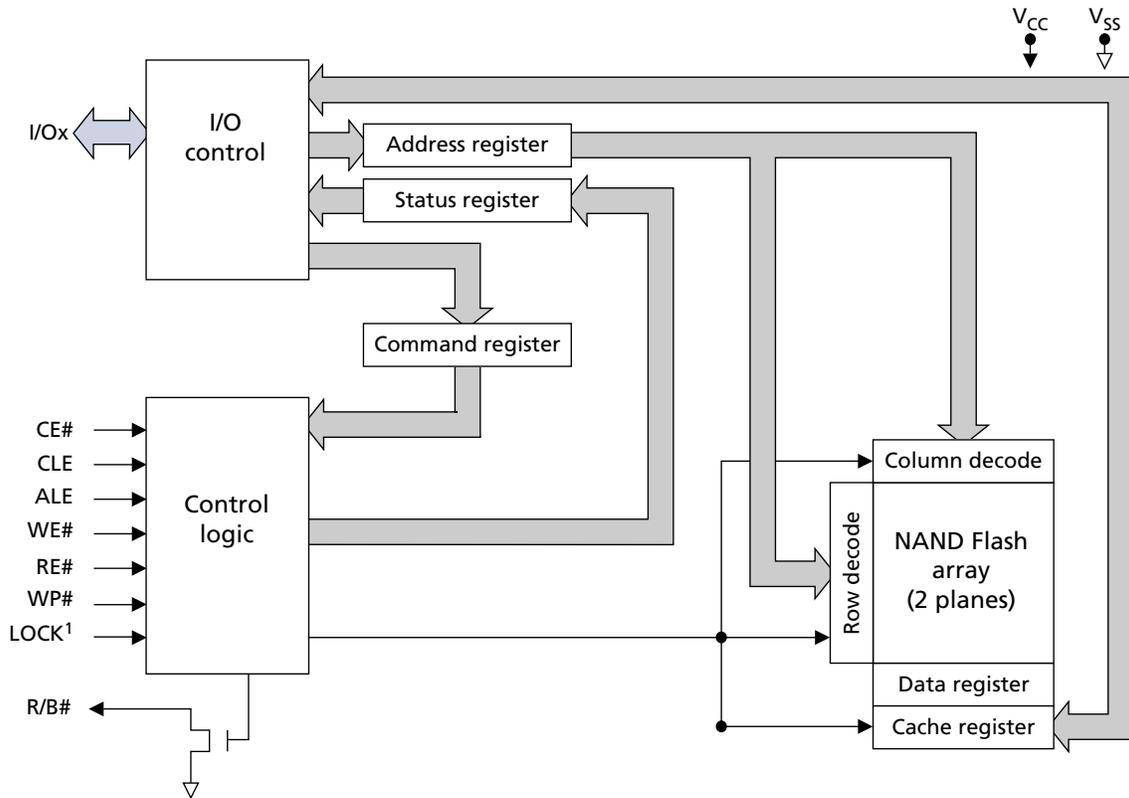
Architecture

These devices use NAND Flash electrical and command interfaces. Data, commands, and addresses are multiplexed onto the same pins and received by I/O control circuits. The commands received at the I/O control circuits are latched by a command register and are transferred to control logic circuits for generating internal signals to control device operations. The addresses are latched by an address register and sent to a row decoder to select a row address, or to a column decoder to select a column address.

Data is transferred to or from the NAND Flash memory array, byte by byte (x8) or word by word (x16), through a data register and a cache register.

The NAND Flash memory array is programmed and read using page-based operations and is erased using block-based operations. During normal page operations, the data and cache registers act as a single register. During cache operations, the data and cache registers operate independently to increase data throughput. The status register reports the status of die operations.

Figure 8: NAND Flash Die (LUN) Functional Block Diagram

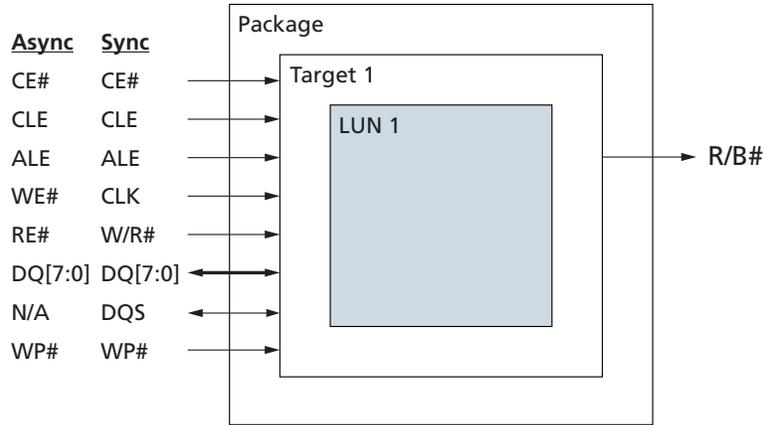


Note: 1. The LOCK pin is used on the 1.8V device.



Device and Array Organization

Figure 9: Device Organization for Single-Die Package (TSOP/BGA)



Note: 1. TSOP devices do not support the synchronous interface.

Figure 10: Array Organization – x8

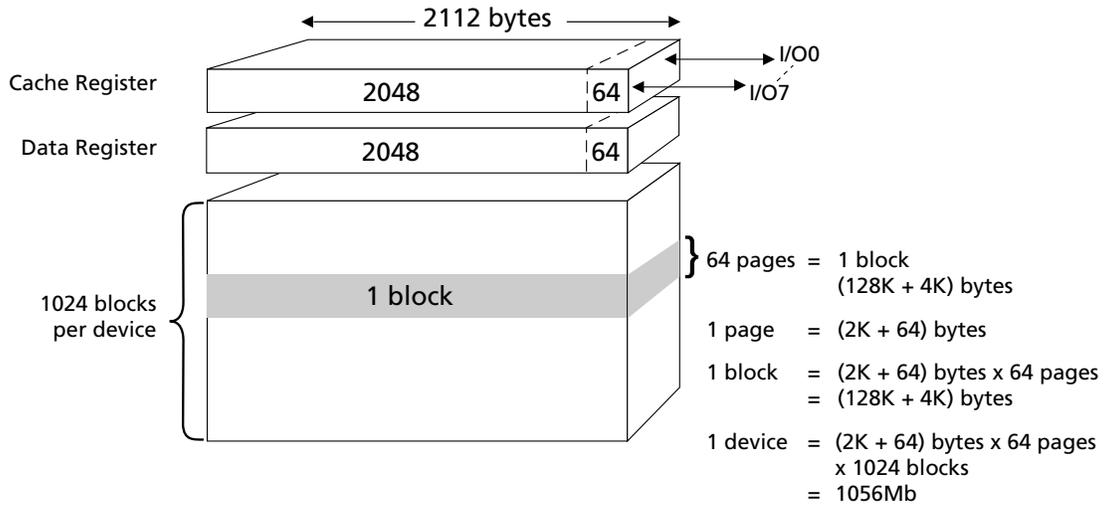


Table 2: Array Addressing (x8)

Cycle	I/O7	I/O6	I/O5	I/O4	I/OQ3	I/O2	I/O1	I/O0
First	CA7	CA6	CA5	CA4	CA3	CA2	CA1	CA0
Second	LOW	LOW	LOW	LOW	CA11 ¹	CA10	CA9	CA8
Third	BA7	BA6 ³	PA5	PA4	PA3	PA2	PA1	PA0
Fourth	BA15	BA14	BA13	BA12	BA11	BA10	BA9	BA8

- Notes: 1. If CA11 is 1, then CA[10:6] must be 0.
 2. Block address concatenated with page address = actual page address; CAx = column address; PAx = page address; BAx = block address.
 3. BA6 is the plane-select bit: Plane 0: BA[6] = 0 Plane 1: BA[6] = 1



1Gb x8, x16: NAND Flash Memory Device and Array Organization

Figure 11: Array Organization – x16

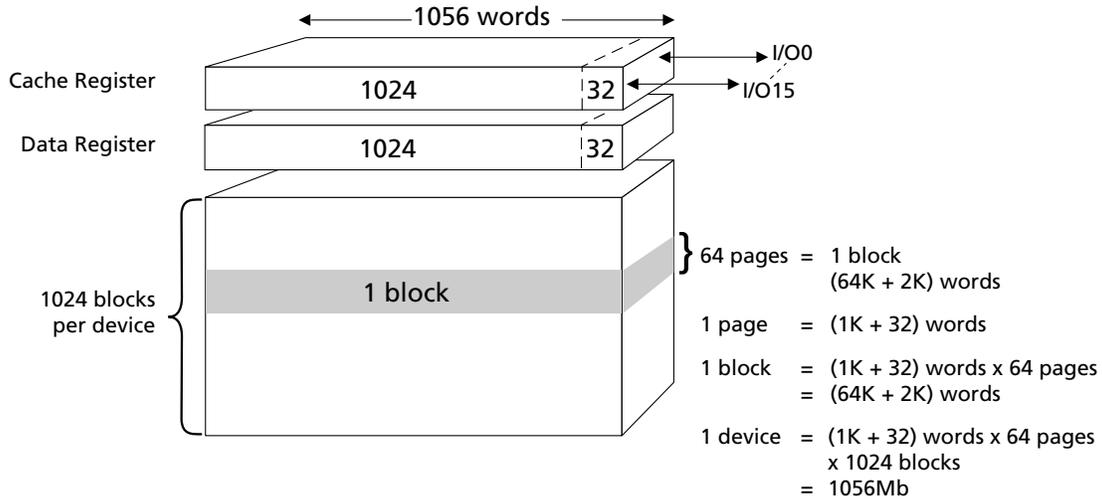


Table 3: Array Addressing (x16)

Cycle	I/O[15:8]	I/O7	I/O6	I/O5	I/O4	I/O3	I/O2	I/O1	I/O0
First	LOW	CA7	CA6	CA5	CA4	CA3	CA2	CA1	CA0
Second	LOW	LOW	LOW	LOW	LOW	LOW	CA10 ¹	CA9	CA8
Third	LOW	BA7	BA6 ³	PA5	PA4	PA3	PA2	PA1	PA0
Fourth	LOW	BA15	BA14	BA13	BA12	BA11	BA10	BA9	BA8

- Notes:
1. If CA10 is 1, then CA[9:5] must be 0.
 2. Block address concatenated with page address = actual page address. CAx = column address; PAx = page address; BAx = block address.
 3. I/O[15:8] are not used during the addressing sequence and should be driven LOW.
 4. BA6 is the plane-select bit: Plane 0: BA[6] = 0 Plane 1: BA[6] = 1



1Gb x8, x16: NAND Flash Memory Asynchronous Interface Bus Operation

Asynchronous Interface Bus Operation

The bus on the device is multiplexed. Data I/O, addresses, and commands all share the same pins. I/O[15:8] are used only for data in the x16 configuration. Addresses and commands are always supplied on I/O[7:0].

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

Table 4: Asynchronous Interface Mode Selection

Mode ¹	CE#	CLE	ALE	WE#	RE#	I/Ox	WP#
Standby ²	H	X	X	X	X	X	0V/V _{CC}
Command input	L	H	L		H	X	H
Address input	L	L	H		H	X	H
Data input	L	L	L		H	X	H
Data output	L	L	L	H		X	X
Write protect	X	X	X	X	X	X	L

Notes: 1. Mode selection settings for this table: H = Logic level HIGH; L = Logic level LOW; X = V_{IH} or V_{IL}.

2. WP# should be biased to CMOS LOW or HIGH for standby.

Asynchronous Enable/Standby

When the device is not performing an operation, the CE# pin is typically driven HIGH and the device enters standby mode. The memory will enter standby if CE# goes HIGH while data is being transferred and the device is not busy. This helps reduce power consumption.

The CE# “Don’t Care” operation enables the NAND Flash to reside on the same asynchronous memory bus as other Flash or SRAM devices. Other devices on the memory bus can then be accessed while the NAND Flash is busy with internal operations. This capability is important for designs that require multiple NAND Flash devices on the same bus.

A HIGH CLE signal indicates that a command cycle is taking place. A HIGH ALE signal signifies that an ADDRESS INPUT cycle is occurring.

Asynchronous Commands

An asynchronous command is written from I/O[7:0] to the command register on the rising edge of WE# when CE# is LOW, ALE is LOW, CLE is HIGH, and RE# is HIGH.

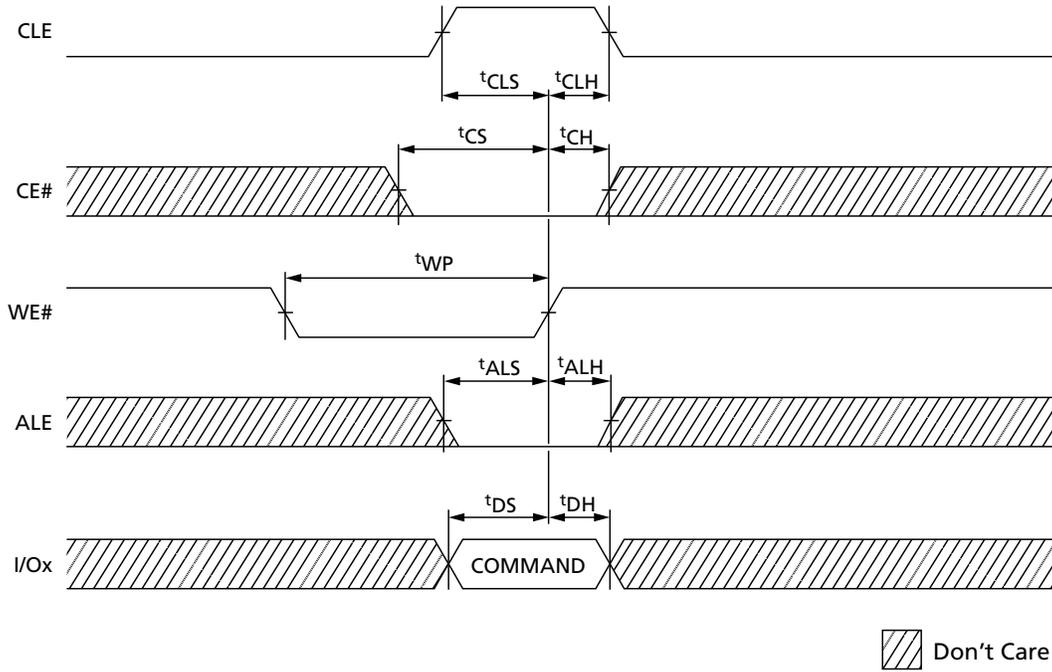
Commands are typically ignored by die (LUNs) that are busy (RDY = 0); however, some commands, including READ STATUS (70h) and READ STATUS ENHANCED (78h), are accepted by die (LUNs) even when they are busy.

For devices with a x16 interface, I/O[15:8] must be written with zeros when a command is issued.



1Gb x8, x16: NAND Flash Memory Asynchronous Interface Bus Operation

Figure 12: Asynchronous Command Latch Cycle





1Gb x8, x16: NAND Flash Memory Asynchronous Interface Bus Operation

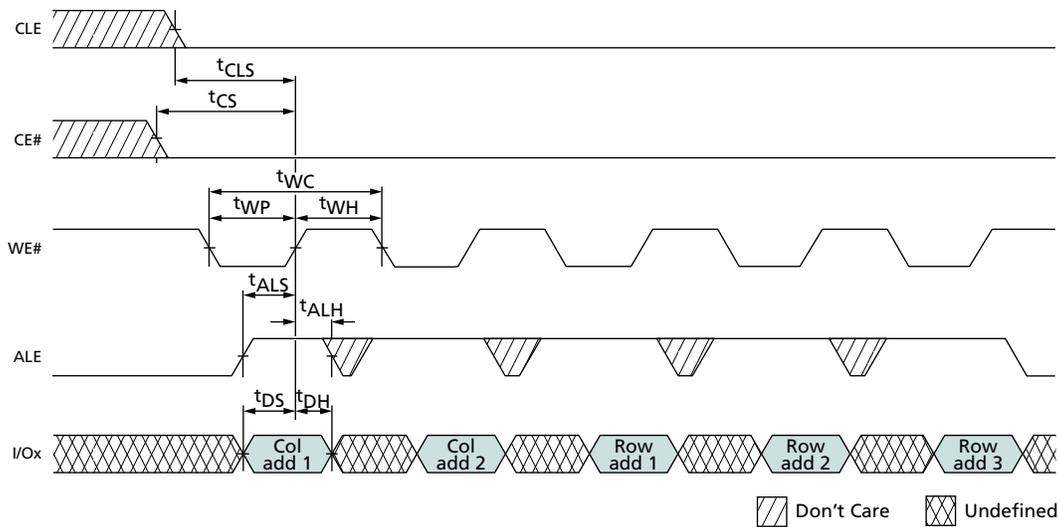
Asynchronous Addresses

An asynchronous address is written from I/O[7:0] to the address register on the rising edge of WE# when CE# is LOW, ALE is HIGH, CLE is LOW, and RE# is HIGH.

Bits that are not part of the address space must be LOW (see Device and Array Organization). The number of cycles required for each command varies. Refer to the command descriptions to determine addressing requirements.

Addresses are typically ignored by die (LUNs) that are busy (RDY = 0); however, some addresses are accepted by die (LUNs) even when they are busy; for example, like address cycles that follow the READ STATUS ENHANCED (78h) command.

Figure 13: Asynchronous Address Latch Cycle





1Gb x8, x16: NAND Flash Memory Asynchronous Interface Bus Operation

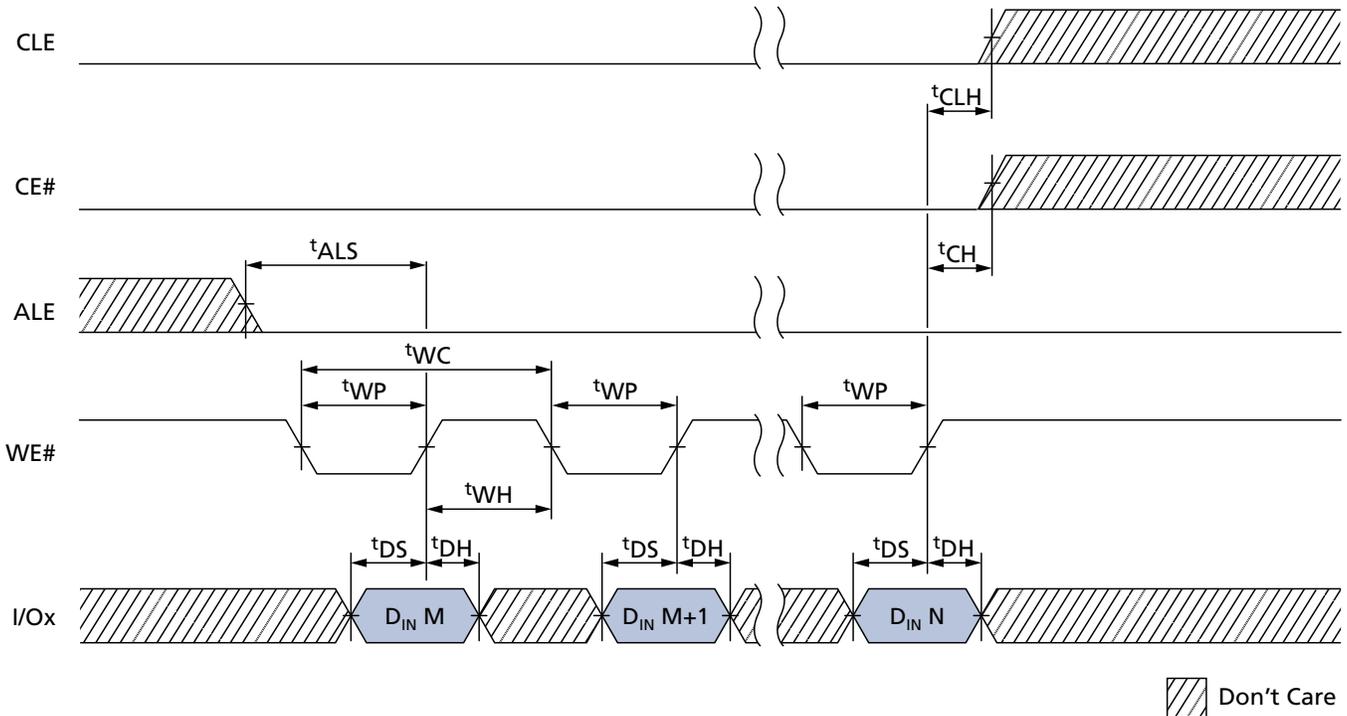
Asynchronous Data Input

Data is written from I/O[7:0] to the cache register of the selected die (LUN) on the rising edge of WE# when CE# is LOW, ALE is LOW, CLE is LOW, and RE# is HIGH.

Data input is ignored by die (LUNs) that are not selected or are busy (RDY = 0). Data is written to the data register on the rising edge of WE# when CE#, CLE, and ALE are LOW, and the device is not busy.

Data is input on I/O[7:0] on x8 devices and on I/O[15:0] on x16 devices.

Figure 14: Asynchronous Data Input Cycles



Don't Care



1Gb x8, x16: NAND Flash Memory Asynchronous Interface Bus Operation

Asynchronous Data Output

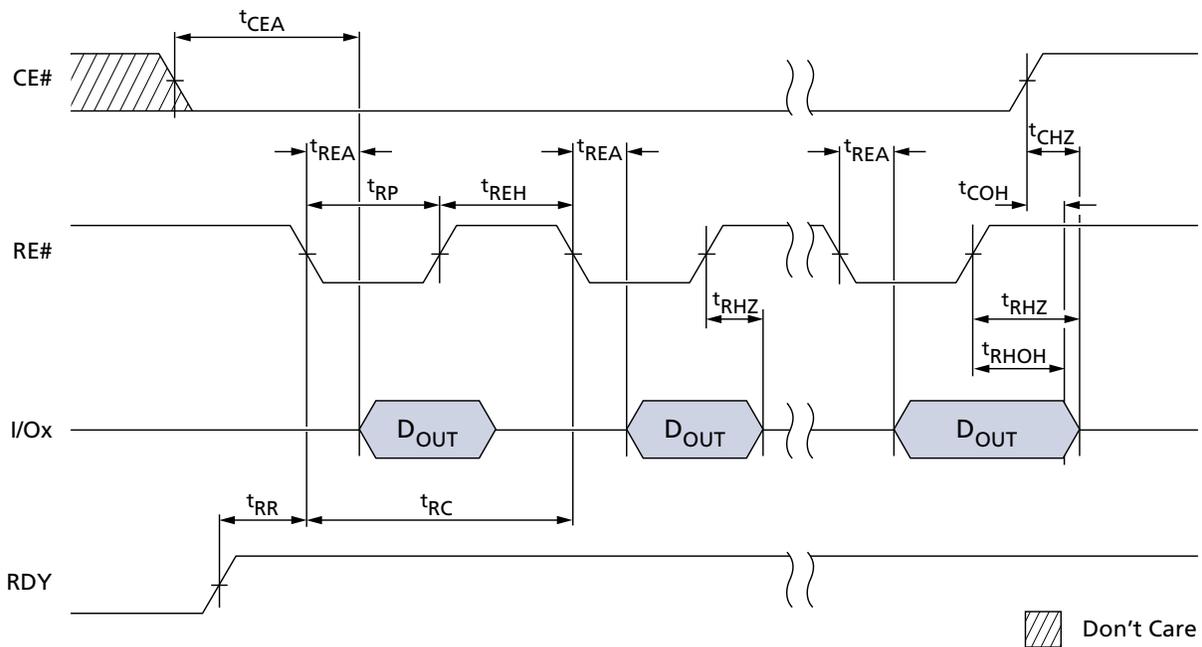
Data can be output from a die (LUN) if it is in a READY state. Data output is supported following a READ operation from the NAND Flash array. Data is output from the cache register of the selected die (LUN) to I/O[7:0] on the falling edge of RE# when CE# is LOW, ALE is LOW, CLE is LOW, and WE# is HIGH.

If the host controller is using a t_{RC} of 30ns or greater, the host can latch the data on the rising edge of RE# (see the figure below for proper timing). If the host controller is using a t_{RC} of less than 30ns, the host can latch the data on the next falling edge of RE#.

Using the READ STATUS ENHANCED (78h) command prevents data contention following an interleaved die (multi-LUN) operation. After issuing the READ STATUS ENHANCED (78h) command, to enable data output, issue the READ MODE (00h) command.

Data output requests are typically ignored by a die (LUN) that is busy (RDY = 0); however, it is possible to output data from the status register even when a die (LUN) is busy by first issuing the READ STATUS or READ STATUS ENHANCED (78h) command.

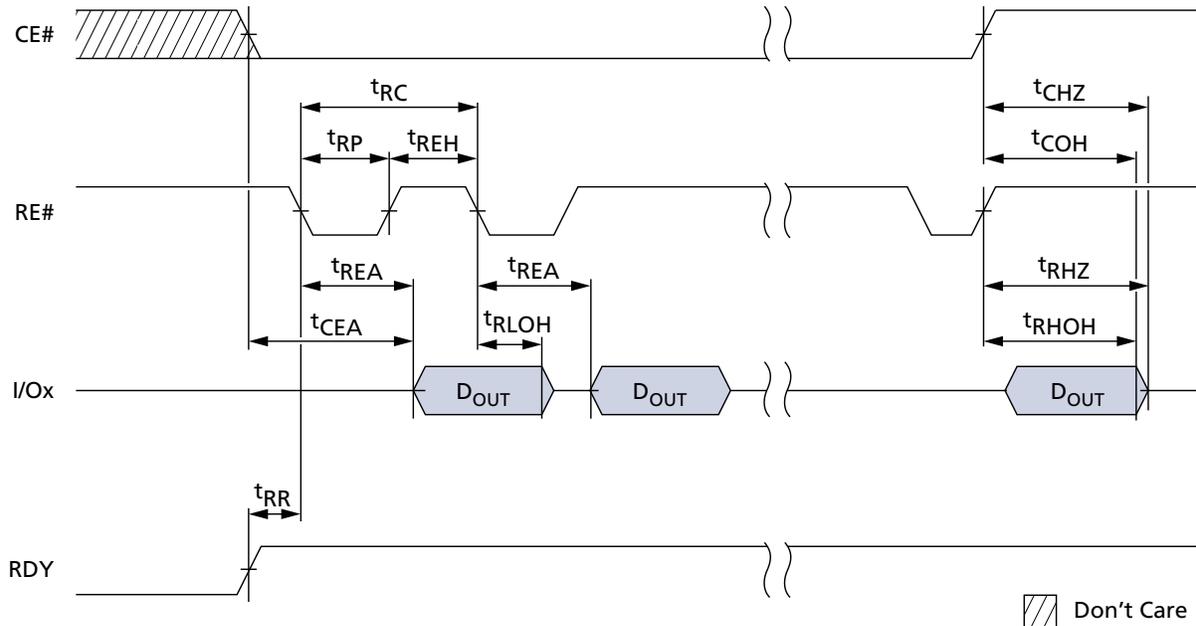
Figure 15: Asynchronous Data Output Cycles





1Gb x8, x16: NAND Flash Memory Asynchronous Interface Bus Operation

Figure 16: Asynchronous Data Output Cycles (EDO Mode)



Write Protect#

The write protect# (WP#) signal enables or disables PROGRAM and ERASE operations to a target. When WP# is LOW, PROGRAM and ERASE operations are disabled. When WP# is HIGH, PROGRAM and ERASE operations are enabled. When WP# is LOW or toggled LOW during a READ operation, read will be performed as normal. It is recommended that the host drive WP# LOW during power-on until V_{CC} is stable to prevent inadvertent PROGRAM and ERASE operations (see Device Initialization for additional details).

If WP# is toggled during PROGRAM or ERASE (while RB# is LOW), then the following will occur

- The PROGRAM or ERASE operation is aborted
- In asynchronous mode, toggling WP# LOW during a NAND PROGRAM or ERASE operation will act like a RESET (FFh) command. In synchronous mode, it will act like a SYNCHRONOUS RESET (FCh) command
- The data that was being programmed or erased (targeted page or block) is not valid anymore
- The status register will be set to 60h until a RESET, new operation, or new power up command is given

After a command sequence is complete and the target is ready, WP# can be transitioned. After WP# is transitioned, the host must wait t_{WW} before issuing a new command.

The WP# signal is always an active input, even when CE# is HIGH. This signal should not be multiplexed with other signals.

Ready/Busy#

The ready/busy# (R/B#) signal provides a hardware method of indicating whether a target is ready or busy. A target is busy when one or more of its die (LUNs) are busy (RDY = 0). A target is ready when all of its die (LUNs) are ready (RDY = 1). Because each die (LUN) contains a status register, it is possible to determine the independent status of each die (LUN) by



1Gb x8, x16: NAND Flash Memory Asynchronous Interface Bus Operation

polling its status register instead of using the R/B# signal (see Status Operations for details regarding die (LUN) status).

This signal requires a pull-up resistor, R_p , for proper operation. R/B# is HIGH when the target is ready, and transitions LOW when the target is busy. The signal's open-drain driver enables multiple R/B# outputs to be OR-tied. Typically, R/B# is connected to an interrupt pin on the system controller.

The combination of R_p and capacitive loading of the R/B# circuit determines the rise time of the R/B# signal. The actual value used for R_p depends on the system timing requirements. Large values of R_p cause R/B# to be delayed significantly. Between the 10% and 90% points on the R/B# waveform, the rise time is approximately two time constants (TC).

$$T_C = R \times C$$

Where $R = R_p$ (resistance of pull-up resistor), and $C =$ total capacitive load.

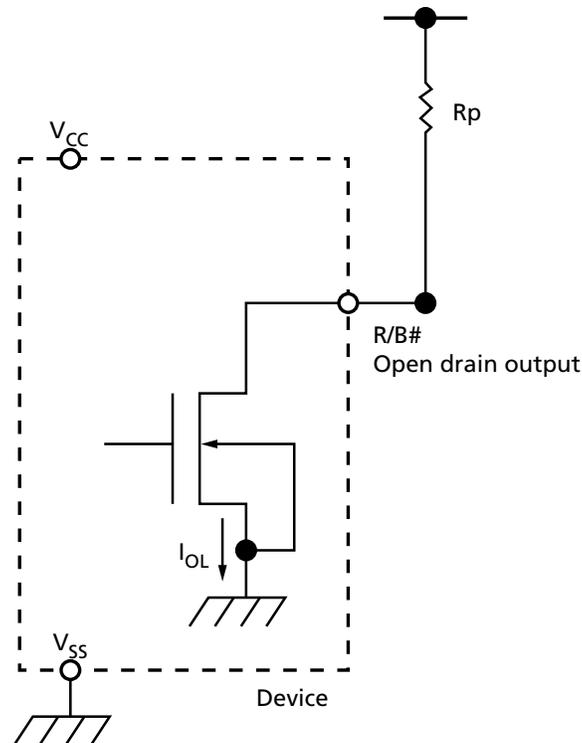
The fall time of the R/B# signal is determined mainly by the output impedance of the R/B# signal and the total load capacitance. Approximate R_p values using a circuit load of 100pF are provided in 22.

The minimum value for R_p is determined by the output drive capability of the R/B# signal, the output voltage swing, and V_{CC} .

$$R_p = \frac{V_{CC} (MAX) - V_{OL} (MAX)}{I_{OL} + \Sigma_{IL}}$$

Where Σ_{IL} is the sum of the input currents of all devices tied to the R/B# pin.

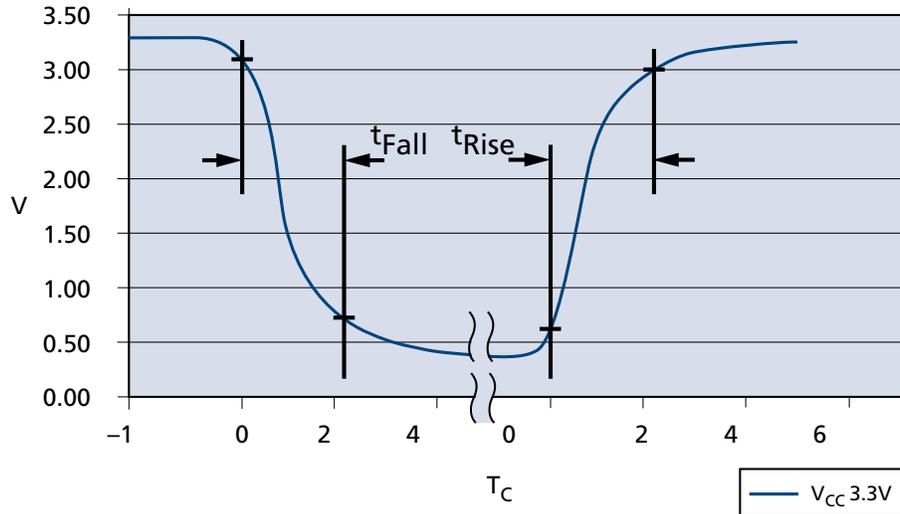
Figure 17: READ/BUSY# Open Drain





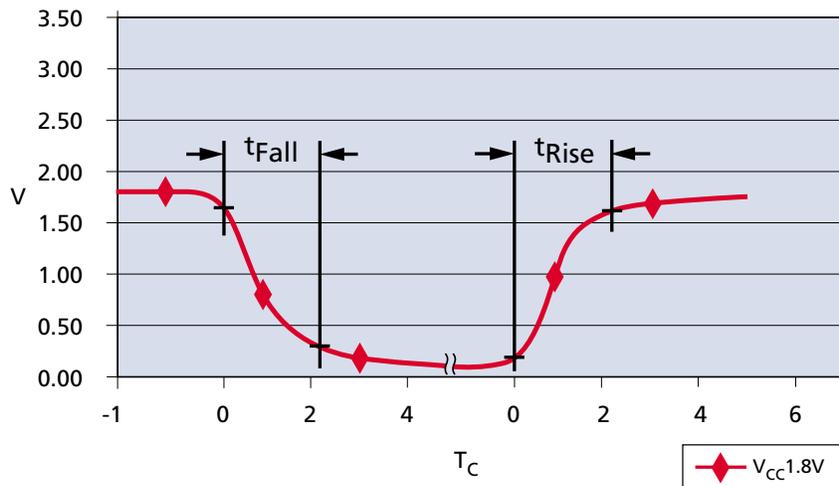
**1Gb x8, x16: NAND Flash Memory
Asynchronous Interface Bus Operation**

Figure 18: t_{Fall} and t_{Rise} (3.3V V_{CC})



- Notes:
1. t_{Fall} and t_{Rise} calculated at 10% and 90% points.
 2. t_{Rise} dependent on external capacitance and resistive loading and output transistor impedance.
 3. t_{Rise} primarily dependent on external pull-up resistor and external capacitive loading.
 4. $t_{Fall} = 10ns$ at 3.3V.
 5. See TC values in 22 for approximate R_p value and TC.

Figure 19: t_{Fall} and t_{Rise} (1.8V V_{CC})



- Notes:
1. t_{Fall} and t_{Rise} are calculated at 10% and 90% points.
 2. t_{Rise} is primarily dependent on external pull-up resistor and external capacitive loading.
 3. $t_{Fall} \approx 7ns$ at 1.8V.
 4. See TC values in 22 for TC and approximate R_p value.



**1Gb x8, x16: NAND Flash Memory
Asynchronous Interface Bus Operation**

Figure 20: I_{OL} vs. R_p ($V_{CC} = 3.3V V_{CC}$)

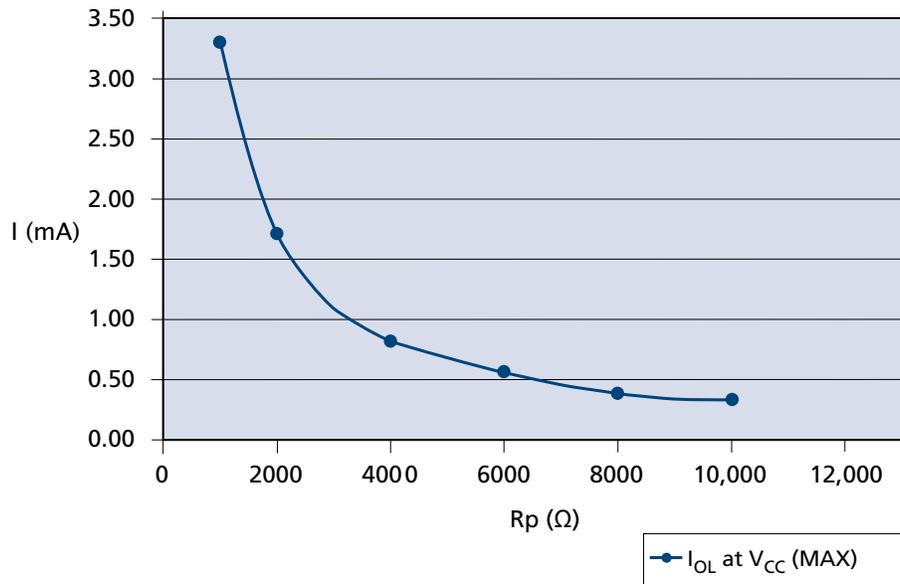
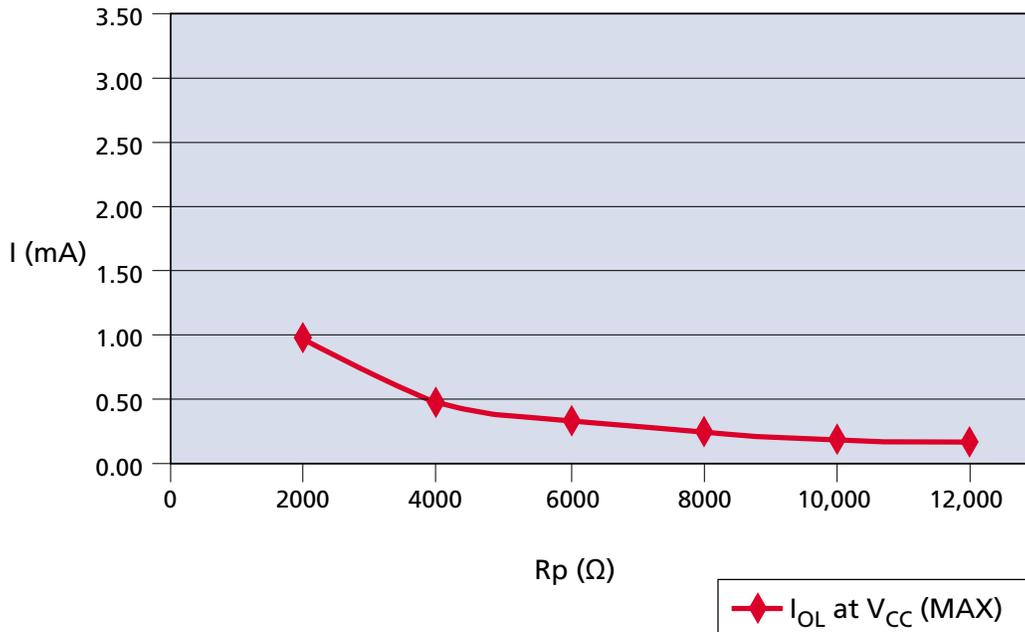


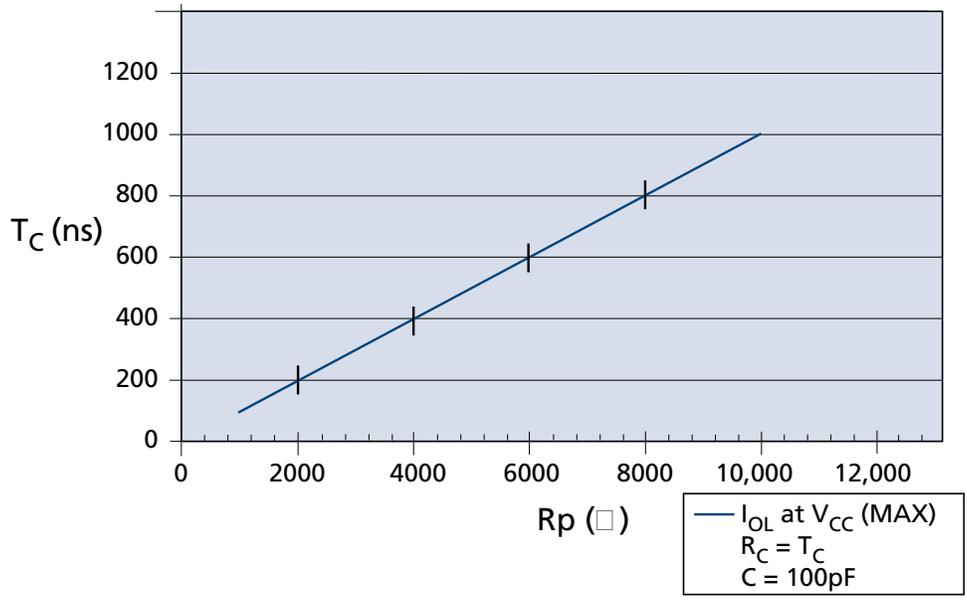
Figure 21: I_{OL} vs. R_p (1.8V V_{CC})





1Gb x8, x16: NAND Flash Memory Asynchronous Interface Bus Operation

Figure 22: TC vs. Rp



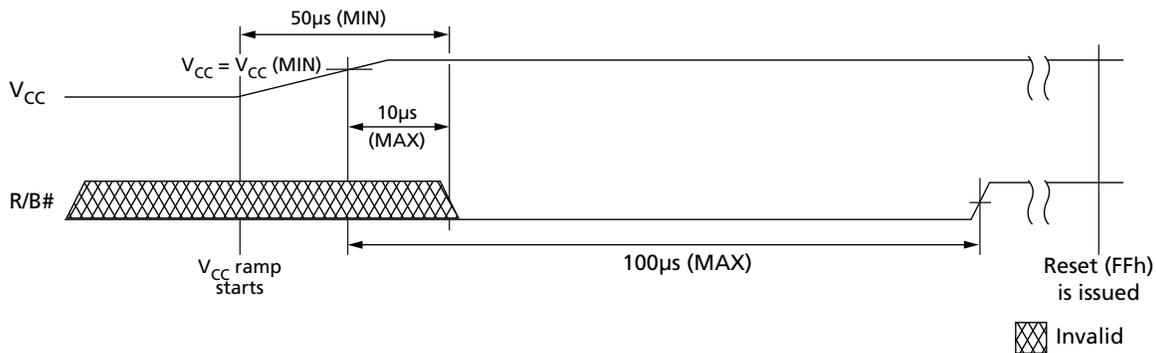


Device Initialization

Micron NAND Flash devices are designed to prevent data corruption during power transitions. V_{CC} is internally monitored. (The WP# signal supports additional hardware protection during power transitions.) When ramping V_{CC} , use the following procedure to initialize the device:

1. Ramp V_{CC} .
2. The host must wait for R/B# to be valid and HIGH before issuing RESET (FFh) to any target. The R/B# signal becomes valid when $50\mu\text{s}$ has elapsed since the beginning the V_{CC} ramp, and $10\mu\text{s}$ has elapsed since V_{CC} reaches $V_{CC,\text{min}}$.
3. If not monitoring R/B#, the host must wait at least $100\mu\text{s}$ after V_{CC} reaches $V_{CC,\text{min}}$. If monitoring R/B#, the host must wait until R/B# is HIGH.
4. The asynchronous interface is active by default for each target. Each LUN draws less than an average of 10mA (I_{ST}) measured over intervals of 1ms until the RESET (FFh) command is issued.
5. The RESET (FFh) command must be the first command issued to all targets (CE#s) after the NAND Flash device is powered on. Each target will be busy for 1ms after a RESET command is issued. The RESET busy time can be monitored by polling R/B# or issuing the READ STATUS (70h) command to poll the status register.
6. The device is now initialized and ready for normal operation.

Figure 23: R/B# Power-On Behavior





Command Definitions

Table 5: Command Set

Command	Command Cycle #1	Number of Valid Address Cycles	Data Input Cycles	Command Cycle #2	Valid While Selected LUN is Busy ¹	Valid While Other LUNs are Busy ²	Notes
Reset Operations							
RESET	FFh	0	–	–	Yes	Yes	
Identification Operation							
READ ID	90h	1	–	–	No	No	
READ PARAMETER PAGE	ECh	1	–	–	No	No	
READ UNIQUE ID	EDh	1	–	–	No	No	
Feature Operations							
GET FEATURES	EEh	1	–	–	No	No	
SET FEATURES	EFh	1	4	–	No	No	
Status Operations							
READ STATUS	70h	0	–	–	Yes		
READ STATUS ENHANCED	78h	3	–	–	Yes	Yes	
Column Address Operations							
RANDOM DATA READ	05h	2	–	E0h	No	Yes	
RANDOM DATA INPUT	85h	2	Optional	–	No	Yes	
PROGRAM FOR INTERNAL DATA MOVE	85h	5	Optional	–	No	Yes	3
READ OPERATIONS							
READ MODE	00h	0	–	–	No	Yes	
READ PAGE	00h	5	–	30h	No	Yes	
READ PAGE CACHE SEQUENTIAL	31h	0	–	–	No	Yes	4, 5
READ PAGE CACHE RANDOM	00h	5	–	31h	No	Yes	4, 5
READ PAGE CACHE LAST	3Fh	0	–	–	No	Yes	4, 5
Program Operations							
PROGRAM PAGE	80h	5	Yes	10h	No	Yes	
PROGRAM PAGE CACHE	80h	5	Yes	15h	No	Yes	4, 6
Erase Operations							
ERASE BLOCK	60h	3	–	D0h	No	Yes	
Internal Data Move Operations							
READ FOR INTERNAL DATA MOVE	00h	5	–	35h	No	Yes	3
PROGRAM FOR INTERNAL DATA MOVE	85h	5	Optional	10h	No	Yes	


Table 5: Command Set (Continued)

Command	Command Cycle #1	Number of Valid Address Cycles	Data Input Cycles	Command Cycle #2	Valid While Selected LUN is Busy ¹	Valid While Other LUNs are Busy ²	Notes
Block Lock Operations							
BLOCK UNLOCK LOW	23h	3	–	–	No	Yes	
BLOCK UNLOCK HIGH	24h	3	–	–	No	Yes	
BLOCK LOCK	2Ah	–	–	–	No	Yes	
BLOCK LOCK-TIGHT	2Ch	–	–	–	No	Yes	
BLOCK LOCK READ STATUS	7Ah	3	–	–	No	Yes	
One-Time Programmable (OTP) Operations							
OTP DATA LOCK BY PAGE (ONFI)	80h	5	No	10h	No	No	7
OTP DATA PROGRAM (ONFI)	80h	5	Yes	10h	No	No	7
OTP DATA READ (ONFI)	00h	5	No	30h	No	No	7

Notes: 1. Busy means RDY = 0.

2. These commands can be used for interleaved die (multi-LUN) operations (see).
3. Do not cross plane address boundaries when using READ for INTERNAL DATA MOVE and PROGRAM for INTERNAL DATA MOVE.
4. These commands supported only with ECC disabled.
5. Issuing a READ PAGE CACHE series (31h, 00h-31h, 3Fh) command when the array is busy (RDY = 1, ARDY = 0) is supported if the previous command was a READ PAGE (00h-30h) or READ PAGE CACHE series command; otherwise, it is prohibited.
6. Issuing a PROGRAM PAGE CACHE (80h-15h) command when the array is busy (RDY = 1, ARDY = 0) is supported if the previous command was a PROGRAM PAGE CACHE (80h-15h) command; otherwise, it is prohibited.
7. OTP commands can be entered only after issuing the SET FEATURES command with the feature address.


Table 6: Two-Plane Command Set

Note 4 applies to all parameters and conditions

Command	Command Cycle #1	Number of Valid Address Cycles	Command Cycle #2	Number of Valid Address Cycles	Command Cycle #3	Valid While Selected LUN is Busy	Valid While Other LUNs are Busy	Notes
READ PAGE TWO-PLANE	00h	5	00h	5	30h	No	Yes	
READ FOR TWO-PLANE INTERNAL DATA MOVE	00h	5	00h	5	35h	No	Yes	1
RANDOM DATA READ TWO-PLANE	06h	5	E0h	–	–	No	Yes	2
PROGRAM PAGE TWO-PLANE	80h	5	11h-80h	5	10h	No	Yes	
PROGRAM PAGE CACHE MODE TWO-PLANE	80h	5	11h-80h	5	15h	No	Yes	
PROGRAM FOR TWO-PLANE INTERNAL DATA MOVE	85h	5	11h-85h	5	10h	No	Yes	1
BLOCK ERASE TWO-PLANE	60h	3	D1h-60h	–	D0h	No	Yes	3

- Notes: 1. Do not cross plane boundaries when using READ FOR INTERNAL DATA MOVE TWO-PLANE or PROGRAM FOR TWO-PLANE INTERNAL DATA MOVE.
 2. The RANDOM DATA READ TWO-PLANE command is limited to use with the PAGE READ TWO-PLANE command.
 3. D1h command can be omitted.
 4. These commands supported only with ECC disabled.



Reset Operations

RESET (FFh)

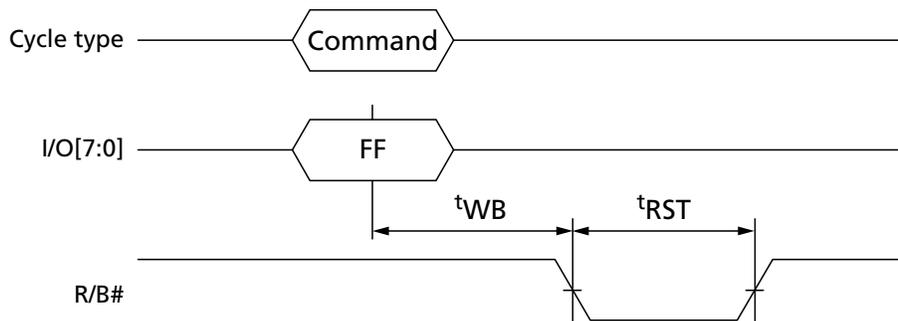
The RESET command is used to put the memory device into a known condition and to abort the command sequence in progress.

READ, PROGRAM, and ERASE commands can be aborted while the device is in the busy state. The contents of the memory location being programmed or the block being erased are no longer valid. The data may be partially erased or programmed, and is invalid. The command register is cleared and is ready for the next command. The data register and cache register contents are marked invalid.

The status register contains the value E0h when WP# is HIGH; otherwise it is written with a 60h value. R/B# goes LOW for t_{RST} after the RESET command is written to the command register.

The RESET command must be issued to all CE#s as the first command after power-on. The device will be busy for a maximum of 1ms.

Figure 24: RESET (FFh) Operation





Identification Operations

READ ID (90h)

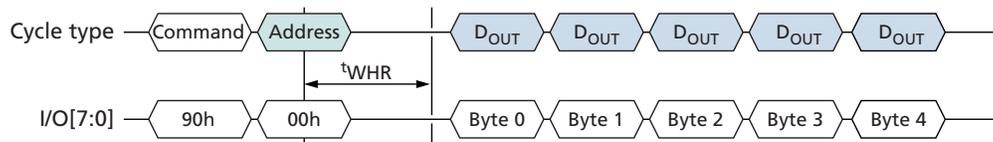
The READ ID (90h) command is used to read identifier codes programmed into the target. This command is accepted by the target only when all die (LUNs) on the target are idle.

Writing 90h to the command register puts the target in read ID mode. The target stays in this mode until another valid command is issued.

When the 90h command is followed by an 00h address cycle, the target returns a 5-byte identifier code that includes the manufacturer ID, device configuration, and part-specific information.

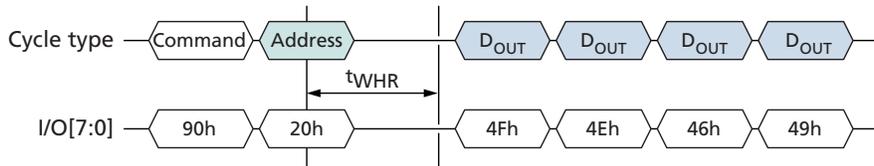
When the 90h command is followed by a 20h address cycle, the target returns the 4-byte ONFI identifier code.

Figure 25: READ ID (90h) with 00h Address Operation



Note: 1. See READ ID Parameter tables for byte definitions.

Figure 26: READ ID (90h) with 20h Address Operation



Note: 1. See READ ID Parameter tables for byte definitions.



READ ID Parameter Tables

Table 7: READ ID Parameters for Address 00h

		Options	I/07	I/06	I/05	I/04	I/03	I/02	I/01	I/00	Value
Byte 0 – Manufacturer ID											
Manufacturer		Micron	0	0	1	0	1	1	0	0	2Ch
Byte 1 – Device ID											
MT29F1G08ABAEA		1Gb, x8, 3.3V	1	1	1	1	0	0	0	1	F1h
MT29F1G08ABBEA		1Gb, x8, 1.8V	1	0	1	0	0	0	0	1	A1h
MT29F1G16ABBEA		1Gb, x16, 1.8V	1	0	1	1	0	0	0	1	B1h
Byte 2											
Number of die per CE		1							0	0	00b
Cell type		SLC					0	0			00b
Number of simultaneously programmed pages		1			0	0					00b
Interleaved operations between multiple die		Not supported		0							0b
Cache programming		Supported	1								1b
Byte value		MT29F1G08ABAEA	1	0	0	0	0	0	0	0	80h
		MT29F1G08ABBEA	1	0	0	0	0	0	0	0	80h
		MT29F1G16ABBEA	1	0	0	0	0	0	0	0	80h
Byte 3											
Page size		2KB							0	1	01b
Spare area size (bytes)		64B						1			1b
Block size (without spare)		128KB			0	1					01b
Organization		x8		0							0b
		x16		1							1b
Serial access (MIN)		1.8V 25ns	0				0				0xx0b
		3.3V 20ns	1				0				1xx0b
Byte value		MT29F1G08ABAEA	1	0	0	1	0	1	0	1	95h
		MT29F1G08ABBEA	0	0	0	1	0	1	0	1	15h
		MT29F1G16ABBEA	0	1	0	1	0	1	0	1	55h
Byte 4											
Reserved									0	0	00b
Planes per CE# ¹		2					0	1			01b
Plane size		512Mb		0	0	0					000b
Reserved			0								0b



1Gb x8, x16: NAND Flash Memory READ ID Parameter Tables

Table 7: READ ID Parameters for Address 00h (Continued)

	Options	I/07	I/06	I/05	I/04	I/03	I/02	I/01	I/00	Value
Byte value	MT29F1G08ABAEA	0	0	0	0	0	1	0	0	04h
	MT29F1G08ABBEA	0	0	0	0	0	1	0	0	04h
	MT29F1G16ABBEA	0	0	0	0	0	1	0	0	04h

Notes: 1. Only single-plane operations are supported.
2. b = binary; h = hexadecimal

Table 8: READ ID Parameters for Address 20h

Byte	Options	I/07	I/06	I/05	I/04	I/03	I/02	I/01	I/00	Value
0	"O"	0	1	0	0	1	1	1	1	4Fh
1	"N"	0	1	0	0	1	1	1	0	4Eh
2	"F"	0	1	0	0	0	1	1	0	46h
3	"I"	0	1	0	0	1	0	0	1	49h
4	Undefined	X	X	X	X	X	X	X	X	XXh

Notes: 1. h = hexadecimal



READ PARAMETER PAGE (ECh)

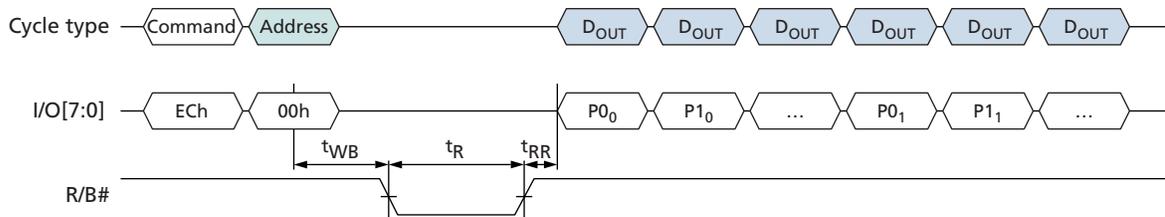
The READ PARAMETER PAGE (ECh) command is used to read the ONFI parameter page programmed into the target. This command is accepted by the target only when all die (LUNs) on the target are idle.

Writing ECh to the command register puts the target in read parameter page mode. The target stays in this mode until another valid command is issued.

When the ECh command is followed by an 00h address cycle, the target goes busy for t_R . If the READ STATUS (70h) command is used to monitor for command completion, the READ MODE (00h) command must be used to re-enable data output mode. Use of the READ STATUS ENHANCED (78h) command is prohibited while the target is busy and during data output.

To insure data integrity, x8 devices contain at least eight copies of the parameter page, and x16 devices contain at least four copies of the parameter page. Each parameter page is 256 bytes. If the initial READ PARAMETER PAGE (ECh) command fails to retrieve a correct copy of the parameter page, the command can be reissued until a correct copy is retrieved. If desired, the RANDOM DATA READ (05h-E0h) command can be used to change the location of data output.

Figure 27: READ PARAMETER (ECh) Operation





1Gb x8, x16: NAND Flash Memory Parameter Page Data Structure Tables

Byte	Description	Value	
67–79	Reserved	00h, 00h	
80–83	Number of data bytes per page	00h, 08h, 00h, 00h	
84–85	Number of spare bytes per page	40h, 00h	
86–89	Number of data bytes per partial page	00h, 02h, 00h, 00h	
90–91	Number of spare bytes per partial page	10h, 00h	
92–95	Number of pages per block	40h, 00h, 00h, 00h	
96–99	Number of blocks per unit	00h, 04h, 00h, 00h	
100	Number of logical units	01h	
101	Number of address cycles	22h	
102	Number of bits per cell	01h	
103–104	Bad blocks maximum per unit	14h, 00h	
105–106	Block endurance	01h, 05h	
107	Guaranteed valid blocks at beginning of target	01h	
108–109	Block endurance for guaranteed valid blocks	00h, 00h	
110	Number of programs per page	04h	
111	Partial programming attributes	00h	
112	Number of bits ECC bits	04h	
113	Number of interleaved address bits	00h	
114	Interleaved operation attributes	00h	
115–127	Reserved	00h, 00h	
128	I/O pin capacitance	0Ah	
129–130	Timing mode support	MT29F1G08ABAEAWP	3Fh, 00h
		MT29F1G08ABBEAHC	1Fh, 00h
		MT29F1G16ABBEAHC	1Fh, 00h
		MT29F1G08ABBEAH4	1Fh, 00h
		MT29F1G16ABBEAH4	1Fh, 00h
		MT29F1G08ABAEAH4	3Fh, 00h
		MT29F1G08ABAEA3W	3Fh, 00h
		MT29F1G08ABBEA3W	1Fh, 00h
		MT29F1G16ABBEA3W	1Fh, 00h



READ UNIQUE ID (EDh)

The READ UNIQUE ID (EDh) command is used to read a unique identifier programmed into the target. This command is accepted by the target only when all die (LUNs) on the target are idle.

Writing EDh to the command register puts the target in read unique ID mode. The target stays in this mode until another valid command is issued.

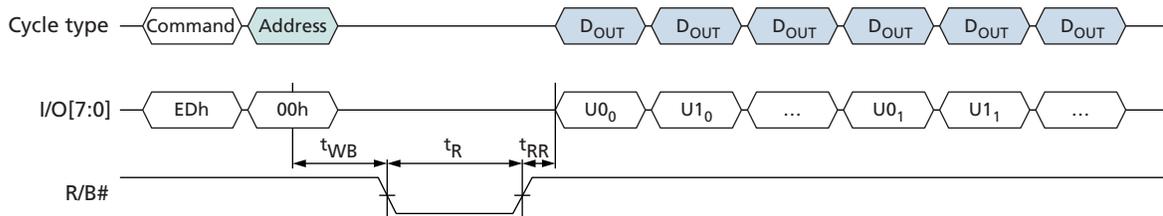
When the EDh command is followed by an 00h address cycle, the target goes busy for t_R . If the READ STATUS (70h) command is used to monitor for command completion, the READ MODE (00h) command must be used to re-enable data output mode.

After t_R completes, the host enables data output mode to read the unique ID. When the asynchronous interface is active, one data byte is output per RE# toggle.

Sixteen copies of the unique ID data are stored in the device. Each copy is 32 bytes. The first 16 bytes of a 32-byte copy are unique data, and the second 16 bytes are the complement of the first 16 bytes. The host should XOR the first 16 bytes with the second 16 bytes. If the result is 16 bytes of FFh, then that copy of the unique ID data is correct. In the event that a non-FFh result is returned, the host can repeat the XOR operation on a subsequent copy of the unique ID data. If desired, the RANDOM DATA READ (05h-E0h) command can be used to change the data output location.

The upper eight I/Os on a x16 device are not used and are a “Don’t Care” for x16 devices.

Figure 28: READ UNIQUE ID (EDh) Operation





Feature Operations

The SET FEATURES (EFh) and GET FEATURES (EEh) commands are used to modify the target's default power-on behavior. These commands use a one-byte feature address to determine which subfeature parameters will be read or modified. Each feature address (in the 00h to FFh range) is defined in below. The SET FEATURES (EFh) command writes subfeature parameters (P1–P4) to the specified feature address. The GET FEATURES command reads the subfeature parameters (P1–P4) at the specified feature address.

Table 10: Feature Address Definitions

Feature Address	Definition
00h	Reserved
01h	Timing mode
02h–7Fh	Reserved
80h	Programmable output drive strength
81h	Programmable RB# pull-down strength
82h–FFh	Reserved
90h	Array operation mode

Table 11: Feature Address 90h – Array Operation Mode

Subfeature Parameter	Options	I/O7	I/O6	I/O5	I/O4	I/O3	I/O2	I/O1	I/O0	Value	Notes
P1											
Operation mode option	Normal	Reserved (0)							0	00h	1
	OTP operation	Reserved (0)							1	01h	
	OTP protection	Reserved (0)					1	1	03h		
		Reserved (0)								00h	
		Reserved (0)								00h	
P2											
Reserved		Reserved (0)								00h	
P3											
Reserved		Reserved (0)								00h	
P4											
Reserved		Reserved (0)								00h	

Notes: 1. These bits are reset to 00h on power cycle.

SET FEATURES (EFh)

The SET FEATURES (EFh) command writes the subfeature parameters (P1–P4) to the specified feature address to enable or disable target-specific features. This command is accepted by the target only when all die (LUNs) on the target are idle.



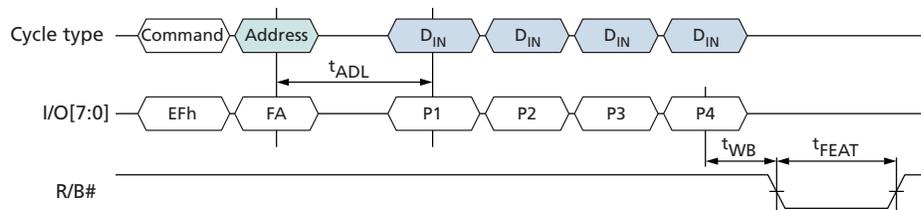
Writing EFh to the command register puts the target in the set features mode. The target stays in this mode until another command is issued.

The EFh command is followed by a valid feature address. The host waits for t_{ADL} before the subfeature parameters are input. When the asynchronous interface is active, one subfeature parameter is latched per rising edge of WE#.

After all four subfeature parameters are input, the target goes busy for t_{FEAT} . The READ STATUS (70h) command can be used to monitor for command completion.

Feature address 01h (timing mode) operation is unique. If SET FEATURES is used to modify the interface type, the target will be busy for t_{ITC} .

Figure 29: SET FEATURES (EFh) Operation



GET FEATURES (EEh)

The GET FEATURES (EEh) command reads the subfeature parameters (P1–P4) from the specified feature address. This command is accepted by the target only when all die (LUNs) on the target are idle.

Writing EEh to the command register puts the target in get features mode. The target stays in this mode until another valid command is issued.

When the EEh command is followed by a feature address, the target goes busy for t_{FEAT} . If the READ STATUS (70h) command is used to monitor for command completion, the READ MODE (00h) command must be used to re-enable data output mode. During and prior to data output, use of the READ STATUS ENHANCED (78h) command is prohibited prior to and during data output.

After t_{FEAT} completes, the host enables data output mode to read the subfeature parameters.

Figure 30: GET FEATURES (EEh) Operation

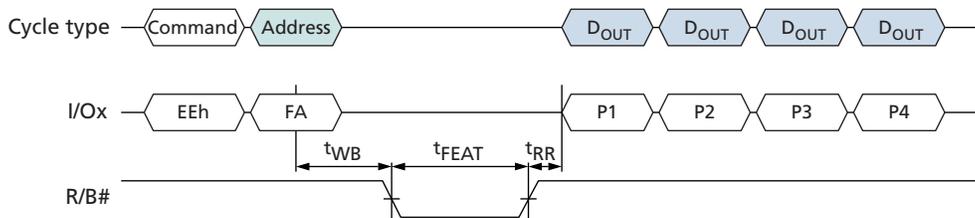


Table 12: Feature Addresses 01h: Timing Mode

Subfeature Parameter	Options	I/O7	I/O6	I/O5	I/O4	I/O3	I/O2	I/O1	I/O0	Value	Notes
P1											



1Gb x8, x16: NAND Flash Memory Feature Operations

Table 12: Feature Addresses 01h: Timing Mode (Continued)

Subfeature Parameter	Options	I/O7	I/O6	I/O5	I/O4	I/O3	I/O2	I/O1	I/O0	Value	Notes
Timing mode	Mode 0 (default)	Reserved (0)					0	0	0	00h	1, 2
	Mode 1	Reserved (0)					0	0	1	01h	2
	Mode 2	Reserved (0)					0	1	0	02h	2
	Mode 3	Reserved (0)					0	1	1	03h	2
	Mode 4	Reserved (0)					1	0	0	04h	2
	Mode 5	Reserved (0)					1	0	1	05h	3
P2											
		Reserved (0)								00h	
P3											
		Reserved (0)								00h	
P4											
		Reserved (0)								00h	

- Notes: 1. The timing mode feature address is used to change the default timing mode. The timing mode should be selected to indicate the maximum speed at which the device will receive commands, addresses, and data cycles. The five supported settings for the timing mode are shown. The default timing mode is mode 0. The device returns to mode 0 when the device is power cycled. Supported timing modes are reported in the parameter page.
2. Supported for both 1.8V and 3.3V.
 3. Supported for 3.3V only.


Table 13: Feature Addresses 80h: Programmable I/O Drive Strength

Subfeature Parameter	Options	I/O7	I/O6	I/O5	I/O4	I/O3	I/O2	I/O1	I/O0	Value	Notes
P1											
I/O drive strength	Full (default)							0	0	00h	1
	Three-quarters							0	1	01h	
	One-half							1	0	02h	
	One-quarter							1	1	03h	
P2											
										00h	
P3											
										00h	
P4											
										00h	

Notes: 1. The programmable drive strength feature address is used to change the default I/O drive strength. Drive strength should be selected based on expected loading of the memory bus. This table shows the four supported output drive strength settings. The default drive strength is full strength. The device returns to the default drive strength mode when the device is power cycled. AC timing parameters may need to be relaxed if I/O drive strength is not set to full.

Table 14: Feature Addresses 81h: Programmable R/B# Pull-Down Strength

Subfeature Parameter	Options	I/O7	I/O6	I/O5	I/O4	I/O3	I/O2	I/O1	I/O0	Value	Notes
P1											
R/B# pull-down strength	Full (default)							0	0	00h	1
	Three-quarters							0	1	01h	
	One-half							1	0	02h	
	One-quarter							1	1	03h	
P2											
										00h	
P3											
										00h	
P4											
										00h	

Notes: 1. This feature address is used to change the default R/B# pull-down strength. Its strength should be selected based on the expected loading of R/B#. Full strength is the default, power-on value.



Status Operations

Each die (LUN) provides its status independently of other die (LUNs) on the same target through its 8-bit status register.

After the READ STATUS (70h) or READ STATUS ENHANCED (78h) command is issued, status register output is enabled. The contents of the status register are returned on I/O[7:0] for each data output request.

When the asynchronous interface is active and status register output is enabled, changes in the status register are seen on I/O[7:0] as long as CE# and RE# are LOW; it is not necessary to toggle RE# to see the status register update.

While monitoring the status register to determine when a data transfer from the Flash array to the data register (⁴R) is complete, the host must issue the READ MODE (00h) command to disable the status register and enable data output (see Read Operations).

The READ STATUS (70h) command returns the status of the most recently selected die (LUN). To prevent data contention during or following an interleaved die (multi-LUN) operation, the host must enable only one die (LUN) for status output by using the READ STATUS ENHANCED (78h) command (see Interleaved Die (Multi-LUN) Operations).

Table 15: Status Register Definition

SR Bit	Program Page	Program Page Cache Mode	Page Read	Page Read Cache Mode	Block Erase	Description
7	Write protect	Write protect	Write protect	Write protect	Write protect	0 = Protected 1 = Not protected
6	RDY	RDY cache ¹	RDY	RDY cache ¹	RDY	0 = Busy 1 = Ready
5	ARDY	ARDY ²	ARDY	ARDY ²	ARDY	0 = Busy 1 = Ready
4	–	–	–	–	–	Reserved (0)
3	–	–	–	–	–	Reserved (0)
2	–	–	–	–	–	Reserved (0)
1	–	FAILC (N–1)	–	–	–	0 = Pass 1 = Fail
0	FAIL	FAIL (N)	–	–	FAIL	0 = Pass 1 = Fail

Notes: 1. Status register bit 6 is 1 when the cache is ready to accept new data. R/B# follows bit 6.

2. Status register bit 5 is 0 during the actual programming operation. If cache mode is used, this bit will be 1 when all internal operations are complete.

READ STATUS (70h)

The READ STATUS (70h) command returns the status of the last-selected die (LUN) on a target. This command is accepted by the last-selected die (LUN) even when it is busy (RDY = 0).

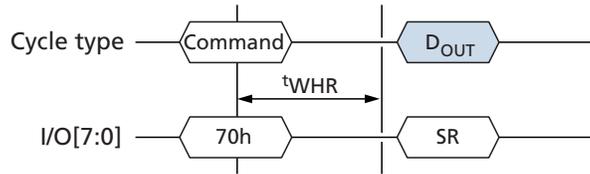
If there is only one die (LUN) per target, the READ STATUS (70h) command can be used to return status following any NAND command.

In devices that have more than one die (LUN) per target, during and following interleaved die (multi-LUN) operations, the READ STATUS ENHANCED (78h) command must be used to select the



die (LUN) that should report status. In this situation, using the READ STATUS (70h) command will result in bus contention, as two or more die (LUNs) could respond until the next operation is issued. The READ STATUS (70h) command can be used following all single-die (LUN) operations.

Figure 31: READ STATUS (70h) Operation



READ STATUS ENHANCED (78h)

The READ STATUS ENHANCED (78h) command returns the status of the addressed die (LUN) on a target even when it is busy (RDY = 0). This command is accepted by all die (LUNs), even when they are BUSY (RDY = 0).

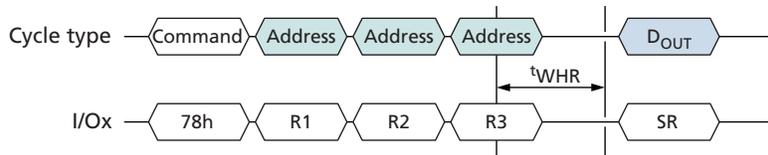
Writing 78h to the command register, followed by three row address cycles containing the page, block, and LUN addresses, puts the selected die (LUN) into read status mode. The selected die (LUN) stays in this mode until another valid command is issued. Die (LUNs) that are not addressed are deselected to avoid bus contention.

The selected LUN's status is returned when the host requests data output. The RDY and ARDY bits of the status register are shared for all planes on the selected die (LUN). The FAILC and FAIL bits are specific to the plane specified in the row address.

The READ STATUS ENHANCED (78h) command also enables the selected die (LUN) for data output. To begin data output following a READ-series operation after the selected die (LUN) is ready (RDY = 1), issue the READ MODE (00h) command, then begin data output. If the host needs to change the cache register that will output data, use the RANDOM DATA READ TWO-PLANE (06h-E0h) command after the die (LUN) is ready.

Use of the READ STATUS ENHANCED (78h) command is prohibited during the power-on RESET (FFh) command and when OTP mode is enabled. It is also prohibited following some of the other reset, identification, and configuration operations. See individual operations for specific details.

Figure 32: READ STATUS ENHANCED (78h) Operation





Column Address Operations

The column address operations affect how data is input to and output from the cache registers within the selected die (LUNs). These features provide host flexibility for managing data, especially when the host internal buffer is smaller than the number of data bytes or words in the cache register.

When the asynchronous interface is active, column address operations can address any byte in the selected cache register.

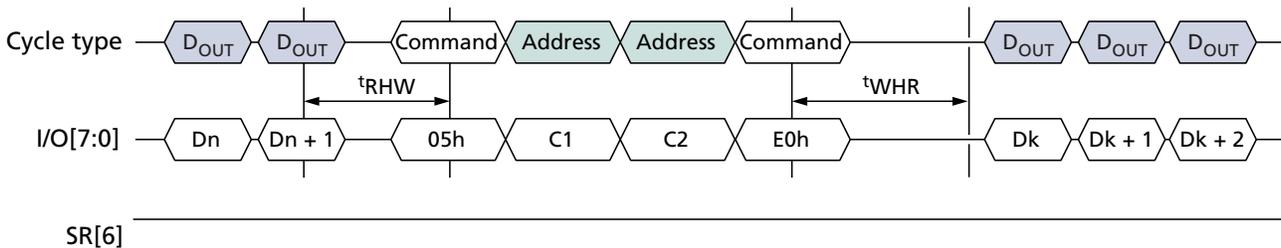
RANDOM DATA READ (05h-E0h)

The RANDOM DATA READ (05h-E0h) command changes the column address of the selected cache register and enables data output from the last selected die (LUN). This command is accepted by the selected die (LUN) when it is ready (RDY = 1; ARDY = 1). It is also accepted by the selected die (LUN) during CACHE READ operations (RDY = 1; ARDY = 0).

Writing 05h to the command register, followed by two column address cycles containing the column address, followed by the E0h command, puts the selected die (LUN) into data output mode. After the E0h command cycle is issued, the host must wait at least t_{WHR} before requesting data output. The selected die (LUN) stays in data output mode until another valid command is issued.

In devices with more than one die (LUN) per target, during and following interleaved die (multi-LUN) operations, the READ STATUS ENHANCED (78h) command must be issued prior to issuing the RANDOM DATA READ (05h-E0h). In this situation, using the RANDOM DATA READ (05h-E0h) command without the READ STATUS ENHANCED (78h) command will result in bus contention because two or more die (LUNs) could output data.

Figure 33: RANDOM DATA READ (05h-E0h) Operation





RANDOM DATA READ TWO-PLANE (06h-E0h)

The RANDOM DATA READ TWO-PLANE (06h-E0h) command enables data output on the addressed die's (LUN's) cache register at the specified column address. This command is accepted by a die (LUN) when it is ready (RDY = 1; ARDY = 1).

Writing 06h to the command register, followed by two column address cycles and three row address cycles, followed by E0h, enables data output mode on the address LUN's cache register at the specified column address. After the E0h command cycle is issued, the host must wait at least t_{WHR} before requesting data output. The selected die (LUN) stays in data output mode until another valid command is issued.

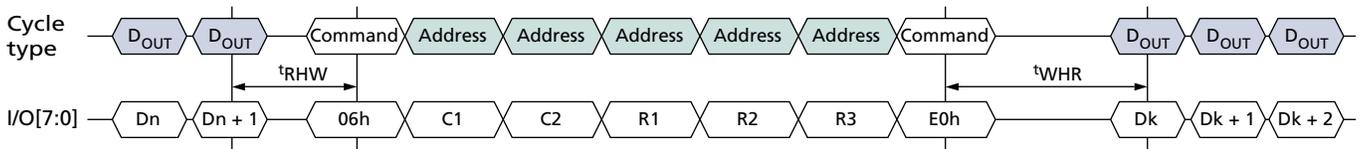
Following a two-plane read page operation, the RANDOM DATA READ TWO-PLANE (06h-E0h) command is used to select the cache register to be enabled for data output. After data output is complete on the selected plane, the command can be issued again to begin data output on another plane.

In devices with more than one die (LUN) per target, after all of the die (LUNs) on the target are ready (RDY = 1), the RANDOM DATA READ TWO-PLANE (06h-E0h) command can be used following an interleaved die (multi-LUN) read operation. Die (LUNs) that are not addressed are deselected to avoid bus contention.

In devices with more than one die (LUN) per target, during interleaved die (multi-LUN) operations where more than one or more die (LUNs) are busy (RDY = 1; ARDY = 0 or RDY = 0; ARDY = 0), the READ STATUS ENHANCED (78h) command must be issued to the die (LUN) to be selected prior to issuing the RANDOM DATA READ TWO-PLANE (06h-E0h). In this situation, using the RANDOM DATA READ TWO-PLANE (06h-E0h) command without the READ STATUS ENHANCED (78h) command will result in bus contention, as two or more die (LUNs) could output data.

If there is a need to update the column address without selecting a new cache register or LUN, the RANDOM DATA READ (05h-E0h) command can be used instead.

Figure 34: RANDOM DATA READ TWO-PLANE (06h-E0h) Operation





RANDOM DATA INPUT (85h)

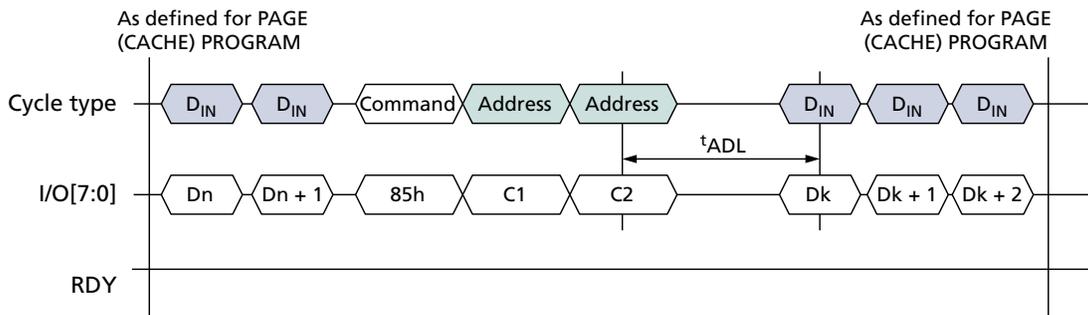
The RANDOM DATA INPUT (85h) command changes the column address of the selected cache register and enables data input on the last-selected die (LUN). This command is accepted by the selected die (LUN) when it is ready (RDY = 1; ARDY = 1). It is also accepted by the selected die (LUN) during cache program operations (RDY = 1; ARDY = 0).

Writing 85h to the command register, followed by two column address cycles containing the column address, puts the selected die (LUN) into data input mode. After the second address cycle is issued, the host must wait at least t_{ADL} before inputting data. The selected die (LUN) stays in data input mode until another valid command is issued. Though data input mode is enabled, data input from the host is optional. Data input begins at the column address specified.

The RANDOM DATA INPUT (85h) command is allowed after the required address cycles are specified, but prior to the final command cycle (10h, 11h, 15h) of the following commands while data input is permitted: PROGRAM PAGE (80h-10h), PROGRAM PAGE CACHE (80h-15h), PROGRAM FOR INTERNAL DATA MOVE (85h-10h), and PROGRAM FOR TWO-PLANE INTERNAL DATA MOVE (85h-11h).

In devices that have more than one die (LUN) per target, the RANDOM DATA INPUT (85h) command can be used with other commands that support interleaved die (multi-LUN) operations.

Figure 35: RANDOM DATA INPUT (85h) Operation





PROGRAM FOR INTERNAL DATA INPUT (85h)

The PROGRAM FOR INTERNAL DATA INPUT (85h) command changes the row address (block and page) where the cache register contents will be programmed in the NAND Flash array. It also changes the column address of the selected cache register and enables data input on the specified die (LUN). This command is accepted by the selected die (LUN) when it is ready (RDY = 1; ARDY = 1). It is also accepted by the selected die (LUN) during cache programming operations (RDY = 1; ARDY = 0).

Write 85h to the command register. Then write two column address cycles and three row address cycles. This updates the page and block destination of the selected device for the addressed LUN and puts the cache register into data input mode. After the fifth address cycle is issued the host must wait at least ^tADL before inputting data. The selected LUN stays in data input mode until another valid command is issued. Though data input mode is enabled, data input from the host is optional. Data input begins at the column address specified.

The PROGRAM FOR INTERNAL DATA INPUT (85h) command is allowed after the required address cycles are specified, but prior to the final command cycle (10h, 11h, 15h) of the following commands while data input is permitted: PROGRAM PAGE (80h-10h), PROGRAM PAGE TWO-PLANE (80h-11h), PROGRAM PAGE CACHE (80h-15h), PROGRAM FOR INTERNAL DATA MOVE (85h-10h), and PROGRAM FOR TWO-PLANE INTERNAL DATA MOVE (85h-11h). When used with these commands, the LUN address and plane select bits are required to be identical to the LUN address and plane select bits originally specified.

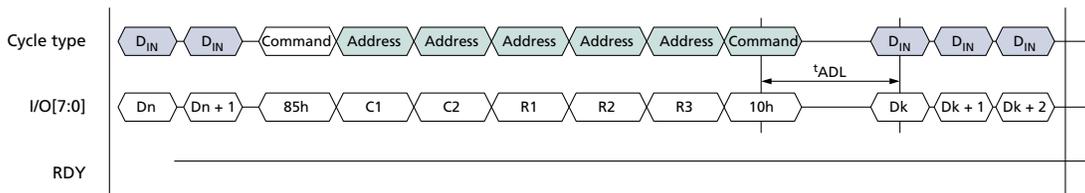
The PROGRAM FOR INTERNAL DATA INPUT (85h) command enables the host to modify the original page and block address for the data in the cache register to a new page and block address.

In devices that have more than one die (LUN) per target, the PROGRAM FOR INTERNAL DATA INPUT (85h) command can be used with other commands that support interleaved die (multi-LUN) operations.

The PROGRAM FOR INTERNAL DATA INPUT (85h) command can be used with the RANDOM DATA READ (05h-E0h) or RANDOM DATA READ TWO-PLANE (06h-E0h) commands to read and modify cache register contents in small sections prior to programming cache register contents to the NAND Flash array. This capability can reduce the amount of buffer memory used in the host controller.

The RANDOM DATA INPUT (85h) command can be used during the PROGRAM FOR INTERNAL DATA MOVE command sequence to modify one or more bytes of the original data. First, data is copied into the cache register using the 00h-35h command sequence, then the RANDOM DATA INPUT (85h) command is written along with the address of the data to be modified next. New data is input on the external data pins. This copies the new data into the cache register.

Figure 36: PROGRAM FOR INTERNAL DATA INPUT (85h) Operation





Read Operations

The READ PAGE (00h-30h) command, when issued by itself, reads one page from the NAND Flash array to its cache register and enables data output for that cache register.

During data output the following commands can be used to read and modify the data in the cache registers: RANDOM DATA READ (05h-E0h) and RANDOM DATA INPUT (85h).

Read Cache Operations

To increase data throughput, the READ PAGE CACHE series (31h, 00h-31h) commands can be used to output data from the cache register while concurrently copying a page from the NAND Flash array to the data register.

To begin a read page cache sequence, begin by reading a page from the NAND Flash array to its corresponding cache register using the READ PAGE (00h-30h) command.

R/B# goes LOW during ^tR and the selected die (LUN) is busy (RDY = 0, ARDY = 0). After ^tR (R/B# is HIGH and RDY = 1, ARDY = 1), issue either of these commands:

- READ PAGE CACHE SEQUENTIAL (31h) – copies the next sequential page from the NAND Flash array to the data register
- READ PAGE CACHE RANDOM (00h-31h) – copies the page specified in this command from the NAND Flash array to its corresponding data register

After the READ PAGE CACHE series (31h, 00h-31h) command has been issued, R/B# goes LOW on the target, and RDY = 0 and ARDY = 0 on the die (LUN) for ^tRCBSY while the next page begins copying data from the array to the data register. After ^tRCBSY,

R/B# goes HIGH and the die's (LUN's) status register bits indicate the device is busy with a cache operation (RDY = 1, ARDY = 0). The cache register becomes available and the page requested in the READ PAGE CACHE operation is transferred to the data register. At this point, data can be output from the cache register, beginning at column address 0. The RANDOM DATA READ (05h-E0h) command can be used to change the column address of the data output by the die (LUN).

After outputting the desired number of bytes from the cache register, either an additional READ PAGE CACHE series (31h, 00h-31h) operation can be started or the READ PAGE CACHE LAST (3Fh) command can be issued.

If the READ PAGE CACHE LAST (3Fh) command is issued, R/B# goes LOW on the target, and RDY = 0 and ARDY = 0 on the die (LUN) for ^tRCBSY while the data register is copied into the cache register. After ^tRCBSY, R/B# goes HIGH and RDY = 1 and

ARDY = 1, indicating that the cache register is available and that the die (LUN) is ready. Data can then be output from the cache register, beginning at column address 0. The RANDOM DATA READ (05h-E0h) command can be used to change the column address of the data being output.

For READ PAGE CACHE series (31h, 00h-31h, 3Fh), during the die (LUN) busy time, ^tRCBSY, when RDY = 0 and ARDY = 0, the only valid commands are status operations (70h, 78h) and RESET (FFh). When RDY = 1 and ARDY = 0, the only valid commands during READ PAGE CACHE series (31h, 00h-31h) operations are status operations (70h, 78h), READ MODE (00h), READ PAGE CACHE series (31h, 00h-31h), RANDOM DATA READ (05h-E0h), and RESET (FFh).



Two-Plane Read Operations

Two-plane read page operations improve data throughput by copying data from more than one plane simultaneously to the specified cache registers. This is done by prepending one or more READ PAGE TWO-PLANE (00h-00h-30h) commands in front of the READ PAGE (00h-30h) command.

When the die (LUN) is ready, the RANDOM DATA READ TWO-PLANE (06h-E0h) command determines which plane outputs data. During data output, the following commands can be used to read and modify the data in the cache registers: RANDOM DATA READ (05h-E0h) and RANDOM DATA INPUT (85h).

Two-Plane Read Cache Operations

Two-plane read cache operations can be used to output data from more than one cache register while concurrently copying one or more pages from the NAND Flash array to the data register. This is done by prepending READ PAGE TWO-PLANE (00h-00h-30h) commands in front of the PAGE READ CACHE RANDOM (00h-31h) command.

To begin a two-plane read page cache sequence, begin by issuing a READ PAGE TWO-PLANE operation using the READ PAGE TWO-PLANE (00h-00h-30h) and READ PAGE (00h-30h) commands. R/B# goes LOW during ^tR and the selected die (LUN) is busy (RDY = 0, ARDY = 0). After ^tR (R/B# is HIGH and RDY = 1, ARDY = 1), issue either of these commands:

- READ PAGE CACHE SEQUENTIAL (31h) – copies the next sequential pages from the previously addressed planes from the NAND Flash array to the data registers.
- READ PAGE TWO-PLANE (00h-00h-30h) [in some cases, followed by READ PAGE CACHE RANDOM (00h-31h)] – copies the pages specified from the NAND Flash array to the corresponding data registers.

After the READ PAGE CACHE series (31h, 00h-31h) command has been issued, R/B# goes LOW on the target, and RDY = 0 and ARDY = 0 on the die (LUN) for ^tRCBSY while the next pages begin copying data from the array to the data registers. After ^tRCBSY, R/B# goes HIGH and the LUN's status register bits indicate the device is busy with a cache operation (RDY = 1, ARDY = 0). The cache registers become available and the pages requested in the READ PAGE CACHE operation are transferred to the data registers. Issue the RANDOM DATA READ TWO-PLANE (06h-E0h) command to determine which cache register will output data. After data is output, the RANDOM DATA READ TWO-PLANE (06h-E0h) command can be used to output data from other cache registers. After a cache register has been selected, the RANDOM DATA READ (05h-E0h) command can be used to change the column address of the data output.

After outputting data from the cache registers, either an additional TWO-PLANE READ CACHE series (31h, 00h-31h) operation can be started or the READ PAGE CACHE LAST (3Fh) command can be issued.

If the READ PAGE CACHE LAST (3Fh) command is issued, R/B# goes LOW on the target, and RDY = 0 and ARDY = 0 on the die (LUN) for ^tRCBSY while the data registers are copied into the cache registers. After ^tRCBSY, R/B# goes HIGH and RDY = 1 and ARDY = 1, indicating that the cache registers are available and that the die (LUN) is ready. Issue the RANDOM DATA READ TWO-PLANE (06h-E0h) command to determine which cache register will output data. After data is output, the RANDOM DATA READ TWO-PLANE (06h-E0h) command can be used to output data from other cache registers. After a cache register has been selected, the RANDOM DATA READ (05h-E0h) command can be used to change the column address of the data output.

For READ PAGE CACHE series (31h, 00h-31h, 3Fh), during the die (LUN) busy time, ^tRCBSY, when RDY = 0 and ARDY = 0, the only valid commands are status operations (70h, 78h) and RESET (FFh). When RDY = 1 and ARDY = 0, the only valid commands during READ PAGE CACHE series (31h, 00h-31h)



operations are status operations (70h, 78h), READ MODE (00h), two-plane read cache series (31h, 00h-00h-30h, 00h-31h), RANDOM DATA READ (06h-E0h, 05h-E0h), and RESET (FFh).

READ MODE (00h)

The READ MODE (00h) command disables status output and enables data output for the last-selected die (LUN) and cache register after a READ operation (00h-30h, 00h-3Ah, 00h-35h) has been monitored with a status operation (70h, 78h). This command is accepted by the die (LUN) when it is ready (RDY = 1, ARDY = 1). It is also accepted by the die (LUN) during READ PAGE CACHE (31h, 00h-31h) operations (RDY = 1 and ARDY = 0).

In devices that have more than one die (LUN) per target, during and following interleaved die (multi-LUN) operations, the READ STATUS ENHANCED (78h) command must be used to select only one die (LUN) prior to issuing the READ MODE (00h) command. This prevents bus contention.

READ PAGE (00h-30h)

The READ PAGE (00h-30h) command copies a page from the NAND Flash array to its respective cache register and enables data output. This command is accepted by the die (LUN) when it is ready (RDY = 1, ARDY = 1).

To read a page from the NAND Flash array, write the 00h command to the command register, then write n address cycles to the address registers, and conclude with the 30h command. The selected die (LUN) will go busy (RDY = 0, ARDY = 0) for t_R as data is transferred.

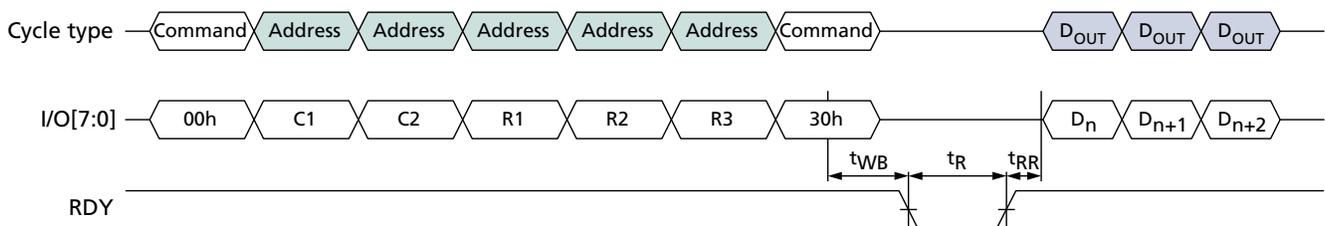
To determine the progress of the data transfer, the host can monitor the target's R/B# signal or, alternatively, the status operations (70h, 78h) can be used. If the status operations are used to monitor the LUN's status, when the die (LUN) is ready (RDY = 1, ARDY = 1), the host disables status output and enables data output by issuing the READ MODE (00h) command. When the host requests data output, output begins at the column address specified.

During data output the RANDOM DATA READ (05h-E0h) command can be issued.

In devices that have more than one die (LUN) per target, during and following interleaved die (multi-LUN) operations the READ STATUS ENHANCED (78h) command must be used to select only one die (LUN) prior to the issue of the READ MODE (00h) command. This prevents bus contention.

The READ PAGE (00h-30h) command is used as the final command of a two-plane read operation. It is preceded by one or more READ PAGE TWO-PLANE (00h-00h-30h) commands. Data is transferred from the NAND Flash array for all of the addressed planes to their respective cache registers. When the die (LUN) is ready (RDY = 1, ARDY = 1), data output is enabled for the cache register linked to the plane addressed in the READ PAGE (00h-30h) command. When the host requests data output, output begins at the column address last specified in the READ PAGE (00h-30h) command. The RANDOM DATA READ TWO-PLANE (06h-E0h) command is used to enable data output in the other cache registers.

Figure 37: READ PAGE (00h-30h) Operation





READ PAGE CACHE SEQUENTIAL (31h)

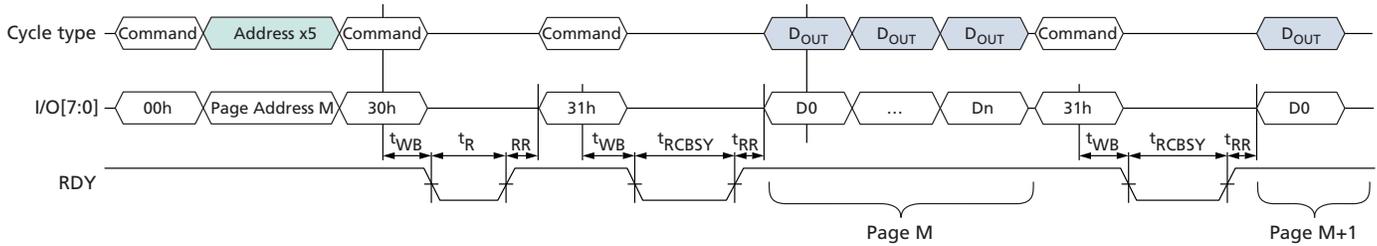
The READ PAGE CACHE SEQUENTIAL (31h) command reads the next sequential page within a block into the data register while the previous page is output from the cache register. This command is accepted by the die (LUN) when it is ready (RDY = 1, ARDY = 1). It is also accepted by the die (LUN) during READ PAGE CACHE (31h, 00h-31h) operations (RDY = 1 and ARDY = 0).

To issue this command, write 31h to the command register. After this command is issued, R/B# goes LOW and the die (LUN) is busy (RDY = 0, ARDY = 0) for t_{RCBSY} . After t_{RCBSY} , R/B# goes HIGH and the die (LUN) is busy with a cache operation (RDY = 1, ARDY = 0), indicating that the cache register is available and that the specified page is copying from the NAND Flash array to the data register. At this point, data can be output from the cache register beginning at column address 0. The RANDOM DATA READ (05h-E0h) command can be used to change the column address of the data being output from the cache register.

The READ PAGE CACHE SEQUENTIAL (31h) command can be used to cross block boundaries. If the READ PAGE CACHE SEQUENTIAL (31h) command is issued after the last page of a block is read into the data register, the next page read will be the next logical block in which the 31h command was issued. Do not issue the READ PAGE CACHE SEQUENTIAL (31h) to cross die (LUN) boundaries. Instead, issue the READ PAGE CACHE LAST (3Fh) command.



Figure 38: READ PAGE CACHE SEQUENTIAL (31h) Operation



READ PAGE CACHE RANDOM (00h-31h)

The READ PAGE CACHE RANDOM (00h-31h) command reads the specified block and page into the data register while the previous page is output from the cache register. This command is accepted by the die (LUN) when it is ready (RDY = 1, ARDY = 1). It is also accepted by the die (LUN) during READ PAGE CACHE (31h, 00h-31h) operations (RDY = 1 and ARDY = 0).

To issue this command, write 00h to the command register, then write *n* address cycles to the address register, and conclude by writing 31h to the command register. The column address in the address specified is ignored. The die (LUN) address must match the same die (LUN) address as the previous READ PAGE (00h-30h) command or, if applicable, the previous READ PAGE CACHE RANDOM (00h-31h) command.

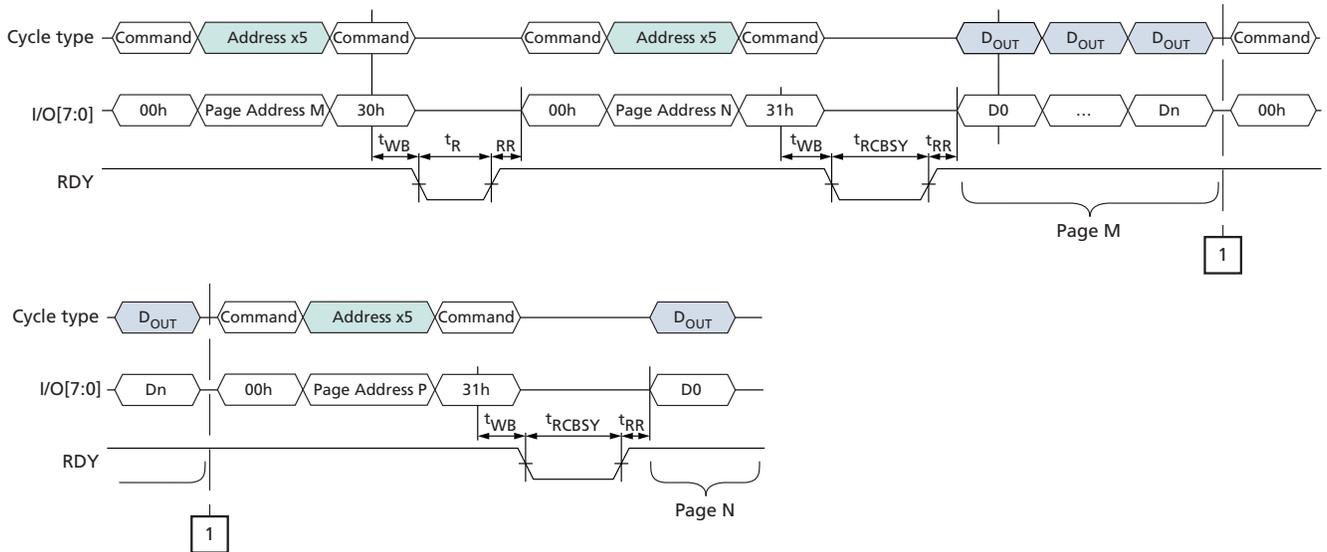
After this command is issued, R/B# goes LOW and the die (LUN) is busy (RDY = 0, ARDY = 0) for ^tRCBSY. After ^tRCBSY, R/B# goes HIGH and the die (LUN) is busy with a cache operation (RDY = 1, ARDY = 0), indicating that the cache register is available and that the specified page is copying from the NAND Flash array to the data register. At this point, data can be output from the cache register beginning at column address 0. The RANDOM DATA READ (05h-E0h) command can be used to change the column address of the data being output from the cache register.

In devices that have more than one die (LUN) per target, during and following interleaved die (multi-LUN) operations the READ STATUS ENHANCED (78h) command followed by the READ MODE (00h) command must be used to select only one die (LUN) and prevent bus contention.



1Gb x8, x16: NAND Flash Memory Read Operations

Figure 39: READ PAGE CACHE RANDOM (00h-31h) Operation





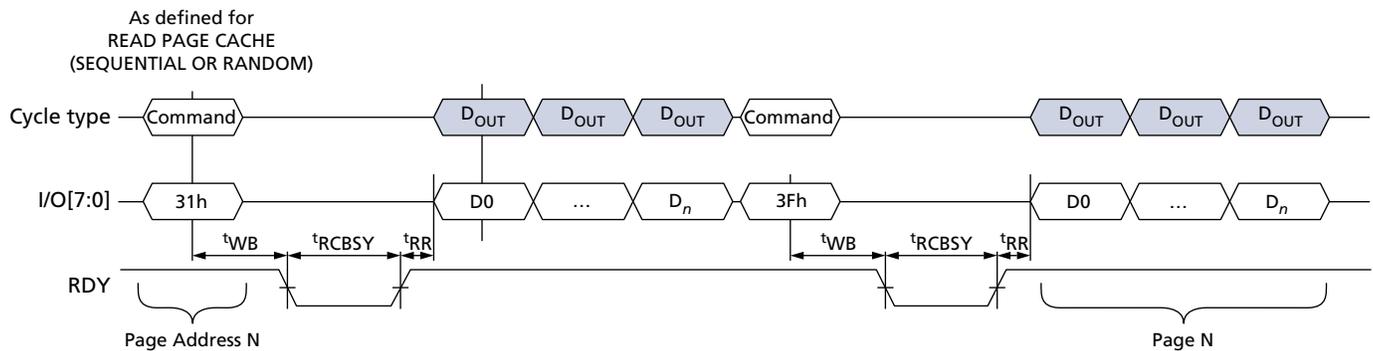
READ PAGE CACHE LAST (3Fh)

The READ PAGE CACHE LAST (3Fh) command ends the read page cache sequence and copies a page from the data register to the cache register. This command is accepted by the die (LUN) when it is ready (RDY = 1, ARDY = 1). It is also accepted by the die (LUN) during READ PAGE CACHE (31h, 00h-31h) operations (RDY = 1 and ARDY = 0).

To issue the READ PAGE CACHE LAST (3Fh) command, write 3Fh to the command register. After this command is issued, R/B# goes LOW and the die (LUN) is busy (RDY = 0, ARDY = 0) for t_{RCBSY} . After t_{RCBSY} , R/B# goes HIGH and the die (LUN) is ready (RDY = 1, ARDY = 1). At this point, data can be output from the cache register, beginning at column address 0. The RANDOM DATA READ (05h-E0h) command can be used to change the column address of the data being output from the cache register.

In devices that have more than one LUN per target, during and following interleaved die (multi-LUN) operations the READ STATUS ENHANCED (78h) command followed by the READ MODE (00h) command must be used to select only one die (LUN) and prevent bus contention.

Figure 40: READ PAGE CACHE LAST (3Fh) Operation





READ PAGE TWO-PLANE 00h-00h-30h

The READ PAGE TWO-PLANE (00h-00h-30h) operation is similar to the PAGE READ (00h-30h) operation. It transfers two pages of data from the NAND Flash array to the data registers. Each page must be from a different plane on the same die.

To enter the READ PAGE TWO-PLANE mode, write the 00h command to the command register, and then write five address cycles for plane 0 (BA6 = 0). Next, write the 00h command to the command register, and five address cycles for plane 1 (BA6 = 1). Finally, issue the 30h command. The first-plane and second-plane addresses must meet the two-plane addressing requirements, and, in addition, they must have identical column addresses.

After the 30h command is written, page data is transferred from both planes to their respective data registers in ^tR. During these transfers, R/B# goes LOW. When the transfers are complete, R/B# goes HIGH. To read out the data from the plane 0 data register, pulse RE# repeatedly. After the data cycle from the plane 0 address completes, issue a RANDOM DATA READ TWO-PLANE (06h-E0h) command to select the plane 1 address, then repeatedly pulse RE# to read out the data from the plane 1 data register.

Alternatively, the READ STATUS (70h) command can monitor data transfers. When the transfers are complete, status register bit 6 is set to 1. To read data from the first of the two planes, the user must first issue the RANDOM DATA READ TWO-PLANE (06h-E0h) command and pulse RE# repeatedly.

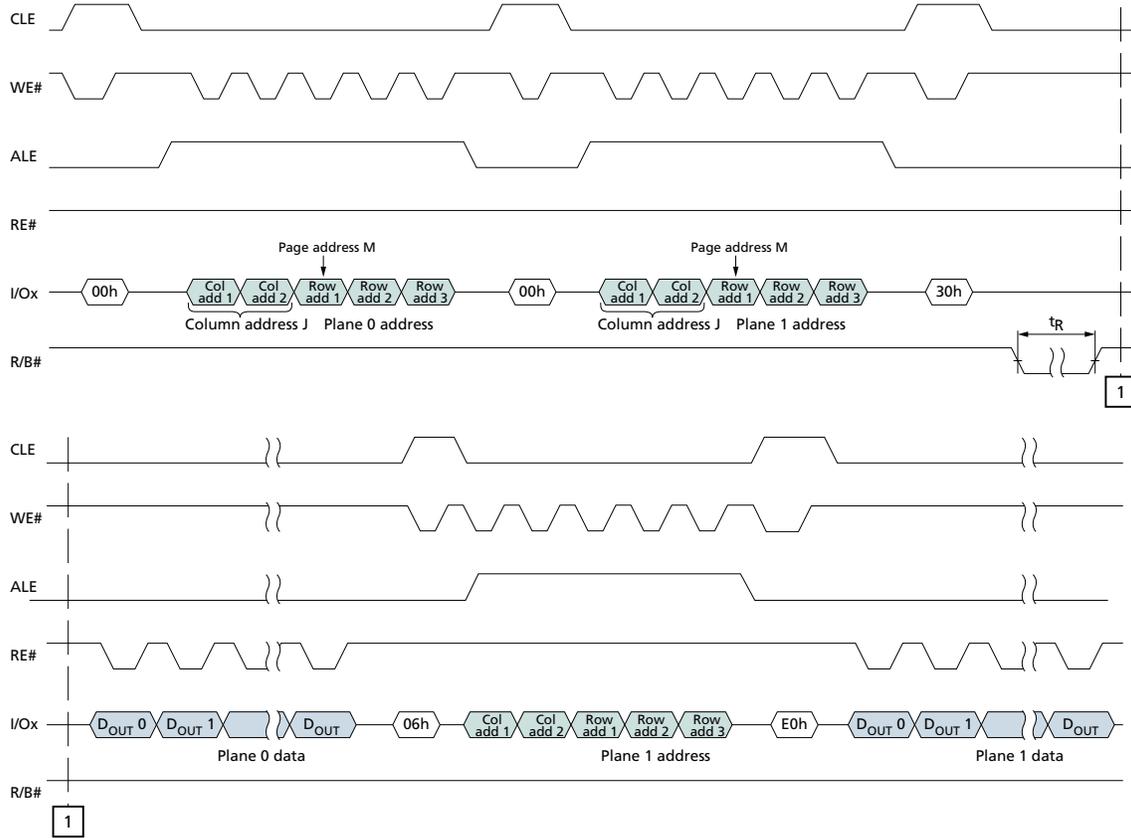
When the data cycle is complete, issue a RANDOM DATA READ TWO-PLANE (06h-E0h) command to select the other plane. To output the data beginning at the specified column address, pulse RE# repeatedly.

Use of the READ STATUS ENHANCED (78h) command is prohibited during and following a PAGE READ TWO-PLANE operation.



1Gb x8, x16: NAND Flash Memory Read Operations

Figure 41: READ PAGE TWO-PLANE (00h-00h-30h) Operation





Program Operations

Program operations are used to move data from the cache or data registers to the NAND array. During a program operation the contents of the cache and/or data registers are modified by the internal control logic.

Within a block, pages must be programmed sequentially from the least significant page address to the most significant page address (0, 1, 2,, 63). During a program operation, the contents of the cache and/or data registers are modified by the internal control logic.

Program Operations

The PROGRAM PAGE (80h-10h) command, when not preceded by the PROGRAM PAGE TWO-PLANE (80h-11h) command, programs one page from the cache register to the NAND Flash array. When the die (LUN) is ready (RDY = 1, ARDY = 1), the host should check the FAIL bit to verify that the operation has completed successfully.

Program Cache Operations

The PROGRAM PAGE CACHE (80h-15h) command can be used to improve program operation system performance. When this command is issued, the die (LUN) goes busy (RDY = 0, ARDY = 0) while the cache register contents are copied to the data register, and the die (LUN) is busy with a program cache operation (RDY = 1, ARDY = 0). While the contents of the data register are moved to the NAND Flash array, the cache register is available for an additional PROGRAM PAGE CACHE (80h-15h) or PROGRAM PAGE (80h-10h) command.

For PROGRAM PAGE CACHE series (80h-15h) operations, during the die (LUN) busy times, ^tCBSY and ^tLPROG, when RDY = 0 and ARDY = 0, the only valid commands are status operations (70h, 78h) and reset (FFh). When RDY = 1 and ARDY = 0, the only valid commands during PROGRAM PAGE CACHE series (80h-15h) operations are status operations (70h, 78h), PROGRAM PAGE CACHE (80h-15h), PROGRAM PAGE (80h-10h), RANDOM DATA INPUT (85h), PROGRAM FOR INTERNAL DATA INPUT (85h), and RESET (FFh).

Two-Plane Program Operations

The PROGRAM PAGE TWO-PLANE (80h-11h) command can be used to improve program operation system performance by enabling multiple pages to be moved from the cache registers to different planes of the NAND Flash array. This is done by prepending one or more PROGRAM PAGE TWO-PLANE (80h-11h) commands in front of the PROGRAM PAGE (80h-10h) command.

Two-Plane Program Cache Operations

The PROGRAM PAGE TWO-PLANE (80h-11h) command can be used to improve program cache operation system performance by enabling multiple pages to be moved from the cache registers to the data registers and, while the pages are being transferred from the data registers to different planes of the NAND Flash array, free the cache registers to receive data input from the host. This is done by prepending one or more PROGRAM PAGE TWO-PLANE (80h-11h) commands in front of the PROGRAM PAGE CACHE (80h-15h) command.

PROGRAM PAGE (80h-10h)

The PROGRAM PAGE (80h-10h) command enables the host to input data to a cache register, and moves the data from the cache register to the specified block and page address in the array of the selected die (LUN). This command is accepted by the die (LUN) when it is ready (RDY = 1, ARDY = 1). It is also accepted by the die (LUN) when it is busy with a PROGRAM PAGE CACHE (80h-15h) operation (RDY = 1, ARDY = 0).



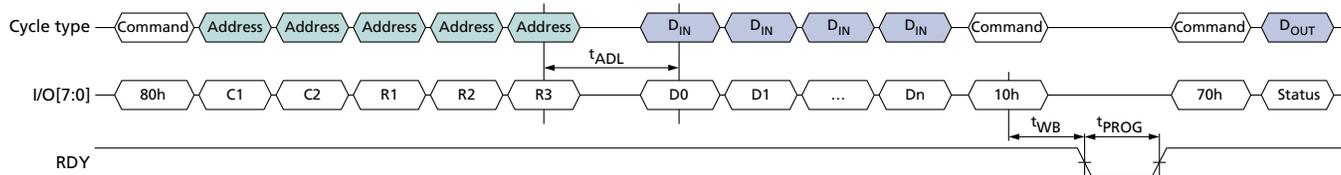
To input a page to the cache register and move it to the NAND array at the block and page address specified, write 80h to the command register. Unless this command has been preceded by a PROGRAM PAGE TWO-PLANE (80h-11h) command, issuing the 80h to the command register clears all of the cache registers' contents on the selected target. Then write n address cycles containing the column address and row address. Data input cycles follow. Serial data is input beginning at the column address specified. At any time during the data input cycle the RANDOM DATA INPUT (85h) and PROGRAM FOR INTERNAL DATA INPUT (85h) commands may be issued. When data input is complete, write 10h to the command register. The selected LUN will go busy (RDY = 0, ARDY = 0) for t_{PROG} as data is transferred.

To determine the progress of the data transfer, the host can monitor the target's R/B# signal or, alternatively, the status operations (70h, 78h) may be used. When the die (LUN) is ready (RDY = 1, ARDY = 1), the host should check the status of the FAIL bit.

In devices that have more than one die (LUN) per target, during and following interleaved die (multi-LUN) operations, the READ STATUS ENHANCED (78h) command must be used to select only one die (LUN) for status output. Use of the READ STATUS (70h) command could cause more than one die (LUN) to respond, resulting in bus contention.

The PROGRAM PAGE (80h-10h) command is used as the final command of a two-plane program operation. It is preceded by one or more PROGRAM PAGE TWO-PLANE (80h-11h) commands. Data is transferred from the cache registers for all of the addressed planes to the NAND array. The host should check the status of the operation by using the status operations (70h, 78h).

Figure 42: PROGRAM PAGE (80h-10h) Operation



PROGRAM PAGE CACHE (80h-15h)

The PROGRAM PAGE CACHE (80h-15h) command enables the host to input data to a cache register; copies the data from the cache register to the data register; then moves the data register contents to the specified block and page address in the array of the selected die (LUN). After the data is copied to the data register, the cache register is available for additional PROGRAM PAGE CACHE (80h-15h) or PROGRAM PAGE (80h-10h) commands. The PROGRAM PAGE CACHE (80h-15h) command is accepted by the die (LUN) when it is ready (RDY = 1, ARDY = 1). It is also accepted by the die (LUN) when busy with a PROGRAM PAGE CACHE (80h-15h) operation (RDY = 1, ARDY = 0).

To input a page to the cache register to move it to the NAND array at the block and page address specified, write 80h to the command register. Unless this command has been preceded by a PROGRAM PAGE TWO-PLANE (80h-11h) command, issuing the 80h to the command register clears all of the cache registers' contents on the selected target. Then write n address cycles containing the column address and row address. Data input cycles follow. Serial data is input beginning at the column address specified. At any time during the data input cycle the RANDOM DATA INPUT (85h) and PROGRAM FOR INTERNAL DATA INPUT (85h) commands may be issued. When data input is complete, write 15h to the command register. The selected LUN will go busy

(RDY = 0, ARDY = 0) for t_{CBSY} to allow the data register to become available from a previous program cache operation, to copy data from the cache register to the data register, and then to begin moving the data register contents to the specified page and block address.



1Gb x8, x16: NAND Flash Memory Program Operations

To determine the progress of ^tCBSY, the host can monitor the target's R/B# signal or, alternatively, the status operations (70h, 78h) can be used. When the LUN's status shows that it is busy with a PROGRAM CACHE operation (RDY = 1, ARDY = 0), the host should check the status of the FAILC bit to see if a previous cache operation was successful.

If, after ^tCBSY, the host wants to wait for the program cache operation to complete, without issuing the PROGRAM PAGE (80h-10h) command, the host should monitor ARDY until it is 1. The host should then check the status of the FAIL and FAILC bits.

In devices with more than one die (LUN) per target, during and following interleaved die (multi-LUN) operations, the READ STATUS ENHANCED (78h) command must be used to select only one die (LUN) for status output. Use of the READ STATUS (70h) command could cause more than one die (LUN) to respond, resulting in bus contention.

The PROGRAM PAGE CACHE (80h-15h) command is used as the final command of a two-plane program cache operation. It is preceded by one or more PROGRAM PAGE TWO-PLANE (80h-11h) commands. Data for all of the addressed planes is transferred from the cache registers to the corresponding data registers, then moved to the NAND Flash array. The host should check the status of the operation by using the status operations (70h, 78h).



1Gb x8, x16: NAND Flash Memory Program Operations

Figure 43: PROGRAM PAGE CACHE (80h–15h) Operation (Start)

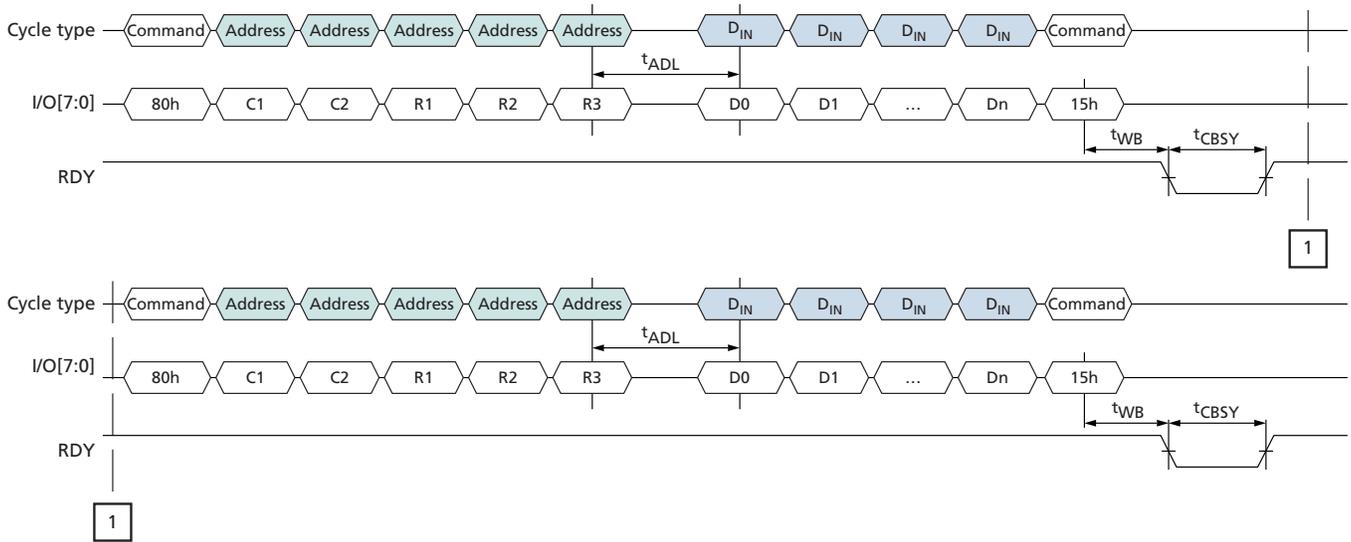
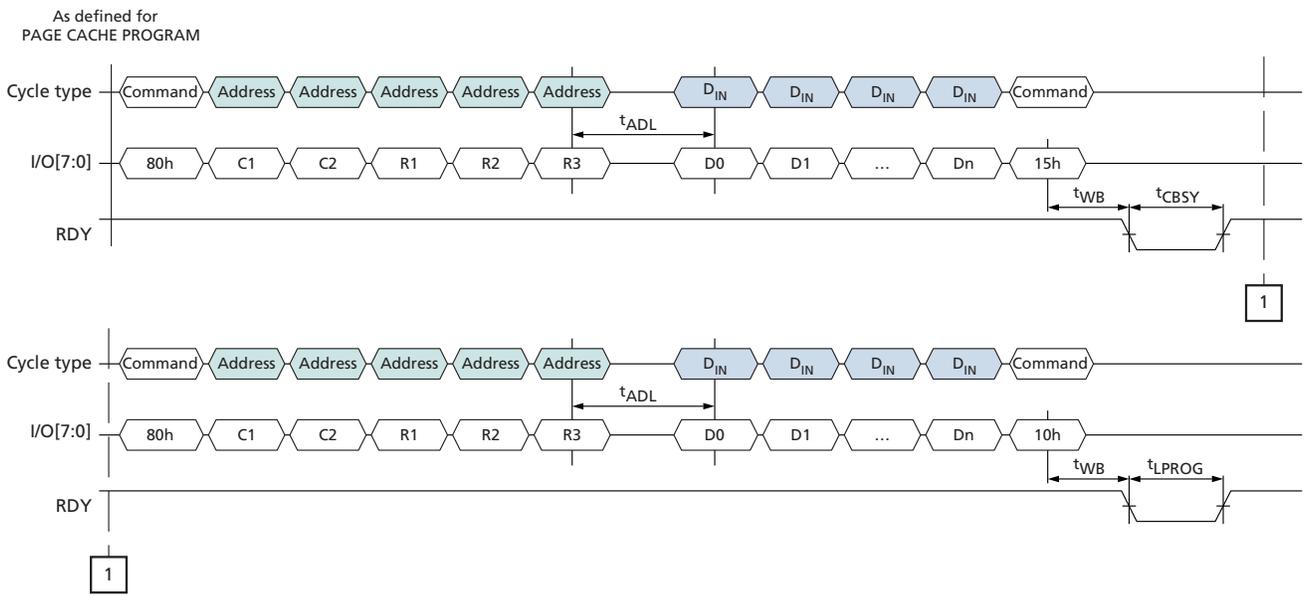


Figure 44: PROGRAM PAGE CACHE (80h–15h) Operation (End)





PROGRAM PAGE TWO-PLANE (80h-11h)

The PROGRAM PAGE TWO-PLANE (80h-11h) command enables the host to input data to the addressed plane's cache register and queue the cache register to ultimately be moved to the NAND Flash array. This command can be issued one or more times. Each time a new plane address is specified that plane is also queued for data transfer. To input data for the final plane and to begin the program operation for all previously queued planes, issue either the PROGRAM PAGE (80h-10h) command or the PROGRAM PAGE CACHE (80h-15h) command. All of the queued planes will move the data to the NAND Flash array. This command is accepted by the die (LUN) when it is ready (RDY = 1).

To input a page to the cache register and queue it to be moved to the NAND Flash array at the block and page address specified, write 80h to the command register. Unless this command has been preceded by a PROGRAM PAGE TWO-PLANE (80h-11h) command, issuing the 80h to the command register clears all of the cache registers' contents on the selected target. Write five address cycles containing the column address and row address; data input cycles follow. Serial data is input beginning at the column address specified. At any time during the data input cycle, the RANDOM DATA INPUT (85h) and PROGRAM FOR INTERNAL DATA INPUT (85h) commands can be issued. When data input is complete, write 11h to the command register. The selected die (LUN) will go busy (RDY = 0, ARDY = 0) for t_{DBSY} .

To determine the progress of t_{DBSY} , the host can monitor the target's R/B# signal or, alternatively, the status operations (70h, 78h) can be used. When the LUN's status shows that it is ready (RDY = 1), additional PROGRAM PAGE TWO-PLANE (80h-11h) commands can be issued to queue additional planes for data transfer. Alternatively, the PROGRAM PAGE (80h-10h) or PROGRAM PAGE CACHE (80h-15h) commands can be issued.

When the PROGRAM PAGE (80h-10h) command is used as the final command of a two-plane program operation, data is transferred from the cache registers to the NAND Flash array for all of the addressed planes during t_{PROG} . When the die (LUN) is ready (RDY = 1, ARDY = 1), the host should check the status of the FAIL bit for each of the planes to verify that programming completed successfully.

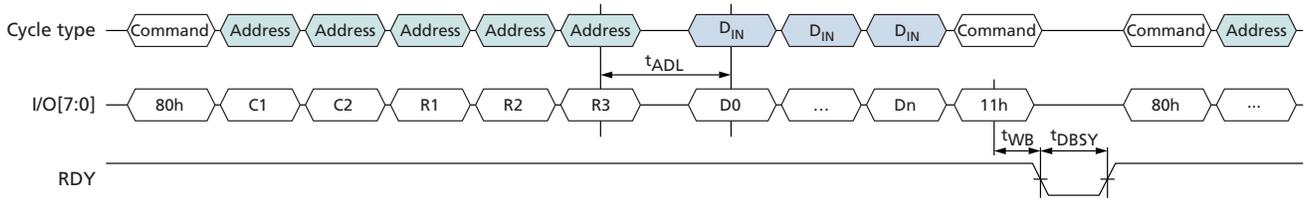
When the PROGRAM PAGE CACHE (80h-15h) command is used as the final command of a program cache two-plane operation, data is transferred from the cache registers to the data registers after the previous array operations finish. The data is then moved from the data registers to the NAND Flash array for all of the addressed planes. This occurs during t_{CBSY} . After t_{CBSY} , the host should check the status of the FAILC bit for each of the planes from the previous program cache operation, if any, to verify that programming completed successfully.

For the PROGRAM PAGE TWO-PLANE (80h-11h), PROGRAM PAGE (80h-10h), and PROGRAM PAGE CACHE (80h-15h) commands, see Two-Plane Operations for two-plane addressing requirements.



1Gb x8, x16: NAND Flash Memory Program Operations

Figure 45: PROGRAM PAGE TWO-PLANE (80h–11h) Operation





Erase Operations

Erase operations are used to clear the contents of a block in the NAND Flash array to prepare its pages for program operations.

Erase Operations

The ERASE BLOCK (60h-D0h) command, when not preceded by the ERASE BLOCK TWO-PLANE (60h-D1h) command, erases one block in the NAND Flash array. When the die (LUN) is ready (RDY = 1, ARDY = 1), the host should check the FAIL bit to verify that this operation completed successfully.

TWO-PLANE ERASE Operations

The ERASE BLOCK TWO-PLANE (60h-D1h) command can be used to further system performance of erase operations by allowing more than one block to be erased in the NAND array. This is done by prepending one or more ERASE BLOCK TWO-PLANE (60h-D1h) commands in front of the ERASE BLOCK (60h-D0h) command. See Two-Plane Operations for details.

ERASE BLOCK (60h-D0h)

The ERASE BLOCK (60h-D0h) command erases the specified block in the NAND Flash array. This command is accepted by the die (LUN) when it is ready (RDY = 1, ARDY = 1).

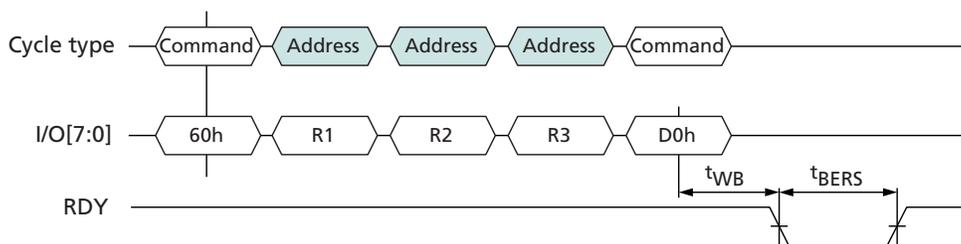
To erase a block, write 60h to the command register. Then write three address cycles containing the row address; the page address is ignored. Conclude by writing D0h to the command register. The selected die (LUN) will go busy (RDY = 0, ARDY = 0) for t_{BERS} while the block is erased.

To determine the progress of an ERASE operation, the host can monitor the target's R/B# signal, or alternatively, the status operations (70h, 78h) can be used. When the die (LUN) is ready (RDY = 1, ARDY = 1) the host should check the status of the FAIL bit.

In devices that have more than one die (LUN) per target, during and following interleaved die (multi-LUN) operations, the READ STATUS ENHANCED (78h) command must be used to select only one die (LUN) for status output. Use of the READ STATUS (70h) command could cause more than one die (LUN) to respond, resulting in bus contention.

The ERASE BLOCK (60h-D0h) command is used as the final command of an erase two-plane operation. It is preceded by one or more ERASE BLOCK TWO-PLANE (60h-D1h) commands. All blocks in the addressed planes are erased. The host should check the status of the operation by using the status operations (70h, 78h). See Two-Plane Operations for two-plane addressing requirements.

Figure 46: ERASE BLOCK (60h-D0h) Operation



ERASE BLOCK TWO-PLANE (60h-D1h)

The ERASE BLOCK TWO-PLANE (60h-D1h) command queues a block in the specified plane to be erased in the NAND Flash array. This command can be issued one or more times. Each time a new plane address is specified, that plane is also queued for a block to be erased. To specify the final block to be erased and to begin the ERASE operation for all previously queued planes, issue the ERASE



1Gb x8, x16: NAND Flash Memory Erase Operations

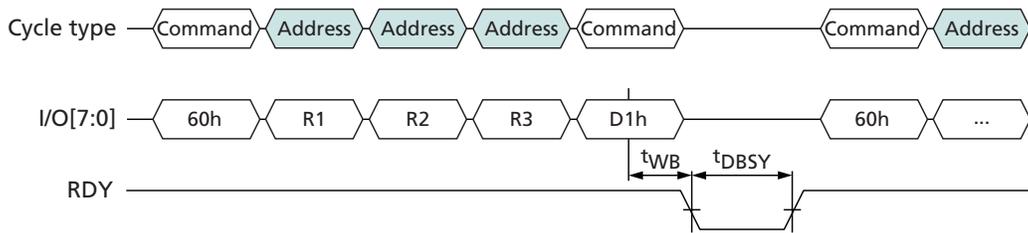
BLOCK (60h-D0h) command. This command is accepted by the die (LUN) when it is ready (RDY = 1, ARDY = 1).

To queue a block to be erased, write 60h to the command register, then write three address cycles containing the row address; the page address is ignored. Conclude by writing D1h to the command register. The selected die (LUN) will go busy (RDY = 0, ARDY = 0) for t_{DBSY} .

To determine the progress of t_{DBSY} , the host can monitor the target's R/B# signal, or alternatively, the status operations (70h, 78h) can be used. When the LUN's status shows that it is ready (RDY = 1, ARDY = 1), additional ERASE BLOCK TWO-PLANE (60h-D1h) commands can be issued to queue additional planes for erase. Alternatively, the ERASE BLOCK (60h-D0h) command can be issued to erase all of the queued blocks.

For two-plane addressing requirements for the ERASE BLOCK TWO-PLANE (60h-D1h) and ERASE BLOCK (60h-D0h) commands, see Two-Plane Operations.

Figure 47: ERASE BLOCK TWO-PLANE (60h-D1h) Operation





Internal Data Move Operations

Internal data move operations make it possible to transfer data within a device from one page to another using the cache register. This is particularly useful for block management and wear leveling. The INTERNAL DATA MOVE operation is restricted to only within even blocks or only within odd blocks.

The INTERNAL DATA MOVE operation is a two-step process consisting of a READ FOR INTERNAL DATA MOVE (00h-35h) and a PROGRAM FOR INTERNAL DATA MOVE (85h-10h) command. To move data from one page to another, first issue the READ FOR INTERNAL DATA MOVE (00h-35h) command. When the die (LUN) is ready (RDY = 1, ARDY = 1), the host can transfer the data to a new page by issuing the PROGRAM FOR INTERNAL DATA MOVE (85h-10h) command. When the die (LUN) is again ready (RDY = 1, ARDY = 1), the host should check the FAIL bit to verify that this operation completed successfully.

To prevent bit errors from accumulating over multiple INTERNAL DATA MOVE operations, it is recommended that the host read the data out of the cache register after the READ FOR INTERNAL DATA MOVE (00h-35h) completes and prior to issuing the PROGRAM FOR INTERNAL DATA MOVE (85h-10h) command. The RANDOM DATA READ (05h-E0h) command can be used to change the column address. The host should check the data for ECC errors and correct them. When the PROGRAM FOR INTERNAL DATA MOVE (85h-10h) command is issued, any corrected data can be input. The PROGRAM FOR INTERNAL DATA INPUT (85h) command can be used to change the column address.

Between the READ FOR INTERNAL DATA MOVE (00h-35h) and PROGRAM FOR INTERNAL DATA MOVE (85h-10h) commands, the following commands are supported: status operation (70h) and column address operations (05h-E0h, 85h). The RESET operation (FFh) can be issued after READ FOR INTERNAL DATA MOVE (00h-35h), but the contents of the cache registers on the target are not valid.

READ FOR INTERNAL DATA MOVE (00h-35h)

The READ FOR INTERNAL DATA MOVE (00h-35h) command is functionally identical to the READ PAGE (00h-30h) command, except that 35h is written to the command register instead of 30h.

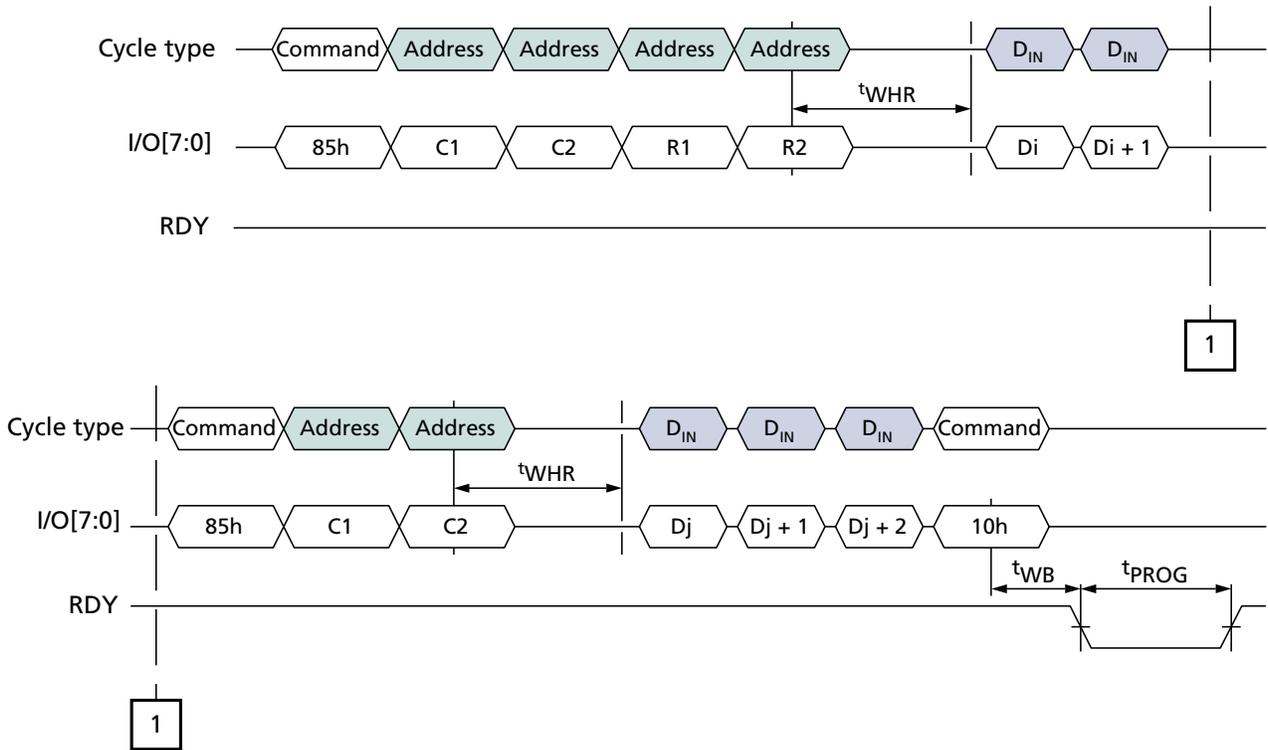
It is recommended that the host read the data out of the device to verify the data prior to issuing the PROGRAM FOR INTERNAL DATA MOVE (85h-10h) command to prevent the propagation of data errors.



**1Gb x8, x16: NAND Flash Memory
Internal Data Move Operations**

Figure 48: READ FOR INTERNAL DATA MOVE (00h-35h) Operation

Figure 49: READ FOR INTERNAL DATA MOVE (00h-35h) with RANDOM DATA READ (05h-E0h)





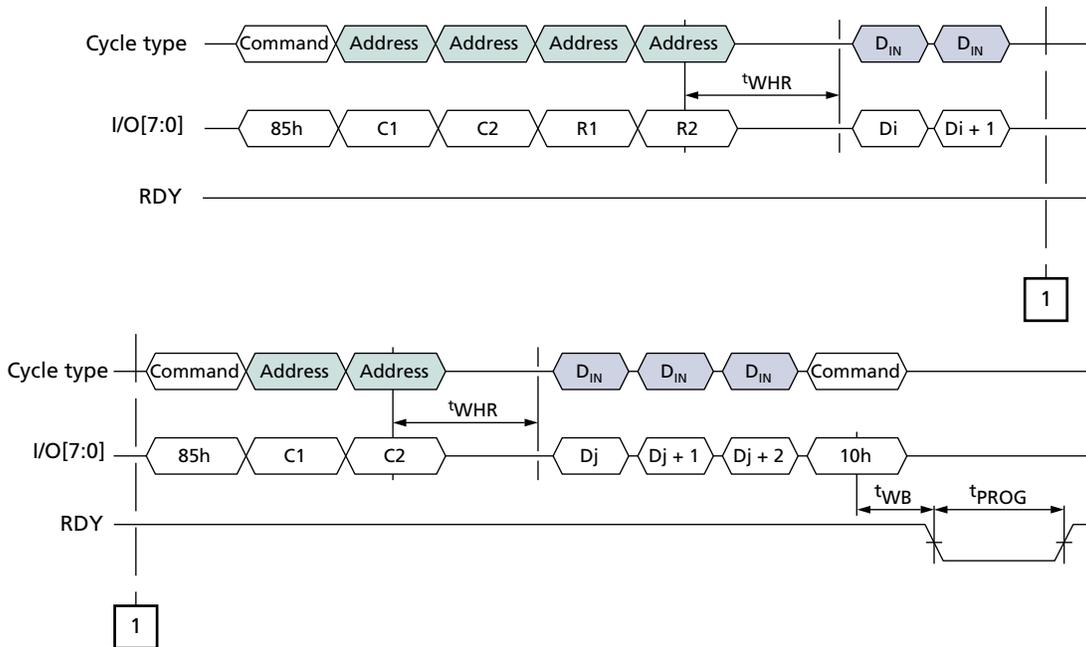
PROGRAM FOR INTERNAL DATA MOVE (85h-10h)

The PROGRAM FOR INTERNAL DATA MOVE (85h-10h) command is functionally identical to the PROGRAM PAGE (80h-10h) command, except that when 85h is written to the command register, cache register contents are not cleared.

Figure 50: PROGRAM FOR INTERNAL DATA MOVE (85h-10h)



Figure 51: PROGRAM FOR INTERNAL DATA MOVE (85h-10h) with RANDOM DATA INPUT (85h)





Block Lock Feature

The block lock feature protects either the entire device or ranges of blocks from being programmed and erased. Using the block lock feature is preferable to using WP# to prevent PROGRAM and ERASE operations.

Block lock is enabled and disabled at power-on through the LOCK pin. At power-on, if LOCK is LOW, all BLOCK LOCK commands are disabled. However if LOCK is HIGH at power-on, the BLOCK LOCK commands are enabled and, by default, all the blocks on the device are protected, or locked, from PROGRAM and ERASE operations, even if WP# is HIGH.

Before the contents of the device can be modified, the device must first be unlocked. Either a range of blocks or the entire device may be unlocked. PROGRAM and ERASE operations complete successfully only in the block ranges that have been unlocked. Blocks, once unlocked, can be locked again to protect them from further PROGRAM and ERASE operations.

Blocks that are locked can be protected further, or locked tight. When locked tight, the device's blocks can no longer be locked or unlocked.

WP# and Block Lock

The following is true when the block lock feature is enabled:

- Holding WP# LOW locks all blocks, provided the blocks are not locked tight.
- If WP# is held LOW to lock blocks, then returned to HIGH, a new UNLOCK command must be issued to unlock blocks.

UNLOCK (23h-24h)

By default at power-on, if LOCK is HIGH, all the blocks are locked and protected from PROGRAM and ERASE operations. The UNLOCK (23h) command is used to unlock a range of blocks. Unlocked blocks have no protection and can be programmed or erased.

The UNLOCK command uses two registers, a lower boundary block address register and an upper boundary block address register, and the invert area bit to determine what range of blocks are unlocked. When the invert area bit = 0, the range of blocks within the lower and upper boundary address registers are unlocked. When the invert area bit = 1, the range of blocks outside the boundaries of the lower and upper boundary address registers are unlocked. The lower boundary block address must be less than the upper boundary block address. The figures below show examples of how the lower and upper boundary address registers work with the invert area bit.

To unlock a range of blocks, issue the UNLOCK (23h) command followed by the appropriate address cycles that indicate the lower boundary block address. Then issue the 24h command followed by the appropriate address cycles that indicate the upper boundary block address. The least significant page address bit, PA0, should be set to 1 if setting the invert area bit; otherwise, it should be 0. The other page address bits should be 0.

Only one range of blocks can be specified in the lower and upper boundary block address registers. If after unlocking a range of blocks the UNLOCK command is again issued, the new block address range determines which blocks are unlocked. The previous unlocked block address range is not retained.



**1Gb x8, x16: NAND Flash Memory
Block Lock Feature**

Figure 52: Flash Array Protected: Invert Area Bit = 0

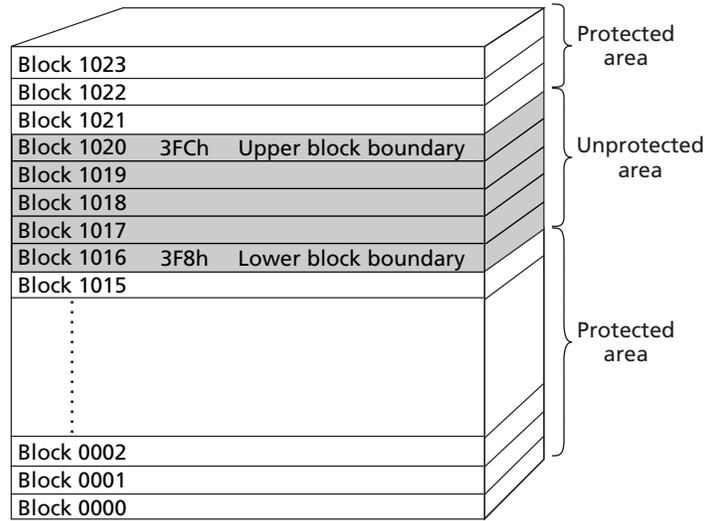


Figure 53: Flash Array Protected: Invert Area Bit = 1

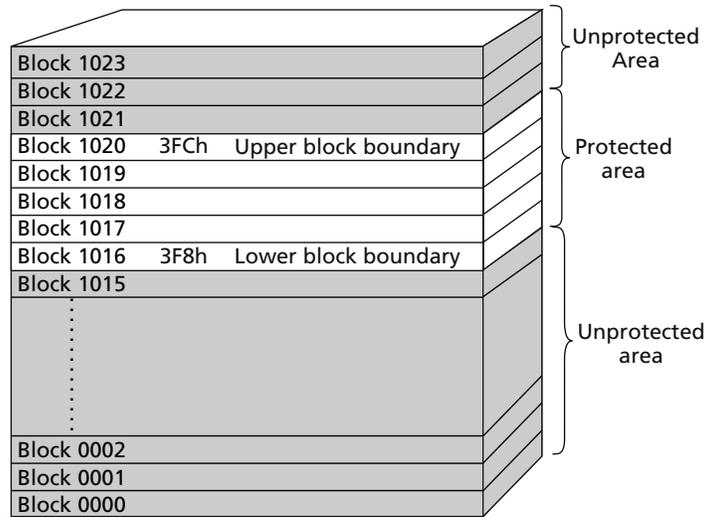




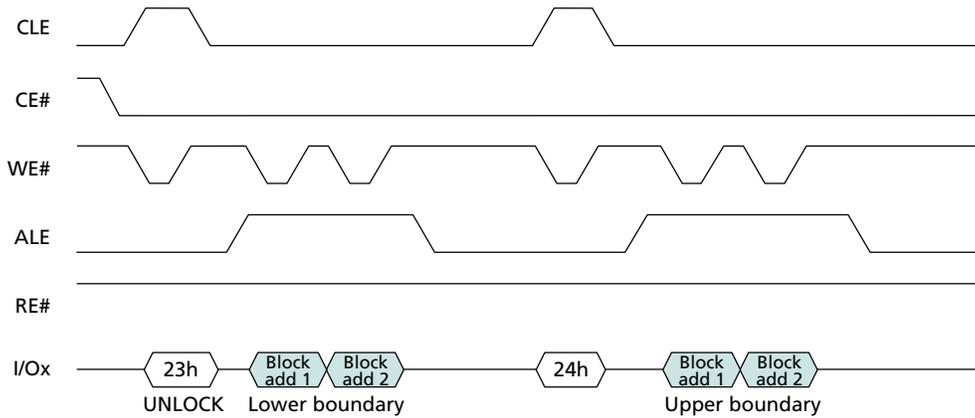
Table 16: Block Lock Address Cycle Assignments

ALE Cycle	I/O[15:8] ¹	I/O7	I/O6	I/O5	I/O4	I/O3	I/O2	I/O1	I/O0
First	LOW	BA7	BA6	LOW	LOW	LOW	LOW	LOW	Invert area bit ²
Second	LOW	BA15	BA14	BA13	BA12	BA11	BA10	BA9	BA8

Notes: 1. I/O[15:8] is applicable only for x16 devices.

2. Invert area bit is applicable for 24h command; it may be LOW or HIGH for 23h command.

Figure 54: UNLOCK Operation





LOCK (2Ah)

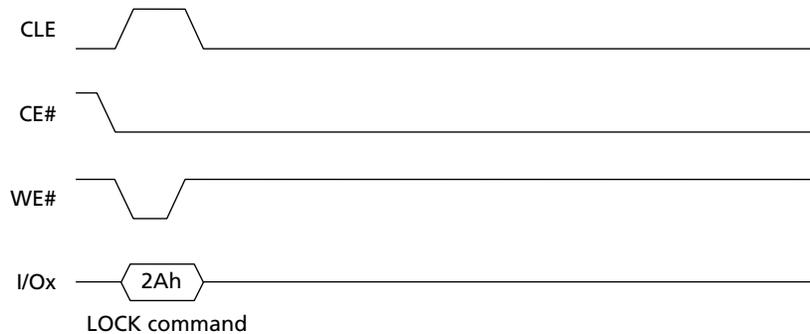
By default at power-on, if LOCK is HIGH, all the blocks are locked and protected from PROGRAM and ERASE operations. If portions of the device are unlocked using the UNLOCK (23h) command, they can be locked again using the LOCK (2Ah) command. The LOCK command locks all of the blocks in the device. Locked blocks are write-protected from PROGRAM and ERASE operations.

To lock all of the blocks in the device, issue the LOCK (2Ah) command.

When a PROGRAM or ERASE operation is issued to a locked block, R/B# goes LOW for t_{LBSY} . The PROGRAM or ERASE operation does not complete. Any READ STATUS command reports bit 7 as 0, indicating that the block is protected.

The LOCK (2Ah) command is disabled if LOCK is LOW at power-on or if the device is locked tight.

Figure 55: LOCK Operation





LOCK TIGHT (2Ch)

The LOCK TIGHT (2Ch) command prevents locked blocks from being unlocked and also prevents unlocked blocks from being locked. When this command is issued, the UNLOCK (23h) and LOCK (2Ah) commands are disabled. This provides an additional level of protection against inadvertent PROGRAM and ERASE operations to locked blocks.

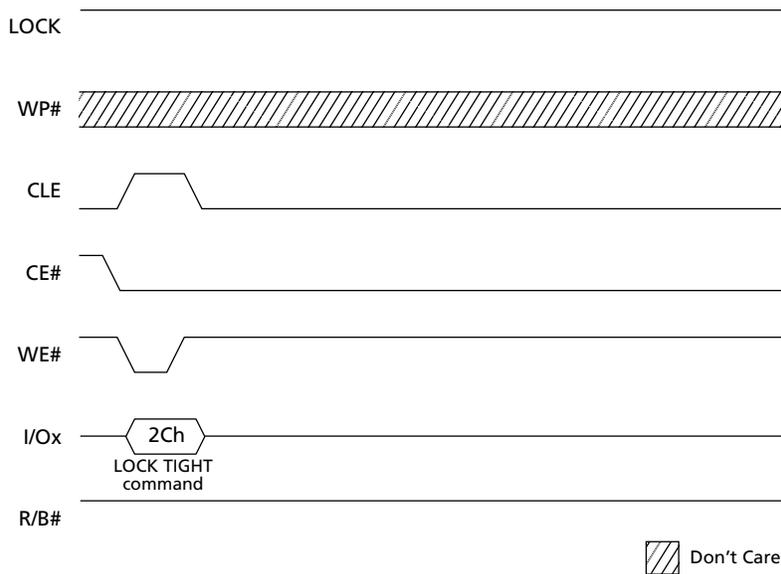
To implement LOCK TIGHT in all of the locked blocks in the device, verify that WP# is HIGH and then issue the LOCK TIGHT (2Ch) command.

When a PROGRAM or ERASE operation is issued to a locked block that has also been locked tight, R/B# goes LOW for ^tLBSY. The PROGRAM or ERASE operation does not complete. The READ STATUS (70h) command reports bit 7 as 0, indicating that the block is protected. PROGRAM and ERASE operations complete successfully to blocks that were not locked at the time the LOCK TIGHT command was issued.

After the LOCK TIGHT command is issued, the command cannot be disabled via a software command. Lock tight status can be disabled only by power cycling the device or toggling WP#. When the lock tight status is disabled, all of the blocks become locked, the same as if the LOCK (2Ah) command had been issued.

The LOCK TIGHT (2Ch) command is disabled if LOCK is LOW at power-on.

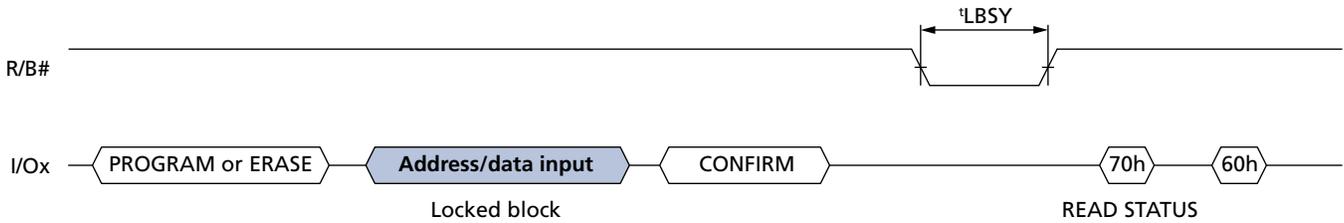
Figure 56: LOCK TIGHT Operation





**1Gb x8, x16: NAND Flash Memory
Block Lock Feature**

Figure 57: PROGRAM/ERASE Issued to Locked Block



BLOCK LOCK READ STATUS (7Ah)

The BLOCK LOCK READ STATUS (7Ah) command is used to determine the protection status of individual blocks. The address cycles have the same format, as shown below, and the invert area bit should be set LOW. On the falling edge of RE# the I/O pins output the block lock status register, which contains the information on the protection status of the block.

Table 17: Block Lock Status Register Bit Definitions

Block Lock Status Register Definitions	I/O[7:3]	I/O2 (Lock#)	I/O1 (LT#)	I/O0 (LT)
Block is locked tight	X	0	0	1
Block is locked	X	0	1	0
Block is unlocked, and device is locked tight	X	1	0	1
Block is unlocked, and device is not locked tight	X	1	1	0

Figure 58: BLOCK LOCK READ STATUS

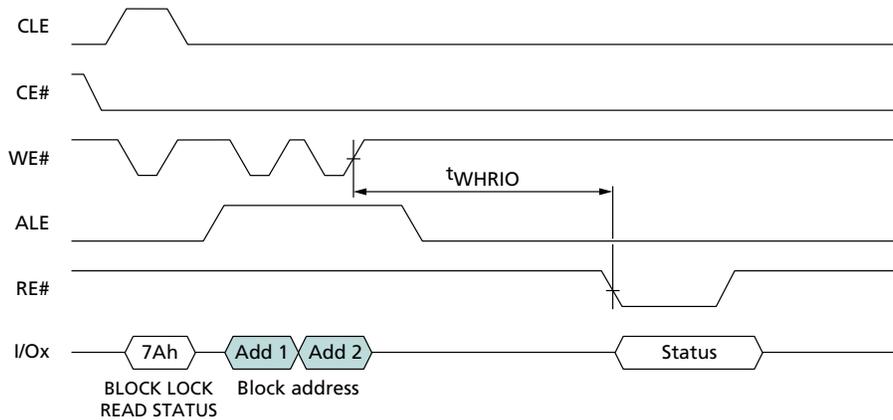
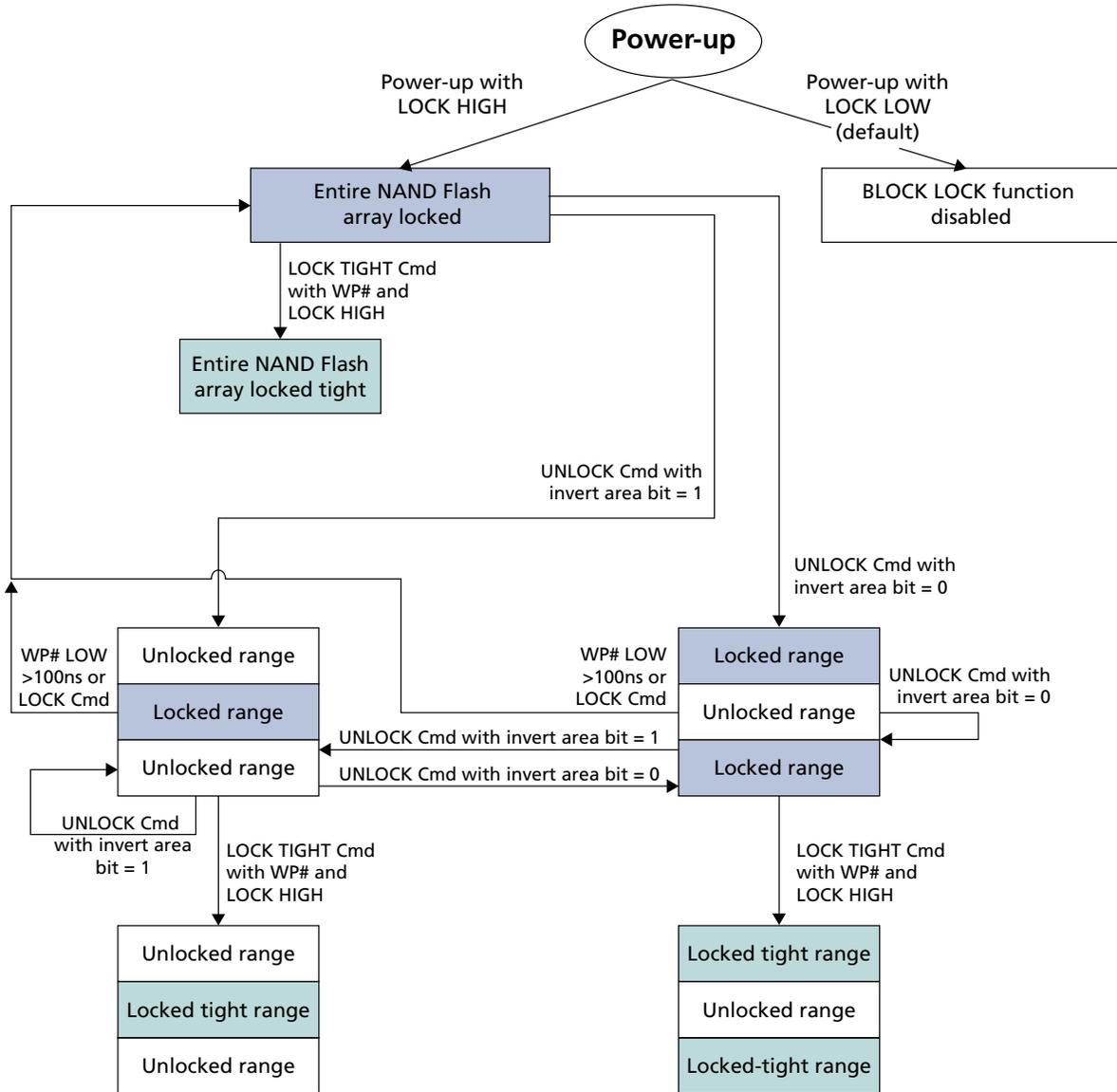




Figure 59: BLOCK LOCK Flowchart





One-Time Programmable (OTP) Operations

This Micron NAND Flash device offers a protected, one-time programmable NAND Flash memory area. Thirty full pages (2112 bytes per page) of OTP data are available on the device, and the entire range is guaranteed to be good. The OTP area is accessible only through the OTP commands. Customers can use the OTP area any way they choose; typical uses include programming serial numbers or other data for permanent storage.

The OTP area leaves the factory in an unwritten state (all bits are 1s). Programming or partial-page programming enables the user to program only 0 bits in the OTP area. The OTP area cannot be erased, whether it is protected or not. Protecting the OTP area prevents further programming of that area.

Micron provides a unique way to program and verify data before permanently protecting it and preventing future changes. The OTP area is only accessible while in OTP operation mode. To set the device to OTP operation mode, issue the SET FEATURE (EFh) command to feature address 90h and write 01h to P1, followed by three cycles of 00h to P2-P4. For parameters to enter OTP mode, see Features Operations.

When the device is in OTP operation mode, all subsequent PAGE READ (00h-30h) and PROGRAM PAGE (80h-10h) commands are applied to the OTP area. The OTP area is assigned to page addresses 02h-1Fh. To program an OTP page, issue the PROGRAM PAGE (80h-10h) command. The pages must be programmed in the ascending order. Similarly, to read an OTP page, issue the PAGE READ (00h-30h) command.

Protecting the OTP is done by entering OTP protect mode. To set the device to OTP protect mode, issue the SET FEATURE (EFh) command to feature address 90h and write 03h to P1, followed by three cycles of 00h to P2-P4.

To determine whether the device is busy during an OTP operation, either monitor R/B# or use the READ STATUS (70h) command.

To exit OTP operation or protect mode, write 00h to P1 at feature address 90h.

**OTP DATA PROGRAM (80h-10h)**

The OTP DATA PROGRAM (80h-10h) command is used to write data to the pages within the OTP area. An entire page can be programmed at one time, or a page can be partially programmed up to eight times. Only the OTP area allows up to eight partial-page programs. The rest of the blocks support only four partial-page programs. There is no ERASE operation for OTP pages.

PROGRAM PAGE enables programming into an offset of an OTP page using two bytes of the column address (CA[12:0]). The command is compatible with the RANDOM DATA INPUT (85h) command. The PROGRAM PAGE command will not execute if the OTP area has been protected.

To use the PROGRAM PAGE command, issue the 80h command. Issue n address cycles. The first two address cycles are the column address. For the remaining cycles, select a page in the range of 02h-00h through 1Fh-00h. Next, write from 1–2112 bytes of data. After data input is complete, issue the 10h command. The internal control logic automatically executes the proper programming algorithm and controls the necessary timing for programming and verification.

R/B# goes LOW for the duration of the array programming time (t^{PROG}). The READ STATUS (70h) command is the only valid command for reading status in OTP operation mode. Bit 5 of the status register reflects the state of R/B#. When the device is ready, read bit 0 of the status register to determine whether the operation passed or failed (see Status Operations). Each OTP page can be programmed to 8 partial-page programming.

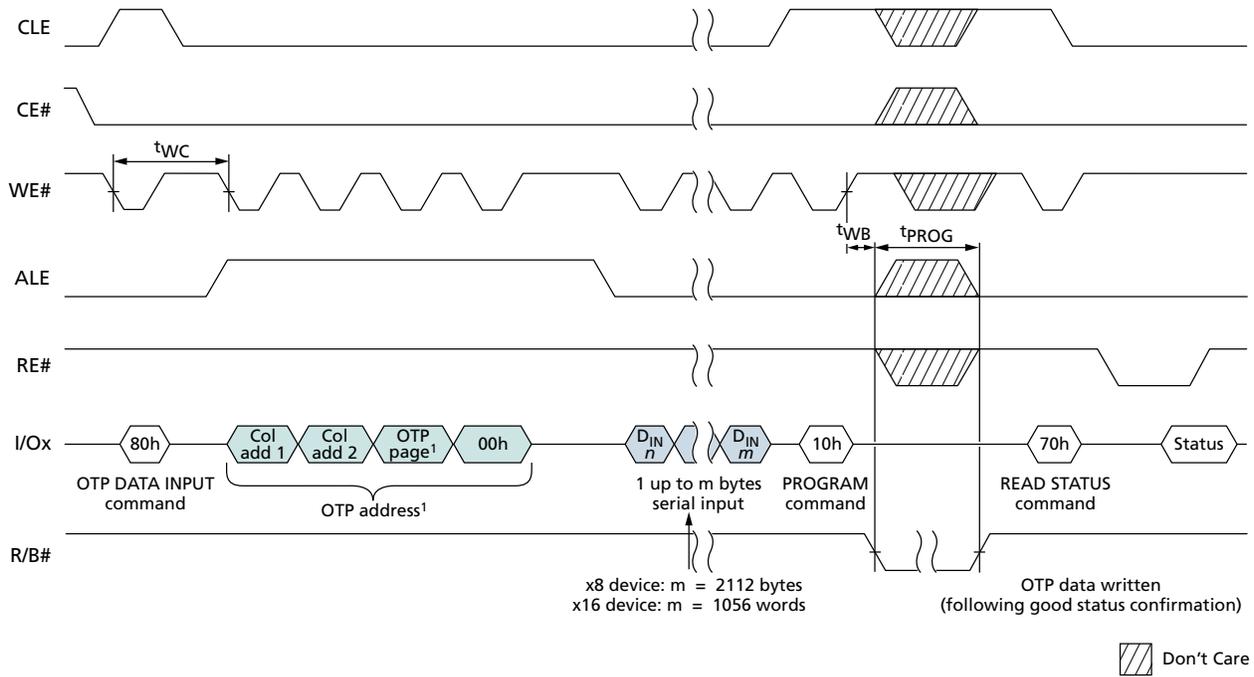


1Gb x8, x16: NAND Flash Memory One-Time Programmable (OTP) Operations

RANDOM DATA INPUT (85h)

After the initial OTP data set is input, additional data can be written to a new column address with the RANDOM DATA INPUT (85h) command. The RANDOM DATA INPUT command can be used any number of times in the same page prior to the OTP PAGE WRITE (10h) command being issued.

Figure 60: OTP DATA PROGRAM (After Entering OTP Operation Mode)

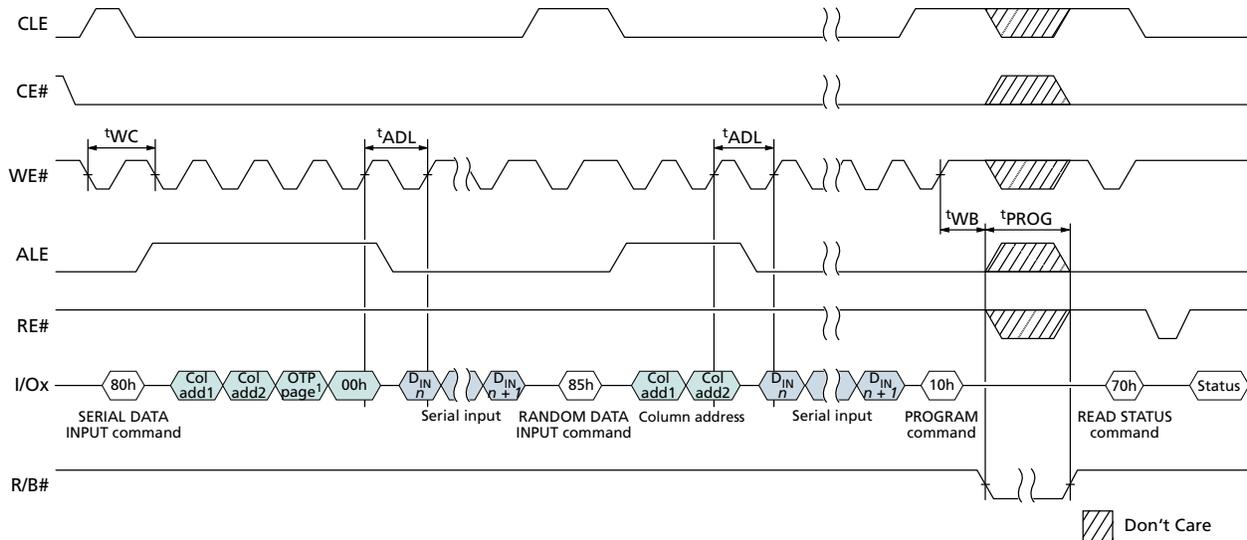


Note: 1. The OTP page must be within the 02h–1Fh range.



1Gb x8, x16: NAND Flash Memory One-Time Programmable (OTP) Operations

Figure 61: OTP DATA PROGRAM Operation with RANDOM DATA INPUT (After Entering OTP Operation Mode)



Note: 1. The OTP page must be within the 02h–1Fh range.

OTP DATA PROTECT (80h-10)

The OTP DATA PROTECT (80h-10h) command is used to prevent further programming of the pages in the OTP area. To protect the OTP area, the target must be in OTP operation mode.

To protect all data in the OTP area, issue the 80h command. Issue n address cycles including the column address, OTP protect page address and block address; the column and block addresses are fixed to 0. Next, write 00h data for the first byte location and issue the 10h command. R/B# goes LOW for the duration of the array programming time, t_{PROG} .

After the data is protected, it cannot be programmed further. When the OTP area is protected, the pages within the area are no longer programmable and cannot be unprotected.

The READ STATUS (70h) command is the only valid command for reading status in OTP operation mode. The RDY bit of the status register will reflect the state of R/B#. Use of the READ STATUS ENHANCED (78h) command is prohibited.

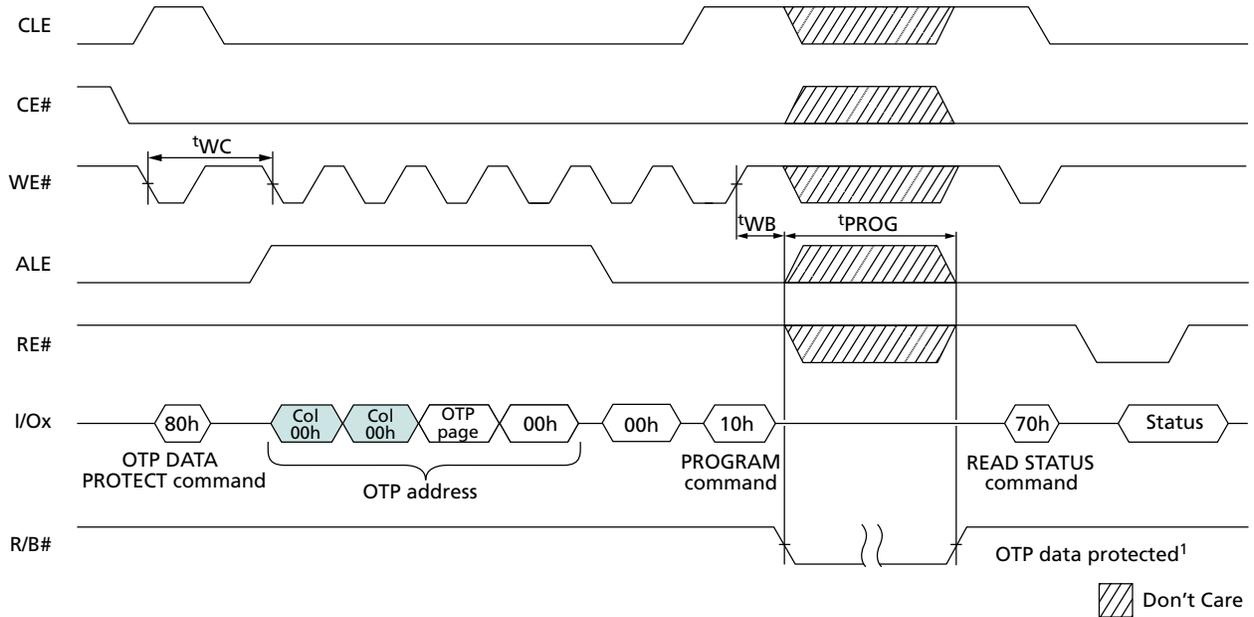
When the target is ready, read the FAIL bit of the status register to determine if the operation passed or failed.

If the OTP DATA PROTECT (80h-10h) command is issued after the OTP area has already been protected, R/B# goes LOW for t_{OBSY} . After t_{OBSY} , the status register is set to 60h.



1Gb x8, x16: NAND Flash Memory One-Time Programmable (OTP) Operations

Figure 62: OTP DATA PROTECT Operation (After Entering OTP Protect Mode)



Note: 1. OTP data is protected following a good status confirmation.



1Gb x8, x16: NAND Flash Memory One-Time Programmable (OTP) Operations

OTP DATA READ (00h-30h)

To read data from the OTP area, set the device to OTP operation mode, then issue the PAGE READ (00h-30h) command. Data can be read from OTP pages within the OTP area whether the area is protected or not.

To use the PAGE READ command for reading data from the OTP area, issue the 00h command, and then issue five address cycles: for the first two cycles, the column address; and for the remaining address cycles, select a page in the range of 02h-00h-00h through 1Fh-00h-00h. Lastly, issue the 30h command. The PAGE READ CACHE MODE command is not supported on OTP pages.

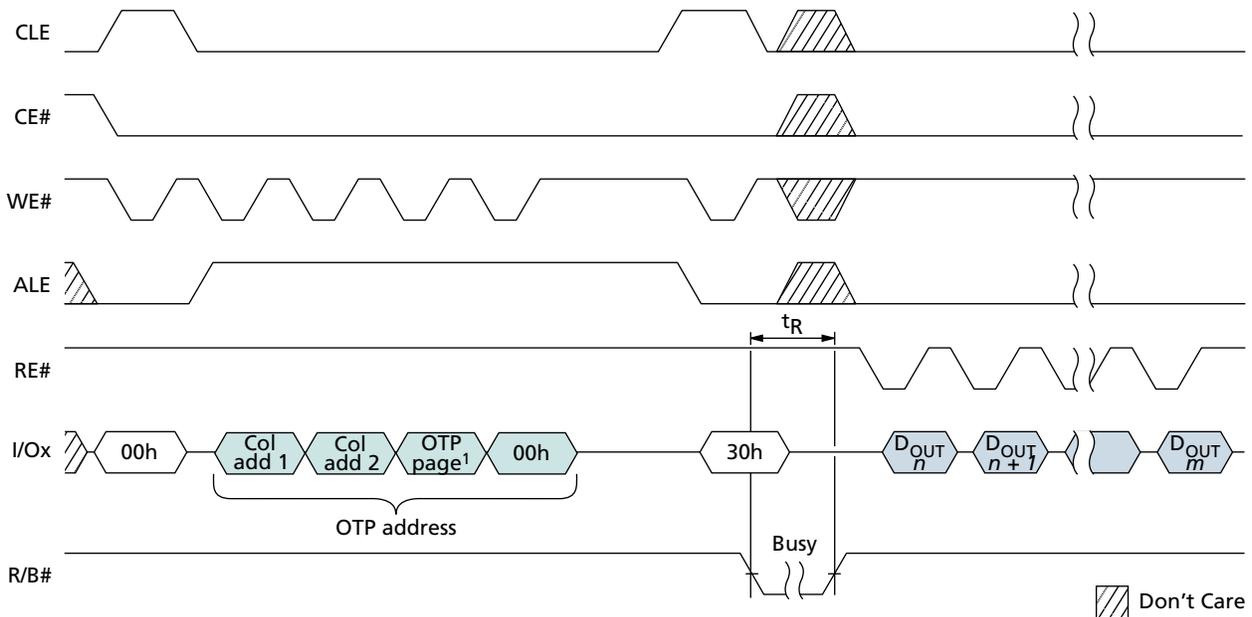
R/B# goes LOW (\bar{t}_R) while the data is moved from the OTP page to the data register. The READ STATUS (70h) command is the only valid command for reading status in OTP operation mode. Bit 5 of the status register reflects the state of R/B# (see Status Operations).

Normal READ operation timings apply to OTP read accesses. Additional pages within the OTP area can be selected by repeating the OTP DATA READ command.

The PAGE READ command is compatible with the RANDOM DATA OUTPUT (05h-E0h) command.

Only data on the current page can be read. Pulsing RE# outputs data sequentially.

Figure 63: OTP DATA READ

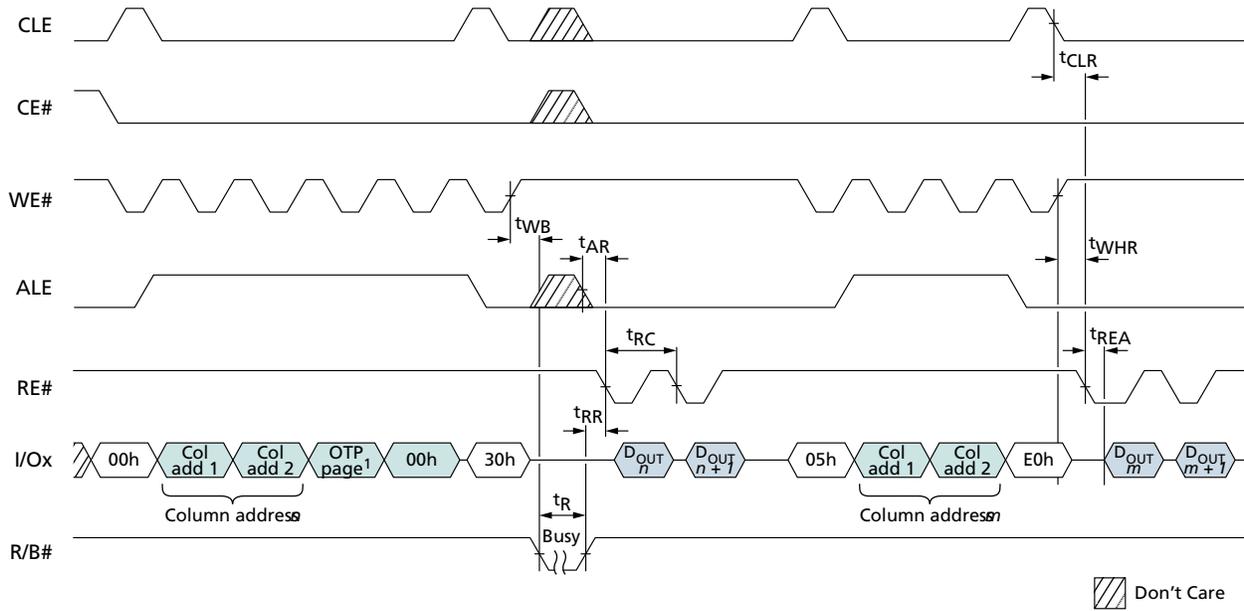


Note: 1. The OTP page must be within the 02h–1Fh range.



1Gb x8, x16: NAND Flash Memory One-Time Programmable (OTP) Operations

Figure 64: OTP DATA READ with RANDOM DATA READ Operation



Note: 1. The OTP page must be within the range 02h–1Fh.



Error Management

Table 18: Error Management Details

Description	Requirement
Minimum number of valid blocks (NVB) per LUN	1004
Total available blocks per LUN	1024
First spare area location	x8: byte 2048 x16: word 1024
Bad-block mark	x8: 00h x16: 0000h
Minimum required ECC	4-bit ECC per 528 bytes of data
Minimum required ECC for block 0 if PROGRAM/ERASE cycles are less than 1000	1-bit ECC per 528 bytes



Output Drive Impedance

Because NAND Flash is designed for use in systems that are typically point-to-point connections, an option to control the drive strength of the output buffers is provided. Drive strength should be selected based on the expected loading of the memory bus. There are four supported settings for the output drivers: overdrive 2, overdrive 1, nominal, and underdrive.

The nominal output drive strength setting is the power-on default value. The host can select a different drive strength setting using the SET FEATURES (EFh) command.

The output impedance range from minimum to maximum covers process, voltage, and temperature variations. Devices are not guaranteed to be at the nominal line.

Table 19: Output Drive Strength Conditions ($V_{CCQ} = 1.7\text{--}1.95\text{V}$)

Range	Process	Voltage	Temperature
Minimum	Fast-Fast	1.95V	T_A (MIN)
Nominal	Typical-Typical	1.8V	+25°C
Maximum	Slow-Slow	1.7V	T_A (MAX)

Table 20: Output Drive Strength Impedance Values ($V_{CCQ} = 1.7\text{--}1.95\text{V}$)

Output Strength	Rpd/Rpu	V_{OUT} to V_{SSQ}	Minimum	Nominal	Maximum	Unit
Overdrive 2	Rpd	$V_{CCQ} \times 0.2$	7.5	13.5	34	ohms
		$V_{CCQ} \times 0.5$	9	18	31	ohms
		$V_{CCQ} \times 0.8$	11	23.5	44	ohms
	Rpu	$V_{CCQ} \times 0.2$	11	23.5	44	ohms
		$V_{CCQ} \times 0.5$	9	18	31	ohms
		$V_{CCQ} \times 0.8$	7.5	13.5	34	ohms
Overdrive 1	Rpd	$V_{CCQ} \times 0.2$	10.5	19	47	ohms
		$V_{CCQ} \times 0.5$	13	25	44	ohms
		$V_{CCQ} \times 0.8$	16	32.5	61.5	ohms
	Rpu	$V_{CCQ} \times 0.2$	16	32.5	61.5	ohms
		$V_{CCQ} \times 0.5$	13	25	44	ohms
		$V_{CCQ} \times 0.8$	10.5	19	47	ohms
Nominal	Rpd	$V_{CCQ} \times 0.2$	15	27	66.5	ohms
		$V_{CCQ} \times 0.5$	18	35	62.5	ohms
		$V_{CCQ} \times 0.8$	22	52	88	ohms
	Rpu	$V_{CCQ} \times 0.2$	22	52	88	ohms
		$V_{CCQ} \times 0.5$	18	35	62.5	ohms
		$V_{CCQ} \times 0.8$	15	27	66.5	ohms


**1Gb x8, x16: NAND Flash Memory
Output Drive Impedance**
Table 20: Output Drive Strength Impedance Values ($V_{CCQ} = 1.7\text{--}1.95\text{V}$)

Output Strength	Rpd/Rpu	V_{OUT} to V_{SSQ}	Minimum	Nominal	Maximum	Unit
Underdrive	Rpd	$V_{CCQ} \times 0.2$	21.5	39	95	ohms
		$V_{CCQ} \times 0.5$	26	50	90	ohms
		$V_{CCQ} \times 0.8$	31.5	66.5	126.5	ohms
	Rpu	$V_{CCQ} \times 0.2$	31.5	66.5	126.5	ohms
		$V_{CCQ} \times 0.5$	26	50	90	ohms
		$V_{CCQ} \times 0.8$	21.5	39	95	ohms

Table 21: Output Drive Strength Conditions ($V_{CCQ} = 2.7\text{--}3.6\text{V}$)

Range	Process	Voltage	Temperature
Minimum	Fast-Fast	3.6V	T_A (MIN)
Nominal	Typical-Typical	3.3V	+25°C
Maximum	Slow-Slow	2.7V	T_A (MAX)

Table 22: Output Drive Strength Impedance Values ($V_{CCQ} = 2.7\text{--}3.6\text{V}$)

Output Strength	Rpd/Rpu	V_{OUT} to V_{SSQ}	Minimum	Nominal	Maximum	Unit
Overdrive 2	Rpd	$V_{CCQ} \times 0.2$	7.0	16.2	28.7	ohms
		$V_{CCQ} \times 0.5$	9.0	18.0	36.0	ohms
		$V_{CCQ} \times 0.8$	11.8	21.0	50.0	ohms
	Rpu	$V_{CCQ} \times 0.2$	11.8	21.0	50.0	ohms
		$V_{CCQ} \times 0.5$	9.0	18.0	36.0	ohms
		$V_{CCQ} \times 0.8$	7.0	14.0	28.7	ohms
Overdrive 1	Rpd	$V_{CCQ} \times 0.2$	9.3	22.3	40.0	ohms
		$V_{CCQ} \times 0.5$	12.6	25.0	50.0	ohms
		$V_{CCQ} \times 0.8$	16.3	29.0	68.0	ohms
	Rpu	$V_{CCQ} \times 0.2$	16.3	29.0	68.0	ohms
		$V_{CCQ} \times 0.5$	12.6	25.0	50.0	ohms
		$V_{CCQ} \times 0.8$	9.3	19.0	40.0	ohms
Nominal	Rpd	$V_{CCQ} \times 0.2$	12.8	32.0	58.0	ohms
		$V_{CCQ} \times 0.5$	18.0	35.0	70.0	ohms
		$V_{CCQ} \times 0.8$	23.0	40.0	95.0	ohms
	Rpu	$V_{CCQ} \times 0.2$	23.0	40.0	95.0	ohms
		$V_{CCQ} \times 0.5$	18.0	35.0	70.0	ohms
		$V_{CCQ} \times 0.8$	12.8	32.0	58.0	ohms



1Gb x8, x16: NAND Flash Memory Output Drive Impedance

Table 22: Output Drive Strength Impedance Values ($V_{CCQ} = 2.7\text{--}3.6\text{V}$)

Output Strength	Rpd/Rpu	V_{OUT} to V_{SSQ}	Minimum	Nominal	Maximum	Unit
Underdrive	Rpd	$V_{CCQ} \times 0.2$	18.4	45.0	80.0	ohms
		$V_{CCQ} \times 0.5$	25.0	50.0	100.0	ohms
		$V_{CCQ} \times 0.8$	32.0	57.0	136.0	ohms
	Rpu	$V_{CCQ} \times 0.2$	32.0	57.0	136.0	ohms
		$V_{CCQ} \times 0.5$	25.0	50.0	100.0	ohms
		$V_{CCQ} \times 0.8$	18.4	45.0	80.0	ohms

Table 23: Pull-Up and Pull-Down Output Impedance Mismatch

Drive Strength	Minimum	Maximum	Unit	Notes
Overdrive 2	0	6.3	ohms	1, 2
Overdrive 1	0	8.8	ohms	1, 2
Nominal	0	12.3	ohms	1, 2
Underdrive	0	17.5	ohms	1, 2

Notes: 1. Mismatch is the absolute value between pull-up and pull-down impedances. Both are measured at the same temperature and voltage.

2. Test conditions: $V_{CCQ} = V_{CCQ}(\text{MIN})$, $V_{OUT} = V_{CCQ} \times 0.5$, $T_A = T_{OPER}$.



AC Overshoot/Undershoot Specifications

The supported AC overshoot and undershoot area depends on the timing mode selected by the host.

Table 24: Asynchronous Overshoot/Undershoot Parameters

Parameter	Timing Mode						Unit
	0	1	2	3	4	5	
Maximum peak amplitude provided for overshoot area	1	1	1	1	1	1	V
Maximum peak amplitude provided for undershoot area	1	1	1	1	1	1	V
Maximum overshoot area above V_{CCQ}	3	3	3	3	3	3	V-ns
Maximum undershoot area below V_{SSQ}	3	3	3	3	3	3	V-ns

Figure 65: Overshoot

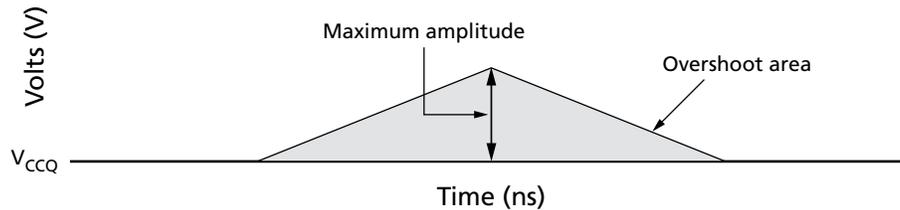
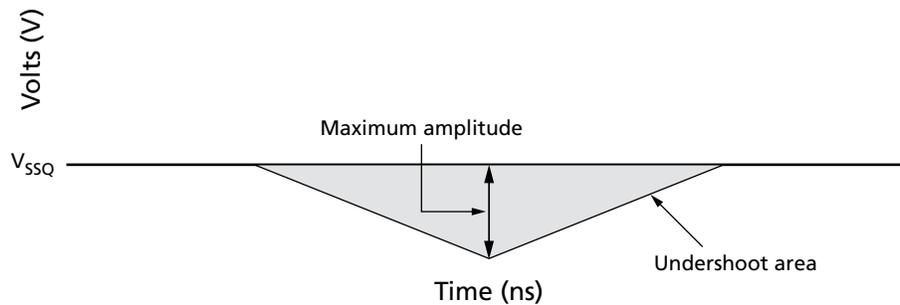


Figure 66: Undershoot





Output Slew Rate

The output slew rate is tested using the following setup with only one die per DQ channel.

Table 25: Test Conditions for Output Slew Rate

Parameter	Value
$V_{OL(DC)}$	$0.3 \times V_{CCQ}$
$V_{OH(DC)}$	$0.7 \times V_{CCQ}$
$V_{OL(AC)}$	$0.2 \times V_{CCQ}$
$V_{OH(AC)}$	$0.8 \times V_{CCQ}$
Rising edge (t_{RISE})	$V_{OL(DC)}$ to $V_{OH(AC)}$
Falling edge (t_{FALL})	$V_{OH(DC)}$ to $V_{OL(AC)}$
Output capacitive load (C_{LOAD})	5pF
Temperature range	T_A

Table 26: Output Slew Rate ($V_{CCQ} = 1.7\text{--}1.95\text{V}$)

Output Drive Strength	Min	Max	Unit
Overdrive 2	1	5.5	V/ns
Overdrive 1	0.85	5	V/ns
Nominal	0.75	4	V/ns
Underdrive	0.6	4	V/ns

Table 27: Output Slew Rate ($V_{CCQ} = 2.7\text{--}3.6\text{V}$)

Output Drive Strength	Min	Max	Unit
Overdrive 2	1.5	10.0	V/ns
Overdrive 1	1.5	9.0	V/ns
Nominal	1.2	7.0	V/ns
Underdrive	1.0	5.5	V/ns



Electrical Specifications

Stresses greater than those listed can cause permanent damage to the device. This is a stress rating only, and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not guaranteed. Exposure to absolute maximum rating conditions for extended periods can affect reliability.

Table 28: Absolute Maximum Ratings

Voltage on any pin relative to V_{SS}

Parameter/Condition		Symbol	Min	Max	Unit
Voltage Input	3.3V	V_{IN}	-0.6	4.6	V
	1.8V		-0.6	2.4	V
V_{CC} supply voltage	3.3V	V_{CC}	-0.6	4.6	V
	1.8V		-0.6	2.4	V
Storage temperature		T_{STG}	-65	150	°C
Short circuit output current, I/Os		-	-	5	mA

Table 29: Recommended Operating Conditions

Parameter/Condition		Symbol	Min	Typ	Max	Unit
Operating temperature	Commercial	T_A	0	-	70	°C
	Industrial		-40	-	85	°C
V_{CC} supply voltage	3.3V	V_{CC}	2.7	3.3	3.6	V
	1.8V		1.7	1.8	1.95	V
Ground supply voltage		V_{SS}	0	0	0	V

Table 30: Valid Blocks

Parameter	Symbol	Device	Min	Max	Unit	Notes
Valid block number	NVB	3.3V/1.8V	1004	1024	Blocks	1

Notes: 1. Invalid blocks are blocks that contain one or more bad bits. The device may contain bad blocks upon shipment. Additional bad blocks may develop over time; however, the total number of available blocks will not drop below NVB during the endurance life of the device. Do not erase or program blocks marked invalid by the factory.



1Gb x8, x16: NAND Flash Memory Electrical Specifications

Table 31: Capacitance

Description	Symbol	Max	Unit	Notes
Input capacitance	C_{IN}	10	pF	1, 2
Input/output capacitance (I/O)	C_{IO}	10	pF	1, 2

Notes: 1. These parameters are verified in device characterization and are not 100% tested.
 2. Test conditions: $T_C = 25^\circ\text{C}$; $f = 1\text{ MHz}$; $V_{IN} = 0\text{V}$.

Table 32: Test Conditions

Parameter		Value	Notes
Input pulse levels		0.0V to V_{CC}	
Input rise and fall times		5ns	
Input and output timing levels		$V_{CC}/2$	
Output load	3.3V	1 TTL GATE and $CL = 30\text{pF}$	1
	1.8V	1 TTL GATE and $CL = 30\text{pF}$	1

Notes: 1. These parameters are verified in device characterization and are not 100% tested.



Electrical Specifications – AC Characteristics and Operating Conditions

Table 33: AC Characteristics: Command, Data, and Address Input (3.3V)

Parameter	Symbol	Min	Max	Unit	Notes
ALE to data start	t_{ADL}	70	–	ns	2
ALE hold time	t_{ALH}	5	–	ns	
ALE setup time	t_{ALS}	10	–	ns	
CE# hold time	t_{CH}	5	–	ns	
CLE hold time	t_{CLH}	5	–	ns	
CLE setup time	t_{CLS}	10	–	ns	
CE# setup time	t_{CS}	15	–	ns	
Data hold time	t_{DH}	5	–	ns	
Data setup time	t_{DS}	7	–	ns	
WRITE cycle time	t_{WC}	20	–	ns	2
WE# pulse width HIGH	t_{WH}	7	–	ns	2
WE# pulse width	t_{WP}	10	–	ns	2
WP# transition to WE# LOW	t_{WW}	100	–	ns	

Notes: 1. Operating mode timings meet ONFI timing mode 5 parameters.

2. Timing for t_{ADL} begins in the address cycle, on the final rising edge of WE#, and ends with the first rising edge of WE# for data input.

3. Note 1 applies to all.

Table 34: AC Characteristics: Command, Data, and Address Input (1.8V)

Parameter	Symbol	Min	Max	Unit	Notes
ALE to data start	t_{ADL}	70	–	ns	2
ALE hold time	t_{ALH}	5	–	ns	
ALE setup time	t_{ALS}	10	–	ns	
CE# hold time	t_{CH}	5	–	ns	
CLE hold time	t_{CLH}	5	–	ns	
CLE setup time	t_{CLS}	10	–	ns	
CE# setup time	t_{CS}	20	–	ns	
Data hold time	t_{DH}	5	–	ns	
Data setup time	t_{DS}	10	–	ns	
WRITE cycle time	t_{WC}	25	–	ns	2
WE# pulse width HIGH	t_{WH}	10	–	ns	2
WE# pulse width	t_{WP}	12	–	ns	2



1Gb x8, x16: NAND Flash Memory

Electrical Specifications – AC Characteristics and Operating Conditions

Table 34: AC Characteristics: Command, Data, and Address Input (1.8V) (Continued)

Parameter	Symbol	Min	Max	Unit	Notes
WP# transition to WE# LOW	t_{WW}	100	–	ns	

Notes: 1. Operating mode timings meet ONFI timing mode 4 parameters.

2. Timing for t_{ADL} begins in the address cycle on the final rising edge of WE#, and ends with the first rising edge of WE# for data input.
3. Note 1 applies to all.



1Gb x8, x16: NAND Flash Memory

Electrical Specifications – AC Characteristics and Operating Conditions

Table 35: AC Characteristics: Normal Operation (3.3V)

Note 1 applies to all

Parameter	Symbol	Min	Max	Unit	Notes
ALE to RE# delay	t_{AR}	10	–	ns	
CE# access time	t_{CEA}	–	25	ns	
CE# HIGH to output High-Z	t_{CHZ}	–	50	ns	2
CLE to RE# delay	t_{CLR}	10	–	ns	
CE# HIGH to output hold	t_{COH}	15	–	ns	
Output High-Z to RE# LOW	t_{IR}	0	–	ns	
READ cycle time	t_{RC}	20	–	ns	
RE# access time	t_{REA}	–	16	ns	
RE# HIGH hold time	t_{REH}	7	–	ns	
RE# HIGH to output hold	t_{RHOH}	15	–	ns	
RE# HIGH to WE# LOW	t_{RHW}	100	–	ns	
RE# HIGH to output High-Z	t_{RHZ}	–	100	ns	2
RE# LOW to output hold	t_{RLOH}	5	–	ns	
RE# pulse width	t_{RP}	10	–	ns	
Ready to RE# LOW	t_{RR}	20	–	ns	
Reset time (READ/PROGRAM/ERASE)	t_{RST}	–	5/10/500	μ s	3
WE# HIGH to busy	t_{WB}	–	100	ns	
WE# HIGH to RE# LOW	t_{WHR}	60	–	ns	

- Notes: 1. AC characteristics may need to be relaxed if I/O drive strength is not set to full.
 2. Transition is measured ± 200 mV from steady-state voltage with load. This parameter is sampled and not 100% tested.
 3. The first time the RESET (FFh) command is issued while the device is idle, the device will go busy for a maximum of 1ms. Thereafter, the device goes busy for a maximum of 5 μ s.

Table 36: AC Characteristics: Normal Operation (1.8V)

Parameter	Symbol	Min	Max	Unit	Notes
ALE to RE# delay	t_{AR}	10	–	ns	
CE# access time	t_{CEA}	–	25	ns	
CE# HIGH to output High-Z	t_{CHZ}	–	50	ns	2
CLE to RE# delay	t_{CLR}	10	–	ns	
CE# HIGH to output hold	t_{COH}	15	–	ns	
Output High-Z to RE# LOW	t_{IR}	0	–	ns	
READ cycle time	t_{RC}	25	–	ns	



1Gb x8, x16: NAND Flash Memory Electrical Specifications – AC Characteristics and Operating Conditions

Table 36: AC Characteristics: Normal Operation (1.8V) (Continued)

Parameter	Symbol	Min	Max	Unit	Notes
RE# access time	t_{REA}	–	22	ns	
RE# HIGH hold time	t_{REH}	10	–	ns	
RE# HIGH to output hold	t_{RHOH}	15	–	ns	
RE# HIGH to WE# LOW	t_{RHW}	100	–	ns	
RE# HIGH to output High-Z	t_{RHZ}	–	65	ns	2
RE# LOW to output hold	t_{RLOH}	3	–	ns	
RE# pulse width	t_{RP}	12	–	ns	
Ready to RE# LOW	t_{RR}	20	–	ns	
Reset time (READ/PROGRAM/ERASE)	t_{RST}	–	5/10/500	μ s	3
WE# HIGH to busy	t_{WB}	–	100	ns	
WE# HIGH to RE# LOW	t_{WHR}	80	–	ns	

- Notes: 1. AC characteristics may need to be relaxed if I/O drive strength is not set to full.
 2. Transition is measured ± 200 mV from steady-state voltage with load. This parameter is sampled and not 100% tested.
 3. The first time the RESET (FFh) command is issued while the device is idle, the device will be busy for a maximum of 1ms. Thereafter, the device is busy for a maximum of 5 μ s.
 4. Note 1 applies to all.



Electrical Specifications – DC Characteristics and Operating Conditions

Table 37: DC Characteristics and Operating Conditions (3.3V)

Parameter	Conditions	Symbol	Min	Typ	Max	Unit	Notes
Sequential READ current	$t_{RC} = t_{RC}(\text{MIN}); CE\# = V_{IL}; I_{OUT} = 0\text{mA}$	I_{CC1}	–	25	35	mA	
PROGRAM current	–	I_{CC2}	–	25	35	mA	
ERASE current	–	I_{CC3}	–	25	35	mA	
Standby current (TTL)	$CE\# = V_{IH}; WP\# = 0V/V_{CC}$	I_{SB1}	–	–	1	mA	
Standby current (CMOS)	$CE\# = V_{CC} - 0.2V; WP\# = 0V/V_{CC}$	I_{SB2}	–	20	100	μA	
Staggered power-up current	Rise time = 1ms Line capacitance = 0.1 μF	I_{ST}	–	–	10 per die	mA	1
Input leakage current	$V_{IN} = 0V \text{ to } V_{CC}$	I_{LI}	–	–	± 10	μA	
Output leakage current	$V_{OUT} = 0V \text{ to } V_{CC}$	I_{LO}	–	–	± 10	μA	
Input high voltage	I/O[7:0], I/O[15:0], CE#, CLE, ALE, WE#, RE#, WP#	V_{IH}	$0.8 \times V_{CC}$	–	$V_{CC} + 0.3$	V	
Input low voltage, all inputs	–	V_{IL}	–0.3	–	$0.2 \times V_{CC}$	V	
Output high voltage	$I_{OH} = -400\mu\text{A}$	V_{OH}	$0.67 \times V_{CC}$	–	–	V	3
Output low voltage	$I_{OL} = 2.1\text{mA}$	V_{OL}	–	–	0.4	V	3
Output low current	$V_{OL} = 0.4V$	$I_{OL}(\text{R/B}\#)$	8	10	–	mA	2

- Notes: 1. Measurement is taken with 1ms averaging intervals and begins after V_{CC} reaches $V_{CC}(\text{MIN})$.
 2. $I_{OL}(\text{RB}\#)$ may need to be relaxed if R/B pull-down strength is not set to full.
 3. V_{OH} and V_{OL} may need to be relaxed if I/O drive strength is not set to full.



1Gb x8, x16: NAND Flash Memory

Electrical Specifications – DC Characteristics and Operating Conditions

Table 38: DC Characteristics and Operating Conditions (1.8V)

Parameter	Conditions	Symbol	Min	Typ	Max	Unit	Notes
Sequential READ current	$t_{RC} = t_{RC}(\text{MIN}); CE\# = V_{IL}; I_{OUT} = 0\text{mA}$	I_{CC1}	–	13	20	mA	1, 2
PROGRAM current	–	I_{CC2}	–	10	20	mA	1, 2
ERASE current	–	I_{CC3}	–	10	20	mA	1, 2
Standby current (TTL)	$CE\# = V_{IH}; WP\# = 0V/V_{CC}$	I_{SB1}	–	–	1	mA	
Standby current (CMOS)	$CE\# = V_{CC} - 0.2V; WP\# = 0V/V_{CC}$	I_{SB2}	–	10	50	μA	
Staggered power-up current	Rise time = 1ms Line capacitance = 0.1 μF	I_{ST}	–	–	10 per die	mA	3
Input leakage current	$V_{IN} = 0V \text{ to } V_{CC}$	I_{LI}	–	–	± 10	μA	
Output leakage current	$V_{OUT} = 0V \text{ to } V_{CC}$	I_{LO}	–	–	± 10	μA	
Input high voltage	I/O[7:0], I/O[15:0], CE#, CLE, ALE, WE#, RE#, WP#	V_{IH}	$0.8 \times V_{CC}$	–	$V_{CC} + 0.3$	V	
Input low voltage, all inputs	–	V_{IL}	–0.3	–	$0.2 \times V_{CC}$	V	
Output high voltage	$I_{OH} = -100\mu\text{A}$	V_{OH}	$V_{CC} - 0.1$	–	–	V	4
Output low voltage	$I_{OL} = +100\mu\text{A}$	V_{OL}	–	–	0.1	V	4
Output low current (R/B#)	$V_{OL} = 0.2V$	$I_{OL}(\text{R/B}\#)$	3	4	–	mA	5

- Notes: 1. Typical and maximum values are for single-plane operation only.
 2. Values are for single-die operations. Values could be higher for interleaved-die operations.
 3. Measurement is taken with 1ms averaging intervals and begins after V_{CC} reaches $V_{CC}(\text{MIN})$.
 4. Test conditions for V_{OH} and V_{OL} .
 5. DC characteristics may need to be relaxed if R/B# pull-down strength is not set to full.



1Gb x8, x16: NAND Flash Memory Electrical Specifications – Program/Erase Characteristics

Electrical Specifications – Program/Erase Characteristics

Table 39: Program/Erase Characteristics

Parameter	Symbol	Typ	Max	Unit	Notes
Number of partial-page programs	NOP	–	4	cycles	
BLOCK ERASE operation time	t_{BERS}	0.7	3	ms	
Busy time for PROGRAM CACHE operation	t_{CBSY}	3	600	μ s	2
Cache read busy time	t_{RCBSY}	3	25	μ s	
Busy time for SET FEATURES and GET FEATURES operations	t_{FEAT}	–	1	μ s	
Busy time for OTP DATA PROGRAM operation if OTP is protected	t_{OBSY}	–	30	μ s	
PROGRAM PAGE operation time	t_{PROG}	200	600	μ s	3
Data transfer from Flash array to data register	t_R	–	25	μ s	4

- Notes: 1. Applies to entire table: Typical is nominal voltage and room temperature.
 2. t_{CBSY} MAX time depends on timing between internal program completion and data-in.
 3. Typical program time is defined as the time within which more than 50% of the pages are programmed at nominal voltage and room temperature.
 4. AC characteristics may need to be relaxed if I/O drive strength is not set to full.



Asynchronous Interface Timing Diagrams

Figure 67: RESET Operation

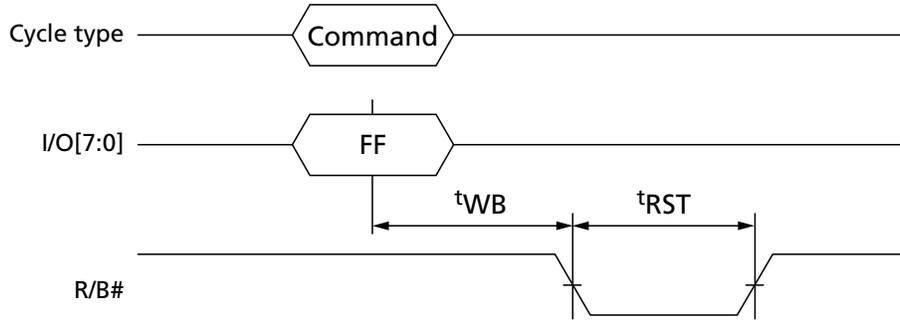
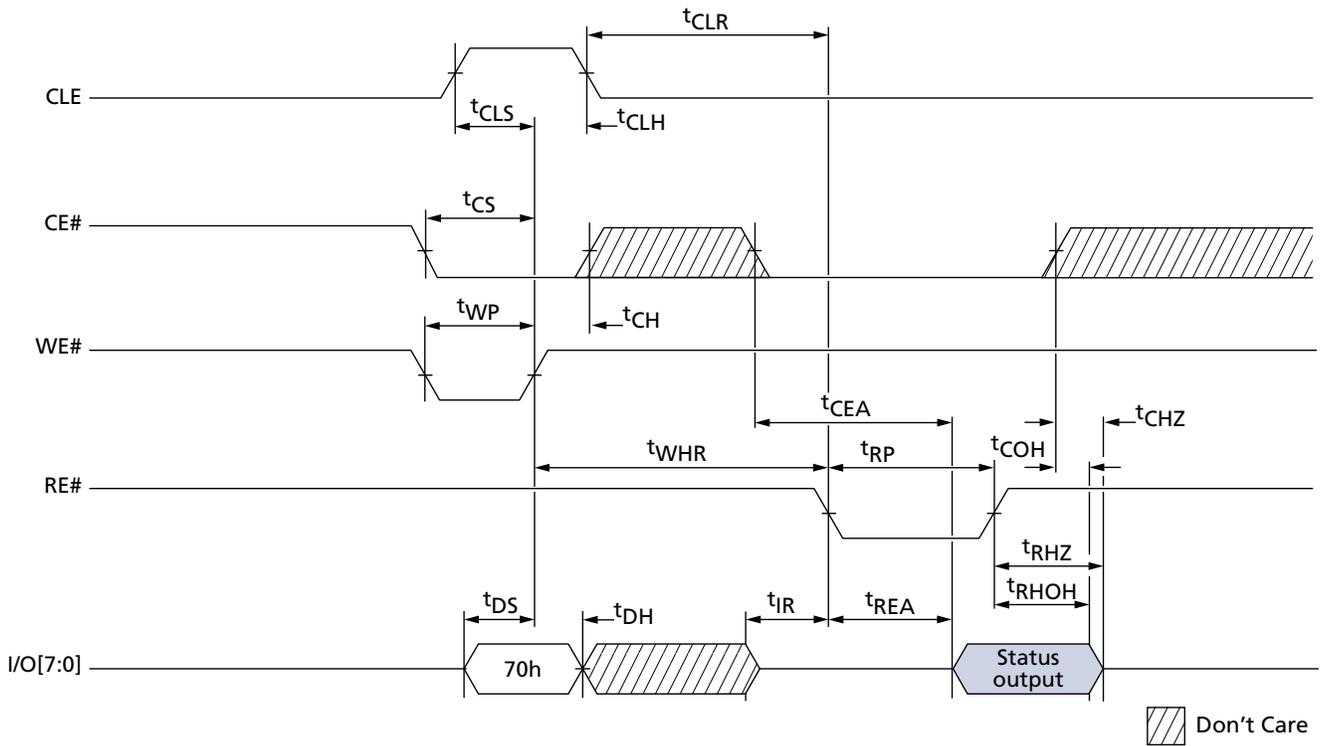


Figure 68: READ STATUS Cycle





1Gb x8, x16: NAND Flash Memory Asynchronous Interface Timing Diagrams

Figure 69: READ STATUS ENHANCED Cycle

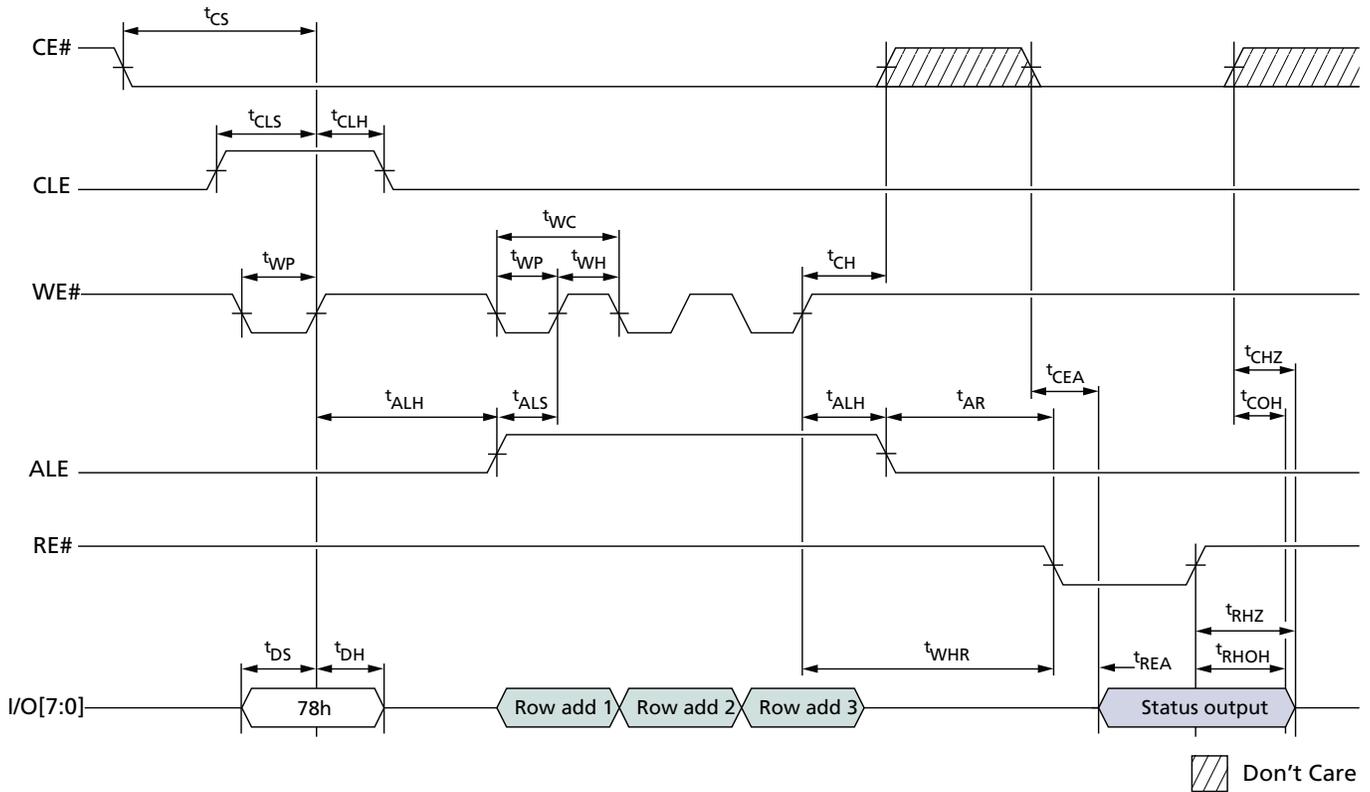
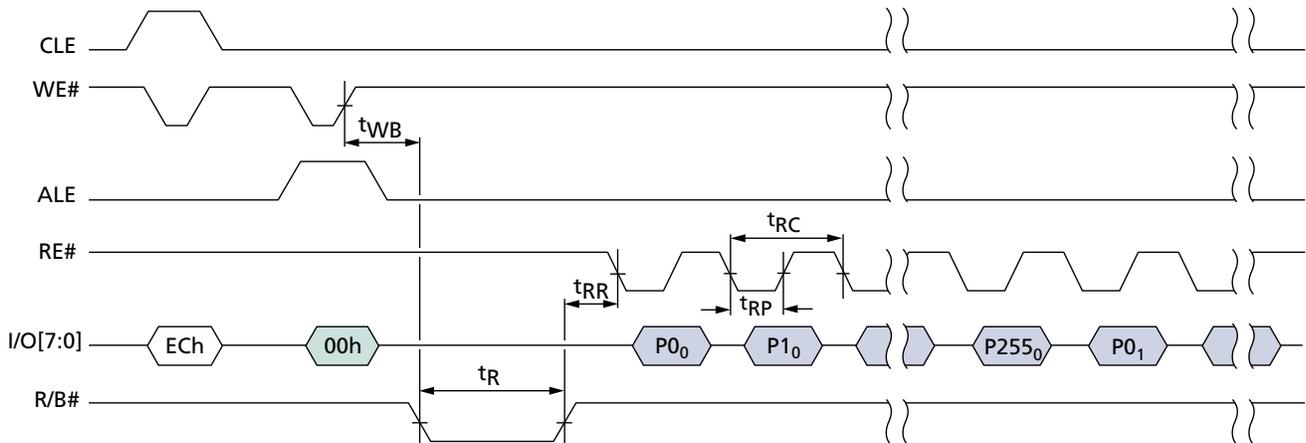


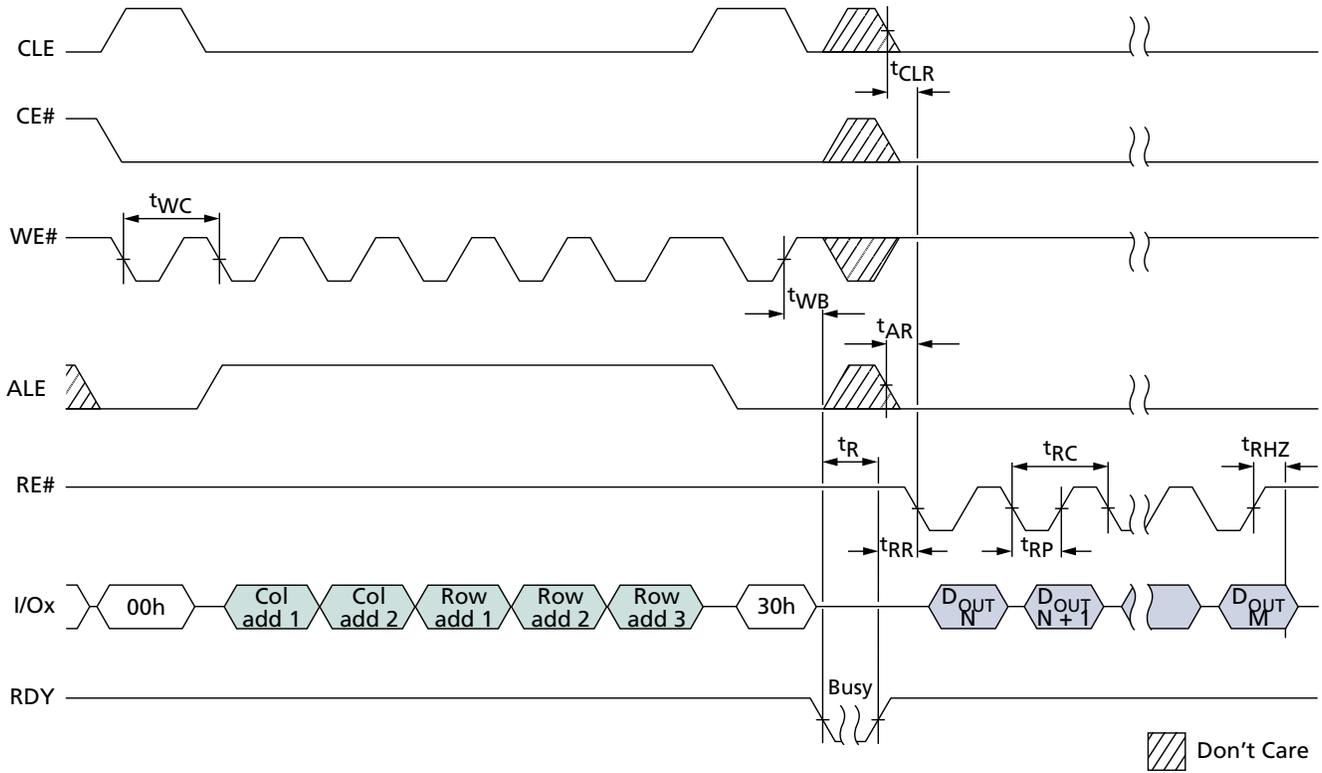
Figure 70: READ PARAMETER PAGE





1Gb x8, x16: NAND Flash Memory Asynchronous Interface Timing Diagrams

Figure 71: READ PAGE





1Gb x8, x16: NAND Flash Memory Asynchronous Interface Timing Diagrams

Figure 72: READ PAGE Operation with CE# "Don't Care"

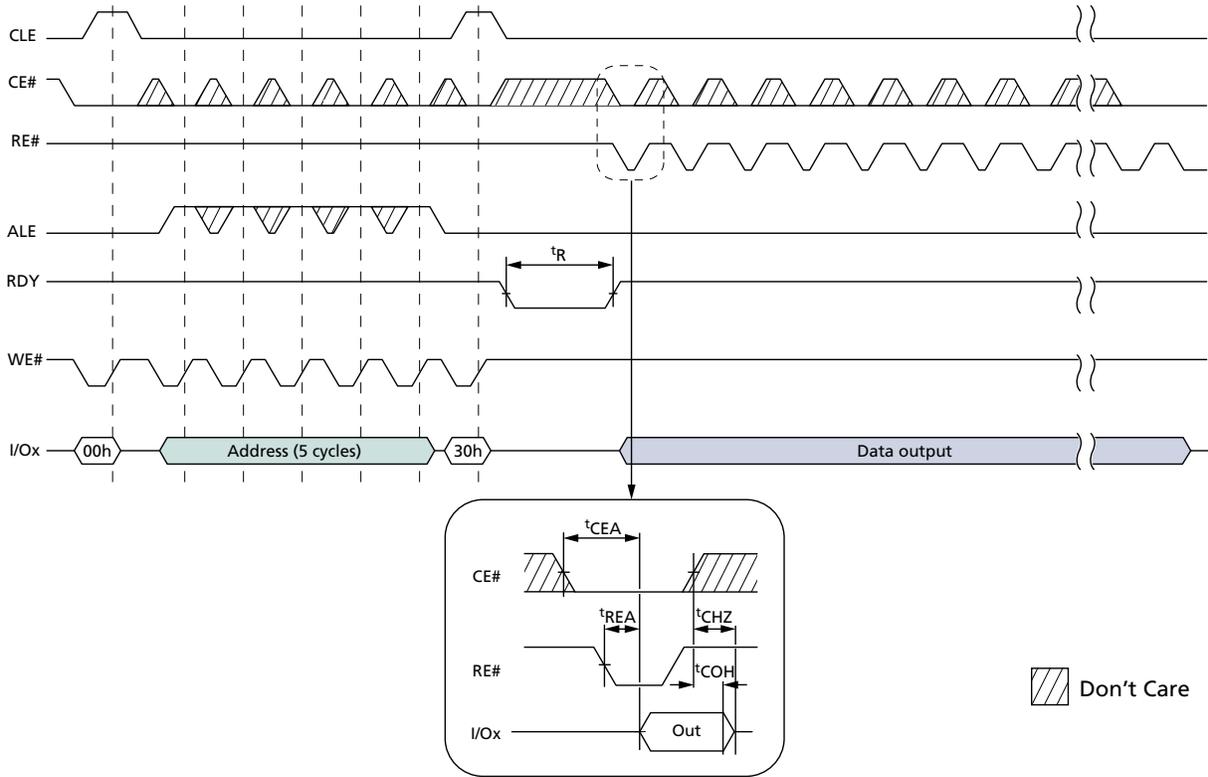
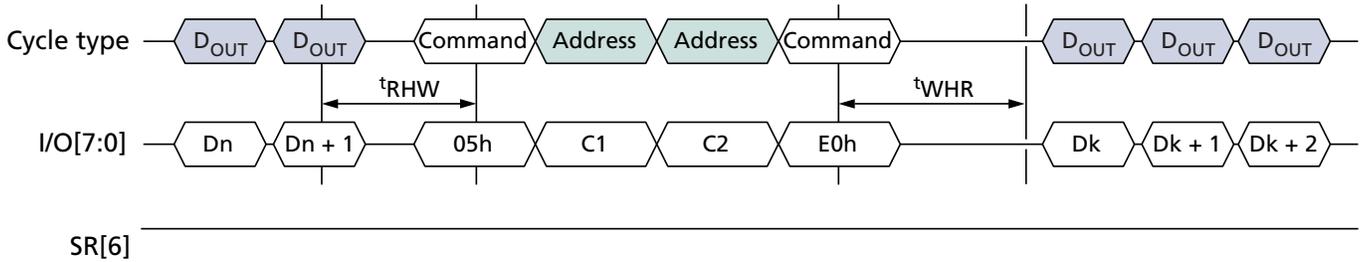


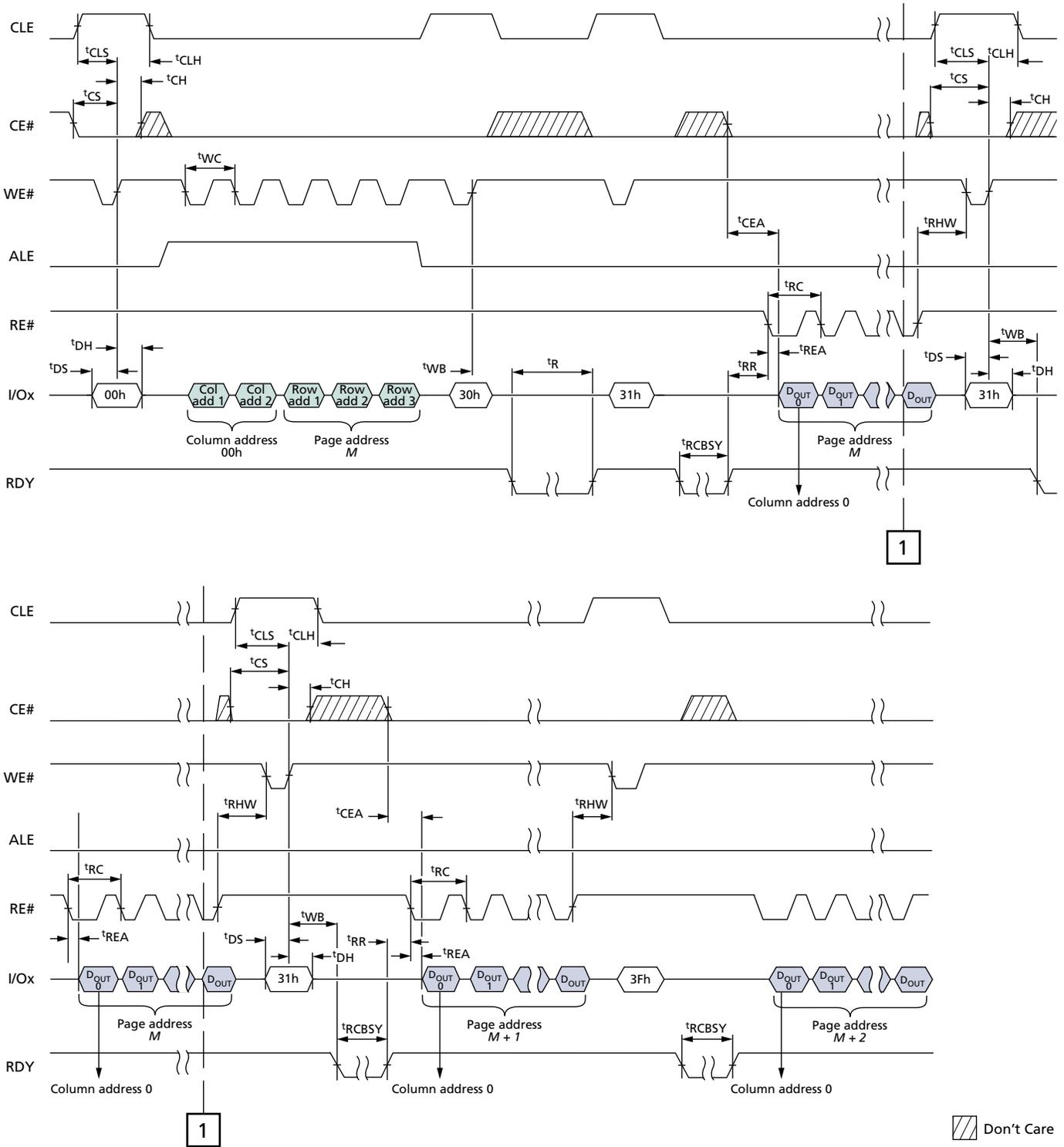
Figure 73: RANDOM DATA READ





1Gb x8, x16: NAND Flash Memory Asynchronous Interface Timing Diagrams

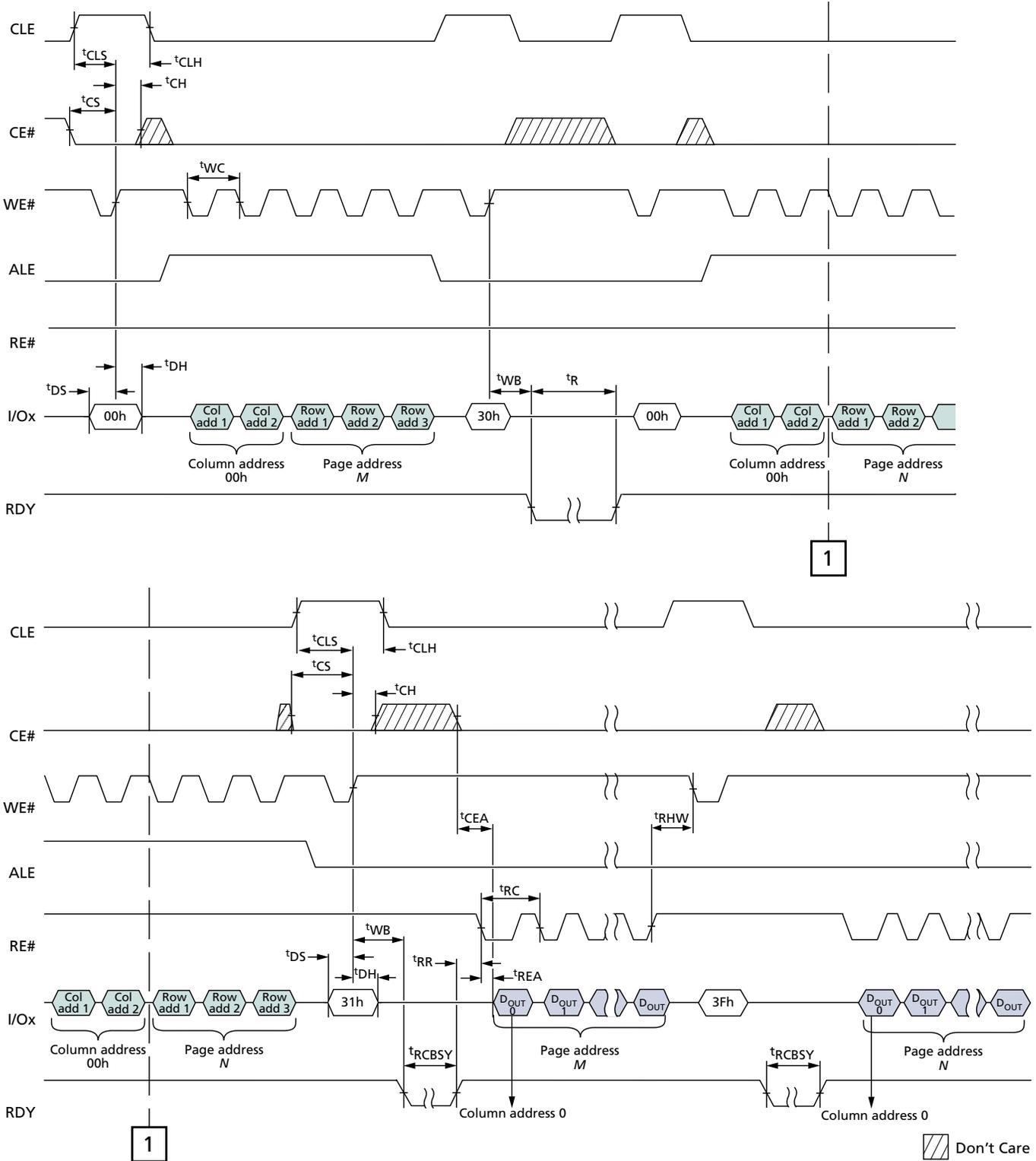
Figure 74: READ PAGE CACHE SEQUENTIAL





1Gb x8, x16: NAND Flash Memory Asynchronous Interface Timing Diagrams

Figure 75: READ PAGE CACHE RANDOM





1Gb x8, x16: NAND Flash Memory Asynchronous Interface Timing Diagrams

Figure 76: READ ID Operation

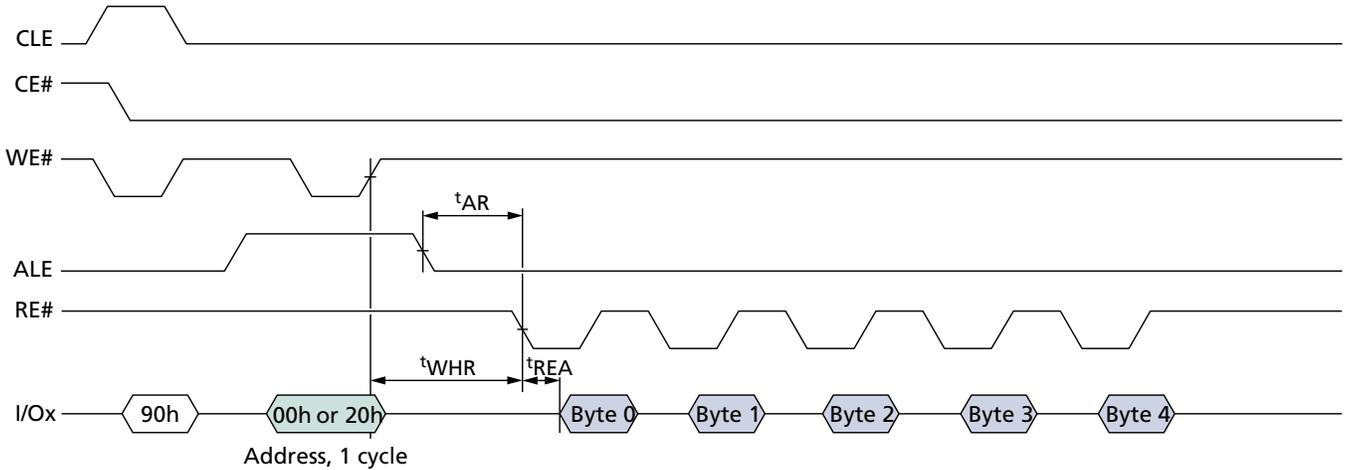
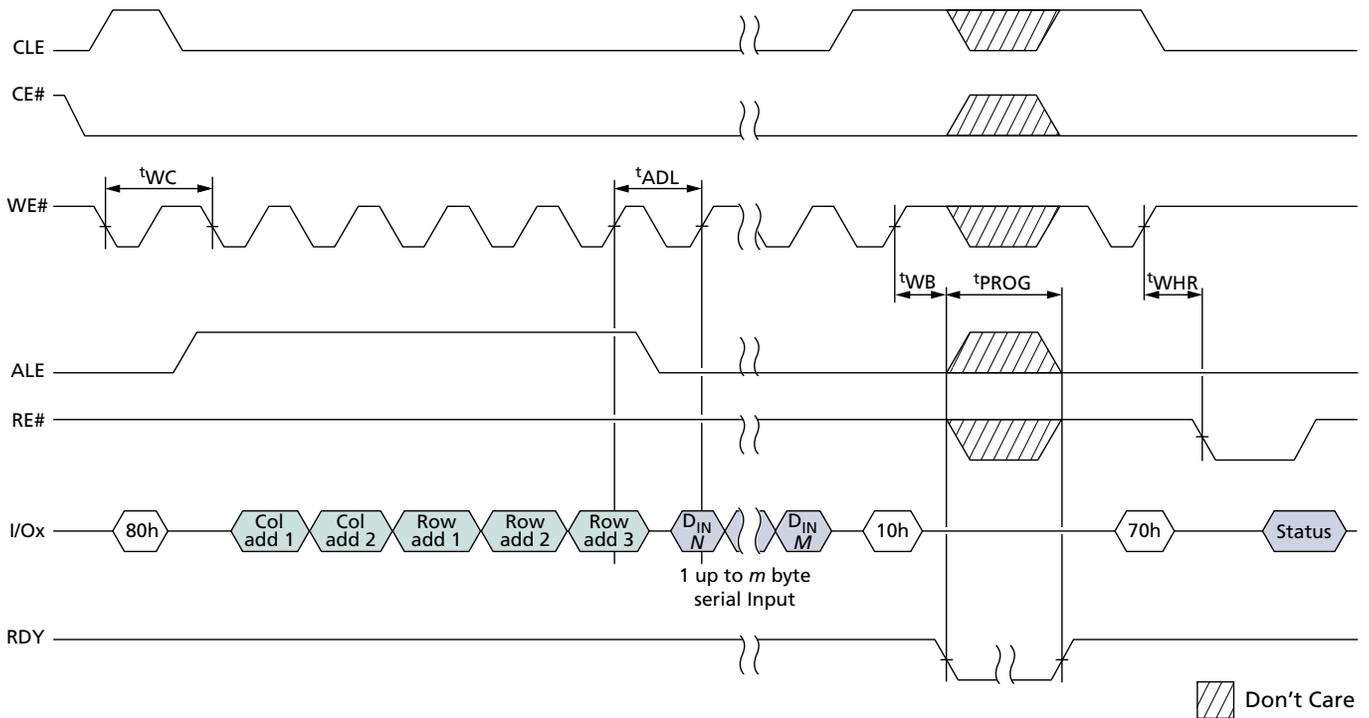


Figure 77: PROGRAM PAGE Operation





1Gb x8, x16: NAND Flash Memory Asynchronous Interface Timing Diagrams

Figure 78: PROGRAM PAGE Operation with CE# "Don't Care"

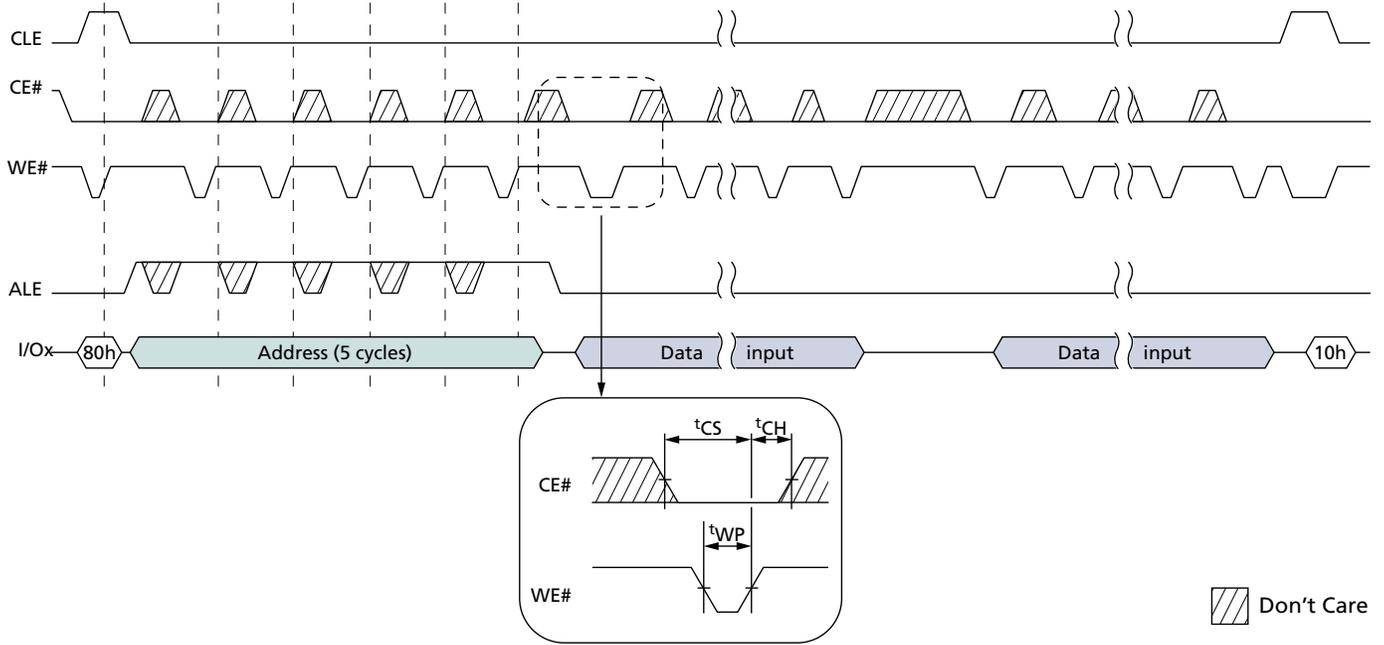
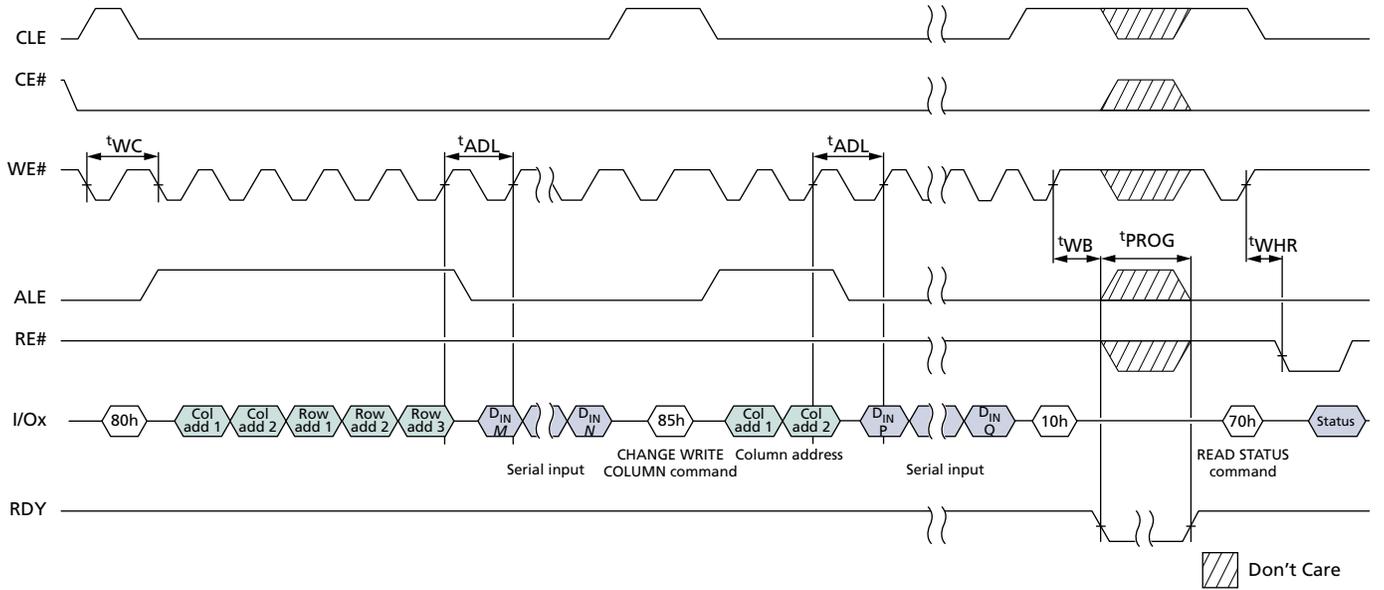


Figure 79: PROGRAM PAGE Operation with RANDOM DATA INPUT





1Gb x8, x16: NAND Flash Memory Asynchronous Interface Timing Diagrams

Figure 80: PROGRAM PAGE CACHE

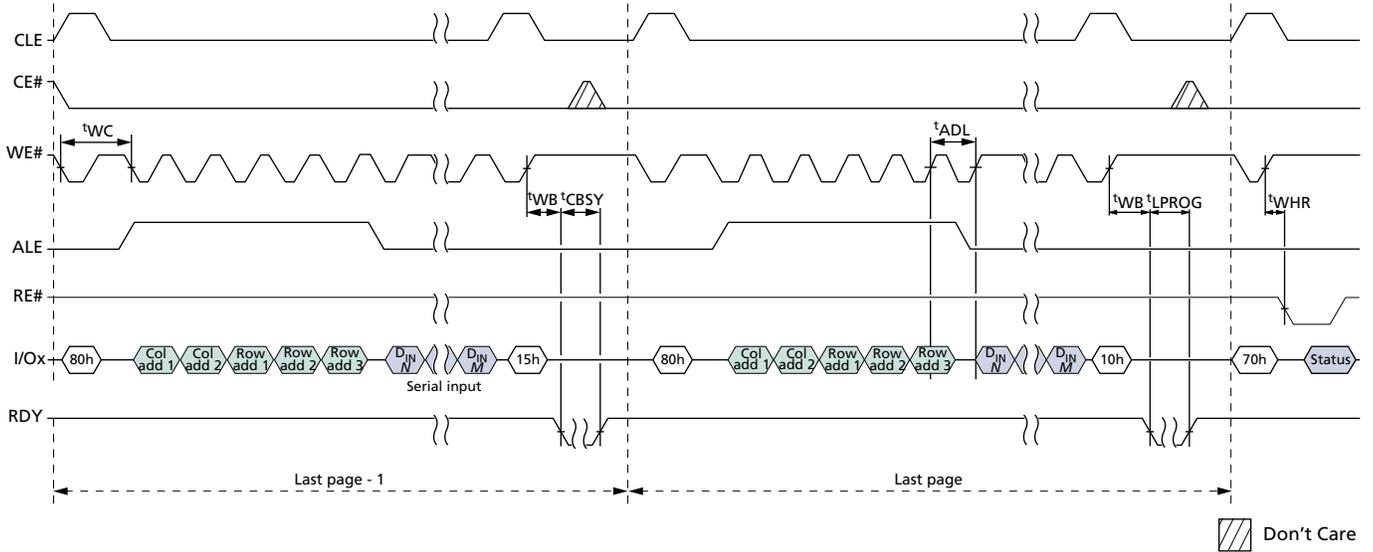
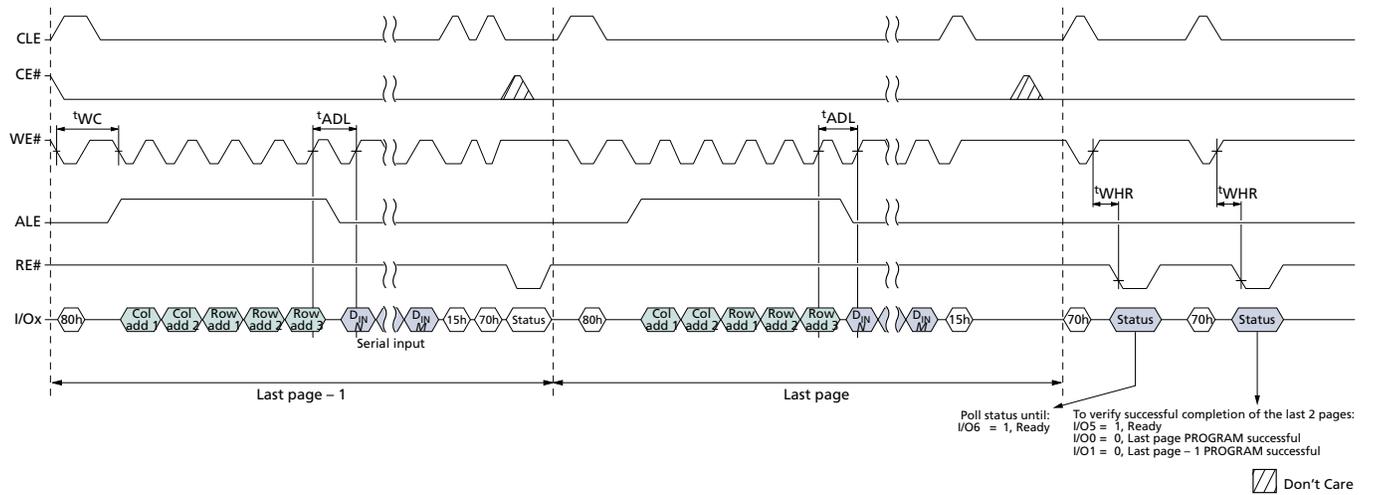


Figure 81: PROGRAM PAGE CACHE Ending on 15h





1Gb x8, x16: NAND Flash Memory Asynchronous Interface Timing Diagrams

Figure 82: INTERNAL DATA MOVE

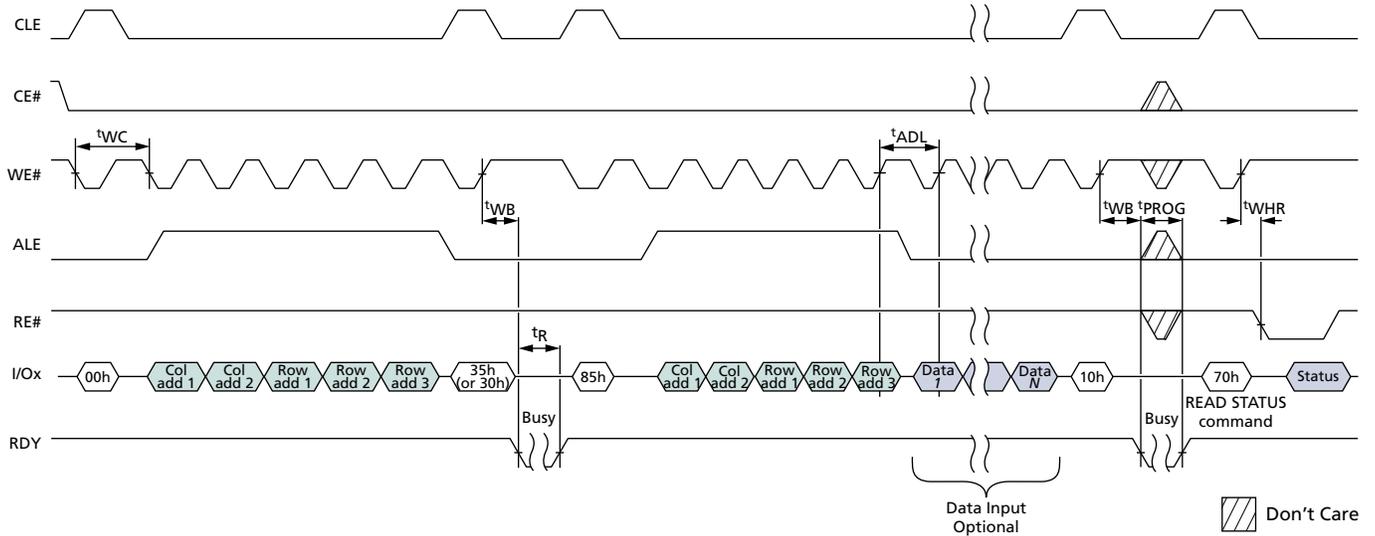
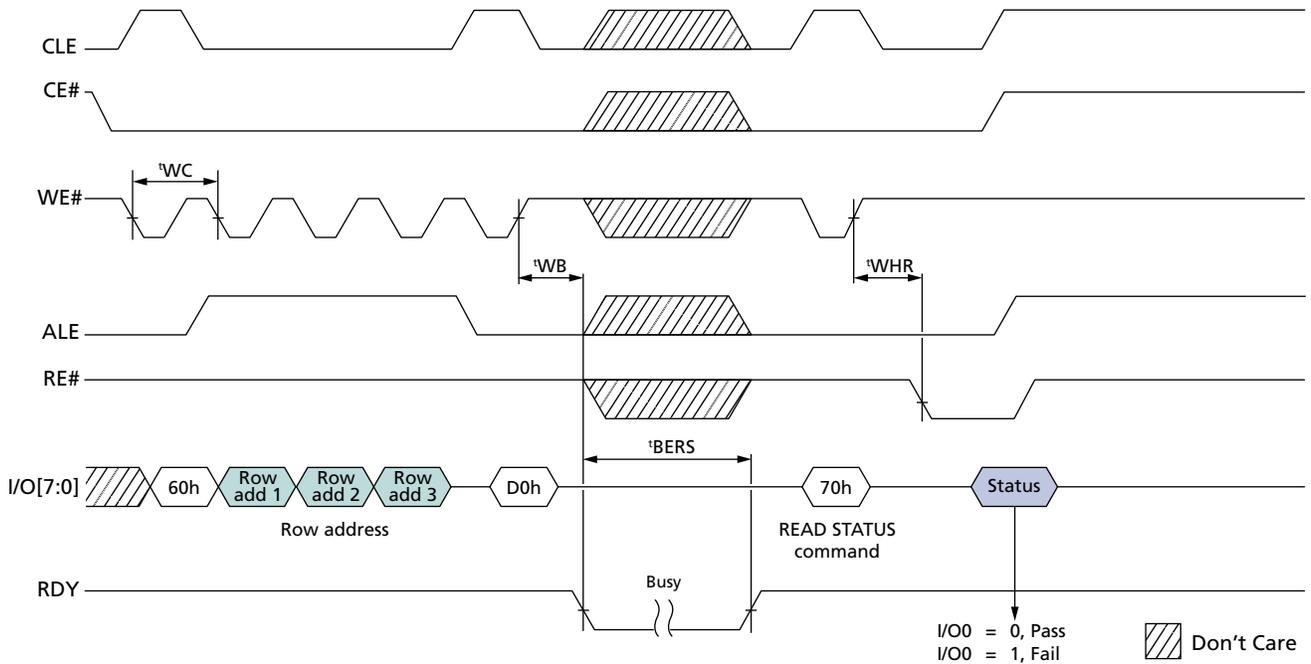


Figure 83: ERASE BLOCK Operation





Revision History

Rev. O – 04/2023

- Added COMPONENT_REVISION 1 to indicate new leadframe (L/F) material in Part Numbering Information section.

Rev. N – 02/2018

- Added Important Notes and Warnings section for further clarification aligning to industry standards.

Rev. M – 01/2018

- Updated the part numbering information page.

Rev. L – 02/2015

- Made minor format changes per Micron conventions

Rev. K – 10/2014

- Updated the x8 and x16 Array Organization figures

Rev. J – 04/2014

- Updated the ONFI statement in the READ PARAMETER PAGE (ECh) section and the LOCK TIGHT command section

Rev. I – 08/2013

- Updated Block Lock Feature and Lock Tight in Block Lock Feature

Rev. H – 02/2013

- Changed status to Production

Rev. G – 11/2012

- Updated part number chart with option X for product longevity program (PLP) under Special Options

Rev. F – 08/2012

- Updated the Marketing Part Number Chart

Rev. E – 07/2012

- Added LOCK pin description to Table 1
- Added note 2 to Figure 2

Rev. D – 02/2012

- Updated I_{SB2} spec in 3.3V DC Characteristics and Operating Conditions table

Rev. C – 02/2012

- Updated Parameter Page Data Structure Tables



- Updated 63-ball package drawing (H4)

Rev. B – 11/2011

- Command Definitions topic, Command Set table: Changed OTP DATA LOCK BY BLOCK (ONFI) to OTP DATA LOCK BY PAGE (ONFI).
- One-Time Programmable (OTP) Operations topic, OTP DATA PROTECT (80h-10) section: Updated content.

Rev. A – 08/2011

- Initial version

8000 S. Federal Way, P.O. Box 6, Boise, ID 83707-0006
208-368-4000, micron.com/support

Micron and the Micron logo are trademarks of Micron Technology, Inc.
All other trademarks are the property of their respective owners.

This data sheet contains minimum and maximum limits specified over the power supply and temperature range set forth herein. Although considered final, these specifications are subject to change, as further product development and data characterization sometimes occur.