

# LH28F004SU-Z1

4M (512K × 8) Flash Memory

## FEATURES

- 512K × 8 Word Configuration
- 5 V Write/Erase Operation (5 V  $V_{PP}$ )
  - No Requirement for DC/DC Converter to Write/Erase
- 100 ns Maximum Access Time
- 32 Independently Lockable Blocks (16K)
- 100,000 Erase Cycles per Block
- Automated Byte Write/Block Erase
  - Command User Interface
  - Status Register
  - $\overline{RY}/\overline{BY}$  Status Output
- System Performance Enhancement
  - Erase Suspend for Read
  - Two-Byte Write
  - Full Chip Erase
- Data Protection
  - Hardware Erase/Write Lockout during Power Transitions
  - Software Erase/Write Lockout
- Independently Lockable for Write/Erase on Each Block (Lock Block and Protect Set/Reset)
- 5  $\mu\text{A}$  (Typ.)  $I_{CC}$  in CMOS Standby
- 0.2  $\mu\text{A}$  (Typ.) Deep Power-Down
- State-of-the-Art 0.55  $\mu\text{m}$  ETOX™ Flash Technology
- 40-pin, 1.2 mm × 10 mm × 20 mm TSOP (Type I) Package

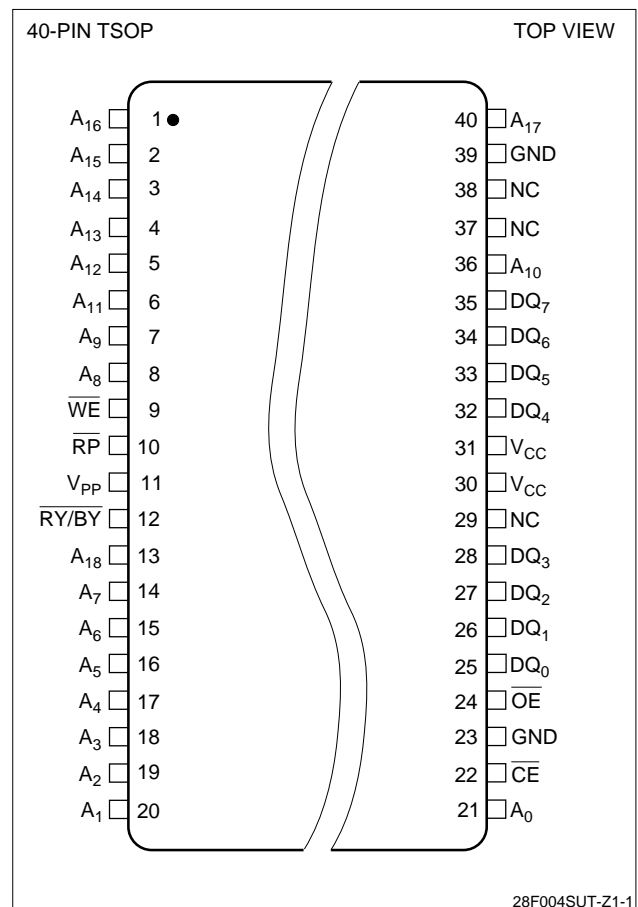
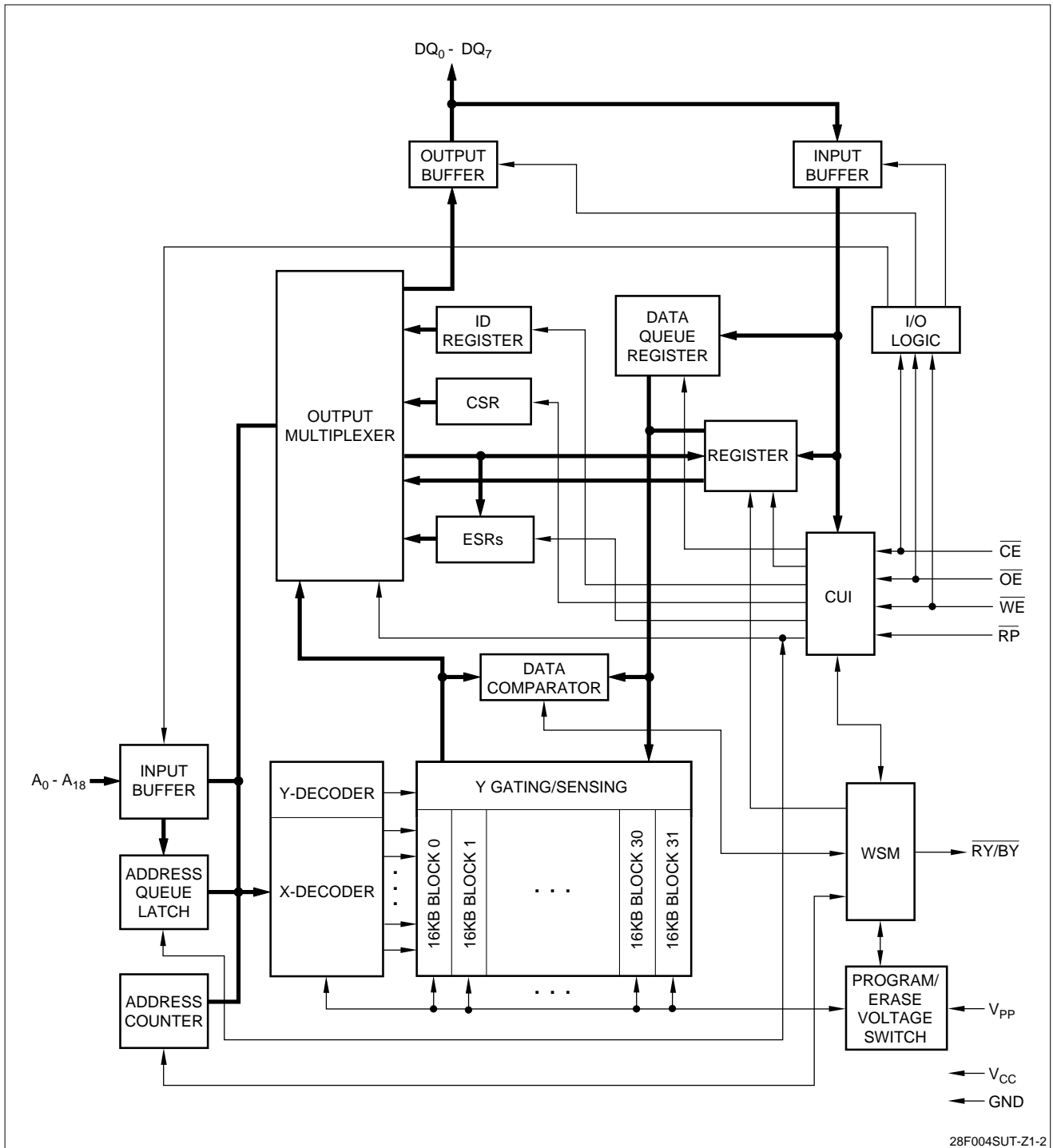


Figure 1. TSOP Configuration



28F004SUT-Z1-2

Figure 2. LH28F004SU-Z1 Block Diagram

## PIN DESCRIPTION

SYMBOL	TYPE	NAME AND FUNCTION
$A_0 - A_{13}$	INPUT	<b>WORD-SELECT ADDRESSES:</b> Select a word within one 16K block. These addresses are latched during Data Writes.
$A_{14} - A_{18}$	INPUT	<b>BLOCK-SELECT ADDRESSES:</b> Select 1 of 32 Erase blocks. These addresses are latched during Data Writes, Erase and Lock-Block operations.
$DQ_0 - DQ_7$	INPUT/OUTPUT	<b>DATA INPUT/OUTPUT:</b> Inputs data and commands during CUI write cycles. Outputs array, buffer, identifier or status data in the appropriate Read mode. Floated when the chip is de-selected or the outputs are disabled.
$\overline{CE}$	INPUT	<b>CHIP ENABLE INPUT:</b> Activate the device's control logic, input buffers, decoders and sense amplifiers. $\overline{CE}$ must be low to select the device.
$\overline{RP}$	INPUT	<b>RESET/POWER-DOWN:</b> $\overline{RP}$ low places the device in a Deep Power-Down state. All circuits that burn static power, even those circuits enabled in standby mode, are turned off. When returning from Deep Power-Down, a recovery time of 550 ns is required to allow these circuits to power-up. When $\overline{RP}$ goes low, any current or pending WSM operation(s) are terminated, and the device is reset. All Status Registers return to ready (with all status flags cleared).
$\overline{OE}$	INPUT	<b>OUTPUT ENABLE:</b> Gates device data through the output buffers when low. The outputs float to tri-state off when $\overline{OE}$ is high.
$\overline{WE}$	INPUT	<b>WRITE ENABLE:</b> Controls access to the CUI, Data Queue Registers and Address Queue Latches. $\overline{WE}$ is active low, and latches both address and data (command or array) on its rising edge.
$\overline{RY}/\overline{BY}$	OPEN DRAIN OUTPUT	<b>READY/BUSY:</b> Indicates status of the internal WSM. When low, it indicates that the WSM is busy performing an operation. When the WSM is ready for new operation or Erase is Suspended, or the device is in deep power-down mode $\overline{RY}/\overline{BY}$ pin is floated.
$V_{PP}$	SUPPLY	<b>ERASE/WRITE POWER SUPPLY (5.0 V ±0.5 V):</b> For erasing memory array blocks or writing words/bytes into the flash array.
$V_{CC}$	SUPPLY	<b>DEVICE POWER SUPPLY (5.0 V ±0.5 V):</b> Do not leave any power pins floating.
GND	SUPPLY	<b>GROUND FOR ALL INTERNAL CIRCUITRY:</b> Do not leave any ground pins floating.
NC		<b>NO CONNECT:</b> No internal connection to die, lead may be driven or left floating

## INTRODUCTION

Sharp's LH28F004SU-Z1 4M Flash Memory is a revolutionary architecture which enables the design of truly mobile, high performance, personal computing and communication products. With innovative capabilities, 5 V single voltage operation and very high read/write performance, the LH28F004SU-Z1 is also the ideal choice for designing embedded mass storage flash memory systems.

The LH28F004SU-Z1 is a very high density, highest performance non-volatile read/write solution for solid-state storage applications. Its independently lockable 32 symmetrical blocked architecture (16K each) extended cycling, low power operation, very fast write and read performance and selective block locking provide a highly flexible memory component suitable for high density memory cards, Resident Flash Arrays and PCMCIA-ATA Flash Drives. The LH28F004SU-Z1's single power supply operation enables the design of memory cards which can be read/written in 5.0 V systems. Its x8 architecture allows the optimization of memory to processor interface. The flexible block locking option enables bundling of executable application software in a Resident Flash Array or memory card. Manufactured on Sharp's 0.55  $\mu\text{m}$  ETOX™ process technology, the LH28F004SU-Z1 is the most cost-effective, high-density 5.0 V flash memory.

## Description

The LH28F004SU-Z1 is a high performance 4M (4,194,304 bit) block erasable non-volatile random access memory organized as 512K × 8. The LH28F004SU-Z1 includes thirty-two 16K (16,384) blocks. A chip memory map is shown in Figure 3.

The implementation of a new architecture, with many enhanced features, will improve the device operating characteristics and results in greater product reliability and ease of use.

Among the significant enhancements of the LH28F004SU-Z1:

- 5 V Read, Write/Erase Operations (5 V  $V_{CC}$ ,  $V_{PP}$ )
- Low Power Capability
- Improved Write Performance
- Dedicated Block Write/Erase Protection
- Command-Controlled Memory Protection Set/Reset Capability

The LH28F004SU-Z1 will be available in a 40-pin, 1.2 mm thick × 10 mm × 20 mm TSOP (Type I) package. This form factor and pinout allow for very high board layout densities.

A Commander User Interface (CUI) serves as the system interface between the microprocessor or microcontroller and the internal memory operation.

Internal Algorithm Automation allows Byte Writes and Block Erase operations to be executed using a Two-Write command sequence to the CUI in the same way as the LH28F008SA 8M Flash Memory.

A Superset of commands have been added to the basic LH28F008SA command-set to achieve higher write performance and provide additional capabilities. These new commands and features include:

- Software Locking of Memory Blocks
- Memory Protection Set/Reset Capability
- Two-Byte Successive Writes in 8-bit Systems
- Erase All Unlocked Blocks

Writing of memory data is performed typically within 13  $\mu\text{s}$ . A Block Erase operation erases one of the 32 blocks in typically 0.6 seconds, independent of the other blocks.

LH28F004SU-Z1 allows to erase all unlocked blocks. It is desirable in case you have to implement Erase operation maximum 32 times.

LH28F004SU-Z1 enables Two-Byte serial Write which is operated by three times command input. This feature can improve system write performance by up to typically 10  $\mu\text{s}$  per byte.

All operations are started by a sequence of Write commands to the device. Status Register (described in detail later) and a  $\overline{\text{RY}}/\overline{\text{BY}}$  output pin provide information on the progress of the requested operation.

Same as the LH28F008SA, LH28F004SU-Z1 requires an operation to complete before the next operation can be requested, also it allows to suspend block erase to read data from any other block, and allow to resume erase operation.

The LH28F004SU-Z1 provides user-selectable block locking to protect code or data such as Device Drivers, PCMCIA card information, ROM-Executable OS or Application Code. Each block has an associated non-volatile lock-bit which determines the lock status of the block. In addition, the LH28F004SU-Z1 has a software controlled master Write Protect circuit which prevents any modifications to memory blocks whose lock-bits are set.

When the device power-up or  $\overline{RP}$  turns High, Write Protect Set/Confirm command must be written. Otherwise, all lock bits in the device remain being locked, can't perform the Write to each block and single Block Erase. Write Protect Set/Confirm command must be written to reflect the actual lock status. However, when the device power-on or  $\overline{RP}$  turns High, Erase All Unlocked Blocks can be used. If used, Erase is performed with reflecting actual lock status, and after that Write and Block Erase can be used.

The LH28F004SU-Z1 contains Status Register to accomplish various functions:

- A Compatible Status Register (CSR) which is 100% compatible with the LH28F008SA Flash Memory's Status Register. This register, when used alone, provides a straightforward upgrade capability to the LH28F004SU-Z1 from a LH28F008SA based design.

The LH28F004SU-Z1 incorporates an open drain  $\overline{RY}/\overline{BY}$  output pin. This feature allows the user to OR-tie many  $\overline{RY}/\overline{BY}$  pins together in a multiple memory configuration such as a Resident Flash Array.

The LH28F004SU-Z1 is specified for a maximum access time of 100 ns ( $t_{ACC}$ ) at 5 V operation (4.5 to 5.5 V) over the commercial temperature range (0 to +70°C).

The LH28F004SU-Z1 incorporates an Automatic Power Saving (APS) feature which substantially reduces the active current when the device is in static mode of operation (addresses not switching).

In APS mode, the typical  $I_{CC}$  current is 2 mA at 5.0 V.

A Deep Power-Down mode of operation is invoked when the  $\overline{RP}$  (called  $\overline{PWD}$  on the LH28F008SA) pin transitions low. This mode brings the device power consumption to less than 5  $\mu$ A, and provides additional write protection by acting as a device reset pin during power transitions. A reset time of 550 ns is required from  $\overline{RP}$  switching high until outputs are again valid. In the Deep Power-Down state, the WSM is reset (any current operation will abort) and the CSR register is cleared.

A CMOS Standby mode of operation is enabled when  $\overline{CE}$  transitions high and  $\overline{RP}$  stays high with all input control pins at CMOS levels. In this mode, the device draws an  $I_{CC}$  standby current of 10  $\mu$ A.

## MEMORY MAP

7FFFFH	16KB BLOCK	31
7C000H	16KB BLOCK	30
7BFFFH	16KB BLOCK	30
78000H	16KB BLOCK	29
77FFFH	16KB BLOCK	29
74000H	16KB BLOCK	28
73FFFH	16KB BLOCK	28
70000H	16KB BLOCK	27
6FFFFH	16KB BLOCK	27
6C000H	16KB BLOCK	26
6BFFFH	16KB BLOCK	26
68000H	16KB BLOCK	25
67FFFH	16KB BLOCK	25
64000H	16KB BLOCK	24
63FFFH	16KB BLOCK	24
60000H	16KB BLOCK	23
5FFFFH	16KB BLOCK	23
5C000H	16KB BLOCK	22
5BFFFH	16KB BLOCK	22
58000H	16KB BLOCK	21
57FFFH	16KB BLOCK	21
54000H	16KB BLOCK	20
53FFFH	16KB BLOCK	20
50000H	16KB BLOCK	19
4FFFFH	16KB BLOCK	19
4C000H	16KB BLOCK	18
4BFFFH	16KB BLOCK	18
48000H	16KB BLOCK	17
47FFFH	16KB BLOCK	17
44000H	16KB BLOCK	16
43FFFH	16KB BLOCK	16
40000H	16KB BLOCK	15
3FFFFH	16KB BLOCK	15
3C000H	16KB BLOCK	14
3BFFFH	16KB BLOCK	14
38000H	16KB BLOCK	13
37FFFH	16KB BLOCK	13
34000H	16KB BLOCK	12
33FFFH	16KB BLOCK	12
30000H	16KB BLOCK	11
2FFFFH	16KB BLOCK	11
2C000H	16KB BLOCK	10
2BFFFH	16KB BLOCK	10
28000H	16KB BLOCK	9
27FFFH	16KB BLOCK	9
24000H	16KB BLOCK	8
23FFFH	16KB BLOCK	8
20000H	16KB BLOCK	7
1FFFFH	16KB BLOCK	7
1C000H	16KB BLOCK	6
1BFFFH	16KB BLOCK	6
18000H	16KB BLOCK	5
17FFFH	16KB BLOCK	5
14000H	16KB BLOCK	4
13FFFH	16KB BLOCK	4
10000H	16KB BLOCK	3
0FFFFH	16KB BLOCK	3
0C000H	16KB BLOCK	2
0BFFFH	16KB BLOCK	2
08000H	16KB BLOCK	1
07FFFH	16KB BLOCK	1
04000H	16KB BLOCK	0
03FFFH	16KB BLOCK	0
00000H	16KB BLOCK	0

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Figure 3. Memory Map

## BUS OPERATIONS, COMMANDS AND STATUS REGISTER DEFINITIONS

### Bus Operations

MODE	$\overline{RP}$	$\overline{CE}$	$\overline{OE}$	$\overline{WE}$	$A_0$	$DQ_{0-7}$	RY/BY#	NOTE
Read	$V_{IH}$	$V_{IL}$	$V_{IL}$	$V_{IH}$	X	$D_{OUT}$	X	1, 2, 7
Output Disable	$V_{IH}$	$V_{IL}$	$V_{IH}$	$V_{IH}$	X	High-Z	X	1, 6, 7
Standby	$V_{IH}$	$V_{IH}$	X	X	X	High-Z	X	1, 6, 7
Deep Power-Down	$V_{IL}$	X	X	X	X	High-Z	$V_{OH}$	1, 3
Manufacturer ID	$V_{IH}$	$V_{IL}$	$V_{IL}$	$V_{IH}$	$V_{IL}$	B0H	$V_{OH}$	4
Device ID	$V_{IH}$	$V_{IL}$	$V_{IL}$	$V_{IH}$	$V_{IH}$	ID	$V_{OH}$	4
Write	$V_{IH}$	$V_{IL}$	$V_{IH}$	$V_{IL}$	X	$D_{IN}$	X	1, 5, 6

#### NOTES:

- X can be  $V_{IH}$  or  $V_{IL}$  for address or control pins except for  $\overline{RY}/\overline{BY}$ , which is either  $V_{OL}$  or  $V_{OH}$ .
- $\overline{RY}/\overline{BY}$  output is open drain. When the WSM is ready, Erase is suspended or the device is in deep power-down mode,  $\overline{RY}/\overline{BY}$  will be at  $V_{OH}$  if it is tied to  $V_{CC}$  through a resistor. When the  $\overline{RY}/\overline{BY}$  at  $V_{OL}$  is independent of  $\overline{OE}$  while a WSM operation is in progress.
- $\overline{RP}$  at  $GND \pm 0.2 V$  ensures the lowest deep power-down current.
- $A_0$  at  $V_{IL}$  provide manufacturer ID codes.  $A_0$  at  $V_{IH}$  provide device ID codes. Device ID code = 21H. All other addresses are set to zero.
- Commands for different Erase operations, Data Write Operations, and lock-block operations can only be successfully completed when  $V_{PP} = V_{PPH}$ .
- While the WSM is running,  $\overline{RY}/\overline{BY}$  in Level-Mode (default) stays at  $V_{OL}$  until all operations are complete.  $\overline{RY}/\overline{BY}$  goes to  $V_{OH}$  when the WSM is not busy or in erase suspend mode.
- $\overline{RY}/\overline{BY}$  may be at  $V_{OL}$  while the WSM is busy performing various operations. For example, a status register read during a write operation.
- Only to  $\overline{RP}$ ,  $V_{IH} (MIN.) = 2.4 V$  at TTL-level input.

## LH28F008SA-Compatible Mode Command Bus Definitions

COMMAND	FIRST BUS CYCLE			SECOND BUS CYCLE			NOTE
	OPER.	ADDRESS	DATA	OPER.	ADDRESS	DATA	
Read Array	Write	X	FFH	Read	AA	AD	
Intelligent Identifier	Write	X	90H	Read	IA	ID	1
Read Compatible Status Register	Write	X	70H	Read	X	CSR D	2
Clear Status Register	Write	X	50H				3
Word Write	Write	X	40H	Write	WA	WD	
Alternate Word Write	Write	X	10H	Write	WA	WD	
Block Erase/Confirm	Write	X	20H	Write	BA	D0H	4
Erase Suspend/Resume	Write	X	B0H	Write	X	D0H	4

**ADDRESS**

AA = Array Address  
 BA = Block Address  
 IA = Identifier Address  
 WA = Write Address  
 X = Don't Care

**DATA**

AD = Array Data  
 CSR D = CSR Data  
 ID = Identifier Data  
 WD = Write Data

**NOTES:**

- Following the intelligent identifier command, two Read operations access the manufacturer and device signature codes.
- The CSR is automatically available after device enters Data Write, Erase or Suspend operations.
- Clears CSR.3, CSR.4, and CSR.5. See Status register definitions.
- While device performs Block Erase, if you issue Erase Suspend command (B0H), be sure to confirm ESS (Erase-Suspend-Status) is set to 1 on compatible status register. In the case, ESS bit was not set to 1, also completed the Erase (ESS = 0, WSMS = 1), be sure to issue Resume command (D0H) after completed next Erase command. Beside, when the Erase Suspend command is issued, while the device is not in Erase, be sure to issue Resume command (D0H) after the next erase complete.

## LH28F004SU-Z1 Performance Enhancement Command Bus Definitions

COMMAND	MODE	FIRST BUS CYCLE			SECOND BUS CYCLE			THIRD BUS CYCLE			NOTE
		OPER.	ADD.	DATA	OPER.	ADD.	DATA	OPER.	ADD.	DATA	
Protect Set/Confirm		Write	X	57H	Write	0FFH	D0H				1, 2
Protect Reset/Confirm		Write	X	47H	Write	0FFH	D0H				3
Lock Block/Confirm		Write	X	77H	Write	BA	D0H				1, 2, 4
Erase All Unlocked Blocks		Write	X	A7H	Write	X	D0H				1, 2
Two-Byte Write	x8	Write	X	FBH	Write	A10	WD (L, H)	Write	WA	WD (H, L)	1, 2, 5

**ADDRESS**

BA = Block Address  
 WA = Write Address  
 X = Don't Care

**DATA**

AD = Array Data  
 WD (L, H) = Write Data (Low, High)  
 WD (H, L) = Write Data (High, Low)

**NOTES:**

- After initial device power-up, or return from deep power-down mode, the block lock status bit default to the locked state independent of the data in the corresponding lock bits. In order to upload the lock bit status, it requires to write Protect Set/Confirm command.
- To reflect the actual lock-bit status, the Protect Set/Confirm command must be written after Lock Block/Confirm command.
- When Protect Reset/Confirm command is written, all blocks can be written and erased regardless of the state of the lock-bits.
- The Lock Block/Confirm command must be written after Protect Reset/Confirm command was written.
- A<sub>10</sub> is automatically complemented to load second byte of data A<sub>10</sub> value determines which WD is supplied first: A<sub>10</sub> = 0 looks at the WDL, A<sub>10</sub> = 1 looks at the WDH.
- Second bus cycle address of Protect Set/Confirm and Protect Reset/Confirm command is 0FFH. Specifically A<sub>9</sub> - A<sub>8</sub> = 0, A<sub>7</sub> - A<sub>0</sub> = 1, others are don't care.

**Compatible Status Register**

WSMS	ESS	ES	DWS	VPPS	R	R	R
7	6	5	4	3	2	1	0

<p>CSR.7 = WRITE STATE MACHINE STATUS (WSMS)                  1 = Ready                  2 = Busy</p> <p>CSR.6 = ERASE-SUSPEND STATUS (ESS)                  1 = Erase Suspended                  0 = Erase in Progress/Completed</p> <p>CSR.5 = ERASE STATUS (ES)                  1 = Error in Block Erasure                  0 = Successful Block Erase</p> <p>CSR.4 = DATA-WRITE STATUS (DWS)                  1 = Error in Data Write                  0 = Data Write Successful</p> <p>CSR.3 = V<sub>PP</sub> STATUS (VPPS)                  1 = V<sub>PP</sub> Low Detect, Operation Abort                  0 = V<sub>PP</sub> OK</p>	<p><b>NOTES:</b></p> <ol style="list-style-type: none"> <li>1. <math>\overline{R\bar{Y}}/\overline{B\bar{Y}}</math> output or WSMS bit must be checked to determine completion of an operation (Erase Suspend, Erase or Data Write) before the appropriate Status bit (ESS, ES or DWS) is checked for success.</li> <li>2. If DWS and ES are set to '1' during an erase attempt, an improper command sequence was entered. Clear the CSR and attempt the operation again.</li> <li>3. The VPPS bit, unlike an A/D converter, does not provide continuous indication of V<sub>PP</sub> level. The WSM interrogates V<sub>PP</sub>'s level only after the Data-Write or Erase command sequences have been entered, and informs the system if V<sub>PP</sub> has not been switched on. VPPS is not guaranteed to report accurate feedback between V<sub>PPL</sub> and V<sub>PPH</sub>.</li> <li>4. CSR.2 - CSR.0 = Reserved for further enhancements. These bits are reserved for future use and should be masked out when polling the CSR.</li> </ol>
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**4M FLASH MEMORY SOFTWARE ALGORITHMS**

**Overview**

With the advanced Command User Interface, its Performance Enhancement commands and Status Registers, the software code required to perform a given operation may become more intensive but it will result in much higher write/erase performance compared with current flash memory architectures.

The software flowcharts describing how a given operation proceeds are shown here. Figures 4 through 6 depict flowcharts using the 2nd generation flash device in the LH28F008SA-compatible mode. Figures 7 through 12 depict flowcharts using the 2nd generation flash device's performance enhancement commands mode.

When the device power-up or the device is reset by  $\overline{R\bar{P}}$  pin, all blocks come up locked. Therefore, Word Write, Two Byte Serial Write and Block Erase can not

be performed in each block. However, at that time, Erase All Unlocked Block is performed normally, if used, and reflect actual lock status, also the unlocked block data is erased. When the device power-up or the device is reset by  $\overline{R\bar{P}}$  pin, Set Write Protect command must be written to reflect actual block lock status.

Reset Write Protect command must be written before Write Block Lock command. To reflect actual block lock status, Set Write Protect command is succeeded.

Reset Write Protect command enables Write/Erase operation to each block.

In the case of Block Erase is performed, the block lock information is also erased. Block Lock command and Set Write Protect command must be written to prohibit Write/Erase operation to each block.

There are unassigned commands. It is not recommended that the customer use any command other than the valid commands specified in "Command Bus Definitions". Sharp reserved the right to redefine these codes for future functions.



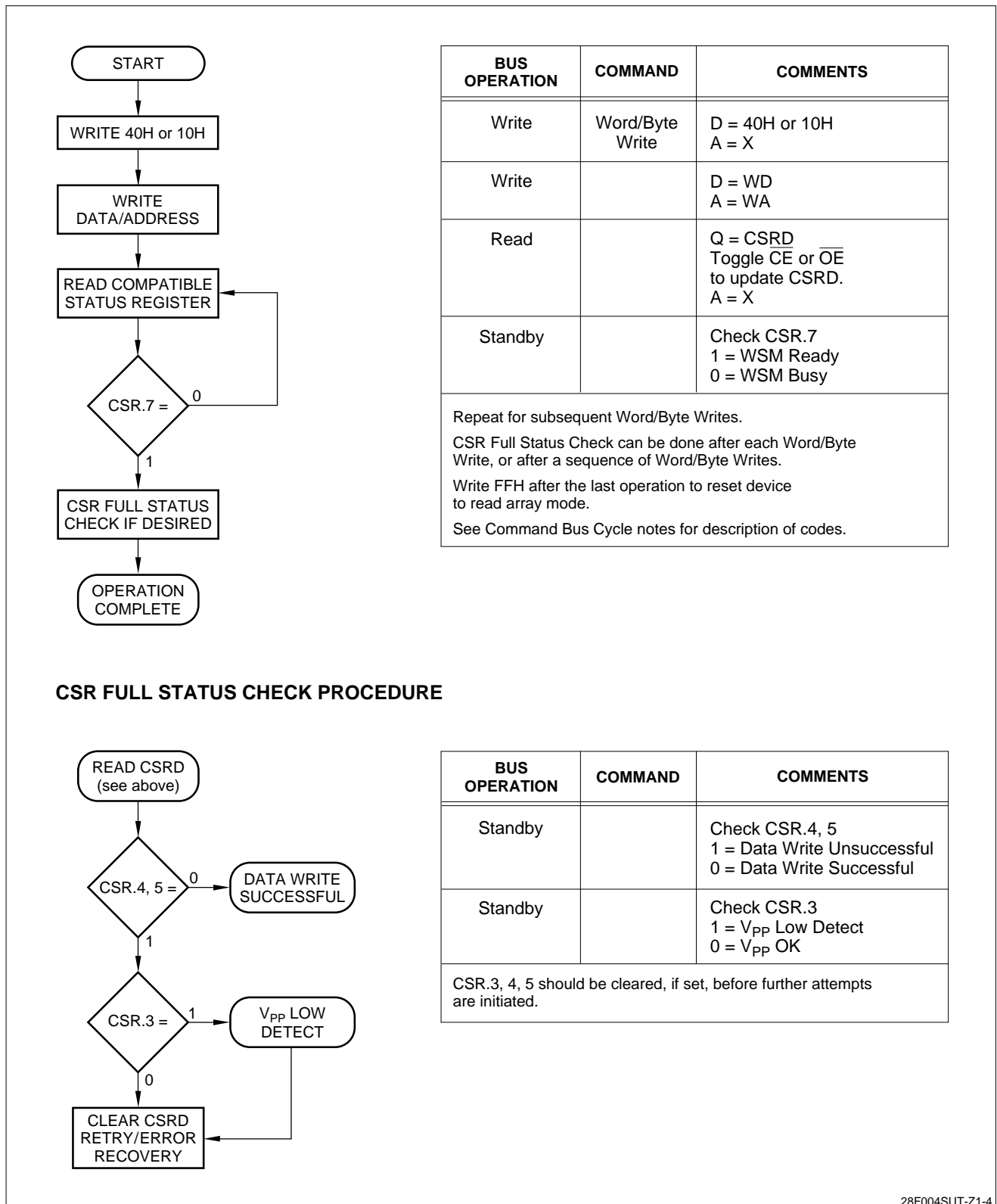


Figure 4. Word/Byte Writes with Compatible Status Register

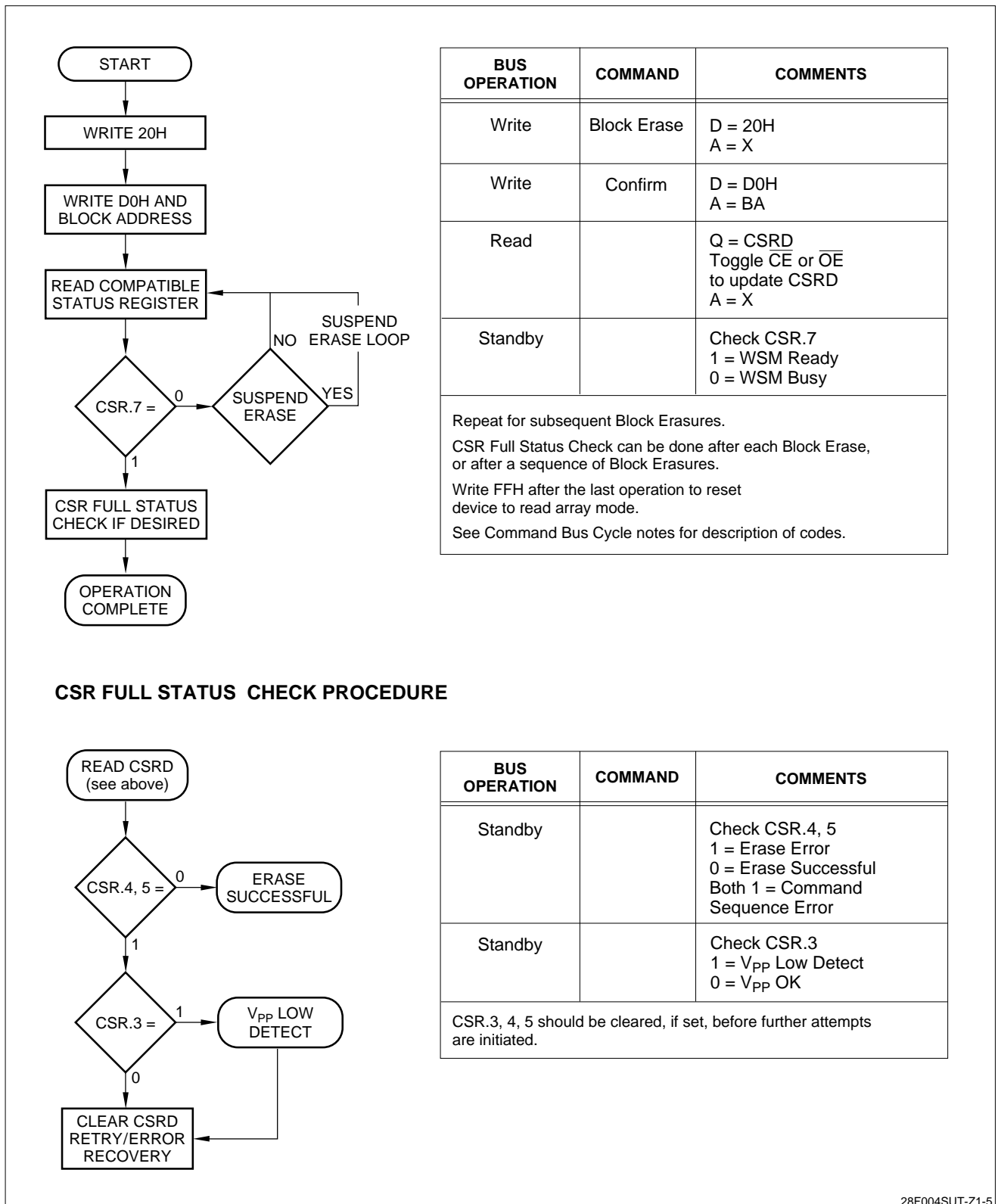


Figure 5. Block Erase with Compatible Status Register

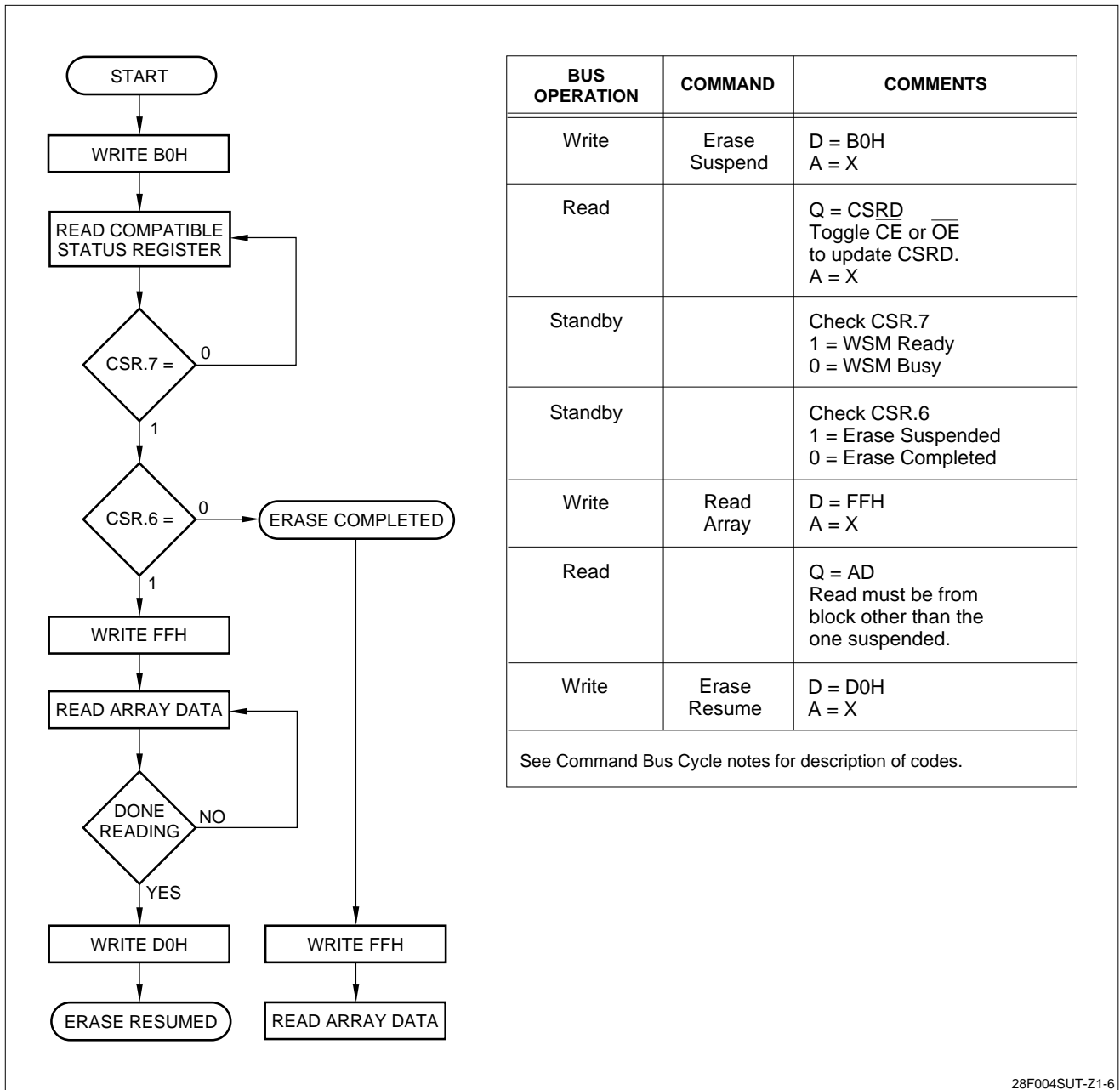


Figure 6. Erase Suspend to Read array with Compatible Status Register

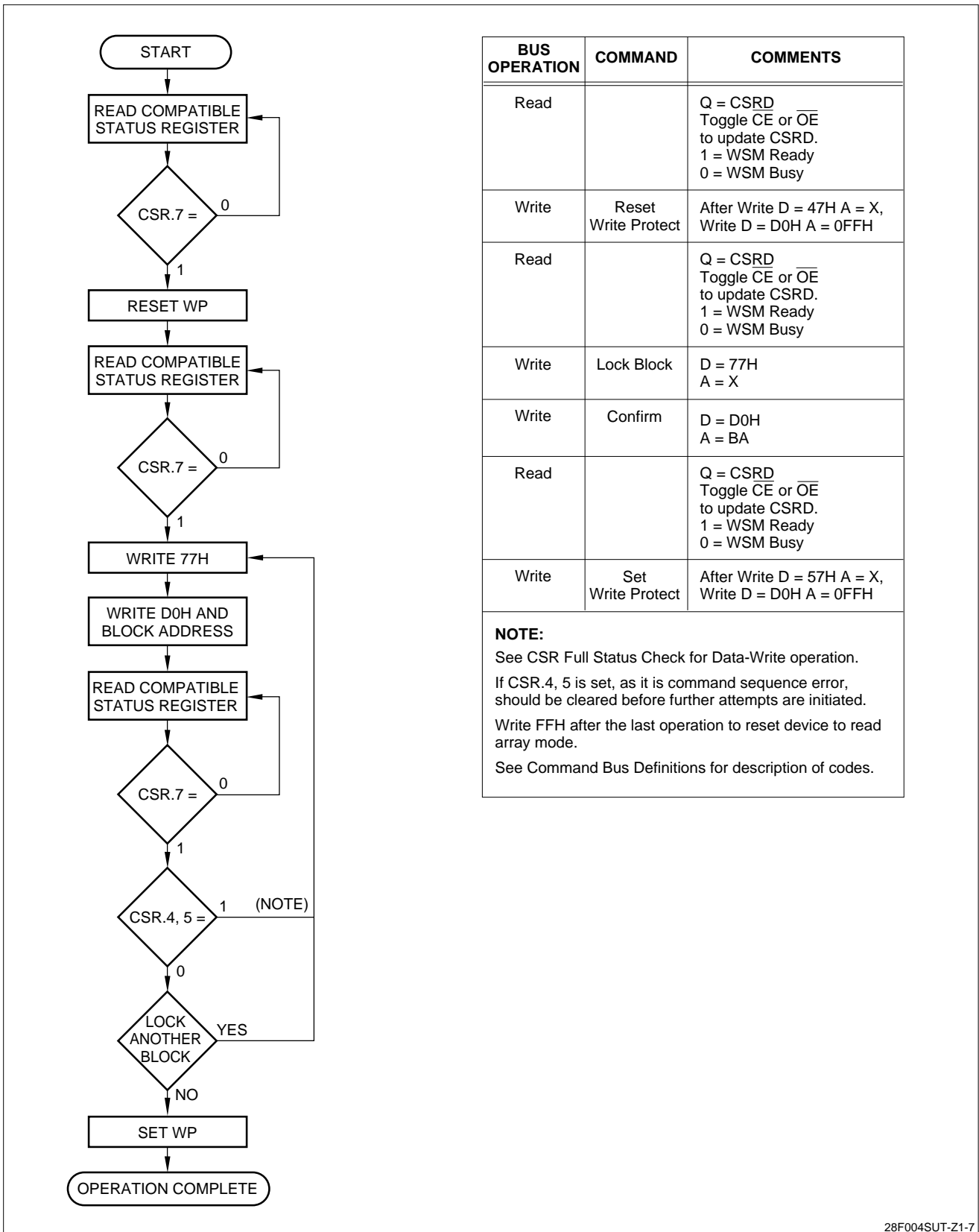


Figure 7. Block Locking Scheme

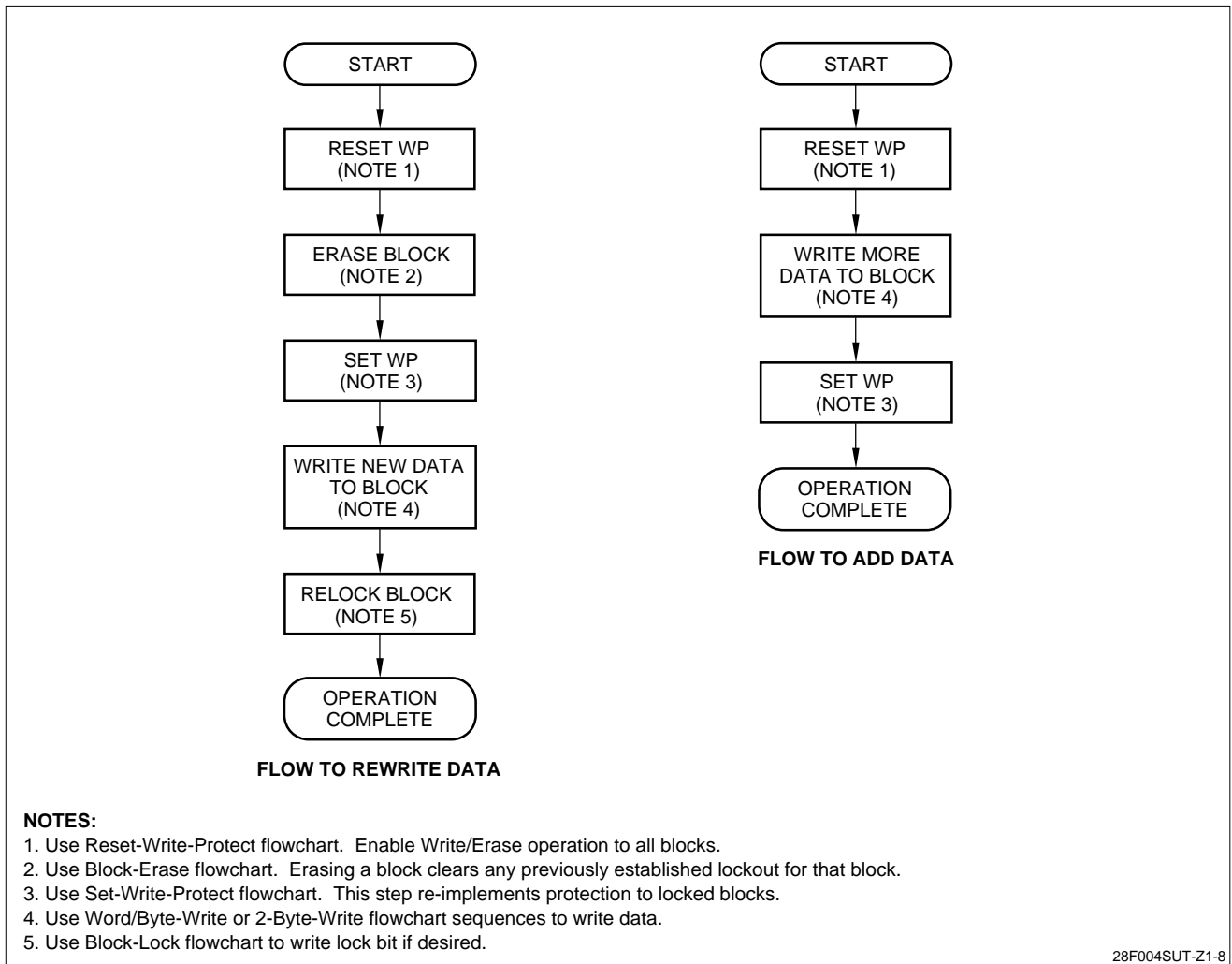
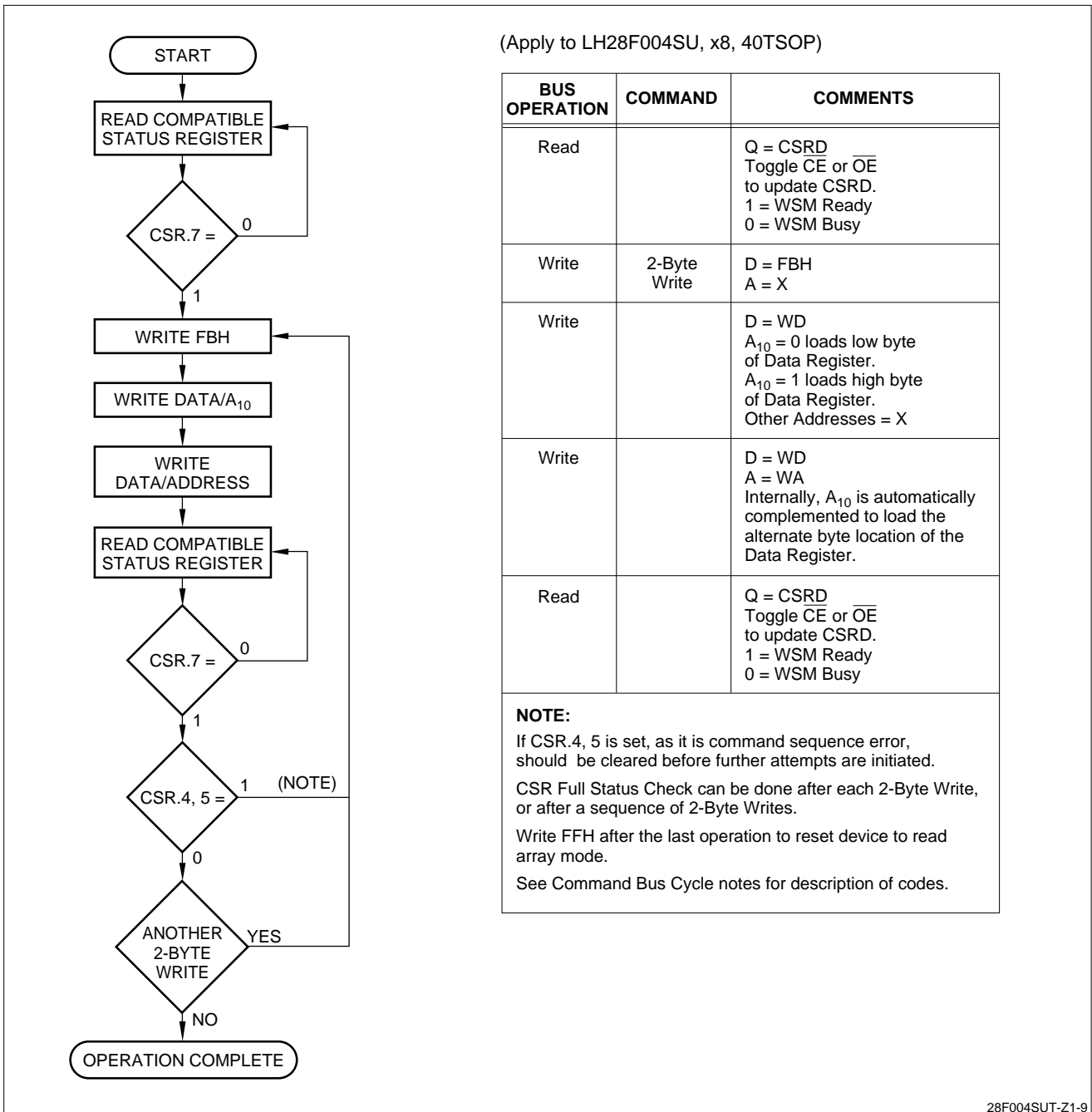


Figure 8. Updating Data in a Locked Block



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Figure 9. Two-Byte Serial Writes with Compatible Status Registers (40-pin TSOP)

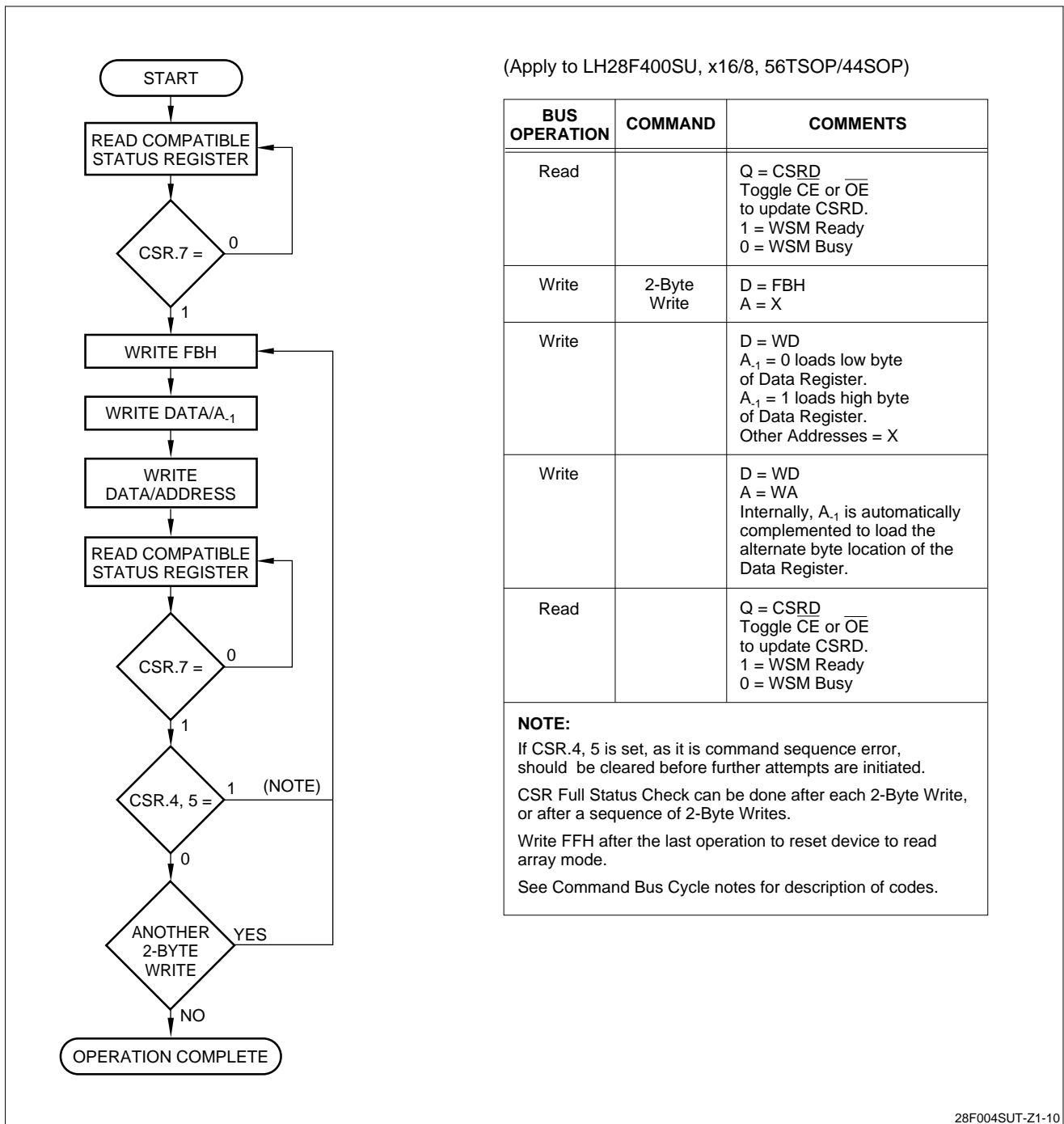
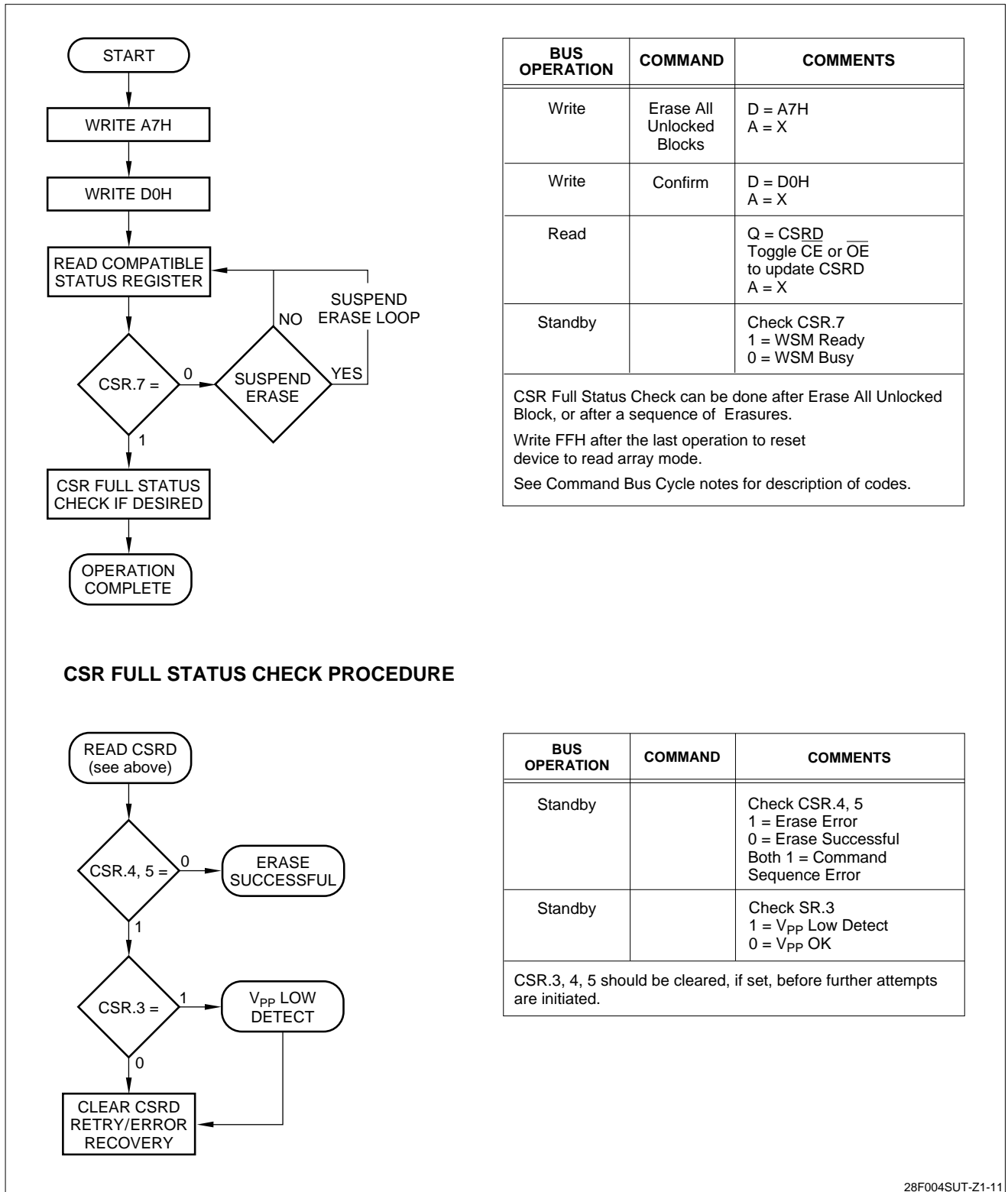


Figure 10. Two-Byte Serial Writes with Compatible Status Registers (56-pin TSOP, 44-pin SOP)



BUS OPERATION	COMMAND	COMMENTS
Write	Erase All Unlocked Blocks	D = A7H A = X
Write	Confirm	D = D0H A = X
Read		Q = CSRD Toggle CE or OE to update CSRD A = X
Standby		Check CSR.7 1 = WSM Ready 0 = WSM Busy

CSR Full Status Check can be done after Erase All Unlocked Block, or after a sequence of Erasures.  
 Write FFH after the last operation to reset device to read array mode.  
 See Command Bus Cycle notes for description of codes.

**CSR FULL STATUS CHECK PROCEDURE**

BUS OPERATION	COMMAND	COMMENTS
Standby		Check CSR.4, 5 1 = Erase Error 0 = Erase Successful Both 1 = Command Sequence Error
Standby		Check SR.3 1 = V <sub>PP</sub> Low Detect 0 = V <sub>PP</sub> OK

CSR.3, 4, 5 should be cleared, if set, before further attempts are initiated.

Figure 11. Erase All Unlocked Blocks with Compatible Status Registers

28F004SUT-Z1-11



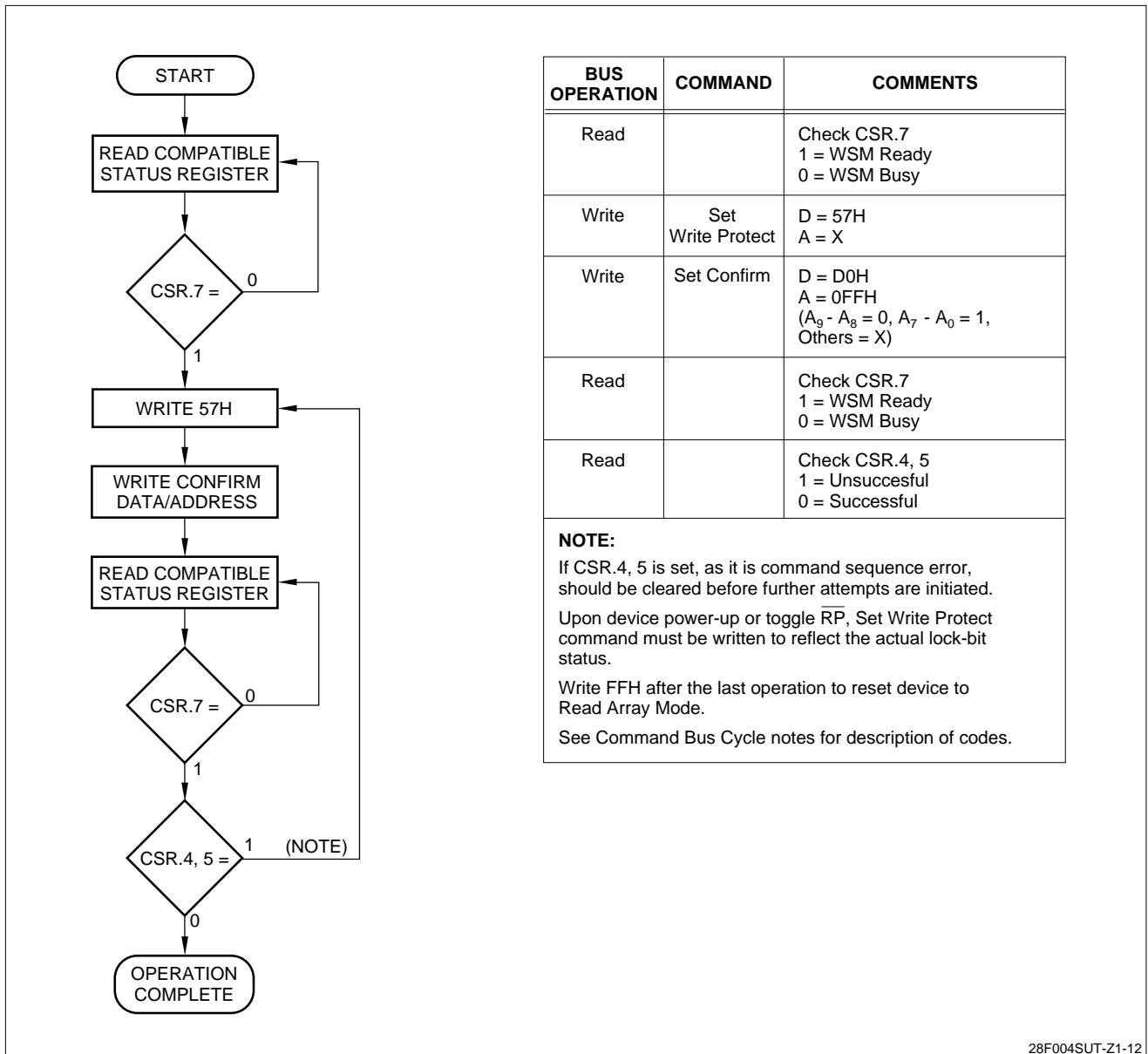


Figure 12. Set Write Protect

28F004SUT-Z1-12

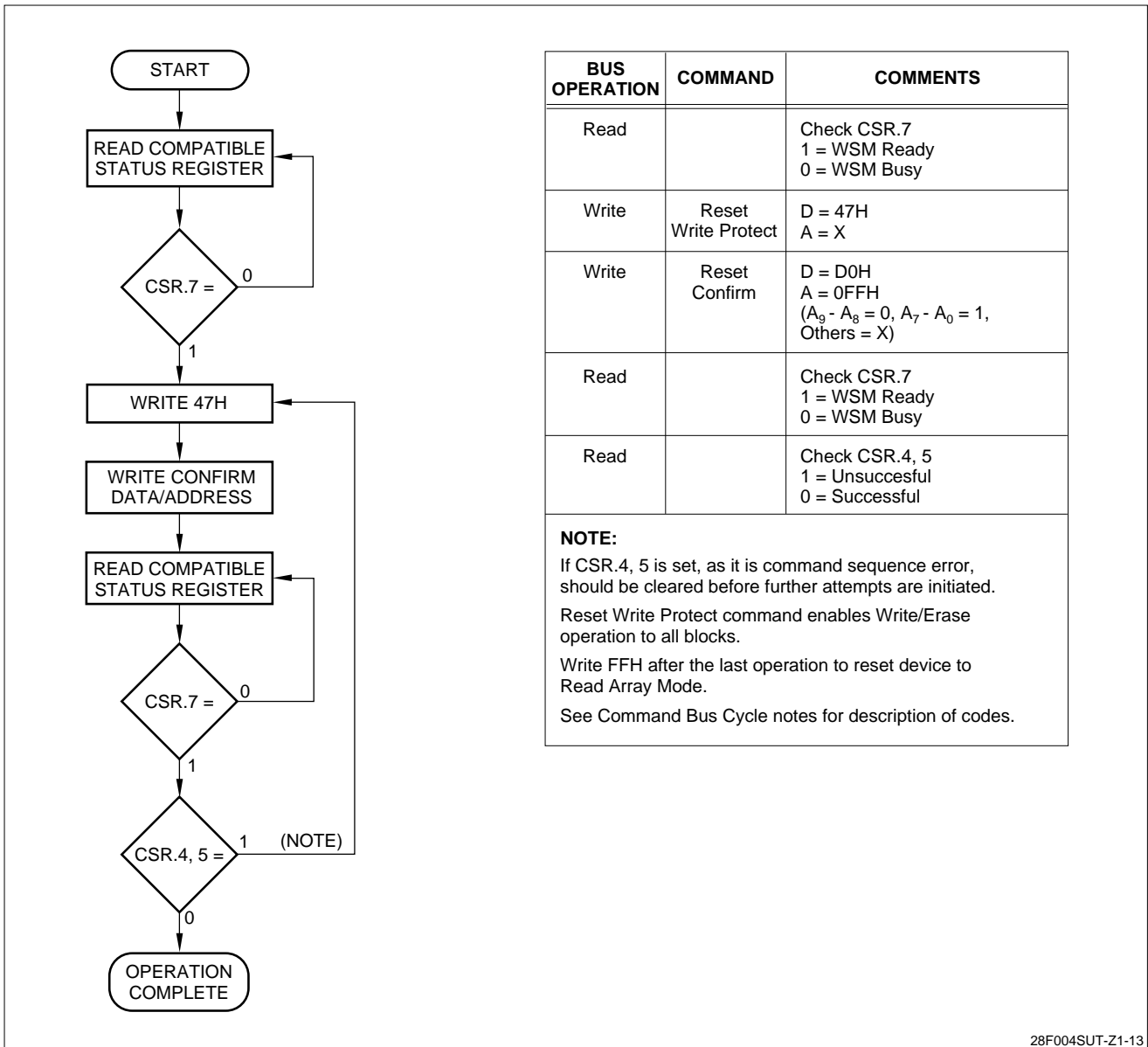


Figure 13. Reset Write Protect

**ELECTRICAL SPECIFICATIONS****Absolute Maximum Ratings\***

Temperature under bias ..... 0°C to +80°C

Storage temperature ..... -65°C to +125°C

*\*WARNING: Stressing the device beyond the “Absolute Maximum Ratings” may cause permanent damage. These are stress ratings only. Operation beyond the “Operating Conditions” is not recommended and extended exposure beyond the “Operating Conditions” may affect device reliability.*

**V<sub>CC</sub> = 5.0 V ± 0.5 V Systems<sup>4</sup>**

SYMBOL	PARAMETER	MIN.	MAX.	UNITS	TEST CONDITIONS	NOTE
T <sub>A</sub>	Operating Temperature, Commercial	0	70.0	°C	Ambient Temperature	1
V <sub>CC</sub>	V <sub>CC</sub> with Respect to GND	-0.2	7.0	V		2
V <sub>PP</sub>	V <sub>PP</sub> Supply Voltage with Respect to GND	-0.2	7.0	V		2
V	Voltage on any Pin (Except V <sub>CC</sub> , V <sub>PP</sub> ) with Respect to GND	-0.5	7.0	V		2
I	Current into any Non-Supply Pin		±30	mA		
I <sub>OUT</sub>	Output Short Circuit Current		100.0	mA		3

**NOTES:**

1. Operating temperature is for commercial product defined by this specification.
2. Minimum DC voltage is -0.5 V on input/output pins. During transitions, this level may undershoot to -2.0 V for periods < 20 ns. Maximum DC voltage on input/output pins is V<sub>CC</sub> + 0.5 V which, during transitions, may overshoot to V<sub>CC</sub> + 2.0 V for periods < 20 ns.
3. Output shorted for no more than one second. No more than one output shorted at a time.
4. AC specifications are valid at both voltage ranges. See DC Characteristics tables for voltage range-specific specifications.

**Capacitance****For 5.0 V Systems**

SYMBOL	PARAMETER	TYP.	MAX.	UNITS	TEST CONDITIONS	NOTE
C <sub>IN</sub>	Capacitance Looking into an Address/Control Pin	7	10	pF	T <sub>A</sub> = 25°C, f = 1.0 MHz	1
	Capacitance Looking into an Address/Control Pin A <sub>10</sub>	9	12	pF	T <sub>A</sub> = 25°C, f = 1.0 MHz	1
C <sub>OUT</sub>	Capacitance Looking into an Output Pin	9	12	pF	T <sub>A</sub> = 25°C, f = 1.0 MHz	1
C <sub>LOAD</sub>	Load Capacitance Driven by Outputs for Timing Specifications		100	pF	For V <sub>CC</sub> = 5.0 V ±0.5 V	1
	Equivalent Testing Load Circuit V <sub>CC</sub> ± 10%		2.5	ns	25 Ω transmission line delay	

**NOTE:**

1. Sampled, not 100% tested.

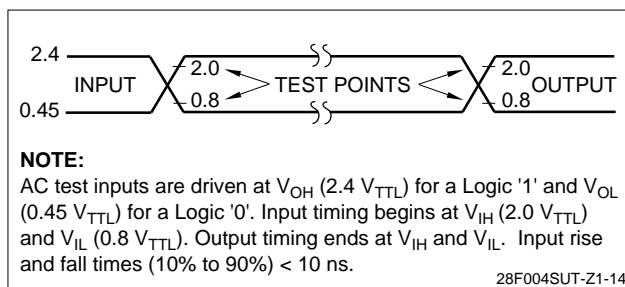
### Timing Nomenclature

For 5.0 V systems use the standard JEDEC cross point definitions.

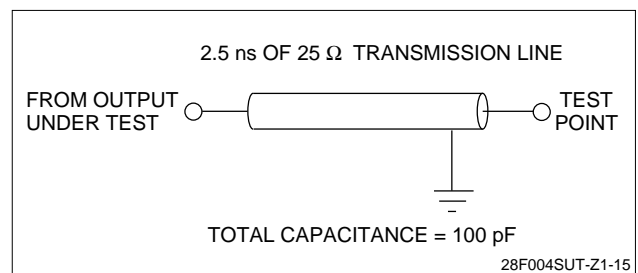
Each timing parameter consists of 5 characters. Some common examples are defined below:

- $t_{CE}$   $t_{ELQV}$  time (t) from  $\overline{CE}$  (E) going low (L) to the outputs (Q) becoming valid (V)
- $t_{OE}$   $t_{GLQV}$  time (t) from  $\overline{OE}$  (G) going low (L) to the outputs (Q) becoming valid (V)
- $t_{ACC}$   $t_{AVQV}$  time (t) from address (A) valid (V) to the outputs (Q) becoming valid (V)
- $t_{AS}$   $t_{AVWH}$  time (t) from address (A) valid (V) to  $\overline{WE}$  (W) going high (H)
- $t_{DH}$   $t_{WHDX}$  time (t) from  $\overline{WE}$  (W) going high (H) to when the data (D) can become undefined (X)

	PIN CHARACTERS		PIN STATES
A	Address Inputs	H	High
D	Data Inputs	L	Low
Q	Data Outputs	V	Valid
E	$\overline{CE}$ (Chip Enable)	X	Driven, but not necessarily valid
G	$\overline{OE}$ (Output Enable)	Z	High Impedance
W	$\overline{WE}$ (Write Enable)		
P	$\overline{RP}$ (Deep Power-Down Pin)		
R	$\overline{RY}/\overline{BY}$ (Ready/Busy)		
V	Any Voltage Level		
5 V	$V_{CC}$ at 4.5 V Min.		



**Figure 14. Transient Input/Output Reference Waveform ( $V_{CC} = 5.0 V$ )**



**Figure 15. Transient Equivalent Testing Load Circuit ( $V_{CC} = 5.0 V$ )**

## DC Characteristics

$$V_{CC} = 5.0\text{ V} \pm 0.5\text{ V}, T_A = 0^\circ\text{C to } +70^\circ\text{C}$$

SYMBOL	PARAMETER	TYP.	MIN.	MAX.	UNITS	TEST CONDITIONS	NOTE
$I_{IL}$	Input Load Current			$\pm 1$	$\mu\text{A}$	$V_{CC} = V_{CC\text{ MAX.}}, V_{IN} = V_{CC}$ or GND	1
$I_{LO}$	Output Leakage Current			$\pm 10$	$\mu\text{A}$	$V_{CC} = V_{CC\text{ MAX.}}, V_{IN} = V_{CC}$ or GND	1
$I_{CCS}$	$V_{CC}$ Standby Current	5		10	$\mu\text{A}$	$V_{CC} = V_{CC\text{ MAX.}},$ $\overline{CE}, \overline{RP} = V_{CC} \pm 0.2\text{ V}$	1,4
		1		4	$\text{mA}$	$V_{CC} = V_{CC\text{ MAX.}},$ $\overline{CE}, \overline{RP} = V_{IH}$	
$I_{CCD}$	$V_{CC}$ Deep Power-Down Current	0.2		5	$\mu\text{A}$	$\overline{RP} = \text{GND} \pm 0.2\text{ V}$	1
$I_{CCR}^1$	$V_{CC}$ Read Current			60	$\text{mA}$	$V_{CC} = V_{CC\text{ MAX.}},$ CMOS: $\overline{CE} = \text{GND} \pm 0.2\text{ V}$ Inputs = GND $\pm 0.2\text{ V}$ or $V_{CC} \pm 0.2\text{ V}$ TTL: $\overline{CE} = V_{IL}$ Inputs = $V_{IL}$ or $V_{IH}$ $f = 10\text{ MHz}, I_{OUT} = 0\text{ mA}$	1, 3, 4
$I_{CCR}^2$	$V_{CC}$ Read Current	13		30	$\text{mA}$	$V_{CC} = V_{CC\text{ MAX.}},$ CMOS: $\overline{CE} = \text{GND} \pm 0.2\text{ V}$ Inputs = GND $\pm 0.2\text{ V}$ or $V_{CC} \pm 0.2\text{ V}$ TTL: $\overline{CE} = V_{IL}$ Inputs = $V_{IL}$ or $V_{IH}$ $f = 5\text{ MHz}, I_{OUT} = 0\text{ mA}$	1, 3, 4
$I_{CCW}$	$V_{CC}$ Write Current	18		35	$\text{mA}$	Byte/Two-Byte Serial Write in Progress	1
$I_{CCE}$	$V_{CC}$ Block Erase Current	18		25	$\text{mA}$	Block Erase in Progress	1
$I_{CCES}$	$V_{CC}$ Erase Suspend Current	5		10	$\text{mA}$	$\overline{CE} = V_{IH}$ Block Erase Suspended	1, 2
$I_{PPS}$	$V_{CC}$ Standby Current			$\pm 10$	$\mu\text{A}$	$V_{PP} \leq V_{CC}$	1
$I_{PPD}$	$V_{PP}$ Deep Power-Down Current	0.2		5	$\mu\text{A}$	$\overline{RP} = \text{GND} \pm 0.2\text{ V}$	1

## DC Characteristics (Continued)

$$V_{CC} = 5.0\text{ V} \pm 0.5\text{ V}, T_A = 0^\circ\text{C to } +70^\circ\text{C}$$

SYMBOL	PARAMETER	TYPE	MIN.	MAX.	UNITS	TEST CONDITIONS	NOTE
$I_{PPR}$	$V_{PP}$ Read Current	65		200	$\mu\text{A}$	$V_{PP} > V_{CC}$	1
$I_{PPW}$	$V_{PP}$ Write Current	15		35	mA	$V_{PP} = V_{PPH}$ , Byte/Two-Byte Serial Write in Progress	1
$I_{PPE}$	$V_{PP}$ Erase Current	20		40	mA	$V_{PP} = V_{PPH}$ , Block Erase in Progress	1
$I_{PPES}$	$V_{PP}$ Erase Suspend Current	65		200	$\mu\text{A}$	$V_{PP} = V_{PPH}$ , Block Erase Suspended	1
$V_{IL}$	Input Low Voltage		-0.5	0.8	V		5
$V_{IH}$	Input High Voltage		2.0	$V_{CC} + 0.5$	V		
$V_{OL}$	Output Low Voltage			0.45	V	$V_{CC} = V_{CC}$ MIN. and $I_{OL} = 5.8\text{ mA}$	
$V_{OH}^1$	Output High Voltage		$0.85 V_{CC}$		V	$I_{OL} = -2.5\text{ mA}$ $V_{CC} = V_{CC}$ MIN.	
$V_{OH}^2$			$V_{CC} - 0.4$		V	$I_{OL} = -100\ \mu\text{A}$ $V_{CC} = V_{CC}$ MIN.	
$V_{PPL}$	$V_{PP}$ during Normal Operations		0.0	5.5	V		
$V_{PPH}$	$V_{PP}$ during Write/Erase Operations	5.0	4.5	5.5	V		
$V_{LKO}$	$V_{CC}$ Erase/Write Lock Voltage		1.4		V		

## NOTES:

- All currents are in RMS unless otherwise noted. Typical values at  $V_{CC} = 5.0\text{ V}$ ,  $V_{PP} = 5.0\text{ V}$ ,  $T = 25^\circ\text{C}$ . These currents are valid for all product versions (package and speeds).
- $I_{CCES}$  is specified with the device de-selected. If the device is read while in erase suspend mode, current draw is the sum of  $I_{CCES}$  and  $I_{CCR}$ .
- Automatic Power Saving (APS) reduces  $I_{CCR}$  to less than 2 mA in Static operation.
- CMOS inputs are either  $V_{CC} \pm 0.2\text{ V}$  or  $\text{GND} \pm 0.2\text{ V}$ . TTL Inputs are either  $V_{IL}$  or  $V_{IH}$ .
- Only to  $\overline{\text{RP}}$ ,  $V_{IH}$  (Min.) = 2.4 V at TTL-level input.

**AC Characteristics - Read Only Operations<sup>1</sup>**

$$V_{CC} = 5.0\text{ V} \pm 0.5\text{ V}, T_A = 0^\circ\text{C to } +70^\circ\text{C}$$

SYMBOL	PARAMETER	MIN.	MAX.	UNITS	NOTE
$t_{AVAV}$	Read Cycle Time	100		ns	
$t_{AVGL}$	Address Setup to $\overline{OE}$ Going Low	0		ns	3
$t_{AVQV}$	Address to Output Delay		100	ns	
$t_{ELQV}$	$\overline{CE}$ to Output Delay		100	ns	2
$t_{PHQV}$	$\overline{RP}$ High to Output Delay		550	ns	4
$t_{GLQV}$	$\overline{OE}$ to Output Delay		40	ns	2
$t_{ELQX}$	$\overline{CE}$ to Output in Low Z	0		ns	3
$t_{EHQZ}$	$\overline{CE}$ to Output in High Z		35	ns	3
$t_{GLQX}$	$\overline{OE}$ to Output in Low Z	0		ns	3
$t_{GHQZ}$	$\overline{OE}$ to Output in High Z		35	ns	3
$t_{OH}$	Output Hold from Address, $\overline{CE}$ or $\overline{OE}$ change, whichever occurs first	0		ns	3

**NOTES:**

1. See AC Input/Output Reference Waveforms for timing measurements, Figure 4.
2.  $\overline{OE}$  may be delayed up to  $t_{ELQV} - t_{GLQV}$  after the falling edge of  $\overline{CE}$  without impact on  $t_{ELQV}$ .
3. Sampled, not 100% tested.
4. Only to  $\overline{RP}$ ,  $V_{IH}$  (MIN.) = 2.4 V.

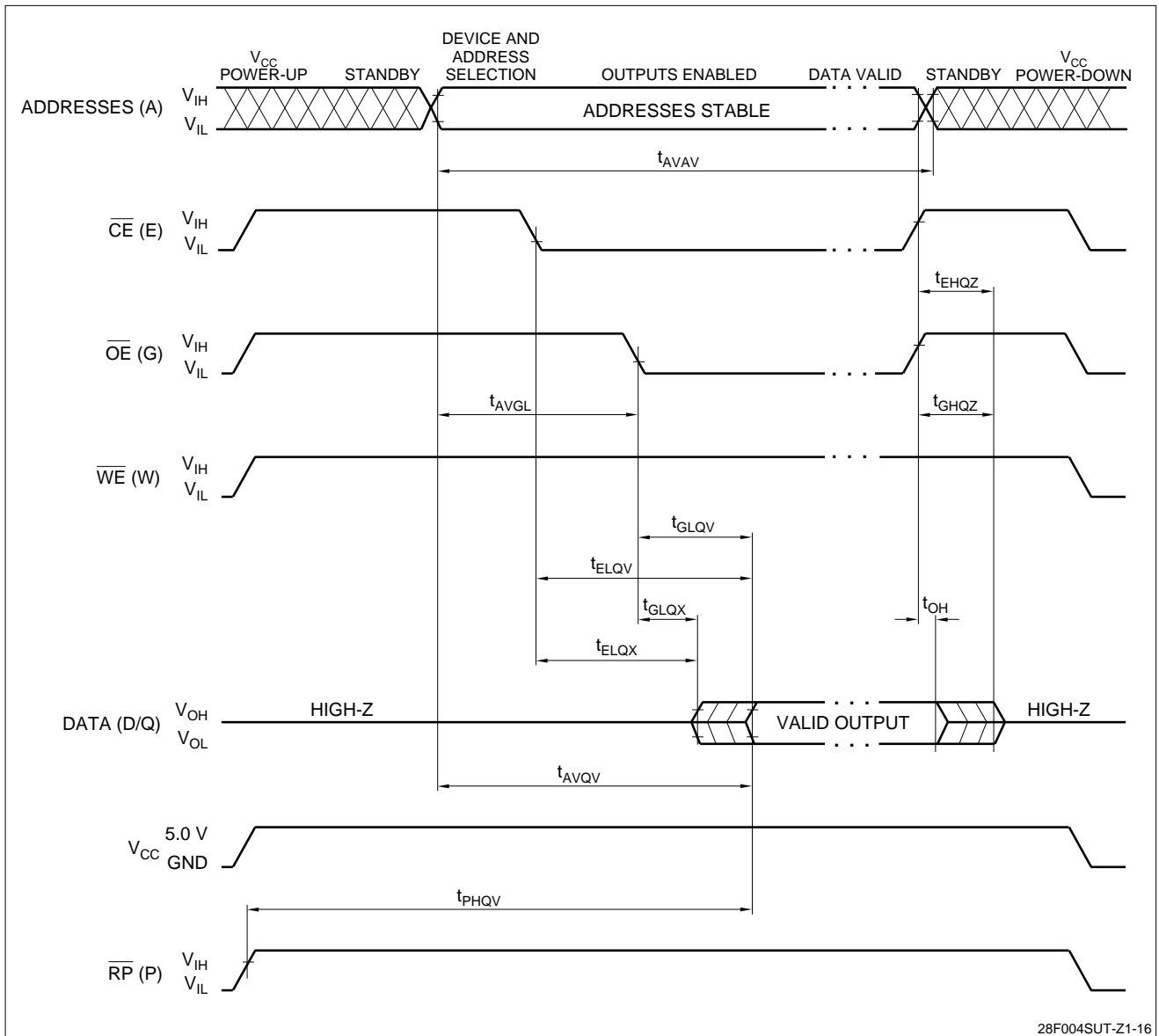
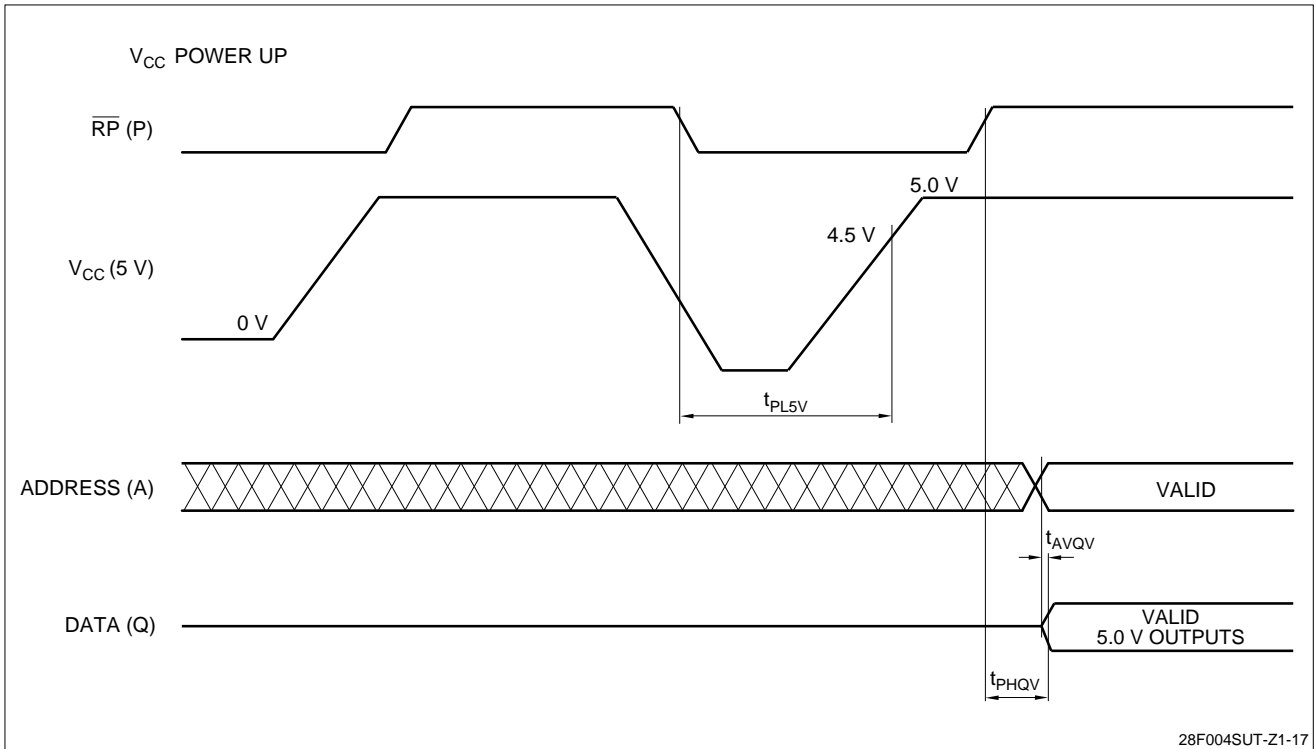


Figure 16. Read Timing Waveforms

28F004SUT-Z1-16



**POWER-UP AND RESET TIMINGS**



**Figure 17. V<sub>CC</sub> Power-Up and  $\overline{RP}$  Reset Waveforms**

SYMBOL	PARAMETER	MIN.	MAX.	UNITS	NOTE
$t_{PL5V}$	$\overline{RP}\#$ Low to $V_{CC}$ at 4.5 V MIN.	0		$\mu s$	1
$t_{AVQV}$	Address Valid to Data Valid for $V_{CC}$ 5 V $\pm$ 10%		100	ns	2
$t_{PHQV}$	$\overline{RP}\#$ High to Data Valid for $V_{CC}$ 5 V $\pm$ 10%		550	ns	2

**NOTES:**

$\overline{CE}$  and  $\overline{OE}$  are switched low after Power-Up.

1. The power supply may start to switch concurrently with  $\overline{RP}$  going Low.
2. The address access time and  $\overline{RP}$  high to data valid time are shown for 5 V  $V_{CC}$  operation. Refer to the AC Characteristics Read Only Operations also.

**AC Characteristics for  $\overline{WE}$  - Controlled Command Write Operations<sup>1</sup>**

$$V_{CC} = 5.0\text{ V} \pm 0.5\text{ V}, T_A = 0^\circ\text{C to } +70^\circ\text{C}$$

SYMBOL	PARAMETER	TYP.	MIN.	MAX.	UNITS	NOTE
$t_{AVAV}$	Write Cycle Time		100		ns	
$t_{VPWH}$	$V_{PP}$ Set up to $\overline{WE}$ Going High		100		ns	3
$t_{PHEL}$	$\overline{RP}$ Setup to $\overline{CE}$ Going Low		480		ns	
$t_{ELWL}$	$\overline{CE}$ Setup to $\overline{WE}$ Going Low		0		ns	
$t_{AVWH}$	Address Setup to $\overline{WE}$ Going High		60		ns	2, 6
$t_{DVWH}$	Data Setup to $\overline{WE}$ Going High		60		ns	2, 6
$t_{WLWH}$	$\overline{WE}$ Pulse Width		60		ns	
$t_{WHDX}$	Data Hold from $\overline{WE}$ High		0		ns	2
$t_{WHAX}$	Address Hold from $\overline{WE}$ High		10		ns	2
$t_{WHEH}$	$\overline{CE}$ Hold from $\overline{WE}$ High		10		ns	
$t_{WHWL}$	$\overline{WE}$ Pulse Width High		50		ns	
$t_{GHWL}$	Read Recovery before Write		0		ns	
$t_{WHRL}$	$\overline{WE}$ High to $\overline{RY}/\overline{BY}$ Going Low			100	ns	
$t_{RHPL}$	$\overline{RP}$ Hold from Valid Status Register Data and $\overline{RY}/\overline{BY}$ High		0		ns	3
$t_{PHWL}$	$\overline{RP}$ High Recovery to $\overline{WE}$ Going Low		1		$\mu\text{s}$	
$t_{WHGL}$	Write Recovery before Read		80		ns	
$t_{QVVL}$	$V_{PP}$ Hold from Valid Status Register Data and $\overline{RY}/\overline{BY}$ High		0		$\mu\text{s}$	
$t_{WHQV}^1$	Duration of Byte Write Operation	13	4.5		$\mu\text{s}$	4, 5
$t_{WHQV}^2$	Duration of Block Erase Operation		0.3		s	4

**NOTES:**

1. Read timing during write and erase are the same as for normal read.
2. Refer to command definition tables for valid address and data values.
3. Sampled, but not 100% tested.
4. Write/Erase durations are measured to valid Status Register (CSR) Data.
5. Byte write operations are typically performed with 1 Programming Pulse.
6. Address and Data are latched on the rising edge of  $\overline{WE}$  for all Command Write operations.

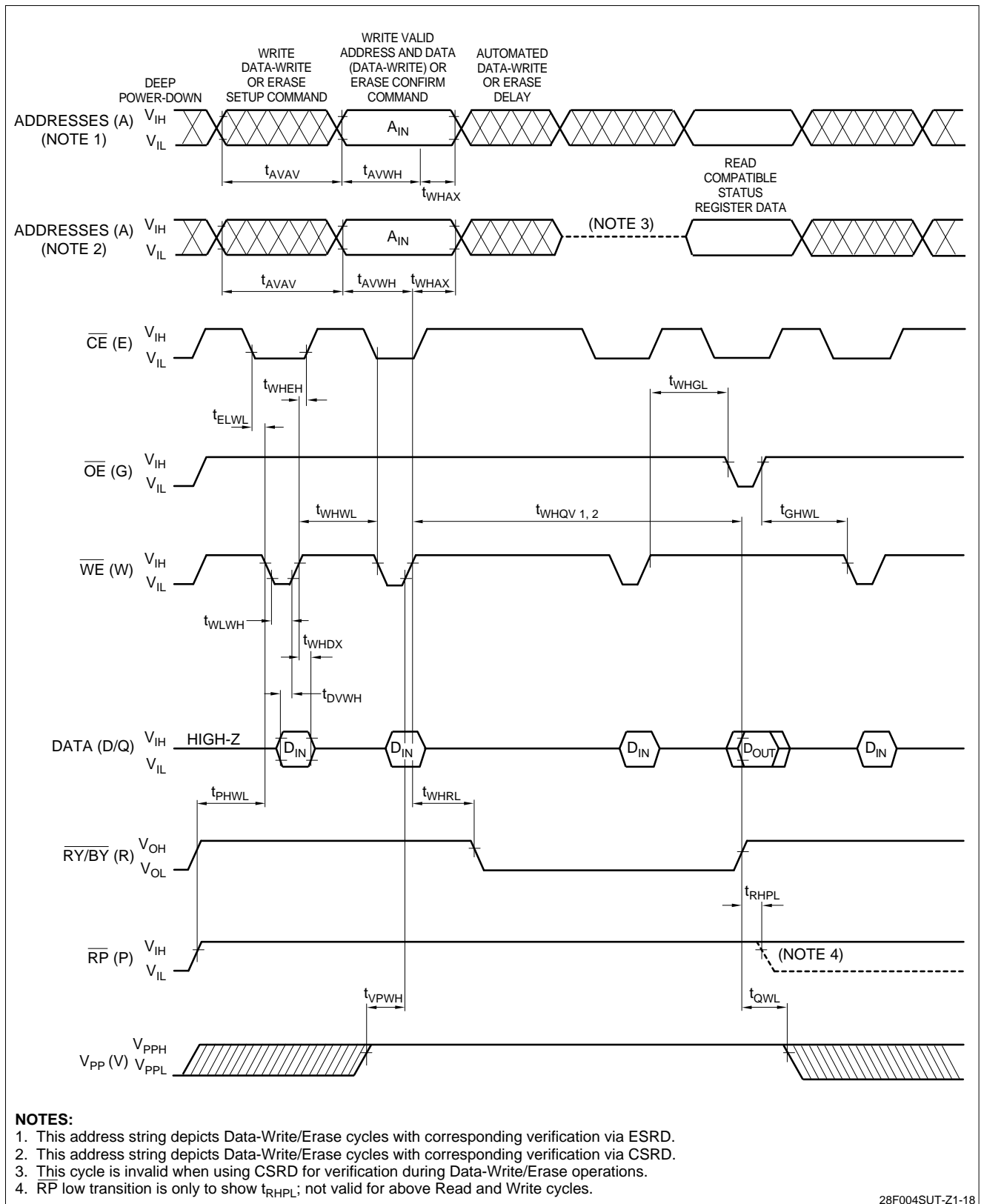


Figure 18. AC Waveforms for Command Write Operations

**AC Characteristics for  $\overline{CE}$  - Controlled Command Write Operations<sup>1</sup>**

$$V_{CC} = 5.0\text{ V} \pm 0.5\text{ V}, T_A = 0^\circ\text{C to } +70^\circ\text{C}$$

SYMBOL	PARAMETER	TYP.	MIN.	MAX.	UNITS	NOTE
$t_{AVAV}$	Write Cycle Time		100		ns	
$t_{PHWL}$	$\overline{RP}$ Setup to $\overline{WE}$ Going Low		480		ns	3
$t_{VPEH}$	$V_{PP}$ Setup to $\overline{CE}$ Going High		100		ns	3
$t_{WLEL}$	$\overline{WE}$ Setup to $\overline{CE}$ Going Low		0		ns	
$t_{AVEH}$	Address Setup to $\overline{CE}$ Going High		60		ns	2, 6
$t_{DVEH}$	Data Setup to $\overline{CE}$ Going High		60		ns	2, 6
$t_{ELEH}$	$\overline{CE}$ Pulse Width		60		ns	
$t_{EHDX}$	Data Hold from $\overline{CE}$ High		0		ns	2
$t_{EHAX}$	Address Hold from $\overline{CE}$ High		10		ns	2
$t_{EHWH}$	$\overline{WE}$ Hold from $\overline{CE}$ High		10		ns	
$t_{EHEL}$	$\overline{CE}$ Pulse Width High		50		ns	
$t_{GHLE}$	Read Recovery before Write		0		ns	
$t_{EHRL}$	$\overline{CE}$ High to $\overline{RY}/\overline{BY}$ Going Low			100	ns	
$t_{RHPL}$	$\overline{RP}$ Hold from Valid Status Register Data and $\overline{RY}/\overline{BY}$ High		0		ns	3
$t_{PHEL}$	$\overline{RP}$ High Recovery to $\overline{CE}$ Going Low		1		$\mu\text{s}$	
$t_{EHGL}$	Write Recovery before Read		80		ns	
$t_{QVVL}$	$V_{PP}$ Hold from Valid Status Register Data and $\overline{RY}/\overline{BY}\#$ High		0		$\mu\text{s}$	
$t_{EHQV}^1$	Duration of Byte Write Operation	13	4.5		$\mu\text{s}$	4, 5
$t_{EHQV}^2$	Duration of Block Erase Operation		0.3		s	4

**NOTES:**

1. Read timing during write and erase are the same as for normal read.
2. Refer to command definition tables for valid address and data values.
3. Sampled, but not 100% tested.
4. Write/Erase durations are measured to valid Status Register (CSR) Data.
5. Byte Write operations are typically performed with 1 Programming Pulse.
6. Address and Data are latched on the rising edge of  $\overline{CE}$  for all Command Write operations.

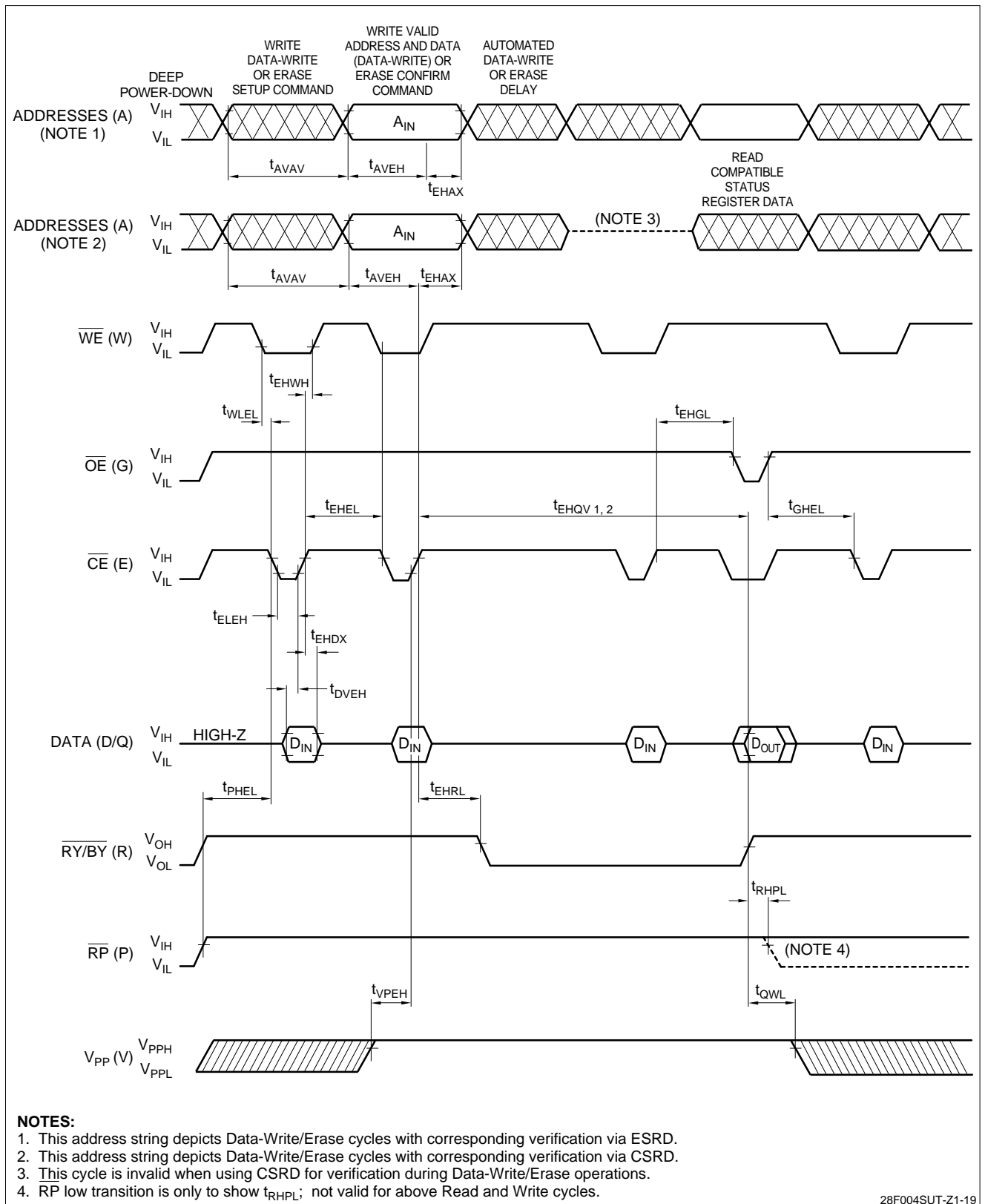


Figure 19. Alternate AC Waveforms for Command Write Operations

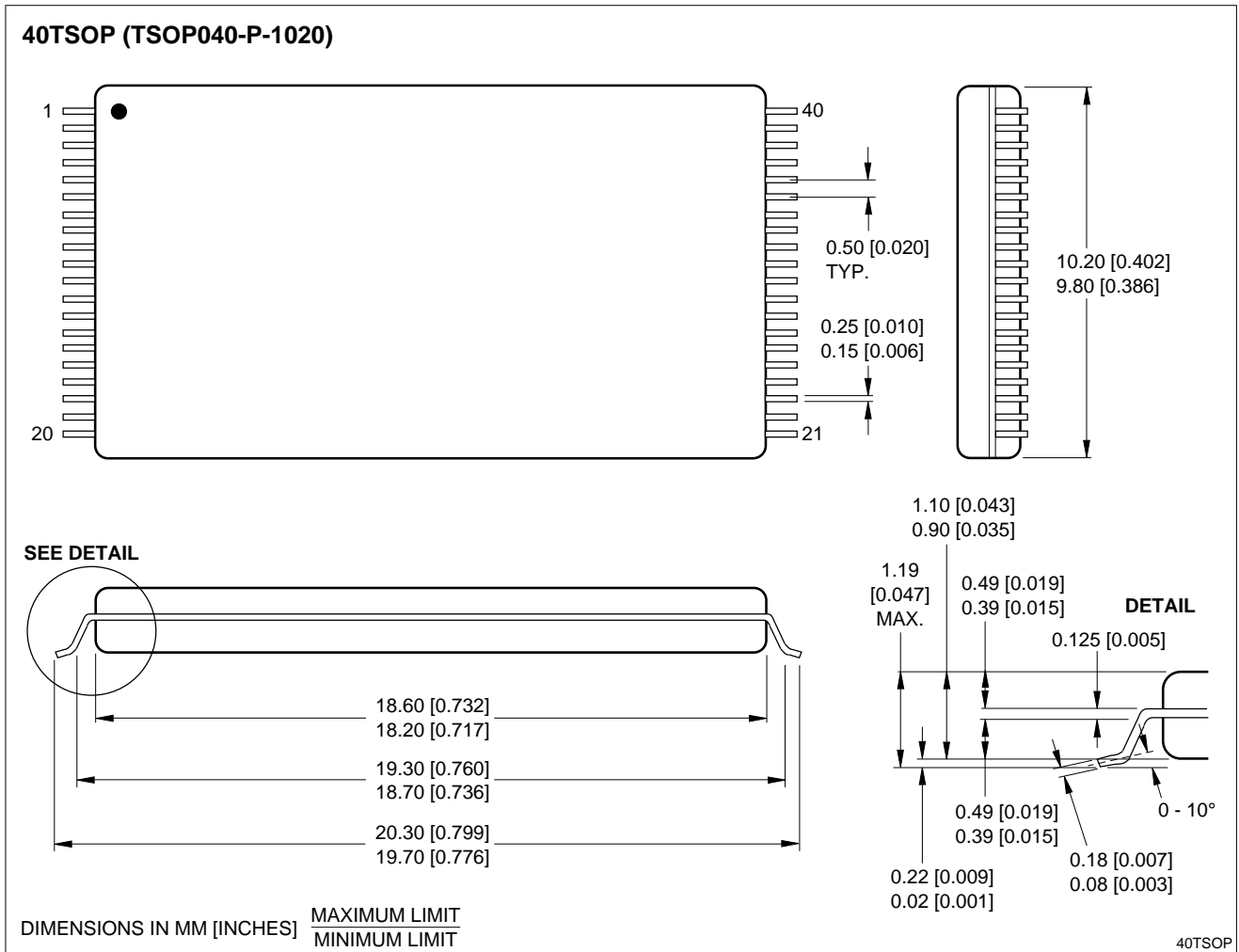
## Erase and Byte Write Performance

$$V_{CC} = 5.0\text{ V} \pm 0.5\text{ V}, T_A = 0^\circ\text{C to } +70^\circ\text{C}$$

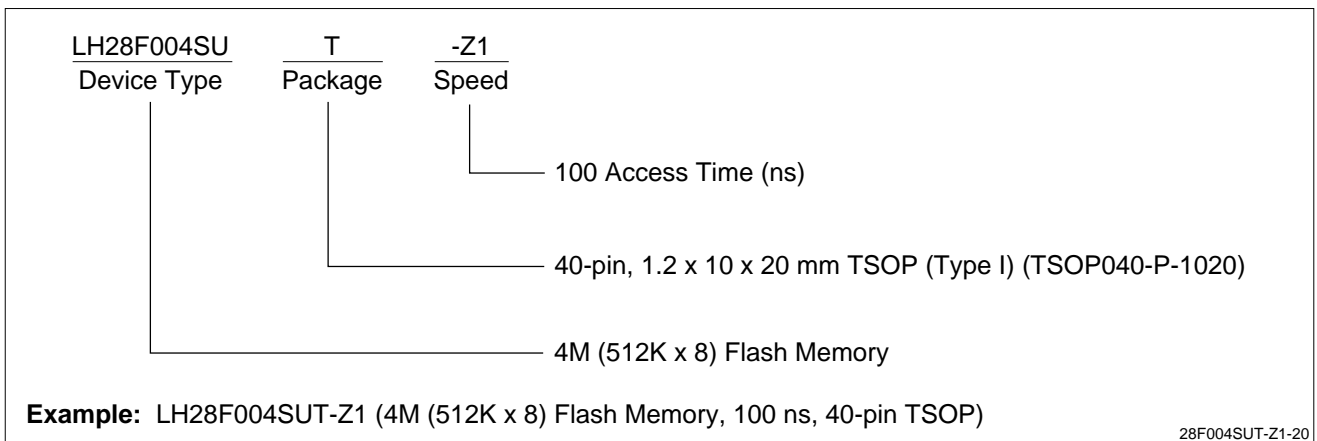
SYMBOL	PARAMETER	TYP. <sup>(1)</sup>	MIN.	MAX.	UNITS	TEST CONDITIONS	NOTE
$t_{WHRH}^1$	Byte Write Time	13			$\mu\text{s}$		2
$t_{WHRH}^2$	Two-Byte Serial Write Time	20			$\mu\text{s}$		2
$t_{WHRH}^3$	16KB Block Write Time	0.22		1.0	s	Byte Write Mode	2
$t_{WHRH}^4$	16KB Block Write Time	0.17		1.0	s	Two-Byte Serial Write Mode	2
	Block Erase Time (16KB)	0.6		10	s		2
	Full Chip Erase Time	8.8 - 14.4			s		2, 3

### NOTES:

1. 25°C,  $V_{PP} = 5.0\text{ V}$
2. Excludes System-Level Overhead.
3. Depends on the number of protected blocks.



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