LH28F016SU

16M (1M × 16/2M × 8)
5 V Single Voltage Flash Memory

FEATURES

- 5 V Write/Erase Operation (5 V V_{PP})
  - No Requirement for DC/DC Converter to Write/Erase
- User-Selectable 3.3 V or 5 V V_{CC}
- User-Configurable ×8 or ×16 Operation
- Access Times: 70/100 ns
- 0.32 MB/sec Write Transfer Rate
- 1 Million Erase Cycles per Block
- 56-Lead, 1.2 mm × 14 mm × 20 mm TSOP Package
- Revolutionary Architecture
  - Pipelined Command Execution
  - Write During Erase
  - Command Superset of SHARP LH28F008SA
- 10 µA (MAX.) I_{CC} in CMOS Standby
- 5 µA (MAX.) Deep Power-Down
- 32 Independently Lockable Blocks
- State-of-the-Art 0.6 µm ETOX ™ [1] Flash Technology

DESCRIPTION

SHARP's LH28F016SU 16M 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 LH28F016SU is also the ideal choice for designing embedded mass storage flash memory systems.

The LH28F016SU is a very high density, highest performance non-volatile read/write solution for solid-state storage applications. Its symmetrically blocked architecture (100% compatible with the LH28F008SA 8M Flash memory), extended cycling, low power 3.3 V 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 LH28F016SU's dual read voltage enables the design of memory cards which can interchangeably be read/written in 3.3 V and 5.0 V systems. Its ×8/×16 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 0.6 µm ETOX ™ [1] process technology, the LH28F016SU is the most cost-effective, high-density 3.3 V flash memory.

[1] ETOX is a trademark of Intel Corporation.

1.0 INTRODUCTION

The data sheet is intended to give an overview of the chip feature-set and of the operating AC/DC specifications.

1.1 Product Overview

The LH28F016SU is a high performance 16M (16,777,216 bit) block erasable non-volatile random access memory organized as either 1 Mword x 16 or 2 Mbyte x 8. The LH28F016SU includes thirty-two 64 KB (65,536) blocks or thirty-two 32-KW (32,768) 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.

Some significant enhancements of the LH28F016SU include:

- 5 V Write/Erase Operation (5 V V_{PP})
- 3.3 V Low Power Capability
- Improved Write Performance
- Dedicated Block Write/Erase Protection

A 3/5# input pin reconfigures the device internally for optimized 3.3 V or 5.0 V read/write operation.

The LH28F016SU will be available in a 56-lead, 1.2 mm thick, 14 mm × 20 mm TSOP type 1 package. This form factor and pinout allow for very high board layout densities.

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

Internal Algorithm Automation allows Byte/Word 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:

- Page Buffer Writes to Flash
- Command Queuing Capability
- Automatic Data Writes During Erase
- Software Locking of Memory Blocks
- Two-Byte Successive Writes in 8-bit Systems
- Erase All Unlocked Blocks

Writing of memory data is performed in either byte or word increments typically within 8 µsec, a 25% improvement over the LH28F008SA. A Block Erase operation erases one of the 32 blocks in typically 0.7 sec, independent of the other blocks, which is about 55% improvement over the LH28F008SA.

Each block can be written and erased a minimum of 100,000 cycles. Systems can achieve 1 million Block Erase Cycles by providing wear-leveling algorithms and graceful block retirement. These techniques have already been employed in many flash file systems and Hard Disk Drive designs.

The LH28F016SU incorporates two Page Buffers of 256 Bytes (128 Words) each to allow page data writes. This feature can improve a system write performance by up to 4.8 times over previous flash memory devices.

All operations are started by a sequence of Write commands to the device. Three Status Registers (described in detail later) and a RY/BY# output pin provide information on the progress of the requested operation.

While the LH28F008SA requires an operation to complete before the next operation can be requested, the LH28F016SU allows queuing of the next operation while the memory executes the current operation. This eliminates system overhead when writing several bytes in a row to the array or erasing several blocks at the same time. The LH28F016SU can also perform write operations to one block of memory while performing erase of another block.

The LH28F016SU provides user-selectable block locking to protect code or data such as Device Drivers, PCMCIA card information, ROM-Executable O/S or Application Code. Each block has an associated non-volatile lock-bit which determines the lock status of the block. In addition, the LH28F016SU has a master Write Protect pin (WP#) which prevents any modifications to memory blocks whose lock-bits are set.

The LH28F016SU contains three types of Status Registers 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 LH28F016SU from a LH28F008SA-based design.
- A Global Status Register (GSR) which informs the system of command Queue status, Page Buffer status, and overall Write Status Machine (WSM) status.
- 32 Block Status Registers (BSRs) which provide block-specific status information such as the block lock-bit status.

The GSR and BSR memory maps for Byte-Wide and Word-Wide modes are shown in Figures 4.1 and 4.2.

The LH28F016SU incorporates an open drain RY/BY# output pin. This feature allows the user to OR-tie many RY/BY# pins together in a multiple memory configuration such as a Resident Flash Array.

The LH28F016SU also incorporates a dual chip-enable function with two input pins, CE_0# and CE_1#. These pins have exactly the same functionality as the regular chip-enable pin CE# on the LH28F008SA. For minimum chip designs, CE_1# may be tied to ground and use CE_0# as the chip enable input. The LH28F016SU uses the logical combination of these two signals to enable or disable the entire chip. Both CE_0# and CE_1# must be active low to enable the device and if either one becomes inactive, the chip will be disabled. This feature, along with the open drain RY/BY# pin, allows the system designer to reduce the number of control pins used in a large array of 16M devices.

The BYTE# pin allows either ×8 or ×16 read/writes to the LH28F016SU. BYTE# at logic low selects 8-bit mode with address A_0 selecting between low byte and high byte. On the other hand, BYTE# at logic high enables 16-bit operation with address A_1 becoming the lowest order address and address A_0 is not used (don't care). A device diagram is shown in Figure 1.

The LH28F016SU is specified for a maximum access time of each version, as follows:

LH28F016SUT-70

Operating Temperature	V_{CC} Supply	Max. Access (t_{ACC})
0 - 70 °C	4.75 - 5.25 V	70 ns
0 - 70 °C	4.5 - 5.5 V	80 ns
0 - 70 °C	3.0 - 3.6 V	120 ns

LH28F016SU-10

Operating Temperature	V_{CC} Supply	Max. Access (t_{ACC})
0 - 70 °C	4.5 - 5.5 V	100 ns
0 - 70 °C	3.0 - 3.6 V	150 ns

The LH28F016SU 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 (1 mA at 3.3 V).

A Deep Power-Down mode of operation is invoked when the RP# (called $\overline{PWD}$ on the LH28F008SA) pin transitions low. This mode brings the device power consumption to less than 5 µA, typically, and provides additional write protection by acting as a device reset pin during power transitions. A 5 ns longer reset time than access time is required from 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, GSR, and BSR registers are cleared.

A CMOS Standby mode of operation is enabled when either CE_0# or CE_1# transitions high and RP# stays high with all input control pins at CMOS levels. In this mode, the device typically draws an I_{CC} standby current of 10 µA.

2.0 DEVICE PINOUT

The LH28F016SU 56L-TSOP Type I pinout configuration is shown in Figure 2.

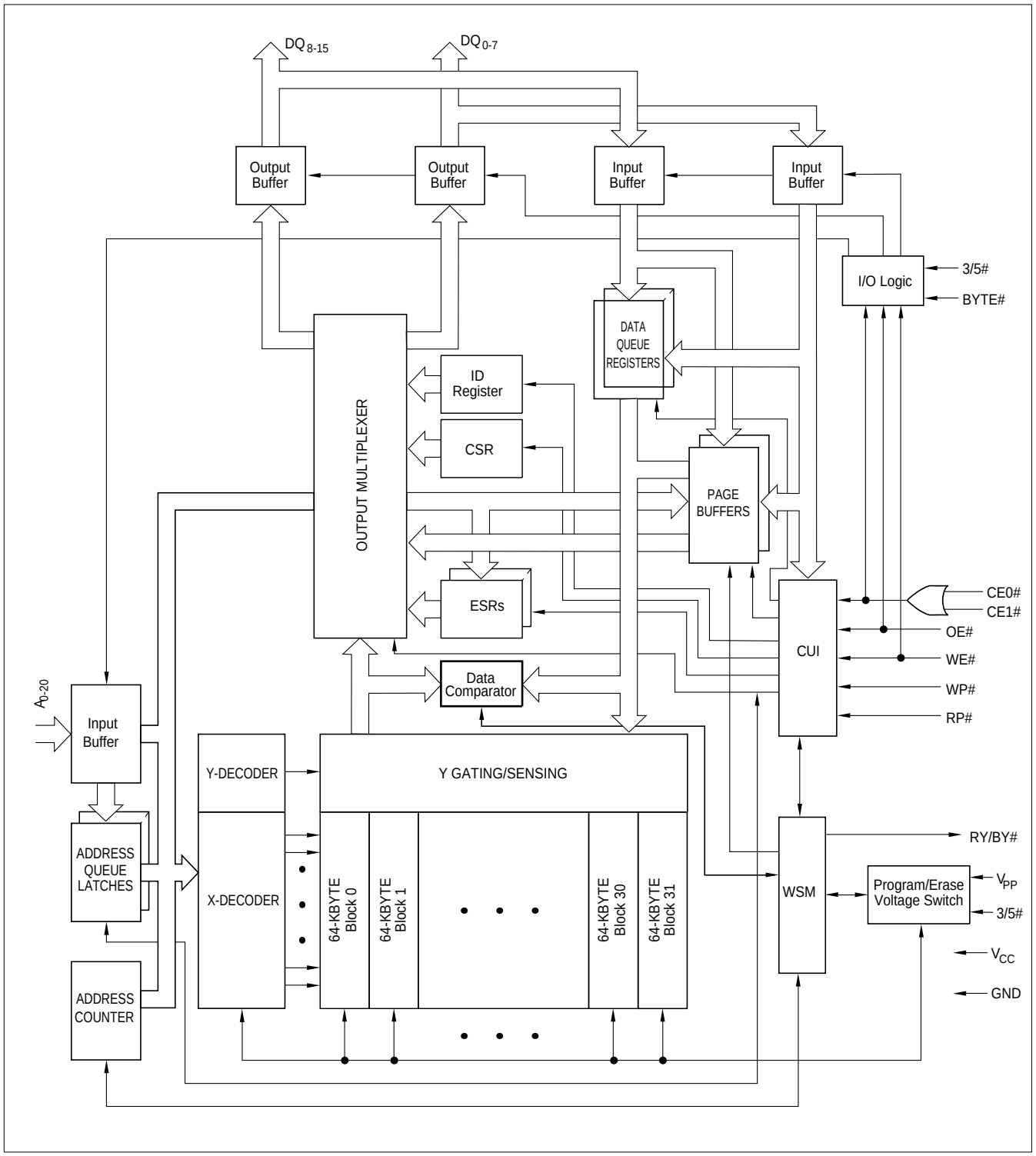


Figure 1. LH28F016 SU Block Diagram
Architectural Evolution Includes Page Buffers, Queue Registers, and Extended Status Registers

2.1 Lead Descriptions

Symbol	Type	Name and Function
A_0	INPUT	**BYTE-SELECT ADDRESS:** Selects between high and low byte when device is in x8 mode. This address is latched in x8 Data Writes. Not used in x16 mode (i.e., the A_0 input buffer is turned off when BYTE# is high).
A_1-A_{15}	INPUT	**WORD-SELECT ADDRESSES:** Select a word within one 64-Kbyte block. A_{6-15} selects 1 of 1024 rows, and A_{1-5} selects 16 of 512 columns. These addresses are latched during Data Writes.
A_{16}-A_{20}	INPUT	**BLOCK-SELECT ADDRESSES:** Select 1 of 32 Erase blocks. These addresses are latched during Data Writes, Erase and Lock-Block operations.
DQ_0-DQ_7	INPUT/OUTPUT	**LOW-BYTE DATA BUS:** 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.
DQ_8-DQ_{15}	INPUT/OUTPUT	**HIGH-BYTE DATA BUS:** Inputs data during x16 Data-Write operations. Outputs array, buffer or identifier data in the appropriate Read mode; not used for Status register reads. Floated when the chip is de-selected or the outputs are disabled.
CE_0#, CE_1#	INPUT	**CHIP ENABLE INPUTS:** Activate the device's control logic, input buffers, decoders and sense amplifiers. With either CE_0# or CE_1# high, the device is de-selected and power consumption reduces to Standby levels upon completion of any current Data-Write or Erase operations. Both CE_0#, CE_1# must be low to select the device. All timing specifications are the same for both signals. Device Selection occurs with the latter falling edge of CE_0# or CE_1#. The first rising edge of CE_0# or CE_1# disables the device.
RP#	INPUT	**RESET/POWER-DOWN:** 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 5 ns is required to allow these circuits to power-up for Read mode, and another 395 ns is required to enter Program or Erase mode. When 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).
OE#	INPUT	**OUTPUT ENABLE:** Gates device data through the output buffers when low. The outputs float to tri-state off when OE# is high. **NOTE:** CE_X# overrides OE#, and OE# overrides WE#.
WE#	INPUT	**WRITE ENABLE:** Controls access to the CUI, Page Buffers, Data Queue Registers and Address Queue Latches. WE# is active low, and latches both address and data (command or array) on its rising edge.
RY/BY#	OPEN DRAIN OUTPUT	**READY/BUSY:** Indicates status of the internal WSM. When low, it indicates that the WSM is busy performing an operation. RY/BY# high indicates that the WSM is ready for new operations (or WSM has completed all pending operations), or Erase is Suspended, or the device is in deep power-down mode. This output is always active (i.e., not floated to tri-state off when OE# or CE_0#, CE_1# are high), except if a RY/BY# Pin Disable command is issued.

2.1 Lead Descriptions (Continued)

Symbol	Type	Name and Function
WP#	INPUT	**WRITE PROTECT:** Erase blocks can be locked by writing a non-volatile lock-bit for each block. When WP# is low, those locked blocks as reflected by the Block-Lock Status bits (BSR.6), are protected from inadvertent Data Writes or Erases. When WP# is high, all blocks can be Written or Erased regardless of the state of the lock-bits. The WP# input buffer is disabled when RP# transitions low (deep power-down mode).
BYTE#	INPUT	**BYTE ENABLE:** BYTE# low places device in x8 mode. All data is then input or output on DQ_{0-7}, and DQ_{8-15} float. Address A_0 selects between the high and low byte. BYTE# high places the device in x16 mode, and turns off the A_0 input buffer. Address A_1, then becomes the lowest order address.
3/5#	INPUT	**3.3/5.0 VOLT SELECT:** 3/5# high configures internal circuits for 3.3V operation. 3/5# low configures internal circuits for 5.0V operation. **NOTES:** Reading the array with 3/5# high in a 5.0V system could damage the device. There is a significant delay from 3/5# switching to valid data.
V_{PP}	SUPPLY	**ERASE/WRITE POWER SUPPLY (5.0V ± 0.5V):** For erasing memory array blocks or writing words/bytes/pages into the flash array.
V_{CC}	SUPPLY	**DEVICE POWER SUPPLY (3.3V ± 0.3V, 5.0V ± 0.5V):** Do not leave any power pins floating.
GND	SUPPLY	**GROUND FOR ALL INTERNAL CIRCUITRY:** Do not leave any ground pins floating.
NC		**NO CONNECT:** No internal connection to die, lead may be driven or left floating.

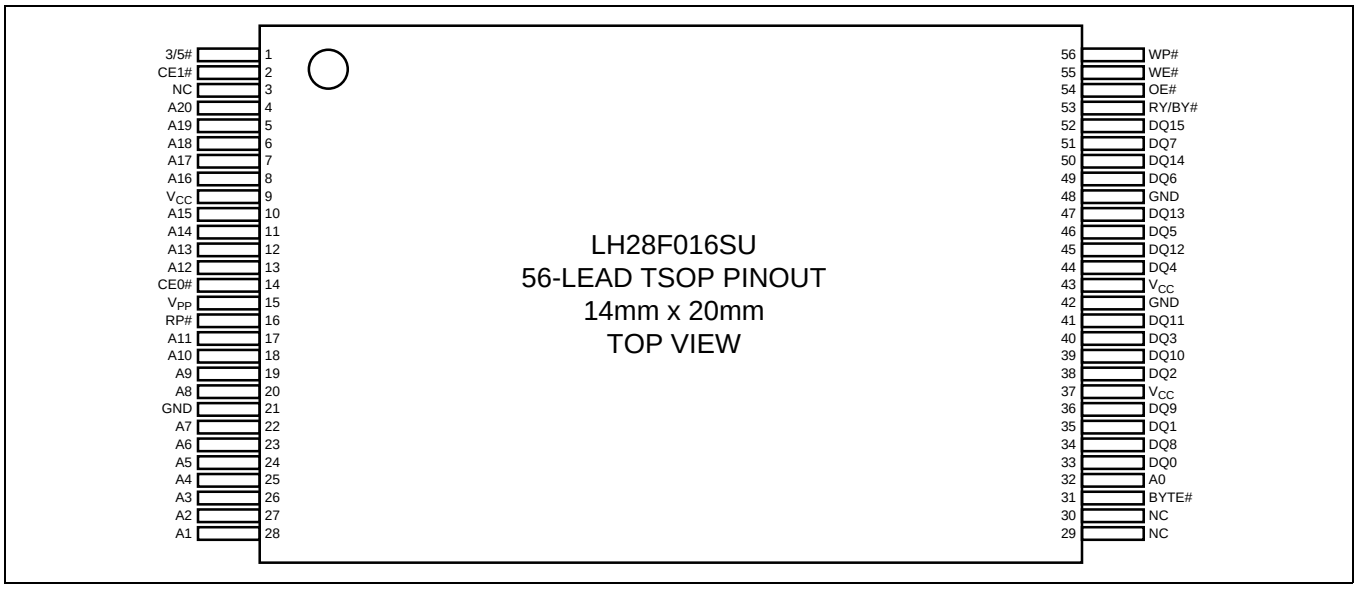


Figure 2. TSOP Configuration

NOTE:
56-LEAD TSOP Mechanical Diagrams and Dimensions are shown at the end of this specification

3.0 MEMORY MAPS

1FFFFFH 1F0000H	64 KByte Block	31
1EFFFFH 1E0000H	64 KByte Block	30
1DFFFFH 1D0000H	64 KByte Block	29
1CFFFFH 1C0000H	64 KByte Block	28
1BFFFFH 1B0000H	64 KByte Block	27
1AFFFFH 1A0000H	64 KByte Block	26
19FFFFH 190000H	64 KByte Block	25
18FFFFH 180000H	64 KByte Block	24
17FFFFH 170000H	64 KByte Block	23
16FFFFH 160000H	64 KByte Block	22
15FFFFH 150000H	64 KByte Block	21
14FFFFH 140000H	64 KByte Block	20
13FFFFH 130000H	64 KByte Block	19
12FFFFH 120000H	64 KByte Block	18
11FFFFH 110000H	64 KByte Block	17
10FFFFH 100000H	64 KByte Block	16
0FFFFFH 0F0000H	64 KByte Block	15
0EFFFFH 0E0000H	64 KByte Block	14
0DFFFFH 0D0000H	64 KByte Block	13
0CFFFFH 0C0000H	64 KByte Block	12
0BFFFFH 0B0000H	64 KByte Block	11
0AFFFFH 0A0000H	64 KByte Block	10
09FFFFH 090000H	64 KByte Block	9
08FFFFH 080000H	64 KByte Block	8
07FFFFH 070000H	64 KByte Block	7
06FFFFH 060000H	64 KByte Block	6
05FFFFH 050000H	64 KByte Block	5
04FFFFH 040000H	64 KByte Block	4
03FFFFH 030000H	64 KByte Block	3
02FFFFH 020000H	64 KByte Block	2
01FFFFH 010000H	64 KByte Block	1
00FFFFH 000000H	64 KByte Block	0

Figure 3. LH28F016SU Memory Map (Byte-Wide Mode)

3.1 Extended Status Registers Memory Map

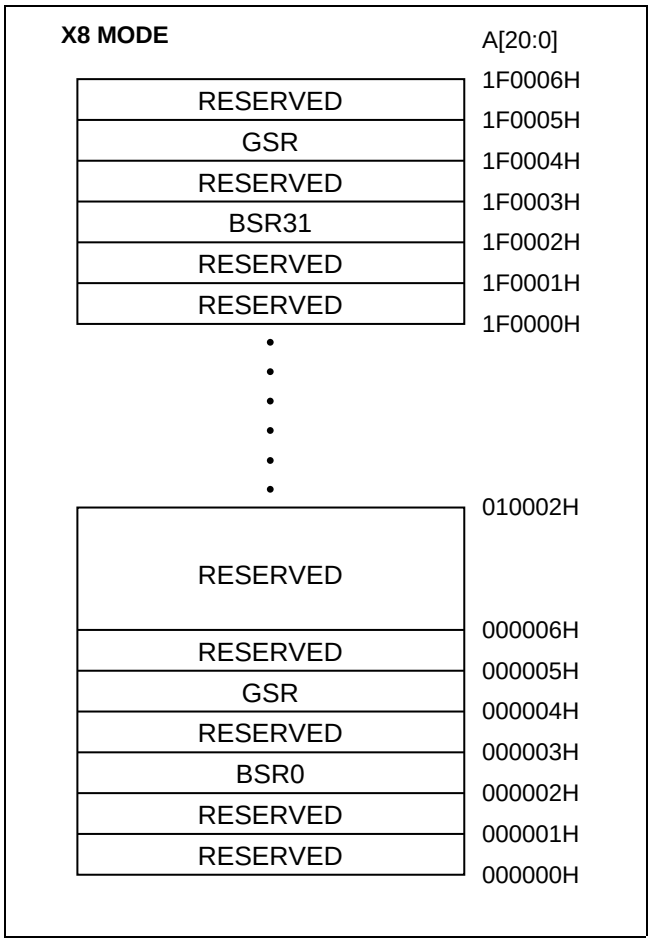


Figure 4.1. Extended Status Register Memory Map (Byte-Wide Mode)

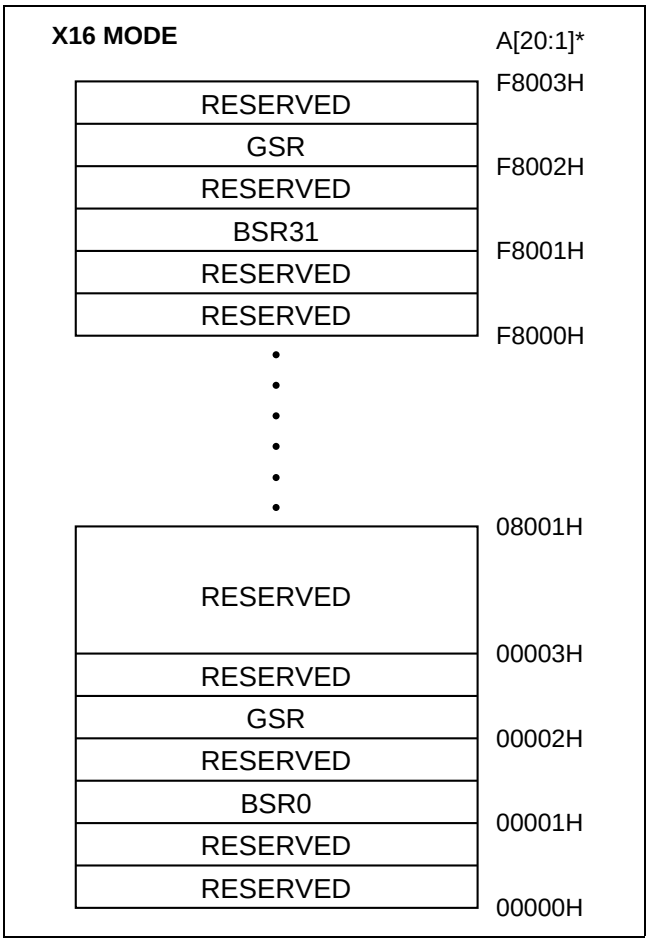


Figure 4.2. Extended Status Register Memory Map (Word-Wide Mode)

* In Word-wide mode A_0 don't care, address values are ignored A_0.

4.0 BUS OPERATIONS, COMMANDS, AND STATUS REGISTER DEFINITIONS

4.1 Bus Operations for Word-Wide Mode (BYTE# = V_{IH})

Mode	Notes	RP#	CE_1#	CE_0#	OE#	WE#	A_1	DQ_{0-15}	RY/BY#
Read	1,2	V_{IH}	V_{IL}	V_{IL}	V_{IL}	V_{IH}	X	D_{OUT}	X
Output Disable	1,6	V_{IH}	V_{IL}	V_{IL}	V_{IH}	V_{IH}	X	High Z	X
Standby	1,6	V_{IH}	V_{IL} V_{IH} V_{IH}	V_{IH} V_{IL} V_{IH}	X	X	X	High Z	X
Deep Power-Down	1,3	V_{IL}	X	X	X	X	X	High Z	V_{OH}
Manufacturer ID	4	V_{IH}	V_{IL}	V_{IL}	V_{IL}	V_{IH}	V_{IL}	00B0H	V_{OH}
Device ID	4	V_{IH}	V_{IL}	V_{IL}	V_{IL}	V_{IH}	V_{IH}	6688H	V_{OH}
Write	1,5,6	V_{IH}	V_{IL}	V_{IL}	V_{IH}	V_{IL}	X	D_{IN}	X

4.2 Bus Operations For Byte-Wide Mode (BYTE# = V_{IL})

Mode	Notes	RP#	CE_1#	CE_0#	OE#	WE#	A_0	DQ_{0-7}	RY/BY#
Read	1,2	V_{IH}	V_{IL}	V_{IL}	V_{IL}	V_{IH}	X	D_{OUT}	X
Output Disable	1,6	V_{IH}	V_{IL}	V_{IL}	V_{IH}	V_{IH}	X	High Z	X
Standby	1,6	V_{IH}	V_{IL} V_{IH} V_{IH}	V_{IH} V_{IL} V_{IH}	X	X	X	High Z	X
Deep Power-Down	1,3	V_{IL}	X	X	X	X	X	High Z	V_{OH}
Manufacturer ID	4	V_{IH}	V_{IL}	V_{IL}	V_{IL}	V_{IH}	V_{IL}	B0H	V_{OH}
Device ID	4	V_{IH}	V_{IL}	V_{IL}	V_{IL}	V_{IH}	V_{IH}	88H	V_{OH}
Write	1,5,6	V_{IH}	V_{IL}	V_{IL}	V_{IH}	V_{IL}	X	D_{IN}	X

NOTES:

1. X can be V_{IH} or V_{IL} for address or control pins except for RY/BY#, which is either V_{OL} or V_{OH}.
2. RY/BY# output is open drain. When the WSM is ready, Erase is suspended or the device is in deep power-down mode, RY/BY# will be at V_{OH} if it is tied to V_{CC} through a resistor. When the RY/BY# at V_{OH} is independent of OE# while a WSM operation is in progress.
3. RP# at GND ±0.2 V ensures the lowest deep power-down current.
4. A_0 and A_1 at V_{IL} provide manufacturer ID codes in ×8 and ×6 modes respectively.
   A_0 and A_1 at V_{IH} provide device ID codes in ×8 and ×16 modes respectively. All other addresses are set to zero.
5. Commands for different Erase operations, Data Write operations of Lock-Block operations can only be successfully completed when $V_{PP} = V_{PPH}$.
6. While the WSM is running, RY/BY# in Level-Mode (default) stays at V_{OL} until all operations are complete. RY/BY# goes to V_{OH} when the WSM is not busy or in erase suspend mode.

4.3 LH28F008SA-Compatible Mode Command Bus Definitions

Command	Notes	First Bus Cycle			Second Bus Cycle		
		Oper	Addr	Data	Oper	Addr	Data
Read Array		Write	X	FFH	Read	AA	AD
Intelligent Identifier	1	Write	X	90H	Read	IA	ID
Read Compatible Status Register	2	Write	X	70H	Read	X	CSRD
Clear Status Register	3	Write	X	50H			
Word/Byte Write		Write	X	40H	Write	WA	WD
Alternate Word/Byte Write		Write	X	10H	Write	WA	WD
Block Erase/Confirm	4	Write	X	20H	Write	BA	D0H
Erase Suspend/Resume	4	Write	X	B0H	Write	X	D0H

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

DATA
AD = Array Data
CSRD = CSR Data
ID = Identifier Data
WD = Write Data

NOTES:
1. Following the intelligent identifier command, two Read operations access the manufacturer and device signature codes.
2. The CSR is automatically available after device enters Data Write, Erase, or Suspend operations.
3. Clears CSR.3, CSR.4 and CSR.5. Also clears GSR.5 and all BSR.5 and BSR.2 bits. See Status register definitions.
4. 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, WASM = 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 completed. When you use Erase Suspend/Resume command, we recommend to issue serial Block Erase command (20H, D0H) and Resume command (D0H). (Refer to 4.4 Performance Enhancement Command Bus Definitions.)

4.4 LH28F016SU-Performance Enhancement Command Bus Definitions

Command	Mode	Notes	First Bus Cycle			Second Bus Cycle			Third Bus Cycle		
			Oper	Addr	Data	Oper	Addr	Data	Oper	Addr	Data
Read Extended Status Register		1	Write	X	71H	Read	RA	GSRD BSRD			
Page Buffer Swap		7	Write	X	72H						
Read Page Buffer			Write	X	75H	Read	PA	PD			
Single Load to Page Buffer			Write	X	74H	Write	PA	PD			
Sequential Load to Page Buffer	x8	4,6,10	Write	X	E0H	Write	X	BCL	Write	X	BCH
	x16	4,5,6,10	Write	X	E0H	Write	X	WCL	Write	X	WCH
Page Buffer Write to Flash	x8	3,4,9,10	Write	X	0CH	Write	A0	BC(L,H)	Write	WA	BC(H,L)
	x16	4,5,10	Write	X	0CH	Write	X	WCL	Write	WA	WCH
Two-Byte Write	x8	3	Write	X	FBH	Write	A0	WD(L,H)	Write	WA	WD(H,L)
Block Erase /Confirm		11	Write	X	20H	Write	BA	D0H	Write	X	D0H
Lock Block /Confirm			Write	X	77H	Write	BA	D0H			
Upload Status Bits /Confirm		2	Write	X	97H	Write	X	D0H			
Upload Device Information			Write	X	99H	Write	X	D0H			
Erase All Unlocked Blocks/Confirm			Write	X	A7H	Write	X	D0H			
RY/BY# Enable to Level-Mode		8	Write	X	96H	Write	X	01H			
RY/BY# Pulse-On-Write		8	Write	X	96H	Write	X	02H			
RY/BY# Pulse-On-Erase		8	Write	X	96H	Write	X	03H			
RY/BY# Disable		8	Write	X	96H	Write	X	04H			
Sleep			Write	X	F0H						
Abort			Write	X	80H						

ADDRESS
BA = Block Address
PA = Page Buffer Address
RA = Extended Register Address
WA = Write Address
X = Don't Care

DATA
AD = Array Data
PD = Page Buffer Data
BSRD = BSR Data
GSRD = GSR Data

WC (L.H) = Word Count (Low, High)
BC (L.H) = Byte Count (Low, High)
WD (L.H) = Write Data (Low, High)

NOTES:

1. RA can be the GSR address or any BSR address. See Figure 4.1 and 4.2 for Extended Status Register Memory Maps.
2. Upon device power-up, all BSR lock-bits come up locked. The Upload Status Bits command must be written to reflect the actual lock-bit status.
3. A_0 is automatically complemented to load second byte of data. BYTE# must be at V_{IL}.
   A_0 value determines which WD/BC is supplied first: A_0 = 0 looks at the WDL/BCL, A_0 = 1 looks at the WDH/BCH.
4. BCH/WCH must be at 00H for this product because of the 256-Byte (128 Word) Page Buffer size and to avoid writing the Page Buffer contents into more than one 256-Byte segment within an array block. They are simply shown for future Page Buffer expandability.
5. In ×16 mode, only the lower byte DQ_{0-7} is used for WCL and WCH. The upper byte DQ_{8-15} is a don't care.
6. PA and PD (whose count is given in cycles 2 and 3) are supplied starting in the 4th cycle which is not shown.
7. This command allows the user to swap between available Page Buffers (0 or 1).
8. These commands reconfigure RY/BY# output to one of two pulse-modes or enable and disable the RY/BY# function.
9. Write address, WA, is the Destination address in the flash array which must match the Source address in the Page Buffer. Refer to the LH28F016SU User's Manual.
10. BCL = 00H corresponds to a Byte count of 1. Similarly, WCL = 00H corresponds to a Word count of 1.
11. Unless you issue erase suspend command, it is no necessary to input D0H on third bus cycle.

4.5 Compatible Status Register

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

CSR.7 = WRITE STATE MACHINE STATUS (WSMS)
1 = Ready
0 = Busy

CSR.6 = ERASE-SUSPEND STATUS (ESS)
1 = Erase Suspended
0 = Erase in Progress/Completed

CSR.5 = ERASE STATUS (ES)
1 = Error in Block Erasure
0 = Successful Block Erase

CSR.4 = DATA-WRITE STATUS (DWS)
1 = Error in Data Write
0 = Data Write Successful

CSR.3 = V_{PP} STATUS (VPPS)
1 = V_{PP} Low Detect, Operation Abort
0 = V_{PP} OK

NOTES:

RY/BY# 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.

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.

The VPPS bit, unlike an A/D converter, does not provide continuous indication of V_{PP} level. The WSM interrogates V_{PP}'s level only after the Data-Write or Erase command sequences have been entered, and informs the system if V_{PP} has not been switched on. VPPS is not guaranteed to report accurate feedback between V_{PPL} and V_{PPH}.

CSR.2-0 = RESERVED FOR FUTURE ENHANCEMENTS
These bits are reserved for future use: mask them out when polling the CSR.

4.6 Global Status Register

WSMS	OSS	DOS	DSS	QS	PBAS	PBS	PBSS
7	6	5	4	3	2	1	0

GSR.7 = WRITE STATE MACHINE STATUS (WSMS)
1 = Ready
0 = Busy

GSR.6 = OPERATION SUSPEND STATUS (OSS)
1 = Operation Suspended
0 = Operation in Progress/Completed

GSR.5 = DEVICE OPERATION STATUS (DOS)
1 = Operation Unsuccessful
0 = Operation Successful or Currently Running

GSR.4 = DEVICE SLEEP STATUS (DSS)
1 = Device in Sleep
0 = Device Not in Sleep

MATRIX 5/4
00 = Operation Successful or Currently Running — If operation currently running, then GSR.7 = 0.
01 = Device in Sleep Mode or Pending Sleep — If device pending sleep, then GSR.7 = 0.
10 = Operation Unsuccessful
11 = Operation Unsuccessful or Aborted — Operation aborted: Unsuccessful due to Abort command.

GSR.3 = QUEUE STATUS (QS)
1 = Queue Full
0 = Queue Available

GSR.2 = PAGE BUFFER AVAILABLE STATUS (PBAS)
1 = One or Two Page Buffers Available — The device contains two Page Buffers.
0 = No Page Buffer Available

GSR.1 = PAGE BUFFER STATUS (PBS)
1 = Selected Page Buffer Ready
0 = Selected Page Buffer Busy — Selected Page Buffer is currently busy with WSM operation.

GSR.0 = PAGE BUFFER SELECT STATUS (PBSS)
1 = Page Buffer 1 Selected
0 = Page Buffer 0 Selected

NOTES:

[1] RY/BY# output or WSMS bit must be checked to determine completion of an operation (Block Lock, Suspend, any RY/BY# reconfiguration, Upload Status Bits, Erase or Data Write) before the appropriate Status bit (OSS or DOS) is checked for success.

NOTE:

1. When multiple operations are queued, checking BSR.7 only provides indication of completion for that particular block. GSR.7 provides indication when all queued operations are completed.

4.7 Block Status Register

BS	BLS	BOS	BOAS	QS	VPPS	R	R
7	6	5	4	3	2	1	0

BSR.7 = BLOCK STATUS (BS)
1 = Ready
0 = Busy

BSR.6 = BLOCK-LOCK STATUS (BLS)
1 = Block Unlocked for Write/Erase
0 = Block Locked for Write/Erase

BSR.5 = BLOCK OPERATION STATUS (BOS)
1 = Operation Unsuccessful
0 = Operation Successful or Currently Running

BSR.4 = BLOCK OPERATION ABORT STATUS (BOAS)
1 = Operation Aborted
0 = Operation Not Aborted

MATRIX 5/4
00 = Operation Successful or Currently Running
01 = Not a valid Combination
10 = Operation Unsuccessful
11 = Operation Aborted

BSR.3 = QUEUE STATUS (QS)
1 = Queue Full
0 = Queue Available

BSR.2 = V_{PP} STATUS (VPPS)
1 = V_{PP} Low Detect, Operation Abort
0 = V_{PP} OK

NOTES:

[1] RY/BY# output or BS bit must be checked to determine completion of an operation (Block Lock, Suspend, Erase or Data Write) before the appropriate Status bits (BOS, BLS) is checked for success.

The BOAS bit will not be set until BSR.7 = 1.

Operation halted via Abort command.

NOTES:

BSR.1-0 = RESERVED FOR FUTURE ENHANCEMENTS
These bits are reserved for future use; mask them out when polling the BSRs.

1. When multiple operations are queued, checking BSR.7 only provides indication of completion for that particular block. GSR.7 provides indication when all queued operations are completed.

5.0 ELECTRICAL SPECIFICATIONS

5.1 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_{CC} = 3.3 V ±0.3 V Systems (4)

Symbol	Parameter	Notes	Min	Max	Units	Test Conditions
T_A	Operating Temperature, Commercial	1	0	70	˚C	Ambient Temperature
V_{CC}	V_{CC} with Respect to GND	2	- 0.2	7.0	V	
V_{PP}	V_{PP} Supply Voltage with Respect to GND	2	- 0.2	7.0	V	
V	Voltage on any Pin (except V_{CC}, V_{PP}) with Respect to GND	2	- 0.5	V_{CC} + 0.5	V	
I	Current into any Non-Supply Pin			± 30	mA	
I_{OUT}	Output Short Circuit Current	3		100	mA	

V_{CC} = 5.0 V ±0.5 V Systems (4)

Symbol	Parameter	Notes	Min	Max	Units	Test Conditions
T_A	Operating Temperature, Commercial	1	0	70	˚C	Ambient Temperature
V_{CC}	V_{CC} with Respect to GND	2	- 0.2	7.0	V	
V_{PP}	V_{PP} Supply Voltage with Respect to GND	2	- 0.2	7.0	V	
V	Voltage on any Pin (except V_{CC}, V_{PP}) with Respect to GND	2	- 0.5	7.0	V	
I	Current into any Non-Supply Pin			± 30	mA	
I_{OUT}	Output Short Circuit Current	3		100	mA	

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_{CC} + 0.5 V which, during transitions, may overshoot to V_{CC} + 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.

5.2 Capacitance

For a 3.3 V System

Symbol	Parameter	Note	Typ	Max	Units	Test Conditions
C_{IN}	Capacitance Looking into an Address/Control Pin	1	6	8	pF	T_A = 25°C, f = 1.0 MHz
C_{OUT}	Capacitance Looking into an Output Pin	1	8	12	pF	T_A = 25°C, f = 1.0 MHz
C_{LOAD}	Load Capacitance Driven by Outputs for Timing Specifications	1		50	pF	For V_{CC} = 3.3V ± 0.3V
	Equivalent Testing Load Circuit			2.5	ns	50Ω transmission line delay

For a 5.0 V System:

Symbol	Parameter	Note	Typ	Max	Units	Test Conditions
C_{IN}	Capacitance Looking into an Address/Control Pin	1	6	8	pF	T_A = 25°C, f = 1.0 MHz
C_{OUT}	Capacitance Looking into an Output Pin	1	8	12	pF	T_A = 25°C, f = 1.0 MHz
C_{LOAD}	Load Capacitance Driven by Outputs for Timing Specifications	1		100	pF	For V_{CC} = 5.0V ± 0.5V
	Equivalent Testing Load Circuit			2.5	ns	25Ω transmission line delay

NOTE:
1. Sampled, not 100% tested.

5.3 Timing Nomenclature

All 3.3 V system timings are measured from where signals cross 1.5 V.

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} tELQV time(t) from CE# (E) going low (L) to the outputs (Q) becoming valid (V)
t_{OE} tGLQV time(t) from 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} tAVWH time(t) from address (A) valid (V) to WE# (W) going high (H)
t_{DH} tWHDX time(t) from 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	CE# (Chip Enable)	X	Driven, but not necessarily valid
G	OE# (Output Enable)	Z	High Impedance
W	WE# (Write Enable)		
P	RP# (Deep Power-Down Pin)		
R	RY/BY# (Ready/Busy#)		
V	Any Voltage Level		
Y	3/5# Pin		
5V	V_{CC} at 4.5V Minimum		
3V	V_{CC} at 3.0V Minimum		

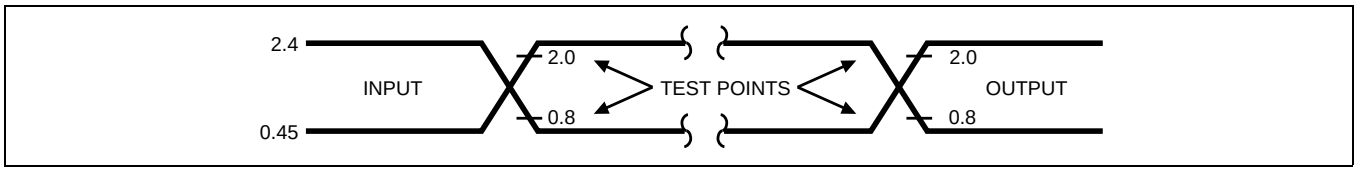


Figure 5. Transient Input/Output Reference Waveform (V_{CC} = 5.0 V)

AC test inputs are driven at V_{OH} (2.4 V_{TTL}) for a Logic "1" and V_{OL} (0.45 V_{TTL}) for a Logic "0." Input timing begins at V_{IH} (2.0 V_{TTL}) and V_{IL} (0.8 V_{TTL}). Output timing ends at V_{IH} and V_{IL}. Input rise and fall times (10% to 90%) <10 ns.

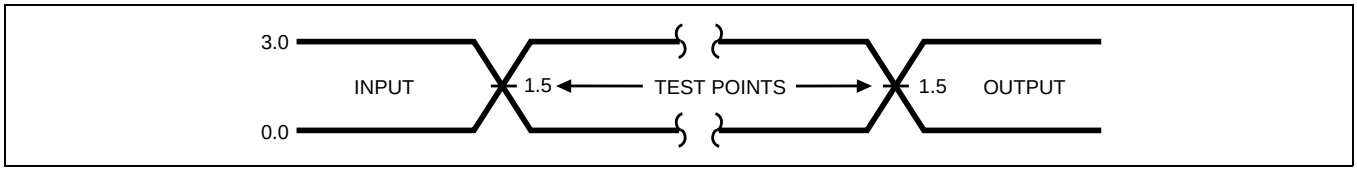


Figure 6. Transient Input/Output Reference Waveform (V_{CC} = 3.3 V)

AC test inputs are driven at 3.0 V for a Logic "1" and 0.0 V for a Logic "0." Input timing begins, and output timing ends, at 1.5 V. Input rise and fall times (10% to 90%) <10 ns.

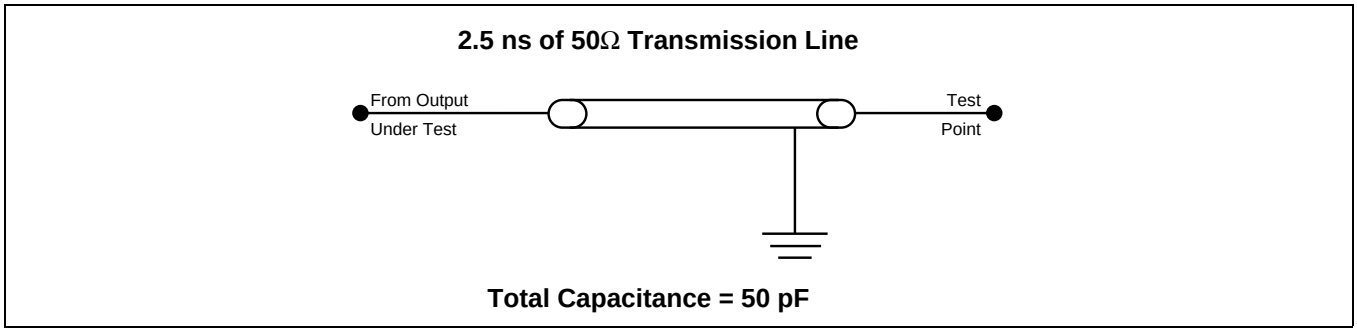


Figure 7. Transient Equivalent Testing Load Circuit (V_{CC} = 3.3 V)

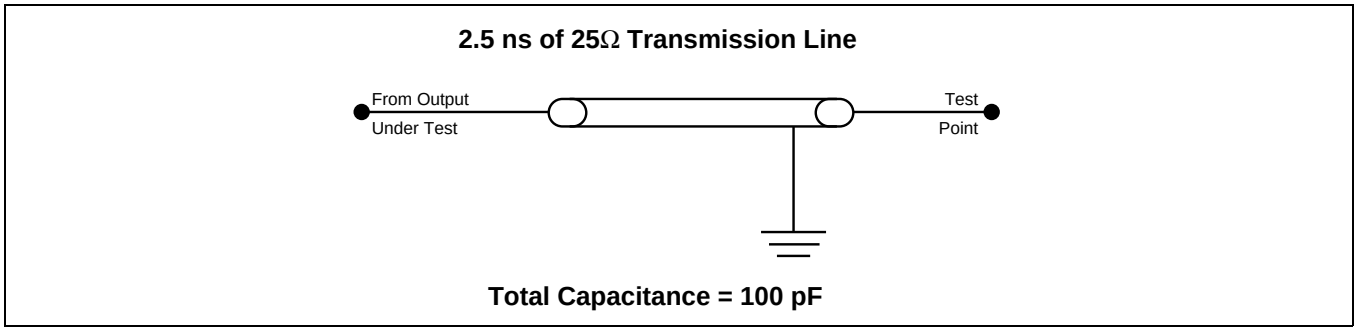


Figure 8. Transient Equivalent Testing Load Circuit (V_{CC} = 5.0 V)

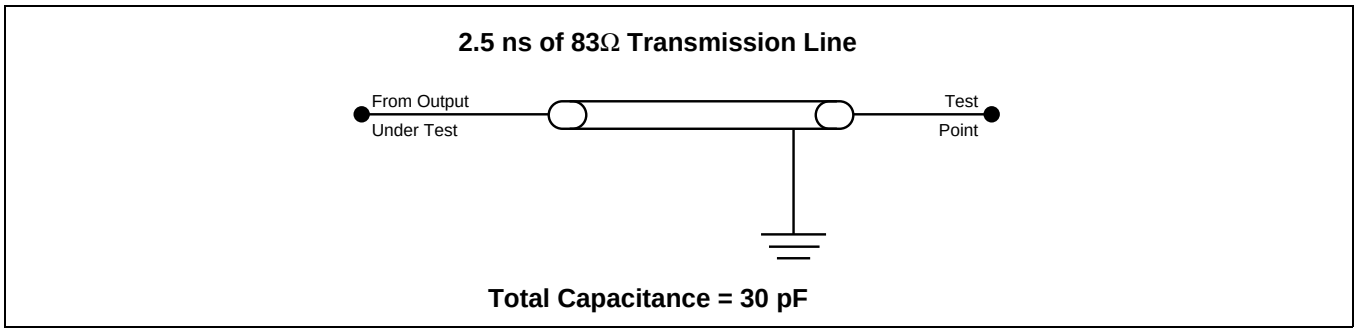


Figure 9. High Speed Transient Equivalent Testing Load Circuit (V_{CC} = 5.0 V ±5%)

5.4 DC Characteristics

V_{CC} = 3.3 V ±0.3 V, T_A = 0°C to + 70°C
3/5# = Pin Set High for 3.3 V Operations

Symbol	Parameter	Notes	Min	Typ	Max	Units	Test Conditions
I_{IL}	Input Load Current	1			± 1	µA	$V_{CC} = V_{CC}$ Max, $V_{IN} = V_{CC}$ or GND
I_{LO}	Output Leakage Current	1			± 10	µA	$V_{CC} = V_{CC}$ Max, $V_{IN} = V_{CC}$ or GND
I_{CCS}	V_{CC} Standby Current	1,4		4	8	µA	$V_{CC} = V_{CC}$ Max, CE_0#, CE_1#, RP# = V_{CC} ± 0.2V BYTE#, WP#, 3/5# = V_{CC} ± 0.2V or GND ± 0.2V
				1	4	mA	$V_{CC} = V_{CC}$ Max, CE_0#, CE_1#, RP# = V_{IH} BYTE#, WP#, 3/5# = V_{IH} or V_{IL}
I_{CCD}	V_{CC} Deep Power-Down Current	1		1	5	µA	RP# = GND ± 0.2V
$I_{CCR}1$	V_{CC} Read Current	1,3,4		30	35	mA	$V_{CC} = V_{CC}$ Max, CMOS: CE_0#, CE_1# = GND ± 0.2V BYTE# = GND ± 0.2V or V_{CC} ± 0.2V Inputs = GND ± 0.2V or V_{CC} ± 0.2V, TTL: CE_0#, CE_1# = V_{IL}, BYTE# = V_{IL} or V_{IH} Inputs = V_{IL} or V_{IH}, f = 8 MHz, I_{OUT} = 0 mA
$I_{CCR}2$	V_{CC} Read Current	1,3,4		15	20	mA	$V_{CC} = V_{CC}$ Max, CMOS: CE_0#, CE_1# = GND ± 0.2V, BYTE# = V_{CC} ± 0.2V or GND ± 0.2V Inputs = GND ± 0.2V or V_{CC} ± 0.2V, TTL: CE_0#, CE_1# = V_{IL} BYTE# = V_{IH} or V_{IL} Inputs = V_{IL} or V_{IH}, f = 4 MHz, I_{OUT} = 0 mA
I_{CCW}	V_{CC} Write Current	1		8	12	mA	Word/Byte Write in Progress
I_{CCE}	V_{CC} Block Erase Current	1		6	12	mA	Block Erase in Progress
I_{CCES}	V_{CC} Erase Suspend Current	1,2		3	6	mA	CE_0#, CE_1# =V_{IH} Block Erase Suspended
I_{PPS}	V_{PP} Standby Current	1		± 1	± 10	µA	$V_{PP} \leq V_{CC}$
I_{PPD}	V_{PP} Deep Power-Down Current	1		0.2	5	µA	RP# = GND ± 0.2V

DC Characteristics (Continued)

V_{CC} = 3.3 V ±0.3 V, T_A = 0°C to + 70°C
3/5# = Pin Set High for 3.3 V Operations

Symbol	Parameter	Notes	Min	Typ	Max	Units	Test Conditions
I_{PPR}	V_{PP} Read Current	1			200	µA	$V_{PP} > V_{CC}$
I_{PPW}	V_{PP} Write Current	1		40	60	mA	$V_{PP} = V_{PPH}$, Word/Byte Write in Progress
I_{PPE}	V_{PP} Erase Current	1		20	40	mA	$V_{PP} = V_{PPH}$, Block Erase in Progress
I_{PPES}	V_{PP} Erase Suspend Current	1			200	µA	$V_{PP} = V_{PPH}$, Block Erase Suspended
V_{IL}	Input Low Voltage		- 0.3		0.8	V	
V_{IH}	Input High Voltage		2.0		V_{CC} + 0.3	V	
V_{OL}	Output Low Voltage				0.4	V	$V_{CC} = V_{CC}$ Min and I_{OL} = 4 mA
$V_{OH}1$	Output High Voltage		2.4			V	I_{OH} = - 2.0 mA $V_{CC} = V_{CC}$ Min
$V_{OH}2$			V_{CC} - 0.2			V	I_{OH} = - 100 µA $V_{CC} = V_{CC}$ Min
V_{PPL}	V_{PP} during Normal Operations		0.0		5.5	V	
V_{PPH}	V_{PP} during Write/ Erase Operations		4.5	5.0	5.5	V	
V_{LKO}	V_{CC} Erase/Write Lock Voltage		2.0			V	

NOTES:

1. All currents are in RMS unless otherwise noted. Typical values at V_{CC} = 3.3 V, V_{PP} = 5.0 V, T = 25°C. These currents are valid for all product versions (package and speeds).
2. I_{CCES} is specified with the device deselected. If the device is read while in erase suspend mode, current draw is the sum of I_{CCES} and I_{CCR}.
3. Automatic Power Saving (APS) reduces I_{CCR} to less than 1 mA in static operation.
4. CMOS Inputs are either V_{CC} ±0.2 V or GND ±0.2 V. TTL Inputs are either V_{IL} or V_{IH}.

5.5 DC Characteristics

V_{CC} = 5.0 V ±0.5 V, T_A = 0°C to + 70°C
3/5# Pin Set Low for 5 V Operations

Symbol	Parameter	Notes	Min	Typ	Max	Units	Test Conditions
I_{IL}	Input Load Current	1			± 1	µA	$V_{CC} = V_{CC}$ Max, $V_{IN} = V_{CC}$ or GND
I_{LO}	Output Leakage Current	1			± 10	µA	$V_{CC} = V_{CC}$ Max, $V_{IN} = V_{CC}$ or GND
I_{CCS}	V_{CC} Standby Current	1,4		5	10	µA	$V_{CC} = V_{CC}$ Max, CE_0#, CE_1#, RP# = V_{CC} ± 0.2V BYTE#, WP#, 3/5# = V_{CC} ± 0.2V or GND ± 0.2V
				2	4	mA	$V_{CC} = V_{CC}$ Max, CE_0#, CE_1#, RP# = V_{IH} BYTE#, WP#, 3/5# = V_{IH} or V_{IL}
I_{CCD}	V_{CC} Deep Power-Down Current	1		1	5	µA	RP# = GND ± 0.2V
$I_{CCR}1$	V_{CC} Read Current	1,3,4		50	60	mA	$V_{CC} = V_{CC}$ Max, CMOS: CE_0#, CE_1# = GND ± 0.2V BYTE# = GND ± 0.2V or V_{CC} ± 0.2V Inputs = GND ± 0.2V or V_{CC} ± 0.2V, TTL: CE_0#, CE_1# = V_{IL}, BYTE# = V_{IL} or V_{IH} Inputs = V_{IL} or V_{IH}, f = 10 MHz, I_{OUT} = 0 mA
$I_{CCR}2$	V_{CC} Read Current	1,3,4		30	35	mA	$V_{CC} = V_{CC}$ Max, CMOS: CE_0#, CE_1# = GND ± 0.2V, BYTE# = V_{CC} ± 0.2V or GND ± 0.2V Inputs = GND ± 0.2V or V_{CC} ± 0.2V, TTL: CE_0#, CE_1# = V_{IL} BYTE# = V_{IH} or V_{IL} Inputs = V_{IL} or V_{IH}, f = 5 MHz, I_{OUT} = 0 mA
I_{CCW}	V_{CC} Write Current	1		25	35	mA	Word/Byte Write in Progress
I_{CCE}	V_{CC} Block Erase Current	1		18	25	mA	Block Erase in Progress
I_{CCES}	V_{CC} Erase Suspend Current	1,2		5	10	mA	CE_0#, CE_1# =V_{IH} Block Erase Suspended
I_{PPS}	V_{PP} Standby Current	1			± 10	µA	$V_{PP} \leq V_{CC}$
I_{PPD}	V_{PP} Deep Power-Down Current	1		0.2	5	µA	RP# = GND ± 0.2V

DC Characteristics (Continued)

V_{CC} = 5.0 V ±0.5 V, T_A = 0°C to + 70°C
3/5# Pin Set Low for 5 V Operations

Symbol	Parameter	Notes	Min	Typ	Max	Units	Test Conditions
I_{PPR}	V_{PP} Read Current	1		65	200	µA	$V_{PP} > V_{CC}$
I_{PPW}	V_{PP} Write Current	1		40	60	mA	$V_{PP} = V_{PPH}$, Word/Byte Write in Progress
I_{PPE}	V_{PP} Erase Current	1		20	40	mA	$V_{PP} = V_{PPH}$, Block Erase in Progress
I_{PPES}	V_{PP} Erase Suspend Current	1		65	200	µA	$V_{PP} = V_{PPH}$, Block Erase Suspended
V_{IL}	Input Low Voltage		- 0.5		0.8	V	
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 mA
$V_{OH}1$	Output High Voltage		0.85 Vcc			V	I_{OH} = - 2.5 mA $V_{CC} = V_{CC}$ Min
$V_{OH}2$			V_{CC} - 0.4			V	I_{OH} = - 100 µA $V_{CC} = V_{CC}$ Min
V_{PPL}	V_{PP} during Normal Operations		0.0		5.5	V	
V_{PPH}	V_{PP} during Write/ Erase Operations		4.5	5.0	5.5	V	
V_{LKO}	V_{CC} Erase/Write Lock Voltage		2.0			V	

NOTES:

1. All currents are in RMS unless otherwise noted. Typical values at V_{CC} = 5.0 V, V_{PP} = 5.0 V, T = 25°C. These currents are valid for all product versions (package and speeds).
2. I_{CCES} is specified with the device deselected. If the device is read while in erase suspend mode, current draw is the sum of I_{CCES} and I_{CCR}.
3. Automatic Power Saving (APS) reduces I_{CCR} to less than 2 mA in Static operation.
4. CMOS Inputs are either V_{CC} ±0.2 V or GND ±0.2 V. TTL Inputs are either V_{IL} or V_{IH}.

5.6 AC Characteristics - Read Only Operations [1]

V_{CC} = 3.3 V ±0.3 V, T_A = 0°C to +70°C

Symbol	Parameter	Notes	LH28F016SUT-70		LH28F016SUT-10		Units
			Min	Max	Min	Max	
t_{AVAV}	Read Cycle Time		120		150		ns
t_{AVEL}	Address Setup to CE# Going Low	3,4	10		10		ns
t_{AVGL}	Address Setup to OE# Going Low	3,4	0		0		ns
t_{AVQV}	Address to Output Delay			120		150	ns
t_{ELQV}	CE# to Output Delay	2		120		150	ns
t_{PHQV}	RP# High to Output Delay			125		155	ns
t_{GLQV}	OE# to Output Delay	2		45		50	ns
t_{ELQX}	CE# to Output in Low Z	3	0		0		ns
t_{EHQZ}	CE# to Output in High Z	3		50		55	ns
t_{GLQX}	OE# to Output in Low Z	3	0		0		ns
t_{GHQZ}	OE# to Output in High Z	3		30		40	ns
t_{OH}	Output Hold from Address, CE# or OE# Change, Whichever Occurs First	3	0		0		ns
t_{FLQV} t_{FHQV}	BYTE# to Output Delay	3		120		150	ns
t_{FLQZ}	BYTE# Low to Output in High Z	3		30		40	ns
t_{ELFL} t_{ELFH}	CE# Low to BYTE# High or Low	3		5		5	ns

AC Characteristics - Read Only Operations [1] (Continued)

V_{CC} = 5.0 V ±0.25 V, T_A = 0°C to +70°C

Symbol	Parameter	Notes	LH28F016SUT-70		Units
			Min	Max	
t_{AVAV}	Read Cycle Time		70		ns
t_{AVEL}	Address Setup to CE# Going Low	3,4	10		ns
t_{AVGL}	Address Setup to OE# Going Low	3,4	0		ns
t_{AVQV}	Address to Output Delay			70	ns
t_{ELQV}	CE# to Output Delay	2		70	ns
t_{PHQV}	RP# High to Output Delay			75	ns
t_{GLQV}	OE# to Output Delay	2		30	ns
t_{ELQX}	CE# to Output in Low Z	3	0		ns
t_{EHQZ}	CE# to Output in High Z	3		25	ns
t_{GLQX}	OE# to Output in Low Z	3	0		ns
t_{GHQZ}	OE# to Output in High Z	3		25	ns
t_{OH}	Output Hold from Address, CE# or OE# Change, Whichever Occurs First	3	0		ns
t_{FLQV} t_{FHQV}	BYTE# to Output Delay	3		70	ns
t_{FLQZ}	BYTE# Low to Output in High Z	3		25	ns
t_{ELFL} t_{ELFH}	CE# Low to BYTE# High or Low	3		5	ns

NOTES:

1. See AC Input/Output Reference Waveforms for timing measurements, Figures 5 and 6.
2. OE# may be delayed up to t_{ELQV} - t_{GLQV} after the falling edge of CE# without impact on t_{ELQV}.
3. Sampled, not 100% tested.
4. This timing parameter is used to latch the correct BSR data onto the outputs.

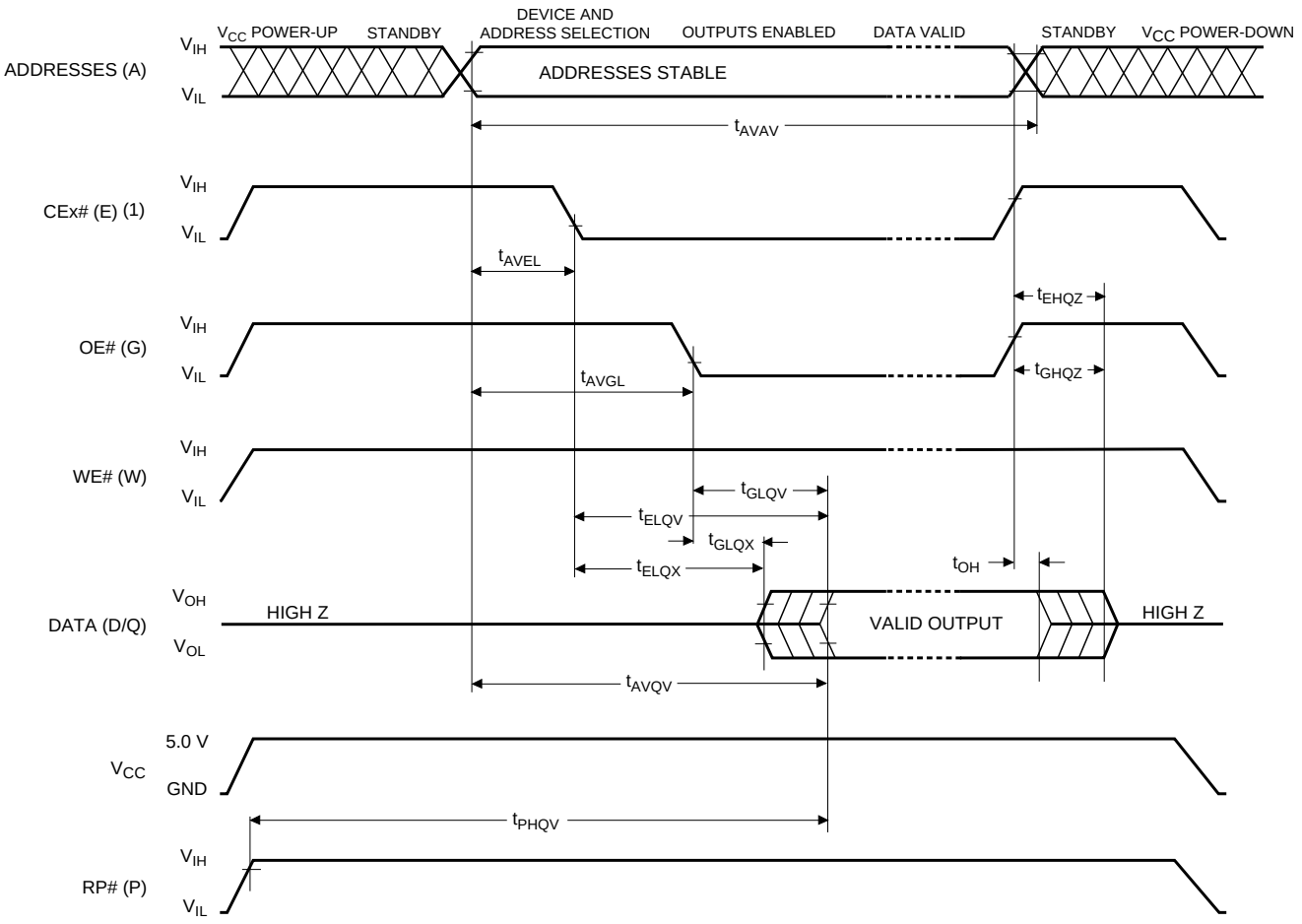
AC Characteristics - Read Only Operations [1] (Continued)

V_{CC} = 5.0 V ±0.5 V, T_A = 0°C to +70°C

Symbol	Parameter	Notes	LH28F016SUT-70		LH28F016SUT-10		Units
			Min	Max	Min	Max	
t_{AVAV}	Read Cycle Time		80		100		ns
t_{AVEL}	Address Setup to CE# Going Low	3,4	10		10		ns
t_{AVGL}	Address Setup to OE# Going Low	3,4	0		0		ns
t_{AVQV}	Address to Output Delay			80		100	ns
t_{ELQV}	CE# to Output Delay	2		80		100	ns
t_{PHQV}	RP# High to Output Delay			85		105	ns
t_{GLQV}	OE# to Output Delay	2		35		40	ns
t_{ELQX}	CE# to Output in Low Z	3	0		0		ns
t_{EHQZ}	CE# to Output in High Z	3		30		35	ns
t_{GLQX}	OE# to Output in Low Z	3	0		0		ns
t_{GHQZ}	OE# to Output in High Z	3		30		35	ns
t_{OH}	Output Hold from Address, CE# or OE# Change, Whichever Occurs First	3	0		0		ns
t_{FLQV} t_{FHQV}	BYTE# to Output Delay	3		80		100	ns
t_{FLQZ}	BYTE# Low to Output in High Z	3		30		30	ns
t_{ELFL} t_{ELFH}	CE# Low to BYTE# High or Low	3		5		5	ns

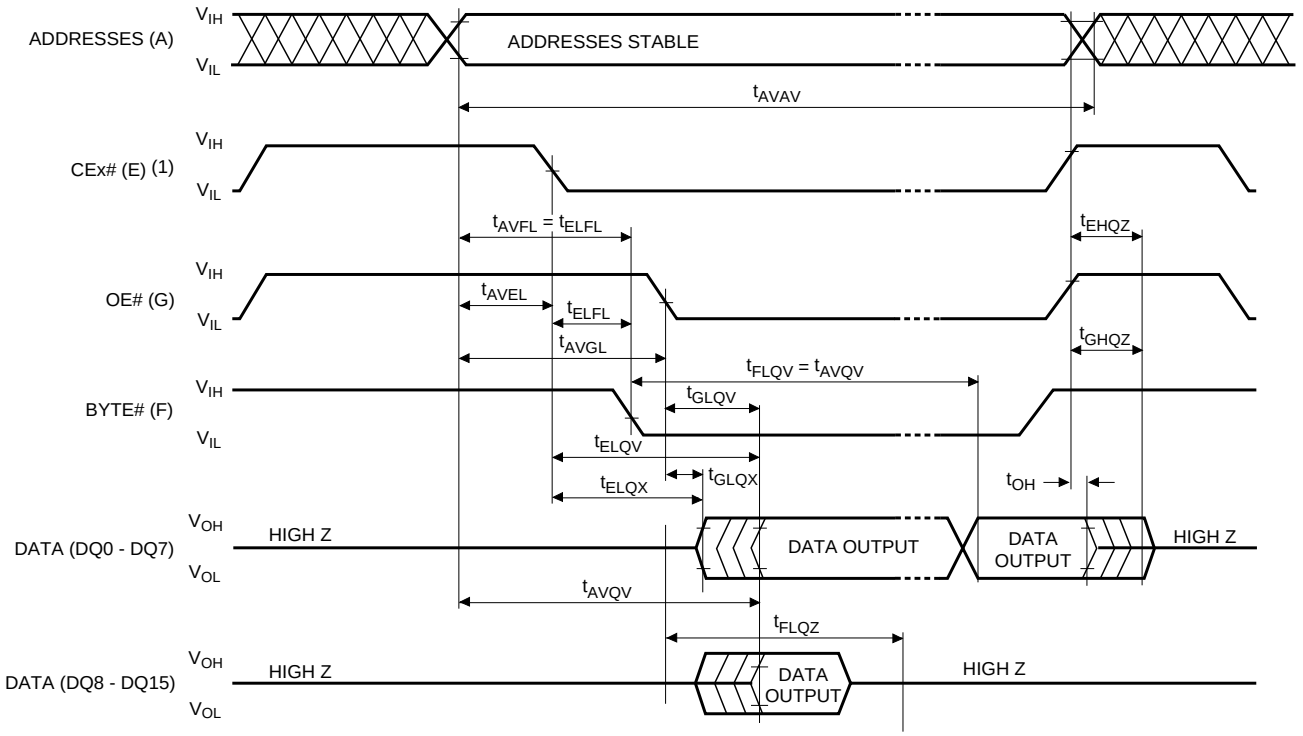
NOTES:

1. See AC Input/Output Reference Waveforms for timing measurements, Figures 5 and 6.
2. OE# may be delayed up to t_{ELQV} - t_{GLQV} after the falling edge of CE# without impact on t_{ELQV}.
3. Sampled, not 100% tested.
4. This timing parameter is used to latch the correct BSR data onto the outputs.



NOTE: CE_X# is defined as the latter of CE_0 # or CE_1# going Low or the first of CE_0# or CE_1# going High.

Figure 10. Read Timing Waveforms



NOTE: CE_X# is defined as the latter of CE_0 # or CE_1# going Low or the first of CE_0# or CE_1# going Hight.

Figure 11. BYTE# Timing Waveforms

5.7 Power-Up and Reset Timings

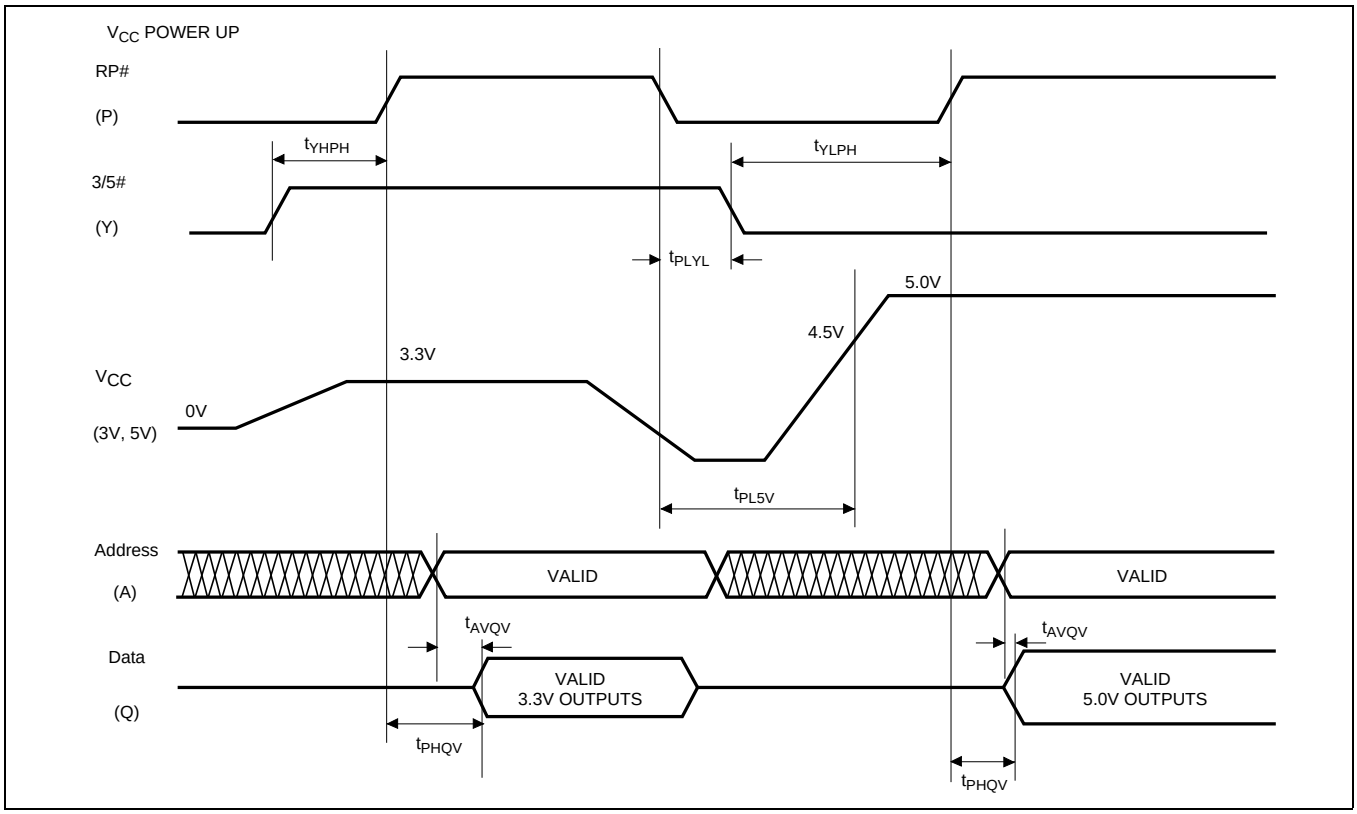


Figure 12. V_{CC} Power-Up and RP# Reset Waveforms

Symbol	Parameter	Note	LH28F016SUT-70		LH28F016SUT-10		Unit
			Min	Max	Min	Max	
t_{PLYL} t_{PLYH}	RP# Low to 3/5 # Low (High)		0		0		µs
t_{YLPH} t_{YHPH}	3/5# Low (High) to RP # High	1	2		2		µs
t_{PL5V} t_{PL3V}	RP# Low to V_{CC} at 4.5V Minimum (to V_{CC} at 3.0V min or 3.6V max)	2	0		0		µs
t_{AVQV}	Address Valid to Data Valid for V_{CC} = 5V ± 10%	3		80		100	ns
t_{PHQV}	RP# High to Data Valid for V_{CC} = 5V ± 10%	3		85		105	ns

NOTES:

CE_0#, CE_1#, and OE# are switched low after Power-Up.

1. Minimum of 2 µs is required to meet the specified t_{PHQV} times.
2. The power supply may start to switch concurrently with RP# going Low.
3. The address access time and RP# high to data valid time are shown for 5 V V_{CC} operation. Refer to the AC Characteristics Read Only Operations 3.3 V V_{CC} operation and all other speed options.

5.8 AC Characteristics for WE# - Controlled Command Write Operations (1)

V_{CC} = 3.3 V ±0.3 V, T_A = 0°C to + 70°C

Symbol	Parameter	Notes	LH28F016SUT-70			LH28F016SUT-10			Unit
			Min	Typ	Max	Min	Typ	Max	
t_{AVAV}	Write Cycle Time		120			150			ns
t_{VPWH}	V_{PP} Setup to WE# Going High	3	100			100			ns
t_{PHEL}	RP# Setup to CE# Going Low		480			480			ns
t_{ELWL}	CE# Setup to WE# Going Low		10			10			ns
t_{AVWH}	Address Setup to WE# Going High	2,6	75			75			ns
t_{DVWH}	Data Setup to WE# Going High	2,6	75			75			ns
t_{WLWH}	WE# Pulse Width		75			75			ns
t_{WHDX}	Data Hold from WE# High	2	10			10			ns
t_{WHAX}	Address Hold from WE# High	2	10			10			ns
t_{WHEH}	CE# Hold from WE# High		10			10			ns
t_{WHWL}	WE# Pulse Width High		45			75			ns
t_{GHWL}	Read Recovery before Write		0			0			ns
t_{WHRL}	WE# High to RY/BY# Going Low				100			100	ns
t_{RHPL}	RP# Hold from Valid Status Register (CSR, GSR, BSR) Data and RY/BY# High	3	0			0			ns
t_{PHWL}	RP# High Recovery to WE# Going Low		1			1			µs
t_{WHGL}	Write Recovery before Read		95			120			ns
t_{QVVL}	V_{PP} Hold from Valid Status Register (CSR, GSR, BSR) Data and RY/BY# High		0			0			µs
$t_{WHQV}1$	Duration of Word/Byte Write Operation	4,5	5	12		5	12		µs
$t_{WHQV}2$	Duration of Block Erase Operation	4	0.3			0.3			s

AC Characteristics for WE# - Controlled Command Write Operations (1) (Continued)

V_{CC} = 5.0 ±0.25 V, T_A = 0°C to +70°C

Symbol	Parameter	Notes	LH28F016SUT-70			Unit
			Min	Typ	Max	
t_{AVAV}	Write Cycle Time		70			ns
t_{VPWH}	V_{PP} Setup to WE# Going High	3	100			ns
t_{PHEL}	RP# Setup to CE# Going Low		480			ns
t_{ELWL}	CE# Setup to WE# Going Low		0			ns
t_{AVWH}	Address Setup to WE# Going High	2,6	50			ns
t_{DVWH}	Data Setup to WE# Going High	2,6	50			ns
t_{WLWH}	WE# Pulse Width		40			ns
t_{WHDX}	Data Hold from WE# High	2	0			ns
t_{WHAX}	Address Hold from WE# High	2	10			ns
t_{WHEH}	CE# Hold from WE# High		10			ns
t_{WHWL}	WE# Pulse Width High		30			ns
t_{GHWL}	Read Recovery before Write		0			ns
t_{WHRL}	WE# High to RY/BY# Going Low				100	ns
t_{RHPL}	RP# Hold from Valid Status Register (CSR, GSR, BSR) Data and RY/BY# High	3	0			ns
t_{PHWL}	RP# High Recovery to WE# Going Low		1			µs
t_{WHGL}	Write Recovery before Read		60			ns
t_{QVVL}	V_{PP} Hold from Valid Status Register (CSR, GSR, BSR) Data and RY/BY# High		0			µs
$t_{WHQV}1$	Duration of Word/Byte Write Operation	4,5	4.5	8		µs
$t_{WHQV}2$	Duration of Block Erase Operation	4	0.3			s

NOTES:

CE# is defined as the latter of CE_0# or CE_1# going Low or the first of CE_0# or CE_1# going High.

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. Word/Byte write operations are typically performed with 1 Programming Pulse.
6. Address and Data are latched on the rising edge of WE# for all Command Write operations.

AC Characteristics for WE# - Controlled Command Write Operations (1) (Continued)

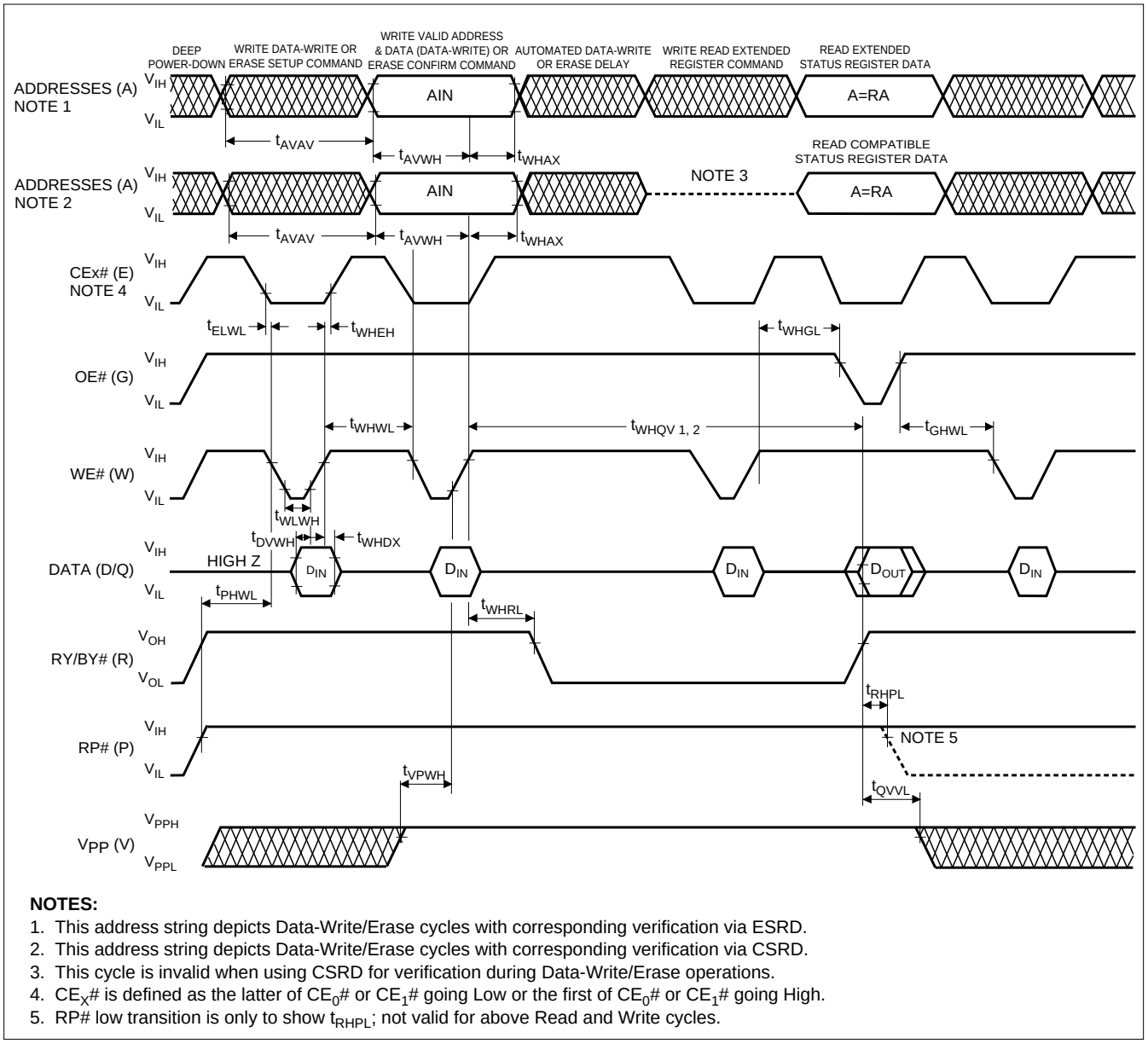
V_{CC} = 5.0 ±0.5 V, T_A = 0°C to +70°C

Symbol	Parameter	Notes	LH28F016SUT-70			LH28F016SUT-10			Unit
			Min	Typ	Max	Min	Typ	Max	
t_{AVAV}	Write Cycle Time		80			100			ns
t_{VPWH}	V_{PP} Setup to WE# Going High	3	100			100			ns
t_{PHEL}	RP# Setup to CE# Going Low		480			480			ns
t_{ELWL}	CE# Setup to WE# Going Low		0			0			ns
t_{AVWH}	Address Setup to WE# Going High	2,6	50			50			ns
t_{DVWH}	Data Setup to WE# Going High	2,6	50			50			ns
t_{WLWH}	WE# Pulse Width		50			50			ns
t_{WHDX}	Data Hold from WE# High	2	0			0			ns
t_{WHAX}	Address Hold from WE# High	2	10			10			ns
t_{WHEH}	CE# Hold from WE# High		10			10			ns
t_{WHWL}	WE# Pulse Width High		30			50			ns
t_{GHWL}	Read Recovery before Write		0			0			ns
t_{WHRL}	WE# High to RY/BY# Going Low				100			100	ns
t_{RHPL}	RP# Hold from Valid Status Register (CSR, GSR, BSR) Data and RY/BY# High	3	0			0			ns
t_{PHWL}	RP# High Recovery to WE# Going Low		1			1			µs
t_{WHGL}	Write Recovery before Read		65			80			ns
t_{QVVL}	V_{PP} Hold from Valid Status Register (CSR, GSR, BSR) Data and RY/BY# High		0			0			µs
$t_{WHQV}1$	Duration of Word/Byte Write Operation	4,5	4.5	8		4.5	8		µs
$t_{WHQV}2$	Duration of Block Erase Operation	4	0.3			0.3			s

NOTES:

CE# is defined as the latter of CE_0# or CE_1# going Low or the first of CE_0# or CE_1# going High.

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. Word/Byte write operations are typically performed with 1 Programming Pulse.
6. Address and Data are latched on the rising edge of WE# for all Command Write operations.



NOTES:
1. This address string depicts Data-Write/Erase cycles with corresponding verification via ESRD.
2. This address string depicts Data-Write/Erase cycles with corresponding verification via CSRD.
3. This cycle is invalid when using CSRD for verification during Data-Write/Erase operations.
4. CE_X# is defined as the latter of CE_0# or CE_1# going Low or the first of CE_0# or CE_1# going High.
5. RP# low transition is only to show t_{RHPL}; not valid for above Read and Write cycles.

Figure 13. AC Waveforms for Command Write Operations

5.9 AC Characteristics for CE# - Controlled Command Write Operations (1)

V_{CC} = 3.3 V ±0.3 V, T_A = 0°C to + 70°C

Symbol	Parameter	Notes	LH28F016SUT-70			LH28F016SUT-10			Unit
			Min	Typ	Max	Min	Typ	Max	
t_{AVAV}	Write Cycle Time		120			150			ns
t_{PHWL}	RP# Setup to WE# Going Low		480			480			ns
t_{VPEH}	V_{PP} Setup to CE# Going High	3	100			100			ns
t_{WLEL}	WE# Setup to CE# Going Low		0			0			ns
t_{AVEH}	Address Setup to CE# Going High	2,6	75			75			ns
t_{DVEH}	Data Setup to CE# Going High	2,6	75			75			ns
t_{ELEH}	CE# Pulse Width		75			75			ns
t_{EHDX}	Data Hold from CE# High	2	10			10			ns
t_{EHAX}	Address Hold from CE# High	2	10			10			ns
t_{EHWH}	WE# Hold from CE# High		10			10			ns
t_{EHEL}	CE# Pulse Width High		45			75			ns
t_{GHEL}	Read Recovery before Write		0			0			ns
t_{EHRL}	CE# High to RY/BY# Going Low		0		100	0		100	ns
t_{RHPL}	RP# Hold from Valid Status Register (CSR, GSR, BSR) Data and RY/BY# High	3	0			0			ns
t_{PHEL}	RP# High Recovery to CE# Going Low		1			1			µs
t_{EHGL}	Write Recovery before Read		95			120			ns
t_{QVVL}	V_{PP} Hold from Valid Status Register (CSR, GSR, BSR) Data and RY/BY# High		0			0			µs
$t_{EHQV}1$	Duration of Word/Byte Write Operation	4,5	5	12		5	12		µs
$t_{EHQV}2$	Duration of Block Erase Operation	4	0.3			0.3			s

AC Characteristics for CE# - Controlled Command Write Operations (1) (Continued)

V_{CC} = 5.0 V ±0.25 V, T_A = 0°C to + 70°C

Symbol	Parameter	Notes	LH28F016SUT-70			Unit
			Min	Typ	Max	
t_{AVAV}	Write Cycle Time		70			ns
t_{PHWL}	RP# Setup to WE# Going Low	3	480			ns
t_{VPEH}	V_{PP} Setup to CE# Going High	3	100			ns
t_{WLEL}	WE# Setup to CE# Going Low		0			ns
t_{AVEH}	Address Setup to CE# Going High	2,6	50			ns
t_{DVEH}	Data Setup to CE# Going High	2,6	50			ns
t_{ELEH}	CE# Pulse Width		40			ns
t_{EHDX}	Data Hold from CE# High	2	0			ns
t_{EHAX}	Address Hold from CE# High	2	10			ns
t_{EHWH}	WE# Hold from CE# High		10			ns
t_{EHEL}	CE# Pulse Width High		30			ns
t_{GHEL}	Read Recovery before Write		0			ns
t_{EHRL}	CE# High to RY/BY# Going Low				100	ns
t_{RHPL}	RP# Hold from Valid Status Register (CSR, GSR, BSR) Data and RY/BY# High	3	0			ns
t_{PHEL}	RP# High Recovery to CE# Going Low		1			µs
t_{EHGL}	Write Recovery before Read		60			ns
t_{QVVL}	VPP Hold from Valid Status Register (CSR, GSR, BSR) Data and RY/BY# High		0			µs
$t_{EHQV}1$	Duration of Word/Byte Write Operation	4,5	4.5	8		µs
$t_{EHQV}2$	Duration of Block Erase Operation	4	0.3			s

NOTES:

CE# is defined as the latter of CE_0# or CE_1# going Low or the first of CE_0# or CE_1# going High.

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. Word/Byte write operations are typically performed with 1 Programming Pulse.
6. Address and Data are latched on the rising edge of CE# for all Command Write Operations.

AC Characteristics for CE# - Controlled Command Write Operations (1) (Continued)

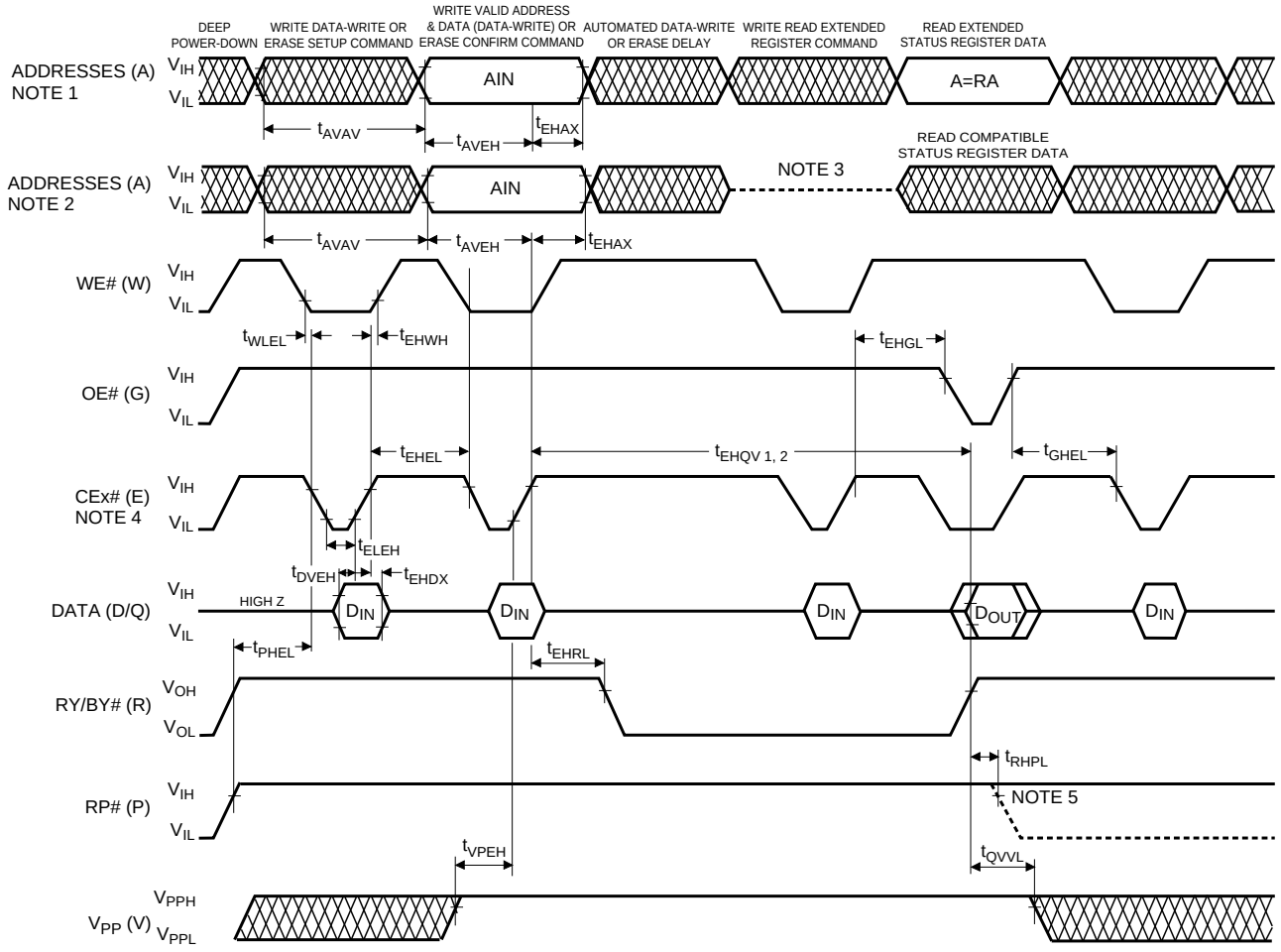
V_{CC} = 5.0 V ±0.5 V, T_A = 0°C to + 70°C

Symbol	Parameter	Notes	LH28F016SUT-70			LH28F016SUT-10			Unit
			Min	Typ	Max	Min	Typ	Max	
t_{AVAV}	Write Cycle Time		80			100			ns
t_{PHWL}	RP# Setup to WE# Going Low	3	480			480			ns
t_{VPEH}	V_{PP} Setup to CE# Going High	3	100			100			ns
t_{WLEL}	WE# Setup to CE# Going Low		0			0			ns
t_{AVEH}	Address Setup to CE# Going High	2,6	50			50			ns
t_{DVEH}	Data Setup to CE# Going High	2,6	50			50			ns
t_{ELEH}	CE# Pulse Width		50			50			ns
t_{EHDX}	Data Hold from CE# High	2	0			0			ns
t_{EHAX}	Address Hold from CE# High	2	10			10			ns
t_{EHWH}	WE# Hold from CE# High		10			10			ns
t_{EHEL}	CE# Pulse Width High		30			50			ns
t_{GHEL}	Read Recovery before Write		0			0			ns
t_{EHRL}	CE# High to RY/BY# Going Low				100			100	ns
t_{RHPL}	RP# Hold from Valid Status Register (CSR, GSR, BSR) Data and RY/BY# High	3	0			0			ns
t_{PHEL}	RP# High Recovery to CE# Going Low		1			1			µs
t_{EHGL}	Write Recovery before Read		65			80			ns
t_{QVVL}	V_{PP} Hold from Valid Status Register (CSR, GSR, BSR) Data and RY/BY# High		0			0			µs
$t_{EHQV}1$	Duration of Word/Byte Write Operation	4,5	4.5	8		4.5	8		µs
$t_{EHQV}2$	Duration of Block Erase Operation	4	0.3			0.3			s

NOTES:

CE# is defined as the latter of CE_0# or CE_1# going Low or the first of CE_0# or CE_1# going High.

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. Word/Byte write operations are typically performed with 1 Programming Pulse.
6. Address and Data are latched on the rising edge of CE# for all Command Write Operations.



NOTES:
1. This address string depicts Data-Write/Erase cycles with corresponding verification via ESRD.
2. This address string depicts Data-Write/Erase cycles with corresponding verification via CSRD.
3. This cycle is invalid when using CSRD for verification during Data-Write/Erase operations.
4. CE_X# is defined as the latter of CE_0# or CE_1# going Low or the first of CE_0# or CE_1# going High.
5. RP# low transition is only to show t_{RHPL}; not valid for above Read and Write cycles.

Figure 14. Alternate AC Waveforms for Command Write Operations

5.10 AC Characteristics for Page Buffer Write Operations (1)

V_{CC} = 5.0 V ±0.25 V, T_A = 0°C to + 70°C

Symbol	Parameter	Notes	LH28F016SUT-70			LH28F016SUT-10			Unit
			Min	Typ	Max	Min	Typ	Max	
t_{AVAV}	Write Cycle Time		120			150			ns
t_{ELWL}	CE# Setup to WE# Going Low		10			10			ns
t_{AVWL}	Address Setup to WE# Going Low	3	0			0			ns
t_{DVWH}	Data Setup to WE# Going High	2	75			75			ns
t_{WLWH}	WE# Pulse Width		75			75			ns
t_{WHDX}	Data Hold from WE# High	2	10			10			ns
t_{WHAX}	Address Hold from WE# High	2	10			10			ns
t_{WHEH}	CE# Hold from WE# High		10			10			ns
t_{WHWL}	WE# Pulse Width High		45			75			ns
t_{GHWL}	Read Recovery before Write		0			0			ns
t_{WHGL}	Write Recovery before Read		95			120			ns

NOTES:

CE# is defined as the latter of CE_0# or CE_1# going Low or the first of CE_0# or CE_1# going High.

1. These are WE#-controlled write timings, equivalent CE#-controlled write timings apply.
2. Sampled, but not 100% tested.
3. Address must be valid during the entire WE# Low pulse.

AC Characteristics for Page Buffer Write Operations [1] (Continued)

V_{CC} = 3.3 V ±0.3 V, T_A = 0°C to + 70°C

Symbol	Parameter	Notes	LH28F016SUT-70			LH28F016SUT-10			Unit
			Min	Typ	Max	Min	Typ	Max	
t_{AVAV}	Write Cycle Time		80			100			ns
t_{ELWL}	CE# Setup to WE# Going Low		0			0			ns
t_{AVWL}	Address Setup to WE# Going Low	3	0			0			ns
t_{DVWH}	Data Setup to WE# Going High	2	50			50			ns
t_{WLWH}	WE# Pulse Width		50			50			ns
t_{WHDX}	Data Hold from WE# High	2	0			0			ns
t_{WHAX}	Address Hold from WE# High	2	10			10			ns
t_{WHEH}	CE# Hold from WE# High		10			10			ns
t_{WHWL}	WE# Pulse Width High		30			50			ns
t_{GHWL}	Read Recovery before Write		0			0			ns
t_{WHGL}	Write Recovery before Read		65			80			ns

V_{CC} = 5.0 V ±0.5 V, T_A = 0°C to + 70°C

Symbol	Parameter	Notes	LH28F16SUT-70			LH28F016SUT-10			Unit
			Min	Typ	Max	Min	Typ	Max	
t_{AVAV}	Write Cycle Time		80			100			ns
t_{ELWL}	CE# Setup to WE# Going Low		0			0			ns
t_{AVWL}	Address Setup to WE# Going Low	3	0			0			ns
t_{DVWH}	Data Setup to WE# Going High	2	50			50			ns
t_{WLWH}	WE# Pulse Width		50			50			ns
t_{WHDX}	Data Hold from WE# High	2	0			0			ns
t_{WHAX}	Address Hold from WE# High	2	10			10			ns
t_{WHEH}	CE# Hold from WE# High		10			10			ns
t_{WHWL}	WE# Pulse Width High		30			30			ns
t_{GHWL}	Read Recovery before Write		0			0			ns
t_{WHGL}	Write Recovery before Read		65			80			ns

NOTES:

CE# is defined as the latter of CE_0# or CE_1# going Low or the first of CE_0# or CE_1# going High.

1. These are WE#-controlled write timings, equivalent CE#-controlled write timings apply.
2. Sampled, but not 100% tested.
3. Address must be valid during the entire WE# Low pulse.

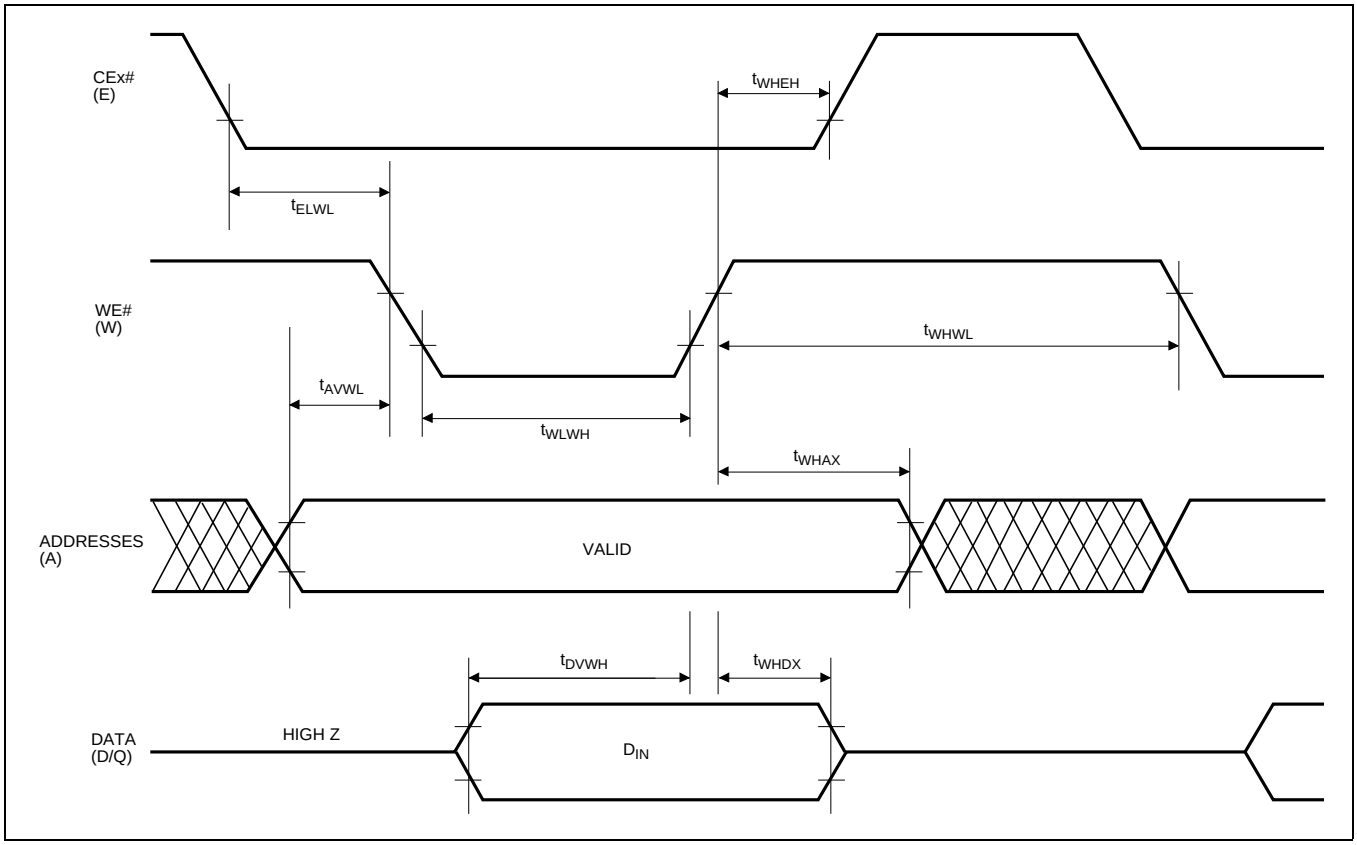


Figure 15. Page Buffer Write Timing Waveforms

5.11 Erase and Word/Byte Write Performance

V_{CC} = 3.3 V ±0.3 V, T_A = 0°C to + 70°C

Symbol	Parameter	Notes	Min	Typ(1)	Max	Units	Test Conditions
$t_{WHRH}1$	Word/Byte Write Time	2		12		µs	
$t_{WHRH}2$	Block Write Time	2		0.8	2.1	s	Byte Write Mode
$t_{WHRH}3$	Block Write Time	2		0.4	1.0	s	Word Write Mode
	Block Erase Time	2		0.9	10	s	
	Full Chip Erase Time	2		28.8		s	

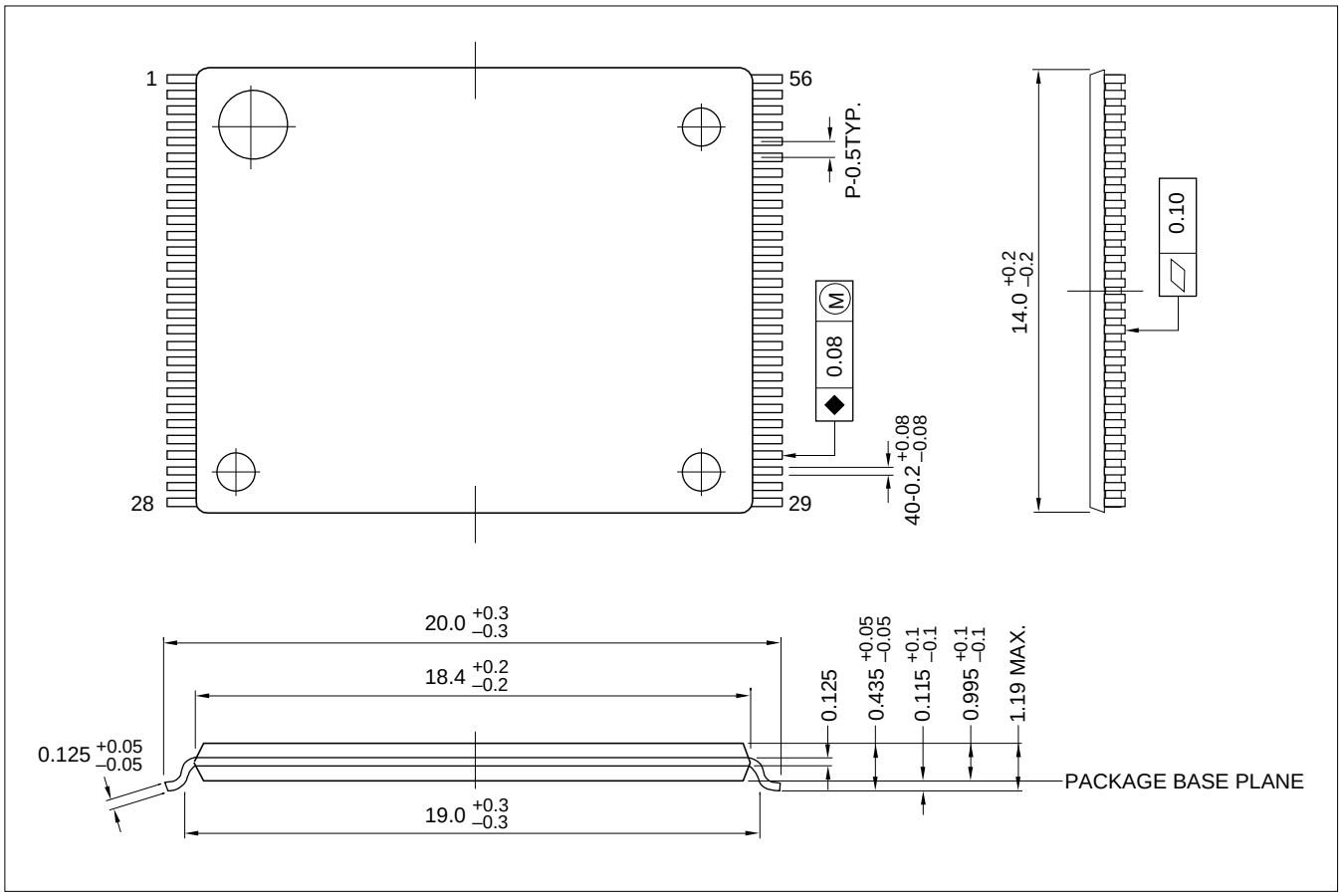
V_{CC} = 5.0 V ±0.5 V, T_A = 0°C to + 70°C

Symbol	Parameter	Notes	Min	Typ(1)	Max	Units	Test Conditions
$t_{WHRH}1$	Word/Byte Write Time	2		8		µs	
$t_{WHRH}2$	Block Write Time	2		0.54	2.1	s	Byte Write Mode
$t_{WHRH}3$	Block Write Time	2		0.27	1.0	s	Word Write Mode
	Block Erase Time	2		0.7	10	s	
	Full Chip Erase Time	2		22.4		s	

NOTES:

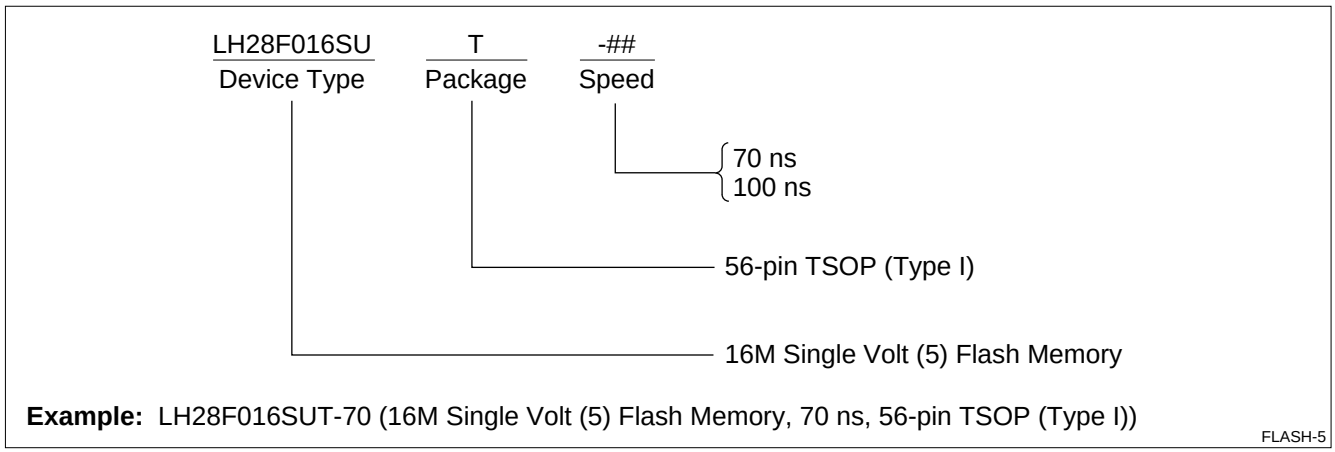
1. 25°C, V_{PP} = 5.0V.
2. Excludes System-Level Overhead.

PACKAGE DIAGRAM



56-Lead TSOP

ORDERING INFORMATION



Example: LH28F016SUT-70 (16M Single Volt (5) Flash Memory, 70 ns, 56-pin TSOP (Type I))

FLASH-5