



M28F256

256K (32K x 8) CMOS FLASH MEMORY

Military

T-46-13-27

- Flash Electrical Chip-Erase
— 1 Second Typical
- Quick-Pulse Programming™
— 100 μ s Typical Byte-Program
— 4 Second Chip-Program
- 100 Erase/Program Cycles
- 200 ns Access Time
- 12.75V V_{pp}
- Command Register Architecture for
Microprocessor/Microcontroller
Compatible Write Interface
- Low Power Consumption
— 100 μ A Maximum Standby Current
- ETOX™ Flash-Memory Technology
— EPROM-Compatible Process Base
— High-Volume Manufacturing
Experience

Intel's M28F256 is a 256 kbit-wide CMOS flash-memory. It offers the most cost-effective and reliable alternative for updatable non-volatile memory. The M28F256 adds electrical chip-erase and reprogramming to EPROM technology. Memory contents of the M28F256 can be erased and reprogrammed: 1) in a socket; 2) in a PROM-programmer; 3) on-board during subassembly test; 4) in-system during final test; and 5) in-system after-sale.

The M28F256 is targeted for alterable code-, data-storage applications where traditional EEPROM functionality (byte erasure) is either not required or is not cost-effective. The M28F256 can also be applied where EPROM ultraviolet erasure is impractical or too time consuming.

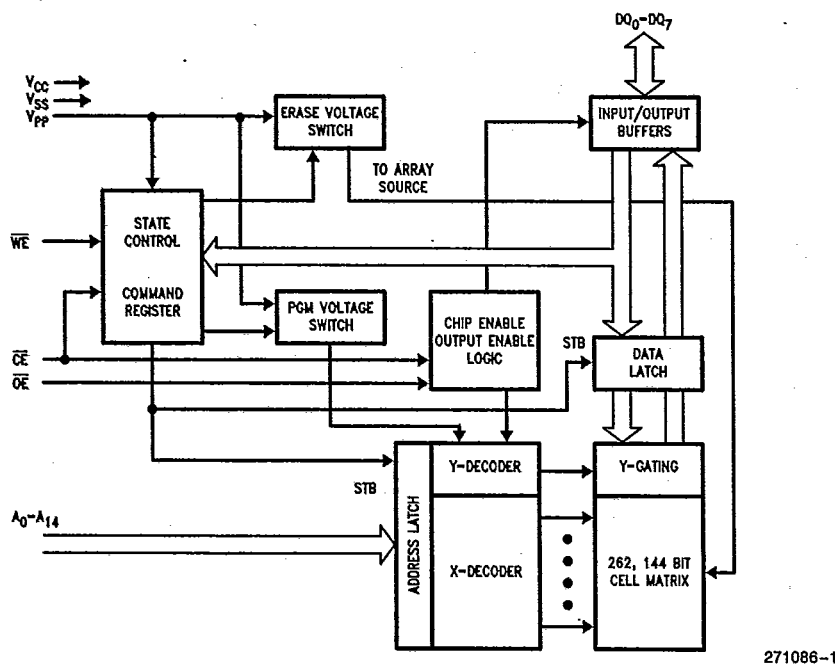


Figure 1. M28F256 Block Diagram



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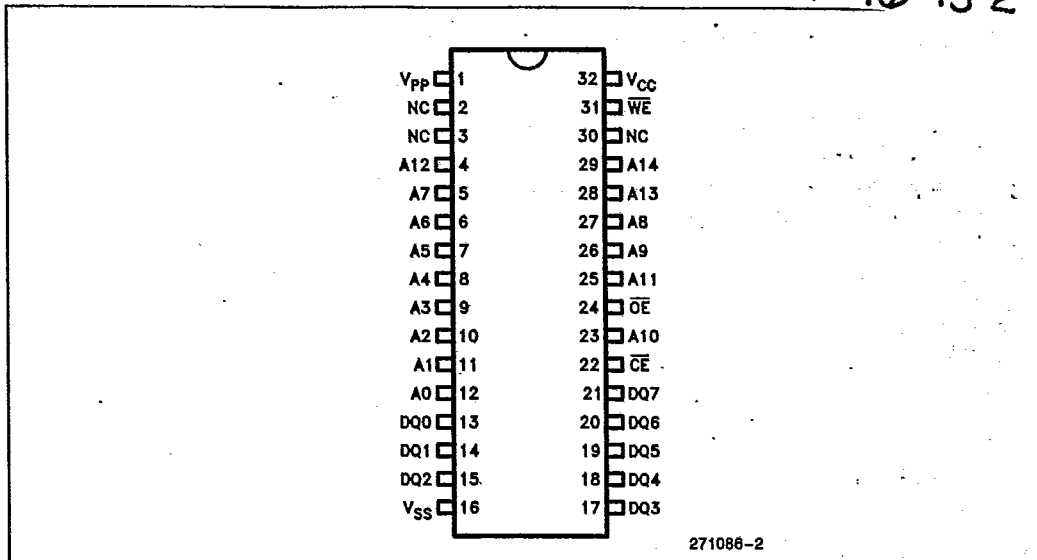


Figure 2. MD28F256 Pin Configuration

Table 1. Pin Description

Symbol	Type	Name and Function
A ₀ -A ₁₄	INPUT	ADDRESS INPUTS for memory addresses. Addresses are internally latched during a write cycle.
DQ ₀ -DQ ₇	INPUT/OUTPUT	DATA INPUT/OUTPUT: Inputs data during memory write cycles; outputs data during memory read cycles. The data pins are active high and float to tri-state OFF when the chip is deselected or the outputs are disabled. Data is internally latched during a write cycle.
\overline{CE}	INPUT	CHIP ENABLE: Activates the device's control logic, input buffers, decoders and sense amplifiers. \overline{CE} is active low; \overline{CE} high deselects the memory device and reduces power consumption to standby levels.
\overline{OE}	INPUT	OUTPUT ENABLE: Gates the device's output through the data buffers during a read cycle. \overline{OE} is active low.
\overline{WE}	INPUT	WRITE ENABLE: Controls writes to the control register and the array. Write enable is active low. Addresses are latched on the falling edge and data is latched on the rising edge of the \overline{WE} pulse. Note: With $V_{pp} = V_{ppL}$, memory contents cannot be altered.
V _{pp}		ERASE/PROGRAM POWER SUPPLY for writing the command register, erasing the entire array, or programming bytes in the array.
V _{cc}		DEVICE POWER SUPPLY (5V ±5%)
V _{ss}		GROUND
NC		NO INTERNAL CONNECTION to device. Pin may be driven or left floating.



T.46-13-27

APPLICATIONS

The M28F256 flash-memory adds electrical chip-erase and reprogrammability to EPROM non-volatility and ease of use. As such, the M28F256 is ideal for storing code or data-tables in embedded control applications where periodic updates are required.

The need for code updates pervades all phases of a system's life—from prototyping to system manufacture to after-sale service. In the factory, during prototyping, revisions to control code necessitate ultraviolet erasure and reprogramming of EPROM-based prototype codes. The M28F256 replaces the 15- to 20-minute ultraviolet erasure with one-second electrical erasure. Electrical chip-erase and reprogramming occur in the same workstation or PROM-programmer socket.

Diagnostics, performed at subassembly or final assembly stages, often require the socketing of EPROMs. Socketed test codes are ultimately replaced with EPROMs containing the final program. With electrical chip-erase and reprogramming, the M28F256 is soldered to the circuit board. Test codes are programmed into the M28F256 as it resides on the circuit board. Ultimately, the final code can be downloaded to the device. The M28F256's in-circuit alterability eliminates unnecessary handling and less-reliable socketed connections, while adding greater test flexibility.

Material and labor costs associated with code changes increase at higher levels of system integration—the most costly being code updates after sale. Code "bugs", or the desire to augment system functionality, prompt after-sale code updates. Field revisions to EPROM-based code require the removal of EPROM components or entire boards. The service technician performs the twenty-minute ultraviolet erasure and reprogramming on-site, or returns boards to the factory for rework. An alternate approach is to use one-time-programmable EPROMs. The service technician removes the "old" devices and replaces them with updated versions. The used components are discarded.

The M28F256's electrical chip-erase, byte reprogrammability, and complete nonvolatility fit well with data accumulation needs. Electrical chip-erase gives the designer a "blank-slate" on which to load data. Data can be periodically off-loaded for analysis-erasing the slate and repeating the cycle. Multiple devices can maintain a "rolling window" of accumulated data.

Designing with the in-circuit alterable M28F256 eliminates socketed memories, reduces overall material costs, and drastically cuts the labor costs associated with code updates. With the M28F256, code updates are implemented locally via an edge-connector, or remotely over a serial communication link.

A high degree of on-chip feature integration simplifies memory-to-processor interfacing. Figure 3 illustrates

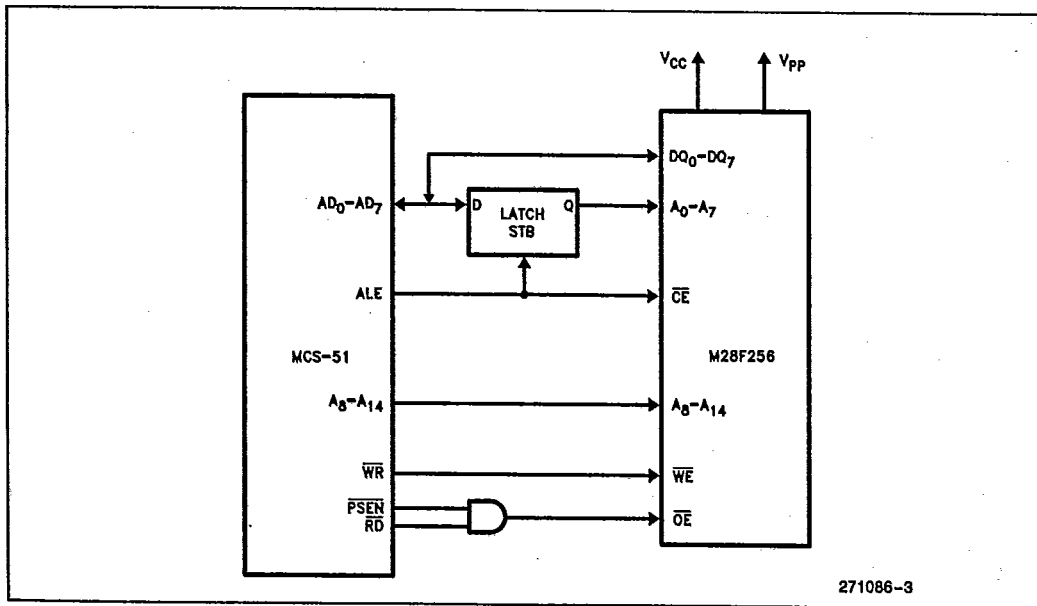


Figure 3. M28F256 in an MCS[®]-51 System

T-46-13-27

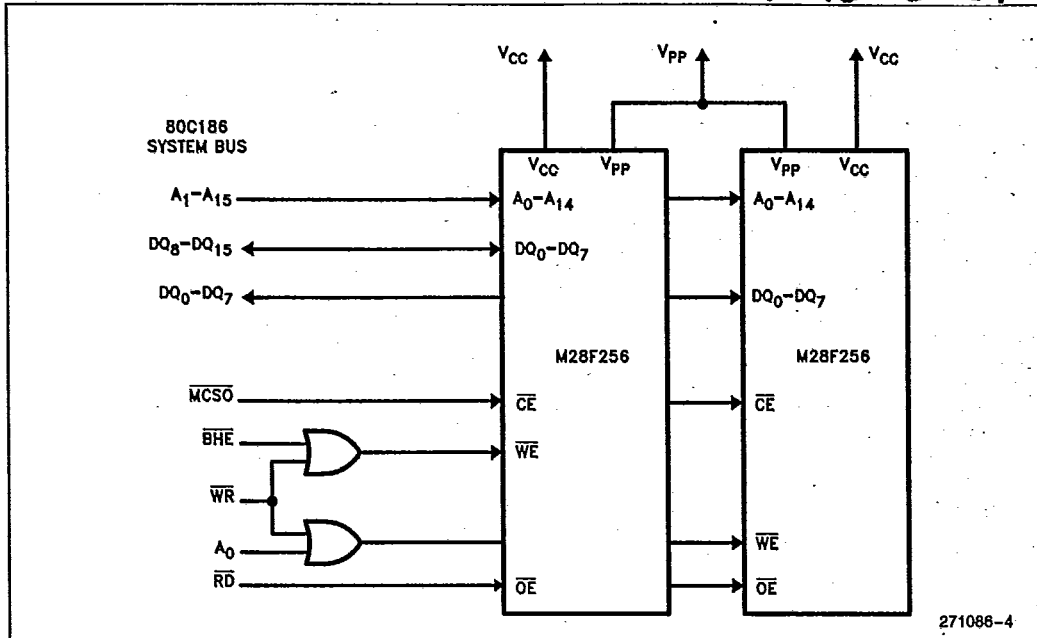


Figure 4. M28F256 in a 80C186 System

trates the interface between the MCS[®]-51 microcontroller and one M28F256 flash-memory in a minimum chip-count system. Figure 4 depicts two M28F256s tied to the 80C186 system bus. In both instances, the M28F256's architecture minimizes interface circuitry needed for complete in-circuit updates of memory contents. (Comprehensive system design information is included in AP-316, "Using the 28F256 Flash Memory for In-System Reprogrammable Nonvolatile Storage", Order Number 292046-002).

With cost-effective electrical erasure and reprogramming, the M28F256 fills the functionality gap between traditional EPROMs and E²PROMs. EPROM-compatible specifications, straightforward interfacing, and in-circuit alterability allows designers to easily augment memory flexibility and satisfy the need for updatable code-storage in today's designs.

PRINCIPLES OF OPERATION

Flash-memory augments EPROM functionality with in-circuit electrical erasure and reprogramming. The M28F256 introduces a command register to manage this new functionality. The command register allows for: 100% TTL-level control inputs; fixed power supplies during erasure and programming; and maximum EPROM compatibility.

In the absence of high voltage on the V_{PP} pin, the M28F256 is a read-only memory. Manipulation of the external memory-control pins yields the standard EPROM read, standby, output disable, and Intelligent Identifier™ operations.

The same EPROM read, standby, and output disable operations are available when high voltage is applied to the V_{PP} pin. In addition, high voltage on V_{PP} enables erasure and programming of the device. All functions associated with altering memory contents—Intelligent Identifier, erase, erase verify, program, and program verify—are accessed via the command register.

Commands are written to the register using standard microprocessor write timings. Register contents serve as input to an internal state-machine which controls the erase and programming circuitry. Write cycles also internally latch addresses and data needed for programming or erase operations. With the appropriate command written to the register, standard microprocessor read timings output array data, access the Intelligent Identifier codes, or output data for erase and program verification.

The command register is only alterable when V_{PP} is at high voltage. Depending upon the application, the system designer may choose to make the V_{PP} power supply switchable—available only when memory updates are desired. When high voltage is removed,



T-46-13-27

Table 2. M28F256 Bus Operations

Pins		V _{PP} (1)	A ₀	A ₉	CE	OE	WE	DQ ₀ -DQ ₇
Operation								
READ-ONLY	Read	V _{PPL}	A ₀	A ₉	V _{IL}	V _{IL}	V _{IH}	Data Out
	Output Disable	V _{PPL}	X(7)	X(7)	V _{IL}	V _{IH}	V _{IH}	Tri-State
	Standby	V _{PPL}	X(7)	X(7)	V _{IH}	X(7)	X(7)	Tri-State
	intelligent ID™ Manufacturer(2)	V _{PPL}	V _{IL}	V _{ID} (3)	V _{IL}	V _{IL}	V _{IH}	Data = 89H
	intelligent ID™ Device(2)	V _{PPL}	V _{IH}	V _{ID} (3)	V _{IL}	V _{IL}	V _{IH}	Data = B2H
READ/WRITE	Read	V _{PPH}	A ₀	A ₉	V _{IL}	V _{IL}	V _{IH}	Data Out(4)
	Output Disable	V _{PPH}	X(7)	X(7)	V _{IL}	V _{IH}	V _{IH}	Tri-State
	Standby(5)	V _{PPH}	X(7)	X(7)	V _{IH}	X(7)	X(7)	Tri-State
	Write	V _{PPH}	A ₀	A ₉	V _{IL}	V _{IH}	V _{IL}	Data In(6)

NOTES:

1. V_{PPL} may be ground, a no-connect with a resistor tied to ground, or $\leq V_{CC} + 2.0V$. V_{PPH} is the programming voltage specified for the device. Refer to D.C. Characteristics. When V_{PP} = V_{PPL} memory contents can be read but not written or erased.
2. Manufacturer and device codes may also be accessed via a command register write sequence. Refer to Table 3. Device code B2H requires V_{PPH} = 12.75V \pm 0.25V.
3. 11.5V \leq V_{ID} \leq 13.0V.
4. Read operations with V_{PP} = V_{PPH} may access array data or the intelligent ID™.
5. With V_{PP} at high voltage, the standby current equals I_{CC} + I_{PP} (standby).
6. Refer to Table 3 for valid Data-In during a write operation.
7. X can be V_{IL} or V_{IH}.

the contents of the register default to the read command, making the M28F256 a read-only memory. Memory contents cannot be altered.

Or, the system designer may choose to "hardwire" V_{PP}, making the high voltage supply constantly available. In this instance, all operations are performed in conjunction with the command register. The M28F256 is designed to accommodate either design practice, and to encourage optimization of the processor-memory interface.

BUS OPERATIONS**Read**

The M28F256 has two control functions, both of which must be logically active, to obtain data at the outputs. Chip-Enable (CE) is the power control and should be used for device selection. Output-Enable (OE) is the output control and should be used to gate data from the output pins, independent of device selection. Figure 7 illustrates read timing waveforms.

The read-only operation accesses array data when V_{PP} is low (V_{PPL}). When V_{PP} is high (V_{PPH}), the read operation can be used to access array data, to out-

put the intelligent Identifier™ codes, and to access data for program/erase verification.

Output Disable

With Output-Enable at a logic-high level (V_{IH}), output from the device is disabled. Output pins are placed in a high-impedance state.

Standby

With Chip-Enable at a logic-high level, the standby operation disables most of the M28F256's circuitry and substantially reduces device power consumption. The outputs are placed in a high-impedance state, independent of the Output-Enable signal. If the M28F256 is deselected during erasure, programming, or program/erase verification, the device draws active current until the operation is terminated.

intelligent Identifier™

The intelligent Identifier operation outputs the manufacturer code (89H) and device code (B2H). Programming equipment automatically matches the device with its proper erase and programming algorithms.



T-46-13-27

With Chip-Enable and Output-Enable at a logic low level, raising A9 to high voltage activates the operation. Data read from locations 0000H and 0001H represent the manufacturer's code and the device code, respectively.

The manufacturer- and device-codes can also be read via the command register, for instances where the M28F256 is erased and reprogrammed in the target system. Following a write of 80H to the command register, a read from address location 0000H outputs the manufacturer code (89H). A read from address 0001H outputs the device code (B2H).

Write

Device erasure and programming are accomplished via the command register, when high voltage is applied to the V_{pp} pin. The contents of the register serve as input to the internal state-machine. The state-machine outputs dictate the function of the device.

The command register itself does not occupy an addressable memory location. The register is a latch used to store the command, along with address and data information needed to execute the command.

The command register is written by bringing Write-Enable to a logic-low level (V_{IL}), while Chip-Enable is low. Addresses are latched on the falling edge of Write-Enable, while data is latched on the rising edge of the Write-Enable pulse. Standard microprocessor write timings are used.

The three high-order register bits (R7, R6, R5) encode the control functions. All other register bits, R4 to R0, must be zero. The only exception is the reset command, when FFH is written to the register. Register bits R7-R0 correspond to data inputs D7-D0.

Refer to A.C. Write Characteristics and the Erase/Programming Waveforms for specific timing parameters.

COMMAND DEFINITIONS

When low voltage is applied to the V_{pp} pin, the contents of the command register default to 00H, enabling read-only operations.

Placing high voltage on the V_{pp} pin enables read/write operations. Device operations are selected by writing specific data patterns into the command register. Table 3 defines these M28F256 register commands.

Table 3. Command Definitions

Command	Bus Cycles Req'd	First Bus Cycle			Second Bus Cycle		
		Operation(1)	Address(2)	Data(3)	Operation(1)	Address(2)	Data(3)
Read Memory	1	Write	X	00H			
Read intelligent ID™(4)	1	Write	X	80H	Read	IA	ID
Set-up Erase/Erased(5)	2	Write	X	20H	Write	X	20H
Erase Verify(5)	2	Write	EA	A0H	Read	X	EVD
Set-up Program/Program(6)	2	Write	X	40H	Write	PA	PD
Program Verify(6)	2	Write	X	C0H	Read	X	PVD
Reset(7)	2	Write	X	FFH	Write	X	FFH

NOTES:

- Bus operations are defined in Table 2.
- IA = Identifier address: 00H for manufacturer code, 01H for device code.
EA = Address of memory location to be read during erase verify.
PA = Address of memory location to be programmed.
Addresses are latched on the falling edge of the Write-Enable pulse.
- ID = Data read from location IA during device identification (Mfr = 89H, Device = B2H).
EVD = Data read from location EA during erase verify.
PD = Data to be programmed at location PA. Data is latched on the rising edge of Write-Enable.
PVD = Data read from location PA during program verify. PA is latched on the Program command.
- Following the Read intelligent ID command, two read operations access manufacturer and device codes.
- Figure 6 illustrates the Quick-Erase™ Algorithm.
- Figure 5 illustrates the Quick-Pulse Programming™ Algorithm.
- The second bus cycle must be followed by the desired command register write.



T-46-13-27

Read Command

While V_{PP} is high, for erasure and programming, memory contents can be accessed via the read command. The read operation is initiated by writing 00H into the command register. Microprocessor read cycles retrieve array data. The device remains enabled for reads until the command register contents are altered.

The default contents of the register upon V_{PP} power-up is 00H. This default value ensures that no spurious alteration of memory contents occurs during the V_{PP} power transition. Where the V_{PP} supply is hard-wired to the M28F256, the device powers-up and remains enabled for reads until the command-register contents are changed. Refer to the A.C. Read Characteristics and Waveforms for specific timing parameters.

Intelligent Identifier™ Command

Flash-memories are intended for use in applications where the local CPU alters memory contents. As such, manufacturer- and device-codes must be accessible while the device resides in the target system. PROM programmers typically access signature codes by raising A9 to a high voltage. However, multiplexing high voltage onto address lines is not desired system-design practice.

The M28F256 contains an intelligent Identifier operation to supplement traditional PROM-programming methodology. The operation is initiated by writing 80H into the command register. Following the command write, a read cycle from address 0000H retrieves the manufacturer code of 89H. A read cycle from address 0001H returns the device code of B2H. To terminate the operation, it is necessary to write another valid command into the register.

Set-up Erase/Erase Commands

Set-up Erase is a command-only operation that stages the device for electrical erasure of all bytes in the array. The set-up erase operation is performed by writing 20H to the command register.

To commence chip-erasure, the erase command (20H) must again be written to the register. The erase operation begins with the rising edge of the Write-Enable pulse and terminates with the rising edge of the next Write-Enable pulse (i.e., Erase-Verify Command).

This two-step sequence of set-up followed by execution ensures that memory contents are not accidentally erased. Also, chip-erasure can only occur when

high voltage is applied to the V_{PP} pin. In the absence of this high voltage, memory contents are protected against erasure. Refer to A.C. Erase Characteristics and Waveforms for specific timing parameters.

Erase-Verify Command

The erase command erases all bytes of the array in parallel. After each erase operation, all bytes must be verified. The erase verify operation is initiated by writing A0H into the command register. The address for the byte to be verified must be supplied as it is latched on the falling edge of the Write-Enable pulse. The register write terminates the erase operation with the rising edge of its Write-Enable pulse.

The M28F256 applies an internally-generated margin voltage to the addressed byte. Reading FFH from the addressed byte indicates that all bits in the byte are erased.

The erase-verify command must be written to the command register prior to each byte verification to latch its address. The process continues for each byte in the array until a byte does not return FFH data, or the last address is accessed.

In the case where the data read is not FFH, another erase operation is performed. (Refer to Set-up Erase/Erase). Verification then resumes from the address of the last-verified byte. Once all bytes in the array have been verified, the erase step is complete. The device can be programmed. At this point, the verify operation is terminated by writing a valid command (e.g. Program Set-up) to the command register. Figure 6, the Quick-Erase™ Algorithm, illustrates how commands and bus operations are combined to perform electrical erasure of the M28F256. Refer to A.C. Erase Characteristics and Waveforms for specific timing parameters.

Set-up Program/Program Commands

Set-up program is a command-only operation that stages the device for byte programming. Writing 40H into the command register performs the set-up operation.

Once the program set-up operation is performed, the next Write-Enable pulse causes a transition to an active programming operation. Addresses are internally latched on the falling edge of the Write-Enable pulse. Data is internally latched on the rising edge of the Write-Enable pulse. The rising edge of Write-Enable also begins the programming operation. The programming operation terminates with the next rising edge of Write-Enable, used to write the program-verify command. Refer to A.C. Program-



T-46-13-27-

ming Characteristics and Waveforms for specific timing parameters.

Program-Verify Command

The M28F256 is programmed on a byte-by-byte basis. Byte programming may occur sequentially or at random. Following each programming operation, the byte just programmed must be verified.

The program-verify operation is initiated by writing C0H into the command register. The register write terminates the programming operation with the rising edge of its Write-Enable pulse. The program-verify operation stages the device for verification of the byte last programmed. No new address information is latched.

The M28F256 applies an internally-generated margin voltage to the byte. A microprocessor read cycle outputs the data. A successful comparison between the programmed byte and true data means that the byte is successfully programmed. Programming then proceeds to the next desired byte location. Figure 5, the M28F256 Quick-Pulse Programming™ Algorithm, illustrates how commands are combined with bus operations to perform byte programming. Refer to A.C. Programming Characteristics and Waveforms for specific timing parameters.

Reset Command

A reset command is provided as a means to safely abort the erase- or program-command sequences. Following either set-up command (erase or program) with two consecutive writes of FFH will safely abort the operation. Memory contents will not be altered. A valid command must then be written to place the device in the desired state.

QUICK-PULSE PROGRAMMING™ ALGORITHM

The Quick-Pulse Programming algorithm uses programming operations of 100 μ s duration. Each oper-

ation is followed by a byte verification to determine when the addressed byte has been successfully programmed. The algorithm allows for up to 25 programming operations per byte, although most bytes verify on the first or second operation. The entire sequence of programming and byte verification is performed with V_{pp} at high voltage. Figure 5 illustrates the Quick-Pulse Programming algorithm.

QUICK-ERASE™ ALGORITHM

Intel's Quick-Erase algorithm yields fast and reliable electrical erasure of memory contents. The algorithm employs a closed-loop flow, similar to the Quick-Pulse Programming™ algorithm, to simultaneously remove charge from all bits in the array.

Erase begins with a read of memory contents. The M28F256 is erased when shipped from the factory. Reading FFH data from the device would immediately be followed by device programming.

Uniform and reliable erasure is ensured by first programming all bits in the device to their charged state (Data = 00H). This is accomplished, using the Quick-Pulse Programming algorithm, in approximately four seconds.

Erase execution then continues with an initial erase operation. Erase verification (data = FFH) begins at address 0000H and continues through the array to the last address, or until data other than FFH is encountered. With each erase operation, an increasing number of bytes verify to the erased state. Erase efficiency may be improved by storing the address of the last byte verified in a register. Following the next erase operation, verification starts at that stored address location. A total of seventy-nine erase operations are allowed. Erasure typically occurs in one second. Figure 6 illustrates the Quick-Erase Algorithm.



T.46-13-27

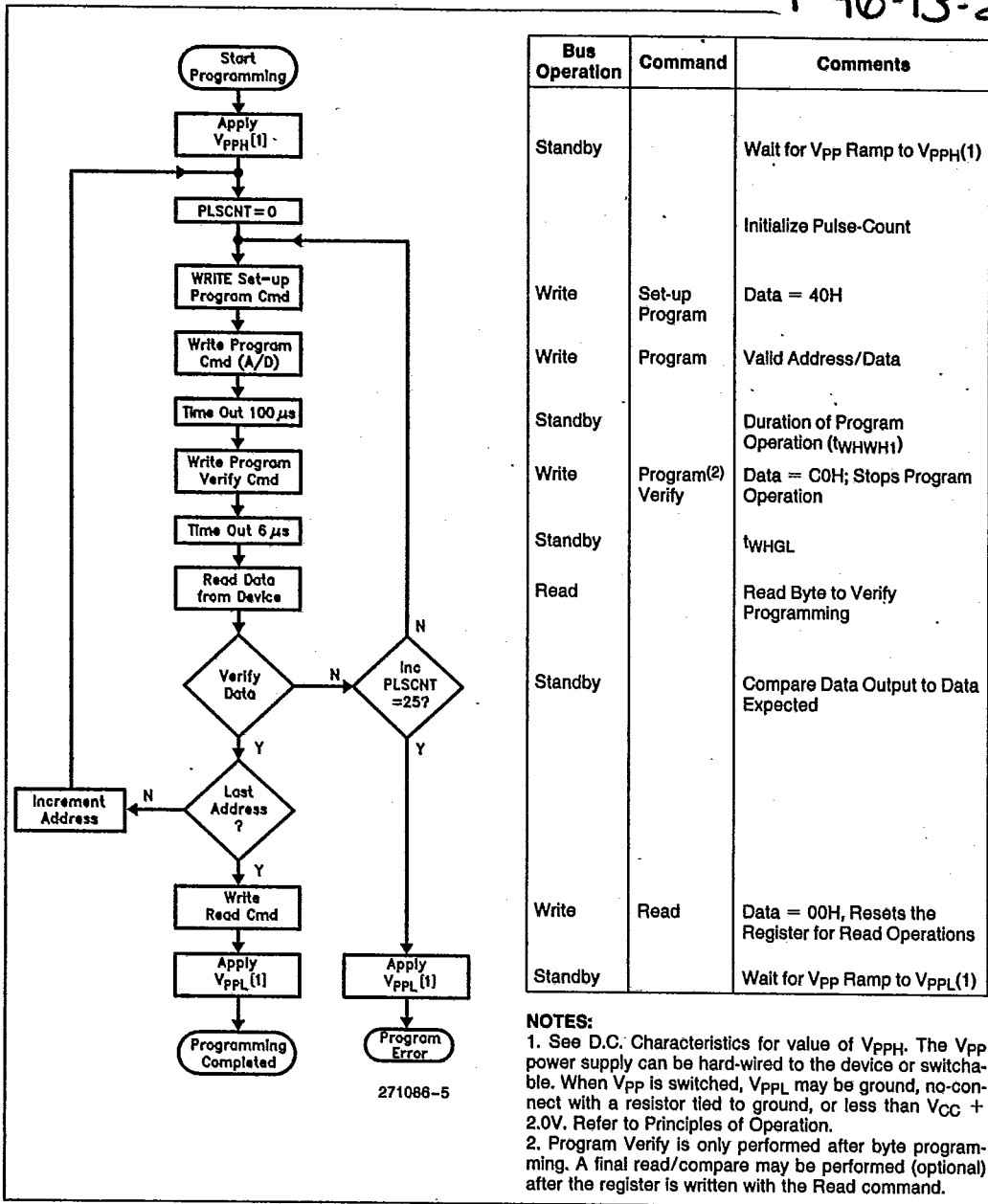


Figure 5. M28F256 Quick-Pulse Programming™ Algorithm



T-46-13-27

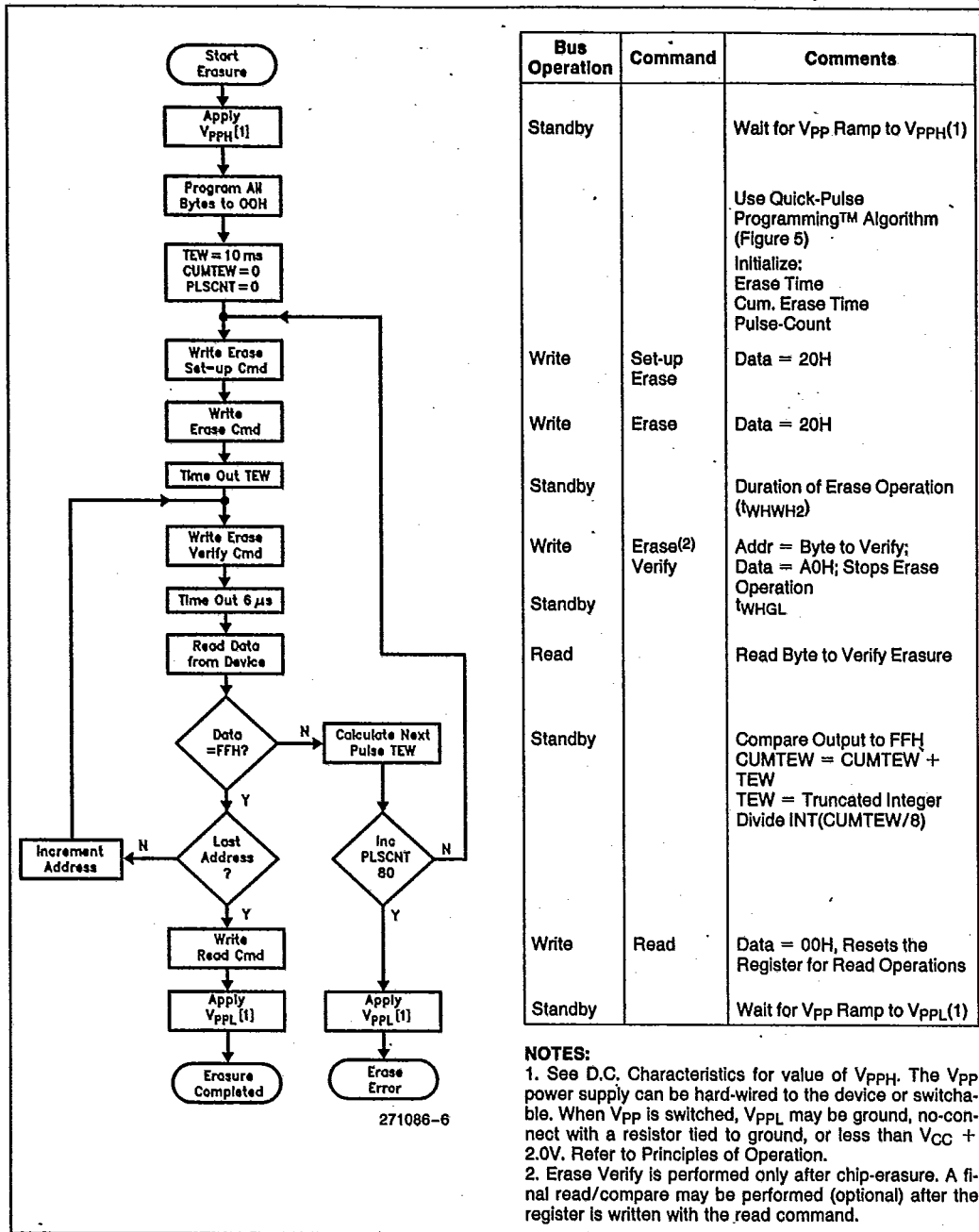


Figure 6. M28F256 Quick-Erase™ Algorithm



T-46-13-27

DESIGN CONSIDERATIONS

Two-Line Output Control

Flash-memories are often used in larger memory arrays. Intel provides two read-control inputs to accommodate multiple memory connections. Two-line control provides for:

- the lowest possible memory power dissipation and,
- complete assurance that outputs bus contention will not occur.

To efficiently use these two control inputs, an address-decoder output should drive chip-enable, while the system's read signal controls all flash-memories and other parallel memories. This assures that only enabled memory devices have active outputs, while deselected devices maintain the low power standby condition.

Power Supply Decoupling

Flash-memory power-switching characteristics require careful device decoupling. System designers are interested in three supply current (I_{CC}) issues—standby, active, and transient current peaks produced by falling and rising edges of chip-enable. The capacitive and inductive loads on the device outputs determine the magnitudes of these peaks.

Two-line control and proper decoupling capacitor selection will suppress transient voltage peaks. Each device should have a $0.1 \mu\text{F}$ ceramic capacitor connected between V_{CC} and V_{SS} , and between V_{PP} and V_{SS} .

Place the high-frequency, low-inherent-inductance capacitors as close as possible to the devices. Also, for every eight devices, a $4.7 \mu\text{F}$ electrolytic capacitor should be placed at the array's power supply

connection, between V_{CC} and V_{SS} . The bulk capacitor will overcome voltage slumps caused by printed-circuit-board trace inductance, and will supply charge to the smaller capacitors as needed.

V_{pp} Trace on Printed Circuit Boards

Programming flash-memories, while they reside in the target system, requires that the printed circuit board designer pay attention to the V_{PP} power supply trace. The V_{PP} pin supplies the memory cell current for programming. Use similar trace widths and layout considerations given the V_{CC} power bus. Adequate V_{PP} supply traces and decoupling will decrease V_{PP} voltage spikes and overshoots.

Power Up/Down Sequencing

The M28F256 is designed to offer protection against accidental erasure or programming, caused by spurious system-level signals that may exist during power transitions. The M28F256 powers-up in its read-only state. Also, with its control register architecture, alteration of memory contents only occurs after successful completion of the two-step command sequences. While these precautions are sufficient for most applications, it is recommended that V_{CC} reach its steady-state value before raising V_{PP} above $V_{CC} + 2.0\text{V}$. In addition, upon powering-down, V_{PP} should be below $V_{CC} + 2.0\text{V}$, before lowering V_{CC} .

ADDITIONAL INFORMATION ORDER NUMBER

AP-316, "Using the 28F256 Flash Memory for In-System Reprogrammable Nonvolatile Storage"	292046
ER-21 "Intel's 27F256 and 28F256 Flash Memories"	294004
ER-20 "ETOX™ Flash Memory Technology"	294005
RR-60 "ETOX™ Flash Memory Reliability Data Summary"	293002



T-46-13-27

ABSOLUTE MAXIMUM RATINGS*

Case Temperature under Bias . . .	-55°C to +125°C
Storage Temperature	-65°C to +150°C
Voltage on Any Pin with Respect to Ground	-2.0V to +7.0V(1)
Voltage on Pin A ₉ with Respect to Ground	-2.0V to +13.5V(1, 2)
V _{PP} Supply Voltage with Respect to Ground During Erase/Program	-2.0V to +14.0V(1, 2)
V _{CC} Supply Voltage with Respect to Ground	-2.0V to +7.0V(1)
Output Short Circuit Current	100 mA(3)

*Notice: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

NOTICE: Specifications contained within the following tables are subject to change.

NOTES:

1. Minimum D.C. input voltage is -0.5V. During transitions, inputs may undershoot to -2.0V for periods less than 20 ns. Maximum D.C. voltage on output pins is V_{CC} + 0.5V, which may overshoot to V_{CC} + 2.0V for periods less than 20 ns.
2. Maximum D.C. voltage on A₉ or V_{PP} may overshoot to +14.0V for periods less than 20 ns.
3. Output shorted for no more than one second. No more than one output shorted at a time.

OPERATING CONDITIONS

Symbol	Parameter	Limits		Unit	Comments
		Min	Max		
T _C	Case Temperature (Instant On)	-55	+125	°C	
V _{CC}	V _{CC} Supply Voltage	4.75	5.25	V	

D.C. CHARACTERISTICS—TTL/NMOS COMPATIBLE

(Over Specified Operating Conditions)

Symbol	Parameter	Limits		Unit	Comments
		Min	Max		
I _{LI}	Input Leakage Current		±1.0	μA	V _{CC} = V _{CC} Max V _{IN} = V _{CC} or V _{SS}
I _{LO}	Output Leakage Current		±1.0	μA	V _{CC} = V _{CC} Max V _{OUT} = V _{CC} or V _{SS}
I _{CCS}	V _{CC} Standby Current		1.0	mA	V _{CC} = V _{CC} Max CE = V _{IH}
I _{CC1}	V _{CC} Active Read Current		30	mA	V _{CC} = V _{CC} Max, CE = V _{IL} f = 6 MHz, I _{OUT} = 0 mA
I _{CC2}	V _{CC} Programming Current		30	mA	CE = V _{IL} Programming in Progress
I _{CC3}	V _{CC} Erase Current		30	mA	CE = V _{IL} Erase in Progress
I _{PPS}	V _{PP} Leakage Current		±1.0	μA	V _{PP} = V _{PPL}



T-46-13-27-

D.C. CHARACTERISTICS—TTL/NMOS COMPATIBLE (Continued)

Symbol	Parameter	Limits		Unit	Comments
		Min	Max		
I _{PP1}	V _{PP} Read Current		200	μA	V _{PP} = V _{PPH}
I _{PP2}	V _{PP} Programming Current		30	mA	V _{PP} = V _{PPH} Programming in Progress
I _{PP3}	V _{PP} Erase Current		30	mA	V _{PP} = V _{PPH} Erasure in Progress
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	I _{OL} = 2.1 mA V _{CC} = V _{CC} Min
V _{OH1}	Output High Voltage	2.4		V	I _{OH} = -2.5 mA V _{CC} = V _{CC} Min
V _{ID}	A ₉ intelligent Identifier™ Voltage	11.50	13.00	V	A ₉ = V _{ID}
I _{ID}	A ₉ intelligent Identifier™ Current		500	μA	A ₉ = V _{ID}
V _{PPL}	V _{PP} during Read-Only Operations	0.00	V _{CC} + 2.0V	V	NOTE: Erase/Program are inhibited when V _{PP} = V _{PPL}
V _{PPH}	V _{PP} during Read/Write Operations	12.50	13.00	V	

D.C. CHARACTERISTICS—CMOS COMPATIBLE (Over Specified Operating Conditions)

Symbol	Parameter	Limits		Unit	Comments
		Min	Max		
I _{LI}	Input Leakage Current		±1.0	μA	V _{CC} = V _{CC} Max V _{IN} = V _{CC} or V _{SS}
I _{LO}	Output Leakage Current		±1.0	μA	V _{CC} = V _{CC} Max V _{OUT} = V _{CC} or V _{SS}
I _{CCS}	V _{CC} Standby Current		100	μA	V _{CC} = V _{CC} Max CE = V _{IH}
I _{CC1}	V _{CC} Active Read Current		30	mA	V _{CC} = V _{CC} Max, CE = V _{IL} f = 6 MHz, I _{OUT} = 0 mA
I _{CC2}	V _{CC} Programming Current		30	mA	CE = V _{IL} Programming in Progress
I _{CC3}	V _{CC} Erase Current		30	mA	CE = V _{IL} Erasure in Progress
I _{PPS}	V _{PP} Leakage Current		1.0	μA	V _{PP} = V _{PPL}



T-46-13-27

D.C. CHARACTERISTICS—CMOS COMPATIBLE (Continued)

Symbol	Parameter	Limits		Unit	Comments
		Min	Max		
I _{PP1}	V _{PP} Read Current		200	μA	V _{PP} = V _{PPH}
I _{PP2}	V _{PP} Programming Current		30	mA	V _{PP} = V _{PPH} Programming in Progress
I _{PP3}	V _{PP} Erase Current		30	mA	V _{PP} = V _{PPH} Erasure in Progress
V _{IL}	Input Low Voltage	-0.5	0.8	V	
V _{IH}	Input High Voltage	0.7 V _{CC}	V _{CC} + 0.5	V	
V _{OL}	Output Low Voltage		0.45	V	I _{OL} = 2.1 mA V _{CC} = V _{CC} Min
V _{OH1}	Output High Voltage	0.85 V _{CC}		V	I _{OH} = -2.5 mA, V _{CC} = V _{CC} Min
V _{OH2}		V _{CC} - 0.4			
V _{ID}	A ₉ intelligent Identifier™ Voltage	11.50	13.00	V	A ₉ = V _{ID}
I _{ID}	A ₉ intelligent Identifier™ Current		500	μA	A ₉ = V _{ID}
V _{PPL}	V _{PP} during Read-Only Operations	0.00	V _{CC} + 2.0V	V	NOTE: Erase/Programs are inhibited when V _{PP} = V _{PPL}
V _{PPH}	V _{PP} during Read/Write Operations	12.50	13.00	V	

CAPACITANCE T_C = 25°C, f = 1.0 MHz

Symbol	Parameter	Limits		Unit	Conditions
		Min	Max		
C _{IN}	Address/Control Capacitance		6	pF	V _{IN} = 0V
C _{OUT}	Output Capacitance		12	pF	V _{OUT} = 0V

A.C. TEST CONDITIONS

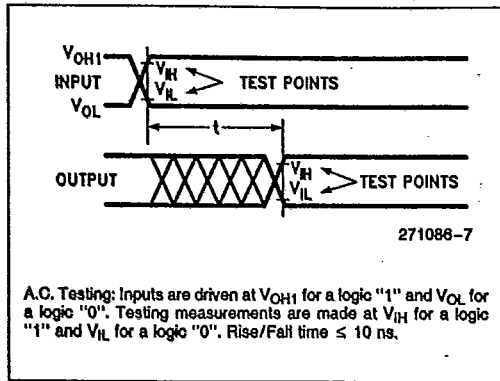
Input Rise and Fall Times (10% to 90%) 10 ns

Input Pulse Levels V_{OL} and V_{OH1}Input Timing Reference Level V_{IL} and V_{IH}Output Timing Reference Level V_{IL} and V_{IH}

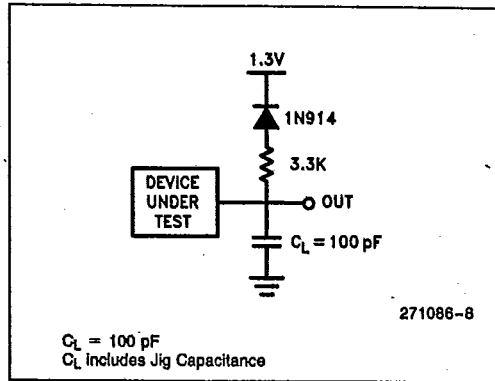


T-46-13-27

A.C. TESTING INPUT/OUTPUT WAVEFORM



A.C. TESTING LOAD CIRCUIT

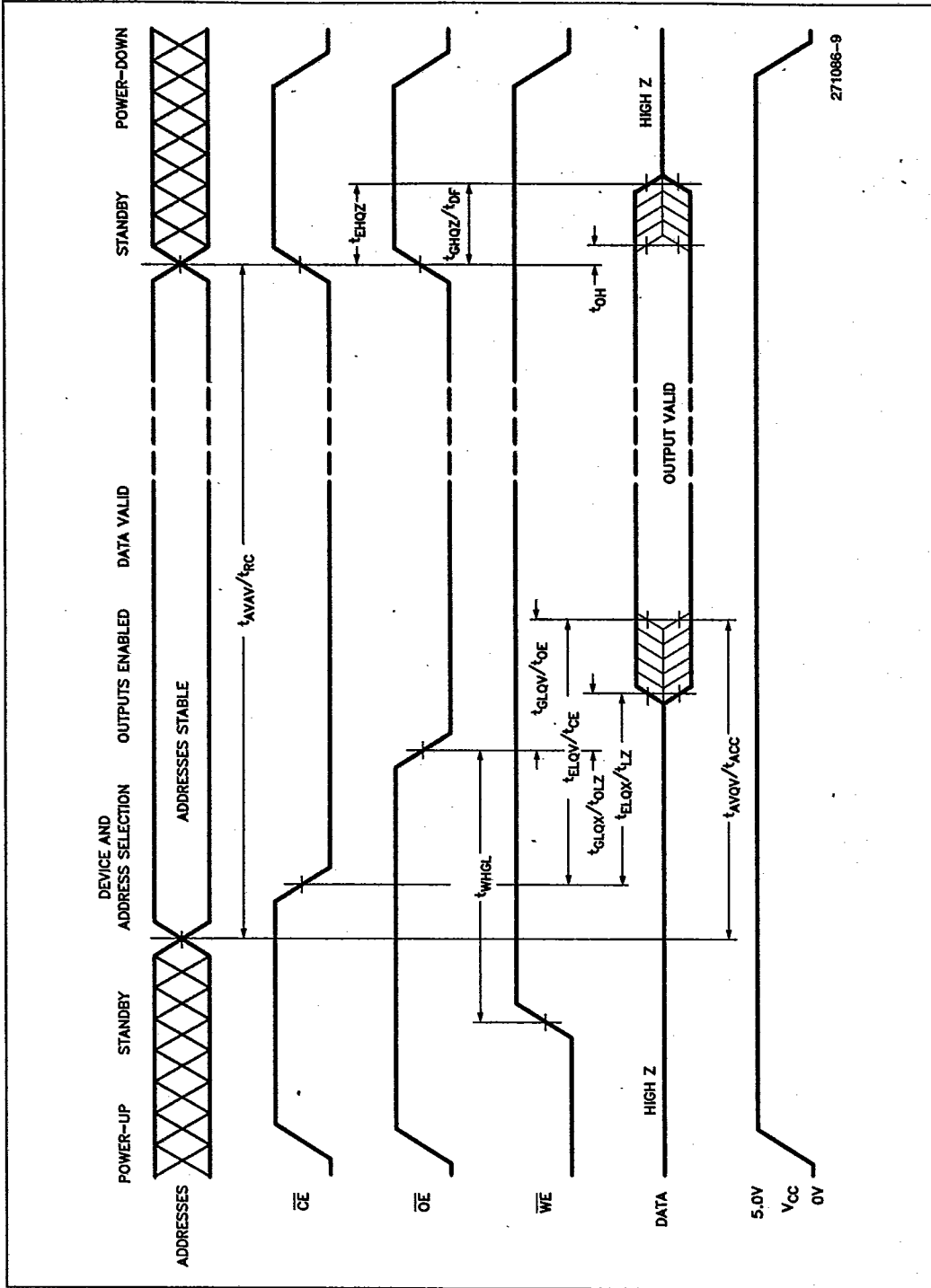


A.C. CHARACTERISTICS—Read-Only Operations (Over Specified Operating Conditions)

Versions		M28F256-20		M28F256-25		Unit
Symbol	Characteristic	Min	Max	Min	Max	
t_{AVAV}/t_{RC}	Read Cycle Time	200		250		ns
t_{ELQV}/t_{CE}	Chip Enable Access Time		200		250	ns
t_{AVQV}/t_{ACC}	Address Access Time		200		250	ns
t_{GLQV}/t_{OE}	Output Enable Access Time		75		80	ns
t_{ELQX}/t_{LZ}	Chip Enable to Output in Low Z	0		0		ns
t_{EHQZ}	Chip Disable to Output in High Z		60		65	ns
t_{GLQX}/t_{OLZ}	Output Enable to Output in Low Z	0		0		ns
t_{GHQZ}/t_{DF}	Output Disable to Output in High Z		45		55	ns
t_{OH}	Output Hold from Address, \overline{CE} , or OE Change(1)	0		0		ns
t_{WHGL}	Write Recovery Time before Read	6		6		μ s

NOTES:
1. Whichever occurs first.

T 46-13-27



271086-9

Figure 7. A.C. Waveforms for Read Operations



T-46-13-27

A.C. CHARACTERISTICS—Write/Erase/Program Operations(1)

Versions		M28F256-20		M28F256-25		Unit
Symbol	Characteristic	Min	Max	Min	Max	
t _{AVAV} /t _{WC}	Write Cycle Time	200		250		ns
t _{AVWL} /t _{AS}	Address Set-Up Time	0		0		ns
t _{WLAX} /t _{AH}	Address Hold Time	75		90		ns
t _{DVWH} /t _{DS}	Data Set-up Time	50		50		ns
t _{WHDX} /t _{DH}	Data Hold Time	10		10		ns
t _{WHGL}	Write Recovery Time before Read	6		6		μs
t _{GHWL}	Read Recovery Time before Write	0		0		μs
t _{ELWL} /t _{CS}	Chip Enable Set-Up Time	0		0		ns
t _{WHEH} /t _{CH}	Chip Enable Hold Time	0		0		ns
t _{WLWH} /t _{WP}	Write Pulse Width	60		75		ns
t _{WHWL} /t _{WPH}	Write Pulse Width High	60		75		ns
t _{WHWH1}	Duration of Programming Operation	95	150	95	150	μs
t _{WHWH2}	Duration of Erase Operation	(2)	(2) + 5%	(2)	(2) + 5%	
t _{EHVP}	Chip Enable Set-Up Time to V _{pp} Ramp	100		100		ns
t _{PEL}	V _{pp} Set-Up Time to Chip Enable Low	100		100		ns

NOTES:

1. Read timing characteristics during read/write operations are the same as during read-only operations. Refer to A.C. Characteristics for Read-Only Operations.

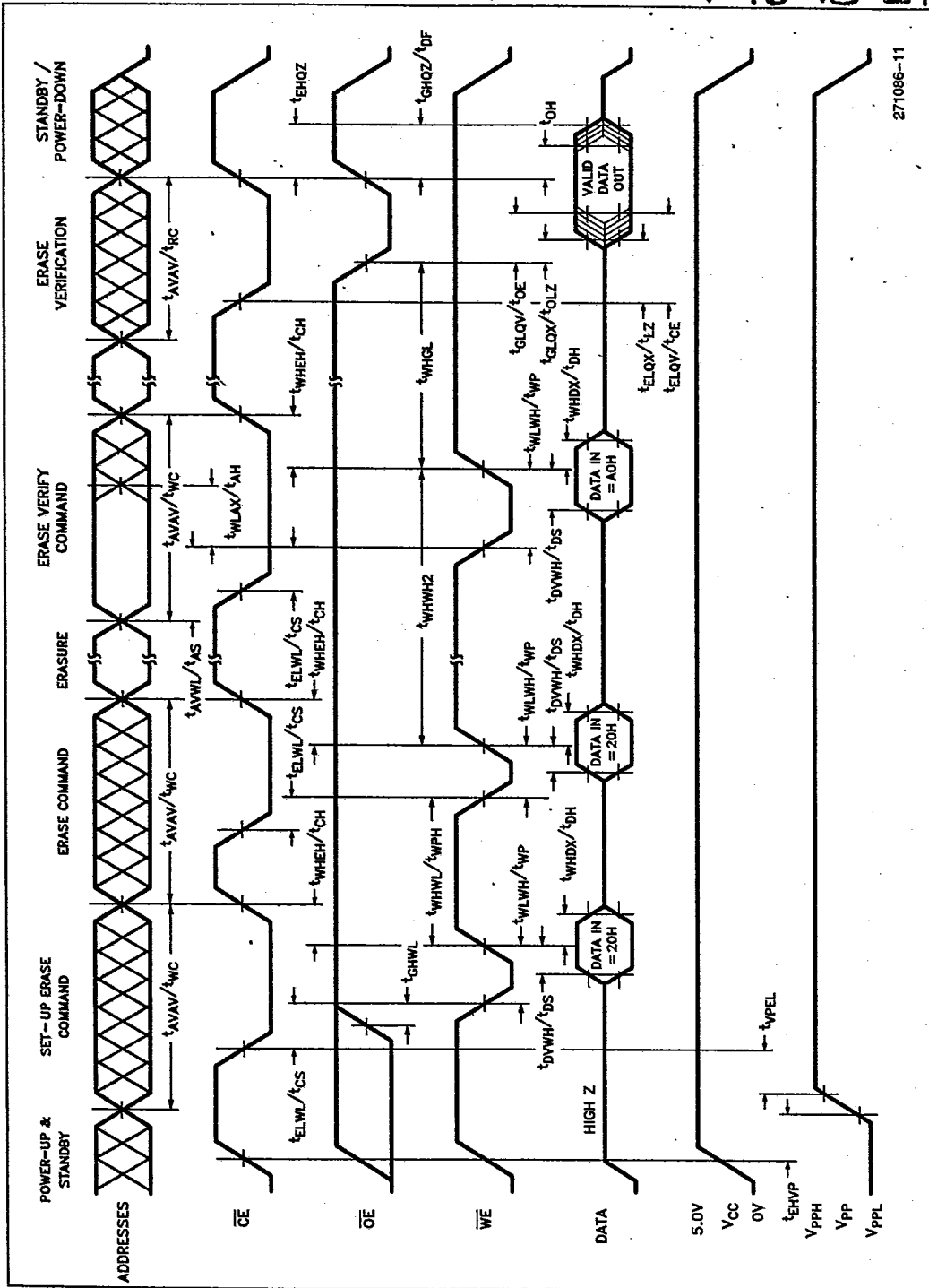
2. The duration of each erase operation is variable and is calculated in the Quick-Erase™ Algorithm. The duration of the current erase operation is equal to the truncated value of cumulative erase time divided by eight (integer divide).

$$TEW = \text{Truncated Integer Divider (CUMTEW/8)}$$

The duration of the erase operation actually applied can exceed the calculated value by a maximum tolerance of 5%. Refer to Figure 6 for additional details.



T.46-13-27



271086-11

Figure 9. A.C. Waveforms for Erase Operations