



PRELIMINARY

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## 28F256 256K (32K x 8) CMOS FLASH MEMORY

- Flash Electrical Chip-Erase
  - 1 Second Typical Chip-Erase
- Quick-Pulse Programming™ Algorithm
  - 100  $\mu$ s Typical Byte-Program
  - 4 Second Chip-Program
- 100 Min Erase/Program Cycles (10K Min Version Avail 1H90)
- 12.0V  $V_{pp}$  Supply
- High-Performance Speeds
  - 170 ns Maximum Access Time
- Low Power Consumption
  - 100  $\mu$ A Maximum Standby Current
- Command Register Architecture for Microprocessor/Microcontroller Compatible Write Interface
- Noise Immunity Features
  - $\pm 10\%$   $V_{CC}$  Tolerance
  - Maximum Latch-Up Immunity through EPI Processing
- ETOX™ Flash-Memory Technology
  - EPROM-Compatible Process Base
  - High-Volume Manufacturing Experience
- Compatible with JEDEC-Standard Byte-Wide EPROM Pinouts
  - 32-Pin Cerdip
  - 32-Lead PLCC

(See Packaging Spec., Order #231369)

Intel's 28F256 CMOS flash-memory offers the most cost-effective and reliable alternative for updatable non-volatile memory. The 28F256 adds electrical chip-erasure and reprogramming to familiar EPROM technology. Memory contents can be erased and reprogrammed: in a test socket; in a PROM-programmer socket; on-board during subassembly test; in-system during final test; and in-system after-sale. The 28F256 increases memory flexibility, while contributing to time- and cost-savings. The 28F256 is targeted for alterable code- or data-storage applications where traditional E<sup>2</sup>PROM functionality (byte-erasure) is either not required or not cost-effective. The 28F256 can also be applied where EPROM ultraviolet erasure is impractical or time-consuming.

The 28F256 is a 256-kilobit non-volatile memory organized as 32768 bytes of 8 bits. Intel's 28F256 is offered in 32-pin Cerdip or 32-lead PLCC packages. Pin assignments conform to JEDEC standards for byte-wide EPROMs.

Intel's 28F256 employs advanced CMOS circuitry for systems requiring high-performance access speeds, low power consumption, and immunity to noise. Its 170 nanosecond access time provides no-WAIT-state performance for a wide range of microprocessors and microcontrollers. Maximum standby current of 100  $\mu$ A translates into power savings when the device is deselected. Finally, the highest degree of latch-up protection is achieved through Intel's unique EPI processing. Prevention of latch-up is provided for stresses up to 100 mA on address and data pins, from  $-1V$  to  $V_{CC} + 1V$ .

With Intel's ETOX™ (EPROM tunnel oxide) process base, the 28F256 levers years of EPROM experience to yield the highest levels of quality, reliability, and cost-effectiveness.



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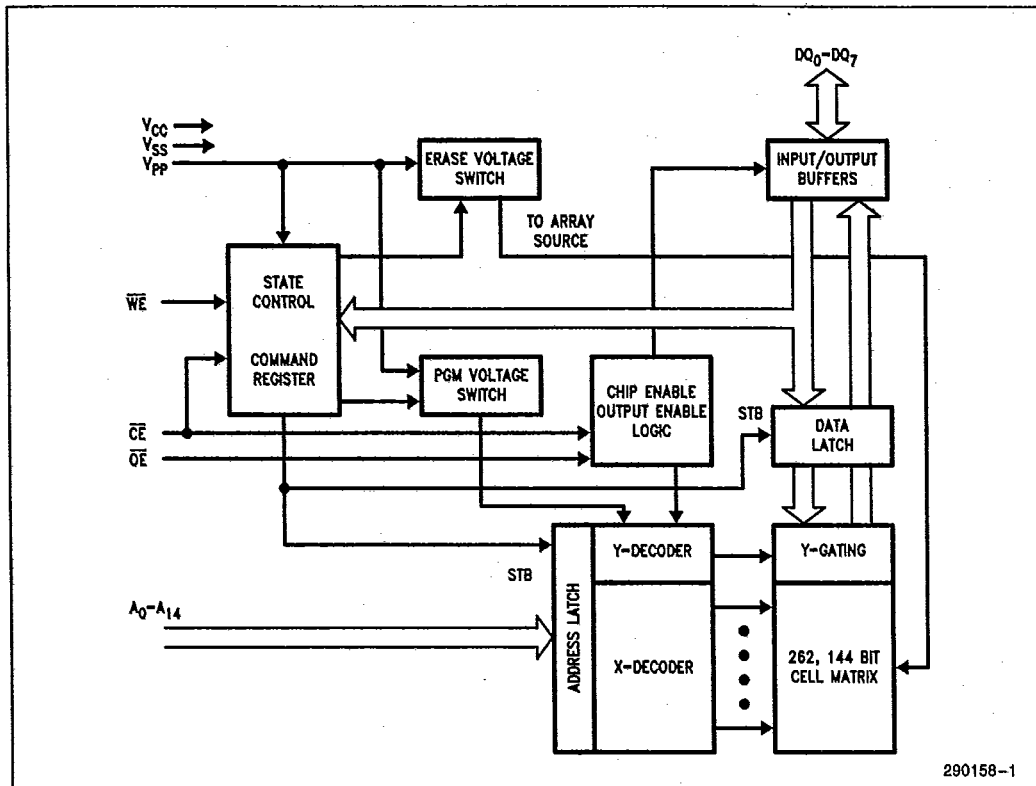


Figure 1. 28F256 Block Diagram



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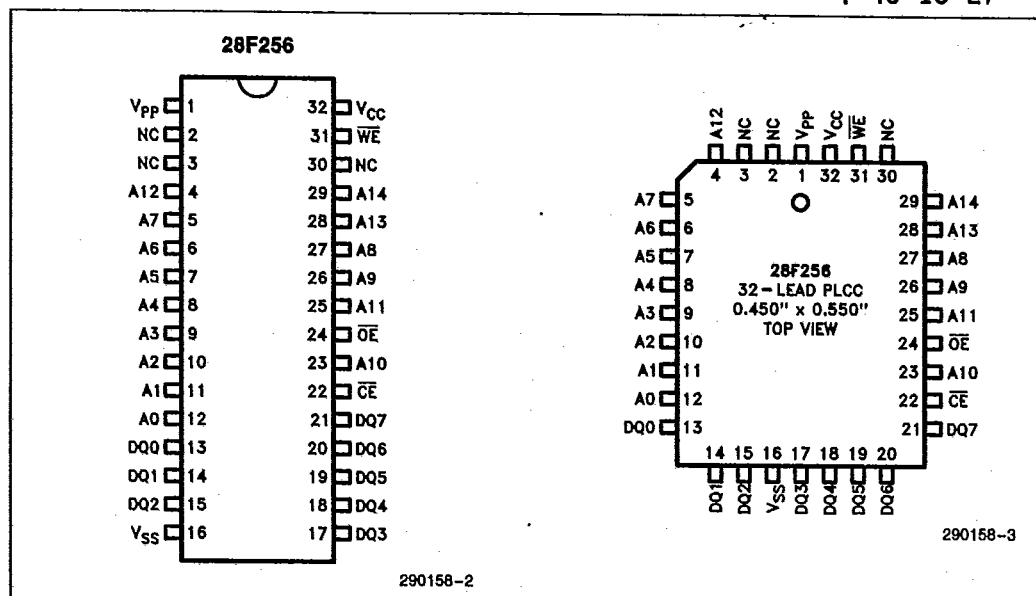


Figure 2. 28F256 Pin Configurations

Table 1. Pin Description

| Symbol                           | Type         | Name and Function                                                                                                                                                                                                                                                                             |
|----------------------------------|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A <sub>0</sub> -A <sub>14</sub>  | INPUT        | <b>ADDRESS INPUTS</b> for memory addresses. Addresses are internally latched during a write cycle.                                                                                                                                                                                            |
| DQ <sub>0</sub> -DQ <sub>7</sub> | INPUT/OUTPUT | <b>DATA INPUT/OUTPUT:</b> 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        | <b>CHIP ENABLE:</b> 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        | <b>OUTPUT ENABLE:</b> Gates the devices output through the data buffers during a read cycle. $\overline{OE}$ is active low.                                                                                                                                                                   |
| WE                               | INPUT        | <b>WRITE ENABLE:</b> 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 WE pulse.<br><b>Note:</b> With $V_{PP} \leq V_{CC} + 2V$ , memory contents cannot be altered. |
| V <sub>PP</sub>                  |              | <b>ERASE/PROGRAM POWER SUPPLY</b> for writing the command register, erasing the entire array, or programming bytes in the array.                                                                                                                                                              |
| V <sub>CC</sub>                  |              | <b>DEVICE POWER SUPPLY</b> (5V $\pm$ 10%)                                                                                                                                                                                                                                                     |
| V <sub>SS</sub>                  |              | <b>GROUND</b>                                                                                                                                                                                                                                                                                 |
| NC                               |              | <b>NO INTERNAL CONNECTION</b> to device. Pin may be driven or left floating.                                                                                                                                                                                                                  |



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## APPLICATIONS

The 28F256 flash-memory adds electrical chip-erase and reprogrammability to EPROM non-volatility and ease of use. The 28F256 is ideal for storing code or data-tables in applications where periodic updates are required. With a minimum of 10,000 erase/program cycles available as an option, the 28F256 also serves as a dense, nonvolatile data acquisition and storage medium.

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 28F256 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 28F256 is soldered to the circuit board. Test codes are programmed into the 28F256 as it resides on the circuit board. Ultimately, the final code can be downloaded to the device. The 28F256'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.

Designing with the in-circuit alterable 28F256 eliminates socketed memories, reduces overall material costs, and drastically cuts the labor costs associated with code updates. With the 28F256, code updates are implemented locally via an edge-connector, or remotely over a serial communication link.

The 28F256's electrical chip-erase, byte reprogrammability, and complete nonvolatility fit well with data accumulation needs. Electrical chip-erase gives the designer a "blank-slate" in which to log data. Data can be periodically off-loaded for analysis—erasing the slate and repeating the cycle. Or, multiple devices can maintain a "rolling window" of accumulated data.

A high degree of on-chip feature integration simplifies memory-to-processor interfacing. Figure 3 illustrates the interface between the MCS®-51 micro-

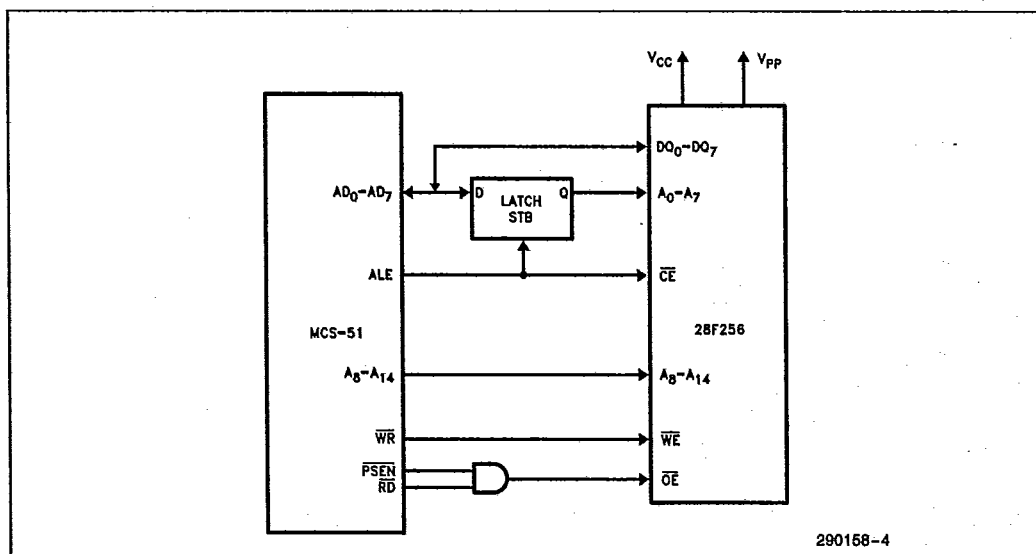


Figure 3. 28F256 in an MCS®-51 System

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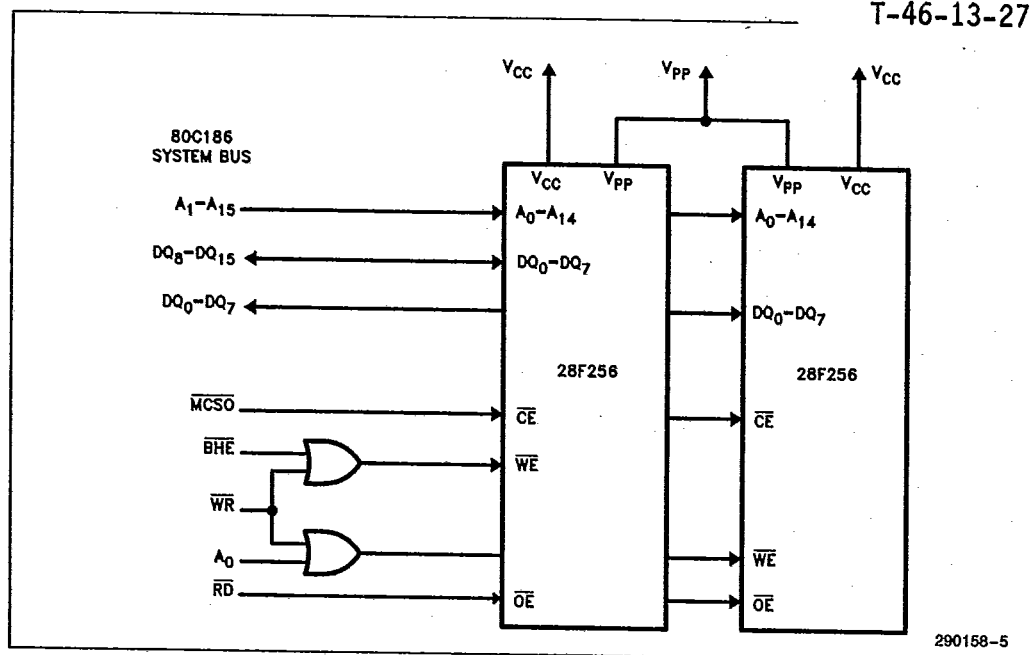


Figure 4. 28F256 in a 80C186 System

controller and one 28F256 flash-memory in a minimum chip-count system. Figure 4 depicts two 28F256s tied to the 80C186 system bus. In both instances, the 28F256'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 in-system reprogramming and extended cycling capability, the 28F256 fills the functionality gap between traditional EPROMs and E<sup>2</sup>PROMs. EPROM-compatible specifications, straightforward interfacing, and in-circuit alterability allows designers to easily augment memory flexibility and satisfy the need for updatable nonvolatile storage in today's designs.

## PRINCIPLES OF OPERATION

Flash-memory augments EPROM functionality with in-circuit electrical erasure and reprogramming. The 28F256 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<sub>pp</sub> pin, the 28F256 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<sub>pp</sub> pin. In addition, high voltage on V<sub>pp</sub> 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<sub>pp</sub> is at high voltage. Depending upon the application, the system designer may choose to make the V<sub>pp</sub> power supply switchable—available only when memory updates are desired. When high voltage is removed,



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Table 2. 28F256 Bus Operations

| Pins       |                                 | V <sub>PP</sub> (1) | A <sub>0</sub>  | A <sub>9</sub>      | CE              | OE              | WE              | DQ <sub>0</sub> -DQ <sub>7</sub> |
|------------|---------------------------------|---------------------|-----------------|---------------------|-----------------|-----------------|-----------------|----------------------------------|
| Operation  |                                 |                     |                 |                     |                 |                 |                 |                                  |
| READ-ONLY  | Read                            | V <sub>PPL</sub>    | A <sub>0</sub>  | A <sub>9</sub>      | V <sub>IL</sub> | V <sub>IL</sub> | V <sub>IH</sub> | Data Out                         |
|            | Output Disable                  | V <sub>PPL</sub>    | X               | X                   | V <sub>IL</sub> | V <sub>IH</sub> | V <sub>IH</sub> | Tri-State                        |
|            | Standby                         | V <sub>PPL</sub>    | X               | X                   | V <sub>IH</sub> | X               | X               | Tri-State                        |
|            | intelligent ID™ Manufacturer(2) | V <sub>PPL</sub>    | V <sub>IL</sub> | V <sub>ID</sub> (3) | V <sub>IL</sub> | V <sub>IL</sub> | V <sub>IH</sub> | Data = 89H                       |
|            | intelligent ID™ Device(2)       | V <sub>PPL</sub>    | V <sub>IH</sub> | V <sub>ID</sub> (3) | V <sub>IL</sub> | V <sub>IL</sub> | V <sub>IH</sub> | Data = B1H<br>or B2H             |
| READ/WRITE | Read                            | V <sub>PPH</sub>    | A <sub>0</sub>  | A <sub>9</sub>      | V <sub>IL</sub> | V <sub>IL</sub> | V <sub>IH</sub> | Data Out(4)                      |
|            | Output Disable                  | V <sub>PPH</sub>    | X               | X                   | V <sub>IL</sub> | V <sub>IH</sub> | V <sub>IH</sub> | Tri-State                        |
|            | Standby(5)                      | V <sub>PPH</sub>    | X               | X                   | V <sub>IH</sub> | X               | X               | Tri-State                        |
|            | Write                           | V <sub>PPH</sub>    | A <sub>0</sub>  | A <sub>9</sub>      | V <sub>IL</sub> | V <sub>IH</sub> | V <sub>IL</sub> | Data In(6)                       |

**NOTES:**

1. V<sub>PPL</sub> may be ground, a no-connect with a resistor tied to ground, or  $\leq V_{CC} + 2.0V$ . V<sub>PPH</sub> is the programming voltage specified for the device. Refer to D.C. Characteristics. When V<sub>PP</sub> = V<sub>PPL</sub> 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 B1H requires V<sub>PPH</sub> = 12.0V  $\pm 5\%$ . Device code B2H requires V<sub>PPH</sub> = 12.75V  $\pm 0.25V$ . All other addresses low.
3. 11.5V  $\leq V_{ID} \leq 13.0V$ .
4. Read operations with V<sub>PP</sub> = V<sub>PPH</sub> may access array data or the intelligent ID™.
5. With V<sub>PP</sub> at high voltage, the standby current equals I<sub>CC</sub> + I<sub>PP</sub> (standby).
6. Refer to Table 3 for valid Data-In during a write operation.
7. X can be V<sub>IL</sub> or V<sub>IH</sub>.

the contents of the register default to the read command, making the 28F256 a read-only memory. Memory contents cannot be altered.

Or, the system designer may choose to "hardwire" V<sub>PP</sub>, making the high voltage supply constantly available. In this instance, all operations are performed in conjunction with the command register. The 28F256 is designed to accommodate either design practice, and to encourage optimization of the processor-memory interface.

**BUS OPERATIONS****Read**

The 28F256 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 operation only accesses array data when V<sub>PP</sub> is low (V<sub>PPL</sub>). When V<sub>PP</sub> is high (V<sub>PPH</sub>), the read operation can be used to access array data, to output the intelligent Identifier™ codes, and to access data for program/erase verification.

**Output Disable**

With Output-Enable at a logic-high level (V<sub>IH</sub>), 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 28F256'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 28F256 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 (B1H). Programming equipment automatically matches the device with its proper erase and programming algorithms.



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With Chip-Enable and Output-Enable at a logic low level, raising A9 to high voltage (11.5V–13.0V) 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 28F256 is erased and reprogrammed in the target system. Following a write of 90H to the command register, a read from address location 0000H outputs the manufacturer code (89H). A read from address 0001H outputs the device code (B1H).

### Write

Device erasure and programming are accomplished via the command register, when high voltage is applied to the Vpp 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 Vpp pin, the contents of the command register default to 00H, enabling read-only operations.

Placing high voltage on the Vpp pin enables read/write operations. Device operations are selected by writing specific data patterns into the command register. Table 3 defines these 28F256 register commands.

Table 3. Command Definitions

| Command                   | Bus Cycles | First Bus Cycle |            |         | Second Bus Cycle |            |         |
|---------------------------|------------|-----------------|------------|---------|------------------|------------|---------|
|                           | Req'd      | 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          | 90H     | Read             | IA         | ID      |
| Set-up Erase/Erase(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 = B1H).  
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.

**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 28F256, 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 28F256 contains an Intelligent Identifier operation to supplement traditional PROM-programming methodology. The operation is initiated by writing 90H 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 B1H or 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 28F256 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 28F256. 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-



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ming Characteristics and Waveforms for specific timing parameters.

#### Program-Verify Command

The 28F256 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 28F256 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 7, the 28F256 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  $\mu$ s duration. Each operation 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 Vpp at high voltage. Figure 7 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 28F256 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 8 illustrates the Quick-Erase Algorithm.

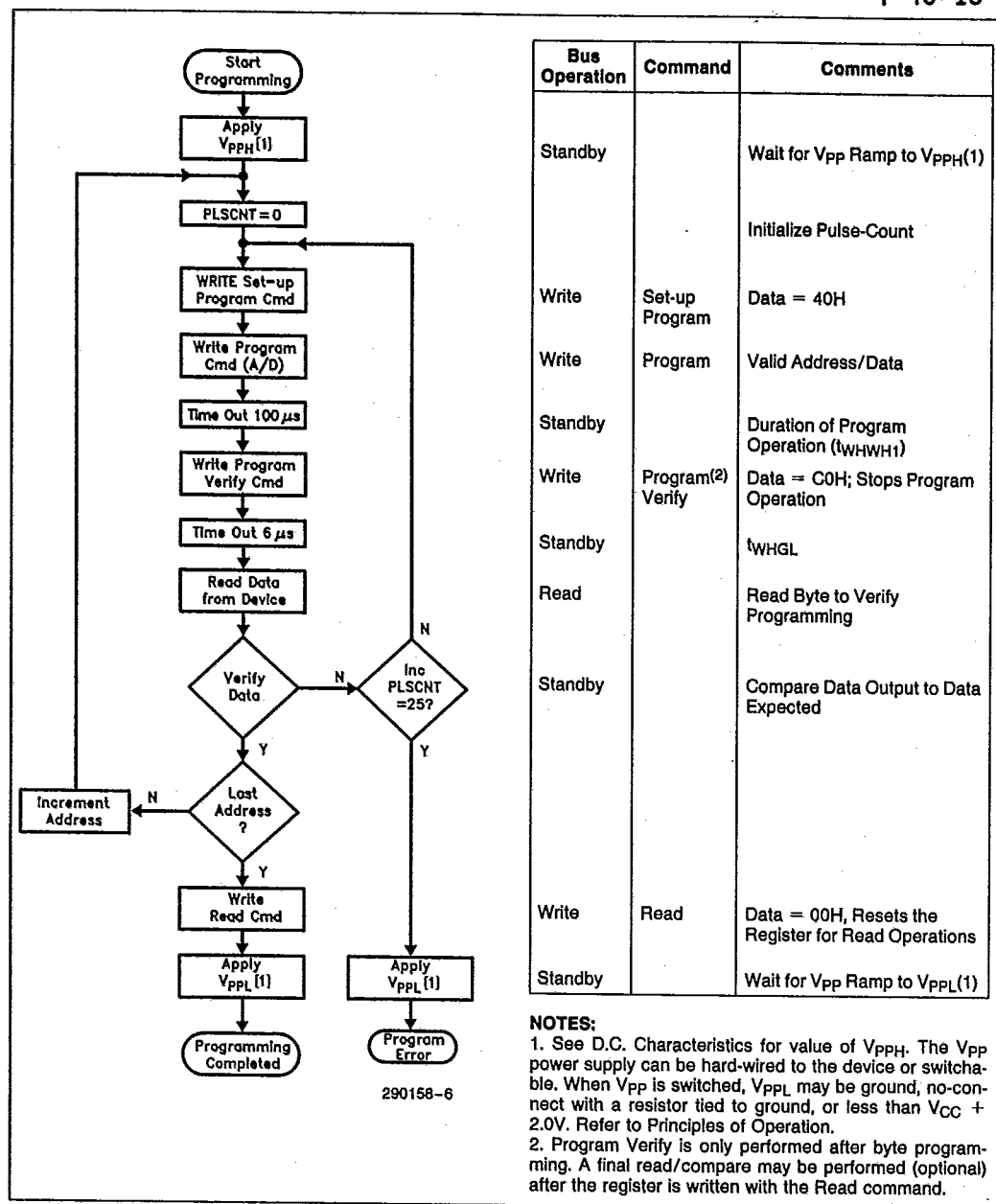


Figure 7. 28F256 Quick-Pulse Programming™ Algorithm



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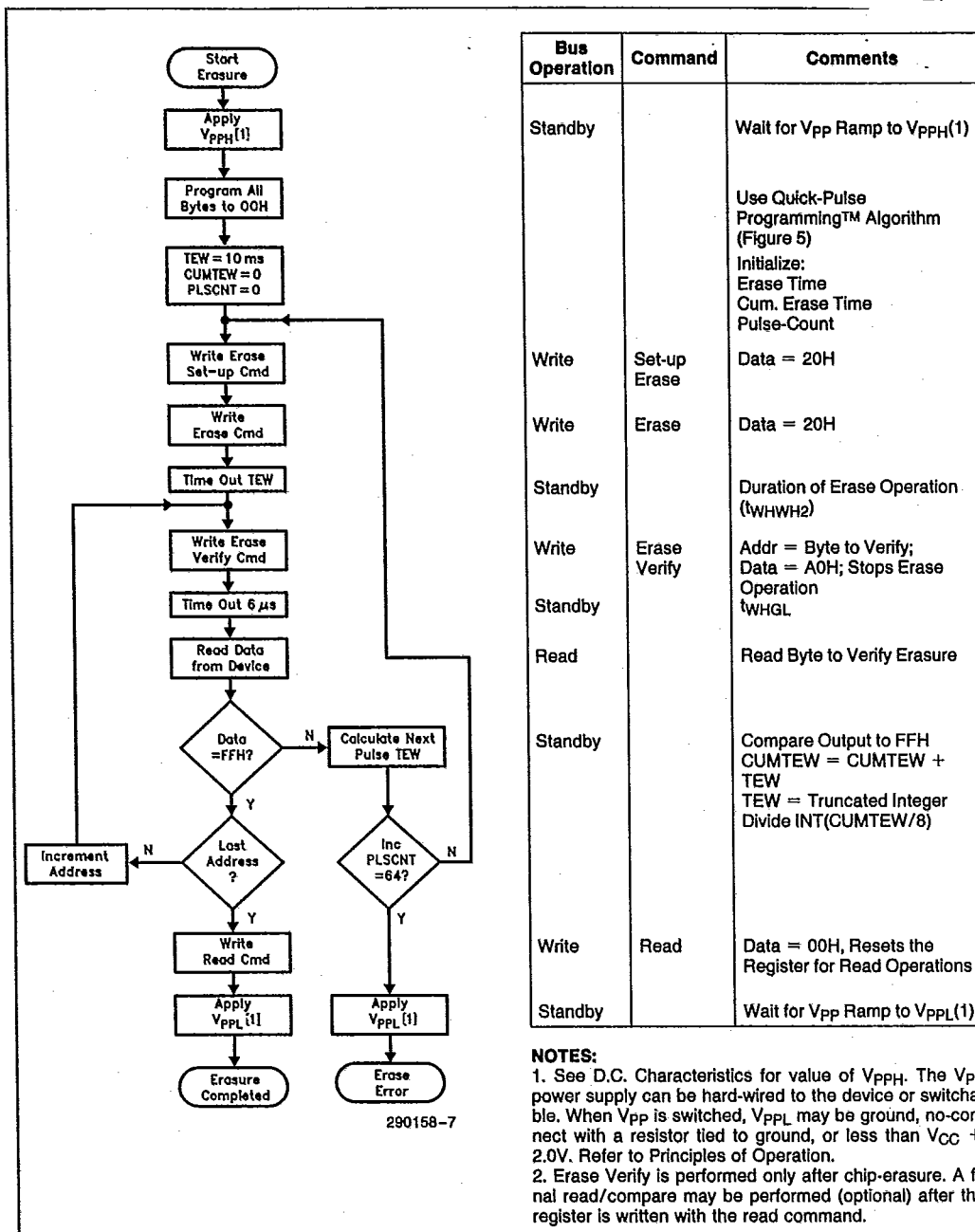


Figure 8. 28F256 Quick-Erase™ Algorithm



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## 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 output 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  $\mu$ 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  $\mu$ 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 28F256 is designed to offer protection against accidental erasure or programming, caused by spurious system-level signals that may exist during power transitions. The 28F256 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  $V_{CC} + 2.0V$ . In addition, upon powering-down,  $V_{PP}$  should be below  $V_{CC} + 2.0V$ , before lowering  $V_{CC}$ .

### Additional Information

|                                                                                          | Order Number |
|------------------------------------------------------------------------------------------|--------------|
| AP-316, "Using the 28F256 Flash Memory for In-System Reprogrammable Nonvolatile Storage" | 292046       |
| 27F256 Data Sheet                                                                        | 290157       |
| 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       |

**ABSOLUTE MAXIMUM RATINGS\***

|                                     |                           |
|-------------------------------------|---------------------------|
| Operating Temperature               |                           |
| During Read                         | .....0°C to +70°C(1)      |
| During Erase/Program                | .....0°C to +70°C         |
| Temperature Under Bias              | .....-10°C to +80°C       |
| Storage Temperature                 | .....-65°C to +125°C      |
| Voltage on Any Pin with             |                           |
| Respect to Ground                   | .....-2.0V to +7.0V(2)    |
| Voltage on Pin A <sub>9</sub> with  |                           |
| Respect to Ground                   | .....-2.0V to +13.5V(2,3) |
| V <sub>PP</sub> Supply Voltage with |                           |
| Respect to Ground                   |                           |
| During Erase/Program                | .....-2.0V to +14.0V(2,3) |
| V <sub>CC</sub> Supply Voltage with |                           |
| Respect to Ground                   | .....-2.0V to +7.0V(2)    |
| Output Short Circuit Current        | .....100 mA(4)            |

*\*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. Operating temperature is for commercial product defined by this specification.
2. 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<sub>CC</sub> + 0.5V, which may overshoot to V<sub>CC</sub> + 2.0V for periods less than 20 ns.
3. Maximum D.C. voltage on A<sub>9</sub> or V<sub>PP</sub> may overshoot to +14.0V for periods less than 20 ns.
4. 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 <sub>A</sub>  | Operating Temperature          | 0      | 70   | °C   | For Read-Only and Read/Write Operations |
| V <sub>CC</sub> | V <sub>CC</sub> Supply Voltage | 4.50   | 5.50 | V    |                                         |

**D.C. CHARACTERISTICS—TTL/NMOS COMPATIBLE**

| Symbol           | Parameter                           | Limits |      | Unit | Test Conditions                                                                                   |
|------------------|-------------------------------------|--------|------|------|---------------------------------------------------------------------------------------------------|
|                  |                                     | Min    | Max  |      |                                                                                                   |
| I <sub>LI</sub>  | Input Leakage Current               |        | ±1.0 | μA   | V <sub>CC</sub> = V <sub>CC</sub> Max<br>V <sub>IN</sub> = V <sub>CC</sub> or V <sub>SS</sub>     |
| I <sub>LO</sub>  | Output Leakage Current              |        | ±10  | μA   | V <sub>CC</sub> = V <sub>CC</sub> Max<br>V <sub>OUT</sub> = V <sub>CC</sub> or V <sub>SS</sub>    |
| I <sub>CCS</sub> | V <sub>CC</sub> Standby Current     |        | 1.0  | mA   | V <sub>CC</sub> = V <sub>CC</sub> Max<br>CE = V <sub>IH</sub>                                     |
| I <sub>CC1</sub> | V <sub>CC</sub> Active Read Current |        | 30   | mA   | V <sub>CC</sub> = V <sub>CC</sub> Max, CE = V <sub>IL</sub><br>f = 6 MHz, I <sub>OUT</sub> = 0 mA |
| I <sub>CC2</sub> | V <sub>CC</sub> Programming Current |        | 30   | mA   | Programming in Progress                                                                           |
| I <sub>CC3</sub> | V <sub>CC</sub> Erase Current       |        | 30   | mA   | Erase in Progress                                                                                 |
| I <sub>PPS</sub> | V <sub>PP</sub> Leakage Current     |        | ±10  | μA   | V <sub>PP</sub> = V <sub>PPL</sub>                                                                |



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

| Symbol            | Parameter                                                     | Limits         |                        | Unit | Test Conditions                                                                     |
|-------------------|---------------------------------------------------------------|----------------|------------------------|------|-------------------------------------------------------------------------------------|
|                   |                                                               | Min            | Max                    |      |                                                                                     |
| I <sub>PP1</sub>  | V <sub>PP</sub> Read Current                                  |                | 200                    | μA   | V <sub>PP</sub> = V <sub>PPH</sub>                                                  |
| I <sub>PP2</sub>  | V <sub>PP</sub> Programming Current                           |                | 30                     | mA   | V <sub>PP</sub> = V <sub>PPH</sub><br>Programming in Progress                       |
| I <sub>PP3</sub>  | V <sub>PP</sub> Erase Current                                 |                | 30                     | mA   | V <sub>PP</sub> = V <sub>PPH</sub><br>Erasure in Progress                           |
| V <sub>IL</sub>   | Input Low Voltage                                             | -0.5           | 0.8                    | V    |                                                                                     |
| V <sub>IH</sub>   | Input High Voltage                                            | 2.0            | V <sub>CC</sub> + 0.5  | V    |                                                                                     |
| V <sub>OL</sub>   | Output Low Voltage                                            |                | 0.45                   | V    | I <sub>OL</sub> = 2.1 mA<br>V <sub>CC</sub> = V <sub>CC</sub> Min                   |
| V <sub>OH1</sub>  | Output High Voltage                                           | 2.4            |                        | V    | I <sub>OH</sub> = -2.5 mA<br>V <sub>CC</sub> = V <sub>CC</sub> Min                  |
| V <sub>ID</sub>   | A <sub>9</sub> intelligent Identifier™ Voltage                | 11.50          | 13.00                  | V    | A <sub>9</sub> = V <sub>ID</sub>                                                    |
| I <sub>ID</sub>   | A <sub>9</sub> intelligent Identifier™ Current                |                | 500                    | μA   | A <sub>9</sub> = V <sub>ID</sub>                                                    |
| V <sub>PPL</sub>  | V <sub>PP</sub> during Read-Only Operations                   | 0.00           | V <sub>CC</sub> + 2.0V | V    | <b>NOTE:</b> Erase/Program are<br>Inhibited when V <sub>PP</sub> = V <sub>PPL</sub> |
| V <sub>PPH</sub>  | V <sub>PP</sub> during Read/Write Operations                  | 11.40<br>12.50 | 12.60<br>13.00         | V    | B1H; V <sub>PP</sub> = 12.0V Device<br>B2H; V <sub>PP</sub> = 12.75V Device         |
| V <sub>PPDV</sub> | V <sub>PPH</sub> Difference between<br>Erase/Program & Verify |                | 0.20                   | V    | B1H; V <sub>PP</sub> = 12.0V Device                                                 |

**D.C. CHARACTERISTICS—CMOS COMPATIBLE**

| Symbol           | Parameter                           | Limits |       | Unit | Test Conditions                                                                                   |
|------------------|-------------------------------------|--------|-------|------|---------------------------------------------------------------------------------------------------|
|                  |                                     | Min    | Max   |      |                                                                                                   |
| I <sub>LI</sub>  | Input Leakage Current               |        | ± 1.0 | μA   | V <sub>CC</sub> = V <sub>CC</sub> Max<br>V <sub>IN</sub> = V <sub>CC</sub> or V <sub>SS</sub>     |
| I <sub>LO</sub>  | Output Leakage Current              |        | ± 10  | μA   | V <sub>CC</sub> = V <sub>CC</sub> Max<br>V <sub>OUT</sub> = V <sub>CC</sub> or V <sub>SS</sub>    |
| I <sub>CCS</sub> | V <sub>CC</sub> Standby Current     |        | 100   | μA   | V <sub>CC</sub> = V <sub>CC</sub> Max<br>CE = V <sub>CC</sub> ± 2V                                |
| I <sub>CC1</sub> | V <sub>CC</sub> Active Read Current |        | 30    | mA   | V <sub>CC</sub> = V <sub>CC</sub> Max, CE = V <sub>IL</sub><br>f = 6 MHz, I <sub>OUT</sub> = 0 mA |
| I <sub>CC2</sub> | V <sub>CC</sub> Programming Current |        | 30    | mA   | Programming in Progress                                                                           |
| I <sub>CC3</sub> | V <sub>CC</sub> Erase Current       |        | 30    | mA   | Erasure in Progress                                                                               |
| I <sub>PPS</sub> | V <sub>PP</sub> Leakage Current     |        | ± 10  | μA   | V <sub>PP</sub> = V <sub>PPL</sub>                                                                |



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**D.C. CHARACTERISTICS—CMOS COMPATIBLE** (Continued)

| Symbol            | Parameter                                                     | Limits                |                        | Unit | Test Conditions                                                                      |
|-------------------|---------------------------------------------------------------|-----------------------|------------------------|------|--------------------------------------------------------------------------------------|
|                   |                                                               | Min                   | Max                    |      |                                                                                      |
| I <sub>PP1</sub>  | V <sub>PP</sub> Read Current                                  |                       | 200                    | μA   | V <sub>PP</sub> = V <sub>PPH</sub>                                                   |
| I <sub>PP2</sub>  | V <sub>PP</sub> Programming Current                           |                       | 30                     | mA   | V <sub>PP</sub> = V <sub>PPH</sub><br>Programming in Progress                        |
| I <sub>PP3</sub>  | V <sub>PP</sub> Erase Current                                 |                       | 30                     | mA   | V <sub>PP</sub> = V <sub>PPH</sub><br>Erase in Progress                              |
| V <sub>IL</sub>   | Input Low Voltage                                             | -0.5                  | 0.8                    | V    |                                                                                      |
| V <sub>IH</sub>   | Input High Voltage                                            | 0.7 V <sub>CC</sub>   | V <sub>CC</sub> + 0.5  | V    |                                                                                      |
| V <sub>OL</sub>   | Output Low Voltage                                            |                       | 0.45                   | V    | I <sub>OL</sub> = 2.1 mA<br>V <sub>CC</sub> = V <sub>CC</sub> Min                    |
| V <sub>OH1</sub>  | Output High Voltage                                           | 0.85 V <sub>CC</sub>  |                        | V    | I <sub>OH</sub> = -2.5 mA, V <sub>CC</sub> = V <sub>CC</sub> Min                     |
| V <sub>OH2</sub>  |                                                               | V <sub>CC</sub> - 0.4 |                        |      | I <sub>OH</sub> = -100 μA, V <sub>CC</sub> = V <sub>CC</sub> Min                     |
| V <sub>ID</sub>   | A <sub>9</sub> intelligent Identifier™ Voltage                | 11.50                 | 13.00                  | V    | A <sub>9</sub> = V <sub>ID</sub>                                                     |
| I <sub>ID</sub>   | A <sub>9</sub> intelligent Identifier™ Current                |                       | 500                    | μA   | A <sub>9</sub> = V <sub>ID</sub>                                                     |
| V <sub>PPL</sub>  | V <sub>PP</sub> during Read-Only Operations                   | 0.00                  | V <sub>CC</sub> + 2.0V | V    | <b>NOTE:</b> Erase/Programs are<br>Inhibited when V <sub>PP</sub> = V <sub>PPL</sub> |
| V <sub>PPH</sub>  | V <sub>PP</sub> during Read/Write Operations                  | 11.40                 | 12.60                  | V    | V <sub>PP</sub> = 12.0V                                                              |
| V <sub>PPDV</sub> | V <sub>PPH</sub> Difference between<br>Erase/Program & Verify |                       | 0.20                   | V    | B1H; V <sub>PP</sub> = 12.0V Device                                                  |

**CAPACITANCE**(1) T<sub>A</sub> = 25°C, f = 1.0 MHz

| Symbol           | Parameter                   | Limits |     | Unit | Conditions            |
|------------------|-----------------------------|--------|-----|------|-----------------------|
|                  |                             | Min    | Max |      |                       |
| C <sub>IN</sub>  | Address/Control Capacitance |        | 6   | pF   | V <sub>IN</sub> = 0V  |
| C <sub>OUT</sub> | Output Capacitance          |        | 12  | pF   | V <sub>OUT</sub> = 0V |

**NOTE:**

1. Sampled, not 100% tested.

**A.C. TEST CONDITIONS**

Input Rise and Fall Times (10% to 90%) ..... 10 ns  
 Input Pulse Levels ..... V<sub>OL</sub> and V<sub>OH1</sub>  
 Input Timing Reference Level ..... V<sub>IL</sub> and V<sub>IH</sub>  
 Output Timing Reference Level ..... V<sub>IL</sub> and V<sub>IH</sub>

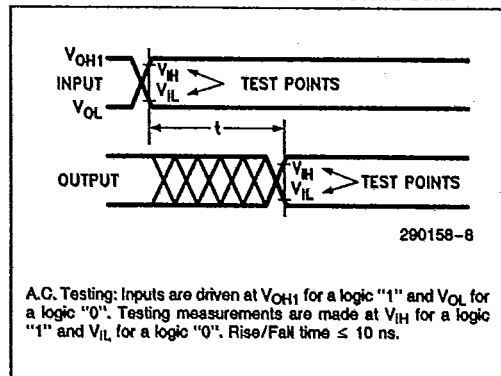


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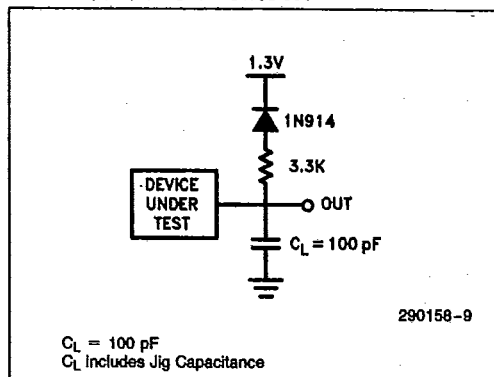
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## A.C. TESTING INPUT/OUTPUT WAVEFORM



## A.C. TESTING LOAD CIRCUIT



## A.C. CHARACTERISTICS—Read-Only Operations

| Versions           |                                                                          | 28F256-170<br>P1C2 |     | 28F256-200<br>P1C2 |     | 28F256-250<br>P1C2 |     | Unit    |
|--------------------|--------------------------------------------------------------------------|--------------------|-----|--------------------|-----|--------------------|-----|---------|
| Symbol             | Characteristic                                                           | Min                | Max | Min                | Max | Min                | Max |         |
| $t_{AVAV}/t_{RC}$  | Read Cycle Time                                                          | 170                |     | 200                |     | 250                |     | ns      |
| $t_{ELQV}/t_{CE}$  | Chip Enable Access Time                                                  |                    | 170 |                    | 200 |                    | 250 | ns      |
| $t_{AVQV}/t_{ACC}$ | Address Access Time                                                      |                    | 170 |                    | 200 |                    | 250 | ns      |
| $t_{GLQV}/t_{OE}$  | Output Enable Access Time                                                |                    | 70  |                    | 75  |                    | 80  | ns      |
| $t_{ELQX}/t_{LZ}$  | Chip Enable to Output in Low Z                                           | 0                  |     | 0                  |     | 0                  |     | ns      |
| $t_{EHQZ}$         | Chip Disable to Output in High Z                                         |                    | 55  |                    | 60  |                    | 65  | ns      |
| $t_{GLQX}/t_{OLZ}$ | Output Enable to Output in Low Z                                         | 0                  |     | 0                  |     | 0                  |     | ns      |
| $t_{GHQZ}/t_{DF}$  | Output Disable to Output in High Z                                       |                    | 35  |                    | 45  |                    | 55  | ns      |
| $t_{OH}$           | Output Hold from Address, $\overline{CE}$ , or $\overline{OE}$ Change(1) | 0                  |     | 0                  |     | 0                  |     | ns      |
| $t_{WHGL}$         | Write Recovery Time before Read                                          | 6                  |     | 6                  |     | 6                  |     | $\mu$ s |

## NOTES:

1. Whichever occurs first.
2. Rise/Fall Time  $\leq 10$  ns.



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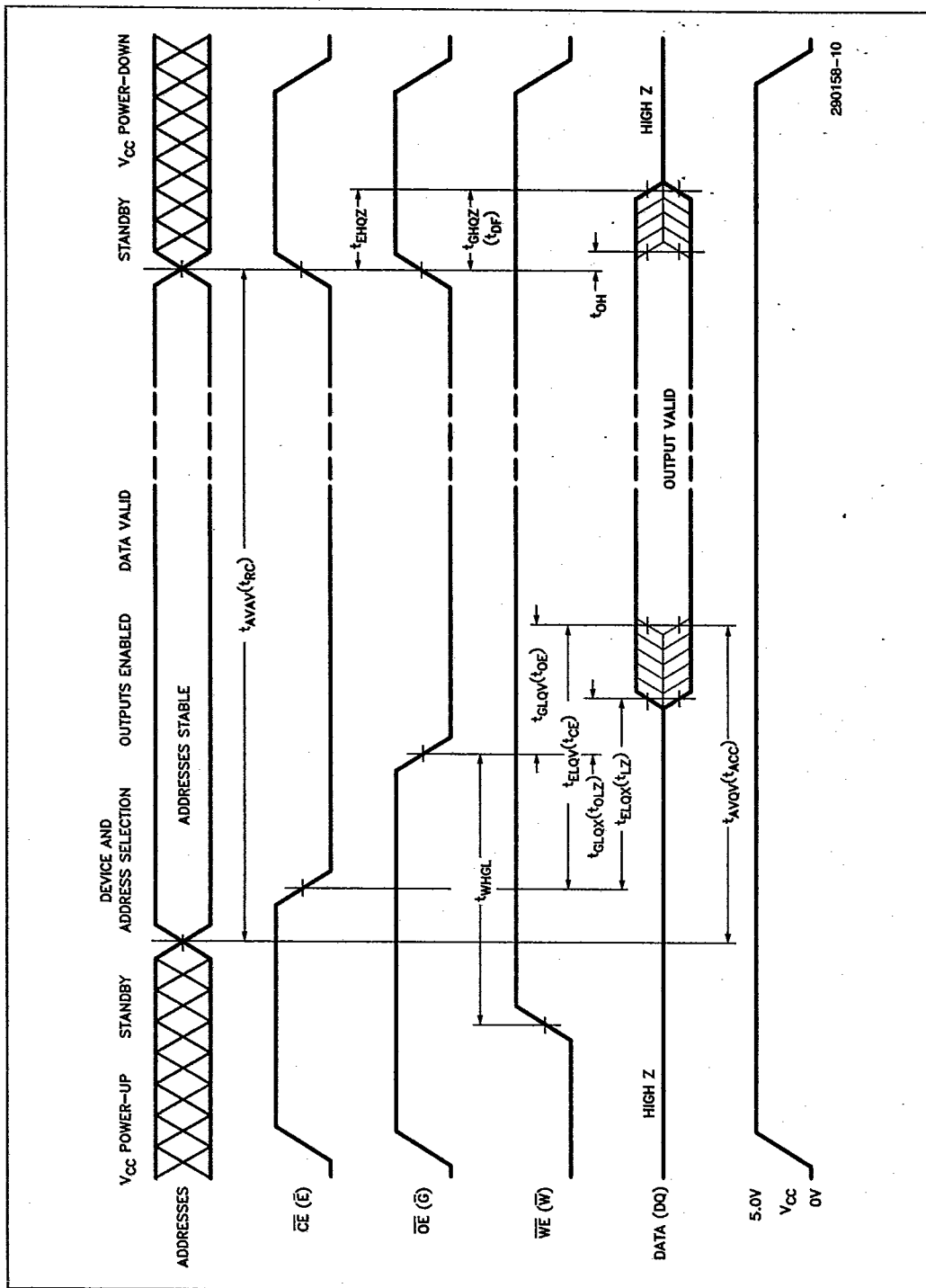


Figure 9. A.C. Waveforms for Read Operations



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

| Versions                            |                                                   | 28F256-170<br>P1C2 |          | 28F256-200<br>P1C2 |          | 28F256-250<br>P1C2 |          | Unit |
|-------------------------------------|---------------------------------------------------|--------------------|----------|--------------------|----------|--------------------|----------|------|
| Symbol                              | Characteristic                                    | Min                | Max      | Min                | Max      | Min                | Max      |      |
| t <sub>AVAV</sub> /t <sub>WC</sub>  | Write Cycle Time                                  | 170                |          | 200                |          | 250                |          | ns   |
| t <sub>AVWL</sub> /t <sub>AS</sub>  | Address Set-Up Time                               | 0                  |          | 0                  |          | 0                  |          | ns   |
| t <sub>WLAX</sub> /t <sub>AH</sub>  | Address Hold Time                                 | 60                 |          | 75                 |          | 90                 |          | ns   |
| t <sub>DVWH</sub> /t <sub>DS</sub>  | Data Set-up Time                                  | 50                 |          | 50                 |          | 50                 |          | ns   |
| t <sub>WHDX</sub> /t <sub>DH</sub>  | Data Hold Time                                    | 10                 |          | 10                 |          | 10                 |          | ns   |
| t <sub>WHGL</sub>                   | Write Recovery Time<br>before Read                | 6                  |          | 6                  |          | 6                  |          | μs   |
| t <sub>GHWL</sub>                   | Read Recovery Time<br>before Write                | 0                  |          | 0                  |          | 0                  |          | μs   |
| t <sub>ELWL</sub> /t <sub>CS</sub>  | Chip Enable<br>Set-Up Time                        | 20                 |          | 20                 |          | 20                 |          | ns   |
| t <sub>WHEH</sub> /t <sub>CH</sub>  | Chip Enable<br>Hold Time                          | 0                  |          | 0                  |          | 0                  |          | ns   |
| t <sub>WLWH</sub> /t <sub>WP</sub>  | Write Pulse Width                                 | 50                 |          | 60                 |          | 75                 |          | ns   |
| t <sub>WHWL</sub> /t <sub>WPH</sub> | Write Pulse<br>Width High                         | 50                 |          | 60                 |          | 75                 |          | ns   |
| t <sub>ELEH</sub>                   | Alternate Write<br>Pulse Width                    | 70                 |          | 80                 |          | 85                 |          | ns   |
| t <sub>WHWH1</sub>                  | Duration of<br>Programming Operation              | 95                 | 150      | 95                 | 150      | 95                 | 150      | μs   |
| t <sub>WHWH2</sub>                  | Duration of<br>Erase Operation                    | (2)                | (2) + 5% | (2)                | (2) + 5% | (2)                | (2) + 5% |      |
| t <sub>VPEL</sub>                   | V <sub>pp</sub> Set-Up<br>Time to Chip Enable Low | 100                |          | 100                |          | 100                |          | ns   |

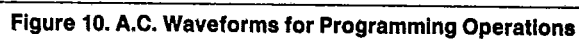
**NOTES:**

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 (CUMTEW) 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.





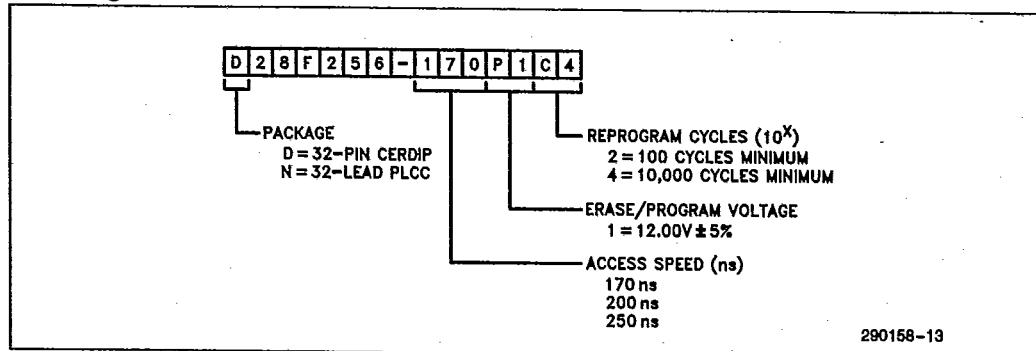


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## Ordering Information



## VALID COMBINATIONS:

|                 |                 |
|-----------------|-----------------|
| D28F256-170P1C2 | N28F256-170P1C2 |
| D28F256-200P1C2 | N28F256-200P1C2 |
| D28F256-250P1C2 | N28F256-250P1C2 |

## ADDITIONAL INFORMATION

AP-316, "Using the 28F256 Flash Memory for In-System Reprogrammable Non-Volatile Storage"

ER-21, "Intel's 27F256 and 28F257 Flash Memories"

ER-20, "ETOX™ Flash Memory Technology"

RR-60, "ETOX™ Flash Memory Reliability Data Summary"

**Order  
Number**  
292046

294004

294005

293002