# TMS28F010B
131072 BY 8-BIT
FLASH MEMORY

SMJS824B – MAY 1995 – REVISED AUGUST 1997

- **Organization . . . 131 072 by 8 Bits**
- **Pin Compatible With Existing 1-Megabit EPROMs**
- **V_{CC} Tolerance ±10%**
- **All Inputs/Outputs TTL Compatible**
- **Maximum Access/Minimum Cycle Time**
  '28F010B-90   90 ns
  '28F010B-10   100 ns
  '28F010B-12   120 ns
  '28F010B-15   150 ns
- **Industry-Standard Programming Algorithm**
- **PEP4 Version Available With 168-Hour Burn-In, and Choice of Operating Temperature Ranges**
- **100 000 and 10 000 Program/Erase-Cycle Versions Available**
- **Latchup Immunity of 250 mA on All Input and Output Lines**
- **Low Power Dissipation (V_{CC} = 5.5 V)**
  –Active Write . . . 55 mW
  –Active Read . . . 165 mW
  –Electrical Erase . . . 82.5 mW
  –Standby . . . 0.55 mW
   (CMOS-Input Levels)
- **Automotive Temperature Range**
  – 40°C to 125°C

**FM PACKAGE
(TOP VIEW)**
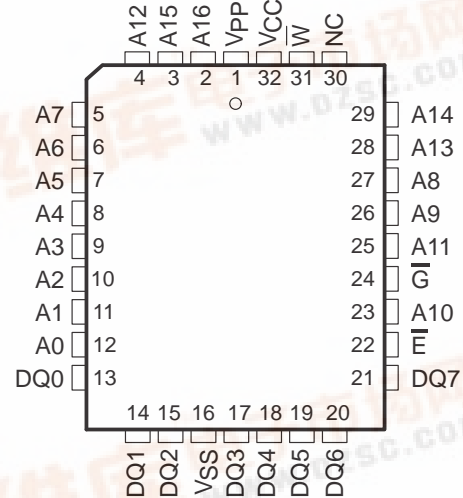
PIN NOMENCLATURE	
A0 – A16	Address Inputs
DQ0 – DQ7	Inputs (programming)/Outputs
$\overline{E}$	Chip Enable
$\overline{G}$	Output Enable
NC	No Internal Connection
V_{CC}	5-V Power Supply
V_{PP}	12-V Power Supply†
V_{SS}	Ground
$\overline{W}$	Write Enable

† Only in Program Mode

description

The TMS28F010B is a 131 072 by 8 bit (1 048 576-bit), programmable read-only memory that can be electrically bulk-erased and reprogrammed. It is available in 100 000 and 10 000 program/erase-endurance-cycle versions.
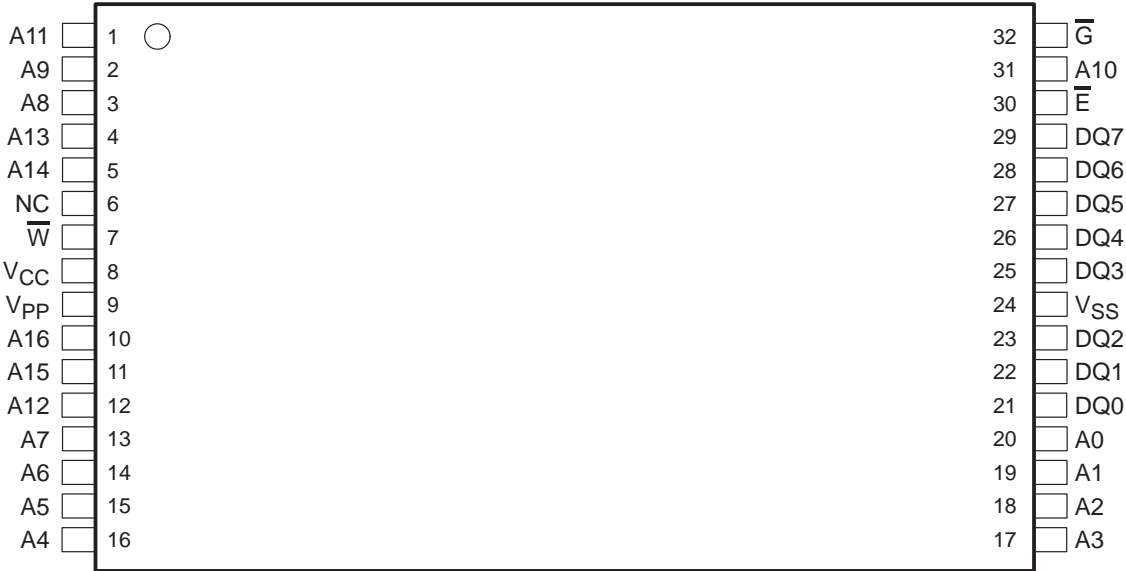
The TMS28F010B Flash Memory is offered in a 32-lead plastic leaded chip-carrier package (shown above) using 1,25-mm (50-mil) lead spacing (FM suffix), a 32-lead thin small-outline package (DD suffix), and a reverse pinout TSOP package (DU suffix) both shown on the following page.

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.
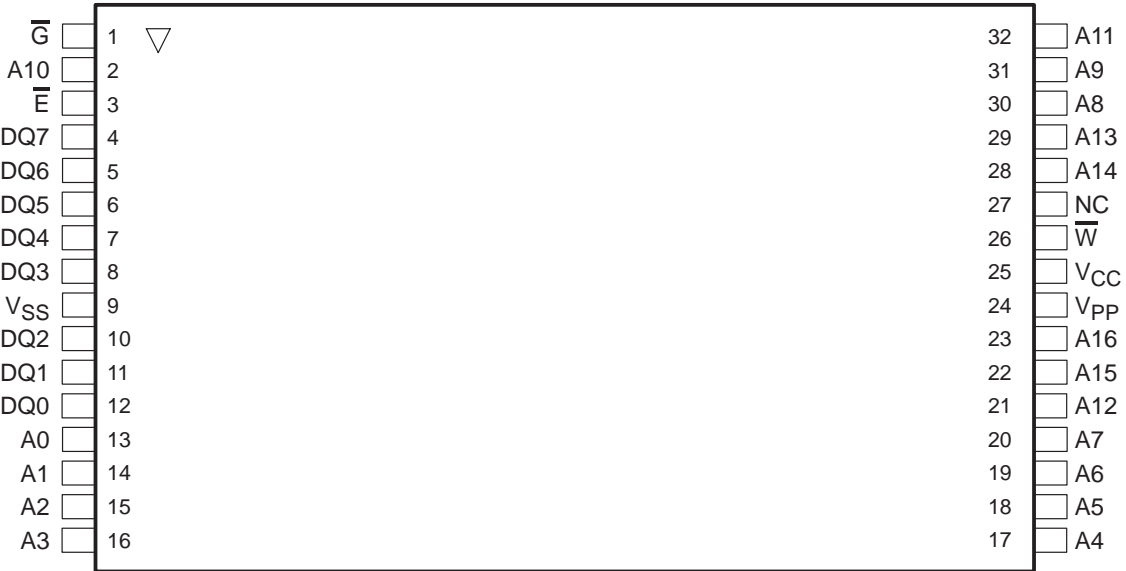
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TEXAS INSTRUMENTS

DD PACKAGE
(TOP VIEW)

Pin	Signal		Pin	Signal
1	A11		32	$\overline{G}$
2	A9		31	A10
3	A8		30	$\overline{E}$
4	A13		29	DQ7
5	A14		28	DQ6
6	NC		27	DQ5
7	$\overline{W}$		26	DQ4
8	V_{CC}		25	DQ3
9	V_{PP}		24	V_{SS}
10	A16		23	DQ2
11	A15		22	DQ1
12	A12		21	DQ0
13	A7		20	A0
14	A6		19	A1
15	A5		18	A2
16	A4		17	A3

DU PACKAGE
REVERSE PINOUT
(TOP VIEW)

Pin	Signal		Pin	Signal
1	$\overline{G}$		32	A11
2	A10		31	A9
3	$\overline{E}$		30	A8
4	DQ7		29	A13
5	DQ6		28	A14
6	DQ5		27	NC
7	DQ4		26	$\overline{W}$
8	DQ3		25	V_{CC}
9	V_{SS}		24	V_{PP}
10	DQ2		23	A16
11	DQ1		22	A15
12	DQ0		21	A12
13	A0		20	A7
14	A1		19	A6
15	A2		18	A5
16	A3		17	A4

device symbol nomenclature
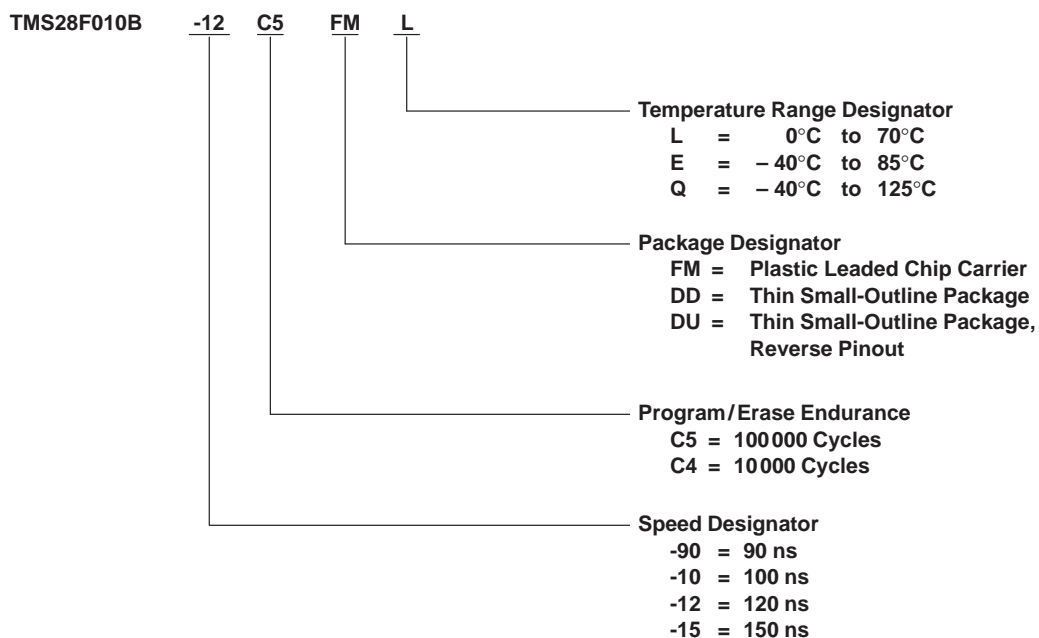
TMS28F010B   -12   C5   FM   L

Temperature Range Designator
L   =   0°C   to   70°C
E   =   – 40°C   to   85°C
Q   =   – 40°C   to   125°C

Package Designator
FM =   Plastic Leaded Chip Carrier
DD =   Thin Small-Outline Package
DU =   Thin Small-Outline Package,
Reverse Pinout

Program / Erase Endurance
C5 = 100 000 Cycles
C4 = 10 000 Cycles

Speed Designator
-90 = 90 ns
-10 = 100 ns
-12 = 120 ns
-15 = 150 ns

logic symbol†
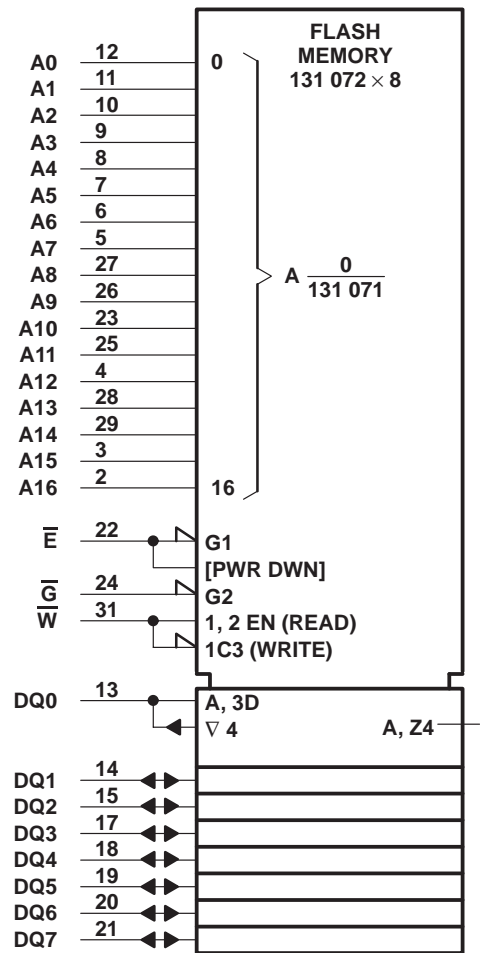
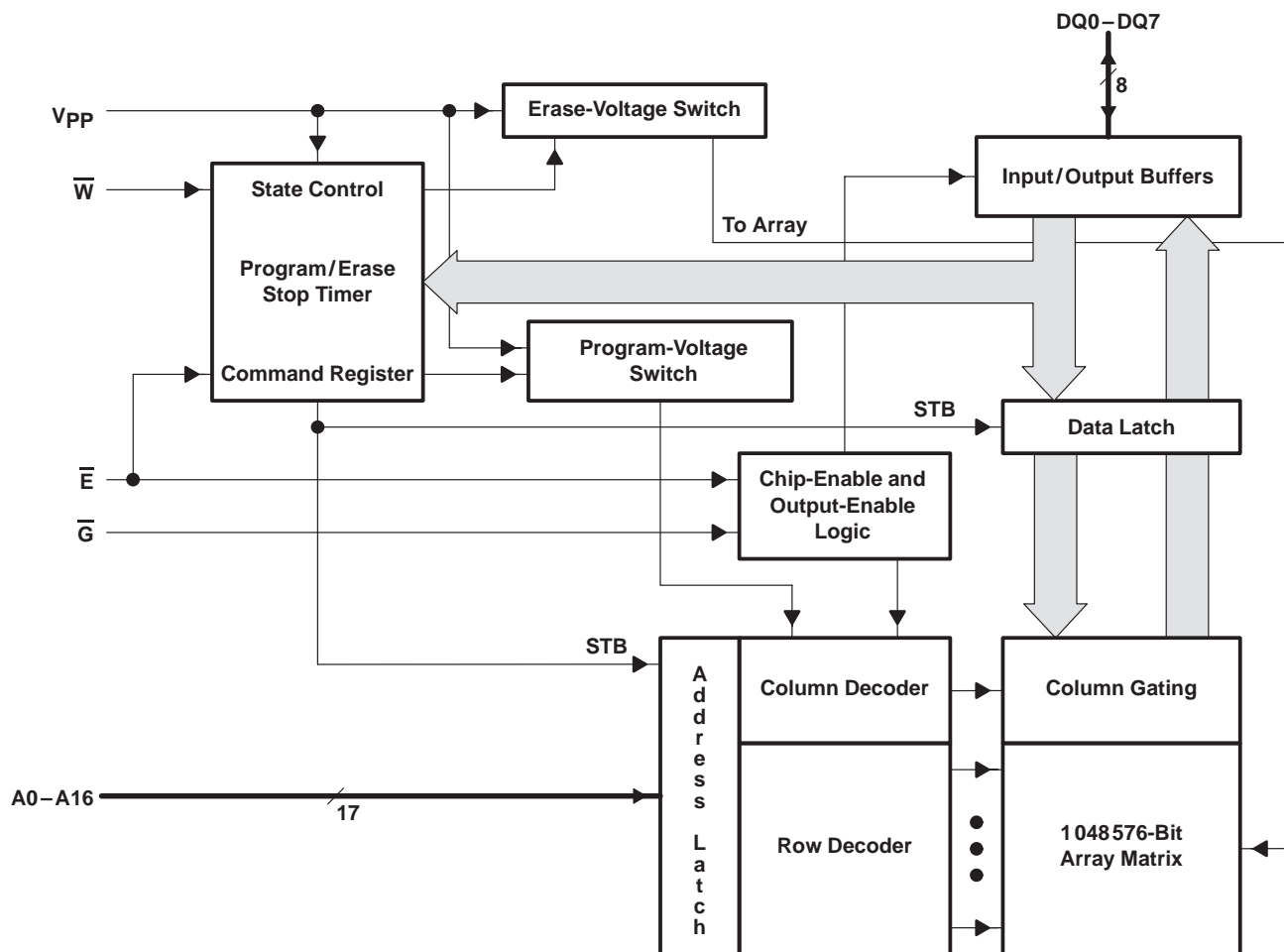
† This symbol is in accordance with ANSI/IEEE Std 91-1984 and IEC Publication 617-12.
  Pin numbers shown are for the FM package.

functional block diagram

TMS28F010B
131072 BY 8-BIT
FLASH MEMORY

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operation

Modes of operation are shown in Table 1.

Table 1. Operation Modes

MODE		V_{PP}‡ (1)	$\overline{E}$ (22)	$\overline{G}$ (24)	A0 (12)	A9 (26)	$\overline{W}$ (31)	DQ0–DQ7 (13–15, 17–21)
Read	Read	V_{PPL}	V_{IL}	V_{IL}	X	X	V_{IH}	Data Out
	Output Disable	V_{PPL}	V_{IL}	V_{IH}	X	X	V_{IH}	Hi-Z
	Standby and Write Inhibit	V_{PPL}	V_{IH}	X	X	X	X	Hi-Z
	Algorithm-Selection Mode	V_{PPL}	V_{IL}	V_{IL}	V_{IL}	V_{ID}	V_{IH}	Mfr Equivalent Code 89h
					V_{IH}			Device Equivalent Code B4h
Read/ Write	Read	V_{PPH}	V_{IL}	V_{IL}	X	X	V_{IH}	Data Out
	Output Disable	V_{PPH}	V_{IL}	V_{IH}	X	X	V_{IH}	Hi-Z
	Standby and Write Inhibit	V_{PPH}	V_{IH}	X	X	X	X	Hi-Z
	Write	V_{PPH}	V_{IL}	V_{IH}	X	X	V_{IL}	Data In

† X can be V_{IL} or V_{IH}.
‡ $V_{PPL} \leq V_{CC} + 2\,V$; V_{PPH} is the programming voltage specified for the device. For more details, refer to the recommended operating conditions.

read/output disable

When the outputs of two or more TMS28F010Bs are connected in parallel on the same bus, the output of any particular device in the circuit can be read with no interference from the competing outputs of other devices. To read the output of the TMS28F010B, a low-level signal is applied to the $\overline{E}$ and $\overline{G}$ pins. All other devices in the circuit should have their outputs disabled by applying a high-level signal to one of these pins.

standby and write inhibit

Active I_{CC} current can be reduced from 30 mA to 1 mA by applying a high TTL level on $\overline{E}$ or to 100 µA with a high CMOS level on $\overline{E}$. In this mode, all outputs are in the high-impedance state. The TMS28F010B draws active current when it is deselected during programming, erasure, or program/erase verification. It continues to draw active current until the operation is terminated.

algorithm-selection mode

The algorithm-selection mode provides access to a binary code identifying the correct programming and erase algorithms. This mode is activated when A9 (pin 26) is forced to V_{ID}. Two identifier bytes are accessed by toggling A0. All other addresses must be held low. A0 low selects the manufacturer equivalent code 89h, and A0 high selects the device equivalent code B4h, as shown in Table 2.

Table 2. Algorithm-Selection Modes

IDENTIFIER§	PINS									
	A0	DQ7	DQ6	DQ5	DQ4	DQ3	DQ2	DQ1	DQ0	HEX
Manufacturer Equivalent Code	V_{IL}	1	0	0	0	1	0	0	1	89
Device Equivalent Code	V_{IH}	1	0	1	1	0	1	0	0	B4

§ $\overline{E} = \overline{G} = V_{IL}$, A1–A8 = V_{IL}, A9 = V_{ID}, A10–A16 = V_{IL}, $V_{PP} = V_{PPL}$.

programming and erasure

In the erased state, all bits are at a logic 1. Before erasing the device, all memory bits must be programmed to a logic 0. Afterwards, the entire chip is erased. At this point, the bits, now logic 1s, can be programmed accordingly. Refer to the Fastwrite and Fasterase algorithms for further detail.

command register

The command register controls the program and erase functions of the TMS28F010B. The algorithm-selection mode can be activated using the command register in addition to the previously described method. When V_{PP} is high, the contents of the command register and the function being performed can be changed. The command register is written to when $\overline{E}$ is low and $\overline{W}$ is pulsed low. The address is latched on the leading edge of the pulse, while the data is latched on the trailing edge. Accidental programming or erasure is minimized because two commands must be executed to invoke either operation. The command register is inhibited when V_{CC} is below the erase/write lockout voltage, V_{LKO}.

power supply considerations

Each device should have a 0.1-μF ceramic capacitor connected between V_{CC} and V_{SS} to suppress circuit noise. Changes in current drain on V_{PP} require it to have a bypass capacitor as well. Printed-circuit traces for both power supplies should be appropriate to handle the current demand.

command definitions

See Table 3 for command definitions.

Table 3. Command Definitions

COMMAND	REQUIRED BUS CYCLES	FIRST BUS CYCLE			SECOND BUS CYCLE		
		OPERATION†	ADDRESS	DATA	OPERATION†	ADDRESS	DATA
Read	1	Write	X	00h	Read	RA	RD
Algorithm-Selection Mode	3	Write	X	90h	Read	0000 0001	89h B4h
Set-Up-Erase/Erase	2	Write	X	20h	Write	X	20h
Erase Verify	2	Write	EA	A0h	Read	X	EVD
Set-Up-Program/Program	2	Write	X	40h	Write	PA	PD
Program Verify	2	Write	X	C0h	Read	X	PVD
Reset	2	Write	X	FFh	Write	X	FFh

† Modes of operation are defined in Table 1.

Legend:

EA — Address of memory location to be read during erase verify
RA — Address of memory location to be read
PA — Address of memory location to be programmed. Address is latched on the falling edge of $\overline{W}$
RD — Data read from location RA during the read operation
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 $\overline{W}$
PVD — Data read from location PA during program verify

read command

Memory contents can be accessed while V_{PP} is high or low. When V_{PP} is high, writing 00h into the command register invokes the read operation. When the device is powered up, the default contents of the command register are 00h and the read operation is enabled. The read operation remains enabled until a different valid command is written to the command register.

algorithm-selection mode command

The algorithm-selection mode is activated by writing 90h into the command register. The manufacturer-equivalent code (89h) is identified by the value read from address location 0000h, and the device-equivalent code (B4h) is identified by the value read from address location 0001h.

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command definitions (continued)

set-up-erase/erase commands

The erase-algorithm initiates with $\overline{E} = V_{IL}$, $\overline{W} = V_{IL}$, $\overline{G} = V_{IH}$, $V_{PP} = V_{PPH}$, and $V_{CC} = 5$ V. To enter the erase mode, write the set-up-erase command, 20h, into the command register. After the TMS28F010B is in the erase mode, writing a second erase command, 20h, into the command register invokes the erase operation. The erase operation begins on the rising edge of $\overline{W}$ and ends on the rising edge of the next $\overline{W}$. The erase operation requires at least 9.5 ms to complete before the erase-verify command, A0h, can be loaded.

Maximum erase timing is controlled by the internal stop timer. When the stop timer terminates the erase operation, the device enters an inactive state and remains inactive until a command is received.

program-verify command

The TMS28F010B can be programmed sequentially or randomly because it is programmed one byte at a time. Each byte must be verified after it is programmed. The program-verify operation prepares the device to verify the most recently programmed byte. To invoke the program-verify operation, C0h must be written into the command register. The program-verify operation ends on the rising edge of $\overline{W}$.

While verifying a byte, the TMS28F010B applies an internal margin voltage to the designated byte. If the true data and programmed data match, programming continues to the next designated byte location; otherwise, the byte must be reprogrammed. Figure 1 shows how commands and bus operations are combined for byte programming.

erase-verify command

All bytes must be verified following an erase operation. After the erase operation is complete, an erased byte can be verified by writing the erase-verify command, A0h, into the command register. This command causes the device to exit the erase mode on the rising edge of $\overline{W}$. The address of the byte to be verified is latched on the falling edge of $\overline{W}$. The erase-verify operation remains enabled until a command is written to the command register.

To determine whether or not all the bytes have been erased, the TMS28F010B applies a margin voltage to each byte. If FFh is read from the byte, all bits in the designated byte have been erased. The erase-verify operation continues until all of the bytes have been verified. If FFh is not read from a byte, an additional erase operation needs to be executed. Figure 2 shows the combination of commands and bus operations for electrically erasing the TMS28F010B.

set-up-program/program commands

The programming algorithm initiates with $\overline{E} = V_{IL}$, $\overline{W} = V_{IL}$, $\overline{G} = V_{IH}$, $V_{PP} = V_{PPH}$, and $V_{CC} = 5$ V. To enter the programming mode, write the set-up-program command, 40h, into the command register. The programming operation is invoked by the next write-enable pulse. Addresses are latched internally on the falling edge of $\overline{W}$, and data is latched internally on the rising edge of $\overline{W}$. The programming operation begins on the rising edge of $\overline{W}$ and ends on the rising edge of the next $\overline{W}$ pulse. The program operation requires 10 μs for completion before the program-verify command, C0h, can be loaded.

Maximum program timing is controlled by the internal stop timer. When the stop timer terminates the program operation, the device enters an inactive state and remains inactive until a command is received.

reset command

To reset the TMS28F010B after set-up-erase command or set-up-program command operations without changing the contents in memory, write FFh into the command register two consecutive times. After executing the reset command, the device defaults to the read mode.

Fastwrite algorithm

The TMS28F010B is programmed using the Texas Instruments Fastwrite algorithm shown in Figure 1. This algorithm programs in a nominal time of two seconds.

Fasterase algorithm

The TMS28F010B is erased using the Texas Instruments Fasterase algorithm shown in Figure 2. The memory array needs to be completely programmed (using the Fastwrite algorithm) before erasure begins. Erasure typically occurs in one second.

parallel erasure

To reduce total erase time, several devices can be erased in parallel. Since each Flash Memory can erase at a different rate, every device must be verified separately after each erase pulse. After a given device has been successfully erased, the erase command should not be issued to this device again. All devices that complete erasure should be masked until the parallel erasure process is finished (see Figure 3).

Examples of how to mask a device during parallel erase include driving the $\overline{E}$ pin high, writing the read command (00h) to the device when the others receive a set-up-erase or erase command, or disconnecting it from all electrical signals with relays or other types of switches.

TEXAS
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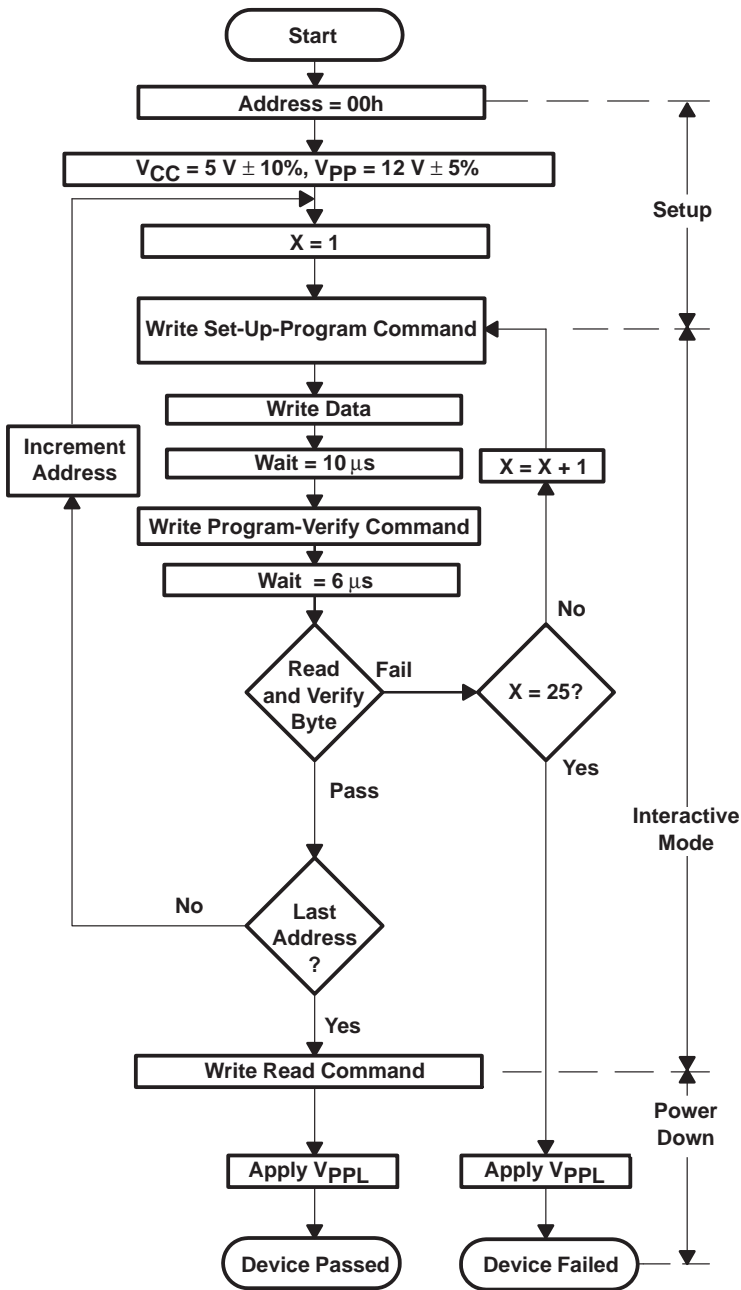
Bus Operation	Command	Comments
Initialize Address		
Standby		Wait for V_{PP} to ramp to V_{PPH} (see Note A) Initialize pulse count
Write	Set-Up-Program Write	Data = 40h
Write	Write Data	Valid address / data
Standby		Wait = 10 μs
Write	Program-Verify	Data = C0h; ends Program operation
Standby		Wait = 6 μs
Read		Read byte to verify Programming; compare output to expected output
—	—	—
Write	Read	Data = 00h; resets register for read operations
Standby		Wait for V_{PP} to ramp to V_{PPL} (see Note B)

NOTES: A. Refer to the recommended operating conditions for the value of V_{PPH}.
   B. Refer to the recommended operating conditions for the value of V_{PPL}.

Figure 1. Programming Flowchart: Fastwrite Algorithm

Flowchart (left side):

- Start
- Preprogram
- All Bytes = 00h ? — No → Program All Bytes to 00h
- Yes
- Address = 00h
- $V_{CC} = 5\ V \pm 10\%$, $V_{PP} = 12\ V \pm 5\%$
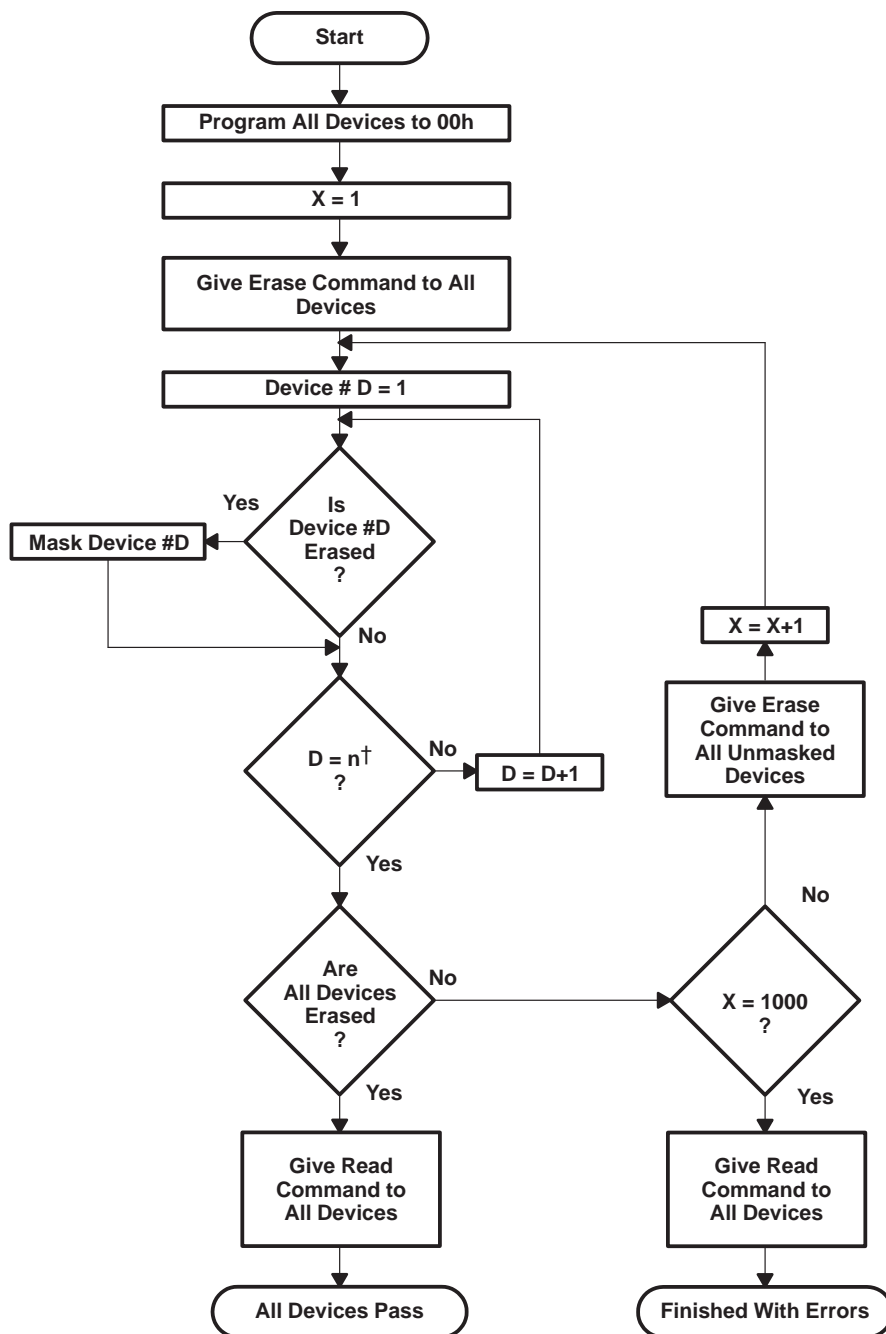- Setup
- X = 1
- Write Set-Up-Erase Command
- Write-Erase Command
- Wait = 10 ms
- X = X + 1
- Write Erase-Verify Command
- Interactive Mode
- Wait = 6 μs
- Increment Address
- Read and Verify Byte — Fail → X = 1000? — No; Yes
- Pass
- Last Address? — No; Yes
- Write Read Command
- Power Down
- Apply V_{PPL} → Device Passed
- Apply V_{PPL} → Device Failed

Bus Operation	Command	Comments
		Entire memory must = 00h before erasure Use Fastwrite programming algorithm
		Initialize addresses
Standby		Wait for V_{PP} to ramp to V_{PPH} (see Note A)
		Initialize pulse count
Write	Set-Up-Erase	Data = 20h
Write	Erase	Data = 20h
Standby		Wait = 10 ms
Write	Erase Verify	Addr = Byte to verify; Data = A0h; ends the erase operation
Standby		Wait = 6 μs
Read		Read byte to verify erasure; compare output to FFh
Write	Read	Data = 00h; resets register for read operations
Standby		Wait for V_{PP} to ramp to V_{PPL} (see Note B)

NOTES: A. Refer to the recommended operating conditions for the value of V_{PPH}.
B. Refer to the recommended operating conditions for the value of V_{PPL}.

Figure 2. Flash-Erase Flowchart: Fasterase Algorithm

```
                        ┌─────────────┐
                        │    Start    │
                        └──────┬──────┘
                               │
                    ┌──────────▼──────────┐
                    │ Program All Devices │
                    │       to 00h        │
                    └──────────┬──────────┘
                               │
                    ┌──────────▼──────────┐
                    │        X = 1        │
                    └──────────┬──────────┘
                               │
                    ┌──────────▼──────────┐
                    │ Give Erase Command  │
                    │   to All Devices    │
                    └──────────┬──────────┘
                               │
                    ┌──────────▼──────────┐
                    │   Device # D = 1    │
                    └──────────┬──────────┘
```

Yes — Mask Device #D

Is Device #D Erased ?

No

D = n† ?   No → D = D+1

Yes

Are All Devices Erased ?   No → X = 1000 ?

X = X+1

Give Erase Command to All Unmasked Devices

Yes — Give Read Command to All Devices — All Devices Pass

No

Yes — Give Read Command to All Devices — Finished With Errors

† n = number of devices being erased.

Figure 3. Parallel-Erase Flow Diagram

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage range, V_{CC} (see Note 1) .... −0.6 V to 7 V
Supply voltage range, V_{PP} .... −0.6 V to 14 V
Input voltage range (see Note 2): All inputs except A9 .... −0.6 V to V_{CC} + 1 V
                             A9 .... −0.6 V to 13.5 V
Output voltage range (see Note 3) .... −0.6 V to V_{CC} + 1 V
Operating free-air temperature range during read/erase/program, T_A
        L .... 0°C to 70°C
        E .... −40°C to 85°C
        Q .... −40°C to 125°C
Storage temperature range, T_{stg} .... −65°C to 150°C

† Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES: 1. All voltage values are with respect to V_{SS}.
        2. The voltage on any input pin can undershoot to −2 V for periods less than 20 ns.
        3. The voltage on any output pin can overshoot to 7 V for periods less than 20 ns.

recommended operating conditions

			MIN	TYP	MAX	UNIT
V_{CC}	Supply voltage	During write/read/flash erase	4.5	5	5.5	V
V_{PP}	Supply voltage	During read only (V_{PPL})	0		V_{CC} + 2	V
		During write/read/flash erase (V_{PPH})	11.4	12	12.6	V
V_{IH}	High-level dc input voltage	TTL	2		V_{CC}+0.5	V
		CMOS	V_{CC} − 0.5		V_{CC}+0.5	
V_{IL}	Low-level dc input voltage	TTL	−0.5		0.8	V
		CMOS	GND − 0.2		GND+0.2	
V_{ID}	Voltage level on A9 for algorithm-selection mode		11.5		13	V

electrical characteristics over recommended ranges of supply voltage and operating free-air temperature

PARAMETER		TEST CONDITIONS		MIN	MAX	UNIT
V_{OH}	High-level output voltage	$I_{OH} = -2.5$ mA		2.4		V
		$I_{OH} = -100$ µA		$V_{CC} - 0.4$		
V_{OL}	Low-level output voltage	$I_{OL} = 5.8$ mA			0.45	V
		$I_{OL} = 100$ µA			0.1	
I_{ID}	A9 algorithm-selection-mode current	$A9 = V_{ID}$ max			200	µA
I_I	Input current (leakage)	All except A9	$V_I = 0$ V to 5.5 V		±1	µA
		A9	$V_I = 0$ V to 13 V		±200	
I_O	Output current (leakage)	$V_O = 0$ V to V_{CC}			±10	µA
I_{PP1}	V_{PP} supply current (read/standby)	$V_{PP} = V_{PPH}$, Read mode			200	µA
		$V_{PP} = V_{PPL}$			±10	µA
I_{PP2}	V_{PP} supply current (during program pulse)	$V_{PP} = V_{PPH}$			30	mA
I_{PP3}	V_{PP} supply current (during flash erase)	$V_{PP} = V_{PPH}$			30	mA
I_{PP4}	V_{PP} supply current (during program/erase-verify) (see Note 4)	$V_{PP} = V_{PPH}$			5.0	mA
I_{CCS}	V_{CC} supply current (standby)	TTL-input level	$V_{CC} = 5.5$ V, $\overline{E} = V_{IH}$		1	mA
		CMOS-input level	$V_{CC} = 5.5$ V, $\overline{E} = V_{CC}$		100	µA
I_{CC1}	V_{CC} supply current (active read)	$V_{CC} = 5.5$ V $\overline{E} = V_{IL}$, $f = 6$ MHz, $I_{OUT} = 0$ mA			30	mA
I_{CC2}	V_{CC} average supply current (active write) (see Note 4)	$V_{CC} = 5.5$ V, $\overline{E} = V_{IL}$, Programming in progress			10	mA
I_{CC3}	V_{CC} average supply current (flash erase) (see Note 4)	$V_{CC} = 5.5$ V, $\overline{E} = V_{IL}$, Erasure in progress			15	mA
I_{CC4}	V_{CC} average supply current (program/erase-verify) (see Note 4)	$V_{CC} = 5.5$ V, $\overline{E} = V_{IL}$, $V_{PP} = V_{PPH}$, Program/erase-verify in progress			15	mA
V_{LKO}	V_{CC} erase/write-lockout voltage	$V_{PP} = V_{PPH}$		2.5		V

NOTE 4: Characterization data available.

capacitance over recommended ranges of supply voltage and operating free-air temperature, $f = 1$ MHz†

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
C_i	Input capacitance	$V_I = 0$ V, $f = 1$ MHz		6	pF
C_o	Output capacitance	$V_O = 0$ V, $f = 1$ MHz		12	pF

† Capacitance measurements are made on sample basis only.

switching characteristics over recommended ranges of supply voltage and operating free-air temperature

PARAMETER		TEST CONDITIONS	ALTERNATE SYMBOL	'28F010B-90		'28F010B-10		'28F010B-12		'28F010B-15		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$t_{a(A)}$	Access time from address, A0–A16	C_L = 100 pF, 1 Series 74 TTL load, Input $t_r \le$ 20 ns, Input $t_f \le$ 20 ns	t_{AVQV}		90		100		120		150	ns
$t_{a(E)}$	Access time from chip enable, $\overline{E}$		t_{ELQV}		90		100		120		150	ns
$t_{en(G)}$	Access time from output enable, $\overline{G}$		t_{GLQV}		35		45		50		55	ns
$t_{c(R)}$	Cycle time, read		t_{AVAV}	90		100		120		150		ns
$t_{d(E)}$	Delay time, $\overline{E}$ low to low-Z output		t_{ELQX}	0		0		0		0		ns
$t_{d(G)}$	Delay time, $\overline{G}$ low to low-Z output		t_{GLQX}	0		0		0		0		ns
$t_{dis(E)}$	Chip disable time to Hi-Z output		t_{EHQZ}	0	45	0	55	0	55	0	55	ns
$t_{dis(G)}$	Output disable time to Hi-Z output		t_{GHQZ}	0	30	0	30	0	30	0	35	ns
$t_{h(D)}$	Hold time, data valid from address, $\overline{E}$ or $\overline{G}$†		t_{AXQX}	0		0		0		0		ns
$t_{rec(W)}$	Write recovery time before read		t_{WHGL}	6		6		6		6		µs

† Whichever occurs first

timing requirements–write/erase/program operations

PARAMETER		ALTERNATE SYMBOL	'28F010B-90			'28F010B-10			UNIT
			MIN	NOM	MAX	MIN	NOM	MAX	
$t_{c(W)}$	Cycle time, write using $\overline{W}$	t_{AVAV}	90			100			ns
$t_{c(W)PR}$	Cycle time, programming operation	t_{WHWH1}	10			10			µs
$t_{c(W)ER}$	Cycle time, erase operation	t_{WHWH2}	9.5			9.5	10		ms
$t_{h(A)}$	Hold time, address	t_{WLAX}	40			55			ns
$t_{h(E)}$	Hold time, $\overline{E}$	t_{WHEH}	0			0			ns
$t_{h(WHD)}$	Hold time, data valid after $\overline{W}$ high	t_{WHDX}	10			10			ns
$t_{su(A)}$	Setup time, address	t_{AVWL}	0			0			ns
$t_{su(D)}$	Setup time, data	t_{DVWH}	40			50			ns
$t_{su(E)}$	Setup time, $\overline{E}$ before $\overline{W}$	t_{ELWL}	15			20			ns
$t_{su(VPPEL)}$	Setup time, V_{PP} to $\overline{E}$ going low	t_{VPEL}	1			1			µs
$t_{rec(W)}$	Recovery time, $\overline{W}$ before read	t_{WHGL}	6			6			µs
$t_{rec(R)}$	Recovery time, read before $\overline{W}$	t_{GHWL}	0			0			µs
$t_{w(W)}$	Pulse duration, $\overline{W}$ (see Note 5)	t_{WLWH}	40			60			ns
$t_{w(WH)}$	Pulse duration, $\overline{W}$ high	t_{WHWL}	20			20			ns
$t_{r(VPP)}$	Rise time, V_{PP}	t_{VPPR}	1			1			µs
$t_{f(VPP)}$	Fall time, V_{PP}	t_{VPPF}	1			1			µs

PARAMETER		ALTERNATE SYMBOL	'28F010B-12			'28F010B-15			UNIT
			MIN	NOM	MAX	MIN	NOM	MAX	
$t_{c(W)}$	Cycle time, write using $\overline{W}$	t_{AVAV}	120			150			ns
$t_{c(W)PR}$	Cycle time, programming operation	t_{WHWH1}	10			10			µs
$t_{c(W)ER}$	Cycle time, erase operation	t_{WHWH2}	9.5	10		9.5	10		ms
$t_{h(A)}$	Hold time, address	t_{WLAX}	60			60			ns
$t_{h(E)}$	Hold time, $\overline{E}$	t_{WHEH}	0			0			ns
$t_{h(WHD)}$	Hold time, data valid after $\overline{W}$ high	t_{WHDX}	10			10			ns
$t_{su(A)}$	Setup time, address	t_{AVWL}	0			0			ns
$t_{su(D)}$	Setup time, data	t_{DVWH}	50			50			ns
$t_{su(E)}$	Setup time, $\overline{E}$ before $\overline{W}$	t_{ELWL}	20			20			ns
$t_{su(VPPEL)}$	Setup time, V_{PP} to $\overline{E}$ low	t_{VPEL}	1			1			µs
$t_{rec(W)}$	Recovery time, $\overline{W}$ before read	t_{WHGL}	6			6			µs
$t_{rec(R)}$	Recovery time, read before $\overline{W}$	t_{GHWL}	0			0			µs
$t_{w(W)}$	Pulse duration, $\overline{W}$ (see Note 5)	t_{WLWH}	60			60			ns
$t_{w(WH)}$	Pulse duration, $\overline{W}$ high	t_{WHWL}	20			20			ns
$t_{r(VPP)}$	Rise time, V_{PP}	t_{VPPR}	1			1			µs
$t_{f(VPP)}$	Fall time, V_{PP}	t_{VPPF}	1			1			µs

NOTE 5: Rise/fall time ≤ 10 ns

timing requirements — alternative $\overline{E}$-controlled writes

| PARAMETER		ALTERNATE SYMBOL	'28F010B-90		'28F010B-10		'28F010B-12		'28F010B-15		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$t_{c(W)}$	Cycle time, write using $\overline{E}$	t_{AVAV}	90		100		120		150		ns
$t_{c(E)PR}$	Cycle time, programming operation	t_{EHEH}	10		10		10		10		μs
$t_{h(EA)}$	Hold time, address	t_{ELAX}	45		75		80		80		ns
$t_{h(ED)}$	Hold time, data	t_{EHDX}	10		10		10		10		ns
$t_{h(W)}$	Hold time, $\overline{W}$	t_{EHWH}	0		0		0		0		ns
$t_{su(A)}$	Setup time, address	t_{AVEL}	0		0		0		0		ns
$t_{su(D)}$	Setup time, data	t_{DVEH}	35		50		50		50		ns
$t_{su(W)}$	Setup time, $\overline{W}$ before $\overline{E}$	t_{WLEL}	0		0		0		0		ns
$t_{su(VPPEL)}$	Setup time, V_{PP} to $\overline{E}$ low	t_{VPEL}	1		1		1		1		μs
$t_{rec(E)R}$	Recovery time, write using $\overline{E}$ before read	t_{EHGL}	6		6		6		6		μs
$t_{rec(E)W}$	Recovery time, read before write using $\overline{E}$	t_{GHEL}	0		0		0		0		μs
$t_{w(E)}$	Pulse duration, write using $\overline{E}$	t_{ELEH}	45		70		70		70		ns
$t_{w(EH)}$	Pulse duration, write, $\overline{E}$ high	t_{EHEL}	20		20		20		20		ns

PARAMETER MEASUREMENT INFORMATION
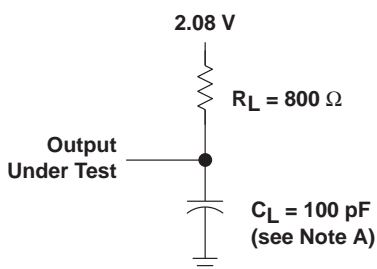
NOTE A: C_L includes probe and fixture capacitance.

Figure 4. AC Test Output Load Circuit

AC testing input/output waveforms
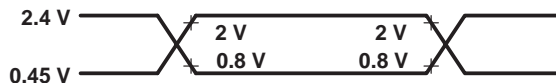
AC testing inputs are driven at 2.4 V for logic high and 0.45 V for logic low. Timing measurements are made at 2 V for logic high and 0.8 V for logic low on both inputs and outputs. Each device should have a 0.1-μF ceramic capacitor connected between V_{CC} and V_{SS} as close as possible to the device pins.

PARAMETER MEASUREMENT INFORMATION
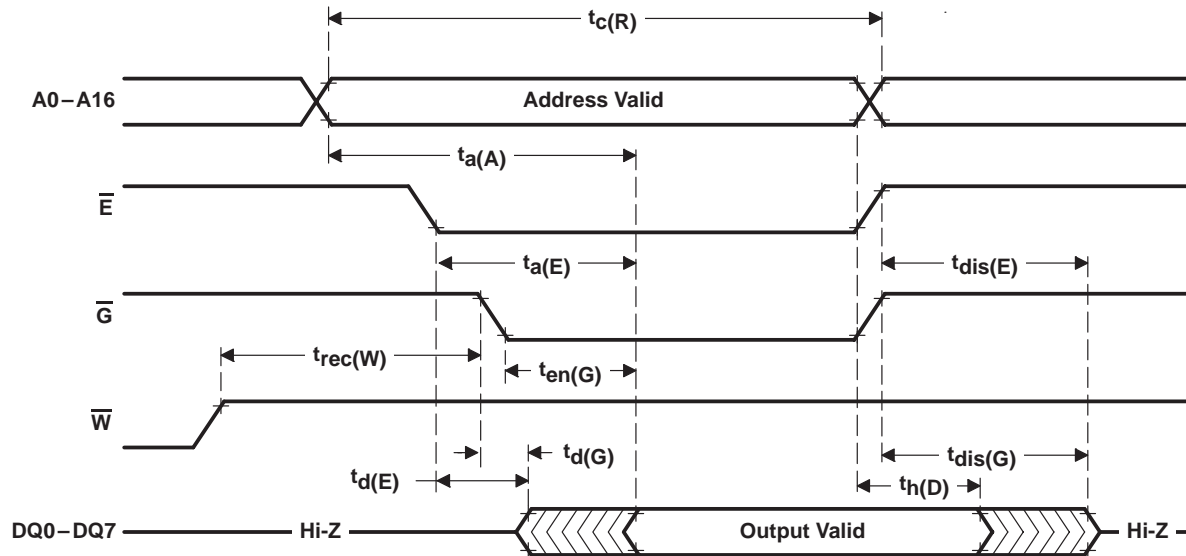
Figure 5. Read-Cycle Timing

PARAMETER MEASUREMENT INFORMATION
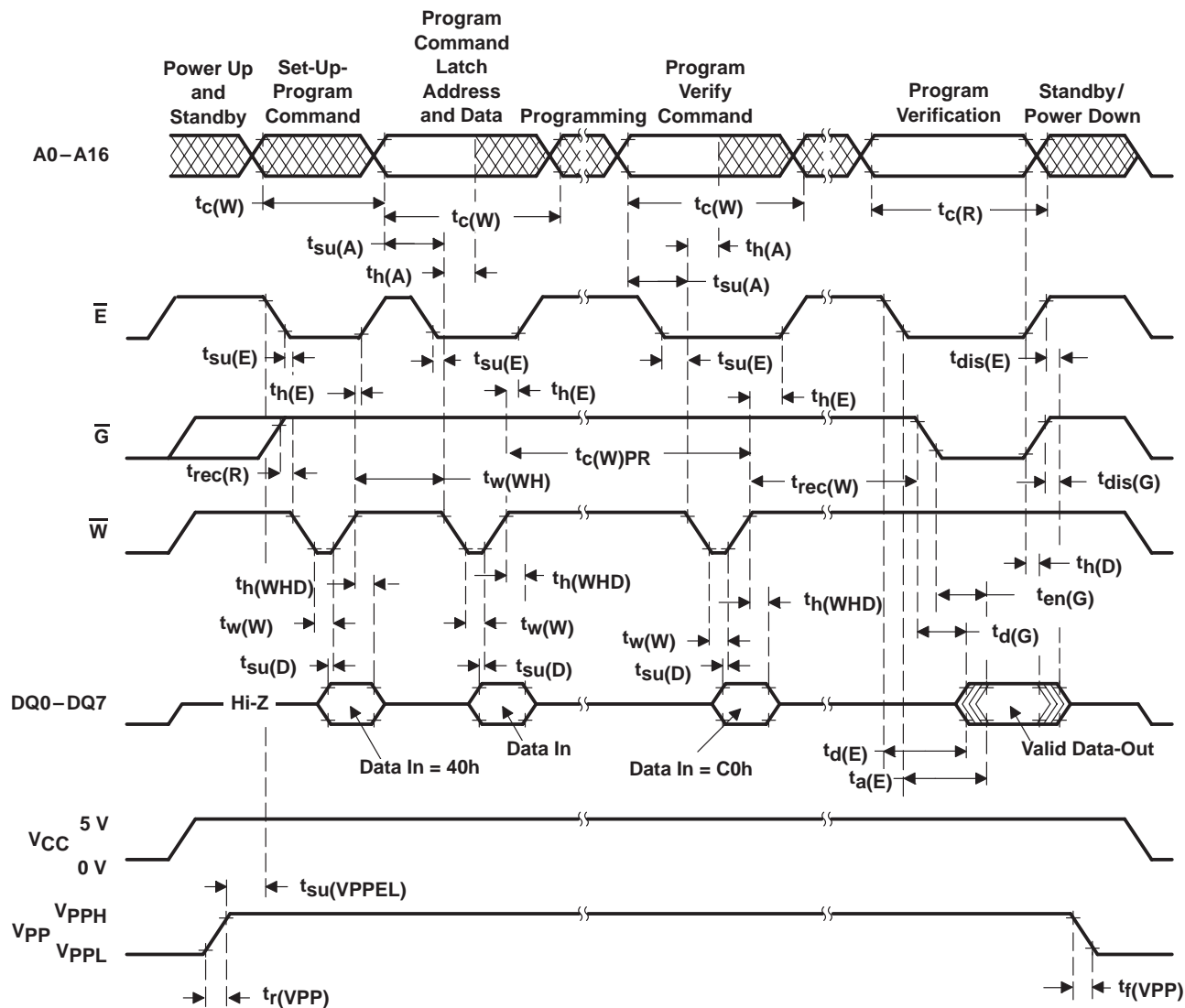
Figure 6. Write-Cycle Timing

PARAMETER MEASUREMENT INFORMATION
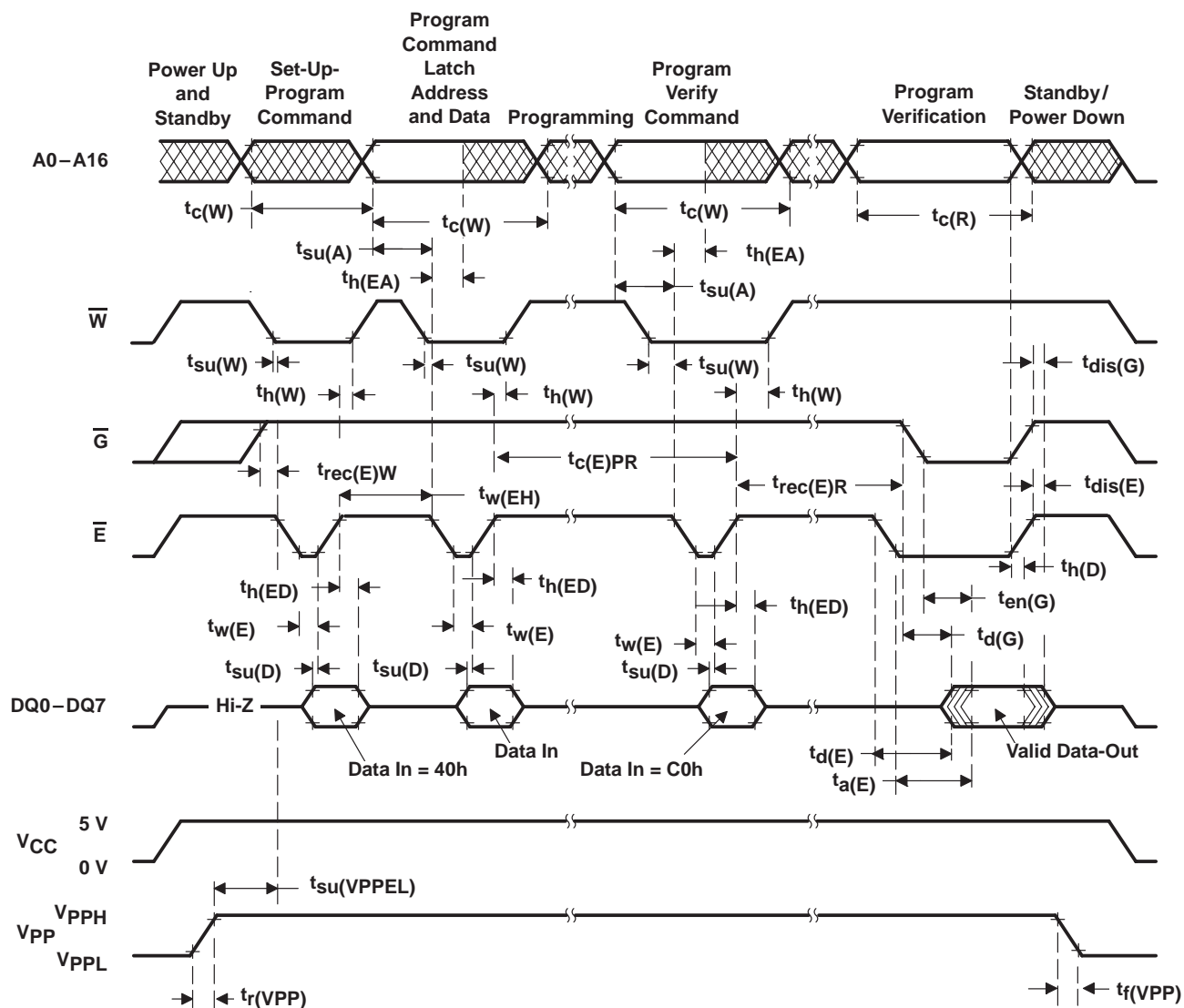
Figure 7. Write-Cycle (Alternative E̅-Controlled Writes) Timing

TEXAS
INSTRUMENTS

PARAMETER MEASUREMENT INFORMATION
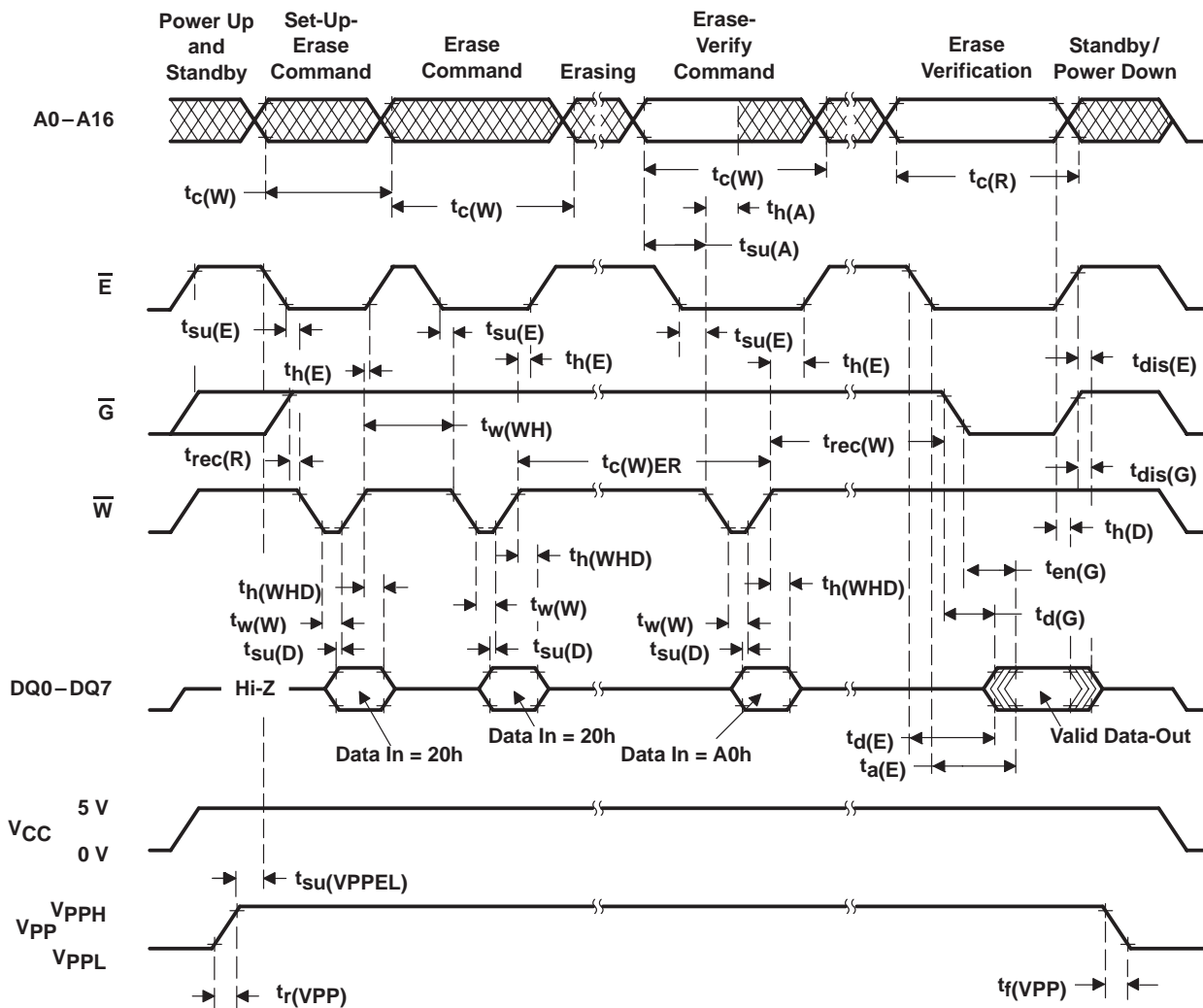
Figure 8. Flash-Erase-Cycle Timing

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