TOSHIBA CMOS DIGITAL INTEGRATED CIRCUIT SILICON MONOLITHIC

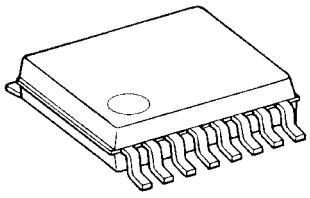
TC7MTX02FK

Digital temperature compensation IC

Due to the demand for compactness and lower power dissipation, circuits for portable devices are being manufactured as individual chips. In particular, during the manufacture of modular devices comprised of several individual discrete devices, significant time and effort must be devoted to adjusting the temperature characteristic of each discrete device individually, In addition, the demand for low power consumption is increasing.

In response to these requirements, Toshiba have developed a digital temperature compensation IC.

Toshiba have implemented this device completely in CMOS, obviating the need to use combinations of individual electronic components, such as thermistors and resistors, as was the case previously. The new digital temperature compensation IC incorporates a temperature sensor, an E^2PROM and a DA converter. The IC is accurate to within ±6ºC.



VSSOP16-P-0030-0.50

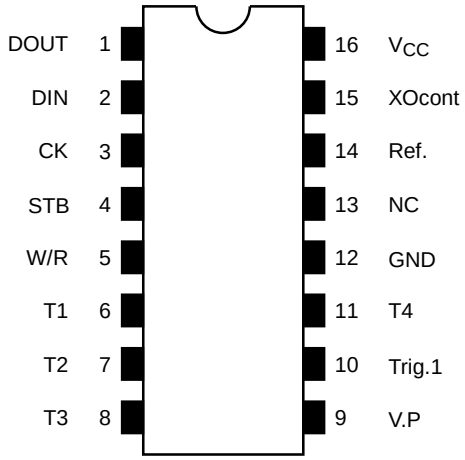
Weight: 0.02 g (typ.)

To meet the demand for compactness, the IC comes in the World's smallest and flattest 16-pin package (US16).

Features

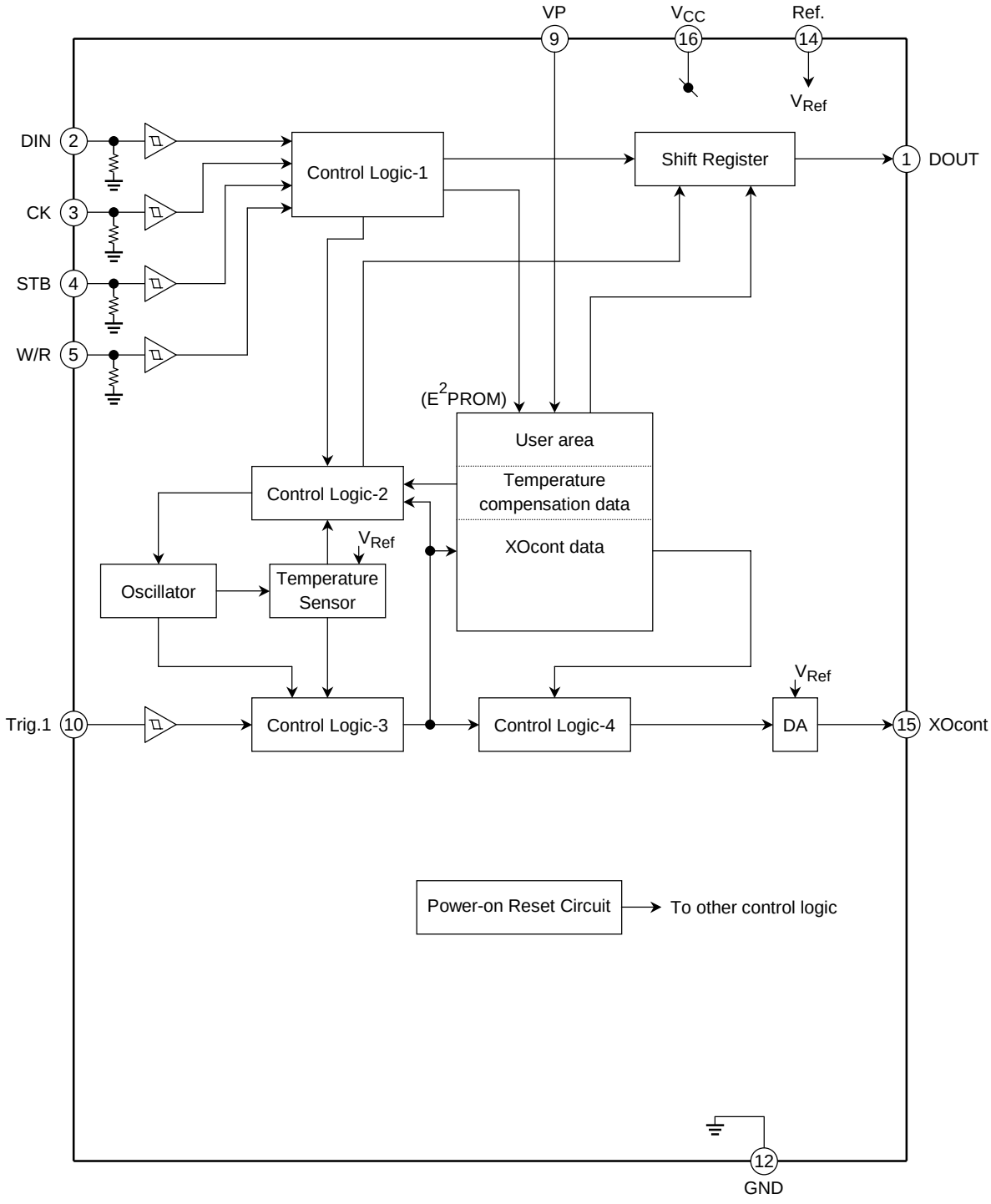
- Temperature compensation precision:
  ±6°C (in the range −40~85°C)
- Analog output (XOcont):
  Outputs an analog voltage whose level corresponds to 2°C increments in the above temperature range.
  Control resolution: 10.98 mV (typ.)/Bit
  Linearity: ±1LSB
  Output response speed: 500 µs
- Supply voltage operating range: 2.7~3.6 V
- Built-in E^2PROM : Write voltage 17 V (min)~19 V (max)
  : Write time: 10 ms
- Reference voltage (V_{Ref}): 2.8 V (typ.)
- Current dissipation: 1.0 mA (max) @25°C
- ESD: ±2000 V or more (MIL-STD method)
- Latch-up: ±200 mA or more

Pin Layout (top view)



Note: All pins (T1~T4) must be connected to the V_{CC} or the GND.

Block Diagram



Pins 2~5 incorporate pull-down resistors ($R \simeq 10\ k\Omega$)

Description of Operation

Operation of E^2PROM read/write OP codes

The operations listed below in the Operation mode selection table are performed using the five pins V.P, W/R, STB, CK and DIN.

All operations modes other than Normal Operation Mode are triggered by 8-bit serial data input on DIN and CK on the rising edge of STB. The operation mode is determined by the combination of the W/R signal and the OP code.

Operation mode selection table

No.	Operating Mode	STB	W/R	V.P	Serial input on DIN (CK)							
					DI1	DI2	DI3	DI4	DI5	DI6	DI7	DI8
1	E^2PROM write mode	H	H	18 V	H	A6	A5	A4	A3	A2	A1	A0
2	E^2PROM read mode	H	L	—	H	A6	A5	A4	A3	A2	A1	A0
3	E^2PROM All-erase mode	H	H	18 V	L	H	L	L	L	*	*	*
4	E^2PROM All-write overwrite mode	H	H	18 V	L	H	L	L	H	*	*	*
5	Temperature data read mode (before compensation: ADC output)	H	L	—	L	H	L	H	L	*	*	*
6	Temperature data read mode (after compensation: register output)	H	L	—	L	H	L	H	H	*	*	*
7	Normal operation mode	L	L	—	*	*	*	*	*	*	*	*

—: NC or V_{CC}, *: Don't care, A6~A0: specify address of E^2PROM word

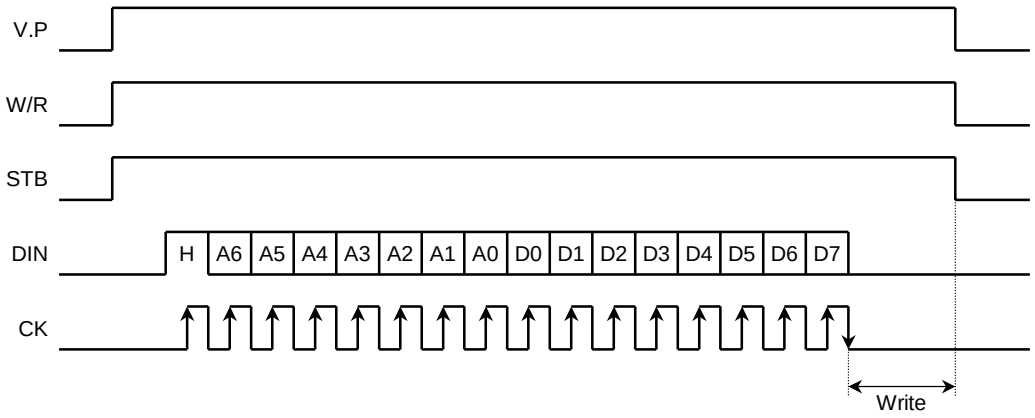
1. E^2PROM Write Mode (V.P = 18 V, W/R = "H", DI1 = "H")

Input of an OP code (DI1 = H, A6~A0 = address of word to be written) on DIN (while 18 V is applied to V.P, W/R = H and STB = H) writes data D0~D7 to the E^2PROM at the timing shown below.

Note that if D0~D7 are all High, a Byte Erase (all bits are set to H) is performed.

The write starts on the falling edge of the 16^{th} CK pulse and ends when STB goes Low.

During a write, DOUT is High-Impedance.

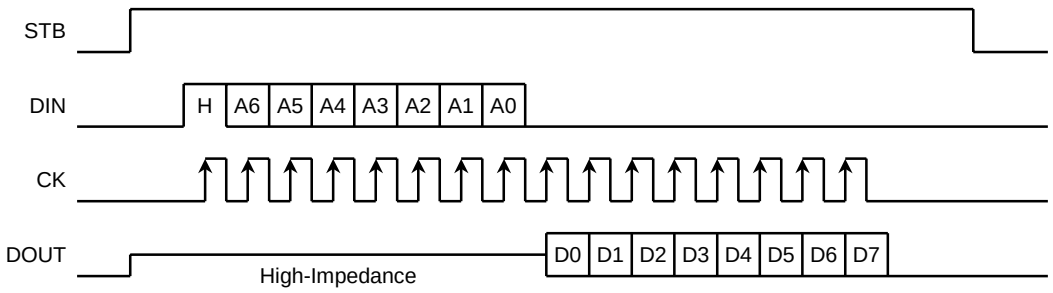


Data Write Mode timing chart

2. E^2PROM Read Mode (W/R = "L", DI1 = "H")

Input of an OP code (DI1 = H, A6~A0 = address of word to be read) on DIN (while W/R = L and STB = H) reads data D0~D7 from the E^2PROM to DOUT.

The read ends when STB goes Low.



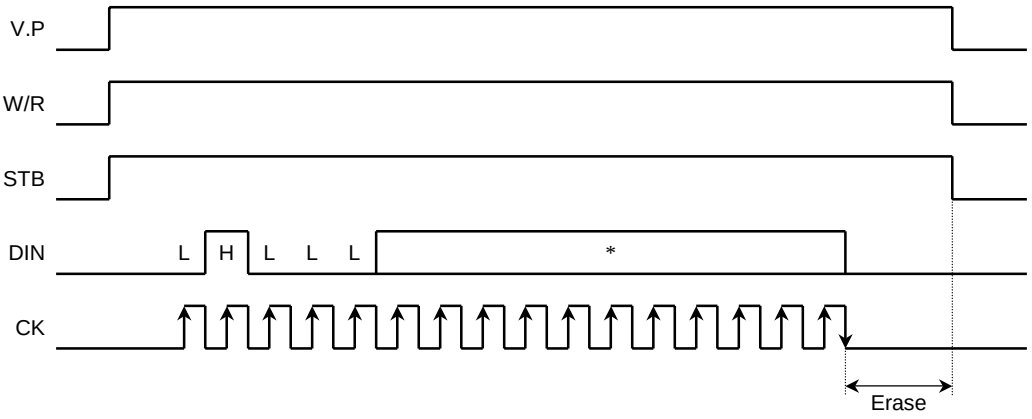
Data Read Mode timing chart

3. E^2PROM All-erase Mode

(V.P = 18 V, W/R = "H", DI1 = "L", DI2 = "H", DI3 = "L", DI4 = "L", DI5 = "L")

Input of an OP code (DI1 = L, DI2 = H, DI3 = L, DI4 = L, DI5 = L) to DIN (while 18 V is applied to V.P, W/R = H and STB = H) proceeds to erase all data in the E2PROM (all bits are set to H), starting on the falling edge of the 16th CK pulse and continuing until STB goes Low.

During Erase Mode, DOUT is High-Impedance.



*: Don't care

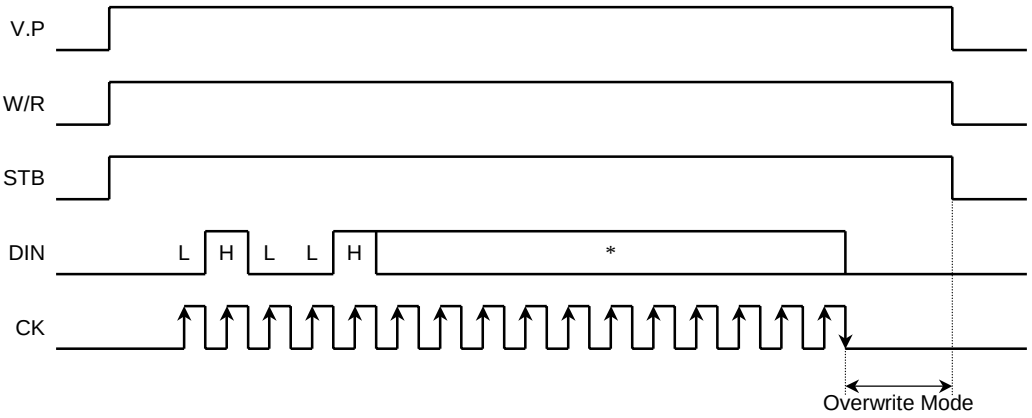
E^2PROM Erase Mode timing chart

4. E^2PROM All-write Mode

(V.P = 18 V, W/R = "H", DI1 = "L", DI2 = "H", DI3 = "L", DI4 = "L", DI5 = "H")

Input of an OP code (DI1 = L, DI2 = H, DI3 = L, DI4 = L, DI5 = H) on DIN (while 18 V is applied to V.P, W/R = H and STB = H) proceeds to overwrite the entire E^2PROM (all bits are set to L), starting on the falling edge of the 16^{th} CK pulse and continuing until STB goes Low.

During Overwrite Mode, DOUT is High-Impedance.



*: Don't care

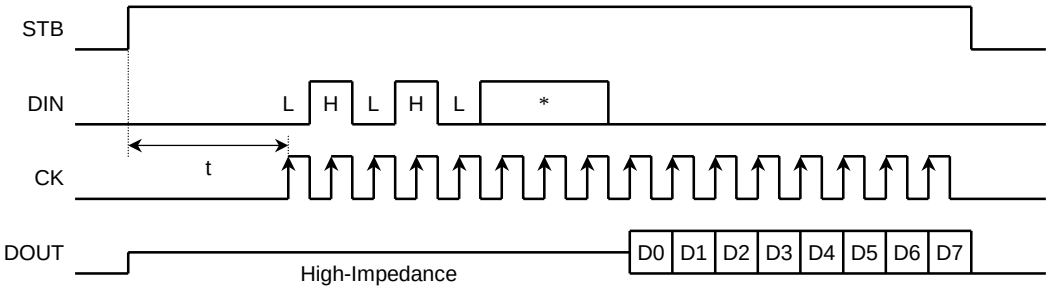
E^2PROM All-write timing chart

5. Temperature Data Read Mode (before compensation: temperature sensor output)

(W/R = "L", DI1 = "L", DI2 = "H", DI3 = "L", DI4 = "H", DI5 = "L")

Input of an OP code (DI1 = L, DI2 = H, DI3 = L, DI4 = H, DI5 = L) on DIN converts the analog data from the temperature sensor to 8-bit digital data and outputs it on DOUT.

The read ends when STB goes Low.



*: Don't care

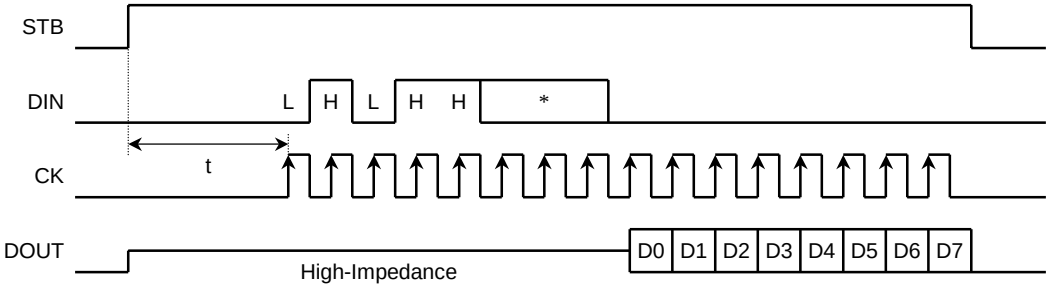
Timing chart for Temperature Data Read Mode (pre-compensation)

Note 1: The temperature sensor is triggered on the rising edge of STB. Allow a period of length t to elapse so that operation can stabilize.

6. Temperature Data Read Mode (after compensation: register output) (W/R = "L", DI1 = "L", DI2 = "H", DI3 = "L", DI4 = "H", DI5 = "H")

Input of an OP code (DI1 = L, DI2 = H, DI3 = L, DI4 = H, DI5 = H) on DIN outputs an 8-bit address on DOUT corresponding to the current temperature (sum of 8-bit temperature sensor output and 25°C temperature compensation data sensor stored at E^2PROM address 0FH).

The read ends when STB goes Low.



*: Don't care

Timing chart for Temperature Data Read Mode (post-compensation)

Note 1: The temperature sensor is triggered on the rising edge of STB. Allow a period of length t to elapse so that operation can stabilize.

7. Normal Operation Mode (STB = "L")

While STB = L, all inputs on W/R, CK and DIN are invalid and the IC is in Normal Operation Mode (this is referred to as XOcont Output Control state).

During Normal Operation Mode, the DOUT output level reflects the power-on reset status.

(Output level is High during power-on reset and Low after release of power-on reset.)

E^2PROM Contents

The E^2PROM is organized as 8 bits x 124 words (= 992 bits) and its contents is as shown below.

E^2PROM Data Save Map

Word (HEX)	BIT 0	1	2	3	4	5	6	7	Word (HEX)	BIT 0	1	2	3	4	5	6	7	Word (HEX)	BIT 0	1	2	3	4	5	6	7
00	Reserved for users								30	XOcont (–5°C)								60	XOcont (91°C)							
01	As above								31	XOcont (–3°C)								61	Reserved for users							
02	As above								32	Xocont (–1°C)								62	As above							
03	As above								33	XOcont (1°C)								63	As above							
04	As above								34	XOcont (3°C)								64	As above							
05	As above								35	XOcont (5°C)								65	As above							
06	As above								36	XOcont (7°C)								66	As above							
07	As above								37	XOcont (9°C)								67	As above							
08	As above								38	XOcont (11°C)								68	As above							
09	As above								39	XOcont (13°C)								69	As above							
0A	As above								3A	XOcont (15°C)								6A	As above							
0B	As above								3B	XOcont (17°C)								6B	As above							
0C	As above								3C	XOcont (19°C)								6C	As above							
0D	As above								3D	XOcont (21°C)								6D	As above							
0E	As above								3E	XOcont (23°C)								6E	As above							
0F	25°C temperature sensor compensation data								3F	XOcont (25°C)								6F	As above							
10	Reserved for users								40	XOcont (27°C)								70	As above							
11	As above								41	XOcont (29°C)								71	As above							
12	As above								42	XOcont (31°C)								72	As above							
13	As above								43	XOcont (33°C)								73	As above							
14	As above								44	XOcont (35°C)								74	As above							
15	As above								45	XOcont (37°C)								75	As above							
16	As above								46	XOcont (39°C)								76	As above							
17	As above								47	XOcont (41°C)								77	As above							
18	As above								48	XOcont (43°C)								78	As above							
19	As above								49	XOcont (45°C)								79	As above							
1A	As above								4A	XOcont (47°C)								7A	As above							
1B	As above								4B	XOcont (49°C)								7B	As above							
1C	XOcont (–45°C)								4C	XOcont (51°C)																
1D	XOcont (–43°C)								4D	XOcont (53°C)																
1E	XOcont (–41°C)								4E	XOcont (55°C)																
1F	XOcont (–39°C)								4F	XOcont (57°C)																
20	XOcont (–37°C)								50	XOcont (59°C)																
21	XOcont (–35°C)								51	XOcont (61°C)																
22	XOcont (–33°C)								52	XOcont (63°C)																
23	XOcont (–31°C)								53	XOcont (65°C)																
24	XOcont (–29°C)								54	XOcont (67°C)																
25	XOcont (–27°C)								55	XOcont (69°C)																
26	XOcont (–25°C)								56	XOcont (71°C)																
27	XOcont (–23°C)								57	XOcont (73°C)																
28	XOcont (–21°C)								58	XOcont (75°C)																
29	XOcont (–19°C)								59	XOcont (77°C)																
2A	XOcont (–17°C)								5A	XOcont (79°C)																
2B	XOcont (–15°C)								5B	XOcont (81°C)																
2C	XOcont (–13°C)								5C	XOcont (83°C)																
2D	XOcont (–11°C)								5D	XOcont (85°C)																
2E	XOcont (–9°C)								5E	XOcont (87°C)																
2F	XOcont (–7°C)								5F	XOcont (89°C)																

(Contents of addresses 00H~0EH, 10H~1BH, 61H~7BH): Reserved area for users

(Contents of address 0FH): 25°C temperature sensor compensation data (8-bit data is used to compensate for temperature fluctuation in sensor ICs.)

(Contents of addresses 1CH~60H): XOcont temperature data (temperature range: –45°C~91°C, 8-bit data, one value for each 2°C increment)

XOcont Output Operation

XOcont is the output pin used to output temperature compensation data (XOcont data) corresponding to the output from the built-in temperature sensor. Data corresponding to each 2°C temperature increment is stored in the E²PROM.

1. Output at power-on

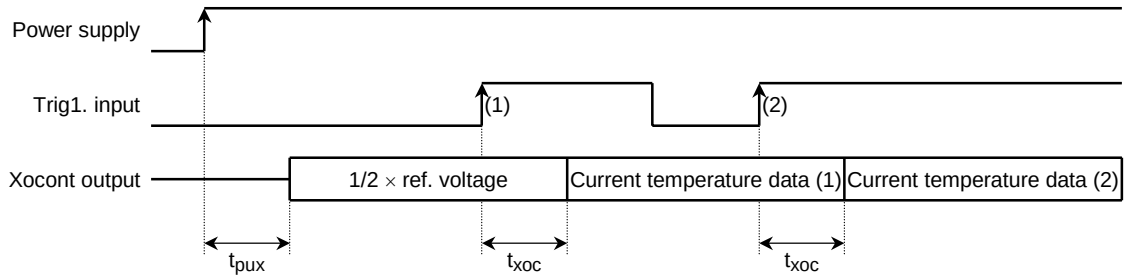
At power-on, 1/2 x ref. voltage (80H) is output on XOcont.

Delay time tpux, from power-on to start of output of 1/2 x ref. voltage, is 100 μs or less.

2. Output caused by trigger input

The rising edge of the Trig.1 input triggers the built-in temperature sensor. The sum of the temperature sensor output and 25°C temperature sensor compensation data (stored at address 0FH) is used as the XOcont data address. The XOcont data is converted to an analog voltage level and output on XOcont.

The delay time txoc, from Trig.1 input to start of voltage output, is 500 μs or less.



Output timing for XOcont

3. XOcont data

The XOcont data is stored at addresses 1CH~60H of the E²PROM and is used as compensation data corresponding to every 2°C increment in the ambient temperature range −45°C~91°C.

The voltage output on XOcont corresponds to the 8-bit data stored in the E²PROM (0 V for the value stored at address 00H; V_{Ref} for the value stored at address FFH).

Temperature Sensor

The IC incorporates a temperature sensor which can detect temperatures with an accuracy of 2°C. The sum of the output from the temperature sensor (after conversion to a digital value) and the 25°C temperature sensor compensation data (stored at address 0FH) is used as the E^2PROM address of the compensation data.

In Normal Operation Mode, the temperature sensor is inactive. The sensor is triggered by the rising edge of STB or by the Trig.1 input. On completion of operation, the sensor returns to its inactive state.

The 25°C temperature sensor compensation data can be written to address 0FH of the E^2PROM as follows:

1. Measurement of ambient temperature and device temperature data (before compensation)

- The ambient temperature of the test environment is measured.
- Read the temperature data of TC7MTX02FK before compensation

2. Calculation of 25°C temperature sensor compensation data

- If the ambient temperature is 25°C, the compensation data can be calculated as follows:
  25°C temperature sensor compensation data = 3FH – temperature data before compensation
- If the ambient temperature is not 25°C, add the difference between the ambient temperature and 25°C to the result of the above calculation.
  The following table shows 25°C temperature sensor compensation values corresponding to the ambient temperature and the raw temperature data

25°C temperature sensor compensation values corresponding to the ambient temperature and the temperature data before compensation

Temperature Data before Compensation (TC7MTX02FK)	Ambient Temperature in Test Environment								
	21°C	22°C	23°C	24°C	25°C	26°C	27°C	28°C	29°C
41	FC	FC	FD	FD	FE	FE	FF	FF	00
40	FD	FD	FE	FE	FF	FF	00	00	01
3F	FE	FE	FF	FF	00	00	01	01	02
3E	FF	FF	00	00	01	01	02	02	03
3D	00	00	01	01	02	02	03	03	04
3C	01	01	02	02	03	03	04	04	05
3B	02	02	03	03	04	04	05	05	06
3A	03	03	04	04	05	05	06	06	07
39	04	04	05	05	06	06	07	07	08
38	05	05	06	06	07	07	08	08	09
37	06	06	07	07	08	08	09	09	0A
36	07	07	08	08	09	09	0A	0A	0B
35	08	08	09	09	0A	0A	0B	0B	0C
34	09	09	0A	0A	0B	0B	0C	0C	0D

All values above are hexadecimal.

3. E^2PROM Write

This instruction writes the 25°C address compensation data to address 0FH in the E^2PROM.

Maximum Ratings (GND = 0.0 V)

Characteristic	Symbol	Rating	Unit	Pin
Supply voltage	V_{CC}	−0.5~6.5	V	V_{CC}
E^2PROM write voltage	V_P	−0.5~20.0	V	V.P
Reference voltage	V_{Ref}	−0.5~V_{CC} + 0.5	V	Ref.
Input voltage	V_{IN}	−0.5~6.5	V	DIN, CK, STB, W/R, Trig1
Output voltage	V_{OUT}	−0.5~V_{CC} + 0.5	V	DOUT, XOcont
Input current	I_{IN}	±10	mA	DIN, CK, STB, W/R, Trig1
Power dissipation	P_D	180	mW	
Storage temperature	T_{stg}	−40~125	°C	

Recommended Operating Conditions (GND = 0.0 V)

Characteristic	Symbol	Min	Typ.	Max	Unit
Supply voltage	V_{CC}	2.7	3.0	3.6	V
E^2PROM write voltage	V_P	17.0	18.0	19.0	V
Reference voltage	V_{Ref}	2.7	2.8	2.9	V
Input voltage	V_{IN}	0	—	V_{CC}	V
Input rise/fall time	$t_{r\phi}$, $t_{f\phi}$	—	—	1.0	μs
Power-on rise time	t_V	100	—	—	μs
Operating temperature	T_{opr}	−40	—	85	°C

E^2PROM Characteristics

Characteristic	Symbol	Test Circuit	Min	Typ.	Max	Unit
No. of rewrites	N_{wr}	Ta = 25°C, V_{CC} = 3.0 V, V_P = 18.0 V	10000	—	—	Times
Data retention time	t_{RET}	Ta = −40~85°C	10	—	—	Years

DC Characteristics (GND = 0.0 V)

Characteristic	Symbol	Test Circuit	Ta = −40°C		Ta = 25°C			Ta = 85°C		Unit
			Min	Max	Min	Typ.	Min	Min	Max	
High-level input voltage	V_{IH}	V_{CC} = 2.7~3.3 V	2.0	—	2.0	—	—	2.0	—	V
Low-level input voltage	V_{IL}	V_{CC} = 2.7~3.3 V	—	0.5	—	—	0.5	—	0.5	V
Hysteresis voltage	V_H	V_{CC} = 3.0V	—	—	—	0.3	—	—	—	V
High-level output current (DOUT)	I_{OH}	V_{CC} = 3.0 V V_{OH} = 2.4 V	4.0	—	4.0	7.0	—	3.2	—	mA
Low-level output current (DOUT)	I_{OL}	V_{CC} = 3.0 V V_{OL} = 0.4 V	4.0	—	4.0	8.5	—	3.2	—	mA
Input current	I_{IN}	V_{CC} = 3.3 V V_{IN} = 0 or 3.3 V	—	±1.0	—	—	±1.0	—	±5.0	μA
Three-state OFF leakage current (DOUT)	I_{OZ}	V_{CC} = 3.3 V V_{OUT} = 0 or 3.3 V	—	±1.0	—	—	±1.0	—	±5.0	μA
Pull-down resistance (DIN, CK, STB, W/R)	R_{PD}	V_{CC} = 2.7~3.3 V	—	—	4	10	20	—	—	kΩ
Auto-reset release voltage	V_{RD}		—	2.5	—	1.8	2.5	—	2.5	V
Static current dissipation	I_{CC}	V_{CC} = 3.0 V (Note 2) V_{IN} = V_{CC} or GND	—	—	—	0.5	1.0	—	—	mA
Static current dissipation	I_{REF}	V_{CC} = 2.8 V (Note2) V_{IN} = V_{CC} or GND	—	—	—	0.1	1.0	—	—	mA

Note2: The current generated by setting the input pins with pull-down resistors to High is not included.

AC Characteristics
(Ta = 25°C, V_{CC} = 3.0 V, V_{Ref} = 2.8 V, GND = 0 V, C_L = 50 pF, Input: t_r, t_f = 6 ns)

E^2PROM Write Timing (applies to Operation Modes 1, 3 and 4)

Characteristic	Symbol	Test Circuit	Typ	Limit	Unit
Minimum VP power-on timing time (V.P power supply – STB input)	t_{sv}	Figure 1	—	0	ns
Minimum VP power-off timing time (STB input – V.P power supply)	t_{hv}	Figure 1	—	0	ns
Minimum VP power supply cut-off pulse width	t_{wL}	Figure 1	—	10	μs
Minimum set-up time (W/R input – STB input)	t_{sw}	Figure 1	—	0	ns
Minimum hold time (W/R input – STB input)	t_{hw}	Figure 1	—	40	ns
Minimum removal time (STB input – CK input)	t_{rem}	Figure 1	−5	40	ns
Minimum write time (CK input – W/R input)	t_{pws}	Figure 1	—	10	ms
Minimum pulse width (STB input)	t_{wL}	Figure 1	—	10	μs
Minimum clock cycle time (CK input)	t_{cyc}	Figure 1	0.2	2	μs
Minimum clock pulse width (CK input)	t_{wH} t_{wL}	Figure 1	0.1	1	μs
Minimum set-up time (DIN input – CK input)	t_{su}	Figure 1	−3	40	ns
Minimum hold time (DIN input – CK input)	t_h	Figure 1	5	40	ns

E^2PROM Read Timing (applies to Operation Mode 2)

Characteristic	Symbol	Test Circuit	Typ	Limit	Unit
Minimum set-up time (W/R input – STB input)	t_{sr}	Figure 2	—	0	ns
Minimum hold time (W/R input – STB input)	t_{hr}	Figure 2	—	0	ns
Minimum removal time (STB input – CK input)	t_{rem}	Figure 2	−5	40	ns
Minimum pulse width (STB input)	t_{wL}	Figure 2	0.1	1	μs
Minimum clock cycle time (CK input)	t_{cyc}	Figure 2	0.2	2	μs
Minimum clock pulse width (CK input)	t_{wH} t_{wL}	Figure 2	0.1	1	μs
Minimum set-up time (DIN input – CK input)	t_{su}	Figure 2	−3	40	ns
Minimum hold time (DIN input – CK input)	t_h	Figure 2	5	40	ns
Propagation delay time (CK input – DOUT output)	t_{pZH} t_{pZL}	On first DOUT output Figure 2	15	100	ns
Propagation delay time (CK input – DOUT output)	t_{pLH} t_{pHL}	On second and subsequent DOUT outputs Figure 2	15	100	ns
Output Disable time (STB input – DOUT output)	t_{PLZ} t_{pHL}	Figure 2	20	100	ns

Timing in Other Modes (applies to Operation Modes 5 and 6)

Characteristic	Symbol	Test Circuit	Typ	Limit	Unit
Minimum removal time (STB input – CK input)	t_{rem}	Operation modes 5 and 6 (temperature data read modes) Figure 2	140	400	μs

Note3: All characteristics except for t_{rem} are the same as those for the E^2PROM read timing.

Characteristics of Analog Block (Ta = 25°C, V_{CC} = 2.80 V, V_{Ref} = 2.80 V, GND = 0 V)

XOcont Output

Characteristic	Symbol	Test Circuit	Ta = 25°C			Ta = −40~85°C		Unit
			Min	Typ.	Max	Min	Max	
XOcont output response time (Trig.1 – XOcont)	t_{xoc}	Figure 3	—	200	450	—	500	μs
XOcont output voltage	V_{XOC}	XOcont data: 80H XOcont output < 1 μA	1380	1400	1420	1380	1420	mV
XOcont output voltage variation	ΔV_{XOC}	XOcont data1 per bit XOcont output < 1 μA	—	10.98	—	—	—	mV
XOcont output voltage linearity	ΔNLX	XOcont data: 00H ≦ DATA ≦ FFH (Note 4)	—	±1	±1	—	±1	LSB

Temperature Sensor

Characteristic	Symbol	Test Circuit	Min	Typ.	Max	Unit
Temperature sensor output Value (output at Ta = 25°C before compensation)	Tsen1	Ta = 25°C Temperature sensor output before compensation	30H	3AH	44H	—
Temperature sensor output Value (output at Ta = −40°C before compensation)	Tsen2	Ta = −40°C Temperature sensor output before compensation	0FH	19H	23H	—
Temperature sensor output Value (output at Ta = 85°C before compensation)	Tsen3	Ta = 85°C Temperature sensor output before compensation	4EH	58H	62H	—
Temperature sensor output Variation	ΔTS	Per 1°C	—	2	—	LSB
Temperature sensor output Linearity	ΔNLT	−40°C ≦ Ta ≦ 85°C (Note4)	—	±1	±6	LSB

Note 4: The linearity is the deviation of the actual characteristic curve from the expected variation.

Timing Charts

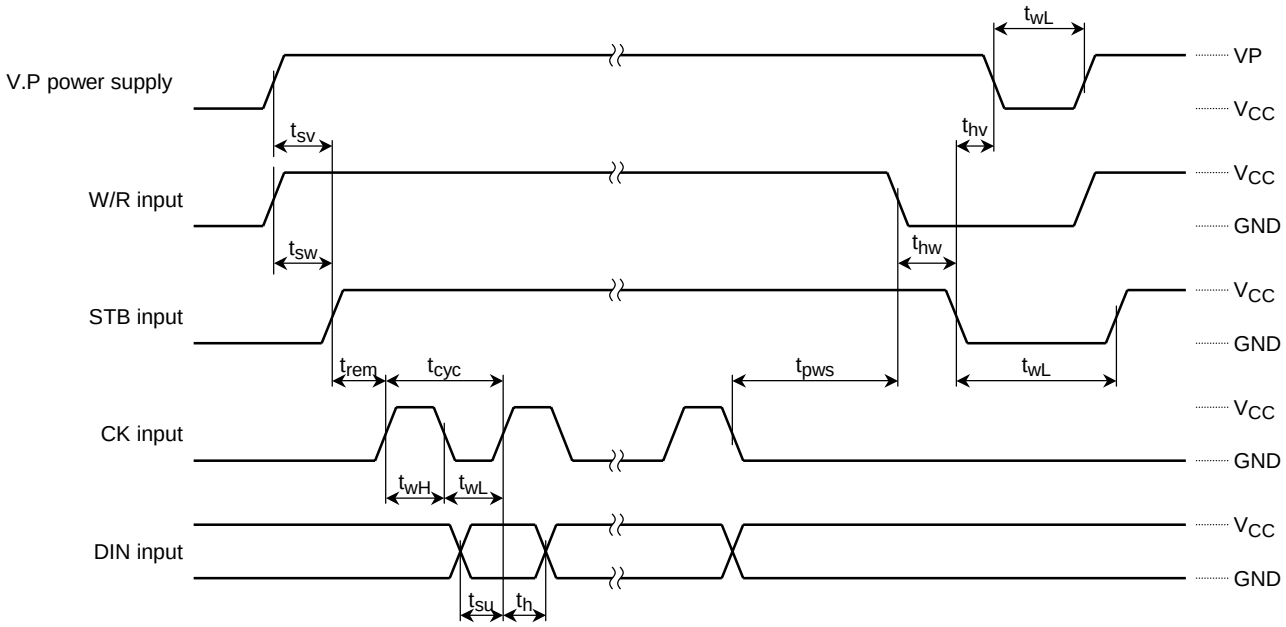


Figure 1 Timing chart for E^{2}PROM Write Mode

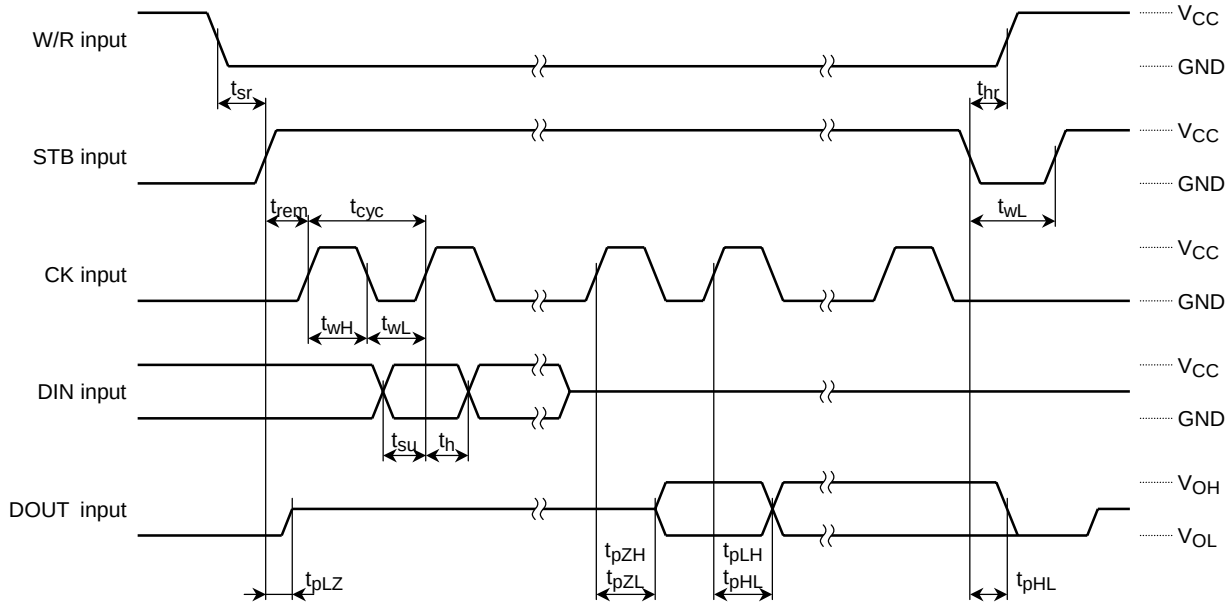


Figure 2 Timing chart for E^{2}PROM Read Mode and other operation modes

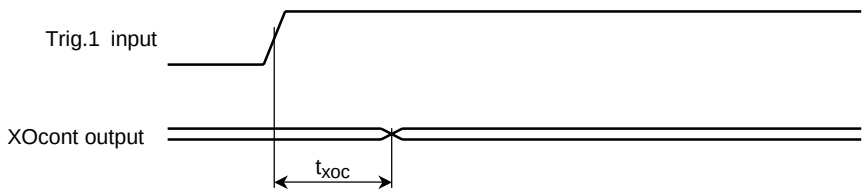
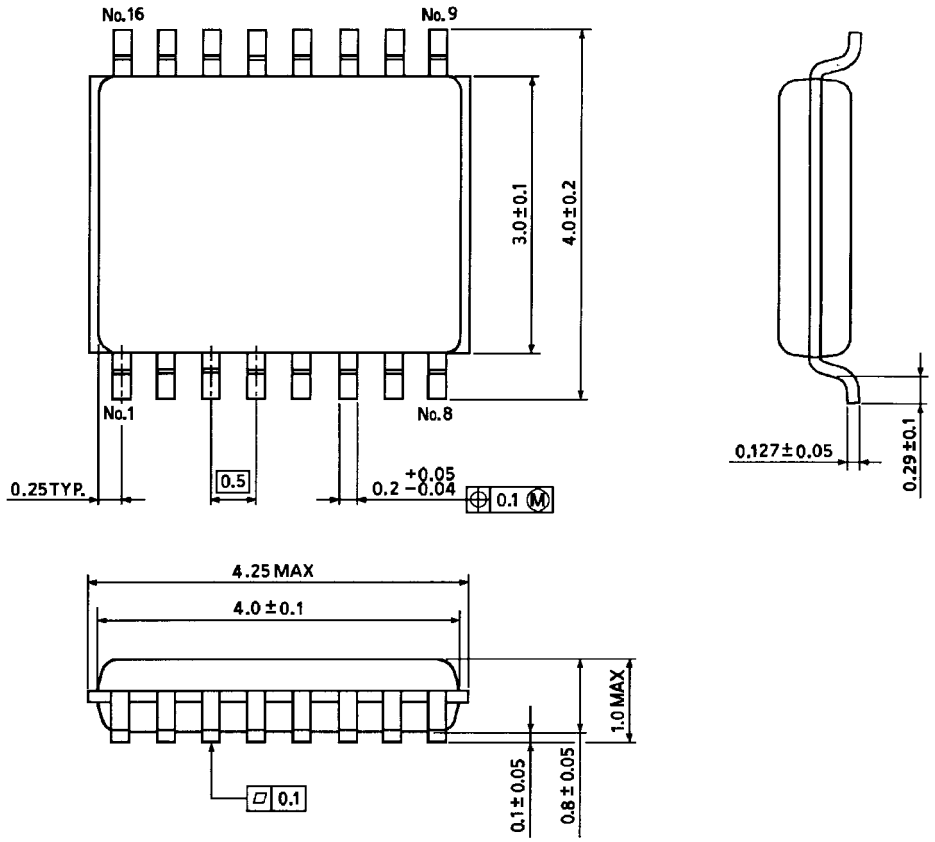


Figure 3 Timing chart for analog output

Package Dimensions

VSSOP16-P-0030-0.50 Unit : mm



Weight: 0.02 g (typ.)

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000707EBA

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