Digital Output Temperature Sensor with I²C and SMBus Interface

Features

- Accuracy
  - to ±1℃ (typical) from −40 ℃ to + 125 ℃
- Address
  - Supports up to 32 I²C Addresses
- Wide Supply Range
  - 2.2 ~ 5.5 V
- Digital Interface: SMBus, I²C
- Software Compatibility with Industry Standard LM75 and TMP75
- Resolution: 12 bits
- Alert Pin Function

Applications

- Power-Supply Temperature Monitoring
- Computer Peripheral Thermal Protection
- Notebook Computers
- Battery Management
- Thermostat Controls
- Environmental Monitoring and HVAC
- Electro Mechanical Device Temperature

Description

The TPTMP75 is a digital temperature sensor ideal for replacement of negative temperature coefficient (NTC) and positive temperature coefficient (PTC) thermistor. The accuracy of the device is typical ± 1°C without requirements of calibration or external signal conditioning.

The device includes an on-chip 12-bit analog-to-digital converter (ADC), which offers resolutions down to 0.0625°C.

The device has SMBus, two-wire, and I²C interface compatibility. It also has SMBUS Alert function.

The device is specified for operation over a temperature range from −40°C to 125 °C.

The TPTMP75 is ideal for extended temperature measurement in a variety of communication, computer, consumer, environmental, industrial, and instrumentation applications.

Typical Application Circuit

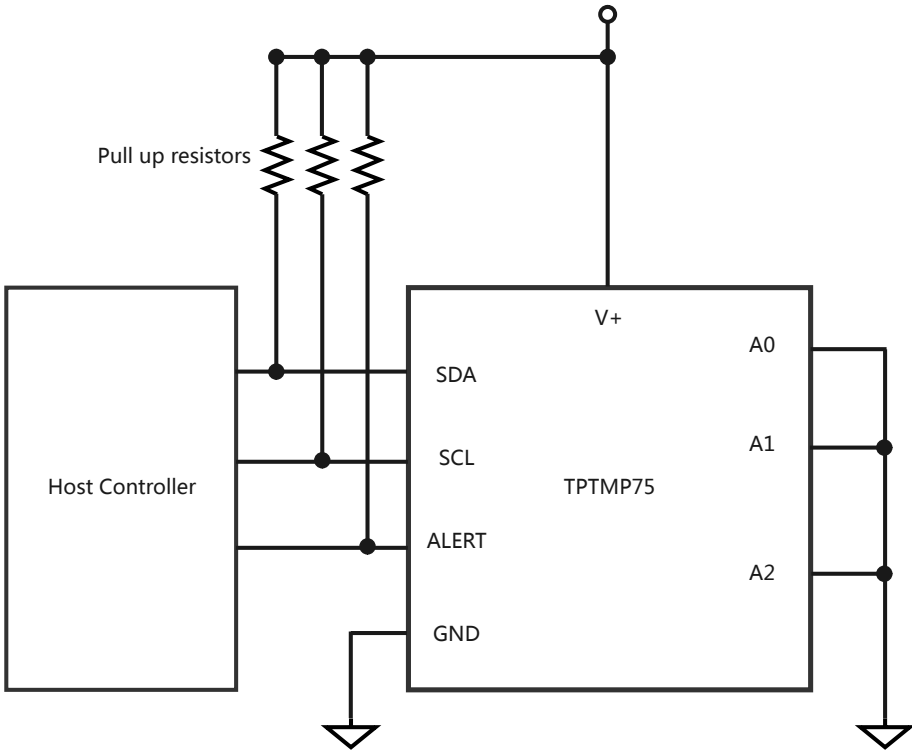


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Product Family Table

Order Number	Resolution	Package
TPTMP75-SO1R	12	SOP8
TPTMP75-VS1R	12	MSOP8

Revision History

Date	Revision	Notes
2023-08-01	Rev.A.0	Release version.
2023-09-26	Rev.A.1	Update Data fall time value.
2024-01-15	Rev.A.2	Update temperature range for ±1℃

Pin Configuration and Functions

TPTMP75
SOP8 and MSOP8 Packages
Top View

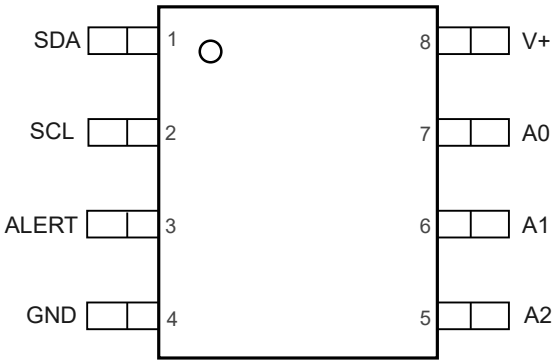


Table 1. Pin Functions

Pin		Type	Description
NO.	Name		
1	SDA	I/O	Serial data, open drain output.
2	SCL	I	Serial clock.
3	ALERT	O	Alert signal, open drain output.
4	GND	-	Ground.
5	A2	I	Address select A2.
6	A1	I	Address select A1.
7	A0	I	Address select A0.
8	V+	I	Supply voltage.

Specifications

Absolute Maximum Ratings (1)

Parameter		Min	Max	Unit
	Power Supply, V+		6.5	V
	Input Voltage	–0.5	6.5	V
	Input Current		10	mA
T_J	Junction Temperature		150	°C
T_{STG}	Storage Temperature	–60	130	°C

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

ESD, Electrostatic Discharge Protection

Parameter		Condition	Minimum Level	Unit
HBM	Human Body Model ESD	ANSI/ESDA/JEDEC JS-001 (1)	2	kV
CDM	Charged Device Model ESD	ANSI/ESDA/JEDEC JS-002 (2)	1	kV

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

Recommended Operating Conditions

Parameter		Min	Nom	Max	Unit
	Supply Voltage	2.2		5.5	V
T_A	Operating Free-air Temperature	–40		125	°C

Thermal Information

Thermal Metric		MSOP8	SOP8	Unit
$R_{\theta JA}$	Junction-to-ambient thermal resistance	146.22	112.2	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	45.51	45.57	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	109.61	90.63	°C/W

Electrical Characteristics

All test conditions: T_A = −40°C to +125°C and V+ = 2.2 V to 5.5 V, unless otherwise noted.

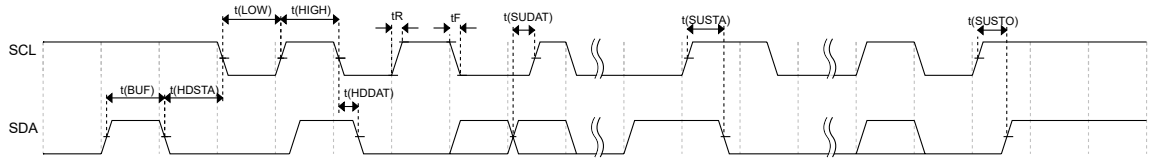
Parameter		Test Conditions	Min	Typ	Max	Unit
Temperature Input						
Range			–40		125	°C
Accuracy (temperature error)		−20°C to +85°C		±0.5	±1	°C
		−40°C to +85°C		±0.5	±1.5	°C
		−40°C to +125°C		±1	±2	°C
	Accuracy (temperature error) vs supply			0.01		°C/V
	Resolution (1)	Selectable		0.0625		°C
Digital Input/Output						
	Input Capacitance			3		pF
V_{IH}	High-level Input Logic		0.7(V+)		6	V
V_{IL}	Low-level Input Logic		−0.5		0.3(V+)	V
I_{IN}	Leakage Input Current	0 V ≤ V_{IN}≤ 6 V		1		µA
	Input Voltage Hysteresis	SCL and SDA pins		500		mV
V_{OL}	Low-level Output Logic	I_{OL}= 3 mA	0	0.15	0.4	V
	Resolution			12		Bits
	One Shot			11.2	13	ms
	Conversion Time	R1 = 0, R0 = 0 (default)		27.5		ms
		R1 = 0, R0 = 1		55		ms
		R1 = 1, R0 = 0		110		ms
		R1 = 1, R0 = 1		220		ms
	Timeout Time			25		ms
Power Supply						
	Operating Range		2.2		5.5	V
I_Q	Quiescent Current	R1 = 0, R0 = 0 (default)		59	66	µA
		R1 = 0, R0 = 1		35	43	µA
		R1 = 1, R0 = 0		23	31	µA
		R1 = 1, R0 = 1		23	31	µA
I_{SD}	Shutdown Current			0.3		µA
Temperature Range						
	Specified Range		–40		125	°C

Timing Requirements

Minimum and maximum specifications are over −40°C to 125°C and V+ = 2.2 V to 5.5 V (unless otherwise noted).

Parameter			Fast Mode		High-speed Mode		Unit
			Min	Max	Min	Max	
$f_{(SCL)}$	SCL operating frequency		0.001	0.4	0.001	2.56	MHz
$t_{(BUF)}$	Bus-free time between STOP and START conditions		1300		160		ns
$t_{(HDSTA)}$	Hold time after repeated START condition. After this period, the first clock is generated.		600		160		ns
$t_{(SUSTA)}$	Repeated START condition setup time		600		160		ns
$t_{(SUSTO)}$	STOP condition setup time		600		160		ns
$t_{(HDDAT)}$	Data hold time		0		0	130	ns
$t_{(SUDAT)}$	Data setup time		100		20		ns
$t_{(LOW)}$	SCL clock low period		1300		280		ns
$t_{(HIGH)}$	SCL clock high period		600		100		ns
t_{FD}	Data fall time			300		150	ns
t_{RC}	Clock rise time			300		40	ns
		SCLK ≤ 100 kHz, see the Timing Diagrams section		1000		40	ns
t_{FC}	Clock fall time			300		40	ns

Timing Diagrams



Detailed Description

Overview

The TPTMP75 is a digital temperature sensor optimal for thermal management and thermal protection applications. The device is SMBus and I²C interface-compatible.

Functional Block Diagram

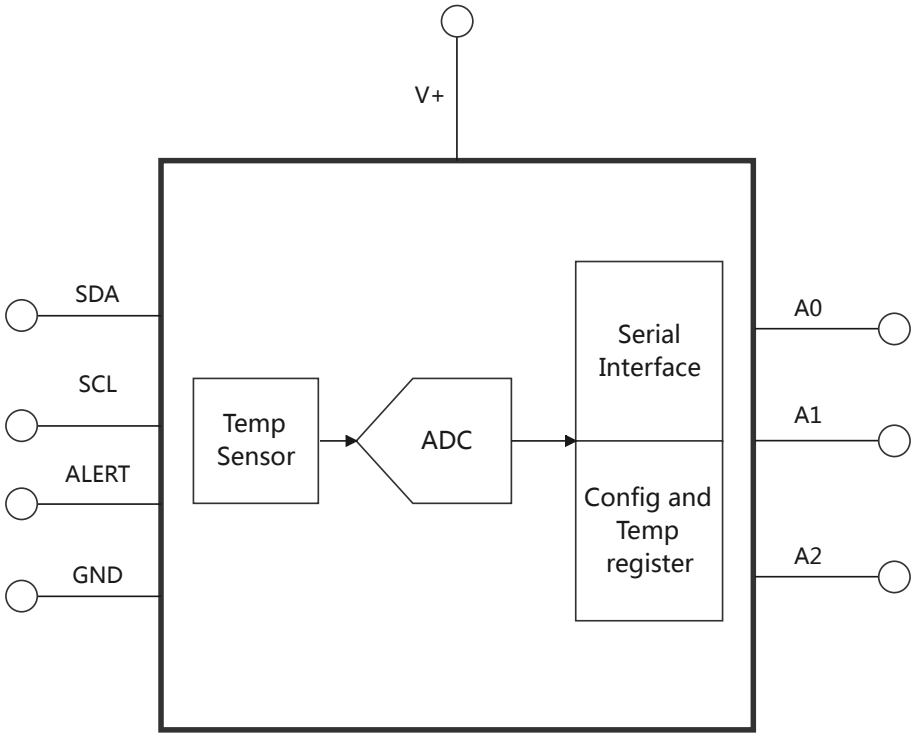


Figure 1. Functional Block Diagram

Feature Description

Digital Temperature Output

The temperature register of the TPTMP75 is a 12-bit register that stores the output of the most recent conversion. Two bytes should be read to obtain data. Negative numbers are represented in binary twos complement format.

Table 2. Temperature Data Format

TEMPERATURE (°C)	DIGITAL OUTPUT	
	BINARY	HEX
128	0111 1111 1111	7FF
127.9375	0111 1111 1111	7FF
100	0110 0100 0000	640
80	0101 0000 0000	500

TEMPERATURE (°C)	DIGITAL OUTPUT	
	BINARY	HEX
75	0100 1011 0000	4B0
50	0011 0010 0000	320
25	0001 1001 0000	190
0.25	0000 0000 0100	004
0	0000 0000 0000	000
–0.25	1111 1111 1100	FFC
–25	1110 0111 0000	E70
–55	1100 1001 0000	C90

Serial Interface

The TPTMP75 operates as slave device on the SMBus, two-wire, and I2C interface-compatible bus. The device supports fast and high-speed modes.

Bus Overview

The device that initiates the transfer is called a *master*, and the devices controlled by the master are *slaves*. The bus must be controlled by a master device that generates the serial clock (SCL), controls the bus access, and generates the START and STOP conditions.

To address a specific device, a START condition is initiated, indicated by pulling the data line (SDA) from a high to low logic level when SCL is high. All slaves on the bus shift in the slave address byte, with the last bit indicating whether a read or write operation is intended. During the ninth clock pulse, the slave being addressed responds to the master by generating an acknowledge and pulling SDA low.

Data transfer is then initiated and sent over eight clock pulses followed by an acknowledge bit. During data transfer SDA must remain stable when SCL is high because any change in SDA when SCL is high is interpreted as a control signal.

When all data are transferred, the master generates a STOP condition indicated by pulling SDA from low to high when SCL is high.

Serial Bus Address

The device address byte consists of seven address bits and a direction bit indicating the intent of executing a read or write operation.

The device features three address pins to allow up to 32 devices to be addressed on a single bus interface.

Table 3. Address Pins State

A2	A1	A0	7-BIT ADDRESS		A2	A1	A0	7-BIT ADDRESS
0	0	SDA	1000000		0	SDA	SDA	1010000
0	0	SCL	1000001		0	SDA	SCL	1010001
0	1	SDA	1000010		0	SCL	SDA	1010010
0	1	SCL	1000011		0	SCL	SCL	1010011
1	0	SDA	1000100		1	SDA	SDA	1010100
1	0	SCL	1000101		1	SDA	SCL	1010101

A2	A1	A0	7-BIT ADDRESS		A2	A1	A0	7-BIT ADDRESS
1	1	SDA	1000110		1	SCL	SDA	1010110
1	1	SCL	1000111		1	SCL	SCL	1010111
0	0	0	1001000		0	SDA	0	1011000
0	0	1	1001001		0	SDA	1	1011001
0	1	0	1001010		0	SCL	0	1011010
0	1	1	1001011		0	SCL	1	1011011
1	0	0	1001100		1	SDA	0	1011100
1	0	1	1001101		1	SDA	1	1011101
1	1	0	1001110		1	SCL	0	1011110
1	1	1	1001111		1	SCL	1	1011111

Writing and Reading to TPTMP75

Accessing a particular register on the device is accomplished by writing the appropriate value to the pointer register. After Reset, the register value is set to zero. The value for the pointer register is the first byte transferred after the device address byte with the R/W bit low. Every write operation to the device requires a value for the pointer register.

SMBus Alert Function

The TPTMP75 supports the SMBus Alert function. When the device is operating in interrupt mode (TM = 1), the ALERT pin can be connected as an SMBus Alert signal.

When reading from the device, the last value stored in the pointer register by a write operation is used to determine which register is read by a read operation. When a host senses that an alert condition is present on the ALERT line, the host sends an SMBus Alert command (00011001) on the bus. If the ALERT pin of the device is active, the devices acknowledge the SMBus Alert command and respond by returning the device address on the SDA line. The eighth bit (LSB) of the device address byte indicates if the temperature exceeding T_{HIGH} or falling below T_{LOW} caused the alert condition. This bit is equal to POL if the temperature is greater than or equal to T_{HIGH}. This bit is equal to $\overline{POL}$ if the temperature is less than T_{LOW}.

If multiple devices on the bus respond to the SMBus Alert command, arbitration during the device address portion of the SMBus Alert command determines which device clears the alert status. If the TPTMP75 wins the arbitration, the ALERT pin becomes inactive at the completion of the SMBus Alert command. If the TPTMP75 loses the arbitration, the ALERT pin remains active.

General Call Reset Function

The TPTMP75 responds to the two-wire general call address (0000 000) if the eighth bit is 0. The device acknowledges the general call address and responds to commands in the second byte. If the second byte is 00000 110, the TPTMP75 resets the internal registers to the power-up reset values.

High Speed Mode

For the two-wire bus to operate at frequencies above 400 kHz, the host device must issue an HS mode host code (00001XXX) as the first byte after a START condition to switch the bus to high-speed operation. The TPTMP75 device does not acknowledge this byte, but it does switch the input filters on the SDA and SCL and the output filters on the SDA to operate in HS mode. After the HS mode host code is issued, the host transmits a two-wire device address to initiate a data transfer operation. The bus continues to operate in HS mode until a STOP condition occurs on the bus. Upon receiving the STOP condition, the TPTMP75 switches the input and output filters back to fast-mode operation.

Time Out Function

The TPTMP75 resets the serial interface if SDA is held low by the device for 25 ms (typical) between a START and STOP condition. The device releases the SDA bus and waits for a START condition. To avoid activating the time-out function, a communication speed of at least 1 kHz must be maintained.

Functional Modes

Shutdown Mode

Shutdown mode (SD) of the TPTMP75 allows the user to conserve power by shutting down all device circuitry except for the serial interface, which significantly reduces the current consumption. SD is initiated when the SD bit in the configuration register is set to 1. When SD is equal to 0, the device stays in continuous conversion mode.

One-Shot Mode

The TPTMP75 features a one-shot mode (OS) temperature measurement. When the device is in shutdown mode, writing 1 to the OS bit starts a single temperature conversion. The device returns to the shutdown state at the completion of the single conversion. This feature is useful to reduce power consumption in the TPTMP75 when continuous temperature monitoring is not required.

Continuous Conversion Mode

When the device is operating in continuous conversion mode (SD=0), every conversion cycle consists of an active conversion, followed by a standby. The device consumes a higher current during an active conversion, and lower current during standby.

Thermostat Mode

The thermostat mode bit indicates whether ALERT pin operates in comparator mode (TM = 0) or interrupt mode (TM = 1). ALERT pin mode is controlled by TM (bit 9) of the configuration register. Any write to the TM bit changes the ALERT pin to a none active condition, clears the faults count, and clears the alert interrupt history. The ALERT pin can be disabled in both comparator and interrupt modes if both limit registers are set to the rail values T_{LOW} = –128°C and T_{HIGH} = +127.9375°C

Comparator Mode (TM=0)

In comparator mode (TM = 0), the ALERT pin becomes active when the temperature equals or exceeds the value in T_{HIGH} for a consecutive number of Fault Queue bits [F1:F0]. The ALERT pin remains active until the temperature falls below the indicated T_{LOW} value for the same number of faults.

The difference between the two limits acts as a hysteresis on the comparator output, and a fault counter prevents false alerts as a result of system noise. The SMBus Alert response function is ignored in the comparator mode.

Polarity Mode (POL)

The polarity bit allows the user to adjust the polarity of the ALERT pin output. If the POL bit is set to 0 (default), the ALERT pin becomes active low. When POL bit is set to 1, the ALERT pin becomes active high and the state of the ALERT pin is inverted.

Serial Interface

The TPTMP75 supports I2C and SMBus interface-compatible interface.

Register Table

TPTMP75 Register Map

ADDRESS	TYPE	RESET	ACRONYM	REGISTER NAME
00h	R	0000h	TEMP	Temperature result register
01h	R/W	00FFh	CFGR	Configuration register
02h	R/W	4B00h	LLIM	Low limit register
03h	R/W	5000h	HLIM	High limit register

Temperature Result Register

The temperature register of the TPTMP75 is a 12-bit register. Data is in the complement format of binary two, with first 12 bits indicating temperature and all remaining bits equal to zero. The least significant byte does not have to be read if that information is not needed.

BIT	FIELD	TYPE	RESET	DESCRIPTION
15:4	T[11:0]	R	000h	12-bit, read-only register that stores the most recent temperature conversion results.
3:0	—	R	0h	Not used

Configuration Register

The configuration register is a 16-bit register used to control the operational modes. The register supports single-byte read and write and it has software compatibility with other xx75 standard temperature sensors like TMP75 and LM75. When a single byte write is performed, the data byte on the I²C bus updates the register bits 15-8. Similarly when a single byte read is performed, the data bits 15-8 is transferred over the I²C bus.

BIT	FIELD	TYPE	RESET	DESCRIPTION
15	OS	R/W	0	One-shot conversion mode. Writing 1, starts a single temperature conversion. Read returns 0.
14:13	R[1:0]	R/W	0	Conversion rate setting when device is in continuous conversion mode 00: 27 ms conversion rate 01: 55 ms conversion rate 10: 110 ms conversion rate 11: 220 ms conversion rate (35 ms TMP1075N)
12:11	F[1:0]	R/W	0	Consecutive fault measurements to trigger the alert function 00: 1 fault 01: 2 faults 10: 3 faults (4 faults TMP1075N) 11: 4 faults (6 faults TMP1075N)
10	POL	R/W	0	Polarity of the output pin 0: Active low ALERT pin 1: Active high ALERT pin
9	TM	R/W	0	Selects the function of the ALERT pin 0: ALERT pin functions in comparator mode 1: ALERT pin functions in interrupt mode

BIT	FIELD	TYPE	RESET	DESCRIPTION
8	SD	R/W	0	Sets the device in shutdown mode to conserve power 0: Device is in continuous conversion 1: Device is in shutdown mode
7:0	—	R/W	FFh	Reserved

Low Limit Register

The register is a 12-bit register and data is represented in complement format of the two.

BIT	FIELD	TYPE	RESET	DESCRIPTION
15:4	L[11:0]	R/W	4B0h	12-bit, read-write register that stores the low limit for comparison with temperature results.
3:0	—	R/W	0h	Not used

High Limit Register

The register is a 12-bit register and data is represented in complement format of the two.

BIT	FIELD	TYPE	RESET	DESCRIPTION
15:4	H[11:0]	R/W	500h	12-bit, read-write register that stores the high limit for comparison with temperature results.
3:0	—	R/W	0h	Not used

Application and Implementation

Application Information

The TPTMP75 is used to measure the PCB temperature of the location it is mounted. The device requires no external components for operation except for pullup resistors on SCL, SDA, and ALERT. A 0.1-µF bypass capacitor on supply is recommended.

The sensing device of the device is the device itself. Thermal paths run through the package leads as well as the plastic package. The lower thermal resistance of metal causes the leads to provide the primary thermal path.

Typical Application

Figure 2 shows the typical application schematic.

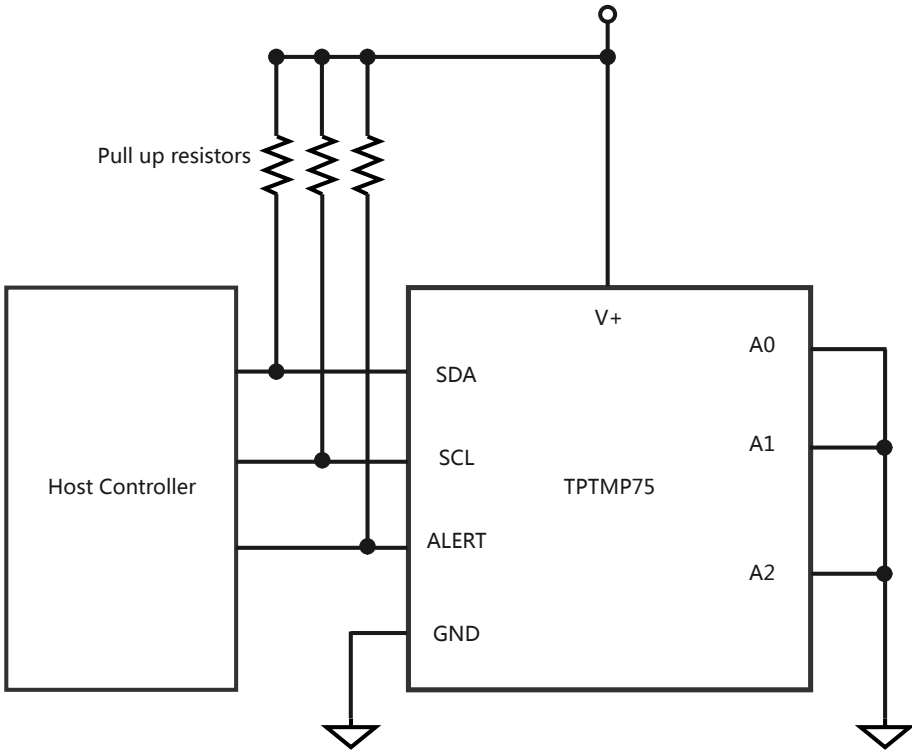


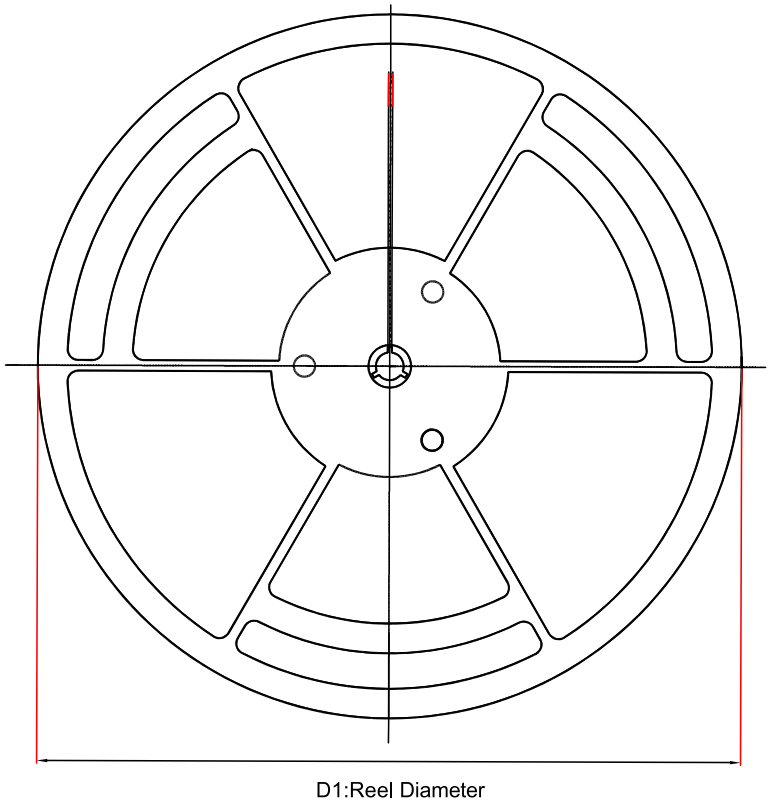
Figure 2. Typical Application Circuit

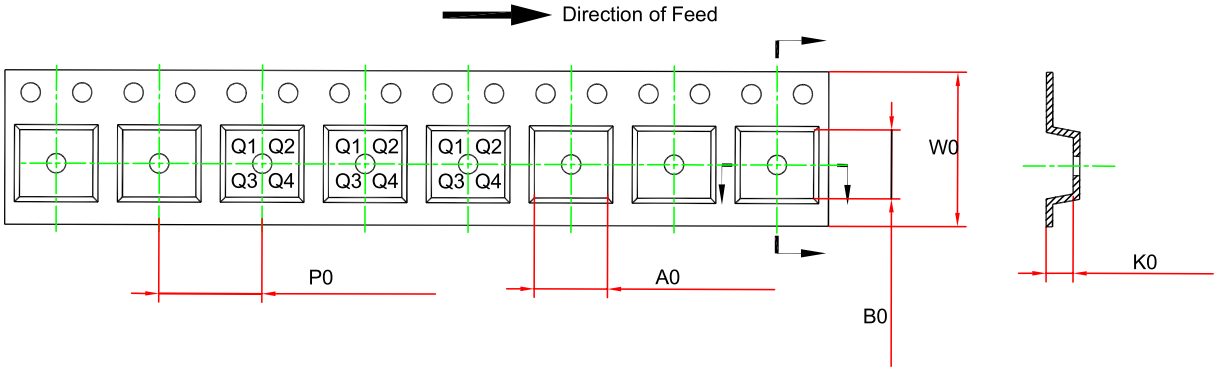
Layout

Layout Guideline

- Place the power-supply bypass capacitor as close as possible to the supply and ground pins.
- The recommended value of this bypass capacitor is 0.01 µF.
- Additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies.
- Pull up the open-drain output pins SDA , SCL, and ALERT through 5- kΩ pullup resistors.

Tape and Reel Information



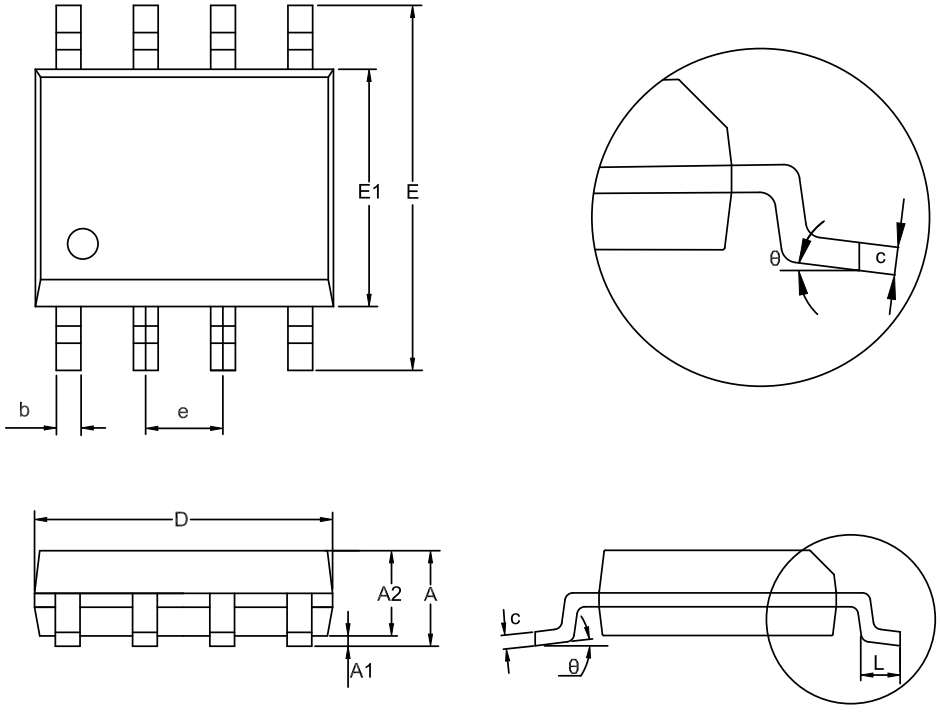


Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPTMP75-SO1R	SOP8	330	17.6	6.5	5.4	2	8	12	Q1
TPTMP75-VS1R	MSOP8	330	17.6	5.2	3.3	1.3	8	12	Q1

Package Outline Dimensions

SOP8

Package Outline Dimensions SO1(SOP-8-A)



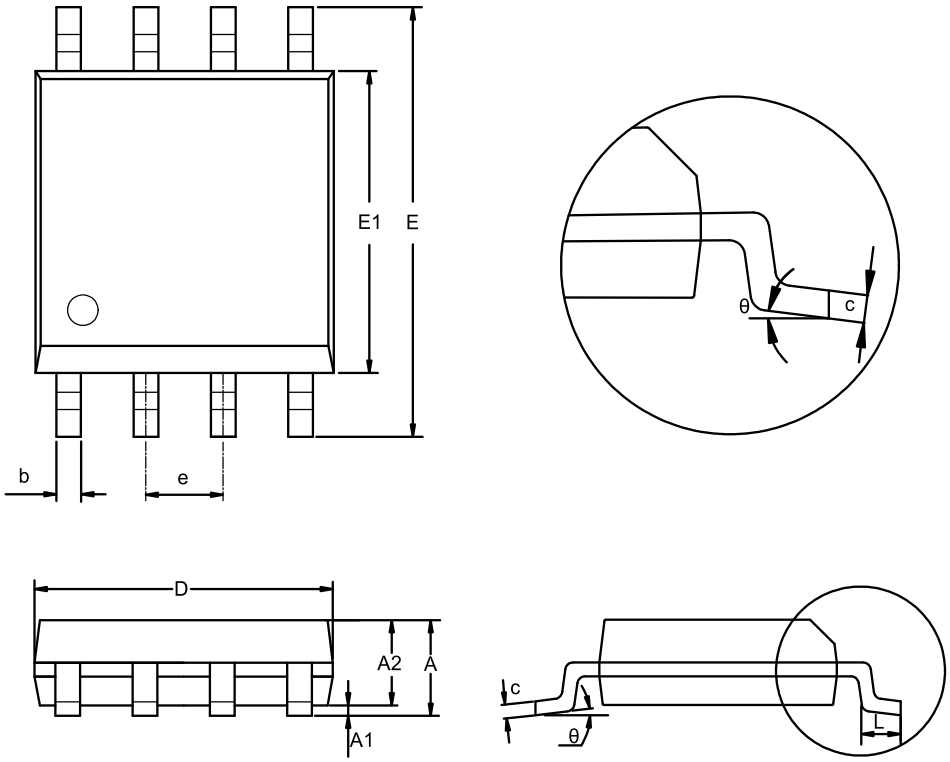
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.550	0.049	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050 BSC	
L	0.400	1.000	0.016	0.039
θ	0	8°	0	8°

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

MSOP8

Package Outline Dimensions VS1(MSOP-8-A)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.800	1.100	0.031	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	4.700	5.100	0.185	0.201
E1	2.900	3.100	0.114	0.122
e	0.650 BSC		0.026 BSC	
L	0.400	0.800	0.016	0.031
θ	0	8°	0	8°

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

Order Information

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TPTMP75-SO1R	−40 to 125°C	SOP8	TMP75	1	Tape and Reel, 4000	Green
TPTMP75-VS1R (1)	−40 to 125°C	MSOP8	TMP75	2	Tape and Reel, 3000	Green

(1) Need 2 months to sample.

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