

SENSYLINK Microelectronics

(CT75)

Digital Temperature Sensor

***CT75 is a Digital Temperature Sensor with $\pm 0.5^{\circ}\text{C}$ Accuracy
Compatible with SMBus, I²C and 2-wire Interface.
It is ideally used in HVAC, Thermal management and Portable
Devices etc.***

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Description

CT75 is a digital temperature sensor with ±0.5°C accuracy. Temperature data can be read out directly via digital interface (compatible with SMBus, I²C or 2-wire) by MCU, Bluetooth Chip or SoC chip.

CT75 supports I²C communication with speed up to 400 kHz. Each chip is specially calibrated for ±0.5°C(Max.) accuracy over 0°C to 50°C range in factory before shipment to customers. There is no need for re-calibration anymore for ±0.5°C accuracy.

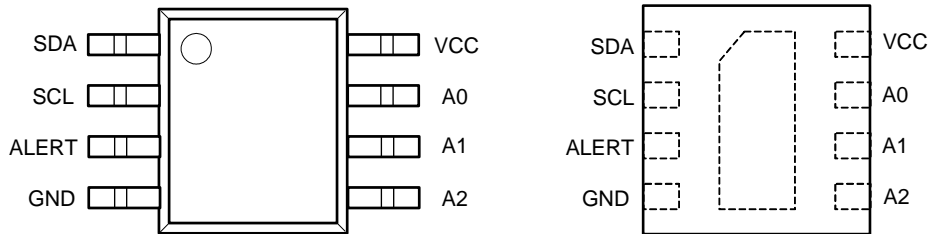
It includes a high precision band-gap circuit, a 12-bit analog to digital converter that can offer 0.0625°C resolution, a calibration unit with non-volatile memory, and a digital interface block.

It has ALERT logic output pin with open drain structure, which is selectable for active low or high by programming. ALERT response is compatible with SMBus ALERT Response Address (ARA).

CT75 can also be used as standalone thermostat.

Available Package: SOP-8/MSOP-8 and DFN3x3-8.

PIN Configurations (Top View)



SOP-8/MSOP-8(Package Code M/MM) DFN3x3-8(package Code DN)

Features

- Operation Voltage: 1.75V to 5.5V
- Average Quiescent Current: 3.0uA (Typ.) (1Con/s)
- Shutdown Current: 1.0uA (Typ.)
- Temperature Accuracy without calibration:
 - Maximum: ±0.5°C from 0°C to 50°C
 - Maximum: ±1°C from -20°C to 85°C
 - Maximum: ±1.5°C from -40°C to 125°C
- 12 bit ADC for 0.0625°C resolution
- Compatible industry LM75 with performance improved
- Compatible with SMBus, 2-wire and I²C interface
- Programmable Over/Under Temperature
- Programmable Active Low or High for ALERT pin
- Support SMBus ALERT Response Address(ARA)
- Generate 32 different slave address by setup A0, A1, A2 pin
- Temperature Range: -40°C to 125°C

Applications

- Smart HVAC System
- Thermal Management

Typical Application

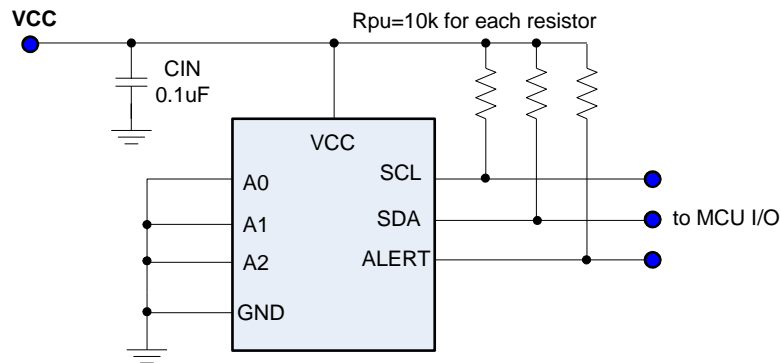


Figure 1. Typical Application of CT75

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Pin Description

PIN No.	PIN Name	Description
1	SDA	Digital interface data input or output pin, need a pull-up resistor to VCC.
2	SCL	Digital interface clock input pin, need a pull-up resistor to VCC.
3	ALERT	To Indicate ALERT of over or under Temperature programmed by setting T _{HIGH} /T _{LOW} register, it is open drain output with programmable active low or high. Need a pull-up resistor to VCC in application.
4	GND	Ground pin.
5	A2	Address selection pins, the chip can be defined total 32 different slave address by connecting these pins to GND, VCC, SCL or SDA pin respectively. Do not leave this pins open. See 1.5.1 Slave Address for detail.
6	A1	
7	A0	
8	VCC	Power supply input pin, using 0.1uF low ESR ceramic capacitor to ground

Function Block

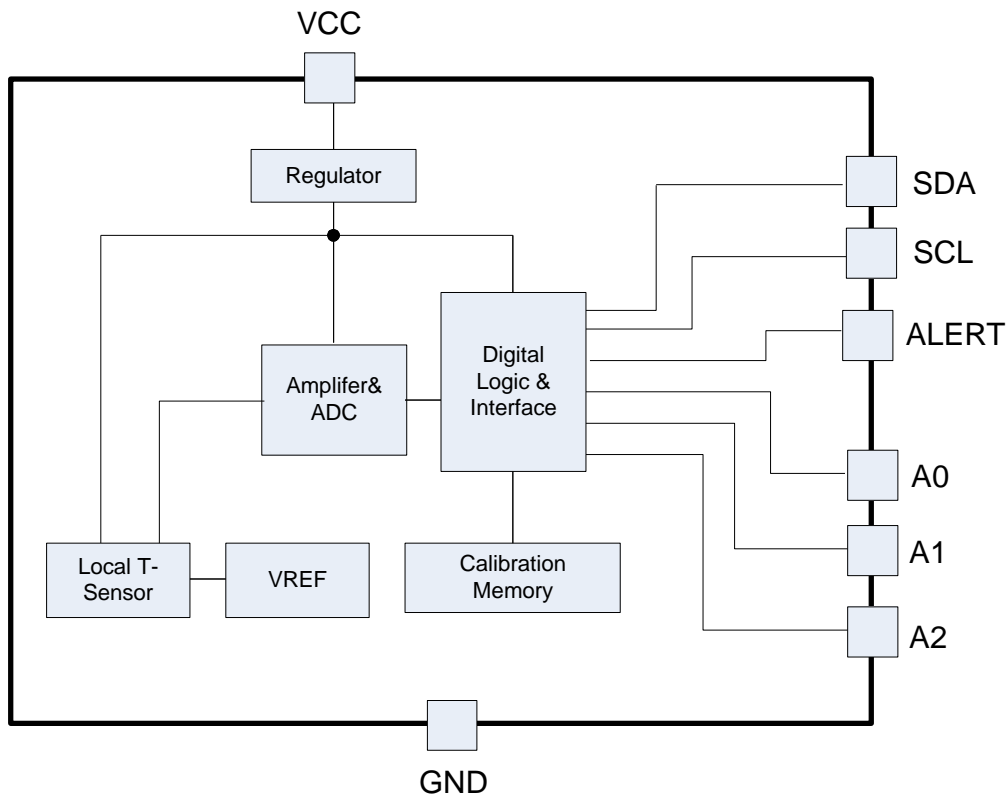
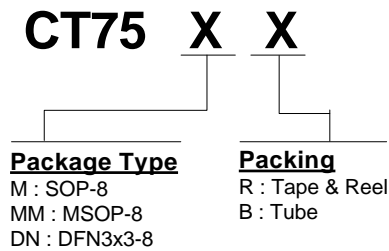


Figure 2. CT75 function block

±0.5°C Digital Temperature Sensor with Digital Interface

Ordering Information



Order PN	Accuracy	Green ¹	Package	Marking ID ^{Note 1}	Packing	MPQ	Operation Temperature
CT75MR	±0.5°C	Halogen free	SOP-8	75 YWWAXX	Tape & Reel	4,000	-40°C~+125°C
CT75MB	±0.5°C	Halogen free	SOP-8	75 YWWAXX	Tube	10,000	-40°C~+125°C
CT75MMR	±0.5°C	Halogen free	MSOP-8	75 YWWAXX	Tape & Reel	3,000	-40°C~+125°C
CT75MMB	±0.5°C	Halogen free	MSOP-8	75 YWWAXX	Tube	32,000	-40°C~+125°C
CT75DNR	±0.5°C	Halogen free	DFN3x3-8	75 YWWAXX	Tape & Reel	3,000	-40°C~+125°C

Notes 1

1. Based on ROHS Y2012 spec, Halogen free covers lead free. So most package types Sensylink offers only states halogen free, instead of lead free.

2. Marking ID includes 2 rows of characters. In general, the 1st row of characters are part number, and the 2nd row of characters are date code plus production information.

- 1) Generally, date code is represented by 3 numbers. The number stands for year and work week information. e.g. 501 stands for the first work week of year 2015; 621 stands for the 21st work week of year 2016.
- 2) Right after the date code information, the next 2-3 numbers or letters are specified to stand for supplier or production location information.

±0.5°C Digital Temperature Sensor with Digital Interface

Absolute Maximum Ratings (Note 2)

Parameter	Symbol	Value	Unit
Supply Voltage	V_{CC} to GND	-0.3 to 5.5	V
SDA, SCL, A0, A1, A2 Voltage	$V_{SDA}/V_{SCL}/V_{A0}/V_{A1}/V_{A2}$ to GND	-0.3 to 5.5	V
ALERT Voltage	V_{ALERT} to GND	-0.3 to 5.5	V
Storage temperature Range	T_{STG}	-65 to 150	°C
Lead Temperature (Soldering, 10 Seconds)	T_{LEAD}	260	°C
ESD MM	ESD_{MM}	400	V
ESD HBM	ESD_{HBM}	4000	V
ESD CDM	ESD_{CDM}	1000	V

Note 2

- Stresses greater than those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at the "Absolute Maximum Ratings" conditions or any other conditions beyond those indicated under "Recommended Operating Conditions" is not recommended. Exposure to "Absolute Maximum Ratings" for extended periods may affect device reliability.

Recommended Operating Conditions

Parameter	Symbol	Value	Unit
Supply Voltage	V_{CC}	1.75 ~ 5.5	V
Ambient Operation Temperature Range	T_A	-40 ~ +125	°C

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Electrical Characteristics (Note 3)

Test Conditions: $C_{IN} = 0.1\mu F$, $V_{CC} = 3.3V$, $T_A = -40$ to $125^\circ C$ unless otherwise specified. All limits are 100% tested at $T_A = 25^\circ C$.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Supply Voltage	V_{CC}		1.75		5.5	V
Temperature Accuracy	T_{AC}	$T_A = 0$ to $50^\circ C$	-0.5		0.5	$^\circ C$
		$T_A = -20$ to $85^\circ C$	-1		1	$^\circ C$
		$T_A = -40$ to $125^\circ C$	-1.5		1.5	$^\circ C$
Temperature Resolution			0.0625			$^\circ C$
Average Operating Current	I_{AOC}	$V_{IN} = 3.3V$, 1.0 con/s		3.0	4.5	μA
Shutdown Current	$I_{SHUTDOWN}$	STB bit = 1, force SDA/SCL to VCC or GND		1.0	3.0	μA
Open Drain Output Voltage	V_{OL}	ALERT pin, sink 5mA	0		0.5	V
Open Drain Leakage	I_{ODL}	ALERT pin	-1.0		1.0	μA
Conversion time	t_{CON}	From active to finish completely		30		ms
Digital Interface						
Logic Input Capacitance	C_{IL}	SDA, SCL pin		3.0		pF
Logic Input High Voltage	V_{IH}	SDA, SCL pin	$0.7 \cdot V_{CC}$		$V_{CC} + 0.3$	V
Logic Input Low Voltage	V_{IL}	SDA, SCL pin	-0.3		$0.3 \cdot V_{CC}$	V
Logic Input Current	I_{INL}	SDA, SCL pin	-1.0		1.0	μA
Logic Output Sink Current	I_{OLS}	SDA, ALERT pin, forced 0.2V		5.0		mA
SCL frequency	f_{CLK}	Fast Mode	1		400	kHz
		High Speed Mode	0.001		3	MHz
Timeout of detecting clock low period time	t_{TOUT}	SMBus Communication		30		ms
Clock low period time	t_{LOW}	Fast Mode	1300			ns
Clock high period time	t_{HIGH}	Fast Mode	600			ns
Bus free time	t_{BUF}	Between Stop and Start condition	1200			ns
Hold time after Start condition	$t_{HD:STA}$		600			ns
Repeated Start condition setup time	$t_{SU:STA}$		600			ns
Stop condition setup time	$t_{SU:STO}$		600			ns
Data Hold time	$t_{HD:DAT}$		100			ns
Data Setup time	$t_{SU:DAT}$		100			ns
Clock/Data fall time	t_F				300	ns
Clock/Data rise time	t_{SR}				1000	ns

Note 3:

- All devices are 100% production tested at $T_A = +25^\circ C$; All specifications over the automotive temperature range is guaranteed by design, not production tested.

±0.5°C Digital Temperature Sensor with Digital Interface

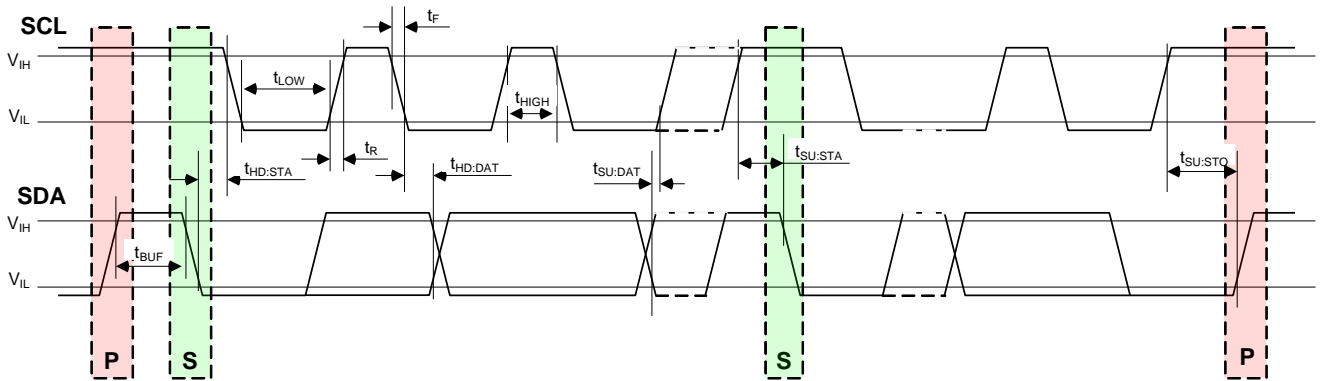


Figure 3. SMBus/I²C Timing Diagram

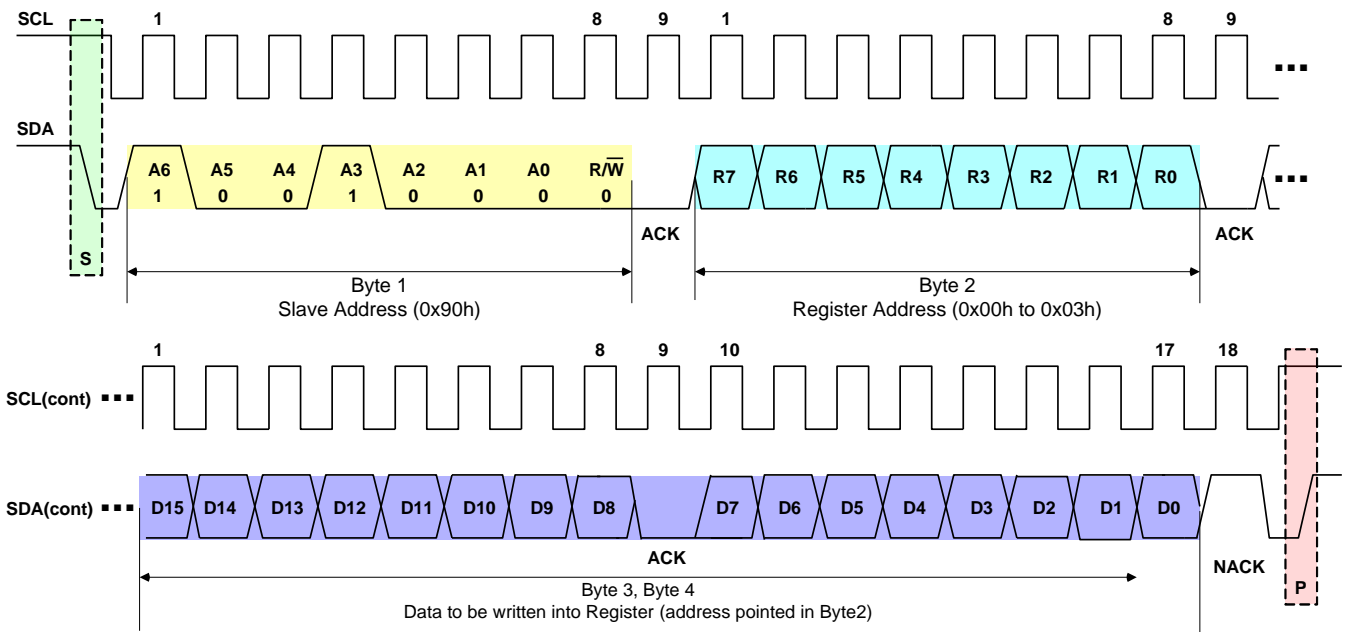


Figure 4. SMBus/I²C Write Word (2-Bytes) Timing Diagram

±0.5°C Digital Temperature Sensor with Digital Interface

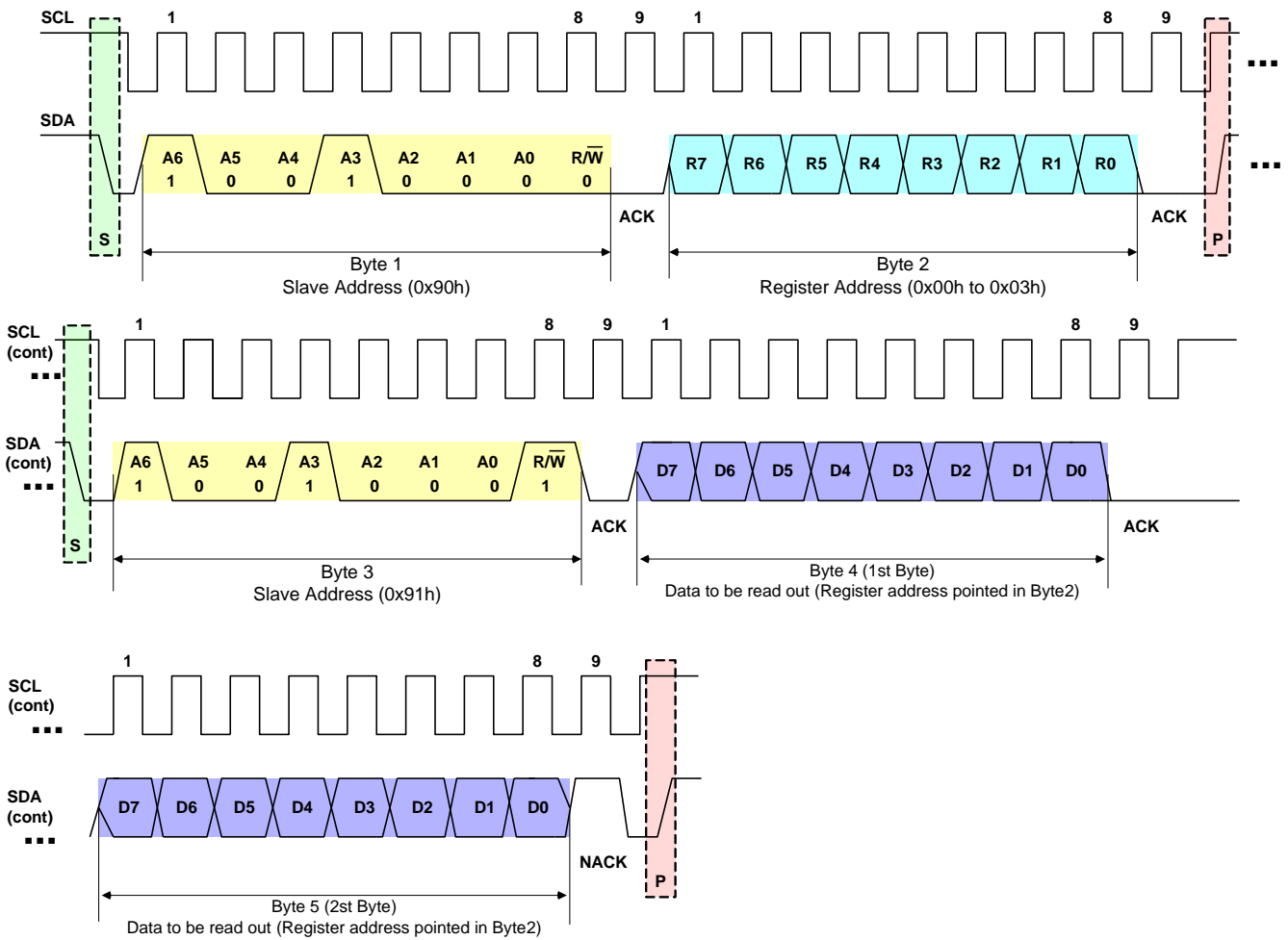


Figure 5. SMBus/I²C Read Word (2-Bytes) Timing Diagram

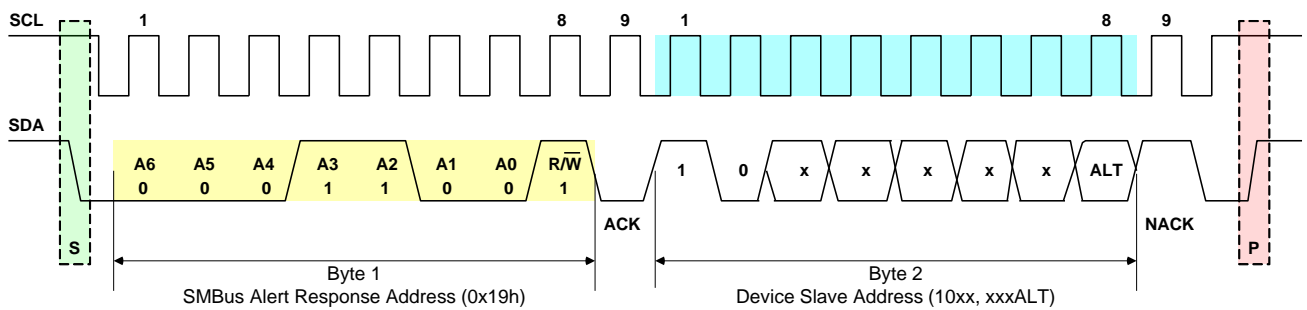


Figure 6. SMBus ALERT Response Diagram

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Characteristics (VCC=3.0V/5.0V)

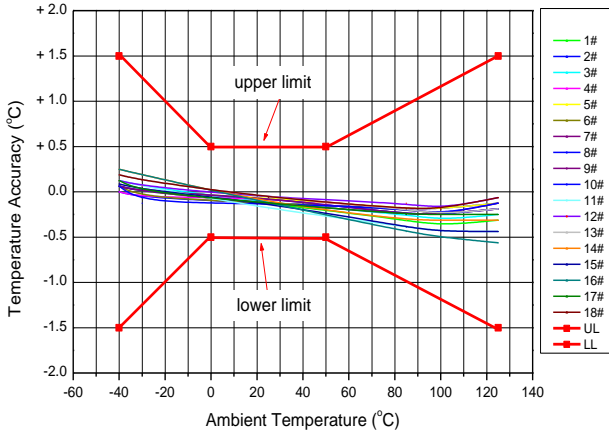


Figure 7. Temperature Accuracy vs. Temperature

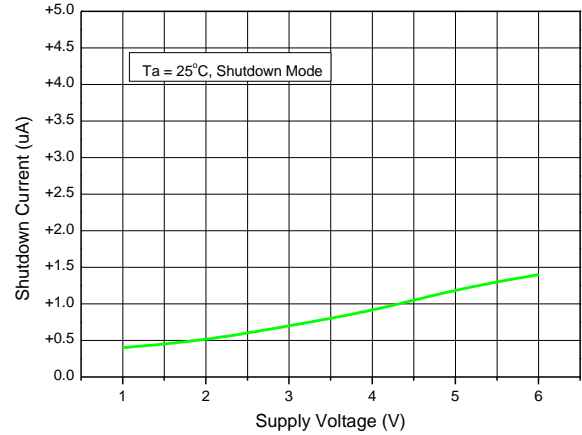


Figure 9. Shutdown Current vs. Supply Voltage

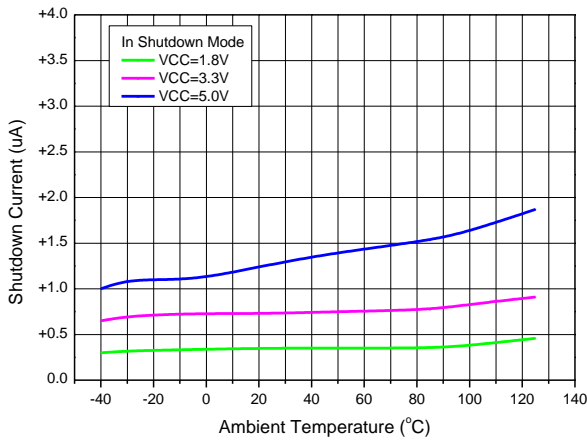


Figure 8. Shutdown Current vs. Temperature

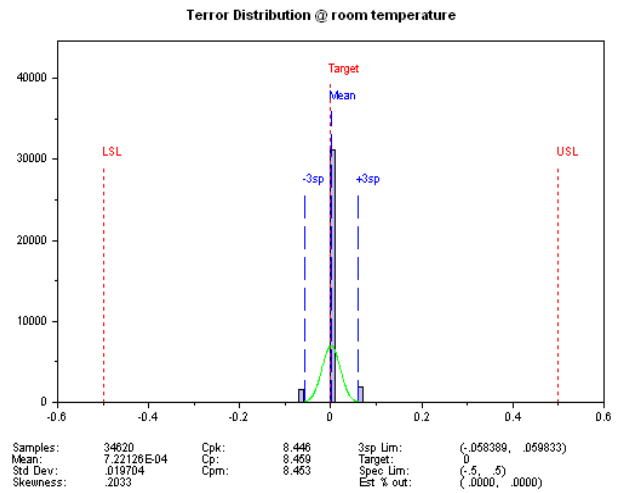


Figure 10. Temperature Error Distribution

±0.5°C Digital Temperature Sensor with Digital Interface

1 Function Descriptions

The chip can sense temperature and convert it into digital data by a 12-bit ADC. Also the chip supports programmable high-/low-limit temperature settings. If the measured temperature meets or exceeds the high-limit temperature, ALERT pin will be asserted (be set low or high, depending on POL bit of configuration register). Once the measured temperature goes below the low-limit temperature (programmable by user), ALERT pin will be released (comparator mode).

1.1 Digital Output of Temperature Data

The temperature measurement data is stored in read only temperature register. The temperature register is in 12-bit binary format (set EM bit as '0') or 13-bit binary format (set EM bit as '1') with 2-Bytes. This 2-Bytes temperature data must be read at the same time in each reading cycle, 1st-Byte is MSB followed by 2nd-Byte, the LSB. The relationship between temperature data in Celsius degree and binary data is shown as below tables.

Table 1. 12-bit Temperature Data (EM bit = 0)

Temperature (°C)	12-bit Digital Output (HEX)	12-bit Digital Output (BIN)
+128.000	0x7FF0	0 1 1 1, 1 1 1 1, 1 1 1 1 (0 0 0 0)
+127.9375	0x7FF0	0 1 1 1, 1 1 1 1, 1 1 1 1 (0 0 0 0)
+100.000	0x6400	0 1 1 0, 0 1 0 0, 0 0 0 0 (0 0 0 0)
+25.000	0x1900	0 0 0 1, 1 0 0 1, 0 0 0 0 (0 0 0 0)
+0.250	0x0040	0 0 0 0, 0 0 0 0, 0 1 0 0 (0 0 0 0)
0.000	0x0000	0 0 0 0, 0 0 0 0, 0 0 0 0 (0 0 0 0)
-0.0625	0xFFFF	1 1 1 1, 1 1 1 1, 1 1 1 1 (0 0 0 0)
-0.250	0xFFC0	1 1 1 1, 1 1 1 1, 1 1 0 0 (0 0 0 0)
-25.000	0xE700	1 1 1 0, 0 1 1 1, 0 0 0 0 (0 0 0 0)

Table 2. 13-bit Temperature Data (EM bit = 1)

Temperature (°C)	13-bit Digital Output (HEX)	8-bit Digital Output (BIN) (MSB) 1 st Byte	5-bit Digital Output (BIN) (LSB) 2 nd Byte
+150.000	0x4B01	0 1 0 0, 1 0 1 1	0 0 0 0, 0 (0 0 1)
+128.000	0x4001	0 1 0 0, 0 0 0 0	0 0 0 0, 0 (0 0 1)
+127.9375	0x3FF9	0 0 1 1, 1 1 1 1	1 1 1 1, 1 (0 0 1)
+100.000	0x3201	0 0 1 1, 0 0 1 0	0 0 0 0, 0 (0 0 1)
+25.000	0x0C81	0 0 0 0, 1 1 0 0	1 0 0 0, 0 (0 0 1)
+0.250	0x0021	0 0 0 0, 0 0 0 0	0 0 1 0, 0 (0 0 1)
0.000	0x0001	0 0 0 0, 0 0 0 0	0 0 0 0, 0 (0 0 1)
-0.0625	0xFFFF9	1 1 1 1, 1 1 1 1	1 1 1 1, 1 (0 0 1)
-0.250	0xFFE1	1 1 1 1, 1 1 1 1	1 1 1 0, 0 (0 0 1)
-25.000	0xF381	1 1 1 1, 0 0 1 1	1 0 0 0, 0 (0 0 1)

1.2 Temperature Higher than 128

When temperature is higher than 128°C, it can be expressed in binary register data by setting EM bit as '1', shown as above Table 2. In extended format, the resolution of AD converter does not change, but '+128' bit is added. For example, 12-bit format for 100°C is 0x6400, in which 0x64 is from 1st Byte, and 0x00 is from 2nd Byte. 13-bit format for 100°C is 0x3201, in which 0x32 is from 1st Byte, and 0x01 is from 2nd Byte. The default for EM bit is '0' after Power-on reset.

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1.3 Register Map

The chip has 4 registers assigned address from 0x00 to 0x03, and there are 2 Bytes (1st Byte and 2nd Byte), total 16 bits for each register, shown as below table.

Table 3. Register Map

Register Address	Register Name	Attribution	Default Data	BIT								
				7	6	5	4	3	2	1	0	
0x00 ^{Note 4}	Temp_MSB (1 st Byte)	R/O	N/A	Temp_Data[11:4]								
	Temp_LSB (2 nd Byte)	R/O	N/A	Temp_Data[3:0]								
0x01	Config_MSB (1 st Byte)	R/W	0x00	OS	CR1	CR0	F1	F0	POL	ALTM	SD	
	Config_LSB (2 nd Byte)	R/W	0x00	0	0	AL	EM	0	0	0	0	
0x02 ^{Note 4}	Low_Temp_Set_MSB (1 st Byte)	R/W	0x4B	Low_Temp_Setup_Data[11:4]								
	Low_Temp_Set_LSB (2 nd Byte)	R/W	0x00	Low_Temp_Setup_Data[3:0]								
0x03 ^{Note 4}	High_Temp_Set_MSB (1 st Byte)	R/W	0x50	High_Temp_Setup_Data[11:4]								
	High_Temp_Set_LSB (2 nd Byte)	R/W	0x00	High_Temp_Setup_Data[3:0]								

Note 4, if set EM as '1', Temp data is expressed in 13-bit format, 1st Byte, 8 bits data [12:5] is used as MSB, and 2nd Byte, 5 bits data [4:0] in left justified is used as LSB.

1.4 Register Description

1.4.1 Temp_Data, Temperature Data

Register Address: 0x00

Register Attribution: Read only

Default Data: N/A

BIT (1 st Byte)	7	6	5	4	3	2	1	0
Name: Temp_MSB (1 st Byte)	Temp_Data[11:4]							
Temperature Data (°C) [12-bit]	SIGN	64	32	16	8	4	2	1
12-bit format	T11	T10	T9	T8	T7	T6	T5	T4
Temperature Data (°C) [13-bit]	(SIGN)	(128)	(64)	(32)	(16)	(8)	(4)	(2)
13-bit format	(T12)	(T11)	(T10)	(T9)	(T8)	(T7)	(T6)	(T5)

BIT (2 nd Byte)	7	6	5	4	3	2	1	0
Name: Temp_LSB (2 nd Byte)	Temp_Data[3:0]							
Temperature Data (°C) [12-bit]	0.5	0.25	0.125	0.0625	0	0	0	0
12-bit format	T3	T2	T1	T0	0	0	0	0
Temperature Data (°C) [13-bit]	(1)	(0.5)	(0.25)	(0.125)	(0.0625)	0	0	(1)
13-bit format	(T4)	(T3)	(T2)	(T1)	(T0)	(0)	(0)	(1)

1.4.2 Config, Configuration Setup register

Register Address: 0x01

Register Attribution: Read/Write

Default Data: 0x00 for 1st Byte, 0x20 for 2nd Byte after POR. If user used only 1-Byte, it is ok to read/write 1-Byte command via digital interface; the only 1st Byte (MSB) will be accessed.

BIT	7	6	5	4	3	2	1	0
1 st Byte	OS	CR1	CR0	F1	F0	POL	ALTM	SD
	0	0	0	0	0	0	0	0
2 nd Byte	Reserved		AL	EM	Reserved			
	0	0	1	0	0	0	0	0

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OS, One shot Conversion bit

When the device is in shutdown mode, setting this bit as '1' will trigger a single time temperature conversion. During the conversion, the OS bit reads as '0'. The device returns to shutdown mode once it completes the single conversion. This feature is used for reducing power consumption when continuous temperature monitoring is not necessary.

CR1, CR0, Conversion Rate Selection bits

These 2 bits allow user to setup different conversion rate for temperature. The default is 00 after POR, meaning the conversion rate is 8Hz, i.e. 8 times conversion every second.

CR1	CR0	Conversion Rate / Conversion Time
0	0	8.0Hz / 0.125s (default)
0	1	4.0Hz / 0.25s
1	0	1.0Hz / 1.0s
1	1	0.25Hz / 4.0s

F1, F0, Fault Queue bits

These 2 bits are used to setup the number of fault conditions to trigger alert. The default is 00 after POR, which means one time fault. This feature is used to prevent a false alert, which is immune to certain noise in application.

F1	F0	Fault Queue Number
0	0	1 (default)
0	1	2
1	0	4
1	1	6

POL, Alert Output Polarity bit

This bit allows user to setup the polarity of ALERT pin for output. The default is 0 after POR, meaning ALERT pin is active low. When POL bit is set as '1', the ALERT pin becomes active high and the state of ALERT pin is inverted.

ALTM, Alert Operation Mode bit

This bit allows user to select ALERT pin operation mode: Comparator Mode or Interrupt Mode. The default is 0 after POR to select Comparator Mode. For detail information, see ALERT output section.

SD, Shutdown bit

This bit allows user to shut down the chip and to make the chip enter into standby mode once writing '1'. The default value is '0', which sets the chip to be in Normal working mode. During shutdown mode, the temperature data is kept as those of last time, no anymore update, and all function blocks are turned-off except interface. Set this bit as '0' can allow the chip be out of shutdown mode. In shutdown mode, the operation current is about 1.0uA in typical.

±0.5°C Digital Temperature Sensor with Digital Interface

EM, Extended Mode bit

This bit allows user to select 12-bit (EM = 0) or 13-bit (EM = 1) temperature data. When EM bit is set as '1', the temperature resolution is still 0.0625°C resolution. However, the expression range is extended from -255 to +255.

AL, Alert Status bit

The AL bit indicates the Alert status with read-only attribution. In addition, this bit is always read as the inversion of POL bit. When the POL bit equals 0, the AL bit reads as 1 until the measured temperature equals or exceeds Temperature (HIGH) for the programmed number of consecutive faults, causing the AL bit to read as 0. The AL bit continues to read as 0 until the temperature falls below Temperature (LOW) for the programmed number of consecutive faults, when it again reads as 1. Vice versa, when the POL bit is '1', the AL bit reads as 0 until the temperature equals or exceeds Temperature (HIGH). And the AL bit is set as 0 again once the temperature falls below Temperature (LOW). The status of the TM bit does not affect the status of the AL bit.

1.4.3 Low_Temp_Set, Setup Low Temperature Limitation register

Register Address: 0x02

Register Attribution: Read/Write

Default Data: 0x4B (1st Byte) 0x00 (2nd Byte) after POR.

BIT	BIT	7	6	5	4	3	2	1	0
1 st Byte	12-bit	L11	L10	L9	L8	L7	L6	L5	L4
	13-bit	(L12)	(L11)	(L10)	(L9)	(L8)	(L7)	(L6)	(L5)
	Default	0	1	0	0	1	0	1	1
2 nd Byte	12-bit	L3	L2	L1	L0	0	0	0	0
	13-bit	(L4)	(L3)	(L2)	(L1)	(L0)	(0)	(0)	(0)
	Default	0	0	0	0	0	0	0	0

The high-/low- limit temperature data is determined by High_Temp_Set register [0x03] and Low_Temp_Set register [0x02] with same format as Temp_Data register [0x00], which could be in 12-bit or 13-bit binary format. The chip compares Temp_Data [0x00] register and High_Temp_Set register [0x03]/Low_Temp_Set register [0x02] in each conversion cycle, which will affect ALT pin output. The default value is 0x4B00 with 12-bit binary format, which means 75°C. For other low-limit temperature data chip, please contact our sales.

1.4.4 High_Temp_Set, Setup High Temperature Limitation register

Register Address: 0x03

Register Attribution: Read/Write

Default Data: 0x50 (1st Byte) 0x00 (2nd Byte) after POR.

BIT	BIT	7	6	5	4	3	2	1	0
1 st Byte	12-bit	H11	H10	H9	H8	H7	H6	H5	H4
	13-bit	(H12)	(H11)	(H10)	(H9)	(H8)	(H7)	(H6)	(H5)
	Default	0	1	0	1	0	0	0	0
2 nd Byte	12-bit	H3	H2	H1	H0	0	0	0	0
	13-bit	(H4)	(H3)	(H2)	(H1)	(H0)	(0)	(0)	(0)
	Default	0	0	0	0	0	0	0	0

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The high-/low- limit temperature data is determined by High_Temp_Set register [0x03] and Low_Temp_Set register [0x02] with same format as Temp_Data register [0x00], which could be in 12-bit or 13-bit binary format. The chip compares Temp_Data [0x00] register and High_Temp_Set register [0x03]/Low_Temp_Set register [0x02] in each conversion cycle, which will affect ALT pin output. The default value is 0x5000 with 12-bit binary format, which means 80°C. For other low-limit temperature data chip, please contact our sales.

1.5 SMBus Digital Interface

1.5.1 Slave Address

The SMBus or I²C slave address of this device can be configured 32 different addresses by setting [A2], [A1] and [A0] pin. See below table for detail, which permit connecting total 32 devices in one SMBus.

No.	A2	A1	A0	R/W	Slave Address in Hex [R/W]
1	GND	GND	GND	1/0	0x91/0x90
2	GND	GND	VCC	1/0	0x93/0x92
3	GND	VCC	GND	1/0	0x95/0x94
4	GND	VCC	VCC	1/0	0x97/0x96
5	VCC	GND	GND	1/0	0x99/0x98
6	VCC	GND	VCC	1/0	0x9B/0x9A
7	VCC	VCC	GND	1/0	0x9D/0x9C
8	VCC	VCC	VCC	1/0	0x9F/0x9E
9	GND	GND	SDA	1/0	0x81/0x80
10	GND	GND	SCL	1/0	0x83/0x82
11	GND	VCC	SDA	1/0	0x85/0x84
12	GND	VCC	SCL	1/0	0x87/0x86
13	VCC	GND	SDA	1/0	0x89/0x88
14	VCC	GND	SCL	1/0	0x8B/0x8A
15	VCC	VCC	SDA	1/0	0x8D/0x8C
16	VCC	VCC	SCL	1/0	0x8F/0x8E
17	GND	SDA	SDA	1/0	0xA1/0xA0
18	GND	SDA	SCL	1/0	0xA3/0xA2
19	GND	SCL	SDA	1/0	0xA5/0xA4
20	GND	SCL	SCL	1/0	0xA7/0xA6
21	VCC	SDA	SDA	1/0	0xA9/0xA8
22	VCC	SDA	SCL	1/0	0xAB/0xAA
23	VCC	SCL	SDA	1/0	0xAD/0xAC
24	VCC	SCL	SCL	1/0	0xAF/0xAE
25	GND	SDA	GND	1/0	0xB1/0xB0
26	GND	SDA	VCC	1/0	0xB3/0xB2
27	GND	SCL	GND	1/0	0xB5/0xB4
28	GND	SCL	VCC	1/0	0xB7/0xB6
29	VCC	SDA	GND	1/0	0xB9/0xB8
30	VCC	SDA	VCC	1/0	0xBB/0xBA
31	VCC	SCL	GND	1/0	0xBD/0xBC
32	VCC	SCL	VCC	1/0	0xBF/0xBE

1.5.2 Timeout

The chip supports SMBus timeout. If the data (SDA PIN) or clock (SCL PIN) is held low for longer than 30ms (Typ.), the chip will reset its SMBus protocol and be ready for a new transmission.

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1.5.3 SMBus Protocol

The chip supports four standard SMBus protocols Send Byte, Read Byte, Write Byte and Receive Byte, shown as below tables.

Write Byte

S	Slave Add	R/W	ACK	Reg Add	ACK	Reg Data	ACK	P
	0x80 to 0xBE	0	0	0x00 to 0x03	0	XXh	0	

Read Byte

S	Slave Add	R/W	ACK	Reg Add	ACK	S	Slave Add	R/W	ACK	Reg Data	NACK	P
	0x80 to 0xBE	0	0	0x00 to 0x03	0		0x80 to 0xBE	1	0	XXh ¹	1	

Send Byte

S	Slave Add	R/W	ACK	Reg Add	ACK	P
	0x80 to 0xBE	0	0	XXh	0	

Receive Byte

S	Slave Add	R/W	ACK	Reg Add	NACK	P
	0x80 to 0xBE	1	0	XXh	1	

Here S means SMBus Start to communication; P, means communication STOP.

Slave Add, means the chip's slave address.

Reg Add, means pointed register address.

Reg Data, means data to be written into register or read from register.

For this chip, each register includes 2 Bytes, so generally reading or writing operation is based on 1 Word (2-Bytes). Also it is permitted to read 1 byte for read/write, then the 1st byte will be accessed in first.

1.5.4 Compatible with I²C

The chip is compatible with both SMBus and I²C. The major difference between SMBus and I²C are shown as below. For more information, refer to SMBus specification v2.0 and I²C specification v2.1.

- Besides DC specification difference, this chip supports I²C fast mode (400kHz) and standard mode (100kHz), which can cover SMBus maximum frequency 100kHz. For SMBus protocol, the minimum frequency is 10 kHz. There is no such limitation for I²C.
- For SMBus protocol, the communication will be reset if holding clock or data low with duration over 30ms (Typ.). There is no timeout for I²C.
- ARA (Alert Response Address) general call is only valid interrupt in SMBus, not valid in I²C.

1.5.5 General Call

The CT75 device responds to a 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 0000 0110, the CT75 internal registers are reset to power-up values.

1.5.6 High-Speed (Hs) Mode

If the master needs to run at frequencies above 400 kHz in I²C, the master device must issue an Hs-mode master code (0000 1xxx) as the first byte after a START condition to switch the bus to high-speed operation. After the Hs-mode master code has been issued, the master transmits a slave address to initiate a data-transfer operation. The bus continues to operate in Hs-mode until a STOP condition occurs on the bus.

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Upon receiving the STOP condition, the CT75 device will return to fast-mode operation. below is the example for reading operation in high speed mode.

S	Hs-mode code	Slave Add	R/W	ACK	Reg Add	ACK	Sr	Slave Add	R/W	ACK	Reg Data	NACK	P
	0x08 to 0x0F	0x80 to 0xBE	0	0	0x00 to 0x03	0		0x80 to 0xBE	1	0	XXh	1	

1.6 ALERT Output

ALERT pin is output with open drain, which can be set active low or active high by setting POL bit. In addition, this pin is triggered when the measured temperature equals or exceeds the high-limitation temperature setup in the registers of High_Temp_Set. There are two types of ALERT output mode: comparator mode and interrupt mode.

1.6.1 Comparator mode (ALTM = 0)

Below Figure shows the mechanism of the ALERT output in comparator mode. In this mode, the ALERT pin will become active if the monitored temperature equals or exceeds the value setup in High_Temp_Set [0x03] register for a consecutive number of faults according to setup by F1 and F0 bits. The ALERT pin keeps active until the temperature falls below the value setup in Low_Temp_Set [0x02] register.

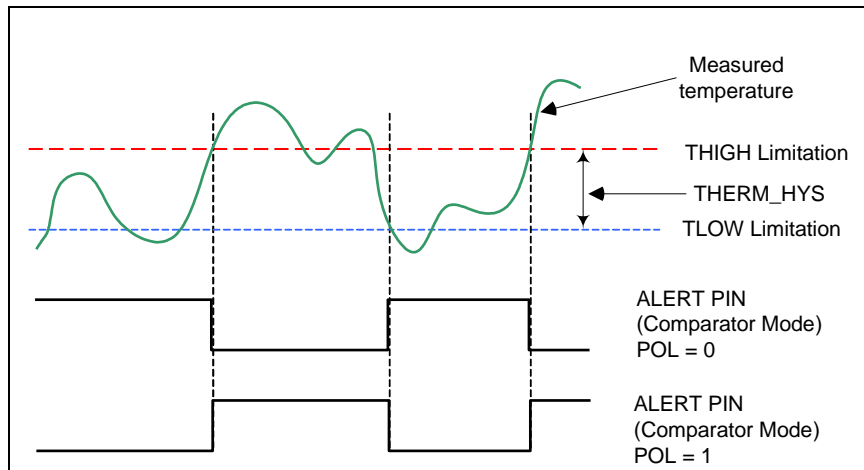


Figure 11 ALERT pin output in comparator mode

1.6.2 Interrupt mode (ALTM = 1)

Below Figure shows the mechanism of the ALERT pin output in interrupt mode. In this mode, the ALERT pin becomes active when the temperature equals or exceeds the value setup in High_Temp_Set [0x03] register for a consecutive number of faults according to setup by F1 and F0 bits. The ALERT pin keeps active until a read operation of any register happens or the chip responds to SMBus Alert Response Address (ARA) successfully. When ALERT pin is cleared, it will become active again only when the temperature falls below the value setup in Low_Temp_Set [0x02] register, and keeps active until being cleared by reading register or responding to SMBus ARA, ALERT pin is also cleared by setting the chip in shutdown mode.

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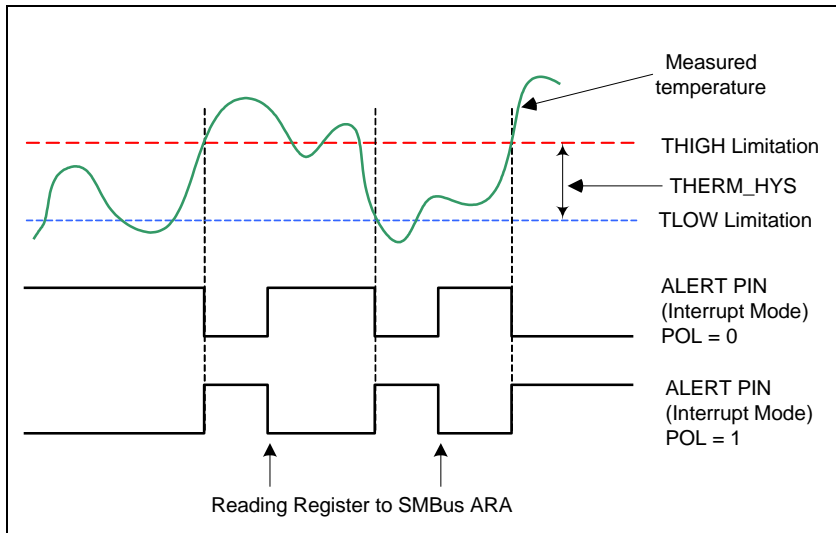


Figure 12 ALERT pin output in interrupt mode

1.6.3 SMBus Alert Response Address (ARA)

The chip supports the SMBus alert function feature. When the chip operates in interrupt mode (ALTM=1), it can be connected as SMBus alert signal, used as a processor interrupt or as SMBus ALERT. When the master detects that the ALERT pin is asserted, it will send Alert Response Address (ARA) to general address (0001, 1001b). All devices with active interrupts will respond with client address. If the alert pin is active, the device acknowledges the SMBus command by returning the slave address from SDA line. If more devices than one on the bus respond SMBus ARA, arbitration during the slave address portion of SMBus ARA determines which device clears the alert trigger. The device with the highest priority (lowest address) wins the arbitration. If the chip wins the arbitration, ALERT pin is released after completion of SMBus ARA command. If the chip loses the arbitration, it will keep ALERT pin active. See System Management Bus (SMBus) Specification for more detail. Below Figure shows the mechanism of the ALERT output SMBus Alert mode.

S	Slave Add	R/W	ACK	Reg Add	ACK	P
	0001,100	1	0	100x,xxxS	1	

Here Reg Add presented the chip real actual address setup by user. S bit indicates if the alert condition is caused by the temperature exceeding T(HIGH) or falling below T(LOW). The S bit is '1' if the temperature is greater than T(HIGH), or '0' if the temperature is less than T(LOW).

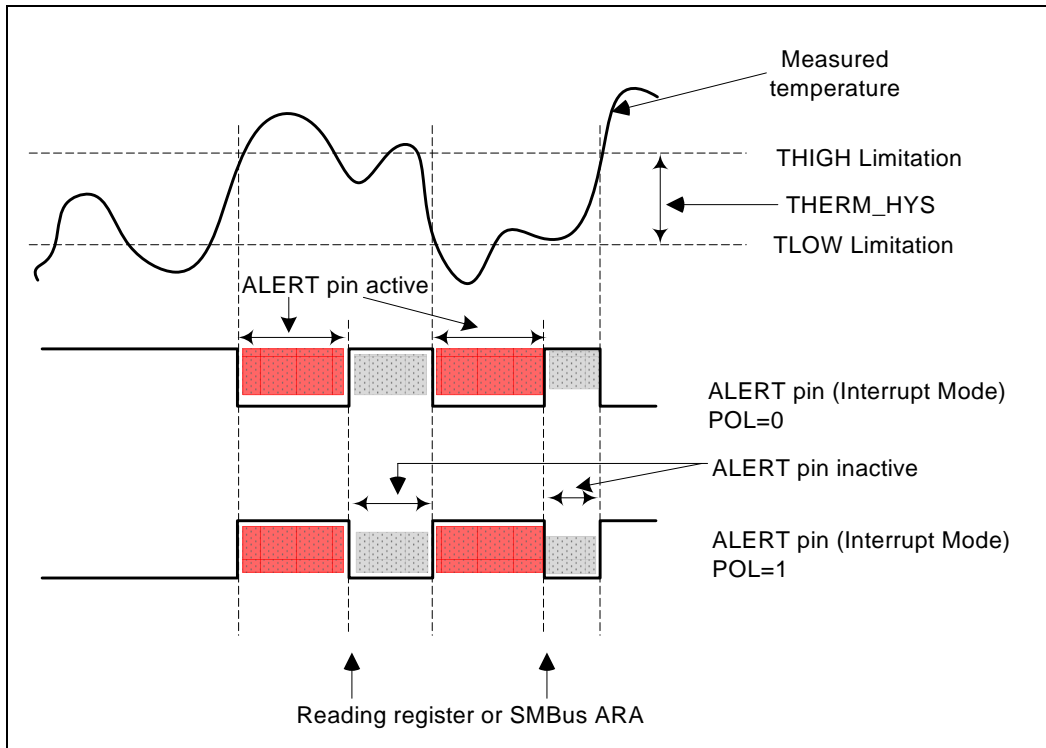
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Figure 13 ALERT pin in SMBus Alert Response (ARA)

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2 Application Information

2.1 How to Improve Temperature Accuracy

The temperature measurement of the chip is based on semiconductor physics principle --Forward voltage of diode is a function of temperature. The formula is shown as below.

$$V_F = \frac{kT}{q} \ln\left(\frac{I_F}{I_S}\right)$$

Here,

V_F -- forward voltage

I_F -- forward current

I_S -- reverse saturation current

k -- Boltzmann constant

T -- Temperature in K

q -- Electric charge constant

To cover wide temperature range, i.e. -40 °C to 125°C, a very small voltage variation is corresponding to every degree C temperature change. Sensylink has applied many ways to improve measurement accuracy in chip circuits design, such as compensation, trimming etc. In real system design, however, some factors that can increase measurement error need to be considered. Most issues that usually occur are highlighted as below.

2.1.1 Noise between VCC and GND

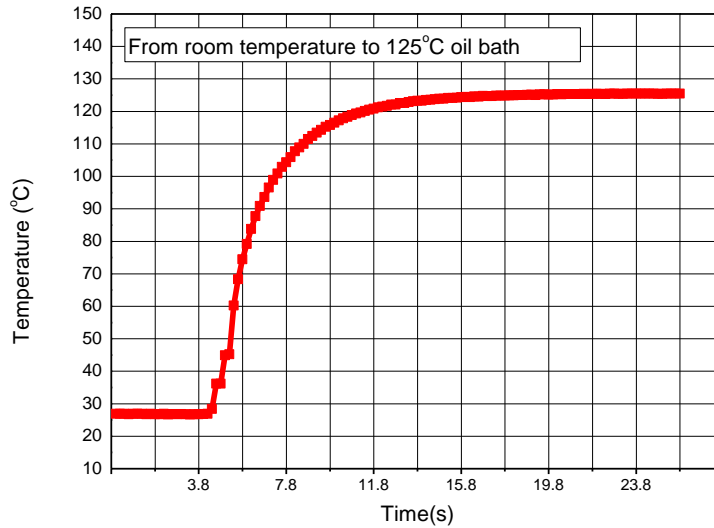
It is very necessary to place a low ESR ceramic cap (C_{IN}) between VCC and GND pin to filter digital noise, although suppression noise circuit has been built inside the chip. This filter cap should be placed as close as possible to the chip. The recommended capacitance is 0.1uF.

2.1.2 Thermal Response Time

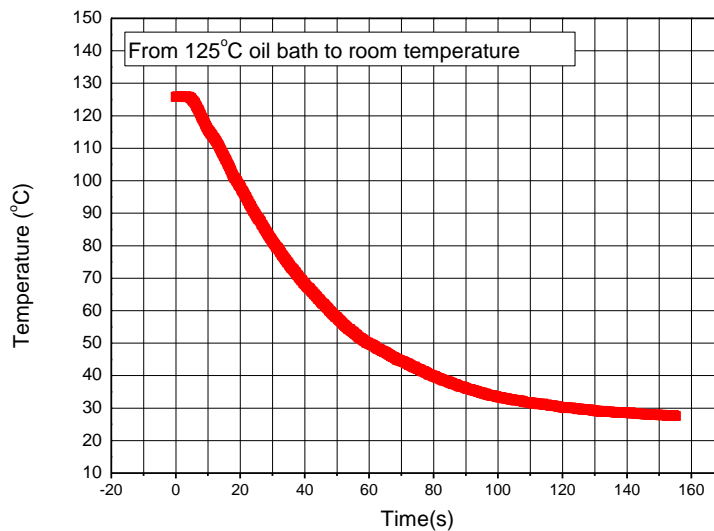
It is very necessary to wait enough time for obvious temperature changing of target due to thermal time constant, e.g. food temperature could change from -20°C to 20°C when taken out of refrigerator, which could take over ten minutes to reach thermal equilibrium eventually. Enough time is still needed for the target to reach thermal equilibrium, even forcing temperature transient into target object. For this chip, the temperature step response changing from room temperature to oil bath of 125°C is shown as below. (Based on SOP-8 package)

Room Temperature	Target Temperature	Change ratio	Delta T	Time (s)
26.8 °C	125.0 °C	63%	61.9 °C	2.3
		80%	78.5°C	3.8
		90%	88.4°C	5.6
		100%	98.2°C	20.0

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Vice versa, it will take longer time, about 150s, when the chip temperature is back to room temperature, once taking the chip out of oil bath of 125°C. See below plot.



2.2 PCB Layout

Cautions below are important to improve temperature measurement accuracy in PCB layout design.

2.2.1 Device placement

It is better to place the chip away from any thermal source (e.g. power device in board), high-speed digital bus (e.g. memory bus), coil device (e.g. inductors) and wireless antenna (e.g. Bluetooth, WiFi, and RF). It is recommended to place the chip close to the remote diode.

2.2.2 Cin, Pull-up resistor

It is better to place Cin as close as possible to VCC and GND pins of the chip. The recommended Cin value is 0.1uF with low ESR ceramic cap although using multi caps, such as

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1.0uF plus 0.1uF or 0.01uF, is ok, which can suppress digital noise with different frequency range.

User has to put a pull-up resistor with 4.7k to 10k for SDA and SCL pins respectively. It is ok to use smaller resistors such as 2k-3k in real application, if multi slave devices are used in the same bus.

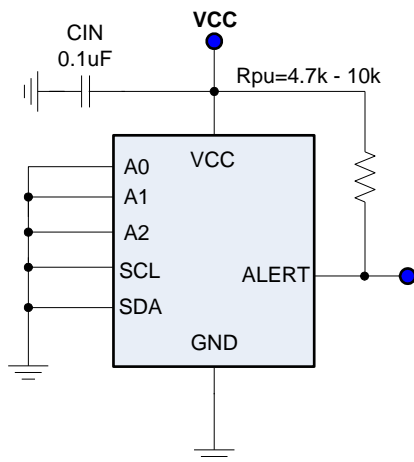
2.3 Standalone Thermostat

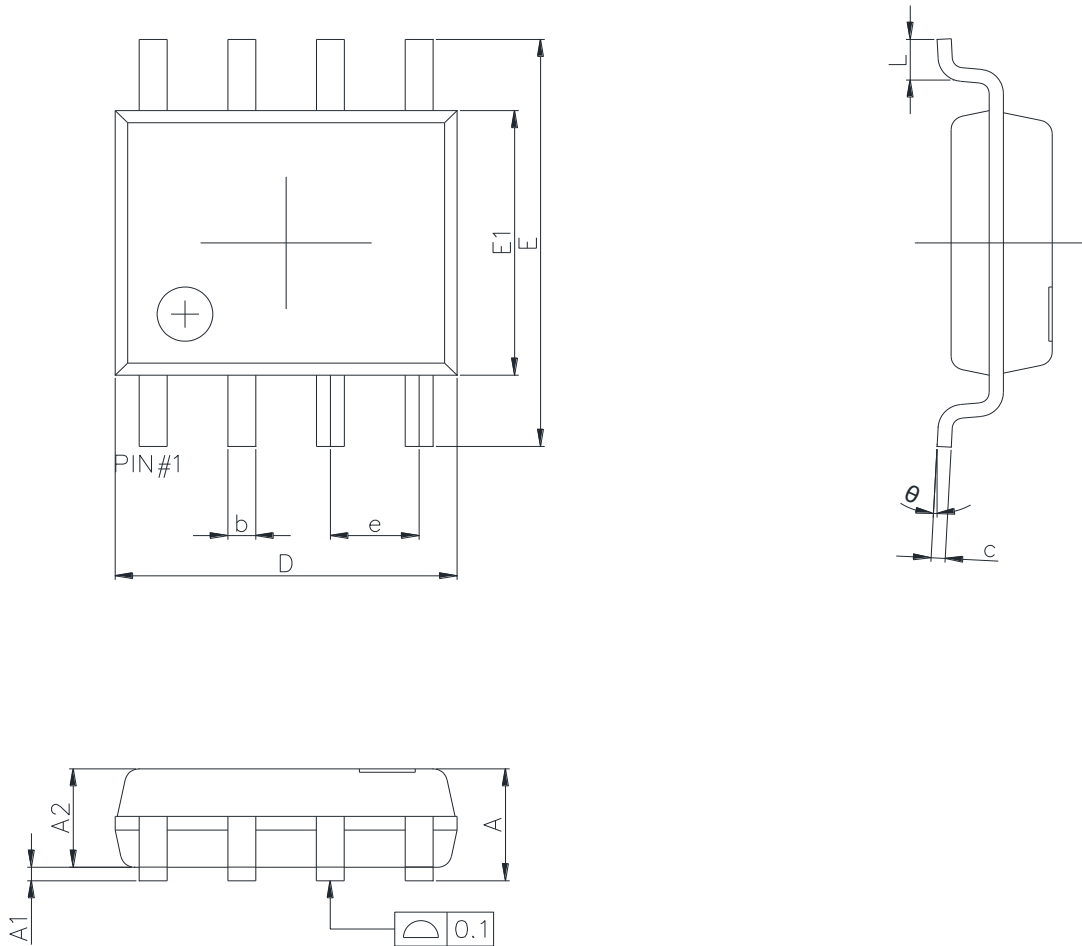
CT75 can also be used as standalone thermostat shown as below. It does not need external MCU to setup High/Low limitation temperature via SMBus/I2C communication. The trigger temperature and hysteresis temperature can be setup in factory before shipping to customer. For example,

Trigger temperate is 55°C, and Hysteresis temperature is 5°C.

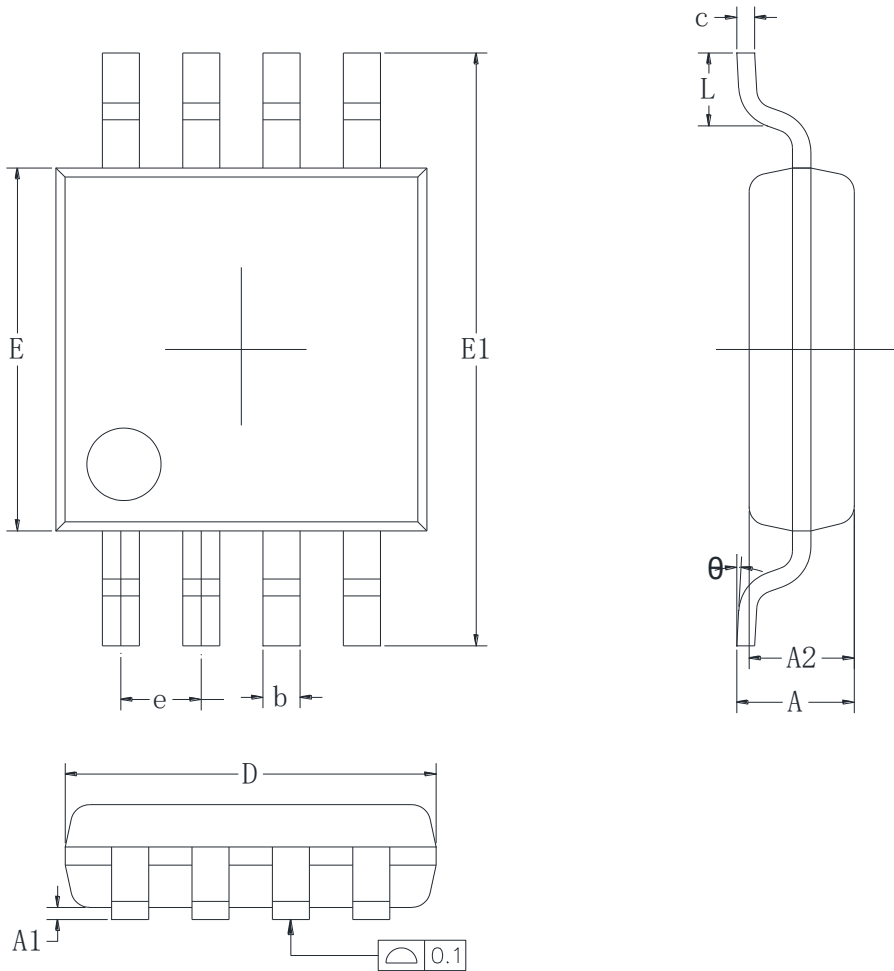
Which means when the chip temperature equals or exceeds 55°C, the ALERT pin will be set low. And once the temperature of the chip drops below 50°C (55 - 5), the ALERT pin will be released back to high (pulled by Rpu to VCC).

Please contact Sensylink sales for specific Trigger, Hysteresis temperature you want.

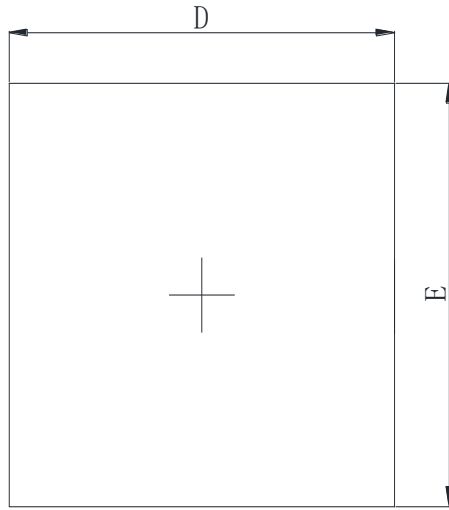
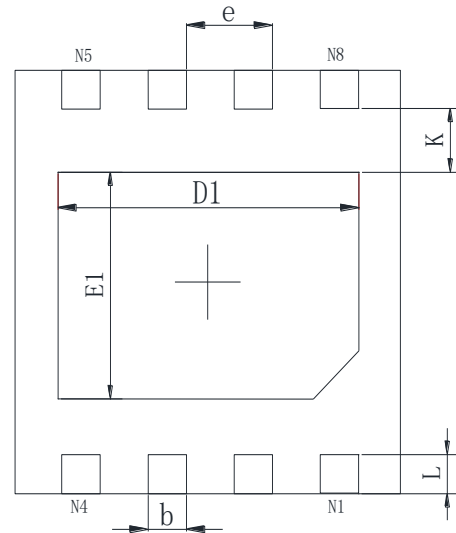
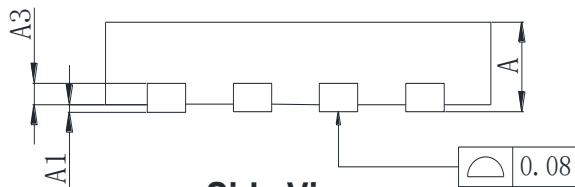


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Package Outline Dimensions (SOP-8)
SOP-8 Unit (mm)


Symbol	Dimensions in Millimeters		Dimensions in Inches	
	Min.	Max.	Min.	Max.
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.250	1.650	0.049	0.065
b	0.33	0.51	0.013	0.020
c	0.17	0.25	0.007	0.010
D	4.700	5.100	0.185	0.201
E	5.800	6.200	0.228	0.244
E1	3.700	4.100	0.146	0.161
e	1.270 (BSC)		0.050 (BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

Package Outline Dimensions (MSOP-8)
MSOP-8 Unit (mm)


Symbol	Dimensions in Millimeters		Dimensions in Inches	
	Min.	Max.	Min.	Max.
A	0.820	1.100	0.032	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	0.250	0.004	0.010
D	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
E1	4.700	5.100	0.185	0.201
e	0.650 (BSC)		0.026 (BSC)	
L	0.400	0.800	0.016	0.031
θ	0°	8°	0°	8°

Package Outline Dimensions (DFN3x3-8)
DFN3x3-8 Unit (mm)

Top View

Bottom View

Side View

Symbol	Dimensions in Millimeters		Dimensions in Inches	
	Min.	Max.	Min.	Max.
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.203REF.		0.008REF	
D	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
D1	2.200	2.600	0.087	0.102
E1	1.400	1.800	0.055	0.071
k	0.250MIN.		0.010REF	
b	0.250	0.350	0.010	0.014
e	0.650TYP.		0.026TYP	
L	0.200	0.400	0.008	0.016

±0.5°C Digital Temperature Sensor with Digital Interface**Revision History**

Version	Date	Change Content
Ver1.0	2017/05	Initial
Ver1.1	2017/10	update characteristics plots
Ver1.2	2018/01	Add DFN package
Ver1.3	2018/07	Update register description
Ver1.4	2018/11	Update Sensylink Logo
Ver1.5	2018/12	Update ordering information
Ver1.6	2019/01	Update shutdown current
Ver1.7	2019/02	Update timeout description
Ver1.8	2019/03	Update voltage range
Ver1.9	2019/06	Update Slave Address
Ver2.0	2019/09	Update Time Out
Ver2.1	2019/10	Update Hold Time
Ver2.2	2019/12	Update Current
Ver2.3	2020/04	Update Packing Outline Dimensions



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