

SENSYLINK Microelectronics

(CT7318)

Remote and Local Temperature Sensor

CT7318 is a 2-channel (Remote and Local) Digital Temperature Sensor with $\pm 1^{\circ}\text{C}$ Accuracy and SMBus Interface.

It is ideally used in Temperature Sensing and Monitoring Systems, such as Computer, Telecom Equipment, Multi-cell Battery Pack and Smart HVAC System etc.

±1°C Remote and Local Temperature Sensor with Digital Interface

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±1°C Remote and Local Temperature Sensor with Digital Interface

Description

The CT7318 is a digital temperature sensor with ±1°C accuracy. Temperature data can be read out directly via SMBus interface by MCU or SoC chip.

CT7318 has two independent channels: one remote and one local sensors. The remote sensor could be connected to an external Diode or BJT transistor (diode-connected mode).

Each chip is calibrated in factory before shipment to customers. There is no need for re-calibration anymore for ±1°C accuracy.

It includes a band-gap circuit, an Analog to Digital converter, a calibration unit with non-volatile memory and a digital interface block.

It integrates an 11-bit ADC, which can offer 0.125°C resolution. The maximum temperature readout range can be up to 160°C plus offset shifting register.

It has 2 logic output pin (**ALERT**, **THERM**) with open drain structure, which are active low as default.

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

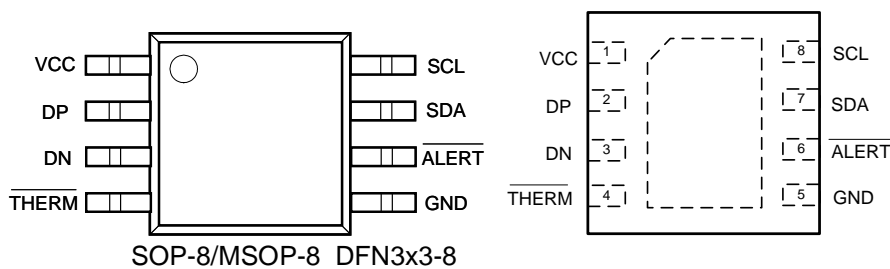
Features

- Operation Voltage: 3.0V to 5.5V
- Average Quiescent Current: 45uA at 4.0s/con, 105uA at 1.0s/con
- Standby Current: 1.0uA (Max.)
- Temperature Accuracy without calibration: ±1°C from 0°C to 100°C, ±2°C from -40°C to 125°C
- 11 bit ADC for 0.125°C resolution
- Digital interface compatible with SMBus, 2-wire and I²C
- Temperature Range up to 160°C plus offset shifting register for Remote Sensor Channel
- Programmable Over/Under Alarm Temperature and Hysteresis Temperature
- Independent Remote and Local Temperature Sensing Channel
- Support SMBus ALERT Response Address
- Temperature Range: -40°C to 125°C

Applications

- Desktop & Notebook Computer
- Telecom Equipment
- Multi-cell Battery Pack
- Smart HVAC System

PIN Configurations (Top View)



Typical Application

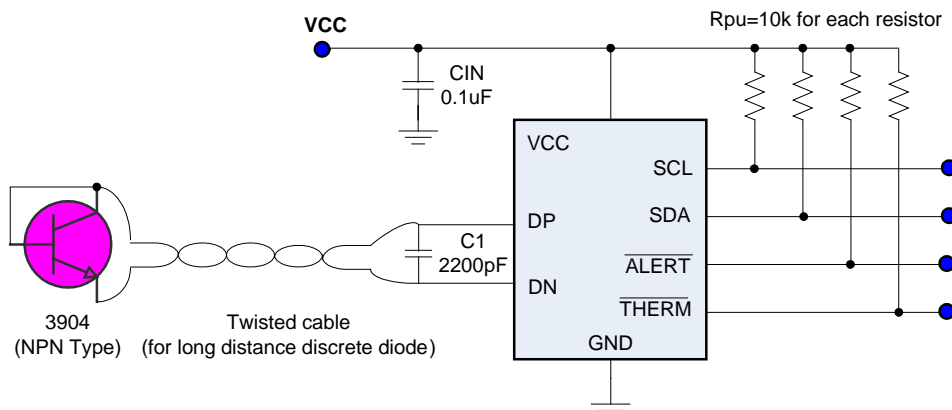


Figure 1. Typical Application of CT7318

±1°C Remote and Local Temperature Sensor with Digital Interface

Pin Description

PIN No.	PIN Name	Description
1	VCC	Power supply input pin, using 0.1uF low ESR ceramic capacitor to ground
2	DP	Remote sensor positive input pin, it could be positive node of Diodes, or BJT transistor (diode-connected mode). it is recommended to use 2200pF bypass capacitor to remove noise between DP and DN pin.
3	DN	Remote sensor positive input pin, it could be negative node of Diodes, or BJT transistor (diode-connected mode). it is recommended to use 2200pF bypass capacitor to remove noise between DP and DN pin.
4	$\overline{\text{THERM}}$	Open drain output with active low. need a pull-up resistor to VCC.
5	GND	Ground pin.
6	$\overline{\text{ALERT}}$	Open drain output with active low. need a pull-up resistor to VCC.
7	SDA	Digital interface data input or output pin, need a pull-up resistor to VCC.
8	SCL	Digital interface clock input pin, need a pull-up resistor to VCC.

Function Block

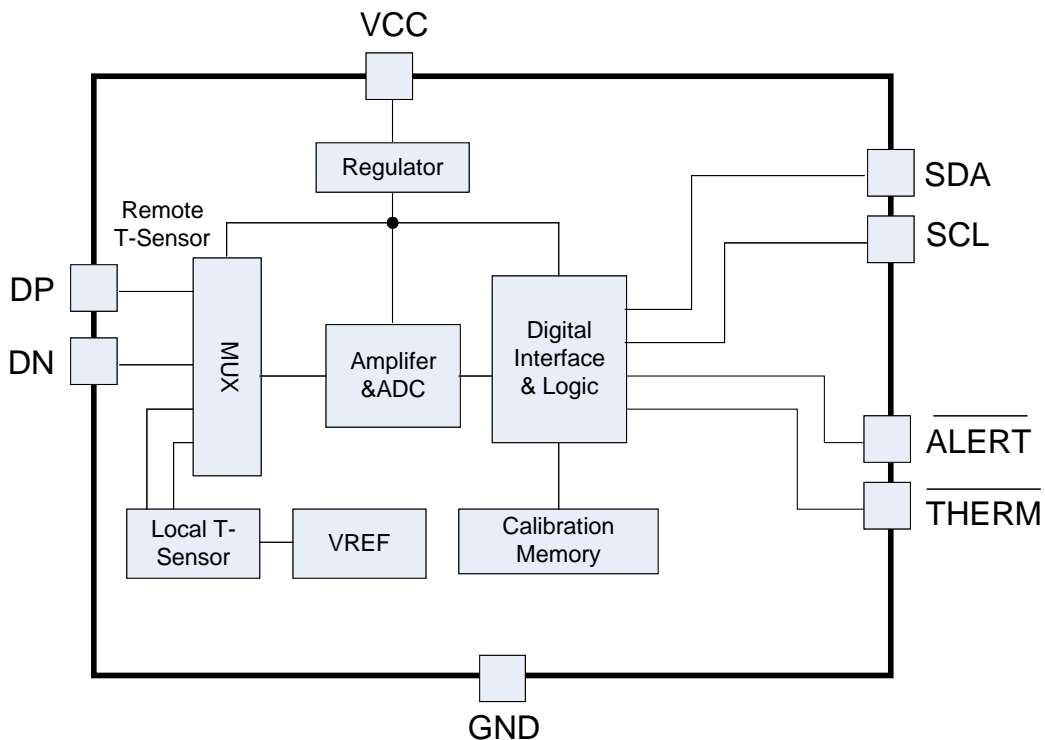
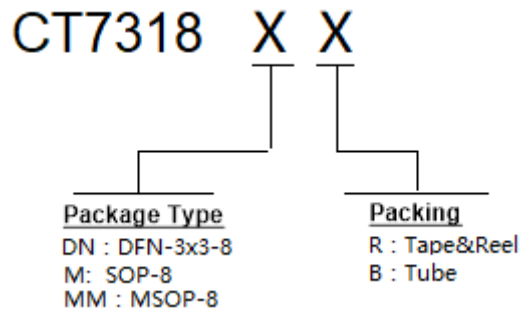


Figure 2. CT7318 function block

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Ordering Information



Order PN	Green ¹	Package	Marking ID ²	Packing	MOQ	MPQ	Operation Temperature
CT7318DNR	Halogen free	DFN3x3-8	7318 YWWAXX	Tape & Reel	3000	120,,000	-40°C~+125°C
CT7318MR	Halogen free	SOP-8	7318 YWWAXX	Tape & Reel	4,000	64,000	-40°C~+125°C
CT7318MB	Halogen free	SOP-8	7318 YWWA	Tube	10,000	50,000	-40°C~+125°C
CT7318MMR	Halogen free	MSOP-8	7318 YWWAXX	Tape & Reel	3,000	48,000	-40°C~+125°C
CT7318MMB	Halogen free	MSOP-8	7318 YWWAXX	Tube	32,000	128,000	-40°C~+125°C

Notes

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 stands for supplier or production location information.

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Absolute Maximum Ratings (Note3)

Parameter	Symbol	Value	Unit
Supply Voltage	V_{CC} to GND	-0.3 to 5.5	V
SDA, SCL Voltage	V_{SDA}/V_{SCL} to GND	-0.3 to 5.5	V
DXP Voltage	V_{DXP} to GND	-0.3 to $V_{CC}+0.3$	V
DXN Voltage	V_{DXN} to GND	-0.3 to 0.8	V
$\overline{\text{THERM}}$, $\overline{\text{ALERT}}$ Voltage	$V_{\text{THERM}}/V_{\text{ALERT}}$ to GND	-0.3 to 5.5	V
DXN Current	I_{DXN} to GND	±1.0	mA
Operation junction temperature	T_J	-50 to 150	°C
Storage temperature Range	T_{STG}	-65 to 150	°C
Lead Temperature (Soldering, 10 Seconds)	T_{LEAD}	260	°C
ESD Machine Mode	ESD_{MM}	±600	V
ESD Human Body Mode	ESD_{HBM}	±6000	V
ESD Charge Device Mode	ESD_{CDM}	±1000	V

Note3

1. 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.
2. Using 2oz dual layer (Top, Bottom) FR4 PCB with 4x4 mm² cooper as thermal PAD

Recommended Operating Conditions

Parameter	Symbol	Value	Unit
Supply Voltage	V_{CC}	3.0 ~ 5.0	V
Ambient Operation Temperature Range	T_A	-40~+125	°C

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Electrical Characteristics (Note4)

Test Condition: $C_{IN} = 0.1\mu F$, $C_1 = 2200pF$, $V_{CC} = 3.0V$ to $5.0V$, $T_A = -30$ to $125^\circ C$ unless otherwise specified, all limits are 100% test at $T_A = 25^\circ C$.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Supply Voltage	V_{CC}		3.0		5.0	V
Under Voltage Lock-out Threshold	V_{UVLO}			2.8		V
Under Voltage Lock-out Hysteresis	V_{UVLOHY}			0.12		V
Temperature Accuracy (Remote Sensor)	T_{RAC}	$T_A = 0$ to $110^\circ C$	-1.0		1.0	$^\circ C$
		$T_A = -40$ to $125^\circ C$	-1.8		1.8	$^\circ C$
Temperature Accuracy (Local Sensor)	T_{LAC}	$T_A = 0$ to $110^\circ C$	-1.0		1.0	$^\circ C$
		$T_A = -40$ to $125^\circ C$	-2.0		2.0	$^\circ C$
Average Operating Current	I_{AOC}	$V_{IN} = 3.3V$, 4.0 s/con		43		μA
		$V_{IN} = 5.0V$, 4.0 s/con		47		μA
		$V_{IN} = 3.3V$, 1.0 s/con		100		μA
		$V_{IN} = 5.0V$, 1.0 s/con		110		μA
Shutdown Current	$I_{SHUTDOWN}$	Enable STB bit, force SDA/SCL to VCC or GND			1.0	μA
Open Drain Output Voltage	V_{OL}	<u>ALERT</u> , <u>THERM</u> pin, sink 5mA	0		0.2	V
Open Drain Leakage	I_{ODL}	<u>ALERT</u> , <u>THERM</u> pin	-1.0		1.0	μA
Conversion time (both sensors)	t_{CON}	From active to finish completely		125		ms
Digital Interface						
Logic Input Capacitance	C_{IL}	SDA, SCL pin		3.0		pF
Logic Input High Voltage	V_{IH}	SDA, SCL pin	$0.8 \cdot V_{CC}$		V_{CC}	V
Logic Input High Voltage	V_{IL}	SDA, SCL pin	0		$0.2 \cdot V_{CC}$	V
Logic Input Current	I_{INL}	SDA, SCL pin	-1.0		1.0	μA
Logic Output Sink Current	I_{OLS}	SDA, <u>ALERT</u> , <u>THERM</u> pin, forced 0.2V		5.0		mA
SCL frequency	f_{CLK}	SCL pin	20		400	kHz
Timeout of detecting clock low period time	t_{TOUT}			30		ms
Clock low period time	t_{LOW}		4.7			μs
Clock high period time	t_{HIGH}		4.0		50	μs
Bus free time	t_{BUF}	Between Stop and Start condition	4.7			μs
Hold time after Start condition	$t_{HD:STA}$		4.0			μs
Repeated Start condition setup time	$t_{SU:STA}$		4.7			μs
Stop condition setup time	$t_{SU:STO}$		4.0			μs
Data Hold time	$t_{HD:DAT}$		300			ns
Data Setup time	$t_{SU:DAT}$		250			ns
Clock/Data fall time	t_F				300	ns
Clock/Data rise time	t_{SR}				1000	ns

Note 4:

- 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.
- No parasitic diode between EN pin and VIN pin.

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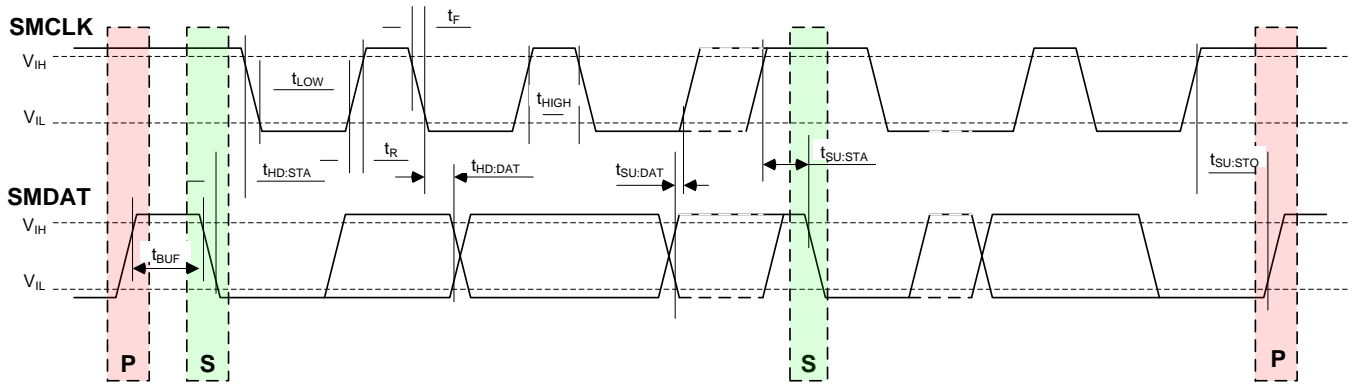


Figure 3. SMBusTimingDiagram

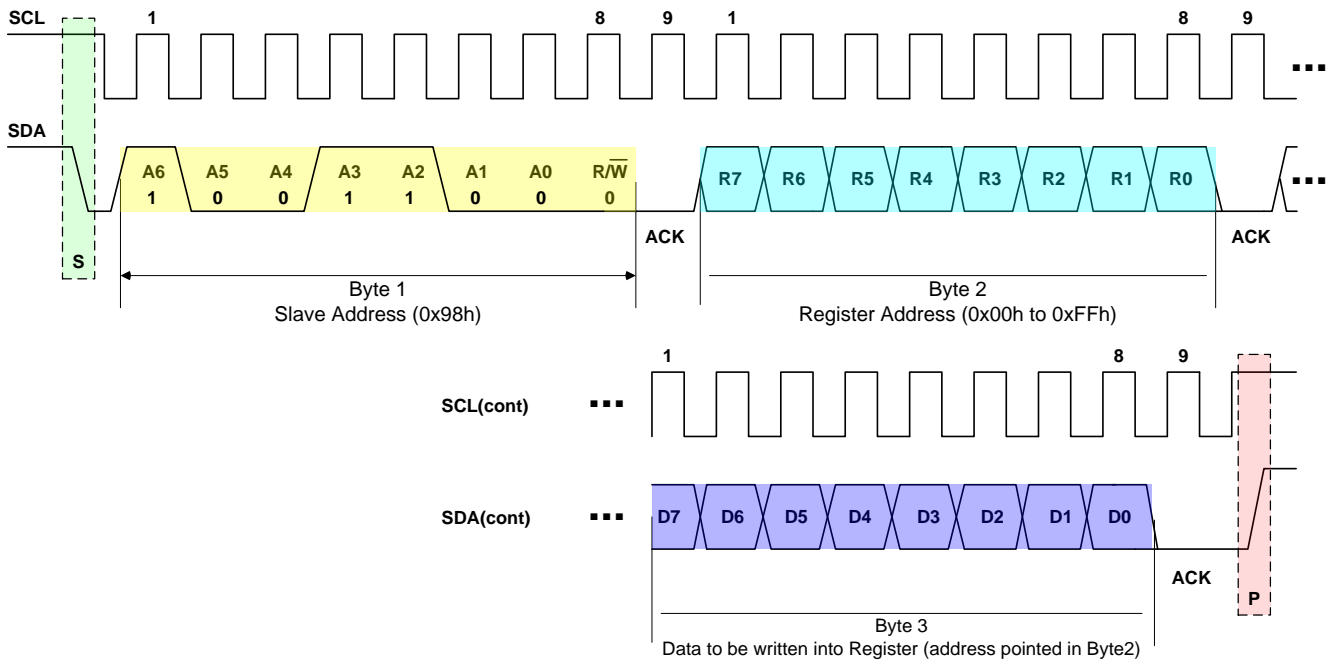


Figure 4. SMBus Write Timing Diagram

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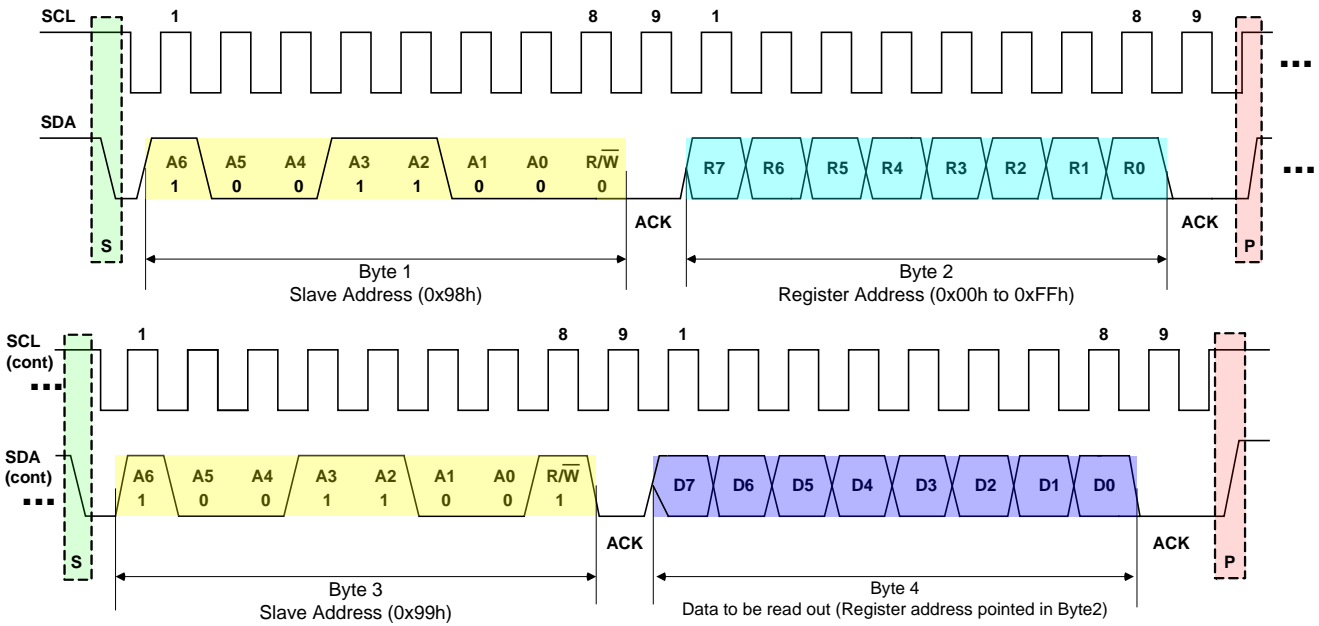


Figure 5. SMBus Read Timing Diagram

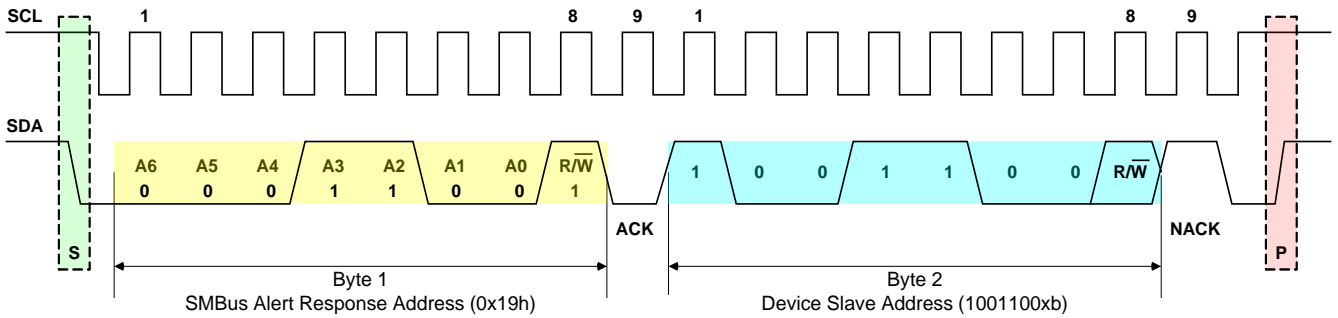


Figure 6. SMBus ALERT Response Diagram

$\pm 1^{\circ}\text{C}$ Remote and Local Temperature Sensor with Digital Interface

Characteristics(VCC=3.0V/5.0V)

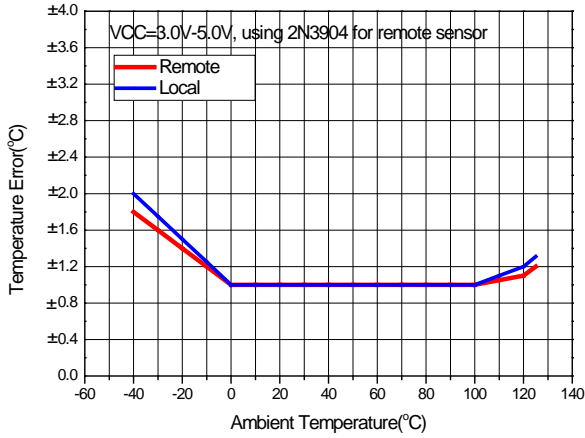


Figure 7. Temperature Error(Max.) vs. Temperature

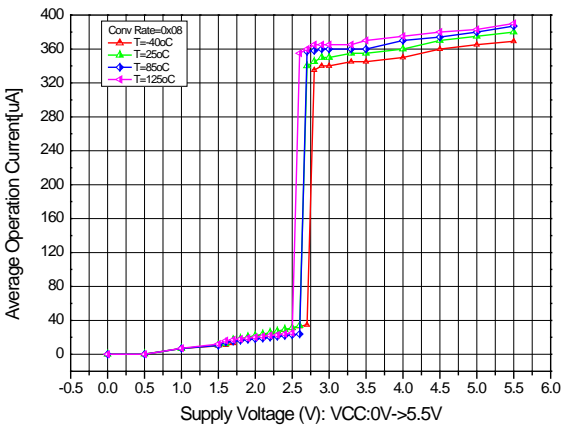


Figure 8. Average Operating current vs. Temperature

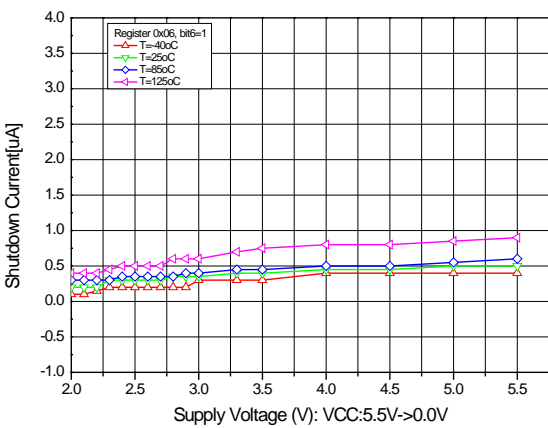


Figure 9. Shutdown current vs. Temperature (3.0V/5.0V)

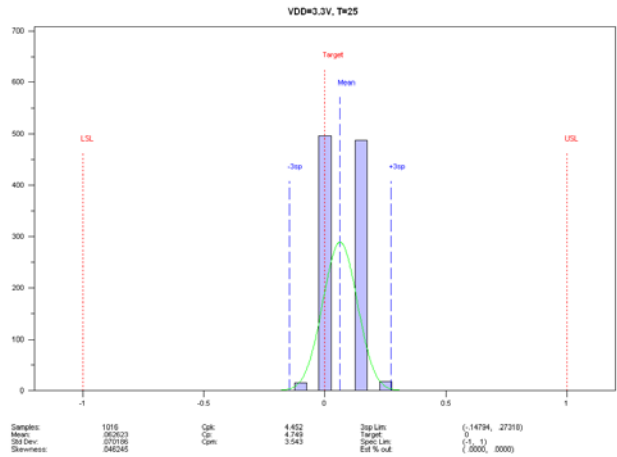


Figure 10. Local Temperature Error Distribution

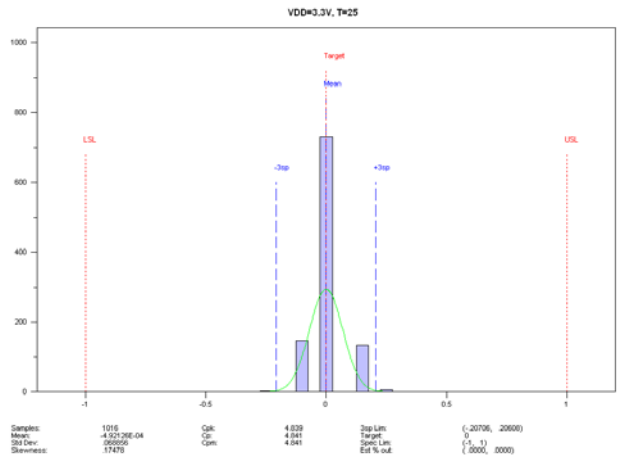


Figure 11. Remote Temperature Error Distribution

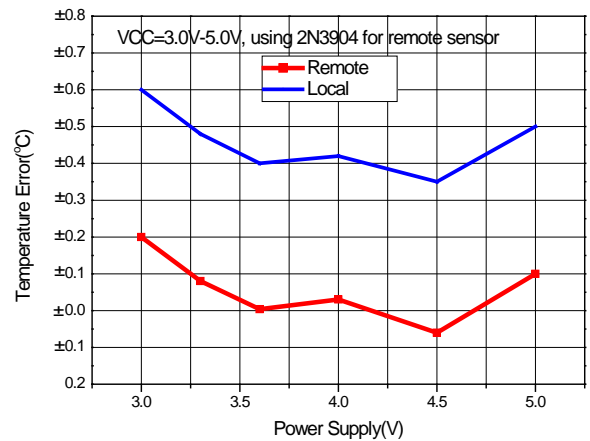


Figure 12. Temperature Error vs. Power Supply

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1 Function Descriptions

The chip can sense the local and remote temperatures and convert them into digital data by an 11-bit ADC and two remote and local sensors. Also the chip supports programmable high-/low- limit temperature settings for both sensor channels. If the measured temperature goes below the low-limit or above high-limit, **ALERT** pin will be asserted. If the measured temperature meets or exceeds THERM limit (programmable by user), **THERM** pin will be asserted.

1.1 Digital Output of Temperature Data

The temperature measurement data are in the local temperature and remote temperature register (Read Only). Both Remote and Local sensor temperatures are stored in 11-bit binary format with the eight most significant bits[MSB] stored in a high byte register and the three least significant bits stored in the three LSB positions of the low byte register. And all other bits of low byte register are set to zero.

Table 1. Sensor Temperature vs. 8-bit Digital Data

Temperature (°C)	8-bit Digital Output (HEX)	8-bit Digital Output (BIN)
+127	0x7F	0 1 1 1 , 1 1 1 1
+100	0x64	0 1 1 0 , 0 1 0 0
+25	0x19	0 0 0 1 , 1 0 0 1
+2	0x02	0 0 0 0 , 0 0 1 0
+1	0x01	0 0 0 0 , 0 0 0 1
0	0x00	0 0 0 0 , 0 0 0 0
-1	0xFF	1 1 1 1 , 1 1 1 1
-2	0xFE	1 1 1 1 , 1 1 1 0
-25	0xE7	1 1 1 0 , 0 1 1 1
-100	0x9C	1 0 0 1 , 1 1 0 0
-127	0x81	1 0 0 0 , 0 0 0 1
-128	0x80	1 0 0 0 , 0 0 0 0

Table 2. Sensor Temperature vs. 11-bit Digital Data

Temperature (°C)	11-bit Digital Output (HEX)	8-bit Digital Output (BIN) (MSB)	3-bit Digital Output (BIN) (LSB)
+127.875	0x7F7	0 1 1 1 , 1 1 1 1	1 1 1 X , X X X X
+100.500	0x642	0 1 1 0 , 0 1 0 0	0 1 0 X , X X X X
+25.750	0x196	0 0 0 1 , 1 0 0 1	1 1 0 X , X X X X
+2.250	0x02	0 0 0 0 , 0 0 1 0	0 1 0 X , X X X X
+1.125	0x01	0 0 0 0 , 0 0 0 1	0 0 1 X , X X X X
0.000	0x00	0 0 0 0 , 0 0 0 0	0 0 0 X , X X X X
-1.125	0xFF	1 1 1 1 , 1 1 1 0	1 1 1 X , X X X X
-2.250	0xFE	1 1 1 1 , 1 1 0 1	1 1 0 X , X X X X
-25.750	0xE7	1 1 1 0 , 0 1 1 0	0 1 0 X , X X X X
-100.500	0x9C	1 0 0 1 , 1 0 1 1	1 0 0 X , X X X X
-127.875	0x81	1 0 0 0 , 0 0 0 0	0 0 1 X , X X X X

1.2 Remote Sensor Higher than 127°C

When temperature of remote sensor is higher than 127°C, the offset register RTOFS should be set to a minus number and the remote temperature register RRTE reading should be interpreted with the same offset. For example, if the maximum remote temperature is 150°C then set the remote temperature offset register RTOFS to -23(11101001b in 2's complement)(127+23=150). With this setting, if the RRTE register

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reading is 100°C then add 23°C to it. The result of 123°C is the remote temperature. If reading is 120°C, then 143°C is the converted result by the chip.

1.3 Register Map

All registers are 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	LT	RO	0x00	LT[7:0]							
0x01	RT_MSB	RO	0x00	RT[10:3]							
0x02	Alert_Status	RO	N/A	ADC_B	STS_LTHA	Reserved	STS_RTH_A	STS_RTL_A	STS_RTO	STS_RTM	STS_LTM
0x03	Configuration	R/W	0x25	ALERT_MSK	STB	Reserved			EN_RTM	EN_CT	EN_FQ
0x04	Conv_Rate	R/W	0x08	Reserved				Conv_rate[3:0]			
0x05	LT_HAT	R/W	0x46	LT_HAT[7:0]							
0x06	Reserved										
0x07	RT_HAT_MSB	R/W	0x46	RT_HAT[10:3]							
0x08	RT_LAT_MSB	R/W	0xD8	RT_LAT[10:3]							
0x09	Configuration	R/W	0x25	ALERT_MSK	STB	Reserved			EN_RTM	EN_CT	EN_FQ
0x0A	Conv_Rate	R/W	0x08	Reserved				Conv_rate[3:0]			
0x0B	LT_HAT	R/W	0x46	LT_HAT[7:0]							
0x0C	Reserved										
0x0D	RT_HAT_MSB	R/W	0x46	RT_HAT[10:3]							
0x0E	RT_LAT_MSB	R/W	0xD8	RT_LAT[10:3]							
0x0F	One_Short_Con	WO	0xFF								
0x10	RT_LSB	RO	0x00	RT[2:0]			Reserved				
0x11	RT_OFS_MSB	R/W	0x00	RT_OFS[10:3]							
0x12	RT_OFS_LSB	R/W	0x00	RT_OFS[2:0]			Reserved				
0x13	RT_HAT_LSB	R/W	0x00	RT_HAT[2:0]			Reserved				
0x14	RT_LAT_LSB	R/W	0x00	RT_LAT[2:0]			Reserved				
0x15	LT_LSB	R/W	0x00	LT[2:0]			Reserved				
0x16	ALERT_MASK	R/W	0x07	MSK_LTH	Reserved		MSK_RTH	MSK_RTL	Reserved	MSK_RTT	MSK_LTM
0x19	RT_THERM	R/W	-	RT_THERM[7:0]							
0x20	LT_THERM	R/W	-	LT_THERM[7:0]							
0x21	THERM_HYS	R/W	0x0A	Reserved				THERM_HYS[4:0]			
0xBF	ALERT_MODE	R/W	0x00								
0xFD	Chip_ID	RO	0x50	0x50h							
0xFE	Manufacturer_ID	RO	0x59	0x59h							
0xFF	Device_ID	RO	0x8D	0x8Dh							

1.4 Register Description

1.4.1 LT, Local Temperature Data

Register Address: 0x00

Register Attribution: Read only

±1°C Remote and Local Temperature Sensor with Digital Interface

Default Data: 0x00 in Standby mode after POR

BIT	7	6	5	4	3	2	1	0
Name	LT[7:0]							
Temperature Data	SIGN	64	32	16	8	4	2	1

1.4.2 RT_MSB, Remote Temperature MSB Data

Register Address: 0x01

Register Attribution: Read only

Default Data: 0x00 in Standby mode after POR

BIT	7	6	5	4	3	2	1	0
Name	RT[10:3], it is MSB data, plus LSB data RT[2:0] forms complete RT Temperature Data							
Temperature Data	SIGN	64	32	16	8	4	2	1

1.4.3 Alert_Status, show the chip alert status

Register Address: 0x02

Register Attribution: Read Only

Default Data: N/A

BIT	7	6	5	4	3	2	1	0
Name	ADC_B	STS_LTHA	Reserved	STS_RTHA	STS_RTLA	STS_RTO	STS_RTM	STS_LTM
Default	N/A							

BIT	Name	Description
7	ADC_B	1 -- means ADC is busy for Data converting
6	STS_LTHA	1 -- means temperature in local sensor is higher than local sensor set high limit
5	Reserved	
4	STS_RTHA	1 -- means temperature in remote sensor is higher than remote sensor set high limit
3	STS_RTLA	1 -- means temperature in remote sensor is lower than remote sensor set low limit
2	STS_RTO	1 -- means remote diode is open/disconnected
1	STS_RTM	1 -- means remote sensor THERM alarm active
0	STS_LTM	1 -- means local sensor THERM alarm active

1.4.4 Configuration, for configuring the chip

Register Address: 0x03 and 0x09

Register Attribution: Read/Write

Default Data: 0x25

BIT	7	6	5	4	3	2	1	0
Name	ALERT_MSK	STB	Reserved			EN_RTM	EN_CT	EN_FQ

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Default	0	0	1	0	0	1	0	1
---------	---	---	---	---	---	---	---	---

BIT	Name	Description
7	ALERT_MSK	0 --Do not mask all ALERT interrupt function; 1 --mask all ALERT interrupt function;
6	STB	0 -- the chip is active and working normally; 1 -- Stop monitoring both Local and Remote sensor Temperature, the chip is going standby mode.
5	Reserved	
4	Reserved	
3	Reserved	
2	EN_RTM	0 -- disable remote sensor temperature monitor; 1 --enable remote sensor temperature monitor.
1	EN_CT	0 -- disable to change THERM limit temperature of POR value; 1 -- enable to change THERM limit temperature of POR value.
0	EN_FQ	0 -- disable fault queue function, which means ALERT pin and THERM pin will not be active when monitoring any sensor is above set high point or below set low point; 1 -- enable fault queue function, which means ALERT pin and THERM pin will be active when monitoring any sensor is above set high point or below set low point.

1.4.5 Conv_Rate, Conversion Rate of ADC

Register Address: 0x04 and 0x0A

Register Attribution: Read/Write

Default Data: 0x08

BIT	7	6	5	4	3	2	1	0
Name	Reserved					Conv_rate[3:0]		
Default	0	0	0	0	1	0	0	0

Data (HEX)	Conversion Rate Frequency (Hz)/Time(s)
0x00h	0.0625/16.00
0x01h	0.125/8.000
0x02h	0.250/4.000
0x03h	0.500/2.000
0x04h	1.000/1.000
0x05h	2.000/0.500
0x06h	4.000/0.250
0x07h	8.000/0.125
0x08h	16.00/0.0625
0x09h-0xFFh	Reserved

1.4.6 LT_HAT, Local Sensor high ALERT temperature for setup

Register Address: 0x05 and 0x0B

Register Attribution: Read/Write

Default Data: 0x46, which means 70°C.

BIT	7	6	5	4	3	2	1	0
Name	LT_HAT[7:0]							

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Data	SIGN	64	32	16	8	4	2	1
Default	0	1	0	0	0	1	1	0

1.4.7 RT_HAT_MSB, Remote sensor high ALERT temperature MSB data for setup

Register Address: 0x07 and 0x0D

Register Attribution: Read/Write

Default Data: 0x46, which stands for 70°C.

BIT	7	6	5	4	3	2	1	0
Name	RT_HAT_MSB[10:3]							
Data	SIGN	64	32	16	8	4	2	1
Default	0	1	0	0	0	1	1	0

1.4.8 RT_LAT_MSB, Remote sensor low ALERT temperature MSB Data for setup

Register Address: 0x08 and 0x0E

Register Attribution: Read/Write

Default Data: 0xD8, which stands for -40°C.

BIT	7	6	5	4	3	2	1	0
Name	RT_LAT_MSB[10:3]							
Data	SIGN	64	32	16	8	4	2	1
Default	1	1	0	1	1	0	0	0

1.4.9 One_Short_Con, one short register used for one conversion cycle

Register Address: 0x0F

Register Attribution: Write only

Default Data: 0xFF, used to get one conversion cycle temperature data by writing any data into this register in send-byte communication format, when the chip enters into Standby mode.

1.4.10 RT_LSB, remote temperature LSB data

Register Address: 0x10

Register Attribution: Read only

Default Data: 0x00 after POR

BIT	7	6	5	4	3	2	1	0
Name	RT[2:0], it is LSB data, plus MSB data RT[10:3] forms complete RT Temperature Data							
Temperature Data(oC)	0.5	0.25	0.125	Reserved				

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1.4.11 RT_OFS_MSB, Remote Sensor OFFSET Temperature MSB Data

Register Address: 0x11

Register Attribution: Read/Write

Default Data: 0x00 after POR

BIT	7	6	5	4	3	2	1	0
Name	RT_OFS [10:3], it is Remote Sensor Offset Temperature MSB data, plus LSB data RT_OFS[2:0] forms complete Offset Temperature Data, this 11bit data is additional temperature data used when Temperature is higher than 127°C. see 1.2 Remote Sensor Higher than 127°C							
Temperature Data(oC)	SIGN	64	32	16	8	4	2	1

1.4.12 RT_OFS_LSB, Remote Sensor OFFSET Temperature LSB Data

Register Address: 0x12

Register Attribution: Read/Write

Default Data: 0x00 after POR

BIT	7	6	5	4	3	2	1	0
Name	RT_OFS [10:3], it is Remote Sensor Offset Temperature MSB data, plus LSB data RT_OFS[2:0] forms complete Offset Temperature Data, this 11bit data is additional temperature data used when Temperature is higher than 127°C. see 1.2 Remote Sensor Higher than 127°C							
Temperature Data(oC)	0.5	0.25	0.125	Reserved				

1.4.13 RT_HTA_LSB, Remote sensor high ALERT temperature LSB data for setup

Register Address: 0x13

Register Attribution: Read/Write

Default Data: 0x00

BIT	7	6	5	4	3	2	1	0
Name	RT_HAT [2:0]			Reserved				
Temperature Data(oC)	0.5	0.25	0.125					
Default	0	0	0	0	0	0	0	0

1.4.14 RT_LAT_LSB, Remote sensor low ALERT temperature LSB Data for setup

Register Address: 0x14

Register Attribution: Read/Write

Default Data: 0x00

BIT	7	6	5	4	3	2	1	0
Name	RT_LAT [2:0]			Reserved				
Temperature Data(oC)	0.5	0.25	0.125					
Default	0	0	0	0	0	0	0	0

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1.4.15 LT_LSB, local temperature LSB data

Register Address: 0x15

Register Attribution: Read/Write

Default Data: 0x00

BIT	7	6	5	4	3	2	1	0
Name	LT [2:0], it is LSB data, plus MSB data LT [10:3] forms complete LT Temperature Data							
Temperature Data(oC)	0.5	0.25	0.125	Reserved				

1.4.16 ALERT_MASK, Mask ALERT setup option

Register Address: 0x16

Register Attribution: Read/Write

Default Data: 0x07

BIT	7	6	5	4	3	2	1	0
Name	MSK_LTH	Reserved		MSK_RTH	MSK_RTL	Reserved	MSK_RTT	MSK_LTT
Default	0	0	0	0	0	1	1	1

BIT	Name	Description
7	MSK_LTH	0 -- Disable local temperature high ALERT mask; 1 -- Enable local temperature high ALERT mask
6	Reserved	
5	Reserved	
4	MSK_RTH	0 -- Disable remote temperature high ALERT mask; 1 -- Enable remote temperature high ALERT mask
3	MSK_RTL	0 -- Disable remote temperature low ALERT mask; 1 -- Enable remote temperature low ALERT mask
2	Reserved	
1	MSK_RTT	0 -- Disable remote temperature THERM limit mask; 1 -- Enable remote temperature THERM limit mask
0	MSK_LTT	0 -- Disable local temperature THERM limit mask; 1 -- Enable local temperature THERM limit mask

1.4.17 RT_THERM, Remote Sensor THERM limit temperature setup

Register Address: 0x19

Register Attribution: Read/Write

Default Data: it depends on $\overline{\text{THERM}}$ pin and $\overline{\text{ALERT}}$ pin pull-up resistors combinations shown as below table. and this register cannot be written with any data until EN_CT bit (bit1 of Configuration Register 0x03) is set '1'.

Table 4. Remote Sensor THERM limit setup vs. $\overline{\text{THERM}}$ pin & $\overline{\text{ALERT}}$ pin pull-up Resistor

Temperature (°C)		$\overline{\text{THERM}}$ pin				
		2kohm	7.5kohm	10.5kohm	14.0kohm	18.7kohm
$\overline{\text{ALERT}}$ pin	2kohm	77	87	97	107	117
	7.5kohm	79	89	99	109	119
	10.5kohm	81	91	101	111	121
	14.0kohm	83	93	103	113	123
	18.7kohm	85	95	105	115	125

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1.4.18 LT_THERM, Local Sensor THERM limit temperature setup

Register Address: 0x20

Register Attribution: Read/Write

Default Data: it depends on $\overline{\text{THERM}}$ pin and $\overline{\text{ALERT}}$ pin pull-up resistors combinations shown as below table. And this register cannot be written with any data until EN_CT bit (bit1 of Configuration Register 0x03) is set '1'.

Table 5. Local Sensor THERM limit setup vs. $\overline{\text{THERM}}$ pin & $\overline{\text{ALERT}}$ pin pull-up Resistor

Temperature (°C)		$\overline{\text{THERM}}$ pin				
		2kohm	7.5kohm	10.5kohm	14.0kohm	18.7kohm
$\overline{\text{ALERT}}$ pin	2kohm	77	87	97	107	117
	7.5kohm	79	89	99	109	119
	10.5kohm	81	91	101	111	121
	14.0kohm	83	93	103	113	123
	18.7kohm	85	95	105	115	125

1.4.19 THERM_HYS, THERM Temperature Hysterisis Window Temperature

Register Address: 0x21

Register Attribution: Read/Write

Default Data: 0x0A, stands for 10°C, This register cannot be written with any data until EN_CT bit (Configuration Register 0x03 bit1) is set '1'.

BIT	7	6	5	4	3	2	1	0
Name	Reserved			RT_HAT [2:0], range can be set from 0 to 32°C				
Data				16	8	4	2	1
Default				0	1	0	1	0

1.4.20 ALERT_MODE, Alert Mode Selection

Register Address: 0xBF

Register Attribution: Read/Write

Default Data: 0x00.

BIT	7	6	5	4	3	2	1	0
Name	Reserved							ALERT_MS
Default	0	0	0	0	0	0	0	0

BIT	Name	Description
Bit[7:1]	Reserved	
0	ALERT_MS	0 -- SMBus ALERT mode or Interrupt; 1 -- Comparator Mode

1.4.21 Chip_ID

Register Address: 0xFD

Register Attribution: Read Only

Default Data: 0x50.

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1.4.22 Manufacturer ID

Register Address: 0xFE
 Register Attribution: Read Only
 Default Data: 0x59.

1.4.23 Device ID

Register Address: 0xFF
 Register Attribution: Read Only
 Default Data: 0x8D.

1.5 Remote and Local Temperature Sensor Channel

For remote sensor channel, 300μV of voltage offset forced between DXP and DXN will cause about 1°C error. And equivalent ESR in series with the remote diode connection will cause about +0.30°C error per ohm.

1.6 Operating Mode, Active and Standby

The chip has 2 operation modes.

- 1). Active (Run, by setting bit6 of Configuration Register as '0'): In this mode, the ADC is doing conversion on all temperature sensor channels at the programmed conversion rate. The temperature data is updated and limitation is checked at the end of every conversion cycle. In this mode, writing to the one-shot register will do nothing.
- 2). Standby (Stop, by setting bit6 of Configuration Register as '1'): In this mode, most circuit blocks are powered down to reduce operation current. The SMBus is fully active and the chip will return requested data. Writing to the one-shot register will enable all temperature sensor channels. Once all the sensor channels are updated, the chip will return to standby mode.

1.7 One Shot Register

One shot register is used to perform one shot command. When the chip is in Standby mode and ADC_B bit of Status Register is '0', writing any data to one shot register will cause ADC to update both temperature sensor measurements. In active mode, writing to one shot register does no effect to the chip.

This register is Write Only. Data written to this register is not stored and is always read as 0xFF.

1.8 SMBus Digital Interface

1.8.1 Slave Address

The SMBus or I²C slave address of this device is 10011000b (0x98h in HEX) in write mode, and 10011001b (0x99h in HEX) in read mode. If 3 or more of these devices in one SMBus are used, customers have to select thermal sensor with different slave address. Please contact Sensylink sales for more information.

	A6	A5	A4	A3	A2	A1	A0	R/W
Read	1	0	0	1	1	0	0	1/0

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Write	1	0	0	1	1	0	0	0
-------	---	---	---	---	---	---	---	---

1.8.2 Timeout

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

1.8.3 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
	1001100	0	0	XXh	0	XXh	0	

Read Byte

S	Slave Add	R/W	ACK	Reg Add	ACK	S	Slave Add	R/W	ACK	Reg Data	NACK	P
	1001100	0	0	XXh	0		1001100	1	0	0	1	

Send Byte

S	Slave Add	R/W	ACK	Reg Add	ACK	P
	1001100	0	0	XXh	0	

Receive Byte

S	Slave Add	R/W	ACK	Reg Add	NACK	P
	1001100	1	0	XXh	1	

Here S means SMBus Start to communication with master, P, means communication STOP.

Slave Add, means the chip's SMBus address.

Reg Add, means pointed Register Address.

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

1.8.4 Compatible with I²C

The chip is compatible with both SMBus and I²C. And 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.

- 1). This chip supports I²C fast mode (400kHz) and standard mode (100kHz), which can cover SMBus maximum frequency 100kHz.
- 2). For SMBus protocol, the minimum frequency is 10kHz. There is no such limitation for I²C.
- 3). For SMBus protocol, slave device will reset if hold clock at '0' longer than 30ms. There is no timeout for I²C.
- 4). ARA (Alert Response Address) general call is only valid interrupt in SMBus, not valid in I²C.

1.9 ALERT Output

ALERTpin is active-low output with open drain, which is triggered when measured temperature exceeds the limitation setup in the limit registers. Bit6 of Status Register [0x02] will be set '1' once Local temperature exceeds the temperature setup in LT_HAT[0x05]. Bit4 of Status Register [0x02] will be set '1' once Remote temperature exceeds the temperature setup in RT_HAT[0x07, 0x13] and bit3 of Status Register [0x02] will be set '1' once Remote temperature drops below the temperature setup in RT_LAT[0x08, 0x14]. All above situations are called

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ALERT trigger. Once ALERT trigger happened, ALERT pin can be setup and released with three types of output mode: comparator mode, interrupt mode, and SMBus ALERT Response mode

1.9.1 Comparator mode

Below Figure shows the mechanism of the ALERT output in comparator mode. In this mode, the $\overline{\text{ALERT}}$ pin will be asserted (active low) by writing '0' into bit7 of Configuration register [0x03] during ALERT trigger. And ALERT pin can be released by any of below 2 conditions: 1) Be out of ALERT trigger situation caused by setting relevant MASK bit as '1' for ALERT_MASK register [0x16], or temperature is kept between higher and lower limitations. 2). Set bit7 of Configuration register [0x03] as '1'. In this mode, for bit7 of Configuration register [0x03] readout value is same as written value.

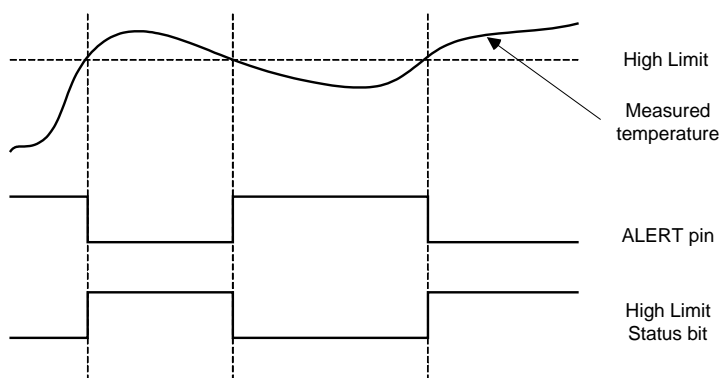


Figure 13 $\overline{\text{ALERT}}$ pin output in comparator mode

1.9.2 Interrupt mode

Below Figure shows the mechanism of the $\overline{\text{ALERT}}$ pin output interrupt mode. In this mode, the $\overline{\text{ALERT}}$ pin will be asserted (active low) by writing '0' into bit7 of Configuration register [0x03] during ALERT trigger. And ALERT pin can be released by any of below 3 conditions: 1).Reading Status register [0x02]. 2). Reset bit7 of Configuration register [0x03] as '0'. 3). SMBus alert response happened. In this mode, for bit7 of Configuration register [0x03] readout value is always '1'.

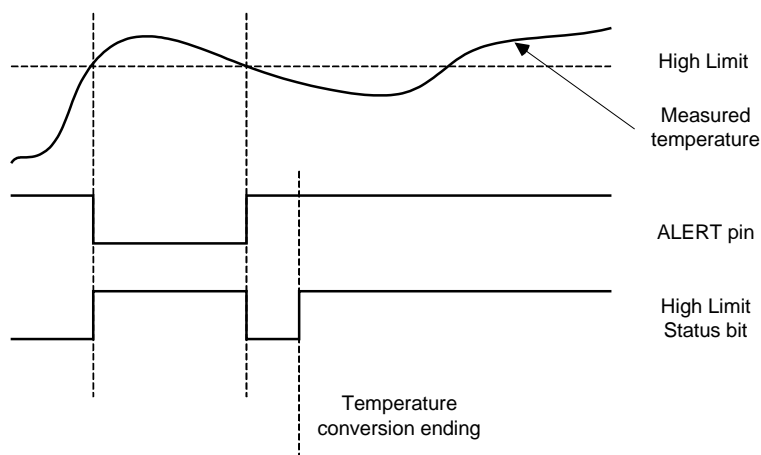


Figure 14 $\overline{\text{ALERT}}$ pin output in interrupt mode

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1.9.3 SMBus Alert Response Mode

It can be used as a processor interrupt or as SMBus ALERT. When the master detects that $\overline{\text{ALERT}}$ pin is asserted, it will send Alert Response Address (ARA) to general address (0001, 100xb). All devices with active interrupts will respond with client address.

Below Figure shows the mechanism of the ALERT output SMBus Alert mode. In this mode, the ALERT output is connected to the SMBus alert line which has more than one device connected to it. Through such and implementation, SMBus alert mode can assist the master in resolving which slave generates an interrupt. When the measured temperature falls outside of the allowed range, the $\overline{\text{ALERT}}$ pin will be pulled low and the corresponding alert flags in Status Register will be set to 1. The ALERT mask bit will just be set if there is a read command for Status Register or when SMBus ALERT Response Address (ARA) occurs from master (Alert Response Address is 0001100xb). Meanwhile, the chip will generate and return its own address to the master. If the temperature never falls outside of the allowed range, the latched $\overline{\text{ALERT}}$ pin can release by the reset ALERT mask bit and the latched corresponding alert flags in Status Register can release by reading command for Status Register.

S	Slave Add	R/W	ACK	Reg Add	ACK	P
	0001100	1	0	1001 100xb	1	

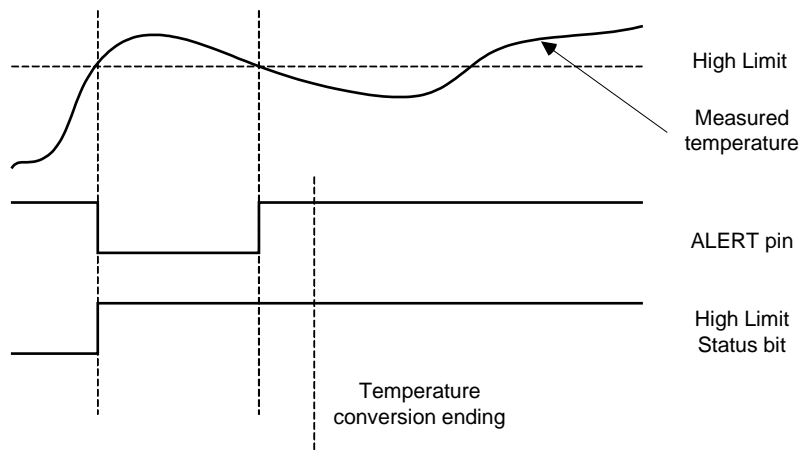


Figure 15 $\overline{\text{ALERT}}$ pin in SMBus Alert Response mode

1.10 $\overline{\text{THERM}}$ Output

$\overline{\text{THERM}}$ pin is also an active low output with open drain. The THERM is asserted and pulled low when any of the measured temperatures exceeds the THERM limitation temperature programmed by user in Register 0x19, 0x20. Once $\overline{\text{THERM}}$ pin outputs low, it will remain asserted and will not be set high until all measured temperature is lower than THERM limit minus THERM Hysteresis(also programmable in 0x21). When the $\overline{\text{THERM}}$ pin is asserted, THERM Status bits of Alert Status Registers will be set respectively and will not be cleared until the $\overline{\text{THERM}}$ pin is de-asserted. The ALERT-MSK bit of Configuration Register will be reset after Status Register is read. Below Figure shows this mechanism.

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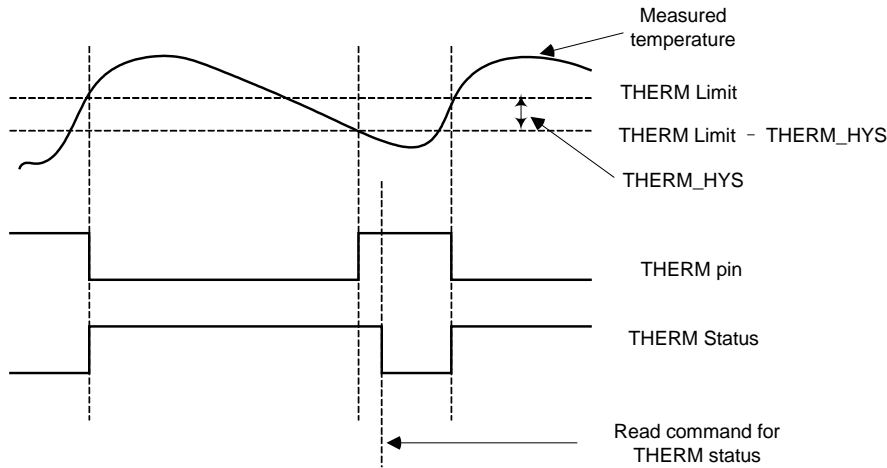


Figure 16 THERM pin output

1.11 Diode Fault Alarm

The chip can detect an open on DP and DN pin (e.g. no external diode connection) or a short between DP and DN pin. In each temperature measurement cycle, the chip checks diode fault for external diode channel. When a diode short is detected, the $\overline{\text{ALERT}}$ pin is asserted (unless masked by user's program) and the temperature data is 0x80h(MSB) and 0x00(LSB) read from RT_MSB register [0x01] and RT_LSB register [0x10], which means the temperature is -128°C. Also, STS_RTLO bit of Alert_Status register is set '1'. If the chip detects an open before power-on reset, temperature will show 0°C, also STS_RTO bit of Alert_Status register is set '1'. If open is detected after power-on reset, however, the temperature data shown represents the result that was converted in the last cycle, and it will NOT get updated. Also STS_RTO bit of Alert_Status register will be set '1'.

1.12 External Diode Selection

The chip is designed to measure both local and remote temperatures. For remote temperature sensing, the chip needs connection to an external diode, which could be a discrete diode or a discrete BJT (PNP type or NPN type) transistor with diode-connected. The external diode also can be substrate parasitic BJT transistor inside CPU or other GPU chips.

For Remote sensor channel, temperature accuracy depends on external PN junction. It is better to select small-signal BJT transistor of proper performance with diode-connected. Proper performance includes below,

- 1). Vbe is between 250mV at 10uA and 950mv at 300uA;
- 2). Beta or current DC gain, is equal or larger than 30;
- 3). base resistance is below 100ohm.

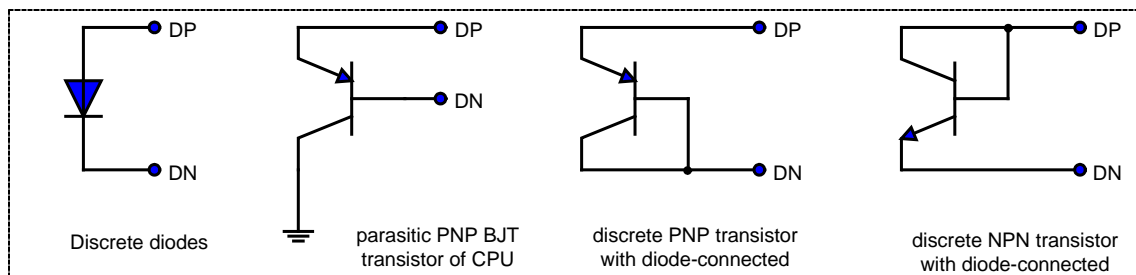


Figure 17 External Diode Connection

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1.13 POR and UVLO

The chip uses volatile memory. To prevent unclean power-supply conditions, which could happen in system application, from corrupting the data in memory and causing an expected situation, a POR voltage detector monitors VCC and clears the memory if VCC falls below threshold voltage (1.7V in typical). When VCC rises above threshold voltage, the logic blocks begin operating. Then the chip block will work normally along with VCC rising high enough gradually.

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2 Applications 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. For this chip, 200µV voltage between DP and DN pin stands for about 1°C. 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 Parasitic ESR of Remote Diode

Parasitic series resistance in the remote diode will cause about +0.45°C error per ohm. So it is very necessary to place the chip as close as possible to the external remote diode in PCB layout. If the remote diode channel is NOT used, it is better to leave these pins open.

2.1.2 Noise between DP and DN

Since 200uV stands for about 1°C, any common-mode noise between DP and DN pin will cause temperature measurement error. So it is very necessary to place a low ESR ceramic cap across DP and DN pin to filter noise. The recommended capacitance is 2200pF.

2.1.3 Thermal Response Time

It is very necessary to wait enough time for obvious temperature changing of target due to thermal time constant, e.g. taking food out of refrigerator, temperature changes from -20°C to 20°C, which could takeover 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 example, changing 100°C suddenly around this chip, it will take about 15 minutes to reach thermal equilibrium on this chip die under 1°C accuracy.

2.1.4 Self-heating

For local sensor, self-heating could affect temperature measurement accuracy. It always brings positive error. It could be estimated as below steps.

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Step 1, Estimating the chip power consumption, caused by average operating current and sink current at $\overline{\text{ALERT}}$ pin, $\overline{\text{THERM}}$ pin.

$$Pd1 = V_{CC} * I_{AOC} = 5.0V * 350\mu A = 1.75mW$$

(Assuming Vcc is 5.0V, conversion rate is 8Hz.)

$$Pd2 = V_{OL} * I_{SINK} = 0.1V * 0.5mA * 2 = 0.1mW$$

(Assuming in normal operating, both $\overline{\text{ALERT}}$ pin and $\overline{\text{THERM}}$ pins are active, and pull-up resistors are 10k)

$$Pd \text{ total} = Pd1 + Pd2 = 1.75mW + 0.1mW = 1.85mW$$

Step 2, Estimating junction temperature error caused by power consumption,

$$\Delta T_j = Pd \text{ total} * \Theta_{JA} = 1.85mW * 140^{\circ}\text{C/W} = 0.26^{\circ}\text{C}$$

2.1.5 Setup by System Software

It is necessary to properly setup/optimize system software to improve reliability and consistency of the temperature data. Below is the guideline for reading temperature data with 1Hz frequency.

- 1). Setup conversion rate register (0x08) as 4Hz;
- 2). Read the temperature data 4 times in one second;
- 3). Average out the above 4 temperature data
- 4). Do moving-average repeatedly for the last 4 average temperature readings
- 5). Compensate positive temperature error caused by self-heating, which could be estimated by the calculation in 2.1.4;
- 6). Compensate error caused by environment temperature around the chip, which could be obtained by another local sensor;
- 7). Output above temperature data once every second.

2.1.6 Select proper external Diode, see external diode selection.

2.2 PCB Layout

Cautions below are important to improve temperature measurement 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, RF). It is recommended to place the chip close to the remote diode.

2.2.2 DP, DN Route in PCB

It is better to draw the traces of DP and DN netlist as a pair trace and to make sure that the two are always kept with the same distance and the same layer in PCB board. Also it is better NOT TO change PCB layer for this pair trace, which means to keep trace to the same layer as the chip and remote diode (Top or Bottom layer).

The recommended trace width of DP, DN pair trace is 0.3mm - 0.325mm.

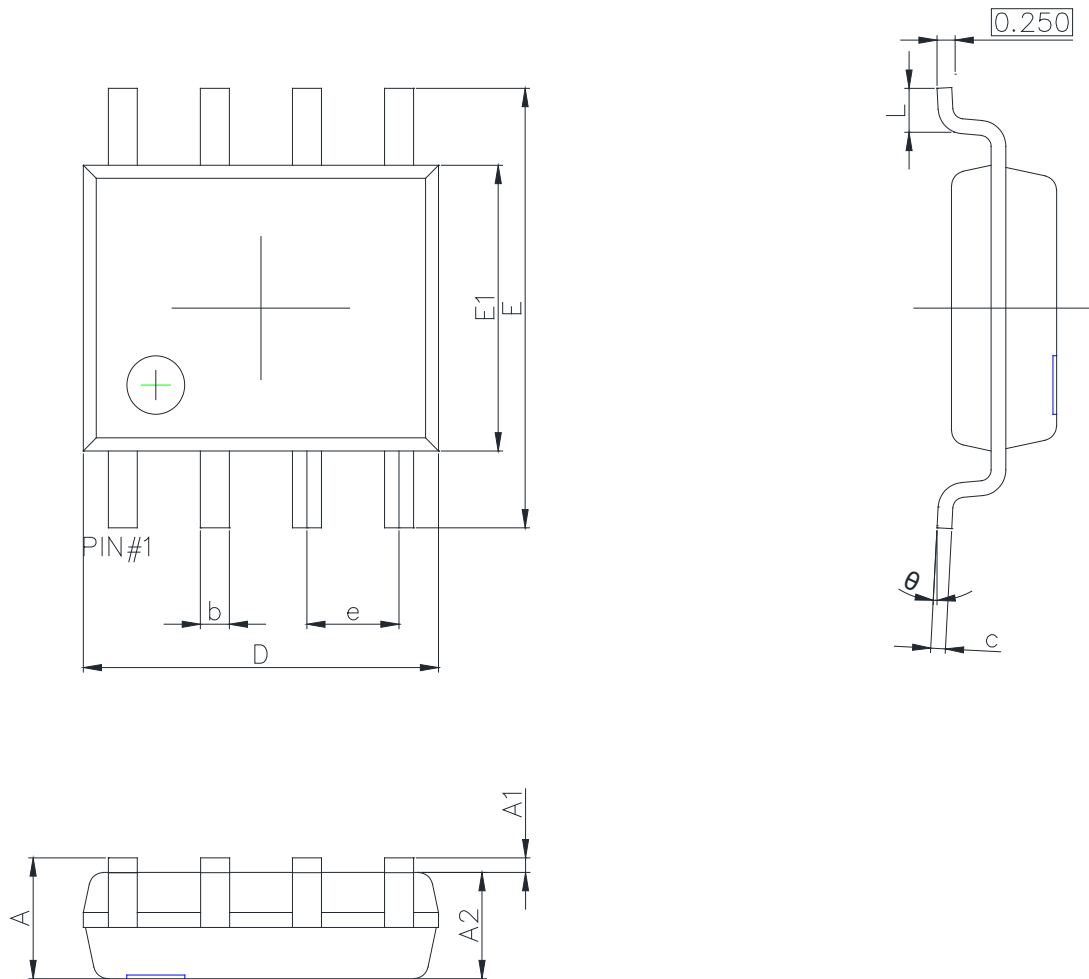
$\pm 1^{\circ}\text{C}$ Remote and Local Temperature Sensor with Digital Interface

2.2.3 Twisted cable and shield

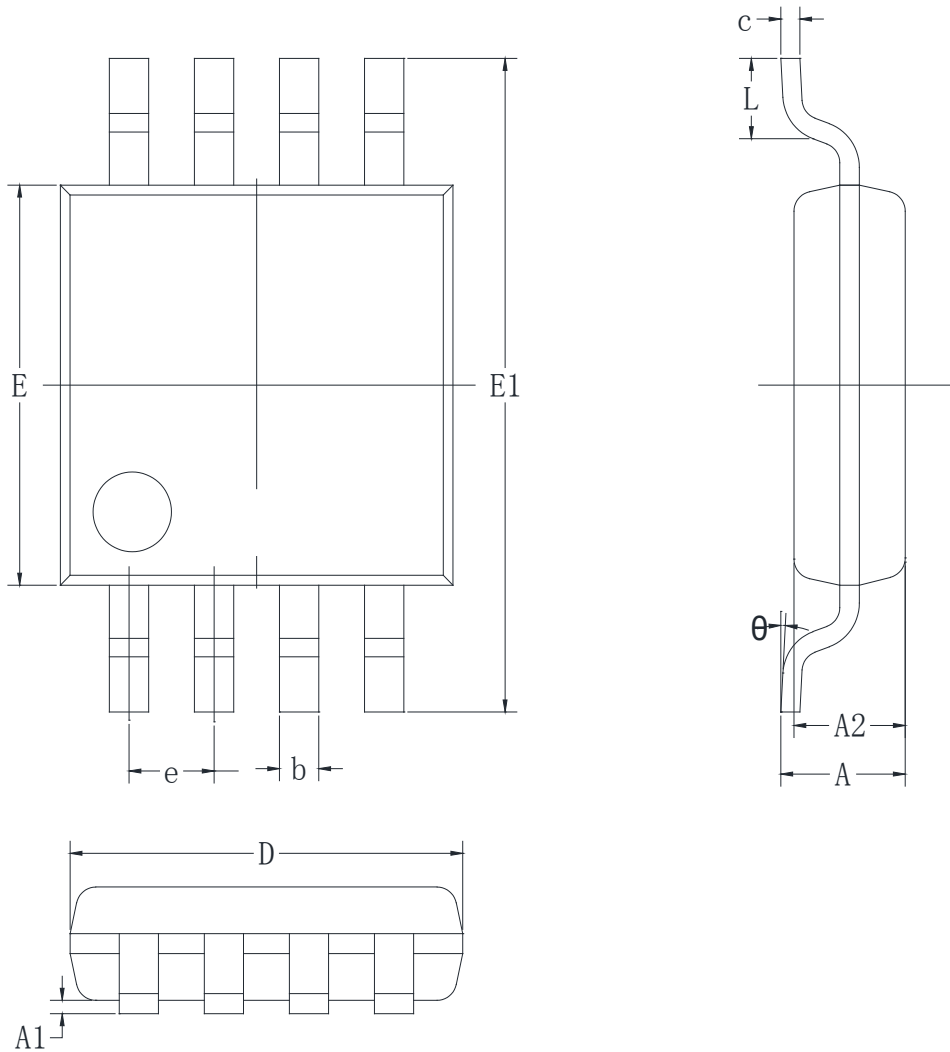
Another method is to use ground shield around the DP, DN pair trace, which could reduce digital noise.

Twisted cable with shield is recommended for long distance temperature measurement that uses a discrete diode as the remote sensor. Shield is shorted to ground.

Do not forget to compensate temperature error caused by ESR in software.

$\pm 1^{\circ}\text{C}$ Remote and Local Temperature Sensor with Digital Interface
Package Outline Dimensions
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°

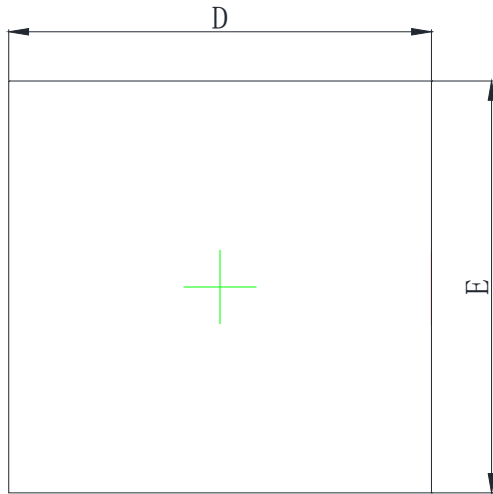
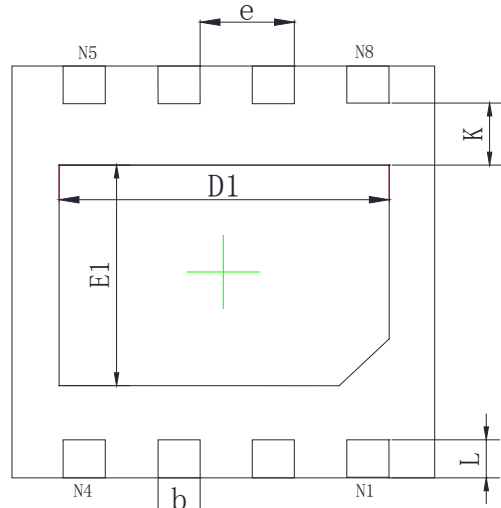
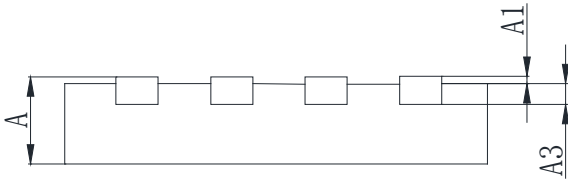
$\pm 1^{\circ}\text{C}$ Remote and Local Temperature Sensor with Digital Interface
Package Outline Dimensions
MSOP-8 Unit (mm)


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
theta	0°	8°	0°	8°

$\pm 1^{\circ}\text{C}$ Remote and Local Temperature Sensor with Digital Interface
Package Outline Dimensions

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	2.400	0.087	0.094
E1	1.400	1.600	0.055	0.063
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



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