Digital Remote and Local Temperature Sensor with SMBus Serial Interface

General Description

The uS5004 is a digital thermometer to monitor both remote and local temperature, it accurately measures its own temperature and the remote temperature that mounted 2N3904 diode-connected transistor that can replace conventional thermistors and thermocouples.

The standard 2-wire interface System Management Bus (SMBus) accepts Write byte, Read byte, Send byte, and Receive byte command to communicate with uS5004. The device data format of remote temperature measurement is 11bits, with each bit of the extended 3bits corresponding 0.125°C.

Features

- Remote and Local Temperature Measurements
- Do Not Need to Calibrate
- SMBus Interface
- Accuracy : Remote ±1°C, Local ±3°C
- Supply Voltage Range from 3.3V ±10%
- RoHS Compliant and Halogen Free
- WDFN2x2 - 8L and MSOP - 8L Packages

Applications

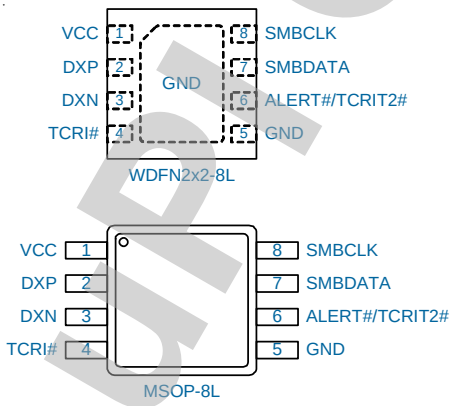
- System Thermal Management (Desktop, Laptops, Workstations, Servers)
- Test and Measurement
- Industrial Controller

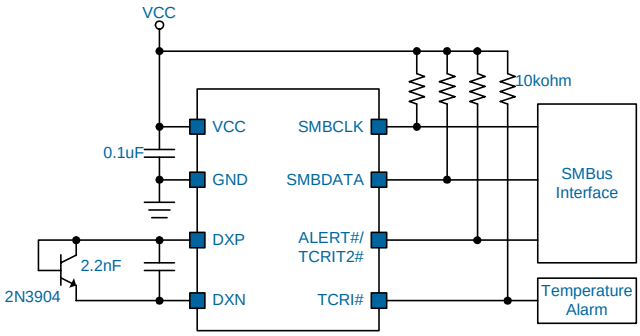
Ordering Information

Order Number	Package	Remark	Top Marking
uS5004PDN8	WDFN2x2 - 8L	7bits slave address: 0x4C	DT
uS5004QDN8		7bits slave address: 0x4D	TBD
uS5004PRA8	MSOP - 8L	7bits slave address: 0x4C	uS5004P
uS5004QRA8		7bits slave address: 0x4D	TBD

Note:
(1) Please check the sample/production availability with uPI representatives.
(2) uPI products are compatible with the current IPC/JEDEC J-STD-020 requirement. They are halogen-free, RoHS compliant and 100% matte tin (Sn) plating that are suitable for use in SnPb or Pb-free soldering processes.

Pin Configuration & Typical Application Circuit



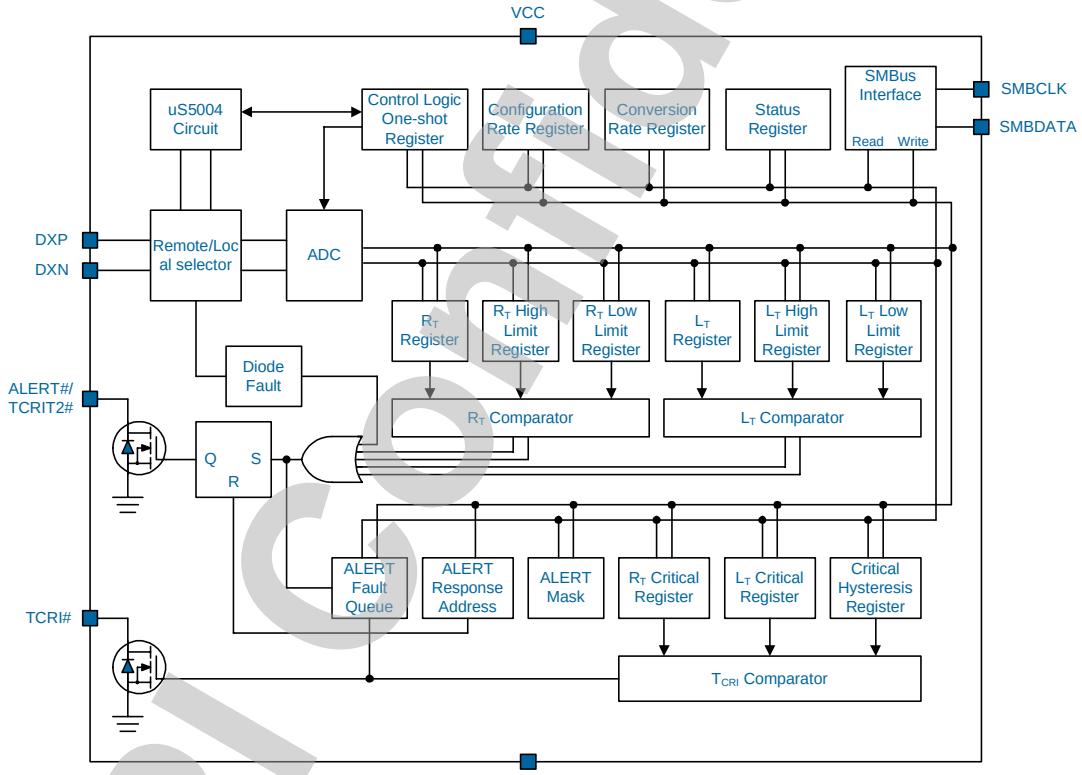


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Functional Pin Description

Pin Name	Pin Function
VCC	**Supply voltage input.** Connect to 3.3V +/-10% and bypass to GND with a 0.1uF capacitor.
DXP	**Positive input for remote-diode.**
DXN	**Negative input for remote-diode.**
TCRI#	**It is an open-drain output that requires a pull-up resistor to VCC.**
GND	**Ground.**
ALERT#/ TCRIT2#	**Open drain ALERT output.** This can also be configured as a second TCRIT2# output. Requires pullup resistor.
SMBDATA	**SMBus data line, open drain digital data input/output.**
SMBCLK	**SMBus clock input.**

Functional Block Diagram



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Functional Description

The uS5004 is a temperature sensor that measures local and remote temperature by using its own diode and a mounted diode-connected transistor, and operates by standard 2-wire SMBus interface.

ADC Temperature Measurement

The uS5004 temperature sensor forces currents to both remote and local diodes, measures their voltages and an analog to digital converter (ADC) automatically computes remote and local temperature once the conversion has started.

ADC Conversion Process

Both channels are simultaneously converted in auto-convert mode or one-shot command is written, the results of remote and local temperatures are updated until the end of conversion. If the ADC_Busy status bit is in the busy status, it means ADC is running a new conversion, but the previous results are still available. Therefore, if one of remote and local temperature measurement is not needed, the user can neglect the result of the unused one or write the RT_MntEn bit low in the configuration register to disable remote temperature measurement.

Standby Mode

Standby mode disables ADC and stops conversion when forcing the MNT_STOP bit high in the configuration byte. In this mode, all data is retained in memory that the master can still read and write by using SMBus interface, and be forced to convert once by entering the one-shot command.

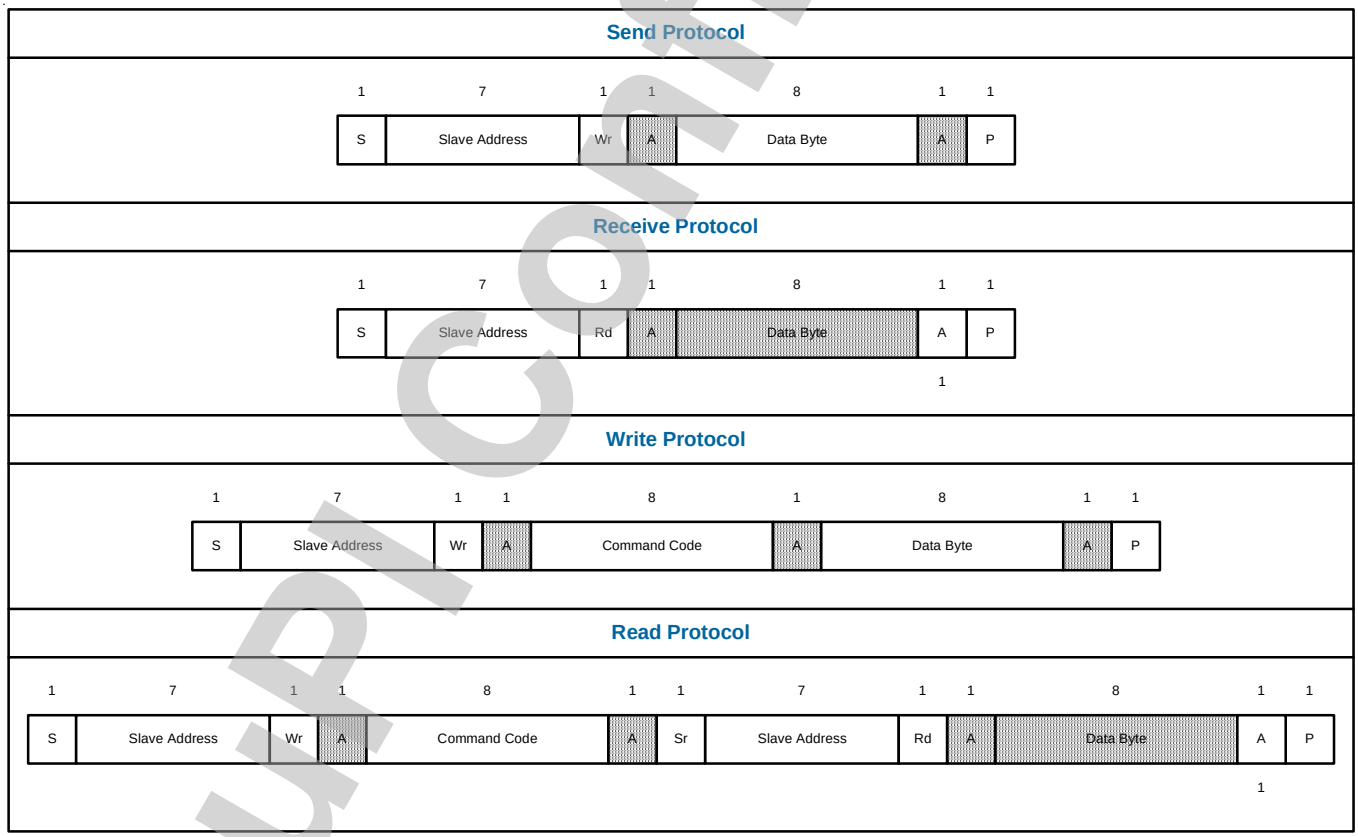
One-Shot Register Command

The one-shot register command initiates the ADC in standby mode. If ADC is running when initiates, the previous data would not be stored. The 0Fh register is written by using the SMBus write protocol.

SMBus Interface

The data of uS5004 transfers by using the standard 2-wire SMBus send, receive, write and read protocol.

Table 1. SMBus Protocol



S: Start, Wr: Write, Rd: Read, A: ACK, Sr: Repeat Start, P: Stop, ☐: Master to slave, ▨: slave to master

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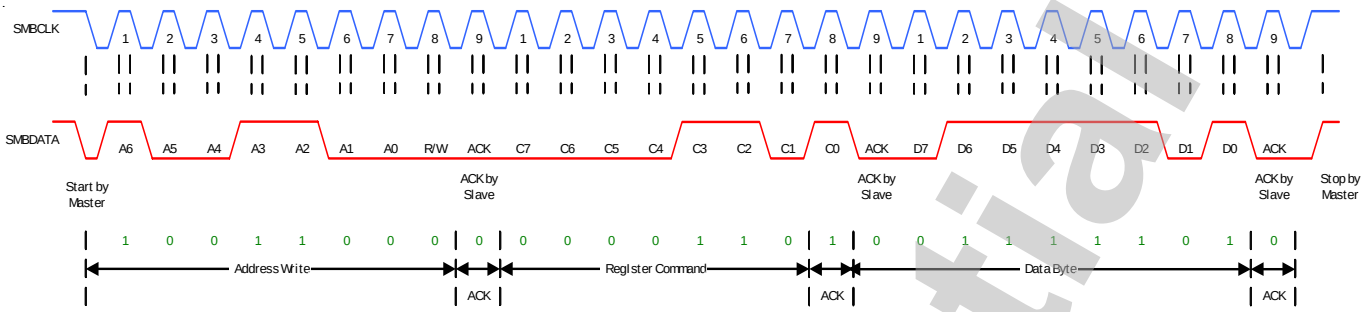


Figure 1. Write example

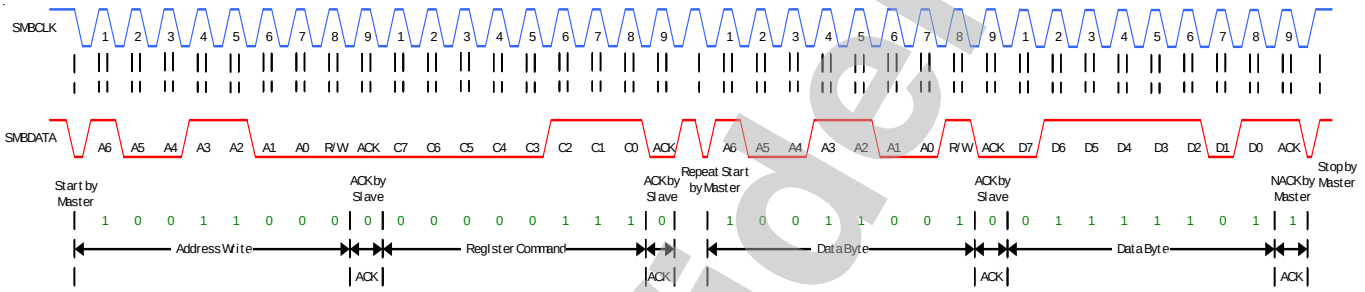


Figure 2.Read example

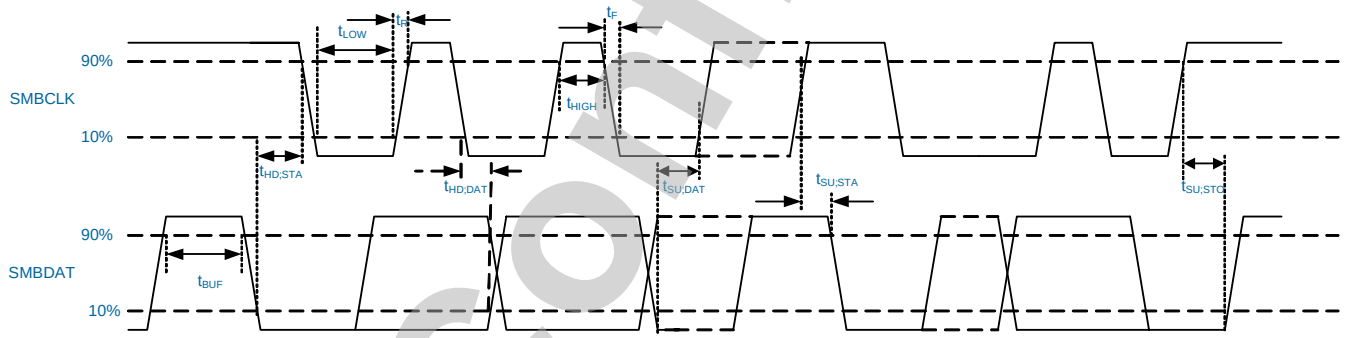


Figure 3. SMBus Communication Timing

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Slave Address

The uS5004 is the slave on the SMBus, and has 7bits slave address as following:

	A6	A5	A4	A3	A2	A1	A0
uS5004P	1	0	0	1	1	0	0
uS5004Q	1	0	0	1	1	0	1

Data Register

The master selected 8bits register command transmitted data read/write of the slave device through the SMBus communication.

Table 2. Register Command Assignment

Register Command	Register Name	Attr.	Function Description	Default
00h	VRLT	RO	Read local diode temperature(LT)	00h
01h	VRRT	RO	Read remote diode temperature(RTMSB)	00h
02h	ALSTS	RO	Read ALERT status	00h
03h	RCFR	RO	Read configuration data format	05h
04h	RCRR	RO	Read conversion rate	08h
05h	RLTHT	RO	Read LT high limit ALERT temperature Alarm	46h
06h	RLTLT	RO	Read LT low limit ALERT temperature Alarm	D8h
07h	RRTHTM(MSB)	RO	Read RTMSB high limit ALERT temperature Alarm	55h
08h	RRTLTM(MSB)	RO	Read RTMSB low limit ALERT temperature Alarm	D8h
09h	WCFR	WO	Write configuration data format	FFh
0Ah	WCRR	WO	Write conversion rate	FFh
0Bh	WLTHAT	WO	Write LT high limit ALERT temperature Alarm	FFh
0Ch	WLTLAT	WO	Write LT low limit ALERT temperature Alarm	FFh
0Dh	WRTHATM(MSB)	WO	Write RTMSB high limit ALERT temperature Alarm	FFh
0Eh	WRTLATM(MSB)	WO	Write RTMSB low limit ALERT temperature Alarm	FFh
0Fh	OSHT	WO	Write one-shot conversion command	FFh
10h	VRRT(LSB)	RO	Read remote diode temperature(RTLSB)	00h
11h	OFTRTM(MSB)	RW	Read/Write offset remote temperature(RTMSB) byte	00h
12h	OFTRTL(LSB)	RW	Read/Write offset remote temperature(RTLSB) byte	00h
13h	RTHATL(LSB)	RW	Read/Write LSB high limit extend byte	00h
14h	RTLATL(LSB)	RW	Read/Write LSB low limit extend byte	00h
16h	AMSK	RW	ALERT mask	04h
19h	RTCT	RW	Read/Write RTMSB critical	64h
20h	LTCT	RW	Read/Write LT Critical	55h
21h	CTH	RW	Critical temperature hysteresis	0Ah
22h	ALERTFQ	RW	SMBus Timeout & FaultQueue Number	87h
BFh	RTFAM	RW	RT Filter & ALERT mode	00h
FCh	SMBADD	RW	SMBus address	4Ch
FDh	VID	RO	Version ID	00h
FEh	MID	RO	Manufacturer ID	EFh
FFh	DID	RO	Device ID	17h

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Temperature Data Format

Both local and remote temperature data can only be read from the local and remote temperature register. Local temperature data is 8 bits, and remote temperature data is represented by 11bits, 2s complements with each data bit representing 0.125°C. When reading the 01h register, the data of 10h register will be memorized, so user should read both register to receive remote temperature completely.

Table 3. Remote temperature data format

Temp. (°C)	Data Format				
	11 Bits Count				
	MSB(-128 ~ +127)			LSB(0 ~ 0.875)	N/A
+127.875	0	111	1111	111	0 0000
+126.375	0	111	1110	001	0 0000
+25.5	0	001	1001	100	0 0000
+1.75	0	000	0001	110	0 0000
+0.5	0	000	0000	100	0 0000
+0.125	0	000	0000	001	0 0000
0	0	000	0000	000	0 0000
-0.125	1	111	1111	111	0 0000
-1.125	1	111	1110	111	0 0000
-25.5	1	110	0110	100	0 0000
-40.0	1	101	1000	000	0 0000

ALERT Interrupt

The ALERT interrupt is open drain and requires a pull-up resister to an external source. It detects high/low remote/local temperature limit, critical temperature and remote diode is disconnected. The interrupt pulls the ALERT line low and causes the status of remote temperature bit high once ALERT alarms. It will be cleared by reading the SMBus reserved ALERT Response Address (Receive Protocol) or the status byte.

Table 4. ALERT Response Address

A6	A5	A4	A3	A2	A1	A0
0	0	0	1	1	0	0

TCRI# Output

The TCRI# output is open drain and requires a pull-up resistor to an external source, it is always in high level, but it is in low level when STS_RTC or STS_LTC bit of status byte is set to 1, which indicates that the remote or local in over temperature condition. It is released to high level when the temperature is lower than value of the RTCRI or LTCRI minus CTH (Critical Temperature Hysteresis), with the register 21h provides user to set the critical temperature hysteresis.

TCRIT2# Output

ALERT#/TCRIT2# pin can be configured as either an ALERT# output or as an TCRIT2# output. TCRIT2# asserts low when the temperature exceeds the programmed local and/or remote high temperature limits. It is reset in the same manner as TCRI# and is not maskable.

Local and Remote Temperature Byte(00h, 01h, 10h)

Table 5. Temperature Data Format for LT(00h) and RTMSB (01h)

Bit	A7	A6	A5	A4	A3	A2	A1	A0
Value	SIGN	64	32	16	8	4	2	1

- 1 LSB= 1°C

Table 6. Temperature Data Format for RTLSB (10h)

Bit	A7	A6	A5	A4	A3	A2	A1	A0
Value	0.5	0.25	0.125	0	0	0	0	0

- 1 LSB= 0.125°C

Status Byte(02h)

The status byte detects the status of ADC, remote diode and both temperature, it indicates whether the ADC is converting, whether the remote diode is open-circuit or the temperature alarm is activated or not. The status byte is cleared by successfully reading. In the one-shot mode, the status byte only can be read after the end of conversion.

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Table 7. Status Byte Data Format

Bit	Name	Function
7	ADC_Busy	1: ADC is busy, it will not cause ALERT output to be pulled low
6	STS_LTHA	1: L_T over L_T high limit ALERT temperature
5	STS_LTLA	1: L_T above L_T low limit ALERT temperature
4	STS_RTHA	1: R_T over R_T high limit ALERT temperature
3	STS_RTLA	1: R_T over R_T low limit ALERT temperature
2	STS_RTO	1: remote diode is disconnected, or DXP is short-circuit to DXN
1	STS_RTC	1: L_T over L_T critical
0	STS_LTC	1: R_T over R_T critical

Configuration Byte(03h, 09h)

The configuration byte shows information of ALERT MASK, ADC mode, remote temperature, POR TCRI# and ALERT fault queue. If ALERT interrupt occurred, the Alert_MSK bit will be set high automatically by reading the status byte or ALERT Response Address.

Bit 5 determines the configuration of Pin 6(ALERT#/ TCRIT2#) on the uS5004. If Bit 5 is 0 (default), then Pin 6 is configured as an ALERT# output. If Bit 5 is 1, then Pin 6 is configured as a TCRIT2# output. Bit 7, the ALERT mask bit, is only active when Pin 6 is configured as an ALERT# output. If Pin 6 is set up as a TCRIT2# output, then Bit 7 has no effect.

Table 8. Configuration Byte Data Format

Bit	Name	Function
7	Alert_MSK	0: ALERT Interrupt is enable
6	MNT_stop	0: auto-convert mode, 1: standby mode
5	TCRIT2#_En	0:ALERT# 1:TCRIT2#
4-3	RSVD	Reserved
2	RT_MntEn	0: Disable monitor R_T, 1: Enable
1	TC_WrEn	0: Disable Override POR Value of Critical Temperature
0	FaultQueue_En	1: ALERT fault queue mode

Conversion Rate Byte(04h/0Ah)

The conversion rate register command applies 0.0625Hz to 16Hz conversion rate to exchange the internal ADC conversion time in auto-convert mode. It is initiated by setting the MNT_STOP bit, one-shot command or power up, and the state of POR is 16Hz.

Table 9. Conversion Rate Byte Data Format

Conversion Rate Read/Write Command: 04h/0Ah	
Data	**Conversion Rate(Hz)**
00h	0.0625
01h	0.125
02h	0.25
03h	0.5
04h	1
05h	2
06h	4
07h	8
08h	16

Local and Remote High Limit Alert Temperature Alarm Byte(05h, 07h, 13h, 0Bh, 0Dh)

Table 10. Local and Remote High Limit Alert Temperature Alarm Data Format

Bit	A7	A6	A5	A4	A3	A2	A1	A0
Value	SIGN	64	32	16	8	4	2	1

- Power-on default is 70°C. 1 LSB= 1°C

Table 11. Remote LSB High Limit Alert Temperature Alarm Data Format(13h)

Bit	A7	A6	A5	A4	A3	A2	A1	A0
Value	0.5	0.25	0.125	0	0	0	0	0

- Power-on default is 0°C. 1 LSB= 0.125°C

Local and Remote Low Limit Alert Temperature Alarm Byte(06h, 08h, 14h, 0Ch, 0Eh)

Table 12. Local and Remote Low Limit Alert Temperature Alarm Data Format

Bit	A7	A6	A5	A4	A3	A2	A1	A0
Value	SIGN	64	32	16	8	4	2	1

- Power-on default is 0°C. 1 LSB= 1°C

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Table 13. Remote LSB High Limit Alert Temperature Alarm Data Format (12h, 14h)

Bit	A7	A6	A5	A4	A3	A2	A1	A0
Value	0.5	0.25	0.125	0	0	0	0	0

● Power-on default is 0°C. 1 LSB= 0.125°C

Offset Register Byte(11h, 12h)

User can program the offset register command to extend the R_T limit if remote temperature measurement is higher than 127°C, and the offset byte should be set the minus value. For example, if the remote offset temperature value is set to -27°C(11100101b, 2s complements), and the remote temperature data format reading is 122°C, the real temperature should be 149°C (122°C - (-27°C)).

Table 14. Offset Remote Temperature RTMSB Byte(11h)

Bit	A7	A6	A5	A4	A3	A2	A1	A0
Value	SIGN	64	32	16	8	4	2	1

● Power-on default is 0°C. 1 LSB= 1°C

Table 15. Offset Remote Temperature RTLSB Byte(12h)

Bit	A7	A6	A5	A4	A3	A2	A1	A0
Value	0.15	0.25	0.125	0	0	0	0	0

● Power-on default is 0°C. 1 LSB= 0.125°C

ALERT Mask Byte(16h)

The ALERT mask byte is mapping to the conditions of ALERT alarm, it can mask every ALERT alarm by setting bits high in the ALERT Mask byte. Notice that the ALERT mask byte works only the Alert_MSK bit low in the configuration byte.

Table 16. Alert Mask Byte Data Format

Bit	Name	Function
7	Reserved	N/A
6	MSK_LTHA	1: L_T high limit Alert masked
5	MSK_LTHA	1: L_T low limit Alert masked
4	MSK_RTHA	1: R_T high limit Alert masked
3	MSK_RTLA	1: R_T high limit Alert masked
2	MSK_RTO	1: R_T open circuit Alert masked
1	MSK_RTC	1: R_T cirtical masked
0	MSK_LTC	1: L_T cirtical masked

Local and Remote Critical Byte(19h, 20h)

Table 17. Local and Remote Critical Data Format

Bit	A7	A6	A5	A4	A3	A2	A1	A0
Value	SIGN	64	32	16	8	4	2	1

● Local Power-on default critical = 85°C

Remote Power-on default critical = 100°C

1 LSB= 1°C

Critical Temperature Hysteresis Byte(21h)

Table 18. Critical Temperature Hysteresis Data Format

Bit	A7	A6	A5	A4	A3	A2	A1	A0
Value				16	8	4	2	1

● Power-on default is 10°C

1 LSB= 1°C, Maximum Value = 31

ALERT Fault Queue

The ALERT fault queue can be set from the Fault Queue_En bit of configuration byte(09h), it does not trigger the ALERT interrupt until three consecutive out of limit remote temperatures of the High/Low ALERT temperature and critical temperature occurred.

RT Filter & ALERT Mode Register Byte(BFh)

The RTFAM byte can set the R_T filter and the ALERT Mode, the table below shows the function description. The R_T filter has four state to suppress erroneous remote temperature readings due to noise, Figure 4, 5 depict the R_T filter reaction to both step response and an impulse input response. Besides, user can set the AM bit high into ALERT comparator mode, it always detects the limit and critical temperature. In ALERT comparator mode, when it is over the limit, the ALERT output is low; and it is high when it is under the limit. Figure 6 shows response of the comparator mode.

Table 19. RT Filter & ALERT Mode Register Byte Data Format

Bit	Name	Function
7~3	Reserved	0
2~1	RTF	00: Filter1, 01: Filter2, 10: Filter3, 11: Filter4
0	AM	0: ALERT interrupt mode, 1: Comparator mode

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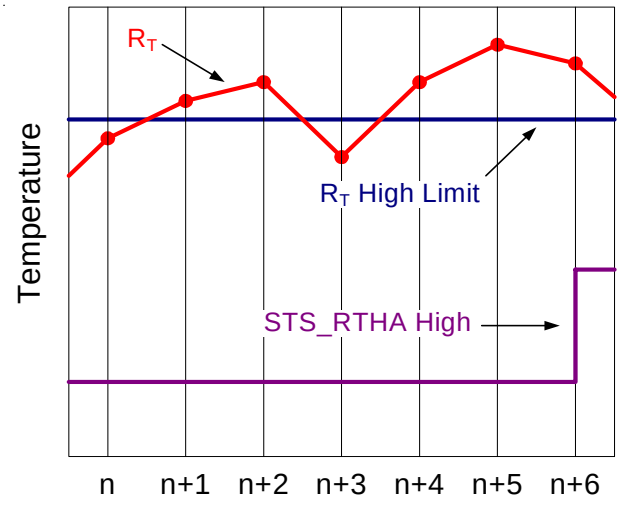


Figure 4. Fault Queue Mode

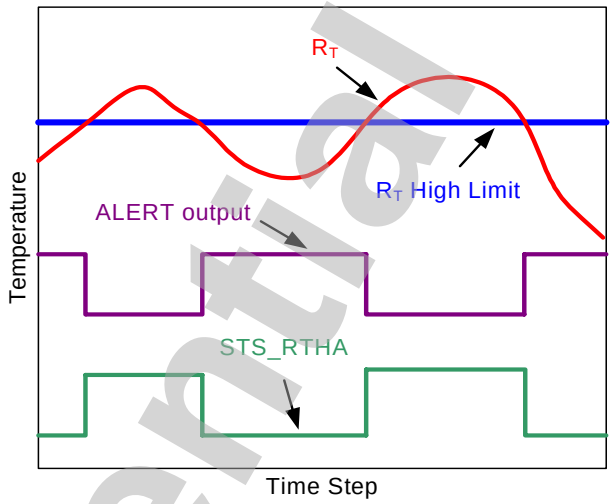


Figure 7. ALERT Comparator Mode

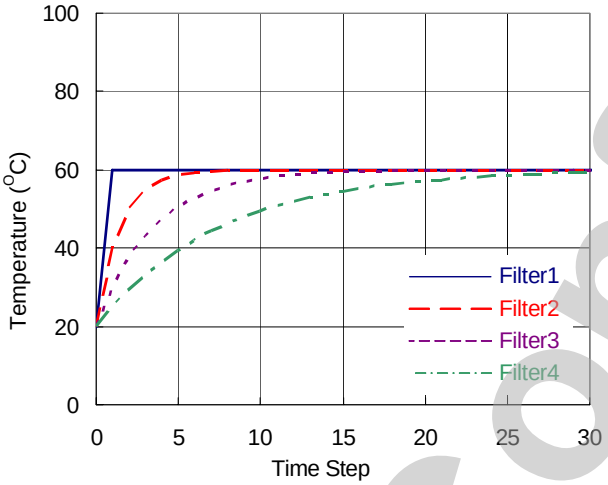


Figure 5. R_T Filter by Step Response

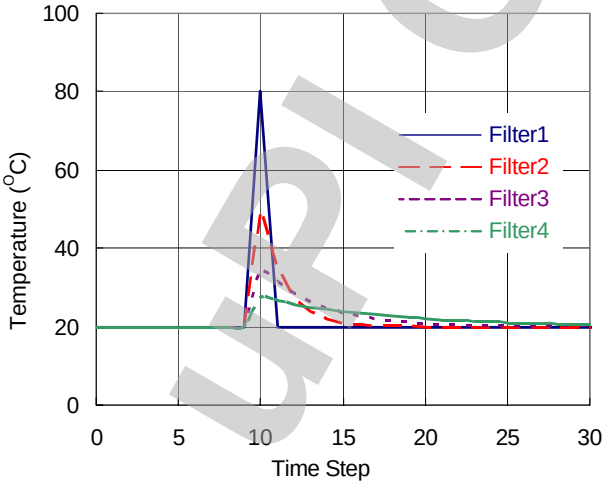


Figure 6. R_T Filter by Impulse Response

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Absolute Maximum Rating

(Note 1)

Supply Input Voltage

- V_{CC} to GND ---------- -0.3V to +4.6V
- DXP to GND ---------- -0.3V to V_{CC}+0.3V
- DXN to GND ---------- -0.3V to +0.8V

SMBCLK, SMBDATA, ALERT to GND ---------- -0.3V to +4.6V

SMBDATA, ALERT Current ---------- -1mA to +50mA

DXN Current ---------- ±1mA

Storage Temperature Range ---------- -65°C to +150°C

Junction Temperature ---------- +150°C

Reflow Temperature (Soldering, 10 sec) ---------- 260°C

ESD Rating (Note 2)

- HBM (Human Body Mode) ---------- 2kV
- MM (Machine Mode) ---------- 200V

Thermal Information

Package Thermal Resistance (Note 3)

- WDFN2x2 - 8L θ_{JA} ---------- 155°C/W
- WDFN2x2 - 8L θ_{JC} ---------- 20°C/W
- MSOP - 8L θ_{JA} ---------- 160°C/W
- MSOP - 8L θ_{JC} ---------- 40°C/W

Power Dissipation, P_D @ TA = 25°C

- WDFN2x2 - 8L ---------- 0.65W
- MSOP - 8L ---------- 0.63W

Recommended Operation Conditions

(Note 4)

Operating Junction Temperature Range ---------- -40°C to +125°C

Operating Ambient Temperature Range ---------- -40°C to +85°C

Input Voltage, V_{IN} ---------- 3V to 3.6V

Note 1. θ_{JA} is measured in the nature convection at T_A = 25°C on a low effective thermal conductivity test board. The case temperature location for measuring θ_{JC} is on the top of the package.

Note 2. T_J is the junction temperature of the remote diode.

Note 3. Guaranteed by design but not 100% tested.

Note 4. The device is not guaranteed to function outside its operating conditions.

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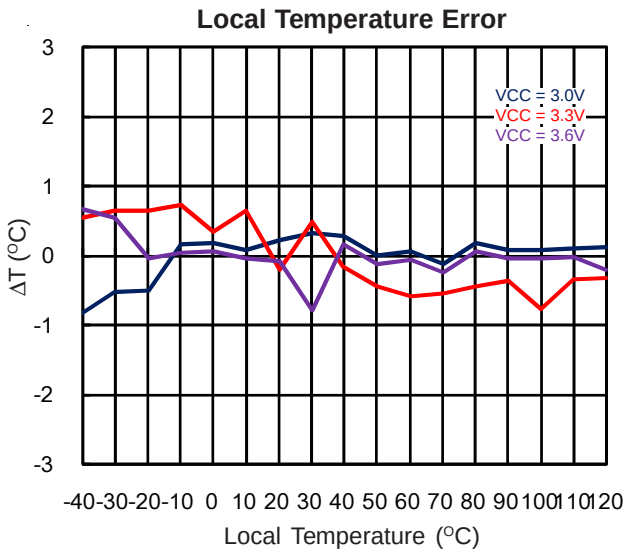
Electrical Characteristics

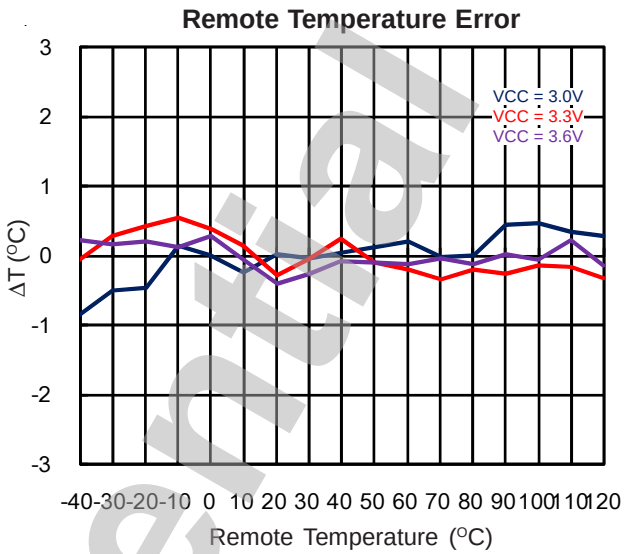
(V_{CC} = +3.3V, T_A = 0°C to +85°C, unless otherwise specified)
Parameters with MIN and/ or MAX limits are 100% tested at +25°C, unless otherwise specified.

Prameter	Test Conditions		Min	Typ	Max	Unit
Supply Input Voltage						
Remote - Diode Temp. Error (Note1)	T_J = +60°C to +100°C		-1	--	+1	°C
	T_J = 0°C to +125°C (Note2)		-3	--	+3	
Local Diode Temp. Error	T_A = +60°C to +100°C		-3	--	+3	°C
	T_A = 0°C to +100°C (Note2)		-5	--	+5	
Supply Voltage			3.0	3.3	3.6	V
UVLO Threshold	VCC input, disables A/D conversion, rising edge		--	2.7	--	V
UVLO Hysteresis			--	25	--	mV
Standby Supply Current	Standby mode. Input forced to VCC/GND.		--	6	--	uA
Average Operation Supply Current	Auto - convert mode. Inputs forced to VCC/ GND	0.5 conv/sec	--	107	--	uA
		8.0 conv/sec	--	400	--	
Conversion Time	From stop bit conversion complete		--	125	--	ms
Conversion Rate Timing	Conversion - Rate Control Byte = 04h, 1Hz		--	1	--	sec
SMBus Interface						
Logic Input High Voltage	STBY, SMBCLK, SMBDATA; Vcc = 3.3V		1.4	--	--	V
Logic Input Low Voltage	STBY, SMBCLK, SMBDATA; Vcc = 3.3V		--	--	0.8	V
Logic Output Low Sink Current	ALERT, SMBDATA forced to 0.4V		6	--	--	mA
ALERT Output High Leakage Current	ALERT forced to 3.3V		--	--	1	uA
Logic Input Current	Logic inputs forced to VCC or GND		-2	--	2	uA
SMBus Operating Frequency	f_{SMB}		10	--	100	kHz
SMBus Timeout	SMBCLK low time for interface reset		25	--	35	ms
SMBCLK Clock Low Time	t_{LOW} , 10% to 10% points		4.7	--	--	us
SMBCLK Clock High Time	t_{HIGH} , 90% to 90% points		4	--	50	us
Bus free time between Stop and Start Condition	t_{BUF}		4.7	--	--	us
SMBus Repeated Start - Condition Setup Time	$t_{SU:STA}$, 90% to 90% points		4.7	--	--	us
SMBus Start - Condition Hold Time	$t_{HD:STA}$, 10% of SMBDATA to 90% of SMBCLK		4	--	--	us
SMBus Stop - Condition Setup Time	$t_{SU:STO}$, 90% of SMBCLK to 10% of SMBDATA		4	--	--	us
SMBus Data Valid to SMBCLK Rising - Edge Time	$t_{SU:DAT}$, 10% or 90% of SMBDATA to 10% of SMBCLK		250	--	--	ns
SMBus Data - Hold Time	$t_{HD:DAT}$		300	--	--	ns
Rising Time of both SMBCLK and SMBDAT	t_R, 10% to 90% points		--	--	1000	ns
Falling Time of both SMBCLK and SMBDAT	t_F, 90% to 10% points		--	--	300	ns

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Typical Operation Characteristics

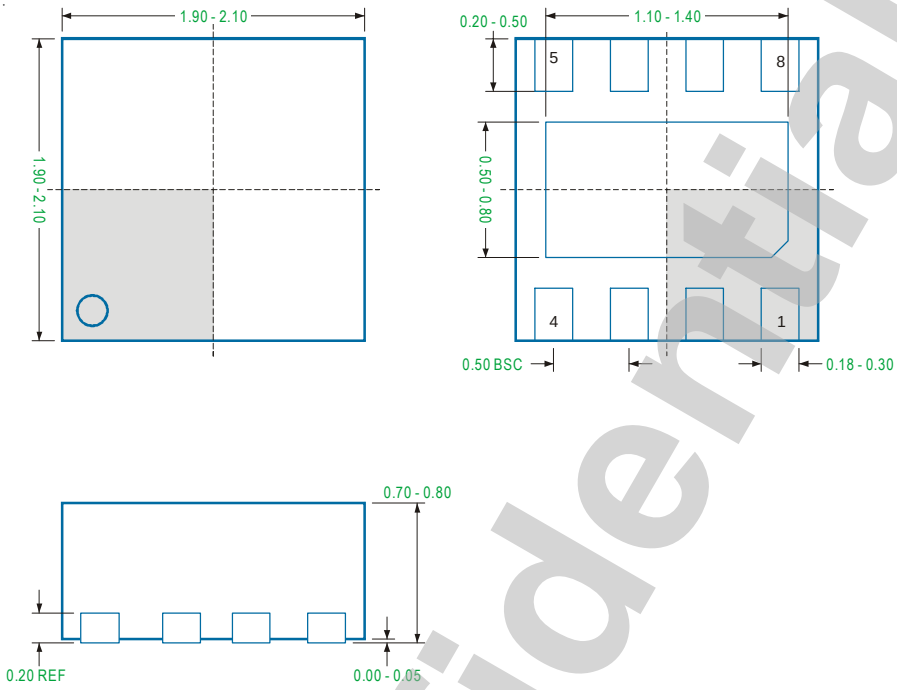




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Package Information

WDFN2x2 - 8L



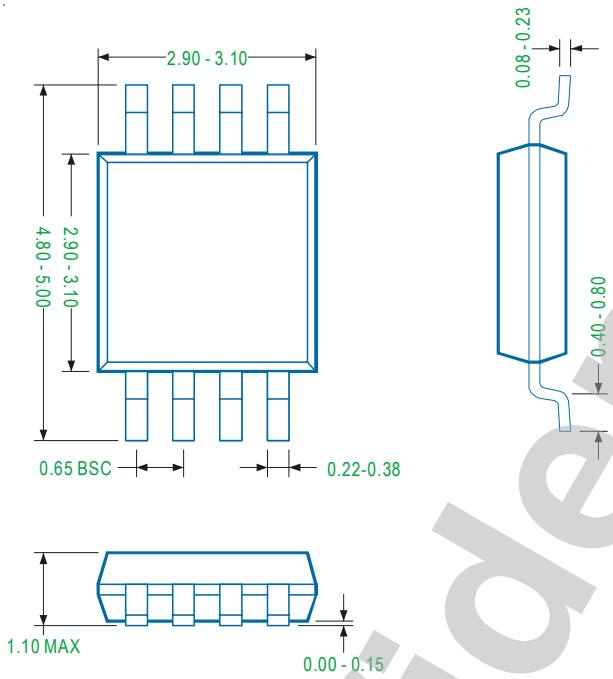
Note

1. Package Outline Unit Description:
   BSC: Basic. Represents theoretical exact dimension or dimension target
   MIN: Minimum dimension specified.
   MAX: Maximum dimension specified.
   REF: Reference. Represents dimension for reference use only. This value is not a device specification.
   TYP. Typical. Provided as a general value. This value is not a device specification.
2. Dimensions in Millimeters.
3. Drawing not to scale.
4. These dimensions do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm.

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Package Information

MSOP - 8L



Note

1. Package Outline Unit Description:
   BSC: Basic. Represents theoretical exact dimension or dimension target
   MIN: Minimum dimension specified.
   MAX: Maximum dimension specified.
   REF: Reference. Represents dimension for reference use only. This value is not a device specification.
   TYP. Typical. Provided as a general value. This value is not a device specification.
2. Dimensions in Millimeters.
3. Drawing not to scale.
4. These dimensions do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm.

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