EMC1002

1°C Dual SMBus Sensor with Resistance Error Correction

PRODUCT FEATURES

Datasheet

General Description

The EMC1002 is an SMBus temperature sensor that monitors up to two temperature zones and can generate two system interrupts. With ±1°C measurement accuracy, the EMC1002 provides a low-cost solution for critical temperature monitoring applications. Extended features include automatic resistance error correction and programmable ideality factor configuration eliminating both major sources of temperature measurement error.[1] The 11-bit sigma delta temperature-to-digital converter provides superb linearity, excellent noise immunity and repeatable temperature readings.

The EMC1002 generates two separate interrupts with programmable thermal trip points. The THERM output operates as a thermostat with programmable threshold and hysteresis. The ALERT output can be configured as a maskable SMBus alert with programmable window comparator limits, or a second THERM output.

The EMC1002 is pin compatible with the ADT7461, ADM1032, LM99, and the MAX6649.

1.Patents pending.

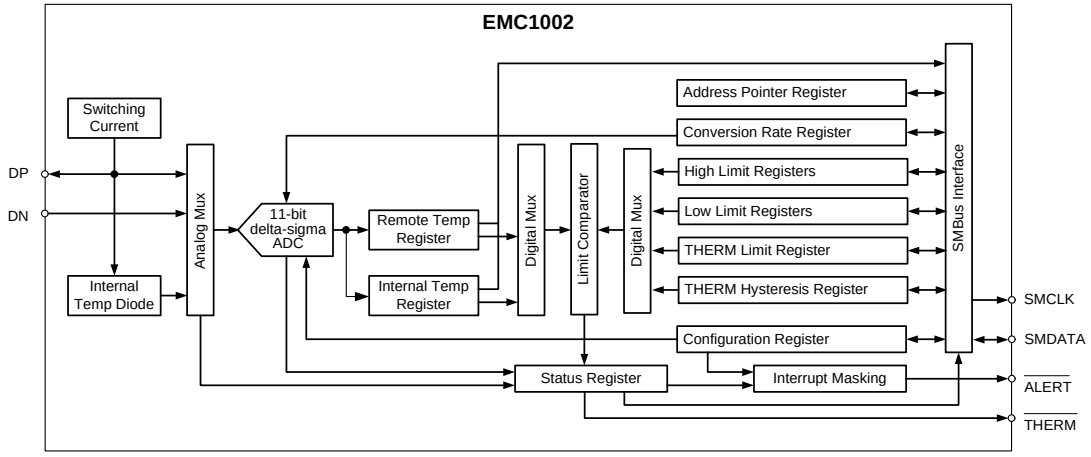
Features

- Resistance Error Correction
- Ideality Factor Configuration
- Select 1 of 4 SMBus addresses with external resistor
- Remote Thermal Zones
  - ±1°C Accuracy (40°C to 80°C)
  - 0.125°C resolution
- Internal Thermal Zone
  - ±3°C Accuracy (0°C to 85°C)
- Maskable Interrupt using ALERT
- One-shot Command during standby
- Programmable temperature conversion rate
- Extended temperature (-64°C to 191°C) available
- Over-limit filtering with consecutive counter
- Small 8-pin MSOP lead-free RoHS Compliant package

Applications

- Desktop and Notebook Computers
- Smart batteries
- Industrial/Automotive
- Other Electronic Systems

Simplified Block Diagram



ORDER NUMBERS:

EMC1002-1-ACZL-TR FOR 8 PIN, MSOP LEAD-FREE ROHS COMPLIANT PACKAGE (Fixed Address, Tape and Reel)

EMC1002-2-ACZL-TR FOR 8 PIN, MSOP LEAD-FREE ROHS COMPLIANT PACKAGE (Variable Address, Tape and Reel)

See Table 1.2, “Ordering Information,” on page 3**.**

Reel size is 4,000 pieces.

Evaluation Board available upon request. (EVB-EMC1002)

80 ARKAY DRIVE, HAUPPAUGE, NY 11788 (631) 435-6000, FAX (631) 273-3123

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Chapter 1 Pin Configuration

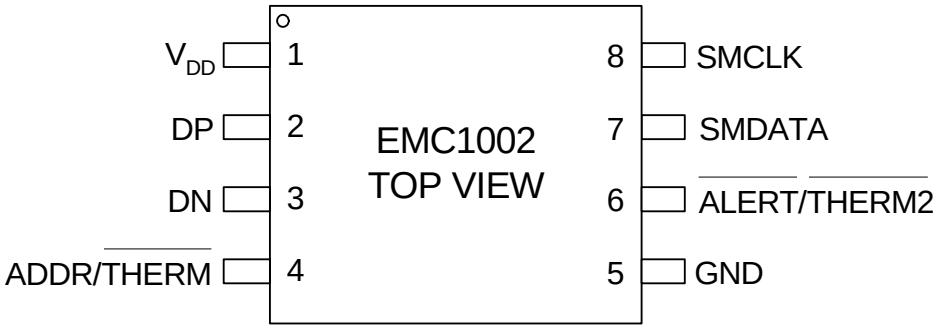


Figure 1.1 EMC1002 Pin Configuration

Table 1.1 Pin Description

PIN	PIN NO.	DESCRIPTION
V_{DD}	1	Supply Voltage, 3.0V to 3.6V.
DP	2	Anode connection for remote temperature diode.
DN	3	Cathode connection for remote temperature diode.
ADDR/$\overline{\text{THERM}}$	4	Logic output that can be used to turn on/off a fan or throttle a CPU clock in the event of an over-temperature condition. This is an open-drain output. For the EMC1002-2, this pin is sampled following power up and the value of the pull-up resistor determines the SMBus slave address per Table 1.2 on page 3. Total capacitance on this pin must not exceed 100 pf, and the pull-up resistor must be connected to the same supply voltage as V_{DD}.
GND	5	Ground.
$\overline{\text{ALERT}}$/$\overline{\text{THERM2}}$	6	Logic output used as interrupt, SMBus alert or as a second THERM output. This is an open-drain output.
SMDATA	7	SMBus data input/output. This is an open-drain output.
SMCLK	8	SMBus clock input.

Table 1.2 Ordering Information

PART NUMBER	$\overline{\text{ADDR}}$/$\overline{\text{THERM}}$ PULL-UP RESISTOR	SMBUS ADDRESS
EMC1002-1	1kΩ or greater (If unused, connect to GND)	1001 100b
EMC1002-2	7.5kΩ ±5% Note 1.1 Note 1.2	1001 100b
	12kΩ ±5% Note 1.2	1001 101b
	20kΩ ±5% Note 1.2	0111 100b
	33kΩ ±5% Note 1.2	0111 101b

Note 1.1 This value must be greater than 1kΩ ±5% and less than or equal to 7.5kΩ ±5%.

Note 1.2 The pull-up resistor must be connected to V_{DD} (pin 1), less than 100pf capacitance on pin.

Table 1.3 Absolute Maximum Ratings

PARAMETER	RATING	UNIT
Supply Voltage V_{DD}	-0.3 to 5.0	V
Voltage on $\overline{ALERT}$/$\overline{THERM2}$, SMDATA and SMCLK pins	-0.3 to 5.5	V
Voltage on any other pin	-0.3 to V_{DD}+0.3	V
Operating Temperature Range	-40 to +125	°C
Storage Temperature Range	-55 to +150	°C
Lead Temperature Range	Refer to JEDEC Spec. J-STD-020	
Package Thermal Characteristics for MSOP-8 (TSSOP)		
Power Dissipation	TBD	
Thermal Resistance (at 0 air flow)	109.6	°C/W
ESD Rating, All Pins (Human Body Model)	2000	V

Note: Stresses above those listed could cause damage to the device. This is a stress rating only and functional operation of the device at any other condition above those indicated in the operation sections of this specification is not implied. When powering this device from laboratory or system power supplies, it is important that the Absolute Maximum Ratings not be exceeded or device failure can result. Some power supplies exhibit voltage spikes on their outputs when the AC power is switched on or off. In addition, voltage transients on the AC power line may appear on the DC output. If this possibility exists, it is suggested that a clamp circuit be used.

Chapter 2 Electrical Characteristics

Table 2.1 Electrical Characteristics

V_{DD}=3.0V to 3.6V, T_A= -40°C to +125°C, Typical values at T_A = 27°C unless otherwise noted						
PARAMETER	**SYMBOL**	**MIN**	**TYP**	**MAX**	**UNITS**	**CONDITIONS**
DC Power						
Supply Voltage	V_{DD}	3.0	3.3	3.6	V	
Average Operating Current	I_{DD}		47	50	µA	0.0625 conversions/s See Table 4.6, "Conversion Rates," on page 15
	I_{PD}		4.8	10	µA	Standby mode
Internal Temperature Monitor						
Temperature Accuracy			± 1 TBD	± 3	°C °C	0°C≤T_A≤85°C -40°C≤T_A≤125°C
Temperature Resolution			0.5		°C	
External Temperature Monitor						
Temperature Accuracy Remote Diode 40°C to 80°C Remote Diode 0°C to 125°C				± 1 ± 3	°C °C	15°C≤T_A≤70°C -40°C≤T_A≤125°C
Temperature Resolution			0.125		°C	
Voltage Tolerance						
Voltage at pin (ADDR/$\overline{\text{THERM}}$,)	V_{TOL}	-0.3		3.6	V	
Voltage at pin ($\overline{\text{ALERT}}$/$\overline{\text{THERM2}}$, SMDATA,SMCLK)	V_{TOL}	-0.3		5.5	V	
Digital Outputs (ADDR/$\overline{\text{THERM}}$, $\overline{\text{ALERT}}$/$\overline{\text{THERM2}}$)						
Output Low Voltage	V_{OL}			0.4	V	I_{OUT}=-4mA
High Level Leakage Current	I_{OH}		0.1	1	µA	V_{OUT}=V_{DD}
SMBus Interface (SMDATA,SMCLK)						
Input High Level	V_{IH}	2.0			V	
Input Low Level	V_{IL}			0.8	V	
Input High/Low Current	I_{IH}/I_{IL}	-1		1	µA	
Hysteresis			500		mV	
Input Capacitance			5		pF	
Output Low Sink Current		6			mA	SMDATA = 0.6V
SMBus Timing						
Clock Frequency	F_{SMB}	10		400	kHz	

Table 2.1 Electrical Characteristics (continued)

V_{DD}=3.0V to 3.6V, T_A= -40°C to +125°C, Typical values at T_A = 27°C unless otherwise noted						
PARAMETER	**SYMBOL**	**MIN**	**TYP**	**MAX**	**UNITS**	**CONDITIONS**
Spike Suppression				50	ns	
Bus free time Start to Stop	T_{BUF}	1.3			µS	
Hold time Start	$T_{HD:STA}$	0.6			µS	
Setup time Start	$T_{SU:STA}$	0.6			µS	
Setup time Stop	$T_{SU:STO}$	0.6			µS	
Data Hold Time	$T_{HD:DAT}$	0.3			µS	
Data Setup Time	$T_{SU:DAT}$	100			ns	
Clock Low Period	T_{LOW}	1.3			µS	
Clock High Period	T_{HIGH}	0.6			µS	
Clock/Data Fall Time	T_F	*		300	ns	*Min = 20+0.1C_b ns
Clock/Data Rise Time	T_R	*		300 Note 2.1	ns	*Min = 20+0.1C_b ns
Capacitive Load (each bus line)	C_b	0.6		400	pF	

Note 2.1 300nS rise time max is required for 400kHz bus operation. For lower clock frequencies, the maximum rise time is (0.1/F_{SMB})+50nS

Chapter 3 System Management Bus Interface Protocol

A host controller, such as an SMSC I/O controller, communicates with the EMC1002 via the two wire serial interface named SMBus. The SMBus interface is used to read and write registers in the EMC1002, which is a slave-only device. A detailed timing diagram is shown in Figure 3.1.

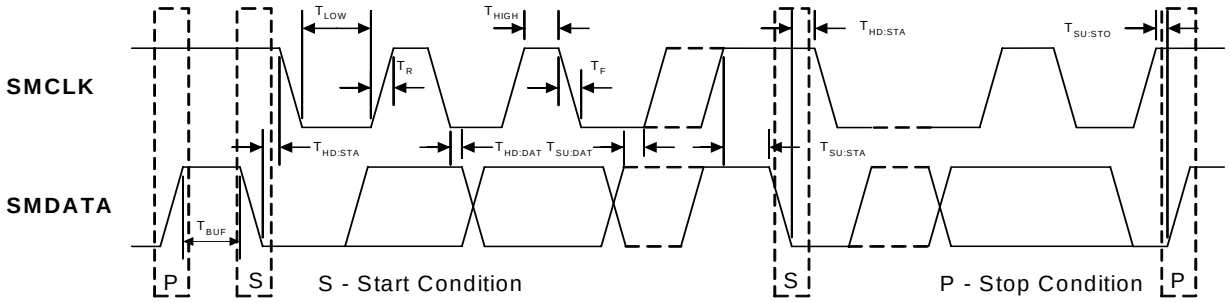


Figure 3.1 System Management Bus Timing Diagram

The EMC1002 implements a subset of the SMBus specification and supports Write Byte, Read Byte, Send Byte, Receive Byte, and Alert Response Address protocols. as shown. In the tables that describe the protocol, the “gray” columns indicate that the slave is driving the bus.

3.1 Write Byte

The Write Byte protocol is used to write one byte of data to the registers as shown below:

Table 3.1 SMBus Write Byte Protocol

START	SLAVE ADDRESS	WR	ACK	COMMAND	ACK	DATA	ACK	STOP
1	7	1	1	8	1	8	1	1

3.2 Read Byte

The Read Byte protocol is used to read one byte of data from the registers as shown below:

Table 3.2 SMBus Read Byte Protocol

START	SLAVE ADDRESS	WR	ACK	COMMAND	ACK	START	SLAVE ADDRESS	RD	ACK	DATA	NACK	STOP
1	7	1	1	8	1	1	7	1	1	8	1	1

3.3 Send Byte

The Send Byte protocol is used to set the Internal Address Register to the correct Address. The Send Byte can be followed by the Receive Byte protocol described below in order to read data from the register. The send byte protocol cannot be used to write data - if data is to be written to a register then the write byte protocol must be used as described in subsection above. The send byte protocol is shown in Table 3.3, "SMBus Send Byte Protocol," on page 7.

Table 3.3 SMBus Send Byte Protocol

FIELD:	START	SLAVE ADDR	WR	ACK	REG. ADDR	ACK	STOP
Bits:	1	7	1	1	8	1	1

3.4 Receive Byte

The Receive Byte protocol is used to read data from a register when the internal register address pointer is known to be at the right location (e.g. set via Send Byte). This can be used for consecutive reads of the same register as shown below:

Table 3.4 SMBus Receive Byte Protocol

FIELD:	START	SLAVE ADDR	RD	ACK	REG. DATA	NACK	STOP
Bits:	1	7	1	1	8	1	1

3.5 Alert Response Address

The $\overline{\text{ALERT}}$/$\overline{\text{THERM2}}$ output can be used as an SMBALERT# as described in Section 4.5 on page 11. The Alert Response Address is polled by the Host whenever it detects an SMBALERT#, i.e. when the $\overline{\text{ALERT}}$/$\overline{\text{THERM2}}$ pin is asserted. The EMC1002 will acknowledge the Alert Response Address and respond with its device address as shown below:

Table 3.5 Modified SMBus Receive Byte Protocol Response to ARA

FIELD:	START	ALERT RESPONSE ADDRESS	RD	ACK	EMC1002 SLAVE ADDRESS	NACK	STOP
Bits:	1	7	1	1	8	1	1

3.6 SMBus Addresses

The EMC1002-2 may be configured to one of four 7-bit slave addresses that are enabled based on the pull-up resistor on the ADDR/$\overline{\text{THERM}}$ pin. The value of this pull-up resistor determines the slave address per Table 1.2, “Ordering Information,” on page 3. Attempting to communicate with the EMC1002 SMBus interface with an invalid slave address or invalid protocol results in no response from the device and does not affect its register contents. The EMC1002 supports stretching of the SMCLK signal by other devices on the SMBus but will not perform this operation itself. The EMC1002 has an SMBus timeout feature. Bit 7 of the Consecutive Alert register enables this function when set to 1 (the default setting is 0). When this feature is enabled, the SMBus will timeout after approximately 25ms of inactivity.

Chapter 4 Product Description

The EMC1002 is an SMBus sensor that can monitor internal temperature and one remote diode temperature. The sensor is typically used with an SMBus host such as an SMSC SIO device or an SMSC fan control chip.

Thermal management is performed in cooperation with the host device. The host reads the temperature data from the EMC1002 and takes appropriate action such as controlling fan speed or processor clock frequency. The EMC1002 has programmable temperature limit registers that define a safe operating window. After the host has configured the temperature limits, the EMC1002 can perform as a free-running independent watchdog to warn the host of temperature hot spots without requiring the host to poll the device.

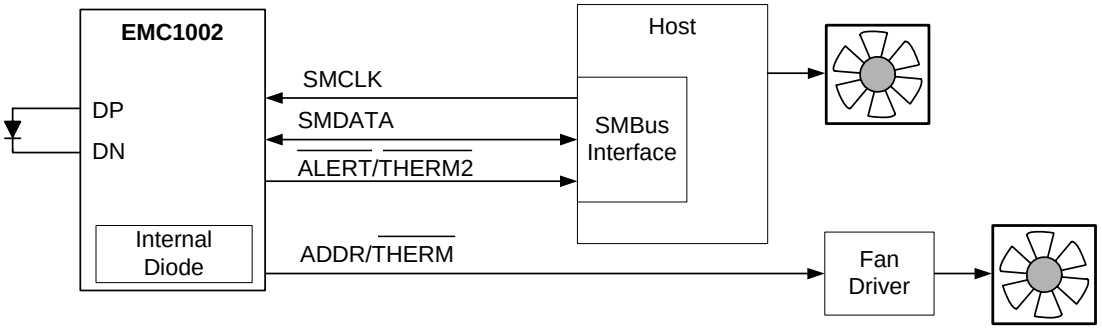


Figure 4.1 System Overview

The EMC1002 has two basic modes of operation:

- Run Mode: In this mode, the EMC1002 continuously converts temperature data and updates its registers. The rate of temperature conversion is configured as shown in 4.11, "Conversion Rate Register," on page 15.
- Standby Mode: In this mode, the EMC1002 is placed in standby to conserve power as described in 4.7, "Standby Mode," on page 13.

4.1 Temperature Monitors

Thermal diode temperature measurements are based on the change in forward bias voltage (ΔV_{BE}) of a diode when operated at two different currents:

$$\Delta V_{BE} = V_{BE_HIGH} - V_{BE_LOW} = \frac{\eta kT}{q} \ln\left(\frac{I_{HIGH}}{I_{LOW}}\right)$$

where:

k = Boltzmann's constant

T = absolute temperature in Kelvin

q = electron charge

η = diode ideality factor

The change in ΔV_{BE} voltage is proportional to absolute temperature T.

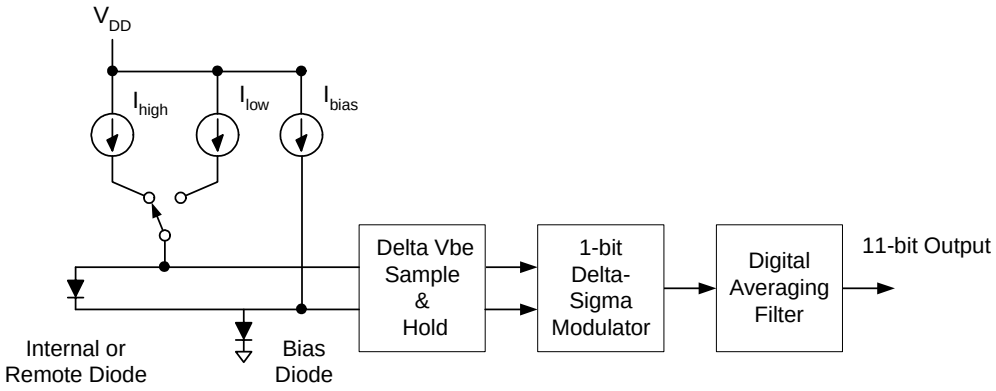


Figure 4.2 Detailed Block Diagram

Figure 4.2 shows a detailed block diagram of the temperature measurement circuit. The EMC1002 incorporates switched capacitor technology that integrates the temperature diode ΔV_{BE} from different bias currents. The negative terminal, DN, for the temperature diode is internally biased with a forward diode voltage referenced to ground.

The advantages of this architecture over Nyquist rate FLASH or SAR converters are superb linearity and inherent noise immunity. The linearity can be directly attributed to the delta-sigma ADC single-bit comparator while the noise immunity is achieved by the ~20ms integration time which translates to 50Hz input noise bandwidth.

4.2 Resistance Error Correction

The EMC1002 includes active resistance error correction implemented in the analog front end of the chip. Without this automatic feature, voltage developed across the parasitic resistance in the remote diode path causes the temperature to read higher than the true zone temperature. The error introduced by parasitic resistance is approximately +0.7°C per ohm. Sources of parasitic resistance include bulk resistance in the remote temperature transistor junctions along with resistance in the printed circuit board traces and package leads.

Resistance error correction in the EMC1002 eliminates the need to characterize and compensate for parasitic resistance in the remote diode path.

4.3 Ideality Factor Configuration

Temperature sensors like the EMC1002 are typically designed for remote diodes with an ideality factor of 1.008. When the diode does not have this exact factor, an error is introduced in the temperature measurement. Programmable offset registers are sometimes used to compensate for this error, but this correction is only perfect at one temperature since the error introduced by ideality factor mismatch is a function of temperature. The higher the temperature measured, the greater the error introduced. The EMC1002 provides a 6-bit ideality factor register for the remote diode. The ideality factor of the remote diode is programmed in a register to eliminate errors across all temperatures. See section 4.16, "Ideality Factor Register," on page 16 for details on programming this register.

4.4 Temperature Measurement Results and Data

The 11-bit temperature measurement results are stored in temperature value registers. The EMC1002 has two temperature ranges and the default range is from 0 to 127°C. This range uses binary number format, and the most significant bit is not used. The extended range is from –64°C to +191°C and is binary offset by 64°C. Table 4.1 shows the two temperature data formats with an LSB equivalent to 0.125°C. The format is selected as described in 4.10, "Configuration Register," on page 14.

Table 4.1 Temperature Data Format

ACTUAL TEMP. (°C)	DEFAULT RANGE BINARY	EXTENDED RANGE OFFSET BINARY
-63	0000 0000 000 Note 4.1	0000 0001 000 Note 4.2
-0.125	0000 0000 000 Note 4.1	0011 1111 111
0	0000 0000 000 Note 4.1	0100 0000 000
+0.125	0000 0000 001	0100 0000 001
+0.250	0000 0000 010	0100 0000 010
+1	0000 0001 000	0100 0001 000
+127	0111 1111 000 Note 4.3	1011 1110 000
+128	0111 1111 000 Note 4.3	1011 1111 000
+190	0111 1111 000 Note 4.3	1111 1110 000
+191	0111 1111 000 Note 4.3	1111 1111 000 Note 4.4

Note 4.1 Data in Binary Format reads 0000 0000 000 for all temperatures ≤ 0.00°C.

Note 4.2 Data in Offset Binary Format reads 0000 0000 000 for all temperatures ≤ -64°C.

Note 4.3 Data in Binary Format reads 0111 1111 000 for all temperatures ≥ +127°C.

Note 4.4 Data in Offset Binary Format reads 1111 1111 000 for all temperatures ≥ +191°C.

The 11-bit temperature data is stored with the 8 most significant bits stored in the High Byte register and the 3 least significant bits in the Low Byte register. The Low Byte register contains the three least significant bits as outlined in Table 4.2. These bits are stored in the upper three bits of the register, and the five LSB positions of this register always read zero. In Table 4.2, the upper case “B” shows the bit position of a 16-bit word created by concatenating the High Byte and Low Byte, and the lower case “b” shows the bit position in the 11-bit temperature data. The resolution of the internal temperature is 0.5°C and the b1 and b0 bits of the Internal Temperature Value Low Byte register will always read 0.

Table 4.2 Bit Position of Two Byte Values

HIGH BYTE								LOW BYTE							
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0	0	0	0	0	0

4.5 $\overline{\text{ALERT}}/\overline{\text{THERM2}}$ Output

The $\overline{\text{ALERT}}/\overline{\text{THERM2}}$ output asserts if an out of limit measurement is detected as described in 4.12, "Limit Registers," on page 16. The $\overline{\text{ALERT}}/\overline{\text{THERM2}}$ pin is an open drain output and requires a pull-up resistor to V_{DD}.The $\overline{\text{ALERT}}/\overline{\text{THERM2}}$ pin can be used as an SMBALERT#, or may be configured as a second $\overline{\text{THERM}}$ output.

As described in the SMBus specification, an SMBus slave may inform the SMBus master that it wants to talk by asserting the SMBALERT# signal. One or more $\overline{\text{ALERT}}$ outputs can be hardwired together as a wired-or bus to a common input.

The $\overline{\text{ALERT}}$/$\overline{\text{THERM2}}$ pin de-asserts when the EMC1002 responds to an alert response address (ARA=0001 100) sent by the host if the out of limit condition no longer exists, but it does not reset if the error condition remains. The $\overline{\text{ALERT}}$/$\overline{\text{THERM2}}$ pin can be masked so that it will not assert in the event of an out of limit temperature measurement, except when it is configured as a second $\overline{\text{THERM}}$ pin.

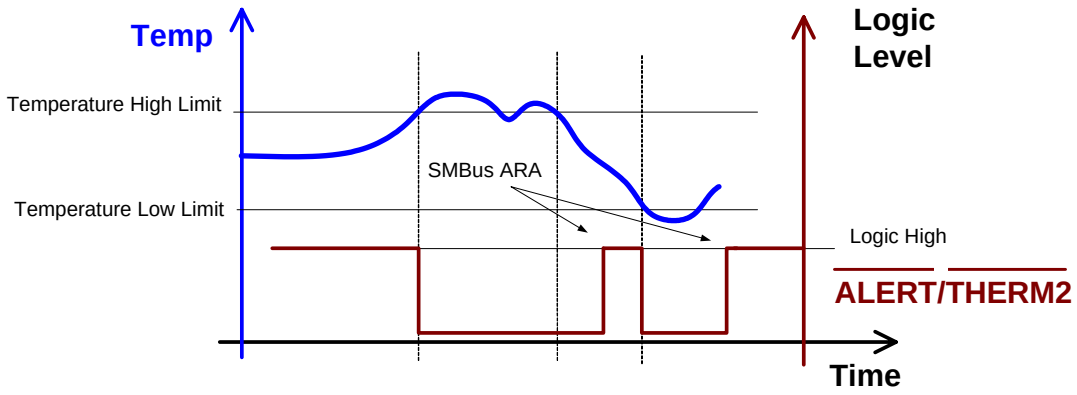


Figure 4.3 $\overline{\text{ALERT}}$/$\overline{\text{THERM2}}$ Response to Temperature Limits Exceeded

The $\overline{\text{ALERT}}$/$\overline{\text{THERM2}}$ pin can be configured as a second $\overline{\text{THERM}}$ pin that asserts when the temperature measurement exceeds the Temperature High Limit value. In this mode, the output will not de-assert until the temperature drops below the Temperature High Limit minus the THERM Hysteresis value.

4.6 ADDR/$\overline{\text{THERM}}$ Output

The ADDR/$\overline{\text{THERM}}$ output asserts if the temperature measurement exceeds the programmable THERM limit. It can be used to drive a fan or other fail-safe devices. The ADDR/$\overline{\text{THERM}}$ pin is open drain and requires a pull-up resistor to V_{DD}. For the EMC1002-2, the value of this pull-up resistor determines the slave address per Table 1.2 on page 3. The ADDR/$\overline{\text{THERM}}$ pin cannot be masked. Do not exceed 100pf capacitance total on this pin.

When the ADDR/$\overline{\text{THERM}}$ pin is asserted, it will not de-assert until the temperature drops below the THERM limit minus the THERM hysteresis value.

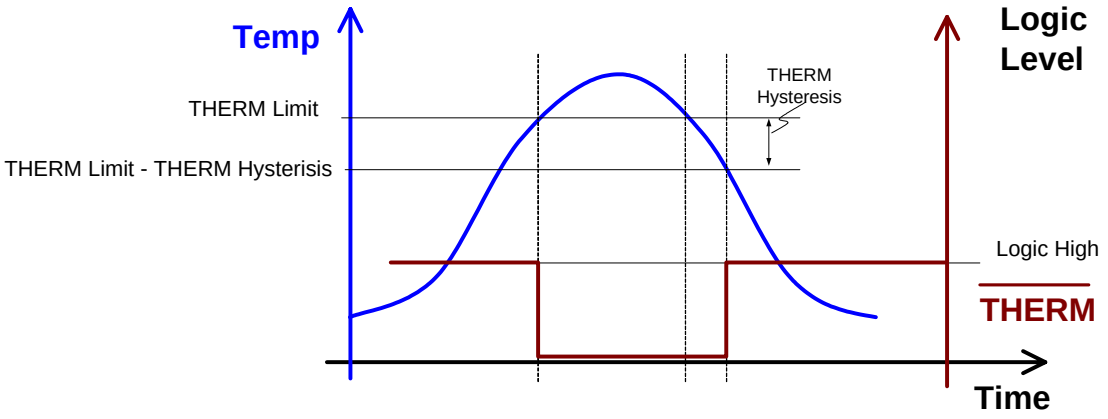


Figure 4.4 ADDR/$\overline{\text{THERM}}$ Output Response to Temperature Limit Exceeded

4.7 Standby Mode

The EMC1002 can be set to standby mode (low power) by setting a bit in the Configuration Register as described in 4.10, "Configuration Register," on page 14. This shuts down all internal analog functions while the SMBus remains enabled. When the EMC1002 is in standby mode, a One-Shot command measurement can be initiated. The user may also write new values to the limit registers described in 4.12, "Limit Registers," on page 16 while in standby. If the previously stored temperature is outside any of the new limits, the ALERT/THERM2 output will respond as described in Section 4.5 and the ADDR/THERM output will respond as described in Section 4.6.

4.8 Register Allocation

The registers shown in Table 4.3 are accessible through the SMBus.

Table 4.3 EMC1002 Register Map

READ ADDRESS (HEX)	WRITE ADDRESS (HEX)	REGISTER NAME	POWER-ON DEFAULT
00	N/A	Internal Temperature Value High Byte	0000 0000
01	N/A	Remote Temperature Value High Byte	0000 0000
02	N/A	Status	undefined
03	09	Configuration	0000 0000
04	0A	Conversion Rate	0000 1000
05	0B	Internal Temperature High Limit	0101 0101 (85°C)
06	0C	Internal Temperature Low Limit	0000 0000 (0°C)
07	0D	Remote Temperature High Limit High Byte	0101 0101 (85°C)
08	0E	Remote Temperature Low Limit High Byte	0000 0000 (0°C)
N/A	0F	One-Shot	
10	N/A	Remote Temperature Value Low Byte	0000 0000
11	11	Scratchpad Byte 1	0000 0000
12	12	Scratchpad Byte 2	0000 0000
13	13	Remote Temperature High Limit Low Byte	0000 0000
14	14	Remote Temperature Low Limit Low Byte	0000 0000
19	19	Remote THERM Limit	0101 0101 (85°C)
20	20	Internal THERM Limit	0101 0101 (85°C)
21	21	THERM Hysteresis	0000 1010 (10°C)
22	22	Consecutive ALERT	0000 0001
27	27	Remote Ideality Factor	0001 0010 (1.008)
29	N/A	Internal Temperature Value Low Byte	0000 0000
FD		Product ID	0000 0010 - EMC1002-1 0000 0011 - EMC1002-2
FE	N/A	Manufacture ID	0101 1101
FF	N/A	Revision Number	0000 0001 Note 4.5

Note 4.5 Revision number may change. Please obtain the latest version of this document from the SMSC web site.

At device power-up, the default values are stored in registers as shown. A power-on-reset is initiated when power is first applied to the part and the V_{DD} supply exceeds the POR threshold. Reads of undefined registers will return 00h and writes to undefined registers will be ignored.

The EMC1002 uses an interlock mechanism that locks the low byte value when the high byte register is read. This prevents updates to the low byte register between high byte and low byte reads. This

interlock mechanism requires that the high byte register always be read prior to reading the low byte register.

4.9 Status Register

The status register is a read only register that stores the operational status of the part.

Table 4.4 Status Register

STATUS REGISTER		
BIT	**NAME**	**FUNCTION**
7	Busy	1 when ADC is converting
6	LHIGH	1 when Internal Temperature High Limit is exceeded
5	LLOW	1 when Internal Temperature Low Limit is exceeded
4	R1HIGH	1 when Remote Temperature High Limit is exceeded
3	R1LOW	1 when Remote Temperature Low Limit is exceeded
2	FAULT	1 when Remote is open circuit
1	R1THRM	1 when Remote THERM Limit is exceeded
0	LTHRM	1 when Internal THERM Limit is exceeded

Bit 7 indicates that the ADC is busy converting a value. Bits 6 and 5 indicate that the internal temperature is above or below its high or low limits respectively. Likewise, bits 4 and 3 indicate that remote temperature is above or below its limits. See 4.12, "Limit Registers," on page 16 for detail on the limits are compared. Bit 2 indicates that an open circuit on the remote diode anode connection has been detected. Bits 1 and 0 indicate that the remote temperature or the internal temperature has exceeded their respective THERM limits. If bits 1 or 0 go high the ADDR/$\overline{\text{THERM}}$ signal will be asserted.

When the status register is read, bits 2 through 6 will individually clear provided that the error condition for that bit no longer exists. The $\overline{\text{ALERT}}$/$\overline{\text{THERM2}}$ output is latched and will not be reset until the host has responded to the SMBALERT# with an alert response address. The $\overline{\text{ALERT}}$/$\overline{\text{THERM2}}$ signal will not reset if the status register has not been cleared.

4.10 Configuration Register

The configuration register controls the functionality of the temperature measurements.

Table 4.5 Configuration Register

CONFIGURATION REGISTER			
BIT	**NAME**	**FUNCTION**	**DEFAULT**
7	MASK1	0 = $\overline{\text{ALERT}}$ enabled 1 = ALERT disabled	0
6	RUN/STOP	0 = Active mode (continuously running) 1 = Standby mode	0

Table 4.5 Configuration Register (continued)

CONFIGURATION REGISTER			
BIT	**NAME**	**FUNCTION**	**DEFAULT**
5	$\overline{\text{ALERT}}$ or $\overline{\text{THERM2}}$	0 = $\overline{\text{ALERT}}$ 1 = $\overline{\text{THERM2}}$	0
4 – 3	Reserved		0
2	Temperature Range Select	0 = 0°C to 127°C 1 = -64°C to 191°C	0
1-0	Reserved		0

Bit 7 is used to mask the $\overline{\text{ALERT}}$/$\overline{\text{THERM2}}$ output. When this bit is set to 0, any out of limit condition will assert $\overline{\text{ALERT}}$/$\overline{\text{THERM2}}$. This bit is ignored if the $\overline{\text{ALERT}}$/$\overline{\text{THERM2}}$ pin is configured as $\overline{\text{THERM2}}$ signal by bit 5.

Bit 6 initiates ADC conversions. When this bit is low, the ADC will convert temperatures in a continuous mode. When this bit is high, the ADC will be in standby mode, thus reducing supply current significantly though the SMBus will still be active. If bit 6 is 1 and the one-shot register is written to, the ADC will execute a temperature measurement and then return to standby mode.

Bit 5 sets the $\overline{\text{ALERT}}$/$\overline{\text{THERM2}}$ pin to act as either an SMBALERT# signal or as the $\overline{\text{THERM2}}$ signal. If bit 5 is set to 1 the $\overline{\text{ALERT}}$/$\overline{\text{THERM2}}$ pin acts as the $\overline{\text{THERM2}}$ signal and bit 7 is ignored.

Bit 2 selects the range and format of the temperature as shown in Table 4.1, “Temperature Data Format,” on page 11

4.11 Conversion Rate Register

The conversion rate register determines how many times the temperature value will be updated per second. The lowest 4 bits configure a programmable delay that waits between consecutive conversion cycles to obtain the desired conversion rate. Table 4.6 shows the conversion rate and the associated quiescent current.

Table 4.6 Conversion Rates

CONVERSION RATE		
VALUE	**CONVERSIONS/SECOND**	**TYPICAL QUIESCENT CURRENT (μA)**
00h	0.0625	47
01h	0.125	50
02h	0.25	53
03h	0.5	56
04h	1	68
05h	2	78
06h	4	106
07h	8	165
08h	16	281
09h	32	500
0Ah	64	550
0Bh to FFh	Reserved	

4.12 Limit Registers

The EMC1002 compares the limit registers to the measured temperature. The data format of the programmed limits for this comparison is the same as the measurement data format determined by the Configuration Register. The user is required to update the limit registers to the new format when changing between measurement data formats.

The user can configure high and low temperature limits and an independent THERM limit. The temperature high limit (T_H) is an 11-bit value that is set by the Temperature High Limit High Byte register and the Temperature High Limit Low Byte register. The Temperature High Limit Low Byte register contains the three least significant bits as shown in Table 4.2 on page 11.

The temperature low limit (T_L) is an 11-bit value that is set by the Temperature Low Limit High Byte register and the Temperature Low Limit Low Byte register as shown in Table 4.2 on page 11.

The limits are automatically compared to the temperature measurement results (T_M) and have been exceeded if ($T_M \leq T_L$ or $T_M > T_H$). If either limit is exceeded then the appropriate bit is set high in the status register and the $\overline{\text{ALERT}}/\overline{\text{THERM2}}$ output will respond as described in Section 4.5 on page 11.

The THERM limit (T_{TH}) is a single byte value set by the THERM Limit register. Exceeding the THERM limit asserts the ADDR/$\overline{\text{THERM}}$ signal as described in Section 4.6 on page 12. When the $\overline{\text{ALERT}}/\overline{\text{THERM2}}$ pin is configured as $\overline{\text{THERM2}}$, then exceeding the high limit asserts this pin.

4.13 THERM Hysteresis Register

The THERM hysteresis register holds a hysteresis value that impacts the de-assertion of $\overline{\text{THERM}}$ as shown in Figure 4.4 on page 12. It defaults to 10°C and can be set by the user at any time after power up. When the $\overline{\text{ALERT}}/\overline{\text{THERM2}}$ pin is configured as $\overline{\text{THERM2}}$, then the output will not de-assert until the temperature drops below the Temperature High Limit minus the THERM Hysteresis value.

4.14 One-Shot Register

Writing to the one-shot register while in standby mode initiates a conversion and comparison cycle. The EMC1002 will execute a temperature measurement, compare the data to the limit registers and return to the standby mode. A write to the one-shot register will be ignored if it occurs while the EMC1002 is in run mode.

4.15 Scratchpad Registers

The scratchpad registers may be used to verify SMBus communications. These registers do not have any affect on the operation of the device, and may be written and read via the SMBus.

4.16 Ideality Factor Register

The ideality factor registers are used to program the remote diode ideality factor into the EMC1002 so that this error source can be eliminated. The default ideality factor is 1.008 and has a value of XX010010b or 12h.

Table 4.7 Diode Ideality Factor Values

DIODE IDEALITY FACTOR	VALUE	DIODE IDEALITY FACTOR	VALUE	DIODE IDEALITY FACTOR	VALUE	DIODE IDEALITY FACTOR	VALUE
0.9850	XX00 0000	**1.0054**	XX01 0000	**1.0267**	XX10 0000	**1.0489**	XX11 0000
0.9862	XX00 0001	**1.0067**	XX01 0001	**1.0280**	XX10 0001	**1.0503**	XX11 0001
0.9875	XX00 0010	**1.0080**	XX01 0010	**1.0294**	XX10 0010	**1.0517**	XX11 0010

Table 4.7 Diode Ideality Factor Values (continued)

DIODE IDEALITY FACTOR	VALUE	DIODE IDEALITY FACTOR	VALUE	DIODE IDEALITY FACTOR	VALUE	DIODE IDEALITY FACTOR	VALUE
0.9888	XX00 0011	**1.0093**	XX01 0011	**1.0308**	XX10 0011	**1.0531**	XX11 0011
0.9900	XX00 0100	**1.0106**	XX01 0100	**1.0321**	XX10 0100	**1.0546**	XX11 0100
0.9913	XX00 0101	**1.0119**	XX01 0101	**1.0335**	XX10 0101	**1.0560**	XX11 0101
0.9925	XX00 0110	**1.0133**	XX01 0110	**1.0349**	XX10 0110	**1.0574**	XX11 0110
0.9938	XX00 0111	**1.0146**	XX01 0111	**1.0363**	XX10 0111	**1.0589**	XX11 0111
0.9951	XX00 1000	**1.0159**	XX01 1000	**1.0377**	XX10 1000	**1.0603**	XX11 1000
0.9964	XX00 1001	**1.0173**	XX01 1001	**1.0391**	XX10 1001	**1.0618**	XX11 1001
0.9976	XX00 1010	**1.0186**	XX01 1010	**1.0404**	XX10 1010	**1.0632**	XX11 1010
0.9989	XX00 1011	**1.0199**	XX01 1011	**1.0418**	XX10 1011	**1.0647**	XX11 1011
1.0002	XX00 1100	**1.0213**	XX01 1100	**1.0432**	XX10 1100	**1.0661**	XX11 1100
1.0015	XX00 1101	**1.0226**	XX01 1101	**1.0446**	XX10 1101	**1.0676**	XX11 1101
1.0028	XX00 1110	**1.0240**	XX01 1110	**1.0460**	XX10 1110	**1.0690**	XX11 1110
1.0041	XX00 1111	**1.0253**	XX01 1111	**1.0475**	XX10 1111	**1.0705**	XX11 1111

4.17 Consecutive ALERT Register

Bit 7 of the Consecutive ALERT register enables the SMBus timeout feature when set to 1 (the default setting is 0). When enabled, the SMBus will timeout after approximately 25ms of inactivity. Table 4.9 describes how bits 3-1 of the Consecutive ALERT register set how many consecutive error conditions must occur for each temperature measurement zone before the $\overline{\text{ALERT}}/\overline{\text{THERM2}}$ signal is asserted. These error conditions include diode faults and exceeding temperature limits. The default value is one which means that any out-of-limit measurement or any diode fault will cause the $\overline{\text{ALERT}}/\overline{\text{THERM2}}$ pin to be asserted. Any combination of bits 3-1 other than those shown will result in a value of one.

Table 4.8 Consecutive ALERT Register

BIT	NAME	FUNCTION	DEFAULT
7	SMBTE	0 = SMBus timeout disabled 1 = SMBus timeout enabled	0
6-4	Reserved		0
3-1	ALERTNUM	See Table 4.9	0
0	Reserved		0

Table 4.9 Consecutive ALERT Value

NUMBER OF EVENTS REQUIRED	VALUE		
	b3	b2	b1
1	0	0	0
2	0	0	1
3	0	1	1
4	1	1	1

Chapter 5 Application Information

This chapter provides information on maintaining accuracy when using diodes as remote sensors with SMSC Environmental Monitoring and Control devices. It is assumed that the users have some familiarity with hardware design and transistor characteristics.

SMSC supplies a family Environmental Monitoring and Control (EMC) devices that are capable of accurately measuring temperatures. Most devices include an internal temperature sensor along with the ability to measure one or more external sensors. The characteristics of an appropriate diode for use as the external sensor are listed in this chapter. Recommendations for the printed circuit board layout are provided to help reduce error caused by electrical noise or trace resistance.

5.1 Maintaining Accuracy

5.1.1 Physical Factors

Temperature measurement is performed by measuring the change in forward bias voltage of a diode when different currents are forced through the junction. The circuit board itself can impact the ability to accurately measure these small changes in voltage.

5.1.1.1 Layout

Apply the following guidelines when designing the printed circuit board:

1. Route the remote diode traces on the top layer.
2. Place a ground guard signal on both sides of the differential pair. This guard band should be connected to the ground plane at least every 0.25 inches.
3. Place a ground plane on the layer immediately below the diode traces.
4. Keep the diode traces as short as possible.
5. Keep the diode traces parallel, and the length of the two traces identical within 0.3 inches.
6. Use a trace width of 0.01 inches with a 0.01 inch guard band on each side.
7. Keep the diode traces away from sources of high frequency noise such as power supply filtering or high speed digital signals.
8. When the diode traces must cross high speed digital signals, make them cross at a 90 degree angle.
9. Avoid joints of copper to solder that can introduce thermocouple effects.

These recommendations are illustrated in Figure 5.1 Routing the Diode Traces on page 18.

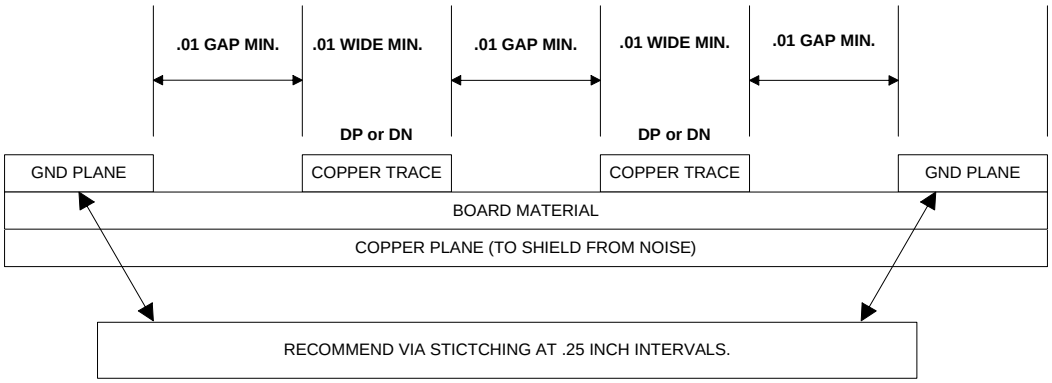


Figure 5.1 Routing the Diode Traces

5.1.1.2 Bypass Capacitors

Accurate temperature measurements require a clean, stable power supply. Locate a 0.1µF capacitor as close as possible to the power pin with a good ground. A low ESR capacitor (such as a 10µF ceramic) should be placed across the power source. Add additional power supply filtering in systems that have a noisy power supply.

A capacitor may be placed across the DP/DN pair at the remote sensor in noisy environments. Do not exceed a value of 2.2nF if this capacitor is installed.

5.1.1.3 Manufacturing

Circuit board assembly processes may leave a residue on the board. This residue can result in unexpected leakage currents that may introduce errors if the circuit board is not clean. For example, processes that use water-soluble soldering fluxes have been known to cause problems if the board is not kept clean.

5.1.1.4 Thermal Considerations

Keep the sensor in good thermal contact with the component to be measured. The temperature of the leads of a discrete diode will greatly impact the temperature of the diode junction. Make use of the printed circuit board to disperse any self-heating that may occur.

5.1.1.5 Remote Sensors Connected by Cables

When connecting remote diodes with a cable (instead of traces on the PCB) use shielded twisted pair cable. The shield should be attached to ground near the EMC1002, and should be left unconnected at the sensor end. Belden 8451 cable is a good choice for this application.

5.1.2 Sensor Characteristics

The characteristics of the diode junction used for temperature sensing will affect the accuracy of the measurement.

5.1.2.1 Selecting a Sensor

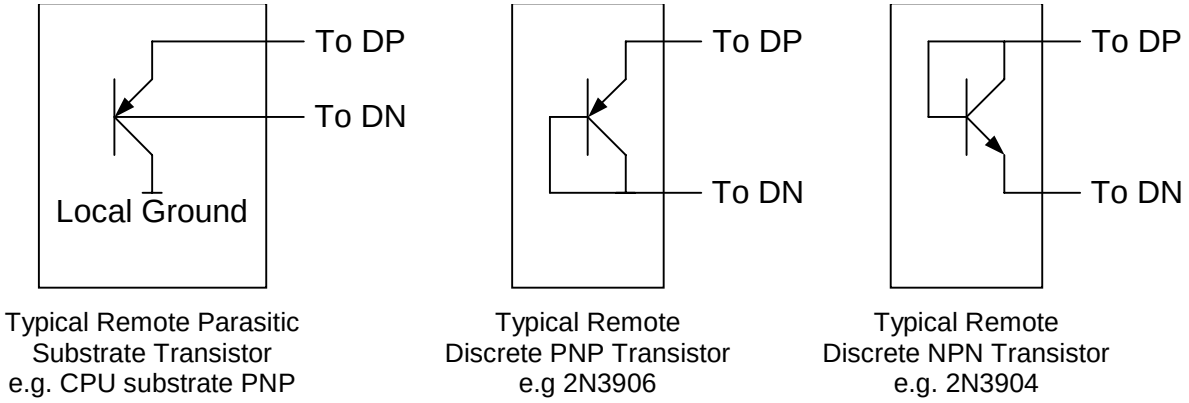
A diode connected small signal transistor is recommended. Silicon diodes are not a good choice for remote sensors. Small signal transistors such as the 2N3904 or the 2N3906 are recommended. Select a transistor with a constant value of h_{FE} in the range of 2.5 to 220 microamps. The magnitude of h_{FE} is not critical, and the variation in h_{FE} from one device to another cancels out of the temperature equations.

5.1.2.2 Compensating for Ideality of the diode

The remote diode may have an ideality factor based on the manufacturing process. Inaccuracy in the temperature measurement resulting from this ideality factor may be eliminated by configuring the ideality factor register. The EMC1002 is trimmed to an ideality factor of 1.008.

5.1.2.3 Circuit Connections

The more negative terminal for the remote temperature diode, DN, is internally biased with a forward diode voltage. Terminal DN is not referenced to ground. Remote temperature diodes can be constructed as shown in Figure 5.2 Remote Temperature Diode Examples on page 20.



Typical Remote Parasitic Substrate Transistor e.g. CPU substrate PNP

Typical Remote Discrete PNP Transistor e.g 2N3906

Typical Remote Discrete NPN Transistor e.g. 2N3904

Figure 5.2 Remote Temperature Diode Examples

Environmental Monitoring and Control (EMC) devices supplied by SMSC are designed to make accurate temperature measurements. Careful design of the printed circuit board and proper selection of the remote sensing diode will help to maintain the accuracy.

Chapter 6 Package Outline

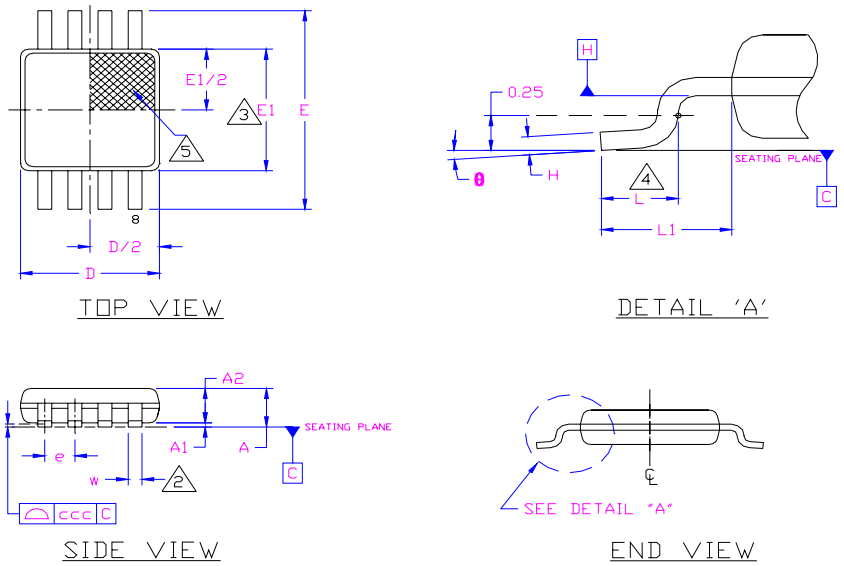


Figure 6.1 8-Pin MSOP and 8-Pin MSOP (Lead-Free) Package Outline - 3x3mm Body 0.65mm Pitch

Table 6.1 8-Pin MSOP and 8-Pin MSOP (Lead-Free) Package Parameters

	MIN	NOMINAL	MAX	REMARKS
A	0.80	~	1.10	Overall Package Height
A1	0.05	~	0.15	Standoff
A2	0.75	0.85	0.95	Body Thickness
D	2.80	3.00	3.20	X Body Size
E	4.65	4.90	5.15	Y Span
E1	2.80	~	3.20	Y body Size
H	0.08	~	0.23	Lead Foot Thickness
L	0.40	~	0.80	Lead Foot Length
L1	0.95 REF			Lead Length
e	0.65 BSC			Lead Pitch
θ	0^o	~	8^o	Lead Foot Angle
W	0.22	~	0.38	Lead Width
ccc	~	~	0.10	Coplanarity

Notes:

1. Controlling Unit: millimeters.
2. Tolerance on the true position of the leads is ± 0.065 mm maximum.
3. Package body dimensions D and E1 do not include mold protrusion or flash. Dimensions D and E1 to be determined at datum plane H. Maximum mold protrusion or flash is 0.15mm (0.006 inches) per end, and 0.15mm (0.006 inches) per side.
4. Dimension for foot length L measured at the gauge plane 0.25 mm above the seating plane.
5. Details of pin 1 identifier are optional but must be located within the zone indicated.