EMCT03

Triple SMBus Temperature Monitor

Datasheet

GENERAL DESCRIPTION

The EMCT03 is a System Management Bus (SMBus) temperature sensor that is capable of monitoring three temperature zones for a PC or embedded environment. The three temperature zones consist of two external and one internal temperature diode. In cooperation with a host device, such as a Super I/O (SIO), thermal management can be performed. Communication takes place over a standard two wire System Management Bus (SMBus). The internal 11 bit delta sigma ADC architecture with digital filtering attributes to superb linearity and immunity to interference and noise.

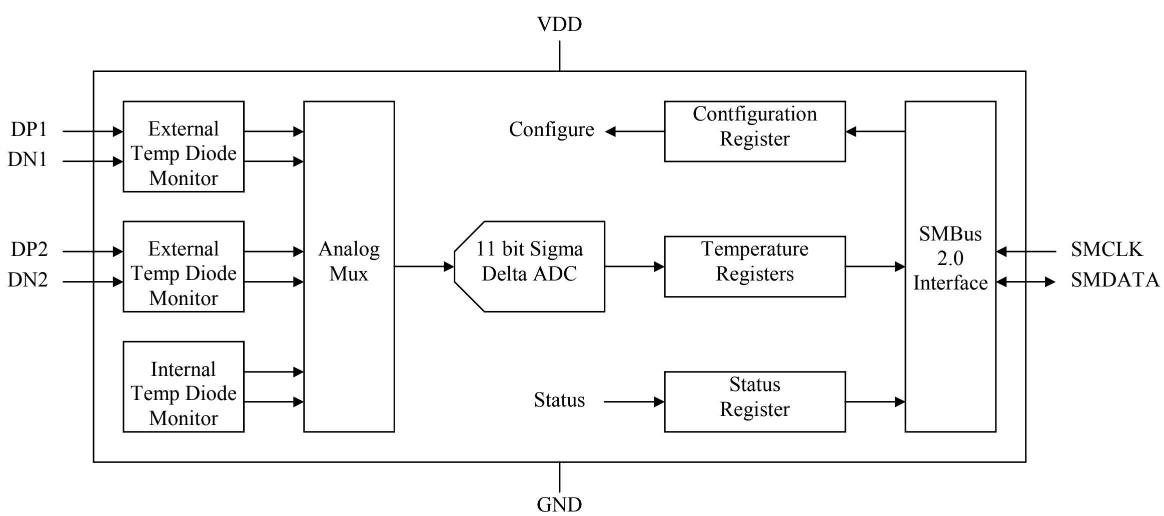
APPLICATIONS

- Desktop and Notebook Computers
- Thermostats
- Smart batteries
- Industrial / Automotive

FEATURES

- Supply:
  - 3.0V to 3.6V
  - Programmable conversion rate
  - < 1mA Active Mode
  - < 3uA in Power Down
- SMBus 2.0 Compliant interface
  - Two programmable addresses
- Two External Temperature Monitors:
  - Range -64°C to +191°C
  - 0.125°C resolution
  - ±1°C Accuracy 40°C to 80°C
  - Diode Fault Reporting
- Internal Temperature Monitor
  - Range 0°C to +85°C
  - 0.125°C resolution
  - ±3°C Accuracy 0°C to 85°C
- TSSOP-8/MSOP-8 3x3mm Package

SIMPLIFIED BLOCK DIAGRAM



ORDERING INFORMATION

Order Number(s):
EMCT03 for 8 pin MSOP or TSSOP package

80 Arkay Drive
Hauppauge, NY 11788
(631) 435-6000
FAX (631) 273-3123

Chapter 1 Pin Configuration

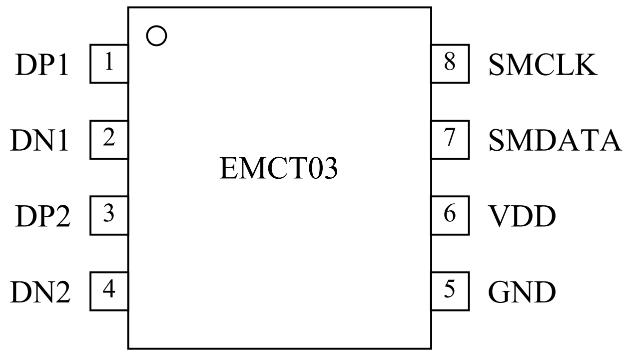


Figure 1.1 EMCT03 Pin Configuration

Table 1.1 Pin Description

PIN	PIN NO.	DESCRIPTION
DP1	1	Positive Analog Input for External Temperature Diode 1
DN1	2	Negative Analog Input for External Temperature Diode 1
DP2	3	Positive Analog Input for External Temperature Diode 2
DN2	4	Negative Analog Input for External Temperature Diode 2
GND	5	Ground
VDD	6	Supply Voltage
SMDATA	7	System Management Bus Clock Input
SMCLK	8	System Management Bus Data Input/Output, open drain output

Table 1.2 Absolute Maximum Ratings

DESCRIPTION	RATING	UNIT
Supply Voltage VDD	-0.3 to 5.0	V
Voltage on any other pin	-0.3 to VDD+0.3	V
Operating Temperature Range	0 to 85	°C
Storage Temperature Range	-55 to 150	°C
ESD Rating, All Pins Human Body Model	2000	V

Chapter 2 Electrical Characteristics

VDD=3.3V±10%, Temp=0°C to 85°C, unless otherwise noted.

CHARACTERISTIC	MIN	TYP	MAX	UNIT
DC Power				
Supply Voltage VDD	3.0	3.3	3.6	V
Current Consumption from VDD: 16 sets of conversions per second 8 sets of conversions per second 4 full sets of conversions per second 2 full sets of conversions per second 1 full set of conversions per second Power Down			3 1.75 1 700 500 3	mA mA mA µA µA µA
POR Threshold		2.5		V
Internal Temperature Monitor				
Temperature Accuracy 0°C to 85°C		± 1	± 3	°C
Temperature Resolution		0.125		°C
Two External Temperature Monitors				
Temperature Accuracy 40°C to 80°C 0°C to 125°C			± 1 ± 3	°C °C
Temperature Resolution		0.125		°C
Current Source Low Level High Level		10 170		µA µA
ADC				
Conversion Time for all three sensors		60		ms
Wake-up from STOP mode (During one shot command or transition to RUN mode)			1	ms
Resolution		11		bit
Differential Non Linearity			± 1	LSB
Integral Non Linearity			± 1	LSB

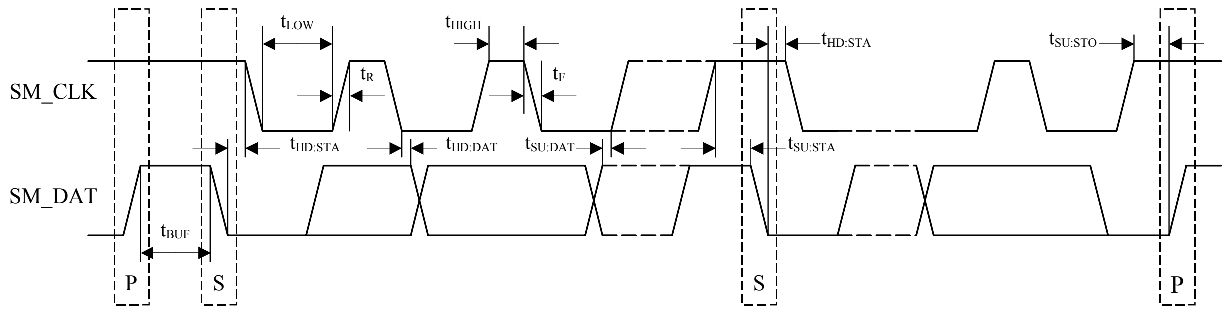


Figure 2.1 System Management Bus Timing Diagram

VDD=3.3V±10%, Temp=0°C to 85°C, unless otherwise noted.

CHARACTERISTIC	MIN	TYP	MAX	UNIT
System Management Bus Timing				
Operating Frequency, F_{SMB}	10		400	kHz
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		0.9	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, $_{TF}$			300	ns
Clock/Data Rise Time, $_{TF}$			300	ns
System Management Bus SM_CLK, SM_DAT				
Input High Current			10	µA
Input Low Current			-10	µA
Input Capacitance			10	pF
Low Input Level			0.8	V
High Input Level	2.0			V
Hysteresis		500		mV
Low Output Level @ 4mA			0.4	V

Chapter 3 Product Description

The EMCT03 is an SMBus sensor that is capable of monitoring three temperature zones for use in a personal computer or embedded environment. The part is meant to be used as a companion to one of SMSC's broad line of SIO host circuits.

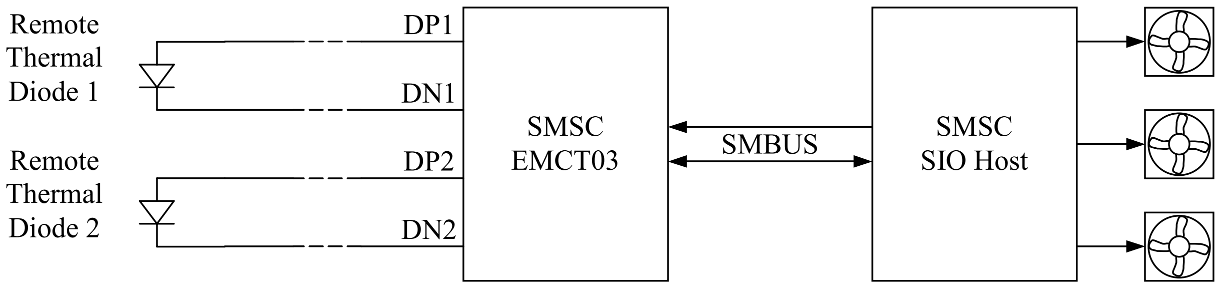


Figure 3.1 System Overview

In cooperation with the host device, thermal management can be performed as outlined in Figure 3.1 above. Thermal management consists of the host reading the temperature data from both the two remote and internal temperature diodes of the EMCT03 and controlling the speed of one or multiple fans. Since the EMCT03 incorporates one internal and two external temperature diode, three separate thermal zones can be monitored and controlled with this application. Also, measured temperature levels can quickly be compared to preset limits within the SIO circuit which in turn will take the appropriate actions and/or signals the rest of the system when values are found to be out of limit.

The EMCT03 has two basic modes of operation:

- Run mode: In this mode, the EMCT03 continuously converts temperature data and updates its registers. Conversion rate is set through the configuration register and ranges from 1 to 16 full sets of three temperature conversions per second.
- Stop Mode: In this mode, the EMCT03 is completely powered down drawing a maximum current of only 3uA. The SMBus is still operating though and a one-shot command can be given which will force the circuit in Run mode temporarily for 1 full set of temperature conversions. The EMCT03 will return to Stop mode after the one shot conversion has finished.

3.1 Temperature Monitors

Thermal diode temperature measurements are based on the change in forward bias voltage of a diode when operated at two different currents:

$$V_{be\_high} - V_{be\_low} = n\frac{KT}{q}\ln\left(\frac{I_{high}}{I_{low}}\right) \qquad (1)$$

where:

K is Boltzmann's constant

T is Absolute Temperature in Kelvin

q is Charge Electron

n is Diode Ideality factor

The change in forward bias voltage is now proportional to absolute temperature T.

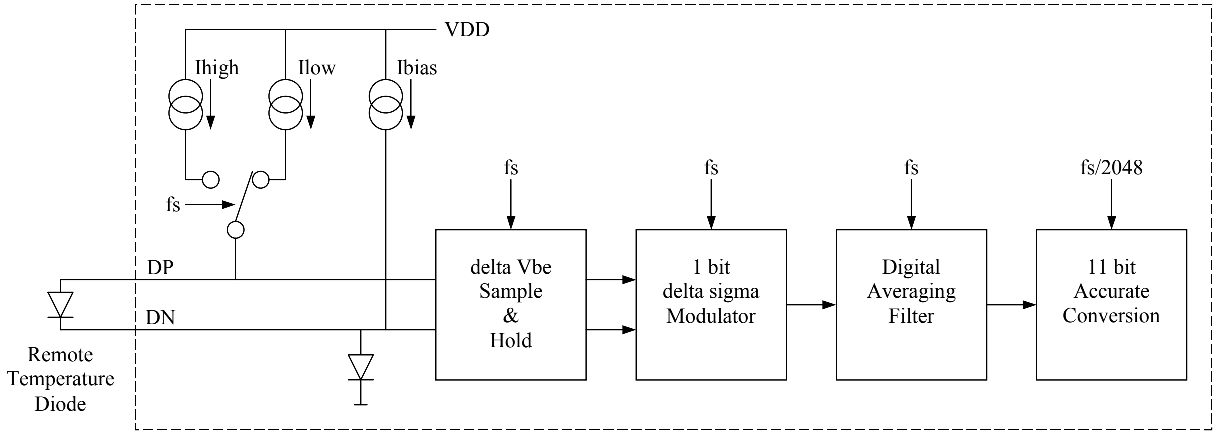


Figure 3.2 Block Diagram of Temperature Measurement Circuit

Figure 3.2 shows a detailed block diagram of the temperature measurement circuit. As shown, the EMCT03 incorporates switched capacitor technology that samples the external remote temperature diode voltage at two bias currents and holds the difference voltage. The sample frequency is 100kHz and the current levels Ihigh and Ilow are 170uA and 10uA respectively. The negative terminal for the remote temperature diode, DN, is internally biased with a forward diode voltage referenced to ground.

The output of the switched capacitor sample and hold circuit interfaces to a single bit delta sigma analog to digital converter. This ADC runs at 100kHz sample frequency and its output is digitally filtered and averaged over 2048 samples effectively generating 11 bit accuracy.

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 digital averaging filter. The overall effective bandwidth of the system is fs/2048 which translates to a 50Hz bandwidth at 100kHz sample rate. Conversion time equals about 20ms per temperature monitor which equals 60ms total for three monitors.

The 11 bit conversion can be displayed in either legacy format or in extended range format. In Legacy format, the temperature range covers –64ºC to 127ºC while in extended format, temperature readings span -64ºC to 191ºC. It should be noted that the latter range is really meant to cover thermal diodes with a non ideal curvature caused by factor n in equation (1) not being equal to exactly 1.000. In general, it is not recommended to run silicon based thermal diodes at temperatures above 150ºC.

3.2 System Management Bus Interface Protocol

The EMCT03 communicates with a host controller, such as an SMSC SIO, through the SMBus. The SMBus is a two wire serial communication protocol between a computer host and its peripheral devices. Detailed timing diagrams can be found in the electrical characteristics of the SMBus. The EMCT03 is SMBus 2.0 compatible and supports Write Byte, Send Byte, Read Byte and Receive Byte as valid protocols as shown below:

3.2.1 Write Byte

The write Byte is used to write one byte of data to the registers as shown in Table 3.1 below:

Table 3.1 SMBus Write Byte Protocol

Start	Slave Address	WR	ACK	Register Address	ACK	Register Data	ACK	STOP
1	7	1	1	8	1	8	1	1

3.2.2 Read Byte

The Read Byte protocol is used to read one byte of data from the registers as shown in Table 3.2 below:

Table 3.2 SMBus Read Byte Protocol

Start	Slave Address	WR	ACK	Register Address	ACK	START	Slave Address	RD	ACK	Register Data	NACK	STOP
1	7	1	1	8	1	1	7	1	1	8	1	1

3.2.3 Send Byte

The Send Byte protocol is used to set the internal address register pointer to the correct address location. No data is transferred during the Send Byte protocol as shown in Table 3.3 below:

Table 3.3 SMBus Send Byte Protocol

START	SLAVE ADDRESS	WR	ACK	REGISTER ADDRESS	ACK	STOP
1	7	1	1	8	1	1

3.2.4 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 in Table 3.4:

Table 3.4 SMBus Receive Byte Protocol

START	SLAVE ADDRESS	RD	ACK	REGISTER ADDRESS	NACK	STOP
1	7	1	1	8	1	1

The EMCT03 is available with two 7-bit slave addresses:

Table 3.5 SMBus Address

CONDITION	EMCT03 ADDRESS
EMCT03 Default Address	1001100
EMCT03 Alternate Address	1001101

Attempting to communicate with the EMCT03 SMBus interface with an invalid slave address or invalid protocol, results in no response from the part and will not affect its register content. The EMCT03 supports stretching of the SMCLK signal by other devices on the SMBus but will not perform this operation itself.

3.3 Register Allocation

The following registers are accessible through the SMBus:

Table 3.6 Register Table

REGISTER READ ADDRESS	REGISTER WRITE ADDRESS	REGISTER NAME	DEFAULT VALUE
00h	N/A	Legacy Format Internal Temperature High Byte	00h
23h	N/A	Legacy Format Internal Temperature Low Byte	00h
01h	N/A	Legacy Format Remote Temperature 1 High Byte	00h
10h	N/A	Legacy Format Remote Temperature 1 Low Byte	00h
F8h	N/A	Legacy Format Remote Temperature 2 High Byte	00h
F9h	N/A	Legacy Format Remote Temperature 2 Low Byte	00h
FAh	N/A	Extended Format Remote Temperature 1 High Byte	00h
FBh	N/A	Extended Format Remote Temperature 1 Low Byte	00h
FCh	N/A	Extended Format Remote Temperature 2 High Byte	00h
FDh	N/A	Extended Format Remote Temperature 2 Low Byte	00h
02h	N/A	Status register	00h
03h	09h	Configuration register	47h
N/A	0Fh	Reserved for One Shot Command	--
FEh	N/A	Manufacturer Identifier	5Dh
FFh	N/A	Silicon Revision Identifier	01h
11h, 16h, 4Ah, 60h, 61h, 62h, 79h, 7Ah	11h, 16h, 4Ah, 60h, 61h, 62h, 79h, 7Ah	Registers Reserved for production test	

During Power on Reset (POR), the default values are stored in the registers. A POR is initiated when power is first applied to the part and the voltage on the VDD supply surpasses the POR level as specified in the electrical characteristics. Any reads to undefined registers will return 00h. Writes to any undefined registers will not have an effect.

The EMCT03 uses an interlock mechanism that prevents changes in register content when fresh readings come in from the ADC during successive reads from a host. When the High Byte is read, the last conversion value is latched into the High Byte and Low Byte. Please note that the interlock mechanism is only effective when reading the High Byte first.

3.4 Temperature Monitor Registers

As shown in Table 3.6, each temperature monitor has two byte wide data registers. The external monitors are equipped with both legacy and extended data format. The 11 bit data temperature is stored aligned to the left resulting in the High Byte to contain temperature in 1°C steps and the Low Byte to contain fractions of °C as outlined below:

Table 3.7 High Byte Temperature Register

REGISTER	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
Temperature High Byte Registers 00h, 01h, F8h, FAh, FCh	SIGN	64	32	16	8	4	2	1

Table 3.8 Low Byte Temperature Register

REGISTER	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
Temperature Low Byte Registers 23h, 10h, F9h, FBh, FDh	0.500	0.250	0.125	0	0	0	0	0

3.5 Legacy Temperature Data Format Registers 00h, 23h, 01h, 10h, F8h, F9h:

For registers displaying legacy temperature data format, the temperature range spans from –63.875ºC to +127.875ºC with 0,125ºC resolution. Temperatures outside this range are clipped to –63.875ºC and +127.875ºC. Data is stored in the registers in 2's compliment as shown in Table 3.9:

Table 3.9 Legacy Temperature Data Format

TEMPERATURE (°C)	2'S COMPLIMENT	HEX
Diode Fault	1000 0000 0000 0000	8000
= -63.875	1100 0000 0010 0000	C020
-63	1100 0001 0000 0000	C100
-1	1111 1111 0000 0000	FF00
0	0000 0000 0000 0000	0000
+0.125	0000 0000 0010 0000	0020
+1	0000 0001 0000 0000	0100
+127	0111 1111 0000 0000	7F00
≥ +127.875	0111 1111 1110 0000	7FE0

3.6 Extended Temperature Data Format Registers FAh, FBh, FCh, FDh

For registers displaying extended temperature data format, a value of 64d is subtracted from the Legacy Format output. This effectively extends the range to cover higher external temperature measurements while still maintaining the 2's compliment format. Obviously, the host will have to compensate and add 64d to the read temperature data. This format spans from –63.875ºC to +191.875ºC with 0.125ºC resolution. Temperatures outside this range are limited to –63.875ºC and +191.875ºC. Table 3.10 shows example temperature readings and register content for this data format.

Table 3.10 Extended Temperature Data Format

ACTUAL TEMP. (°C)	-64°C OFFSET (°C)	2'S COMPLIMENT OF -64°C OFFSET	HEX
Diode Fault		1000 0000 0000 0000	8000
= -63.875	-127.875	1000 0000 0010 0000	8020
-63	-127	1000 0001 0000 0000	8100
-1	-65	1011 1111 0000 0000	BF00
0	-64	1100 0000 0000 0000	C000
+0.125	-63.875	1100 0000 0010 0000	C020
+1	-63	1100 0001 0000 0000	C100
+63	-1	1111 1111 0000 0000	FF00
+64	0	0000 0000 0000 0000	0000
+65	1	0000 0001 0000 0000	0100
+191	127	0111 1111 0000 0000	7F00
= +191.875	127.875	0111 1111 1110 0000	7FE0

Table 3.9 and Table 3.10 show that temperature data is stored in 2's compliment in both Legacy and Extended Temperature Data Format. Both extended and legacy temperature formats are updated simultaneously after every conversion cycle. Code 8000h is reserved for diode fault signaling which occurs when open or short conditions are present between the external DP and DN pins.

3.7 Status Register

Table 3.11 Status Register

REGISTER	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0	DEF
Status	Busy	-	-	-	-	-	D2	D1	00h

The Status register is a read only register and returns the operational status of the part. It indicates an external diode fault conditions through bit 0 and 1. When either D1 or D2 is set, a faulty diode connection is detected for external diode 1 or external diode 2 respectively. Also, when diode faults are detected, temperature readings for the faulty external diode will return 8000h. The EMCT03 detects both open and short conditions for the DP1/2 and DN1/2 pins. Bit 7 of the status register will be set when the parts ADC is busy converting data.

3.8 Configuration Register

Table 3.12 Configuration Register

REGISTER	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0	DEF
Configuration	-	nRun/Stop	-	-	-	CR2	CR1	CR0	47h

Bits 0 through bit 2 of the configuration register set the ADC conversion rate of the part:

Table 3.13 Configuration Registers Conversion Rate

CR2, CR1, CR0	CONVERSION RATE
000	Reserved
001	Reserved
010	Reserved
011	1 Conversions per second
100	2 Conversions per second
101	4 Conversions per second
110	8 Conversions per second
111	16 Conversions per second

A conversion for all 3 temperature readings takes about 60ms. Therefore, the maximum conversion rate, equals 16 conversions per second.

Bits 6 set of the Configuration Register sets the power mode of the part:

Table 3.14 Configuration Registers Data Format

NRUN/STOP	DESCRIPTION
0	Active or Run mode
1	Inactive or Stop mode

In active or run mode, the EMCT03 will operate at the preset conversion rate. In inactive or stop mode, the part is powered down minimizing current consumption to less than 3uA. The SMBus is fully operational in either mode. In inactive or stop mode, a WRITE command to the One Shot register (01h), will trigger a one time conversion of the 3 temperature monitors. After the part finishes the conversion, it will go back to inactive/stop mode. The host can now read the updated temperature information.

Chapter 4 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 electical noise or trace resistance.

4.1 Maintaining Accuracy

4.1.1 Physical Factors

Temperature measurement is performed by measuring the change in forward bias voltage of a diode when two different currents are forced through the junction. The circuit board itself can impact the ability to accurately measure these small changes in voltage. For example, an excessive amount of series resistance can introduce error in the measurement.

4.1.1.1 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. The total distance should not exceed 8 inches.
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 4.1 Routing the Diode Traces on page 13.

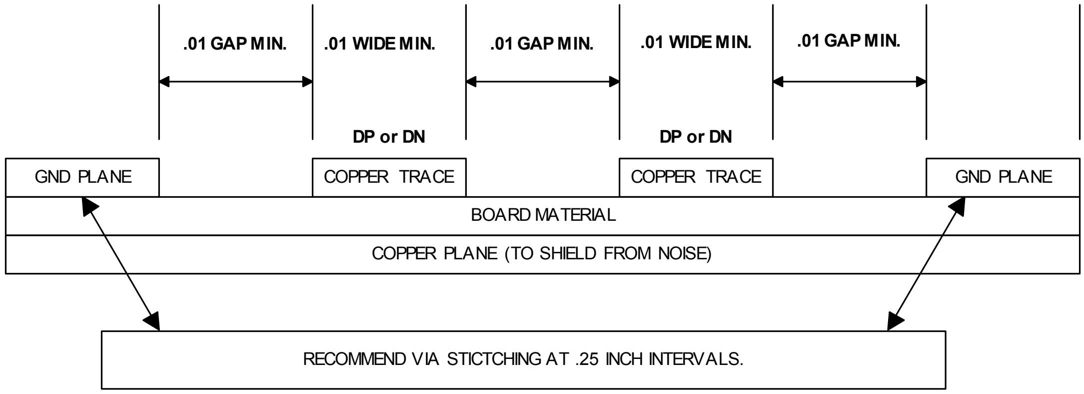


Figure 4.1 Routing the Diode Traces

4.1.1.2 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.

4.1.1.3 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.

4.1.1.4 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.

4.1.2 Sensor Characteristics

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

4.1.2.1 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. Desired characteristics for the sensor include the following:

1. Constant value of h_{FE} in the range of 7.5 to 130 microamps. Variation in h_{FE} from one device to another or one manufacturer to another cancels out of the temperature equations.
2. The lowest emitter and base resistance values will also be helpful as a matter of series input resistance

4.1.2.2 Compensating for Non-Ideality

The remote diode may have a non-ideality factor based on the manufacturing process. Inaccuracy in the temperature measurement resulting from this non-ideality factor may be eliminated by calibrating the remote diode with the temperature sensor. Refer to the product data sheet for register information on a specific component.

4.1.2.3 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 4.2 Remote Temperature Diode Examples on page 14.

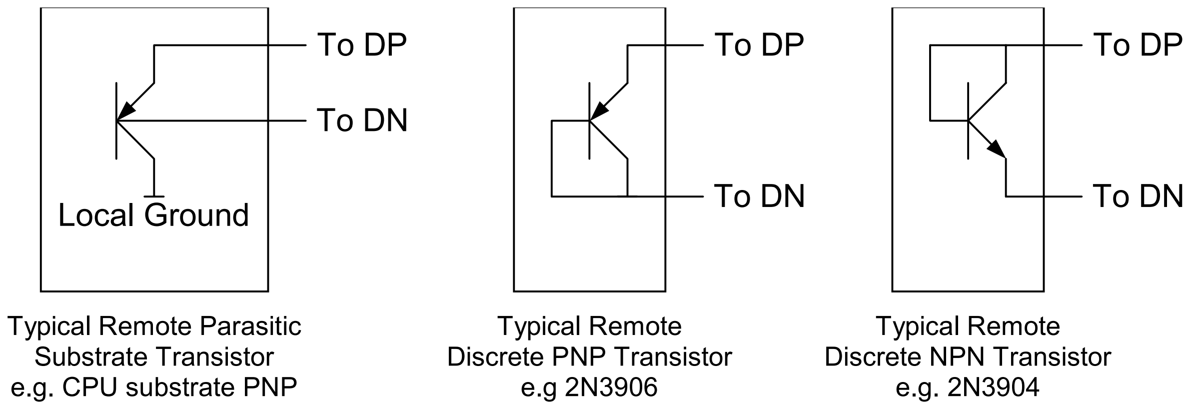


Figure 4.2 Remote Temperature Diode Examples

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 5 Package Outline

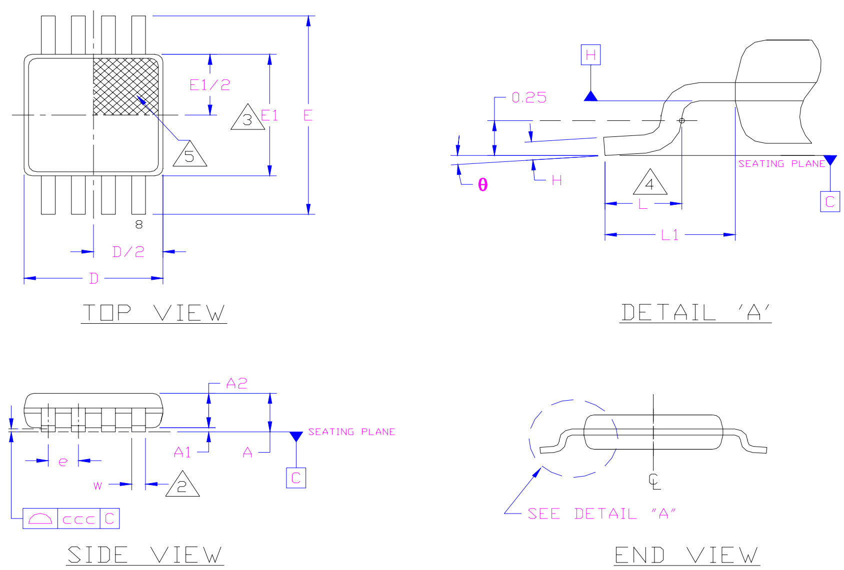


Figure 5.1 8 Pin TSSOP/MSOP Package Outline - 3x3mm Body 0.65mm Pitch

Table 5.1 8 Pin TSSOP/MSOP 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.