



# 1°C Temperature Sensor with Beta Compensation

## PRODUCT FEATURES

Datasheet

### General Description

The EMC1402 is a high accuracy, low cost, System Management Bus (SMBus) temperature sensor. Advanced features such as Resistance Error Correction (REC), Beta Compensation (to support CPU diodes requiring the BJT/transistor model including 45nm, 65nm and 90nm processors) and automatic diode type detection combine to provide a robust solution for complex environmental monitoring applications.

Each device provides  $\pm 1^\circ$  accuracy for external diode temperatures and  $\pm 2^\circ\text{C}$  accuracy for the internal diode temperature. The EMC1402 monitors two temperature channels (one external and one internal).

Resistance Error Correction automatically eliminates the temperature error caused by series resistance allowing greater flexibility in routing thermal diodes. Beta Compensation eliminates temperature errors caused by low, variable beta transistors common in today's fine geometry processors. The automatic beta detection feature monitors the external diode/transistor and determines the optimum sensor settings for accurate temperature measurements regardless of processor technology. This frees the user from providing unique sensor configurations for each temperature monitoring application. These advanced features plus  $\pm 1^\circ\text{C}$  measurement accuracy provide a low-cost, highly flexible and accurate solution for critical temperature monitoring applications.

### Applications

- Notebook Computers
- Desktop Computers
- Industrial
- Embedded applications

### Features

- Support for diodes requiring the BJT/transistor model
  - supports 45nm, 65nm, and 90nm CPU thermal diodes.
- Pin compatible with ADM1032, MAX6649, and LM99
- Automatically determines external diode type and optimal settings
- Resistance Error Correction
- External Temperature Monitors
  - $\pm 1^\circ\text{C}$  Accuracy ( $60^\circ\text{C} < T_{\text{DIODE}} < 100^\circ\text{C}$ )
  - 0.125°C Resolution
- Internal Temperature Monitor
  - $\pm 2^\circ\text{C}$  accuracy
- 3.3V Supply Voltage
- Programmable temperature limits for ALERT and THERM
- Available in Small 8-pin MSOP Lead-free RoHS Compliant Package

**Ordering Information:****EMC1402-1-ACZL-TR FOR 8-PIN, MSOP LEAD-FREE ROHS COMPLIANT PACKAGE****EMC1402-2-ACZL-TR FOR 8-PIN, MSOP LEAD-FREE ROHS COMPLIANT PACKAGE****EMC1402-3-ACZL-TR FOR 8-PIN, MSOP LEAD-FREE ROHS COMPLIANT PACKAGE****EMC1402-4-ACZL-TR FOR 8-PIN, MSOP LEAD-FREE ROHS COMPLIANT PACKAGE****Note:** See [Table 1.1, "Part Selection"](#) for SMBus addressing options.**REEL SIZE IS 4,000 PIECES.****This product meets the halogen maximum concentration values per IEC61249-2-21****For RoHS compliance and environmental information, please visit [www.smsc.com/rohs](http://www.smsc.com/rohs)***Please contact your SMSC sales representative for additional documentation related to this product such as application notes, anomaly sheets, and design guidelines.*

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# Chapter 1 Block Diagram

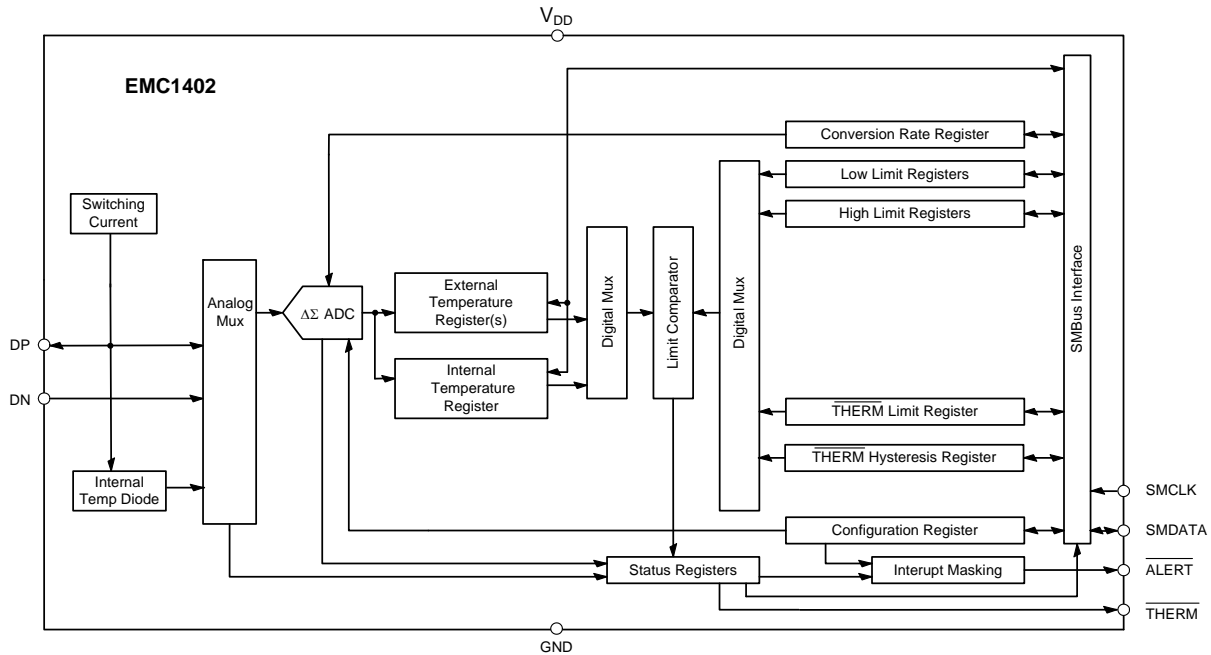


Figure 1.1 EMC1402 Block Diagram

## 1.1 Part Selection

The EMC1402 device configuration is highlighted below.

Table 1.1 Part Selection

PART NUMBER	SMBUS ADDRESS	FUNCTIONALITY				PRODUCT ID
		EXTERNAL DIODES	DIODE 1 DEFAULT CONFIGURATION	DIODE 2 DEFAULT CONFIGURATION	OTHER	
EMC1402 - 1	1001_100xb	1	Detect Diode w/ REC enabled	N/A	Software programmable and maskable High Limits	20h
EMC1402 - 2	1001_101xb					
EMC1402 - 3	0011_000xb					
EMC1402 - 4	0101_001xb				Software programmable THERM Limits	

## Chapter 2 Pin Description

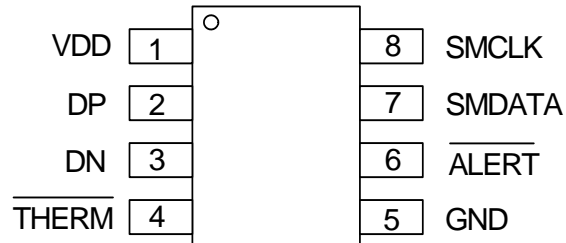


Figure 2.1 EMC1402 Pin Diagram

Table 2.1 EMC1402 Pin Description

PIN NUMBER	NAME	FUNCTION	TYPE
1	VDD	Power supply	Power
2	DP	External diode positive (anode) connection	AIO
3	DN	External diode negative (cathode) connection	AIO
4	$\overline{\text{THERM}}$	Active low Critical $\overline{\text{THERM}}$ output signal - requires pull-up resistor	OD (5V)
5	GND	Ground	Power
6	$\overline{\text{ALERT}}$	Active low digital $\overline{\text{ALERT}}$ output signal - requires pull-up resistor	OD (5V)
7	SMDATA	SMBus Data input/output - requires pull-up resistor	DIOD (5V)
8	SMCLK	SMBus Clock input - requires pull-up resistor	DI (5V)

**APPLICATION NOTE:** For the 5V tolerant pins that have a pull-up resistor ( $\overline{\text{SMCLK}}$ ,  $\overline{\text{SMDATA}}$ ,  $\overline{\text{THERM}}$ , and  $\overline{\text{ALERT}}$ ), the voltage difference between VDD and the pull-up voltage must never exceed 3.6V.

The pin types are described below:

Power - these pins are used to supply either VDD or GND to the device.

AIO - Analog Input / Output.

DI - Digital Input.

OD - Open Drain Digital Output.

DIOD - Digital Input / Open Drain Output.



## Chapter 3 Electrical Specifications

### 3.1 Absolute Maximum Ratings

Table 3.1 Absolute Maximum Ratings

DESCRIPTION	RATING	UNIT
Supply Voltage ( $V_{DD}$ )	-0.3 to 4.0	V
Voltage on 5V tolerant pins ( $V_{5VT\_pin}$ )	-0.3 to 5.5	V
Voltage on 5V tolerant pins ( $ V_{5VT\_pin} - V_{DD} $ ) (see <a href="#">Note 3.1</a> )	-0.3 to 3.6	V
Voltage on any other pin to Ground	-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		
Thermal Resistance ( $\theta_{j-a}$ )	140.8	°C/W
ESD Rating, All pins HBM	2000	V

**Note:** Stresses at or above those listed could cause permanent 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.

**Note 3.1** For the 5V tolerant pins that have a pull-up resistor ( $\overline{SMCLK}$ ,  $\overline{SMDATA}$ ,  $\overline{THERM}$ , and  $\overline{ALERT}$ ), the pull-up voltage must not exceed 3.6V when the device is unpowered.

## 3.2 Electrical Specifications

**Table 3.2 Electrical Specifications**

V <sub>DD</sub> = 3.0V to 3.6V, T <sub>A</sub> = -40°C to 125°C, all typical values at T <sub>A</sub> = 27°C unless otherwise noted.						
CHARACTERISTIC	SYMBOL	MIN	TYP	MAX	UNITS	CONDITIONS
DC Power						
Supply Voltage	V <sub>DD</sub>	3.0	3.3	3.6	V	
Supply Current	I <sub>DD</sub>		430	850	uA	1 conversion / sec, dynamic averaging disabled
			930	1200	uA	4 conversions / sec, dynamic averaging enabled
			1120		uA	≥ 16 conversions / sec, dynamic averaging enabled
Standby Supply Current	I <sub>DD</sub>		170	230	uA	Device in Standby mode, no SMBus communications, ALERT and THERM pins not asserted.
Internal Temperature Monitor						
Temperature Accuracy			±0.25	±1	°C	-5°C < T <sub>A</sub> < 100°C
				±2	°C	-40°C < T <sub>A</sub> < 125°C
Temperature Resolution			0.125		°C	
External Temperature Monitor						
Temperature Accuracy			±0.25	±1	°C	+20°C < T <sub>DIODE</sub> < +110°C 0°C < T <sub>A</sub> < 100°C
				±0.5	±2	°C
Temperature Resolution			0.125		°C	
Conversion Time all Channels	t <sub>CONV</sub>		190		ms	EMC1402, default settings
Capacitive Filter	C <sub>FILTER</sub>		2.2	2.5	nF	Connected across external diode
ALERT and THERM pins						
Output Low Voltage	V <sub>OL</sub>	0.4			V	I <sub>SINK</sub> = 8mA
Leakage Current	I <sub>LEAK</sub>			±5	uA	ALERT and THERM pins Device powered or unpowered T <sub>A</sub> < 85°C pull-up voltage ≤ 3.6V

### 3.3 SMBus Electrical Characteristics

**Table 3.3 SMBus Electrical Specifications**

V <sub>DD</sub> = 3.0V to 3.6V, T <sub>A</sub> = -40°C to 125°C, all typical values are at T <sub>A</sub> = 27°C unless otherwise noted.						
CHARACTERISTIC	SYMBOL	MIN	TYP	MAX	UNITS	CONDITIONS
SMBus Interface						
Input High Voltage	V <sub>IH</sub>	2.0		V <sub>DD</sub>	V	5V Tolerant
Input Low Voltage	V <sub>IL</sub>	-0.3		0.8	V	5V Tolerant
Input High/Low Current	I <sub>IH</sub> / I <sub>IL</sub>			±5	uA	Powered or unpowered T <sub>A</sub> < 85°C
Hysteresis			420		mV	
Input Capacitance	C <sub>IN</sub>		5		pF	
Output Low Sink Current	I <sub>OL</sub>	8.2		15	mA	SMDATA = 0.4V
SMBus Timing						
Clock Frequency	f <sub>SMB</sub>	10		400	kHz	
Spike Suppression	t <sub>SP</sub>			50	ns	
Bus free time Start to Stop	t <sub>BUF</sub>	1.3			us	
Hold Time: Start	t <sub>HD:STA</sub>	0.6			us	
Setup Time: Start	t <sub>SU:STA</sub>	0.6			us	
Setup Time: Stop	t <sub>SU:STP</sub>	0.6			us	
Data Hold Time	t <sub>HD:DAT</sub>	0			us	When transmitting to the master
Data Hold Time	t <sub>HD:DAT</sub>	0.3			us	When receiving from the master
Data Setup Time	t <sub>SU:DAT</sub>	100			ns	
Clock Low Period	t <sub>LOW</sub>	1.3			us	
Clock High Period	t <sub>HIGH</sub>	0.6			us	
Clock/Data Fall time	t <sub>FALL</sub>			300	ns	Min = 20+0.1C <sub>LOAD</sub> ns
Clock/Data Rise time	t <sub>RISE</sub>			300	ns	Min = 20+0.1C <sub>LOAD</sub> ns
Capacitive Load	C <sub>LOAD</sub>			400	pF	per bus line

## Chapter 4 System Management Bus Interface Protocol

### 4.1 System Management Bus Interface Protocol

The EMC1402 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. A detailed timing diagram is shown in [Figure 4.1](#).

For the first 15ms after power-up the device may not respond to SMBus communications.

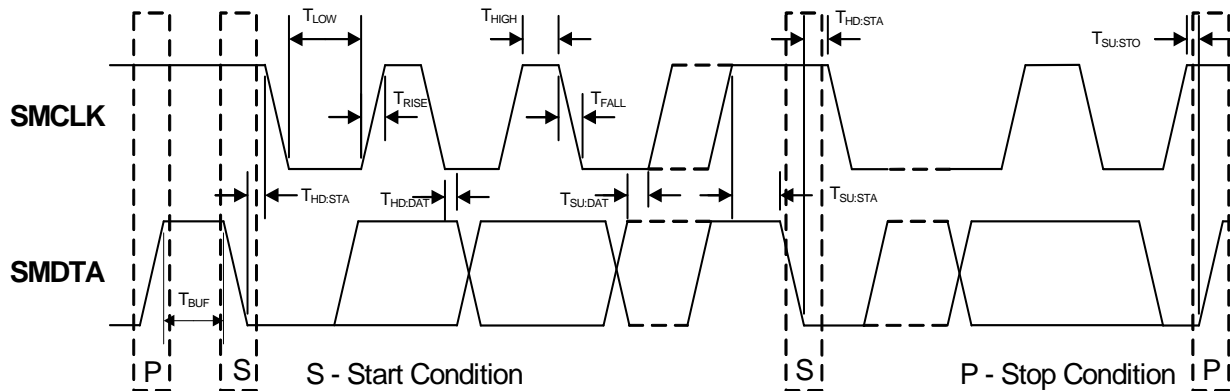


Figure 4.1 SMBus Timing Diagram

The EMC1402 is SMBus 2.0 compatible and support Send Byte, Read Byte, Write Byte, Receive Byte, and the Alert Response Address as valid protocols as shown below.

All of the below protocols use the convention in [Table 4.1](#).

Table 4.1 Protocol Format

DATA SENT TO DEVICE	DATA SENT TO THE HOST
# of bits sent	# of bits sent

Attempting to communicate with the EMC1402 SMBus interface with an invalid slave address or invalid protocol will result in no response from the device and will not affect its register contents. Stretching of the SMCLK signal is supported, provided other devices on the SMBus control the timing.

### 4.2 Write Byte

The Write Byte is used to write one byte of data to the registers as shown below [Table 4.2](#):

Table 4.2 Write Byte Protocol

START	SLAVE ADDRESS	WR	ACK	REGISTER ADDRESS	ACK	REGISTER DATA	ACK	STOP
1 -> 0	1001_100	0	0	XXh	0	XXh	0	0 -> 1

### 4.3 Read Byte

The Read Byte protocol is used to read one byte of data from the registers as shown in [Table 4.3](#).

**Table 4.3 Read Byte Protocol**

START	SLAVE ADDRESS	WR	ACK	REGISTER ADDRESS	ACK	START	SLAVE ADDRESS	RD	ACK	REGISTER DATA	NACK	STOP
1 -> 0	1001_100	0	1	XXh	0	1 -> 0	1001_100	1	1	XX	1	0 -> 1

### 4.4 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 4.4](#).

**Table 4.4 Send Byte Protocol**

START	SLAVE ADDRESS	WR	ACK	REGISTER ADDRESS	ACK	STOP
1 -> 0	1001_100	0	0	XXh	0	0 -> 1

### 4.5 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 is used for consecutive reads of the same register as shown in [Table 4.5](#).

**Table 4.5 Receive Byte Protocol**

START	SLAVE ADDRESS	RD	ACK	REGISTER DATA	NACK	STOP
1 -> 0	1001_100	1	0	XXh	1	0 -> 1

### 4.6 Alert Response Address

The  $\overline{\text{ALERT}}$  output can be used as a processor interrupt or as an SMBus Alert.

When it detects that the  $\overline{\text{ALERT}}$  pin is asserted, the host will send the Alert Response Address (ARA) to the general address of 0001\_100xb. All devices with active interrupts will respond with their client address as shown in [Table 4.6](#).

**Table 4.6 Alert Response Address Protocol**

START	ALERT RESPONSE ADDRESS	RD	ACK	DEVICE ADDRESS	NACK	STOP
1 -> 0	0001_100	1	0	1001_1000	1	0 -> 1

The EMC1402 will respond to the ARA in the following way:

1. Send Slave Address and verify that full slave address was sent (i.e. the SMBus communication from the device was not prematurely stopped due to a bus contention event).
2. Set the MASK bit to clear the  $\overline{\text{ALERT}}$  pin.

**APPLICATION NOTE:** The ARA does not clear the Status Register and if the MASK bit is cleared prior to the Status Register being cleared, the  $\overline{\text{ALERT}}$  pin will be reasserted.

## 4.7 SMBus Address

The EMC1402 responds to hard-wired SMBus slave address as shown in [Table 1.1](#).

**Note:** Other addresses are available. Contact SMSC for more information.

## 4.8 SMBus Timeout

The EMC1402 supports SMBus Timeout. If the clock line is held low for longer than 30ms, the device will reset its SMBus protocol. This function can be enabled by setting the TIMEOUT bit in the Consecutive Alert Register (see [Section 6.11](#)).

## Chapter 5 Product Description

The EMC1402 is an SMBus temperature sensor. The EMC1402 monitors one internal diode and one externally connected temperature diode.

Thermal management is performed in cooperation with a host device. This consists of the host reading the temperature data of both the external and internal temperature diodes of the EMC1402 and using that data to control the speed of one or more fans.

The EMC1402 has two levels of monitoring. The first provides a maskable  $\overline{\text{ALERT}}$  signal to the host when the measured temperatures exceeds user programmable limits. This allows the EMC1402 to be used as an independent thermal watchdog to warn the host of temperature hot spots without direct control by the host. The second level of monitoring provides a non maskable interrupt on the  $\overline{\text{THERM}}$  pin if the measured temperatures meet or exceed a second programmable limit.

Since the EMC1402 automatically corrects for temperature errors due to series resistance in temperature diode lines, there is greater flexibility in where external diodes are positioned and better measurement accuracy than previously available with non-resistance error correcting devices. The automatic beta detection feature means that there is no need to program the device according to which type of diode is present. This also includes CPU diodes that require the transistor or BJT model for monitoring their temperature. Therefore, the EMC1402 can power up ready to operate for any system configuration.

Figure 5.1 shows a system level block diagram of the EMC1402.

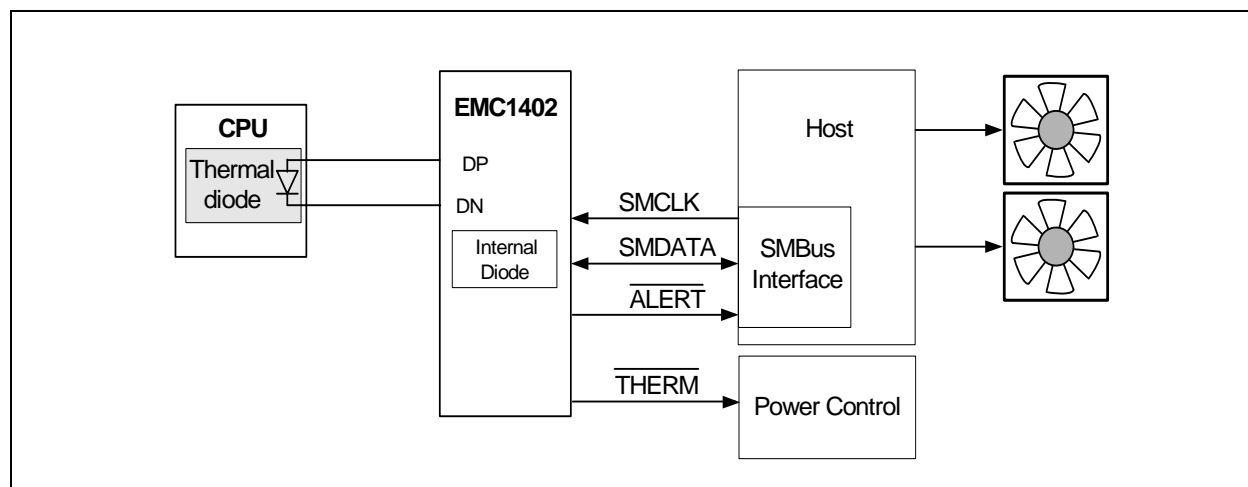


Figure 5.1 System Diagram for EMC1402

### 5.1 Modes of Operation

The EMC1402 has two modes of operation.

- Active (Run) - In this mode of operation, the ADC is converting on all temperature channels at the programmed conversion rate. The temperature data is updated at the end of every conversion and the limits are checked. In Active mode, writing to the one-shot register will do nothing.
- Standby (Stop) - In this mode of operation, the majority of circuitry is powered down to reduce supply current. The temperature data is not updated and the limits are not checked. In this mode of operation, the SMBus is fully active and the part will return requested data. Writing to the one-shot register will enable the device to update all temperature channels. Once all the channels are updated, the device will return to the Standby mode.

### 5.1.1 Conversion Rates

The EMC1402 may be configured for different conversion rates based on the system requirements. The conversion rate is configured as described in [Section 6.5](#). The default conversion rate is 4 conversions per second. Other available conversion rates are shown in [Table 6.6](#).

### 5.1.2 Dynamic Averaging

Dynamic averaging causes the EMC1402 to measure the external diode channels for an extended time based on the selected conversion rate. This functionality can be disabled for increased power savings at the lower conversion rates (see [Section 6.4](#)). When dynamic averaging is enabled, the device will automatically adjust the sampling and measurement time for the external diode channels. This allows the device to average 2x or 16x longer than the normal 11 bit operation (nominally 21ms per channel) while still maintaining the selected conversion rate. The benefits of dynamic averaging are improved noise rejection due to the longer integration time as well as less random variation of the temperature measurement.

When enabled, the dynamic averaging applies when a one-shot command is issued. The device will perform the desired averaging during the one-shot operation according to the selected conversion rate.

When enabled, the dynamic averaging will affect the average supply current based on the chosen conversion rate as shown in [Table 5.1](#) for the EMC1402.

**Table 5.1 Supply Current vs. Conversion Rate for EMC1402**

CONVERSION RATE	AVERAGE SUPPLY CURRENT		AVERAGING FACTOR (BASED ON 11-BIT OPERATION)	
	ENABLED (DEFAULT)	DISABLED	ENABLED (DEFAULT)	DISABLED
1 / 16 sec	660uA	430uA	16x	1x
1 / 8 sec	660uA	430uA	16x	1x
1 / 4 sec	660uA	430uA	16x	1x
1 / 2 sec	660uA	430uA	16x	1x
1 / sec	660uA	430uA	16x	1x
2 / sec	930uA	475uA	16x	1x
4 / sec (default)	950uA	510uA	8x	1x
8 / sec	1010uA	630uA	4x	1x
16 / sec	1020uA	775uA	2x	1x
32 / sec	1050uA	1050uA	1x	1x
64 / sec	1100uA	1100uA	0.5x	0.5x

## 5.2 THERM Output

The THERM output is asserted independently of the ALERT output and cannot be masked. Whenever any of the measured temperatures exceed the user programmed THERM Limit values for the programmed number of consecutive measurements, the THERM output is asserted. Once it has been asserted, it will remain asserted until all measured temperatures drop below the THERM Limit minus the THERM Hysteresis (also programmable).



When the  $\overline{\text{THERM}}$  pin is asserted, the Therm status bits will likewise be set. Reading these bits will not clear them until the  $\overline{\text{THERM}}$  pin is deasserted. Once the  $\overline{\text{THERM}}$  pin is deasserted, the THERM status bits will be automatically cleared.

## 5.3 $\overline{\text{ALERT}}$ Output

The  $\overline{\text{ALERT}}$  pin is an open drain output and requires a pull-up resistor to  $V_{DD}$  and has two modes of operation: interrupt mode and comparator Mode. The mode of the  $\overline{\text{ALERT}}$  output is selected via the ALERT / COMP bit in the Configuration Register (see [Section 6.4](#)).

### 5.3.1 $\overline{\text{ALERT}}$ Pin Interrupt Mode

When configured to operate in interrupt mode, the  $\overline{\text{ALERT}}$  pin asserts low when an out of limit measurement ( $\geq$  high limit or  $<$  low limit) is detected on any diode or when a diode fault is detected. The  $\overline{\text{ALERT}}$  pin will remain asserted as long as an out-of-limit condition remains. Once the out-of-limit condition has been removed, the  $\overline{\text{ALERT}}$  pin will remain asserted until the appropriate status bits are cleared.

The  $\overline{\text{ALERT}}$  pin can be masked by setting the MASK bit. Once the  $\overline{\text{ALERT}}$  pin has been masked, it will be de-asserted and remain de-asserted until the MASK bit is cleared by the user. Any interrupt conditions that occur while the  $\overline{\text{ALERT}}$  pin is masked will update the Status Register normally.

The  $\overline{\text{ALERT}}$  pin is used as an interrupt signal or as an Smbus Alert signal that allows an SMBus slave to communicate an error condition to the master. One or more ALERT outputs can be hard-wired together.

### 5.3.2 $\overline{\text{ALERT}}$ Pin Comparator Mode

When the ALERT pin is configured to operate in comparator mode it will be asserted if any of the measured temperatures exceeds the respective high limit. The  $\overline{\text{ALERT}}$  pin will remain asserted until all temperatures drop below the corresponding high limit minus the THERM Hysteresis value.

When the  $\overline{\text{ALERT}}$  pin is asserted in comparator mode, the corresponding high limit status bits will be set. Reading these bits will not clear them until the  $\overline{\text{ALERT}}$  pin is deasserted. Once the ALERT pin is deasserted, the status bits will be automatically cleared.

The MASK bit will not block the  $\overline{\text{ALERT}}$  pin in this mode, however the individual channel masks (see [Section 6.10](#)) will prevent the respective channel from asserting the  $\overline{\text{ALERT}}$  pin.

## 5.4 Beta Compensation

The EMC1402 is configured to monitor the temperature of basic diodes (e.g. 2N3904), or CPU thermal diodes. It automatically detects the type of external diode (CPU diode or diode connected transistor) and determines the optimal setting to reduce temperature errors introduced by beta variation. Compensating for this error is also known as implementing the transistor or BJT model for temperature measurement.

For discrete transistors configured with the collector and base shorted together, the beta is generally sufficiently high such that the percent change in beta variation is very small. For example, a 10% variation in beta for two forced emitter currents with a transistor whose ideal beta is 50 would contribute approximately 0.25°C error at 100°C. However for substrate transistors where the base-emitter junction is used for temperature measurement and the collector is tied to the substrate, the proportional beta variation will cause large error. For example, a 10% variation in beta for two forced emitter currents with a transistor whose ideal beta is 0.5 would contribute approximately 8.25°C error at 100°C.

## 5.5 Resistance Error Correction (REC)

Parasitic resistance in series with the external diodes will limit the accuracy obtainable from temperature measurement devices. The voltage developed across this resistance by the switching diode currents cause the temperature measurement to read higher than the true temperature. Contributors to series resistance are PCB trace resistance, on die (i.e. on the processor) metal

resistance, bulk resistance in the base and emitter of the temperature transistor. Typically, the error caused by series resistance is +0.7°C per ohm. The EMC1402 automatically corrects up to 100 ohms of series resistance.

## 5.6 Programmable External Diode Ideality Factor

The EMC1402 is designed for external diodes with an ideality factor of 1.008. Not all external diodes, processor or discrete, will have this exact value. This variation of the ideality factor introduces error in the temperature measurement which must be corrected for. This correction is typically done using programmable offset registers. Since an ideality factor mismatch introduces an error that is a function of temperature, this correction is only accurate within a small range of temperatures. To provide maximum flexibility to the user, the EMC1402 provides a 6-bit register for each external diode where the ideality factor of the diode used is programmed to eliminate errors across all temperatures.

**APPLICATION NOTE:** When monitoring a substrate transistor or CPU diode and beta compensation is enabled, the Ideality Factor should not be adjusted. Beta Compensation automatically corrects for most ideality errors.

## 5.7 Diode Faults

The EMC1402 detects an open on the DP and DN pins, and a short across the DP and DN pins. For each temperature measurement made, the device checks for a diode fault on the external diode channel(s). When a diode fault is detected, the ALERT pin asserts (unless masked, see [Section 5.8](#)) and the temperature data reads 00h in the MSB and LSB registers (note: the low limit will not be checked). A diode fault is defined as one of the following: an open between DP and DN, a short from  $V_{DD}$  to DP, or a short from  $V_{DD}$  to DN.

If a short occurs across DP and DN or a short occurs from DP to GND, the low limit status bit is set and the ALERT pin asserts (unless masked). This condition is indistinguishable from a temperature measurement of 0.000degC (-64°C in extended range) resulting in temperature data of 00h in the MSB and LSB registers.

If a short from DN to GND occurs (with a diode connected), temperature measurements will continue as normal with no alerts.

## 5.8 Consecutive Alerts

The EMC1402 contains multiple consecutive alert counters. One set of counters applies to the  $\overline{\text{ALERT}}$  pin and the second set of counters applies to the  $\overline{\text{THERM}}$  pin. Each temperature measurement channel has a separate consecutive alert counter for each of the  $\overline{\text{ALERT}}$  and  $\overline{\text{THERM}}$  pins. All counters are user programmable and determine the number of consecutive measurements that a temperature channel(s) must be out-of-limit or reporting a diode fault before the corresponding pin is asserted.

See [Section 6.11](#) for more details on the consecutive alert function.

## 5.9 Digital Filter

To reduce the effect of noise and temperature spikes on the reported temperature, the External Diode channel uses a programmable digital filter. This filter can be configured as Level 1, Level 2, or Disabled. The typical filter performance is shown in [Figure 5.2](#) and [Figure 5.3](#).

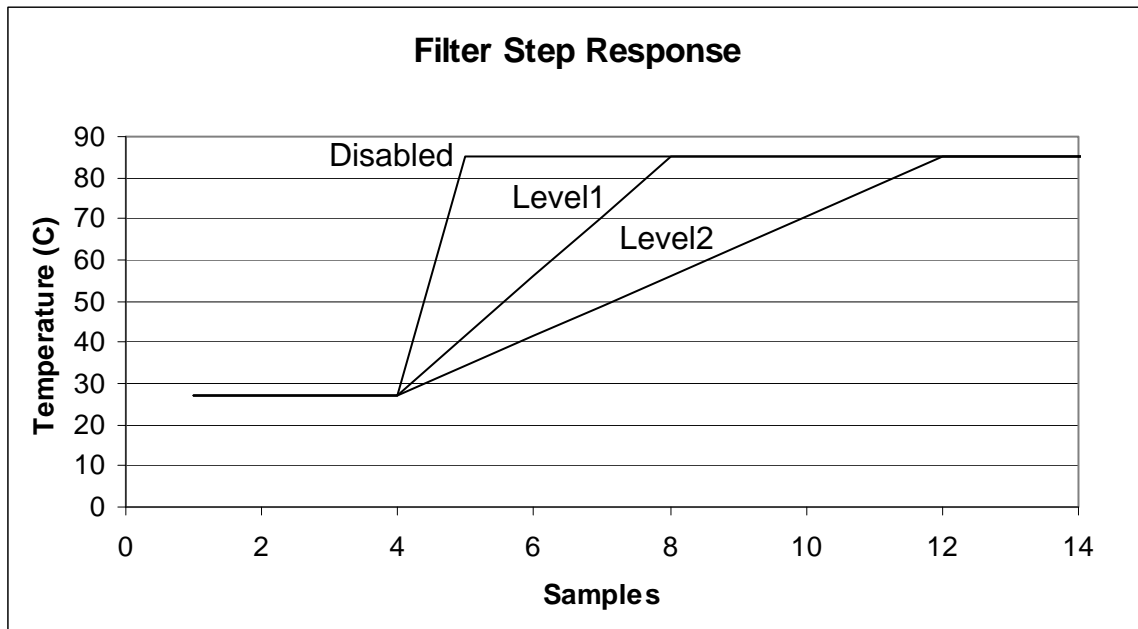


Figure 5.2 Temperature Filter Step Response

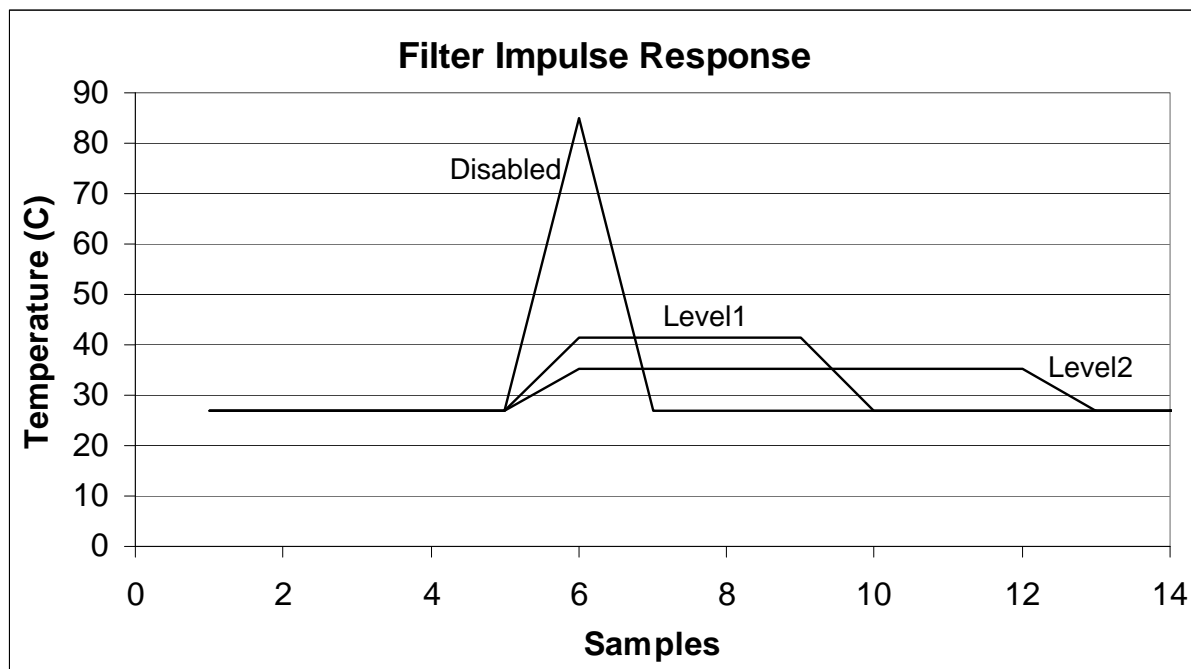


Figure 5.3 Temperature Filter Impulse Response

## 5.10 Temperature Monitors

In general, thermal diode temperature measurements are based on the change in forward bias voltage of a diode when operated at two different currents. This  $\Delta V_{BE}$  is proportional to absolute temperature as shown in the following equation:

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

where:

$k$  = Boltzmann's constant

$T$  = absolute temperature in Kelvin [1]

$q$  = electron charge

$\eta$  = diode ideality factor

Figure 5.4 shows a block diagram of the temperature measurement circuit. The negative terminal for the remote temperature diode, DN, is internally biased with a forward diode voltage referenced to ground.

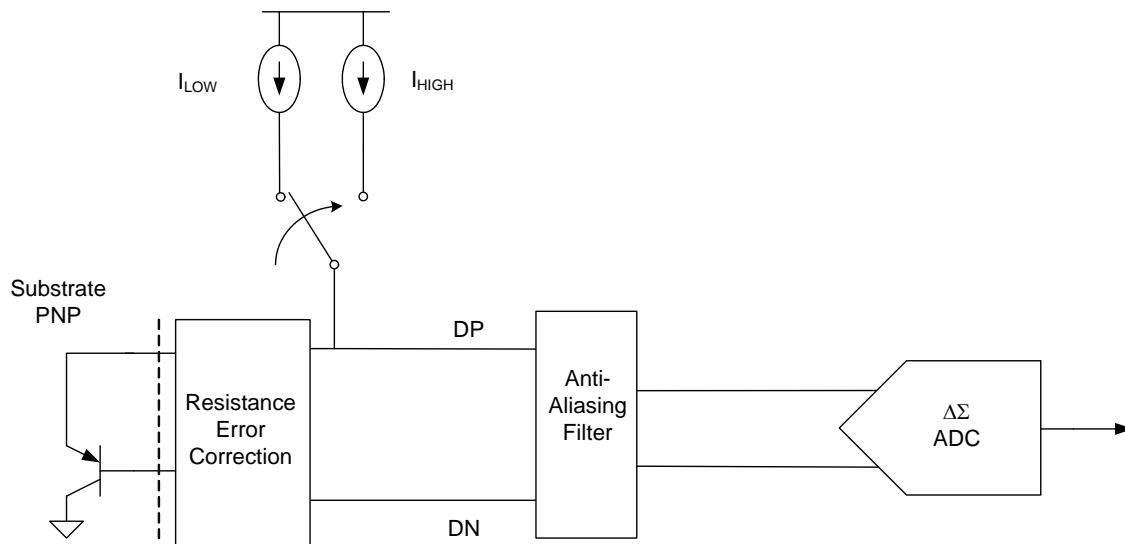


Figure 5.4 Block Diagram of Temperature Monitoring Circuit

## 5.11 Temperature Measurement Results and Data

The temperature measurement results are stored in the internal and external temperature registers. These are then compared with the values stored in the high and low limit registers. Both external and internal temperature measurements are stored in 11-bit format with the eight (8) most significant bits stored in a high byte register and the three (3) least significant bits stored in the three (3) MSB positions of the low byte register. All other bits of the low byte register are set to zero.

The EMC1402 has two selectable temperature ranges. The default range is from 0°C to +127°C and the temperature is represented as binary number able to report a temperature from 0°C to +127.875°C in 0.125°C steps.

The extended range is an extended temperature range from -64°C to +191°C. The data format is a binary number offset by 64°C. The extended range is used to measure temperature diodes with a large known offset (such as AMD processor diodes) where the diode temperature plus the offset would be equivalent to a temperature higher than +127°C.

Table 5.2 shows the default and extended range formats.

Table 5.2 Temperature Data Format

TEMPERATURE (°C)	DEFAULT RANGE 0°C TO 127°C	EXTENDED RANGE -64°C TO 191°C
Diode Fault	000 0000 0000	000 0000 0000
-64	000 0000 0000	000 0000 0000 <a href="#">Note 5.2</a>
-1	000 0000 0000	001 1111 1000
0	000 0000 0000 <a href="#">Note 5.1</a>	010 0000 0000
0.125	000 0000 0001	010 0000 0001
1	000 0000 1000	010 0000 1000
64	010 0000 0000	100 0000 0000
65	010 0000 1000	100 0000 1000
127	011 1111 1000	101 1111 1000
127.875	011 1111 1111	101 1111 1111
128	011 1111 1111 <a href="#">Note 5.3</a>	110 0000 0000
190	011 1111 1111	111 1111 0000
191	011 1111 1111	111 1111 1000
>= 191.875	011 1111 1111	111 1111 1111 <a href="#">Note 5.4</a>

**Note 5.1** In default mode, all temperatures < 0°C will be reported as 0°C.

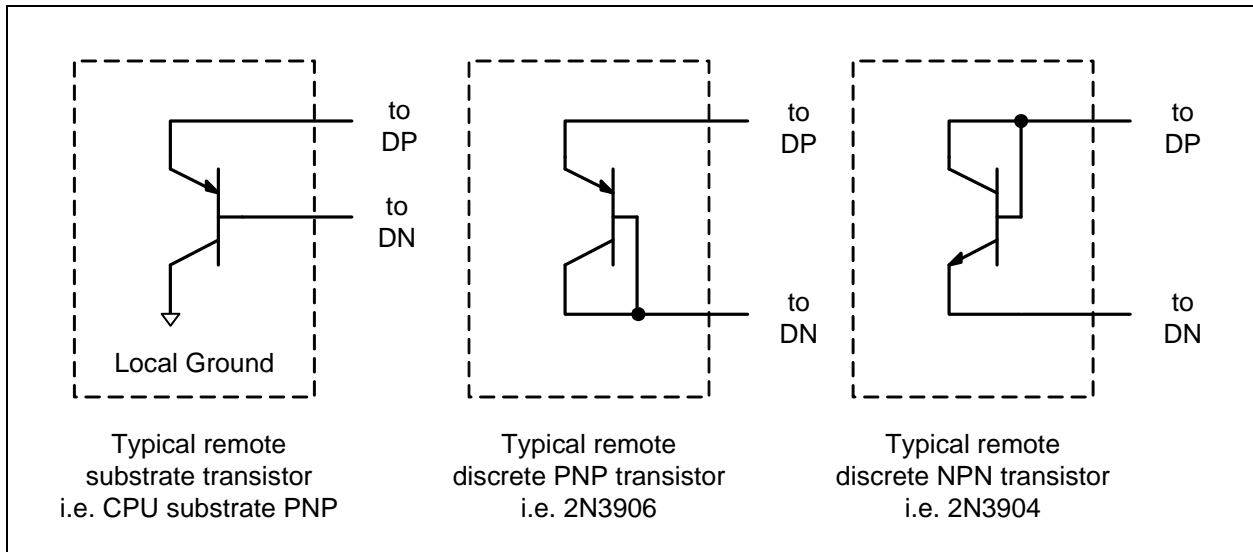
**Note 5.2** In the extended range, all temperatures < -64°C will be reported as -64°C.

**Note 5.3** For the default range, all temperatures > +127.875°C will be reported as +127.875°C.

**Note 5.4** For the extended range, all temperatures > +191.875°C will be reported as +191.875°C.

## 5.12 External Diode Connections

The EMC1402 can be configured to measure a CPU substrate transistor, a discrete 2N3904 thermal diode, or an AMD processor diode. The diode can be connected in a variety of ways as indicated in [Figure 5.5](#).


**Figure 5.5 Diode Configurations**

## Chapter 6 Register Description

The registers shown in [Table 6.1](#) are accessible through the SMBus. An entry of '-' indicates that the bit is not used and will always read '0'.

**Table 6.1 Register Set in Hexadecimal Order**

REGISTER ADDRESS	R/W	REGISTER NAME	FUNCTION	DEFAULT VALUE	PAGE
00h	R	Internal Diode Data High Byte	Stores the integer data for the Internal Diode	00h	Page 25
01h	R	External Diode Data High Byte	Stores the integer data for the External Diode	00h	
02h	R-C	Status	Stores status bits for the Internal Diode and External Diodes	00h	Page 25
03h	R/W	Configuration	Controls the general operation of the device (mirrored at address 09h)	00h	Page 26
04h	R/W	Conversion Rate	Controls the conversion rate for updating temperature data (mirrored at address 0Ah)	06h (4/sec)	Page 27
05h	R/W	Internal Diode High Limit	Stores the 8-bit high limit for the Internal Diode (mirrored at address 0Bh)	55h (85°C)	Page 28
06h	R/W	Internal Diode Low Limit	Stores the 8-bit low limit for the Internal Diode (mirrored at address 0Ch)	00h (0°C)	
07h	R/W	External Diode High Limit High Byte	Stores the integer portion of the high limit for the External Diode (mirrored at register 0Dh)	55h (85°C)	
08h	R/W	External Diode Low Limit High Byte	Stores the integer portion of the low limit for the External Diode (mirrored at register 0Eh)	00h (0°C)	
09h	R/W	Configuration	Controls the general operation of the device (mirrored at address 03h)	00h	Page 26
0Ah	R/W	Conversion Rate	Controls the conversion rate for updating temperature data (mirrored at address 04h)	06h (4/sec)	Page 27

**Table 6.1 Register Set in Hexadecimal Order (continued)**

REGISTER ADDRESS	R/W	REGISTER NAME	FUNCTION	DEFAULT VALUE	PAGE
0Bh	R/W	Internal Diode High Limit	Stores the 8-bit high limit for the Internal Diode (mirrored at address 05h)	55h (85°C)	Page 28
0Ch	R/W	Internal Diode Low Limit	Stores the 8-bit low limit for the Internal Diode (mirrored at address 06h)	00h (0°C)	
0Dh	R/W	External Diode High Limit High Byte	Stores the integer portion of the high limit for the External Diode (mirrored at register 07h)	55h (85°C)	
0Eh	R/W	External Diode Low Limit High Byte	Stores the integer portion of the low limit for the External Diode (mirrored at register 08h)	00h (0°C)	
0Fh	W	One shot	A write to this register initiates a one shot update.	00h	Page 29
10h	R	External Diode Data Low Byte	Stores the fractional data for the External Diode	00h	Page 25
11h	R/W	Scratchpad	Scratchpad register for software compatibility	00h	Page 28
12h	R/W	Scratchpad	Scratchpad register for software compatibility	00h	Page 28
13h	R/W	External Diode High Limit Low Byte	Stores the fractional portion of the high limit for the External Diode	00h	Page 28
14h	R/W	External Diode Low Limit Low Byte	Stores the fractional portion of the low limit for the External Diode	00h	
19h	R/W	External Diode THERM Limit	Stores the 8-bit critical temperature limit for the External Diode	55h (85°C)	Page 29
1Fh	R/W	Channel Mask Register	Controls the masking of individual channels	00h	Page 29
20h	R/W	Internal Diode THERM Limit	Stores the 8-bit critical temperature limit for the Internal Diode	55h (85°C)	Page 29
21h	R/W	THERM Hysteresis	Stores the 8-bit hysteresis value that applies to all THERM limits	0Ah (10°C)	
22h	R/W	Consecutive ALERT	Controls the number of out-of-limit conditions that must occur before an interrupt is asserted	70h	Page 30
25h	R/W	External Diode 1 Beta Configuration	Stores the Beta Compensation circuitry settings for External Diode 1	08h	Page 31
27h	R/W	External Diode 1 Ideality Factor	Stores the ideality factor for External Diode 1	12h (1.008)	Page 32
29h	R	Internal Diode Data Low Byte	Stores the fractional data for the Internal Diode	00h	Page 25



Table 6.1 Register Set in Hexadecimal Order (continued)

REGISTER ADDRESS	R/W	REGISTER NAME	FUNCTION	DEFAULT VALUE	PAGE
40h	R/W	Filter Control	Controls the digital filter setting for the External Diode channel	00h	Page 34
FDh	R	Product ID	Stores a fixed value that identifies each product	Table 6.21	Page 34
FEh	R	SMSC ID	Stores a fixed value that represents SMSC	5Dh	Page 35
FFh	R	Revision	Stores a fixed value that represents the revision number	01h or 04h	Page 35

## 6.1 Data Read Interlock

When any temperature channel high byte register is read, the corresponding low byte is copied into an internal 'shadow' register. The user is free to read the low byte at any time and be guaranteed that it will correspond to the previously read high byte. Regardless if the low byte is read or not, reading from the same high byte register again will automatically refresh this stored low byte data.

## 6.2 Temperature Data Registers

Table 6.2 Temperature Data Registers

ADDR	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
00h	R	Internal Diode High Byte	128	64	32	16	8	4	2	1	00h
29h	R	Internal Diode Low Byte	0.5	0.25	0.125	-	-	-	-	-	00h
01h	R	External Diode High Byte	128	64	32	16	8	4	2	1	00h
10h	R	External Diode Low Byte	0.5	0.25	0.125	-	-	-	-	-	00h

As shown in Table 6.2, all temperatures are stored as an 11-bit value with the high byte representing the integer value and the low byte representing the fractional value left justified to occupy the MSBits.

## 6.3 Status Register

Table 6.3 Status Register

ADDR	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
02h	R-C	Status	BUSY	IHIGH	ILOW	EHIGH	ELOW	FAULT	ETHERM	ITHERM	00h

The Status Register reports the operating status of the Internal Diode and External Diode 1 channels. When any of the bits are set (excluding the BUSY bit) either the  $\overline{\text{ALERT}}$  or  $\overline{\text{THERM}}$  pin is being asserted.

The  $\overline{\text{ALERT}}$  and  $\overline{\text{THERM}}$  pins are controlled by the respective consecutive alert counters (see [Section 6.11](#)) and will not be asserted until the programmed consecutive alert count has been reached. The status bits (except  $\overline{\text{E1THERM}}$  and  $\overline{\text{ITHERM}}$ ) will remain set until read unless the  $\overline{\text{ALERT}}$  pin is configured as a second  $\overline{\text{THERM}}$  output (see [Section 5.3.2](#)).

Bit 7 - BUSY - This bit indicates that the ADC is currently converting. This bit does not cause either the  $\overline{\text{ALERT}}$  or  $\overline{\text{THERM}}$  pins to be asserted.

Bit 6 - IHIGH - This bit is set when the Internal Diode channel exceeds its programmed high limit. When set, this bit will assert the  $\overline{\text{ALERT}}$  pin.

Bit 5 - ILOW - This bit is set when the Internal Diode channel drops below its programmed low limit. When set, this bit will assert the  $\overline{\text{ALERT}}$  pin.

Bit 4 - EHIGH - This bit is set when the External Diode channel exceeds its programmed high limit. When set, this bit will assert the  $\overline{\text{ALERT}}$  pin.

Bit 3 - ELOW - This bit is set when the External Diode channel drops below its programmed low limit. When set, this bit will assert the  $\overline{\text{ALERT}}$  pin.

Bit 2 - FAULT - This bit is asserted when a diode fault is detected. When set, this bit will assert the  $\overline{\text{ALERT}}$  pin.

Bit 1 - ETHERM - This bit is set when the External Diode channel exceeds the programmed  $\overline{\text{THERM}}$  limit. When set, this bit will assert the  $\overline{\text{THERM}}$  pin. This bit will remain set until the  $\overline{\text{THERM}}$  pin is released at which point it will be automatically cleared.

Bit 0 - ITHERM - This bit is set when the Internal Diode channel exceeds the programmed  $\overline{\text{THERM}}$  limit. When set, this bit will assert the  $\overline{\text{THERM}}$  pin. This bit will remain set until the  $\overline{\text{THERM}}$  pin is released at which point it will be automatically cleared.

## 6.4 Configuration Register

**Table 6.4 Configuration Register**

ADDR	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
03h	R/W	Configuration	MASK_ ALL	RUN/ STOP	ALERT/ COMP	RECD	-	RANGE	DAVG_ DIS	-	00h
09h											

The Configuration Register controls the basic operation of the device. This register is fully accessible at either address.

Bit 7 - MASK\_ALL - Masks the  $\overline{\text{ALERT}}$  pin from asserting.

- '0' (default) - The  $\overline{\text{ALERT}}$  pin is not masked. If any of the appropriate status bits are set the  $\overline{\text{ALERT}}$  pin will be asserted.
- '1' - The  $\overline{\text{ALERT}}$  pin is masked. It will not be asserted for any interrupt condition unless it is configured as a secondary  $\overline{\text{THERM}}$  pin. The Status Register will be updated normally.

Bit 6 - RUN / STOP - Controls Active/Standby modes.

- '0' (default) - The device is in Active mode and converting on all channels.
- '1' - The device is in Standby mode and not converting.

Bit 5 - ALERT/COMP - Controls the operation of the  $\overline{\text{ALERT}}$  pin.

- '0' (default) - The  $\overline{\text{ALERT}}$  pin acts as described in [Section 5.3](#).
- '1' - The  $\overline{\text{ALERT}}$  pin acts in comparator mode as described in [Section 5.3.2](#). In this mode the MASK\_ALL bit is ignored.

Bit 4 - RECD - Disables the Resistance Error Correction (REC) for External Diode.

- '0' (default) - REC is enabled for the External Diode.

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- '1' - REC is disabled for the External Diode 1.

Bit 2 - RANGE - Configures the measurement range and data format of the temperature channels.

- '0' (default) - The temperature measurement range is 0°C to +127.875°C and the data format is binary.
- '1' -The temperature measurement range is -64°C to +191.875°C and the data format is offset binary (see [Table 5.2](#)).

Bit 1 - DAVG\_DIS - Disables the dynamic averaging feature on all temperature channels.

- '0' (default) - The dynamic averaging feature is enabled. All temperature channels will be converted with an averaging factor that is based on the conversion rate as shown in [Table 5.1](#).
- '1' - The dynamic averaging feature is disabled. All temperature channels will be converted with a maximum averaging factor of 1x (equivalent to 11-bit conversion). For higher conversion rates, this averaging factor will be reduced as shown in [Table 5.1](#).

## 6.5 Conversion Rate Register

**Table 6.5 Conversion Rate Register**

ADDR	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
04h	R/W	Conversion Rate	-	-	-	-	CONV[3:0]				06h (4/sec)
0Ah											

The Conversion Rate Register controls how often the temperature measurement channels are updated and compared against the limits. This register is fully accessible at either address.

Bits 3-0 - CONV[3:0] - Determines the conversion rate as shown in [Table 6.6](#).

**Table 6.6 Conversion Rate**

CONV[3:0]					CONVERSIONS / SECOND
HEX	3	2	1	0	
0h	0	0	0	0	1 / 16
1h	0	0	0	1	1 / 8
2h	0	0	1	0	1 / 4
3h	0	0	1	1	1 / 2
4h	0	1	0	0	1
5h	0	1	0	1	2
6h	0	1	1	0	4 (default)
7h	0	1	1	1	8
8h	1	0	0	0	16
9h	1	0	0	1	32
Ah	1	0	1	0	64
Bh - Fh	All others				1

## 6.6 Limit Registers

**Table 6.7 Temperature Limit Registers**

ADDR.	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
05h	R/W	Internal Diode High Limit	128	64	32	16	8	4	2	1	55h (85°C)
0Bh											
06h	R/W	Internal Diode Low Limit	128	64	32	16	8	4	2	1	00h (0°C)
0Ch											
07h	R/W	External Diode High Limit High Byte	128	64	32	16	8	4	2	1	55h (85°C)
0Dh											
13h	R/W	External Diode High Limit Low Byte	0.5	0.25	0.125	-	-	-	-	-	00h
08h	R/W	External Diode Low Limit High Byte	128	64	32	16	8	4	2	1	00h (0°C)
0Eh											
14h	R/W	External Diode Low Limit Low Byte	0.5	0.25	0.125	-	-	-	-	-	00h

The device contains both high and low limits for all temperature channels. If the measured temperature exceeds the high limit, then the corresponding status bit is set and the ALERT pin is asserted. Likewise, if the measured temperature is less than or equal to the low limit, the corresponding status bit is set and the ALERT pin is asserted.

The data format for the limits must match the selected data format for the temperature so that if the extended temperature range is used, the limits must be programmed in the extended data format.

The limit registers with multiple addresses are fully accessible at either address.

When the device is in standby mode, updating the limit registers will have no affect until the next conversion cycle occurs. This can be initiated via a write to the One Shot Register or by clearing the RUN / STOP bit in the Configuration Register (see [Section 6.4](#)).

## 6.7 Scratchpad Registers

**Table 6.8 Scratchpad Register**

ADDR	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
11h	R/W	Scratchpad	7	6	5	4	3	2	1	0	00h
12h	R/W	Scratchpad	7	6	5	4	3	2	1	0	00h

The Scratchpad Registers are Read Write registers that are used for place holders to be software compatible with legacy programs. Reading from the registers will return what is written to them.

## 6.8 One Shot Register

Table 6.9 One Shot Register

ADDR.	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
0Fh	W	One Shot	Writing to this register initiates a single conversion cycle. Data is not stored and always reads 00h								00h

The One Shot Register is used to initiate a one shot command. Writing to the one shot register, when the device is in standby mode and BUSY bit (in Status Register) is '0', will immediately cause the ADC to update all temperature measurements. Writing to the One Shot Register while the device is in active mode will have no affect.

## 6.9 Therm Limit Registers

Table 6.10 Therm Limit Registers

ADDR.	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
19h	R/W	External Diode THERM Limit	128	64	32	16	8	4	2	1	55h (85°C)
20h	R/W	Internal Diode THERM Limit	128	64	32	16	8	4	2	1	55h (85°C)
21h	R/W	THERM Hysteresis	128	64	32	16	8	4	2	1	0Ah (10°C)

The THERM Limit Registers are used to determine whether a critical thermal event has occurred. If the measured temperature exceeds the THERM Limit, then the  $\overline{\text{THERM}}$  pin is asserted. The limit setting must match the chosen data format of the temperature reading registers.

Unlike the  $\overline{\text{ALERT}}$  pin, the  $\overline{\text{THERM}}$  pin cannot be masked. Additionally, the  $\overline{\text{THERM}}$  pin will be released once the temperature drops below the corresponding threshold minus the THERM Hysteresis.

## 6.10 Channel Mask Register

Table 6.11 Channel Mask Register

ADDR.	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
1Fh	R/W	Channel Mask	-	-	-	-	-	-	E MASK	INT MASK	00h

The Channel Mask Register controls individual channel masking. When a channel is masked, the  $\overline{\text{ALERT}}$  pin will not be asserted when the masked channel reads a diode fault or out of limit error. The channel mask does not mask the  $\overline{\text{THERM}}$  pin.

Bit 1 - EMASK - Masks the  $\overline{\text{ALERT}}$  pin from asserting when the External Diode channel is out of limit or reports a diode fault.

- '0' (default) - The External Diode channel will cause the  $\overline{\text{ALERT}}$  pin to be asserted if it is out of limit or reports a diode fault.

- '1' - The External Diode channel will not cause the  $\overline{\text{ALERT}}$  pin to be asserted if it is out of limit or reports a diode fault.

Bit 0 - INTMASK - Masks the  $\overline{\text{ALERT}}$  pin from asserting when the Internal Diode temperature is out of limit.

- '0' (default) - The Internal Diode channel will cause the  $\overline{\text{ALERT}}$  pin to be asserted if it is out of limit.
- '1' - The Internal Diode channel will not cause the  $\overline{\text{ALERT}}$  pin to be asserted if it is out of limit.

## 6.11 Consecutive ALERT Register

**Table 6.12 Consecutive ALERT Register**

ADDR.	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
22h	R/W	Consecutive ALERT	TIME OUT	CTHRM[2:0]			CALRT[2:0]			-	70h

The Consecutive ALERT Register determines how many times an out-of-limit error or diode fault must be detected in consecutive measurements before the  $\overline{\text{ALERT}}$  or  $\overline{\text{THERM}}$  pin is asserted. Additionally, the Consecutive ALERT Register controls the SMBus Timeout functionality.

An out-of-limit condition (i.e. HIGH, LOW, or FAULT) occurring on the same temperature channel in consecutive measurements will increment the consecutive alert counter. The counters will also be reset if no out-of-limit condition or diode fault condition occurs in a consecutive reading.

When the ALERT pin is configured as an interrupt, when the consecutive alert counter reaches its programmed value, the following will occur: the STATUS bit(s) for that channel and the last error condition(s) (i.e. EHIGH) will be set to '1', the  $\overline{\text{ALERT}}$  pin will be asserted, the consecutive alert counter will be cleared, and measurements will continue.

When the  $\overline{\text{ALERT}}$  pin is configured as a comparator, the consecutive alert counter will ignore diode fault and low limit errors and only increment if the measured temperature exceeds the High Limit. Additionally, once the consecutive alert counter reaches the programmed limit, the  $\overline{\text{ALERT}}$  pin will be asserted, but the counter will not be reset. It will remain set until the temperature drops below the High Limit minus the THERM Hysteresis value.

For example, if the CALRT[2:0] bits are set for 4 consecutive alerts, the high limits are set at 70°C, and none of the channels are masked, then the  $\overline{\text{ALERT}}$  pin will be asserted after the following four measurements:

1. Internal Diode reads 71°C and the external diode reads 69°C. Consecutive alert counter for INT is incremented to 1.
2. Both the Internal Diode and the External Diode read 71°C. Consecutive alert counter for INT is incremented to 2 and for EXT is set to 1.
3. The External Diode reads 71°C and the Internal Diode reads 69°C. Consecutive alert counter for INT is cleared and EXT is incremented to 2.
4. The Internal Diode reads 71°C and the external diode reads 71°C. Consecutive alert counter for INT is set to 1 and EXT is incremented to 3.
5. The Internal Diode reads 71°C and the external diode reads 71°C. Consecutive alert counter for INT is incremented to 2 and EXT is incremented to 4. The appropriate status bits are set for EXT and the  $\overline{\text{ALERT}}$  pin is asserted. EXT counter is reset to 0 and all other counters hold the last value until the next temperature measurement.

Bit 7 - TIMEOUT - Determines whether the SMBus Timeout function is enabled.

- '0' (default) - The SMBus Timeout feature is disabled. The SMCLK line can be held low indefinitely without the device resetting its SMBus protocol.

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- '1' - The SMBus Timeout feature is enabled. If the SMCLK line is held low for more than 30ms, then the device will reset the SMBus protocol.

Bits 6-4 - CTHRM[2:0] - Determines the number of consecutive measurements that must exceed the corresponding THERM Limit before the THERM pin is asserted. All temperature channels use this value to set the respective counters. The consecutive THERM counter is incremented whenever any measurement exceed the corresponding THERM Limit.

If the temperature drops below the THERM limit, then the counter is reset. If a number of consecutive measurements above the THERM limit occurs, then the THERM pin is asserted low.

Once the THERM pin has been asserted, the consecutive therm counter will not reset until the corresponding temperature drops below the THERM Limit minus the THERM Hysteresis value.

The bits are decoded as shown in [Table 6.13](#). The default setting is 4 consecutive out of limit conversions.

Bits 3-1 - CALRT[2:0] - Determine the number of consecutive measurements that must have an out of limit condition or diode fault before the ALERT pin is asserted. All temperature channels use this value to set the respective counters. The bits are decoded as shown in [Table 6.13](#). The default setting is 1 consecutive out of limit conversion.

Table 6.13 Consecutive Alert / THERM Settings

2	1	0	NUMBER OF CONSECUTIVE OUT OF LIMIT MEASUREMENTS
0	0	0	1 (default for CALRT[2:0])
0	0	1	2
0	1	1	3
1	1	1	4 (default for CTHRM[2:0])

## 6.12 Beta Configuration Registers

Table 6.14 Beta Configuration Registers

ADDR.	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
25h	R/W	External Diode 1 Beta Configuration	-	-	-	-	ENABLE	BETA[2:0]			08h

This register is used to set the Beta Compensation factor that is used for the external diode channel.

Bit 3 - ENABLE - Enables the Beta Compensation factor autodetection function.

- '0' - The Beta Compensation Factor autodetection circuitry is disabled. The External Diode will always use the Beta Compensation factor set by the BETA[2:0] bits.
- '1' (default) - The Beta Compensation factor autodetection circuitry is enabled. At the beginning of every conversion, the optimal Beta Compensation factor setting will be determined and applied. The BETA[2:0] bits will be automatically updated to indicate the current setting.

Bit 2-0 - BETA[2:0] - These bits always reflect the current beta configuration settings. If autodetection circuitry is enabled, then these bits will be updated automatically and writing to these bits will have no effect. If the autodetection circuitry is disabled, then these bits will determine the beta configuration setting that is used for their respective channels.

Care should be taken when setting the BETA[2:0] bits when the autodetection circuitry is disabled. If the Beta Compensation factor is set at a beta value that is higher than the transistor beta, then the circuit may introduce measurement errors. When measuring a discrete thermal diode (such as 2N3904) or a CPU diode that functions like a discrete thermal diode (such as an AMD processor diode), then the BETA[2:0] bits should be set to '111b'.

**Table 6.15 CPU Beta Values**

HEX	ENABLE	BETA[2:0]			MINIMUM BETA
		2	1	0	
0h	0	0	0	0	0.11
1h	0	0	0	1	0.18
2h	0	0	1	0	0.25
3h	0	0	1	1	0.33
4h	0	1	0	0	0.43
5h	0	1	0	1	1.00
6h	0	1	1	0	2.33
7h	0	1	1	1	Disabled
8h - Fh	1	X	X	X	Autodetection

## 6.13 External Diode Ideality Factor Registers

**Table 6.16 Ideality Configuration Registers**

ADDR.	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
27h	R/W	External Diode 1 Ideality Factor	-	-	IDEALITY[5:0]						12h

These registers store the ideality factors that are applied to the external diodes. [Table 6.17](#) defines each setting and the corresponding ideality factor. Beta Compensation and Resistance Error Correction automatically correct for most diode ideality errors, therefore it is not recommended that these settings be updated without consulting SMSC.

**Table 6.17 Ideality Factor Look-Up Table (Diode Model)**

SETTING	FACTOR	SETTING	FACTOR	SETTING	FACTOR
08h	0.9949	18h	1.0159	28h	1.0371
09h	0.9962	19h	1.0172	29h	1.0384
0Ah	0.9975	1Ah	1.0185	2Ah	1.0397
0Bh	0.9988	1Bh	1.0200	2Bh	1.0410



Table 6.17 Ideality Factor Look-Up Table (Diode Model) (continued)

SETTING	FACTOR	SETTING	FACTOR	SETTING	FACTOR
0Ch	1.0001	1Ch	1.0212	2Ch	1.0423
0Dh	1.0014	1Dh	1.0226	2Dh	1.0436
0Eh	1.0027	1Eh	1.0239	2Eh	1.0449
0Fh	1.0040	1Fh	1.0253	2Fh	1.0462
10h	1.0053	20h	1.0267	30h	1.0475
11h	1.0066	21h	1.0280	31h	1.0488
12h	1.0080	22h	1.0293	32h	1.0501
13h	1.0093	23h	1.0306	33h	1.0514
14h	1.0106	24h	1.0319	34h	1.0527
15h	1.0119	25h	1.0332	35h	1.0540
16h	1.0133	26h	1.0345	36h	1.0553
17h	1.0146	27h	1.0358	37h	1.0566

For CPU substrate transistors that require the BJT transistor model, the ideality factor behaves slightly differently than for discrete diode-connected transistors. Refer to [Table 6.18](#) when using a CPU substrate transistor.

Table 6.18 Substrate Diode Ideality Factor Look-Up Table (BJT Model)

SETTING	FACTOR	SETTING	FACTOR	SETTING	FACTOR
08h	0.9869	18h	1.0079	28h	1.0291
09h	0.9882	19h	1.0092	29h	1.0304
0Ah	0.9895	1Ah	1.0105	2Ah	1.0317
0Bh	0.9908	1Bh	1.0120	2Bh	1.0330
0Ch	0.9921	1Ch	1.0132	2Ch	1.0343
0Dh	0.9934	1Dh	1.0146	2Dh	1.0356
0Eh	0.9947	1Eh	1.0159	2Eh	1.0369
0Fh	0.9960	1Fh	1.0173	2Fh	1.0382
10h	0.9973	20h	1.0187	30h	1.0395
11h	0.9986	21h	1.0200	31h	1.0408
12h	1.0000	22h	1.0213	32h	1.0421
13h	1.0013	23h	1.0226	33h	1.0434
14h	1.0026	24h	1.0239	34h	1.0447
15h	1.0039	25h	1.0252	35h	1.0460
16h	1.0053	26h	1.0265	36h	1.0473

**Table 6.18 Substrate Diode Ideality Factor Look-Up Table (BJT Model) (continued)**

SETTING	FACTOR	SETTING	FACTOR	SETTING	FACTOR
17h	1.0066	27h	1.0278	37h	1.0486

**APPLICATION NOTE:** When measuring a 65nm Intel CPUs, the Ideality Setting should be the default 12h. When measuring 45nm Intel CPUs, the Ideality Setting should be 15h.

## 6.14 Filter Control Register

**Table 6.19 Filter Configuration Register**

ADDR.	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
40h	R/W	Filter Control	-	-	-	-	-	-	FILTER[1:0]		00h

The Filter Configuration Register controls the digital filter on the External Diode channel.

Bits 1-0 - FILTER[1:0] - Control the level of digital filtering that is applied to the External Diode temperature measurements as shown in [Table 6.20](#). See [Figure 5.2](#) and [Figure 5.3](#) for examples on the filter behavior.

**Table 6.20 Filter Settings**

FILTER[1:0]		AVERAGING
1	0	
0	0	Disabled (default)
0	1	Level 1
1	0	Level 1
1	1	Level 2

## 6.15 Product ID Register

**Table 6.21 Product ID Register**

ADDR	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
FDh	R	Product ID	0	0	1	0	0	0	0	0	20h EMC1402

The Product ID Register holds a unique value that identifies the device.

## 6.16 SMSC ID Register (FEh)

Table 6.22 Manufacturer ID Register

ADDR.	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
FEh	R	SMSC ID	0	1	0	1	1	1	0	1	5Dh

The Manufacturer ID register contains an 8 bit word that identifies the SMSC as the manufacturer of the EMC1402.

## 6.17 Revision Register (FFh)

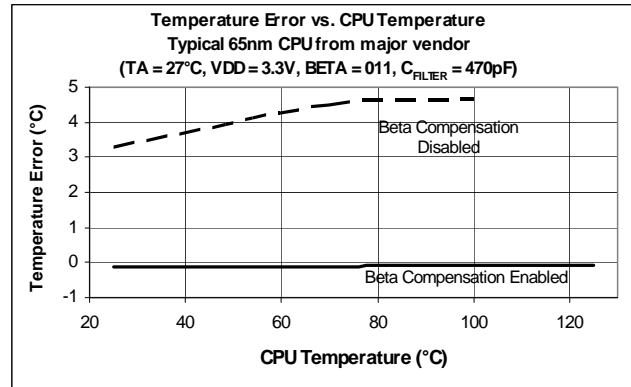
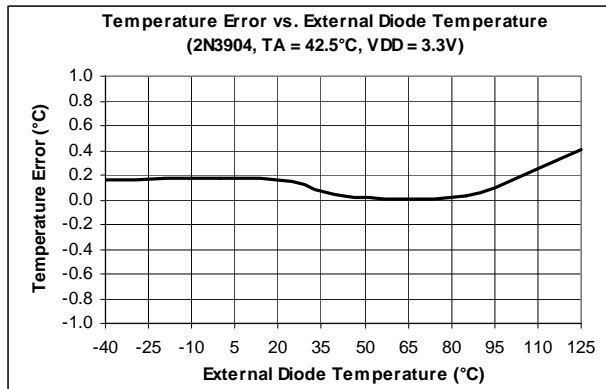
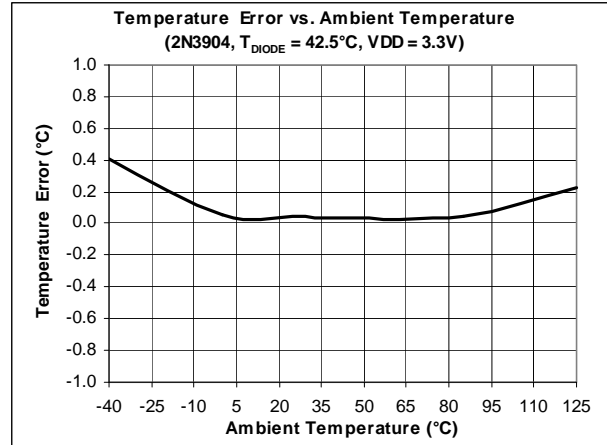
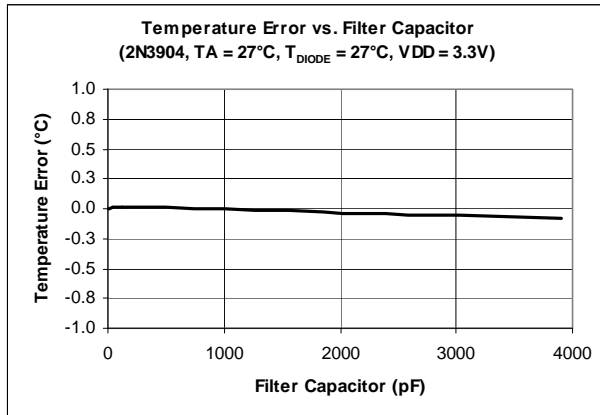
Table 6.23 Revision Register

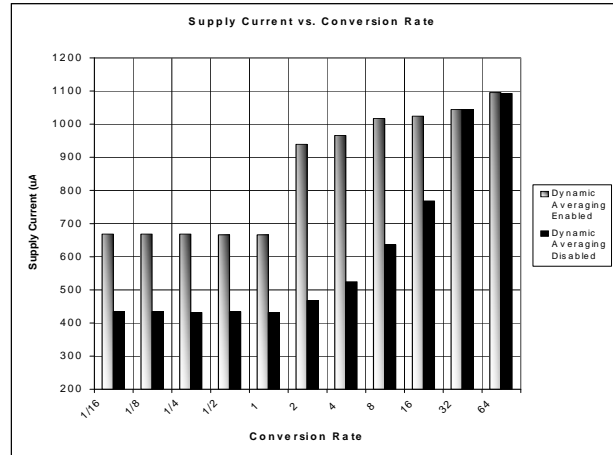
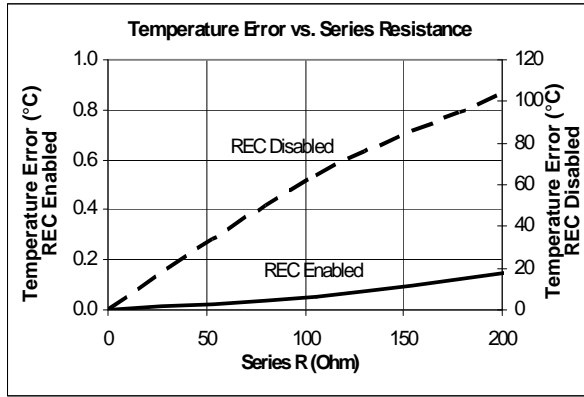
ADDR.	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
FFh	R	Revision	0	0	0	0	0	0	0	1	01h
FFh	R	Revision	0	0	0	0	0	1	0	0	04h

The Revision register contains an 8-bit word that identifies the die revision. It can be 01h or 04h.

### ENGINEERING NOTE:

## Chapter 7 Typical Operating Curves





# Chapter 8 Package Information

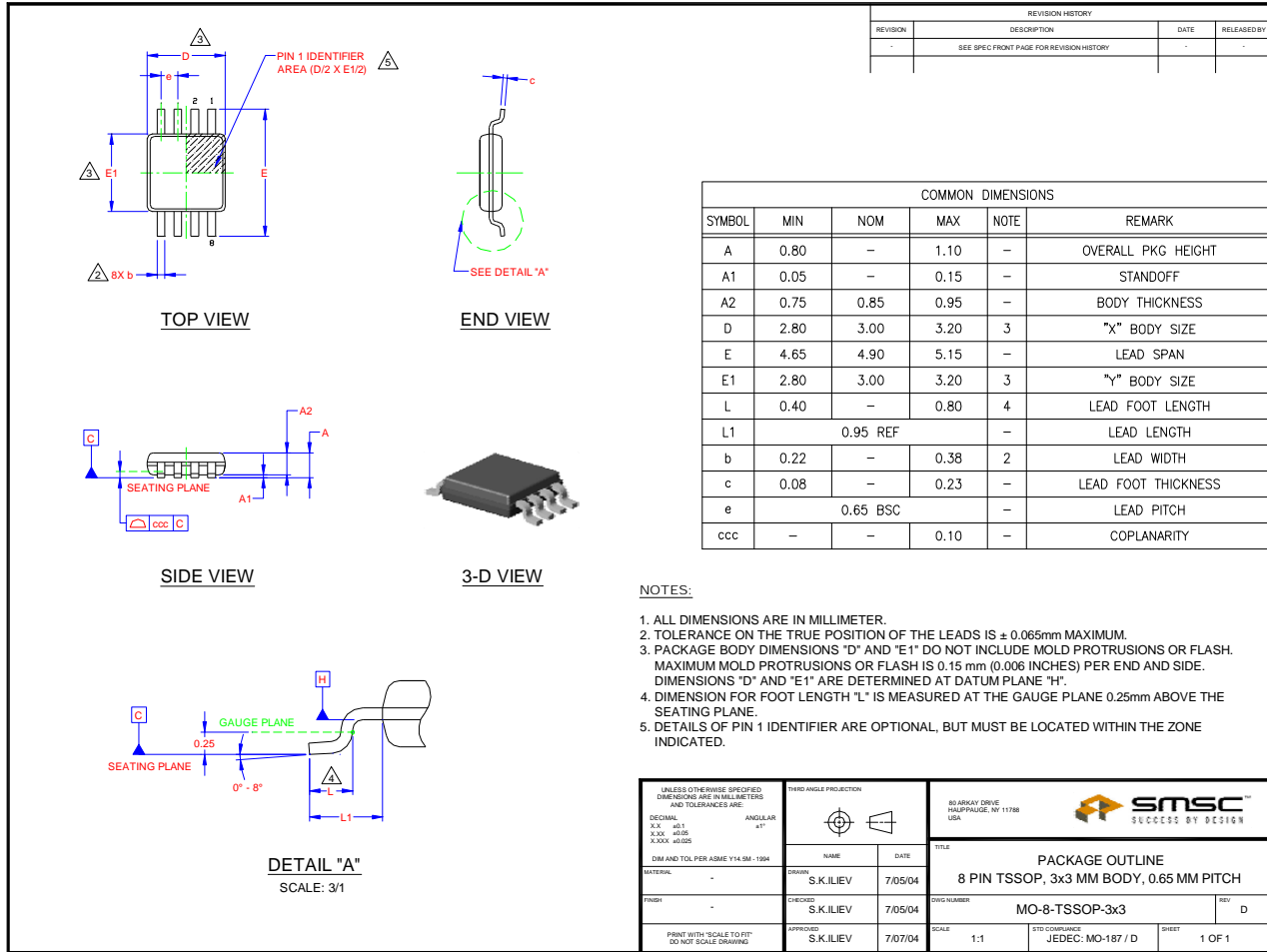


Figure 8.1 8-Pin MSOP / TSSOP Package

## 8.1 Package Markings

All devices will be marked on the first line of the top side with "1402". On the second line, they will be marked with the appropriate -X number (-1, -2, etc), the Functional Revision "B" and Country Code (CC).

## Chapter 9 Datasheet Revision History

**Table 9.1 Customer Revision History**

REVISION LEVEL & DATE	SECTION/FIGURE/ENTRY	CORRECTION
Rev. 2.0 (08-10-12)	Table 3.3, "SMBus Electrical Specifications"	Added conditions for $t_{HD:DAT}$ . Data hold time minimum of 0.3 $\mu$ s is required when receiving from the master. Data hold time is 0 $\mu$ s min when transmitting to the master.
	Section 6.17, "Revision Register (FFh)"	Added row to indicate that revision ID can be 04h. Revision ID may be 04h or 01h.
Rev. 1.36 (07-02-09)	Table 2.1, "EMC1402 Pin Description"	In pin description table, added to function column: "requires pull-up resistor" for SMDATA and SMCLK pins
	Table 2.1, "EMC1402 Pin Description"	Identified 5V tolerant pins. Added the following application note below table: "For the 5V tolerant pins that have a pull-up resistor (SMCLK, SMDATA, THERM, and ALERT), the voltage difference between VDD and the pull-up voltage must never exceed 3.6V."
	Table 3.1, "Absolute Maximum Ratings"	Updated voltage limits for 5V tolerant pins with pull-up resistors.  Added the following note below table: "For the 5V tolerant pins that have a pull-up resistor (SMCLK, SMDATA, THERM, and ALERT), the pull-up voltage must not exceed 3.6V when the device is unpowered."
	Table 3.2, "Electrical Specifications"	Added leakage current.
Rev. 1.35 (04-17-09)	Table 2.1, "EMC1402 Pin Description"	"Preliminary" removed from table title
Rev. 1.34 (02-27-09)	Table 5.2, "Temperature Data Format"	Extended range for -1 updated from 001 1111 1111 to 001 1111 1000



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