EMC1412

Multiple Channel 1°C Temperature Sensor with Beta Compensation

PRODUCT FEATURES

Datasheet

General Description

The EMC1412 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.

The EMC1412 monitors two temperature channels (one external and one internal). It provides ±1°C accuracy for both external and internal diode temperatures.

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 ±1°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

- Programmable SMBus address
- Support for diodes requiring the BJT/transistor model
  - supports 45nm, 65nm, and 90nm CPU thermal diodes
- Automatically determines external diode type and optimal settings
- Resistance Error Correction
- External Temperature Monitor
  - ±1°C max accuracy (20°C < T_{DIODE} < 110°C)
  - 0.125°C resolution
  - Supports up to 2.2nF diode filter capacitor
- Internal Temperature Monitor
  - ±1°C accuracy
  - 0.125°C resolution
- 3.3V Supply Voltage
- Programmable temperature limits for $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$
- Available in small 8-pin 2mm x 3mm TDFN lead-free RoHS compliant package
- Available in small 8-pin MSOP lead-free RoHS compliant package

Ordering Information:

ORDERING NUMBER	PACKAGE	FEATURES	SMBUS ADDRESS
EMC1412-A-ACZL-TR	8-pin MSOP (lead-free RoHS compliant	Two temperature sensors, $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ pins, programmable SMBus address	Selectable via $\overline{\text{THERM}}$ pull-up
EMC1412-A-AC3-TR	8-pin TDFN 2mm x 3mm (lead-free RoHS compliant	Two temperature sensors, $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ pins, fixed SMBus address	Selectable via $\overline{\text{THERM}}$ pull-up
EMC1412-1-ACZL-TR	8-pin MSOP (lead-free RoHS compliant	Two temperature sensors, $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ pins, fixed SMBus address	1001_100(r/$\overline{\text{w}}$)
EMC1412-1-AC3-TR	8-pin TDFN 2mm x 3mm (lead-free RoHS compliant	Two temperature sensors, $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ pins, fixed SMBus address	1001_100(r/$\overline{\text{w}}$)
EMC1412-2-ACZL-TR	8-pin MSOP (lead-free RoHS compliant	Two temperature sensors, $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ pins, fixed SMBus address	1001_101(r/$\overline{\text{w}}$)

REEL SIZE IS 4,000 PIECES FOR THE MSOP

REEL SIZE IS 5,000 PIECES FOR THE TDFN

This product meets the halogen maximum concentration values per IEC61249-2-21

For RoHS compliance and environmental information, please visit www.smsc.com/rohs

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Table of Contents

Chapter 1 Block Diagram 7

Chapter 2 Delta 7
2.1 Functional Delta from EMC1412 rev A to rev B 7

Chapter 3 Pin Description 8

Chapter 4 Electrical Specifications 10
4.1 Absolute Maximum Ratings 10
4.2 Electrical Specifications 11
4.3 SMBus Electrical Characteristics 12

Chapter 5 System Management Bus Interface Protocol 13
5.1 Communications Protocol 13
5.1.1 SMBus Start Bit 13
5.1.2 SMBus Address and RD / WR Bit 13
5.1.3 THERM Pin Considerations 14
5.1.4 SMBus Data Bytes 14
5.1.5 SMBus ACK and NACK Bits 14
5.1.6 SMBus Stop Bit 15
5.1.7 SMBus Timeout 15
5.1.8 SMBus and I^2C Compatibility 15
5.2 SMBus Protocols 15
5.2.1 Write Byte 15
5.2.2 Read Byte 16
5.2.3 Send Byte 16
5.2.4 Receive Byte 16
5.3 Alert Response Address 16

Chapter 6 Product Description 18
6.1 Modes of Operation 18
6.1.1 Conversion Rates 18
6.1.2 Dynamic Averaging 19
6.2 THERM Output 19
6.3 ALERT Output 20
6.3.1 ALERT Pin Interrupt Mode 20
6.3.2 ALERT Pin Comparator Mode 20
6.4 Temperature Measurement 20
6.4.1 Beta Compensation 20
6.4.2 Resistance Error Correction (REC) 21
6.4.3 Programmable External Diode Ideality Factor 21
6.5 Diode Faults 21
6.6 Consecutive Alerts 21
6.7 Digital Filter 21
6.8 Temperature Measurement Results and Data 23
6.9 External Diode Connections 24

Chapter 7 Register Description 25
7.1 Data Read Interlock 27
7.2 Temperature Data Registers 27

7.3 Status Register 27
7.4 Configuration Register 28
7.5 Conversion Rate Register 29
7.6 Limit Registers 30
7.7 Scratchpad Registers 30
7.8 One Shot Register 31
7.9 Therm Limit Registers 31
7.10 Channel Mask Register 31
7.11 Consecutive ALERT Register 32
7.12 Beta Configuration Register 33
7.13 External Diode Ideality Factor Register 34
7.14 Filter Control Register 36
7.15 Product ID Register 36
7.16 SMSC ID Register 36
7.17 Revision Register 37

Chapter 8 Typical Operating Curves 38

Chapter 9 Package Information 40
9.1 Package Markings 43

Chapter 10 Document Revision History 46

List of Figures

Figure 1.1 EMC1412 Block Diagram 7
Figure 3.1 EMC1412 Pin Diagram, MSOP-8. 8
Figure 3.2 EMC1412 Pin Diagram, TDFN-8 2mm x 3mm. 8
Figure 5.1 SMBus Timing Diagram 13
Figure 5.2 Isolating THERM Pin 14
Figure 6.1 System Diagram for EMC1412 18
Figure 6.2 Temperature Filter Step Response 22
Figure 6.3 Temperature Filter Impulse Response. 22
Figure 6.4 Diode Configurations 24
Figure 9.1 EMC1412 2mm x 3mm TDFN Package Drawing. 40
Figure 9.2 EMC1412 2mm x 3mm TDFN Package Dimensions 41
Figure 9.3 EMC1412 2mm x 3mm TDFN Package PCB Land Pattern. 41
Figure 9.4 8-Pin MSOP / TSSOP Package 42
Figure 9.5 EMC1412-1 8-Pin TDFN Package Markings 43
Figure 9.6 EMC1412-A 8-Pin TDFN Package Markings 44
Figure 9.7 EMC1412 8-Pin MSOP Package Markings 45

List of Tables

Table 3.1 EMC1412 Pin Description . . . 8
Table 3.2 Pin Types . . . 9
Table 4.1 Absolute Maximum Ratings . . . 10
Table 4.2 Electrical Specifications . . . 11
Table 4.3 SMBus Electrical Specifications . . . 12
Table 5.1 SMBus Address Decode . . . 13
Table 5.2 Protocol Format . . . 15
Table 5.3 Write Byte Protocol . . . 15
Table 5.4 Read Byte Protocol . . . 16
Table 5.5 Send Byte Protocol . . . 16
Table 5.6 Receive Byte Protocol . . . 16
Table 5.7 Alert Response Address Protocol . . . 16
Table 6.1 Supply Current vs. Conversion Rate for EMC1412 . . . 19
Table 6.2 Temperature Data Format . . . 23
Table 7.1 Register Set in Hexadecimal Order . . . 25
Table 7.2 Temperature Data Registers . . . 27
Table 7.3 Status Register . . . 27
Table 7.4 Configuration Register . . . 28
Table 7.5 Conversion Rate Register . . . 29
Table 7.6 Conversion Rate . . . 29
Table 7.7 Temperature Limit Registers . . . 30
Table 7.8 Scratchpad Register . . . 30
Table 7.9 One Shot Register . . . 31
Table 7.10 Therm Limit Registers . . . 31
Table 7.11 Channel Mask Register . . . 31
Table 7.12 Consecutive ALERT Register . . . 32
Table 7.13 Consecutive Alert / Therm Settings . . . 33
Table 7.14 Beta Configuration Register . . . 33
Table 7.15 CPU Beta Values . . . 34
Table 7.16 Ideality Configuration Registers . . . 34
Table 7.17 Ideality Factor Look-Up Table (Diode Model) . . . 34
Table 7.18 Substrate Diode Ideality Factor Look-Up Table (BJT Model) . . . 35
Table 7.19 Filter Configuration Register . . . 36
Table 7.20 FILTER Decode . . . 36
Table 7.21 Product ID Register . . . 36
Table 7.22 Manufacturer ID Register . . . 36
Table 7.23 Revision Register . . . 37
Table 10.1 Customer Revision History . . . 46

Chapter 1 Block Diagram

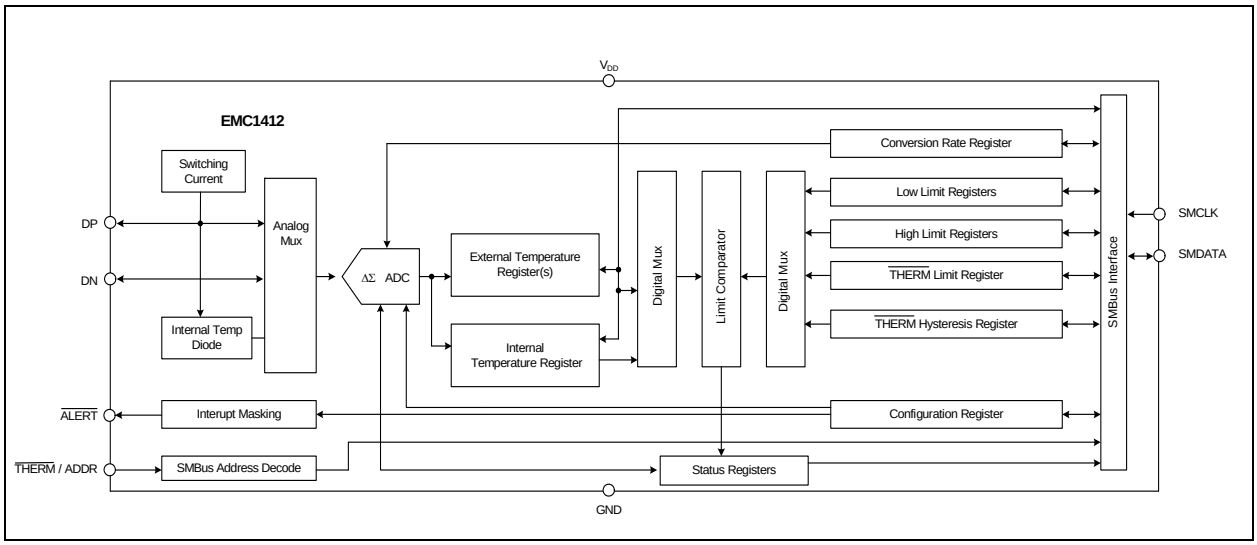


Figure 1.1 EMC1412 Block Diagram

Chapter 2 Delta

2.1 Functional Delta from EMC1412 rev A to rev B

1. Updated revision number to 04h.

Chapter 3 Pin Description

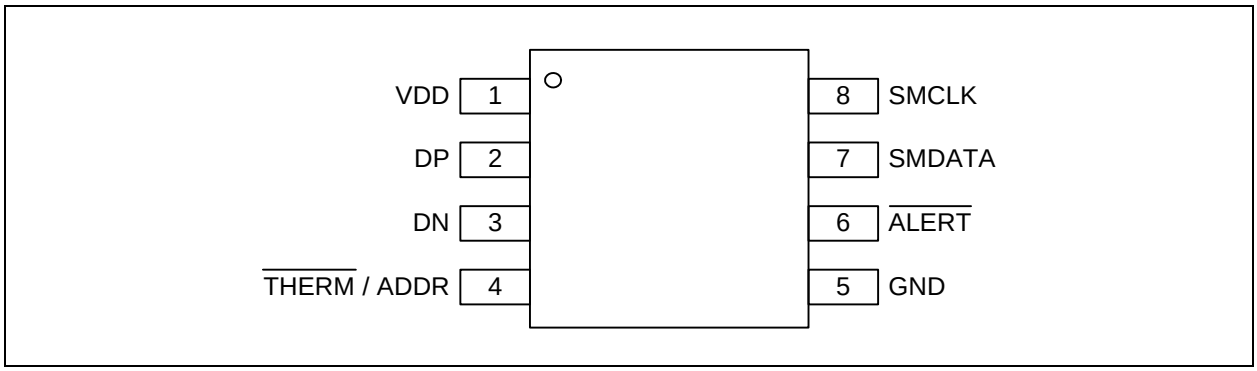


Figure 3.1 EMC1412 Pin Diagram, MSOP-8

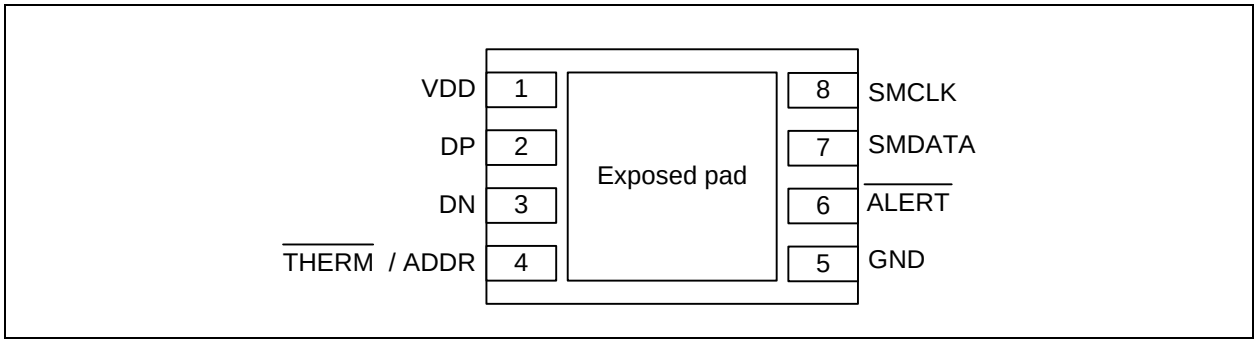


Figure 3.2 EMC1412 Pin Diagram, TDFN-8 2mm x 3mm

Table 3.1 EMC1412 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	$\overline{\text{THERM}}$ / ADDR	$\overline{\text{THERM}}$ - Active low Critical $\overline{\text{THERM}}$ output signal - requires pull-up resistor	OD (5V)
		ADDR - Selects SMBus address based on 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)

Table 3.1 EMC1412 Pin Description

PIN NUMBER	NAME	FUNCTION	TYPE
7	SMDATA	SMBus Data input/output - requires pull-up resistor	DIOD (5V)
8	SMCLK	SMBus Clock input - requires pull-up resistor	DI (5V)
Bottom Pad	Exposed Pad	Not internally connected, but recommend grounding.	-

APPLICATION NOTE: For the 5V tolerant pins that have a pull-up resistor (SMCLK, 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 Table 3.2.

Table 3.2 Pin Types

PIN TYPE	DESCRIPTION
Power	This pin is used to supply power or ground to the device.
AIO	Analog Input / Output -This pin is used as an I/O for analog signals.
DI	Digital Input - This pin is used as a digital input. This pin is 5V tolerant.
DIOD	Digital Input / Open Drain Output - This pin is used as a digital I/O. When it is used as an output, it is open drain and requires a pull-up resistor. This pin is 5V tolerant.
OD	Open Drain Digital Output - This pin is used as a digital output. It is open drain and requires a pull-up resistor. This pin is 5V tolerant.

Chapter 4 Electrical Specifications

4.1 Absolute Maximum Ratings

Table 4.1 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 Note 4.1)	0 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 (θ_{j-a})	140.8	°C/W
Package Thermal Characteristics for TDFN-8		
Thermal Resistance (θ_{j-a})	89	°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.

Note 4.1 For the 5V tolerant pins that have a pull-up resistor (SMCLK, SMDATA, $\overline{\text{THERM}}$, and $\overline{\text{ALERT}}$), the pull-up voltage must not exceed 3.6V when the device is unpowered.

4.2 Electrical Specifications

Table 4.2 Electrical Specifications

V_{DD} = 3.0V to 3.6V, T_A = -40°C to 125°C, all typical values at T_A = 27°C unless otherwise noted.						
CHARACTERISTIC	**SYMBOL**	**MIN**	**TYP**	**MAX**	**UNITS**	**CONDITIONS**
DC Power						
Supply Voltage	V_{DD}	3.0	3.3	3.6	V	
Supply Current	I_{DD}		430	850	µA	1 conversion / sec, dynamic averaging disabled
			930	1200	µA	4 conversions / sec, dynamic averaging enabled
			1120		µA	≥ 16 conversions / sec, dynamic averaging enabled
Standby Supply Current	I_{DD}		170	230	µA	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_A < 100°C
				±2	°C	-40°C < T_A < 125°C
Temperature Resolution			0.125		°C	
External Temperature Monitor						
Temperature Accuracy			±0.25	±1	°C	+20°C < T_{DIODE} < +110°C 0°C < T_A < 100°C
			±0.5	±2	°C	-40°C < T_{DIODE} < 127°C
Temperature Resolution			0.125		°C	
Conversion Time all Channels	t_{CONV}		190		ms	default settings
Capacitive Filter	C_{FILTER}		2.2	2.7	nF	Connected across external diode
$\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ pins						
Output Low Voltage	V_{OL}	0.4			V	I_{SINK} = 8mA
Leakage Current	I_{LEAK}			±5	µA	$\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ pins Device powered or unpowered T_A < 85°C pull-up voltage ≤ 3.6V

4.3 SMBus Electrical Characteristics

Table 4.3 SMBus Electrical Specifications

V_{DD} = 3.0V to 3.6V, T_A = -40°C to 125°C, all typical values are at T_A = 27°C unless otherwise noted.						
CHARACTERISTIC	**SYMBOL**	**MIN**	**TYP**	**MAX**	**UNITS**	**CONDITIONS**
SMBus Interface						
Input High Voltage	V_{IH}	2.0		V_{DD}	V	5V Tolerant
Input Low Voltage	V_{IL}	-0.3		0.8	V	5V Tolerant
Leakage Current	I_{LEAK}			±5	µA	Powered or unpowered TA < 85°C
Hysteresis			420		mV	
Input Capacitance	C_{IN}		5		pF	
Output Low Sink Current	I_{OL}	8.2		15	mA	SMDATA = 0.4V
SMBus Timing						
Clock Frequency	f_{SMB}	10		400	kHz	
Spike Suppression	t_{SP}			50	ns	
Bus Free Time Stop to Start	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			µs	When transmitting to the master
Data Hold Time	$t_{HD:DAT}$	0.3			µs	When receiving from the master
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_{FALL}			300	ns	Min = $20+0.1C_{LOAD}$ ns
Clock/Data Rise time	t_{RISE}			300	ns	Min = $20+0.1C_{LOAD}$ ns
Capacitive Load	C_{LOAD}			400	pF	per bus line

Chapter 5 System Management Bus Interface Protocol

5.1 Communications Protocol

The EMC1412 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 5.1.

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

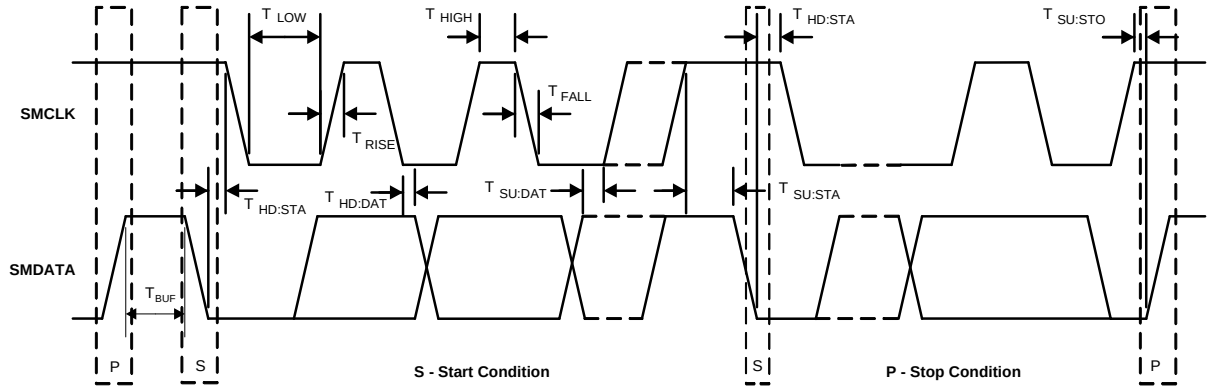


Figure 5.1 SMBus Timing Diagram

5.1.1 SMBus Start Bit

The SMBus Start bit is defined as a transition of the SMBus Data line from a logic ‘1’ state to a logic ‘0’ state while the SMBus Clock line is in a logic ‘1’ state.

5.1.2 SMBus Address and RD / $\overline{WR}$ Bit

The SMBus Address Byte consists of the 7-bit client address followed by the RD / $\overline{WR}$ indicator bit. If this RD / $\overline{WR}$ bit is a logic ‘0’, the SMBus Host is writing data to the client device. If this RD / $\overline{WR}$ bit is a logic ‘1’, the SMBus Host is reading data from the client device.

The EMC1412-A SMBus slave address is determined by the pull-up resistor on the $\overline{THERM}$ pin as shown in Table 5.1, "SMBus Address Decode".

The Address decode is performed by pulling known currents from VDD through the external resistor causing the pin voltage to drop based on the respective current / resistor relationship. This pin voltage is compared against a threshold that determines the value of the pull-up resistor.

Table 5.1 SMBus Address Decode

PULL UP RESISTOR ON THERM PIN (±5%)	SMBUS ADDRESS
4.7k	1111_100(r/$\overline{w}$)b
6.8k	1011_100(r/$\overline{w}$)b
10k	1001_100(r/$\overline{w}$)b

Table 5.1 SMBus Address Decode (continued)

PULL UP RESISTOR ON THERM PIN (±5%)	SMBUS ADDRESS
15k	1101_100(r/$\overline{w}$)b
22k	0011_100(r/$\overline{w}$)b
33k	0111_100(r/$\overline{w}$)b

The EMC1412-1 SMBus address is hard coded to 1001_100(r/$\overline{w}$).

The EMC1412-2 SMBus address is hard coded to 1001_101(r/$\overline{w}$).

5.1.3 $\overline{\text{THERM}}$ Pin Considerations

Because of the decode method used to determine the SMBus Address, it is important that the pull-up resistance on the $\overline{\text{THERM}}$ pin be within the tolerances shown in Table 5.1. Additionally, the pull-up resistor on the $\overline{\text{THERM}}$ pin must be connected to the same 3.3V supply that drives the VDD pin.

For 15ms after power up, the $\overline{\text{THERM}}$ pin must not be pulled low or the SMBus address will not be decoded properly. If the system requirements do not permit these conditions, the $\overline{\text{THERM}}$ pin must be isolated from its hard-wired OR'd bus during this time.

One method of isolating this pin is shown in Figure 5.2.

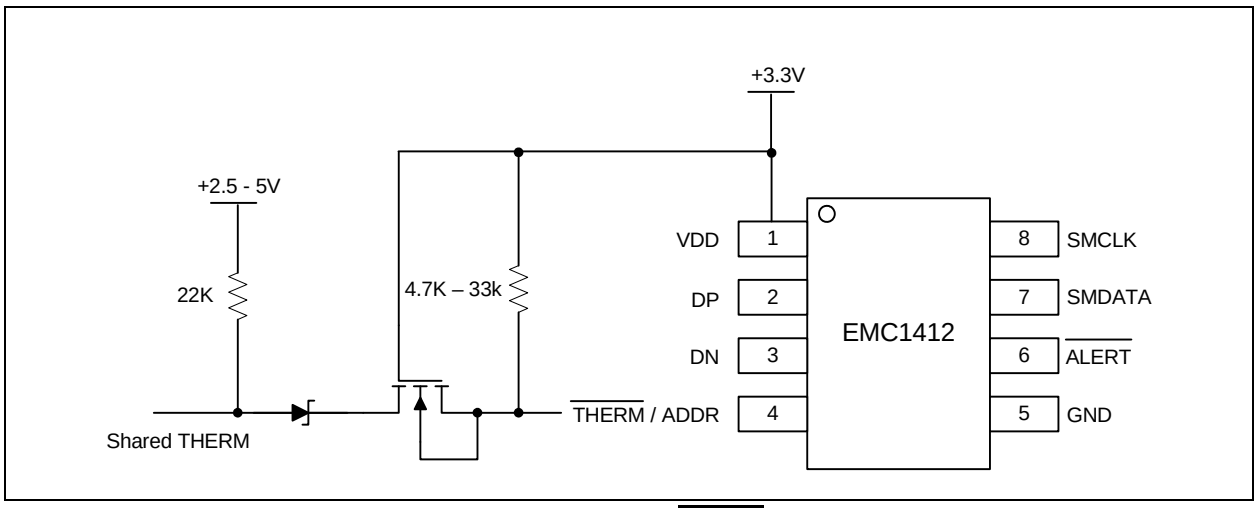


Figure 5.2 Isolating $\overline{\text{THERM}}$ Pin

5.1.4 SMBus Data Bytes

All SMBus Data bytes are sent most significant bit first and composed of 8-bits of information.

5.1.5 SMBus ACK and NACK Bits

The SMBus client will acknowledge all data bytes that it receives. This is done by the client device pulling the SMBus data line low after the 8th bit of each byte that is transmitted. This applies to the Write Byte protocol.

The Host will NACK (not acknowledge) the last data byte to be received from the client by holding the SMBus data line high after the 8th data bit has been sent.

5.1.6 SMBus Stop Bit

The SMBus Stop bit is defined as a transition of the SMBus Data line from a logic '0' state to a logic '1' state while the SMBus clock line is in a logic '1' state. When the device detects an SMBus Stop bit and it has been communicating with the SMBus protocol, it will reset its client interface and prepare to receive further communications.

5.1.7 SMBus Timeout

The EMC1412 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 7.11).

5.1.8 SMBus and I²C Compatibility

The EMC1412 is compatible with SMBus and I²C. The major differences between SMBus and I²C devices are highlighted here. For more information, refer to the SMBus 2.0 and I²C specifications. For information on using the EMC1412 in an I²C system, refer to SMSC AN 14.0 SMSC Dedicated Slave Devices in I²C Systems.

1. EMC1412 supports I²C fast mode at 400kHz. This covers the SMBus max time of 100kHz.
2. Minimum frequency for SMBus communications is 10kHz.
3. The SMBus client protocol will reset if the clock is held at a logic '0' for longer than 30ms. This timeout functionality is disabled by default in the EMC1412 and can be enabled by writing to the TIMEOUT bit. I²C does not have a timeout.
4. I²C devices do not support the Alert Response Address functionality (which is optional for SMBus).

Attempting to communicate with the EMC1412 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.

5.2 SMBus Protocols

The device supports 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 5.2.

Table 5.2 Protocol Format

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

5.2.1 Write Byte

The Write Byte is used to write one byte of data to the registers, as shown in Table 5.3.

Table 5.3 Write Byte Protocol

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

5.2.2 Read Byte

The Read Byte protocol is used to read one byte of data from the registers as shown in Table 5.4.

Table 5.4 Read Byte Protocol

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

5.2.3 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 5.5.

Table 5.5 Send Byte Protocol

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

5.2.4 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 is used for consecutive reads of the same register as shown in Table 5.6.

Table 5.6 Receive Byte Protocol

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

5.3 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 5.7.

Table 5.7 Alert Response Address Protocol

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

The EMC1412 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.

Chapter 6 Product Description

The EMC1412 is an SMBus temperature sensor. The EMC1412 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 EMC1412 and using that data to control the speed of one or more fans.

The EMC1412 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 EMC1412 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.

Figure 6.1 shows a system level block diagram of the EMC1412.

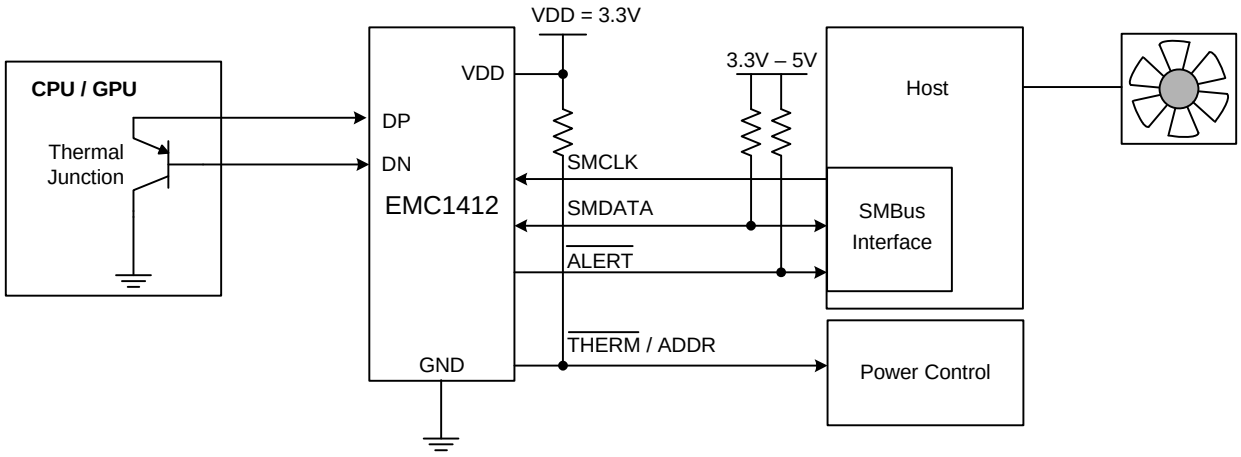


Figure 6.1 System Diagram for EMC1412

6.1 Modes of Operation

The EMC1412 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.

6.1.1 Conversion Rates

The EMC1412 may be configured for different conversion rates based on the system requirements. The conversion rate is configured as described in Section 7.5. The default conversion rate is 4 conversions per second. Other available conversion rates are shown in Table 7.6, "Conversion Rate".

6.1.2 Dynamic Averaging

Dynamic averaging causes the EMC1412 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 7.4, "Configuration Register"). 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 6.1**.**

Table 6.1 Supply Current vs. Conversion Rate for EMC1412

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

6.2 $\overline{\text{THERM}}$ Output

The $\overline{\text{THERM}}$ output is asserted independently of the $\overline{\text{ALERT}}$ 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 $\overline{\text{THERM}}$ 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.

6.3 ALERT Output

The 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 ALERT output is selected via the ALERT / COMP bit in the Configuration Register (see Section 7.4).

6.3.1 ALERT Pin Interrupt Mode

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

The ALERT pin can be masked by setting the MASK_ALL bit. Once the ALERT pin has been masked, it will be de-asserted and remain de-asserted until the MASK_ALL bit is cleared by the user. Any interrupt conditions that occur while the ALERT pin is masked will update the Status Register normally. There are also individual channel masks (see Section 7.10).

The 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.

6.3.2 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 ALERT pin will remain asserted until all temperatures drop below the corresponding high limit minus the Therm Hysteresis value.

When the 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 ALERT pin is deasserted. Once the ALERT pin is deasserted, the status bits will be automatically cleared.

The MASK_ALL bit will not block the ALERT pin in this mode; however, the individual channel masks (see Section 7.10) will prevent the respective channel from asserting the ALERT pin.

6.4 Temperature Measurement

The EMC1412 can monitor the temperature of one externally connected diode. The external diode channel is configured with Resistance Error Correction and Beta Compensation based on user settings and system requirements.

The device contains programmable High, Low, and Therm limits for all measured temperature channels. If the measured temperature goes below the Low limit or above the High limit, the ALERT pin can be asserted (based on user settings). If the measured temperature meets or exceeds the Therm Limit, the THERM pin is asserted unconditionally, providing two tiers of temperature detection.

6.4.1 Beta Compensation

The EMC1412 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.

6.4.2 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 EMC1412 automatically corrects up to 100 ohms of series resistance.

6.4.3 Programmable External Diode Ideality Factor

The EMC1412 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 EMC1412 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.

6.5 Diode Faults

The EMC1412 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 $\overline{\text{ALERT}}$ pin asserts (unless masked, see Section 6.6) 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 $\overline{\text{ALERT}}$ pin asserts (unless masked). This condition is indistinguishable from a temperature measurement of 0.000°C (-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.

6.6 Consecutive Alerts

The EMC1412 contain 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 7.11, "Consecutive ALERT Register" for more details on the consecutive alert function.

6.7 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 (default) (see Section 7.14). The typical filter performance is shown in Figure 6.2 and Figure 6.3.

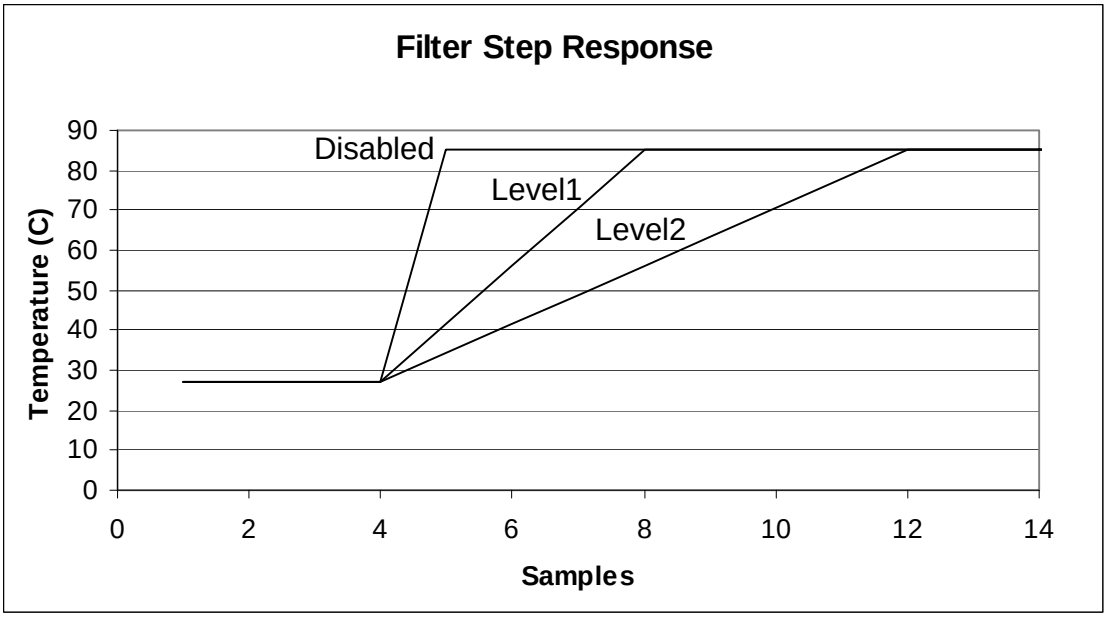


Figure 6.2 Temperature Filter Step Response

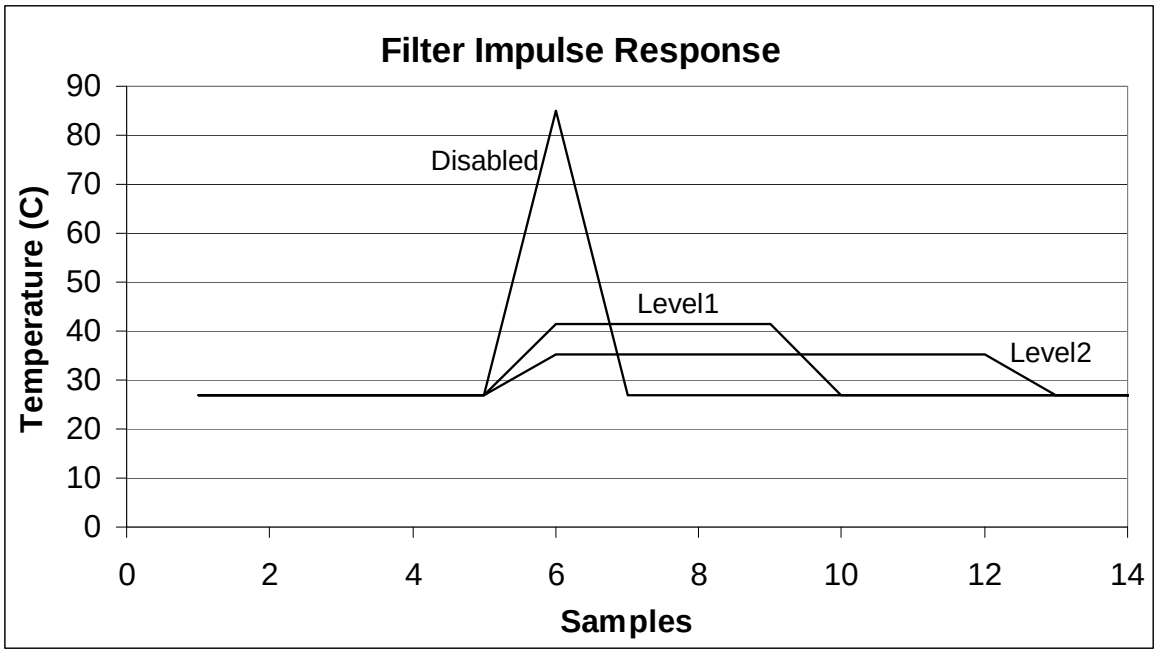


Figure 6.3 Temperature Filter Impulse Response

6.8 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 EMC1412 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 6.2 shows the default and extended range formats.

Table 6.2 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 Note 6.2
-1	000 0000 0000	001 1111 1000
0	000 0000 0000 Note 6.1	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 Note 6.3	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 Note 6.4

Note 6.1 In default mode, all temperatures < 0°C will be reported as 0°C.

Note 6.2 In the extended range, all temperatures < -64°C will be reported as -64°C.

Note 6.3 For the default range, all temperatures > +127.875°C will be reported as +127.875°C.

Note 6.4 For the extended range, all temperatures > +191.875°C will be reported as +191.875°C.

6.9 External Diode Connections

The EMC1412 can be configured to measure a CPU substrate transistor, a discrete 2N3904 thermal diode, or an AMD processor diode. The diodes can be connected as indicated in Figure 6.4.

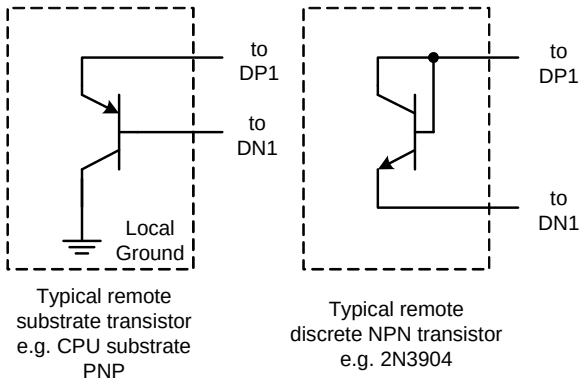


Figure 6.4 Diode Configurations

Chapter 7 Register Description

The registers shown in Table 7.1 are accessible through the SMBus. An entry of '-' indicates that the bit is not used and will always read '0'.

Table 7.1 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 27
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 Diode	00h	Page 27
03h	R/W	Configuration	Controls the general operation of the device (mirrored at address 09h)	00h	Page 28
04h	R/W	Conversion Rate	Controls the conversion rate for updating temperature data (mirrored at address 0Ah)	06h (4/sec)	Page 29
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 30
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 28
0Ah	R/W	Conversion Rate	Controls the conversion rate for updating temperature data (mirrored at address 04h)	06h (4/sec)	Page 29

Table 7.1 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 30
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 31
10h	R	External Diode Data Low Byte	Stores the fractional data for the External Diode	00h	Page 27
11h	R/W	Scratchpad	Scratchpad register for software compatibility	00h	Page 30
12h	R/W	Scratchpad	Scratchpad register for software compatibility	00h	Page 30
13h	R/W	External Diode High Limit Low Byte	Stores the fractional portion of the high limit for the External Diode	00h	Page 30
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 31
1Fh	R/W	Channel Mask Register	Controls the masking of individual channels	00h	Page 31
20h	R/W	Internal Diode Therm Limit	Stores the 8-bit critical temperature limit for the Internal Diode	55h (85°C)	Page 31
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 32
25h	R/W	External Diode Beta Configuration	Stores the Beta Compensation circuitry settings for External Diode	08h	Page 33
27h	R/W	External Diode Ideality Factor	Stores the ideality factor for the External Diode	12h (1.008)	Page 34
29h	R	Internal Diode Data Low Byte	Stores the fractional data for the Internal Diode	00h	Page 27
40h	R/W	Filter Control	Controls the digital filter setting for the External Diode channel	00h	Page 36

Table 7.1 Register Set in Hexadecimal Order (continued)

REGISTER ADDRESS	R/W	REGISTER NAME	FUNCTION	DEFAULT VALUE	PAGE
FDh	R	Product ID	Stores a fixed value that identifies the device	20h	Page 36
FEh	R	Manufacturer ID	Stores a fixed value that represents SMSC	5Dh	Page 36
FFh	R	Revision	Stores a fixed value that represents the revision number	04h	Page 37

7.1 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.

7.2 Temperature Data Registers

Table 7.2 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 7.2, 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.

7.3 Status Register

Table 7.3 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 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 7.11) and will not be asserted until the programmed consecutive alert count has been reached.

The status bits (except E1THERM and ITHERM) will remain set until read unless the ALERT pin is configured as a second THERM output (see Section 6.3.2).

Bit 7 - BUSY - This bit indicates that the ADC is currently converting. This bit does not cause either the ALERT or 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 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 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 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 ALERT pin.

Bit 2 - FAULT - This bit is asserted when a diode fault is detected. When set, this bit will assert the ALERT pin.

Bit 1 - ETHERM - This bit is set when the External Diode channel exceeds the programmed Therm Limit. When set, this bit will assert the THERM pin. This bit will remain set until the 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 Therm Limit. When set, this bit will assert the THERM pin. This bit will remain set until the THERM pin is released at which point it will be automatically cleared.

7.4 Configuration Register

Table 7.4 Configuration Register

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

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

Bit 7 - MASK_ALL - Masks the ALERT pin from asserting.

- '0' - (default) - The ALERT pin is not masked. If any of the appropriate status bits are set the ALERT pin will be asserted.
- '1' - - The ALERT pin is masked. It will not be asserted for any interrupt condition unless it is configured in comparator mode. 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 ALERT pin.

- '0' (default) - The ALERT pin acts as described in Section 6.3.
- '1' - The ALERT pin acts in comparator mode as described in Section 6.3.2. In this mode the MASK_ALL bit is ignored.

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

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

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 6.2).

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 6.1.
- '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 6.1.

7.5 Conversion Rate Register

Table 7.5 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 7.6.

Table 7.6 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

7.6 Limit Registers

Table 7.7 Temperature Limit Registers

ADDR.	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
05h 0Bh	R/W	Internal Diode High Limit	128	64	32	16	8	4	2	1	55h (85°C)
06h 0Ch	R/W	Internal Diode Low Limit	128	64	32	16	8	4	2	1	00h (0°C)
07h 0Dh	R/W	External Diode High Limit High Byte	128	64	32	16	8	4	2	1	55h (85°C)
13h	R/W	External Diode High Limit Low Byte	0.5	0.25	0.125	-	-	-	-	-	00h
08h 0Eh	R/W	External Diode Low Limit High Byte	128	64	32	16	8	4	2	1	00h (0°C)
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 $\overline{\text{ALERT}}$ 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 $\overline{\text{ALERT}}$ 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 effect 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 7.4).

7.7 Scratchpad Registers

Table 7.8 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.

7.8 One Shot Register

Table 7.9 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 effect.

7.9 Therm Limit Registers

Table 7.10 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, 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.

7.10 Channel Mask Register

Table 7.11 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.

7.11 Consecutive ALERT Register

Table 7.12 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 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 $\overline{\text{ALERT}}$ 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 on an EMC1412 device, 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 read 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.

- '1' - The SMBus Timeout feature is enabled. If the SMCLK line is held low for more than 30ms, 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 $\overline{\text{THERM}}$ 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, the counter is reset. If a number of consecutive measurements above the Therm Limit occurs, the $\overline{\text{THERM}}$ pin is asserted low.

Once the $\overline{\text{THERM}}$ 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 7.13. 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 $\overline{\text{ALERT}}$ pin is asserted. All temperature channels use this value to set the respective counters. The bits are decoded as shown in Table 7.13. The default setting is 1 consecutive out of limit conversion.

Table 7.13 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])

7.12 Beta Configuration Register

Table 7.14 Beta Configuration Register

ADDR.	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
25h	R/W	External Diode 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 auto-detection function.

- '0' - The Beta Compensation Factor auto-detection circuitry is disabled.
- '1' (default) - The Beta Compensation factor auto-detection 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 auto-detection circuitry is enabled, these bits will be updated automatically and writing to these bits will have no effect. If the auto-detection circuitry is disabled, these bits will determine the beta configuration setting.

Care should be taken when setting the BETA[2:0] bits when the auto-detection circuitry is disabled. If the Beta Compensation factor is set at a beta value that is higher than the transistor beta, 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), the BETA[2:0] bits should be set to '111b'.

Table 7.15 CPU Beta Values

HEX	ENABLEX	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	Auto-detection

7.13 External Diode Ideality Factor Register

Table 7.16 Ideality Configuration Registers

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

This register stores the ideality factors that are applied to the external diode. Table 7.17 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 7.17 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
0Ch	1.0001	1Ch	1.0212	2Ch	1.0423

Table 7.17 Ideality Factor Look-Up Table (Diode Model) (continued)

SETTING	FACTOR	SETTING	FACTOR	SETTING	FACTOR
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 7.18 when using a CPU substrate transistor.

Table 7.18 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
17h	1.0066	27h	1.0278	37h	1.0486

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

7.14 Filter Control Register

Table 7.19 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 measurement as shown in Table 7.20. See Figure 6.2 and Figure 6.3 for examples on the filter behavior.

Table 7.20 FILTER Decode

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

7.15 Product ID Register

Table 7.21 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

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

7.16 SMSC ID Register

Table 7.22 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 EMC1412.

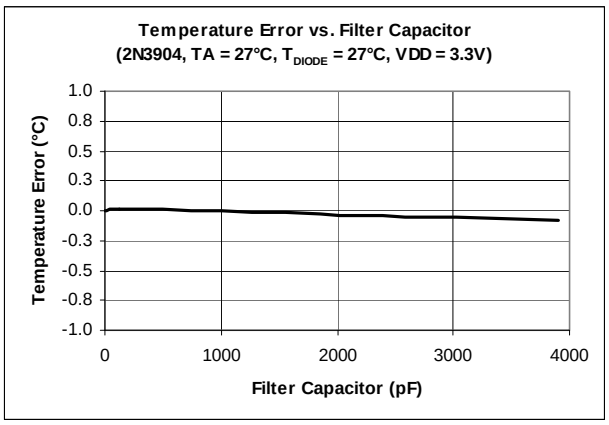
7.17 Revision Register

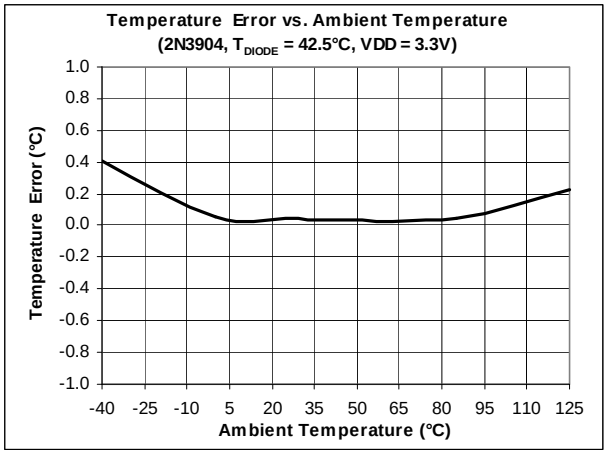
Table 7.23 Revision Register

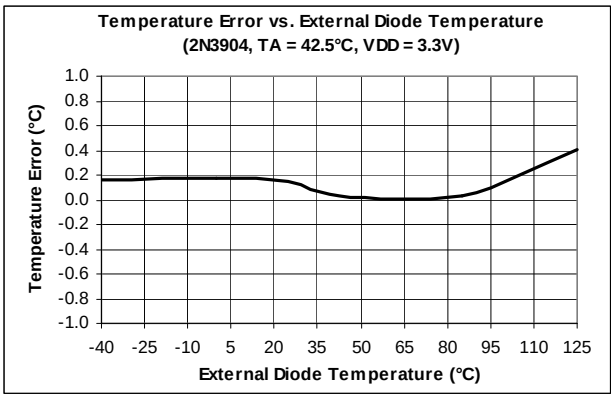
ADDR.	R/W	REGISTER	B7	B6	B5	B4	B3	B2	B1	B0	DEFAULT
FFh	R	Revision	0	0	0	0	0	1	0	0	04h

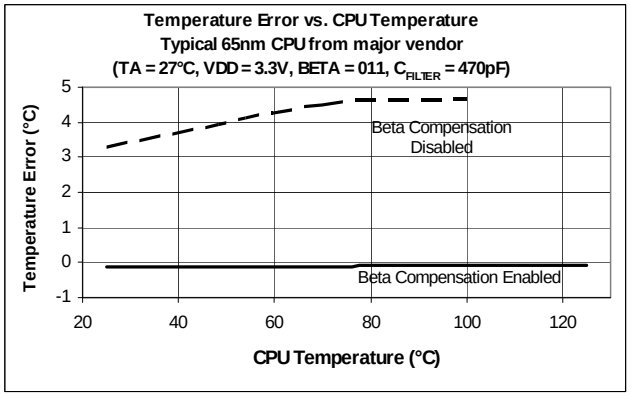
The Revision register contains an 8-bit word that identifies the die revision.

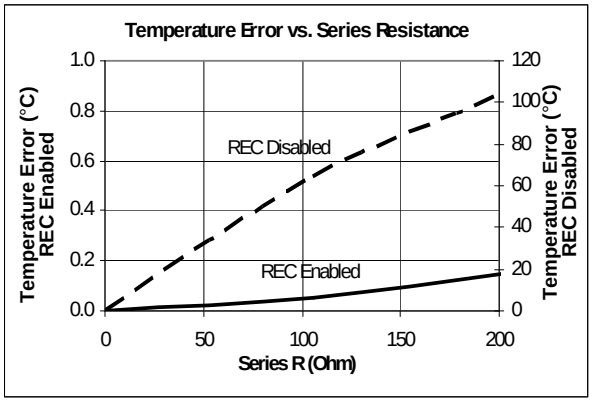
Chapter 8 Typical Operating Curves

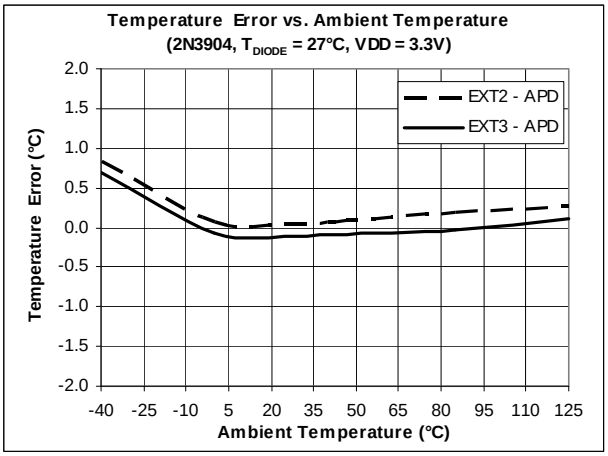


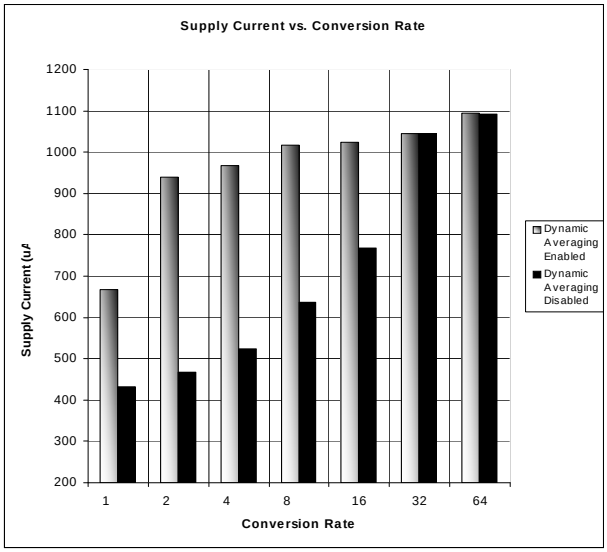







Temperature Error vs. Series Resistance
Temperature Error (°C) REC Enabled
Temperature Error (°C) REC Disabled
REC Disabled
REC Enabled
Series R (Ohm)
0.0
0.2
0.4
0.6
0.8
1.0
0
20
40
60
80
100
120
0
50
100
150
200


Temperature Error vs. Ambient Temperature
(2N3904, T DIODE = 27°C, VDD = 3.3V)
Temperature Error (°C)
EXT2 - APD
EXT3 - APD
Ambient Temperature (°C)
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-40
-25
-10
5
20
35
50
65
80
95
110
125


Supply Current vs. Conversion Rate
Supply Current (uA
Dynamic Averaging Enabled
Dynamic Averaging Disabled
Conversion Rate
1200
1100
1000
900
800
700
600
500
400
300
200
1
2
4
8
16
32
64

Chapter 9 Package Information

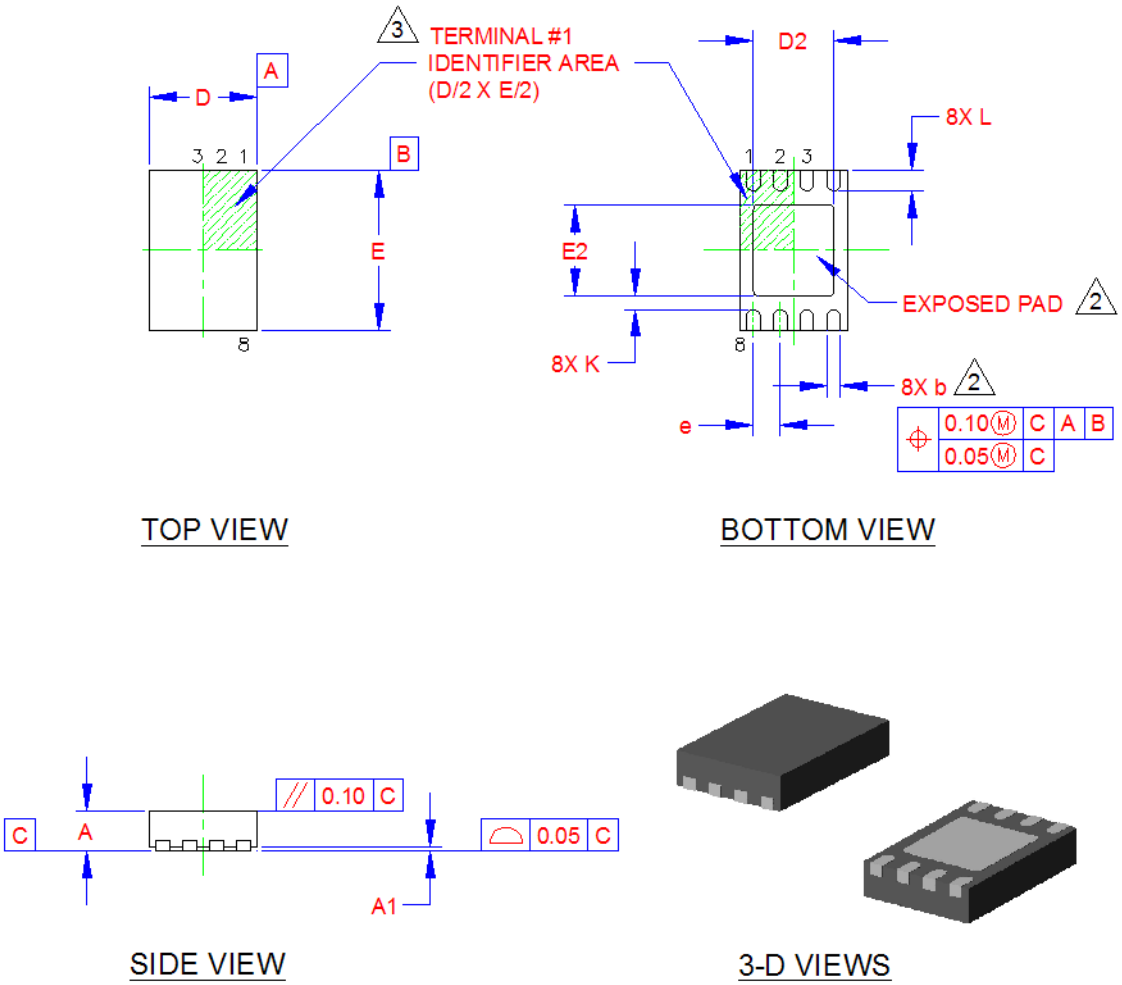
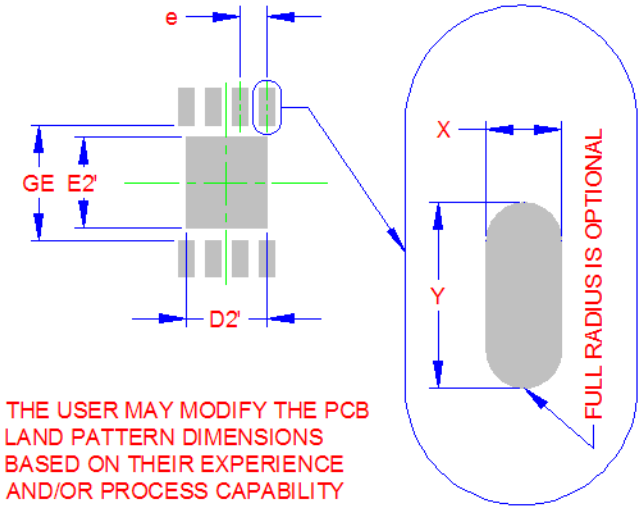


Figure 9.1 EMC1412 2mm x 3mm TDFN Package Drawing

COMMON DIMENSIONS					
SYMBOL	MIN	NOM	MAX	NOTE	REMARK
A	0.70	0.75	0.80	-	OVERALL PACKAGE HEIGHT
A1	0	0.02	0.05	-	STANDOFF
D	1.90	2.00	2.10	-	X BODY SIZE
E	2.90	3.00	3.10	-	Y BODY SIZE
D2	1.40	1.50	1.60	2	X EXPOSED PAD SIZE
E2	1.60	1.70	1.80	2	Y EXPOSED PAD SIZE
L	0.35	0.40	0.45	-	TERMINAL LENGTH
b	0.18	0.25	0.30	2	TERMINAL WIDTH
K	0.20	0.25	-	-	CENTER PAD TO PIN CLEARANCE
e	0.50 BSC			-	TERMINAL PITCH

NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. UNILATERAL COPLANARITY ZONE APPLIES TO THE EXPOSED PAD, AS WELL AS THE TERMINALS. DIMENSIONS "b" APPLIES TO PLATED TERMINALS AND IT IS MEASURED BETWEEN 0.15 AND 0.30 mm FROM THE TERMINAL TIP.
3. DETAILS OF TERMINAL #1 IDENTIFIER ARE OPTIONAL BUT MUST BE LOCATED WITHIN THE AREA INDICATED.

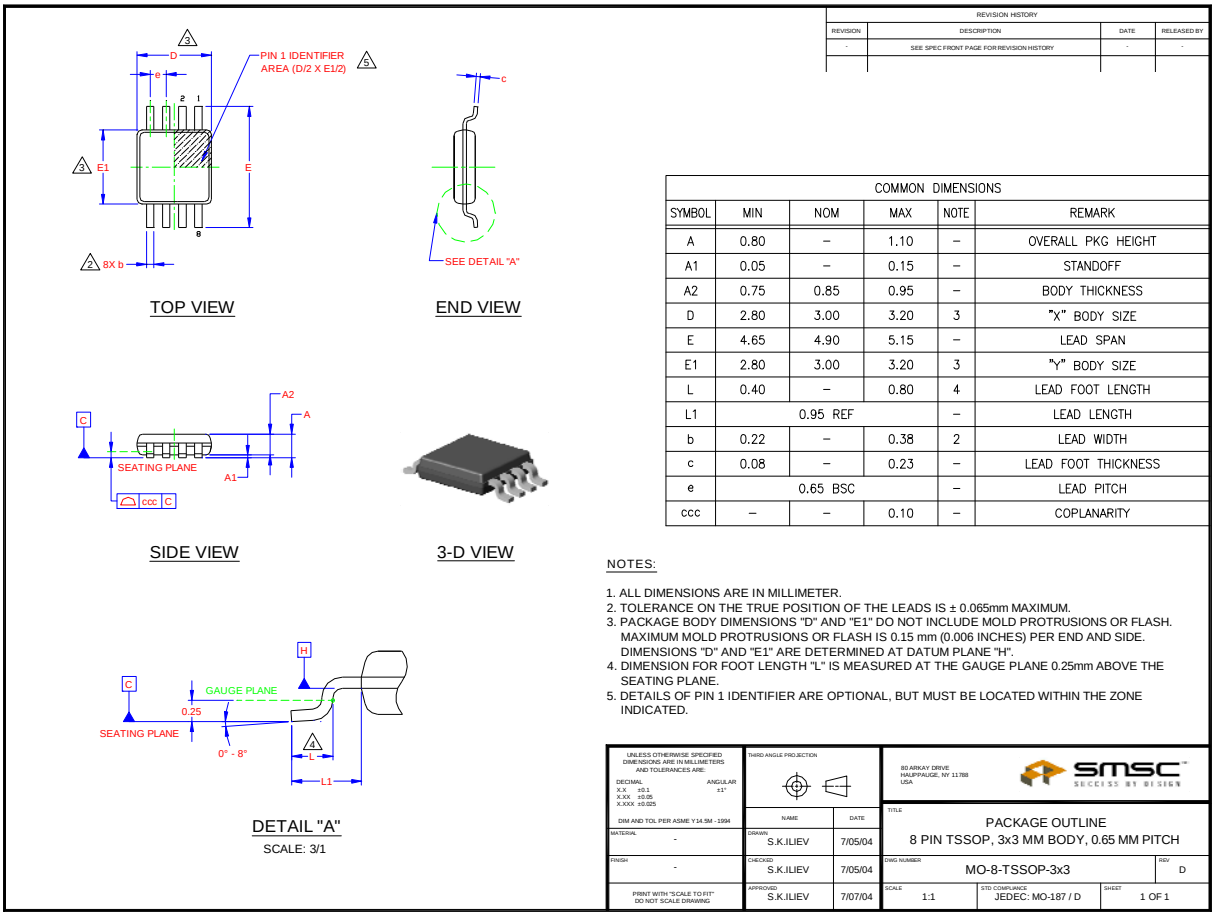
Figure 9.2 EMC1412 2mm x 3mm TDFN Package Dimensions



LAND PATTERN DIMENSIONS			
SYMBOL	MIN	NOM	MAX
GE	2.10	-	2.20
D2'	-	1.50	1.50
E2'	-	1.70	1.70
X	-	-	0.28
Y	-	-	0.69
e	0.50		

RECOMMENDED PCB LAND PATTERN

Figure 9.3 EMC1412 2mm x 3mm TDFN Package PCB Land Pattern



REVISION HISTORY

REVISION	DESCRIPTION	DATE	RELEASED BY
-	SEE SPEC FRONT PAGE FOR REVISION HISTORY	-	-

COMMON DIMENSIONS					
SYMBOL	MIN	NOM	MAX	NOTE	REMARK
A	0.80	–	1.10	–	OVERALL PKG HEIGHT
A1	0.05	–	0.15	–	STANDOFF
A2	0.75	0.85	0.95	–	BODY THICKNESS
D	2.80	3.00	3.20	3	"X" BODY SIZE
E	4.65	4.90	5.15	–	LEAD SPAN
E1	2.80	3.00	3.20	3	"Y" BODY SIZE
L	0.40	–	0.80	4	LEAD FOOT LENGTH
L1		0.95 REF		–	LEAD LENGTH
b	0.22	–	0.38	2	LEAD WIDTH
c	0.08	–	0.23	–	LEAD FOOT THICKNESS
e		0.65 BSC		–	LEAD PITCH
ccc	–	–	0.10	–	COPLANARITY

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETER.
2. TOLERANCE ON THE TRUE POSITION OF THE LEADS IS ± 0.065mm MAXIMUM.
3. PACKAGE BODY DIMENSIONS "D" AND "E1" DO NOT INCLUDE MOLD PROTRUSIONS OR FLASH. MAXIMUM MOLD PROTRUSIONS OR FLASH IS 0.15 mm (0.006 INCHES) PER END AND SIDE. DIMENSIONS "D" AND "E1" ARE DETERMINED AT DATUM PLANE "H".
4. DIMENSION FOR FOOT LENGTH "L" IS MEASURED AT THE GAUGE PLANE 0.25mm ABOVE THE SEATING PLANE.
5. DETAILS OF PIN 1 IDENTIFIER ARE OPTIONAL, BUT MUST BE LOCATED WITHIN THE ZONE INDICATED.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETERS AND TOLERANCES ARE:
DECIMAL X.X ±0.1 X.XX ±0.05 X.XXX ±0.025
ANGULAR ±1°
DIM AND TOL PER ASME Y 14.5M - 1994
MATERIAL -
FINISH -
PRINT WITH "SCALE TO FIT" DO NOT SCALE DRAWING

THIRD ANGLE PROJECTION

	NAME	DATE
DRAWN	S.K.ILIEV	7/05/04
CHECKED	S.K.ILIEV	7/05/04
APPROVED	S.K.ILIEV	7/07/04

80 ARKAY DRIVE HAUPPAUGE, NY 11788 USA

TITLE: PACKAGE OUTLINE 8 PIN TSSOP, 3x3 MM BODY, 0.65 MM PITCH

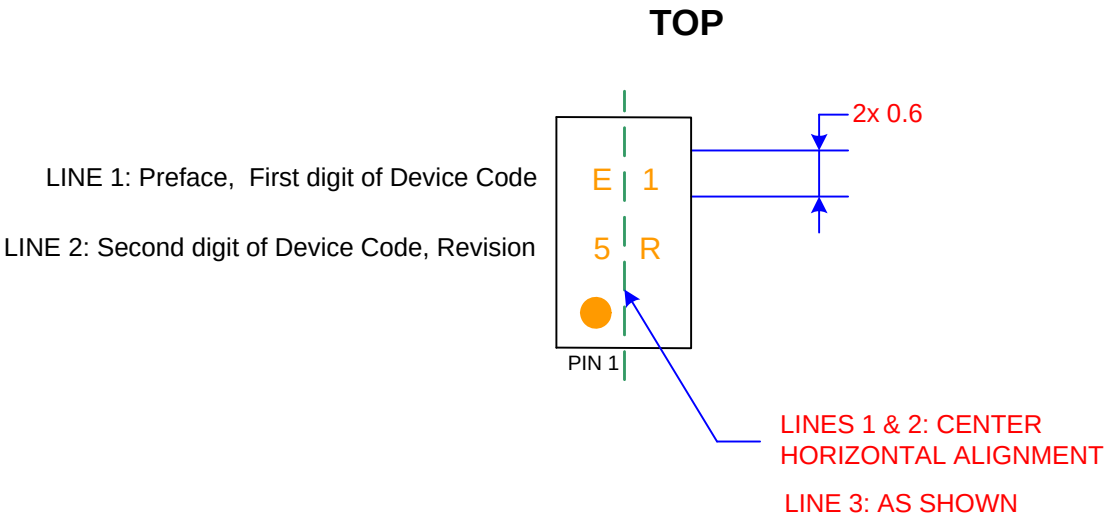
DWG NUMBER: MO-8-TSSOP-3x3 REV: D

SCALE: 1:1 STD COMPLIANCE: JEDEC: MO-187 / D SHEET: 1 OF 1

Figure 9.4 8-Pin MSOP / TSSOP Package

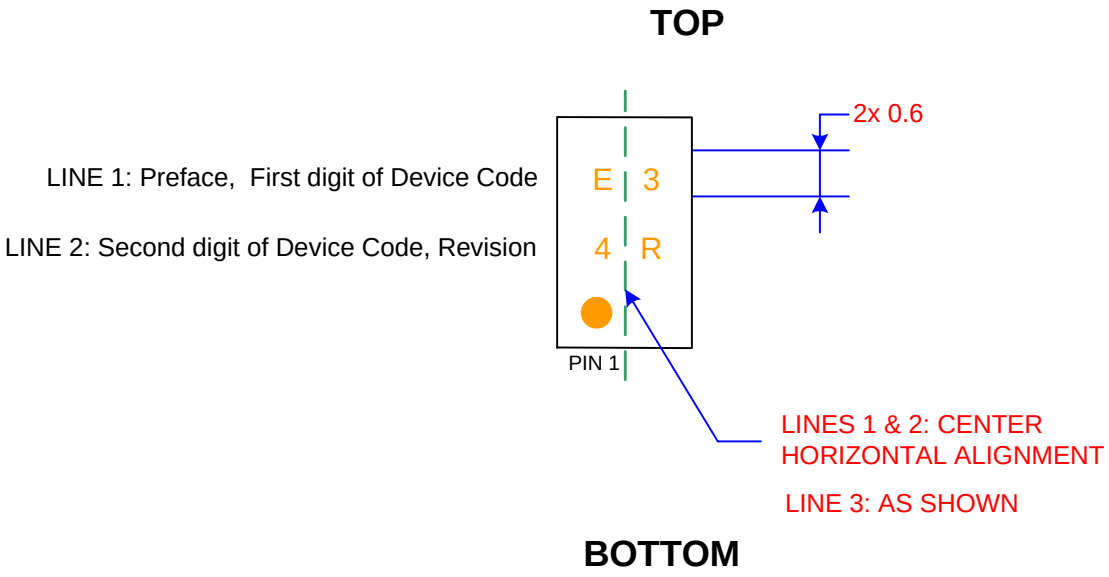
9.1 Package Markings

The devices will be marked as shown in Figure 9.5, Figure 9.6 and Figure 9.7.



BOTTOM MARKING IS NOT ALLOWED

Figure 9.5 EMC1412-1 8-Pin TDFN Package Markings



BOTTOM MARKING IS NOT ALLOWED

Figure 9.6 EMC1412-A 8-Pin TDFN Package Markings

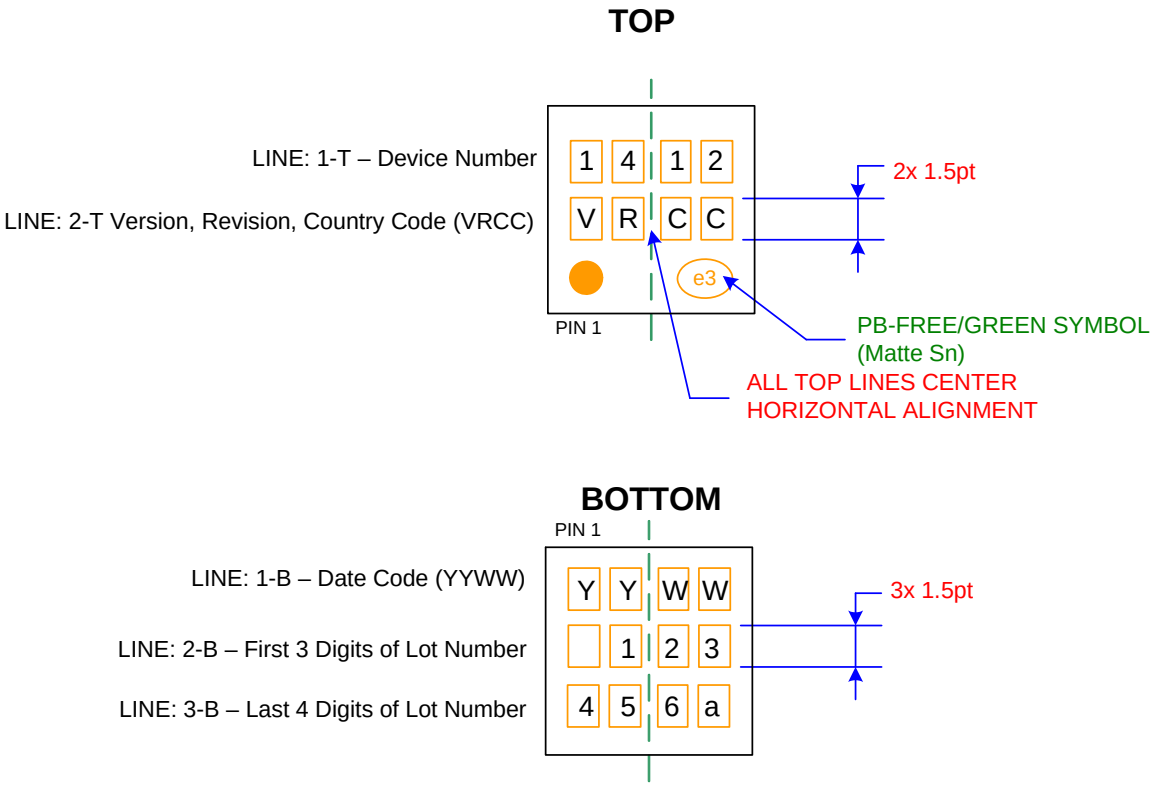


Figure 9.7 EMC1412 8-Pin MSOP Package Markings

Chapter 10 Document Revision History

Table 10.1 Customer Revision History

REVISION LEVEL & DATE	SECTION/FIGURE/ENTRY	CORRECTION
Rev. 1.41 (02-23-12)	Chapter 3, Pin Description	Labeled exposed pad in pinout figure and added row in pin description table. Recommendation is to ground the exposed pad.
Rev. 1.40 (01-05-12)	Table 4.3, "SMBus Electrical Specifications"	Added conditions for $t_{HD:DAT}$. Data hold time minimum of 0.3µs is required when receiving from the master.
	Section 5.1.8, "SMBus and I2C Compatibility"	Renamed from “SMBus and I2C Compliance.” First paragraph, added first sentence: “The EMC1412 is compatible with SMBus and I^2C.” And added last sentence: “For information on using the EMC1412 in an I^2C system, refer to SMSC AN 14.0 SMSC Dedicated Slave Devices in I^2C Systems.”
Rev. 1.38 (09-30-10)	Table 4.2, "Electrical Specifications"	Filter MAX changed from “2.5nF” to “2.7nF”.
	Section 7.17, "Revision Register"	Set revision ID to 04h.
	Chapter 5, System Management Bus Interface Protocol	Updated error on ACK bit settings and reorganized chapter information and moved ALERT pin considerations.
	Chapter 6, Product Description	Reorganized information for temperature monitoring and ALERT pin considerations.
Rev. 1.37 (12-23-09)	Section 7.17, "Revision Register"	Changed default from 01h to 03h to match the actual value.
Rev. 1.36 (09-19-09)	Ordering Information	Added EMC1412-1-AC3-TR in an 8-pin TDFN package.
	Section 4.1, "Absolute Maximum Ratings"	Updated voltage on 5V tolerant pins with pull up from -0.3 to 3.6 to 0 to 3.6. Added thermal characteristics for TDFN package.
	Chapter 9, Package Information	Added package information for the TDFN.
	Section 9.1, "Package Markings"	Added package marking information for the TDFN.
Rev. 1.35 (05-06-09)	Pin Table	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, ALERT), the voltage difference between VDD and the pull-up voltage must never exceed 3.6V.”

Table 10.1 Customer Revision History (continued)

REVISION LEVEL & DATE	SECTION/FIGURE/ENTRY	CORRECTION
	Table 4.1, "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, ALERT), the pull-up voltage must not exceed 3.6V when the device is unpowered.”
	Table 4.2, "Electrical Specifications"	Added leakage current
Rev. 1.34 (12-02-08)	Initial document creation	

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