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EMC1413/EMC1414

Multiple Channel 1°C Temperature Sensors with Beta Compensation

PRODUCT FEATURES

General Description

The EMC1413/EMC1414 are high accuracy, low cost, System Management Bus (SMBus) temperature sensors. Advanced features such as Resistance Error Correction (REC), Beta Compensation (to support CPU diodes requiring the BJT/transistor model) and automatic diode type detection combine to provide a robust solution for complex environmental monitoring applications.

The EMC1413 monitors three temperature channels and the EMC1414 monitors four temperature channels. 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 each 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 including advanced processor geometries
- Automatically determines external diode type and optimal settings
- Resistance Error Correction
- Up to 3 External Temperature Monitors
  — ±1°C max accuracy ($20°C < T_{DIODE} < 110°C$)
  — 0.125°C resolution
  — Supports up to 2.2nF diode filter capacitor
  — Anti-parallel diodes for extra diode support (EMC1414 only)
- Internal Temperature Monitor
  — ±1°C accuracy
  — 0.125°C resolution
- 3.3V Supply Voltage
- Programmable temperature limits for $\overline{\text{ALERT}}$
- Available in these RoHS compliant packages
  — 10-pin 3mm x 3mm DFN
  — 10-pin MSOP

Ordering Information:

ORDERING NUMBER	PACKAGE	FEATURES	SMBUS ADDRESS
EMC1413-1-AIZL-TR	10-pin MSOP (RoHS compliant)	Up to three temperature sensors, $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ pins, fixed SMBus address	1001_100(r/$\overline{\text{w}}$)
EMC1413-A-AIZL-TR	10-pin MSOP (RoHS compliant)	Up to three temperature sensors, $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ pins, programmable SMBus address	Selectable via $\overline{\text{THERM}}$ pull-up
EMC1413-A-AIA-TR	10-pin DFN 3mm x 3mm (RoHS compliant)	Up to three temperature sensors, $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ pins, programmable SMBus address	Selectable via $\overline{\text{THERM}}$ pull-up
EMC1413-3-AIZL-TR	10-pin MSOP (RoHS compliant)	Up to three temperature sensors, $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ pins, programmable SMBus address	0011_000(r/$\overline{\text{w}}$)
EMC1414-1-AIZL-TR	10-pin MSOP (RoHS compliant)	Up to four temperature sensors, $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ pins, fixed SMBus address	1001_100(r/$\overline{\text{w}}$)
EMC1414-A-AIZL-TR	10-pin MSOP (RoHS compliant)	Up to four temperature sensors, $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ pins, programmable SMBus address	Selectable via $\overline{\text{THERM}}$ pull-up
EMC1414-A-AIA-TR	10-pin DFN 3mm x 3mm (RoHS compliant)	Up to four temperature sensors, $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ pins, programmable SMBus address	Selectable via $\overline{\text{THERM}}$ pull-up

REEL SIZE IS 4,000 PIECES

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

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An errata sheet, describing minor operational differences from the data sheet and recommended workarounds, may exist for current devices. As device/documentation issues become known to us, we will publish an errata sheet. The errata will specify the revision of silicon and revision of document to which it applies.

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• Microchip's Worldwide Web site; http://www.microchip.com
• Your local Microchip sales office (see last page)

When contacting a sales office, please specify which device, revision of silicon and data sheet (include -literature number) you are using.

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1. Updated revision number to 04h.

Chapter 3 Pin Description
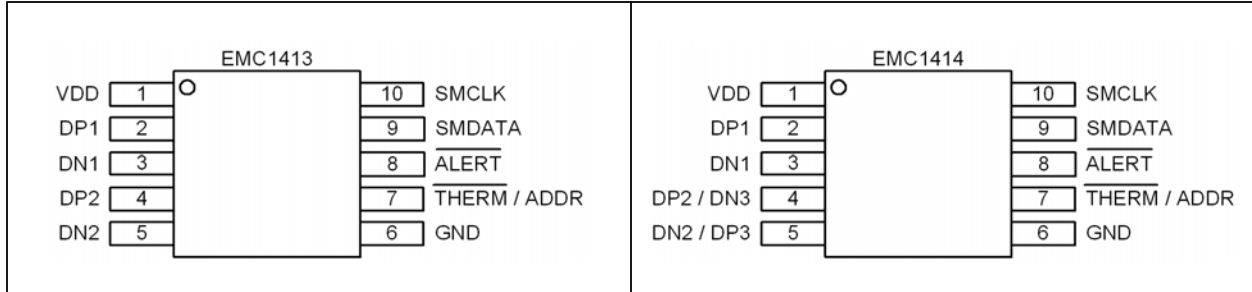
Figure 3.1 EMC1413 / 1414 Pin Diagram, MSOP-10
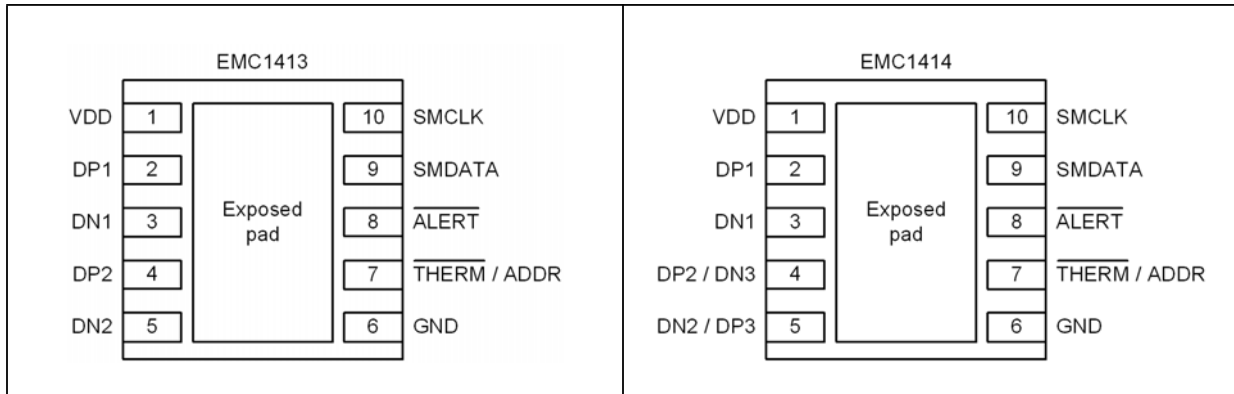
Figure 3.2 EMC1413 / EMC1414 Pin Diagram, DFN-10

Table 3.1 EMC1413 / EMC1414 Pin Description

PIN NUMBER	NAME	FUNCTION	TYPE
1	VDD	Power supply	Power
2	DP1	External diode 1 positive (anode) connection	AIO
3	DN1	External diode 1 negative (cathode) connection	AIO
4	DP2 / DN3	External diode 2 positive (anode) connection / External Diode 3 negative (cathode) connection for anti-parallel diodes (EMC1414 only)	AIO
5	DN2 / DP3	External diode 2 negative (cathode) connection / External Diode 3 positive (anode) connection for anti-parallel diodes (EMC1414 only)	AIO
6	GND	Ground	Power

Table 3.1 EMC1413 / EMC1414 Pin Description (continued)

PIN NUMBER	NAME	FUNCTION	TYPE
7	$\overline{\text{THERM}}$ / ADDR	THERM - Critical $\overline{\text{THERM}}$ output signal - requires pull-up resistor	OD (5V)
		ADDR - Selects SMBus address based on pull-up resistor	OD (5V)
8	$\overline{\text{ALERT}}$	Active low digital $\overline{\text{ALERT}}$ output signal - requires pull-up resist	OD (5V)
9	SMDATA	SMBus Data input/output - requires pull-up resistor	DIOD (5V)
10	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-10		
Thermal Resistance (θ_{j-a})	132.2	°C/W
Package Thermal Characteristics for DFN-10		
Thermal Resistance (θ_{j-a})	77.1	°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	$\geq$ 16 conversions / sec, dynamic averaging enabled
Standby Supply Current	I_{DD}		170	230	µA	Device in Standby mode, no SMBus communications, $\overline{ALERT}$ and $\overline{THERM}$ 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}		150		ms	default settings
Capacitive Filter	C_{FILTER}		2.2	2.7	nF	Connected across external diode
$\overline{ALERT}$ and $\overline{THERM}$ pins						
Output Low Voltage	V_{OL}	0.4			V	I_{SINK} = 8mA
Leakage Current	I_{LEAK}			±5	µA	$\overline{ALERT}$ and $\overline{THERM}$ pins Device powered or unpowered T_A < 85°C pull-up voltage $\leq$ 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 EMC1413/EMC1414 communicates with a host controller, such as a Microchip 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.

.
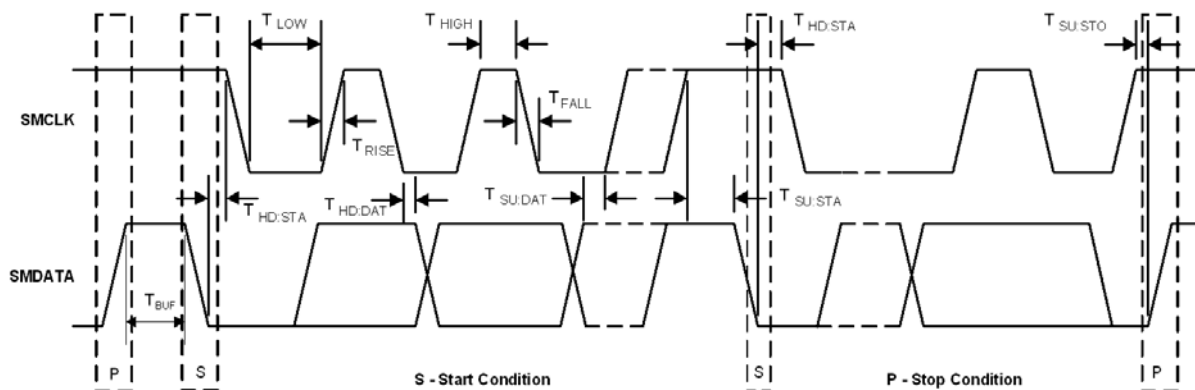
Figure 5.1 SMBus Timing Diagram

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 / $\overline{\text{WR}}$ Bit

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

The EMC1413-A and EMC1414-A SMBus slave address is determined by the pull-up resistor on the $\overline{\text{THERM}}$ 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/$\overline{\text{w}}$)b
6.8k	1011_100(r/$\overline{\text{w}}$)b
10k	1001_100(r/$\overline{\text{w}}$)b

Table 5.1 SMBus Address Decode (continued)

PULL UP RESISTOR ON THERM PIN (±5%)	SMBUS ADDRESS
15k	1101_100(r/w̄)b
22k	0011_100(r/w̄)b
33k	0111_100(r/w̄)b

The EMC1413-1 SMBus address is hard coded to 1001_100(r/w̄).

The EMC1413-3 SMBus address is hard coded to 0011_000(r/w̄).

The EMC1414-1 SMBus address is hard coded to 1001_100(r/w̄).

5.1.3   THERM Pin Considerations

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

For 15ms after power up, the 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 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.
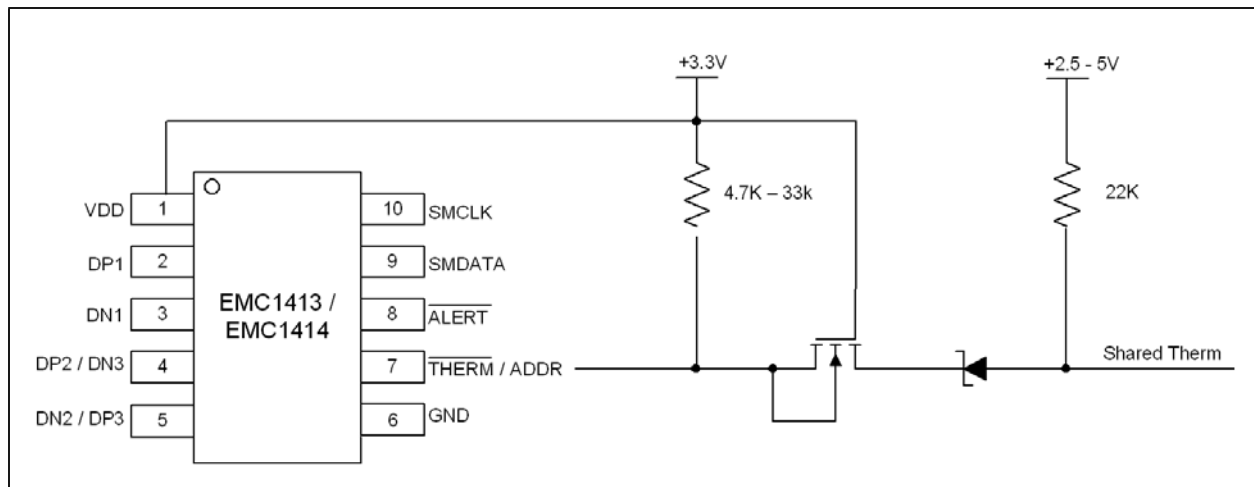
Figure 5.2 Isolating THERM Pin

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 EMC1413/EMC1414 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 7.12).

5.1.8   SMBus and I^{2}C Compatibility

The EMC1413/EMC1414 is compatible with SMBus and I^{2}C. The major differences between SMBus and I^{2}C devices are highlighted here. For more information, refer to the SMBus 2.0 and I^{2}C specifications. For information on using the EMC1413/EMC1414 in an I^{2}C system, refer to AN 14.0 Dedicated Slave Devices in I^{2}C Systems.

1. EMC1413/EMC1414 supports I^{2}C 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 EMC1413/EMC1414 and can be enabled by writing to the TIMEOUT bit. I^{2}C does not have a timeout.

4. I^{2}C devices do not support the Alert Response Address functionality (which is optional for SMBus).

Attempting to communicate with the EMC1413/EMC1414 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 EMC1413/EMC1414 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 EMC1413/EMC1414 is an SMBus temperature sensor. The EMC1413 and EMC1414 monitor one internal diode and up to two (EMC1413) or three (EMC1414) externally connected temperature diodes.

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 EMC1413/EMC1414 and using that data to control the speed of one or more fans.

The EMC1413 and EMC1414 have 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 EMC1413 and EMC1414 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.

For the EMC1414, External Diode channels 2 and 3 are only compatible with general purpose diodes (such as a 2N3904). For the EMC1413, the External Diode 2 channel is compatible with any diode type.

Figure 6.1 shows a system level block diagram of the EMC1414 and Figure 6.2 shows a system level block diagram of the EMC1413.
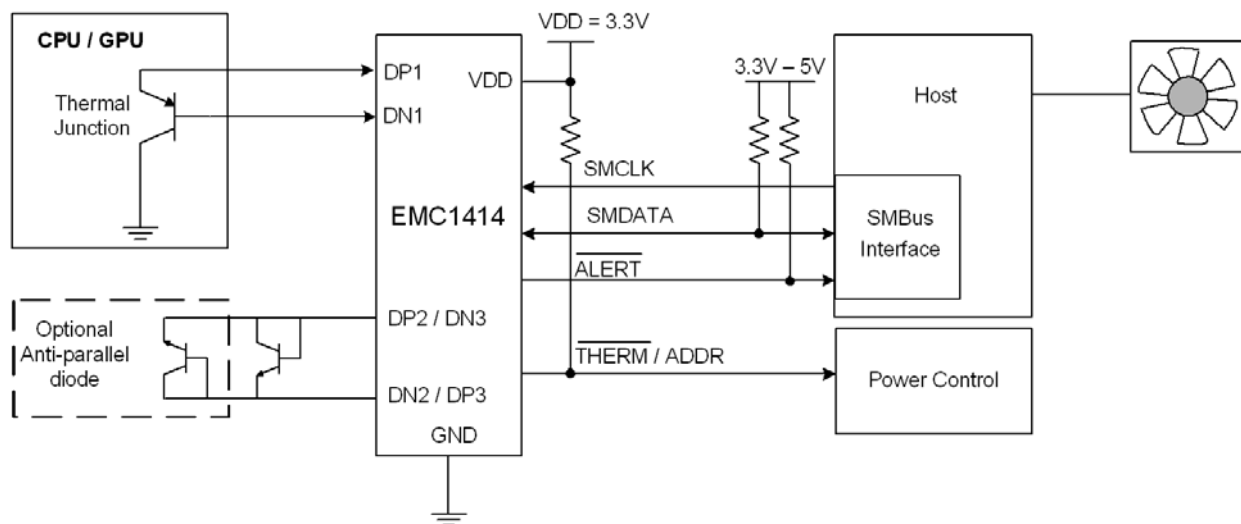

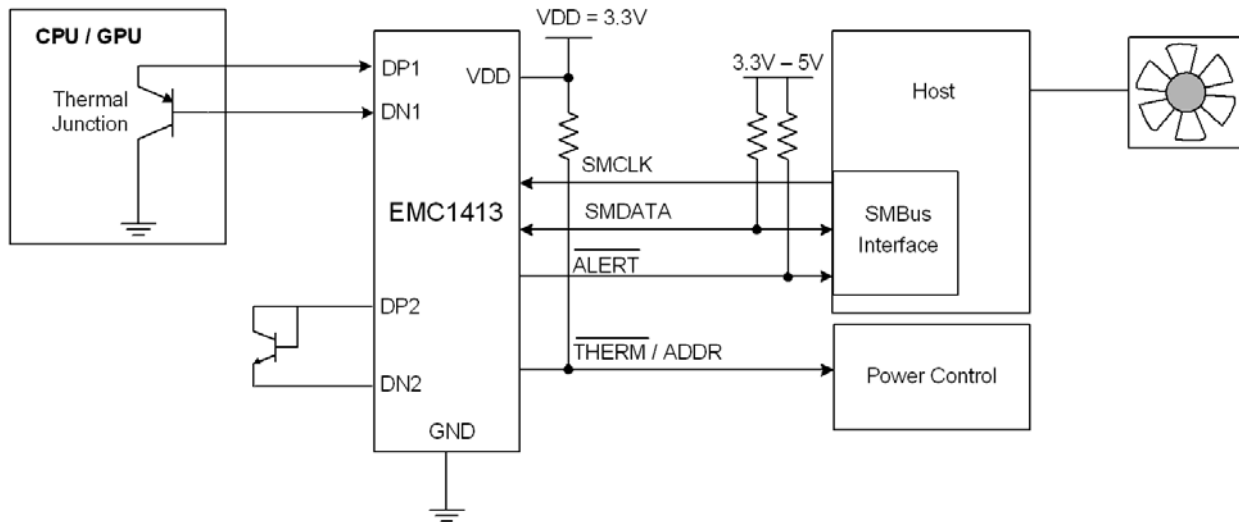**Figure 6.1 System Diagram for EMC1414**

Figure 6.2 System Diagram for EMC1413

6.1   Modes of Operation

The EMC1413 and EMC1414 have 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 EMC1413/EMC1414 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 EMC1413/EMC1414 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 EMC1413/EMC1414

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	8x	1x
2 / sec	930uA	475uA	4x	1x
4 / sec (default)	950uA	510uA	2x	1x
8 / sec	1010uA	630uA	1x	1x
16 / sec	1020uA	775uA	0.5x	0.5x
32 / sec	1050uA	1050uA	0.25x	0.25x
64 / sec	1100uA	1100uA	0.125x	0.125x

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 $\overline{\text{ALERT}}$ 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 7.4).

6.3.1 $\overline{\text{ALERT}}$ 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_ALL bit. Once the $\overline{\text{ALERT}}$ 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 $\overline{\text{ALERT}}$ pin is masked will update the Status Register normally. There are also individual channel masks (see Section 7.11).

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 $\overline{\text{ALERT}}$ outputs can be hard-wired together.

6.3.2 $\overline{\text{ALERT}}$ Pin Comparator Mode

When the $\overline{\text{ALERT}}$ 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 $\overline{\text{ALERT}}$ pin is deasserted, the status bits will be automatically cleared.

The MASK_ALL bit will not block the $\overline{\text{ALERT}}$ pin in this mode; however, the individual channel masks (see Section 7.11) will prevent the respective channel from asserting the $\overline{\text{ALERT}}$ pin.

6.4 Temperature Measurement

The EMC1413/EMC1414 can monitor the temperature of up to two / three externally connected diodes. Each 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 $\overline{\text{ALERT}}$ pin can be asserted (based on user settings). If the measured temperature meets or exceeds the Therm Limit, the $\overline{\text{THERM}}$ pin is asserted unconditionally, providing two tiers of temperature detection.

6.4.1 Beta Compensation

The EMC1413/EMC1414 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.

For the EMC1414, the External Diode 2 and External Diode 3 channels do not support Beta Compensation.

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 EMC1413/EMC1414 automatically corrects up to 100 ohms of series resistance.

6.4.3 Programmable External Diode Ideality Factor

The EMC1413/EMC1414 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 EMC1413/EMC1414 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 EMC1413/EMC1414 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 EMC1413/EMC1414 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 7.12, "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 1 channel uses a programmable digital filter. This filter can be configured as Level 1, Level 2, or Disabled (default) (see Section 7.18). The typical filter performance is shown in Figure 6.3 and Figure 6.4.
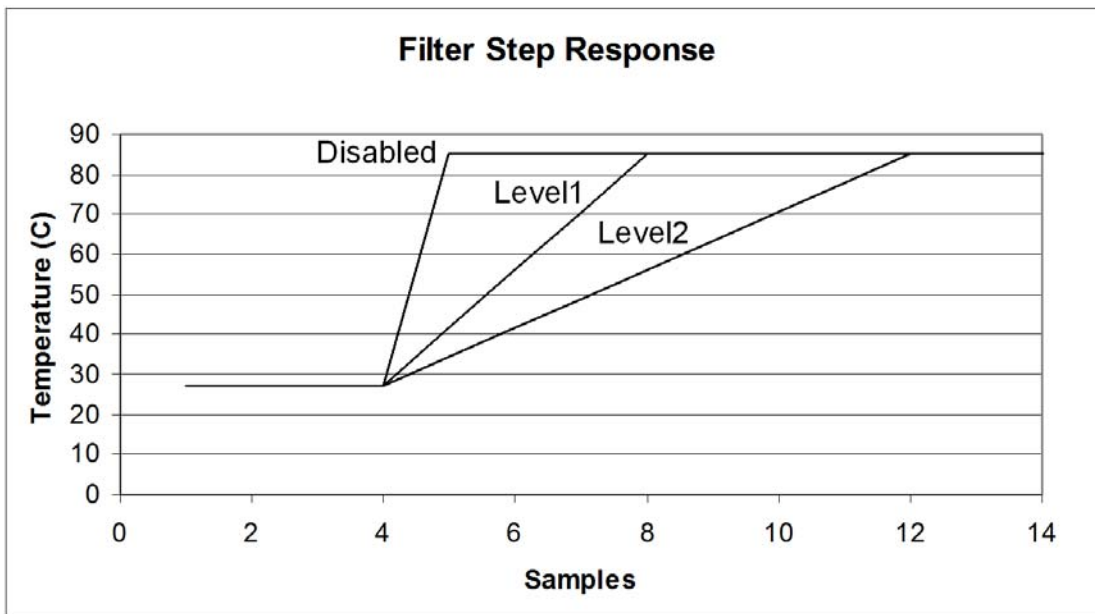
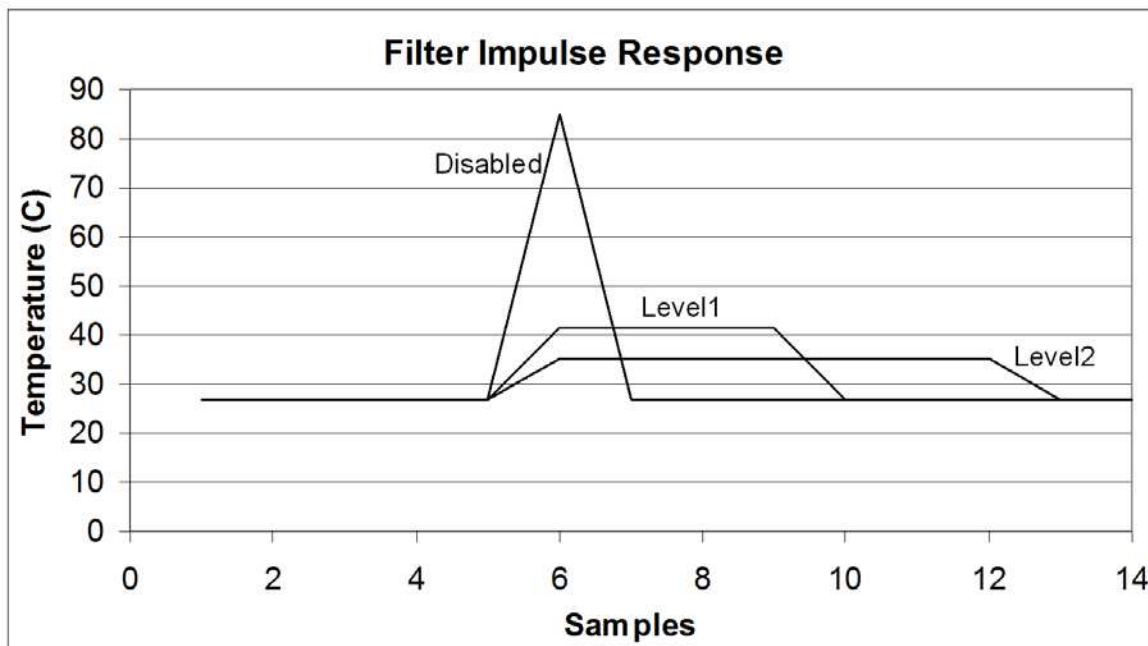**Figure 6.3 Temperature Filter Step Response**

Figure 6.4 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 EMC1413/EMC1414 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   Anti-parallel Diode Connections

The EMC1414 supports reading two external diodes on the same set of pins (DP2, DN2). These diodes are connected as shown in Figure 6.1. Due to the anti-parallel connection of these diodes, both diodes will be reverse biased by a V_{BE} voltage (approximately 0.7V). Because of this reverse bias, only discrete thermal diodes (such as a 2N3904) are recommended to be placed on these pins.

6.10   External Diode Connections

The EMC1413/EMC1414 can be configured to measure a CPU substrate transistor, a discrete 2N3904 thermal diode, or an AMD processor diode on the External Diode 1 channel only. For the EMC1414 the External Diode 2 and External Diode 3 channels are configured to measure a pair of discrete anti-parallel diodes (shared on pins DP2 and DN2). The supported configurations for the external diode channels are shown in Figure 6.5.
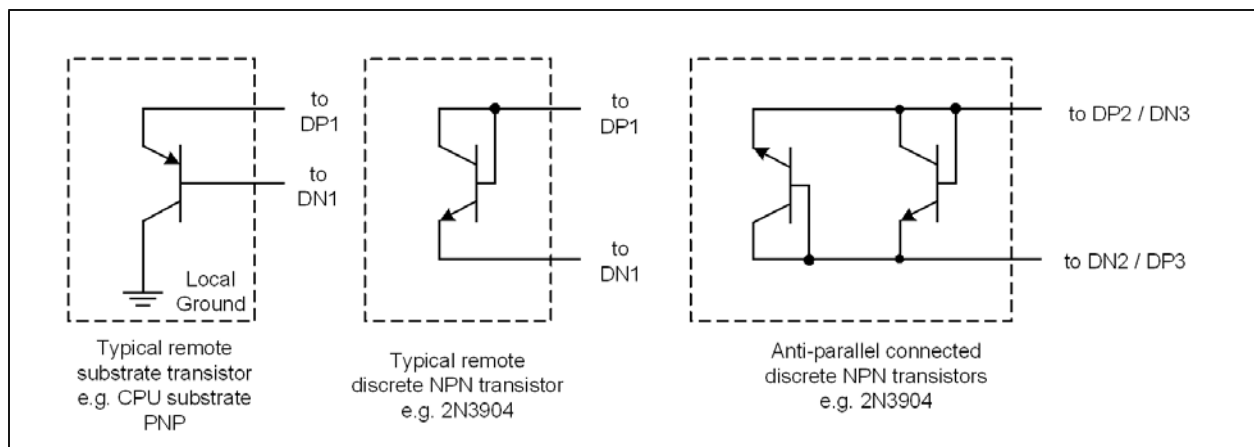

Figure 6.5 Diode Configurations