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MICROCHIP

EMC1403/EMC1404

1°C Temperature Sensor with Beta Compensation

PRODUCT FEATURES

Data Sheet

General Description

The EMC1403 and EMC1404 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 including 45nm, 65nm and 90nm processors) and automatic diode type detection combine to provide a robust solution for complex environmental monitoring applications.

Each device provides ±1° accuracy for external diode temperatures and ±2°C accuracy for the internal diode temperature. The EMC1403 monitors three temperature channels (two external and one internal). The EMC1404 monitors four temperature channels (three external and one internal).

Resistance Error Correction automatically eliminates the temperature error caused by series resistance allowing greater flexibility in routing thermal diodes. Beta Compensation eliminates temperature errors caused by low, variable beta transistors common in today's fine geometry processors. The automatic beta detection feature monitors 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

- 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 Monitors
  — ±1°C Accuracy (60°C < T_{DIODE} < 100°C)
  — 0.125°C Resolution
  — Anti-parallel diodes for extra diode support
- Internal Temperature Monitor
  — ±2°C accuracy
- 3.3V Supply Voltage
- Programmable temperature limits for $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$
- Available in these RoHS Compliant Packages
  — 10-pin 3mm x 3mm DFN
  — 10-pin MSOP
  — 14-pin SOIC

Ordering Information:

EMC1403-1-AIZL-TR for 10-pin, MSOP RoHS Compliant Package
EMC1403-2-AIZL-TR for 10-pin, MSOP RoHS Compliant Package
EMC1403-3-AIZL-TR for 10-pin, MSOP RoHS Compliant Package
EMC1403-4-AIZL-TR for 10-pin, MSOP RoHS Compliant Package
EMC1403-1-AIA-TR for 10-pin, DFN RoHS Compliant Package
EMC1403-2-AIA-TR for 10-pin, DFN RoHS Compliant Package
EMC1403-3-AIA-TR for 10-pin, DFN RoHS Compliant Package
EMC1403-4-AIA-TR for 10-pin, DFN RoHS Compliant Package
EMC1403-1-YZT-TR for 14-pin, SOIC RoHS Compliant Package
EMC1403-2-YZt-TR for 14-pin, SOIC RoHS Compliant Package
EMC1403-3-YZt-TR for 14-pin, SOIC RoHS Compliant Package
EMC1403-4-YZt-TR for 14-pin, SOIC RoHS Compliant Package
EMC1404-1-AIZL-TR for 10-pin, MSOP RoHS Compliant Package
EMC1404-2-AIZL-TR for 10-pin, MSOP RoHS Compliant Package
EMC1404-3-AIZL-TR for 10-pin, MSOP RoHS Compliant Package
EMC1404-4-AIZL-TR for 10-pin, MSOP RoHS Compliant Package

Note: See Table 1.1, "Part Selection" for SMBus addressing options.

REEL SIZE IS 4,000 PIECES.

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

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Chapter 1 Block Diagram

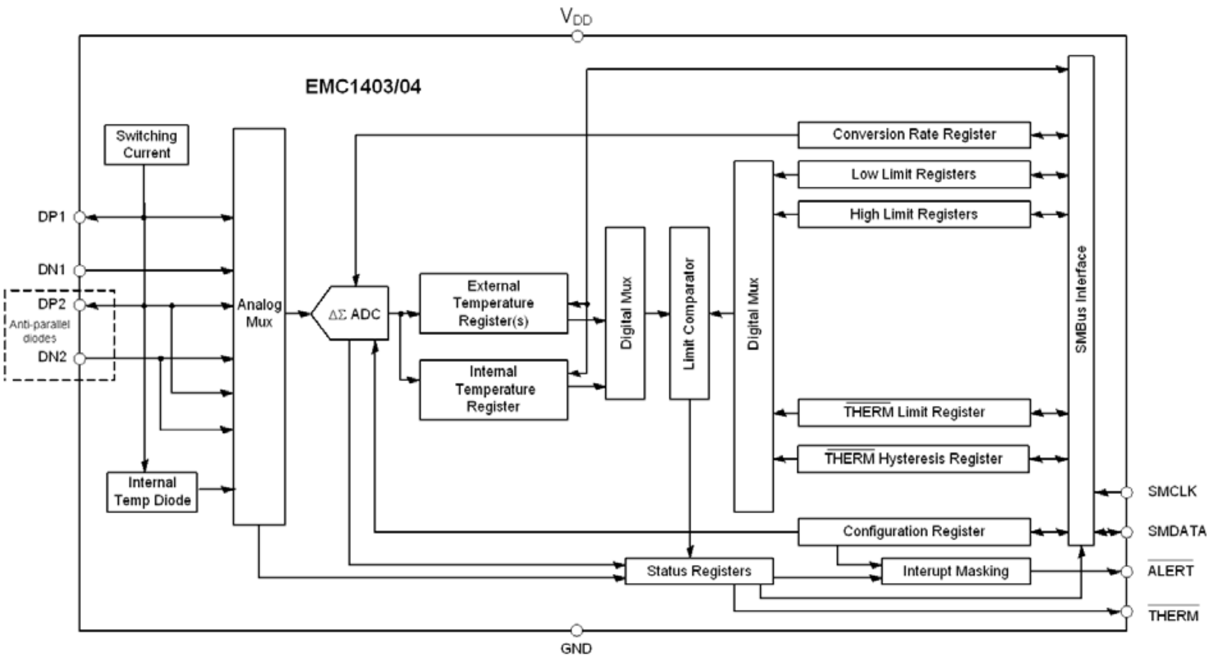

Figure 1.1 EMC1403/EMC1404 Block Diagram

1.1 Part Selection

The EMC1403 and EMC1404 device configuration is highlighted below.

Table 1.1 Part Selection

PART NUMBER	SMBUS ADDRESS	FUNCTIONALITY				PRODUCT ID
		EXTERNAL DIODES	DIODE 1 DEFAULT CONFIGURATION	DIODE 2 DEFAULT CONFIGURATION	OTHER	
EMC1403 - 1 - AIZL	1001_100xb	2	Detect Diode w/ REC enabled	Detect Diode w/ REC enabled	Software programmable and maskable High Limits Software programmable THERM Limits	21h
EMC1403 - 2 - AIZL	1001_101xb					
EMC1403 - 3 - AIZL	0011_000xb					
EMC1403 - 4 - AIZL	0101_001xb					

Table 1.1 Part Selection (continued)

PART NUMBER	SMBUS ADDRESS	FUNCTIONALITY				PRODUCT ID
		EXTERNAL DIODES	DIODE 1 DEFAULT CONFIGURATION	DIODE 2 DEFAULT CONFIGURATION	OTHER	
EMC1403 - 1 - AIA	1001_100xb	2	Detect Diode w/ REC enabled	Detect Diode w/ REC enabled	Software programmable and maskable High Limits Software programmable THERM Limits	21h
EMC1403 - 2 - AIA	1001_101xb					
EMC1403 - 3 - AIA	0011_000xb					
EMC1403 - 4 - AIA	0101_001xb					
EMC1403 - 1 - YZT	1001_100xb	2	Detect Diode w/ REC enabled	Detect Diode w/ REC enabled	Software programmable and maskable High Limits Software programmable THERM Limits	21h
EMC1403 - 2 - YZT	1001_101xb					
EMC1403 - 3 - YZT	0011_000xb					
EMC1403 - 4 - YZT	0101_001xb					
EMC1404 - 1	1001_100xb	3	Detect Diode w/ REC enabled	Fixed 2N3904 in anti-parallel diode configuration Note 1.1	Software programmable and maskable High Limits Software programmable THERM Limits	25h
EMC1404 - 2	1001_101xb					
EMC1404 - 3	0011_000xb					
EMC1404 - 4	0101_001xb					

Note 1.1 External 2 and external 3 channels have beta configuration hard wired to ‘0111b’ and REC enabled.

Chapter 2 Pin Description

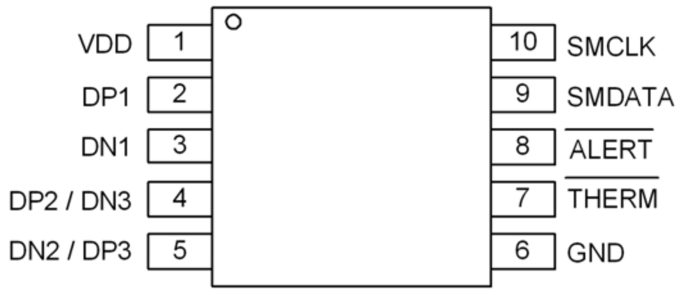

Figure 2.1 EMC1403/EMC1404 Pin Diagram, MSOP-10

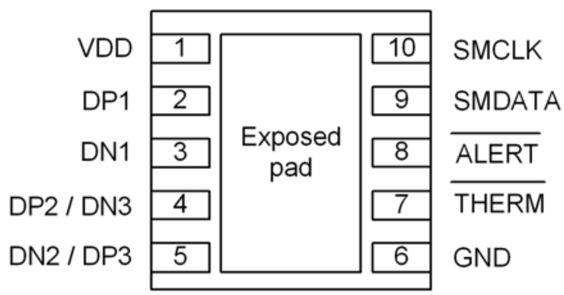

Figure 2.2 EMC1403/EMC1404 Pin Diagram, DFN-10

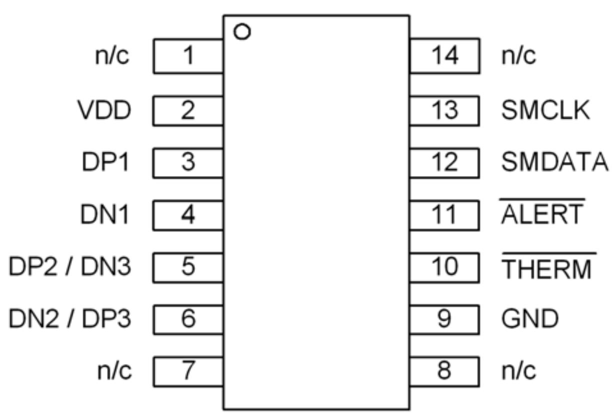

Figure 2.3 EMC1403/EMC1404 Pin Diagram, SOIC-14

Table 2.1 EMC1403 and EMC1404 Pin Description

PIN NUMBER 10-PIN	PIN NUMBER 14-PIN	NAME	FUNCTION	TYPE
n/a	1	n/c	Not Internally Connected	n/a
1	2	VDD	Power supply	Power
2	3	DP1	External diode 1 positive (anode) connection	AIO
3	4	DN1	External diode 1 negative (cathode) connection	AIO
4	5	DP2 / DN3	External diode 2 positive (anode) connection / External Diode 3 negative (cathode) connection for anti-parallel diodes	AIO
5	6	DN2 / DP3	External diode 2 negative (cathode) connection / External Diode 3 positive (anode) connection for anti-parallel diodes	AIO
n/a	7	n/c	Not Internally Connected	n/a
n/a	8	n/c	Not Internally Connected	n/a
6	9	GND	Ground	Power
7	10	$\overline{\text{THERM}}$	Critical $\overline{\text{THERM}}$ output signal - requires pull-up resistor	OD (5V)
8	11	$\overline{\text{ALERT}}$	Active low digital $\overline{\text{ALERT}}$ output signal - requires pull-up resistor	OD (5V)
9	12	SMDATA	SMBus Data input/output - requires pull-up resistor	DIOD (5V)
10	13	SMCLK	SMBus Clock input - requires pull-up resistor	DI (5V)
n/a	14	n/c	Not Internally Connected	n/a
DFN Bottom Pad	n/a	Exposed Pad	Not Internally Connected, recommend grounding.	n/a

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 below:

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

AIO - Analog Input / Output.

DI - Digital Input.

OD - Open Drain Digital Output.

DIOD - Digital Input / Open Drain Output.

Chapter 3 Electrical Specifications

3.1 Absolute Maximum Ratings

Table 3.1 Absolute Maximum Ratings

DESCRIPTION	RATING	UNIT
Supply Voltage (V_{DD})	-0.3 to 4.0	V
Voltage on 5V tolerant pins (V_{5VT_pin})	-0.3 to 5.5	V
Voltage on 5V tolerant pins ($\|V_{5VT\_pin} - V_{DD}\|$) (see Note 3.1)	-0.3 to 3.6	V
Voltage on any other pin to Ground	-0.3 to V_{DD} +0.3	V
Operating Temperature Range	-40 to +125	°C
Storage Temperature Range	-55 to +150	°C
Lead Temperature Range	Refer to JEDEC Spec. J-STD-020	
Package Thermal Characteristics for MSOP-10		
Thermal Resistance (θ_{j-a})	132.2	°C/W
Package Thermal Characteristics for SOIC-14		
Thermal Resistance (θ_{j-a})	77.7	°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. When powering this device from laboratory or system power supplies, it is important that the Absolute Maximum Ratings not be exceeded or device failure can result. Some power supplies exhibit voltage spikes on their outputs when the AC power is switched on or off. In addition, voltage transients on the AC power line may appear on the DC output. If this possibility exists, it is suggested that a clamp circuit be used.

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

3.2 Electrical Specifications

Table 3.2 Electrical Specifications

V_{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	uA	1 conversion / sec, dynamic averaging disabled
			930	1200	uA	4 conversions / sec, dynamic averaging enabled
			1120		uA	$\geq$ 16 conversions / sec, dynamic averaging enabled
Standby Supply Current	I_{DD}		170	230	uA	Device in Standby mode, no SMBus communications, ALERT and THERM pins not asserted.
Internal Temperature Monitor						
Temperature Accuracy			±0.25	±1	°C	-5°C < T_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	
	t_{CONV}		190		ms	EMC1403, default settings
	t_{CONV}		150		ms	EMC1404, default settings
Capacitive Filter	C_{FILTER}		2.2	2.5	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	uA	$\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ pins Device powered or unpowered T_A < 85°C pull-up voltage $\leq$ 3.6V

3.3 SMBus Electrical Characteristics

Table 3.3 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
Input High/Low Current	I_{IH} / I_{IL}			±5	uA	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 Start to Stop	t_{BUF}	1.3			us	
Hold Time: Start	$t_{HD:STA}$	0.6			us	
Setup Time: Start	$t_{SU:STA}$	0.6			us	
Setup Time: Stop	$t_{SU:STP}$	0.6			us	
Data Hold Time	$t_{HD:DAT}$	0			us	When transmitting to the master
Data Hold Time	$t_{HD:DAT}$	0.3			us	When receiving from the master
Data Setup Time	$t_{SU:DAT}$	100			ns	
Clock Low Period	t_{LOW}	1.3			us	
Clock High Period	t_{HIGH}	0.6			us	
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 4 System Management Bus Interface Protocol

4.1 System Management Bus Interface Protocol

The EMC1403 and EMC1404 communicate with a host controller, such as an SIO, through the SMBus. The SMBus is a two-wire serial communication protocol between a computer host and its peripheral devices. A detailed timing diagram is shown in Figure 4.1.

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

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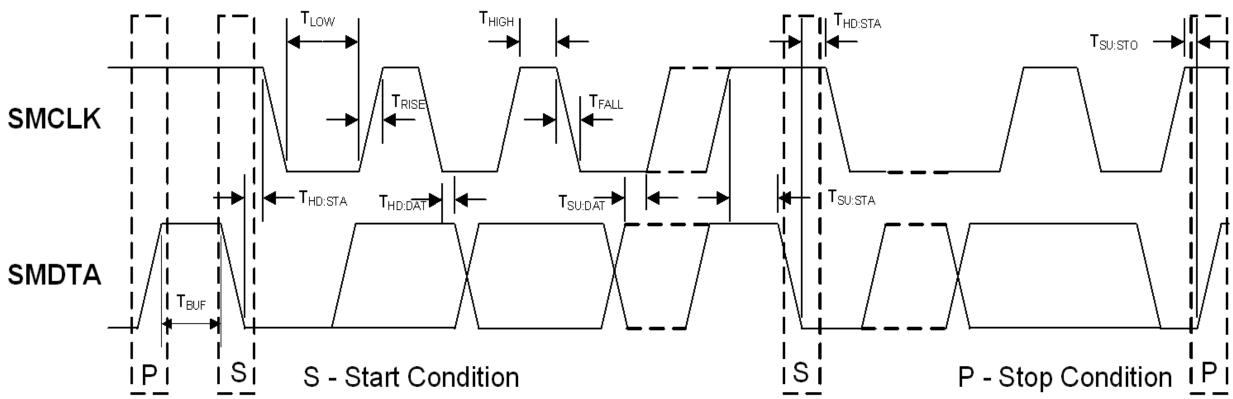

Figure 4.1 SMBus Timing Diagram

The EMC1403 and EMC1404 are SMBus 2.0 compatible and support Send Byte, Read Byte, Write Byte, Receive Byte, and the Alert Response Address as valid protocols as shown below.

All of the below protocols use the convention in Table 4.1.

Table 4.1 Protocol Format

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

Attempting to communicate with the EMC1403 and EMC1404 SMBus interface with an invalid slave address or invalid protocol will result in no response from the device and will not affect its register contents. Stretching of the SMCLK signal is supported, provided other devices on the SMBus control the timing.

4.2 Write Byte

The Write Byte is used to write one byte of data to the registers as shown below Table 4.2:

Table 4.2 Write Byte Protocol

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

4.3 Read Byte

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

Table 4.3 Read Byte Protocol

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

4.4 Send Byte

The Send Byte protocol is used to set the internal address register pointer to the correct address location. No data is transferred during the Send Byte protocol as shown in Table 4.4.

Table 4.4 Send Byte Protocol

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

4.5 Receive Byte

The Receive Byte protocol is used to read data from a register when the internal register address pointer is known to be at the right location (e.g. set via Send Byte). This is used for consecutive reads of the same register as shown in Table 4.5.

Table 4.5 Receive Byte Protocol

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

4.6 Alert Response Address

The ALERT output can be used as a processor interrupt or as an SMBus Alert.

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

Table 4.6 Alert Response Address Protocol

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

The EMC1403 and EMC1404 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 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 ALERT pin will be reasserted.

4.7 SMBus Address

The EMC1403 and EMC1404 respond to hard-wired SMBus slave address as shown in Table 1.1.

Note: Other addresses are available. Contact Microchip for more information.

4.8 SMBus Timeout

The EMC1403 and EMC1404 support SMBus Timeout. If the clock line is held low for longer than 30ms, the device will reset its SMBus protocol. This function can be enabled by setting the TIMEOUT bit in the Consecutive Alert Register (see Section 6.12).

Chapter 5 Product Description

The EMC1403 and EMC1404 are SMBus temperature sensors. The EMC1403 monitors one internal diode and two externally connected temperature diodes. The EMC1404 monitors one internal diode and three 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 EMC1403 and EMC1404 and using that data to control the speed of one or more fans.

The EMC1403 and EMC1404 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 EMC1403 or EMC1404 to be used as an independent thermal watchdog to warn the host of temperature hot spots without direct control by the host. The second level of monitoring provides a non maskable interrupt on the $\overline{\text{THERM}}$ pin if the measured temperatures meet or exceed a second programmable limit.

Since the EMC1403 and EMC1404 automatically correct for temperature errors due to series resistance in temperature diode lines, there is greater flexibility in where external diodes are positioned and better measurement accuracy than previously available with non-resistance error correcting devices. The automatic beta detection feature means that there is no need to program the device according to which type of diode is present on the External Diode 1 channel. This also includes CPU diodes that require the transistor or BJT model for monitoring their temperature. Therefore, the EMC1403/EMC1404 can power up ready to operate for any system configuration.

For the EMC1404, External Diode channels 2 and 3 are only compatible with general purpose diodes (such as a 2N3904).

Figure 5.1 shows a system level block diagram of the EMC1403. Figure 5.2 shows a system level block diagram of the EMC1404.

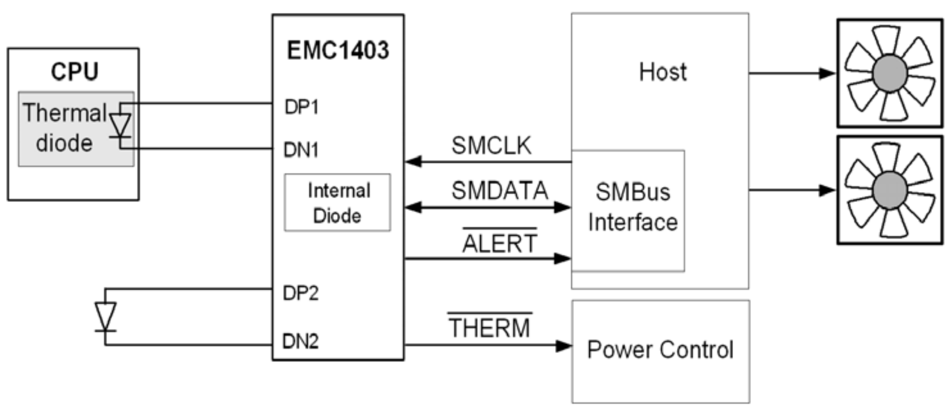

Figure 5.1 System Diagram for EMC1403

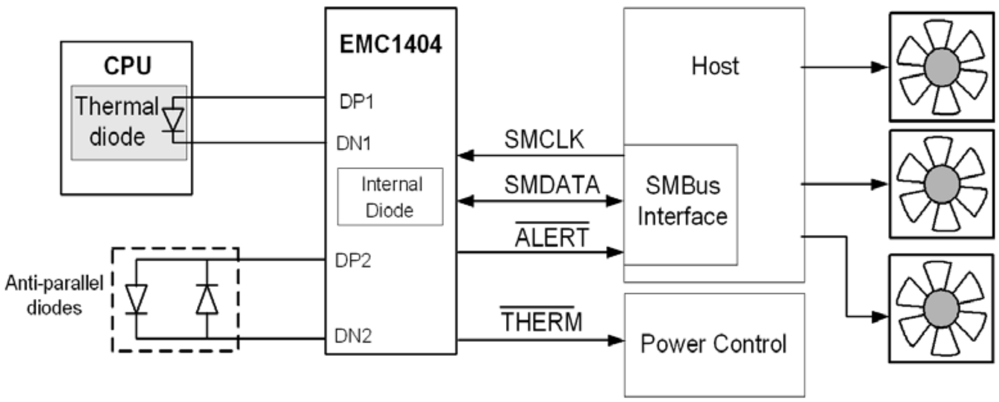

Figure 5.2 System Diagram for EMC1404

5.1 Modes of Operation

The EMC1403 and EMC1404 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.

5.1.1 Conversion Rates

The EMC1403 and EMC1404 may be configured for different conversion rates based on the system requirements. The conversion rate is configured as described in Section 6.5. The default conversion rate is 4 conversions per second. Other available conversion rates are shown in Table 6.6.

5.1.2 Dynamic Averaging

Dynamic averaging causes the EMC1403 and EMC1404 to measure the external diode channels for an extended time based on the selected conversion rate. This functionality can be disabled for increased power savings at the lower conversion rates (see Section 6.4). When dynamic averaging is enabled, the device will automatically adjust the sampling and measurement time for the external diode channels. This allows the device to average 2x or 16x longer than the normal 11 bit operation (nominally 21ms per channel) while still maintaining the selected conversion rate. The benefits of dynamic averaging are improved noise rejection due to the longer integration time as well as less random variation of the temperature measurement.

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

When enabled, the dynamic averaging will affect the average supply current based on the chosen conversion rate as shown in Table 5.1 for EMC1403.

Table 5.1 Supply Current vs. Conversion Rate for EMC1403

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

When enabled, the dynamic averaging will affect the average supply current based on the chosen conversion rate as shown in Table 5.2 for EMC1404.

Table 5.2 Supply Current vs. Conversion Rate for EMC1404

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

Table 5.2 Supply Current vs. Conversion Rate for EMC1404 (continued)

CONVERSION RATE	AVERAGE SUPPLY CURRENT		AVERAGING FACTOR (BASED ON 11-BIT OPERATION)	
	ENABLED (DEFAULT)	DISABLED	ENABLED (DEFAULT)	DISABLED
32 / sec	1050uA	1050uA	0.25x	0.25x
64 / sec	1100uA	1100uA	0.125x	0.125x

5.2 THERM Output

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

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

5.3 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 6.4).

5.3.1 ALERT Pin Interrupt Mode

When configured to operate in interrupt mode, the 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 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 bit. Once the ALERT pin has been masked, it will be de-asserted and remain de-asserted until the MASK bit is cleared by the user. Any interrupt conditions that occur while the ALERT pin is masked will update the Status Register normally.

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.

5.3.2 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 bit will not block the ALERT pin in this mode, however the individual channel masks (see Section 6.11) will prevent the respective channel from asserting the ALERT pin.

5.4 Beta Compensation

The EMC1403 and EMC1404 are 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 for the External Diode 1 channel only. 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.

The External Diode 2 and External Diode 3 channels do not support Beta Compensation.

5.5 Resistance Error Correction (REC)

Parasitic resistance in series with the external diodes will limit the accuracy obtainable from temperature measurement devices. The voltage developed across this resistance by the switching diode currents cause the temperature measurement to read higher than the true temperature. Contributors to series resistance are PCB trace resistance, on die (i.e. on the processor) metal resistance, bulk resistance in the base and emitter of the temperature transistor. Typically, the error caused by series resistance is +0.7°C per ohm. The EMC1403 and EMC1404 automatically correct up to 100 ohms of series resistance.

5.6 Programmable External Diode Ideality Factor

The EMC1403 and EMC1404 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 EMC1403 and EMC1404 provides a 6-bit register for each external diode where the ideality factor of the diode used is programmed to eliminate errors across all temperatures.

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

5.7 Diode Faults

The EMC1403 and EMC1404 detect an open on the DP and DN pins, and a short across the DP and DN pins. For each temperature measurement made, the device checks for a diode fault on the external diode channel(s). When a diode fault is detected, the ALERT pin asserts (unless masked, see Section 5.8) and the temperature data reads 00h in the MSB and LSB registers (note: the low limit will not be checked). A diode fault is defined as one of the following: an open between DP and DN, a short from V_{DD} to DP, or a short from V_{DD} to DN.

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

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

5.8 Consecutive Alerts

The EMC1403 and EMC1404 contain multiple consecutive alert counters. One set of counters applies to the ALERT pin and the second set of counters applies to the THERM pin. Each temperature measurement channel has a separate consecutive alert counter for each of the ALERT and THERM pins. All counters are user programmable and determine the number of consecutive measurements that a temperature channel(s) must be out-of-limit or reporting a diode fault before the corresponding pin is asserted.

See Section 6.12 for more details on the consecutive alert function.

5.9 Digital Filter

To reduce the effect of noise and temperature spikes on the reported temperature, the External Diode 1 channel uses a programmable digital filter. This filter can be configured as Level 1, Level 2, or Disabled. The typical filter performance is shown in Figure 5.3 and Figure 5.4.

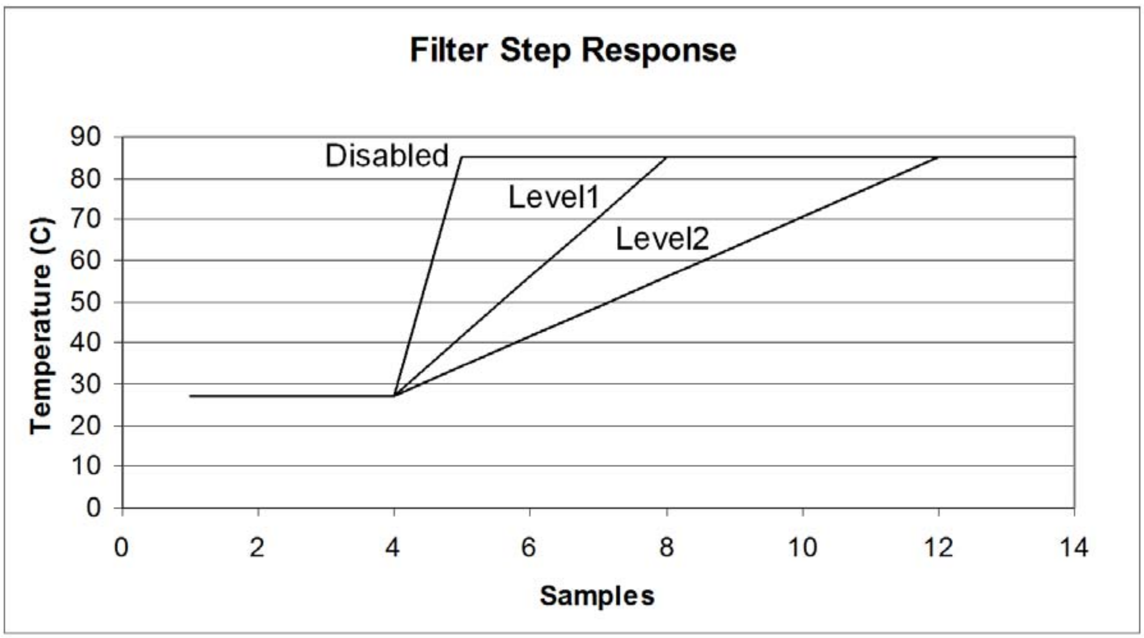

Figure 5.3 Temperature Filter Step Response

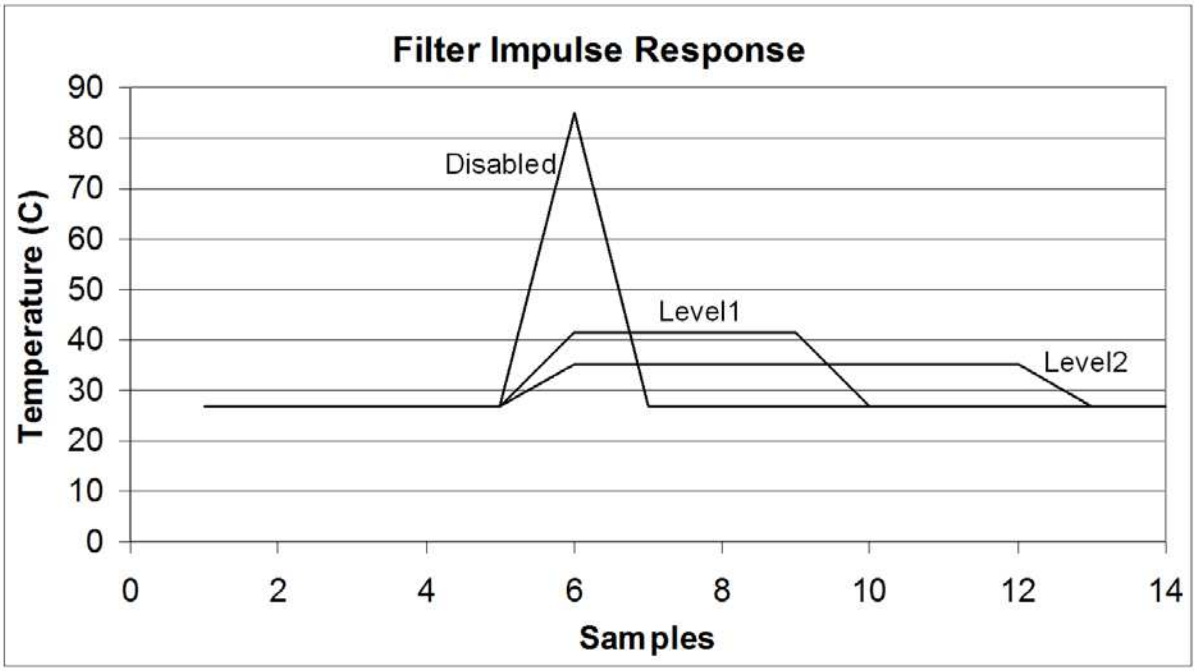

Figure 5.4 Temperature Filter Impulse Response

5.10 Temperature Monitors

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

$$\Delta V_{BE} = \frac{\eta kT}{q} \ln\left(\frac{I_{HIGH}}{I_{LOW}}\right) \quad [1]$$

where:

k = Boltzmann's constant

T = absolute temperature in Kelvin

q = electron charge

η = diode ideality factor

Figure 5.5 shows a block diagram of the temperature measurement circuit. The negative terminal for the remote temperature diode, DN, is internally biased with a forward diode voltage referenced to ground.

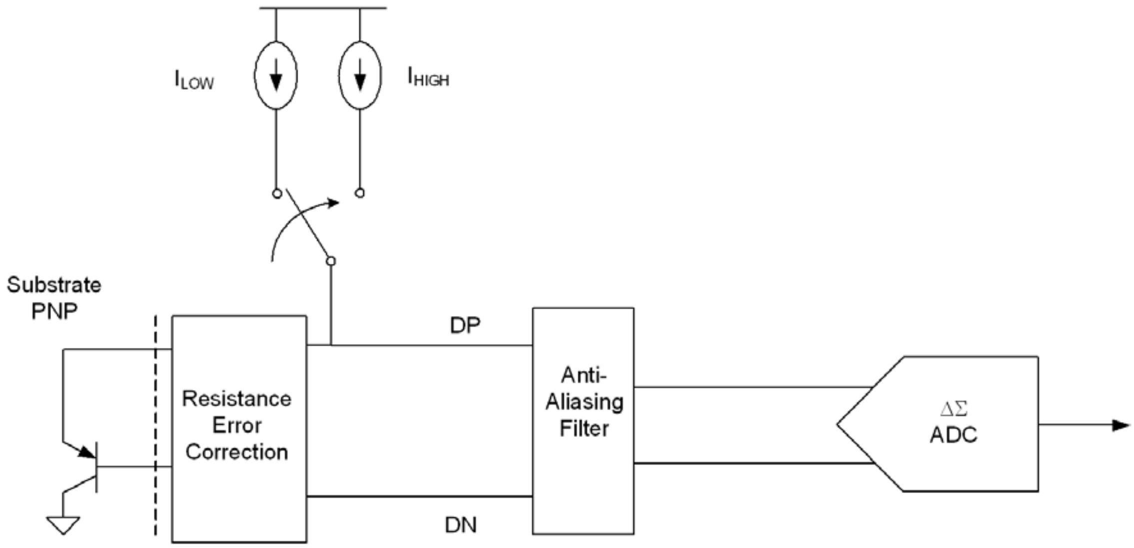

Figure 5.5 Block Diagram of Temperature Monitoring Circuit

5.11 Temperature Measurement Results and Data

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

The EMC1403 and EMC1404 have two selectable temperature ranges. The default range is from 0°C to +127°C and the temperature is represented as binary number able to report a temperature from 0°C to +127.875°C in 0.125°C steps.

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

Table 5.3 shows the default and extended range formats.

Table 5.3 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 5.2
-1	000 0000 0000	001 1111 1000
0	000 0000 0000 Note 5.1	010 0000 0000
0.125	000 0000 0001	010 0000 0001
1	000 0000 1000	010 0000 1000

Table 5.3 Temperature Data Format (continued)

TEMPERATURE (°C)	DEFAULT RANGE 0°C TO 127°C	EXTENDED RANGE -64°C TO 191°C
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 5.3	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 5.4

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

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

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

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

5.12 Anti-parallel Diode Connections

The EMC1404 supports reading two external diodes on the same set of pins (DP2, DN2). These diodes are connected as shown in Figure 5.2. 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.

5.13 External Diode Connections

The EMC1403 can be configured to measure a CPU substrate transistor, a discrete 2N3904 thermal diode, or an AMD processor diode. The diodes can be connected in a variety of ways as indicated in Figure 5.6.

The EMC1404 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. 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 5.6.