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EMC1188

Quad Channel 1°C Temperature Sensor with Hardware Thermal Shutdown and 1.8V SMBus Communications

PRODUCT FEATURES

Datasheet

General Description

The EMC1188 is a high accuracy, low cost, 1.8V System Management Bus (SMBus) compatible temperature sensor. Advanced features such as Resistance Error Correction (REC), Beta Compensation (to support CPU diodes requiring the BJT/transistor model including 65nm and lower geometry processors) and automatic diode type detection combine to provide a robust solution for complex environmental monitoring applications. The ability to communicate at 1.8V SMBus levels provides compatible I/O for the advanced processors found in today's tablet and smartphone applications.

The EMC1188 monitors four temperature (three external and one internal) channels, providing $\pm 1^\circ\text{C}$ accuracy for both external and internal diode temperatures.

Additionally, the EMC1188 provides a hardware programmable system shutdown feature that is programmed at part power-up via two pull-up resistor values and that cannot be masked or corrupted through the SMBus.

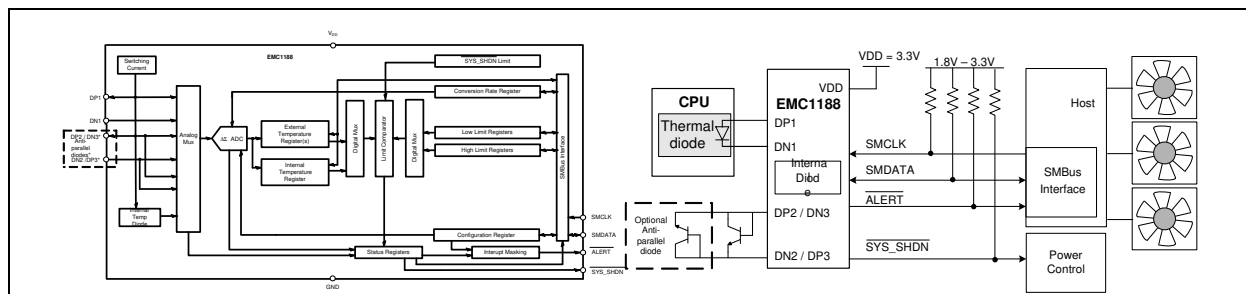
REC automatically eliminates the temperature error caused by series resistance allowing greater flexibility in routing thermal diodes. Frequency hopping* and analog filters ensure remote diode traces can be as far as eight (8) inches without degrading the signal. Beta Compensation eliminates temperature errors caused by low, variable beta transistors common in today's fine geometry processors. The automatic beta detection feature monitors the external diode/transistor and determines the optimum sensor settings for accurate temperature measurements regardless of processor technology. This frees the user from providing unique sensor configurations for each temperature monitoring application. These advanced features plus $\pm 1^\circ\text{C}$ measurement accuracy provide a low-cost, highly flexible and accurate solution for critical temperature monitoring applications.

Applications

- Notebook Computers
- Desktop Computers
- Industrial
- Embedded applications

Features

- **Hardware Thermal Shutdown**
 - triggers dedicated SYS_SHDN pin
 - hardware configured range 77°C to 112°C in 1°C steps
 - cannot be disabled or modified by software
- Support for diodes requiring the BJT/transistor model
 - Supports 65nm and lower geometry CPU thermal diodes
- Pin and register compatible with EMC1424
- Automatically determines external diode type and optimal settings
- Resistance Error Correction
- Frequency hops the remote sample frequency to reject DC converter and other coherent noise sources*
- Consecutive Alert queue to further reduce false Alerts
- Up to 3 External Temperature Monitor
 - 25°C typ, $\pm 1^\circ\text{C}$ max accuracy ($20^\circ\text{C} < T_{\text{DIODE}} < 110^\circ\text{C}$)
 - 0.125°C resolution
 - Supports up to 2.2nF diode filter capacitor
- Anti-parallel diodes for extra diode support Internal Temperature Monitor
 - $\pm 1^\circ\text{C}$ accuracy
 - 0.125°C resolution
- 3.3V Supply Voltage
- 1.8V SMBus operation
- Programmable temperature limits for $\overline{\text{ALERT}}$ (85°C default high limit and 0°C default low limit)
- Available in small 10-pin 3mm x 3mm DFN RoHS compliant package



* Technology covered under the US patent 7,193,543.

Ordering Information:

ORDERING NUMBER	PACKAGE	FEATURES	SMBUS ADDRESS
EMC1188-1-AIA-TR	10-pin DFN 3mm x 3mm (RoHS compliant)	Up to four temperature sensors, hardware set system shutdown, $\overline{\text{ALERT}}$ and $\overline{\text{SYS_SHDN}}$ pins, fixed SMBus address	1001_1100(r/w)

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

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

Please contact your SMSC sales representative for additional documentation related to this product such as application notes, anomaly sheets, and design guidelines.

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Table of Contents

Chapter 1 Block Diagram	7
Chapter 2 Pin Description	8
Chapter 3 Electrical Specifications	10
3.1 Absolute Maximum Ratings	10
3.2 Electrical Specifications	10
3.3 SMBus Electrical Characteristics	11
Chapter 4 System Management Bus Interface Protocol	13
4.1 Communications Protocol	13
4.1.1 SMBus Start Bit	13
4.1.2 SMBus Address and RD / WR Bit	13
4.1.3 SMBus Data Bytes	13
4.1.4 SMBus ACK and NACK Bits	13
4.1.5 SMBus Stop Bit	14
4.1.6 SMBus Timeout	14
4.1.7 SMBus and I ² C Compatibility	14
4.2 SMBus Protocols	14
4.2.1 Write Byte	15
4.2.2 Read Byte	15
4.2.3 Send Byte	15
4.2.4 Receive Byte	15
4.3 Alert Response Address	16
Chapter 5 Product Description	17
5.1 Conversion Rates	17
5.2 Dynamic Averaging	17
5.3 .SYS_SHDN Output	18
5.4 Hardware Thermal Shutdown Limit	19
5.5 ALERT Output	20
5.5.1 ALERT Pin Interrupt Mode	20
5.5.2 ALERT Pin Comparator Mode	20
5.6 ALERT and SYS_SHDN Pin Considerations	20
5.7 Temperature Measurement	21
5.7.1 Beta Compensation	21
5.7.2 Resistance Error Correction (REC)	21
5.7.3 Programmable External Diode Ideality Factor	22
5.8 Diode Faults	22
5.9 Consecutive Alerts	22
5.10 Digital Filter	22
5.11 Temperature Measurement Results and Data	24
Chapter 6 Register Description	25
6.1 Data Read Interlock	28
6.2 Temperature Data Registers	28
6.3 Status Register 02h	29
6.4 Configuration Register 03h / 09h	30

6.5 Conversion Rate Register 04h / 0Ah	31
6.6 Limit Registers	32
6.7 Scratchpad Registers 11h and 12h	33
6.8 Therm Limit Registers	33
6.9 External Diode Fault Register 1Bh	34
6.10 Software Thermal Shutdown Configuration Register 1Dh	34
6.11 Hardware Thermal Shutdown Limit Register 1Eh	35
6.12 Channel Mask Register 1Fh	36
6.13 Consecutive ALERT Register 22h	36
6.14 Beta Configuration Register 26h	38
6.15 External Diode Ideality Factor Register 27h	39
6.16 High Limit Status Register 35h	41
6.17 Low Limit Status Register 36h	41
6.18 Therm Limit Status Register 37h	42
6.19 Filter Control Register 40h	42
6.20 Product ID Register	43
6.21 SMSC ID Register	43
6.22 Revision Register	43
Chapter 7 Typical Operating Curves	44
Chapter 8 Package Information	45
8.1 Package Markings	46
Chapter 9 Datasheet Revision History	48

List of Figures

Figure 1.1	EMC1188 Block Diagram	7
Figure 2.1	EMC1188 Pin Diagram DFN-10	8
Figure 4.1	SMBus Timing Diagram	13
Figure 5.1	System Diagram for EMC1188	17
Figure 5.2	Block Diagram of Hardware Thermal Shutdown	19
Figure 5.3	Isolating ALERT and SYS_SHDN Pin	21
Figure 5.4	Temperature Filter Step Response	23
Figure 5.5	Temperature Filter Impulse Response	23
Figure 8.1	10-Pin DFN Package Drawing	45
Figure 8.2	10-Pin DFN Package Dimensions	46
Figure 8.3	10 Pin DFN PCB Footprint	46
Figure 8.4	EMC1188-1 10-Pin DFN Package Markings	47

List of Tables

Table 2.1	EMC1188 Pin Description	8
Table 2.2	Pin Types	9
Table 3.1	Absolute Maximum Ratings	10
Table 3.2	Electrical Specifications	10
Table 3.3	SMBus Electrical Specifications	11
Table 4.1	Protocol Format	14
Table 4.2	Write Byte Protocol	15
Table 4.3	Read Byte Protocol	15
Table 4.4	Send Byte Protocol	15
Table 4.5	Receive Byte Protocol	15
Table 4.6	Alert Response Address Protocol	16
Table 5.1	Supply Current vs. Conversion Rate for EMC1188	18
Table 5.2	SYS_SHDN Threshold Temperature	19
Table 5.3	Temperature Data Format	24
Table 6.1	Register Set in Hexadecimal Order	25
Table 6.2	Temperature Data Registers	28
Table 6.3	Status Register	29
Table 6.4	Configuration Register	30
Table 6.5	Conversion Rate Register	31
Table 6.6	Conversion Rate	31
Table 6.7	Temperature Limit Registers	32
Table 6.8	Scratchpad Register	33
Table 6.9	Therm Limit Registers	33
Table 6.10	External Diode Fault Register	34
Table 6.11	Software Thermal Shutdown Configuration Register	34
Table 6.12	Hardware Thermal Shutdown Limit Register	35
Table 6.13	Channel Mask Register	36
Table 6.14	Consecutive ALERT Register	36
Table 6.15	Consecutive Alert / Therm Settings	38
Table 6.16	Beta Configuration Register	38
Table 6.17	CPU Beta Values	38
Table 6.18	Ideality Configuration Registers	39
Table 6.19	Ideality Factor Look-Up Table (Diode Model)	39
Table 6.20	Substrate Diode Ideality Factor Look-Up Table (BJT Model)	40
Table 6.21	High Limit Status Register	41
Table 6.22	Low Limit Status Register	41
Table 6.23	Therm Limit Status Register	42
Table 6.24	Filter Configuration Register	42
Table 6.25	FILTER Decode	43
Table 6.26	Product ID Register	43
Table 6.27	Manufacturer ID Register	43
Table 6.28	Revision Register	43
Table 9.1	Customer Revision History	48

Chapter 1 Block Diagram

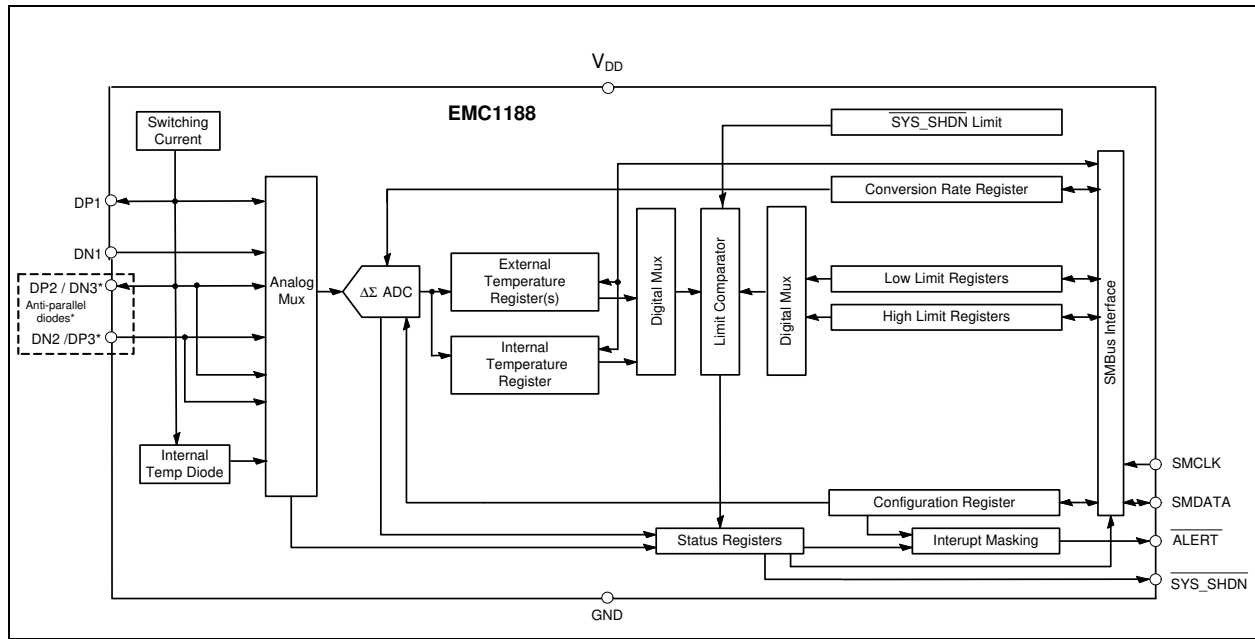


Figure 1.1 EMC1188 Block Diagram

Chapter 2 Pin Description

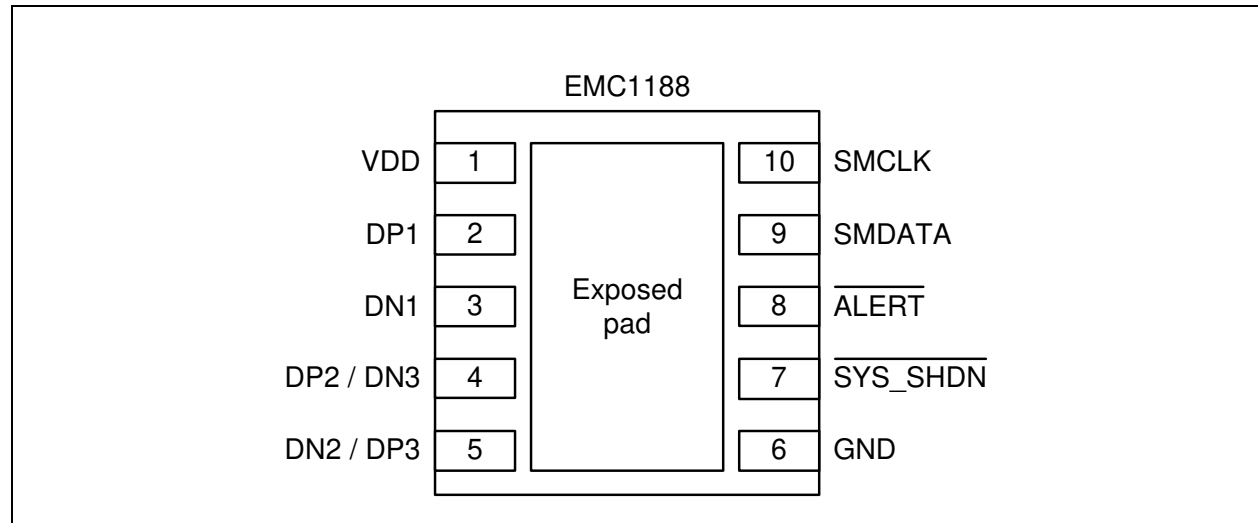


Figure 2.1 EMC1188 Pin Diagram DFN-10

Table 2.1 EMC1188 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	AIO
5	DN2 / DP3	External diode 2 negative (cathode) connection / External Diode 3 positive (anode) connection for anti-parallel diodes	AIO
6	GND	Ground	Power
7	$\overline{\text{SYS_SHDN}}$	Active low system shutdown output signal - requires pull-up resistor which selects the Hardware Thermal Shutdown Limit	OD (5V)
8	$\overline{\text{ALERT}}$	Active low digital ALERT output signal - requires pull-up resist	OD (5V)
9	SMDATA	SMBus Data input/output - requires pull-up resistor	DIOD (5V)

Table 2.1 EMC1188 Pin Description (continued)

PIN NUMBER	NAME	FUNCTION	TYPE
10	SMCLK	SMBus Clock input - requires pull-up resistor	DI (5V)
Bottom Pad	Exposed Pad	Not internally connected, but recommend grounding.	-

The pin types are described [Table 2.2](#).

Table 2.2 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 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 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	
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 3.1 For the 5V tolerant pins that have a pull-up resistor (SMCLK, SMDATA, SYS_SHDN and 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 $3.6V$, $T_A = -40^{\circ}C$ to $125^{\circ}C$, all typical values at $T_A = 27^{\circ}C$ 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}		200	410	μA	0.0625 conversion / sec, dynamic averaging disabled
			215	425	μA	1 conversion / sec, dynamic averaging disabled
			325	465	μA	4 conversions / sec, dynamic averaging disabled
			890	1050	μA	4 conversions / sec, dynamic averaging enabled

Table 3.2 Electrical Specifications (continued)

$V_{DD} = 3.0V$ to $3.6V$, $T_A = -40^{\circ}C$ to $125^{\circ}C$, all typical values at $T_A = 27^{\circ}C$ unless otherwise noted.						
CHARACTERISTIC	SYMBOL	MIN	TYP	MAX	UNITS	CONDITIONS
			1120		μA	≥ 16 conversions / sec, dynamic averaging enabled
Internal Temperature Monitor						
Temperature Accuracy			± 0.25	± 1	$^{\circ}C$	$-5^{\circ}C < T_A < 100^{\circ}C$
				± 2	$^{\circ}C$	$-40^{\circ}C < T_A < 125^{\circ}C$
Temperature Resolution			0.125		$^{\circ}C$	
External Temperature Monitor						
Temperature Accuracy			± 0.25	± 1	$^{\circ}C$	$+20^{\circ}C < T_{DIODE} < +110^{\circ}C$ $0^{\circ}C < T_A < 100^{\circ}C$
			± 0.5	± 2	$^{\circ}C$	$-40^{\circ}C < T_{DIODE} < 127^{\circ}C$
Temperature Resolution			0.125		$^{\circ}C$	
Capacitive Filter	C_{FILTER}		2.2	2.7	nF	Connected across external diode
$\overline{ALERT}$ and SYS_SHDN pins						
Output Low Voltage	V_{OL}	0.4			V	$I_{SINK} = 8mA$
Leakage Current	I_{LEAK}			± 5	μA	$\overline{ALERT}$ and pins Device powered or unpowered $T_A < 85^{\circ}C$ pull-up voltage $\leq 3.6V$

3.3 SMBus Electrical Characteristics

Table 3.3 SMBus Electrical Specifications

$V_{DD} = 3.0$ to $3.6V$, $T_A = -40^{\circ}C$ to $125^{\circ}C$, all typical values are at $T_A = 27^{\circ}C$ unless otherwise noted.						
CHARACTERISTIC	SYMBOL	MIN	TYP	MAX	UNITS	CONDITIONS
SMBus Interface						
Input High Voltage	V_{IH}	1.4		V_{DD}	V	5V Tolerant. Voltage threshold based on 1.8V operation
Input Low Voltage	V_{IL}	-0.3		0.8	V	5V Tolerant. Voltage threshold based on 1.8V operation
Leakage Current	I_{LEAK}			± 5	μA	Powered or unpowered $T_A < 85^{\circ}C$
Hysteresis		50			mV	
Input Capacitance	C_{IN}		5		pF	
Output Low Sink Current	I_{OL}	8.2		15	mA	$SMDATA = 0.4V$

Table 3.3 SMBus Electrical Specifications (continued)

$V_{DD} = 3.0$ to $3.6V$, $T_A = -40^{\circ}C$ to $125^{\circ}C$, all typical values are at $T_A = 27^{\circ}C$ unless otherwise noted.						
CHARACTERISTIC	SYMBOL	MIN	TYP	MAX	UNITS	CONDITIONS
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
Timeout	$t_{TIMEOUT}$	25		35	ms	Disabled by default

Chapter 4 System Management Bus Interface Protocol

4.1 Communications Protocol

The EMC1188 communicates with a host controller, such as an SMSC SIO, through the SMBus. The SMBus is a two-wire serial communication protocol between a computer host and its peripheral devices. A detailed timing diagram is shown in [Figure 4.1](#).

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

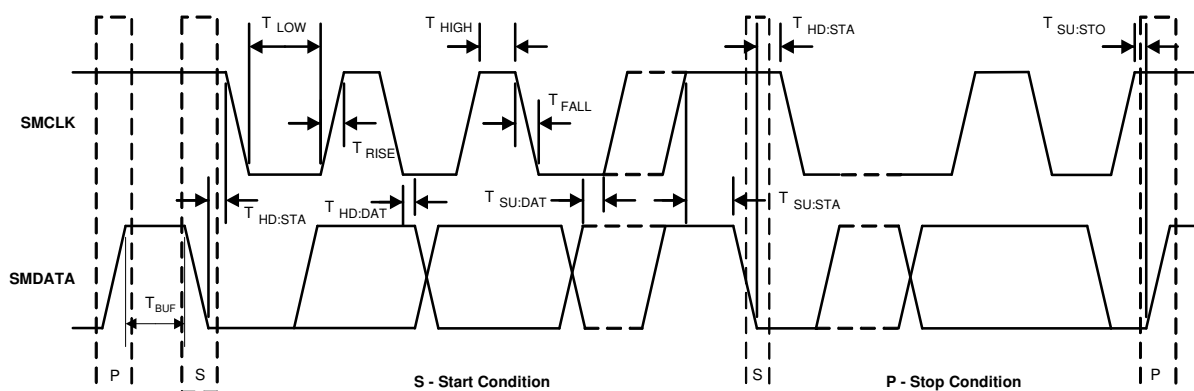


Figure 4.1 SMBus Timing Diagram

4.1.1 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.

4.1.2 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 EMC1188-1 SMBus address is hard coded to 1001_1100(r/w).

4.1.3 SMBus Data Bytes

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

4.1.4 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.

4.1.5 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.

4.1.6 SMBus Timeout

The EMC1188 supports SMBus Timeout. If the clock line is held low for longer than t_{TIMEOUT} , the device will reset its SMBus protocol. This function can be enabled by setting the TIMEOUT bit (see [Section 6.13, "Consecutive ALERT Register 22h"](#)).

4.1.7 SMBus and I²C Compatibility

The EMC1188 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 EMC1188 in an I²C system, refer to SMSC AN 14.0 SMSC Dedicated Slave Devices in I²C Systems.

1. EMC1188 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 EMC1188 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 EMC1188 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 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 4.1](#).

Table 4.1 Protocol Format

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

4.2.1 Write Byte

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

Table 4.2 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

4.2.2 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	YYYY_YYY	0	0	XXh	0	1 -> 0	YYYY_YYY	1	0	XX	1	0 -> 1

4.2.3 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 4.4](#).

Table 4.4 Send Byte Protocol

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

4.2.4 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 4.5](#).

Table 4.5 Receive Byte Protocol

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

4.3 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 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	YYYY_YYY	1	0 -> 1

The EMC1188 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_ALL bit to clear the $\overline{\text{ALERT}}$ pin.

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

Chapter 5 Product Description

The is an SMBus temperature sensor with Hardware Thermal Shutdown. The EMC1188 monitors one internal diode and up to 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 EMC1188 and using that data to control the speed of one or more fans.

The EMC1188 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 EMC1188 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 asserts the $\overline{\text{SYS_SHDN}}$ pin when the External Diode temperature exceeds a hardware specified threshold temperature. Additionally, the internal diode and External Diode 2 and 3 can be configured to assert the $\overline{\text{SYS_SHDN}}$ pin when the measured temperature exceeds user programmable limits.

For the EMC1188, 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 EMC1188.

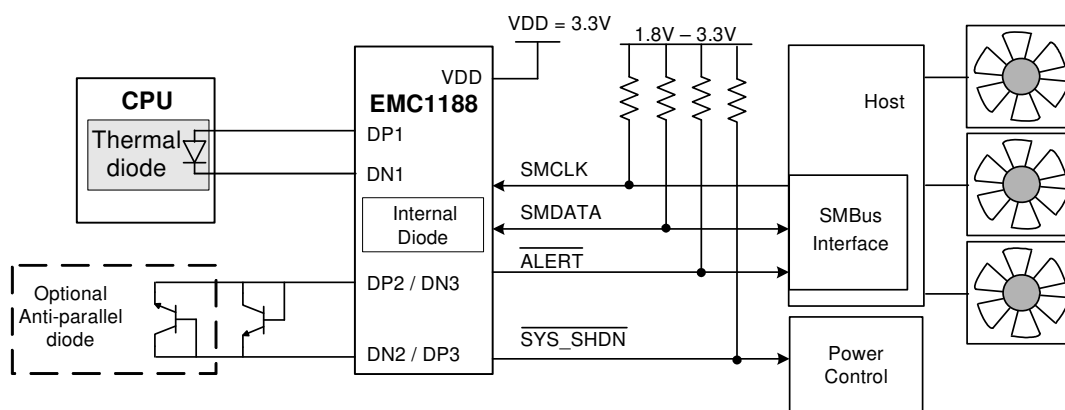


Figure 5.1 System Diagram for EMC1188

5.1 Conversion Rates

The EMC1188 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](#), "Conversion Rate".

5.2 Dynamic Averaging

Dynamic averaging causes the EMC1188 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](#), "Configuration Register 03h / 09h"). 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](#).

Table 5.1 Supply Current vs. Conversion Rate for EMC1188

CONVERSION RATE	AVERAGE SUPPLY CURRENT (TYPICAL)		AVERAGING FACTOR (BASED ON 11-BIT OPERATION)	
	ENABLED (DEFAULT)	DISABLED	ENABLED (DEFAULT)	DISABLED
1 / 16 sec	230uA	220uA	16x	1x
1 / 8 sec	275uA	220uA	16x	1x
1 / 4 sec	350uA	220uA	16x	1x
1 / 2 sec	405uA	220uA	16x	1x
1 / sec	480uA	250uA	8x	1x
2 / sec	850uA	290uA	4x	1x
4 / sec (default)	890uA	370uA	2x	1x
8 / sec	970uA	525uA	1x	1x
16 / sec	990uA	690uA	0.5x	0.5x
32 / sec	1030uA	1050uA	0.25x	0.25x
64 / sec	1500uA	1100uA	0.125x	0.125x

5.3 SYS_SHDN Output

The SYS_SHDN output is asserted independently of the ALERT output and cannot be masked. If the External Diode 1 temperature exceeds the Hardware Thermal Shutdown Limit for the programmed number of consecutive measurements, the SYS_SHDN pin is asserted.

The Hardware Thermal Shutdown Limit is defined at power-up via the pull-up resistors on the SYS_SHDN and ALERT pins as shown in [Table 5.2](#). This limit cannot be modified or masked via software.

In addition to External Diode 1 channel triggering the SYS_SHDN pin when the measured temperature exceeds the Hardware Thermal Shutdown Limit, each of the measurement channels can be configured to assert the SYS_SHDN pin when they exceed the corresponding THERM Limit.

When the SYS_SHDN pin is asserted, it will not release until the External Diode 1 temperature drops below the Hardware Thermal Shutdown Limit minus 10°C and all other measured temperatures drop below the THERM Limit minus the THERM Hysteresis value (when linked to SYS_SHDN).

[Figure 5.2](#) shows a block diagram of the interaction between the input channels and the SYS_SHDN pin.

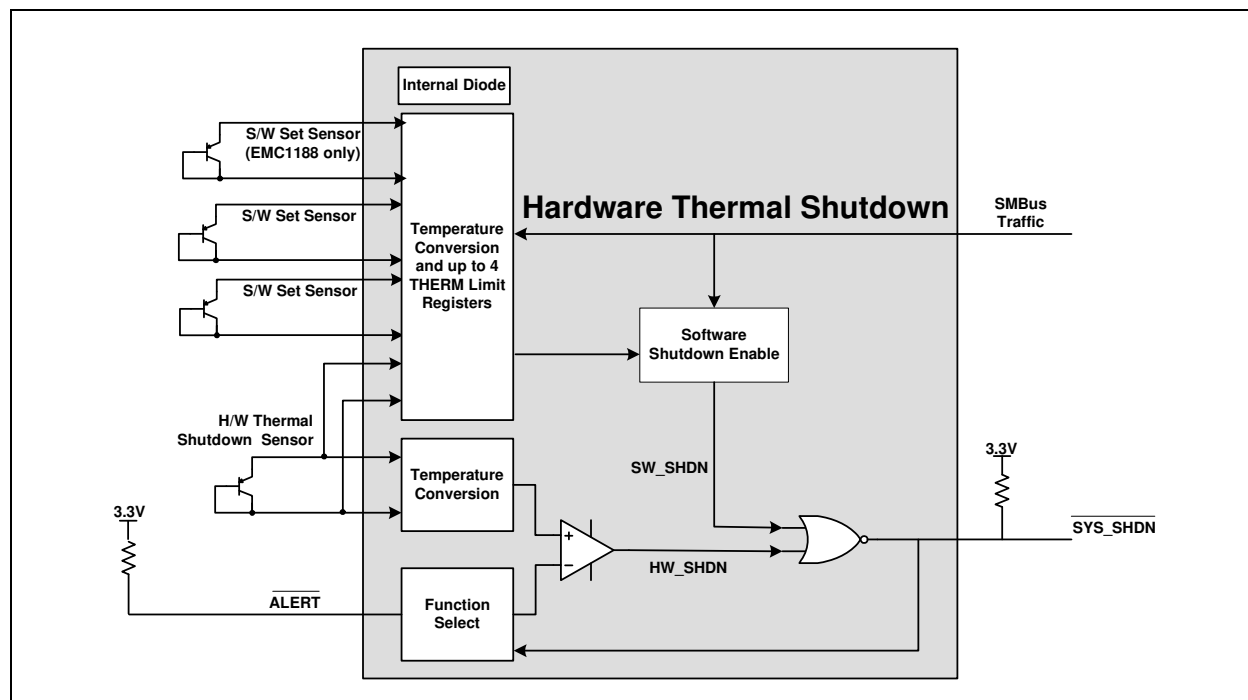


Figure 5.2 Block Diagram of Hardware Thermal Shutdown

5.4 Hardware Thermal Shutdown Limit

The Hardware Thermal Shutdown Limit temperature is determined by pull-up resistors on the SYS_SHDN and ALERT pins shown in [Table 5.2](#).

Table 5.2 SYS_SHDN Threshold Temperature

SYS_SHDN PULL-UP ALERT PULL-UP	4.7K OHM ±10%	6.8K OHM ±10%	10K OHM ±10%	15K OHM ±10%	22K OHM ±10%	33K OHM ±10%
4.7K OHM ±10%	77°C	83°C	89°C	95°C	101°C	107°C
6.8K OHM ±10%	78°C	84°C	90°C	96°C	102°C	108°C
10K OHM ±10%	79°C	85°C	91°C	97°C	103°C	109°C
15K OHM ±10%	80°C	86°C	92°C	98°C	104°C	110°C
22K OHM ±10%	81°C	87°C	93°C	99°C	105°C	111°C
33K OHM ±10%	82°C	88°C	94°C	100°C	106°C	112°C

5.5 **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](#)).

5.5.1 **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, functioning as any standard **ALERT** in on the SMBus. 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 6.12](#)).

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.

5.5.2 **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.

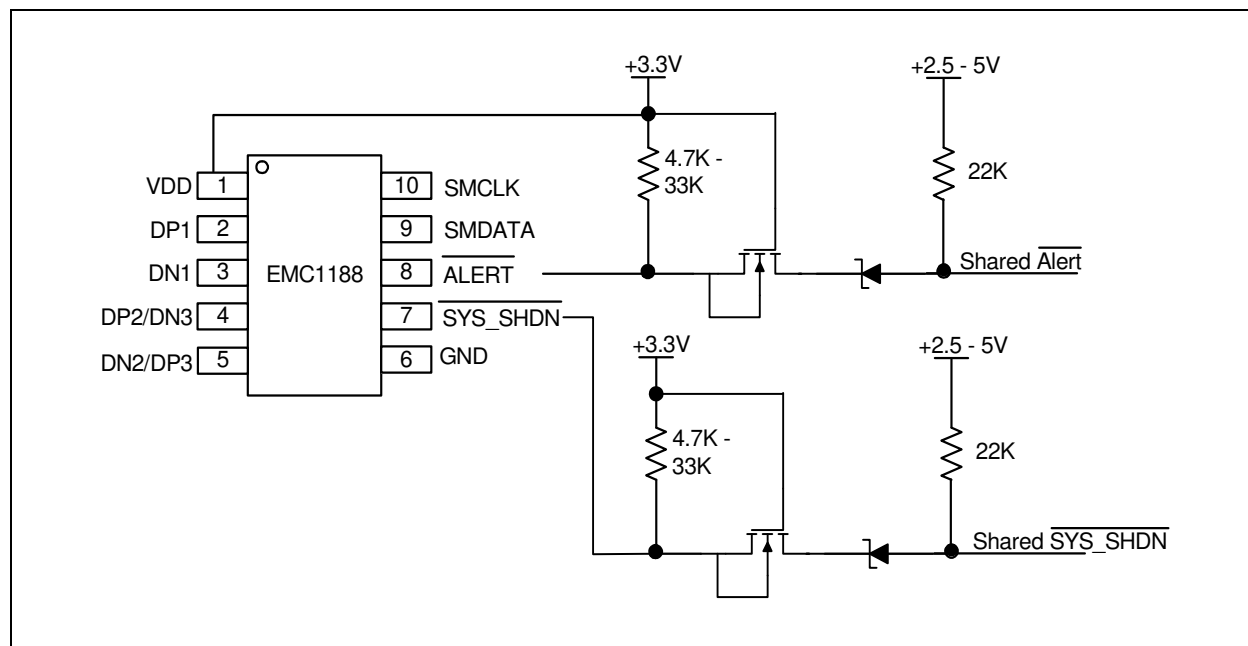
The **MASK_ALL** bit will not block the **ALERT** pin in this mode; however, the individual channel masks (see [Section 6.12](#)) will prevent the respective channel from asserting the **ALERT** pin.

5.6 **ALERT** and **SYS_SHDN** Pin Considerations

Because of the decode method used to determine the Hardware Thermal Shutdown Limit, it is important that the pull-up resistance on both the **ALERT** and **SYS_SHDN** pins be within the tolerances shown in [Table 5.2](#). Additionally, the pull-up resistor on the **ALERT** and **SYS_SHDN** pins must be connected to the same 3.3V supply that drives the **VDD** pin.

For 15ms after power up, the **ALERT** and **SYS_SHDN** pins must not be pulled low or the Hardware Thermal Shutdown Limit will not be decoded properly. If the system requirements do not permit these conditions, the **ALERT** and **SYS_SHDN** pins must be isolated from their respective busses during this time.

One method of isolating the **ALERT** pin is shown in [Figure 5.3](#).

Figure 5.3 Isolating ALERT and SYS_SHDN Pin

5.7 Temperature Measurement

The EMC1188 can monitor the temperature of up to three externally connected diode.

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).

5.7.1 Beta Compensation

The EMC1188 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 EMC1188 the External Diode 2 and External Diode 3 channels do not support Beta Compensation.

5.7.2 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 EMC1188 automatically corrects up to 100 ohms of series resistance.

5.7.3 Programmable External Diode Ideality Factor

The EMC1188 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 EMC1188 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.

5.8 Diode Faults

The EMC1188 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 5.9](#)) 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.

5.9 Consecutive Alerts

The EMC1188 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 $\overline{\text{SYS_SHDN}}$ pin. Each temperature measurement channel has a separate consecutive alert counter for each of the $\overline{\text{ALERT}}$ and $\overline{\text{SYS_SHDN}}$ 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 6.13, "Consecutive ALERT Register 22h"](#) for more details on the consecutive alert function.

5.10 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 6.19](#)). The typical filter performance is shown in [Figure 5.4](#) and [Figure 5.5](#).

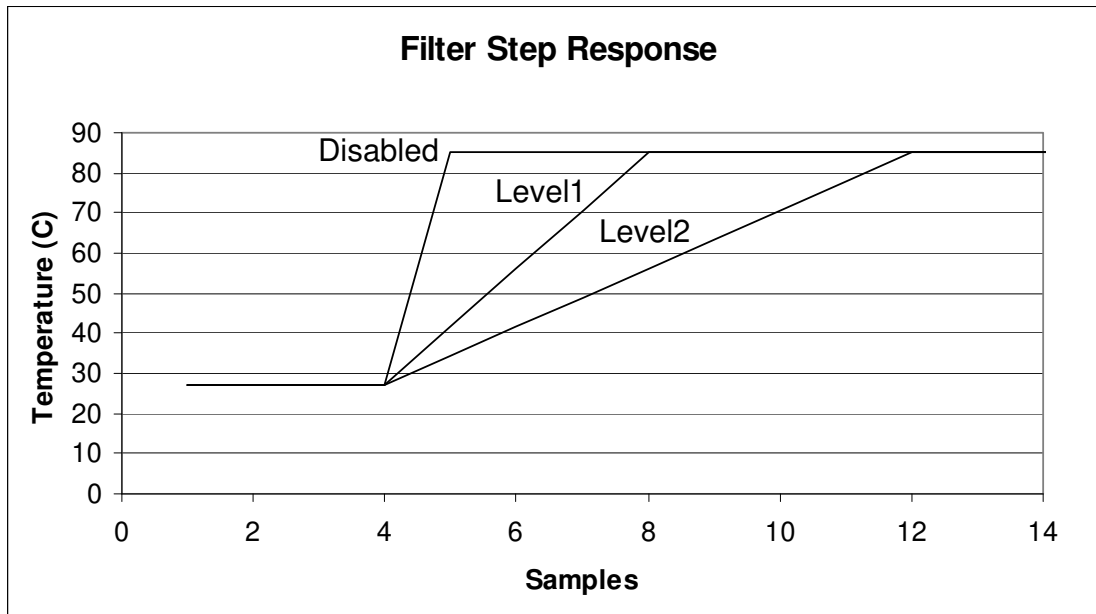


Figure 5.4 Temperature Filter Step Response

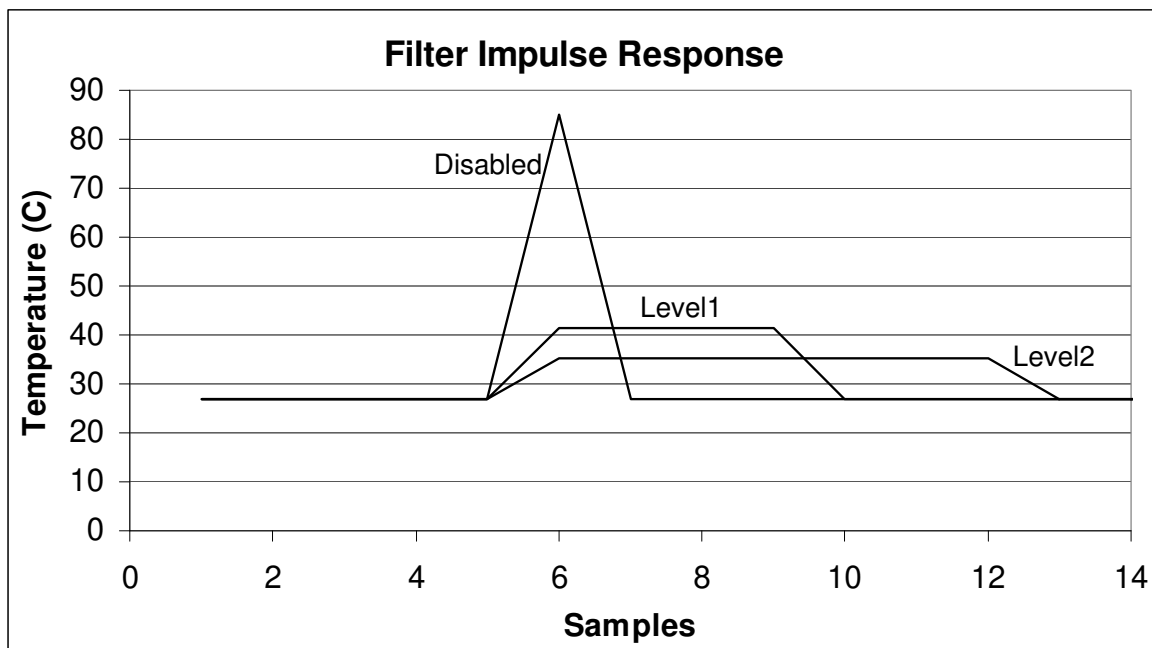


Figure 5.5 Temperature Filter Impulse Response

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 EMC1188 has two selectable temperature ranges. The default range is from 0°C to +127°C and the temperature is represented as binary number able to report a temperature from 0°C to +127.875°C in 0.125°C steps.

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

Table 5.3 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
-1	000 0000 0000	001 1111 1000
0	000 0000 0000	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	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

Chapter 6 Register Description

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

Table 6.1 Register Set in Hexadecimal Order

REGISTER ADDRESS	R/W	REGISTER NAME	FUNCTION	DEFAULT VALUE	PAGE
00h	R	Internal Diode Data High Byte	Stores the integer data for the Internal Diode	00h	Page 28
01h	R	External Diode Data High Byte	Stores the integer data for External Diode	00h	
02h	R	Status	Stores the status bits for the Internal Diode and External Diode	00h	Page 28
03h	R/W	Configuration	Controls the general operation of the device (mirrored at address 09h)		Page 30
04h	R/W	Conversion Rate	Controls the conversion rate for updating temperature data (mirrored at address 0Ah)	06h (4/sec)	Page 31
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 32
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 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 External Diode (mirrored at register 0Eh)	00h (0°C)	
09h	R/W	Configuration	Controls the general operation of the device (mirrored at address 03h)		Page 30
0Ah	R/W	Conversion Rate	Controls the conversion rate for updating temperature data (mirrored at address 04h)	06h (4/sec)	Page 31