

±1°C Remote and Local Temperature Sensor with SMBus Serial Interface

Features

- Two Channels: Measures Both Remote and Local Temperatures
- No Calibration Required
- Built-in Noise-Buster for Remote Sensor
- SMBus 2-Wire Serial Interface
- Programmable Under/Overtemperature Alarms
- Supports SMBus Alert Response
- Accuracy:
 - ±1°C (-10°C to +80°C, remote)
 - ±3°C (-40°C to +127°C, local)
- 320µA (typ) Average Supply Current During Conversion
- +3V to +3.6V Supply Range
- MSOP-8 and TDFN3X3-8 Package
- Remote Temperature Measurement up to 160°C by using offset shifting method (see "Measure Remote Temperature Higher Than 127°C" section)

Applications

Desktop and Notebook Computers
 Smart Battery Packs
 LAN Servers
 Industrial Controllers

Central Office Telecom Equipment
 Test and Measurement
 Multi-Chip Modules

General Description

The G788 is a precise digital thermometer that reports the temperature of both a remote sensor and its own package. The remote sensor is a diode-connected transistor typically a low-cost, easily mounted 2N3904 NPN type that replace conventional thermistors or thermocouples. Remote accuracy is ±1°C with no calibration needed. It also has a build-in noise filtering function in remote sensor measuring the diode temperature. The remote channel can also measure the die temperature of other ICs, such as microprocessors, that contain an on-chip, diode-connected transistor.

The 2-wire serial interface accepts standard System Management Bus (SMBus) Write Byte, Read Byte, Send Byte, and Receive Byte commands to program the alarm thresholds and to read temperature data. The data format is 11bits plus sign, with each bit corresponding to 0.125°C, in two's-complement format. Measurements can be done automatically and autonomously, with the conversion rate programmed by the user or programmed to operate in a single-shot mode. The adjustable rate allows the user to control the supply current drain.

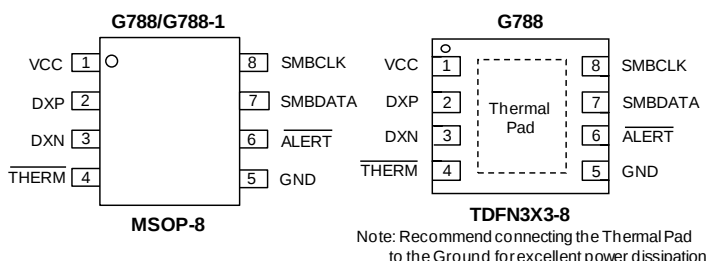
The G788 and G788-1 have the same functions but different SMBus slave addresses. This allows for one of each to be on the bus at the same time.

Ordering Information

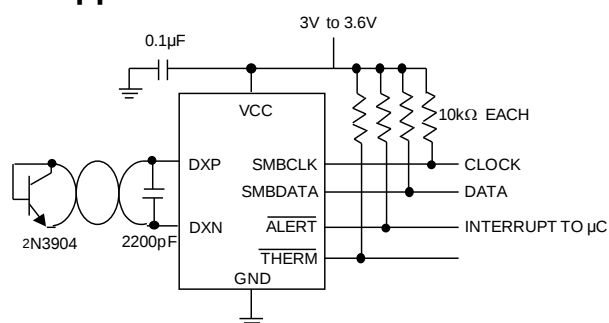
ORDER NUMBER	MARKING	TEMP. RANGE	PACKAGE (Green)
G788P81U	G788	-55°C to +127°C	MSOP-8
G788-1P81U	G788-1	-55°C to +127°C	MSOP-8
G788RD1U	788	-55°C to +127°C	TDFN3X3-8

Note: P8: MSOP-8 RD: TDFN3X3-8
 1: Bonding Code
 U: Tape & Reel
 Green : Lead Free / Halogen Free.

Pin Configuration



Typical Application Circuit



Absolute Maximum Ratings

VCC to GND -0.3V to +3.6V
 DXP to GND -0.3V to VCC + 0.3V
 DXN to GND. -0.3V to +0.8V
 SMBCLK, SMBDATA, ALERT to GND -0.3V to +3.6V
 SMBDATA, ALERT Current -1mA to +50mA
 DXN Current. ±1mA
 ESD Protection (SMBCLK, SMBDATA, ALERT, human body model) 2000V
 Thermal Resistance Junction to Ambient (θ_{JA} , T_A =+70°C)*
 MSOP-8. 140°C/W
 TDFN3X3-8 140°C/W

Continuous Power Dissipation (T_A = +70°C)
 Thermal Resistance Junction to Case (θ_{JC})*
 MSOP-8. 55°C/W
 TDFN3X3-8 30°C/W
 ESD Protection (other pins, human body model).2000V
 Continuous Power Dissipation (T_A = +70°C)
 MSOP (derate 7.14mW/°C above +70°C) 571mW
 Operating Temperature Range. . . . -55°C to +127°C
 Junction Temperature. +150°C
 Storage temperature Range. -65°C to +165°C
 Reflow Temperature (soldering, 10sec). 260°C

*Please refer to Minimum Footprint PCB Layout Section

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Electrical Characteristics

(VCC = + 3.3V, T_A = 0°C to +85°C.)

The device is not guaranteed to function outside its operating conditions. Parameters with MIN and/or MAX limits are 100% tested at +25°C, unless otherwise specified.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Temperature Error, Remote Diode (Note 1)	T_R = -10°C to +80°C, VCC = 3.0V to 3.6V		-1	---	+1	°C
	T_R = -40°C to +127°C (Note 2)		-2	---	+2	
Temperature Error, Local Diode	T_A = -10°C to +80°C		-1	---	+1	°C
	T_A = -40°C to +127°C (Note 2)		-3	---	+3	
Supply-Voltage Range			3.0	---	3.6	V
Undervoltage Lockout Threshold	VCC input, disables A/D conversion, rising edge		---	2.2	---	V
Undervoltage Lockout Hysteresis			---	50	---	mV
Power-On Reset Threshold	VCC, falling edge		---	1.7	---	V
POR Threshold Hysteresis			---	50	---	mV
Standby Supply Current	Logic inputs forced to VCC or GND	SMBus static	---	3	---	μA
		Hardware or software standby, SMBCLK at 10kHz	---	4	---	
Average Operating Supply Current	Auto-convert mode. Logic inputs forced to VCC or GND	0.5 conv/sec	---	35	---	μA
		8.0 conv/sec	---	320	---	
Conversion Time	From stop bit to conversion complete (both channels)		---	125	---	ms
Conversion Rate Timing	Conversion-Rate Control Byte=04h, 1Hz		---	1	---	sec
Remote-Diode Source Current	DXP forced to 1.5V	High level	---	176	200	μA
		Low level	---	11	12.5	

Electrical Characteristics (continued)

(VCC = + 3.3V, T_A = 0°C to +85°C, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
SMBus Interface					
Logic Input High Voltage	STBY, SMBCLK, SMBDATA; Vcc = 3V to 3.6V	2.4	---	---	V
Logic Input Low Voltage	STBY, SMBCLK, SMBDATA; Vcc = 3V to 3.6V	---	---	0.8	V
Logic Output Low Sink Current	ALERT, SMBDATA forced to 0.4V	6	---	---	mA
ALERT Output High Leakage Current	ALERT forced to 3.6V	---	---	1	μA
Logic Input Current	Logic inputs forced to VCC or GND	-2	---	2	μA
SMBus Input Capacitance	SMBCLK, SMBDATA	---	5	---	pF
SMBus Clock Frequency		---	---	100	kHz
SMBus Timeout	SMBCLK low time for interface reset	---	30	---	ms
SMBCLK Clock Low Time	t _{LOW} , 10% to 10% points	4.7	---	---	μs
SMBCLK Clock High Time	t _{HIGH} , 90% to 90% points	4	---	---	μs
SMBus Start-Condition Setup Time		4.7	---	---	μs
SMBus Repeated Start-Condition Setup Time	t _{SU:STA} , 90% to 90% points	500	---	---	ns
SMBus Start-Condition Hold Time	t _{HD:STA} , 10% of SMBDATA to 90% of SMBCLK	4	---	---	μs
SMBus Stop-Condition Setup Time	t _{SD:STO} , 90% of SMBCLK to 10% of SMBDATA	4	---	---	μs
SMBus Data Valid to SMBCLK Rising-Edge Time	t _{SU:DAT} , 10% or 90% of SMBDATA to 10% of SMBCLK	800	---	---	ns
SMBus Data-Hold Time	t _{HD:DAT}	300	---	---	ns
SMBCLK Falling Edge to SMBus Data-Valid Time	Master clocking in data	---	---	1	μs

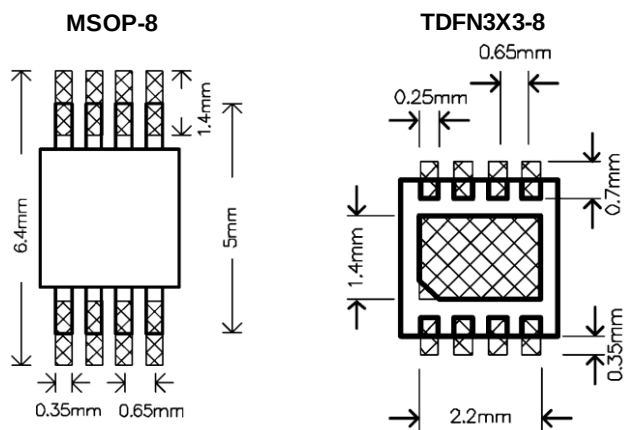
Note 1: A remote diode is any diode-connected transistor from Table1. T_R is the junction temperature of the remote diode. See Remote Diode Selection for remote diode forward voltage requirements.

Note 2: Guaranteed by design but not 100% tested.

Pin Description

PIN	NAME	FUNCTION
1	VCC	Supply Voltage Input, 3V to 3.6V. Bypass to GND with a 0.1μF capacitor.
2	DXP	Combined Current Source and A/D Positive Input for remote-diode channel. Do not leave DXP floating; tie DXP to DXN if no remote diode is used. Place a 2200pF capacitor between DXP and DXN for noise filtering.
3	DXN	Combined Current Sink and A/D Negative Input.
4	THERM	Open-drain output. Requires pull-up to VCC.
5	GND	Ground
6	ALERT	SMBus Alert (interrupt) Output, open drain
7	SMBDATA	SMBus Serial-Data Input / Output, open drain
8	SMBCLK	SMBus Serial-Clock Input

Minimum Footprint PCB Layout Section



Detailed Description

The G788 is a temperature sensor designed to work in conjunction with an external microcontroller (μC) or other intelligence in thermostatic, process-control, or monitoring applications. The μC is typically a power-management or keyboard controller, generating SMBus serial commands by "bit-banging" general-purpose input-output (GPIO) pins or via a dedicated SMBus interface block.

Essentially an serial analog-to digital converter (ADC) with a sophisticated front end, the G788 contains a switched current source, a multiplexer, an ADC, an SMBus interface, and associated control logic (Figure 1). Temperature data from the ADC is loaded into two data registers, where it is automatically compared with data previously stored in several over/under- temperature alarm registers.

ADC and Multiplexer

The ADC is an averaging type that integrates over a 60ms period (each channel, typical), with excellent noise rejection.

The multiplexer automatically steers bias currents through the remote and local diodes, measures their forward voltages, and computes their temperatures. Both channels are automatically converted once the conversion process has started, either in free-running or single-shot mode. If one of the two channels is not used, the device still performs both measurements, and the user can simply ignore the results of the unused channel. If the remote diode channel is unused, tie DXP to DXN rather than leaving the pins open.

The worst-case DXP-DXN differential input voltage range is 0.25V to 0.95V.

Excess resistance in series with the remote diode causes about $+0.6^\circ\text{C}$ error per ohm. Likewise, $240\mu\text{V}$ of offset voltage forced on DXP-DXN causes about 1°C error.

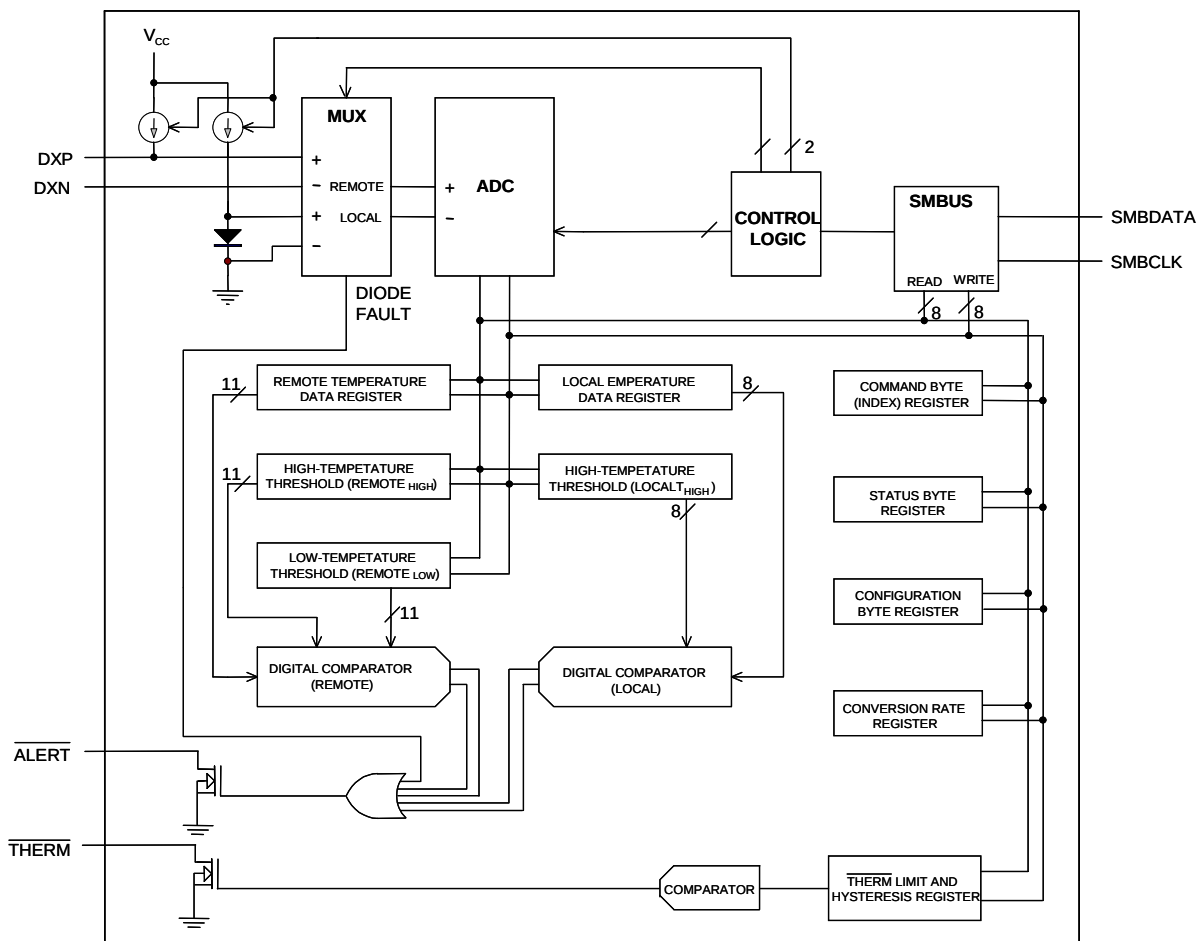


Figure 1. Functional Diagram

A/D Conversion Sequence

If a Start command is written (or generated automatically in the free-running auto-convert mode), both channels are converted, and the results of both measurements are available after the end of conversion. A BUSY status bit in the status byte shows that the device is actually performing a new conversion; however, even if the ADC is busy, the results of the previous conversion are always available.

Remote Diode Selection

Temperature accuracy depends on having a good-quality, diode-connected small-signal transistor. The G788 can also directly measure the die temperature of CPUs and other integrated circuits having on-board temperature-sensing diodes.

The transistor must be a small-signal type with a relatively high forward voltage; otherwise, the A/D input voltage range can be violated. The forward voltage must be greater than 0.25V at 10 μ A; check to ensure this is true at the highest expected temperature. The forward voltage must be less than 0.95V at 300 μ A; check to ensure this is true at the lowest expected temperature. Large power transistors don't work at all. Also, ensure that the base resistance is less than 100 Ω . Tight specifications for forward-current gain (+50 to +150, for example) indicate that the manufacturer has good process controls and that the devices have consistent V_{be} characteristics.

Thermal Mass and Self-Heating

Thermal mass can seriously degrade the G788's effective accuracy. The thermal time constant of the SOP- package is about 140 in still air. For the G788 junction temperature to settle to within +1 $^{\circ}$ C after a sudden +100 $^{\circ}$ C change requires about five time constants or 12 minutes. The use of smaller packages for remote sensors, such as SOT23s, improves the situation. Take care to account for thermal gradients between the heat source and the sensor, and ensure that stray air currents across the sensor package do not interfere with measurement accuracy. Self-heating does not significantly affect measurement accuracy. Remote-sensor self-heating due to the diode current source is negligible. For the local diode, the worst-case error occurs when auto-converting at the fastest rate and simultaneously sinking maximum current at the ALERT output. For example, at an 8Hz rate and with ALERT sinking 1mA, the typical power dissipation is $V_{CC} \times 320\mu A$ plus $0.4V \times 1mA$. Package theta J-A is about 120 $^{\circ}$ C/W, so with $V_{CC} = 3.3V$ and no copper PC board heat-sinking, the resulting temperature rise is:

$$\Delta T = 1.45mW \times 120^{\circ}C/W = 0.17^{\circ}C$$

Even with these contrived circumstances, it is difficult to introduce significant self-heating errors.

Transistors 2N3904 or 2N3906 are suitable sensing devices to use. Please refer to Table 1.

Table 1. Remote-Sensor Transistor Manufacturers

MANUFACTURER	MODEL NUMBER
Philips	PMBS3904
Motorola(USA)	MMBT3904
National Semiconductor (USA)	MMBT3904
Fairchild Semiconductor	MMBT3906

Note: Both 2N3904, 2N3906 transistors must be diode-connected, i.e., base shorted to collector. As Figure 2.

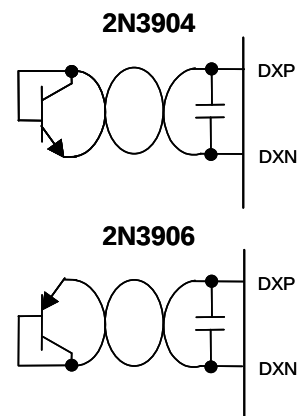


Figure 2.

ADC Noise Filtering

The ADC is an integrating type with inherently good noise rejection. Micropower operation places constraints on high-frequency noise rejection; therefore, careful PC board layout and proper external noise filtering are required for high-accuracy remote measurements in electrically noisy environments.

High-frequency EMI is best filtered at DXP and DXN with an external 2200pF capacitor. This value can be increased to about 3300pF(max), including cable capacitance. Higher capacitance than 3300pF introduces errors due to the rise time of the switched current source.

Nearly all noise sources tested cause the ADC measurements to be higher than the actual temperature, typically by +1 $^{\circ}$ C to 10 $^{\circ}$ C, depending on the frequency and amplitude.

PC Board Layout

Place the G788 as close as practical to the remote diode. In a noisy environment, such as a computer motherboard, this distance can be 4 in. to 8 in. (typical) or more as long as the worst noise sources (such as CRTs, clock generators, memory buses, and ISA/PCI buses) are avoided.

Do not route the DXP-DXN lines next to the deflection coils of a CRT. Also, do not route the traces across a fast memory bus, which can easily introduce $+30^{\circ}\text{C}$ error, even with good filtering. Otherwise, most noise sources are fairly benign.

Route the DXP and DXN traces in parallel and in close proximity to each other, away from any high-voltage traces such as $+12\text{V}_{\text{DC}}$. Leakage currents from PC board contamination must be dealt with carefully, since a $10\text{M}\Omega$ leakage path from DXP to ground causes about $+1^{\circ}\text{C}$ error.

Connect guard traces to GND on either side of the DXP-DXN traces (Figure 3). With guard traces in place, routing near high-voltage traces is no longer an issue.

Route through as few vias and crossunders as possible to minimize copper/solder thermocouple effects.

When introducing a thermocouple, make sure that both the DXP and the DXN paths have matching thermocouples. In general, PC board-induced thermocouples are not a serious problem. A copper-solder thermocouple exhibits $3\mu\text{V}/^{\circ}\text{C}$, and it takes about $240\mu\text{V}$ of voltage error at DXP-DXN to cause a $+1^{\circ}\text{C}$ measurement error. So, most parasitic thermocouple errors are swamped out.

Use wide traces. Narrow ones are more inductive and tend to pick up radiated noise. The 10 mil widths and spacing recommended on Figure 3 aren't absolutely necessary (as they offer only a minor improvement in leakage and noise), but try to use them where practical.

Keep in mind that copper can't be used as an EMI shield, and only ferrous materials such as steel work will. Placing a copper ground plane between the DXP-DXN traces and traces carrying high-frequency noise signals does not help reduce EMI.

PC Board Layout Checklist

- Place the G788 close to a remote diode.
- Keep traces away from high voltages ($+12\text{V}$ bus).
- Keep traces away from fast data buses and CRTs.
- Use recommended trace widths and spacing.
- Place a ground plane under the traces
- Use guard traces flanking DXP and DXN and connecting to GND.
- Place the noise filter and the $0.1\mu\text{F}$ VCC bypass capacitors close to the G788.

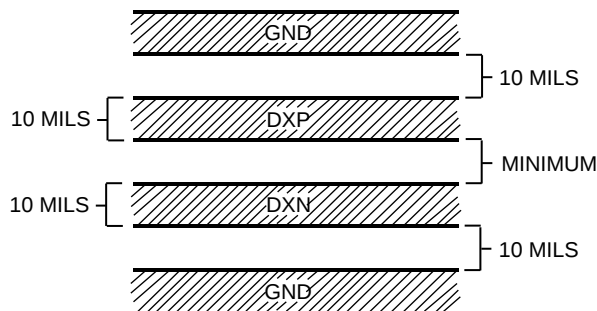


Figure 3. Recommended DXP/DXN PC Traces

Twisted Pair and Shielded Cables

For remote-sensor distances longer than 8 in., or in particularly noisy environments, a twisted pair is recommended. Its practical length is 6 feet to 12 feet (typical) before noise becomes a problem, as tested in a noisy electronics laboratory. For longer distances, the best solution is a shielded twisted pair like that used for audio microphones. Connect the twisted pair to DXP and DXN and the shield to GND, and leave the shield's remote end unterminated.

Excess capacitance at DX limits practical remote sensor distances (see Typical Operating Characteristics). For very long cable runs, the cable's parasitic capacitance often provides noise filtering, so the 2200pF capacitor can often be removed or reduced in value. Cable resistance also affects remote-sensor accuracy; 1Ω series resistance introduces about $+0.6^{\circ}\text{C}$ error.

Low-Power Standby Mode

Standby mode disables the ADC and reduces the supply-current drain to about $10\mu\text{A}$. Enter standby mode by forcing high to the $\overline{\text{RUN}}/\text{STOP}$ bit in the configuration byte register. Software standby mode behaves such that all data is retained in memory, and the SMB interface is alive and listening for reads and writes.

Software standby mode is not a shutdown mode. With activity on the SMBus, extra supply current is drawn (see Typical Operating Characteristics). In software standby mode, the G788 can be forced to perform A/D conversions via the one-shot command, despite the $\overline{\text{RUN}}/\text{STOP}$ bit being high.

If software standby command is received while a conversion is in progress, the conversion cycle is truncated, and the data from that conversion is not latched into either temperature reading register. The previous data is not changed and remains available.

Supply-current drain during the 125ms conversion period is always about 320 μ A. Slowing down the conversion rate reduces the average supply current (see Typical Operating Characteristics). In between conversions, the instantaneous supply current is about 25 μ A due to the current consumed by the conversion rate timer. In standby mode, supply current drops to about 3 μ A. At very low supply voltages (under the power-on-reset threshold), the supply current is higher due to the address pin bias currents. It can be as high as 100 μ A, depending on ADD0 and ADD1 settings.

SMBus Digital Interface

From a software perspective, the G788 appears as a set of byte-wide registers that contain temperature data, alarm threshold values, or control bits. A standard SMBus 2-wire serial interface is used to read temperature data and write control bits and alarm threshold data.

Each A/D channel within the device responds to the same SMBus slave address for normal reads and writes.

The G788 employs four standard SMBus protocols: Write Byte, Read Byte, Send Byte, and Receive Byte (Figure 4). The shorter Receive Byte protocol allows quicker transfers, provided that the correct data register was previously selected by a Read Byte instruction. Use caution with the shorter protocols in multi-master systems, since a second master could overwrite the command byte without informing the first master.

The temperature data format is 11bits plus sign in twos-complement form for remote channel, with each data bit representing 0.125 $^{\circ}$ C (Table 2, Table 3), transmitted MSB first.

Table 2. Temperature Data Format (Two's-Complement)

TEMP. ($^{\circ}$ C)	DIGITAL OUTPUT			
	DATA BITS			
	SIGN	MSB	LSB	EXT
+127.875	0	111	1111	111
+126.375	0	111	1110	011
+25.5	0	001	1001	100
+1.75	0	000	0001	110
+0.5	0	000	0000	100
+0.125	0	000	0000	001
-0.125	1	111	1111	111
-1.125	1	111	1110	111
-25.5	1	110	0110	100
-55.25	1	100	1000	110
-65.000	1	011	1111	000

Table 3. Extended Temperature Data Format

EXTENDED RESOLUTION	DATA BITS
0.000 $^{\circ}$ C	0000 0000
0.125 $^{\circ}$ C	0010 0000
0.250 $^{\circ}$ C	0100 0000
0.375 $^{\circ}$ C	0110 0000
0.500 $^{\circ}$ C	1000 0000
0.625 $^{\circ}$ C	1010 0000
0.750 $^{\circ}$ C	1100 0000
0.875 $^{\circ}$ C	1110 0000

Write Byte Format

S	ADDRESS	WR	ACK	COMMAND	ACK	DATA	ACK	P
	7 bits			8 bits		8 bits		1

Slave Address: equivalent to chip- select line of a 3-wire interface

Command Byte: selects which register you are writing to

Data byte: data goes into the register set by the command byte (to set thresholds, configuration masks, and sampling rate)

Read Byte Format

S	ADDRESS	WR	ACK	COMMAND	ACK	S	ADDRESS	RD	ACK	DATA	///	P
	7 bits			8bits			7bits			8 bits		

Slave Address: equivalent to chip- select line

Command Byte: selects which register you are reading from

Slave Address: repeated due to change in data-flow direction

Data byte: reads from the register set by the command byte

Send Byte Format

S	ADDRESS	WR	ACK	COMMAND	ACK	P
	7 bits			8 bits		

Command Byte: sends command with no data, usually used for one-shot command

Receive Byte Format

S	ADDRESS	RD	ACK	DATA	///	P
	7 bits			8 bits		

Data Byte: reads data from the register commanded by the last Read Byte or Write Byte transmission; also used for SMBus Alert Response return address

S = Start condition Shaded = Slave transmission P = Stop condition /// = Not acknowledged

Figure 4. SMBus Protocols

Slave Address

The G788 appears to the SMBus as one device having a common address for both ADC channels.

The G788 and G788-1 have the following SMBus slave address:

	A6	A5	A4	A3	A2	A1	A0
G788	1	0	0	1	1	0	0
G788-1	1	0	0	1	1	0	1

The G788 also responds to the SMBus Alert Response slave address (see the Alert Response Address section).

One-Shot Register

The One-shot register is to initiate a single conversion and comparison cycle when the device is in standby mode and auto conversion mode. The write operation to this register causes one-shot conversion and the data written to it is irrelevant and is not stored.

Serial Bus Interface Reinitialization

When SMBCLK are held low for more than 30ms (typical) during an SMBus communication the G788 will reinitiate its bus interface and be ready for a new transmission.

Diode Fault Alarm

There is a fault detector at DXP that detects whether the remote diode has an open-circuit condition. At the beginning of each conversion, the diode fault is checked, and the status byte is updated. This fault detector is a simple voltage detector. If DXP rises above $V_{CC} - 1V$ (typical) due to the diode current source, a fault is detected and the device alarms through pulling $\overline{ALERT}$ low while the remote temperature reading doesn't update in this condition. Note that the diode fault isn't checked until a conversion is initiated, so immediately after power-on reset the status byte indicates no fault is present, even if the diode path is broken.

If the remote channel is shorted (DXP to DXN or DXP to GND), the ADC reads 1000 0000(-128°C) so as not to trip either the T_{HIGH} or T_{LOW} alarms at their POR settings.

$\overline{ALERT}$ Output

The G788 $\overline{ALERT}$ pin is an active-low open-drain output pin which is triggered when measured temperature exceeds the limitation defined in the limit registers. There are three types of $\overline{ALERT}$ output mode: the $\overline{ALERT}$ output comparator mode, the $\overline{ALERT}$ output interrupt mode, and the $\overline{ALERT}$ output SMBus $\overline{ALERT}$ mode.

$\overline{ALERT}$ Output Comparator Mode

Figure 5 shows the mechanism of the $\overline{ALERT}$ output comparator mode. In this mode, the $\overline{ALERT}$ pin will be alerted if the monitored temperature is out-of-limit and the $\overline{ALERT}$ pin keeps low until the temperature goes back to the target range.

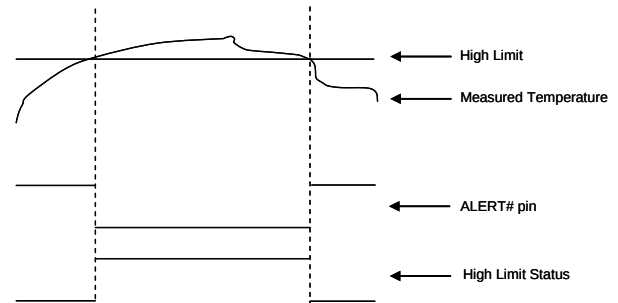


Figure 5

$\overline{ALERT}$ Output Interrupt Mode

Figure 6 shows the mechanism of the $\overline{ALERT}$ output interrupt mode. In this mode, the G788 will set the ALERT mask bit of Configuration Register during a read of the Status Register if any flag in Status Register, except the ADC_Busy flag is set. This prevents further $\overline{ALERT}$ triggering until the master has reset the ALERT mask bit (write 0 to Alert_MSK), at the end of the interrupt service routine. The Status Register flags are cleared only upon a read Status Register command from the master and will be re-alerted at the end of the next temperature conversion if the measured temperature still falls outside of the allowed range.

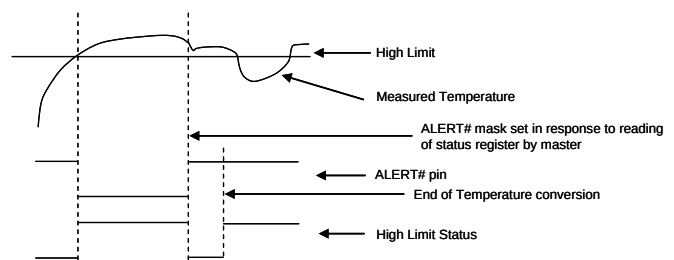


Figure 6

ALERT Output SMB_{US} alert Mode

Figure 7 shows the mechanism of the $\overline{\text{ALERT}}$ output SMBus alert mode. In this mode, the $\overline{\text{ALERT}}$ output of the G788 is connected to the SMBus alert line which has more than one device connected to it. Through such an implementation, SMBus alert mode can assist the master in resolving which slave generates an interrupt. When the measured temperature falls outside of the allowed range, the $\overline{\text{ALERT}}$ pin will be pulled low and the corresponding alert flags in Status Register will be set to 1. The ALERT mask bit will just be set if there is a read command for Status Register or when SMBus $\overline{\text{ALERT}}$ Response Address (ARA) occurs from master (Alert Response Address is 0001100x). Meanwhile, the G788 will generate and return its own address to the master. If the temperature never falls outside of the allowed range, the latched $\overline{\text{ALERT}}$ pin can release by the reset ALERT mask bit and the latched corresponding alert flags in Status Register can release by reading command for Status Register.

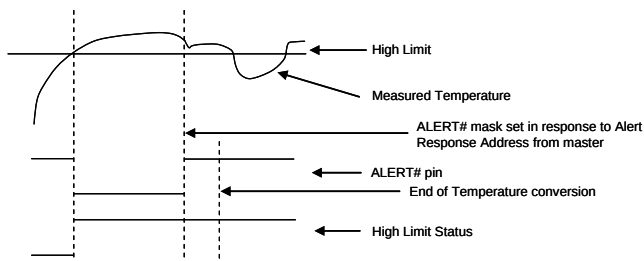


Figure 7

Operation of the THERM Function

A local and remote $\overline{\text{THERM}}$ limit can be programmed into the G788 to set the temperature limit above which the $\overline{\text{THERM}}$ pin asserts low and the bit 1, of status byte will be set to 1 corresponding to remote and local over temperature. These two bits won't be cleared to 0 by reading status byte if the over temperature condition remains. A hysteresis value is provided by writing the register 21h to set the temperature threshold to release the $\overline{\text{THERM}}$ pin alarm state. The releasing temperature is the value of register 19h, 20h minus the value in register 21h. The format of register 21h is 2's complement. The $\overline{\text{THERM}}$ signal is open drain and requires a pull-up resistor to power supply.

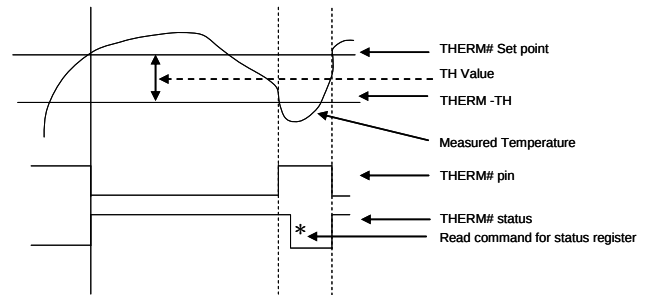


Figure 8

Command Byte Functions

The 8-bit command byte register (Table 5) is the master index that points to the various other registers within the G788. The register's POR state is 0000 0000, so that a Receive Byte transmission (a protocol that lacks the command byte) that occurs immediately after POR returns the current local temperature data.

The one-shot command immediately forces a new conversion cycle to begin. In software standby mode ($\overline{\text{RUN}}/\text{STOP}$ bit = high), a new conversion is begun, after which the device returns to standby mode. If a conversion is in progress when a one-shot command is received in auto-convert mode ($\overline{\text{RUN}}/\text{STOP}$ bit = low) between conversions, a new conversion begins, the conversion rate timer is reset, and the next automatic conversion takes place after a full delay elapses.

Configuration Byte Functions

The configuration byte register (Table 6) is used to mask interrupts and to put the device in software standby mode. The other bits are empty.

Status Byte Functions

The status byte register (Table 7) indicates which (if any) temperature thresholds have been exceeded. This byte also indicates whether or not the ADC is converting and whether there is an open circuit in the remote diode DXP-DXN path. After POR, the normal state of all the flag bits is zero, assuming none of the alarm conditions are present. The status byte is cleared by any successful read of the status, unless the fault persists. Note that the $\overline{\text{ALERT}}$ interrupt latch is not automatically cleared when the status flag bit is cleared.

When reading the status byte, you must check for internal bus collisions caused by asynchronous ADC timing, or else disable the ADC prior to reading the status byte (via the $\overline{\text{RUN}}/\text{STOP}$ bit in the configuration byte). In one-shot mode, read the status byte only after the conversion is complete, which is approximately 125ms max after the one-shot conversion is commanded.

Table 5. Command-Byte Bit Assignments

REGISTER	COMMAND	POR STATE	FUNCTION
RLTS	00h	0000 0000*	Read local temperature. It returns latest temperature
RRTE	01h	0000 0000*	Read remote temperature. It returns latest temperature
RSL	02h	N/A	Read status byte (flags, busy signal)
RCL	03h	0010 0101	Read configuration byte
RCRA	04h	0000 1000	Read conversion rate byte
RLHN	05h	0100 0110	Read local T _{HIGH} limit
Reserved	06h	-	Reserved
RRHI	07h	0100 0110	Read remote T _{HIGH} limit
RRLS	08h	1101 1000	Read remote T _{LOW} limit
WCA	09h	N/A	Write configuration byte
WCRW	0Ah	N/A	Write conversion rate byte
WLHO	0Bh	N/A	Write local T _{HIGH} limit
Reserved	0Ch	N/A	Reserved
WRHA	0Dh	N/A	Write remote T _{HIGH} limit
WRLN	0Eh	N/A	Write remote T _{LOW} limit
OSHT	0Fh	N/A	One-shot command (use send-byte format)
RTEXT	10h	0	Remote temperature extended byte
RTOFS	11h	0	Remote temperature offset high byte
RTOFSEXT	12h	0	Remote temperature offset extended byte
RLEXT	13h	0	Remote T _{HIGH} limit extended byte
RHEXT	14h	0	Remote T _{LOW} limit extended byte
Alert Mask	16h	0000 0111	Mask Alert condition
RTTHERM	19h	-	Remote temperature T _{HERM} limit
LTHERM	20h	-	Local temperature T _{HERM} limit
THERMHYST	21h	0000 1010 (10)	T _{HERM} hysteresis
Reserved	2Dh	-	Reserved
Reserved	2Eh	-	Reserved
Reserved	2Fh	-	Reserved
Alert mode	BFh	00	Alert mode
CID	FDh	0101 0000	chip ID
MFGIO	FEh	0100 0111	Manufacturer ID
DEVID	FFh	1001 0000	Device ID

*If the device is in standby mode at POR, both temperature registers read 0°C.

Table 6. Configuration-Byte Bit Assignments

BIT	NAME	POR STATE	FUNCTION
7 (MSB)	MASK	0	Masks all $\overline{\text{ALERT}}$ interrupts when high.
6	RUN / STOP	0	Standby mode control bit. If high, the device immediately stops converting and enters standby mode. If low, the device converts in either one-shot or timer mode.
2	EN_RT1	1	Enable Remote Diode 1 monitoring.
1	EN_WTC	0	Enable Override POR Value of $\overline{\text{THERM}}$ Limit Temperature
0	EN_Fault Queue	1	Enable Fault Queue function. $\overline{\text{ALERT}}$ and $\overline{\text{THERM}}$ will be generated if monitor result of any channel is three successive times above or below high/low set point.

Table 7. Status-Byte Bit Assignments

BIT	NAME	FUNCTION
7 (MSB)	BUSY	A high indicates that the ADC is busy converting.
6	LHIGH*	A high indicates that the local high-temperature alarm has activated.
4	RHIGH*	A high indicates that the remote high-temperature alarm has activated.
3	RLOW*	A high indicates that the remote low-temperature alarm has activated.
2	OPEN*	A high indicates a remote-diode continuity (open-circuit) fault.
1	RTHRM	A high indicates a remote temperature $\overline{\text{THERM}}$ alarm has activated.
0 (LSB)	LTHRM	A high indicates a local temperature $\overline{\text{THERM}}$ alarm has activated.

*These flags stay high until cleared by POR, or until the status byte register is read.

Table 8. Conversion-Rate Control Byte

DATA	CONVERSION RATE (Hz)
00h	0.0625
01h	0.125
02h	0.25
03h	0.5
04h	1
05h	2
06h	4
07h	8
08h	16
09h to FFh	RFU

To check for internal bus collisions, read the status byte. If the least significant seven bits are ones, discard the data and read the status byte again. The status bits LHIGH, LLOW, RHIGH, and RLOW are refreshed on the SMBus clock edge immediately following the stop condition, so there is no danger of losing temperature-related status data as a result of an internal bus collision. The OPEN status bit (diode continuity fault) is only refreshed at the beginning of a conversion, so OPEN data is lost. The $\overline{\text{ALERT}}$ interrupt latch is independent of the status byte register, so no false alerts are generated by an internal bus collision.

When auto-converting, if the THIGH and TLOW limits are close together, it's possible for both high-temp and low-temp status bits to be set, depending on the amount of time between status read operations (especially when converting at the fastest rate). In these circumstances, it's best not to rely on the status bits to indicate reversals in long-term temperature changes and instead use a current temperature reading to establish the trend direction.

For bit 1 and bit 0, a high indicates a temperature alarm happened for remote and local diode respectively. $\overline{\text{THERM}}$ pin also asserts. These two bits wouldn't be cleared when reading status byte.

Conversion Rate Byte

The conversion rate register (Table 8) programs the time interval between conversions in free-running auto-convert mode. This variable rate control reduces the supply current in portable-equipment applications. The conversion rate byte's POR state is 08h (16Hz). The G788 looks only at the 4 LSB bits of this register, so the upper 4 bits are "don't care" bits, which should be set to zero. The conversion rate tolerance is $\pm 25\%$ at any rate setting.

Valid A/D conversion results for both channels are available one total conversion time (125ms, typical) after initiating a conversion, whether conversion is initiated via the $\overline{\text{RUN}}$ /STOP bit, one-shot command, or initial power-up.

POR and UVLO

The G788 has a volatile memory. To prevent ambiguous power-supply conditions from corrupting the data in memory and causing erratic behavior, a POR voltage detector monitors VCC and clears the memory if VCC falls below 1.7V (typical, see Electrical Characteristics table). When power is first applied and VCC rises above 1.7V (typical), the logic blocks begin operating, although reads and writes at V_{CC} levels below 3V are not recommended. A second VCC comparator, the ADC UVLO comparator, prevents the ADC from converting until there is sufficient headroom ($V_{CC} = 2.8V$ typical).

Measure Remote Temperature Higher Than 127°C

When it comes to measure remote temperature higher than 127°C, the offset register RTOFS should be set a minus number and the remote temperature register RRTE reading should be interpreted with the same offset. For example, if the maximum remote temperature is 150°C then set the remote temperature offset register RTOFS to -23(11101001b in 2's complement) ($127+23=150$). With this setting, if the RRTE register reading is 100°C then add 23°C to it, the result 123°C is the remote temperature. If reading is 120°C then 143°C is the converted result by G788.

Table 9. Alert Mask

BIT	NAME	FUNCTION
7 (MSB)	MSK_LTH	Local Diode Temperature High Alert Mask
4	MSK_RT1H	Remote Diode 1 Temperature High Alert Mask
3	MSK_RT1L	Remote Diode 1 Temperature Low Alert Mask

Table 10. Remote temperature $\overline{\text{THERM}}$ limit

The default value is trapping after power up 100ms by different pull-up resistors of $\overline{\text{THERM}}$ and $\overline{\text{ALERT}}$ pin:

TEMPERATURE (°C)		$\overline{\text{THERM}}$				
		2K Ω	7.5K Ω	10.5K Ω	14K Ω	18.7K Ω
ALERT#	2K Ω	77	87	97	107	117
	7.5K Ω	79	89	99	109	119
	10.5K Ω	81	91	101	111	121
	14K Ω	83	93	103	113	123
	18.7K Ω	85	95	105	115	125

Local temperature $\overline{\text{THERM}}$ limit

Same as Table 10. The default value is trapping after power up 100ms by different pull-up resistors of $\overline{\text{THERM}}$ and $\overline{\text{ALERT}}$ pin:

Table 11. Alert Mode

BIT	NAME	FUNCTION
0 (LSB)	ALERT_MD	ALERT mode configuration. 0 = Interrupt or SMBus alert mode 1 = Comparator mode

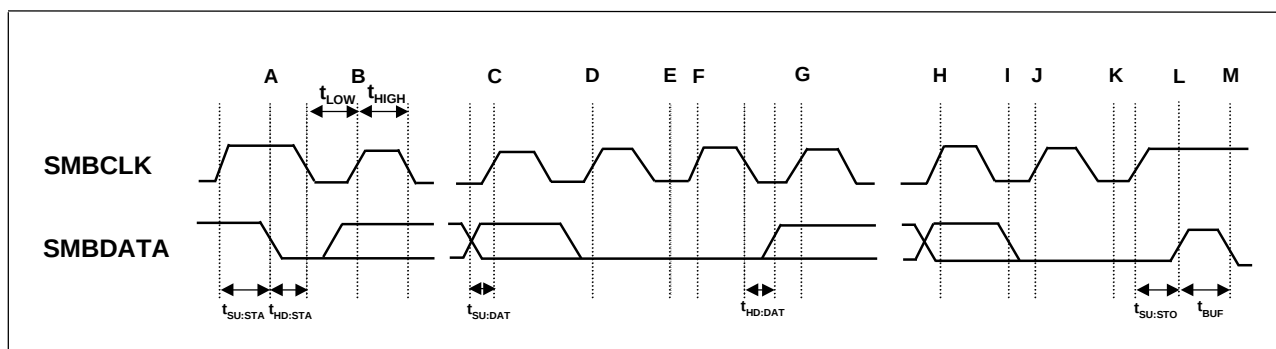


Figure 9. SMBus Write Timing Diagram

- | | |
|---|---|
| A = start condition | H = LSB of data clocked into slave |
| B = MSB of address clocked into slave | I = slave pulls SMBDATA line low |
| C = LSB of address clocked into slave | J = acknowledge clocked into master |
| D = R/W bit clocked into slave | K = acknowledge clocked pulse |
| E = slave pulls SMBDATA line low | L = stop condition data executed by slave |
| F = acknowledge bit clocked into master | M = new start condition |
| G = MSB of data clocked into slave | |

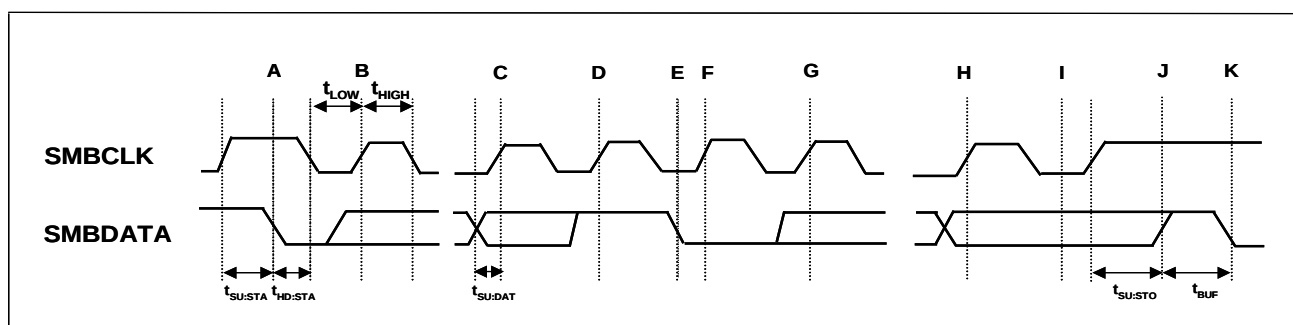
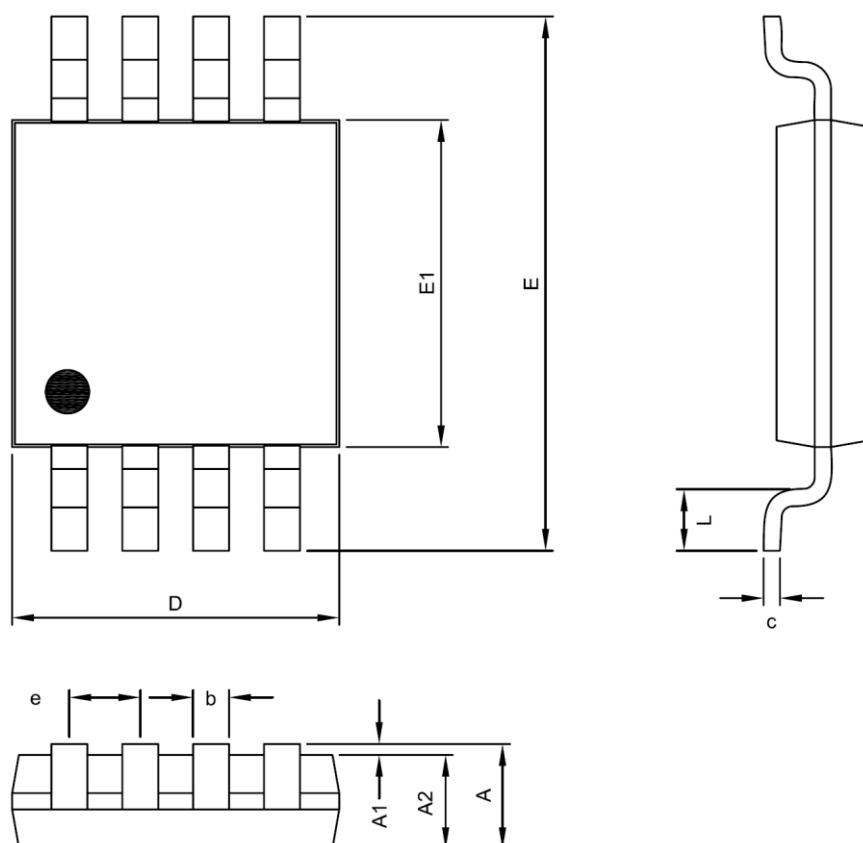
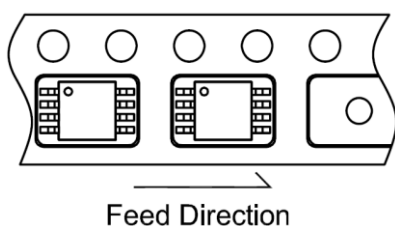


Figure 10. SMBus Read Timing Diagram

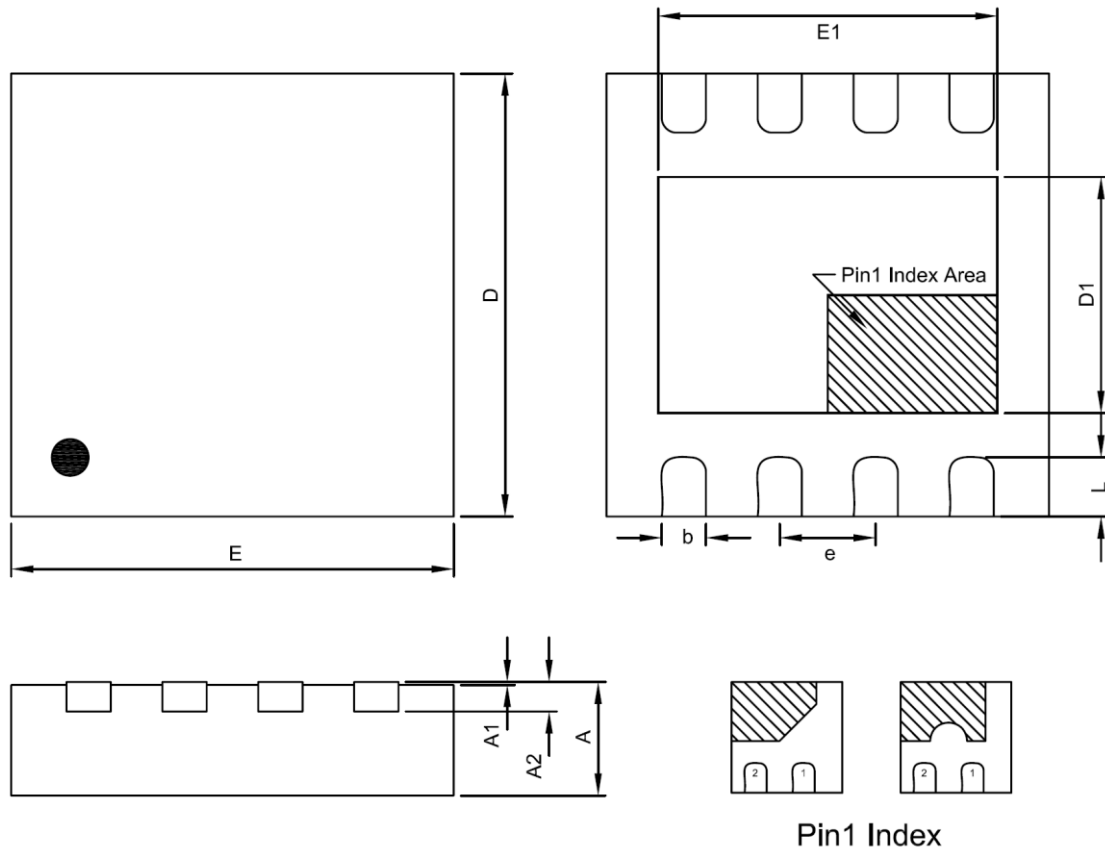
- | | |
|---|-------------------------------------|
| A = start condition | G = MSB of data clocked into master |
| B = MSB of address clocked into slave | H = LSB of data clocked into master |
| C = LSB of address clocked into slave | I = acknowledge clocked pulse |
| D = R/W bit clocked into slave | J = stop condition |
| E = slave pulls SMBDATA line low | K = new start condition |
| F = acknowledge bit clocked into master | |

Package Information

MSOP-8 Package

Symbol	DIMENSION IN MM			DIMENSION IN INCH		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.81	0.95	1.10	0.032	0.037	0.043
A1	0.00	---	0.15	0.000	---	0.006
A2	0.75	0.86	0.96	0.030	0.034	0.038
D	2.85	3.00	3.15	0.112	0.118	0.124
E	4.75	4.90	5.05	0.187	0.193	0.199
E1	2.85	3.00	3.15	0.112	0.118	0.124
b	0.22	0.30	0.38	0.009	0.012	0.015
c	0.15 REF			0.006 REF		
e	0.65 BSC			0.026 BSC		
L	0.4	0.53	0.8	0.016	0.021	0.031

Taping Specification


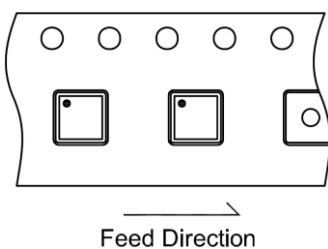
PACKAGE	Q'TY/REEL
MSOP-8	3,000 ea



TDFN3X3-8 Package

Symbol	DIMENSION IN MM			DIMENSION IN INCH		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.70	0.75	0.80	0.0276	0.0295	0.0315
A1	0.00	---	0.05	0.0000	---	0.0020
A2	0.20 REF			0.0079 REF		
D	2.95	3.00	3.05	0.1161	0.1181	0.1201
E	2.95	3.00	3.05	0.1161	0.1181	0.1201
D1	1.40	1.50	1.60	0.0551	0.0591	0.0630
E1	2.20	2.30	2.40	0.0866	0.0906	0.0945
b	0.20	0.30	0.35	0.0079	0.0118	0.0138
e	0.65 BSC			0.0256 BSC		
L	0.35	0.45	0.525	0.0138	0.0177	0.0207

Taping Specification



PACKAGE	Q'TY/REEL
TDFN3X3-8	3,000 ea

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