Two Remote Temperature Sensors and One Fan Controller with SMBus Serial Interface and System Reset Circuit

Features

- Measures Two Remote Temperatures
- No Calibration Required
- SMBus 2-Wire Serial Interface
- Programmable Under/Over-temperature Alarms
- Programmable Thermal Shutdown Signal
- Supports SMBus Alert Response
- Accuracy: ±5°C (-40°C to + 125°C, remote)
  ±3°C (+60°C to + 100°C, remote)
- +4.5V to +5.5V Supply Range
- Fan speed control range: 3,000 to 30,000 rpm
- Fan speed accuracy: ±2%
- Built-in MOSFET switch
- Internal current-limit and over-temperature protection for fan control
- Watchdog for fan control
- Alarm for fan failure
- Precision Monitoring of 5V Power-Supply Voltage
- 340ms Typical Power-On Reset Pulse Width
- $\overline{\text{RESET}}$ Output
- Guaranteed $\overline{\text{RESET}}$ Valid to V_{CC}=1V
- Power Supply Transient Immunity
- No External Components needed for reset function
- Small, 16-Pin SSOP Package

Applications

- Desktop and Notebook
- Central Office Computers
- Telecom Equipment
- Smart Battery Packs
- Test and Measurement
- LAN Servers
- Multi-Chip Modules
- Industrial Controls

General Description

The G768D contains a precise digital thermometer, a fan controller, and a system-reset circuit.

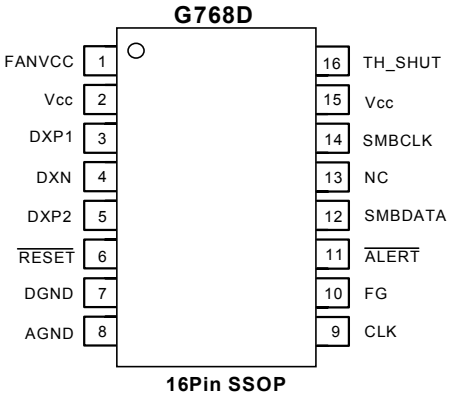
Except for one less fan controller, G768D is backward compatible with G768B. G768D has 2 more functions, fan-failure detection and programmable thermal shutdown signal.

The thermometer reports the temperature of 2 remote sensors. The remote sensors are diode-connected transistors typically a low-cost, easily mounted 2N3904 NPN type that replace conventional thermistors or thermocouples. Remote accuracy is ±5°C for multiple transistor manufacturers, with no calibration needed. 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 7 bits plus sign, with each bit corresponding to 1°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.

G768D also contains a fan speed controller. It connects directly to the fans and performs closed-loop control of the fan speed independently. The only external component required is a 10µF capacitor per channel. It determines the current fan speed based on the fan rotation pulses and an externally supplied 32.768KHz clock.

Pin Configuration



Ordering Information

PART NUMBER	TEMP. RANGE	PIN-PACKAGE
G768D	-55°C to +125°C	16SSOP

It uses LDO method and an on-chip MOSFET to control the fan speed to ±2% of the programmed speed.

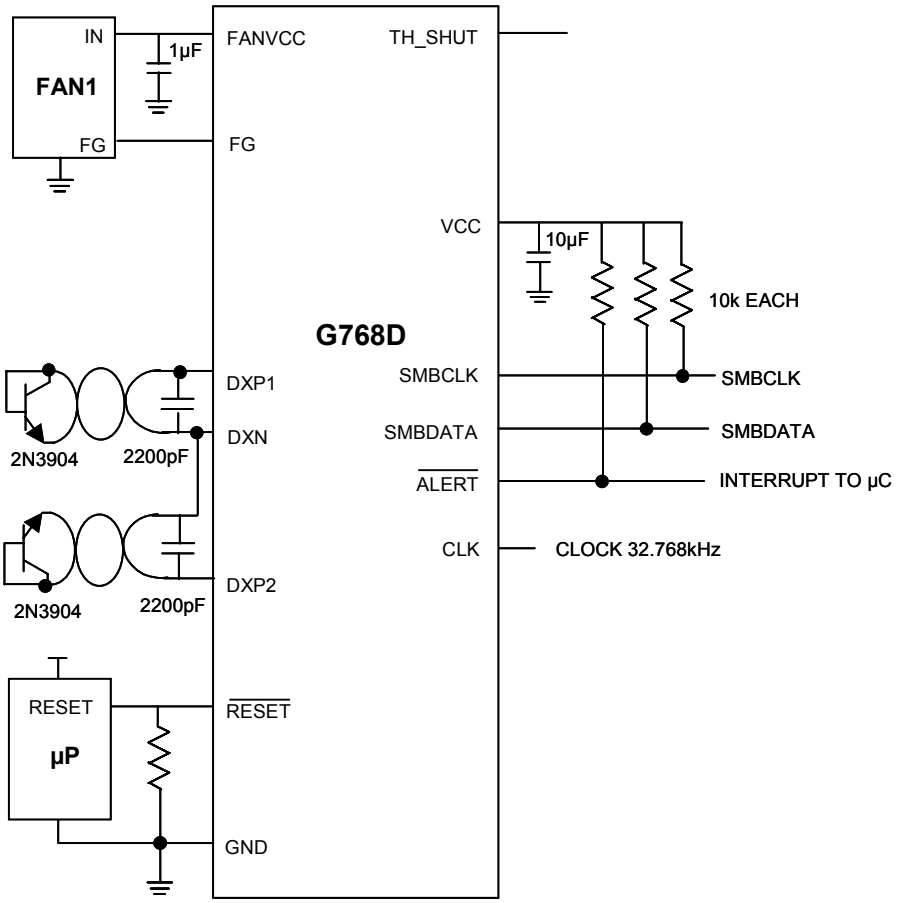
The desired fan speed is also programmed via SMBus™. The actual fan speed and fan status can be read via the SMBus™. Short-circuit protection is implemented to prevent damages to the fan and this IC itself. The accepted frequency of fan rotation pulses is 100~1000Hz, which corresponds to 3,000 to 30,000 rpm for a typical fan that produces two pulses per revolution. The G768D also turns on the fans by hardware watchdog system. The fan controller would fully turn on the fan when any of the following conditions happens.

1. when either of the remote temperature is higher than its own T_{MAX}.
2. when either of these two remote diodes is open.
3. when both remote diodes are short.

The G768D also contains a microprocessor (μP) supervisory circuit used to monitor the power supplies in μP and digital systems. They provide excellent circuit reliability and low cost by eliminating external components and adjustments when used with 5V-powered circuits. This circuit asserts a reset signal whenever the V_{CC} supply voltage declines below a preset threshold, keeping it asserted for at least 140ms after V_{CC} has risen above the reset threshold. The G768D has an active-low $\overline{RESET}$ output. The reset comparator is designed to ignore fast transients on V_{CC}. Reset threshold of this circuit is set to 4.4V typical.

The G768D is available in a small, 16-pin SSOP surface-mount package.

Typical Operating Circuit



Absolute Maximum Ratings

V_{CC} to GND.....-0.3V to +6V
DXP1, DXP2 to GND.....0.3V to (V_{CC} + 0.3V)
DXN to GND.....-0.3V to +0.8V
CLK, FG, SMBCLK, SMBDATA, $\overline{ALERT}$ to GND.....-0.3V to +6V
SMBDATA, $\overline{ALERT}$ Current.....-1mA to +50mA
DXN Current.....±1mA
ESD Protection (SMBCLK, SMBDATA, $\overline{ALERT}$, human body model).....2000V
ESD Protection (other pins, human body model)...2000V
Continuous Power Dissipation (T_A= +70°C) SSOP (de-rate 8.30mW/°C above +70°C).....667mW
Operating Temperature Range...-55°C to +125°C
Junction Temperature.....+150°C
Storage temperature Range.....-65°C to +165°C
Lead Temperature (soldering, 10sec).....+300°C

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

(V_{CC} = + 5V, T_A = 60°C, unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Temperature Sensor						
Temperature Resolution (Note 1)	Monotonicity guaranteed		8			Bits
Temperature Error, Remote Diode (Notes 2 and 3)	T_R = 0°C to +125°C		-5		5	°C
	T_R = 60°C to +100°C		-3		3	
Temperature Error, Local Diode (Notes 1 and 2)	Including long-term drift	T_A = +60°C to +100°C	-3		3	°C
Supply-Voltage Range			4.5	5	5.5	V
Under-voltage Lockout Threshold	V_{CC} input, disables A/D conversion, rising edge		2.6	2.8	2.95	V
Under-voltage Lockout Hysteresis				50		mV
Power-On Reset Threshold	V_{CC}, falling edge		1.0	1.7	2.5	V
POR Threshold Hysteresis				50		mV
Standby Supply Current	Logic inputs forced to V_{CC} or GND	SMBus static		3	10	µA
		Hardware or software standby, SMBCLK at 10kHz		200		
Average Operating Supply Current	Auto-convert mode, average measured over 4sec. Logic inputs forced to V_{CC} or GND	0.25 conv/sec		250	300	µA
		2.0 conv/sec		300	350	
Conversion Time	From stop bit to conversion complete (all channels)		94	125	156	ms
Conversion Rate Timing Error	Auto-convert mode		-25		25	%
Remote-Diode Source Current	DXP forced to 1.5V	High level	120	160	200	µA
		Low level	15	20	25	
Fan Controller						
Supply voltage	V_{CC}		4.5	5	5.5	V
Shutdown current	Fan speed = 0rpm			2	5	µA
MOSFET on resistance				0.2	0.25	Ω
Short-circuit current limit				0.5		A
Input logic low	VIL				0.7.	V
Input logic high	VIH		1.0			V
Clock frequency	CLK			32.768		KHz
FANVCC over-current trig			600			mA
FANVCC current limit			500			mA
FG input Positive-going threshold voltage	V_{CC}=5V			1		V
FG input Negative-going threshold voltage	V_{CC}=5V			0.7		V
FG input Hysteresis voltage	V_{CC}=5V			0.3		V

Electrical Characteristics (continued)

(V_{CC} = + 5V, T_A = 60°C, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
SMBus Interface					
Logic Input High Voltage	SMBCLK, SMBDATA; V_{CC} = 4.5V to 5.5V	2.4			V
Logic Input Low Voltage	SMBCLK, SMBDATA; V_{CC} = 4.5V to 5.5V			0.8	V
Logic Output Low Sink Current	$\overline{ALERT}$, SMBDATA forced to 0.4V	6			mA
$\overline{ALERT}$ Output High Leakage Current	$\overline{ALERT}$ forced to 5.5V			1	µA
Logic Input Current	Logic inputs forced to V_{CC} or GND	-2		2	µA
SMBus Input Capacitance	SMBCLK, SMBDATA		5		pF
SMBus Clock Frequency	(Note 4)	DC		100	KHz
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 Start-Condition Setup Time	$t_{SD:STO}$, 90% of SMBDATA 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	$t_{HD:DAT}$(Note 5)	0			µs
SMBCLK Falling Edge to SMBus Data-Valid Time	Master clocking in data			1	µs

Electrical Characteristics (continued)

(V_{CC} =full range, T_A= 60°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Reset Threshold	V_{TH}		4.2	4.4	4.5	V
Reset Active Timeout Period				340		ms
$\overline{RESET}$ Output Voltage Low	V_{OL}	V_{CC}=V_{TH} min, I_{SINK}=3.2mA			0.4	V
$\overline{RESET}$ Output Voltage High	V_{OH}	V_{CC}>V_{TH} max, I_{SOURCE}=5.0mA	V_{CC}-1.5			V

Note 1: Guaranteed but not 100% tested.

Note 2: Quantization error is not included in specifications for temperature accuracy. For example, if the G768D device temperature is exactly +66.7°C, or +68°C (due to the quantization error plus the +1/2°C offset used for rounding up) and still be within the guaranteed ±3°C error limits for the +60°C to +100°C temperature range. See Table3.

Note 3: 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 4: The SMBus logic block is a static design that works with clock frequencies down to DC. While slow operation is possible, it violates the 10kHz minimum clock frequency and SMBus specifications, and may monopolize the bus.

Note 5: Note that a transition must internally provide at least a hold time in order to bridge the undefined region (300ns max) of SMBCLK's falling edge.

Pin Description

PIN	NAME	FUNCTION
1	FANVCC	Output connected to V_{CC} of fan.
2,15	V_{CC}	Supply Voltage Input, 4.5V to 5.5V. Bypass to GND with a 0.1µF capacitor.
3	DXP1	Combined Current Source and A/D Positive Input for remote-diode channel 1. Do not leave DXP1 floating; tie DXP1 to DXN if no remote diode on channel 1 is used. Place a 2200pF capacitor between DXP1 and DXN for noise filtering.
4	DXN	Combined Current Sink and A/D Negative Input. DXN is common negative node of both remote diodes on channel 1 and 2. The traces of DXP1-DXN and DXP2-DXN pairs should be routed independently. The common DXN should be connected together as close as possible to the IC. DXN is internally connected to the GND pin for signal ground use.
5	DXP2	Combined Current Source and A/D Positive Input for remote-diode channel 2. Do not leave DXP2 floating; tie DXP2 to DXN if no remote diode on channel 2 is used. Place a 2200pF capacitor between DXP2 and DXN for noise filtering.
6	$\overline{\text{RESET}}$	$\overline{\text{RESET}}$ Output remains low while V_{CC} is below the reset threshold, and for 340ms after V_{CC} rises above the reset threshold.
7	DGND	Digital Ground.
8	AGND	Analog Ground.
9	CLK	32.768KHz clock input for fan controller.
10	FG	Fan pulse input.
11	$\overline{\text{ALERT}}$	SMBus Alert (interrupt) Output, open drain.
12	SMBDATA	SMBus Serial-Data Input / Output, open drain.
13	NC	
14	SMBCLK	SMBus Serial-Clock Input.
16	TH_SHUT	Thermal Shutdown Output, push-pull output.

Detailed Description

The G768D (patents pending) is a 3-in-1 IC. It consists of one temperature sensor, 1 fan speed controller and provides system-reset function.

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

Essentially a 12-bit serial analog-to-digital converter (ADC) with a sophisticated front end, the G768D contains a switched current source, a multiplexer, an ADC, an SMBus interface, one fan controller, a reset circuit 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 four over/under-temperature alarm registers.

ADC and Multiplexer

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

The multiplexer automatically steers bias currents through two remote diodes, measures their forward voltages, and computes their temperatures. All channels are converted automatically 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 all measurements, and the user can simply ignore the results of the unused channel. If the remote diode channel is unused, tie DXPx to DXN rather than leaving the pins open.

The DXN input is internally connected to the ground node inside the chip to set up the analog to digital (A/D) inputs for a differential measurement. 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 +1/2°C error per ohm. Likewise, 200µV of offset voltage forced on DXP-DXN causes about 1°C error.

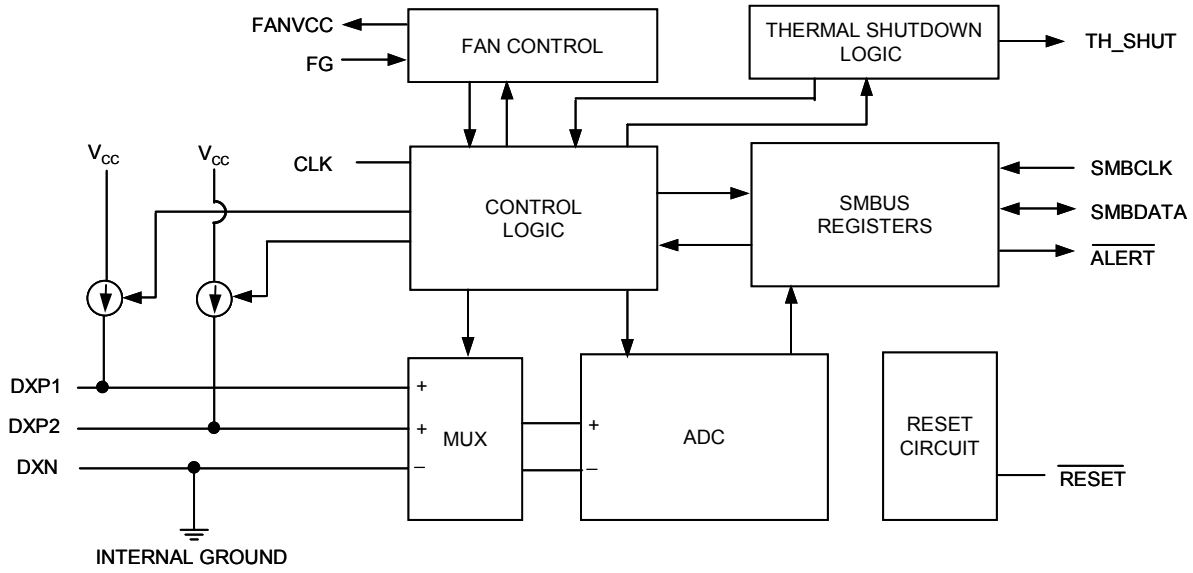


Fig 1. Functional Diagram

A/D Conversion Sequence

If a Start command is written (or generated automatically in the free-running auto-convert mode), both two 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. Accuracy has been experimentally verified for all of the devices listed in Table 1. The G768D 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 10µA; check to ensure this is true at the highest expected temperature. The forward voltage must be less than 0.95V at 200A; 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 100Ω. 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 VBE characteristics.

Thermal Mass and Self-Heating

Thermal mass can seriously degrade the G768D's effective accuracy. The thermal time constant of the SSOP-16 package is about 140sec in still air. For the G768D junction temperature to settle to within +1°C after a sudden +100°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 current across the sensor package do not interfere with measurement accuracy.

Table 1. Remote-Sensor Transistor Manufacturers

MANUFACTURER	MODEL NUMBER
Philips	PMBS 3904
Motorola (USA)	MMBT3904
National Semiconductor (USA)	MMBT3904

Note:Transistors must be diode-connected (base short -ed to collector).

ADC Noise Filtering

The ADC is an integrating type with inherently good noise rejection, especially of low-frequency signals such as 60Hz/120Hz power-supply hum. Micro-power 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°C to 10°C, depending on the frequency and amplitude (see Typical Operating Characteristics).

PC Board Layout

Place the G768D 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°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 +12VDC. Leakage currents from PC board contamination must be dealt with carefully, since a 20MΩ leakage path from DXP to ground causes about +1°C error.

Route the 2 pairs of DXP1-DXN and DXP2-DXN traces independently (Figure 2a). Connect the common DXN as close as possible to the DXN pin on IC (Figure 2a).
Connect guard traces to GND on either side of the DXP-DXN traces (Figure 2b). 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.

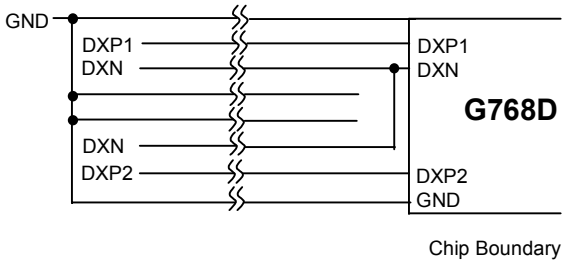
When introducing a thermocouple, make sure that both the DXP and the DXN paths have matching thermocouples. In general, PC board- induced thermocouples are not a serious problem, A copper-solder thermocouple exhibits 3μV/°C, and it takes about 200μV of voltage error at DXP-DXN to cause a +1°C measurement 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 2 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 steelwork will. Placing a copper ground plane between the DXP-DXN traces and traces carrying high-frequency noise signals do not help reduce EMI.

PC Board Layout Checklist

- Place the G768D close to a remote diode.
- Keep traces away from high voltages (+12V 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.
- Route two DXPx-DXN pairs independently
- Connect the common DXN as close as possible to the DXN pin on IC.
- Place the noise filter and the 0.1μF V_{CC} bypass capacitors close to the G768D.



- **Fig 2(a) Connect the common DXN as close as possible to the DXN pin on IC.**

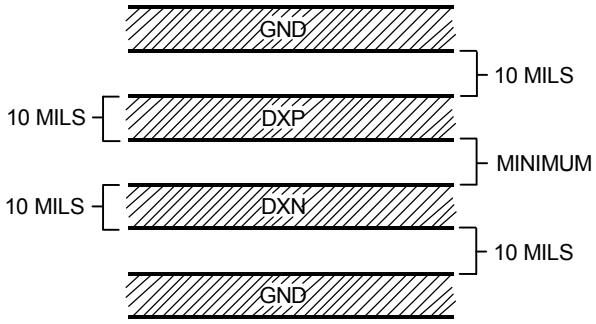


Fig 2 (b) Recommended DXP/DXN PC

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 12feet (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 + 1°C error.

Low-Power Standby Mode

Standby mode disables the ADC and reduces the supply-current drain to less than 10µA. Enter standby mode via the RUN/STOP bit in the configuration byte register. In standby mode, all data is retained in memory, and the SMB interface is alive and listening for reads and writes. This is valid for temperature sensor only.

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 G768D can be forced to perform temperature measurement via the one-shot command, despite the RUN/STOP bit being high.

Supply-current drain during the 125ms conversion period is always about 500µA. Slowing down the conversion rate reduces the average supply current (see Typical Operating Characteristics). In between conversions, the instantaneous supply current is about 200µA due to the current consumed by the system resetting circuit.

Fan Controller

Since the fan speed is measured by counting the number of 32.768KHz cycles between the rising edges of two fan speed pulses. In this way, we are actually measuring the period of the fan speed. To avoid the cost of doing division to obtain the speed, this count number, N, is used in the PWM control algorithm, thus, the desired fan speed should be programmed by writing the corresponding count number. The count number is given by:

N: Count Number

P: FG pulses number per revolution

P=1 ⇒ N = 983040 / rpm

P=2 ⇒ N = 491520 / rpm

P=4 ⇒ N = 245762 / rpm

Some selected count number for P=2 are listed below.

Table 2.

Rpm	N
3000	164
4000	123
5000	98
6000	82
7000	70
8000	61
9000	55
10000	49
20000	25
30000	16

To stop the fan, program the fan speed register to 255. This also makes the fan controller enter power saving mode.

Controlling Fan at Lower Speed

For stably controlling fans at lower rotation speed, three schemes are recommended as below:

1.Use larger decoupling capacitors between FANVCC and GND.

2.Shunt a capacitor of 1µF-2µF on FG pin to GND.

3.Use fans with open-collector FG outputs.

When controlling fans under lower rotation speed, the output voltage of FANVCC would be too low for fan to generate recognizable FG signals.

Using decouple capacitors on FANVCC and FG is to increase the SNR on FG pins. While using fans with open-collector FG outputs can thoroughly solve the problem, because the logic high level of FG would be fixed to 5V.

Reset Immunity Negative-Going V_{CC} Transients

In addition to issuing a reset to the microprocessor (µP) during power-up, power-down, and brownout conditions, the G768D is relatively immune to short duration negative-going V_{CC} transients (glitches).

Typically, for the G768D, a V_{CC} transient that goes 100mV below the reset threshold and lasts 20µs or less will not cause a reset pulse. A 0.1µF bypass capacitor mounted as close as possible to the V_{CC} pin provides additional transient immunity.

Ensuring a Valid Reset Output Down to V_{CC} = 0V

When V_{CC} falls below 1V, the G768D $\overline{RESET}$ output no longer sinks current-it becomes an open circuit. Therefore, high-impedance CMOS logic inputs connected to $\overline{RESET}$ can drift to undetermined voltages. This presents no problem in most applications, since most µP and other circuitry is inoperative with V_{CC} below 1V. However, in applications where $\overline{RESET}$ must be valid down to 0V, adding a pull-down resistor to $\overline{RESET}$ causes any stray leakage currents to flow to ground, holding $\overline{RESET}$ low (Figure 3). R1's value is not critical; 100kΩ is large enough not to load $\overline{RESET}$ and small enough to pull $\overline{RESET}$ to ground.

Interfacing to µPs with Bi-directional Reset Pins

A µP with bi-directional reset pins (such as the Motorola 68HC11 series) can connect to the G768D reset output. If, for example, the G768D $\overline{RESET}$ output is asserted high and the µP wants to pull it low, indeterminate logic levels may result. To correct this, connect a 4.7kΩ resistor between the G768D $\overline{RESET}$ output and the µP reset I/O (Figure 4). Buffer the G768D $\overline{RESET}$ output to other system components.

SMBus Digital Interface

From a software perspective, the G768D appears as a set of byte-wide registers that contain temperature data, alarm threshold values, fan speed data, 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 and fan control channel within the device responds to the same SMBus slave address for normal reads and writes.

The G768D employs four standard SMBus protocols: Write Byte, Read Byte, Send Byte, and Receive Byte (Figure 5). 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 over-write the command byte without informing the first master.

The temperature data format is 7bits plus sign in twos-complement form for each channel, with each data bit representing 1°C (Table3), transmitted MSB first. Measurements are offset by +1/2°C to minimize internal rounding errors; for example, +99.6°C is reported as +100°C.

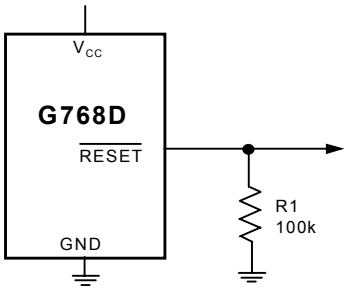


Fig 3 RESET Valid to V_{CC} = Ground Circuit

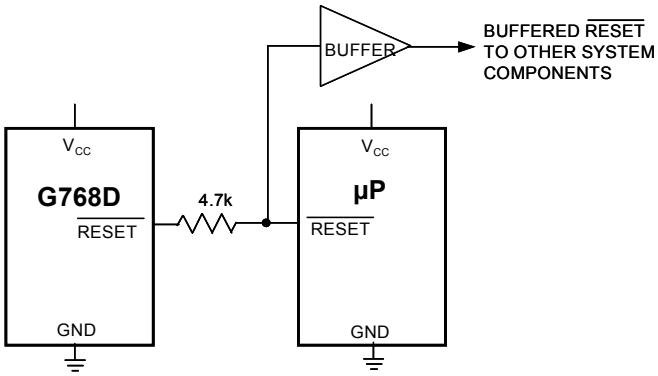


Fig 4. Interfacing to µPs with Bi-directional Reset I/O

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			8 bits			7 bits			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

Fig 5. SMBus Protocols

Table 3. Data Format (Twos-Complement)

TEMP. (°C)	ROUND TEMP. (°C)	DIGITAL OUTPUT DATA BITS		
		SIGN	MSB	LSB
+130.00	+127	0	111	1111
+127.00	+127	0	111	1111
+126.50	+127	0	111	1111
+126.00	+126	0	111	1110
+25.25	+25	0	001	1001
+0.50	+1	0	000	0001
+0.25	+0	0	000	0000
+0.00	+0	0	000	0000
-0.25	+0	0	000	0000
-0.50	+0	0	000	0000
-0.75	-1	1	111	1111
-1.00	-1	1	111	1111
-25.00	-25	1	110	0111
-25.50	-25	1	110	0110
-54.75	-55	1	100	1001
-55.00	-55	1	100	1001
-65.00	-65	1	011	1111
-70.00	-65	1	011	1111

Alarm Threshold Registers

Four registers store alarm threshold data, with high-temperature (THIGH) and low-temperature (TLOW) registers for each A/D channel. If either measured temperature equals or exceeds the corresponding alarm threshold value, an $\overline{\text{ALERT}}$ interrupt is asserted.

The power-on-reset (POR) state of both THIGH registers is full scale (0111 1111, or +127°C). The POR state of both TLOW registers is 1100 1001 or -55°C.

Diode Fault Alarm

There is a continuity 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. 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 0000 0000 so as not to trip either the THIGH or TLOW alarms at their POR settings. In applications that are never subjected to 0°C in normal operation, a 0000 0000 result can be checked to indicate a fault condition in which DXP is accidentally short circuited. Similarly, if DXP is short circuited to V_{CC}, the ADC reads +127°C for both channels, and the device alarms.

$\overline{\text{ALERT}}$ Interrupts

The $\overline{\text{ALERT}}$ interrupt output signal is latched and can only be cleared by reading the Alert Response address. Interrupts are generated in response to THIGH and TLOW comparisons and when the remote diode is disconnected (for continuity fault detection). The interrupt does not halt automatic conversions; new temperature data continues to be available over the SMBus interface after $\overline{\text{ALERT}}$ is asserted. The interrupt output rupt output pin is open-drain so that device can share a common interrupt line. The interrupt rate can never exceed the conversion rate.

The interface responds to the SMBus Alert Response address, an interrupt pointer return-address feature (see Alert Response Address section). Prior to taking corrective action, always check to ensure that an interrupt is valid by reading the current temperature.

Alert Response Address

The SMBus Alert Response interrupt pointer provides quick fault identification for simple slave devices that lack the complex, expensive logic needed to be a bus master. Upon receiving an $\overline{\text{ALERT}}$ interrupt signal, the host master can broadcast a Receive Byte transmission to the Alert Response slave address (0001 100). Then any slave device that generated an interrupt attempts to identify itself by putting its own address on the bus.

Table 4. Command-Byte Bit Assignments

REGISTER	COMMAND	POR STATE	FUNCTION
RRTE2	00h	0000 0000b	Read 2nd remote temperature: returns latest temperature
RRTE1	01h	0000 0000b	Read 1st remote temperature: returns latest temperature
RSL	02h	N/A	Read status byte (flags, busy signal)
RCL	03h	0000 0000b	Read configuration byte
RCRA	04h	0000 0010b	Read conversion rate byte
RRHI2	05h	0111 1111b (127)	Read 2nd remote THIGH limit
RRLS2	06h	1100 1001b(-55)	Read 2nd remote TLOW limit
RRHI1	07h	0111 1111b (127)	Read 1st remote THIGH limit
RRLS1	08h	1100 1001b (-55)	Read 1st remote TLOW limit
WCA	09h	N/A	Write configuration byte
WCRW	0Ah	N/A	Write conversion rate byte
WRHA2	0Bh	N/A	Write 2nd remote THIGH limit
WRLN2	0Ch	N/A	Write 2nd remote TLOW limit
WRHA1	0Dh	N/A	Write 1st remote THIGH limit
WRLN1	0Eh	N/A	Write 1st remote TLOW limit
OSHT	0Fh	N/A	One-shot command (use send-byte format)
SET_CNT1	10h	1111 1111b	Write 1st fan programmed speed register
ACT_CNT1	11h	1111 1111b	Read 1st fan actual speed register
FAN_STA1	12h	10b	Read 1st fan status register
TMAX1	31h	0100 0110b (70)	1st remote TMAX
THYST1	32h	0011 1100b (60)	1st remote THYST
TMAX2	33h	0100 0110b (70)	2nd remote TMAX
THYST2	34h	0011 1100b (60)	2nd remote THYST
TCRIT1	35h	0110 1100b (108)	Critical temperature for 1st remote temperaure sensor
TCRIT2	36h	0101 1000b (88)	Critical temperature for 2nd remote temperaure sensor

The Alert Response can activate several different slave devices simultaneously, similar to the SMBus General Call. If more than one slave attempts to respond, bus arbitration rules apply, and the device with the lower address code wins. The losing device does not generate an acknowledge and continues to hold the $\overline{ALERT}$ line low until serviced (implies that the host interrupt input is level sensitive). Successful reading of the alert response address clears the interrupt latch.

Command Byte Functions

The 8-bit command byte register (Table 4) is the master index that points to the various other registers within the G768D. 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 ($\overline{RUN}$/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 (RUN/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 contents are listed in table 5. Bit 7(MASK) is used to mask $\overline{ALERT}$ interrupt. Bit 6 ($\overline{RUN}$/STOP) is to put the device in software standby mode. Setting bit 5 (DET_FAN) with logic 1 can activate the detection of fan failure. Logic 1 in bit 4 (EN_TH_SHUT) makes thermal shutdown function valid and logic 0 disables this function and keep TH_SHUT pin low. Bit 3~0 forms thermal shutdown fault queue. The number of faults these bits decided are listed in table 6.

Thermal Status Byte Functions

The thermal status byte register (02h) (Table 6) 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 DXPx-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 $\overline{ALERT}$ 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 $\overline{RUN}$/STOP bit in the configuration byte). In one-shot mode, read the status byte only after the conversion is complete, which is 150ms max after the one-shot conversion is commanded.

Table 5. Configuration-Byte Bit Assignments

BIT	NAME	POR STATE	FUNCTION
7 (MSB)	MASK	0	Masks all $\overline{ALERT}$ interrupts when high.
6	$\overline{RUN}$ / 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.
5	DET_FAN	0	Validation of the fan failure detection. If high, activated. If low, disable.
4	EN_TH_SHUT	1	Validation of the fault queue function of thermal shutdown.
3-0	FQ_TH_SHUT	0010b	Fault Queue. Number of faults necessary to detect before setting TH_SHUT output to avoid false tripping due to noise.

Table 6. Number of Faults assigned by FQ_TH_SHUT

FQ_TH_SHUT	Number of Faults
0000b	1
0001b	2
0010b	3(Power-up default)
0011b	4
0100b	5
0101b	6
0110b	7
0111b	8

FQ_TH_SHUT	Number of Faults
1000b	9
1001b	10
1010b	11
1011b	12
1100b	13
1101b	14
1110b	15
1111b	16

Table 7. Status-Byte Bit Assignments

BIT	NAME	FUNCTION
7(MSB)	BUSY	A high indicates that the ADC is busy converting.
6	RHIGH2*	A high indicates that the 2nd diode high-temperature alarm has activated.
5	RLOW2*	A high indicates that the 2nd diode low-temperature alarm has activated.
4	RHIGH1*	A high indicates that the 1st diode high-temperature alarm has activated.
3	RLOW1*	A high indicates that the 1st diode low-temperature alarm has activated.
2	OPEN*	A high indicates a remote-diode continuity (open-circuit) fault.
1	RFU	Reserved for future use (returns 0)
0(LSB)	FAN_FAIL*	A high indicates that the fan failure 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)	Temperature Sensor Average Supply Current (μA TYP, at V_{CC} = 5V)
00h	0.0625	30
01h	0.125	33
02h	0.25	35
03h	0.5	48
04h	1	70
05h	2	128
06h	4	225
07h	8	425
08h to FFh	RFU	-

Table 9. RLTS and RRTE Temp Register Update Timing Chart

OPERATING MODE	CONVERSION INITIATED BY:	NEW CONVERSION RATE (CHANGED VIA WRITE TO CRW)	TIME UNTIL RLTS AND RRTE ARE UPDATED
Auto-Convert	Power-on reset	N/A (0.25Hz)	156ms max
Auto-Convert	1-shot command, while idling between automatic conversions	N/A	156ms max
Auto-Convert	1-shot command that occurs during a conversion	N/A	When current conversion is complete (1-shot is ignored)
Auto-Convert	Rate timer	0.0625Hz	20sec
Auto-Convert	Rate timer	0.125Hz	10sec
Auto-Convert	Rate timer	0.25Hz	5sec
Auto-Convert	Rate timer	0.5Hz	2.5sec
Auto-Convert	Rate timer	1Hz	1.25sec
Auto-Convert	Rate timer	2Hz	625ms
Auto-Convert	Rate timer	4Hz	312.5ms
Auto-Convert	Rate timer	8Hz	237.5ms
Software Standby	RUN/STOP bit	N/A	156ms
Software Standby	1-shot command	N/A	156ms

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.

Temperature Conversion Rate Byte

The conversion rate register (Table 7) 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 02h (0.25Hz). The G768D looks only at the 3 LSB bits of this register, so the upper 5 bits are "don't care" bits, which should be set to zero. The conversion rate tolerance is ±25% at any rate setting.

Valid A/D conversion results for all channels are available one total conversion time (125ms nominal, 156ms maximum) after initiating a conversion, whether conversion is initiated via the RUN/STOP bit, one-shot command, or initial power-up. Changing the conversion rate can also affect the delay until new results are available. See Table 8.

Programmed fan speed register

The programmed fan speed register 10h is read / write register. They contain the count number of the desired fan speed. Power up default is FFh.

Actual fan speed register

The actual fan speed register 11h is read only. They contain the count number of the actual fan speed. Power up default is FFh.

Fan status register

The fan status registers 12h is read only. Its bit 0 is set to 1 when the actual fan speed is ±20% outside the desired speed. Its bit 1 is set to 1 when fan speed is below 1920 rpm. Power up default is 0000_0010b.

Watchdog for fan control

Four temperature threshold registers intervene the control of fan. Pin FANVCC go high when one of the remote temperature, DX1 and DX2, rises above the respective TMAX. The control is not released until both temperature values drop below their THYST Besides, the fan controller also fully turns on the fan when either of the two remote diodes is open or both are short.

The power-up default values for TMAX and THYST are +70°C and +60°C, respectively. This allows the G768D to be used in the occasion when system fails and loses the fan control of G768D.

Slave Addresses

The G768D appears to the SMBus as one device having a common address for all the ADC and fan control channels. The device address is fixed to be 7Ah for write and 7Bh for read.

The G768D also responds to the SMBus Alert Response slave address (see the Alert Response Address section).

POR and UVLO

The G768D 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 V_{CC} and clears the memory if V_{CC} falls below 1.7V (typical, see Electrical Characteristics table). When power is first applied and V_{CC} rises above 1.75V (typical), the logic blocks begin operating, although reads and writes at V_{CC} levels below 3V are not recommended. A second V_{CC} comparator, the ADC UVLO comparator, prevents the ADC from converting until there is sufficient headroom (V_{CC} = 2.8V typical).

Power-Up Defaults:

- Interrupt latch is cleared.
- ADC begins auto /converting at a 0.25Hz rate.
- Command byte is set to 00h to facilitate quick remote Receive Byte queries.
- THIGH and TLOW registers are set to max and min limits, respectively

Detection On fan Failure

Setting bit 5 (DET_FAN) of CONFIGURATION-BYTE register with logic 1 activates the detection of fan failure. G768D detects fan failure via FG pin. G768D defines fan failure as no transition on FG pin for about 0.5sec or the fan measurement result is 255 counts for consecutive 8 times, it takes about 0.25sec. Once fan failure is detected the ALERT# will be set to logic low and the bit 0 (FAN_FAIL) of STATUS-BYTE will be set to logic high.

To clear the ALERT# signal caused by fan failure, the DET_FAN bit should be set to 0 then issue an ARA command on serial bus.

Thermal Shutdown Signal

When the temperature of DX1 reaches or exceeds the Tcrit1 threshold consecutively for the times equal to the number of faults of the FQ_TH_SHUT registers, TH_SHUT pin becomes logic high. The same mechanism is duplicated for DX2. There fore, either one of DX1, DX2 continuously over their respective Tcrit, the TH_SHUT will assert logic high to indicate a thermal shutdown event.

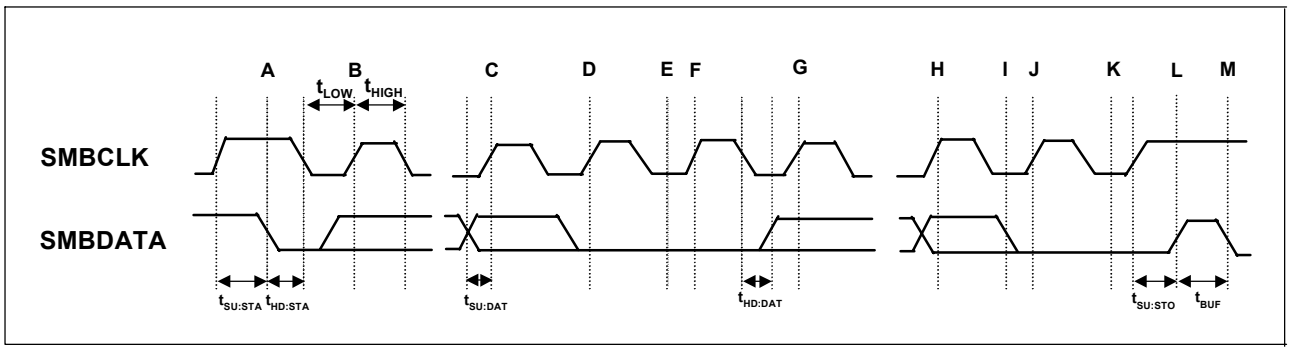


Figure 6. SMBus Write Timing Diagram

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

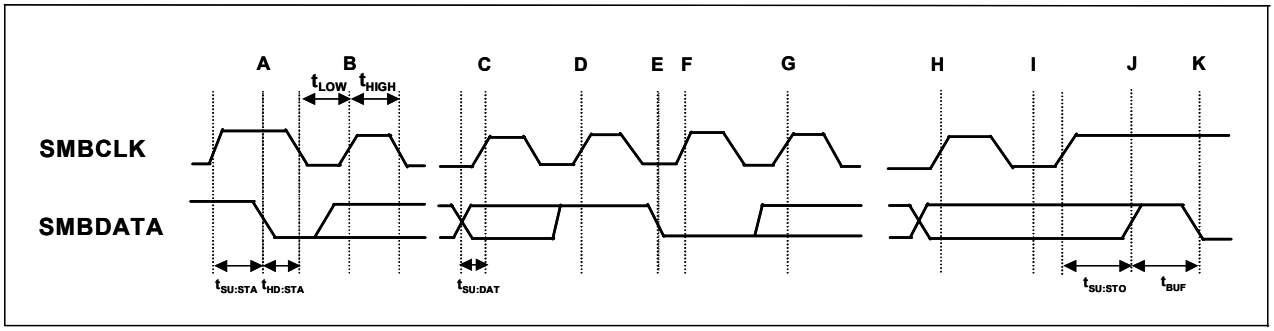
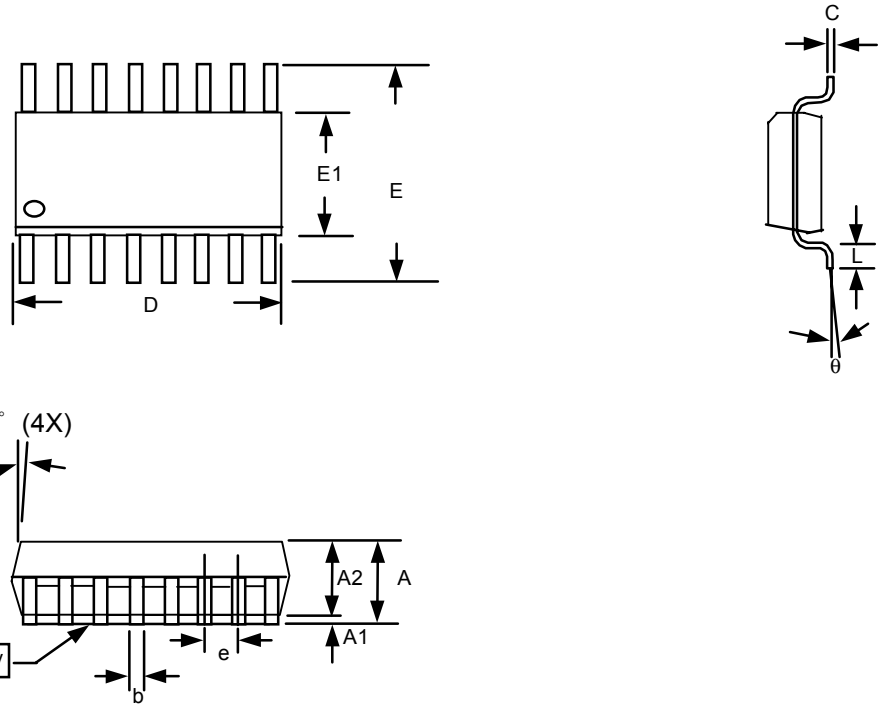


Figure 7. SMBus Read Timing Diagram

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

Package Information

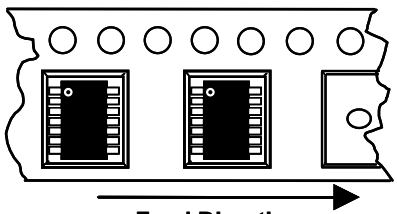


Note:

1. Package body sizes exclude mold flash and gate burrs
2. Dimension L is measured in gage plane
3. Tolerance 0.10mm unless other wise specified
4. Controlling dimension is millimeter converted inch dimensions are not necessarily exact.

SYMBOLS	DIMENSION IN MM			DIMENSION IN INCH		
	MIN	NOM	MAX	MIN	NOM	MAX
A	1.35	1.60	1.75	0.053	0.064	0.069
A1	0.10	-----	0.25	0.004	-----	0.010
A2	-----	1.45	-----	-----	0.057	-----
b	0.20	0.25	0.30	0.008	0.010	0.012
C	0.19	-----	0.25	0.007	-----	0.010
D	4.80	-----	5.00	0.189	-----	0.197
E	5.80	-----	6.20	0.228	-----	0.244
E1	3.80	-----	4.00	0.150	-----	0.157
e	-----	0.64	-----	-----	0.025	-----
L	0.40	-----	1.27	0.016	-----	0.050
y	-----	-----	0.10	-----	-----	0.004
θ	0º	-----	8º	0º	-----	8º

Taping Specification



Feed Direction

Typical SSOP Package Orientation