

## Digital Temperature Sensor and Thermal Watchdog with Two-Wire Interface

### Features

- SMBus interface
- Programmable Trip Point ( $T_{OS}$ ) and Hysteresis ( $T_{HYST}$ )
- Separate open-drain output pin operates as interrupt or comparator at output
- Register readback capability
- Power up defaults permit stand-alone operation as thermostat
- Shutdown mode to minimize power consumption
- Up to 8 G751s can be connected to a single bus

### Key Specifications

- Supply Voltage 3.0V to 5.5V
- Supply Current
 

|           |                   |
|-----------|-------------------|
| operating | 280 $\mu$ A (typ) |
|           | 1mA (max)         |
| shutdown  | 2 $\mu$ A (typ)   |
- Temperature Accuracy
 

|                |                             |
|----------------|-----------------------------|
| -25°C to 100°C | $\pm 2^\circ\text{C}$ (max) |
| -55°C to 125°C | $\pm 3^\circ\text{C}$ (max) |

### Applications

- System Thermal Management
- Personal Computers
- Office Electronics
- Electronic Test Equipment

### General Description

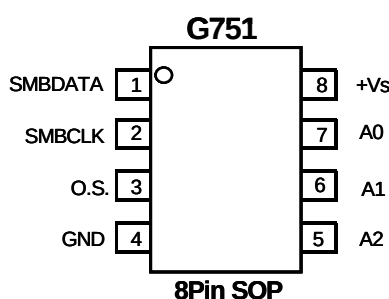
The G751 is a temperature sensor, Delta-Sigma analog-to-digital converter, and digital over-temperature detector with SMBus interface. The host can query the G751 at any time to read temperature. The open-drain Over temperature Shutdown (O.S.) output becomes active when the temperature exceeds a programmable limit. This pin can operate in either "Comparator" or "Interrupt" mode.

The host can program both the temperature alarm threshold ( $T_{OS}$ ) and the temperature at which the alarm condition goes away ( $T_{HYST}$ ). In addition, the host can read back the contents of the G751's  $T_{OS}$  and  $T_{HYST}$  registers. The sensor powers up in Comparator mode with default thresholds of 50°C  $T_{OS}$  45°C  $T_{HYST}$ . for G751-1 and 80°C  $T_{OS}$ , 75°C  $T_{HYST}$  for G751-2.

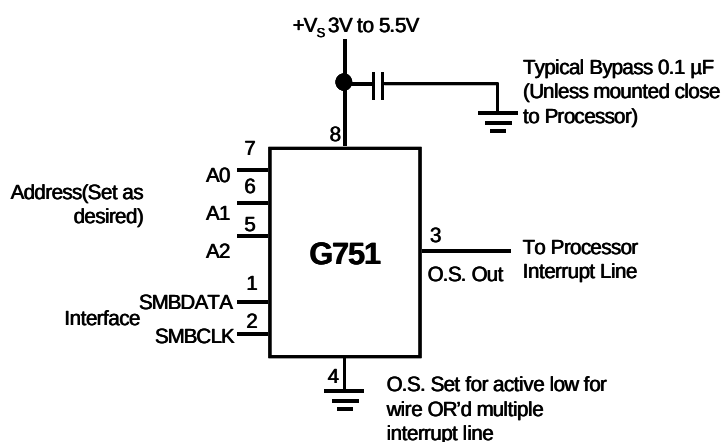
### Ordering Information

| PART   | $T_{OS}$ $T_{HYST}$ | Transport Media             | PACKAGE |
|--------|---------------------|-----------------------------|---------|
| G751-1 | 50°C/45°C           | 2500 Units on Tape and Reel | 8 SOP   |
| G751-2 | 80°C /75°C          | 2500 Units on Tape and Reel | 8 SOP   |

### Pin Configuration



### Typical Application



**Absolute Maximum Ratings.**

Supply Voltage.....-0.3V to 6.5V  
 Voltage at any Pin.....-0.3V to +Vs +0.3V  
 Input Current at any Pin.....5mA  
 Package Input Current.....20mA  
 O.S. Output Sink Current.....10mA  
 O.S. Output Voltage.....6.5V  
 Storage Temperature.....-65°C to +150°C  
 Soldering Information, Lead Temperature  
 SOP Package  
 Vapor Phase (60 seconds).....215°C  
 Infrared (15 seconds).....220°C  
 ESD Susceptibility  
 Human Body Model.....2000V  
 Machine  
 Model.....200V

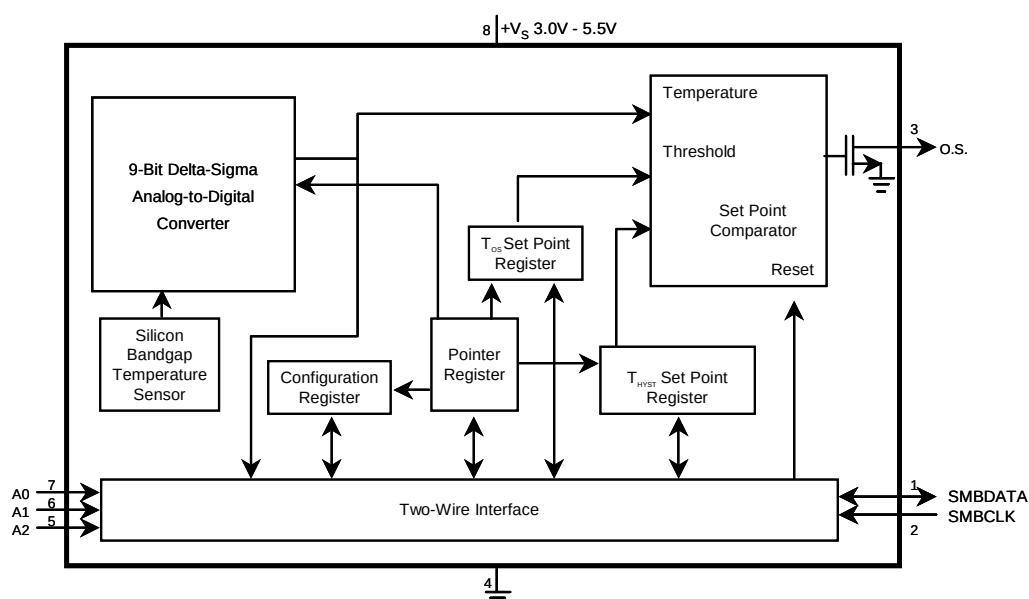
**Operating Ratings**

Specified Temperature Range..... $T_{MIN}$  to  $T_{MAX}$   
 -55°C to +125°C  
 Supply Voltage Range (+Vs).....+3.0V to +5.5V

**Temperature-to-Digital Converter Characteristics**

Unless otherwise noted, these specifications apply for +Vs=+3.3V Vdc. **Boldface limits apply for  $T_A=T_J=T_{MIN}$  to  $T_{MAX}$** ; all other limits  $T_A=T_J=+25^\circ\text{C}$ , unless otherwise noted.

| PARAMETER                                    | CONDITIONS                                                                                         | TYPICAL   | LIMITS                                                     | UNITS                                  |
|----------------------------------------------|----------------------------------------------------------------------------------------------------|-----------|------------------------------------------------------------|----------------------------------------|
| Accuracy                                     | $T_A=-25^\circ\text{C}$ to $+100^\circ\text{C}$<br>$T_A=-55^\circ\text{C}$ to $+125^\circ\text{C}$ |           | <b><math>\pm 2.0</math></b><br><b><math>\pm 3.0</math></b> | $^\circ\text{C}$ (max)                 |
| Resolution                                   |                                                                                                    | 9         |                                                            | Bits                                   |
| Temperature Conversion Time                  |                                                                                                    | 100       |                                                            | Ms                                     |
| Quiescent Current                            | SMBus Inactive<br>SMBus Active<br>Shutdown Mode                                                    | 0.25<br>1 | <b>1.0</b>                                                 | Ma<br>mA (max)<br>$\mu\text{A}$        |
| O.S. Output Saturation Voltage               | $I_{OUT} = 4.0\text{mA}$                                                                           |           | <b>0.8</b>                                                 | V (max)                                |
| O.S. Delay                                   |                                                                                                    |           | <b>1</b><br><b>6</b>                                       | Conversions (min)<br>Conversions (max) |
| $T_{OS}$ Default Temperature G751-1/G751-2   |                                                                                                    | 50/80     |                                                            | $^\circ\text{C}$                       |
| $T_{HYST}$ Default Temperature G751-1/G751-2 |                                                                                                    | 45/75     |                                                            | $^\circ\text{C}$                       |

**Block Diagram**

## Logic Electrical Characteristics

### Digital DC Characteristics

Unless otherwise noted, these specifications apply for  $+V_s = +3.3$  Vdc. **Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$** ; all other limits  $T_A = T_J = +25^\circ\text{C}$ , unless otherwise noted.

| SYMBOL      | PARAMETER                 | CONDITIONS                             | TYPICAL | LIMITS                            | UNITS               |
|-------------|---------------------------|----------------------------------------|---------|-----------------------------------|---------------------|
| $V_{IN(1)}$ | Logical "1" Input Voltage |                                        |         | $+V_s \times 0.7$<br>$+V_s + 0.5$ | V (min)<br>V (max)  |
| $V_{IN(0)}$ | Logical "0" Input Voltage |                                        |         | <b>-0.3</b><br>$+V_s \times 0.3$  | V (min)<br>V (max)  |
| $I_{IN(1)}$ | Logical "1" Input Current | $V_{IN} = 5V$                          | 0.005   | <b>1.0</b>                        | $\mu\text{A}$       |
| $I_{IN(0)}$ | Logical "0" Input Current | $V_{IN} = 0V$                          | -0.005  | <b>-1.0</b>                       | $\mu\text{A}$       |
| $C_{IN}$    | All Digital Inputs        |                                        | 20      |                                   | PF                  |
| $I_{OH}$    | High Level Output Current | $V_{OH} = 5V$                          |         | <b>100</b>                        | $\mu\text{A}$ (max) |
| $V_{OL}$    | Low Level Output Voltage  | $I_{OL} = 3\text{ma}$                  |         | <b>0.4</b>                        | V (max)             |
| $t_{OF}$    | Output Fall Time          | $C_L = 400\text{pF}, I_O = 3\text{ma}$ |         | <b>250</b>                        | ns (max)            |

### SMBus Digital Switching Characteristics

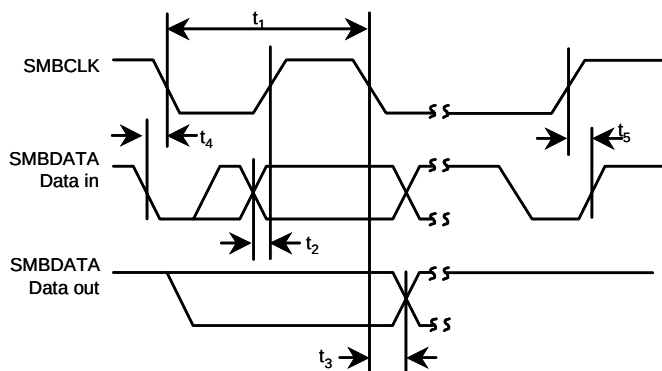
Unless otherwise noted, these specifications apply for  $+V_s = +3.3$  Vdc and  $C_L$  (load capacitance) on output lines = 80pF unless otherwise specified. **Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$** ; all other limits  $T_A = T_J = +25^\circ\text{C}$ , unless otherwise noted.

The switching characteristics of the G751 fully meet or exceed the published specifications of the SMBus. The following parameters are the timing relationships between SMBCLK and SMBDATA signals related to the G751. They are not the SMBus specifications.

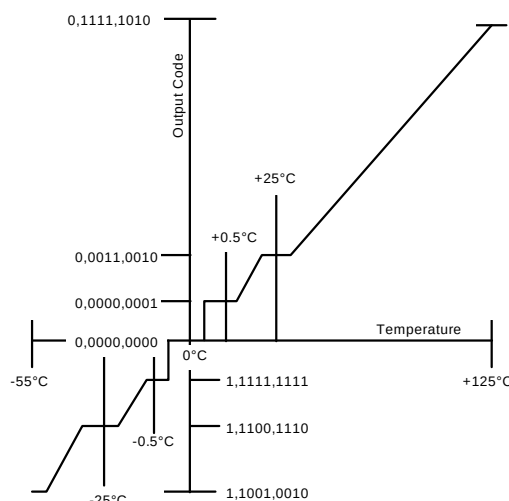
| SYMBOL | PARAMETER                                                 | CONDITIONS | TYPICAL | LIMITS | UNITS               |
|--------|-----------------------------------------------------------|------------|---------|--------|---------------------|
| $t_1$  | SMBCLK (Clock) Period                                     |            |         | 2.5    | $\mu\text{s}$ (min) |
| $t_2$  | Data in Set-Up Time to SMBCLK High                        |            |         | 100    | ns (min)            |
| $t_3$  | Data Out Stable after SMBCLK Low                          |            |         | 0      | ns (min)            |
| $t_4$  | SMBDATA Low Set-Up Time to SMBCLK Low (Start Condition)   |            |         | 100    | ns (min)            |
| $t_5$  | SMBDATA High Hold Time after SMBCLK High (Stop Condition) |            |         | 100    | ns (min)            |

## Pin Description

| PIN   | LABEL   | FUNCTION                                   | TYPICAL CONNECTION                          |
|-------|---------|--------------------------------------------|---------------------------------------------|
| 1     | SMBDATA | SMBus Serial Bi-Directional Data Line      | From Controller                             |
| 2     | SMBCLK  | SMBus Clock Input                          | From Controller                             |
| 3     | O.S.    | Overtemperature Shutdown Open Drain Output | Pull Up Resistor, Controller Interrupt Line |
| 4     | GND     | Power Supply Ground                        | Ground                                      |
| 5,6,7 | A0-A2   | User-Set SMBus Address Inputs              | Ground (Low, "0") or $+V_s$ (High, "1")     |
| 8     | $+V_s$  | Positive Supply Voltage Input              | DC Voltage from 3V to 5.5V                  |



## Logic Electrical Characteristics



**Temperature-to-Digital Transfer Function (Non-linear scale for clarity)**

## Functional Description

The G751 temperature sensor incorporates a band-gap type temperature sensor and 9-bit ADC (Delta-Sigma Analog- to-Digital Converter). The temperature data output of the G751 is available at all times via the SMBus. If a conversion is in progress, it will be stopped and restarted after the read. A digital comparator is also incorporated that compares a series of readings, the number of which is user-selectable, to user-programmable setpoint and hysteresis values. The comparator trips the O.S. output line, which is programmable for mode and polarity.

### O.S. Output, $T_{OS}$ and $T_{HYST}$ Limits

In Comparator mode the O.S. Output behaves like a thermostat. The output becomes active when temperature exceeds the  $T_{OS}$  limit, and leaves the active state when the temperature drops below the  $T_{HYST}$  limit. In this mode the O.S. output can be used to turn a cooling fan on, initiate an emergency system shutdown, or reduce system clock speed. Shutdown mode does not reset O.S. state in a comparator mode.

In interrupt mode exceeding  $T_{OS}$  also makes O.S. active but O.S. will remain active indefinitely until reset by reading any register via the SMBus interface. Once O.S. has been activated by crossing  $T_{OS}$ , then reset, it can be activated again only by Temperature going below  $T_{HYST}$ . Again, it will remain active indefinitely until being reset by a read. Placing the G751 in shutdown mode also resets the O.S. output.

## Default Modes

G751 always powers up in a known state. G751 power up default conditions are:

1. Comparator mode
2.  $T_{OS}$  set to 50°C for G751-1, to 80°C for G751-2
3.  $T_{HYST}$  set to 45°C for G751-1, to 75°C for G751-2
4. O.S. active low
5. Pointer set to "00"; Temperature Register

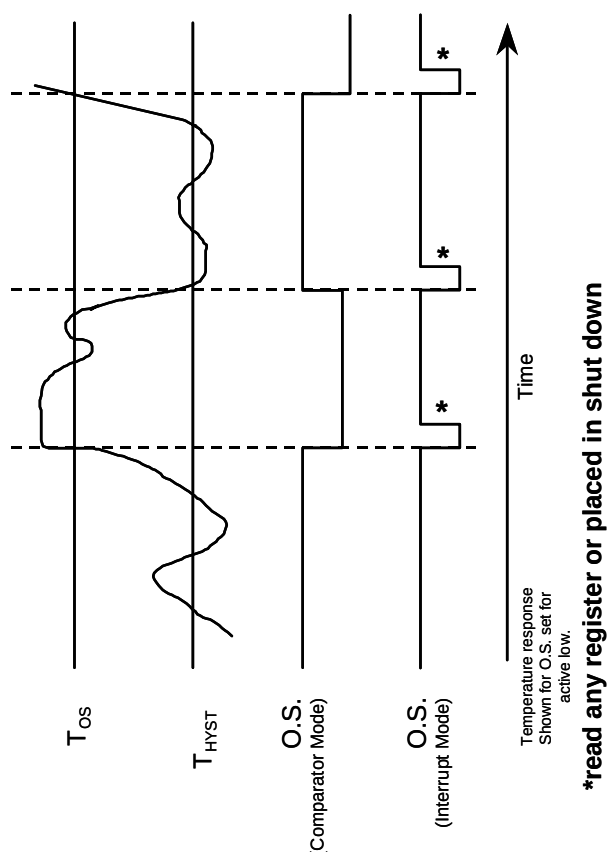
With these operating conditions G751 can act as a stand-alone thermostat with the above temperature settings. Connection to an SMBus is not required.

## SMBus Interface

The G751 operates as a slave on the SMBus, so the SMBCLK line is an input (no clock is generated by the G751) and the SMBDATA line is a bi-directional serial data path. According to SMBus specifications, the G751 has a 7-bit slave address. The four most significant bits of the slave address are hard wired inside the G751 and are "1001". The three least significant bits of the address are assigned to pins A2-A0, and are set by connecting these pins to ground for a low, (0); or to +Vs for a high, (1).

Therefore, the complete slave address is:

|     |   |   |   |     |    |    |
|-----|---|---|---|-----|----|----|
| 1   | 0 | 0 | 1 | A2  | A1 | A0 |
| MSB |   |   |   | LSB |    |    |



**Figure1 O.S. Output Temperature Response Diagram**

### Temperature Data Format

Temperature data can be read from the Temperature,  $T_{OS}$  Set Point, and  $T_{HYST}$  Set Point registers; and written to the  $T_{OS}$  Set Point, and  $T_{HYST}$  Set Point registers. Temperature data is represented by a 9-bit, two's complement word with an LSB (Least Significant Bit) equal to  $0.5^{\circ}\text{C}$ :

| TEMPERATURE | DIGITAL OUTPUT |      |
|-------------|----------------|------|
|             | BINARY         | HEX  |
| +125°C      | 0 1111 1010    | 0FAh |
| +25°C       | 0 0011 0010    | 032h |
| +0.5°C      | 0 0000 0001    | 001h |
| 0°C         | 0 0000 0000    | 000h |
| -0.5°C      | 1 1111 1111    | 1FFh |
| -25°C       | 1 1100 1110    | 1CEh |
| -55°C       | 1 1001 0010    | 192h |

### Shutdown Mode

Shutdown mode is enabled by setting the shutdown bit in the Configuration register via the SMBus. Shutdown mode reduces power supply current to  $1\text{ }\mu\text{A}$  typical. In interrupt mode O.S. is reset if previously set and is undefined in Comparator mode during shutdown. The SMBus interface remains active. Activity on the clock and data lines of the SMBus may slightly increase shutdown mode quiescent current.  $T_{OS}$ ,  $T_{HYST}$ , and Configuration registers can be read from and written to in shutdown mode.

### Fault Queue

A fault queue of up to 6 faults is provided to prevent false tripping of O.S. when the G751 is used in noisy environments. The number of faults set in the queue must occur consecutively to set the O.S. output.

### Comparator/Interrupt Mode

As indicated in the O.S. Output Temperature Response Diagram, Figure 1, the events that trigger O.S. are identical for either Comparator or Interrupt mode. The most important difference is that in Interrupt mode the O.S. will remain set indefinitely once it has been set. To reset O.S. while in Interrupt mode, perform a read from any register in the G751.

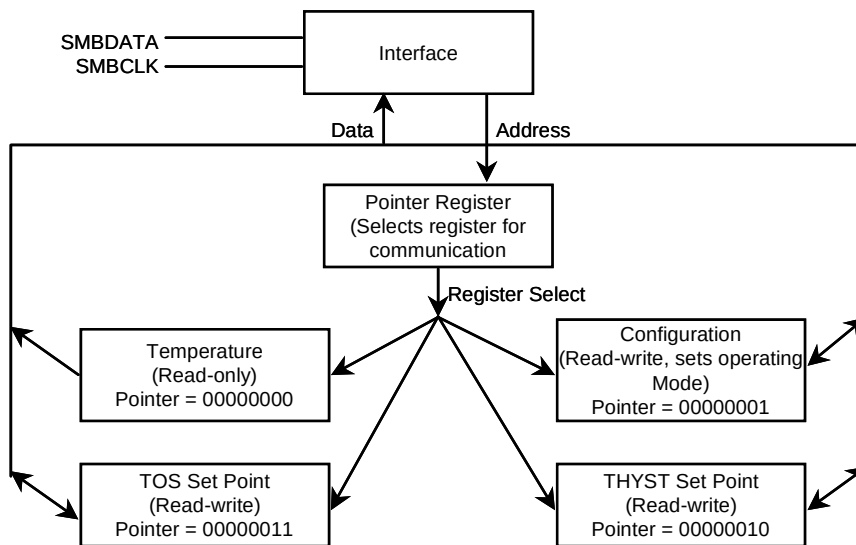
### O.S. Output

The O.S. output is an open-drain output and does not have an internal pull-up. A "high" level will not be observed on this pin until pull-up current is provided from some external source, typically a pull-up resistor. Choice of resistor value depends on many system factors but, in general, the pull-up resistor should be as large as possible. This will minimize any errors due to internal heating of the G751. The maximum resistance of the pull up, based on G751 specification for High Level Output Current, to provide a 2V high level, is  $30\text{k}\Omega$ .

### O.S. Polarity

The O.S. output can be programmed via the configuration register to be either active low (default mode), or active high. In active low mode the O.S. output goes low when triggered exactly as shown on the O.S. Output Temperature Response Diagram, Figure 1. Active high simply inverts the polarity of the O.S. output.

## Internal Register Structure



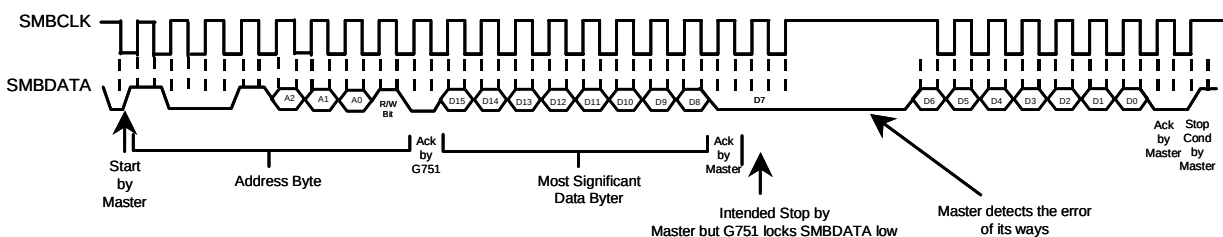
There are four data registers in the G751, selected by the Pointer register. At power-up the Pointer is set to "00"; the location for the Temperature Register. The Pointer register latches whatever the last location it was set to. In Interrupt Mode, a read from the G751, or placing the device in shutdown mode, resets the O.S. output. All registers are read and write, except the Temperature register which is read only.

A write to the G751 will always include the address byte and the Pointer byte. A write to the Configuration register requires one data byte, and the  $T_{OS}$  and  $T_{HYST}$  registers require two data bytes.

Reading the G751 can take place either of two ways: If the location latched in the Pointer is correct (most of the time it is expected that the Pointer will point to Temperature register because it will be the data most frequently read from the G751), then the read can simply consist of an address byte, followed by retrieving the corresponding number of data bytes. If the Pointer needs to be set, than an address byte, pointer byte, repeat start, and another address byte will accomplish a read.

The first data byte is the most significant byte with most signification bit first, permitting only as much data as necessary to be read to determine temperature condition. For instance, if the first four bits of the temperature data indicates an overtemperature condition, the host processor could immediately take action to remedy the excessive temperatures. At the end of a read, the G751 can accept either Acknowledge or No Acknowledge from the Master (No Acknowledge is typically used as a signal for the slave that the Master has read its last byte).

An inadvertent 8-bit read from a 16-bit register, with the D7 bit low, can cause the G751 to stop in a state where the SDA line is held low as shown in Figure 2. This can prevent any further bus communication until at least 9 additional clock cycles have occurred. Alternatively, the master can issue clock cycles until SDA goes high, at which time issuing a "Stop" condition will reset the G751.



**Figure 2. Inadvertent 8-Bit Read from 16-Bit Register where D7 is Zero**

## Pointer Register

(Selects which registers will be read from or written to):

| P7 | P6 | P5 | P4 | P3 | P2 | P1              | P0 |
|----|----|----|----|----|----|-----------------|----|
| 0  | 0  | 0  | 0  | 0  | 0  | Register Select |    |

P0-P1 :Register Select:

| P1 | P0 | REGISTER                                   |
|----|----|--------------------------------------------|
| 0  | 0  | Temperature (Read only) (Power-up default) |
| 0  | 1  | Configuration (Read/Write)                 |
| 1  | 0  | T <sub>HYST</sub> (Read/Write)             |
| 1  | 1  | T <sub>OS</sub> (Read/Write)               |

P2-P7 :Must be kept zero.

## Temperature Register

(Read Only):

| D15 | D14   | D13   | D12   | D11   | D10   | D9    | D8    | D7  | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|-----|-------|-------|-------|-------|-------|-------|-------|-----|----|----|----|----|----|----|----|
| MSB | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | LSB | X  | X  | X  | X  | X  | X  | X  |

D0-D6 :Undefined

D7-D15 :Temperature Data. One LSB = 0.5°C. Two's complement format.

## Configuration Register

(Read/Write):

| D7 | D6 | D5 | D4          | D3 | D2            | D1      | D0       |
|----|----|----|-------------|----|---------------|---------|----------|
| 0  | 0  | 0  | Fault Queue |    | O.S. Polarity | Cmp/Int | Shutdown |

Power up default is with all bits "0" (zero).

D0 :Shutdown : When set to 1 the G751 goes to low power shutdown mode.

D1 :Comparator / Interrupt mode : 0 is Comparator mode, 1 is Interrupt mode.

D2 :O.S. Polarity : 0 is active low, 1 is active high. O.S. is an open-drain output under all conditions.

D3-D4 :Fault Queue : Number of faults necessary to detect before setting O.S. output to avoid false tripping due to noise :

| D4 | D3 | NUMBER OF FAULTS     |
|----|----|----------------------|
| 0  | 0  | 1 (Power-up default) |
| 0  | 1  | 2                    |
| 1  | 0  | 4                    |
| 1  | 1  | 6                    |

D5-D7 :These bits are used for production testing and must be kept zero for normal operation.

## T<sub>HYST</sub> and T<sub>OS</sub> Register

(Read/Write):

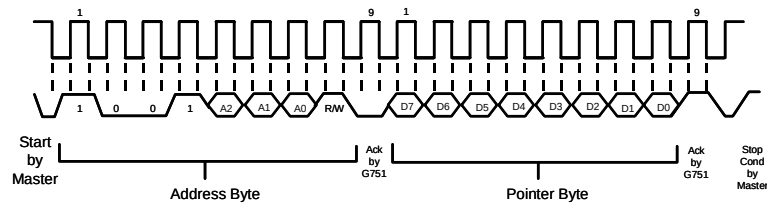
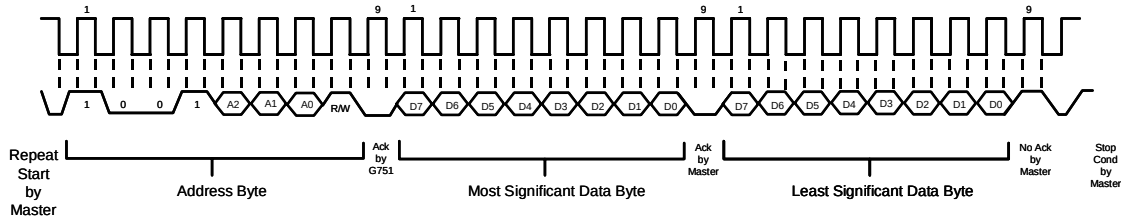
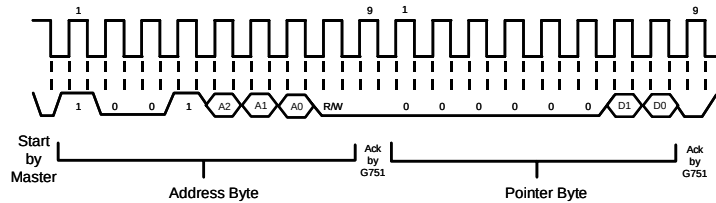
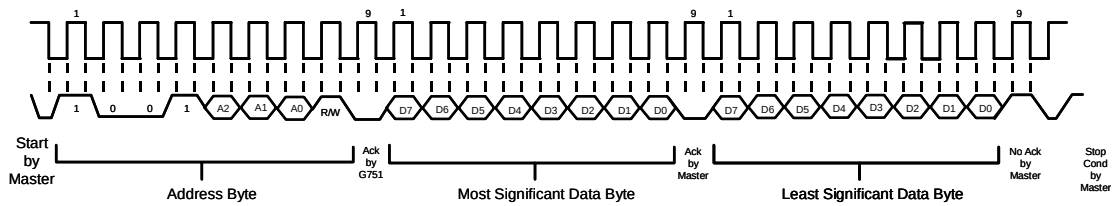
| D15 | D14   | D13   | D12   | D11   | D10   | D9    | D8    | D7  | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|-----|-------|-------|-------|-------|-------|-------|-------|-----|----|----|----|----|----|----|----|
| MSB | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | LSB | X  | X  | X  | X  | X  | X  | X  |

D0-D6 :Undefined

D7-D15 :T<sub>HYST</sub> Or T<sub>OS</sub> Trip Temperature Data. Power up default is T<sub>OS</sub> = 50°C /80°C for G751-1/G751-2, T<sub>HYST</sub> = 45°C /75°C for G751-1/G751-2.

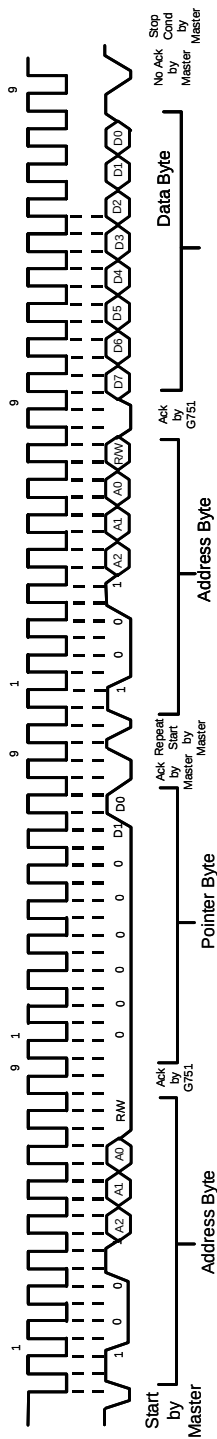


## SMBus Timing Diagrams

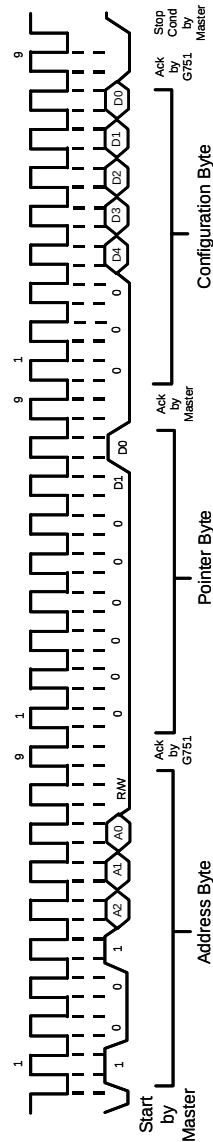




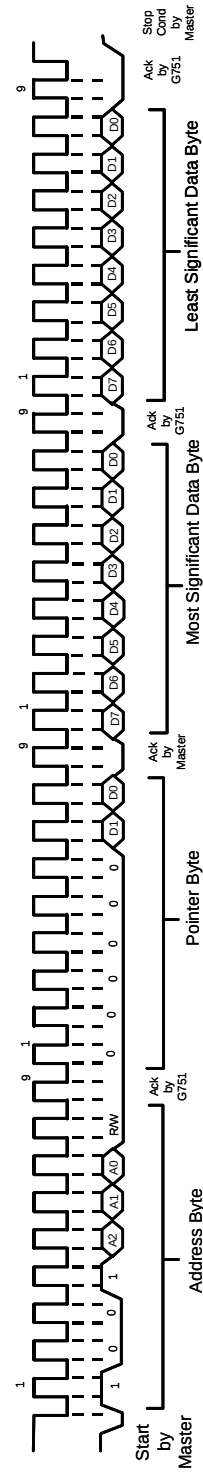
## Timing Diagrams (Continued)



(a) Typical Pointer Set followed by Immediate Read from Configuration Register

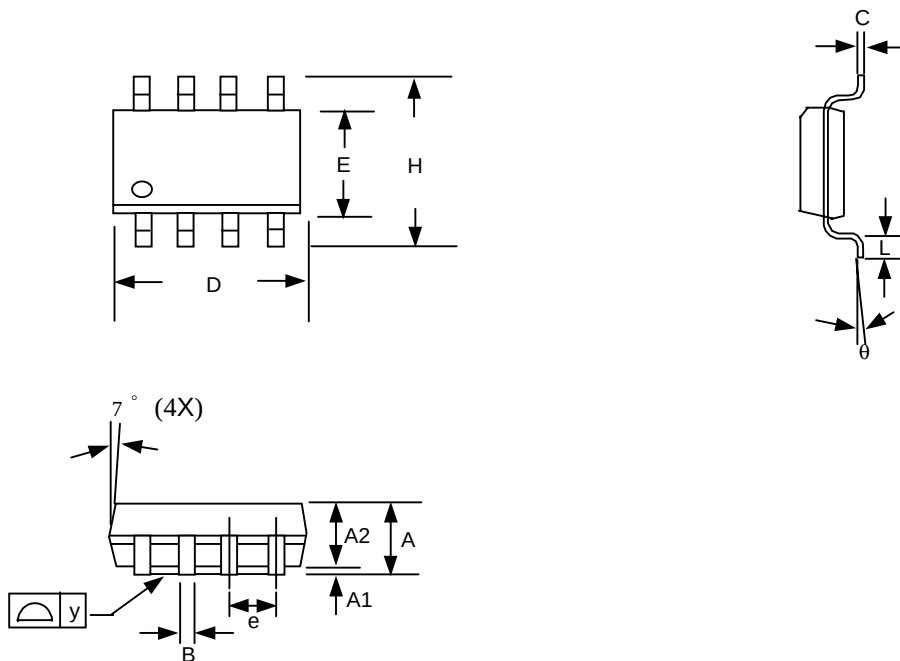


(b) Configuration Register Write



(c)  $T_{OS}$  and  $T_{HYS}$  Write

## 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 otherwise specified
4. Controlling dimension is millimeter converted inch dimensions are not necessarily exact.

| SYMBOL   | DIMENSION IN MM |       |       | DIMENSION IN INCH |       |       |
|----------|-----------------|-------|-------|-------------------|-------|-------|
|          | MIN.            | NOM.  | MAX.  | MIN.              | NOM.  | MAX.  |
| A        | 1.35            | 1.60  | 1.75  | 0.053             | 0.063 | 0.069 |
| A1       | 0.10            | ----- | 0.25  | 0.004             | ----- | 0.010 |
| A2       | -----           | 1.45  | ----- | -----             | 0.057 | ----- |
| B        | 0.33            | ----- | 0.51  | 0.013             | ----- | 0.020 |
| C        | 0.19            | ----- | 0.25  | 0.007             | ----- | 0.010 |
| D        | 4.80            | ----- | 5.00  | 0.189             | ----- | 0.197 |
| E        | 3.80            | ----- | 4.00  | 0.150             | ----- | 0.157 |
| e        | -----           | 1.27  | ----- | -----             | 0.050 | ----- |
| H        | 5.80            | ----- | 6.20  | 0.228             | ----- | 0.244 |
| L        | 0.40            | ----- | 1.27  | 0.016             | ----- | 0.050 |
| y        | -----           | ----- | 0.10  | -----             | ----- | 0.004 |
| $\theta$ | 0°              | ----- | 8°    | 0°                | ----- | 8°    |

## Taping Specification

