High Accuracy Digital Temperature Sensor and Thermal Watchdog with Two-Wire Interface

Features

- **Multiple Device Access**
- **SMBus Compatible Interface**
- **Resolution: 8 Bits**
- **Digital Output**
- **WLCSP2X2-4 package 0.4mm pitch**
- **Register Readback Capability**
- **Shutdown Mode to Minimize Power Consumption**

Applications

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

General Description

The G754 is a temperature sensor, analog-to-digital converter, and digital over- temperature detector with SMBus interface. The host can query the G754 at any time to read temperature.

Key Specifications

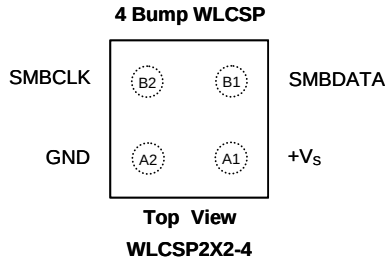
- **Supply Voltage** **1.6V to 3.6V**
- **Supply Current at 0.25 Conv/s** **7.5µA (typ)**
  15µA (max)
  Shutdown **0.5µA (max)**
- **Temperature Accuracy**
  -10°C to +100°C, +Vs=1.8V **±2°C (max)**
  -40°C to +125°C, +Vs=1.8V **±3°C (max)**

Ordering Information

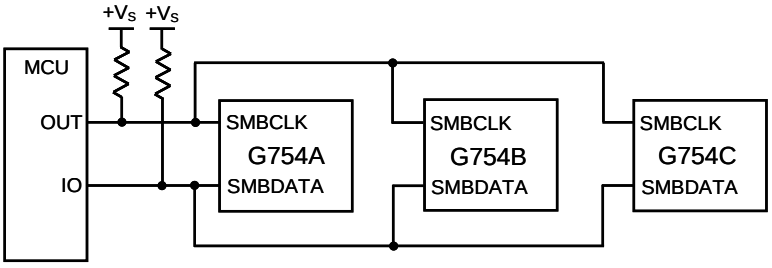
ORDER NUMBER	MARKING	PACKAGE (Green)
G754ABE1U	7A x	WLCSP2X2-4
G754BBE1U	7B x	WLCSP2X2-4
G754CBE1U	7C x	WLCSP2X2-4
G754DBE1U	7D x	WLCSP2X2-4
G754EBE1U	7E x	WLCSP2X2-4
G754FBE1U	7F x	WLCSP2X2-4
G754GBE1U	7G x	WLCSP2X2-4
G754HBE1U	7H x	WLCSP2X2-4

Note: BE: WLCSP2X2-4
1 : Bonding Code
U: Tape & Reel
Green : Lead Free / Halogen Free.

Pin Configuration



Typical Application Circuit



Absolute Maximum Ratings

$+V_S$ to GND.. . . . . .-0.3V to +3.6V
SMBCLK, SMBDAT., to GND. . . . . -0.3V to +3.6V
SMBDATA Current. . . . . -1mA to +50mA
Thermal Resistance Junction to Ambient, (θ_{JA})*
WLCSP2X2-4. . . . . .130°C/W
Continuous Power Dissipation (T_A= +25°C)*
WLCSP2X2-4 . . . . . 0.7W

Operating Temperature Range . . . . . -55°C to +125°C
Junction Temperature. . . . . .+150°C
Storage temperature Range. . . . . .-60°C to +150°C
Reflow Temperature (soldering,10sec) . . . . . .+260°C
ESD(HBM) 2KV
ESD(CDM) 1KV

*Measured using the PCB with area 40mm x 33mm.

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.

Temperature-to-Digital Converter Characteristics

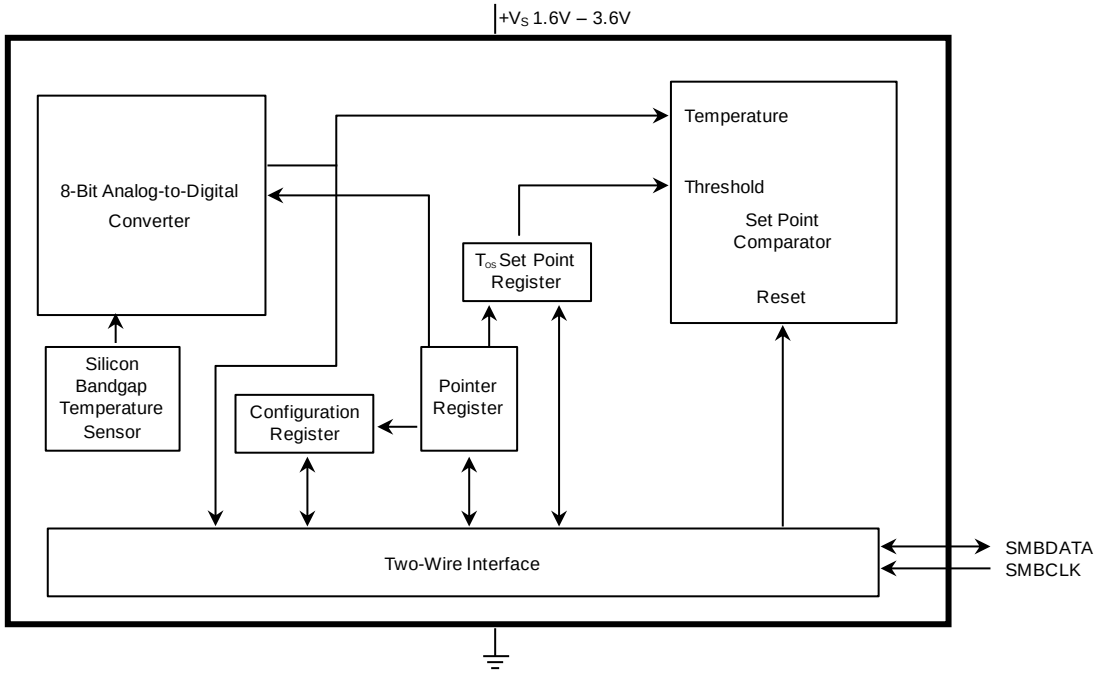
Unless otherwise noted, these specifications apply for +Vs=+1.8V Vdc. **Boldface limits apply for T_A=T_J=T_{MIN} to T_{MAX}**; all other limits T_A=T_J= +25°C, unless otherwise noted.

PARAMETER	CONDITIONS	TYPICAL	LIMITS	UNITS
Accuracy	T_A=-10°C to +100°C, +Vs=1.8V	0	±2	°C
	T_A=-40°C to +125°C, +Vs=1.8V	±1	±3	
v.s. Supply		±0.2	±0.5	°C/V
Resolution		8	---	Bits
Conversion mode	CR1 = 0, CR0 = 0 (default)	0.25	---	Conv/s
	CR1 = 0, CR0 = 1	1	---	Conv/s
	CR1 = 1, CR0 = 0	4	---	Conv/s
	CR1 = 1, CR0 = 1	8	---	Conv/s
Timeout Time		30	40	ms
Quiescent Current	Serial Bus Inactive, CR1 = 0, CR0 = 0 (default), V+ = 1.8V	7.5	15	µA
	Serial Bus Active, SMBCLK Frequency = 400kHz	15	---	µA
	Serial Bus Active, SMBCLK Frequency = 3.4MHz	45	---	µA
Shutdown Current	Serial Bus Inactive, V+ = 1.8V	0.2	0.5	µA
	Serial Bus Active, SMBCLK Frequency = 400kHz	10	---	µA
	Serial Bus Active, SMBCLK Frequency = 3.4MHz	40	---	µA

Pin Description

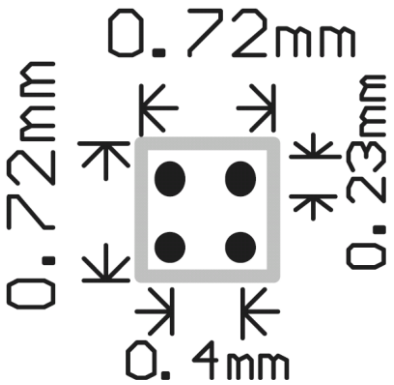
PIN	LABEL	FUNCTION	TYPICAL CONNECTION
A1	+Vs	Positive Supply Voltage Input	DC Voltage from 1.6V to 3.6V
A2	GND	Power Supply Ground	Ground
B1	SMBDATA	SMBus Serial Bi-Directional Data Line	From Controller
B2	SMBCLK	SMBus Clock Input	From Controller

Block Diagram



Minimum Footprint PCB Layout Section

WLCSP2X2-4 (BE)



Logic Electrical Characteristics

Digital DC Characteristics

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

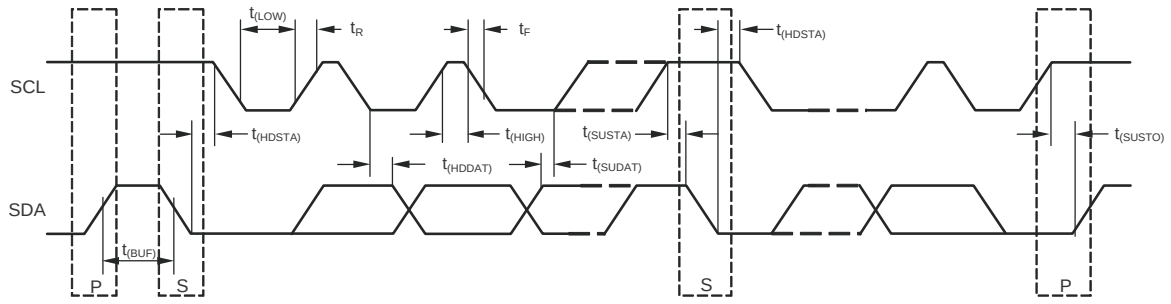
SYMBOL	PARAMETER	CONDITIONS	TYPICAL	LIMITS	UNITS
$V_{IN\ (1)}$	Logical "1" Input Voltage		---	+Vs× 0.7	V (min)
			---	+Vs + 0.5	V (max)
$V_{IN\ (0)}$	Logical "0" Input Voltage		---	-0.5	V (min)
			---	+Vs×0.3	V (max)
$I_{IN\ (1)}$	Logical "1" Intput Current	V_{IN}=3.3V	0.005	1.0	μA
$I_{IN\ (0)}$	Logical "0" Intput Current	V_{IN}=0V	-0.005	-1.0	μA
C_{IN}	All Digital Inputs		20	---	pF
V_{OL}	Low Level Output Voltage	I_{OL}=2mA	---	0.4	V (max)
t_{OF}	Output Fall Time	C_L=400pF,I_O=3mA	---	250	ns (max)

SMBus Digital Switching Characteristics

Unless otherwise noted, these specifications apply for +Vs = +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°C, unless otherwise noted.

The switching characteristics of the G754 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 G754. They are not the SMBus specifications.

PARAMETER	SYMBOL	FAST MODE		HIGH-SPEED MODE		UNIT
		MIN	MAX	MIN	MAX	
SCL operating frequency, VS > 1.7 V	$f_{(SCL)}$	0.001	0.4	0.001	3.4	MHz
SCL operating frequency, VS < 1.7 V	$f_{(SCL)}$	0.001	0.4	0.001	2.75	MHz
Bus free time between STOP and START condition	$t_{(BUF)}$	600	---	160	---	ns
Hold time after repeated START condition. After this period, the first clock is generated.	$t_{(HDSTA)}$	100	---	100	---	ns
Repeated START condition setup time	$t_{(SUSTA)}$	100	---	100	---	ns
STOP condition setup Time	$t_{(SUSTO)}$	100	---	100	---	ns
Data hold time	$t_{(HDDAT)}$	20	400	10	125	ns
Data setup time	$t_{(SUDAT)}$	100	---	10	---	ns
SCL clock low period, VS > 1.7 V	$t_{(LOW)}$	1300	---	160	---	ns
SCL clock low period, VS < 1.7 V	$t_{(LOW)}$	1300	---	200	---	ns
SCL clock high period	$t_{(HIGH)}$	600	---	60	---	ns
Clock/data fall time	t_F	---	300	---	---	ns
Clock/data rise time	t_R	---	300	---	160	ns
Clock/data rise time for SCLK ≤ 100 kHz	t_R	---	1000	---	---	ns



NOTE: P = STOP, S = START.

Functional Description

The G754 temperature sensor incorporates a band-gap type temperature sensor and 8-bit ADC (Analog-to-Digital Converter). The temperature data output of the G754 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.

SMBus Digital Interface

From a software perspective, the G754 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.

In addition, the G754 has the capability of executing multiple device access (MDA) commands that allow multiple G754s to respond to a single global bus command. MDA commands reduce communication time and power in a bus that contains multiple G754 devices. The G754 serial interface is designed to support up to eight G754 devices on a single bus. The G754 is offered with eight internal interface addresses. Each unique address option can be used as a location or temperature zone designator. The G754 responds to standard I2C/SMBus slave protocols that allow the internal registers to be written to or read from on an individual basis. The G754 also responds to MDA commands that allow all the devices on the bus to be written to or read from, without having to send the individual address and commands to each device.

Serial Bus Address

To communicate with the G754, the master must first address slave devices via a slave address byte. The slave address byte consists of seven address bits, and a direction bit that indicates the intent of executing a read or write operation.

The G754 is available in eight versions, each with a different slave address, as shown in Table 1. These addresses can be used as either a location or a temperature zone designator.

Table 1. Device Slave Addresses

PRODUCT	TWO-WIRE ADDRESS
G754A	1110000
G754B	1110001
G754C	1110010
G754D	1110011
G754E	1110100
G754F	1110101
G754G	1110110
G754H	1110111

Writing/Reading Operation

Accessing a particular register on the G754 is accomplished by writing the appropriate value to the Pointer Register. The value for the Pointer Register is the first byte transferred after the slave address byte with the $R/\overline{W}$ bit low. Every write operation to the G754 requires a value for the Pointer Register (see Figure 1).

When reading from the G754, the last value stored in the Pointer Register by a write operation is used to determine which register is read by a read operation. To change the register pointer for a read operation, a new value must be written to the Pointer Register. This action is accomplished by issuing a slave address byte with the $R/\overline{W}$ bit low, followed by the Pointer Register byte. No additional data are required. The master can then generate a START condition and send the slave address byte with the $R/\overline{W}$ bit high to initiate the read command. See Figure 2 for details of this sequence. If repeated reads from the same register are desired, it is not necessary to continually send the Pointer Register bytes; the G754 remembers the Pointer Register value until it is changed by the next write operation, or the G754 is reset.

Slave Mode Operations

The G754 can operate as a slave receiver or slave transmitter. As a slave device, the G754 never drives the SCL line.

Slave Receiver Mode

The first byte transmitted by the master is the slave address, with the R/$\overline{W}$ bit low. The G754 then acknowledges reception of a valid address. The next byte transmitted by the master is the Pointer Register. The G754 then acknowledges reception of the Pointer Register byte. The next byte is written to the register addressed by the Pointer Register. The G754 acknowledges reception of the data byte. The master can terminate data transfer by generating a START or STOP condition.

Slave Transmitter Mode

The first byte transmitted by the master is the slave address, with the R/$\overline{W}$ bit high. The slave acknowledges reception of a valid slave address. The next byte is transmitted by the slave of the register indicated by the Pointer Register. The master acknowledges reception of the data byte. The master can terminate data transfer by generating a *Not-Acknowledge* on reception of the data byte, or generating a START or STOP condition.

General Call

The G754 responds to a two-wire General Call address (0000000) if the eighth bit is '0'. The device acknowledges the General Call address and responds to commands in the second byte. If the second byte is 00000110, the G754 internal registers are reset to power-up values. The G754 does not support the General Address acquire command.

High-Speed (Hs) Mode

In order for the two-wire bus to operate at frequencies above 400kHz, the master device must issue an Hs-mode master code (00001xxx) as the first byte after a START condition to switch the bus to high-speed operation. The G754 does not acknowledge this byte, but switches its input filters on SMBDATA and SMBCLK and its output filters on SMBDATA to operate in Hs-mode, allowing transfers at up to 3.4MHz. After the Hs-mode master code has been issued, the master transmits a START condition followed by a two-wire slave address to initiate a data transfer operation. The bus continues to operate in Hs-mode until a STOP condition occurs on the bus. Upon receiving the STOP condition, the G754 switches the input and output filters back to the default fast-mode operation.

Timeout Function

The G754 resets the serial interface if SCL is held low for 30ms (typ). The G754 releases the bus if it is pulled low and waits for a START condition. To avoid activating the timeout function, it is necessary to maintain a communication speed of at least 1kHz for SCL operating frequency.

Multiple Device Access

The G754 supports Multiple Device Access (MDA), which allows the master to communicate with multiple G754 devices on the same bus interface with one interface transaction. MDA commands consist of an MDA read address (00000001) and an MDA write address (00000000). The device devices are on the bus, the master must transmit an acknowledges the MDA address and responds to the MDA read address followed by four bytes and four command accordingly. In order for MDA to function acknowledges in order to complete the MDA read correctly, different product versions of the G754 transaction. must be used in the system; see Table 1.

Multiple Device Access Write

The master transmits an MDA write address followed by the pointer address of the register to be accessed; see Table 2. Following the pointer, all of the G754 devices on the bus acknowledge and wait for the next byte of data to be written to the addressed registers. When the data byte is received by the G754 devices, they store and acknowledge the transmitted byte. The G754's store the same data on all devices on the bus in one transaction; see Figure 3.

Table 2. Pointer Addresses

P1	P0	REGISTER
0	0	Temperature Register (Read Only)
0	1	Configuration Register (Read/Write)
1	0	T_{LOW} Register (Read/Write)
1	1	T_{HIGH} Register (Read/Write)

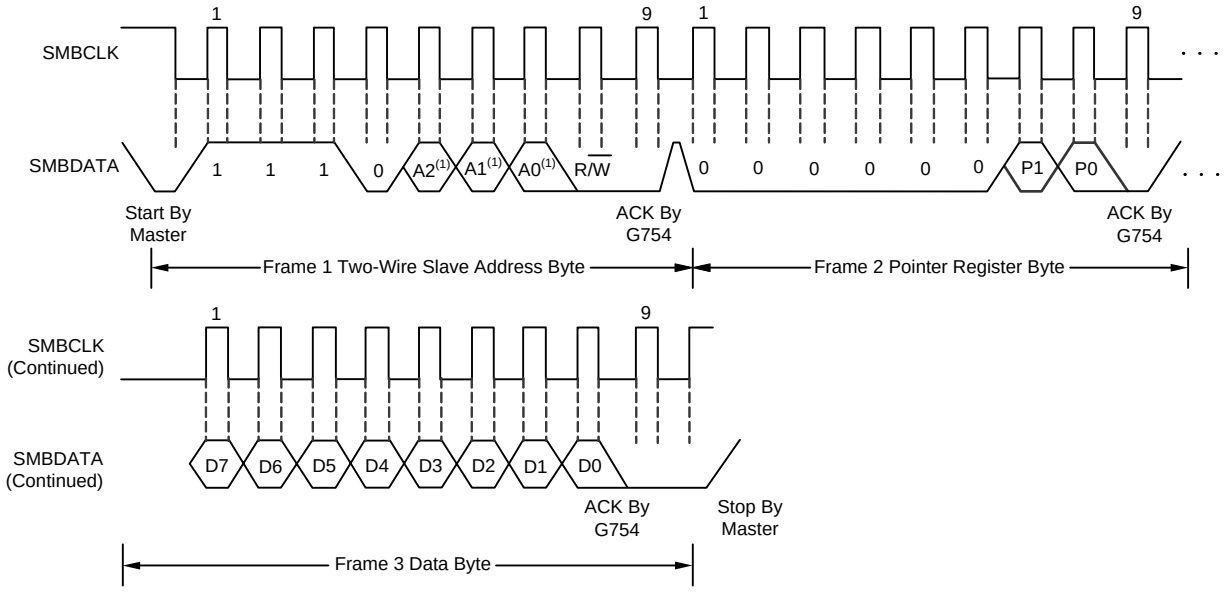
Multiple Device Access Read

Note that before an MDA read transaction can begin, the master must first send an MDA write transaction in order to set the appropriate pointer address of the register to be accessed, as stated in the previous section. The master can then transmit an MDA read address followed by a read byte for each G754 used on the bus. For example, if a G754A and G754B are used on the same bus and an MDA read address is sent, the address must be followed by two bytes of data and two master acknowledges.

The G754A sends data on the first byte and the G754B sends data on the second byte. The master must issue an acknowledge for each byte read in order to read all of the G754 devices on the bus; see Figure 4. If the master does not acknowledge each byte of data, the G754s stop sending subsequent data for any remaining devices.

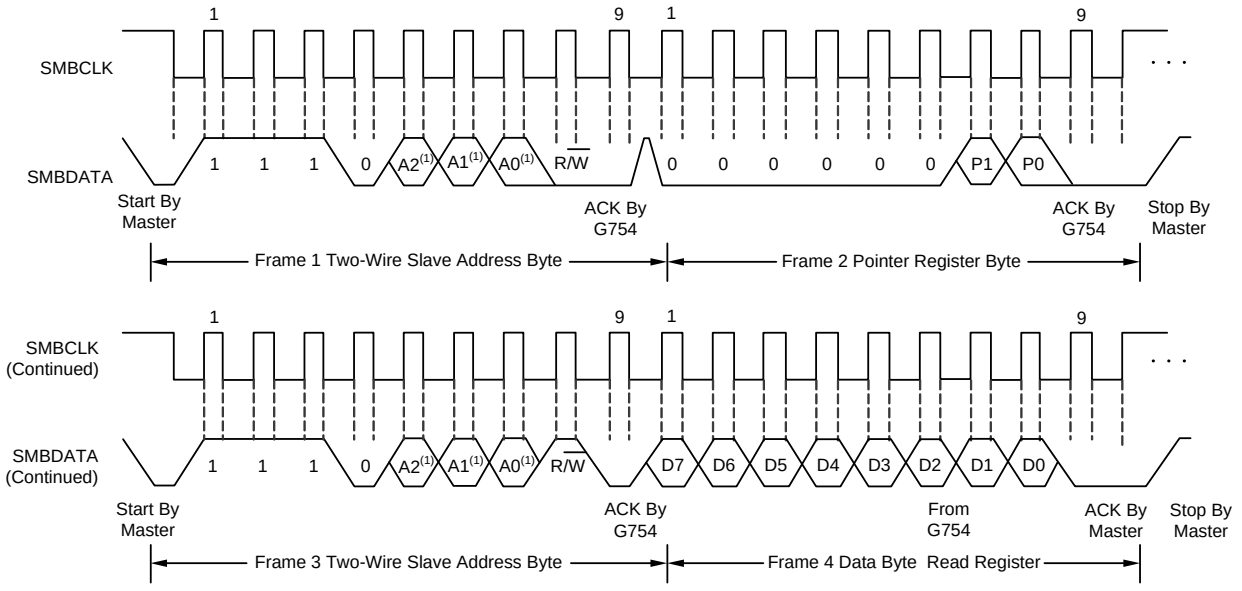
Up to eight G754 devices can be on the same bus and respond to MDA commands; see Table 1.

NOTE: If the bus contains an incomplete sequence of G754 device addresses, the master must transmit all required dummy bytes for the missing device address to allow for normal MDA read operation. For example, if the G754A, G754B, and G754D devices are on the bus, the master must transmit an MDA read address followed by four bytes and four acknowledges in order to complete the MDA read transaction.



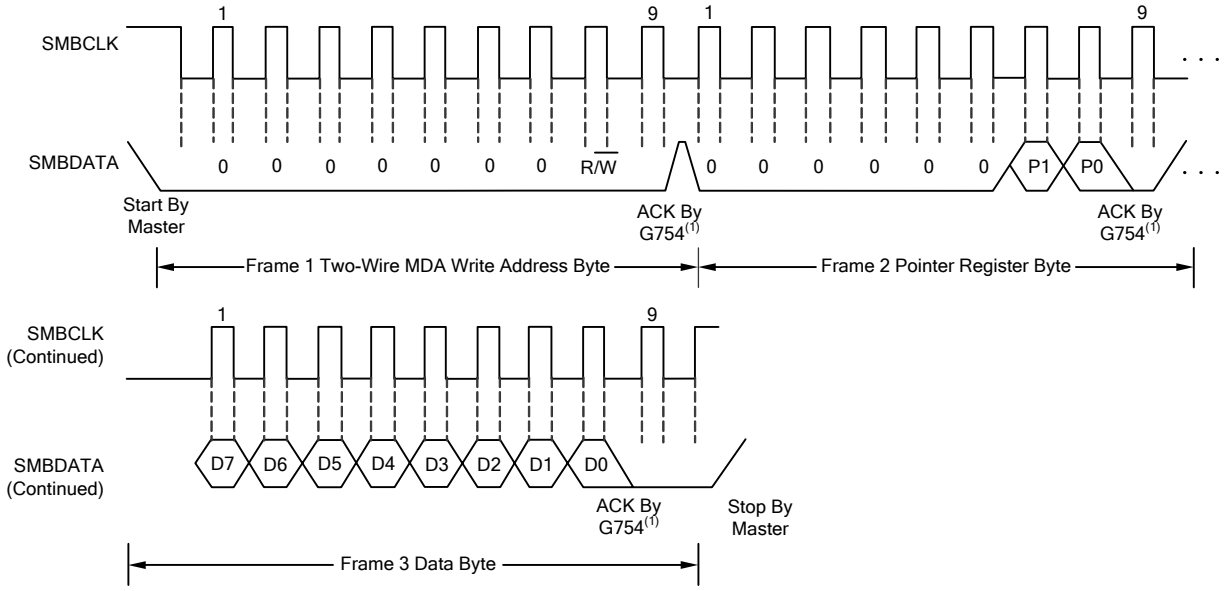
(1) The value of A0, A1 and A2 are determined by the G754 version; see Table 1.

(**Figure 1. Two-Wire Timing Diagram for Write Word Format**



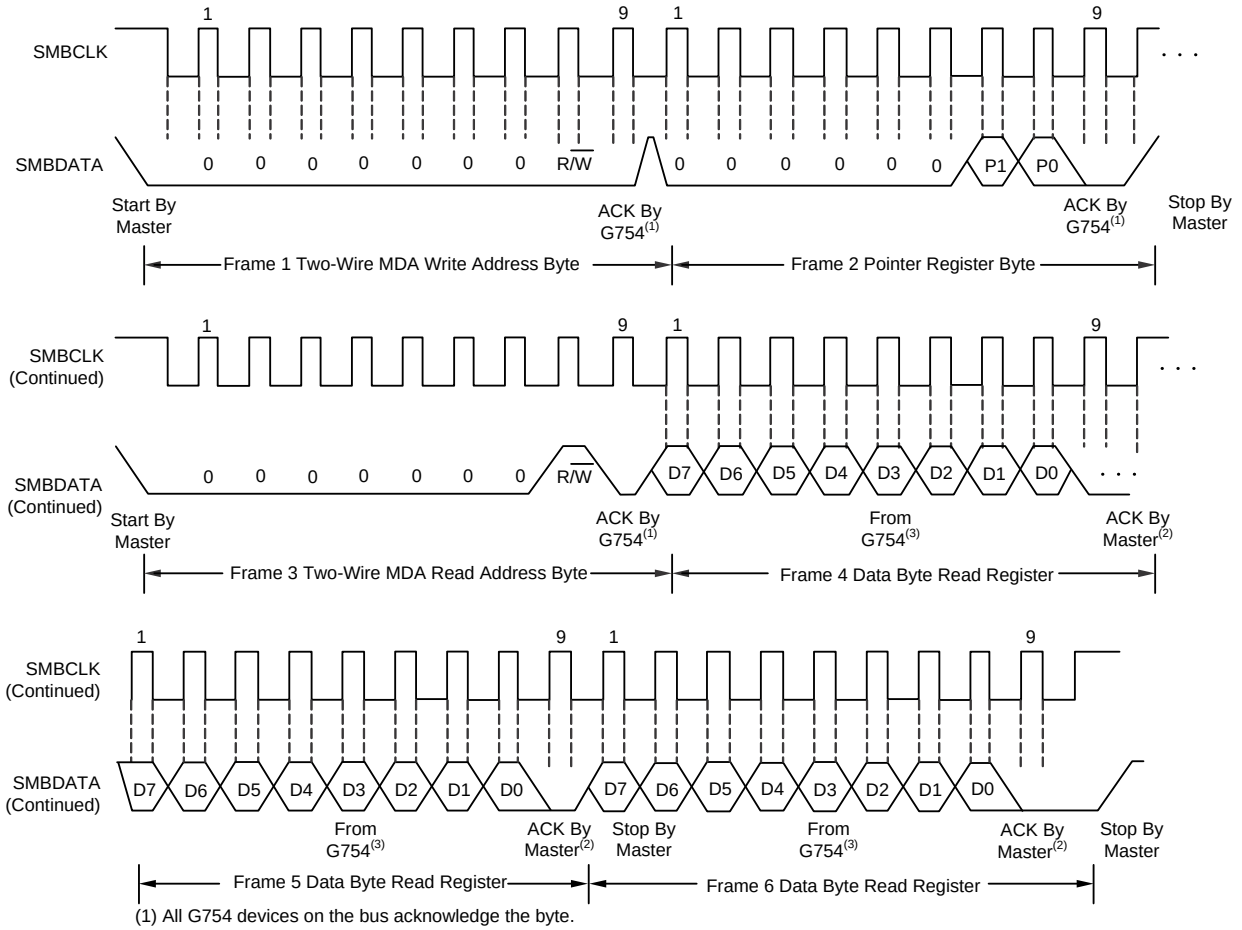
(1) The value of A0, A1 and A2 are determined by the G754 version; see Table 1.

Figure 2. Two-Wire Timing Diagram for Read Word Format



(1) All G754 devices on the bus acknowledge the byte.

Figure 3. Two-Wire Timing Diagram MDA Write Word Format



(1) All G754 devices on the bus acknowledge the byte.
(2) The master must issue an acknowledge for each byte read in order to read all of the G754 devices on the bus.
(3) Three G754 devices used in this case; up to eight devices can be used (see Table 1).

Figure 4. Two-Wire Timing Diagram MDA Read Word Format Using Typical Application (Front Page)

Table 3. Temperature Data Format (Two's-Complement)

TEMP (°C)	SIGN	MSB	LSB
+127	0	111	1111
+25	0	001	1001
+1	0	000	0001
-1.	1	111	1111
-25	1	110	0111
-65	1	011	1111

The temperature data format is 8bits plus sign in twos-complement form, transmitted MSB first.

REGISTER	COMMAND	POR STATE	FUNCTINON
LT	00h	0000 0000*	Temperature Register (Read Only)
CONFIG	01h	0000 0010	Configuration Register (Read/Write)
TLOW	02h	1111 0110	TLOW Register (Read/Write)
THIGH	03h	0011 1100	THIGH Register (Read/Write)

Configuration Register

The Configuration Register is an eight-bit read/write register used to store bits that control the operational modes of the temperature sensor. Read/write operations are performed MSB first. The format and power-up/reset value of the Configuration Register is shown in Table 4. All registers are updated at the end of the data byte.

Table 4. Configuration and Power-Up/Reset Format

D7	D6	D5	D4	D3	D2	D1	D0
ID	CR1	CR0	FH	FL	LC	M1	M0
0	0	0	0	0	0	1	0

Temperature Watchdog Function

The G754 contains a watchdog function that monitors device temperature and compares the result to the values stored in the temperature limit registers (T_{HIGH} and T_{LOW}) in order to determine if the device temperature is within these set limits. If the temperature of the G754 becomes greater than the value in the T_{HIGH} register, then the flag-high bit (FH) in the configuration register is set to '1'. If the temperature falls below value in the T_{LOW} register, then the flag-low bit (FL) is set to '1'. If both flag bits remain '0', then the temperature is within the temperature window set by the temperature limit registers, as shown in Figure 5.

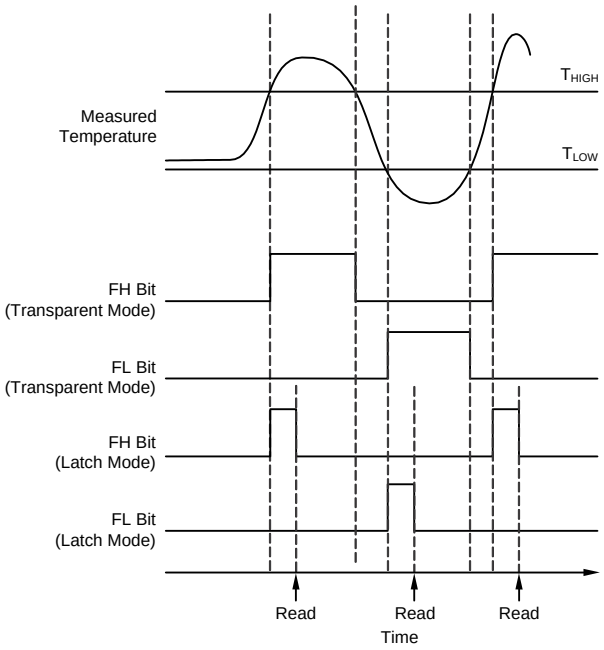


Figure 5. Temperature Flag Functional Diagram

The latch bit (LC) in the configuration register is used to latch the value of the flag bits (FH and FL) until the master issues a read command to the configuration register. The flag bits are set to '0' if a read command is received by the G754, or if LC='0' and the temperature is within the temperature limits. The power-on default values for these bits are FH='0', FL='0', and LC='0'.

Conversion Rate

The conversion rate bits, CR1and CR0 located in the Configuration Register, configure the G754 for conversion rates of 8Hz, 4Hz, 1Hz, or 0.25Hz (default). The G754 has a typical conversion time of 26ms. To achieve different conversion rates, the G754 performs a single conversion and then powers down and waits for the appropriate delay set by CR1 and CR0. Table 5 shows the settings for CR1 and CR0.

Table 5. Conversion Rate Settings

CR1	CR0	CONVERSION RATE
0	0	0.25Hz (default)
0	1	1Hz
1	0	4Hz
1	1	8Hz

Shutdown Mode (M1='0', M0='0')

Shutdown mode saves maximum power by shutting down all device circuitry other than the serial interface, reducing current consumption to typically less than 0.5μA. Shutdown mode is enabled when bits M1 and M0 (in the Configuration Register)='00'. The device shuts down when the current conversion is completed.

One-Shot (M1='0', M0='1')

The G754 features a Ono-Shot Temperature Measurement mode. When the device is in Shutdown mode, writing a '01' to bits M1 and M0 starts a single temperature conversion. During the conversion, bits M1 and M0 read '01'. The device returns to the shutdown state at the completion of the single conversion. After the conversion, bits M1 and M0 read '00'. This feature is useful for reducing power consumption in the G754 when continuous temperature monitoring is not required.

As a result of the short conversion time, the G754 can achieve a higher conversion rate. A single conversion typically takes 26ms and a read can take place in less than 20μs. When using One-Shot mode, 30 or more conversions per second are possible.

Continuous Conversion Mode (M1 = '1')

When the G754 is in Continuous Conversion mode (m1='1'), a single conversion is performed at a rate determined by the conversion rate bits, CR1 and CR0 (in the Configuration Register). The G754 performs a single conversion and then powers down and waits for the appropriate delay set by CR1 and CR0. see Table 6 for CR1 and CR0 settings.

Temperature Limit Registers

The T_{HIGH} and T_{LOW} registers are used to store the temperature limit thresholds for the G754 watchdog function. At the end of each temperature measurement, the G754 compares the temperature results to each of these limits. If the temperature result is greater than the T_{HIGH} limit, then the FH bit in the configuration register is set to '1'. If the temperature result is less than the T_{LOW} limit, then the FL bit in the configuration register is set to '1'; see Figure 5.

Table 6 and Table 7 describe the format for the T_{HIGH} and T_{LOW} registers. Power-up reset values for T_{HIGH} and T_{LOW} are: T_{HIGH}=+60°C and T_{LOW}=-10°C . The format of the data for T_{HIGH} and T_{LOW} is the same as for the Temperature Register.

Table 6. T_{HIGH} Register

D7	D6	D5	D4	D3	D2	D1	D0
H7	H6	H5	H4	H3	H2	H1	H0

Table 7. T_{LOW} Register

D7	D6	D5	D4	D3	D2	D1	D0
L7	L6	L5	L4	L3	L2	L1	L0

Bus Overview

The device that initiates the transfer is called a *master*, and the devices controlled by the master are *slaves*. The bus must be controlled by a master device that generates the serial clock (SMBCLK), controls the bus access, and generates the START and STOP conditions.

To address a specific device, a START condition is initiated, indicated by pulling the data line (SMBDATA) from a high to low logic level while SMBCLK is high. All slaves on the bus shift in the slave address byte on the rising edge of the clock, with the last bit indicating whether a read or write operation is intended. During the ninth clock pulse, the slave being addressed responds to the master by generating an Acknowledge and pulling SMBDATA low.

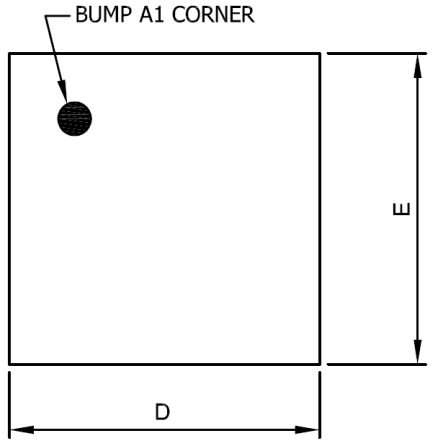
Data transfer is then initiated and sent over eight clock pulses followed by an Acknowledge Bit. During data transfer, SMBDATA must remain stable while SMBCLK is high, because any change in SMBDATA while SMBCLK is high is interpreted as a START or STOP signal.

Once all data have been transferred, the master generates a STOP condition indicated by pulling SMBDATA from low to high , while SMBCLK is high.

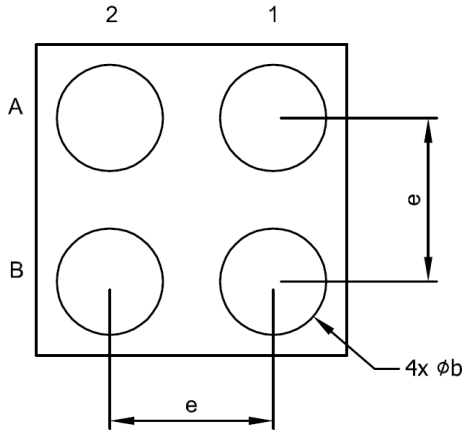
Serial Interface

The G754 operates as a slave device only on the two-wire bus and SMBus. Connections to the bus are made via the open-drain I/O lines SMBDATA and SMBCLK. The SMBDATA and SMBCLK pins feature integrated spike suppression filters and Schmitt triggers to minimize the effects of input spikes and bus noise. The G754 Supports the transmission protocol for both fast (1kHz to 400kHz) and high-speed (1kHz to 3.4MHz) modes. All data bytes are transmitted MSB first.

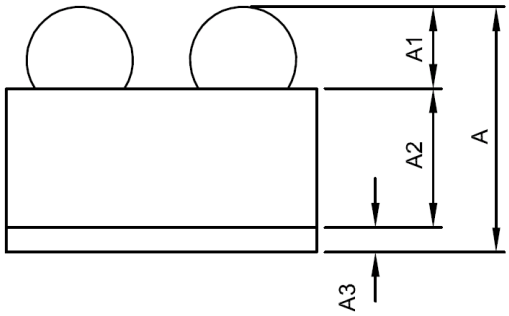
Package Information



Top View



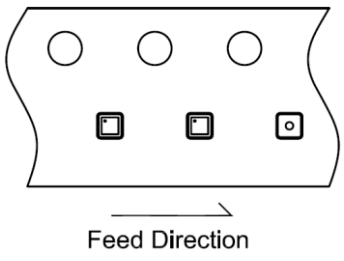
Bottom View



WLCSP2X2-4 Package

Symbol	DIMENSION IN MM			DIMENSION IN INCH		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.540	0.600	0.660	0.0213	0.0236	0.0260
A1	0.170	0.200	0.230	0.0067	0.0079	0.0091
A2	0.350	0.375	0.400	0.0138	0.0148	0.0157
A3	0.020	0.025	0.030	0.0008	0.0010	0.0012
D	0.720	0.760	0.800	0.0283	0.0299	0.0315
E	0.720	0.760	0.800	0.0283	0.0299	0.0315
b	0.230	0.260	0.290	0.0091	0.0102	0.0114
e	0.40 BSC			0.0157 BSC		

Taping Specification



PACKAGE	Q'TY/REEL
WLCSP2X2-4 (400)	3,000 ea