SGM451
±1℃ Local and Remote Temperature Sensor with η-Factor and Offset Correction, Series-Resistance Cancellation, and Programmable Digital Filter

GENERAL DESCRIPTION

The SGM451 device is a high-accuracy, low-power temperature sensor which integrates local and remote temperature channels. The remote temperature sensors connected with SGM451 are typically low-cost discrete NPN or PNP transistors, or substrate thermal transistors or diodes that are integral parts of microprocessors, microcontrollers, or FPGAs. The temperature is represented as a 12-bit digital code for both the local and remote sensors, giving a resolution of 0.0625℃. This device can measure the temperature of the local and remote diode sensors with an accuracy of ±0.5℃ (TYP).

Communication with the SGM451 is accomplished via the two-wire serial interface which is compatible with the SMBus communication protocol. Through this interface the SGM451 internal registers may be accessed.

The SGM451 has advanced features such as series resistance cancellation, programmable non-ideality factor (η-factor), programmable offset, programmable temperature limits, and a programmable digital filter are combined to provide a robust thermal monitoring solution with improved accuracy and noise immunity.

The SGM451 device is ideal for high-accuracy temperature measurements in multiple locations in application system. It also operates over a supply voltage range from 3.0V to 5.5V making it possible to use it in a wide range of applications including low power devices. The device operates over a wide temperature range of -40℃ to +125℃.

FEATURES

- **Local and Remote Diode Sensors Accuracy: ±0.5℃ (TYP)**
- **Local and Remote Channels Resolution: 0.0625℃**
- **Supply and Logic Voltage Range: 3.0V to 5.5V**
- **Operating Current: 16μA (TYP)**
- **Shutdown Current: 0.5μA (TYP)**
- **Series Resistance Cancellation**
- **η-Factor and Offset Correction**
- **Programmable Digital Filter**
- **Diode Fault Detection**
- **Two-Wire and SMBus Serial Interface**
- **Available in a Green TDFN-2×2-8BL Package**

APPLICATIONS

CPU, GPU, DSP and FPGA Computing System
Smart Phones and Tablets
Servers, Desktops and Notebooks
Telecom Equipment
Storage Area Networks (SANs)

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM451	TDFN-2×2-8BL	-40℃ to +125℃	SGM451XTEA8G/TR	451 XXXX	Tape and Reel, 3000

MARKING INFORMATION

NOTE: XXXX = Date Code and Trace Code.

X XXX
- Trace Code
- Date Code - Year

Green (RoHS & HSF): SG Micro Corp defines "Green" to mean Pb-Free (RoHS compatible) and free of halogen substances. If you have additional comments or questions, please contact your SGMICRO representative directly.

ABSOLUTE MAXIMUM RATINGS

Power Supply, V_{CC} .... -0.3V to 5.5V
Input Voltage
nTHERM, nALERT/nTHERM2, SDA and SCL .. -0.3V to 5.5V
D+ Only .... -0.3V to V_{CC} + 0.3V
D- Only .... -0.3V to 0.3V
Input Current 10mA
Junction Temperature .... +150℃
Storage Temperature Range .... -65℃ to +150℃
Lead Temperature (Soldering, 10s) .... +260℃

RECOMMENDED OPERATING CONDITIONS

Supply Voltage Range .... 3.0V to 5.5V
Operating Temperature Range .... -40℃ to +125℃

OVERSTRESS CAUTION

Stresses beyond those listed in Absolute Maximum Ratings may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect reliability. Functional operation of the device at any conditions beyond those indicated in the Recommended Operating Conditions section is not implied.

ESD SENSITIVITY CAUTION

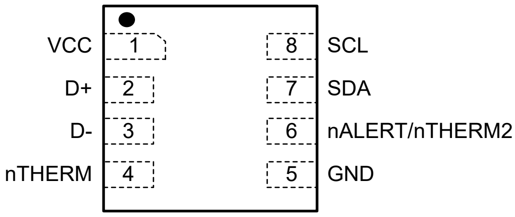
This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because even small parametric changes could cause the device not to meet the published specifications.

DISCLAIMER

SG Micro Corp reserves the right to make any change in circuit design, or specifications without prior notice.

PIN CONFIGURATION

(TOP VIEW)



TDFN-2×2-8BL

PIN DESCRIPTION

PIN	NAME	TYPE	DESCRIPTION
1	VCC	P	Positive Supply Voltage, 3.0V to 5.5V.
2	D+	AI	Positive Connection to Remote Temperature Sensor.
3	D-	AI	Negative Connection to Remote Temperature Sensor.
4	nTHERM	DO	Thermal Shutdown or Fan-Control Pin. Open-drain; requires an external pull-up resistor to voltage between 3.0V and 5.5V.
5	GND	G	Supply Ground Connection.
6	nALERT/nTHERM2	DO	Interrupt or SMBus Alert Output. Can be configured as a second nTHERM output. Open-drain; requires an external pull-up resistor to voltage between 3.0V and 5.5V.
7	SDA	I/O	Serial Data Line for SMBus. Open-drain; requires an external pull-up resistor to voltage between 3.0V and 5.5V.
8	SCL	DI	Serial Clock Line for SMBus. Input; requires an external pull-up resistor to voltage between 3.0V and 5.5V if driven by open-drain output.

ELECTRICAL CHARACTERISTICS

(V_{CC} = 3.3V, typical values are at T_A = +25℃, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Temperature Error					
Local Temperature Sensor (TE_{LOCAL})	T_A = 0℃ to +70℃		±0.5		℃
	T_A = -40℃ to +125℃		±1		℃
Remote Temperature Sensor (TE_{REMOTE})	T_A = 0℃ to +70℃, T_D = -55℃ to +150℃		±1		℃
	T_A = -40℃ to +100℃, T_D = -55℃ to +150℃		±1.5		℃
	T_A = -40℃ to +125℃, T_D = -55℃ to +150℃		±2		℃
Remote Temperature Sensor vs. Supply (Local or Remote)	V_{CC} = 3.0V to 5.5V		±0.05		℃/V
Temperature Measurement					
Conversion Time	One-Shot mode, local and remote total		32		ms
Local Temperature Sensor Resolution			12		Bits
Remote Temperature Sensor Resolution			12		Bits
Remote Sensor Source Current, High	Series resistance 1kΩ max		120		μA
Remote Sensor Source Current, Medium			45		μA
Remote Sensor Source Current, Low			7.5		μA
Remote Transistor Ideality Factor (η)	SGM451 optimized ideality factor		1.008		
SMBus Interface					
High-Level Input Voltage (V_{IH})			1.4		V
Low-Level Input Voltage (V_{IL})			0.5		V
Hysteresis			120		mV
SMBus Output Low Sink Current		6			mA
Low-Level Output Voltage (V_{OL})	I_{OUT} = 6mA		0.15		V
Logic Input Current	0V ≤ V_I ≤ 5.0V		0.005		μA
SMBus Input Capacitance			3		pF
SMBus Clock Frequency		0.01		2.5	MHz
SMBus Time-Out			25		ms
Digital Outputs (nTHERM and nALERT/nTHERM2)					
Low-Level Output Voltage (V_{OL})	I_O = 6mA		0.15		V
High-Level Output Leakage Current (I_{OH})	V_O = V_{CC}		0.005		μA
Power Supply					
Specified Voltage Range (V_{CC})		3.0		5.5	V
Quiescent Current (I_Q)	0.0625 conversions per second		16		μA
	16 conversions per second		100		μA
	32 conversions per second		180		μA
	Serial bus inactive, shutdown mode		0.5		μA
Power-On Reset Threshold (V_{POR})			2.8		V

TIMING REQUIREMENTS

PARAMETER	SYMBOL	FAST MODE			HIGH-SPEED MODE			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
SCL Operating Frequency	f_{SCL}	0.001	0.4		0.001		2.5	MHz
Bus Free Time between STOP and START Condition	t_{BUF}	1300			260			ns
Hold Time after Repeated START Condition (After this period, the first clock is generated.)	t_{HDSTA}	600			160			ns
Repeated START Condition Setup Time	t_{SUSTA}	600			160			ns
STOP Condition Setup Time	t_{SUSTO}	600			160			ns
Data Hold Time	t_{HDDAT}	0		900	0		150	ns
Data Setup Time	t_{SUDAT}	100			30			ns
SCL Clock Low Period	t_{LOW}	1300			260			ns
SCL Clock High Period	t_{HIGH}	600			60			ns
Data Fall and Rise Time	t_F, t_R (SDA)			300			80	ns
Clock Fall and Rise Time	t_F, t_R (SCL)			300			40	ns
Rise Time for SCL ≤ 100kHz	t_R			1000				ns

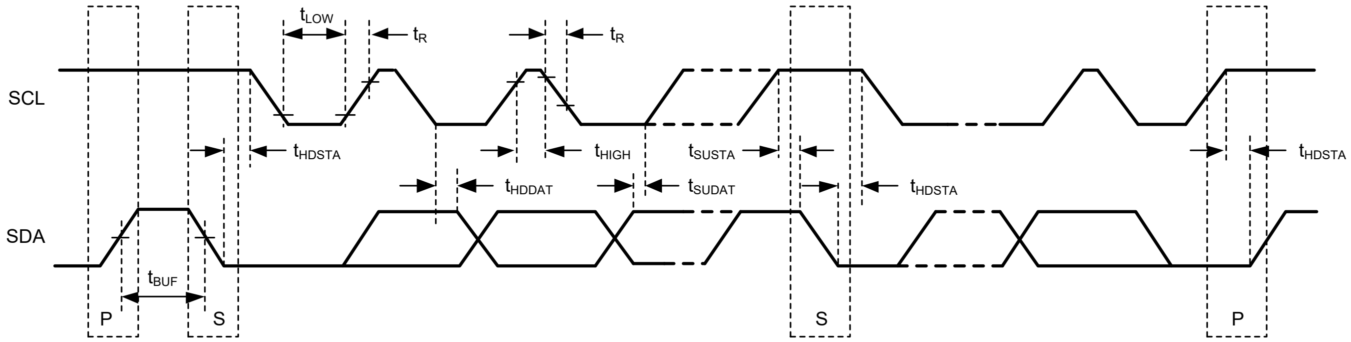


Figure 1. Two-Wire Timing Diagram

TYPICAL APPLICATION

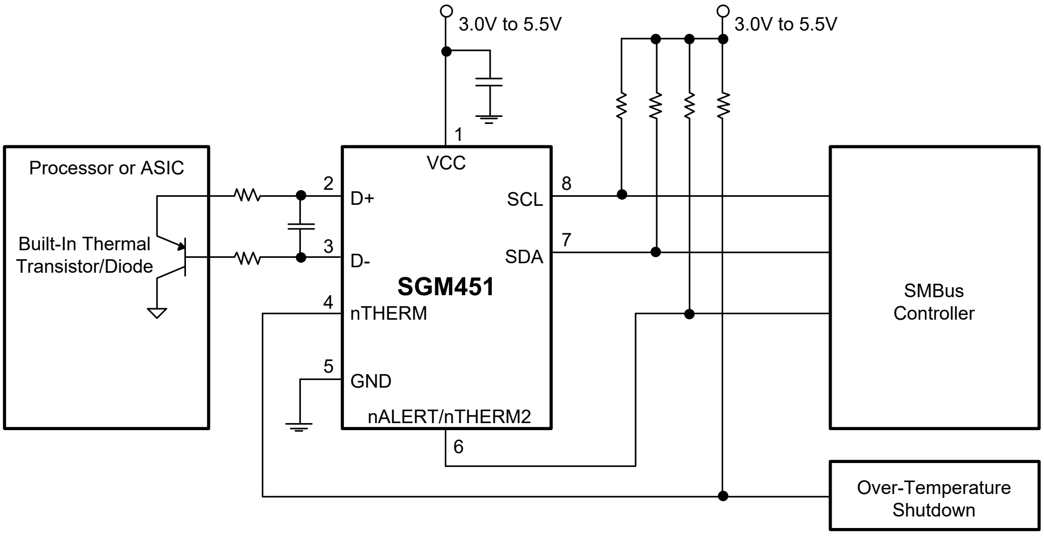


Figure 2. Typical Application Circuit

FUNCTIONAL BLOCK DIAGRAM

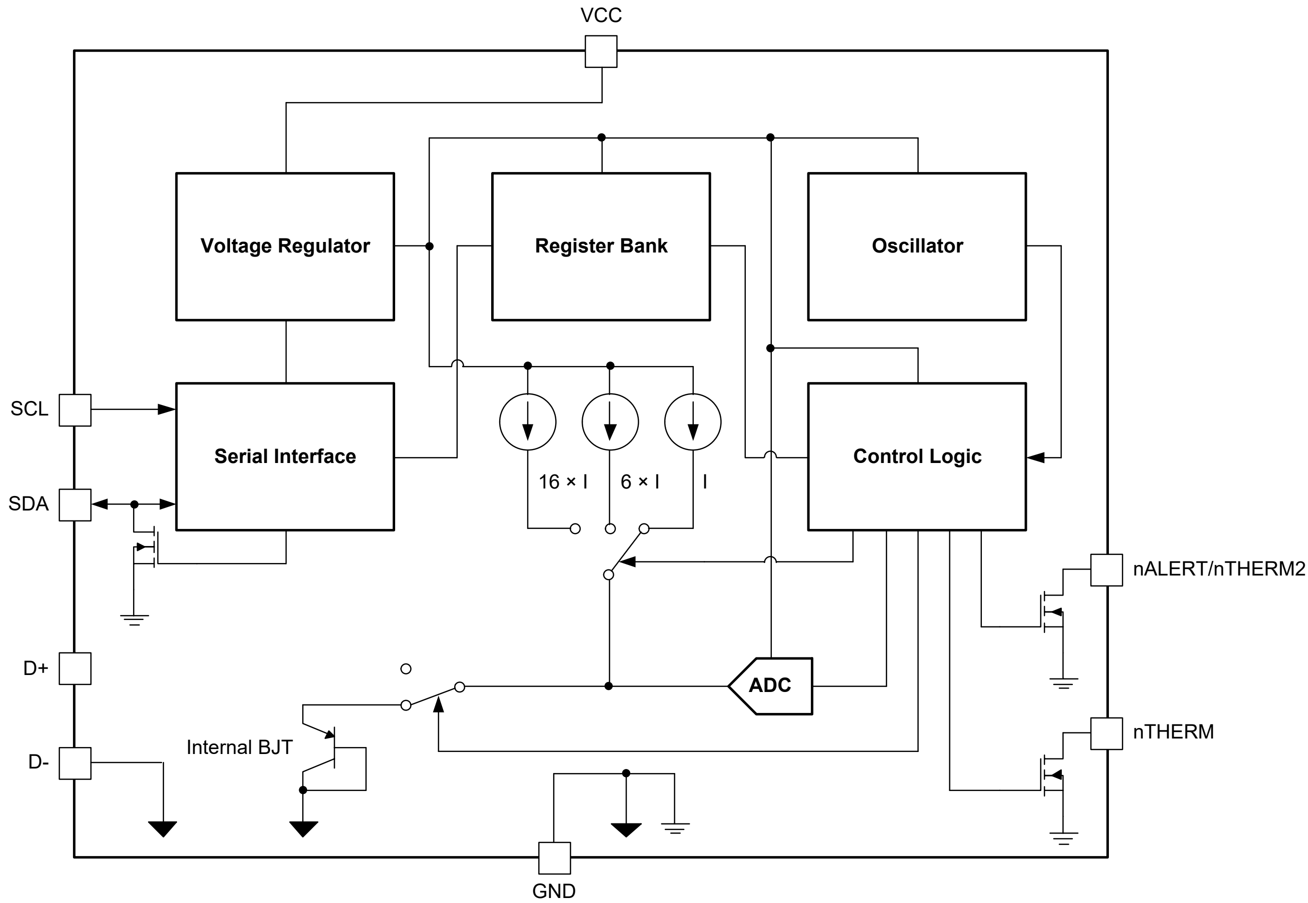


Figure 3. Block Diagram

DETAILED DESCRIPTION

Temperature Measurement Data

The local and remote temperature sensors have a resolution of 12 bits (0.0625℃). Temperature data that result from conversions within the default measurement range are represented in binary form, as shown in the Standard Binary column of Table 1. Any temperature below 0℃ results in a data value of 0 (00h). Likewise, temperatures above +127℃ result in a data value of 127 (7Fh). The device can be set to measure over an extended temperature range by changing RANGE bit of configuration register from low to high. The change in measurement range and data format from standard binary to extended binary occurs at the next temperature conversion. For data captured in the extended temperature range configuration, an offset of 64 (40h) is added to the standard binary value, as shown in the Extended Binary column of Table 1. This configuration allows measurement of temperatures as low as -64℃, and as high as +191℃; however, most temperature-sensing diodes only measure with the range of -55℃ to +150℃. Additionally, the SGM451 device is specified only for ambient temperatures range from -40℃ to +125℃; parameters in the Absolute Maximum Ratings must be observed.

Both local and remote temperature data use two bytes for data storage. The high-byte value stores the temperature with 1℃ resolution. The second or low-byte stores the decimal fraction value of the temperature and allows a higher measurement resolution, as shown in Table 2. The measurement resolution of the local and remote channels are both 0.0625℃.

Table 1. Temperature Data Format (Local and Remote Temperature High Bytes)

Temperature (℃)	Local and Remote Temperature Register High-Byte Value (1℃ Resolution)			
	Standard Binary [(1)]		Extended Binary [(2)]	
	Binary	Hex	Binary	Hex
-64	00000000	00	00000000	00
-50	00000000	00	00001110	0E
-25	00000000	00	00100111	27
0	00000000	00	01000000	40
1	00000001	01	01000001	41
5	00000101	05	01000101	45
10	00001010	0A	01001010	4A
25	00011001	19	01011001	59
50	00110010	32	01110010	72
75	01001011	4B	10001011	8B
100	01100100	64	10100100	A4
125	01111101	7D	10111101	BD
127	01111111	7F	10111111	BF
150	01111111	7F	11010110	D6
175	01111111	7F	11101111	EF
191	01111111	7F	11111111	FF

NOTES:
1. Resolution is 1℃/count. Negative values produce a read of 0℃.
2. Resolution is 1℃/count. All values are unsigned with a -64℃ offset.

DETAILED DESCRIPTION (continued)

Table 2. Decimal Fraction Temperature Data Format (Local and Remote Temperature Low Bytes)

Temperature (℃)	Local and Remote Temperature Register Low-Byte Value (0.0625℃ Resolution)	
	Standard and Extended Binary (1)	Hex
0	00000000	00
0.0625	00010000	10
0.1250	00100000	20
0.1875	00110000	30
0.2500	01000000	40
0.3125	01010000	50
0.3750	01100000	60
0.4375	01110000	70
0.5000	10000000	80
0.5625	10010000	90
0.6250	10100000	A0
0.6875	10110000	B0
0.7500	11000000	C0
0.8125	11010000	D0
0.8750	11100000	E0
0.9375	11110000	F0

NOTE:
1. Resolution is 0.0625℃/count. All possible values are shown.

Standard Binary-to-Decimal Temperature Data Calculation Example

- High-byte conversion (for example, 01110011):
  Convert the right-justified binary high-byte to hexadecimal.
  From hexadecimal, multiply the first number by $16^0 = 1$ and the second number by $16^1 = 16$.
  The sum equals the decimal equivalent.
  01110011 → 73h → $(3 \times 16^0) + (7 \times 16^1) = 115$

- Low-byte conversion (for example, 01110000):
  Convert the left-justified binary low-byte to decimal, use bits D[7:4] and ignore bits D[3:0] because they do not affect the value of the number.
  The sum equals the decimal equivalent.
  0111 → $(0 \times 1/2)^1 + (1 \times 1/2)^2 + (1 \times 1/2)^3 + (1 \times 1/2)^4 = 0.4375$

Standard Decimal-to-Binary Temperature Data Calculation Example

- For positive temperatures (for example, 20℃):
  (20℃)/(1℃/count) = 20 → 14h → 00010100
  Convert the number to binary code with 8-bit, right-justified format, and MSB = 0 to denote a positive sign.
  20℃ is stored as 00010100 → 14h.

- For negative temperatures (for example, -20℃):
  (|-20|)/(1℃/count) = 20 → 14h → 00010100
  Generate the two's complement of a negative number by complementing the absolute value binary number and adding 1.
  -20℃ is stored as 11101100 → ECh.

DETAILED DESCRIPTION (continued)

Series Resistance Cancellation

Series resistance cancellation automatically eliminates the temperature error caused by the resistance of the routing to the remote transistor or by the resistors of the optional external low-pass filter. A total of up to 1kΩ of series resistance can be cancelled by the SGM451 device, eliminating the need for additional characterization and temperature offset correction.

Differential Input Capacitance

The SGM451 tolerates differential input capacitance of up to 1000pF with minimal change in temperature error.

Filtering

Remote junction temperature sensors are usually implemented in a noisy environment. Noise is most often created by fast digital signals, and it can corrupt measurements. The SGM451 device has a built-in, 65kHz filter on the inputs of D+ and D- to minimize the effects of noise. However, a bypass capacitor placed differentially across the inputs of the remote temperature sensor is recommended to make the application more robust against unwanted coupled signals. For this capacitor, select a value of between 100pF and 1nF. Some applications attain better overall accuracy with additional series resistance; however, this increased accuracy is application specific. When series resistance is added, the total value should not be greater than 1kΩ. If filtering is required, suggested component values are 100pF and 50Ω on each input; exact values are application specific.

Additionally, a digital filter is available for the remote temperature measurements to further reduce the effect of noise. This filter is programmable and has two levels when enabled. Level 1 performs a moving average of four consecutive samples. Level 2 performs a moving average of eight consecutive samples. The value stored in the remote temperature register is the output of the digital filter, and the nALERT and nTHERM limits are compared to it. This provides additional immunity to noise and spikes on the nALERT and nTHERM outputs. The filter responses are shown in Figure 4. The filter can be enabled or disabled by programming the desired levels in the digital filter control register. The digital filter is disabled by default and on POR.

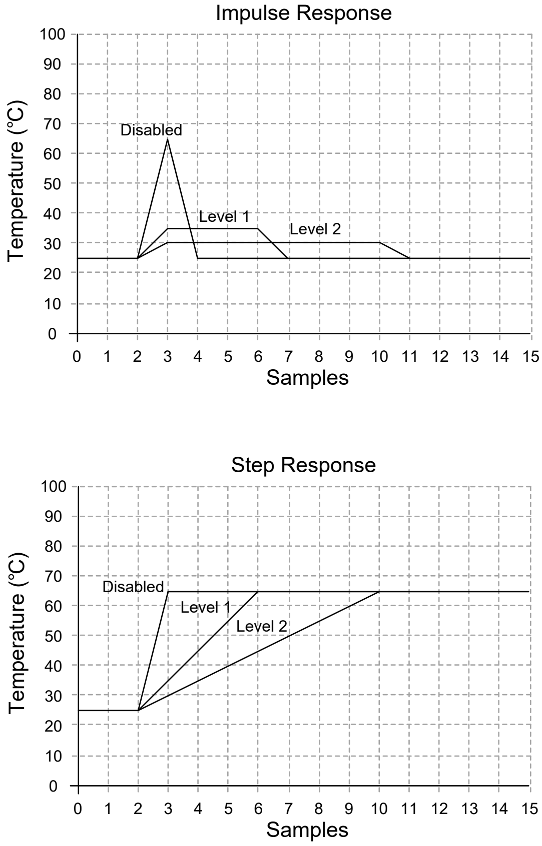


Figure 4. Filter Response to Impulse and Step Inputs

Sensor Fault

The SGM451 device can sense a fault at the D+ input resulting from incorrect diode connection. The SGM451 device can also sense an open circuit. Short-circuit conditions return a value of -64℃. The detection circuitry consists of a voltage comparator that trips when the voltage at D+ exceeds V_{CC} - 0.3V (TYP). The comparator output is continuously checked during a conversion. If a fault is detected, then OPEN bit in the status register is set to 1.

When not using the remote sensor with the SGM451 device, the D+ and D- inputs must be connected together to prevent meaningless fault warnings.

DETAILED DESCRIPTION (continued)

nALERT and nTHERM Functions

The operation of the nALERT (pin 6) and nTHERM (pin 4) interrupts is shown in Figure 5. The operation of the nTHERM (pin 4) and nTHERM2 (pin 6) interrupts is shown in Figure 6.

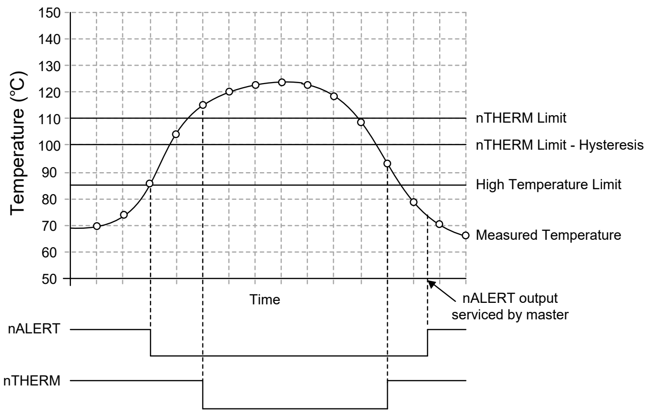


Figure 5. nALERT and nTHERM Interrupt Operation

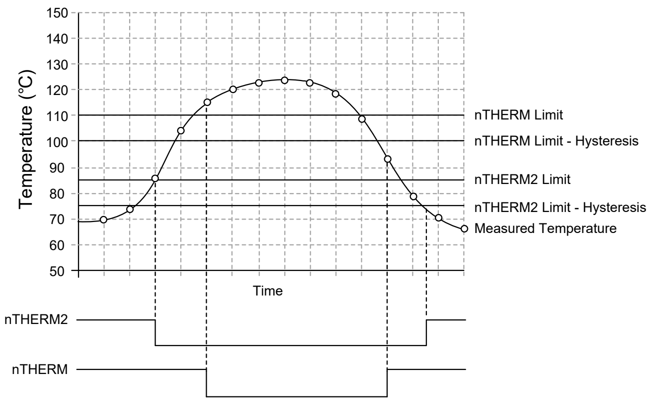


Figure 6. nTHERM and nTHERM2 Interrupt Operation

The hysteresis value is stored in the nTHERM hysteresis register. The value of the CONAL[2:0] bits in the consecutive nALERT register determines the number of limit violations before the nALERT pin is tripped. The default value is 000 and corresponds to one violation, 001 programs two consecutive violations, 011 programs three consecutive violations, and 111 programs four consecutive violations. This provides additional filtering for the nALERT pin state.

Device Functional Modes

Shutdown Mode (SD)

The SGM451 shutdown mode enables the user to save maximum power by shutting down all device circuitry other than the serial interface, reducing current consumption to typically 0.5μA. Shutdown mode is enabled when the SD bit (bit 6) of the configuration register is high; the device shuts down after the current conversion is finished. When the SD bit is low, the device maintains a continuous-conversion state.

One-Shot Mode

When the SGM451 device is in shutdown mode (SD = 1 in the configuration register), a single conversion is started by writing any value to the one-shot start register, pointer address 0Fh. This write operation starts one conversion and comparison cycle on both the local and the remote sensors. The SGM451 device returns to shutdown mode when the cycle completes. The value of the data sent in the write command is irrelevant and is not stored by the SGM451 device.

Programming

Serial Interface

The SGM451 device operates only as a slave device on either the two-wire bus or the SMBus. Connections to either bus are made using the open-drain I/O lines, SDA and SCL. The SDA and SCL pins feature integrated spike suppression filters and Schmitt triggers to minimize the effects of input spikes and bus noise. The SGM451 device supports the transmission protocol for fast (1kHz to 400kHz) and high-speed (1kHz to 2.5MHz) modes. All data bytes are transmitted MSB first.

Bus Overview

The SGM451 device is SMBus interface compatible. In SMBus protocol, 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 (SCL), controls the bus access, and generates the START and STOP conditions.

DETAILED DESCRIPTION (continued)

To address a specific device, a START condition is initiated. A START condition is indicated by pulling the data line (SDA) from a high-to-low logic level while SCL is high. All slaves on the bus shift in the slave address byte, 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 bit and pulling SDA low.

Data transfer is then initiated and sent over eight clock pulses followed by an acknowledge bit. During data transfer SDA must remain stable while SCL is high, because any change in SDA while SCL is high is interpreted as a control signal.

After all data have been transferred, the master generates a STOP condition. A STOP condition is indicated by pulling SDA from low to high, while SCL is high.

Bus Definitions

The SGM451 device is two-wire and SMBus-compatible. Figure 7 and Figure 8 show the timing for various operations on the SGM451 device. The bus definitions are as follows:

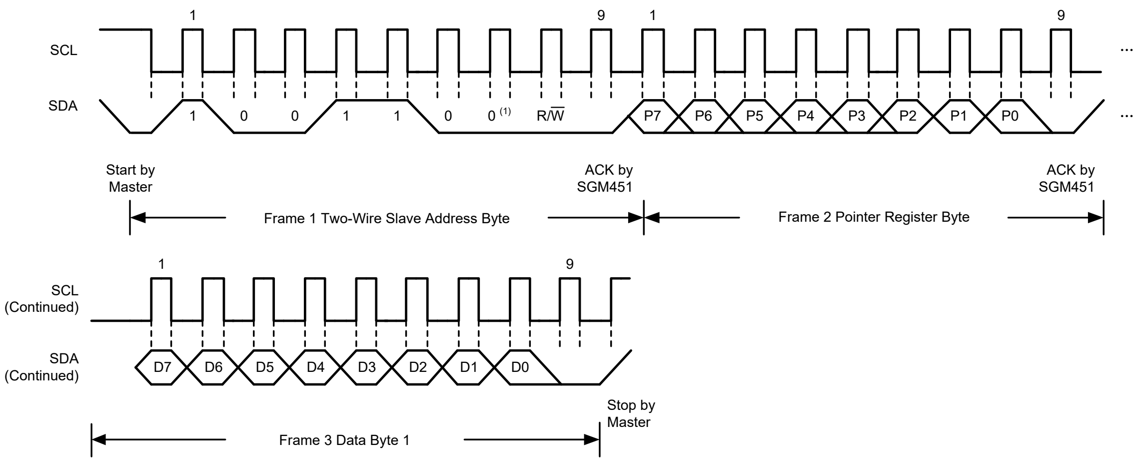
Acknowledge: Each receiving device, when addressed, is obliged to generate an acknowledge bit. A device that acknowledges must pull down the SDA line during the acknowledge clock pulse in such a way that the SDA line is stable low during the high period of the acknowledge clock pulse. Take setup and hold times into account. On a master receive, data transfer termination can be signaled by the master generating a not-acknowledge on the last byte that has been transmitted by the slave.

Bus Idle: Both SDA and SCL lines remain high.

Data Transfer: The number of data bytes transferred between a START and a STOP condition is not limited and is determined by the master device. The receiver acknowledges data transfer.

Start Data Transfer: A change in the state of the SDA line, from high to low, while the SCL line is high, defines a start condition. Each data transfer initiates with a START condition.

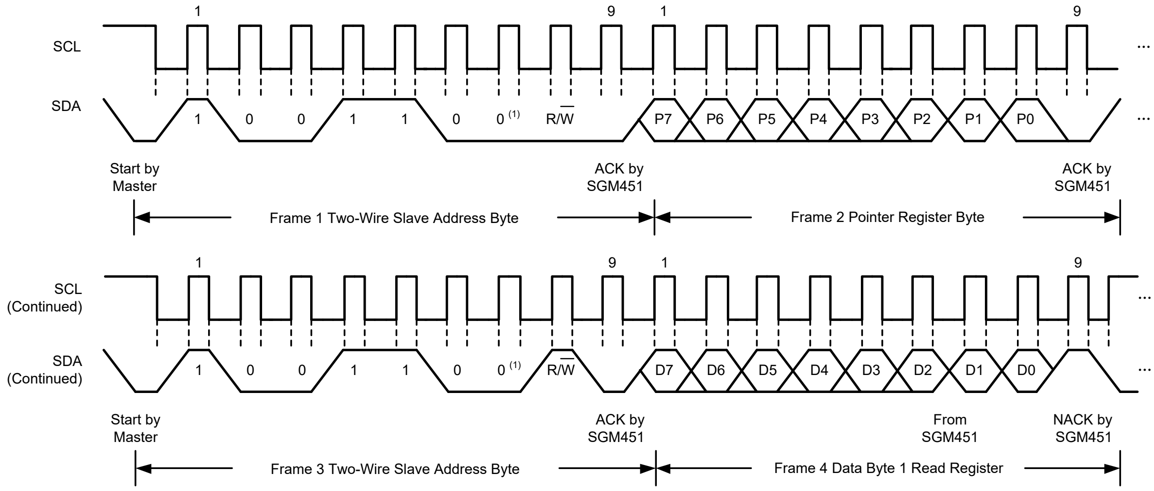
Stop Data Transfer: A change in the state of the SDA line from low to high while the SCL line is high defines a STOP condition. Each data transfer terminates with a repeated START or STOP condition.



NOTE: 1. Slave Address 1001100 Shown

Figure 7. Two-Wire Timing Diagram for Write Word Format

DETAILED DESCRIPTION (continued)



NOTES:

1. Slave address 1001100 shown.
2. Master should leave SDA high to terminate a single-byte read operation.

Figure 8. Two-Wire Timing Diagram for Single-Byte Read Format

Serial Bus Address

To communicate with the SGM451 device, the master must first address slave devices using a slave address byte. The slave address byte consists of seven address bits, and a direction bit indicating the intent of executing a read or write operation. The SGM451 device has a device address of 4Ch (1001100). Additional factory-programmed device addresses are available upon request.

Read and Write Operations

Accessing a particular register on the SGM451 device 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 SGM451 device requires a value for the pointer register (see Figure 7).

When reading from the SGM451 device 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 which register is read for a read operation, a new value must be written to the pointer register. This transaction 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 8 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, because the SGM451 device retains the pointer register value until it is changed by the next write operation. The register bytes are sent MSB first, followed by the LSB.

Read operations should be terminated by issuing a not-acknowledge command at the end of the last byte to be read. For single-byte operation, the master must leave the SDA line high during the acknowledge time of the first byte that is read from the slave.

Time-Out Function

If the SMBus time-out function is enabled, the SGM451 device resets the serial interface if either SCL or SDA are held low for 25ms (TYP) between a START and STOP condition. If the SGM451 device is holding the bus low, the device releases the bus and waits for a START condition. To avoid activating the time-out function, maintaining a communication speed of at least 1kHz for the SCL operating frequency is necessary. The SMBTO bit (bit 7) of the consecutive nALERT register controls the time-out enable. Setting the SMBTO bit to a value of 0 (default) disables the time-out. Setting the SMBTO bit to a value of 1 enables the function.

DETAILED DESCRIPTION (continued)

High-Speed Mode

For the two-wire bus to operate at frequencies above 1MHz, the master device must issue a high-speed mode (HS-mode) master code (00001xxx) as the first byte after a START condition to switch the bus to high-speed operation. The SGM451 device does not acknowledge this byte, but switches the input filters on SDA and SCL and the output filter on SDA to operate in HS-mode, allowing transfers at up to 2.5MHz. After the HS-mode master code has been issued, the master transmits 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 SGM451 device switches the input and output filters back to fast mode operation.

General Call Reset

The SGM451 device supports reset using the two-wire general call address 00h (00000000). The SGM451 device acknowledges the general call address and responds to the second byte. If the second byte is 06h (00000110), the SGM451 device executes a software reset. This software reset restores the power-on reset state to all SGM451 registers, and it aborts any conversion in progress. The SGM451 device takes no action in response to other values in the second byte.

REGISTER MAP

Table 3. Register Map

Pointer Read (Hex)	Pointer Write (Hex)	POR (Hex)	Bit Description								Register Description
			D7	D6	D5	D4	D3	D2	D1	D0	
00	N/A	00	LT11	LT10	LT9	LT8	LT7	LT6	LT5	LT4	Local Temperature High Byte Register
01	N/A	00	RT11	RT10	RT9	RT8	RT7	RT6	RT5	RT4	Remote Temperature High Byte Register
02	N/A	N/A	BUSY	LHIGH	LLOW	RHIGH	RLOW	OPEN	RTHRM	LTHRM	Status Register
03	09	00	MASK1	SD	nALERT/ nTHERM2	0	0	RANGE	0	0	Configuration Register
04	0A	08	0	0	0	0	CR3	CR2	CR1	CR0	Conversion Rate Register
05	0B	55	LTHL11	LTHL10	LTHL9	LTHL8	LTHL7	LTHL6	LTHL5	LTHL4	Local Temperature High Limit Register
06	0C	00	LTLL11	LTLL10	LTLL9	LTLL8	LTLL7	LTLL6	LTLL5	LTLL4	Local Temperature Low Limit Register
07	0D	00	RTHL11	RTHL10	RTHL9	RTHL8	RTHL7	RTHL6	RTHL5	RTHL4	Remote Temperature High Limit High Byte Register
08	0E	00	RTLL11	RTLL10	RTLL9	RTLL8	RTLL7	RTLL6	RTLL5	RTLL4	Remote Temperature Low Limit High Byte Register
N/A	0F	N/A	X	X	X	X	X	X	X	X	One-Shot Start Register (1)
10	N/A	00	RT3	RT2	RT1	RT0	0	0	0	0	Remote Temperature Low Byte Register
11	11	00	RTOS11	RTOS10	RTOS9	RTOS8	RTOS7	RTOS6	RTOS5	RTOS4	Remote Temperature Offset High Byte Register
12	12	00	RTOS3	RTOS2	RTOS1	RTOS0	0	0	0	0	Remote Temperature Offset Low Byte Register
13	13	00	RTHL3	RTHL2	RTHL1	RTHL0	0	0	0	0	Remote Temperature High Limit Low Byte Register
14	14	00	RTLL3	RTLL2	RTLL1	RTLL0	0	0	0	0	Remote Temperature Low Limit Low Byte Register
15	N/A	00	LT3	LT2	LT1	LT0	0	0	0	0	Local Temperature Low Byte Register
19	19	6C	RTH11	RTH10	RTH9	RTH8	RTH7	RTH6	RTH5	RTH4	Remote Temperature nTHERM Limit Register
20	20	55	LTH11	LTH10	LTH9	LTH8	LTH7	LTH6	LTH5	LTH4	Local Temperature nTHERM Limit Register
21	21	0A	HYS11	HYS10	HYS9	HYS8	HYS7	HYS6	HYS5	HYS4	nTHERM Hysteresis Register
22	22	01	SMBTO	0	0	0	CONAL2	CONAL1	CONAL0	1	Consecutive nALERT Register
23	23	00	NC7	NC6	NC5	NC4	NC3	NC2	NC1	NC0	η-Factor Correction Register
24	24	00	0	0	0	0	0	0	DF1	DF0	Digital Filter Control Register
FE	N/A	55	0	1	0	1	0	1	0	1	Manufacturer Identification Register

NOTE:

1. X = undefined. Writing any value to this register initiates a one-shot start; see the One-Shot Mode section.

REGISTER INFORMATION

The SGM451 device contains multiple registers for holding configuration information, temperature measurement results, and status information. These registers are described in Figure 9 and Table 3.

Pointer Register

Figure 9 shows the internal register structure of the SGM451 device. The 8-bit pointer register is used to address a given data register. The pointer register identifies which of the data registers should respond to a read or write command on the two-wire bus. This register is set with every write command. A write command must be issued to set the proper value in the pointer register before executing a read command. Table 3 describes the pointer register and the internal structure of the SGM451 registers. The power-on reset (POR) value of the pointer register is 00h (00000000).

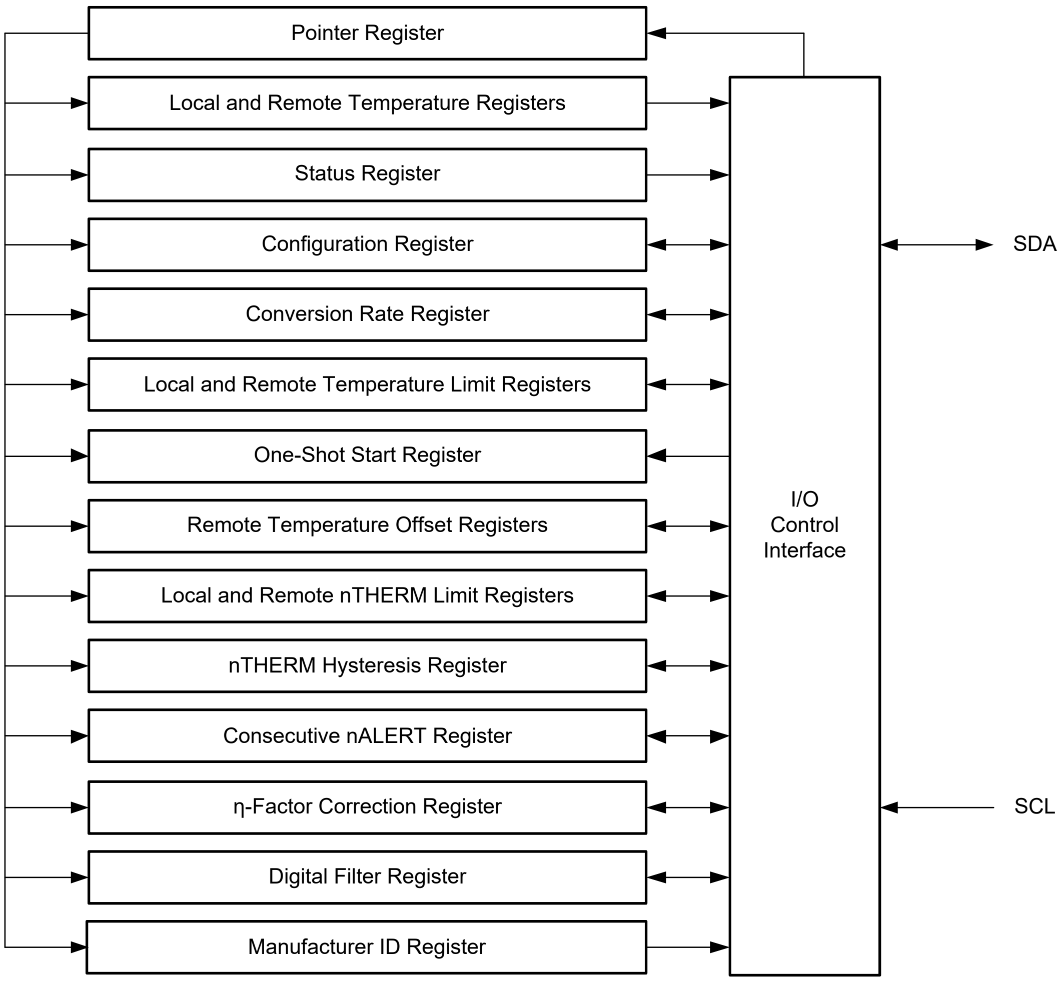


Figure 9. Internal Register Structure

RESISTER INFORMATION (continued)

Local and Remote Temperature Registers

The SGM451 device has multiple 8-bit registers that hold temperature measurement results. The eight most significant bits (MSBs) of the local temperature sensor result are stored in register 00h, while the four least significant bits (LSBs) are stored in register 15h (the four MSBs of register 15h). The eight MSBs of the remote temperature sensor result are stored in register 01h, and the four LSBs are stored in register 10h (the four MSBs of register 10h). The four LSBs of both the local sensor and the remote sensor indicate the temperature value after the decimal point (for example, if the temperature result is 10.0625℃, the high byte is 00001010 and the low byte is 00010000). These registers are read-only and are updated by the ADC each time a temperature measurement.

When the full temperature value is needed, reading the MSB value first causes the LSB value to be locked (the ADC does not write to it) until it is read. The same thing happens upon reading the LSB value first (the MSB value is locked until it is read). This mechanism assures that both bytes of the read operation are from the same ADC conversion. This assurance remains valid only until another register is read. For proper operation, read the high byte of the temperature result first. Read the low byte register in the next read command; if the LSBs are not needed, the register may be left unread. The power-on reset value of all temperature registers is 00h.

Status Register

The status register reports the state of the temperature ADC, the temperature limit comparators, and the connection to the remote sensor. Table 8 lists the status register bits. The status register is read-only, and is read by accessing pointer address 02h.

The LHIGH and LLOW bits indicate a local sensor over-temperature or under-temperature event, respectively. The RHIGH and RLOW bits indicate a remote sensor over-temperature or under-temperature event, respectively. The OPEN bit indicates an open-circuit condition on the remote sensor. When pin 6 is configured as the nALERT output, the five flags are NORed together. If any of the five flags are high, the nALERT interrupt latch is set and the nALERT output goes low. Reading the status register clears the five flags, provided that the condition that caused the setting of the flags is not present anymore (that is, the value of the corresponding result register is within the limits, or the remote sensor is connected properly and functional). The nALERT interrupt latch (and the nALERT pin correspondingly) is not reset by reading the status register. The reset is done by the master reading the temperature sensor device address to service the interrupt, and only if the flags have been reset and the condition that caused them to be set is not present.

The RTHRM and LTHRM flags are set when the corresponding temperature exceeds the programmed nTHERM limit. They are reset automatically when the temperature returns to within the limits. The nTHERM output goes low in the case of over-temperature on either the local or the remote channel, and goes high as soon as the measurements are within the limits again. The nTHERM hysteresis register (21h) allows hysteresis to be added so that the flag resets and the output goes high when the temperature returns to or goes below the limit value minus the hysteresis value.

When pin 6 is configured as nTHERM2, only the high limits matter. The LHIGH and RHIGH flags are set if the respective temperatures exceed the limit values, and the pin goes low to indicate the event. The LLOW and RLOW flags have no effect on nTHERM2, and the output behaves the same way when configured as nTHERM.

Configuration Register

MASK1 of the configuration register masks the nALERT output. If MASK1 bit is 0 (default), the nALERT output is enabled. If MASK1 bit is set to 1, the nALERT output is disabled. This configuration applies only if the value of nALERT/nTHERM2 bit is 0 (that is, pin 6 is configured as the nALERT output). If pin 6 is configured as the nTHERM2 output, the value of the MASK1 bit has no effect.

RESISTER INFORMATION (continued)

The SD bit enables or disables the temperature-measurement circuitry. If SD bit is set to 0 (default), the SGM451 device converts continuously at the rate set in the conversion rate register. When SD bit is set to 1, the SGM451 device stops converting when the current conversion sequence is complete and enters a shutdown mode. When SD bit is set to 0 again, the SGM451 resumes continuous conversions. When SD bit is set to 1, a single conversion can be started by writing to the one-shot start register. See the One-Shot Mode section for more information.

nALERT/nTHERM2 bit sets the configuration of pin 6. If the nALERT/nTHERM2 bit is set to 0 (default), then pin 6 is configured as the nALERT output; if it is set to 1, then pin 6 is configured as the THERM2 output.

The temperature range is set by configuring RANGE of the configuration register. Setting this bit low (default) configures the device for the standard measurement range (0℃ to +127℃); temperature conversions are stored in the standard binary format. Setting RANGE bit high configures the device for the extended measurement range (-64℃ to +191℃); temperature conversions are stored in the extended binary format (see Table 1).

The remaining bits of the configuration register are reserved and must always be set to 0. The power-on reset value for this register is 00h.

Conversion Rate Register

The conversion rate register (read address 04h, write address 0Ah) controls the rate at which temperature conversions are performed. This register adjusts the idle time between conversions but not the conversion time itself, thereby allowing the SGM451 power dissipation to be balanced with the temperature register update rate. Table 4 lists the conversion rate options and corresponding time between conversions. The default value of the register is 08h, which gives a default rate of 16 conversions per second.

Table 4. Conversion Rate

Value	Conversions per Second	Time (Seconds)
00h	0.0625	16
01h	0.125	8
02h	0.25	4
03h	0.5	2
04h	1	1
05h	2	0.5
06h	4	0.25
07h	8	0.125
08h	16 (default)	0.0625 (default)
09h	32	0.03125

Remote Temperature Offset Registers

The offset register allows the SGM451 device to store any system offset compensation value that might be observed from precision calibration. The value in the register is stored in the same format as the temperature result, and is added to the remote temperature result upon every conversion. Combined with the η-factor correction, this function allows for very accurate system calibration over the entire temperature range.

η-Factor Correction Register

The SGM451 device allows for a different η-factor value to be used for converting remote channel measurements to temperature. The remote channel uses sequential current excitation to extract a differential VBE voltage measurement to determine the temperature of the remote transistor. Equation 1 shows this voltage and temperature.

$$V_{BE2}-V_{BE1}=\frac{\eta kT}{q}\ln\left(\frac{I_2}{I_1}\right) \quad (1)$$

The value η in Equation 1 is a characteristic of the particular transistor used for the remote channel. The power-on reset value for the SGM451 device is η = 1.008. The value in the η-factor correction register may be used to adjust the effective η-factor according to Equation 2 and Equation 3.

$$\eta_{EFF}=\frac{1.008\times 2088}{2088+N_{ADJUST}} \quad (2)$$

$$N_{ADJUST}=\frac{1.008\times 2088}{\eta_{EFF}}-2088 \quad (3)$$

RESISTER INFORMATION (continued)

The η-factor correction value must be stored in twos complement format, yielding an effective data range from -128 to 127. The η-factor correction value is written to and read from pointer address 23h. The register power-on reset value is 00h, thus having no effect unless a different value is written to it.

Table 5. η-Factor Range

N_{ADJUST}			η
Binary	Hex	Decimal	
01111111	7F	127	0.950198
00001010	0A	10	1.003195
00001000	08	8	1.004152
00000110	06	6	1.005111
00000100	04	4	1.006072
00000010	02	2	1.007035
00000001	01	1	1.007517
00000000	00	0	1.008
11111111	FF	-1	1.008483
11111110	FE	-2	1.008967
11111100	FC	-4	1.009935
11111010	FA	-6	1.010905
11111000	F8	-8	1.011877
11110110	F6	-10	1.012851
10000000	80	-128	1.073837

Manufacturer ID Register

The SGM451 device allows for the two-wire bus controller to query the device for manufacturer and device IDs to enable software identification of the device at the particular two-wire bus address. The manufacturer ID is obtained by reading from pointer address FEh. The SGM451 device reads 55h for the manufacturer code.

RESISTER DESCRIPTION

All registers are 8-bit and individual bits are named from D[0] (LSB) to D[7] (MSB).
R/W: Read/Write bit(s)
R: Read only bit(s)
PORV: Power-On-Reset Value

Local Temperature High Byte Register

Offset: Read = 00h; Write = N/A; R
PORV = 00h

Table 6. Local Temperature High Byte Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:0]	LT[11:4]	R	00000000	Local Temperature High Byte. The resolution of the LSB in this register is 1℃. This register is read-only and is updated by the ADC each time a temperature measurement is completed. When the full temperature value is needed, reading the high byte register first causes the low byte register value to be locked (the ADC does not write to it) until it is read. The same thing happens upon reading the low byte register value first (the high byte register value is locked until it is read). This mechanism assures that both bytes of the read operation are from the same ADC conversion. This assurance remains valid only until another register is read. For proper operation, read the high byte of the temperature result first. Read the low byte register in the next read command; if the low byte is not needed, the register may be left unread.

Remote Temperature High Byte Register

Offset: Read = 01h; Write = N/A; R
PORV = 00h

Table 7. Remote Temperature High Byte Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:0]	RT[11:4]	R	00000000	Remote Temperature High Byte. The resolution of the LSB in this register is 1℃. This register is read-only and is updated by the ADC each time a temperature measurement is completed. When the full temperature value is needed, reading the high byte register first causes the low byte register value to be locked (the ADC does not write to it) until it is read. The same thing happens upon reading the low byte register value first (the high byte register value is locked until it is read). This mechanism assures that both bytes of the read operation are from the same ADC conversion. This assurance remains valid only until another register is read. For proper operation, read the high byte of the temperature result first. Read the low byte register in the next read command; if the low byte is not needed, the register may be left unread.

RESISTER DESCRIPTION (continued)

Status Register

Offset: Read = 02h; Write = N/A; R

PORV = N/A

Table 8. Status Register Details

BIT	BIT NAME	TYPE	PORV	DESCRIPTION
D[7]	BUSY	R	N/A	ADC Status Indicator. 0 = ADC is not converting. 1 = ADC is converting.
D[6]	LHIGH	R	N/A	Local Temperature High Limit Status Indicator. (1) 0 = Local temperature value does not exceed the local temperature high limit register value. 1 = Local temperature value exceeds the local temperature high limit register value. This bit is cleared upon reading the status register providing that the condition causing the over temperature result is no longer present.
D[5]	LLOW	R	N/A	Local Temperature Low Limit Status Indicator. (1) 0 = Local temperature value is not below the local temperature low limit register value. 1 = Local temperature value is below the local temperature low limit register value. This bit is cleared upon reading the status register providing that the condition causing the under temperature result is no longer present.
D[4]	RHIGH	R	N/A	Remote Temperature High Limit Status Indicator. (1) 0 = Remote temperature value does not exceed the remote temperature high limit register value. 1 = Remote temperature value exceeds the remote temperature high limit register value. This bit is cleared upon reading the status register providing that the condition causing the over temperature result is no longer present.
D[3]	RLOW	R	N/A	Remote Temperature Low Limit Status Indicator. (1) 0 = Remote temperature value is not below the remote temperature low limit register value. 1 = Remote temperature value is below the remote temperature low limit register value. This bit is cleared upon reading the status register providing that the condition causing the under temperature result is no longer present.
D[2]	OPEN	R	N/A	Remote Junction Open Circuit Detection. (1) 0 = The remote junction is not an open circuit. 1 = The remote junction is an open circuit. This bit is cleared upon reading the status register providing that the condition causing the open circuit is no longer present.
D[1]	RTHRM	R	N/A	Remote nTHERM Limit Status Indicator. 0 = Remote nTHERM limit is not tripped. 1 = Remote nTHERM limit is tripped. This bit is cleared upon reading the status register providing that the condition causing the over temperature result is no longer present.
D[0]	LTHRM	R	N/A	Local nTHERM Limit Status Indicator. 0 = Local nTHERM limit is not tripped. 1 = Local nTHERM limit is tripped. This bit is cleared upon reading the status register providing that the condition causing the over temperature result is no longer present.

NOTE:

1. These flags stay high until the status register is read or they are reset by a POR when pin 6 is configured as nALERT. Only bit 2 (OPEN) stays high until the status register is read or it is reset by a POR when pin 6 is configured as nTHERM2.

RESISTER DESCRIPTION (continued)

Configuration Register

Offset: Read = 03h; Write = 09h; R/W

PORV = 00h

Table 9. Configuration Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7]	MASK1	R/W	0	Mask the nALERT Output. 0 = nALERT is enabled.(default) 1 = nALERT is disabled.
D[6]	SD	R/W	0	Device Shutdown Control. 0 = Places the device in continuous conversion mode. (default) 1 = Places the device is in shutdown mode.
D[5]	nALERT/nTHERM2	R/W	0	nALERT or nTHERM2 Configuration Select of Pin 6. 0 = nALERT output. (default) 1 = nTHERM2 output.
D[4:3]	RESERVED	R/W	00	Reserved.
D[2]	RANGE	R/W	0	Configure the Temperature Measurement Range. 0 = 0℃ to +127℃ (default) 1 = -64℃ to +191℃
D[1:0]	RESERVED	R/W	00	Reserved.

Conversion Rate Register

Offset: Read = 04h; Write = 0Ah; R/W

PORV = 08h

Table 10. Conversion Rate Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:4]	RESERVED	R/W	0000	Reserved.
D[3:0]	CR[3:0]	R/W	1000	Conversion Rate Selection. Refer to Table 4.

RESISTER DESCRIPTION (continued)

Local Temperature High Limit Register

Offset: Read = 05h; Write = 0Bh; R/W

PORV = 55h

Table 11. Local Temperature High Limit Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:0]	LTHL[11:4]	R/W	01010101	These bits determine the value of the high temperature limit to which the local temperature measurement is compared. The resolution of the LSB in this register is 1℃.

Local Temperature Low Limit Register

Offset: Read = 06h; Write = 0Ch; R/W

PORV = 00h

Table 12. Local Temperature Low Limit Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:0]	LTLL[11:4]	R/W	00000000	These bits determine the value of the low temperature limit to which the local temperature measurement is compared. The resolution of the LSB in this register is 1℃.

Remote Temperature High Limit High Byte Register

Offset: Read = 07h; Write = 0Dh; R/W

PORV = 55h

Table 13. Remote Temperature High Limit High Byte Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:0]	RTHL[11:4]	R/W	01010101	These bits determine the value of the high byte of the high temperature limit to which the remote temperature measurement is compared. The resolution of the LSB in this register is 1℃.

Remote Temperature Low Limit High Byte Register

Offset: Read = 08h; Write = 0Eh; R/W

PORV = 00h

Table 14. Remote Temperature Low Limit High Byte Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:0]	RTLL[11:4]	R/W	00000000	These bits determine the value of high byte of the low temperature limit to which the remote temperature measurement is compared. The resolution of the LSB in this register is 1℃.

One-Shot Start Register

Offset: Read = N/A; Write = 0Fh; W

PORV = N/A

Table 15. One-Shot Start Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:0]	X	W	N/A	When the device is in the shutdown mode writing any value to this register will trigger a one-shot temperature conversion.

RESISTER DESCRIPTION (continued)

Remote Temperature Low Byte Register

Offset: Read = 10h; Write = N/A; R

PORV = 00h

Table 16. Remote Temperature Low Byte Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:4]	RT[3:0]	R	0000	Remote temperature low byte. The resolution of the LSB in this register is 0.0625℃. This register is read-only and is updated by the ADC each time a temperature measurement is completed. When the full temperature value is needed, reading the high byte register first causes the low byte register value to be locked (the ADC does not write to it) until it is read. The same thing happens upon reading the low byte register value first (the high byte register value is locked until it is read). This mechanism assures that both bytes of the read operation are from the same ADC conversion. This assurance remains valid only until another register is read. For proper operation, read the high byte of the temperature result first. Read the low byte register in the next read command; if the low byte is not needed, the register may be left unread. The resolution of these four bits is 0.0625℃.
D[3:0]	Reserved	R	0000	Reserved

Remote Temperature Offset High Byte Register

Offset: Read = 11h; Write = 11h; R/W

PORV =00h

Table 17. Remote Temperature Offset High Byte Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:0]	RTOS[11:4]	R/W	00000000	Remote temperature offset high byte. The value of this register is added to the value the ADC conversion with the result stored in the remote temperature register. This register is used to add or subtract a temperature offset value to the ADC conversion result in applications requiring calibration. The resolution of the LSB in this register is 1℃.

Remote Temperature Offset Low Byte Register

Offset: Read = 12h; Write = 12h; R/W

PORV =00h

Table 18. Remote Temperature Offset Low Byte Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:4]	RTOS[3:0]	R/W	0000	Remote temperature offset low byte. The value of this register is added to the value the ADC conversion with the result stored in the remote temperature register. This register is used to add or subtract a temperature offset value to the ADC conversion result in applications requiring calibration. The resolution of these four bits is 0.0625℃.
D[3:0]	Reserved	R/W	0000	Reserved

RESISTER DESCRIPTION (continued)

Remote Temperature High Limit Low Byte Register

Offset: Read = 13h; Write = 13h; R/W

PORV =00h

Table 19. Remote Temperature High Limit Low Byte Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:4]	RTHL[3:0]	R/W	0000	These bits determine the value of the low byte of the high temperature limit to which the remote temperature measurement is compared. The resolution of the four bits in this register is 0.0625℃.
D[3:0]	Reserved	R/W	0000	Reserved

Remote Temperature Low Limit Low Byte Register

Offset: Read = 14h; Write = 14h; R/W

PORV =00h

Table 20. Remote Temperature Low Limit Low Byte Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:4]	RTLL[3:0]	R/W	0000	These bits determine the value of the low byte of the low temperature limit to which the remote temperature measurement is compared. The resolution of the four bits in this register is 0.0625℃.
D[3:0]	Reserved	R/W	0000	Reserved

Local Temperature Low Byte Register

Offset: Read = 15h; Write = N/A; R

PORV =00h

Table 21. Local Temperature Low Byte Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:4]	LT[3:0]	R	0000	Local temperature low byte. The resolution of the four bits in this register is 0.0625℃. This register is read-only and is updated by the ADC each time a temperature measurement is completed. When the full temperature value is needed, reading the high byte register first causes the low byte register value to be locked (the ADC does not write to it) until it is read. The same thing happens upon reading the low byte register value first (the high byte register value is locked until it is read). This mechanism assures that both bytes of the read operation are from the same ADC conversion. This assurance remains valid only until another register is read. For proper operation, read the high byte of the temperature result first. Read the low byte register in the next read command; if the low byte is not needed, the register may be left unread.
D[3:0]	Reserved	R	0000	Reserved

RESISTER DESCRIPTION (continued)

Remote Temperature nTHERM Limit Register

Offset: Read = 19h; Write = 19h; R/W

PORV =6Ch

Table 22. Remote Temperature nTHERM Limit Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:0]	RTH[11:4]	R/W	01101100	Remote Temperature nTHERM Limit. These bits determine the value of the nTHERM limit to which the remote temperature measurement is compared. The resolution of the LSB in this register is 1℃.

Local Temperature nTHERM Limit Register

Offset: Read = 20h; Write = 20h; R/W

PORV = 55h

Table 23. Local Temperature nTHERM Limit Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:0]	LTH[11:4]	R/W	01010101	Local Temperature nTHERM Limit. These bits determine the value of the nTHERM limit to which the local temperature measurement is compared. The resolution of the LSB in this register is 1℃.

nTHERM Hysteresis Register

Offset: Read = 21h; Write = 21h; R/W

PORV = 0Ah

Table 24. nTHERM Hysteresis Register Field Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:0]	HYS[11:4]	R/W	00001010	nTHERM Hysteresis Value. These bits determine the amount of hysteresis applied to the nTHERM function. The resolution of the LSB in this register is 1℃.

Consecutive nALERT Register

Offset: Read = 22h; Write = 22h; R/W

PORV = 01h

Table 25. Consecutive nALERT Register Field Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7]	SMBTO	R/W	0	SMBus time-out enable or disable. Refer to Time-out Function. 0 = Disables the SMBus time-out feature. (default) 1 = Enables the SMBus time-out feature.
D[6:4]	Reserved	R/W	000	Reserved.
D[3:1]	CONAL[2:0]	R/W	000	Number of Consecutive Out-of-Limit Measurements Required. 000 = 1 (default) 001 = 2 011 = 3 111 = 4
D[0]	Reserved	R/W	1	Reserved.

RESISTER DESCRIPTION (continued)

η-Factor Correction Register

Offset: Read = 23h; Write = 23h; R/W

PORV = 00h

Table 26. η-Factor Correction Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:0]	NC[7:0]	R/W	00000000	η-factor value Refer to Table 5.

Digital Filter Control Register

Offset: Read = 24h; Write = 24h; R/W

PORV = 00h

Table 27. Digital Filter Control Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:2]	Reserved	R/W	00000	
D[1:0]	DF[1:0]	R/W	00	Number of Remote Temperature Measurements Averaged. 00 = Averaging off (default) 01 = 4 10 = 8 11 = Not used

Manufacturer ID Register

Offset: Read = FEh; Write = N/A; R

PORV = 55h

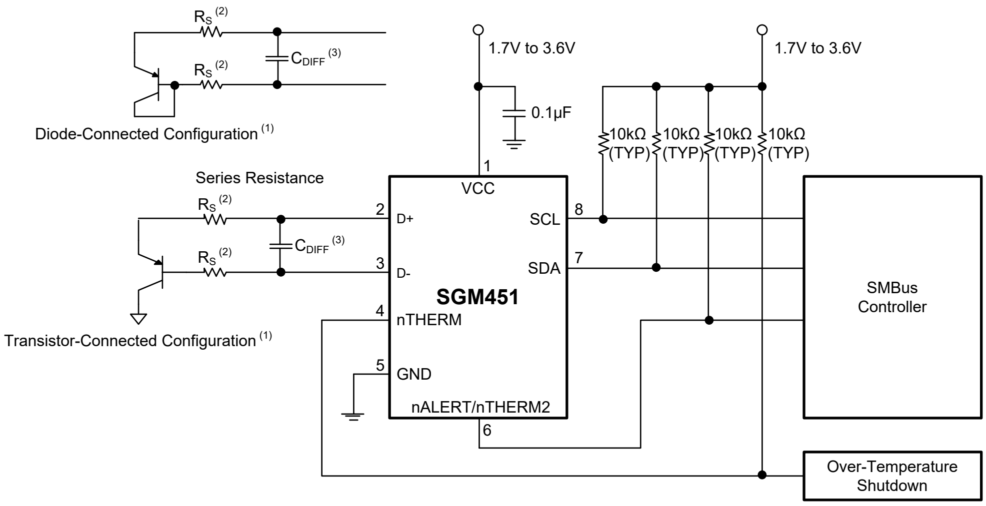
Table 28. Manufacturer ID Register Details

BITS	BIT NAME	TYPE	PORV	DESCRIPTION
D[7:0]	ID[7:0]	R	01010101	Manufacturer Identification Information.

APPLICATION INFORMATION

The SGM451 device requires only a transistor connected between the D+ and D- pins for remote temperature measurement. Tie the D+ pin to GND if the remote channel is not used and only the local temperature is measured. The SDA, nALERT and nTHERM pins (and SCL, if driven by an open-drain output) require pull-up resistors as part of the communication bus. A 0.1μF power-supply decoupling capacitor is recommended for local bypassing.

Figure 10 shows the typical configuration for the SGM451 device.



NOTES:
1. Diode-connected configuration provides better settling time. Transistor-connected configuration provides better series resistance cancellation.
2. R_S (optional) should be < 1kΩ in most applications. Selection of R_S depends on application; see the Filtering section.
3. C_{DIFF} (optional) should be < 1000pF in most applications. Selection of C_{DIFF} depends on application; see the Filtering section and Remote Temperature Error vs. Differential Capacitance.

Figure 10. SGM451 Basic Connections Using a Discrete Remote Transistor

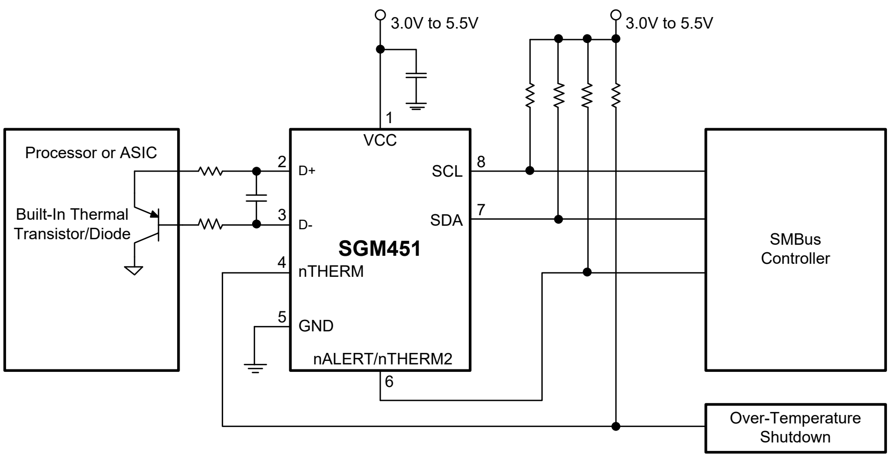


Figure 11. SGM451 Basic Connections Using a Processor Built-In Remote Transistor

APPLICATION INFORMATION (continued)

Design Requirements

The SGM451 device is designed to be used with either discrete transistors or substrate transistors built into processor chips and ASICs. Either NPN or PNP transistors can be used, as long as the base-emitter junction is used as the remote temperature sense. NPN transistors must be diode-connected. PNP transistors can either be transistor-connected or diode-connected (see Figure 10).

Errors in remote temperature sensor readings are typically the consequence of the ideality factor and current excitation used by the SGM451 device versus the manufacturer-specified operating current for a given transistor. Some manufacturers specify a high-level and low-level current for the temperature-sensing substrate transistors. The SGM451 device uses 7.5μA for I_{LOW} and 120μA for I_{HIGH}.

The ideality factor (η) is a measured characteristic of a remote temperature sensor diode as compared to an ideal diode. The SGM451 allows for different η-factor values; see the η-Factor Correction Register section.

The ideality factor for the SGM451 device is trimmed to be 1.008. For transistors that have an ideality factor that does not match the SGM451. Equation 4 can be used to calculate the temperature error. For the equation to be used correctly, actual temperature (℃) must be converted to Kelvin (K).

$$T_{ERR}=\left(\frac{\eta\text{-}1.008}{1.008}\right)\times\left(273.15+T(C^{\circ})\right) \quad (4)$$

where:
T_{ERR} = error in the SGM451 device because η ≠ 1.008,
η = ideality factor of remote temperature sensor,
T(℃) = actual temperature,
Degree delta is the same for ℃ and K.

For η = 1.004 and T(℃) = 100℃:

$$T_{ERR}=\left(\frac{1.004-1.008}{1.008}\right)\times\left(273.15+100℃\right) \quad (5)$$

$$T_{ERR}=-1.48℃$$

If a discrete transistor is used as the remote temperature sensor with the SGM451, the best accuracy can be achieved by selecting the transistor according to the following criteria:

1. Base-emitter voltage > 0.25V at 7.5μA, at the highest-sensed temperature.
2. Base-emitter voltage < 0.95V at 120μA, at the lowest-sensed temperature.
3. Base resistance < 100Ω.
4. Tight control of V_{BE} characteristics indicated by small variations in h_{FE} (that is, 50 to 150).

Based on this criteria, two recommended small-signal transistors are the 2N3904 (NPN) or 2N3906 (PNP).

Detailed Design Procedure

The local temperature sensor inside the SGM451 device monitors the ambient air around the device. The thermal time constant for the SGM451 device is approximately two seconds. This constant implies that if the ambient air changes quickly by 100℃, it would take the SGM451 device about 10 seconds (that is, five thermal time constants) to settle to within 1℃ of the final value. In most applications, the SGM451 package is in electrical, and therefore thermal, contact with the printed circuit board (PCB), as well as subjected to forced airflow. The accuracy of the measured temperature directly depends on how accurately the PCB and forced airflow temperatures represent the temperature that the SGM451 is measuring. Additionally, the internal power dissipation of the SGM451 can cause the temperature to rise above the ambient or PCB temperature. The internal power dissipated as a result of exciting the remote temperature sensor is negligible because of the small currents used. For a 3.3V supply and maximum conversion rate of 16 conversions per second, the SGM451 device dissipates 0.33mW (PD_{IQ} = 3.3V × 100μA). A θ_{JA} of 171.3℃/W causes the junction temperature to rise approximately 0.09℃ above the ambient.

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POWER SUPPLY RECOMMENDATIONS

The temperature measurement accuracy of the SGM451 device depends on the remote and/or local temperature sensor being at the same temperature as the system point being monitored. Clearly, if the temperature sensor is not in good thermal contact with the part of the system being monitored, then there will be a delay in the response of the sensor to a temperature change in the system. For remote temperature-sensing applications using a substrate transistor (or a small, SOT23 transistor) placed close to the device being monitored, this delay is usually not a concern.

The SGM451 device operates with a power supply range of 3.0V to 5.5V. The device is optimized for operation at a 3.3V supply but can measure temperature accurately in the full supply range.

A power supply bypass capacitor is recommended. Place this capacitor as close as possible to the supply and ground pins of the device. A typical value for this supply bypass capacitor is 0.1μF. Applications with noisy or high-impedance power supplies may require additional decoupling capacitors to reject power supply noise.

LAYOUT

Remote temperature sensing on the SGM451 device measures very small voltages using very low currents; therefore, noise at the device inputs must be minimized. Most applications using the SGM451 have high digital content, with several clocks and logic level transitions creating a noisy environment. Layout should adhere to the following guidelines:

1. Place the SGM451 device as close to the remote junction sensor as possible.

2. Route the D+ and D- traces next to each other and shield them from adjacent signals through the use of ground guard traces. If a multilayer PCB is used, bury these traces between ground or VCC planes to shield them from extrinsic noise sources. 5mil (0.127mm) PCB traces are recommended.

3. Minimize additional thermocouple junctions caused by copper-to-solder connections. If these junctions are used, make the same number and approximate locations of copper-to-solder connections in both the D+ and D- connections to cancel any thermocouple effects.

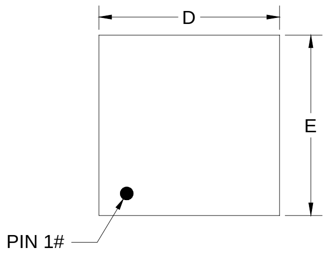
4. Use a 0.1μF local bypass capacitor directly between the VCC and GND of the SGM451 device. For optimum measurement performance, minimize filter capacitance between D+ and D- to 1000pF or less. This capacitance includes any cable capacitance between the remote temperature sensor and the SGM451 device.

5. If the connection between the remote temperature sensor and the SGM451 device is less than 8in (20.32cm) long, use a twisted-wire pair connection. For lengths greater than 8in, use a twisted, shielded pair with the shield grounded as close to the SGM451 device as possible. Leave the remote sensor connection end of the shield wire open to avoid ground loops and 60Hz pickup.

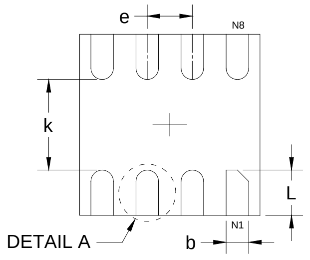
6. Thoroughly clean and remove all flux residue in and around the pins of the SGM451 device to avoid temperature offset readings as a result of leakage paths between D+ and GND, or between D+ and VCC.

PACKAGE OUTLINE DIMENSIONS

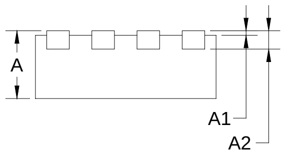
TDFN-2×2-8BL



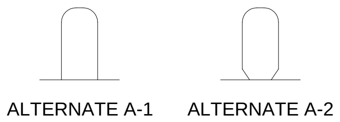
TOP VIEW



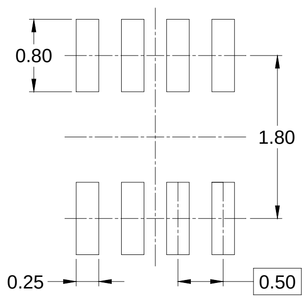
BOTTOM VIEW



SIDE VIEW



DETAIL A
ALTERNATE TERMINAL CONSTRUCTION



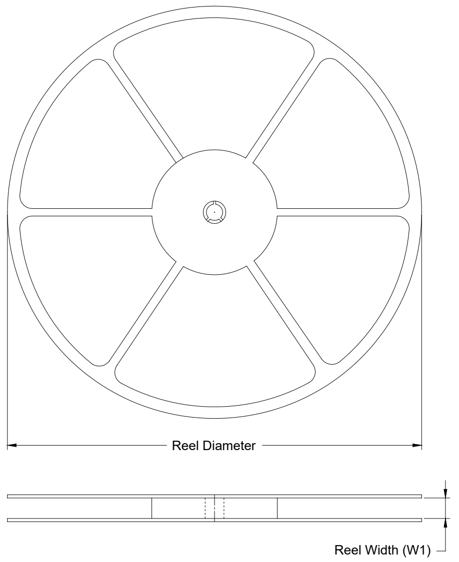
RECOMMENDED LAND PATTERN (Unit: mm)

Symbol	Dimensions In Millimeters		
	MIN	MOD	MAX
A	0.700	0.750	0.800
A1	0.000	0.020	0.050
A2	0.203 REF		
D	2.000 BSC		
E	2.000 BSC		
b	0.200	0.250	0.300
e	0.500 BSC		
L	0.450	0.500	0.550
k	1.000 REF		

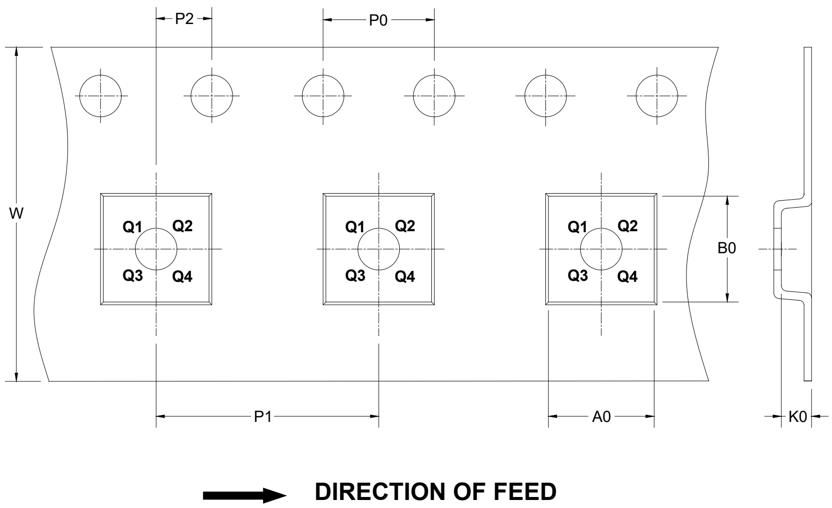
NOTE: This drawing is subject to change without notice.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



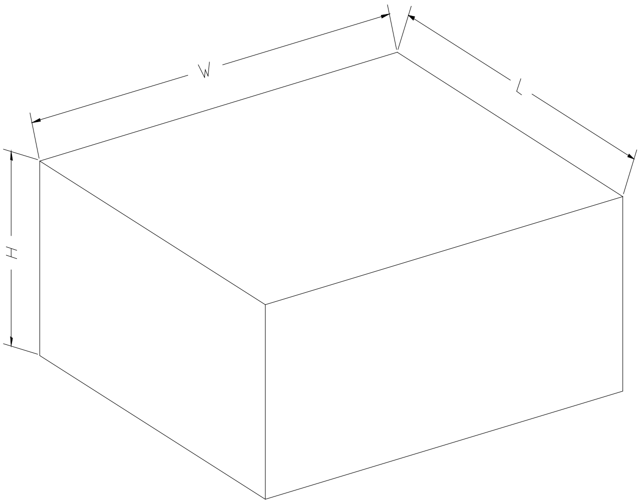
NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
TDFN-2×2-8BL	7″	9.5	2.30	2.30	1.10	4.0	4.0	2.0	8.0	Q1

DD0001

CARTON BOX DIMENSIONS



NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
7″ (Option)	368	227	224	8
7″	442	410	224	18

DD0002