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

GENERAL DESCRIPTION

The SGM451 is a high-accuracy and low-power temperature sensor which integrates local and remote temperature channels. The remote sensor which is connected to the SGM451 is made by discrete transistors or diodes, which would be the integrated inside the MCU and FPGA. The SGM451 is a 12-bit device with a resolution of only 0.0625℃. This device can measure the temperature of the local diode sensors with an accuracy of ±0.3℃ (TYP) and remote diode sensors with an accuracy of ±0.8℃ (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.

There are many advantages of SGM451, such as cancelling the series resistance, calibrating the offset, changing the cutoff frequency of the digital filter, changing the limitation of temperature and non-ideality factor with programming. The above factors are significant to improve the accuracy of the SGM451.

The SGM451 is suitable for high precision temperature measurements in multiple locations in application system. The wide supply voltage range from 3.0V to 5.5V makes the SGM451 possible to use in a wide range of applications, including low power devices. The device operates over a wide temperature range of -40℃ to +125℃.

FEATURES

- **Temperature Accuracy**
  - **Local Diode Sensor: ±0.3℃ (TYP)**
  - **Remote Diode Sensor: ±0.8℃ (TYP)**
- **Local and Remote Channels Resolution: 0.0625℃**
- **Supply and Logic Voltage Range: 3.0V to 5.5V**
- **Support 1.8V I^2C Bus Voltage at 3.3V Power Supply**
- **Operating Current: 15μA (TYP)**
- **Shutdown Current: 0.4μA (TYP)**
- **Cancelling the Series Resistor**
- **η-Factor**
- **Calibrating the Offset**
- **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 Computers
Servers and Desktops
Storage Area Networks (SANs)
Telecom Equipment

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.

XXXX

- X (first) — Date Code - Year
- XXX — Trace Code

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℃
ESD Susceptibility
HBM 4000V
CDM 1000V

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

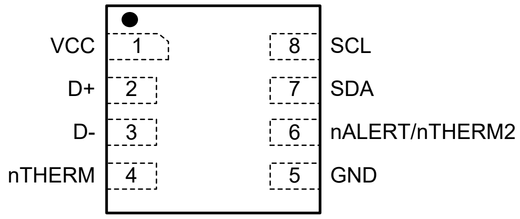
This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance 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	3.0V to 5.5V Power Supply Pin.
2	D+	AI	Positive Side Connected to Remote Temperature Sensor.
3	D-	AI	Negative Side Connected to Remote Temperature Sensor.
4	nTHERM	DO	Thermal Shutdown or Fan-Control Open-Drain Output Pin. An external pull-up resistor to voltage between 3.0V and 5.5V is required.
5	GND	G	Ground.
6	nALERT/nTHERM2	DO	Interrupt or SMBus Alert Output Pin. It can be used as another nTHERM open-drain output. An external pull-up resistor to voltage between 3.0V and 5.5V is required.
7	SDA	I/O	Data Input/Output Pin. Open-drain. An external pull-up resistor to voltage between 3.0V and 5.5V is required.
8	SCL	DI	Clock Input Pin for SMBus. If it is driven by open-drain output, an external pull-up resistor to voltage between 3.0V and 5.5V is required.

NOTE: AI: analog input, DI: digital input, DO: digital output, I/O: input/output G: ground, P: power.

ELECTRICAL CHARACTERISTICS

(V_{CC} = 3.3V, T_A = -40℃ to +125℃, typical values are at T_A = T_J = +25℃, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Temperature Error					
Local Temperature Sensor (TE_{LOCAL})	T_A = -20℃ to +85℃	-0.8	±0.3	0.8	℃
	T_A = -40℃ to +125℃	-1.2	±0.4	1.2	
Remote Temperature Sensor (TE_{REMOTE})	T_A = -20℃ to +85℃, T_D = -55℃ to +150℃	-2.0	±0.8	2.0	℃
	T_A = -40℃ to +125℃, T_D = -55℃ to +150℃	-3.0	±1.5	3.0	
Local Temperature Sensor vs. Supply	V_{CC} = 3.0V to 5.5V	-0.08	±0.02	0.08	℃/V
Remote Temperature Sensor vs. Supply		-0.2	±0.1	0.2	
Temperature Measurement					
Conversion Time	One-Shot mode, local and remote total	28	32	36	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})		1.6			V
Low-Level Input Voltage (V_{IL})				0.8	V
Hysteresis			120		mV
SMBus Output Low Sink Current		3			mA
Low-Level Output Voltage (V_{OL})	I_O = 3mA		0.1	0.3	V
Logic Input Current	0V ≤ V_I ≤ 5.0V		0.02	1	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 = 3mA		0.1	0.3	V
High-Level Output Leakage Current (I_{OH})	V_O = V_{CC}		0.02	1	μA
Power Supply					
Specified Voltage Range (V_{CC})		3.0		5.5	V
Quiescent Current (I_Q)	0.0625 conversions per second		15	29	μA
	16 conversions per second		93	134	
	32 conversions per second		122	172	
	Serial bus inactive, shutdown mode, T_A = 25℃		0.4	0.65	
	Serial bus inactive, shutdown mode		0.4	10	
	Serial bus active, f_S = 400kHz, shutdown mode		25		
	Serial bus active, f_S = 2.5MHz, shutdown mode		155		
Power-On Reset Threshold (V_{POR})			2.8	3.0	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

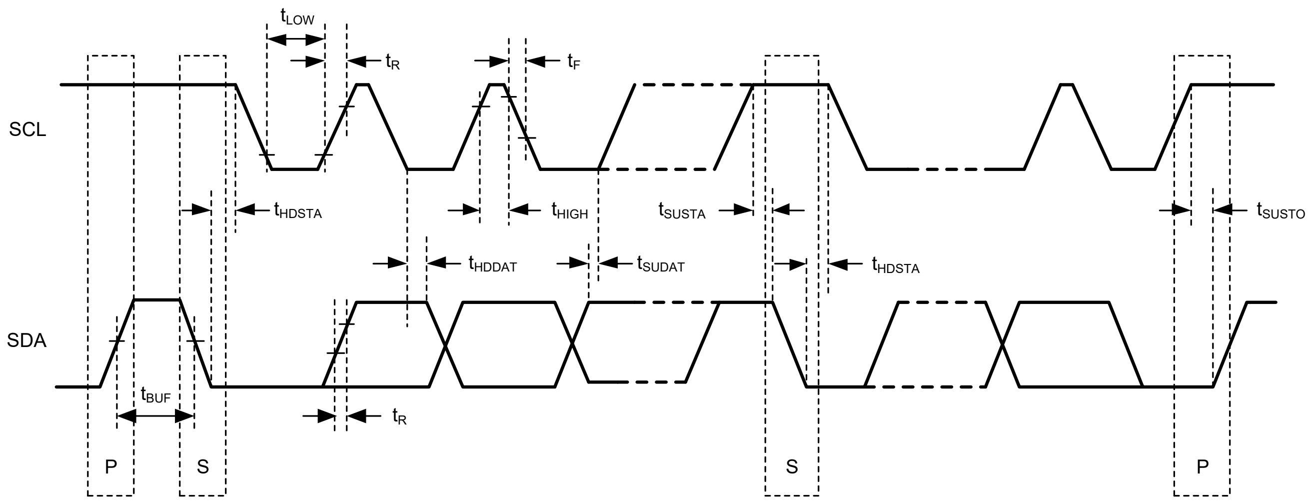
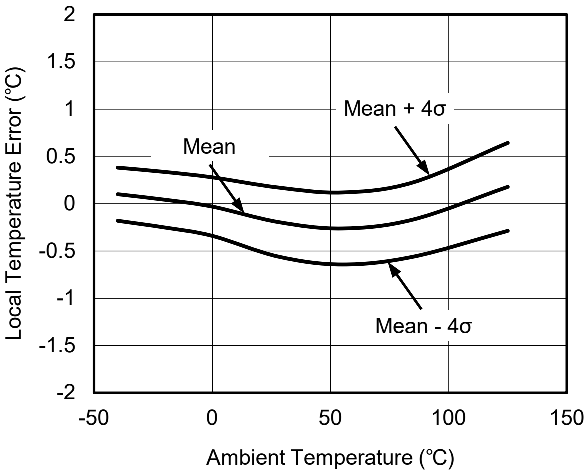


Figure 1. Two-Wire Timing Diagram

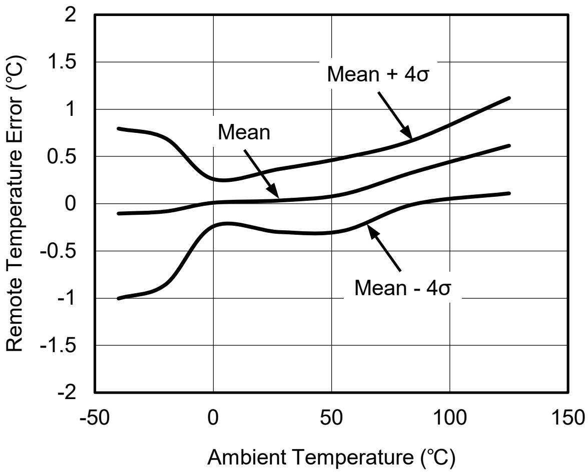
TYPICAL PERFORMANCE CHARACTERISTICS

V_{CC} = 3.3V and T_A = +25℃, unless otherwise noted.

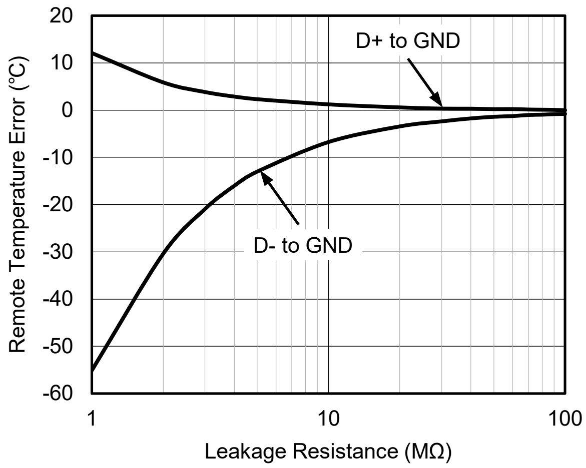
Local Temperature Error vs. Temperature



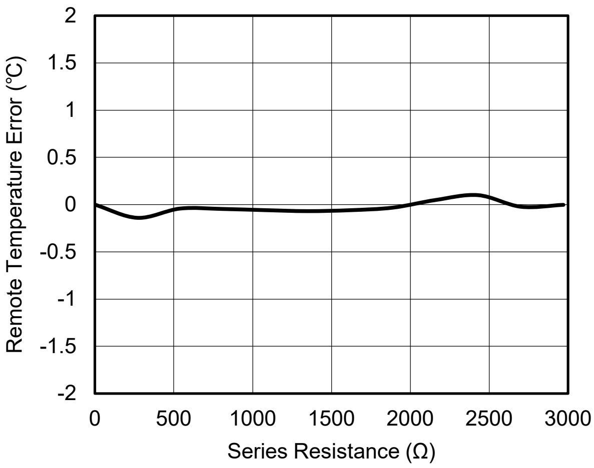
Remote Temperature Error vs. Temperature



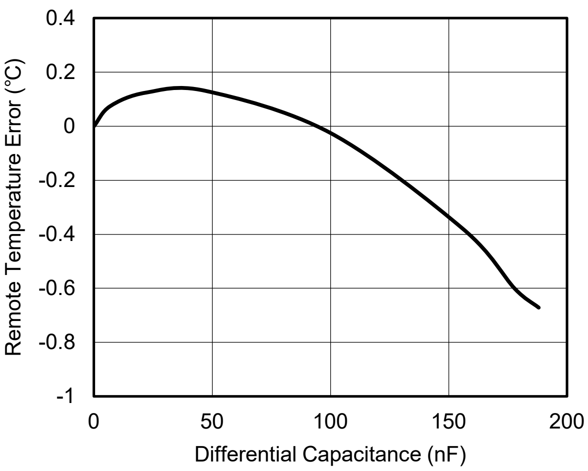
Remote Temperature Error vs. Leakage Resistance



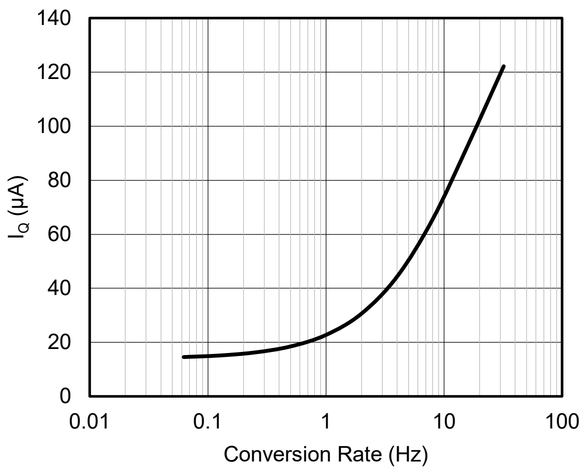
Remote Temperature Error vs. Series Resistance



Remote Temperature Error vs. Differential Capacitance

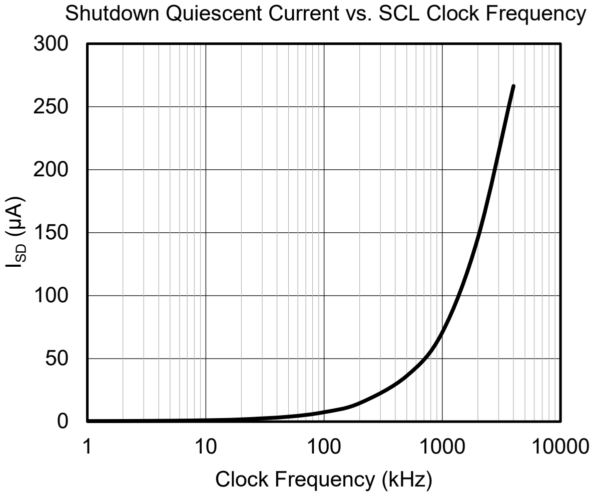


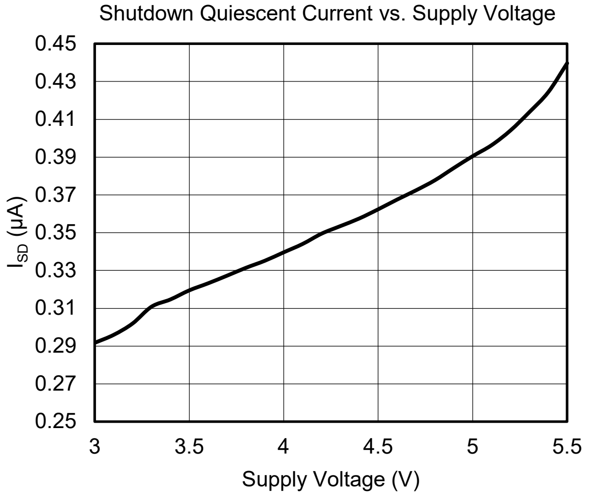
Quiescent Current vs. Conversion Rate

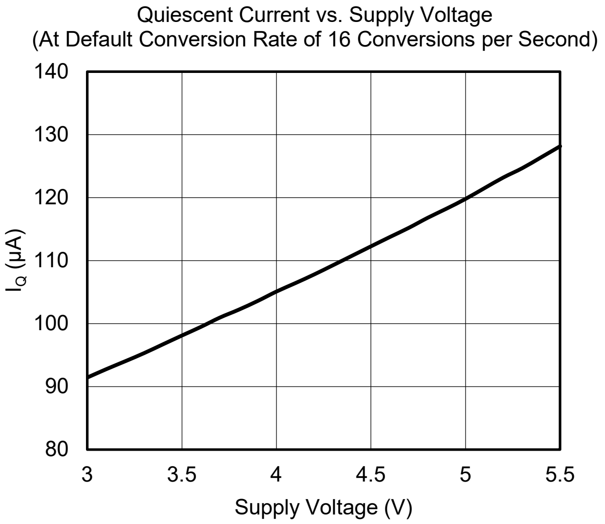


TYPICAL PERFORMANCE CHARACTERISTICS (continued)

V_{CC} = 3.3V and T_A = +25℃, unless otherwise noted.







TYPICAL APPLICATION

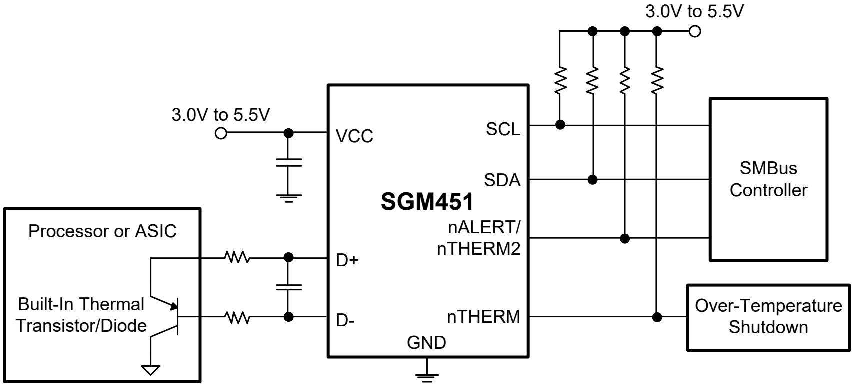


Figure 2. Typical Application Circuit

FUNCTIONAL BLOCK DIAGRAM

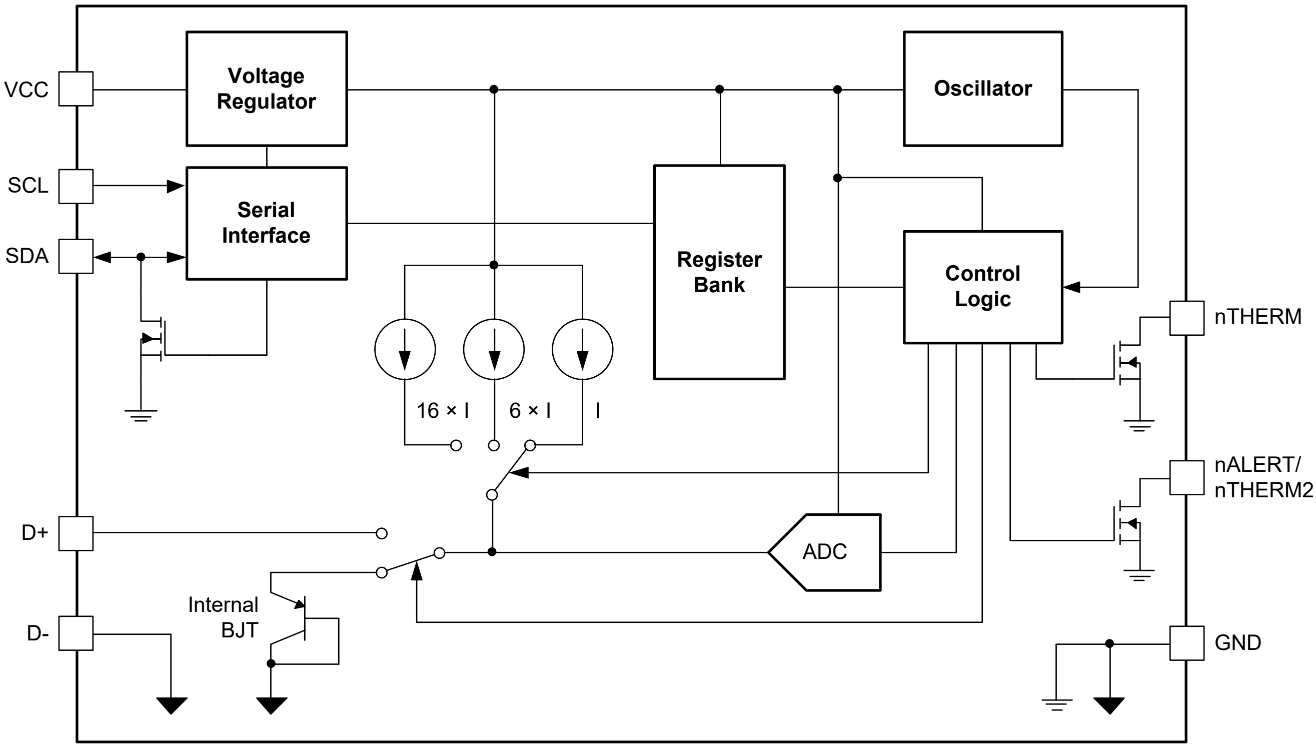


Figure 3. Block Diagram

DETAILED DESCRIPTION

Temperature Measurement Data

The resolution of the local and remote temperature sensor is 12 bits with 0.0625 ℃ (LSB). Table 1 illustrates the corresponding binary form of different temperatures. If the measured temperature is below 0℃ , the binary form is equal to 00h all the time. Likewise, if the temperature is above +127℃, the binary form is equal to 7Fh. If the RANGE bit of the configuration register is changed from low to high, then the measured range of the temperature is extended (see Table 1). An additional 40h is added to the standard binary to get the extended binary of the temperature. For extended mode, the measured temperature range is from -64℃ to +191℃. However, the temperature range which is from -55℃ to +150℃ is mostly considered by the traditional temperature sensors. Moreover, the allowable ambient temperature for operating the SGM451 is specified from -40℃ to +125℃, which is stated by the part of Absolute Maximum Ratings.

For storing the data of temperature, both remote and local one use two bytes. For higher byte, it stores the measured temperature with 1 ℃ resolution. The decimal fraction value of the temperature is stored at the lower bytes to indicated a resolution of 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.

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 → $(0 \times 1/2)^1 + (1 \times 1/2)^2 + (1 \times 1/2)^3 + (1 \times 1/2)^4 = 0.4375$

DETAILED DESCRIPTION (continued)

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.

Series Resistance Cancellation

The technology of cancelling the series resistance can eliminate the measuring error which would be caused by the resistance of PCB trace or RC low-pass filter. The maximum resistance that can be cancelled by the SGM451 is 1kΩ, so there is no need for the customers to use the additional temperature offset correction to eliminate the effect.

Differential Input Capacitance

The maximum allowable capacitor which is placed between the differential inputs is 1000pF, which can barely cause the error of temperature.

Filtering

Remote sensors would be placed into a noisy environment. The digital signals (noise) will corrupt the accuracy of the measurement. There is a 65kHz filter integrated at the input part of the SGM451. However, the capacitor which is placed between the two inputs is also necessary for SGM451 to enhance the robustness to against the noise. Also, the value of the capacitance should be between the range of 100pF and 1000pF. To obtain better accuracy, the customers would add additional resistors. However, SGMICRO recommends that this additional resistance should be less than 1kΩ. On top of this, if the filter is needed, the suggested RC values of the low-pass filter are 50Ω and 100pF.

Moreover, the customer can use the internal digital filter to further reduce the influence of the noise. There are two levels for the programmable digital filter. For Level 1 and 2, there are 4 and 8 consecutive samples respectively. Moreover, the output of the programmable filter is stored inside the result register of the remote temperature, and the nALERT and nTHERM limits are compared to it. Also, the immunity of the nALERT/nTHERM pin is enhanced for the noise and spikes. Figure 4 illustrates the response of filter for both Level 1 and 2. Also, the customers can enable or disable the digital filter by programming. For disabling the digital filter, the POR or default mode can accomplish it.

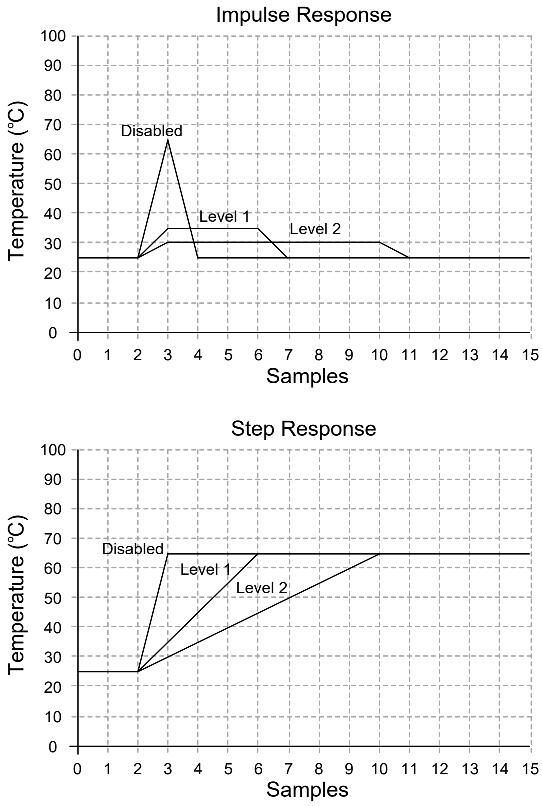


Figure 4. Filter Response to Impulse and Step Inputs

Sensor Fault

If the connection of the diode is incorrect, there will be a fault signal at the D+ pin of the SGM451. The open circuit can be sensed by SGM451. For the condition of short-circuit, the equivalent temperature is equal to -64℃. Also, if the voltage level at D+ exceeds V_{CC} - 0.3V, the internal detection circuit which consists of a comparator will trip. The internal comparator will check if there is a fault during the conversion, and the OPEN bit will be set to 1 if there is a fault.

If the remote sensor is not taken into account, the D+ and D- should be connected together for preventing any meaningless warning of fault.

DETAILED DESCRIPTION (continued)

nALERT and nTHERM Functions

Figure 5 shows the operation of the nALERT and nTHERM interrupt. Figure 6 shows the operation of the nTHERM and nTHERM2 interrupt.

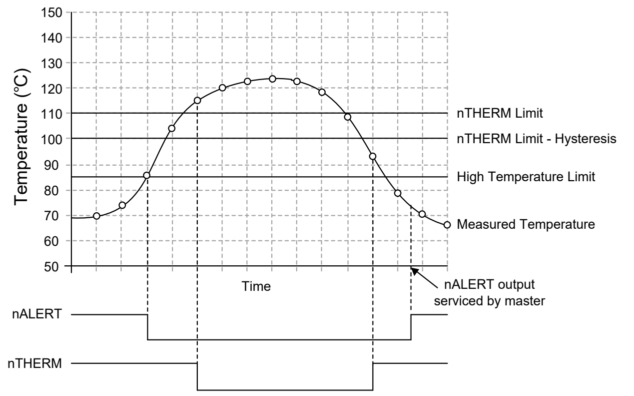


Figure 5. nALERT and nTHERM Interrupt Operation

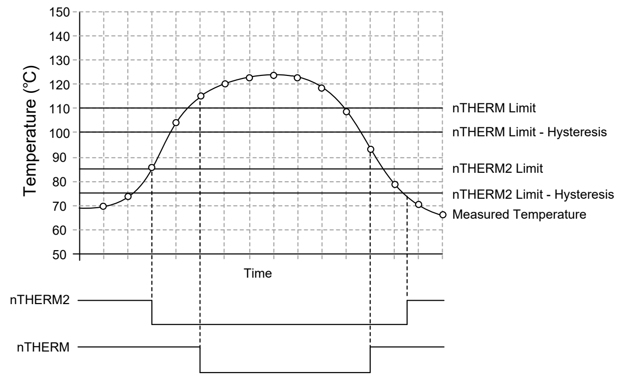


Figure 6. nTHERM and nTHERM2 Interrupt Operation

The register of nTHERM stores the information of the hysteresis value of the temperature sensor. Inside the nALERT register, the number of limits is determined by the bits of CONAL[2:0]. 000 stands for one violation; 001 stands for two consecutive violations; 011 stands for three consecutive violations and 111 stands for four consecutive violations. Then, the additional filtering is provided by the nALERT pin.

Device Functional Modes

Shutdown Mode (SD)

The maximum power of the device can be saved by shutdown the circuitry of the SGM451 other than the digital series interface. If the shutdown mode is launched, the SD bit of the configuration register should be pulled high, and the device cannot shut down until the current conversion is accomplished. On the contrary, if the SD bit is pulled low, it means that the device is in the continuous-conversion mode.

One-Shot Mode

If the SD bit of the configuration register is 1, the SGM451 will be in shutdown mode. Once the one-shot start register is written by any values, the single conversion will be started. The pointer address is 0Fh. This write operation starts one conversion and comparison cycle on both the local and the remote sensors. While the cycle of the process is completed, the SGM451 will be returned to the shutdown mode. When write command is launched, the information of it is irrelevant and cannot be stored to the SGM451.

Programming

Serial Interface

In two-wire or SMBus system, the SGM451 can be operated only as a slave device. The SDA and SCL lines are the two main wires of for the digital interface. The Schmitt triggers and the filter that can suppress the spikes are integrated to significantly decrease the effect of the bus noise or input spikes. The SGM451 can be used for fast (1kHz to 400kHz) and high-speed (1kHz to 2.5MHz) mode and the MSB bit is the first bit that transmitted.

Bus Overview

The SMBus interface is used in the SGM451 device. For the protocol of SMBus, the device which initiates the transfer called Master device and the device which is controlled by the Master is called Slave. The bus should be controlled by the Master device which can generate the signal of START, STOP and SCL condition.

The START signal must be initiated at first to get the communication between Master and Slave address. The SDA line should be pulled from high to low for a START condition. Then the Master device will send the corresponding Slave address with the $R/\overline{W}$ bit. For the ninth clock pulse, the slave address will send an acknowledge bit by pulling the SDA line to low.

After that, the data transfer is started and the Master sends eight clock pulsed which is followed by an Acknowledge pulse. Moreover, the SDA pulse must be stable while the SCL pulse is high so that it cannot be recognized as a control signal.

If the data transfer is finished, the STOP condition will be sent by the Master device. When STOP condition occurs, the SDA will change from low to high while SCL is in high position.

DETAILED DESCRIPTION (continued)

Bus Definitions

For the digital interface of the SGM451, it uses two-wire communication. The timing sequence of the SGM451 for two-wire interface is shown in Figure 7 and Figure 8 respectively.

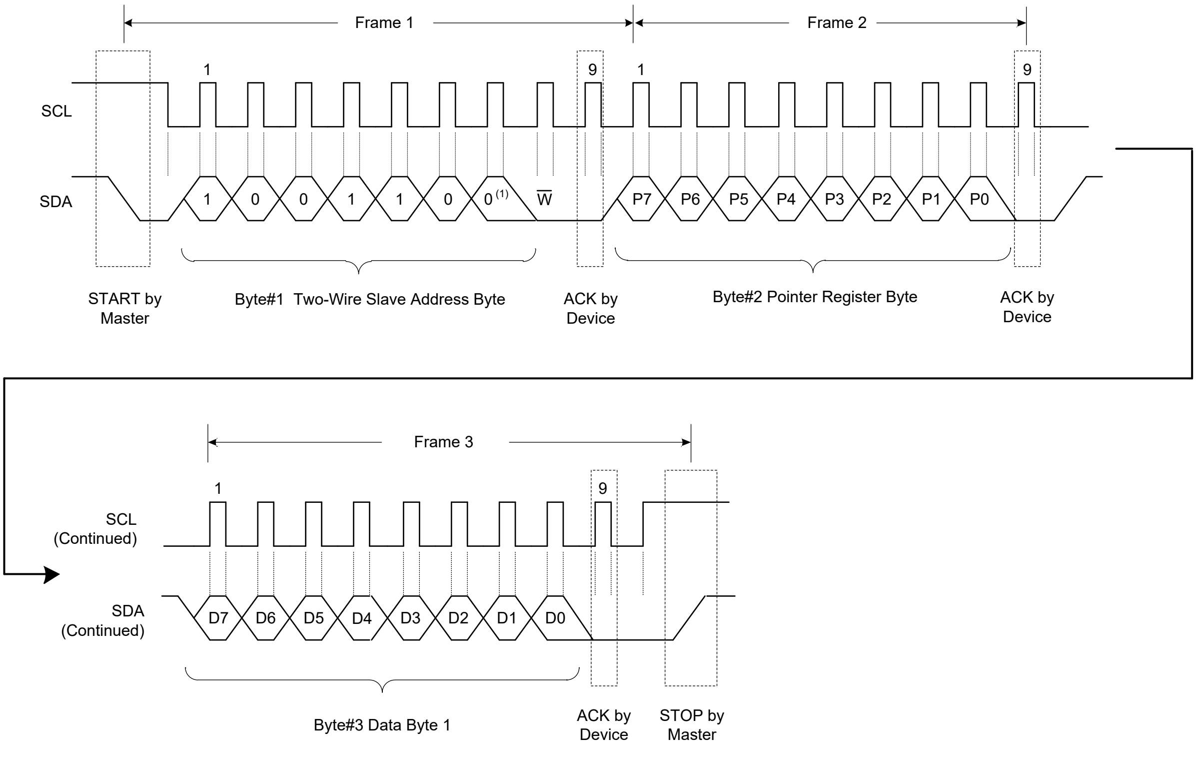
Acknowledge: Once the slave address is addressed, it will send an acknowledge bit to indicate that it is addressed successfully. When acknowledge occurs, the SDA line is pulled low in a stable level while SCL is in high position. Take setup and hold times into account. When the Master device acts as a receiver, it can send a non-acknowledge at the end of the data bits to indicate that the transfer is terminated.

Bus Idle: When bus idle occurs, the SDA and SCL keep in high position all the time.

Data Transfer: The amount of data transferred by the Master device is unlimited. The receive device will send an acknowledge bit to indicate that it has receive the data successfully.

Start Data Transfer: For each data transfer, the START condition will always take into first lead. When START condition occurs, the SDA line goes from high to low while SCL line is still in high position.

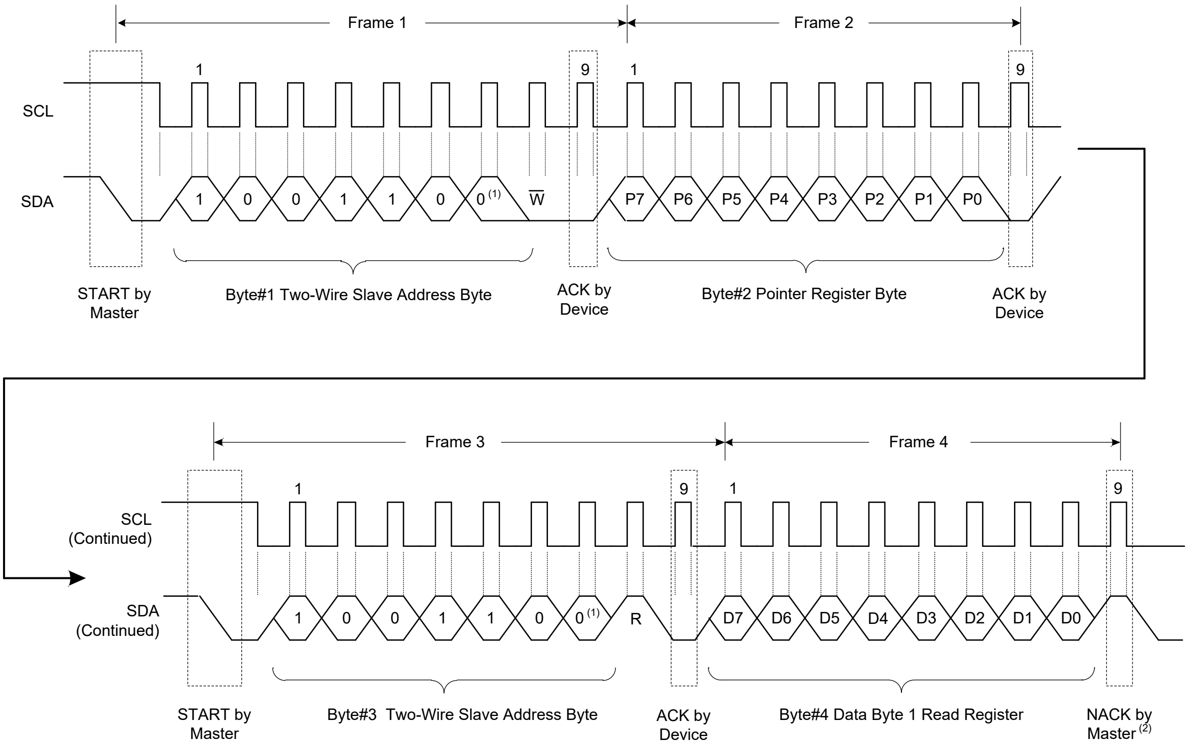
Stop Data Transfer: For STOP condition, the SDA line goes from low to high while SCL remains in high position. Once the data transfer is terminated, the repeated START or STOP condition will be operated.



NOTE: 1. Slave Address is 1001100.

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

DETAILED DESCRIPTION (continued)



NOTES:

1. Slave Address is 1001100.
2. To terminate a single-byte read operation, Master should leave SDA high.

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

Serial Bus Address

To successfully communicate with the SGM451, the Master device should send the address byte to the SGM451 at first. There are 7 address bits inside the slave address byte, and followed by one bit which indicates the state of write or read. The slave address of the SGM451 is 4Ch (1001100b).

Read and Write Operations

After sending the address of the pointer register to the SGM451 with the $R/\overline{W}$ bit low, the Master will send the corresponding byte of the pointer address to get the access to this register, and then accomplishes the write process. The byte of the pointer address is always required before sending data to the configuration.

When processing the read condition, the last value restored in the pointer register is used to indicate which pointer register is read. If the operator needs to read another data of the specific pointer address, the corresponding address should be written to the pointer register byte. The transaction is finished by sending the corresponding slave address, and followed by the specific pointer address byte that the operator desires to read. From the time sequence which is shown in Figure 8, the Master can generate a START condition at first and then send the slave address byte that followed by $R/\overline{W}$ = 1.

It is no need for the Master to send the bytes of the pointer address continually if the repeated read is required. The reason is that the value of the pointer address is retained by the device unless the operator starts a write operation. The MSB is sent at first and the LSB is sent at least.

Once the read operation is terminated, the not-acknowledge bit should be sent at the end of the bytes to be read. For single-byte operation, the SDA line should be kept in high position within the time period of acknowledge time before the data transferred from the receiver.

DETAILED DESCRIPTION (continued)

Time-Out Function

If the function of time-out for SMBus is enabled, the serial interface for the SGM451 will be reset at the situation which the SDA and SCL hold low for 25ms during the transmission between START and STOP. If the bus for SGM451 is hold low, the bus will be released and wait for the incoming START condition. If the time-out function is undesired, please make sure that the communication frequency should be set at least 1000Hz to avoid it. Inside the consecutive nALERT register, the bit 7 (SMBTO) controls the on and off of the time-out function. The time-out function will be disabled if the bit 7 is set to 0. If the customer needs the time-out function, set this bit to 1.

High-Speed Mode

If the communication frequency of the two-wire bus is above 1MHz, the corresponding Master code (00001xxx) should be transferred after the START condition to indicate a high-speed mode. However, the SGM451 does not acknowledge this byte, but switches the input and output filter to allow a communication frequency up to 2.5MHz. After issuing the HS code to the SGM451, the Master can transfer the slave address to start the communication through the two-wire bus. The bus will continue to communicate with the high-speed mode until the STOP condition. Once the slave receives the STOP condition, the input and output filters of the SGM451 will be switched back to the cutoff frequency of fast mode.

General Call Reset

The SGM451 can be reset by the two-wire general call address 00h (00000000). The first byte is acknowledged by the SGM451. If the second byte that the slave received is 06h (00000110), the software reset of the SGM451 should be launched. The software reset will restore the state of the power-on reset to all of the SGM451 so that the communication will be stopped.

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	BUS_FLEX	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

There are a lot of registers inside the SGM451 to indicate the results of temperature, holding the information of configuration and status information, which are described in Figure 9 and Table 3.

Pointer Register

The registers inside the SGM451 are shown in Figure 9. The pointer register is used to address the data register.

The meaning of the pointer register is that it can identify which data register is to be read or write. Before every command of write, the pointer register is set properly. Before enabling the read command, a write command must be issued to set the appropriate value in the pointer register. The information of the pointer register is shown in Table 3, and the power-on reset value of the pointer register is set to be 00h (00000000).

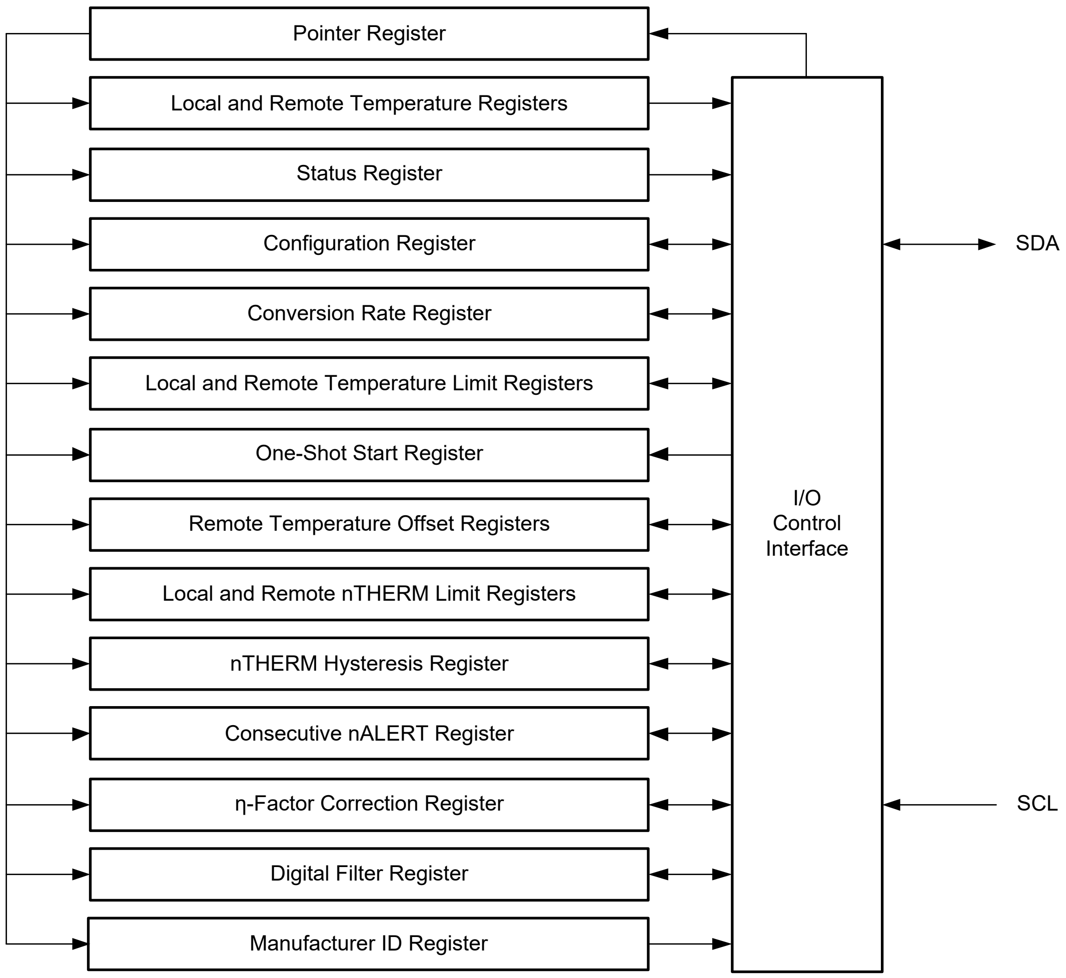


Figure 9. Internal Register Structure

RESISTER INFORMATION (continued)

Local and Remote Temperature Registers

The digital temperature result of the SGM451 is stored inside the multiple 8-bit registers. The register 00h is used to store the most significant bits (MSB) of a 12-bit digital data result, while the rest least significant bits (LSB) are stored inside the register 15h (these four bits are the MSB of 15h). The register 01h is used to restore the eight most significant bits of the remote temperature result, while the register 10h is used to restore the least significant bits of the remote result (these four bits are the MSB of 10h). The four least significant bits of the both remote and local measuring result illustrates the part after the decimal point (for instance, if the temperature result is 10.0625℃, the high byte is 00001010 and the low byte is 00010000). The registers illustrated above are read-only and be updated after measuring.

If the customers need the result of full temperature, the rest LSB values will be locked until be read (the internal ADC is not prepare to write to it) if the MSB is read firstly. Similarly, the MSB values will be locked until it is read if the LSB values are read first. For typically reading, the register which stores the high bytes of the temperature result should be read while the one which stores low bytes need to be read after the next read command. However, the MSB will be left if the four least significant bits are not required. The power-on reset value of all temperature registers is 00h.

Status Register

The status register of the SGM451 is used to indicate the state of the internal ADC, the connection of the remote sensor and the comparators which limit the temperature. The bits of the status register are listed in Table 8. Also, this register is read only and it can be access by pointer address 02h.

The over- and under-temperature events are illustrated by the two bits of LHIGH and LLOW, while the remote over- and under-temperature events are illustrated by the two bits of RHIGH and RLOW respectively. The open circuit condition is illustrated by the OPEN bit. If the pin 6 of the SGM451 is configured as the output of the nALERT, the 5 flags should be nALERT together. The nALERT will move to the low position and the nALERT interrupt latch is set once any of the five flags are high. The five flags will be cleared if the read condition is launched, which means that the settings for the flags are not present anymore (to explain, the test value is within the limitation of measurement, or the remote sensor for the SGM451 is connected correctly). The latch for the nALERT cannot be reset by the reading of the status register. The reset mechanism can be finalized by reading the temperature sensor device address in order to provide an interrupt, and only if finishing the reset mechanism of the flags and the condition which can cause temperature set is disappeared.

The two flags which are RTHRM and LTHRM can be set if the measured temperature is higher than the limitation of nTHERM. Also, these two flags can be reset by the SGM451 itself if the measured temperature is within the limitation of the nTHERM that be programmed. To specify, the nTHERM will be in low position if the situation of over-temperature for both local and remote channel, and it will be in high position again if the measured temperature is within the limitation. In addition, the hysteresis register of nTHERM (21h) can be used for the flags reset.

The high limit should be the only one to be taken into consideration if the pin 6 of the SGM451 is configured as nTHERM2. For example, if the respective temperatures are higher than the limitation, both LHIGH and RHIGH flags will be set and this pin is pulled low to illustrate these events. However, the LLOW and HLOW are not related to the nTHERM2 so that the output behavior is the same as nTHERM.

Configuration Register

The output of nALERT is masked by the configuration register of MASK1. The nALERT output will be enabled if the bit of MASK1 is 0, which is the default setting of SGM451. However, the nALERT output will be disabled if the bit of MASK1 is 1. However, this register only works if the bit value of nALERT/nTHERM is equal to 0 (that is, pin 6 is configured as the output of nALERT).If the output of the nTHERM2 is applied by pin 6, there will be no effect for MASK1.

RESISTER INFORMATION (continued)

The temperature measurement circuitry which is inside the SGM451 is controlled to be on and off by the SD bit. The SGM451 will be in continuous mode if the SD bit is set to 0 and the conversion rate can be set in the conversion rate register. Also, if the SD bite is set to 1 by the customer, the device will be in shutdown mode after completing the conversion of the data sequence. The SGM451 will resume operating in the continuous mode if the SD bit is set to 0 again. A single conversion will be launched by writing to the one-shot start register if the SD bit is set to 1.

The configuration of pin 6 is set by the bit of nALERT/nTHERM2. The pin 6 of the SGM451 will be configured as the output once the bit of nALERT/nTHERM2 is equal to 0 and will be configured as the output of THERM2 once this bit is set to 1.

The configuring RANGE sets the measuring temperature range of the SGM451. The standard temperature of measuring is from 0℃ to +127℃ by setting the RANGE bit to 0. If the customers desire to measure the temperature with larger temperature range (-64℃ to +191℃), the RANGE should be set to 1.

For the remaining binary part of the configuration register, these bits should always be set to 0. For this register, the value of the power-on reset is 00h.

Conversion Rate Register

The conversion rate of the temperature is controlled by the register of the conversion rate (read address 04h, write address 0Ah), which means that it can only adjust the idle time between two temperature conversions and not the conversion time of the SGM451. The conversion time and the idle time between two temperature conversions are show in Table 4. The default value of the SGM451 for the conversion rate is 16 conversions per second, and the value for this register is 08h.

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 system offset value of the SGM451 can be stored inside the offset register to indicate by the calibration. Moreover, the format of the stored value inside the offset registers is the same as that of temperature result, which will be added into the result of the remote temperature result upon each conversion. The function is required for accuracy calibration of the system and combined with the η-factor.

η-Factor Correction Register

The η-factor is used for converting the value of the remote result to the temperature. The sequential current excitation is used for obtaining the temperature of the remote transistor by the differential voltage of V_{BE}. The following equation illustrates the calculation of the temperature:

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

The value η illustrates the characteristic of the specific transistor which is used for the remote channel. Also, this value of the power on reset is η = 1.008. The correction register is used for adjust the value of η, and the following two equations indicate this:

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

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

RESISTER INFORMATION (continued)

Since the data range of the measurement is from -128 to 127, so that the two's component format should be taken into account to express negative decimal data. Also, the η-factor can be read or written from the pointer address which is 23h. The power-on reset value of the register is 00h, which means that there is no effect for this register if there is no different value to be 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

Also, the SGM451 allows the two-wire bus interface to search for its manufacturer and device IDs in order to launch the software identification. Also, the ID of the manufacture can be obtained by reading the register which is FEh. The SGM451 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. For the resolution of the SGM451, it is 1℃. This register can be read only and be updated once the measurement of temperature is completed. If the customers desire to read the full temperature value and the high byte register is read in this case, the value of the low register byte will be locked (ADC will not write to it). Also, the same thing happens if the low byte is read. The advantage of this technology is that both the high byte and the low byte are read from the same ADC which is inside the device. SGMICRO recommends that the high byte should be read at first, and then send the read command again to read the low byte. If the low byte is not needed, please leave it 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. For the resolution of the SGM451, it is 1℃. This register can be read only and be updated once the measurement of temperature is completed. If the customers desire to read the full temperature value and the high byte register is read in this case, the value of the low register byte will be locked (ADC will not write to it). Also, the same thing happens if the low byte is read. The advantage of this technology is that both the high byte and the low byte are read from the same ADC which is inside the device. SGMICRO recommends that the high byte should be read at first, and then send the read command again to read the low byte. If the low byte is not needed, please leave it 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 = The local temperature value is not higher than the value of local temperature high limit register. 1 = The local temperature value is higher than the value of local temperature high limit register. 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 = The local temperature value is not lower than the value of local temperature low limit register. 1 = The local temperature value is lower than the value of local temperature low limit register. 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 = The remote temperature value is not higher than the value of remote temperature high limit register. 1 = The remote temperature value is higher than the value of remote temperature high limit register. 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 = The remote temperature value is not lower than the value of remote temperature low limit register. 1 = The remote temperature value is lower than the value of remote temperature low limit register. 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]	RESERVED	R/W	0	Reserved.
D[0]	BUS_FLEX	R/W	0	If the I^2C bus voltage is lower than the V_{CC}, the internal leakage blocking circuit will be turned off. Also, once the V_{BUS} is lower than V_{CC} - 0.3V, the V_{CC} sees leakage but the I^2C interface can still be operated. For the two situations which are V_{BUS} = 1.8V and V_{CC} = 3.3V, V_{BUS} = 3.3V and V_{CC} = 5V. The power down current will be increased and the leakage current will be removed with setting the BUS_FLEX equal to 1.

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, write 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 can be read only and be updated once the measurement of temperature is completed. If the customers desire to read the full temperature value and the high byte register is read in this case, the value of the low register byte will be locked (ADC will not write to it). Also, the same thing happens if the low byte is read. The advantage of this technology is that both the high byte and the low byte are read from the same ADC which is inside the device. SGMICRO recommends that the high byte should be read at first, and then send the read command again to read the low byte. If the low byte is not needed, please leave it unread.
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 which is inside the register will be added to the result. For the desired calibration for the application, the value is added of subtracted by the result of the internal ADC. The resolution for the least significant bit of the internal ADC 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 which is inside the register will be added to the result. For the desired calibration for the application, the value is added of subtracted by the result of the internal ADC. 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 can be read only and be updated once the measurement of temperature is completed. If the customers desire to read the full temperature value and the high byte register is read in this case, the value of the low register byte will be locked (ADC will not write to it). Also, the same thing happens if the low byte is read. The advantage of this technology is that both the high byte and the low byte are read from the same ADC which is inside the device. SGMICRO recommends that the high byte should be read at first, and then send the read command again to read the low byte. If the low byte is not needed, please leave it 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

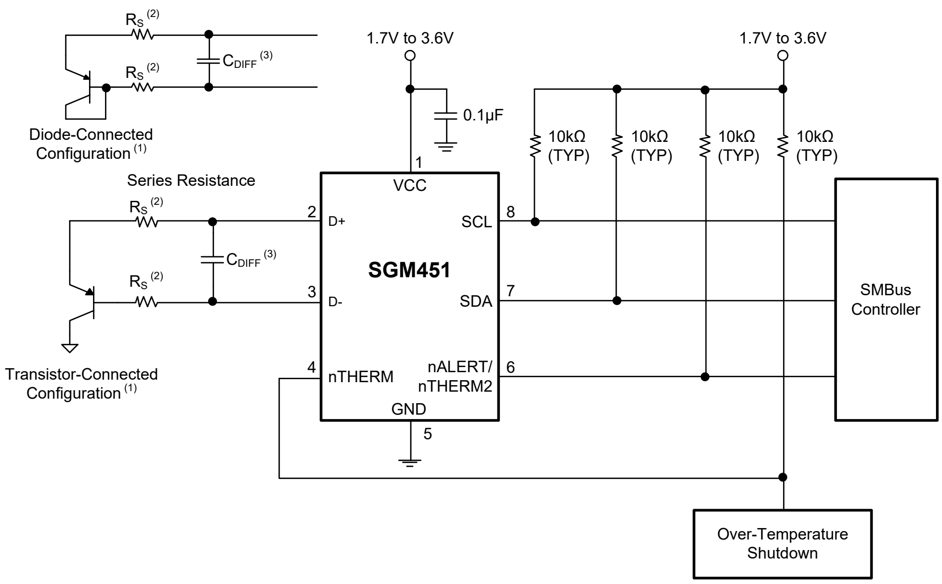
Table 28. Manufacturer ID Register Details

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

APPLICATION INFORMATION

For measuring the remote temperature with SGM451, an external transistor is required to be connected with D+ and D- pins. For measuring local temperature only, connecting D+ and D- pins with GND. The pull-up resistors are required for the pins of SDA, SCL and nALERT/nTHERM2. The 0.1μF bypass capacitor is required at the VCC pin.

Figure 10 shows the typical configuration of SGM451.



NOTES:

1. For better settling time, the configuration of Diode-Connected should be selected. For cancelling the series resistance, Transistor-Connected Configuration is a good choice.
2. The value of R_S should be less than 1kΩ. Also, the selection of R_S depends on the situation of application, see the Filtering Section.
3. For most of the applications, the capacitance of C_{DIFF} is less than 1nF. Also, the selection depends on the different situation of applications. Please see the Filtering Section.

Figure 10. SGM451 Basic Connections Using a Discrete Remote Transistor

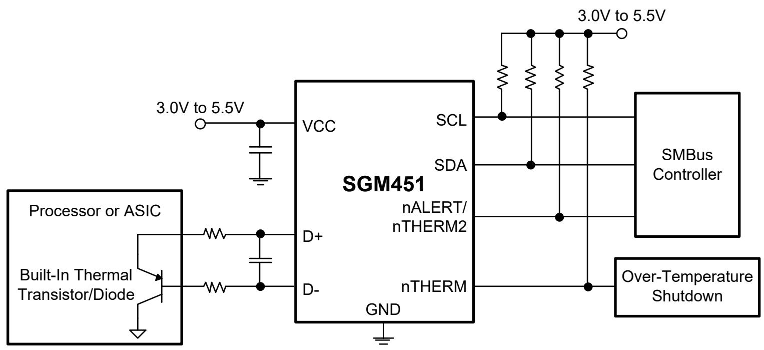


Figure 11. SGM451 Basic Connections Using a Processor Built-In Remote Transistor

APPLICATION INFORMATION (continued)

Design Requirements

For the processor and the ASICs which are inside the SGM451, the substrate transistor or discrete transistor is taken into account. Also, for remote measurement, a base-emitter junction is also considered for this application. If NPN transistor is used, the structure of the NPN should be diode-connected. Also, if PNP transistor is used, both diode-connection and transistor-connection can be used (see Figure 10).

The error always exists when measuring remote temperature source. Also, the reading of the remote measurement depends on the ideality factor and current excitation of the SGM451 itself, and the operating current of the used external transistor. The high-level and low-level current will be labeled by the manufacturers of the substrate transistor. For the SGM451, the transistor with I_{LOW} = 7.5μA and I_{HIGH} = 120μA should be considered.

The comparison of the measured characteristics for diode of remote temperature sensor and ideal diode is expressed as the ideality factor (η). Different η-factor values are allowed by SGM451; see the η-Factor Correction Register section.

The trimmed value for the η-factor of the SGM451 is 1.008. The Equation 4 is used to calculate the error if the ideality factor of the transistor does not match that of the SGM451. For the equation to be used correctly, The actual temperature (℃) must be converted to Kelvin (K).

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

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℃:

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

$$T_{ERR}=-1.48℃$$

For the remote temperature case, if the discrete transistor is taken into account, the following criteria should be referenced for selecting.

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

The 2N3904 (NPN) or 2N3906 (PNP) small-signal transistor is recommended based on this criteria.

Detailed Design Procedure

The ambient air is monitored by the local temperature sensor which is inside the SGM451. The thermal time constant for the measurement is around two seconds. For example, if the time changes by 100℃, the SGM451 will need 10s (five time constants) to settle the digital output to the stable final value within the accuracy of 1℃. However, for most of the applications, the SGM451 will be contacted electrically with the PCB board, which means that the airflow will take place. Also, the accuracy of the measurement depends on the extent of the temperature of PCB board and the forced airflow. In addition, the power dissipation of SGM451 itself will also cause the accuracy problem as it may result in the temperature to rise beyond the temperature of ambient and PCB board. Also, the power dissipation which is used for exciting the remote sensor can be ignored as the current that will be used in this application is small. For instance, if the supply voltage of the SGM451 is 3.3V and the conversion rate for measuring the temperature is 16 conversions/second, the dissipated power by the SGM451 is 330μW (PD_{IQ} = 3.3V × 100μA). The temperature will be 0.09℃ higher than the ambient temperature if the θ_{JA} is equal to 171.3℃/W.

APPLICATION INFORMATION (continued)

Power Supply Recommendations

In detail, there will be a time delay if the device is not in good thermal contact with the monitored system point. However, if the substrate transistor is placed close to the monitored device, the delay can be negligible.

The supported power supply voltage for the SGM451 is from 3.0V to 5.5V. The recommended power supply voltage for the device is 3.3V and the SGM451 can measure temperature accurately at full power supply range.

The bypass capacitor is needed for the power supply pin. Also, the capacitor should be placed as close as possible to the power supply pin for better performance. The typical value for the bypass capacitor is 100nF. If the power supply is noisy, an additional bypass capacitor is also required.

LAYOUT

For the remote measurement condition, the SGM451 needs to measure small voltages with low currents, which means that the input noise of the SGM451 should be minimized. For most of the applications, there would be some digital contents such as clock and logic transitions that would affect the accuracy of the SGM451. These following guidelines should be followed:

1. The SGM451 should be placed as close as possible to the remote sensor.

2. The PCB trace for D+ and D- should be placed as close as possible, and the adjacent signals should be shielded with the ground guard traces. For multilayer PCB layers, burying these two signals between ground or VCC plane is a good choice to isolate the extrinsic noise sources. The 5 mil width PCB trace is recommended.

3. Minimize additional thermocouple junctions caused by copper-to-solder connections. However, if the junction is considered to be used, make sure that the number and the location of the junction are the same as each other.

4. The 100nF bypass capacitor should be taken into consideration between the VCC and GND of the SGM451. For improving the performance of the measurement, the filtering capacitors should be placed as 1nF. This capacitance includes the cable capacitance between the remote sensor and the SGM451.

5. For remote testing, the twist-wire connection should be taken into consideration if the length is less than 8 in (203.2mm). The twisted, shielded pair with shield ground should be used and placed as close as possible to the SGM451 if the length is greater than 8 in. To avoid the ground loops and the pickup of 60Hz, the remote sensor connection end of the shield wire should be left open.

6. The flux residue which is around the pins of SGM451 should be removed and cleaned so that the leakage paths will be reduced.

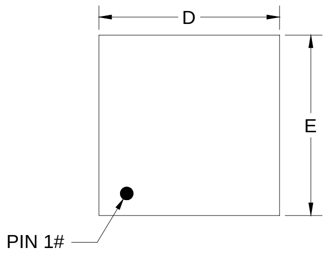
REVISION HISTORY

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

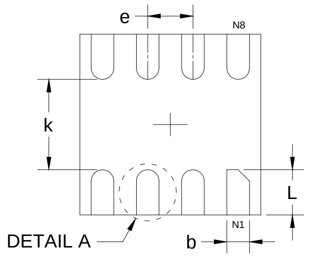
Changes from Original (DECEMBER 2020) to REV.A	Page
Changed from product preview to production data	All

PACKAGE OUTLINE DIMENSIONS

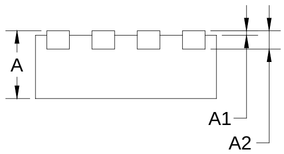
TDFN-2×2-8BL



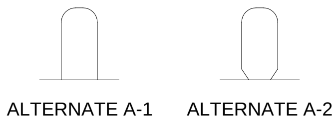
TOP VIEW



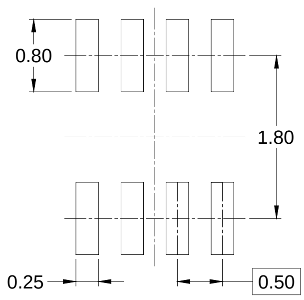
BOTTOM VIEW



SIDE VIEW



DETAIL A
ALTERNATE TERMINAL CONSTRUCTION



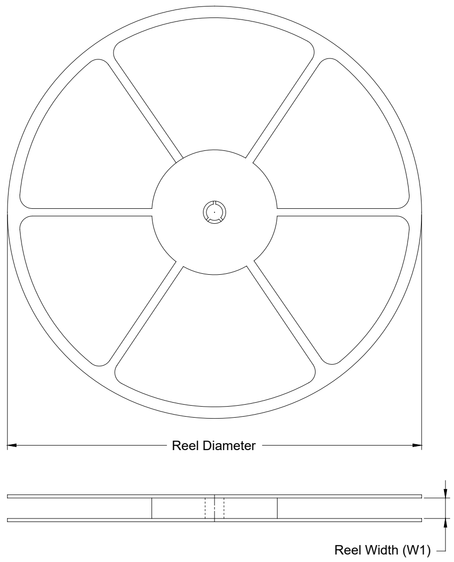
RECOMMENDED LAND PATTERN (Unit: mm)

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		

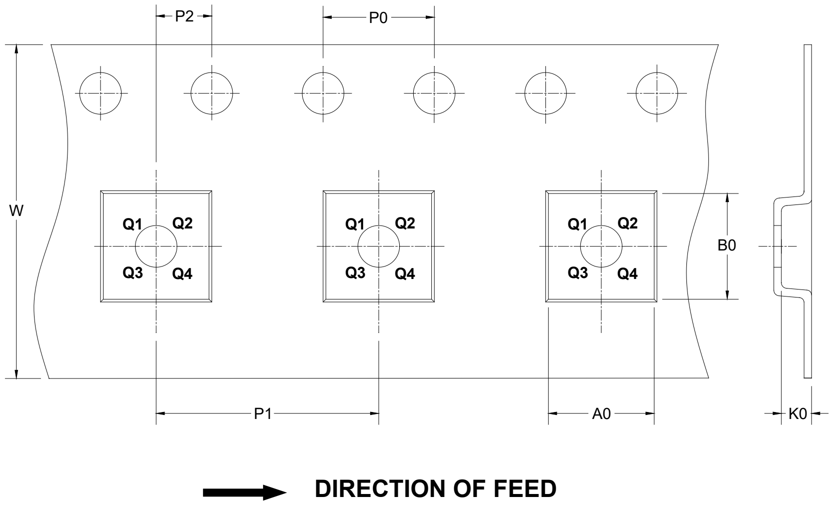
NOTE: This drawing is subject to change without notice.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



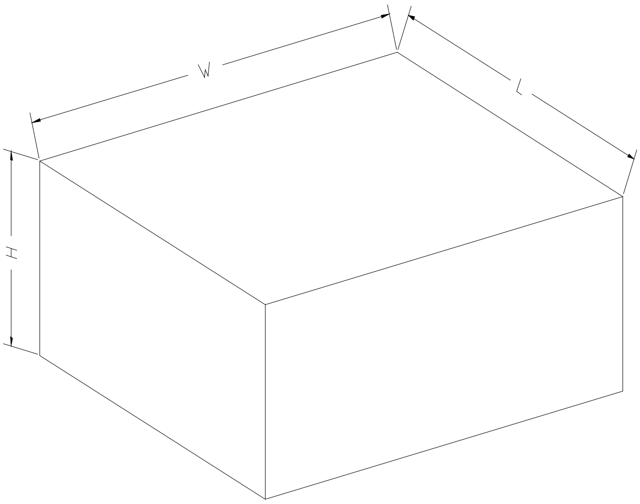
NOTE: The picture is only for reference. Please make the object as the standard.

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