SGM90801
120V, 16-Bit, Precise Digital Power Monitor AFE with SPI Interface

GENERAL DESCRIPTION

The SGM90801 is an analog front end (AFE) designed for precise digital power monitoring with a SPI digital interface. The device provides bus supply voltage, shunt voltage and internal temperature monitor. The internal high resolution ADC, with flexible configurations including calibration value, conversion times as well as average numbers support direct fetch of current values in amperes and power values in watts.

The SGM90801 can measure a differential input voltage of ±163.84mV with common-mode voltage from 0V to 120V while the shunt voltage measurement pins IN+ and IN- can survive under a wide common-mode voltage from -10V to 120V. The bus voltage measurement supports the range from 0V to 120V or 0V to 85V. The integrated temperature sensor has ±1℃ (TYP) accuracy for die temperature measurement, which is useful in the system level temperature calibrations.

With low offset and drift design of the SGM90801, it is suitable for applications under wide range of temperature variation and simplifies the calibration. These features also make the device suitable for precise sensing systems. Two shunt voltage input ranges help expand the current measurement range.

FEATURES

- **High Accuracy and High Resolution:**
  - **True 16-Bit Sigma-Delta (Σ-Δ) ADC**
  - **Gain Error: ±0.4% (MAX)**
  - **Offset: ±32μV (MAX)**
  - **Common-Mode Rejection: 120dB (MIN)**
  - **Input Bias Current: 3nA (MAX)**
- **Two Shunt Voltage Measurement Ranges: ±163.84mV and ±40.96mV**
- **Two Bus Voltage Measurement Ranges: 0V to 85V and 0V to 120V**
- **10MHz SPI Interface**
- **Available in a Green MSOP-10 Package**

APPLICATIONS

Enterprise Servers
Telecom Equipment
Storage Battery Charging and Discharging
Power Managements
Test Equipment

TYPICAL APPLICATION

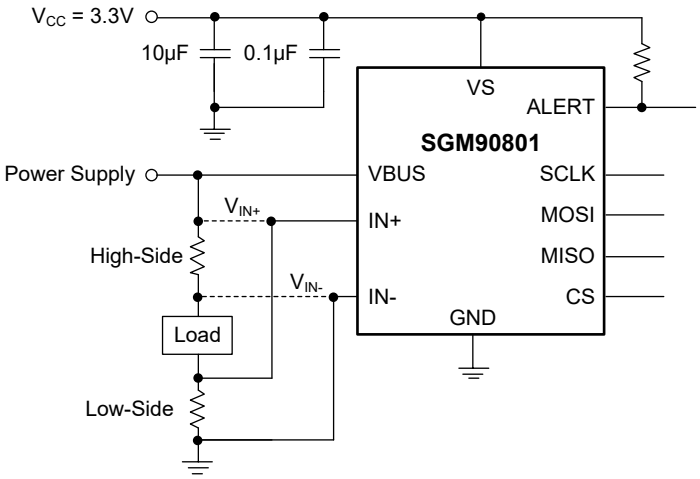


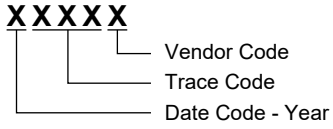
Figure 1. High-Side or Low-Side Sensing Application Circuit

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM90801	MSOP-10	-40℃ to +125℃	SGM90801XMS10G/TR	SGM1TR XMS10 XXXXX	Tape and Reel, 4000
			SGM90801XMS10SG/TR	SGM1TR XMS10 XXXXX	Tape and Reel, 500

MARKING INFORMATION

NOTE: XXXXX = Date Code, Trace Code and Vendor 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

Supply Voltage, V_S 6V
Analog Inputs, IN+, IN-
Differential (V_{IN+} - V_{IN-}) ..... -40V to 40V
Common-Mode (V_{IN+} + V_{IN-})/2 ..... -10V to 125V
VBUS Voltage, V_{VBUS} ..... -0.3V to 125V
V_{MOSI}, V_{MISO}, V_{SCLK}, V_{ALERT} ..... -0.3V to V_S + 0.3V
Input Current into Any Pin, I_{IN} 5mA
Digital Output Current, I_{OUT} 10mA
Package Thermal Resistance
MSOP-10, θ_{JA} ..... 128.1℃/W
MSOP-10, θ_{JB} ..... 73.4℃/W
MSOP-10, θ_{JC} ..... 37.9℃/W
Junction Temperature ..... +150℃
Storage Temperature Range ..... -65℃ to +150℃
Lead Temperature (Soldering, 10s) ..... +260℃
ESD Susceptibility (1) (2)
HBM ..... ±2000V
CDM ..... ±1000V

NOTES:

1. For human body model (HBM), all pins comply with ANSI/ESDA/JEDEC JS-001 specifications.

2. For charged device model (CDM), all pins comply with ANSI/ESDA/JEDEC JS-002 specifications.

RECOMMENDED OPERATING CONDITIONS

Common-Mode Input Voltage, V_{CM} ..... 0V to 120V
Operating Supply Voltage, V_S ..... 2.7V to 5.5V
Operating Ambient 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.

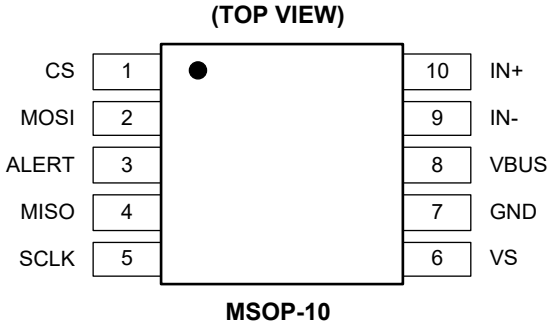
ESD SENSITIVITY CAUTION

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



PIN DESCRIPTION

PIN	NAME	I/O	FUNCTION
1	CS	DI	Active Low SPI Selected Pin.
2	MOSI	DI	SPI Digital Data Input Pin.
3	ALERT	DO	Open-Drain Alert Output. Default state is active low.
4	MISO	DI	Push-Pull SPI Digital Data Output Pin.
5	SCLK	DI	SPI Clock Input Pin.
6	VS	P	2.7V to 5.5V Power Supply.
7	GND	G	Ground.
8	VBUS	AI	Bus Voltage Input.
9	IN-	AI	Device Negative Input. For high-side applications, connect it to load side of sense resistor. For low-side applications, connect it to ground side of sense resistor.
10	IN+	AI	Device Positive Input. For high-side applications, connect it to power supply side of sense resistor. For low-side applications, connect it to load side of sense resistor.

NOTE: DI = digital input, AI = analog input, DO = digital output, P = power, G = ground.

ELECTRICAL CHARACTERISTICS

(V_S = 3.3V, V_{SENSE} = V_{IN+} - V_{IN-} = 0V, V_{CM} = V_{IN-} = 48V and T_A = +25℃, unless otherwise noted.)

PARAMETER		SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input							
Common-Mode Input Range		V_{CM}	T_A = -40℃ to +125℃	0		120	V
Shunt Voltage	Input Range	V_{SHUNT}	VSHUNTRANGE = 0, T_A = -40℃ to +125℃	-163.84		163.84	mV
			VSHUNTRANGE = 1, T_A = -40℃ to +125℃	-40.96		40.96	mV
	Offset Voltage	V_{OSS}	V_{CM} = 48V		±5	±32	μV
			V_{CM} = 0V		±5	±32	
	Offset Voltage Drift	V_{OSS_DRIFT}	vs. Temperature, T_A = -40℃ to +125℃		±80	±300	nV/℃
Bus Voltage	Input Range	V_{BUS}	VBUSRANGE = 0	0		85	V
			VBUSRANGE = 1	0		120	
	Offset Voltage	V_{OSB}	V_{BUS} = 400mV		±2	±45	mV
	Offset Voltage Drift	V_{OSB_DRIFT}	vs. Temperature, T_A = -40℃ to +125℃		±200	±750	μV/℃
Common-Mode Rejection		CMRR	0V < V_{CM} < 120V, T_A = -40℃ to +125℃	120	150		dB
Shunt Offset Voltage vs. Power Supply		PSRR	V_S = 2.7V to 5.5V, T_A = -40℃ to +125℃		±3.0	±25	μV/V
VBUS Offset Voltage vs. Power Supply		PSRR	V_S = 2.7V to 5.5V		±10		mV/V
Input Bias Current (IN+, IN- Pins) (1)		I_B			0.4	3	nA
VBUS Pin Input Impedance		Z_{VBUS}	Active mode		1	1.1	MΩ
VBUS Pin Leakage Current		I_{VBUS}	Shutdown mode		2		nA
Input Differential Impedance		R_{DIFF}	Active mode, V_{IN+} - V_{IN-} < 164mV		50		kΩ
DC Accuracy							
Shunt Voltage (2)	Gain Error	G_{SERR}			±0.03	±0.4	%
	Gain Error Drift	G_{S_DRFT}			±10	±30	ppm/℃
VBUS Voltage	Gain Error	G_{BERR}			±0.03	±0.25	%
	Gain Error Drift	G_{B_DRFT}			±20	±50	ppm/℃
Power Total Measurement Error (TME) (2)		P_{TME}	T_A = -40℃ to +125℃		±0.2	±0.9	%
ADC Resolution					16		Bits
1 LSB Step Size	Shunt Voltage		VSHUNTRANGE = 0		5		μV
			VSHUNTRANGE = 1		1.25		
	Bus Voltage		VBUSRANGE = 0		3.125		mV
			VBUSRANGE = 1		4		
	Temperature				125		m℃
ADC Conversion Time (3)		t_{CT}	Conversion time field = 0h		50		μs
			Conversion time field = 1h		84		
			Conversion time field = 2h		150		
			Conversion time field = 3h		280		
			Conversion time field = 4h		540		
			Conversion time field = 5h		1.052		ms
			Conversion time field = 6h		2.074		
			Conversion time field = 7h		4.120		
Integral Non-Linearity		INL			±3		m%
Differential Non-Linearity		DNL			0.2		LSB

ELECTRICAL CHARACTERISTICS (continued)

(V_S = 3.3V, V_{SENSE} = V_{IN+} - V_{IN-} = 0V, V_{CM} = V_{IN-} = 48V and T_A = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Clock Source						
Internal Oscillator Frequency	f_{OSC}			1		MHz
Internal Oscillator Frequency Tolerance	f_{OSC_TOL}	T_A = +25℃			±2	%
		T_A = -40℃ to +125℃			±3	%
Temperature Sensor						
Measurement Range			-40		+125	℃
Temperature Accuracy (1)		T_A = +25℃		±0.5	±2	℃
		T_A = -40℃ to +125℃		±1	±3	℃
Power Supply						
Supply Voltage	V_S		2.7		5.5	V
Quiescent Current	I_Q	V_{SENSE} = 0V, T_A = +25℃		900	1100	μA
		V_{SENSE} = 0V, T_A = -40℃ to +125℃			1200	μA
Shutdown Current	I_{SD}	Shutdown mode		2.5	4.0	μA
Device Start-up Time	t_{POR}	Power-up (NPOR)		200		μs
		From shutdown mode		50		
Digital Input/Output						
High-Level Input Voltage	V_{IH}		1.2		5.5	V
Low-Level Input Voltage	V_{IL}				0.4	V
Low-Level Output Voltage	V_{OL}	I_{OL} = 1mA		0.22	0.4	V
High-Level Output Voltage	V_{OH}	I_{OL} = 1mA	V_S - 0.4		V_S	V
Digital Leakage Input Current	I_{IO_LEAK}	0 ≤ V_{IN} ≤ V_S		0.05	0.2	μA

NOTES:

1. Guaranteed by design.
2. These values are indicated after the settling of the system.
3. Subject to oscillator accuracy and drift.

TIMING REQUIREMENT

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS
SPI Bit Frequency	f_{SPI}			10	MHz
SCLK High Time	t_{SCLK_H}	40			ns
SCLK Low Time	t_{SCLK_L}	40			ns
CS Fall to First SCLK Rise Time	t_{CSF_SCLKR}	10			ns
Last SCLK Fall to CS Rise Time	t_{SCLKF_CSR}	10			ns
Sequential Transfer Delay (1)	t_{FRM_DLY}	50			ns
MOSI Rise and Fall time, 10MHz SCLK	t_{MOSI_RF}			15	ns
MOSI Data Setup Time	t_{MOSI_ST}	10			ns
MOSI Data Hold Time	t_{MOSI_HLD}	20			ns
MISO Rise and Fall time, C_{LOAD} = 200pF	t_{MISO_RF}			15	ns
MISO Data Setup Time	t_{MISO_ST}	20			ns
MISO Data Hold Time	t_{MISO_HLD}	20			ns
CS falling Edge to MISO Data Valid Delay Time	$t_{CS\_MISO\_DLY}$			25	ns
CS rising Edge to MISO High Impedance Delay Time	$t_{CS\_MISO\_HIZ}$			25	ns

NOTE: Optional. The SPI interface can operate without the CS pin if it is held low.

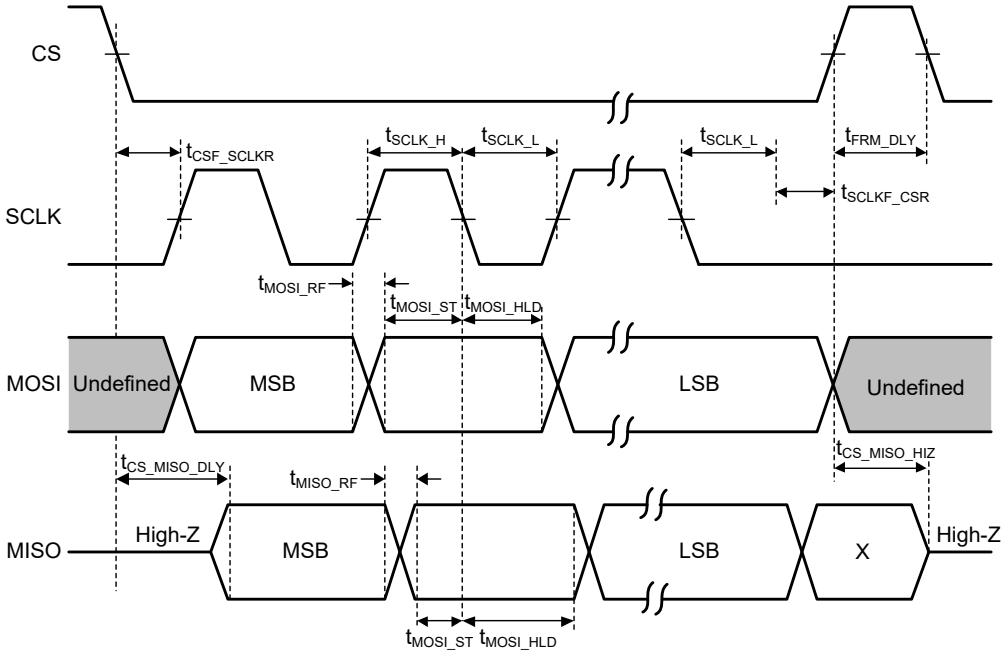
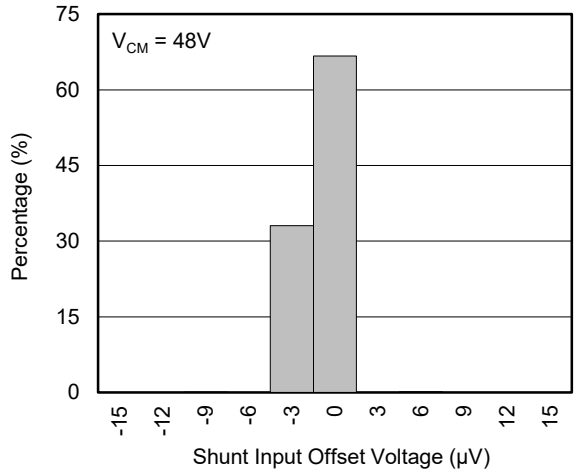


Figure 2. SPI Timing Diagram

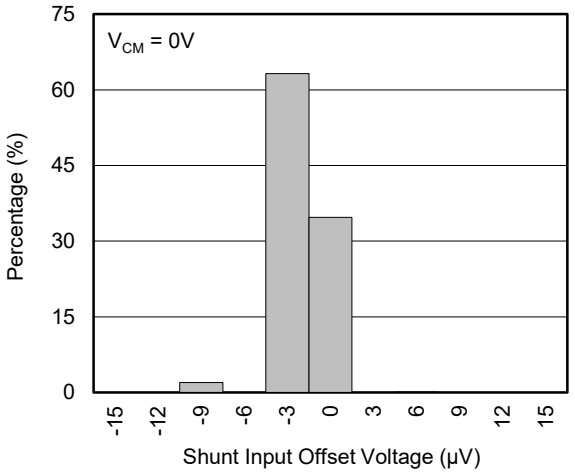
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = +25℃, V_S = 3.3V, V_{CM} = 48V, V_{SENSE} = 0V, and V_{BUS} = 48V unless otherwise noted.

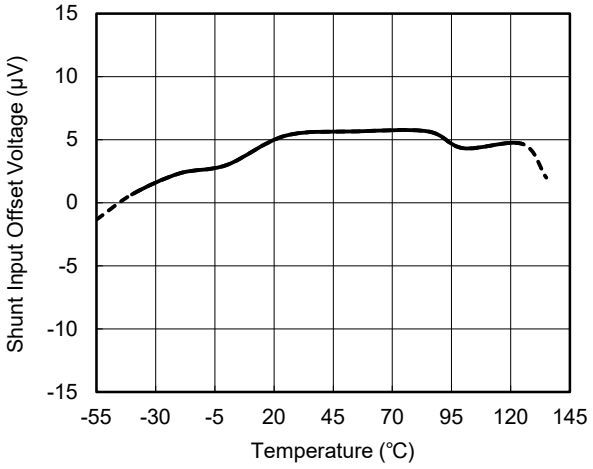
Shunt Input Offset Voltage Production Distribution



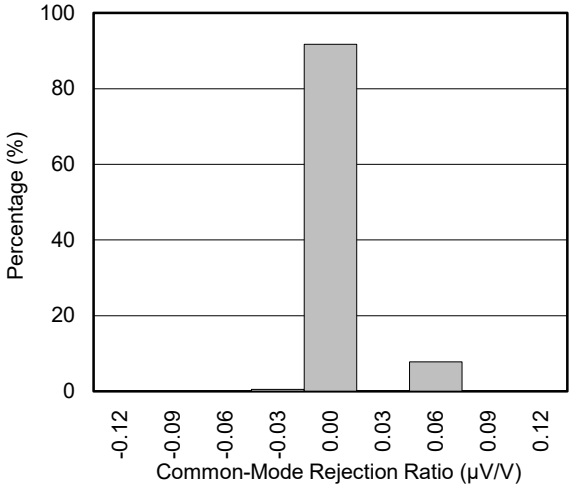
Shunt Input Offset Voltage Production Distribution



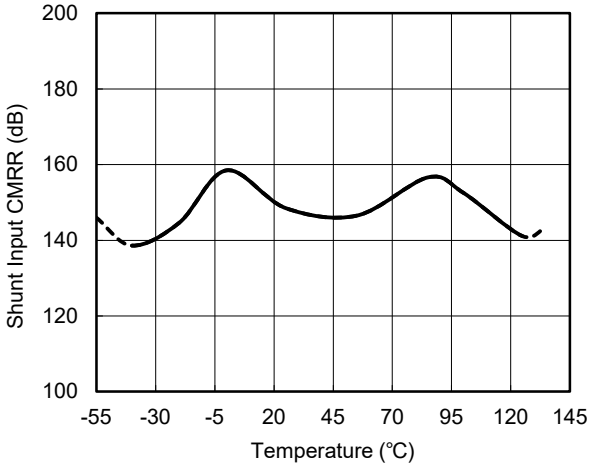
Shunt Input Offset Voltage vs. Temperature



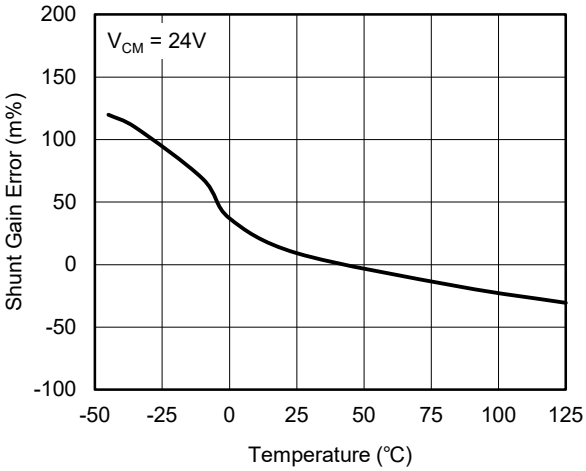
Common-Mode Rejection Ratio Production Distribution



Shunt Input Common-Mode Rejection Ratio vs. Temperature



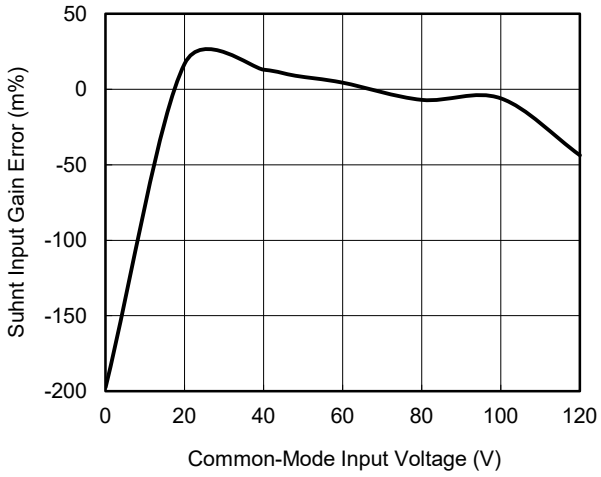
Shunt Input Gain Error vs. Temperature



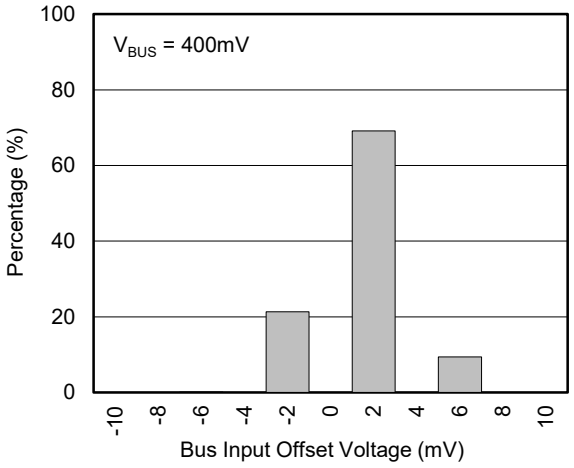
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T_A = +25℃, V_S = 3.3V, V_{CM} = 48V, V_{SENSE} = 0V, and V_{BUS} = 48V unless otherwise noted.

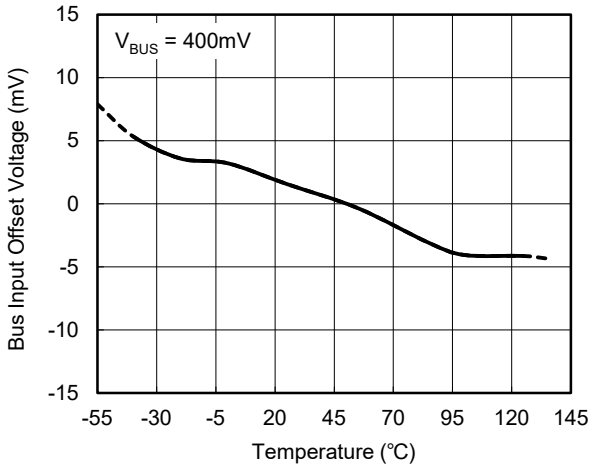
Shunt Input Gain Error vs. Common-Mode Voltage



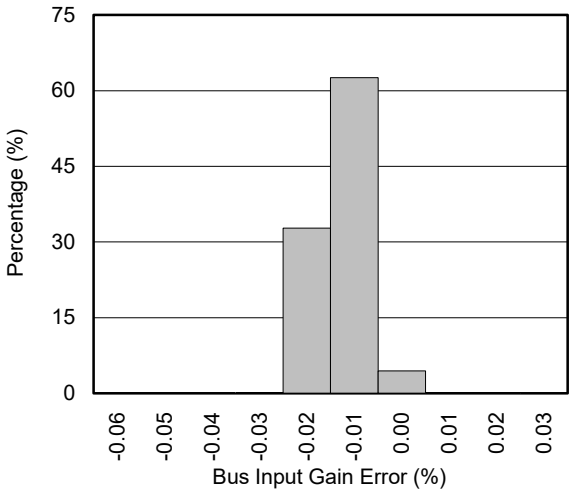
Bus Input Offset Voltage Production Distribution



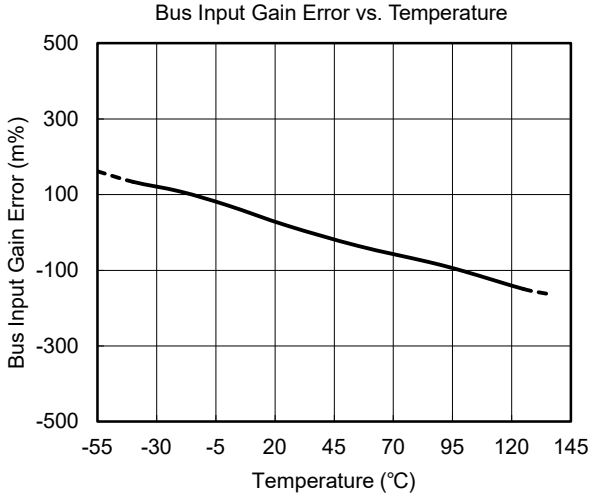
Bus Input Offset Voltage vs. Temperature



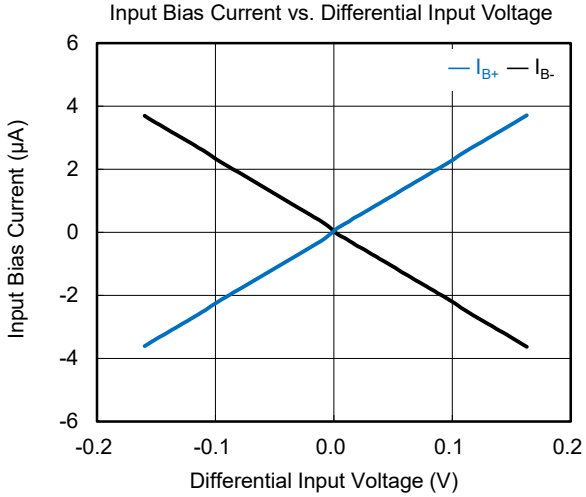
Bus Input Gain Error Production Distribution



Bus Input Gain Error vs. Temperature



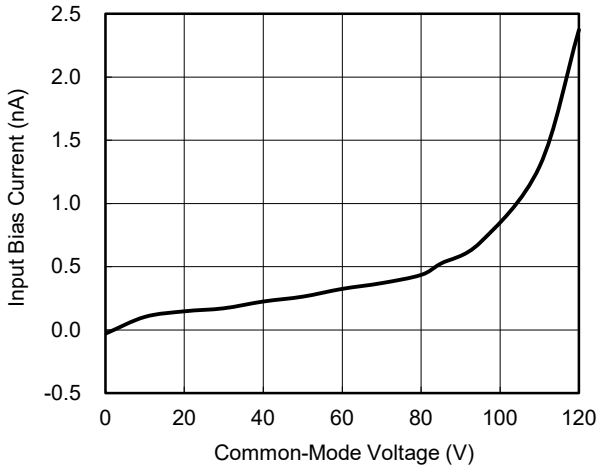
Input Bias Current vs. Differential Input Voltage



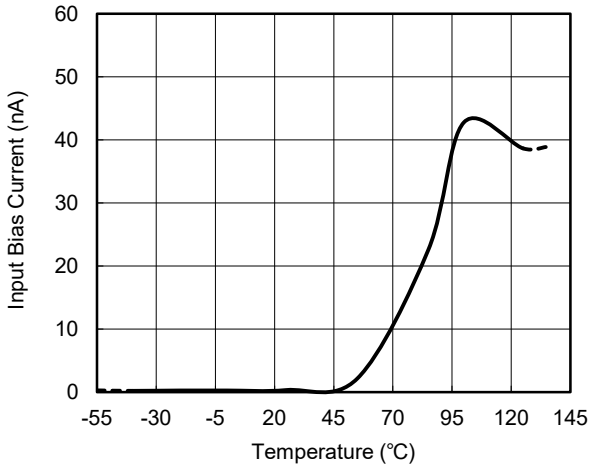
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T_A = +25℃, V_S = 3.3V, V_{CM} = 48V, V_{SENSE} = 0V, and V_{BUS} = 48V unless otherwise noted.

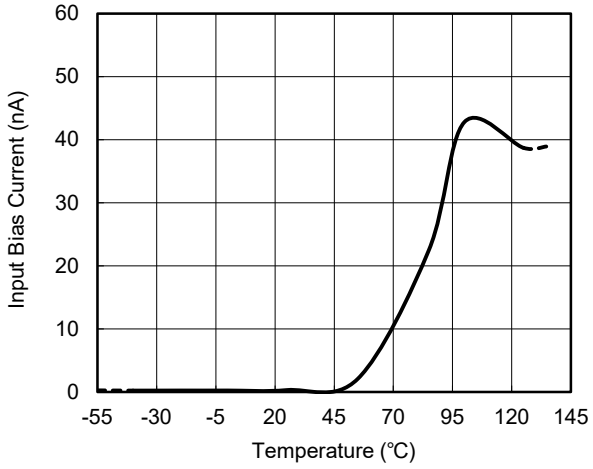
Input Bias Current (I_{B+} or I_{B-}) vs. Common-Mode Voltage



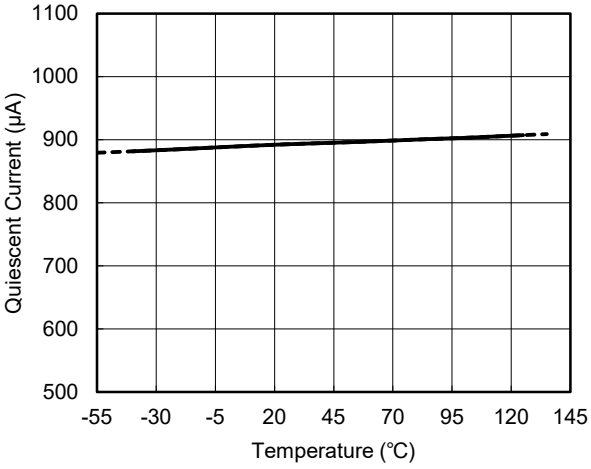
Input Bias Current vs. Temperature



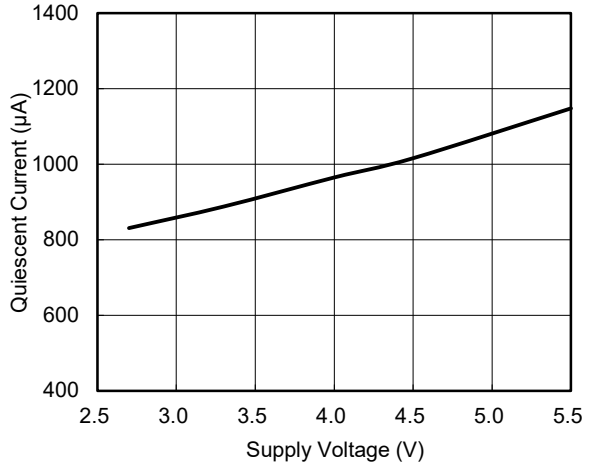
Input Bias Current vs. Temperature, Shutdown



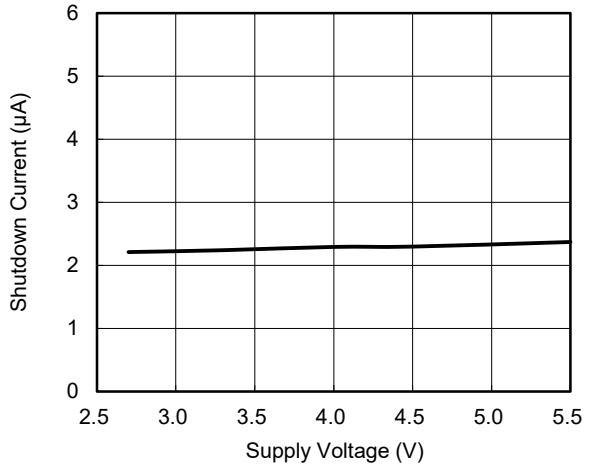
Quiescent Current vs. Temperature



Quiescent Current vs. Supply Voltage



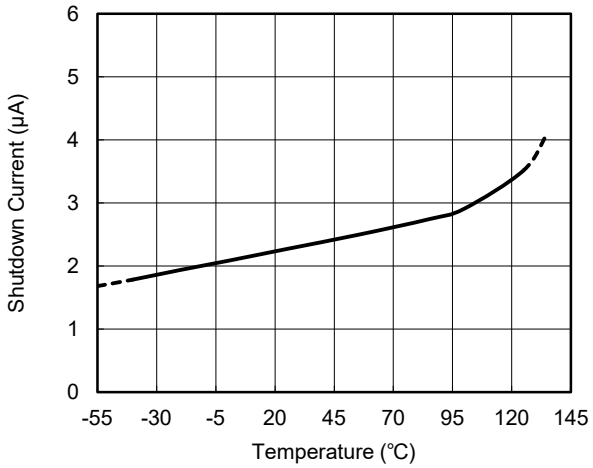
Shutdown Current vs. Supply Voltage



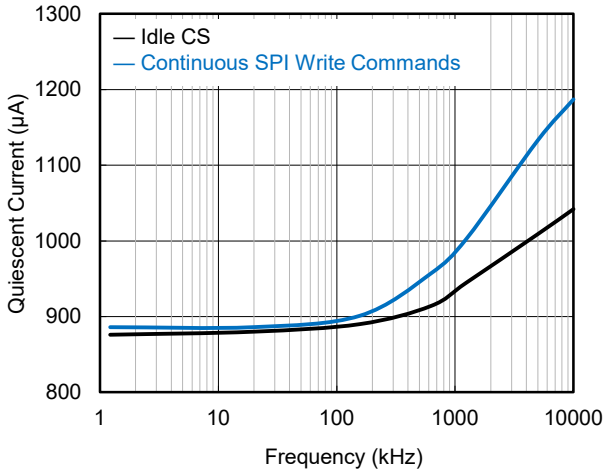
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T_A = +25℃, V_S = 3.3V, V_{CM} = 48V, V_{SENSE} = 0V, and V_{BUS} = 48V unless otherwise noted.

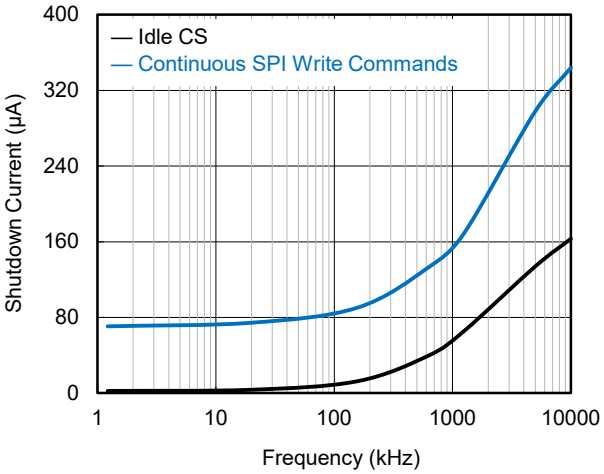
Shutdown Current vs. Temperature



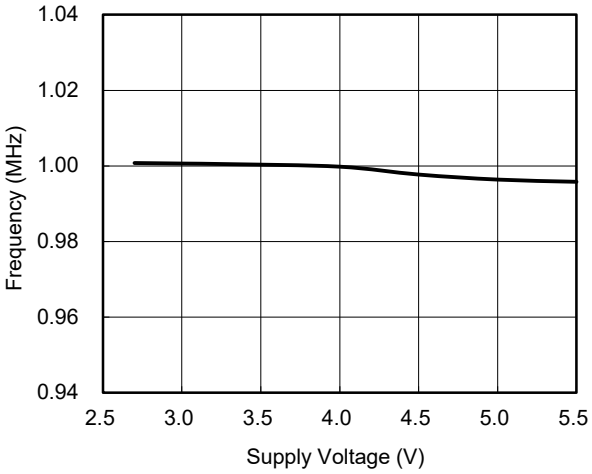
Quiescent Current vs. Clock Frequency



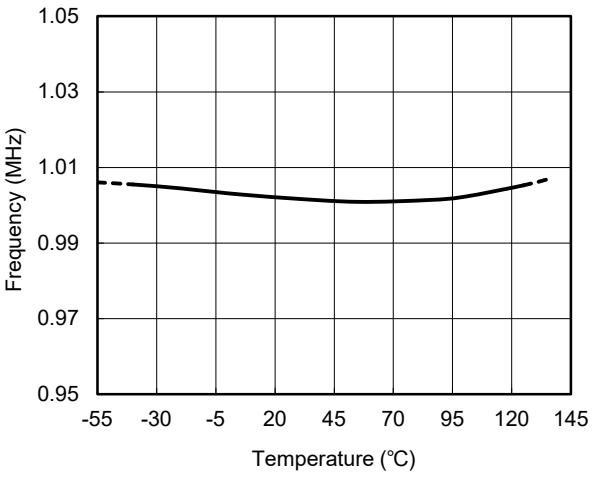
Shutdown Current vs. Clock Frequency



Internal Clock Frequency vs. Power Supply



Internal Clock Frequency vs. Temperature



FUNCTIONAL BLOCK DIAGRAM

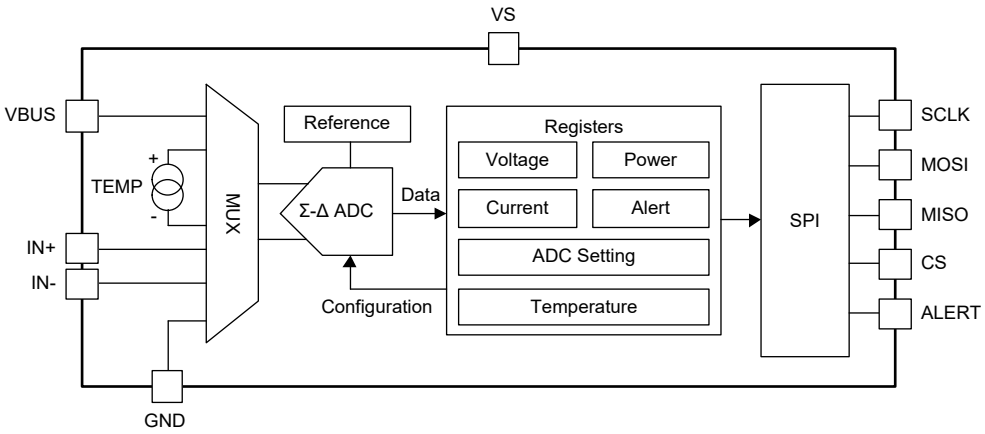


Figure 3. SGM90801 Block Diagram

DETAILED DESCRIPTION

Overview

The SGM90801 is an analog front end (AFE) specified for voltage, bi-directional current, internal temperature and power monitor. Since voltage, current, temperature and power values can be directly read out from the registers, the SGM90801 is suitable for fast decision-making control system.

The SGM90801 also provides multiple combinations of conversion times and average numbers so as to meet various accuracy and speed requirements in different measurement applications.

Feature Description

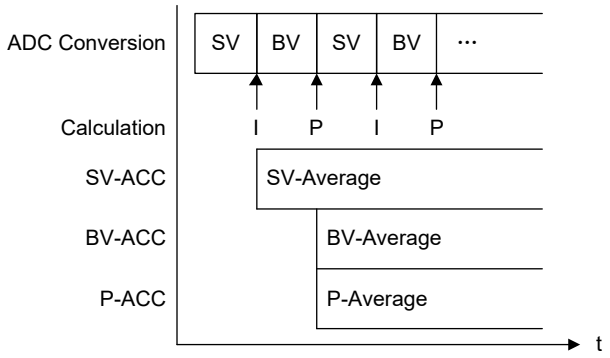
Voltage, Current and Temperature Measurement

The SGM90801 can work under a power supply from 2.7V to 5.5V, which is independent from the bus voltage of the power line to measure. By connecting the bus voltage to VBUS pin, the SGM90801 is able to measure the bus voltage range from 0V to 120V or 0V to 85V. By connecting the shunt resistor to IN+ and IN- pins, the shunt voltage is measured which is generated by the shunt resistor value times the current going through. The current value can be calculated according to the shunt voltage measured and the calibration register value. With bus voltage and current values achieved, it is easy to get the corresponding power value. The internal temperature sensor measures the die temperature range from -40℃ to +125℃ with an accuracy of ±1℃. Note that the bus voltage, shunt voltage and temperature sensor channels are connected to one common ADC core via an internal multiplexor, which is shown in Figure 3. In other words, these voltages and temperature cannot be measured simultaneously.

Moreover, the SGM90801 provides the conversion ready flag, which is available as the CNVRF bit in the DIAG_ALRT register, to indicate that the conversions are done. This bit is set when all conversions, internal calculations and averaging are complete. Besides the CNVRF bit, the ALERT pin can also be used to inform that the conversions are complete. Set the CNVR bit in the DIAG_ALRT register to enable this feature.

Power Calculation

Figure 4 shows the procedure of how power value is calculated from bus voltage and shunt voltage. In the measurement stage, shunt voltage and bus voltage are measured in turn. As soon as the shunt voltage value is converted, the calculation of the current will start in the background based on the shunt voltage value and the calibration value of the shunt calibration (SHUNT_CAL) register (0x02). If no calibration value is set, the current value will be 0. The power value will be calculated in the background as soon as the bus voltage value is converted. The power value is calculated based on the bus voltage value and the current value just calculated. Similarly, if no calibration value is set, the power value will be 0. However, all bus voltage value, shunt voltage value and power value will be pushed into three independent accumulators rather than final output registers. These final output registers including shunt voltage measurement (VSHUNT) register (0x04), bus voltage measurement (VBUS) register (0x05), and power result (POWER) register (0x08) will only update and could be read when all those N rounds samples are converted and averaged. Here, N is the AVG bits set in the ADC configuration (ADC_CONFIG) register (0x01).



Note: SV: Shunt Voltage; BV: Bus Voltage; I: Current; P: Power.

Figure 4. Power Calculation Scheme

Low Bias Current

Low input bias current is an attractive feature of the SGM90801. First of all, it reduces the current consumption of the SGM90801 even if the device is off. This helps to improve the system power efficiency, especially when the device is shutdown. Also, the input filters are often used in practical applications. The low bias current feature helps to reduce the accuracy degradation caused by the input filters.

DETAILED DESCRIPTION (continued)

Multiple Functional Modes

The SGM90801 can work in continuous mode or triggered mode. Continuous mode means that the internal ADC continuously captures and converts data while triggered mode means that the ADC only captures and converts once when triggered. Different operating modes can be set according to the MODE bits of the ADC_CONFIG register. When the MODE bits are set to Bh, the device is configured to continuously measure bus voltage and shunt voltage. First, the internal ADC converts the shunt voltage and then converts the bus voltage next. As long as the shunt voltage value is achieved, the current value will be calculated at once. After the bus voltage is achieved, with the current value calculated together, the power value will also be calculated right away. Until now, the device finishes one round conversion. As the device supports doing averaging internally through setting AVG bits of the ADC_CONFIG register, the bus voltage, shunt voltage and the power value are converted and accumulated round by round and finally averaged by the average number. The final values can be updated in their corresponding registers as long as all of the averaging is finished.

Also, the continuous mode allows converting the shunt voltage, the bus voltage or the temperature only or any combinations among these three items so as to meet different measurement requirements.

In triggered mode, the SGM90801 only does conversions, internal calculations and averaging once when the MODE bits of the ADC_CONFIG register are set to one of the seven triggered modes from 1h to 7h. After finishing one round trigger, the device enters shutdown mode automatically. Setting the MODE bits again starts another trigger.

Besides continuous mode and triggered mode, the SGM90801 also provides power down mode. In power down mode, the device dramatically reduces the power consumption as well as the current going into the inputs. To enter power down mode, set the MODE bits of the ADC_CONFIG register to 0h or 8h. Although the device is in power down mode, all the registers can still be written to or read from. To exit the power down mode, write to these MODE bits with any one of the continuous mode or triggered mode. It takes 60μs to fully recover from power down mode.

Low Latency Digital Filter

An internally integrated low-pass digital filter performs decimation and noise reduction on ADC output data. This filter dynamically adjusts to varying output data rates, achieving signal settling within a single conversion cycle. Users select output conversion periods (t_{CT}) from 50μs to 4.12ms. The primary amplitude notch automatically aligns with the Nyquist frequency (f_{NOTCH} = 1/(2 × t_{CT})), causing filter cutoff frequency to scale proportionally with the output data rate. Figure 5 illustrates the response profile at t_{CT} = 1.052ms.

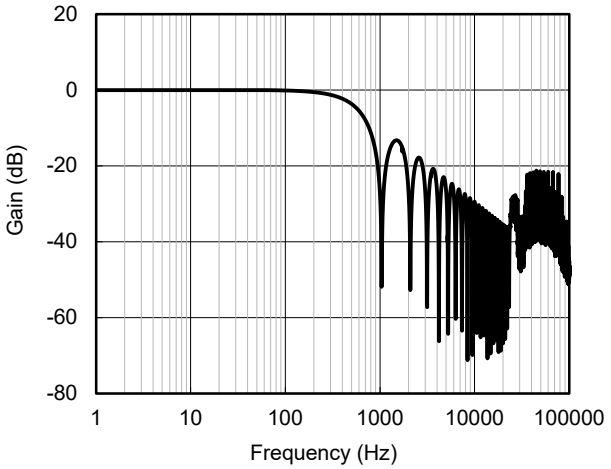


Figure 5. ADC Frequency Response

Conversion Time and Averaging Considerations

The SGM90801 provides a series of conversion time for shunt voltage, bus voltage and temperature measurements. The user could choose different conversion time by setting the VBUSCT bits, the VSHCT bits and the VTCT bits of the ADC_CONFIG register. Besides, the SGM90801 also provides averaging to further improve the accuracy and reduce noise. By setting the AVG bits of the ADC_CONFIG register, the user can choose average number from 1 to 1024. With flexible combinations of conversion time and average number, it is friendly for the user to optimize the timing requirements. For example, the bus voltage conversion time is set to 1.052ms, the shunt voltage conversion time is set to 4.12ms, the temperature conversion time is set to 150μs and the averaging mode is set to 16, the total time consumption of one round measurement will be (1.052 + 4.12 + 0.15) × 16 ≈ 85.152ms. Moreover, the internal calculations of current and power value do not contribute to extra conversion time.

DETAILED DESCRIPTION (continued)

That is to say, the final values of the shunt voltage register, the bus voltage register, the power register and the current register update every 85.152ms.

There are trade-offs between the conversion times and average times used. The averaging can filter the input signal, thus effectively improving the measurement accuracy. With more average times, the device would reduce the noise of the input signal more effectively.

Similarly, the conversion time also affects the measurement accuracy. A longer conversion time results in better measurement accuracy. Therefore, to achieve the highest measurement accuracy, use the longest conversion time with the most average times, provided that the time requirements of the system are met. The impact of conversion time and averaging on an input signal is demonstrated in Figure 6 and Figure 7 below.

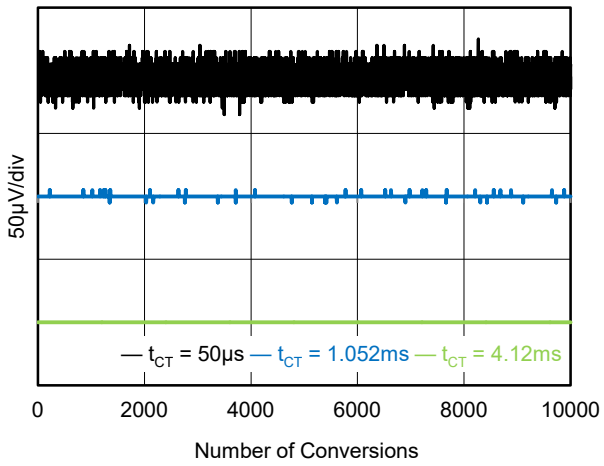


Figure 6. Noise vs. Conversion Time (Averaging = 1)

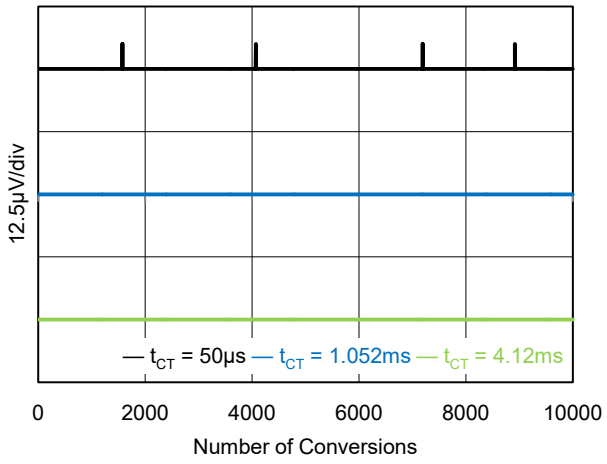


Figure 7. Noise vs. Conversion Time (Averaging = 128)

Conversion Finish Indicator

The SGM90801 provides the conversion ready flag, which is available as the CNVRF bit in the DIAG_ALRT register, to indicate that the conversions are done. This bit is set when all conversions, internal calculations and averaging are complete. Besides the CNVRF bit, the Alert pin could also be used to inform that the conversions are complete. Set the CNVR bit of the diagnostic flags and alert (DIAG_ALRT) register to enable this feature.

Programmable Delay

The SGM90801 also provides programmable delay feature to meet the synchronization requirements in multiple external devices' measurements. By setting the CONVDLY bits in the configuration (CONFIG) register (0x00), the SGM90801 conversions can be delayed from 0ms to 510ms with a step of 2ms. For example, if a time aligned bus voltage and shunt voltage measurement is required in the system, two SGM90801 devices can be adopted with well programmed delay so that one device measures the bus voltage while the other one measures the shunt voltage simultaneously. Note that the feature only provides a coarse synchronization mechanism and will probably be lost over time.

Internal Precision Oscillator and Digital Filters

The SGM90801 has a well-trimmed internal oscillator working at 1MHz. This oscillator provides the clock source for not only ADC core but also digital filters. Digital filters help reduce the output noise and adjust the final data rates. Different conversion time leads to different digital filter bandwidth. The precise clock ensures the filter response stable across temperature. However, it takes about 300μs for this precise oscillator to get the final stability when powered up.

Alert Function

The alert function provided by the SGM90801 consists of the DIAG_ALRT register, several threshold registers and the ALERT pin. The ALERT pin is a shared indicator for all enabled alarm events. All available alarm events are defined in the DIAG_ALRT register.

DETAILED DESCRIPTION (continued)

The relationship between alarm events and their compare threshold registers are listed in Table 1.

Table 1. ALERT Events Registers

Alarm Event	Alarm Status Bit (0x0B)	Threshold Register
Temperature Over-Limit	TMPOL	TEMP_LIMIT (0x10)
Shunt Over Voltage-Limit	SHNTOL	SOVL (0x0C)
Shunt Under Voltage-Limit	SHNTUL	SUVL (0x0D)
Bus Voltage Over-Limit	BUSOL	BOVL (0x0E)
Bus Voltage Under-Limit	BUSUL	BUVL (0x0F)
Power Over-Limit	POL	PWR_LIMIT (0x11)

When the ALERT pin is triggered, a read operation of the diagnostic flags and alert (DIAG_ALRT) register can tell which alarm event has occurred. By default, the ALERT pin status and the alarm status bits of the DIAG_ALRT register are self-cleared. To latch the status when alarm events happen, set the ALATCH bit of the DIAG_ALRT register before. Next time alarm events happen, the Alert pin status and the alarm status bits of the DIAG_ALRT register will never be cleared until the DIAG_ALRT register is read.

Other alarm events such as math overflow (MATHOF) and memory status (MEMSTAT) are also described in the DIAG_ALRT register.

As mentioned above, the ALERT pin could be used to indicate the conversions ready as well. Therefore, using the ALERT pin to show not only the conversions ready but also alarm events at the same time is feasible. Set CNVR bit of the DIAG_ALRT Register to enable. Under this situation, when the Alert pin is asserted, the user should read the CNVRF bit and the alarm status bits of the DIAG_ALRT register to identify the source.

The SGM90801 also provides slow alert mode. Set the SLOWALERT bit of the DIAG_ALRT Register to enable the slow alert feature, which compares the threshold to the averaged data. Otherwise, the device compares the threshold to each converted ADC value. This feature helps to reduce the possibility of false alert caused by noise.

The SGM90801 provides the user the capability to define the polarity of the ALERT pin. Write to the APOL bit of the DIAG_ALRT register to select whether active-high or active-low.

Last, the ALERT pin is an open-drain pin. A pull-up resistor is needed if the user wants to use this Alert pin. Otherwise, leaving this pin floating will not impact the other functions of the SGM90801.

The ALERT pin can be configured to report the ADC conversion complete event as well. Along with bus over-voltage, shunt over-voltage, over-temperature and other events, the ALERT pin can be set to a multi-alert configuration. Figure 8 is an example for this feature.

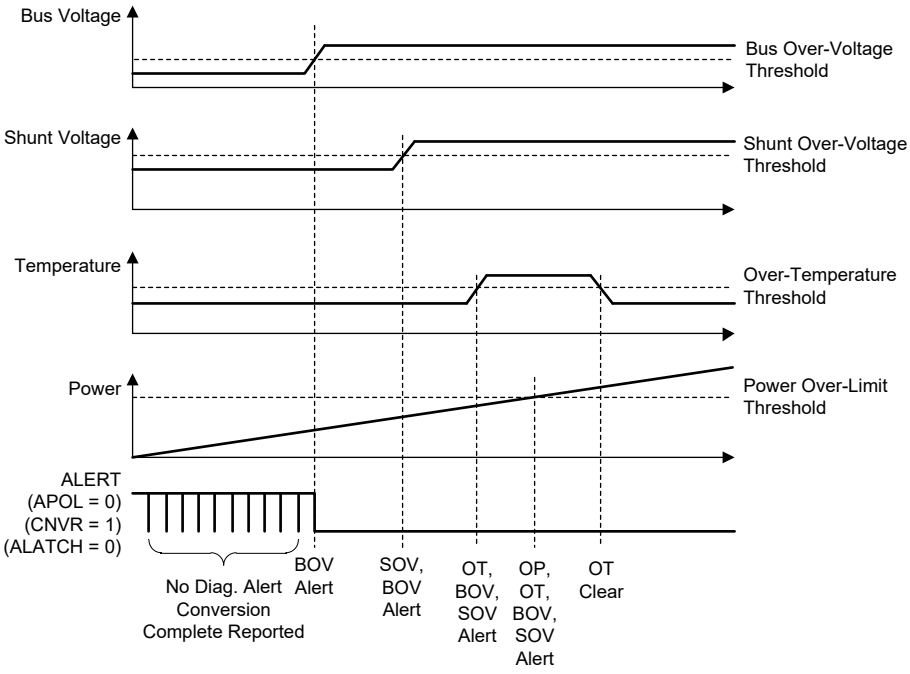


Figure 8. Multi-Alert Configuration

DETAILED DESCRIPTION (continued)

Digital Interface

SPI Interface

For the full-duplex SPI communication, the SGM90801 is the slave device. There are four pins for the SPI interface of the SGM90801, which are CS, SCLK, MOSI and MISO. The SCLK acts as an input pin of the slave device, and it can receive the clock signal from the master device, such as an MCU. Also, the MOSI can receive the commands sent from the master device. Then, MISO can send the result data to the master device, and it is an output pin of the slave. In addition, CS is an input pin of the slave device, receiving the chip select signal from the master. And it remains high if there is no SPI communication. In this situation, the MISO enters a tri-stated condition.

Timing for Register Writing and Reading

Figure 6 indicates the write commands of the SPI interface. First, the CS changes from high to low to start the SPI communication. Moreover, the master sends the 6-bit address of the register, constant “0” and followed by an R/$\overline{W}$ bit “0” to indicate writing. After that, the 16-bit data will be followed to finish the writing frame. After transmitting 16-bit data, the CS pin will change from low to high to stop the SPI communication. In addition, the old value of register will be shifted to the MISO while the new value of register is written. Both the register address and the register data are most significant bit (MSB) first.

Figure 7 indicates the read commands of the SPI interface. First, the CS changes from high to low to start the SPI communication. Moreover, the master sends the 6-bit address of the register, constant “0” and followed by an R/$\overline{W}$ bit “1” to indicate reading. After that, the register data will be shifted to the MISO pin from ninth clock. Both the register address and the register data are most significant bit (MSB) first. However, the length of the SPI read frame is not constant, for instance, POWER register (0x08), and it should be changed according to the size of the register.

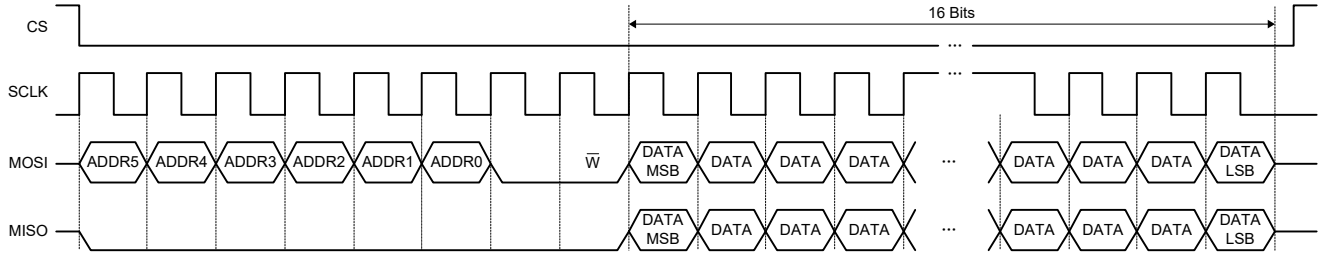


Figure 9. SPI Write Frame

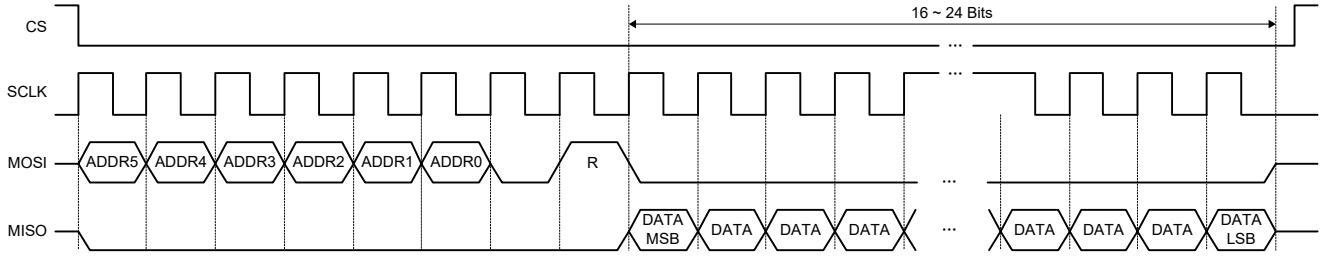


Figure 10. SPI Read Frame

Table 2. First 8-MSB Bits of SPI Frame

COMMAND	B7	B6	B5	B4	B3	B2	B1	B0
READ	ADDR5	ADDR4	ADDR3	ADDR2	ADDR1	ADDR0	0	1
WRITE								0

REGISTER MAPS

Summary Register Map

Table 3 lists the SGM90801 registers.

Table 3. SGM90801 Registers

Address	Register Name	Acronym	Register Size (bits)
0x00	Configuration	CONFIG	16
0x01	ADC Configuration	ADC_CONFIG	16
0x02	Shunt Calibration	SHUNT_CAL	16
0x04	Shunt Voltage Measurement	VSHUNT	16
0x05	Bus Voltage Measurement	VBUS	16
0x06	Temperature Measurement	DIETEMP	16
0x07	Current Result	CURRENT	16
0x08	Power Result	POWER	24
0x0B	Diagnostic Flags and Alert	DIAG_ALRT	16
0x0C	Shunt Over-Voltage Threshold	SOVL	16
0x0D	Shunt Under-Voltage Threshold	SUVL	16
0x0E	Bus Over-Voltage Threshold	BOVL	16
0x0F	Bus Under-Voltage Threshold	BUVL	16
0x10	Temperature Over-Limit Threshold	TEMP_LIMIT	16
0x11	Power Over-Limit Threshold	PWR_LIMIT	16
0x3E	Manufacturer ID	MANUFACTURER_ID	16
0x3F	Device ID	DEVICE_ID	16

Detailed Register Maps

Bit Types:

R: Read only

R/W: Read/Write

REG0x00: Configuration (CONFIG) Register [reset = 0h]

BITS	BIT NAME	TYPE	DEFAULT	DESCRIPTION
D[15]	RST	R/W	0h	Set to 1 to trigger a system reset. 0h = Normal Operation (default) 1h = Resets all registers to their default values. This bit is self-cleared.
D[14]	RESERVED	R	0h	Reserved.
D[13:6]	CONVDLY	R/W	0h	Set the Delay for initial ADC conversion in steps of 2ms. 0h = 0s (default) 1h = 2ms … FFh = 510ms
D[5]	VBUSRANGE	R/W	0h	VBUS full scale range selection across VBUS and GND. 0h = 85V (default) 1h = 120V
D[4]	VSHUNTRANGE	R/W	0h	Shunt voltage range selection. 0h = ±163.84mV (default) 1h = ±40.96mV
D[3:0]	RESERVED	R	0h	Reserved.

REGISTER MAPS (continued)

REG0x01: ADC Configuration (ADC_CONFIG) Register [reset = FB68h]

BITS	BIT NAME	TYPE	DEFAULT	DESCRIPTION
D[15:12]	MODE	R/W	Fh	Triggered or continuous mode selection for bus voltage, shunt voltage or temperature measurement. 0h = Shutdown 1h = Triggered bus voltage, single shot 2h = Triggered shunt voltage triggered, single shot 3h = Triggered shunt voltage and bus voltage, single shot 4h = Triggered temperature, single shot 5h = Triggered temperature and bus voltage, single shot 6h = Triggered temperature and shunt voltage, single shot 7h = Triggered bus voltage, shunt voltage and temperature, single shot 8h = Shutdown 9h = Continuous bus voltage only Ah = Continuous shunt voltage only Bh = Continuous shunt and bus voltage Ch = Continuous temperature only Dh = Continuous bus voltage and temperature Eh = Continuous temperature and shunt voltage Fh = Continuous bus, shunt voltage and temperature (default)
D[11:9]	VBUSCT	R/W	5h	Bus voltage measurement conversion period. 0h = 50μs 1h = 84μs 2h = 150μs 3h = 280μs 4h = 540μs 5h = 1.052ms (default) 6h = 2.074ms 7h = 4.120ms
D[8:6]	VSHCT	R/W	5h	Shunt voltage measurement conversion period. 0h = 50μs 1h = 84μs 2h = 150μs 3h = 280μs 4h = 540μs 5h = 1.052ms (default) 6h = 2.074ms 7h = 4.120ms
D[5:3]	VTCT	R/W	5h	Temperature measurement conversion period. 0h = 50μs 1h = 84μs 2h = 150μs 3h = 280μs 4h = 540μs 5h = 1.052ms (default) 6h = 2.074ms 7h = 4.120ms
D[2:0]	AVG	R/W	0h	Averaging count. This averaging count will be applied to all active inputs. If D[2:0] > 0h, the output data will be updated at the end of the averaging. 0h = 1 (default) 1h = 4 2h = 16 3h = 64 4h = 128 5h = 256 6h = 512 7h = 1024

REGISTER MAPS (continued)

REG0x02: Shunt Calibration (SHUNT_CAL) Register [reset = 1000h]

BITS	BIT NAME	TYPE	DEFAULT	DESCRIPTION
D[15]	RESERVED	R	0h	Reserved.
D[14:0]	SHUNT_CAL	R/W	1000h	The main purpose of this register is to represent the shunt resister with the multiplying coefficient so that the current register value can be obtained correctly. Also, the current resolution is set by this register.

REG0x04: Shunt Voltage Measurement (VSHUNT) Register [reset = 0h]

BITS	BIT NAME	TYPE	DEFAULT	DESCRIPTION
D[15:0]	VSHUNT	R	0h	Shunt voltage conversion result in two's complement value. 5μV/LSB when VSHUNTRANGE = 0 1.25μV/LSB when VSHUNTRANGE = 1

REG0x05: Bus Voltage Measurement (VBUS) Register [reset = 0h]

BITS	BIT NAME	TYPE	DEFAULT	DESCRIPTION
D[15:0]	VBUS	R	0h	Bus voltage conversion result in two's complement value. 3.125mV/LSB when VBUSRANGE = 0 4mV/LSB when VBUSRANGE = 1

REG0x06: Temperature Measurement (DIETEMP) Register [reset = 0h]

BITS	BIT NAME	TYPE	DEFAULT	DESCRIPTION
D[15:4]	DIETEMP	R	0h	Internal die temperature measurement. Two's complement value. Conversion factor: 125m°C/LSB
D[3:0]	RESERVED	R	0h	Reserved.

REG0x07: Current Result (CURRENT) Register [reset = 0h]

BITS	BIT NAME	TYPE	DEFAULT	DESCRIPTION
D[15:0]	CURRENT	R	0h	Calculated current value in two's complement value whose unit is Amperes.

REG0x08: Power Result (POWER) Register [reset = 0h]

BITS	BIT NAME	TYPE	DEFAULT	DESCRIPTION
D[23:0]	POWER	R	0h	Calculated power output in unsigned format, whose unit is watts.

REGISTER MAPS (continued)

REG0x0B: Diagnostic Flags and Alert (DIAG_ALRT) Register [reset = 0001h]

BITS	BIT NAME	TYPE	DEFAULT	DESCRIPTION
D[15]	ALATCH	R/W	0h	When this bit is set to 0, the alert function enters transparent mode, which means the alert flag as well as the ALERT pin will recover to idle state as soon as the fault event is cleared. When this bit is set to 1, the alert function enters Latch mode, which means the ALERT Flag as well as the ALERT pin will keep active until the DIAG_ALERT Register (0x0B) is read. 0h = Transparent 1h = Latched
D[14]	CNVR	R/W	0h	If this bit is set to 1, the ALERT pin goes high along with the CNVR bit, which represents the ADC conversion is completed. 0h = Disable conversion ready flag on ALERT pin 1h = Enables conversion ready flag on ALERT pin
D[13]	SLOWALERT	R/W	0h	If this bit is set to 1, the alert function will be asserted after the averaged value is updated in the register. It can decrease the speed of the alert response. 0h = ALERT comparison on non-averaged (ADC) value 1h = ALERT comparison on averaged value
D[12]	APOL	R/W	0h	The polarity of the alert pin can be set by this bit. 0h = Normal (Active-low, open-drain) 1h = Inverted (active-high, open-drain)
D[11:10]	RESERVED	R	0h	Reserved.
D[9]	MATHOF	R	0h	This bit will set to 1 if the current and the power value are overflowed. 0h = Normal 1h = Overflow This bit can be cleared by start another conversion.
D[8]	RESERVED	R	0h	Reserved.
D[7]	TMPOL	R	0h	If the temperature exceeds the threshold limited in the TEMP_LIMIT register, this bit will be set to 1. 0h = Normal 1h = Over-Temperature Event When ALATCH = 1, this bit is cleared by reading the DIAG_ALRT register.
D[6]	SHNTOL	R	0h	If the shunt voltage exceeds the threshold limited in the SOVL register, this bit will be set to 1. 0h = Normal 1h = Over Shunt Voltage Event When ALATCH = 1, this bit is cleared by reading the register.
D[5]	SHNTUL	R	0h	If the shunt voltage is lower than the threshold limited in the SUVL register, this bit will be set to 1. 0h = Normal 1h = Under Shunt Voltage Event When ALATCH = 1, this bit is cleared by reading the register.
D[4]	BUSOL	R	0h	If the bus voltage exceeds the threshold limited in the BOVL register, this bit will be set to 1. 0h = Normal 1h = Bus Over-Limit Event When ALATCH = 1, this bit is cleared by reading the register.
D[3]	BUSUL	R	0h	If the bus voltage is lower than the threshold limited in the BUVL register, this bit will be set to 1. 0h = Normal 1h = Bus Under-Limit Event When ALATCH = 1, this bit is cleared by reading the register.
D[2]	POL	R	0h	If the power value exceeds the threshold limited in the PWR_LIMIT register, this bit will be set to 1. 0h = Normal 1h = Power Over-Limit Event When ALATCH = 1, this bit is cleared by reading the register.
D[1]	CNVRF	R	0h	If the conversion is finished, this bit will be set to 1. 0h = Normal 1h = Conversion is complete When ALATCH = 1, this bit is cleared by reading the register or starting a new triggered conversion.
D[0]	MEMSTAT	R	1h	If this bit is 0, it means that there is a checksum error in the memory space of the device. 0h = Memory Checksum Error 1h = Normal Operation

REGISTER MAPS (continued)

REG0x0C: Shunt Over-Voltage Threshold (SOVL) Register [reset = 7FFFh]

The shunt value of 0V will trigger this alarm once the entered value for this register is negative. Also, if the negative value asserts into the SOVL register, the SOVL should be larger than the measured negative values to trip the alarm.

BITS	BIT NAME	TYPE	DEFAULT	DESCRIPTION
D[15:0]	SOVL	R/W	7FFFh	This value is used for detecting the over-limit event for the shunt voltage (over-current protection). Two's complement value. Conversion Factor: 5μV/LSB when VSHUNTRANGE = 0 1.25μV/LSB when VSHUNTRANGE = 1.

REG0x0D: Shunt Under-Voltage Threshold (SUVL) Register [reset = 8000h]

BITS	BIT NAME	TYPE	DEFAULT	DESCRIPTION
D[15:0]	SUVL	R/W	8000h	This value is used for detecting the under-limit event for the shunt voltage (under-current protection). Two's complement value. Conversion Factor: 5μV/LSB when VSHUNTRANGE = 0 1.25μV/LSB when VSHUNTRANGE = 1.

REG0x0E: Bus Over-Voltage Threshold (BOVL) Register [reset = 7FFFh]

BITS	BIT NAME	TYPE	DEFAULT	DESCRIPTION
D[15]	RESERVED	R	0h	Reserved. Always read 0.
D[14:0]	BOVL	R/W	7FFFh	This value is used for detecting the over-limit event for the bus voltage (over-voltage protection). The entered value should be positive only. Conversion factor: 3.125mV/LSB when VBUSRANGE = 0 4mV/LSB when VBUSRANGE = 1.

REG0x0F: Bus Under-Voltage Threshold (BUVL) Register [reset = 0h]

BITS	BIT NAME	TYPE	DEFAULT	DESCRIPTION
D[15]	RESERVED	R	0h	Reserved. Always read 0.
D[14:0]	BUVL	R/W	0h	This value is used for detecting the under-limit event for the bus voltage (under-voltage protection). The entered value should be positive only. Conversion factor: 3.125mV/LSB when VBUSRANGE = 0 4mV/LSB when VBUSRANGE = 1.

REG0x10: Temperature Over-Limit Threshold (TEMP_LIMIT) Register [reset = 7FF0h]

BITS	BIT NAME	TYPE	DEFAULT	DESCRIPTION
D[15:4]	TOL	R/W	7FFh	This value is used for detecting the over-limit event for the temperature (over-temperature protection). Two's complement value. Conversion factor: 125m℃/LSB.
D[3:0]	RESERVED	R	0h	Reserved.

REG0x11: Power Over-Limit Threshold (PWR_LIMIT) Register [reset = FFFFh]

BITS	BIT NAME	TYPE	DEFAULT	DESCRIPTION
D[15:0]	POL	R/W	FFFFh	This value is used for detecting the over-limit event for the power (over-power protection). The entered value should be positive only. Conversion factor: 256 × Power LSB.

REG0x3E: Manufacturer ID (MANUFACTURER_ID) Register [reset = 5347h]

BITS	BIT NAME	TYPE	DEFAULT	DESCRIPTION
D[15:0]	MANFID	R	5347h	Reads back SG in ASCII.

REG0x3F: Device ID (DEVICE_ID) Register [reset = 8011h]

BITS	BIT NAME	TYPE	DEFAULT	DESCRIPTION
D[15:4]	DIEID	R	801h	Device ID.
D[3:0]	REV_ID	R	1h	Revision ID.

APPLICATION INFORMATION

Measurement Range and Resolution of Device

Both the shunt and bus measurement support two different voltage range for the operator to select. According to the CONFIG register, the VSHUNTRANGE bit can be modified so that the shunt range can be selected either ±163.84mV or ±40.96mV with the resolution of 16 bits. Also, the VBUSRANGE bit can be modified so that the bus range can be selected either 0V to 85V or 0V to 120V with the resolution of 16 bits. In addition, the maximum supported range for temperature sensor is from -40℃ to 125℃ with the resolution of 12 bits.

The following table indicates the conclusion of the measurement range and the step for bus, shunt and temperature.

Table 4. ADC Full Scale Values

PARAMETER	FULL SCALE VALUE	RESOLUTION
Bus Voltage	0V to 85V (VBUSRANGE = 0)	3.125mV/LSB
	0V to 120V (VBUSRANGE = 1)	4mV/LSB
Shunt Voltage	±163.84mV (VSHUNTRANGE = 0)	5μV/LSB
	±40.96mV (VSHUNTRANGE = 1)	1.25μV/LSB
Temperature	-40℃ to +125℃	125m℃/LSB

VSHUNT (0x04h), VBUS (0x05h) and DIETEMP (0x06h) registers indicate the results of shunt, bus and temperature after the end of the conversion. Also, the shunt voltage indicates the amplitude and the direction of the current, so that the measurement of the shunt is bidirectional. The value of the temperature is also bidirectional. In addition, the bus measurement is always positive as the minimum voltage at the VBUS pin is -0.3V. For example, to calculate the value of the shunt voltage, it is the result of the shunt voltage code multiplies the specific selected step.

Moreover, the current and power registers are also provided for the customers, the following content indicates the internal calculation of the power and current register.

Current and Power Calculations

The unit of the current measurement for SGM90801 is Ampere. Also, for calculating the amplitude of the current, the calculated value should be written into the SHUNT_CAL (in Equation 1) which is dependent on the value of the expected current and R_{SHUNT} so that the current result can be updated correctly in the current register. Within the expression of SHUNT_CAL, the CURRENT_LSB term specifics the step for the current measurement in Ampere, which is calculated in Equation 2. Normally, for simplify the conversion result which is inside the current register, the round-number of the CURRENT_LSB should be less than 8x.

$$SHUNT\_CAL = 819.2 \times 10^6 \times CURRENT\_LSB \times R_{SHUNT} \quad (1)$$

Where:

819.2×10^6 indicates the proportional term of the Equation 1.

For VSHUNTRANGE = 1, the value of SHUNT_CAL should be multiplied by 4.

$$CURRENT\_LSB = \frac{\text{Maximum Expected Current}}{2^{15}} \quad (2)$$

The result of current is calculated internally based on the result of shunt measurement and the writing value of the SHUNT_CAL register. Also, the operator should make sure that the writing value of the SHUNT_CAL is less than 0x7FFFh, otherwise the result of the current result is wrong. In addition, if the value of SHUNT_CAL is 0 or MATHOF event occurs, the value of the current measurement is 0.

The current measurement can be obtained correctly if the value is properly written inside the SHUNT_CAL register. Equation 3 indicates that the current measurement in Ampere is the multiplication of the current code and CURRENT_LSB.

$$\text{Current (A)} = CURRENT\_LSB \times CURRENT \quad (3)$$

where:

The term of CURRENT is the coding value which is read from the current register.

The relationship between the 24-bit power code which is read from the power register and the power in Watt is shown in Equation 4.

$$\text{Power (W)} = 0.2 \times CURRENT\_LSB \times POWER \quad (4)$$

where:

The term of CURRENT_LSB is the step value for the current measurement which is shown in Equation 2.

The term of POWER is the 24-bit power code which is read from the power register.

APPLICATION INFORMATION (continued)

ADC Output Data Rate and Noise Performance

The 1/f noise or white noise is the dominated noise for the Noise-free ENOB test of Shunt voltage. Also, the increasing of the number of averaging and the conversion time can improve the result of ENOB. The conversion time of ADC determined the effective resolution and noise performance. The averaging mechanism can also decrease the digital noise and enhanced ENOB. In addition, the flexibility of different conversion time and averaging will improved the performance of SNR and dynamic range without increasing the offset.

Table 5 indicates that the ENOB result is changed for the value of ADC conversion time, Shunt ADC range and averaging. The value of ENOB is evaluated and calculated based on the peak-to-peak noise of the shunt result of SGM90801.

Table 5. Noise Performance (for 2000 Consecutive Samples)

ADC Conversion Time Period (μs)	Output Sample Averaging (Samples)	Output Sample Period (ms)	Noise-Free ENOB (±163.84mV) (VSHUNTRANGE = 0)	Noise-Free ENOB (±40.96mV) (VSHUNTRANGE = 1)
50	1	0.05	12.4	10.4
84		0.084	12.9	11.0
150		0.15	13.4	11.5
280		0.28	14.1	12.0
540		0.54	14.7	12.5
1052		1.052	15.7	13.4
2074		2.074	15.7	14.1
4120		4.12	16.0	15.7
50	4	0.2	13.1	11.5
84		0.336	13.7	11.8
150		0.6	14.7	12.4
280		1.12	14.7	13.1
540		2.16	15.7	14.1
1052		4.208	16.0	14.7
2074		8.296	16.0	14.7
4120		16.48	16.0	14.7
50	16	0.8	14.7	12.5
84		1.344	14.7	13.1
150		2.4	14.7	13.7
280		4.48	16.0	14.1
540		8.64	16.0	14.7
1052		16.832	16.0	14.7
2074		33.184	16.0	15.7
4120		65.92	16.0	15.7
50	64	3.2	15.7	13.7
84		5.376	15.7	13.7
150		9.6	16.0	14.7
280		17.92	16.0	14.7
540		34.56	16.0	15.7
1052		67.328	16.0	15.7
2074		132.736	16.0	15.7
4120		263.68	16.0	15.7

APPLICATION INFORMATION (continued)

ADC Conversion Time Period (μs)	Output Sample Averaging (Samples)	Output Sample Period (ms)	Noise-Free ENOB (±163.84mV) (VSHUNTRANGE = 0)	Noise-Free ENOB (±40.96mV) (VSHUNTRANGE = 1)
50	128	6.4	15.7	13.7
84		10.752	15.7	14.7
150		19.2	16.0	14.7
280		35.84	16.0	15.7
540		69.12	16.0	15.7
1052		134.656	16.0	15.7
2074		265.472	16.0	16.0
4120		527.36	16.0	16.0
50	256	12.8	16.0	14.7
84		21.504	16.0	14.7
150		38.4	16.0	14.7
280		71.68	16.0	15.7
540		138.24	16.0	15.7
1052		269.312	16.0	16.0
2074		530.944	16.0	16.0
4120		1054.72	16.0	16.0
50	512	25.6	16.0	14.7
84		43	16.0	15.7
150		76.8	16.0	15.7
280		143.36	16.0	15.7
540		276.48	16.0	15.7
1052		538.624	16.0	16.0
2074		1061.888	16.0	16.0
4120		2109.44	16.0	16.0
50	1024	51.2	16.0	14.7
84		86.016	16.0	15.7
150		153.6	16.0	15.7
280		286.72	16.0	15.7
540		552.96	16.0	15.7
1052		1077.248	16.0	16.0
2074		2123.776	16.0	16.0
4120		4218.88	16.0	16.0

Input Filtering Considerations

As the above section mentioned, the configuration of the ADC conversion time and averaging (in ADC_CONFIG register) can enhanced the performance of Noise-free ENOB. In addition, both the ADC conversion time and averaging can be set to configure the value of bus and shunt voltage independently so that the power bus can be monitored accurately.

The operator should make sure that the transient at the input terminals should be far from the harmonics of the sampling rate which may cause the noise issue though the ADC itself has an excellent noise rejection. These signals are at 1MHz or higher so that the input EMI filter can be added to filter the input noise and place small resistors for decreasing the effect of gain error. Also, the component of the EMI filter can be the resistors (less than 33Ω) and the ceramic capacitor (100nF to 1μF).

APPLICATION INFORMATION (continued)

Figure 11 illustrates the input EMI filter of SGM90801.

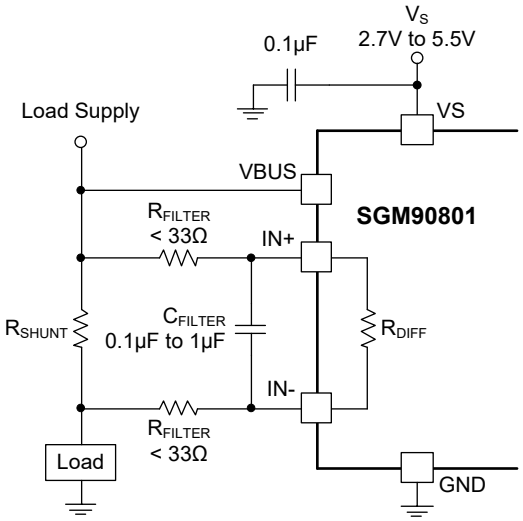


Figure 11. Input Filtering

Make sure that the largest input differential range cannot exceed the absolute rating which is mentioned in that section.

One of the situations could be that the one of the input terminals is shorted to ground. The inductive kickback will occur when the short circuit case is removed and the kickback voltage has the potential to exceed the common-mode range (0V to 120V) and maximum differential range (±40V). Commonly, the transzorb combined with sufficient energy storage capacitance at the input can prevent the device from kickback voltage.

For the high-side current sensing applications, if the large-storage and electrolytic capacitors are not placed at the one or both side of the input shunt terminals, the overstress will occur as the excessive dV/dt for short-circuit conditions. Moreover, large dV/dt can trigger the protection of ESD for short circuit condition. For protecting and preventing the device from damaging by excessive dV/dt, the series 10Ω resistors should be placed at the two input terminals of SGM90801.

According to the R_{DIFF} of the SGM90801, the input series resistors should be less than 33Ω for the consideration of the non-linearity and gain error.

Typical Application

Figure 12 illustrates the application of the high-side current monitor. According to the two advantages which are low offset voltage and input bias current, the SGM90801 can measure the current accurately within the two specific ranges which are ±163.84mV and ±40.96mV. Moreover, the shunt resistor should be selected properly to meet the two shunt voltage ranges which are ±163.84mV and ±40.96mV.

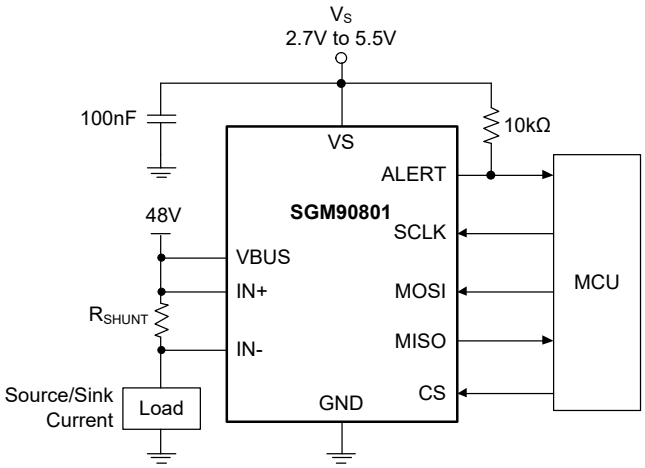


Figure 12. High-side Sensing Application Diagram

Design Requirements

The SGM90801 can monitor the shunt voltage which is produced by the load current (I_{LOAD} × R_{SHUNT}). After calibration, the device can also monitor the bus voltage and power. In addition, the alert pin can be used for monitoring the threshold alert event and the conversion-ready event, which depends on the configuration of the 0x0B register.

The parameters of the application are shown in Table 6 and the specific circuit is shown in Figure 12.

Table 6. Design Parameters

Design Parameter	Example Value
Power Supply Voltage (V_S)	5V
Bus Supply Rail (V_{CM})	48V
Bus Supply Rail Over-Voltage Fault Threshold	52V
Average Current	6A
Over-Current Fault Threshold (I_{MAX})	10A
ADC Range Selection (V_{SENSE_MAX})	±163.84mV
Temperature	+25℃

APPLICATION INFORMATION (continued)

Detailed Design Procedure

Select the Shunt Resistor

According to the value of Table 6, the maximum value of the shunt resistor should be calculated based on the value of the maximum current (I_{MAX}) and the ADC Range (V_{SENSE_MAX}). Also, the maximum value of V_{SHUNT} cannot exceed the value of V_{SENSE_MAX}. The allowable maximum value of R_{SHUNT} is 16.38mΩ which is calculated with the Equation 5 so that the 16.2mΩ is taken into consideration as it is the closest standard value of the resistor. On top of this, the value of R_{SHUNT} should be able to handle the power dissipation which is caused by the load current.

$$R_{SHUNT} < \frac{V_{SENSE\_MAX}}{I_{MAX}} \quad (5)$$

Configure the Device

The steps of programming the SGM90801 are essential. Once the device is powered up, the register value for the CONFIG and ADC_CONFIG is set to the default value. For the default state after powering on, the shunt ADC range is set to ±163.84mV, and the conversion state is continuous bus voltage, shunt and temperature (ADC_CONFIG [15:12] = Fh). However, if the default register value cannot meet the applications, the value inside the specific register should be rewritten after powering up the device.

Program the Shunt Calibration Register

The calibration register should be programmed before each powering up of V_S. For programming this register, the correct current LSB should be calculated with Equation 2. The calculated current LSB is 305.1758μA with a maximum expected current of 10A. The 4050d (FD2h) is the written value in the Calibration Register according to the selected maximum current and shunt resistor.

Set Desired Fault Thresholds

The fault threshold registers which are shown in Table 1 can be written for setting the specific alert threshold for the shunt, bus, temperature and power events.

If the operator desires the shunt over-voltage event, the specific value can be set in SOVL register for the over-voltage event. Also, the written value in this register should be the decimal value of the multiplication of the shunt resistor and the over-current threshold. In Table 6, the values of the resistor and over-current threshold are 16.2mΩ and 10A respectively, which result in 162mV of the over-voltage threshold. After that, the written value inside the SOVL register should be 162mV divided by the shunt LSB.

For the application, the written value in SOVL register should be 162mV/5μV = 32400d (7E90h).

If the operator desires the bus over-voltage event, the specific value can be set in BOVL register for the over-voltage event. The designed bus over-voltage threshold is 52V in this application. Moreover, if the designed VBUSRANGE (CONFIG [5]) is equal to 0, then the written value inside the BOVL should be 52V/3.125mV = 16640d (4100h), which is similar with SOVL.

If the operator desires the power over-limit event, the specific value can be set in the POWER_LIMIT register for the over-power event. Also, the value of POWER LSB used in POWER_LIMIT Register should be 256 times greater than that of the POWER Register. The reason for that is the length of POWER_LIMIT Register is 16-bit long while the length of POWER Register is 24-bit long.

All of the stored value inside the threshold register can be reset to the default value once V_S is repowered.

Calculate Returned Value

Table 7 illustrates the returned value, LSB value and calculated value for the application in Table 6.

Table 7. Calculating Returned Values

Parameter	Returned Value	LSB Value	Calculated Value
Shunt Voltage (V)	19440d	5μV/LSB	0.0972V
Current (A)	19660d	$10A/2^{15}$ = 305.176μA/LSB	5.9997A
Bus Voltage (V)	15360d	3.125mV/LSB	48V
Power (W)	4718604d	Current_LSB × 0.2 = 61.035156μW/LSB	288W
Temperature (℃)	200d	125m℃/LSB	+25℃

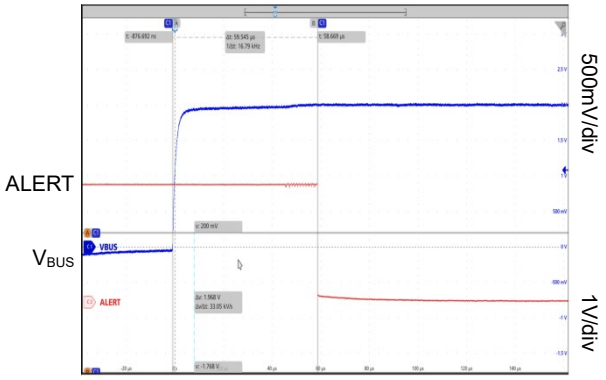
The value of shunt, current, bus (positive only) and temperature are two's complement value. For the principle of two's complement value, the most significant bit should be 1 for the returned value of the registers that are negative. To calculate the corresponding decimal value of them, all of these bits should be converted and plus 1 to get an unsigned binary value, and then multiply the corresponding LSB (negative) of it to obtain the measured value.

APPLICATION INFORMATION (continued)

For instance, if the read value inside the Shunt Register is 1011 0100 0001 0000, which means that the applied voltage at the input of ADC is negative (MSB = 1). Based on the algorithm of two's complement value, the read value should be inverted and plus 1 to get the unsigned binary value which is 0100 1011 1111 0000 (19440d). In addition, the value should be 19440d × (-5μV/LSB) = -0.0972V as the measured value is negative (MSB = 1).

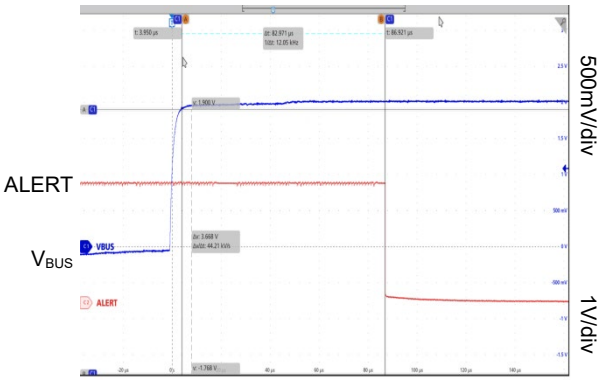
Application Curves

The following two figures illustrate the alert response time for bus threshold event, with SLOW_ALERT = 0, bus conversion time = 50μs, 1AVG and bus conversion only configuration. The variation always exists for the continuous conversion mode as the alert event is not synchronized to the ADC. In addition, as the internal ADC is sampling constantly so that the fault event starts from 0V should be slower than the fault event starts from the threshold. Since the relationship between threshold event and ADC conversion is not simple to predict, so that the critical value for the alert response time for SHUNT or BUS only application should be 2 times of the conversion time.



Time (20μs/div)

Figure 13. Alert Response Time (Sampled Values Significantly Above Threshold)



Time (20μs/div)

Figure 14. Alert Response Time (Sampled Values Slightly Above Threshold)

Power Supply Recommendations

The applied common-mode voltage can be significant larger than the power supply V_S due to the internal circuitry. For example, the common-mode voltage applied to SGM90801 can be as high as 120V and monitored it accurately with power supply V_S = 3.3V. Note that the device can also be applied the common-mode voltage which from 0V to 120V without power supply (V_S). Also, disconnecting GND pin is not allowed for all of the applications.

The 0.1μF bypass capacitor should be placed as close as possible to the terminals of V_S and GND pin for better performance. For the noisy supply such as DC/DC, additional 10μF bypass capacitor is required.

Layout Guidelines

Kelvin or 4-wire connection should be considered for the layout of shunt resistor, which can guarantee that the only applied impedance at the input pins is the shunt resistance. However, poor layout of shunt resistor could result in additional impedance applied to the input of ADC and affect the accuracy of measurement. Because of the low ohmic of shunt resistor, any other unwanted impedance will cause an error of measurement as the carrying current would be very large. On top of this, the bypass capacitor should be placed as close as possible to the V_S and GND pins.

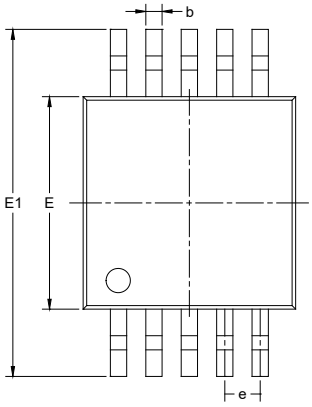
REVISION HISTORY

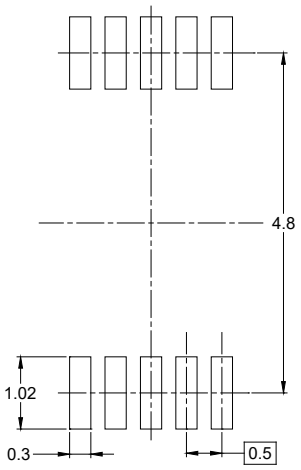
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original to REV.A (MAY 2026)	Page
Changed from product preview to production data	All

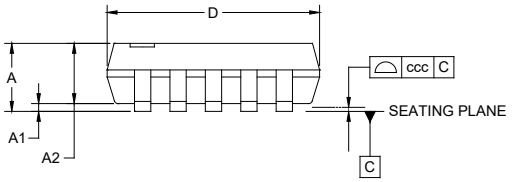
PACKAGE OUTLINE DIMENSIONS

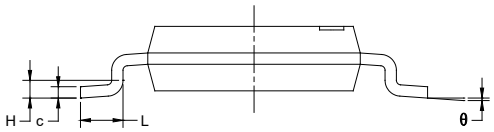
MSOP-10





RECOMMENDED LAND PATTERN (Unit: mm)



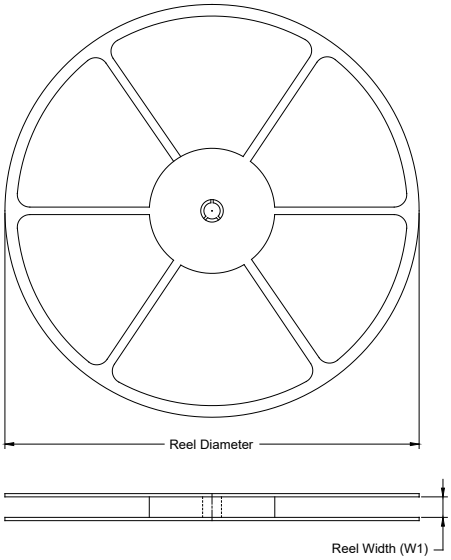


Symbol	Dimensions In Millimeters		
	MIN	NOM	MAX
A	-	-	1.100
A1	0.000	-	0.150
A2	0.750	-	0.950
b	0.170	-	0.330
c	0.080	-	0.230
D	2.900	-	3.100
E	2.900	-	3.100
E1	4.750	-	5.050
e	0.500 BSC		
H	0.250 TYP		
L	0.400	-	0.800
θ	0°	-	8°
ccc	0.100		

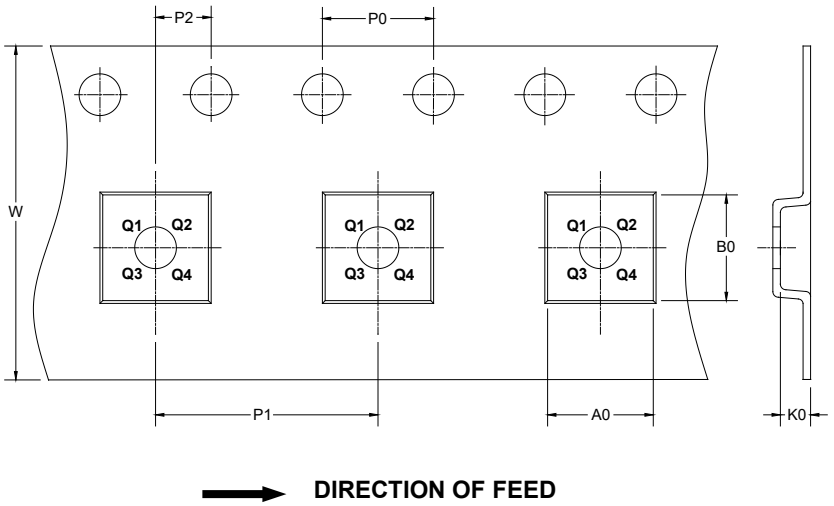
NOTES:
1. This drawing is subject to change without notice.
2. The dimensions do not include mold flashes, protrusions or gate burrs.
3. Reference JEDEC MO-187.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



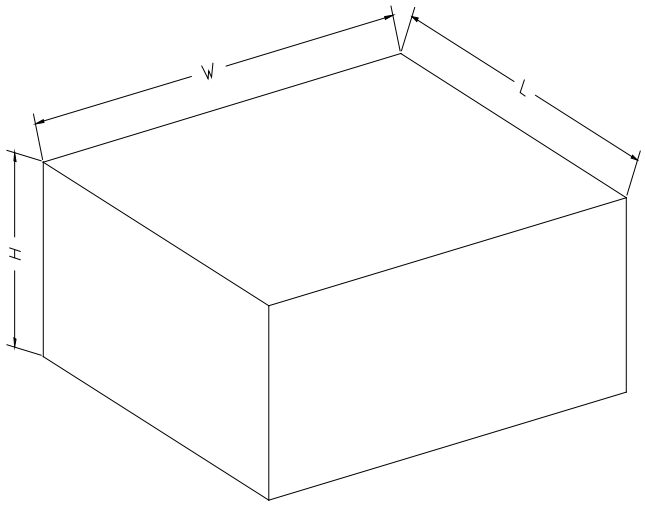
NOTE: The picture is only for reference. Please make the object as the standard.

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
MSOP-10	13"	12.4	5.20	3.30	1.50	4.0	8.0	2.0	12.0	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
13″	386	280	370	5

DD0002