SGM8198
High-side Measurement Current Shunt Monitor

GENERAL DESCRIPTION

The SGM8198 is a high-side, unipolar, current shunt monitor. Wide input common mode voltage range, high-speed, low quiescent current and tiny packaging enable SGM8198 to be used in a variety of applications.

Input common mode voltage can range from 2.7V to 36V for the SGM8198. Quiescent current is only 65µA, which permits connecting the power supply to either side of the current measurement shunt with minimal error.

The device converts a differential input voltage to a current output. This current is converted back to a voltage with an external load resistor that sets any gain from 1 to over 100. Although designed for current shunt measurement, the circuit invites creative applications in measurement and level shifting.

The SGM8198 is available in a Green SOT-23-5 package. It is specified for the -40℃ to +125℃ temperature range.

FEATURES

- **Unipolar High-side Current Measurement Circuit**
- **Wide Supply Voltage Range: 2.7V to 36V**
- **Wide Input Common Mode Voltage Range: 2.7V to 36V**
- **Single Resistor Gain Set**
- **Low Quiescent Current: 65µA (TYP)**
- **-40℃ to +125℃ Operating Temperature Range**
- **Available in a Green SOT-23-5 Package**

APPLICATIONS

Current Shunt Measurements
Portable and Battery-Backup Systems
Battery Chargers
Power Managements
Cell Phones
Precision Current Sources

TYPICAL APPLICATION

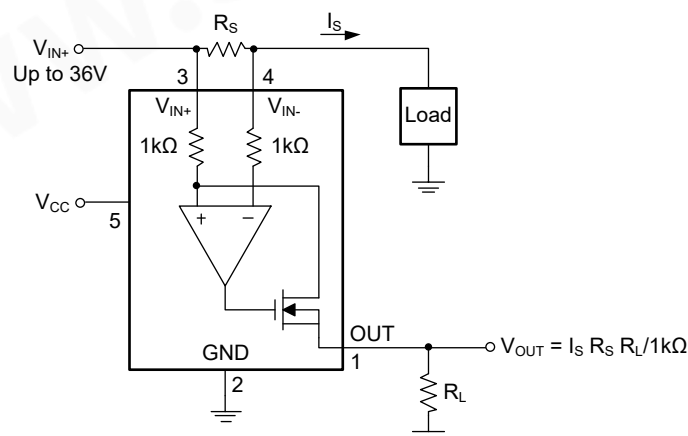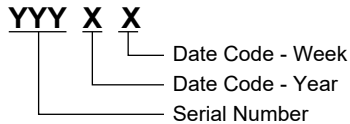**Figure 1. Typical Application Circuit**

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM8198	SOT-23-5	-40℃ to +125℃	SGM8198XN5G/TR	GMCXX	Tape and Reel, 3000

MARKING INFORMATION

NOTE: XX = Date Code.

YYY X X
        └── Date Code - Week
    └────── Date Code - Year
└─────────── Serial Number

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 Range .... -0.3V to 40V
Analog Inputs (V_{IN+}, V_{IN-}) Common Mode Voltage Range
.... -0.3V to 40V
Analog Output Voltage Range, V_{OUT} .... -0.3V to 40V
Input Current into Any Pin 10mA
Package Thermal Resistance
SOT-23-5, θ_{JA} .... 199℃/W
Junction Temperature ....+150℃
Storage Temperature Range ....-65℃ to +150℃
Lead Temperature (Soldering, 10s) ....+260℃
ESD Susceptibility
HBM 2000V
CDM.. 1000V

RECOMMENDED OPERATING CONDITIONS

Operating Voltage Range....................................2.7V to 36V
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)

SOT-23-5
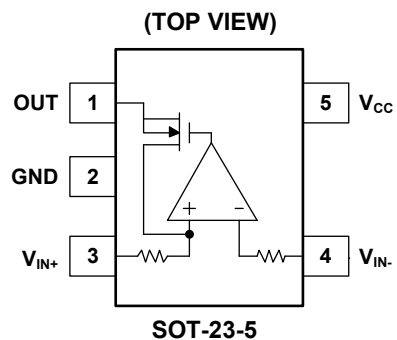
ELECTRICAL CHARACTERISTICS

(At T_A = -40℃ to +125℃, V_{CC} = 5V, V_{IN+} = 12V and R_L = 1kΩ, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Characteristics						
Full-Scale Sense Voltage		$V_{SENSE} = V_{IN+} - V_{IN-}$		100	500	mV
Input Offset Voltage [1] RTI	V_{OS}	V_{IN+} = 2.7V to 36V		±30	±550	µV
Input Offset Voltage Drift	$\Delta V_{OS}/\Delta T$			1		µV/℃
Input Bias Current	I_B			16		µA
Input Common Mode Voltage Range	V_{CM}		2.7		36	V
Common Mode Rejection Ratio	CMRR	V_{IN+} = 2.7V to 36V, V_{SENSE} = 50mV	104	140		dB
Output Characteristics						
Transconductance	g_m	V_{SENSE} = 10mV to 150mV	990	1000	1010	µA/V
Transconductance vs. Temperature	$\Delta g_m/\Delta T$	V_{SENSE} = 10mV to 150mV		10		nA/℃
Nonlinearity Error	INL	V_{SENSE} = 10mV to 150mV		±0.01	±0.13	%
Total Output Error		V_{SENSE} = 100mV		±0.25	±1.8	%
Output Voltage		Swing to power supply, V_{CC}	V_{CC} - 1.85	V_{CC} - 1.6		V
		Swing to common mode, V_{CM}	V_{CM} - 1.25	V_{CM} - 1		
Power Supply						
Operating Voltage Range	V_{CC}		2.7		36	V
Quiescent Current	I_Q	V_{SENSE} = 0, I_{OUT} = 0		65	90	µA
Power Supply Rejection Ratio	PSRR	V_{CC} = 2.7V to 36V, V_{SENSE} = 50mV		0.1	5	µV/V
Frequency Response						
Bandwidth	BW	R_L = 10kΩ		480		kHz
		R_L = 20kΩ		270		
Settling Time to 0.1%		5V step, R_L = 10kΩ		15		µs
		5V step, R_L = 20kΩ		15		
Noise						
Total Output Current Noise		BW = 100kHz		6		nA$_{RMS}$
Output Current Noise Density				20		pA/$\sqrt{HZ}$

NOTE:

1. Defined as the amount of input voltage, V_{SENSE}, to drive the output to zero.
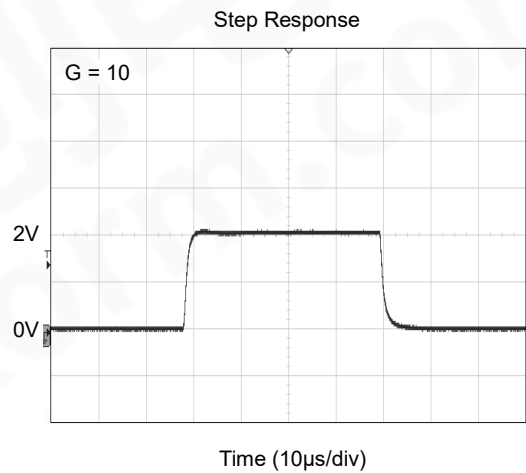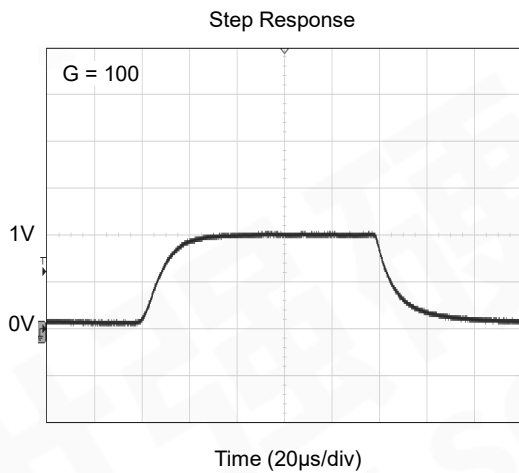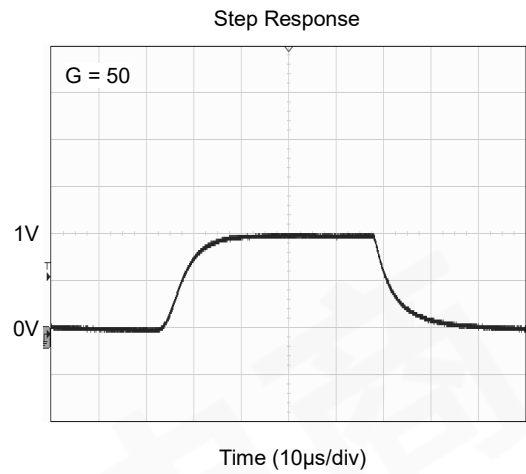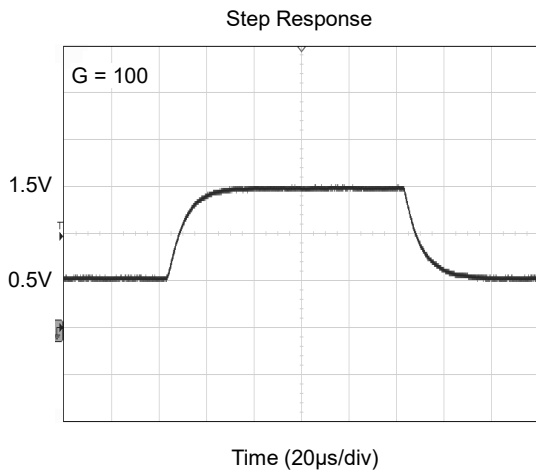
TYPICAL PERFORMANCE CHARACTERISTICS

At T_A = +25℃, V_{CC} = 5V, V_{IN+} = 12V and R_L = 1kΩ, unless otherwise noted.

Total Output Error vs. Supply Voltage

Quiescent Current vs. Supply Voltage

Total Output Error vs. Input Voltage

Gain vs. Frequency

CMRR vs. Frequency

PSRR vs. Frequency
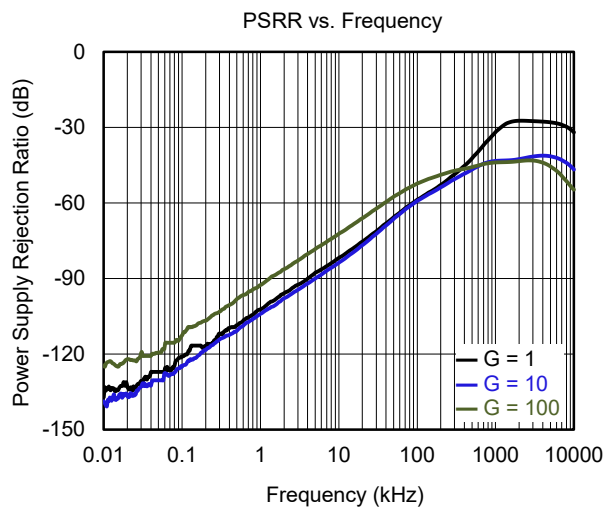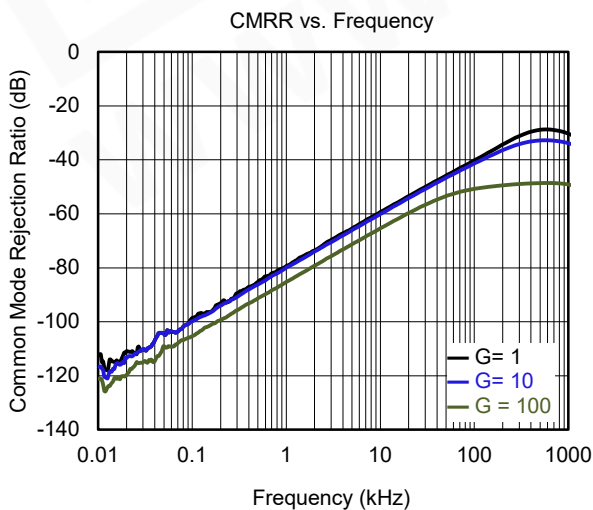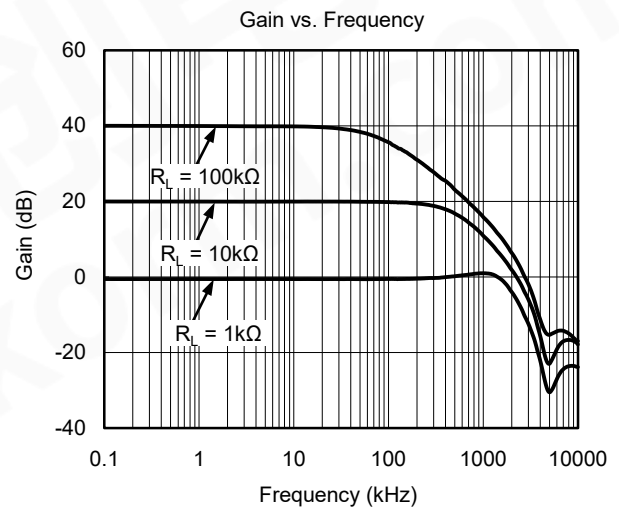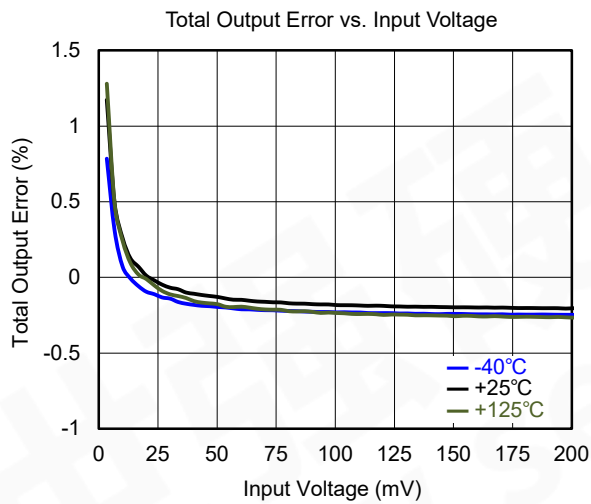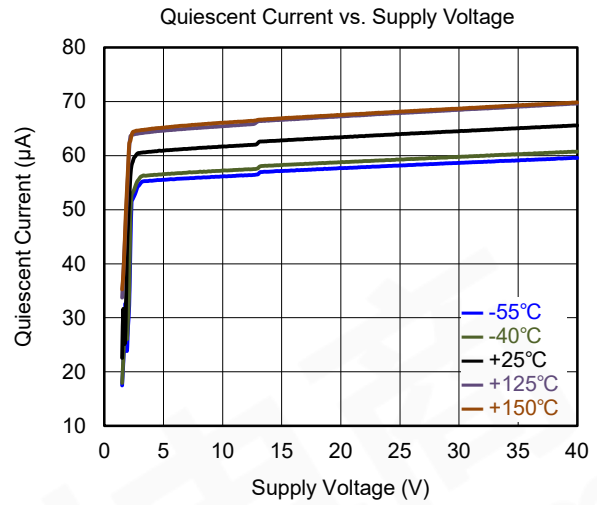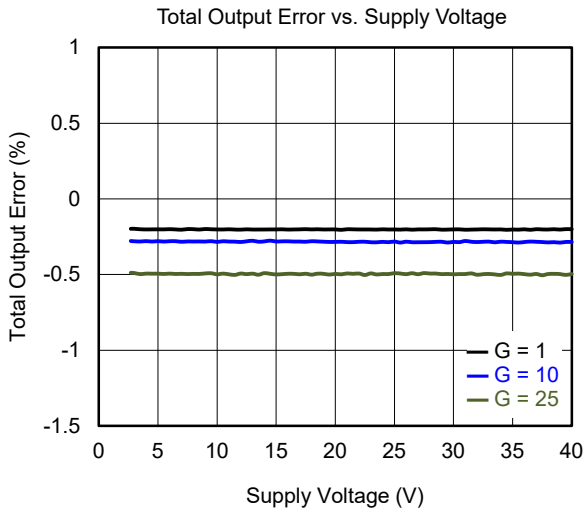
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At T_A = +25℃, V_{CC} = 5V, V_{IN+} = 12V and R_L = 1kΩ, unless otherwise noted.

Step Response

Time (20µs/div)

Step Response

Time (10µs/div)

Step Response

Time (20µs/div)

Step Response

Time (10µs/div)
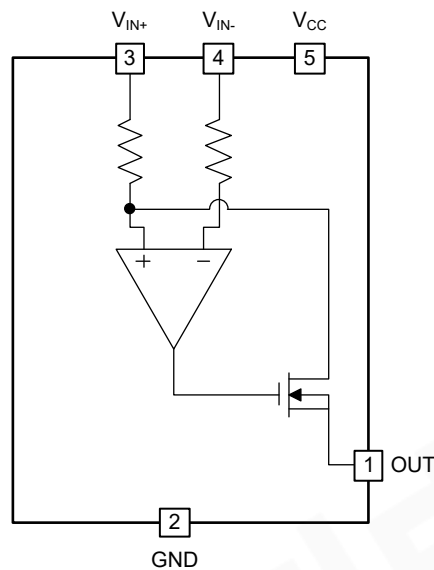
FUNCTIONAL BLOCK DIAGRAM

Figure 2. Functional Block Diagram

FEATURE DESCRIPTION

Overview

The SGM8198 device is comprised of a high voltage, precision operational amplifier, precision resistors trimmed in production to an absolute tolerance and a low noise output transistor. The SGM8198 device can be powered from a single power supply and its input voltage can exceed the power supply voltage. The SGM8198 device is ideal for measuring small differential voltages, such as those generated across a shunt resistor in the presence of large, common mode voltages. See Functional Block Diagram, which illustrates the functional components within the SGM8198 device.

Output Voltage Range

The output of the SGM8198 is a current, which is converted to a voltage by the load resistor, R_L. The output current remains accurate within the compliance voltage range of the output circuitry. The shunt voltage and the input common mode and power supply voltages limit the maximum possible output swing.

Bandwidth

Measurement bandwidth is affected by the value of the load resistor, R_L. High gain produced by high values of R_L will yield a narrower measurement bandwidth. For widest possible bandwidth, keep the capacitive load on the output to a minimum. Reduction in bandwidth due to capacitive load is shown in the Typical Performance Characteristics.

If bandwidth limit (filtering) is desired, a capacitor can be added to the output (see Figure 5). This will not cause instability.

Device Functional Modes

For proper operation, the SGM8198 device must operate within its specified limits. Operating either device outside of its specified power supply voltage range or its specified common mode range will result in unexpected behavior and is not recommended. Additionally operating the output beyond their specified limits with respect to power supply voltage and input common mode voltage will also produce unexpected results. See Electrical Characteristics for the device specifications.

APPLICATION INFORMATION

Operation

Figure 3 illustrates the basic circuit diagram for the SGM8198. Load current, I_S, is drawn from supply V_S through shunt resistor R_S. The voltage drop in shunt resistor V_S is forced across R_{G1} by the internal operational amplifier, causing current to flow into the drain of M1. The external resistor R_L converts the output current to a voltage, V_{OUT}, at the OUT pin.

The transfer function for the SGM8198 is given by Equation 1:

$$I_{OUT} = g_m \left(V_{IN+} - V_{IN-} \right) \qquad (1)$$

where g_m = 1000µA/V.

In the circuit of Figure 3, the input voltage, $(V_{IN+} - V_{IN-})$, is equal to $I_S \times R_S$ and the output voltage, V_{OUT}, is equal to $I_{OUT} \times R_L$. The transconductance, g_m, of the SGM8198 is 1000µA/V. The complete transfer function for the current measurement amplifier in this application is given by Equation 2:

$$V_{OUT} = (I_S)(R_S)(1000µA/V)(R_L) \qquad (2)$$

The maximum differential input voltage for accurate measurements is 0.5V, which produces a 500µA output current. A differential input voltage up to 2V will not cause damage. Differential measurements (pins 3 and 4) must be unipolar with a more-positive voltage applied to pin 3. If a more-negative voltage is applied to pin 3, the output current, I_{OUT}, is zero, but it will not cause damage.

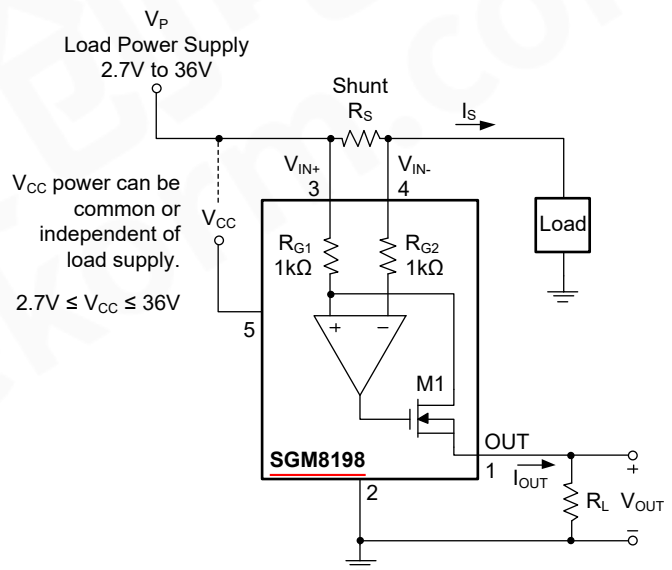| Voltage Gain	Exact R_L (Ω)	Nearest 1% R_L (Ω)
1	1k	1k
2	2k	2k
5	5k	4.99k
10	10k	10k
20	20k	20k
50	50k	49k
100	100k	100k

Figure 3. Basic Circuit Connections

TYPICAL APPLICATIONS

The SGM8198 is designed for current shunt measurement circuits, as shown in Figure 3, but its basic function is useful in a wide range of circuitry. A few examples are illustrated in Figure 7 through Figure 10.
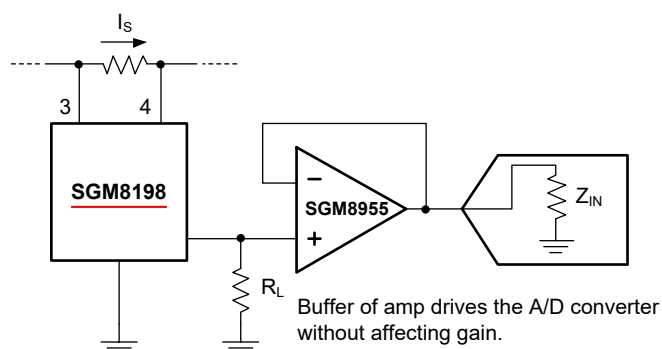
Buffering Output to Drive an ADC

Figure 4. Buffering Output to Drive the A/D Converter

Design Requirements

Digitize the output of the SGM8198 device using a 1MSPS analog-to-digital converter (ADC).

Detailed Design Procedure

Selecting R_S and R_L

In Figure 3 the value chosen for the shunt resistor, R_S, depends on the application and is a compromise between small-signal accuracy and maximum permissible voltage loss in the measurement line. High-value R_S provides better accuracy at lower currents by minimizing the effects of offset, while low-value R_S minimizes voltage loss in the supply line. For most applications, best performance is attained with an R_S value that provides a full-scale shunt voltage of 50mV to 100mV; maximum input voltage for accurate measurements is 500mV.

R_L is chosen to provide the desired full-scale output voltage. The output impedance of the SGM8198 OUT terminal is very high, which permits using R_L up to 100kΩ with excellent accuracy. The input impedance of

any additional circuitry at the output must be much higher than the value of R_L to avoid degrading accuracy.

Some analog-to-digital converters (ADC) have input impedances that will significantly affect measurement gain. The input impedance of the ADC can be included as part of the effective R_L if its input can be modeled as a resistor to ground. Alternatively, an operational amplifier can be used to buffer the ADC input, as shown in Figure 4. The SGM8198 is a current output device, and as such has an inherently large output impedance. The output currents from the amplifier are converted to an output voltage through the load resistor, R_L, connected from the amplifier output to ground. The ratio of the load resistor value to the internal resistor value determines the voltage gain of the system.

In many applications digitizing the output of the SGM8198 device is required. This is accomplished by connecting the output of the amplifier to an ADC. It is very common for an ADC to have a dynamic input impedance. If the SGM8198 output is connected directly to an ADC input, the input impedance of the ADC is effectively connected in parallel with the gain setting resistor R_L. This parallel impedance combination will affect the gain of the system and the impact on the gain is difficult to estimate accurately. A simple solution that eliminates the paralleling of impedances, simplifying the gain of the circuit is to place a buffer amplifier, such as the SGM8955, between the output of the SGM8198 device and the input to the ADC.

Figure 4 illustrates this concept. A low-pass filter can be placed between the SGM8955 output and the input to the ADC. The filter capacitor is required to provide any instantaneous demand for current required by the input stage of the ADC. The filter resistor is required to isolate the SGM8955 output from the filter capacitor to maintain circuit stability. The values for the filter components will vary according to the operational amplifier used for the buffer and the particular ADC selected.

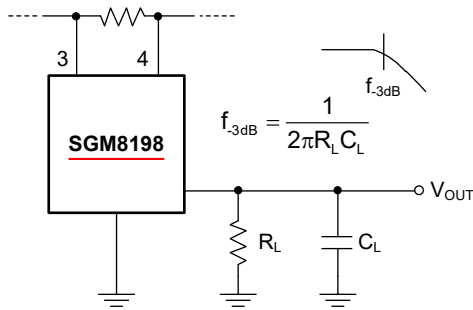# TYPICAL APPLICATIONS (Continued)

Output Filter

$$f_{-3dB} = \frac{1}{2\pi R_L C_L}$$

Figure 5. Output Filter

Design Requirements
Filter the output of the SGM8198 device.

Detailed Design Procedure
A low-pass filter can be formed at the output of the SGM8198 device simply by placing a capacitor of the desired value in parallel with the load resistor. First, determine the value of the load resistor needed to achieve the desired gain. See the table in Figure 3. Next, determine the capacitor value that will result in the desired cutoff frequency according to the equation shown in Figure 5. Figure 6 illustrates various combinations of gain settings (determined by R_L) and filter capacitors.
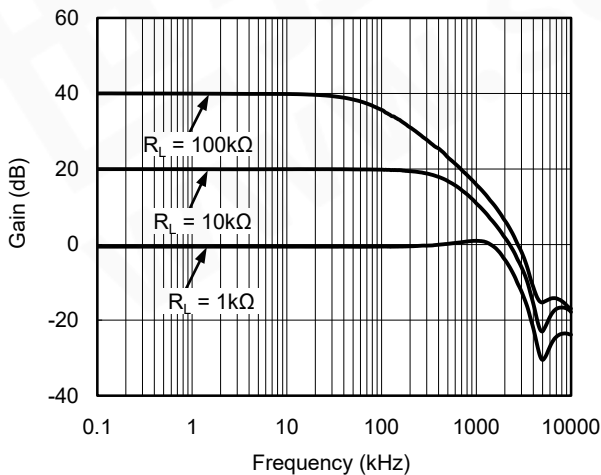
Application Curve

Figure 6. Gain vs. Frequency

Offsetting the Output Voltage

For many applications using only a single power supply, it may be required to level shift the output voltage away from ground when there is no load current flowing in the shunt resistor. Level shifting the output of the SGM8198 device is easily accomplished by one of the two simple methods shown in Figure 7. The method on the left-hand side of Figure 7 illustrates a simple voltage divider method. This method is useful for applications that require the output of the SGM8198 device to remain centered with respect to the power supply at zero load current through the shunt resistor. Using this method, the gain is determined by the parallel combination of R_1 and R_2 while the output offset is determined by the voltage divider ratio R_1 and R_2. For applications that may require a fixed value of output offset, independent of the power supply voltage, the current source method shown on the right-hand side of Figure 7 is recommended. With this method, a constant current source is used to generate a constant output offset. Using this method, the gain is determined by R_L and the offset is determined by the product of the value of the current source and R_L.
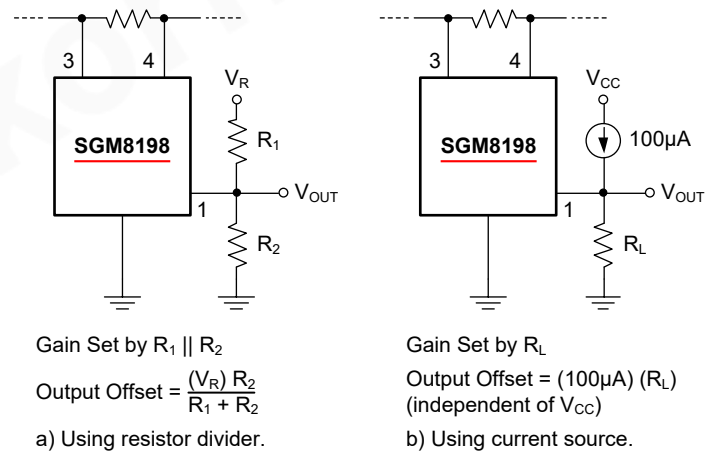

Gain Set by $R_1 \parallel R_2$

Output Offset $= \dfrac{(V_R) R_2}{R_1 + R_2}$

a) Using resistor divider.

Gain Set by R_L

Output Offset $= (100\mu A) (R_L)$
(independent of V_{CC})

b) Using current source.

Figure 7. Offsetting the Output Voltage

TYPICAL APPLICATIONS (Continued)

Bipolar Current Measurement

The SGM8198 device can be configured as shown in Figure 8 in applications where measuring current bi-directionally is required. Two SGM8198 devices are required connecting their inputs across the shunt resistor as shown in Figure 8. A comparator, such as the SGM8740, is used to detect the polarity of the load current. The magnitude of the load current is monitored across the resistor connected between ground and the connection labeled Output. In this example, the 20kΩ resistor results in a gain of 20V/V. The 10kΩ resistors connected in series with the SGM8198 output current are used to develop a voltage across the comparator inputs. Two diodes are required to prevent current flowing into the SGM8198 output, as only one device at a time is providing current to the Output connection of the circuit.
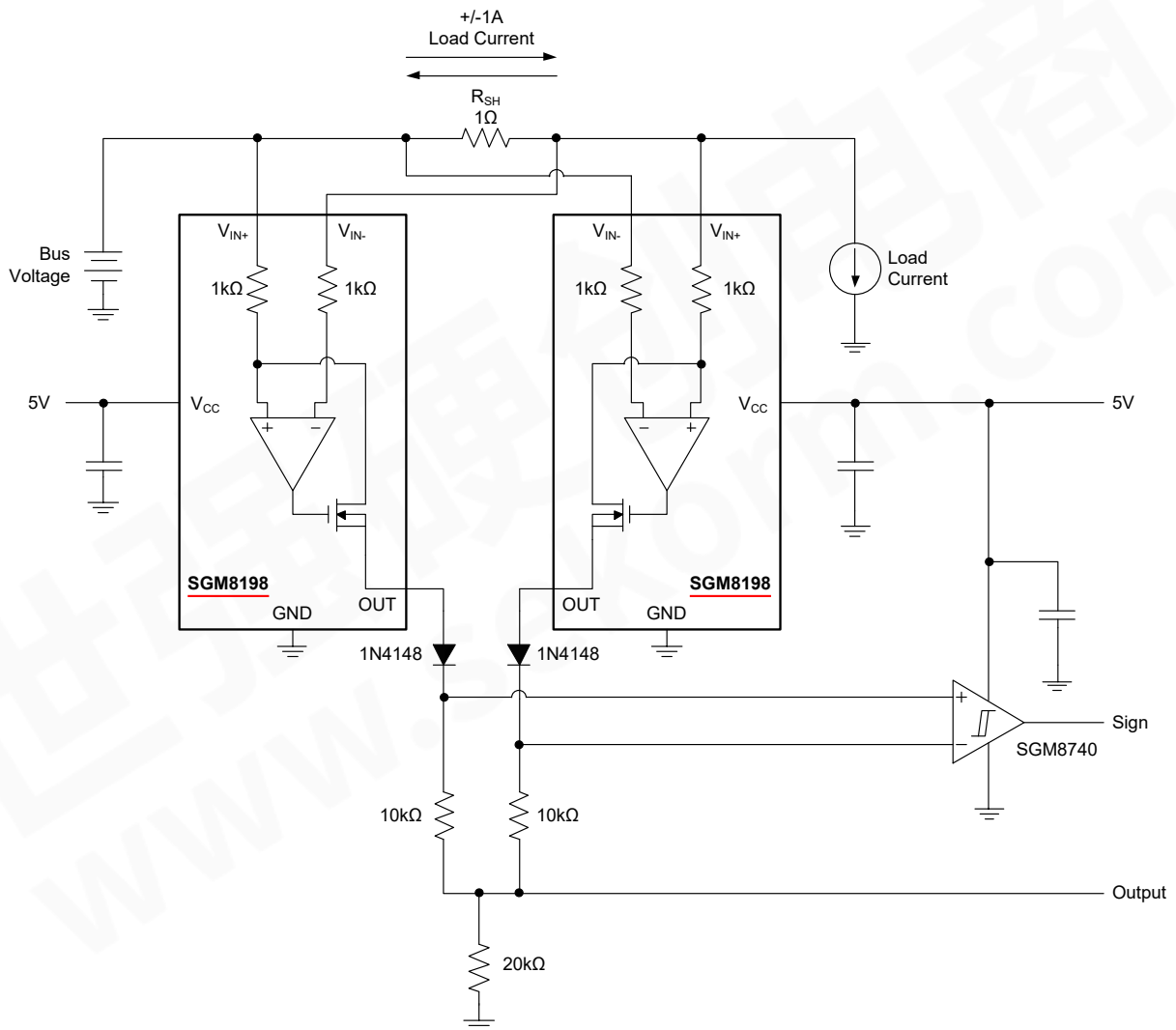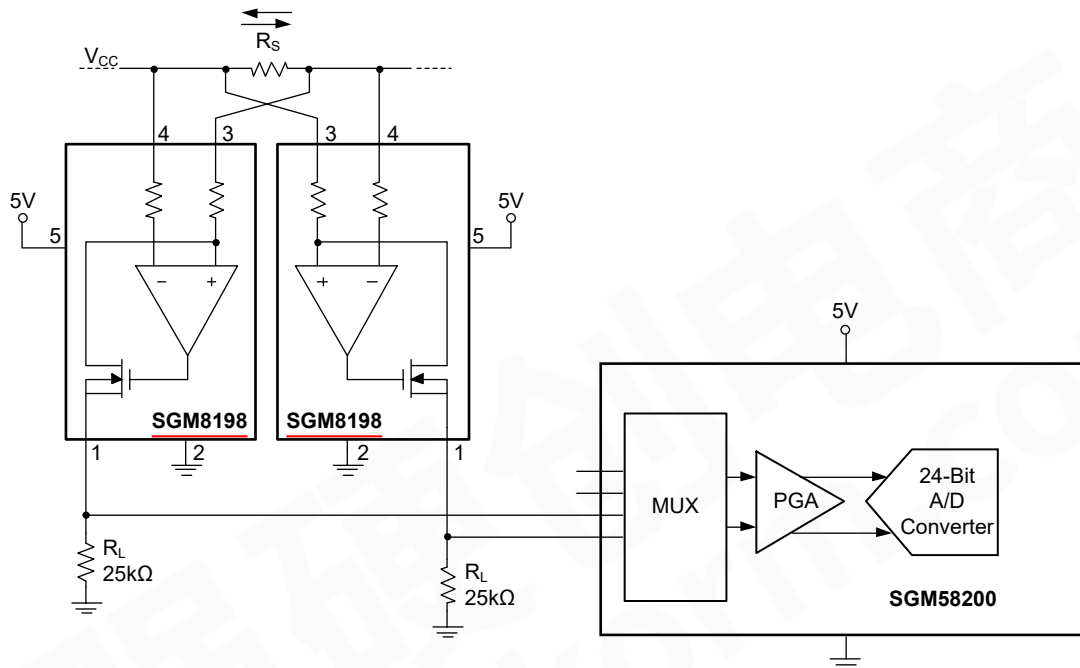

Figure 8. Bipolar Current Measurement

TYPICAL APPLICATIONS (Continued)

Bipolar Current Measurement Using a Differential Input of the A/D Converter

The SGM8198 device can be used with an ADC such as the SGM58200 programmed for differential mode operation. Figure 9 illustrates this configuration. In this configuration, the use of two SGM8198 devices allows for bi-directional current measurement. Depending upon the polarity of the current, one of the SGM8198 devices will provide an output voltage while the other output is zero. In this way, the ADC will read the polarity of current directly, without the need for additional circuitry.

The A/D converter is programmed for differential input.
Depending on the polarity of the current, one SGM8198 provides
an output voltage whereas the output of the other is zero.

Figure 9. Bipolar Current Measurement Using a Differential Input of the A/D Converter

TYPICAL APPLICATIONS (Continued)

Multiplexed Measurement Using Logic Signal for Power

Multiple loads can be measured as illustrated in Figure 10. In this configuration, each SGM8198 device is powered by the digital I/O from the SGM58200. Multiplexing is achieved by switching on or off each of the desired I/O.
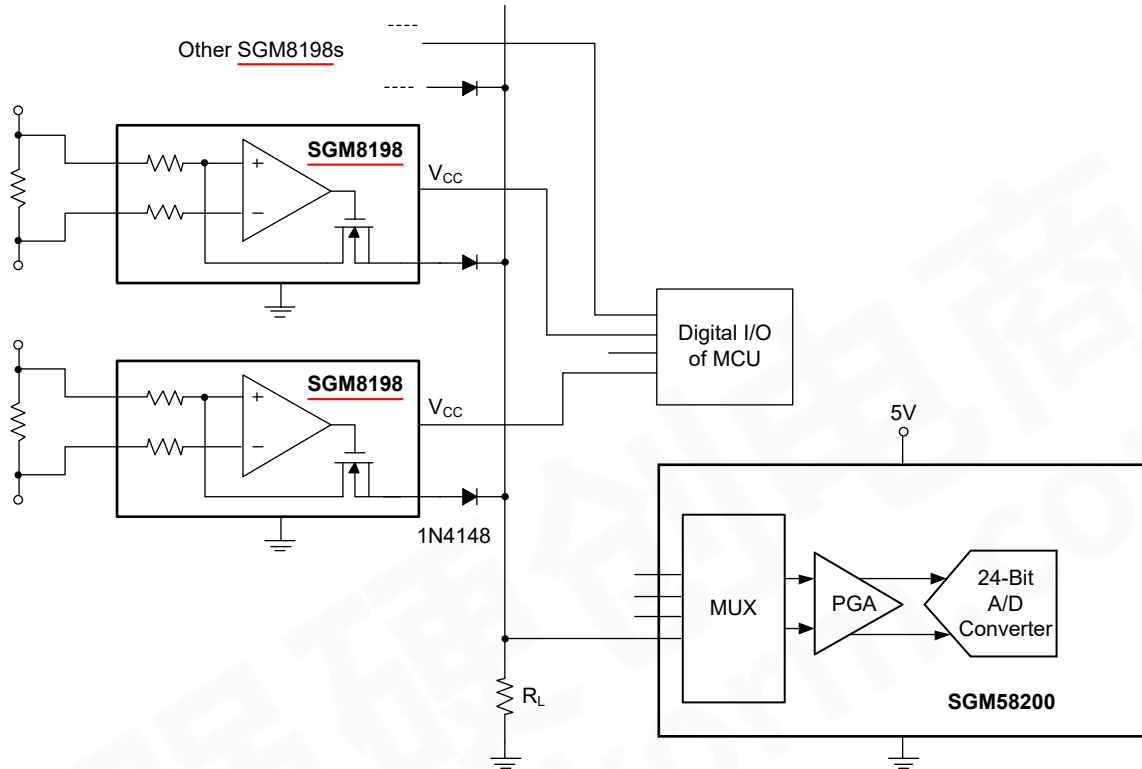

Figure 10. Multiplexed Measurement Using Logic Signal for Power

POWER SUPPLY RECOMMENDATIONS

The input circuitry of the SGM8198 can accurately measure beyond its power supply voltage, V_{CC}. For example, the V_{CC} power supply can be 5V, whereas the load power supply voltage is up to 36V. SG Micro recommends placing a 0.1μF capacitor near the VCC pin on the SGM8198. Additional capacitance may be required for applications with noisy supply voltages.

LAYOUT

Layout Guidelines

Figure 11 shows the basic connection of the SGM8198. The input pins, V_{IN+} and V_{IN-}, must be connected as closely as possible to the shunt resistor to minimize any resistance in series with the shunt resistance. The output resistor, R_L, is shown connected between pin 1 and ground. Best accuracy is achieved with the output voltage measured directly across R_L. This is especially important in high-current systems where load current could flow in the ground connections, affecting the measurement accuracy.

No power supply bypass capacitors are required for stability of the SGM8198. However, applications with noisy or high-impedance power supplies may require decoupling capacitors to reject power supply noise; connect the bypass capacitors close to the device pins.
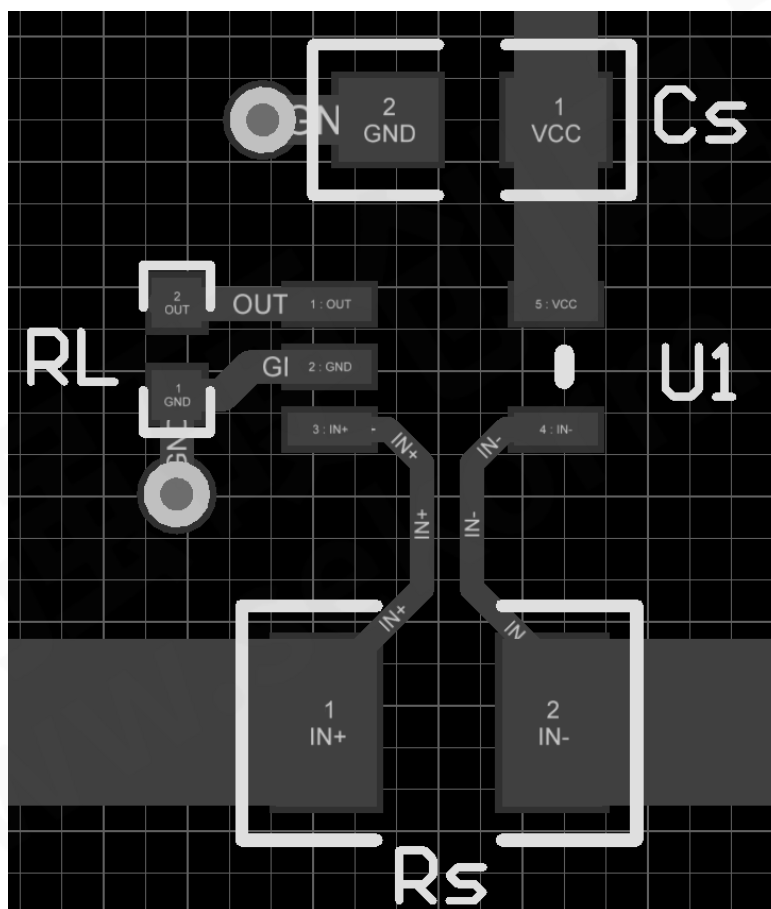
Layout Example
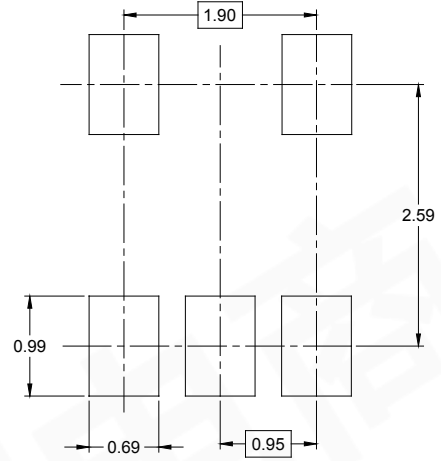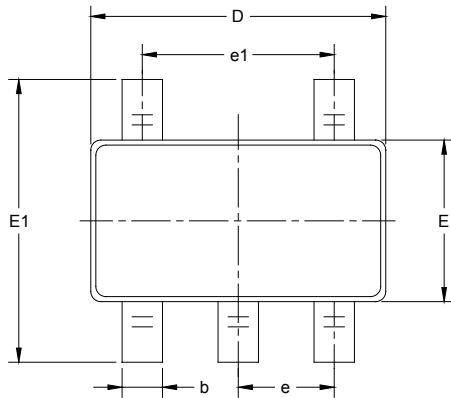

Figure 11. Typical Layout Example

REVISION HISTORY

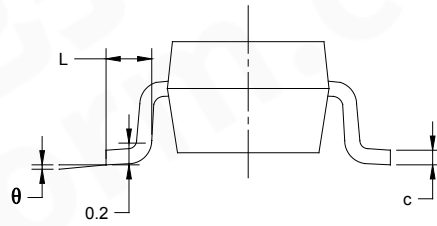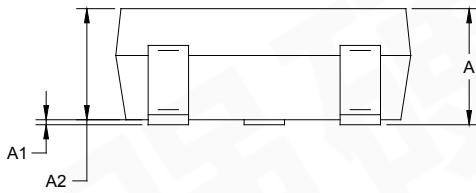NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

PACKAGE OUTLINE DIMENSIONS

SOT-23-5

RECOMMENDED LAND PATTERN (Unit: mm)

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	**MAX**	**MIN**	**MAX**
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950 BSC		0.037 BSC	
e1	1.900 BSC		0.075 BSC	
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

PACKAGE INFORMATION

TAPE AND REEL INFORMATION

REEL DIMENSIONS

TAPE DIMENSIONS
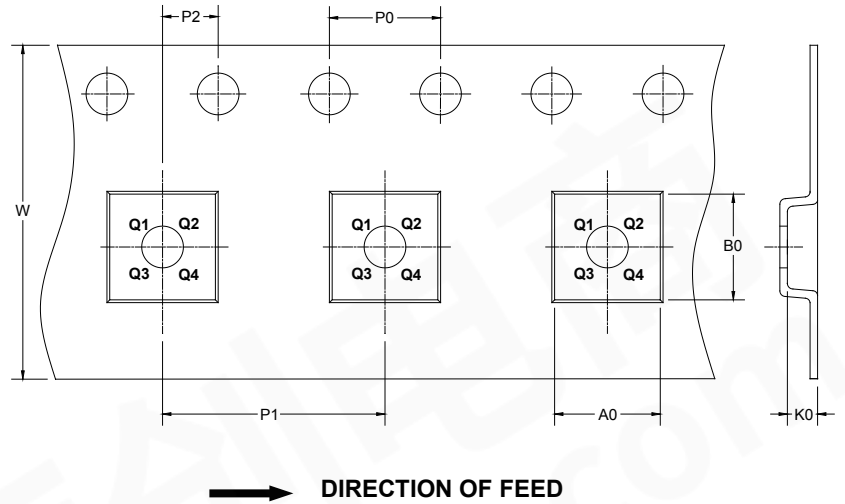
DIRECTION OF FEED

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
SOT-23-5	7″	9.5	3.20	3.20	1.40	4.0	4.0	2.0	8.0	Q3

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