

# 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 65 $\mu$ A, 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 °C to +125 °C 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: 65 $\mu$ A (TYP)
- -40°C to +125°C 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

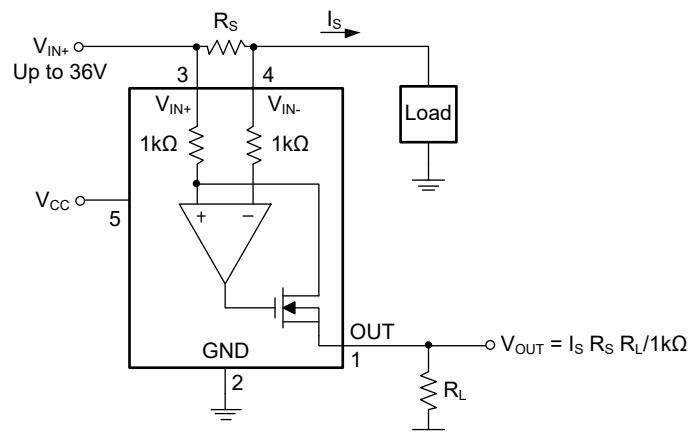


Figure 1. Typical Application Circuit

## PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM8198	SOT-23-5	-40°C to +125°C	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, $\theta_{JA}$ .....	199°C/W
Junction Temperature .....	+150°C
Storage Temperature Range .....	-65°C to +150°C
Lead Temperature (Soldering, 10s) .....	+260°C
ESD Susceptibility .....	
HBM .....	2000V
CDM .....	1000V

## RECOMMENDED OPERATING CONDITIONS

Operating Voltage Range .....	2.7V to 36V
Operating Temperature Range .....	-40°C to +125°C

## 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.

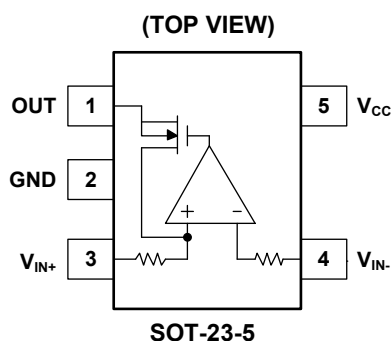
## ESD SENSITIVITY CAUTION

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



## ELECTRICAL CHARACTERISTICS

(At  $T_A = -40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ,  $V_{CC} = 5\text{V}$ ,  $V_{IN+} = 12\text{V}$  and  $R_L = 1\text{k}\Omega$ , unless otherwise noted.)

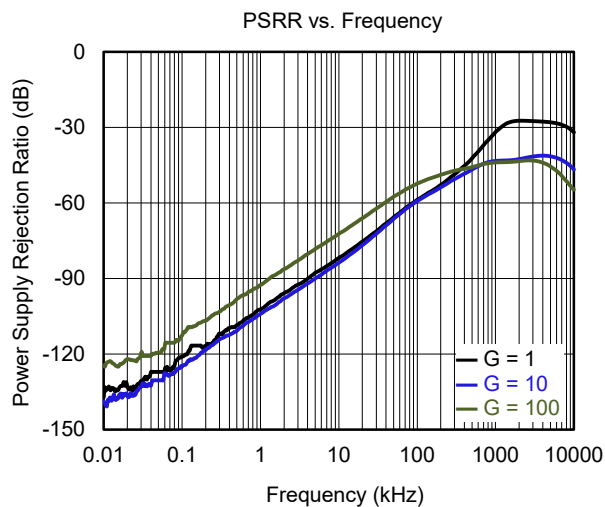
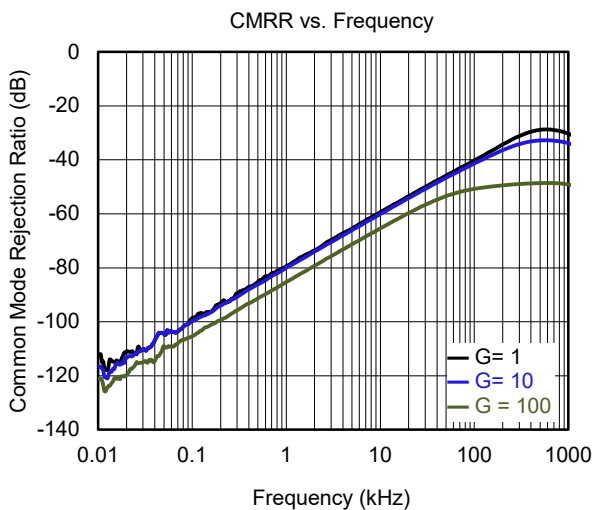
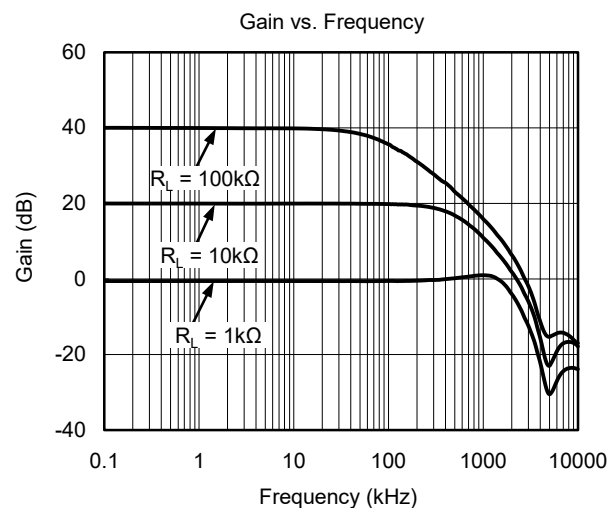
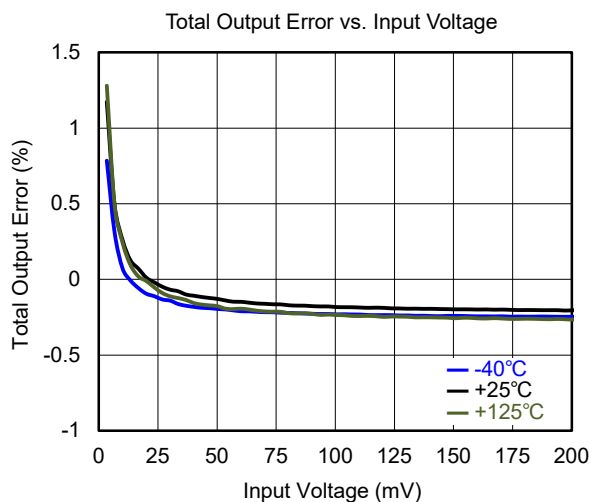
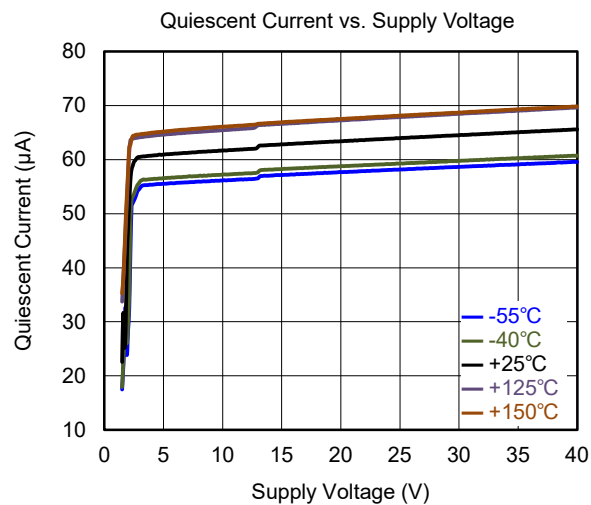
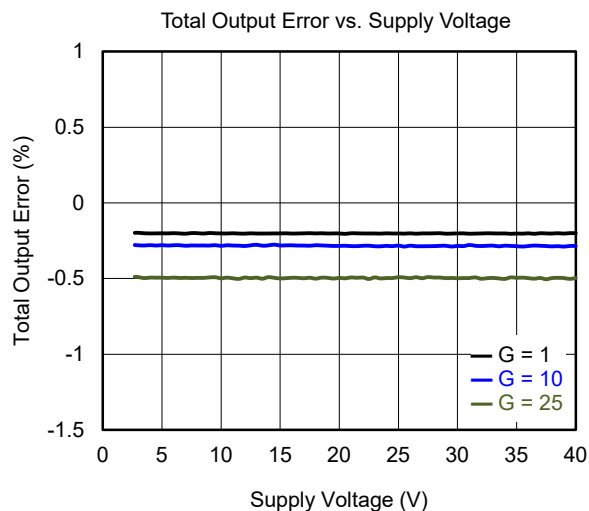
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Characteristics						
Full-Scale Sense Voltage		$V_{\text{SENSE}} = V_{\text{IN}+} - V_{\text{IN}-}$		100	500	mV
Input Offset Voltage <sup>(1)</sup> RTI	$V_{\text{OS}}$	$V_{\text{IN}+} = 2.7\text{V}$ to 36V		±30	±550	μV
Input Offset Voltage Drift	$\Delta V_{\text{OS}}/\Delta T$			1		μV/°C
Input Bias Current	$I_{\text{B}}$			16		μA
Input Common Mode Voltage Range	$V_{\text{CM}}$		2.7		36	V
Common Mode Rejection Ratio	CMRR	$V_{\text{IN}+} = 2.7\text{V}$ to 36V, $V_{\text{SENSE}} = 50\text{mV}$	104	140		dB
Output Characteristics						
Transconductance	$g_{\text{m}}$	$V_{\text{SENSE}} = 10\text{mV}$ to 150mV	990	1000	1010	μA/V
Transconductance vs. Temperature	$\Delta g_{\text{m}}/\Delta T$	$V_{\text{SENSE}} = 10\text{mV}$ to 150mV		10		nA/°C
Nonlinearity Error	INL	$V_{\text{SENSE}} = 10\text{mV}$ to 150mV		±0.01	±0.13	%
Total Output Error		$V_{\text{SENSE}} = 100\text{mV}$		±0.25	±1.8	%
Output Voltage		Swing to power supply, $V_{\text{CC}}$	$V_{\text{CC}} - 1.85$	$V_{\text{CC}} - 1.6$		V
		Swing to common mode, $V_{\text{CM}}$	$V_{\text{CM}} - 1.25$	$V_{\text{CM}} - 1$		
Power Supply						
Operating Voltage Range	$V_{\text{CC}}$		2.7		36	V
Quiescent Current	$I_{\text{Q}}$	$V_{\text{SENSE}} = 0$ , $I_{\text{OUT}} = 0$		65	90	μA
Power Supply Rejection Ratio	PSRR	$V_{\text{CC}} = 2.7\text{V}$ to 36V, $V_{\text{SENSE}} = 50\text{mV}$		0.1	5	μV/V
Frequency Response						
Bandwidth	BW	$R_{\text{L}} = 10\text{k}\Omega$		480		kHz
		$R_{\text{L}} = 20\text{k}\Omega$		270		
Settling Time to 0.1%		5V step, $R_{\text{L}} = 10\text{k}\Omega$		15		μs
		5V step, $R_{\text{L}} = 20\text{k}\Omega$		15		
Noise						
Total Output Current Noise		BW = 100kHz		6		nA <sub>RMS</sub>
Output Current Noise Density				20		pA/√Hz

## NOTE:

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

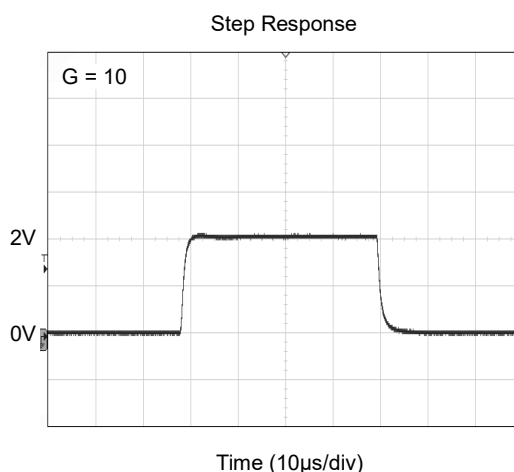
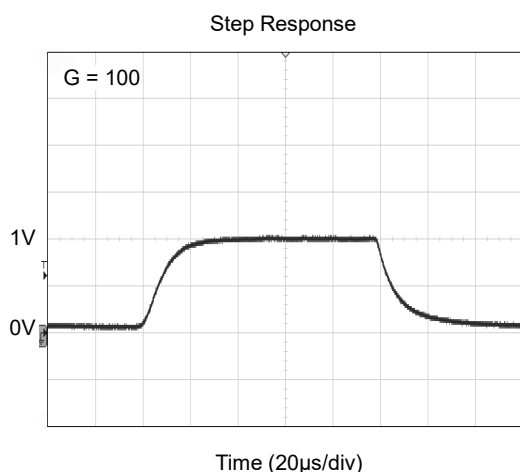
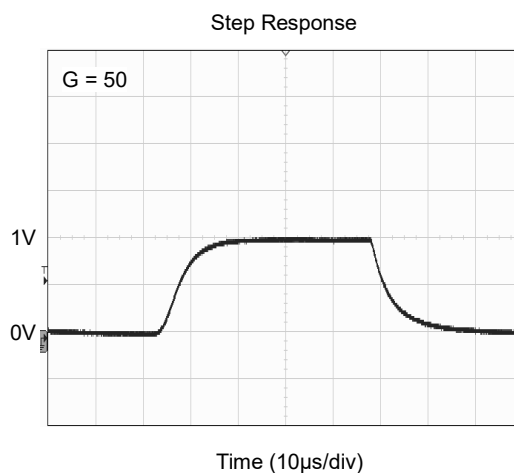
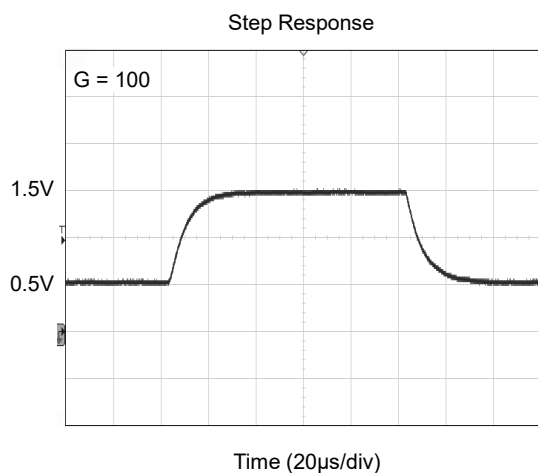
## TYPICAL PERFORMANCE CHARACTERISTICS

At  $T_A = +25^\circ\text{C}$ ,  $V_{CC} = 5\text{V}$ ,  $V_{IN+} = 12\text{V}$  and  $R_L = 1\text{k}\Omega$ , unless otherwise noted.



**TYPICAL PERFORMANCE CHARACTERISTICS (continued)**

At  $T_A = +25^\circ\text{C}$ ,  $V_{CC} = 5\text{V}$ ,  $V_{IN+} = 12\text{V}$  and  $R_L = 1\text{k}\Omega$ , unless otherwise noted.



## FUNCTIONAL BLOCK DIAGRAM

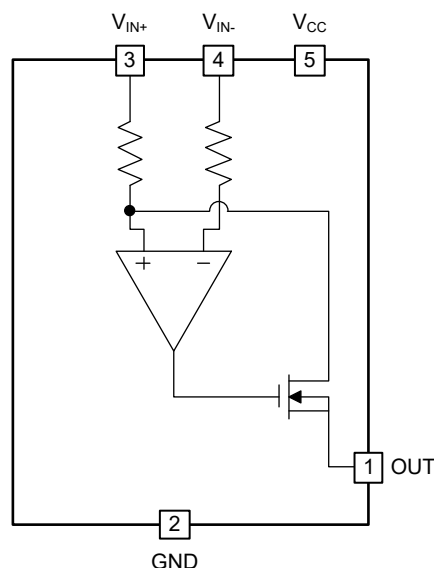


Figure 2. Functional Block Diagram

## 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:

$$I_{OUT} = g_m (V_{IN+} - V_{IN-}) \quad (1)$$

where  $g_m = 1000\mu A/V$ .

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  $1000\mu A/V$ . The complete transfer function for the current measurement amplifier in this application is given by Equation 2:

$$V_{OUT} = (I_S) (R_S) (1000\mu A/V) (R_L) \quad (2)$$

The maximum differential input voltage for accurate measurements is 0.5V, which produces a  $500\mu A$  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 $R_L$ ( $\Omega$ )	Nearest 1% $R_L$ ( $\Omega$ )
1	1k	1k
2	2k	2k
5	5k	4.99k
10	10k	10k
20	20k	20k
50	50k	49k
100	100k	100k

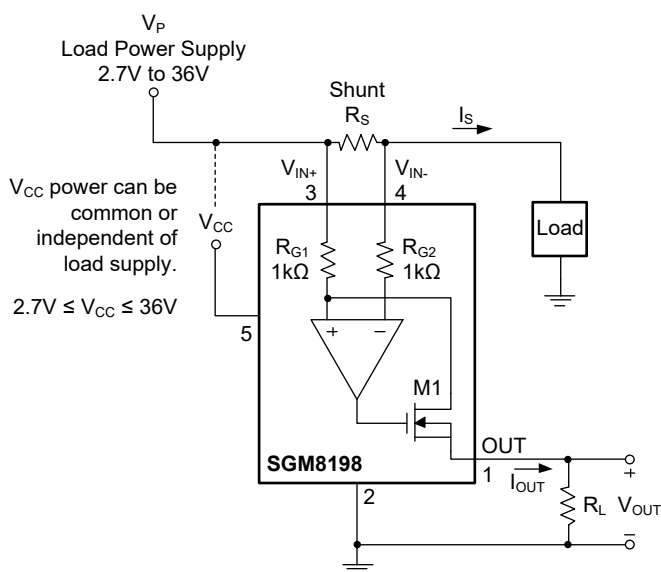


Figure 3. Basic Circuit Connections

## 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

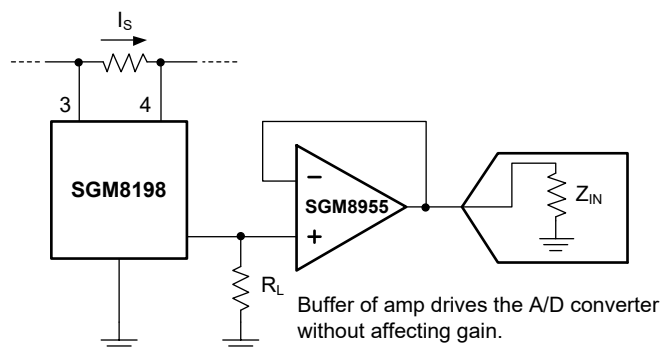


Figure 4. Buffering Output to Drive the A/D Converter

### 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 100k $\Omega$  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

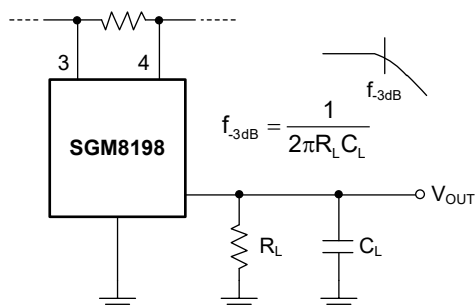


Figure 5. Output Filter

## 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

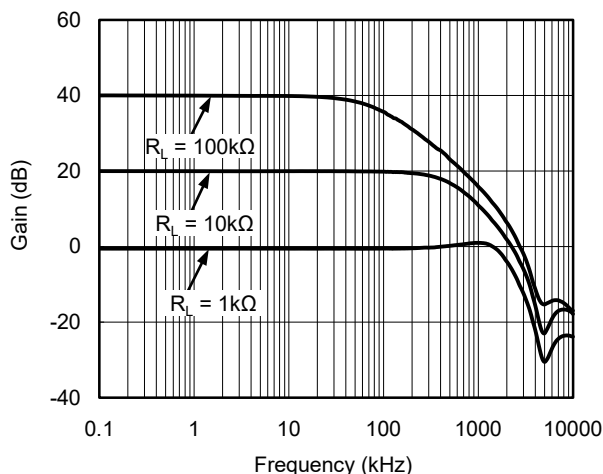


Figure 6. Gain vs. Frequency

## 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  $R_L$ .

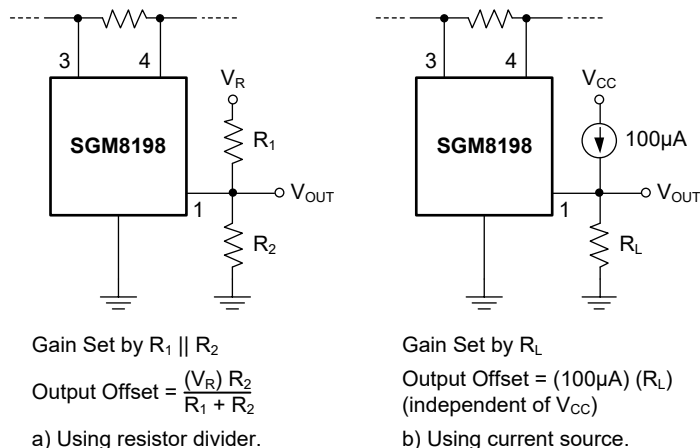


Figure 7. Offsetting the Output Voltage

## 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 20k $\Omega$  resistor results in a gain of 20V/V. The 10k $\Omega$  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.

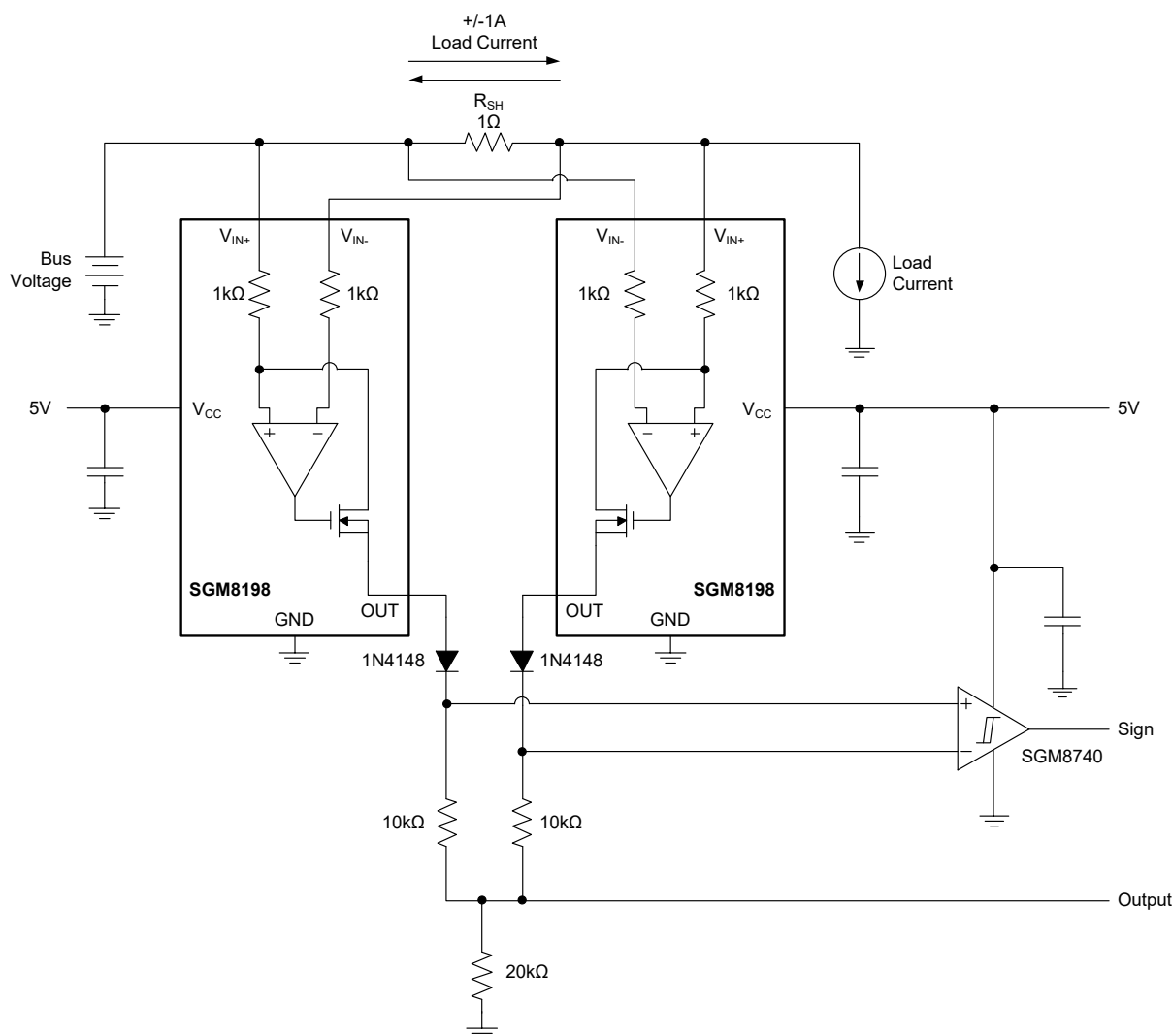
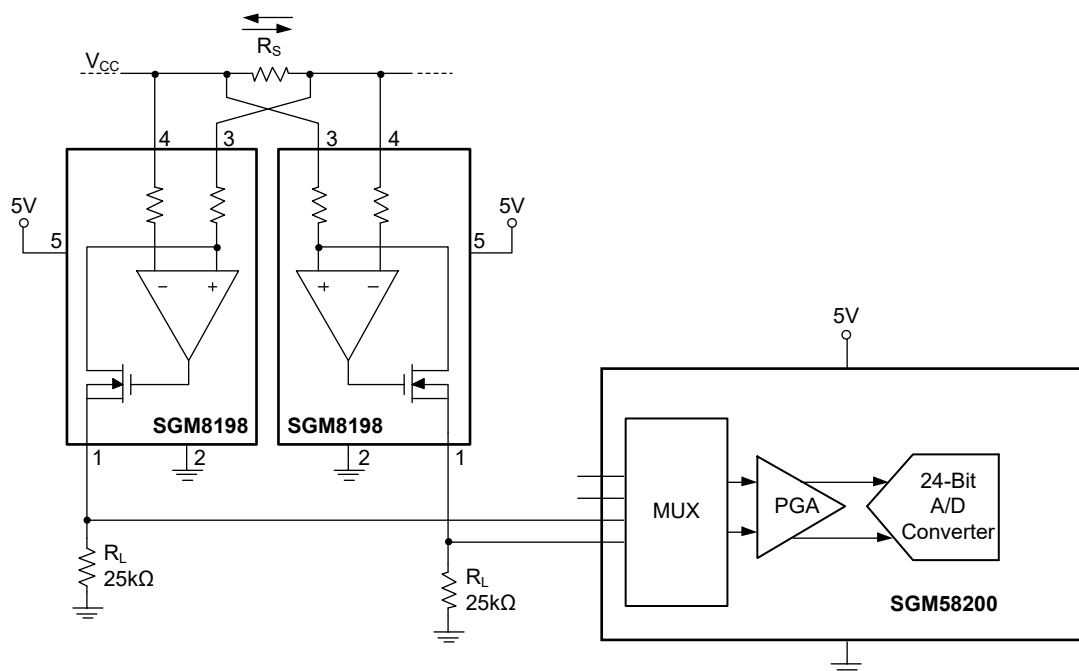


Figure 8. Bipolar Current Measurement

## 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.

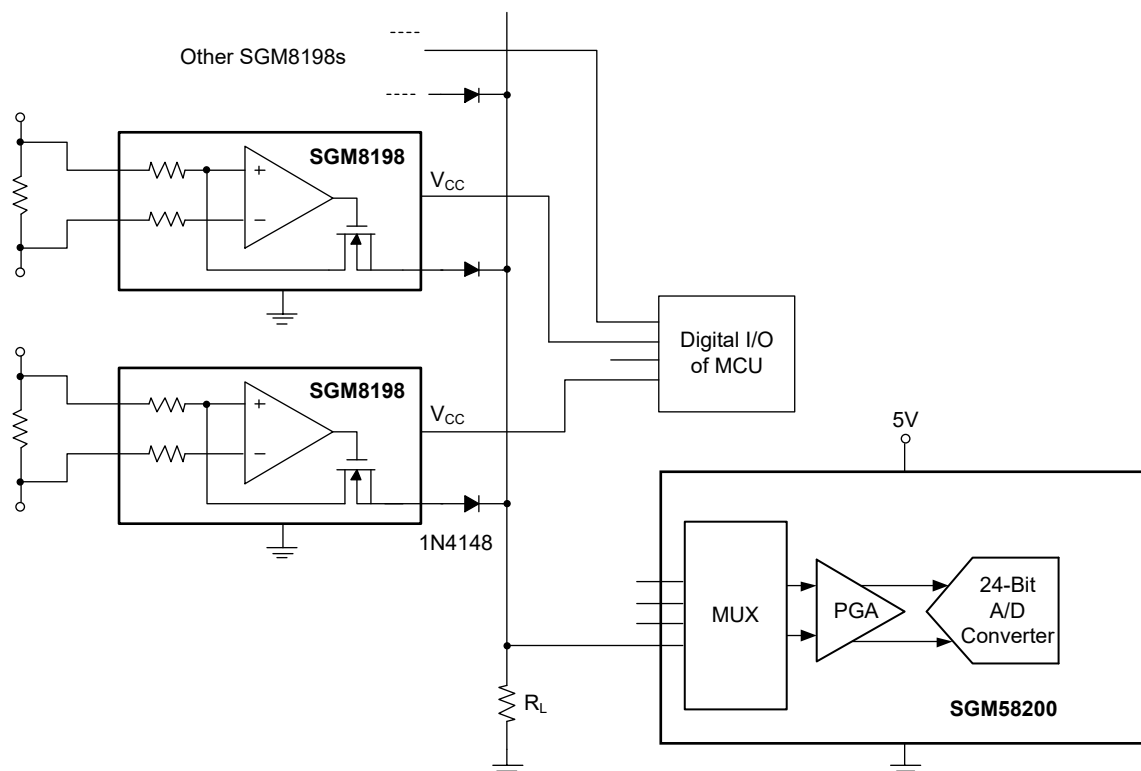


Figure 10. Multiplexed Measurement Using Logic Signal for Power

## 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 0.1 $\mu$ F 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

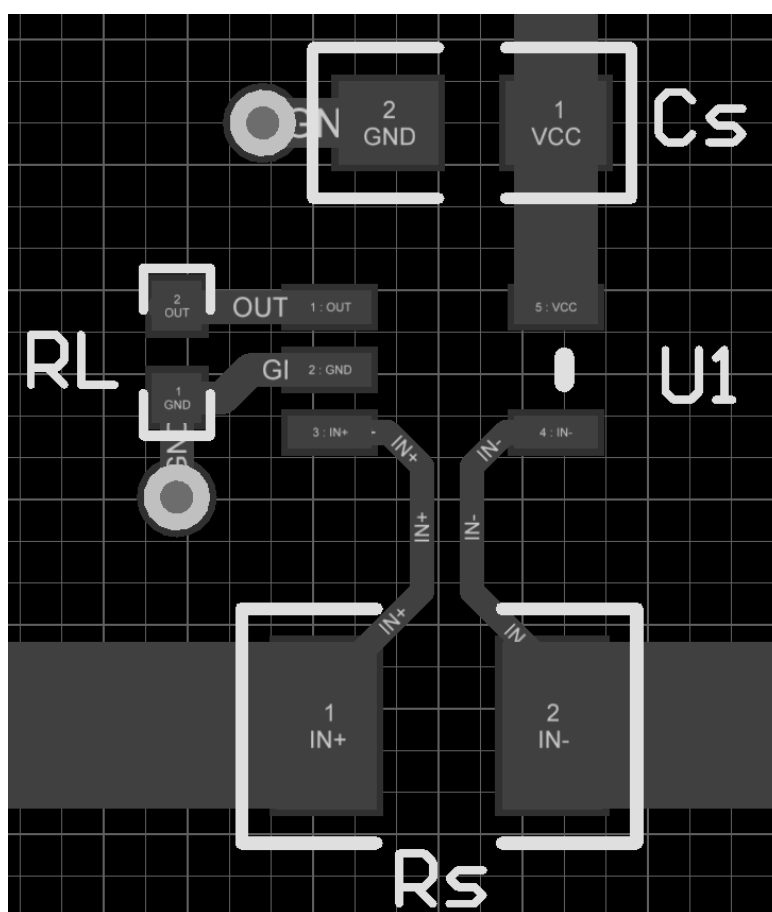


Figure 11. Typical Layout Example

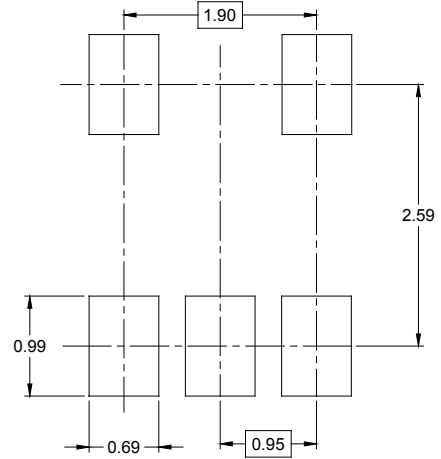
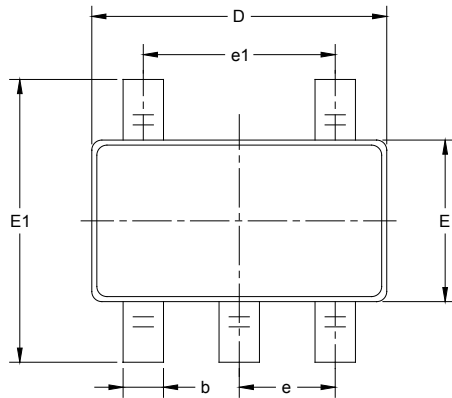
REVISION HISTORY

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

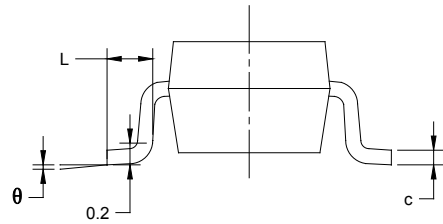
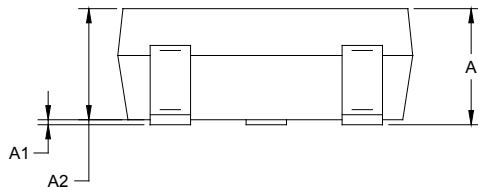
JANUARY 2021 – REV.A.1 to REV.A.2	Page
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Updated Electrical Characteristics section .....	3
Changes from Original (DECEMBER 2018) to REV.A	Page
Changed from product preview to production data.....	All

## PACKAGE OUTLINE DIMENSIONS

### SOT-23-5



RECOMMENDED LAND PATTERN (Unit: mm)

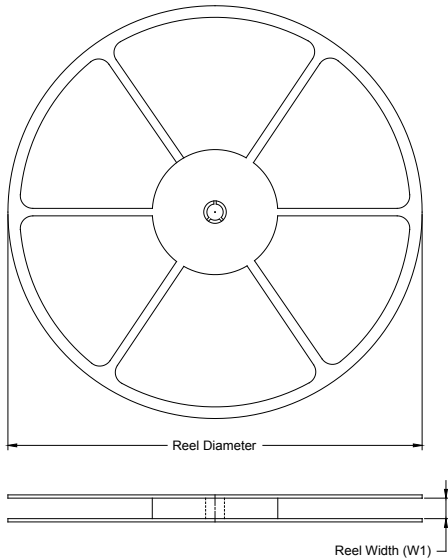


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950 BSC		0.037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

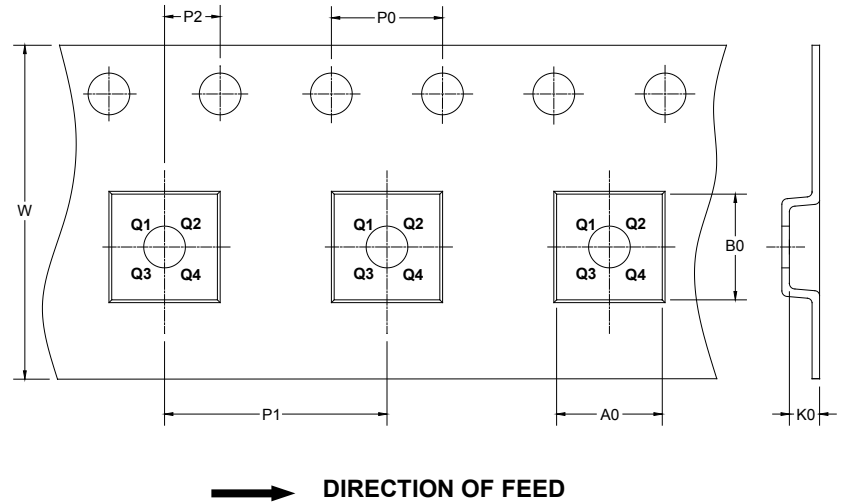
## PACKAGE INFORMATION

### TAPE AND REEL INFORMATION

#### REEL DIMENSIONS



#### TAPE DIMENSIONS



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

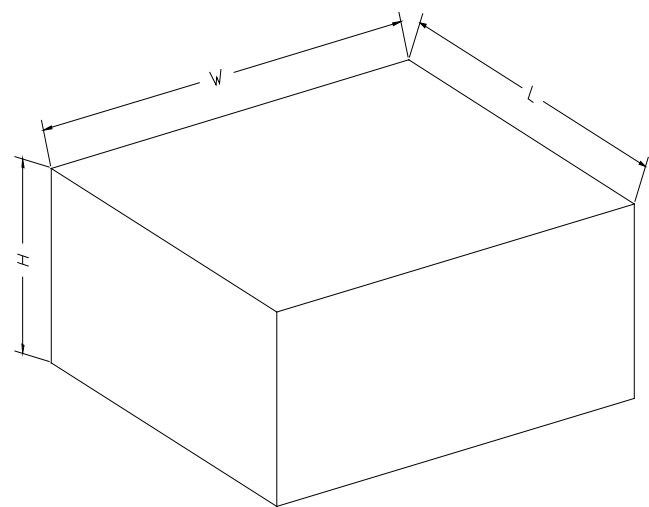
#### KEY PARAMETER LIST OF TAPE AND REEL

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

DD00001



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

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