SGM8959-1/ SGM8959-2
Low V_{OS}, Low Noise, High Precision Zero-Drift Operational Amplifiers

GENERAL DESCRIPTION

The single SGM8959-1 and dual SGM8959-2 CMOS operational amplifiers provide very low offset voltage and zero-drift over time and temperature.

The miniature, high precision, low quiescent current amplifiers offer high-impedance inputs that have a wide input common mode range and rail-to-rail output that swings within 5mV of the rails. Single or dual supplies as low as 1.8V (±0.9V) and up to 5.5V (±2.75V) may be used. They are optimized for low voltage, single-supply operation.

The SGM8959-1/2 offer excellent CMRR without the crossover associated with traditional complementary input stages. This design results in superior performance for driving analog-to-digital converters (ADCs) without degradation of differential linearity.

The single SGM8959-1 is available in Green SOT-23-5, SC70-5 and SOIC-8 packages. The dual SGM8959-2 is available in Green SOIC-8 and TDFN-3×3-8L packages. They are specified over -40℃ to +125℃ temperature range.

FEATURES

- **Low Offset Voltage: 10μV (MAX)**
- **Input Voltage Noise: 8nV/$\sqrt{Hz}$**
- **Low 0.1Hz to 10Hz Noise: 0.2μV_{PP}**
- **Quiescent Current: 380μA/Amplifier (TYP)**
- **Integrated EMI Filter**
- **Single or Dual Supply Operation**
- **Supply Voltage Range: 1.8V to 5.5V**
- **Rail-to-Rail Input and Output**
- **Gain-Bandwidth: 3.9MHz**
- **Slew Rate : 1.0V/μs**
- **-40℃ to +125℃ Operating Temperature Range**
- **Small Packaging:**
  SGM8959-1 Available in Green SOT-23-5, SC70-5 and SOIC-8 Packages
  SGM8959-2 Available in Green SOIC-8 and TDFN-3×3-8L Packages

APPLICATIONS

Transducer Applications
Temperature Measurements
Electronic Scales
Medical Instrumentation
Battery-Powered Instruments
Handheld Test Equipment

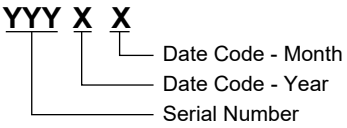
PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM8959-1	SOT-23-5	-40℃ to +125℃	SGM8959-1XN5G/TR	GD4XX	Tape and Reel, 3000
	SC70-5	-40℃ to +125℃	SGM8959-1XC5G/TR	GCDXX	Tape and Reel, 3000
	SOIC-8	-40℃ to +125℃	SGM8959-1XS8G/TR	SGM 89591XS8 XXXXX	Tape and Reel, 2500
SGM8959-2	SOIC-8	-40℃ to +125℃	SGM8959-2XS8G/TR	SGM 89592XS8 XXXXX	Tape and Reel, 2500
	TDFN-3×3-8L	-40℃ to +125℃	SGM8959-2XTDB8G/TR	SGM GD5DB XXXXX	Tape and Reel, 4000

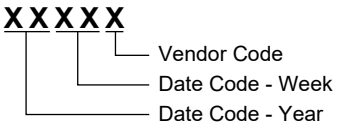
MARKING INFORMATION

NOTE: XX = Date Code. XXXXX = Date Code and Vendor Code.

SOT-23-5/SC70-5



SOIC-8/TDFN-3×3-8L



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.....6V
Junction Temperature.....+150℃
Storage Temperature Range.....-65℃ to +150℃
Lead Temperature (Soldering, 10s).....+260℃
ESD Susceptibility
HBM.....4000V
MM.....400V
CDM.....1000V

RECOMMENDED OPERATING CONDITIONS

Specified Voltage Range.....1.8V to 5.5V
Operating Temperature Range.....-40℃ to +125℃

OVERSTRESS CAUTION

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

ESD SENSITIVITY CAUTION

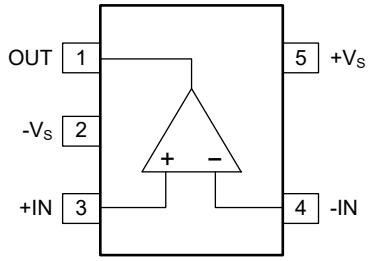
This integrated circuit can be damaged by ESD if you don't pay attention to ESD protection. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

DISCLAIMER

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

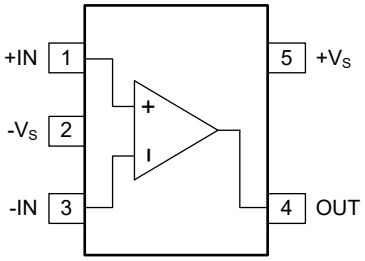
PIN CONFIGURATIONS

SGM8959-1 (TOP VIEW)



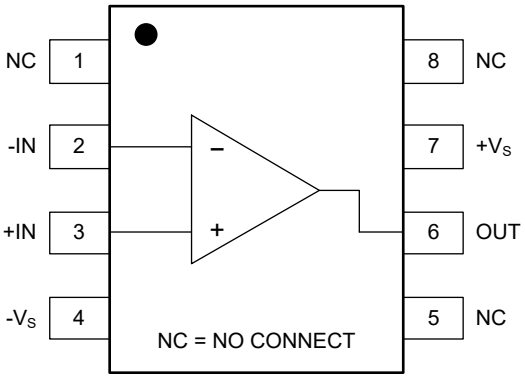
SOT-23-5

SGM8959-1 (TOP VIEW)



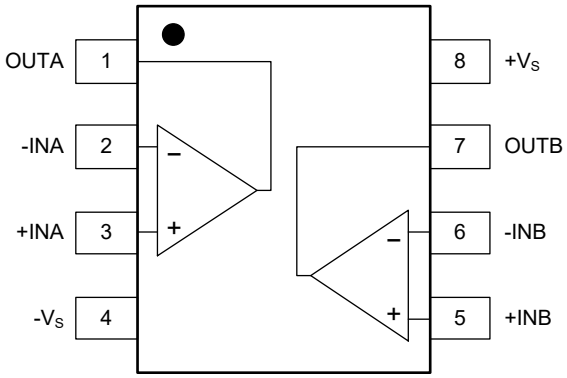
SC70-5

SGM8959-1 (TOP VIEW)



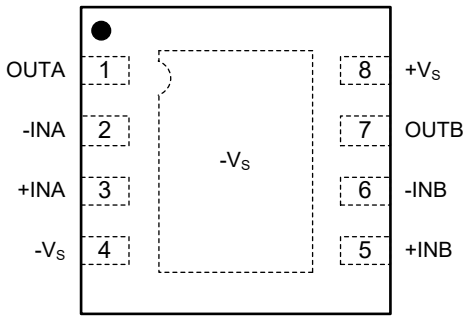
SOIC-8

SGM8959-2 (TOP VIEW)



SOIC-8

SGM8959-2 (TOP VIEW)



TDFN-3×3-8L

NOTE: For TDFN-3×3-8L package, exposed pad can be connected to $-V_S$ or left floating.

ELECTRICAL CHARACTERISTICS

(V_S = 5V, V_{CM} = V_S/2, V_{OUT} = V_S/2, and R_L = 10kΩ to V_S/2, Full = -40℃ to +125℃, typical values are at T_A = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
Input Characteristics							
Input Offset Voltage	V_{OS}	V_S = 5V	+25℃		2.5	10	μV
			Full			28	
Input Offset Voltage Drift	$\Delta V_{OS}/\Delta T$		Full		0.032		μV/℃
Input Bias Current	I_B		+25℃		350		pA
Input Offset Current	I_{OS}		+25℃		700		pA
Input Common Mode Voltage Range	V_{CM}		Full	$(-V_S)$ - 0.1		$(+V_S)$ + 0.1	V
Common Mode Rejection Ratio	CMRR	$-V_S < V_{CM} < V_S$	+25℃	107	123		dB
			Full	105			
Open-Loop Voltage Gain	A_{OL}	$(-V_S)$ + 0.1V < V_{OUT} < $(+V_S)$ - 0.1V, R_L = 10kΩ	+25℃	110	127		dB
Output Characteristics							
Output Voltage Swing from Rail		R_L = 10kΩ	+25℃		5	10	mV
Short-Circuit Current	I_{SC}		+25℃	25	42		mA
Capacitive Load Drive			+25℃	See Typical Performance Characteristics			
Power Supply							
Specified Voltage Range	V_S		Full	1.8		5.5	V
Power Supply Rejection Ratio	PSRR	V_S = 1.8V to 5.5V, V_{CM} = 0.2V	+25℃		1	4	μV/V
			Full			5	
Quiescent Current/Amplifier	I_Q	I_{OUT} = 0	+25℃		380	560	μA
			Full			665	
Turn-On Time		G = +1, V_{IN} = 0.1V, R_L = 10kΩ, C_L = 30pF	+25℃		33		μs
Dynamic Performance							
Gain-Bandwidth Product	GBP	C_L = 30pF	+25℃		4		MHz
Slew Rate	SR	G = +1, V_{OUT} = $2V_{PP}$, C_L = 30pF	+25℃		1		V/μs
Noise							
Input Voltage Noise		f = 0.1Hz to 10Hz	+25℃		0.2		μV_{PP}
Input Voltage Noise Density	e_n	f = 1kHz	+25℃		8		$nV/\sqrt{Hz}$

ELECTRICAL CHARACTERISTICS (continued)

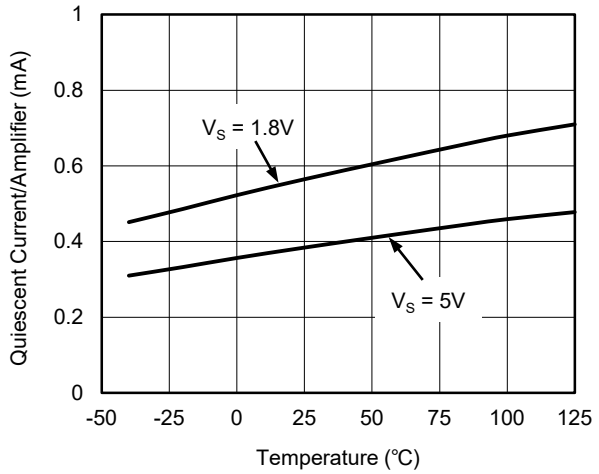
(V_S = 1.8V, V_{CM} = V_S/2, V_{OUT} = V_S/2, and R_L = 10kΩ to V_S/2, Full = -40℃ to +125℃, typical values are at T_A = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
Input Characteristics							
Input Offset Voltage	V_{OS}	V_S = 1.8V	+25℃		3.0	10	μV
			Full			29	
Input Offset Voltage Drift	$\Delta V_{OS}/\Delta T$		Full		0.035		μV/℃
Input Bias Current	I_B		+25℃		350		pA
Input Offset Current	I_{OS}		+25℃		700		pA
Input Common Mode Voltage Range	V_{CM}		Full	$(-V_S)$ - 0.1		$(+V_S)$ + 0.1	V
Common Mode Rejection Ratio	CMRR	$-V_S < V_{CM} < V_S$	+25℃	104	122		dB
			Full	69			
Open-Loop Voltage Gain	A_{OL}	$(-V_S)$ + 0.1V < V_{OUT} < $(+V_S)$ - 0.1V, R_L = 10kΩ	+25℃	109	127		dB
Output Characteristics							
Output Voltage Swing from Rail		R_L = 10kΩ	+25℃		3	6	mV
Short-Circuit Current	I_{SC}		+25℃	7.5	12		mA
Capacitive Load Drive			+25℃	See Typical Performance Characteristics			
Power Supply							
Specified Voltage Range	V_S		Full	1.8		5.5	V
Power Supply Rejection Ratio	PSRR	V_S = 1.8V to 5.5V, V_{CM} = 0.2V	+25℃		1	4	μV/V
			Full			5	
Quiescent Current/Amplifier	I_Q	I_{OUT} = 0	+25℃		560	780	μA
			Full			950	
Turn-On Time		G = +1, V_{IN} = 0.1V, R_L = 10kΩ, C_L = 30pF	+25℃		63		μs
Dynamic Performance							
Gain-Bandwidth Product	GBP	C_L = 30pF	+25℃		3.5		MHz
Slew Rate	SR	G = +1, V_{OUT} = $1V_{PP}$, C_L = 30pF	+25℃		0.6		V/μs
Noise							
Input Voltage Noise		f = 0.1Hz to 10Hz	+25℃		0.3		μV_{PP}
Input Voltage Noise Density	e_n	f = 1kHz	+25℃		14		$nV/\sqrt{Hz}$

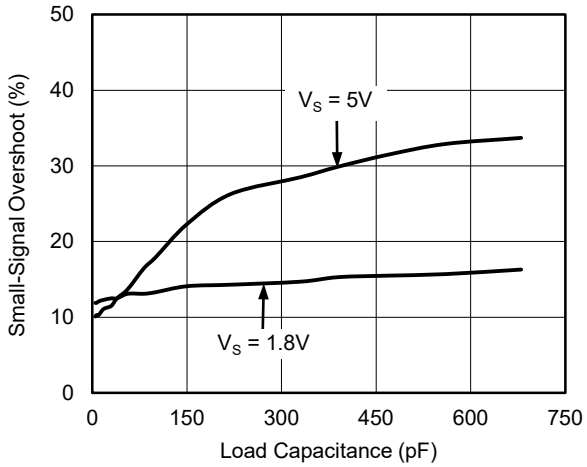
TYPICAL PERFORMANCE CHARACTERISTICS

At T_A = +25℃, unless otherwise noted.

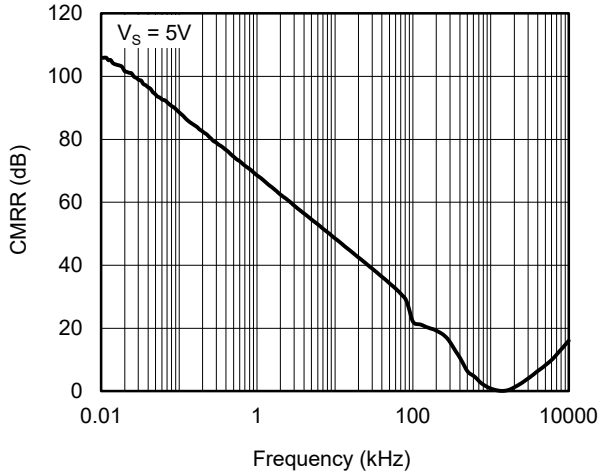
Quiescent Current vs. Temperature



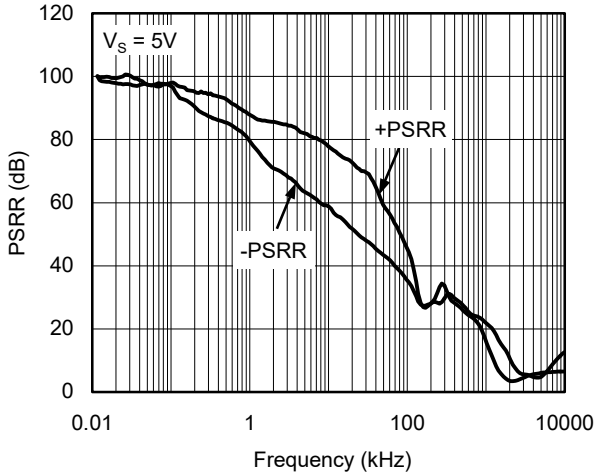
Small-Signal Overshoot vs. Load Capacitance



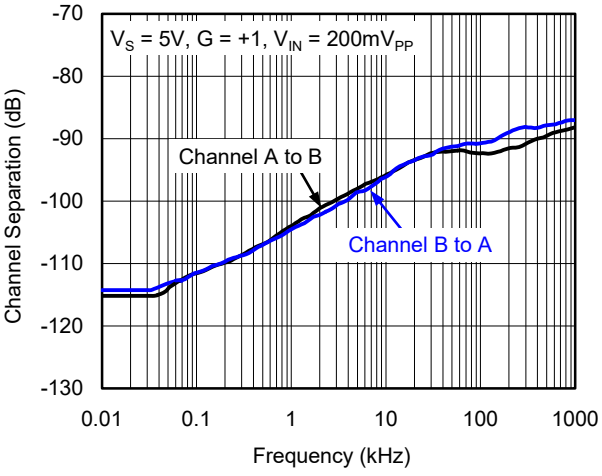
Common Mode Rejection Ratio vs. Frequency



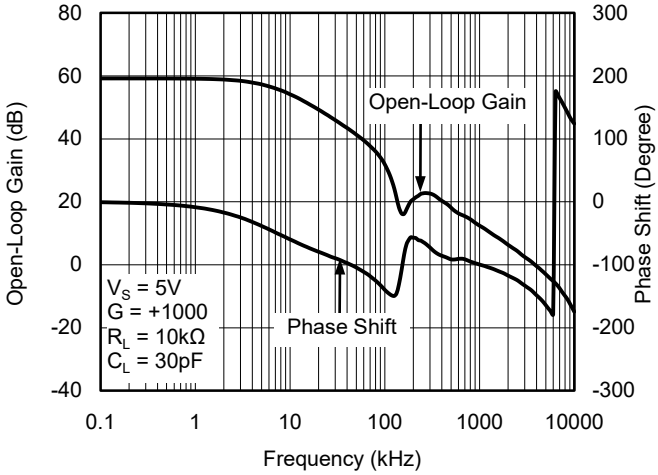
Power Supply Rejection Ratio vs. Frequency



Channel Separation vs. Frequency



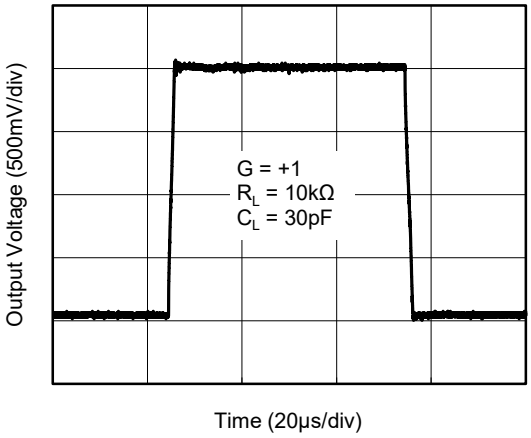
Open-Loop Gain and Phase Shift vs. Frequency



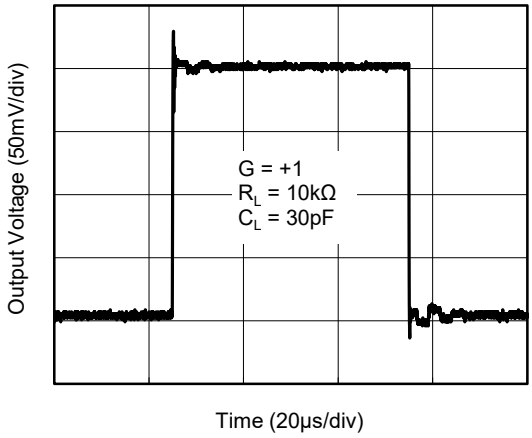
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At T_A = +25℃, unless otherwise noted.

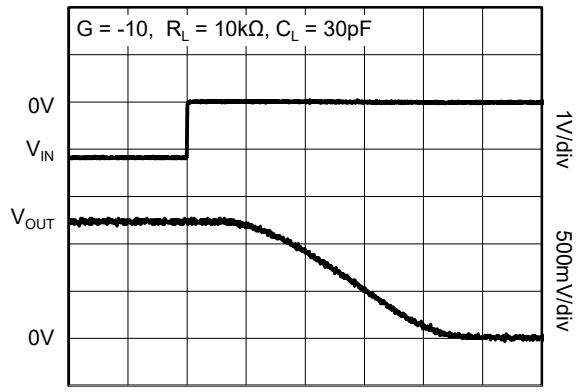
Large-Signal Step Response



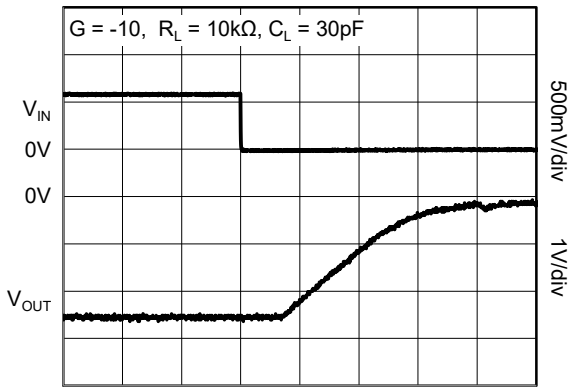
Small-Signal Step Response



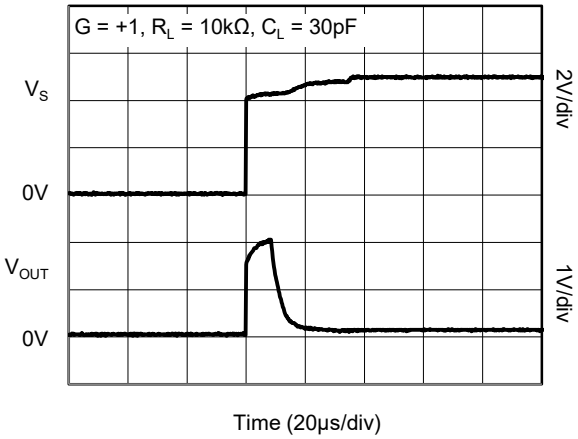
Positive Over-Voltage Recovery



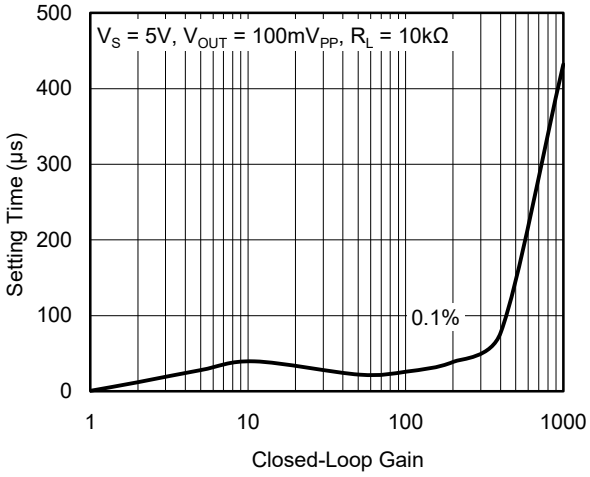
Negative Over-Voltage Recovery



Turn-On Time



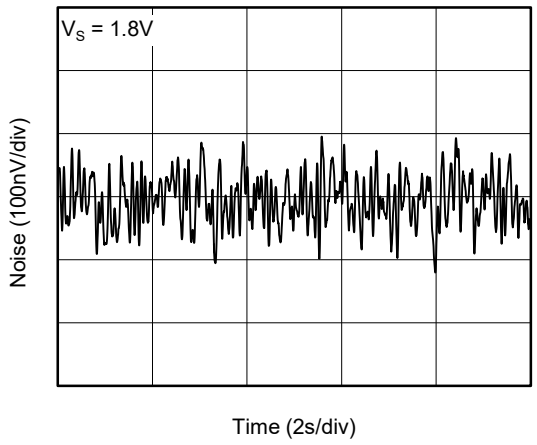
Settling Time vs. Closed-Loop Gain



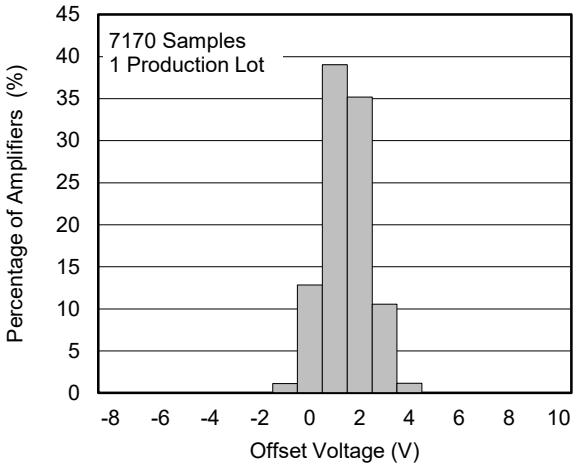
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At T_A = +25℃, unless otherwise noted.

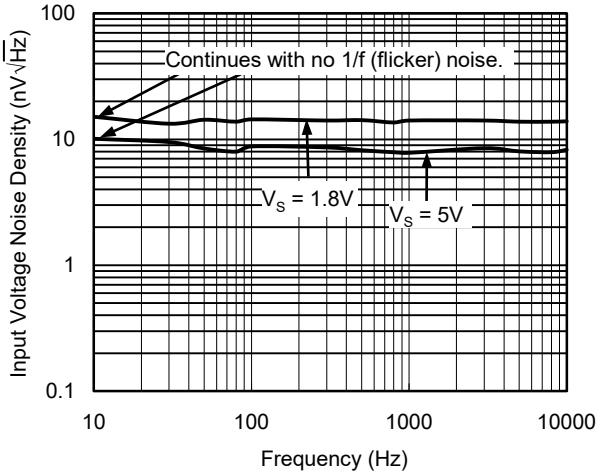
0.1Hz to 10Hz Noise



Offset Voltage Production Distribution



Input Voltage Noise Density vs. Frequency



APPLICATION INFORMATION

The SGM8959-1 and SGM8959-2 are unity-gain stable and free from unexpected output phase reversal. They provide low offset voltage and very low drift over time and temperature. For lowest offset voltage and precision performance, circuit layout and mechanical conditions should be optimized. Avoid temperature gradients that create thermoelectric (Seebeck) effects in the thermocouple junctions formed from connecting dissimilar conductors. These thermally-generated potentials can be made to cancel by ensuring they are equal on both input terminals. Other layout and design considerations include:

• Use low thermoelectric-coefficient conditions (avoid dissimilar metals).
• Thermally isolate components from power supplies or other heat sources.
• Shield operational amplifier and input circuitry from air currents, such as cooling fans.

Following these guidelines will reduce the likelihood of junctions at different temperatures, which can cause thermoelectric voltages of 0.032μV/℃ or higher, depending on materials used.

Operating Voltage

The SGM8959-1/2 operational amplifiers operate over a power supply range of 1.8V to 5.5V (±0.9V to ±2.75V). Supply voltages higher than 6V (absolute maximum) can permanently damage the device.

Input Voltage

The SGM8959-1/2 input common mode voltage range extends 0.1V beyond the supply rails. The SGM8959-1/2 are designed to cover the full range without the troublesome transition region found in some other rail-to-rail amplifiers.

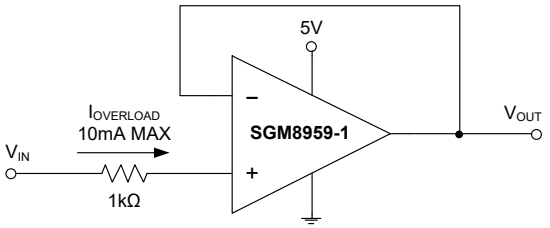
Normally, input bias current is about 350pA; however, input voltages exceeding the power supplies can cause excessive current flowing into or out of the input pins. Momentary voltages greater than the power supply can be tolerated if the input current is limited to 10mA. This limitation is easily accomplished with an input resistor, as shown in Figure 1.

Internal Offset Correction

The SGM8959-1/2 operational amplifiers use an auto-calibration technique in the signal path. Upon power-up, the amplifier requires approximately 33μs to achieve specified V_{OS} accuracy.

Achieving Output Swing to the Operational Amplifier Negative Rail

Some applications require output voltage swings from 0V to a positive full-scale voltage (such as 2.5V) with excellent accuracy. With most single-supply operational amplifiers, problems arise when the output signal approaches 0V, near the lower output swing limit of a single-supply operational amplifier. A good single-supply operational amplifier may swing close to single-supply ground, but will not reach ground. The output of the SGM8959-1/2 can be made to swing to ground, or slightly below, on a single-supply power source. To do so requires the use of another resistor and an additional, more negative, power supply than the operational amplifier negative supply. A pull-down resistor may be connected between the output and the additional negative supply to pull the output down below the value that the output would otherwise achieve, as shown in Figure 2.



NOTE: Current-limit resistor required if input voltage exceeds supply rails by ≥ 0.5V.

Figure 1. Input Current Protection

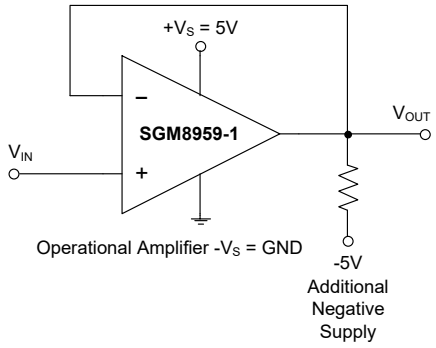


Figure 2. For V_{OUT} Range to Ground

APPLICATION INFORMATION (continued)

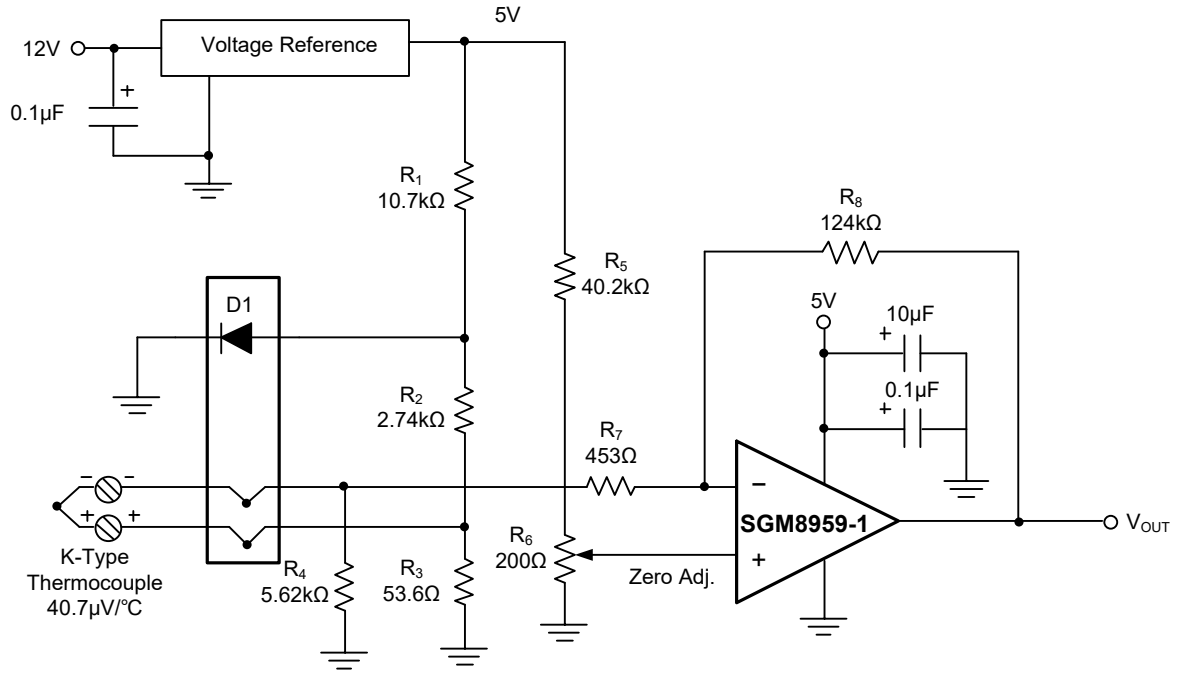


Figure 3. Temperature Measurement

General Layout Guidelines

Attention to good layout practices is always recommended. Keep traces short and, when possible, use a printed circuit board (PCB) ground plane with surface-mount components placed as close to the device pins as possible. Place a 0.1μF capacitor closely across the supply pins. These guidelines should be applied throughout the analog circuit to improve performance and provide benefits such as reducing the EMI (electromagnetic interference) susceptibility. Operational amplifiers vary in their susceptibility to radio frequency interference (RFI). RFI can generally be identified as a variation in offset voltage or DC signal levels with changes in the interfering RF signal. The SGM8959-1/2 have been specifically designed to minimize susceptibility to RFI and demonstrate remarkably low sensitivity. Strong RF fields may still cause varying offset levels.

Figure 4 shows the basic configuration for a bridge amplifier.

A low-side current shunt monitor is shown in Figure 5. R_N are operational resistors used to isolate the ADC from the noise of the digital I^2C bus. Since the ADC is a 16-bit converter, a precision reference is essential for maximum accuracy. Related application circuits are shown in Figure 6 ~ 8.

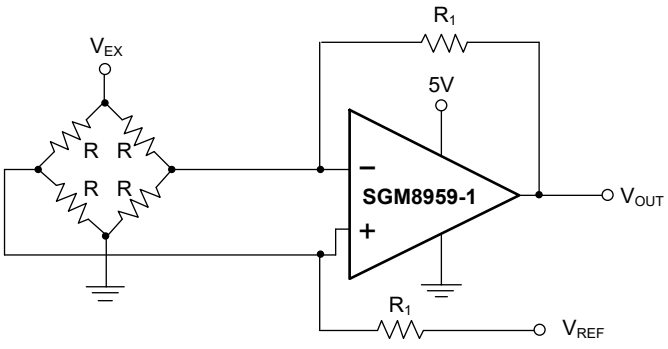


Figure 4. Bridge Amplifier Configuration

APPLICATION INFORMATION (continued)

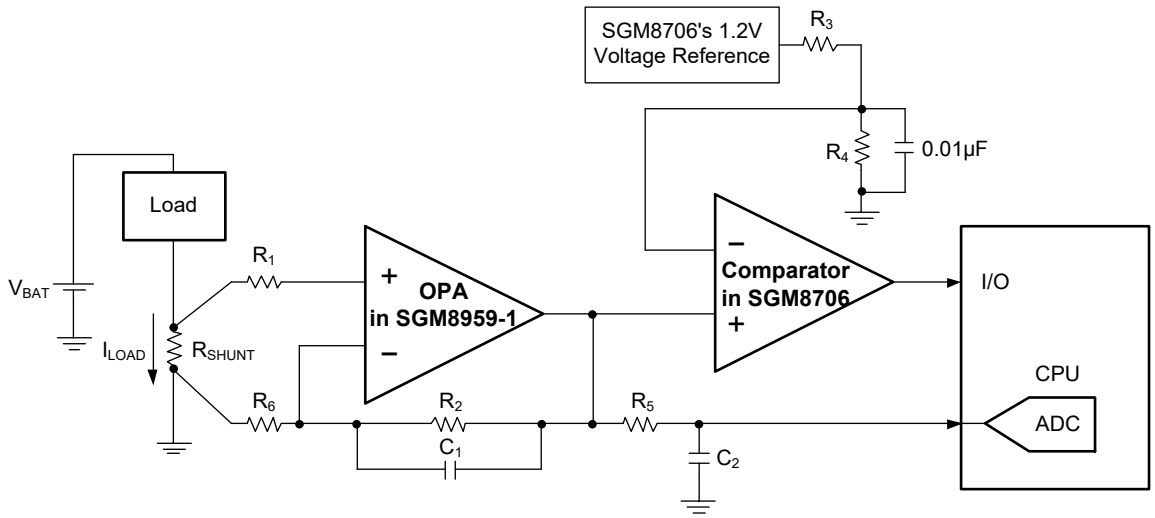
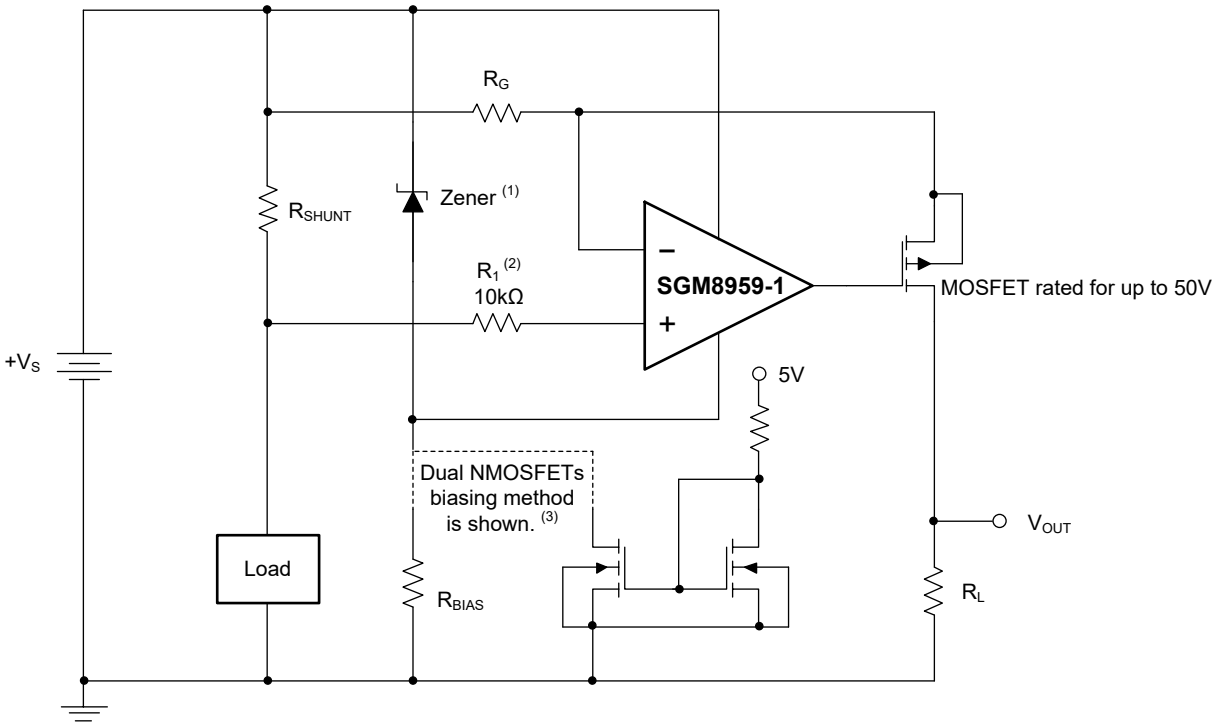


Figure 5. Low-side Current Shunt Monitor



NOTES: (1) Zener rated for operational amplifier supply capability (that is, 5.1V for SGM8959-1 and SGM8959-2).
(2) Current-limit resistor.
(3) Choose Zener biasing resistor or dual NMOSFETs.

Figure 6. High-side Current Shunt Monitor

APPLICATION INFORMATION (continued)

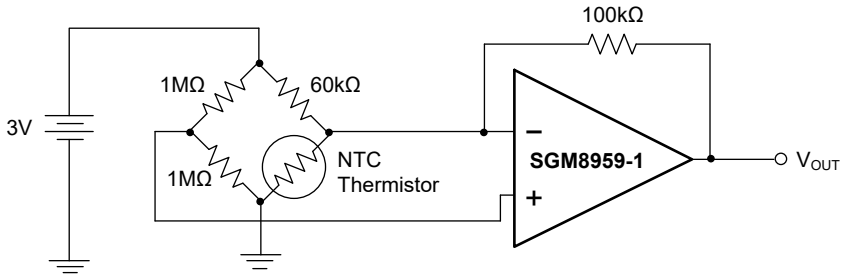


Figure 7. Thermistor Measurement

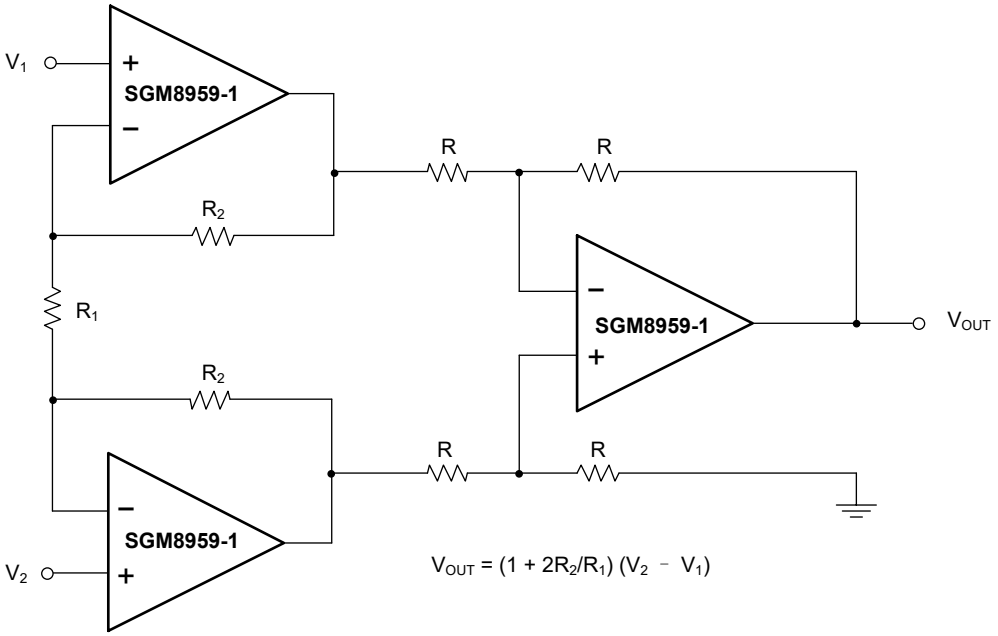
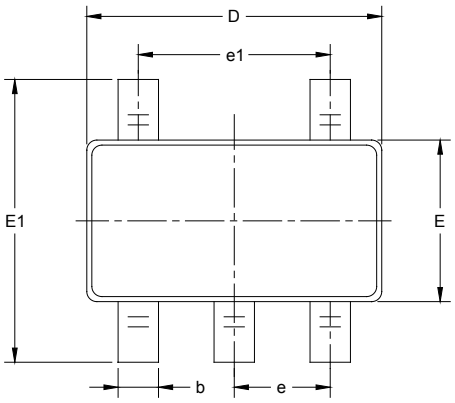
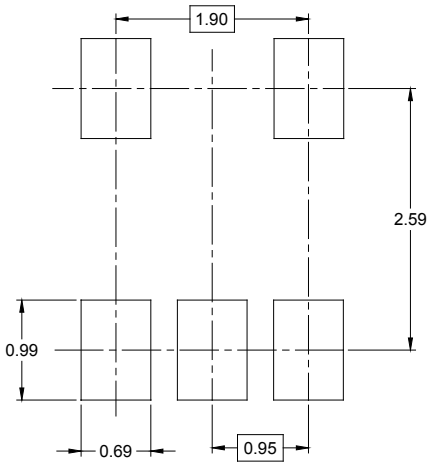


Figure 8. Precision Instrumentation Amplifier Configuration

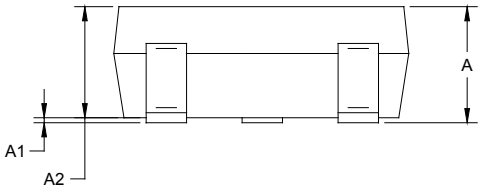
PACKAGE OUTLINE DIMENSIONS

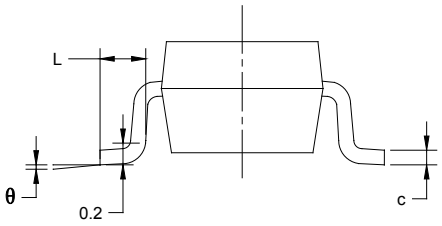
SOT-23-5





RECOMMENDED LAND PATTERN (Unit: mm)

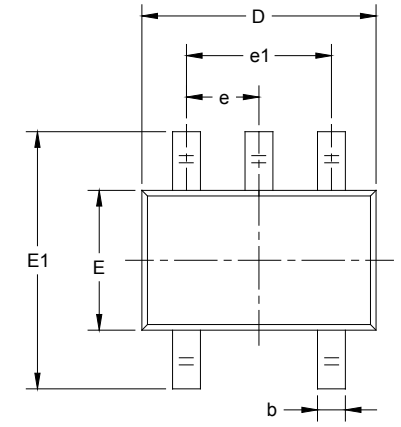


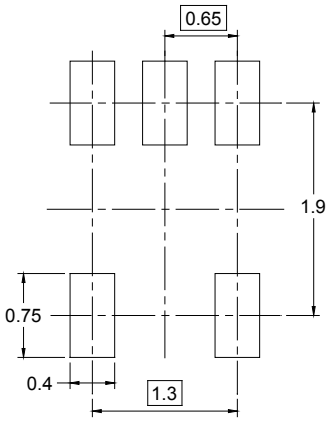


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950 BSC		0.037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

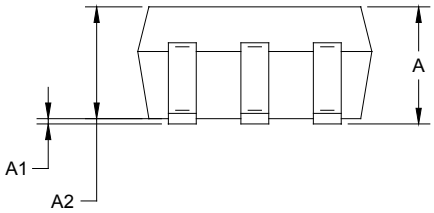
PACKAGE OUTLINE DIMENSIONS

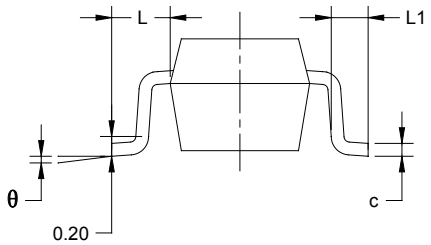
SC70-5





RECOMMENDED LAND PATTERN (Unit: mm)

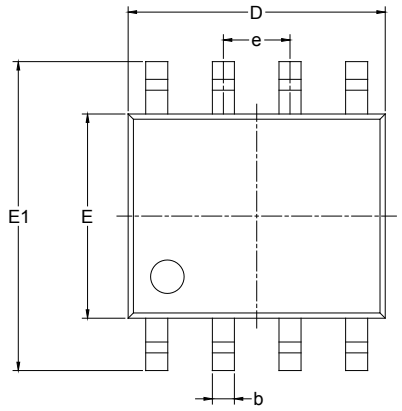


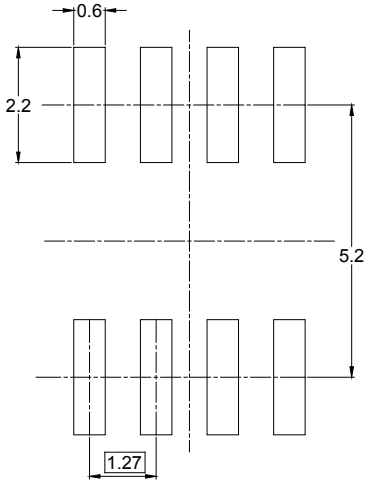


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.900	1.100	0.035	0.043
A1	0.000	0.100	0.000	0.004
A2	0.900	1.000	0.035	0.039
b	0.150	0.350	0.006	0.014
c	0.080	0.150	0.003	0.006
D	2.000	2.200	0.079	0.087
E	1.150	1.350	0.045	0.053
E1	2.150	2.450	0.085	0.096
e	0.65 TYP		0.026 TYP	
e1	1.300 BSC		0.051 BSC	
L	0.525 REF		0.021 REF	
L1	0.260	0.460	0.010	0.018
θ	0°	8°	0°	8°

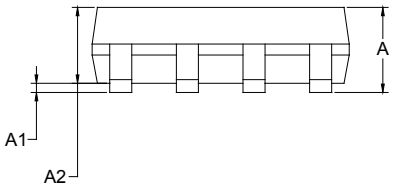
PACKAGE OUTLINE DIMENSIONS

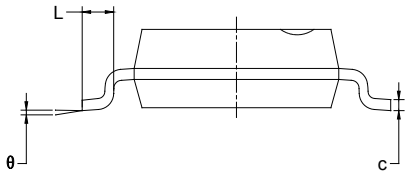
SOIC-8





RECOMMENDED LAND PATTERN (Unit: mm)

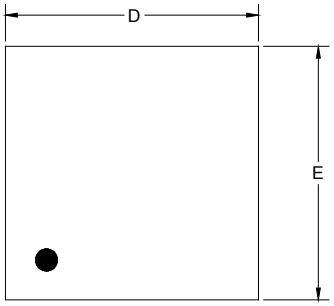




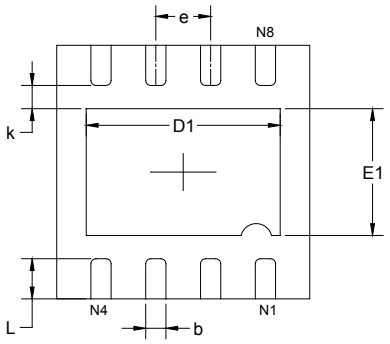
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.27 BSC		0.050 BSC	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

PACKAGE OUTLINE DIMENSIONS

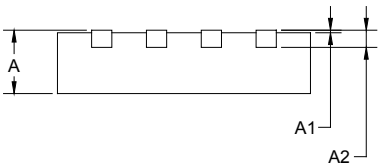
TDFN-3×3-8L



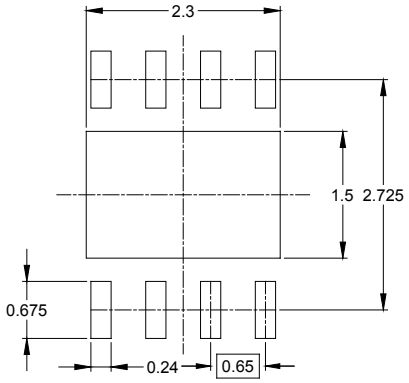
TOP VIEW



BOTTOM VIEW



SIDE VIEW

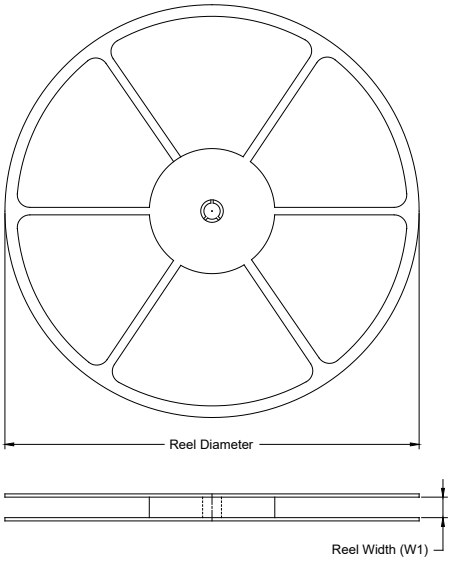


RECOMMENDED LAND PATTERN (Unit: mm)

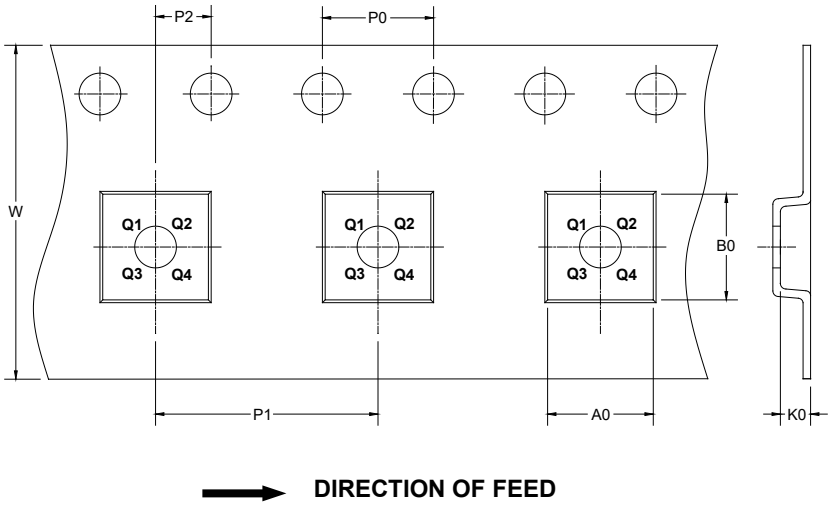
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A2	0.203 REF		0.008 REF	
D	2.900	3.100	0.114	0.122
D1	2.200	2.400	0.087	0.094
E	2.900	3.100	0.114	0.122
E1	1.400	1.600	0.055	0.063
k	0.200 MIN		0.008 MIN	
b	0.180	0.300	0.007	0.012
e	0.650 TYP		0.026 TYP	
L	0.375	0.575	0.015	0.023

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



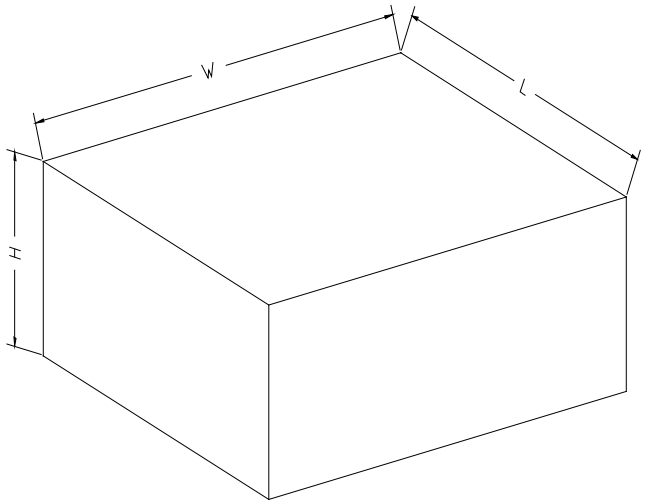
NOTE: The picture is only for reference. Please make the object as the standard.

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
SC70-5	7″	9.5	2.25	2.55	1.20	4.0	4.0	2.0	8.0	Q3
SOIC-8	13″	12.4	6.40	5.40	2.10	4.0	8.0	2.0	12.0	Q1
TDFN-3×3-8L	13″	12.4	3.35	3.35	1.13	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
7″ (Option)	368	227	224	8
7″	442	410	224	18
13″	386	280	370	5

DD0002