SGM8970-3
1.8mA, 27MHz, High Precision, Rail-to-Rail Output, Low Noise, CMOS Operational Amplifier

GENERAL DESCRIPTION

The SGM8970-3 is a single, low noise, high precision operational amplifier optimized for low voltage operation. The device can operate from 2.1V to 5.5V single supply, and consumes only 1.8mA quiescent current at 5.5V. The supply current is 0.1μA in power-down mode. The device supports rail-to-rail output operation.

The SGM8970-3 offers a 240μV maximum input offset, 27MHz gain-bandwidth product and 30V/μs slew rate.

The SGM8970-3 is available in a Green SOT-23-6 package. It is specified over the extended industrial temperature range (-40℃ to +125℃).

FEATURES

- **Input Offset Voltage: 240μV (MAX)**
- **High Gain-Bandwidth Product: 27MHz**
- **High Slew Rate: 30V/μs**
- **Settling Time to 0.1% with 2V Step: 150ns**
- **Overload Recovery Time: 80ns**
- **Low Noise: 8nV/$\sqrt{Hz}$ at 10kHz**
- **Non Rail-to-Rail Input**
- **Rail-to-Rail Output**
- **Supply Voltage Range: 2.1V to 5.5V**
- **Input Voltage Range: -0.1V to 4V with V_S = 5.5V**
- **Low Power:**
  Supply Current: 1.8mA (TYP)
  Supply Current when Disabled: 0.1μA (TYP)
- **-40℃ to +125℃ Operating Temperature Range**
- **Available in a Green SOT-23-6 Package**

APPLICATIONS

Sensors
Audio
Active Filters
A/D Converters
Communications
Test Equipment
Photodiode Amplification
Battery-Powered Instrumentation

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM8970-3	SOT-23-6	-40℃ to +125℃	SGM8970-3XN6G/TR	SWIXX	Tape and Reel, 3000

MARKING INFORMATION

NOTE: XX = Date Code.

YYY X X
- X — Date Code - Week
- X — Date Code - Year
- YYY — 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, $+V_S$ to $-V_S$ 6V
Input Common Mode Voltage Range .... $(-V_S) - 0.3V$ to $(+V_S) + 0.3V$
Junction Temperature .... +150℃
Storage Temperature Range .... -65℃ to +150℃
Lead Temperature (Soldering, 10s) .... +260℃
ESD Susceptibility
HBM 3000V
CDM 1000V

RECOMMENDED OPERATING CONDITIONS

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

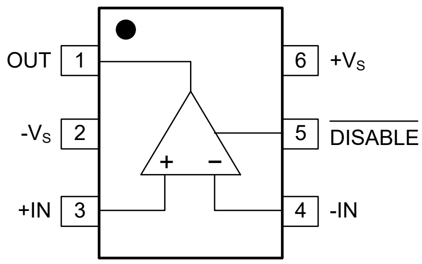
This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance 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-23-6

ELECTRICAL CHARACTERISTICS

(V_S = 2.1V to 5.5V or ±1.05V to ±2.75V, V_{CM} = (V_S - 1.5V)/2 and R_L = 600Ω tied to (V_S - 1.5V)/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}		+25℃		50	240	μV
			Full			800	
Input Offset Voltage Drift	$\Delta V_{OS}/\Delta T$	V_S = ±2.75V, T_A = -40℃ to +25℃	Full		1		μV/℃
Input Bias Current	I_B		+25℃		3	120	pA
			Full			3000	
Input Offset Current	I_{OS}		+25℃		3	120	pA
			Full			4000	
Input Common Mode Voltage Range	V_{CM}		Full	(-V_S) - 0.1		(+V_S) - 1.5	V
Common Mode Rejection Ratio	CMRR	V_S = 5.5V, V_{CM} = -0.1V to (+V_S) - 1.5V	+25℃	87	103		dB
			Full	84			
		V_S = 2.1V, V_{CM} = -0.1V to (+V_S) - 1.5V	+25℃	74	88		
			Full	71			
Open-Loop Voltage Gain	A_{OL}	V_S = 2.1V, R_L = 600Ω, (-V_S) + 0.25V < V_{OUT} < (+V_S) - 0.25V	+25℃	92	118		dB
			Full	89			
		V_S = 5.5V, R_L = 600Ω, (-V_S) + 0.25V < V_{OUT} < (+V_S) - 0.25V	+25℃	100	128		
			Full	97			
		V_S = 2.1V, R_L = 10kΩ, (-V_S) + 0.15V < V_{OUT} < (+V_S) - 0.15V	+25℃	94	120		
			Full	91			
		V_S = 5.5V, R_L = 10kΩ, (-V_S) + 0.15V < V_{OUT} < (+V_S) - 0.15V	+25℃	100	124		
			Full	97			
Output Characteristics							
Output Voltage Swing from Rail	V_{OUT}	V_S = 5.5V, R_L = 600Ω tied to V_S/2	+25℃		80	100	mV
			Full			105	
		V_S = 5.5V, R_L = 10kΩ tied to V_S/2	+25℃		5	12	
			Full			14	
Output Current	I_{OUT}	V_S = 5.5V	+25℃	75	90		mA
			Full	65			

ELECTRICAL CHARACTERISTICS (continued)

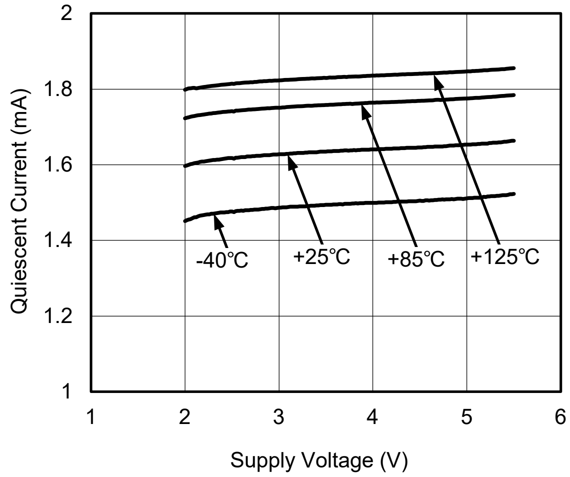
(V_S = 2.1V to 5.5V or ±1.05V to ±2.75V, V_{CM} = (V_S - 1.5V)/2 and R_L = 600Ω tied to (V_S - 1.5V)/2, Full = -40℃ to +125℃, typical values are at T_A = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
Power-Down Disable							
Turn-On Time	t_{ON}	V_S = 5.5V	+25℃		15		μs
Turn-Off Time	t_{OFF}	V_S = 5.5V	+25℃		0.2		μs
Input High Voltage	V_{IH}	V_S = 2.1V	Full	1.3			V
		V_S = 5.5V	Full	2.1			
Input Low Voltage	V_{IL}	V_S = 2.1V	Full			0.4	V
		V_S = 5.5V	Full			0.7	
High-Level Input Current	I_{IH}	$\overline{\text{DISABLE}}$ = +V_S	Full		±0.1	±1	μA
Low-Level Input Current	I_{IL}	$\overline{\text{DISABLE}}$ = -V_S	Full		±0.1	±1	μA
Power Supply							
Operating Voltage Range	V_S		Full	2.1		5.5	V
Power Supply Rejection Ratio	PSRR	V_S = 2.1V to 5.5V, V_{CM} = (-V_S) + 0.5V	+25℃	92	110		dB
			Full	89			
Quiescent Current	I_Q	I_{OUT} = 0A, $\overline{\text{DISABLE}}$ = +V_S	+25℃		1.8	2.3	mA
			Full			2.5	
Supply Current when Disabled		I_{OUT} = 0A, $\overline{\text{DISABLE}}$ = +V_S	+25℃		0.1	1	μA
			Full			2	
Dynamic Performance							
Gain-Bandwidth Product	GBP	V_S = 5.5V	+25℃		27		MHz
Phase Margin	φ_O	V_S = 5.5V	+25℃		55		°
Slew Rate	SR	V_S = 5.5V, G = +1, 2V output step	+25℃		30		V/μs
Settling Time to 0.1%	t_S	V_S = 5.5V, G = +1, 2V output step	+25℃		150		ns
Overload Recovery Time		V_S = 5.5V, V_{IN} × G = V_S	+25℃		80		ns
Total Harmonic Distortion + Noise	THD+N	V_S = 5.5V, V_{OUT} = 2V_{P-P}, G = +1, f = 10kHz, R_L = 600Ω, BW = 22Hz to 80kHz	+25℃		0.0003		%
Noise							
Input Voltage Noise Density	e_n	f = 1kHz	+25℃		18		nV/√Hz
		f = 10kHz	+25℃		8		

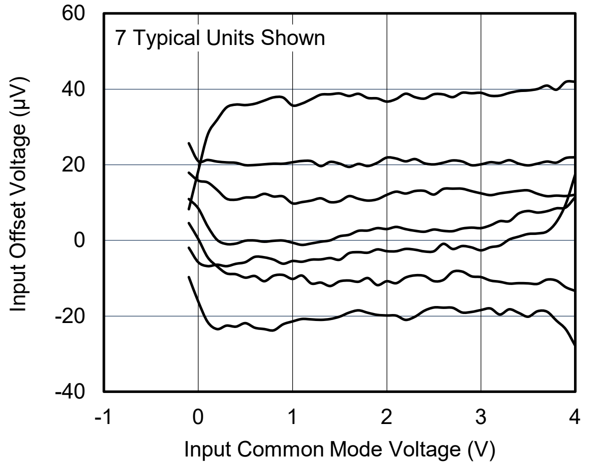
TYPICAL PERFORMANCE CHARACTERISTICS

At T_A = +25℃, V_S = 5.5V, V_{CM} = 2V, and R_L = 600Ω tied to 2V, unless otherwise noted.

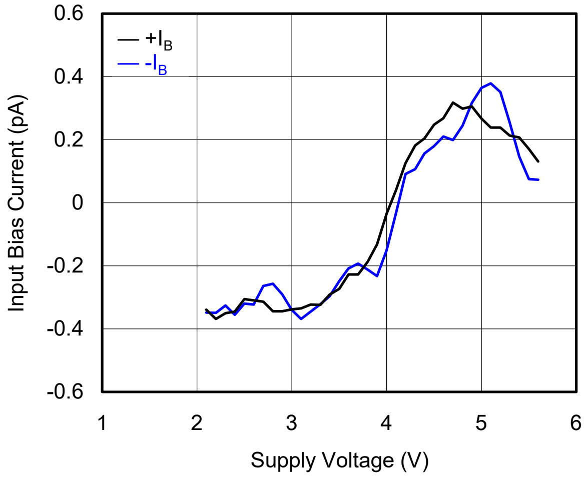
Quiescent Current vs. Supply Voltage



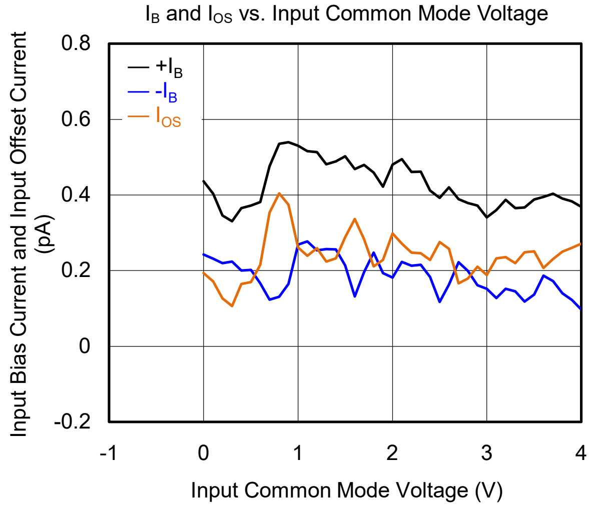
Input Offset Voltage vs. Input Common Mode Voltage



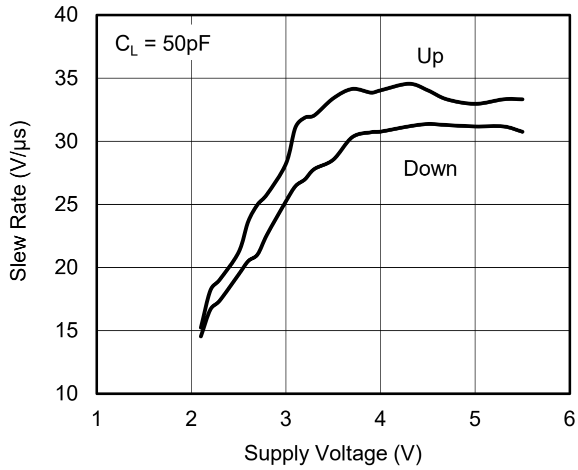
Input Bias Current vs. Supply Voltage



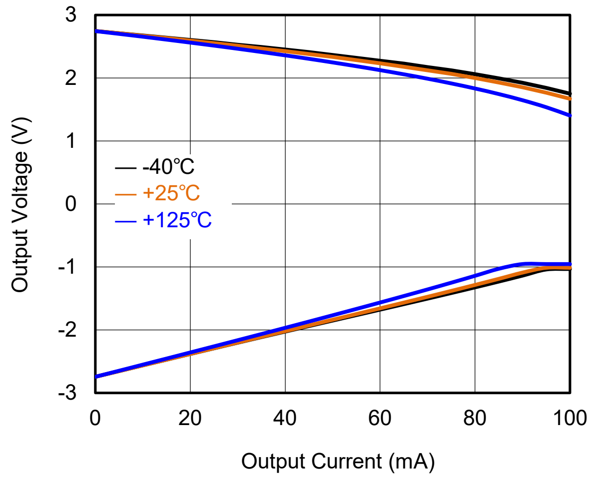
I_B and I_{OS} vs. Input Common Mode Voltage



Slew Rate vs. Supply Voltage



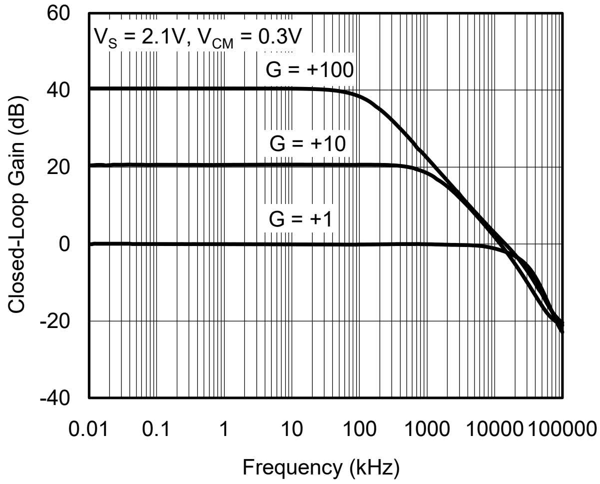
Output Voltage Swing vs. Output Current



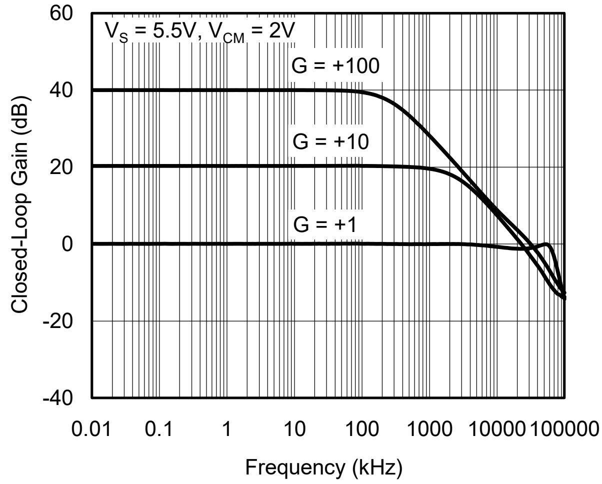
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At T_A = +25℃, V_S = 5.5V, V_{CM} = 2V, and R_L = 600Ω tied to 2V, unless otherwise noted.

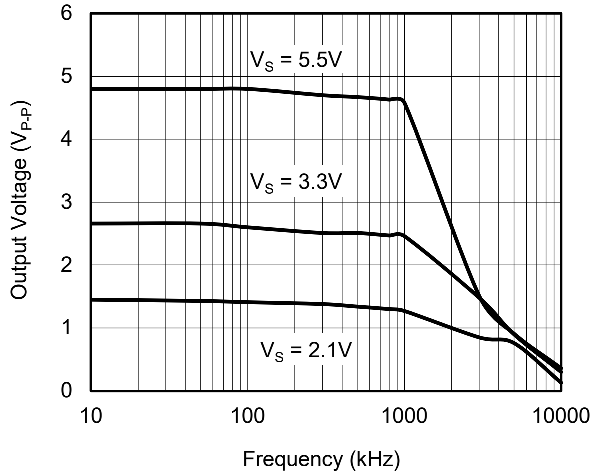
Closed-Loop Gain vs. Frequency



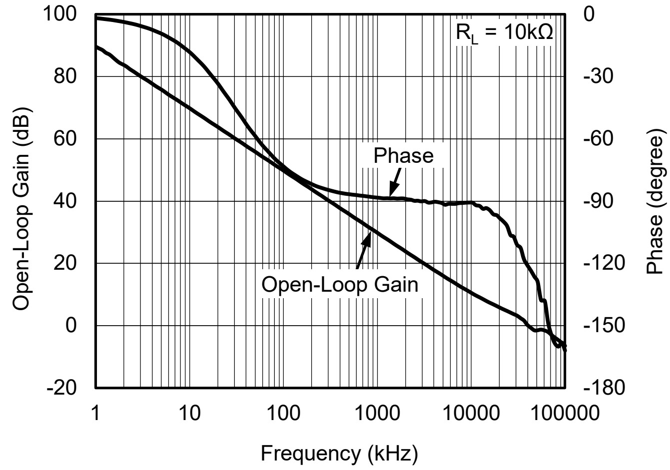
Closed-Loop Gain vs. Frequency



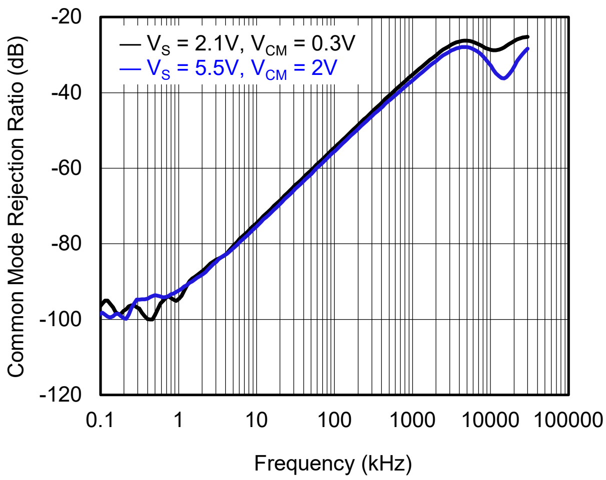
Maximum Output Voltage vs. Frequency



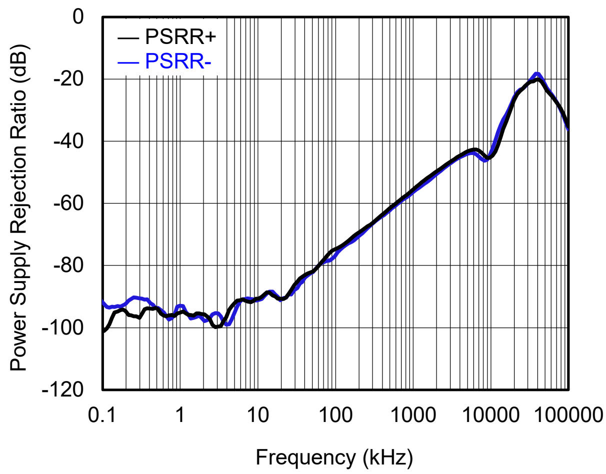
Open-Loop Gain and Phase vs. Frequency



CMRR vs. Frequency



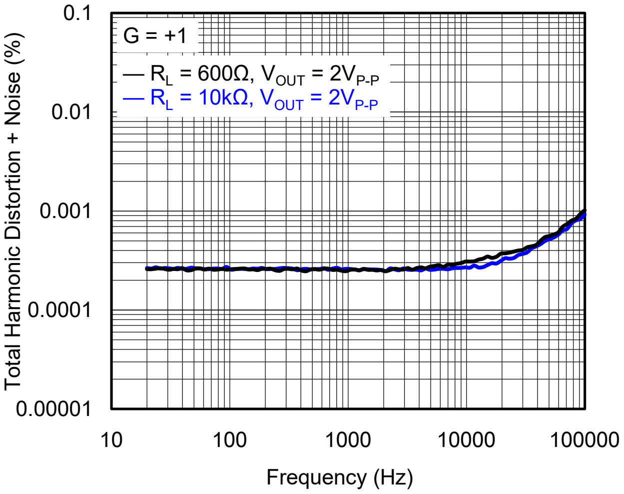
PSRR vs. Frequency



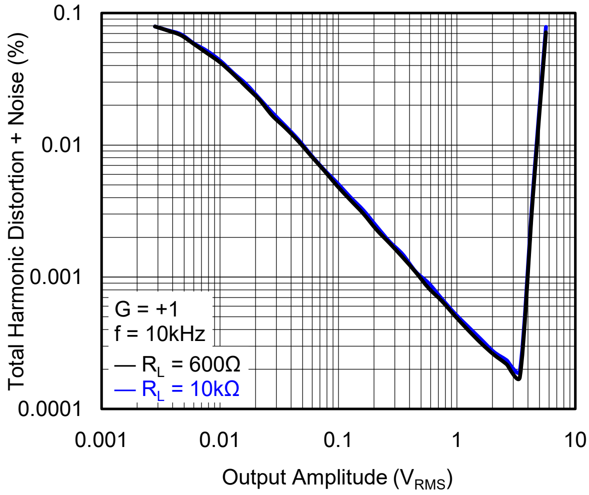
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At T_A = +25℃, V_S = 5.5V, V_{CM} = 2V, and R_L = 600Ω tied to 2V, unless otherwise noted.

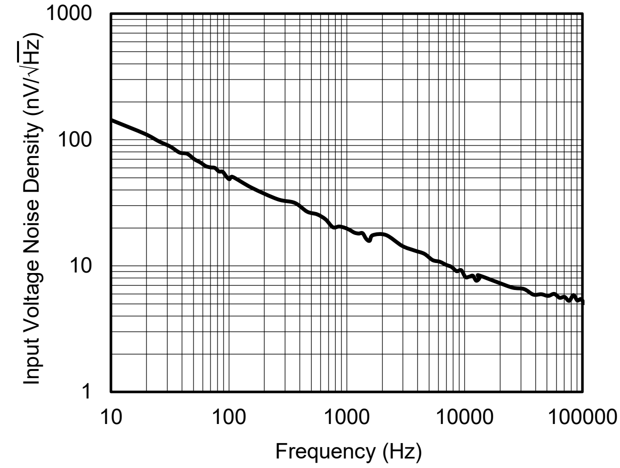
THD+N vs. Frequency



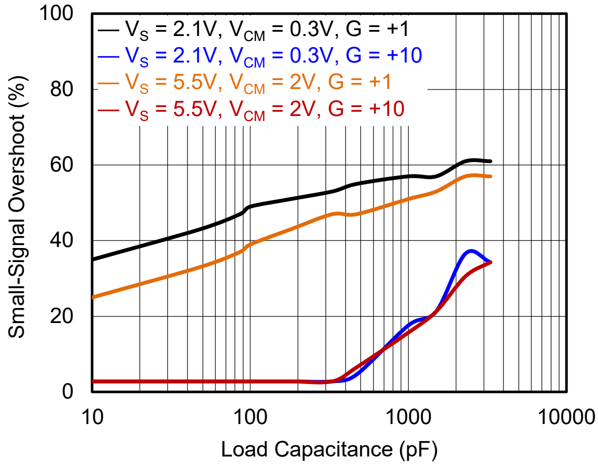
THD+N vs. Output Amplitude



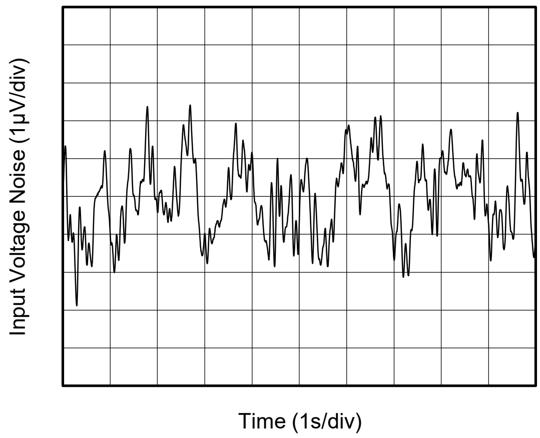
Input Voltage Noise Density vs. Frequency



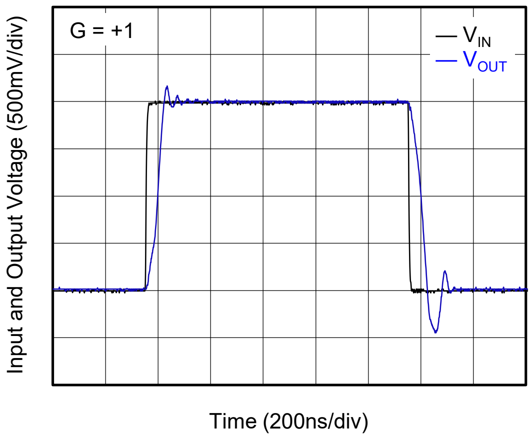
Small-Signal Overshoot vs. Capacitive Load



0.1Hz to 10Hz Input Voltage Noise



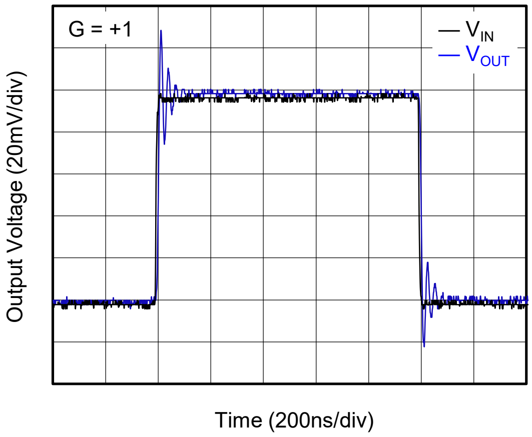
Large-Signal Step Response



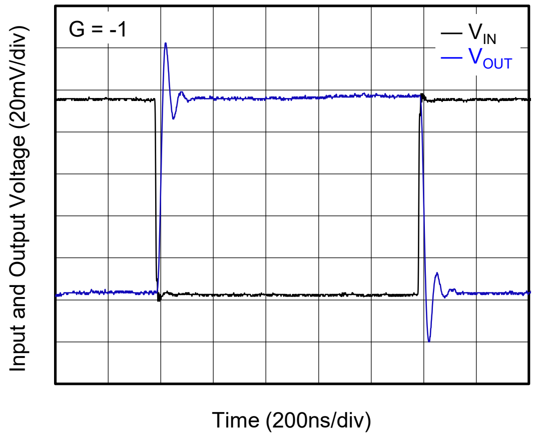
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At T_A = +25℃, V_S = 5.5V, V_{CM} = 2V, and R_L = 600Ω tied to 2V, unless otherwise noted.

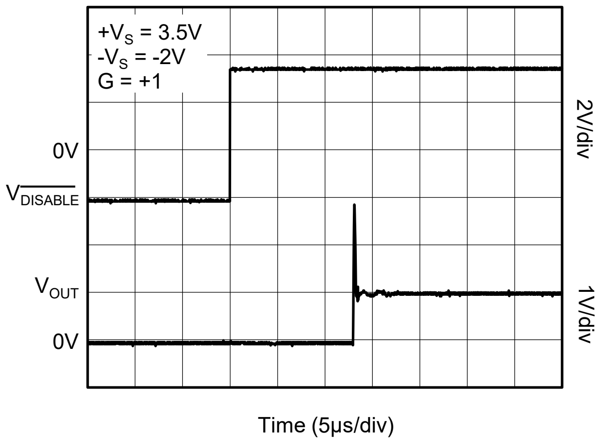
Small-Signal Step Response



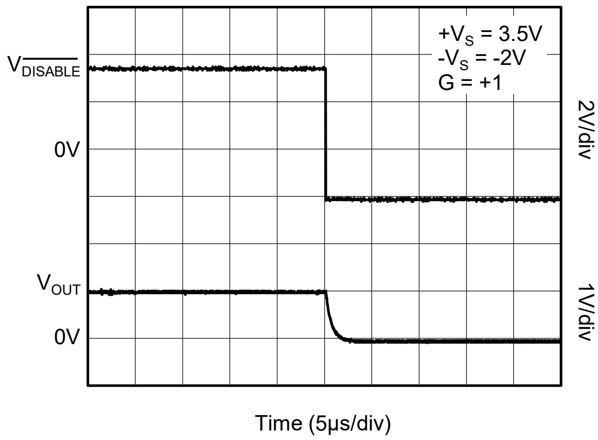
Small-Signal Step Response



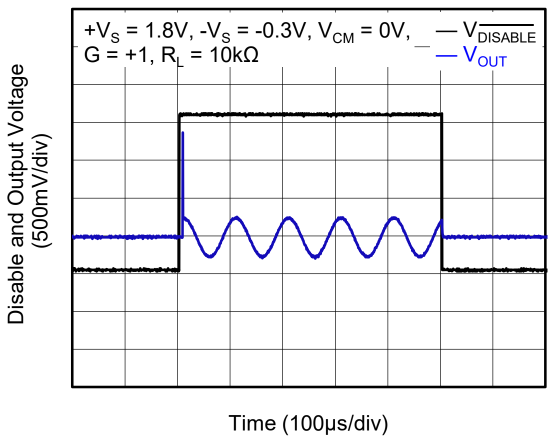
Turn-On Transient



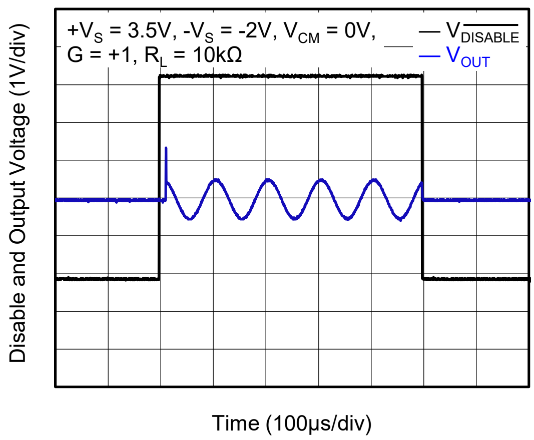
Turn-Off Transient



Turn-On and Turn-Off Transient (Low Supply)

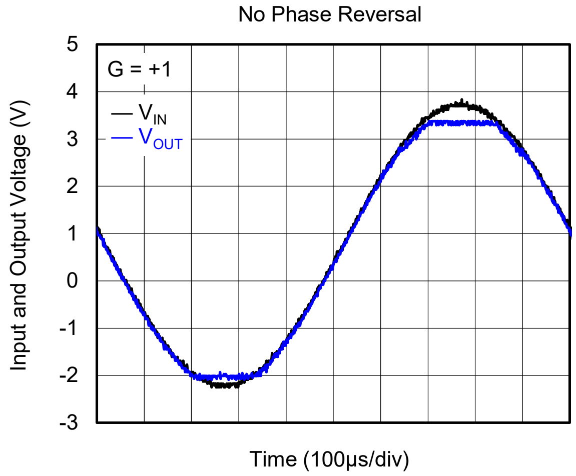


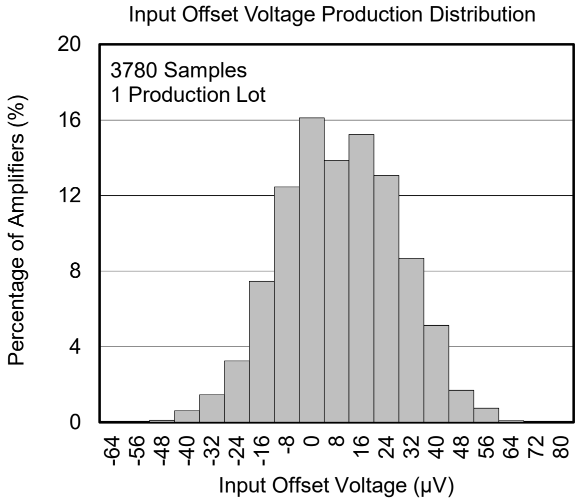
Turn-On and Turn-Off Transient (High Supply)

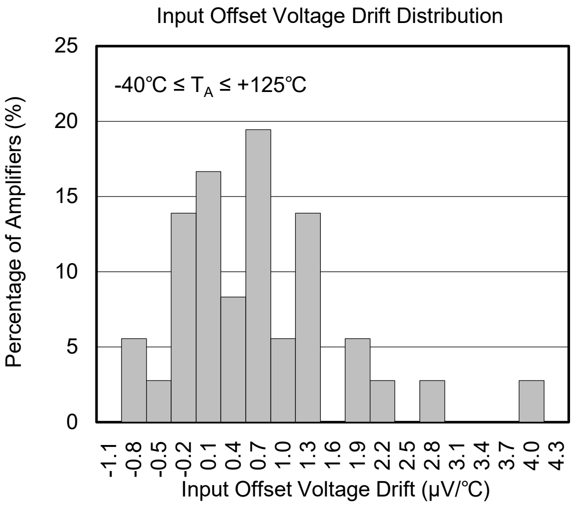


TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At T_A = +25℃, V_S = 5.5V, V_{CM} = 2V, and R_L = 600Ω tied to 2V, unless otherwise noted.







APPLICATION INFORMATION

Non Rail-to-Rail Input

When SGM8970-3 works at the power supply between 2.1V and 5.5V, the input common mode voltage range is from ($-V_S$) - 0.1V to ($+V_S$) - 1.5V. In Figure 1, the ESD diodes between the inputs and the power supply rails will clamp the input voltage not to exceed the rails.

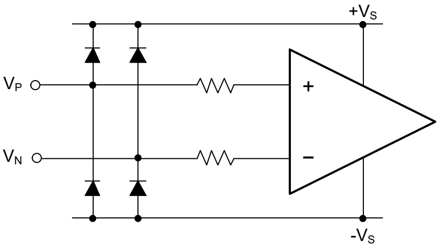


Figure 1. Input Equivalent Circuit

Input Current-Limit Protection

For ESD diode clamping protection, when the current flowing through ESD diode exceeds the maximum rating value, the ESD diode and amplifier will be damaged, so current-limit protection will be added in some applications. One resistor is selected to limit the current not to exceed the maximum rating value. In Figure 2, a series input resistor is used to limit the input current to less than 10mA, but the drawback of this current-limit resistor is that it contributes thermal noise at the amplifier input. If this resistor must be added, its value must be selected as small as possible.

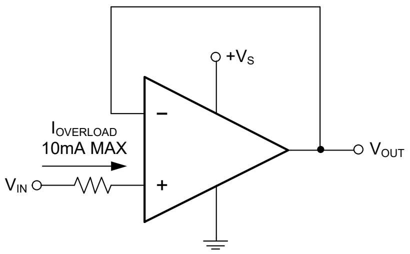


Figure 2. Input Current-Limit Protection

Rail-to-Rail Output

The SGM8970-3 supports rail-to-rail output operation. In single power supply application, for example, when $+V_S$ = 5.5V, $-V_S$ = GND, 10kΩ load resistor is tied from OUT pin to $V_S/2$, the typical output swing range is from 0.005V to 5.495V.

Driving Capacitive Loads

The SGM8970-3 is designed for unity-gain stable for capacitive load up to 470pF. If greater capacitive load must be driven in application, the circuit in Figure 3 can be used. In this circuit, the IR drop voltage generated by R_{ISO} is compensated by feedback loop.

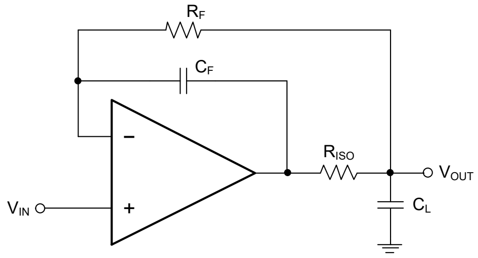


Figure 3. Circuit to Drive Heavy Capacitive Load

Power Supply Decoupling and Layout

A clean and low noise power supply is very important in amplifier circuit design, besides of input signal noise, the power supply is one of important source of noise to the amplifier through $+V_S$ and $-V_S$ pins. Power supply bypassing is an effective method to clear up the noise at power supply, and the low impedance path to ground of decoupling capacitor will bypass the noise to GND. In application, 10μF ceramic capacitor paralleled with 0.1μF or 0.01μF ceramic capacitor is used in Figure 4. The ceramic capacitors should be placed as close as possible to $+V_S$ and $-V_S$ power supply pins.

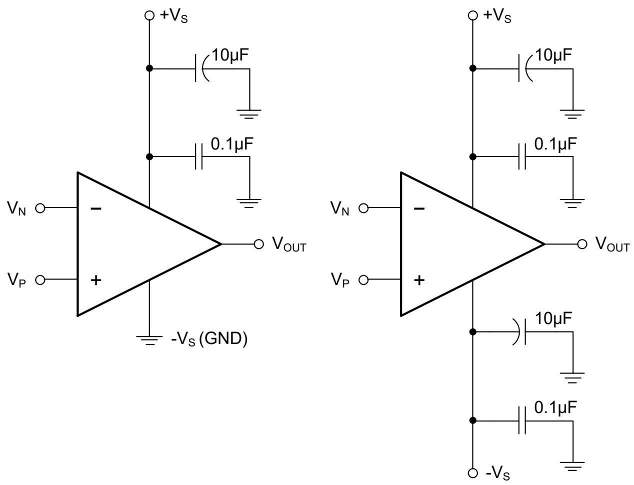


Figure 4. Amplifier Power Supply Bypassing

APPLICATION INFORMATION (continued)

Grounding

In low speed application, one node grounding technique is the simplest and most effective method to eliminate the noise generated by grounding. In high speed application, the general method to eliminate noise is to use a complete ground plane technique, and the whole ground plane will help distribute heat and reduce EMI noise pickup.

Reduce Input-to-Output Coupling

To reduce the input-to-output coupling, the input traces must be placed as far away from the power supply or output traces as possible. The sensitive trace must not be placed in parallel with the noisy trace in same layer. They must be placed perpendicularly in different layers to reduce the crosstalk. These PCB layout techniques will help to reduce unwanted positive feedback and noise.

Typical Application Circuits

Difference Amplifier

The circuit in Figure 5 is a design example of classical difference amplifier. If $R_4/R_3 = R_2/R_1$, then $V_{OUT} = (V_P - V_N) \times R_2/R_1 + V_{REF}$.

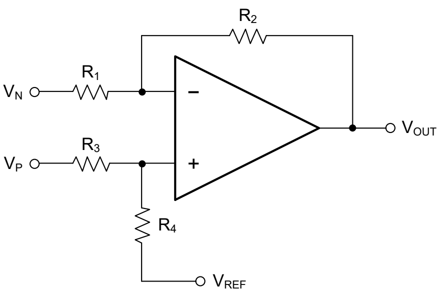


Figure 5. Difference Amplifier

High Input Impedance Difference Amplifier

The circuit in Figure 6 is a design example of high input impedance difference amplifier, the added amplifiers at the input are used to increase the input impedance and eliminate drawback of low input impedance in Figure 5.

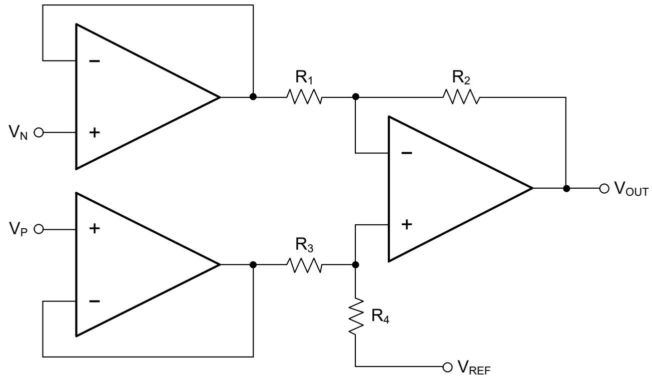


Figure 6. High Input Impedance Difference Amplifier

Active Low-Pass Filter

The circuit in Figure 7 is a design example of active low-pass filter, the DC gain is equal to $-R_2/R_1$ and the -3dB corner frequency is equal to $1/2\pi R_2C$. In this design, the filter bandwidth must be less than the bandwidth of the amplifier, the resistor values must be selected as low as possible to reduce ringing or oscillation generated by the parasitic parameters in PCB layout.

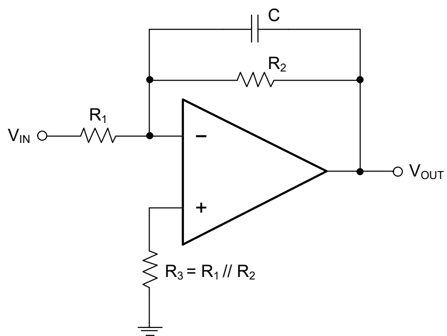


Figure 7. Active Low-Pass Filter

REVISION HISTORY

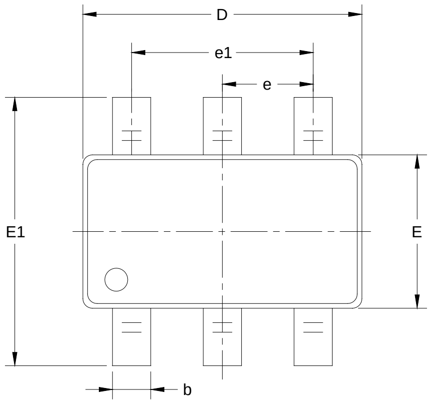
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

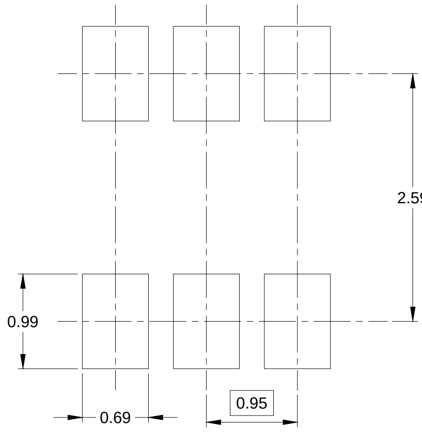
AUGUST 2022 – REV.A to REV.A.1	Page
Updated Typical Performance Characteristics section	8

Changes from Original (FEBRUARY 2022) to REV.A	Page
Changed from product preview to production data	All

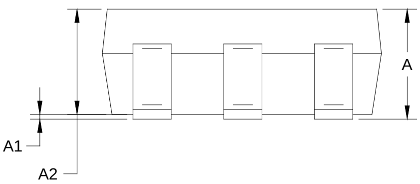
PACKAGE OUTLINE DIMENSIONS

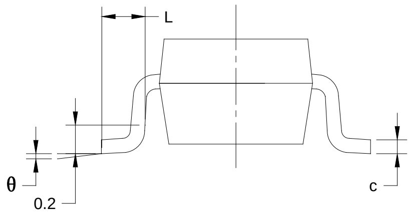
SOT-23-6





RECOMMENDED LAND PATTERN (Unit: mm)



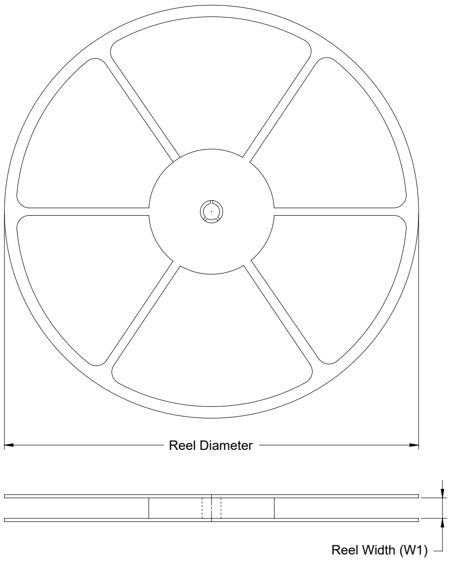


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950 BSC		0.037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

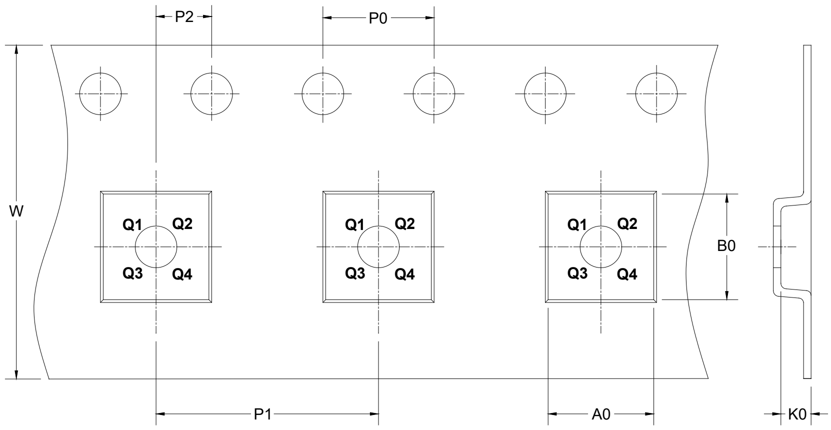
NOTES:
1. Body dimensions do not include mode flash or protrusion.
2. This drawing is subject to change without notice.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



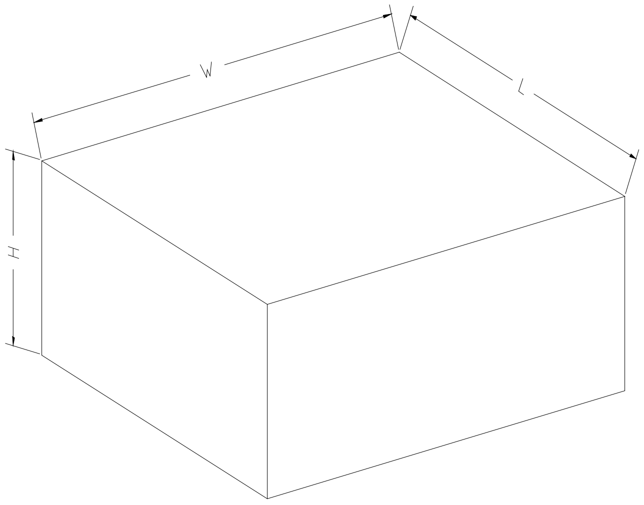
NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
SOT-23-6	7″	9.5	3.23	3.17	1.37	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