SGM621
Low Power, Low Noise, Rail-to-Rail Output, Instrumentation Amplifier

GENERAL DESCRIPTION

The SGM621 is a high accuracy, high voltage instrumentation amplifier, which is designed to set any gain from 1 to 10000 with one external resistor. The device works well in battery-powered applications due to the low power consumption of 1.3mA typical quiescent current. The SGM621 provides SOIC-8 and MSOP-8 packages which are much smaller than discrete classical-three-OPAs circuits.

The SGM621 provides 120ppm (MAX) non-linearity and 150μV (MAX) low input offset voltage. The device also features low noise, low bias current and low power. The combination of these characteristics makes it a good choice for applications requiring excellent DC performance.

The SGM621 offers 6nV/$\sqrt{Hz}$ low input voltage noise, 300fA/$\sqrt{Hz}$ input current noise at 1kHz, and 0.4μV_{P-P} in the 0.1Hz to 10Hz band. It is suitable for pre-amplifier applications. The 10μs settling time to 0.01% makes SGM621 appropriate for multiplexed applications.

The SGM621 is available in Green SOIC-8 and MSOP-8 packages. It is specified over the extended -40℃ to +125℃ temperature range.

FEATURES

- **Single External Resistor Gain Set (Set Gain from 1 to 10000)**
- **Input Offset Voltage: 150μV (MAX)**
- **Input Bias Current: 15nA (TYP)**
- **Common Mode Rejection Ratio: 105dB (TYP) (G = 10)**
- **Input Voltage Noise: 6nV/$\sqrt{Hz}$ at 1kHz**
- **0.1Hz to 10Hz Voltage Noise: 0.4μV_{P-P}**
- **Bandwidth: 140kHz (G = 100)**
- **Settling Time to 0.01%: 10μs (G = 100)**
- **Rail-to-Rail Output**
- **Support Single or Dual Power Supplies: 4.6V to 36V or ±2.3V to ±18V**
- **Low Power Supply Current: 1.3mA (TYP)**
- **-40℃ to +125℃ Operating Temperature Range**
- **Available in Green SOIC-8 and MSOP-8 Packages**

APPLICATIONS

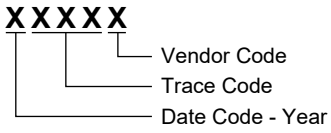
Precision Current Measurement
Pressure Measurement

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM621	SOIC-8	-40℃ to +125℃	SGM621XS8G/TR	SGM 621XS8 XXXXX	Tape and Reel, 4000
	MSOP-8	-40℃ to +125℃	SGM621XMS8G/TR	SGM621 XMS8 XXXXX	Tape and Reel, 4000

MARKING INFORMATION

XXXXX = Date Code, Trace Code and Vendor Code.



Green (RoHS & HSF): SG Micro Corp defines "Green" to mean Pb-Free (RoHS compatible) and free of halogen substances. If you have additional comments or questions, please contact your SGMICRO representative directly.

ABSOLUTE MAXIMUM RATINGS

Supply Voltage, $+V_S$ to $-V_S$ 40V
Input Common Mode Voltage ..... $\pm V_S$
Junction Temperature ..... +150℃
Storage Temperature Range ..... -65℃ to +150℃
Lead Temperature (Soldering, 10s) ..... +260℃
ESD Susceptibility
HBM 7000V
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

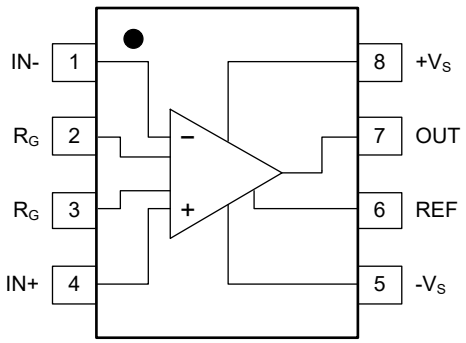
This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance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

(TOP VIEW)



SOIC-8/MSOP-8

PIN DESCRIPTION

PIN	NAME	FUNCTION
1	IN-	Inverting Input Pin
2, 3	R_G	Gain Setting Pin. The gain can be set by placing the resistor across R_G. $G = 1 + (49.4k\Omega/R_G)$.
4	IN+	Non-Inverting Input Pin.
5	$-V_S$	Negative Power Supply Pin.
6	REF	Voltage Reference Pin. A voltage source with low impedance can be placed to supply this terminal in order to shift the output level.
7	OUT	Output Pin.
8	$+V_S$	Positive Power Supply Pin.

ELECTRICAL CHARACTERISTICS

(V_S = ±15V, R_L = 2kΩ, Full = -40℃ to +125℃, typical values are at T_A = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS		TEMP	MIN	TYP	MAX	UNITS
Gain (G = 1 + (49.4kΩ/R_G))								
Gain Range					1		10000	
Gain Error (1)	GE	V_{OUT} = -10V to +10V	G = 1	+25℃		0.01	0.1	%
				Full			0.15	
			G = 10	+25℃		0.15	0.3	
				Full			0.6	
			G = 100	+25℃		0.15	0.3	
				Full			0.6	
			G = 1000	+25℃		0.15	0.6	
				Full			0.8	
Gain Temperature Coefficient			G = 1	Full		1		ppm/℃
			G > 1	Full		20		
Non-Linearity		V_{OUT} = -10V to +10V	G = 1	+25℃		10	70	ppm
				Full			100	
			G = 10	+25℃		10	70	
				Full			100	
			G = 100	+25℃		10	70	
				Full			100	
			G = 1000	+25℃		20	120	
				Full			170	
Voltage Offset (Total RTI Error = V_{OSI} + V_{OSO}/G)								
Input Offset Voltage	V_{OSI}	V_S = ±5V to ±15V		+25℃		50	150	μV
				Full			200	
Input Offset Voltage Drift	$\Delta V_{OSI}/\Delta T$			Full		0.2		μV/℃
Output Offset Voltage	V_{OSO}	V_S = ±5V to ±15V		+25℃		400	1200	μV
				Full			1600	
Output Offset Voltage Drift	$\Delta V_{OSO}/\Delta T$			Full		1.5		μV/℃
Offset Referred to the Input vs. Supply	PSRR	V_S = ±2.3V to ±18V	G = 1	+25℃	105	110		dB
				Full	102			
			G = 10	+25℃	125	130		
				Full	122			
			G = 100	+25℃	128	140		
				Full	125			
			G = 1000	+25℃	128	140		
				Full	125			
Input Current								
Input Bias Current	I_B			+25℃		15	25	nA
				Full			35	
Average Temperature Coefficient of Input Bias Current	$\Delta I_B/\Delta T$			Full		0.15		nA/℃
Input Offset Current	I_{OS}			+25℃		5	20	nA
				Full			25	
Average Temperature Coefficient of Input Offset Current	$\Delta I_{OS}/\Delta T$			Full		0.05		nA/℃

NOTE: 1. Effects of external resistor R_G is not included.

ELECTRICAL CHARACTERISTICS (continued)

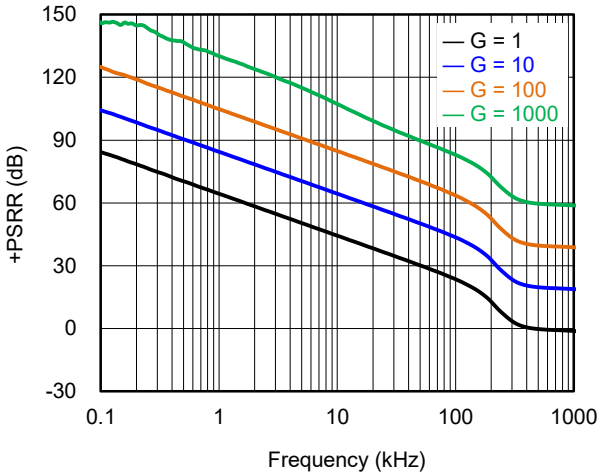
(V_S = ±15V, R_L = 2kΩ, Full = -40℃ to +125℃, typical values are at T_A = +25℃, unless otherwise noted.)

PARAMETER		SYMBOL	CONDITIONS		TEMP	MIN	TYP	MAX	UNITS
Input									
Input Impedance	Differential	Z_{DIFF}			+25℃		10 || 4		GΩ || pF
	Common Mode	Z_{CM}			+25℃		10 || 4		GΩ || pF
Input Voltage Range			V_S = ±2.3V to ±5V		+25℃	$(-V_S)$ + 1.9		$(+V_S)$ - 1.2	V
					Full	$(-V_S)$ + 2.1		$(+V_S)$ - 1.3	
			V_S = ±5V to ±18V		+25℃	$(-V_S)$ + 1.9		$(+V_S)$ - 1.4	
					Full	$(-V_S)$ + 2.1		$(+V_S)$ - 1.4	
Common Mode Rejection Ratio with 1kΩ Source Imbalance		CMRR	V_{CM} = -10V to +10V	G = 1	+25℃	70	85		dB
					Full	67			
				G = 10	+25℃	90	105		
					Full	87			
				G = 100	+25℃	103	120		
					Full	100			
				G = 1000	+25℃	103	120		
					Full	100			
Reference Input									
Reference Input Resistance		R_{REF}			+25℃		18		kΩ
Reference Input Current		I_{REF}	V_{IN+} = V_{IN-} = 0V, V_{REF} = 0V		+25℃		30	40	μA
					Full			50	
Output Characteristics									
Output Voltage Swing		V_{OH}	R_L = 2kΩ, V_S = ±18V		+25℃		310	400	mV
					Full			600	
		V_{OL}	R_L = 2kΩ, V_S = ±18V		+25℃		150	220	
					Full			300	
Short-Circuit Current		I_{SC}	V_S = ±2.3V to ±18V, R_L = 50Ω to V_S/2		+25℃	19	24		mA
					Full	14			
Power Supply									
Quiescent Current		I_Q	V_S = ±2.3V to ±18V, I_{OUT} = 0A		+25℃		1.3	1.7	mA
					Full			2.2	
Dynamic Response									
Small-Signal -3dB Bandwidth		BW		G = 1	+25℃		3900		kHz
				G = 10	+25℃		1000		
				G = 100	+25℃		140		
				G = 1000	+25℃		17		
Slew Rate		SR	V_{OUT} = 1V_{P-P} Step	G = 1	+25℃		1.2		V/μs
Settling Time to 0.01%		t_S	V_{OUT} = 10V_{P-P} Step	G = 1 to 100	+25℃		10		μs
				G = 1000	+25℃		51		
Noise									
Input Voltage Noise Density		e_{ni}	f = 1kHz		+25℃		6		nV/√Hz
Output Voltage Noise Density		e_{no}	f = 1kHz		+25℃		80		nV/√Hz
0.1Hz to 10Hz Voltage Noise, RTI			f = 0.1Hz to 10Hz	G = 1	+25℃		6		$μV_{P-P}$
				G = 10	+25℃		1		
				G = 100	+25℃		0.4		
				G = 1000	+25℃		0.4		
Input Current Noise Density, RTI		i_n	f = 1kHz		+25℃		300		fA/√Hz
0.1Hz to 10Hz Current Noise, RTI			f = 0.1Hz to 10Hz		+25℃		15		pA_{P-P}

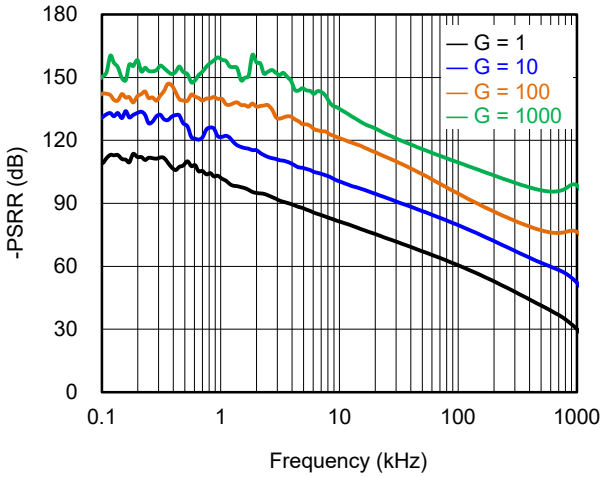
TYPICAL PERFORMANCE CHARACTERISTICS

At T_A = +25℃, V_S = ±15V, unless otherwise noted.

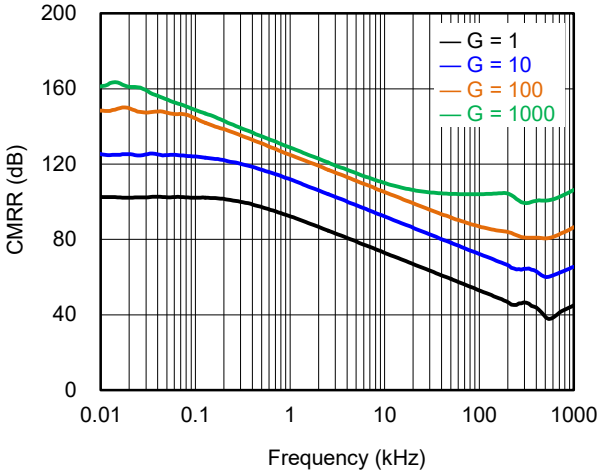
PSRR vs. Frequency



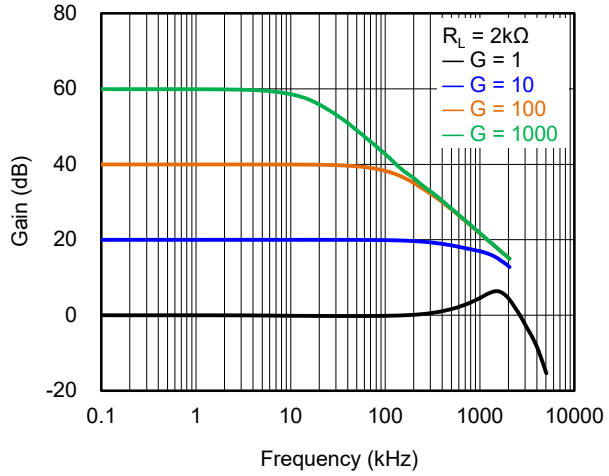
PSRR vs. Frequency



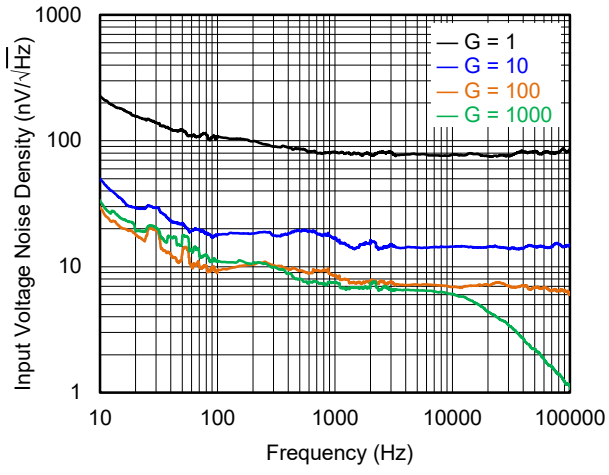
CMRR vs. Frequency



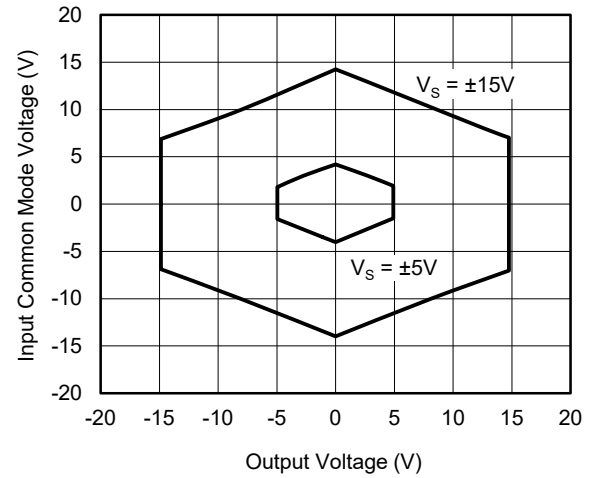
Gain vs. Frequency



Input Voltage Noise Density vs. Frequency



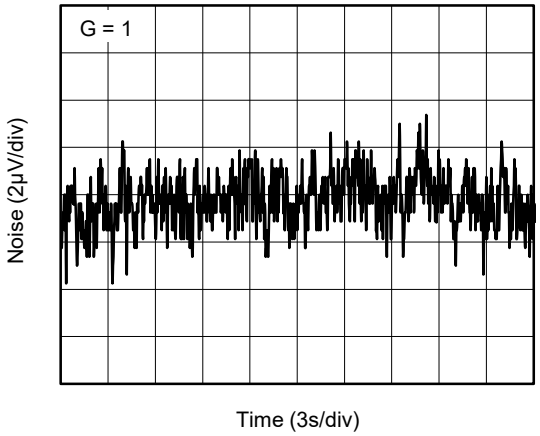
Input Common Mode Voltage vs. Output Voltage



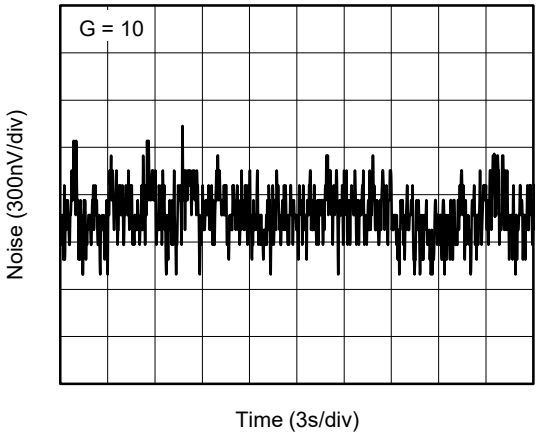
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At T_A = +25℃, V_S = ±15V, unless otherwise noted.

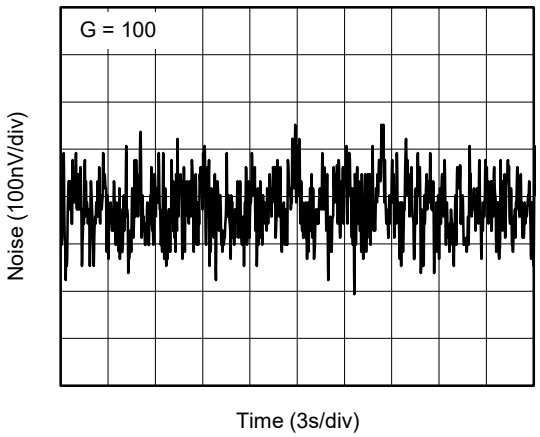
0.1Hz to 10Hz Input Voltage Noise



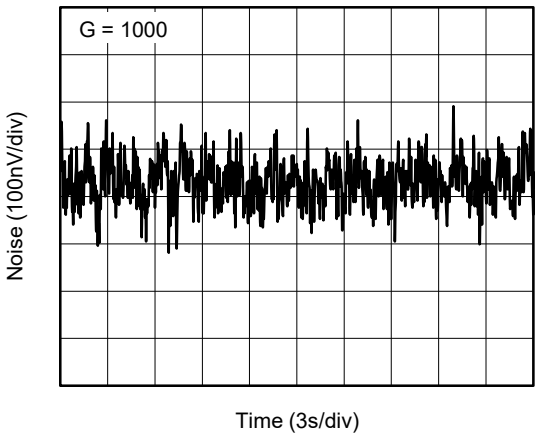
0.1Hz to 10Hz Input Voltage Noise



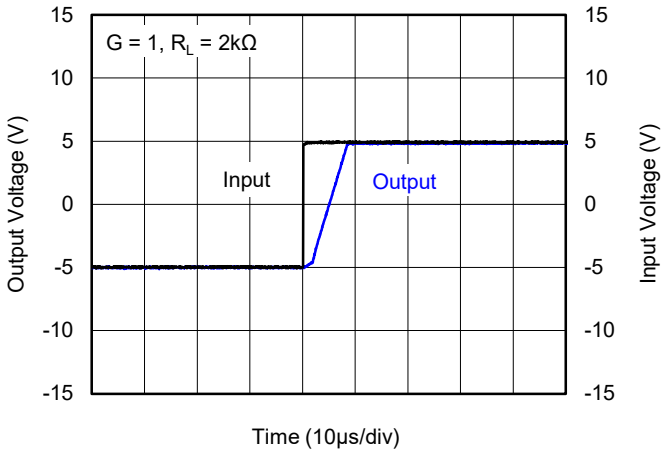
0.1Hz to 10Hz Input Voltage Noise



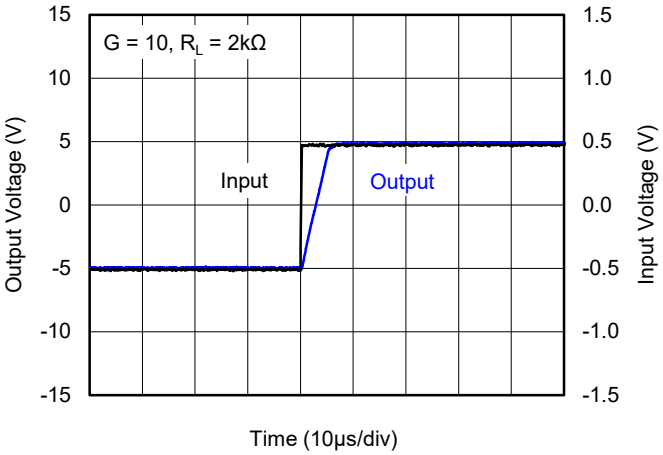
0.1Hz to 10Hz Input Voltage Noise



Settling Time



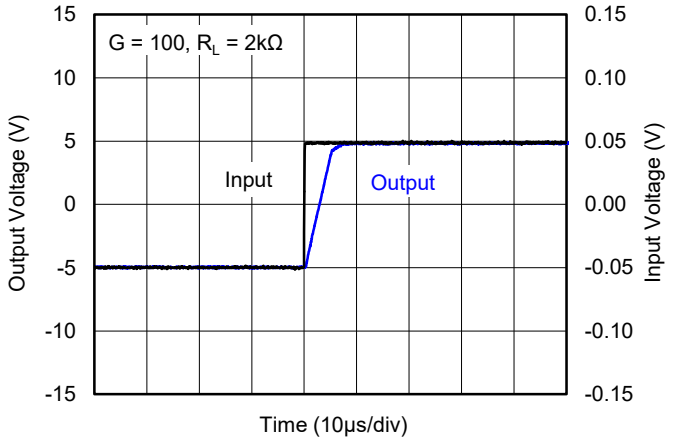
Settling Time



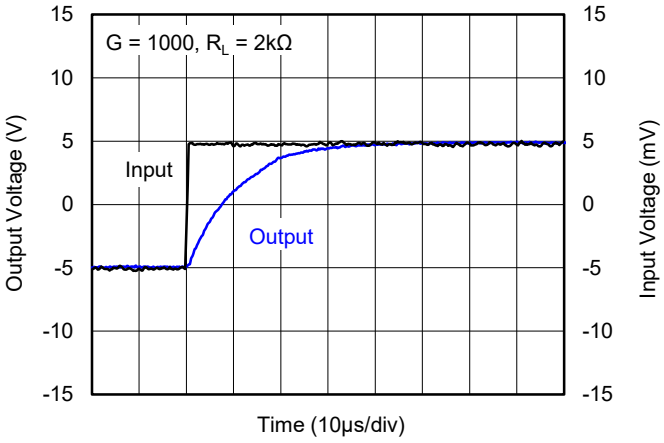
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At T_A = +25℃, V_S = ±15V, unless otherwise noted.

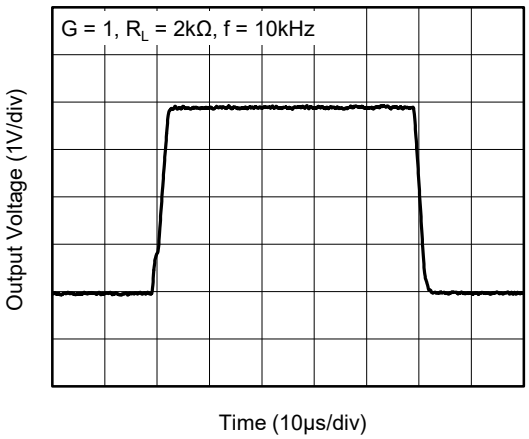
Settling Time



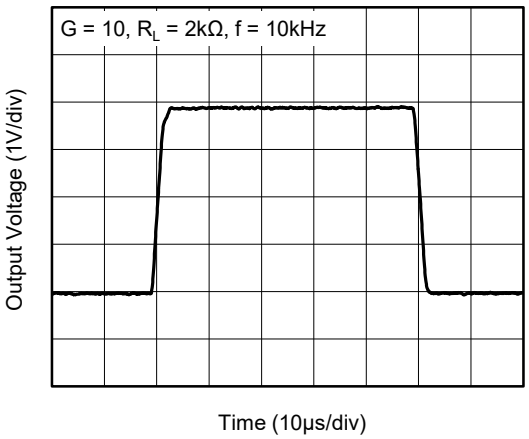
Settling Time



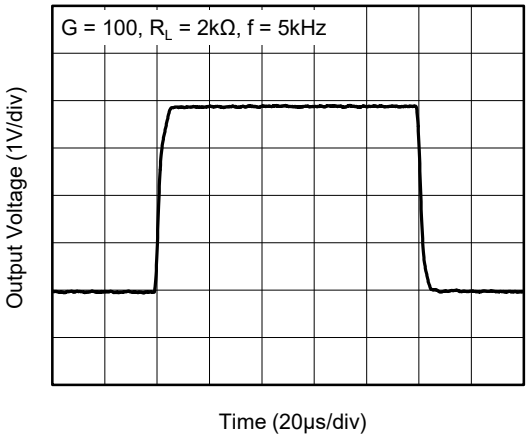
Large-Signal Step Response



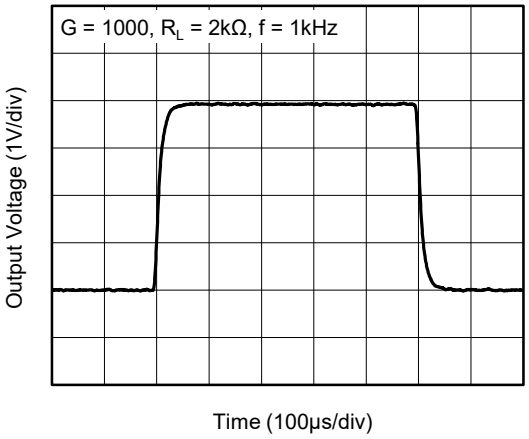
Large-Signal Step Response



Large-Signal Step Response



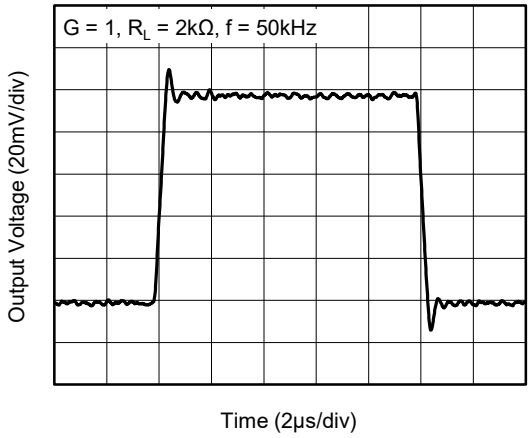
Large-Signal Step Response



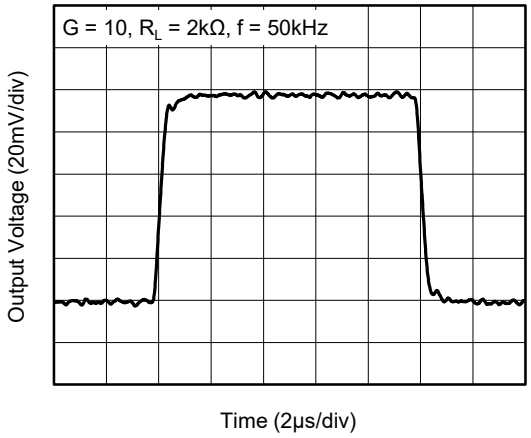
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At T_A = +25℃, V_S = ±15V, unless otherwise noted.

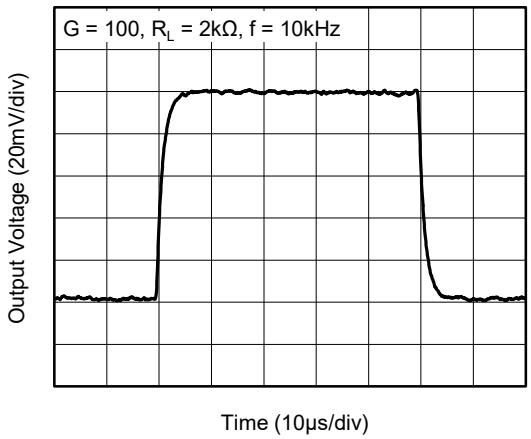
Small-Signal Step Response



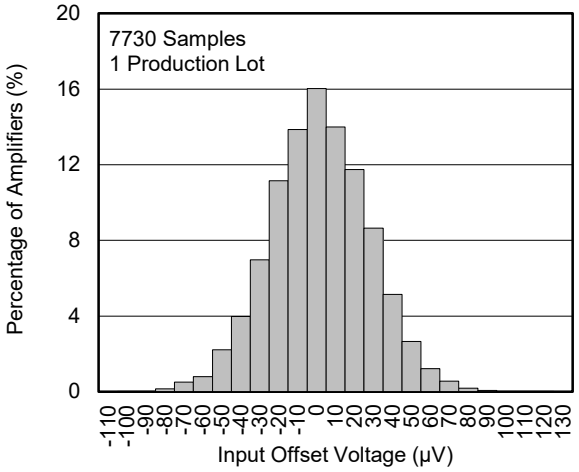
Small-Signal Step Response



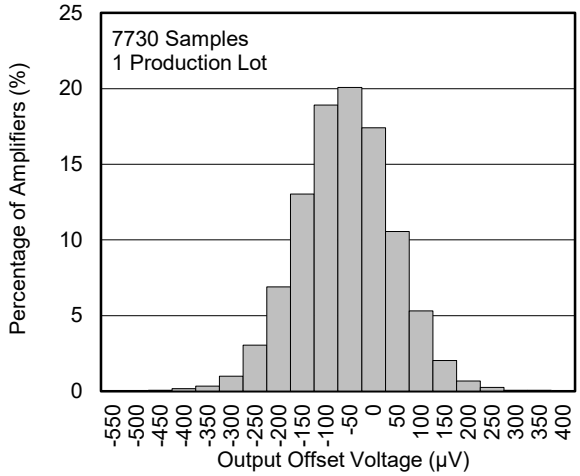
Small-Signal Step Response



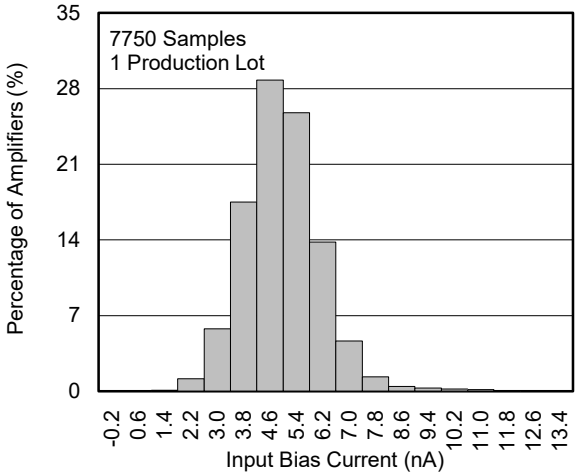
Input Offset Voltage Production Distribution



Output Offset Voltage Production Distribution



Input Bias Current Production Distribution



OPERATION THEORY

The SGM621 is modified with the classic three-op-amp and it is a holistic instrumentation amplifier.

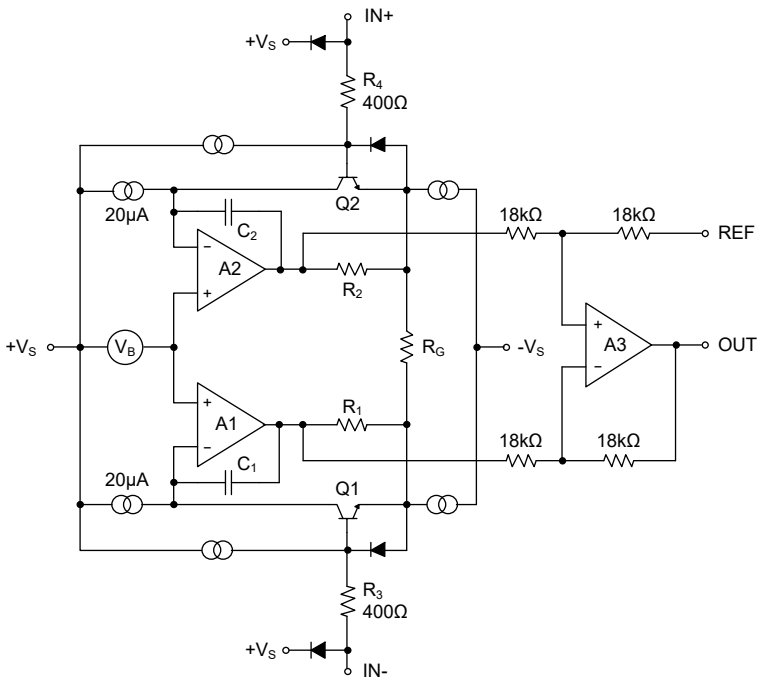


Figure 1. Simplified Schematic

The high precision input is provided by the two input transistor Q1 and Q2 (Figure 1) and this results in 10 × lower bias current of the input pins. The constant collector current of Q1 and Q2 is maintained by the two loops Q1-A1-R1 and Q2-A2-R2, so the input voltage is impressed across the gain setting resistor R_G of the amplifier. The differential gain from A1/A2 outputs can be expressed by G = 1+ (R_1+R_2)/R_G. The unity-gain subtractor (A3) can reject the common mode signal so that SGM621 produces a single-ended output with REF pin biased.

The transconductance of the pre-amplifier is determined by the resistance of R_G. The transconductance will increase gradually to that of the input transistors if the resistance of R_G is reduced for larger gains. The important benefits are shown below:

◆ Boosting the open-loop gain can also increase the programmed gain, so that the related error of gain is reduced.

◆ The gain-bandwidth product which is determined by the two capacitors C_1, C_2 and the transconductance of the pre-amplifier can increase with programmed gain, so that the frequency response is enhanced.

◆ Reducing the input voltage noise to 6nV/$\sqrt{Hz}$, and it is determined by the base resistance and the collector current of the input.

The integrated resistors (R_1 and R_2) inside the SGM621 are set to 24.7kΩ, so that the gain can be programmed with the external resistor R_G.

The equation of gain is shown as below:

$$G = \frac{49.4k\Omega}{R_G} + 1$$

$$R_G = \frac{49.4k\Omega}{G - 1}$$

APPLICATION INFORMATION

Pressure Measurement

SGM621 is widely used in the application of bridge, such as measuring the pressure in weigh scales. It is also suitable for detecting the pressure sensor with higher resistance due to high input impedance.

Figure 2 shows the pressure transducer bridge of 5kΩ which is powered by a 5V single supply. In such a circuit, the bridge consumes only 1mA. The buffered voltage divider and SGM621 can condition the output signal with typical 3.3mA supply current.

The advantage of small size for SGM621 is attractive for the transducers of pressure. Because of the low noise and drift, it can also be used in the application of diagnostic non-invasive blood pressure measurement.

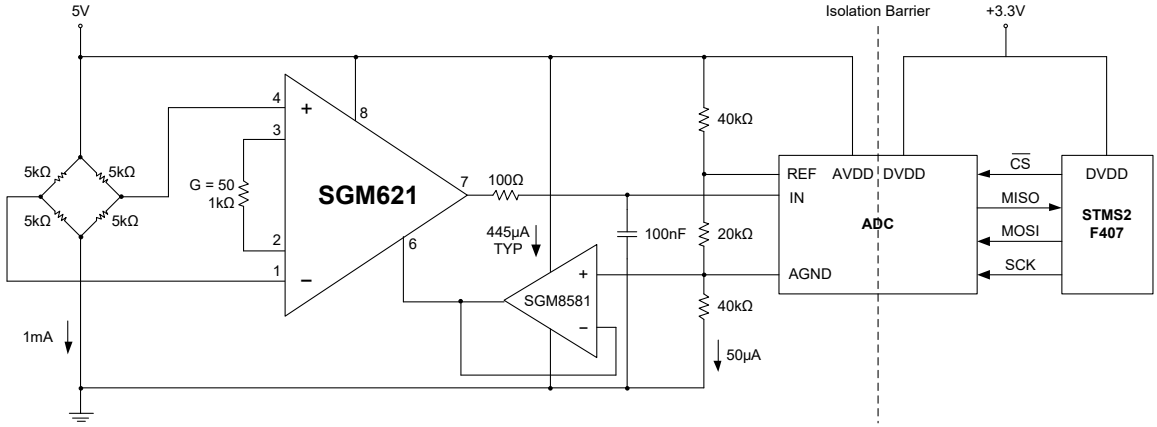


Figure 2. The Operation of the Pressure Monitor Circuit with 5V Single Supply

Medical ECG Amplifier

Because of the advantage of low current noise, SGM621 can be used in ECG monitors (Figure 3) where the source resistances can reach 1MΩ or higher. It is the best choice to use SGM621 in the battery-powered data recorders as it can operate on the condition of low supply voltage, low power and space-saving packages.

Moreover, for better performance, combining with the advantages of low voltage noise, low current and low bias currents can enhance the dynamic range of SGM621.

The stability of the right leg drive loop can be maintained by the capacitor C_1. Moreover, for protecting the patient from the possible harm, the isolation safeguards should be added between the patient and the circuit part.

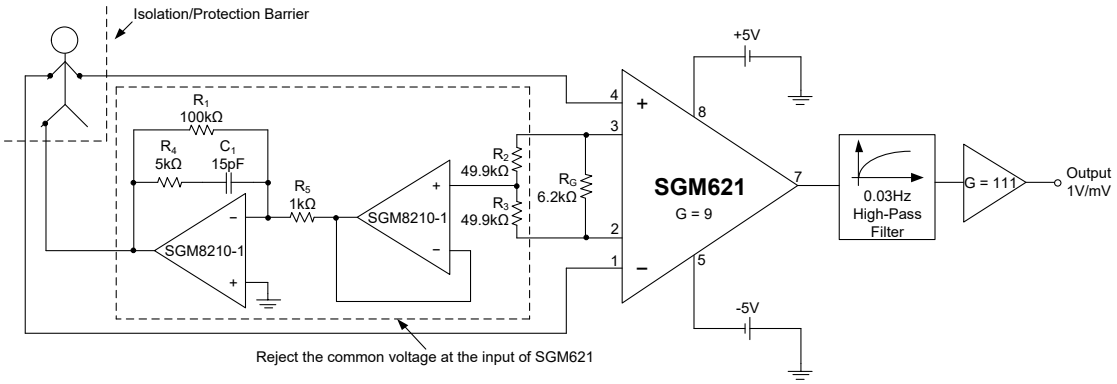


Figure 3. The Circuit of Medical ECG Monitor

APPLICATION INFORMATION (continued)

Precision V-I Converter

It's easy to realize a precision current source (Figure 4) utilizing one SGM621, another operational amplifier and two resistors. To obtain a better CMRR of SGM621, a buffer should be placed between the REF pin and the OUT pin of the amplifier. The equation which is shown in Figure 4 illustrates the output current of the circuit.

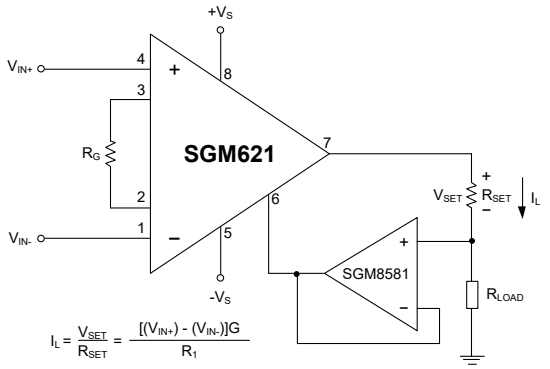


Figure 4. Precision Voltage-to-Current Converter

Input and Output Offset Voltage

Two main sources which are error of input and output result in the low errors of SGM621. When referred to the input, the output error should be divided by the gain of the instrumentation amplifier. From the equations which are shown as below, the input error takes a leading position at large gains while the output error takes a leading position at small gains.

Total Error Referred to Input (RTI) = Input Error + (Output Error/G)

Total Error Referred to Output (RTO) = (Input Error × G) + Output Error

Terminal of Reference

If the load does not support a precision GND, the REF pin is useful here since it can add a DC bias voltage directly at the output of the SGM621, and the permitted range of V_{REF} should be lower than 2V (or less than V_S if V_S < 2V). On top of these, to keep better CMRR, the parasitic resistor at this pin should be low.

Selection of Gain

The gain of the instrumentation amplifier is determined by the external resistor R_G. The accuracy of the external resistor R_G is important as it may influence the error of gain. It is recommended that selecting the resistor with 0.1% or 1% precision is a good choice. The following table shows the gain effect with the selection of 1% or 0.1% precision resistor. Also, leaving the pin 2 and pin 3 (the place of R_G) open can make the gain of SGM621 equals to 1.

$$R_G = \frac{49.4k\Omega}{G - 1}$$

As mentioned before, the gain error can be minimized by equivalent parasitic resistor in series with R_G. Moreover, low TC of 1ppm/℃ is required for the selection of R_G to avoid the gain drift of SGM621.

Table 1. Different Values for Gain Resistor

1% STD Table Value of R_G (Ω)	Calculated Gain	0.1% STD Table Value of R_G (Ω)	Calculated Gain
49.9k	1.990	49.3k	2.002
12.4k	4.984	12.4k	4.984
5.49k	9.998	5.49k	9.998
2.61k	19.93	2.61k	19.93
1.00k	50.40	1.01k	49.91
499	100.0	499	100.0
249	199.4	249	199.4
100	495.0	98.8	501.0
49.9	991.0	49.3	1003.0

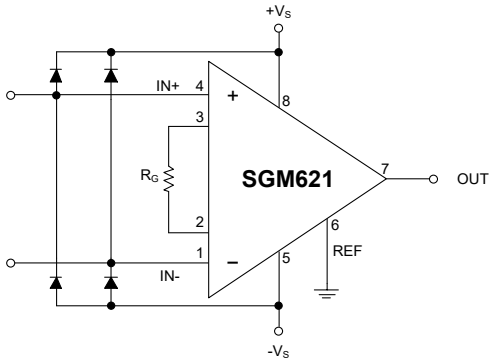


Figure 5. Diode for Protecting V_{IN} from Larger than V_S

APPLICATION INFORMATION (continued)

RF Interference

One of the characteristics of instrumentation amplifier is rectifying the small signal which is out of the band. This kind of disturbance can be described as the small biased voltage. All of the high frequency components can be filtered by the R-C network which is placed in the input position of the instrumentation amplifier, as shown in Figure 6. The following equation shows the equation of filtering frequency for the differential and common mode part of the input signal.

$$FilterFreq_{DIFF} = \frac{1}{2\pi R(2C_D + C_C)}$$

$$FilterFreq_{CM} = \frac{1}{2\pi RC_C}$$

$C_D \geq 10C_C$ is required in the above equation.

The capacitor C_D influences the quality of the differential signal, while C_C influences the quality of the common mode signal. The common mode rejection ratio would be reduced if the R × C_C is mismatched. To reduce this negative influence and obtain a good CMRR, it is recommended that the capacitance of C_D should be 10 times larger than C_C. To conclude, the larger the ratio of C_D:C_C is, the less negative influence to the circuit.

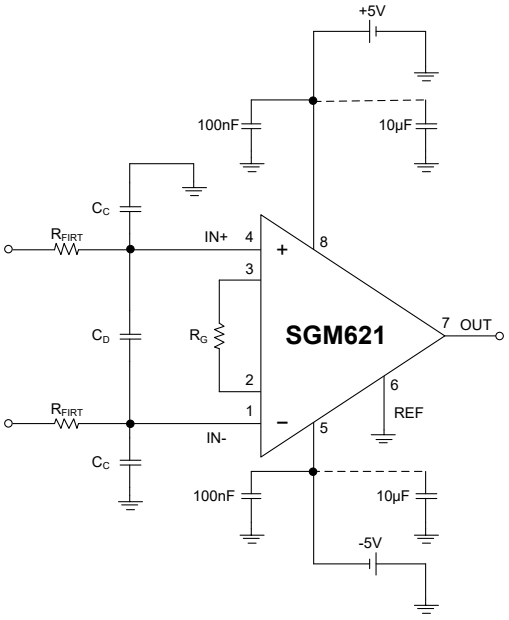


Figure 6. One Method to Reduce the Interference of RF

Common Mode Rejection

The common mode rejection ratio of the instrumentation amplifier is high as it can measure the differential signal between the two inputs when both IN+ and IN- increase or decrease equally. Also, this specification can be defined in the whole range of input voltage.

To obtain a best CMRR, it is recommended that the REF pin should be connected to a low impedance input and the difference of impedance between two inputs should be as small as possible. Also, using shielded cable can effectively reduce the noise of the circuit, and it should be driven properly for better value of CMRR. The following two figures (Figure 7 and Figure 8) illustrate the method to increase the CMRR for alternating circuit by bootstrapping the capacitance of the shielded cable, and this kind of method can also reduce the mismatching of capacitance at the inputs.

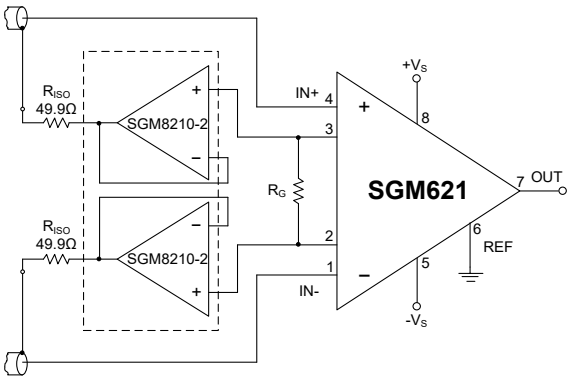


Figure 7. Differential Input Shield Driving

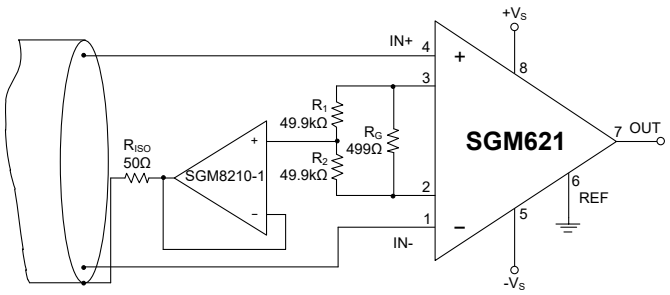


Figure 8. Common Mode Input Shield Driving

APPLICATION INFORMATION (continued)

Isolation of Grounding

For solving the problems of grounding, REF pin should be connected to the "local ground" as the output of the instrumentation amplifier is biased with V_{REF}.

Because of the noisy environment of the digital circuit, the component of data-acquisition such as Analog Digital Converter (ADC) has two pins which are AGND and DGND. Also, the isolation can be made by using a single line or 0Ω resistor. However, each returns of ground should be separated so that the current flow from the sensitive point could be minimized. Also, the ground returns between analog and digital should be tied together with one point, which is shown in ADC part of Figure 9.

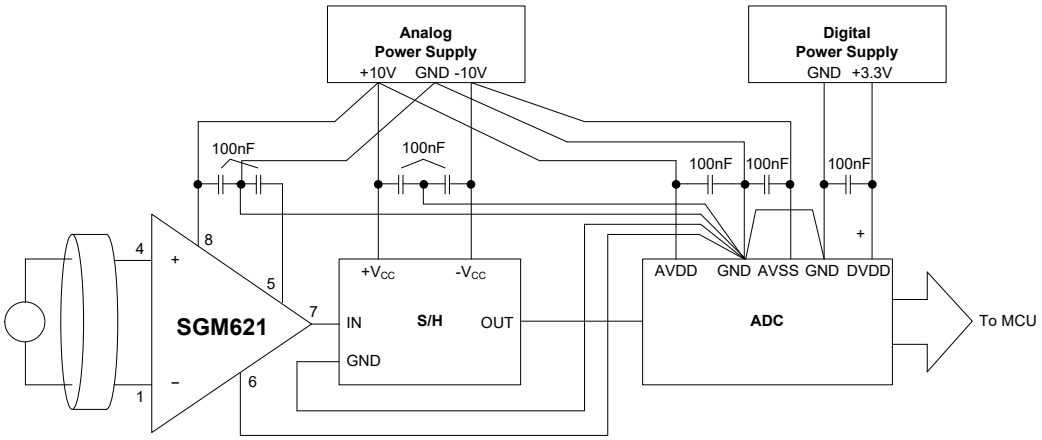


Figure 9. Isolation of Grounding

Return of Grounding for I_B

The bias current (I_B) at the inputs is needed for operating and biasing the transistor at the input stage of the instrumentation amplifier, so it is also necessary to design a ground return path for the bias current. For example, for operating the floating inputs of the amplifier (see Figure 10 ~ 12), such as AC-coupled transformer, there should be an electrical line between the input and the ground for ground return of bias current.

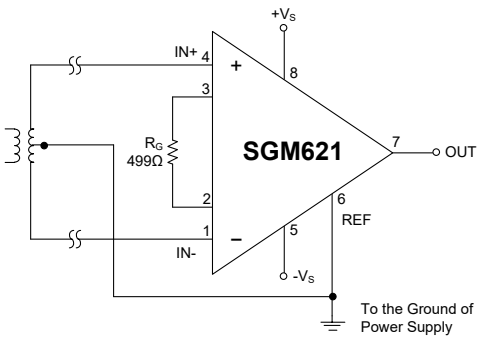


Figure 10. Return of Grounding for I_B with Transformer-Coupled Inputs

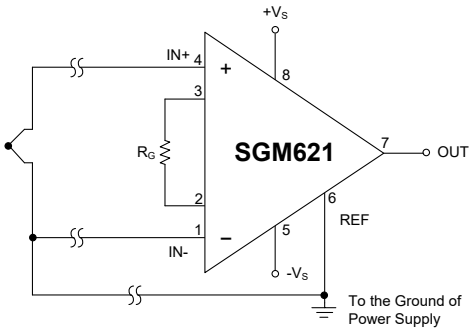


Figure 11. Return of Grounding for I_B with Thermocouple Inputs

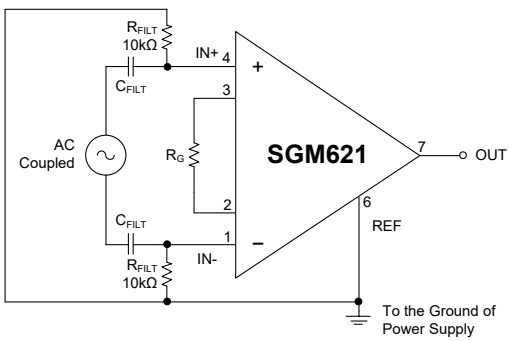


Figure 12. Return of Grounding for I_B with AC-Coupled Input

REVISION HISTORY

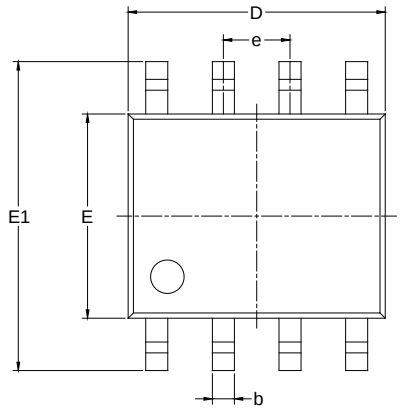
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

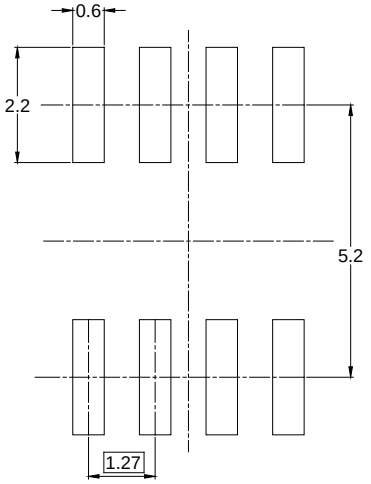
MARCH 2022 – REV.A to REV.A.1	Page
Updated Electrical Characteristics section	5

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

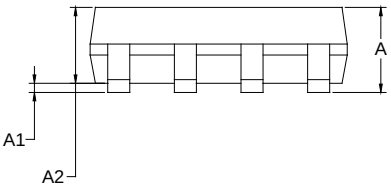
PACKAGE OUTLINE DIMENSIONS

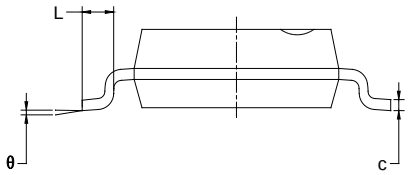
SOIC-8





RECOMMENDED LAND PATTERN (Unit: mm)



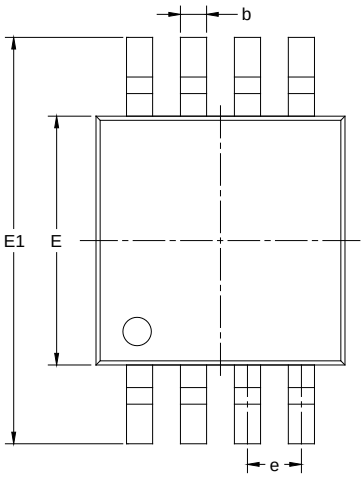


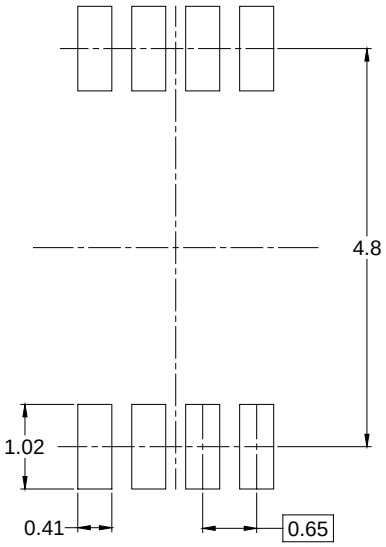
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.27 BSC		0.050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

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

PACKAGE OUTLINE DIMENSIONS

MSOP-8





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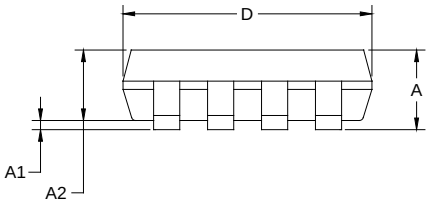
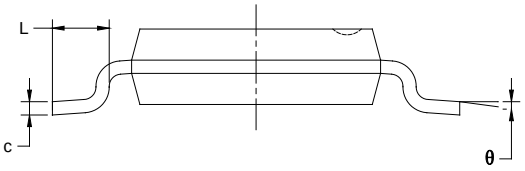


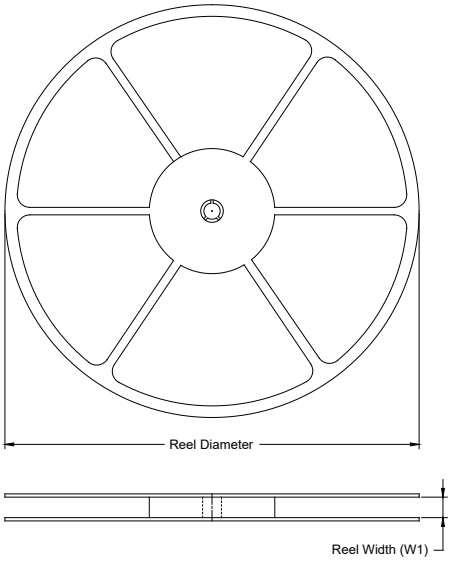


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
e	0.650 BSC		0.026 BSC	
L	0.400	0.800	0.016	0.031
θ	0°	6°	0°	6°

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



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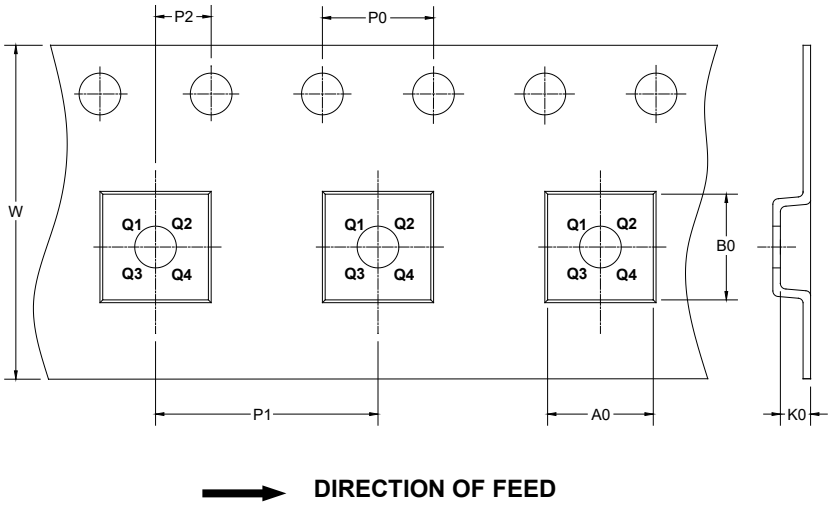


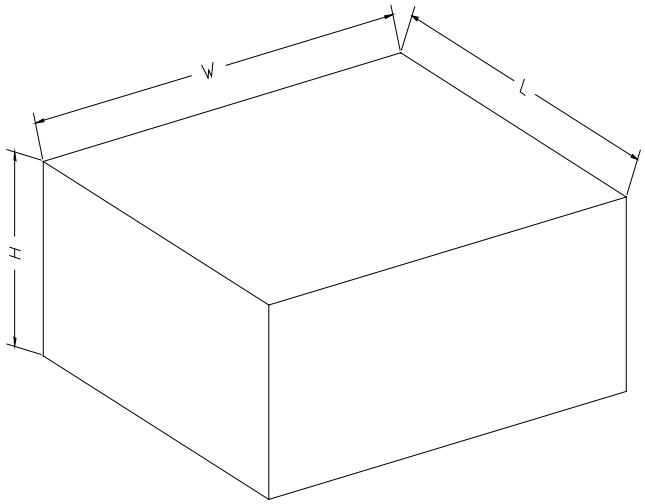
NOTE: The picture is only for reference. Please make the object as the standard.

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
SOIC-8	13″	12.4	6.40	5.40	2.10	4.0	8.0	2.0	12.0	Q1
MSOP-8	13″	12.4	5.20	3.30	1.50	4.0	8.0	2.0	12.0	Q1

DD0001

CARTON BOX DIMENSIONS



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

KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
13″	386	280	370	5

DD0002