

# SGM321/SGM358/SGM324 1MHz, 60 $\mu$ A, Rail-to-Rail I/O CMOS Operational Amplifiers

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## GENERAL DESCRIPTION

The SGM321 (single), SGM358 (dual) and SGM324 (quad) are low cost, rail-to-rail input and output voltage feedback amplifiers. They have a wide input common mode voltage range and output voltage swing, and take the minimum operating supply voltage down to 2.1V. The maximum recommended supply voltage is 5.5V. All are specified over the extended -40°C to +85°C temperature range.

The SGM321/358/324 provide 1MHz bandwidth at a low current consumption of 60 $\mu$ A/amplifier. Very low input bias currents of 10pA enable SGM321/358/324 to be used for integrators, photodiode amplifiers and piezoelectric sensors. Rail-to-rail input and output are useful to designers for buffering ASIC in single-supply systems.

Applications for this series of amplifiers include safety monitoring, portable equipment, battery and power supply control, and signal conditioning and interfacing for transducers in very low power systems.

The SGM321 is available in Green SOT-23-5 and SC70-5 packages. The SGM358 is available in Green SOIC-8, MSOP-8 and DIP-8 packages. The SGM324 is available in Green SOIC-14 and TSSOP-14 packages.

## FEATURES

- **Low Cost**
- **Rail-to-Rail Input and Output**
- **Input Offset Voltage: 5mV (MAX)**
- **Unity Gain Stable**
- **Gain-Bandwidth Product: 1MHz**
- **Very Low Input Bias Current: 10pA**
- **Supply Voltage Range: 2.1V to 5.5V**
- **Input Voltage Range:**
  - 0.1V to 5.6V with  $V_S = 5.5V$
- **Low Supply Current: 60 $\mu$ A/Amplifier**
- **Small Packaging:**
  - SGM321 Available in SOT-23-5 and SC70-5**
  - SGM358 Available in SOIC-8, MSOP-8 and DIP-8**
  - SGM324 Available in SOIC-14 and TSSOP-14**

## APPLICATIONS

ASIC Input or Output Amplifier  
Sensor Interface  
Piezoelectric Transducer Amplifier  
Medical Instrumentation  
Mobile Communication  
Audio Output  
Portable System  
Smoke Detector  
Notebook PC  
PCMCIA Card  
Battery-Powered Equipment  
DSP Interface

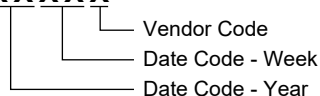
**PACKAGE/ORDERING INFORMATION**

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM321	SC70-5	-40°C to +85°C	SGM321YC5/TR	321	Tape and Reel, 3000
	SOT-23-5	-40°C to +85°C	SGM321YN5/TR	321	Tape and Reel, 3000
	SOT-23-5	-40°C to +85°C	SGM321BYN5/TR	321B	Tape and Reel, 3000
SGM358	SOIC-8	-40°C to +85°C	SGM358YS/TR	SGM358YS XXXXX	Tape and Reel, 4000
	MSOP-8	-40°C to +85°C	SGM358YMS/TR	SGM358 YMS XXXXX	Tape and Reel, 3000
	DIP-8	-40°C to +85°C	SGM358YP	SGM358YP XXXXX	20 Tube (1000pcs)
SGM324	SOIC-14	-40°C to +85°C	SGM324YS14/TR	SGM324YS14 XXXXX	Tape and Reel, 2500
	TSSOP-14	-40°C to +85°C	SGM324YTS14/TR	SGM324 YTS14 XXXXX	Tape and Reel, 3000

**MARKING INFORMATION**

NOTE: XXXXX = Date Code and Vendor Code.

**XXXXX**



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 <sub>S</sub> to -V <sub>S</sub> .....	6V
Input Common Mode Voltage Range ..... (-V <sub>S</sub> ) - 0.3V to (+V <sub>S</sub> ) + 0.3V	
Package Thermal Resistance @ T <sub>A</sub> = +25°C	
SC70-5, θ <sub>JA</sub> .....	333°C/W
SOT-23-5, θ <sub>JA</sub> .....	190°C/W
SOIC-8, θ <sub>JA</sub> .....	125°C/W
MSOP-8, θ <sub>JA</sub> .....	216°C/W
Junction Temperature.....	+150°C
Storage Temperature Range.....	-65°C to +150°C
Lead Temperature (Soldering, 10s).....	+260°C
ESD Susceptibility	
HBM.....	4000V
MM.....	400V

**RECOMMENDED OPERATING CONDITIONS**

Operating Temperature Range.....	-40°C to +85°C
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**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.

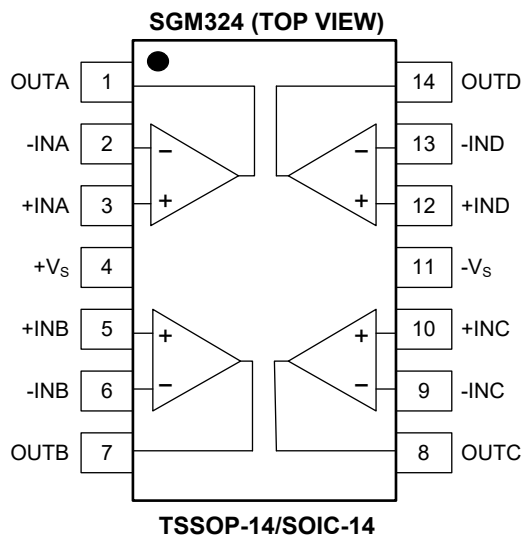
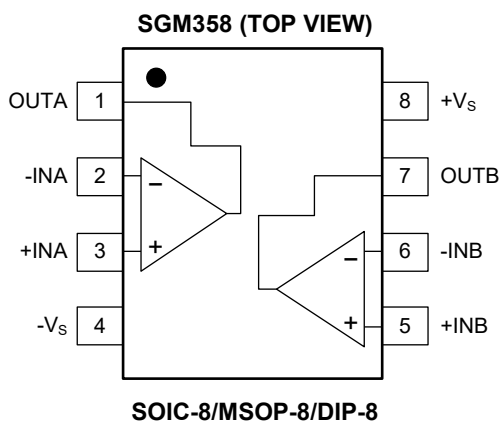
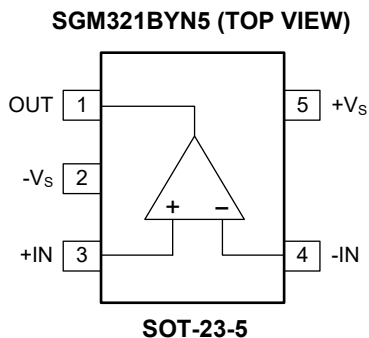
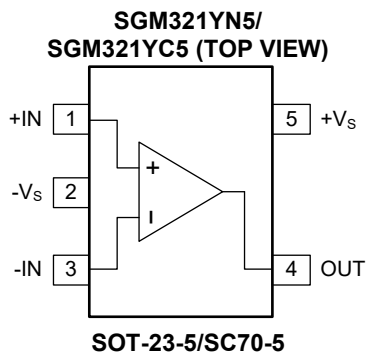
**ESD SENSITIVITY CAUTION**

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**

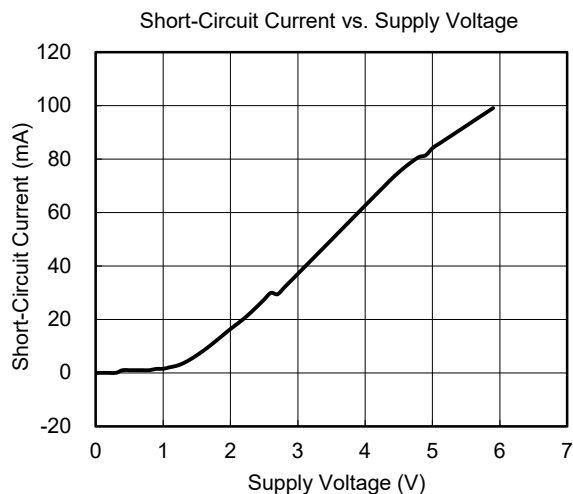
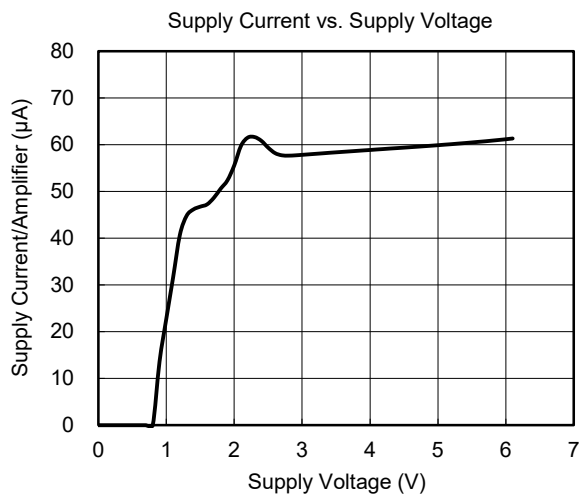
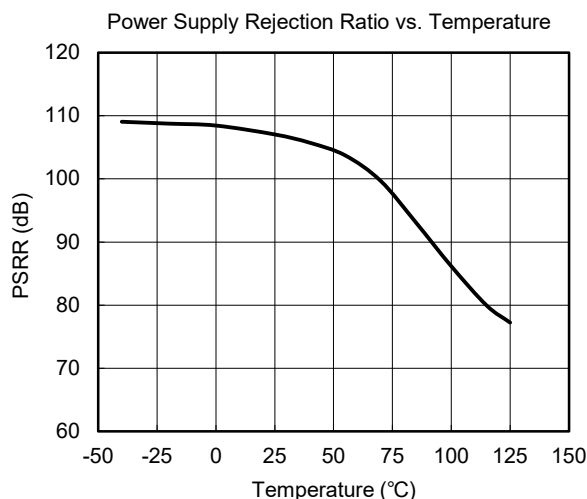
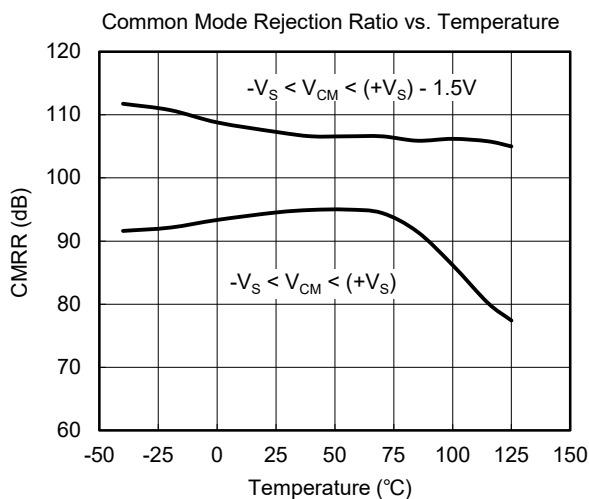
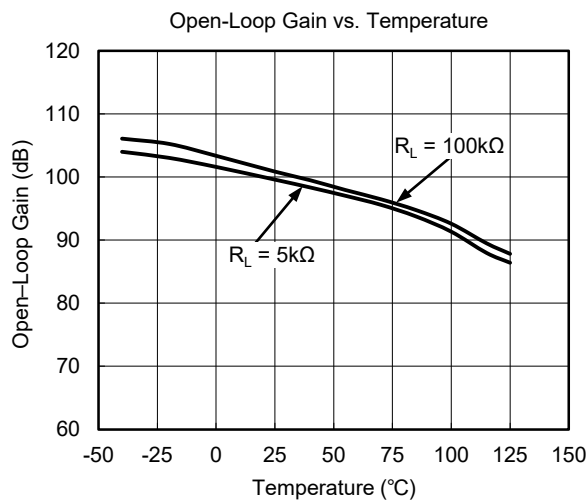
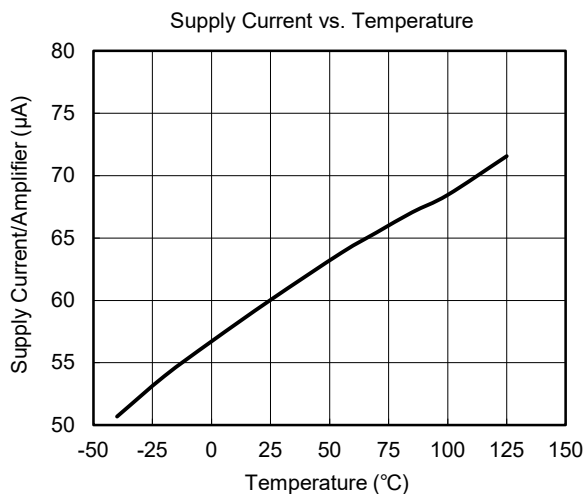


**ELECTRICAL CHARACTERISTICS**(At  $V_S = +5V$ ,  $R_L = 100k\Omega$  connected to  $V_S/2$ , and  $V_{OUT} = V_S/2$ , unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	SGM321/358/324					
			TYP	MIN/MAX OVER TEMPERATURE			UNITS	MINMAX
			+25°C	+25°C	-40°C to +85°C			
<b>INPUT CHARACTERISTICS</b>								
Input Offset Voltage	$V_{OS}$	$V_{CM} = V_S/2$	0.8	5	5.6	mV	MAX	
Input Bias Current	$I_B$		10			pA	TYP	
Input Offset Current	$I_{OS}$		10			pA	TYP	
Input Common Mode Voltage Range	$V_{CM}$	$V_S = 5.5V$	-0.1 to 5.6			V	TYP	
Common Mode Rejection Ratio	CMRR	$V_S = 5.5V, V_{CM} = -0.1V$ to 4V	70	62	62	dB	MIN	
		$V_S = 5.5V, V_{CM} = -0.1V$ to 5.6V	68	56	55			
Open-Loop Voltage Gain	$A_{OL}$	$R_L = 5k\Omega, V_{OUT} = 0.1V$ to 4.9V	80	70	70	dB	MIN	
		$R_L = 100k\Omega, V_{OUT} = 0.035V$ to 4.965V	84	80	80			
Input Offset Voltage Drift	$\Delta V_{OS}/\Delta T$		2.7			$\mu V/^\circ C$	TYP	
<b>OUTPUT CHARACTERISTICS</b>								
Output Voltage Swing from Rail	$V_{OH}$	$R_L = 100k\Omega$	4.997	4.980	4.970	V	MIN	
	$V_{OL}$	$R_L = 100k\Omega$	5	20	30	mV	MAX	
	$V_{OH}$	$R_L = 10k\Omega$	4.992	4.970	4.960	V	MIN	
	$V_{OL}$	$R_L = 10k\Omega$	8	30	40	mV	MAX	
Output Current	$I_{SOURCE}$	$R_L = 10\Omega$ to $V_S/2$	84	60	45	mA	MIN	
	$I_{SINK}$		75	60	45			
<b>POWER SUPPLY</b>								
Operating Voltage Range				2.1	2.5	V	MIN	
				5.5	5.5	V	MAX	
Power Supply Rejection Ratio	PSRR	$V_S = 2.5V$ to 5.5V, $V_{CM} = 0.5V$	82	60	58	dB	MIN	
Quiescent Current/Amplifier	$I_Q$		60	80	86	$\mu A$	MAX	
<b>DYNAMIC PERFORMANCE</b> ( $C_L = 100pF$ )								
Gain-Bandwidth Product	GBP		1			MHz	TYP	
Slew Rate	SR	$G = +1, 2V$ Output Step	0.52			V/ $\mu s$	TYP	
Settling Time to 0.1%	$t_s$	$G = +1, 2V$ Output Step	5.3			$\mu s$	TYP	
Overload Recovery Time		$V_{IN} \cdot G = V_S$	2.6			$\mu s$	TYP	
<b>NOISE PERFORMANCE</b>								
Input Voltage Noise Density	$e_n$	$f = 1kHz$	27			nV/ $\sqrt{Hz}$	TYP	
		$f = 10kHz$	20			nV/ $\sqrt{Hz}$	TYP	

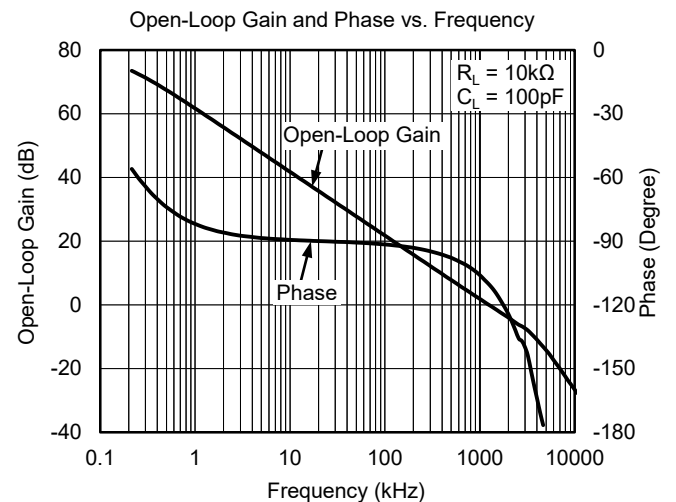
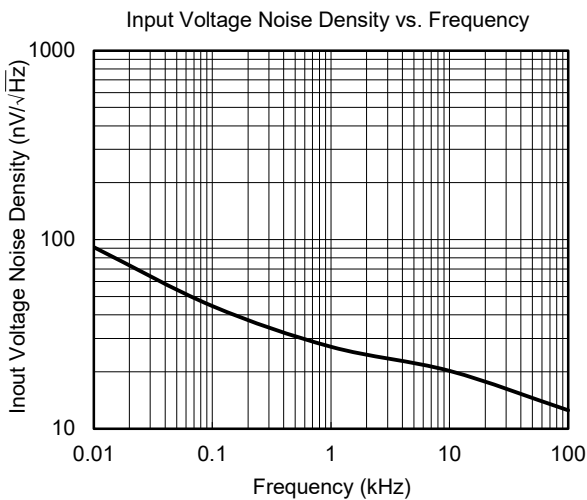
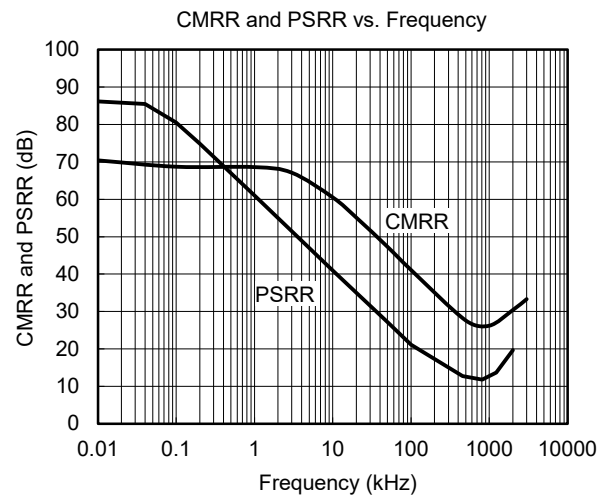
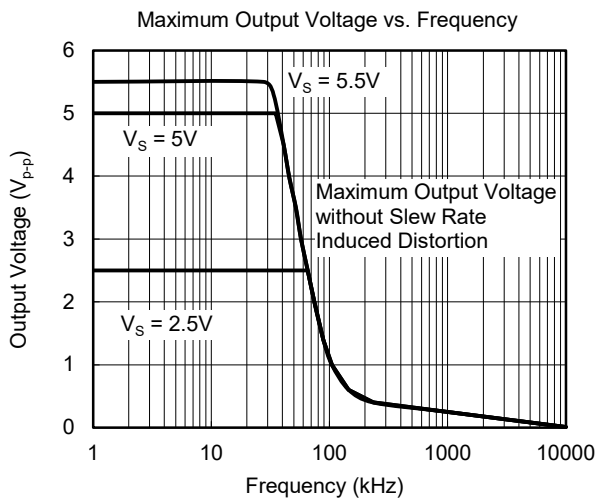
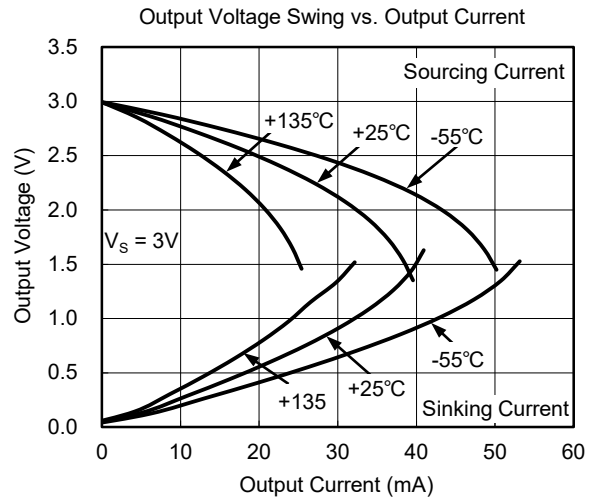
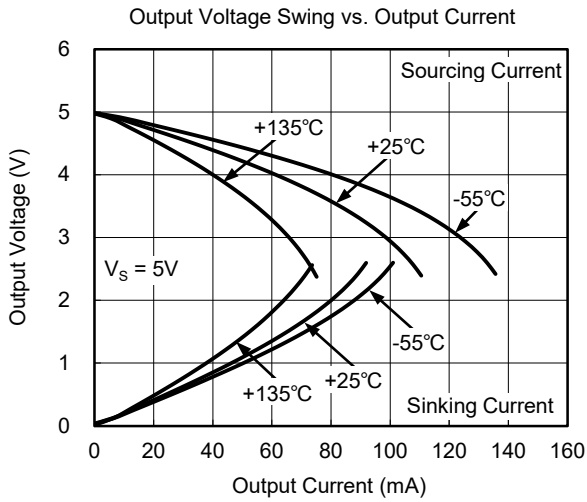
TYPICAL PERFORMANCE CHARACTERISTICS

At  $T_A = +25^\circ\text{C}$ ,  $V_S = 5\text{V}$ , and  $R_L = 100\text{k}\Omega$  connected to  $V_S/2$ , unless otherwise noted.



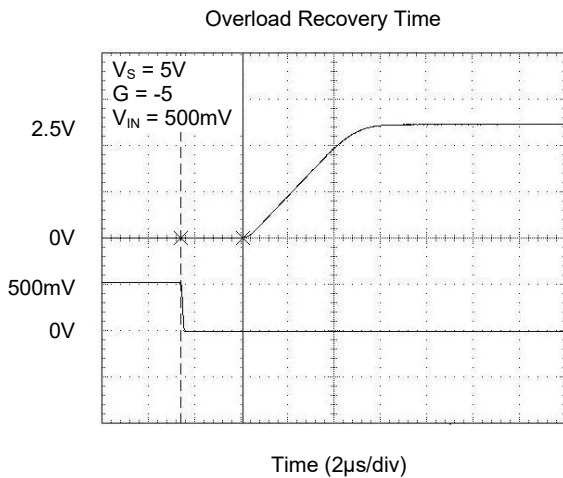
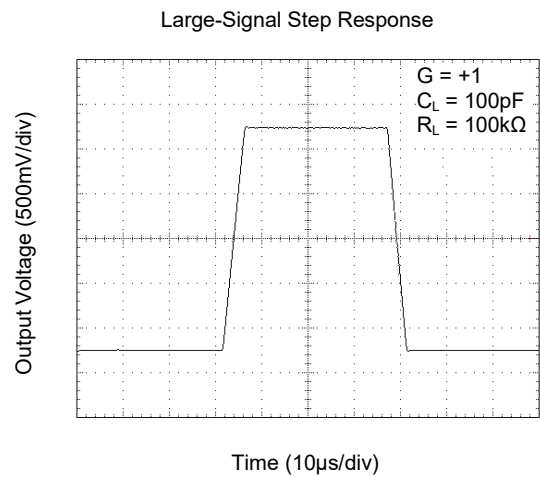
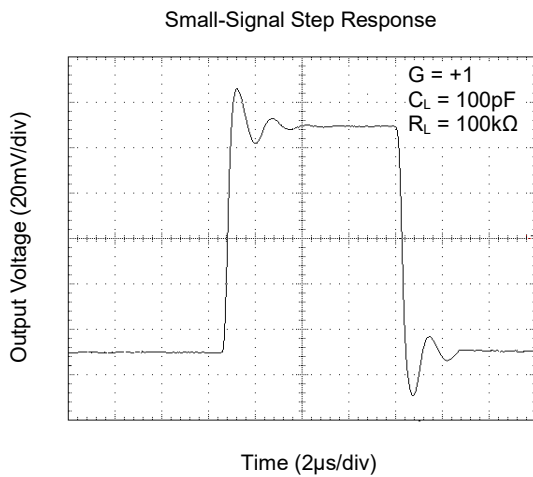
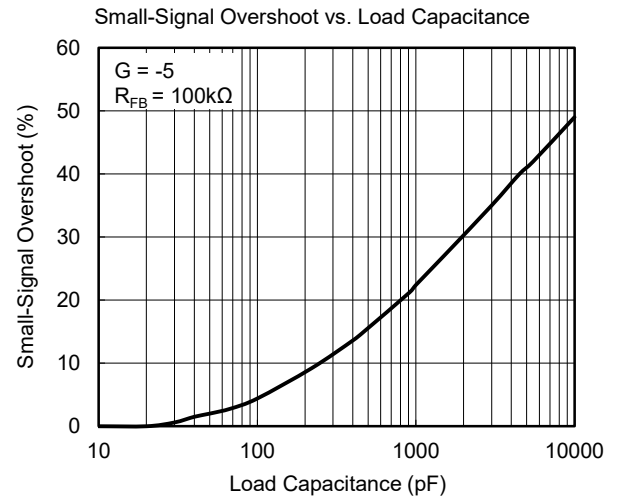
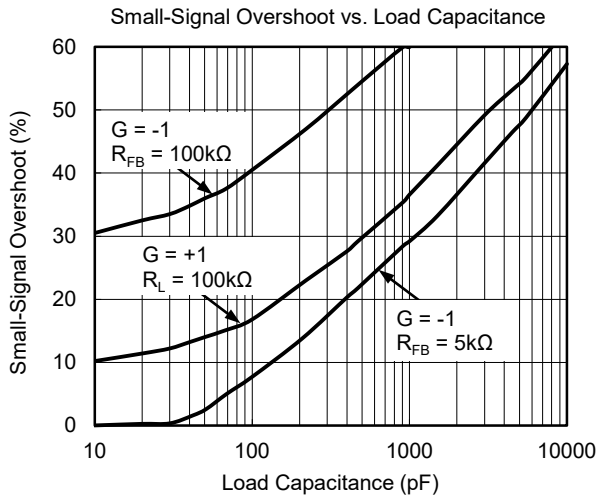
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At  $T_A = +25^\circ\text{C}$ ,  $V_S = 5\text{V}$ , and  $R_L = 100\text{k}\Omega$  connected to  $V_S/2$ , unless otherwise noted.



**TYPICAL PERFORMANCE CHARACTERISTICS (continued)**

At  $T_A = +25^\circ\text{C}$ ,  $V_S = 5\text{V}$ , and  $R_L = 100\text{k}\Omega$  connected to  $V_S/2$ , unless otherwise noted.



APPLICATION NOTES

Driving Capacitive Loads

The SGM321/SGM358/SGM324 can directly drive 250pF in unity-gain without oscillation. The unity-gain follower (buffer) is the most sensitive configuration to capacitive loading. Direct capacitive loading reduces the phase margin of amplifiers and this results in ringing or even oscillation. Applications that require greater capacitive driving capability should use an isolation resistor between the output and the capacitive load like the circuit in Figure 1. The isolation resistor  $R_{ISO}$  and the load capacitor  $C_L$  form a zero to increase stability. The bigger the  $R_{ISO}$  resistor value, the more stable  $V_{OUT}$  will be. Note that this method results in a loss of gain accuracy because  $R_{ISO}$  forms a voltage divider with the  $R_{LOAD}$ .

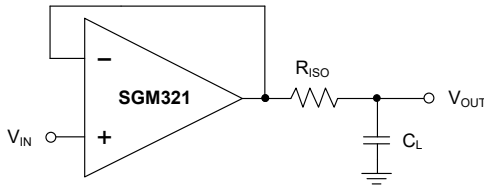


Figure 1. Indirectly Driving Heavy Capacitive Load

An improved circuit is shown in Figure 2. It provides DC accuracy as well as AC stability.  $R_F$  provides the DC accuracy by connecting the inverting input with the output.  $C_F$  and  $R_{ISO}$  serve to counteract the loss of phase margin by feeding the high frequency component of the output signal back to the amplifier's inverting input, thereby preserving phase margin in the overall feedback loop.

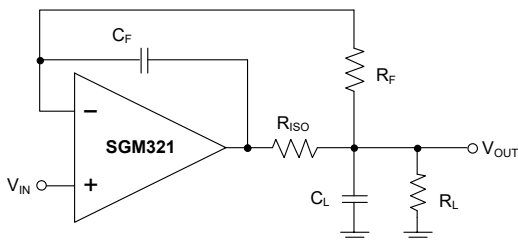


Figure 2. Indirectly Driving Heavy Capacitive Load with DC Accuracy

For non-buffer configuration, there are two other ways to increase the phase margin: (a) by increasing the amplifier's closed-loop gain or (b) by placing a capacitor in parallel with the feedback resistor to counteract the parasitic capacitance associated with inverting node.

Power Supply Bypassing and Layout

The SGM321/SGM358/SGM324 can operate from either a single 2.1V to 5.5V supply or dual  $\pm 1.05V$  to  $\pm 2.75V$  supplies. For single-supply operation, bypass the power supply  $+V_S$  with a  $0.1\mu F$  ceramic capacitor which should be placed close to the  $+V_S$  pin. For dual-supply operation, both the  $+V_S$  and the  $-V_S$  supplies should be bypassed to ground with separate  $0.1\mu F$  ceramic capacitors.  $2.2\mu F$  tantalum capacitor can be added for better performance.

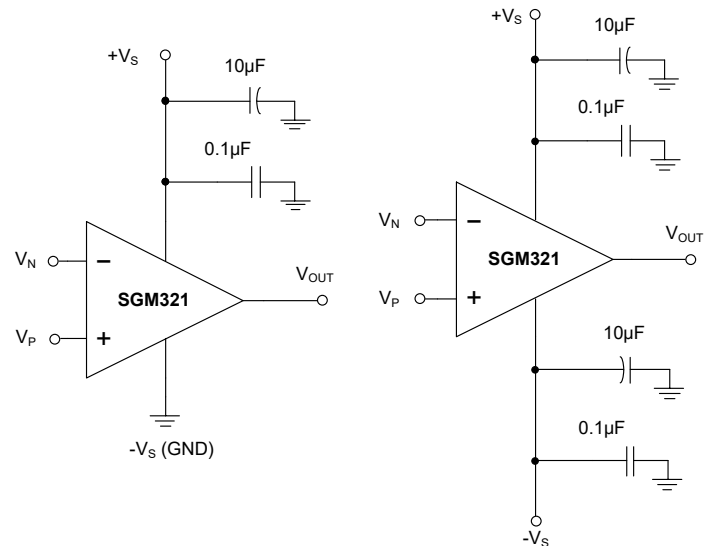


Figure 3. Amplifier with Bypass Capacitors



TYPICAL APPLICATION CIRCUITS

Differential Amplifier

The circuit shown in Figure 4 performs the difference function. If the resistor ratios are equal ( $R_4/R_3 = R_2/R_1$ ), then  $V_{OUT} = (V_P - V_N) \times R_2/R_1 + V_{REF}$ .

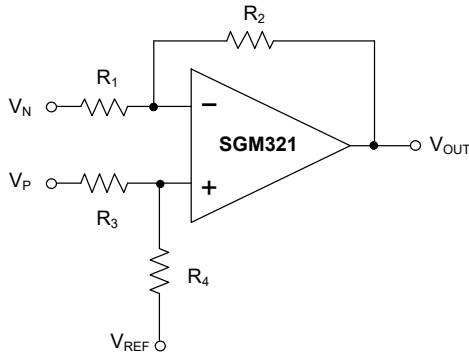


Figure 4. Differential Amplifier

Instrumentation Amplifier

The circuit in Figure 5 performs the same function as that in Figure 4 but with a high input impedance.

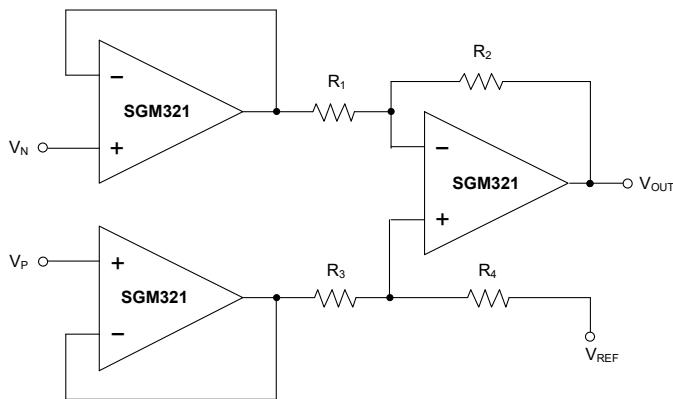


Figure 5. Instrumentation Amplifier

Active Low-Pass Filter

The low-pass filter shown in Figure 6 has a DC gain of  $(-R_2/R_1)$  and the -3dB corner frequency is  $1/2\pi R_2 C$ . Make sure the filter bandwidth is within the bandwidth of the amplifier. Feedback resistors with large values can couple with parasitic capacitance and cause undesired effects such as ringing or oscillation in high-speed amplifiers. Keep resistor values as low as possible and consistent with output loading consideration.

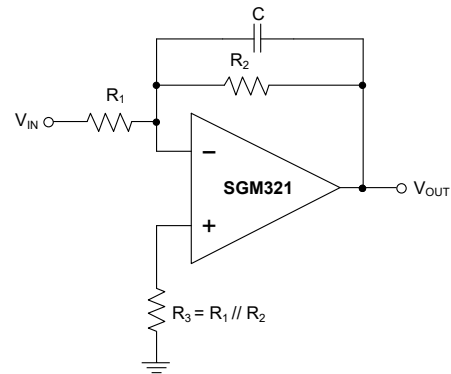


Figure 6. Active Low-Pass Filter

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## **REVISION HISTORY**

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

<b>APRIL 2019 – REV.E.1 to REV.E.2</b>	<b>Page</b>
Added Open-Loop Gain and Phase vs. Frequency .....	6

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<b>MARCH 2017 – REV.E to REV.E.1</b>	<b>Page</b>
Updated Package/Ordering Information section .....	2

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<b>NOVEMBER 2015 – REV.D.4 to REV.E</b>	<b>Page</b>
Updated Packing Option of DIP-8 .....	2
Updated SOIC-14 and TSSOP-14 packages .....	14, 15

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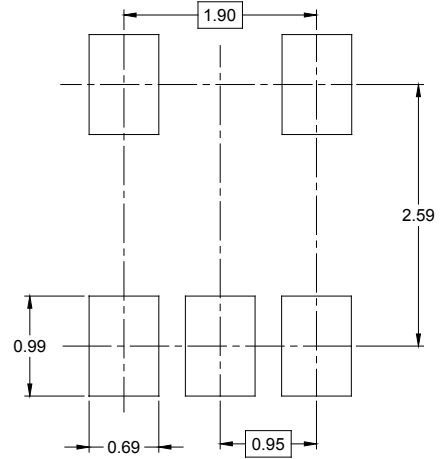
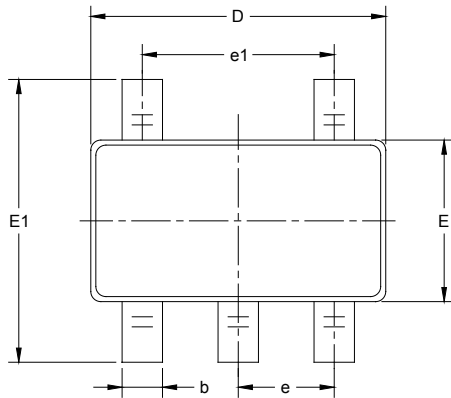
<b>JANUARY 2013 – REV.D.3 to REV.D.4</b>	<b>Page</b>
Added Tape and Reel Information section .....	16, 17

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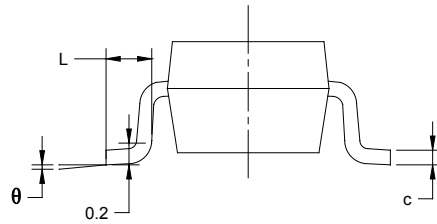
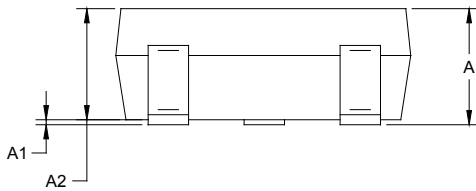
# PACKAGE INFORMATION

## PACKAGE OUTLINE DIMENSIONS

### SOT-23-5



RECOMMENDED LAND PATTERN (Unit: mm)

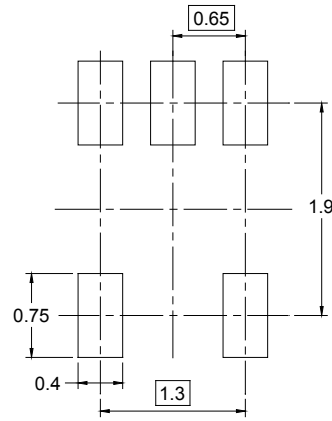
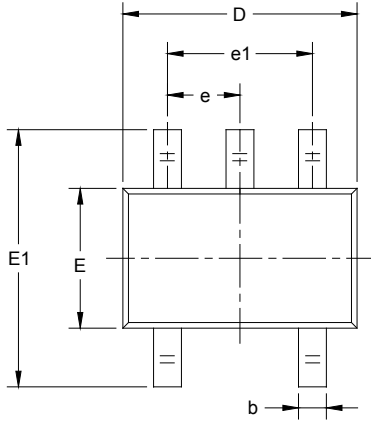


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950 BSC		0.037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

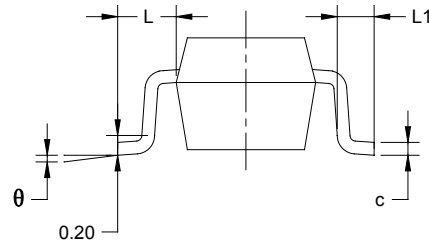
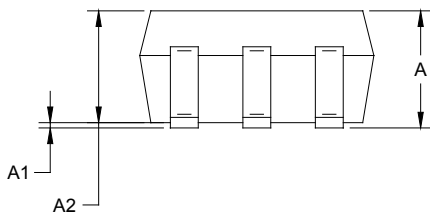
# PACKAGE INFORMATION

## PACKAGE OUTLINE DIMENSIONS

### SC70-5



RECOMMENDED LAND PATTERN (Unit: mm)

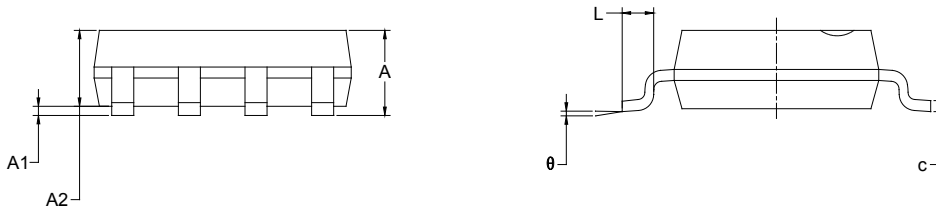
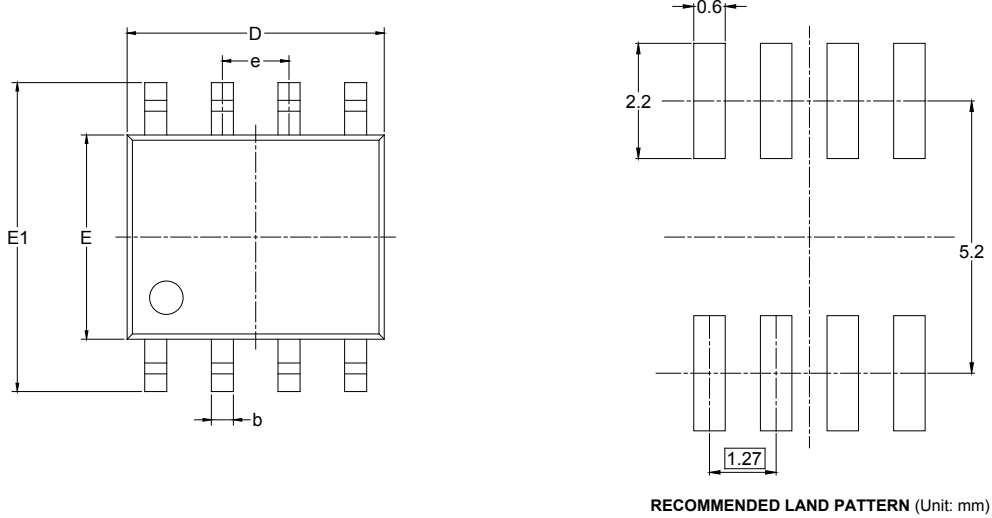


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.900	1.100	0.035	0.043
A1	0.000	0.100	0.000	0.004
A2	0.900	1.000	0.035	0.039
b	0.150	0.350	0.006	0.014
c	0.080	0.150	0.003	0.006
D	2.000	2.200	0.079	0.087
E	1.150	1.350	0.045	0.053
E1	2.150	2.450	0.085	0.096
e	0.65 TYP		0.026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

# PACKAGE INFORMATION

## PACKAGE OUTLINE DIMENSIONS

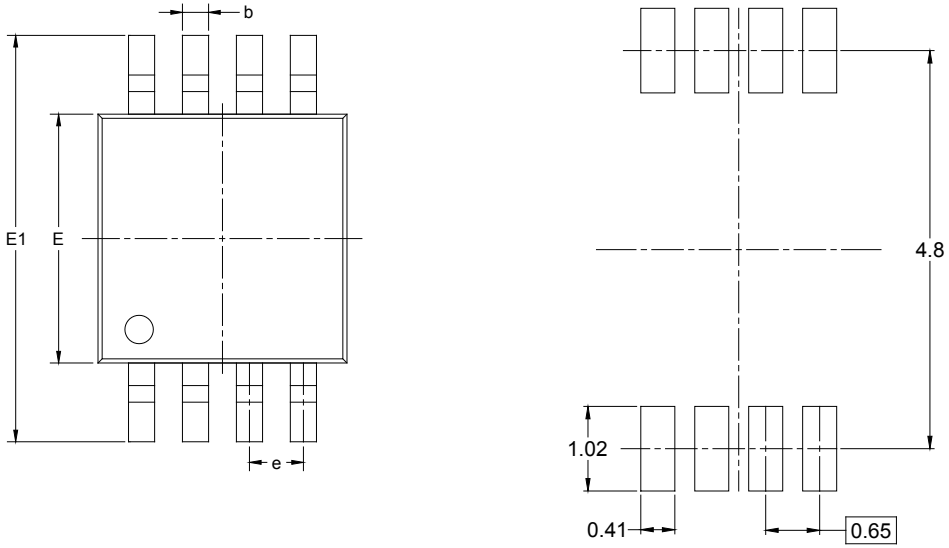
### SOIC-8



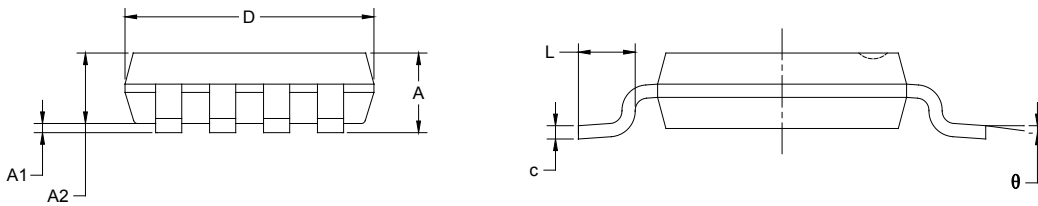
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.27 BSC		0.050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

PACKAGE OUTLINE DIMENSIONS

MSOP-8



RECOMMENDED LAND PATTERN (Unit: mm)

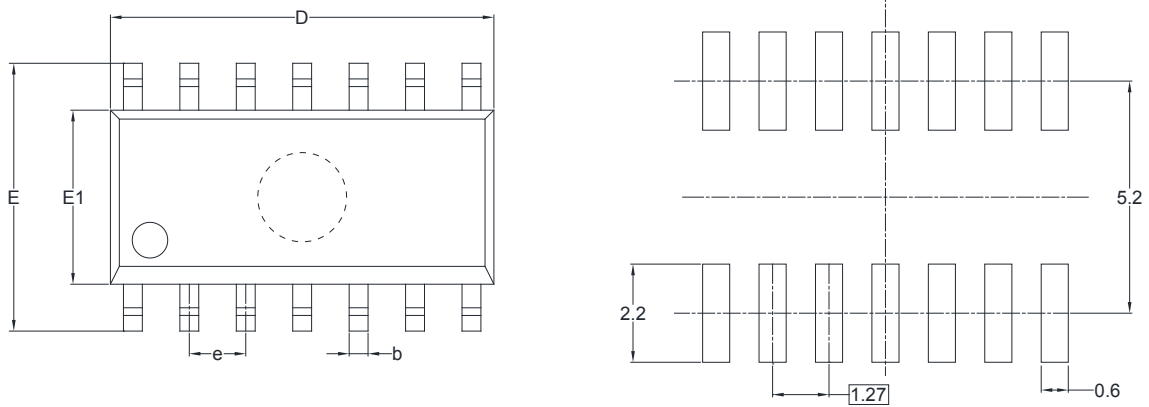


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
e	0.650 BSC		0.026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

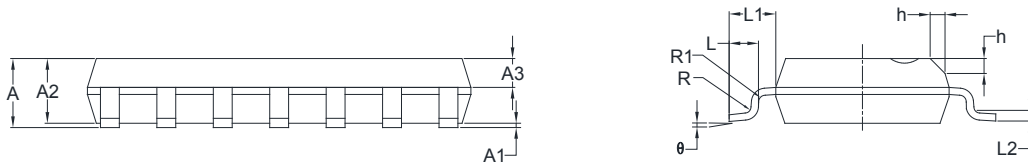
# PACKAGE INFORMATION

## PACKAGE OUTLINE DIMENSIONS

### SOIC-14



RECOMMENDED LAND PATTERN (Unit: mm)

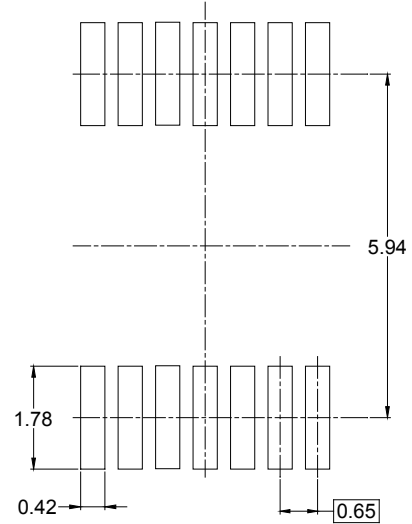
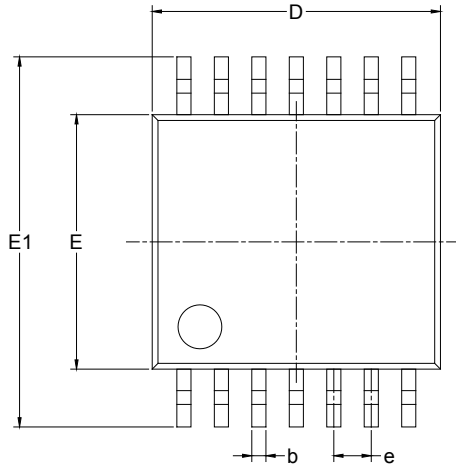


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.35	1.75	0.053	0.069
A1	0.10	0.25	0.004	0.010
A2	1.25	1.65	0.049	0.065
A3	0.55	0.75	0.022	0.030
b	0.36	0.49	0.014	0.019
D	8.53	8.73	0.336	0.344
E	5.80	6.20	0.228	0.244
E1	3.80	4.00	0.150	0.157
e	1.27 BSC		0.050 BSC	
L	0.45	0.80	0.018	0.032
L1	1.04 REF		0.040 REF	
L2	0.25 BSC		0.01 BSC	
R	0.07		0.003	
R1	0.07		0.003	
h	0.30	0.50	0.012	0.020
θ	0°	8°	0°	8°

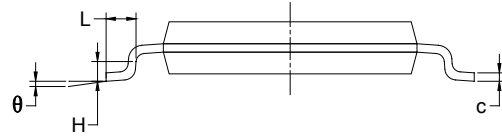
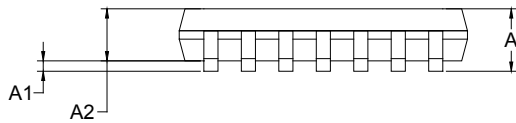
# PACKAGE INFORMATION

## PACKAGE OUTLINE DIMENSIONS

### TSSOP-14



RECOMMENDED LAND PATTERN (Unit: mm)



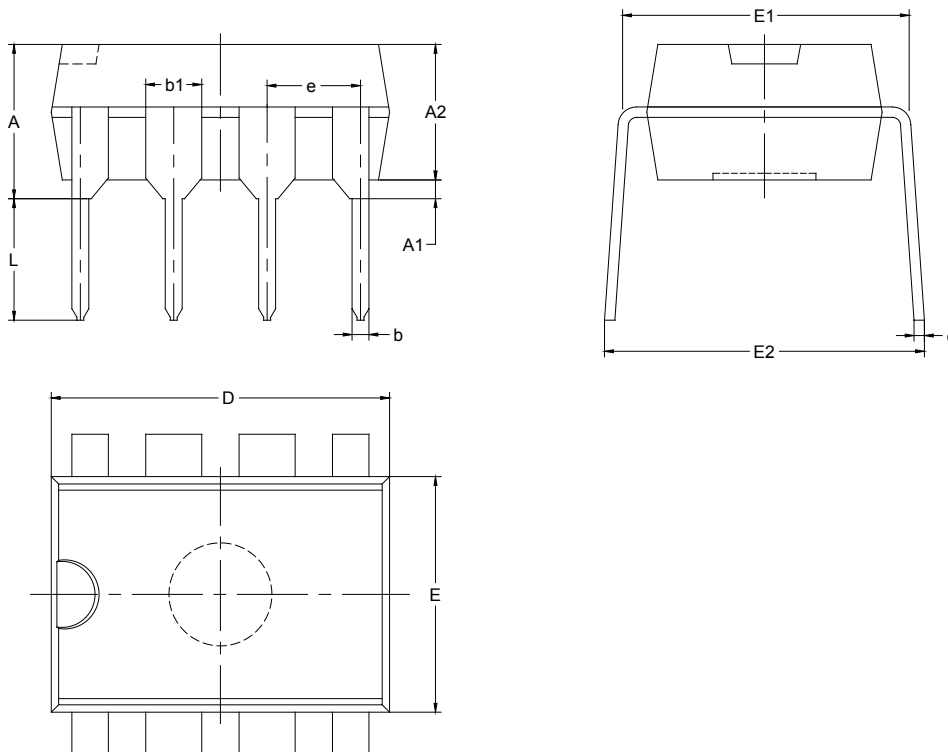
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A		1.200		0.047
A1	0.050	0.150	0.002	0.006
A2	0.800	1.050	0.031	0.041
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
D	4.860	5.100	0.191	0.201
E	4.300	4.500	0.169	0.177
E1	6.250	6.550	0.246	0.258
e	0.650 BSC		0.026 BSC	
L	0.500	0.700	0.02	0.028
H	0.25 TYP		0.01 TYP	
$\theta$	1°	7°	1°	7°



## PACKAGE INFORMATION

### PACKAGE OUTLINE DIMENSIONS

#### DIP-8

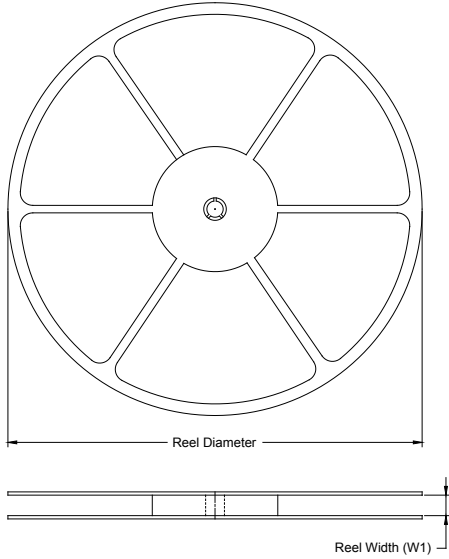


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	3.710	4.310	0.146	0.170
A1	0.510		0.020	
A2	3.200	3.600	0.126	0.142
b	0.380	0.570	0.015	0.022
b1	1.524 BSC		0.060 BSC	
c	0.204	0.360	0.008	0.014
D	9.000	9.400	0.354	0.370
E	6.200	6.600	0.244	0.260
E1	7.320	7.920	0.288	0.312
e	2.540 BSC		0.100 BSC	
L	3.000	3.600	0.118	0.142
E2	8.400	9.000	0.331	0.354

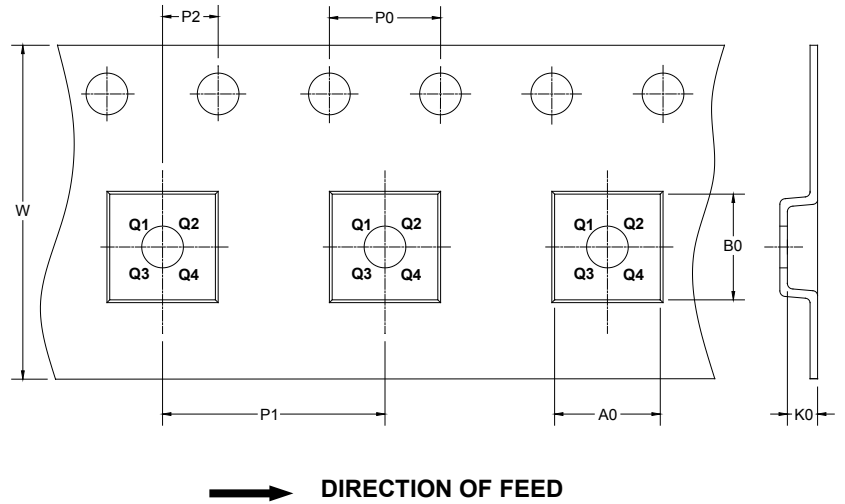
# PACKAGE INFORMATION

## 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
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
MSOP-8	13"	12.4	5.20	3.30	1.50	4.0	8.0	2.0	12.0	Q1
SOIC-14	13"	16.4	6.60	9.30	2.10	4.0	8.0	2.0	16.0	Q1
TSSOP-14	13"	12.4	6.95	5.60	1.20	4.0	8.0	2.0	12.0	Q1

# PACKAGE INFORMATION

## 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