

### Features

- Single-Supply Operation from +1.8V ~ +6V
- Rail-to-Rail Input / Output
- Gain-Bandwidth Product: 1MHz (Typ)
- Low Input Bias Current: 1pA (Typ)
- Low Offset Voltage: 3.5mV (Max)
- Quiescent Current: 75µA per Amplifier (Typ)
- Embedded RF Anti-EMI Filter
- Operating Temperature: -40°C ~ +125°C
- Small Package:
  - GS6001 Available in SOT23-5 and SC70-5 Packages
  - GS6002 Available in SOP-8 and MSOP-8 Packages
  - GS6004 Available in SOP-14 and TSSOP-14 Packages

### General Description

The GS600X family have a high gain-bandwidth product of 1MHz, a slew rate of 0.8V/µs, and a quiescent current of 75µA/amplifier at 5V. The GS600X family is designed to provide optimal performance in low voltage and low noise systems. They provide rail-to-rail output swing into heavy loads. The input common mode voltage range includes ground, and the maximum input offset voltage is 3.5mV for GS600X family. They are specified over the extended industrial temperature range (-40°C to +125°C). The operating range is from 1.8V to 6V. The GS6001 single is available in Green SC70-5 and SOT23-5 packages. The GS6002 dual is available in Green SOP-8 and MSOP-8 packages. The GS6004 Quad is available in Green SOP-14 and TSSOP-14 packages.

### Applications

- ASIC Input or Output Amplifier
- Sensor Interface
- Medical Communication
- Smoke Detectors
- Audio Output
- Piezoelectric Transducer Amplifier
- Medical Instrumentation
- Portable Systems

### Pin Configuration

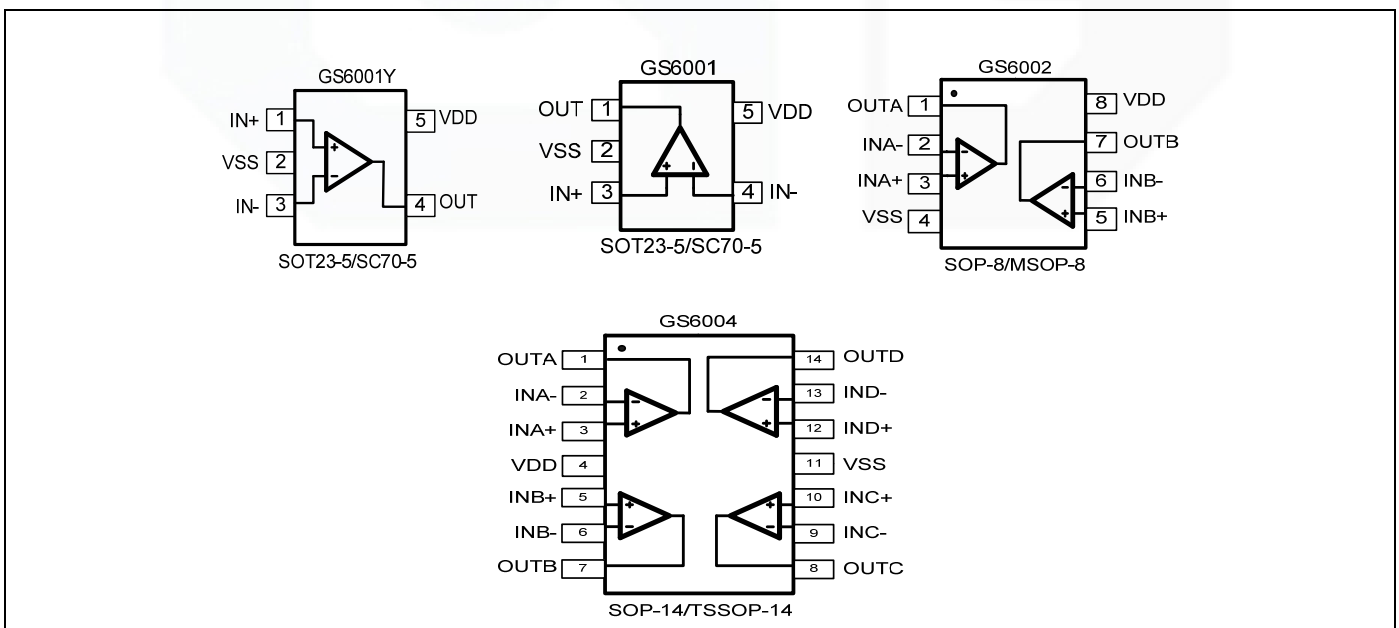


Figure 1. Pin Assignment Diagram

### Absolute Maximum Ratings

Condition	Min	Max
Power Supply Voltage (V <sub>DD</sub> to V <sub>SS</sub> )	-0.5V	+7.5V
Analog Input Voltage (IN+ or IN-)	V <sub>SS</sub> -0.5V	V <sub>DD</sub> +0.5V
PDB Input Voltage	V <sub>SS</sub> -0.5V	+7V
Operating Temperature Range	-40°C	+125°C
Junction Temperature	+160°C	
Storage Temperature Range	-55°C	+150°C
Lead Temperature (soldering, 10sec)	+260°C	
<b>Package Thermal Resistance (T<sub>A</sub>=+25°C)</b>		
SOP-8, θ <sub>JA</sub>	125°C/W	
MSOP-8, θ <sub>JA</sub>	216°C/W	
SOT23-5, θ <sub>JA</sub>	190°C/W	
SC70-5, θ <sub>JA</sub>	333°C/W	
<b>ESD Susceptibility</b>		
HBM	6KV	
MM	400V	

Note: Stress greater than those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions outside those indicated in the operational sections of this specification are not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

### Package/Ordering Information

MODEL	CHANNEL	ORDER NUMBER	PACKAGE DESCRIPTION	PACKAGE OPTION	MARKING INFORMATION
GS6001	Single	GS6001-CR	SC70-5	Tape and Reel,3000	6001
		GS6001-TR	SOT23-5	Tape and Reel,3000	6001
		GS6001Y-CR	SC70-5	Tape and Reel,3000	6001Y/321
		GS6001Y-TR	SOT23-5	Tape and Reel,3000	6001Y/321
GS6002	Dual	GS6002-SR	SOP-8	Tape and Reel,4000	GS6002
		GS6002-MR	MSOP-8	Tape and Reel,3000	GS6002
GS6004	Quad	GS6004-TR	TSSOP-14	Tape and Reel,3000	GS6004
		GS6004-SR	SOP-14	Tape and Reel,2500	GS6004

## Electrical Characteristics

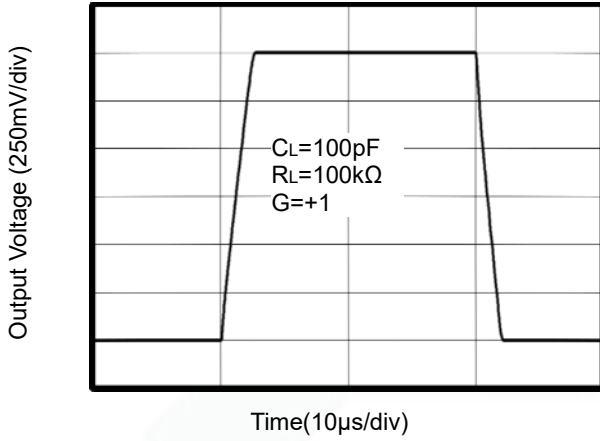
 (At  $V_S = +5V$ ,  $R_L = 100k\Omega$  connected to  $V_S/2$ , and  $V_{OUT} = V_S/2$ , unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	GS6001/2/4				
			TYP	MIN/MAX OVER TEMPERATURE			
			+25°C	+25°C	-40°C to +85°C	UNITS	MIN/MAX
<b>INPUT CHARACTERISTICS</b>							
Input Offset Voltage	$V_{OS}$	$V_{CM} = V_S/2$	0.8	3.5	5.6	mV	MAX
Input Bias Current	$I_B$		1			pA	TYP
Input Offset Current	$I_{OS}$		1			pA	TYP
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	$A_{OL}$	$R_L = 5k\Omega, V_O = +0.1V$ to +4.9V	80	70	70	dB	MIN
		$R_L = 10k\Omega, V_O = +0.1V$ to +4.9V	100	94	85		
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				1.8	1.8	V	MIN
				6	6	V	MAX
Power Supply Rejection Ratio	PSRR	$V_S = +2.5V$ to +6V, $V_{CM} = +0.5V$	82	60	58	dB	MIN
Quiescent Current / Amplifier	$I_Q$		75	110	125	$\mu A$	MAX
<b>DYNAMIC PERFORMANCE (CL = 100pF)</b>							
Gain-Bandwidth Product	GBP		1			MHz	TYP
Slew Rate	SR	$G = +1, 2V$ Output Step	0.8			$V/\mu s$	TYP
Settling Time to 0.1%	$t_s$	$G = +1, 2V$ Output Step	5.3			$\mu s$	TYP
Overload Recovery Time		$V_{IN} \cdot Gain = V_S$	2.6			$\mu s$	TYP
<b>NOISE PERFORMANCE</b>							
Voltage Noise Density	$e_n$	f = 1kHz	27			$nV/\sqrt{Hz}$	TYP
		f = 10kHz	20			$nV/\sqrt{Hz}$	TYP

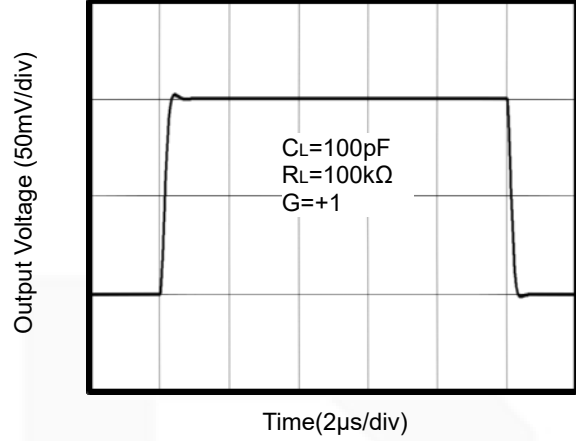
### Typical Performance characteristics

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

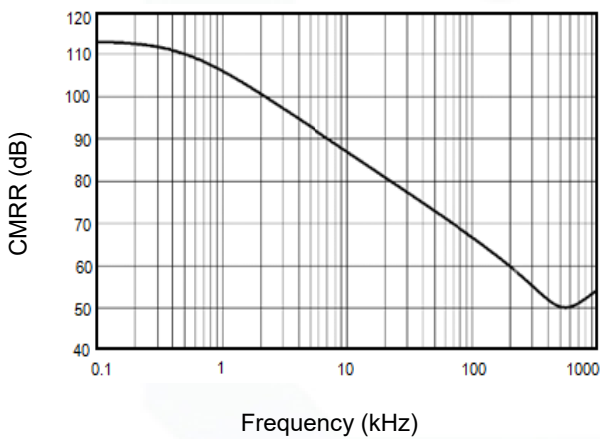
Large Signal Transient Response



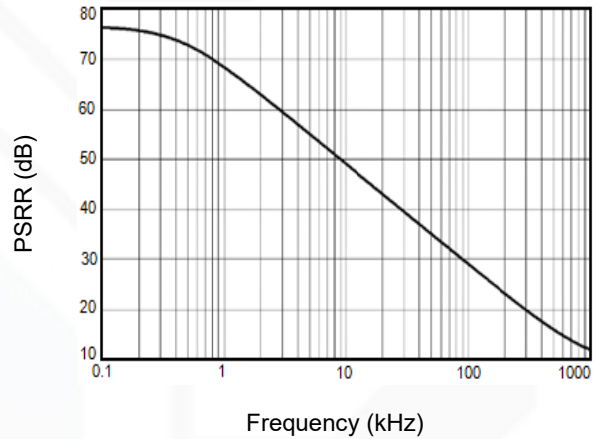
Small Signal Transient Response



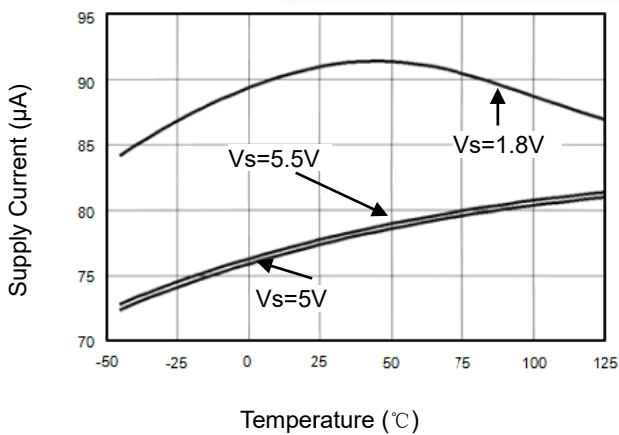
CMRR vs. Frequency



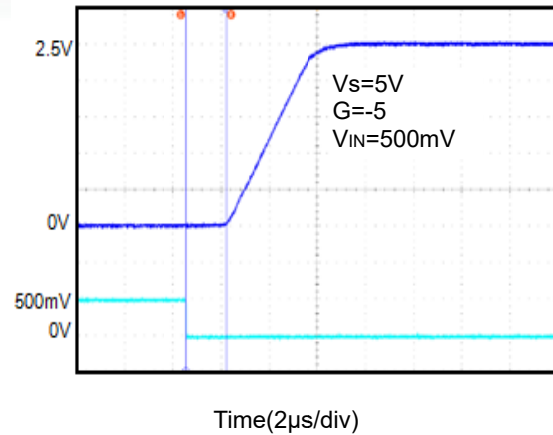
PSRR vs. Frequency



Supply Current vs. Temperature



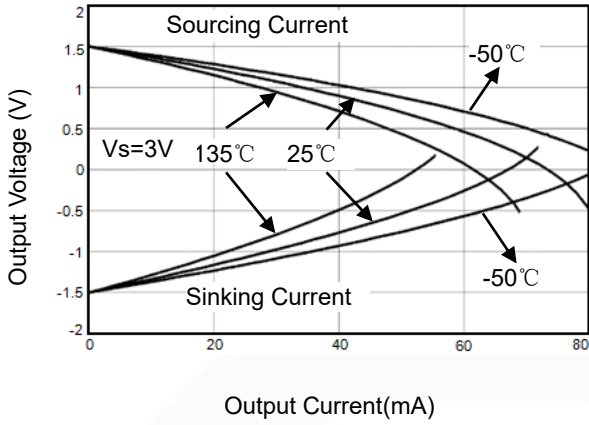
Overload Recovery Time



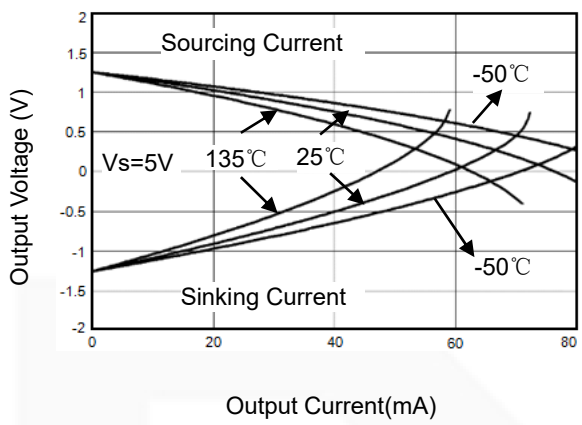
### Typical Performance characteristics

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

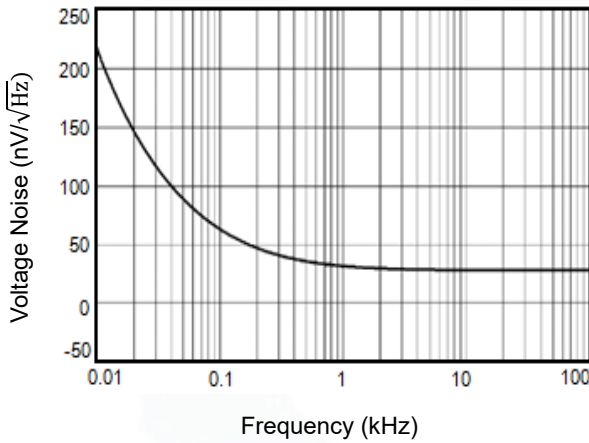
Output Voltage Swing vs. Output Current



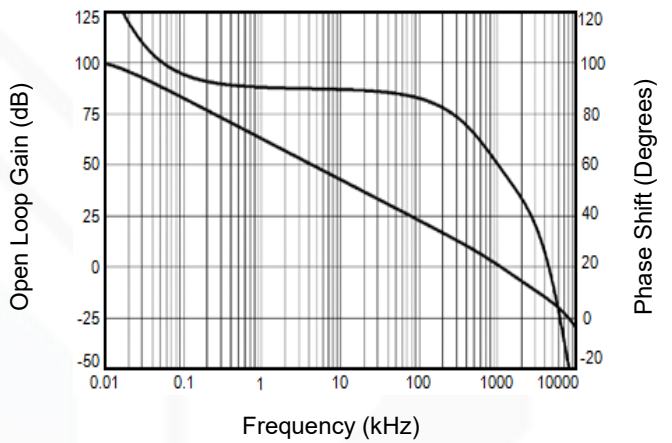
Output Voltage Swing vs. Output Current



Input Voltage Noise Spectral Density vs. Frequency



Open Loop Gain, Phase Shift vs. Frequency



## Application Note

### Size

GS600X family series op amps are unity-gain stable and suitable for a wide range of general-purpose applications. The small footprints of the GS600X family packages save space on printed circuit boards and enable the design of smaller electronic products.

### Power Supply Bypassing and Board Layout

GS600X family series operates from a single 1.8V to 6V supply or dual  $\pm 0.9V$  to  $\pm 3V$  supplies. For best performance, a  $0.1\mu F$  ceramic capacitor should be placed close to the  $V_{DD}$  pin in single supply operation. For dual supply operation, both  $V_{DD}$  and  $V_{SS}$  supplies should be bypassed to ground with separate  $0.1\mu F$  ceramic capacitors.

### Low Supply Current

The low supply current (typical  $75\mu A$  per channel) of GS600X family will help to maximize battery life. They are ideal for battery powered systems.

### Operating Voltage

GS600X family operates under wide input supply voltage (1.8V to 6V). In addition, all temperature specifications apply from  $-40^\circ C$  to  $+125^\circ C$ . Most behavior remains unchanged throughout the full operating voltage range. These guarantees ensure operation throughout the single Li-Ion battery lifetime.

### Rail-to-Rail Input

The input common-mode range of GS600X family extends  $100mV$  beyond the supply rails ( $V_{SS}-0.1V$  to  $V_{DD}+0.1V$ ). This is achieved by using complementary input stage. For normal operation, inputs should be limited to this range.

### Rail-to-Rail Output

Rail-to-Rail output swing provides maximum possible dynamic range at the output. This is particularly important when operating in low supply voltages. The output voltage of GS600X family can typically swing to less than  $10mV$  from supply rail in light resistive loads ( $>100k\Omega$ ), and  $60mV$  of supply rail in moderate resistive loads ( $10k\Omega$ ).

### Capacitive Load Tolerance

The GS600X family is optimized for bandwidth and speed, not for driving capacitive loads. Output capacitance will create a pole in the amplifier's feedback path, leading to excessive peaking and potential oscillation. If dealing with load capacitance is a requirement of the application, the two strategies to consider are (1) using a small resistor in series with the amplifier's output and the load capacitance and (2) reducing the bandwidth of the amplifier's feedback loop by increasing the overall noise gain. Figure 2 shows a unity gain follower using the series resistor strategy. The resistor isolates the output from the capacitance and, more importantly, creates a zero in the feedback path that compensates for the pole created by the output capacitance.

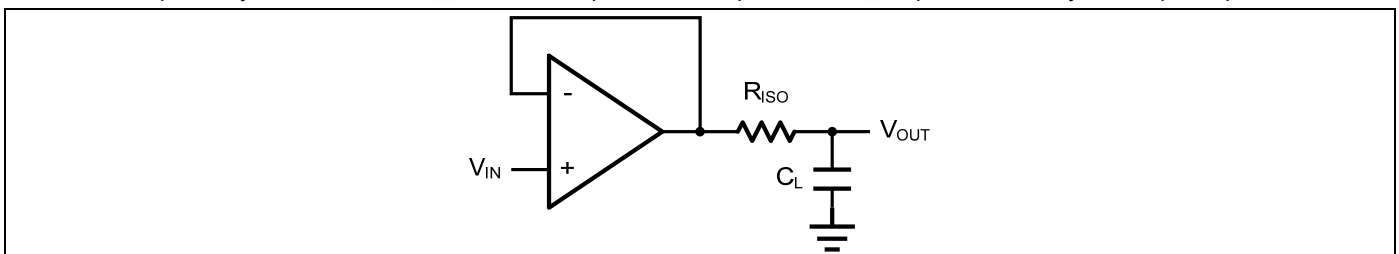


Figure 2 Indirectly Driving a Capacitive Load Using Isolation Resistor

The bigger the  $R_{ISO}$  resistor value, the more stable  $V_{OUT}$  will be. However, if there is a resistive load  $R_L$  in parallel with the capacitive load, a voltage divider (proportional to  $R_{ISO}/R_L$ ) is formed, this will result in a gain error.

The circuit in Figure 3 is an improvement to the one in Figure 2.  $R_F$  provides the DC accuracy by feed-forward the  $V_{IN}$  to  $R_L$ .  $C_F$  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 the phase margin in the overall feedback loop. Capacitive drive can be increased by increasing the value of  $C_F$ . This in turn will slow down the pulse response.

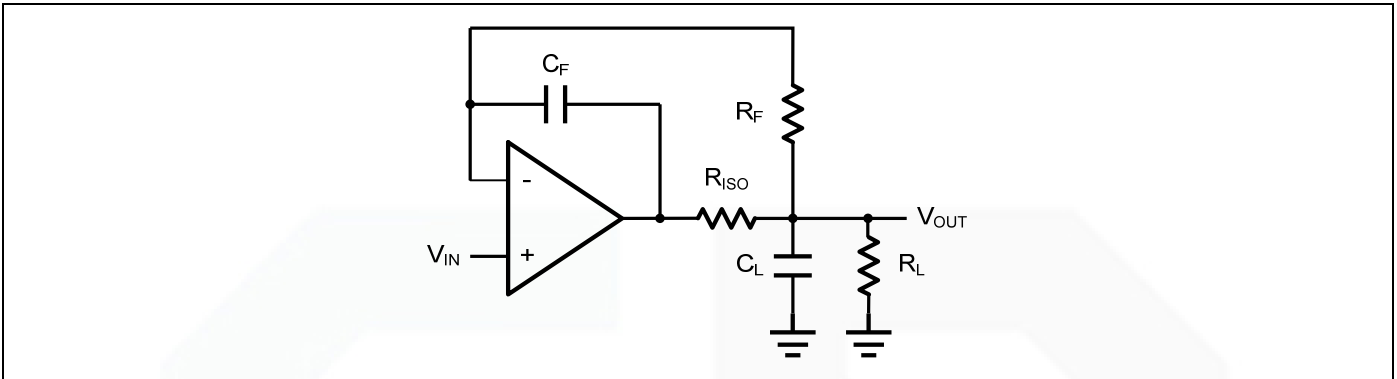


Figure 3. Indirectly Driving a Capacitive Load with DC Accuracy

## Typical Application Circuits

### Differential amplifier

The differential amplifier allows the subtraction of two input voltages or cancellation of a signal common the two inputs. It is useful as a computational amplifier in making a differential to single-end conversion or in rejecting a common mode signal. Figure 4. shown the differential amplifier using GS600X family.

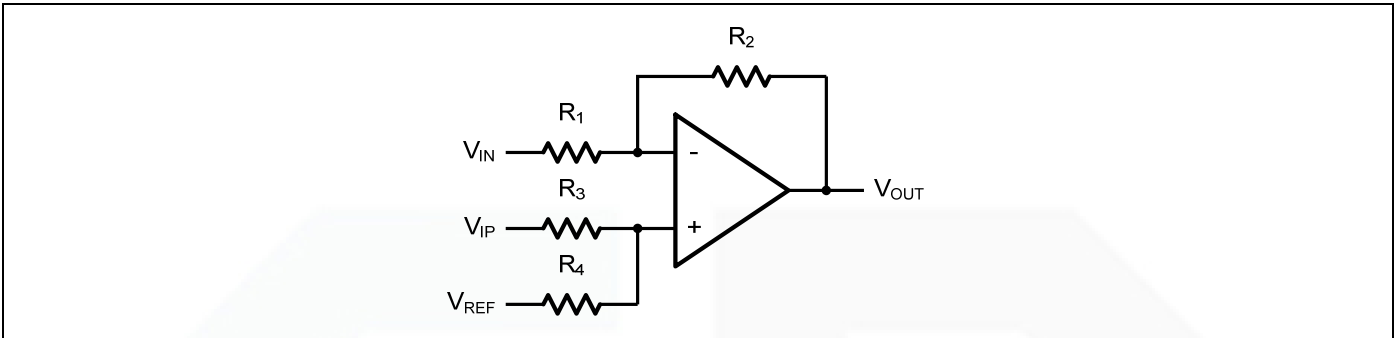


Figure 4. Differential Amplifier

$$V_{OUT} = \left(\frac{R_1+R_2}{R_3+R_4}\right) \frac{R_4}{R_1} V_{IN} - \frac{R_2}{R_1} V_{IP} + \left(\frac{R_1+R_2}{R_3+R_4}\right) \frac{R_3}{R_1} V_{REF}$$

If the resistor ratios are equal (i.e.  $R_1=R_3$  and  $R_2=R_4$ ), then

$$V_{OUT} = \frac{R_2}{R_1} (V_{IP} - V_{IN}) + V_{REF}$$

### Low Pass Active Filter

The low pass active filter is shown in Figure 5. The DC gain is defined by  $-R_2/R_1$ . The filter has a -20dB/decade roll-off after its corner frequency  $f_c=1/(2\pi R_3 C_1)$ .

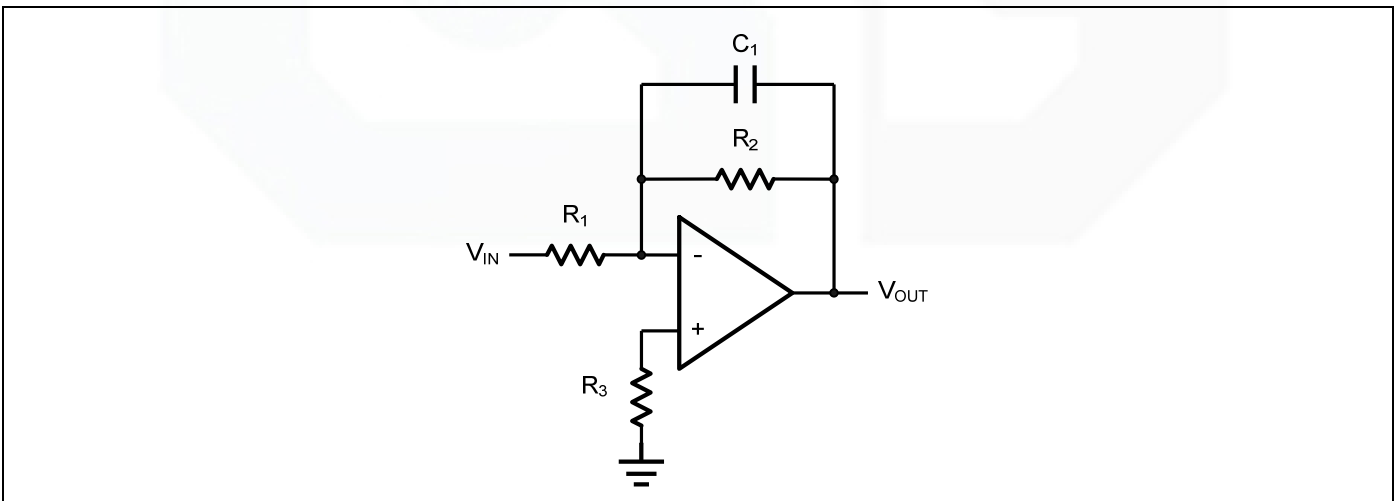


Figure 5. Low Pass Active Filter



Instrumentation Amplifier

The triple GS600X family can be used to build a three-op-amp instrumentation amplifier as shown in Figure 6. The amplifier in Figure 6 is a high input impedance differential amplifier with gain of  $R_2/R_1$ . The two differential voltage followers assure the high input impedance of the amplifier.

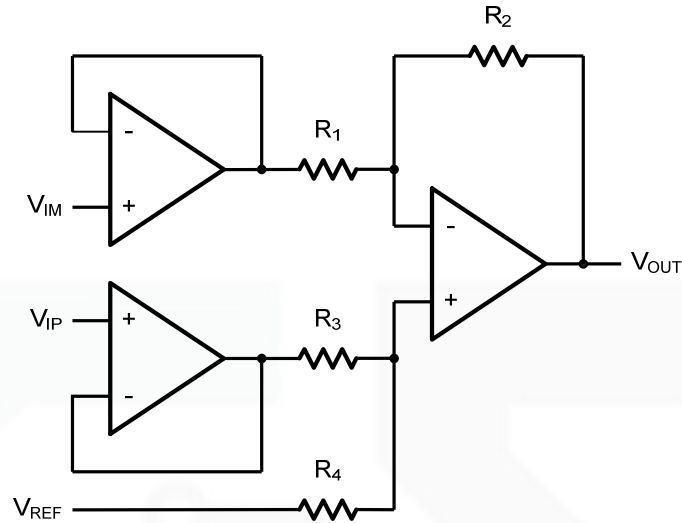
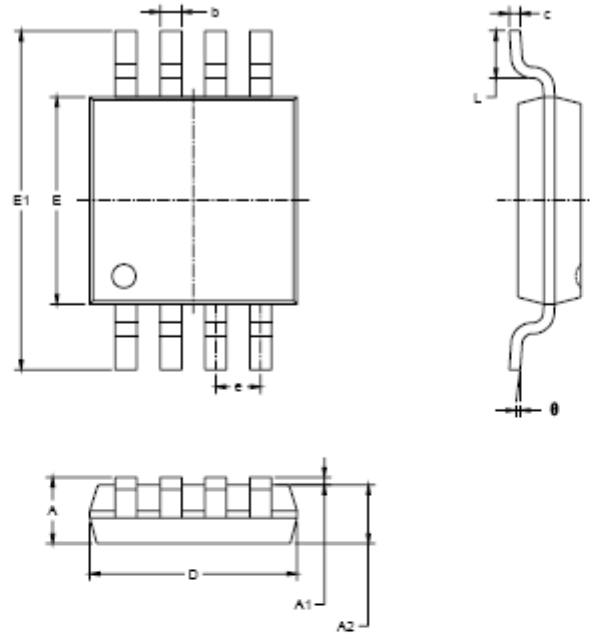


Figure 6. Instrument Amplifier

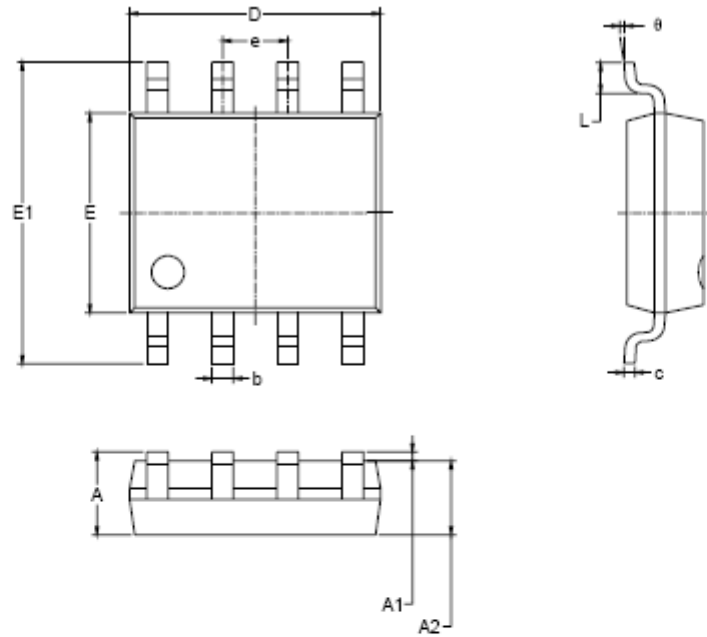
Package Information

MSOP-8



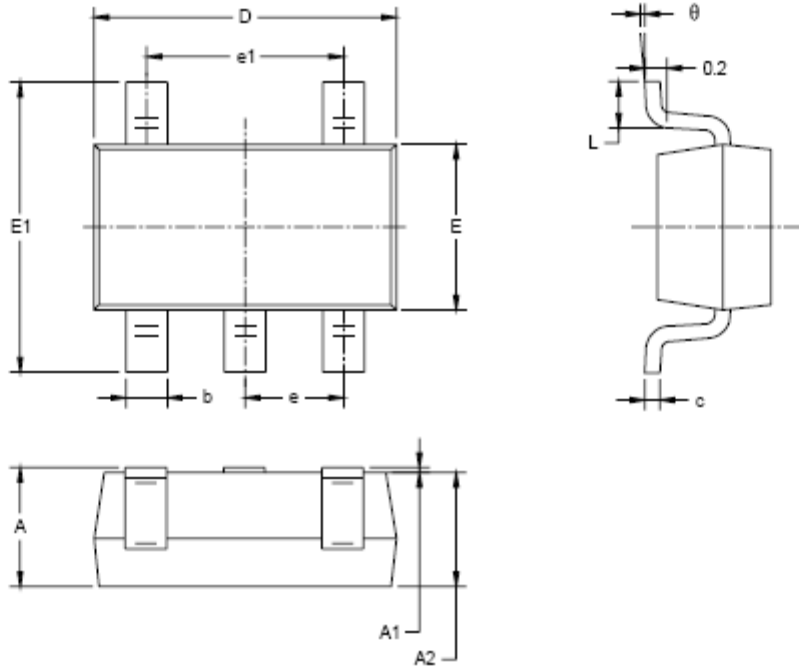
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.008
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
e	0.650 BSC		0.026 BSC	
L	0.400	0.800	0.016	0.031
θ	0°	8°	0°	8°

SOP-8



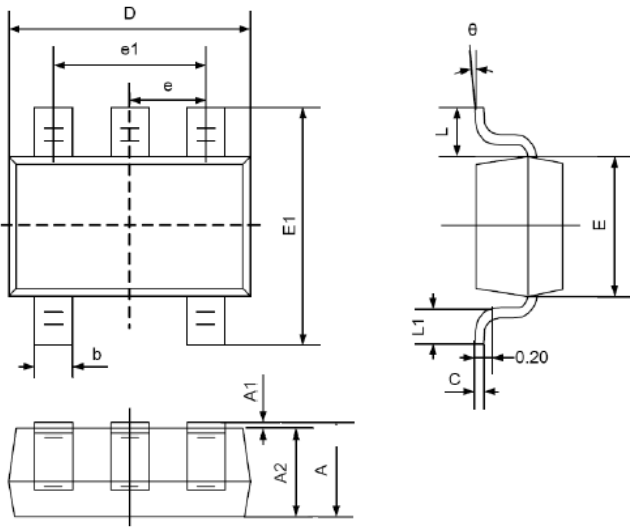
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.27 BSC		0.050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

SOT23-5



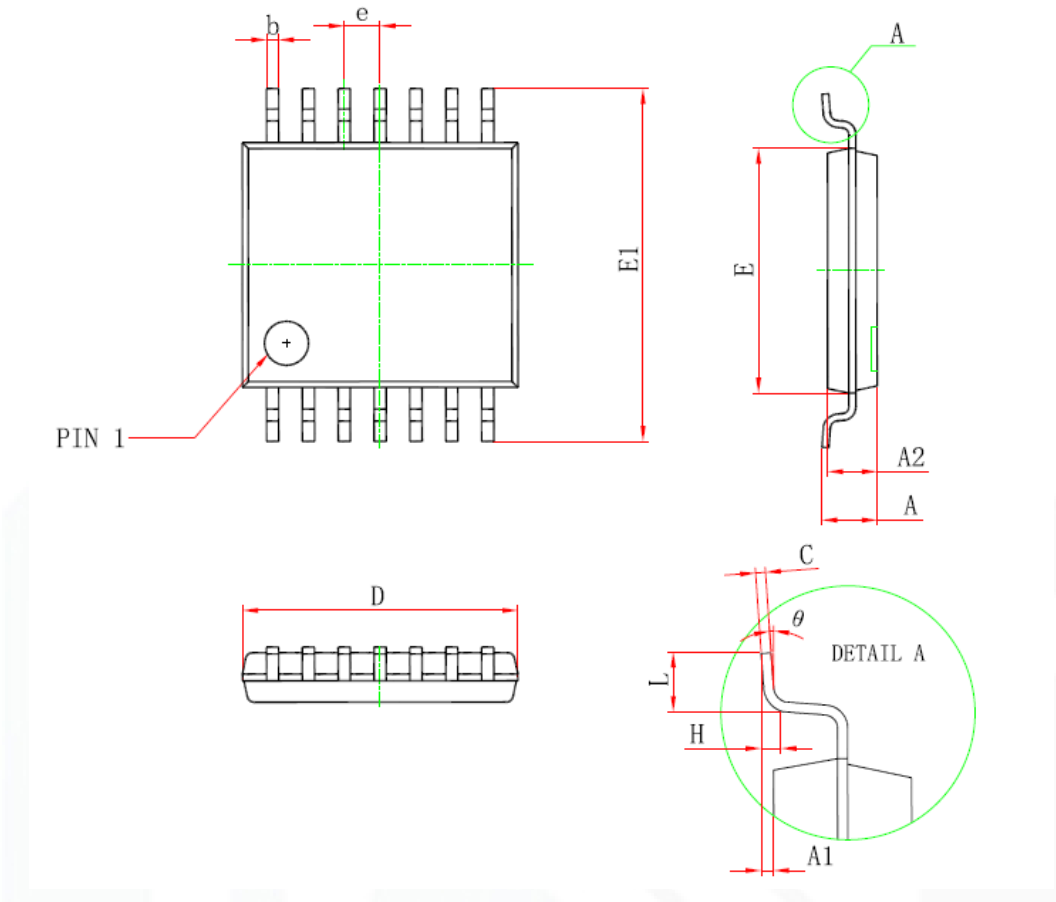
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950 BSC		0.037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

SC70-5



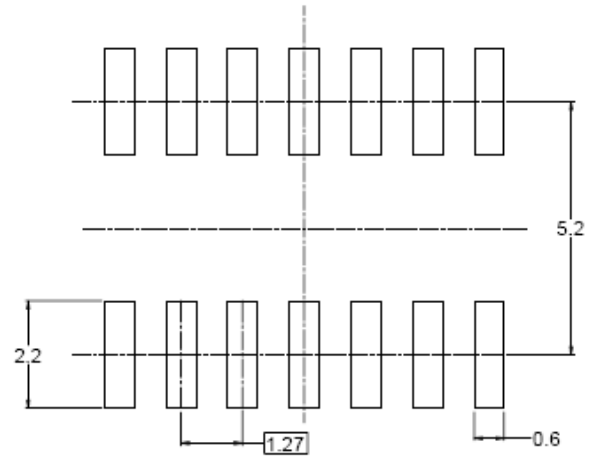
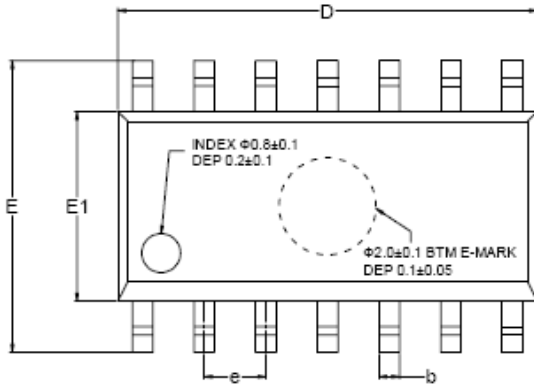
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.900	1.100	0.035	0.043
A1	0.000	0.100	0.000	0.004
A2	0.900	1.000	0.035	0.039
b	0.150	0.350	0.006	0.014
C	0.080	0.150	0.003	0.006
D	2.000	2.200	0.079	0.087
E	1.150	1.350	0.045	0.053
E1	2.150	2.450	0.085	0.096
e	0.650TYP		0.026TYP	
e1	1.200	1.400	0.047	0.055
L	0.525REF		0.021REF	
L1	0.260	0.460	0.010	0.018
θ	0°	8°	0°	8°



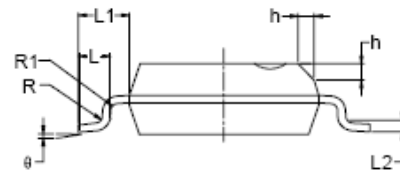
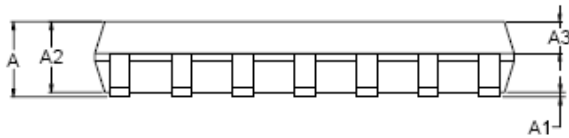


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
D	4.900	5.100	0.193	0.201
E	4.300	4.500	0.169	0.177
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
E1	6.250	6.550	0.246	0.258
A		1.200		0.047
A2	0.800	1.000	0.031	0.039
A1	0.050	0.150	0.002	0.006
e	0.65 (BSC)		0.026 (BSC)	
L	0.500	0.700	0.020	0.028
H	0.25(TYP)		0.01(TYP)	
$\theta$	1°	7°	1°	7°

SOP-14



RECOMMENDED LAND PATTERN (Unit: mm)



Symbol	Dimensions In Millimeters			Dimensions In Inches		
	MIN	MOD	MAX	MIN	MOD	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
$\theta$	0°		8°	0°		8°

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