

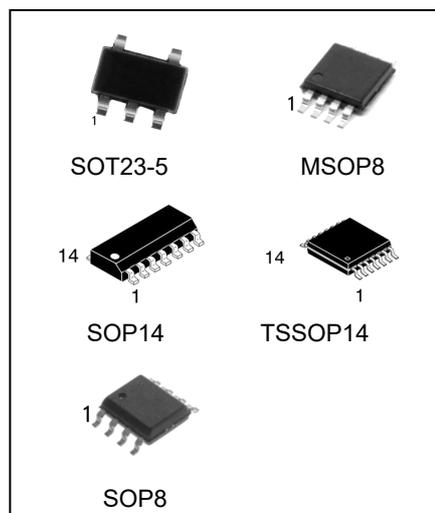
## Features

- Single-Supply Operation from +1.8V ~ +5.5V
- Rail-to-Rail Input / Output
- Gain-Bandwidth Product: 4.5MHz (Typ@25°C)
- Low Input Bias Current: 20pA (Typ@25°C)
- Low Offset Voltage: 30μV (Max @25°C)
- Quiescent Current: 550μA per Amplifier (Typ)
- Operating Temperature: -45°C ~ +125°C
- Zero Drift: 0.01μV/°C (Typ)
- Embedded RF Anti-EMI Filter
- Small Package:

HG376 Available in SOT23-5 and SOP-8 Packages

HG2376 Available in MSOP-8 and SOP-8 Packages

HG4376 Available in SOP-14 and TSSOP-14 Packages



## Ordering Information

DEVICE	Package Type	MARKING	Packing	Packing Qty
HG376M5/TR	SOT23-5	A376	REEL	3000pcs/reel
HG376M/TR	SOP8L	HG376	REEL	2500pcs/reel
HG2376M/TR	SOP8L	HG2376	REEL	2500pcs/reel
HG2376MM/TR	MSOP8L	A2376	REEL	3000pcs/reel
HG4376M/TR	SOP14L	HG4376	REEL	2500pcs/reel
HG4376MT/TR	TSSOP14L	HG4376	REEL	2500pcs/reel

## General Description

The HGx376 amplifier is single/dual/quad supply, micro-power, zero-drift CMOS operational amplifiers, the amplifiers offer bandwidth of 4.5MHz, rail-to-rail inputs and outputs, and single-supply operation from 1.8V to 5.5V. HGx376 uses chopper stabilized technique to provide very low offset voltage (less than 30 $\mu$ V maximum) and near zero drift over temperature. Low quiescent supply current of 550 $\mu$ A per amplifier and very low input bias current of 20pA make the devices an ideal choice for low offset, low power consumption and high impedance applications. The HGx376 offers excellent CMRR without the crossover associated with traditional complementary input stages. This design results in superior performance for driving analog-to-digital converters (ADCs) without degradation of differential linearity.

The HG376 is available in SOT23-5 and SOP-8 packages. And the HG2376 is available in MSOP-8 and SOP-8 packages. The HG4376 Quad is available in Green SOP-14 and TSSOP-14 packages. The extended temperature range of -45 $^{\circ}$ C to +125 $^{\circ}$ C over all supply voltages offers additional design flexibility.

## Applications

- Transducer Application
- Temperature Measurements
- Electronics Scales
- Handheld Test Equipment
- Battery-Powered Instrumentat

## Pin Configuration

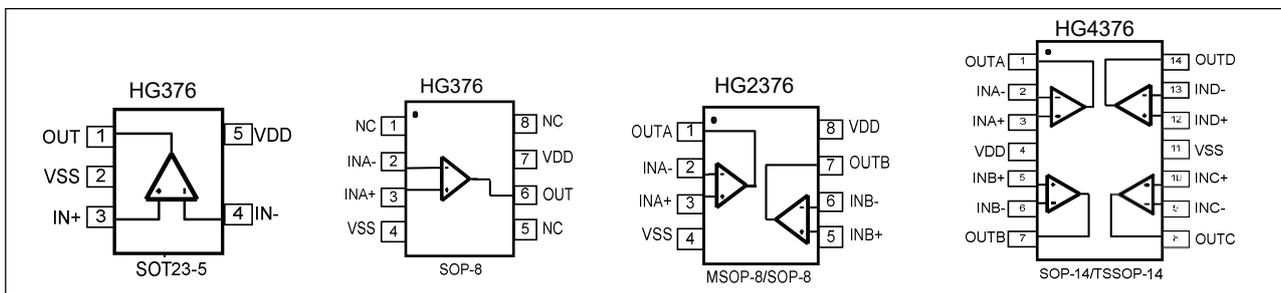


Figure 1. Pin Assignment Diagram

## Absolute Maximum Ratings

Condition	Min	Max
Power Supply Voltage (VDD to Vss)	-0.5V	+7.5V
Analog Input Voltage (IN+ or IN-)	Vss-0.5V	VDD+0.5V
PDB Input Voltage	Vss-0.5V	+7V
Operating Temperature Range	-45°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, $\theta_{JA}$	125°C/W	
MSOP-8, $\theta_{JA}$	216°C/W	
SOT23-5, $\theta_{JA}$	190°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.

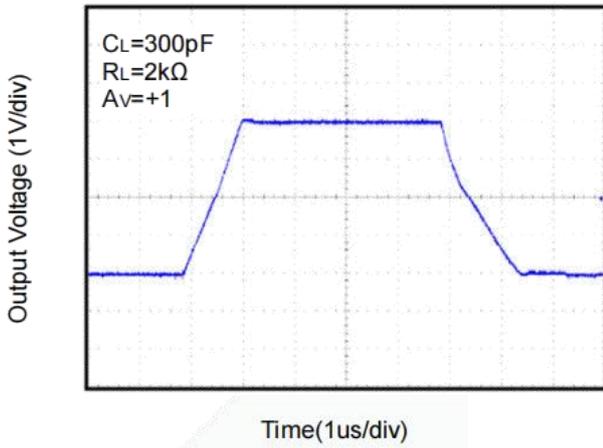
## Electrical Characteristics

(VS = +5V, VCM = +2.5V, VO = +2.5V, TA = +25°C, unless otherwise noted.)

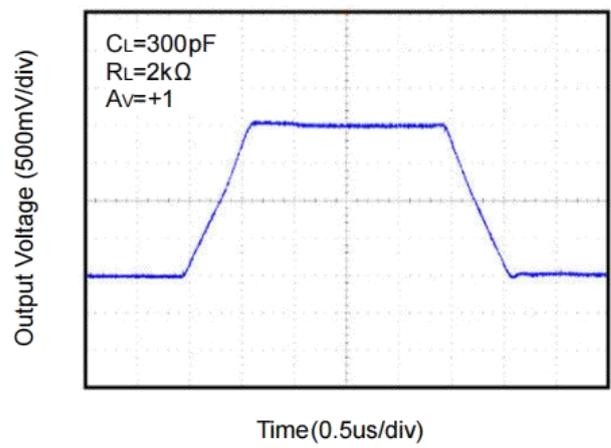
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
<b>INPUT CHARACTERISTICS</b>					
Input Offset Voltage (VOS)			1	30	μV
Input Bias Current (IB)			20		pA
Input Offset Current (IOS)			10		pA
Common-Mode Rejection Ratio (CMRR)	VCM = 0V to 5V		110		dB
Large Signal Voltage Gain (AVO)	RL = 10kΩ, VO = 0.3V to 4.7V		145		dB
Input Offset Voltage Drift (ΔVOS/ΔT)			10	50	nV/°C
<b>OUTPUT CHARACTERISTICS</b>					
Output Voltage High (VOH)	RL = 100kΩ to -VS		4.998		V
	RL = 10kΩ to -VS		4.994		V
Output Voltage Low (VOL)	RL = 100kΩ to +VS		2		mV
	RL = 10kΩ to +VS		5		mV
Short Circuit Limit (ISC)	RL = 10Ω to -VS		43		mA
Output Current (IO)			30		mA
<b>POWER SUPPLY</b>					
Power Supply Rejection Ratio (PSRR)	VS = 2.5V to 5.5V		115		dB
Quiescent Current (IQ)	VO = 0V, RL = 0Ω		550		μA
<b>DYNAMIC PERFORMANCE</b>					
Gain-Bandwidth Product (GBP)	G = +100		4.5		MHz
Slew Rate (SR)	RL = 10kΩ		2.5		V/μs
Overload Recovery Time			0.10		ms
<b>NOISE PERFORMANCE</b>					
Voltage Noise (en p-p)	0Hz to 10Hz		0.2		μVP-P
Voltage Noise Density (en)	f = 1kHz		30		nV/√Hz

**Typical Performance characteristics**

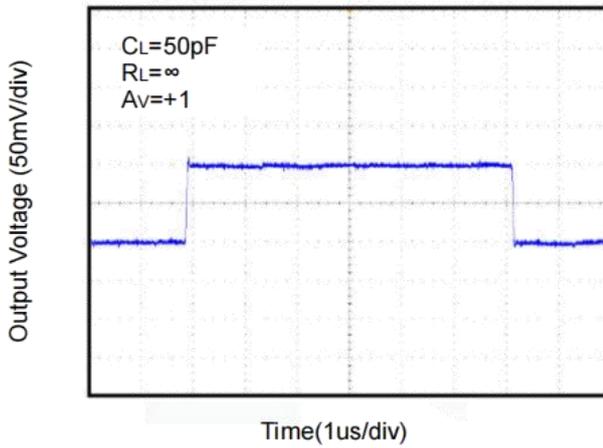
Large Signal Transient Response at +5V



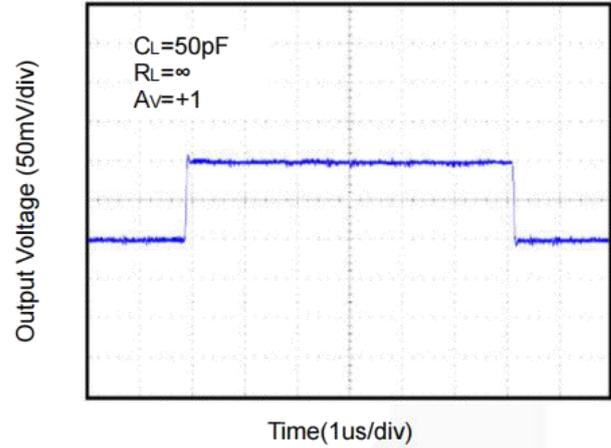
Large Signal Transient Response at +2.5V



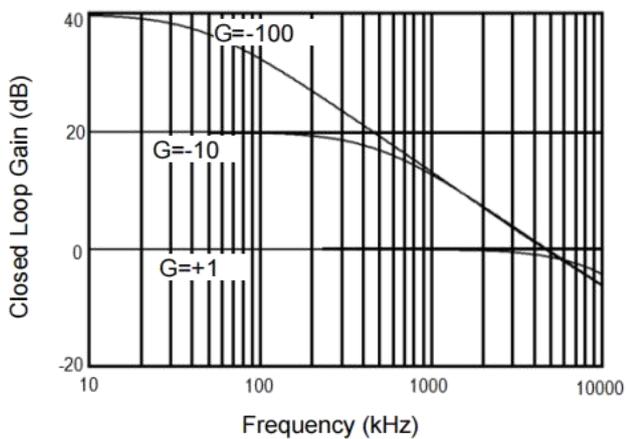
Small Signal Transient Response at +5V



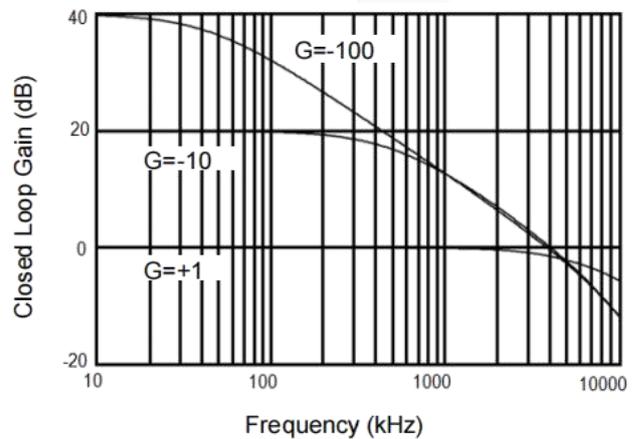
Small Signal Transient Response at +2.5V



Closed Loop Gain vs. Frequency at +5V

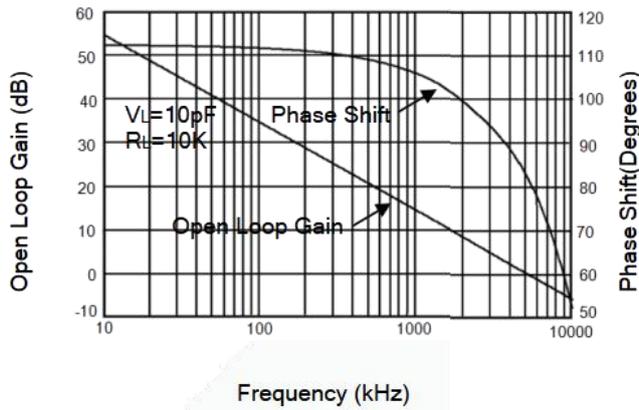


Closed Loop Gain vs. Frequency at +2.5V

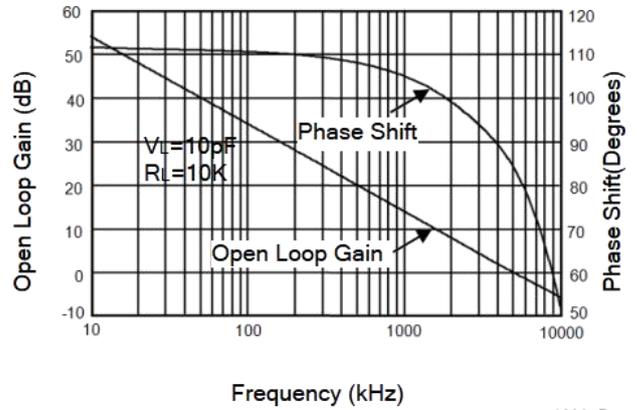


Typical Performance characteristics

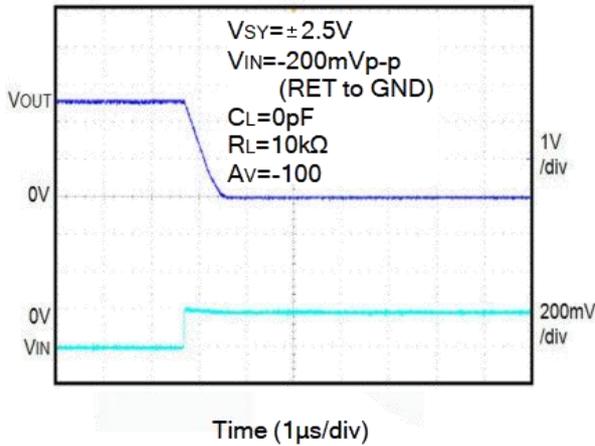
Open Loop Gain, Phase Shift vs. Frequency at +5V



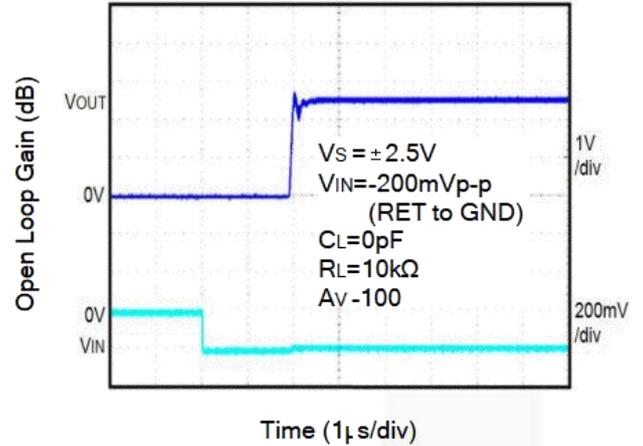
Open Loop Gain, Phase Shift vs. Frequency at +2.5V



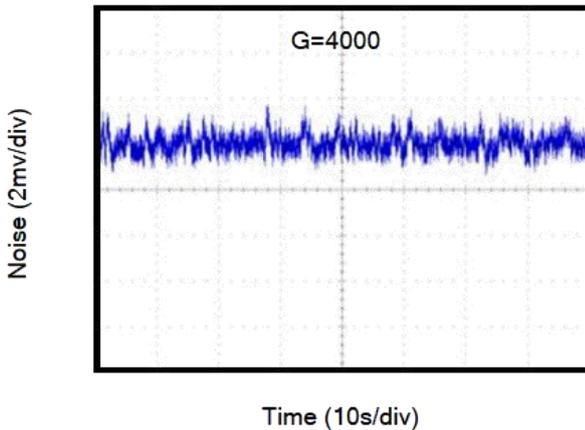
Positive Overvoltage Recovery



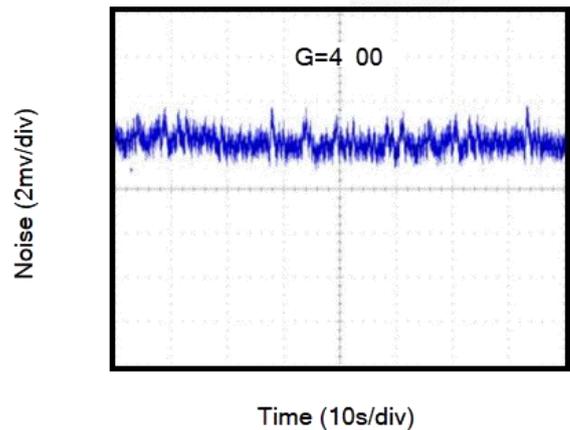
Negative Overvoltage Recovery



0.1Hz to 10Hz Noise at +5V



0.1Hz to 10Hz Noise at +2.5V



## Application Note Size

HGx376 series op amps are unity-gain stable and suitable for a wide range of general-purpose applications. The small footprints of the HGx376 series packages save space on printed circuit boards and enable the design of smaller electronic products.

## Power Supply Bypassing and Board Layout

HGx376 series operates from a single 1.8V to 5.5V supply or dual  $\pm 0.9V$  to  $\pm 2.75V$  supplies. For best performance, a 0.1 $\mu F$  ceramic capacitor should be placed close to the VDD pin in single supply operation. For dual supply operation, both VDD and VSS supplies should be bypassed to ground with separate 0.1 $\mu F$  ceramic capacitors.

## Low Supply Current

The low supply current (typical 550 $\mu A$  per channel) of HGx376 series will help to maximize battery life. They are ideal for battery powered systems.

## Operating Voltage

HGx376 series operate under wide input supply voltage (1.8V to 5.5V). In addition, all temperature specifications apply from -40 °C to +125 °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 HGx376 series extends 100mV beyond the supply rails (VSS-0.1V to VDD+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 HGx376 series can typically swing to less than 5mV from supply rail in light resistive loads (>100k $\Omega$ ), and 60mV of supply rail in moderate resistive loads (10k $\Omega$ ).

## Capacitive Load Tolerance

The HGx376 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.

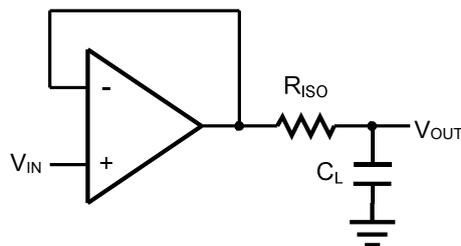


Figure 2. Indirectly Driving a Capacitive Load Using Isolation Resistor

The bigger the RISO resistor value, the more stable VOUT will be. However, if there is a resistive load RL in parallel with the capacitive load, a voltage divider (proportional to RISO/RL) is formed, this will result in a gain error.

The circuit in Figure 3 is an improvement to the one in Figure 2. RF provides the DC accuracy by feed-forward the VIN to RL. CF and RISO 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 CF. This in turn will slow down the pulse response.

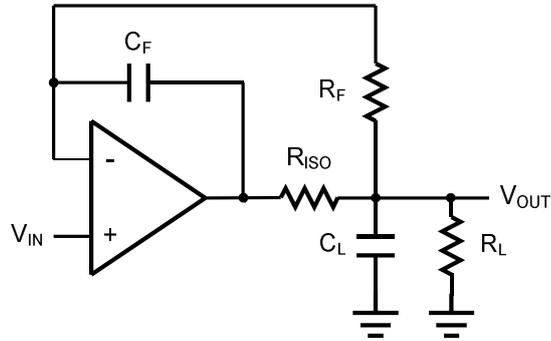


Figure 3. Indirectly Driving a Capacitive Load with DC Accuracy

## 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 HGx376.

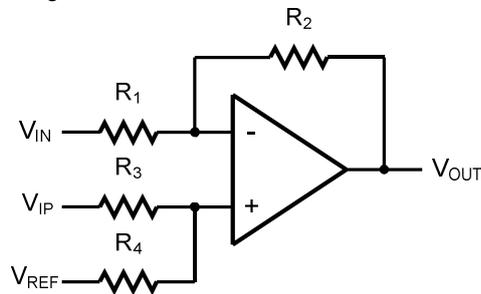


Figure 4. Differential Amplifier

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

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  $-20\text{dB/decade}$  roll-off after its corner frequency  $f_c=1/(2\pi R_3 C_1)$ .

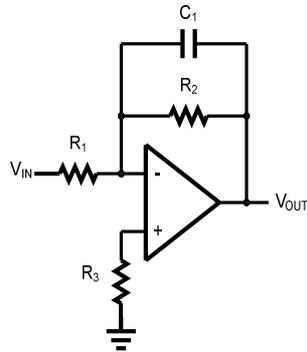


Figure 5. Low Pass Active Filter

### Instrumentation Amplifier

The triple HGx376 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.

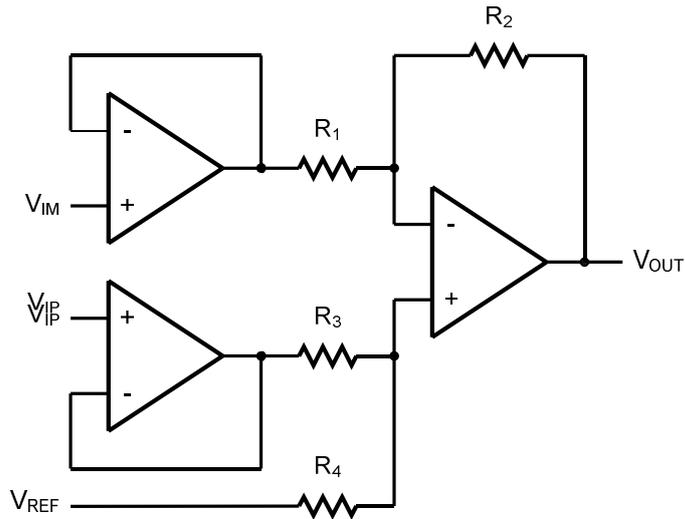
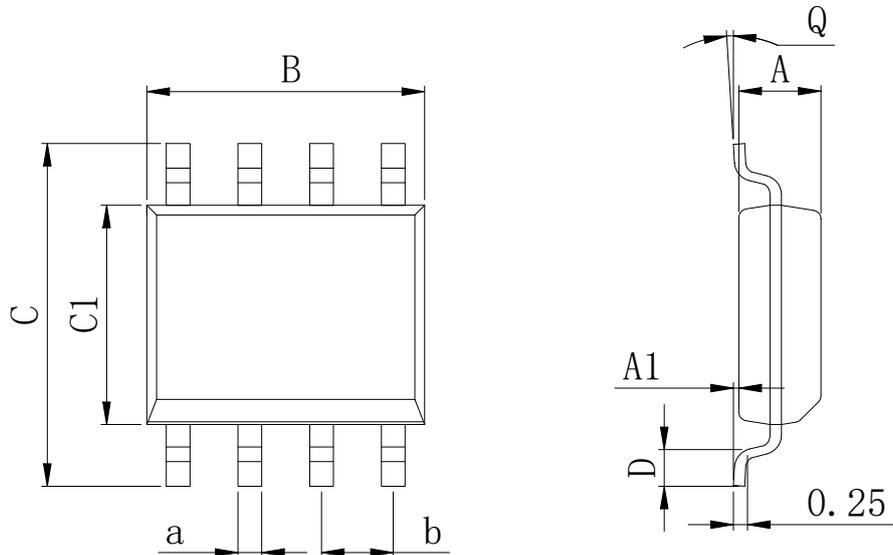


Figure 6. Instrument Amplifier

## Physical Dimensions

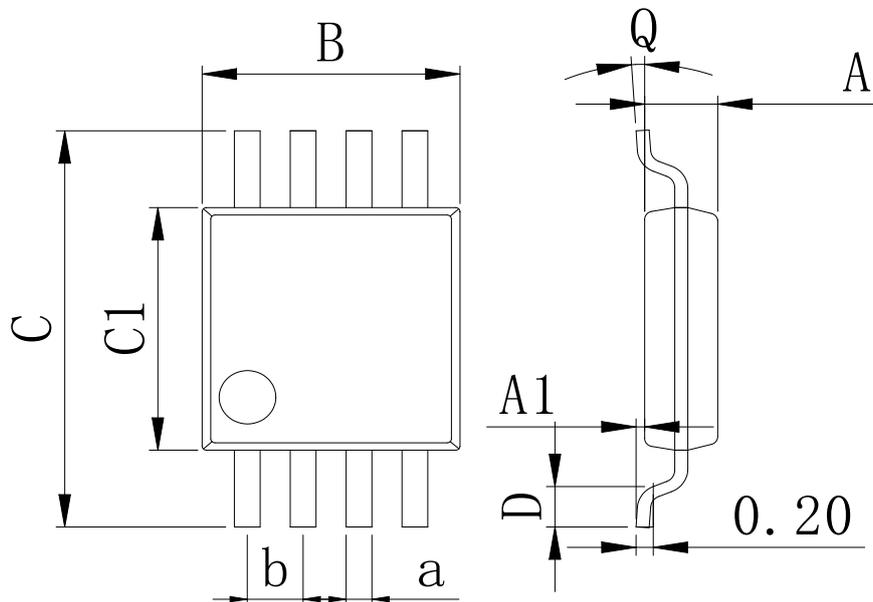
SOP8



Dimensions In Millimeters(SOP8)

Symbol:	A	A1	B	C	C1	D	Q	a	b
Min:	1.35	0.05	4.90	5.80	3.80	0.40	0°	0.35	1.27 BSC
Max:	1.55	0.20	5.10	6.20	4.00	0.80	8°	0.45	

MSOP8

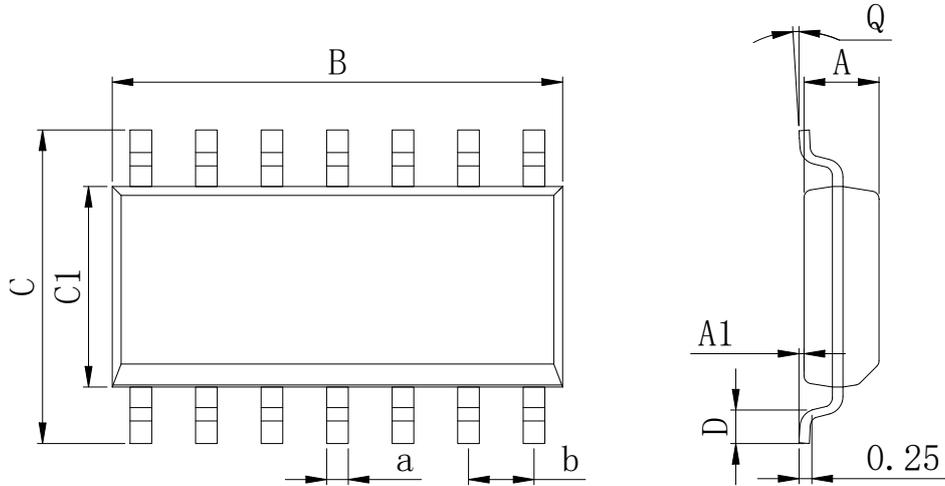


Dimensions In Millimeters(MSOP8)

Symbol:	A	A1	B	C	C1	D	Q	a	b
Min:	0.80	0.05	2.90	4.75	2.90	0.35	0°	0.25	0.65 BSC
Max:	0.90	0.20	3.10	5.05	3.10	0.75	8°	0.35	

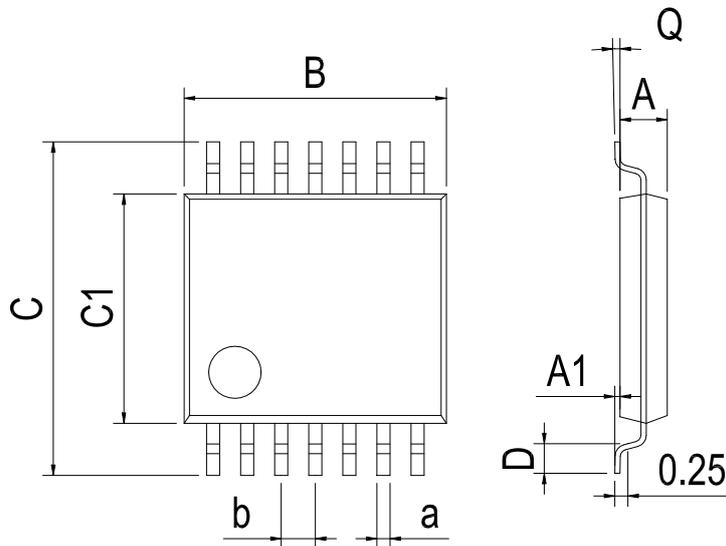
## Physical Dimensions

SOP14



Dimensions In Millimeters(SOP14)									
Symbol:	A	A1	B	C	C1	D	Q	a	b
Min:	1.35	0.05	8.55	5.80	3.80	0.40	0°	0.35	1.27 BSC
Max:	1.55	0.20	8.75	6.20	4.00	0.80	8°	0.45	

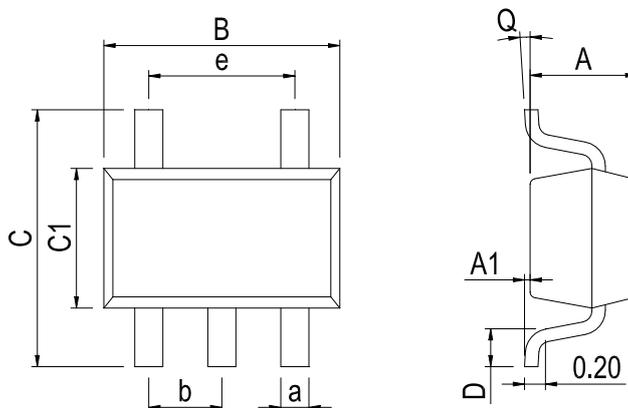
TSSOP14



Dimensions In Millimeters(TSSOP14)									
Symbol:	A	A1	B	C	C1	D	Q	a	b
Min:	0.85	0.05	4.90	6.20	4.30	0.40	0°	0.20	0.65 BSC
Max:	0.95	0.20	5.10	6.60	4.50	0.80	8°	0.25	

## Physical Dimensions

SOT23-5



Dimensions In Millimeters(SOT23-5)

Symbol:	A	A1	B	C	C1	D	Q	a	b	e
Min:	1.05	0.00	2.82	2.65	1.50	0.30	0°	0.30	0.95 BSC	1.90 BSC
Max:	1.15	0.15	3.02	2.95	1.70	0.60	8°	0.40		

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