

## General Description

The EC5731 amplifier is single supply, micro-power, zero-drift CMOS operational amplifier, the amplifier offer bandwidth of 350kHz, rail-to-rail inputs and outputs, and single-supply operation from 2.2V to 5.5V. EC5731 uses chopper stabilized technique to provide very low offset voltage (less than 20 $\mu$ V maximum) and near zero drift over temperature. Low quiescent supply current of 20 $\mu$ A and very low input bias current of 10pA make the devices an ideal choice for low offset, low power consumption and high impedance applications. The single EC5731 is available in space-saving, SOT23-5 and SOP-8 package. The extended temperature range of -40 $^{\circ}$ C to +125 $^{\circ}$ C over all supply voltages offers additional design flexibility.

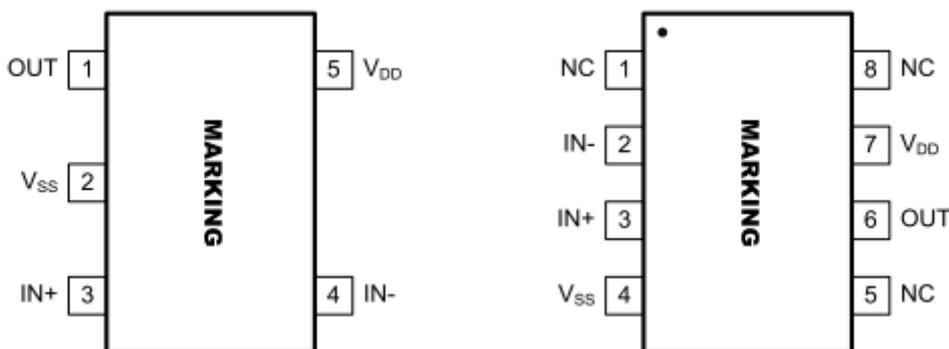
## Features

- Single-Supply Operation from +2.2V ~ +5.5V
- Rail-to-Rail Input / Output
- Gain-Bandwidth Product: 350kHz (Typ.)
- Low Input Bias Current: 10pA (Typ.)
- Quiescent Current: 20 $\mu$ A (Typ.)
- Operating Temperature: -40 $^{\circ}$ C ~ +125 $^{\circ}$ C
- Available in SOT23-5 and SOP8 Packages

## Applications

- Portable Equipment
- Mobile Communications
- Smoke Detector
- Medical Instrumentation
- Battery-Powered Instruments
- Handheld Test Equipment

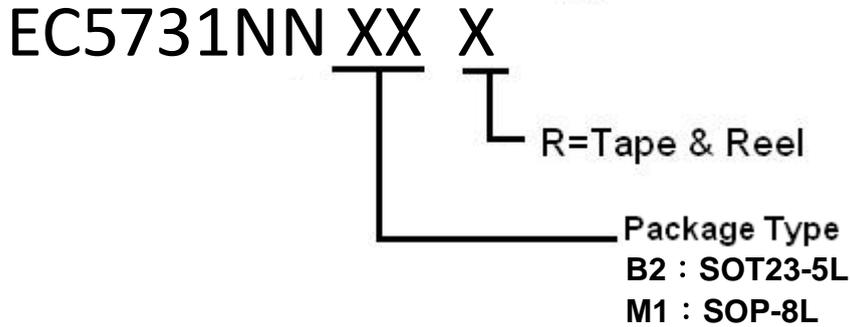
## Pin Assignments



**Figure 1. Pin Assignment Diagram (SOT23-5 and SOP8 Package)**



## Ordering Information



Part Number	Package	Marking	Marking Information
EC5731NNB2R	SOT23-5L	731YW	1. Y : Year code(D=2013;E=2014;F=2015...) 2. W : Week Code( The big character of A~Z is for the week of 1~26, and small a~z is for the week of 27~52.
EC5731NNM1R	SOP-8L	EC5731 LLLLL YYWWT	1. LLLLL : Last five Number of Lot No 2. YY : Year Code 3. WW : Week Code 4. T : Internal Tracking Code

## Application Information

### Size

EC5731 series op amps are unity-gain stable and suitable for a wide range of general-purpose applications. The small footprints of the EC5731 series packages save space on printed circuit boards and enable the design of smaller electronic products.

### Power Supply Bypassing and Board Layout

EC5731 series operates from a single 2.2V to 5.5V supply or dual  $\pm 1.1V$  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 20 $\mu A$ ) of EC5731 series will help to maximize battery life. They are ideal for battery powered Systems

## Operating Voltage

EC5731 series operate under wide input supply voltage (2.2V to 5.5V). In addition, all temperature specifications apply from  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ . 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

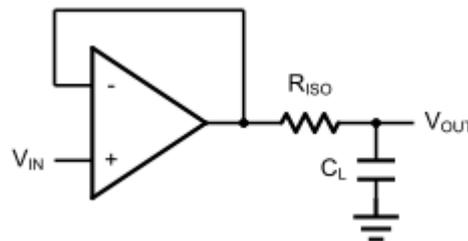
The input common-mode range of EC5731 series extends 100mV beyond the supply rails ( $V_{SS}-0.1\text{V}$  to  $V_{DD}+0.1\text{V}$ ). This is achieved by using complementary input stage. For normal operation, inputs should be limited to this range. Normally, input bias current is about 10pA; however, if the input voltages exceed the power supplies, excessive current can flow into or out of the pins. Momentary voltages greater than the power supply can be tolerated if the input current is limited to 10mA. This limitation can be accomplished with an 5k $\Omega$  series input resistor.

## 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 EC5731 series can typically swing to less than 10mV from supply rail in light resistive loads ( $>100\text{k}\Omega$ ), and 60mV of supply rail in moderate resistive loads (10k $\Omega$ ).

## Capacitive Load Tolerance

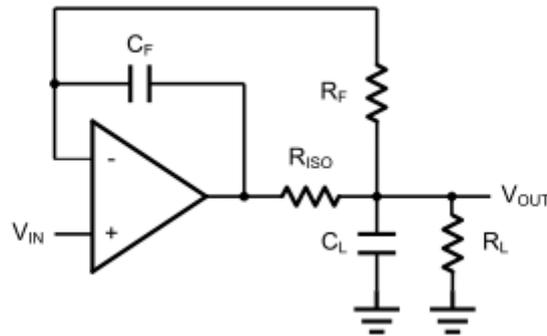
The EC5731 series can directly drive 250pF capacitive load in unity-gain without oscillation. Increasing the gain enhances the amplifier's ability to drive greater capacitive loads. In unity-gain configurations, the capacitive load drive can be improved by inserting an isolation resistor  $R_{ISO}$  in series with the capacitive load, as shown in Figure 2.



**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.

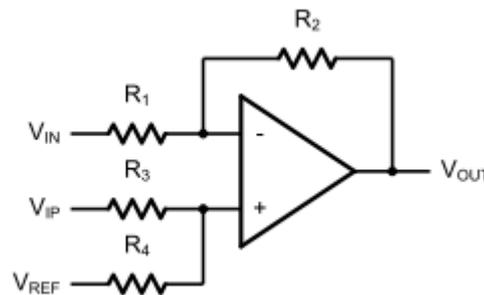
The circuit in Figure 3 is an improvement to the one in Figure 2.  $R_F$  provides the DC accuracy by feed-forward the  $V_{IN}$  to  $R_L$ .  $C_F$  and  $R_{ISO}$  serve to counteract the loss of phase margin by feeding the high frequency component of the output signal back to the amplifier's inverting 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**

### Differential amplifier

The differential amplifier allows the subtraction of two input voltages or cancellation of a signal common to 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 EC5731.



**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

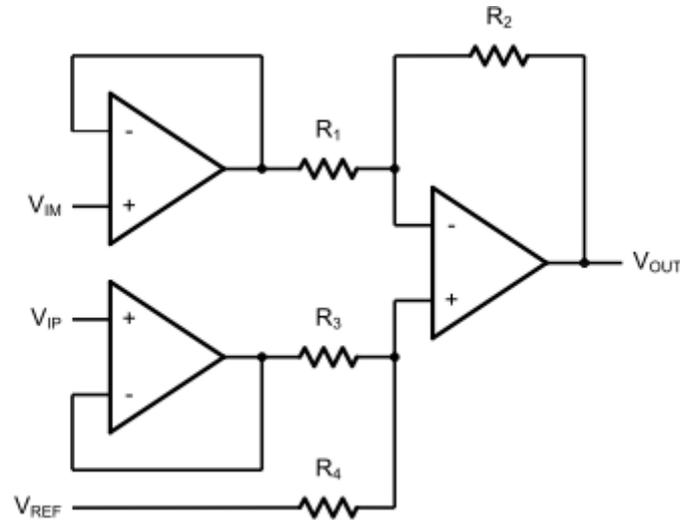
$$V_{OUT} = \frac{R_2}{R_1} (V_{IP} - V_{IN}) + V_{REF}$$

### Instrumentation Amplifier

The input impedance of the previous differential amplifier is set by the resistors  $R_1$ ,  $R_2$ ,  $R_3$ , and  $R_4$ . To maintain the high input impedance, one can use a voltage follower in front of each input as shown in the following two instrumentation amplifiers.

### Three-Op-Amp Instrumentation Amplifier

The triple EC5731 can be used to build a three-op-amp instrumentation amplifier as shown in Figure 5.



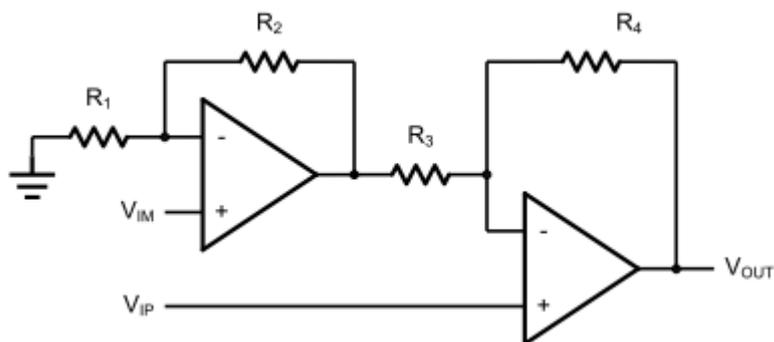
**Figure 5. Three-Op-Amp Instrumentation Amplifier**

The amplifier in Figure 5 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.

$$V_o = \left(1 + \frac{R_4}{R_3}\right)(V_{IP} - V_{IN})$$

### Two-Op-Amp Instrumentation Amplifier

EC5731 can also be used to make a high input impedance two-op-amp instrumentation amplifier as shown in Figure 6.

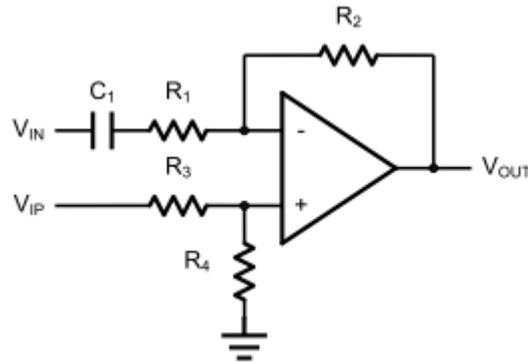


**Figure 6. Two-Op-Amp Instrumentation Amplifier**

Where  $R_1=R_3$  and  $R_2=R_4$ . If all resistors are equal, then  $V_o=2(V_{IP}-V_{IN})$

### Single-Supply Inverting Amplifier

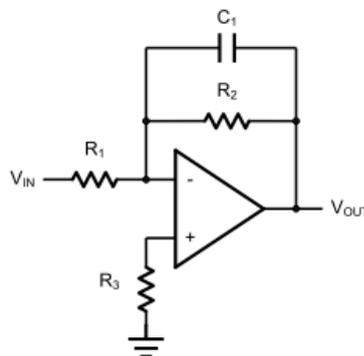
The inverting amplifier is shown in Figure 6. The capacitor C1 is used to block the DC signal going into the AC signal source  $V_{IN}$ . The value of R1 and C1 set the cut-off frequency to  $f_c = 1/(2\pi R_1 C_1)$ . The DC gain is defined by  $V_{OUT} = -(R_2/R_1)V_{IN}$



**Figure 7. Single Supply Inverting Amplifier**

### Low Pass Active Filter

The low pass active filter is shown in Figure 8. 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 8. Low Pass Active Filter**

### Sallen-Key 2nd Order Active Low-Pass Filter

EC5731 can be used to form a 2nd order Sallen-Key active low-pass filter as shown in Figure 9. The transfer function from  $V_{IN}$  to  $V_{OUT}$  is given by

$$\frac{V_{OUT}}{V_{IN}}(S) = \frac{\frac{1}{C_1 C_2 R_1 R_2} A_{LP}}{S^2 + S \left( \frac{1}{C_1 R_1} + \frac{1}{C_1 R_2} + \frac{1}{C_2 R_2} - \frac{A_{LP}}{C_2 R_2} \right) + \frac{1}{C_1 C_2 R_1 R_2}}$$

Where the DC gain is defined by  $A_{LP} = 1 + R_3/R_4$ , and the corner frequency is given by

$$\omega_c = \sqrt{\frac{1}{C_1 C_2 R_1 R_2}}$$

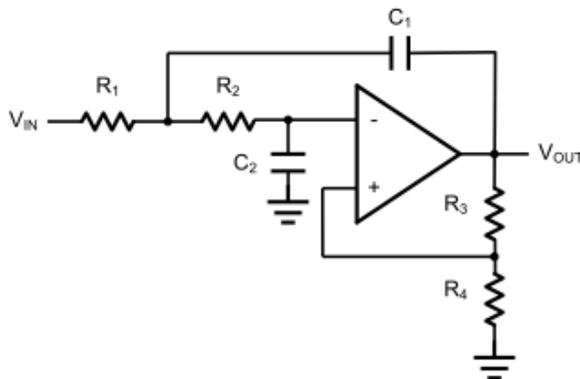
The pole quality factor is given by

$$\frac{\omega C}{Q} = \frac{1}{C_1 R_1} + \frac{1}{C_1 R_2} + \frac{1}{C_2 R_2} - \frac{A_{LP}}{C_2 R_2}$$

Let  $R_1=R_2=R$  and  $C_1=C_2=C$ , the corner frequency and the pole quality factor can be simplified as below

$$\omega_C = \frac{1}{CR}$$

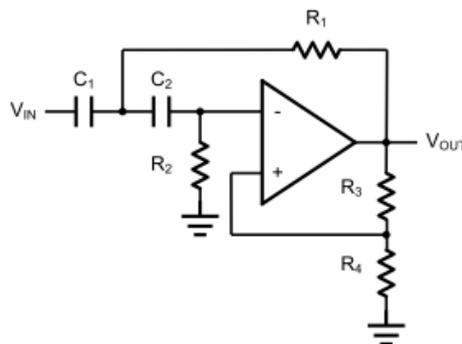
And  $Q=2-R_3/R_4$



**Figure 9. Sallen-Key 2nd Order Active Low-Pass Filter**

### Sallen-Key 2nd Order high-Pass Active Filter

The 2nd order Sallen-key high-pass filter can be built by simply interchanging those frequency selective components  $R_1$ ,  $R_2$ ,  $C_1$ , and  $C_2$  as shown in Figure 10.



**Figure 10. Sallen-Key 2nd Order Active High-Pass Filter**

$$\frac{V_{OUT}}{V_{IN}}(S) = \frac{S^2 A_{HP}}{S^2 + S\left(\frac{1}{C_1 R_1} + \frac{1}{C_2 R_2} + \frac{1-A_{HP}}{C_1 R_1}\right) + \frac{1}{C_1 C_2 R_1 R_2}}$$

Where  $A_{HP}=1+R_3/R_4$



## Electrical Characteristics

### Absolute Maximum Ratings

Condition	Min	Max
Power Supply Voltage ( $V_{DD}$ to $V_{SS}$ )	-0.5V	+7V
Analog Input Voltage ( $IN+$ or $IN-$ )	$V_{SS}-0.5V$	$V_{DD}+0.5V$
PDB Input Voltage	$V_{SS}-0.5V$	+7V
Operating Temperature Range	-40°C	+125°C
Junction Temperature		+150°C
Storage Temperature Range	-65°C	+150°C
Lead Temperature (soldering, 10sec)		+300°C
Package Thermal Resistance ( $T_A=+25^\circ C$ )		
SOP23-5, $\theta_{JA}$		190°C
SOP8, $\theta_{JA}$		130°C

**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

(VDD = +5V, VSS = 0V, VCM = 0V, VOUT = VDD/2, RL=100K tied to VDD/2, SHDNB = VDD, TA = -40°C to +125°C, unless otherwise noted. Typical values are at TA = +25°C.) (Notes 1)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
Supply-Voltage Range	V <sub>DD</sub>	Guaranteed by the PSRR test	2.2	-	5.5	V
Quiescent Supply Current (per Amplifier)		V <sub>DD</sub> = 5V	14	20	26	μA
Input Offset Voltage	V <sub>OS</sub>		-	-	20	μV
Input Offset Voltage Tempco	ΔV <sub>OS</sub> /ΔT		-	-	0.05	μV/°C
Input Bias Current	I <sub>B</sub>	(Note 2)	-	10	-	pA
Input Offset Current	I <sub>OS</sub>	(Note 2)	-	10	-	pA
Input Common-Mode Voltage Range	V <sub>CM</sub>		-0.1	-	V <sub>DD</sub> +0.1	V
Common-Mode Rejection Ratio	CMRR	V <sub>DD</sub> =5.5 V <sub>SS</sub> -0.1V V <sub>CM</sub> V <sub>DD</sub> +0.1V	90	110	-	dB
		V <sub>SS</sub> ≤V <sub>CM</sub> ≤5V	95	115	-	dB
Power-Supply Rejection Ratio	PSRR	V <sub>DD</sub> = +2.5V to +5.5V	85	105	-	dB
Open-Loop Voltage Gain	A <sub>V</sub>	V <sub>DD</sub> =5V, R <sub>L</sub> =100k , 0.05V≤V <sub>O</sub> ≤4.95V	100	120	-	dB
Output Voltage Swing	V <sub>OUT</sub>	V <sub>IN+</sub> -V <sub>IN-</sub>   10mV V <sub>DD</sub> -V <sub>OH</sub>	-	6	-	mV
		R <sub>L</sub> = 100k to V <sub>DD</sub> /2 V <sub>OL</sub> -V <sub>SS</sub>	-	6	-	mV
		V <sub>IN+</sub> -V <sub>IN-</sub>   10mV V <sub>DD</sub> -V <sub>OH</sub>	-	60	-	mV
		R <sub>L</sub> = 5k to V <sub>DD</sub> /2 V <sub>OL</sub> -V <sub>SS</sub>	-	60	-	mV
Output Short-Circuit Current	I <sub>SC</sub>	Sinking or Sourcing	-	5	-	mA
Gain Bandwidth Product	GBW	A <sub>V</sub> = +1V/V	-	350	-	kHz
Slew Rate	SR	A <sub>V</sub> = +1V/V	-	0.1	-	V/μs
Settling Time	t <sub>s</sub>	To 0.1%, V <sub>OUT</sub> = 2V step A <sub>V</sub> = +1V/V	-	20	-	μs
Over Load Recovery Time		V <sub>IN</sub> Gain=V <sub>s</sub>	-	100	-	μs
Input Voltage Noise Density	e <sub>n</sub>	f = 1kHz	-	30	-	nV/ Hz
		f = 10kHz	-	20	-	

**Note 1:** All devices are 100% production tested at TA = +25°C; all specifications over the automotive temperature range is guaranteed by design, not production tested.

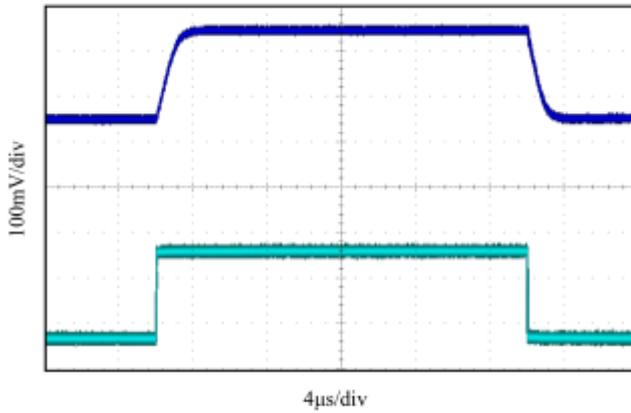
**Note 2:** Parameter is guaranteed by design.

### Typical characteristics

At  $T_A=+25^{\circ}\text{C}$ ,  $R_L=10\text{ k}\Omega$  connected to  $V_{S/2}$  and  $V_{OUT}=V_{S/2}$ , unless otherwise noted.

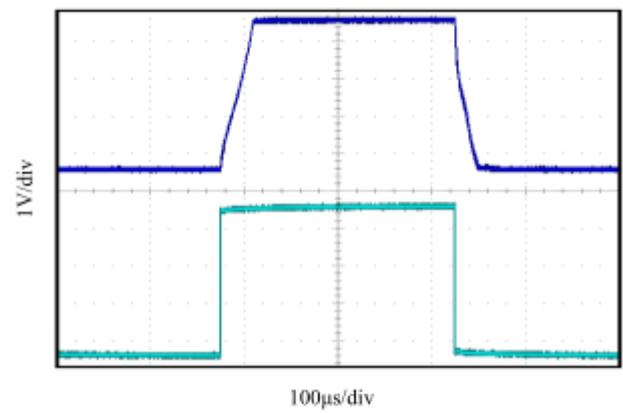
Small Signal Step Response

$G=+1\text{ V/V}$ ,  $R_L=10\text{ k}\Omega$ ,  $C_L=0\text{ pF}$

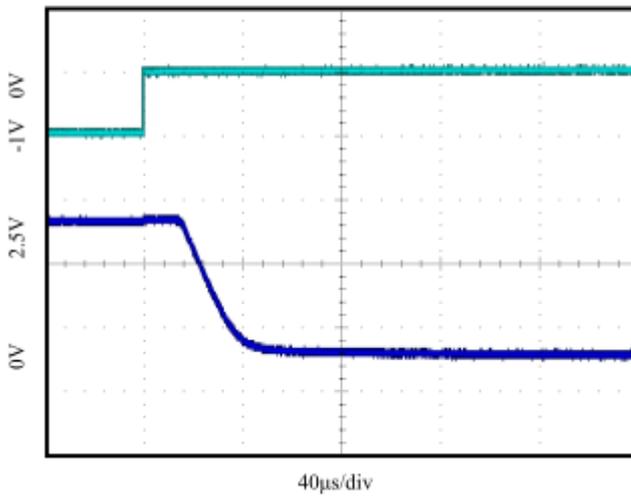


Large Signal Step Response

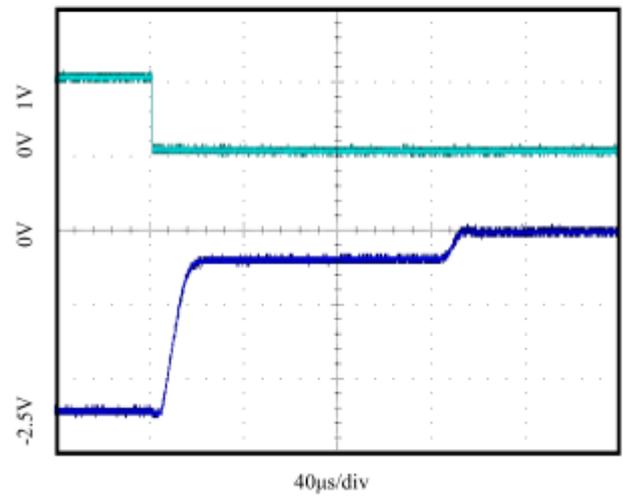
$G=+1\text{ V/V}$ ,  $R_L=100\text{ k}\Omega$ ,  $C_L=100\text{ pF}$



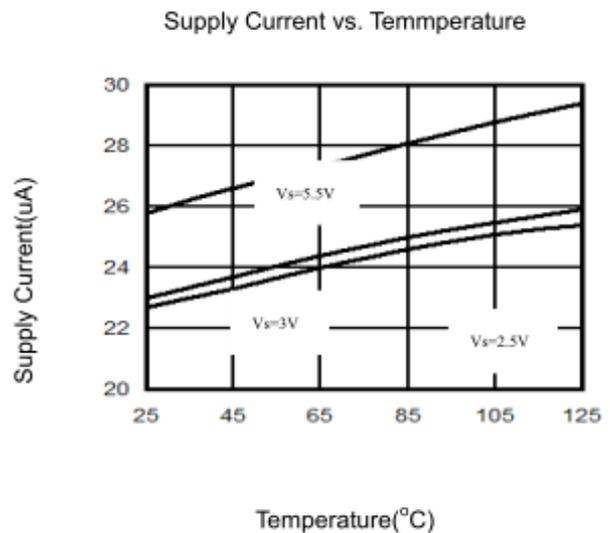
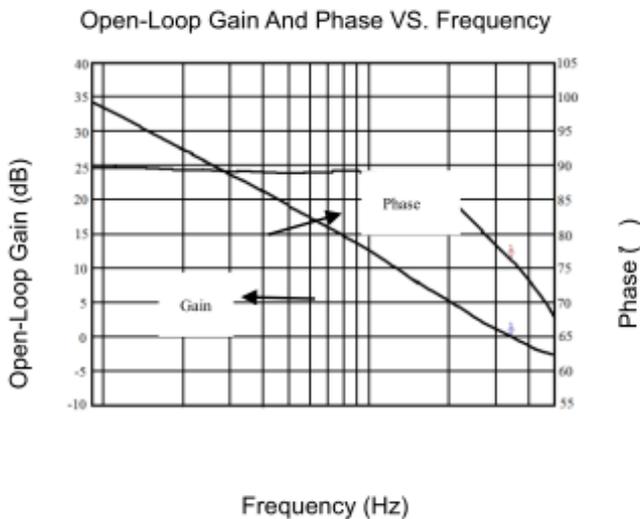
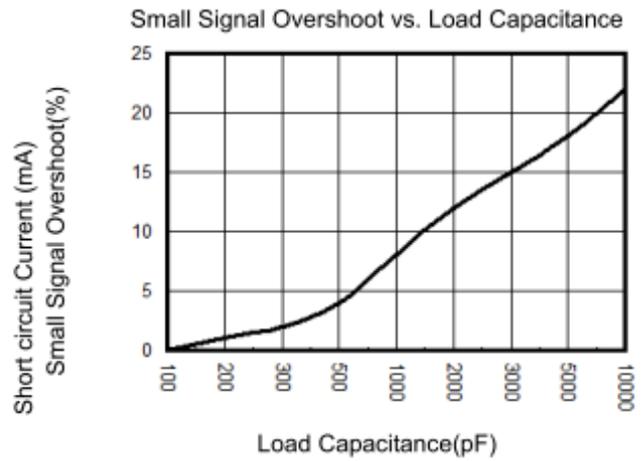
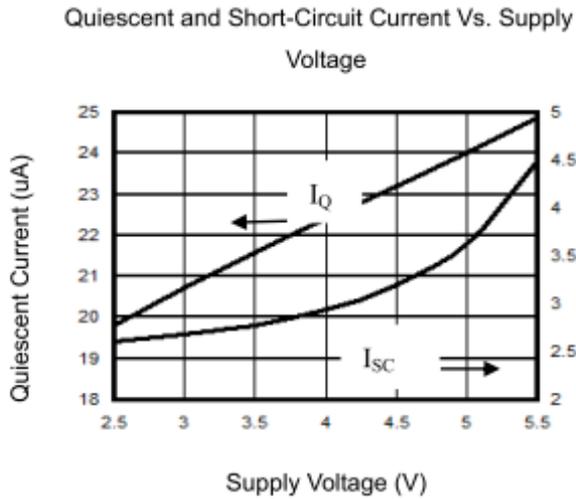
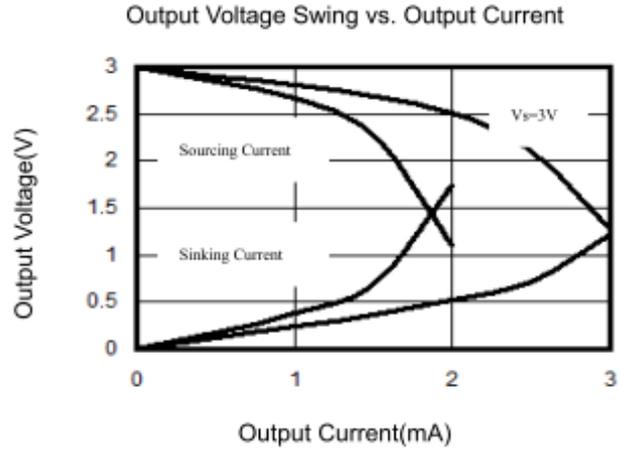
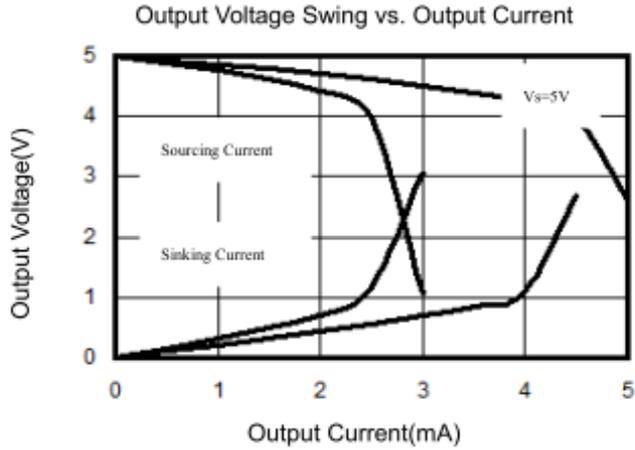
Positive Over-Voltage Recovery



Negative Over-Voltage Recovery

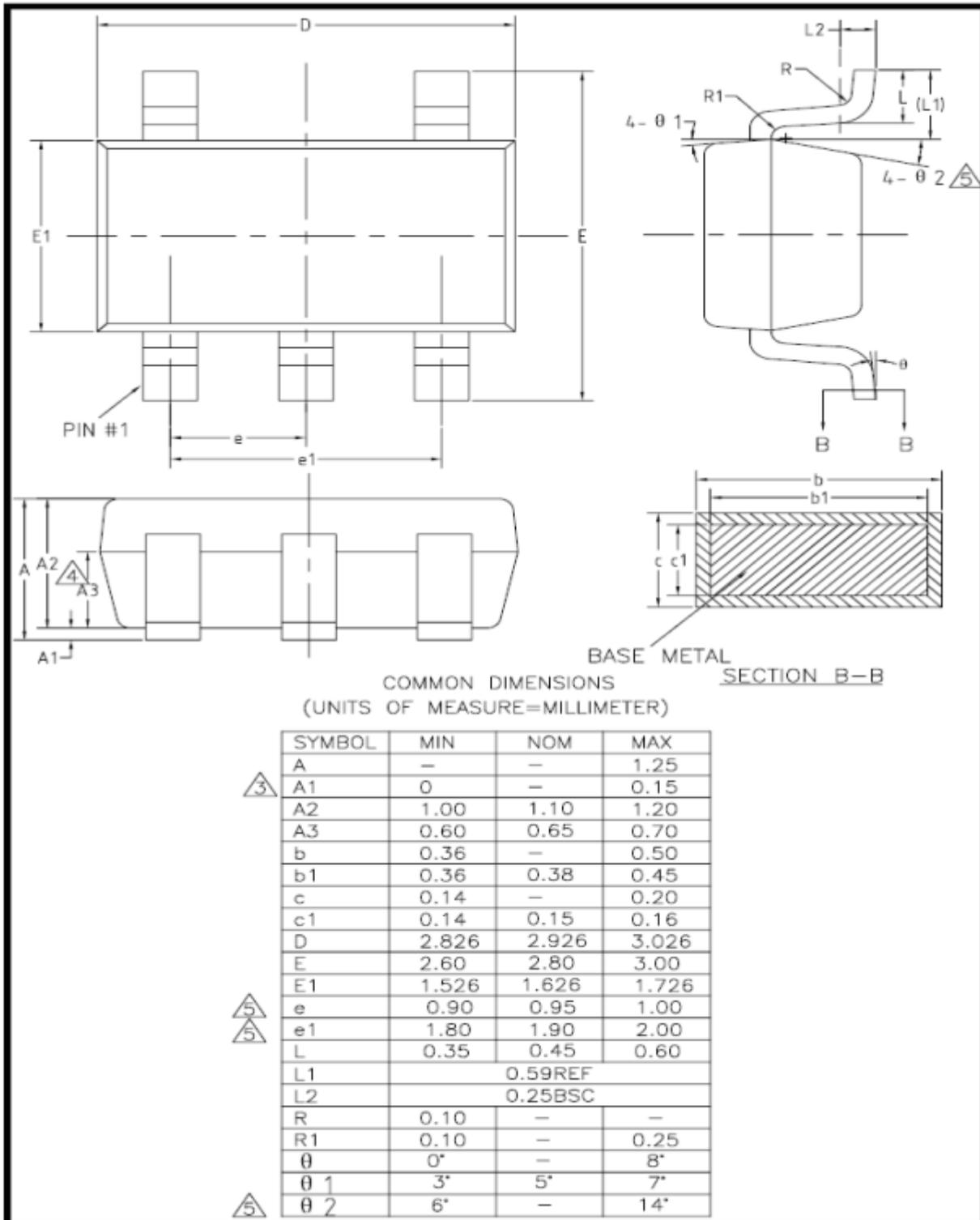


At TA=+25°C, RL=10 kΩ connected to VS/2 and VOUT= VS/2, unless otherwise noted.



Package Information

SOP23-5



SOP8

