

TS911/912/914

RAIL TO RAIL CMOS DUAL OPERATIONAL AMPLIFIER

Features

- Single-Supply: 2.7V to 9V
- Rail-to-Rail Output
- Input Range Includes Ground
- Gain Bandwidth Product: 2 . 8 MHz (typical)
- Unity-Gain Stable
- Low Quiescent Current: 230 μ A/amplifier (typical)
- Temperature Ranges:
 - Industrial: -10°C to +75°C
 - Extended: -20°C to +105°C
- Available in Single, Dual, and Quad

Typical Applications

- Portable Equipment
- A/D Converter Driver
- Photo Diode Pre-amp
- Analog Filters
- Data Acquisition
- Notebooks and PDAs
- Sensor Interface

Available Tools

- SPICE Macro Models
- FilterLab® Software
- Mindi™ Simulation Tool
- MAPS (Microchip Advanced Part Selector)
- Analog Demonstration and Evaluation Boards
- Application Notes

Description

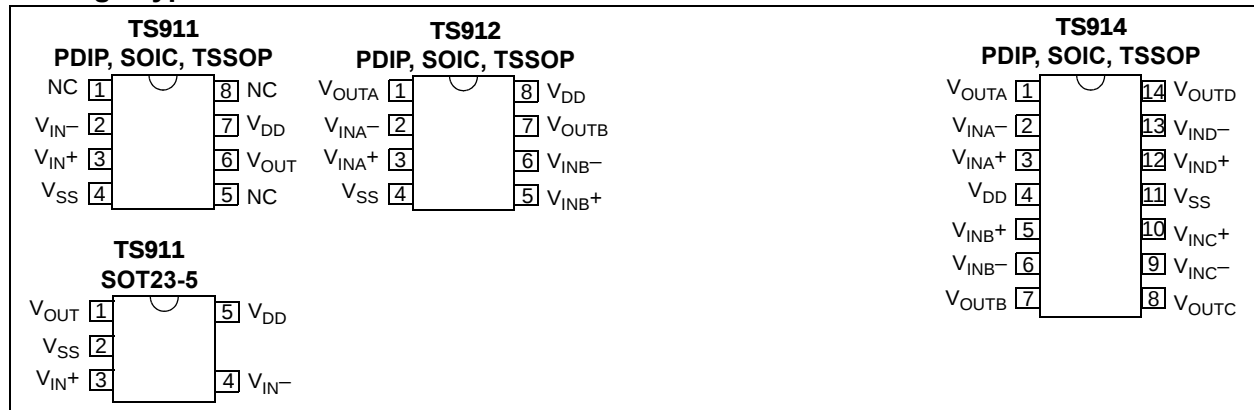
The tudi Technology Inc. TS911-912-914 family of low-power operational amplifiers (op amps) are offered in single (P601), single with Chip Select (CS) (TS911, dual (912), and quad (914) configurations. These op amps utilize an advanced CMOS technology that provides low bias current, high-speed operation, high open-loop gain, and rail-to-rail output swing. This product offering operates with a single supply voltage that can be as low as 2.7V, while drawing 230 μ A (typical) of quiescent current per amplifier, making these amplifiers ideal for single-supply operation.

These devices are appropriate for low power, battery operated circuits due to the low quiescent current, for A/D convert driver amplifiers because of their wide bandwidth or for anti-aliasing filters by virtue of their low input bias current.

The 911, 912, and 914 are available in standard 8-lead PDIP, SOIC, and TSSOP packages. The P601 and P601R are also available in a standard 5-lead SOT-23 package, while the P603 is available in a standard 6-lead SOT-23 package. The P604 is offered in standard 14-lead PDIP, SOIC, and TSSOP packages.

The TS911-912-914 family is available in the Industrial and Extended temperature ranges and has a power supply range of 2.7V to 5 . 5 V.

Package Types



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Absolute Maximum Ratings

Condition	Min	Max
Power Supply Voltage (V _{DD} to V _{SS})	-0.5V	+7.5V
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	+160°C	
Storage Temperature Range	-10°C	+120°C
Lead Temperature (soldering, 10sec)	+260°C	
Package Thermal Resistance (TA=+25°C)		
SOP-8, θ _{JA}	125°C/W	
MSOP-8, θ _{JA}	216°C/W	
SOT23-5, θ _{JA}	190°C/W	
SOT23-6, θ _{JA}	190°C/W	
SC70-5, θ _{JA}	333°C/W	
ESD Susceptibility		
HBM	8KV	
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.

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Electrical Characteristics

(At $V_S=5V$, $T_A = +25^{\circ}C$, $V_{CM} = V_S/2$, $R_L = 600\Omega$, unless otherwise noted.)

PARAMETER	CONDITIONS	TS911/12/14							
		TYP	MIN/MAX OVER TEMPERATURE						MIN / MAX
		+25℃	+25℃	0℃ to 70℃	-40℃ to 85℃	-40℃ to 125℃	UNITS		
INPUT CHARACTERISTICS									
Input Offset Voltage (V _{OS})	V _S = 5.5V	0.8	3.5	3.9	4.3	4.6	mV	MAX	
Input Bias Current (I _B)		1					pA	TYP	
Input Offset Current (I _{OS})		1					pA	TYP	
Input Common Mode Voltage Range (V _{CM})		-0.1 to +5.6					V	TYP	
Common Mode Rejection Ratio (CMRR)	V _S = 5.5V, V _{CM} = -0.1V to 4V	82	65	64	64	63	dB	MIN	
	V _S = 5.5V, V _{CM} = -0.1V to 5.6V	75					dB	MIN	
Open-Loop Voltage Gain (A _{OL})	R _L = 600Ω, V _O = 0.15V to 4.85V	90	80	76	75	68	dB	MIN	
	R _L = 10kΩ, V _O = 0.05V to 4.95V	108					dB	MIN	
Input Offset Voltage Drift (ΔV _{OS} /ΔT)		2.4					μV/℃	TYP	
OUTPUT CHARACTERISTICS									
Output Voltage Swing from Rail	R _L = 600Ω	0.1					V	TYP	
	R _L = 10kΩ	0.015					V	TYP	
Output Current (I _{OUT})		70	55	45	42	38	mA	MIN	
Closed-Loop Output Impedance	f = 100kHz, G = 1	7.5					Ω	TYP	
POWER-DOWN DISABLE									
Turn-On Time		1.1					μs	TYP	
Turn-Off Time		0.3					μs	TYP	
DISABLE Voltage-Off			0.8				V	MAX	
DISABLE Voltage-On			2				V	MIN	
POWER SUPPLY									
Operating Voltage Range	V _S = +2.5V to +5.5V V _{CM} = (-V _S) + 0.5V		2.1	2.1	2.1	2.1	V	MIN	
			5.5	5.5	5.5	5.5	V	MAX	
Power Supply Rejection Ratio (PSRR)									
Quiescent Current/Amplifier (I _Q)		I _{OUT} = 0	91	74	72	72	68	dB	MIN
		1.1	1.5	1.65	1.7	1.85	mA	MAX	

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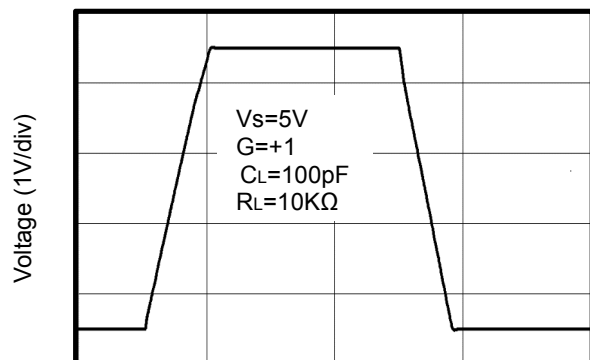
PARAMETER	CONDITIONS	TS911/12/14						
		TYP	MIN/MAX OVER TEMPERATURE					
		+25℃	+25℃	0℃ to 70℃	-40℃ to 85℃	-40℃ to 125℃	UNITS	MIN / MAX
DYNAMIC PERFORMANCE								
Gain-Bandwidth Product (GBP)	R _L = 10kΩ, C _L = 100pF	11					MHz	TYP
Phase Margin (φ _O)	R _L = 10kΩ, C _L = 100pF	51					Degrees	TYP
Full Power Bandwidth (BWP)	< 1% distortion, R _L = 600Ω	400					kHz	TYP
Slew Rate (SR)	G = +1, 2V Step, R _L = 10kΩ	9					V/μs	TYP
Settling Time to 0.1% (t _s)	G = +1, 2V Step, R _L = 600Ω	0.3					μs	TYP
Overload Recovery Time	V _{IN} · Gain = V _S , R _L = 600Ω	1.5					μs	TYP
NOISE PERFORMANCE								
Voltage Noise Density (e _n)	f = 1kHz	11.5					nV / √Hz	TYP
	f = 10kHz	8					nV / √Hz	TYP

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Typical Performance characteristics

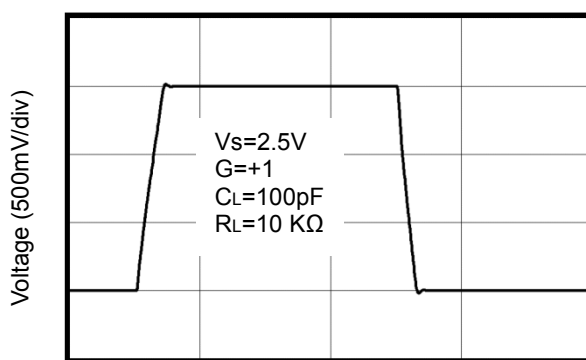
(At $V_s=5V$, $T_A = +25^\circ C$, $V_{CM} = V_s/2$, $R_L = 600\Omega$, unless otherwise noted.)

Large-Signal Step Response



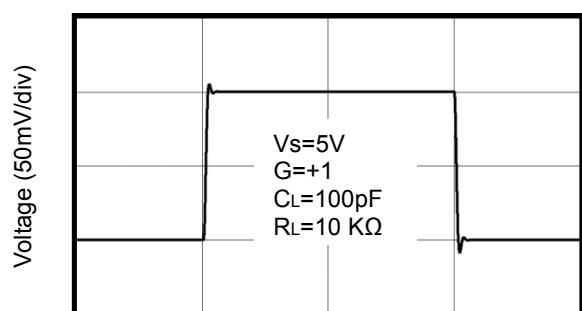
Time (1μs/div)

Large-Signal Step Response



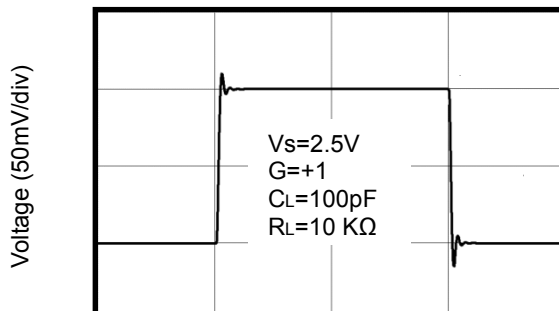
Time (1μs/div)

Small-Signal Step Response



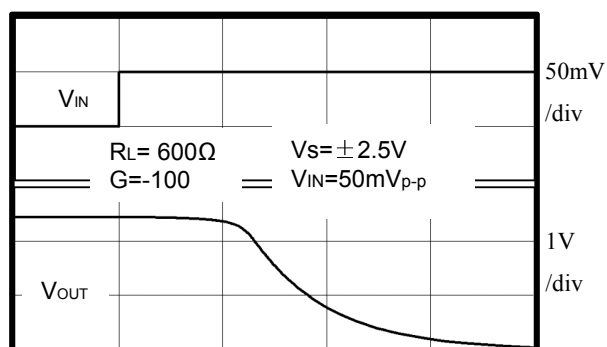
Time (1μs/div)

Small-Signal Step Response



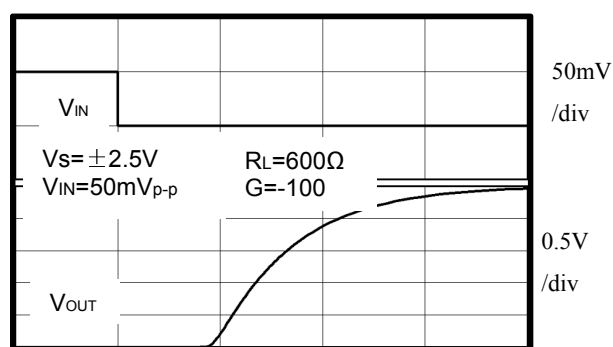
Time (1μs/div)

Positive Overload Recovery



Time (2μs/div)

Negative Overload Recovery



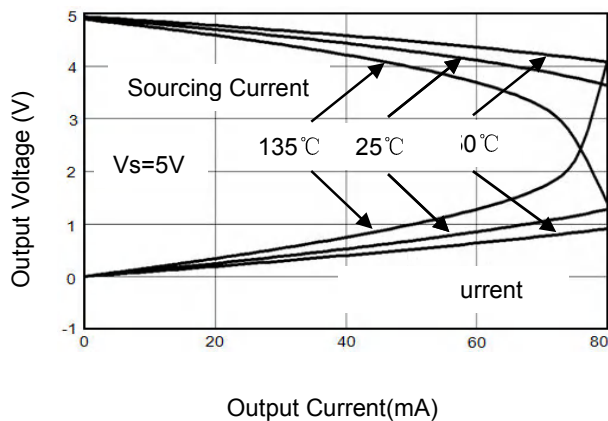
Time (2μs/div)

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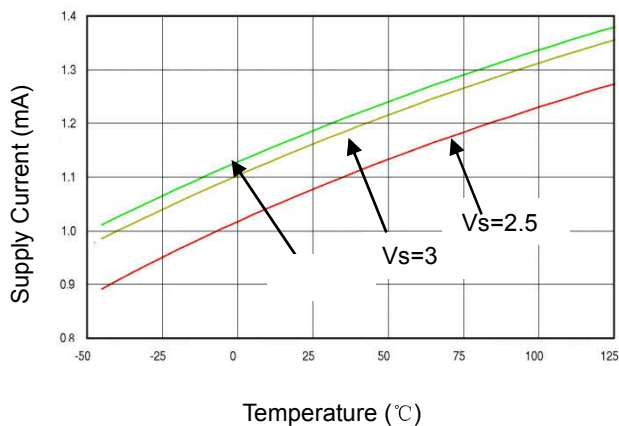
Typical Performance characteristics

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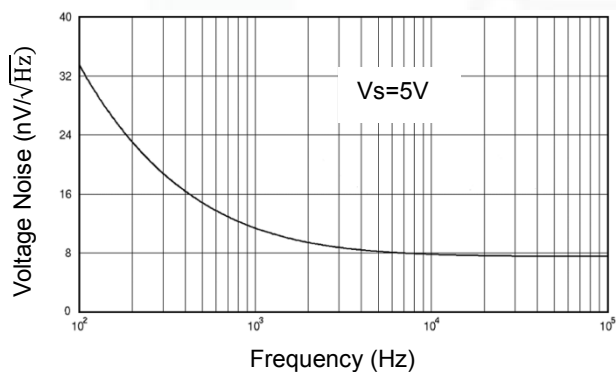
Output Voltage Swing vs. Output Current



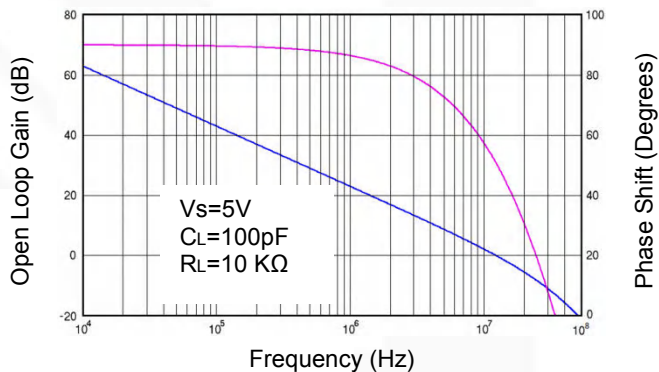
Supply Current vs. Temperature



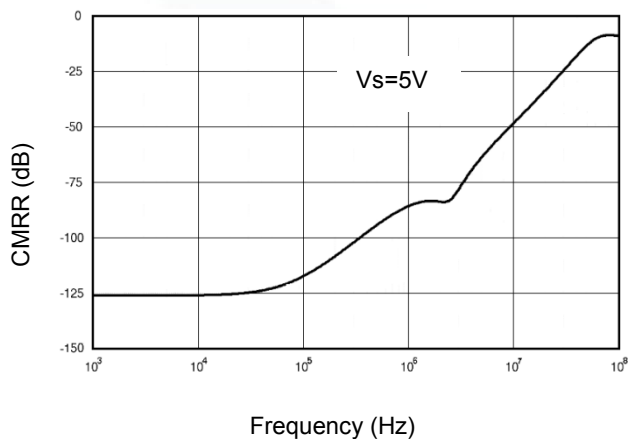
Input Voltage Noise Spectral Density vs. Frequency



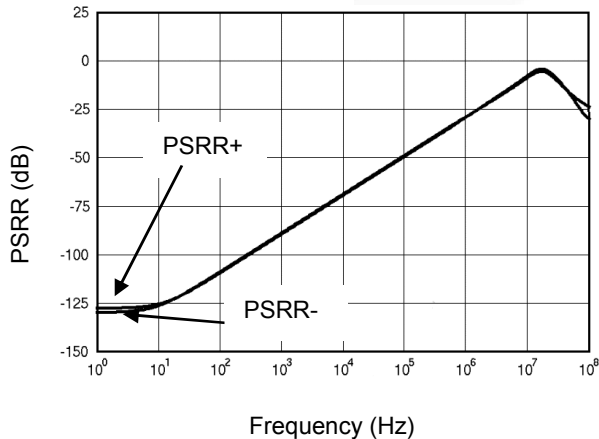
Open Loop Gain, Phase Shift vs. Frequency



CMRR vs. Frequency



PSRR vs. Frequency



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Application Note

Size

P60X series op amps are unity-gain stable and suitable for a wide range of general-purpose applications. The small footprints of the P60X series packages save space on printed circuit boards and enable the design of smaller electronic products.

Power Supply Bypassing and Board Layout

P60X series operates from a single 2.1V to 5.5V supply or dual $\pm 1.05\text{V}$ to $\pm 2.75\text{V}$ supplies. For best performance, a $0.1\mu\text{F}$ 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 $0.1\mu\text{F}$ ceramic capacitors.

Low Supply Current

The low supply current (typical 1.1mA per channel) of P60X series will help to maximize battery life. They are ideal for battery powered systems

Operating Voltage

P60X series operate under wide input supply voltage (2.1V to 5.5V). In addition, all temperature specifications apply from -40°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 P60X series extends 100mV beyond the supply rails ($V_{\text{SS}}-0.1\text{V}$ to $V_{\text{DD}}+0.1\text{V}$). 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 P60X series can typically swing to less than 2mV from supply rail in light resistive loads ($>100\text{k}\Omega$), and 15mV of supply rail in moderate resistive loads ($10\text{k}\Omega$).

Capacitive Load Tolerance

The P60X 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.

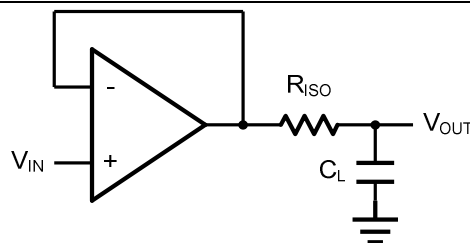


Figure 2. Indirectly Driving a Capacitive Load Using Isolation Resistor

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 $R_{\text{ISO}}/R_{\text{L}}$) 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}

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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.

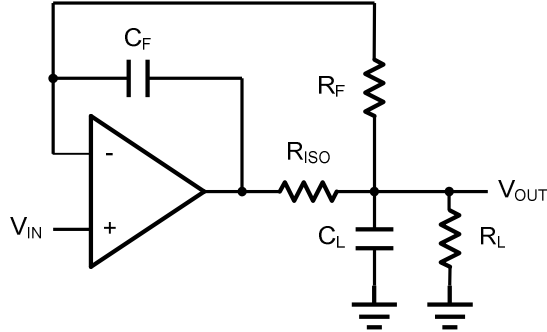


Figure 3. Indirectly Driving a Capacitive Load with DC Accuracy

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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 P60X.

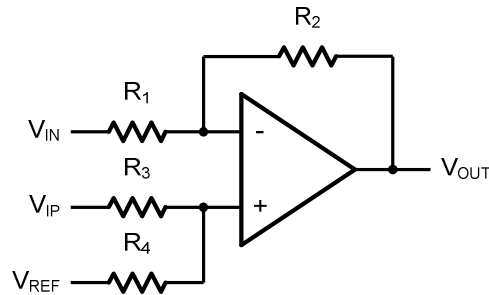


Figure 4. Differential Amplifier

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

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 $f_c = 1/(2\pi R_3 C_1)$.

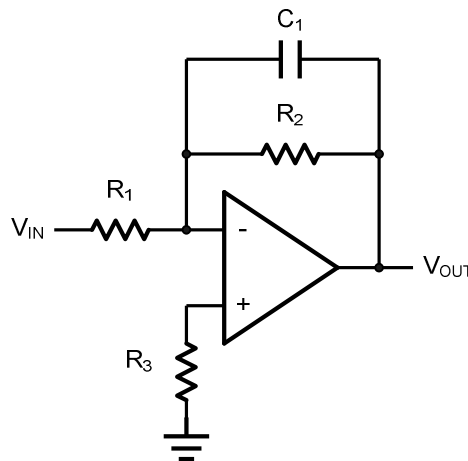


Figure 5. Low Pass Active Filter

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Instrumentation Amplifier

The triple P60X 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.

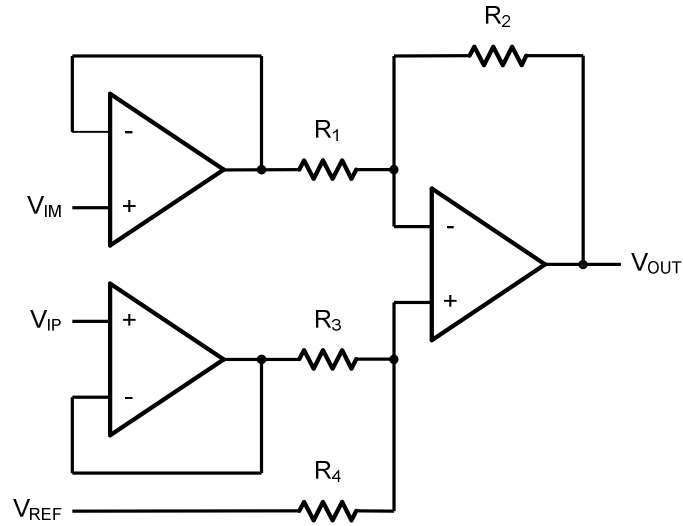
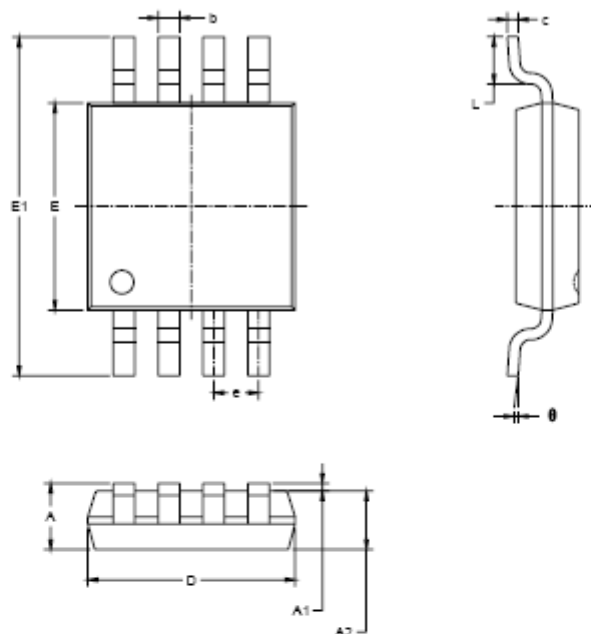


Figure 6. Instrument Amplifier

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Package Information

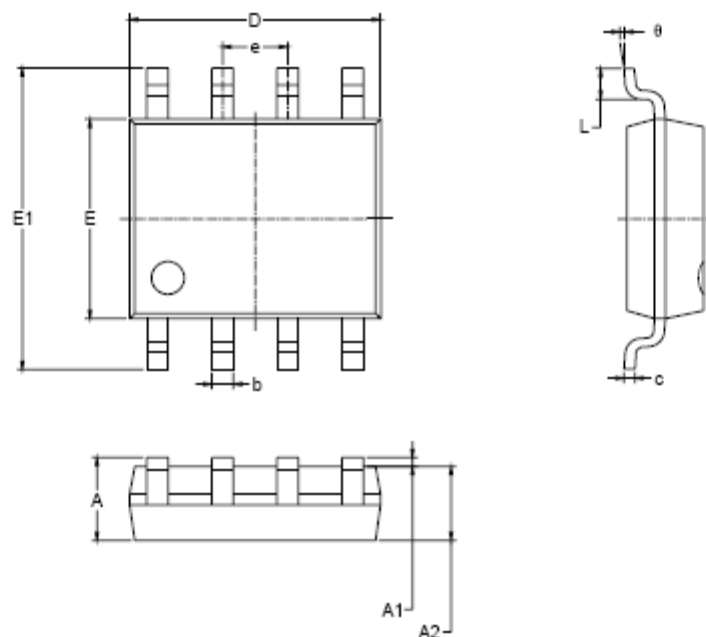
MSOP-8



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	0.006
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°	8°	0°	8°

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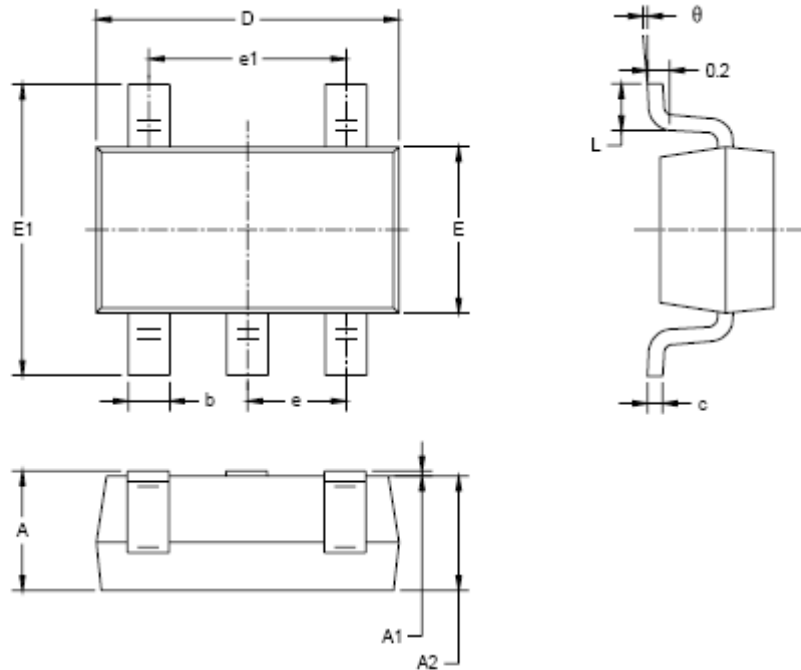
SOP-8



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
θ	0°	8°	0°	8°

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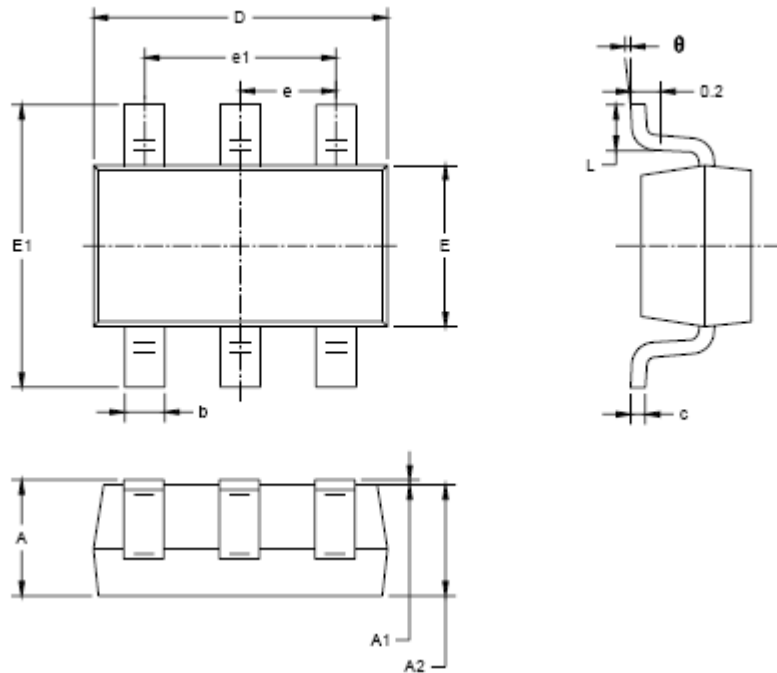
SOT23-5



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°

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SOT23-6



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°

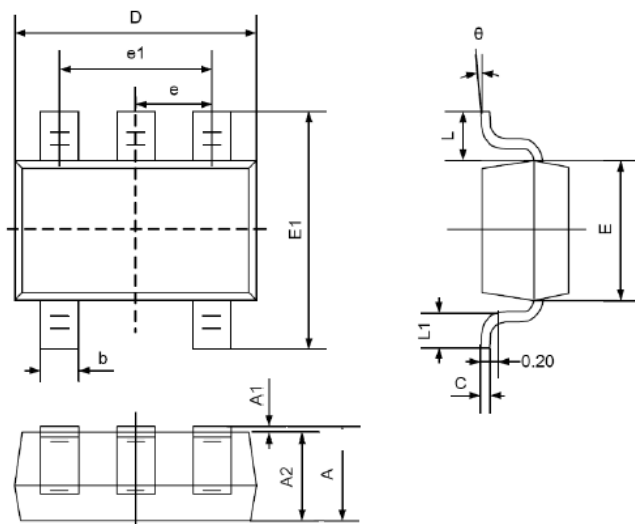
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SC70-5



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°

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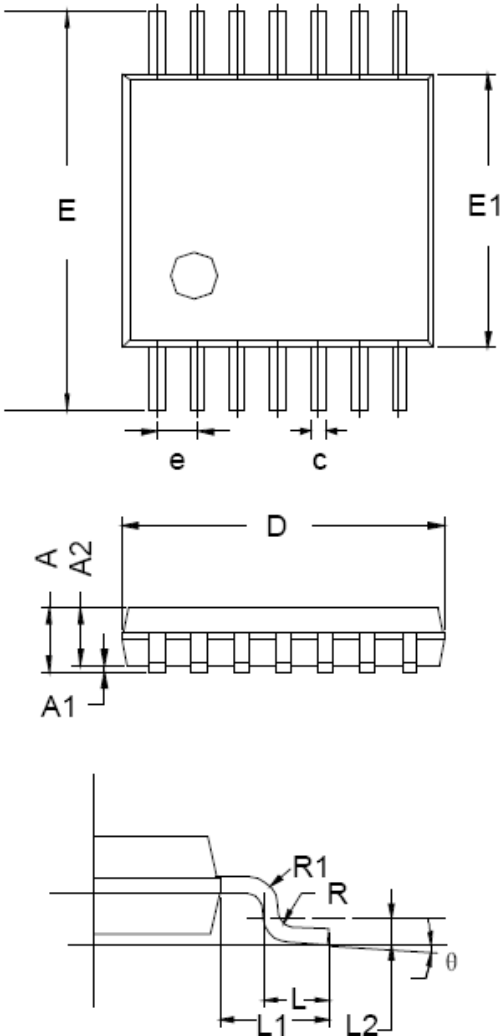
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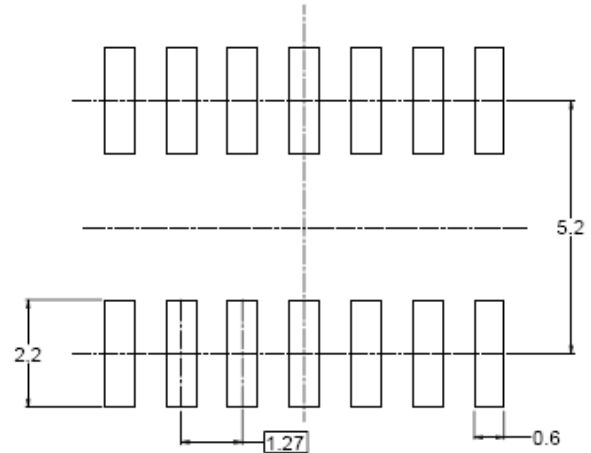
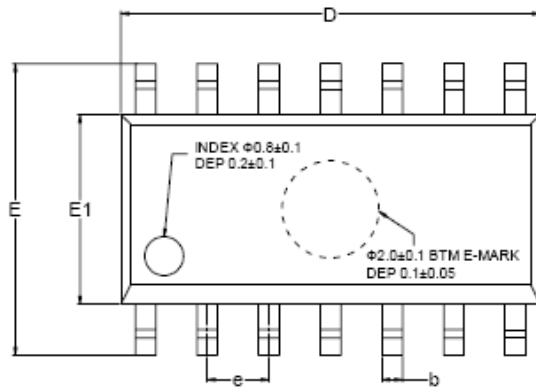


Symbol	Dimensions In Millimeters		
	MIN	TYP	MAX
A	-	-	1.20
A1	0.05	-	0.15
A2	0.90	1.00	1.05
b	0.20	-	0.28
c	0.10	-	0.19
D	4.86	4.96	5.06
E	6.20	6.40	6.60
E1	4.30	4.40	4.50
e	0.65 BSC		
L	0.45	0.60	0.75
L1	1.00 REF		
L2	0.25 BSC		
R	0.09	-	-
θ	0°	-	8°

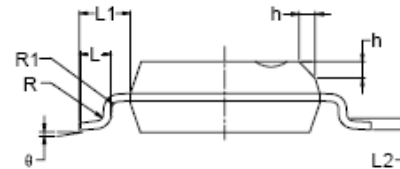
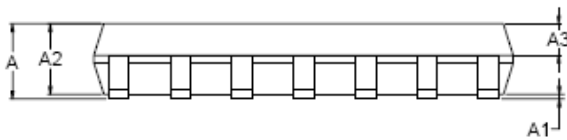
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RECOMMENDED LAND PATTERN (Unit: mm)



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
θ	0°		8°	0°		8°

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