

## 11MHZ CMOS Rail-to-Rail IO Opamps

### General Description

The HX72X have a high gain-bandwidth product of 11 MHz, a slew rate of 9V/ $\mu$ s, and a quiescent current of 1.1mA per amplifier at 5V. The HX721N has a power-down disable feature that reduces the supply current to 90nA. The HX72X are 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 HX72X. They are specified over the extended industrial temperature range (-40°C to +125°C). The operating range is from 2.1V to 5.5V. The HX721 single is available in Green SC70-5, SOT23-5, SOP-8 and MSOP-8 packages. The HX722 dual is available in Green SOP-8 and MSOP-8 packages. The HX724 Quad is available in Green SOP-14 and TSSOP-14 packages. The HX721N single with shutdown is available in Green SOT23-6 and SC70-6 packages.

### Features

- Single-Supply Operation from +2.1V ~ +5.5V
- Rail-to-Rail Input / Output
- Gain-Bandwidth Product: 11MHz (Typ.)
- Low Input Bias Current: 1pA (Typ.)
- Low Offset Voltage: 3.5mV (Max.)
- High Slew Rate: 9V/ $\mu$ s
- Settling Time to 0.1% with 2V Step: 0.3 $\mu$ s
- Low Noise : 8nV/ Hz @10kHz
- Quiescent Current: 1.1mA per Amplifier (Typ.)
- Operating Temperature: -40°C ~ +125°C
- Small Package:
- HX721 Available in SOT23-5 , SC70-5 , SOP-8 and MSOP-8 Packages
- HX722 Available in SOP-8 and MSOP-8 Packages
- HX724 Available in SOP-14 and TSSOP-14 Packages
- HX721N Available in SOT23-6 and SC70-6 Packages

### Applications

- Sensors
- Active Filters
- Cellular and Cordless Phones
- Laptops and PDAs
- Audio
- Handheld Test Equipment
- Battery-Powered Instrumentation
- A/D Converters

### Ordering Information

DEVICE	Package Type	MARKING	Packing	Packing Qty
HX721IDBVRG	SOT23-5	V721	REEL	3000pcs/reel
HX721IDCKRG	SC70-5	V721	REEL	3000pcs/reel
HX721IDRG	SOP-8	HX721	REEL	2500pcs/reel
HX721IDGKRG	MSOP8	V721	REEL	3000pcs/reel
HX721INDBVRG	SOT23-6	V721N	REEL	3000pcs/reel
HX721INDCKRG	SC70-6	V721N	REEL	3000pcs/reel
HX722IDRG	SOP8	HX722	REEL	2500pcs/reel
HX722IDGKRG	MSOP8	HX722	REEL	3000pcs/reel
HX724IDRG	SOP14	HX724	REEL	2500pcs/reel
HX724IPWRG	TSSOP14	HX724	REEL	2500pcs/reel

## Pin Configuration

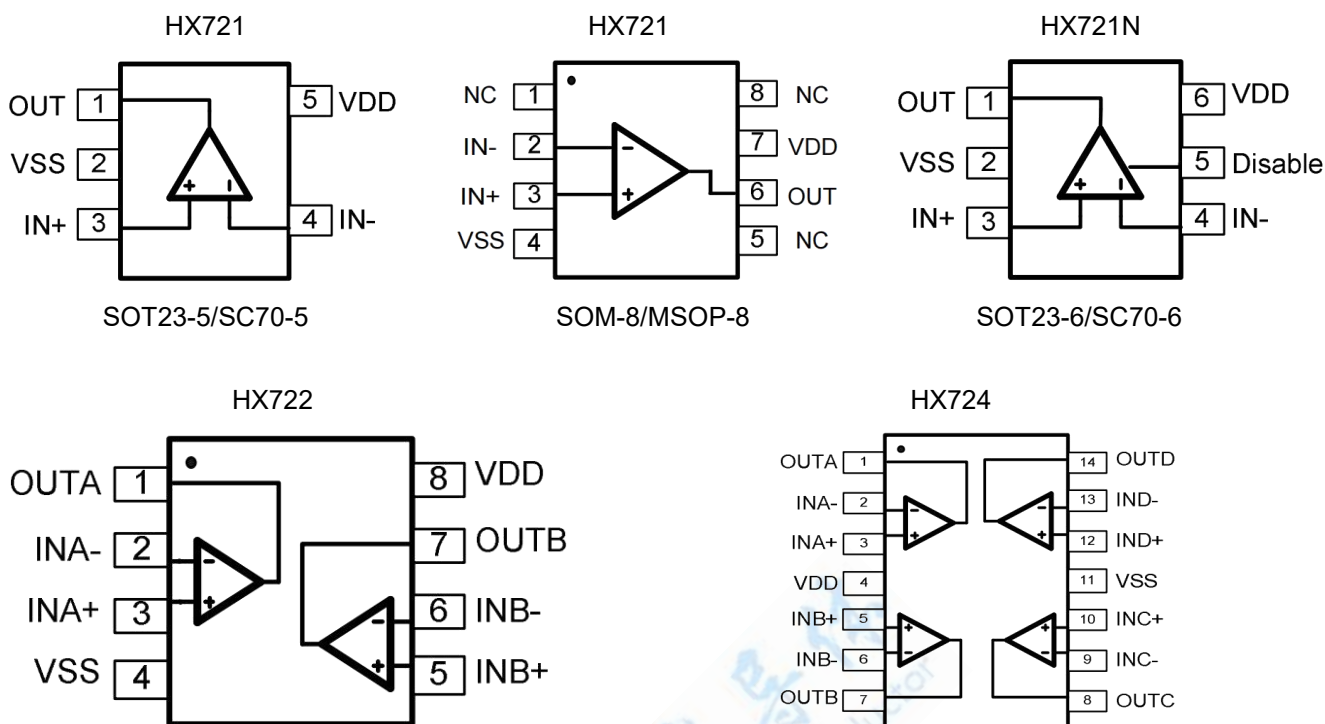


Figure 1. Pin Assignment Diagram

## 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	-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 (TA=+25°C)</b>		
SOP-8, $\theta_{JA}$	-	125°C/W
MSOP-8, $\theta_{JA}$	-	216°C/W
SOT23-5, $\theta_{JA}$	-	190°C/W
SOT23-6, $\theta_{JA}$	-	190°C/W
SC70-5, $\theta_{JA}$	-	333°C/W
<b>ESD Susceptibility</b>		
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.

## Electrical Characteristics

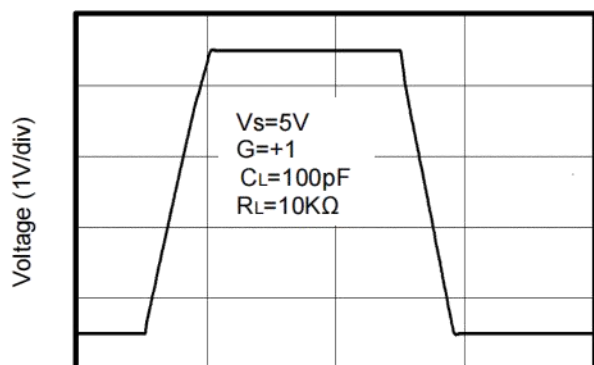
(At  $V_S=5V$ ,  $T_A = +25^{\circ}C$ ,  $V_{CM} = V_S/2$ ,  $R_L = 600\Omega$ , unless otherwise noted.)

PARAMETER	CONDITIONS	HX721/2/4/1N							
		TYP	MIN/MAX OVER TEMPERATURE					UNITS	MIN / MAX
		+25℃	+25℃	0℃ to 70℃	-40℃ to 85℃	-40℃ to 125℃			
INPUT CHARACTERISTICS									
Input Offset Voltage (VOS)	VS = 5.5V	0.8	3.5	3.9	4.3	4.6	mV	MAX	
Input Bias Current (IB)		1					pA	TYP	
Input Offset Current (IOS)		1					pA	TYP	
Input Common Mode Voltage Range (VCM)		-0.1 to +5.6					V	TYP	
Common Mode Rejection Ratio (CMRR)	VS = 5.5V, VCM = -0.1V to 4V	82	65	64	64	63	dB	MIN	
	VS = 5.5V, VCM = -0.1V to 5.6V	75					dB	MIN	
Open-Loop Voltage Gain (AOL)	RL = 600Ω, VO = 0.15V to 4.85V	90	80	76	75	68	dB	MIN	
	RL = 10kΩ, VO = 0.05V to 4.95V	108					dB	MIN	
Input Offset Voltage Drift (ΔVOS/ΔT)		2.4					μV/℃	TYP	
OUTPUT CHARACTERISTICS									
Output Voltage Swing from Rail	RL = 600Ω	0.1					V	TYP	
	RL = 10kΩ	0.015					V	TYP	
Output Current (IOUT)	f = 100kHz, G = 1	70	55	45	42	38	mA	MIN	
Closed-Loop Output Impedance		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			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)	VS = +2.5V to +5.5V	91	74	72	72	68	dB	MIN	
Quiescent Current/Amplifier (IQ)	VCM = (-VS) + 0.5V	1.1	1.5	1.65	1.7	1.85	Ma	MAX	
Supply Current when Disabled (HX721N Only)	IOUT = 0	90					nA	MAX	
DYNAMIC PERFORMANCE									
Gain-Bandwidth Product (GBP)	RL = 10kΩ, CL = 100pF	11					MHz	TYP	
Phase Margin (φO)	RL = 10kΩ, CL = 100pF	51					Degrees	TYP	
Full Power Bandwidth (BWP)	<1% distortion, RL = 600Ω	400					kHz	TYP	
Slew Rate (SR)	G = +1, 2V Step, RL = 10kΩ	9					V/μs	TYP	
Settling Time to 0.1% (ts)	G = +1, 2V Step, RL = 600Ω	0.3					μs	TYP	
Overload Recovery Time	VIN · Gain = VS, RL = 600Ω	1.5					μs	TYP	
NOISE PERFORMANCE									
Voltage Noise Density (en)	f = 1kHz	11.5					nV /Hz	TYP	
	f = 10kHz	8					nV /Hz	TYP	

## Typical Performance characteristics

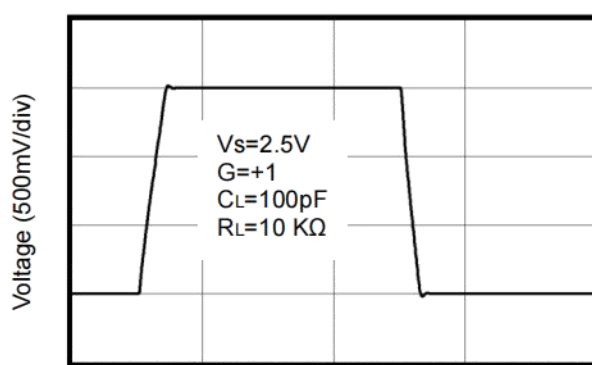
(At  $V_s=5V$ ,  $T_A = +25^\circ C$ ,  $V_{CM} = V_s/2$ ,  $R_L = 600\Omega$ , unless otherwise noted.)

Large-Signal Step Response



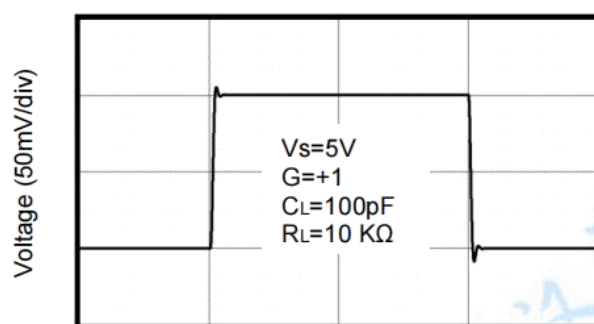
Time (1 $\mu s$ /div)

Large-Signal Step Response



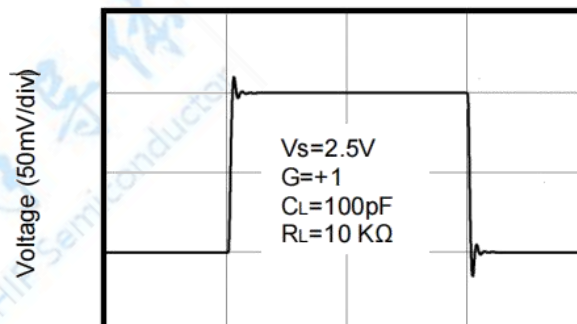
Time (1 $\mu s$ /div)

Small-Signal Step Response



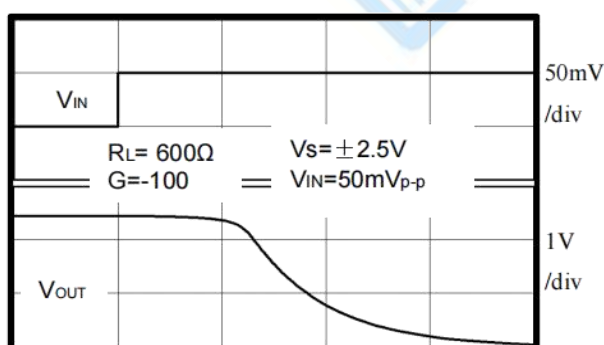
Time (1 $\mu s$ /div)

Small-Signal Step Response



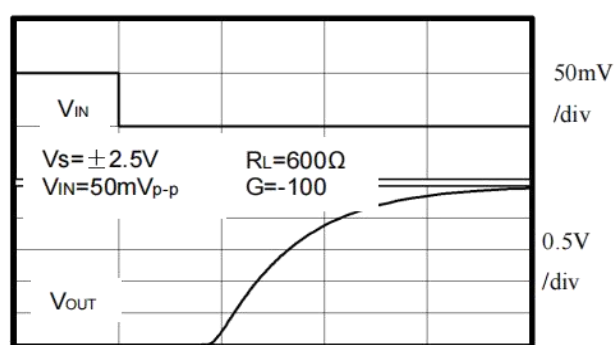
Time (1 $\mu s$ /div)

Positive Overload Recovery



Time (2 $\mu s$ /div)

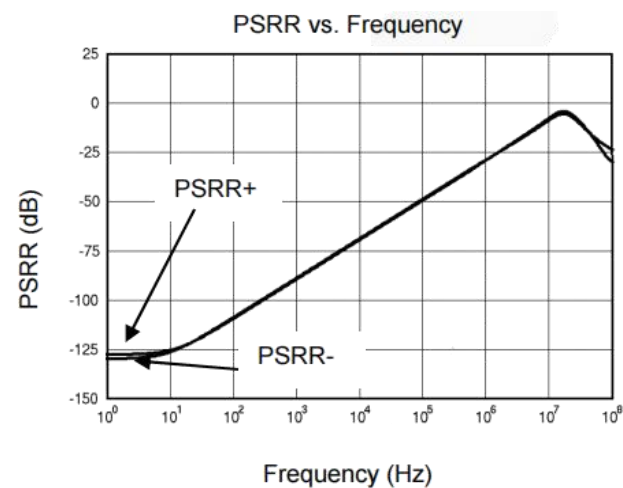
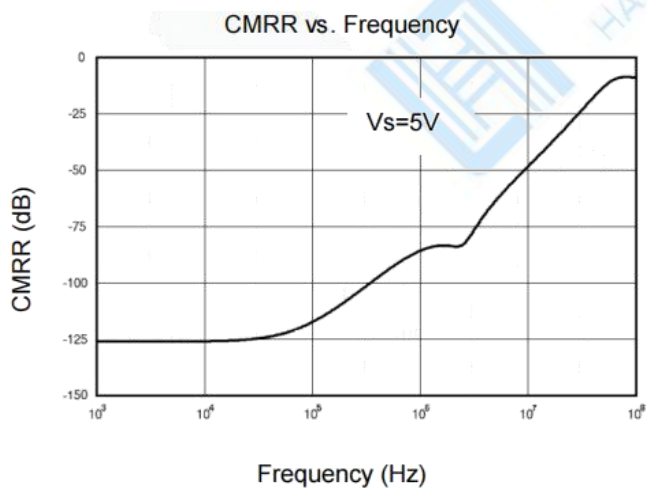
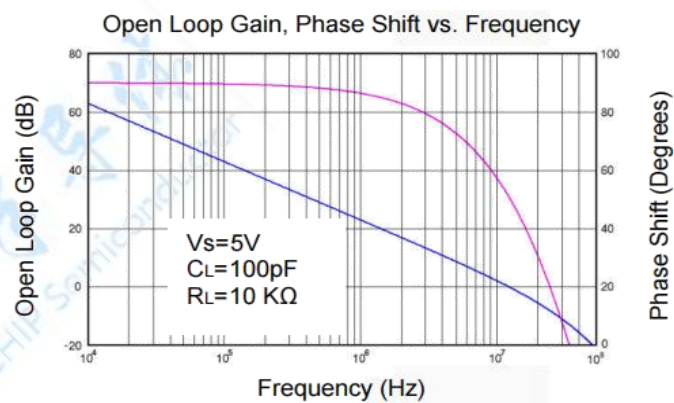
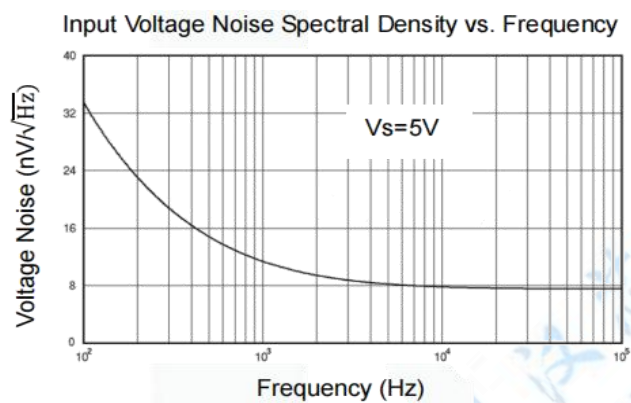
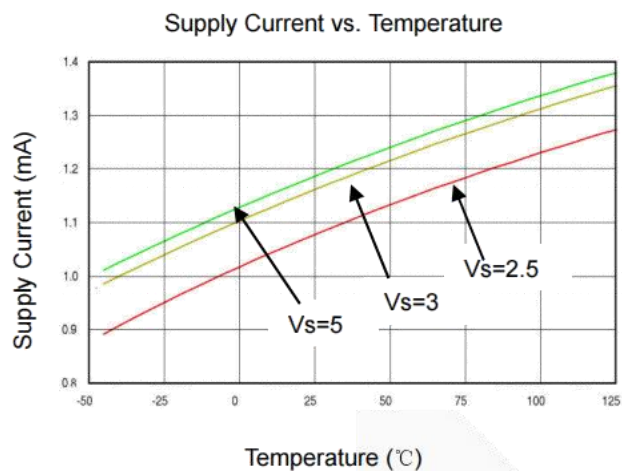
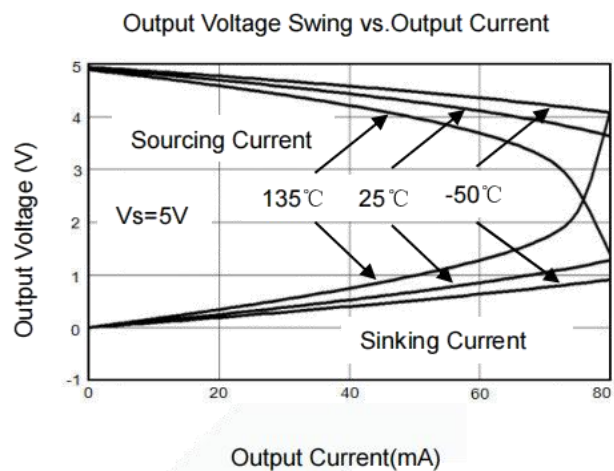
Negative Overload Recovery



Time (2 $\mu s$ /div)

## Typical Performance characteristics

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



## Application Note

### Size

HX72X series op amps are unity-gain stable and suitable for a wide range of general-purpose applications. The small footprints of the HX72X series packages save space on printed circuit boards and enable the design of smaller electronic products.

### Power Supply Bypassing and Board Layout

HX72X 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 VDD pin in single supply operation. For dual supply operation, both VDD and VSS supplies should be bypassed to ground with separate  $0.1\mu\text{F}$  ceramic capacitors.

### Low Supply Current

The low supply current (typical  $1.1\text{mA}$  per channel) of HX72X series will help to maximize battery life. They are ideal for battery powered systems.

### Operating Voltage

HX72X series operate under wide input supply voltage (2.1V 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 HX72X series extends  $100\text{mV}$  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.

### 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 HX72X series can typically swing to less than  $2\text{mV}$  from supply rail in light resistive loads ( $>100\text{k}\Omega$ ), and  $15\text{mV}$  of supply rail in moderate resistive loads ( $10\text{k}\Omega$ ).

### Capacitive Load Tolerance

The HX72X 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.



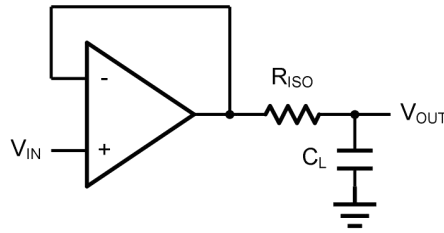


Figure 2. Indirectly Driving a Capacitive Load Using Isolation Resistor

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.

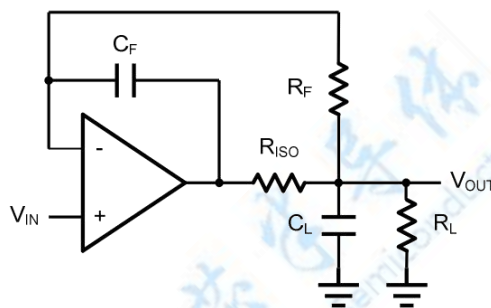


Figure 3. Indirectly Driving a Capacitive Load with DC Accuracy

## Typical Application Circuits

### Differential amplifier

The differential amplifier allows the subtraction of two input voltages or cancellation of a signal common 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. shows the differential amplifier using HX72X.

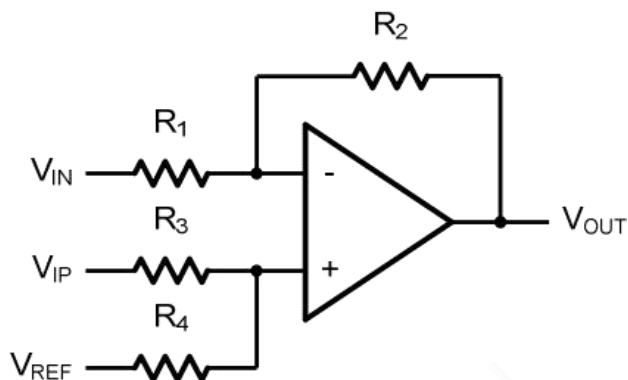


Figure 4. Differential Amplifier

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

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

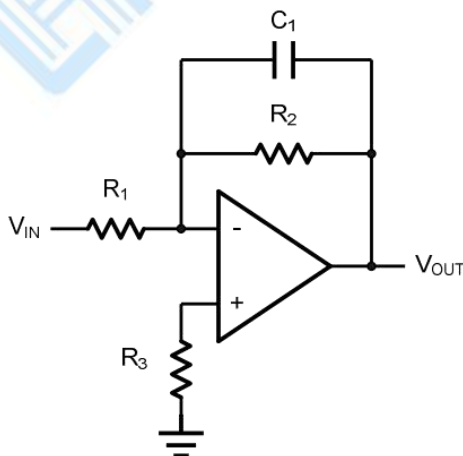


Figure 5. Low Pass Active Filter



## Instrumentation Amplifier

The triple HX72X 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.

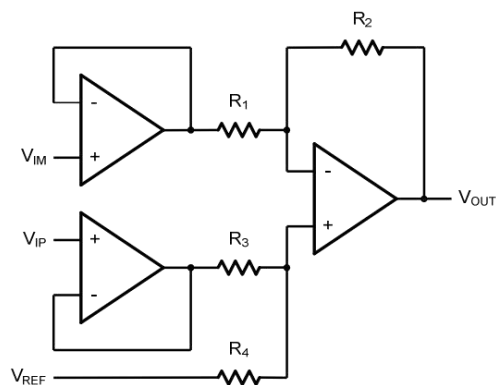
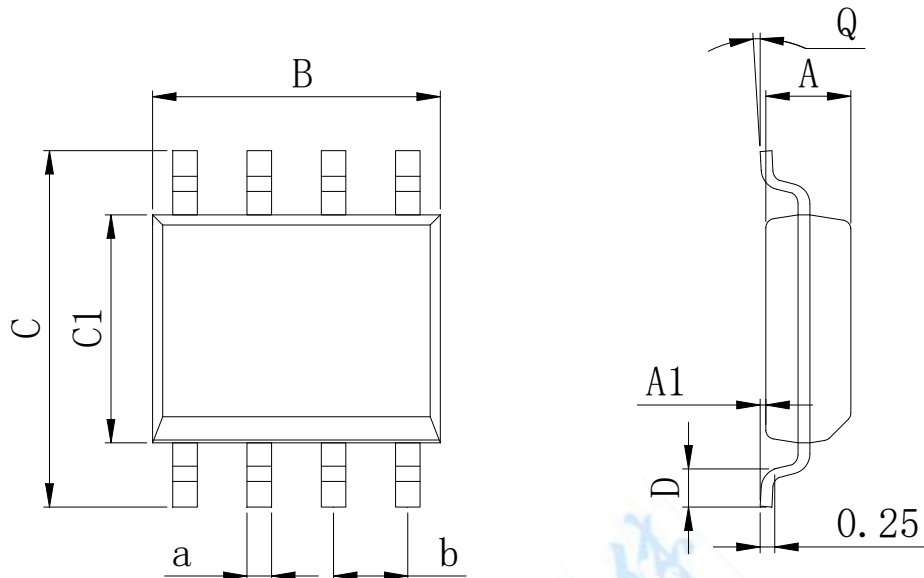


Figure 6. Instrument Amplifier

## Physical Dimensions

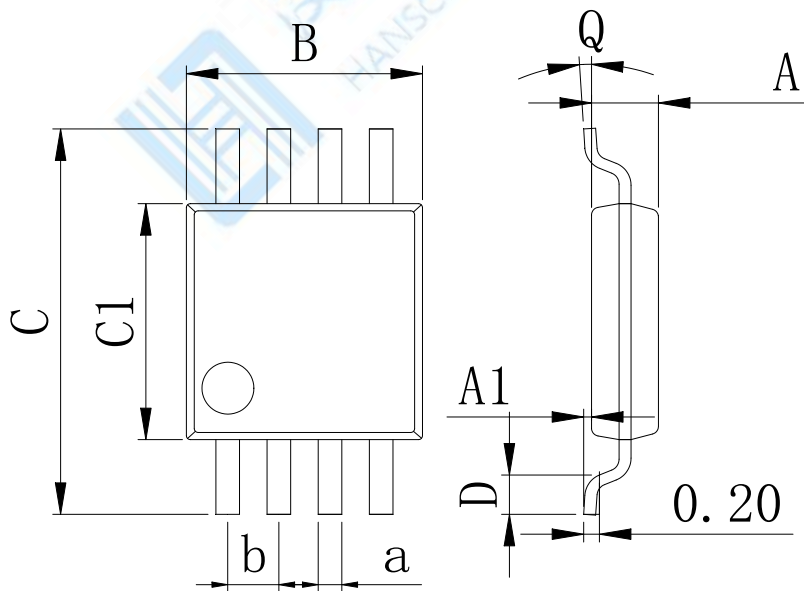
SOP-8L 150mil



Dimensions In Millimeters(SOP8L)

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

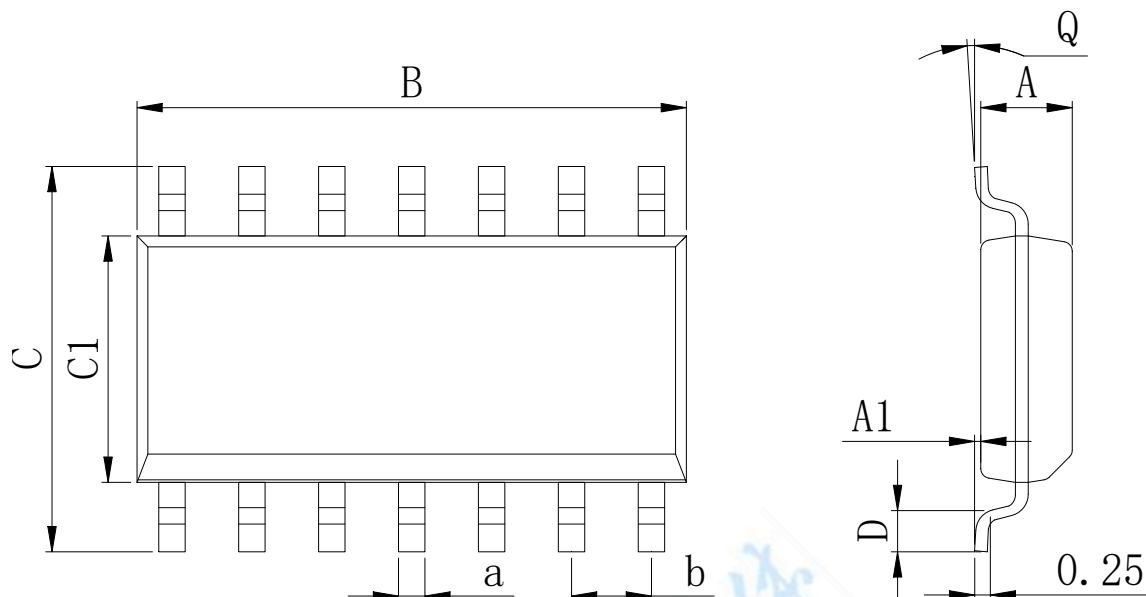


Dimensions In Millimeters(MSOP8L)

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

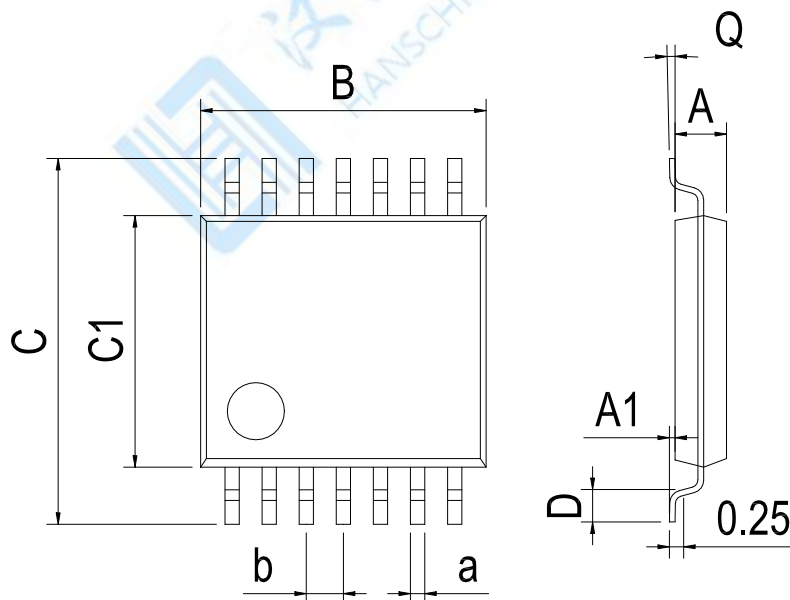
SOP14L



Dimensions In Millimeters(SOP14L)

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	

TSSOP-14L

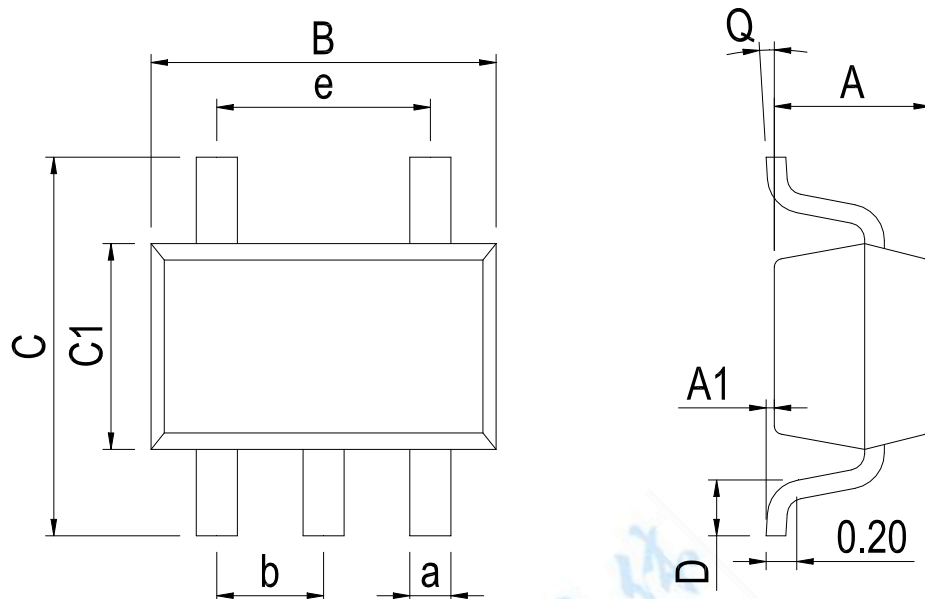


Dimensions In Millimeters(TSSOP14L)

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

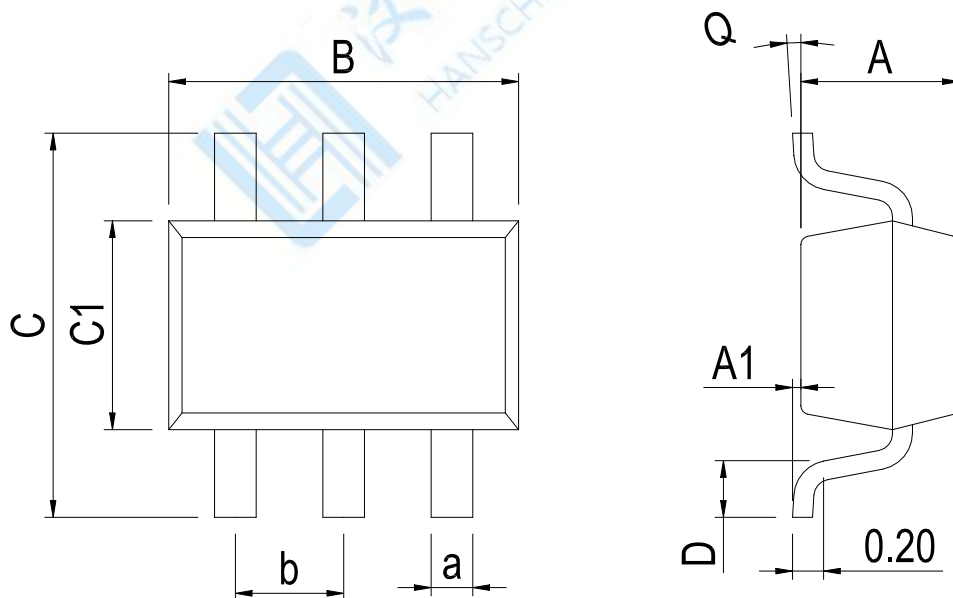
### SOT23-5



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		

### SOT23-6

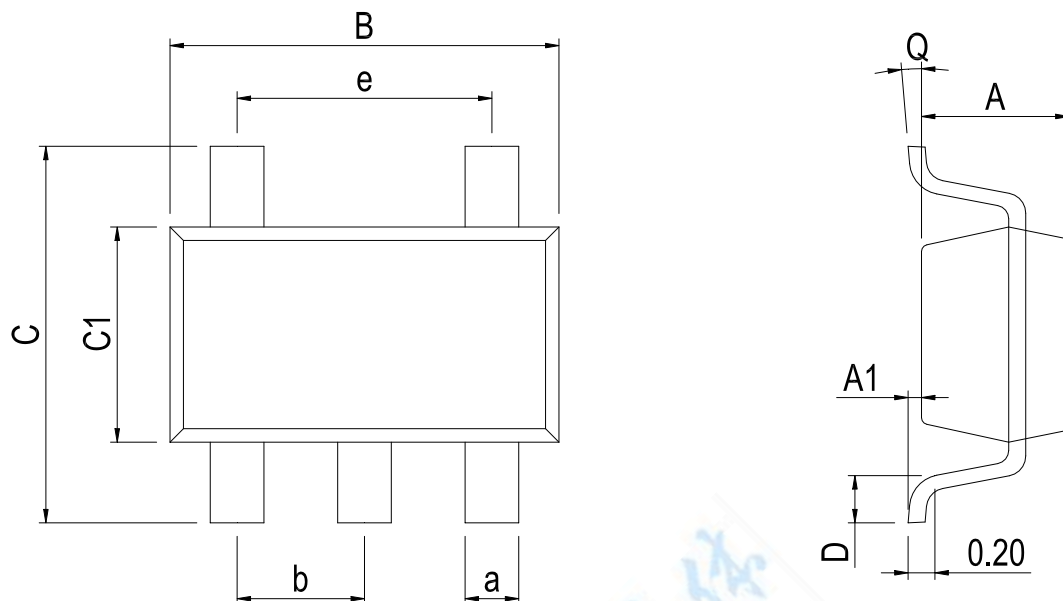


Dimensions In Millimeters(SOT23-6)

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

## Physical Dimensions

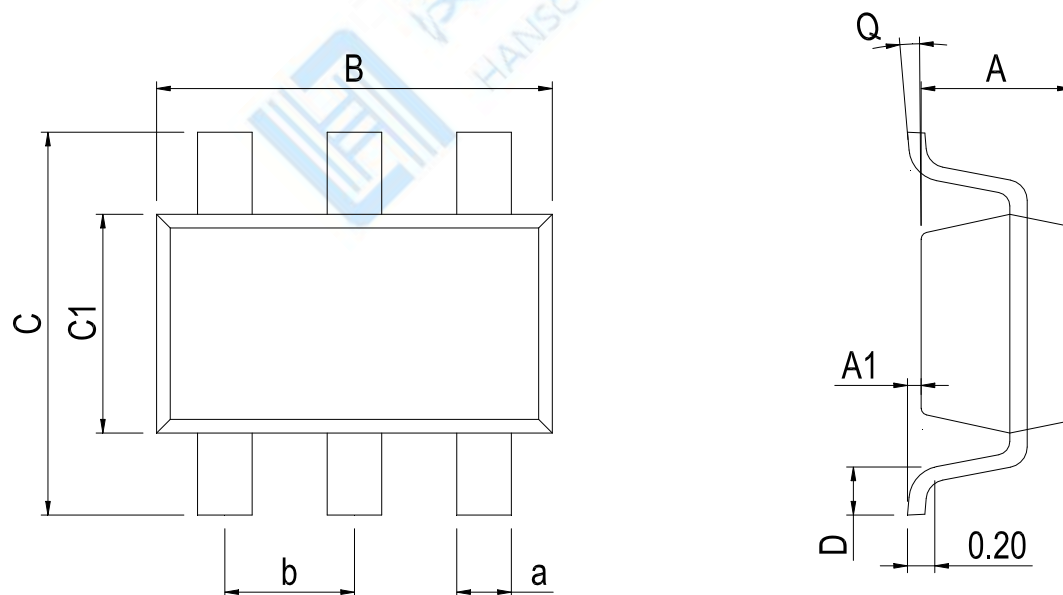
### SC70-5



**Dimensions In Millimeters(SC70-5)**

Symbol:	A	A1	B	C	C1	D	Q	a	b	e
Min:	0.90	0.00	2.00	2.15	1.15	0.26	0°	0.30	0.65	1.30 BSC
Max:	1.00	0.15	2.20	2.45	1.35	0.46	8°	0.40	BSC	

### SC70-6



**Dimensions In Millimeters(SC70-6)**

Symbol:	A	A1	B	C	C1	D	Q	a	b
Min:	0.90	0.00	2.00	2.15	1.15	0.26	0°	0.30	0.65 BSC
Max:	1.00	0.15	2.20	2.45	1.35	0.46	8°	0.40	

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