Precision, Ultralow Noise, RRIO, Zero-Drift Operational Amplifiers

Features

- Low Offset Voltage: ±1.2μV (TYP)
- Input Offset Voltage Drift: ±0.1μV/°C
- Gain Bandwidth Product: 3.7MHz
- Rail-to-Rail Input and Output
- Open-Loop Gain: 140dB (Typical)
- CMRR: 125dB (Typical)
- PSRR: 125dB (Typical)
- Low Noise: 0.15μVp-p (0.1~10Hz)
- Single-Supply Operation: +2.2 V to +5.5 V
- Dual-Supply Operation: ±1.1 V to +2.75 V
- Unity-Gain Stable
- Operating Temperature: -40'C to +125'C

Applications

- Thermocouple/Thermopile
- Load Cell and Bridge Transducers
- Precision Instrumentation
- Electronic Scales
- Medical Instrumentation
- Handheld Test Equipment

General Description

The HCR8531/HCR8532 are ultralow noise, zero-drift operational amplifiers featuring rail-to-rail input and output swing. With an offset voltage of ±1.2 μV offset voltage drift of ±0.1 μV/°C, and typical noise of 0.15 μVPP (0.1Hz to 10Hz), the HCR8531/ HCR8532 are well suited for applications in which error sources cannot be tolerated.

The HCR8531/HCR8532 have a wide operating supply range of 2.2 V to 5.5 V, high gain, and excellent CMRR and PSRR specifications, which make it ideal for applications that require precision amplification of low level signals, such as position and pressure sensors, strain gages, and medical instrumentation.

The HCR8531 /HCR8532 are specified over the extended industrial temperature range (−40°C to +125°C).
The HCR8531 is available in SOT23-5 packages.
The HCR8532 is available in SOIC-8(SOP-8) and MSOP8 packages.

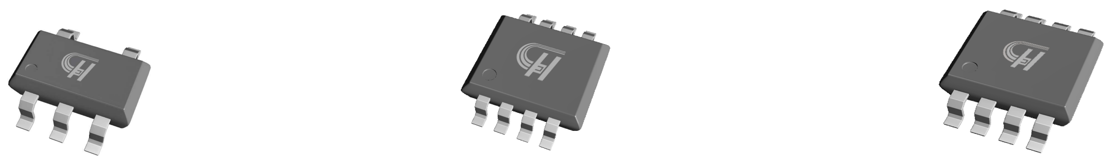
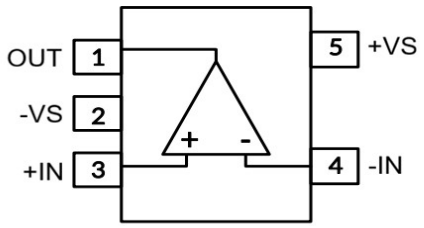


Figure 1. Package Type of HCR8531/HCR8532

Precision, Ultralow Noise, RRIO, Zero-Drift Operational Amplifiers

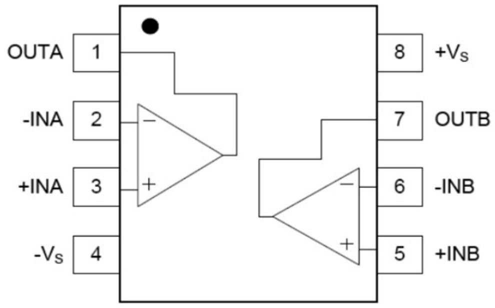
Pin Configuration

HCR8531(TOP VIEW)



SOT23-5

HCR8532(TOP VIEW)

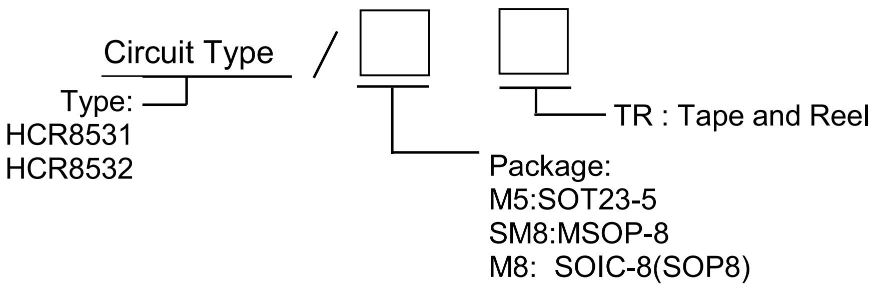


SOIC-8(SOP-8)/MSOP-8

Pin Function Table

Name	Function
+IN, +INA, +INB	Non-inverting Inputs
-IN, -INA, -INB	Inverting Inputs
+Vs	Positive(highest) Power Supply
-Vs	Negative(lowest) Power Supply
OUT, OUTA, OUTB	Outputs

Ordering Information



Ordering Code

Part Number	Channel	Marking (1)	Op Temp('C)	MSL(2)	Package	Package Qty
HCR8531/M5TR	1	8531	-40'C to +125'C	MSL3	SOT23-5	3000pcs/TR
HCR8532/SM8TR	2	HCR8532xx	-40'C to +125'C	MSL3	MSOP-8	4000pcs/TR
HCR8532/M8TR	2	HCR8532xx	-40'C to +125'C	MSL3	SOIC-8 (SOP-8)	4000pcs/TR

note 1: There may be additional marking, which relates to the lot trace code information(data code and vendor code)， the logo or the environmental category on the device.

2: HCRSEMI classify the MSL level with using the common preconditioning setting in our assembly factory conforming to the JEDEC industrial standard J-STD-20F. Please align with HCRSEMI if your end application is quite critical to the preconditioning setting or if you have special requirement.

Absolute Maximum Ratings

Over operating free-air temperature range(unless otherwise noted) (1)

Parameter		Symbol	Min.	Max.	Unit
Supply Voltage, $+V_S$ to $-V_S$		V+	-	6	V
Signal Input Voltage		V_{IN}	(V-)-0.5	(V+)+0.5	V
Signal Output Voltage		Vout	(V-)-0.5	(V+)+0.5	V
Signal Input Current		I_{IN}	-10	+10	mA
Signal Output Current		I_O	-10	+10	mA
Output Short-circuit (3)		-	Continuous		
Thermal Resistance (4) @T_A=+25'C	SOT23-5	θ_{JA}	-	230	'C/W
	SOIC-8 (SOP8)	θ_{JA}	-	110	'C/W
	MSOP-8	θ_{JA}	-	170	'C/W
Storage Temperature Range		T_{STG}	-65 to +150		'C
Operating Temperature Range note 2		T_A	-40 to +125		'C
Junction Temperature (5)		T_J	+150		'C
Lead Temperature (Soldering, 10s)		T_{LEAD}	260		'C
Human Body Model ESD Protection		ESD HBM	±4		KV
Machine Model ESD Protection		ESD MM	1000		V

Note 1. Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.

2. Input terminals are diode-clamped to the power-supply rails. Input signals that can swing more than 0.5V beyond the supply rails should be current-limited to 10mA or less.

3. Short-circuit to ground, one amplifier per package.

4. The package thermal impedance is calculated in accordance with JESD-51.

5. The maximum power dissipation is a function of TJ(MAX), RθJA, and TA. The maximum allowable power dissipation at any ambient temperature is PD = (T J(MAX) - TA) / RθJA. All numbers apply for packages soldered directly onto a PCB.

Recommended Operating Conditions

Parameter		Symbol	Min.	Max.	Unit
Supply Voltage, $+V_S$ to $-V_S$	Signal-supply	V_{IN}	2.2	5.5	V
	Dual-supply		±1.1	±2.75	V
Operating Temperature Range		Ta	-40	+125	'C

Electrical Characteristics

(T_A=25 `C, Vs=+5V, RL=10KΩ, Full= -40'C to +125'C, Unless Otherwise Specified.)

Parameter	Symbol	Conditions	T_A	Min	Type	Max	Unit
Offset Voltage							
Input Offset Voltage	V_{OS}	V_S = 2.2V, V_{CM}=1.1V	25'C	-10	±1.2	+10	uV
		V_S = 5V, V_{CM}=2.5V	25'C	-15	±2	+15	
Input Offset Voltage Average Drift	$\Delta V_{OS}/\Delta T$	-	Full	-	±0.1	-	uV/'C
Input Bias Current:							
Input Bias Current:	I_B	V_{CM}=2.5V	25'C	-	100	-	pA
Input Offset Current:	I_{OS}	V_{CM}=2.5V	25'C	-	100	-	pA
Input Voltage Range							
Common-Mode Voltage Range	V_{CM}	-	Full	(V-)	-	(V+)	V
Common Mode Rejection Ratio	CMRR	V_{CM}= 0V to 5V	25'C	105	125	-	dB
			Full	100	-	-	
Output Characteristics							
Open-Loop Voltage Gain	A_{OL}	RL=10KΩ, Vo=0.1V to 4.9V	25'C	110	130	-	dB
			Full	100	-	-	
Output Swing from Positive Rail	V_{OH}	V_S=5V, R_{LOAD}=10KΩ to V_S/2	25'C	-	5	20	mV
Output Swing from Negative Rail	V_{OL}	V_S=5V, R_{LOAD}=10KΩ to V_S/2	25'C	-	5	20	
Short-Circuit Current	I_{SHRT}	Source	25'C	20	40	-	mA
		Sink	25'C	30	50	-	
Power Supply							
Operating Voltage Range	V_S		Full	2.2	-	5.5	V
Quiescent Current per Amplifier	I_Q	V_S=±2.5V, I_O=0mA	25'C	-	1.5	1.9	mA
			Full	-	-	2.1	
Power-Supply Rejection Ratio	PSRR	V_S= 2.2V to 5.5V	25'C	95	125	-	dB
			Full	90	-	-	
Dynamic Performance							
Gain Bandwidth Product	GBW	-	25'C	-	3.7	-	MHz
Slew Rate	SR	G=+1, CL=100pF	25'C	-	0.7	-	V/uS
Setting Time, 0.1%	ts	G=+1, V_{IN}=2V Step	25'C	-	25	-	us
Overload Recovery Time	t_{OR}	V_{IN}*Gain >=V_S, G=11	25'C	-	1.5	-	us
Turn On Time	t_{ON}	-	25'C	-	60	-	us
Phase Margin	PM	RL=10KΩ, CL=50pF	25'C	-	60	-	'C
Capacitive Load Drive	C_{LOAD}	-	25'C	-	100	-	pF
Noise Performance							
Input Voltage Noise	e_{np-p}	V_S=5V, f=0.1Hz to 10Hz	25'C	-	0.15	-	uV_{pp}
Input Voltage Noise Density	e_n	f=1KHz	25'C	-	5.5	-	nV/ √Hz

Typical Performance Characteristics.

(TA= +25°C, VS= 5V, RL= 10kΩ connected to VS/2, VOUT = VS/2, unless otherwise noted.)

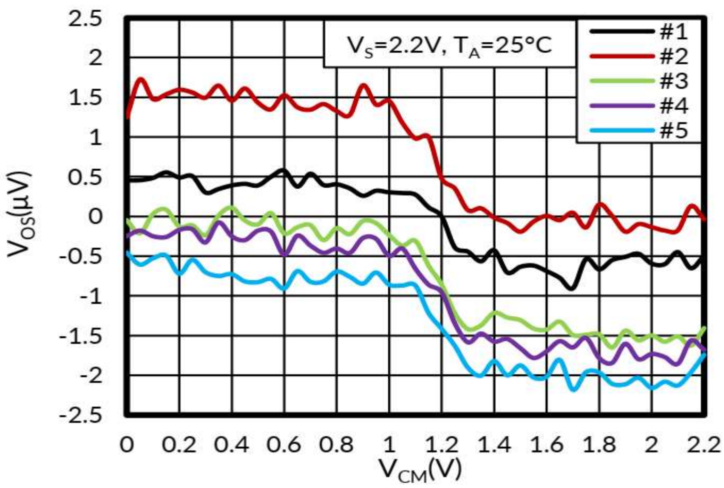


Figure 3. Input Offset Voltage vs Common-Mode Voltage

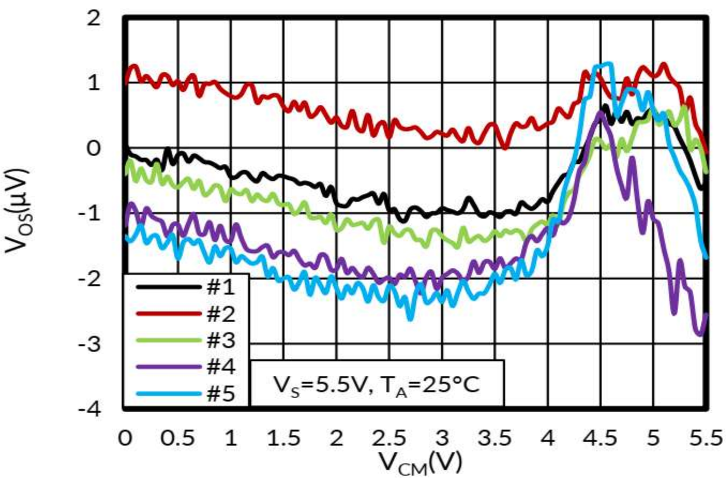


Figure 4. Input Offset Voltage vs Common-Mode Voltage

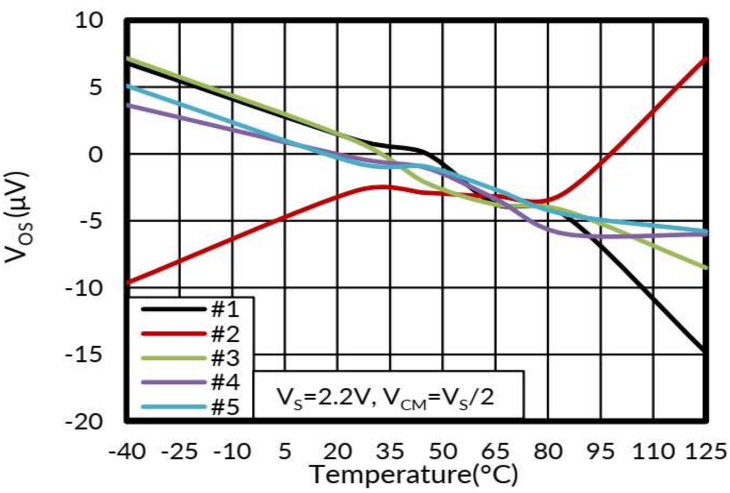


Figure 5. Input Offset Voltage vs Temperature

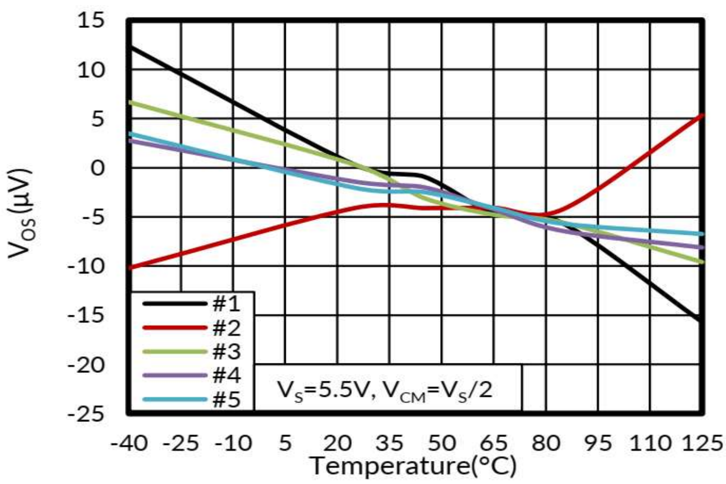


Figure 6. Input Offset Voltage vs Temperature

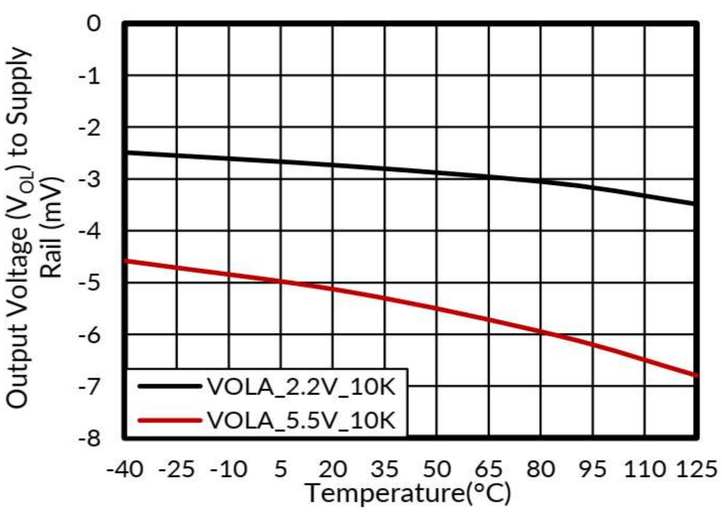


Figure 7. Output Voltage (VOL) to Supply Rail vs Temperature

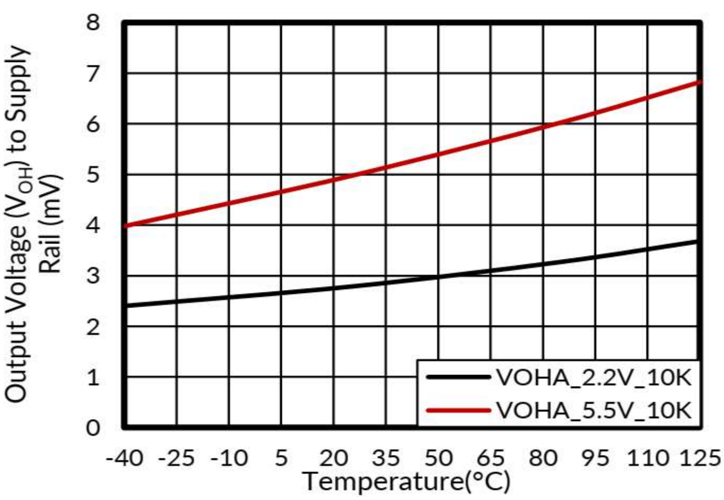


Figure 8. Output Voltage (VOH) to Supply Rail vs Temperature

Typical Performance Characteristics(Con.)

(TA= +25°C, VS= 5V, RL= 10kΩ connected to VS/2, VOUT = VS/2, unless otherwise noted.)

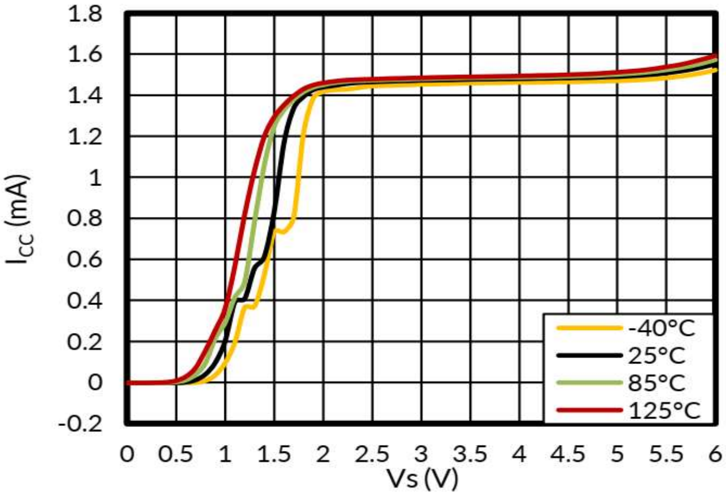


Figure 9. Supply Current vs Supply Voltage

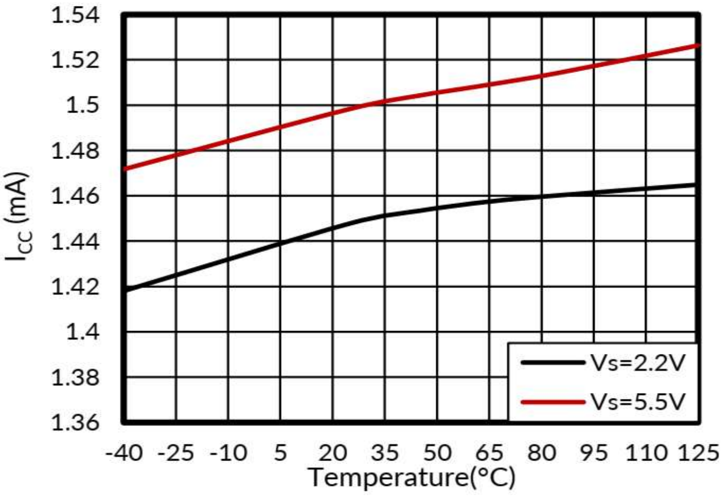


Figure 10. Supply Current vs Temperature

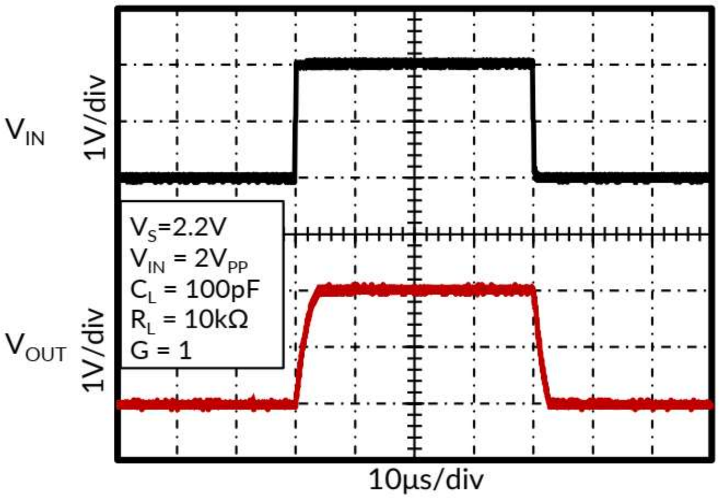


Figure 11. Large Signal Transient Response

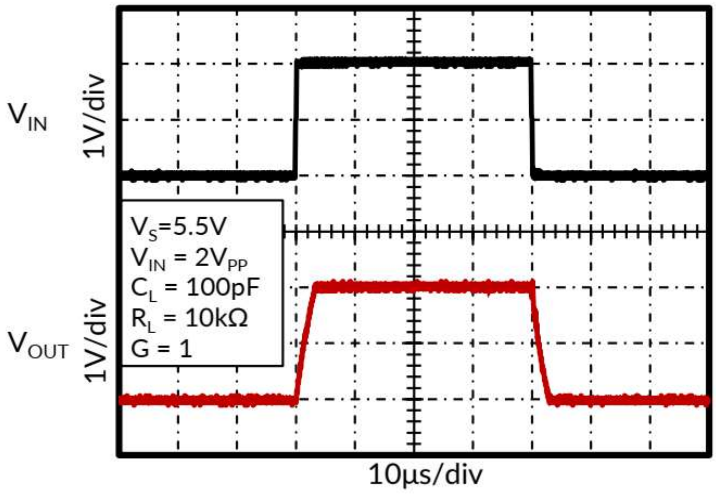


Figure 12. Large Signal Transient Response

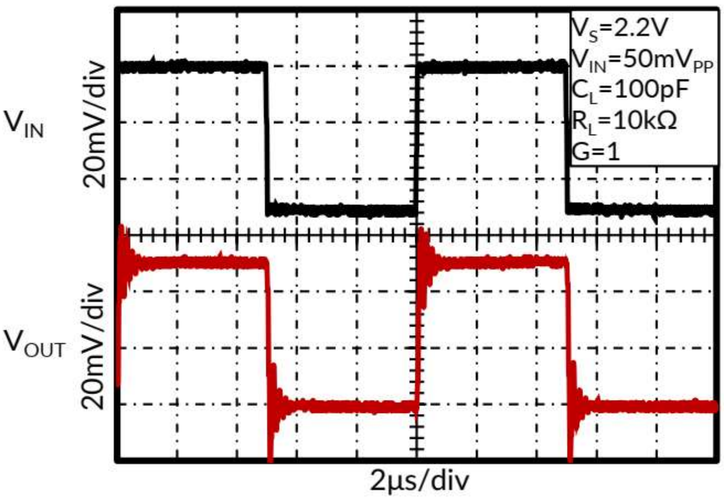


Figure 13. Small Signal Transient Response

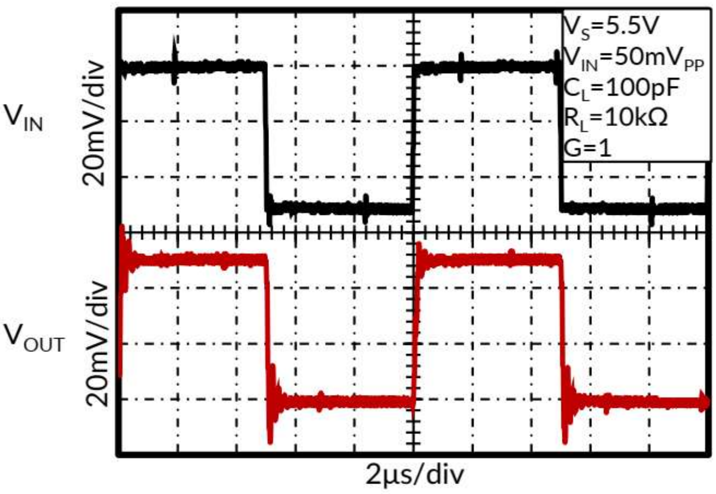


Figure 14. Small Signal Transient Response

Typical Performance Characteristics(Con.)

(TA= +25°C, VS= 5V, RL= 10kΩ connected to VS/2, VOUT = VS/2, unless otherwise noted.)

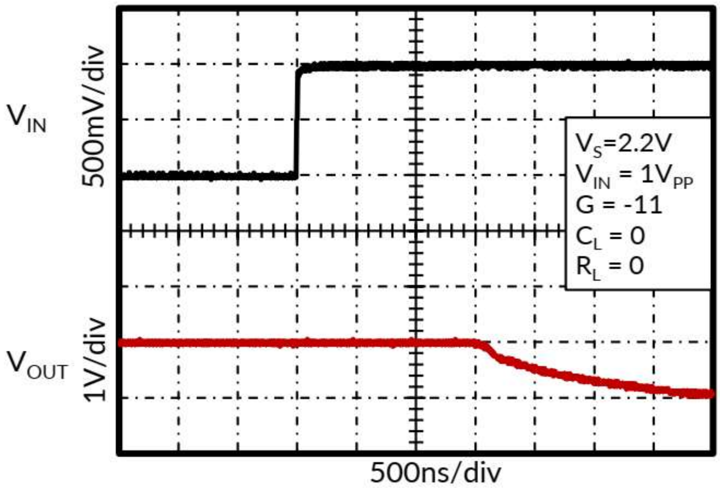


Figure 15. Positive Overload Recovery

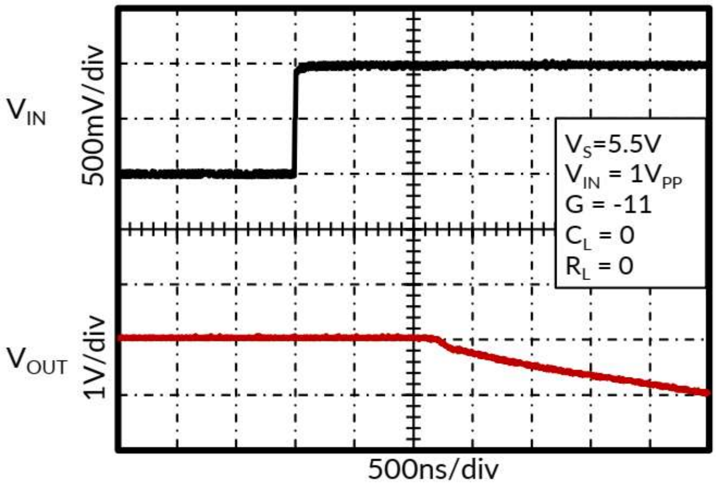


Figure 16. Positive Overload Recovery

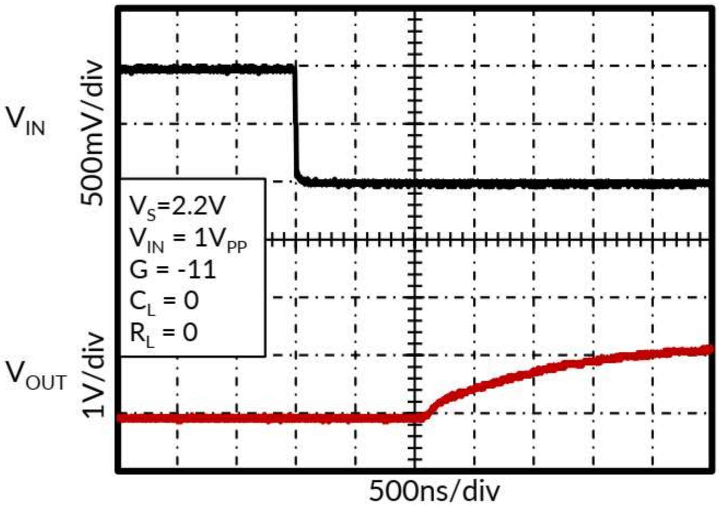


Figure 17. Negative Overload Recovery

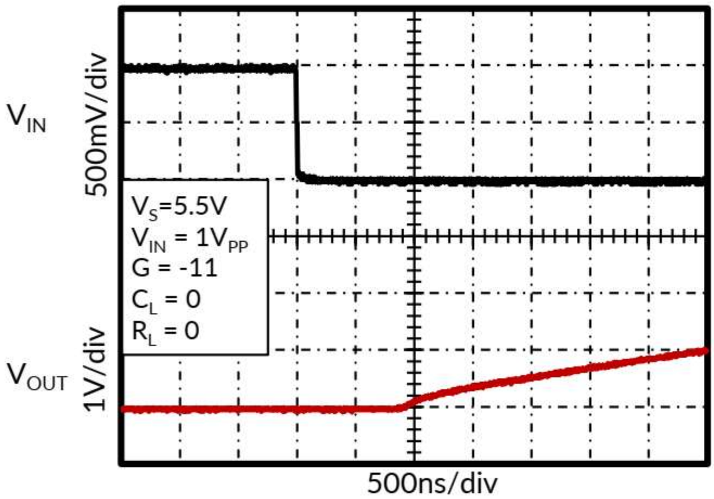


Figure 18. Negative Overload Recovery

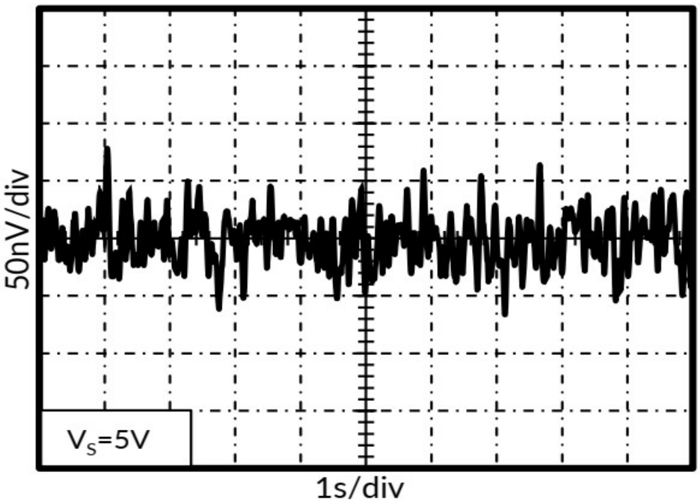


Figure 19. 0.1Hz to 10Hz Noise

Applications Information

The HCR8531/HCR8532 are precision, ultralow noise, zero-drift operational amplifiers that feature a patented chopping technique. This chopping technique offers ultralow input offset voltage of ±1.2 μV typical and input offset voltage drift of ±0.1μV/°C typical.

Offset voltage errors due to common-mode voltage swings and power supply variations are also corrected by the chopping technique, resulting in a typical CMRR figure of 125 dB (at V_{CM}=0V to 5V) and a PSRR figure of 125 dB (at VS=2.2V to 5.5V). The HCR8531 /HCR8532 have low broadband noise of 0.15 μVPP (at f= 0.1Hz to 10Hz and V_S=5V) with no 1/f noise component. These features are ideal for amplification of low level signals in dc or subhertz high precision applications.

Input Protection

The HCR8531/HCR8532 have internal ESD protection diodes that are connected between the inputs and each supply rail. These diodes protect the input transistors in the event of electrostatic discharge and are reverse biased during normal operation. This protection scheme allows voltages as high as approximately 500mV beyond the rails to be applied at the input of either terminal without causing permanent damage.

When either input exceeds one of the supply rails by more than 500mV, the ESD diodes become forward biased and large amounts of current begin to flow through them. Without current limiting, this excessive fault current causes permanent damage to the device. If the inputs are subjected to overvoltage conditions, insert a resistor in series with each input to limit the input current to 10mA maximum. However, consider the resistor thermal noise effect on the entire circuit.

Rail-to-Rail Input and Output

The HCR8531/HCR8532 feature rail-to-rail input and output with a supply voltage from 2.2V to 5.5V. Figure 20 shows the input and output waveforms of the HCR8531 /HCR8532 configured as a unity-gain buffer with a supply voltage of ±2.5 V and a resistive load of 10 kΩ. With an input voltage of ±2.5 V, the HCR8531/HCR8532 allow the output to swing very close to both rails. Additionally, the devices do not exhibit phase reversal.

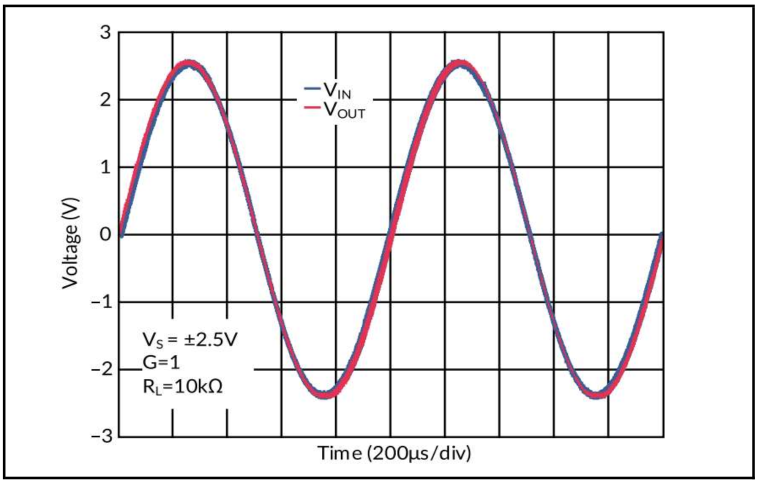


Figure 20. Rail-to-Rail Input and Output

Noise Considerations

1/f Noise

1/f noise, also known as pink noise or flicker noise, is inherent in semiconductor devices and increases as frequency decreases. At low frequency, 1/f noise is a major noise contributor and causes a significant output voltage offset when amplified by the noise gain of the circuit. However, the HCR8531/HCR8532 eliminate the 1/f noise internally, thus making these devices an excellent choice for dc or subhertz high precision applications. The 0.1Hz to 10Hz amplifier voltage noise is only 0.15 μVpp at a supply voltage of 5 V.

The low frequency 1/f noise, which appears as a slow varying offset to the HCR8531/HCR8532, is greatly reduced by the chopping technique. This reduction in 1/f noise allows the HCR8531/HCR8532 to have much

Noise Considerations(Con.)

1/f Noise(con.)

lower noise at dc and low frequency compared to standard low noise amplifiers that are susceptible to 1/f noise

Source Resistance

With 5.5 nV/√Hz of broadband noise at 1 kHz (VS=5 V), the HCR8531/HCR8532 are among the lowest noise zero-drift amplifiers currently available in the industry. Therefore, it is important to carefully select the input source resistance to maintain a total low noise.

The total input referred broadband noise (en total) from any amplifier is primarily a function of three types of noise: input voltage noise, input current noise, and thermal (Johnson) noise from the external resistors.

These uncorrelated noise sources can be summed up in a root sum squared (rss) manner using the following equation:

$$e_{n\,total} = [\,e_n^2 + 4kTR_S + (\,i_n \times R_S\,)^2\,]^{1/2}$$

where:

en is the input voltage noise of the amplifier (V/√Hz)

k is the Boltzmann's constant (1.38×10^{-23} J/K).

T is the temperature in Kelvin (K).

RS is the total input source resistance (Ω).

in is the input current noise of the amplifier (A/√Hz).

The total equivalent rms noise over a specific bandwidth is expressed as

$$e_{n,rms} = e_{n\,total} \times \sqrt{BW}$$

where BW is the bandwidth in hertz

This analysis is valid for broadband noise calculation. If the bandwidth of concern includes the chopping frequency, more complicated calculations must be made to include the effect of the noise energy spectrum at

Source Resistance(con.)

the chopping frequency (see the Residual Voltage Ripple section).

With a low source resistance of RS < 1 kΩ, the voltage noise of the amplifier dominates. As source resistance increases, the thermal noise of RS dominates. As the source resistance increases further, where RS>100 kΩ, the current noise becomes the main contributor to the total input noise.

Voltage Noise Density with Different Gain Configurations

Figure 21 shows the voltage noise density vs closed-loop gain of a zero-drift amplifier from a leading competitor. The voltage noise density of the amplifier increases from 11nV/√Hz to 21nV/√Hz as the closed-loop gain decreases from 1000 to 1.

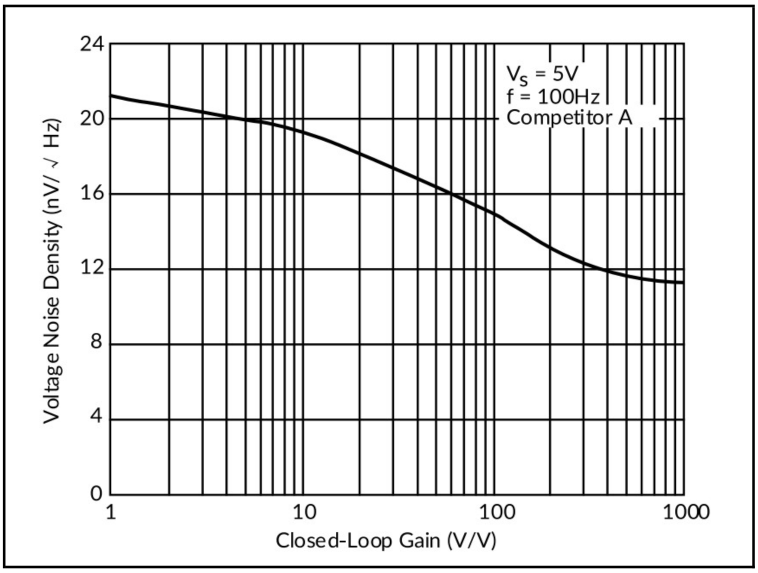


Figure 21. Competitor A: Voltage Noise Density vs Closed-Loop Gain

Figure 22 shows the voltage noise density vs frequency of the HCR8531/HCR8532 for three different gain configurations. The HCR8531/HCR8532 offer a constant input voltage noise density of 6nV/√Hz to 7nV/√Hz, regardless of the gain configuration.

Noise Considerations(Con.)

Voltage Noise Density with Different Gain Configurations(con.)

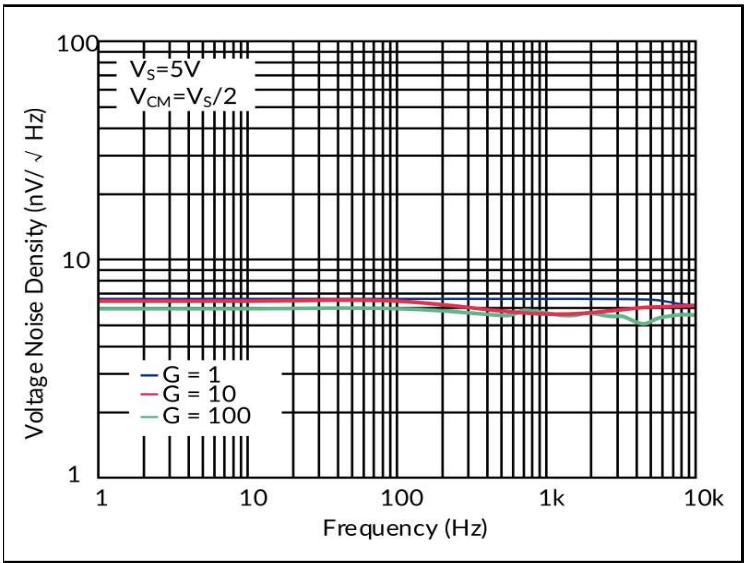


Figure 22. Voltage Noise Density vs Frequency with Different Gain Configurations

Residual Voltage Ripple

Although autocorrection feedback (ACFB) suppresses the chopping related voltage ripple, higher noise spectrum exists at the chopping frequency and its harmonics due to the remaining ripple. Figure 23 shows the voltage noise density of the HCR8531/HCR8532 configured in unity gain. A noise energy spectrum of 50nV/√Hz can be seen at the chopping frequency of 200kHz. This noise energy spectrum is significant when the op amp has a closed-loop frequency that is higher than the chopping frequency.

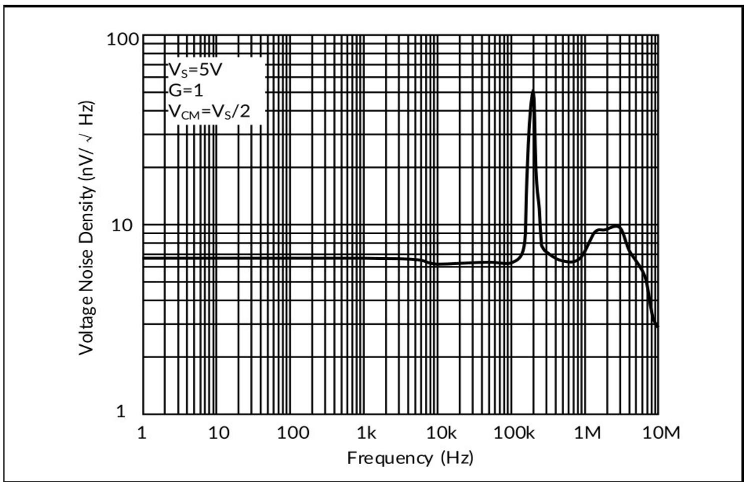


Figure 23. Voltage Noise Density vs Frequency

Residual Voltage Ripple(con.)

To further suppress the noise at the chopping frequency, it is recommended that a post filter be placed at the output of the amplifier.

Comparator Operation

Figure 24 shows the HCR8532 configured as a voltage follower with an input voltage that is always kept at midpoint of the power supplies. The same configuration is applied to the unused channel. A1 and A2 indicate the placement of ammeters to measure supply current. As shown in Figure 25, as expected, in normal operating condition, Is+ = Is− = 3 mA for the dual HCR8532 at 5V of supplies.

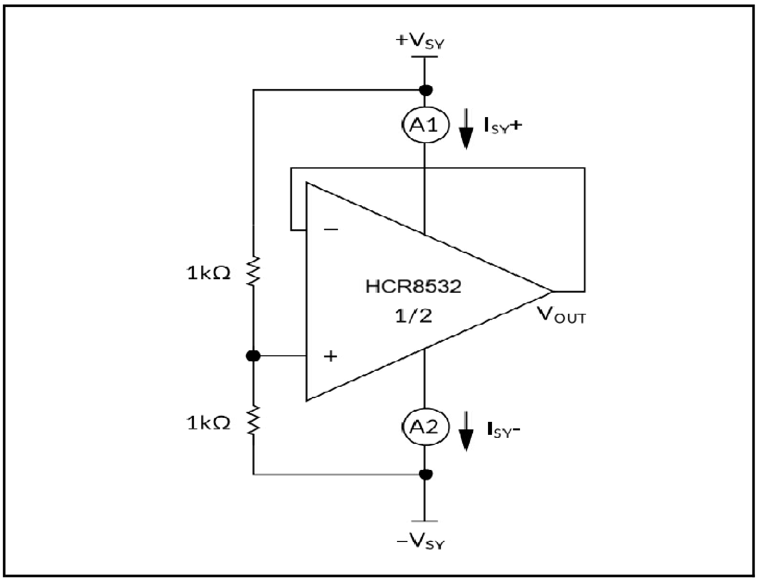


Figure 24. Voltage Follower

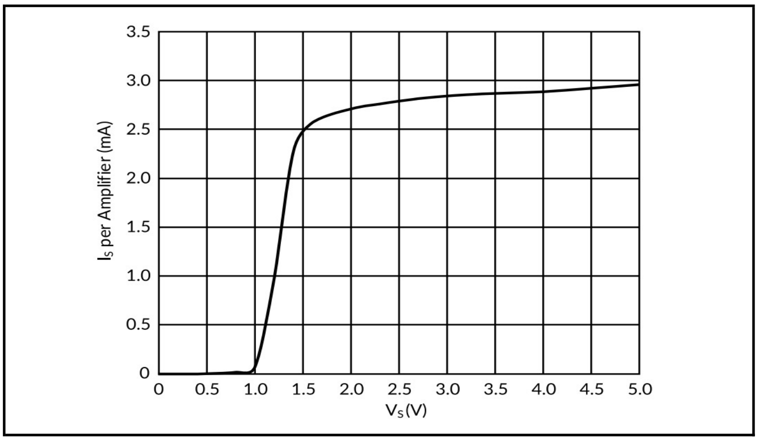


Figure 25. Supply Current vs Supply Voltage

Noise Considerations(Con.)

Comparator Operation(con)

Figure 26 and Figure 27 show the HCR8532 configured as comparators, with 1kΩ resistors in series with the input pins. Figure 28 shows the supply currents for both configurations. Supply currents increase slightly to 3.2mA per dual amplifier at 5 V of supplies.

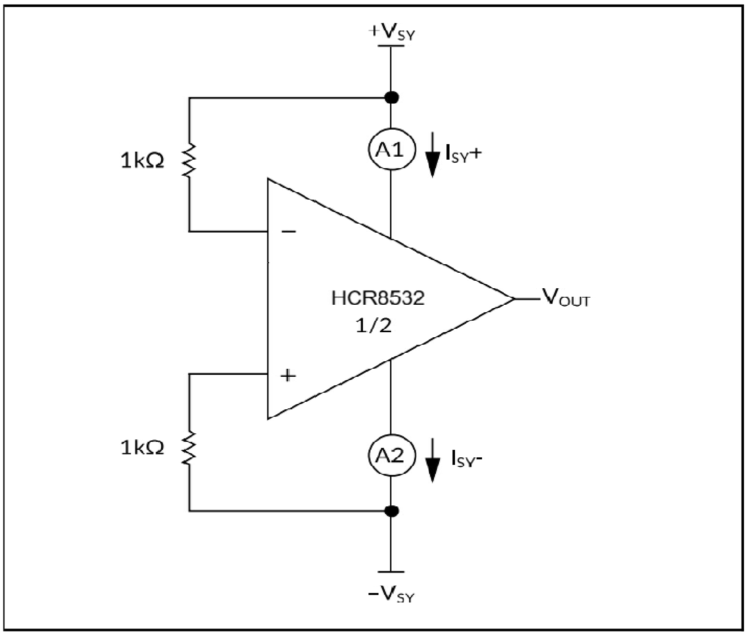


Figure 26. Comparator A

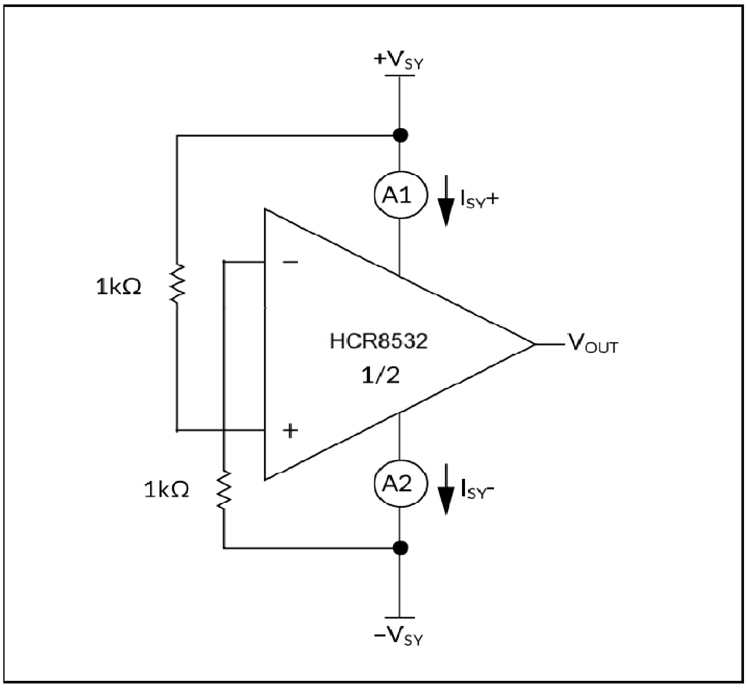


Figure 27. Comparator B

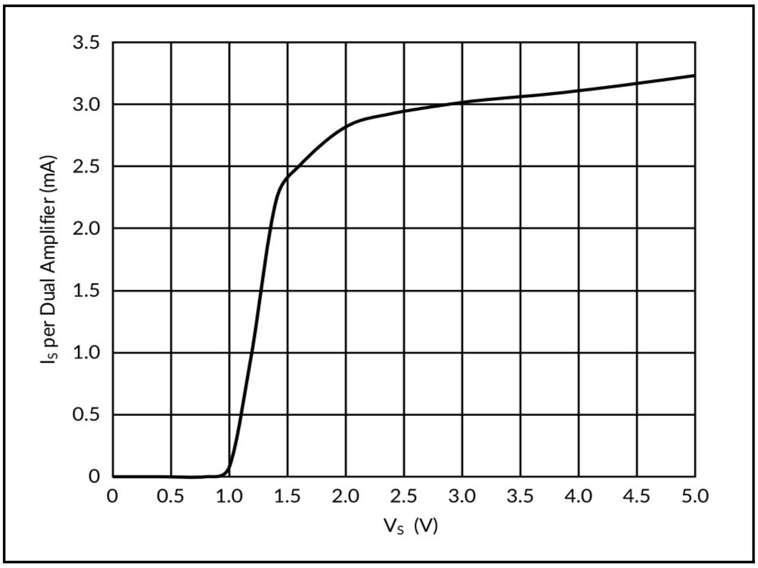


Figure 28. Supply Current vs Supply Voltage (Comparator A and Comparator B)

Layout Guidelines

Attention to good layout practices is always recommend Keep traces short. When possible, use a PCB ground plane with surface-mount components placed as close to the device pins as possible. Place a 0.1uF capacitor closely across the supply pins.

These guidelines should be applied throughout the analog circuit to improve performance and provide benefits such as reducing the EMI susceptibility.

Layout Example

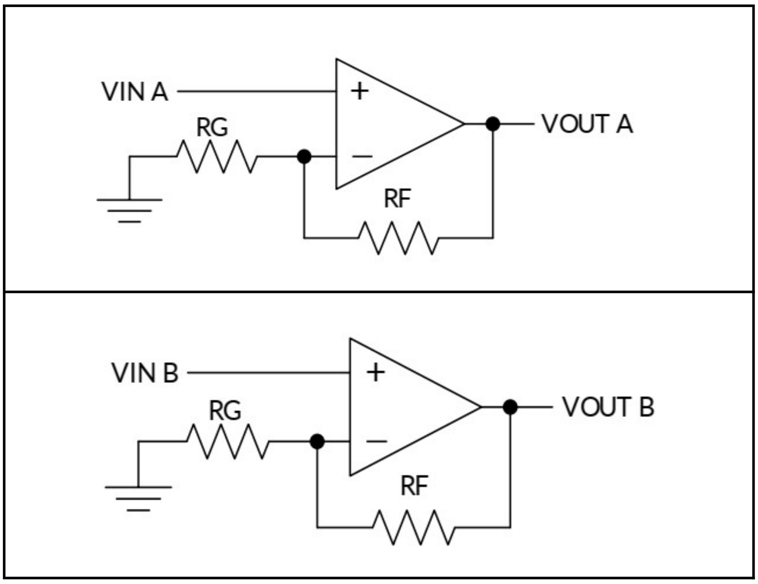
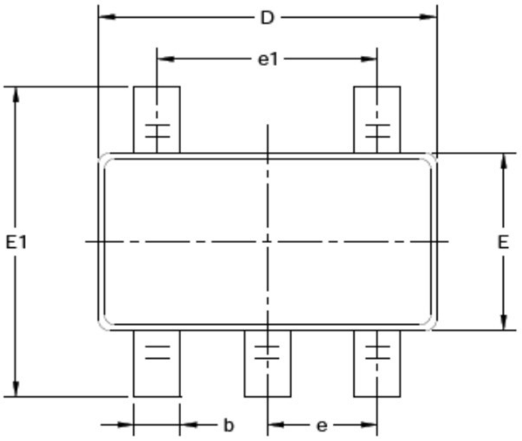
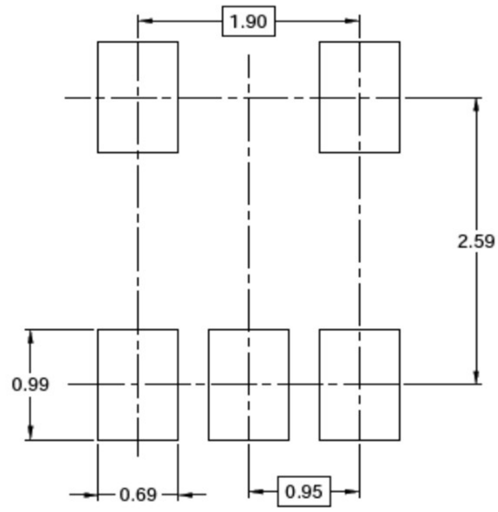


Figure 29. Schematic Representation

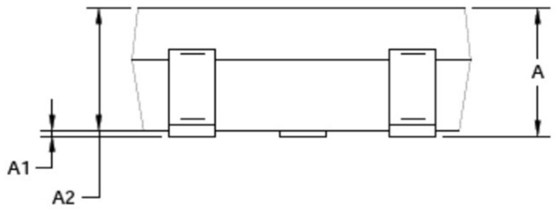
Mechanical Dimensions

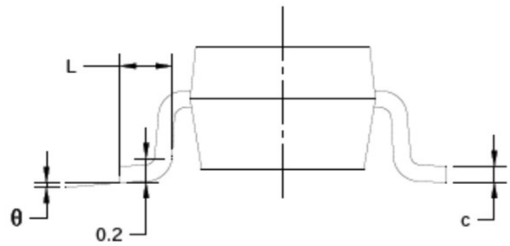
M5: SOT23-5 package





RECOMMENDED LAND PATTERN (Unit: mm)



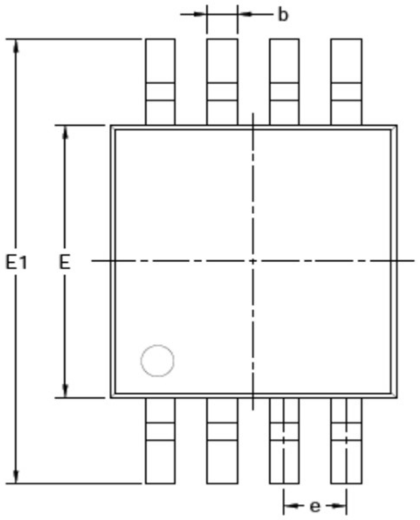


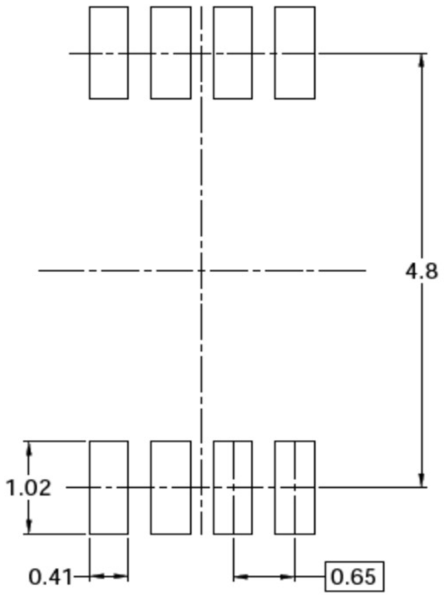
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950 BSC		0.037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

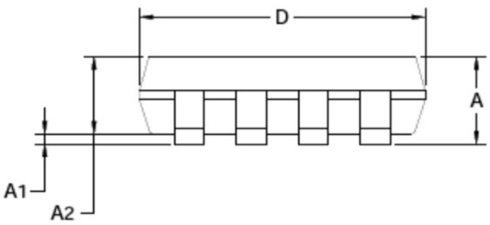
NOTES:
1. Body dimensions do not include mode flash or protrusion.
2. This drawing is subject to change without notice.

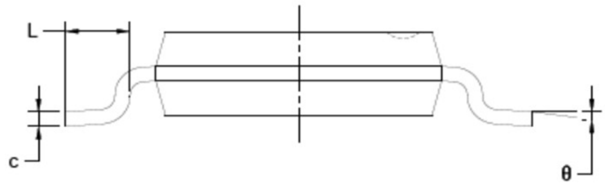
Mechanical Dimensions(Con.)

SM8: MSOP-8 Package







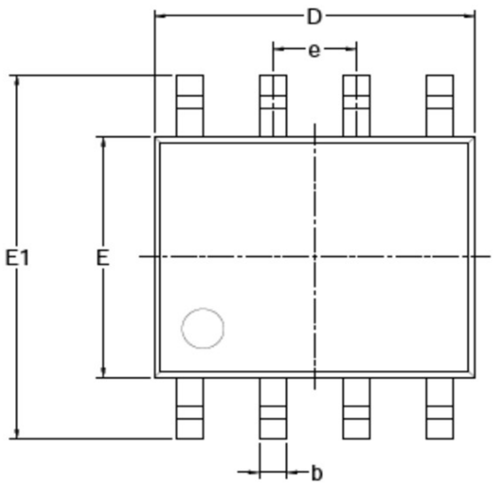


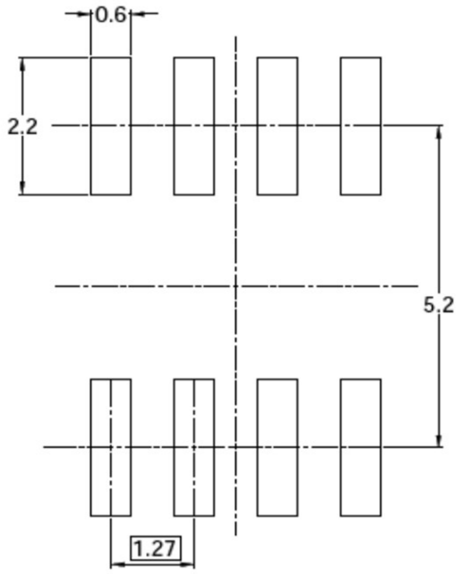
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
e	0.650 BSC		0.026 BSC	
L	0.400	0.800	0.016	0.031
θ	0°	6°	0°	6°

NOTES:
1. Body dimensions do not include mode flash or protrusion.
2. This drawing is subject to change without notice.

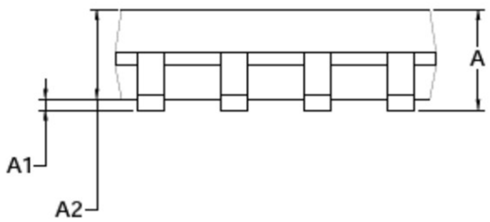
Mechanical Dimensions(Con.)

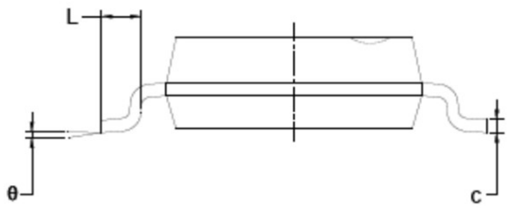
M8: SOIC-8(SOP-8) Package





RECOMMENDED LAND PATTERN (Unit: mm)



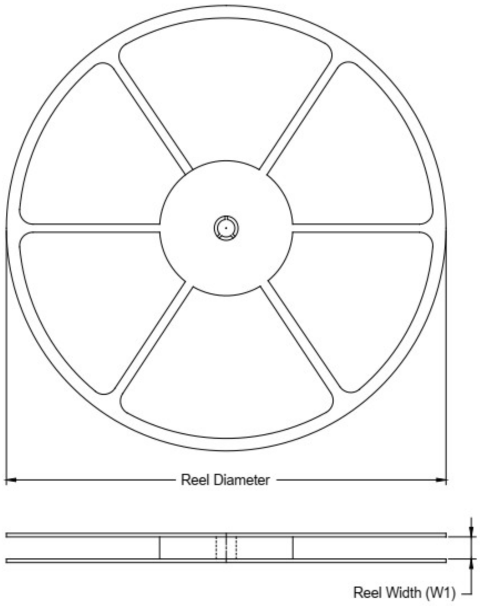


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.27 BSC		0.050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

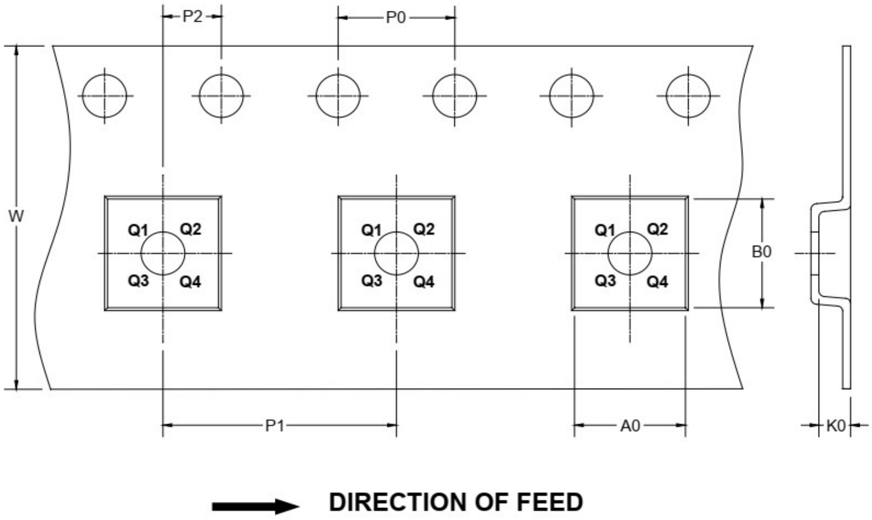
NOTES:
1. Body dimensions do not include mode flash or protrusion.
2. This drawing is subject to change without notice.

Tape and Reel Information

REEL DIMENSIONS



TAPE DIMENSIONS



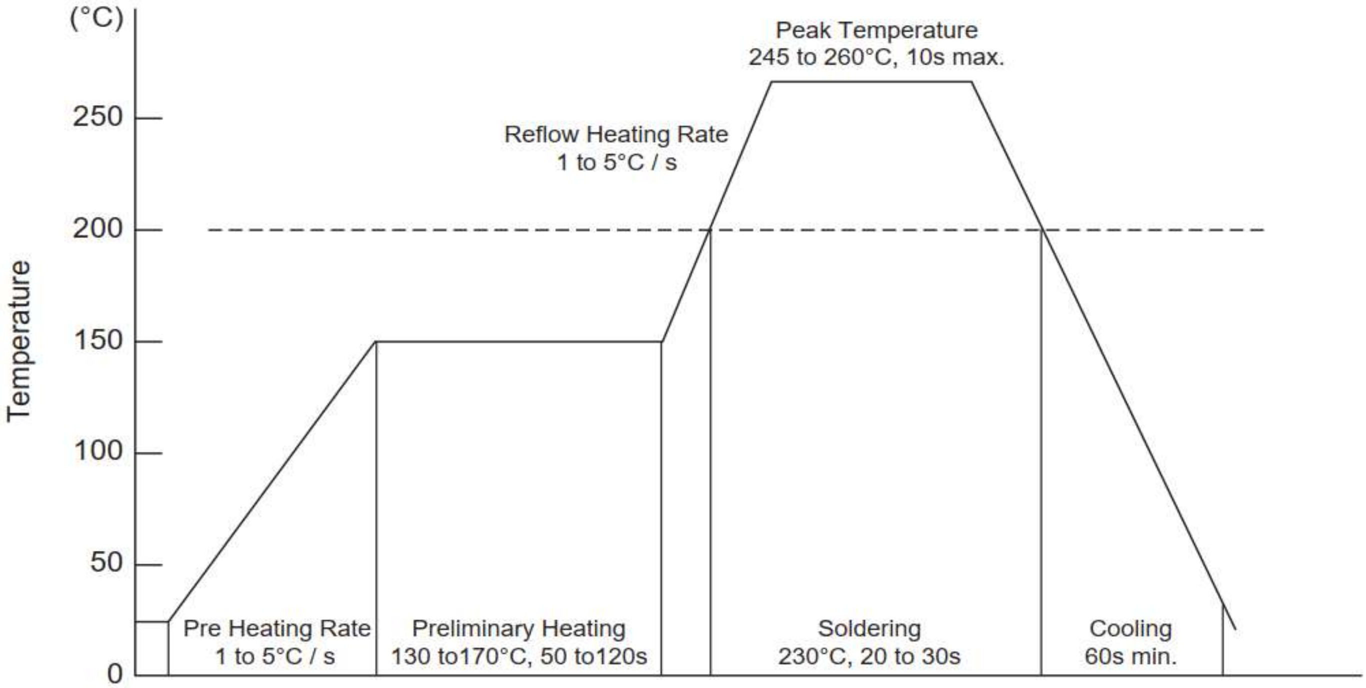
NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
SOT-23-5	7"	9.5	3.20	3.20	1.40	4.0	4.0	2.0	8.0	Q3
SOIC-8	13"	12.4	6.40	5.40	2.10	4.0	8.0	2.0	12.0	Q1
MSOP-8	13"	12.4	5.20	3.30	1.50	4.0	8.0	2.0	12.0	Q1

Conditins of Soldering and Storage

* Recommended condition of reflow soldering



Recommended peak temperature is over 245'C, if peak temperature is below 245'C, you may adjust the following parameters:

* Time length of peak temperature (longer)
* Time length of soldering (longer)
* Thickness of solder paste (thicker)

* Conditions of hand soldering
  * Temperature : 300'C
  * Time : 3s max
  * Times : one time

* Storage conditions
  * Temperature
    5 to 40'C
  * Humidity
    30 to 80% RH
  * Recommended period
    One year after manufacturing