Zero-Drift, Rail-to-Rail I/O CMOS Operational Amplifiers

Features

* Low Offset Voltage: ±1μV (TYP)
* Input Offset Drift: ±0.005μV/°C
* High Gain Bandwidth Product: 350KHz
* Rail-to-Rail Input and Output
* High Gain, CMRR, PSRR: 130dB（TYP）
* High Slew Rate: 0.17V/μs
* Low Noise: 3.2μVp-p (0.01~10Hz)
* Low Power Consumption: 60uA/op Amp
* Overload Recovery Time: 6μs
* Low Supply Voltage: +2.3 V to +5.5 V
* No External Capacitors Required
* Operating Temperature: -40'C to +125'C

Applications

* Temperature Sensors
* Medical/Industrial Instrumentation
* Pressure Sensors
* Battery-Powered Instrumentation
* Active Filtering
* Weight Scale Sensor
* Strain Gage Amplifiers
* Power Converter/Inverter

General Description

The HCR8521/HCR8522/HCR8524 series of CMOS operational amplifiers use auto-zero techniques to simultaneously provide very low offset voltage (5uV max) and near-zero drift over time and temperature. This family of amplifiers has ultra low noise, offset and power.

This miniature, high-precision operational amplifiers offset high input impedance and rail-to-rail input and rail-to-rail output swing. With high gain-bandwidth product of 350KHz and slew rate of 0.17V/us.

Single or dual supplies as low as +2.3V (±1.15V) and up to +5.5V (±2.75V) may be used.

The HCR8521/HCR8522/HCR8524 are specified for the extended industrial and automotive temperature range (-40°C to 125°C). The HCR8521(single) amplifier is available in SOT23-5 packages, The HCR8522(dual) amplifier is available in SOIC-8 and MSOP8 packages. The HCR8524(quad) amplifier is available in SOIC-14 and TSSOP-14 packages.

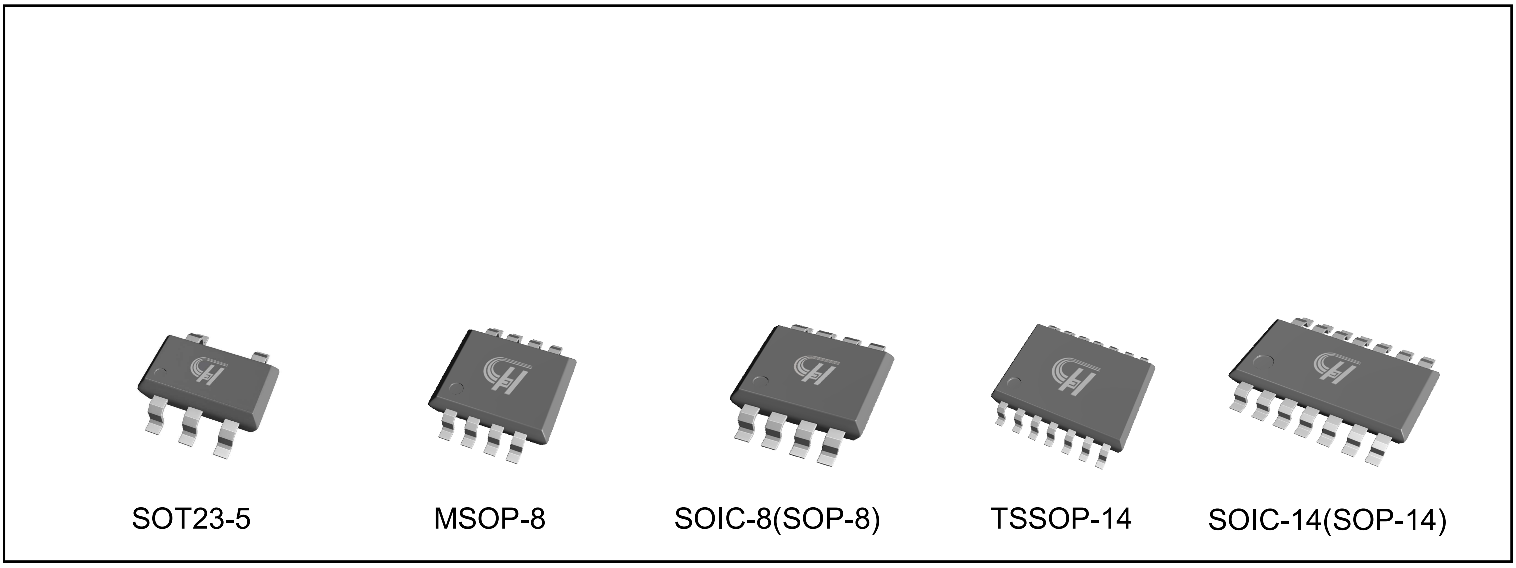
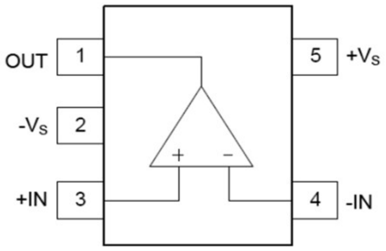


Figure 1. Package Type of HCR8521/HCR8522/HCR8524

Zero-Drift, Rail-to-Rail I/O CMOS Operational Amplifiers

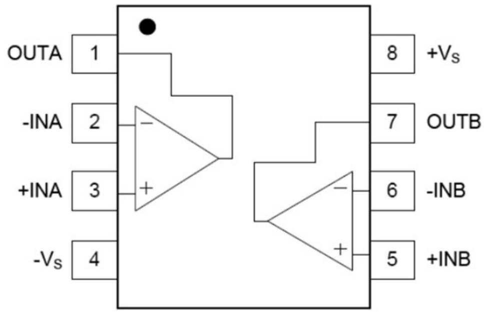
Pin Configuration

HCR8521(TOP VIEW)



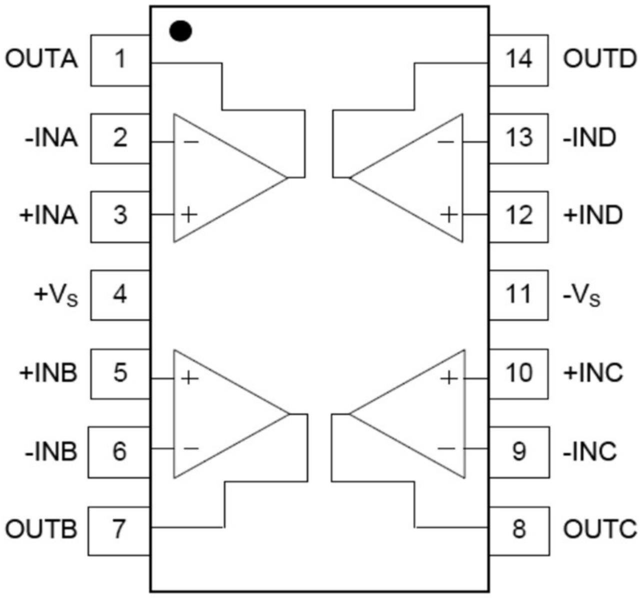
SOT23-5

HCR8522(TOP VIEW)



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

HCR8524 (TOP VIEW)



SOIC-14(SOP-14)/TSSOP14

Figure 2. Pin Configuration of HCR8521/HCR8522/HCR8524(Top View)

Pin Function Table

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

Ordering Information

Circuit Type / □ □

Type:
HCR8521
HCR8522
HCR8524

TR : Tape and Reel

Package:
M5:SOT23-5
SM8:MSOP-8
M8: SOIC-8(SOP8)
TS14: TSSOP-14
M14: SOIC-14(SOP-14)

Ordering Code

Part Number	Channel	Marking (1)	Op Temp('C)	MSL (2)	Package	Package Qty
HCR8521/M5TR	1	8521	-40'C to +125'C	MSL3	SOT23-5	3000pcs/TR
HCR8522/SM8TR	2	HCR8522xx	-40'C to +125'C	MSL3	MSOP-8	4000pcs/TR
HCR8522/M8TR	2	HCR8522xx	-40'C to +125'C	MSL3	SOIC-8 (SOP-8)	4000pcs/TR
HCR8524/TS14TR	4	HCR8524xx	-40'C to +125'C	MSL3	TSSOP14	4000pcs/TR
HCR8524/M14TR	4	HCR8524xx	-40'C to +125'C	MSL3	SOIC-14 (SOP-14)	2500pcs/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, +Vs to -Vs		V+	-	7	V
Signal Input Voltage		VIN	(V-)-0.5	(V+)+0.5	V
Signal Output Voltage		Vout	(V-)-0.5	(V+)+0.5	V
Signal Input Current		IIN	-10	+10	mA
Signal Output Current		IO	-55	+55	mA
Output Short-circuit (3)		-	Continuous		
Thermal Resistance (4) @TA=+25'C	SOT23-5	θJA	-	230	'C/W
	SOIC-8	θJA	-	110	'C/W
	MSOP-8	θJA	-	170	'C/W
	TSSOP-14	θJA	-	90	'C/W
	SOIC-14	θJA	-	105	'C/W
Storage Temperature Range		TSTG	-65 to +150		'C
Operating Temperature Range note 2		TA	-40 to +125		'C
Junction Temperature (5)		TJ	+150		'C
Lead Temperature (Soldering, 10s)		TLEAD	260		'C
Human Body Model ESD Protection		ESD HBM	±5		KV
Machine Model ESD Protection		ESD MM	±400		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, +Vs to -Vs	Signal-supply	VIN	2.3	5.5	V
	Dual-supply		±1.15	±2.75	V
Operating Temperature Range		Ta	-40	+125	'C

Electrical Characteristics

(T_A=25 `C, Vs=+5.5V, RL=10KΩ connected to VS/2V, and V_{OUT}=VS/2. V_{CM}=VS/2, Unless Otherwise Specified.)

Parameter	Symbol	Conditions	Min	Type	Max	Unit
Offset Voltage						
Input Offset Voltage	V_{OS}	V_{CM} =V_S /2	-5	±1.0	5	uV
Input Offset Voltage Average Drift	$\Delta V_{OS}/\Delta T$	-	-	±0.005	±0.05	uV/'C
Power Supply Rejection Ratio	PSRR	Vs=2.3V to 5.5V	110	130	-	dB
Channel Separation, dc		Vs=2.3V to 5.5V	-	0.1	-	uV/V
Input Bias Current:						
Input Bias Current:	I_B	V_{CM}=Vs/2	-	±10	-	pA
Input Offset Current:	I_{OS}	V_{CM}=Vs/2	-	±10	-	pA
Input Voltage Range						
Common-Mode Voltage Range	V_{CM}	-	(V-)-0.1	-	(V+)+0.1	V
Common Mode Rejection Ratio	CMRR	(V-)-0.1V<V_{CM}<(V+)+0.1V	110	130	-	dB
Input Capacitance						
Input differential capacitance			-	1	-	pF
Input common capacitance			-	5	-	pF
Output Characteristics						
Open-Loop Voltage Gain	A_{OL}	RL=10KΩ, Vo=0.3V to 4.7V	110	130	-	dB
Output Voltage High	V_{OH}	R_L=100KΩ to GND	4.99	4.998	-	V
		R_L=10KΩ to GND	4.95	4.98	-	V
Output Voltage Low	V_{OL}	RL=100KΩ to V+	-	1	10	mV
		RL=10KΩ to V+	-	10	30	mV
Short-Circuit Current	I_{SHRT}	-	-	±25	-	mA
Power Supply						
Operating Voltage Range	V_S		2.3	-	5.5	V
Quiescent Current per Amplifier	I_Q	I_{OUT}=0mA	-	60	87	uA
Dynamic Performance						
Gain Bandwidth Product	GBW	-	-	350	-	KHz
Slew Rate	SR	G=+1	-	0.17	-	V/uS
Overload Recovery Time	t_{OR}	-	-	6	-	us
Noise Performance						
Input Voltage Noise	e_{np-p}	f=0.01Hz to 10Hz	-	3.2	-	uV_{pp}
		f=0.01Hz to 1Hz	-	0.97	-	uV_{pp}
Input Voltage Noise Density	e_n	f=1KHz	-	140	-	nV/ √ Hz

Typical Performance Characteristics.

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

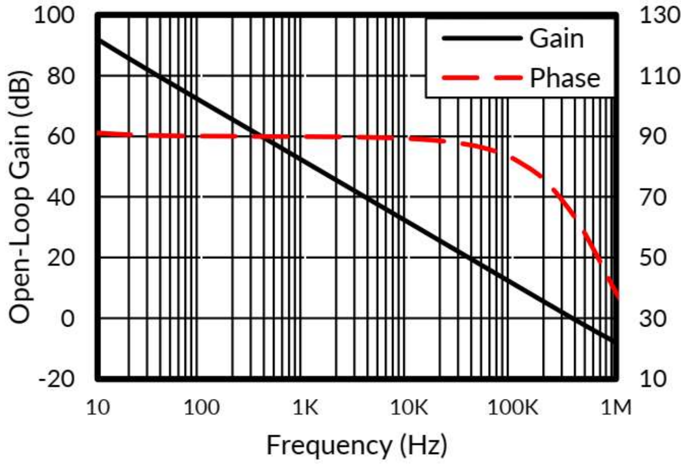


Figure 3. Open-Loop Gain and Phase vs Frequency

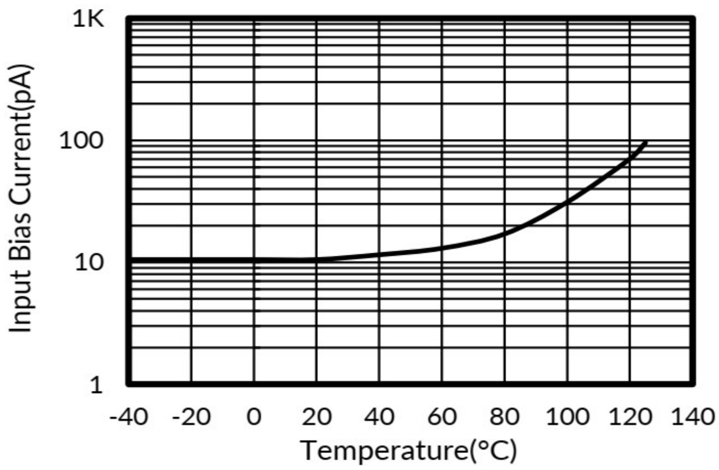


Figure 4. Input Bias Current vs Temperature

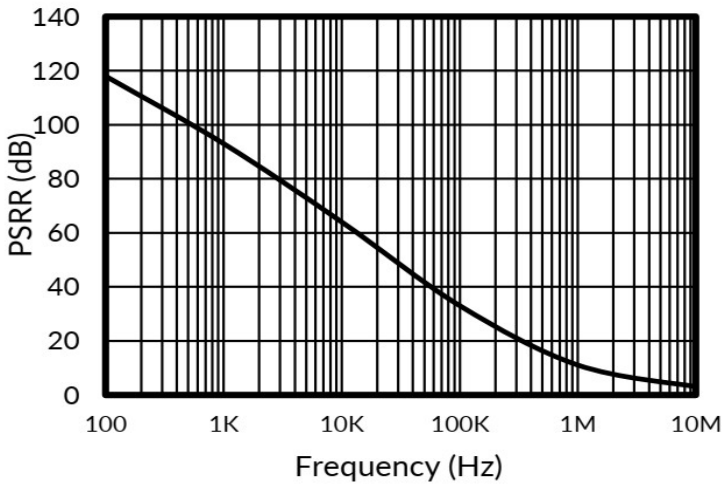


Figure 5. Power-Supply Rejection Ratio vs Frequency

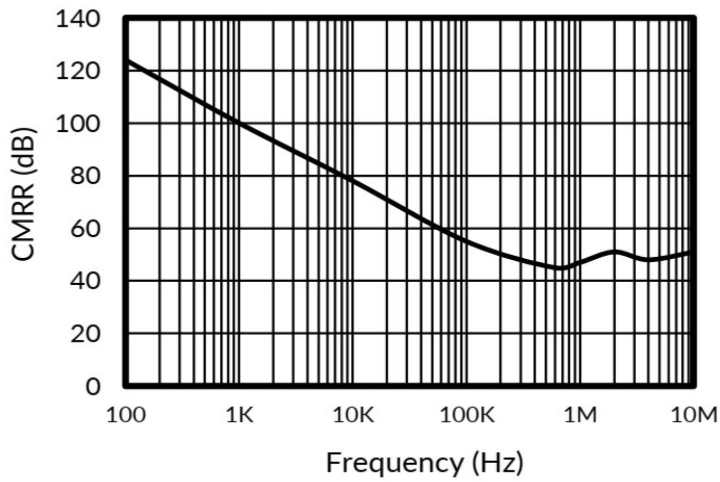


Figure 6. Common-Mode Rejection Ration vs Frequency

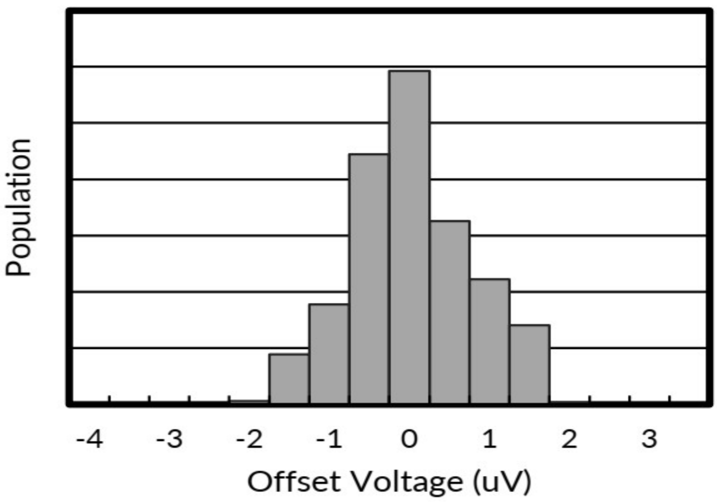


Figure 7. Offset Voltage Production Distribution

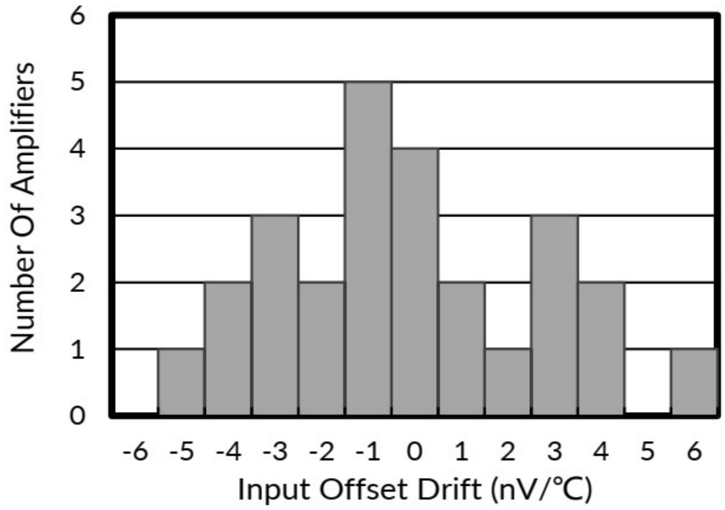


Figure 8. Offset Voltage Drift Production Distribution

Typical Performance Characteristics(Con.)

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

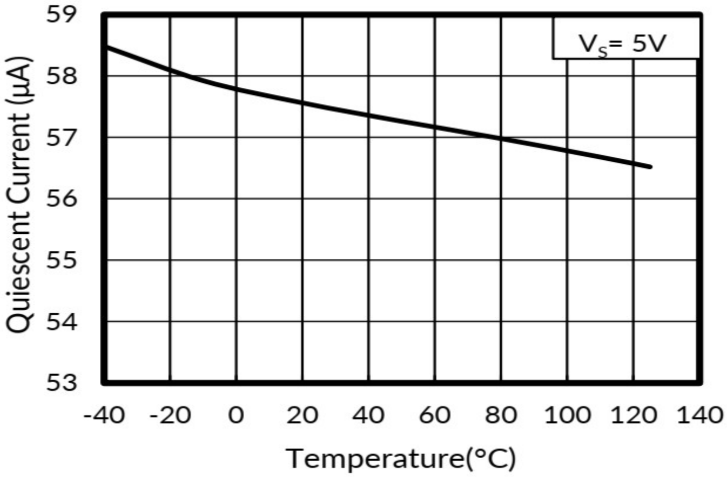


Figure 9. Quiescent Current vs Temperature

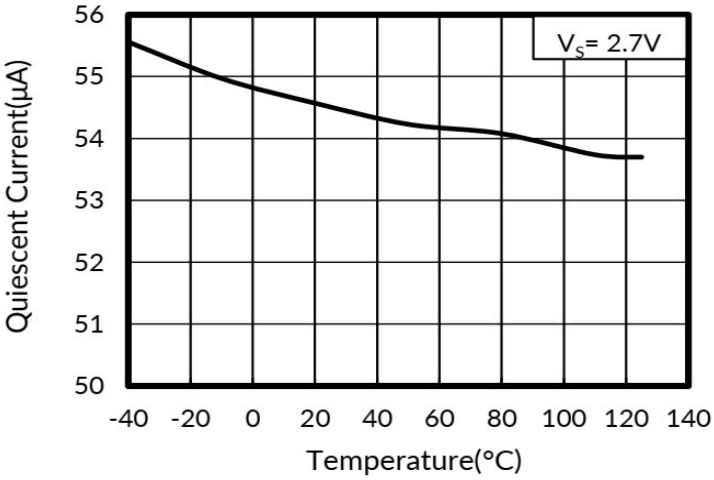


Figure 10. Quiescent Current vs Temperature

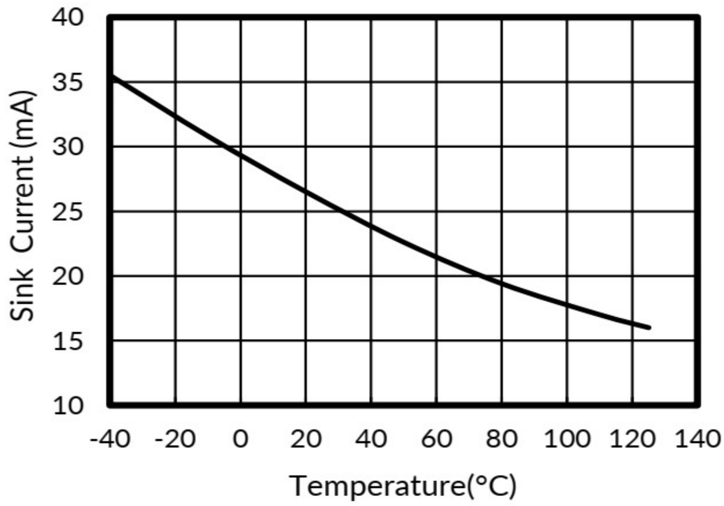


Figure 11. Sink Current vs Temperature

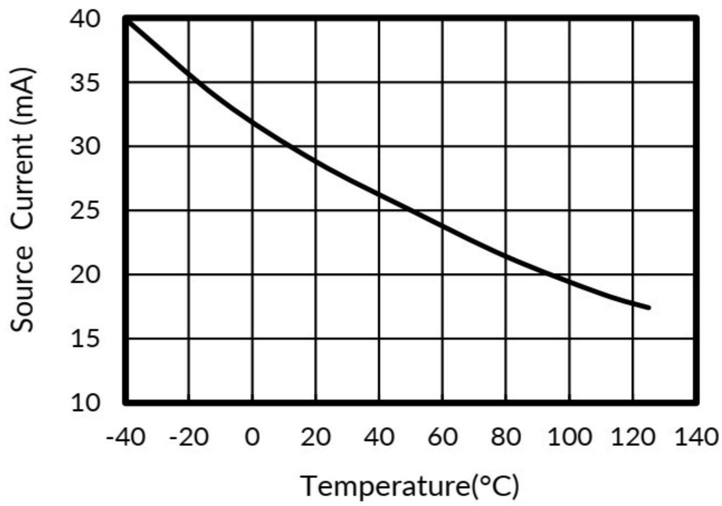


Figure 12. Source Current vs Temperature

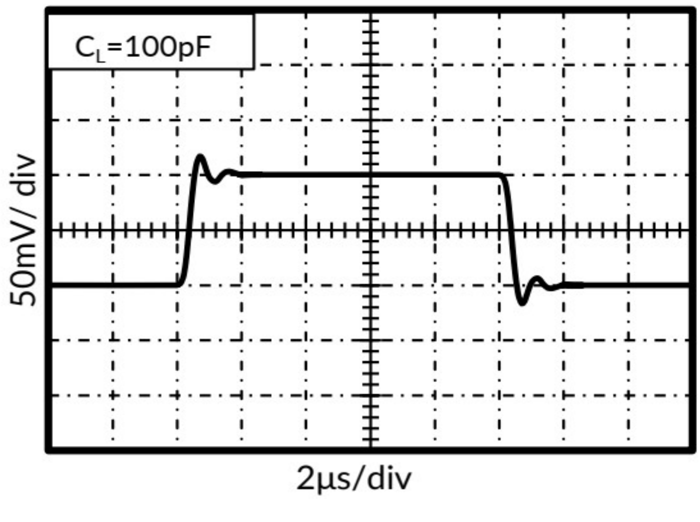


Figure 13. Small-Signal Step Response

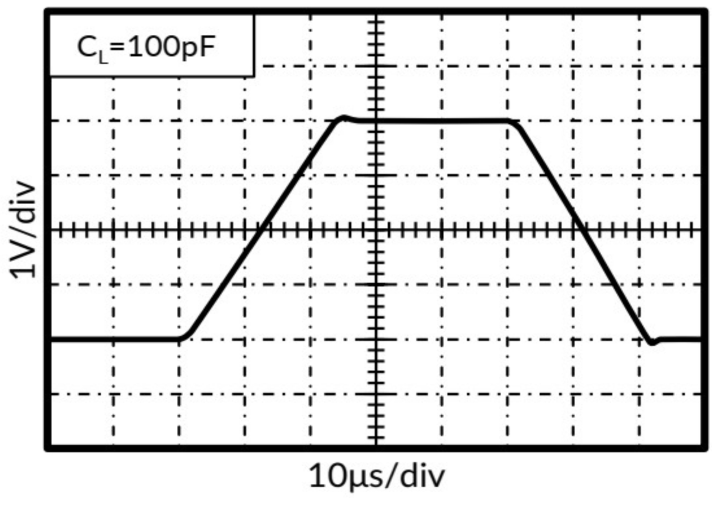


Figure 14. Large-Signal Step Response

Zero-Drift, Rail-to-Rail I/O CMOS Operational Amplifiers

Typical Performance Characteristics(Con.)

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

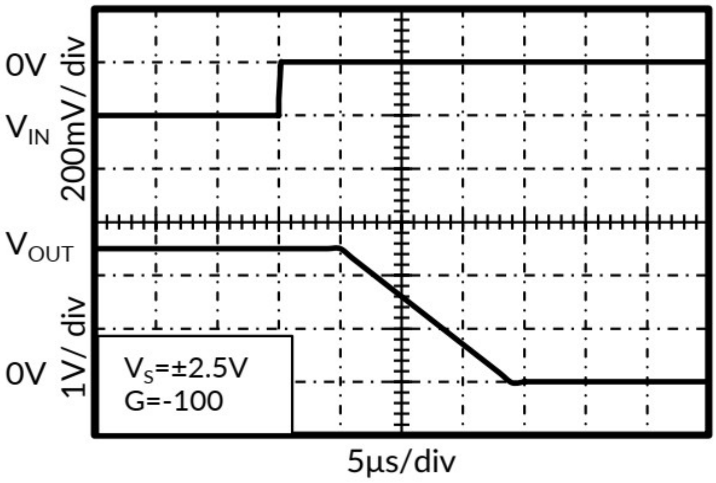


Figure 15. Positive Overvoltage Recovery

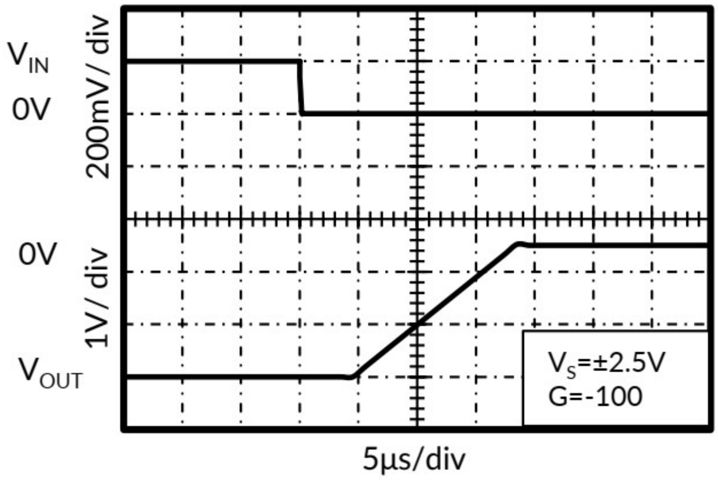


Figure 16. Negative Overvoltage Recovery

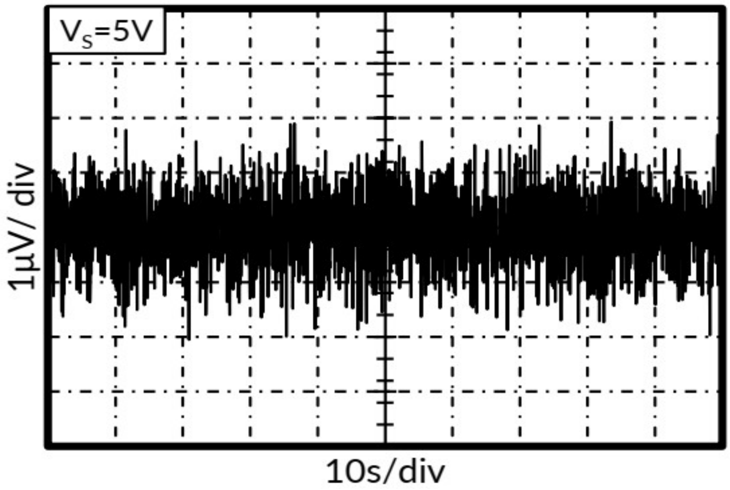


Figure 17. 0.01Hz to 10Hz Noise

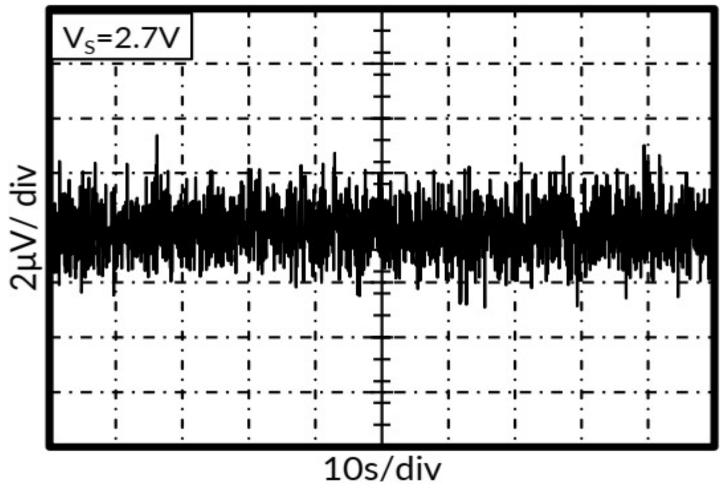


Figure 18. 0.01Hz to 10Hz Noise

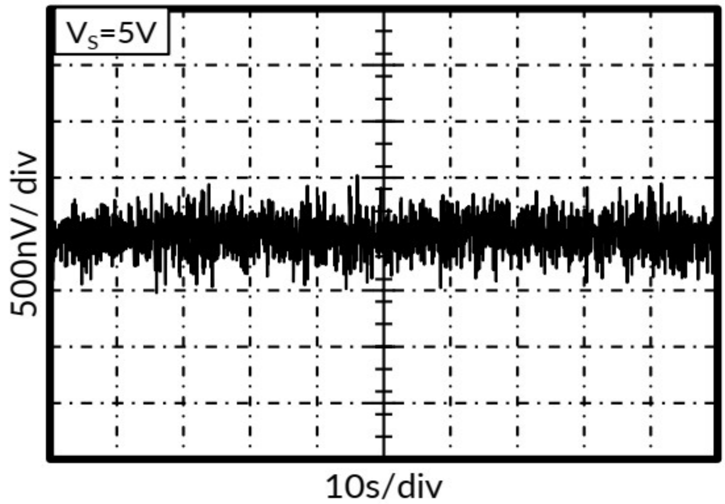


Figure 19. 0.01Hz to 1Hz Noise

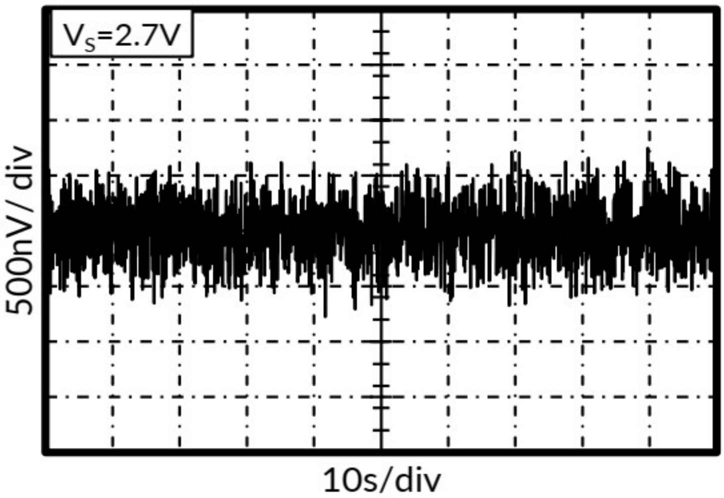


Figure 20. 0.01Hz to 1Hz Noise

Detailed Description

The HCR8521/HCR8522/HCR8524 series op amps are unity-gain stable and free from unexpected output phase reversal. They use auto-zeroing techniques to provide low offset voltage and very low drift over time and temperature.

Good layout practice mandates use of a 0.1μF capacitor placed closely across the supply pins.

For lowest offset voltage and precision performance, circuit layout and mechanical conditions should be optimized. Avoid temperature gradients that create thermoelectric (Seebeck) effects in thermocouple junctions formed from connecting dissimilar conductors. These thermally-generated potentials can be made to cancel by assuring that they are equal on both input terminals.

- Use low thermoelectric-coefficient connections (avoid dissimilar metals).
- Thermally isolate components from power supplies or other heat-sources.
- Shield op amp and input circuitry from air currents, such as cooling fans

Following these guidelines will reduce the likelihood of junctions being at different temperatures, which can cause thermoelectric voltages of 0.1μV/°C or higher, depending on materials used.

Operating Voltage

The HCR8521/HCR8522/HCR8524 series op amps operate over a power-supply range of +2.3V to +5.5V (±1.15V to ±2.75V). Supply voltages higher than 7V (absolute maximum) can permanently damage the amplifier. Parameters that vary over supply voltage or temperature are shown in the Typical Characteristics section of this data sheet.

Application Information

The HCR852X series is a unity-gain stable, precision operational amplifier with very low offset voltage drift; these devices are also free from output phase reversal. Applications with noisy or high-impedance power supplies require decoupling capacitors close to the device power-supply pins. In most cases, 0.1uF capacitors are adequate.

Typical Applications

Bidirectional Current-Sensing

This single-supply, low-side, bidirectional current-sensing solution detects load currents from -1A to 1A. The single-ended output spans from 110mV to 3.19V. This design uses the HCR852X because of its low offset voltage and rail-to-rail input and output. One of the amplifiers is configured as a difference amplifier and the other provides the reference voltage.

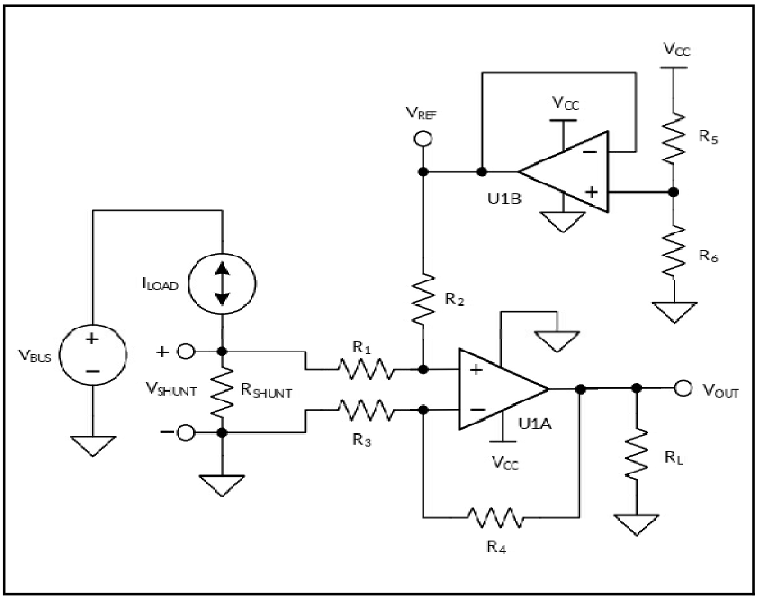


Figure 21. Bidirectional Current-Sensing Schematic

Design Requirements

This solution has the following requirements:

- Supply voltage: 3.3 V
- Input: –1 A to 1 A
- Output: 1.65 V ±1.54 V (110 mV to 3.19 V)

Application Information(Con.)

Detailed Design Procedure

The load current, I_{LOAD}, flows through the shunt resistor (R_{SHUNT}) to develop the shunt voltage, V_{SHUNT}. The shunt voltage is then amplified by the difference amplifier, which consists of U1A and R1 through R4. The gain of the difference amplifier is set by the ratio of R4 to R3. To minimize errors, set R2 = R4 and R1=R3. The reference voltage, V_{REF}, is supplied by buffering a resistor divider using U1B. The transfer function is given by Equation 1.

$$V_{OUT}=V_{SHUNT}\times Gain_{Diff\_Amp}+V_{REF}$$

Where

$$V_{SHUNT}=I_{LOAD}\times R_{SHUNT}$$

$$Gain_{Diff\_Amp}=R4/R3$$

$$V_{REF}=V_{CC}\times[R6/(R5+R6)]$$

There are two types of errors in this design: offset and gain. Gain errors are introduced by the tolerance of the shunt resistor and the ratios of R4 to R3 and, similarly, R2 to R1. Offset errors are introduced by the voltage divider (R5 and R6) and how closely the ratio of R4/R3 matches R2/R1. The latter value impacts the CMRR of the difference amplifier, which ultimately translates to an offset error. Because this is a low-side measurement, the value of VSHUNT is the ground potential for the system load. Therefore, it is important to place a maximum value on V_{SHUNT}. In this design, the maximum value for V_{SHUNT} is set to 100mV. Equation 2 calculates the maximum value of the shunt resistor given a maximum shunt voltage of 100 mV and maximum load current of 1 A.

$$R_{SHUNT(Max)}=\frac{V_{SHUNT(Max)}}{I_{LOAD(Max)}}=\frac{100\text{ mV}}{1\text{ A}}=100\text{ m}\Omega \qquad (2)$$

Application Note

The tolerance of R_{SHUNT} is directly proportional to cost. For this design, a shunt resistor with a tolerance of 0.5% was selected. If greater accuracy is required, select a 0.1% resistor or better.

The load current is bidirectional; therefore, the shunt voltage range is -100 mV to 100mV. This voltage is divided down by R1 and R2 before reaching the operational amplifier, U1A. Take care to ensure that the voltage present at the noninverting node of U1A is within the common-mode range of the device. Therefore, it is important to use an operational amplifier, such as the HCR8521/HCR8522/HCR8524, that has a common-mode range that extends below the negative supply voltage. Finally, to minimize offset error, note that the HCR8521 /HCR8522 /HCR8524 has a typical offset voltage of ±1μV (±5μ V maximum). Given a symmetric load current of –1 A to 1 A, the voltage divider resistors (R5 and R6) must be equal. To be consistent with the shunt resistor, a tolerance of 0.5% was selected. To minimize power consumption, 10kΩ resistors were used. To set the gain of the difference amplifier, the common-mode range and output swing of the HCR8521/HCR8522 /HCR8524 must be considered. Equation 3 and Equation 4 depict the typical commonmode range and maximum output swing, respectively, of the HCR852X given a 3.3V supply.

$$-100mV<V_{CM}<3.4V \qquad (3)$$

$$100mV<V_{OUT}<3.2V \qquad (4)$$

The gain of the difference amplifier can now be calculated as shown in Equation 5.

$$Gain_{Diff\_Amp}=\frac{V_{OUT\_Max}-V_{OUT\_Min}}{R_{SHUNT}\times(I_{MAX}-I_{MIN})}=\frac{3.2\text{ V}-100\text{ mV}}{100\text{ m}\Omega\times[1\text{ A}-(-1\text{A})]}=15.5\frac{V}{V} \qquad (5)$$

The resistor value selected for R1 and R3 was 1kΩ. 15.4kΩ was selected for R2 and R4 because it is the nearest standard value. Therefore, the ideal gain of the difference amplifier is 15.4V/V

Application Note(Con.)

The gain error of the circuit primarily depends on R1 through R4. As a result of this dependence, 0.1% resistors were selected. This configuration reduces the likelihood that the design requires a two-point calibration. A simple one-point calibration, if desired, removes the offset errors introduced by the 0.5% resistors.

Application Curve

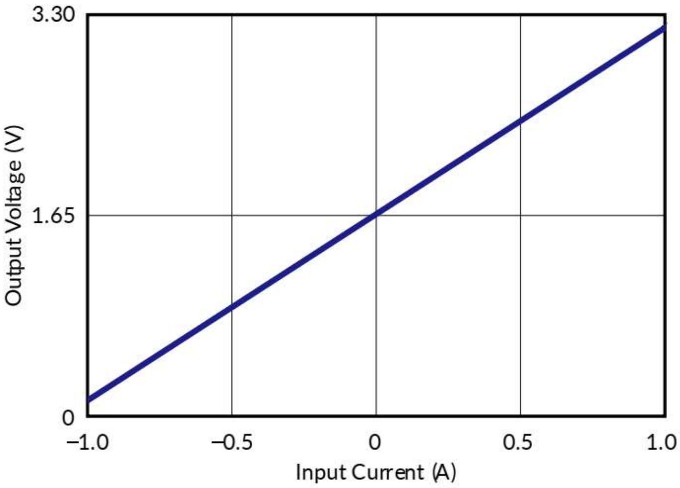


Figure 22. Bidirectional Current-Sensing Circuit Performance: Output Voltage vs Input Current

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

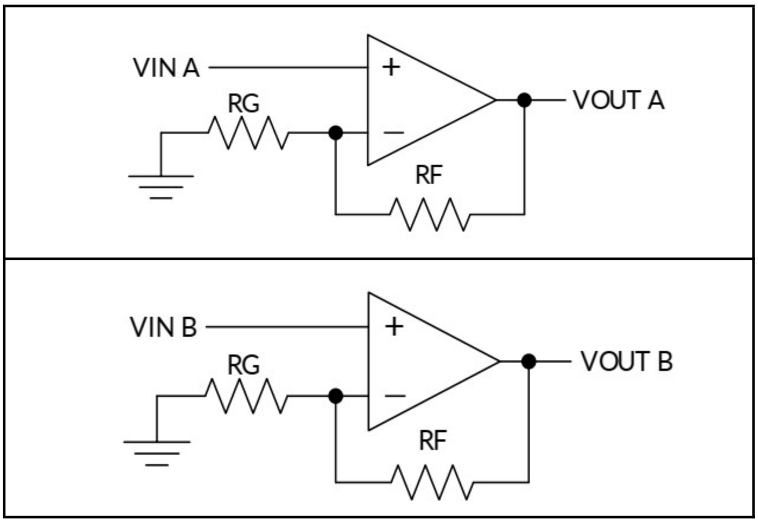
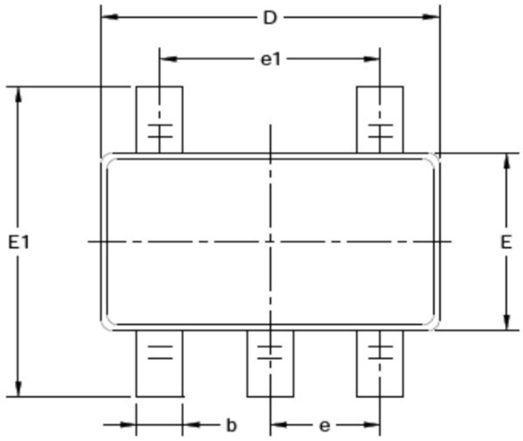


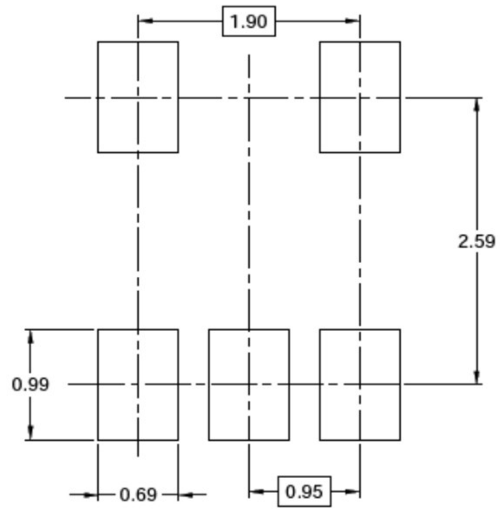
Figure 23. Schematic Representation

Zero-Drift, Rail-to-Rail I/O CMOS Operational Amplifiers

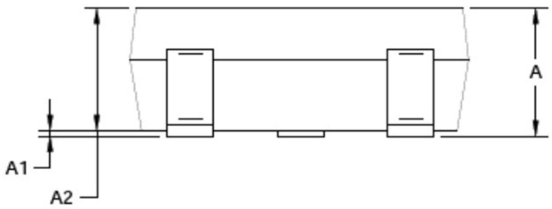
Mechanical Dimensions

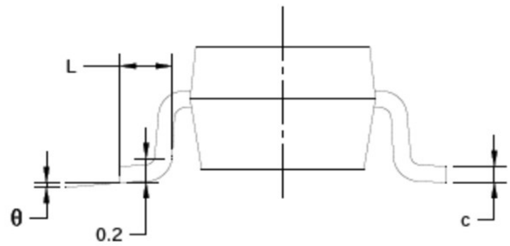
M5: SOT23-5 package





RECOMMENDED LAND PATTERN (Unit: mm)



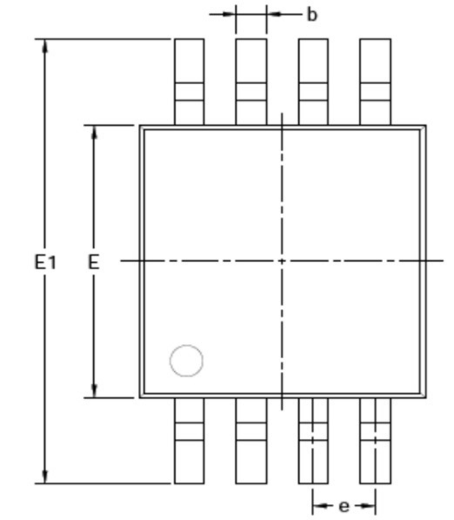


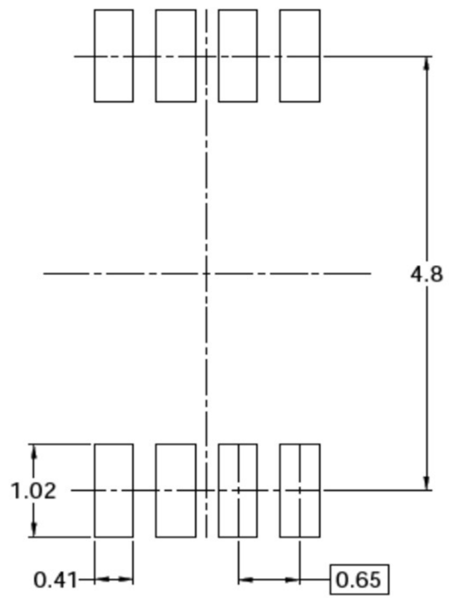
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950 BSC		0.037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

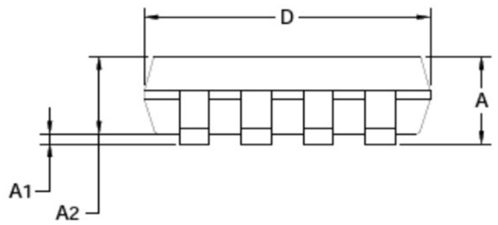
Mechanical Dimensions(Con.)

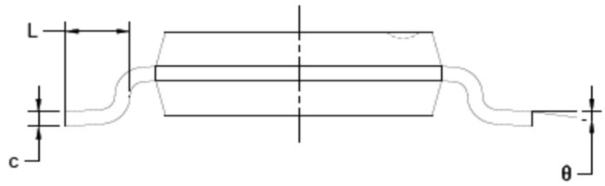
SM8: MSOP-8 Package





RECOMMENDED LAND PATTERN (Unit: mm)



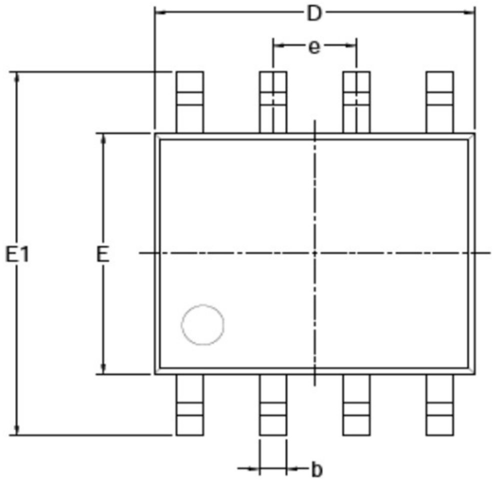


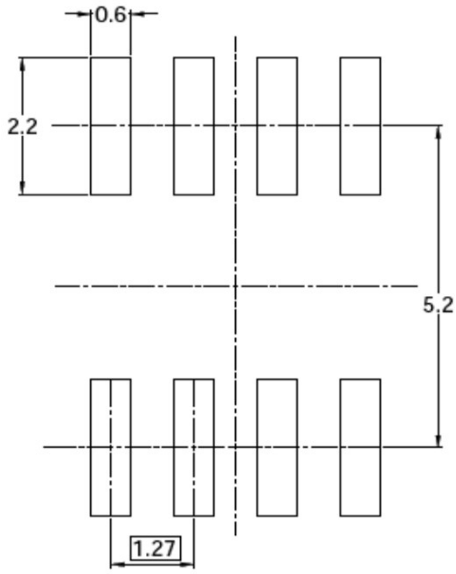
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
e	0.650 BSC		0.026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

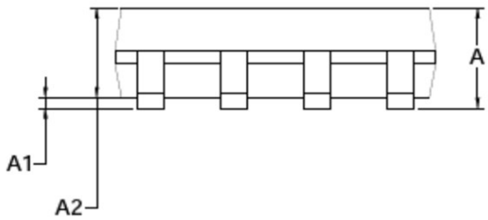
Mechanical Dimensions(Con.)

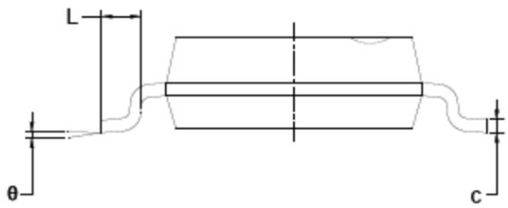
M8: SOIC-8(SOP-8) Package





RECOMMENDED LAND PATTERN (Unit: mm)



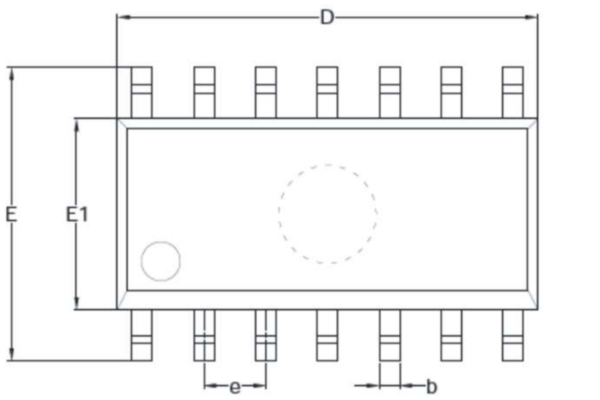


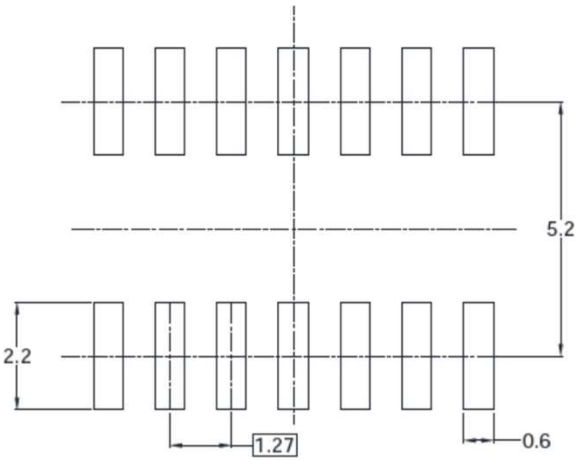
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.27 BSC		0.050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

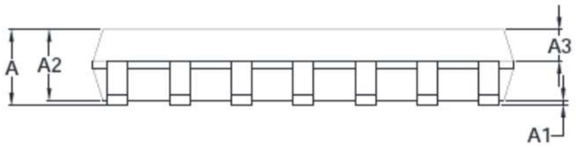
Mechanical Dimensions(Con.)

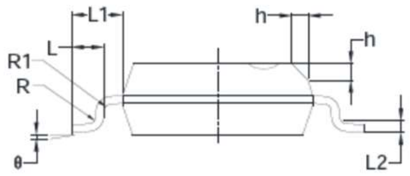
M14: SOIC-14 Package





RECOMMENDED LAND PATTERN (Unit: mm)



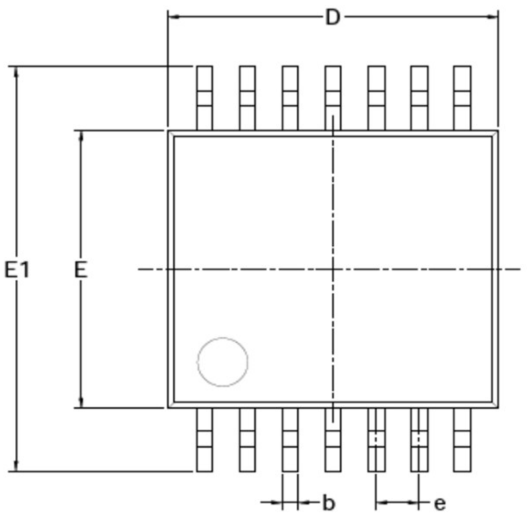


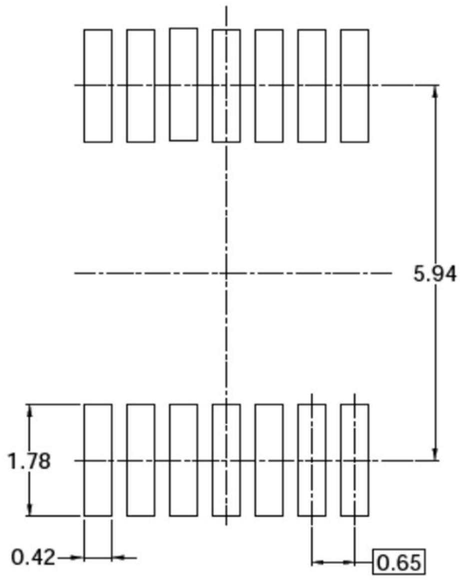
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.35	1.75	0.053	0.069
A1	0.10	0.25	0.004	0.010
A2	1.25	1.65	0.049	0.065
A3	0.55	0.75	0.022	0.030
b	0.36	0.49	0.014	0.019
D	8.53	8.73	0.336	0.344
E	5.80	6.20	0.228	0.244
E1	3.80	4.00	0.150	0.157
e	1.27 BSC		0.050 BSC	
L	0.45	0.80	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°

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

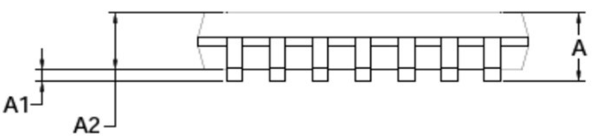
Mechanical Dimensions(Con.)

TS14: TSSOP-14 Package





RECOMMENDED LAND PATTERN (Unit: mm)

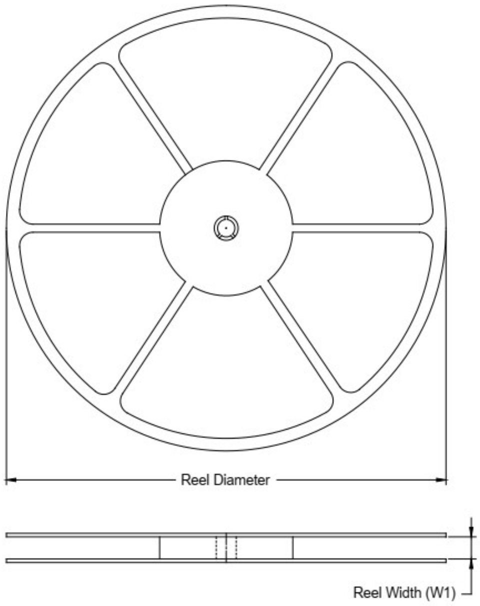


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A		1.200		0.047
A1	0.050	0.150	0.002	0.006
A2	0.800	1.050	0.031	0.041
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
D	4.860	5.100	0.191	0.201
E	4.300	4.500	0.169	0.177
E1	6.250	6.550	0.246	0.258
e	0.650 BSC		0.026 BSC	
L	0.500	0.700	0.02	0.028
H	0.25 TYP		0.01 TYP	
θ	1°	7°	1°	7°

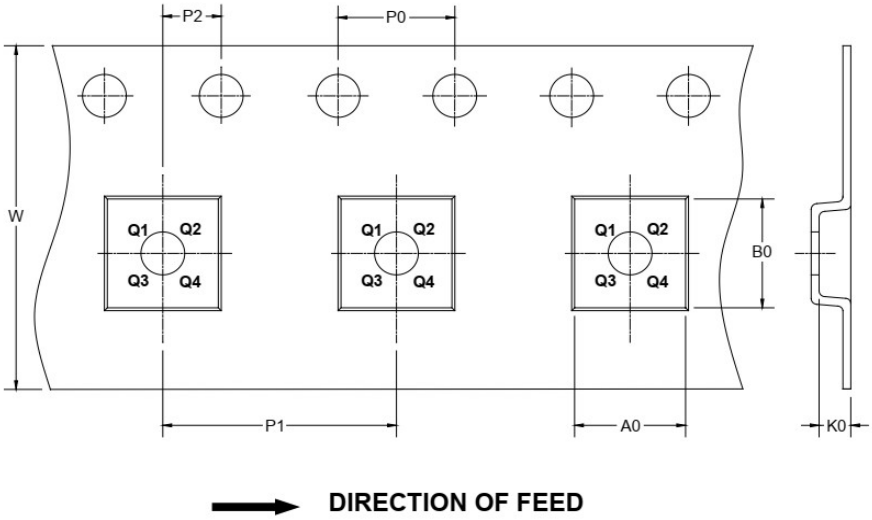
NOTES:
1. Body dimensions do not include mode flash or protrusion.
2. This drawing is subject to change without notice.

Tape and Reel Information

REEL DIMENSIONS



TAPE DIMENSIONS



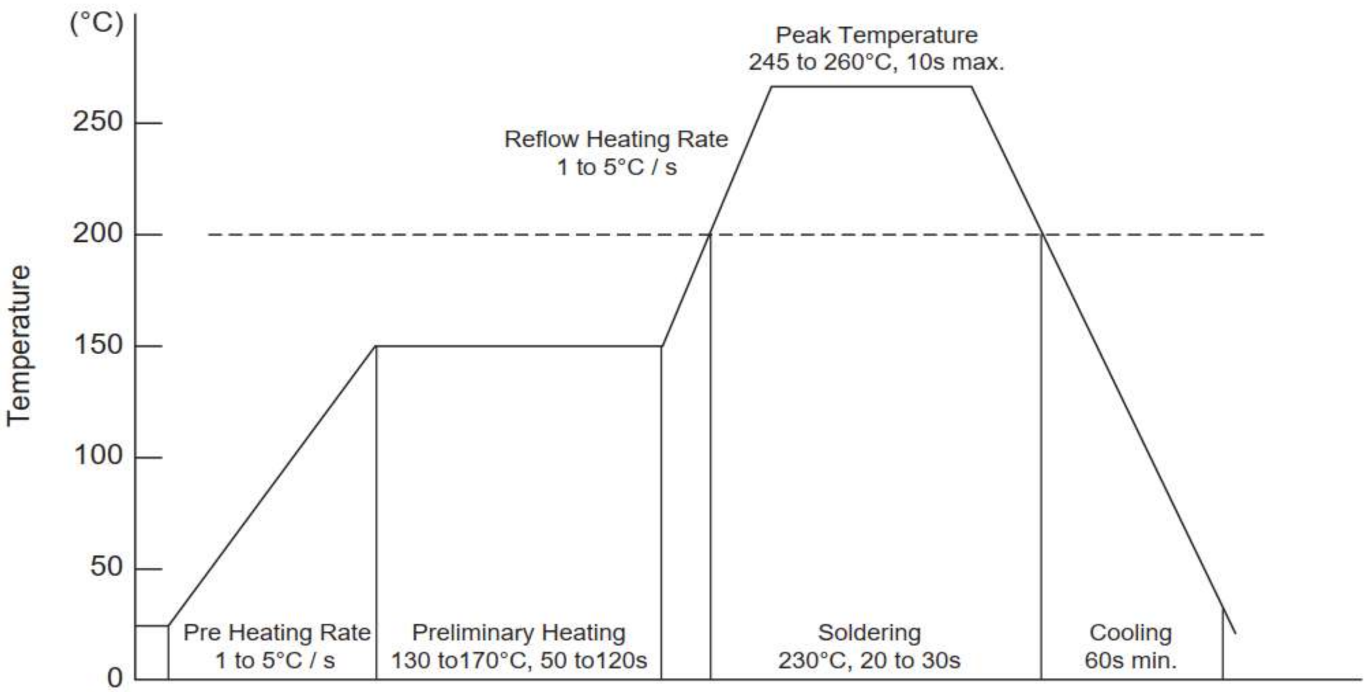
NOTE: The picture is only for reference. Please make the object as the standard.

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
TSSOP14	13"	12.4	6.95	5.60	2.10	4.0	8.0	2.0	12.0	Q1
SOIC-14	13"	16.4	6.60	9.30	2.10	4.0	8.0	2.0	16.0	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