

## 3.6MHz, Rail-to-Rail I/O CMOS Operational Amplifier

### 1 FEATURES

- **HIGH GAIN BANDWIDTH: 3.6MHz**
- **RAIL-TO-RAIL INPUT AND OUTPUT**  
**±0.8mV Typical Vos**
- **INPUT VOLTAGE RANGE: -0.1V to +5.6V**  
**with Vs = 5.5V**
- **SUPPLY RANGE: +2.5V to +5.5V**
- **SHUTDOWN: RS521S/RS522S**
- **SPECIFIED UP TO +125°C**
- **Micro SIZE PACKAGES: SOT23-5, SOT23-6**

### 2 APPLICATIONS

- **SENSORS**
- **PHOTODIODE AMPLIFICATION**
- **ACTIVE FILTERS**
- **TEST EQUIPMENT**
- **DRIVING A/D CONVERTERS**

### 3 DESCRIPTIONS

The RS52X families of products offer low voltage operation and rail-to-rail input and output, as well as excellent speed/power consumption ratio, providing an excellent bandwidth (3.6MHz) and slew rate of 1.8V/us. The op-amps are unity gain stable and feature an ultra-low input bias current.

The devices are ideal for sensor interfaces, active filters and portable applications. The RS521S, RS522S include a shutdown mode. Under logic control, the amplifiers can be switched from normal operation to a standby current that is less than 1uA. The RS52X families of operational amplifiers are specified at the full temperature range of -40°C to +125°C under single or dual power supplies of 2.5V to 5.5V.

**Device Information <sup>(1)</sup>**

PART NUMBER	PACKAGE	BODY SIZE(NOM)
RS521	SOT23-5	2.90mm×1.60mm
	SOT23-6	2.90mm×1.60mm
	SOIC-8(SOP8)	4.90mm×3.90mm
	MSOP-8	3.00mm×3.00mm
RS522	SOIC-8(SOP8)	4.90mm×3.90mm
	MSOP-8	3.00mm×3.00mm
	MSOP-10	3.00mm×3.00mm
RS524	SOIC-14 (SOP14)	8.65mm×3.90mm
	TSSOP-14	5.00mm×4.40mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

## Table of Contents

<b>1 FEATURES</b> .....	1
<b>2 APPLICATIONS</b> .....	1
<b>3 DESCRIPTIONS</b> .....	1
<b>4 Revision History</b> .....	3
<b>5 PACKAGE/ORDERING INFORMATION</b> <sup>(1)</sup> .....	4
<b>6 Pin Configuration and Functions (Top View)</b> .....	5
<b>7 SPECIFICATIONS</b> .....	8
7.1 Absolute Maximum Ratings .....	8
7.2 ESD Ratings.....	8
7.3 Recommended Operating Conditions.....	9
7.4 ELECTRICAL CHARACTERISTICS.....	10
7.5 TYPICAL CHARACTERISTICS .....	12
<b>8 Detailed Description</b> .....	15
8.1 Overview .....	15
8.2 RS521S/RS522S ENABLE FUNCTION .....	15
8.3 Phase Reversal Protection .....	15
8.4 EMI Rejection Ratio (EMIRR) .....	15
8.5 EMIRR IN+ Test Configuration .....	16
<b>9 Application and Implementation</b> .....	17
9.1 APPLICATION NOTE .....	17
9.2 25-kHz Low-pass Filter .....	17
9.3 Design Requirements .....	17
9.4 Detailed Design Procedure .....	17
9.5 Application Curve.....	18
<b>10 LAYOUT</b> .....	19
10.1 Layout Guidelines .....	19
10.2 Layout Example .....	19
<b>11 PACKAGE OUTLINE DIMENSIONS</b> .....	20
<b>12 TAPE AND REEL INFORMATION</b> .....	27

## 4 Revision History

Note: Page numbers for previous revisions may differ from page numbers in the current version.

Version	Change Date	Change Item
C.1	2023/02/10	1. Update Package Qty on Page 2@RevB.4 2. Added TAPE AND REEL INFORMATION

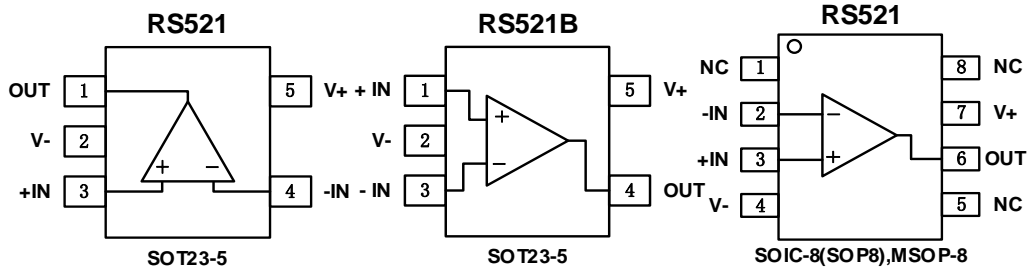
## 5 PACKAGE/ORDERING INFORMATION <sup>(1)</sup>

Orderable Device	Package Type	Pin	Channel	Op Temp(°C)	Device Marking <sup>(2)</sup>	Package Qty
RS521XF	SOT23-5	5	1	-40°C ~125°C	521	Tape and Reel,3000
RS521BXF	SOT23-5	5	1	-40°C ~125°C	521B	Tape and Reel,3000
RS521XK	SOIC-8(SOP8)	8	1	-40°C ~125°C	RS521	Tape and Reel,4000
RS521XM	MSOP-8	8	1	-40°C ~125°C	RS521	Tape and Reel,4000
RS521SXK	SOIC-8(SOP8)	8	1	-40°C ~125°C	RS521S	Tape and Reel,4000
RS521SXH	SOT23-6	6	1	-40°C ~125°C	521S	Tape and Reel,3000
RS522XK	SOIC-8(SOP8)	8	2	-40°C ~125°C	RS522	Tape and Reel,4000
RS522XM	MSOP-8	8	2	-40°C ~125°C	RS522	Tape and Reel,4000
RS522SXN	MSOP-10	10	2	-40°C ~125°C	RS522S	Tape and Reel,4000
RS524XP	SOIC-14(SOP14)	14	4	-40°C ~125°C	RS524	Tape and Reel,4000
RS524XQ	TSSOP-14	14	4	-40°C ~125°C	RS524	Tape and Reel,4000

**NOTE:**

- (1) This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the right-hand navigation.
- (2) 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.

## 6 Pin Configuration and Functions (Top View)

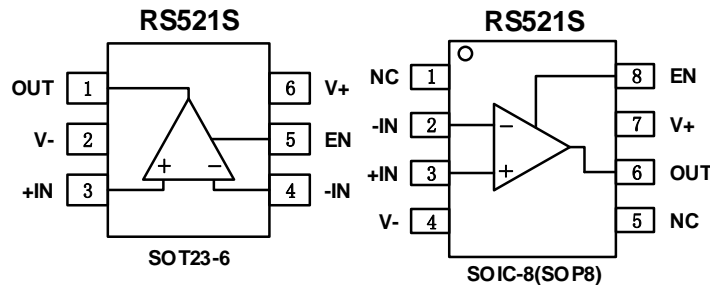


### Pin Description

NAME	PIN			I/O <sup>(1)</sup>	DESCRIPTION
	RS521	RS521B	RS521		
	SOT23-5	SOT23-5	SOIC-8(SOP8)/MSOP-8		
-IN	4	3	2	I	Negative (inverting) input
+IN	3	1	3	I	Positive (noninverting) input
NC <sup>(2)</sup>	-	-	1,5,8	-	No internal connection (can be left floating)
OUT	1	4	6	O	Output
V-	2	2	4	-	Negative (lowest) power supply
V+	5	5	7	-	Positive (highest) power supply

(1) I = Input, O = Output.

(2) There is no internal connection. Typically, GND is the recommended connection to a heat spreading plane.



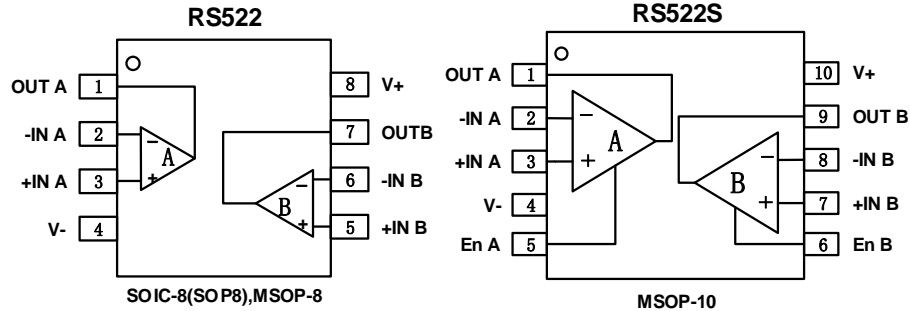
### Pin Description

NAME	PIN		I/O <sup>(1)</sup>	DESCRIPTION
	RS521S			
	SOT23-6	SOIC-8(SOP8)		
-IN	4	2	I	Inverting input
+IN	3	3	I	Noninverting input
OUT	1	6	O	Output
EN	5	8	I	Enable pin. This pin turns the regulator on or off. Low = disabled, high = normal operation (pin must be driven)
NC <sup>(2)</sup>	-	1,5	-	No internal connection (can be left floating)
V-	2	4	-	Negative (lowest) power supply
V+	6	7	-	Positive (highest) power supply

(1) I = Input, O = Output.

(2) There is no internal connection. Typically, GND is the recommended connection to a heat spreading plane.

## Pin Configuration and Functions (Top View)

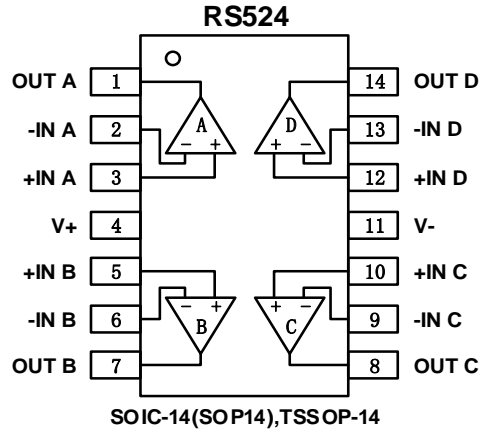


### Pin Description

NAME	PIN		I/O <sup>(1)</sup>	DESCRIPTION
	RS522	RS522S		
	SOIC-8(SOP8)	MSOP-10		
-INA	2	2	I	Inverting input, channel A
+INA	3	3	I	Noninverting input, channel A
-INB	6	8	I	Inverting input, channel B
+INB	5	7	I	Noninverting input, channel B
OUTA	1	1	O	Output, channel A
OUTB	7	9	O	Output, channel B
EnA	-	5	I	Enable pin, channel A. This pin turns the regulator on or off. Low = disabled, high = normal operation (pin must be driven)
EnB	-	6	I	Enable pin, channel B. This pin turns the regulator on or off. Low = disabled, high = normal operation (pin must be driven)
V-	4	4	-	Negative (lowest) power supply
V+	8	10	-	Positive (highest) power supply

(1) I = Input, O = Output.

## Pin Configuration and Functions (Top View)



### Pin Description

NAME	PIN	I/O <sup>(1)</sup>	DESCRIPTION
	SOIC-14(SOP14)/TSSOP-14		
-INA	2	I	Inverting input, channel A
+INA	3	I	Noninverting input, channel A
-INB	6	I	Inverting input, channel B
+INB	5	I	Noninverting input, channel B
-INC	9	I	Inverting input, channel C
+INC	10	I	Noninverting input, channel C
-IND	13	I	Inverting input, channel D
+IND	12	I	Noninverting input, channel D
OUTA	1	O	Output, channel A
OUTB	7	O	Output, channel B
OUTC	8	O	Output, channel C
OUTD	14	O	Output, channel D
V-	11	-	Negative (lowest) power supply
V+	4	-	Positive (highest) power supply

(1) I = Input, O = Output.

## 7 SPECIFICATIONS

### 7.1 Absolute Maximum Ratings

Over operating free-air temperature range (unless otherwise noted) <sup>(1)</sup>

		MIN	MAX	UNIT
Voltage	Supply, $V_s=(V+) - (V-)$		7	V
	Signal input pin <sup>(2)</sup>	(V-)-0.5	(V+) +0.5	
	Signal output pin <sup>(3)</sup>	(V-)-0.5	(V+) +0.5	
Current	Signal input pin <sup>(2)</sup>	-10	10	mA
	Signal output pin <sup>(3)</sup>	-100	100	mA
	Output short-circuit <sup>(4)</sup>	Continuous		
$\theta_{JA}$	Package thermal impedance <sup>(5)</sup>	SOT23-5	230	°C/W
		SOIC-8(SOP8)	110.88	
		MSOP-8	165.7	
		SOIC-14(SOP14)	104.5	
		TSSOP-14	89.21	
		SOT23-6	230	
		MSOP-10	200	
Temperature	Operating range, $T_A$	-40	125	°C
	Junction, $T_J$ <sup>(6)</sup>	-40	150	
	Storage, $T_{stg}$	-65	150	

(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) Output terminals are diode-clamped to the power-supply rails. Output signals that can swing more than 0.5V beyond the supply rails should be current-limited to  $\pm 100$ mA or less.

(4) Short-circuit to ground, one amplifier per package.

(5) The package thermal impedance is calculated in accordance with JESD-51.

(6) The maximum power dissipation is a function of  $T_{J(MAX)}$ ,  $R_{\theta JA}$ , and  $T_A$ . The maximum allowable power dissipation at any ambient temperature is  $P_D = (T_{J(MAX)} - T_A) / R_{\theta JA}$ . All numbers apply for packages soldered directly onto a PCB.

### 7.2 ESD Ratings

The following ESD information is provided for handling of ESD-sensitive devices in an ESD protected area only.

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	$\pm 5000$	V
		Machine Model (MM)	$\pm 400$	

(1) JEDEC document JEP155 states that 500 V HBM allows safe manufacturing with a standard ESD control process.



#### ESD SENSITIVITY CAUTION

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.



### 7.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
Supply voltage , $V_s = (V+) - (V-)$	Single-supply	2.5		5.5	V
	Dual-supply	$\pm 1.25$		$\pm 2.75$	

## 7.4 ELECTRICAL CHARACTERISTICS

(At  $T_A = +25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $R_L = 10\text{k}\Omega$  connected to  $V_S/2$ , and  $V_{OUT} = V_S/2$ ,  $V_{CM} = V_S/2$ , Full <sup>(9)</sup> =  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$ , unless otherwise noted.) <sup>(1)</sup>

PARAMETER	CONDITIONS	$T_J$	RS521S, RS522S RS521, RS522, RS524				
			MIN <sup>(2)</sup>	TYP <sup>(3)</sup>	MAX <sup>(2)</sup>	UNIT	
<b>POWER SUPPLY</b>							
$V_S$	Operating Voltage Range	$25^\circ\text{C}$	2.5		5.5	V	
$I_Q$	Quiescent Current/Amplifier	$25^\circ\text{C}$		260	350	$\mu\text{A}$	
PSRR	Power-Supply Rejection Ratio	$V_S = 2.5\text{V}$ to $5.5\text{V}$ $V_{CM} = (V_-) + 0.5\text{V}$	$25^\circ\text{C}$	76	86	dB	
		Full	69				
<b>INPUT</b>							
$V_{OS}$	Input Offset Voltage	$V_{CM} = V_S/2$	$25^\circ\text{C}$	-3	$\pm 0.8$	3	mV
$V_{OS}$ $T_C$	Input Offset Voltage Average Drift	$V_{CM} = V_S/2$	Full		$\pm 2$		$\mu\text{V}/^\circ\text{C}$
$I_B$	Input Bias Current <sup>(4)</sup> <sup>(5)</sup>		$25^\circ\text{C}$		$\pm 1$	$\pm 10$	pA
$I_{OS}$	Input Offset Current <sup>(4)</sup>		$25^\circ\text{C}$		$\pm 1$	$\pm 10$	pA
$V_{CM}$	Common-Mode Voltage Range	$V_S = 5.5\text{V}$	$25^\circ\text{C}$	-0.1		5.6	V
CMRR	Common-Mode Rejection Ratio	$V_S = 5.5\text{V}$ $V_{CM} = -0.1\text{V}$ to $4\text{V}$	$25^\circ\text{C}$	76	87	dB	
			Full	71			
		$V_S = 5.5\text{V}$ $V_{CM} = -0.1\text{V}$ to $5.6\text{V}$	$25^\circ\text{C}$	62	71		
			Full	60			
<b>OUTPUT</b>							
$A_{OL}$	Open-Loop Voltage Gain	$R_L = 2\text{k}\Omega$ $V_O = 0.15\text{V}$ to $4.85\text{V}$	$25^\circ\text{C}$	100	107	dB	
			Full	86			
		$R_L = 10\text{k}\Omega$ $V_O = 0.05\text{V}$ to $4.95\text{V}$	$25^\circ\text{C}$	100	110		
			Full	87			
	Output Swing From Rail	$R_L = 2\text{k}\Omega$	$25^\circ\text{C}$		31	mV	
		$R_L = 10\text{k}\Omega$			7		
$I_{OUT}$	Output Short-Circuit Current <sup>(6)</sup> <sup>(7)</sup>		$25^\circ\text{C}$		$\pm 80$		mA
<b>FREQUENCY RESPONSE</b>							
SR	Slew Rate <sup>(8)</sup>		$25^\circ\text{C}$		1.8		V/ $\mu\text{s}$
GBP	Gain-Bandwidth Product		$25^\circ\text{C}$		3.6		MHz
PM	Phase Margin		$25^\circ\text{C}$		65		$^\circ$
$t_S$	Setting Time, 0.1%				0.5		$\mu\text{s}$
	Overload Recovery Time	$V_{IN} \cdot \text{Gain} \geq V_S$			0.7		$\mu\text{s}$
<b>NOISE</b>							
$e_n$	Input Voltage Noise Density	$f = 1\text{KHz}$	$25^\circ\text{C}$		15		$\text{nV}/\sqrt{\text{Hz}}$
		$f = 10\text{KHz}$	$25^\circ\text{C}$		13		$\text{nV}/\sqrt{\text{Hz}}$
<b>ENABLE/SHUTDOWN (RS521S, RS522S)</b>							
$I_{Q(OFF)}$	Supply Current in Shutdown		$25^\circ\text{C}$		<1		$\mu\text{A}$
$t_{OFF}$			$25^\circ\text{C}$		3		$\mu\text{s}$
$t_{ON}$			$25^\circ\text{C}$		20		$\mu\text{s}$
$V_L$	Shut Down		$25^\circ\text{C}$	$V_-$		$(V_-) + 0.8$	V
$V_H$	Amplifier Is Active		$25^\circ\text{C}$	$(V_-) + 2$		$V_+$	V

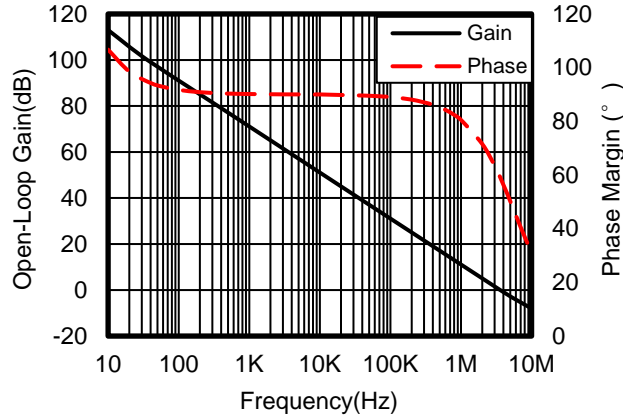
**NOTE:**

- (1) Electrical table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device.
- (2) Limits are 100% production tested at 25°C. Limits over the operating temperature range are ensured through correlations using statistical quality control (SQC) method.
- (3) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration.
- (4) This parameter is ensured by design and/or characterization and is not tested in production.
- (5) Positive current corresponds to current flowing into the device.
- (6) The maximum power dissipation is a function of  $T_{J(MAX)}$ ,  $R_{\theta JA}$ , and  $T_A$ . The maximum allowable power dissipation at any ambient temperature is  $PD = (T_{J(MAX)} - T_A) / R_{\theta JA}$ . All numbers apply for packages soldered directly onto a PCB.
- (7) Short circuit test is a momentary test.
- (8) Number specified is the slower of positive and negative slew rates.
- (9) Specified by characterization only.

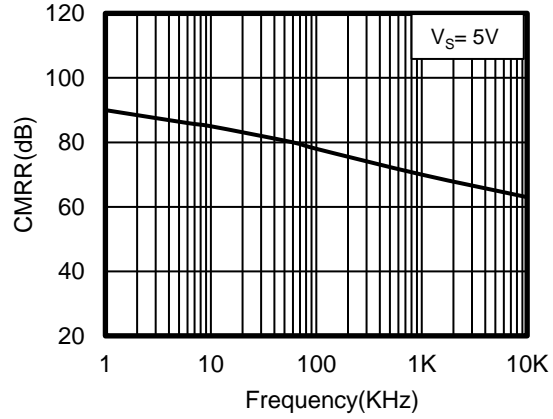
## 7.5 TYPICAL CHARACTERISTICS

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

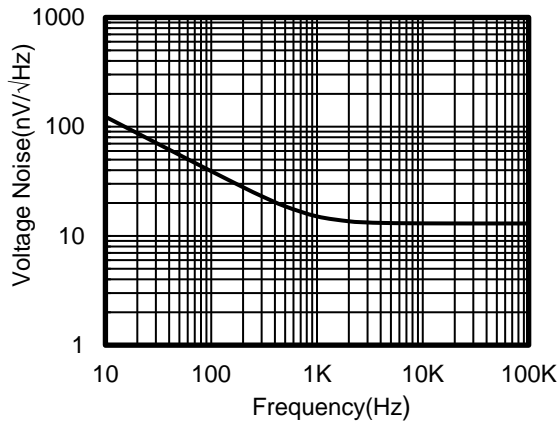
At  $T_A = +25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $R_L = 10\text{k}\Omega$  connected to  $V_S/2$ ,  $V_{OUT} = V_S/2$ , unless otherwise noted.



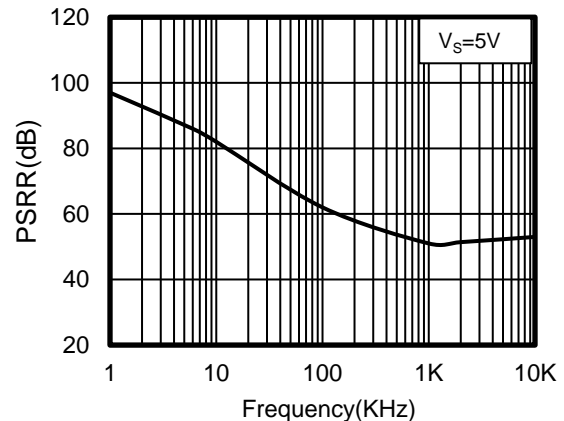
**Figure 1. Open-Loop Gain and Phase vs Frequency**



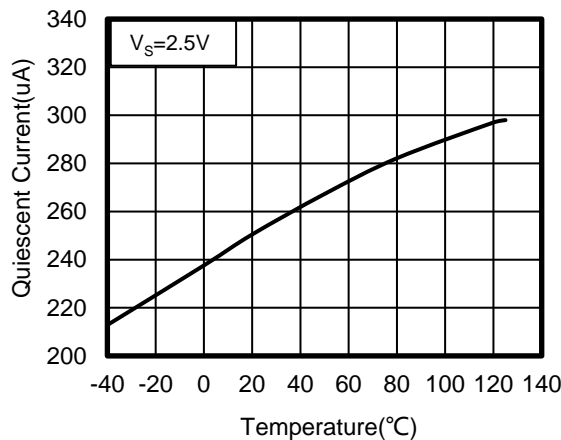
**Figure 2. Common-Mode Rejection Ratio vs Frequency**



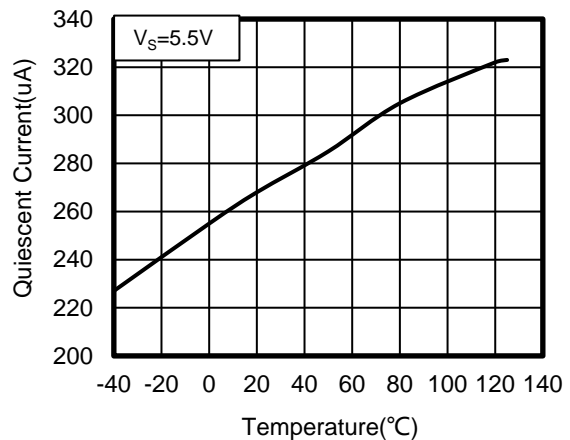
**Figure 3. Input Voltage Noise Spectral Density vs Frequency**



**Figure 4. Power-Supply Rejection Ratio vs Frequency**



**Figure 5. Quiescent Current vs Temperature**



**Figure 6. Quiescent Current vs Temperature**

## TYPICAL CHARACTERISTICS

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

At  $T_A = +25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $R_L = 10\text{k}\Omega$  connected to  $V_S/2$ ,  $V_{OUT} = V_S/2$ , unless otherwise noted.

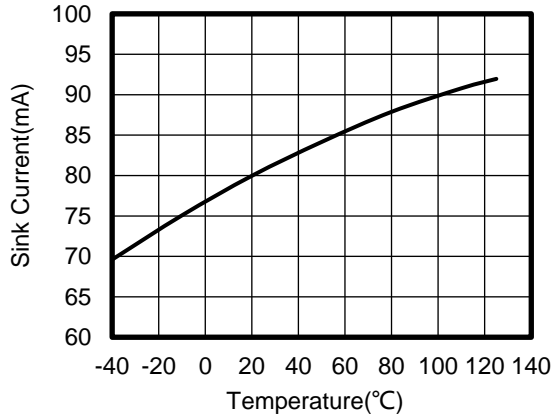


Figure 7. Sink Current vs Temperature

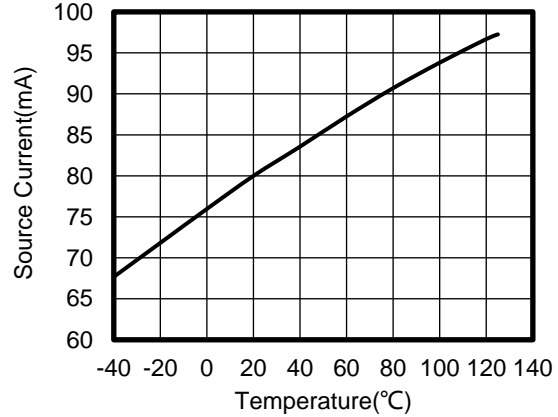


Figure 8. Source Current vs Temperature

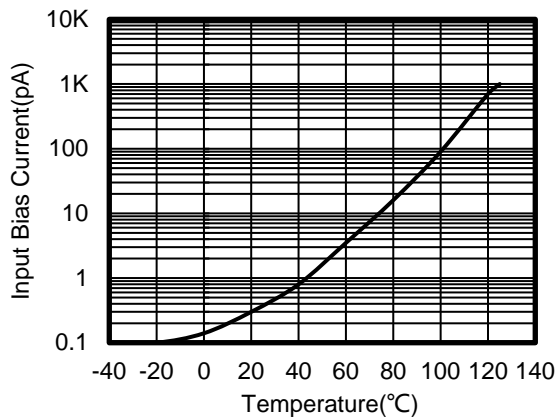


Figure 9. Input Bias Current vs Temperature

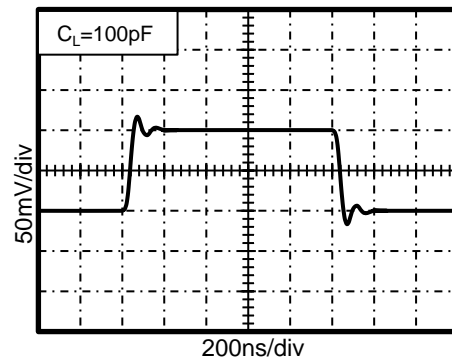


Figure 10. Small-Signal Step Response

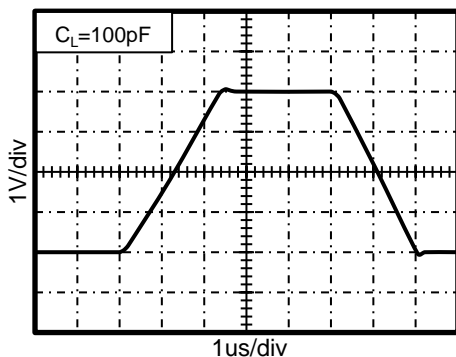


Figure 11. Large-Signal Step Response

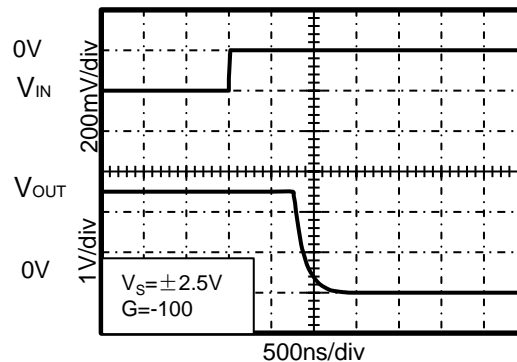


Figure 12. Positive Overvoltage Recovery

## TYPICAL CHARACTERISTICS

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

At  $T_A = +25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $R_L = 10\text{k}\Omega$  connected to  $V_S/2$ ,  $V_{OUT} = V_S/2$ , unless otherwise noted.

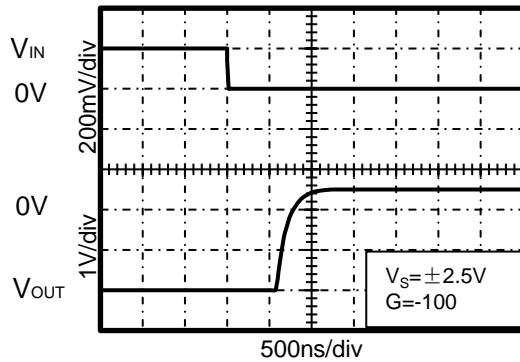


Figure 13. Negative Overvoltage Recovery

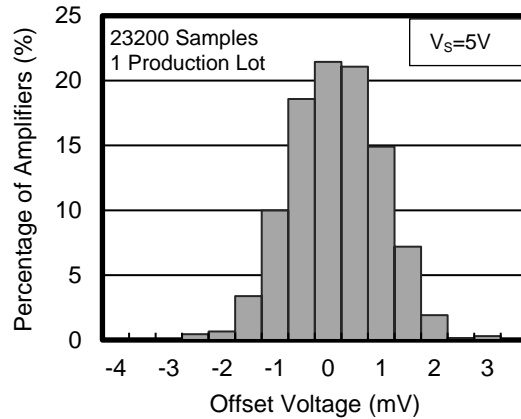


Figure 14. Offset Voltage Production Distribution

## 8 Detailed Description

### 8.1 Overview

The RS521, RS522, RS524, RS521S, RS522S are high precision, rail-to-rail operational amplifiers that can be run from a single-supply voltage 2.5V to 5.5V ( $\pm 1.25V$  to  $\pm 2.75V$ ). Supply voltages higher than 7V (absolute maximum) can permanently damage the amplifier. Rail-to-rail input and output swing significantly increases dynamic range, especially in low-supply applications. Good layout practice mandates use of a 0.1uF capacitor placed closely across the supply pins.

### 8.2 RS521S/RS522S ENABLE FUNCTION

The RS521S/RS522S includes a shutdown mode. Under logic control, the amplifiers can be switched from normal mode to a standby current of 1uA. When the Enable pin is connected to high, the amplifier is active. Connecting Enable low disables the amplifier, and places the amplifier, and place the output in a high-impedance state.

### 8.3 Phase Reversal Protection

The RS52X family has internal phase-reversal protection. Many op amps exhibit phase reversal when the input is driven beyond the linear common-mode range. This condition is most often encountered in noninverting circuits when the input is driven beyond the specified common-mode voltage range, causing the output to reverse into the opposite rail. The input of the RS52X prevents phase reversal with excessive common-mode voltage. Instead, the appropriate rail limits the output voltage. This performance is shown in figure 15.

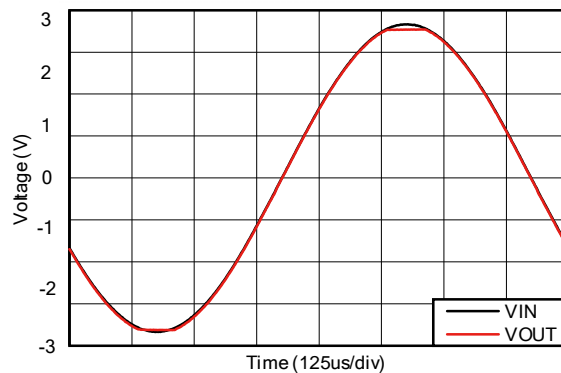


Figure 15. Output Waveform Devoid of Phase Reversal during an Input Overdrive Condition

### 8.4 EMI Rejection Ratio (EMIRR)

The electromagnetic interference (EMI) rejection ratio, or EMIRR, describes the EMI immunity of operational amplifiers. An adverse effect that is common to many operational amplifiers is a change in the offset voltage as a result of RF signal rectification. An operational amplifier that is more efficient at rejecting this change in offset as a result of EMI has a higher EMIRR and is quantified by a decibel value. Measuring EMIRR can be performed in many ways, but this document provides the EMIRR IN+, which specifically describes the EMIRR performance when the RF signal is applied to the noninverting input pin of the operational amplifier. In general, only the noninverting input is tested for EMIRR for the following three reasons:

- Operational amplifier input pins are known to be the most sensitive to EMI, and typically rectify RF signals better than the supply or output pins.
- The noninverting and inverting operational amplifier inputs have symmetrical physical layouts and exhibit nearly matching EMIRR performance.
- EMIRR is easier to measure on noninverting pins than on other pins because the noninverting input pin can be isolated on a printed-circuit-board (PCB). This isolation allows the RF signal to be applied directly to the noninverting input pin with no complex interactions from other components or connecting PCB traces.

## Detailed Description (continued)

The EMIRR IN+ of the RS52X is plotted versus frequency in Figure 16. If available, any dual and quad operational amplifier device versions have approximately identical EMIRR IN+ performance. The RS52X unity-gain bandwidth is 3.7MHz. EMIRR performance below this frequency denotes interfering signals that fall within the operational amplifier bandwidth.

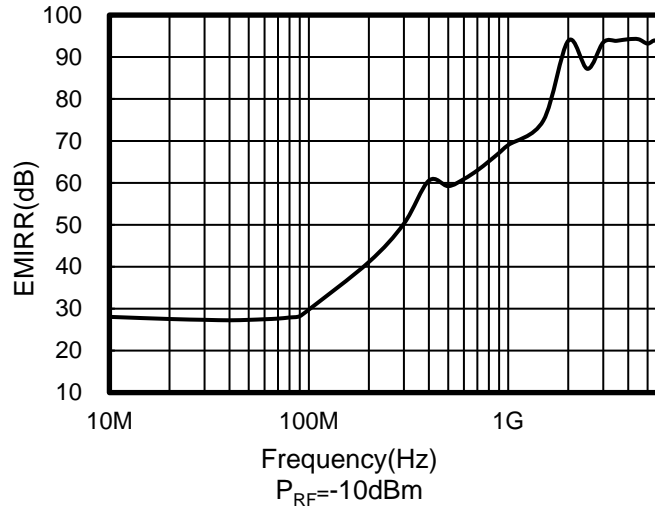


Figure 16. RS52X EMIRR vs Frequency

## 8.5 EMIRR IN+ Test Configuration

Figure 17 shows the circuit configuration for testing the EMIRR IN+. An RF source is connected to the operational amplifier noninverting input pin using a transmission line. The operational amplifier is configured in a unity-gain buffer topology with the output connected to a low-pass filter (LPF) and a digital multimeter (DMM). A large impedance mismatch at the operational amplifier input causes a voltage reflection; however, this effect is characterized and accounted for when determining the EMIRR IN+. The resulting dc offset voltage is sampled and measured by the multimeter. The LPF isolates the multimeter from residual RF signals that can interfere with multimeter accuracy.

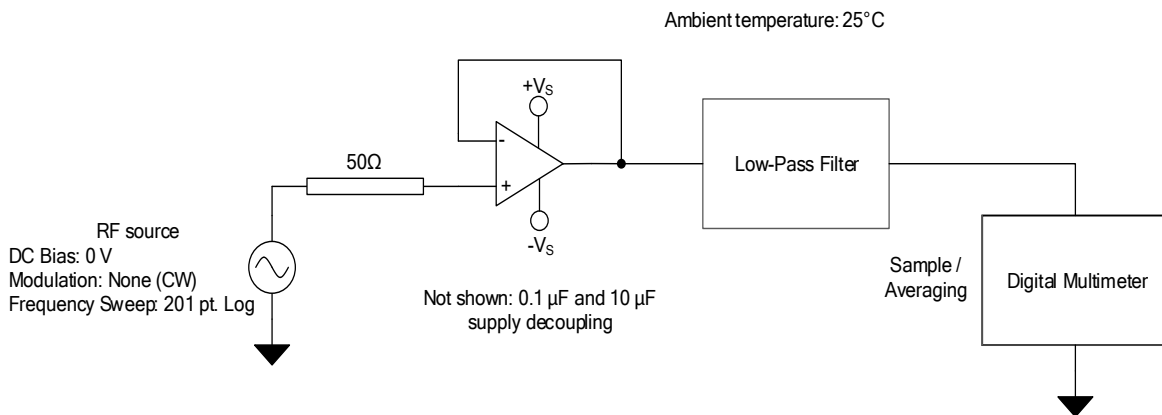


Figure 17. EMIRR IN+ Test Configuration Schematic



## 9 Application and Implementation

Information in the following applications sections is not part of the Runic component specification, and Runic does not warrant its accuracy or completeness. Runic's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

### 9.1 APPLICATION NOTE

The RS52X are high precision, rail-to-rail operational amplifiers that can be run from a single-supply voltage 2.5V to 5.5V ( $\pm 1.25V$  to  $\pm 2.75V$ ). Supply voltages higher than 7V (absolute maximum) can permanently damage the amplifier. Rail-to-rail input and output swing significantly increases dynamic range, especially in low-supply applications. Good layout practice mandates use of a 0.1 $\mu$ F capacitor placed closely across the supply pins.

## Typical Applications

### 9.2 25-kHz Low-pass Filter

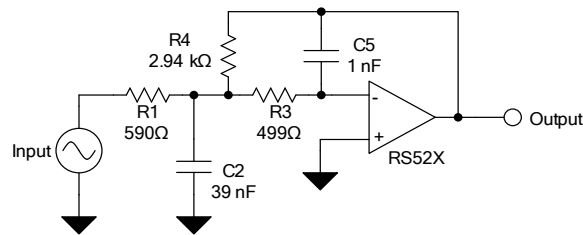


Figure 18. 25-kHz Low-Pass Filter

### 9.3 Design Requirements

Low-pass filters are commonly employed in signal processing applications to reduce noise and prevent aliasing. The RS52X devices are ideally suited to construct high-speed, high-precision active filters. Figure 18 shows a second-order, low-pass filter commonly encountered in signal processing applications.

Use the following parameters for this design example:

- Gain = 5 V/V (inverting gain)
- Low-pass cutoff frequency = 25 kHz
- Second-order Chebyshev filter response with 3-dB gain peaking in the passband

### 9.4 Detailed Design Procedure

The infinite-gain multiple-feedback circuit for a low-pass network function is shown in Figure 18. Use Equation 1 to calculate the voltage transfer function.

$$\frac{\text{Output}}{\text{Input}}(s) = \frac{-1/R_1 R_3 C_2 C_5}{s^2 + (s/C_2) (1/R_1 + 1/R_3 + 1/R_4) + 1/R_3 R_4 C_2 C_5} \quad (1)$$

This circuit produces a signal inversion. For this circuit, the gain at dc and the low-pass cutoff frequency are calculated by Equation 2:

$$\text{Gain} = \frac{R_4}{R_1}$$

$$f_c = \frac{1}{2\pi} \sqrt{1/R_3 R_4 C_2 C_5} \quad (2)$$

### 9.5 Application Curve

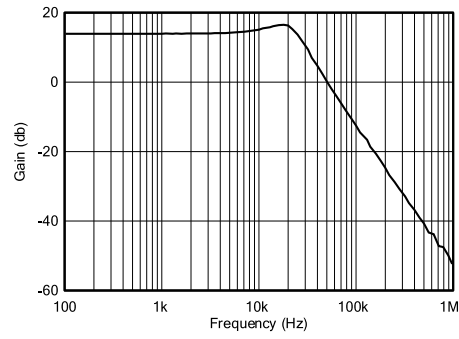


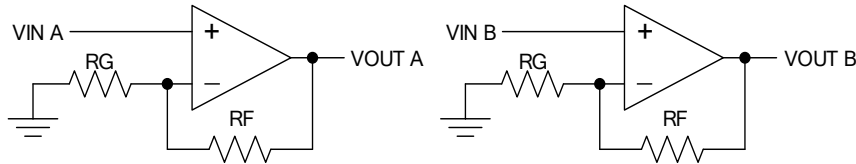
Figure 19. Low-pass filter transfer function

## 10 LAYOUT

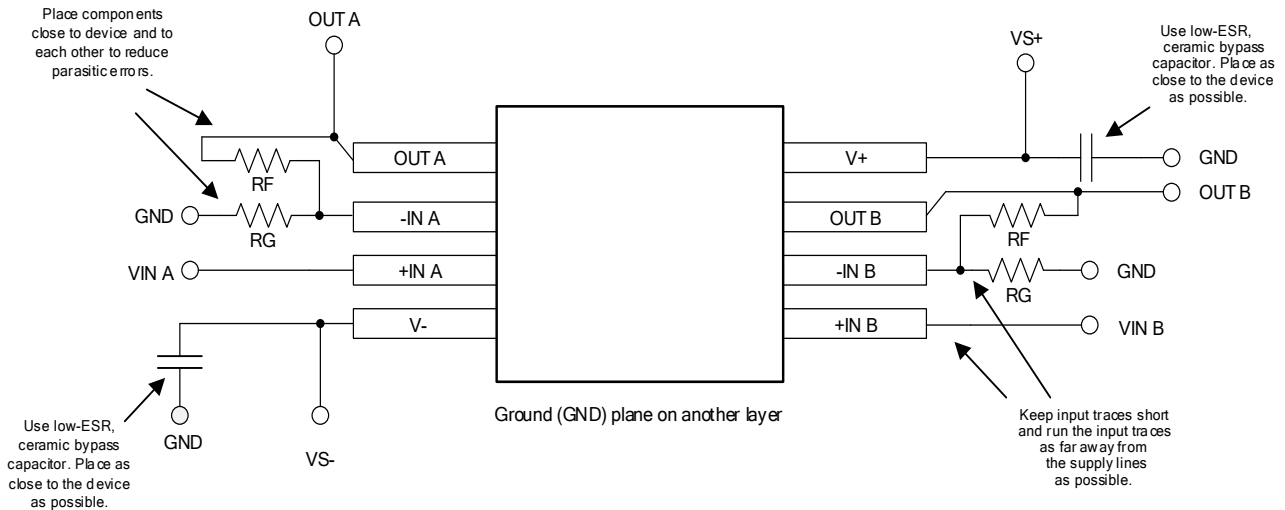
### 10.1 Layout Guidelines

Attention to good layout practices is always recommended. 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.

### 10.2 Layout Example



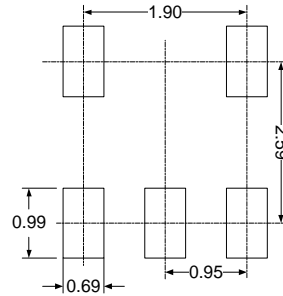
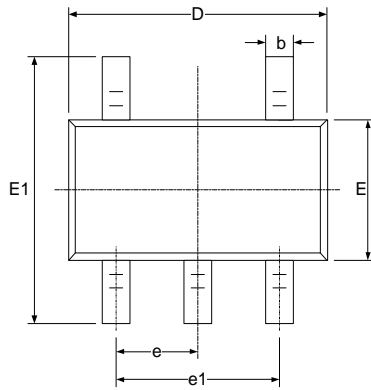
**Figure 20. Schematic Representation**



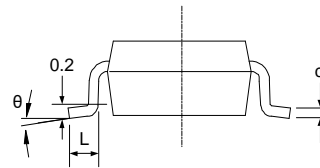
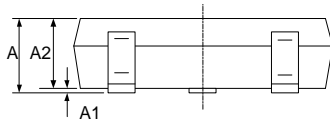
**Figure 21. Layout Example**

NOTE: Layout Recommendations have been shown for dual op-amp only, follow similar precautions for Single and four.

## 11 PACKAGE OUTLINE DIMENSIONS SOT23-5

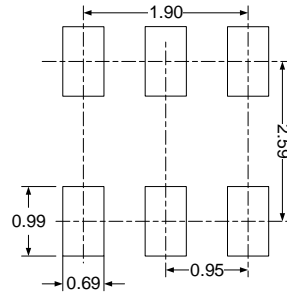
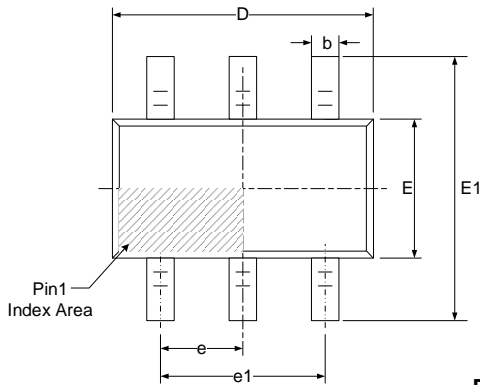


RECOMMENDED LAND PATTERN (Unit: mm)

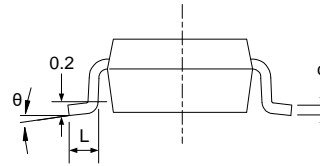
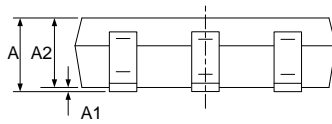


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950(BSC)		0.037(BSC)	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

SOT23-6

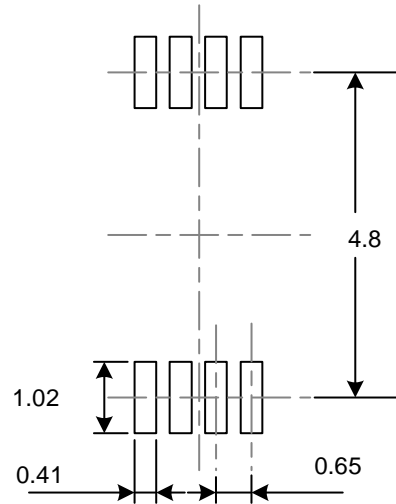
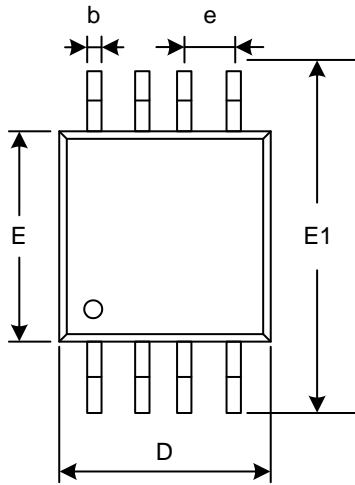


RECOMMENDED LAND PATTERN (Unit: mm)

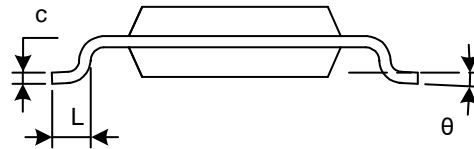
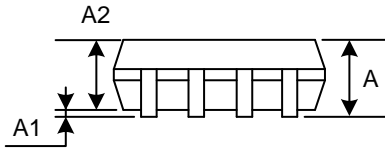


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950(BSC)		0.037(BSC)	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
$\theta$	0°	8°	0°	8°

MSOP-8

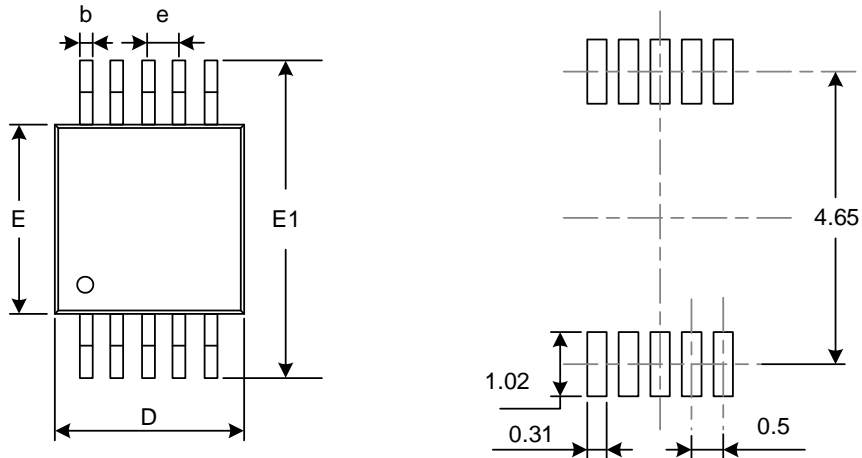


RECOMMENDED LAND PATTERN (Unit: mm)

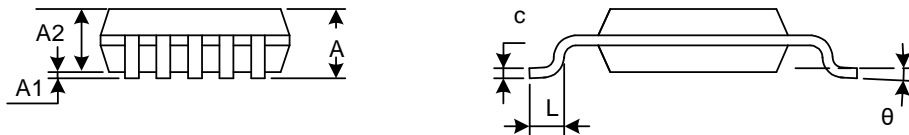


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
e	0.650(BSC)		0.026(BSC)	
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187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

MSOP-10

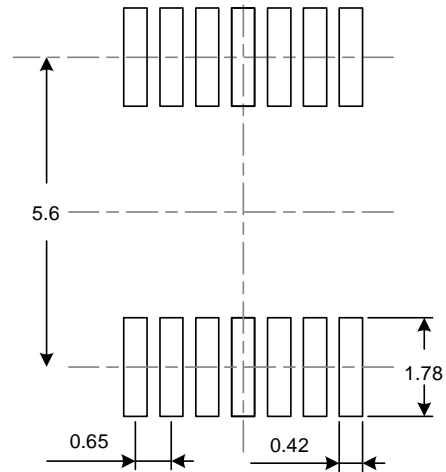
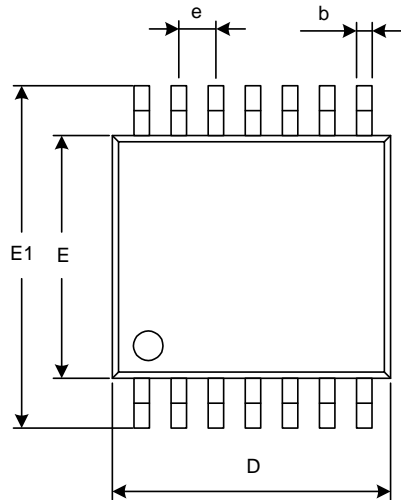


RECOMMENDED LAND PATTERN (Unit: mm)

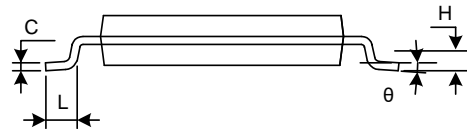
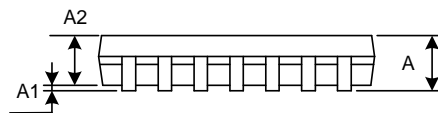


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.180	0.280	0.007	0.011
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
e	0.50(BSC)		0.020(BSC)	
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
L	0.400	0.800	0.016	0.031
θ	0°	6°	0°	6°

TSSOP-14



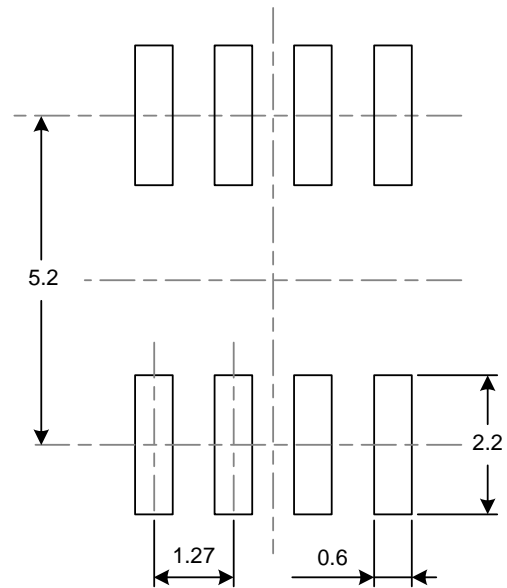
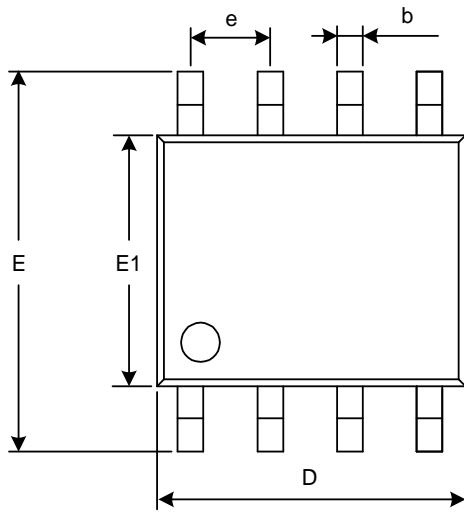
RECOMMENDED LAND PATTERN (Unit: mm)



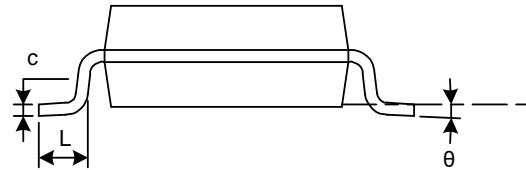
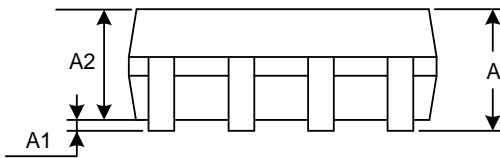
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A		1.200		0.047
A1	0.050	0.150	0.002	0.006
A2	0.800	1.050	0.031	0.041
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
D	4.860	5.100	0.191	0.201
E	4.300	4.500	0.169	0.177
E1	6.250	6.550	0.246	0.258
e	0.650(BSC)		0.026(BSC)	
L	0.500	0.700	0.020	0.028
H	0.25(TYP)		0.01(TYP)	
$\theta$	1°	7°	1°	7°



SOIC-8(SOP8)

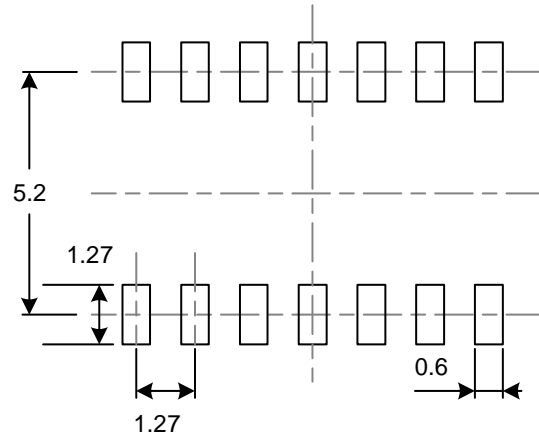
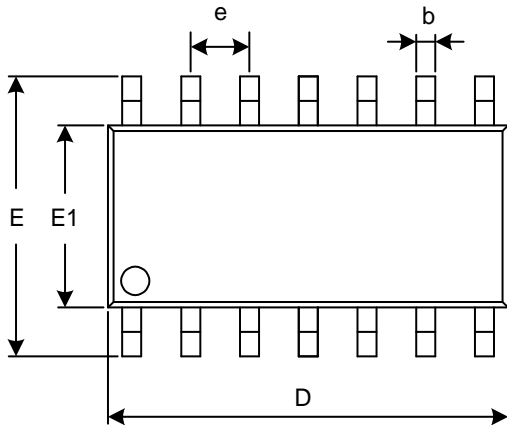


RECOMMENDED LAND PATTERN (Unit: mm)

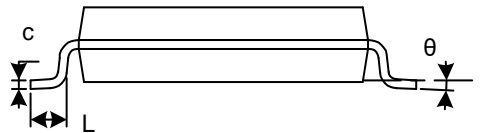
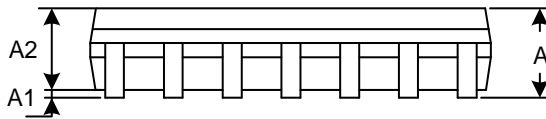


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.800	5.000	0.189	0.197
e	1.270(BSC)		0.050(BSC)	
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
L	0.400	1.270	0.016	0.050
$\theta$	0°	8°	0°	8°

SOIC-14(SOP14)



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	0.310	0.510	0.012	0.020
c	0.100	0.250	0.004	0.010
D	8.450	8.850	0.333	0.348
e	1.270(BSC)		0.050(BSC)	
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
L	0.400	1.270	0.016	0.050
$\theta$	0°	8°	0°	8°

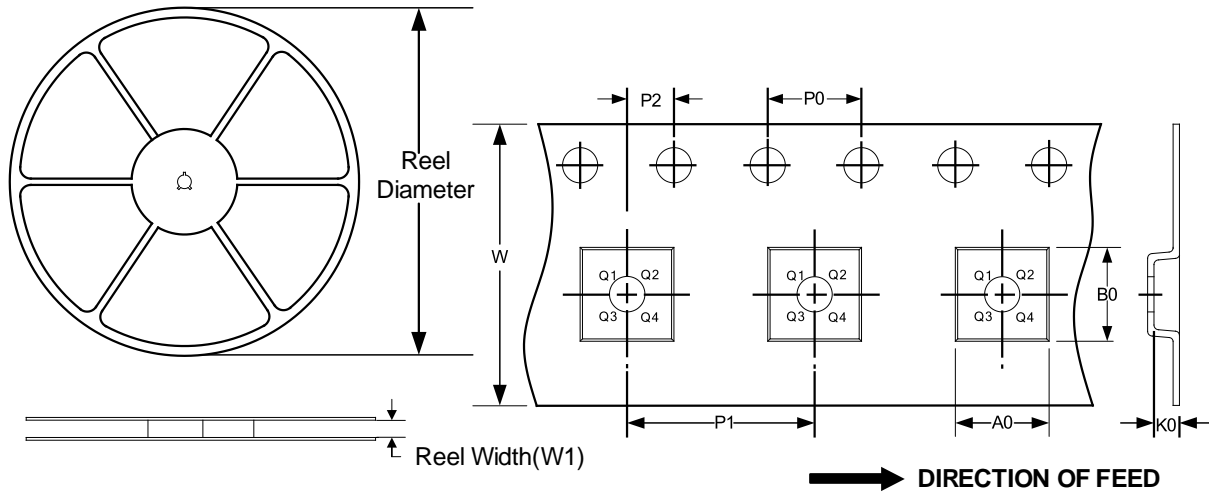
NOTE:

- A. All linear dimension is in millimeters.
- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
- D. BSC: Basic Dimension. Theoretically exact value shown without tolerances.

## 12 TAPE AND REEL INFORMATION

### REEL DIMENSIONS

### TAPE DIMENSION



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(mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
SOT23-5	7"	9.5	3.20	3.20	1.40	4.0	4.0	2.0	8.0	Q3
SOT23-6	7"	9.5	3.17	3.23	1.37	4.0	4.0	2.0	8.0	Q3
SOIC-8(SOP8)	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
MSOP-10	13"	12.4	5.20	3.30	1.20	4.0	8.0	2.0	12.0	Q1
SOIC-14(SOP14)	13"	16.4	6.60	9.30	2.10	4.0	8.0	2.0	16.0	Q1
TSSOP-14	13"	12.4	6.95	5.60	1.20	4.0	8.0	2.0	12.0	Q1

NOTE:

1. All dimensions are nominal.
2. Plastic or metal protrusions of 0.15mm maximum per side are not included.

## **IMPORTANT NOTICE AND DISCLAIMER**

Jiangsu Runic Technology Co., Ltd. will accurately and reliably provide technical and reliability data (including data sheets), design resources (including reference designs), application or other design advice, WEB tools, safety information and other resources, without warranty of any defect, and will not make any express or implied warranty, including but not limited to the warranty of merchantability. Implied warranty that it is suitable for a specific purpose or does not infringe the intellectual property rights of any third party.

These resources are intended for skilled developers designing with Runic products. You will be solely responsible for: (1) Selecting the appropriate products for your application; (2) Designing, validating and testing your application; (3) Ensuring your application meets applicable standards and any other safety, security or other requirements; (4) Runic and the Runic logo are registered trademarks of Runic Incorporated. All trademarks are the property of their respective owners; (5) For change details, review the revision history included in any revised document. The resources are subject to change without notice. Our company will not be liable for the use of this product and the infringement of patents or third-party intellectual property rights due to its use.