1.1MHz, Precision, Rail-to-Rail I/O CMOS Operational Amplifier

FEATURES

- **HIGH GAIN BANDWIDTH:1.1MHz**
- **RAIL-TO-RAIL INPUT AND OUTPUT**
  3mV Max Vos
- **INPUT VOLTAGE RANGE: -0.2V to +5.7V with Vs = 5.5V**
- **SUPPLY RANGE: +2.1V to +5.5V**
- **SPECIFIED UP TO +125°C**
- ***Micro* SIZE PACKAGES: SOT23-5**

APPLICATIONS

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

DESCRIPTION

The RS6331KXF products offer low voltage operation and rail-to-rail input and output, as well as excellent speed/power consumption ratio, providing an excellent bandwidth (1.1MHz) and slew rate of 0.5V/us. The op-amps are unity gain stable and feature an ultra-low input bias current.

The RS6331KXF has lower offset, which is guaranteed not upper than 3mV.

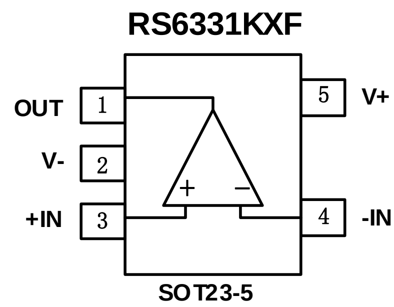
The devices are ideal for sensor interfaces, active filters and portable applications. The RS6331KXF families of operational amplifiers are specified at the full temperature range of −40°C to +125°C under single supplies of 2.1V to 5.5V or dual power supplies of ±1.05V to ±2.75V.

Device Information (1)

PART NUMBER	PACKAGE	BODY SIZE(NOM)
RS6331KXF	SOT23-5	2.90mm×1.60mm

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

Pin Configuration and Functions (Top View)



Pin Description

NAME	PIN RS6331KXF SOT23-5	I/O	DESCRIPTION
-IN	4	I	Negative (inverting) input
+IN	3	I	Positive (noninverting) input
OUT	1	O	Output
V-	2	-	Negative (lowest) power supply
V+	5	-	Positive (highest) power supply

SPECIFICATIONS

Absolute Maximum Ratings

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

		MIN	MAX	UNIT
Voltage	Supply, Vs=(V+) - (V-)		7	V
	Signal input pin (2)	(V-)-0.5	(V+) +0.5	
	Signal output pin (3)	(V-)-0.5	(V+) +0.5	
Current	Signal input pin (2)	-10	10	mA
	Signal output pin (3)	-140	140	mA
	Output short-circuit (4)	Continuous		
Temperature	Operating range, T_A	-40	125	°C
	Junction, T_J		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 ±140mA or less.
(4) Short-circuit to ground, one amplifier per package.

ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM)	±3000	V
		Machine Model (MM)	±200	

Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
Supply voltage, Vs= (V+) - (V-)	Signal-supply	2.1		5.5	V
	Dual-supply	±1.05		±2.75	

Thermal Information:RS6331KXF

THERMAL METRIC (1)		RS6331KXF	UNIT
		5PINS	
		SOT23-5	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	273.8	°C/W
$R_{\theta JC(top)}$	Junction-to-case(top) thermal resistance	126.8	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	85.9	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	10.9	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	84.9	°C/W
$R_{\theta JC(bot)}$	Junction-to-case(bottom) thermal resistance	N/A	°C/W

PACKAGE/ORDERING INFORMATION

Orderable Device	Package Type	Pin	Channel	Op Temp(°C)	Device Marking [1]	Package Qty
RS6331KXF	SOT23-5	5	1	-40℃~125℃	6331K	Tape and Reel,3000

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.

ELECTRICAL CHARACTERISTICS

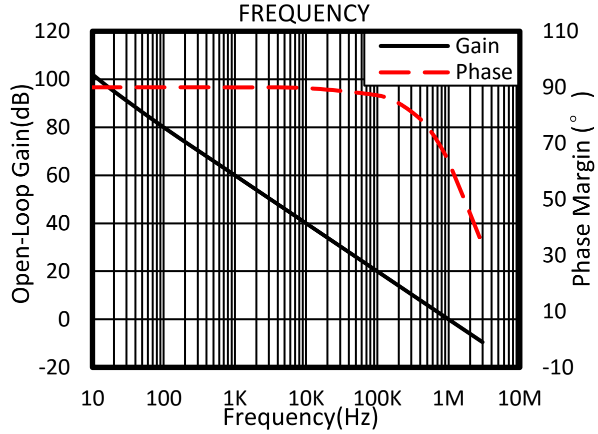
(At T_A = +25°C, Vs=5V, R_L = 10kΩ connected to V_S/2, and V_{OUT} = V_S/2, unless otherwise noted.)

PARAMETER		CONDITIONS	T_J	RS6331KXF MIN	RS6331KXF TYP	RS6331KXF MAX	UNITS
POWER SUPPLY							
Vs	Operating Voltage Range		25°C	2.1		5.5	V
IQ	Quiescent Current/Amplifier		25°C		85	145	uA
PSRR	Power-Supply Rejection Ratio	Vs=2.1V to 5.5V, Vcm=(V-)+0.5V	25°C	75	92		dB
			-40°C to 125°C	65			
t_{ON}	Turn-on time	Vs= 5V			20		us
INPUT							
Vos	Input Offset Voltage		25°C	-3	±0.5	3	mV
Vos Tc	Input Offset Voltage Average Drift	-40°C to 125°C			2		uV/°C
IB	Input Bias Current		25°C		1	10	pA
Ios	Input Offset Current		25°C		1	10	pA
Vcm	Common-Mode Voltage Range	Vs= 5.5V	25°C	-0.2		5.7	V
CMRR	Common-Mode Rejection Ratio	Vs= 5.5V, Vcm =-0.2V to 4V	25°C	75	95		dB
			-40°C to 125°C	68			
		Vs= 5.5V, Vcm =-0.2V to 5.7V	25°C	63	85		
			-40°C to 125°C	57			
OUTPUT							
AOL	Open-Loop Voltage Gain	R_L=2KΩ, Vo= 0.15V to 4.85V	25°C	95	110		dB
			-40°C to 125°C	85			
		R_L=10KΩ, Vo= 0.05V to 4.95V	25°C	100	120		
			-40°C to 125°C	92			
	Output Swing From Rail	R_L=2KΩ	25°C		25		mV
		R_L=10KΩ			8		
Iout	Output Current Source		25°C		110		mA
FREQUENCY RESPONSE							
SR	Slew Rate	C_L=100pF, G=1	25°C		0.5		V/us
GBP	Gain-Bandwidth Product		25°C		1.1		MHz
PM	Phase Margin		25°C		64		°
ts	Setting Time,0.1%	C_L=100pF, Vs= 5V, 2-V step, G=1			6.5		us
	Overload Recovery Time	V_{IN}·Gain≥V_S			4		us
NOISE							
e_n	Input Voltage Noise Density	f = 1KHz	25°C		22		nV/√Hz
		f = 10KHz	25°C		20		nV/√Hz

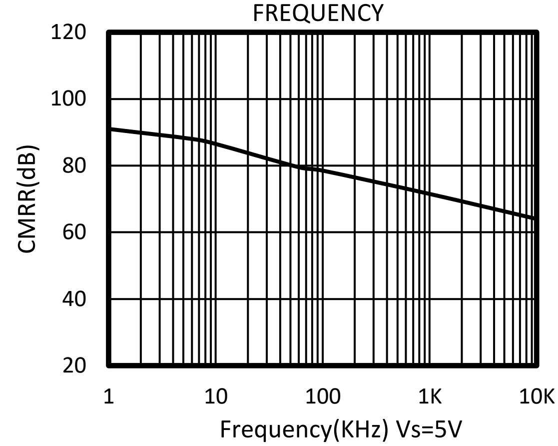
TYPICAL CHARACTERISTICS

At T_A = +25°C, Vs=5V, R_L = 10kΩ connected to $V_S/2$, V_{OUT} = $V_S/2$, unless otherwise noted.

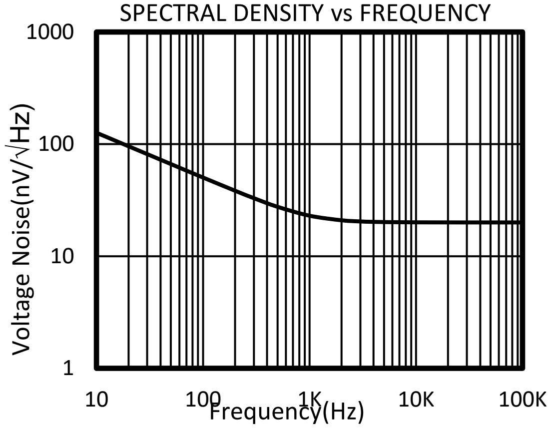
OPEN-LOOP GAIN AND PHASE vs FREQUENCY



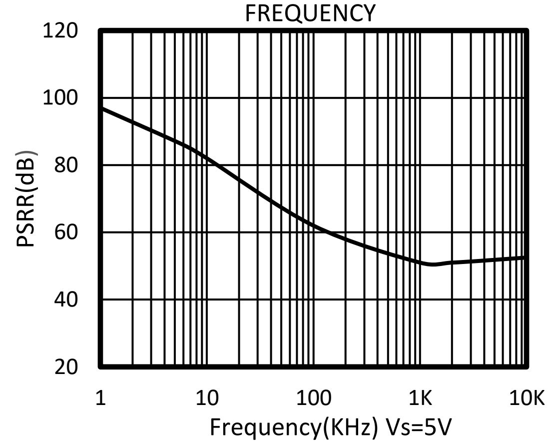
COMMON−MODE REJECTION RATIO vs FREQUENCY



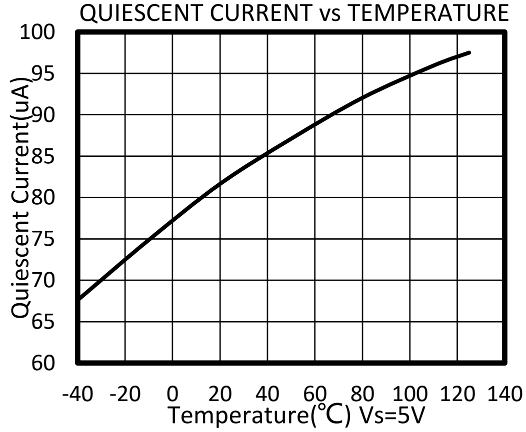
INPUT VOLTAGE NOISE SPECTRAL DENSITY vs FREQUENCY



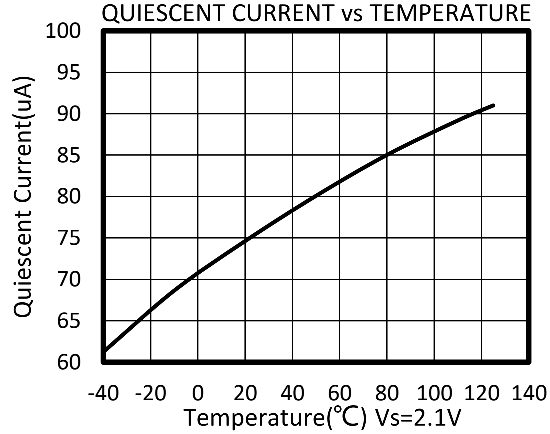
POWER−SUPPLY REJECTION RATIO vs FREQUENCY



QUIESCENT CURRENT vs TEMPERATURE

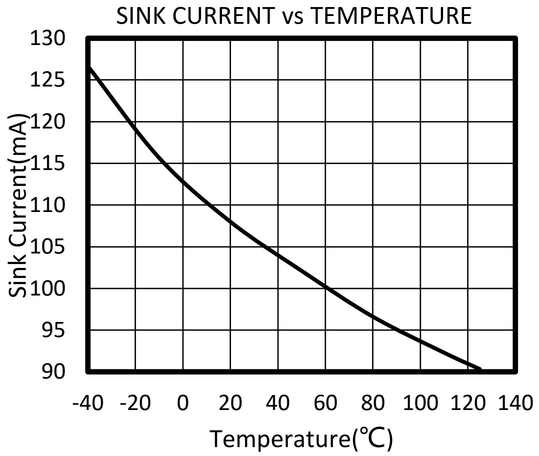


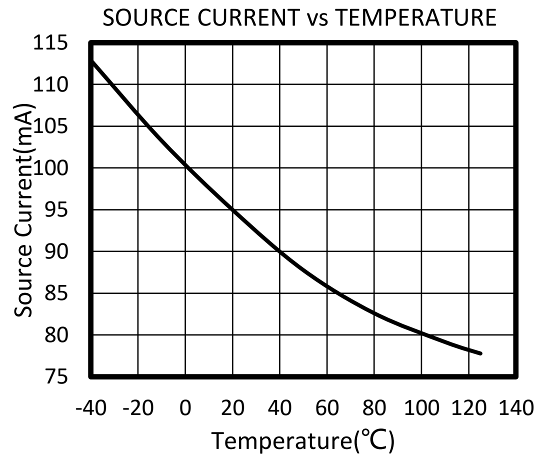
QUIESCENT CURRENT vs TEMPERATURE

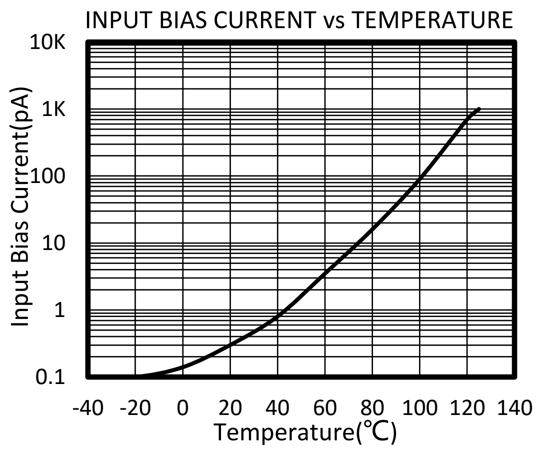


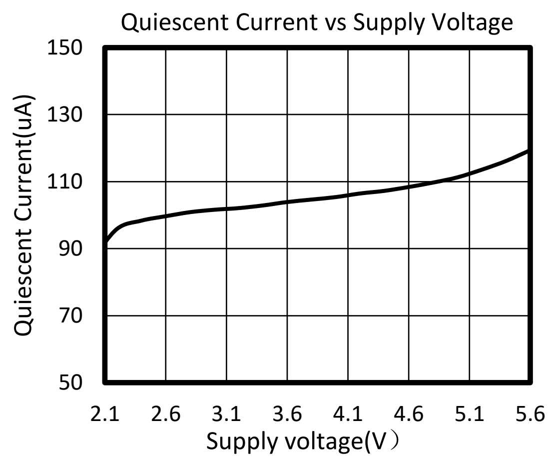
TYPICAL CHARACTERISTICS

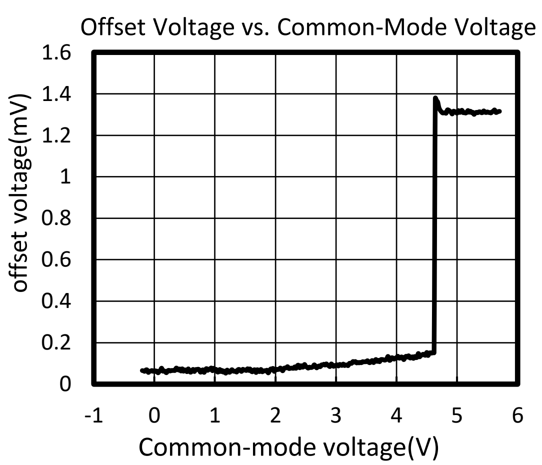
At T_A = +25°C, Vs=5V, R_L = 10kΩ connected to $V_S/2$, V_{OUT} = $V_S/2$, unless otherwise noted.

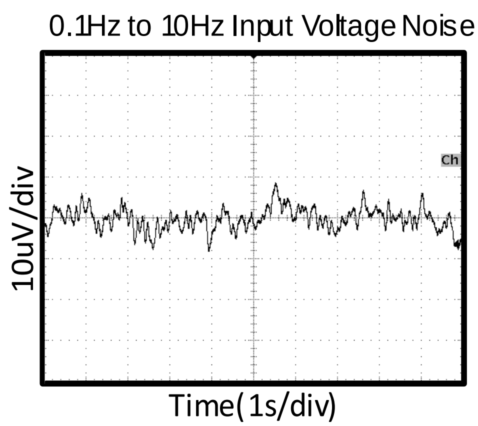








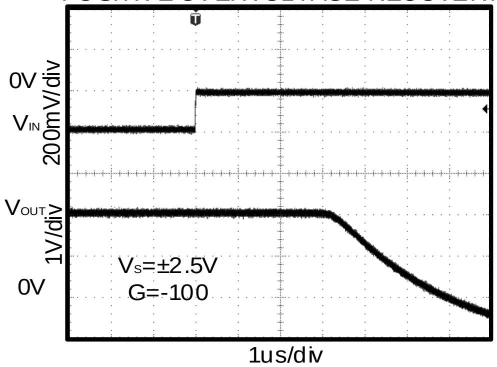




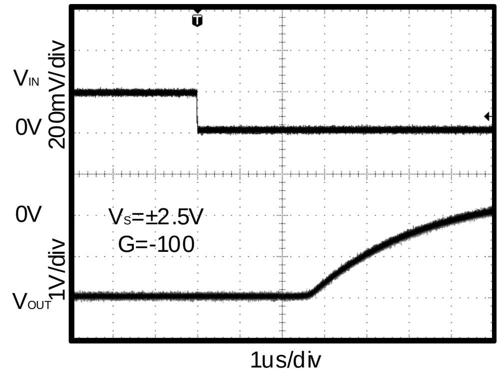
TYPICAL CHARACTERISTICS

At T_A = +25°C, Vs=5V, R_L = 10kΩ connected to V_S/2, V_{OUT} = V_S/2, unless otherwise noted.

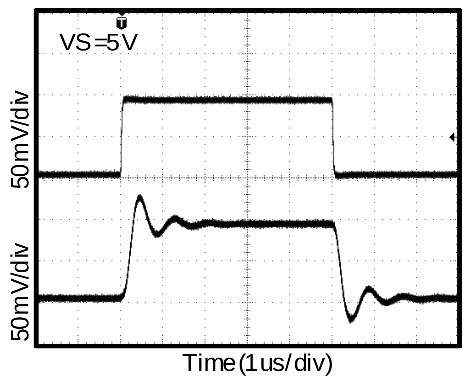
POSITIVE OVERVOLTAGE RECOVERY



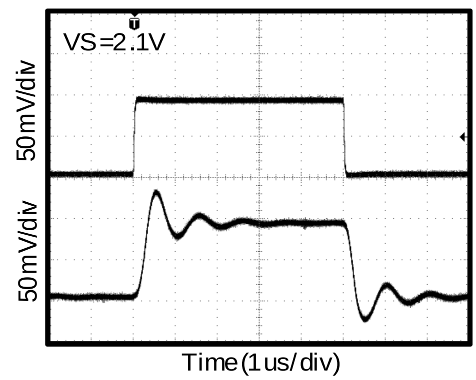
NEGATIVE OVERVOLTAGE RECOVERY



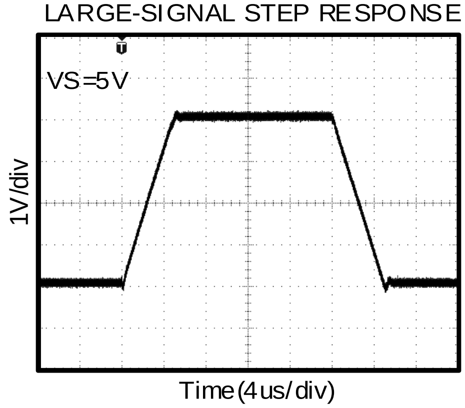
SMALL-SIGNAL STEP RESPONSE



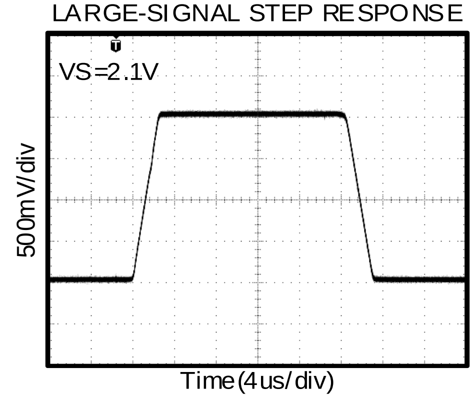
SMALL-SIGNAL STEP RESPONSE



LARGE-SIGNAL STEP RESPONSE

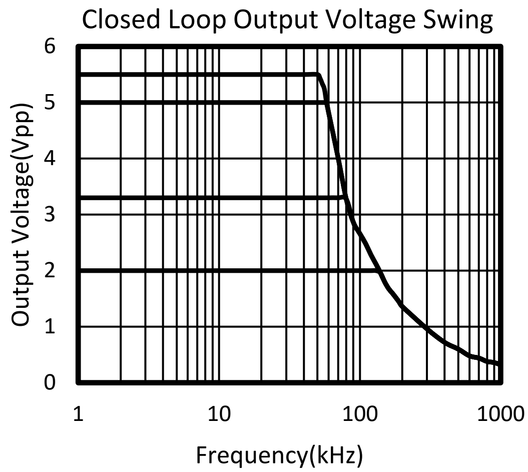


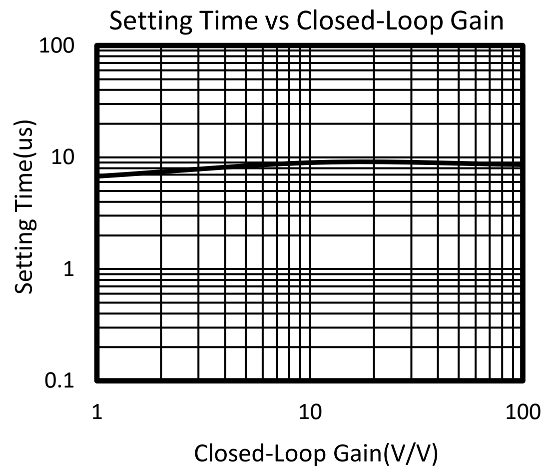
LARGE-SIGNAL STEP RESPONSE



TYPICAL CHARACTERISTICS

At T_A = +25°C, V_S=5V, R_L = 10kΩ connected to $V_S/2$, V_{OUT} = $V_S/2$, unless otherwise noted.





Detailed Description

Overview

The RS6331KXF devices are unity-gain stable, single-channel op amps with low noise and distortion. The device consists of a low noise input stage with a folded cascade and a rail-to-rail output stage. This topology exhibits superior noise and distortion performance across a wide range of supply voltages that are not delivered by legacy commodity audio operational amplifiers.

Phase Reversal Protection

The RS6331KXF 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 RS6331KXF prevents phase reversal with excessive common-mode voltage. Instead, the appropriate rail limits the output voltage. This performance is shown in figure 1.

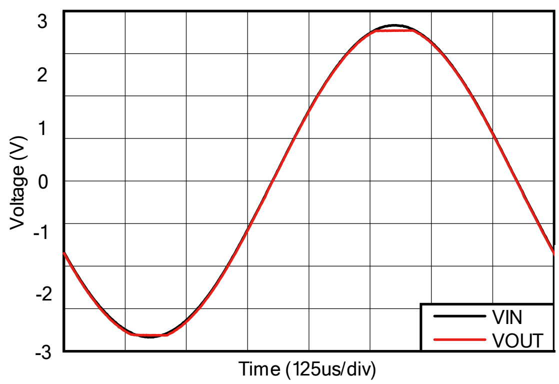


Figure 1. Output Waveform Devoid of Phase Reversal During an Input Overdrive Condition

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 RS6331KXF is plotted versus frequency in Figure 2. If available, any dual and quad operational amplifier device versions have approximately identical EMIRR IN+ performance. The RS6331KXF unity-gain bandwidth is 1.1MHz. EMIRR performance below this frequency denotes interfering signals that fall within the operational amplifier bandwidth.

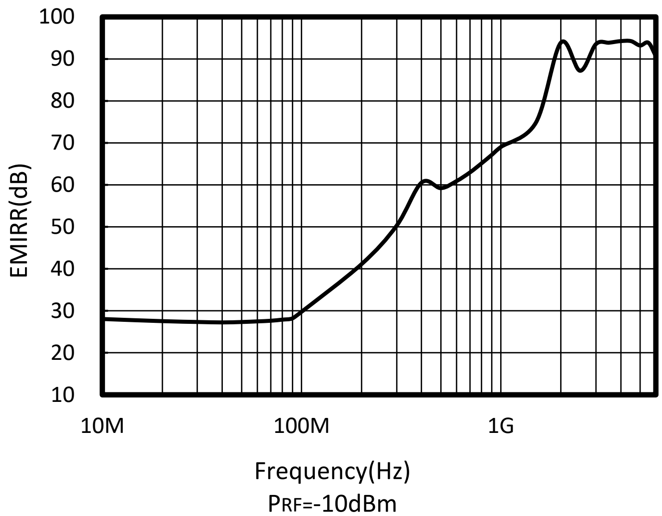


Figure 2.RS6331KXF EMIRR vs Frequency

EMIRR IN+ Test Configuration

Figure 3 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.

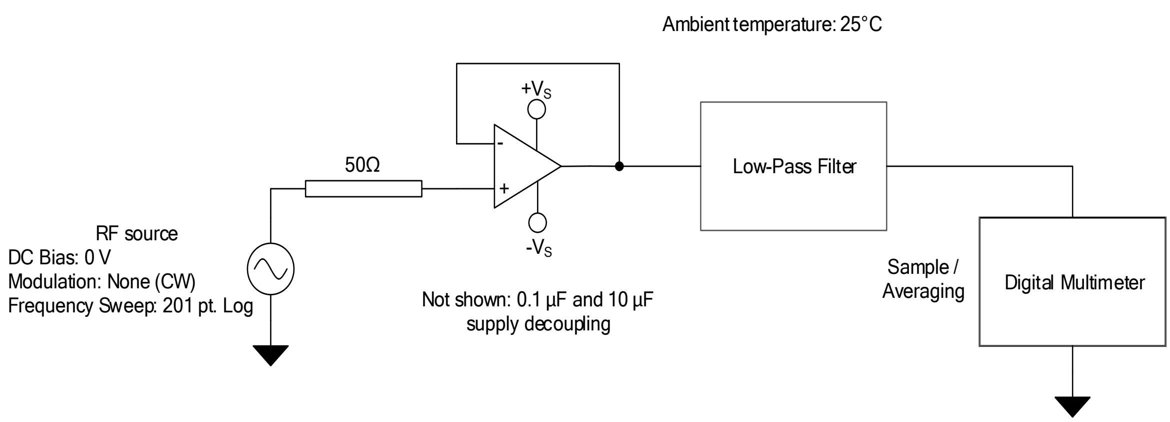


Figure 3. EMIRR IN+ Test Configuration Schematic

APPLICATION NOTE

The RS6331KXF is high precision, rail-to-rail operational amplifiers that can be run from a single-supply voltage 2.1V to 5.5V (±1.05V to ±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 place closely across the supply pins.

Typical Applications

25-kHz Low-pass Filter

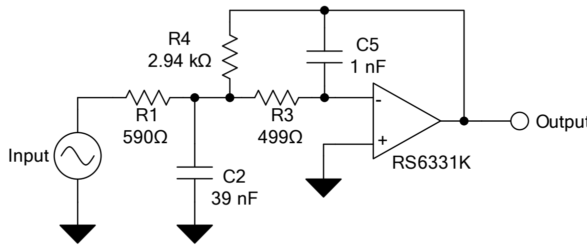


Figure 4. 25-kHz Low-Pass Filter

Design Requirements

Low-pass filters are commonly employed in signal processing applications to reduce noise and prevent aliasing. The RS6331KXF devices are ideally suited to construct high-speed, high-precision active filters. Figure 4 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

Detailed Design Procedure

The infinite-gain multiple-feedback circuit for a low-pass network function is shown in Figure 4. Use Equation 1 to calculate the voltage transfer function.

$$\frac{Output}{Input}(s) = \frac{-1/R_1R_3C_2C_5}{s^2 + (s/C_2)(1/R_1 + 1/R_3 + 1/R_4) + 1/R_3R_4C_2C_5} \quad (1)$$

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

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

$$f_C = \frac{1}{2\pi}\sqrt{(1/R_3R_4C_2C_5)} \quad (2)$$

Application Curve

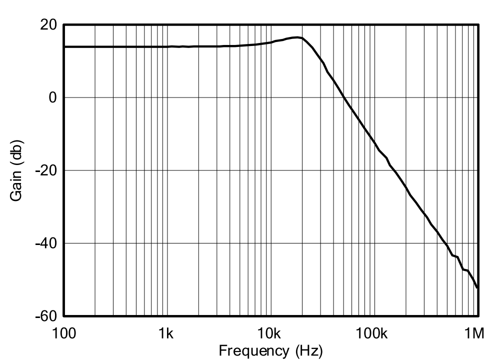


Figure 5. Low pass filter transfer function

LAYOUT

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.

Layout Example

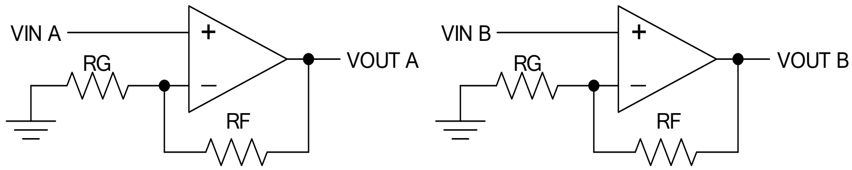


Figure 6. Schematic Representation

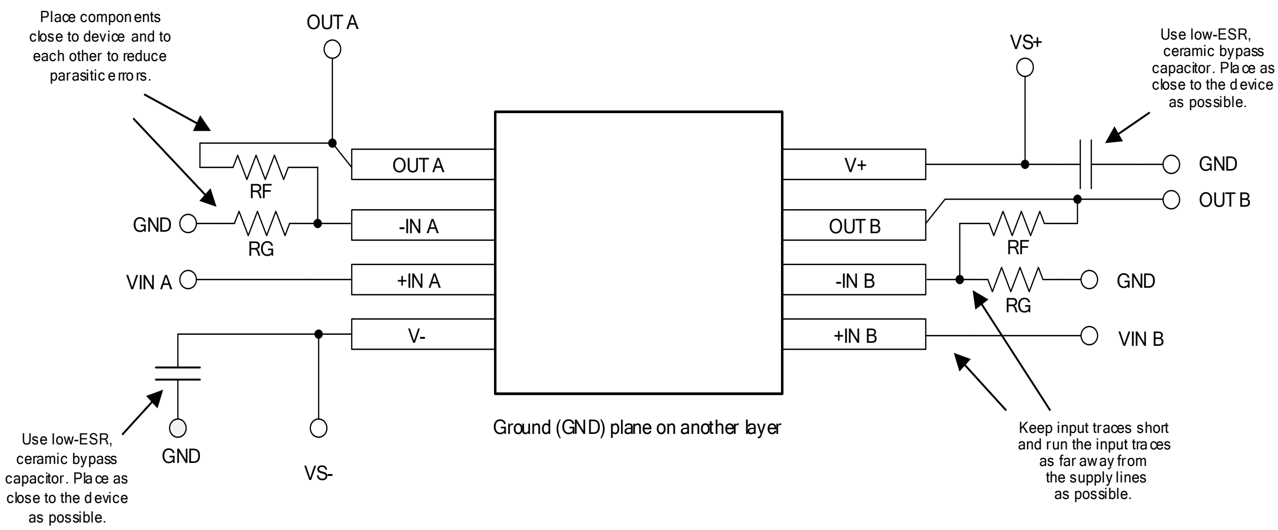
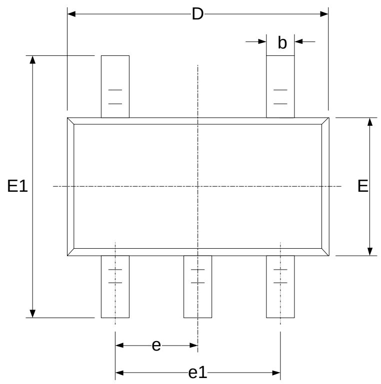
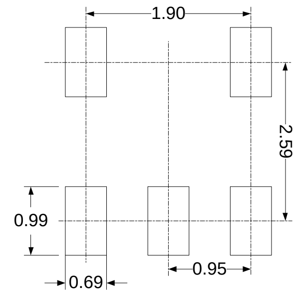


Figure 7. Layout Example

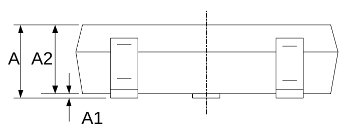
PACKAGE OUTLINE DIMENSIONS

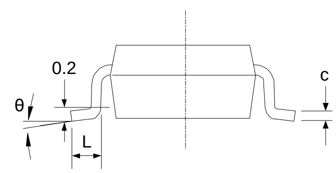
SOT23-5





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°