6.5MHz, 585μA, Rail-to-Rail I/O CMOS Operational Amplifier

FEATURES

- **LOW OFFSET: 5mV (max)**
- **LOW I_B: 10pA (max)**
- **HIGH BANDWIDTH: 6.5MHz**
- **RAIL-TO-RAIL INPUT AND OUTPUT**
- **SINGLE SUPPLY: +2.3V to +5.5V**
- **SHUTDOWN: OPAx373**
- **SPECIFIED UP TO +125°C**
- ***Micro*SIZE PACKAGES: SOT23-5, SOT23-6, and SOT23-8**

APPLICATIONS

- **PORTABLE EQUIPMENT**
- **BATTERY-POWERED DEVICES**
- **ACTIVE FILTERS**
- **DRIVING A/D CONVERTERS**

DESCRIPTION

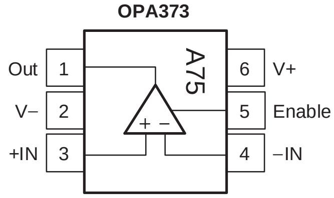
The OPA373 and OPA374 families of operational amplifiers are low power and low cost with excellent bandwidth (6.5MHz) and slew rate (5V/μs). The input range extends 200mV beyond the rails and the output range is within 25mV of the rails. Their speed/power ratio and small size make them ideal for portable and battery-powered applications.

The OPA373 family includes a shutdown mode. Under logic control, the amplifiers can be switched from normal operation to a standby current that is less than 1μA.

The OPA373 and OPA374 families of operational amplifiers are specified for single or dual power supplies of +2.7V to +5.5V, with operation from +2.3V to +5.5V. All models are specified for −40°C to +125°C.

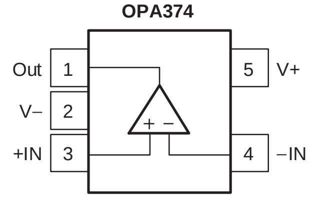
Pin Assignment

OPA373



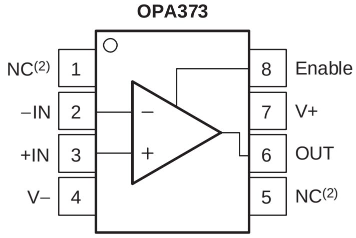
SOT23-6[1]

OPA374



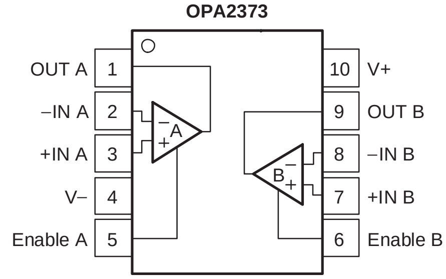
SOT23-5

OPA373



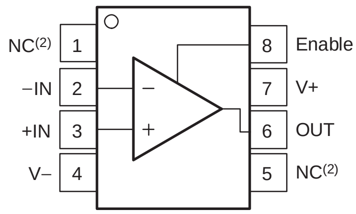
SO-8

OPA2373



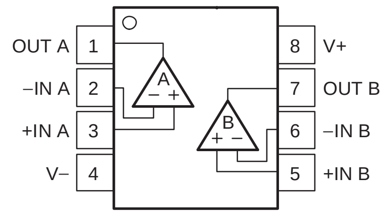
MSOP-10

OPA373



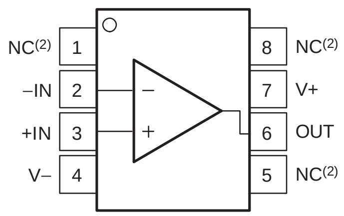
SO-8

OPA2374



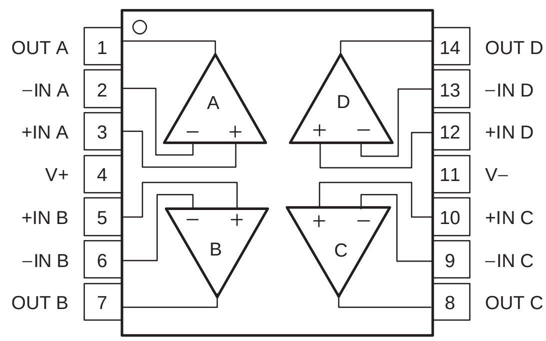
SO-8, SOT23-8

OPA374



SO-8

OPA4374



SO-14, TSSOP-14

(1) Pin 1 of the SOT23-6 is determined by orienting the package marking as shown.
(2) NC indicates no internal connection.

ABSOLUTE MAXIMUM RATINGS(1)

Supply Voltage	+7.0V
Signal Input Terminals, Voltage(2)	−0.5V to (V+) + 0.5V
Current(2)	±10mA
Output Short-Circuit(3)	Continuous
Operating Temperature	−55°C to +150°C
Storage Temperature	−65°C to +150°C
Junction Temperature	+150°C
Lead Temperature (soldering, 10s)	+300°C

(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.

ELECTRICAL CHARACTERISTICS: V_S = +2.7V to +5.5V

Boldface limits apply over the specified temperature range, **T_A = −40°C to +125°C.**

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

PARAMETER		CONDITIONS	OPA373, OPA2373, OPA374, OPA2374, OPA4374 MIN	TYP	MAX	UNIT
OFFSET VOLTAGE						
Input Offset Voltage	V_{OS}	V_S = 5V		1	5	mV
over Temperature					**6.5**	**mV**
Drift	**dV_{OS}/dT**			**3**		**µV/°C**
vs Power Supply	PSRR	V_S = 2.7V to 5.5V, V_{CM} < (V+) − 2V		25	100	µV/V
over Temperature		**V_S = 2.7V to 5.5V, V_{CM} < (V+) − 2V**			**150**	**µV/V**
Channel Separation, DC				0.4		µV/V
f = 1kHz				128		dB
INPUT VOLTAGE RANGE						
Common-Mode Voltage Range	V_{CM}		(V−) − 0.2		(V+) + 0.2	V
Common-Mode Rejection Ratio	CMRR	(V−) − 0.2V < V_{CM} < (V+) − 2V	80	90		dB
over Temperature		**(V−) − 0.2V < V_{CM} < (V+) − 2V**	**70**			**dB**
		V_S = 5.5V, (V−) − 0.2V < V_{CM} < (V+) + 0.2V	66			dB
over Temperature		**V_S = 5.5V, (V−) − 0.2V < V_{CM} < (V+) + 0.2V**	60			**dB**
INPUT BIAS CURRENT						
Input Bias Current	I_B			±0.5	±10	pA
Input Offset Current	I_{OS}			±0.5	±10	pA
INPUT IMPEDANCE						
Differential				10^{13} ∥ 3		Ω ∥ pF
Common-Mode				10^{13} ∥ 6		Ω ∥ pF
NOISE		V_{CM} < (V+) − 2V				
Input Voltage Noise, f = 0.1Hz to 10Hz				10		μV_{PP}
Input Voltage Noise Density, f = 10kHz	e_n			15		nV/√Hz
Input Current Noise Density, f = 10kHz	i_n			4		fA/√Hz
OPEN-LOOP GAIN						
Open-Loop Voltage Gain	A_{OL}	V_S = 5V, R_L = 100kΩ, 0.025V < V_O < 4.975V	94	110		dB
over Temperature		**V_S = 5V, R_L = 100kΩ, 0.025V < V_O < 4.975V**	**80**			**dB**
		V_S = 5V, R_L = 5kΩ, 0.125V < V_O < 4.875V	94	106		dB
over Temperature		**V_S = 5V, R_L = 5kΩ, 0.125V < V_O < 4.875V**	**80**			**dB**
OUTPUT						
Voltage Output Swing from Rail		R_L = 100kΩ		18	25	mV
over Temperature		**R_L = 100kΩ**			**25**	**mV**
		R_L = 5kΩ		100	125	mV
over Temperature		**R_L = 5kΩ**			**125**	**mV**
Short-Circuit Current	I_{SC}			See Typical Characteristics		
Capacitive Load Drive	C_{LOAD}			See Typical Characteristics		
Open-Loop Output Impedance		f = 1MHz, I_O = 0		220		Ω
FREQUENCY RESPONSE		C_L = 100pF				
Gain-Bandwidth Product	GBW			6.5		MHz
Slew Rate	SR	G = +1		5		V/µs
Settling Time, 0.1%	t_S	V_S = 5V, 2V Step, G = +1		1		µs
0.01%		V_S = 5V, 2V Step, G = +1		1.5		µs
Overload Recovery Time		V_{IN} • Gain > V_S		0.3		µs
Total Harmonic Distortion + Noise	THD+N	V_S = 5V, V_O = $3V_{PP}$, G = +1, f = 1kHz		0.0013		%
ENABLE/SHUTDOWN						
t_{OFF}				3		µs
t_{ON}				12		µs
V_L (shutdown)			V−		(V−) + 0.8	V
V_H (amplifier is active)			(V−) + 2		V+	V
Input Bias Current of Enable Pin				0.2		µA
I_{QSD} (per amplifier)				< 0.5	1	µA

ELECTRICAL CHARACTERISTICS: V_S = +2.7V to +5.5V (continued)

Boldface limits apply over the specified temperature range, **T_A = −40°C to +125°C.**

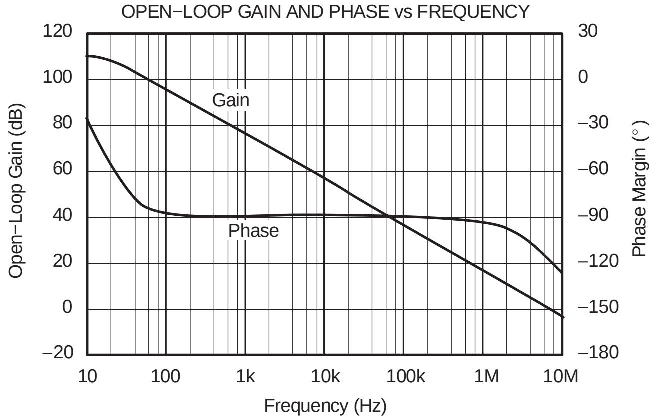
At T_A = +25°C, R_L = 10kΩ connected to V_S/2, and V_{OUT} = V_S/2, unless otherwise noted.

PARAMETER		CONDITIONS	OPA373, OPA2373, OPA374, OPA2374, OPA4374 MIN	TYP	MAX	UNIT
POWER SUPPLY						
Specified Voltage Range	V_S		2.7		5.5	V
Operating Voltage Range				2.3 to 5.5		V
Quiescent Current (per amplifier)	I_Q	I_O = 0		585	750	µA
over Temperature					**800**	µ**A**
TEMPERATURE RANGE						
Specified Range			−40		+125	°C
Operating Range			−55		+150	°C
Storage Range			−65		+150	°C
Thermal Resistance	θ_{JA}					°C/W
SOT23-5, SOT23-6, SOT23-8				+200		°C/W
MSOP-10, SO-8				+150		°C/W
SO-14, TSSOP-14				+100		°C/W

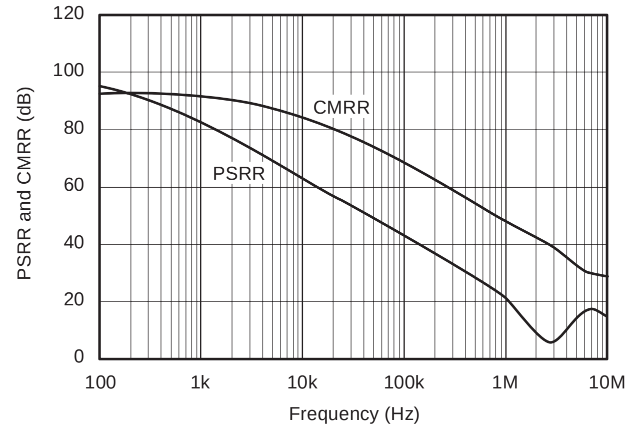
TYPICAL CHARACTERISTICS

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

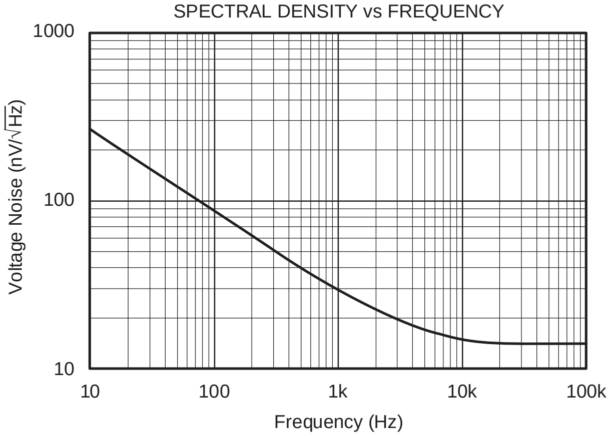
OPEN−LOOP GAIN AND PHASE vs FREQUENCY



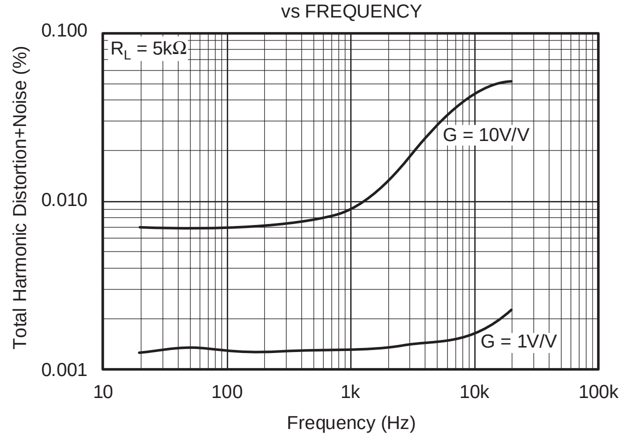
POWER−SUPPLY AND COMMON−MODE REJECTION RATIO vs FREQUENCY



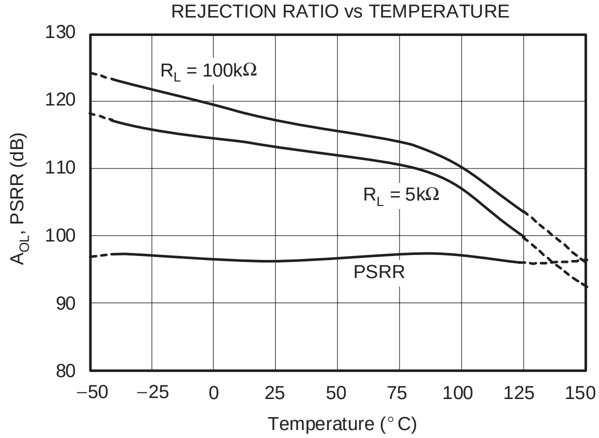
INPUT VOLTAGE NOISE SPECTRAL DENSITY vs FREQUENCY



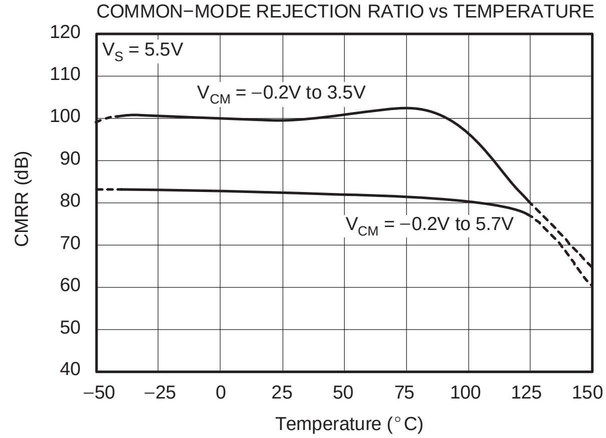
TOTAL HARMONIC DISTORTION+NOISE vs FREQUENCY



OPEN−LOOP GAIN AND POWER−SUPPLY REJECTION RATIO vs TEMPERATURE



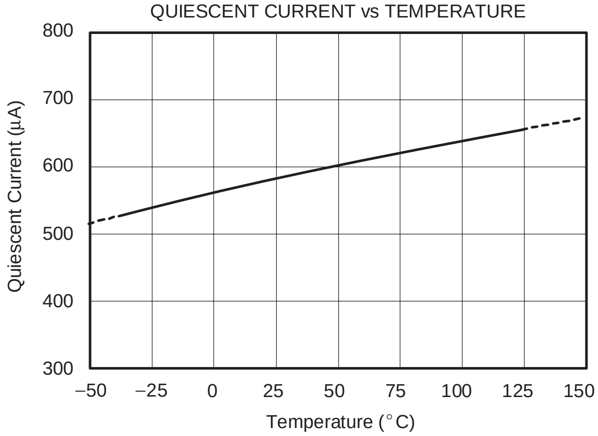
COMMON−MODE REJECTION RATIO vs TEMPERATURE



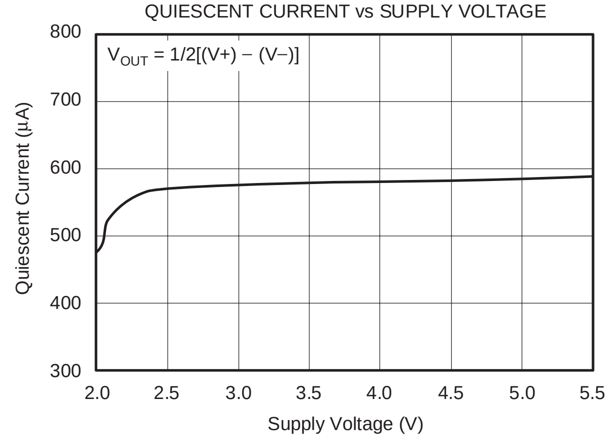
TYPICAL CHARACTERISTICS (continued)

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

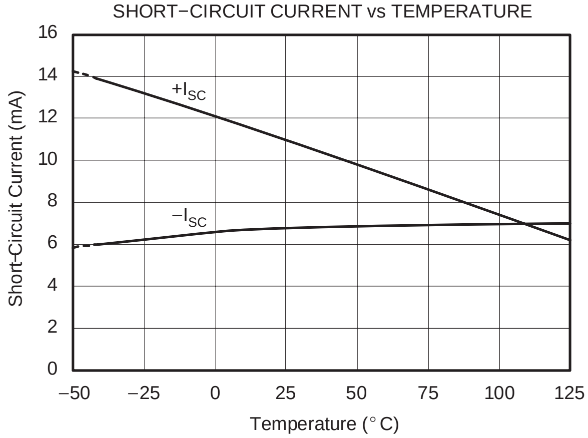
QUIESCENT CURRENT vs TEMPERATURE



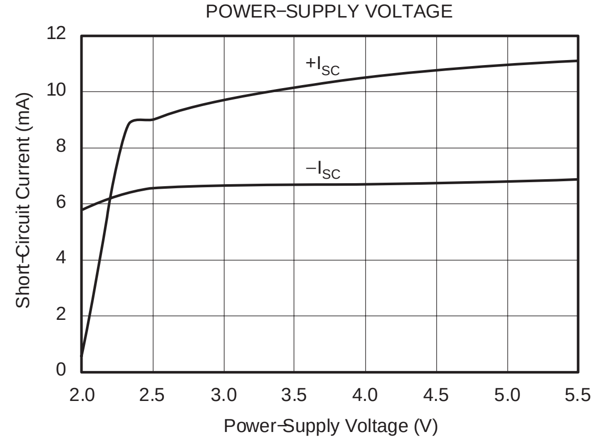
QUIESCENT CURRENT vs SUPPLY VOLTAGE



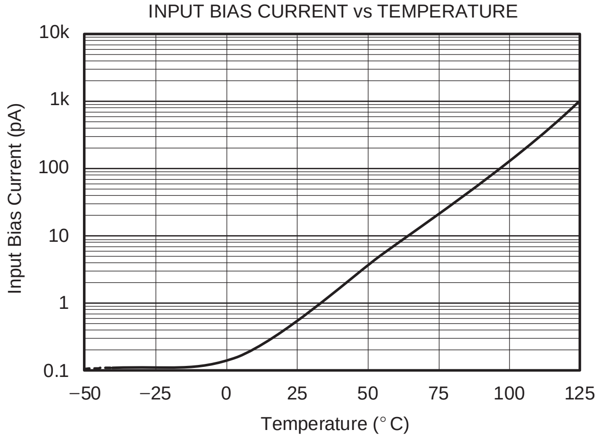
SHORT−CIRCUIT CURRENT vs TEMPERATURE



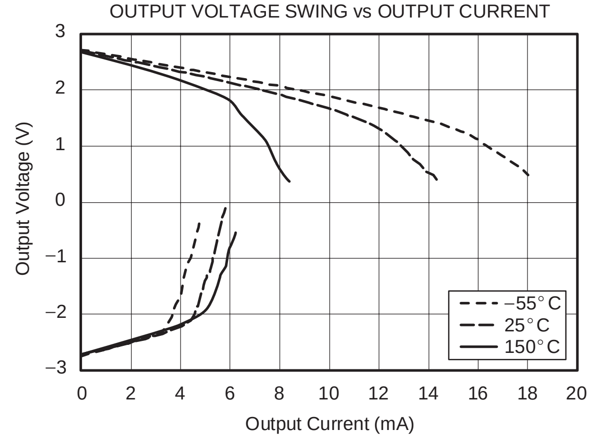
CONTINUOUS SHORT−CIRCUIT CURRENT vs POWER−SUPPLY VOLTAGE



INPUT BIAS CURRENT vs TEMPERATURE



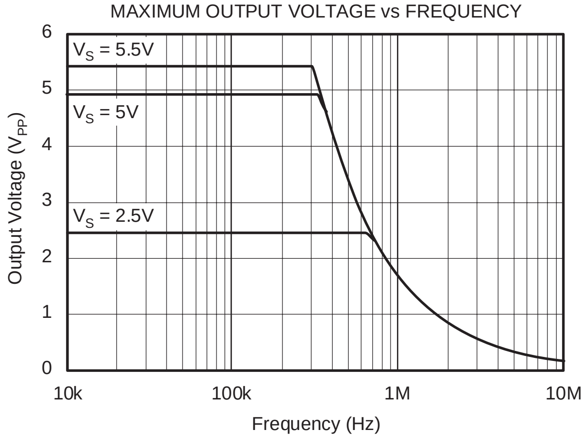
OUTPUT VOLTAGE SWING vs OUTPUT CURRENT



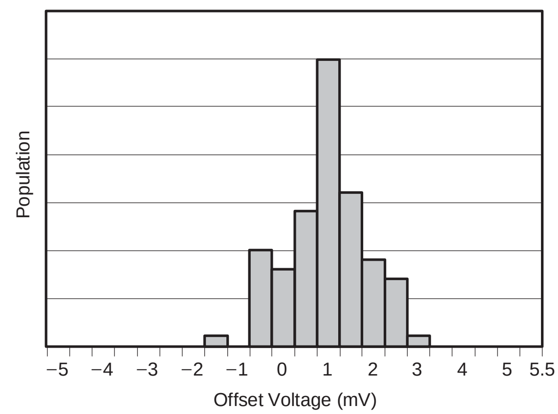
TYPICAL CHARACTERISTICS (continued)

At $T_A = +25°C$, $R_L = 10k\Omega$ connected to $V_S/2$, and $V_{OUT} = V_S/2$, unless otherwise noted.

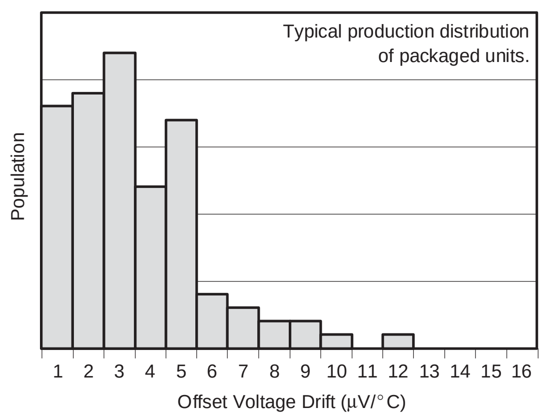
MAXIMUM OUTPUT VOLTAGE vs FREQUENCY



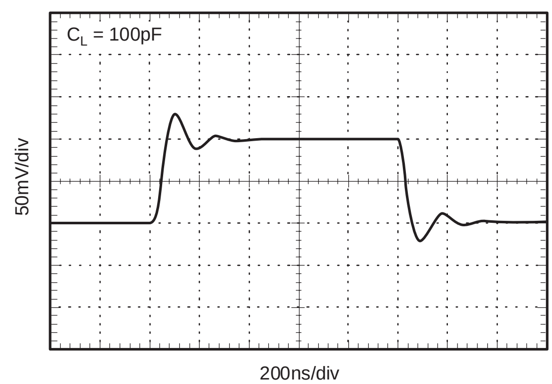
OFFSET VOLTAGE PRODUCTION DISTRIBUTION



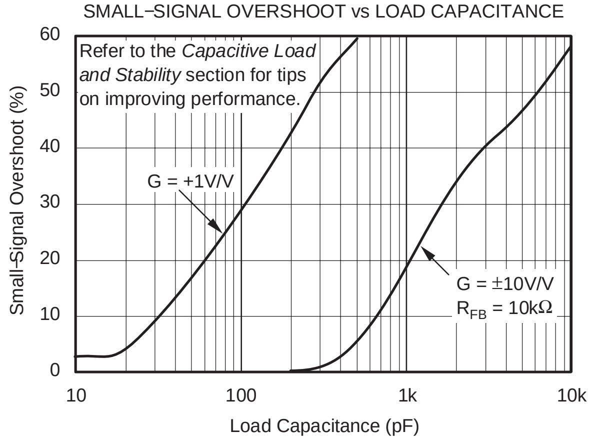
OFFSET VOLTAGE DRIFT MAGNITUDE PRODUCTION DISTRIBUTION



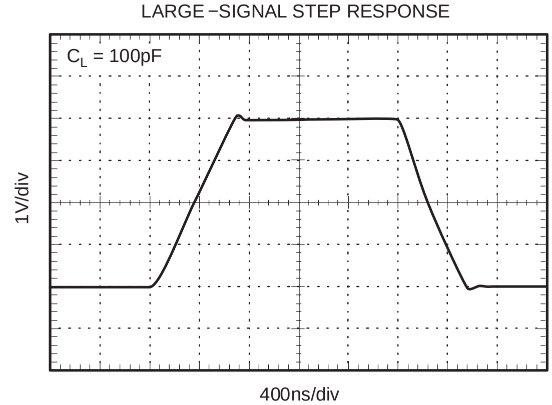
SMALL−SIGNAL STEP RESPONSE



SMALL−SIGNAL OVERSHOOT vs LOAD CAPACITANCE

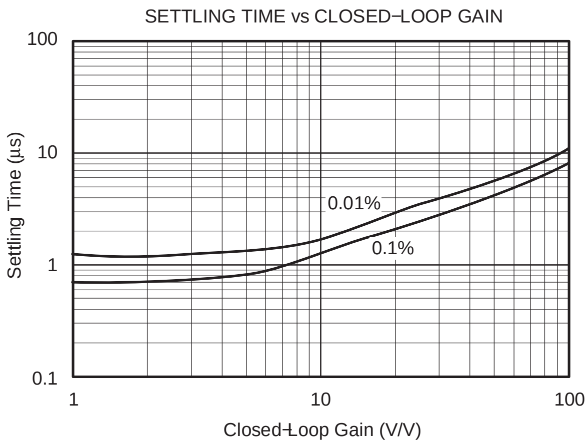


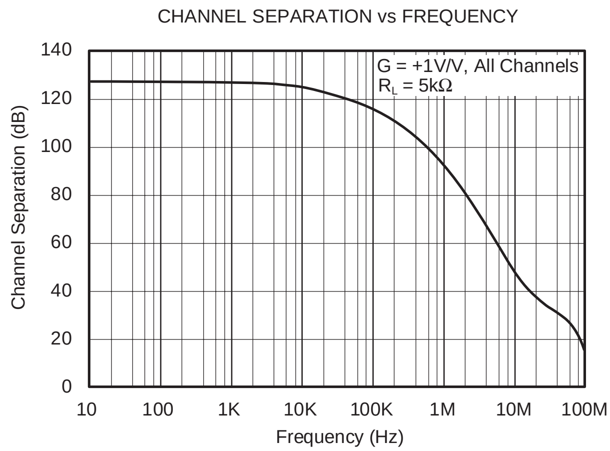
LARGE−SIGNAL STEP RESPONSE



TYPICAL CHARACTERISTICS (continued)

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





APPLICATIONS

The OPA373 and OPA374 series op amps are unity-gain stable and suitable for a wide range of general-purpose applications. Rail-to-rail input and output make them ideal for driving sampling Analog-to-Digital Converters (ADCs). Excellent AC performance makes them well suited for audio applications. The class AB output stage is capable of driving 100kΩ loads connected to any point between V+ and ground.

The input common-mode voltage range includes both rails, allowing the OPA373 and OPA374 series op amps to be used in virtually any single-supply application up to a supply voltage of +5.5V.

Rail-to-rail input and output swing significantly increases dynamic range, especially in low-supply applications.

Power-supply pins should be bypassed with 0.01µF ceramic capacitors.

OPERATING VOLTAGE

The OPA373 and OPA374 op amps are specified and tested over a power-supply range of +2.7V to +5.5V (±1.35V to ±2.75V). However, the supply voltage may range from +2.3V to +5.5V (±1.15V to ±2.75V). Supply voltages higher than 7.0V (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.

COMMON-MODE VOLTAGE RANGE

The input common-mode voltage range of the OPA373 and OPA374 series extends 200mV beyond the supply rails. This is achieved with a complementary input stage—an N-channel input differential pair in parallel with a P-channel differential pair. The N-channel pair is active for input voltages close to the positive rail, typically (V+) − 1.65V to 200mV above the positive supply, while the P-channel pair is on for inputs from 200mV below the negative supply to approximately (V+) − 1.65V. There is a 500mV transition region, typically (V+) − 1.9V to (V+) − 1.4V, in which both pairs are on. This 500mV transition region, shown in Figure 1, can vary ±300mV with process variation. Thus, the transition region (both stages on) can range from (V+) − 2.2V to (V+) − 1.7V on the low end, up to (V+) − 1.6V to (V+) − 1.1V on the high end. Within the 500mV transition region PSRR, CMRR, offset voltage, offset drift, and THD may be degraded compared to operation outside this region.

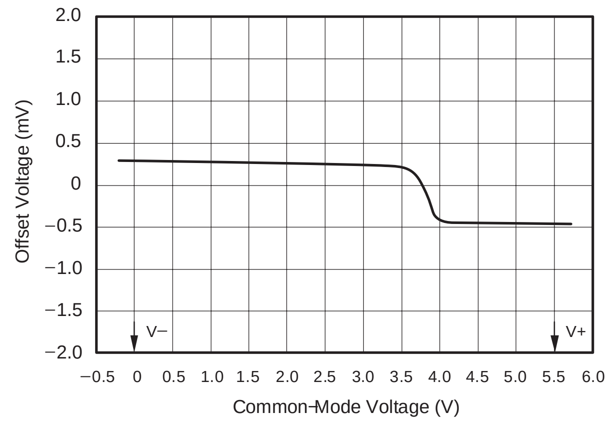


Figure 1. Behavior of Typical Transition Region at Room Temperature

RAIL-TO-RAIL INPUT

The input common-mode range extends from (V−) − 0.2V to (V+) + 0.2V. For normal operation, inputs should be limited to this range. The absolute maximum input voltage is 500mV beyond the supplies. Inputs greater than the input common-mode range but less than the maximum input voltage, while not valid, will not cause any damage to the op amp. Unlike some other op amps, if input current is limited, the inputs may go beyond the supplies without phase inversion, as shown in Figure 2.

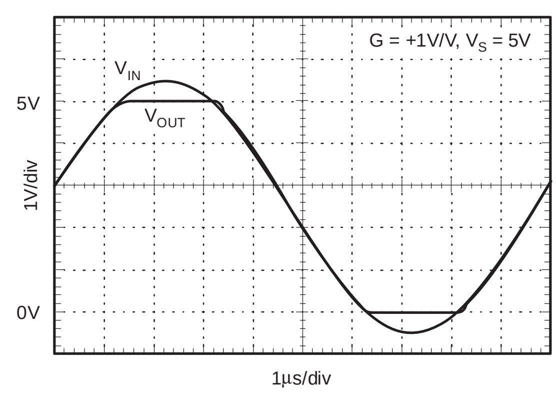


Figure 2. OPA373: No Phase Inversion with Inputs Greater Than the Power-Supply Voltage

Normally, input bias current is approximately 500fA; however, input voltages exceeding the power supplies by more than 500mV can cause excessive current to flow in or out of the input pins. Momentary voltages greater than 500mV beyond the power supply can be tolerated if the current on the input pins is limited to 10mA. This is easily accomplished with an input resistor; see Figure 3. (Many input signals are inherently current-limited to less than 10mA, therefore, a limiting resistor is not required.)

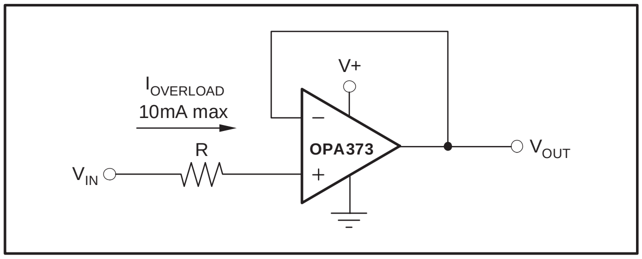


Figure 3. Input Current Protection for Voltages Exceeding the Supply Voltage

RAIL-TO-RAIL OUTPUT

A class AB output stage with common-source transistors is used to achieve rail-to-rail output. For light resistive loads (> 100kΩ), the output voltage can typically swing to within 18mV from the supply rails. With moderate resistive loads (5kΩ to 50kΩ), the output can typically swing to within 100mV from the supply rails and maintain high open-loop gain. See the Typical Characteristics curve, *Output Voltage Swing vs Output Current*, for more information.

CAPACITIVE LOAD AND STABILITY

OPA373 series op amps can drive a wide range of capacitive loads. However, under certain conditions, all op amps may become unstable. Op amp configuration, gain, and load value are just a few of the factors to consider when determining stability. An op amp in unity-gain configuration is the most susceptible to the effects of capacitive load. The capacitive load reacts with the op amp output resistance, along with any additional load resistance, to create a pole in the small-signal response that degrades the phase margin. The OPA373 series op amps perform well in unity-gain configuration, with a pure capacitive load up to approximately 250pF. Increased gains allow the amplifier to drive more capacitance. See the Typical Characteristics curve, *Small-Signal Overshoot vs Capacitive Load*, for further details.

One method of improving capacitive load drive in the unity-gain configuration is to insert a small (10Ω to 20Ω) resistor, R_S, in series with the output, as shown in Figure 4. This significantly reduces ringing while maintaining DC performance for purely capacitive loads. When there is a resistive load in parallel with the capacitive load, R_S must be placed within the feedback loop as shown to allow the feedback loop to compensate for the voltage divider created by R_S and R_L.

In unity-gain inverter configuration, phase margin can be reduced by the reaction between the capacitance at the op amp input and the gain setting resistors, thus degrading capacitive load drive. Best performance is achieved by using small valued resistors. However, when large valued resistors cannot be avoided, a small (4pF to 6pF) capacitor, C_{FB}, can be inserted in the feedback, as shown in Figure 5. This significantly reduces overshoot by compensating the effect of capacitance, C_{IN}, which includes the amplifier input capacitance and PC board parasitic capacitance.

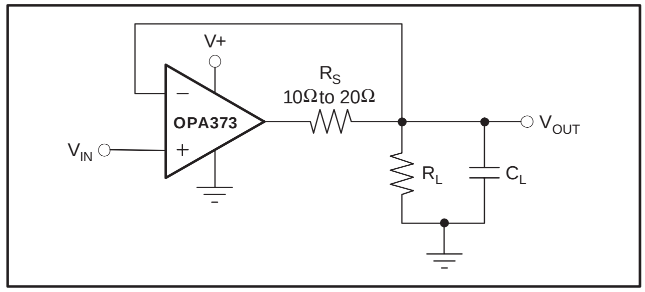


Figure 4. Series Resistor in Unity-Gain Configuration Improves Capacitive Load Drive

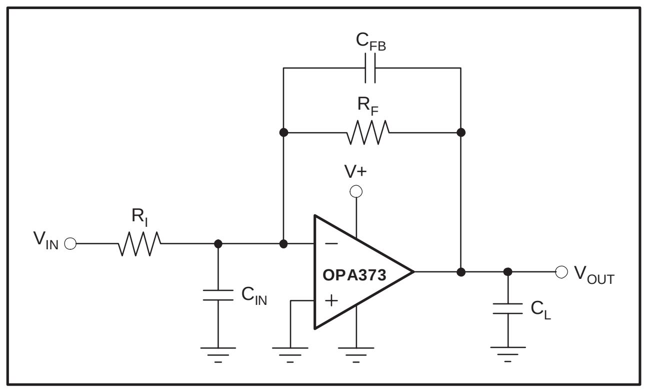


Figure 5. Improving Capacitive Load Drive

For example, when driving a 100pF load in unity-gain inverter configuration, adding a 6pF capacitor in parallel with the 10kΩ feedback resistor decreases overshoot from 57% to 12%, as shown in Figure 6.

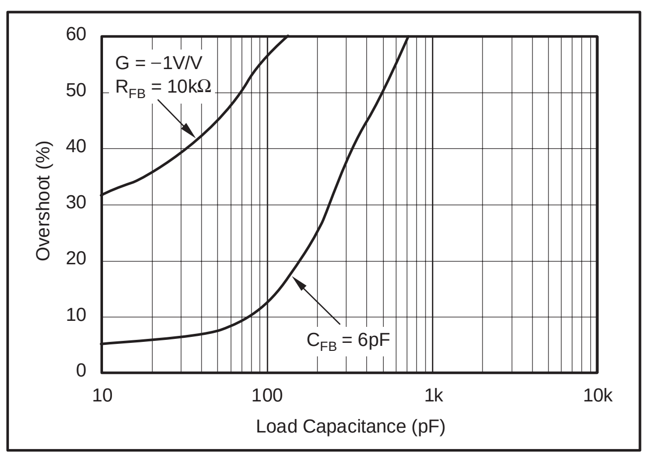


Figure 6. Improving Capacitive Load Drive

DRIVING ADCs

The OPA373 and OPA374 series op amps are optimized for driving medium-speed sampling ADCs. The OPA373 and OPA374 op amps buffer the ADC input capacitance and resulting charge injection, while providing signal gain.

The OPA373 is shown driving the ADS7816 in a basic noninverting configuration, as shown in Figure 7. The ADS7816 is a 12-bit, *Micro*Power sampling converter in the MSOP-8 package. When used with the low-power, miniature packages of the OPA373, the combination is ideal for space-limited, low-power applications. In this configuration, an RC network at the ADC input can be used to provide anti-aliasing filtering.

Figure 8 shows the OPA373 driving the ADS7816 in a speech band-pass filtered data acquisition system. This small, low-cost solution provides the necessary amplification and signal conditioning to interface directly with an electret microphone. This circuit will operate with V_S = 2.7V to 5V.

The OPA373 is shown in the inverting configuration described in Figure 9. In this configuration, filtering may be accomplished with the capacitor across the feedback resistor.

ENABLE/SHUTDOWN

OPA373 and OPA374 series op amps typically require 585μA quiescent current. The enable/shutdown feature of the OPA373 allows the op amp to be shut off in order to reduce this current to less than 1μA.

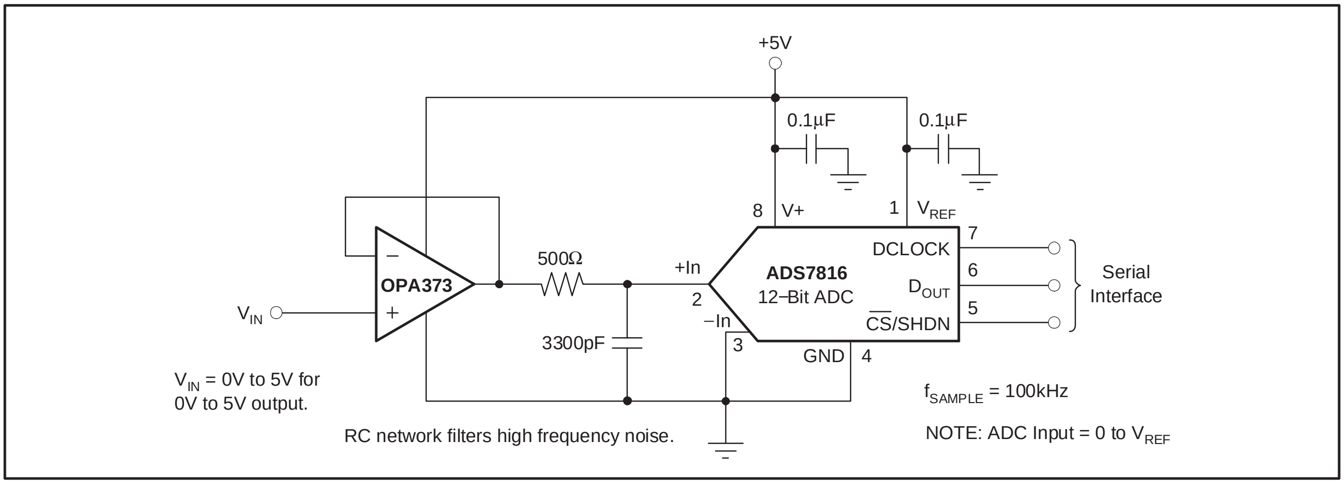


Figure 7. The OPA373 in Noninverting Configuration Driving the ADS7816

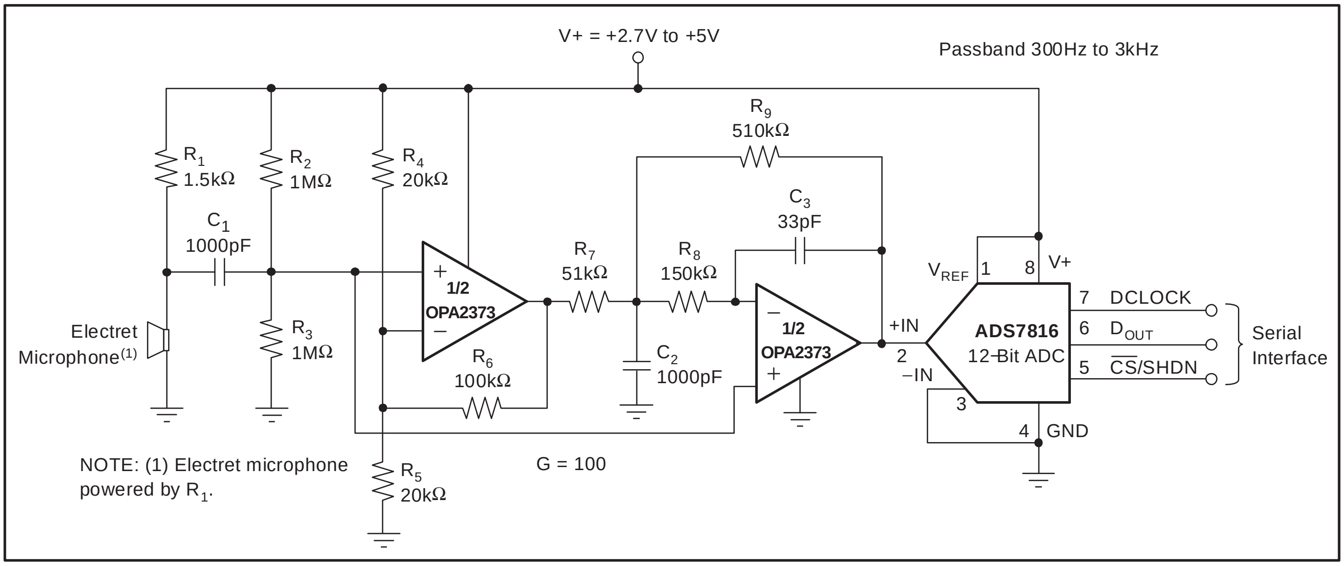


Figure 8. The OPA2373 as a Speech Bypass Filtered Data Acquisition System

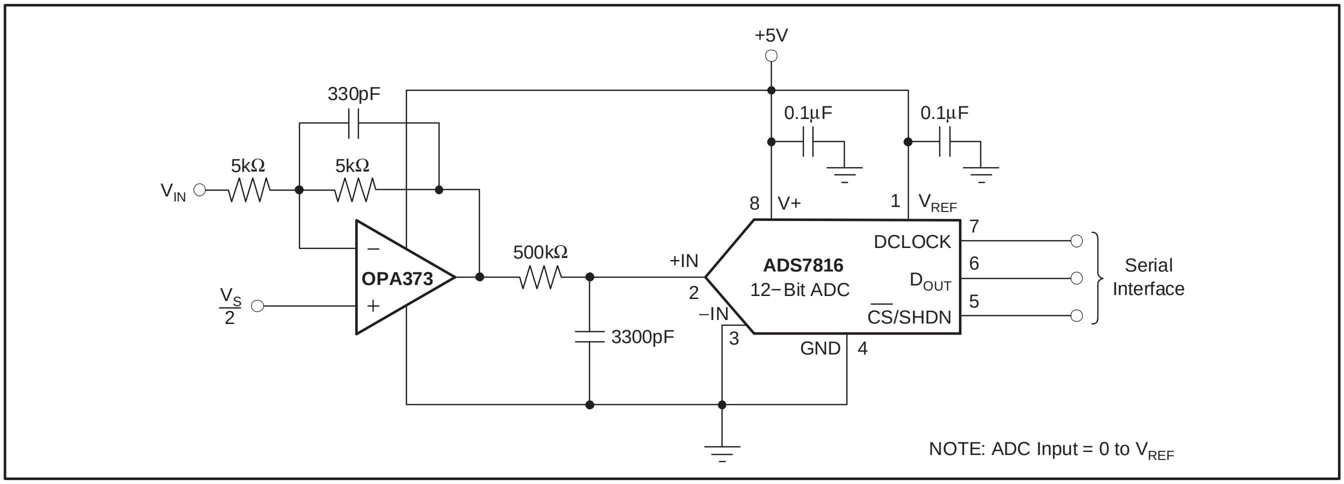


Figure 9. The OPA373 in Inverting Configuration Driving the ADS7816

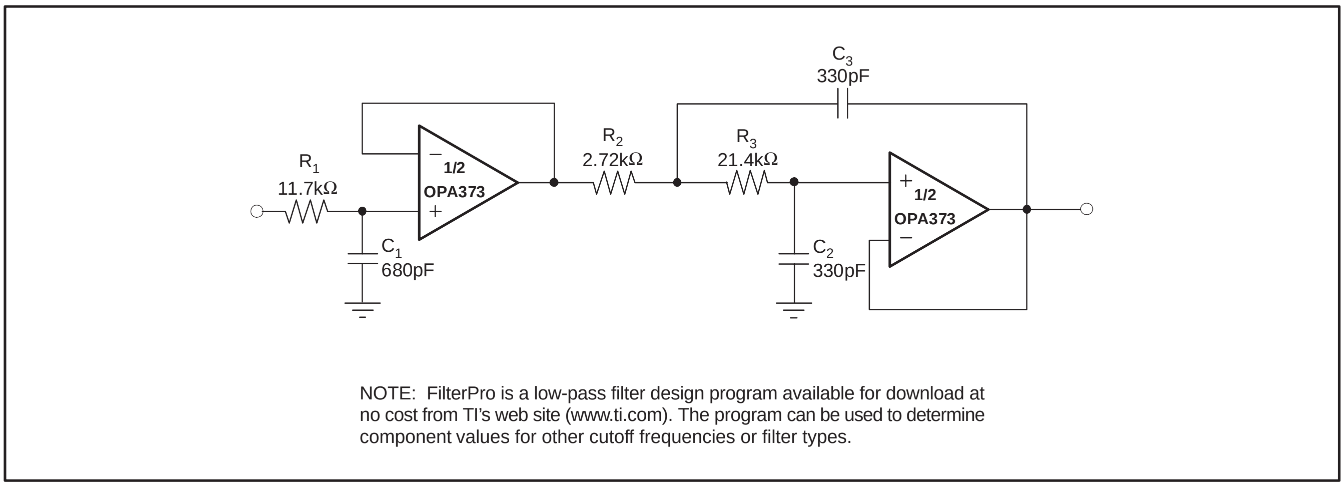


Figure 10. Three-Pole Sallen-Key Butterworth Low-Pass Filter

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