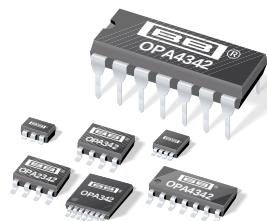




Burr-Brown Products
from Texas Instruments



OPA342
OPA2342
OPA4342

www.ti.com

Low-Cost, Low-Power, Rail-to-Rail OPERATIONAL AMPLIFIERS

MicroAmplifier™ Series

FEATURES

- LOW QUIESCENT CURRENT: 150 μ A typ
- RAIL-TO-RAIL INPUT
- RAIL-TO-RAIL OUTPUT (within 1mV)
- SINGLE SUPPLY CAPABILITY
- LOW COST
- *MicroSIZE* PACKAGE OPTIONS:
 - SOT23-5
 - MSOP-8
 - TSSOP-14
- BANDWIDTH: 1MHz
- SLEW RATE: 1V/ μ s
- THD + NOISE: 0.006%

APPLICATIONS

- COMMUNICATIONS
- PCMCIA CARDS
- DATA ACQUISITION
- PROCESS CONTROL
- AUDIO PROCESSING
- ACTIVE FILTERS
- TEST EQUIPMENT
- CONSUMER ELECTRONICS

DESCRIPTION

The OPA342 series rail-to-rail CMOS operational amplifiers are designed for low-cost, low-power, miniature applications. They are optimized to operate on a single supply as low as 2.5V with an input common-mode voltage range that extends 300mV beyond the supplies.

Rail-to-rail input/output and high-speed operation make them ideal for driving sampling Analog-to-Digital Converters (ADC). They are also well suited for general-purpose and audio applications and providing I/V conversion at the output of Digital-to-Analog Converters (DAC). Single, dual, and quad versions have identical specs for design flexibility.

The OPA342 series offers excellent dynamic response with a quiescent current of only 250 μ A max. Dual and quad designs feature completely independent circuitry for lowest crosstalk and freedom from interaction.

PACKAGE	SINGLE OPA342	DUAL OPA2342	QUAD OPA4342
SOT23-5	✓		
MSOP-8		✓	
SO-8	✓	✓	
TSSOP-14			✓
SO-14			✓
DIP-14			✓

SPICE MODEL available at www.burr-brown.com.



SPECIFICATIONS: $V_S = 2.7V$ to $5.5V$

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

Boldface limits apply over the temperature range, $T_A = -40^\circ C$ to $+85^\circ C$.

PARAMETER	CONDITION	OPA342NA, UA OPA2342EA, UA OPA4342EA, UA, PA			UNITS
		MIN	TYP	MAX	
OFFSET VOLTAGE Input Offset Voltage V_{OS} $T_A = -40^\circ C$ to $+85^\circ C$ vs Temperature dV_{OS}/dT vs Power Supply $PSRR$ $T_A = -40^\circ C$ to $+85^\circ C$ Channel Separation, dc $f = 1kHz$	$V_{CM} = V_S/2$ $V_S = 2.7V$ to $5.5V$, $V_{CM} < (V+) - 1.8V$ $V_S = 2.7V$ to $5.5V$, $V_{CM} < (V+) - 1.8V$		± 1 ± 1 ± 3 30 0.2 132	± 6 ± 6 200 250	mV mV $\mu V/^\circ C$ $\mu V/V$ $\mu V/V$ dB
INPUT BIAS CURRENT Input Bias Current I_B $T_A = -40^\circ C$ to $+85^\circ C$ Input Offset Current I_{OS}			± 0.2 See Typical Curve ± 0.2	± 10 ± 10	pA pA pA
NOISE Input Voltage Noise, $f = 0.1Hz$ to $50kHz$ Input Voltage Noise Density, $f = 1kHz$ e_n Current Noise Density, $f = 1kHz$ i_n			8 30 0.5		μV_{rms} $nV/\sqrt{Hz}$ $fA/\sqrt{Hz}$
INPUT VOLTAGE RANGE Common-Mode Voltage Range V_{CM} Common-Mode Rejection Ratio $CMRR$ $T_A = -40^\circ C$ to $+85^\circ C$ Common-Mode Rejection Ratio $CMRR$ $T_A = -40^\circ C$ to $+85^\circ C$ Common-Mode Rejection Ratio $CMRR$ $T_A = -40^\circ C$ to $+85^\circ C$	$V_S = +5.5V$, $-0.3V < V_{CM} < (V+) - 1.8$ $V_S = +5.5V$, $-0.3V < V_{CM} < (V+) - 1.8$ $V_S = +5.5V$, $-0.3V < V_{CM} < 5.8V$ $V_S = +5.5V$, $-0.3V < V_{CM} < 5.8V$ $V_S = +2.7V$, $-0.3V < V_{CM} < 3V$ $V_S = +2.7V$, $-0.3V < V_{CM} < 3V$	-0.3 76 74 66 64 62 60	88 78 74	$(V+) + 0.3$	V dB dB dB dB dB dB
INPUT IMPEDANCE Differential Common-Mode			$10^{13} \parallel 3$ $10^{13} \parallel 6$		$\Omega \parallel pF$ $\Omega \parallel pF$
OPEN-LOOP GAIN Open-Loop Voltage Gain A_{OL} $T_A = -40^\circ C$ to $+85^\circ C$ $T_A = -40^\circ C$ to $+85^\circ C$	$R_L = 100k\Omega$, $10mV < V_O < (V+) - 10mV$ $R_L = 100k\Omega$, $10mV < V_O < (V+) - 10mV$ $R_L = 5k\Omega$, $400mV < V_O < (V+) - 400mV$ $R_L = 5k\Omega$, $400mV < V_O < (V+) - 400mV$	104 100 96 90	124 114		dB dB dB dB
FREQUENCY RESPONSE Gain-Bandwidth Product GBW Slew Rate SR Settling Time, 0.1% 0.01% Overload Recovery Time Total Harmonic Distortion + Noise, $f = 1kHz$ $THD+N$	$C_L = 100pF$ $G = 1$ $V_S = 5.5V$, 2V Step $V_S = 5.5V$, 2V Step $V_{IN} \cdot G = V_S$ $V_S = 5.5V$, $V_O = 3Vp-p^{(1)}$, $G = 1$		1 1 5 8 2.5 0.006		MHz V/ μs μs μs μs %
OUTPUT Voltage Output Swing from Rail ⁽²⁾ $T_A = -40^\circ C$ to $+85^\circ C$ $T_A = -40^\circ C$ to $+85^\circ C$ Short-Circuit Current I_{SC} Capacitive Load Drive C_{LOAD}	$R_L = 100k\Omega$, $A_{OL} \geq 96dB$ $R_L = 100k\Omega$, $A_{OL} \geq 104dB$ $R_L = 100k\Omega$, $A_{OL} \geq 100dB$ $R_L = 5k\Omega$, $A_{OL} \geq 96dB$ $R_L = 5k\Omega$, $A_{OL} \geq 90dB$ Per Channel		1 3 20 ± 15	10 10 400 400	mV mV mV mV mV mA
POWER SUPPLY Specified Voltage Range V_S Operating Voltage Range Quiescent Current (per amplifier) I_Q $T_A = -40^\circ C$ to $+85^\circ C$	$I_O = 0A$	2.7	2.5 to 5.5 150	5.5 250 300	V V μA μA
TEMPERATURE RANGE Specified Range Operating Range Storage Range Thermal Resistance θ_{JA} SOT23-5 Surface Mount MSOP-8 Surface Mount SO-8 Surface Mount TSSOP-14 Surface Mount SO-14 Surface Mount DIP-14		-40 -55 -65		$+85$ $+125$ $+150$	$^\circ C$ $^\circ C$ $^\circ C$ $^\circ C/W$ $^\circ C/W$ $^\circ C/W$ $^\circ C/W$ $^\circ C/W$ $^\circ C/W$

NOTES: (1) $V_{OUT} = 0.25V$ to $3.25V$. (2) Output voltage swings are measured between the output and power-supply rails.

ABSOLUTE MAXIMUM RATINGS⁽¹⁾

Supply Voltage, V+ to V-	7.5V
Signal Input Terminals, Voltage ⁽²⁾	(V-) -0.5V to (V+) +0.5V
Current ⁽²⁾	10mA
Output Short-Circuit ⁽³⁾	Continuous
Operating Temperature	-55°C to +125°C
Storage Temperature	-65°C to +150°C
Junction Temperature	150°C
Lead Temperature (soldering, 10s)	300°C
ESD Tolerance (Human Body Model)	4000V

NOTES: (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. Functional operation of the device at these conditions, or beyond the specified operating conditions, 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.



ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

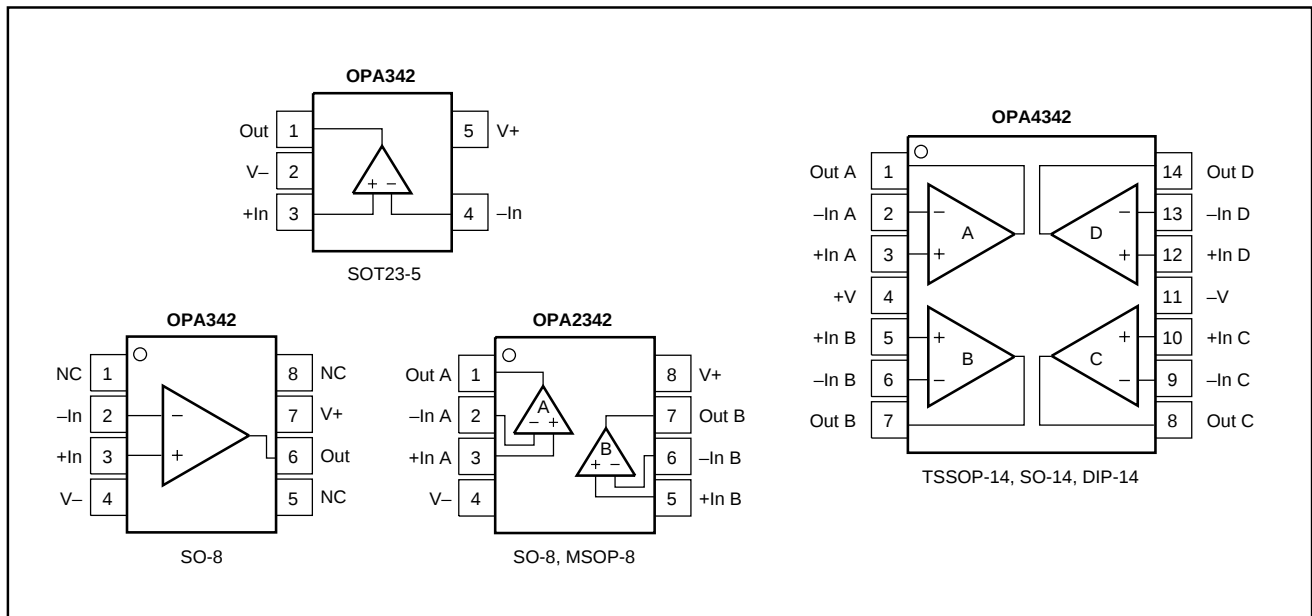
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PACKAGE/ORDERING INFORMATION

PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER ⁽¹⁾	TRANSPORT MEDIA
OPA342NA "	SOT23-5 "	331 "	-40°C to +85°C "	B42 "	OPA342NA/250 OPA342NA/3K	Tape and Reel
OPA342UA "	SO-8 "	182 "	-40°C to +85°C "	OPA342UA "	OPA342UA OPA342UA/2K5	Tape and Reel Rails
OPA2342EA "	MSOP-8 "	337 "	-40°C to +85°C "	C42 "	OPA2342EA/250 OPA2342EA/2K5	Tape and Reel
OPA2342UA "	SO-8 "	182 "	-40°C to +85°C "	OPA2342UA "	OPA2342UA OPA2342UA/2K5	Tape and Reel Rails
OPA4342EA "	TSSOP-14 "	357 "	-40°C to +85°C "	OPA4342EA "	OPA4342EA/250 OPA4342EA/2K5	Tape and Reel
OPA4342UA "	SO-14 "	235 "	-40°C to +85°C "	OPA4342UA "	OPA4342UA OPA4342UA/2K5	Tape and Reel Rails
OPA4342PA "	DIP-14 "	010 "	-40°C to +85°C "	OPA4342PA "	OPA4342PA OPA4342PA	Tape and Reel Rails

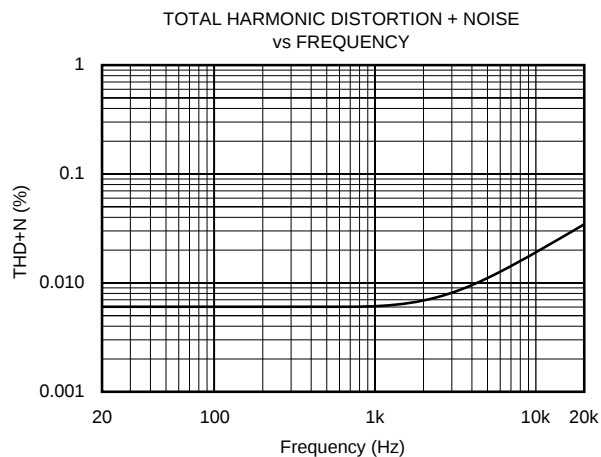
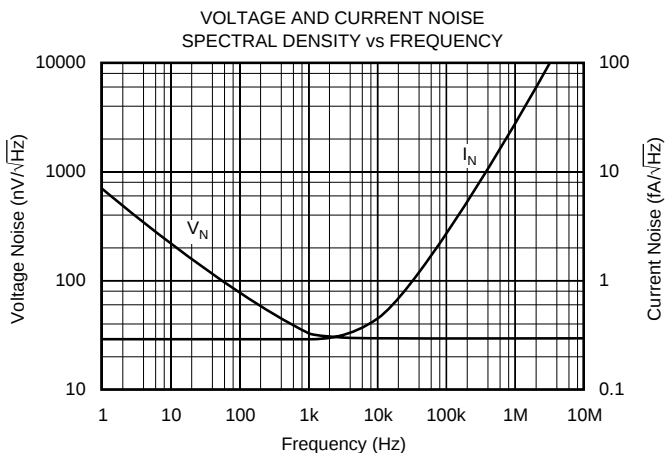
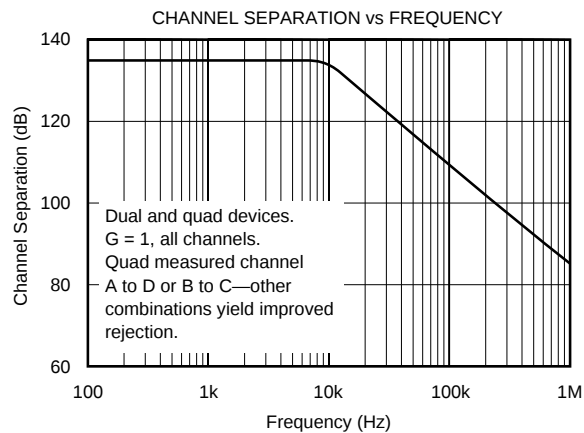
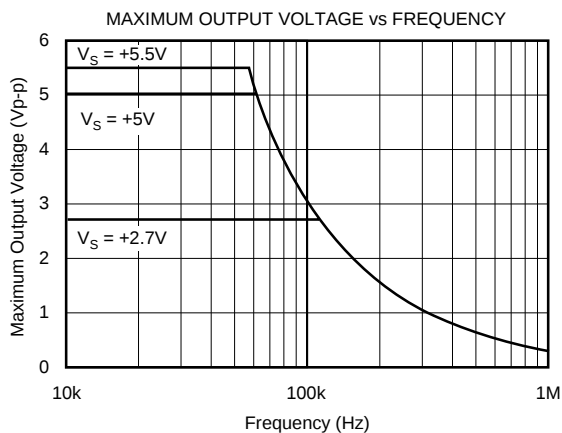
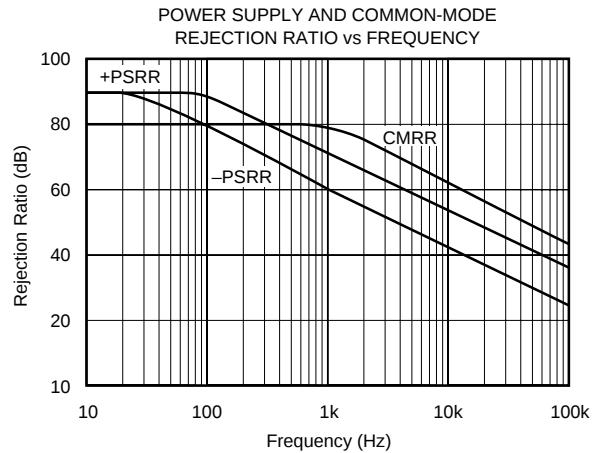
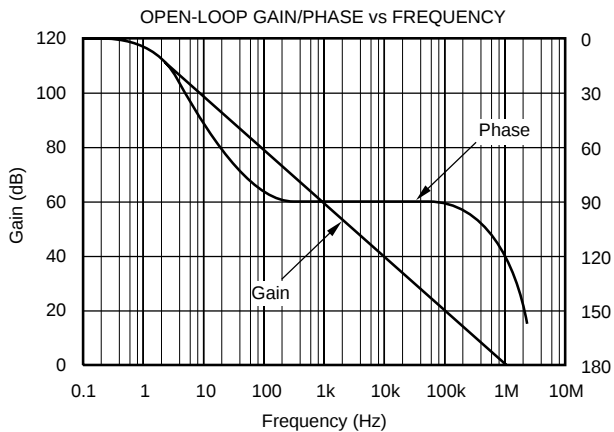
NOTE: (1) Models with a slash (/) are available only in Tape and Reel in the quantities indicated (e.g., /3K indicates 3000 devices per reel). Ordering 3000 pieces of "OPA342NA/3K" will get a single 3000-piece Tape and Reel.

PIN CONFIGURATIONS



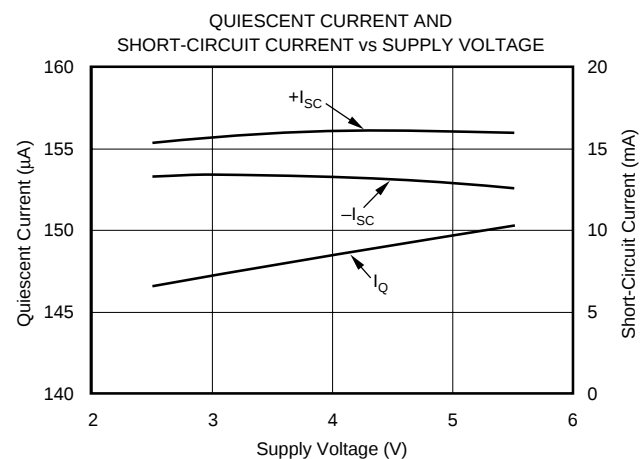
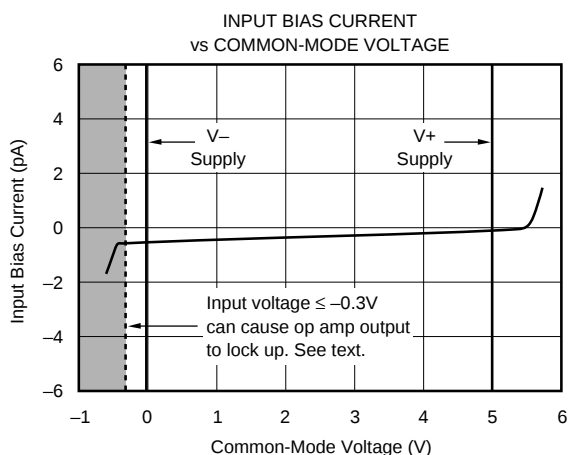
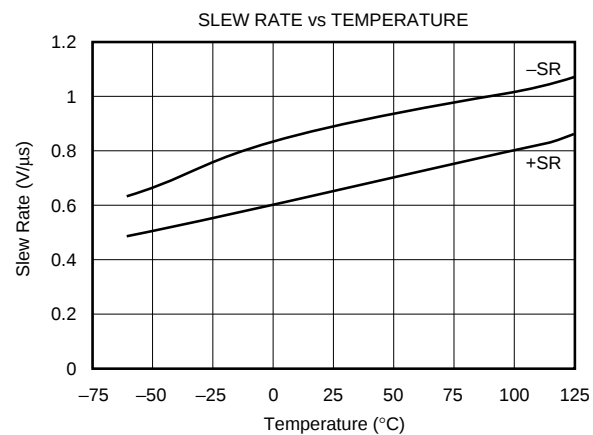
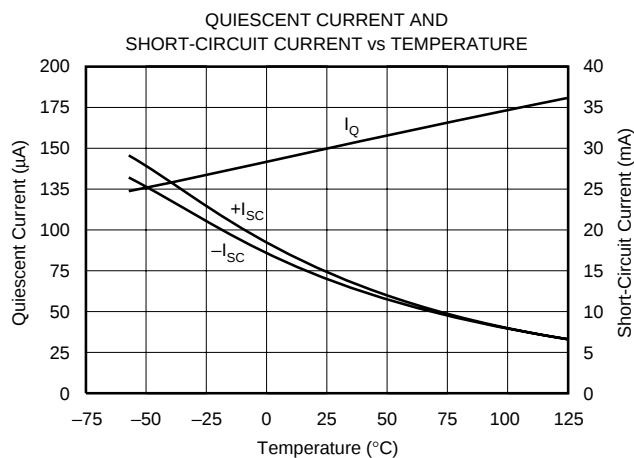
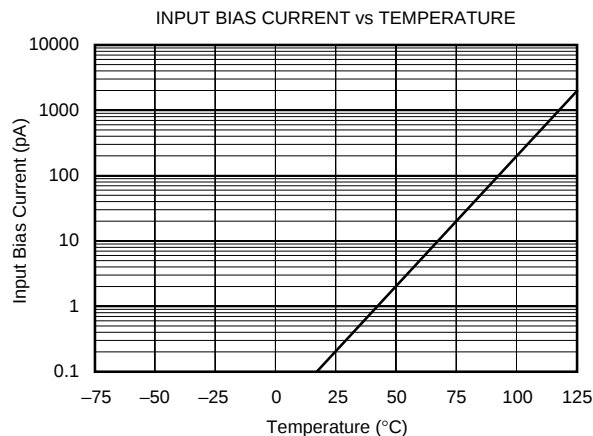
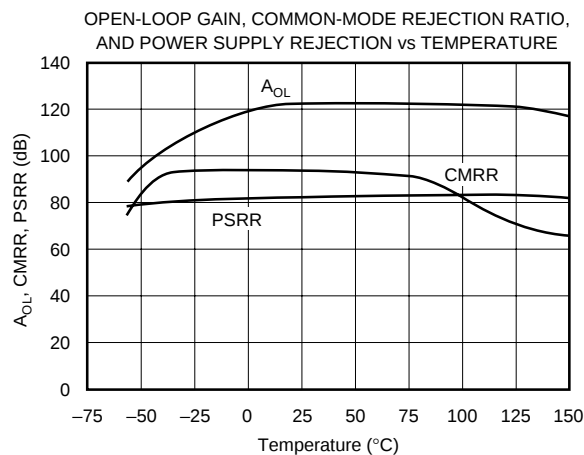
TYPICAL PERFORMANCE CURVES

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



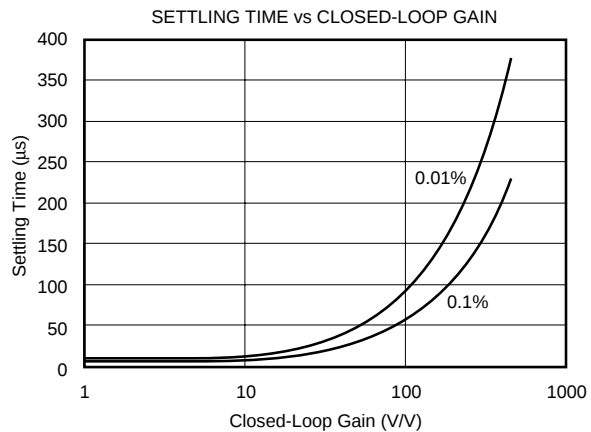
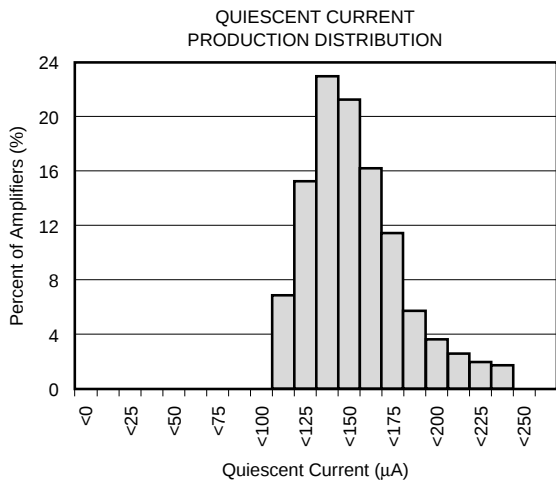
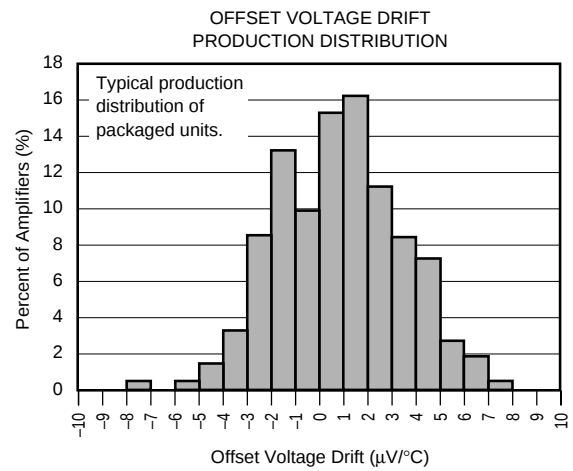
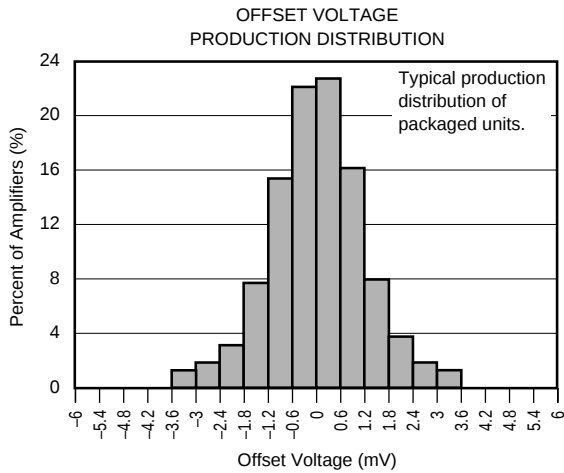
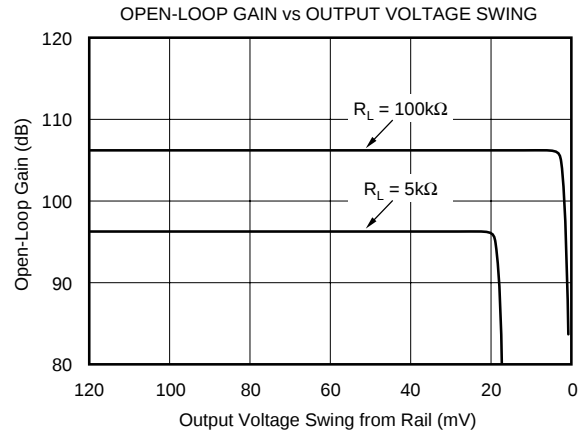
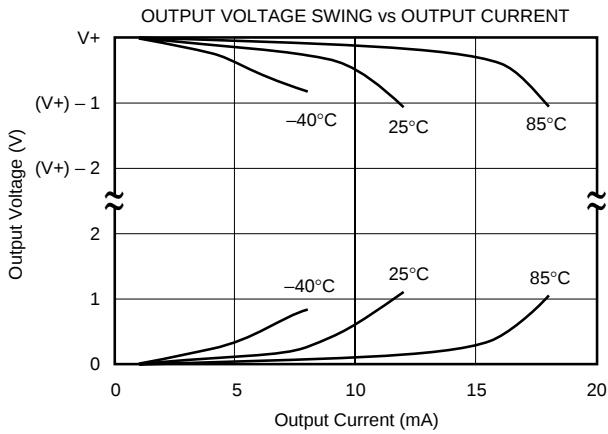
TYPICAL PERFORMANCE CURVES (Cont.)

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



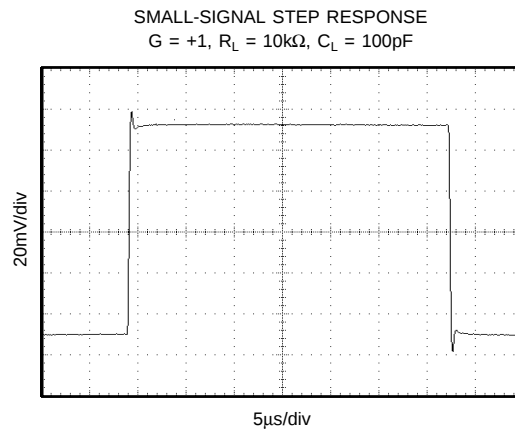
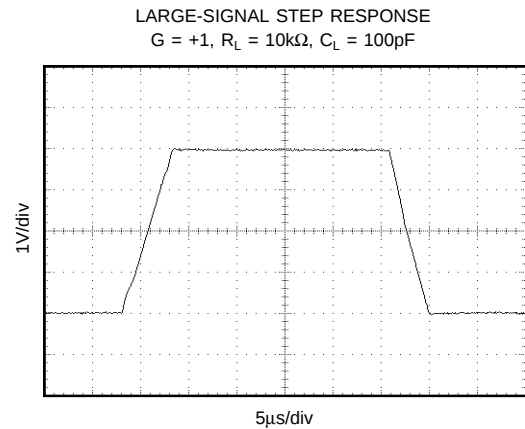
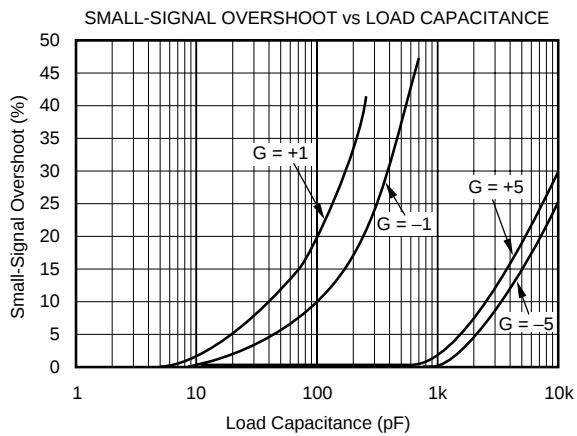
TYPICAL PERFORMANCE CURVES (Cont.)

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



TYPICAL PERFORMANCE CURVES (Cont.)

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



APPLICATIONS INFORMATION

OPA342 series op amps are unity gain stable and can operate on a single supply, making them highly versatile and easy to use.

Rail-to-rail input and output swing significantly increases dynamic range, especially in low supply applications. Figure 1 shows the input and output waveforms for the OPA342 in unity-gain configuration. Operation is from $V_S = +5V$ with a $10k\Omega$ load connected to $V_S/2$. The input is a $5V_{p-p}$ sinusoid. Output voltage is approximately $4.997V_{p-p}$.

Power supply pins should be bypassed with $0.01\mu F$ ceramic capacitors.

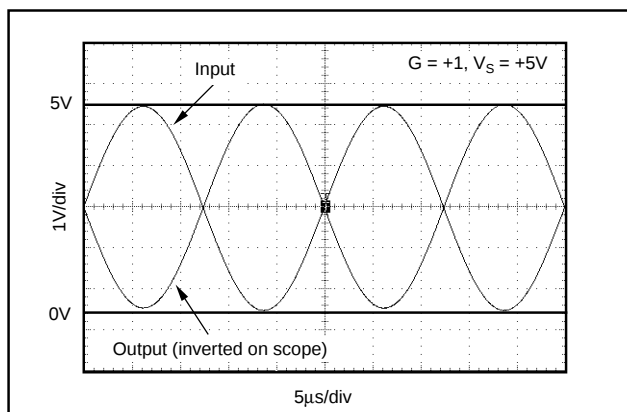


FIGURE 1. Rail-to-Rail Input and Output.

OPERATING VOLTAGE

OPA342 series op amps are fully specified and guaranteed from $+2.7V$ to $+5.5V$. In addition, many specifications apply from $-40^{\circ}C$ to $+85^{\circ}C$. Parameters that vary significantly with operating voltages or temperature are shown in the Typical Performance Curves.

RAIL-TO-RAIL INPUT

The input common-mode voltage range of the OPA342 series extends $300mV$ 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 (see Figure 2). The N-channel pair is active for input voltages close to the positive rail, typically $(V+) - 1.3V$ to $300mV$ above the positive supply, while the P-channel pair is on for inputs from $300mV$ below the negative supply to approximately $(V+) - 1.3V$. There is a small transition region, typically $(V+) - 1.5V$ to $(V+) - 1.1V$, in which both pairs are on. This $400mV$ transition region can vary $300mV$ with process variation. Thus, the transition region (both stages on) can range from $(V+) - 1.8V$ to $(V+) - 1.4V$ on the low end, up to $(V+) - 1.2V$ to $(V+) - 0.8V$ on the high end. Within the $400mV$ transition region PSRR, CMRR, offset voltage, offset drift, and THD may be degraded compared to operation outside this region. For more information on designing with rail-to-rail input op amps, see Figure 3 “Design Optimization with Rail-to-Rail Input Op Amps.”

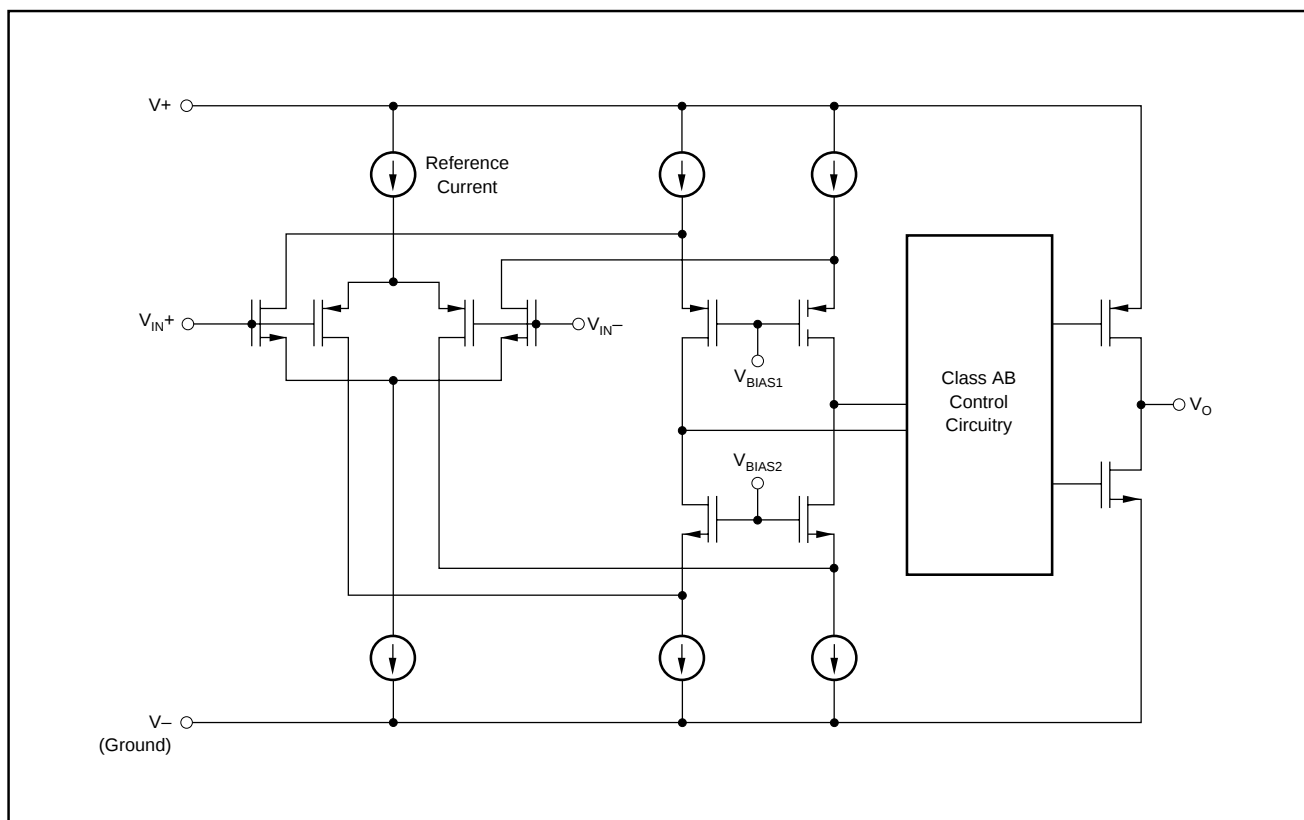


FIGURE 2. Simplified Schematic.

DESIGN OPTIMIZATION WITH RAIL-TO-RAIL INPUT OP AMPS

Rail-to-rail op amps can be used in virtually any op amp configuration. To achieve optimum performance, however, applications using these special double-input-stage op amps may benefit from consideration of their special behavior.

In many applications, operation remains within the common-mode range of only one differential input pair. However some applications exercise the amplifier through the transition region of both differential input stages. Although the two input stages are laser trimmed for excellent matching, a small discontinuity may occur in this transition. Careful selection of the circuit configuration, signal levels and biasing can often avoid this transition region.

With a unity-gain buffer, for example, signals will traverse this transition at approximately 1.3V below V^+ supply and may exhibit a small discontinuity at this point.

The common-mode voltage of the non-inverting amplifier is equal to the input voltage. If the input signal always remains less than the transition voltage, no discontinuity will be created. The closed-loop gain of this configuration can still produce a rail-to-rail output.

Inverting amplifiers have a constant common-mode voltage equal to V_B . If this bias voltage is constant, no discontinuity will be created. The bias voltage can generally be chosen to avoid the transition region.

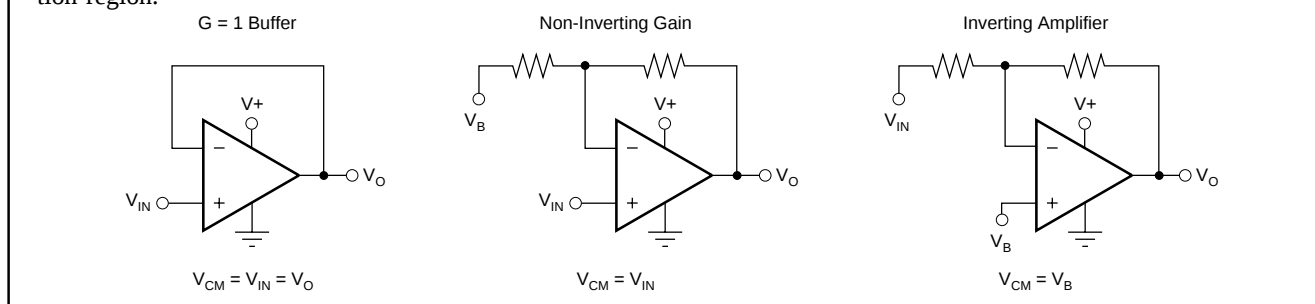


FIGURE 3. Design Optimization with Rail-to-Rail Input Op Amps.

COMMON-MODE REJECTION

The CMRR for the OPA342 is specified in several ways so the best match for a given application may be used. First, the CMRR of the device in the common-mode range below the transition region ($V_{CM} < (V^+) - 1.8V$) is given. This specification is the best indicator of the capability of the device when the application requires use of one of the differential input pairs. Second, the CMRR at $V_S = 5.5V$ over the entire common-mode range is specified. Third, the CMRR at $V_S = 2.7V$ over the entire common-mode range is provided. These last two values include the variations seen through the transition region.

INPUT VOLTAGE BEYOND THE RAILS

If the input voltage can go more than 0.3V below the negative power supply rail (single-supply ground), special precautions are required. If the input voltage goes sufficiently negative, the op amp output may lock up in an inoperative state. A Schottky diode clamp circuit will prevent this—see Figure 4. The series resistor prevents excessive current (greater than 10mA) in the Schottky diode and in the internal ESD protection diode, if the input voltage can exceed the positive supply voltage. If the signal source is limited to less than 10mA, the input resistor is not required.

RAIL-TO-RAIL OUTPUT

A class AB output stage with common-source transistors is used to achieve rail-to-rail output. This output stage is capable of driving 600Ω loads connected to any potential

between V^+ and ground. For light resistive loads ($> 50k\Omega$), the output voltage can typically swing to within 1mV from supply rail. With moderate resistive loads (2kΩ to 50kΩ), the output can swing to within a few tens of milli-volts from the supply rails while maintaining high open-loop gain. See the typical performance curve “Output Voltage Swing vs Output Current.”

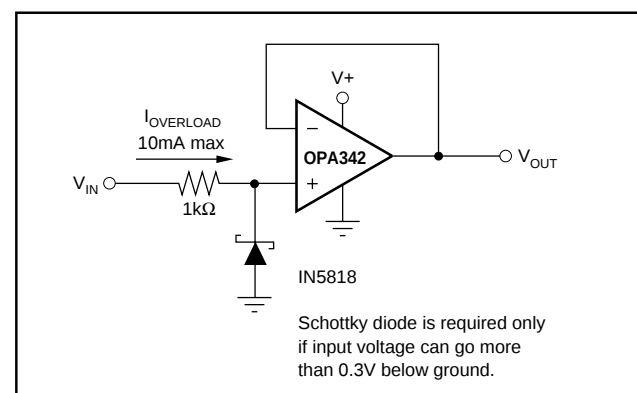


FIGURE 4. Input Current Protection for Voltages Exceeding the Supply Voltage.

CAPACITIVE LOAD AND STABILITY

The OPA342 in a unity-gain configuration can directly drive up to 250pF pure capacitive load. Increasing the gain enhances the amplifier's ability to drive greater capacitive loads. See the typical performance curve “Small-Signal

Overshoot vs Capacitive Load.” In unity-gain configurations, capacitive load drive can be improved by inserting a small (10Ω to 20Ω) resistor, R_S , in series with the output, as shown in Figure 5. This significantly reduces ringing while maintaining dc performance for purely capacitive loads. However, if there is a resistive load in parallel with the capacitive load, a voltage divider is created, introducing a dc error at the output and slightly reducing the output swing. The error introduced is proportional to the ratio R_S/R_L , and is generally negligible.

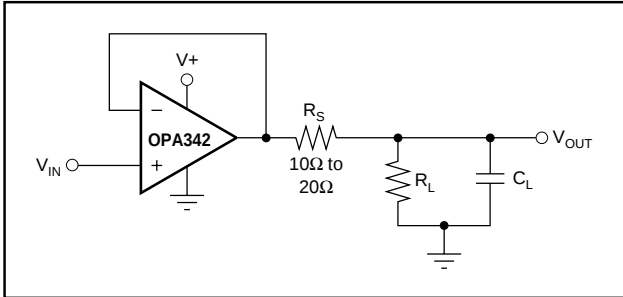


FIGURE 5. Series Resistor in Unity-Gain Configuration Improves Capacitive Load Drive.

DRIVING A/D CONVERTERS

The OPA342 series op amps are optimized for driving medium-speed sampling ADCs. The OPA342 op amps buffer the ADC's input capacitance and resulting charge injection while providing signal gain.

Figure 6 shows the OPA342 in a basic noninverting configuration driving the ADS7822. The ADS7822 is a 12-bit, micro-power sampling converter in the MSOP-8 package. When used with the low-power, miniature packages of the OPA342, the combination is ideal for space-limited, low-power applications. In this configuration, an RC network at the ADC's input can be used to filter charge injection.

Figure 7 shows the OPA2342 driving an ADS7822 in a speech bandpass 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 $+5V$ with less than $500\mu A$ quiescent current.

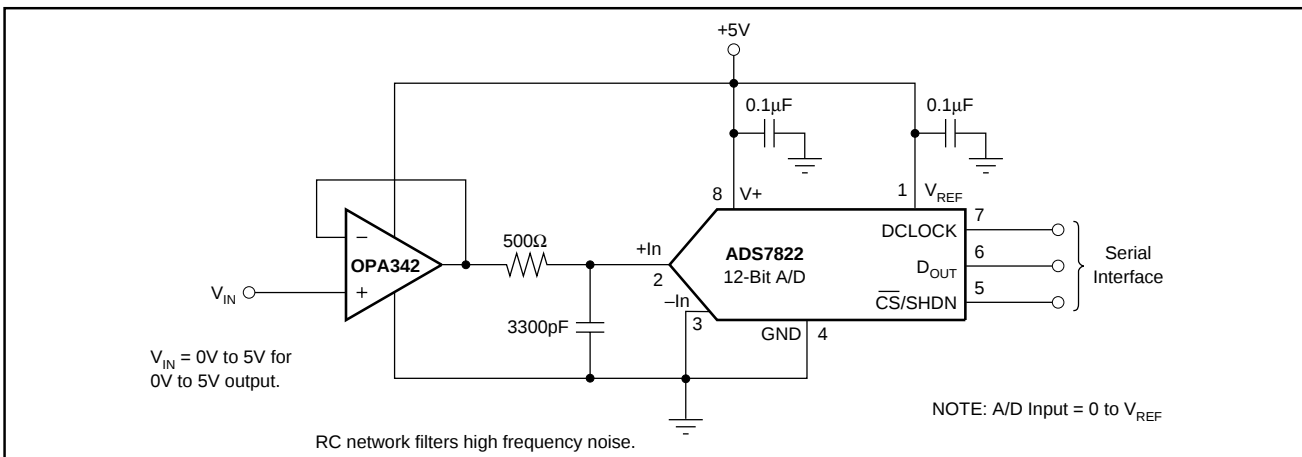


FIGURE 6. OPA342 in Noninverting Configuration Driving ADS7822.

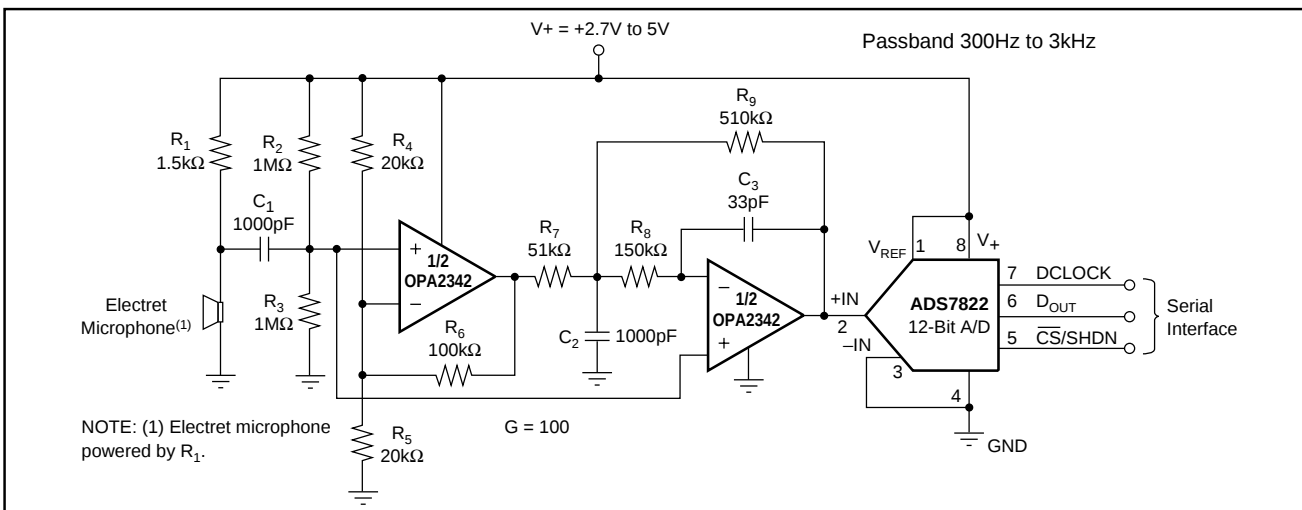


FIGURE 7. Speech Bandpass Filtered Data Acquisition System.

PACKAGING INFORMATION

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾
OPA2342EA/250	ACTIVE	MSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
OPA2342EA/250G4	ACTIVE	MSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
OPA2342EA/2K5	ACTIVE	MSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
OPA2342EA/2K5G4	ACTIVE	MSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
OPA2342UA	ACTIVE	SOIC	D	8	100	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
OPA2342UA/2K5	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
OPA2342UA/2K5G4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
OPA2342UAG4	ACTIVE	SOIC	D	8	100	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
OPA342NA/250	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
OPA342NA/250G4	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
OPA342NA/3K	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
OPA342NA/3KG4	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
OPA342UA	ACTIVE	SOIC	D	8	100	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
OPA342UAG4	ACTIVE	SOIC	D	8	100	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
OPA4342EA/250	ACTIVE	TSSOP	PW	14	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
OPA4342EA/250G4	ACTIVE	TSSOP	PW	14	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
OPA4342PA	ACTIVE	PDIP	N	14	25	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type
OPA4342PAG4	ACTIVE	PDIP	N	14	25	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type
OPA4342UA	ACTIVE	SOIC	D	14	58	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
OPA4342UAG4	ACTIVE	SOIC	D	14	58	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR

⁽¹⁾ The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

⁽²⁾ Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

⁽³⁾ MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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