



1 μ A, Rail-to-Rail I/O CMOS OPERATIONAL AMPLIFIERS

FEATURES

- **LOW SUPPLY CURRENT:** 1 μ A
- **GAIN-BANDWIDTH:** 70kHz
- **UNITY-GAIN STABLE**
- **LOW INPUT BIAS CURRENT:** 10pA (max)
- **WIDE SUPPLY RANGE:** 1.8V to 5.5V
- **INPUT RANGE:** 200mV Beyond Rails
- **OUTPUT SWINGS TO 350mV OF RAILS**
- **OUTPUT DRIVE CURRENT:** 8mA
- **OPEN-LOOP GAIN:** 90dB
- **MicroPACKAGES:** SC70, SOT23-5, SOT23-8

APPLICATIONS

- **BATTERY PACKS AND POWER SUPPLIES**
- **PORTABLE PHONES, PAGERS, AND CAMERAS**
- **SOLAR-POWERED SYSTEMS**
- **SMOKE, GAS, AND FIRE DETECTION SYSTEMS**
- **REMOTE SENSORS**
- **PCMCIA CARDS**
- **DRIVING ANALOG-TO-DIGITAL (A/D) CONVERTERS**
- **MicroPOWER FILTERS**

OPAx349 RELATED PRODUCTS

FEATURES	PRODUCT
1 μ A, 5.5kHz, Rail-To-Rail	TLV240x
1 μ A, 5.5kHz, Rail-To-Rail	TLV224x
7 μ A, 160kHz, Rail-To-Rail, 2.7V to 16V Supply	TLV238x
7 μ A, 160kHz, Rail-To-Rail, Micro Power	TLV27Lx
20 μ A, 500kHz, Rail-To-Rail, 1.8V Micro Power	TLV276x
20 μ A, 350kHz, Rail-To-Rail, Micro Power	OPAx347
45 μ A, 1MHz, Rail-To-Rail, 2.1V to 5.5V Supply	OPAx348

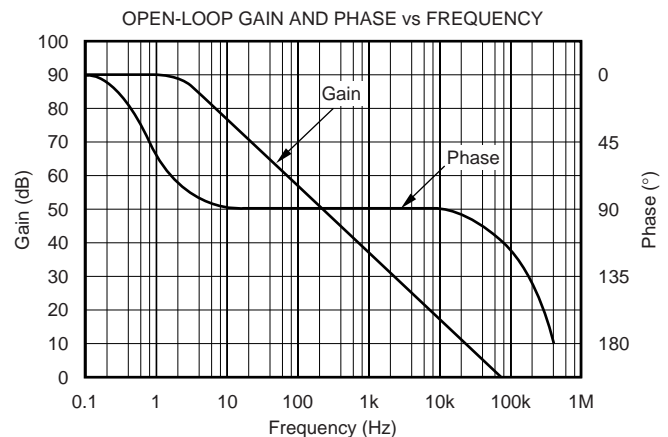
DESCRIPTION

The OPA349 and OPA2349 are ultra-low power operational amplifiers that provide 70kHz bandwidth with only 1 μ A quiescent current. These rail-to-rail input and output amplifiers are specifically designed for battery-powered applications. The input common-mode voltage range extends 200mV beyond the power-supply rails and the output swings to within 350mV of the rails, maintaining wide dynamic range. Unlike some micropower op amps, these parts are unity-gain stable and require no external compensation to achieve wide bandwidth. The OPA349 features a low input bias current that allows the use of large source and feedback resistors.

The OPA349 can be operated with power supplies from 1.8V to 5.5V with little change in performance, ensuring continuing superior performance even in low battery situations.

The OPA349 comes in miniature SOT23-5, SC70, and SO-8 surface-mount packages. The OPA2349 dual is available in SOT23-8, and SO-8 surface-mount packages. These tiny packages are ideal for use in high-density applications, such as PCMCIA cards, battery packs, and portable instruments.

The OPA349 is specified for 0°C to +70°C. The OPA2349 is specified for –40°C to +70°C.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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ABSOLUTE MAXIMUM RATINGS⁽¹⁾

Supply Voltage, V+ to V-	5.5V
Signal Input Terminals, Voltage ⁽²⁾	(V-) - 0.5V to (V+) + 0.5V
Current ⁽²⁾	10mA
Output Short Circuit ⁽³⁾	Continuous
Operating Temperature, OPA2349	-55°C to +125°C
Operating Temperature, OPA349	0°C to +85°C
Storage Temperature	-65°C to +150°C
Junction Temperature	150°C
Lead Temperature (soldering, 3s)	300°C

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, 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.



ELECTROSTATIC DISCHARGE SENSITIVITY

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

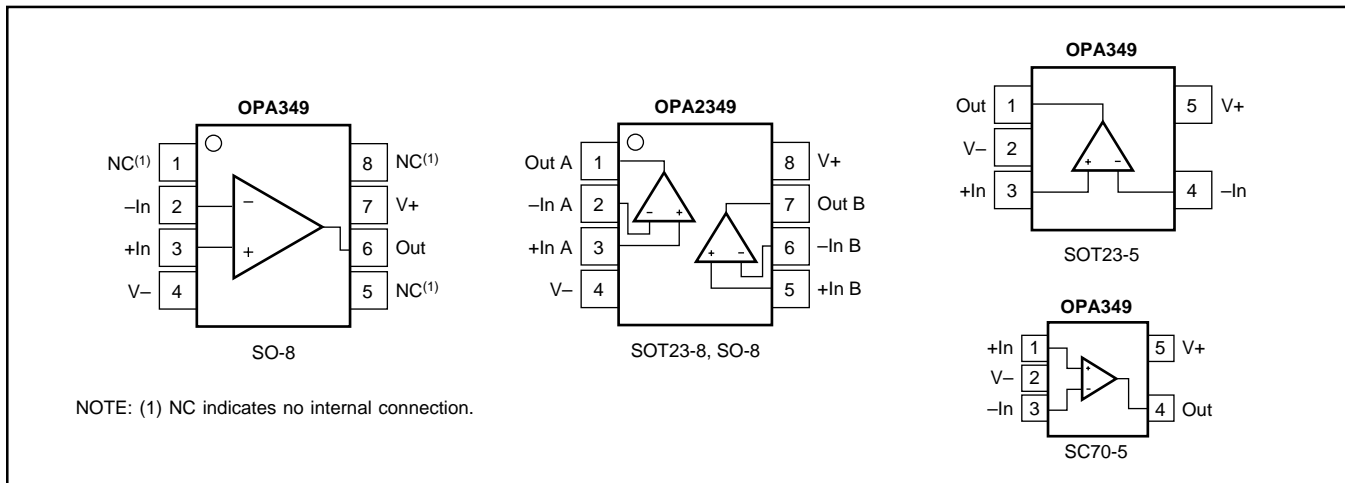
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PACKAGE/ORDERING INFORMATION⁽¹⁾

PRODUCT	PACKAGE	PACKAGE DESIGNATOR ⁽¹⁾	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
Single					
OPA349NA	SOT23-5	DBV	A49	OPA349NA/250	Tape and Reel, 250
"	"	"	"	OPA349NA/3K	Tape and Reel, 3000
OPA349UA	SO-8	D	OPA349UA	OPA349UA	Rails, 100
"	"	"	"	OPA349UA/2K5	Tape and Reel, 2500
OPA349SA	SC70-5	DCK	S49	OPA349SA/250	Tape and Reel, 250
"	"	"	"	OPA349SA/3K	Tape and Reel, 3000
Dual					
OPA2349EA	SOT23-8	DCN	C49	OPA2349EA/250	Tape and Reel, 250
"	"	"	"	OPA2349EA/3K	Tape and Reel, 3000
OPA2349UA	SO-8	D	OPA2349UA	OPA2349UA	Rails, 100
"	"	"	"	OPA2349UA/2K5	Tape and Reel, 2500

NOTE: (1) For the most current package and ordering information, see the Package Option Addendum located at the end of this data sheet.

PIN CONFIGURATIONS



ELECTRICAL CHARACTERISTICS (Single): $V_S = +1.8V$ to $+5.5V$

Boldface limits apply over the specified temperature range, $T_A = 0^\circ\text{C}$ to $+70^\circ\text{C}$.

At $T_A = +25^\circ\text{C}$, and $R_L = 1\text{M}\Omega$ connected to $V_S/2$, unless otherwise noted.

PARAMETER	CONDITION	OPA349			UNITS
		MIN	TYP ⁽¹⁾	MAX	
OFFSET VOLTAGE Input Offset Voltage Over Temperature Drift vs Power-Supply Rejection Ratio Over Temperature	V_{OS} $V_S = 5V, V_{CM} = 2.5V$ $V_S = 1.8V$ to $5.5V, V_{CM} = (V-) + 0.3V$		± 2 ± 2 ± 15 350	± 10 ± 13 1000 3000	mV mV $\mu\text{V}/^\circ\text{C}$ $\mu\text{V}/V$ $\mu\text{V}/V$
INPUT VOLTAGE RANGE Common-Mode Voltage Range Common-Mode Rejection Ratio Over Temperature Over Temperature	V_{CM} CMRR $V_S = +5V, -0.2V < V_{CM} < 5.2V$ $V_S = +5V, -0.2V < V_{CM} < 3.5V$	$(V-) - 0.2$ 48 46 52 50	60 72	$(V+) + 0.2$	V dB dB dB
INPUT BIAS CURRENT Input Bias Current Input Offset Current	I_B I_{OS}		± 0.5 ± 1	± 10 ± 10	pA pA
INPUT IMPEDANCE Differential Common-Mode			$10^{13} \parallel 2$ $10^{13} \parallel 4$		$\Omega \parallel \text{pF}$ $\Omega \parallel \text{pF}$
NOISE Input Voltage Noise, $f = 0.1\text{Hz}$ to 10Hz Input Voltage Noise Density, $f = 1\text{kHz}$ Current Noise Density, $f = 1\text{kHz}$	e_n i_n		8 300 4		$\mu\text{Vp-p}$ $\text{nV}/\sqrt{\text{Hz}}$ $\text{fA}/\sqrt{\text{Hz}}$
OPEN-LOOP GAIN Open-Loop Voltage Gain Over Temperature Open-Loop Voltage Gain Over Temperature	A_{OL} A_{OL} $R_L = 1\text{M}\Omega, V_S = +5.5V, +0.3V < V_O < +5.2V$ $R_L = 10\text{k}\Omega, V_S = +5.5V, +0.35V < V_O < +5.15V$	74 72 74 60	90 90		dB dB dB dB
OUTPUT Voltage Output Swing from Rail Over Temperature Over Temperature Output Current Short-Circuit Current Capacitive Load Drive	C_{LOAD} $R_L = 1\text{M}\Omega, V_S = +5.5V, A_{OL} > 74\text{dB}$ $R_L = 10\text{k}\Omega, V_S = +5.5V, A_{OL} > 74\text{dB}$		± 8 ± 10 See Typical Characteristics	300 300 350 350	mV mV mV mV mA mA
FREQUENCY RESPONSE Gain-Bandwidth Product Slew Rate Settling Time, 0.1% 0.01% Overload Recovery Time	GBW SR t_s t_s	$C_L = 10\text{pF}$ $G = +1$ $V_S = +5V, G = +1$ $V_S = 5V, 1V$ Step $V_S = 5V, 1V$ Step $V_{IN} \cdot \text{Gain} = V_S$	70 0.02 65 80 5		kHz $\text{V}/\mu\text{s}$ μs μs μs
POWER SUPPLY Specified Voltage Range Quiescent Current (per amplifier) Over Temperature	V_S I_Q	$I_Q = 0$	+1.8 1	+5.5 2 10	V μA μA
TEMPERATURE RANGE Specified Range Operating Range Storage Range Thermal Resistance SOT23-5 Surface-Mount SO-8 Surface-Mount SC70-5 Surface-Mount	θ_{JA}		0 0 -65	+70 +85 +150	$^\circ\text{C}$ $^\circ\text{C}$ $^\circ\text{C}$ $^\circ\text{C}/\text{W}$ $^\circ\text{C}/\text{W}$ $^\circ\text{C}/\text{W}$

NOTE: (1) Refer to Typical Characteristic curves.

ELECTRICAL CHARACTERISTICS (Dual): $V_S = +1.8V$ to $+5.5V$

Boldface limits apply over the specified temperature range, $T_A = -40^{\circ}C$ to $+70^{\circ}C$.

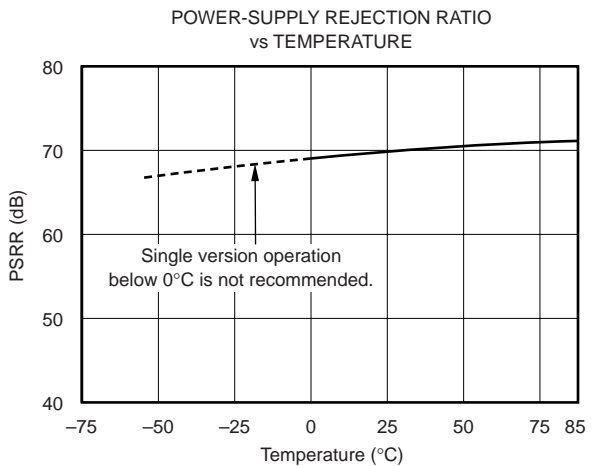
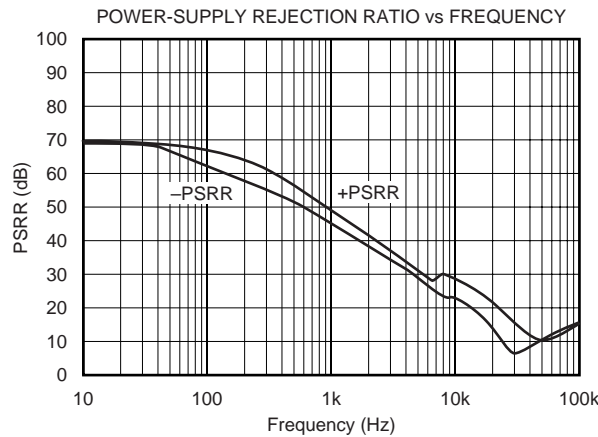
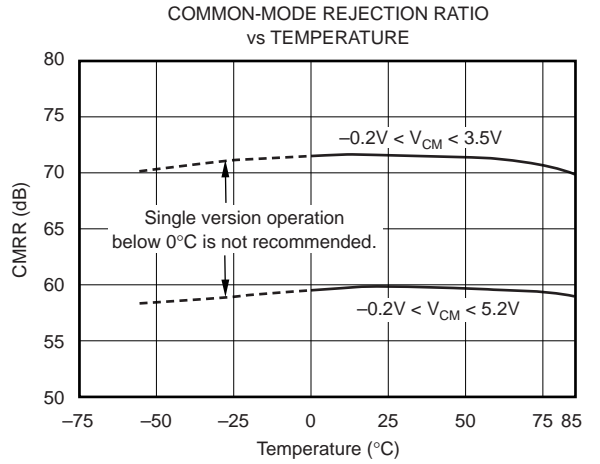
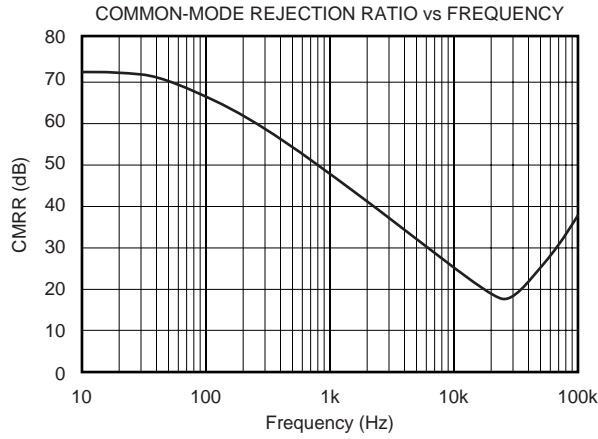
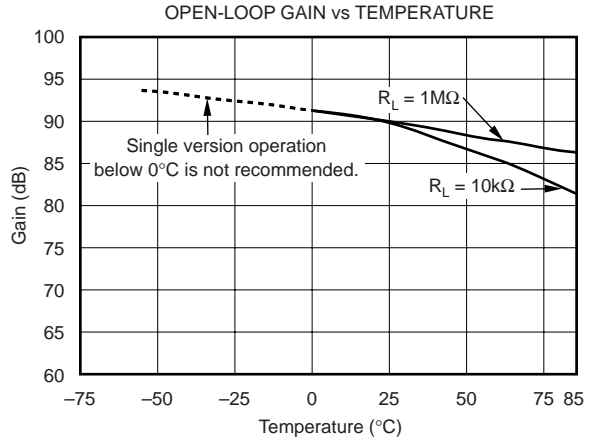
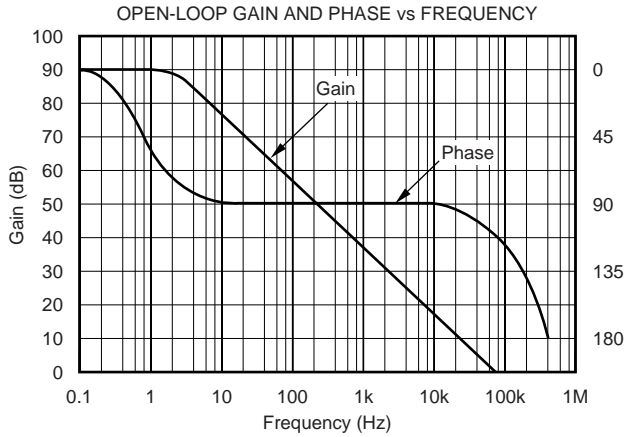
At $T_A = +25^{\circ}C$, and $R_L = 1M\Omega$ connected to $V_S/2$, unless otherwise noted.

PARAMETER	CONDITION	OPA2349			UNITS
		MIN	TYP ⁽¹⁾	MAX	
OFFSET VOLTAGE Input Offset Voltage Over Temperature Drift vs Power Supply Over Temperature Channel Separation, dc	V_{OS} dV_{OS}/dT PSRR $R_L = 100k\Omega$ $f = 1kHz$	$V_S = 5V, V_{CM} = 2.5V$ $V_S = 1.8V$ to $5.5V, V_{CM} = (V-) + 0.3V$	± 2 ± 2 ± 15 350 10 66 ⁽¹⁾	± 10 ± 13 1000 3000	mV mV $\mu V/^{\circ}C$ $\mu V/V$ $\mu V/V$ dB
INPUT VOLTAGE RANGE Common-Mode Voltage Range Common-Mode Rejection Ratio Over Temperature Over Temperature	V_{CM} CMRR	$V_S = +5V, -0.2V < V_{CM} < 5.2V$ $V_S = +5V, -0.2V < V_{CM} < 3.5V$	$(V-) - 0.2$ 48 46 52 50	$(V+) + 0.2$	V dB dB dB
INPUT BIAS CURRENT Input Bias Current Input Offset Current	I_B I_{OS}		± 0.5 ± 1	± 10 ± 10	pA pA
INPUT IMPEDANCE Differential Common-Mode			$10^{13} \parallel 2$ $10^{13} \parallel 4$		$\Omega \parallel pF$ $\Omega \parallel pF$
NOISE Input Voltage Noise, $f = 0.1Hz$ to $10Hz$ Input Voltage Noise Density, $f = 1kHz$ Current Noise Density, $f = 1kHz$	e_n i_n		8 300 4		$\mu Vp-p$ nV/\sqrt{Hz} fA/\sqrt{Hz}
OPEN-LOOP GAIN Open-Loop Voltage Gain Over Temperature Open-Loop Voltage Gain Over Temperature	A_{OL} A_{OL}	$R_L = 1M\Omega, V_S = +5.5V, +0.3V < V_O < +5.2V$ $R_L = 10k\Omega, V_S = +5.5V, +0.35V < V_O < +5.15V$	74 72 74 60	90 90	dB dB dB dB
OUTPUT Voltage Output Swing from Rail Over Temperature Over Temperature Output Current Short-Circuit Current	I_{SC}	$R_L = 1M\Omega, V_S = +5.5V, A_{OL} > 74dB$ $R_L = 10k\Omega, V_S = +5.5V, A_{OL} > 74dB$	150 200 ± 8 ± 10	300 300 350 350	mV mV mV mA mA
FREQUENCY RESPONSE Gain-Bandwidth Product Slew Rate Settling Time, 0.1% 0.01% Overload Recovery Time	GBW SR t_s	$C_L = 10pF$ $G = +1$ $V_S = +5V, G = +1$ $V_S = 5V, 1V$ Step $V_S = 5V, 1V$ Step $V_{IN} \cdot Gain = V_S$	70 0.02 65 80 5		kHz V/ μs μs μs μs
POWER SUPPLY Specified Voltage Range Quiescent Current (per amplifier) Over Temperature	V_S I_Q	$I_Q = 0$	+1.8 1	+5.5 2 10	V μA μA
TEMPERATURE RANGE Specified Range Operating Range Storage Range Thermal Resistance SOT23-8 Surface-Mount SO-8 Surface-Mount	θ_{JA}		-40 -40 -65 200 150	+70 +85 +150	$^{\circ}C$ $^{\circ}C$ $^{\circ}C$ $^{\circ}C/W$ $^{\circ}C/W$

NOTE: (1) Refer to Typical Characteristic curves.

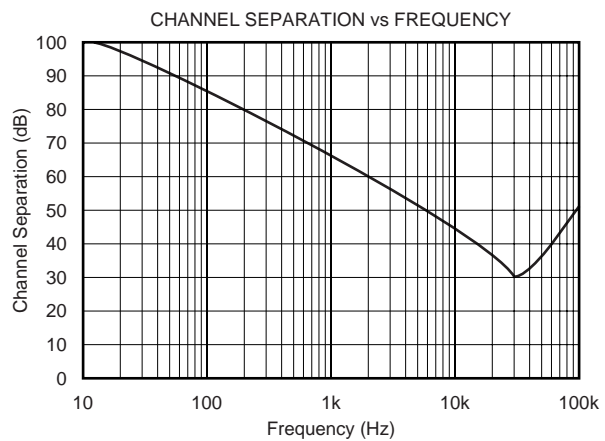
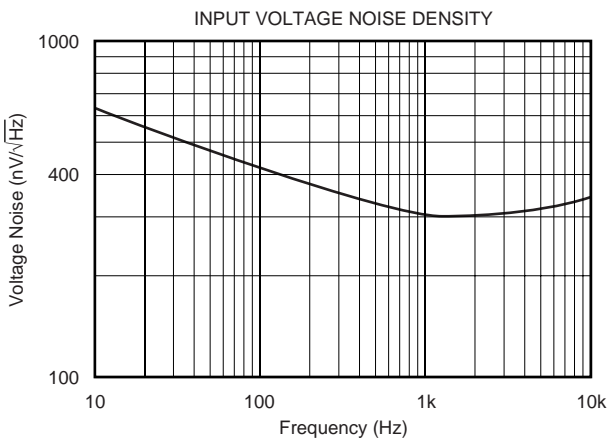
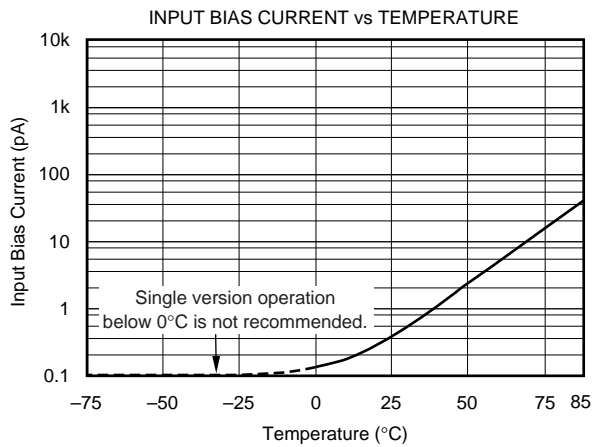
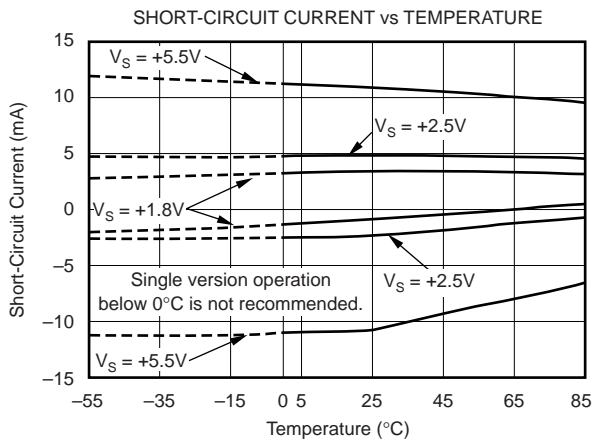
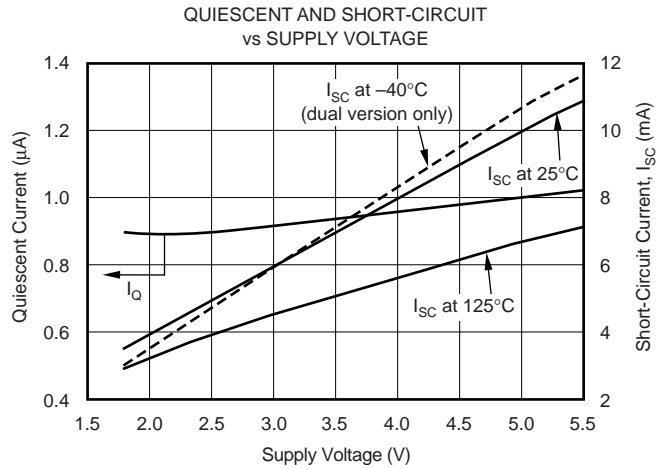
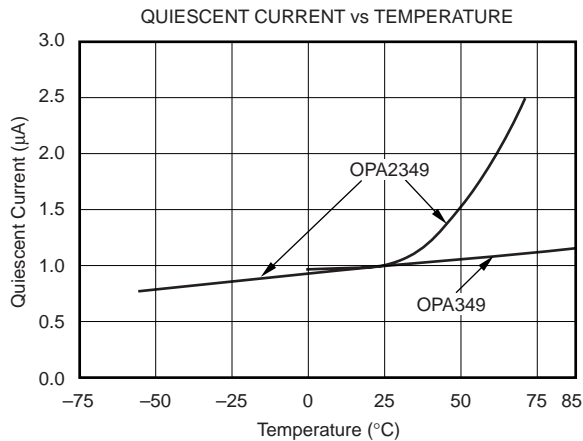
TYPICAL CHARACTERISTICS

At $T_A = +25^\circ\text{C}$, $V_S = +5\text{V}$, and $R_L = 1\text{M}\Omega$ connected to $V_{G/2}$, unless otherwise noted.



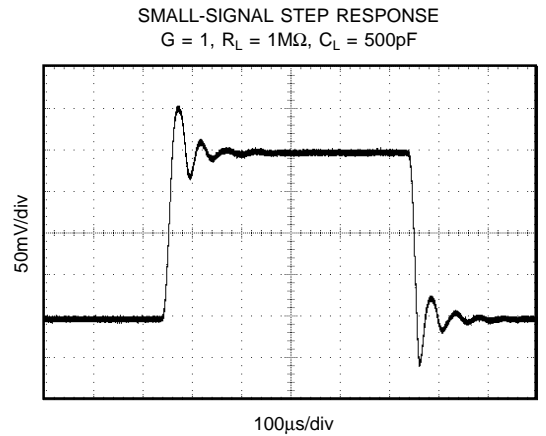
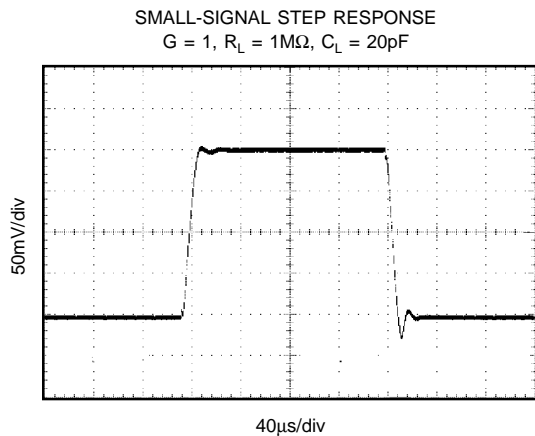
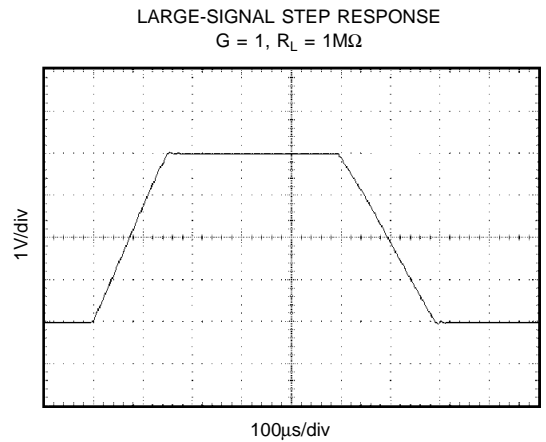
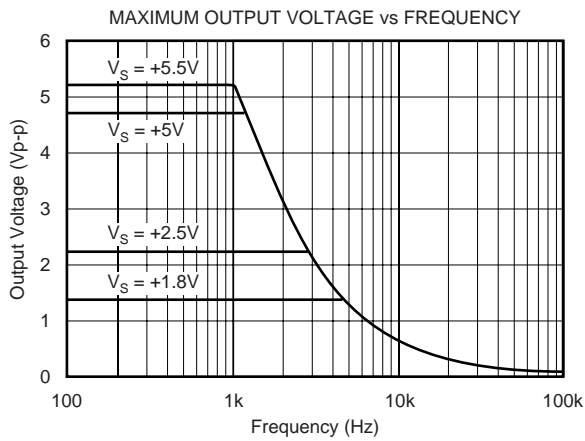
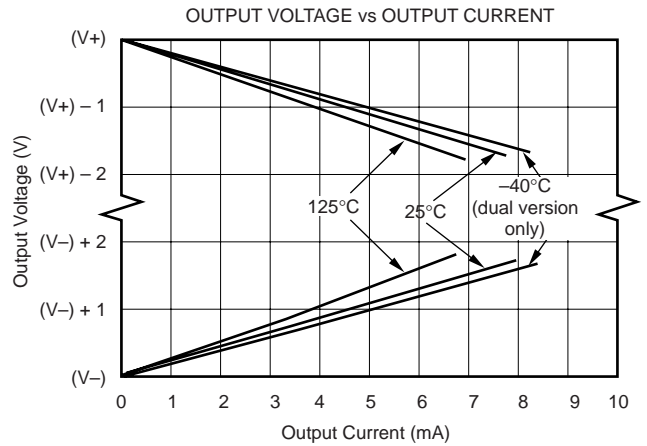
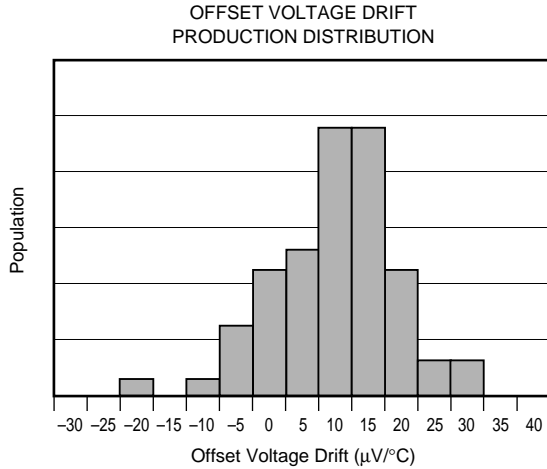
TYPICAL CHARACTERISTICS (Cont.)

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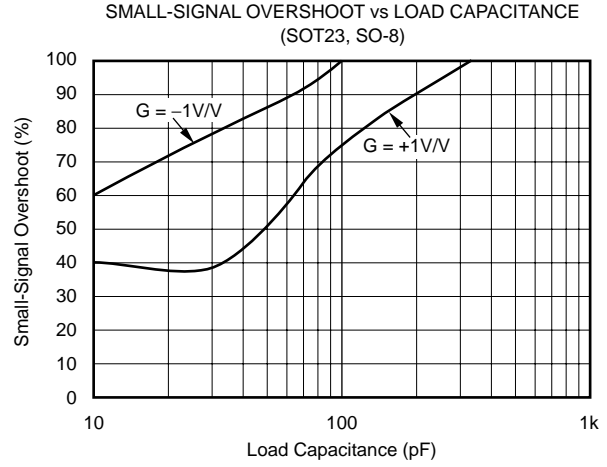
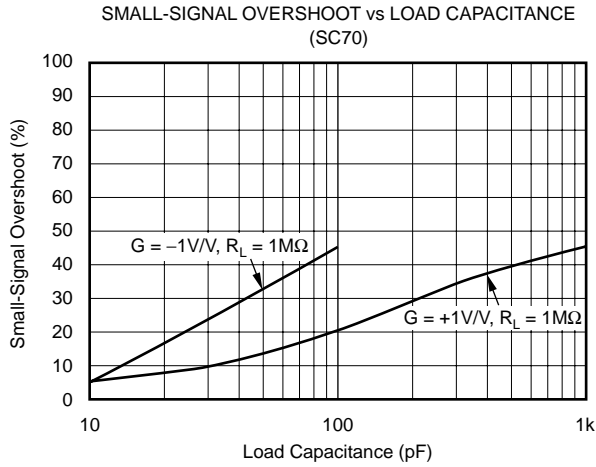
TYPICAL CHARACTERISTICS (Cont.)

At $T_A = +25^\circ\text{C}$, $V_S = +5\text{V}$, and $R_L = 1\text{M}\Omega$ connected to $V_S/2$, unless otherwise noted.



TYPICAL CHARACTERISTICS (Cont.)

At $T_A = +25^\circ\text{C}$, $V_S = +5\text{V}$, and $R_L = 1\text{M}\Omega$ connected to $V_S/2$, unless otherwise noted.



APPLICATIONS INFORMATION

The OPA349 series op amps are unity-gain stable and can operate on a single supply, making them highly versatile and easy to use. Power-supply pins should be bypassed with 0.01 μ F ceramic capacitors.

The OPA349 series op amps are fully specified and tested from +1.8V to +5.5V. Parameters that vary significantly with operating voltages or temperature are shown in the Typical Characteristic curves.

The ultra-low quiescent current of the OPA349 requires careful application circuit techniques to achieve low overall current consumption. Figure 1 shows an ac-coupled amplifier

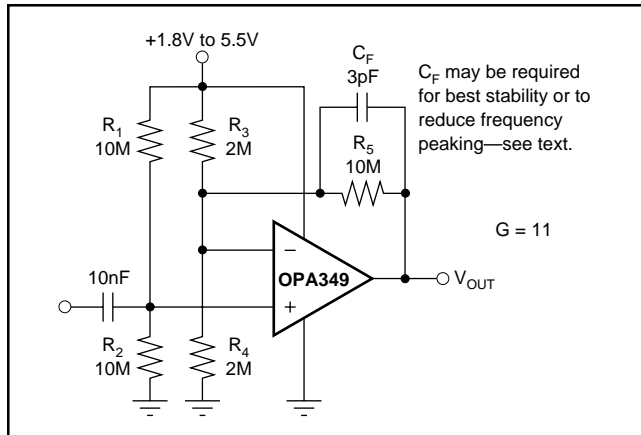


FIGURE 1. AC-Coupled Amplifier.

biased with a voltage divider. Resistor values must be very large to minimize current. The large feedback resistor value reacts with input capacitance and stray capacitance to produce a pole in the feedback network. A feedback capacitor may be required to assure stability and limit overshoot or gain peaking. Check circuit performance carefully to assure that biasing and feedback techniques meet signal and quiescent current requirements.

RAIL-TO-RAIL INPUT

The input common-mode voltage range of the OPA349 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 (as shown in Figure 2). The N-channel pair is active for input voltages close to the positive rail, typically $(V+) - 1.3V$ to 200mV above the positive supply, while the P-channel pair is on for inputs from 200mV below the negative supply to approximately $(V+) - 1.3V$. 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*.

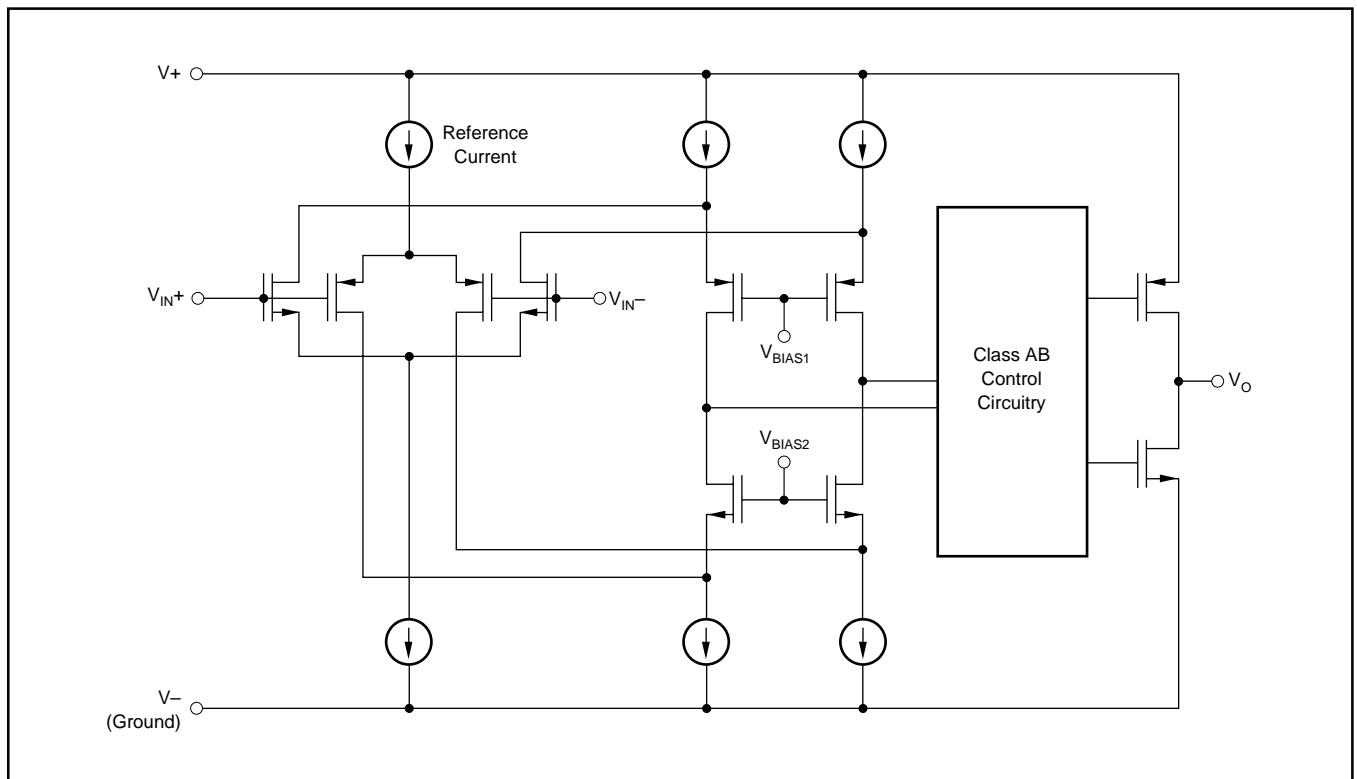


FIGURE 2. Simplified Schematic.

DESIGN OPTIMIZATION WITH RAIL-TO-RAIL INPUT OP AMPS

In most applications, operation is within the range of only one differential pair. However, some applications can subject the amplifier to a common-mode signal in the transition region. Under this condition, the inherent mismatch between the two differential pairs may lead to degradation of the CMRR and THD. The unity-gain buffer configuration is the most problematic—it will traverse through the transition region if a sufficiently

wide input swing is required. A design option would be to configure the op amp as a unity-gain inverter as shown below and hold the noninverting input at a set common-mode voltage outside the transition region. This can be accomplished with a voltage divider from the supply. The voltage divider should be designed such that the biasing point for the noninverting input is outside the transition region.

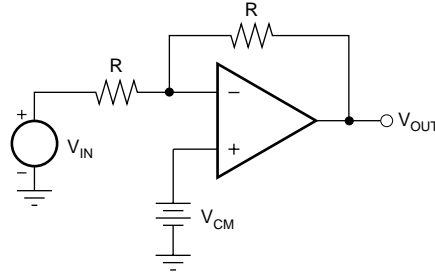


FIGURE 3. Design Optimization.

COMMON-MODE REJECTION

The CMRR for the OPA349 is specified in two 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 ($V_{CM} < (V_+) - 1.5V$) 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 $V_S = 5V$ over the entire common-mode range is specified.

OUTPUT DRIVEN TO V- RAIL

Loads that connect to single-supply ground (or the V- supply pin) can cause the OPA349 or OPA2349 to oscillate if the output voltage is driven into the negative rail (as shown in

Figure 4a). Similarly, loads that can cause current to flow out of the output pin when the output voltage is near V- can cause oscillations. The op amp will recover to normal operation a few microseconds after the output is driven positively out of the rail.

Some op amp applications can produce this condition even without a load connected to V-. The integrator in Figure 4b shows an example of this effect. Assume that the output ramps negatively, and saturates near 0V. Any negative-going step at V_{IN} will produce a positive output current pulse through R_1 and C_1 . This may incite the oscillation. Diode D_1 prevents the input step from pulling output current when the output is saturated at the rail, thus preventing the oscillation.

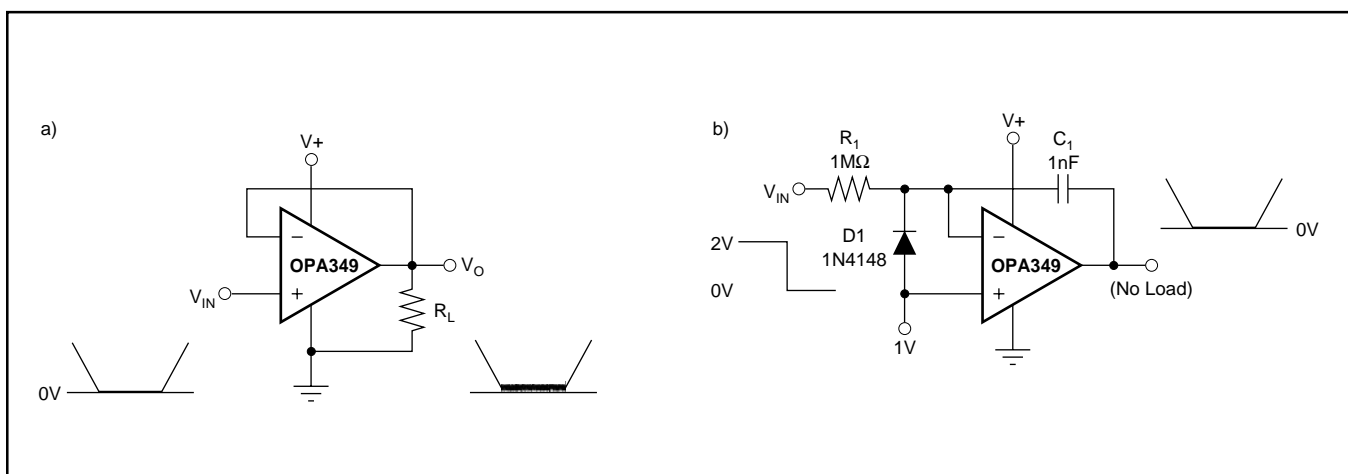


FIGURE 4. Output Driven to Negative Rail.

PACKAGING INFORMATION

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾
OPA2349EA/250	ACTIVE	SOT23	DCN	8	250	TBD	CU SNPB	Level-3-250C-168 HR
OPA2349EA/3K	ACTIVE	SOT23	DCN	8	3000	TBD	CU SNPB	Level-3-250C-168 HR
OPA2349UA	ACTIVE	SOIC	D	8	100	TBD	CU	Level-3-220C-168 HR
OPA2349UA/2K5	ACTIVE	SOIC	D	8	2500	TBD	CU NIPDAU	Level-3-220C-168 HR
OPA349NA/250	ACTIVE	SOT-23	DBV	5	250	TBD	CU NIPDAU	Level-3-250C-168 HR
OPA349NA/3K	ACTIVE	SOT-23	DBV	5	3000	TBD	CU NIPDAU	Level-3-250C-168 HR
OPA349SA/250	ACTIVE	SC70	DCK	5	250	TBD	Call TI	Level-3-235C-168 HR
OPA349SA/3K	ACTIVE	SC70	DCK	5	3000	TBD	Call TI	Level-3-235C-168 HR
OPA349UA	ACTIVE	SOIC	D	8	100	TBD	CU NIPDAU	Level-2-220C-1 YEAR
OPA349UA/2K5	ACTIVE	SOIC	D	8	2500	TBD	CU NIPDAU	Level-2-220C-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) 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.

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)

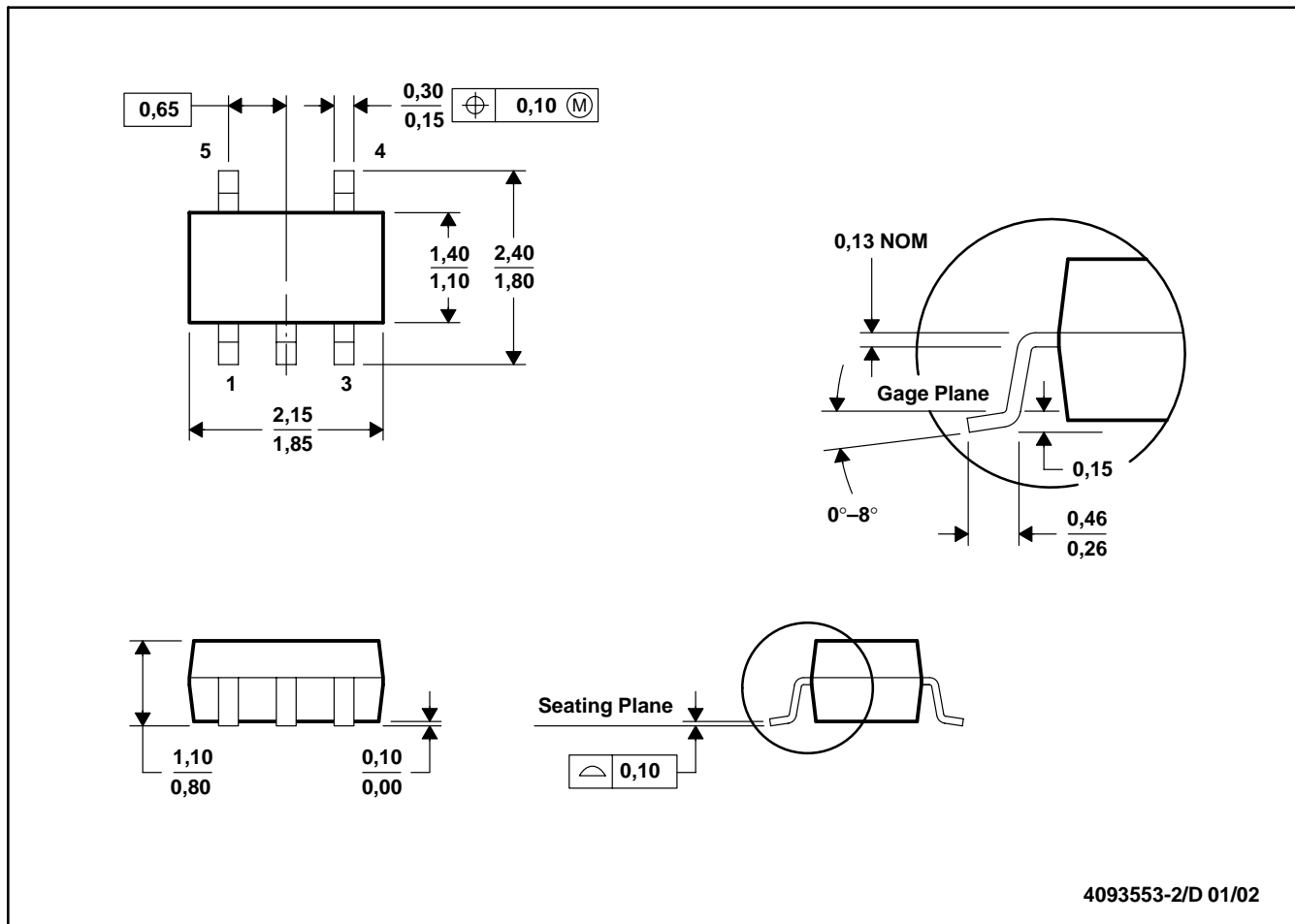
⁽³⁾ MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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DCK (R-PDSO-G5)

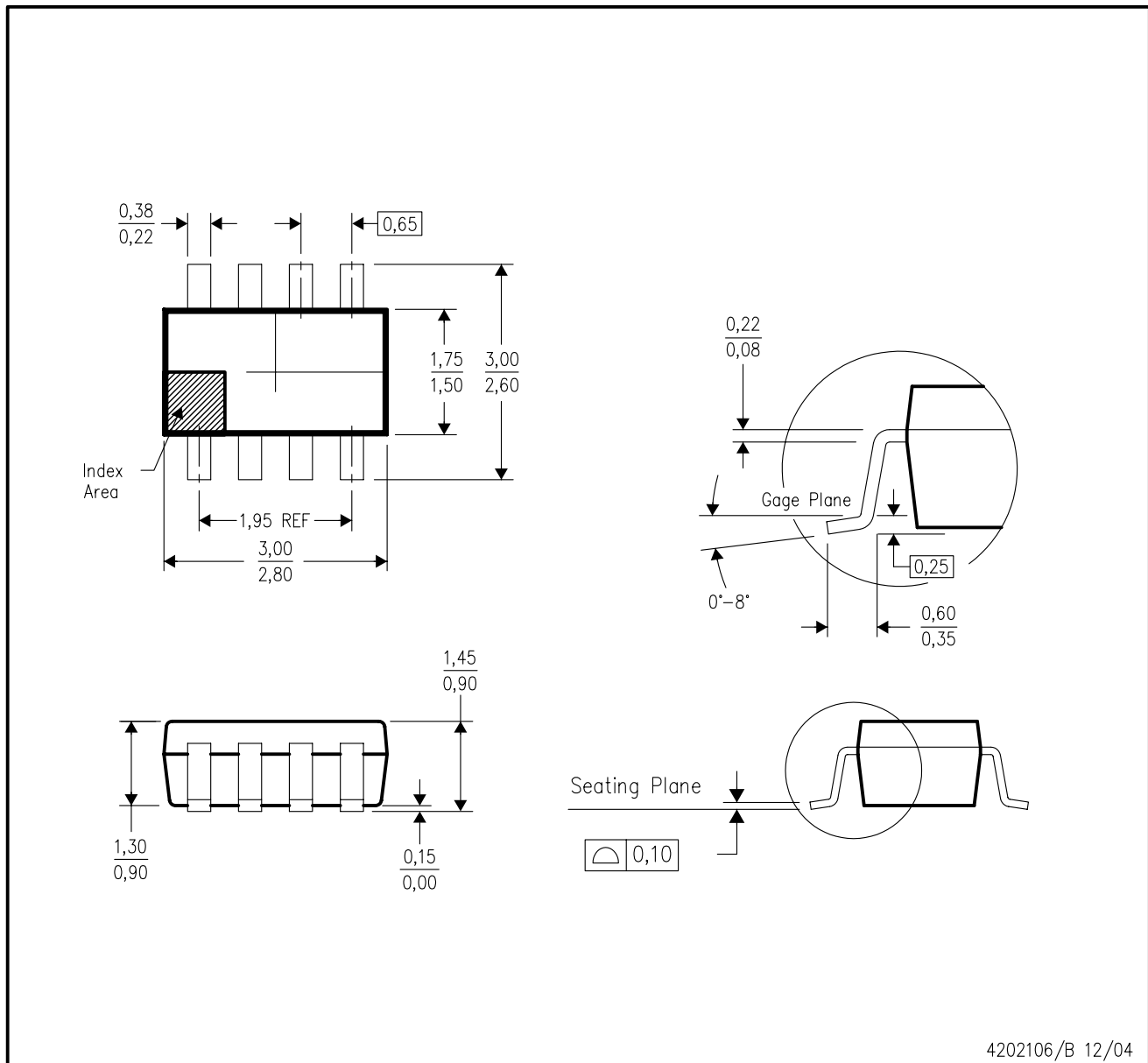
PLASTIC SMALL-OUTLINE PACKAGE



- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. Body dimensions do not include mold flash or protrusion.
 D. Falls within JEDEC MO-203

DCN (R-PDSO-G8)

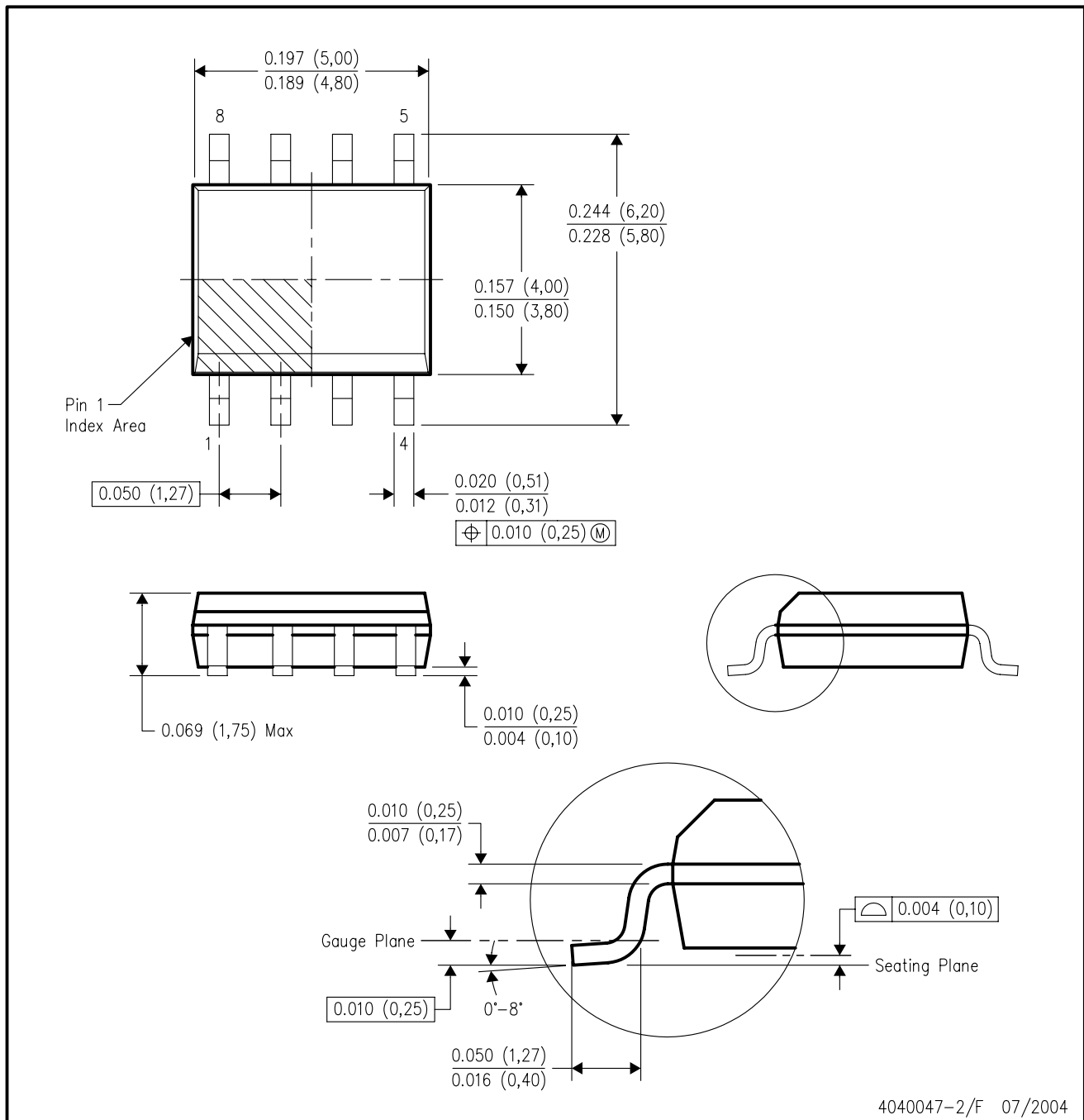
PLASTIC SMALL-OUTLINE



- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - Package outline exclusive of mold flash, metal burr & dambar protrusion/intrusion.
 - Package outline inclusive of solder plating.
 - A visual index feature must be located within the cross-hatched area.
 - Falls within JEDEC MO-178 Variation BA.

D (R-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
 - D. Falls within JEDEC MS-012 variation AA.

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