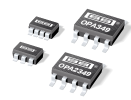
OPA349
OPA2349



SBOS121A – APRIL 2002

1µA, Rail-to-Rail I/O CMOS OPERATIONAL AMPLIFIERS

FEATURES

- LOW SUPPLY CURRENT: 1µA
- 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 150mV OF RAILS
- OUTPUT DRIVE CURRENT: 8mA
- OPEN-LOOP GAIN: 90dB
- *Micro*PACKAGES: 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 A/D CONVERTERS
- *Micro*POWER FILTERS

OPAX349 RELATED PRODUCTS

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

DESCRIPTION

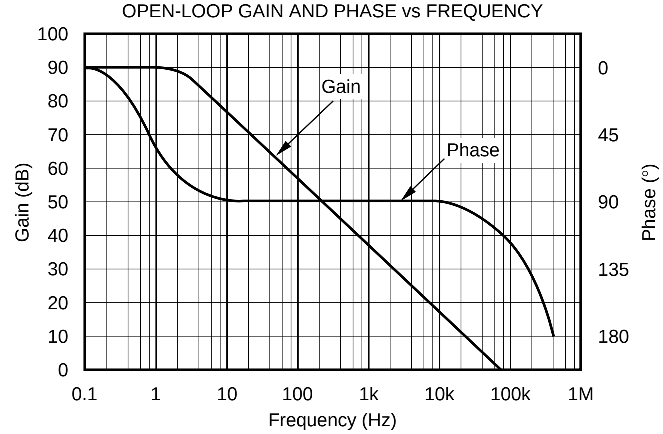
The OPA349 and the OPA2349 are ultra-low power operational amplifiers that provide 70kHz bandwidth with only 1µA quiescent current. These rail-to-rail input and output amplifiers are specifically designed for battery-powered applications. The input common-mode voltage range extends 200mV beyond the power supply rails and the output swings to within 150mV 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.

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.

OPA349 comes in the miniature SOT23-5, SC70, and SO-8 surface mount packages. OPA2349 dual is available in the 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 –40°C to +125°C. The OPA2349 is specified for –40°C to +70°C.

OPEN-LOOP GAIN AND PHASE vs FREQUENCY



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.

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	–55°C to +125°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.

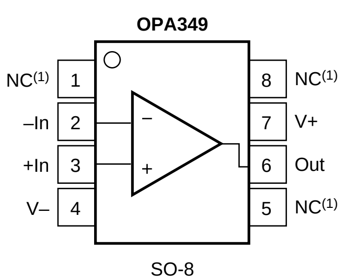
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PACKAGE/ORDERING INFORMATION

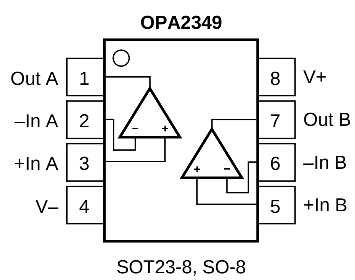
PRODUCT	PACKAGE	PACKAGE DESIGNATOR[1]	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER[2]	TRANSPORT MEDIA, QUANTITY
Single						
OPA349NA	SOT23-5	DBV	–40°C to +125°C	A49	OPA349NA/250	Tape and Reel, 250
"	"	"	"	"	OPA349NA/3K	Tape and Reel, 3000
OPA349UA	SO-8	D	–40°C to +125°C	OPA349UA	OPA349UA	Rails, 100
"	"	"	"	"	OPA349UA/2K5	Tape and Reel, 2500
OPA349SA	SC70-5	DCK	–40°C to +125°C	S49	OPA349SA/250	Tape and Reel, 250
"	"	"	"	"	OPA349SA/3K	Tape and Reel, 3000
Dual						
OPA2349EA	SOT23-8	DCN	–40°C to +70°C	C49	OPA2349EA/250	Tape and Reel, 250
"	"	"	"	"	OPA2349EA/3K	Tape and Reel, 3000
OPA2349UA	SO-8	D	–40°C to +70°C	OPA2349UA	OPA2349UA	Rails, 100
"	"	"	"	"	OPA2349UA/2K5	Tape and Reel, 2500

NOTE: (1) For the most current specifications and package information, refer to our web site at www.ti.com. (2) Models with a (/) are available only in Tape and Reel in the quantities indicated (e.g., /3K indicates 3000 devices per reel). Ordering 3000 pieces of "OPA2349EA/3K" will get a single 3000-piece Tape and Reel.

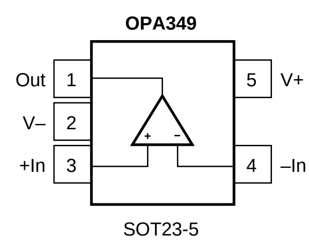
PIN CONFIGURATIONS



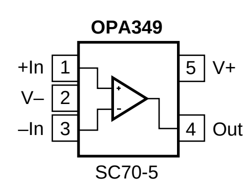
SO-8



SOT23-8, SO-8



SOT23-5



SC70-5

NOTE: (1) NC indicates no internal connection.

ELECTRICAL CHARACTERISTICS (Single): V_S = +1.8V 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 = 1MΩ connected to V_S/2, unless otherwise noted.

PARAMETER		CONDITION	OPA349NA, UA, SA MIN	TYP	MAX	UNITS
OFFSET VOLTAGE						
Input Offset Voltage	V_{OS}	V_S = 5V, V_{CM} = 2.5V		±2	±10	mV
Over Temperature				**±2**	**±13**	**mV**
Drift	**dV_{OS}/dT**			**±15**		**μV/°C**
vs Power Supply	PSRR	V_S = 1.8V to 5.5V, V_{CM} = (V–) + 0.3V		350	1000	μV/V
Over Temperature					**3000**	**μV/V**
INPUT VOLTAGE RANGE						
Common-Mode Voltage Range	V_{CM}		(V–) – 0.2		(V+) + 0.2	V
Common-Mode Rejection Ratio	CMRR	V_S = +5V, –0.2V < V_{CM} < 3.5V	52	72		dB
Over Temperature			**50**			**dB**
		V_S = +5V, –0.2V < V_{CM} < 5.2V	48	60		dB
Over Temperature			**46**			**dB**
INPUT BIAS CURRENT						
Input Bias Current	I_B			±0.5	±10	pA
Input Offset Current	I_{OS}			±1	±10	pA
INPUT IMPEDANCE						
Differential				10^{13} || 2		Ω || pF
Common-Mode				10^{13} || 4		Ω || pF
NOISE						
Input Voltage Noise, f = 0.1Hz to 10Hz				8		μVp-p
Input Voltage Noise Density, f = 1kHz	e_n			300		nV/√Hz
Current Noise Density, f = 1kHz	i_n			4		fA/√Hz
OPEN-LOOP GAIN						
Open-Loop Voltage Gain	A_{OL}	R_L = 1MΩ, V_S = +5.5V, +0.05V < V_O < +5.45V	74	90		dB
Over Temperature			**72**			**dB**
Open-Loop Voltage Gain	A_{OL}	R_L = 10kΩ, V_S = +5.5V, +0.15V < V_O < +5.35V	74	90		dB
Over Temperature			**60**			**dB**
OUTPUT						
Voltage Output Swing from Rail		R_L = 1MΩ, V_S = +5.5V, A_{OL} > 74dB			50	mV
Over Temperature					**50**	**mV**
		R_L = 10kΩ, V_S = +5.5V, A_{OL} > 74dB			150	mV
Over Temperature					**150**	**mV**
Output Current				±8		mA
Short-Circuit Current	I_{SC}			±10		mA
Capacitive Load Drive	C_{LOAD}			See Typical Characteristics		
FREQUENCY RESPONSE		C_L = 10pF				
Gain-Bandwidth Product	GBW	G = +1		70		kHz
Slew Rate	SR	V_S = +5V, G = +1		0.02		V/μs
Settling Time, 0.1%	t_S	V_S = 5V, 1V Step		65		μs
0.01%		V_S = 5V, 1V Step		80		μs
Overload Recovery Time		V_{IN} • Gain = V_S		5		μs
POWER SUPPLY						
Specified Voltage Range			1.8		5.5	V
Quiescent Current (per amplifier)	I_Q	I_O = 0		1	2	μA
Over Temperature					**2.5**	**μA**
TEMPERATURE RANGE						
Specified Range			–40		+125	°C
Storage Range			–65		+150	°C
Thermal Resistance	θ_{JA}					°C/W
SOT23-5 Surface Mount				200		°C/W
SO-8 Surface Mount				150		°C/W
SC70-5 Surface Mount				250		°C/W

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

Boldface limits apply over the specified temperature range, T_A = –40°C to +70°C

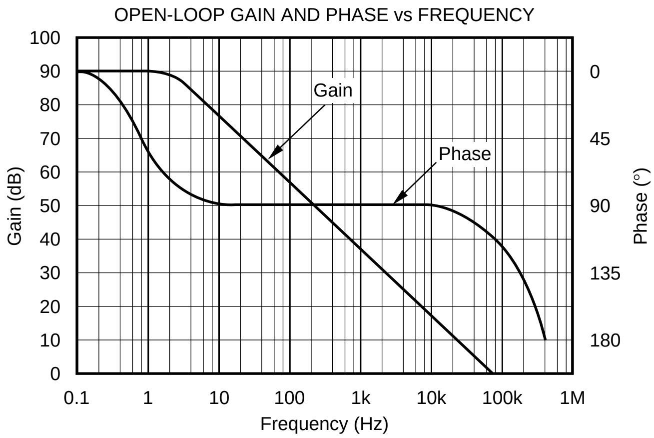
At T_A = +25°C, R_L = 1MΩ connected to V_S/2, unless otherwise noted.

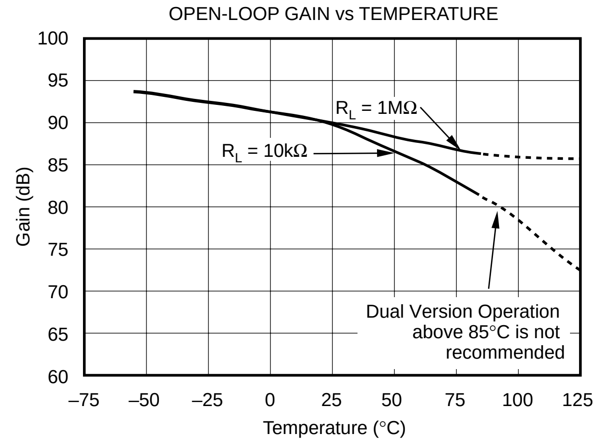
PARAMETER		CONDITION	OPA2349EA, UA MIN	TYP	MAX	UNITS
OFFSET VOLTAGE						
Input Offset Voltage	V_{OS}	V_S = 5V, V_{CM} = 2.5V		±2	±10	mV
Over Temperature				**±2**	**±13**	**mV**
Drift	**dV_{OS}/dT**			**±15**		**μV/°C**
vs Power Supply	PSRR	V_S = 1.8V to 5.5V, V_{CM} = (V–) + 0.3V		350	1000	μV/V
Over Temperature					**3000**	**μV/V**
Channel Separation, dc		R_L = 100kΩ		10		μV/V
		f = 1kHz		66(1)		dB
INPUT VOLTAGE RANGE						
Common-Mode Voltage Range	V_{CM}		(V–) – 0.2		(V+) + 0.2	V
Common-Mode Rejection Ratio	CMRR	V_S = +5V, –0.2V < V_{CM} < 3.5V	52	72		dB
Over Temperature			**50**			**dB**
		V_S = +5V, –0.2V < V_{CM} < 5.2V	48	60		dB
Over Temperature			**46**			**dB**
INPUT BIAS CURRENT						
Input Bias Current	I_B			±0.5	±10	pA
Input Offset Current	I_{OS}			±1	±10	pA
INPUT IMPEDANCE						
Differential				10^{13} || 2		Ω || pF
Common-Mode				10^{13} || 4		Ω || pF
NOISE						
Input Voltage Noise, f = 0.1Hz to 10Hz				8		μVp-p
Input Voltage Noise Density, f = 1kHz	e_n			300		nV/√Hz
Current Noise Density, f = 1kHz	i_n			4		fA/√Hz
OPEN-LOOP GAIN						
Open-Loop Voltage Gain	A_{OL}	R_L = 1MΩ, V_S = +5.5V, +0.3V < V_O < +5.2V	74	90		dB
Over Temperature			**72**			**dB**
Open-Loop Voltage Gain	A_{OL}	R_L = 10kΩ, V_S = +5.5V, +0.35V < V_O < +5.15V	74	90		dB
Over Temperature			**60**			**dB**
OUTPUT						
Voltage Output Swing from Rail		R_L = 1MΩ, V_S = +5.5V, A_{OL} > 74dB		150	300	mV
Over Temperature					**300**	**mV**
		R_L = 10kΩ, V_S = +5.5V, A_{OL} > 74dB		200	350	mV
Over Temperature					**350**	**mV**
Output Current				±8		mA
Short-Circuit Current	I_{SC}			±10		mA
FREQUENCY RESPONSE		C_L = 10pF				
Gain-Bandwidth Product	GBW	G = +1		70		kHz
Slew Rate	SR	V_S = +5V, G = +1		0.02		V/μs
Settling Time, 0.1%	t_S	V_S = 5V, 1V Step		65		μs
0.01%		V_S = 5V, 1V Step		80		μs
Overload Recovery Time		V_{IN} • Gain = V_S		5		μs
POWER SUPPLY						
Specified Voltage Range	V_S		1.8		5.5	V
Quiescent Current (per amplifier)	I_Q	I_O = 0		1	2	μA
Over Temperature					**10**	**μA**
TEMPERATURE RANGE						
Specified Range			–40		+70	°C
Operating Range			–40		+85	°C
Storage Range			–65		+150	°C
Thermal Resistance	θ_{JA}					°C/W
SOT23-8 Surface Mount				200		°C/W
SO-8 Surface Mount				150		°C/W

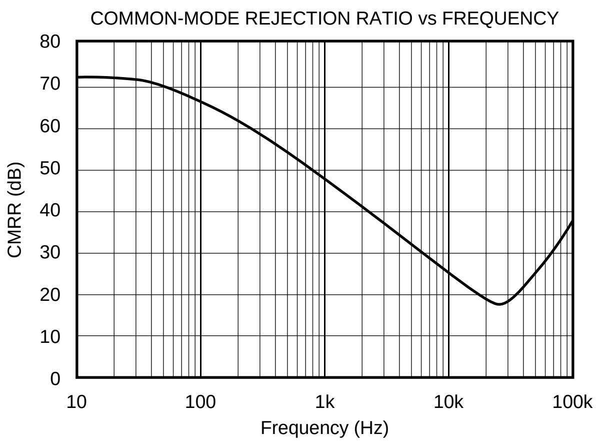
NOTE: (1) Refer to "Typical Characteristics" Curves.

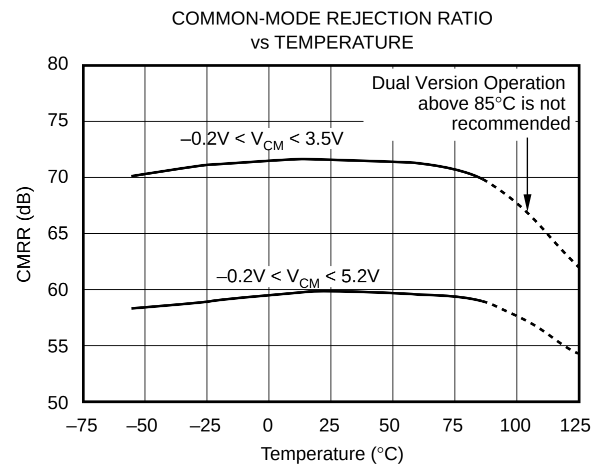
TYPICAL CHARACTERISTICS

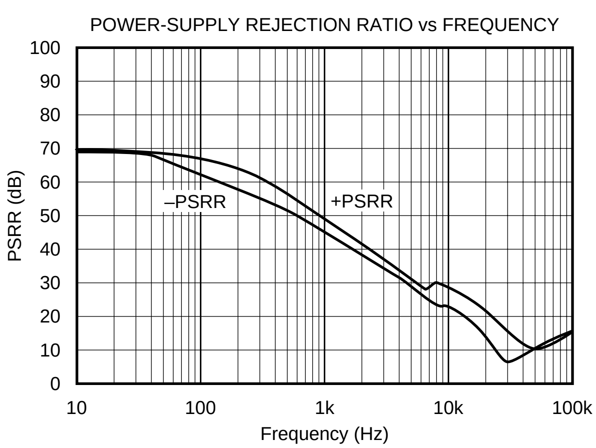
At T_A = +25°C, V_S = +5V, R_L = 1MΩ connected to V_S/2, unless otherwise noted.

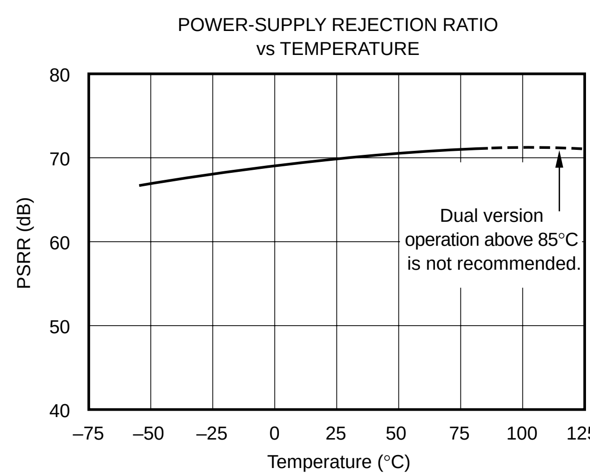








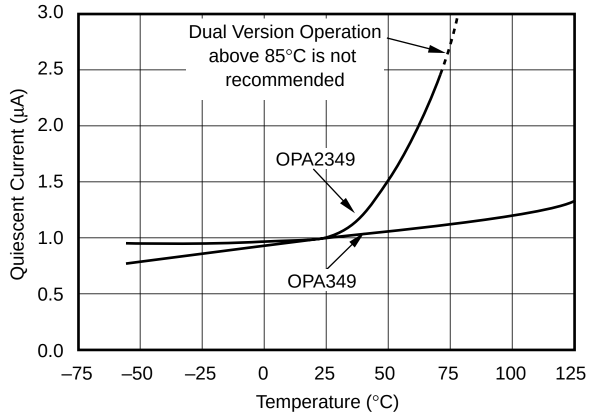




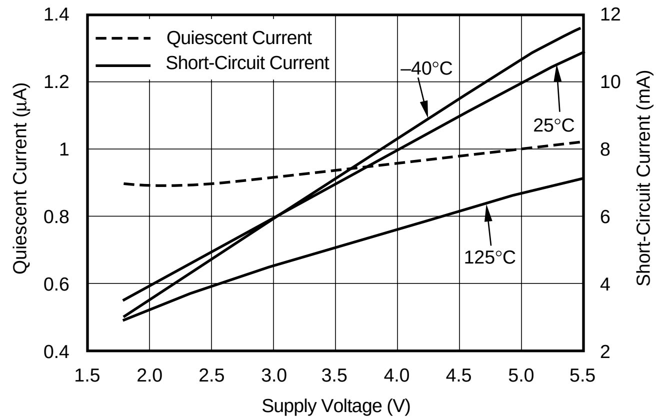
TYPICAL CHARACTERISTICS (Cont.)

At T_A = +25°C, V_S = +5V, R_L = 1MΩ connected to $V_S/2$, unless otherwise noted.

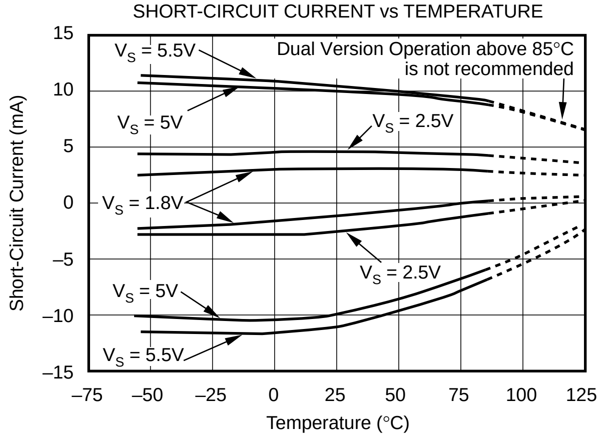
QUIESCENT CURRENT vs TEMPERATURE



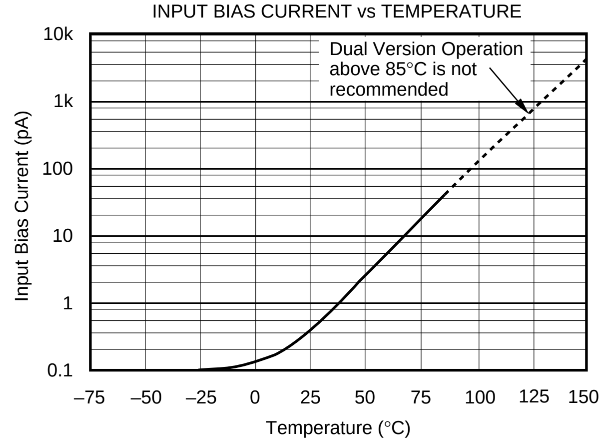
QUIESCENT AND SHORT-CIRCUIT vs SUPPLY VOLTAGE



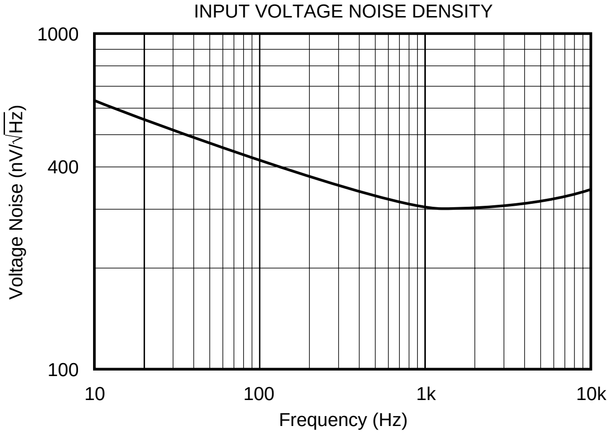
SHORT-CIRCUIT CURRENT vs TEMPERATURE



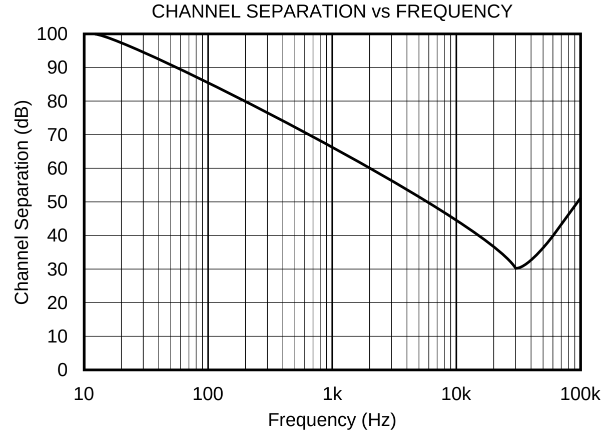
INPUT BIAS CURRENT vs TEMPERATURE



INPUT VOLTAGE NOISE DENSITY

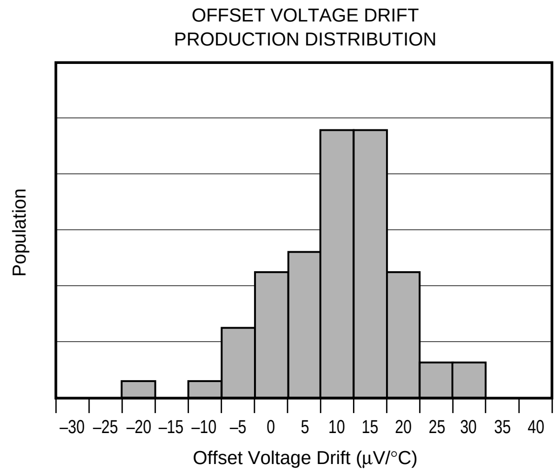


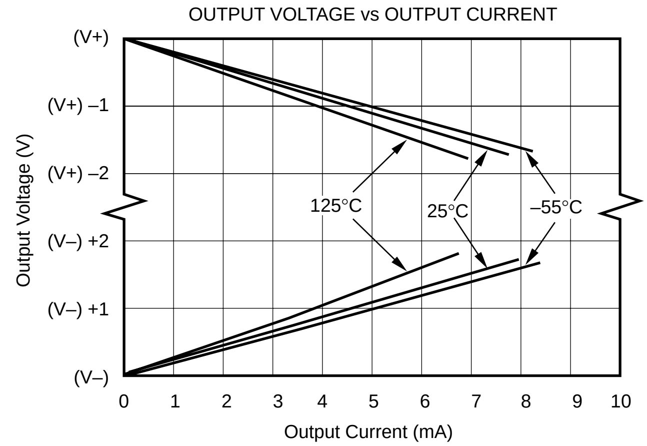
CHANNEL SEPARATION vs FREQUENCY

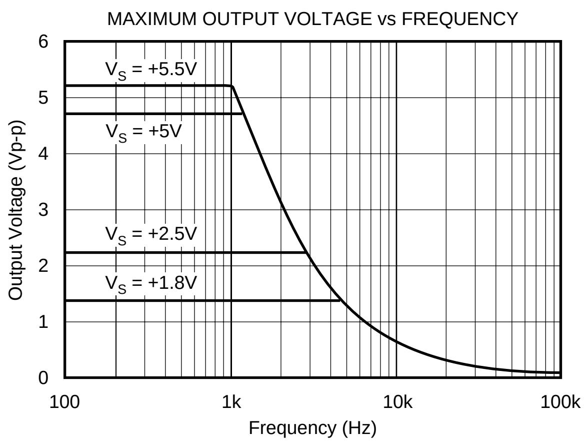


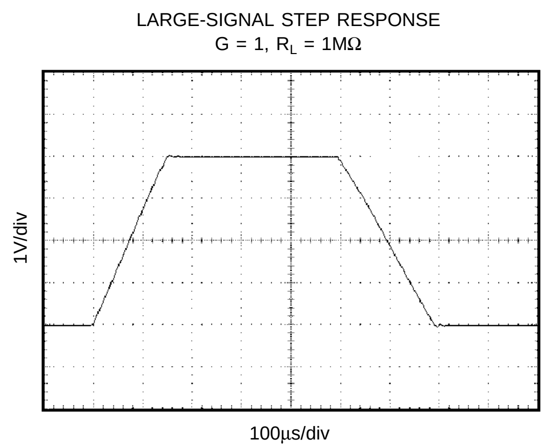
TYPICAL CHARACTERISTICS (Cont.)

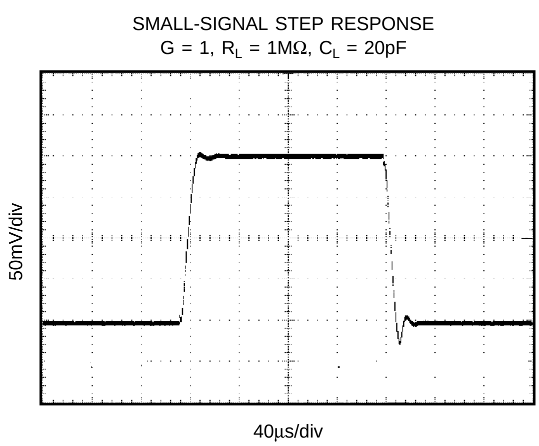
At T_A = +25°C, V_S = +5V, R_L = 1MΩ connected to V_S/2, unless otherwise noted.

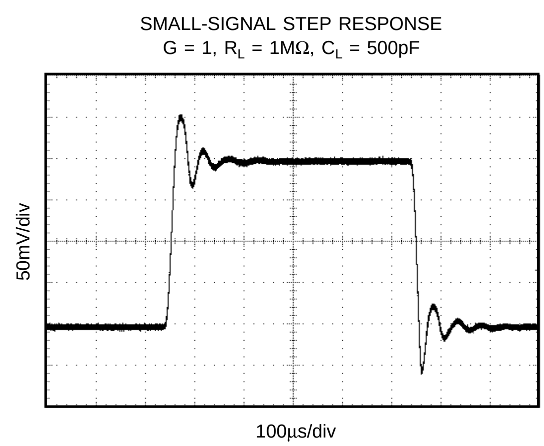






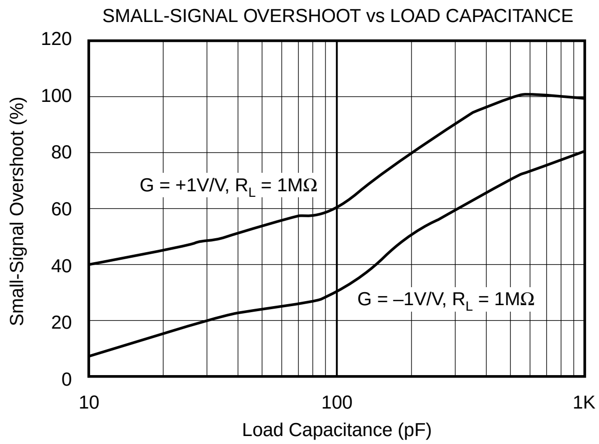






TYPICAL CHARACTERISTICS (Cont.)

At T_A = +25°C, V_S = +5V, R_L = 1MΩ connected to $V_S/2$, unless otherwise noted.



APPLICATIONS INFORMATION

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 0.01µF ceramic capacitors.

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 Characteristics Curves.

The ultra low quiescent current of the OPA349 requires careful applications circuit techniques to achieve low overall current consumption. Figure 1 shows an 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 your signal and quiescent current requirements.

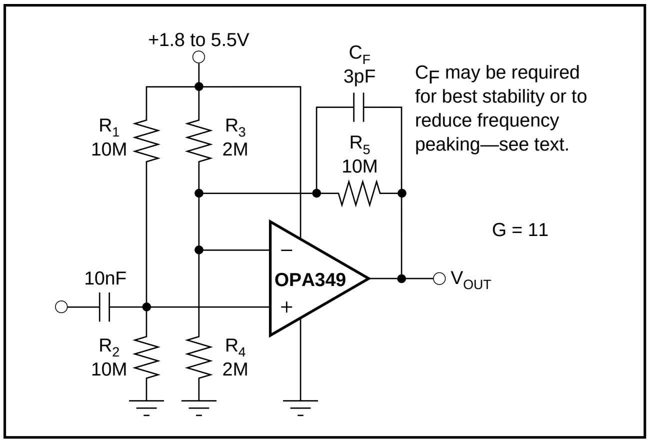


FIGURE 1. AC-Coupled Amplifier.

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.”

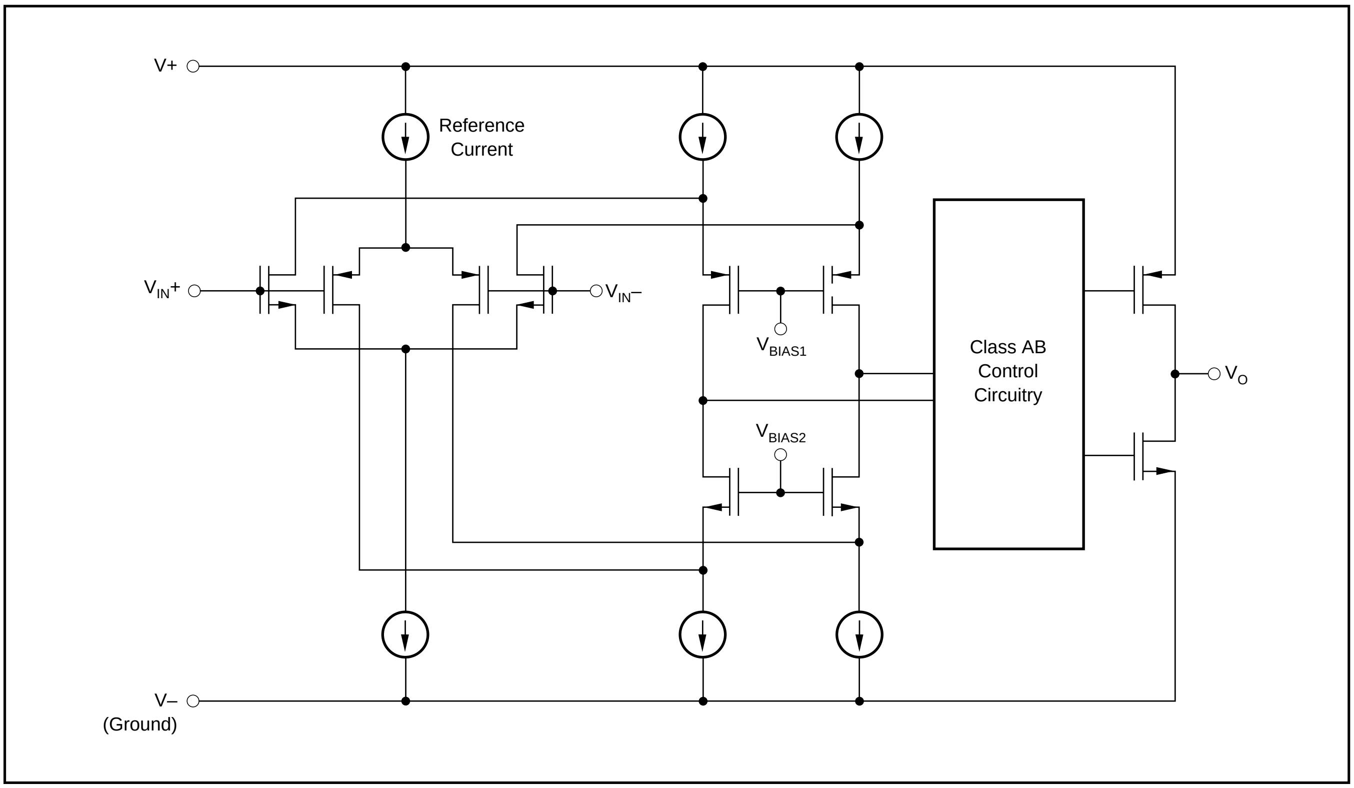


FIGURE 2. Simplified Schematic.

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.

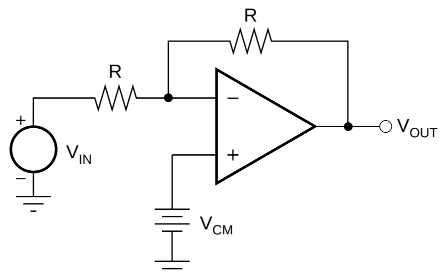


FIGURE 3. Design Optimization.

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 (DUAL VERSION ONLY)

Loads that connect to single-supply ground (or the V- supply pin) can cause the OPA2349 (dual version) to oscillate if the output voltage is driven into the negative rail (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. 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.

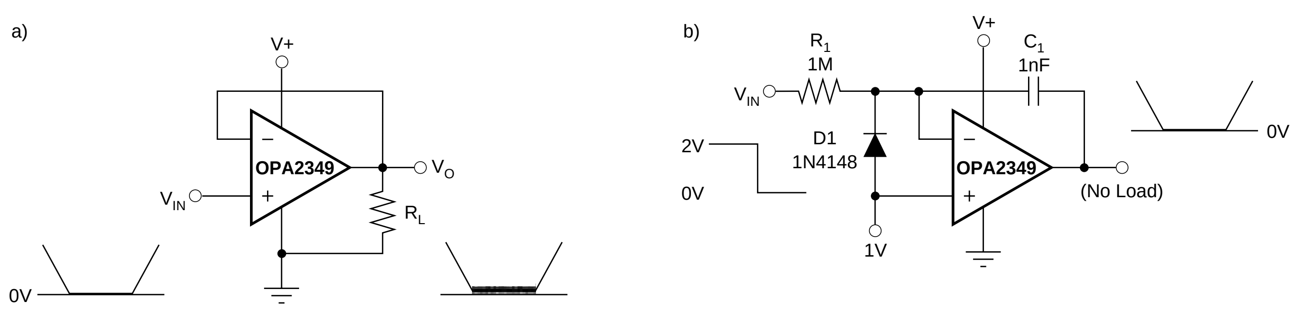
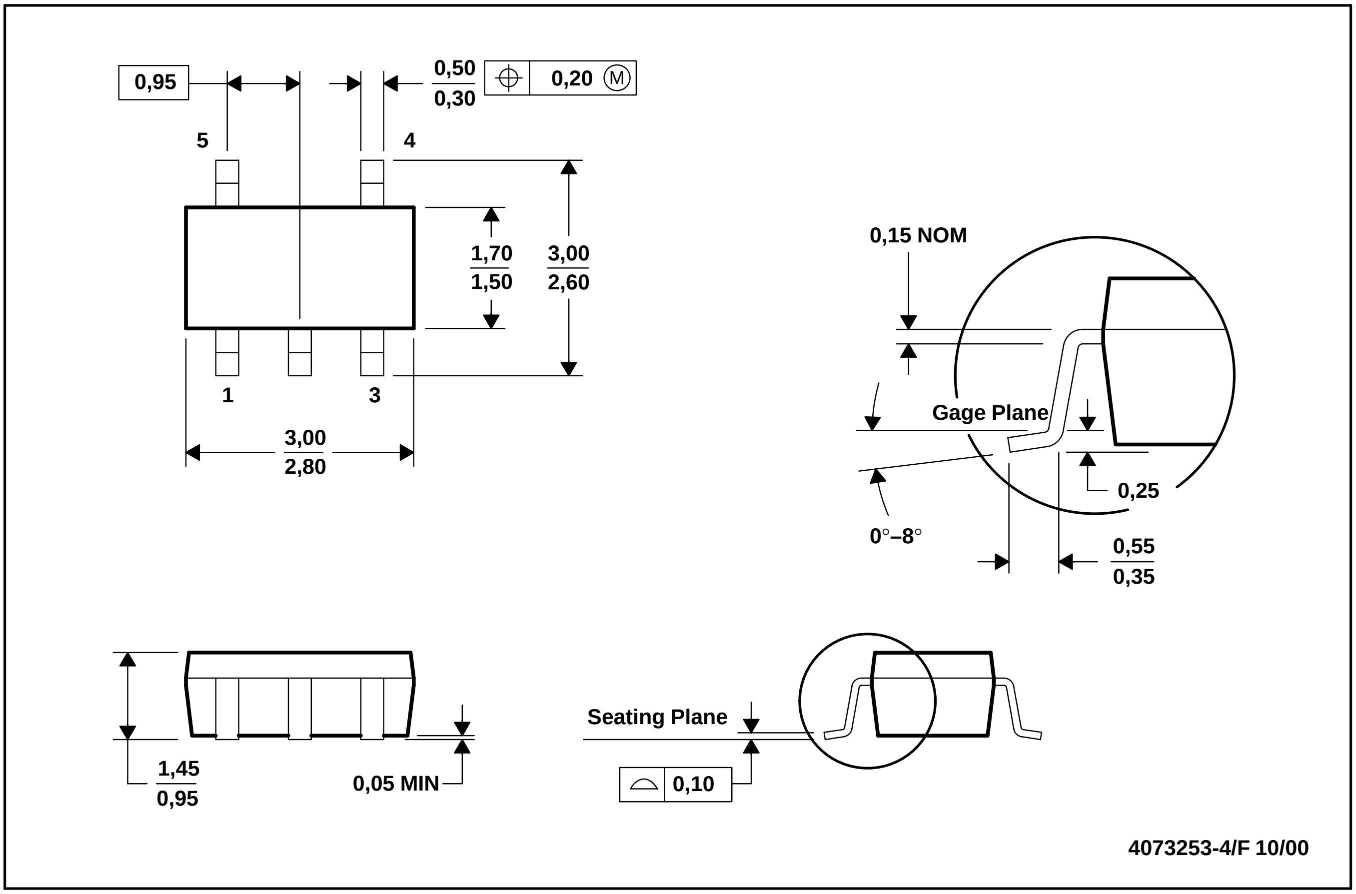


FIGURE 4. Output Driven to Negative Rail (Dual Version Only).

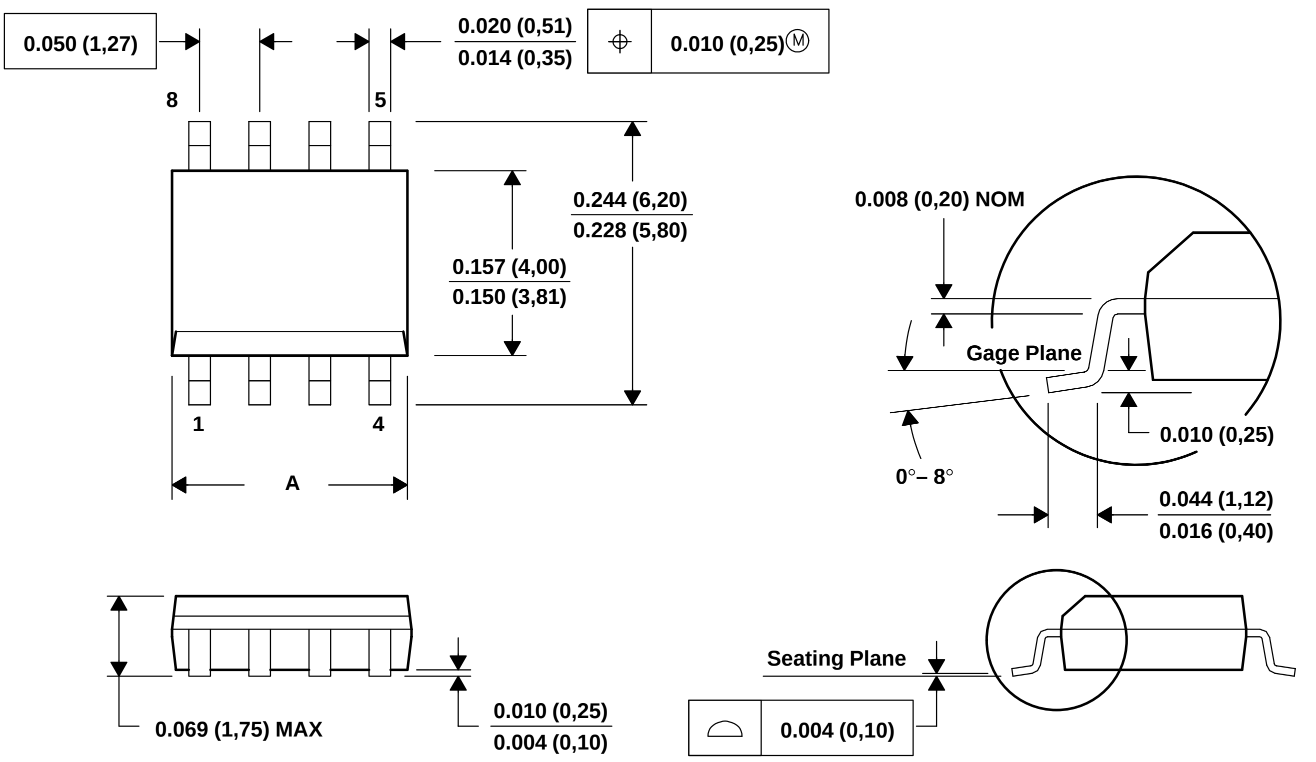
DBV (R-PDSO-G5) **PLASTIC SMALL-OUTLINE**



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-178

D (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

8 PINS SHOWN

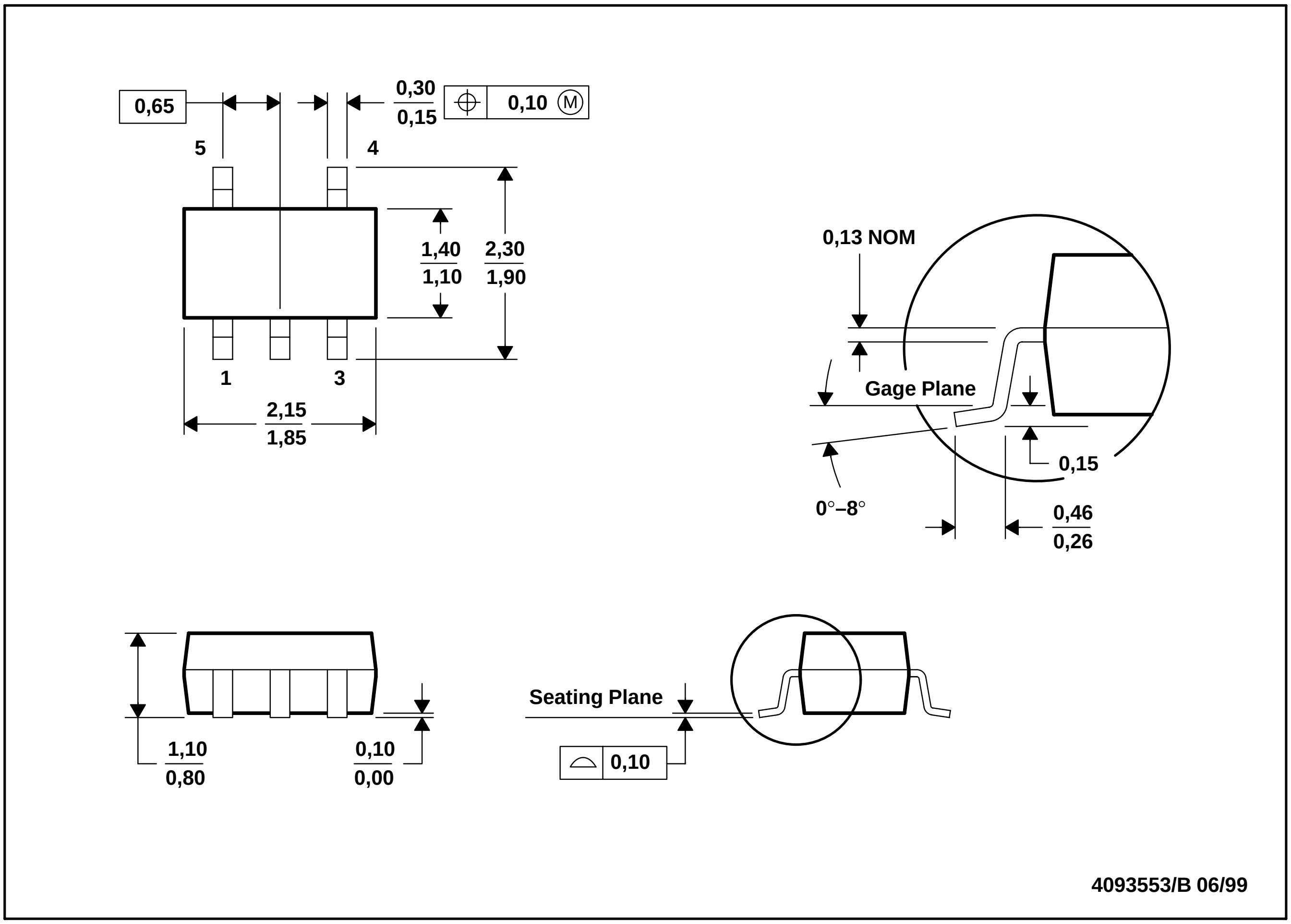


PINS ** / DIM	8	14	16
A MAX	0.197 (5,00)	0.344 (8,75)	0.394 (10,00)
A MIN	0.189 (4,80)	0.337 (8,55)	0.386 (9,80)

4040047/E 09/01

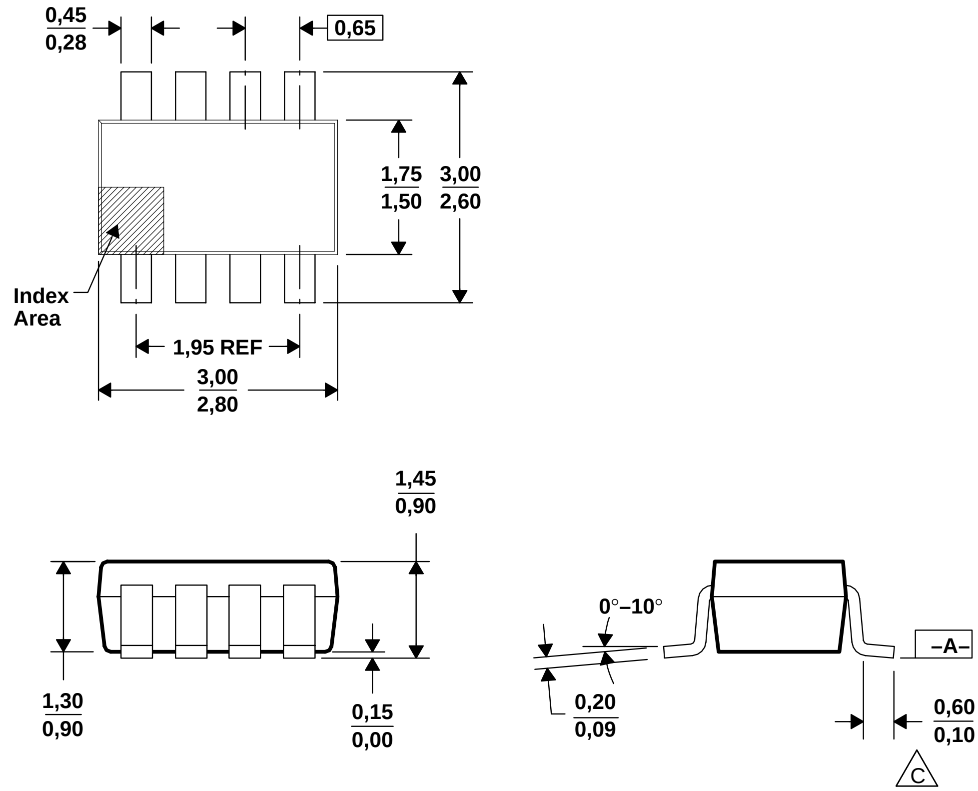
NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
- D. Falls within JEDEC MS-012

DCK (R-PDSO-G5) **PLASTIC SMALL-OUTLINE**



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**



4202106/A 03/01

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Foot length measured reference to flat foot surface parallel to Datum A.
D. Package outline exclusive of mold flash, metal burr and dambar protrusion/intrusion.
E. Package outline inclusive of solder plating.
F. A visual index feature must be located within the cross-hatched area.

Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265