

# SINGLE-SUPPLY, *microPower* CMOS OPERATIONAL AMPLIFIERS

## *microAmplifier™* Series

### FEATURES

- SINGLE-SUPPLY OPERATION
- RAIL-TO-RAIL OUTPUT (within 3mV)
- *microPOWER*:  $I_Q = 20\mu\text{A}/\text{Amplifier}$
- *microSIZE* PACKAGES
- LOW OFFSET VOLTAGE:  $125\mu\text{V max}$
- SPECIFIED FROM  $V_S = 2.3\text{V to } 5.5\text{V}$
- SINGLE, DUAL, AND QUAD VERSIONS

### APPLICATIONS

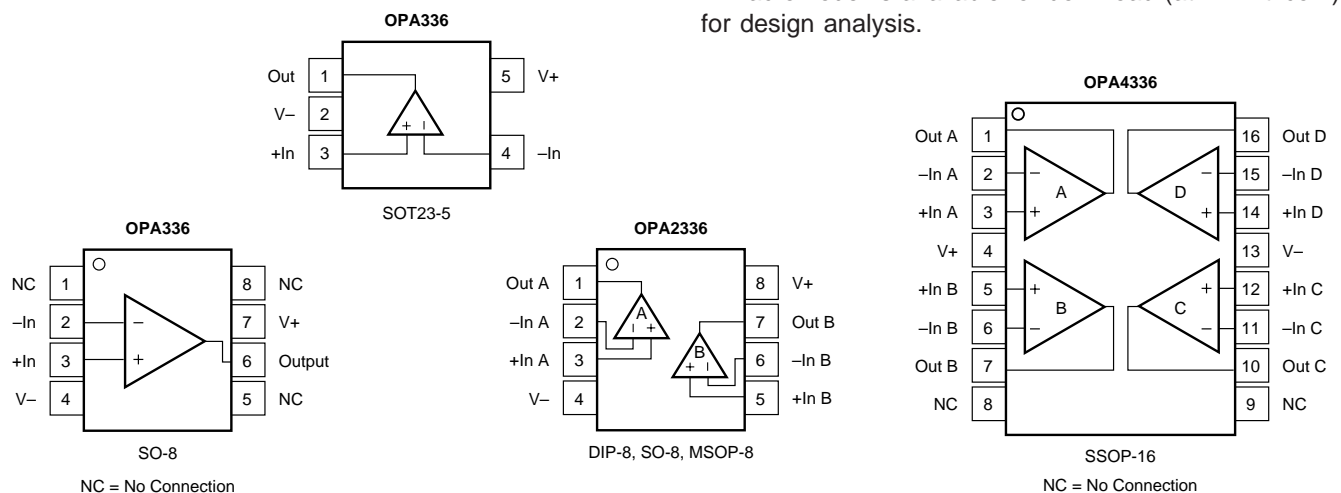
- BATTERY-POWERED INSTRUMENTS
- PORTABLE DEVICES
- HIGH-IMPEDANCE APPLICATIONS
- PHOTODIODE PRE-AMPS
- PRECISION INTEGRATORS
- MEDICAL INSTRUMENTS
- TEST EQUIPMENT

### DESCRIPTION

OPA336 series *microPower* CMOS operational amplifiers are designed for battery-powered applications. They operate on a single supply with operation as low as 2.1V. The output is rail-to-rail and swings to within 3mV of the supplies with a 100kΩ load. The common-mode range extends to the negative supply—ideal for single-supply applications. Single, dual, and quad versions have identical specifications for maximum design flexibility.

In addition to small size and low quiescent current (20μA/amplifier), they feature low offset voltage (125μV max), low input bias current (1pA), and high open-loop gain (115dB). Dual and quad designs feature completely independent circuitry for lowest crosstalk and freedom from interaction.

OPA336 packages are the tiny SOT23-5 surface mount and SO-8 surface-mount. OPA2336 come in the miniature MSOP-8 surface-mount, SO-8 surface-mount, and DIP-8 packages. The OPA4336 package is the space-saving SSOP-16 surface-mount. All are specified from -40°C to +85°C and operate from -55°C to +125°C. A macromodel is available for download (at [www.ti.com](http://www.ti.com)) for design analysis.



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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## PACKAGE/ORDERING INFORMATION<sup>(1)</sup>

PRODUCT	PACKAGE-LEAD	PACKAGE DRAWING DESIGNATOR	PACKAGE MARKING
<b>Single</b> OPA336N OPA336NA OPA336NJ OPA336U OPA336UA OPA336UJ	SOT23-5 SOT23-5 SOT23-5 SO-8 Surface-Mount SO-8 Surface-Mount SO-8 Surface-Mount	DBV DBV DBV D D D	A36 <sup>(2)</sup> A36 <sup>(2)</sup> J36 OPA336U OPA336UA OPA336UJ
<b>Dual</b> OPA2336E OPA2336EA OPA2336P OPA2336PA OPA2336U OPA2336UA	MSOP-8 Surface-Mount MSOP-8 Surface-Mount DIP-8 DIP-8 SO-8 Surface-Mount SO-8 Surface-Mount	DGK DGK P P D D	B36 <sup>(2)</sup> B36 <sup>(2)</sup> OPA2336P OPA2336PA OPA2336U OPA2336UA
<b>Quad</b> OPA4336EA	SSOP-16 Surface-Mount	DBQ	OPA4336EA

NOTES: (1) For the most current package and ordering information, see the package option addendum at the end of this data sheet. (2) Grade will be marked on the Reel.

## ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>

Supply Voltage .....	7.5V
Signal Input Terminals, Voltage <sup>(2)</sup> .....	(V-) -0.3V to (V+) +0.3V
Current <sup>(2)</sup> .....	10mA
Output Short-Circuit <sup>(3)</sup> .....	Continuous
Operating Temperature .....	-55°C to +125°C
Storage Temperature .....	-55°C to +125°C
Junction Temperature .....	150°C
Lead Temperature (soldering, 10s) .....	300°C
ESD Rating:	
Charged Device Model, OPA336 NJ and UJ only (CDM) <sup>(4)</sup> .....	1000V
Human Body Model (HBM) <sup>(4)</sup> .....	500V
Machine Model (MM) <sup>(4)</sup> .....	100V

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 0.3V beyond the supply rails should be current-limited to 10mA or less. (3) Short-circuit to ground, one amplifier per package. (4) OPA336 NJ and UJ have been tested to CDM of 1000V. All other previous package versions have been tested using HBM and MM. Results are shown.



## 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.

# ELECTRICAL CHARACTERISTICS: $V_S = 2.3V$ to $5.5V$

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

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

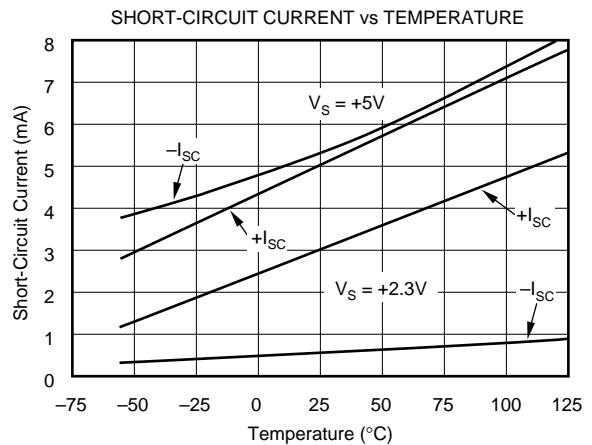
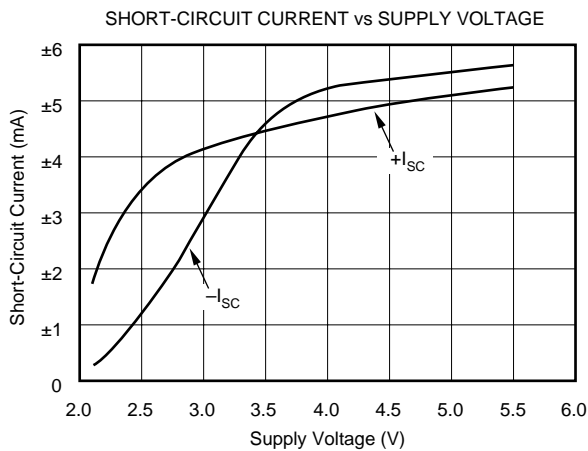
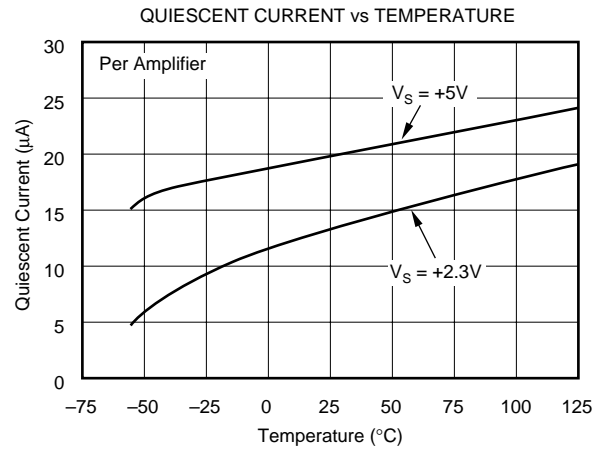
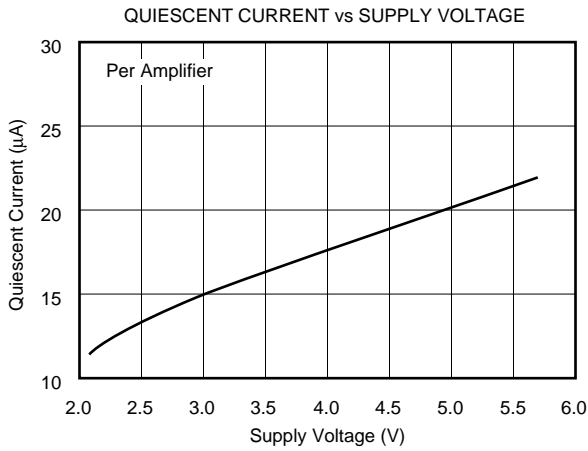
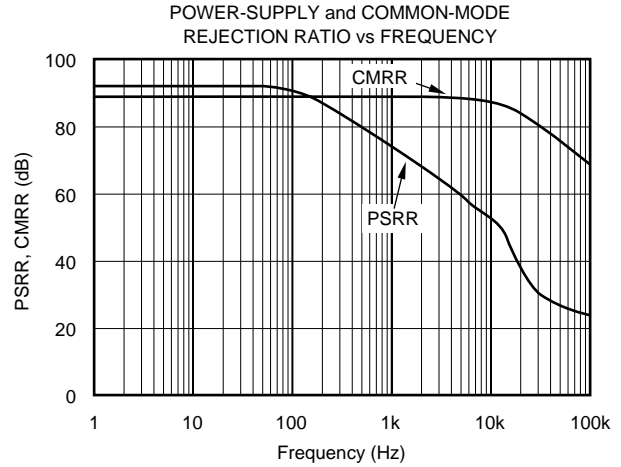
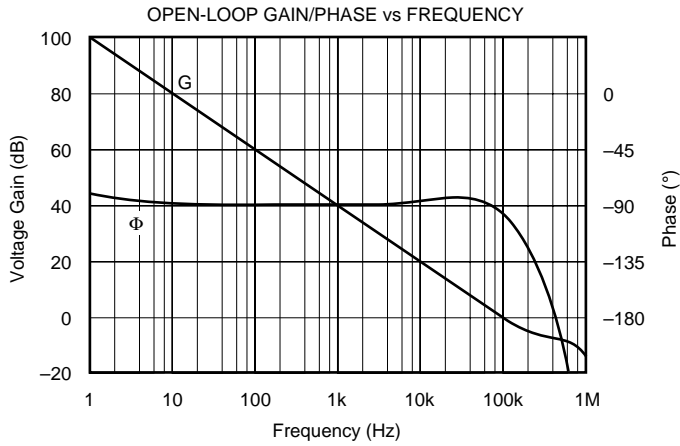
PARAMETER	CONDITION	OPA336N, U OPA2336E, P, U			OPA336NA, UA OPA2336EA, PA, UA OPA4336EA			OPA336NJ, UJ			UNITS
		MIN	TYP <sup>(1)</sup>	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
<b>OFFSET VOLTAGE</b> Input Offset Voltage <b>vs Temperature</b> vs Power Supply <b>Over Temperature</b> Channel Separation, dc	$V_{OS}$ $dV_{OS}/dT$ PSRR $V_S = 2.3V$ to $5.5V$ $V_S = 2.3V$ to $5.5V$		$\pm 60$ <b><math>\pm 1.5</math></b> 25 0.1	$\pm 125$ 100 <b>130</b>		*	$\pm 500$ *		$\pm 500$ *	$\pm 2500$ *	$\mu V$ $\mu V/^{\circ}C$ $\mu V/V$ $\mu V/V$
<b>INPUT BIAS CURRENT</b> Input Bias Current <b>Over Temperature</b> Input Offset Current	$I_B$ $I_{OS}$		$\pm 1$ $\pm 1$	$\pm 10$ <b><math>\pm 60</math></b> $\pm 10$		*	*		*	*	pA pA pA
<b>NOISE</b> Input Voltage Noise, $f = 0.1$ to $10Hz$ Input Voltage Noise Density, $f = 1kHz$ $e_n$ Current Noise Density, $f = 1kHz$ $i_n$			3 40 30			*	*		*	*	$\mu Vp-p$ $nV/\sqrt{Hz}$ $fA/\sqrt{Hz}$
<b>INPUT VOLTAGE RANGE</b> Common-Mode Voltage Range Common-Mode Rejection Ratio <b>Over Temperature</b>	$V_{CM}$ CMRR $-0.2V < V_{CM} < (V+) - 1V$ $-0.2V < V_{CM} < (V+) - 1V$	-0.2 80 <b>76</b>	90	$(V+) - 1$	*	76 <b>74</b>	86	*	76 <b>74</b>	86	V dB dB
<b>INPUT IMPEDANCE</b> Differential Common-Mode			$10^{13} \parallel 2$ $10^{13} \parallel 4$			*	*		*	*	$\Omega \parallel pF$ $\Omega \parallel pF$
<b>OPEN-LOOP GAIN</b> Open-Loop Voltage Gain <b>Over Temperature</b> <b>Over Temperature</b>	$A_{OL}$ $R_L = 25k\Omega, 100mV < V_O < (V+) - 100mV$ $R_L = 25k\Omega, 100mV < V_O < (V+) - 100mV$ $R_L = 5k\Omega, 500mV < V_O < (V+) - 500mV$ $R_L = 5k\Omega, 500mV < V_O < (V+) - 500mV$	100 <b>100</b> 90 <b>90</b>	115 106			90 <b>90</b> *	*		90 <b>90</b> *	*	dB dB dB dB
<b>FREQUENCY RESPONSE</b> Gain-Bandwidth Product Slew Rate Overload Recovery Time	GBW SR $V_S = 5V, G = 1$ $V_S = 5V, G = 1$ $V_{IN} \cdot G = V_S$		100 0.03 100			*	*		*	*	kHz V/ $\mu s$ $\mu s$
<b>OUTPUT</b> Voltage Output Swing from Rail <sup>(2)</sup> <b>Over Temperature</b> <b>Over Temperature</b> Short-Circuit Current Capacitive Load Drive	$R_L = 100k\Omega, A_{OL} \geq 70dB$ $R_L = 25k\Omega, A_{OL} \geq 90dB$ $R_L = 25k\Omega, A_{OL} \geq 90dB$ $R_L = 5k\Omega, A_{OL} \geq 90dB$ $R_L = 5k\Omega, A_{OL} \geq 90dB$		3 20 70 $\pm 5$ See Text	100 <b>100</b> 500 <b>500</b>		*	*		*	*	mV mV mV mV mA pF
<b>POWER SUPPLY</b> Specified Voltage Range Minimum Operating Voltage Quiescent Current (per amplifier) <b>Over Temperature</b>	$V_S$ $I_Q$ $I_O = 0$ $I_O = 0$	2.3	2.1 20	5.5 32 <b>36</b>	*	*	*	*	*	23 38 <b>42</b>	V V $\mu A$ $\mu A$
<b>TEMPERATURE RANGE</b> Specified Range Operating Range Storage Range Thermal Resistance SOT-23-5 Surface-Mount MSOP-8 Surface-Mount SO-8 Surface-Mount DIP-8 SSOP-16 Surface-Mount DIP-14	$\theta_{JA}$	-40 -55 -55		+85 +125 +125	*	*	*	*	*	*	$^{\circ}C$ $^{\circ}C$ $^{\circ}C$ $^{\circ}C/W$ $^{\circ}C/W$ $^{\circ}C/W$ $^{\circ}C/W$ $^{\circ}C/W$ $^{\circ}C/W$

\*Specifications same as OPA2336E, P, U.

NOTES: (1)  $V_S = +5V$ . (2) Output voltage swings are measured between the output and positive and negative power-supply rails.

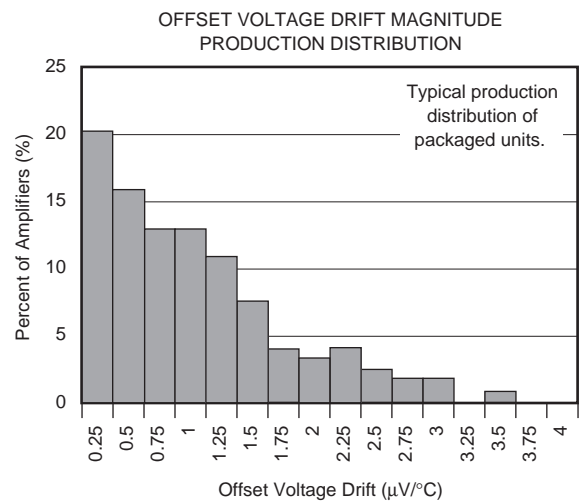
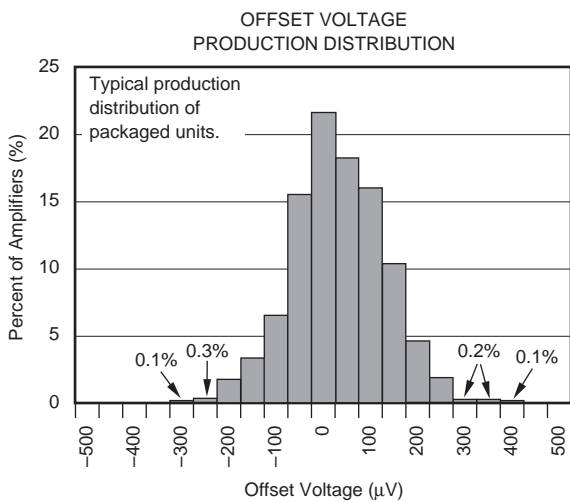
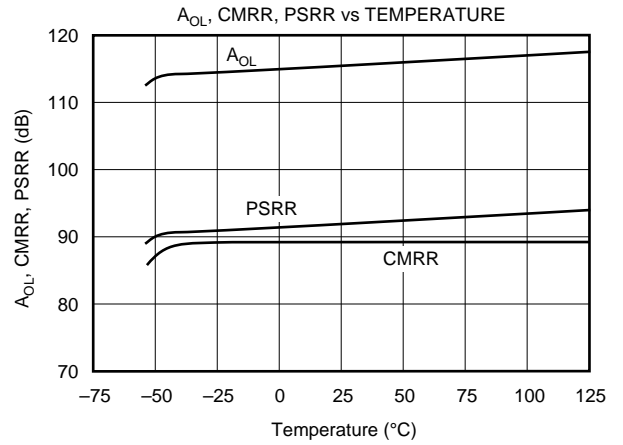
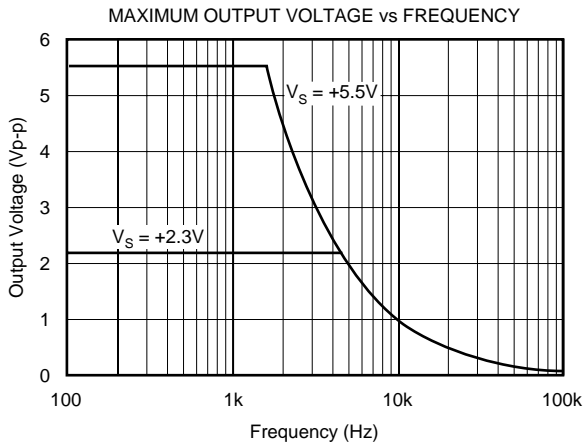
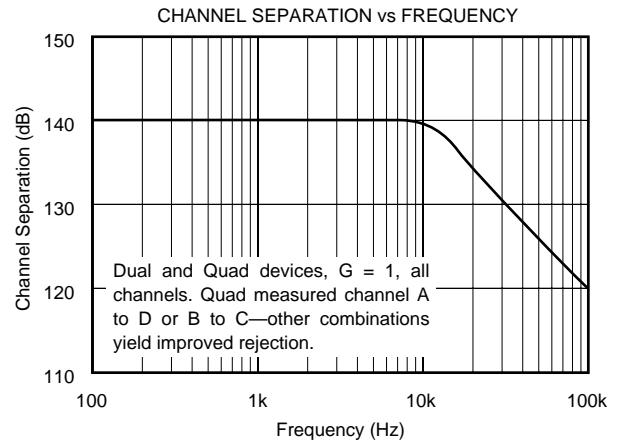
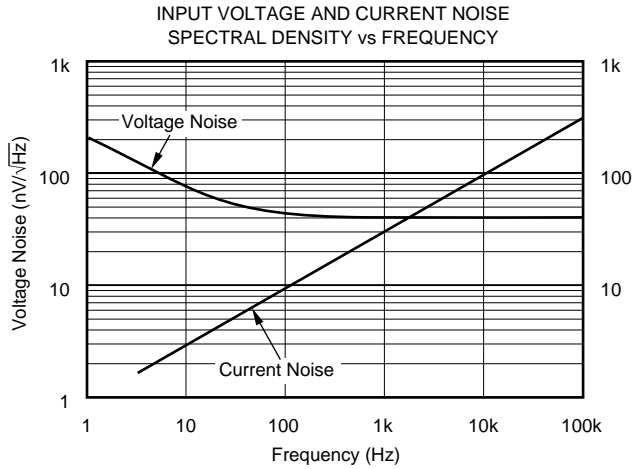
# TYPICAL CHARACTERISTICS

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



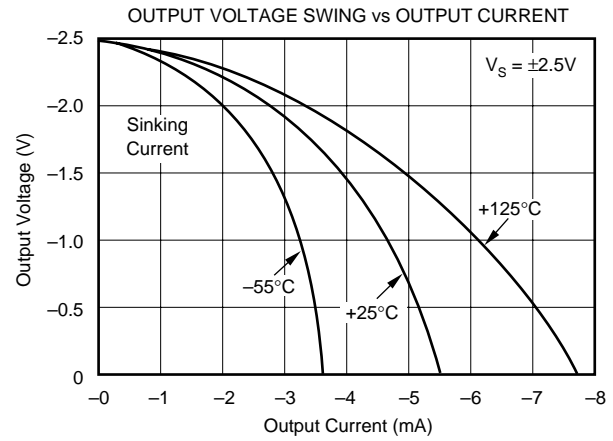
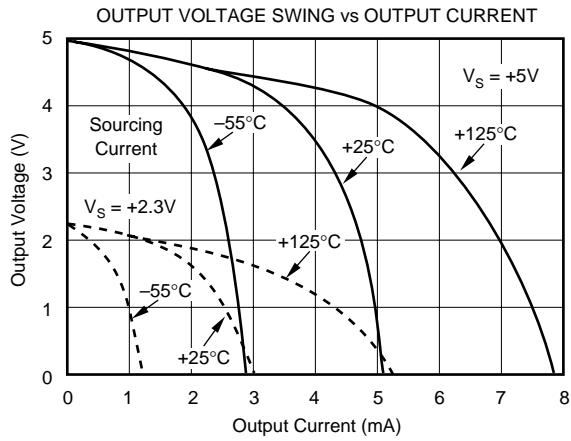
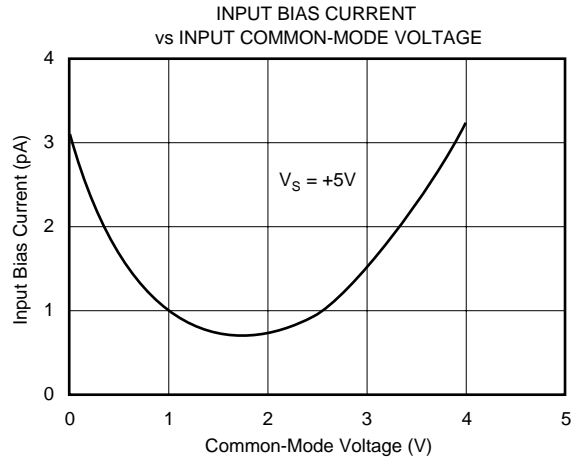
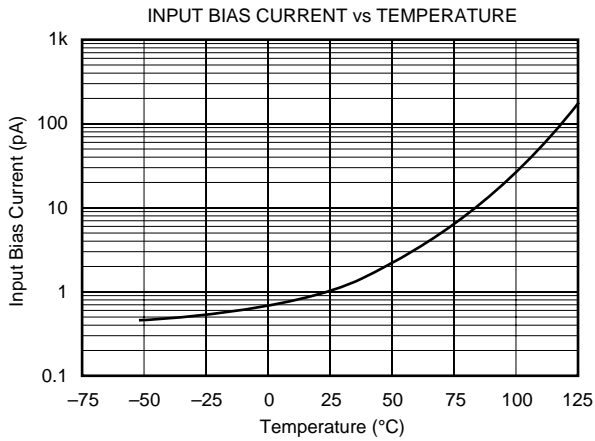
# TYPICAL CHARACTERISTICS (Cont.)

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

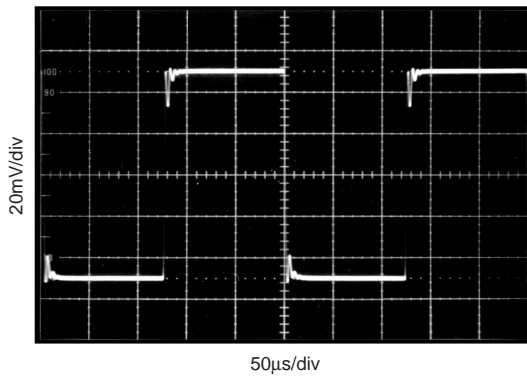


# TYPICAL CHARACTERISTICS (Cont.)

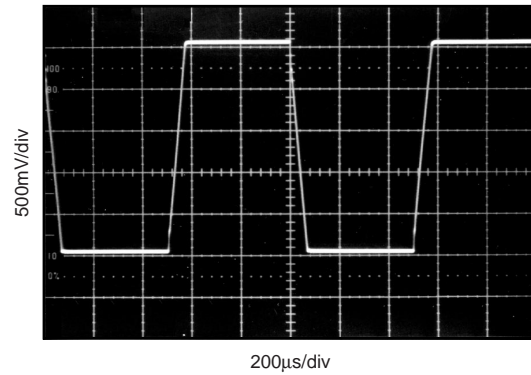
At  $T_A = +25^\circ\text{C}$ ,  $V_S = +5\text{V}$ , and  $R_L = 25\text{k}\Omega$  connected to  $V_S/2$ , unless otherwise noted.



SMALL-SIGNAL STEP RESPONSE  
 $G = 1$ ,  $C_L = 200\text{pF}$ ,  $V_S = +5\text{V}$



LARGE-SIGNAL STEP RESPONSE  
 $G = 1$ ,  $C_L = 620\text{pF}$ ,  $V_S = +5\text{V}$



# APPLICATIONS INFORMATION

OPA336 series op amps are fabricated on a state-of-the-art 0.6 micron CMOS process. They are unity-gain stable and suitable for a wide range of general-purpose applications. Power-supply pins should be bypassed with 0.01μF ceramic capacitors. OPA336 series op amps are protected against reverse battery voltages.

## OPERATING VOLTAGE

OPA336 series op amps can operate from a +2.1V to +5.5V single supply with excellent performance. Most behavior remains unchanged throughout the full operating voltage range. Parameters which vary significantly with operating voltage are shown in the typical characteristics. OPA336 series op amps are fully specified for operation from +2.3V to +5.5V; a single limit applies over the supply range. In addition, many parameters are ensured over the specified temperature range, -40°C to +85°C.

## INPUT VOLTAGE

The input common-mode range of OPA336 series op amps extends from (V-) - 0.2V to (V+) - 1V. For normal operation, inputs should be limited to this range. The absolute maximum input voltage is 300mV beyond the supplies. Thus, inputs greater than the input common-mode range but less than maximum input voltage, while not valid, will not cause any damage to the op amp. Furthermore, the inputs may go beyond the power supplies without phase inversion, as shown in Figure 1, unlike some other op amps.

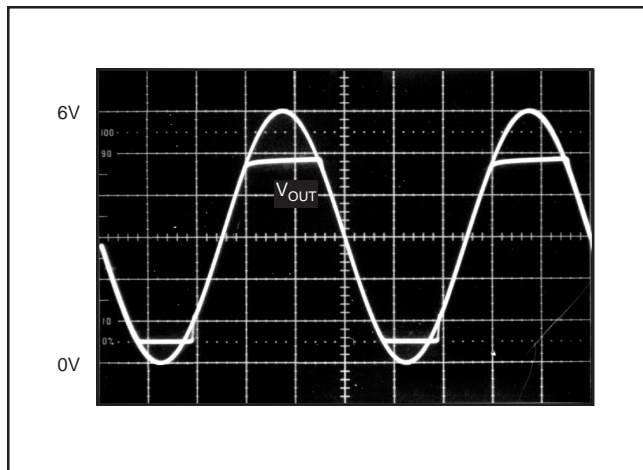


FIGURE 1. No Phase Inversion with Inputs Greater than the Power-Supply Voltage.

Normally, input bias current is approximately 1pA. However, input voltages exceeding the power supplies can cause excessive current to flow in or out of the input pins. Momentary voltages greater than the power supply can be tolerated as long as the current on the input pins is limited to 10mA. This is easily accomplished with an input resistor, as shown in Figure 2.

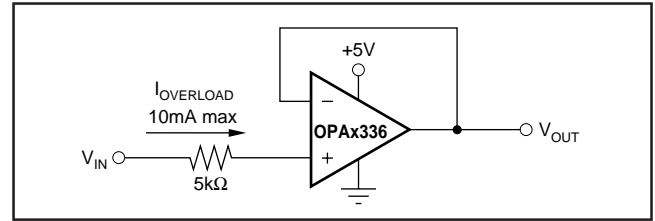


FIGURE 2. Input Current Protection for Voltages Exceeding the Supply Voltage.

## CAPACITIVE LOAD AND STABILITY

OPA336 series op amps can drive a wide range of capacitive loads. However, all op amps under certain conditions may become unstable. Op-amp configuration, gain, and load value are just a few of the factors to consider when determining stability.

When properly configured, OPA336 series op amps can drive approximately 10,000pF. An op amp in unity-gain configuration is the most vulnerable to capacitive load. The capacitive load reacts with the op amp's output resistance, along with any additional load resistance, to create a pole in the response which degrades the phase margin. In unity gain, OPA336 series op amps perform well with a pure capacitive load up to about 300pF. Increasing gain enhances the amplifier's ability to drive loads beyond this level.

One method of improving capacitive load drive in the unity-gain configuration is to insert a 50Ω to 100Ω resistor inside the feedback loop, as shown in Figure 3. This reduces ringing with large capacitive loads while maintaining DC

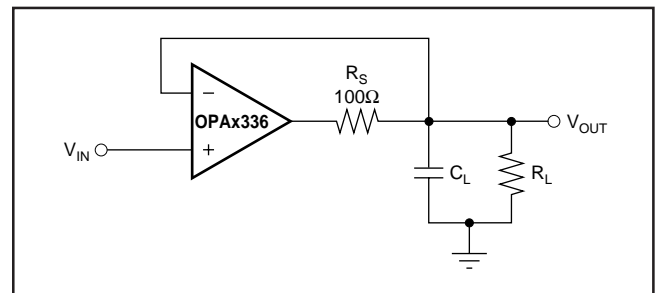


FIGURE 3. Series Resistor in Unity-Gain Configuration Improves Capacitive Load Drive.

accuracy. For example, with  $R_L = 25\text{k}\Omega$ , OPA336 series op amps perform well with capacitive loads in excess of  $1000\text{pF}$ , as shown in Figure 4. Without  $R_S$ , capacitive load drive is typically  $350\text{pF}$  for these conditions, as shown in Figure 5.

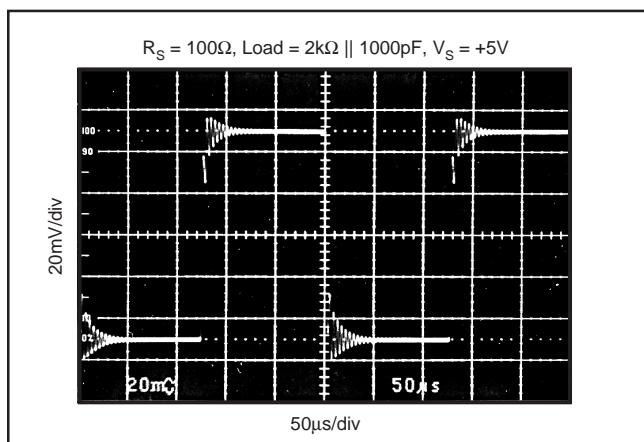


FIGURE 4. Small-Signal Step Response Using Series Resistor to Improve Capacitive Load Drive.

Alternatively, the resistor may be connected in series with the output outside of the feedback loop. However, if there is a resistive load parallel to the capacitive load, it and the series resistor create a voltage divider. This introduces a

Direct Current (DC) error at the output; however, this error may be insignificant. For instance, with  $R_L = 100\text{k}\Omega$  and  $R_S = 100\Omega$ , there is only about a 0.1% error at the output.

Figure 5 shows the recommended operating regions for the OPA336. Decreasing the load resistance generally improves capacitive load drive. Figure 5 also illustrates how stability differs depending on where the resistive load is connected. With  $G = +1$  and  $R_L = 10\text{k}\Omega$  connected to  $V_S/2$ , the OPA336 can typically drive  $500\text{pF}$ . Connecting the same load to ground improves capacitive load drive to  $1000\text{pF}$ .

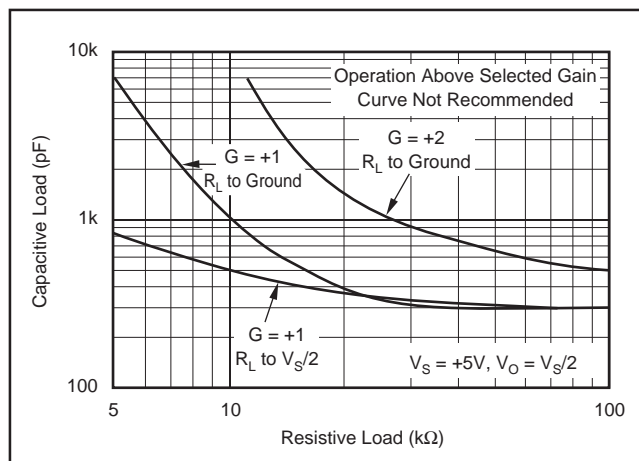


FIGURE 5. Stability—Capacitive Load vs Resistive Load.



**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
OPA2336E/250	ACTIVE	MSOP	DGK	8	250	None	CU NIPDAU	Level-1-235C-UNLIM
OPA2336E/2K5	ACTIVE	MSOP	DGK	8	2500	None	CU NIPDAU	Level-1-235C-UNLIM
OPA2336EA/250	ACTIVE	MSOP	DGK	8	250	None	CU NIPDAU	Level-1-235C-UNLIM
OPA2336EA/2K5	ACTIVE	MSOP	DGK	8	2500	None	CU NIPDAU	Level-1-235C-UNLIM
OPA2336EA/2K5G4	PREVIEW	MSOP	DGK	8	2500	None	Call TI	Call TI
OPA2336P	ACTIVE	PDIP	P	8	50	None	Call TI	Level-NA-NA-NA
OPA2336PA	ACTIVE	PDIP	P	8	50	None	Call TI	Level-NA-NA-NA
OPA2336U	ACTIVE	SOIC	D	8	100	None	CU SNPB	Level-2-220C-1 YEAR
OPA2336U/2K5	ACTIVE	SOIC	D	8	2500	None	CU NIPDAU	Level-2-220C-1 YEAR
OPA2336UA	ACTIVE	SOIC	D	8	100	None	CU SNPB	Level-2-220C-1 YEAR
OPA2336UA/2K5	ACTIVE	SOIC	D	8	2500	None	CU SNPB	Level-2-220C-1 YEAR
OPA2336UA/2K5G4	PREVIEW	SOIC	D	8	2500	None	Call TI	Call TI
OPA336N/250	ACTIVE	SOT-23	DBV	5	250	None	CU NIPDAU	Level-1-235C-UNLIM
OPA336N/3K	ACTIVE	SOT-23	DBV	5	3000	None	CU NIPDAU	Level-1-235C-UNLIM
OPA336NA/250	ACTIVE	SOT-23	DBV	5	250	None	CU NIPDAU	Level-1-235C-UNLIM
OPA336NA/3K	ACTIVE	SOT-23	DBV	5	3000	None	CU NIPDAU	Level-1-235C-UNLIM
OPA336NJ/250	ACTIVE	SOT-23	DBV	5	250	None	CU NIPDAU	Level-3-220C-168 HR
OPA336NJ/3K	ACTIVE	SOT-23	DBV	5	3000	None	CU NIPDAU	Level-3-220C-168 HR
OPA336P	OBSOLETE	PDIP	P	8		None	Call TI	Call TI
OPA336PA	OBSOLETE	PDIP	P	8		None	Call TI	Call TI
OPA336U	ACTIVE	SOIC	D	8	100	None	CU SNPB	Level-2-220C-1 YEAR
OPA336U/2K5	ACTIVE	SOIC	D	8	2500	None	CU SNPB	Level-2-220C-1 YEAR
OPA336UA	ACTIVE	SOIC	D	8	100	None	CU SNPB	Level-2-220C-1 YEAR
OPA336UA/2K5	ACTIVE	SOIC	D	8	2500	None	CU SNPB	Level-2-220C-1 YEAR
OPA4336EA/250	ACTIVE	SSOP/ QSOP	DBQ	16	250	None	CU NIPDAU	Level-3-240C-168 HR
OPA4336EA/2K5	ACTIVE	SSOP/ QSOP	DBQ	16	2500	None	CU NIPDAU	Level-3-240C-168 HR
OPA4336EA/2K5G4	PREVIEW	SSOP/ QSOP	DBQ	16	2500	None	Call TI	Call TI
OPA4336PA	OBSOLETE	PDIP	N	14		None	Call TI	Call TI

<sup>(1)</sup> 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.

<sup>(2)</sup> Eco Plan - May not be currently available - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**None:** Not yet available Lead (Pb-Free).

**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" and in addition, uses package materials that do not contain halogens, including bromine (Br) or antimony (Sb) above 0.1% of total product weight.

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

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P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE



4040082/D 05/98

- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Falls within JEDEC MS-001

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N (R-PDIP-T\*\*)

PLASTIC DUAL-IN-LINE PACKAGE

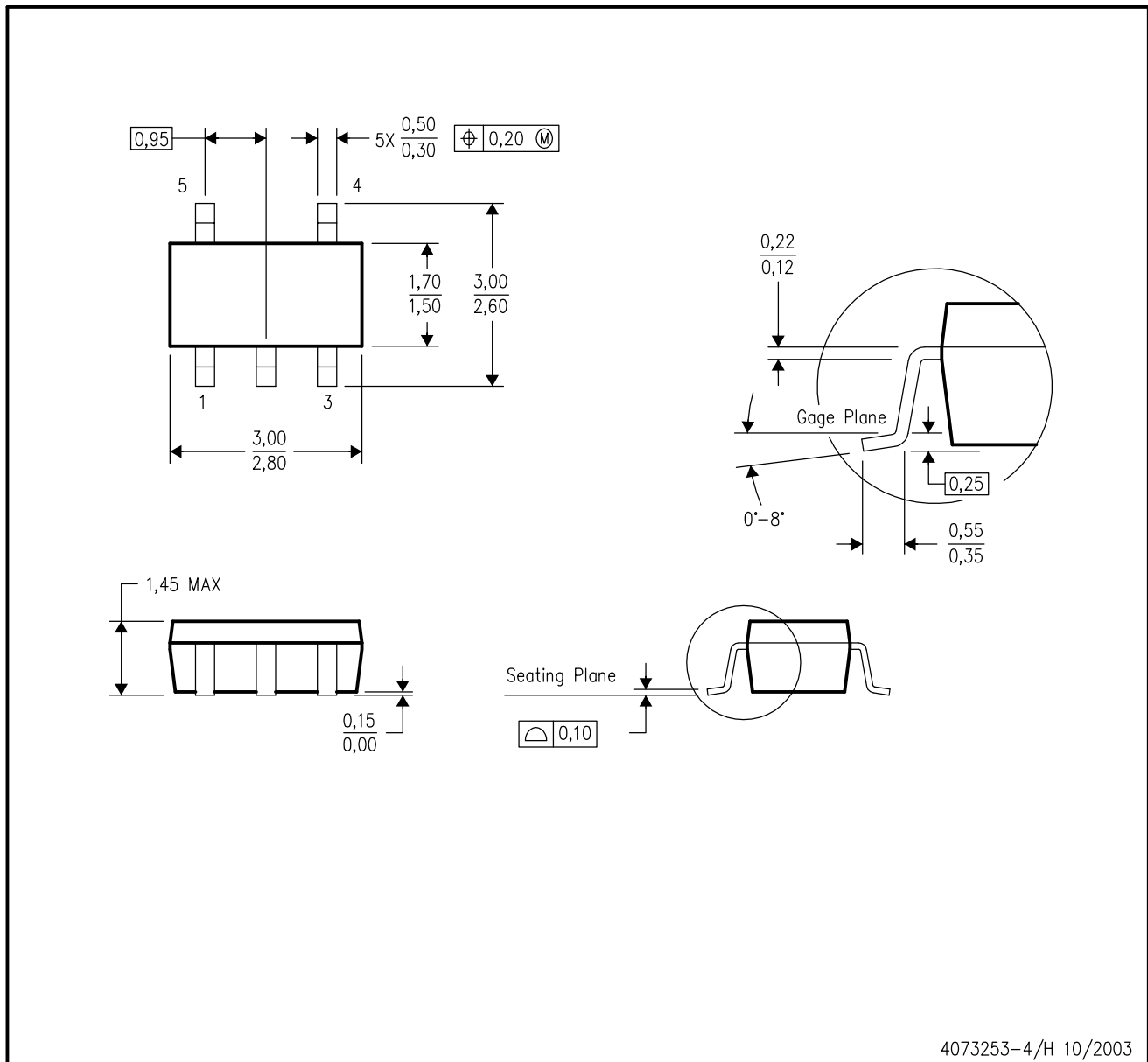
16 PINS SHOWN



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).
  - The 20 pin end lead shoulder width is a vendor option, either half or full width.

DBV (R-PDSO-G5)

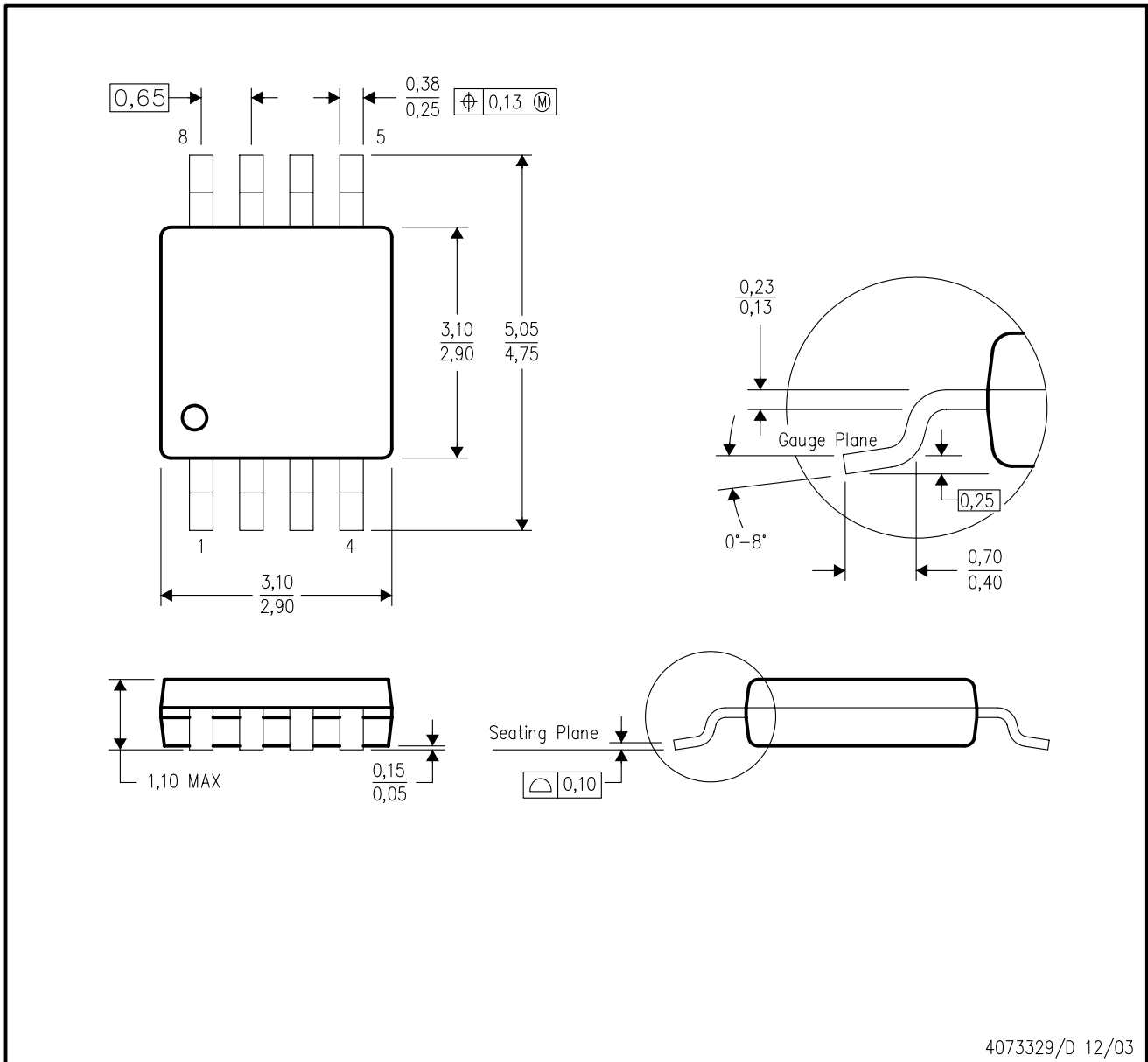
PLASTIC SMALL-OUTLINE PACKAGE



- 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-178 Variation AA.

DGK (S-PDSO-G8)

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-187 variation AA.

D (R-PDSO-G8)

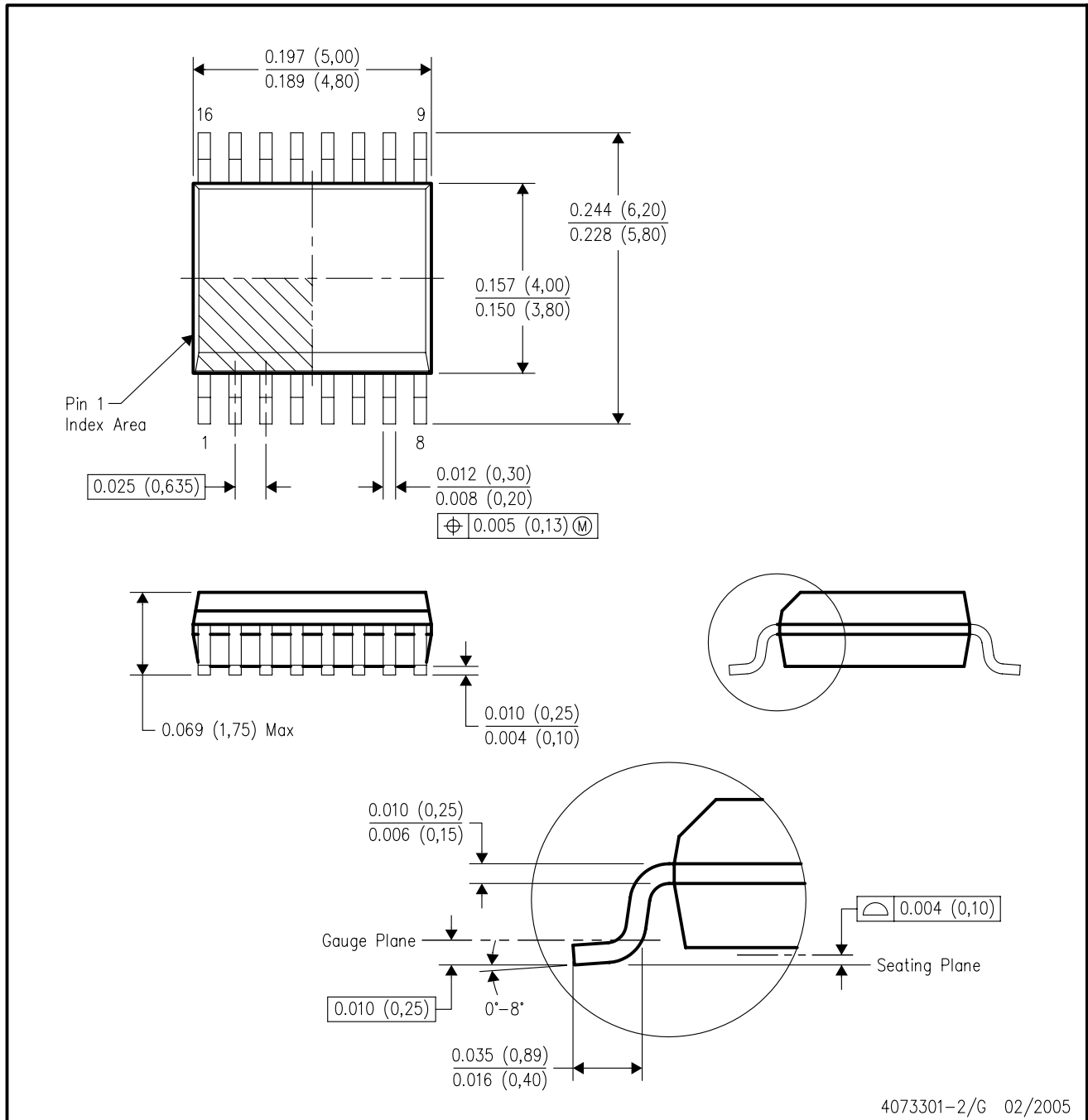
PLASTIC SMALL-OUTLINE PACKAGE



- 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.

DBQ (R-PDSO-G16)

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) per side.
  - D. Falls within JEDEC MO-137 variation AB.



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