



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

FEATURES

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

APPLICATIONS

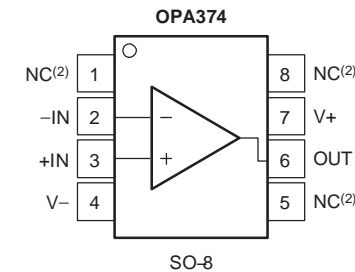
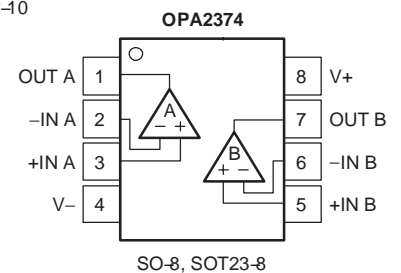
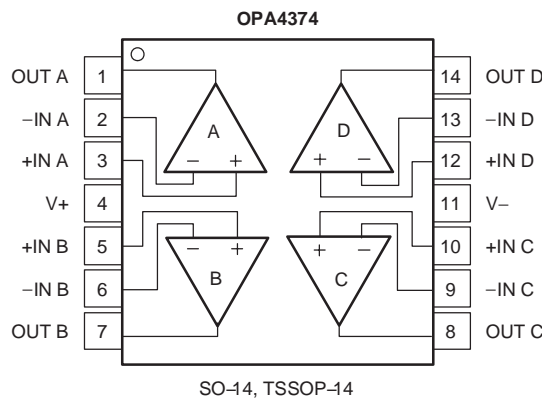
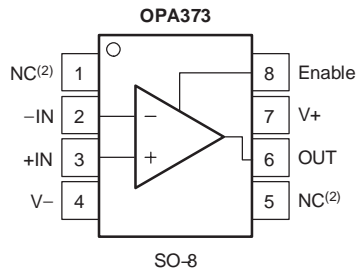
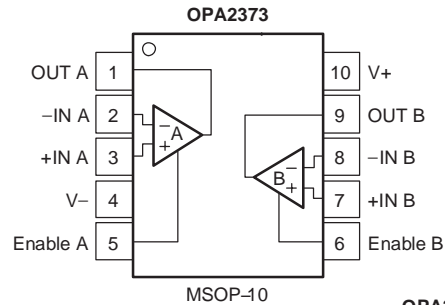
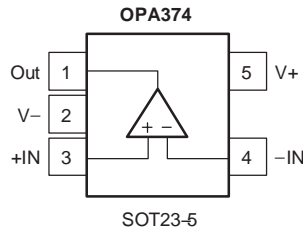
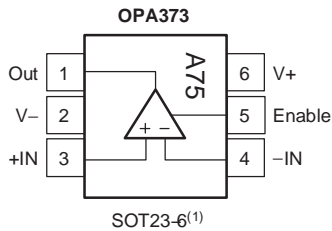
- **PORTABLE EQUIPMENT**
- **BATTERY-POWERED DEVICES**
- **ACTIVE FILTERS**
- **DRIVING A/D CONVERTERS**

DESCRIPTION

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

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

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



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



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(1)

PRODUCT	PACKAGE-LEAD	PACKAGE DESIGNATOR	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
Shutdown						
OPA373	SOT23-6	DBV	-40°C to +125°C	A75	OPA373AIDBVT	Tape and Reel, 250
"	"	"	"	"	OPA373AIDBVR	Tape and Reel, 3000
OPA373	SO-8	D	-40°C to +125°C	OPA373A	OPA373AID	Rails, 100
"	"	"	"	"	OPA373AIDR	Tape and Reel, 2500
OPA2373	MSOP-10	DGS	-40°C to +125°C	AYO	OPA2373AIDGST	Tape and Reel, 250
"	"	"	"	"	OPA2373AIDGSR	Tape and Reel, 2500
Non-Shutdown						
OPA374	SOT23-5	DBV	-40°C to +125°C	A74	OPA374AIDBVT	Tape and Reel, 250
"	"	"	"	"	OPA374AIDBVR	Tape and Reel, 3000
OPA374	SO-8	D	-40°C to +125°C	OPA274A	OPA374AID	Rails, 100
"	"	"	"	"	OPA374AIDR	Tape and Reel, 2500
OPA2374	SOT23-8	DCN	-40°C to +125°C	B74	OPA2374AIDCNT	Tape and Reel, 250
"	"	"	"	"	OPA2374AIDCNR	Tape and Reel, 3000
OPA2374	SO-8	D	-40°C to +125°C	OPA2374A	OPA2374AID	Rails, 100
"	"	"	"	"	OPA2374AIDR	Tape and Reel, 2500
OPA4374	SO-14	D	-40°C to +125°C	OPA4374A	OPA4374AID	Rails, 58
"	"	"	"	"	OPA4374AIDR	Tape and Reel, 2500
OPA4374	TSSOP-14	PW	-40°C to +125°C	OPA4374A	OPA4374AIPWT	Tape and Reel, 250
"	"	"	"	"	OPA4374AIPWR	Tape and Reel, 2500

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

ABSOLUTE MAXIMUM RATINGS(1)

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

- (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.
- (2) Input terminals are diode-clamped to the power-supply rails. Input signals that can swing more than 0.5V beyond the supply rails should be current-limited to 10mA or less.
- (3) Short-circuit to ground, one amplifier per package.



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

Boldface limits apply over the specified temperature range, $T_A = -40^\circ C$ to $+125^\circ C$.

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

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

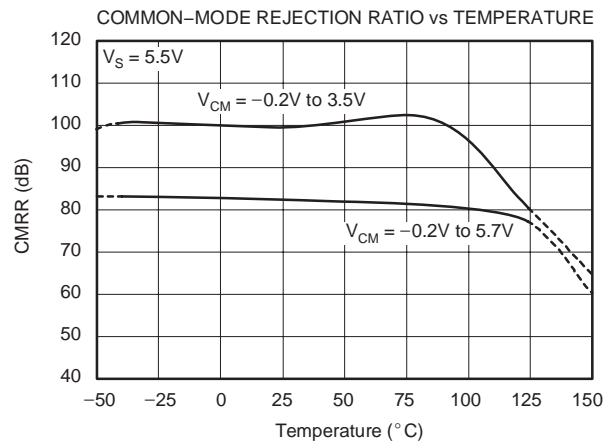
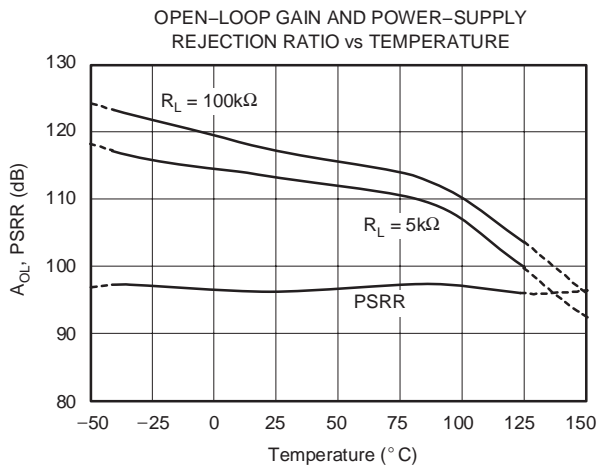
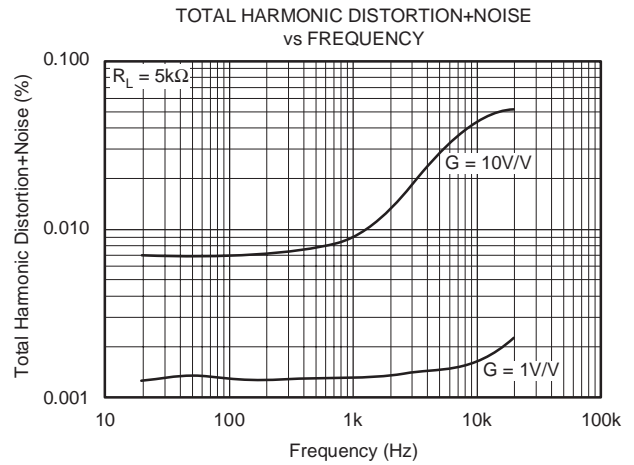
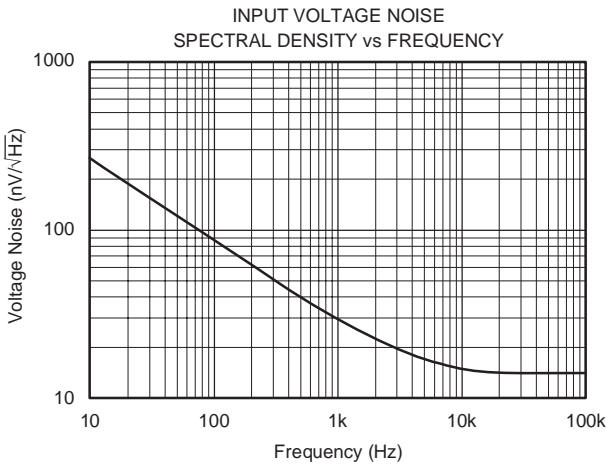
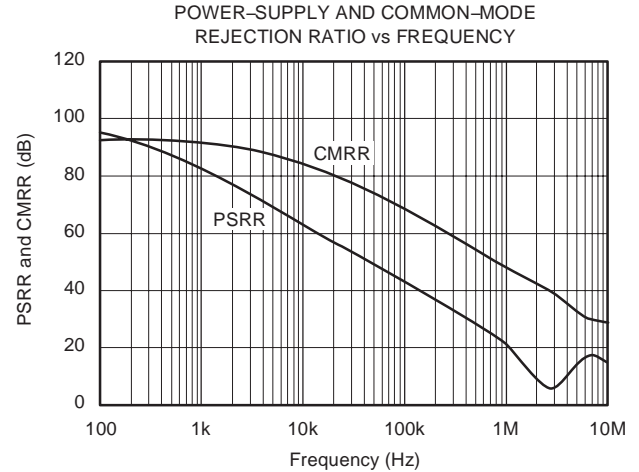
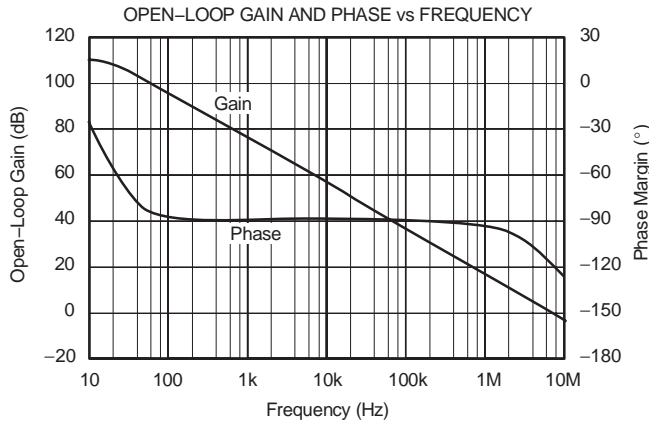
ELECTRICAL CHARACTERISTICS: $V_S = +2.7V$ to $+5.5V$ (continued)
Boldface limits apply over the specified temperature range, $T_A = -40^\circ C$ to $+125^\circ C$.

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

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

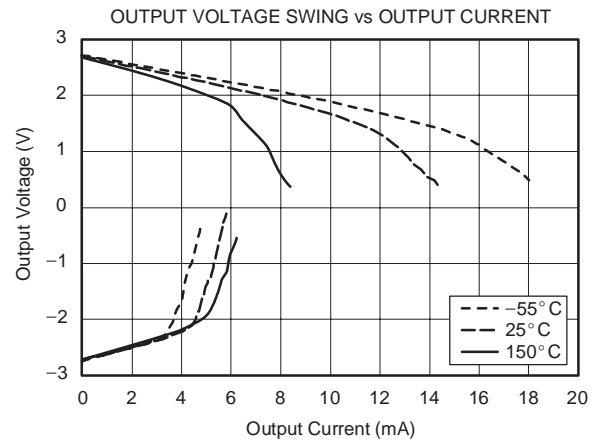
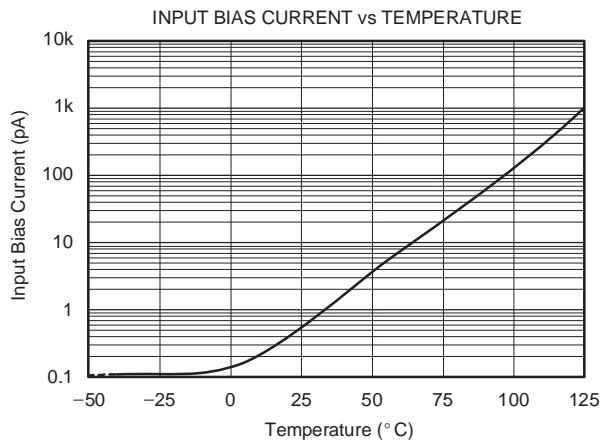
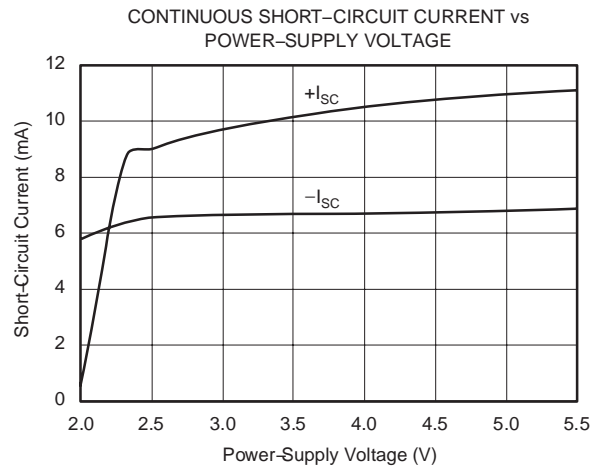
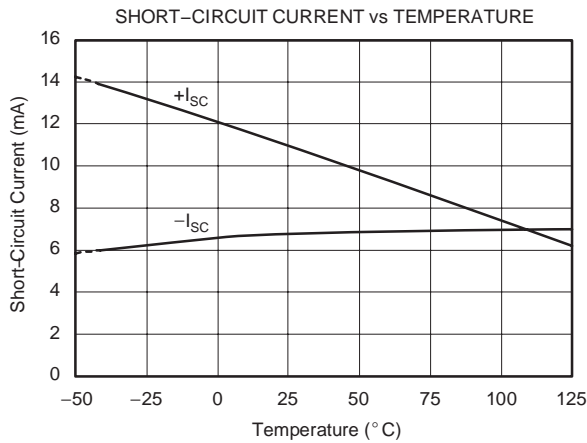
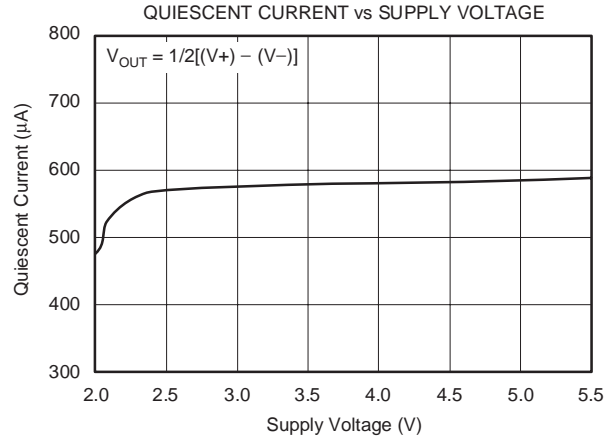
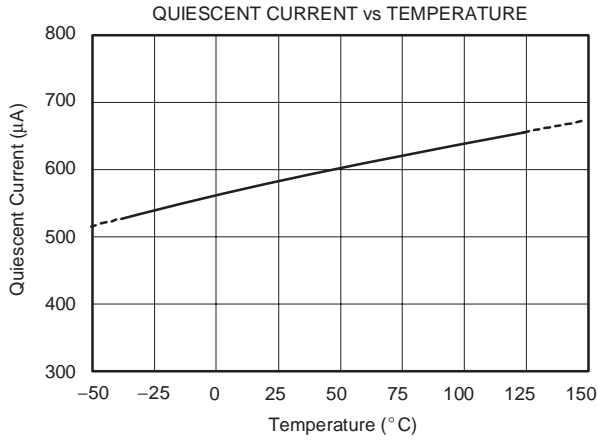
TYPICAL CHARACTERISTICS

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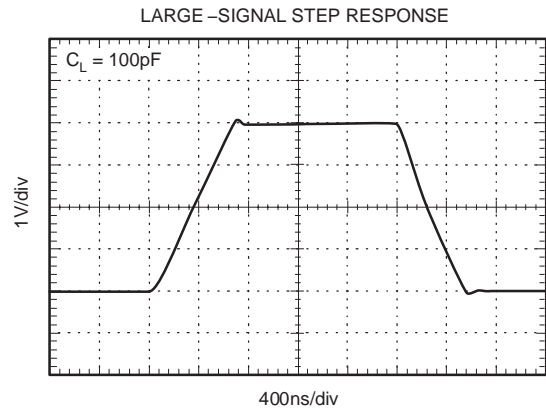
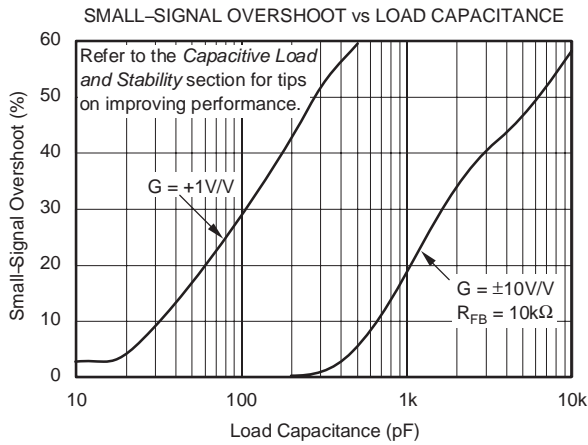
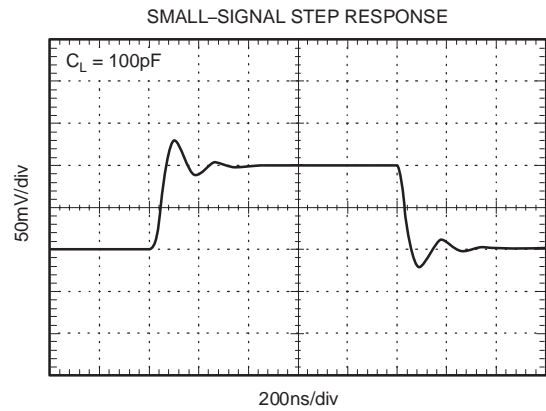
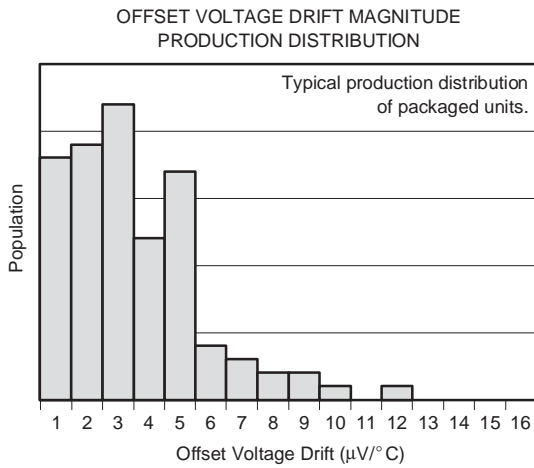
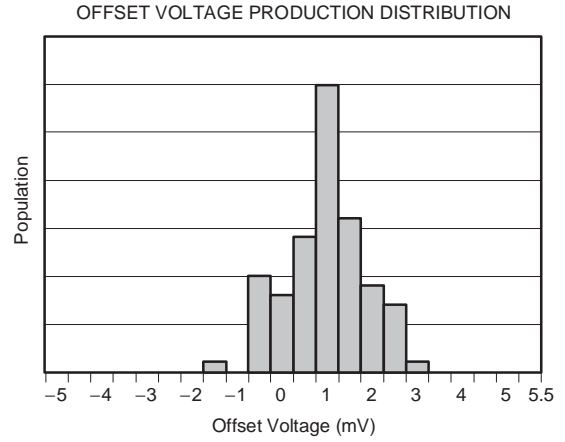
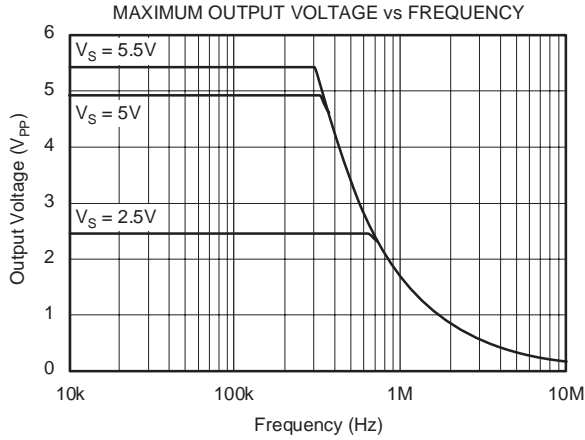
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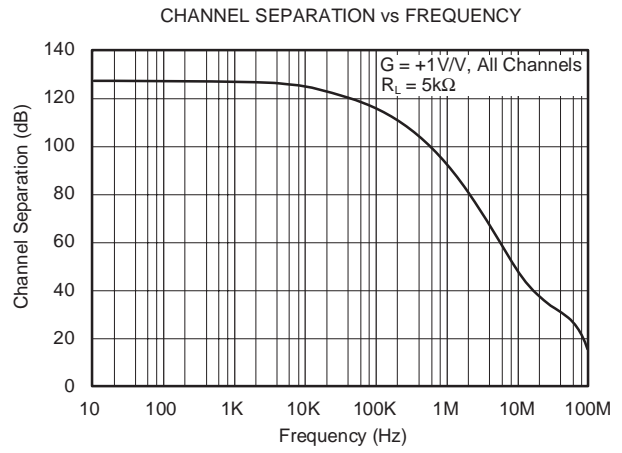
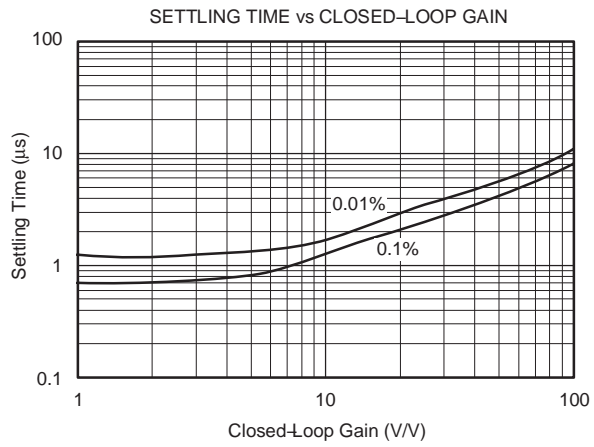
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TYPICAL CHARACTERISTICS (continued)

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



APPLICATIONS

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

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

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

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

OPERATING VOLTAGE

The OPA373 and OPA374 op amps are specified and tested over a power-supply range of +2.7V to +5.5V ($\pm 1.35V$ to $\pm 2.75V$). However, the supply voltage may range from +2.3V to +5.5V ($\pm 1.15V$ to $\pm 2.75V$). Supply voltages higher than 7.0V (absolute maximum) can permanently damage the amplifier. Parameters that vary over supply voltage or temperature are shown in the Typical Characteristics section of this data sheet.

COMMON-MODE VOLTAGE RANGE

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

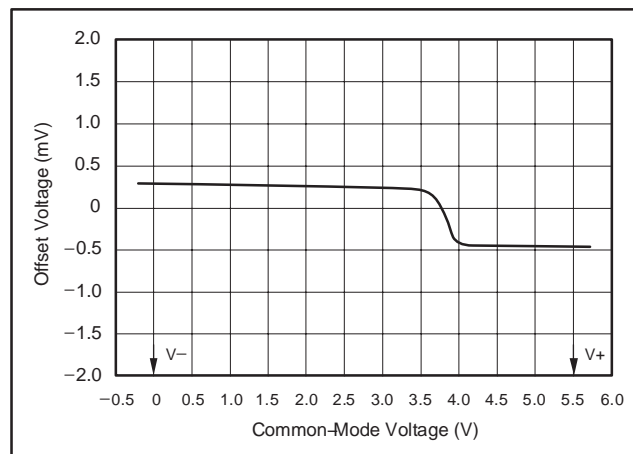


Figure 1. Behavior of Typical Transition Region at Room Temperature

RAIL-TO-RAIL INPUT

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

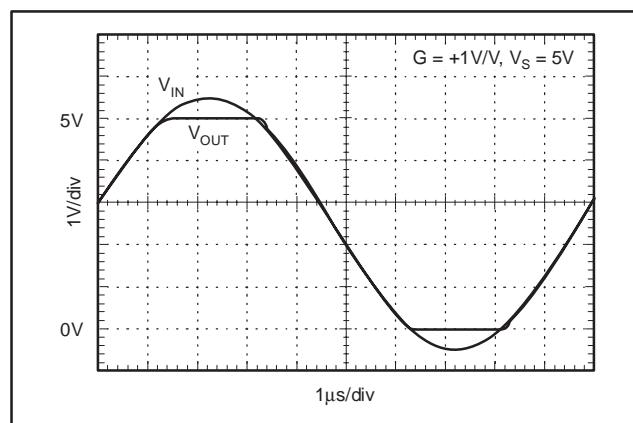


Figure 2. OPA373: No Phase Inversion with Inputs Greater Than the Power-Supply Voltage

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

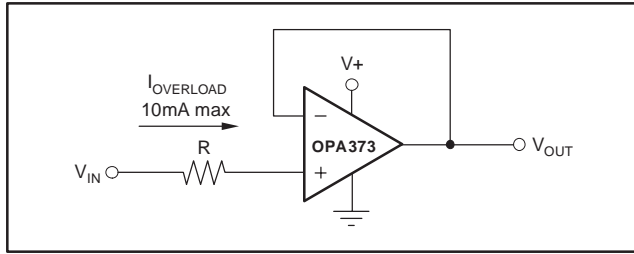


Figure 3. Input Current Protection for Voltages Exceeding the Supply Voltage

RAIL-TO-RAIL OUTPUT

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

CAPACITIVE LOAD AND STABILITY

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

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

In unity-gain inverter configuration, phase margin can be reduced by the reaction between the capacitance at the op amp input and the gain setting resistors, thus degrading capacitive load drive. Best performance is achieved by using small valued resistors. However, when large valued resistors cannot be avoided, a small (4pF to 6pF)

capacitor, C_{FB} , can be inserted in the feedback, as shown in Figure 5. This significantly reduces overshoot by compensating the effect of capacitance, C_{IN} , which includes the amplifier input capacitance and PC board parasitic capacitance.

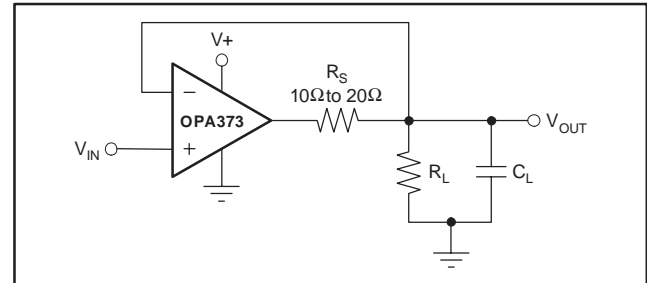


Figure 4. Series Resistor in Unity-Gain Configuration Improves Capacitive Load Drive

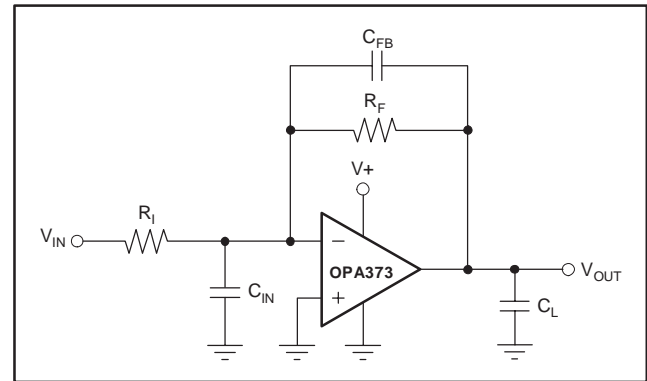


Figure 5. Improving Capacitive Load Drive

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

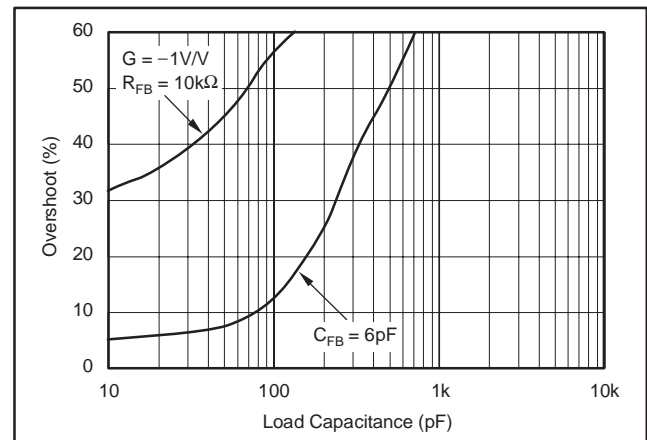


Figure 6. Improving Capacitive Load Drive

DRIVING ADCs

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

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

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

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

ENABLE/SHUTDOWN

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

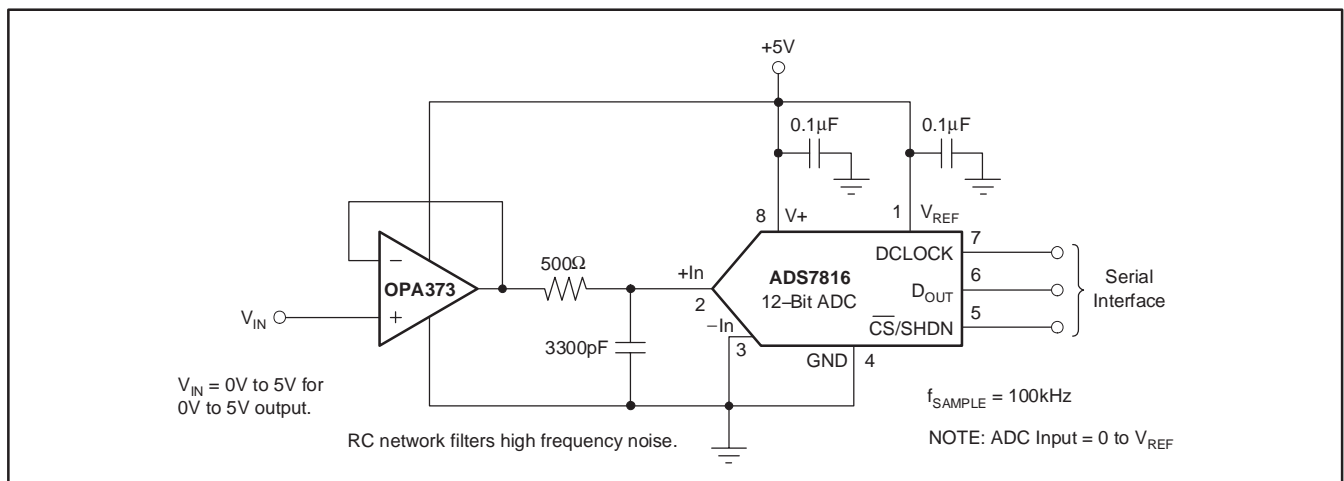


Figure 7. The OPA373 in Noninverting Configuration Driving the ADS7816

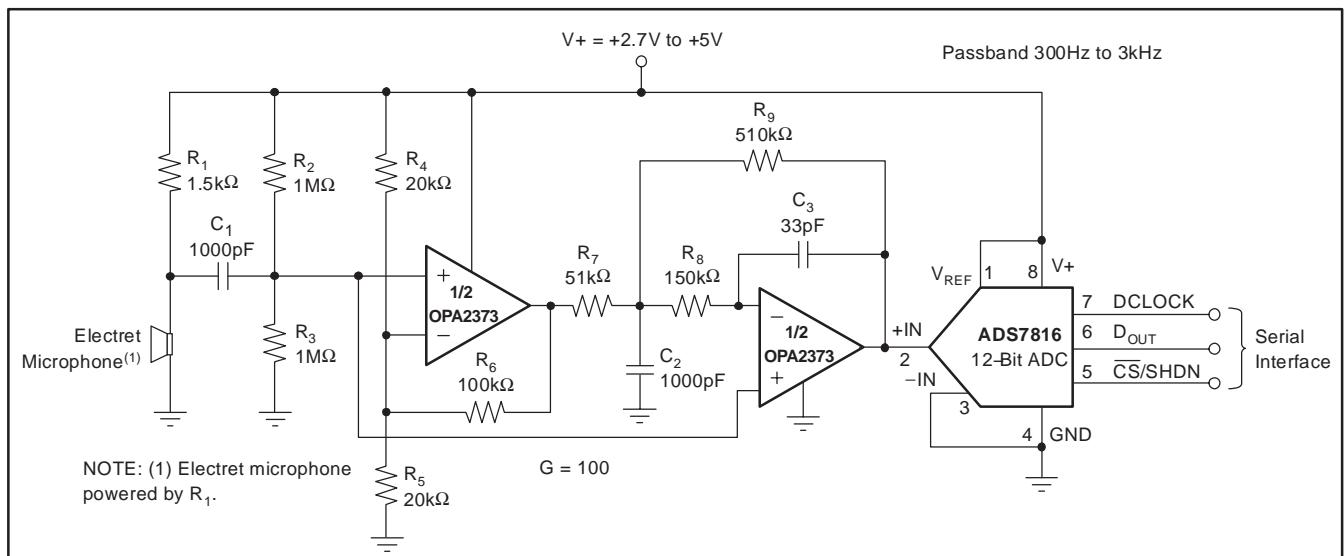


Figure 8. The OPA2373 as a Speech Bypass Filtered Data Acquisition System

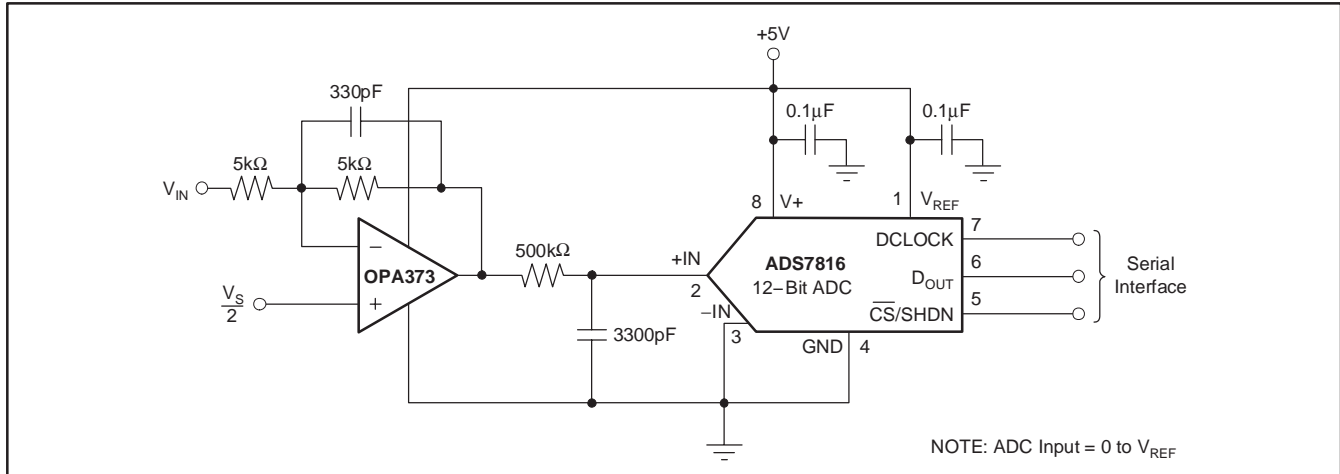


Figure 9. The OPA373 in Inverting Configuration Driving the ADS7816

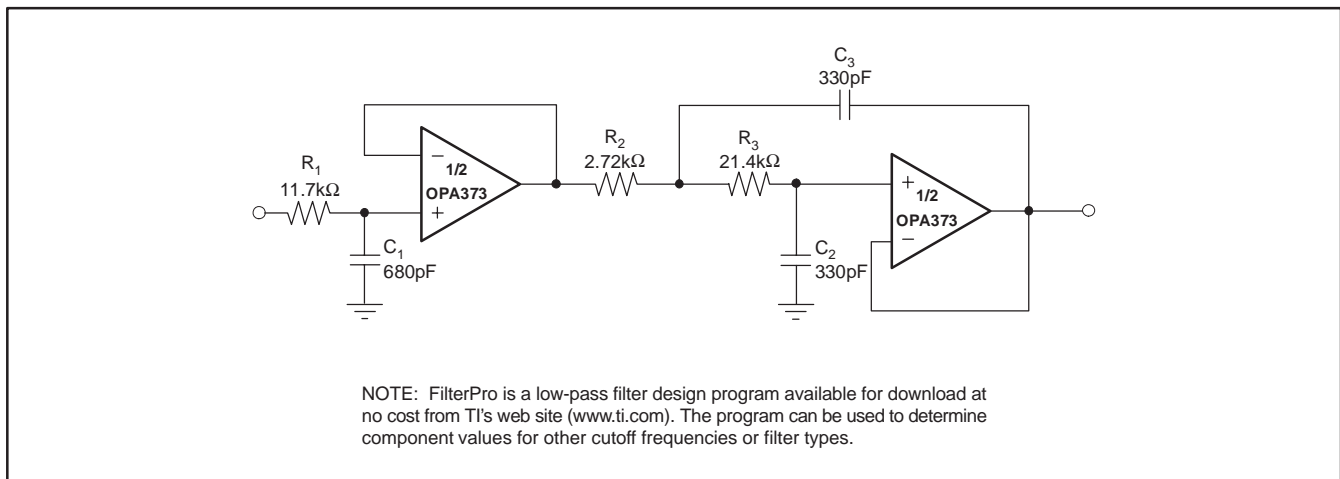
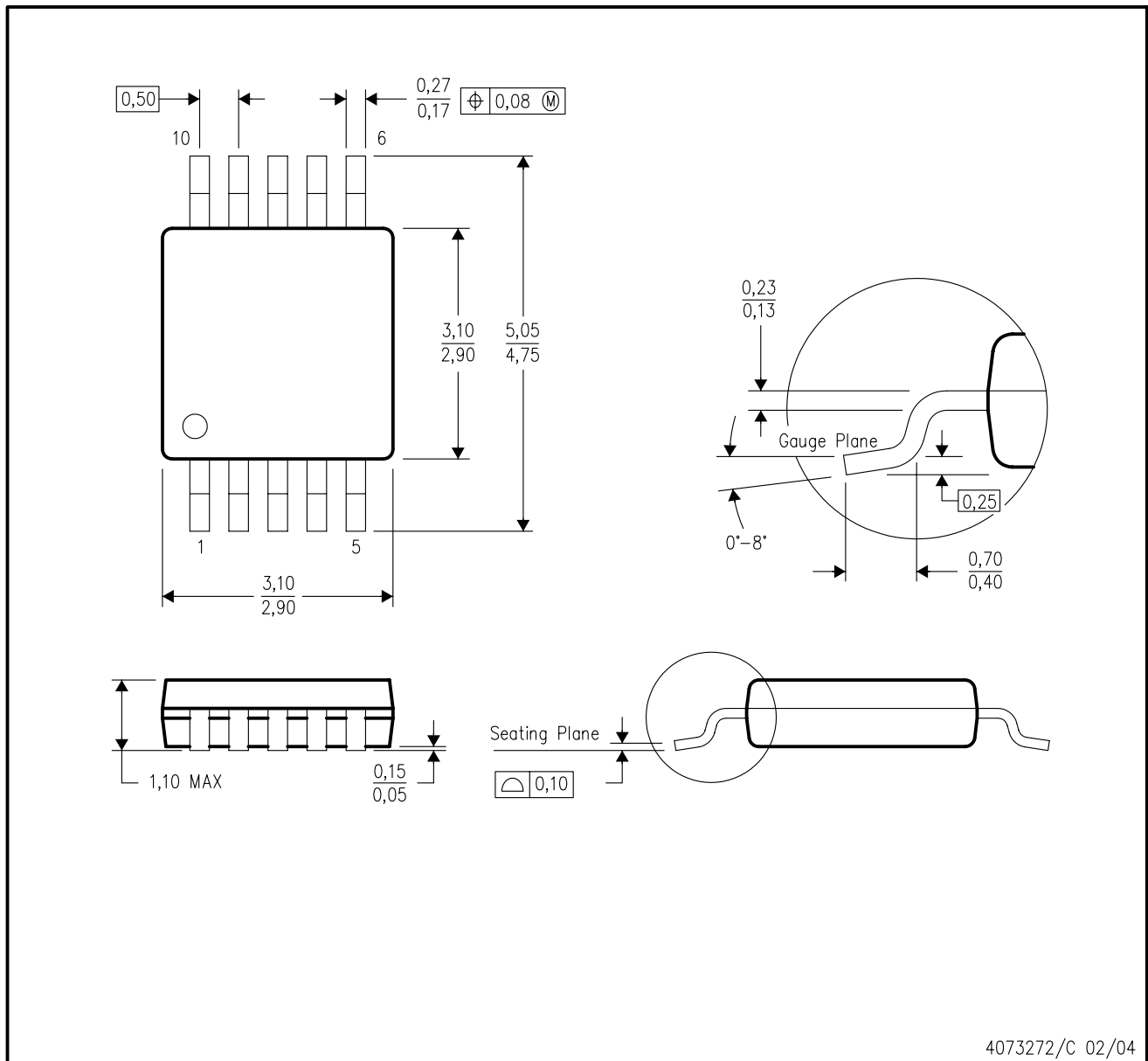


Figure 10. Three-Pole Sallen-Key Butterworth Low-Pass Filter

DGS (S-PDSO-G10)

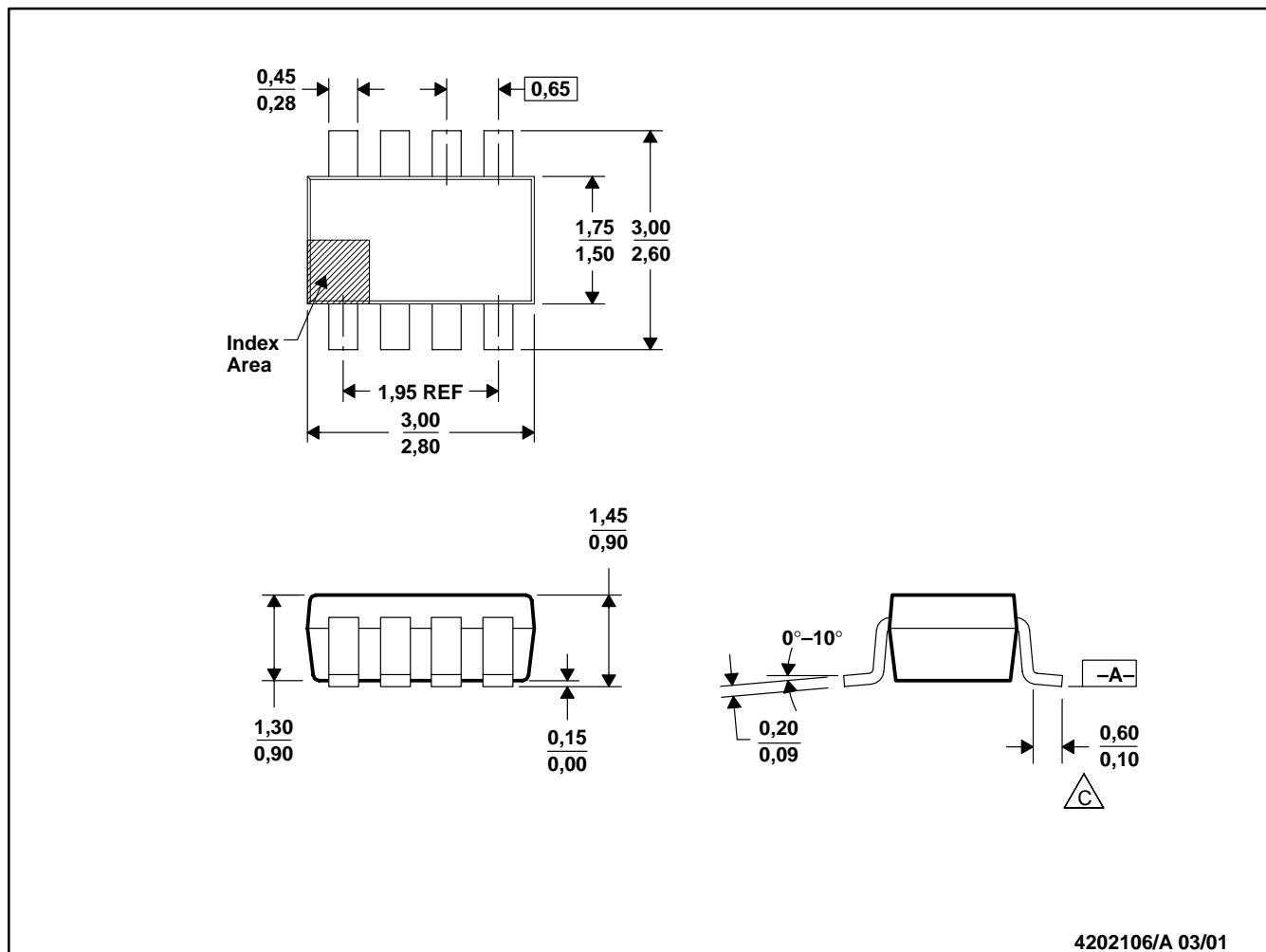
PLASTIC SMALL-OUTLINE PACKAGE



- 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 BA.

DCN (R-PDSO-G8)

PLASTIC SMALL-OUTLINE

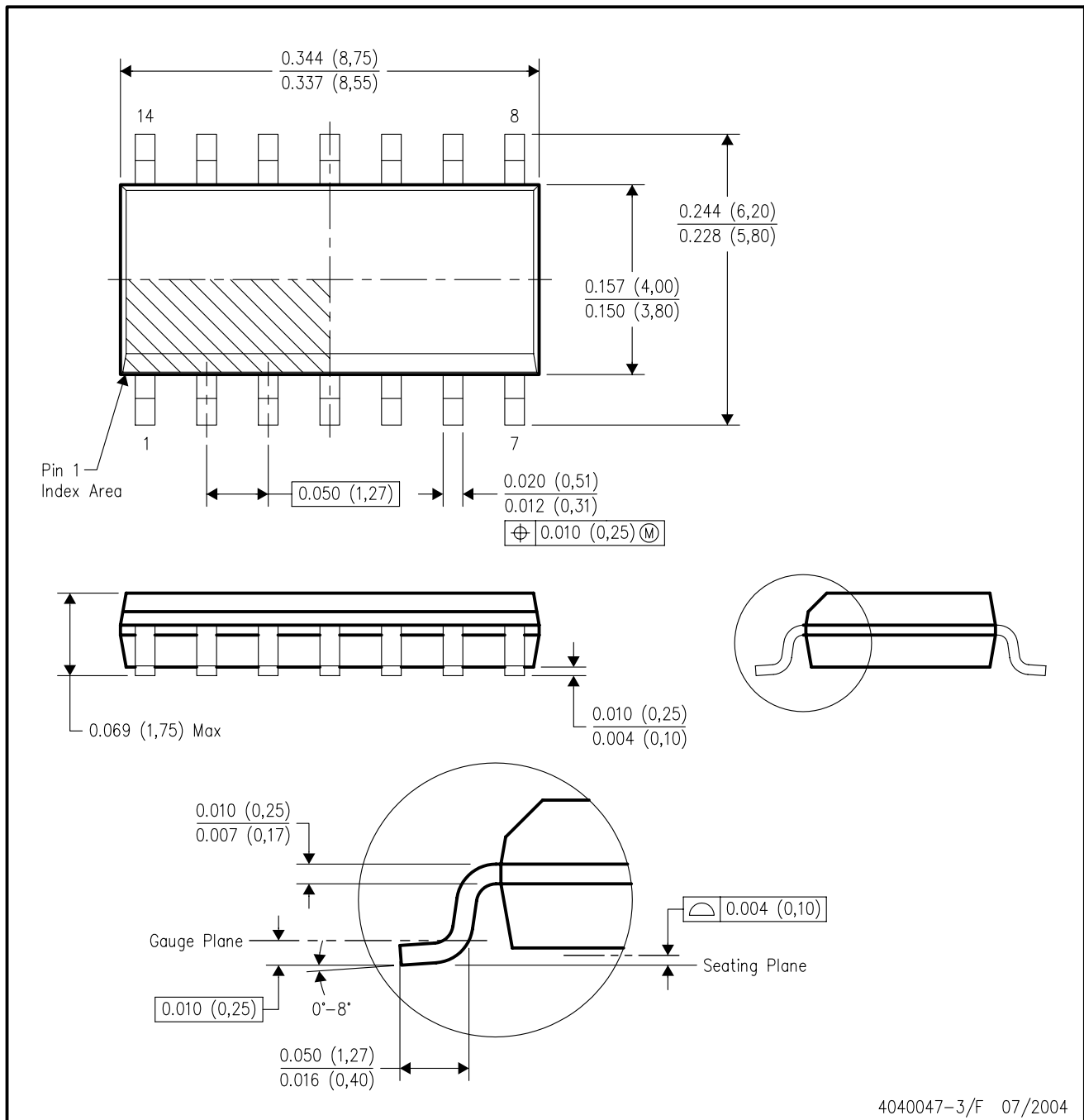


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 B. This drawing is subject to change without notice.
 C. Foot length measured reference to flat foot surface parallel to Datum A.
 D. Package outline exclusive of mold flash, metal burr and dambar protrusion/intrusion.
 E. Package outline inclusive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

D (R-PDSO-G14)

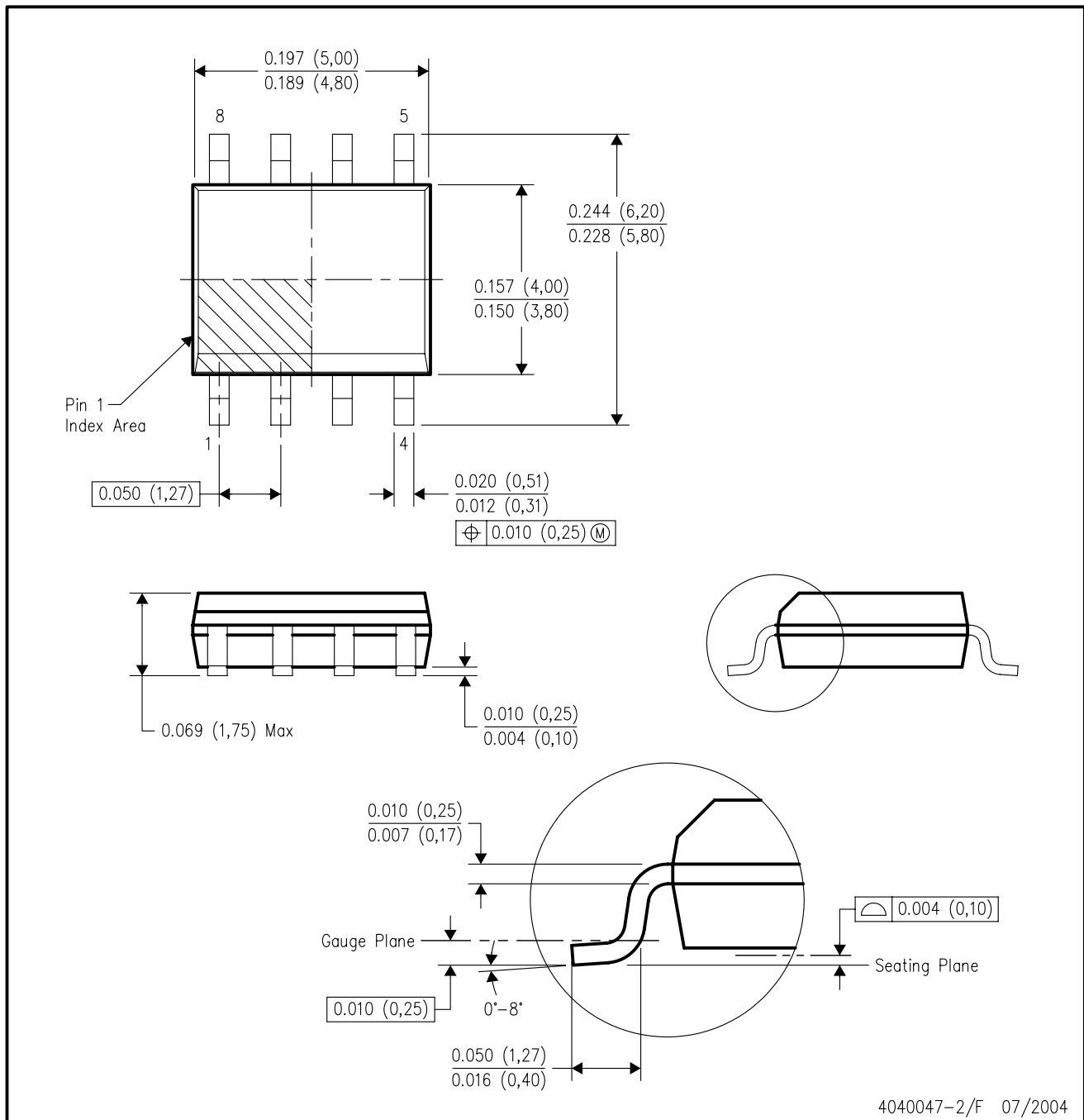
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D (R-PDSO-G8)

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 - D. Falls within JEDEC MS-012 variation AA.

PW (R-PDSO-G**)

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14 PINS SHOWN



4040064/F 01/97

- NOTES: A. All linear dimensions are in millimeters.
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 C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
 D. Falls within JEDEC MO-153

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