

# 1MHz, 45µA, CMOS, Rail-to-Rail OPERATIONAL AMPLIFIERS Value Line Series

Check for Samples: [OPA348](#), [OPA2348](#), [OPA4348](#)

## FEATURES

- **LOW  $I_Q$ :** 45µA Typical
- **LOW COST**
- **RAIL-TO-RAIL INPUT AND OUTPUT**
- **SINGLE SUPPLY:** +2.1V to +5.5V
- **INPUT BIAS CURRENT:** 0.5pA
- **MicroSIZE PACKAGES:** SC70-5, SOT23-8 and TSSOP-14
- **HIGH SPEED: POWER WITH BANDWIDTH:** 1MHz

## APPLICATIONS

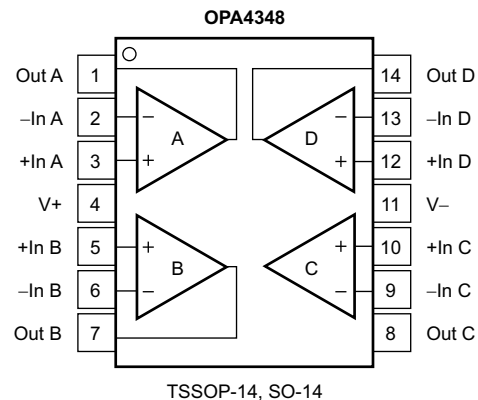
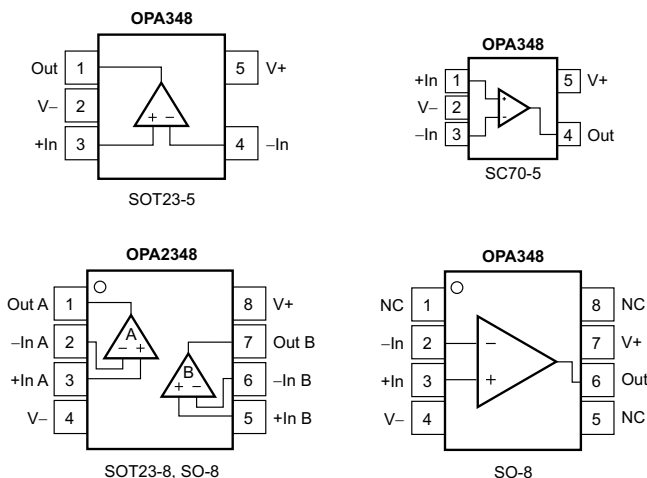
- **PORTABLE EQUIPMENT**
- **BATTERY-POWERED EQUIPMENT**
- **SMOKE ALARMS**
- **CO DETECTORS**
- **MEDICAL INSTRUMENTATION**

## DESCRIPTION

The OPA348 series amplifiers are single supply, low-power, CMOS op amps in micro packaging. Featuring an extended bandwidth of 1MHz, and a supply current of 45µA, the OPA348 series is useful for low-power applications on single supplies of 2.1V to 5.5V.

Low supply current of 45µA, and an input bias current of 0.5pA, make the OPA348 series an optimal candidate for low-power, high-impedance applications such as smoke detectors and other sensors.

The OPA348 is available in the miniature SC70-5, SOT23-5 and SO-8 packages. The OPA2348 is available in SOT23-8 and SO-8 packages, and the OPA4348 is offered in space-saving TSSOP-14 and SO-14 packages. The extended temperature range of –40°C to +125°C over all supply voltages offers additional design flexibility.



| PACKAGES | OPA348 | OPA2348 | OPA4348 |
|----------|--------|---------|---------|
| MSOP-8   |        | X       |         |
| SC70-5   | X      |         |         |
| SO-8     | X      | X       |         |
| SO-14    |        |         | X       |
| SOT23-5  | X      |         |         |
| SOT23-8  |        | X       |         |
| TSSOP-14 |        |         | X       |



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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

For the most current package and ordering information, see the Package Option Addendum at the end of this document, or visit the device product folder at [www.ti.com](http://www.ti.com).

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

|                                                  | VALUE                                              | UNIT |
|--------------------------------------------------|----------------------------------------------------|------|
| Supply Voltage, V <sub>-</sub> to V <sub>+</sub> | 7.5                                                | V    |
| Signal Input Terminals, Voltage <sup>(2)</sup>   | (V <sub>-</sub> ) – 0.5 to (V <sub>+</sub> ) + 0.5 | V    |
| Signal Input Terminals, Current <sup>(2)</sup>   | 10                                                 | mA   |
| Output Short-Circuit <sup>(3)</sup>              | Continuous                                         |      |
| Operating Temperature                            | –65 to +150                                        | °C   |
| Storage Temperature                              | –65 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. Functional operation of the device at these conditions, or beyond the specified operating conditions, is not implied.
- (2) Input terminals are not 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.

**ELECTRICAL CHARACTERISTICS:  $V_S = 2.5V$  to  $5.5V$** 
**Boldface** limits apply over the specified temperature range,  $T_A = -40^{\circ}C$  to  $+125^{\circ}C$ .

At  $T_A = +25^{\circ}C$ ,  $R_L = 100k\Omega$  connected to  $V_S / 2$  and  $V_{OUT} = V_S / 2$ , unless otherwise noted.

| PARAMETER                                     | TEST CONDITIONS                                           | OPA348, OPA2348, OPA4348                    |                       |              | UNIT                                |
|-----------------------------------------------|-----------------------------------------------------------|---------------------------------------------|-----------------------|--------------|-------------------------------------|
|                                               |                                                           | MIN                                         | TYP                   | MAX          |                                     |
| <b>OFFSET VOLTAGE</b>                         |                                                           |                                             |                       |              |                                     |
| Input Offset Voltage $V_{OS}$                 | $V_S = 5V$ , $V_{CM} = (V-) + 0.8V$                       |                                             | 1                     | 5            | mV                                  |
| <b>Over Temperature</b>                       |                                                           |                                             |                       | <b>6</b>     | <b>mV</b>                           |
| <b>Drift</b> $dV_{OS}/dT$                     |                                                           |                                             | <b>4</b>              |              | <b><math>\mu V/^{\circ}C</math></b> |
| vs Power Supply PSRR                          | $V_S = 2.5V$ to $5.5V$ , $V_{CM} < (V+) - 1.7V$           |                                             | 60                    | 175          | $\mu V/V$                           |
| <b>Over Temperature</b>                       | $V_S = 2.5V$ to $5.5V$ , $V_{CM} < (V+) - 1.7V$           |                                             |                       | <b>300</b>   | <b><math>\mu V/V</math></b>         |
| Channel Separation, dc                        |                                                           |                                             | 0.2                   |              | $\mu V/V$                           |
| $f = 1kHz$                                    |                                                           |                                             | 134                   |              | dB                                  |
| <b>INPUT VOLTAGE RANGE</b>                    |                                                           |                                             |                       |              |                                     |
| Common-Mode Voltage Range $V_{CM}$            |                                                           | $(V-) - 0.2$                                |                       | $(V+) + 0.2$ | V                                   |
| Common-Mode Rejection Ratio CMRR              | $(V-) - 0.2V < V_{CM} < (V+) - 1.7V$                      | 70                                          | 82                    |              | dB                                  |
| <b>over Temperature</b>                       | $(V-) < V_{CM} < (V+) - 1.7V$                             | <b>66</b>                                   |                       |              | <b>dB</b>                           |
|                                               | $V_S = 5.5V$ , $(V-) - 0.2V < V_{CM} < (V+) + 0.2V$       | 60                                          | 71                    |              | dB                                  |
| <b>over Temperature</b>                       | $V_S = 5.5V$ , $(V-) < V_{CM} < (V+)$                     | <b>56</b>                                   |                       |              | <b>dB</b>                           |
| <b>INPUT BIAS CURRENT</b>                     |                                                           |                                             |                       |              |                                     |
| Input Bias Current $I_B$                      |                                                           |                                             | $\pm 0.5$             | $\pm 10$     | pA                                  |
| Input Offset Current $I_{OS}$                 |                                                           |                                             | $\pm 0.5$             | $\pm 10$     | pA                                  |
| <b>INPUT IMPEDANCE</b>                        |                                                           |                                             |                       |              |                                     |
| Differential                                  |                                                           |                                             | $10^{13} \parallel 3$ |              | $\Omega \parallel pF$               |
| Common-Mode                                   |                                                           |                                             | $10^{13} \parallel 6$ |              | $\Omega \parallel pF$               |
| <b>NOISE</b>                                  | $V_{CM} < (V+) - 1.7V$                                    |                                             |                       |              |                                     |
| Input Voltage Noise, $f = 0.1Hz$ to $10Hz$    |                                                           |                                             | 10                    |              | $\mu V_{PP}$                        |
| Input Voltage Noise Density, $f = 1kHz$ $e_n$ |                                                           |                                             | 35                    |              | $nV/\sqrt{Hz}$                      |
| Input Current Noise Density, $f = 1kHz$ $i_n$ |                                                           |                                             | 4                     |              | $fA/\sqrt{Hz}$                      |
| <b>OPEN-LOOP GAIN</b>                         |                                                           |                                             |                       |              |                                     |
| Open-Loop Voltage Gain $A_{OL}$               | $V_S = 5V$ , $R_L = 100k\Omega$ , $0.025V < V_O < 4.975V$ | 94                                          | 108                   |              | dB                                  |
| <b>over Temperature</b>                       | $V_S = 5V$ , $R_L = 100k\Omega$ , $0.025V < V_O < 4.975V$ | <b>90</b>                                   |                       |              | <b>dB</b>                           |
|                                               | $V_S = 5V$ , $R_L = 5k\Omega$ , $0.125V < V_O < 4.875V$   | 90                                          | 98                    |              | dB                                  |
| <b>over Temperature</b>                       | $V_S = 5V$ , $R_L = 5k\Omega$ , $0.125V < V_O < 4.875V$   | <b>88</b>                                   |                       |              | <b>dB</b>                           |
| <b>OUTPUT</b>                                 |                                                           |                                             |                       |              |                                     |
| Voltage Output Swing from Rail                | $R_L = 100k\Omega$ , $A_{OL} > 94dB$                      |                                             | 18                    | 25           | mV                                  |
| <b>over Temperature</b>                       | $R_L = 100k\Omega$ , $A_{OL} > 90dB$                      |                                             |                       | <b>25</b>    | <b>mV</b>                           |
|                                               | $R_L = 5k\Omega$ , $A_{OL} > 90dB$                        |                                             | 100                   | 125          | mV                                  |
| <b>over Temperature</b>                       | $R_L = 5k\Omega$ , $A_{OL} > 88dB$                        |                                             |                       | <b>125</b>   | <b>mV</b>                           |
| Short-Circuit Current $I_{SC}$                |                                                           |                                             | $\pm 10$              |              | mA                                  |
| Capacitive Load Drive $C_{LOAD}$              |                                                           | See <a href="#">Typical Characteristics</a> |                       |              |                                     |

## ELECTRICAL CHARACTERISTICS: $V_S = 2.5V$ to $5.5V$ (continued)

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

At  $T_A = +25^{\circ}C$ ,  $R_L = 100k\Omega$  connected to  $V_S / 2$  and  $V_{OUT} = V_S / 2$ , unless otherwise noted.

| PARAMETER                         |               | TEST CONDITIONS                                                      | OPA348, OPA2348, OPA4348 |            |      | UNIT                 |
|-----------------------------------|---------------|----------------------------------------------------------------------|--------------------------|------------|------|----------------------|
|                                   |               |                                                                      | MIN                      | TYP        | MAX  |                      |
| FREQUENCY RESPONSE                |               | $C_L = 100\text{pF}$                                                 |                          |            |      |                      |
| Gain-Bandwidth Product            | GBP           |                                                                      |                          | 1          |      |                      |
| Slew Rate                         | SR            | $G = +1$                                                             |                          | 0.5        |      |                      |
| Settling Time, 0.1%               | $t_s$         | $V_S = 5.5\text{V}$ , 2V Step, $G = +1$                              |                          | 5          |      |                      |
| Settling Time, 0.01%              |               | $V_S = 5.5\text{V}$ , 2V Step, $G = +1$                              |                          | 7          |      |                      |
| Overload Recovery Time            |               | $V_{IN} \times \text{Gain} > V_S$                                    |                          | 1.6        |      |                      |
| Total Harmonic Distortion + Noise | THD+N         | $V_S = 5.5\text{V}$ , $V_O = 3V_{PP}$ , $G = +1$ , $f = 1\text{kHz}$ |                          | 0.0023     |      |                      |
| POWER SUPPLY                      |               |                                                                      |                          |            |      |                      |
| Specified Voltage Range           | $V_S$         |                                                                      | 2.5                      |            | 5.5  |                      |
| Minimum Operating Voltage         |               |                                                                      |                          | 2.1 to 5.5 |      |                      |
| Quiescent Current (per amplifier) | $I_Q$         | $I_O = 0$                                                            |                          | 45         | 65   |                      |
| over Temperature                  |               |                                                                      |                          |            | 75   |                      |
| TEMPERATURE RANGE                 |               |                                                                      |                          |            |      |                      |
| Specified Range                   |               |                                                                      | -40                      |            | +125 | $^{\circ}\text{C}$   |
| Operating Range                   |               |                                                                      | -65                      |            | +150 | $^{\circ}\text{C}$   |
| Storage Range                     |               |                                                                      | -65                      |            | +150 | $^{\circ}\text{C}$   |
| Thermal Resistance                | $\theta_{JA}$ |                                                                      |                          |            |      |                      |
| SOT23-5 Surface-Mount             |               |                                                                      |                          | 200        |      | $^{\circ}\text{C/W}$ |
| SOT23-8 Surface-Mount             |               |                                                                      |                          | 150        |      | $^{\circ}\text{C/W}$ |
| MSOP-8 Surface-Mount              |               |                                                                      |                          | 150        |      | $^{\circ}\text{C/W}$ |
| SO-8 Surface-Mount                |               |                                                                      |                          | 150        |      | $^{\circ}\text{C/W}$ |
| SO-14 Surface-Mount               |               |                                                                      |                          | 100        |      | $^{\circ}\text{C/W}$ |
| TSSOP-14 Surface-Mount            |               |                                                                      |                          | 100        |      | $^{\circ}\text{C/W}$ |
| SC70-5 Surface-Mount              |               |                                                                      |                          | 250        |      | $^{\circ}\text{C/W}$ |

## TYPICAL CHARACTERISTICS

At  $T_A = +25^\circ\text{C}$ ,  $R_L = 100\text{k}\Omega$  connected to  $V_S / 2$  and  $V_{OUT} = V_S / 2$ , unless otherwise noted.

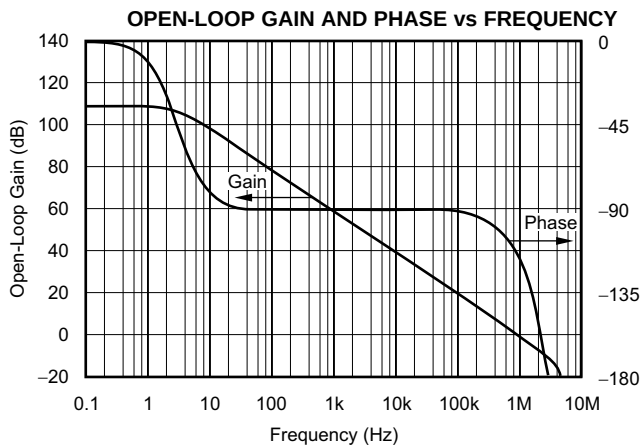


Figure 1.

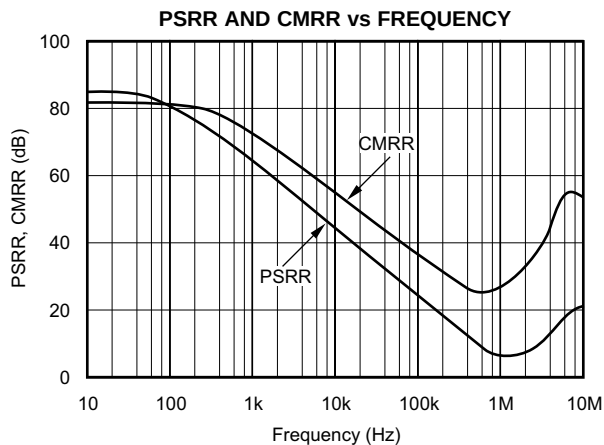


Figure 2.

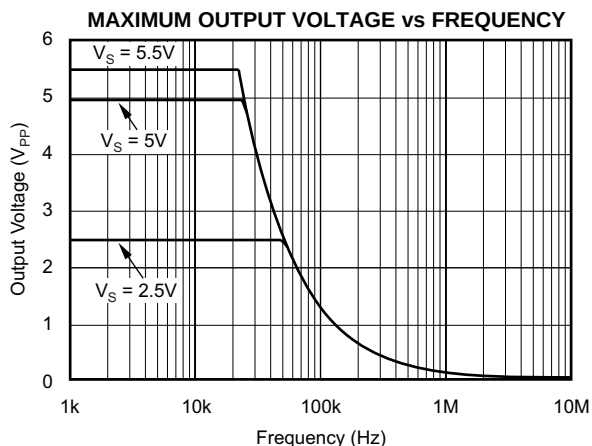


Figure 3.

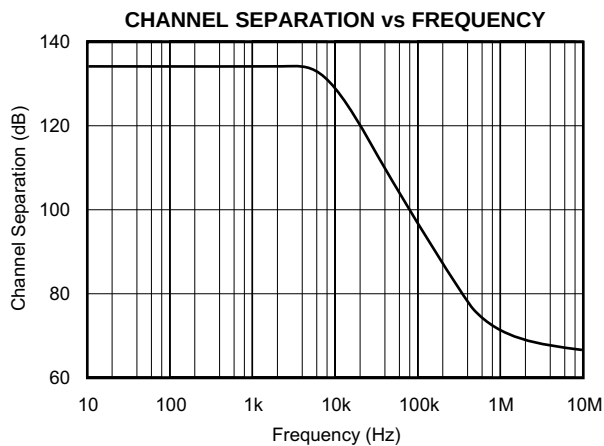


Figure 4.

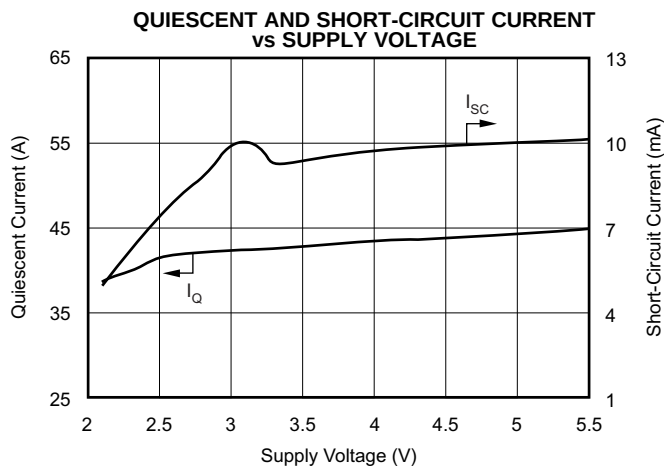


Figure 5.

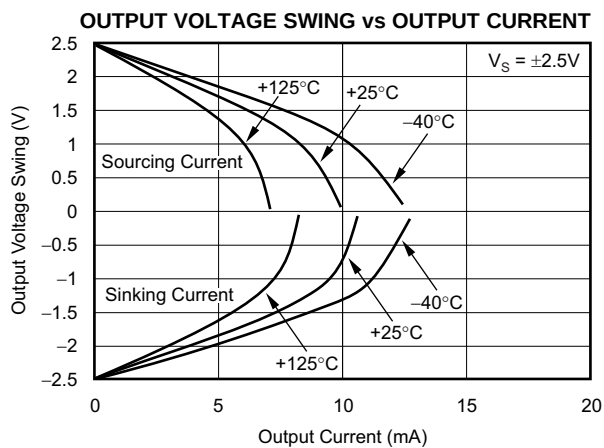


Figure 6.

## TYPICAL CHARACTERISTICS (continued)

At  $T_A = +25^\circ\text{C}$ ,  $R_L = 100\text{k}\Omega$  connected to  $V_S / 2$  and  $V_{OUT} = V_S / 2$ , unless otherwise noted.

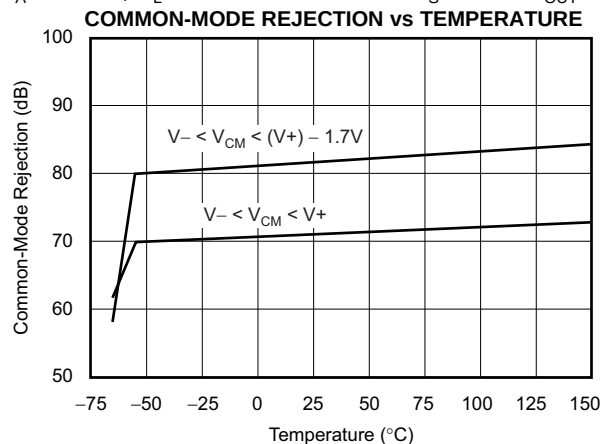


Figure 7.

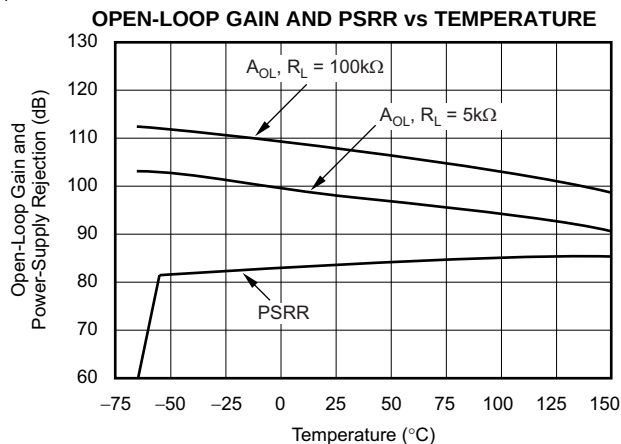


Figure 8.

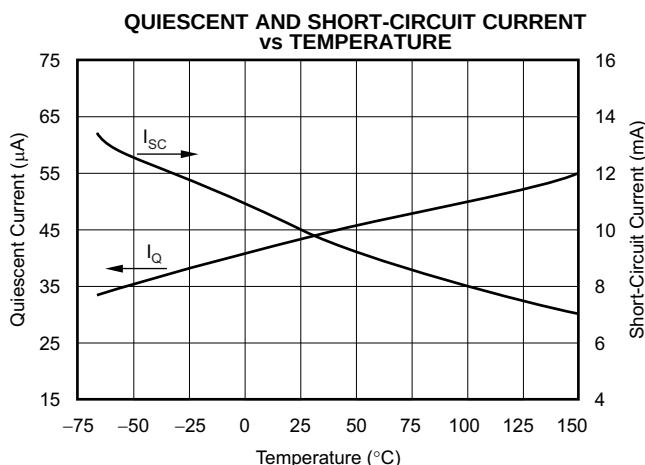


Figure 9.

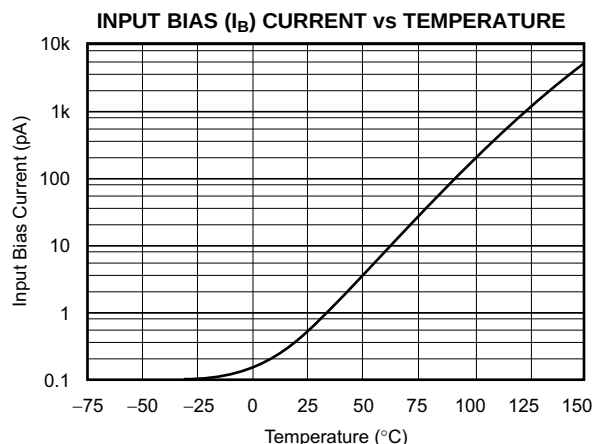


Figure 10.

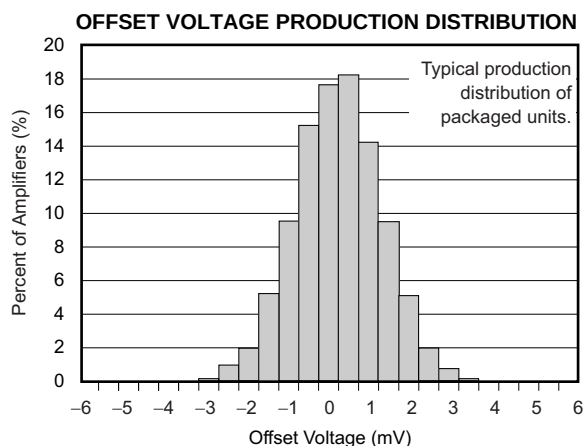


Figure 11.

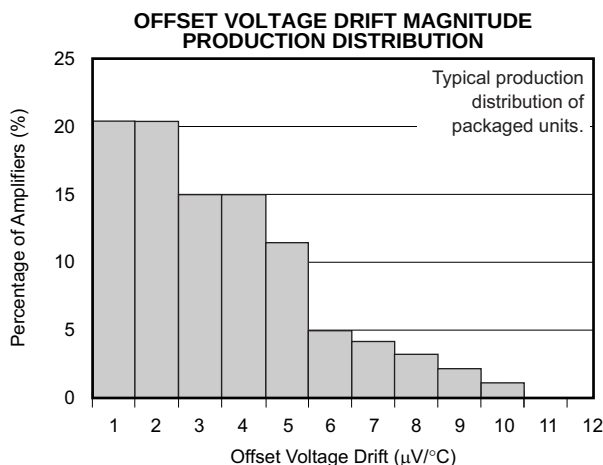


Figure 12.

## TYPICAL CHARACTERISTICS (continued)

At  $T_A = +25^\circ\text{C}$ ,  $R_L = 100\text{k}\Omega$  connected to  $V_S / 2$  and  $V_{OUT} = V_S / 2$ , unless otherwise noted.

### SMALL-SIGNAL OVERSHOOT vs LOAD CAPACITANCE

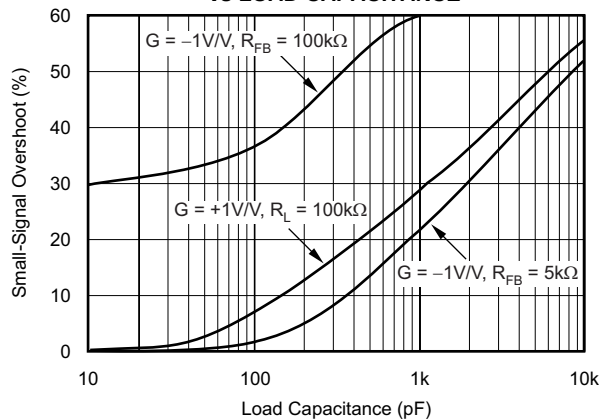


Figure 13.

### PERCENT OVERSHOOT vs LOAD CAPACITANCE

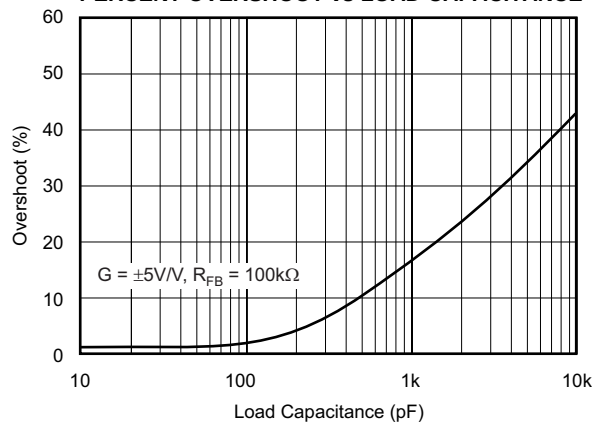


Figure 14.

### SMALL-SIGNAL STEP RESPONSE ( $G = +1\text{V/V}$ , $R_L = 100\text{k}\Omega$ , $C_L = 100\text{pF}$ )

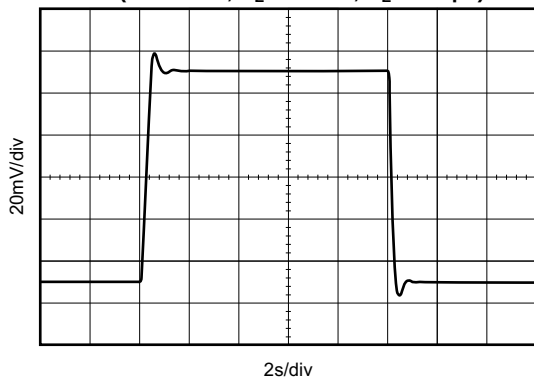


Figure 15.

### LARGE-SIGNAL STEP RESPONSE ( $G = +1\text{V/V}$ , $R_L = 100\text{k}\Omega$ , $C_L = 100\text{pF}$ )

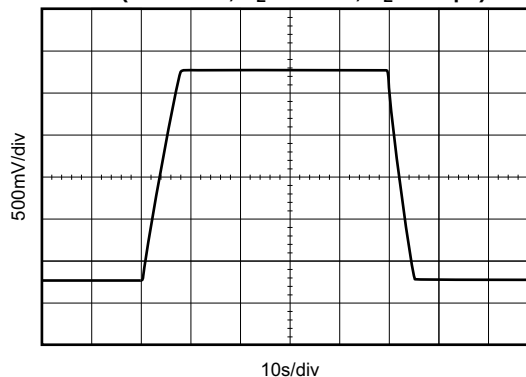


Figure 16.

### INPUT CURRENT AND VOLTAGE NOISE SPECTRAL DENSITY vs FREQUENCY

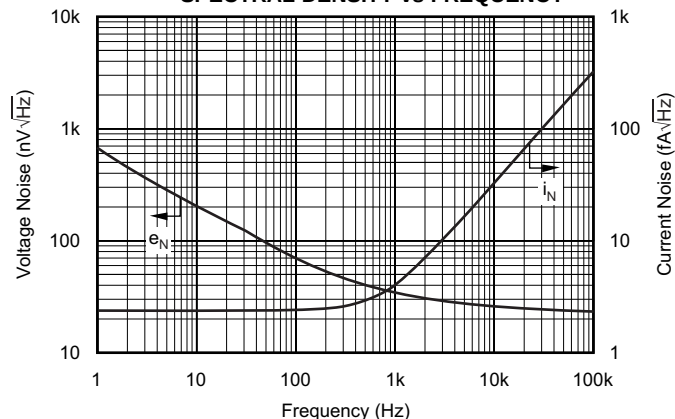


Figure 17.

### TOTAL HARMONIC DISTORTION + NOISE vs FREQUENCY

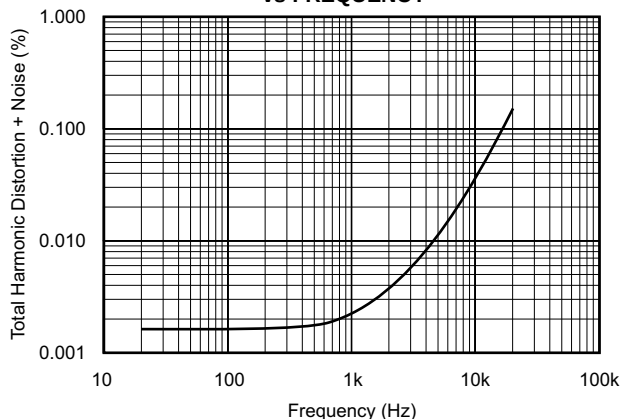


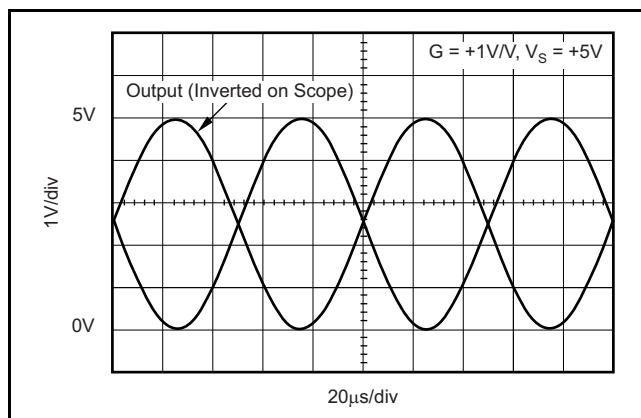
Figure 18.

## APPLICATION INFORMATION

The OPA348 series op amps are unity-gain stable and suitable for a wide range of general-purpose applications.

The OPA348 series features wide bandwidth and unity-gain stability with rail-to-rail input and output for increased dynamic range. Figure 19 shows the input and output waveforms for the OPA348 in unity-gain configuration. Operation is from a single +5V supply with a 100k $\Omega$  load connected to  $V_S/2$ . The input is a 5V<sub>PP</sub> sinusoid. Output voltage is approximately 4.98V<sub>PP</sub>.

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



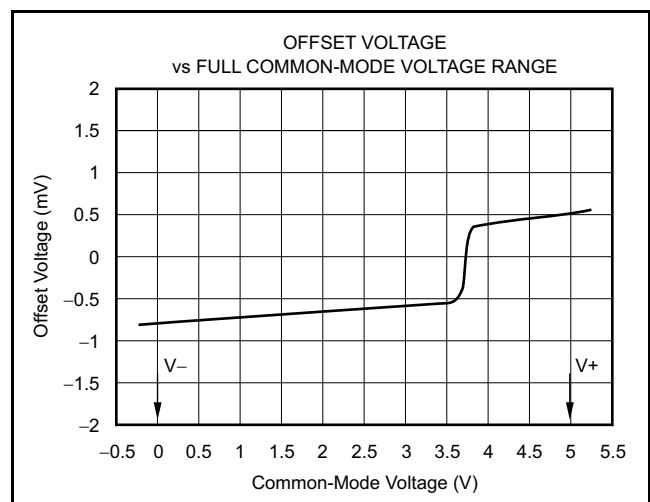
**Figure 19. The OPA348 Features Rail-to-Rail Input/Output**

## OPERATING VOLTAGE

The OPA348 series op amps are fully specified and tested from +2.5V to +5.5V. However, supply voltage may range from +2.1V to +5.5V. Parameters are tested over the specified supply range—a unique feature of the OPA348 series. In addition, all temperature specifications apply from –40°C to +125°C. Most behavior remains virtually unchanged throughout the full operating voltage range. Parameters that vary significantly with operating voltages or temperature are shown in the [Typical Characteristics](#).

## COMMON-MODE VOLTAGE RANGE

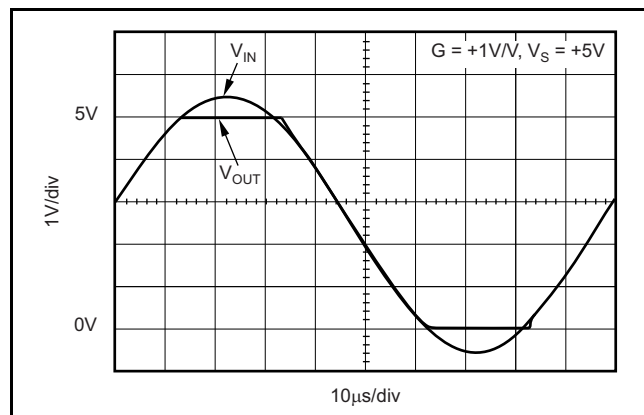
The input common-mode voltage range of the OPA348 series extends 200mV beyond the supply rails. This is achieved with a complementary input stage—an N-channel input differential pair in parallel with a P-channel differential pair. The N-channel pair is active for input voltages close to the positive rail, typically  $(V_+) - 1.2V$  to 300mV above the positive supply, while the P-channel pair is on for inputs from 300mV below the negative supply to approximately  $(V_+) - 1.4V$ . There is a small transition region, typically  $(V_+) - 1.4V$  to  $(V_+) - 1.2V$ , in which both pairs are on. This 200mV transition region, shown in Figure 20, can vary  $\pm 300mV$  with process variation. Thus, the transition region (both stages on) can range from  $(V_+) - 1.7V$  to  $(V_+) - 1.5V$  on the low end, up to  $(V_+) - 1.1V$  to  $(V_+) - 0.9V$  on the high end. Within the 200mV transition region PSRR, CMRR, offset voltage, offset drift, and THD may be degraded compared to operation outside this region.



**Figure 20. Behavior of Typical Transition Region at Room Temperature**

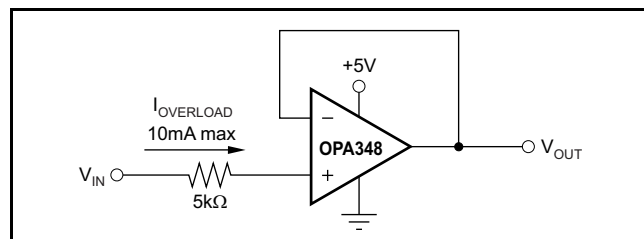
## RAIL-TO-RAIL INPUT

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 power supplies without phase inversion, as shown in Figure 21.



**Figure 21. OPA348—No Phase Inversion with Inputs Greater than the Power-Supply Voltage**

Normally, input currents are 0.5pA. However, large inputs (greater than 500mV beyond the supply rails) can cause excessive current to flow in or out of the input pins. Therefore, as well as keeping the input voltage below the maximum rating, it is also important to limit the input current to less than 10mA. This is easily accomplished with an input voltage resistor, as shown in Figure 22.



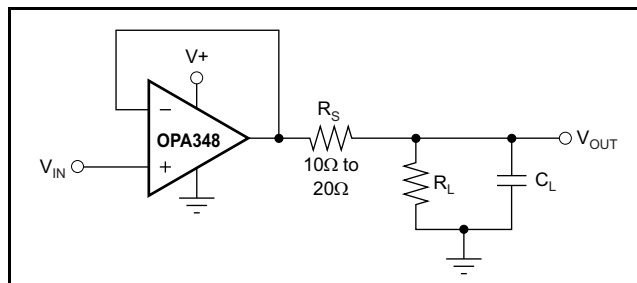
**Figure 22. Input Current Protection for Voltages Exceeding the Supply Voltage**

## RAIL-TO-RAIL OUTPUT

A class AB output stage with common-source transistors is used to achieve rail-to-rail output. This output stage is capable of driving 5kΩ loads connected to any potential between  $V+$  and ground. For light resistive loads ( $> 100kΩ$ ), the output voltage can typically swing to within 18mV from supply rail. With moderate resistive loads (10kΩ to 50kΩ), the output voltage can typically swing to within 100mV of the supply rails while maintaining high open-loop gain (see the typical characteristic *Output Voltage Swing vs Output Current*, Figure 6).

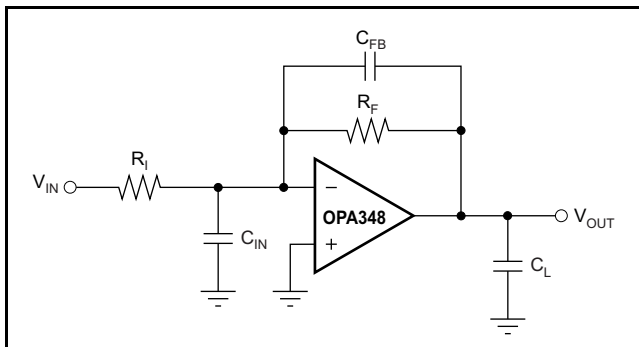
## CAPACITIVE LOAD AND STABILITY

The OPA348 in a unity-gain configuration can directly drive up to 250pF pure capacitive load. Increasing the gain enhances the amplifier's ability to drive greater capacitive loads (see the typical characteristic *Small-Signal Overshoot vs Capacitive Load*, Figure 13). In unity-gain configurations, capacitive load drive can be improved by inserting a small (10Ω to 20Ω) resistor,  $R_S$ , in series with the output, as shown in Figure 23. This significantly reduces ringing while maintaining DC performance for purely capacitive loads. However, if there is a resistive load in parallel with the capacitive load, a voltage divider is created, introducing a Direct Current (DC) error at the output and slightly reducing the output swing. The error introduced is proportional to the ratio  $R_S/R_L$ , and is generally negligible.



**Figure 23. Series Resistor in Unity-Gain Buffer Configuration Improves Capacitive Load Drive**

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. For example, when driving a 500pF load, reducing the resistor values from 100k $\Omega$  to 5k $\Omega$  decreases overshoot from 55% to 13% (see the typical characteristic *Small-Signal Overshoot vs Load Capacitance*, [Figure 13](#)). 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 24](#). This significantly reduces overshoot by compensating the effect of capacitance,  $C_{IN}$ , which includes the amplifier's input capacitance and PC board parasitic capacitance.



**Figure 24. Improving Capacitive Load Drive**

## DRIVING A/D CONVERTERS

The OPA348 series op amps are optimized for driving medium-speed sampling Analog-to-Digital Converters (ADCs). The OPA348 op amps buffer the ADCs input capacitance and resulting charge injection while providing signal gain.

The OPA348 in a basic noninverting configuration driving the ADS7822, see [Figure 25](#). The ADS7822 is a 12-bit, *microPOWER* sampling converter in the MSOP-8 package. When used with the low-power, miniature packages of the OPA348, the combination is ideal for space-limited, low-power applications. In this configuration, an RC network at the ADC's input can be used to provide for anti-aliasing filter and charge injection current.

The OPA348 in noninverting configuration driving ADS7822 limited, low-power applications. In this configuration, an RC network at the ADC's input can be used to provide for antialiasing filter and charge injection current. See [Figure 26](#) for the OPA2348 driving an ADS7822 in a speech bandpass filtered data acquisition system. This small, low-cost solution provides the necessary amplification and signal conditioning to interface directly with an electret microphone. This circuit will operate with  $V_S = 2.7V$  to 5V with less than 250 $\mu A$  typical quiescent current.

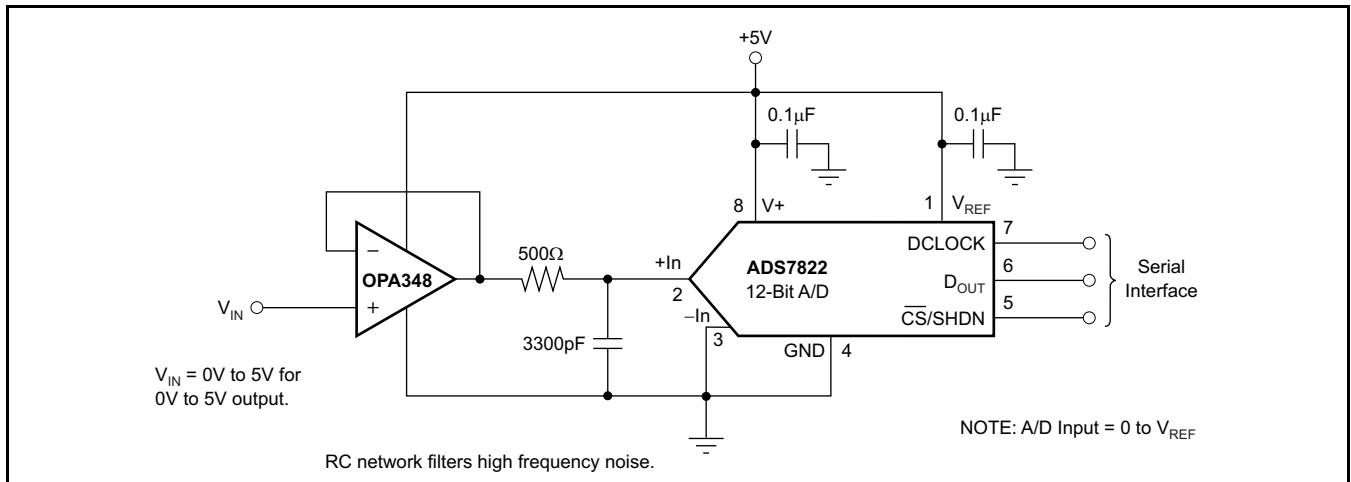


Figure 25. OPA348 in Noninverting Configuration Driving ADS7822

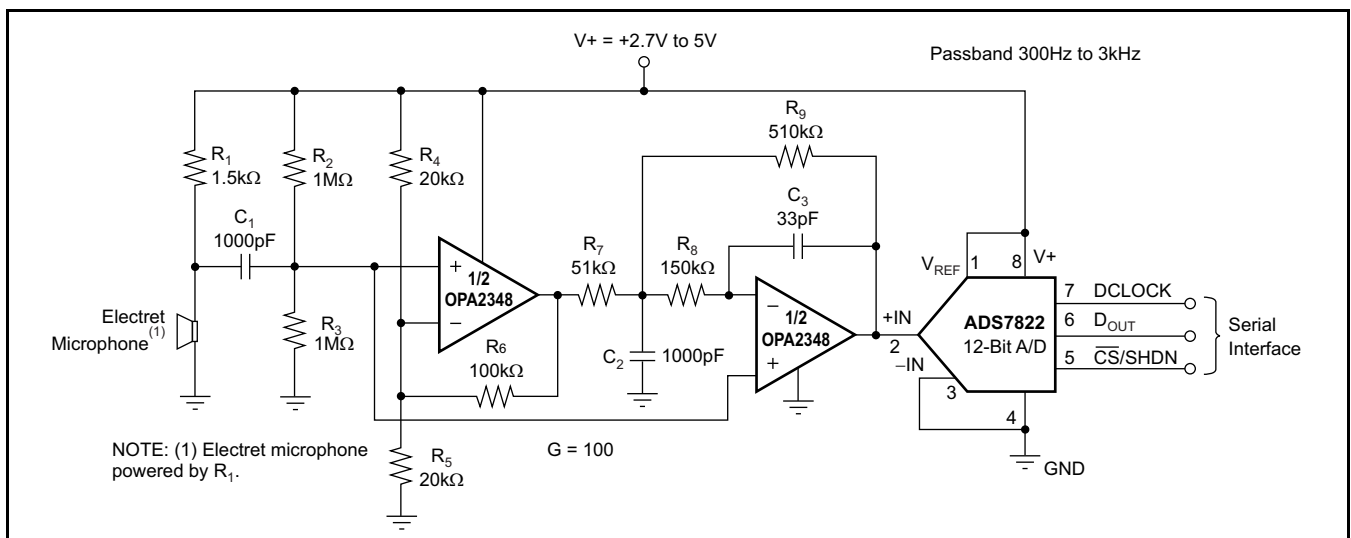


Figure 26. OPA2348 as a Speech Bandpass Filtered Data Acquisition System

## REVISION HISTORY

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

### Changes from Revision F (October 2012) to Revision G Page

- Changed 2nd footnote for Absolute Maximum Ratings table ..... [2](#)

### Changes from Revision E (September 2012) to Revision F Page

- Deleted Package/Ordering Information table data ..... [2](#)

**PACKAGING INFORMATION**

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package Qty | Eco Plan<br>(2)            | Lead/Ball Finish | MSL Peak Temp<br>(3) | Op Temp (°C) | Top-Side Markings<br>(4) | Samples                 |
|------------------|---------------|--------------|--------------------|------|-------------|----------------------------|------------------|----------------------|--------------|--------------------------|-------------------------|
| OPA2348AID       | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | OPA<br>2348A             | <a href="#">Samples</a> |
| OPA2348AIDCNR    | ACTIVE        | SOT-23       | DCN                | 8    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   | -40 to 125   | B48                      | <a href="#">Samples</a> |
| OPA2348AIDCNRG4  | ACTIVE        | SOT-23       | DCN                | 8    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   | -40 to 125   | B48                      | <a href="#">Samples</a> |
| OPA2348AIDCNT    | ACTIVE        | SOT-23       | DCN                | 8    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   | -40 to 125   | B48                      | <a href="#">Samples</a> |
| OPA2348AIDCNTG4  | ACTIVE        | SOT-23       | DCN                | 8    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   | -40 to 125   | B48                      | <a href="#">Samples</a> |
| OPA2348AIDG4     | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | OPA<br>2348A             | <a href="#">Samples</a> |
| OPA2348AIDGK     | ACTIVE        | VSSOP        | DGK                | 8    | 80          | Green (RoHS<br>& no Sb/Br) | CU NIPDAUAG      | Level-2-260C-1 YEAR  | -40 to 125   | OUTQ                     | <a href="#">Samples</a> |
| OPA2348AIDGKR    | ACTIVE        | VSSOP        | DGK                | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAUAG      | Level-2-260C-1 YEAR  | -40 to 125   | OUTQ                     | <a href="#">Samples</a> |
| OPA2348AIDR      | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | OPA<br>2348A             | <a href="#">Samples</a> |
| OPA2348AIDRG4    | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | OPA<br>2348A             | <a href="#">Samples</a> |
| OPA348AID        | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | OPA<br>348A              | <a href="#">Samples</a> |
| OPA348AIDBVR     | ACTIVE        | SOT-23       | DBV                | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | A48                      | <a href="#">Samples</a> |
| OPA348AIDBVRG4   | ACTIVE        | SOT-23       | DBV                | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | A48                      | <a href="#">Samples</a> |
| OPA348AIDBVT     | ACTIVE        | SOT-23       | DBV                | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | A48                      | <a href="#">Samples</a> |
| OPA348AIDBVTG4   | ACTIVE        | SOT-23       | DBV                | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | A48                      | <a href="#">Samples</a> |
| OPA348AIDCKR     | ACTIVE        | SC70         | DCK                | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   | -40 to 125   | S48                      | <a href="#">Samples</a> |
| OPA348AIDCKRG4   | ACTIVE        | SC70         | DCK                | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   | -40 to 125   | S48                      | <a href="#">Samples</a> |

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package Qty | Eco Plan<br>(2)            | Lead/Ball Finish | MSL Peak Temp<br>(3) | Op Temp (°C) | Top-Side Markings<br>(4) | Samples                 |
|------------------|---------------|--------------|--------------------|------|-------------|----------------------------|------------------|----------------------|--------------|--------------------------|-------------------------|
| OPA348AIDCKT     | ACTIVE        | SC70         | DCK                | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   | -40 to 125   | S48                      | <a href="#">Samples</a> |
| OPA348AIDCKTG4   | ACTIVE        | SC70         | DCK                | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM   | -40 to 125   | S48                      | <a href="#">Samples</a> |
| OPA348AIDG4      | ACTIVE        | SOIC         | D                  | 8    | 75          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | OPA<br>348A              | <a href="#">Samples</a> |
| OPA348AIDR       | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | OPA<br>348A              | <a href="#">Samples</a> |
| OPA348AIDRG4     | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | OPA<br>348A              | <a href="#">Samples</a> |
| OPA4348AID       | ACTIVE        | SOIC         | D                  | 14   | 50          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | OPA4348A                 | <a href="#">Samples</a> |
| OPA4348AIDG4     | ACTIVE        | SOIC         | D                  | 14   | 50          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | OPA4348A                 | <a href="#">Samples</a> |
| OPA4348AIDR      | ACTIVE        | SOIC         | D                  | 14   | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | OPA4348A                 | <a href="#">Samples</a> |
| OPA4348AIDRG4    | ACTIVE        | SOIC         | D                  | 14   | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | OPA4348A                 | <a href="#">Samples</a> |
| OPA4348AIPWR     | ACTIVE        | TSSOP        | PW                 | 14   | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | OPA<br>4348A             | <a href="#">Samples</a> |
| OPA4348AIPWRG4   | ACTIVE        | TSSOP        | PW                 | 14   | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | OPA<br>4348A             | <a href="#">Samples</a> |
| OPA4348AIPWT     | ACTIVE        | TSSOP        | PW                 | 14   | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | OPA<br>4348A             | <a href="#">Samples</a> |
| OPA4348AIPWTG4   | ACTIVE        | TSSOP        | PW                 | 14   | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR  | -40 to 125   | OPA<br>4348A             | <a href="#">Samples</a> |

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

**ACTIVE:** Product device recommended for new designs.

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

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

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

**OBSOLETE:** TI has discontinued the production of the device.

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

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

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

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

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

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

<sup>(4)</sup> Only one of markings shown within the brackets will appear on the physical device.

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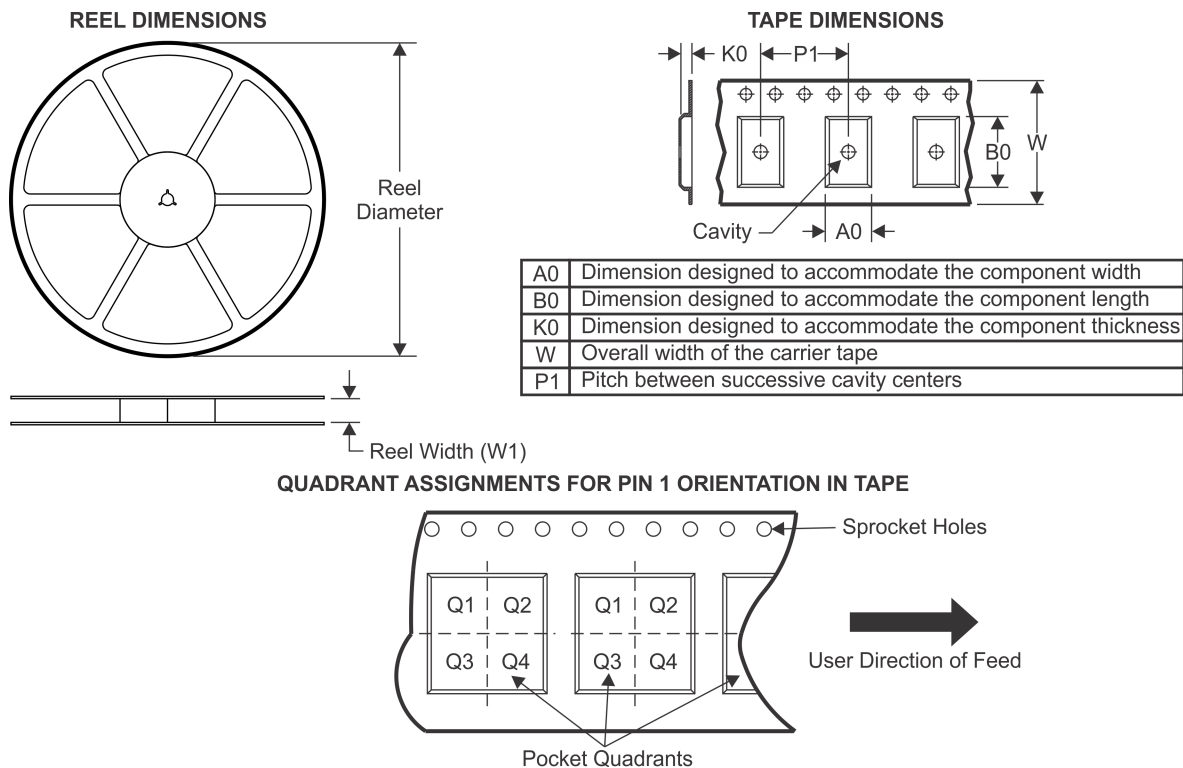
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

#### **OTHER QUALIFIED VERSIONS OF OPA2348, OPA4348 :**

- Automotive: [OPA2348-Q1](#), [OPA4348-Q1](#)

NOTE: Qualified Version Definitions:

- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

**TAPE AND REEL INFORMATION**


\*All dimensions are nominal

| Device        | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| OPA2348AIDCNR | SOT-23       | DCN             | 8    | 3000 | 179.0              | 8.4                | 3.2     | 3.2     | 1.4     | 4.0     | 8.0    | Q3            |
| OPA2348AIDCNT | SOT-23       | DCN             | 8    | 250  | 179.0              | 8.4                | 3.2     | 3.2     | 1.4     | 4.0     | 8.0    | Q3            |
| OPA2348AIDGKR | VSSOP        | DGK             | 8    | 2500 | 330.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| OPA2348AIDR   | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| OPA348AIDBVR  | SOT-23       | DBV             | 5    | 3000 | 179.0              | 8.4                | 3.2     | 3.2     | 1.4     | 4.0     | 8.0    | Q3            |
| OPA348AIDBVR  | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| OPA348AIDCKR  | SC70         | DCK             | 5    | 3000 | 179.0              | 8.4                | 2.2     | 2.5     | 1.2     | 4.0     | 8.0    | Q3            |
| OPA348AIDCKT  | SC70         | DCK             | 5    | 250  | 179.0              | 8.4                | 2.2     | 2.5     | 1.2     | 4.0     | 8.0    | Q3            |
| OPA348AIDR    | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| OPA4348AIDR   | SOIC         | D               | 14   | 2500 | 330.0              | 16.4               | 6.5     | 9.0     | 2.1     | 8.0     | 16.0   | Q1            |
| OPA4348AIPWR  | TSSOP        | PW              | 14   | 2500 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| OPA4348AIPWT  | TSSOP        | PW              | 14   | 250  | 180.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |

## TAPE AND REEL BOX DIMENSIONS

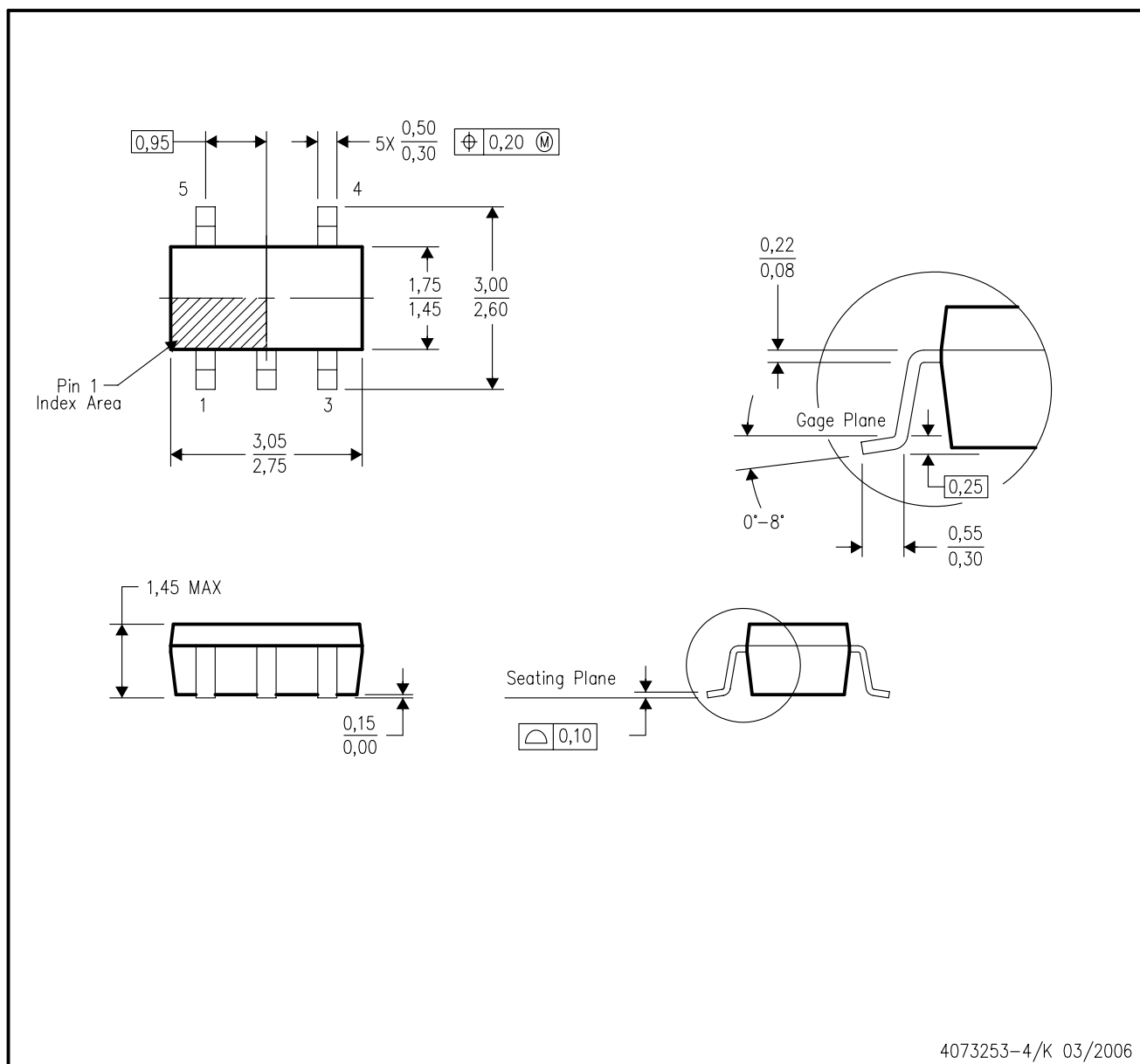


\*All dimensions are nominal

| Device        | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|---------------|--------------|-----------------|------|------|-------------|------------|-------------|
| OPA2348AIDCNR | SOT-23       | DCN             | 8    | 3000 | 203.0       | 203.0      | 35.0        |
| OPA2348AIDCNT | SOT-23       | DCN             | 8    | 250  | 203.0       | 203.0      | 35.0        |
| OPA2348AIDGKR | VSSOP        | DGK             | 8    | 2500 | 366.0       | 364.0      | 50.0        |
| OPA2348AIDR   | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| OPA348AIDBVR  | SOT-23       | DBV             | 5    | 3000 | 195.0       | 200.0      | 45.0        |
| OPA348AIDBVR  | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| OPA348AIDCKR  | SC70         | DCK             | 5    | 3000 | 203.0       | 203.0      | 35.0        |
| OPA348AIDCKT  | SC70         | DCK             | 5    | 250  | 203.0       | 203.0      | 35.0        |
| OPA348AIDR    | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| OPA4348AIDR   | SOIC         | D               | 14   | 2500 | 367.0       | 367.0      | 38.0        |
| OPA4348AIPWR  | TSSOP        | PW              | 14   | 2500 | 367.0       | 367.0      | 35.0        |
| OPA4348AIPWT  | TSSOP        | PW              | 14   | 250  | 210.0       | 185.0      | 35.0        |

## DBV (R-PDSO-G5)

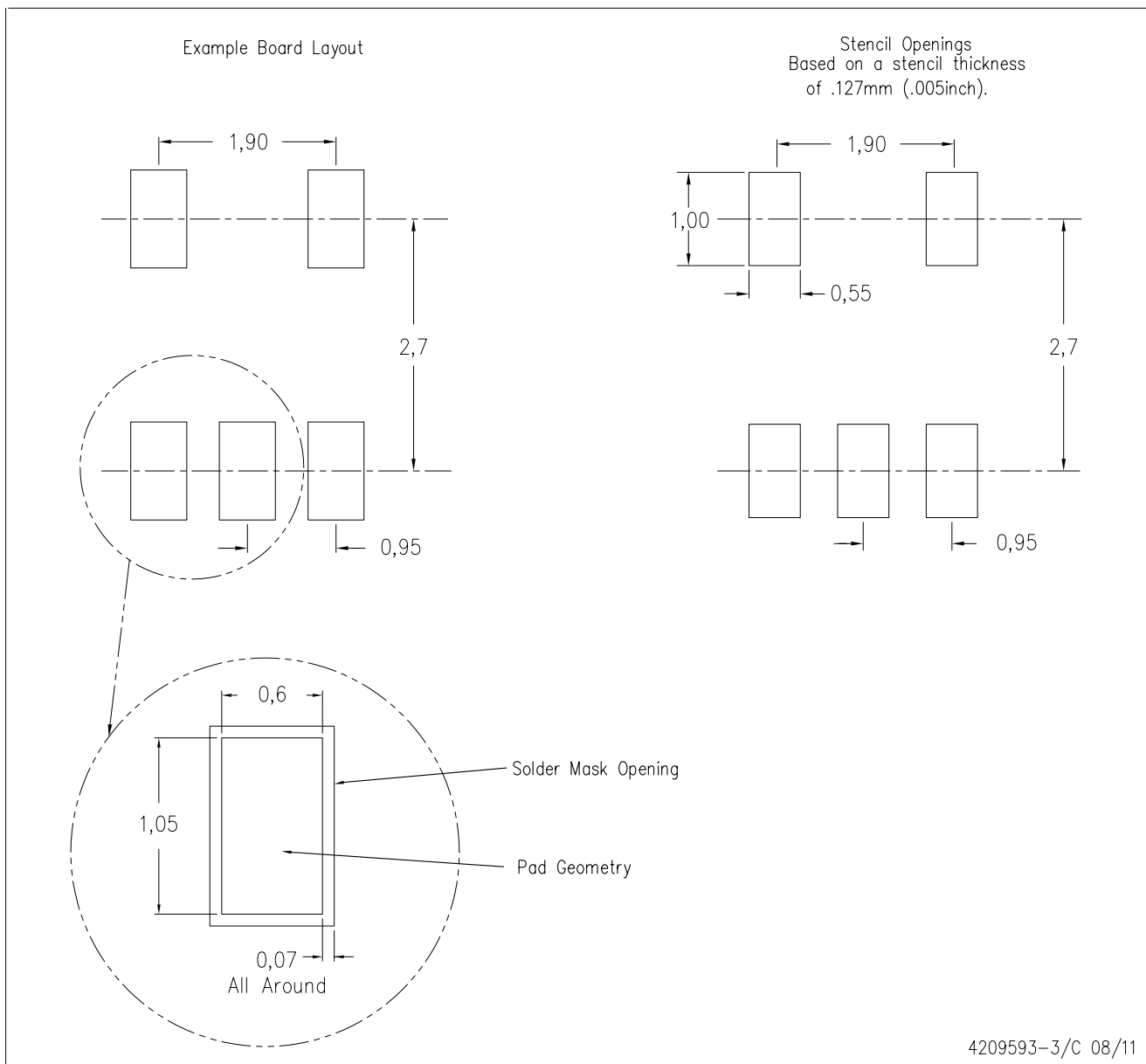
## PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
  - Falls within JEDEC MO-178 Variation AA.

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. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
  - D. Publication IPC-7351 is recommended for alternate designs.
  - E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.

## DCK (R-PDSO-G5)

## PLASTIC SMALL-OUTLINE PACKAGE



4093553-3/G 01/2007

- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
  - Falls within JEDEC MO-203 variation AA.

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. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
  - D. Publication IPC-7351 is recommended for alternate designs.
  - E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.

## DGK (S-PDSO-G8)

## PLASTIC SMALL-OUTLINE PACKAGE

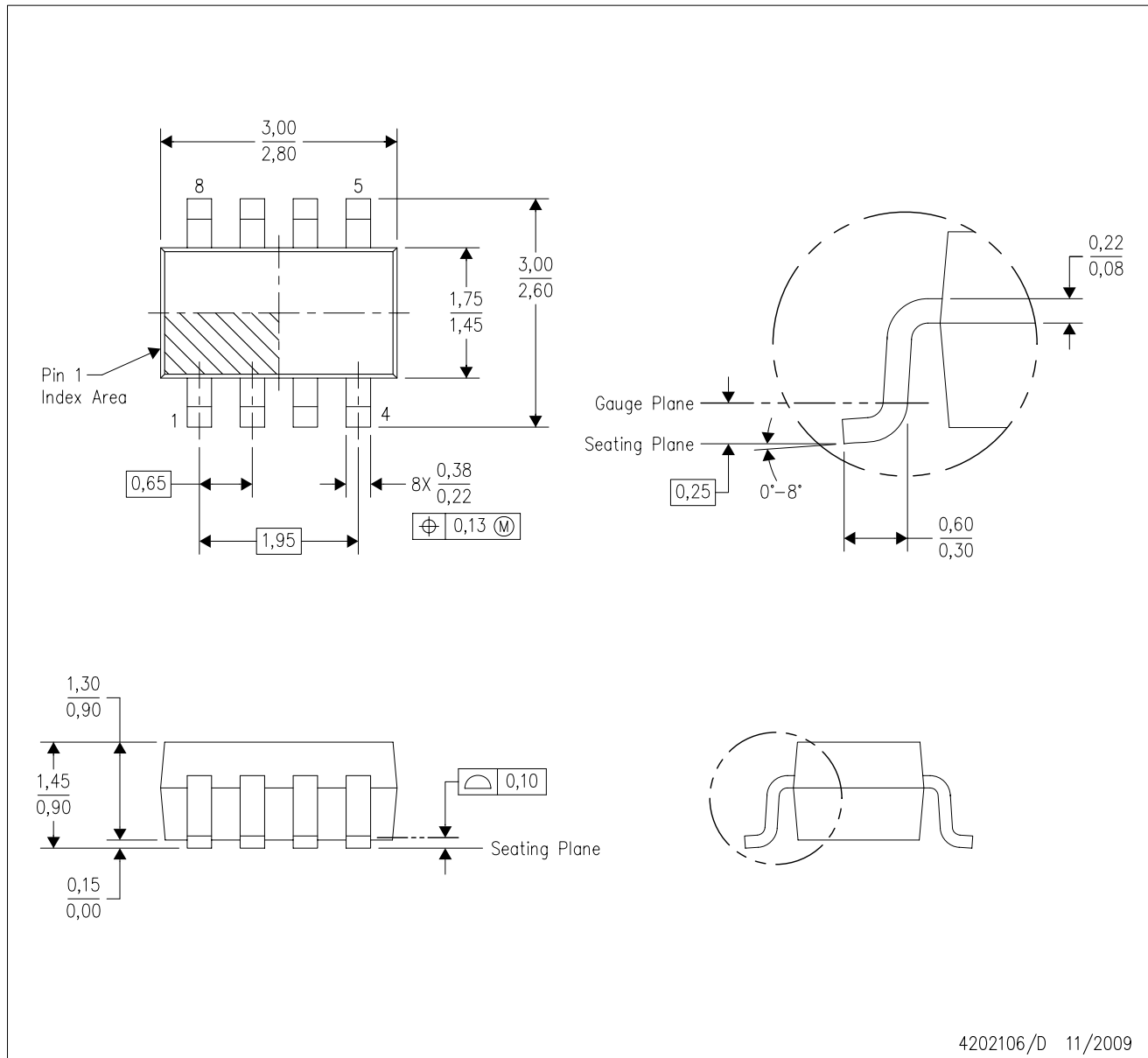


## NOTES:

- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
- D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
- E. Falls within JEDEC MO-187 variation AA, except interlead flash.

DCN (R-PDSO-G8)

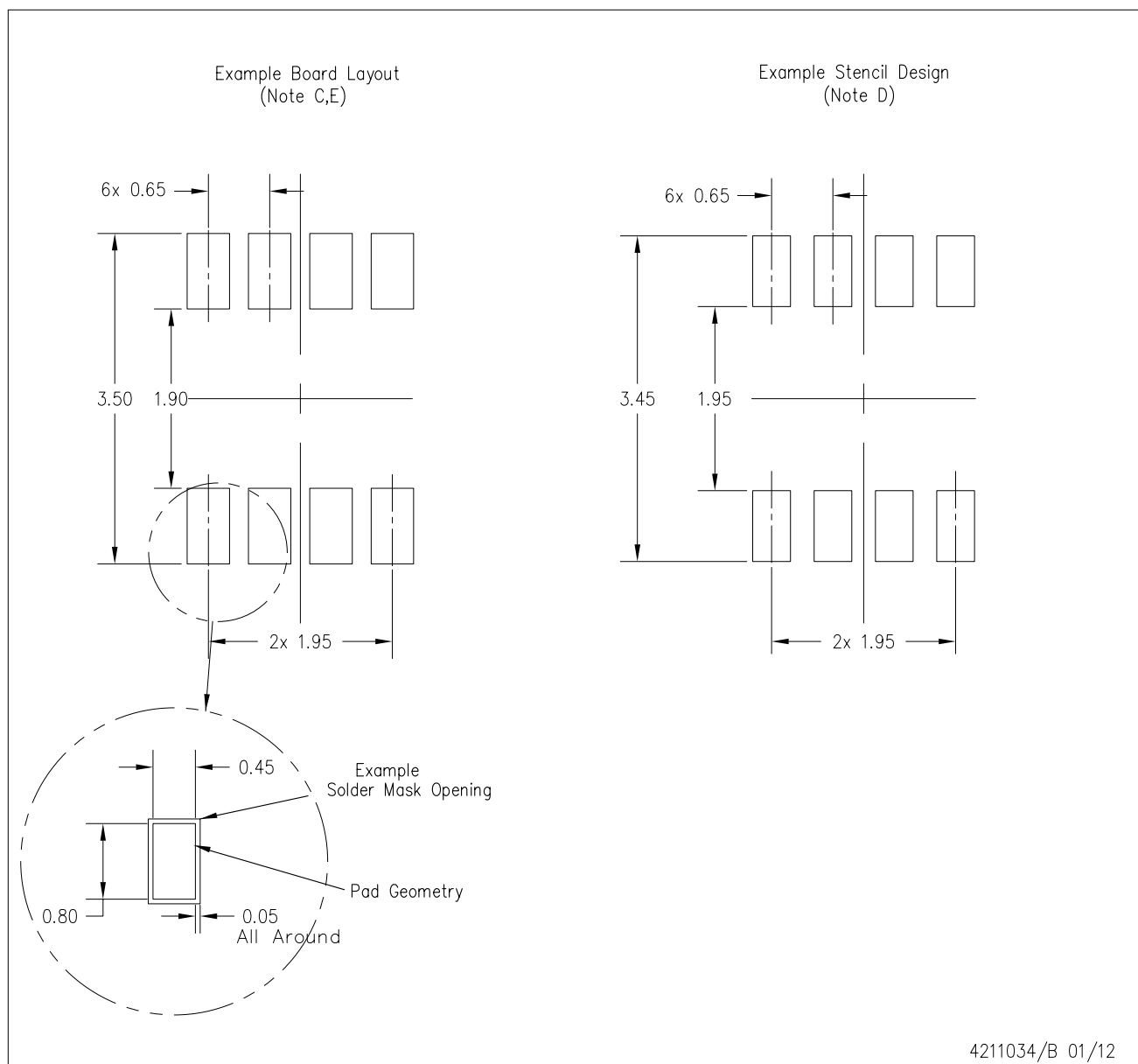
PLASTIC SMALL-OUTLINE PACKAGE (DIE DOWN)



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Package outline exclusive of metal burr & dambar protrusion/intrusion.
  - D. Package outline inclusive of solder plating.
  - E. A visual index feature must be located within the Pin 1 index area.
  - F. Falls within JEDEC MO-178 Variation BA.
  - G. Body dimensions do not include flash or protrusion. Mold flash and protrusion shall not exceed 0.25 per side.

DCN (R-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE (DIE DOWN)



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs.
  - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525.
  - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

D (R-PDSO-G14)

PLASTIC SMALL OUTLINE



NOTES:

- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
- D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
- E. Reference JEDEC MS-012 variation AB.

D (R-PDSO-G14)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs.
  - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

PW (R-PDSO-G14)

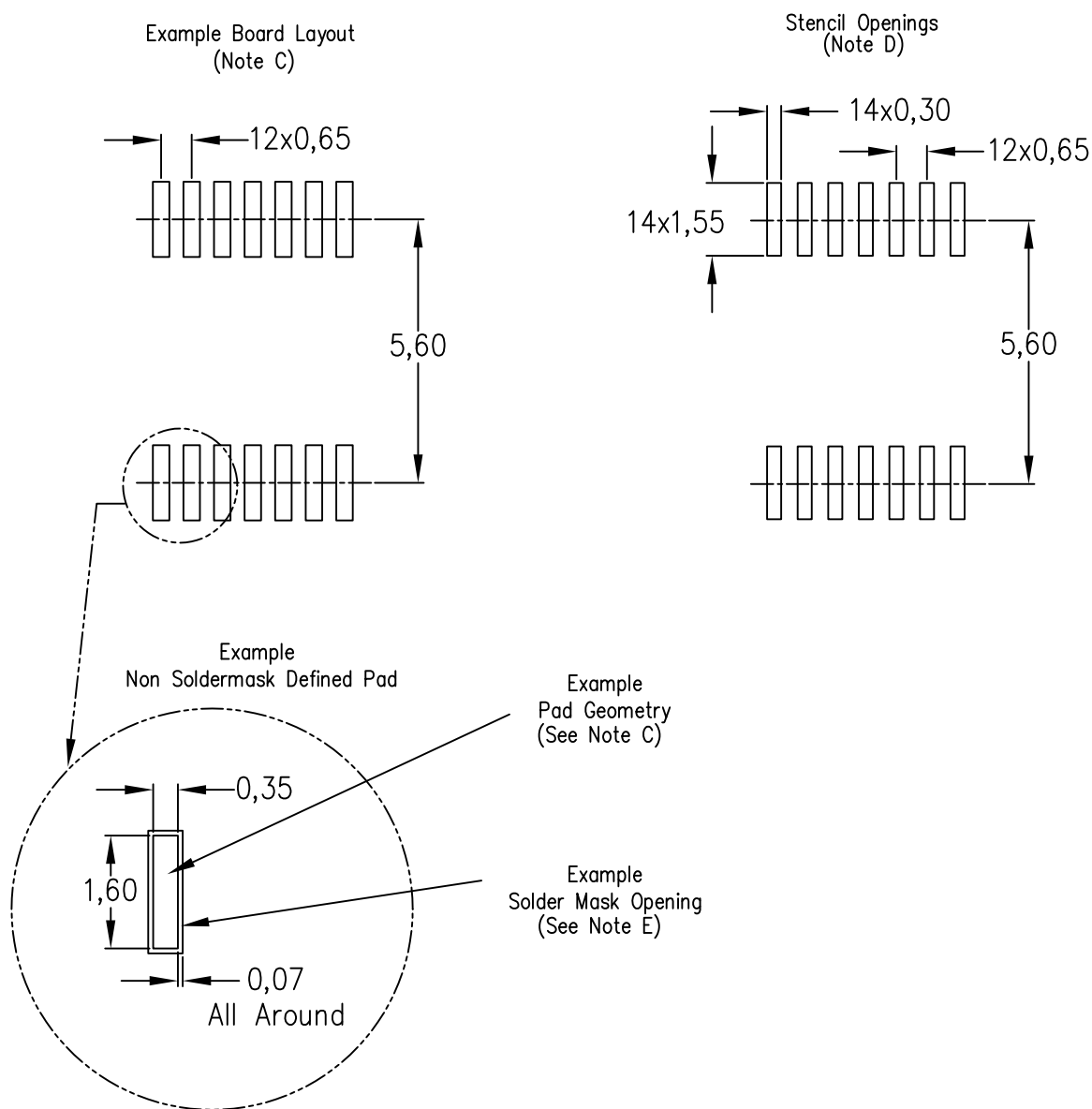
PLASTIC SMALL OUTLINE



4040064-3/G 02/11

PW (R-PDSO-G14)

PLASTIC SMALL OUTLINE

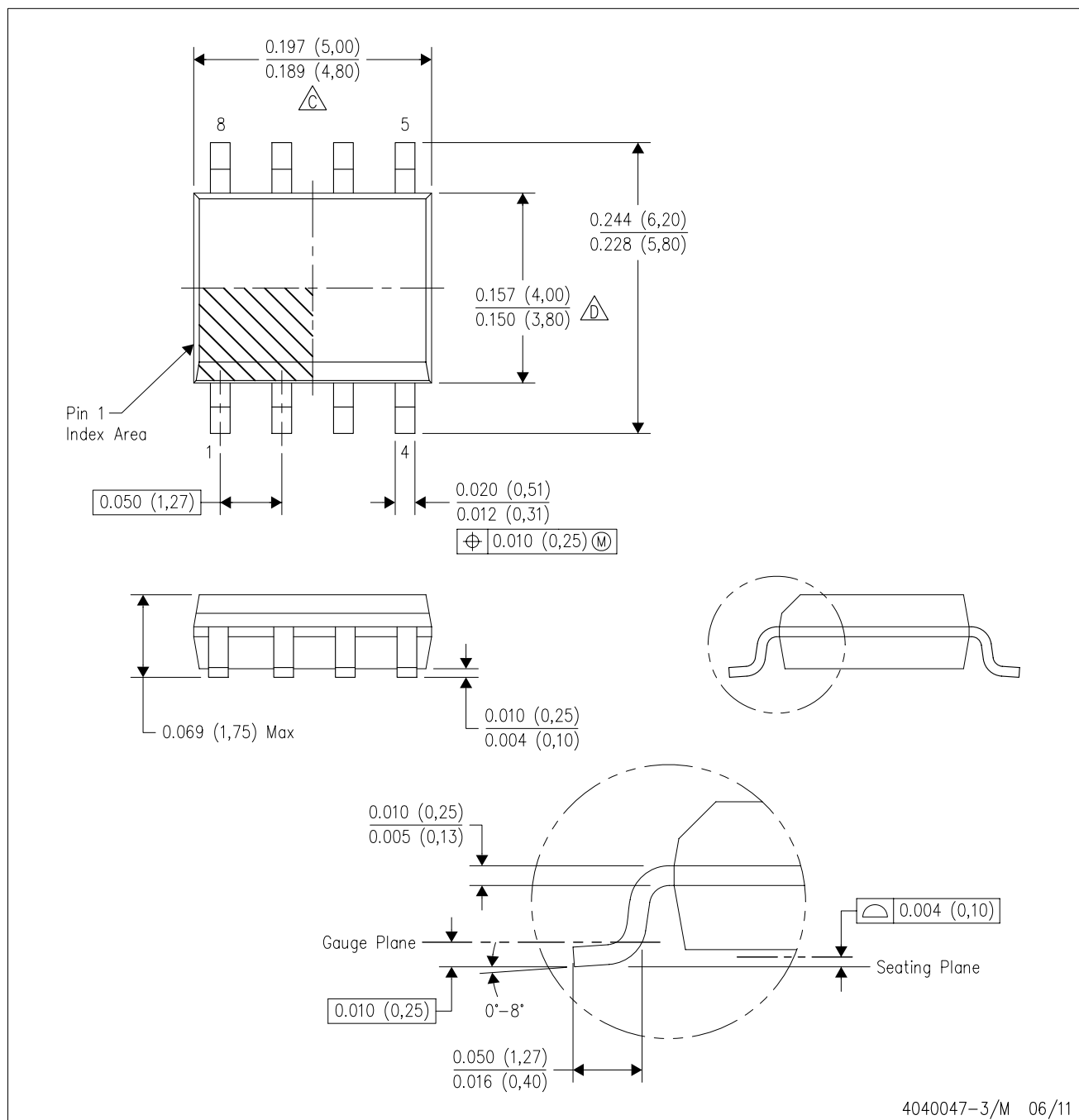


4211284-2/F 12/12

- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs.
  - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - $\triangle C$  Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
  - $\triangle D$  Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
  - E. Reference JEDEC MS-012 variation AA.

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs.
  - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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|                               |                                                                                          |
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