

## 1.8-V, *microPower*, CMOS Operational Amplifiers, Zero-Drift Series

Check for Samples: [OPA333](#), [OPA2333](#)

### FEATURES

- **Low Offset Voltage:** 10  $\mu\text{V}$  (max)
- **Zero Drift:** 0.05  $\mu\text{V}/^\circ\text{C}$  (max)
- **0.01-Hz to 10-Hz Noise:** 1.1  $\mu\text{V}_{\text{PP}}$
- **Quiescent Current:** 17  $\mu\text{A}$
- **Single-Supply Operation**
- **Supply Voltage:** 1.8 V to 5.5 V
- **Rail-to-Rail Input/Output**
- ***microSize* Packages:** SC70 and SOT23

### APPLICATIONS

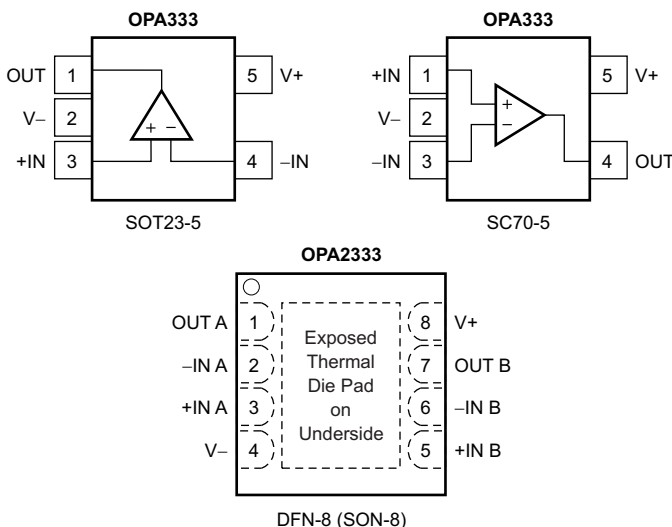
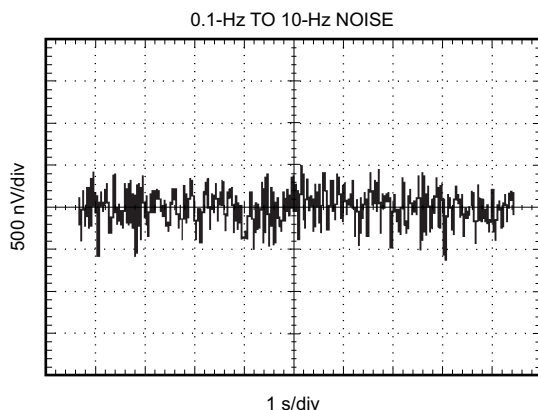
- Transducers
- Temperature Measurements
- Electronic Scales
- Medical Instrumentation
- Battery-Powered Instruments
- Handheld Test Equipment

### DESCRIPTION

The OPA333 series of CMOS operational amplifiers use a proprietary auto-calibration technique to simultaneously provide very low offset voltage (10  $\mu\text{V}$ , max) and near-zero drift over time and temperature. These miniature, high-precision, low quiescent current amplifiers offer high-impedance inputs that have a common-mode range 100 mV beyond the rails, and rail-to-rail output that swings within 50 mV of the rails. Single or dual supplies as low as +1.8 V ( $\pm 0.9$  V) and up to +5.5 V ( $\pm 2.75$  V) can be used. These devices are optimized for low-voltage, single-supply operation.

The OPA333 family offers excellent CMRR without the crossover associated with traditional complementary input stages. This design results in superior performance for driving analog-to-digital converters (ADCs) without degradation of differential linearity.

The OPA333 (single version) is available in the SC70-5, SOT23-5, and SO-8 packages. The OPA2333 (dual version) is offered in DFN-8 (3 mm  $\times$  3 mm), MSOP-8, and SO-8 packages. All versions are specified for operation from  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$ .



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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.

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

- (1) 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 |
|---------------------------------------|---------------------------------------|--------------------|------|
| Voltage                               | Supply                                | +7                 | V    |
|                                       | Signal input terminals <sup>(2)</sup> | –0.3 to (V+) + 0.3 | V    |
| Current                               | Signal input terminals <sup>(2)</sup> | ±10                | mA   |
|                                       | Output short-circuit <sup>(3)</sup>   | Continuous         | mA   |
| Temperature                           | Operating, T <sub>A</sub>             | –40 to +150        | °C   |
|                                       | Storage, T <sub>stg</sub>             | –65 to +150        | °C   |
|                                       | Junction, T <sub>J</sub>              | +150               | °C   |
| Electrostatic discharge (ESD) ratings | Human body model (HBM)                | 4000               | V    |
|                                       | Charged device model (CDM)            | 1000               | V    |
|                                       | Machine model (MM)                    | 400                | V    |

- (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 supported.
- (2) Input terminals are diode-clamped to the power-supply rails. Input signals that can swing more than 0.3 V beyond the supply rails should be current limited to 10 mA or less.
- (3) Short-circuit to ground, one amplifier per package.

**ELECTRICAL CHARACTERISTICS:  $V_S = +1.8\text{ V}$  to  $+5.5\text{ V}$** 

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

| PARAMETER                 |                                    | TEST CONDITIONS                                                                                                                          | MIN                                         | TYP       | MAX           | UNIT                         |
|---------------------------|------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-----------|---------------|------------------------------|
| <b>OFFSET VOLTAGE</b>     |                                    |                                                                                                                                          |                                             |           |               |                              |
| $V_{OS}$                  | Input offset voltage               | $V_S = +5\text{ V}$                                                                                                                      |                                             | 2         | 10            | $\mu\text{V}$                |
| $dV_{OS}/dT$              | Input offset voltage drift         | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                                                                                        |                                             | 0.02      | 0.05          | $\mu\text{V}/^\circ\text{C}$ |
| PSRR                      | Power-supply rejection ratio       | $V_S = +1.8\text{ V}$ to $+5.5\text{ V}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                                             |                                             | 1         | 5             | $\mu\text{V}/\text{V}$       |
|                           | Long-term stability <sup>(1)</sup> |                                                                                                                                          | See note <sup>(1)</sup>                     |           |               | $\mu\text{V}$                |
|                           | Channel separation, dc             |                                                                                                                                          |                                             | 0.1       |               | $\mu\text{V}/\text{V}$       |
| <b>INPUT BIAS CURRENT</b> |                                    |                                                                                                                                          |                                             |           |               |                              |
| $I_B$                     | Input bias current                 | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                                                                                        |                                             | $\pm 70$  | $\pm 200$     | $\text{pA}$                  |
|                           |                                    |                                                                                                                                          |                                             | $\pm 150$ |               | $\text{pA}$                  |
| $I_{OS}$                  | Input offset current               |                                                                                                                                          |                                             | $\pm 140$ | $\pm 400$     | $\text{pA}$                  |
| <b>NOISE</b>              |                                    |                                                                                                                                          |                                             |           |               |                              |
|                           | Input voltage noise                | $f = 0.01\text{ Hz}$ to $1\text{ Hz}$                                                                                                    |                                             | 0.3       |               | $\mu\text{V}_{PP}$           |
|                           |                                    | $f = 0.1\text{ Hz}$ to $10\text{ Hz}$                                                                                                    |                                             | 1.1       |               | $\mu\text{V}_{PP}$           |
| $i_n$                     | Input current noise                | $f = 10\text{ Hz}$                                                                                                                       |                                             | 100       |               | $\text{fA}/\sqrt{\text{Hz}}$ |
| <b>INPUT VOLTAGE</b>      |                                    |                                                                                                                                          |                                             |           |               |                              |
| $V_{CM}$                  | Common-mode voltage range          |                                                                                                                                          | $(V_-) - 0.1$                               |           | $(V_+) + 0.1$ | $\text{V}$                   |
| CMRR                      | Common-mode rejection ratio        | $(V_-) - 0.1\text{ V} < V_{CM} < (V_+) + 0.1\text{ V}$ ,<br>$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                            | 106                                         | 130       |               | $\text{dB}$                  |
| <b>INPUT CAPACITANCE</b>  |                                    |                                                                                                                                          |                                             |           |               |                              |
|                           | Differential                       |                                                                                                                                          |                                             | 2         |               | $\text{pF}$                  |
|                           | Common-mode                        |                                                                                                                                          |                                             | 4         |               | $\text{pF}$                  |
| <b>OPEN-LOOP GAIN</b>     |                                    |                                                                                                                                          |                                             |           |               |                              |
| $A_{OL}$                  | Open-loop voltage gain             | $(V_-) + 100\text{ mV} < V_O < (V_+) - 100\text{ mV}$ ,<br>$R_L = 10\text{ k}\Omega$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ | 106                                         | 130       |               | $\text{dB}$                  |
| <b>FREQUENCY RESPONSE</b> |                                    |                                                                                                                                          |                                             |           |               |                              |
| GBW                       | Gain-bandwidth product             | $C_L = 100\text{ pF}$                                                                                                                    |                                             | 350       |               | $\text{kHz}$                 |
| SR                        | Slew rate                          | $G = +1$                                                                                                                                 |                                             | 0.16      |               | $\text{V}/\mu\text{s}$       |
| <b>OUTPUT</b>             |                                    |                                                                                                                                          |                                             |           |               |                              |
|                           | Voltage output swing from rail     | $R_L = 10\text{ k}\Omega$                                                                                                                |                                             | 30        | 50            | $\text{mV}$                  |
|                           |                                    | $R_L = 10\text{ k}\Omega$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                                                            |                                             |           | 70            | $\text{mV}$                  |
| $I_{SC}$                  | Short-circuit current              |                                                                                                                                          |                                             | $\pm 5$   |               | $\text{mA}$                  |
| $C_L$                     | Capacitive load drive              |                                                                                                                                          | See <a href="#">Typical Characteristics</a> |           |               |                              |
|                           | Open-loop output impedance         | $f = 350\text{ kHz}$ , $I_O = 0\text{ A}$                                                                                                |                                             | 2         |               | $\text{k}\Omega$             |
| <b>POWER SUPPLY</b>       |                                    |                                                                                                                                          |                                             |           |               |                              |
| $V_S$                     | Specified voltage range            |                                                                                                                                          | 1.8                                         |           | 5.5           | $\text{V}$                   |
| $I_Q$                     | Quiescent current per amplifier    | $I_O = 0\text{ A}$                                                                                                                       |                                             | 17        | 25            | $\mu\text{A}$                |
|                           |                                    | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                                                                                        |                                             |           | 28            | $\mu\text{A}$                |
|                           | Turn-on time                       | $V_S = +5\text{ V}$                                                                                                                      |                                             | 100       |               | $\mu\text{s}$                |
| <b>TEMPERATURE</b>        |                                    |                                                                                                                                          |                                             |           |               |                              |
| $T_A$                     | Specified range                    |                                                                                                                                          | -40                                         |           | +125          | $^\circ\text{C}$             |
|                           | Operating range                    |                                                                                                                                          | -40                                         |           | +150          | $^\circ\text{C}$             |
| $T_{stg}$                 | Storage range                      |                                                                                                                                          | -65                                         |           | +150          | $^\circ\text{C}$             |

(1) 300-hour life test at  $+150^\circ\text{C}$  demonstrated randomly distributed variation of approximately  $1\text{ }\mu\text{V}$ .

## THERMAL INFORMATION: OPA333

| THERMAL METRIC <sup>(1)</sup> |                                              | OPA333   |             |            | UNITS |
|-------------------------------|----------------------------------------------|----------|-------------|------------|-------|
|                               |                                              | D (SOIC) | DBV (SOT23) | DCK (SC70) |       |
|                               |                                              | 8 PINS   | 5 PINS      | 5 PINS     |       |
| $\theta_{JA}$                 | Junction-to-ambient thermal resistance       | 140.1    | 220.8       | 298.4      | °C/W  |
| $\theta_{JCTop}$              | Junction-to-case (top) thermal resistance    | 89.8     | 97.5        | 65.4       |       |
| $\theta_{JB}$                 | Junction-to-board thermal resistance         | 80.6     | 61.7        | 97.1       |       |
| $\psi_{JT}$                   | Junction-to-top characterization parameter   | 28.7     | 7.6         | 0.8        |       |
| $\psi_{JB}$                   | Junction-to-board characterization parameter | 80.1     | 61.1        | 95.5       |       |
| $\theta_{JCbott}$             | Junction-to-case (bottom) thermal resistance | N/A      | N/A         | N/A        |       |

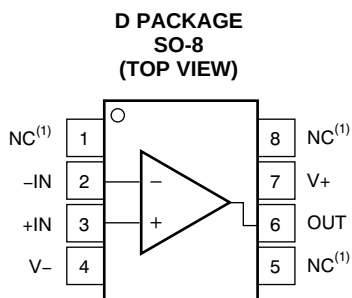
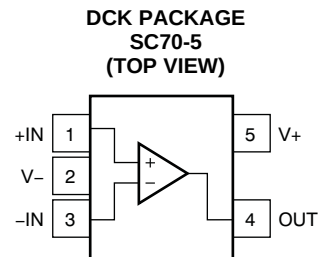
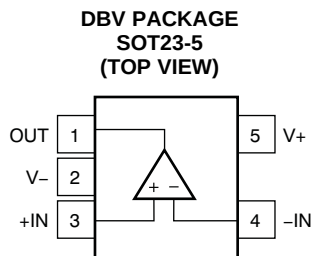
(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).

## THERMAL INFORMATION: OPA2333

| THERMAL METRIC <sup>(1)</sup> |                                              | OPA2333  |            |           | UNITS |
|-------------------------------|----------------------------------------------|----------|------------|-----------|-------|
|                               |                                              | D (SOIC) | DGK (MSOP) | DRB (DFN) |       |
|                               |                                              | 8 PINS   | 8 PINS     | 8 PINS    |       |
| $\theta_{JA}$                 | Junction-to-ambient thermal resistance       | 124.0    | 180.3      | 46.7      | °C/W  |
| $\theta_{JCTop}$              | Junction-to-case (top) thermal resistance    | 73.7     | 48.1       | 26.3      |       |
| $\theta_{JB}$                 | Junction-to-board thermal resistance         | 64.4     | 100.9      | 22.2      |       |
| $\psi_{JT}$                   | Junction-to-top characterization parameter   | 18.0     | 2.4        | 1.6       |       |
| $\psi_{JB}$                   | Junction-to-board characterization parameter | 63.9     | 99.3       | 22.3      |       |
| $\theta_{JCbott}$             | Junction-to-case (bottom) thermal resistance | N/A      | N/A        | 10.1      |       |

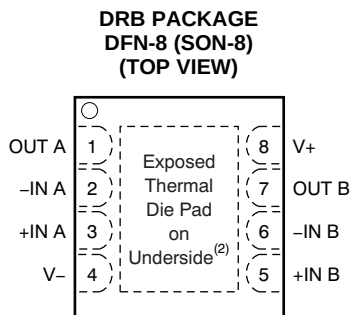
(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).

## PIN CONFIGURATIONS: OPA333

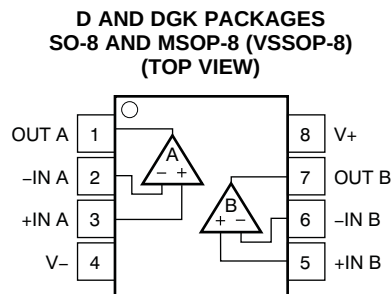


(1) NC denotes no internal connection.

## PIN CONFIGURATIONS: OPA2333



(2) Connect thermal die pad to V-.



## TYPICAL CHARACTERISTICS

**Table 1. List of Typical Characteristics**

| TITLE                                                   | FIGURE                    |
|---------------------------------------------------------|---------------------------|
| OFFSET VOLTAGE PRODUCTION DISTRIBUTION                  | <a href="#">Figure 1</a>  |
| OFFSET VOLTAGE DRIFT PRODUCTION DISTRIBUTION            | <a href="#">Figure 2</a>  |
| OPEN-LOOP GAIN vs FREQUENCY                             | <a href="#">Figure 3</a>  |
| COMMON-MODE REJECTION RATIO vs FREQUENCY                | <a href="#">Figure 4</a>  |
| POWER-SUPPLY REJECTION RATIO vs FREQUENCY               | <a href="#">Figure 5</a>  |
| OUTPUT VOLTAGE SWING vs OUTPUT CURRENT                  | <a href="#">Figure 6</a>  |
| INPUT BIAS CURRENT vs COMMON-MODE VOLTAGE               | <a href="#">Figure 7</a>  |
| INPUT BIAS CURRENT vs TEMPERATURE                       | <a href="#">Figure 8</a>  |
| QUIESCENT CURRENT vs TEMPERATURE                        | <a href="#">Figure 9</a>  |
| LARGE-SIGNAL STEP RESPONSE                              | <a href="#">Figure 10</a> |
| SMALL-SIGNAL STEP RESPONSE                              | <a href="#">Figure 11</a> |
| POSITIVE OVERVOLTAGE RECOVERY                           | <a href="#">Figure 12</a> |
| NEGATIVE OVERVOLTAGE RECOVERY                           | <a href="#">Figure 13</a> |
| SETTLING TIME vs CLOSED-LOOP GAIN                       | <a href="#">Figure 14</a> |
| SMALL-SIGNAL OVERSHOOT vs LOAD CAPACITANCE              | <a href="#">Figure 15</a> |
| 0.1-Hz TO 10-Hz NOISE                                   | <a href="#">Figure 16</a> |
| CURRENT AND VOLTAGE NOISE SPECTRAL DENSITY vs FREQUENCY | <a href="#">Figure 17</a> |

## TYPICAL CHARACTERISTICS

At  $T_A = +25^\circ\text{C}$ ,  $V_S = +5\text{ V}$ , and  $C_L = 0\text{ pF}$ , unless otherwise noted.

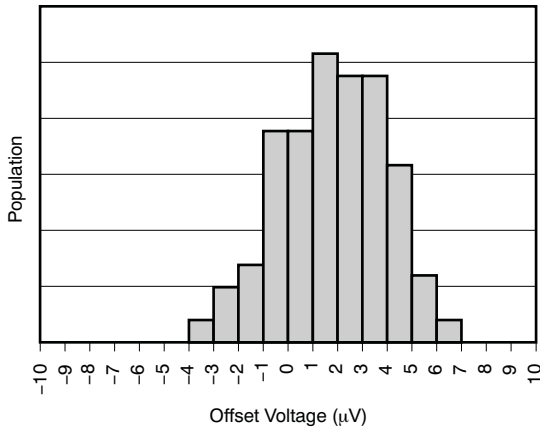


Figure 1. OFFSET VOLTAGE PRODUCTION DISTRIBUTION

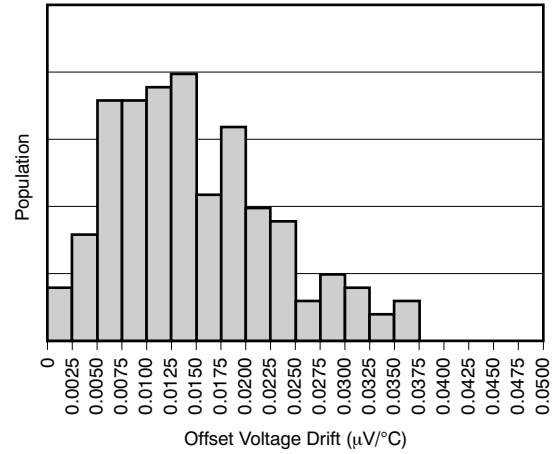


Figure 2. OFFSET VOLTAGE DRIFT PRODUCTION DISTRIBUTION

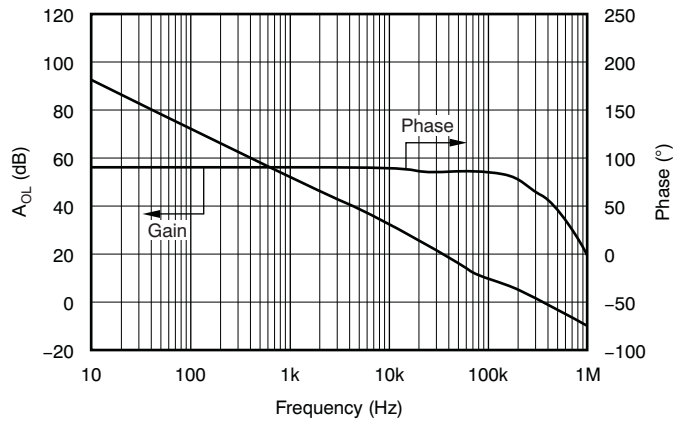


Figure 3. OPEN-LOOP GAIN vs FREQUENCY

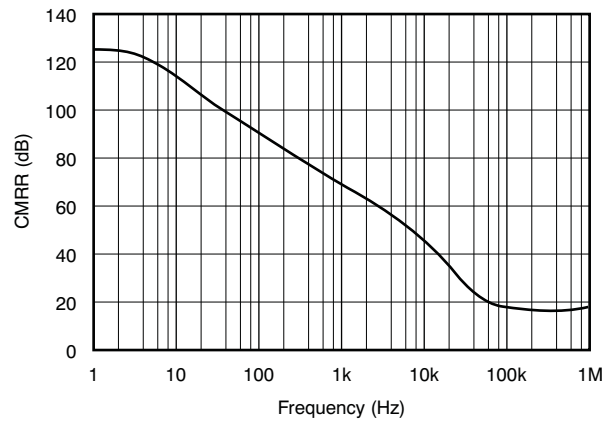


Figure 4. COMMON-MODE REJECTION RATIO vs FREQUENCY

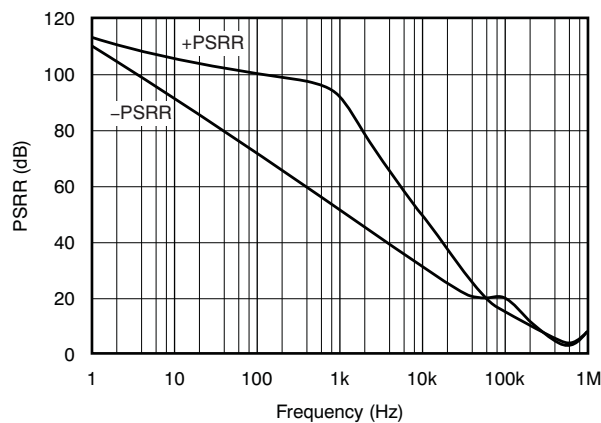


Figure 5. POWER-SUPPLY REJECTION RATIO vs FREQUENCY

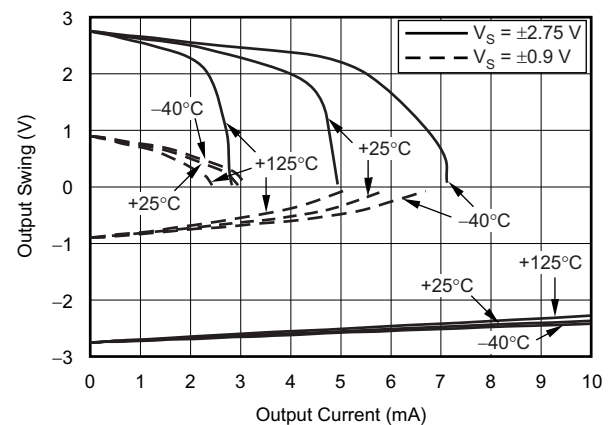


Figure 6. OUTPUT VOLTAGE SWING vs OUTPUT CURRENT

## TYPICAL CHARACTERISTICS (continued)

At  $T_A = +25^\circ\text{C}$ ,  $V_S = +5\text{ V}$ , and  $C_L = 0\text{ pF}$ , unless otherwise noted.

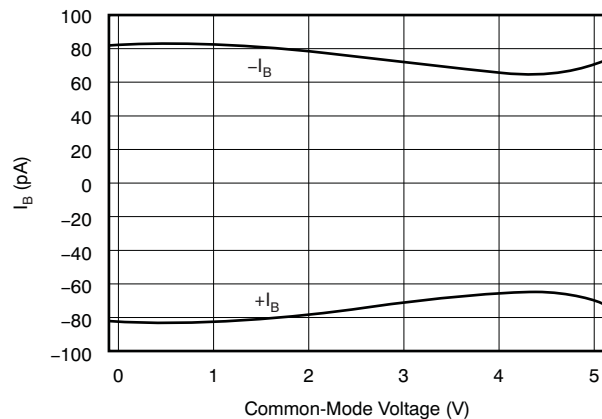


Figure 7. INPUT BIAS CURRENT vs COMMON-MODE VOLTAGE

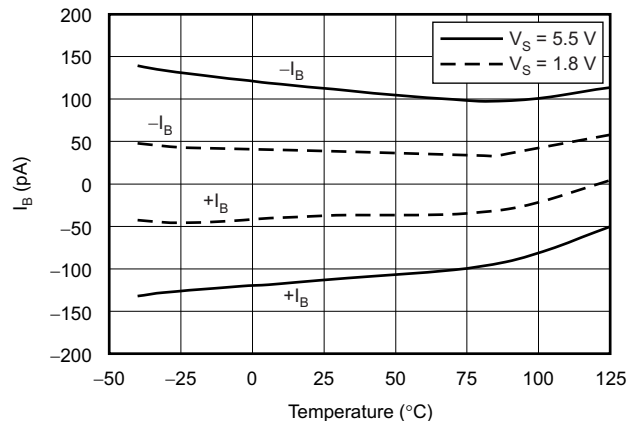


Figure 8. INPUT BIAS CURRENT vs TEMPERATURE

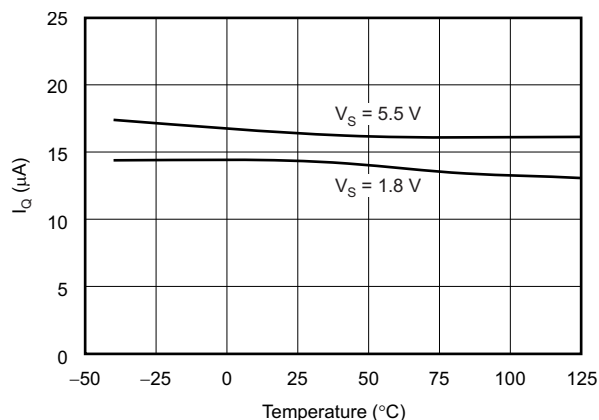


Figure 9. QUIESCENT CURRENT vs TEMPERATURE

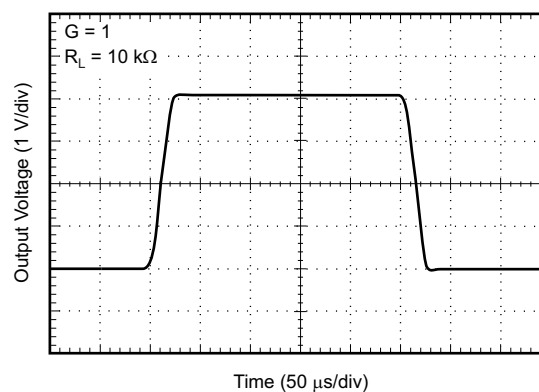


Figure 10. LARGE-SIGNAL STEP RESPONSE

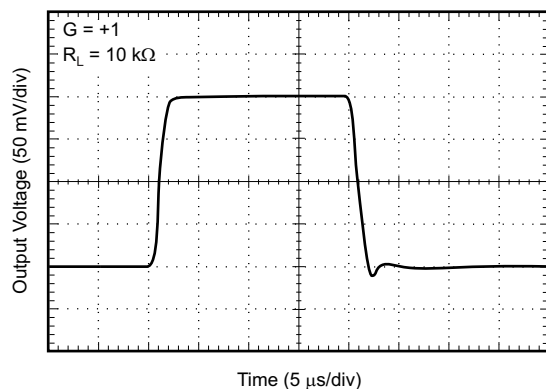


Figure 11. SMALL-SIGNAL STEP RESPONSE

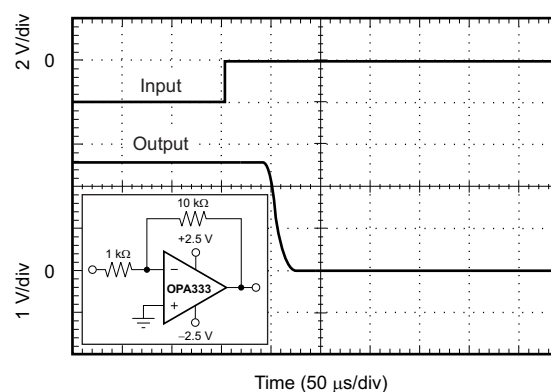
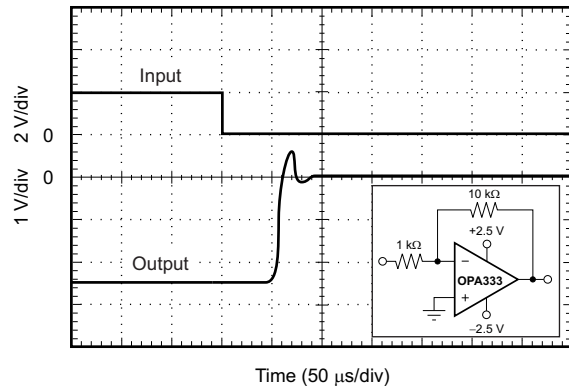


Figure 12. POSITIVE OVERVOLTAGE RECOVERY

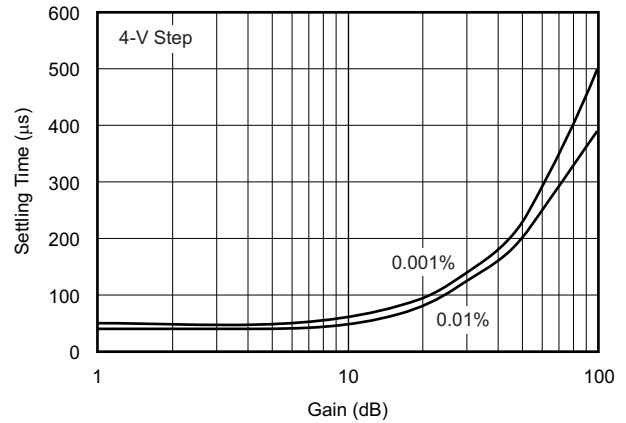


## TYPICAL CHARACTERISTICS (continued)

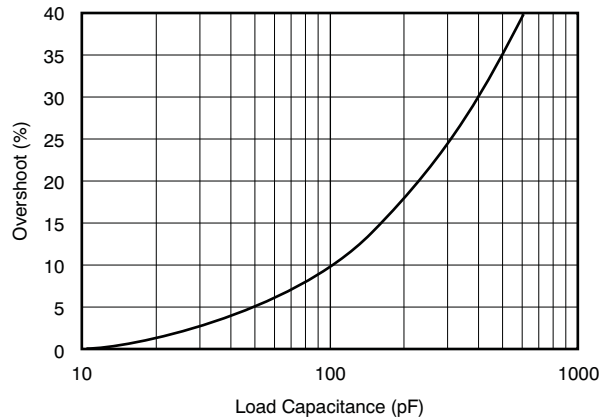
At  $T_A = +25^\circ\text{C}$ ,  $V_S = +5\text{ V}$ , and  $C_L = 0\text{ pF}$ , unless otherwise noted.



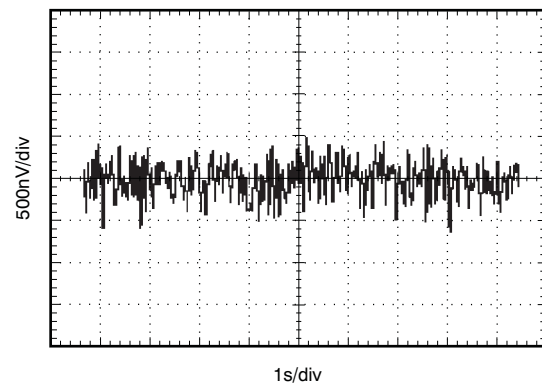
**Figure 13. NEGATIVE OVERVOLTAGE RECOVERY**



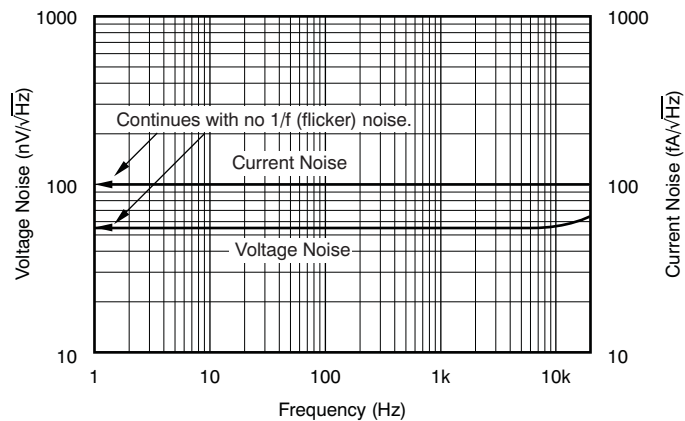
**Figure 14. SETTLING TIME vs CLOSED-LOOP GAIN**



**Figure 15. SMALL-SIGNAL OVERSHOOT  
vs LOAD CAPACITANCE**



**Figure 16. 0.1-Hz TO 10-Hz NOISE**



**Figure 17. CURRENT AND VOLTAGE NOISE SPECTRAL DENSITY vs FREQUENCY**

## DETAILED DESCRIPTION

The OPA333 and OPA2333 are unity-gain stable and free from unexpected output phase reversal. These devices use a proprietary auto-calibration technique to provide low offset voltage and very low drift over time and temperature. For lowest offset voltage and precision performance, optimize circuit layout and mechanical conditions. Avoid temperature gradients that create thermoelectric (Seebeck) effects in the thermocouple junctions formed from connecting dissimilar conductors. Cancel these thermally-generated potentials by assuring they are equal on both input terminals. Other layout and design considerations include:

- Use low thermoelectric-coefficient conditions (avoid dissimilar metals).
- Thermally isolate components from power supplies or other heat sources.
- Shield op amp and input circuitry from air currents, such as cooling fans.

Following these guidelines reduces the likelihood of junctions being at different temperatures, which can cause thermoelectric voltages of 0.1  $\mu\text{V}/^\circ\text{C}$  or higher, depending on materials used.

## OPERATING VOLTAGE

The OPA333 and OPA2333 op amps operate over a power-supply range of +1.8 V to +5.5 V ( $\pm 0.9$  V to  $\pm 2.75$  V). Parameters that vary over supply voltage or temperature are shown in the [Typical Characteristics](#) section.

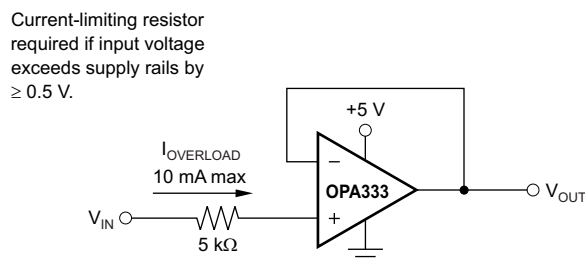
### CAUTION

Supply voltages higher than +7 V (absolute maximum) can permanently damage the device.

## INPUT VOLTAGE

The OPA333 and OPA2333 input common-mode voltage range extends 0.1 V beyond the supply rails. The OPA333 is designed to cover the full range without the troublesome transition region found in some other rail-to-rail amplifiers.

Typically, input bias current is approximately 70 pA; however, input voltages exceeding the power supplies can cause excessive current to flow into or out of the input pins. Momentary voltages greater than the power supply can be tolerated if the input current is limited to 10 mA. This limitation is easily accomplished with an input resistor, as shown in [Figure 18](#).



**Figure 18. Input Current Protection**

## INTERNAL OFFSET CORRECTION

The OPA333 and OPA2333 op amps use an auto-calibration technique with a time-continuous, 350-kHz op amp in the signal path. This amplifier is zero-corrected every 8  $\mu$ s using a proprietary technique. Upon power-up, the amplifier requires approximately 100  $\mu$ s to achieve specified  $V_{OS}$  accuracy. This design has no aliasing or flicker noise.

## ACHIEVING OUTPUT SWING TO THE OP AMP NEGATIVE RAIL

Some applications require output voltage swings from 0 V to a positive full-scale voltage (such as +2.5 V) with excellent accuracy. With most single-supply op amps, problems arise when the output signal approaches 0 V, near the lower output swing limit of a single-supply op amp. A good, single-supply op amp may swing close to single-supply ground, but will not reach ground. The output of the OPA333 and OPA2333 can be made to swing to, or slightly below, ground on a single-supply power source. This swing is achieved with the use of the use of another resistor and an additional, more negative power supply than the op amp negative supply. A pull-down resistor can be connected between the output and the additional negative supply to pull the output down below the value that the output would otherwise achieve, as shown in Figure 19.

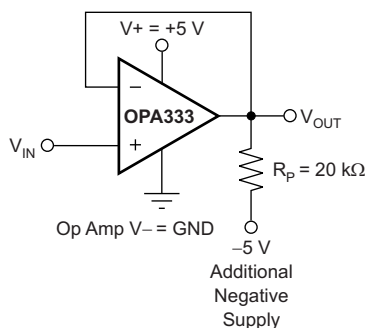


Figure 19.  $V_{OUT}$  Range to Ground

The OPA333 and OPA2333 have an output stage that allows the output voltage to be pulled to the negative supply rail, or slightly below, using the technique previously described. This technique only works with some types of output stages. The OPA333 and OPA2333 are characterized to perform with this technique; the recommended resistor value is approximately 20 k $\Omega$ . Note that this configuration increases the current consumption by several hundreds of microamps. Accuracy is excellent down to 0 V and as low as -2 mV. Limiting and nonlinearity occurs below -2 mV, but excellent accuracy returns after the output is again driven above -2 mV. Lowering the resistance of the pull-down resistor allows the op amp to swing even further below the negative rail. Resistances as low as 10 k $\Omega$  can be used to achieve excellent accuracy down to -10 mV.

## APPLICATION INFORMATION

Figure 20 shows a temperature measurement application

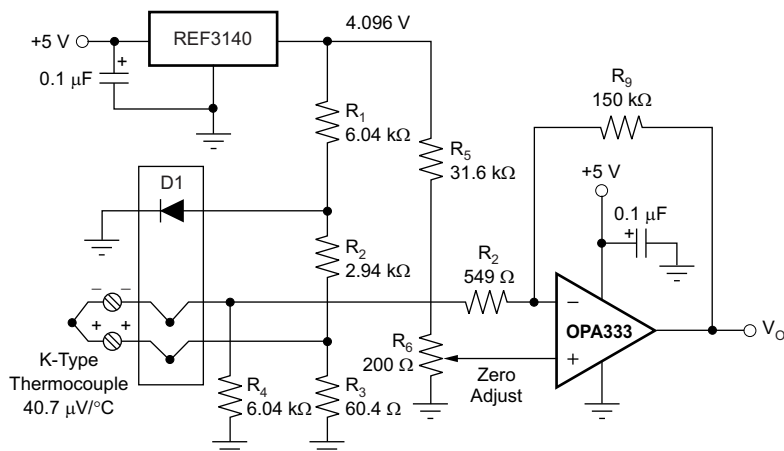


Figure 20. Temperature Measurement

Figure 21 shows the basic configuration for a bridge amplifier.

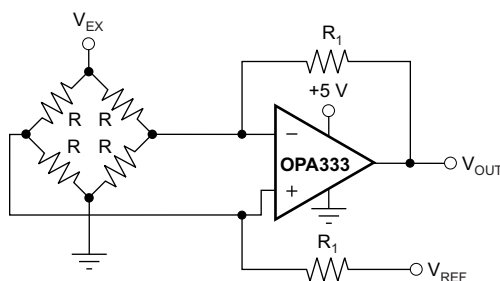
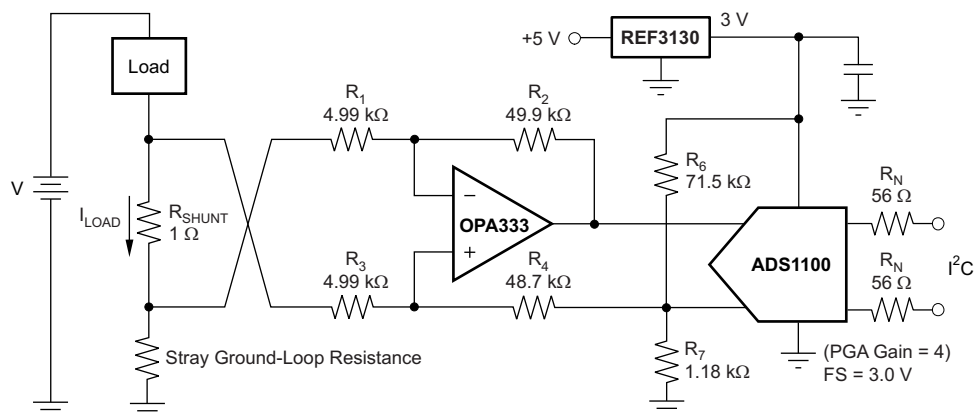


Figure 21. Single Op Amp Bridge Amplifier

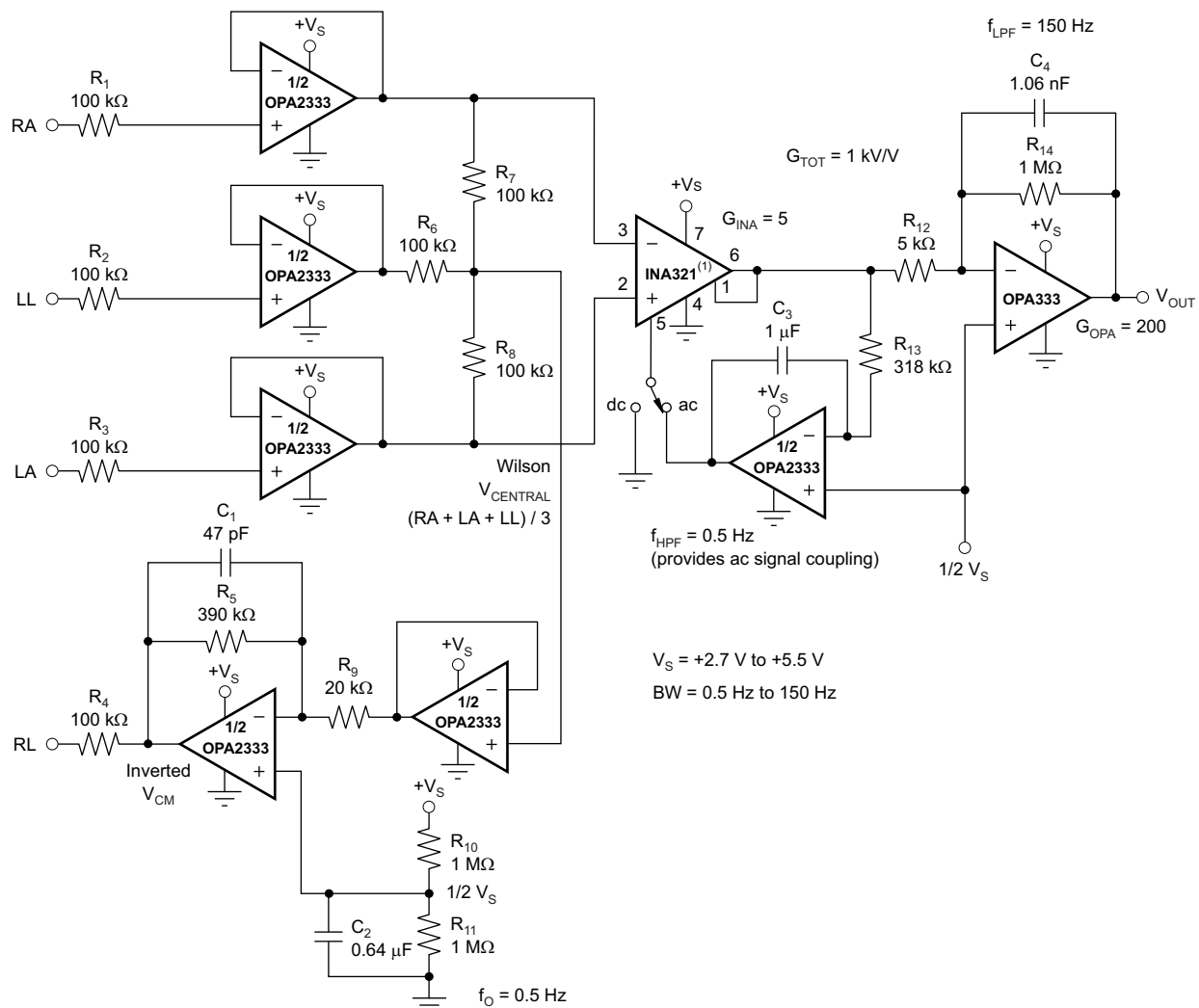
A low-side current shunt monitor is shown in Figure 22.  $R_N$  are operational resistors used to isolate the ADS1100 from the noise of the digital I<sup>2</sup>C bus. The ADS1100 is a 16-bit converter; therefore, a precise reference is essential for maximum accuracy. If absolute accuracy is not required and the 5-V power supply is sufficiently stable, the REF3130 can be omitted.



NOTE: 1% resistors provide adequate common-mode rejection at small ground-loop errors.

Figure 22. Low-Side Current Monitor





- (1) Other instrumentation amplifiers can be used, such as the [INA326](#), which has lower noise, but higher quiescent current.

**Figure 26. Single-Supply, Very Low Power, ECG Circuit**

## LAYOUT GUIDELINES

### GENERAL LAYOUT GUIDELINES

Attention to good layout practices is always recommended. Keep traces short and when possible, use a printed circuit board (PCB) ground plane with surface-mount components placed as close to the device pins as possible. Place a 0.1- $\mu$ F capacitor closely across the supply pins. Apply these guidelines throughout the analog circuit to improve performance and provide benefits, such as reducing the electromagnetic interference (EMI) susceptibility.

Operational amplifiers vary in susceptibility to radio frequency interference (RFI). RFI can generally be identified as a variation in offset voltage or dc signal levels with changes in the interfering RF signal. The OPA333 is specifically designed to minimize susceptibility to RFI and demonstrates remarkably low sensitivity compared to previous generation devices. Strong RF fields may still cause varying offset levels.

### DFN PACKAGE

The OPA2333 is offered in an DFN-8 package (also known as SON). The DFN is a QFN package with lead contacts on only two sides of the bottom of the package. This leadless package maximizes board space and enhances thermal and electrical characteristics through an exposed pad.

DFN packages are physically small, have a smaller routing area, improved thermal performance, and improved electrical parasitics. Additionally, the absence of external leads eliminates bent-lead issues.

The DFN package can be easily mounted using standard PCB assembly techniques. See Application Reports [SLUA271](#), *QFN/SON PCB Attachment* and [SCBA017](#), *Quad Flatpack No-Lead Logic Packages*, both available for download at [www.ti.com](#).

---

#### NOTE

The exposed leadframe die pad on the bottom of the package should be connected to V– or left unconnected.

---

### DFN LAYOUT GUIDELINES

Solder the exposed leadframe die pad on the DFN package to a thermal pad on the PCB. A mechanical drawing showing an example layout is attached at the end of this data sheet. Refinements to this layout may be necessary based on assembly process requirements. Mechanical drawings located at the end of this data sheet list the physical dimensions for the package and pad. The five holes in the landing pattern are optional, and are intended for use with thermal vias that connect the leadframe die pad to the heatsink area on the PCB.

Soldering the exposed pad significantly improves board-level reliability during temperature cycling, key push, package shear, and similar board-level tests. Even with applications that have low-power dissipation, the exposed pad must be soldered to the PCB to provide structural integrity and long-term reliability.

REVISION HISTORY

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

| Changes from Revision C (May 2007) to Revision D                                                                               | Page |
|--------------------------------------------------------------------------------------------------------------------------------|------|
| • Changed data sheet format to most current standard look and feel .....                                                       | 1    |
| • Added OPA2333 DFN-8 pinout to front page .....                                                                               | 1    |
| • Changed 2nd <i>signal input terminals</i> parameter in the Absolute Maximum Ratings from "voltage" to "current" (typo) ..... | 2    |
| • Added OPA333 thermal information table .....                                                                                 | 4    |
| • Added OPA2333 thermal information table .....                                                                                | 4    |
| • Added <a href="#">Table 1</a> .....                                                                                          | 6    |



**PACKAGING INFORMATION**

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| OPA2333AID       | ACTIVE        | SOIC         | D                  | 8    | 75             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | O2333A                  | <a href="#">Samples</a> |
| OPA2333AIDG4     | ACTIVE        | SOIC         | D                  | 8    | 75             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | O2333A                  | <a href="#">Samples</a> |
| OPA2333AIDGKR    | ACTIVE        | VSSOP        | DGK                | 8    | 2500           | Green (RoHS<br>& no Sb/Br) | CU NIPDAUAG             | Level-2-260C-UNLIM   | -40 to 125   | OBAQ                    | <a href="#">Samples</a> |
| OPA2333AIDGKRG4  | ACTIVE        | VSSOP        | DGK                | 8    | 2500           | Green (RoHS<br>& no Sb/Br) | CU NIPDAUAG             | Level-2-260C-UNLIM   | -40 to 125   | OBAQ                    | <a href="#">Samples</a> |
| OPA2333AIDGKT    | ACTIVE        | VSSOP        | DGK                | 8    | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAUAG             | Level-2-260C-UNLIM   | -40 to 125   | OBAQ                    | <a href="#">Samples</a> |
| OPA2333AIDGKTG4  | ACTIVE        | VSSOP        | DGK                | 8    | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAUAG             | Level-2-260C-UNLIM   | -40 to 125   | OBAQ                    | <a href="#">Samples</a> |
| OPA2333AIDR      | ACTIVE        | SOIC         | D                  | 8    | 2500           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | O2333A                  | <a href="#">Samples</a> |
| OPA2333AIDRBR    | ACTIVE        | SON          | DRB                | 8    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 125   | BQZ                     | <a href="#">Samples</a> |
| OPA2333AIDRBRG4  | ACTIVE        | SON          | DRB                | 8    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 125   | BQZ                     | <a href="#">Samples</a> |
| OPA2333AIDRBT    | ACTIVE        | SON          | DRB                | 8    | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 125   | BQZ                     | <a href="#">Samples</a> |
| OPA2333AIDRBTG4  | ACTIVE        | SON          | DRB                | 8    | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 125   | BQZ                     | <a href="#">Samples</a> |
| OPA2333AIDRG4    | ACTIVE        | SOIC         | D                  | 8    | 2500           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | O2333A                  | <a href="#">Samples</a> |
| OPA333AID        | ACTIVE        | SOIC         | D                  | 8    | 75             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | O333A                   | <a href="#">Samples</a> |
| OPA333AIDBVR     | ACTIVE        | SOT-23       | DBV                | 5    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | OAXQ                    | <a href="#">Samples</a> |
| OPA333AIDBVRG4   | ACTIVE        | SOT-23       | DBV                | 5    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | OAXQ                    | <a href="#">Samples</a> |
| OPA333AIDBVT     | ACTIVE        | SOT-23       | DBV                | 5    | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | OAXQ                    | <a href="#">Samples</a> |
| OPA333AIDBVTG4   | ACTIVE        | SOT-23       | DBV                | 5    | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | OAXQ                    | <a href="#">Samples</a> |

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| OPA333AIDCKR     | ACTIVE        | SC70         | DCK                | 5    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | BQY                     | <a href="#">Samples</a> |
| OPA333AIDCKRG4   | ACTIVE        | SC70         | DCK                | 5    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | BQY                     | <a href="#">Samples</a> |
| OPA333AIDCKT     | ACTIVE        | SC70         | DCK                | 5    | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | BQY                     | <a href="#">Samples</a> |
| OPA333AIDCKTG4   | ACTIVE        | SC70         | DCK                | 5    | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | BQY                     | <a href="#">Samples</a> |
| OPA333AIDG4      | ACTIVE        | SOIC         | D                  | 8    | 75             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | O333A                   | <a href="#">Samples</a> |
| OPA333AIDR       | ACTIVE        | SOIC         | D                  | 8    | 2500           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | O333A                   | <a href="#">Samples</a> |
| OPA333AIDRG4     | ACTIVE        | SOIC         | D                  | 8    | 2500           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | O333A                   | <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)

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

<sup>(6)</sup> Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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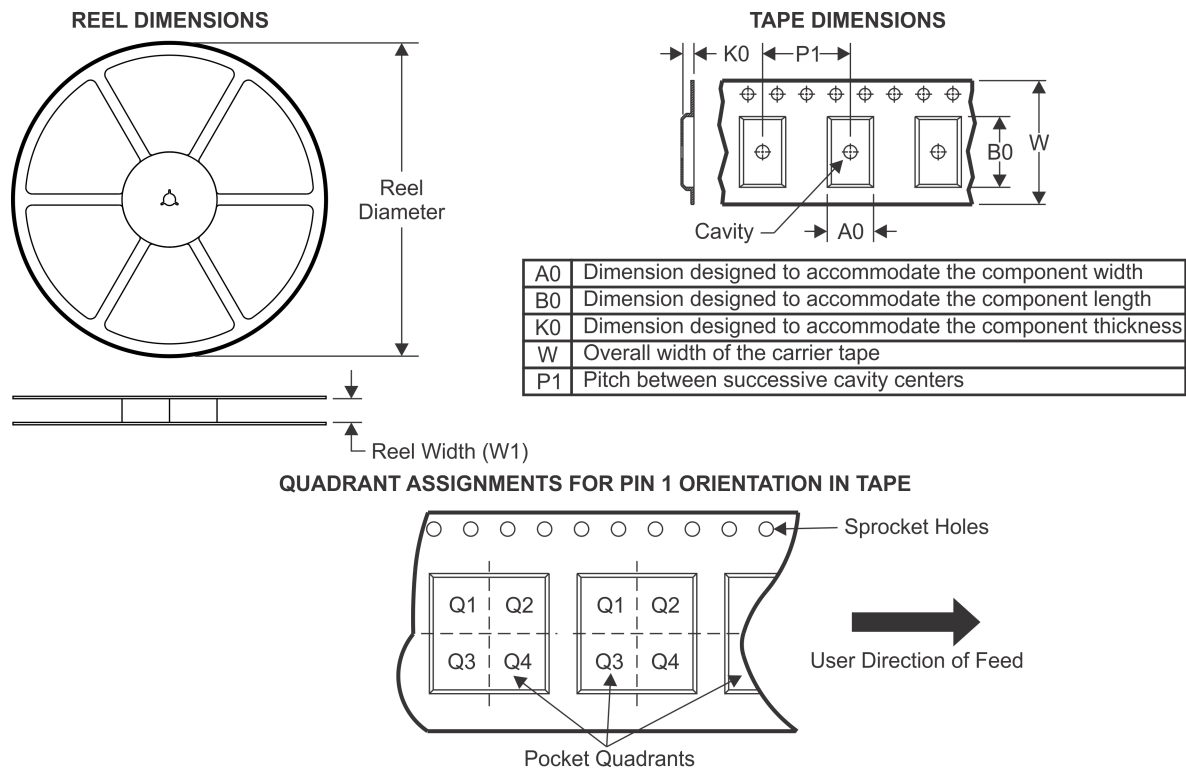
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**OTHER QUALIFIED VERSIONS OF OPA2333, OPA333 :**

- Automotive: [OPA2333-Q1](#), [OPA333-Q1](#)

NOTE: Qualified Version Definitions:

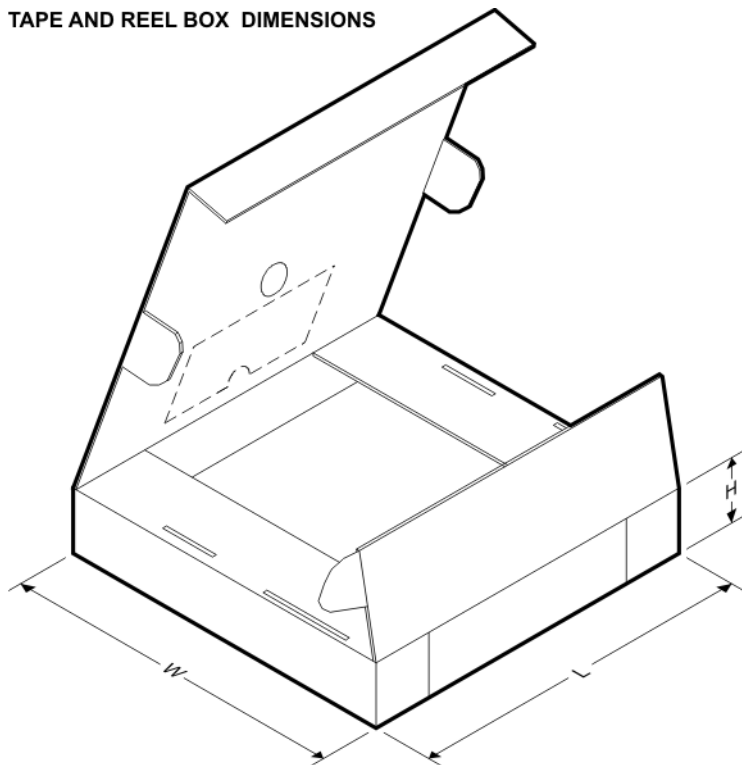
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

**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 |
|---------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| OPA2333AIDGKR | VSSOP        | DGK             | 8    | 2500 | 330.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| OPA2333AIDGKT | VSSOP        | DGK             | 8    | 250  | 330.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| OPA2333AIDR   | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| OPA2333AIDRBR | SON          | DRB             | 8    | 3000 | 330.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |
| OPA2333AIDRBT | SON          | DRB             | 8    | 250  | 180.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |
| OPA333AIDBVR  | SOT-23       | DBV             | 5    | 3000 | 179.0              | 8.4                | 3.2     | 3.2     | 1.4     | 4.0     | 8.0    | Q3            |
| OPA333AIDBVR  | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.3     | 3.2     | 1.4     | 4.0     | 8.0    | Q3            |
| OPA333AIDBVT  | SOT-23       | DBV             | 5    | 250  | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| OPA333AIDCKR  | SC70         | DCK             | 5    | 3000 | 179.0              | 8.4                | 2.2     | 2.5     | 1.2     | 4.0     | 8.0    | Q3            |
| OPA333AIDCKT  | SC70         | DCK             | 5    | 250  | 179.0              | 8.4                | 2.2     | 2.5     | 1.2     | 4.0     | 8.0    | Q3            |
| OPA333AIDR    | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |

## TAPE AND REEL BOX DIMENSIONS

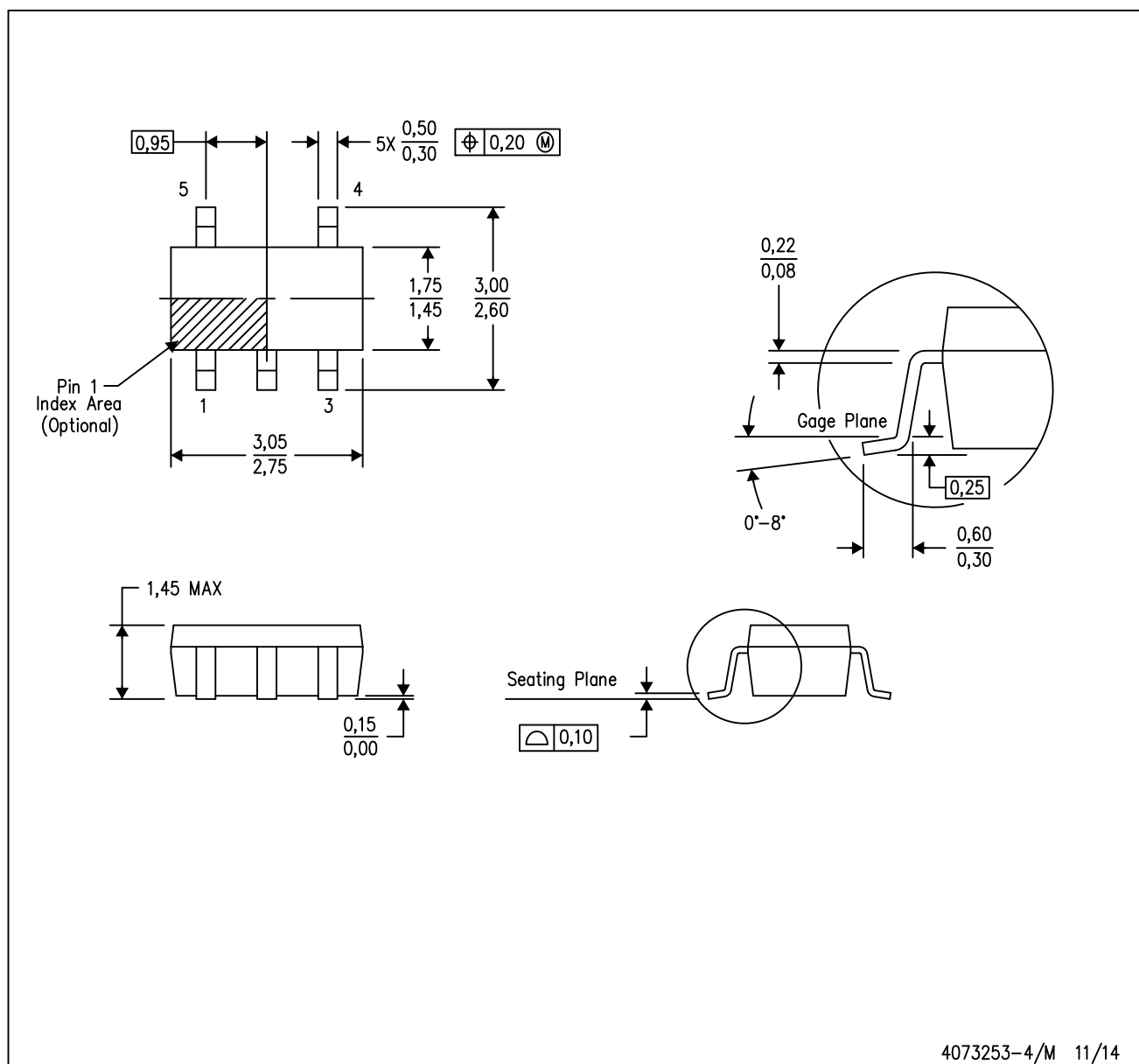


\*All dimensions are nominal

| Device        | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|---------------|--------------|-----------------|------|------|-------------|------------|-------------|
| OPA2333AIDGKR | VSSOP        | DGK             | 8    | 2500 | 364.0       | 364.0      | 27.0        |
| OPA2333AIDGKT | VSSOP        | DGK             | 8    | 250  | 364.0       | 364.0      | 27.0        |
| OPA2333AIDR   | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |
| OPA2333AIDRBR | SON          | DRB             | 8    | 3000 | 367.0       | 367.0      | 35.0        |
| OPA2333AIDRBT | SON          | DRB             | 8    | 250  | 210.0       | 185.0      | 35.0        |
| OPA333AIDBVR  | SOT-23       | DBV             | 5    | 3000 | 203.0       | 203.0      | 35.0        |
| OPA333AIDBVR  | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| OPA333AIDBVT  | SOT-23       | DBV             | 5    | 250  | 180.0       | 180.0      | 18.0        |
| OPA333AIDCKR  | SC70         | DCK             | 5    | 3000 | 203.0       | 203.0      | 35.0        |
| OPA333AIDCKT  | SC70         | DCK             | 5    | 250  | 203.0       | 203.0      | 35.0        |
| OPA333AIDR    | SOIC         | D               | 8    | 2500 | 367.0       | 367.0      | 35.0        |

DBV (R-PDSO-G5)

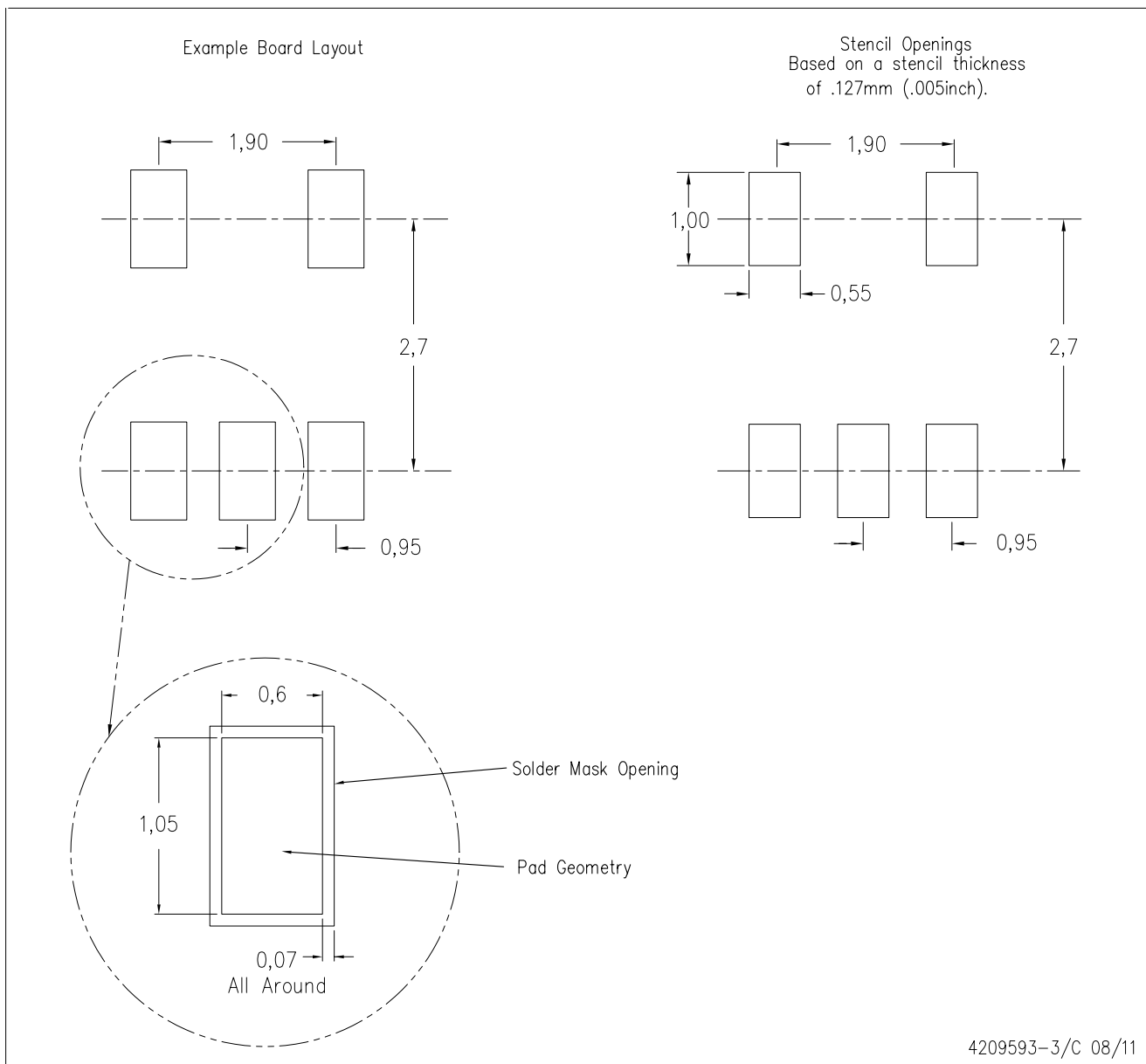
PLASTIC SMALL-OUTLINE PACKAGE



- 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. Mold flash and protrusion shall not exceed 0.15 per side.
  - D. Falls within JEDEC MO-178 Variation AA.

DBV (R-PDSO-G5)

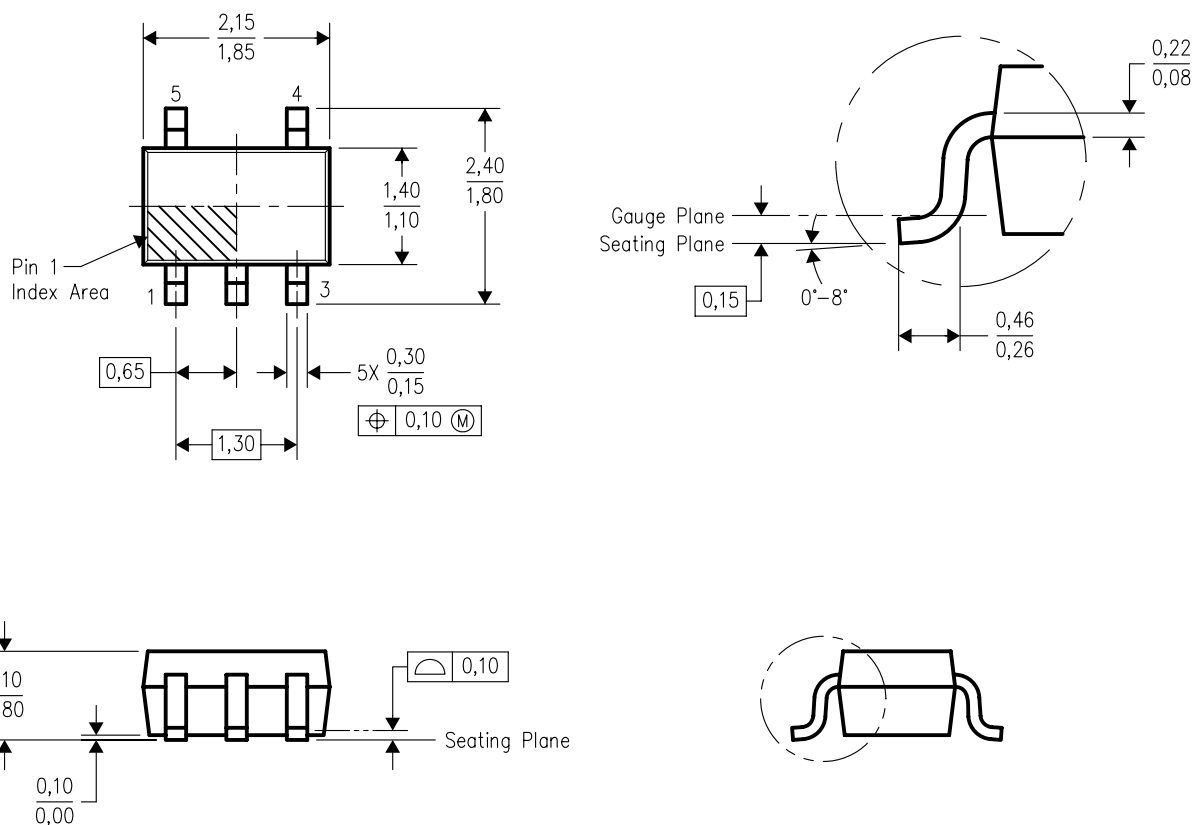
PLASTIC SMALL OUTLINE



- 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



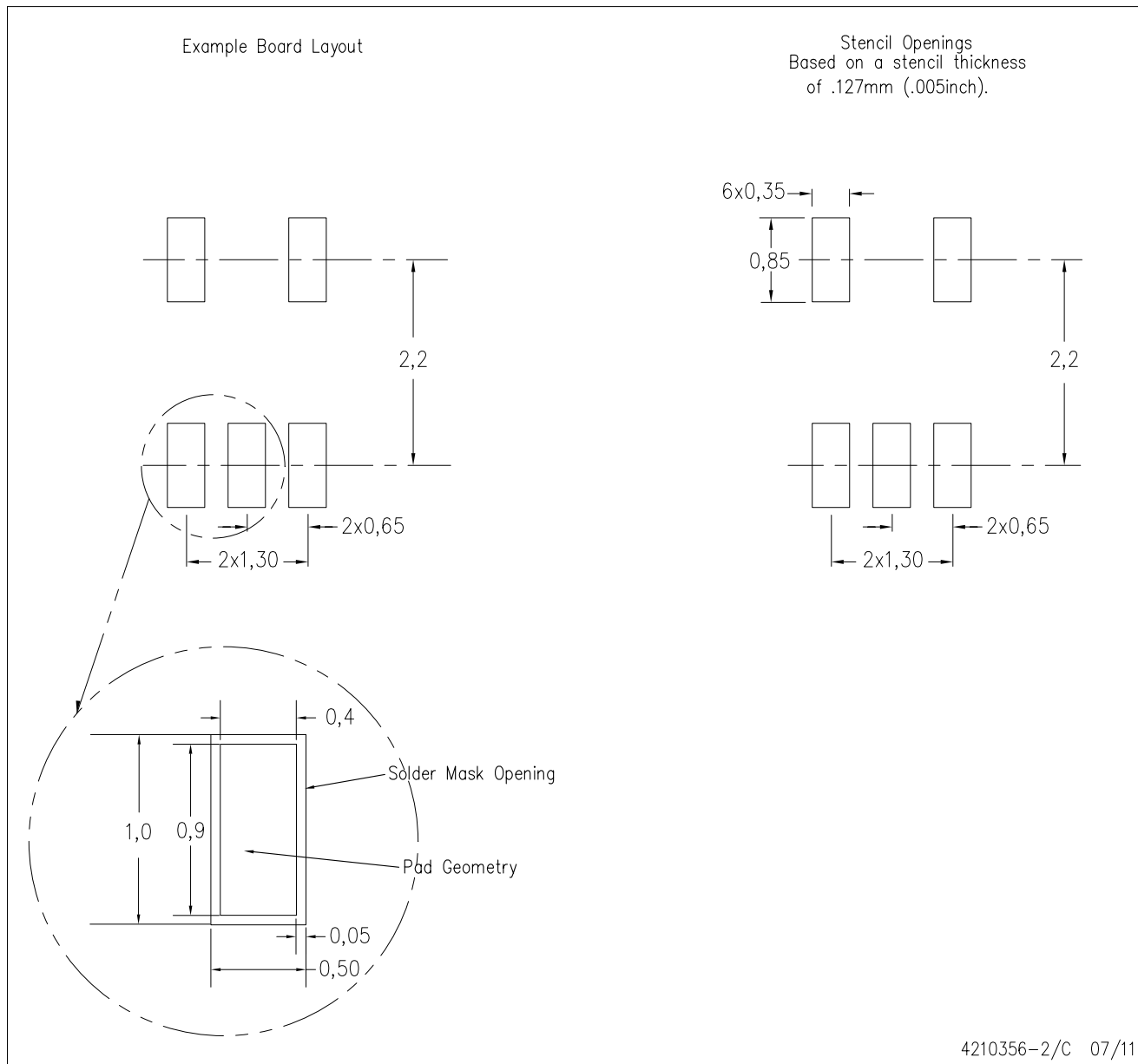
4093553-3/G 01/2007

- 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)

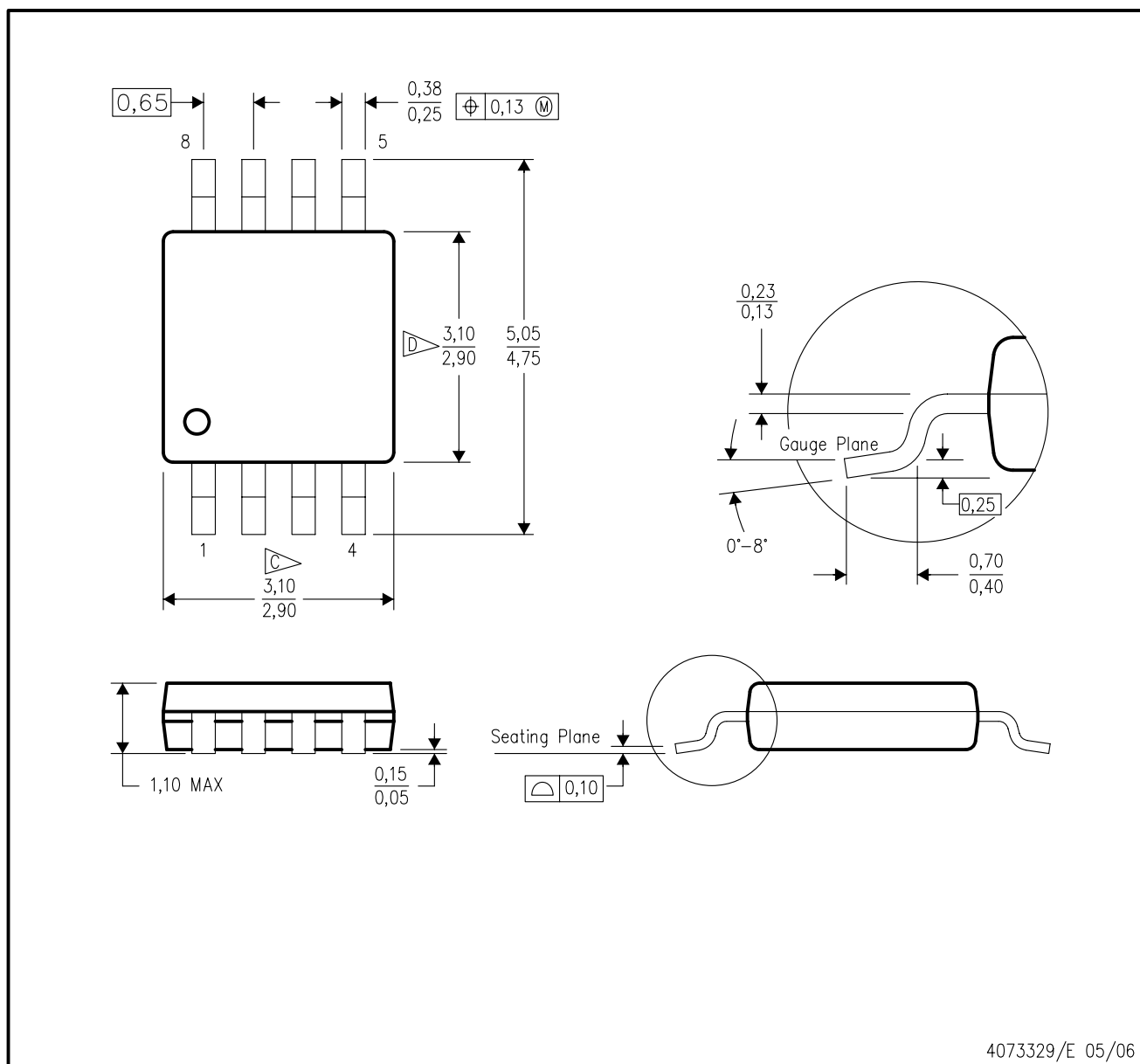
PLASTIC SMALL OUTLINE



- 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)

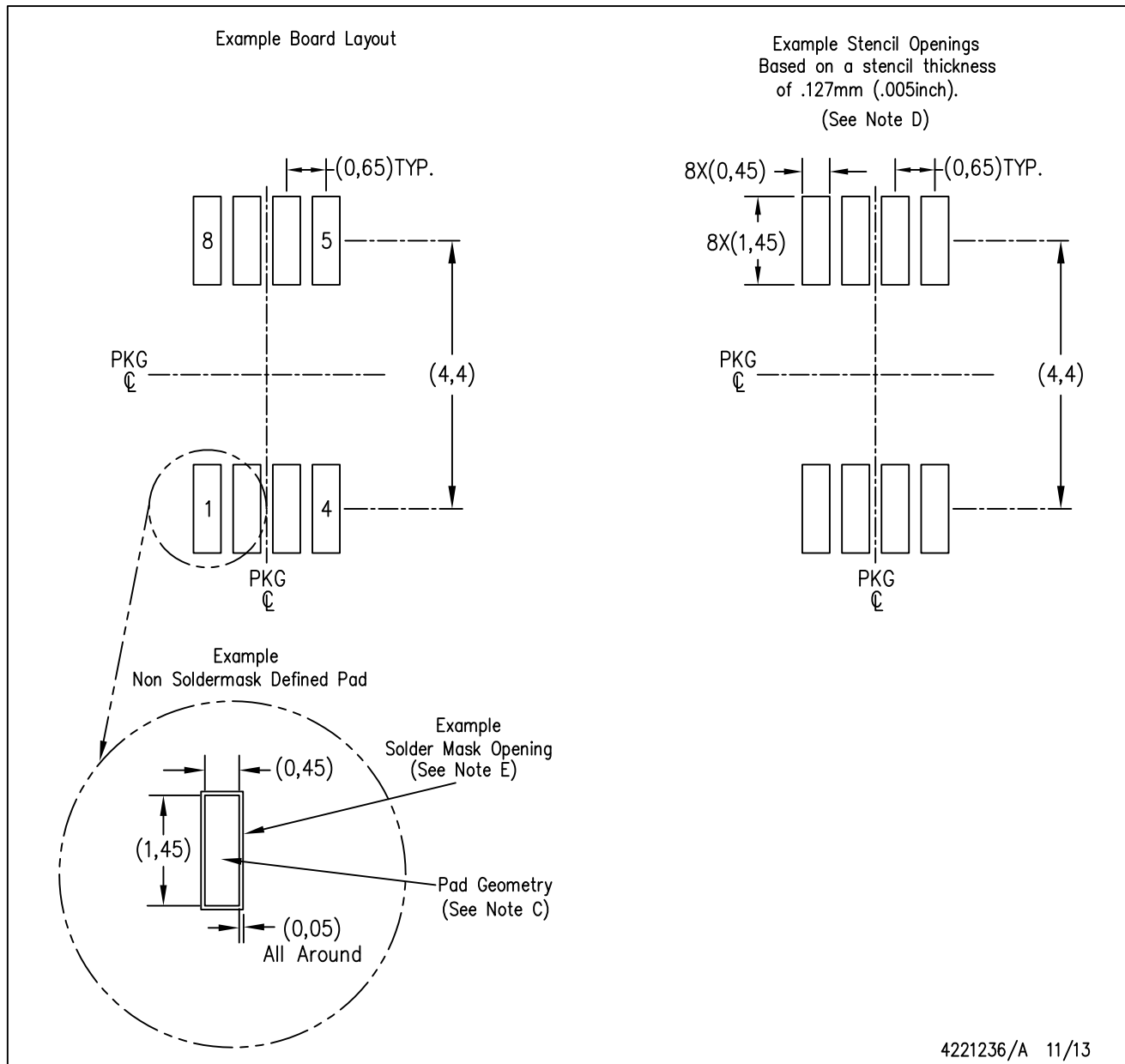
PLASTIC SMALL-OUTLINE PACKAGE



4073329/E 05/06

DGK (S-PDSO-G8)

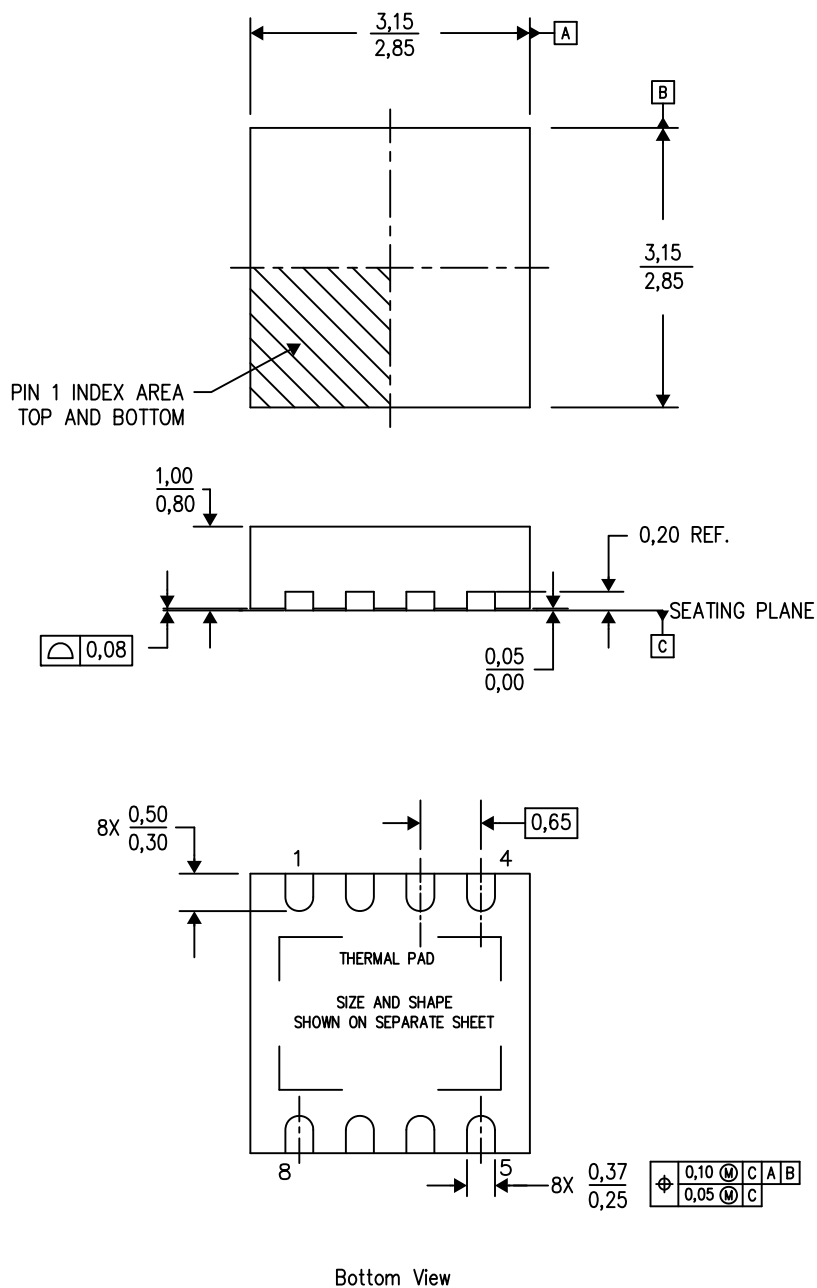
PLASTIC SMALL OUTLINE PACKAGE



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-7351 is recommended for alternate designs.
  - 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.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

DRB (S-PVSON-N8)

PLASTIC SMALL OUTLINE NO-LEAD



4203482-2/K 06/12

- NOTES:
- All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - This drawing is subject to change without notice.
  - Small Outline No-Lead (SON) package configuration.
  - The package thermal pad must be soldered to the board for thermal and mechanical performance.
  - See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.

DRB (S-PVSON-N8)

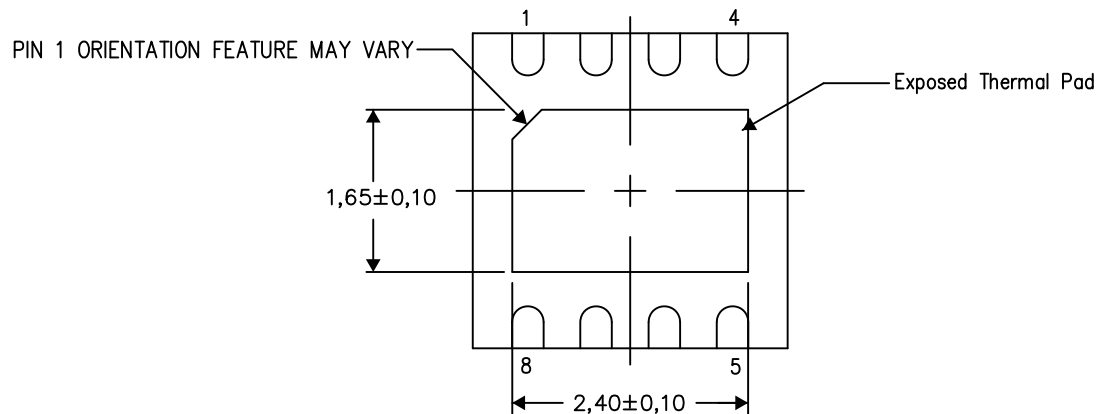
PLASTIC SMALL OUTLINE NO-LEAD

## THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No-Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at [www.ti.com](http://www.ti.com).

The exposed thermal pad dimensions for this package are shown in the following illustration.



Bottom View

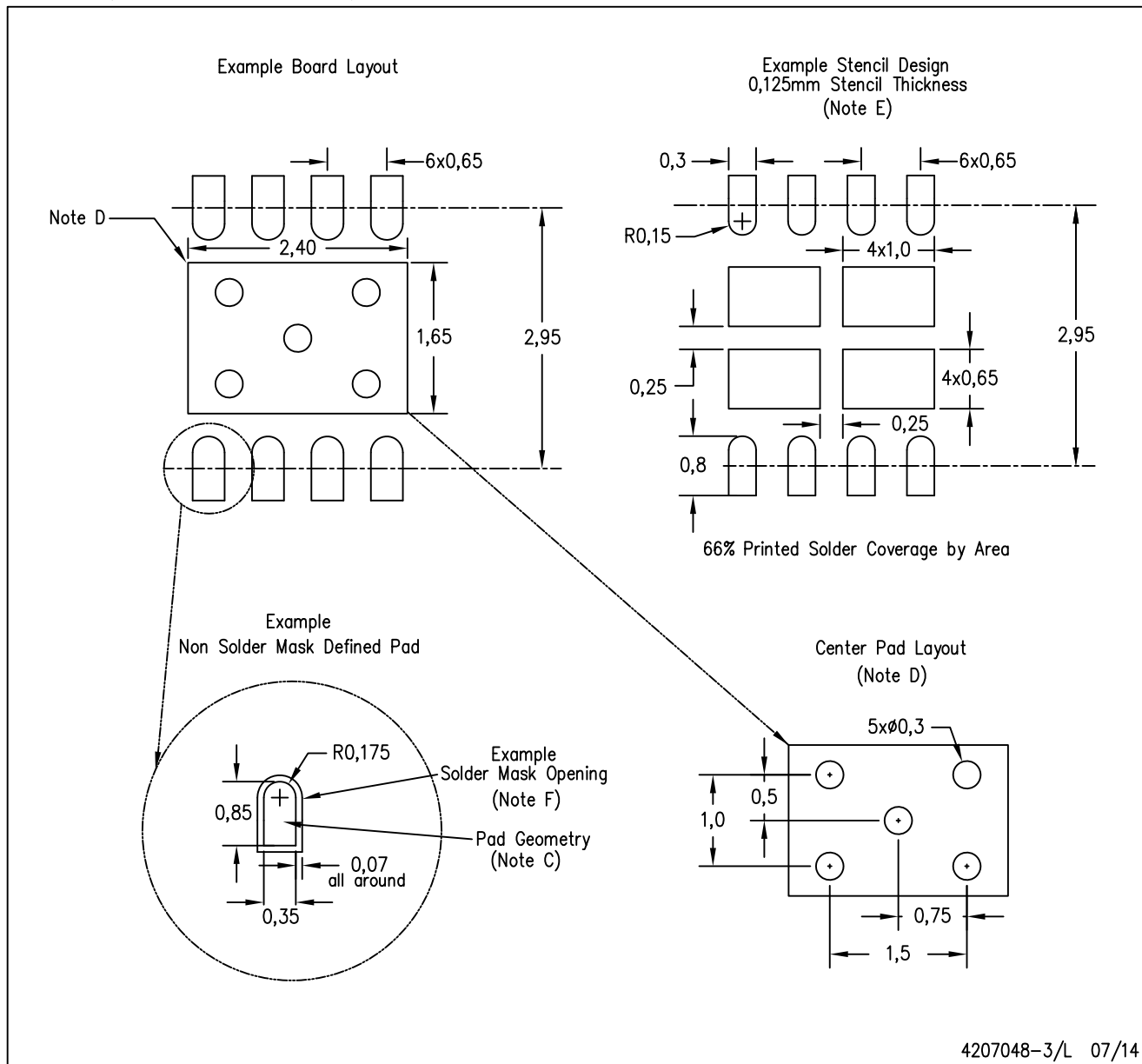
Exposed Thermal Pad Dimensions

4206340-3/P 07/14

NOTE: All linear dimensions are in millimeters

DRB (S-PVSON-N8)

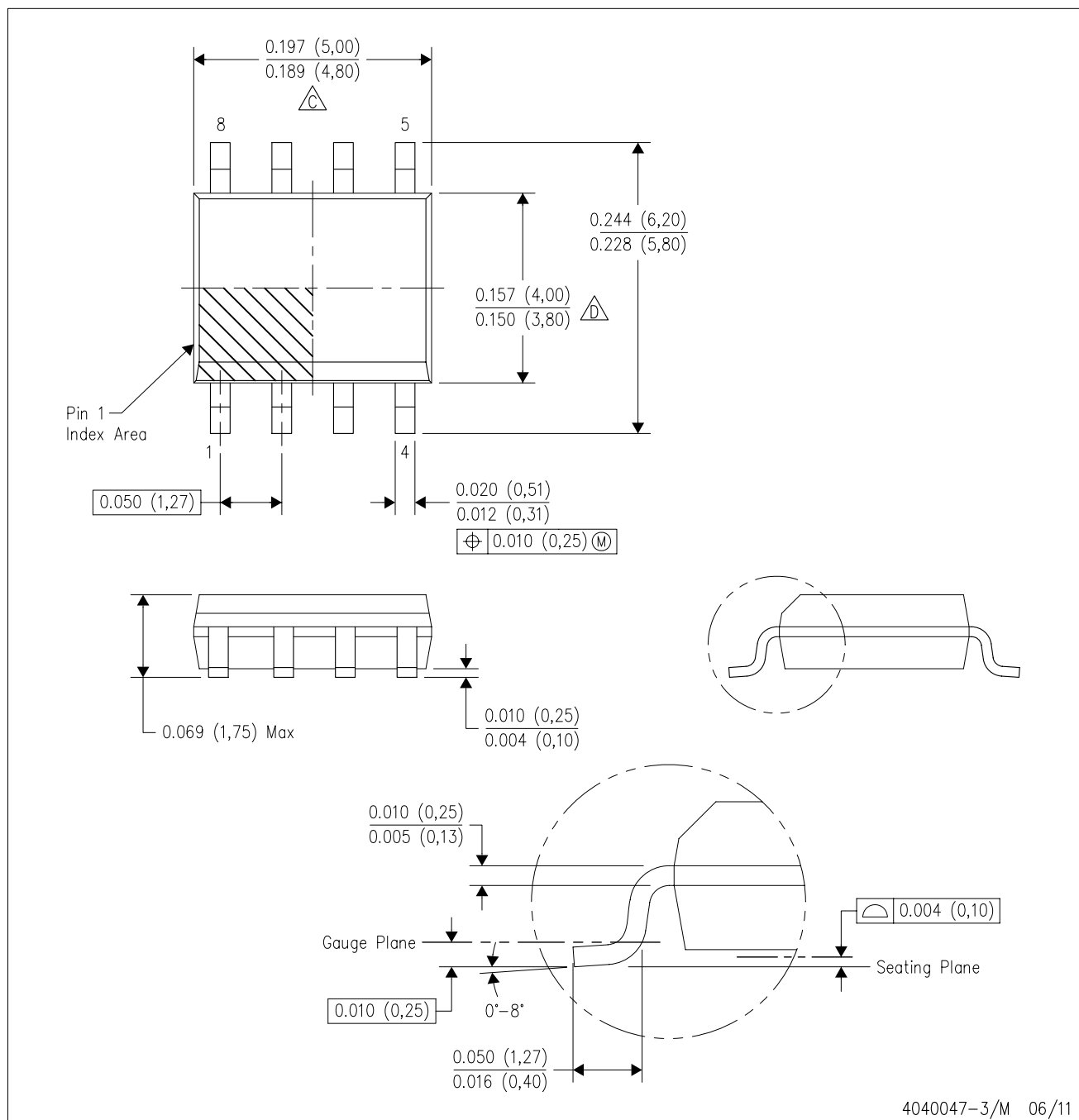
PLASTIC SMALL OUTLINE NO-LEAD



- 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. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, QFN Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - 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. Refer to IPC 7525 for stencil design considerations.
  - F. Customers should contact their board fabrication site for solder mask tolerances.

D (R-PDSO-G8)

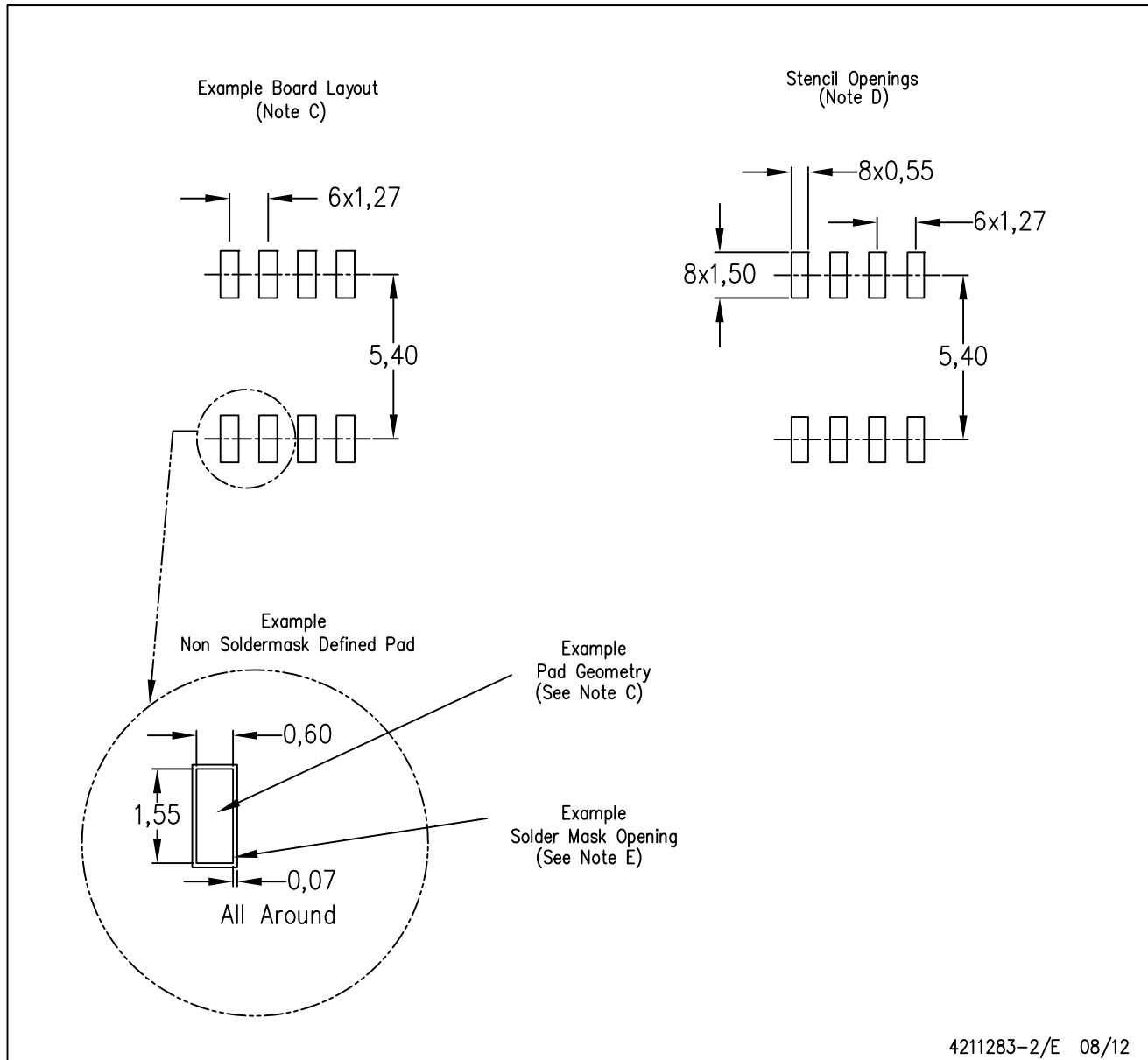
PLASTIC SMALL OUTLINE



- 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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