# REF33xx 3.9-µA, SC70-3, SOT-23-3, and UQFN-8, 30-ppm/°C Drift Voltage Reference

## 1 Features

- Microsize Packages: SC70-3, SOT-23-3, UQFN-8
- Low Supply Current: 3.9 µA (typ)
- Extremely Low Dropout Voltage: 110 mV (typ)
- High Output Current: ±5 mA
- Low Temperature Drift: 30 ppm/°C (max)
- High Initial Accuracy: ±0.15% (max)
- 0.1-Hz to 10-Hz Noise: 35 $\mu V_{PP}$ (REF3312)
- Voltage Options: 1.2 V, 1.8 V, 2.5 V, 3 V, 3.3 V

## 2 Applications

- Portable Equipment
- Tablets and Smartphones
- Hard Disk Drives
- Sensor Modules
- Data Acquisition Systems
- Medical Equipment
- Test Equipment

## 3 Description

The REF33xx is a low-power, precision, low-dropout voltage reference family available in tiny SC70-3 and SOT-23-3 packages, and in a 1.5-mm × 1.5-mm UQFN-8 package. Small size and low power consumption (5-µA max) make the REF33xx ideal for a wide variety of portable and battery-powered applications.

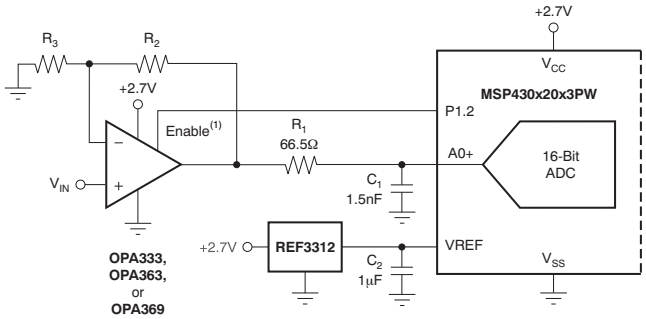
The REF33xx can be operated at a supply voltage 180 mV above the specified output voltage under normal load conditions, with the exception of the REF3312, which has a minimum supply voltage of 1.7 V. All models are specified for the wide temperature range of –40°C to +125°C.

**Device Information(1)**

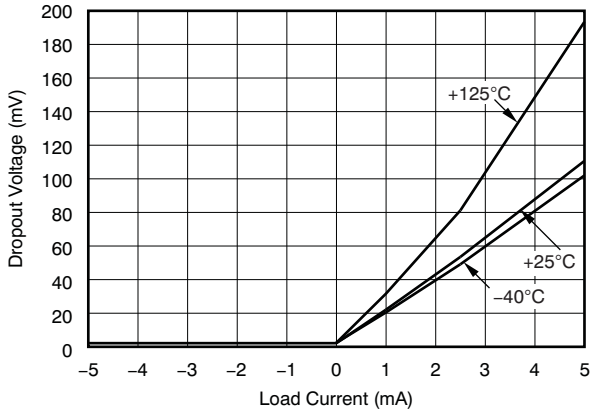
| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|---|---|---|
| REF33xx | SOT-23 (3) | 2.92 mm × 1.30 mm |
| | SC70 (3) | 2.00 mm × 1.25 mm |
| | UQFN (8) | 1.50 mm × 1.50 mm |

(1) For all available packages, see the package option addendum at the end of the datasheet.

**REF3312 in a Single-Supply Signal Chain**




**Dropout Voltage vs Load Current**




An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

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## 4 Revision History

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

**Changes from Revision E (October 2014) to Revision F** — **Page**

- Added REF3317 to data sheet ... 1
- Changed minimum supply voltage value in second paragraph of *Description* section ... 1
- Changed *Device Information* table ... 1
- Changed *ESD Ratings* table: changed title and format, moved $T_{stg}$ parameter to *Absolute Maximum Ratings* table ... 5
- Changed supply voltage value in footnote of *Recommended Operating Conditions* table ... 5
- Changed supply voltage value in footnote 1 of *Electrical Characteristics* table ... 6
- Changed minimum supply voltage value in *Device Functional Modes* section ... 12
- Changed minimum supply voltage value in *Power-Supply Recommendations* section ... 18

**Changes from Revision D (June 2014) to Revision E** — **Page**

- Added REF3325 UQFN package to data sheet ... 1
- Added note to *Applications and Implementation* section ... 13

**Changes from Revision C (March 2014) to Revision D** — **Page**

- Added note to Recommended Operating Conditions ... 5
- Moved *Thermal Hysteresis* section to *Parameter Measurement Information* section ... 10
- Changed *Applications and Implementation* section to latest standard; added new sections ... 13

**Changes from Revision B (February 2014) to Revision C** — **Page**

- Changed Recommended Operating Conditions supply input voltage range maximum value from 55 to 5.5 ... 5


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**Changes from Revision A (September 2007) to Revision B** **Page**

- Changed document format to meet latest data sheet standards; added new sections and moved existing sections ..... 1
- Moved package figures from front page to *Pin Configuration and Functions* ..... 1
- Added new figures to front page ..... 1
- Deleted Ordering Information table; see Package Option Addendum for most current ordering information ..... 4
- Added RSE pin configuration ..... 4
- Added Thermal Information table ..... 5
- Deleted Thermal Resistance parameter in Electrical Characteristics; see new Thermal Information table ..... 7

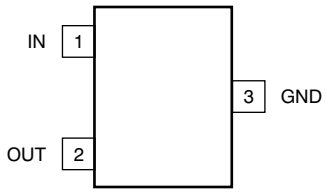
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## 5 Device Comparison

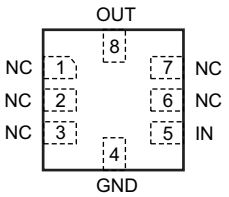
| PRODUCT | DESCRIPTION |
|---|---|
| REF3312 | 1.25 V |
| REF3318 | 1.8 V |
| REF3320 | 2.048 V |
| REF3325 | 2.5 V |
| REF3330 | 3.0 V |
| REF3333 | 3.3 V |

## 6 Pin Configuration and Functions

**REF3312, REF3318, REF3320, REF3325, REF3330, REF3333**
**DBZ Package and DCK Package**
**SOT-23-3, SC70-3**
**(Top View)**




**REF3312, REF3318, REF3320, REF3325, REF3330, REF3333**
**RSE Package**
**UQFN-8**
**(Top View)**




**Pin Functions**

| PIN | | | DESCRIPTION |
|---|---|---|---|
| NAME | DBZ, DCK | RSE | |
| GND | 3 | 4 | Ground |
| IN | 1 | 5 | Input supply voltage |
| NC | — | 1, 2, 3, 6, 7 | Not connected |
| OUT | 2 | 8 | Output voltage |


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# 7 Specifications

## 7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted).(1)

| | | MIN | MAX | UNIT |
|---|---|---|---|---|
| Voltage | Input voltage | | 7.5 | V |
| | Output voltage | | 5 | V |
| Current | Output short-circuit, $I_{SC}$(2) | | 180 | mA |
| Temperature | Operating temperature | –50 | 150 | °C |
| | Junction temperature, $T_J$ | | 150 | °C |
| | Storage temperature, $T_{stg}$ | –65 | 150 | °C |

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) See the *Power-Supply Recommendations* section of this data sheet.

## 7.2 ESD Ratings

| | | | VALUE | UNIT |
|---|---|---|---|---|
| $V_{(ESD)}$ | Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001(1) | ±4000 | V |
| | | Charged device model (CDM), per JEDEC specification JESD22-C101(2) | ±1000 | |
| | | Machine model (MM) | ±200 | |

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

## 7.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted).

| | | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|
| $V_{IN}$ | Supply input voltage(1) | $V_{OUT}$ + 0.2 | | 5.5 | V |
| $I_{OUT}$ | Output current range | –30 | | 30 | mA |

(1) The minimum supply voltage for the REF3312 is 1.7 V.

## 7.4 Thermal Information

| THERMAL METRIC(1) | | REF33xx | | REF3325, REF3330 | UNIT |
|---|---|---|---|---|---|
| | | DCK (SC70) | DBZ (SOT-23) | RSE (UQFN) | |
| | | 3 PINS | 3 PINS | 8 PINS | |
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 279.7 | 313.1 | 61.2 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 136.3 | 144.0 | 32.6 | °C/W |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 56.9 | 109.3 | 16.0 | °C/W |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 11.0 | 18.2 | 1.3 | °C/W |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 56.1 | 107.9 | 16.0 | °C/W |
| $R_{\theta JC(bot)}$ | Junction-to-case (bottom) thermal resistance | N/A | N/A | N/A | °C/W |

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

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## 7.5 Electrical Characteristics

At $T_A$ = 25°C, $V_{IN}$ = 5 V, and $I_{LOAD}$ = 0 mA (unless otherwise noted).

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **REF3312 (1.25 V)** | | | | | | |
| $V_{OUT}$ | Output voltage | | | 1.25 | | V |
| | Initial accuracy | | –0.15% | | 0.15% | |
| | Output voltage noise | f = 0.1 Hz to 10 Hz | | 35 | | $\mu V_{PP}$ |
| **REF3318 (1.8 V)** | | | | | | |
| $V_{OUT}$ | Output voltage | | | 1.8 | | V |
| | Initial accuracy | | –0.15% | | 0.15% | |
| | Output voltage noise | f = 0.1 Hz to 10 Hz | | 50 | | $\mu V_{PP}$ |
| **REF3320 (2.048 V)** | | | | | | |
| $V_{OUT}$ | Output voltage | | | 2.048 | | V |
| | Initial accuracy | | –0.15% | | 0.15% | |
| | Output voltage noise | f = 0.1 Hz to 10 Hz | | 55 | | $\mu V_{PP}$ |
| **REF3325 (2.5 V)** | | | | | | |
| $V_{OUT}$ | Output voltage | | | 2.5 | | V |
| | Initial accuracy | | –0.15% | | 0.15% | |
| | Output voltage noise | f = 0.1 Hz to 10 Hz | | 70 | | $\mu V_{PP}$ |
| **REF3330 (3.0 V)** | | | | | | |
| $V_{OUT}$ | Output voltage | | | 3.0 | | V |
| | Initial accuracy | | –0.15% | | 0.15% | |
| | Output voltage noise | f = 0.1 Hz to 10 Hz | | 84 | | $\mu V_{PP}$ |
| **REF3333 (3.3 V)** | | | | | | |
| $V_{OUT}$ | Output voltage | | | 3.3 | | V |
| | Initial accuracy | | –0.15% | | 0.15% | |
| | Output voltage noise | f = 0.1 Hz to 10 Hz | | 92 | | $\mu V_{PP}$ |
| **REF33xx (REF3312, REF3318, REF3320, REF3325, REF3330, REF3333)** | | | | | | |
| $dV_{OUT}/dT$ | Output voltage temperature drift | –40°C to 85°C | | 9 | 30 | ppm/°C |
| | | –40°C to 125°C | | 8 | 30 | ppm/°C |
| $\Delta V_{O(\Delta VI)}$ | Line regulation | $V_{IN}$ = $V_{OUT}$ + 200 mV to 5.5 V(1) | –50 | 6 | 50 | ppm/V |
| | | 0°C to +70°C | | 6 | | ppm/V |
| | | –40°C to 85°C | | 8 | | ppm/V |
| | | –40°C to 125°C | | 30 | | ppm/V |
| $\Delta V_{O(\Delta IL)}$ | Load regulation | $V_{IN}$ = $V_{OUT}$ + 200 mV(1) | –50 | 6 | 50 | ppm/mA |
| | | $I_{LOAD}$ = ±5 mA, 0°C to 70°C | | 10 | | ppm/mA |
| | | –40°C to 85°C | | 20 | | ppm/mA |
| | | –40°C to 125°C | | 20 | | ppm/mA |
| dT | Thermal hysteresis(2) | | | 90 | | ppm |
| $V_{IN} – V_{OUT}$ | Minimum dropout voltage(1) | $I_{LOAD}$ = ±5 mA | | 110 | 160 | mV |
| | | 0°C to 70°C | | 120 | | mV |
| | | –40°C to 85°C | | 135 | | mV |
| | | –40°C to 125°C | | 180 | | mV |
| | | $I_{LOAD}$ = ±2 mA, –40°C to 85°C | | | 70 | mV |
| $I_{SC}$ | Short-circuit current | Sourcing and sinking | | 35 | | mA |
| | Capacitive load | | 0.1 | | 10 | µF |
| | Turn-on settling time | To 0.1% with $C_L$ = 1 µF | | 2 | | ms |

(1) The minimum supply voltage for the REF3312 is 1.7 V.
(2) The thermal hysteresis procedure is explained in more detail in the *Thermal Hysteresis* section.


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## Electrical Characteristics (continued)

At $T_A$ = 25°C, $V_{IN}$ = 5 V, and $I_{LOAD}$ = 0 mA (unless otherwise noted).

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **POWER SUPPLY** | | | | | | |
| $V_S$ | Specified voltage range | | $V_{OUT}$ + 0.2 (1) | | 5.5 | V |
| | Operating voltage range | $I_{LOAD}$ = 0 mA | | $V_{OUT}$ + 0.005 | 5.5 | V |
| $I_Q$ | Current | | | 3.9 | 5 | µA |
| | | –40°C to 85°C | | 4.4 | 6.5 | µA |
| | | –40°C to 125°C | | 4.8 | 8.5 | µA |
| **TEMPERATURE** | | | | | | |
| $T_A$ | Specified range | | –40 | | 125 | °C |
| | Operating range | | –50 | | 150 | °C |

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## 7.6 Typical Characteristics

At $T_A$ = 25°C and $V_{IN}$ = 5 V, and REF3325 used for typical characteristic measurements (unless otherwise noted).

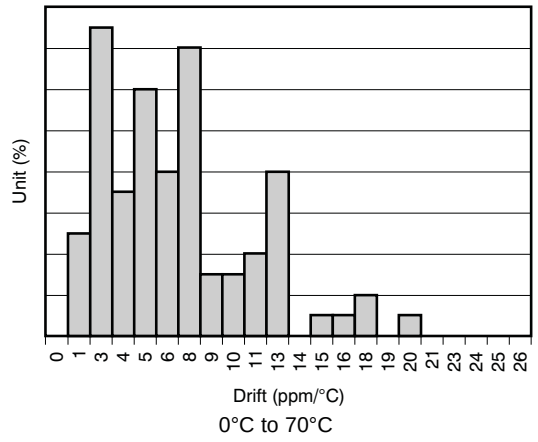



**Figure 1. Temperature Drift**

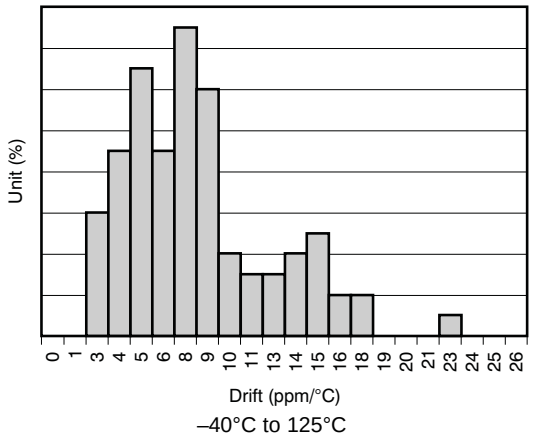



**Figure 2. Temperature Drift**

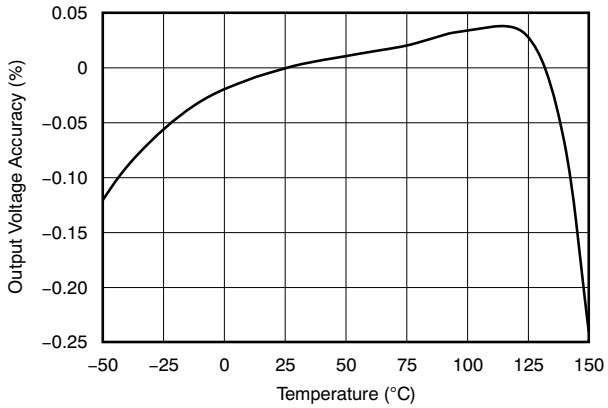



**Figure 3. Output Voltage Accuracy vs Temperature**

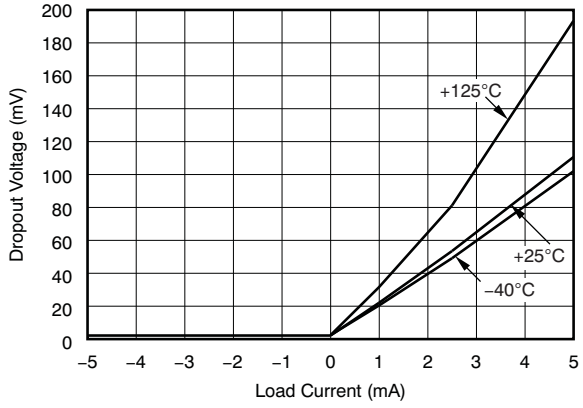



**Figure 4. Dropout Voltage vs Load Current**

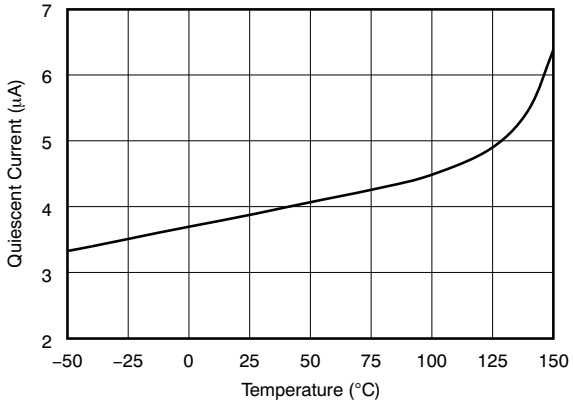



**Figure 5. Quiescent Current vs Temperature**

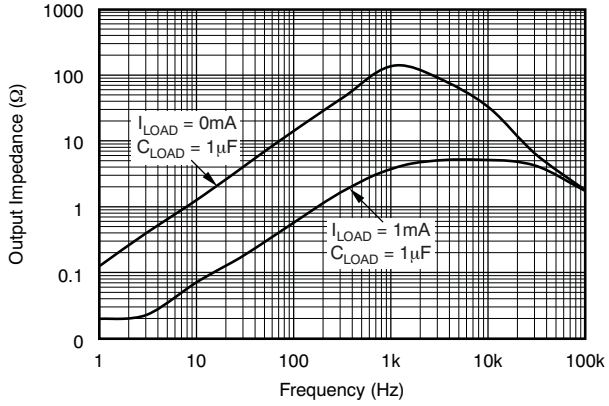



**Figure 6. Output Impedance vs Frequency**


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## Typical Characteristics (continued)

At $T_A$ = 25°C and $V_{IN}$ = 5 V, and REF3325 used for typical characteristic measurements (unless otherwise noted).

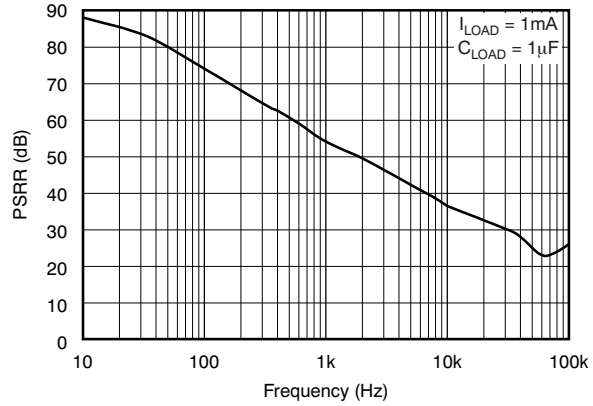



**Figure 7. Power-Supply Rejection Ratio vs Frequency**

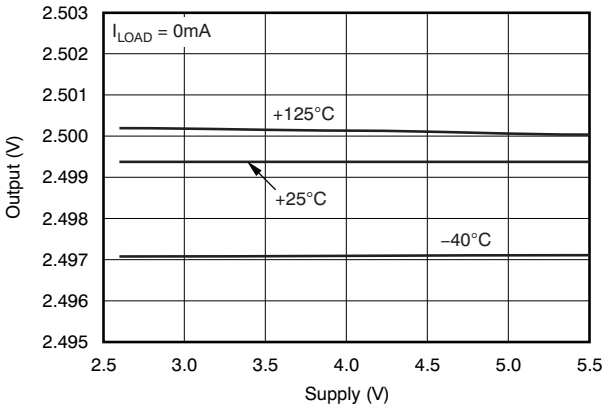



**Figure 8. Output vs Supply**

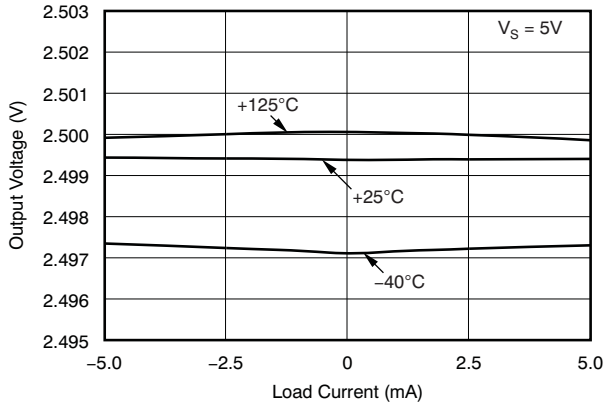



**Figure 9. Output Voltage vs Load Current**

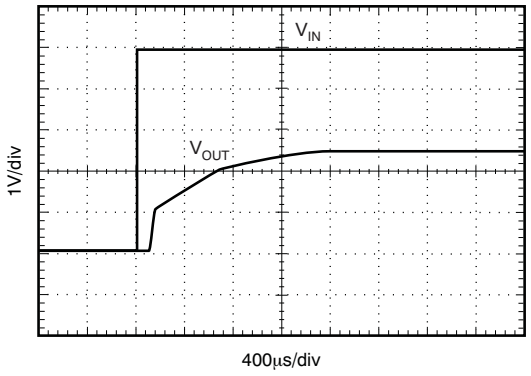



**Figure 10. Step Response**

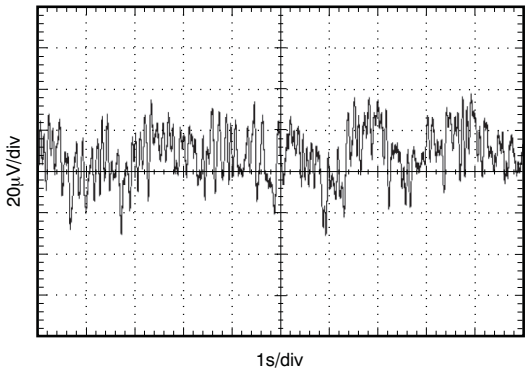



**Figure 11. 0.1-Hz to 10-Hz Noise**

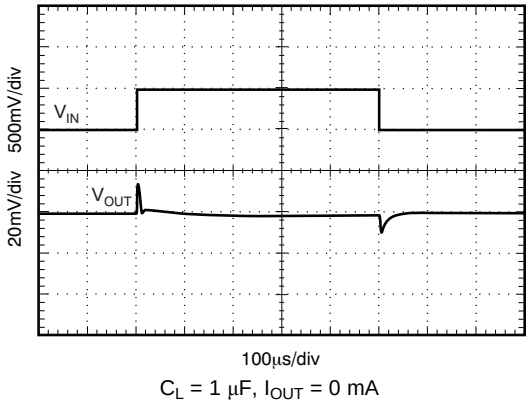
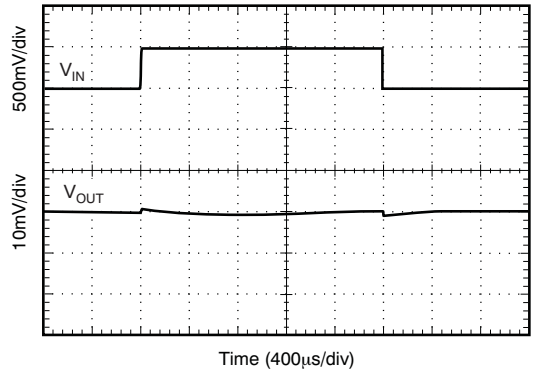



**Figure 12. Line Transient**

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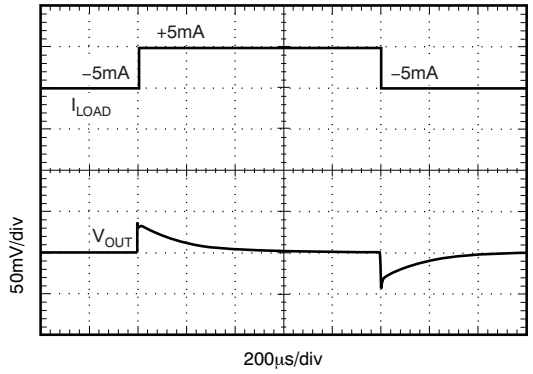
## Typical Characteristics (continued)

At $T_A$ = 25°C and $V_{IN}$ = 5 V, and REF3325 used for typical characteristic measurements (unless otherwise noted).



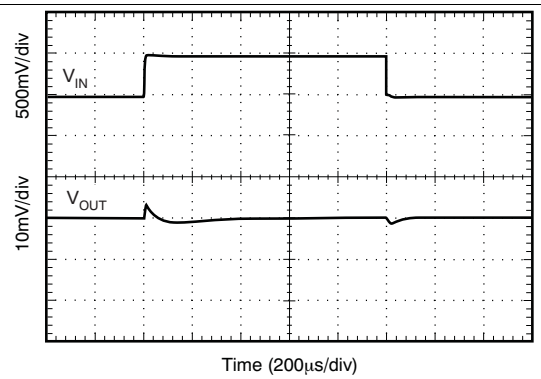

$C_{LOAD}$ = 10 µF, $I_{OUT}$ = 0 mA

**Figure 13. Line Transient**



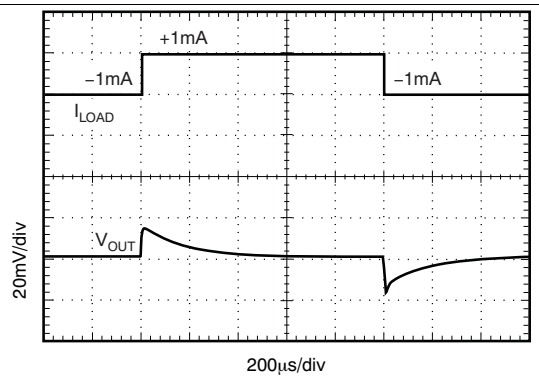

$C_L$ = 1 µF, ±5-mA Output Pulse

**Figure 14. Load Transient**




$C_{LOAD}$ = 10 µF, $I_{OUT}$ = 1 mA

**Figure 15. Line Transient**




$C_L$ = 1 µF, ±1-mA Output Pulse

**Figure 16. Load Transient**

# 8 Parameter Measurement Information

## 8.1 Thermal Hysteresis

Thermal hysteresis for the REF33xx is defined as the change in output voltage after operating the device at 25°C, cycling the device through the specified temperature range, and returning to 25°C. It can be expressed as Equation 1:

$$V_{HYST} = \left( \frac{|V_{PRE} - V_{POST}|}{V_{NOM}} \right) \cdot 10^6 \text{ (ppm)} \quad (1)$$

where

- $V_{HYST}$ = thermal hysteresis (in units of ppm).
- $V_{NOM}$ = the specified output voltage.
- $V_{PRE}$ = output voltage measured at 25°C pretemperature cycling.
- $V_{POST}$ = output voltage measured after the device cycles from 25°C through the specified temperature range of –40°C to 125°C and returns to 25°C.


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# 9 Detailed Description

## 9.1 Overview

The REF33xx is a family of low-power, precision band-gap voltage references that are specifically designed for extremely low dropout, excellent initial voltage accuracy with a high output current. A simplified block diagram of the REF33xx is shown in the *Functional Block Diagram* section. Figure 17 shows the typical connections for the REF33xx. A supply bypass capacitor ranging between 1 μF to 10 μF is recommended. The total capacitive load at the output must be between 0.1 μF to 10 μF to ensure output stability.

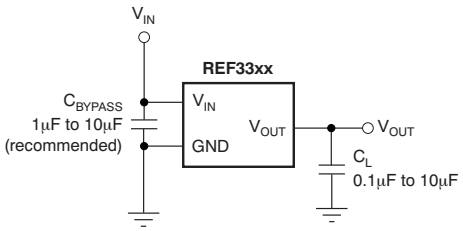
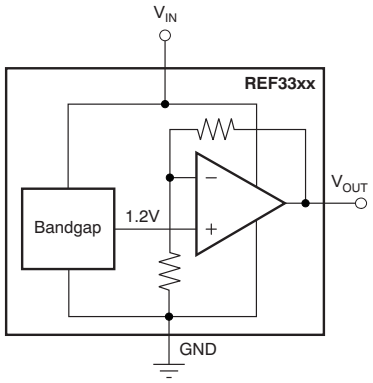



**Figure 17. Basic Connections**

## 9.2 Functional Block Diagram




## 9.3 Feature Description

### 9.3.1 Start-Up Time

The REF33xx features an advanced start-up circuit. Start-up time is almost independent of load (with a 0.1-μF to 10-μF load). Upon startup, the current boost circuit forces the output voltage. When the preset voltage is reached, the REF33xx switches to the second stage of output circuitry to precisely set the output voltage. Figure 18 shows the start-up time of the REF3325 for three different capacitive loads. In all three cases, the output voltage settles within 2 ms.

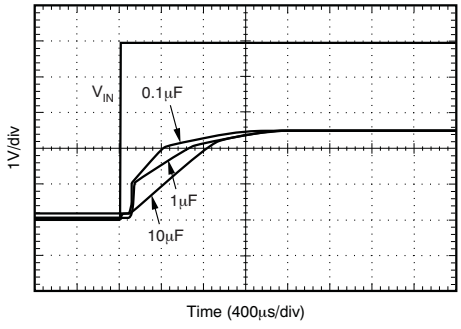



**Figure 18. Start-Up Time**

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## Feature Description (continued)

### 9.3.2 Low Temperature Drift

The REF33xx is designed for minimal drift error, defined as the change in output voltage over temperature. The drift is calculated using the box method, as described in Equation 2:

$$\text{Drift} = \left( \frac{V_{OUTMAX} - V_{OUTMIN}}{V_{OUT} \cdot \text{Temperature Range}} \right) \cdot 10^6 \text{ (ppm)} \quad (2)$$

### 9.3.3 Power Dissipation

The REF33xx family is specified to deliver current loads of ±5 mA over the specified input voltage range. The temperature of the device increases according to Equation 3:

$$T_J = T_A + P_D \cdot R_{\theta JA} \quad (3)$$

where

- $T_J$ = junction temperature (°C).
- $T_A$ = ambient temperature (°C).
- $P_D$ = power dissipation (W) = $V_{IN} \times I_Q + (V_{IN} - V_{OUT})\ I_{OUT}$.
- $R_{\theta JA}$ = Junction-to-ambient thermal resistance (°C/W).

The REF33xx junction temperature must not exceed the absolute maximum rating of 150°C.

### 9.3.4 Noise Performance

Typical 0.1-Hz to 10-Hz voltage noise for each member of the REF33xx family is specified in the *Electrical Characteristics* table. The noise voltage increases with output voltage and operating temperature. Use additional filtering to improve output noise levels. Give special attention to ensure that the output impedance does not degrade output voltage accuracy.

## 9.4 Device Functional Modes

The REF33xx is powered on when the voltage on the IN pin is greater than $V_{OUT}$ + 0.2 V, except for the REF3312, where the minimum supply voltage is 1.7 V. The maximum input voltage for the REF33xx is 5.5 V. Use a supply bypass capacitor ranging between 1 μF to 10 μF. The total capacitive load at the output must be between 0.1 μF to 10 μF to ensure output stability.


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# 10 Applications and Implementation

**NOTE**

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

## 10.1 Application Information

The REF33xx is a family of low-power, precision band-gap voltage references that are specifically designed for extremely low dropout, excellent initial voltage accuracy with a high output current. The extremely small size of the SC70-3, SOT-23-3, and UQFN-8 make these references very attractive for space-constrained applications. The following section describes one common application.

## 10.2 Typical Applications

### 10.2.1 REF3312 in a Bipolar Signal-Chain Configuration

The circuit in Figure 19 consists of a low-power reference and conditioning circuit. This circuit attenuates and level-shifts a bipolar input voltage within the proper input range of a single-supply, low-power, 16-bit ΔΣ analog-to-digital converter (ADC), such as the one inside the MSP430 (or other similar single-supply ADCs). Precision reference circuits are used to level-shift the input signal, provide the ADC reference voltage, and create a well-regulated supply voltage for the low-power analog circuitry. A low-power, zero-drift op amp circuit is used to attenuate and level-shift the input signal.

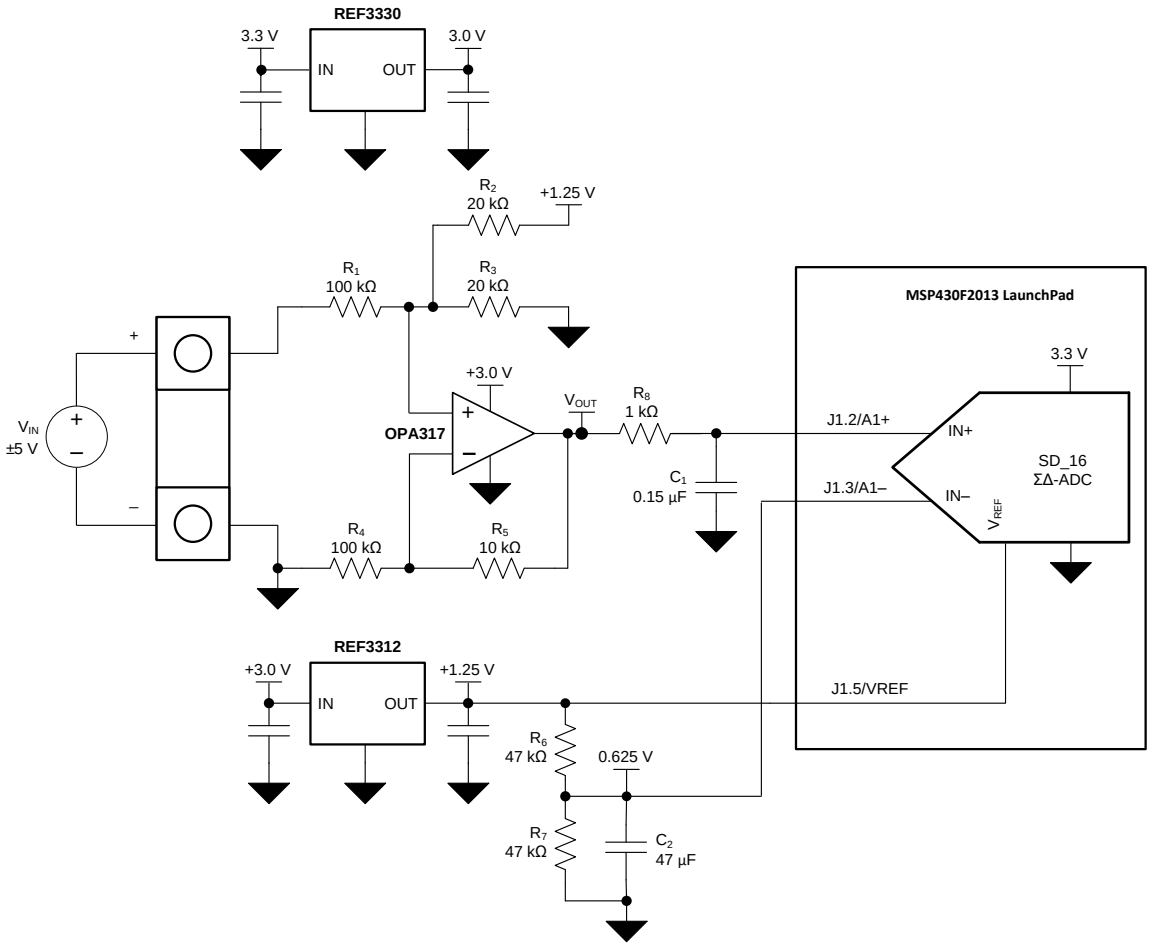



**Figure 19. Bipolar Signal-Chain Configuration**

## Typical Applications (continued)

### 10.2.1.1 Design Requirements

The design requirements are as follows:

- Supply voltage: 3.3 V
- Maximum input voltage: ±6 V
- Specified input voltage: ±5 V
- ADC reference voltage: 1.25 V

### 10.2.1.2 Detailed Design Procedure

Figure 19 depicts a simplified schematic for this design showing the MSP430 ADC inputs and full input conditioning circuitry. The ADC is configured for a bipolar measurement where final conversion result is the differential voltage, $V_{DIFF}$, between the positive and negative ADC inputs, A1+ and A1–. The bipolar, ground-referenced input signal must be level-shifted and attenuated by the op amp so that the output is biased to $V_{REF}$ / 2 and has a differential voltage that is within the $\pm V_{REF}$ / 2 input range of the ADC. The transfer function for the op-amp circuit simplifies to Equation 4.

$$A1+ = \left(\frac{R_3}{R_2 + R_3}\right)V_{REF} + \left(\frac{R_2 \parallel R_3}{R_1}\right)V_{IN}$$

where

- $R_1 = R_4$
- $R_5 = R_2 \parallel R_3$

(4)

The voltage applied to the negative ADC input, A1–, is based on the resistor divider formed by R6 and R7 and is set to $V_{REF}$ / 2 by setting R6 equal to R7, as shown in Equation 5.

$$A1- = \left(\frac{R_7}{R_6 + R_7}\right)V_{REF} = \frac{V_{REF}}{2} \quad (5)$$

#### 10.2.1.2.1 Op Amp Level-Shift Design

The ratio of $R_2$, $R_3$, and the $V_{REF}$ voltage determines the voltage on the output of the op amp when the differential input is 0 V. Select the components so that $V_{OUT}$ is equal to the $V_{REF}$ / 2 voltage when $V_{IN}$ is equal to 0 V, as shown in Equation 6.

$$A1+ = \frac{V_{REF}}{2} = \left(\frac{R_3}{R_2 + R_3}\right)V_{REF}$$

where

- $V_{IN} = 0$ V
- $R_2 = R_3$

(6)

Solve for the value of $R_5$ by setting $R_3$ equal to $R_2$ in Equation 4, as shown in Equation 7:

$$R_5 = \left(\frac{R_2 \cdot R_2}{R_2 + R_2}\right) = \frac{{R_2}^2}{2 \cdot R_2} = \frac{R_2}{2} \quad (7)$$

#### 10.2.1.2.2 Differential Input Attenuator Design

$V_{DIFF}$ is the difference between the two inputs, as shown in Equation 8:

$$V_{DIFF} = (A1+) - (A1-) = \left(\frac{R_3}{R_2 + R_3}\right)V_{REF} + \left(\frac{R_2 \parallel R_3}{R_1}\right)V_{IN} - \frac{V_{REF}}{2} \quad (8)$$


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## Typical Applications (continued)

When the ratio of $R_3$ and $R_2$ equals the ratio of $R_7$ and $R_6$, Equation 8 simplifies to Equation 10.

That is, if:

$$\left(\frac{R_3}{R_2 + R_3}\right)V_{REF} = \left(\frac{R_7}{R_6 + R_7}\right)V_{REF} = \frac{1}{2}V_{REF} \tag{9}$$

Then:

$$V_{DIFF} = \left(\frac{R_2 \parallel R_3}{R_1}\right)V_{IN} \tag{10}$$

Determine the ratio of $R_1$, $R_2$, and $R_3$ by setting A1+ equal to the maximum $V_{DIFF}$ for a full-scale positive or negative input voltage, VIN_MAX, as shown in Equation 11:

$$A1+ = V_{DIFF_MAX} = \left(\frac{R_2 \parallel R_3}{R_1}\right)V_{IN_MAX} \tag{11}$$

$R_2$ equals $R_3$; therefore, Equation 11 simplifies to $R_2$ / 2, resulting in Equation 12:

$$V_{DIFF_MAX} = \left(\frac{R_2}{2 \cdot R_1}\right)V_{IN_MAX} \tag{12}$$

#### 10.2.1.2.3 Input Filtering

Both inputs feature first-order, low-pass, antialiasing filters that limit the bandwidth and noise of the input signals applied to the ADC. The A1+ filter is formed by $R_8$ and $C_1$ and the equation for the –3-dB cutoff frequency is shown in Equation 13:

$$f_{-3dB_A1+} = \frac{1}{2 \cdot \pi \cdot R_8 \cdot C_1} \tag{13}$$

The A1– input filter is formed by $C_2$ and the parallel combination of the $R_6$ and $R_7$ resistors, as shown in Equation 14:

$$f_{-3dB_A1-} = \frac{1}{2 \cdot \pi \cdot \left(\frac{R_6}{2}\right) \cdot C_2} \tag{14}$$

#### 10.2.1.2.4 Component Selection

##### *10.2.1.2.4.1 Voltage References*

The REF33xx series of precision low-power voltage references pair well with the low power consumption of the MSP430, while achieving the target accuracy goals. The 16-bit converter in the MSP430F2013 accepts an external reference voltage from 1 V to 1.5 V with a typical reference input of 1.25 V, as shown in Table 1.

**Table 1. SD16_A, External Reference Input (MSP430F20x3)(1)**

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $V_{REF(I)}$ | Input voltage range | VCC = 3 V, SD16REFON = 0 | 1 | 1.25 | 1.5 | V |
| $I_{REF(I)}$ | Input current | VCC = 3 V, SD16REFON = 0 | | | 50 | nA |

(1) Over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted).

The REF3312 provides the desired 1.25-V reference voltage for the MSP430 ADC. The accuracy of the REF3312 output, shown in the *Electrical Characteristics*, directly affects the accuracy of the entire system and must be less than the desired unadjusted error goals. The REF3312 maximum ±0.15% initial accuracy specification is equal to the unadjusted error design goal of 0.15%, indicating that most of the error budget in this design must be devoted to the reference accuracy.

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The 3.3-V system supply voltage that powers the MSP430 can also supply other devices, and therefore may have regulation and noise issues. The REF3330 creates an accurate and stable 3.0 V output used by the op amp, REF3312, and other low-power analog circuitry. The REF33xx series has a drop-output voltage of $V_{OUT}$ + 200 mV; therefore, as long as the input supply remains above 3.2 V, the REF3330 produces a regulated 3.0 V output. The output current for the REF33xx series is specified at ±5 mA, as shown in Figure 9, and is sufficient for the REF3312 and a low-power op amp.

#### *10.2.1.2.4.2 Op Amp*

The OPA317 op amp is used because of low offset voltage, low offset voltage drift, CMRR, and low power consumption. The dc specifications for the OPA317 can be seen in the OPA317 data sheet, SBOS682, available for download from www.ti.com. The maximum offset of 100 µV accounts for only 0.001% of the full-scale signal, and the low-drift reduces temperature drift effects. Therefore, as previously mentioned, most of the error in this design is from the reference accuracy and passive component tolerances.

#### 10.2.1.2.5 Input Attenuation and Level Shifting

For this design, the bipolar ±5-V input must be attenuated and level shifted so the differential voltage is within the input range of $\pm V_{REF}$ / 2, or ±0.625 V. The accuracy of the op amp output and ADC input may degrade near the supply rails and $V_{REF}$ voltage, so the output is designed to produce a 0.125 V to 1.125 V output, or ±0.5 V for a ±5 V input. Scaling the output this way also increases the allowable input range to ±6 V, and allows for some underscale and overscale voltage measurement and protection.

Use Equation 12 to scale the ±5-V input to a ±0.5-V differential voltage, as shown in Equation 15.

$$0.5\ V = \left(\frac{R_2}{2 \cdot 100\ k\Omega}\right) \cdot 5\ V$$

where

- $R_1 = R_4 = 100\ k\Omega$

(15)

$R_1$ and $R_4$ dominate the input impedance for this design and are therefore selected to be 100 kΩ. Higher values can be selected to increase the input impedance at the expense of input noise.

With the value for $R_2$ and $R_3$ selected as 20 kΩ, the value for $R_5$ is calculated, as shown in Equation 16:

$$R_5 = \left(\frac{R_2}{2}\right) = 10\ k\Omega$$

where

- $R_2 = R_3 = 20\ k\Omega$

(16)

In order for A1– to equal to $V_{REF}$ / 2, $R_6$ must equal $R_7$. Two 47-kΩ resistors are used in order to conserve power without creating an impedance too weak to drive the ADC input.

#### 10.2.1.2.6 Input Filtering

The MSP430 ADC is configured to run from the 1.1-MHz SMCLK with an oversampling rate (OSR) of 256, yielding a sample rate of roughly 4.3 kHz. The input filter cutoff frequency is set to 1 kHz in order to limit the input signal bandwidth, as shown in Equation 17. $R_8$ is 1 kΩ in order to provide isolation from the capacitive load of the low-pass filter, thereby reducing stability concerns.

$$f_{-3dB_A1+} = 1\ kHz = \frac{1}{2 \cdot \pi \cdot R_8 \cdot C_1}$$

where

- $C_1 = \dfrac{1}{2 \cdot \pi \cdot 1\ k\Omega \cdot 1\ kHz} = 159\ nF$

(17)

Reduce $C_1$ to 150 nF so that it is a standard value.

The A1– input of the delta-sigma (ΔΣ) converter is not buffered, and therefore requires a large capacitor to supply the charge for the internal sampling capacitor. A 47-µF capacitor is selected, resulting in the cutoff frequency illustrated in Equation 18.


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$$f_{-3dB_A1-} = \frac{1}{2 \cdot \pi \cdot \left(\frac{R_6}{2}\right) \cdot C_2} = 0.144 \text{ Hz} \quad (18)$$

In applications that cannot tolerate such a low-frequency cutoff, and therefore a long start-up time, buffer the A1– input with another OPA317 to properly drive the ADC input with a lower-input capacitor.

#### 10.2.1.2.7 Passive Component Tolerances and Materials

Resistors $R_1$, $R_2$, $R_3$, $R_4$, $R_5$, $R_6$, and $R_7$ directly affect the accuracy of the circuit. To meet the unadjusted accuracy goals of 0.2%, the resistors used are 0.1%. Select 0.1% resistors for the construction of the difference amplifier circuit to provide a common-mode rejection ratio (CMRR) of at least 60 dB.

### *10.2.1.3 Application Curves*

#### 10.2.1.3.1 DC Performance

The measured dc performance and calculated error of the circuit is shown in Figure 20 and Figure 21, respectively. By applying a two-point gain and offset calibration over the specified ±5-V input range, the calibrated error is shown in Figure 22. The uncalibrated results show errors of 138 μV, or 0.0138%FSR. The calibrated results with a simple two-point calibration show errors under 5 μV, or 0.0005%FSR, in the specified input range of ±5 V.

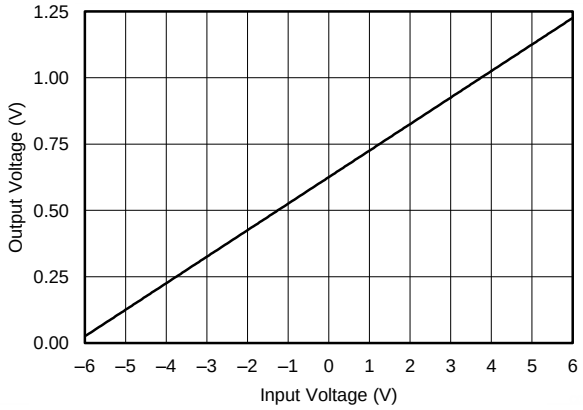



**Figure 20. Measured DC Transfer Function with ±6-V Input**

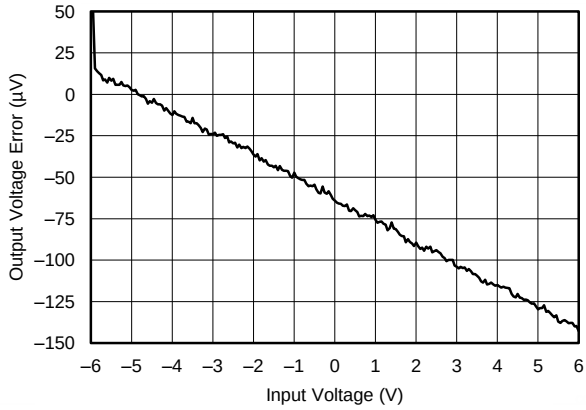



**Figure 21. Measured Output Error with ±6-V Input**

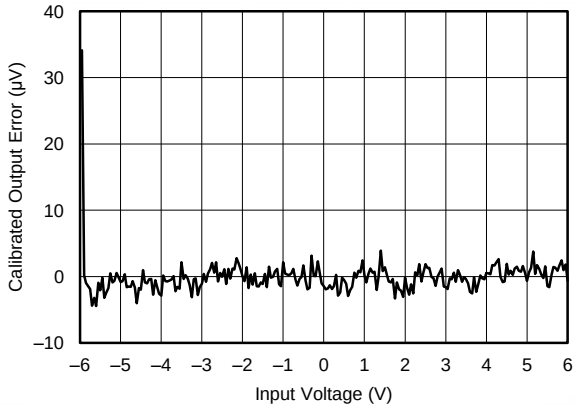



**Figure 22. Calibrated Output Error with ±6-V Input**

#### 10.2.1.3.2 AC Performance

The ac transfer function for the attenuation and level-shifting circuit is shown in Figure 23.

The low-frequency ac CMRR performance is measured to be 62 dB, as shown in Figure 24.

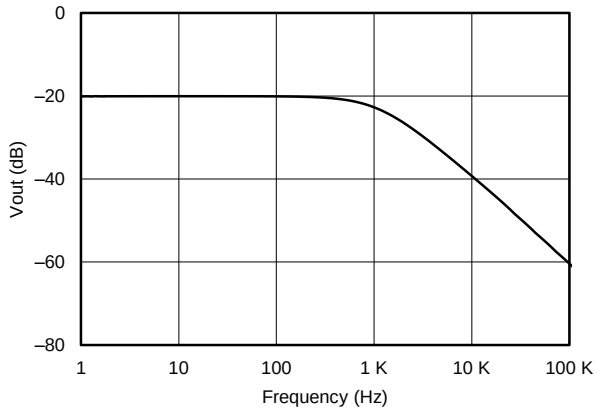



**Figure 23. Measured AC Transfer Function**

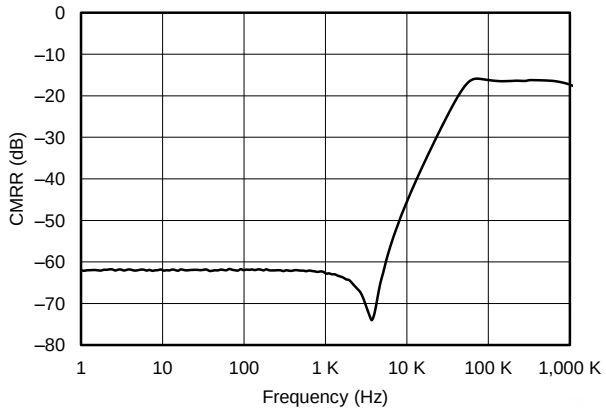



**Figure 24. Measured AC CMRR Results**

## 11 Power-Supply Recommendations

The REF33xx family of voltage references features extremely low dropout voltage, except for the REF3312. The REF3312 has a minimum supply requirement of 1.7 V. These references can be operated with a supply 110 mV above the output voltage with a 5-mA load (typical). For loaded conditions, a typical dropout voltage versus load graph is illustrated in Figure 4 of the *Typical Characteristics*.

If the supply voltage connected to the IN pin is rapidly moved when the REF33xx is connected to a capacitive load, a reverse voltage can discharge through the OUT pin and into the REF33xx. This voltage does not damage the REF33xx, provided that the voltage is less than or equal to 5 V.


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# 12 Layout

## 12.1 Layout Guidelines

For optimal performance of this design, follow standard printed circuit board (PCB) layout guidelines, including proper decoupling close to all integrated circuits and adequate power and ground connections with large copper pours. Select a PCB size with connectors that connect directly to the MSP430 LaunchPad™.

Figure 25 shows an example of a PCB layout for a data acquisition system using the REF33xx.

Some key considerations are:

- Connect a low-ESR, 1-µF ceramic capacitor at the IN pin for bypass, and a 0.1-µF to 10-µF ceramic capacitor at the OUT pin for stability of the REF33xx.
- Decouple other active devices in the system per the device specifications.
- Use a solid ground plane helps distribute heat and reduces EMI noise pickup.
- Place the external components as close to the device as possible. This configuration prevents parasitic errors (such as the Seebeck effect) from occurring.
- Minimize trace length between the reference and bias connections to the ADC to reduce noise pickup.
- Do not run sensitive analog traces in parallel with digital traces. Avoid crossing digital and analog traces if possible, and only make perpendicular crossings when absolutely necessary.

## 12.2 Layout Example

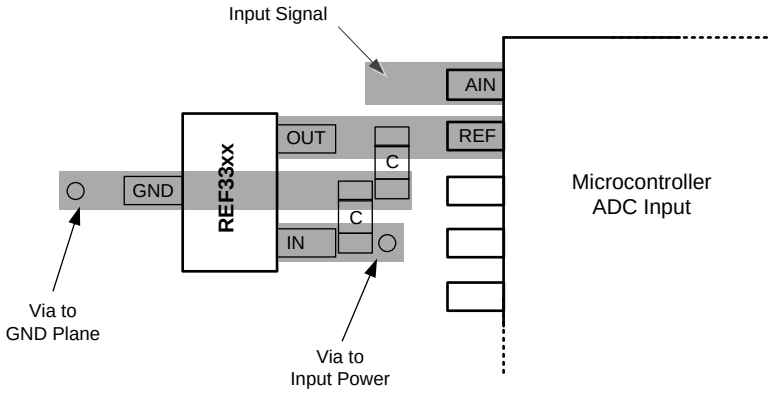



**Figure 25. Layout Example**

# 13 Device and Documentation Support

## 13.1 Documentation Support

### 13.1.1 Related Documentation

*OPAx333 1.8-V, microPower, CMOS Operational Amplifiers, Zero-Drift Series* (SBOS351)

*OPAx363, OPAx364 1.8-V, 7-MHz, 90-dB CMRR, Single-Supply, Rail-to-Rail I/O Operational Amplifier* (SBOS259)

*OPAx369 1.8V, 700nA, Zerø-Crossover Rail-to-Rail I/O Operational Amplifier* (SBOS414)

*INA159 Precision, Gain of 0.2 Level Translation Difference Amplifier* (SBOS333)

## 13.2 Related Links

Table 2 lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

**Table 2. Related Links**

| PARTS | PRODUCT FOLDER | SAMPLE & BUY | TECHNICAL DOCUMENTS | TOOLS & SOFTWARE | SUPPORT & COMMUNITY |
|---|---|---|---|---|---|
| REF3312 | Click here | Click here | Click here | Click here | Click here |
| REF3317 | Click here | Click here | Click here | Click here | Click here |
| REF3318 | Click here | Click here | Click here | Click here | Click here |
| REF3320 | Click here | Click here | Click here | Click here | Click here |
| REF3325 | Click here | Click here | Click here | Click here | Click here |
| REF3330 | Click here | Click here | Click here | Click here | Click here |
| REF3333 | Click here | Click here | Click here | Click here | Click here |

## 13.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

## 13.4 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

**TI E2E™ Online Community** ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

**Design Support** ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

## 13.5 Trademarks

LaunchPad, E2E are trademarks of Texas Instruments.
All other trademarks are the property of their respective owners.

## 13.6 Electrostatic Discharge Caution

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.


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### 13.7 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

## 14 Mechanical, Packaging, and Orderable Information

The following pages include mechanical packaging and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

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## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| REF3312AIDBZR | ACTIVE | SOT-23 | DBZ | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33A | Samples |
| REF3312AIDBZRG4 | ACTIVE | SOT-23 | DBZ | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33A | Samples |
| REF3312AIDBZT | ACTIVE | SOT-23 | DBZ | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33A | Samples |
| REF3312AIDBZTG4 | ACTIVE | SOT-23 | DBZ | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33A | Samples |
| REF3312AIDCKR | ACTIVE | SC70 | DCK | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R12 | Samples |
| REF3312AIDCKRG4 | ACTIVE | SC70 | DCK | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R12 | Samples |
| REF3312AIDCKT | ACTIVE | SC70 | DCK | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R12 | Samples |
| REF3312AIDCKTG4 | ACTIVE | SC70 | DCK | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R12 | Samples |
| REF3312AIRSER | PREVIEW | UQFN | RSE | 8 | 5000 | TBD | Call TI | Call TI | -40 to 125 | | |
| REF3318AIDBZR | ACTIVE | SOT-23 | DBZ | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33B | Samples |
| REF3318AIDBZT | ACTIVE | SOT-23 | DBZ | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33B | Samples |
| REF3318AIDBZTG4 | ACTIVE | SOT-23 | DBZ | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33B | Samples |
| REF3318AIDCKR | ACTIVE | SC70 | DCK | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R18 | Samples |
| REF3318AIDCKRG4 | ACTIVE | SC70 | DCK | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R18 | Samples |
| REF3318AIDCKT | ACTIVE | SC70 | DCK | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R18 | Samples |
| REF3318AIDCKTG4 | ACTIVE | SC70 | DCK | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R18 | Samples |
| REF3318AIRSER | PREVIEW | UQFN | RSE | 8 | 5000 | TBD | Call TI | Call TI | -40 to 125 | | |
| REF3320AIDBZR | ACTIVE | SOT-23 | DBZ | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33C | Samples |

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| REF3320AIDBZRG4 | ACTIVE | SOT-23 | DBZ | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33C | Samples |
| REF3320AIDBZT | ACTIVE | SOT-23 | DBZ | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33C | Samples |
| REF3320AIDBZTG4 | ACTIVE | SOT-23 | DBZ | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33C | Samples |
| REF3320AIDCKR | ACTIVE | SC70 | DCK | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R20 | Samples |
| REF3320AIDCKRG4 | ACTIVE | SC70 | DCK | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R20 | Samples |
| REF3320AIDCKT | ACTIVE | SC70 | DCK | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R20 | Samples |
| REF3320AIDCKTG4 | ACTIVE | SC70 | DCK | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R20 | Samples |
| REF3320AIRSER | PREVIEW | UQFN | RSE | 8 | 5000 | TBD | Call TI | Call TI | -40 to 125 | | |
| REF3325AIDBZR | ACTIVE | SOT-23 | DBZ | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33D | Samples |
| REF3325AIDBZRG4 | ACTIVE | SOT-23 | DBZ | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33D | Samples |
| REF3325AIDBZT | ACTIVE | SOT-23 | DBZ | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33D | Samples |
| REF3325AIDBZTG4 | ACTIVE | SOT-23 | DBZ | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33D | Samples |
| REF3325AIDCKR | ACTIVE | SC70 | DCK | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R25 | Samples |
| REF3325AIDCKRG4 | ACTIVE | SC70 | DCK | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R25 | Samples |
| REF3325AIDCKT | ACTIVE | SC70 | DCK | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R25 | Samples |
| REF3325AIDCKTG4 | ACTIVE | SC70 | DCK | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R25 | Samples |
| REF3325AIRSER | ACTIVE | UQFN | RSE | 8 | 5000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | GN | Samples |
| REF3330AIDBZR | ACTIVE | SOT-23 | DBZ | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33E | Samples |

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| REF3330AIDBZRG4 | ACTIVE | SOT-23 | DBZ | 3 | | TBD | Call TI | Call TI | -40 to 125 | | Samples |
| REF3330AIDBZT | ACTIVE | SOT-23 | DBZ | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33E | Samples |
| REF3330AIDBZTG4 | ACTIVE | SOT-23 | DBZ | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33E | Samples |
| REF3330AIDCKR | ACTIVE | SC70 | DCK | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R30 | Samples |
| REF3330AIDCKRG4 | ACTIVE | SC70 | DCK | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R30 | Samples |
| REF3330AIDCKT | ACTIVE | SC70 | DCK | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R30 | Samples |
| REF3330AIDCKTG4 | ACTIVE | SC70 | DCK | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R30 | Samples |
| REF3330AIRSER | ACTIVE | UQFN | RSE | 8 | 5000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | EN | Samples |
| REF3333AIDBZR | ACTIVE | SOT-23 | DBZ | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33F | Samples |
| REF3333AIDBZRG4 | ACTIVE | SOT-23 | DBZ | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33F | Samples |
| REF3333AIDBZT | ACTIVE | SOT-23 | DBZ | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33F | Samples |
| REF3333AIDBZTG4 | ACTIVE | SOT-23 | DBZ | 3 | | TBD | Call TI | Call TI | -40 to 125 | | Samples |
| REF3333AIDCKR | ACTIVE | SC70 | DCK | 3 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33 | Samples |
| REF3333AIDCKT | ACTIVE | SC70 | DCK | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33 | Samples |
| REF3333AIDCKTG4 | ACTIVE | SC70 | DCK | 3 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | R33 | Samples |
| REF3333AIRSER | PREVIEW | UQFN | RSE | 8 | 5000 | TBD | Call TI | Call TI | -40 to 125 | | |

(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.

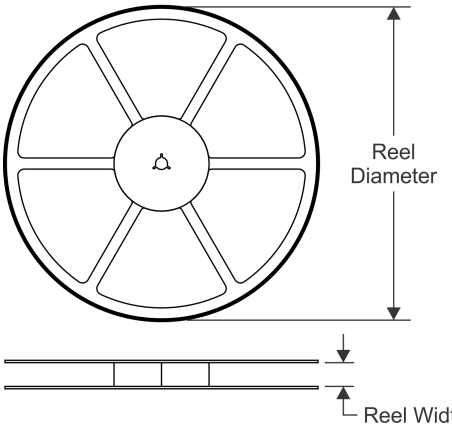
**(6)** Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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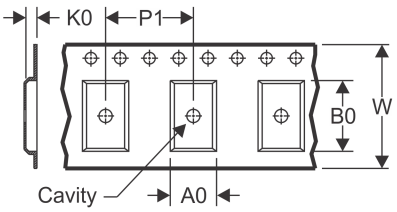
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

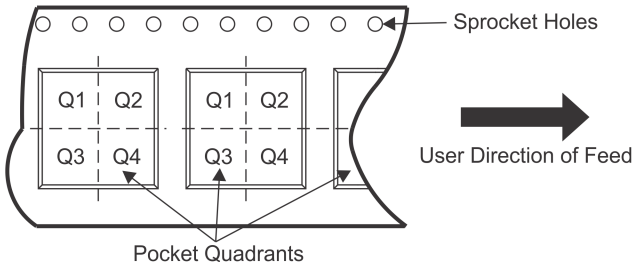



**TAPE DIMENSIONS**




| | |
|---|---|
| A0 | Dimension designed to accommodate the component width |
| B0 | Dimension designed to accommodate the component length |
| K0 | Dimension designed to accommodate the component thickness |
| W | Overall width of the carrier tape |
| P1 | Pitch between successive cavity centers |

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**

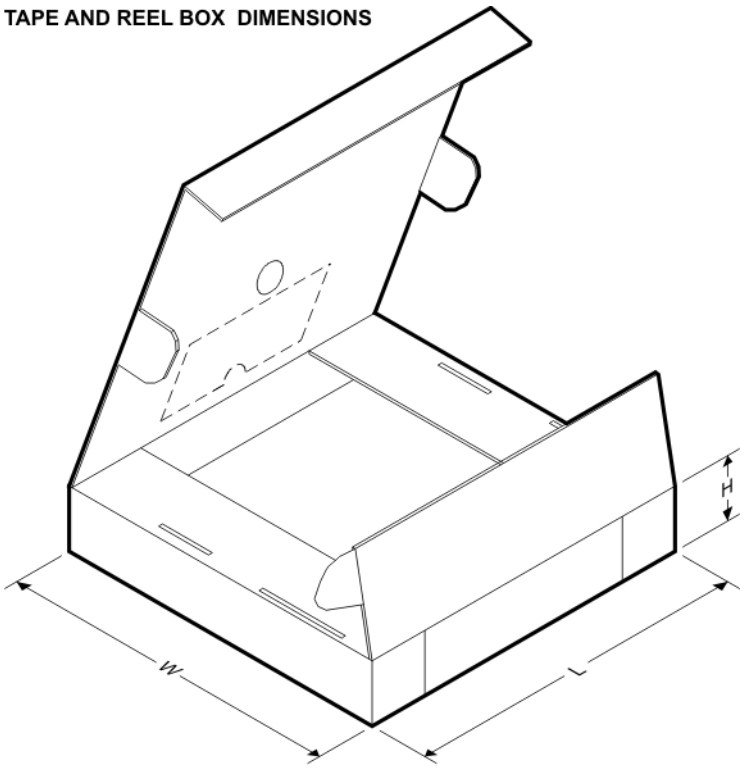



*All dimensions are nominal

| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REF3312AIDBZR | SOT-23 | DBZ | 3 | 3000 | 179.0 | 8.4 | 3.15 | 2.95 | 1.22 | 4.0 | 8.0 | Q3 |
| REF3312AIDBZT | SOT-23 | DBZ | 3 | 250 | 179.0 | 8.4 | 3.15 | 2.95 | 1.22 | 4.0 | 8.0 | Q3 |
| REF3312AIDCKR | SC70 | DCK | 3 | 3000 | 179.0 | 8.4 | 2.4 | 2.4 | 1.19 | 4.0 | 8.0 | Q3 |
| REF3312AIDCKT | SC70 | DCK | 3 | 250 | 179.0 | 8.4 | 2.4 | 2.4 | 1.19 | 4.0 | 8.0 | Q3 |
| REF3318AIDBZR | SOT-23 | DBZ | 3 | 3000 | 179.0 | 8.4 | 3.15 | 2.95 | 1.22 | 4.0 | 8.0 | Q3 |
| REF3318AIDBZT | SOT-23 | DBZ | 3 | 250 | 179.0 | 8.4 | 3.15 | 2.95 | 1.22 | 4.0 | 8.0 | Q3 |
| REF3318AIDCKR | SC70 | DCK | 3 | 3000 | 179.0 | 8.4 | 2.4 | 2.4 | 1.19 | 4.0 | 8.0 | Q3 |
| REF3318AIDCKT | SC70 | DCK | 3 | 250 | 179.0 | 8.4 | 2.4 | 2.4 | 1.19 | 4.0 | 8.0 | Q3 |
| REF3320AIDBZR | SOT-23 | DBZ | 3 | 3000 | 179.0 | 8.4 | 3.15 | 2.95 | 1.22 | 4.0 | 8.0 | Q3 |
| REF3320AIDBZT | SOT-23 | DBZ | 3 | 250 | 179.0 | 8.4 | 3.15 | 2.95 | 1.22 | 4.0 | 8.0 | Q3 |
| REF3320AIDCKR | SC70 | DCK | 3 | 3000 | 179.0 | 8.4 | 2.4 | 2.4 | 1.19 | 4.0 | 8.0 | Q3 |
| REF3320AIDCKT | SC70 | DCK | 3 | 250 | 179.0 | 8.4 | 2.4 | 2.4 | 1.19 | 4.0 | 8.0 | Q3 |
| REF3325AIDBZR | SOT-23 | DBZ | 3 | 3000 | 179.0 | 8.4 | 3.15 | 2.95 | 1.22 | 4.0 | 8.0 | Q3 |
| REF3325AIDBZT | SOT-23 | DBZ | 3 | 250 | 179.0 | 8.4 | 3.15 | 2.95 | 1.22 | 4.0 | 8.0 | Q3 |
| REF3325AIDCKR | SC70 | DCK | 3 | 3000 | 179.0 | 8.4 | 2.4 | 2.4 | 1.19 | 4.0 | 8.0 | Q3 |
| REF3325AIDCKT | SC70 | DCK | 3 | 250 | 179.0 | 8.4 | 2.4 | 2.4 | 1.19 | 4.0 | 8.0 | Q3 |
| REF3325AIRSER | UQFN | RSE | 8 | 5000 | 180.0 | 9.5 | 1.7 | 1.7 | 0.75 | 4.0 | 8.0 | Q2 |
| REF3330AIDBZR | SOT-23 | DBZ | 3 | 3000 | 179.0 | 8.4 | 3.15 | 2.95 | 1.22 | 4.0 | 8.0 | Q3 |

| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REF3330AIDBZT | SOT-23 | DBZ | 3 | 250 | 179.0 | 8.4 | 3.15 | 2.95 | 1.22 | 4.0 | 8.0 | Q3 |
| REF3330AIDCKR | SC70 | DCK | 3 | 3000 | 179.0 | 8.4 | 2.4 | 2.4 | 1.19 | 4.0 | 8.0 | Q3 |
| REF3330AIDCKT | SC70 | DCK | 3 | 250 | 179.0 | 8.4 | 2.4 | 2.4 | 1.19 | 4.0 | 8.0 | Q3 |
| REF3330AIRSER | UQFN | RSE | 8 | 5000 | 180.0 | 9.5 | 1.7 | 1.7 | 0.75 | 4.0 | 8.0 | Q2 |
| REF3333AIDBZR | SOT-23 | DBZ | 3 | 3000 | 179.0 | 8.4 | 3.15 | 2.95 | 1.22 | 4.0 | 8.0 | Q3 |
| REF3333AIDBZT | SOT-23 | DBZ | 3 | 250 | 179.0 | 8.4 | 3.15 | 2.95 | 1.22 | 4.0 | 8.0 | Q3 |
| REF3333AIDCKR | SC70 | DCK | 3 | 3000 | 179.0 | 8.4 | 2.4 | 2.4 | 1.19 | 4.0 | 8.0 | Q3 |
| REF3333AIDCKT | SC70 | DCK | 3 | 250 | 179.0 | 8.4 | 2.4 | 2.4 | 1.19 | 4.0 | 8.0 | Q3 |

**TAPE AND REEL BOX DIMENSIONS**

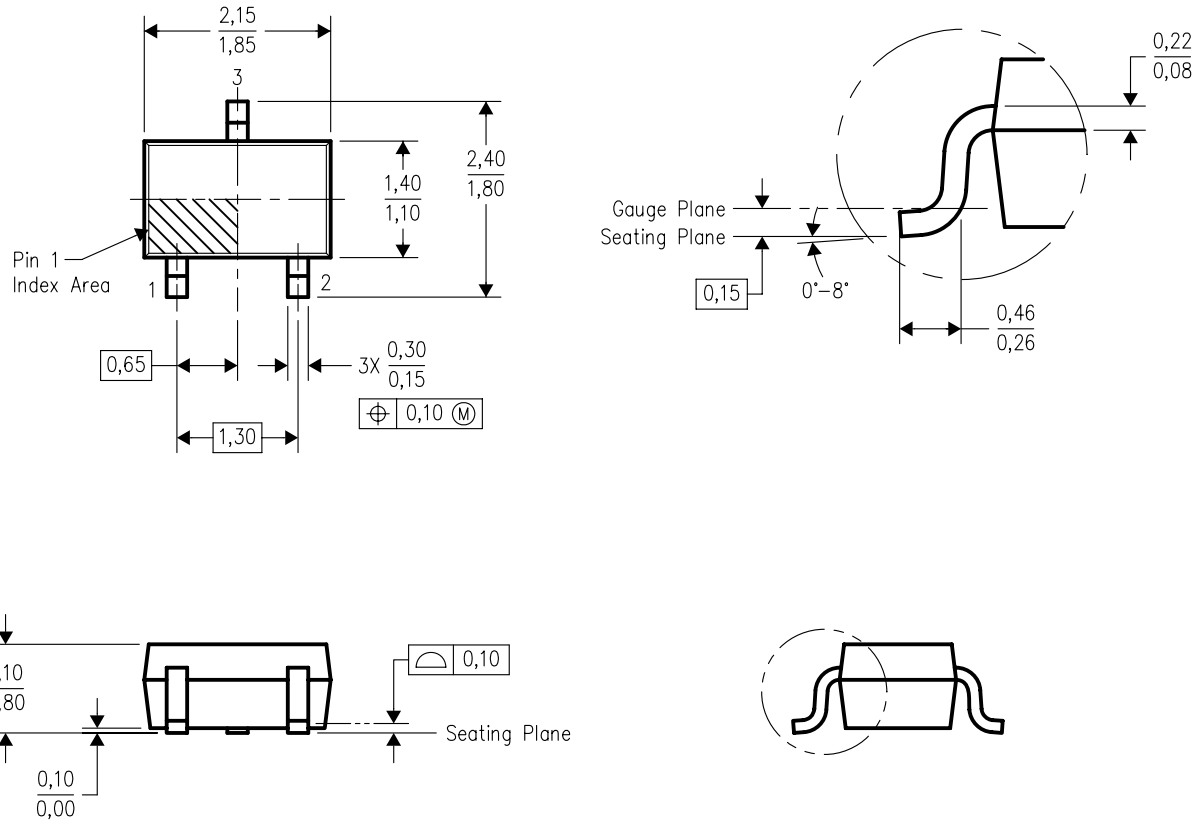



*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| REF3312AIDBZR | SOT-23 | DBZ | 3 | 3000 | 195.0 | 200.0 | 45.0 |
| REF3312AIDBZT | SOT-23 | DBZ | 3 | 250 | 195.0 | 200.0 | 45.0 |
| REF3312AIDCKR | SC70 | DCK | 3 | 3000 | 195.0 | 200.0 | 45.0 |
| REF3312AIDCKT | SC70 | DCK | 3 | 250 | 195.0 | 200.0 | 45.0 |
| REF3318AIDBZR | SOT-23 | DBZ | 3 | 3000 | 195.0 | 200.0 | 45.0 |
| REF3318AIDBZT | SOT-23 | DBZ | 3 | 250 | 195.0 | 200.0 | 45.0 |
| REF3318AIDCKR | SC70 | DCK | 3 | 3000 | 195.0 | 200.0 | 45.0 |
| REF3318AIDCKT | SC70 | DCK | 3 | 250 | 195.0 | 200.0 | 45.0 |
| REF3320AIDBZR | SOT-23 | DBZ | 3 | 3000 | 195.0 | 200.0 | 45.0 |

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| REF3320AIDBZT | SOT-23 | DBZ | 3 | 250 | 195.0 | 200.0 | 45.0 |
| REF3320AIDCKR | SC70 | DCK | 3 | 3000 | 195.0 | 200.0 | 45.0 |
| REF3320AIDCKT | SC70 | DCK | 3 | 250 | 195.0 | 200.0 | 45.0 |
| REF3325AIDBZR | SOT-23 | DBZ | 3 | 3000 | 195.0 | 200.0 | 45.0 |
| REF3325AIDBZT | SOT-23 | DBZ | 3 | 250 | 195.0 | 200.0 | 45.0 |
| REF3325AIDCKR | SC70 | DCK | 3 | 3000 | 195.0 | 200.0 | 45.0 |
| REF3325AIDCKT | SC70 | DCK | 3 | 250 | 195.0 | 200.0 | 45.0 |
| REF3325AIRSER | UQFN | RSE | 8 | 5000 | 184.0 | 184.0 | 19.0 |
| REF3330AIDBZR | SOT-23 | DBZ | 3 | 3000 | 195.0 | 200.0 | 45.0 |
| REF3330AIDBZT | SOT-23 | DBZ | 3 | 250 | 195.0 | 200.0 | 45.0 |
| REF3330AIDCKR | SC70 | DCK | 3 | 3000 | 195.0 | 200.0 | 45.0 |
| REF3330AIDCKT | SC70 | DCK | 3 | 250 | 195.0 | 200.0 | 45.0 |
| REF3330AIRSER | UQFN | RSE | 8 | 5000 | 184.0 | 184.0 | 19.0 |
| REF3333AIDBZR | SOT-23 | DBZ | 3 | 3000 | 195.0 | 200.0 | 45.0 |
| REF3333AIDBZT | SOT-23 | DBZ | 3 | 250 | 195.0 | 200.0 | 45.0 |
| REF3333AIDCKR | SC70 | DCK | 3 | 3000 | 195.0 | 200.0 | 45.0 |
| REF3333AIDCKT | SC70 | DCK | 3 | 250 | 195.0 | 200.0 | 45.0 |

## DCK (R–PDSO–G3) PLASTIC SMALL–OUTLINE PACKAGE




4093553–2/G 01/2007

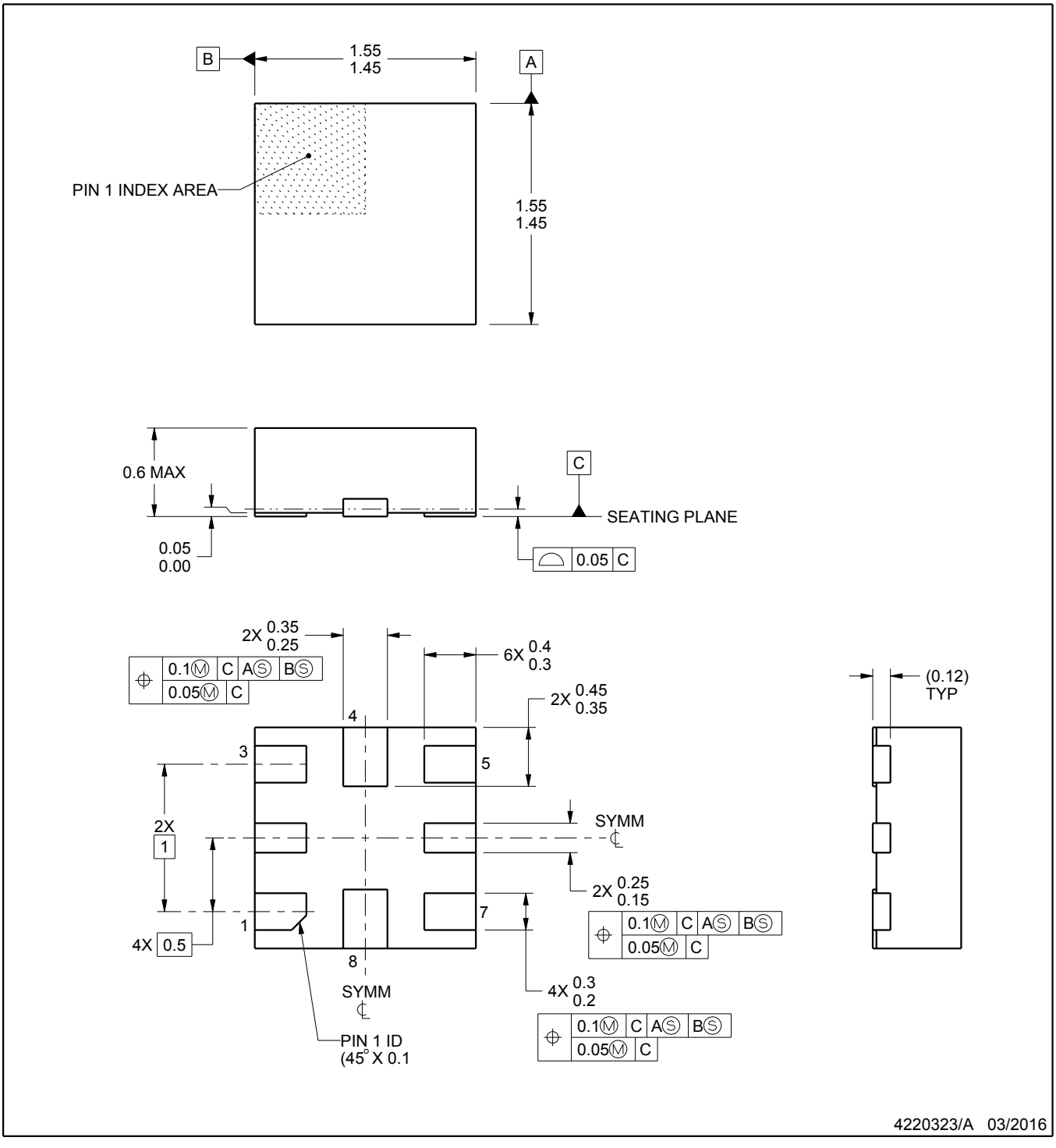
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.

# PACKAGE OUTLINE

## RSE0008A

## UQFN - 0.6 mm max height

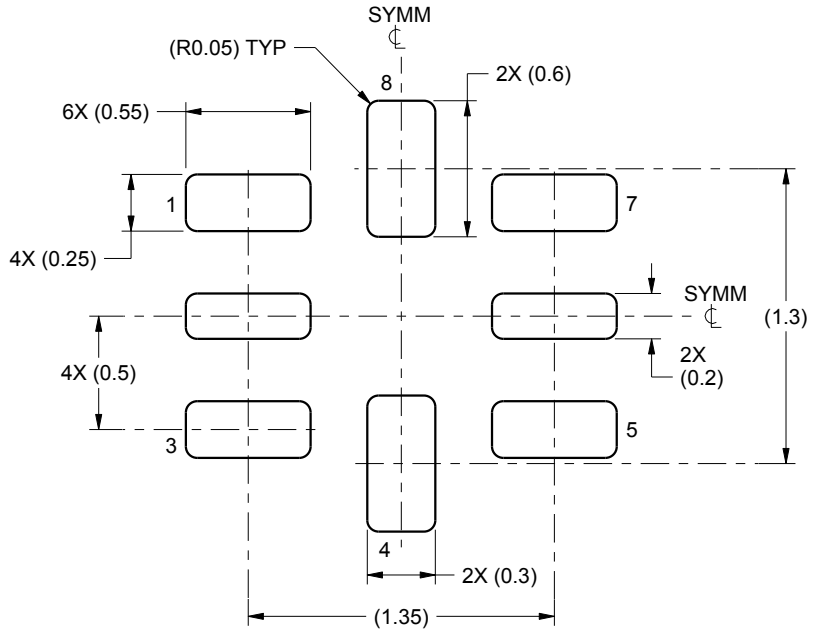
PLASTIC QUAD FLATPACK - NO LEAD



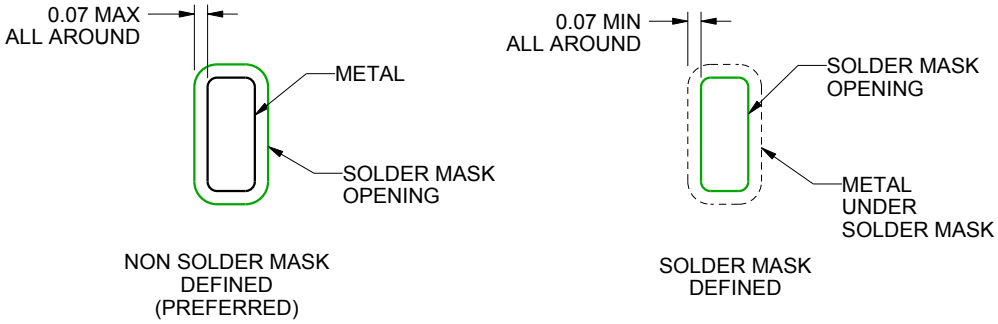

4220323/A 03/2016

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.




LAND PATTERN EXAMPLE
SCALE:30X

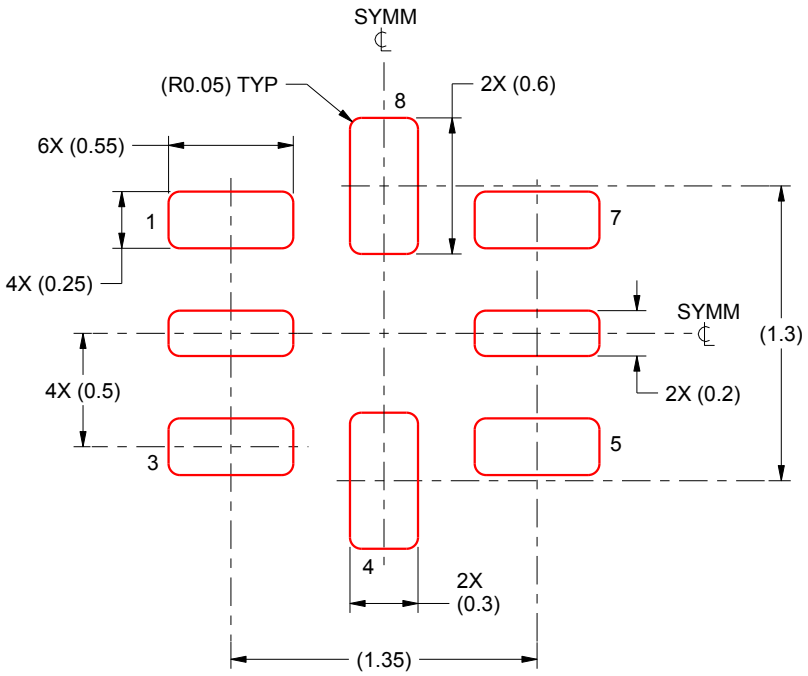



SOLDER MASK DETAILS
NOT TO SCALE

4220323/A 03/2016

NOTES: (continued)

3. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).



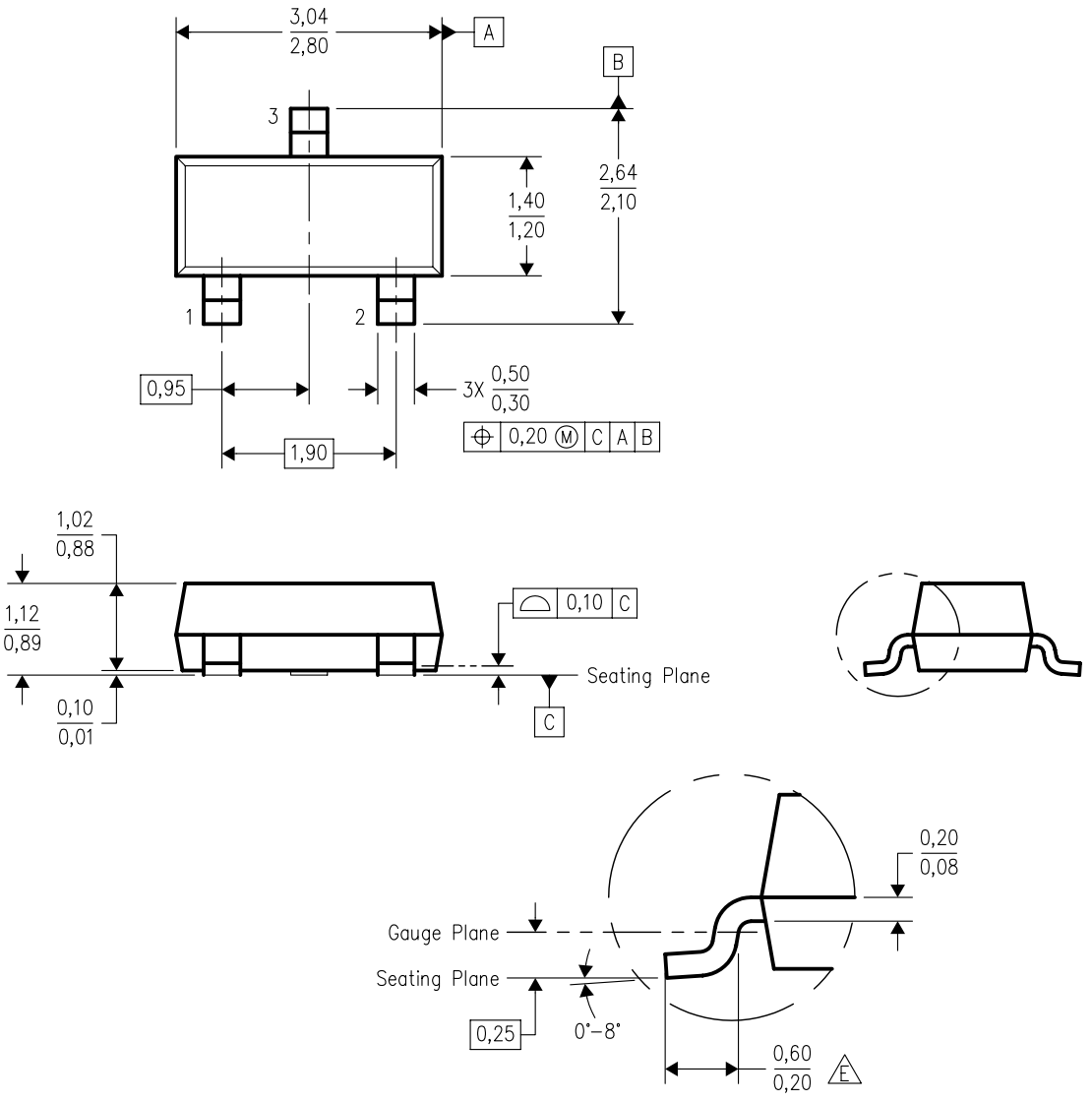

SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICKNESS
SCALE: 30X

4220323/A 03/2016

NOTES: (continued)

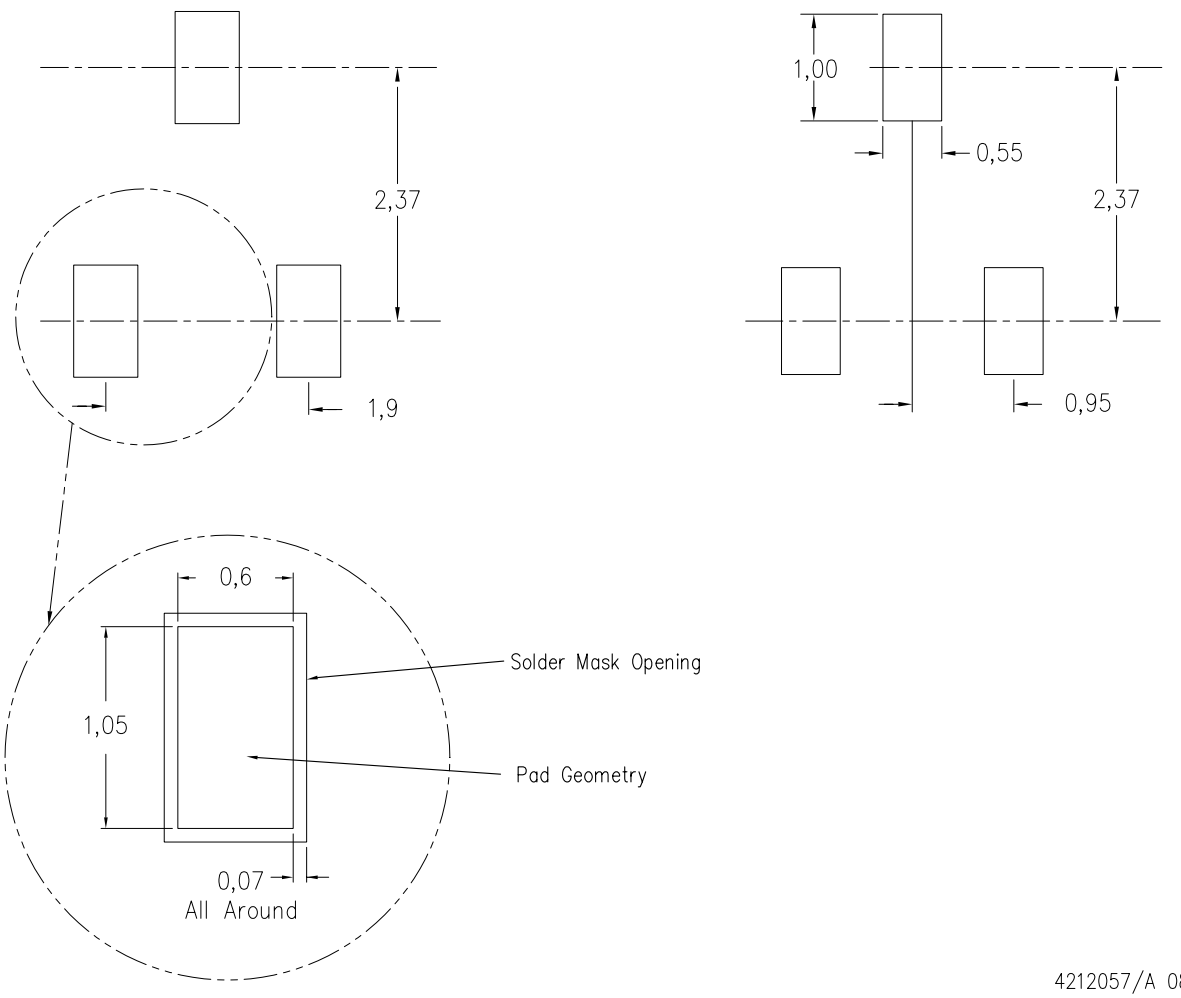
5. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

## DBZ (R–PDSO–G3) PLASTIC SMALL–OUTLINE




NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Lead dimensions are inclusive of plating.
D. Body dimensions are exclusive of mold flash and protrusion. Mold flash and protrusion not to exceed 0.25 per side.
E. Falls within JEDEC TO–236 variation AB, except minimum foot length.

DBZ (R–PDSO–G3) 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.

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