

## 50 ppm/°C MAX, 50 $\mu$ A, CMOS VOLTAGE REFERENCE

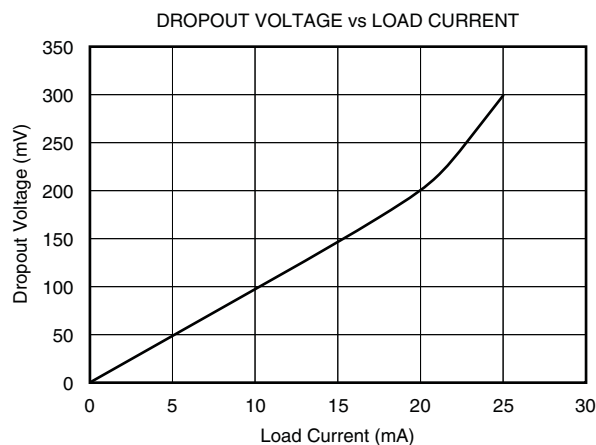
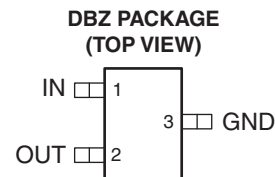
 Check for Samples: [REF3033-Q1](#)

### FEATURES

- Qualified for Automotive Applications
- Low Dropout Voltage: 1 mV
- High Output Current: 25 mA
- High Accuracy: 0.2%
- Low Quiescent Current: 50  $\mu$ A (Max)
- Excellent Specified Drift Performance
  - 50 ppm/°C (Max),  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$
  - 75 ppm/°C (Max),  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$

### APPLICATIONS

- Portable, Battery-Powered Equipment
- Data Acquisition Systems
- Medical Equipment
- Hand-Held Test Equipment



### DESCRIPTION

The REF30xx is a precision low-power low-dropout voltage reference family available in a tiny SOT23-3 (DBV) package.

The REF30xx small size and low power consumption (50  $\mu$ A max) make it ideal for portable and battery-powered applications. The REF30xx does not require a load capacitor.

Unloaded, the REF30xx can be operated with supplies within 1 mV of output voltage. The device is specified for the temperature range of  $-40^\circ\text{C}$  to  $85^\circ\text{C}$ .

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

| $T_A$                                     | PACKAGE <sup>(2)</sup> |              | ORDERABLE PART NUMBER | TOP-SIDE MARKING |
|---|------------------------|--------------|-----------------------|------------------|
| $-40^\circ\text{C}$ to $85^\circ\text{C}$ | SOT-23 – DBV           | Reel of 3000 | REF3033AIDBZRQ1       | REFI             |

- (1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at [www.ti.com](http://www.ti.com).
- (2) Package drawings, thermal data, and symbolization are available at [www.ti.com/packaging](http://www.ti.com/packaging).



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.



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.

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

|  |                            |            |    |
|--|----------------------------|------------|----|
| Input voltage                                |                            | 7          | V  |
| Output short-circuit duration <sup>(2)</sup> |                            | Continuous |    |
| Operating temperature range                  |                            | –40 to 85  | °C |
| Storage temperature range                    |                            | –65 to 150 | °C |
| Junction temperature (T <sub>J</sub> max)    |                            | 150        | °C |
| ESD rating                                   | Human-body model (HBM)     | 2000       | V  |
|  | Charged-device model (CDM) | 1000       |    |

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.

(2) Short circuit to ground

## ELECTRICAL CHARACTERISTICS

**Boldface** limits apply over the specified temperature range, T<sub>A</sub> = –40°C to 85°C.

T<sub>A</sub> = 25°C, I<sub>LOAD</sub> = 0, V<sub>IN</sub> = 5 V (unless otherwise noted)

| PARAMETER   | CONDITIONS  | MIN   | TYP       | MAX       | UNIT              |
|---|---|-------|-----------|-----------|-------------------|
| <b>OUTPUT VOLTAGE</b>                                 |   |       |           |           |                   |
| Output voltage  | V <sub>OUT</sub>  | 3.294 | 3.3       | 3.306     | V                 |
| Initial accuracy                                      |   |       |           | 0.2       | %                 |
| <b>NOISE</b>  |   |       |           |           |                   |
| Output voltage noise                                  | f = 0.1 Hz to 10 Hz   |       | 36        |           | μV <sub>PP</sub>  |
| Voltage noise   | f = 10 Hz to 10 kHz   |       | 105       |           | μV <sub>rms</sub> |
| <b>LINE REGULATION</b>                                |   |       |           |           |                   |
|   | V <sub>REF</sub> + 50 mV ≤ V <sub>IN</sub> ≤ 5.5 V                              |       | 130       | 400       | μV/V              |
| <b>OUTPUT VOLTAGE TEMPERATURE DRIFT<sup>(1)</sup></b> |   |       |           |           |                   |
| dV <sub>OUT</sub> /dT                                 | 0°C ≤ T <sub>A</sub> ≤ 70°C   |       | <b>20</b> | <b>50</b> | <b>ppm/°C</b>     |
|   | –30°C ≤ T <sub>A</sub> ≤ 85°C   |       | <b>28</b> | <b>60</b> | <b>ppm/°C</b>     |
|   | –40°C ≤ T <sub>A</sub> ≤ 85°C   |       | <b>30</b> | <b>65</b> | <b>ppm/°C</b>     |
| <b>LONG-TERM STABILITY</b>                            |   |       |           |           |                   |
|   | 0 to 1000 h   |       | 24        |           | ppm               |
|   | 1000 h to 2000 h  |       | 15        |           | ppm               |
| <b>LOAD REGULATION<sup>(2)</sup></b>                  |   |       |           |           |                   |
| dV <sub>OUT</sub> /dI <sub>LOAD</sub>                 | 0 mA < I <sub>LOAD</sub> < 25 mA<br>V <sub>IN</sub> = V <sub>REF</sub> + 500 mV |       | 3         | 100       | μV/mA             |
| <b>THERMAL HYSTERESIS<sup>(3)</sup></b>               |   |       |           |           |                   |
| dT  |   |       | 25        | 100       | ppm               |
| <b>DROPOUT VOLTAGE</b>                                |   |       |           |           |                   |
| V <sub>IN</sub> – V <sub>OUT</sub>                    |   |       | 1         | 50        | mV                |
| <b>SHORT-CIRCUIT CURRENT</b>                          |   |       |           |           |                   |
| I <sub>SC</sub>                                       |   |       | 45        |           | mA                |
| <b>TURN-ON SETTLING TIME</b>                          |   |       |           |           |                   |
|   | To 0.1%, V <sub>IN</sub> = 5 V, C <sub>L</sub> = 1 μF                           |       | 120       |           | μs                |

(1) Box Method used to determine over temperature drift.

(2) Typical value of load regulation reflects measurements using a force and sense contacts, see [Load Regulation](#) in *Application Information*.

(3) For more detail on the thermal hysteresis procedure, see [Thermal Hysteresis](#) in *Application Information*.

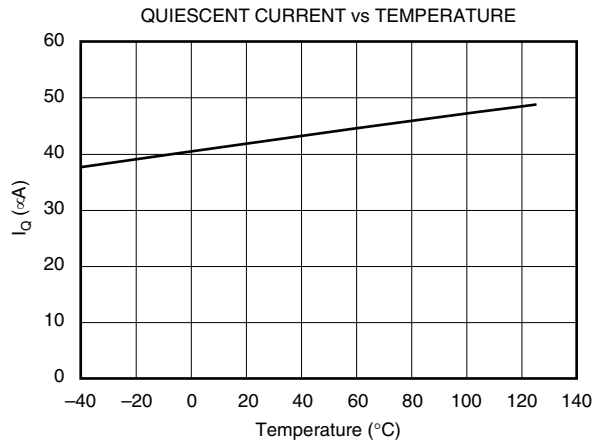
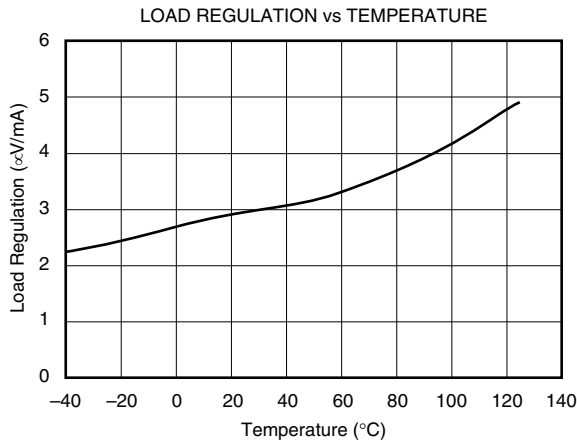
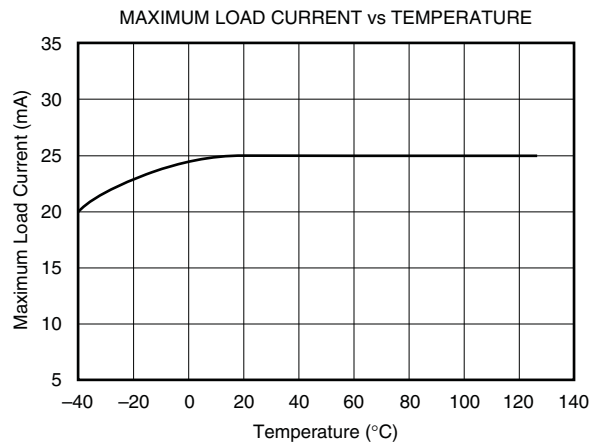
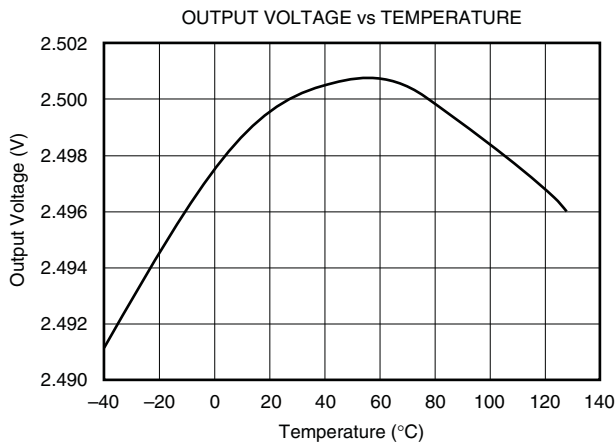
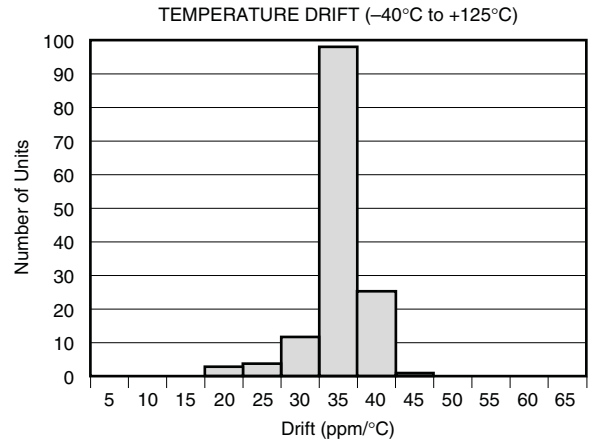
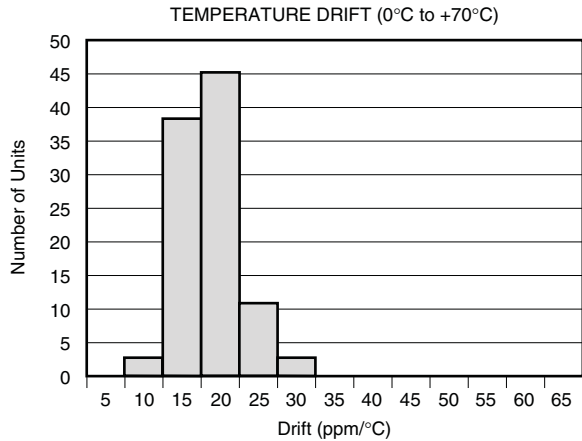
**ELECTRICAL CHARACTERISTICS (continued)**
**Boldface** limits apply over the specified temperature range,  $T_A = -40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

 $T_A = 25^{\circ}\text{C}$ ,  $I_{\text{LOAD}} = 0$ ,  $V_{\text{IN}} = 5\text{ V}$  (unless otherwise noted)

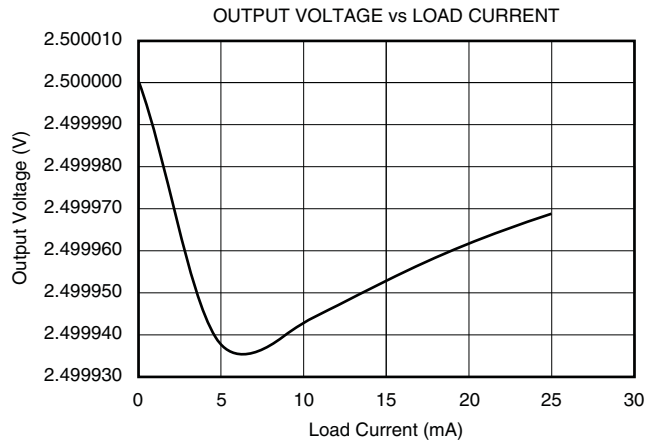
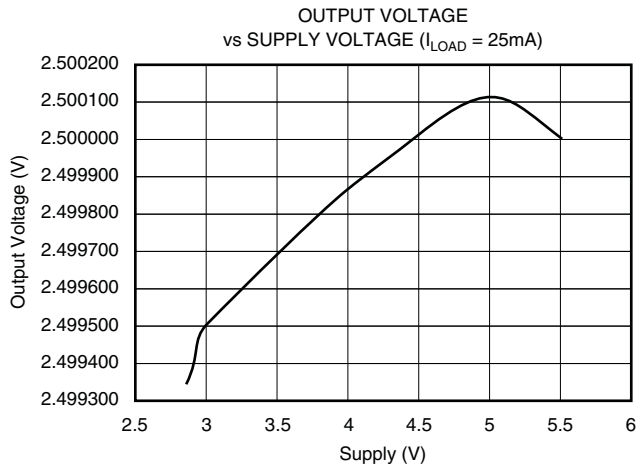
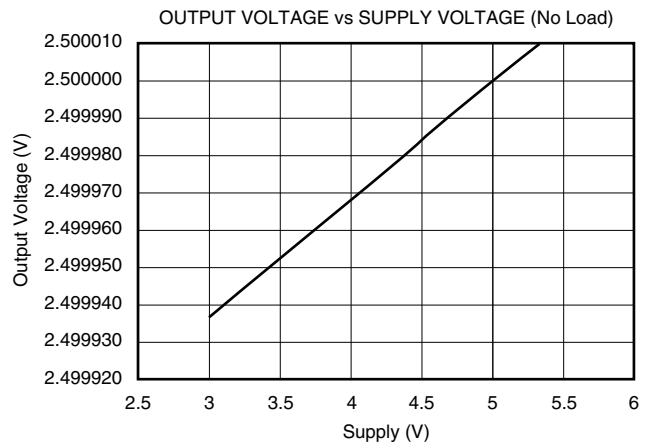
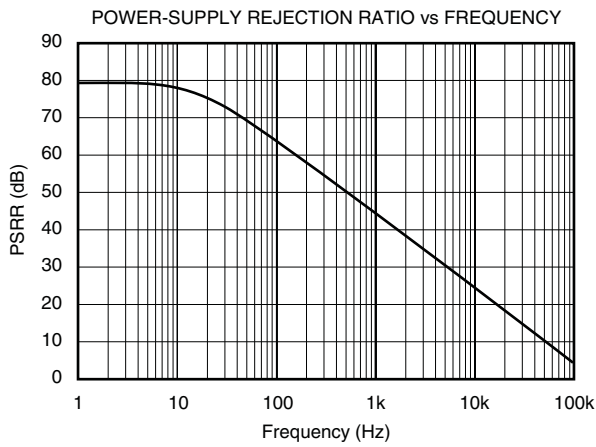
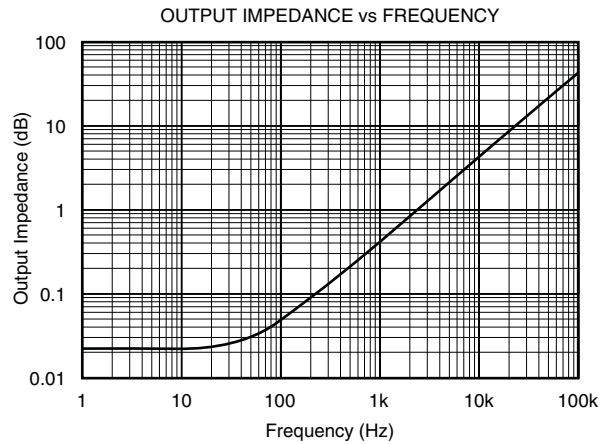
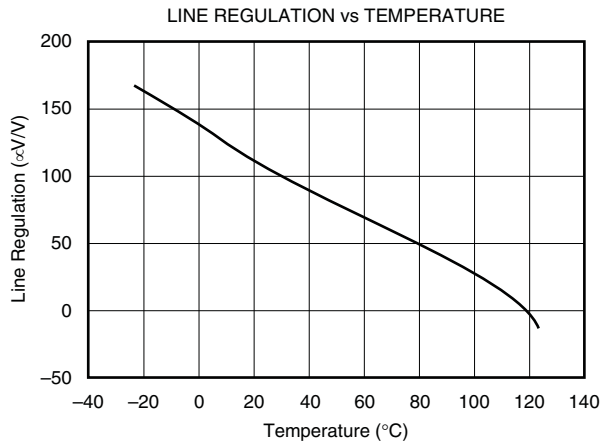
| PARAMETER                | CONDITIONS   | MIN                                       | TYP | MAX        | UNIT                            |
|--------------------------|--|---|-----|------------|---------------------------------|
| <b>POWER SUPPLY</b>      |  |   |     |            |                                 |
| Supply voltage           | $I_{\text{LOAD}} = 0^{(4)}$                            | $V_{\text{REF}} + 0.001$                  |     | 5.5        | V                               |
| <b>Over temperature</b>  | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ | <b><math>V_{\text{REF}} + 0.05</math></b> |     | <b>5.5</b> |                                 |
| Quiescent current        |  |   | 42  | 50         | $\mu\text{A}$                   |
| <b>Over temperature</b>  | $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ |   |     | <b>59</b>  | <b><math>\mu\text{A}</math></b> |
| <b>TEMPERATURE RANGE</b> |  |   |     |            |                                 |
| Specified range          |  | -40                                       |     | 85         | $^{\circ}\text{C}$              |
| Operating range          |  | -40                                       |     | 85         | $^{\circ}\text{C}$              |
| Thermal resistance       |  |   |     |            |                                 |
| Junction to case         | $\theta_{\text{JC}}$                                   |   | 110 |            | $^{\circ}\text{C}/\text{W}$     |
| Junction to free air     | $\theta_{\text{JA}}$                                   |   | 336 |            | $^{\circ}\text{C}/\text{W}$     |

 (4) For  $I_{\text{LOAD}} > 0$ , see *Typical Characteristics*.

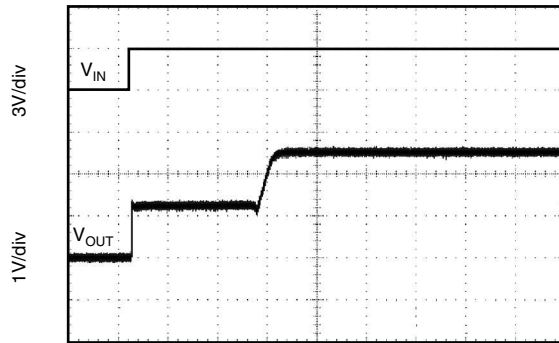
**TYPICAL CHARACTERISTICS**



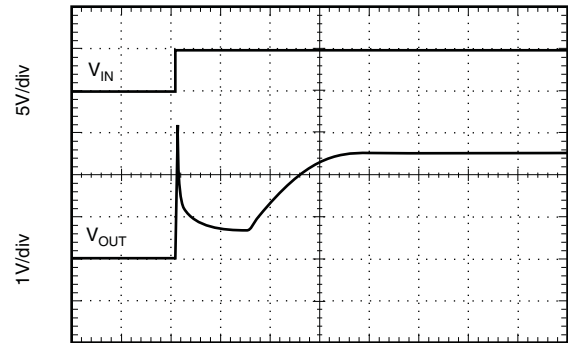
TYPICAL CHARACTERISTICS (continued)



### TYPICAL CHARACTERISTICS (continued)

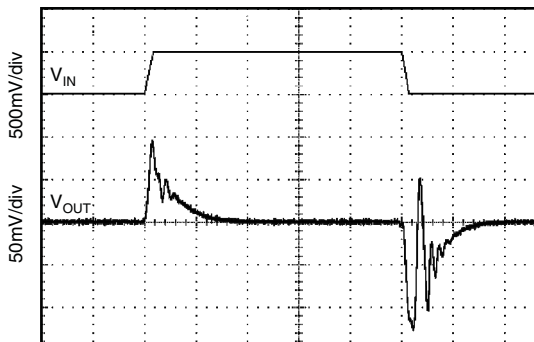
STEP RESPONSE,  $C_L = 0$ , 3V STARTUP

40µs/div

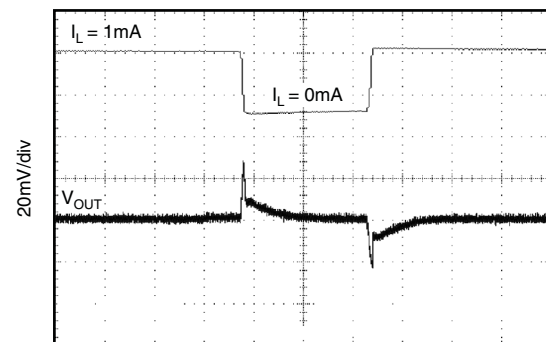
STEP RESPONSE,  $C_L = 0$ , 5V STARTUP

10µs/div

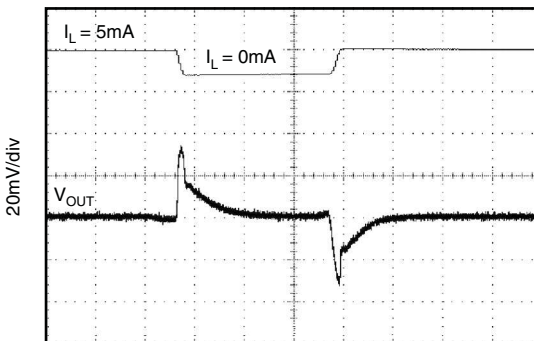
LINE TRANSIENT RESPONSE



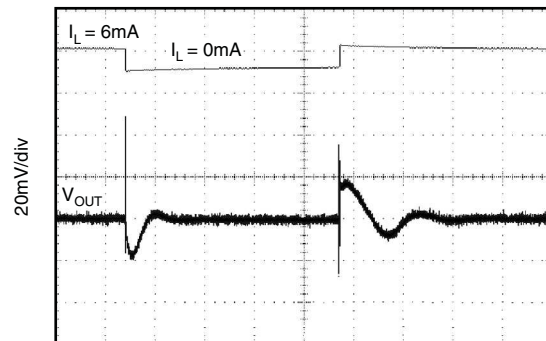
10µs/div

0-1mA LOAD TRANSIENT ( $C_L = 0$ )

10µs/div

0-5mA LOAD TRANSIENT ( $C_L = 0$ )

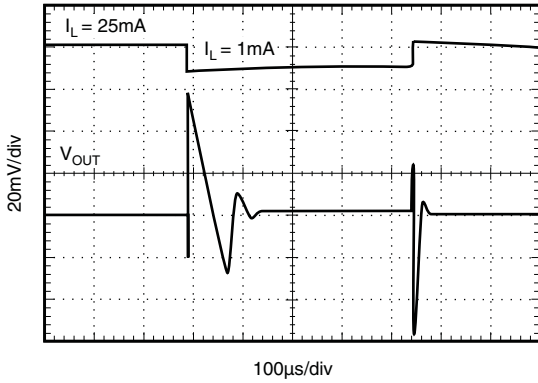
10µs/div

1-6mA LOAD TRANSIENT ( $C_L = 1\mu\text{F}$ )

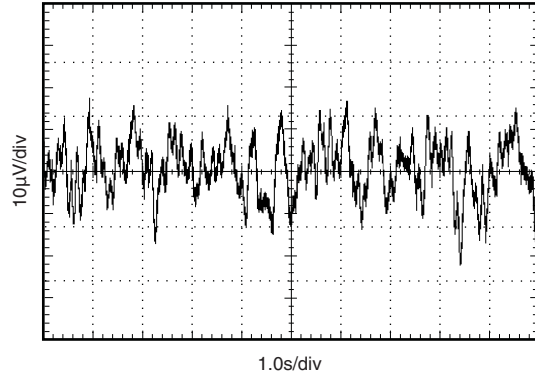
40µs/div

TYPICAL CHARACTERISTICS (continued)

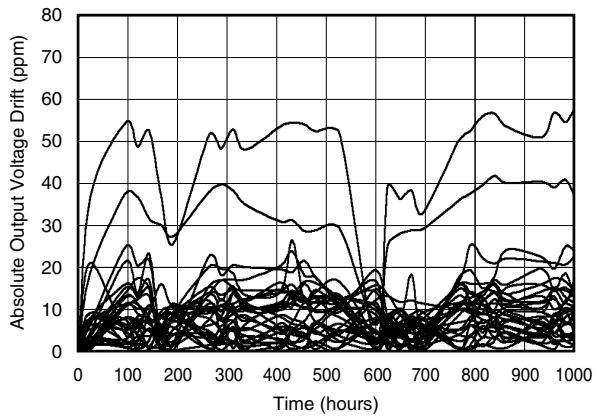
1-25mA LOAD TRANSIENT ( $C_L = 1\mu\text{F}$ )



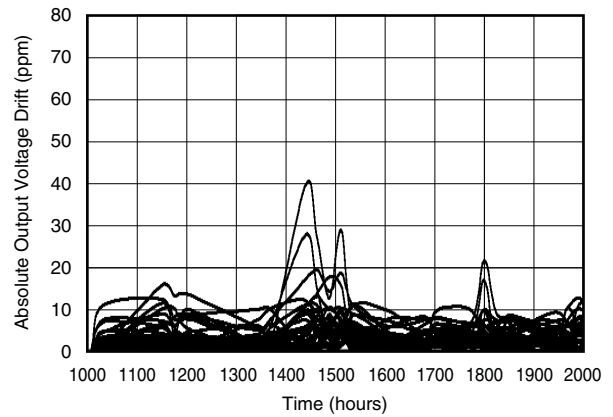
0.1Hz TO 10Hz NOISE



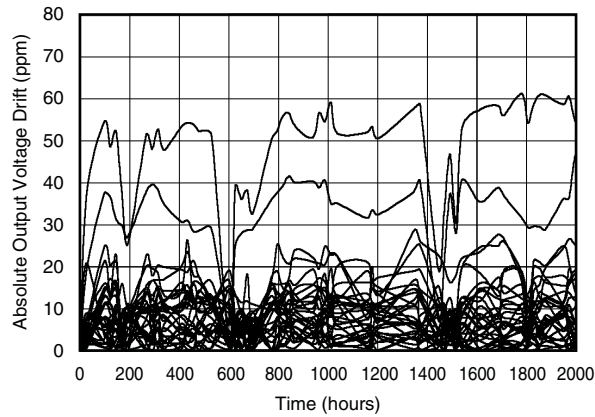
LONG-TERM STABILITY 0 TO 1000 HOURS



LONG-TERM STABILITY 1000 TO 2000 HOURS

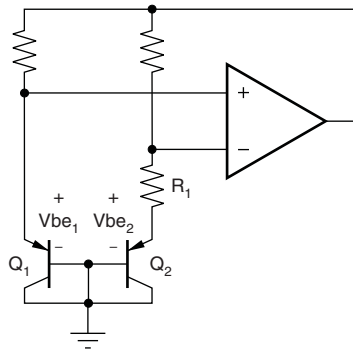


LONG-TERM STABILITY 0 TO 2000 HOURS



## THEORY OF OPERATION

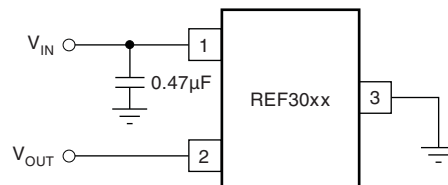
The REF30xx is a series, CMOS, precision bandgap voltage reference. Its basic topology is shown in [Figure 1](#). The transistors Q1 and Q2 are biased such that the current density of Q1 is greater than that of Q2. The difference of the two base-emitter voltages,  $V_{be1} - V_{be2}$ , has a positive temperature coefficient and is forced across resistor R1. This voltage is gained up and added to the base-emitter voltage of Q2, which has a negative coefficient. The resulting output voltage is virtually independent of temperature. The curvature of the bandgap voltage, as seen in the typical curve, "Output Voltage vs Temperature," is due to the slightly nonlinear temperature coefficient of the base-emitter voltage of Q2.



**Figure 1. Simplified Schematic of Bandgap Reference**

## APPLICATION INFORMATION

For normal operation, the REF30xx does not require a capacitor on the output. If a capacitive load is connected, special care must be taken with the combination of low equivalent series resistance (ESR) capacitors and high capacitance. This caution is especially true for low-output voltage devices; therefore, the REF3012 should only have a low-ESR capacitance of 10  $\mu\text{F}$  or less. [Figure 2](#) shows the typical connections required for operation of the REF30xx. A supply bypass capacitor of 0.47  $\mu\text{F}$  is always recommended.



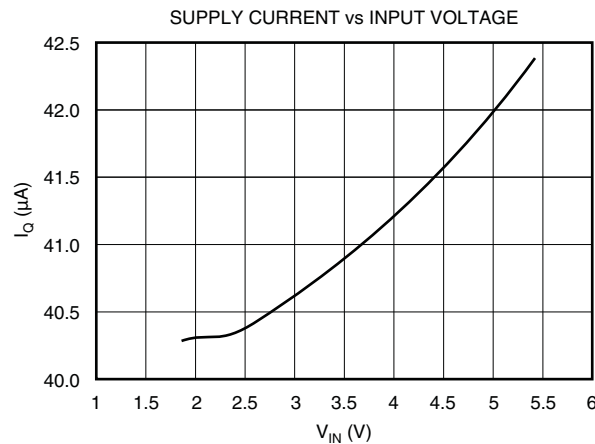
**Figure 2. Typical Connections for Operating REF30xx**

### Supply Voltage

The REF30xx family of references features an extremely low dropout voltage. With the exception of the REF3012, which has a minimum supply requirement of 1.8 V, the REF30xx can be operated with a supply of only 1 mV above the output voltage in an unloaded condition. For loaded conditions, a typical dropout voltage versus load is shown on the cover page.

The REF30xx features a low quiescent current, which is extremely stable over changes in both temperature and supply. The typical room temperature quiescent current is 42  $\mu\text{A}$ , and the maximum quiescent current over temperature is just 59  $\mu\text{A}$ . Additionally, the quiescent current typically changes less than 2.5  $\mu\text{A}$  over the entire supply range, as shown in [Figure 3](#).





**Figure 3. Supply Current vs Supply Voltage**

Supply voltages below the specified levels can cause the REF30xx to momentarily draw currents greater than the typical quiescent current. Using a power supply with a fast rising edge and low output impedance easily prevents this.

**Thermal Hysteresis**

Thermal hysteresis for the REF30xx 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, and can be expressed as:

Where

V<sub>HYST</sub> = Calculated hysteresis

V<sub>PRE</sub> = Output voltage measured at 25°C pretemperature cycling

V<sub>POST</sub> = Output voltage measured when device has been operated at 25°C, cycled through specified range –40°C to 85°C, and returned to operation at 25°C.

**Temperature Drift**

The REF30xx is designed to exhibit minimal drift error, defined as the change in output voltage over varying temperature. Using the "box" method of drift measurement, the REF30xx features a typical drift coefficient of 20 ppm from 0°C to 70°C—the primary temperature range of use for many applications. For automotive temperature ranges of –40°C to 85°C, the REF30xx family drift increases to a typical value of 50 ppm.

**Noise Performance**

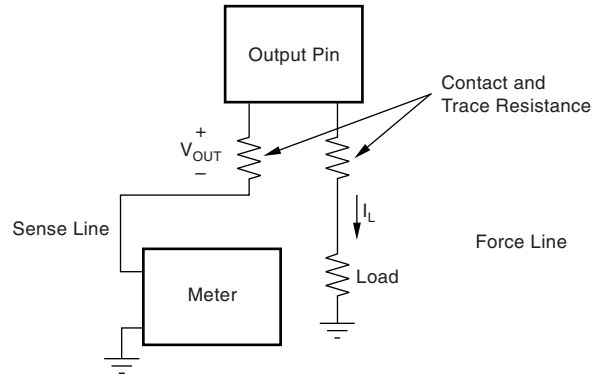
The REF30xx generates noise less than 50 µVp-p between frequencies of 0.1 Hz to 10 Hz, and can be seen in the typical characteristic curve "0.1 to 10Hz Voltage Noise." The noise voltage of the REF30xx increases with output voltage and operating temperature. Additional filtering may be used to improve output noise levels, although care should be taken to ensure the output impedance does not degrade AC performance.

**Long-Term Stability**

Long term stability refers to the change of the output voltage of a reference over a period of months or years. This effect lessens as time progresses as is apparent by the long term stability curves. The typical drift value for the REF30xx is 24 ppm from 0 to 1000 hours and 15 ppm from 1000 to 2000 hours. This parameter is characterized by measuring 30 units at regular intervals for a period of 2000 hours.

## Load Regulation

Load regulation is defined as the change in output voltage due to changes in load current. Load regulation for the REF30xx is measured using force and sense contacts as pictured in Figure 4. The force and sense lines tied to the contact area of the output pin reduce the impact of contact and trace resistance, resulting in accurate measurement of the load regulation contributed solely by the REF30xx. For applications requiring improved load regulation, force and sense lines should be used.

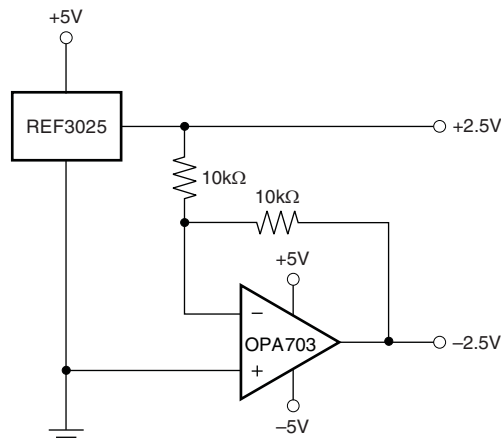


**Figure 4. Accurate Load Regulation**

## Application Circuits

### Negative Reference Voltage

For applications requiring a negative and positive reference voltage, the OPA703 and REF30xx can be used to provide a dual supply reference from a  $\pm 5$ -V supply. Figure 5 shows the REF3025 used to provide a  $\pm 2.5$ -V supply reference voltage. The low offset voltage and low drift of the OPA703 complement the low drift performance of the REF30xx to provide an accurate solution for split-supply applications.



**Figure 5. REF3025 Combined with OPA703 to Create Positive and Negative Reference Voltages**

## Data Acquisition

Often data acquisition systems require stable voltage references to maintain necessary accuracy. The REF30xx family features stability and a wide range of voltages suitable for most microcontrollers and data converters. Figure 6 and Figure 7 show two basic data acquisition systems.

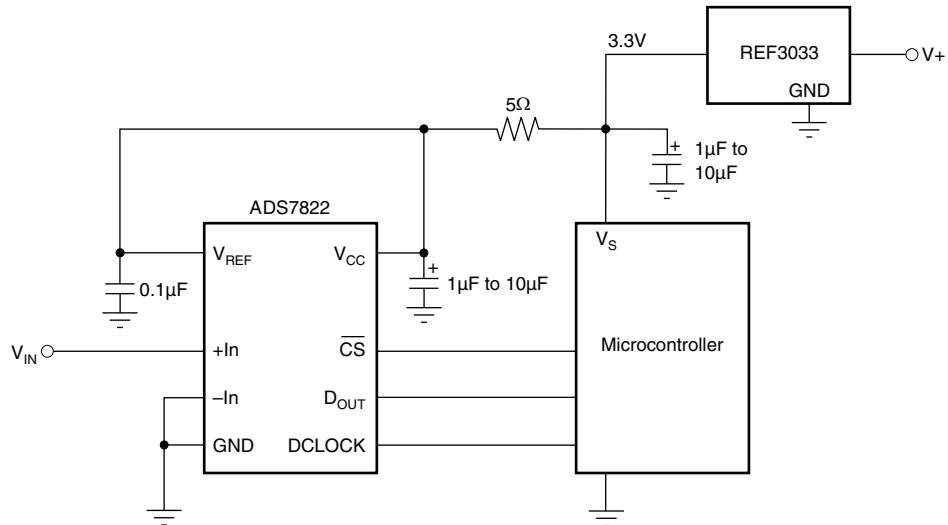


Figure 6. Basic Data Acquisition System 1

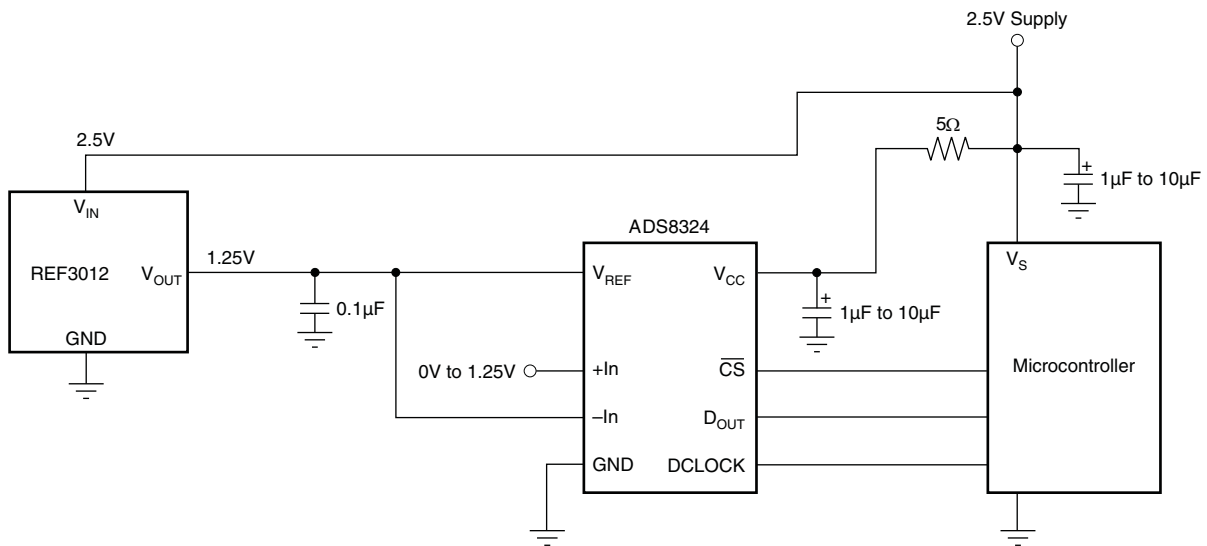


Figure 7. Basic Data Acquisition System 2

**PACKAGING INFORMATION**

| Orderable Device | Status<br>(1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan<br>(2)         | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples |
|------------------|---------------|--------------|-----------------|------|-------------|-------------------------|-------------------------|----------------------|--------------|-------------------------|---------|
| REF3033AIDBZRQ1  | NRND          | SOT-23       | DBZ             | 3    | 3000        | Green (RoHS & no Sb/Br) | NIPDAU                  | Level-2-260C-1 YEAR  | -40 to 85    | REFI                    |         |

(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.

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

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(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.

**OTHER QUALIFIED VERSIONS OF REF3033-Q1 :**

- Catalog: [REF3033](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

## TAPE AND REEL INFORMATION



### 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 |
|-----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| REF3033AIDBZRQ1 | SOT-23       | DBZ             | 3    | 3000 | 179.0              | 8.4                | 3.15    | 2.95    | 1.22    | 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) |
|-----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| REF3033AIDBZRQ1 | SOT-23       | DBZ             | 3    | 3000 | 195.0       | 200.0      | 45.0        |

**GENERIC PACKAGE VIEW**

**DBZ 3**

**SOT-23 - 1.12 mm max height**

SMALL OUTLINE TRANSISTOR



Images above are just a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.

4203227/C



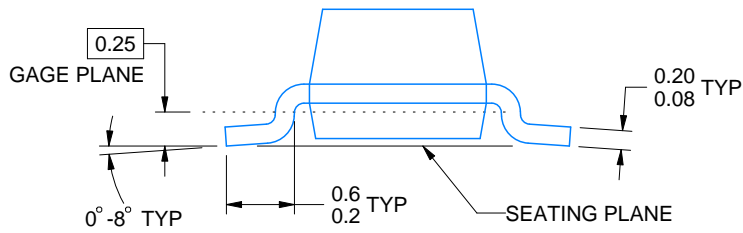
DBZ0003A



# PACKAGE OUTLINE

SOT-23 - 1.12 mm max height

SMALL OUTLINE TRANSISTOR



4214838/C 04/2017

NOTES:

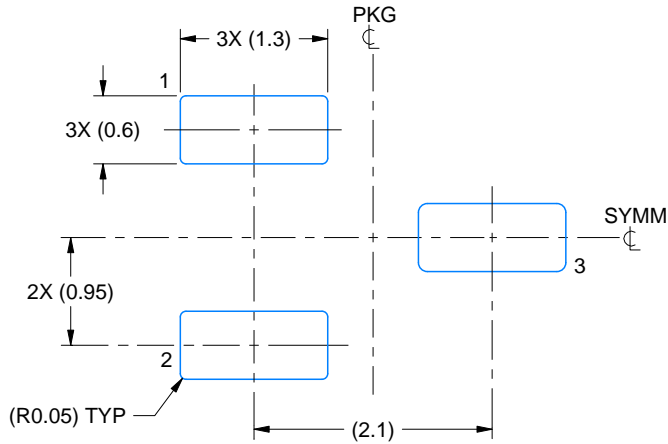
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC registration TO-236, except minimum foot length.

# EXAMPLE BOARD LAYOUT

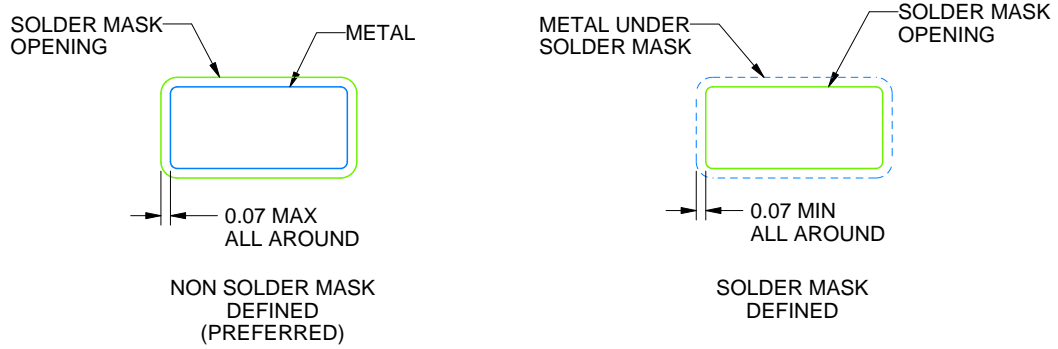
DBZ0003A

SOT-23 - 1.12 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE  
SCALE:15X



SOLDER MASK DETAILS

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NOTES: (continued)

- 4. Publication IPC-7351 may have alternate designs.
- 5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

DBZ0003A

SOT-23 - 1.12 mm max height

SMALL OUTLINE TRANSISTOR



SOLDER PASTE EXAMPLE  
BASED ON 0.125 THICK STENCIL  
SCALE:15X

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NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
7. Board assembly site may have different recommendations for stencil design.

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