

# REF80 Temperature-Controlled Buried Zener Reference with 0.05ppm/°C Drift and < 1ppm Stability

## 1 Features

- 7.6V ultra-precision reference with minimal number of external components
- Ultra-low temperature drift: 0.05ppm/°C
- Excellent long term stability: 0.3ppm (1k hour to 5k hour)
- Integrated heater with temperature stable indicator
- 1/f noise (0.1Hz to 10Hz) : 0.12ppm<sub>pk-pk</sub>
- Input Voltage range: 10V to 16.5V
- Heater supply range: 10V to 42V
- Hermetically sealed ceramic package (20 pin LCCC)

## 2 Applications

- [Parametric measurement unit](#)
- [Lab and field instrumentation](#)
- [Precision weight scales](#)
- [Battery test equipment](#)
- [Digital multimeter](#)
- [Source measurement unit](#)
- [Data acquisition](#)

## 3 Description

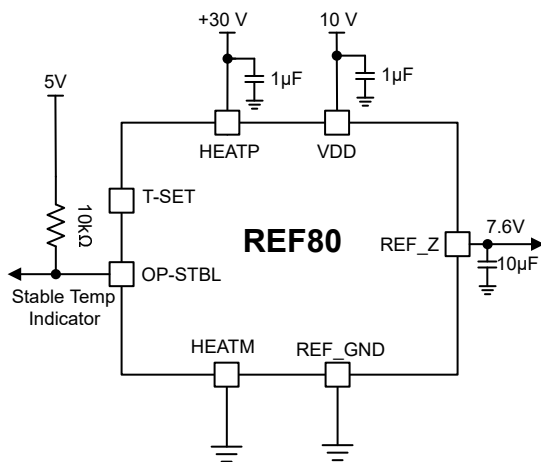
The REF80 is a highly integrated ultra-low drift buried zener precision voltage reference. The REF80 combines a precision 7.6V reference with an internal heater to achieve extremely low temperature drift of 0.05ppm/°C. The integrated heater maintains the internal temperature of the die at a constant set point. This helps the reference voltage stay constant irrespective of ambient temperature variations. The device internal temperature is pre-programmed to eliminate design complexities. This allows for fast design cycles, easy bring up and no dependence on high-cost external precision components.

The REF80 family is available in a 20-pin LCCC package. The LCCC package is a hermetically sealed ceramic package that enables ultra-low long-term stability specification of 0ppm (after settling), critical for applications that demand a long time period without calibration. The package also offers excellent immunity against humidity variation.

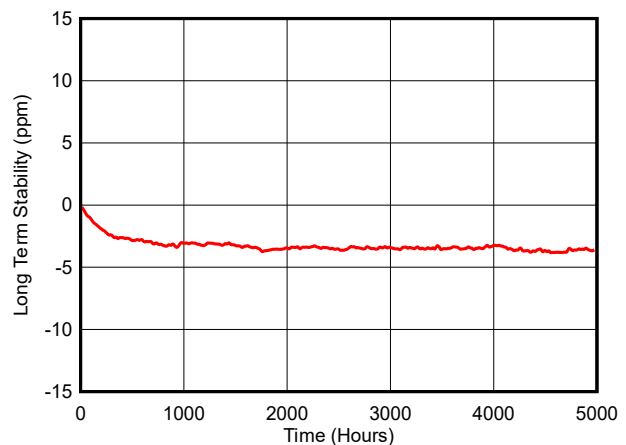
### Device Information

| PART NAME | PACKAGE <sup>(1)</sup> | BODY SIZE (NOM) <sup>(2)</sup> |
|-----------|------------------------|--------------------------------|
| REF80     | LCCC (20)              | 8.89mm × 8.89mm                |

- (1) For all available packages, see the orderable addendum at the end of the data sheet.
- (2) The package size (length × width) is a nominal value and includes pins, where applicable.



**REF80 Circuit Diagram  
(With Supply and Passive Requirement)**



**Reference Voltage Drift Vs Time**



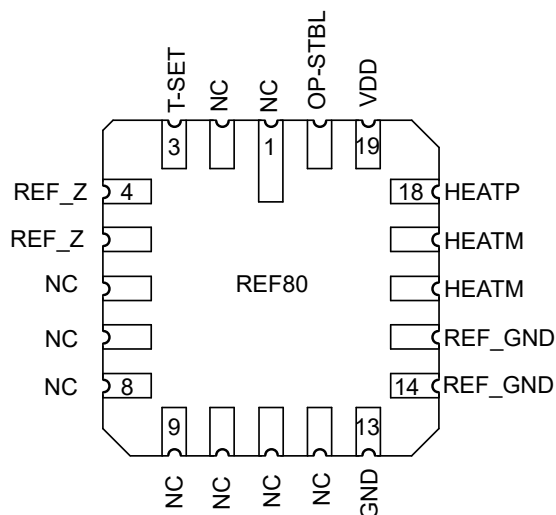
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## 4 Device Comparison Table

| PRODUCT        | V <sub>REF_Z</sub> | Temperature Range |
|----------------|--------------------|-------------------|
| REF80000B1NAJT | 7.6V               | 0°C to 70°C       |

## 5 Pin Configuration and Functions



**Figure 5-1. NAJ Package  
20-Pin LCCC  
Top View**

**Table 5-1. Pin Functions**

| PIN     |            | TYPE       | DESCRIPTION                                                                                                                                                                 |
|---------|------------|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME    | Number     |            |                                                                                                                                                                             |
| NC      | 1, 2, 6-12 | No Connect | No connect pin. Leave this pin floating or connected to GND.                                                                                                                |
| T-SET   | 3          | Input      | Connect resistor to adjust the heater temperature. Leave the pin floating to use factory programmed heater set point. Refer <a href="#">Section 7.3.1</a> for more details. |
| REF_Z   | 4,5        | Output     | Reference voltage output. Connect a 10μF to 100μF output capacitor to REF_GND for the best performance.                                                                     |
| GND     | 13         | Ground     | This pin must be shorted to REF_GND pin.                                                                                                                                    |
| REF_GND | 14, 15     | Ground     | Reference ground pin.                                                                                                                                                       |
| HEATM   | 16, 17     | Power      | Heater power supply negative connection.                                                                                                                                    |
| HEATP   | 18         | Power      | Heater power supply positive connection.                                                                                                                                    |
| VDD     | 19         | Power      | Power supply for buried zener core and buffer.                                                                                                                              |
| OP_STBL | 20         | Output     | Active high open drain output. Indicates the internal heater is stabilized at factory programmed temperature.                                                               |

## 6 Specifications

### 6.1 Absolute Maximum Ratings

over operating free-air temperature range, all the voltages ratings are specified with respect to REF\_GND pin voltage (unless otherwise noted) <sup>(1)</sup>

|                              |                  | MIN  | MAX | UNIT |
|------------------------------|------------------|------|-----|------|
| Voltage                      | VDD, OP_STBL,    | –0.3 | 18  | V    |
|                              | T-set, NC        | –0.3 | 6   | V    |
|                              | REF_Z            | –0.3 | 10  | V    |
|                              | HEATP            | –0.3 | 48  | V    |
|                              | HEATM            | –42  | 0.3 | V    |
|                              | HEATP - HEATM    | 0    | 42  |      |
| Output short circuit current | I <sub>SC</sub>  |      | 30  | mA   |
| Operating temperature range  | T <sub>A</sub>   | –55  | 125 | °C   |
| Storage temperature range    | T <sub>stg</sub> | –65  | 170 | °C   |

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

### 6.2 ESD Ratings

|                    |                         |                                                                                          | VALUE | UNIT |
|--------------------|-------------------------|------------------------------------------------------------------------------------------|-------|------|
| V <sub>(ESD)</sub> | Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins <sup>(1)</sup>              | ±2000 | V    |
|                    |                         | Charged device model (CDM), per JEDEC specification JESD22-C101, all pins <sup>(2)</sup> | ±750  |      |

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

### 6.3 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                              | REF80      |         | UNIT |
|-------------------------------|----------------------------------------------|------------|---------|------|
|                               |                                              | NAJ (LCCC) |         |      |
|                               |                                              | 20 PINS    |         |      |
|                               |                                              | 1s0p JEDEC | REF8EVM |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance       | 103.6      | 141.9   | °C/W |
| R <sub>θJB</sub>              | Junction-to-board thermal resistance         | 45.1       | 55.8    | °C/W |
| Ψ <sub>JT</sub>               | Junction-to-top characterization parameter   | 38.3       | 39.2    | °C/W |
| Ψ <sub>JB</sub>               | Junction-to-board characterization parameter | 45.1       | 55.8    | °C/W |

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

## 6.4 Recommended Operating Conditions

over operating free-air temperature range, all the voltages ratings are specified with respect to REF\_GND pin voltage (unless otherwise noted)

|         |                                            | MIN | NOM | MAX  | UNIT |
|---------|--------------------------------------------|-----|-----|------|------|
| Voltage | VDD                                        | 10  |     | 16.5 | V    |
|         | REF_Z                                      | 0   |     | 8    |      |
|         | VHET Heater voltage, $V_{(HEATP - HEATM)}$ | 10  |     | 42   |      |
|         | HEATP                                      | 0   |     | 42   |      |
|         | HEATM                                      | -42 |     | 0    |      |
|         | OP_STBL                                    | 0   |     | VDD  |      |
| Current | OP_STBL ( $I_{OL}$ )                       | 0   |     | 5    | mA   |
| $T_A$   | Operating temperature                      | -40 |     | 70   | °C   |

## 6.5 Electrical Characteristics

At VDD = 10V, VHET = 30V,  $T_{SET} = 115^{\circ}\text{C}$ ,  $C_{REF\_Z} = 10\mu\text{F}$ ,  $C_{VDD} = 1\mu\text{F}$ ,  $I_L = 0\text{mA}$ , T-SET = Open, OP\_STBL is pulled up to 5V through 10k $\Omega$  resistor, minimum and maximum specifications across supported temperature range, typical specifications  $T_A = 25^{\circ}\text{C}$ ; unless otherwise noted

| PARAMETER                          |                                                       | TEST CONDITION                                                             | MIN  | TYP  | MAX  | UNIT               |
|------------------------------------|-------------------------------------------------------|----------------------------------------------------------------------------|------|------|------|--------------------|
| ACCURACY AND DRIFT                 |                                                       |                                                                            |      |      |      |                    |
| REF_Z                              | Output voltage                                        |                                                                            | 7.6  |      |      | V                  |
|                                    | Output voltage accuracy                               |                                                                            | -50  |      | 50   | mV                 |
|                                    | Output voltage temperature coefficient <sup>(1)</sup> | T <sub>A</sub> = 0°C to 70°C                                               |      | 0.05 | 0.2  | ppm/°C             |
| HYSTERESIS AND LONG-TERM STABILITY |                                                       |                                                                            |      |      |      |                    |
|                                    | Long-term stability                                   | 1000 hours, T <sub>A</sub> = 25°C, T <sub>SET</sub> = 115°C                | 3    |      |      | ppm                |
|                                    |                                                       | 1000 hours to 5000 hours , T <sub>A</sub> = 25°C, T <sub>SET</sub> = 115°C | 0.3  |      |      |                    |
|                                    | Output voltage hysteresis                             | Cycle 1                                                                    | 1    |      |      | ppm                |
|                                    |                                                       | Cycle 2                                                                    | 0.3  |      |      | ppm                |
| NOISE                              |                                                       |                                                                            |      |      |      |                    |
| e <sub>np-p</sub>                  | Low frequency noise                                   | f = 0.1Hz to 10Hz                                                          | 0.12 |      |      | ppm <sub>p-p</sub> |
| e <sub>n</sub>                     | Output voltage noise                                  | f = 10Hz to 100Hz,                                                         | 0.6  |      |      | uV <sub>rms</sub>  |
| LINE REGULATION                    |                                                       |                                                                            |      |      |      |                    |
| ΔV <sub>REF_z</sub> /ΔVDD          | Line regulation                                       | VDD = 10V to 16.5V                                                         | 4    |      | 10   | ppm/V              |
| POWER SUPPLY                       |                                                       |                                                                            |      |      |      |                    |
| VDD                                | Input voltage                                         |                                                                            | 10   |      | 16.5 | V                  |
| VHET                               | Input voltage                                         | (HEATP - HEATM)                                                            | 10   |      | 42   | V                  |
| IHET                               | Start up current                                      |                                                                            | 335  |      |      | mA                 |
|                                    | Quiescent current                                     | T <sub>A</sub> = 25°C, T <sub>SET</sub> = 115°C, VHET = 10V                | 75   |      |      |                    |
|                                    |                                                       | T <sub>A</sub> = 25°C, T <sub>SET</sub> = 115°C, V <sub>HEATER</sub> = 42V | 18   |      |      |                    |
| I <sub>VDD</sub>                   | Quiescent current                                     |                                                                            | 15   |      |      | mA                 |
| TURNON TIME                        |                                                       |                                                                            |      |      |      |                    |
| Start-up                           | V <sub>REF_Z</sub>                                    | REF_Z settled within ±3ppm from VDD and VHET power up time                 | 100  |      |      | sec                |
|                                    | Heater regulation time                                | OP_STBL goes to logic high level form VHET power-up time                   | 250  |      |      | ms                 |

## 6.5 Electrical Characteristics (continued)

At VDD = 10V, VHET= 30V, T<sub>SET</sub> = 115°C, C<sub>REF\_Z</sub> = 10μF, C<sub>VDD</sub> = 1μF, I<sub>L</sub> = 0mA, T-SET = Open, OP\_STBL is pulled up to 5V through 10kΩ resistor, minimum and maximum specifications across supported temperature range, typical specifications T<sub>A</sub> = 25°C; unless otherwise noted

| PARAMETER                       |                                       | TEST CONDITION                                      | MIN | TYP  | MAX | UNIT |
|---------------------------------|---------------------------------------|-----------------------------------------------------|-----|------|-----|------|
| <b>OP_STBL</b>                  |                                       |                                                     |     |      |     |      |
| V <sub>OL</sub>                 | Low level output voltage              | OP_STBL Pin Current I <sub>OL</sub> = 5mA           |     | 0.65 |     | V    |
| I <sub>LKG</sub>                | Leakage Current when output is high   | Pullup Voltage at OP_STBL V <sub>PULLUP</sub> = 18V |     | 100  |     | nA   |
| <b>STABLE CAPACITANCE RANGE</b> |                                       |                                                     |     |      |     |      |
|                                 | Input capacitor range                 |                                                     | 0.1 |      |     | μF   |
|                                 | Output capacitor range <sup>(2)</sup> |                                                     | 10  |      | 100 | μF   |

- (1) Temperature drift is calculated using box method  
 (2) ESR for the capacitor can range from 10mΩ to 400mΩ

## 6.6 Typical Characteristics

At  $T_A = 25^\circ\text{C}$ ,  $V_{IN} = 10\text{V}$ ,  $V_{HET} = 30\text{V}$ ,  $C_{REF\_Z} = 10\mu\text{F}$ ,  $C_{VDD} = 1\mu\text{F}$ , (unless otherwise noted)

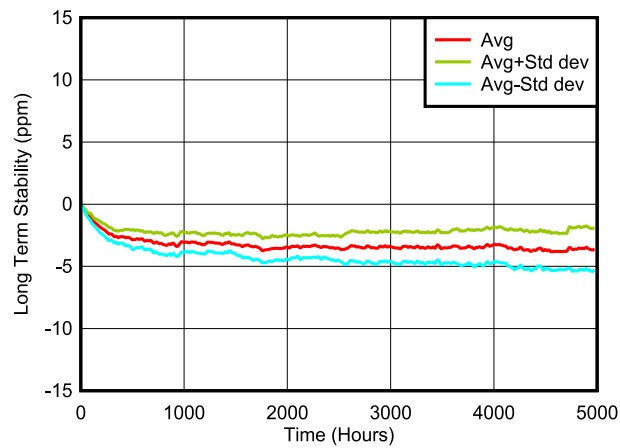


Figure 6-1. Long-Term Stability

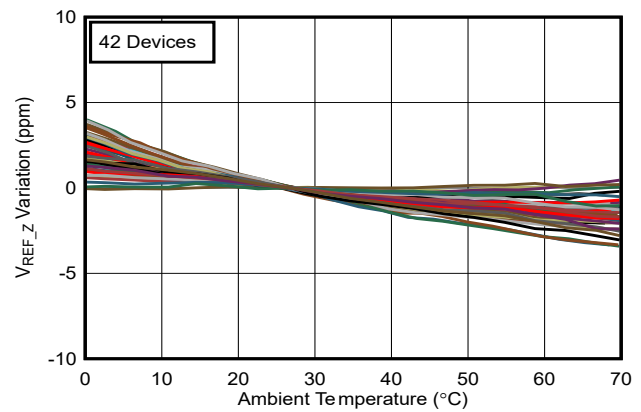


Figure 6-2.  $V_{REF\_Z}$  Vs Free-Air Temperature

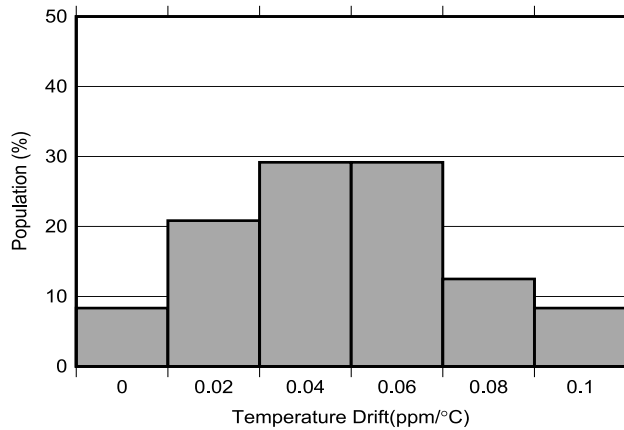


Figure 6-3. Temperature Drift Distribution

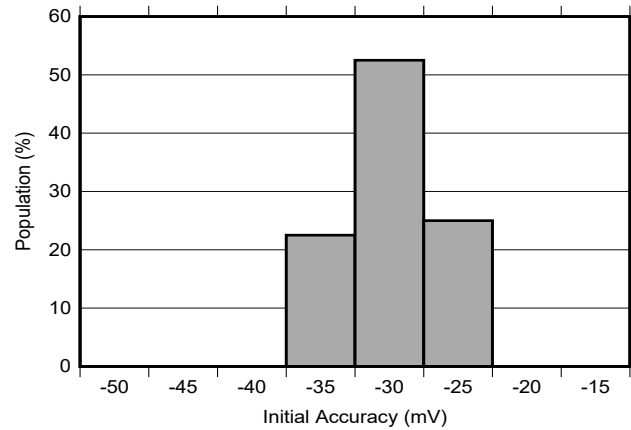


Figure 6-4. Accuracy Distribution

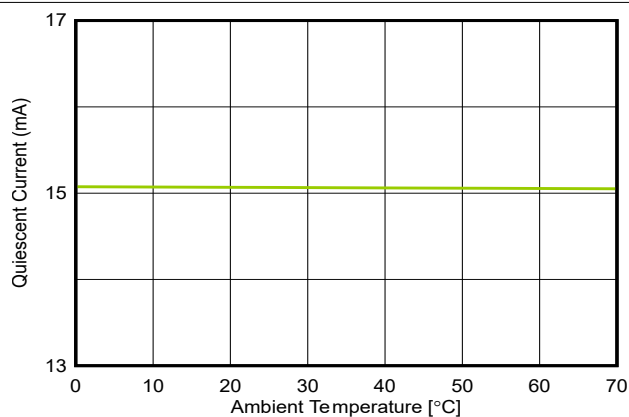


Figure 6-5. Supply Current ( $I_{VDD}$ ) vs Temperature

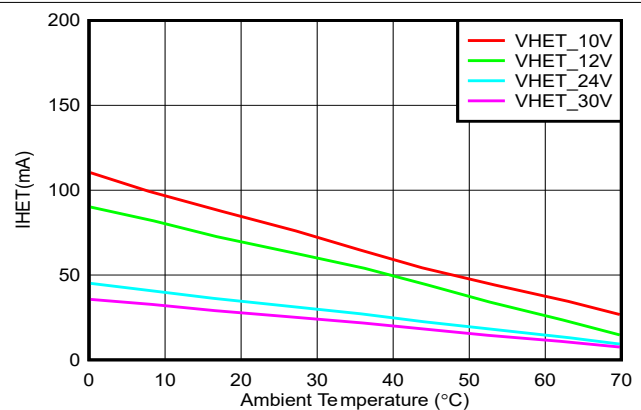
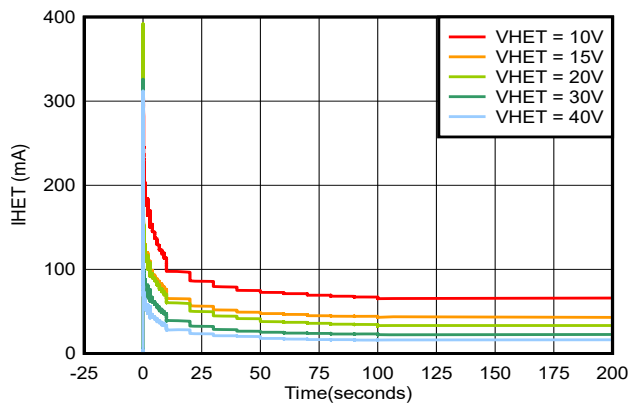


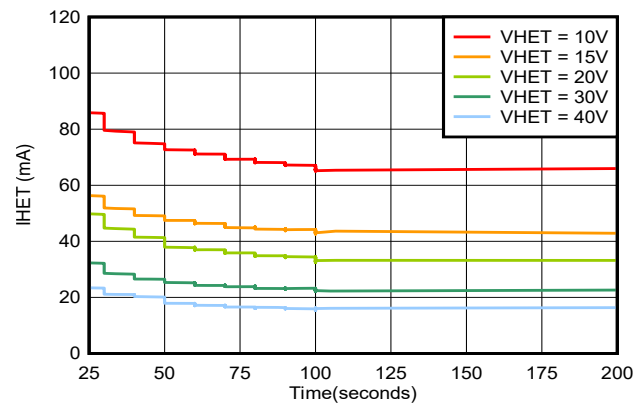
Figure 6-6. Steady State Heater Current  $I_{HET}$  vs Temperature

## 6.6 Typical Characteristics (continued)

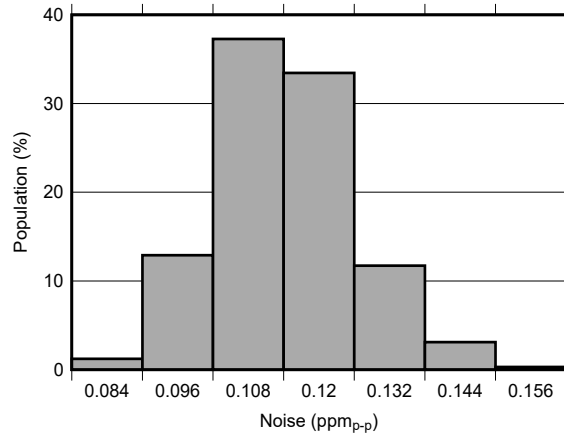
At  $T_A = 25^\circ\text{C}$ ,  $V_{IN} = 10\text{V}$ ,  $V_{HET} = 30\text{V}$ ,  $C_{REF\_Z} = 10\mu\text{F}$ ,  $C_{VDD} = 1\mu\text{F}$ , (unless otherwise noted)



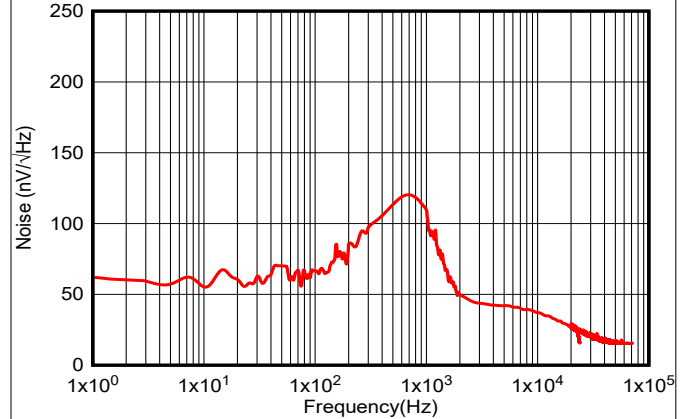
**Figure 6-7. Startup Heater Current  
IHET vs Time**



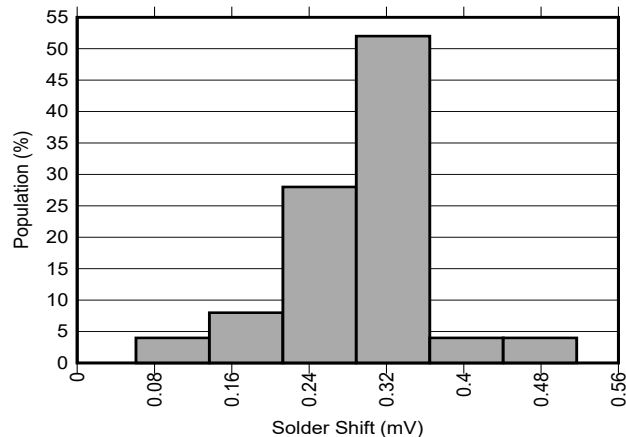
**Figure 6-8. Startup Heater Current (Zoomed View)  
IHET vs Time**



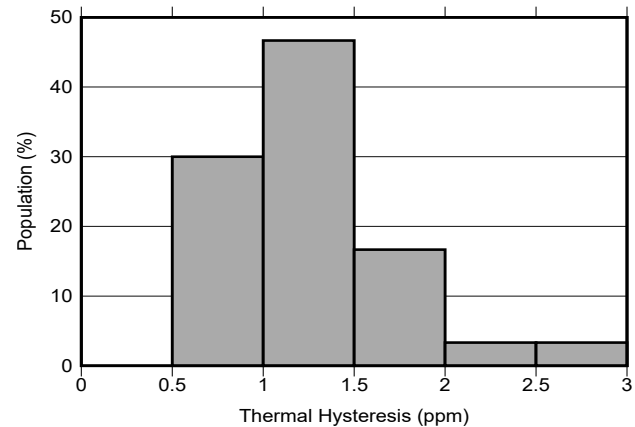
**Figure 6-9. 0.1Hz to 10Hz Voltage Noise Distribution**



**Figure 6-10. Noise Density vs Frequency**



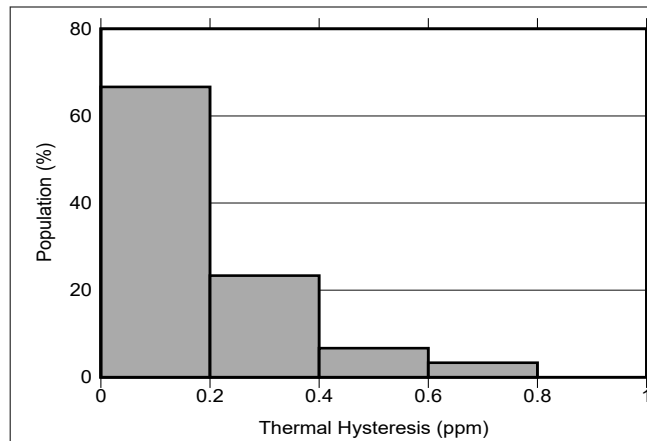
**Figure 6-11. Solder Shift Distribution**



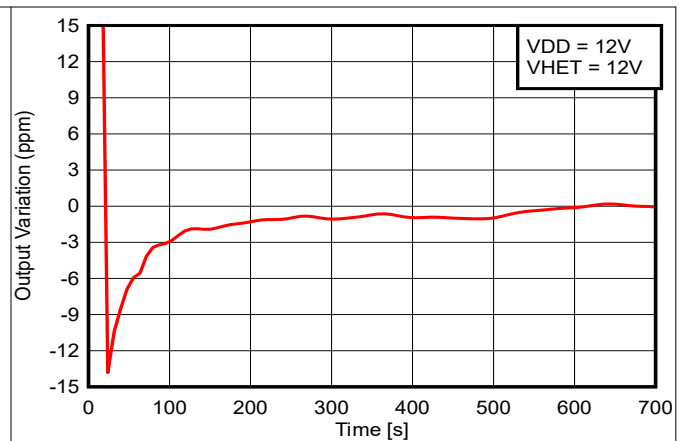
**Figure 6-12. Thermal Hysteresis (Cycle 1) Distribution  
 $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$**

## 6.6 Typical Characteristics (continued)

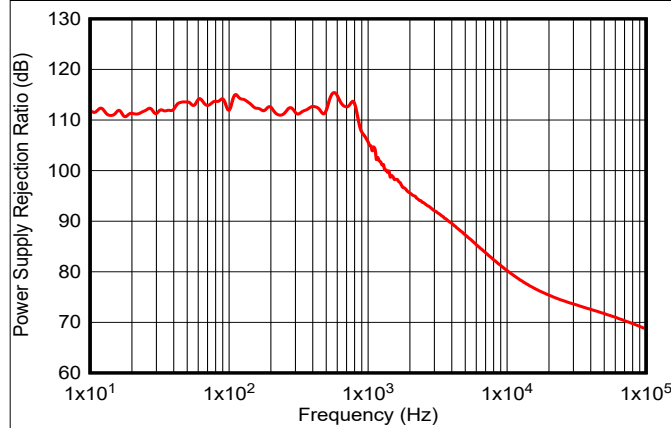
At  $T_A = 25^\circ\text{C}$ ,  $V_{IN} = 10\text{V}$ ,  $V_{HET} = 30\text{V}$ ,  $C_{REF\_Z} = 10\mu\text{F}$ ,  $C_{VDD} = 1\mu\text{F}$ , (unless otherwise noted)



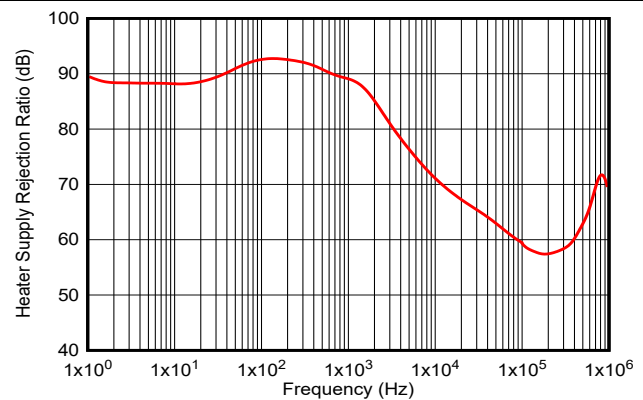
**Figure 6-13. Thermal Hysteresis (Cycle 2) Distribution**  
 $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$



**Figure 6-14. Startup Behavior**



**Figure 6-15. Power-Supply Rejection Ratio vs Frequency**



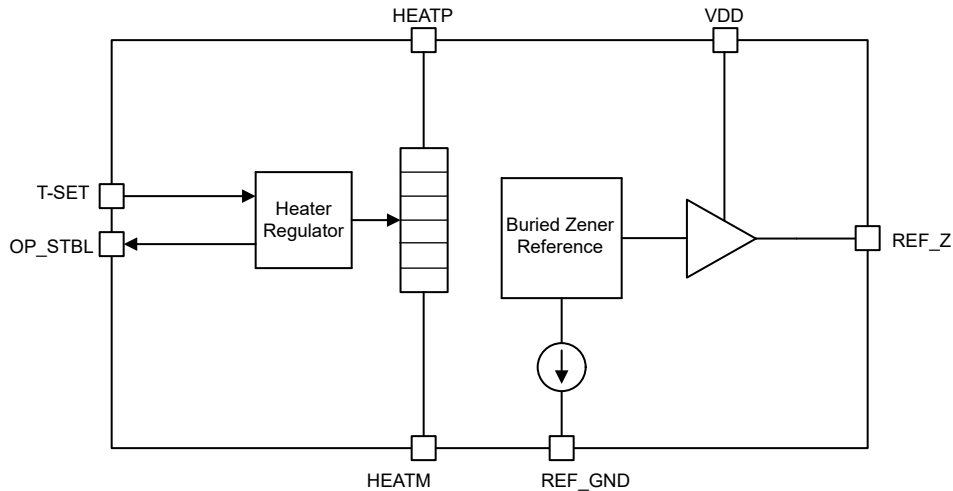
**Figure 6-16. Heater Supply Rejection Ratio vs Frequency**

## 7 Detailed Description

### 7.1 Overview

The REF80 is temperature controlled, buried zener voltage reference specifically designed for excellent voltage stability over time and temperature. The [Figure 7-1](#) is the simplified block diagram of the REF80 showing the generation of voltage reference with buried zener and on chip heater control.

### 7.2 Functional Block Diagram



**Figure 7-1. Functional Block Diagram for REF80**

### 7.3 Feature Description

#### 7.3.1 Heater

REF80 has on chip heater which is factory programmed to  $T_{SET}$  temperature as per [Table 7-1](#) to regulate the temperature of the die within  $\pm 1^\circ\text{C}$ , for the entire operating ambient temperature range. This allows REF80 to achieve ultra low temperature drift of 0.05ppm/ $^\circ\text{C}$ . Heater has dedicated supply pins HEATP and HEATM which run independent of VDD supply pin. The steady state power dissipation of the heater is directly proportional to the difference between ambient temperature  $T_A$  and  $T_{SET}$  as per [Equation 1](#). Heater current depends on (HEATP - HEATM) voltage. Heater takes high transient current at the time of start-up to heat up the device from ambient. REF80 has heater indicator pin OP\_STBL, which de-asserts when the heater reaches within  $\pm 0.1\%$  of  $T_{SET}$ .

**Table 7-1.  $T_{SET}$  of Heater**

| Operating Temperature Range ( $T_A$ )   | $T_{SET}$           |
|-----------------------------------------|---------------------|
| $0^\circ\text{C}$ to $70^\circ\text{C}$ | $115^\circ\text{C}$ |

$$P_{HEATER}(W) = \left( \frac{T_{SET} - T_A}{R_{\theta JA}} \right) - V_{DD} \times I_{VDD} \quad (1)$$

$V_{DD}$  is supply voltage for the chip and  $I_{VDD}$  is the supply current.

$R_{\theta JA}$  depends on board thickness and layout. The data sheet value of  $R_{\theta JA}$  is based on JEDEC standard board.

REF80 offers flexibility to decrease the heater temperature by putting a resistor with less than 2% tolerance on the T-SET pin as per [Table 7-2](#) to save power and reduce the thermal noise for restricted ambient temperature applications.  $T_{SET}$  must be programmed to  $45^\circ\text{C}$  above the max ambient temperature to make sure that the heater is regulating the temperature properly. REF80 samples the value of the resistor at the time of startup and the value of  $T_{SET}$  is modified accordingly. Small drift in resistor value does not impact the  $T_{SET}$  temperature as T-SET pin samples discrete value.

**Table 7-2. T-SET Pin Resistor VS Change in  $T_{SET}$** 

| Resistor on T-SET pin | Heater Temperature             |
|-----------------------|--------------------------------|
| 0                     | $T_{SET}$                      |
| 130k $\Omega$         | $T_{SET} - 10^{\circ}\text{C}$ |
| 360k $\Omega$         | $T_{SET} - 20^{\circ}\text{C}$ |
| 800k $\Omega$         | $T_{SET} - 30^{\circ}\text{C}$ |
| OPEN                  | $T_{SET}$                      |

For the applications that require the device to be turned off, make sure to power off for at least 15 seconds before turning the device back on.

### 7.3.2 Buried Zener Reference

The 7.6V reference output is generated with an ultra low noise buried zener diode which is biased at 15mA current. This buried zener exhibits extremely stable long term stability characteristics, which helps REF80 to achieve an accuracy of calibration grade instruments.

## 8 Parameter Measurement Information

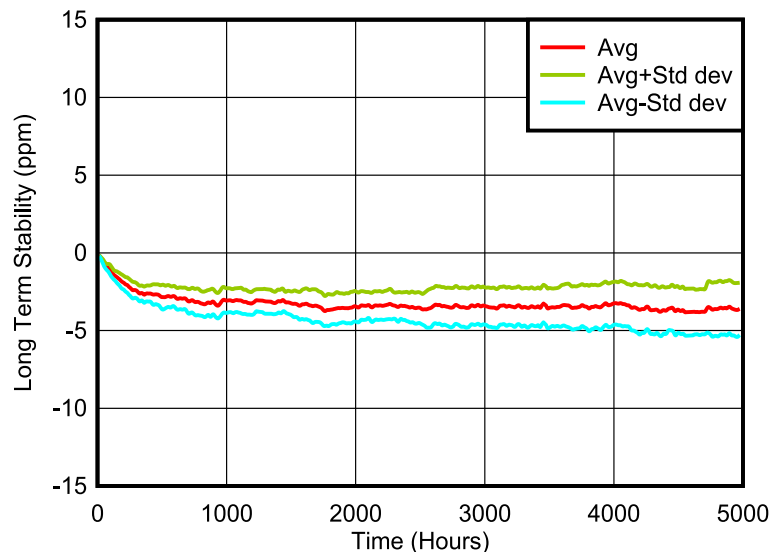
### 8.1 Long-Term Stability

Buried zener references typically exhibit very stable long term stability and are used as an ultra stable reference for internal calibration of the system. The long-term stability value is tested in a typical setup that reflects standard PCB board manufacturing practices for references with a strain modulation structure around the device. The boards are made of standard FR4 material with 35µm of Copper. The devices have been soldered through standard reflow.

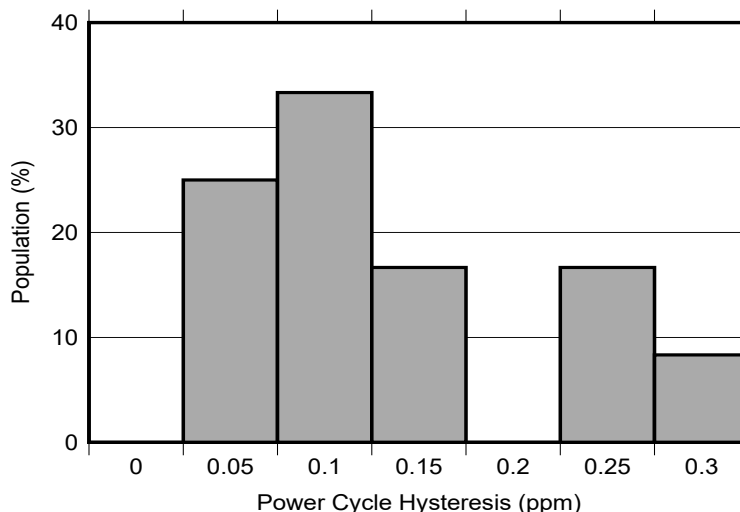
Long term stability setup is designed with utmost care to minimize impact of thermocouple error, strain impact and mechanical vibration in long term stability measurement. The boards are maintained at 25°C in an air drift oven with heater temperature set to 115°C in powered on condition for long term stability measurement.

Typical long-term stability characteristic is expressed as a deviation over time. [Figure 8-1](#) shows the typical drift value for the  $V_{REF\_Z}$  is 3ppm from 0 to 1000 hours. Drift of REF80 gets flat after 1000 hours. Powered-up burn-in at room temperature helps REF80 to achieve best long term stability performance.

Power cycle has minimal impact on the stability of the  $V_{REF\_Z}$  and doesn't change the settled profile. [Figure 8-2](#) shows the behavior of the output when the devices are powered off for 24 hours.



**Figure 8-1. Long Term Stability ( $V_{REF\_Z}$ )**



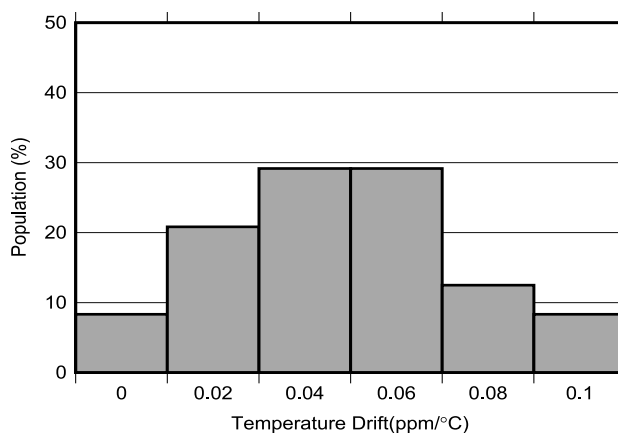
**Figure 8-2. Power Cycle Hysteresis**

## 8.2 Temperature Drift

The REF80 has integrated on chip heater, which is factory programmed to  $T_{SET} = 115^{\circ}\text{C}$  temperature. Heater regulates the  $T_{SET}$  temperature to  $\pm 1^{\circ}\text{C}$  for entire operating temperature range. This results in  $0.05\text{ppm}/^{\circ}\text{C}$  temperature drift coefficient for REF80. [Figure 6-2](#) shows temperature drift profile of 42 devices.

The temperature coefficient is calculated using the box method in which a box is formed by the min/max variation for the nominal output voltage over the operating temperature range. REF80 has a maximum temperature coefficient of  $0.2\text{ppm}/^{\circ}\text{C}$  for  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$  temperature range. The box method specifies limits for the temperature error but does not specify the exact shape and slope of the device under test. See [SLYT183](#) for more information on the box method. The box method equation is shown in [Equation 2](#):

$$\text{Drift}(\text{ppm}/^{\circ}\text{C}) = \left( \frac{V_{\text{REF}(\text{MAX})} - V_{\text{REF}(\text{MIN})}}{V_{\text{REF}(25^{\circ}\text{C})} \times \text{Temperature Range}} \right) \times 10^6 \quad (2)$$



**Figure 8-3. Temperature Drift Distribution**

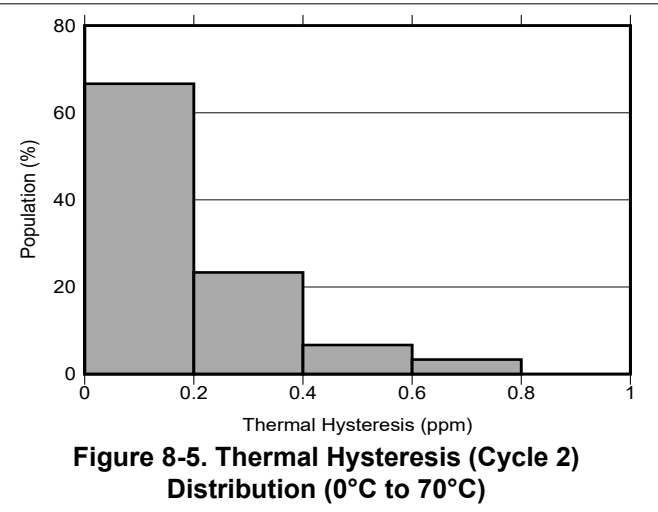
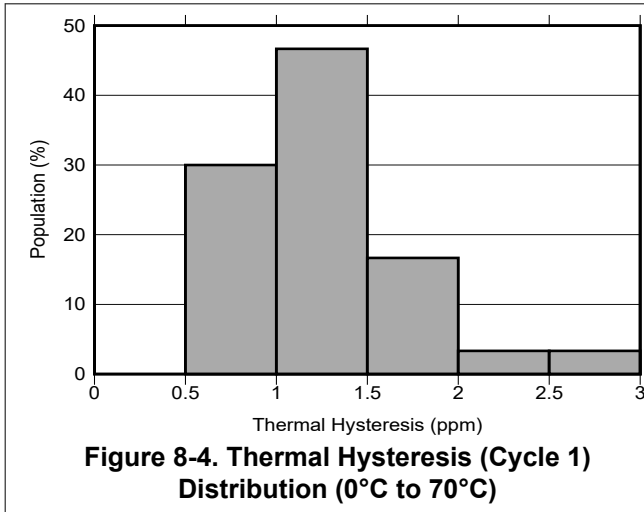
## 8.3 Thermal Hysteresis

Thermal hysteresis is measured with the REF80 soldered to a PCB, similar to a real-world application. Thermal hysteresis for the device is defined as the change in output voltage after operating the device at  $25^{\circ}\text{C}$ , cycling the device through the  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$  temperature range, and returning to  $25^{\circ}\text{C}$ . Thermal hysteresis for REF80 reduces significantly from second cycle onwards as shown in [Figure 8-4](#) and [Figure 8-5](#). Hysteresis can be expressed by [Equation 3](#)

$$V_{\text{HYST}}(\text{ppm}) = \left( \frac{|V_{\text{PRE}} - V_{\text{POST}}|}{V_{\text{PRE}}} \right) \times 10^6 \quad (3)$$

where-

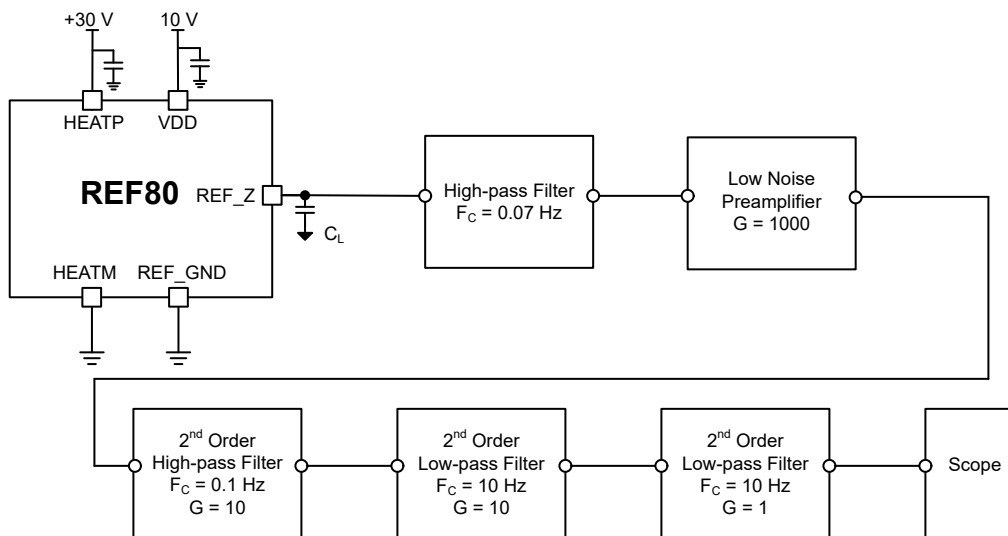
- $V_{\text{HYST}}$  = thermal hysteresis (in units of ppm)
- $V_{\text{PRE}}$  = output voltage measured at 25°C pre-temperature cycling
- $V_{\text{POST}}$  = output voltage measured after the device has cycled from 25°C through the specified temperature range of 0°C to 75°C and returns to 25°C.



## 8.4 Noise Performance

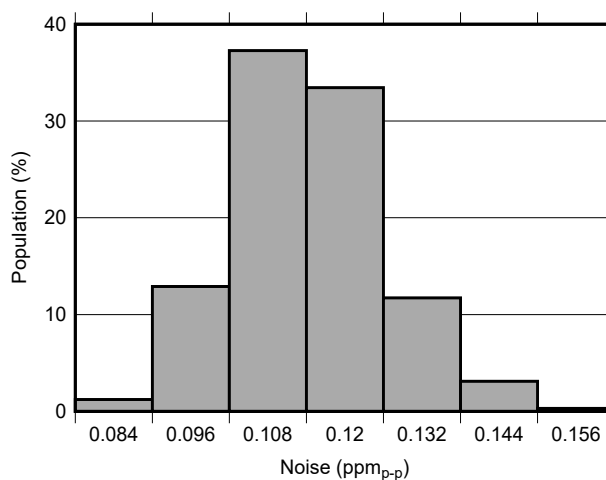
### 8.4.1 1/f Noise

1/f noise, also known as flicker noise, is dominant mostly in the lower frequency bands. Flicker noise affects the device output voltage which can affect the ENOB of the signal chain. REF80 data sheet specifies flicker noise for 0.1Hz to 10Hz frequency band where 1/f noise has maximum power. Flicker noise is measured by filtering the output from 0.1Hz to 10Hz. Since the 1/f noise is an extremely low value, the frequency of interest needs to be amplified and band-pass filtered as shown in [Figure 8-6](#). 1/f noise must be tested in a Faraday cage enclosure to block environmental noise. Refer to application note [Techniques for Noise Measurements in Precision Series References](#) for more detail on noise measurement for precision series references.



**Figure 8-6. 1/f Noise Test Setup**

Typical 1/f noise (0.1Hz to 10Hz) distribution can be seen in [Figure 8-7](#).



**Figure 8-7. 0.1Hz to 10Hz Voltage Noise Distribution**

The 1/f noise is in such a low frequency range that it is not practical to filter out which makes it a key parameter for ultra-low noise measurements. Noise sensitive designs must use the lowest 1/f noise for the highest precision measurements. [Figure 8-8](#) shows the effect of 1/f noise over 10s.

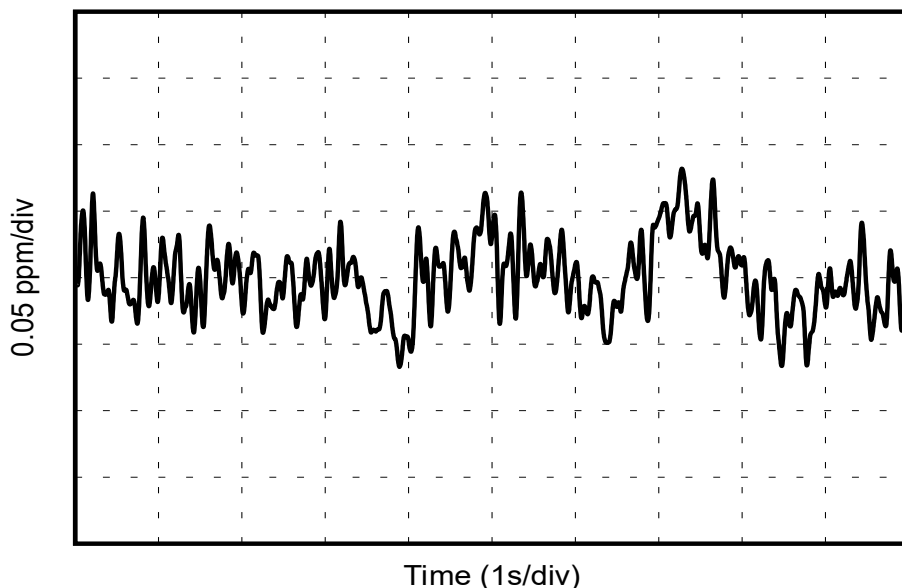


Figure 8-8. 0.1Hz to 10Hz REF\_Z Noise

#### 8.4.2 Broadband Noise

Broadband noise is a noise that appears at higher frequency compared to  $1/f$  noise. The broadband noise is dominated by white noise as shown in Figure 6-10. The broadband noise is measured by high-pass filtering the output of the REF80 and measuring the result on a spectrum analyzer as shown in Figure 8-9. The DC component of the REF80 is removed by using a high-pass filter and then amplified. When measuring broadband noise, you do not need high gain to achieve maximum bandwidth.

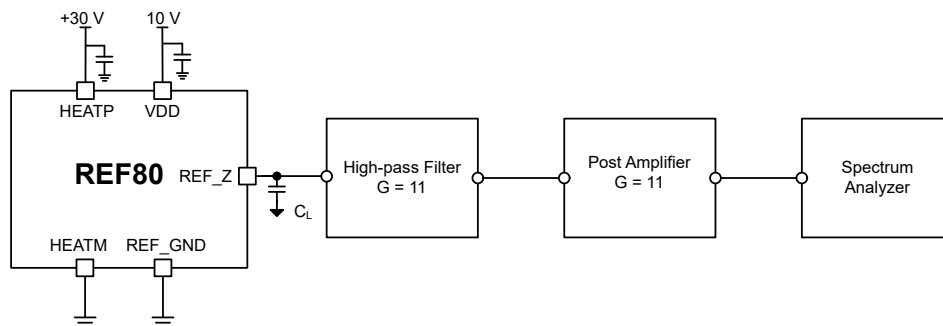


Figure 8-9. Broadband Noise Test Setup

For noise sensitive designs, a low-pass filter can be used to reduce broadband noise output noise levels by removing the high frequency components. When designing a low-pass filter special care must be taken to make sure the output impedance of the filter does not degrade ac performance. This can occur in RC low-pass filters where a large series resistance can impact the load transients due to output current fluctuations.

## 9 Application 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, as well as validating and testing their design implementation to confirm system functionality.

### 9.1 Application Information

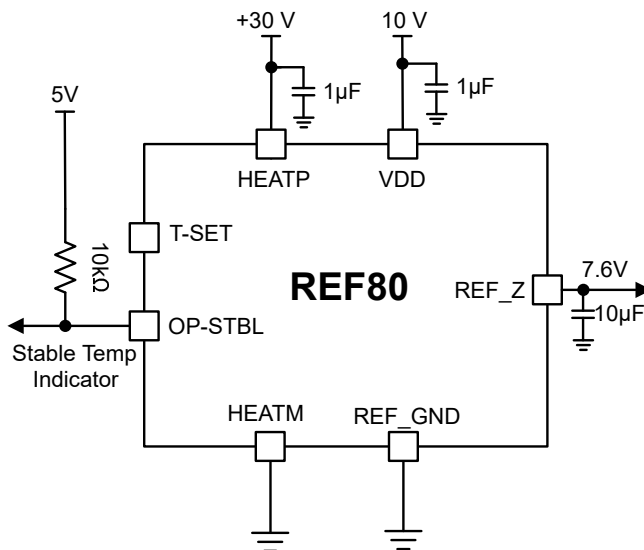
Basic applications convert the REFZ output to calibration signal or connect to  $\leq 5V$  signal for precision data converter. The table below shows the typical applications of REF80 and the companion data converter.

| APPLICATION        | DATA CONVERTER            |
|--------------------|---------------------------|
| Test & Measurement | <a href="#">DAC11001B</a> |

### 9.2 Typical Applications

#### 9.2.1 Typical Application: Basic Voltage Reference Connection

The circuit shown in [Figure 9-1](#) shows the basic configuration for the REF80 references. Connect bypass capacitors according to the guidelines in [Section 9.4.1](#).



**Figure 9-1. Basic Reference Connection**

### 9.2.1.1 Design Requirements

A detailed design procedure is based on a design example. For this design example, use the parameters listed in [Table 9-1](#) as the input parameters.

**Table 9-1. Design Example Parameters**

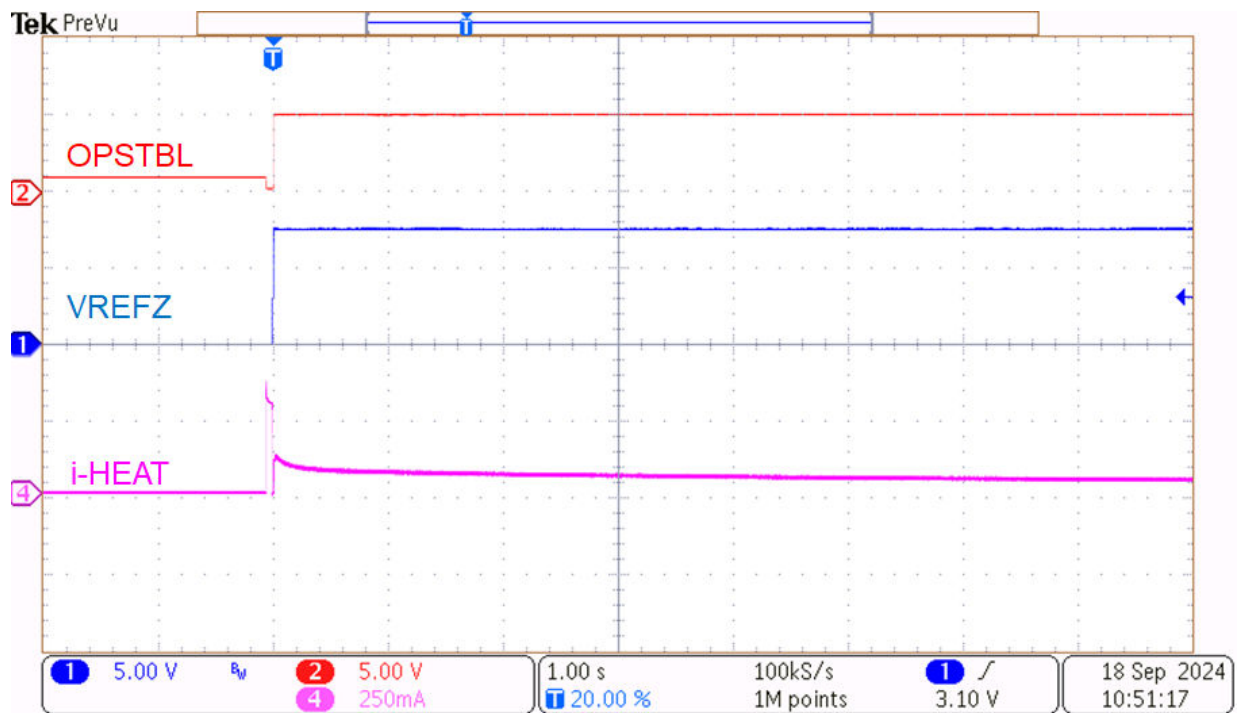
| DESIGN PARAMETER                         | VALUE        |
|------------------------------------------|--------------|
| Input voltage $V_{DD}$                   | 10V          |
| Heater Voltage $V_{HET}$ (HEATP - HEATM) | 30V          |
| Supply decoupling capacitor              | 1 $\mu$ F    |
| Heater supply decoupling capacitor       | 1 $\mu$ F    |
| OP-STBL pull-up resistor                 | 10k $\Omega$ |
| OP-STBL pull-up supply                   | 5V           |

### 9.2.1.2 Detailed Design Procedure

A bulk capacitor (0.1 $\mu$ F to 10 $\mu$ F) must be connected to the VDD, HEATP and HEATM (when not connected to GND) pins to improve transient response in the applications where the supply voltage can fluctuate. Connect an additional 0.1 $\mu$ F capacitor at VDD, HEATP and HEATM pins closer to the device to bypass high frequency supply noise.

A low ESR (maximum 400m $\Omega$ ) capacitor of 1 $\mu$ F to 100 $\mu$ F must be connected to the REF\_Z pin to provide stable output. For very low noise applications, special care must be taken with X7R and other MLCC capacitors due to the piezoelectric effect. More information on how the piezoelectric effect can be explored in systems can be found in [Stress-induced outbursts: Microphonics in ceramic capacitors \(Part 1\)](#) and [Stress-induced outbursts: Microphonics in ceramic capacitors \(Part 2\)](#). Designer must use C0G or film capacitors for noise sensitive applications. OP-STBL indicates that the on chip heater is regulating the temperature. Connect a pullup resistor of 10k $\Omega$  with suitable logic voltage on this pin. The transient start-up response of the REF80 is shown in [REF80 Startup Behavior](#).

### 9.2.1.3 Application Curve



**Figure 9-2. REF80 Startup Behavior**

## 9.2.2 Typical Application Circuits

### 9.2.2.1 Precision Voltage Divider Connection

Precision data converters typically require voltage reference which is less than or equal to 5V. REF80 requires a precision resistor divider followed by low noise buffer to generate reference voltage for data converters as shown in Figure 9-3.

The selection of resistor depends on the current capability (< 1mA is preferred) and noise requirement. Minimum value of resistors are decided by the output current as per Equation 4.

$$R1 + R2 \geq 7.6k\Omega \quad (4)$$

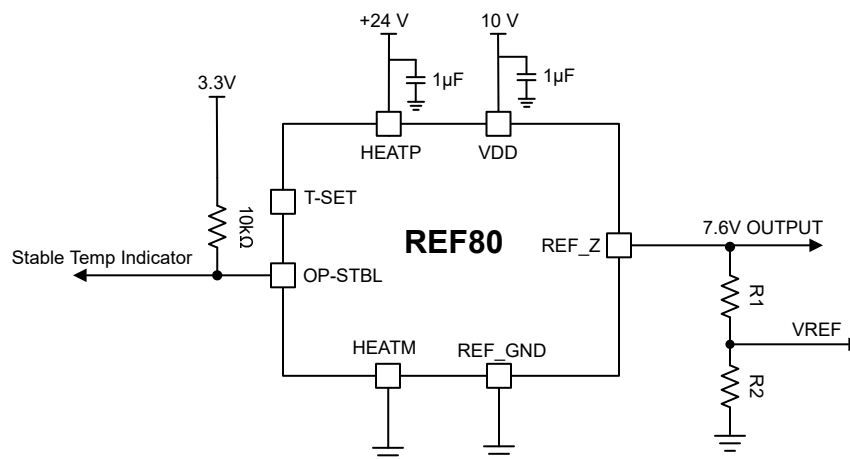
Maximum value of the resistors are decided by the noise consideration. Thermal noise of the resistors (parallel equivalent) is added as per Equation 5

$$V_{REF_{Noise}} = \sqrt{\left(\left(\frac{R2}{R1 + R2} \times REF\_Z_{Noise}\right)^2 + (R1 || R2)_{Thermal\ Noise}\right)^2} \quad (5)$$

Where

- $V_{REF_{Noise}}$  = Reference noise requirement in desired frequency band
- $REF\_Z_{Noise}$  = REF80 noise in desired frequency band
- $R1 || R2_{Thermal\ noise}$  = Thermal noise of parallel equivalent of R1 and R2 resistor

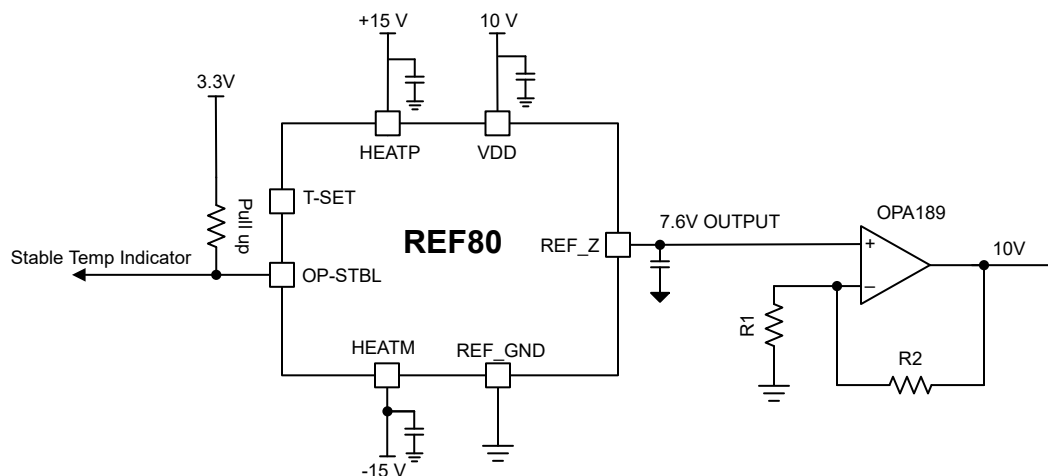
R1 and R2 must be precision foil resistors with matched temperature drift for best performance.



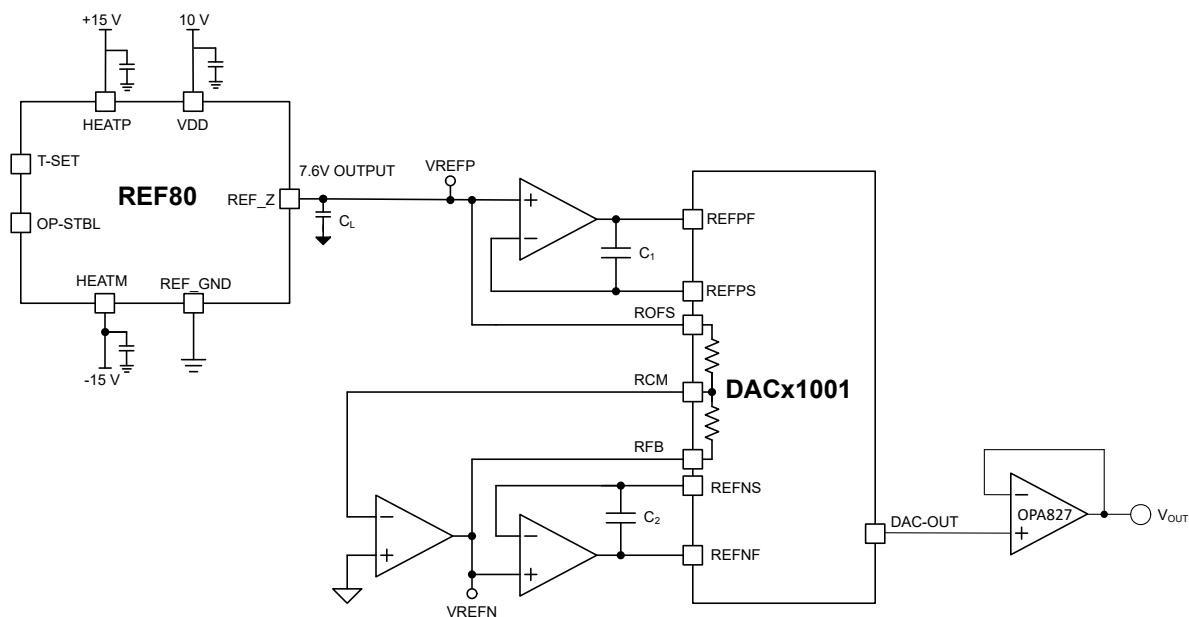
**Figure 9-3. Precision Resistor Divider Connection**

### 9.2.2.2 Calibration Signal

Ultra low long term stability and temperature drift makes REF80 an excellent choice for metrology grade calibration signal generation.



**Figure 9-4. 10V Precision Signal With Amplifier And Precision Resistors**



**Figure 9-5. Precision Signal With DACx1001**

### 9.3 Power Supply Recommendation

The buried zener reference requires a stable power supply of 10V to 16.5V for stable operation of the REF\_Z pin. Potential difference between HEATP and HEATM pin must be 10V to 42V. HEATP must always be connected to a positive supply or ground. HEAM must always be connected to a negative supply or ground. The heater supply must be able to provide high inrush current for fast start-up of the device. TI recommends a supply bypass capacitor ranging between 0.1 $\mu$ F to 10 $\mu$ F.

### 9.4 Layout

#### 9.4.1 Layout Guidelines

Section 9.4.2 illustrates an example of a PCB layout (two layer routing) for a data acquisition system using the REF80. Some key considerations are:

- **Noise performance**
  - Connect low-ESR, 0.1 $\mu$ F ceramic bypass capacitors at V<sub>DD</sub>, HEATM and HEATP of the REF80.
  - Connect 10 $\mu$ F to 100 $\mu$ F class 1 capacitor at REF\_Z of the REF80.
  - 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.
- **Thermal performance**
  - The layout must minimize the heat dissipation to maintain good thermal resistance for REF80.
  - Use minimum copper to route V<sub>DD</sub>, REF\_Z, REF\_GND signal.
  - Use copper as per current requirement for HEATP and HEATM pin.
  - Avoid direct copper pours underneath the package.
  - A shield around the device is recommended to achieve best heater regulation.
- **Seebeck effect**
  - Avoid multiple metal-metal junction to minimize Seebeck effect.
- **Long term stability performance**
  - Provide strain relief directly to pins as shown in the Layout Example.
  - Provide cuts near to the pin, perpendicular to the pins and corners.
  - Avoid single point strain accumulation.

#### 9.4.2 Layout Example

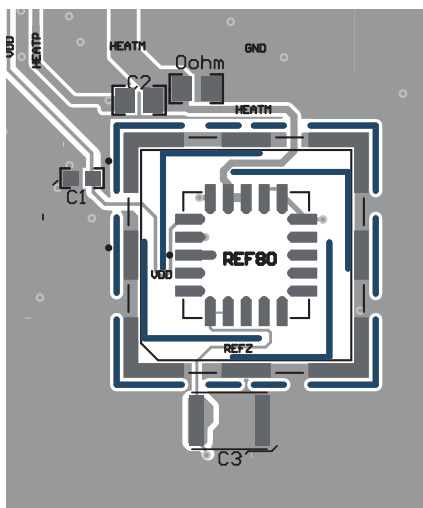


Figure 9-6. Top Layer Layout example for REF80

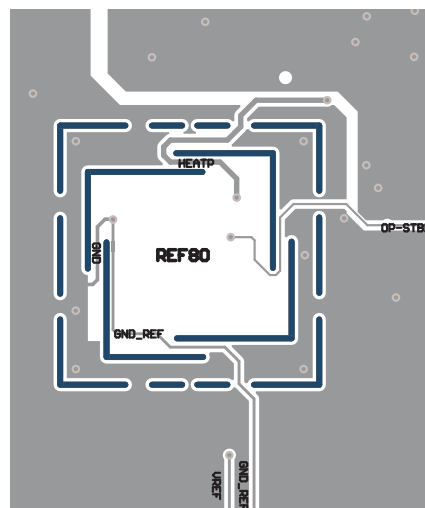


Figure 9-7. Bottom Layer Layout example for REF80

## 10 Device and Documentation Support

### 10.1 Documentation Support

#### 10.1.1 Related Documentation

For related documentation see the following:

- Texas Instruments, [Voltage Reference Design Tips For Data Converters](#)
- Texas Instruments, [Voltage Reference Selection Basics](#)

### 10.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](https://www.ti.com). Click on *Notifications* 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.

### 10.3 Support Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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### 10.4 Trademarks

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### 10.5 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.

### 10.6 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

## 11 Revision History

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

| Changes from Revision * (September 2024) to Revision A (March 2025) | Page |
|---------------------------------------------------------------------|------|
| • Production Data Release.....                                      | 1    |

## 12 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.

## PACKAGING INFORMATION

| Orderable part number          | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|--------------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">REF80000B1NAJT</a> | Active        | Production           | LCCC (NAJ)   20 | 250   SMALL T&R       | Yes         | Call TI                              | N/A for Pkg Type                  | -55 to 125   | REF80A1             |
| REF80000B1NAJT.A               | Active        | Production           | LCCC (NAJ)   20 | 250   SMALL T&R       | No          | Call TI                              | N/A for Pkg Type                  | -55 to 125   | REF80A1             |

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

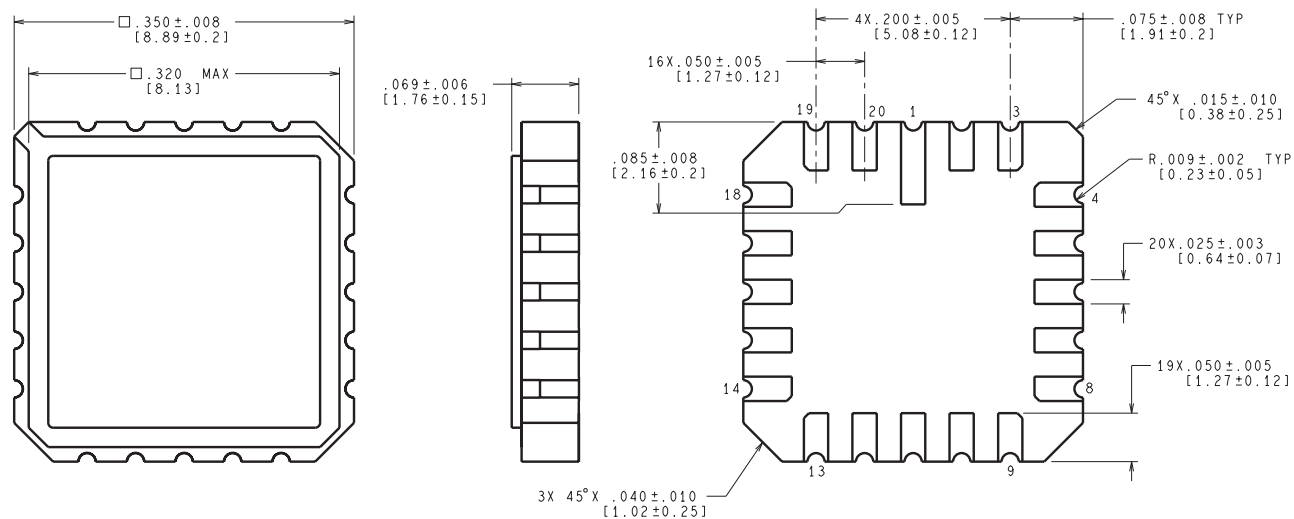
<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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