REF34xx Low-Drift, Low-Power, Small-Footprint Series Voltage Reference

1 Features

- Initial accuracy: ±0.05% (maximum)
- Temperature coefficient : 6 ppm/°C (maximum)
- Operating temperature range: −40°C to +125°C
- Output current: ±10 mA
- Low quiescent current: 95 µA (maximum)
- Ultra-low zero load dropout voltage: 100 mV (maximum)
- Wide input voltage: 12 V
- Output 1/f noise (0.1 Hz to 10 Hz): 3.8 μV_{p-p}/V
- Excellent long-term stability 25 ppm/1000 hrs
- Multiple small footprint 6 pin SOT-23 package pinouts: REF34xx and REF34xxT

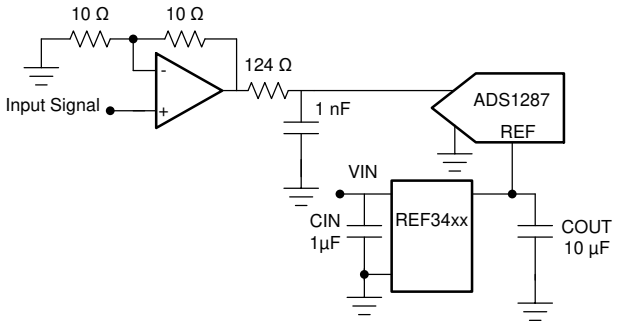
2 Applications

- Data acquisition systems
- Analog I/O modules
- Field transmitters
- Lab & field instrumentation
- Servo drive control modules
- DC power supply, AC source, electronic load

Voltage Reference Recommendation for Data Converters

VOLTAGE REFERENCE	ADC RESOLUTION (1)	DAC RESOLUTION (1)
TL431LI, TLV431	10-b	8-b
LM4040, LM4050, REF30	12-b	10-b
REF31, REF33, REF4132	14-b to 16-b	12-b
REF34, REF50	16-b to 18-b	14-b to 16-b
REF70	18-b+	16-b+

(1) For specific ADC/DAC recommendations, see SNAA320



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Simplified Schematic

3 Description

The REF34xx device is a low temperature drift (6 ppm/°C), low-power, high-precision CMOS voltage reference, featuring ±0.05% initial accuracy, low operating current with power consumption less than 95 µA. This device also offers very low output noise of 3.8 μV_{p-p} /V, which enables its ability to maintain high signal integrity with high-resolution data converters in noise critical systems. With a small SOT-23 package, REF34xx offers enhanced specifications and pin-to-pin replacement for MAX607x, ADR34xx and LT1790 (REF34xxT, no EN pin). The REF34xx family is compatible to most of the ADC and DAC such as ADS1287, DAC8802 and ADS1112.

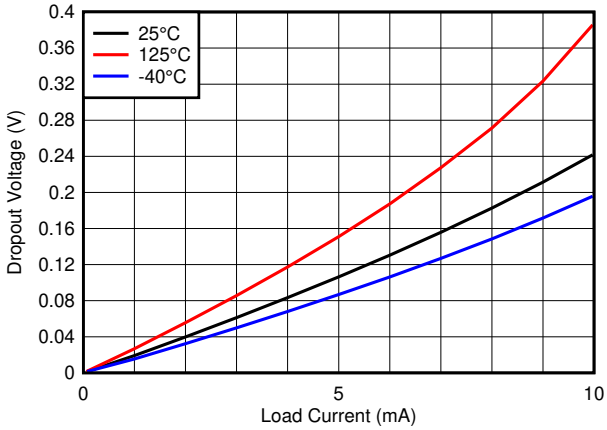
Stability and system reliability are further improved by the low output-voltage hysteresis of the device and low long-term output voltage drift. Furthermore, the small size and low operating current of the devices (95 µA) benefit portable and battery-powered applications.

REF34xx is specified for the wide temperature range of −40°C to +125°C.

Device Information

PART NAME	PACKAGE (1)	BODY SIZE (NOM)
REF34xx REF34xxT	SOT-23 (6)	2.90 mm × 1.60 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet



Dropout vs. Current Load Over Temperature

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 (April 2021) to Revision F (June 2021)	Page
• Added low dropout line item to Features section	1
• Consolidated part numbers in Device Information table	1
• Changed Thermal Information parameters to correctly reflect DBV package	6
• Added second cycle thermal hysteresis plot	14
• Linked product numbers in table to datasheets	19

Changes from Revision D (February 2021) to Revision E (April 2021)	Page
• Removed the "Product Preview" note for the REF34xxT package options	4

Changes from Revision C (January 2021) to Revision D (February 2021)	Page
• Updated description and figures	1
• Changed ENABLE TO EN	1
• Updated values	13

Changes from Revision B (March 2018) to Revision C (February 2021)	Page
• Added "Device Information" to include REF34xxT	1
• Added hyperlinks to "Applications"	1
• Changed "V_{REF}" to "V_{OUT}" throughout document	1
• Updated the numbering format for tables, figures, and cross-references throughout the document	1
• Added REF34xxT to "Device Comparison Table"	4
• Added REF34xxT to "Pin Configuration and Functions"	5
• Fixed pinout numbering	5

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- Added Configuration Information to "Electrical Characteristics” 6
- Changed ABS MAX IN MIN to "-0.3V" 6
- Added REF34xxT to "Layout Guidelines" and "Layout Example" 22

Changes from Revision A (December 2017) to Revision B (March 2018) **Page**

- Added 2 new GPNS: REF3440 and REF3450 1
- Changed "Excellent Long-Term Stability 30 ppm/1000 hrs" to "Excellent Long-Term Stability 25 ppm/1000 hrs" in *Section 1* 1
- Changed "...typical drift value for the REF34xx is 30 ppm from 0 to 1000 hours" to "...typical drift value for the REF34xx is 25 ppm from 0 to 1000 hours" and changed Figure 8-3 in *Section 8.2* 14
- Changed "(as shown in Figure 26)" to " as shown in Figure 9-1 in last paragraph of *Section 10.2.2.2* 20

Changes from Revision * (September 2017) to Revision A (December 2017) **Page**

- Added production release of 2 new output voltage option devices, REF3430 and REF3433 1

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5 Device Comparison Table

PRODUCT		V_{OUT}
REF3425	REF3425T	2.5 V
REF3430	REF3430T	3 V
REF3433	REF3433T	3.3 V
REF3440	REF3440T	4.096 V
REF3450	REF3450T	5 V

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6 Pin Configuration and Functions

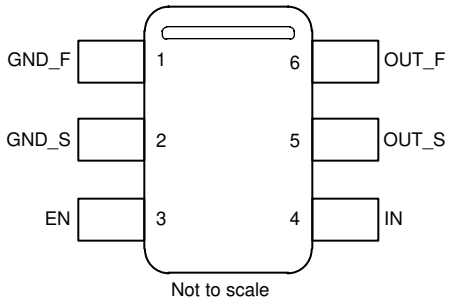


Figure 6-1. REF34xx
DBV Package
6-Pin SOT-23
Top View

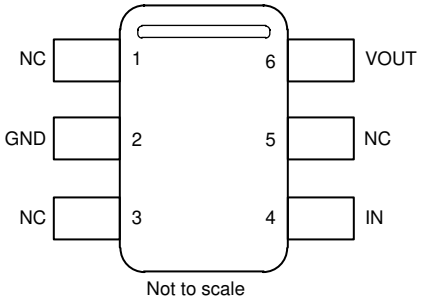


Figure 6-2. REF34xxT
DBV Package
6-Pin SOT-23
Top View

Table 6-1. Pin Functions

PIN			TYPE	DESCRIPTION
NAME	REF34xx (DBV)	REF34xxT (DBV)		
GND_F	1		Ground	Ground force connection.
GND_S	2		Ground	Ground sense connection.
GND		2	Ground	Device ground.
EN	3		Input	Enable connection. Enables or disables the device.
IN	4	4	Power	Input supply voltage connection.
OUT_S	5		Input	Reference voltage output sense connection.
OUT_F	6		Output	Reference voltage output force connection.
VOUT		6	Output	Reference voltage output connection.
NC		1,3,5	-	Not connected. Pin can be left floating or connected to voltage within device operating range.

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7 Specifications

7.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
Input voltage	IN	–0.3	13	V
	EN	–0.3	IN + 0.3	V
Output voltage	V_{OUT}	–0.3	5.5	V
Output short circuit current	I_{SC}		20	mA
Operating temperature range	T_A	–55	150	°C
Storage temperature range	T_{stg}	–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.

7.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±2500	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	±1500	

(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
IN	Input Voltage	V_{OUT} + V_{DO} (1)		12	V
EN	Enable Voltage	0		IN	V
I_L	Output Current	–10		10	mA
T_A	Operating Temperature	–40	25	125	°C

(1) V_{DO} = Dropout voltage

7.4 Thermal Information

THERMAL METRIC(1)		REF34T DBV 6 PINS	REF34 DBV 6 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	122.6	122.6	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	80.2	80.2	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	42	42	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	23.2	23.2	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	41.9	41.9	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	°C/W

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7.5 Electrical Characteristics

At V_{IN} = V_{OUT} + V_{DO}, C_{OUT} = 10 µF, C_{IN} = 0.1 µF, I_L = 0 mA, minimum and maximum specifications at T_A = –40°C to 125°C; Typical specifications at T_A = 25°C unless otherwise noted

PARAMETER		TEST CONDITION		MIN	TYP	MAX	UNIT
ACCURACY AND DRIFT							
	Output voltage accuracy	T_A = 25°C		–0.05		0.05	%
	Output voltage temperature coefficient (1)	–40°C ≤ T_A ≤ 125°C			2.5	6	ppm/°C
LINE & LOAD REGULATION							
$\Delta V_O/\Delta V_{IN}$	Line Regulation	V_{IN} = V_{OUT} + V_{DO} (2) to 12 V			2	15	ppm/V
$\Delta V_O/\Delta I_L$	Load Regulation	I_L = 0 mA to 10mA, V_{IN} = V_{OUT}+ V_{DO} (3)	Sourcing		20	30	ppm/mA
		I_L = 0 mA to –10mA, V_{IN} = V_{OUT}+ V_{DO}, T_A = 25°C (3)	Sinking, REF3425		40	70	
			Sinking, REF3430		43	75	
			Sinking, REF3433		48	84	
			Sinking, REF3440		60	98	
			Sinking, REF3450		70	140	
I_{SC}	Short circuit current	V_{OUT} = 0 V at T_A = 25°C			18	22	mA
NOISE							
e_{np-p}	Low frequency noise (4)	0.1Hz ≤ f ≤ 10Hz			5		$\mu V_{p-p}/V$
		0.1Hz ≤ f ≤ 10Hz (REF3440 and REF3450)			3.8		
e_n	Integrated wide band noise	10Hz ≤ f ≤ 10kHz			24		μV_{rms}
e_n	Output voltage noise density	f = 1kHz			0.25		ppm/$\sqrt{Hz}$
		f = 1kHz (REF3440 and REF3450)			0.2		
LONG TERM STABILITY AND HYSTERESIS							
	Long-term stability (5)	DBV Package	0 to 1000h at 35°C		25		ppm
			1000h to 2000h at 35°C		10		
	Output voltage thermal hysteresis (6)	DBV Package	25°C, –40°C,125°C, 25°C Cycle 1		30		ppm
			25°C, –40°C,125°C, 25°C Cycle 2		10		
TURN-ON TIME							
t_{ON}	Turn-on time	0.1% of output voltage settling, C_L = 10 µF			2.5		ms
CAPACITIVE LOAD							
C_L	Stable output capacitor range	–40°C ≤ T_A ≤ 125°C		0.1		10	µF
OUTPUT VOLTAGE							
V_{OUT}	Output voltage	REF3425, REF3425T			2.5		V
		REF3430, REF3430T			3.0		
		REF3433, REF3433T			3.3		
		REF3440, REF3440T			4.096		
		REF3450, REF3450T			5.0		
POWER SUPPLY							
V_{IN}	Input voltage			V_{OUT} + V_{DO}		12	V
I_L	Output current capacity	V_{IN} = V_{OUT} + V_{DO} to 12 V		–10		10	mA
I_Q	Quiescent current	Active mode			72	95	µA
		Shutdown mode			2.5	3	

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7.5 Electrical Characteristics (continued)

At V_{IN} = V_{OUT} + V_{DO}, C_{OUT} = 10 µF, C_{IN} = 0.1 µF, I_L = 0 mA, minimum and maximum specifications at T_A = –40°C to 125°C; Typical specifications at T_A = 25°C unless otherwise noted

PARAMETER		TEST CONDITION	MIN	TYP	MAX	UNIT
V_{EN}	ENABLE pin voltage	Voltage reference in active mode (EN = 1)	1.6			V
		Voltage reference in shutdown mode (EN = 0)			0.5	
V_{DO}	Dropout voltage	I_L = 0 mA		50	100	mV
		I_L = 10 mA			500	
I_{EN}	ENABLE pin leakage current	V_{EN} = V_{IN} = 12V		1	2	µA

(1) Temperature drift is specified according to the box method. See Low Temperature Drift section for more details.
(2) V_{DO} for line regulation test is 50 mV.
(3) V_{DO} for load regulation test is 500 mV.
(4) The peak-to-peak noise measurement is explained in more detail in section Noise Performance.
(5) Long-term stability measurement procedure is explained in more detail in section Long–Term Stability.
(6) Thermal hysteresis measurement procedure is explained in more detail in section Thermal Hysteresis.

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7.6 Typical Characteristics

at T_A = 25°C, V_{IN} = V_{EN} = 12 V, I_L = 0 mA, C_L = 10 µF, C_{IN} = 0.1 µF (unless otherwise noted)

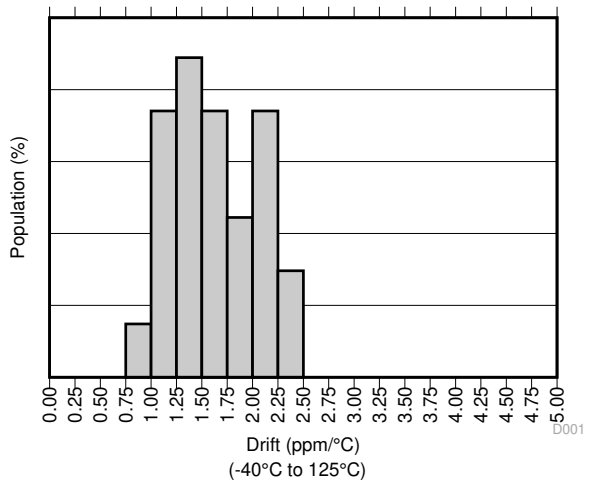


Figure 7-1. Temperature Drift

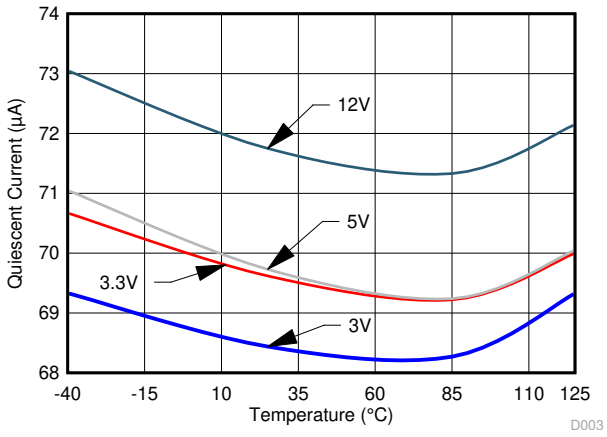


Figure 7-2. V_{IN} vs I_Q over Temperature

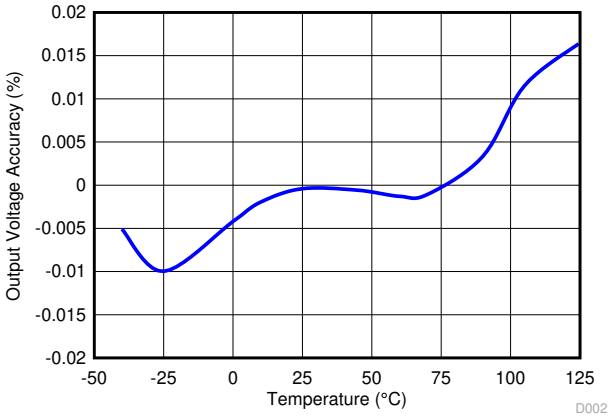


Figure 7-3. Output Voltage Accuracy vs Temperature

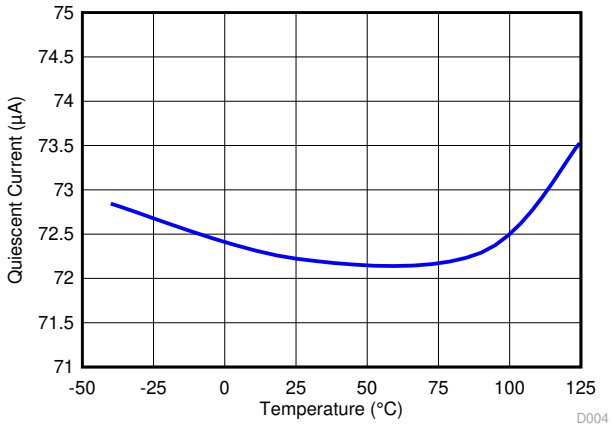


Figure 7-4. Quiescent Current vs Temperature

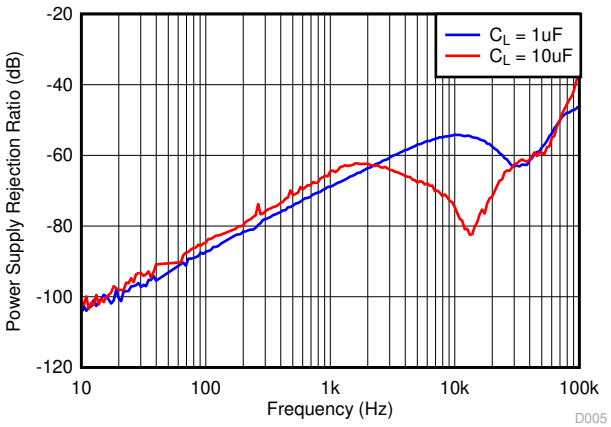


Figure 7-5. Power-Supply Rejection Ratio vs Frequency

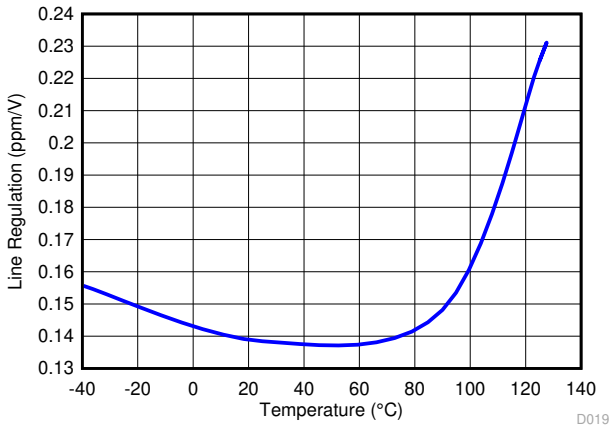


Figure 7-6. Line Regulation

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7.6 Typical Characteristics (continued)

at T_A = 25°C, V_{IN} = V_{EN} = 12 V, I_L = 0 mA, C_L = 10 µF, C_{IN} = 0.1 µF (unless otherwise noted)

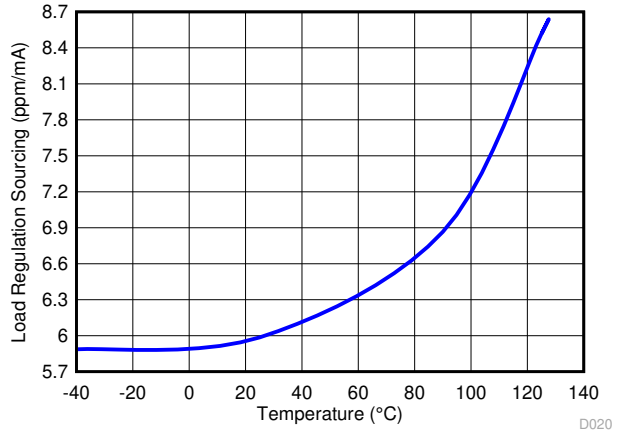


Figure 7-7. Load Regulation Sourcing

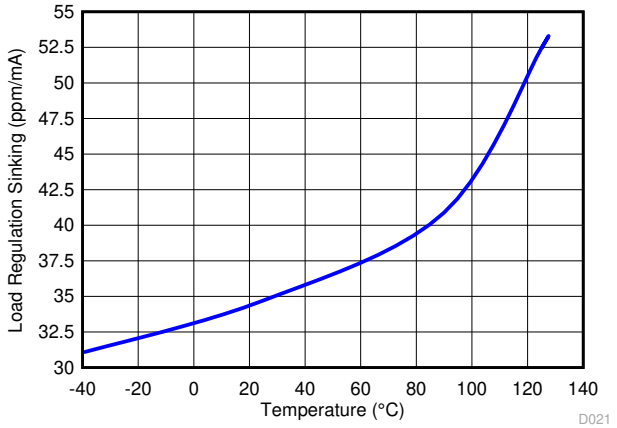


Figure 7-8. Load Regulation Sinking

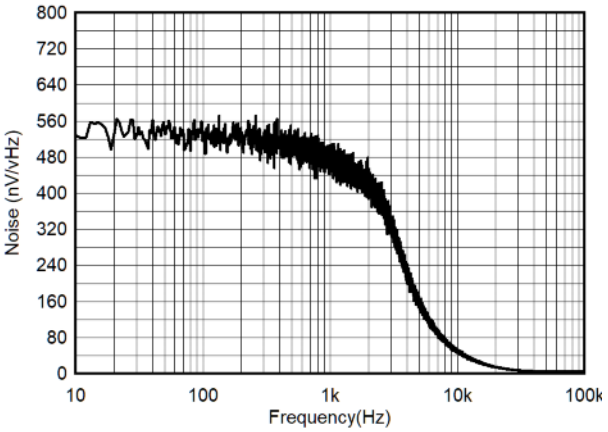


Figure 7-9. Noise Performance 10 Hz to 10 kHz

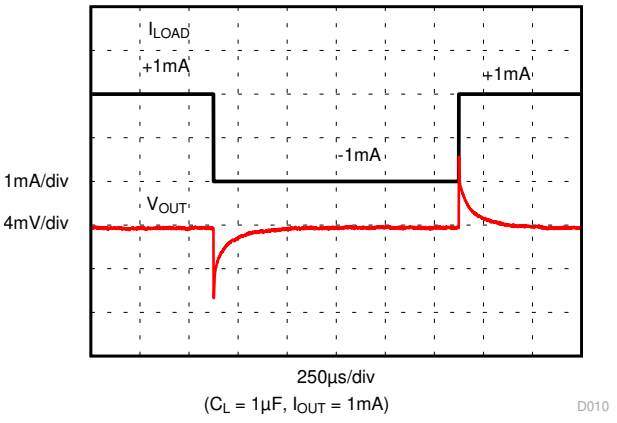


Figure 7-10. Load Transient

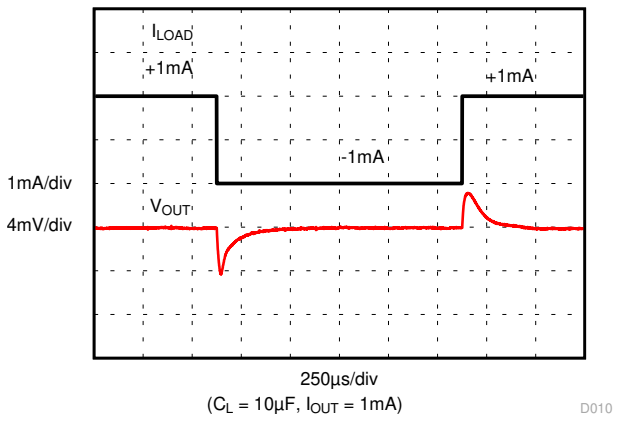


Figure 7-11. Load Transient

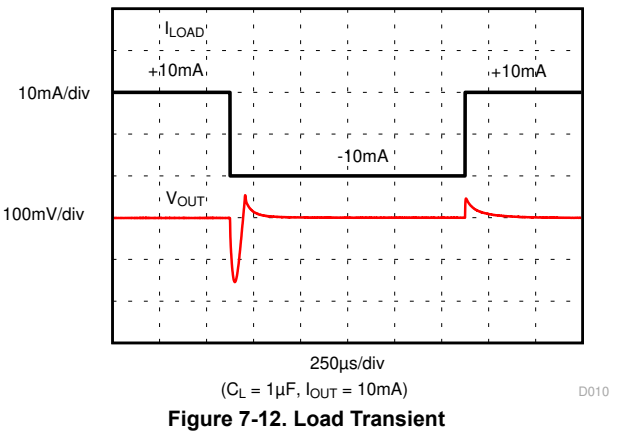


Figure 7-12. Load Transient

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7.6 Typical Characteristics (continued)

at T_A = 25°C, V_{IN} = V_{EN} = 12 V, I_L = 0 mA, C_L = 10 µF, C_{IN} = 0.1 µF (unless otherwise noted)

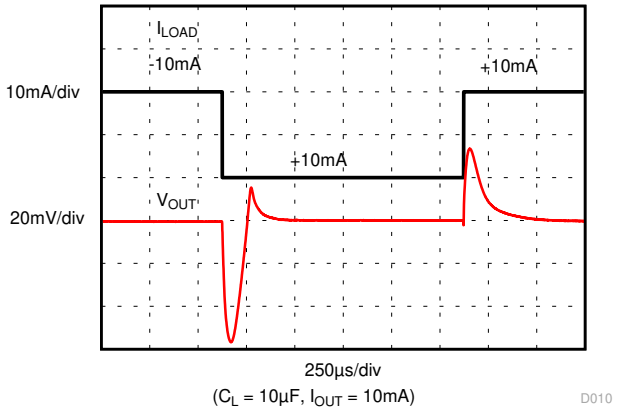


Figure 7-13. Load Transient

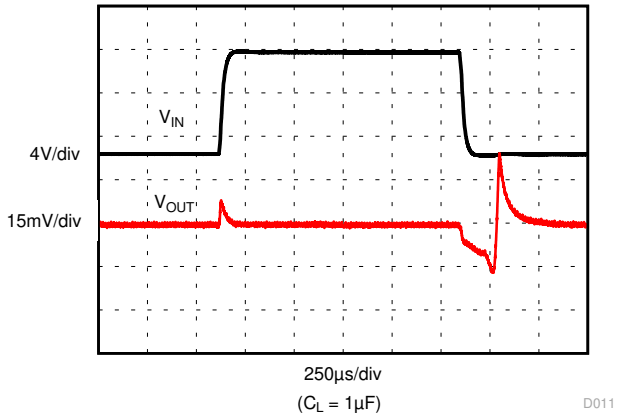


Figure 7-14. Line Transient

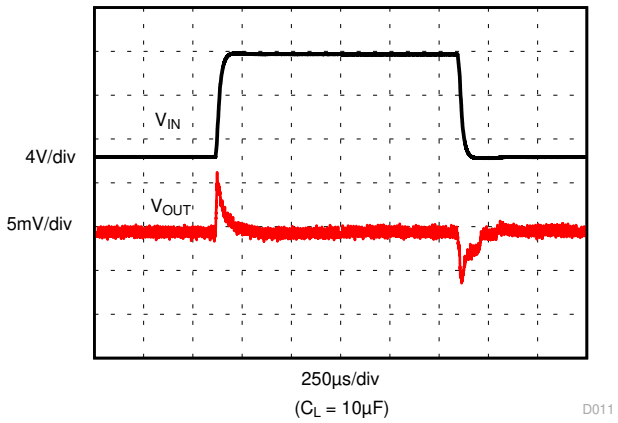


Figure 7-15. Line Transient

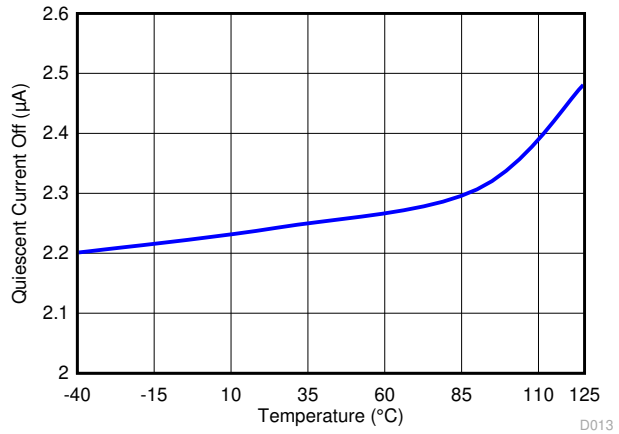


Figure 7-16. Quiescent Current Shutdown Mode

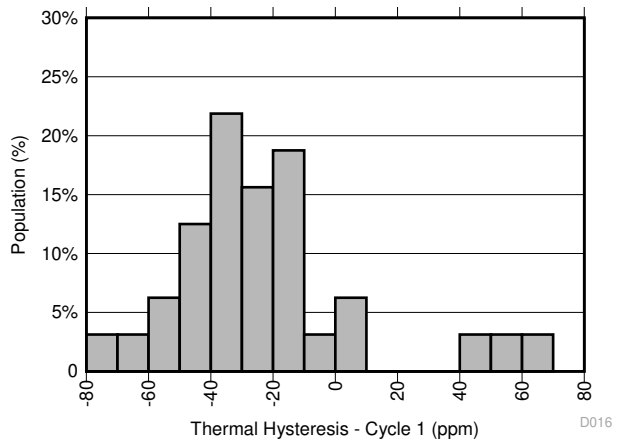


Figure 7-17. Thermal Hysteresis Distribution (Cycle 1)

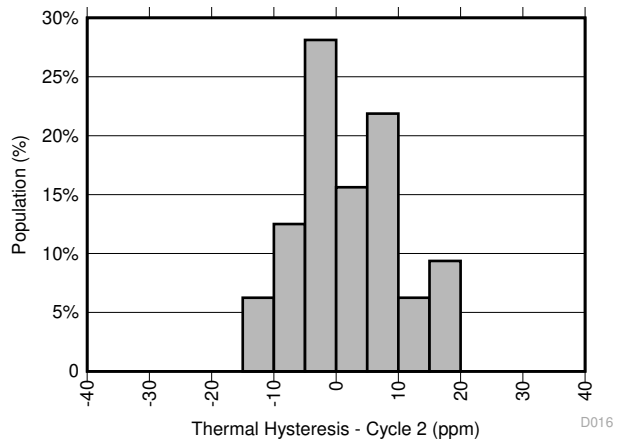
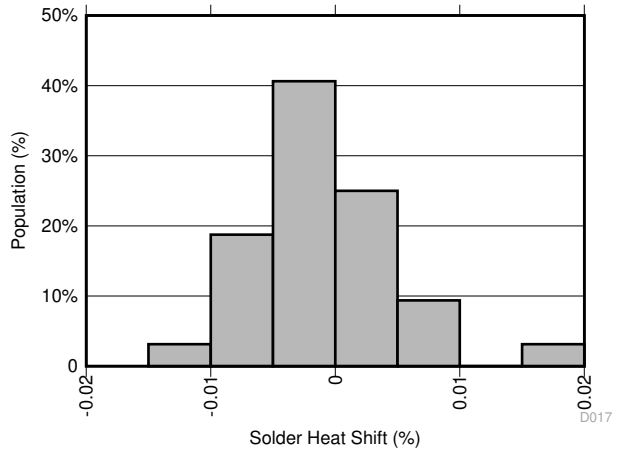


Figure 7-18. Thermal Hysteresis Distribution (Cycle 2)

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7.6 Typical Characteristics (continued)

at T_A = 25°C, V_{IN} = V_{EN} = 12 V, I_L = 0 mA, C_L = 10 µF, C_{IN} = 0.1 µF (unless otherwise noted)



Refer to *Section 8.1* for more information

Figure 7-19. Solder Heat Shift Distribution

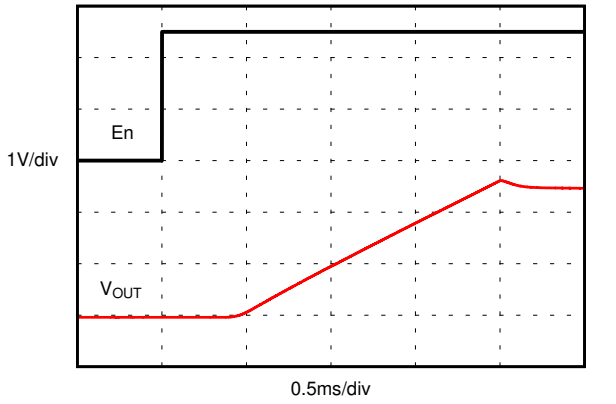


Figure 7-20. Turnon Time (Enable)

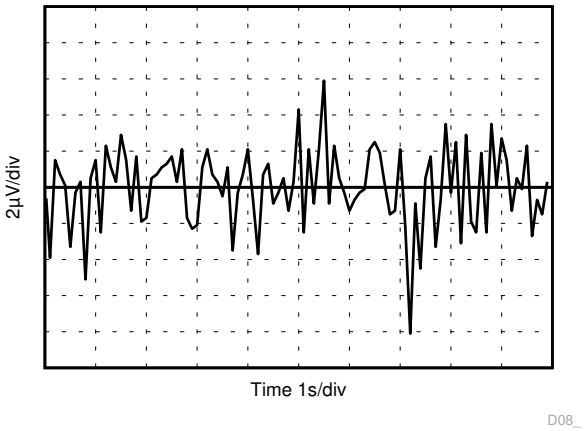


Figure 7-21. 0.1-Hz to 10-Hz Noise (V_{OUT})

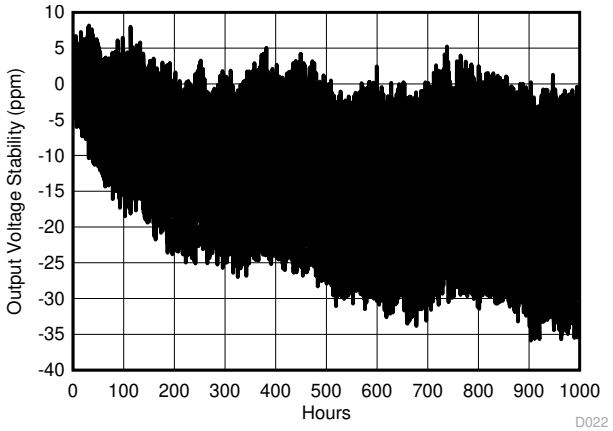


Figure 7-22. Long Term Stability - 1000 hours (V_{OUT})

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8 Parameter Measurement Information

8.1 Solder Heat Shift

The materials used in the manufacture of the REF34xx have differing coefficients of thermal expansion, resulting in stress on the device die when the part is heated. Mechanical and thermal stress on the device die can cause the output voltages to shift, degrading the initial accuracy specifications of the product. Reflow soldering is a common cause of this error.

In order to illustrate this effect, a total of 32 devices were soldered on 2 printed circuit boards [16 devices on each printed circuit board (PCB)] using lead-free solder paste and the paste manufacturer suggested reflow profile. The reflow profile is as shown in Figure 8-1. The printed circuit board is comprised of FR4 material. The board thickness is 1.65 mm and the area is 114 mm × 152 mm.

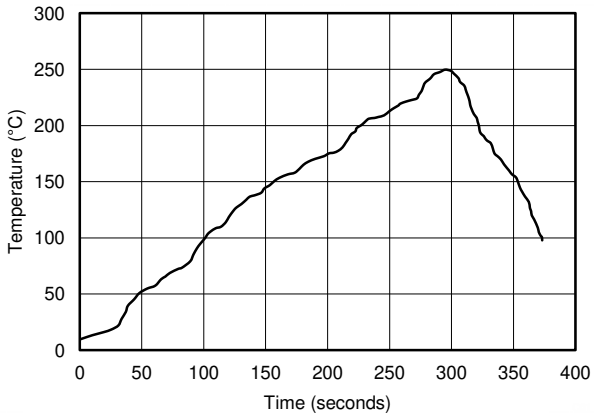


Figure 8-1. Reflow Profile

The reference output voltage is measured before and after the reflow process; the typical shift is displayed in Figure 8-2. Although all tested units exhibit very low shifts (< 0.01%), higher shifts are also possible depending on the size, thickness, and material of the printed circuit board. An important note is that the histograms display the typical shift for exposure to a single reflow profile. Exposure to multiple reflows, as is common on PCBs with surface-mount components on both sides, causes additional shifts in the output bias voltage. If the PCB is exposed to multiple reflows, the device must be soldered in the last pass to minimize its exposure to thermal stress.

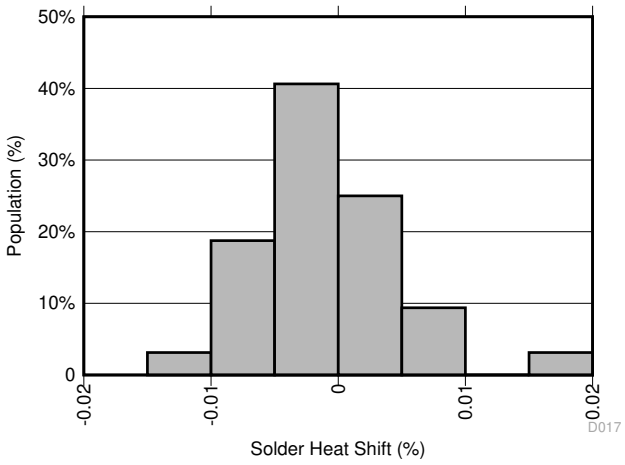


Figure 8-2. Solder Heat Shift Distribution, V_{OUT} (%)

8.2 Long-Term Stability

One of the key parameters of the REF34xx references is long-term stability. Typical characteristic expressed as: curves shows the typical drift value for the REF34xx is 25 ppm from 0 to 1000 hours. This parameter is characterized by measuring 32 units at regular intervals for a period of 1000 hours. It is important to understand that long-term stability is not ensured by design and that the output from the device may shift beyond the typical 25 ppm specification at any time. For systems that require highly stable output voltages over long periods of time, the designer should consider burning in the devices prior to use to minimize the amount of output drift exhibited by the reference over time.

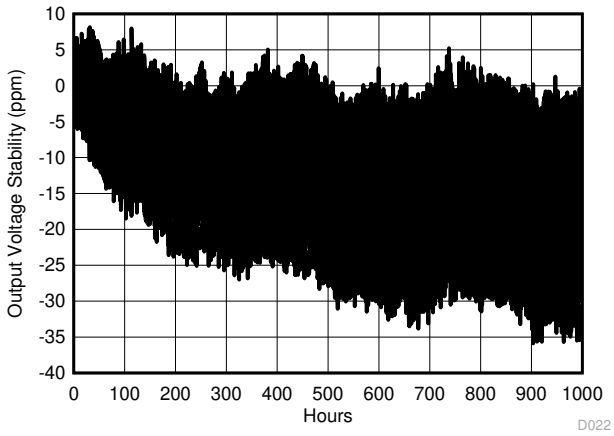


Figure 8-3. Long Term Stability - 1000 hours (V_{OUT})

8.3 Thermal Hysteresis

Thermal hysteresis is measured with the REF34xx 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°C, cycling the device through the specified temperature range, and returning to 25°C. The PCB was baked at 150°C for 30 minutes before thermal hysteresis was measured. Hysteresis can be expressed by Equation 1:

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

where

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

Typical thermal hysteresis distribution is as shown in Figure 8-4 and Figure 8-5.

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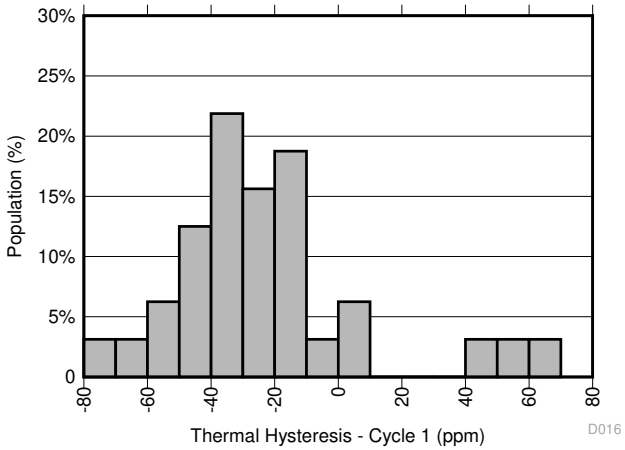


Figure 8-4. Thermal Hysteresis Distribution Cycle 1 (V_{OUT})

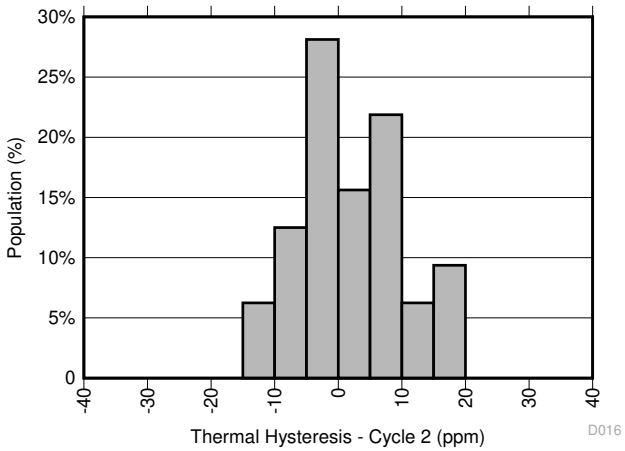


Figure 8-5. Thermal Hysteresis Distribution Cycle 2 (V_{OUT})

8.4 Power Dissipation

The REF34xx voltage references are capable of source and sink up to 10 mA of load current across the rated input voltage range. However, when used in applications subject to high ambient temperatures, the input voltage and load current must be carefully monitored to ensure that the device does not exceeded its maximum power dissipation rating. The maximum power dissipation of the device can be calculated with Equation 2:

$$T_J = T_A + P_D \times R_{\theta JA} \quad (2)$$

where

- P_D is the device power dissipation
- T_J is the device junction temperature
- T_A is the ambient temperature
- $R_{\theta JA}$ is the package (junction-to-air) thermal resistance

Because of this relationship, acceptable load current in high temperature conditions may be less than the maximum current-sourcing capability of the device. In no case should the device be operated outside of its maximum power rating because doing so can result in premature failure or permanent damage to the device.

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8.5 Noise Performance

Typical 0.1-Hz to 10-Hz voltage noise can be seen in Figure 8-6 . Device noise increases with output voltage and operating temperature. Additional filtering can be used to improve output noise levels, although care must be taken to ensure the output impedance does not degrade ac performance. Peak-to-peak noise measurement setup is shown in Figure 8-6.

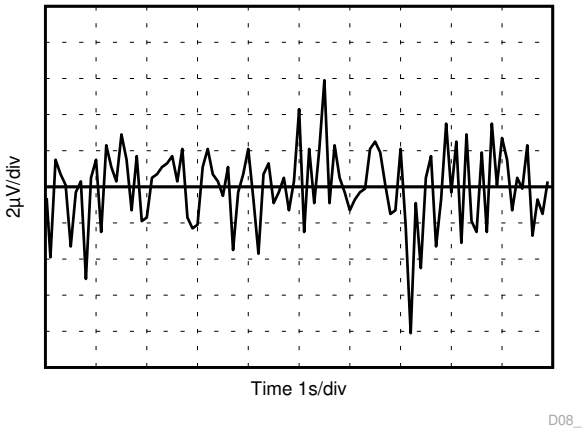


Figure 8-6. 0.1-Hz to 10-Hz Noise (V_{OUT})

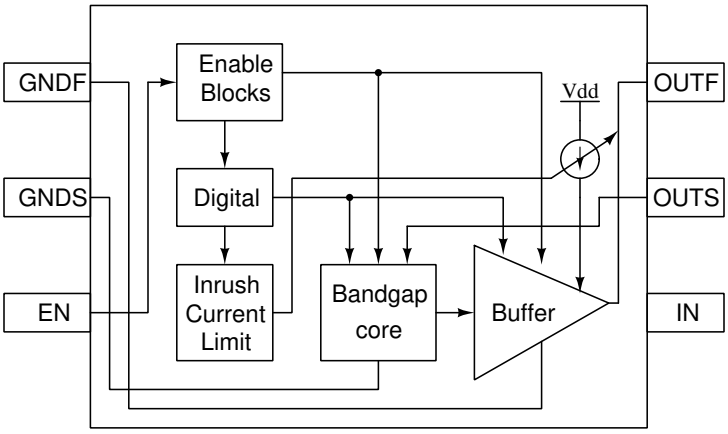
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9 Detailed Description

9.1 Overview

The REF34xx is family of low-noise, precision bandgap voltage references that are specifically designed for excellent initial voltage accuracy and drift. The *Section 9.2* is a simplified block diagram of the REF34xx showing basic band-gap topology.

9.2 Functional Block Diagram



9.3 Feature Description

9.3.1 Supply Voltage

The REF34xx family of references features an extremely low dropout voltage. For loaded conditions, a typical dropout voltage versus load is shown on the front page. The REF34xx features a low quiescent current that is extremely stable over changes in both temperature and supply. The typical room temperature quiescent current is 72 µA, and the maximum quiescent current over temperature is just 95 µA. Supply voltages below the specified levels can cause the REF34xx to momentarily draw currents greater than the typical quiescent current. Use a power supply with a fast rising edge and low output impedance to easily prevent this issue.

9.3.2 Low Temperature Drift

The REF34xx is designed for minimal drift error, which is defined as the change in output voltage over temperature. The drift is calculated using the box method, as described by Equation 3. For this equation, V_{REF} is V_{OUT} which is the output voltage seen at the junction of OUT_F and OUT_S.

$$\text{Drift} = \left(\frac{V_{REF(MAX)} - V_{REF(MIN)}}{V_{REF(25°C)} \times \text{Temperature Range}} \right) \times 10^6 \tag{3}$$

9.3.3 Load Current

The REF34xx family is specified to deliver a current load of ±10 mA per output. The device temperature increases according to Equation 4:

$$T_J = T_A + P_D \times R_{\theta JA} \tag{4}$$

where

- T_J = junction temperature (°C),
- T_A = ambient temperature (°C),
- P_D = power dissipated (W), and
- $R_{\theta JA}$ = junction-to-ambient thermal resistance (°C/W)

The REF34xx maximum junction temperature must not exceed the absolute maximum rating of 150°C.

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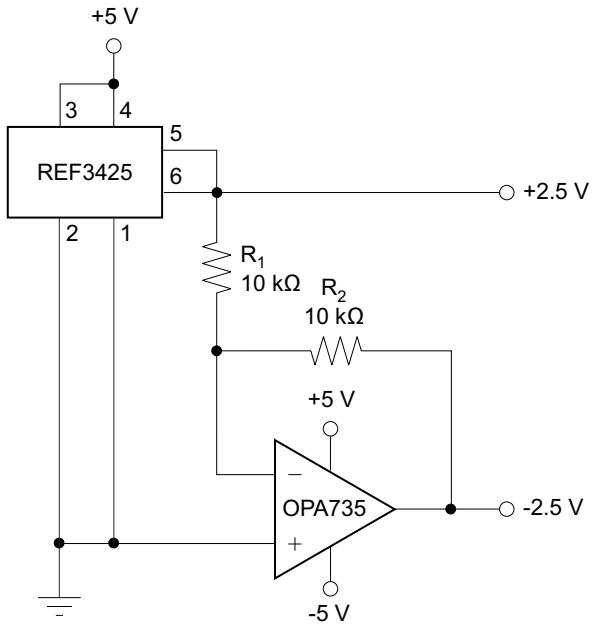
9.4 Device Functional Modes

9.4.1 EN Pin

When the EN pin of the REF34xx is pulled high, the device is in active mode. The device must be in active mode for normal operation. The REF34xx can be placed in a low-power mode by pulling the enable pin, EN, low. When in shutdown mode, the output of the device becomes high impedance and the quiescent current of the device reduces to 2 µA in shutdown mode. The EN pin must not be pulled higher than VIN supply voltage. See the Section 7.5 for logic high and logic low voltage levels.

9.4.2 Negative Reference Voltage

For applications requiring a negative and positive reference voltage, the REF34xx and OPA735 can be used to provide a dual-supply reference from a 5-V supply. Figure 9-1 shows the REF34xx used to provide a 2.5-V supply reference voltage. The low drift performance of the REF34xx complements the low offset voltage and zero drift of the OPA735 to provide an accurate solution for split-supply applications. Take care to match the temperature coefficients of R1 and R2.



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Figure 9-1. REF34xx and OPA735 Create Positive and Negative Reference Voltages

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10 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.

10.1 Application Information

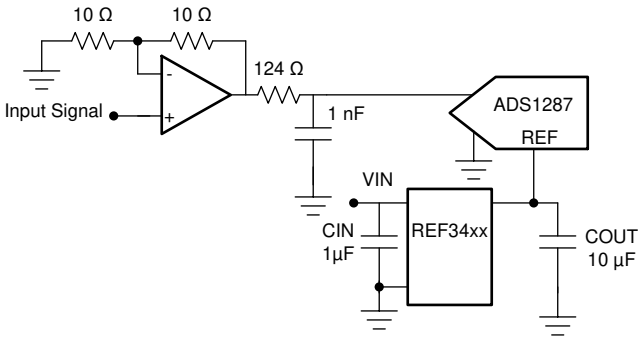
As this device has many applications and setups, there are many situations that this datasheet can not characterize in detail. Basic applications includes positive/negative voltage reference and data acquisition systems. The table below shows the typical application of REF34xx and its companion ADC/DAC.

Table 10-1. Typical Applications and Companion ADC/DAC

Applications	ADC/DAC
PLC - DCS	DAC8881, ADS8332, ADS8568, ADS8317, ADS8588S, ADS1287
Display Test Equipment	ADS8332
Video Surveillance - Thermal Cameras	ADS7279
Medical Blood Glucose Meter	ADS1112

10.2 Typical Application: Basic Voltage Reference Connection

The circuit shown in Figure 10-1 shows the basic configuration for the REF34xx references. Connect bypass capacitors according to the guidelines in *Section 10.2.2.1*.



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Figure 10-1. Basic Reference Connection

10.2.1 Design Requirements

A detailed design procedure is described based on a design example. For this design example, use the parameters listed in Table 10-2 as the input parameters.

Table 10-2. Design Example Parameters

DESIGN PARAMETER	VALUE
Input voltage V_{IN}	5 V
Output voltage V_{OUT}	2.5 V
REF34xx input capacitor	1 µF
REF34xx output capacitor	10 µF

10.2.2 Detailed Design Procedure

10.2.2.1 Input and Output Capacitors

A 1-µF to 10-µF electrolytic or ceramic capacitor can be connected to the input to improve transient response in applications where the supply voltage may fluctuate. Connect an additional 0.1-µF ceramic capacitor in parallel to reduce high frequency supply noise.

A ceramic capacitor of at least a 0.1 µF must be connected to the output to improve stability and help filter out high frequency noise. An additional 1-µF to 10-µF electrolytic or ceramic capacitor can be added in parallel to improve transient performance in response to sudden changes in load current; however, keep in mind that doing so increases the turnon time of the device.

Best performance and stability is attained with low-ESR, low-inductance ceramic chip-type output capacitors (X5R, X7R, or similar). If using an electrolytic capacitor on the output, place a 0.1-µF ceramic capacitor in parallel to reduce overall ESR on the output.

10.2.2.2 4-Wire Kelvin Connections

Current flowing through a PCB trace produces an IR voltage drop, and with longer traces, this drop can reach several millivolts or more, introducing a considerable error into the output voltage of the reference. A 1-inch long, 5-millimeter wide trace of 1-ounce copper has a resistance of approximately 100 mΩ at room temperature; at a load current of 10 mA, this can introduce a full millivolt of error. In an ideal board layout, the reference must be mounted as close as possible to the load to minimize the length of the output traces, and, therefore, the error introduced by voltage drop. However, in applications where this is not possible or convenient, force and sense connections (sometimes referred to as Kelvin sensing connections) are provided as a means of minimizing the IR drop and improving accuracy.

Kelvin connections work by providing a set of high impedance voltage-sensing lines to the output and ground nodes. Because very little current flows through these connections, the IR drop across their traces is negligible, and the output and ground voltage information can be obtain with minimum IR drop error.

It is always advantageous to use Kelvin connections whenever possible. However, in applications where the IR drop is negligible or an extra set of traces cannot be routed to the load, the force and sense pins for both V_{OUT} and GND can simply be tied together, and the device can be used in the same fashion as a normal 3-terminal reference (as shown in Figure 9-1).

10.2.2.3 V_{IN} Slew Rate Considerations

In applications with slow-rising input voltage signals, the reference exhibits overshoot or other transient anomalies that appear on the output. These phenomena also appear during shutdown as the internal circuitry loses power.

To avoid such conditions, ensure that the input voltage wave-form has both a rising and falling slew rate close to 6 V/ms.

10.2.2.4 Shutdown/Enable Feature

The REF34xx references can be switched to a low power shut-down mode when a voltage of 0.5 V or lower is input to the EN pin. Likewise, the reference becomes operational for EN voltages of 1.6 V or higher. During shutdown, the supply current drops to less than 2 µA, useful in applications that are sensitive to power consumption.

If using the shutdown feature, ensure that the EN pin voltage does not fall between 0.5 V and 1.6 V because this causes a large increase in the supply current of the device and may keep the reference from starting up correctly. If not using the shutdown feature, however, the EN pin can simply be tied to the IN pin, and the reference remains operational continuously.

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10.2.3 Application Curves

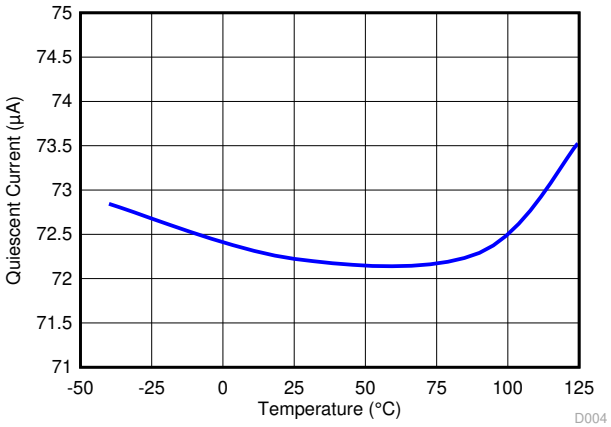


Figure 10-2. Quiescent Current vs Temperature

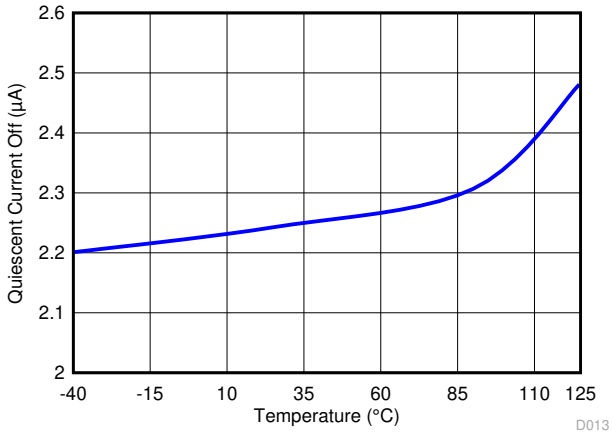


Figure 10-3. Quiescent Current Shutdown Mode

11 Power Supply Recommendations

The REF34xx family of references feature an extremely low-dropout voltage. These references can be operated with a supply of only 50 mV above the output voltage. TI recommends a supply bypass capacitor ranging between 0.1 µF to 10 µF.

12 Layout

12.1 Layout Guidelines

Figure 12-1 illustrates an example of a PCB layout for a data acquisition system using the REF34xx. Some key considerations are:

- Connect low-ESR, 0.1-µF ceramic bypass capacitors at IN, OUT_F, VOUT of the REF34xx and REF34xxT.
- Decouple other active devices in the system per the device specifications.
- Using a solid ground plane helps distribute heat and reduces electromagnetic interference (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.
- 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

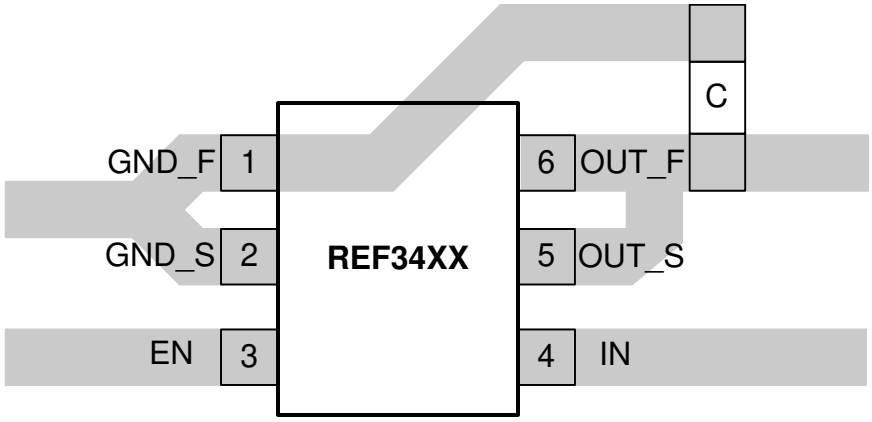


Figure 12-1. REF34xx Layout Example

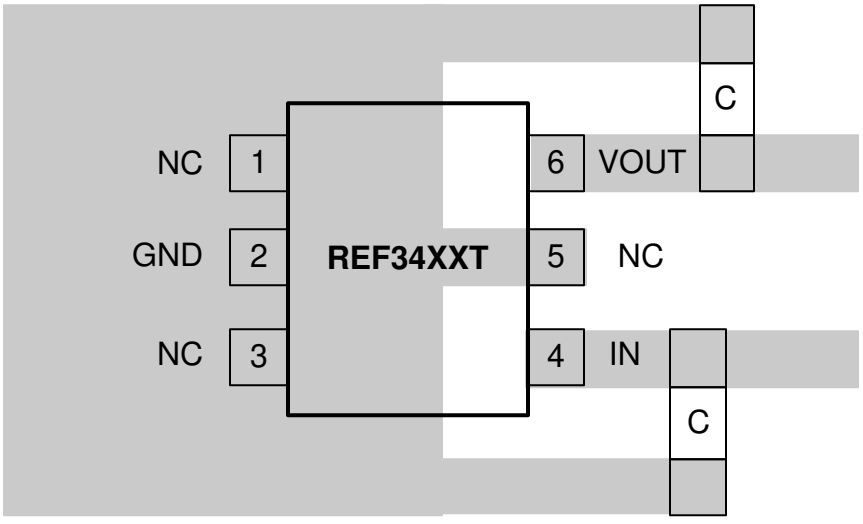


Figure 12-2. REF34xxT Layout Example

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13 Device and Documentation Support

13.1 Documentation Support

13.1.1 Related Documentation

For related documentation see the following:

- *INA21x Voltage Output, Low- or High-Side Measurement, Bidirectional, Zero-Drift Series, Current-Shunt Monitors*
- *Low-Drift Bidirectional Single-Supply Low-Side Current Sensing Reference Design*

13.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Subscribe to updates* 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.

13.3 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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13.5 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.

13.6 Glossary

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 finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
PREF3450TQDBVR	ACTIVE	SOT-23	DBV	6	3000	Non-RoHS & Non-Green	Call TI	Call TI	-40 to 125		Samples
REF3425IDBVR	ACTIVE	SOT-23	DBV	6	3000	RoHS & Green	NIPDAU	Level-2-250C-1 YEAR	-40 to 125	19ED	Samples
REF3425TIDBVR	ACTIVE	SOT-23	DBV	6	3000	RoHS & Green	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	2EVC	Samples
REF3430IDBVR	ACTIVE	SOT-23	DBV	6	3000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	1H6D	Samples
REF3430TIDBVR	ACTIVE	SOT-23	DBV	6	3000	RoHS & Green	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	2EUC	Samples
REF3433IDBVR	ACTIVE	SOT-23	DBV	6	3000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	1H5D	Samples
REF3440IDBVR	ACTIVE	SOT-23	DBV	6	3000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	1MJD	Samples
REF3440TIDBVR	ACTIVE	SOT-23	DBV	6	3000	RoHS & Green	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	2ESC	Samples
REF3450IDBVR	ACTIVE	SOT-23	DBV	6	3000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	1MKD	Samples
REF3450TIDBVR	ACTIVE	SOT-23	DBV	6	3000	RoHS & Green	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	2ERC	Samples

(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) **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 finish/Ball material - Orderable Devices 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.

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OTHER QUALIFIED VERSIONS OF REF3425, REF3430, REF3433, REF3440 :

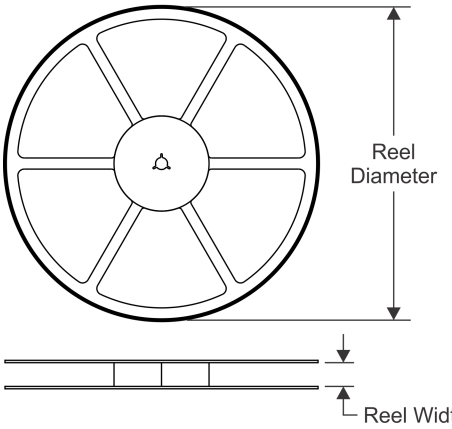
- Enhanced Product : REF3425-EP, REF3430-EP, REF3433-EP, REF3440-EP

NOTE: Qualified Version Definitions:

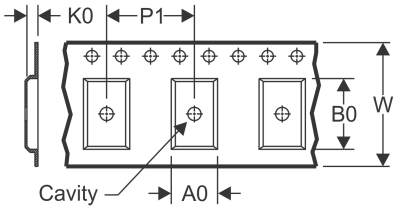
- Enhanced Product - Supports Defense, Aerospace and Medical Applications

TAPE AND REEL INFORMATION

REEL DIMENSIONS

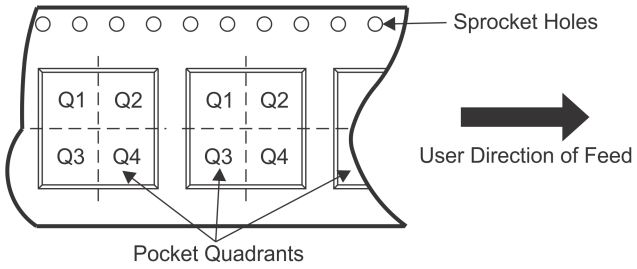


TAPE DIMENSIONS



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

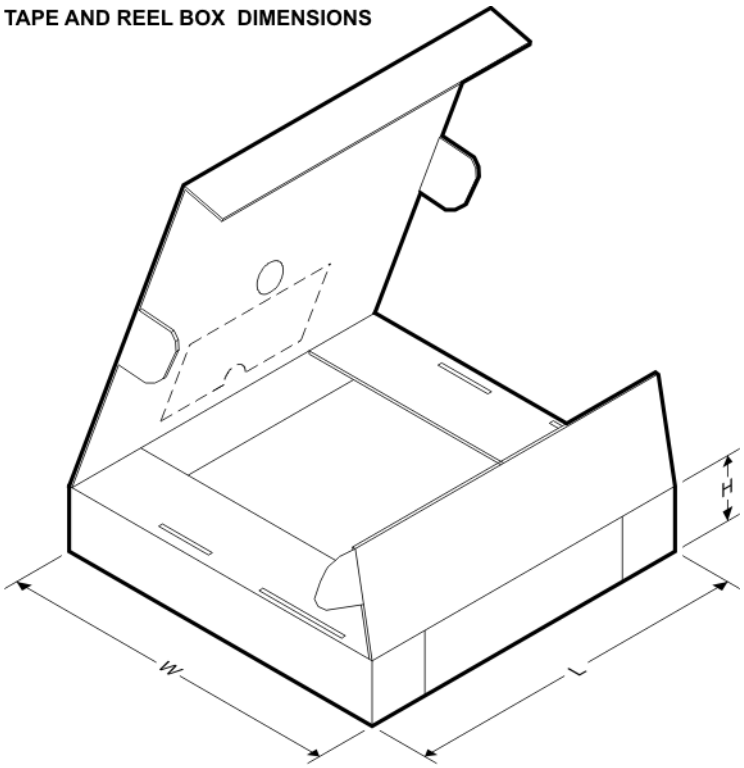
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
REF3425IDBVR	SOT-23	DBV	6	3000	178.0	9.0	3.23	3.17	1.37	4.0	8.0	Q3
REF3425TIDBVR	SOT-23	DBV	6	3000	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
REF3430IDBVR	SOT-23	DBV	6	3000	178.0	9.0	3.23	3.17	1.37	4.0	8.0	Q3
REF3430TIDBVR	SOT-23	DBV	6	3000	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
REF3433IDBVR	SOT-23	DBV	6	3000	178.0	9.0	3.23	3.17	1.37	4.0	8.0	Q3
REF3440IDBVR	SOT-23	DBV	6	3000	178.0	9.0	3.23	3.17	1.37	4.0	8.0	Q3
REF3440TIDBVR	SOT-23	DBV	6	3000	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
REF3450IDBVR	SOT-23	DBV	6	3000	178.0	9.0	3.23	3.17	1.37	4.0	8.0	Q3
REF3450TIDBVR	SOT-23	DBV	6	3000	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

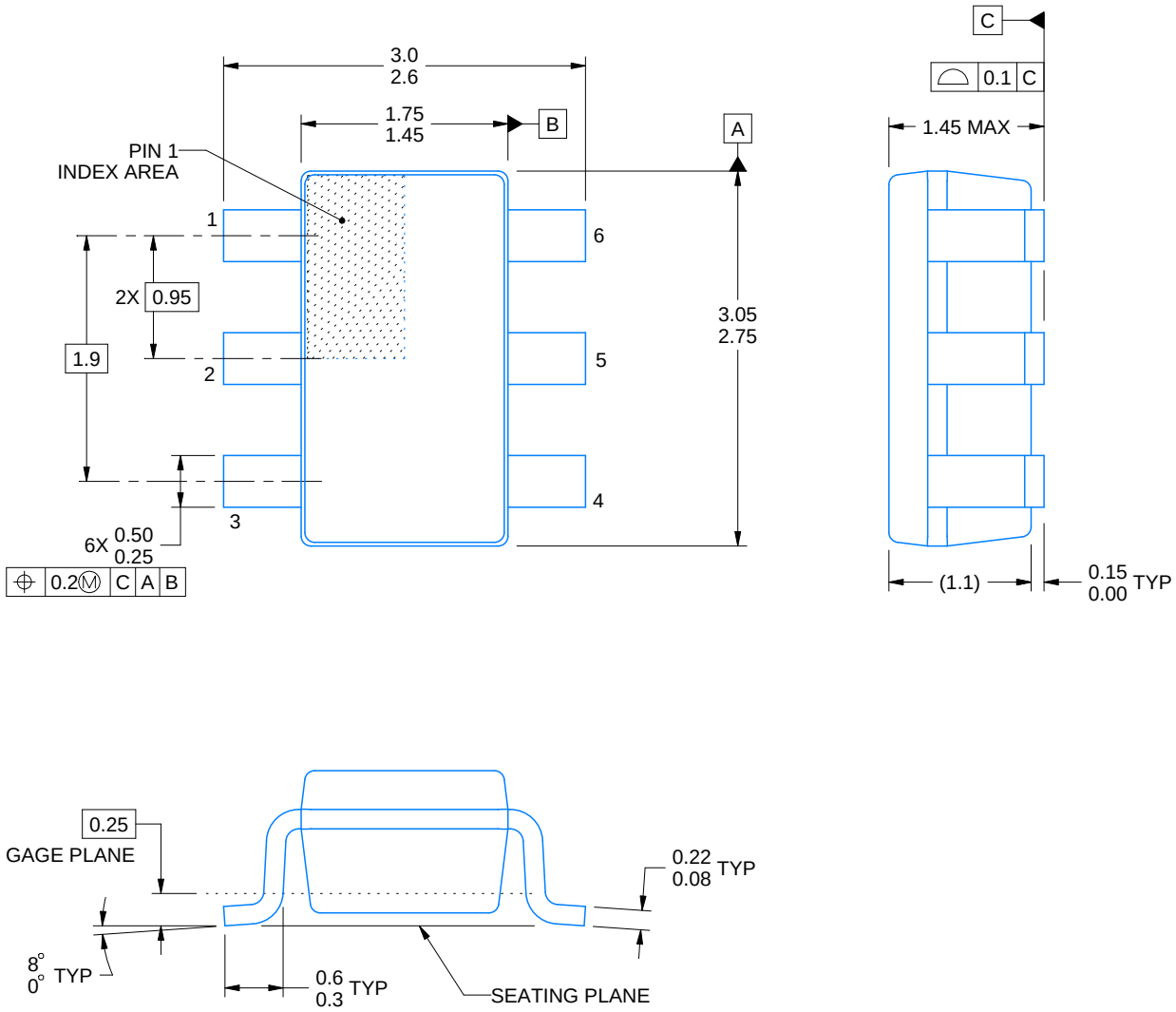
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
REF3425IDBVR	SOT-23	DBV	6	3000	445.0	220.0	345.0
REF3425TIDBVR	SOT-23	DBV	6	3000	213.0	191.0	35.0
REF3430IDBVR	SOT-23	DBV	6	3000	445.0	220.0	345.0
REF3430TIDBVR	SOT-23	DBV	6	3000	213.0	191.0	35.0
REF3433IDBVR	SOT-23	DBV	6	3000	445.0	220.0	345.0
REF3440IDBVR	SOT-23	DBV	6	3000	445.0	220.0	345.0
REF3440TIDBVR	SOT-23	DBV	6	3000	213.0	191.0	35.0
REF3450IDBVR	SOT-23	DBV	6	3000	445.0	220.0	345.0
REF3450TIDBVR	SOT-23	DBV	6	3000	213.0	191.0	35.0

PACKAGE OUTLINE

DBV0006A

SOT-23 - 1.45 mm max height

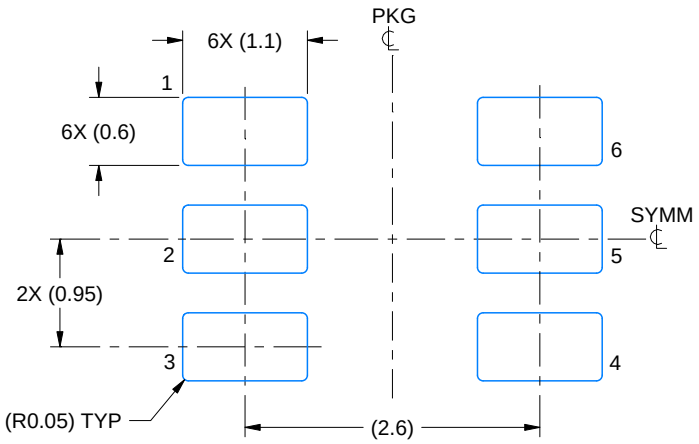
SMALL OUTLINE TRANSISTOR



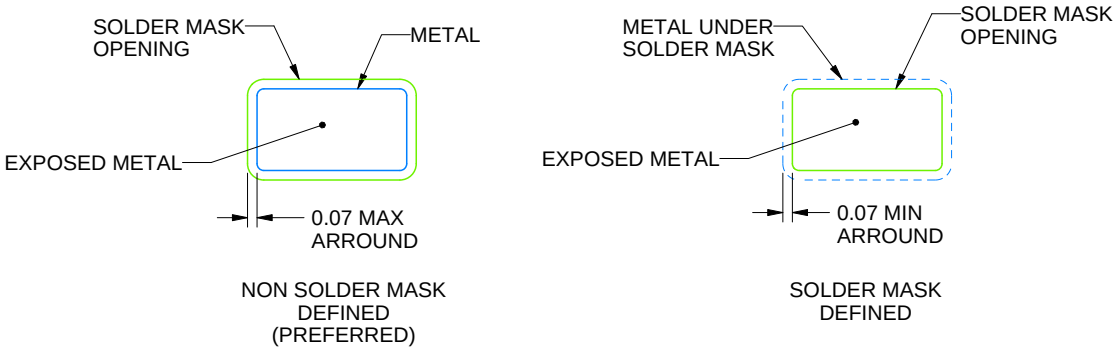
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NOTES:

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. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
4. Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
5. Refernce JEDEC MO-178.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X

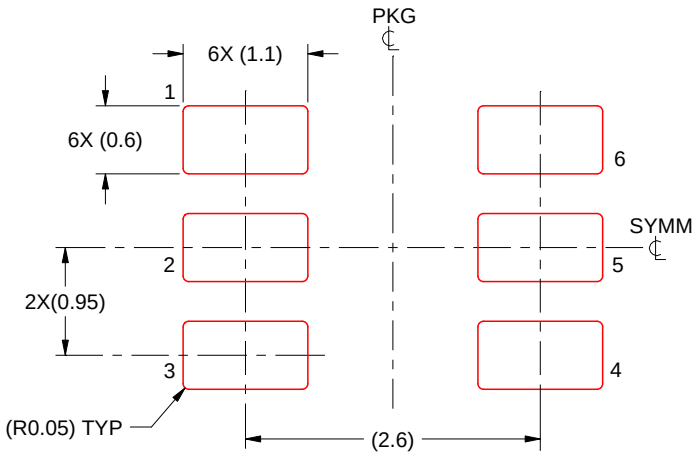


SOLDER MASK DETAILS

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NOTES: (continued)

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



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

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NOTES: (continued)

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

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