REF31xx 15ppm/°C Maximum, 100µA, SOT-23 Series Voltage Reference

1 Features

- *Micro*size package: SOT23-3
- Low dropout: 5mV
- High output current: ±10mA
- High accuracy: 0.2% maximum
- Low I_Q: 115µA maximum
- Excellent specified drift performance:
  - 15ppm/°C (maximum) from 0°C to +70°C
  - 20ppm/°C (maximum) from –40°C to +125°C

2 Applications

- Portable, battery-powered equipment
- Data acquisition systems
- Medical equipment
- Hand-held test equipment

3 Description

The REF31xx is a family of precision, low power, low dropout, series voltage references available in the tiny 3-pin SOT-23 package.

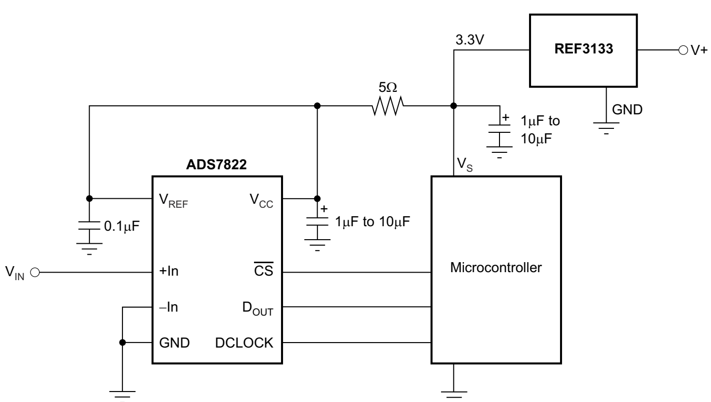
The small size and low power consumption of the device (100µA typical) are designed for portable and battery-powered applications. The REF31xx does not require a load capacitor and can sink or source up to 10mA of output current.

Unloaded, the REF31xx can operate on supplies down to 5mV above the output voltage. All models are specified for the wide temperature range from –40°C to +125°C.

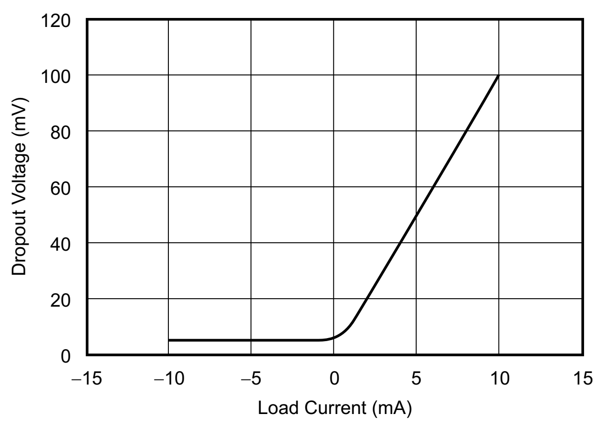
Package Information

PART NUMBER	PACKAGE(1)	PACKAGE SIZE(2)
REF31xx	DBZ (SOT-23, 3)	2.92mm × 2.37mm

(1) For more information, see Section 11.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.



Typical Application



Dropout Voltage vs Load Current

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4 Device Comparison Table

PRODUCT	VOLTAGE (V)
REF3112	1.25
REF3120	2.048
REF3125	2.5
REF3130	3
REF3133	3.3
REF3140	4.096

5 Pin Configuration and Functions

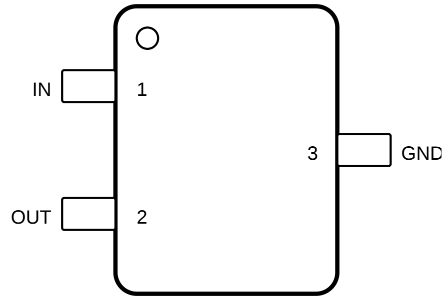


Figure 5-1. DBZ Package 3-Pin SOT-23 Top View

Table 5-1. Pin Functions

PIN		TYPE[(1)]	DESCRIPTION
NO.	NAME		
1	IN	I	Input supply voltage
2	OUT	O	Reference output voltage
3	GND	—	Ground

(1) I = input, O = output

6 Specifications

6.1 Absolute Maximum Ratings

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

	MIN	MAX	UNIT
Supply voltage, V+ to V–		7	V
Output short circuit	Continuous		
Operating temperature	–55	135	°C
Junction temperature		150	°C
Storage temperature, T_{stg}	–65	150	°C

(1) Operation outside the *Absolute Maximum Ratings* may cause permanent device damage. *Absolute Maximum Ratings* do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Conditions*. If used outside the *Recommended Operating Conditions* but within the *Absolute Maximum Ratings*, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[(1)]	±2000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101[(2)]	±1000	

(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 Recommended Operating Conditions

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

		MIN	MAX	UNIT
V_{IN}	Input voltage	V_{REF} + 0.05[(1)]	5.5	V
I_{LOAD}	Load current		25	mA
T_A	Operating temperature	–40	125	°C

(1) Minimum supply voltage for the REF3112 is 1.8V.

6.4 Thermal Information

THERMAL METRIC[(1)]		REF31xx DBZ (SOT-23) 3 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	292.9	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	124.4	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	89	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	11.4	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	87.6	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	—	°C/W

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

6.5 Electrical Characteristics

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
REF3312[(1)] — 1.25V					

6.5 Electrical Characteristics (continued)

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

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{OUT}	Output voltage			1.2475	1.25	1.2525	V
	Initial accuracy			–0.2%		0.2%	
	Output voltage noise		f = 0.1Hz to 10Hz		17		μV_{PP}
			f = 10Hz to 10kHz		24		μV_{RMS}
REF3120 — 2.048V							
V_{OUT}	Output voltage			2.0439	2.048	2.0521	V
	Initial accuracy			–0.2%		0.2%	
	Output voltage noise		f = 0.1Hz to 10Hz		27		μV_{PP}
			f = 10Hz to 10kHz		39		μV_{RMS}
REF3125 — 2.5V							
V_{OUT}	Output voltage			2.495	2.5	2.505	V
	Initial accuracy			–0.2%		0.2%	
	Output voltage noise		f = 0.1Hz to 10Hz		33		μV_{PP}
			f = 10Hz to 10kHz		48		μV_{RMS}
REF3130 — 3V							
V_{OUT}	Output voltage			2.994	3	3.006	V
	Initial accuracy			–0.2%		0.2%	
	Output voltage noise		f = 0.1Hz to 10Hz		39		μV_{PP}
			f = 10Hz to 10kHz		57		μV_{RMS}
REF3133 — 3.3V							
V_{OUT}	Output voltage			3.2934	3.3	3.3066	V
	Initial accuracy			–0.2%		0.2%	
	Output voltage noise		f = 0.1Hz to 10Hz		43		μV_{PP}
			f = 10Hz to 10kHz		63		μV_{RMS}
REF3140 — 4.096V							
V_{OUT}	Output voltage			4.0878	4.096	4.1042	V
	Initial accuracy			–0.2%		0.2%	
	Output voltage noise		f = 0.1Hz to 10Hz		53		μV_{PP}
			f = 10Hz to 10kHz		78		μV_{RMS}
REF31xx (REF3112, REF3120, REF3125, REF3130, REF3133, REF3140)							
dV_{OUT}/dT	Output voltage temperature drift[2]		T_A = 0°C to 70°C.		5	15	ppm/°C
			T_A = –40°C to +125°C.		10	20	
	Long-term stability		0 to 1000 hours		70		ppm
	Line regulation		V_{REF} + 0.05[1] ≤ V_{IN} ≤ 5.5V		20	65	ppm/V
dV_{OUT}/dI_{LOAD}	Load regulation[3]	Sourcing	0mA < I_{LOAD} < 10mA, V_{IN} = V_{REF} + 250mV[1]		10	30	µV/mA
		Sinking	–10mA < I_{LOAD} < 0mA, V_{IN} = V_{REF} + 100mV[1]		20	50	
dT	Thermal hysteresis[4]	First Cycle			100		ppm
		Additional Cycles			25		
$V_{IN} - V_{OUT}$	Dropout voltage[1]		T_A = –40°C to +125°C.		5	50	mV
I_{LOAD}	Output current			–10		10	mA
I_{SC}	Short-circuit current	Sourcing			50		mA
		Sinking			40		

6.5 Electrical Characteristics (continued)

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	Turnon settling time	To 0.1% at V_{IN} = +5V with C_L = 0µF		400		µs
POWER SUPPLY						
V_S	Voltage	I_{LOAD} = 0, T_A = –40°C to +125°C.	V_{REF} + 0.05[1]		5.5	V
I_Q	Quiescent current	I_{LOAD} = 0, T_A = 25°C		100	115	µA
		I_{LOAD} = 0, T_A = –40°C to +125°C		115	135	µA

(1) Minimum supply voltage for the REF3112 is 1.8V.
(2) Box Method used to determine temperature drift.
(3) Typical value of load regulation reflects measurements using force and sense contacts; see Section 7.3.6.
(4) Thermal hysteresis is explained in more detail in Section 8 of this data sheet.

6.6 Typical Characteristics

At T_A = 25°C, V_{IN} = 5V power supply, and REF3125 is used for typical characteristic measurements, unless otherwise noted.

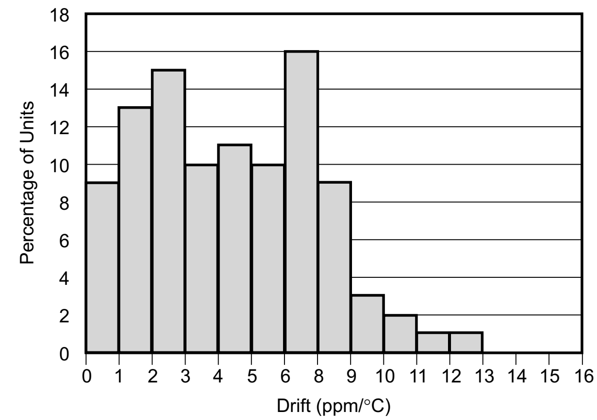


Figure 6-1. Temperature Drift (0°C to 70°C)

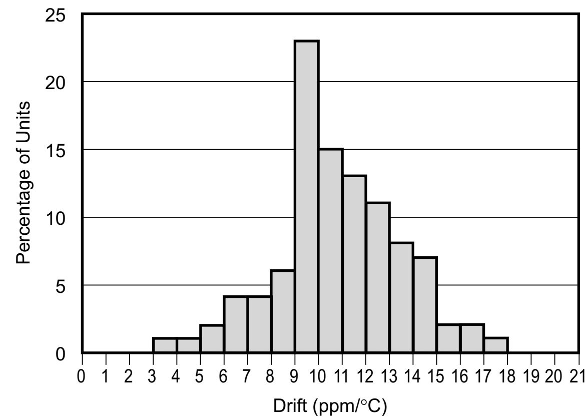


Figure 6-2. Temperature Drift (–40°C to +125°C)

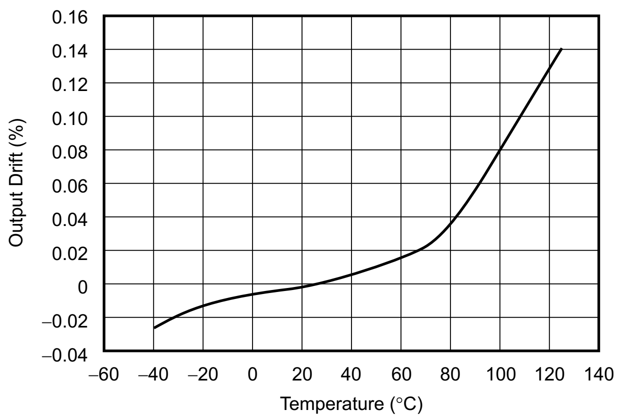


Figure 6-3. Output Voltage vs Temperature

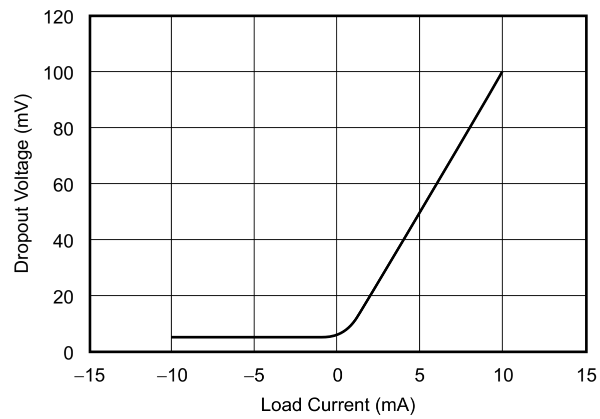


Figure 6-4. Dropout Voltage vs Load Current

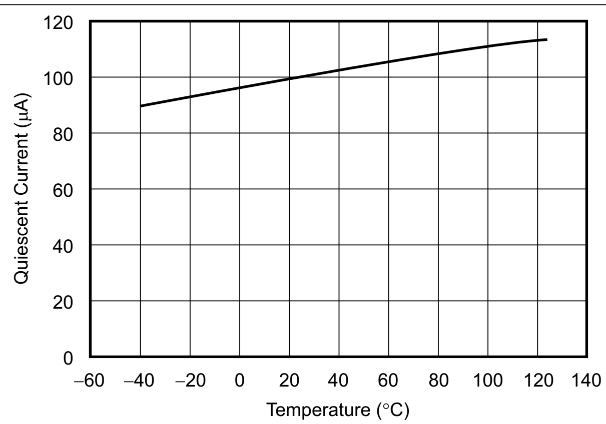


Figure 6-5. Quiescent Current vs Temperature

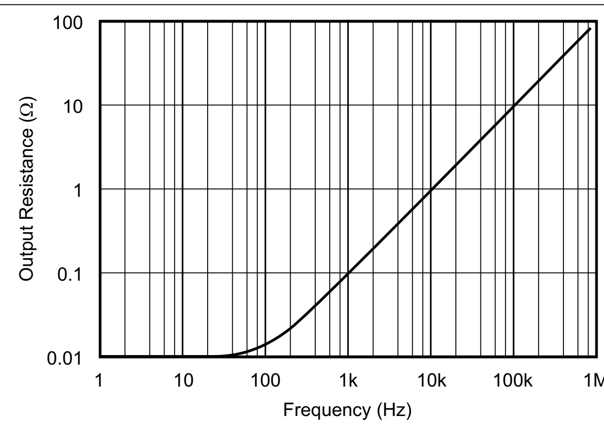


Figure 6-6. Output Impedance vs Frequency

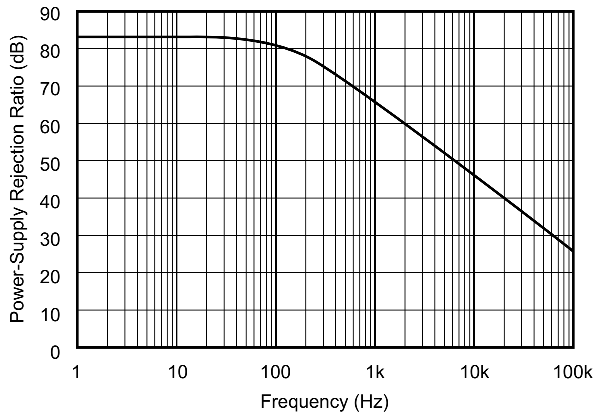


Figure 6-7. PSRR vs Frequency

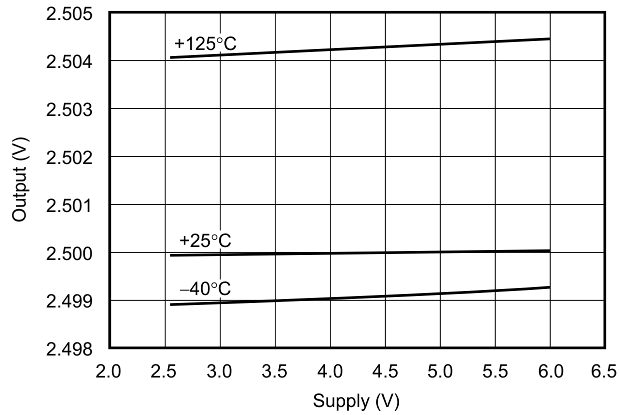


Figure 6-8. Output vs Supply

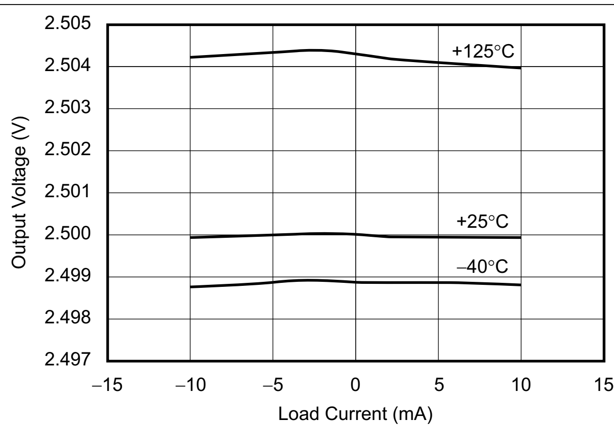


Figure 6-9. Output Voltage vs Load Current

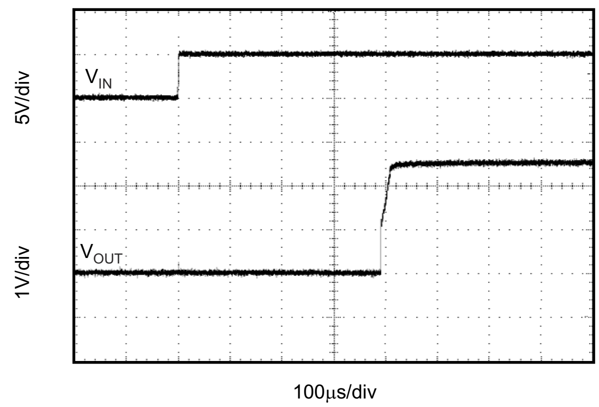


Figure 6-10. Step Response, C_L = 0, 5V Start-Up

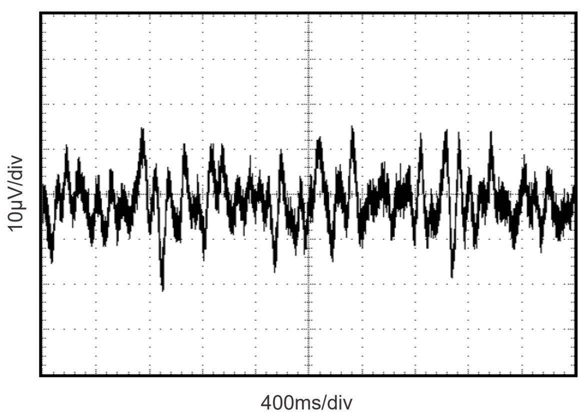


Figure 6-11. 0.1Hz to 10Hz Noise

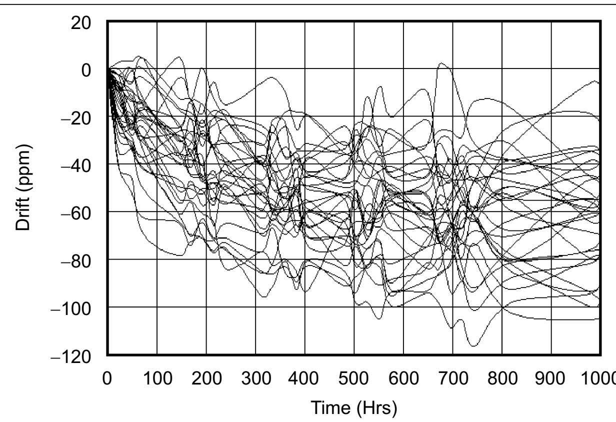


Figure 6-12. REF3112 Long-Term Stability

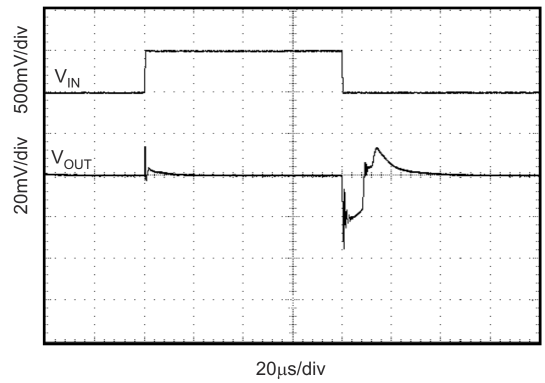


Figure 6-13. Line Transient C_L = 0pF

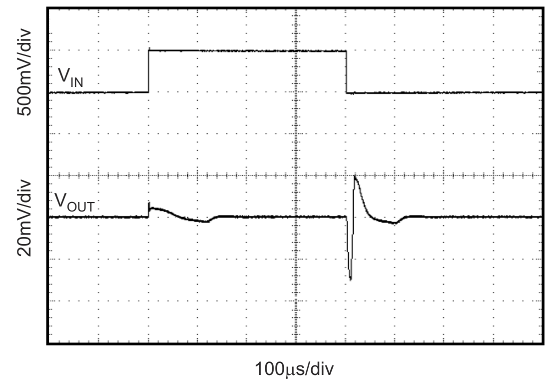


Figure 6-14. Line Transient C_L = 10µF

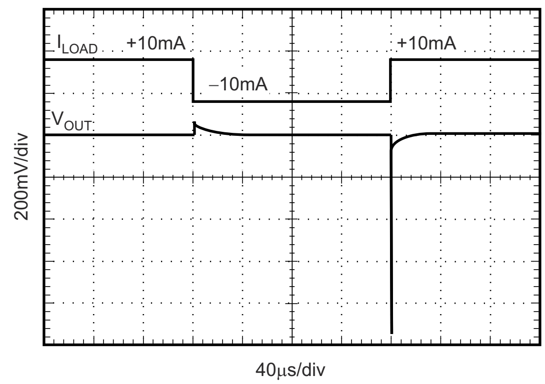


Figure 6-15. Load Transient C_L = 0pF, ±10mA Output Pulse

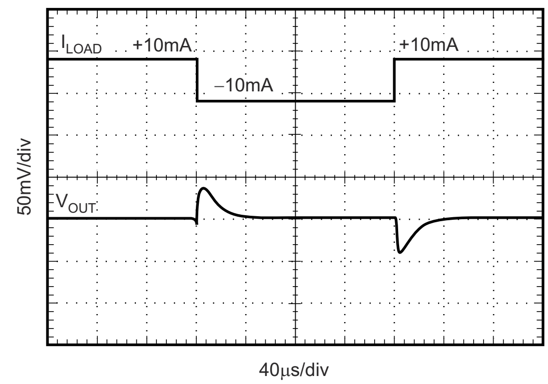


Figure 6-16. Load Transient C_L = 1 µF, ±10mA Output Pulse

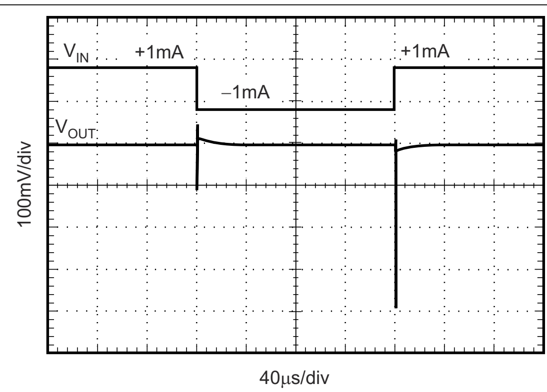


Figure 6-17. Load Transient C_L = 0pF, ±1mA Output Pulse

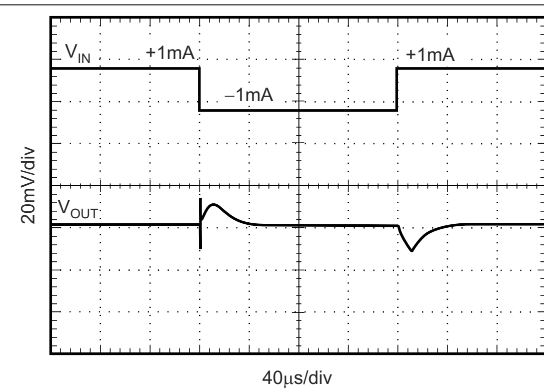


Figure 6-18. Load Transient C_L = 1 µF, ±1mA Output Pulse

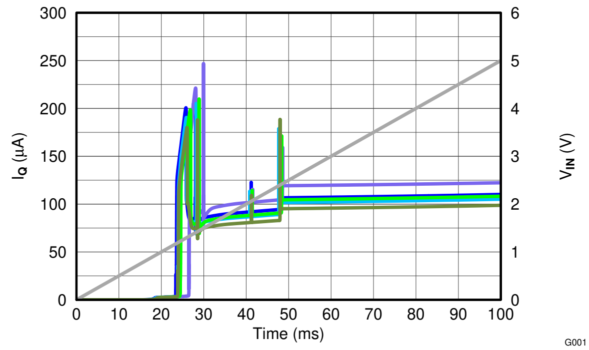


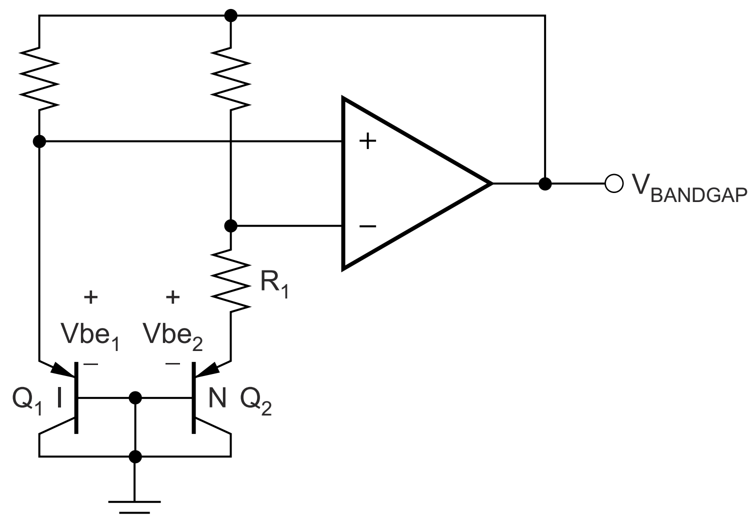
Figure 6-19. REF3125 Start-Up

7 Detailed Description

7.1 Overview

The REF31xx is a family of series, CMOS, precision bandgap voltage references. The basic bandgap topology is shown in Section 7.2. Transistors Q_1 and Q_2 are biased such that the current density of Q_1 is greater than that of Q_2. The difference of the two base-emitter voltages, $Vbe_1 – Vbe_2$, has a positive temperature coefficient and is forced across resistor R_1. This voltage is gained up and added to the base-emitter voltage of Q_2, which has a negative temperature coefficient. The resulting output voltage is virtually independent of temperature. The curvature of the bandgap voltage, as shown in Figure 6-3, is due to the slightly nonlinear temperature coefficient of the base-emitter voltage of Q_2.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Supply Voltage

The REF31xx family of references features an extremely low dropout voltage. With the exception of the REF3112, which has a minimum supply requirement of 1.8V, these references can be operated with a supply of only 5mV above the output voltage in an unloaded condition. For loaded conditions, a typical dropout voltage versus load is shown in Section 6.6.

The REF31xx features a low quiescent current, which is extremely stable over changes in both temperature and supply. The typical room temperature quiescent current is 100μA, and the maximum quiescent current over temperature is just 135μA. The quiescent current typically changes less than 2μA over the entire supply range, as shown in Figure 7-1.

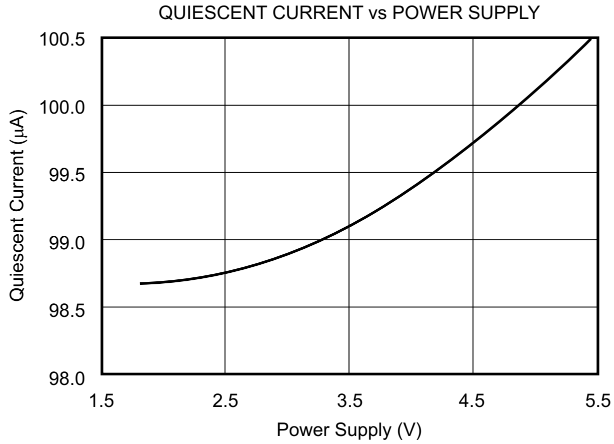


Figure 7-1. Supply Current vs Supply Voltage

Supply voltages below the specified levels can cause the REF31xx to momentarily draw currents greater than the typical quiescent current. This can be prevented by using a power supply with a fast rising edge and low output impedance.

7.3.2 Thermal Hysteresis

Thermal hysteresis for the REF31xx is defined as the change in output voltage after operating the device at 25°C, cycling the device through the specified temperature range, and returning to 25°C. It can be expressed as:

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

Where:

V_{HYST} = Thermal hysteresis.

V_{PRE} = Output voltage measured at 25°C pretemperature cycling.

V_{POST} = Output voltage measured after the device has been cycled through the specified temperature range of –40°C to +125°C and returned to +25°C.

7.3.3 Temperature Drift

The REF31xx is designed to exhibit minimal drift error, defined as the change in output voltage over varying temperature. The drift is calculated using the *box* method, which is described in Equation 2:

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

The REF31xx features a typical drift coefficient of 5ppm from 0°C to 70°C, the primary temperature range for many applications. For the industrial temperature range of –40°C to +125°C, the REF31xx family drift increases to a typical value of 10ppm.

7.3.4 Noise Performance

Typical voltage noise from 0.1Hz to 10Hz is seen in Figure 7-2. The noise voltage of the REF31xx increases with output voltage and operating temperature. Additional filtering can be used to improve output noise levels, although take care to establish that the output impedance does not degrade the AC performance.

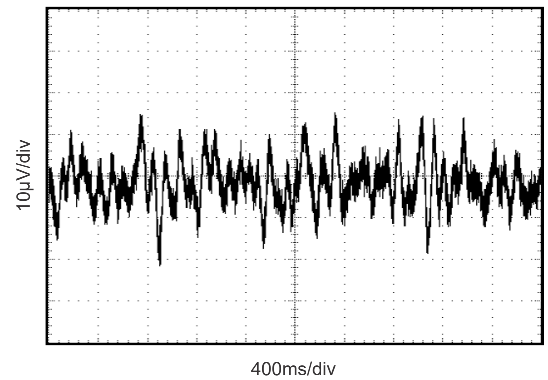


Figure 7-2. 0.1Hz to 10Hz Noise

7.3.5 Long-Term Stability

Long-term stability refers to the change of the output voltage of a reference over a period of months or years. This effect lessens as time progresses, as is shown by the long-term stability curves. The typical drift value for the REF31xx is 70ppm from 0 to 1000 hours. This parameter is characterized by measuring 30 units at regular intervals for a period of 1000 hours.

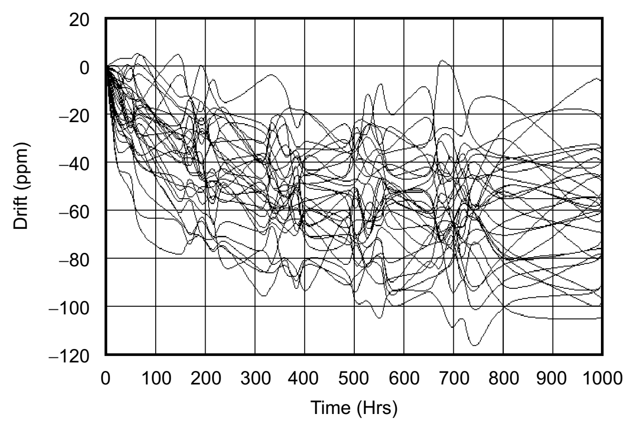


Figure 7-3. REF3112 Long-Term Stability

7.3.6 Load Regulation

Load regulation is defined as the change in output voltage due to changes in load current. The load regulation of the REF31xx is measured using force and sense contacts as pictured in Figure 7-4. The force and sense lines reduce the impact of contact and trace resistance, resulting in accurate measurement of the load regulation contributed solely by the REF31xx. For applications requiring improved load regulation, force and sense lines must be used.

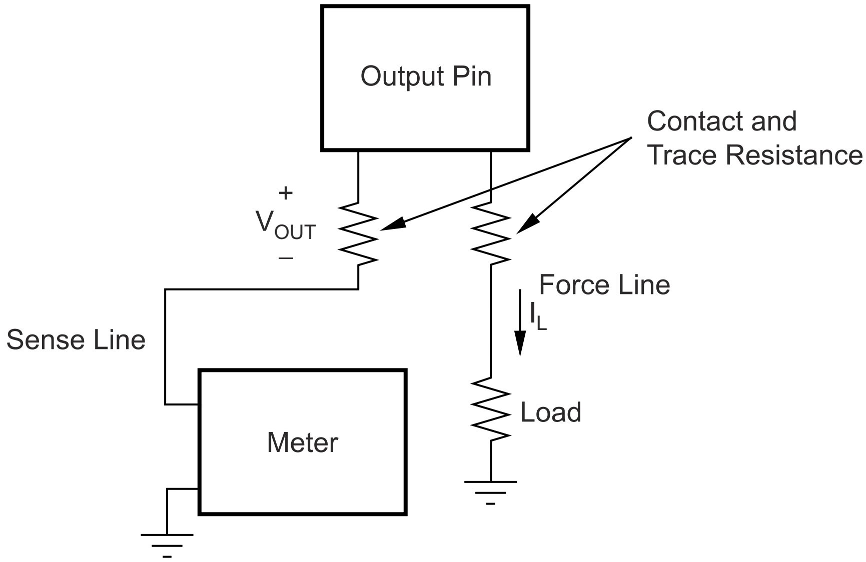


Figure 7-4. Accurate Load Regulation of REF31xx

7.4 Device Functional Modes

7.4.1 Negative Reference Voltage

For applications requiring a negative and positive reference voltage, the REF31xx and OPA703 can be used to provide a dual-supply reference from a ±5V supply. Figure 7-5 shows the REF3125 used to provide a ±2.5V supply reference voltage. The low drift performance of the REF31xx complement the low offset voltage and low drift of the OPA703 to provide an accurate solution for split-supply applications.

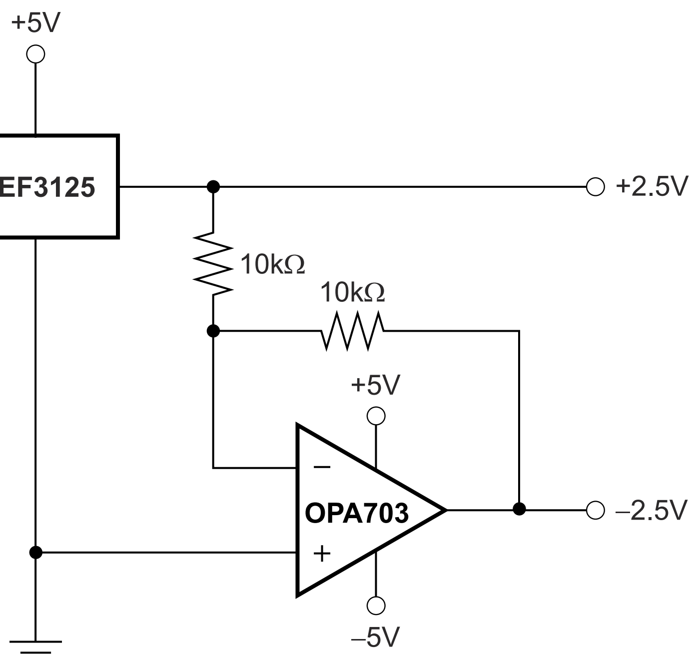


Figure 7-5. REF3125 Combined With OPA703 to Create Positive and Negative Reference Voltages

7.4.2 Data Acquisition

Data acquisition systems often require stable voltage references to maintain accuracy. The REF31xx family features stability and a wide range of voltages suitable for most microcontrollers and data converters. Figure 7-6, Figure 7-7, and Figure 7-8 show basic data acquisition systems.

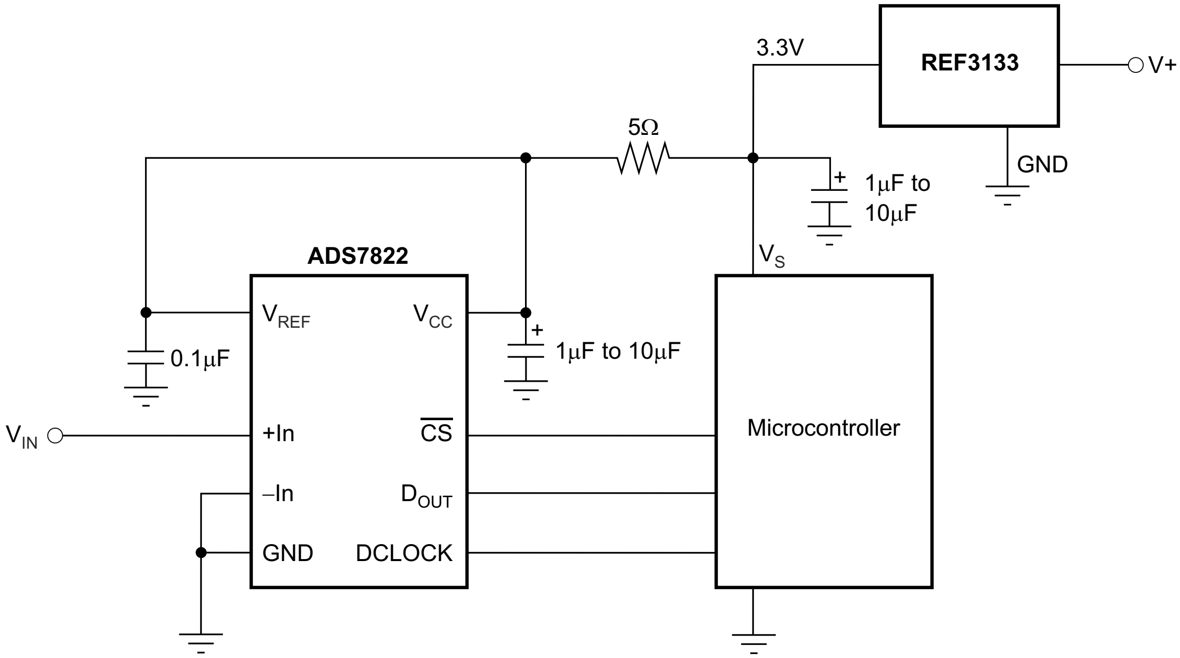


Figure 7-6. Basic Data Acquisition System 1

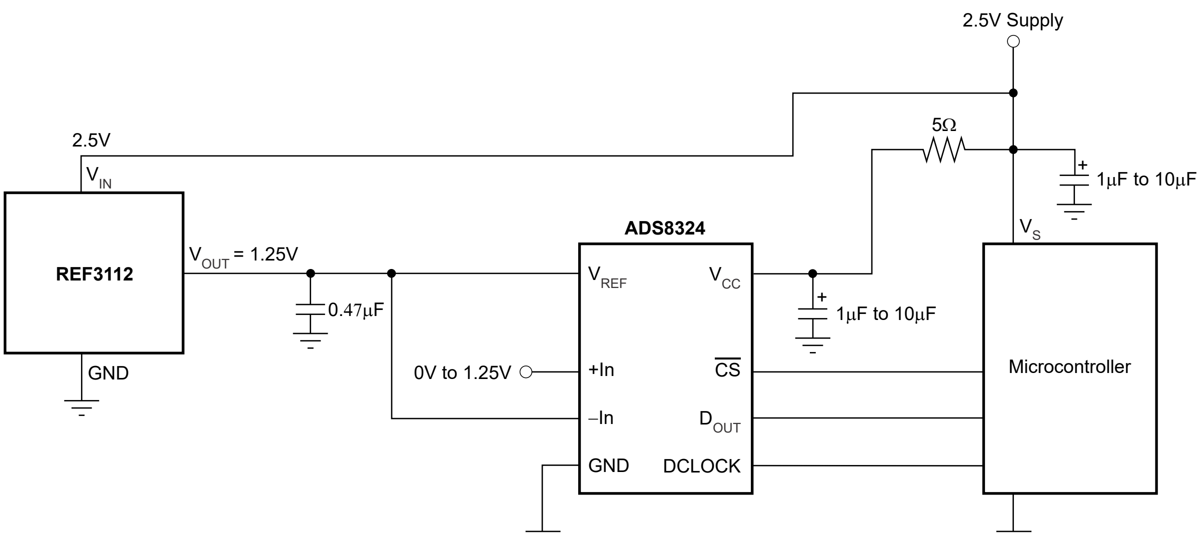


Figure 7-7. Basic Data Acquisition System 2

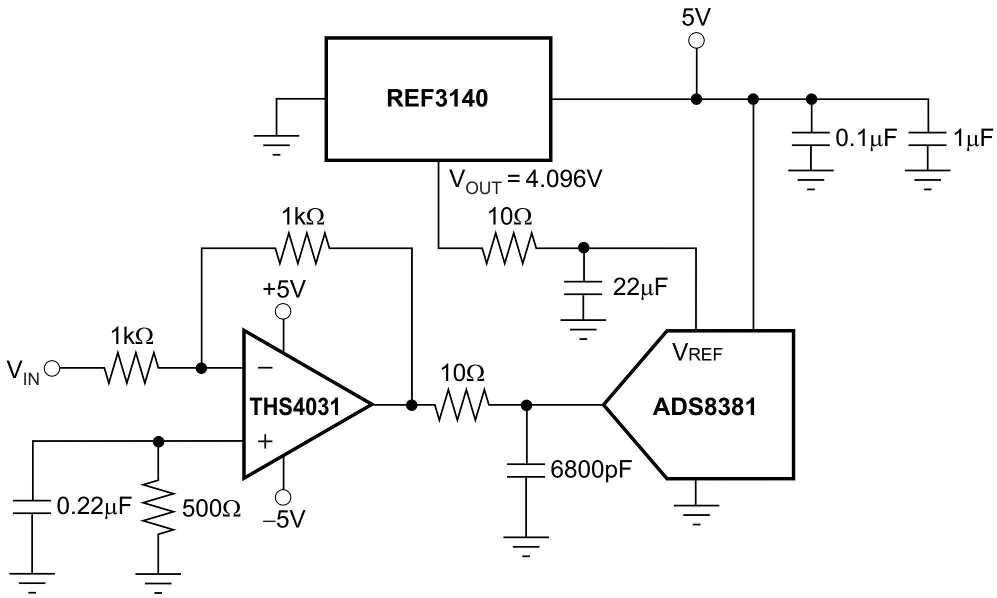


Figure 7-8. REF3140 Provides an Accurate Reference for Driving the ADS8381

8 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.

8.1 Application Information

The REF31xx does not require a load capacitor and is stable with any capacitive load. Figure 8-1 shows typical connections required for operation of the REF31xx. TI recommends a supply bypass capacitor of 0.47µF.

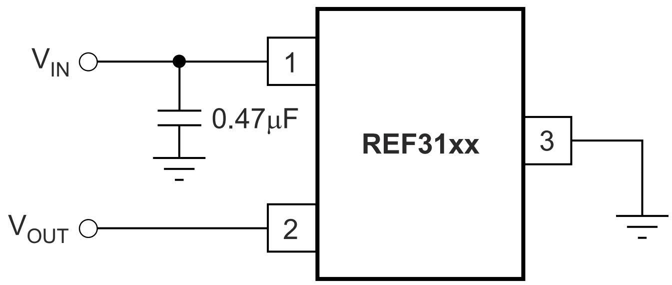


Figure 8-1. Typical Connections for Operating REF31xx

8.2 Typical Application

Figure 8-2 shows a low-power reference and conditioning circuit. This circuit attenuates and level-shifts a bipolar input voltage within the proper input range of a single-supply, low-power, 16-bit ΔΣ ADC, such as the one inside the MSP430™ or other similar single-supply ADCs. Precision reference circuits are used to level-shift the input signal, provide the ADC reference voltage, and to create a well-regulated supply voltage for the low-power analog circuitry. A low-power, zero-drift, op-amp circuit is used to attenuate and level-shift the input signal.

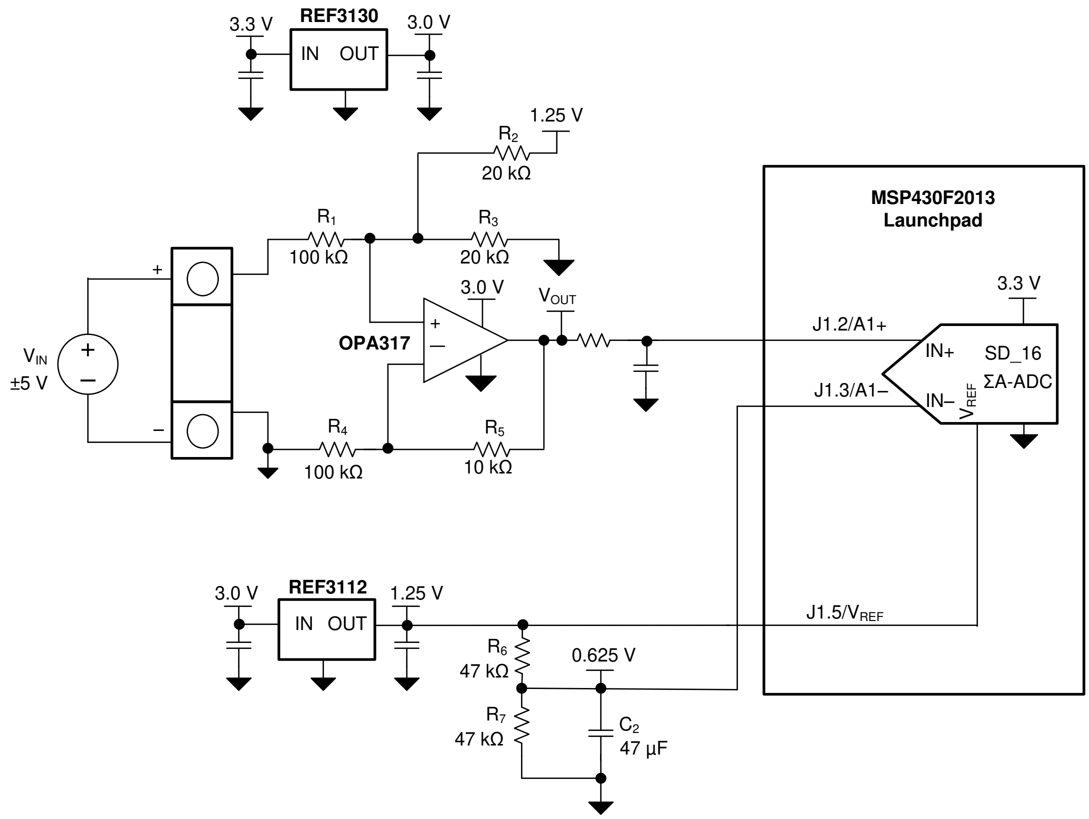


Figure 8-2. Low-Power Reference and Bipolar Voltage Conditioning Circuit for Low-Power ADCs

8.2.1 Design Requirements

- Supply Voltage: 3.3V
- Maximum Input Voltage: ±6V
- Specified Input Voltage: ±5V
- ADC Reference Voltage: 1.25V

The goal for this design is to accurately condition a ±5V bipolar input voltage into a voltage suitable for conversion by a low-voltage ADC with a 1.25V reference voltage, V_{REF}, and an input voltage range of V_{REF} / 2. The circuit should function with reduced performance over a wider input range of at least ±6V to allow for easier protection of overvoltage conditions.

8.2.2 Detailed Design Procedure

Figure 8-2 depicts a simplified schematic for this design showing the MSP430 ADC inputs and full input conditioning circuitry. The ADC is configured for a bipolar measurement where final conversion result is the differential voltage between the voltage at the positive and negative ADC inputs. The bipolar, GND-referenced input signal must be level-shifted and attenuated by the op amp so that the output is biased to VREF/2 and has a differential voltage that is within the ±VREF/2 input range of the ADC.

8.2.3 Application Curves

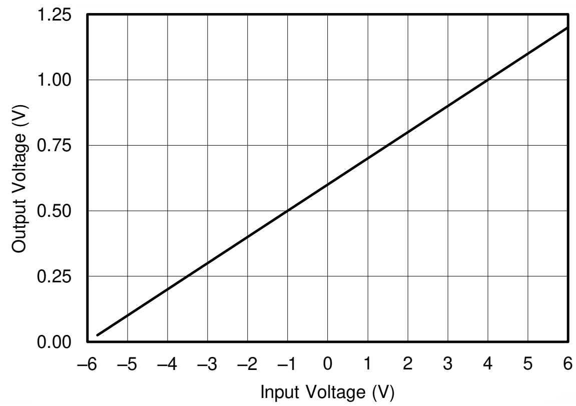


Figure 8-3. OPA317 Output Voltage vs Input Voltage

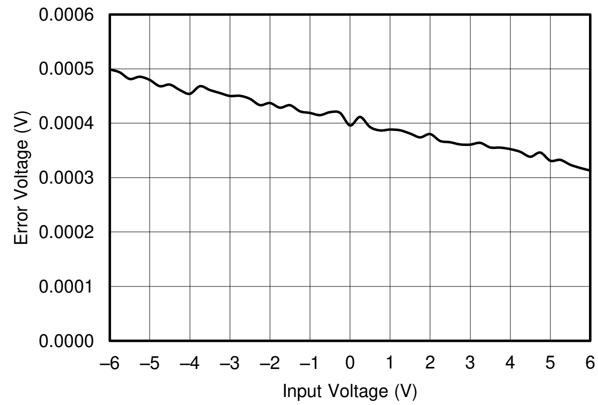


Figure 8-4. OPA317 Output Voltage Error vs Input Voltage

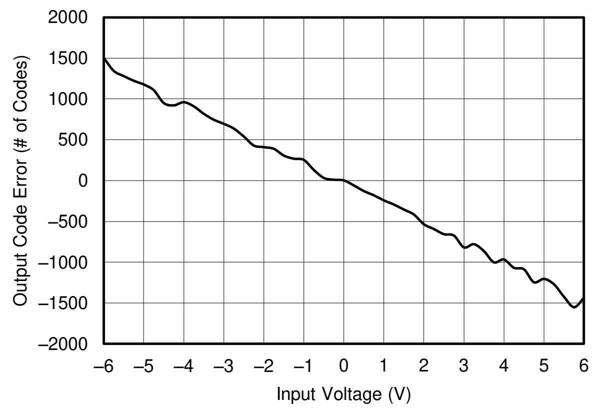


Figure 8-5. Output Code Error vs Input Voltage

8.3 Power Supply Recommendations

The REF31xx family of references features an extremely low dropout voltage. With the exception of the REF3112, which has a minimum supply requirement of 1.8V, these references can be operated with a supply of only 5mV above the output voltage in an unloaded condition. For loaded conditions, a typical dropout voltage versus load is shown in the front page plot, Dropout Voltage vs Load Current. TI recommends a supply bypass capacitor greater than 0.47µF.

8.4 Layout

8.4.1 Layout Guidelines

Figure 8-6 illustrates an example of a printed-circuit board (PCB) layout using the REF31xx. Some key considerations are:

- Connect low-ESR, 0.47µF ceramic bypass capacitors at V_{IN} of the REF31xx
- Decouple other active devices in the system per the device specifications
- Use a solid ground plane to help 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
- Minimize trace length between the reference and bias connections to the INA and ADC to reduce noise pickup
- Do not run sensitive analog traces in parallel with digital traces. Avoid crossing digital and analog traces if possible, and only make perpendicular crossings when absolutely necessary

8.4.2 Layout Example

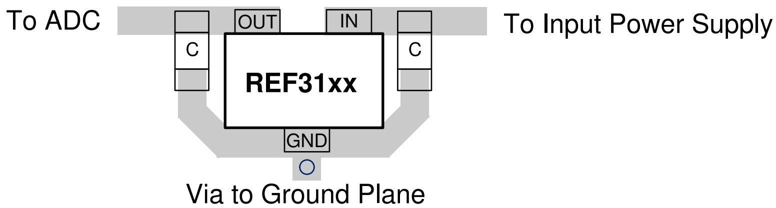


Figure 8-6. Layout Example

9 Device and Documentation Support

9.1 Device Support

For device support, see the following:

Texas Instruments, MSP430 MSP 16-bit and 32-bit Microcontrollers

9.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on 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.

9.3 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.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

9.4 Trademarks

MSP430™ and TI E2E™ are trademarks of Texas Instruments.
All trademarks are the property of their respective owners.

9.5 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.

9.6 Glossary

TI Glossary — This glossary lists and explains terms, acronyms, and definitions.

10 Revision History

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

Changes from Revision D (January 2013) to Revision E (April 2026) — **Page**

- Updated the numbering format for tables, figures, and cross-references throughout the document................. 1
- Moved the REF3112, REF3120, REF3125, REF3130, REF3133, and REF3140 devices to the REF31 product folder on TI.com and updated the datasheet header...1
- Changed *Device Information* table to *Package Information* 1
- Updated bypass capacitor requirements to be consistent across this datasheet...20

Changes from Revision C (February 2006) to Revision D (January 2013) — **Page**

- Added the *Device Information* table, the *Thermal Information* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section.. 1
- Removed the *Ordering Information* table 1
- Moved and updated the SOT23-3 surface mount thermal resistance data from the *Electrical Characteristics* table to the *Thermal Information* table...5

- Removed the boldface type in the *Electrical Characteristics* table and identified when limits apply over the specified temperature range T_A = –40°C to +125°C in the test conditions column 5
- Added Figure 6-19 8

11 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.