



## 15ppm/°C Max, 100µA, SOT23-3 SERIES VOLTAGE REFERENCE

### FEATURES

- **MicroSIZE PACKAGE:** SOT23-3
- **LOW DROPOUT:** 5mV
- **HIGH OUTPUT CURRENT:** ±10mA
- **HIGH ACCURACY:** 0.2% max
- **LOW I<sub>Q</sub>:** 115µA max
- **EXCELLENT SPECIFIED DRIFT PERFORMANCE:**
  - 15ppm/°C (max) from 0°C to +70°C
  - 20ppm/°C (max) from -40°C to +125°C

### APPLICATIONS

- PORTABLE, BATTERY-POWERED EQUIPMENT
- DATA ACQUISITION SYSTEMS
- MEDICAL EQUIPMENT
- HAND-HELD TEST EQUIPMENT

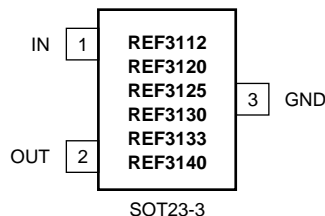
### DESCRIPTION

The REF31xx is a family of precision, low power, low dropout, series voltage references available in the tiny SOT23-3 package.

The REF31xx's small size and low power consumption (100µA typ) make it ideal for portable and battery-powered applications. The REF31xx does not require a load capacitor, but is stable with any capacitive load and can sink/source up to 10mA of output current.

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

PRODUCT	VOLTAGE (V)
REF3112	1.25
REF3120	2.048
REF3125	2.5
REF3130	3.0
REF3133	3.3
REF3140	4.096



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

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

Supply Voltage, V+ to V- .....	7.0V
Output Short-Circuit .....	Continuous
Operating Temperature .....	-55°C to +135°C
Storage Temperature .....	-65°C to +150°C
Junction Temperature .....	+150°C
Lead Temperature (soldering, 10s) .....	+300°C

NOTES: (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.



## ELECTROSTATIC DISCHARGE SENSITIVITY

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.

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

PRODUCT	PACKAGE-LEAD	PACKAGE DESIGNATOR	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
REF3112	SOT23-3	DBZ	-40°C to +125°C	R31A	REF3112AIDBZT	Tape and Reel, 250
"	"	"	"	"	REF3112AIDBZR	Tape and Reel, 3000
REF3120	SOT23-3	DBZ	-40°C to +125°C	R31B	REF3120AIDBZT	Tape and Reel, 250
"	"	"	"	"	REF3120AIDBZR	Tape and Reel, 3000
REF3125	SOT23-3	DBZ	-40°C to +125°C	R31C	REF3125AIDBZT	Tape and Reel, 250
"	"	"	"	"	REF3125AIDBZR	Tape and Reel, 3000
REF3130	SOT23-3	DBZ	-40°C to +125°C	R31E	REF3130AIDBZT	Tape and Reel, 250
"	"	"	"	"	REF3130AIDBZR	Tape and Reel, 3000
REF3133	SOT23-3	DBZ	-40°C to +125°C	R31F	REF3133AIDBZT	Tape and Reel, 250
"	"	"	"	"	REF3133AIDBZR	Tape and Reel, 3000
REF3140	SOT23-3	DBZ	-40°C to +125°C	R31D	REF3140AIDBZT	Tape and Reel, 250
"	"	"	"	"	REF3140AIDBZR	Tape and Reel, 3000

NOTES: (1) For the most current package and ordering information, see the Package Option Addendum located at the end of this data sheet.

## ELECTRICAL CHARACTERISTICS

**Boldface** limits apply over the specified temperature range,  $T_A = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ .

At  $T_A = +25^\circ\text{C}$ ,  $I_{\text{LOAD}} = 0\text{mA}$ ,  $V_{\text{IN}} = 5\text{V}$ , unless otherwise noted.

PARAMETER	CONDITIONS	REF31xx			UNITS
		MIN	TYP	MAX	
<b>REF3112<sup>(1)</sup> - 1.25V</b>					
<b>OUTPUT VOLTAGE</b> Initial Accuracy	$V_{\text{OUT}}$	1.2475 -0.2	1.25	1.2525 0.2	V %
<b>NOISE</b> Output Voltage Noise Voltage Noise	$f = 0.1\text{Hz to }10\text{Hz}$ $f = 10\text{Hz to }10\text{kHz}$		17 24		$\mu\text{V}_{\text{PP}}$ $\mu\text{V}_{\text{rms}}$
<b>REF3120 - 2.048</b>					
<b>OUTPUT VOLTAGE</b> Initial Accuracy	$V_{\text{OUT}}$	2.0439 -0.2	2.048	2.0521 0.2	V %
<b>NOISE</b> Output Voltage Noise Voltage Noise	$f = 0.1\text{Hz to }10\text{Hz}$ $f = 10\text{Hz to }10\text{kHz}$		27 39		$\mu\text{V}_{\text{PP}}$ $\mu\text{V}_{\text{rms}}$
<b>REF3125 - 2.5V</b>					
<b>OUTPUT VOLTAGE</b> Initial Accuracy	$V_{\text{OUT}}$	2.4950 -0.2	2.50	2.5050 0.2	V %
<b>NOISE</b> Output Voltage Noise Voltage Noise	$f = 0.1\text{Hz to }10\text{Hz}$ $f = 10\text{Hz to }10\text{kHz}$		33 48		$\mu\text{V}_{\text{PP}}$ $\mu\text{V}_{\text{rms}}$

# ELECTRICAL CHARACTERISTICS

**Boldface** limits apply over the specified temperature range,  $T_A = -40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

At  $T_A = +25^{\circ}\text{C}$ ,  $I_{\text{LOAD}} = 0\text{mA}$ ,  $V_{\text{IN}} = +5\text{V}$ , unless otherwise noted.

PARAMETER	CONDITIONS	REF31xx			UNITS
		MIN	TYP	MAX	
<b>REF3130 – 3.0V</b>					
<b>OUTPUT VOLTAGE</b> Initial Accuracy	$V_{\text{OUT}}$	2.9940 -0.2	3.0	3.0060 0.2	V %
<b>NOISE</b> Output Voltage Noise Voltage Noise	$f = 0.1\text{Hz to }10\text{Hz}$ $f = 10\text{Hz to }10\text{kHz}$		39 57		$\mu\text{V}_{\text{PP}}$ $\mu\text{V}_{\text{RMS}}$
<b>REF3133 – 3.3V</b>					
<b>OUTPUT VOLTAGE</b> Initial Accuracy	$V_{\text{OUT}}$	3.2934 -0.2	3.30	3.3066 0.2	V %
<b>NOISE</b> Output Voltage Noise Voltage Noise	$f = 0.1\text{Hz to }10\text{Hz}$ $f = 10\text{Hz to }10\text{kHz}$		43 63		$\mu\text{V}_{\text{PP}}$ $\mu\text{V}_{\text{RMS}}$
<b>REF3140 – 4.096V</b>					
<b>OUTPUT VOLTAGE</b> Initial Accuracy	$V_{\text{OUT}}$	4.0878 -0.2	4.096	4.1042 0.2	V %
<b>NOISE</b> Output Voltage Noise Voltage Noise	$f = 0.1\text{Hz to }10\text{Hz}$ $f = 10\text{Hz to }10\text{kHz}$		53 78		$\mu\text{V}_{\text{PP}}$ $\mu\text{V}_{\text{RMS}}$
<b>REF3112, REF3120, REF3125, REF3130, REF3133, REF3140</b>					
<b>OUTPUT VOLTAGE TEMP DRIFT<sup>(2)</sup></b> $dV_{\text{OUT}}/dT$	$0^{\circ}\text{C} \leq T_A \leq +70^{\circ}\text{C}$ $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$		<b>5</b> <b>10</b>	<b>15</b> <b>20</b>	<b>ppm/°C</b> <b>ppm/°C</b>
<b>LONG-TERM STABILITY</b>	0-1000h		70		ppm
<b>LINE REGULATION</b>	$V_{\text{REF}} + 0.05^{(1)} \leq V_{\text{IN}} \leq 5.5\text{V}$		20	65	ppm/V
<b>LOAD REGULATION<sup>(3)</sup></b> $dV_{\text{OUT}}/dI_{\text{LOAD}}$	$0\text{mA} < I_{\text{LOAD}} < 10\text{mA}$ , $V_{\text{IN}} = V_{\text{REF}} + 250\text{mV}^{(1)}$ Sourcing $-10\text{mA} < I_{\text{LOAD}} < 0\text{mA}$ , $V_{\text{IN}} = V_{\text{REF}} + 100\text{mV}^{(1)}$ Sinking		10 20	30 50	$\mu\text{V}/\text{mA}$ $\mu\text{V}/\text{mA}$
<b>THERMAL HYSTERESIS<sup>(4)</sup></b> First Cycle Additional Cycles	dT		100 25		ppm ppm
<b>DROPOUT VOLTAGE<sup>(1)</sup></b> $V_{\text{IN}} - V_{\text{OUT}}$			<b>5</b>	<b>50</b>	<b>mV</b>
<b>OUTPUT CURRENT</b> $I_{\text{LOAD}}$		-10		10	mA
<b>SHORT-CIRCUIT CURRENT</b> $I_{\text{SC}}$ Sourcing Sinking			50 40		mA mA
<b>TURN-ON SETTLING TIME</b>	to 0.1% at $V_{\text{IN}} = +5\text{V}$ with $C_L = 0$		400		$\mu\text{s}$
<b>POWER SUPPLY</b> <b>Voltage</b> $V_S$ <b>Quiescent Current</b> $I_Q$ <b>Over Temperature</b>	$I_L = 0$	$V_{\text{REF}} + 0.05^{(1)}$	100 <b>115</b>	115 <b>135</b>	V $\mu\text{A}$ $\mu\text{A}$
<b>TEMPERATURE RANGE</b> Specified Range Operating Range Storage Range Thermal Resistance SOT23-3 Surface-Mount $\theta_{\text{JA}}$		-40 -55 -65		+125 +135 +150	°C °C °C °C/W

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

(2) Box Method used to determine temperature drift.

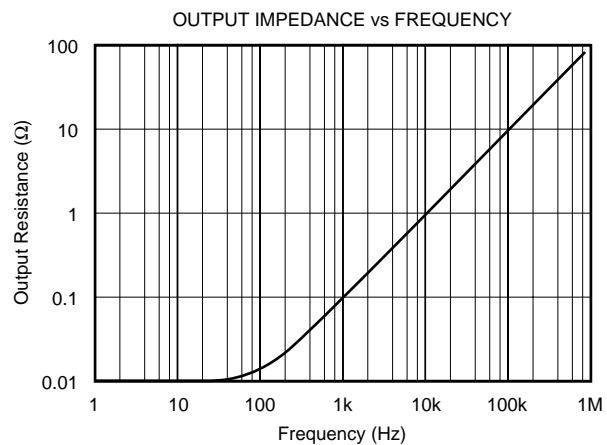
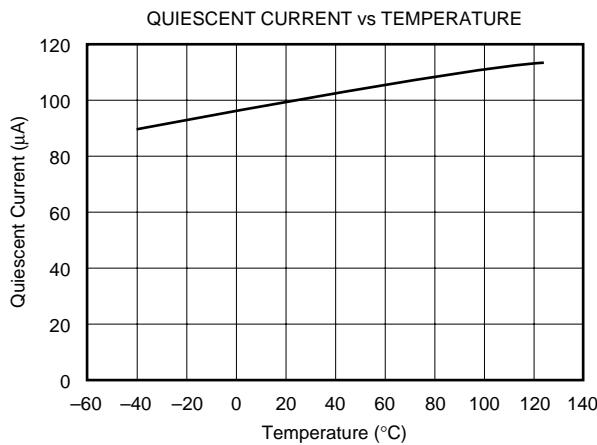
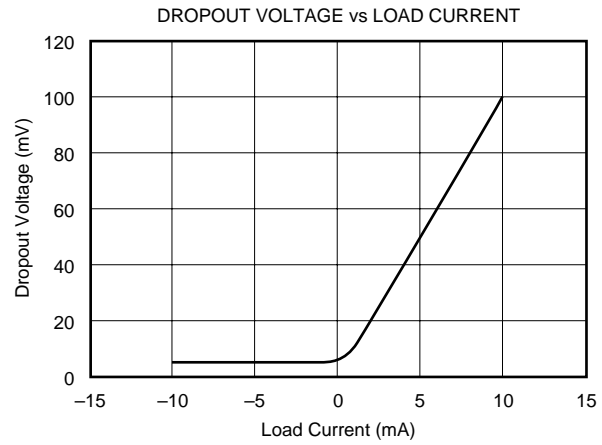
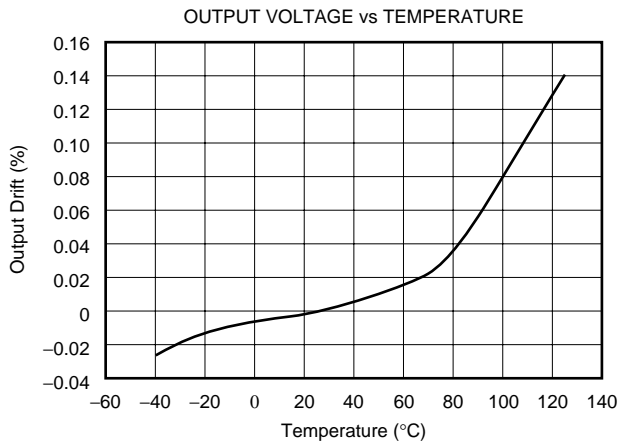
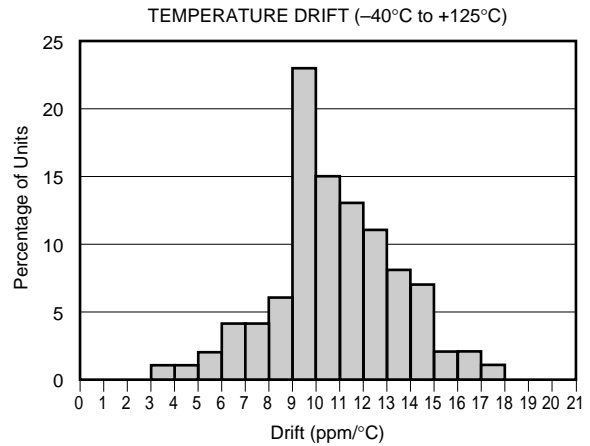
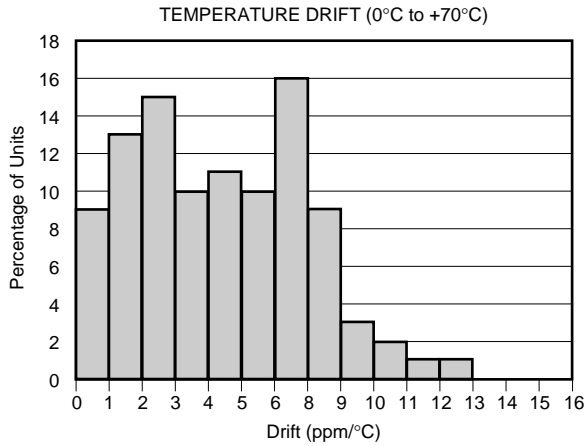
(3) Typical value of load regulation reflects measurements using force and sense contacts, see section *Load Regulation*.

(4) Thermal hysteresis is explained in more detail in Applications Information section of data sheet.

(5) For  $I_L > 0$ , see Typical Characteristic curves.

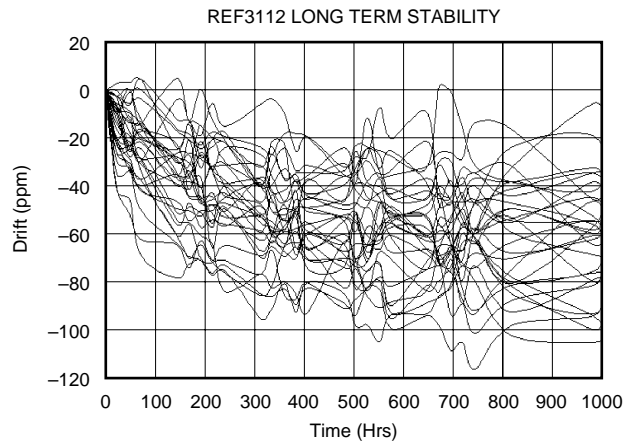
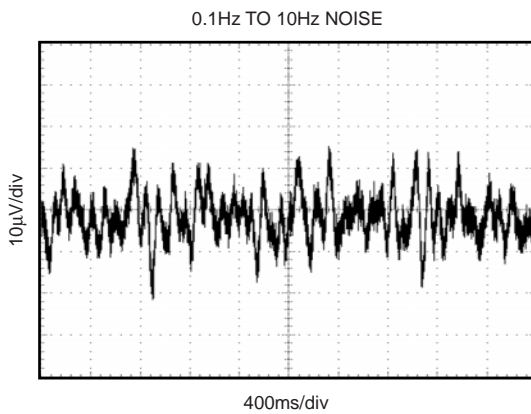
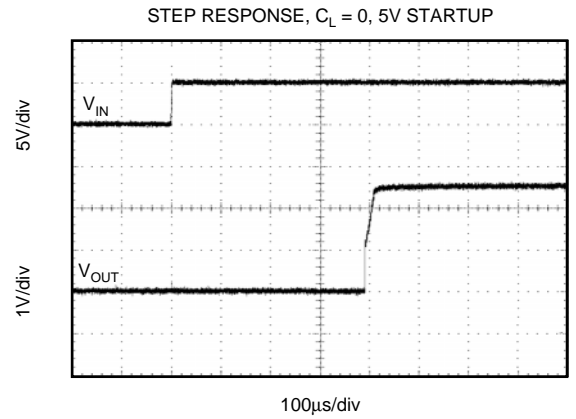
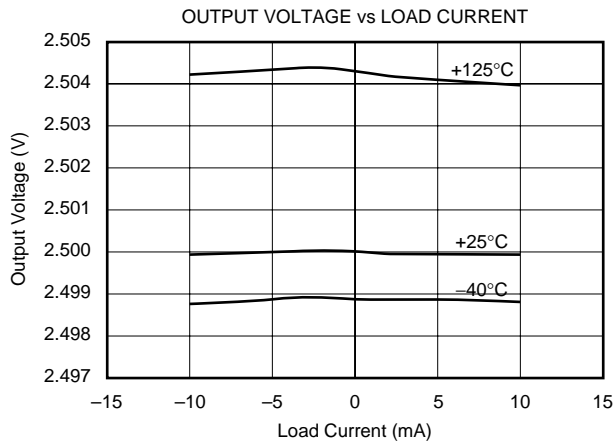
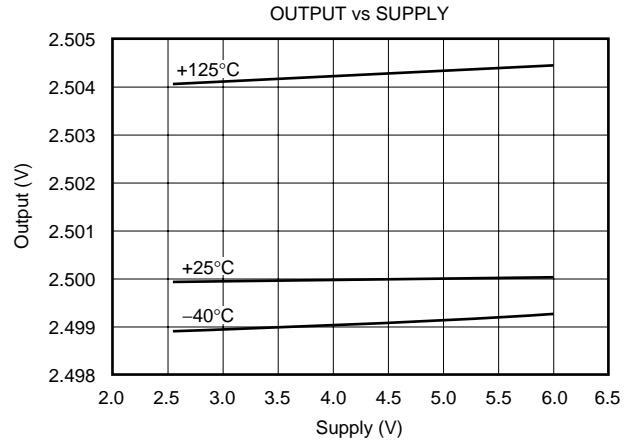
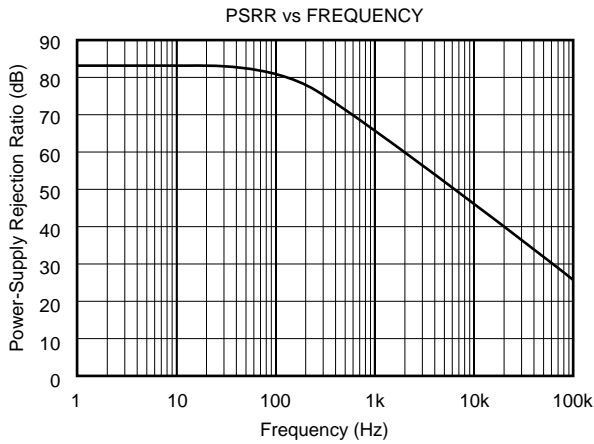
# TYPICAL CHARACTERISTICS

At  $T_A = +25^\circ\text{C}$ ,  $V_{IN} = +5\text{V}$  power supply, REF3125 is used for typical characteristics, unless otherwise noted.



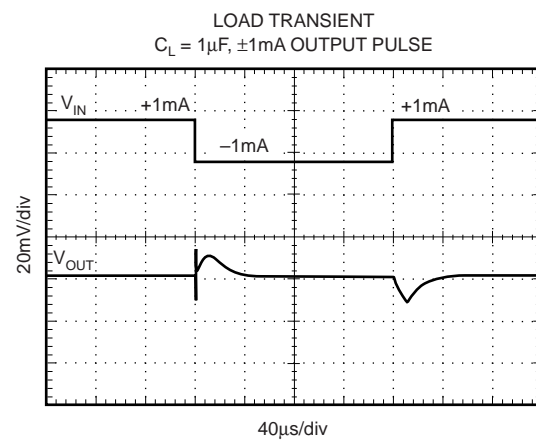
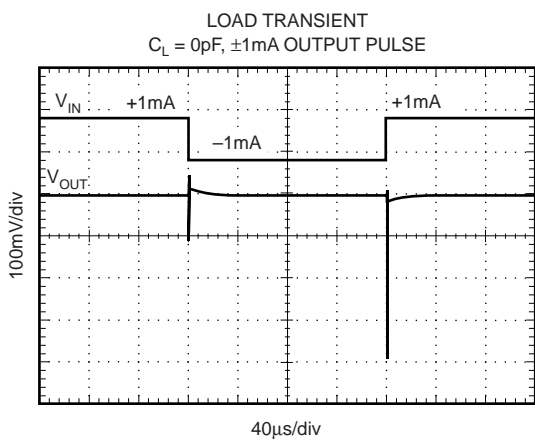
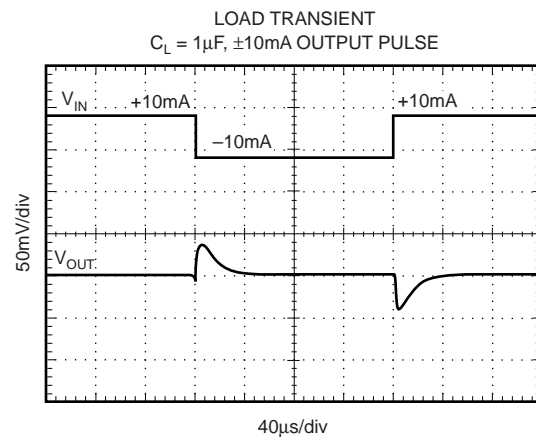
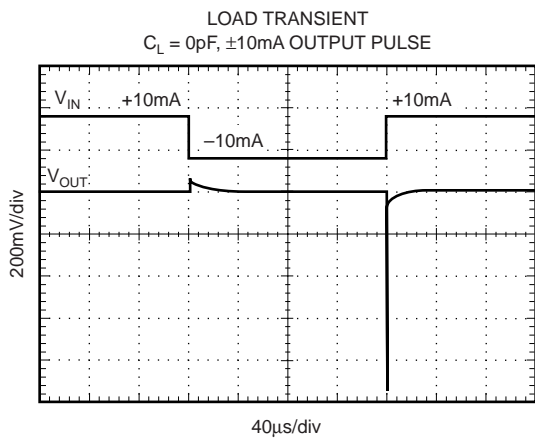
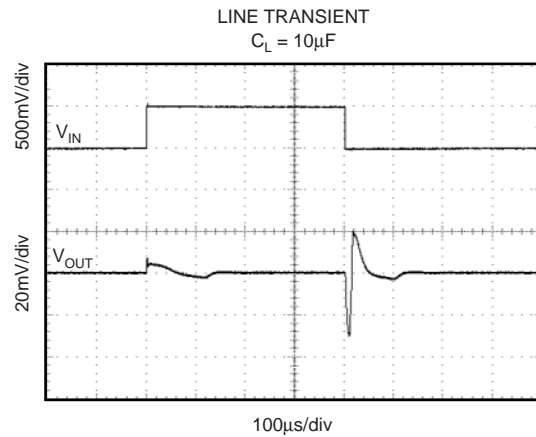
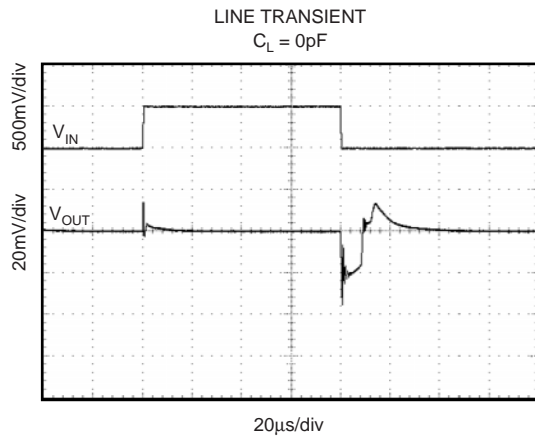
# TYPICAL CHARACTERISTICS (Cont.)

At  $T_A = +25^\circ\text{C}$ ,  $V_{IN} = +5\text{V}$  power supply, REF3125 is used for typical characteristics, unless otherwise noted.



# TYPICAL CHARACTERISTICS (Cont.)

At  $T_A = +25^\circ\text{C}$ ,  $V_{IN} = +5\text{V}$  power supply, REF3125 is used for typical characteristics, unless otherwise noted.



# THEORY OF OPERATION

The REF31xx is a family of series, CMOS, precision bandgap voltage references. The basic bandgap topology is shown in Figure 1. 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,  $V_{be1} - V_{be2}$ , 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.

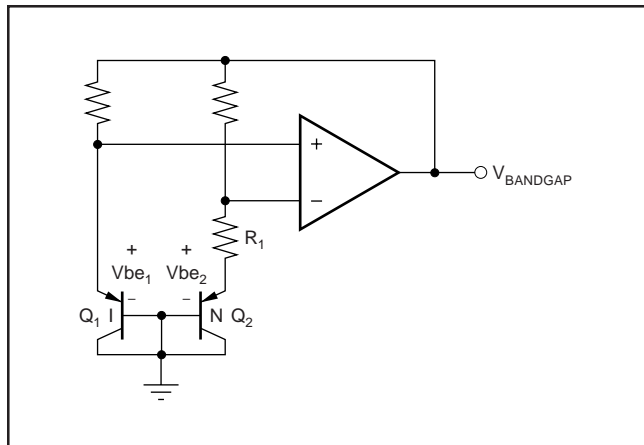


FIGURE 1. Simplified Schematic of Bandgap Reference.

## APPLICATION INFORMATION

The REF31xx does not require a load capacitor and is stable with any capacitive load. Figure 2 shows typical connections required for operation of the REF31xx. A supply bypass capacitor of  $0.47\mu\text{F}$  is recommended.

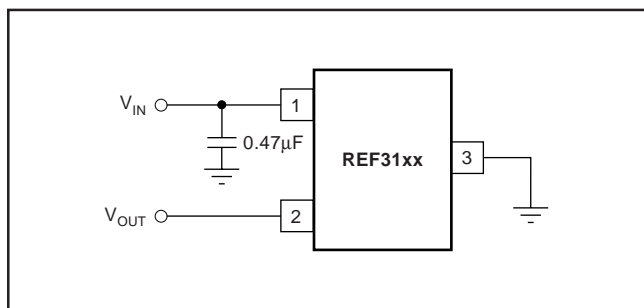


FIGURE 2. Typical Connections for Operating REF31xx.

### 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 the typical curves.

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

$100\mu\text{A}$ , and the maximum quiescent current over temperature is just  $135\mu\text{A}$ . The quiescent current typically changes less than  $2\mu\text{A}$  over the entire supply range, as shown in Figure 3.

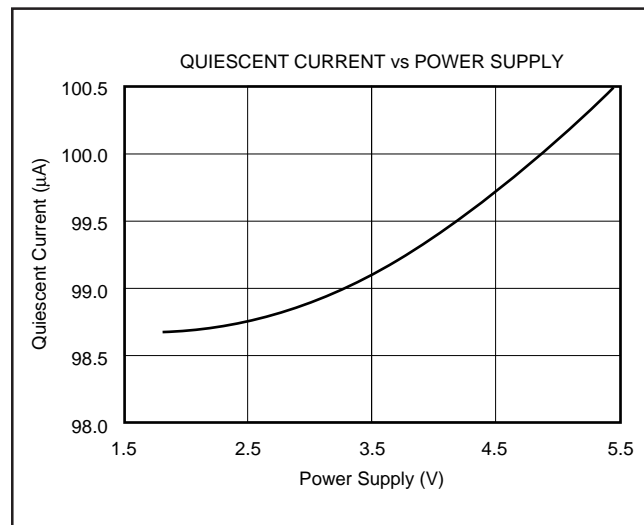


FIGURE 3. Supply Current vs Supply Voltage.

Supply voltages below the specified levels can cause the 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.

### THERMAL HYSTERESIS

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

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

Where:  $V_{\text{HYST}}$  = Thermal hysteresis

$V_{\text{PRE}}$  = Output voltage measured at  $25^\circ\text{C}$  pre-temperature cycling

$V_{\text{POST}}$  = Output voltage measured after the device has been cycled through the specified temperature range of  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$  and returned to  $25^\circ\text{C}$ .

### 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 by the following equation:

$$\left( \frac{V_{\text{OUTMAX}} - V_{\text{OUTMIN}}}{V_{\text{OUT}} \cdot \text{TemperatureRange}} \right) \cdot 10^6 \text{ppm}$$

The REF31xx features a typical drift coefficient of 5ppm from  $0^\circ\text{C}$  to  $70^\circ\text{C}$ —the primary temperature range for many applications. For the industrial temperature range of  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ , the REF31xx family drift increases to a typical value of 10ppm.

## NOISE PERFORMANCE

Typical 0.1Hz to 10Hz voltage noise can be seen in the Typical Characteristic Curve, *0.1 to 10Hz Voltage Noise*. The noise voltage of the REF31xx increases with output voltage and operating temperature. Additional filtering may be used to improve output noise levels, although care should be taken to ensure the output impedance does not degrade the AC performance.

## LONG-TERM STABILITY

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

## 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 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 should be used.

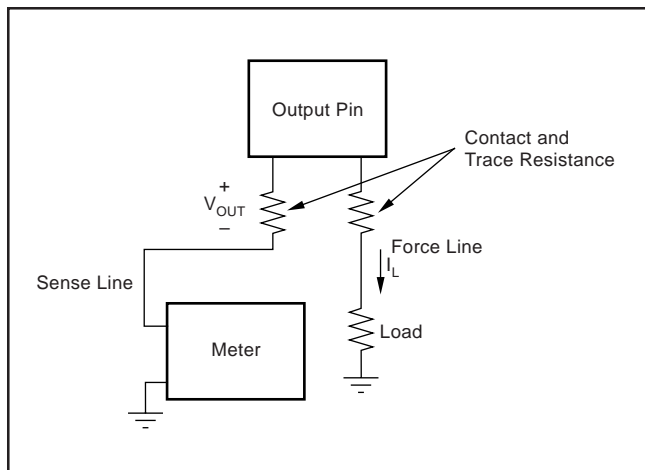


FIGURE 4. Accurate Load Regulation of REF31xx.

# APPLICATION CIRCUITS

## 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  $\pm 5V$  supply. Figure 5 shows the REF3125 used to provide a  $\pm 2.5V$  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.

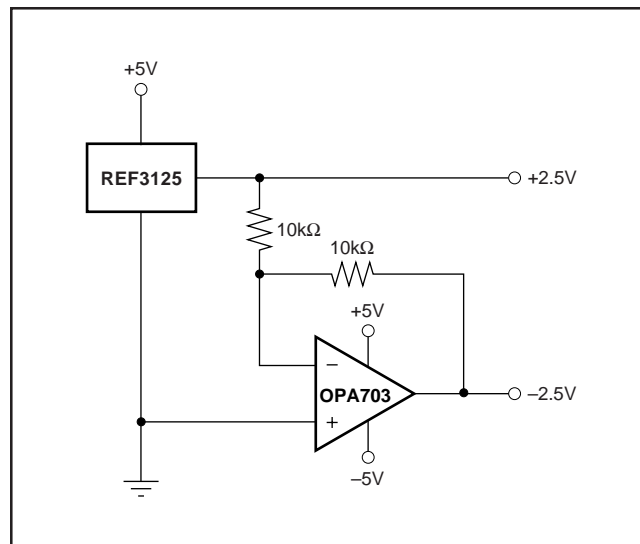


FIGURE 5. REF3125 Combined with OPA703 to Create Positive and Negative Reference Voltages.

## 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 micro-controllers and data converters. Figure 6, Figure 7, and Figure 8 show basic data acquisition systems.



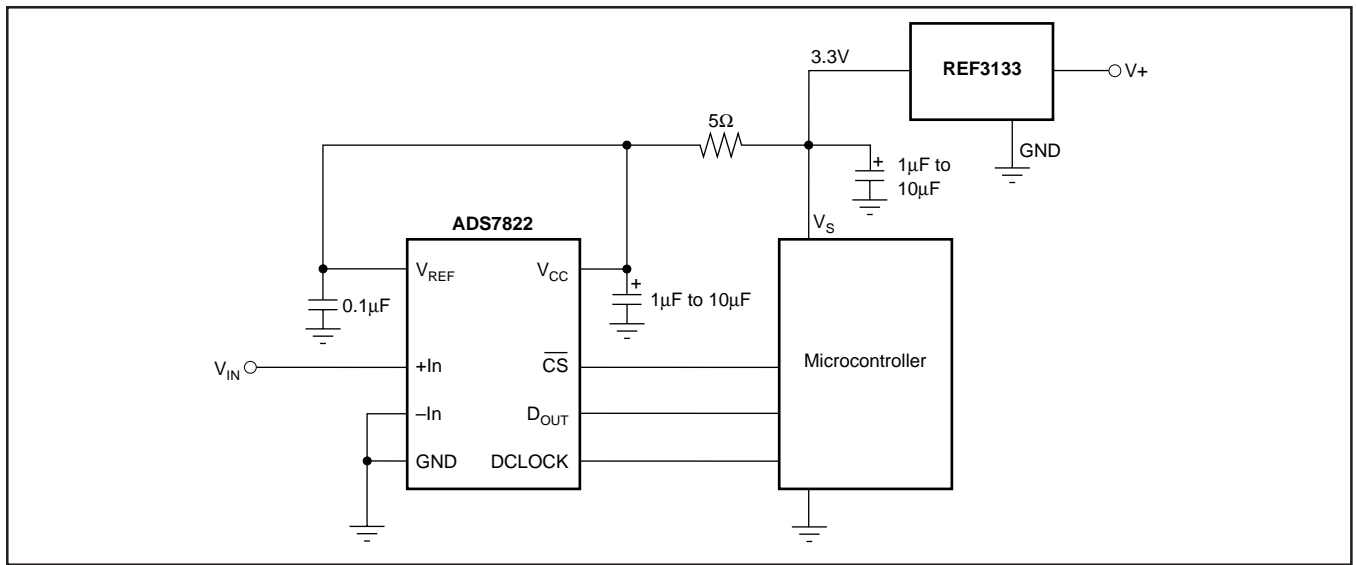


FIGURE 6. Basic Data Acquisition System 1.

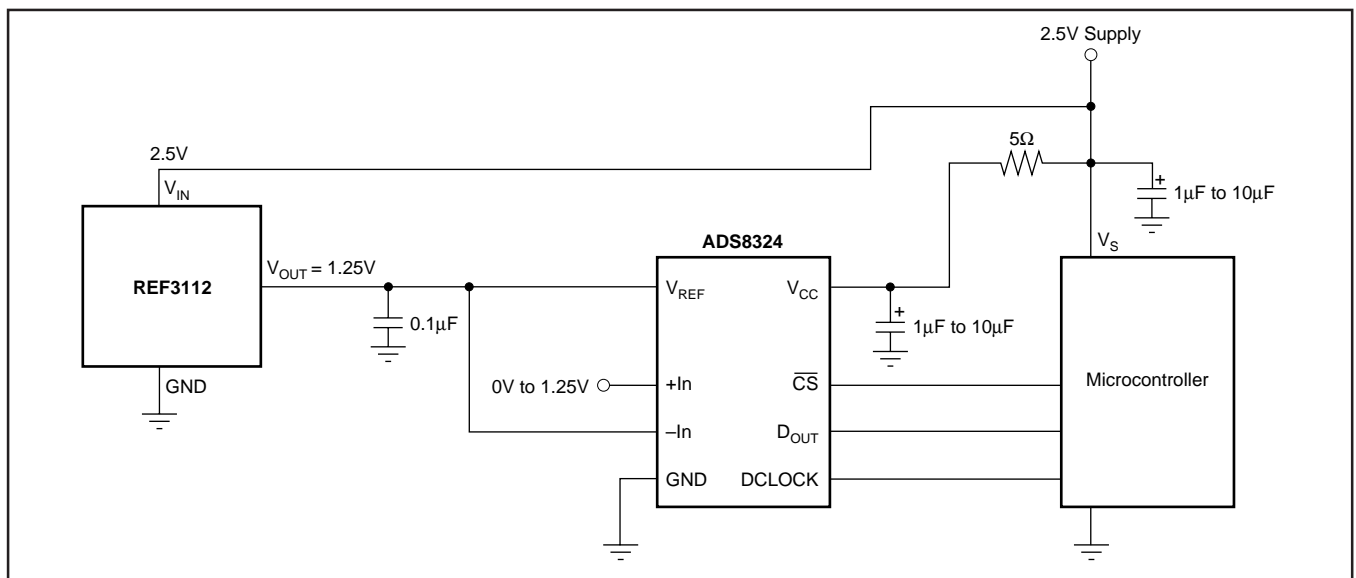


FIGURE 7. Basic Data Acquisition System 2.

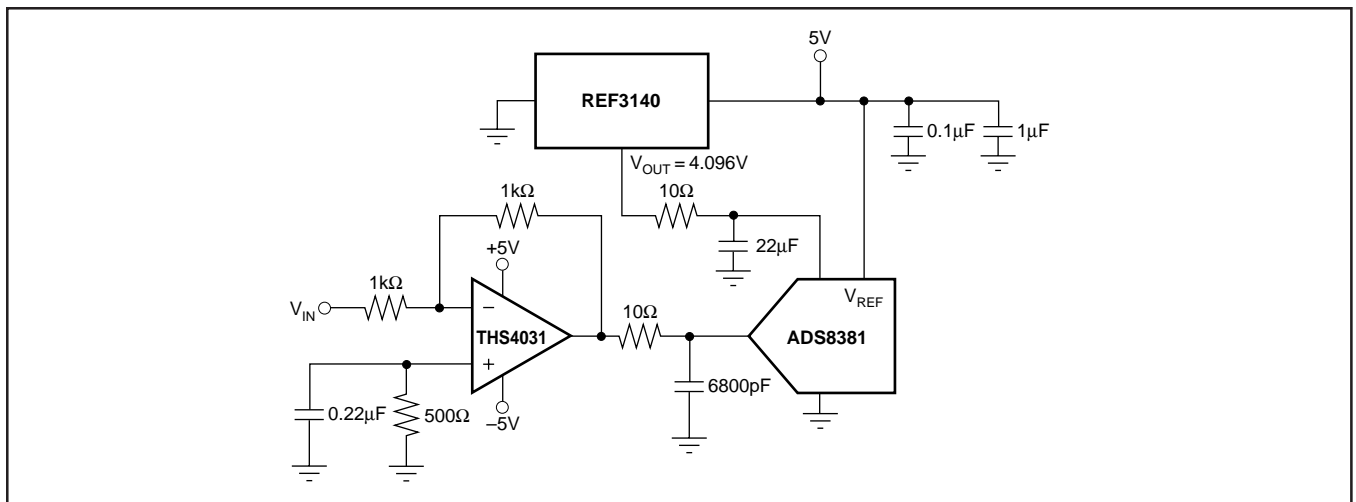
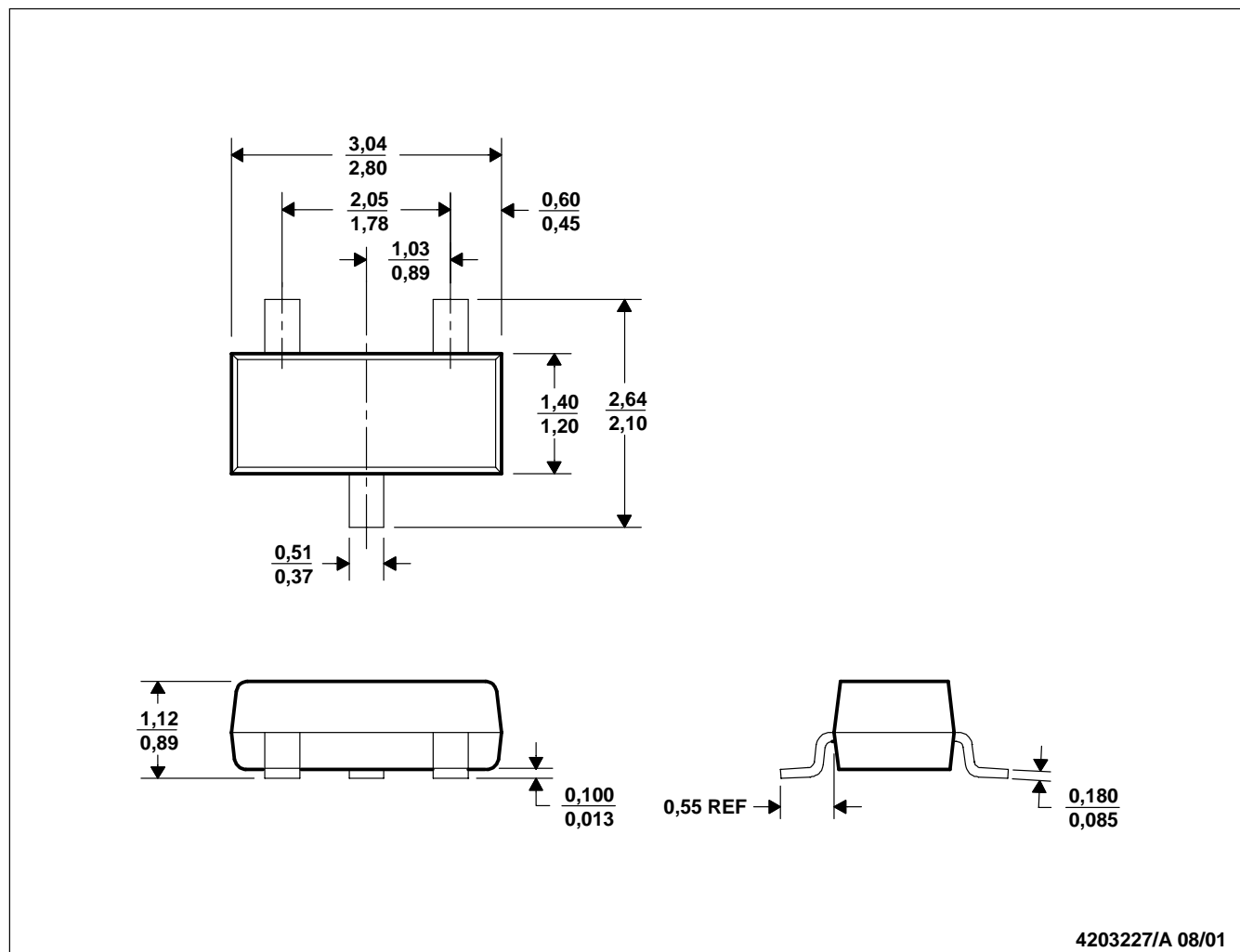


FIGURE 8. REF3140 Provides an Accurate Reference for Driving the ADS8381.

DBZ (R-PDSO-G3)

PLASTIC SMALL-OUTLINE



- NOTES: A. All linear dimensions are in millimeters.  
 B. This drawing is subject to change without notice.  
 C. Dimensions are inclusive of plating.  
 D. Dimensions are exclusive of mold flash and metal burr.

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