50 ppm/°C MAX, 50 μA, CMOS VOLTAGE REFERENCE

Check for Samples: REF3033-Q1

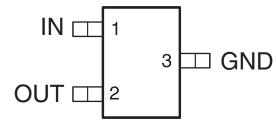
FEATURES

- **Qualified for Automotive Applications**
- **Low Dropout Voltage: 1 mV**
- **High Output Current: 25 mA**
- **High Accuracy: 0.2%**
- **Low Quiescent Current: 50 μA (Max)**
- **Excellent Specified Drift Performance**
  - **50 ppm/°C (Max), T_A = 0°C to 70°C**
  - **75 ppm/°C (Max), T_A = –40°C to 85°C**

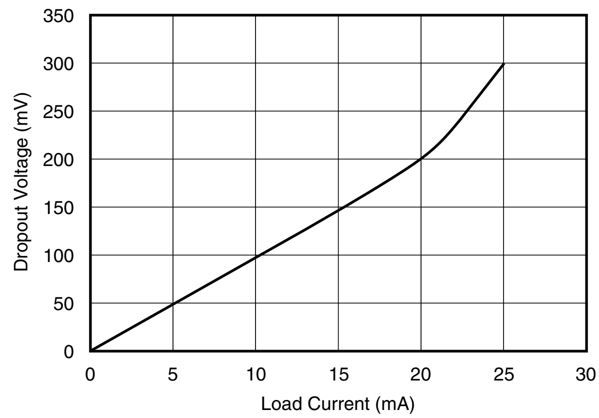
APPLICATIONS

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

DBZ PACKAGE (TOP VIEW)



DROPOUT VOLTAGE vs LOAD CURRENT



DESCRIPTION

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

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

Unloaded, the REF30xx can be operated with supplies within 1 mV of output voltage. The device is specified for the temperature range of –40°C to 85°C.

ORDERING INFORMATION(1)

T_A	PACKAGE(2)		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	SOT-23 – DBV	Reel of 3000	REF3033AIDBZRQ1	REFI

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

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

ABSOLUTE MAXIMUM RATINGS(1)

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

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

ELECTRICAL CHARACTERISTICS

Boldface limits apply over the specified temperature range, **T_A = –40°C to 85°C.**
T_A = 25°C, I_{LOAD} = 0, V_{IN} = 5 V (unless otherwise noted)

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNIT
OUTPUT VOLTAGE						
Output voltage	V_{OUT}	2.7 V < V_{IN} < 18 V	3.294	3.3	3.306	V
Initial accuracy					0.2	%
NOISE						
Output voltage noise		f = 0.1 Hz to 10 Hz		36		μV_{PP}
Voltage noise		f = 10 Hz to 10 kHz		105		μVrms
LINE REGULATION		V_{REF} + 50 mV ≤ V_{IN} ≤ 5.5 V		130	400	μV/V
OUTPUT VOLTAGE TEMPERATURE DRIFT(1)	**dV_{OUT}/dT**					
		0°C ≤ T_A ≤ 70°C		**20**	**50**	**ppm/°C**
		–30°C ≤ T_A ≤ 85°C		**28**	**60**	**ppm/°C**
		–40°C ≤ T_A ≤ 85°C		**30**	**65**	**ppm/°C**
LONG-TERM STABILITY						
		0 to 1000 h		24		ppm
		1000 h to 2000 h		15		ppm
LOAD REGULATION(2)	dV_{OUT}/dI_{LOAD}	0 mA < I_{LOAD} < 25 mA V_{IN} = V_{REF} + 500 mV		3	100	μV/mA
THERMAL HYSTERESIS(3)	dT			25	100	ppm
DROPOUT VOLTAGE	$V_{IN} – V_{OUT}$			1	50	mV
SHORT-CIRCUIT CURRENT	I_{SC}			45		mA
TURN-ON SETTLING TIME		To 0.1%, V_{IN} = 5 V, C_L = 1 μF		120		μs

(1) Box Method used to determine over temperature drift.
(2) Typical value of load regulation reflects measurements using a force and sense contacts, see Load Regulation in *Application Information*.
(3) For more detail on the thermal hysteresis procedure, see Thermal Hysteresis in *Application Information*.

ELECTRICAL CHARACTERISTICS (continued)

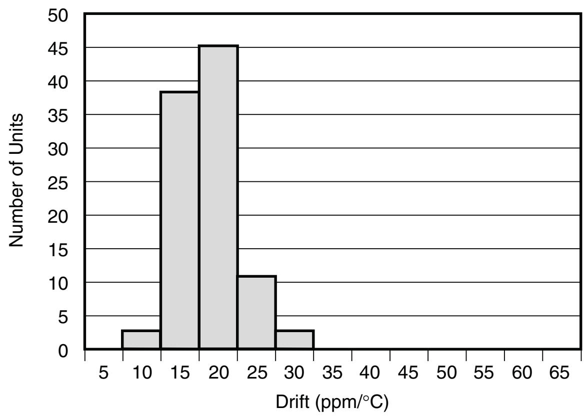
Boldface limits apply over the specified temperature range, **T_A = –40°C to 85°C.**
T_A = 25°C, I_{LOAD} = 0, V_{IN} = 5 V (unless otherwise noted)

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNIT
POWER SUPPLY						
Supply voltage	V_S	I_{LOAD} = 0(4)	V_{REF} + 0.001		5.5	V
Over temperature		**–40°C ≤ T_A ≤ 85°C**	**V_{REF} + 0.05**		**5.5**	
Quiescent current				42	50	μA
Over temperature		**–40°C ≤ T_A ≤ 85°C**			**59**	**μA**
TEMPERATURE RANGE						
Specified range			–40		85	°C
Operating range			–40		85	°C
Thermal resistance						
Junction to case	θ_{JC}			110		°C/W
Junction to free air	θ_{JA}			336		°C/W

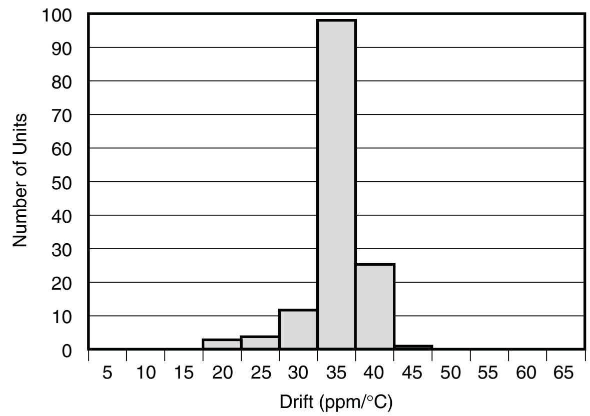
(4) For I_{LOAD} > 0, see *Typical Characteristics*.

TYPICAL CHARACTERISTICS

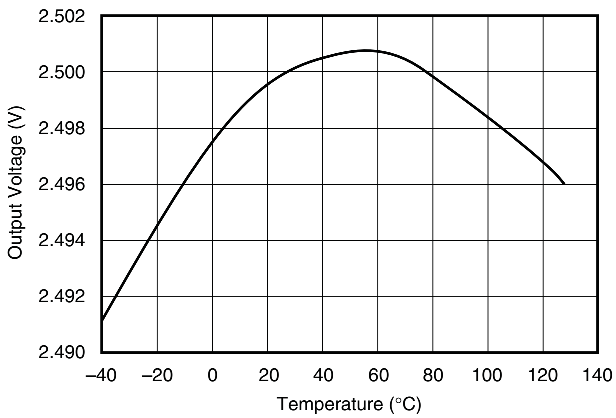
TEMPERATURE DRIFT (0°C to +70°C)



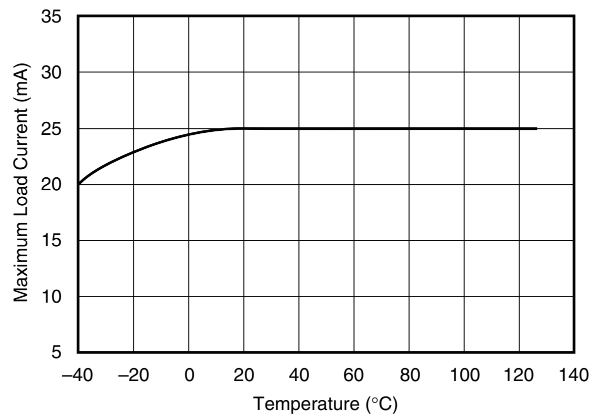
TEMPERATURE DRIFT (–40°C to +125°C)



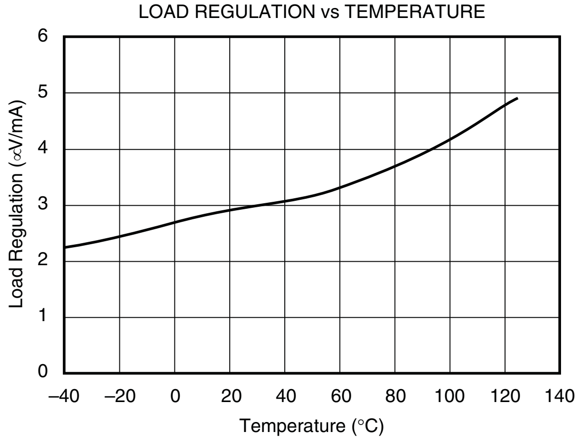
OUTPUT VOLTAGE vs TEMPERATURE



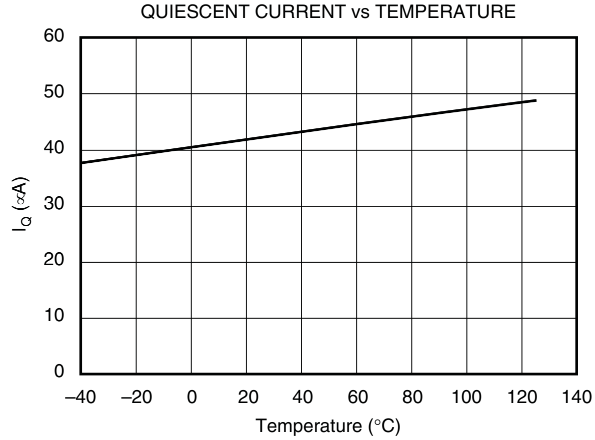
MAXIMUM LOAD CURRENT vs TEMPERATURE



LOAD REGULATION vs TEMPERATURE

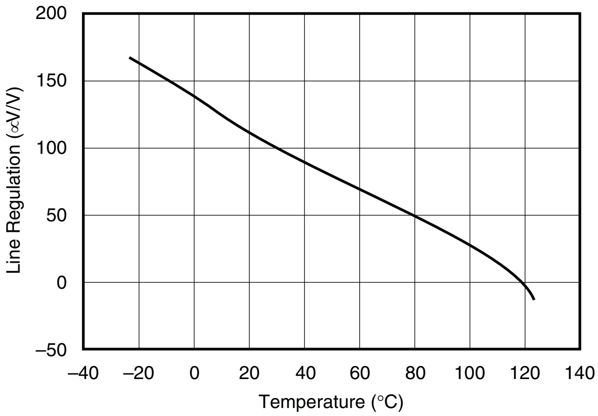


QUIESCENT CURRENT vs TEMPERATURE

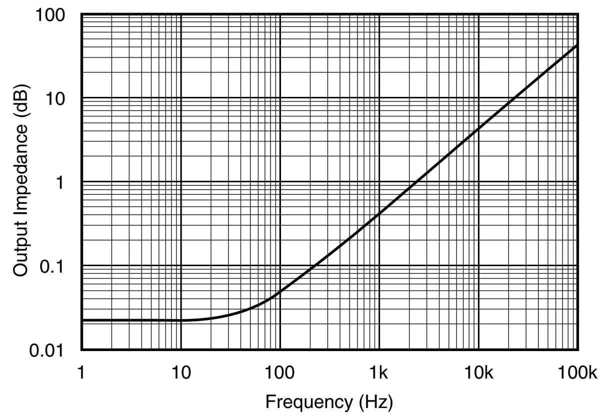


TYPICAL CHARACTERISTICS (continued)

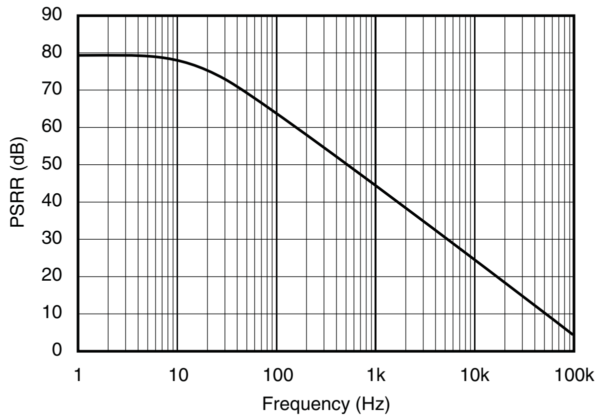
LINE REGULATION vs TEMPERATURE



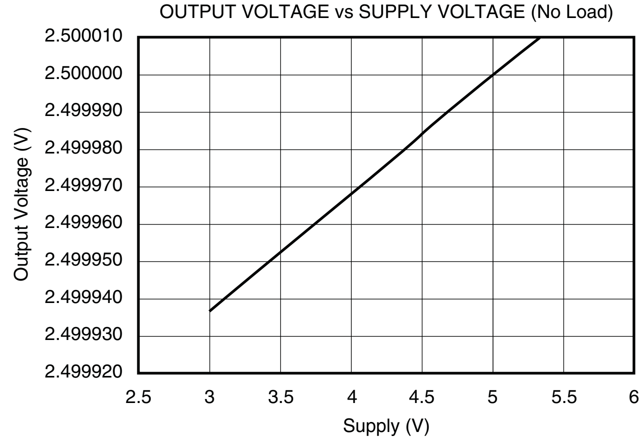
OUTPUT IMPEDANCE vs FREQUENCY



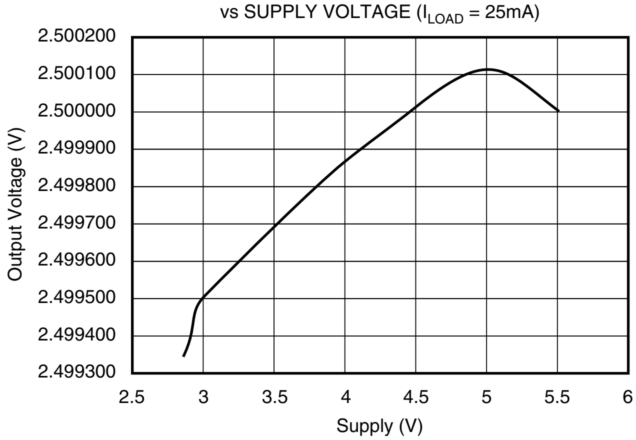
POWER-SUPPLY REJECTION RATIO vs FREQUENCY



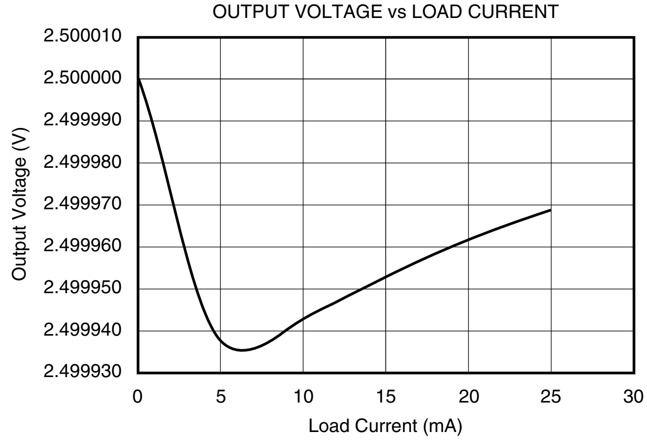
OUTPUT VOLTAGE vs SUPPLY VOLTAGE (No Load)



OUTPUT VOLTAGE
vs SUPPLY VOLTAGE (I_{LOAD} = 25mA)

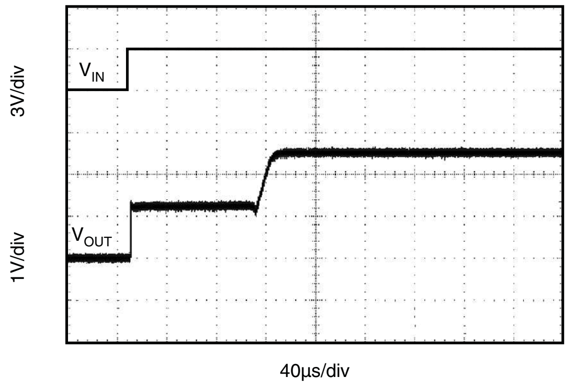


OUTPUT VOLTAGE vs LOAD CURRENT

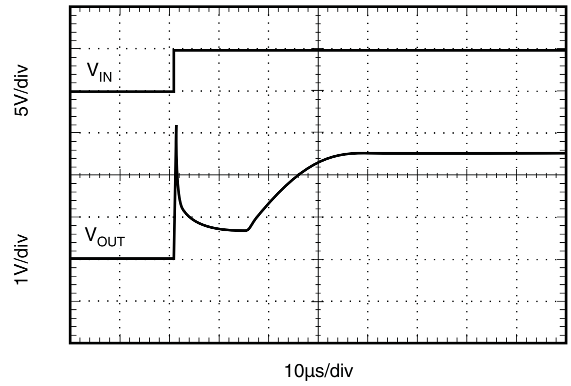


TYPICAL CHARACTERISTICS (continued)

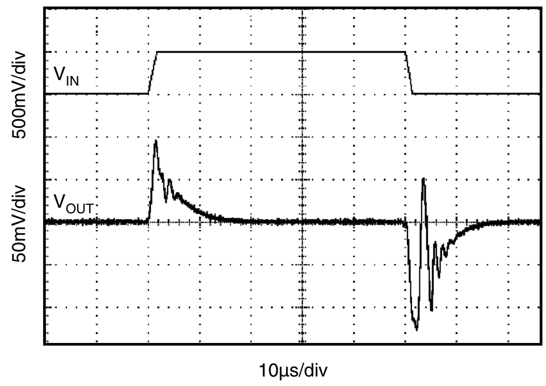
STEP RESPONSE, C_L = 0, 3V STARTUP



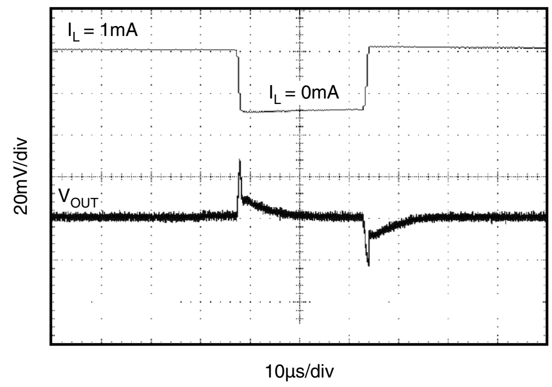
STEP RESPONSE, C_L = 0, 5V STARTUP



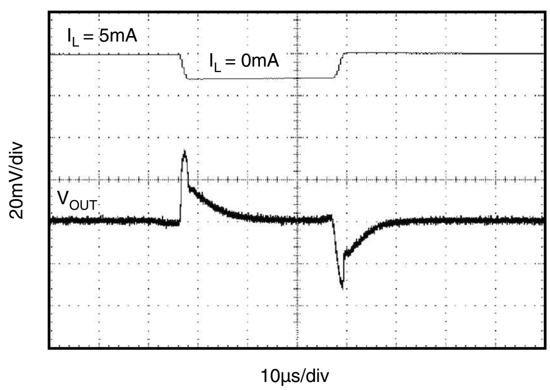
LINE TRANSIENT RESPONSE



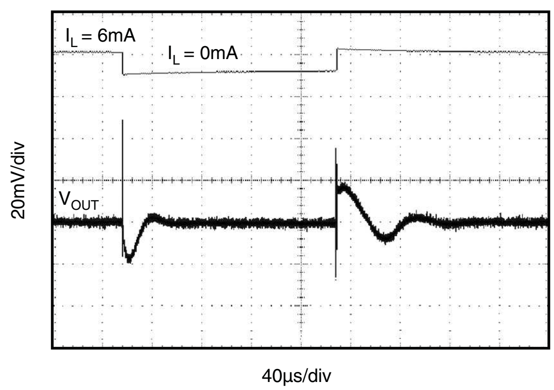
0-1mA LOAD TRANSIENT (C_L = 0)



0-5mA LOAD TRANSIENT (C_L = 0)

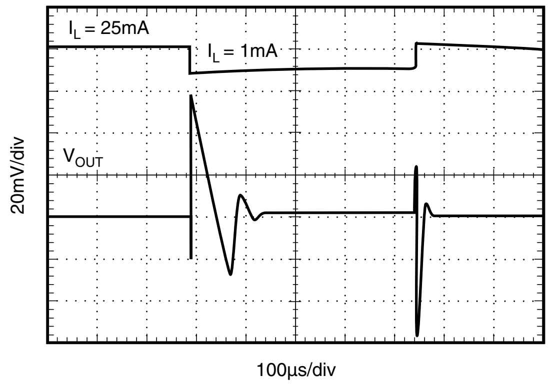


1-6mA LOAD TRANSIENT (C_L =1µF)

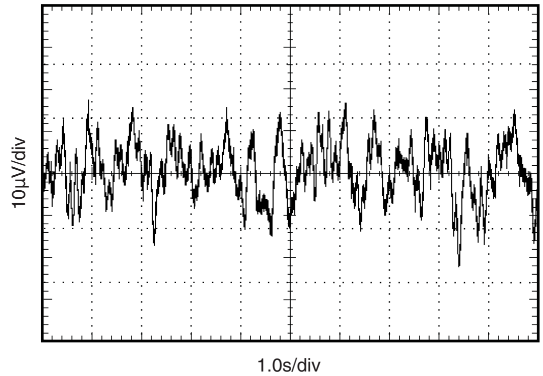


TYPICAL CHARACTERISTICS (continued)

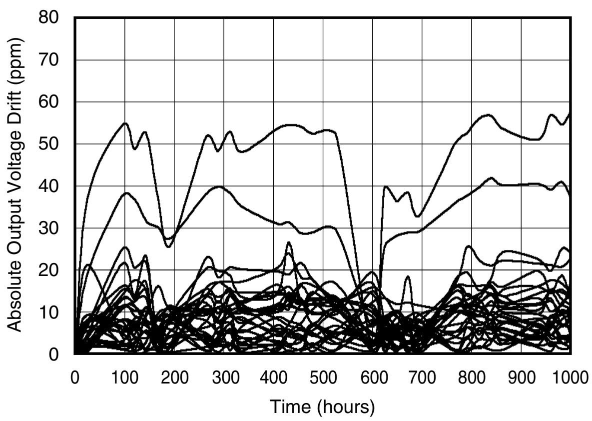
1-25mA LOAD TRANSIENT (C_L = 1µF)



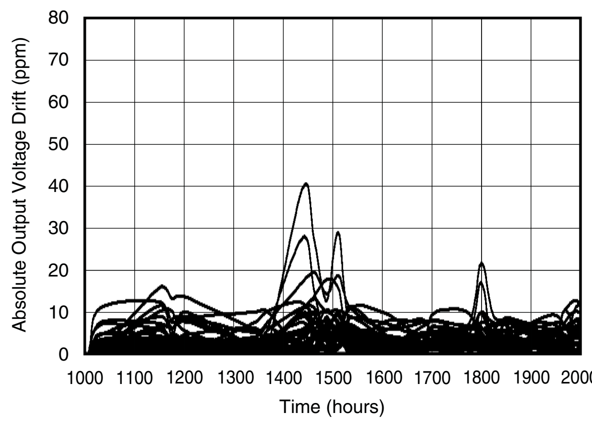
0.1Hz TO 10Hz NOISE



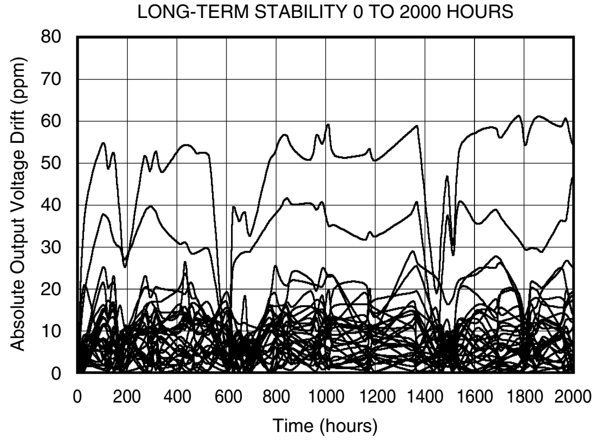
LONG-TERM STABILITY 0 TO 1000 HOURS



LONG-TERM STABILITY 1000 TO 2000 HOURS



LONG-TERM STABILITY 0 TO 2000 HOURS



THEORY OF OPERATION

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

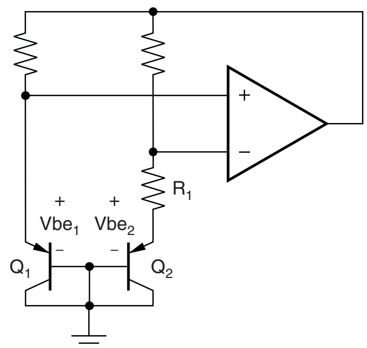


Figure 1. Simplified Schematic of Bandgap Reference

APPLICATION INFORMATION

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

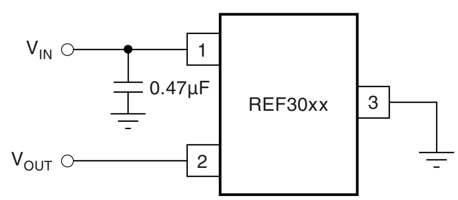


Figure 2. Typical Connections for Operating REF30xx

Supply Voltage

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

The REF30xx features a low quiescent current, which is extremely stable over changes in both temperature and supply. The typical room temperature quiescent current is 42 μA, and the maximum quiescent current over temperature is just 59 μA. Additionally, the quiescent current typically changes less than 2.5 μA over the entire supply range, as shown in Figure 3.

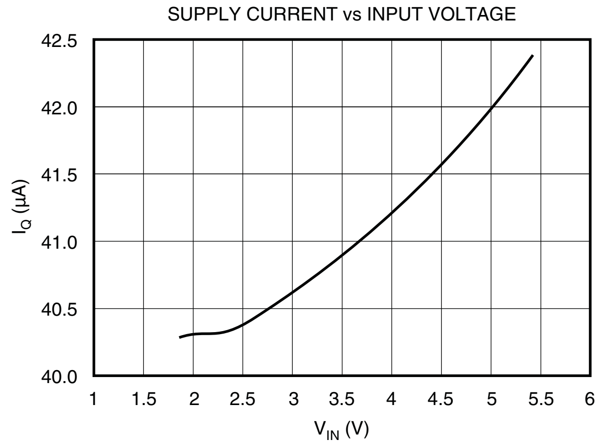


Figure 3. Supply Current vs Supply Voltage

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

Thermal Hysteresis

Thermal hysteresis for the REF30xx is defined as the change in output voltage after operating the device at 25°C, cycling the device through the specified temperature range, and returning to 25°C, and can be expressed as:

Where

V_{HYST} = Calculated hysteresis

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

V_{POST} = Output voltage measured when device has been operated at 25°C, cycled through specified range –40°C to 85°C, and returned to operation at 25°C.

Temperature Drift

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

Noise Performance

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

Long-Term Stability

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

Load Regulation

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

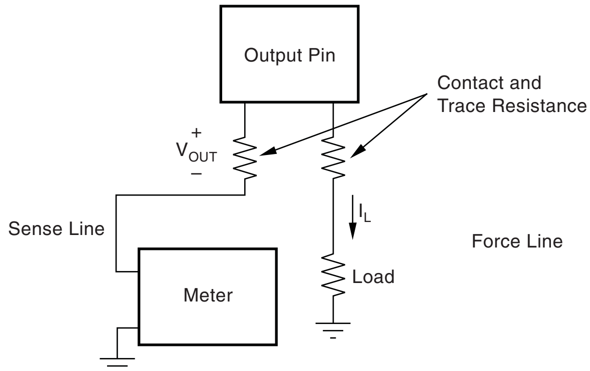


Figure 4. Accurate Load Regulation

Application Circuits

Negative Reference Voltage

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

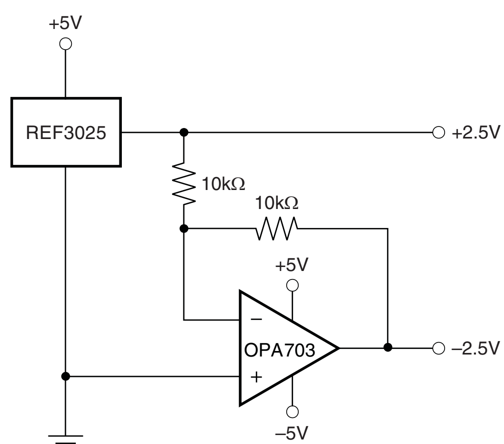


Figure 5. REF3025 Combined with OPA703 to Create Positive and Negative Reference Voltages

Data Acquisition

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

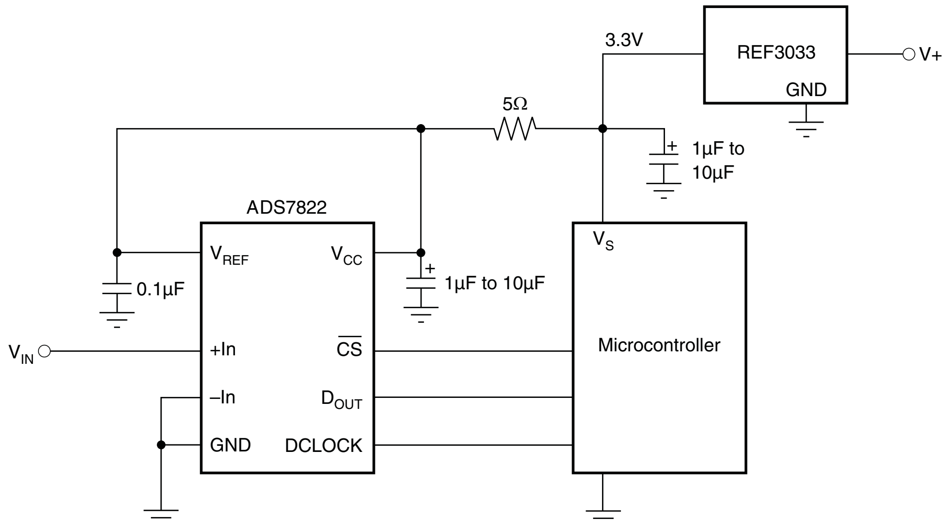


Figure 6. Basic Data Acquisition System 1

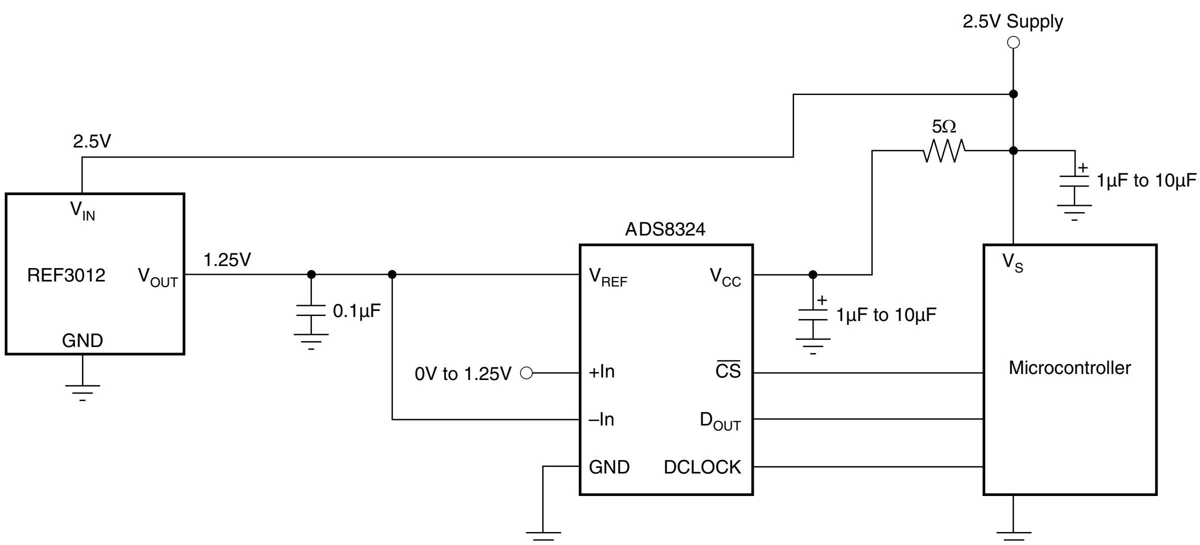


Figure 7. Basic Data Acquisition System 2

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