Burr-Brown Products
from Texas Instruments

REF3212, REF3220
REF3225, REF3230
REF3233, REF3240

SBVS058 −JUNE 2005

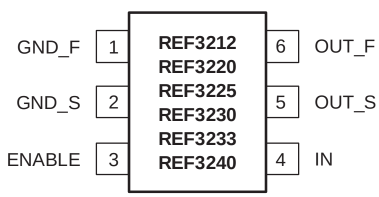
4ppm/°C, 100μA, SOT23-6
SERIES VOLTAGE REFERENCE

FEATURES

- **EXCELLENT SPECIFIED DRIFT PERFORMANCE:**
  7ppm/°C (max) at 0°C to +125°C
  20ppm/°C (max) at −40°C to +125°C
- **MICROSIZE PACKAGE: SOT23-6**
- **HIGH OUTPUT CURRENT: ±10mA**
- **HIGH ACCURACY: 0.01%**
- **LOW QUIESCENT CURRENT: 100μA**
- **LOW DROPOUT: 5mV**

APPLICATIONS

- **PORTABLE EQUIPMENT**
- **DATA ACQUISITION SYSTEMS**
- **MEDICAL EQUIPMENT**
- **TEST EQUIPMENT**



DESCRIPTION

The REF32xx is a very low drift, micropower, low-dropout, precision voltage reference family available in the tiny SOT23-6 package.

The small size and low power consumption (120μA max) of the REF32xx make it ideal for portable and battery-powered applications. This reference is stable with any capacitive load.

The REF32xx can be operated from a supply as low as 5mV above the output voltage, under no load conditions. All models are specified for the wide temperature range of −40°C to +125°C.

AVAILABLE OUTPUT VOLTAGES

PRODUCT	VOLTAGE
REF3212	1.25V
REF3220	2.048V
REF3225	2.5V
REF3230	3.0V
REF3233	3.3V
REF3240	4.096V

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ABSOLUTE MAXIMUM RATINGS(1)

Input Voltage	+7.5V
Operating Temperature	−55°C to +135°C
Storage Temperature	−65°C to +150°C
Junction Temperature	+150°C
Lead Temperature (soldering, 10s)	+300°C
ESD Rating	
Human Body Model	4kV
Charged Device Model	1kV
Machine Model	400V

(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.

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.

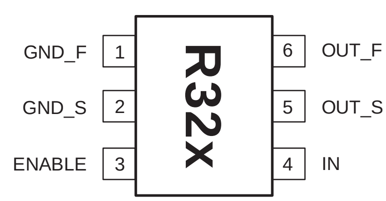
PACKAGE/ORDERING INFORMATION(1)

PRODUCT	OUTPUT VOLTAGE	PACKAGE-LEAD	PACKAGE DESIGNATOR	PACKAGE MARKING
REF3212	1.25V	SOT23-6	DBV	R32A
REF3220	2.048V	SOT23-6	DBV	R32B
REF3225	2.5V	SOT23-6	DBV	R32C
REF3230	3.0V	SOT23-6	DBV	R32D
REF3233	3.30V	SOT23-6	DBV	R32E
REF3240	4.096V	SOT23-6	DBV	R32F

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at www.ti.com.

PIN CONFIGURATION

Top View **SOT23**



NOTE: The location of pin 1 on the REF32xx is determined by orienting the package marking as shown in the diagram above.

ELECTRICAL CHARACTERISTICS

Boldface limits apply over the listed temperature range.

At T_A = +25°C, I_{LOAD} = 0mA, and V_{IN} = 5V, unless otherwise noted.

PARAMETER	CONDITIONS	REF32xx			UNIT
		MIN	TYP	MAX	
REF3212 (1.25V)					
OUTPUT VOLTAGE, V_{OUT}		1.2475	1.25	1.2525	V
Initial Accuracy		−0.2	0.01	0.2	%
NOISE					
Output Voltage Noise	f = 0.1Hz to 10Hz		17		μV_{PP}
Voltage Noise	f = 10Hz to 10kHz		24		μV_{RMS}
REF3220 (2.048V)					
OUTPUT VOLTAGE, V_{OUT}		2.044	2.048	2.052	V
Initial Accuracy		−0.2	0.01	0.2	%
NOISE					
Output Voltage Noise	f = 0.1Hz to 10Hz		27		μV_{PP}
Voltage Noise	f = 10Hz to 10kHz		39		μV_{RMS}
REF3225 (2.5V)					
OUTPUT VOLTAGE, V_{OUT}		2.495	2.50	2.505	V
Initial Accuracy		−0.2	0.01	0.2	%
NOISE					
Output Voltage Noise	f = 0.1Hz to 10Hz		33		μV_{PP}
Voltage Noise	f = 10Hz to 10kHz		48		μV_{RMS}
REF3230 (3V)					
OUTPUT VOLTAGE, V_{OUT}		2.994	3	3.006	V
Initial Accuracy		−0.2	0.01	0.2	%
NOISE					
Output Voltage Noise	f = 0.1Hz to 10Hz		39		μV_{PP}
Voltage Noise	f = 10Hz to 10kHz		57		μV_{RMS}
REF3233 (3.3V)					
OUTPUT VOLTAGE, V_{OUT}		3.293	3.3	3.307	V
Initial Accuracy		−0.2	0.01	0.2	%
NOISE					
Output Voltage Noise	f = 0.1Hz to 10Hz		43		μV_{PP}
Voltage Noise	f = 10Hz to 10kHz		63		μV_{RMS}
REF3240 (4.096V)					
OUTPUT VOLTAGE, V_{OUT}		4.088	4.096	4.104	V
Initial Accuracy		−0.2	0.01	0.2	%
NOISE					
Output Voltage Noise	f = 0.1Hz to 10Hz		53		μV_{PP}
Voltage Noise	f = 10Hz to 10kHz		78		μV_{RMS}

TEXAS INSTRUMENTS
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ELECTRICAL CHARACTERISTICS (continued)

Boldface limits apply over the listed temperature range.

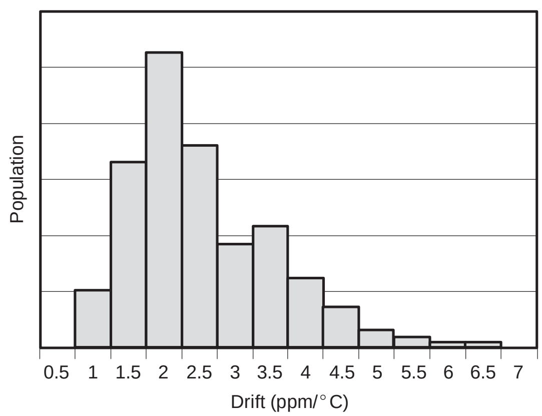
At T_A = +25°C, I_{LOAD} = 0mA, and V_{IN} = 5V, unless otherwise noted.

PARAMETER		CONDITIONS	REF32xx MIN	TYP	MAX	UNIT
REF3212 / REF3220 / REF3225 / REF3230 / REF3233 / REF3240						
OUTPUT VOLTAGE TEMP DRIFT	dV_{OUT}/dT					
		0°C ≤ T_A ≤ +125°C		**4**	**7**	**ppm/°C**
		−40°C ≤ T_A ≤ +125°C		**10.5**	**20**	**ppm/°C**
LONG-TERM STABILITY						
		0 to 1000h		55		ppm
LINE REGULATION		V_{OUT} + 0.05(1) ≤ V_{IN} ≤ 5.5V	−65	15	+65	ppm/V
LOAD REGULATION	dV_{OUT}/dI_{LOAD}					
Sourcing		0mA < I_{LOAD} < 10mA, V_{IN} = V_{OUT} + 250mV(1)	−40	3	40	µV/mA
Sinking		−10mA < I_{LOAD} < 0mA, V_{IN} = V_{OUT} + 100mV(1)	−60	20	60	µV/mA
THERMAL HYSTERESIS(2)	dT					
First cycle				100		ppm
Additional cycles				25		ppm
DROPOUT VOLTAGE(1)	$V_{IN}-V_{OUT}$	**0°C ≤ T_A ≤ +125°C**		**5**	**50**	**mV**
OUTPUT CURRENT	I_{LOAD}	V_{IN} = V_{OUT} + 250mV(1)	−10		10	mA
SHORT-CIRCUIT CURRENT	I_{SC}					
Sourcing				50		mA
Sinking				40		mA
TURN-ON SETTLING TIME		to 0.1% at V_{IN} = 5V with C_L = 0		60		µs
ENABLE/SHUTDOWN						
	V_L	Reference in Shutdown mode	0		0.7	V
	V_H	Reference is active	0.75 × V_{IN}		V_{IN}	V
POWER SUPPLY		I_L = 0				
Voltage	V_{IN}		V_{OUT} + 0.05(1)		5.5	V
Current	I_Q	ENABLE > 0.75 x V_{IN}		100	120	µA
Over-temperature		**0°C ≤ T_A ≤ +125°C**		**115**	**135**	**µA**
Shutdown	I_S	ENABLE < 0.7V		0.1	1	µA
TEMPERATURE RANGE						
Specified			−40		+125	°C
Operating			−55		+135	°C
Storage			−65		+150	°C
Thermal resistance, SOT23-6	θ_{JA}			200		°C/W

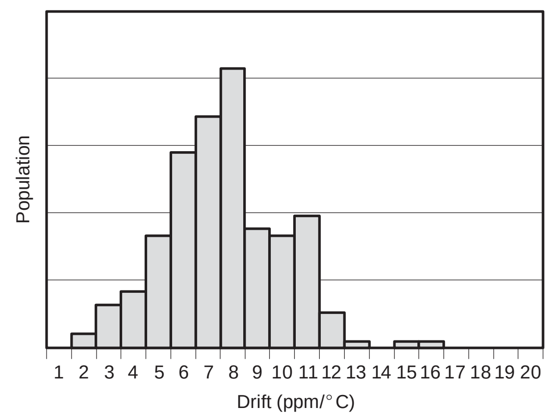
(1) The minimum supply voltage for the REF3212 is 1.8V.
(2) Thermal hysteresis procedure is explained in more detail in the *Applications Information* section.
(3) Load regulation is using force and sense lines; see the *Load Regulation* section for more information.

TYPICAL CHARACTERISTICS

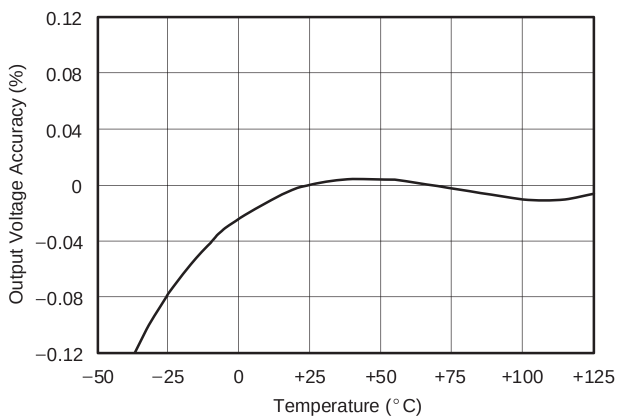
At T_A = +25°C, I_{LOAD} = 0mA, V_{IN} = +5V power supply, REF3225 is used for typical characteristics, unless otherwise noted.



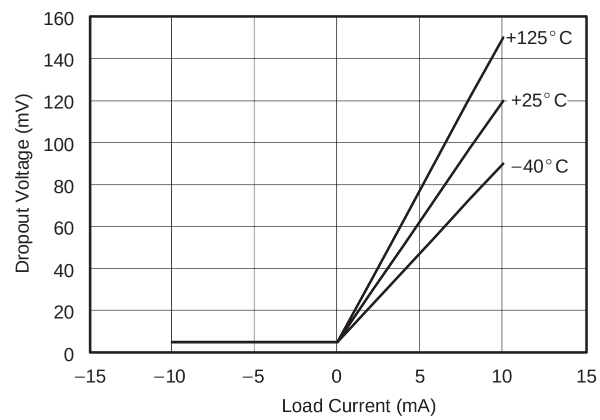
TEMPERATURE DRIFT (0°C to +125°C)



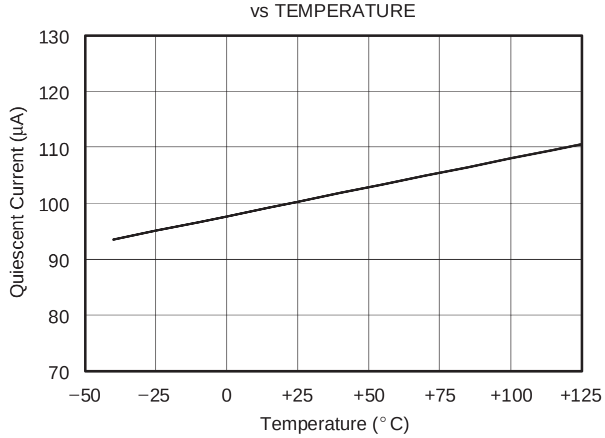
TEMPERATURE DRIFT (−40°C to +125°C)



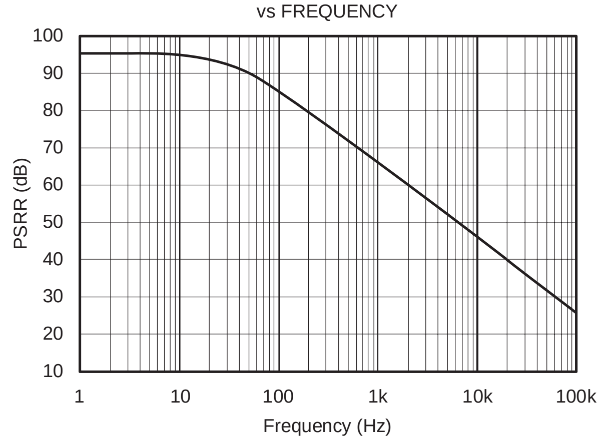
OUTPUT VOLTAGE ACCURACY vs TEMPERATURE



DROPOUT VOLTAGE vs LOAD CURRENT



QUIESCENT CURRENT vs TEMPERATURE

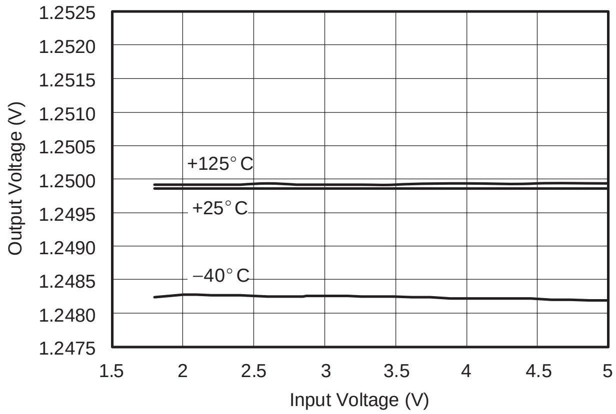


POWER−SUPPLY REJECTION RATIO vs FREQUENCY

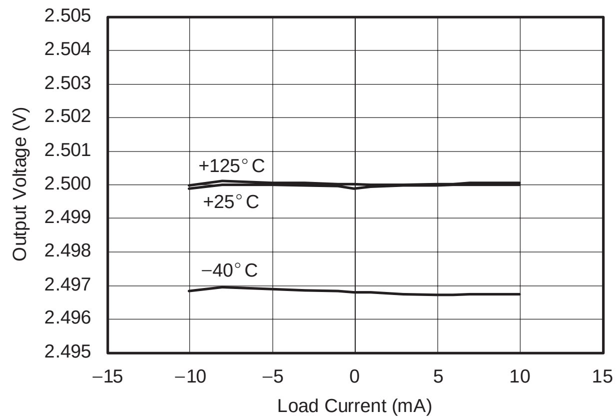
TYPICAL CHARACTERISTICS (continued)

At T_A = +25°C, I_{LOAD} = 0mA, V_{IN} = +5V power supply, REF3225 is used for typical characteristics, unless otherwise noted.

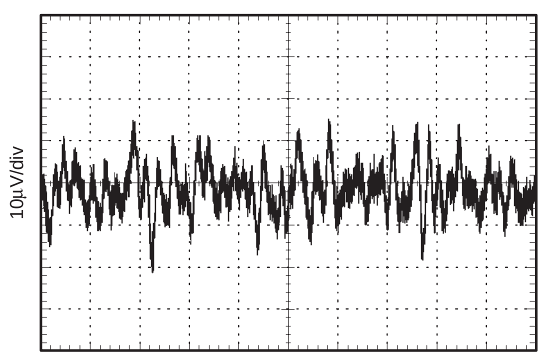
OUTPUT VOLTAGE vs INPUT VOLTAGE (REF3212)



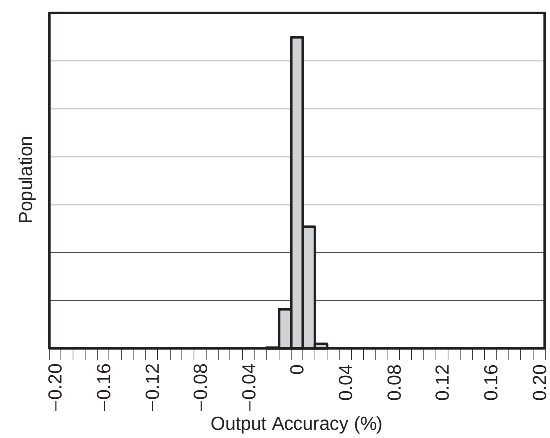
OUTPUT VOLTAGE vs LOAD CURRENT



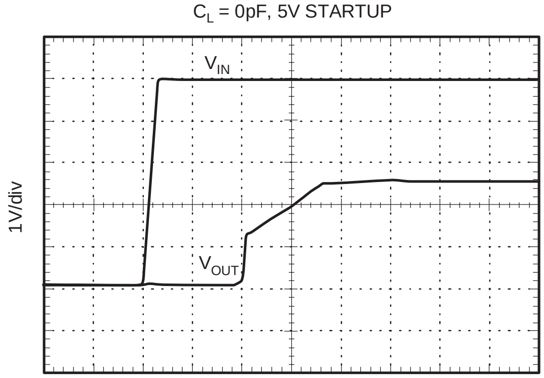
0.1Hz TO 10Hz NOISE



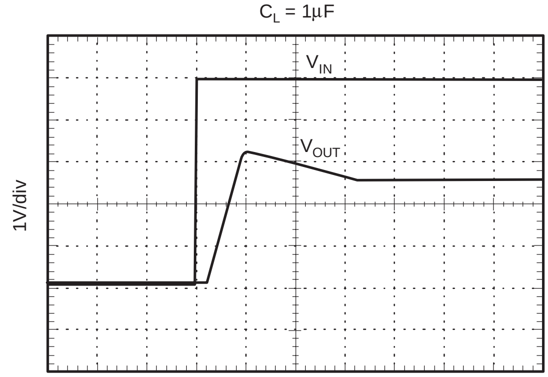
OUTPUT VOLTAGE INITIAL ACCURACY



STEP RESPONSE C_L = 0pF, 5V STARTUP



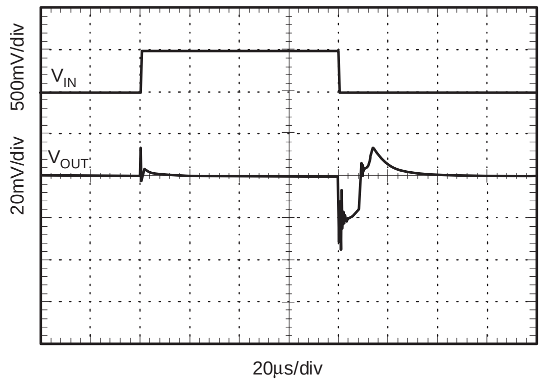
STEP RESPONSE C_L = 1µF



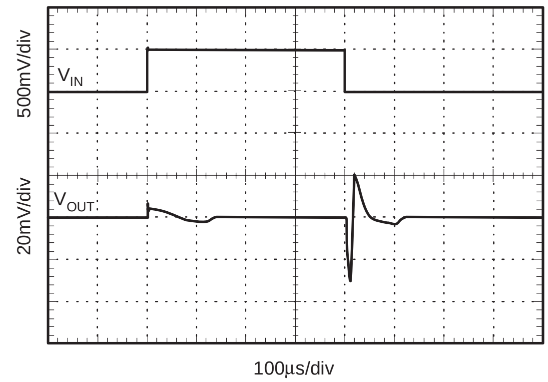
TYPICAL CHARACTERISTICS (continued)

At T_A = +25°C, I_{LOAD} = 0mA, V_{IN} = +5V power supply, REF3225 is used for typical characteristics, unless otherwise noted.

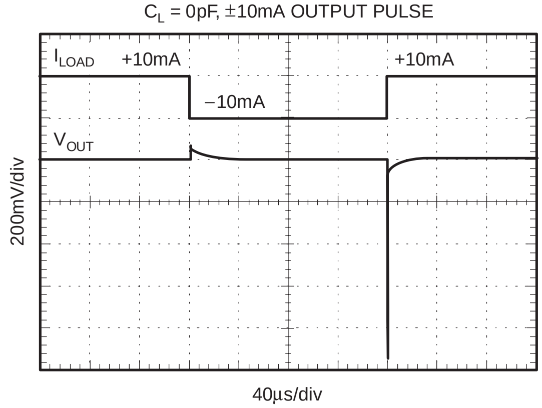
LINE TRANSIENT
C_L = 0pF



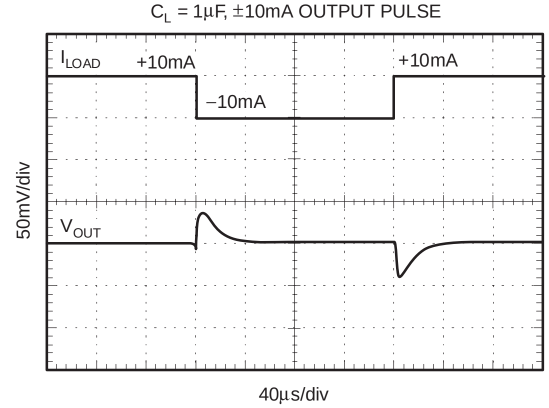
LINE TRANSIENT
C_L = 10µF



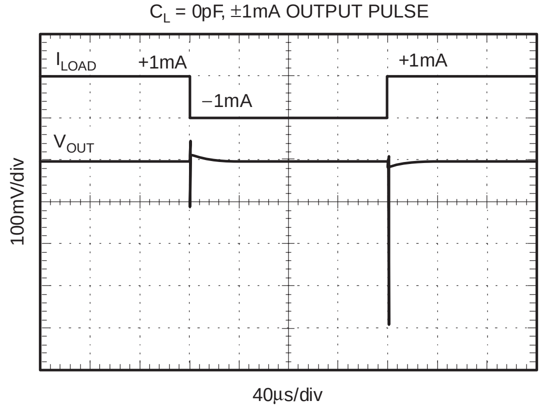
LOAD TRANSIENT
C_L = 0pF, ±10mA OUTPUT PULSE



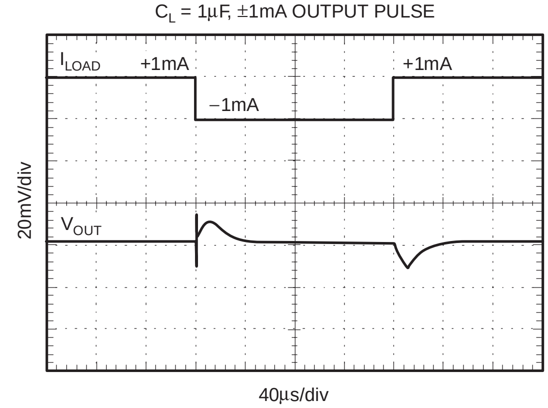
LOAD TRANSIENT
C_L = 1µF, ±10mA OUTPUT PULSE



LOAD TRANSIENT
C_L = 0pF, ±1mA OUTPUT PULSE

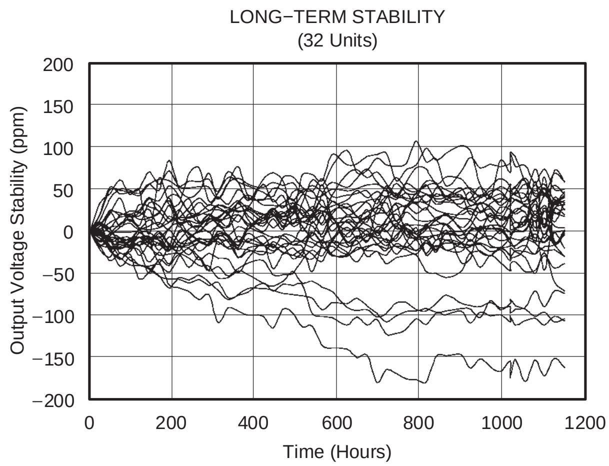


LOAD TRANSIENT
C_L = 1µF, ±1mA OUTPUT PULSE



TYPICAL CHARACTERISTICS (continued)

At T_A = +25°C, I_{LOAD} = 0mA, V_{IN} = +5V power supply, REF3225 is used for typical characteristics, unless otherwise noted.



THEORY OF OPERATION

The REF32xx is a family of CMOS, precision bandgap voltage references. Figure 1 shows the basic bandgap topology. Transistors Q_1 and Q_2 are biased so 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 amplified 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.

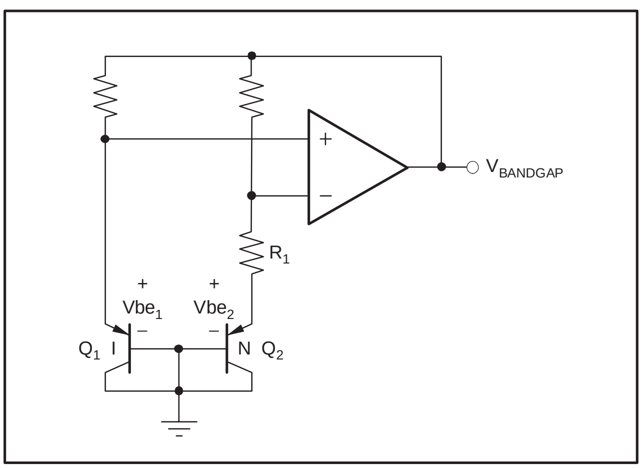


Figure 1. Simplified Schematic of Bandgap Reference

APPLICATION INFORMATION

The REF32xx does not require a load capacitor and is stable with any capacitive load. Figure 2 shows typical connections required for operation of the REF32xx. A supply bypass capacitor of 0.47μF is recommended.

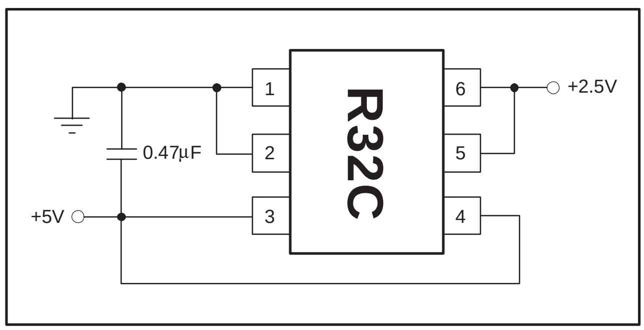


Figure 2. Typical Operating Connections for the REF3225

SUPPLY VOLTAGE

The REF32xx family of references features an extremely low dropout voltage. With the exception of the REF3212, 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 Characteristic curves.

The REF32xx also features a low quiescent current of 100μA, with a maximum quiescent current over temperature of just 135μA. The quiescent current typically changes less than 2μA over the entire supply range, as shown in Figure 3.

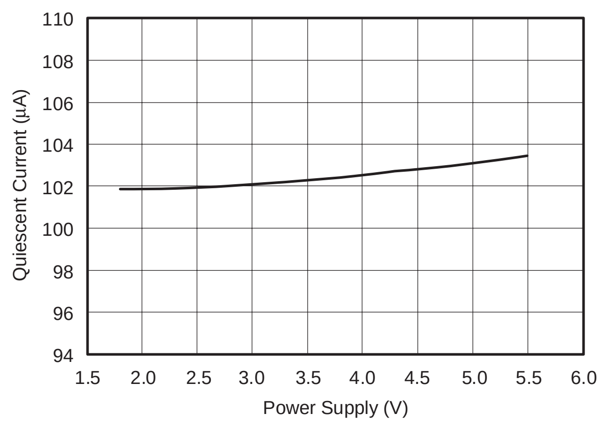


Figure 3. Supply Current vs Supply Voltage

Supply voltages below the specified levels can cause the REF32xx to momentarily draw currents greater than the typical quiescent current. This momentary current draw can be prevented by using a power supply with a fast rising edge and low output impedance.

SHUTDOWN

The REF32xx can be placed in a low-power mode by pulling the ENABLE/SHUTDOWN pin low. When in Shutdown mode, the output of the REF32xx becomes a resistive load to ground. The value of the load depends on the model, and ranges from approximately 100kΩ to 400kΩ.

THERMAL HYSTERESIS

Thermal hysteresis for the REF32xx 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:

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

Where:

V_{HYST} = thermal hysteresis (in units of ppm).

V_{NOM} = the specified output voltage.

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.

TEMPERATURE DRIFT

The REF32xx is designed to exhibit minimal drift error, which is defined as the change in output voltage over varying temperature. The drift is calculated using the box method, as described by the following equation:

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

The REF32xx features a typical drift coefficient of 4ppm/°C from 0°C to +125°C—the primary temperature range for many applications. For the extended industrial temperature range of –40°C to +125°C, the REF32xx family drift increases to a typical value of 10.5ppm/°C.

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 REF32xx increases with output voltage and operating temperature. Additional filtering can 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 shown by the long-term stability Typical Characteristic curves. The typical drift value for the REF32xx is 55ppm from 0 to 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 as a result of changes in load current. The load regulation of the REF32xx is measured using force and sense contacts, as shown in Figure 4. The force and sense lines can be used to effectively eliminate the impact of contact and trace resistance, resulting in accurate voltage at the load. By connecting the force and sense lines at the load, the REF32xx compensates for the contact and trace resistances because it measures and adjusts the voltage actually delivered at the load.

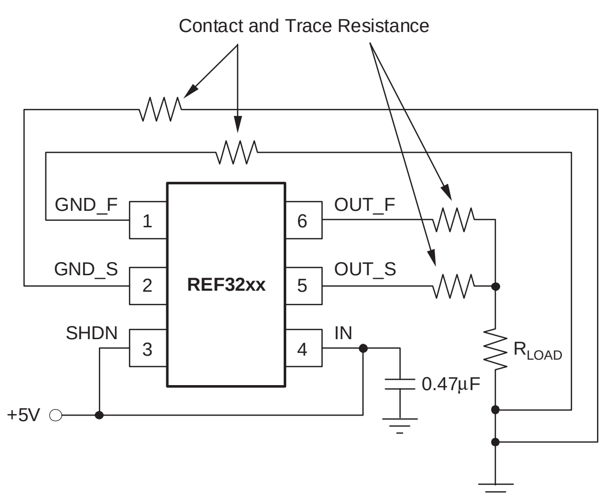


Figure 4. Accurate Load Regulation of REF32xx

APPLICATION CIRCUITS

NEGATIVE REFERENCE VOLTAGE

For applications requiring a negative and positive reference voltage, the REF32xx and OPA735 can be used to provide a dual-supply reference from a ±5V supply. Figure 5 shows the REF3225 used to provide a ±2.5V supply reference voltage. The low drift performance of the REF32xx complements the low offset voltage and zero drift of the OPA735 to provide an accurate solution for split-supply applications. Care must be taken to match the temperature coefficients of R_1 and R_2.

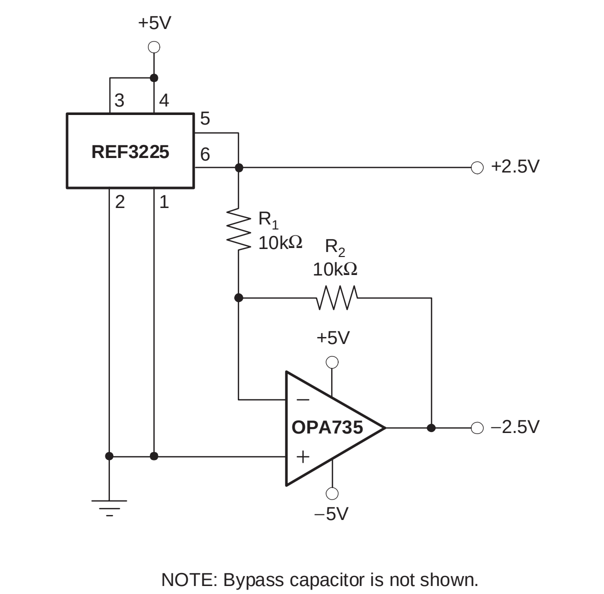


Figure 5. REF3225 Combined with OPA735 to Create Positive and Negative Reference Voltages

DATA ACQUISITION

Data acquisition systems often require stable voltage references to maintain accuracy. The REF32xx family features stability and a wide range of voltages suitable for most microcontrollers and data converters. Figure 6, Figure 7, and Figure 8 show basic data acquisition systems.

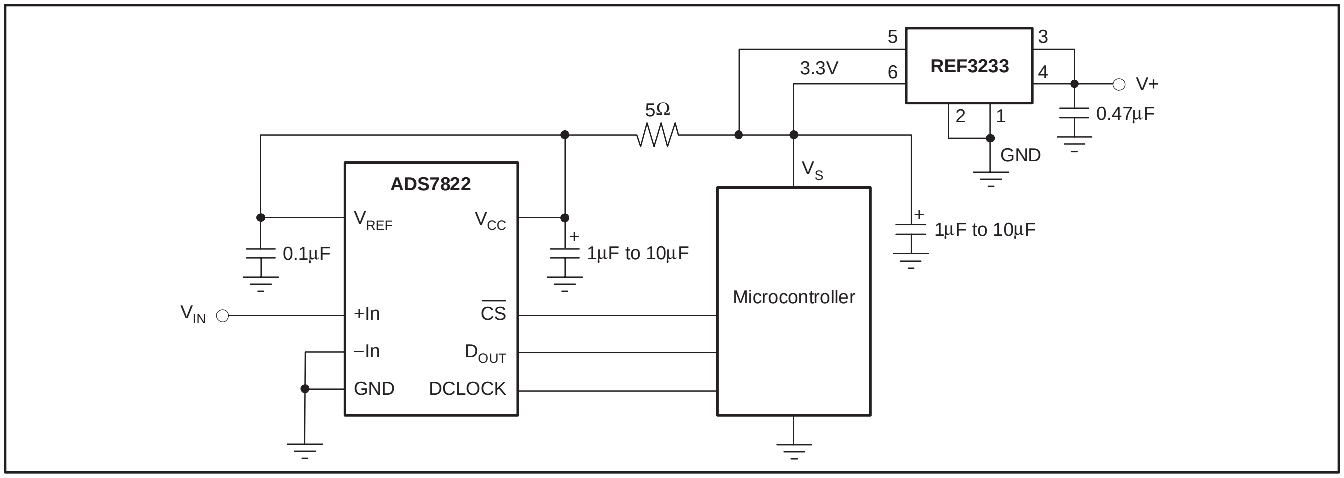


Figure 6. Basic Data Acquisition System 1

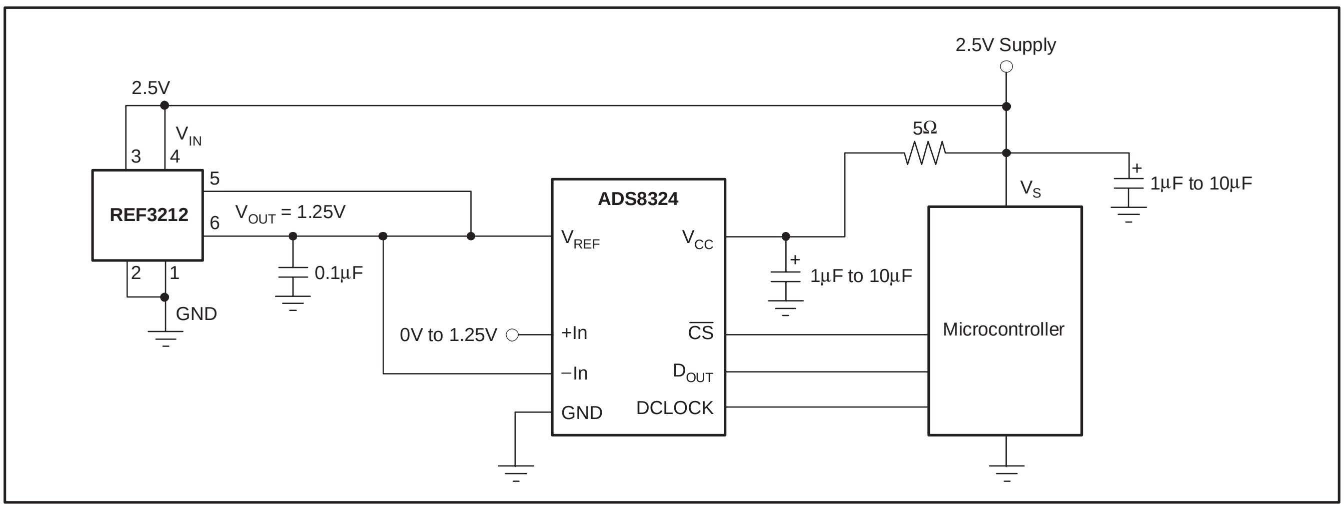


Figure 7. Basic Data Acquisition System 2

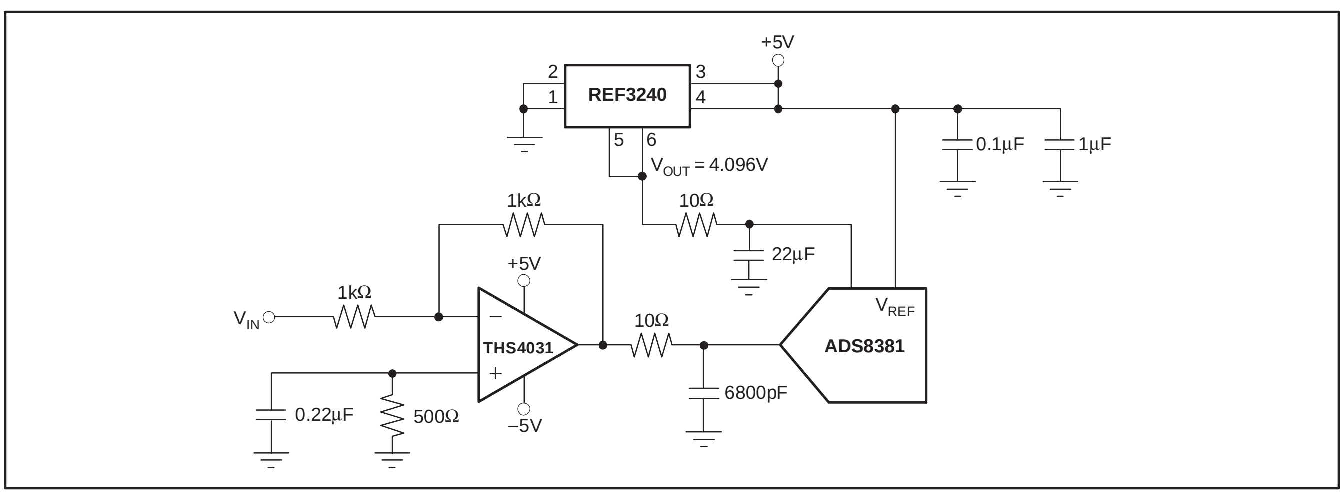


Figure 8. REF3240 Provides an Accurate Reference for Driving the ADS8381

PACKAGING INFORMATION

Orderable Device	Status [(1)]	Package Type	Package Drawing	Pins	Package Qty	Eco Plan [(2)]	Lead/Ball Finish	MSL Peak Temp [(3)]
REF3212AIDBVR	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
REF3212AIDBVT	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
REF3220AIDBVR	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
REF3220AIDBVT	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
REF3225AIDBVR	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
REF3225AIDBVT	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
REF3230AIDBVR	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
REF3230AIDBVT	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
REF3233AIDBVR	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
REF3233AIDBVT	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
REF3240AIDBVR	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
REF3240AIDBVT	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR

[(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)] Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS) or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

[(3)] MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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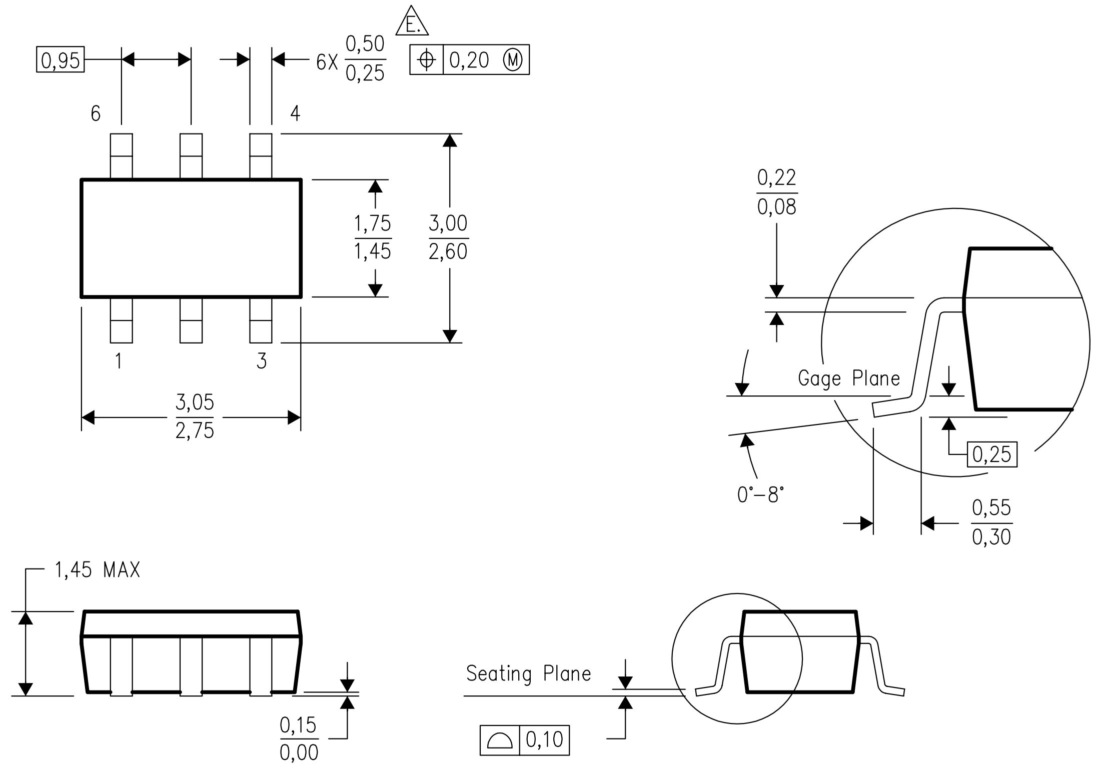
DBV (R-PDSO-G6) PLASTIC SMALL-OUTLINE PACKAGE



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NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion.
- D. Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
- E. Falls within JEDEC MO-178 Variation AB, except minimum lead width.

IMPORTANT NOTICE

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
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Interface	interface.ti.com	Digital Control	www.ti.com/digitalcontrol
Logic	logic.ti.com	Military	www.ti.com/military
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
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Mailing Address: Texas Instruments
Post Office Box 655303 Dallas, Texas 75265