REF3212-EP, REF3220-EP, REF3225-EP
REF3230-EP, REF3233-EP, REF3240-EP
4 ppm/°C, 100 μA SOT23-6 SERIES VOLTAGE REFERENCES

SBVS078A–OCTOBER 2006–REVISED APRIL 2007

FEATURES

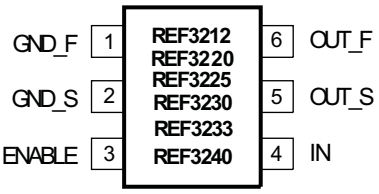
- **Controlled Baseline**
  - **One Assembly/Test Site, One Fabrication Site**
- **Extended Temperature Performance of –55°C to 125°C**
- **Enhanced Diminishing Manufacturing Sources (DMS) Support**
- **Enhanced Product-Change Notification**
- **Qualification Pedigree** (1)
- **Excellent Specified Drift Performance:**
  - **7ppm/°C (Max) at 0°C to 125°C**
  - **20ppm/°C (Max) at –40°C to 125°C**
  - **40ppm/°C (Max) at –55°C to 125°C**
- **Microsize Package: SOT23-6**

(1) Component qualification in accordance with JEDEC and industry standards to ensure reliable operation over an extended temperature range. This includes, but is not limited to, Highly Accelerated Stress Test (HAST) or biased 85/85, temperature cycle, autoclave or unbiased HAST, electromigration, bond intermetallic life, and mold compound life. Such qualification testing should not be viewed as justifying use of this component beyond specified performance and environmental limits.

- **High Output Current: ±10 mA**
- **High Accuracy: 0.01%**
- **Low Quiescent Current: 100 μA**
- **Low Dropout: 5 mV**

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 (120 μA 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 5 mV above the output voltage, under no load conditions. All models are specified for the wide temperature range of –55°C to 125°C.

AVAILABLE OUTPUT VOLTAGES

PRODUCT	VOLTAGE
REF3212	1.25 V
REF3220	2.048 V
REF3225	2.5 V
REF3230	3 V
REF3233	3.3 V
REF3240	4.096 V

PACKAGE/ORDERING INFORMATION(1)

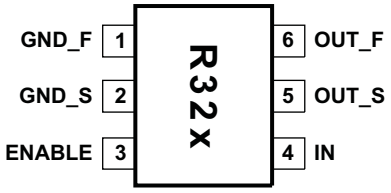
PRODUCT	OUTPUT VOLTAGE	PACKAGE-LEAD	PACKAGE DESIGNATOR(2)	PACKAGE MARKING
REF3212AMDBVREP	1.25 V	SOT23-6	DBV	R3AM
REF3220AMDBVREP	2.048 V	SOT23-6	DBV	R3BM
REF3225AMDBVREP	2.5 V	SOT23-6	DBV	R3CM
REF3230AMDBVREP	3 V	SOT23-6	DBV	R3DM
REF3233AMDBVREP	3.3 V	SOT23-6	DBV	R3EM
REF3240AMDBVREP	4.096 V	SOT23-6	DBV	R3FM

(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.
(2) Package drawings, thermal data, and symbolization are available at www.ti.com/packaging.

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

PIN CONFIGURATION

SOT23-6
(TOP VIEW)



A. The location of pin 1 on the REF32xx is determined by orienting the package marking as shown.

Absolute Maximum Ratings(1)

		MIN	MAX	UNIT
Input voltage			7.5	V
Output short-circuit		Continuous		
Operating temperature range		–55	125	°C
Storage temperature range		–65	150(2)	°C
Junction temperature			150	°C
ESD rating	Human-Body Model		4	kV
	Charged-Device Model		1	
	Machine Model		400	V

(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) Long-term high-temperature storage and/or extended use at maximum recommended operating conditions may result in a reduction of overall device life. See http://www.ti.com/ep_quality for additional information on enhanced plastic packaging.

Electrical Characteristics

Boldface limits apply over the listed temperature range.
T_A = 25°C, I_{LOAD} = 0 mA, and V_{IN} = 5 V (unless otherwise noted)

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
REF3212 (1.25 V)							
V_{OUT}	Output voltage			1.2475	1.25	1.2525	V
	Initial accuracy			–0.2	0.01	0.2	%
Noise	Output voltage noise		f = 0.1 Hz to 10 Hz		17		μV_{PP}
	Voltage noise		f = 10 Hz to 10 kHz		24		μV_{RMS}
REF3220 (2.048 V)							
V_{OUT}		Output voltage		2.044	2.048	2.052	V
		Initial accuracy		–0.2	0.01	0.2	%
Noise		Output voltage noise	f = 0.1 Hz to 10 Hz		27		μV_{PP}
		Voltage noise	f = 10 Hz to 10 kHz		39		μV_{RMS}
REF3225 (2.5 V)							
V_{OUT}	Output voltage			2.495	2.5	2.505	V
	Initial accuracy			–0.2	0.01	0.2	%
Noise	Output voltage noise		f = 0.1 Hz to 10 Hz		33		μV_{PP}
	Voltage noise		f = 10 Hz to 10 kHz		48		μV_{RMS}
REF3230 (3 V)							
V_{OUT}	Output voltage			2.994	3	3.006	V
	Initial accuracy			–0.2	0.01	0.2	%
Noise	Output voltage noise		f = 0.1 Hz to 10 Hz		39		μV_{PP}
	Voltage noise		f = 10 Hz to 10 kHz		57		μV_{RMS}
REF3233 (3.3 V)							
V_{OUT}	Output voltage			3.293	3.3	3.307	V
	Initial accuracy			–0.2	0.01	0.2	%
Noise	Output voltage noise		f = 0.1 Hz to 10 Hz		43		μV_{PP}
	Voltage noise		f = 10 Hz to 10 kHz		63		μV_{RMS}
REF3240 (4.096 V)							
V_{OUT}	Output voltage			4.088	4.096	4.104	V
	Initial accuracy			–0.2	0.01	0.2	%
Noise	Output voltage noise		f = 0.1 Hz to 10 Hz		53		μV_{PP}
	Voltage noise		f = 10 Hz to 10 kHz		78		μV_{RMS}
REF3212/REF3220/REF3225/REF3230/REF3233/REF3240							
dV_{OUT}/dT	Output voltage temperature drift		T_A = 25°C		4	7	ppm/°C
			–55°C ≤ T_A ≤ 125°C		10.5	40	
	Long-term stability		0 tp 1000 h		55		ppm
	Line regulation		V_{OUT} + 0.05[1] ≤ V_{IN} ≤ 5.5 V	–65	15	65	ppm/V
dV_{OUT}/dI_{LOAD}	Load regulation[2]	Sourcing	0 mA < I_{LOAD} < 10 mA, V_{IN} = V_{OUT} + 250 mV[1]	–40	3	40	μV/mA
		Sinking	–10 mA < I_{LOAD} < 0 mA, V_{IN} = V_{OUT} + 100 mV[1]	–60	20	60	
dT	Thermal hysteresis[3]	First cycle			100		ppm
		Additional cycles			25		

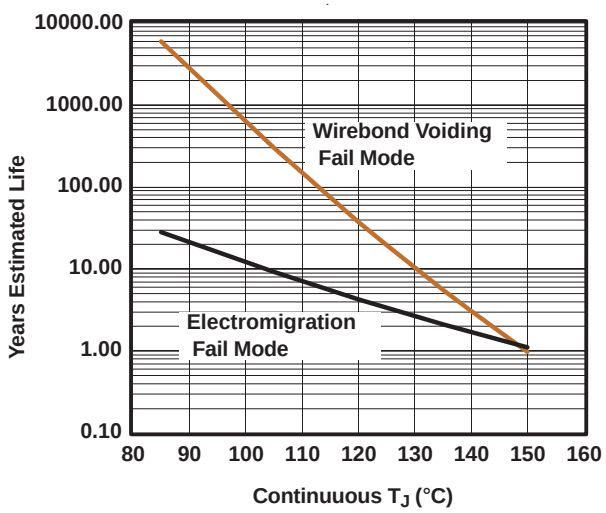
(1) The minimum supply voltage for the REF3212 is 1.8 V.
(2) Load regulation is using force and sense lines; see the *Load Regulation* section for more information
(3) Thermal hysteresis procedure is explained in more detail in the *Applications Information* section.

Electrical Characteristics (continued)

Boldface limits apply over the listed temperature range.
T_A = 25°C, I_{LOAD} = 0 mA, and V_{IN} = 5 V (unless otherwise noted)

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{IN} - V_{OUT}$	Dropout voltage(1)		25°C ≤ T_A ≤ +125°C		5	50	mV
I_{LOAD}	Output current		$V_{IN} = V_{OUT}$ + 250 mV(1)	–10		10	mA
I_{SC}	Short-circuit current	Sourcing			50		mA
		Sinking			40		
	Turn-on settling time		0.1% at V_{IN} = 5 V with C_L = 0		60		μs
V_L	Enable/shutdown		Reference in shutdown mode	0		0.7	V
V_H			Reference is active	0.75 × V_{IN}		V_{IN}	
V_{IN}	Power supply Voltage		I_L = 0	V_{OUT} + 0.05(1)		5.5	V
I_Q	Power supply Current		I_L = 0, ENABLE > 0.75 × V_{IN}		100	120	μA
I_S	Overtemperature shutdown		–55°C ≤ T_A ≤ 125°C		**115**	**135**	μA
			ENABLE < 0.7 V		0.1	1	μA
	Temperature range	Specified		–55		125	°C
		Operating		–55		125	
		Storage		–65		150	
θ_{JA}	Thermal resistance, SOT23-6				200		°C/W

Operating Life Derating Chart



A. See Datasheet for Absolute Maximum and Minimum Recommended Operating Conditions.

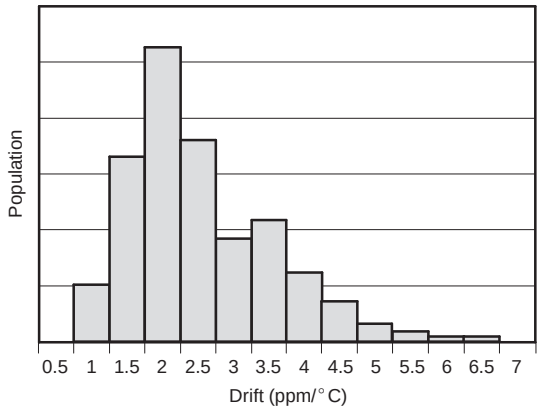
B. Silicon Operating Life Design Goal is 10 years at 105°C Junction Temperature (does not include package interconnect life).

C. Enhanced Plastic Product Disclaimer Applies.

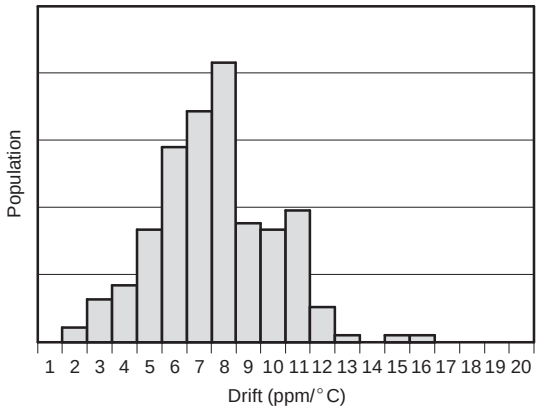
TYPICAL CHARACTERISTICS

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

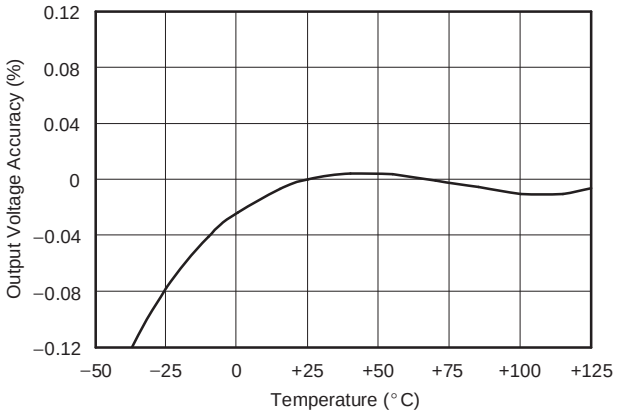
TEMPERATURE DRIFT
(0°C to +125°C)



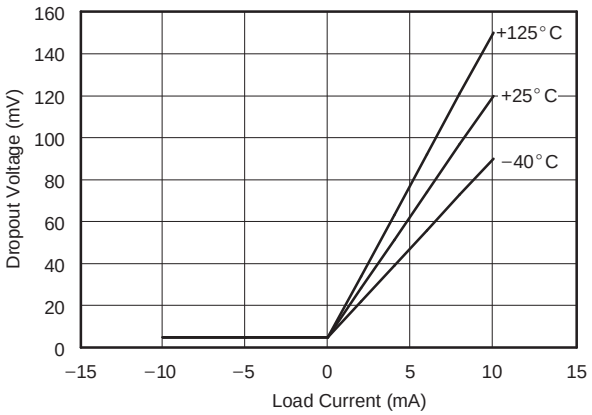
TEMPERATURE DRIFT
(−40°C to +125°C)



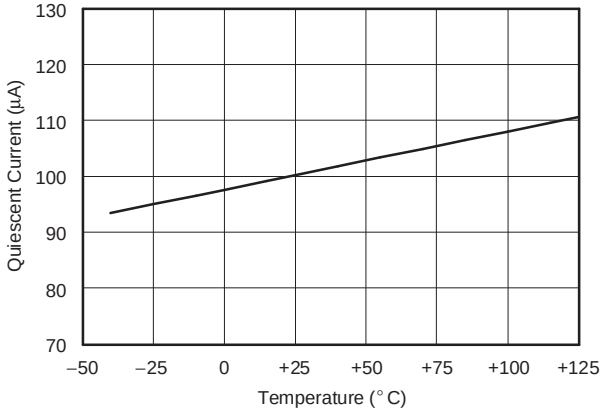
OUTPUT VOLTAGE ACCURACY
vs TEMPERATURE



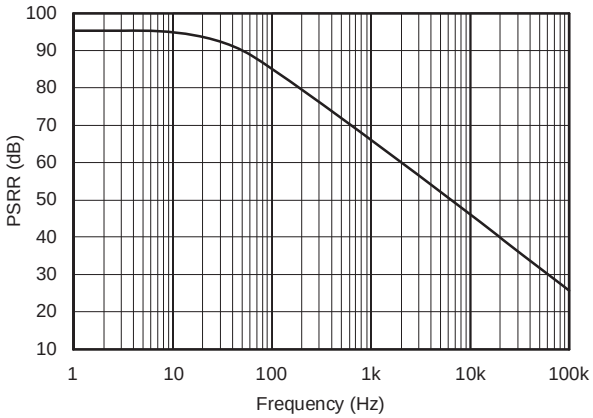
DROPOUT VOLTAGE
vs LOAD CURRENT



QUIESCENT CURRENT
vs TEMPERATURE



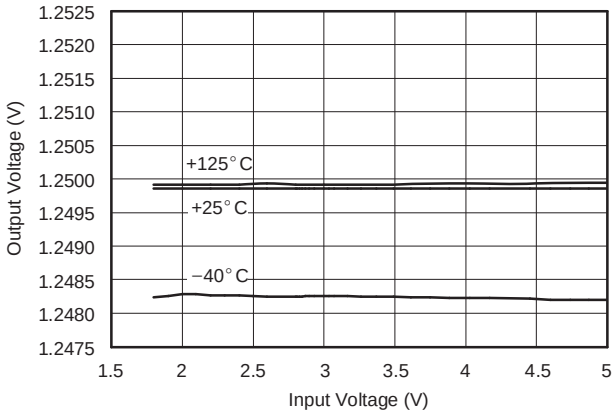
POWER−SUPPLY REJECTION RATIO
vs FREQUENCY



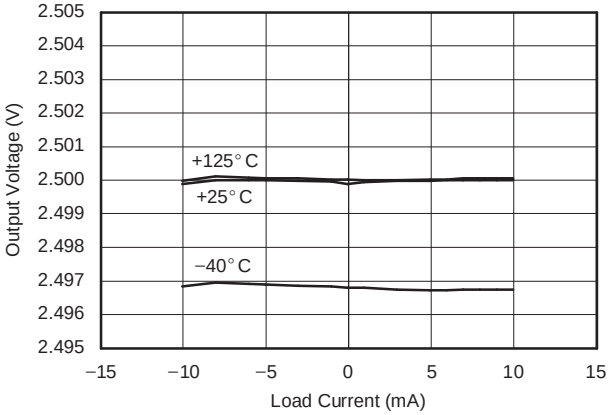
TYPICAL CHARACTERISTICS (continued)

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

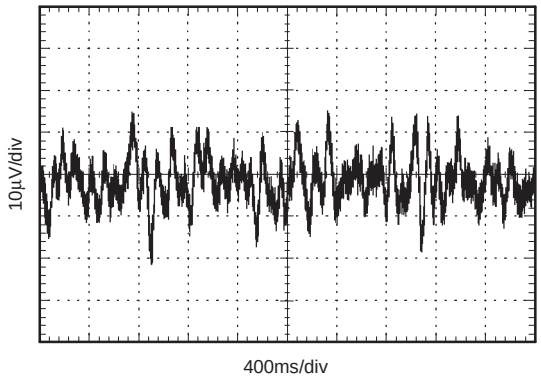
OUTPUT VOLTAGE vs INPUT VOLTAGE
(REF3212)



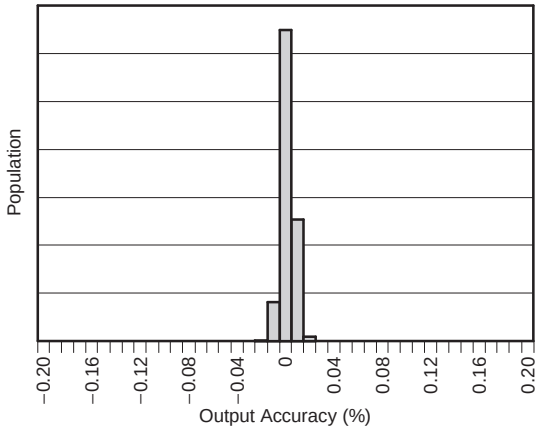
OUTPUT VOLTAGE
vs LOAD CURRENT



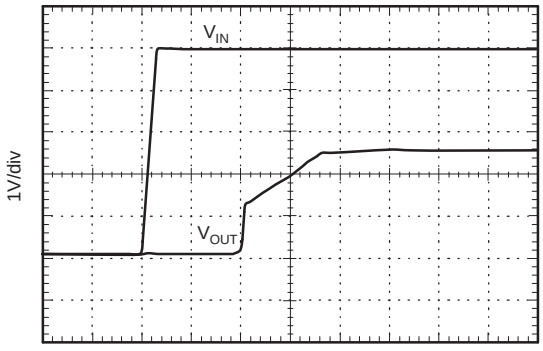
0.1Hz TO 10Hz
NOISE



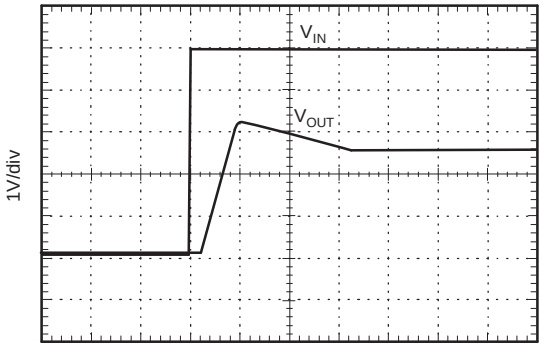
OUTPUT VOLTAGE
INITIAL ACCURACY



STEP RESPONSE
C_L = 0pF, 5V STARTUP



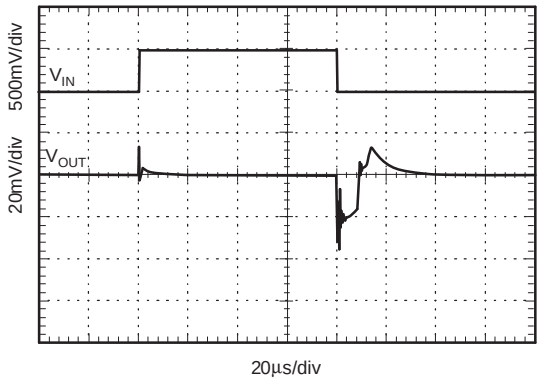
STEP RESPONSE
C_L = 1μF



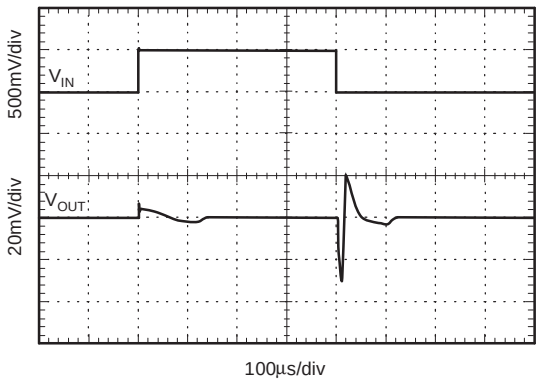
TYPICAL CHARACTERISTICS (continued)

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

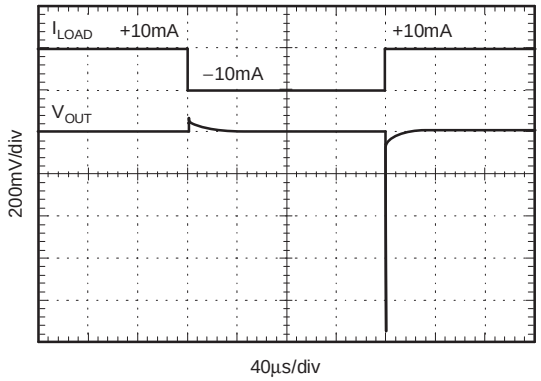
LINE TRANSIENT
C_L = 0pF



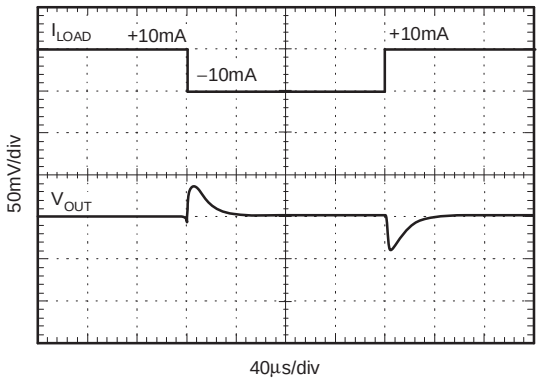
LINE TRANSIENT
C_L = 10µF



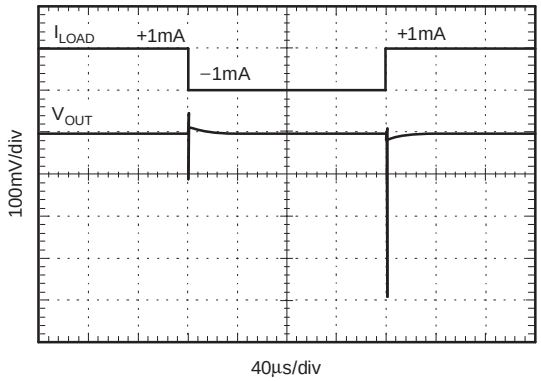
LOAD TRANSIENT
C_L = 0pF, ±10mA OUTPUT PULSE



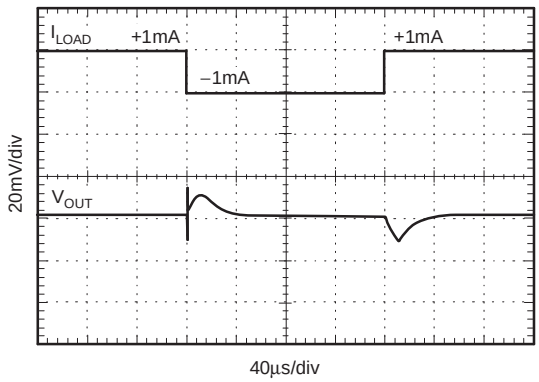
LOAD TRANSIENT
C_L = 1µF, ±10mA OUTPUT PULSE



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

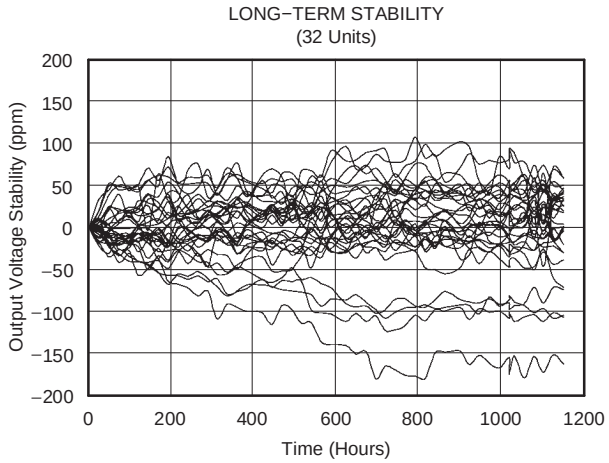


LOAD TRANSIENT
C_L = 1µF, ±1mA OUTPUT PULSE



TYPICAL CHARACTERISTICS (continued)

T_A = 25°C, I_{LOAD} = 0 mA, V_{IN} = 5 V 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.

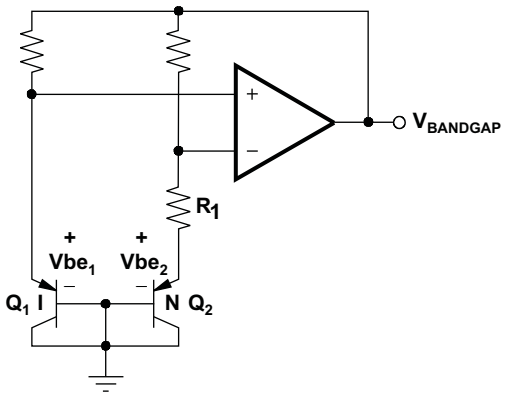


Figure 1. Simplified Schematic of Bandgap Reference

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 0.47 µF is recommended.

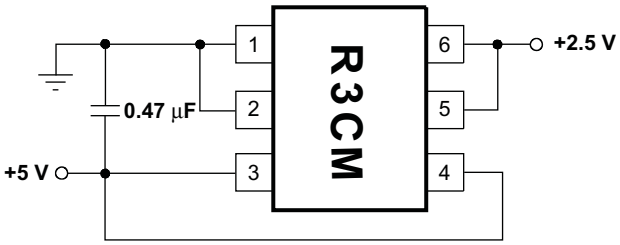


Figure 2. Typical Operating Connections for the REF3225

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 1.8 V, these references can be operated with a supply of only 5 mV 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 100 µA, with a maximum quiescent current over temperature of just 135 µA. The quiescent current typically changes less than 2 µA over the entire supply range, as shown in Figure 3.

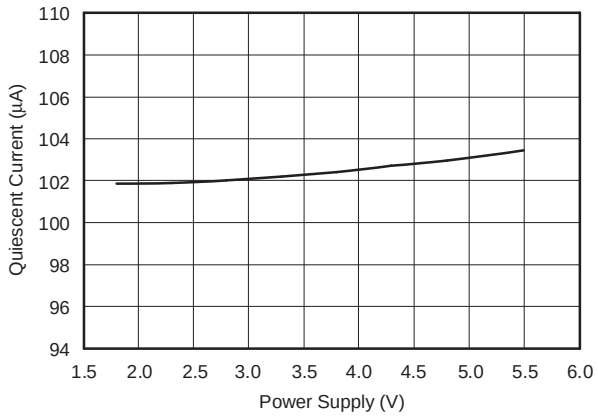


Figure 3. Supply Current vs Supply Voltage

Supply voltages below the specified levels can cause the 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 100 kΩ to 400 kΩ.

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:

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

Where:

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

V_{NOM} = The specified output voltage

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

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

The REF32xx features a typical drift coefficient of 4 ppm/°C from 0°C to 125°C — the primary temperature range for many applications. For the extended temperature range of –55°C to 125°C, the REF32xx family drift increases to a typical value of 10.5 ppm/°C.

Noise Performance

Typical 0.1-Hz to 10-Hz voltage noise can be seen in the Typical Characteristic curve, *0.1-Hz to 10-Hz 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 55 ppm 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.

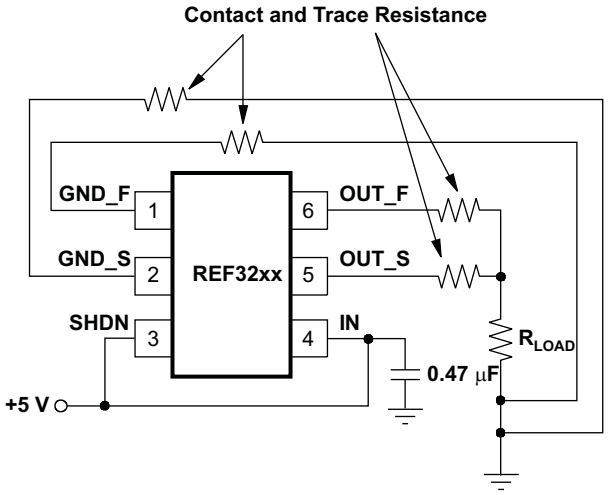
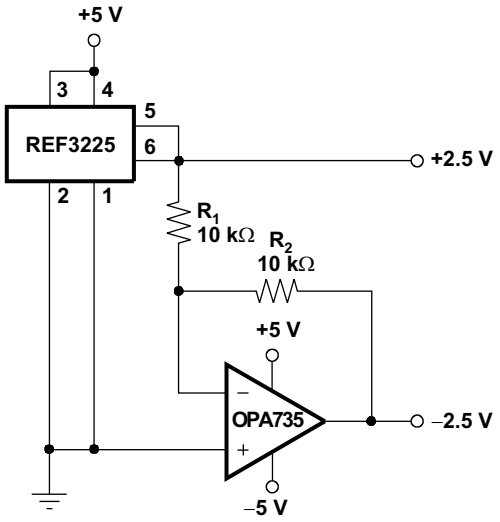


Figure 4. Accurate Load Regulation of REF32xx

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 5-V supply. Figure 5 shows the REF3225 used to provide a 2.5-V 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.



Note: Bypass capacitor is not shown.

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.

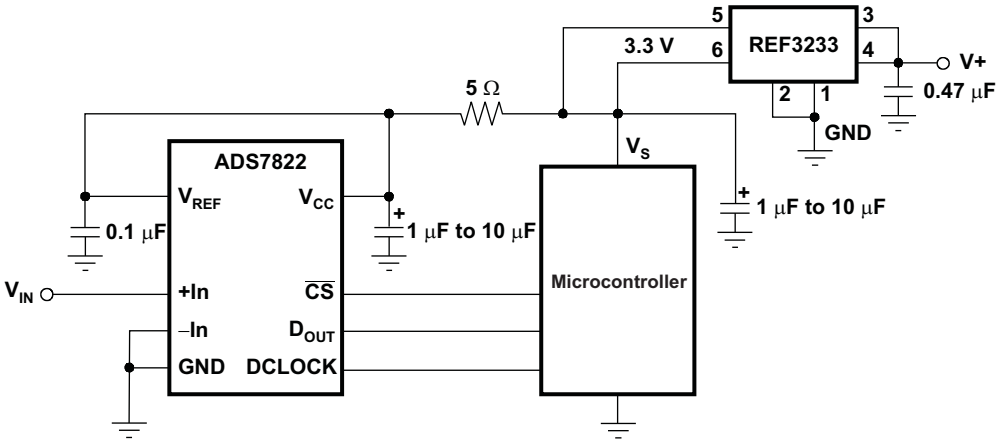


Figure 6. Basic Data Acquisition System 1

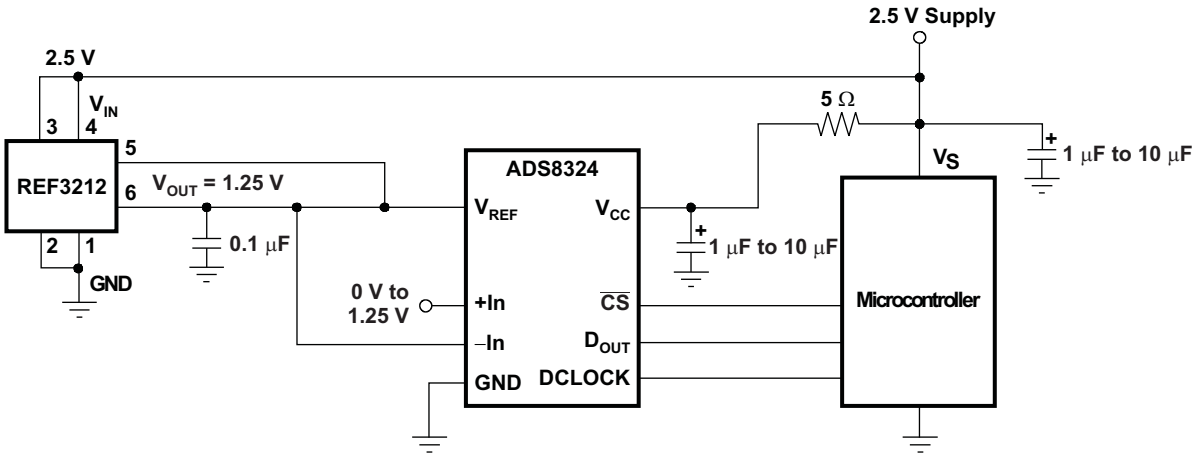


Figure 7. Basic Data Acquisition System 2

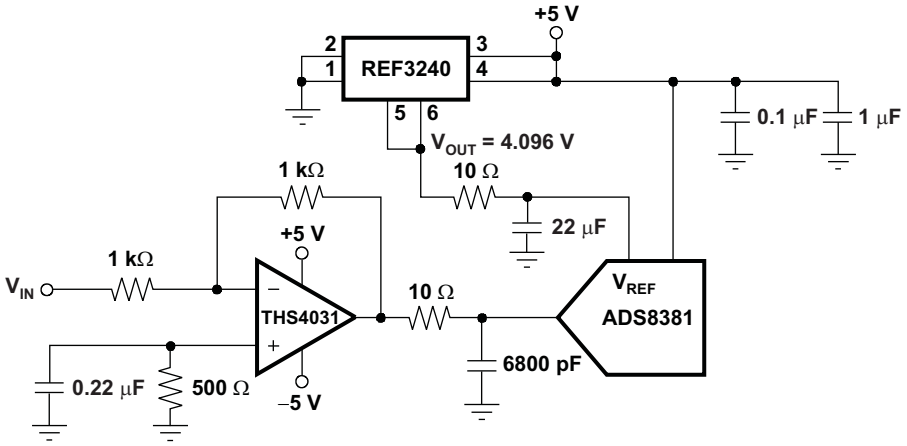


Figure 8. REF3240 Provides an Accurate Reference for Driving the ADS8381

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
REF3212AMDBVREP	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
REF3212AMDBVREPG4	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
REF3220AMDBVREP	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
REF3225AMDBVREP	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
REF3230AMDBVREP	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
REF3233AMDBVREP	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
REF3240AMDBVREP	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
V62/07602-01XE	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
V62/07602-02XE	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
V62/07602-03XE	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
V62/07602-04XE	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
V62/07602-05XE	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
V62/07602-06XE	ACTIVE	SOT-23	DBV	6	3000	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), Pb-Free (RoHS Exempt), 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.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
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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OTHER QUALIFIED VERSIONS OF REF3212-EP, REF3220-EP, REF3225-EP, REF3230-EP, REF3233-EP, REF3240-EP :

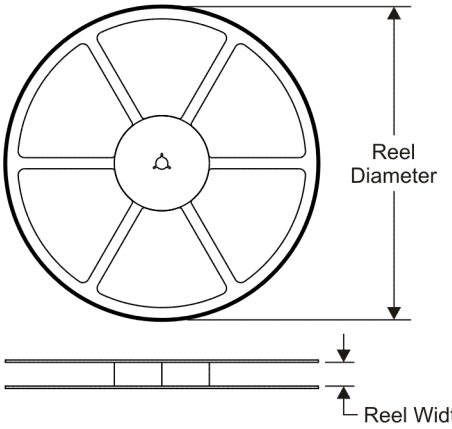
- Catalog: REF3212, REF3220, REF3225, REF3230, REF3233, REF3240

NOTE: Qualified Version Definitions:

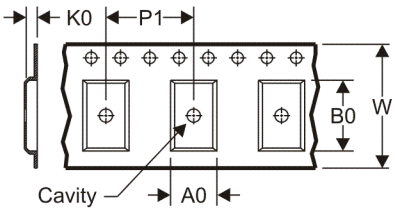
- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION

REEL DIMENSIONS

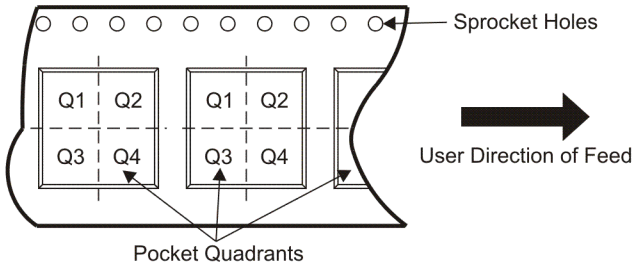


TAPE DIMENSIONS



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

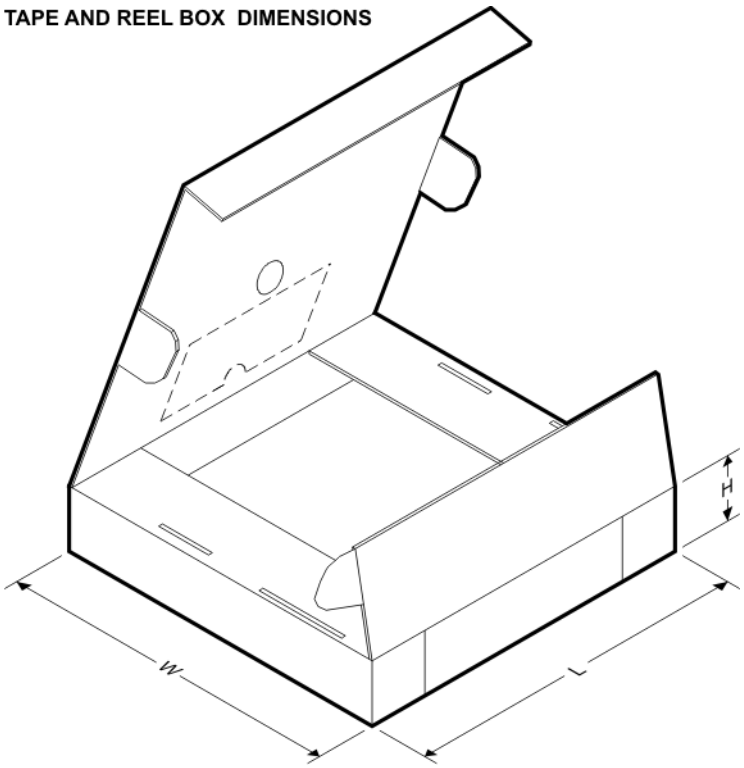
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
REF3240AMDBVREP	SOT-23	DBV	6	3000	180.0	8.4	3.2	3.1	1.4	4.0	8.0	Q3

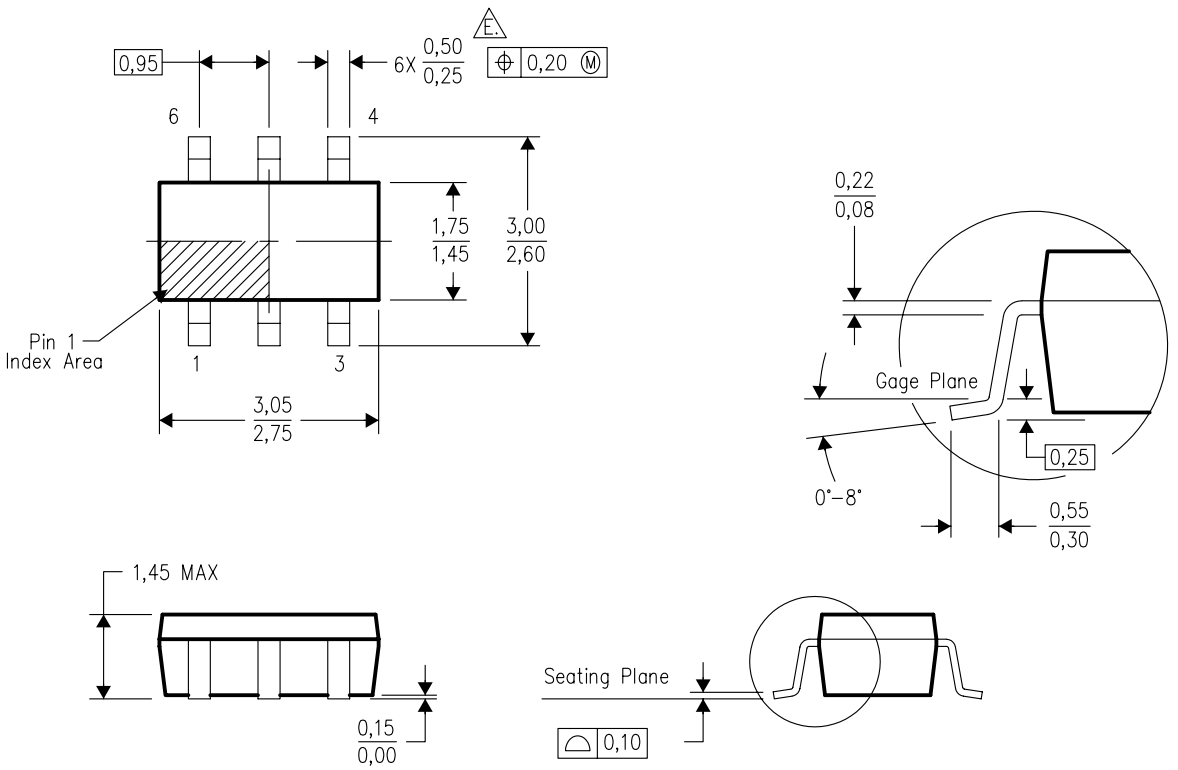
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
REF3240AMDBVREP	SOT-23	DBV	6	3000	184.0	184.0	50.0

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. Mold flash and protrusion shall not exceed 0.15 per side.
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.

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