



## 100ppm/°C, 50µA in SOT23-3 CMOS VOLTAGE REFERENCE

### FEATURES

- **MicroSIZE PACKAGE:** SOT23-3
- **LOW DROPOUT:** 1mV
- **HIGH OUTPUT CURRENT:** 25mA
- **LOW TEMPERATURE DRIFT:** 100ppm/°C max
- **HIGH ACCURACY:** 2%
- **LOW I<sub>Q</sub>:** 50µA max

### APPLICATIONS

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

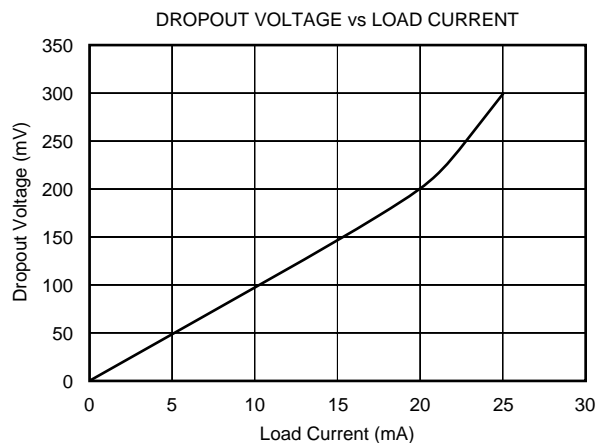
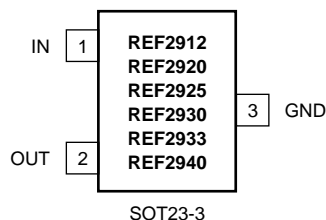
### DESCRIPTION

The REF29xx is a precision, low-power, low-voltage dropout voltage reference family available in a tiny SOT23-3.

The REF29xx's small size and low power consumption (50µA max) make it ideal for portable and battery-powered applications. The REF29xx does not require a load capacitor, but is stable with any capacitive load.

Unloaded, the REF29xx can be operated with supplies within 1mV of output voltage. All models are specified for the wide temperature range, -40°C to +125°C.

PRODUCT	VOLTAGE (V)
REF2912	1.25
REF2920	2.048
REF2925	2.5
REF2930	3.0
REF2933	3.3
REF2940	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.

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

Supply Voltage, V+ to V- .....	7.0V
Output Short-Circuit <sup>(2)</sup> .....	Continuous
Operating Temperature .....	-40°C to +125°C
Storage Temperature .....	-65°C to +125°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.  
(2) Short-circuit to ground.



## 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

PRODUCT	PACKAGE-LEAD	PACKAGE DESIGNATOR <sup>(1)</sup>	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
REF2912	SOT23-3	DBZ	-40°C to +125°C	R29A	REF2912AIDBZT	Tape and Reel, 250
"	"	"	"	"	REF2912AIDBZR	Tape and Reel, 3000
REF2920	SOT23-3	DBZ	-40°C to +125°C	R29B	REF2920AIDBZT	Tape and Reel, 250
"	"	"	"	"	REF2920AIDBZR	Tape and Reel, 3000
REF2925	SOT23-3	DBZ	-40°C to +125°C	R29C	REF2925AIDBZT	Tape and Reel, 250
"	"	"	"	"	REF2925AIDBZR	Tape and Reel, 3000
REF2930	SOT23-3	DBZ	-40°C to +125°C	R29D	REF2930AIDBZT	Tape and Reel, 250
"	"	"	"	"	REF2930AIDBZR	Tape and Reel, 3000
REF2933	SOT23-3	DBZ	-40°C to +125°C	R29E	REF2933AIDBZT	Tape and Reel, 250
"	"	"	"	"	REF2933AIDBZR	Tape and Reel, 3000
REF2940	SOT23-3	DBZ	-40°C to +125°C	R29F	REF2940AIDBZT	Tape and Reel, 250
"	"	"	"	"	REF2940AIDBZR	Tape and Reel, 3000

NOTE: (1) For the most current specifications and package information, refer to our web site at [www.ti.com](http://www.ti.com).

## ELECTRICAL CHARACTERISTICS

**Boldface limits apply over the specified temperature range, T<sub>A</sub> = -40°C to +125°C.**

At T<sub>A</sub> = +25°C, I<sub>LOAD</sub> = 0mA, V<sub>IN</sub> = 5V, unless otherwise noted.

PARAMETER	CONDITIONS	REF29xx			UNITS
		MIN	TYP	MAX	
<b>REF2912-1.25V</b>					
<b>OUTPUT VOLTAGE</b> Initial Accuracy	V <sub>OUT</sub>	1.225	1.25	1.275 2	V %
<b>NOISE</b> Output Voltage Noise Voltage Noise	f = 0.1Hz to 10Hz f = 10Hz to 10kHz		20 42		μVp-p μVrms
<b>LINE REGULATION</b>	1.8V ≤ V <sub>IN</sub> ≤ 5.5V		60	190	μV/V
<b>REF2920</b>					
<b>OUTPUT VOLTAGE</b> Initial Accuracy	V <sub>OUT</sub>	2.007	2.048	2.089 2	V %
<b>NOISE</b> Output Voltage Noise Voltage Noise	f = 0.1Hz to 10Hz f = 10Hz to 10kHz		28 65		μVp-p μVrms
<b>LINE REGULATION</b>	V <sub>REF</sub> + 50mV ≤ V <sub>IN</sub> ≤ 5.5V		110	290	μV/V
<b>REF2925</b>					
<b>OUTPUT VOLTAGE</b> Initial Accuracy	V <sub>OUT</sub>	2.450	2.50	2.550 2	V %
<b>NOISE</b> Output Voltage Noise Voltage Noise	f = 0.1Hz to 10Hz f = 10Hz to 10kHz		35 80		μVp-p μVrms
<b>LINE REGULATION</b>	V <sub>REF</sub> + 50mV ≤ V <sub>IN</sub> ≤ 5.5V		120	325	μV/V

# ELECTRICAL CHARACTERISTICS (Cont.)

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

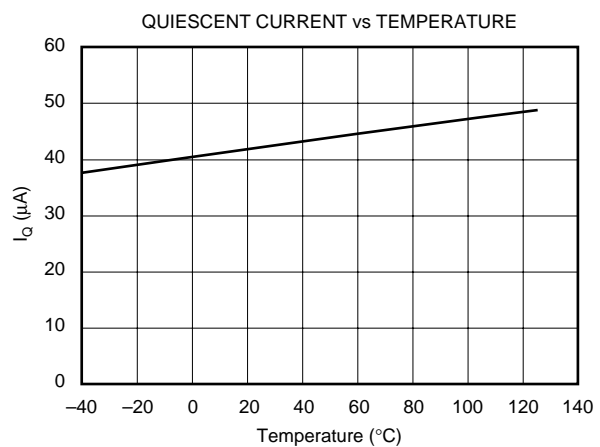
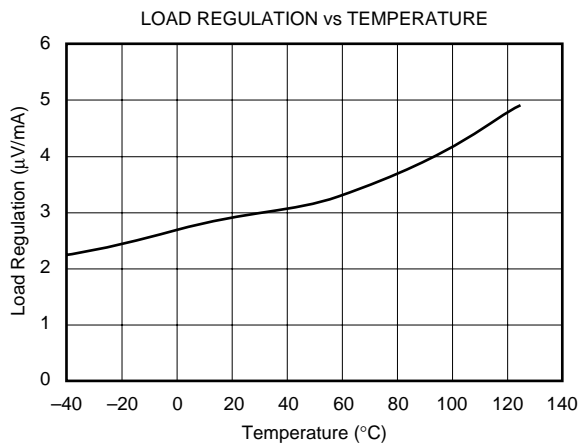
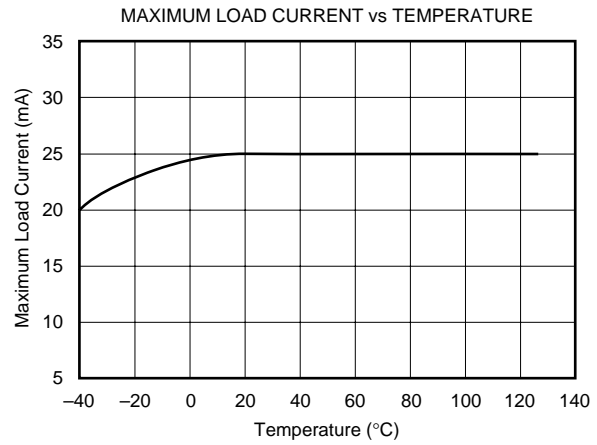
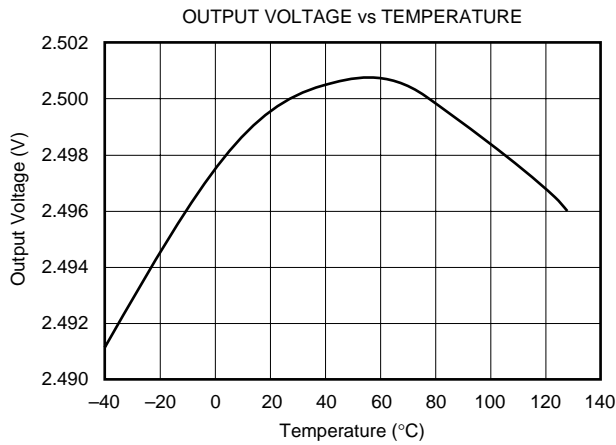
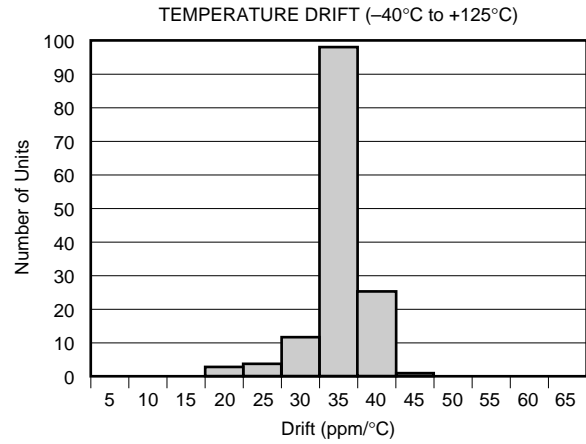
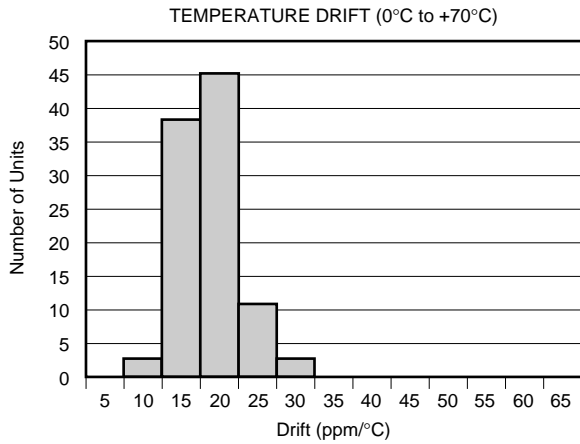
At  $T_A = +25^{\circ}\text{C}$ ,  $I_{\text{LOAD}} = 0\text{mA}$ ,  $V_{\text{IN}} = 5\text{V}$ , unless otherwise noted.

PARAMETER	CONDITIONS	REF29xx			UNITS
		MIN	TYP	MAX	
<b>REF2930</b>					
<b>OUTPUT VOLTAGE</b> Initial Accuracy	$V_{\text{OUT}}$	2.940	3.0	3.06 2	V %
<b>NOISE</b> Output Voltage Noise Voltage Noise	$f = 0.1\text{Hz to }10\text{Hz}$ $f = 10\text{Hz to }10\text{kHz}$				$\mu\text{Vp-p}$ $\mu\text{Vrms}$
<b>LINE REGULATION</b>	$V_{\text{REF}} + 50\text{mV} \leq V_{\text{IN}} \leq 5.5\text{V}$		120	375	$\mu\text{V/V}$
<b>REF2933</b>					
<b>OUTPUT VOLTAGE</b> Initial Accuracy	$V_{\text{OUT}}$	3.234	3.30	3.366 2	V %
<b>NOISE</b> Output Voltage Noise Voltage Noise	$f = 0.1\text{Hz to }10\text{Hz}$ $f = 10\text{Hz to }10\text{kHz}$		41 105		$\mu\text{Vp-p}$ $\mu\text{Vrms}$
<b>LINE REGULATION</b>	$V_{\text{REF}} + 50\text{mV} \leq V_{\text{IN}} \leq 5.5\text{V}$		130	400	$\mu\text{V/V}$
<b>REF2940</b>					
<b>OUTPUT VOLTAGE</b> Initial Accuracy	$V_{\text{OUT}}$	4.014	4.096	4.178 2	V %
<b>NOISE</b> Output Voltage Noise Voltage Noise	$f = 0.1\text{Hz to }10\text{Hz}$ $f = 10\text{Hz to }10\text{kHz}$		45 128		$\mu\text{Vp-p}$ $\mu\text{Vrms}$
<b>LINE REGULATION</b>	$V_{\text{REF}} + 50\text{mV} \leq V_{\text{IN}} \leq 5.5\text{V}$		160	410	$\mu\text{V/V}$
<b>REF2912, REF2920, REF2925, REF2930, REF2933, REF2940</b>					
<b>OUTPUT VOLTAGE TEMP DRIFT</b> <sup>(2)</sup>	$dV_{\text{OUT}}/dT$	$-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$		<b>35</b> <b>100</b>	<b>ppm/°C</b> <b>mA</b>
<b>OUTPUT CURRENT</b>	$I_{\text{LOAD}}$				<b>25</b> <b>ppm</b> <b>ppm</b>
<b>LONG-TERM STABILITY</b>		0-1000 <sub>H</sub> 1000-2000 <sub>H</sub>		24 15	<b>ppm</b> <b>ppm</b>
<b>LOAD REGULATION</b> <sup>(3)</sup>	$dV_{\text{OUT}}/dI_{\text{LOAD}}$	$0\text{mA} < I_{\text{LOAD}} < 25\text{mA}$ , $V_{\text{IN}} = V_{\text{REF}} + 500\text{mV}$ <sup>(1)</sup>		3	100 $\mu\text{V/mA}$
<b>THERMAL HYSTERESIS</b> <sup>(4)</sup>	$dT$			25	100 ppm
<b>DROPOUT VOLTAGE</b>	$V_{\text{IN}} - V_{\text{OUT}}$			1	50 mV
<b>SHORT-CIRCUIT CURRENT</b>	$I_{\text{SC}}$			45	mA
<b>TURN-ON SETTLING TIME</b>		to 0.1% at $V_{\text{IN}} = 5\text{V}$ with $C_L = 0$		120	$\mu\text{s}$
<b>POWER SUPPLY</b> Voltage Over Temperature Quiescent Current Over Temperature	$V_S$  $I_Q$	$I_L = 0$ $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$ $-40^{\circ}\text{C} \leq T_A \leq +125^{\circ}\text{C}$	$V_{\text{REF}} + 0.001$ <sup>(5)</sup> <b><math>V_{\text{REF}} + 0.05</math></b>		5.5 <b>5.5</b> 50 <b>59</b> V V $\mu\text{A}$ $\mu\text{A}$
<b>TEMPERATURE RANGE</b> Specified Range Operating Range Storage Range Thermal Resistance SOT23-3 Surface-Mount	$\theta_{\text{JC}}$ $\theta_{\text{JA}}$			-40 -40 -65	+125 +125 +150 °C °C °C °C/W °C/W

NOTES: (1) Minimum supply voltage for REF2912 is 1.8V. (2) Box Method used to determine over temperature drift. (3) Typical value of load regulation reflects measurements using a force and sense contacts, see text "Load Regulation". (4) Thermal hysteresis procedure is explained in more detail in Applications Information section of data sheet. (5) For  $I_L > 0$ , see Typical Characteristic curves.

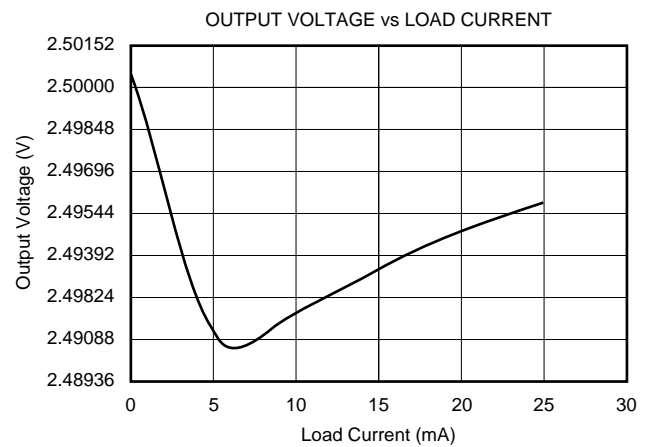
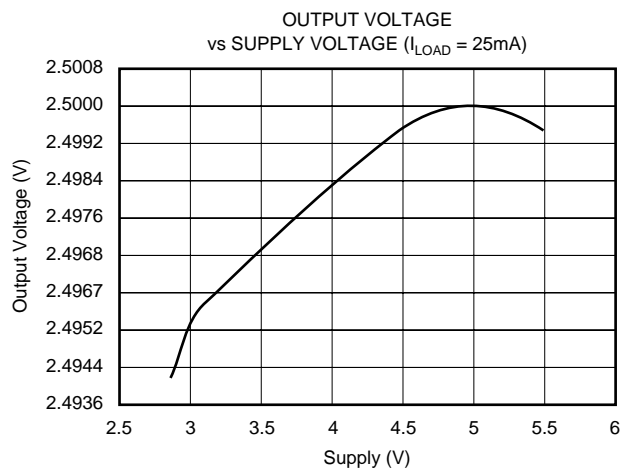
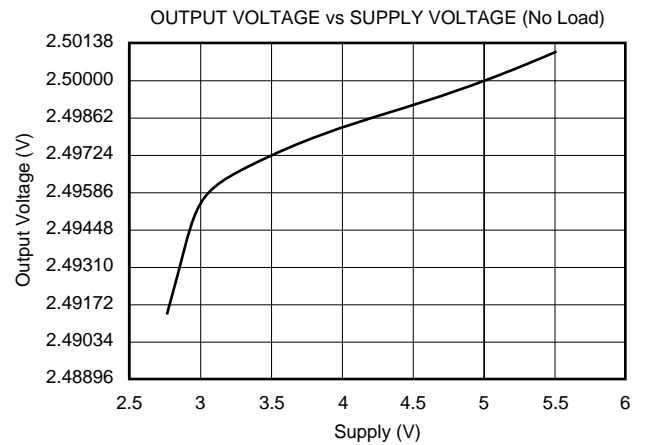
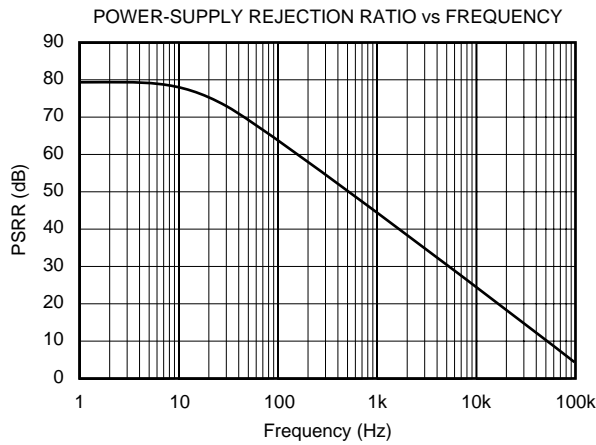
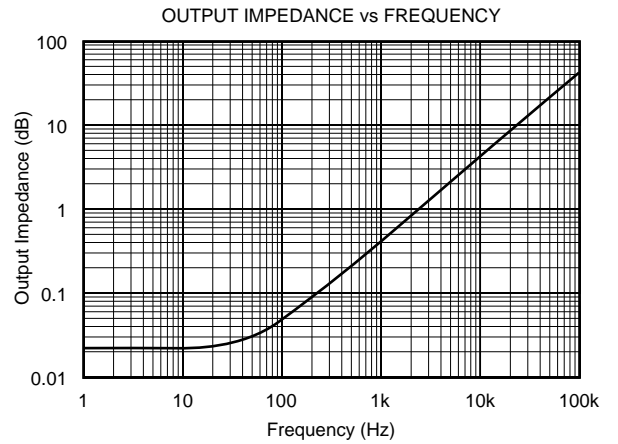
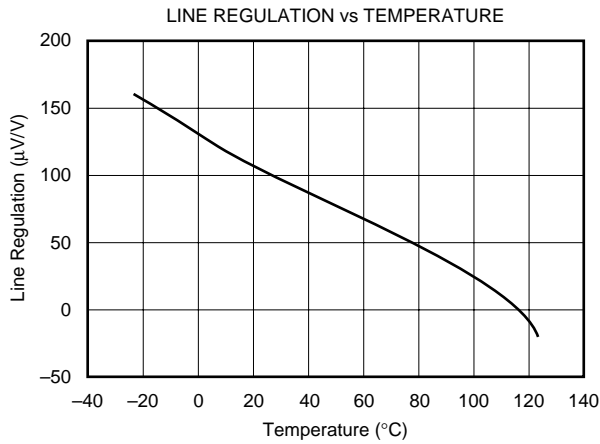
# TYPICAL CHARACTERISTICS

At  $T_A = +25^\circ\text{C}$ ,  $V_{IN} = +5\text{V}$  power supply, REF2925 is used for typical characteristics, unless otherwise noted.



# TYPICAL CHARACTERISTICS (Cont.)

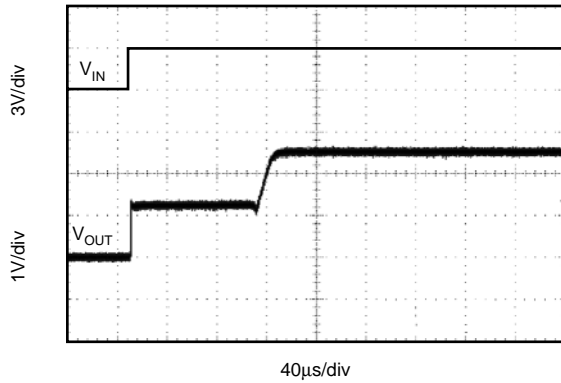
At  $T_A = +25^\circ\text{C}$ ,  $V_{IN} = +5\text{V}$  power supply, REF2925 is used for typical characteristics, unless otherwise noted.



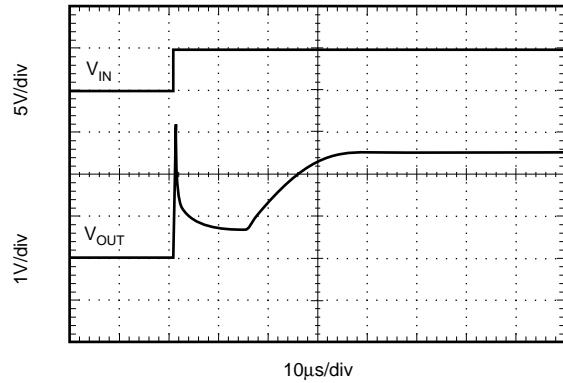
# TYPICAL CHARACTERISTICS (Cont.)

At  $T_A = +25^\circ\text{C}$ ,  $V_{IN} = +5\text{V}$  power supply, REF2925 is used for typical characteristics, unless otherwise noted.

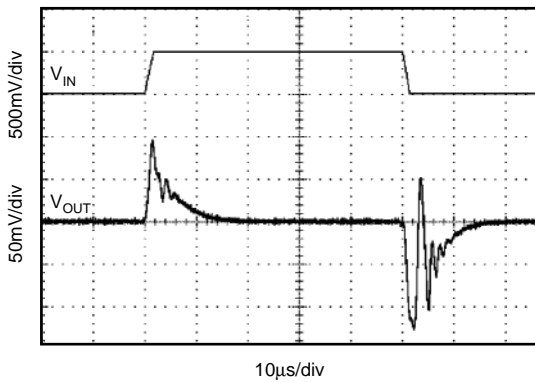
STEP RESPONSE,  $C_L = 0$ , 3V START-UP



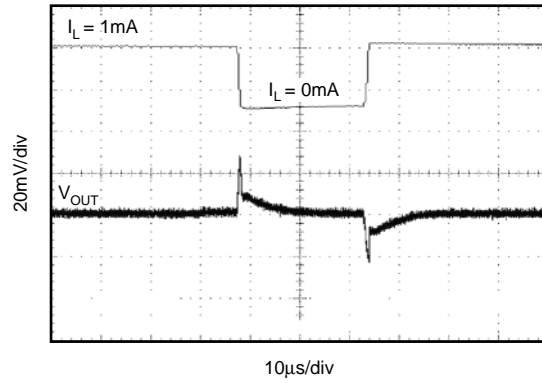
STEP RESPONSE,  $C_L = 0$ , 5V START-UP



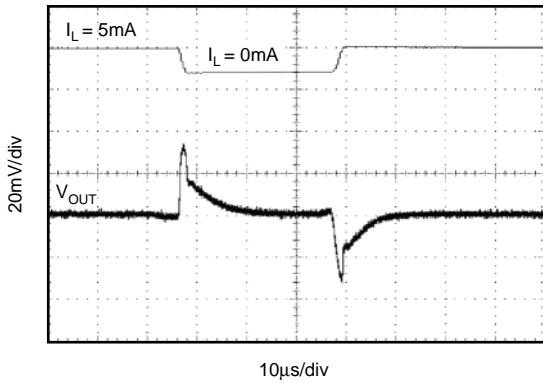
LINE TRANSIENT RESPONSE



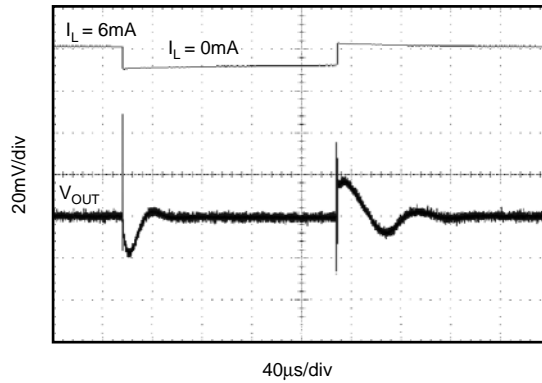
0-1mA LOAD TRANSIENT ( $C_L = 0$ )



0-5mA LOAD TRANSIENT ( $C_L = 0$ )

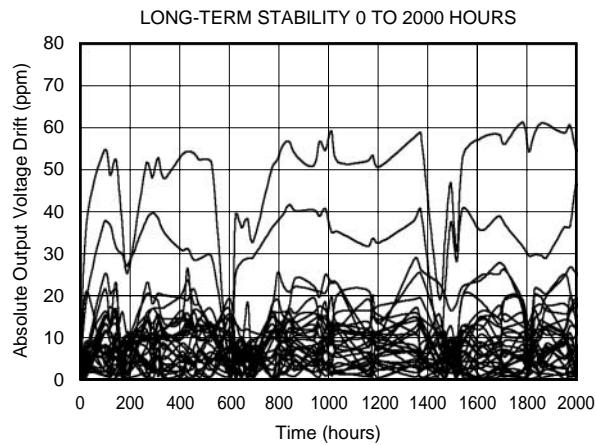
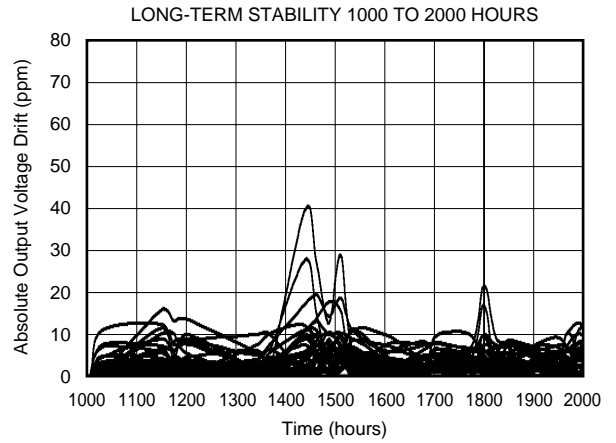
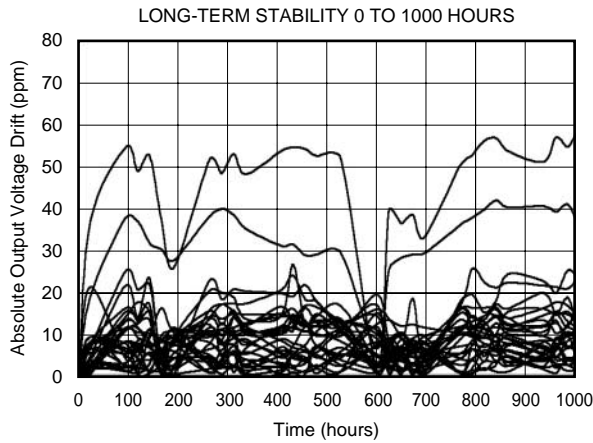
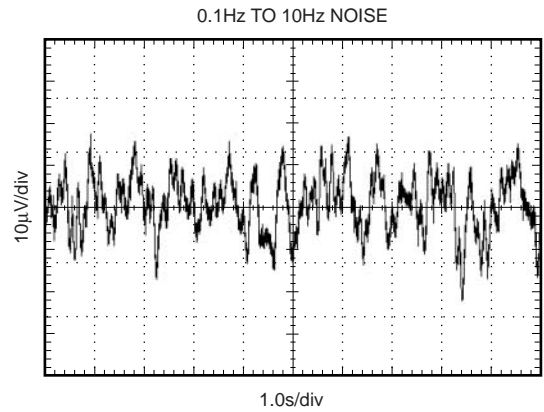
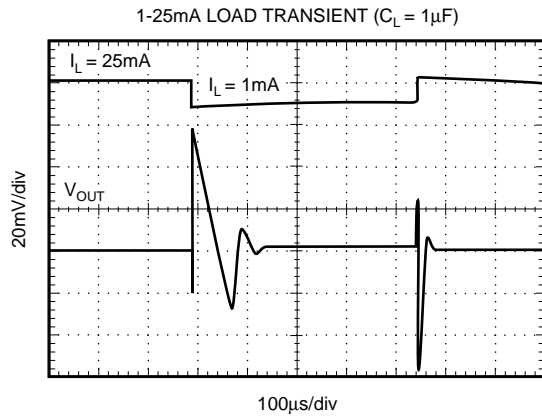


1-6mA LOAD TRANSIENT ( $C_L = 1\mu\text{F}$ )



# TYPICAL CHARACTERISTICS (Cont.)

At  $T_A = +25^\circ\text{C}$ ,  $V_{IN} = +5\text{V}$  power supply, REF2925 is used for typical characteristics, unless otherwise noted.



# THEORY OF OPERATION

The REF29xx is a series, CMOS, precision bandgap voltage reference. Its basic topology is shown in Figure 1. The 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 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  $Q_2$ .

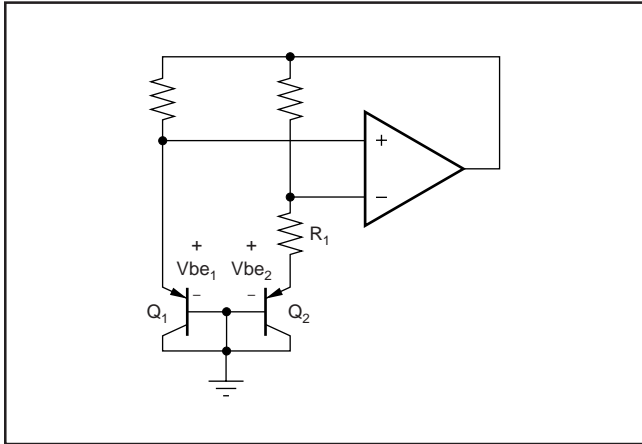


FIGURE 1. Simplified Schematic of Bandgap Reference.

## APPLICATION INFORMATION

The REF29xx does not require a load capacitor, and is stable with any capacitive load. Figure 2 shows typical connections required for operation of the REF29xx. A supply bypass capacitor of  $0.47\mu\text{F}$  is recommended.

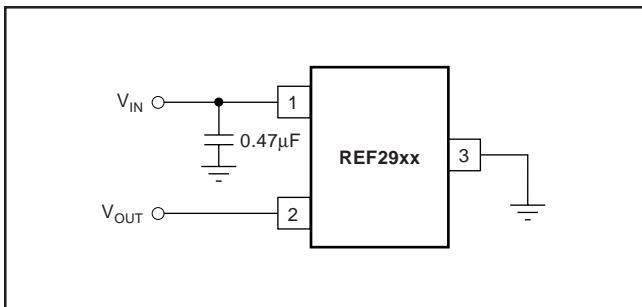


FIGURE 2. Typical Connections for Operating REF29xx.

### SUPPLY VOLTAGE

The REF30xx family of references features an extremely low dropout voltage. With the exception of the REF2912, which has a minimum supply requirement of 1.8V, the REF29xx can be operated with a supply of only 1mV above the output voltage in an unloaded condition. For loaded conditions, a typical dropout voltage versus load is shown on the cover page.

The REF29xx features a low quiescent current, which is extremely stable over changes in both temperature and supply. The typical room temperature quiescent current is  $42\mu\text{A}$ , and the maximum quiescent current over temperature is just  $59\mu\text{A}$ . Additionally, the quiescent current typically changes less than  $2.5\mu\text{A}$  over the entire supply range, as shown in Figure 3.

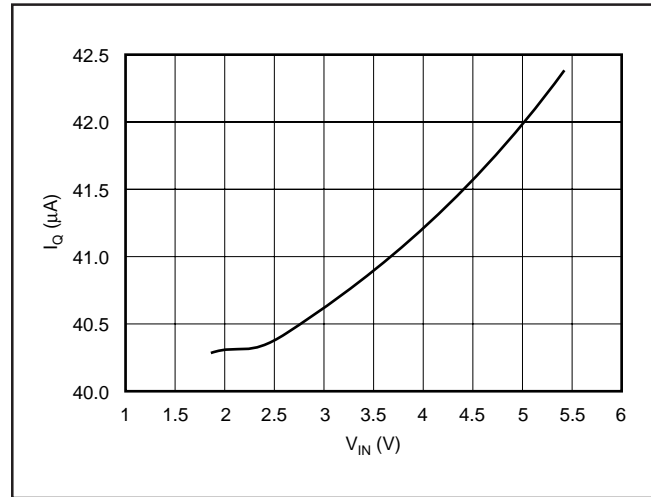


FIGURE 3. Supply Current vs Supply Voltage.

Supply voltages below the specified levels can cause the REF29xx 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 REF29xx 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  $25^\circ\text{C}$ , and 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:  $V_{\text{HYST}}$  = Calculated hysteresis

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

$V_{\text{POST}}$  = Output voltage measured when device has been operated at  $25^\circ\text{C}$ , cycled through specified range  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$  and returned to operation at  $25^\circ\text{C}$

### 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 REF29xx features a typical drift coefficient of 20ppm from  $0^\circ\text{C}$  to  $70^\circ\text{C}$ —the primary temperature range of use for many applications. For industrial temperature ranges of  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ , the REF30xx family drift increases to a typical value of 50ppm.

## NOISE PERFORMANCE

The REF29xx generates noise less than  $50\mu\text{Vp-p}$  between frequencies of 0.1Hz to 10Hz, and can be seen in the Typical Characteristic Curve “0.1 to 10Hz Voltage Noise”. The noise voltage of the REF29xx 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 REF29xx is 24ppm from 0-1000 hours, and 15ppm from 1000-2000 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 REF29xx is measured using force and sense contacts as pictured in Figure 4. The force and sense lines tied to the

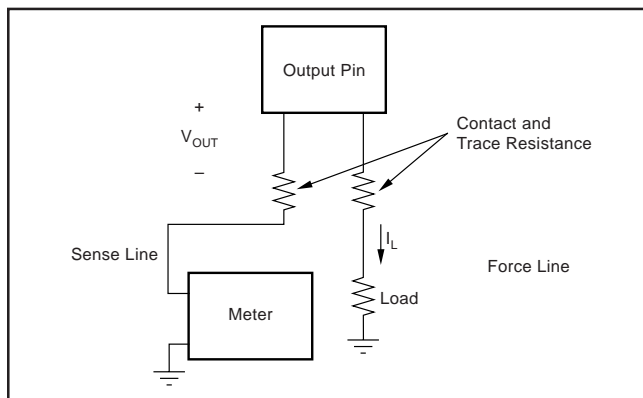


FIGURE 4. Accurate Load Regulation of REF29xx.

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 REF29xx. For applications requiring improved load regulation, force and sense lines should be used.

## APPLICATION CIRCUITS

### Negative Reference Voltage

For applications requiring a negative and positive reference voltage, the OPA703 and REF29xx can be used to provide a dual supply reference from a  $\pm 5\text{V}$  supply. Figure 5 shows the REF2925 used to provide a  $\pm 2.5\text{V}$  supply reference voltage. The low offset voltage and low drift of the OPA703 complement the low drift performance of the REF29xx to provide an accurate solution for split-supply applications.

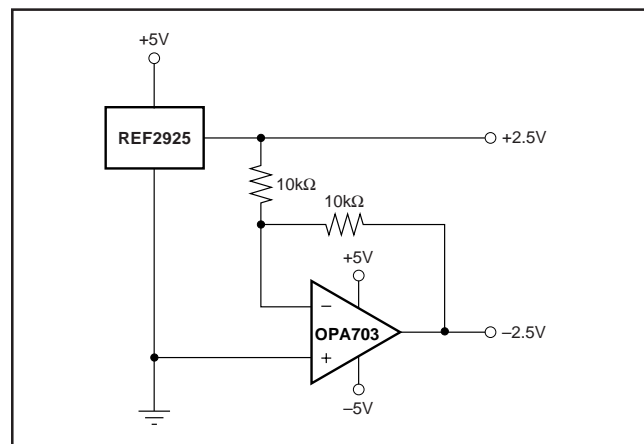


FIGURE 5. REF2925 Combined with OPA703 to Create Positive and Negative Reference Voltages.

## DATA ACQUISITION

Often data acquisition systems require stable voltage references to maintain necessary accuracy. The REF29xx family features stability and a wide range of voltages suitable for most micro-controllers and data converters. See Figure 6 for a basic data acquisition system.

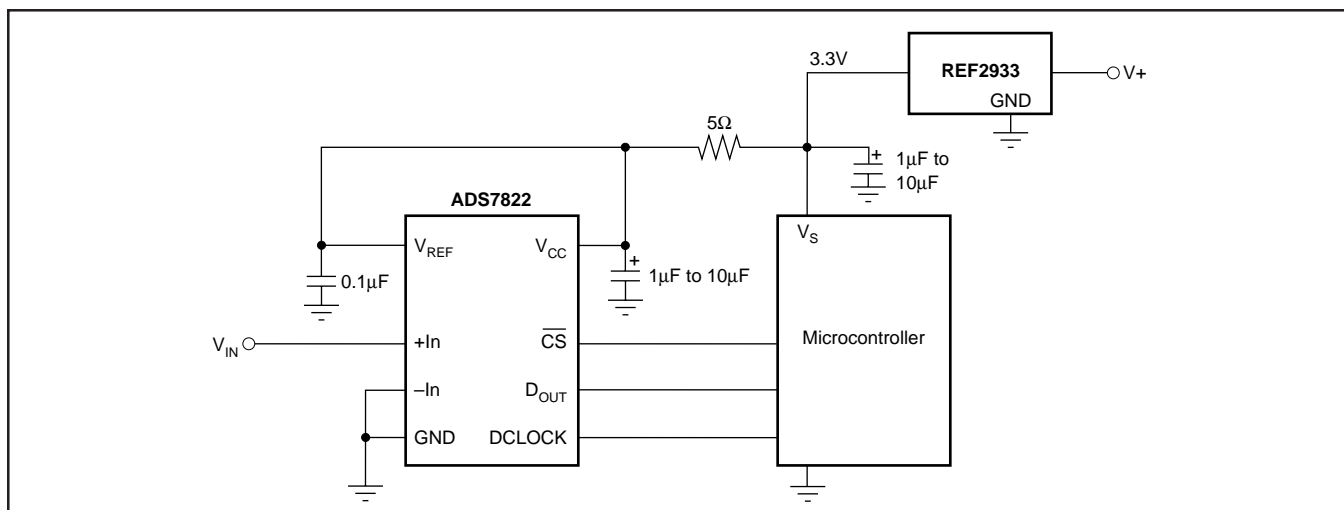
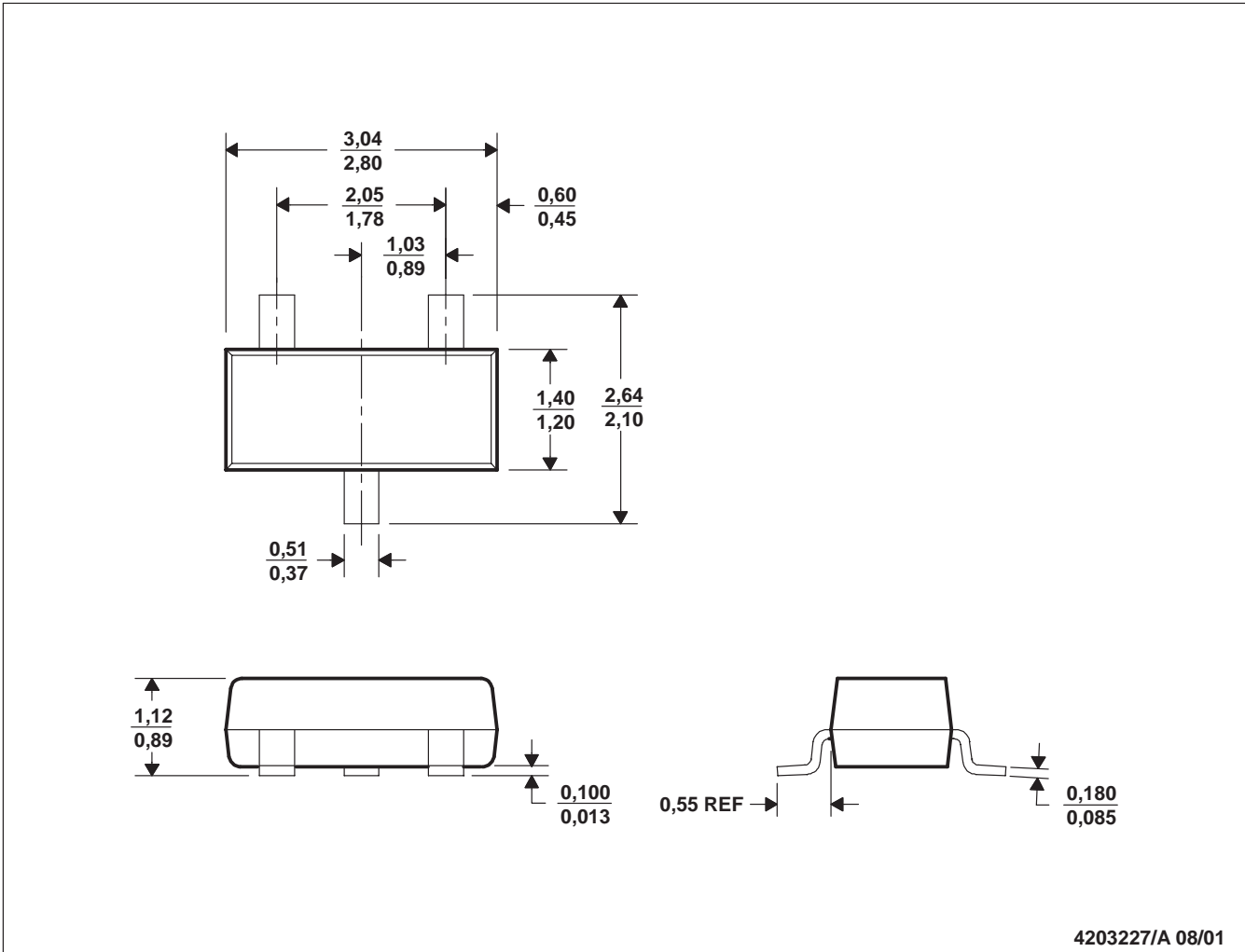


FIGURE 6. Basic Data Acquisition System 1.



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- 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.

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
REF2912AIDBZR	ACTIVE	SOT-23	DBZ	3	3000	None	ALLOY 42 SNPB Level-3-235C-168 HR	
REF2912AIDBZT	ACTIVE	SOT-23	DBZ	3	250	None	ALLOY 42 SNPB Level-3-235C-168 HR	
REF2920AIDBZR	ACTIVE	SOT-23	DBZ	3	3000	None	ALLOY 42 SNPB Level-3-235C-168 HR	
REF2920AIDBZT	ACTIVE	SOT-23	DBZ	3	250	None	ALLOY 42 SNPB Level-3-235C-168 HR	
REF2925AIDBZR	ACTIVE	SOT-23	DBZ	3	3000	None	ALLOY 42 SNPB Level-3-235C-168 HR	
REF2925AIDBZT	ACTIVE	SOT-23	DBZ	3	250	None	ALLOY 42 SNPB Level-3-235C-168 HR	
REF2930AIDBZR	ACTIVE	SOT-23	DBZ	3	3000	None	ALLOY 42 SNPB Level-3-235C-168 HR	
REF2930AIDBZT	ACTIVE	SOT-23	DBZ	3	250	None	ALLOY 42 SNPB Level-3-235C-168 HR	
REF2933AIDBZR	ACTIVE	SOT-23	DBZ	3	3000	None	ALLOY 42 SNPB Level-3-235C-168 HR	
REF2933AIDBZT	ACTIVE	SOT-23	DBZ	3	250	None	ALLOY 42 SNPB Level-3-235C-168 HR	
REF2940AIDBZR	ACTIVE	SOT-23	DBZ	3	3000	None	Call TI	Level-3-235C-168 HR
REF2940AIDBZT	ACTIVE	SOT-23	DBZ	3	250	None	ALLOY 42 SNPB Level-3-235C-168 HR	

<sup>(1)</sup> 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.

<sup>(2)</sup> Eco Plan - May not be currently available - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**None:** Not yet available Lead (Pb-Free).

**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" and in addition, uses package materials that do not contain halogens, including bromine (Br) or antimony (Sb) above 0.1% of total product weight.

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

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