5 V Precision Voltage Reference/Temperature Transducer

REF02

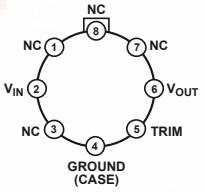
FEATURES

5 V output, ±0.3% max
Temperature voltage output, 1.96 mV/°C
Adjustment range, ±3% min
Excellent temperature stability, 8.5 ppm/°C max
Low noise, 15 µV p-p max
Low supply current, 1.4 mA max
Wide input voltage range, 7 V to 40 V
High load-driving capability, 10 mA
No external components
Short-circuit proof

GENERAL DESCRIPTION

The REF02 precision voltage reference provides a stable 5 V output that can be adjusted over a ±6% range with minimal effect on temperature stability. Single-supply operation over an input voltage range of 7 V to 40 V, low current drain of 1 mA, and excellent temperature stability are achieved with an improved band gap design. Low cost, low noise, and low power make the REF02 an excellent choice whenever a stable voltage reference is required. Applications include DACs and ADCs, portable instrumentation, and digital voltmeters. The versatility of the REF02 is enhanced by its use as a monolithic temperature transducer. For new designs, refer to ADR02.

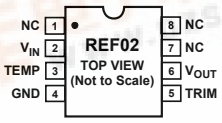
PIN CONFIGURATIONS



NC = NO CONNECT. DO NOT CONNECT ANYTHING ON THESE PINS. SOME OF THEM ARE RESERVED FOR FACTORY TESTING PURPOSES.

00375-F-001

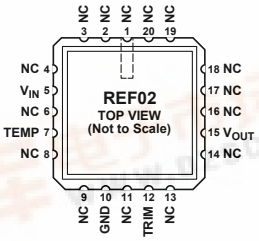
Figure 1. TO-99 (J-Suffix)



NC = NO CONNECT. DO NOT CONNECT ANYTHING ON THESE PINS. SOME OF THEM ARE RESERVED FOR FACTORY TESTING PURPOSES.

00375-F-002

Figure 2. 8-Lead PDIP (P-Suffix), 8-Lease CERDIP (Z-Suffix), 8-Lead SOIC (S-Suffix)



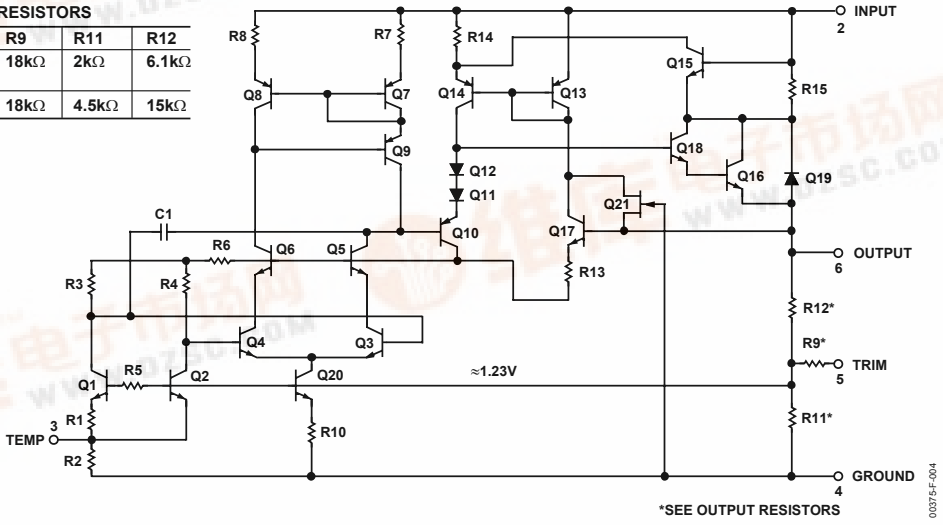
NC = NO CONNECT. DO NOT CONNECT ANYTHING ON THESE PINS. SOME OF THEM ARE RESERVED FOR FACTORY TESTING PURPOSES.

00375-F-003

Figure 3. REF02RC/883 LCC (RC-Suffix)

OUTPUT RESISTORS

REF02 OPTION	R9	R11	R12
Z PACKAGE AND 883C PRODUCT	18kΩ	2kΩ	6.1kΩ
P, S, RJ PACKAGES	18kΩ	4.5kΩ	15kΩ



00375-F-004

Figure 4. Simplified Schematic

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781.329.4700 www.analog.com
Fax: 781.326.8703

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3/04—Data Sheet Changed from Rev. D to Rev. E.

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Revision 0: Initial Version

SPECIFICATIONS

ELECTRICAL SPECIFICATIONS

@ V_{IN} = 15 V, T_A = +25°C, unless otherwise noted.

Table 1.

Parameter	Symbol	Conditions	REF02A/REF02E			REF02/REF02H			Unit
			Min	Typ	Max	Min	Typ	Max	
Output Voltage	V_O	I_L = 0 mA	4.985	5.000	5.015	4.975	5.000	5.025	V
Output Adjustment Range	ΔV_{TRIM}	R_P = 10 kΩ	±3	±6		±3	±6		%
Output Voltage Noise[1]	e_n p-p	0.1 Hz to 10 Hz		10	15		10	15	µV p-p
Line Regulation[2]		V_{IN} = 8 V to 40 V		0.006	0.010		0.006	0.010	%/V
Load Regulation[2]		I_L = 0 mA to 10 mA		0.005	0.010		0.006	0.010	%/mA
Turn-on Settling Time[1]	t_{ON}	To ±0.1% of Final Value		5			5		µs
Quiescent Supply Current	I_{SY}	No Load		1.0	1.4		1.0	1.4	mA
Load Current	I_L		10			10			mA
Sink Current[3]	I_S		−0.3	−0.5		−0.3	−0.5		mA
Short-Circuit Current	I_{SC}	V_O = 0		30			30		mA
Temperature Voltage Output[4]									
Z Package and 883C Product	V_T			630			630		mV
P, S, and J Packages	V_T			550			550		mV

[1] Guaranteed by design.
[2] Line and load regulation specifications include the effect of self-heating.
[3] During sink current test the device meets the output voltage specified.
[4] Limit current in or out of Pin 3 to 50 nA and capacitance on Pin 3 to 30 pF.

ELECTRICAL SPECIFICATIONS

@ V_{IN} = 15 V, −55°C ≤ T_A ≤ +125°C for REF02A and REF02, 0°C ≤T_A ≤ 70°C for REF02E and REF02H, I_L = 0 mA, unless otherwise noted.

Table 2.

Parameter	Symbol	Conditions	REF02A/REF02E			REF02/REF02H			Unit
			Min	Typ	Max	Min	Typ	Max	
Output Voltage Change	ΔV_{OT}	0°C ≤ T_A ≤ 70°C		0.02	0.06		0.07	0.17	%
with Temperature[1, 2]		−55°C ≤T_A ≤+125°C		0.06	0.15		0.18	0.45	%
Output Voltage Temperature Coefficient[3]	TCV_O			3	8.5		10	25	ppm/°C
Change in V_O Temperature Coefficient with Output Adjustment		R_P = 10 kΩ		0.7			0.7		ppm/%
Line Regulation		0°C ≤ T_A ≤ 70°C		0.007	0.012		0.007	0.012	%/V
(V_{IN} = 8 V to 40 V)[4]		−55°C ≤ T_A ≤ +125°C		0.009	0.015		0.009	0.015	%/V
Load Regulation		0°C ≤ T_A ≤ 70°C		0.006	0.010		0.007	0.012	%/mA
(I_L = 0 mA to 8 mA)[4]		−55°C ≤ T_A ≤ +125°C		0.007	0.012		0.009	0.015	%/mA
Temperature Voltage Output Temperature Coefficient[5]	TCV_T								
Z Package and 883C Product				2.10			2.10		mV/°C
P, S, and J Packages				1.96			1.96		mV/°C

[1] ΔV_{OT} is defined as the absolute difference between the maximum output voltage and the minimum output voltage over the specified temperature range expressed as a percentage of 5 V:

$$\Delta V_{OT} = \left| \frac{V_{MAX} - V_{MIN}}{5\ V} \right| \times 100$$

[2] ΔV_{OT} specification applies trimmed to 5,000 V or untrimmed.

[3] TCV_O is defined as ΔV_{OT} divided by the temperature range, i.e.,

$$TCV_O = \frac{\Delta V_{OT}}{70°C}$$

[4] Line and load regulation specifications include the effect of self-heating.

[5] Limit current in or out of Pin 3 to 50 nA and capacitance on Pin 3 to 30 pF.

ELECTRICAL SPECIFICATIONS

@ V_{IN} = 15 V, T_A = 25°C, unless otherwise noted.

Table 3.

			REF02C			REF02D			
Parameter	**Symbol**	**Conditions**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Unit**
Output Voltage	V_O	I_L = 0 mA	4.950	5.000	5.050	4.900	5.000	5.100	V
Output Adjustment Range	ΔV_{TRIM}	R_P = 10 kΩ	±2.7	±6.0		±2.0	±6.0		%
Output Voltage Noise[1]	e_n p-p	0.1 Hz to 10 Hz		12	18		12		µV p-p
Line Regulation[2]		V_{IN}= 8 V to 40 V		0.009	0.015		0.010	0.04	%/V
Load Regulation[2]		I_L = 0 mA to 8 mA		0.006	0.015				%/mA
		I_L = 0 mA to 4 mA					0.015	0.04	%/mA
Turn-On Settling Time[1]	t_{ON}	To ±0.1% of Final Value		5			5		µs
Quiescent Supply Current	I_{SY}	No Load		1.0	1.6		1.0	2.0	mA
Load Current	I_L		8			8			mA
Sink Current[3]	I_S		−0.3	−0.5		−0.3	−0.5		mA
Short-Circuit Current	I_{SC}	V_O = 0		30			30		mA
Temperature Voltage Output[4]									
Z Package and 883C Product	V_T			630			630		mV
P, S, and J Packages	V_T			550			550		mV

[1]Guaranteed by design.
[2]Line and load regulation specifications include the effect of self-heating.
[3] During sink current test the device meets the output voltage specified.
[4]Limit current in or out of Pin 3 to 50 nA and capacitance on Pin 3 to 30 pF.

ELECTRICAL SPECIFICATIONS

@ V_{IN} = 15 V, I_L = 0 mA, 0°C≤T_A ≤ 70°C for REF02CJ, REF02CZ, REF02DP, and −40°C ≤T_A ≤+85°C for REF02CP and REF02CS, unless otherwise noted.

Table 4.

			REF02C			REF02D			
Parameter	**Symbol**	**Conditions**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Unit**
Output Voltage Change with Temperature[1, 2]	ΔV_{OT}			0.14	0.45		0.49	1.7	%
Output Voltage[3]									
Temperature Coefficient	TCV_O			20	65		70	250	ppm/°C
Change in V_O Temperature Coefficient with Output Adjustment		R_P = 10 kΩ		0.7			0.7		ppm/%
Line Regulation[4]		V_{IN}= 8 V to 40 V		0.011	0.018		0.012	0.05	%/V
Load Regulation[4]		I_L= 0 mA to 5 mA		0.008	0.018		0.016	0.05	%/mA
Temperature Voltage Output Temperature Coefficient[5]	TCV_T								
Z Package and 883C Product				2.10			2.10		mV/°C
P, S, and "J" Packages				1.96			1.96		mV/°C

[1] ΔV_{OT} is defined as the absolute difference between the maximum output voltage and the minimum output voltage over the specified temperature range expressed as a percentage of 5 V:

$$\Delta V_{OT} = \left| \frac{V_{MAX} - V_{MIN}}{5\,V} \right| \times 100$$

[2] ΔV_{OT} specification applies trimmed to 5,000 V or untrimmed.

[3] TCV_O is defined as ΔV_{OT} divided by the temperature range, i.e.,

$$TCV_O = \frac{\Delta V_{OT}}{70°C}$$

[4] Line and load regulation specifications include the effect of self-heating.

[5] Limit current in or out of Pin 3 to 50 nA and capacitance on Pin 3 to 30 pF.

ABSOLUTE MAXIMUM RATINGS

Table 5.

Parameter	Rating
Input Voltage	40 V
Output Short-Circuit Duration	
to Ground or V_{IN}	Indefinite
Storage Temperature	
J, RC, and Z Packages	–65°C to +150°C
P Package	–65°C to +125°C
Operating Temperature Range	
REF02A, REF02J, REF02RC	–55°C to +125°C
REF02CJ, REF02CZ	0°C to 70°C
REF02CP, REF02CS, REF02E, REF02H	–40°C to +85°C
Lead Temperature Range (Soldering 10 sec)	300°C

Absolute maximum ratings apply to both DICE packaged parts, unless otherwise noted.

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions outside of those indicated in the operation sections of this specification is not implied. Exposure to absolute maximum ratings for extended periods may affect device reliability.

Table 6. Package Thermal Resistance

Package Type	θ_{JA}	θ_{JC}	Unit
TO-99 (J)	170	24	°C/W
8-Lead CERDIP (Z)	162	26	°C/W
8-Lead PDIP (P)	110	50	°C/W
20-Terminal Ceramic LCC (RC)	120	40	°C/W
8-Lead SOIC (S)	160	44	°C/W

*θ_{JA} is specified for worst-case mounting conditions, i.e. ,θ_{JA} is specified for device in socket for TO, CERDIP, PDIP, and LCC packages; θ_{JA} is specified for device soldered to printed circuit board for SOIC packages.

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although this product features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

TYPICAL PERFORMANCE CHARACTERISTICS

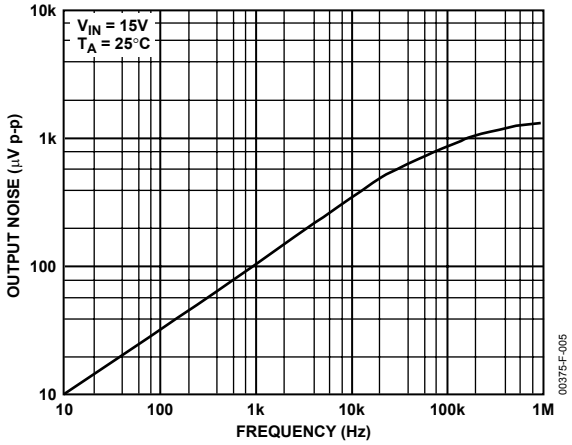


Figure 5. Output Wideband Noise vs. Bandwidth (0.1 Hz to Frequency Indicated)

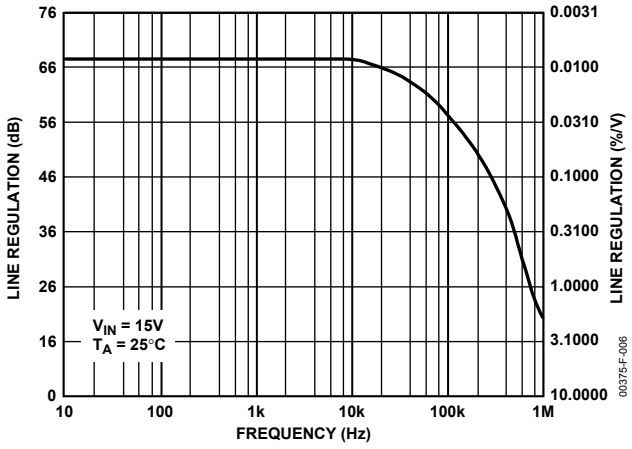


Figure 6. Line Regulation vs. Frequency

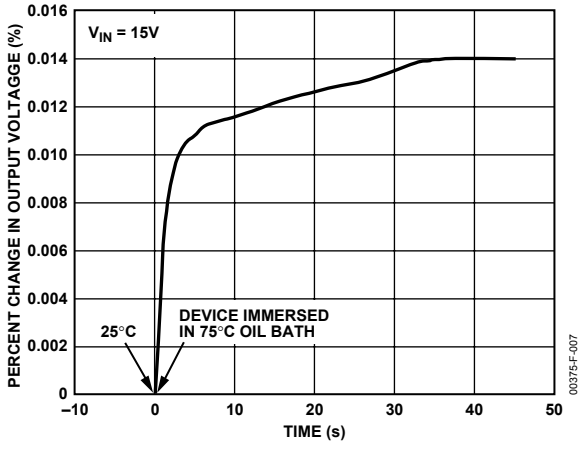


Figure 7. Output Change Due to Thermal Shock

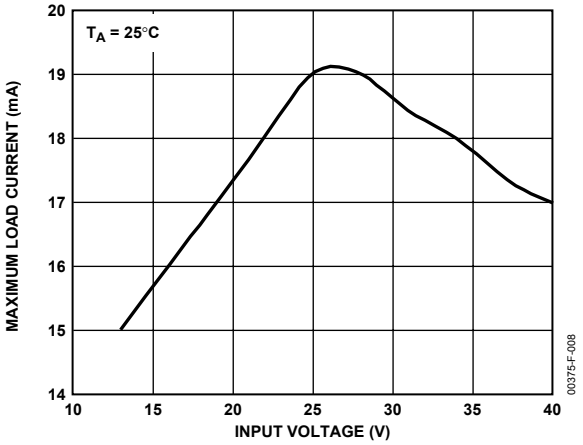


Figure 8. Maximum Load Current vs. Input Voltage

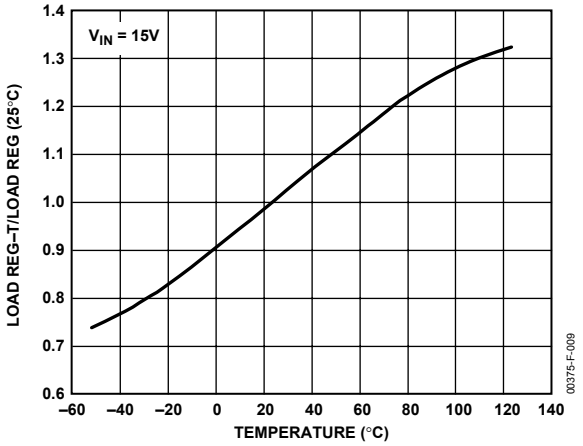


Figure 9. Normalized Load Regulation (ΔIL = 10 mA) vs. Temperature

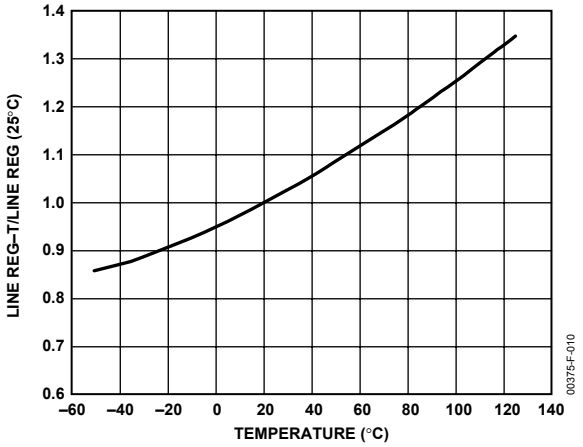


Figure 10. Normalized Line Regulation vs. Temperature

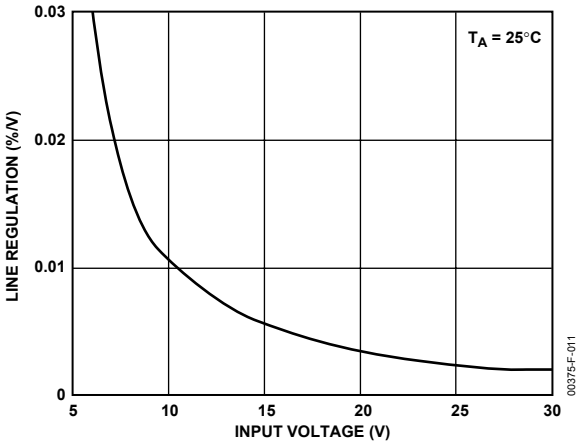


Figure 11. Line Regulation vs. Input Voltage

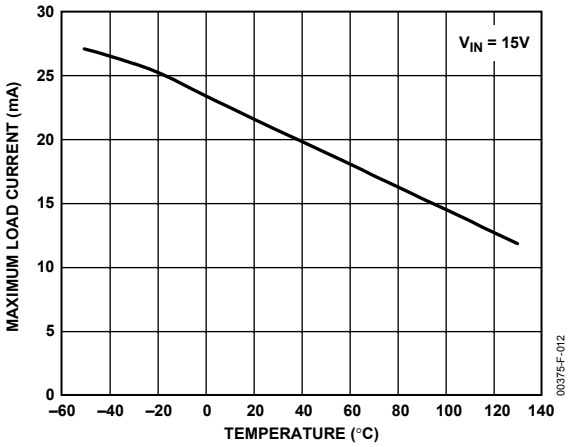


Figure 13. Maximum Load Current vs. Temperature

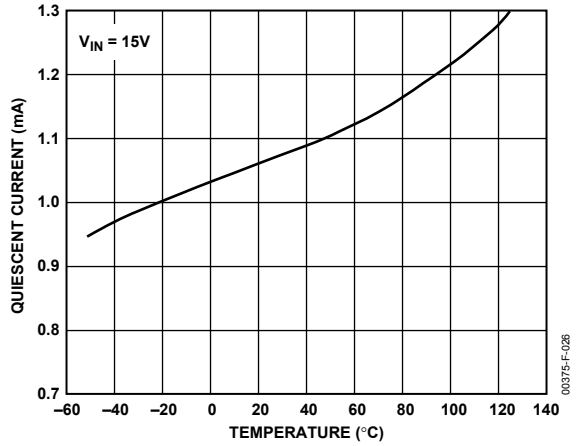


Figure 12 Quiescent Current vs. Temperature

OUTPUT ADJUSTMENT

The REF02 trim terminal can be used to adjust the output voltage over a 5 V ±300 mV range. This feature lets the system designer trim system errors by setting the reference to a voltage other than 5 V. The output also can be set to exactly 5.000 V or to 5.12 V for binary applications.

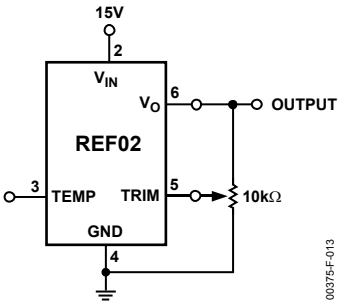


Figure 14. Output Adjustment Circuit

Adjustment of the output does not significantly affect the temperature performance of the device. The temperature coefficient change is approximately 0.7 ppm/°C for 100 mV of output adjustment.

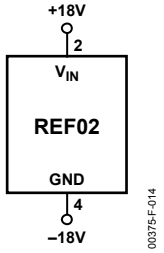


Figure 15. Burn-In Circuit

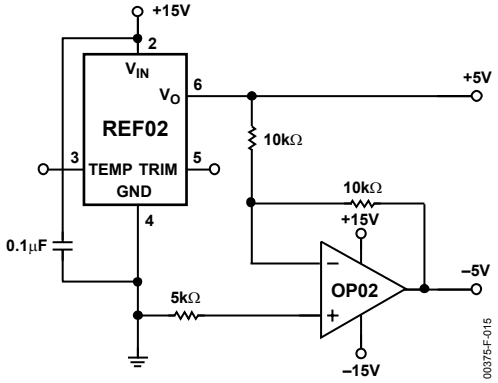


Figure 16. ±5 V Reference

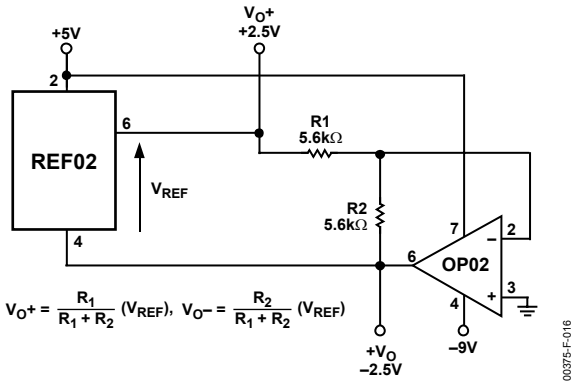


Figure 17. ±2.5 V Reference

TEMPERATURE MONITORING

As described previously, the REF02 provides a TEMP output (Pin 3) that varies linearly with temperature. This output can be used to monitor the temperature change in the system. The voltage at V_{TEMP} is approximately 550 mV at 25°C, and the temperature coefficient is approximately 1.96 mV/°C (see Figure 18).

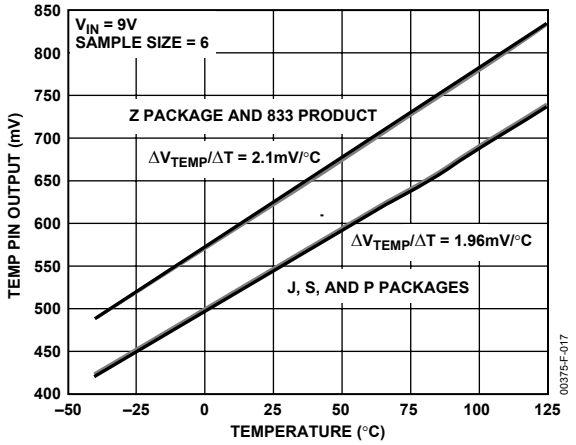


Figure 18. Voltage at TEMP Pin vs. Temperature

A voltage change of 39.2 mV at the TEMP pin corresponds to a 20°C change in temperature.

The TEMP function is provided as a convenience rather than a precise feature. Since the voltage at the TEMP node is acquired from the band gap core, current pulling from this pin will have a significant effect on V_{OUT}. Care must be taken to buffer the TEMP output with a suitable low bias current op amp, such as the AD8601, AD820, or OP1177 (all of which would result in less than a 100 V change in ΔV_{OUT}) See Figure 19. Without buffering, even tens of microamps drawn from the TEMP pin can cause V_{OUT} to fall out of specification.

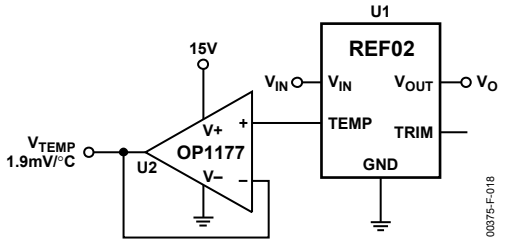


Figure 19. Temperature Monitoring

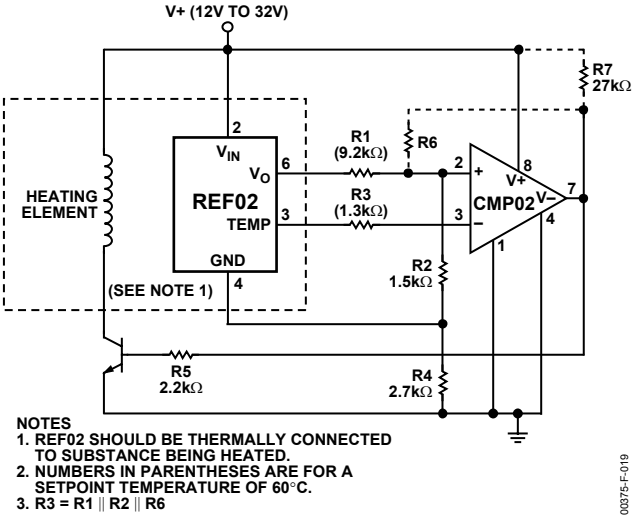


Figure 20. Temperature Controller

REFERENCE STACK WITH EXCELLENT LINE REGULATION

Two REF01s and one REF02 can be stacked to yield 5.000 V, 15.000 V, and 25.000 V outputs. An additional advantage is near-perfect line regulation of the 5.0 V and 15.0 V output. A 27 V to 55 V input change produces an output change that is less than the noise voltage of the devices. A load bypass resistor (RB) provides a path for the supply current (I_{SY}) of the 15.000 V regulator.

In general, any number of REF01s and REF02s can be stacked this way. For example, 10 devices will yield 10 outputs in 5 V or 10 V steps. The line voltage can change from 100 V to 130 V. However, care must be taken to ensure that the total load currents do not exceed the maximum usable current (typically 21 mA).

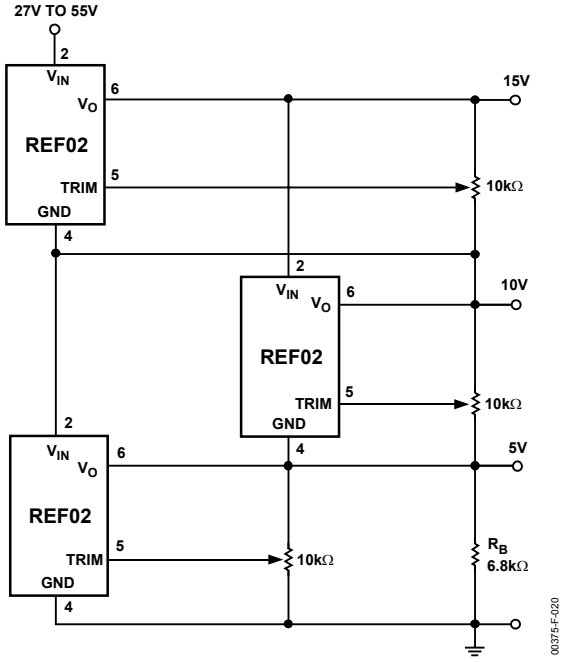


Figure 21. Reference Stack

PRECISION CURRENT SOURCE

A current source with 35 V output compliance and excellent output impedance can be obtained using this circuit. REF02 keeps the line voltage and power dissipation constant in device; the only important error consideration at room temperature is the negative supply rejection of the op amp. The typical 3 μV/V PSRR of the OP02E will create a 20 ppm change (3 μV/V × 35 V/5 V) in output current over a 25 V range. For example, a 5 mA current source can be built (R = 1 kΩ) with 350 MΩ output impedance.

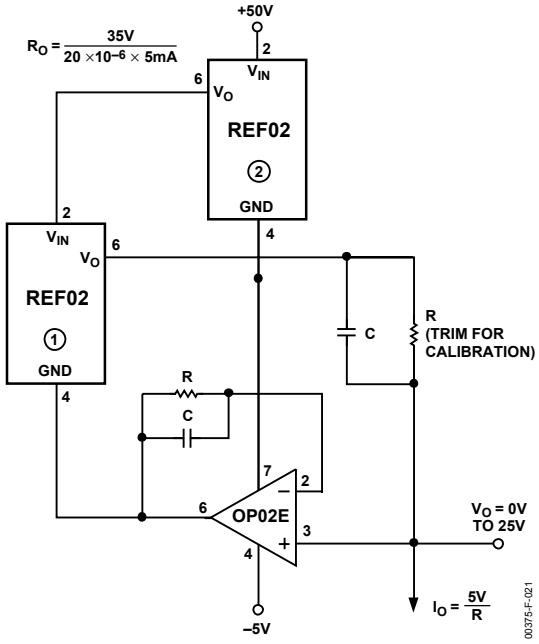


Figure 22. Precision Current Source

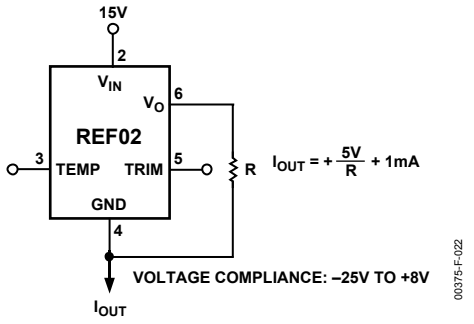


Figure 23. Current Source

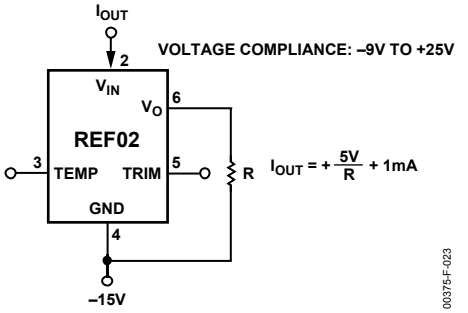


Figure 24. Current Sink

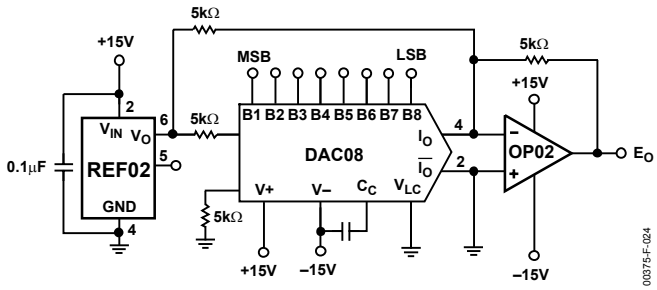


Figure 25. DAC Reference

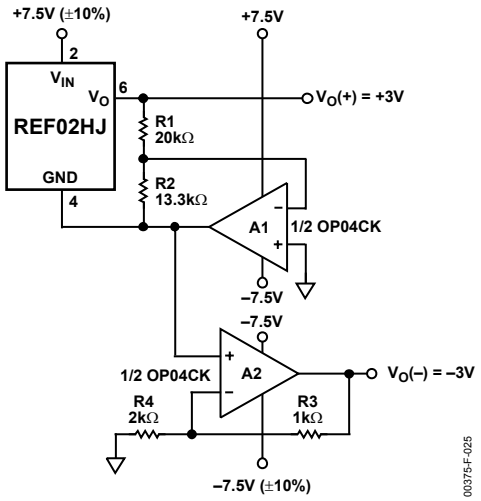
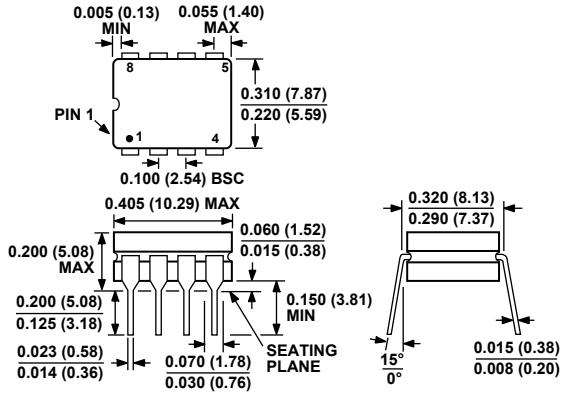


Figure 26. ±3 V Reference

SUPPLY BYPASSING

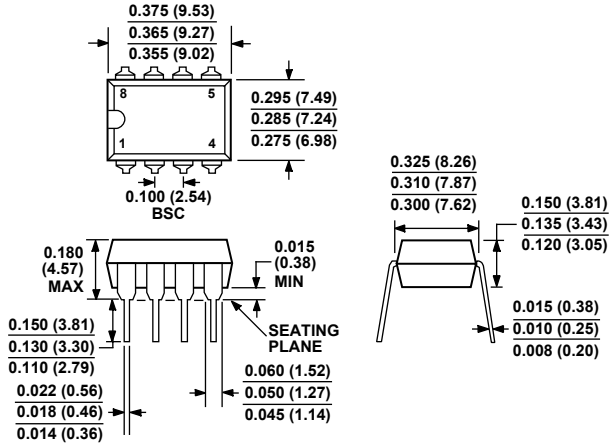
For best results, it is recommended that the power supply pin be bypassed with a 0.1 μF disc ceramic capacitor.

OUTLINE DIMENSIONS



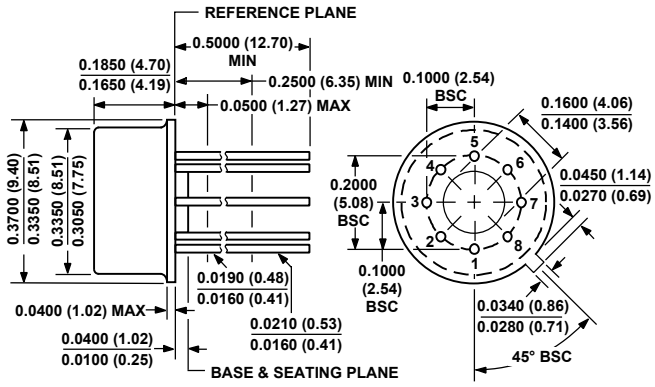
CONTROLLING DIMENSIONS ARE IN INCHES; MILLIMETER DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF INCH EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN

Figure 27. 8-Lead Ceramic Dual In-Line Package (CERDIP)
Z-Suffix
(Q-8)-



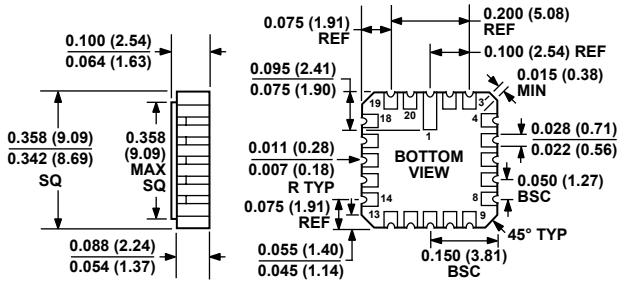
COMPLIANT TO JEDEC STANDARDS MO-095AA
CONTROLLING DIMENSIONS ARE IN INCHES; MILLIMETER DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF INCH EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN

Figure 28. 8-Lead Plastic Dual In-Line Package (PDIP)
P-Suffix
(N-8)



COMPLIANT TO JEDEC STANDARDS MO-002AK
CONTROLLING DIMENSIONS ARE IN INCHES; MILLIMETER DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF INCH EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN

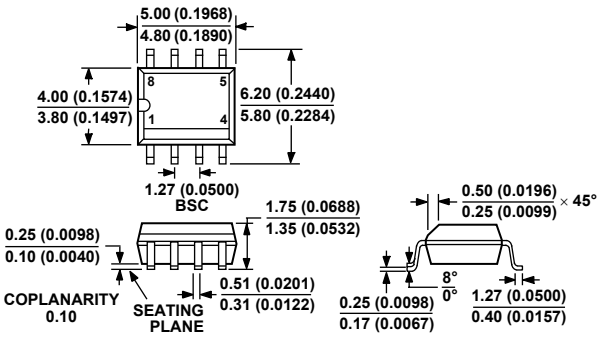
Figure 29. 8-Lead Metal Can [TO-99]
J-Suffix
(H-08)



CONTROLLING DIMENSIONS ARE IN INCHES; MILLIMETER DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF INCH EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN

Figure 30. 20-Terminal Ceramic Leadless Chip Carrier (LCC)
RC-Suffix
(E-20A)

OUTLINE DIMENSIONS



COMPLIANT TO JEDEC STANDARDS MS-012AA
CONTROLLING DIMENSIONS ARE IN MILLIMETERS; INCH DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF MILLIMETER EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN

Figure 31. 8-Lead Standard Small Outline Package (SOIC)
Narrow Body
S-Suffix
(R-8)

ORDERING GUIDE

Model	T_A = 25°C ΔV_{OS} Max (mV)	Operating Temperature Range (°C)[1]	Package Description	Package Option
REF02AJ/883C[2]	±15	–55°C to +125	TO-99	J-8
REF02EJ	±15	–40°C to +85	TO-99	J-8
REF02J	±25	–55°C to +125	TO-99	J-8
REF02HJ	±25	–40°C to +85	TO-99	J-8
REF02CJ	±50	0°C to 70	TO-99	J-8
REF02AZ	±15	–55°C to +125	CERDIP-8	Z-8
REF02AZ/883C[2]	±15	–55°C to +125	CERDIP-8	Z-8
REF02EZ	±15	–40°C to +85	CERDIP-8	Z-8
REF02Z	±25	–55°C to +125	CERDIP-8	Z-8
REF02HZ	±25	–40°C to +85	CERDIP-8	Z-8
REF02CZ	±50	0°C to 70	CERDIP-8	Z-8
REF02HP	±25	–40°C to +85	PDIP-8	P-8
REF02CP	±50	–40°C to +85	PDIP-8	P-8
REF02CS[3]	±50	–40°C to +85	SOIC-8	S-8
REF02CS-REEL	±50	–40°C to +85	SOIC-8	S-8
REF02CSZ-REEL[4]	±50	–40°C to +85	SOIC-8	S-8
REF02CS-REEL7	±50	–40°C to +85	SOIC-8	S-8
REF02HS	±25	–40°C to +85	SOIC-8	S-8
REF02HSZ[4]	±25	–40°C to +85	SOIC-8	S-8
REF02DP	±100	0°C to 70	PDIP-8	P-8
REF02RC/883[2]	±25	–55°C to +125	LCC-20	RC-20

[1]Burn-in is available on commercial and industrial temperature range parts in CERDIP, PDIP, and TO-can packages.
[2]For devices processed in total compliance to MIL-STD-883, add 883 after part number. Consult factory for 883 data sheet.
[3]For availability and burn-in information on SOIC package, contact your local sales office.
[4]Z = Pb-free part.

NOTES

C00375-0-7/04(F)