

# MAXIM

## +5V, +10V Precision Voltage References

REF01/REF02

### General Description

The REF01 and REF02 are precision voltage references that are pretrimmed to within  $\pm 3\%$  of +10V and +5V, respectively. Both references feature excellent temperature stability (as low as 8.5 ppm/ $^{\circ}\text{C}$  worst case), low current drain, and low noise. The REF02 also provides a TEMP pin whose output voltage varies linearly with temperature, making this device suitable for a wide variety of temperature-sensing and control applications. Both devices are available from Maxim in the space-saving SO package, as well as in the standard 8-pin TO-99 and MINI-DIP packages.

### Features

- ◆ Pretrimmed to +5V, +10V  $\pm 0.3\%$
- ◆ Excellent Temperature Stability: 3ppm/ $^{\circ}\text{C}$
- ◆ Low Noise: 10 $\mu\text{Vp-p}$  (REF02)
- ◆ Low Supply Current: 1.4mA max
- ◆ Short-Circuit Proof
- ◆ Linear Temperature Transducer O/P (REF02)

### Ordering Information

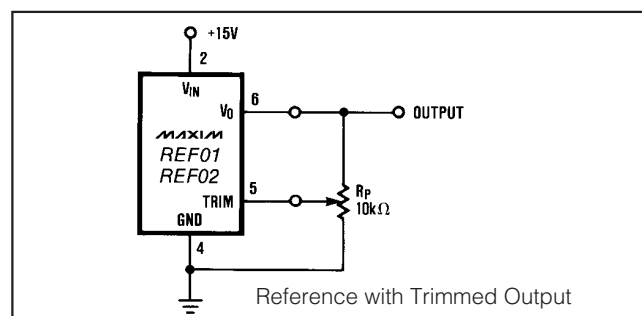
PART	TEMP. RANGE	MAX TEMPCO (ppm/ $^{\circ}\text{C}$ )	INITIAL ERROR (mV)	PIN-PACKAGE
REF01EP	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	8.5	$\pm 30$	8 Plastic DIP
REF01EZ	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	8.5	$\pm 30$	8 CERDIP
REF01HP	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	25	$\pm 50$	8 Plastic DIP
REF01HSA	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	25	$\pm 50$	8 SO
REF01CP	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	65	$\pm 100$	8 Plastic DIP
REF01CSA	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	65	$\pm 100$	8 SO
REF01CZ	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	65	$\pm 100$	8 CERDIP
REF01CESA	-40 $^{\circ}\text{C}$ to +85 $^{\circ}\text{C}$	65	$\pm 100$	8 SO
REF01Z	-55 $^{\circ}\text{C}$ to +125 $^{\circ}\text{C}$	25	$\pm 50$	8 CERDIP
REF02EP	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	8.5	$\pm 15$	8 Plastic DIP
REF02EZ	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	8.5	$\pm 15$	8 CERDIP
REF02HP	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	25	$\pm 25$	8 Plastic DIP
REF02HSA	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	25	$\pm 25$	8 SO
REF02CP	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	65	$\pm 50$	8 Plastic DIP
REF02CSA	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	65	$\pm 50$	8 SO
REF02CZ	0 $^{\circ}\text{C}$ to +70 $^{\circ}\text{C}$	65	$\pm 50$	8 CERDIP
REF02CESA	-40 $^{\circ}\text{C}$ to +85 $^{\circ}\text{C}$	65	$\pm 50$	8 SO
REF02Z	-55 $^{\circ}\text{C}$ to +125 $^{\circ}\text{C}$	25	$\pm 25$	8 CERDIP

Ordering Information continued at end of data sheet.

### Applications

A to D Converters  
D to A Converters  
Digital Voltmeters  
Voltage Regulators  
Threshold Detectors

### Typical Operating Circuit



# +5V, +10V Precision Voltage References

## ABSOLUTE MAXIMUM RATINGS—REF01

Input Voltage	Storage Temperature Range	.....-65°C to +150°C
REF01, A, E, H, All DICE	Operating Temperature Range	
REF01C	REF01A, REF01	.....-55°C to +125°C
Power Dissipation	REF01E, REF01H, REF01C	
T099 (J) (derate at 7.1mW/°C above 80°C)	(except REF01CESA)	.....0°C to +70°C
CERDIP (2) (derate at 6.7mW/°C above 75°C)	REF01CESA	.....-40°C to +85°C
Plastic Dip (P) (derate at 5.6mW/°C above 36°C)	DICE Junction Temperature (T <sub>J</sub> )	.....-65°C to +150°C
Small Outline (S) (derate at 5.0mW/°C above 55°C)	Lead Temperature (soldering, 60s)	.....+300°C
Output Short-Circuit Duration		
(to ground or V <sub>IN</sub> )		.....Indefinite

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS—REF01

(V<sub>IN</sub> = +15V, T<sub>A</sub> = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF01A/E			REF01/H			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	V <sub>O</sub>	I <sub>L</sub> = 0	9.97	10.00	10.03	9.95	10.00	10.05	V
Output Adjustment Range	ΔV <sub>trim</sub>	R <sub>p</sub> = 10kΩ	±3.0	±3.3	—	±3.0	±3.3	—	%
Output Voltage Noise	e <sub>np-p</sub>	0.1Hz to 10Hz (Note 5)	—	20	30	—	20	30	μV <sub>p-p</sub>
Line Regulation (Note 4)		V <sub>IN</sub> = 13V to 33V	—	0.006	0.010	—	0.006	0.010	%/V
Load Regulation (Note 4)		I <sub>L</sub> = 0 to 10mA	—	0.005	0.008	—	0.006	0.010	%/mA
Turn-on Settling Time	t <sub>ON</sub>	To ±0.1% of final value	—	5	—	—	5	—	μs
Quiescent Supply Current	I <sub>SY</sub>	No Load	—	1.0	1.4	—	1.0	1.4	mA
Load Current	I <sub>L</sub>		10	21	—	10	21	—	mA
Sink Current	I <sub>S</sub>		-0.3	-0.5	—	-0.3	-0.5	—	mA
Short-Circuit Current	I <sub>SC</sub>	V <sub>O</sub> = 0	—	30	—	—	30	—	mA

## ELECTRICAL CHARACTERISTICS—REF01

(V<sub>IN</sub> = +15V, -55°C ≤ T<sub>A</sub> ≤ +125°C for REF01A and REF01, 0°C ≤ T<sub>A</sub> ≤ +70°C for REF01E and REF01H, I<sub>L</sub> = 0mA, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF01A/E			REF01/H			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage Change with Temperature (Notes 1, 2)	ΔV <sub>OT</sub>	0°C ≤ T <sub>A</sub> ≤ +70°C -55°C ≤ T <sub>A</sub> ≤ +125°C	—	0.02 0.06	0.06 0.15	—	0.07 0.18	0.17 0.45	%
Output Voltage Temperature Coefficient	TCV <sub>O</sub>	(Note 3)	—	3.0	8.5	—	10.0	25.0	ppm/°C
Change in V <sub>O</sub> Temperature Coefficient with Output Adjustment		R <sub>p</sub> = 10kΩ	—	0.7	—	—	0.7	—	ppm/%
Line Regulation (V <sub>IN</sub> = 13V to 33V)(Note 4)		0°C ≤ T <sub>A</sub> ≤ +70°C -55°C ≤ T <sub>A</sub> ≤ +125°C	—	0.007 0.009	0.012 0.015	—	0.007 0.009	0.012 0.015	%/V
Load Regulation (I <sub>L</sub> = 0 to 8mA)(Note 4)		0°C ≤ T <sub>A</sub> ≤ +70°C -55°C ≤ T <sub>A</sub> ≤ +125°C	—	0.006 0.007	0.010 0.012	—	0.007 0.009	0.012 0.015	%/mA

**Note 1:** ΔV<sub>OT</sub> 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 10V:

$$\Delta V_{OT} = \left| \frac{V_{MAX} - V_{MIN}}{10V} \right| \times 100$$

**Note 2:** ΔV<sub>OT</sub> specification applies trimmed to +10.000V or untrimmed.

**Note 3:** TCV<sub>O</sub> is defined as ΔV<sub>OT</sub> divided by the temperature range.

**Note 4:** Line and Load Regulation specifications include the effect of self heating.

**Note 5:** Sample tested.

# +5V, +10V Precision Voltage References

REF01/REF02

## ELECTRICAL CHARACTERISTICS—REF01 (continued)

( $V_{IN} = +15V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF01C			UNITS
			MIN	TYP	MAX	
Output Voltage	$V_O$	$I_L = 0mA$	9.90	10.00	10.10	V
Output Adjustment Range	$\Delta V_{trim}$	$R_p = 10k\Omega$	$\pm 2.7$	$\pm 3.3$	—	%
Output Voltage Noise	$e_{np-p}$	0.1Hz to 10Hz (Note 5)	—	25	35	$\mu V_{p-p}$
Line Regulation (Note 4)		$V_{IN} = 13V$ to $30V$	—	0.009	0.015	%/V
Load Regulation (Note 4)		$I_L = 0$ to $8mA$ $I_L = 0$ to $4mA$	— —	0.006 0.006	0.015 0.015	%/mA
Turn-on Settling Time	$t_{ON}$	To $\pm 0.1\%$ of final value	—	5	—	$\mu s$
Quiescent Supply Current	$I_{SY}$	No Load	—	1.0	1.6	mA
Load Current	$I_L$		8	21	—	mA
Sink Current	$I_S$		-0.2	-0.5	—	mA
Short-Circuit Current	$I_{SC}$	$V_O = 0$	—	30	—	mA

## ELECTRICAL CHARACTERISTICS—REF01

( $V_{IN} = +15V$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF01C			UNITS
			MIN	TYP	MAX	
Output Voltage Change with Temperature	$\Delta V_{OT}$	(Notes 1 and 2)	—	0.14	0.45	%
Output Voltage Temperature Coefficient	$TCV_O$	(Note 3)	—	20	65	ppm/ $^\circ C$
Change in $V_O$ Temperature Coefficient with Output Adjustment		$R_p = 10k\Omega$	—	0.7	—	ppm/%
Line Regulation (Note 4)		$V_{IN} = 13V$ to $30V$	—	0.011	0.018	%/V
Load Regulation (Note 4)		$I_L = 0$ to $5mA$	—	0.008	0.018	%/mA

**Notes:** See previous page.

### Output Adjustment

The REF01 trim terminal can be used to adjust the voltage over a  $10V \pm 300mV$  range. This feature allows the system designer to trim system errors by setting the reference to a voltage other than 10V, including 10.240V for binary applications (see the *Typical Operating Circuit* section).

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

# +5V, +10V Precision Voltage References

## ABSOLUTE MAXIMUM RATINGS—REF02

Input Voltage	
REF02, A, E, H, All DICE	40V
REF02C, D	30V
Power Dissipation	
T099 (J) (Derate at 7.1mW°C above 80°C)	500mW
CERDIP (2) (Derate at 6.7mW°C above 75°C)	500mW
Plastic Dip (P) (Derate at 5.6mW°C above 36°C)	500mW
Small Outline (S) (Derate at 5.0mW°C above 55°C)	300mW
Storage Temperature Range	-65°C to +150°C

Operating Temperature Range	
REF02A, REF02	-55°C to +125°C
REF02E, REF02H (Except REF02CESA)	0°C to +70°C
REF02C (except REF02CESA), REF02D	0°C to +70°C
REF02CESA	-40°C to +85°C
Lead Temperature (Soldering, 60s)	+300°C
DICE Junction Temperature (T <sub>J</sub> )	-65°C to +150°C
Output Short-Circuit Duration (to Ground or V <sub>IN</sub> )	Indefinite

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS—REF02

(V<sub>IN</sub> = +15V, T<sub>A</sub> = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF02A/E			REF02/H			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	V <sub>O</sub>	I <sub>L</sub> = 0	4.985	5.000	5.015	4.975	5.000	5.025	V
Output Adjustment Range	ΔV <sub>trim</sub>	R <sub>p</sub> = 10kΩ	±3	±6	—	±3	±6	—	%
Output Voltage Noise	e <sub>np-p</sub>	0.1Hz to 10Hz (Note 6)	—	10	15	—	10	15	μV <sub>p-p</sub>
Line Regulation (Note 1)		V <sub>IN</sub> = 8V to 33V	—	0.006	0.010	—	0.006	0.010	%/V
Load Regulation (Note 1)		I <sub>L</sub> = 0 to 10mA	—	0.005	0.010	—	0.006	0.010	%/mA
Turn-on Settling Time	t <sub>ON</sub>	To ±0.1% of final value	—	5	—	—	5	—	μs
Quiescent Supply Current	I <sub>SY</sub>	No Load	—	1.0	1.4	—	1.0	1.4	mA
Load Current	I <sub>L</sub>		10	21	—	10	21	—	mA
Sink Current	I <sub>S</sub>		-0.3	-0.5	—	-0.3	-0.5	—	mA
Short-Circuit Current	I <sub>SC</sub>	V <sub>O</sub> = 0	—	30	—	—	30	—	mA
Temperature Voltage Output	V <sub>T</sub>	(Note 2)	—	630	—	—	630	—	mV

## ELECTRICAL CHARACTERISTICS—REF01

(V<sub>IN</sub> = +15V, -55°C ≤ T<sub>A</sub> ≤ +125°C for REF02A and REF02, 0°C ≤ T<sub>A</sub> ≤ +70°C for REF02E and REF02H, I<sub>L</sub> = 0mA, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF02A/E			REF02/H			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage Change with Temperature (Notes 3, 4)	ΔV <sub>OT</sub>	0°C ≤ T <sub>A</sub> ≤ +70°C -55°C ≤ T <sub>A</sub> ≤ +125°C	—	0.02	0.06	—	0.07	0.17	%
Output Voltage Temperature Coefficient	TCV <sub>O</sub>	(Note 5)	—	3	8.5	—	10	25	ppm/°C
Change in V <sub>O</sub> Temperature Coefficient with Output Adjustment		R <sub>p</sub> = 10kΩ	—	0.7	—	—	0.7	—	ppm/%
Line Regulation (V <sub>IN</sub> = 8V to 33V)(Note 1)		0°C ≤ T <sub>A</sub> ≤ +70°C -55°C ≤ T <sub>A</sub> ≤ +125°C	—	0.007	0.012	—	0.007	0.012	%/V
Load Regulation (I <sub>L</sub> = 0 to 8mA)(Note 1)		0°C ≤ T <sub>A</sub> ≤ +70°C -55°C ≤ T <sub>A</sub> ≤ +125°C	—	0.006	0.010	—	0.007	0.012	%/mA
Temperature Voltage Output Temperature Coefficient	TCV <sub>T</sub>	(Note 2)	—	2.1	—	—	2.1	—	mV/°C

**Note 1:** Line and Load Regulation specifications include the effect of self heating.

**Note 2:** Limit current in or out of pin 3 to 50nA and capacitance on pin 3 to 30pF.

**Note 3:** ΔV<sub>OT</sub> 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 5V:

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

**Note 4:** ΔV<sub>OT</sub> specification applies trimmed to +5.000V or untrimmed.

**Note 5:** TCV<sub>O</sub> is defined as ΔV<sub>OT</sub> divided by the temperature range.

**Note 6:** Sample tested.

# +5V, +10V Precision Voltage References

REF01/REF02

## ELECTRICAL CHARACTERISTICS—REF02

( $V_{IN} = +15V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF02C			REF02D			UNITS	
			MIN	TYP	MAX	MIN	TYP	MAX		
Output Voltage	$V_O$	$I_L = 0mA$	4.950	5.000	5.050	4.900	5.000	5.100	V	
Output Adjustment Range	$\Delta V_{trim}$	$R_p = 10k\Omega$	$\pm 2.7$	$\pm 6.0$	—	$\pm 2.0$	$\pm 6.0$	—	%	
Output Voltage Noise	$e_{np-p}$	0.1Hz to 10Hz (Note 6)	—	12	18	—	12	—	$\mu V_{p-p}$	
Line Regulation (Note 1)		$V_{IN} = 8V$ to $30V$	—	0.009	0.015	—	0.010	0.04	%/V	
Load Regulation (Note 1)		$I_L = 0$ to $8mA$ $I_L = 0$ to $4mA$	—	0.006	0.015	—	—	0.015	0.04	%/mA
Turn-on Settling Time	$t_{ON}$	To $\pm 0.1\%$ of final value	—	5	—	—	5	—	$\mu s$	
Quiescent Supply Current	$I_{SY}$	No Load	—	1.0	1.6	—	1.0	2.0	mA	
Load Current	$I_L$		8	21	—	8	21	—	mA	
Sink Current	$I_S$		-0.2	-0.5	—	-0.2	-0.5	—	mA	
Short-Circuit Current	$I_{SC}$	$V_O = 0$	—	30	—	—	30	—	mA	
Temperature Voltage Output	$V_T$	(Note 2)	—	630	—	—	630	—	mV	

## ELECTRICAL CHARACTERISTICS—REF02

( $V_{IN} = +15V$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$  and  $I_L = 0mA$ , unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF02C			REF02D			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage Change with Temperature	$\Delta V_{OT}$	(Notes 3 and 4)	—	0.14	0.45	—	0.49	1.7	%
Output Voltage Temperature Coefficient	$TCV_O$	(Note 5)	—	20	65	—	70	250	ppm/ $^\circ C$
Change in $V_O$ Temperature Coefficient with Output Adjustment		$R_p = 10k\Omega$	—	0.7	—	—	0.7	—	ppm/%
Line Regulation (Note 1)		$V_{IN} = 8V$ to $30V$	—	0.011	0.018	—	0.012	0.05	%/V
Load Regulation (Note 1)		$I_L = 0$ to $5mA$	—	0.008	0.018	—	0.016	0.05	%/mA
Temperature Voltage Output Temperature Coefficient	$TCV_T$	(Note 2)	—	2.1	—	—	2.1	—	mV/ $^\circ C$

**Notes:** See previous page.

### Output Adjustment

The REF02 trim terminal can be used to adjust the output voltage over a  $5V \pm 300mV$  range. This feature allows the system designer to trim system errors by setting the reference to a voltage other than 5V (refer to the *Typical Operating Circuit* section).

Adjustment of the output does not significantly affect the temperature performance of the device. Typically, the temperature coefficient change is 0.7ppm/ $^\circ C$  for 100mV of output adjustment.

### Temperature Voltage Output

The REF02 provides a temperature-dependent output voltage on the TEMP pin. This voltage is proportional to the absolute temperature, and has a scale factor of approximately 2.1mV/ $^\circ C$  (Figure 2).

$$\text{Output Voltage} = 2.1(T + 273)mV$$

where T = Temperature in  $^\circ C$

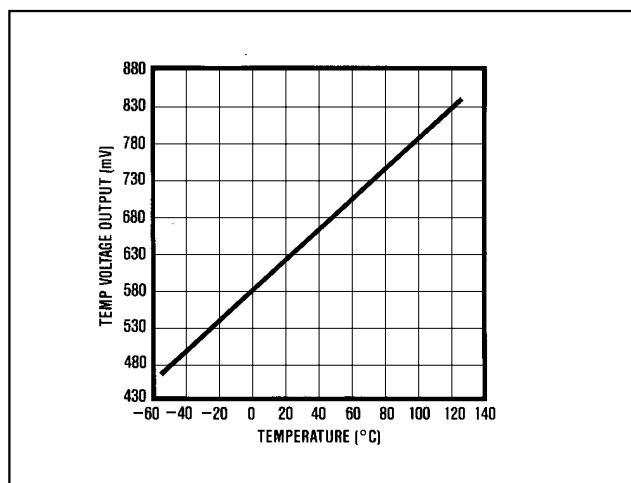
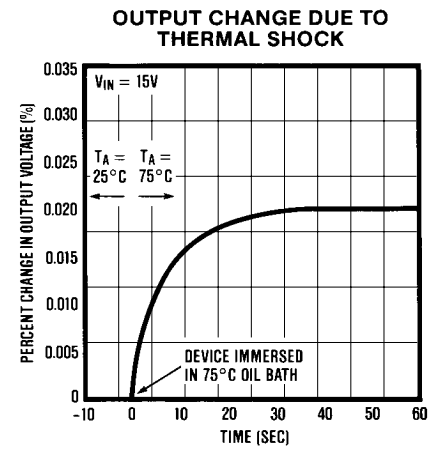
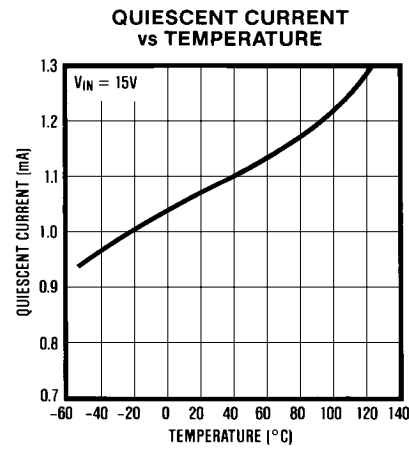
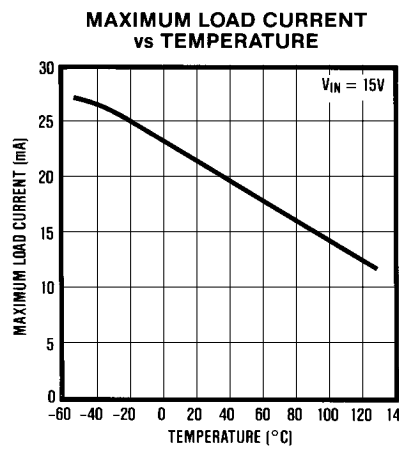
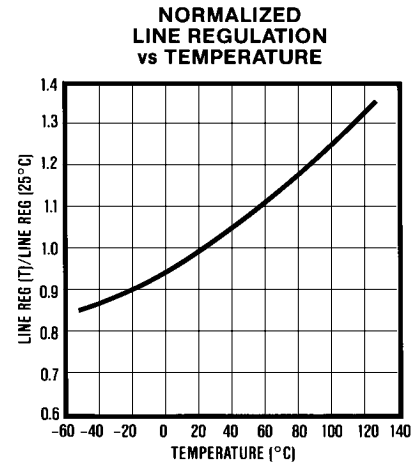
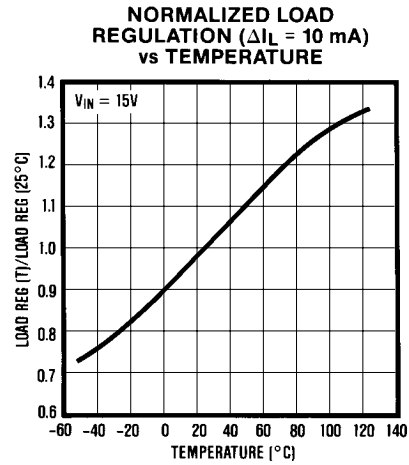
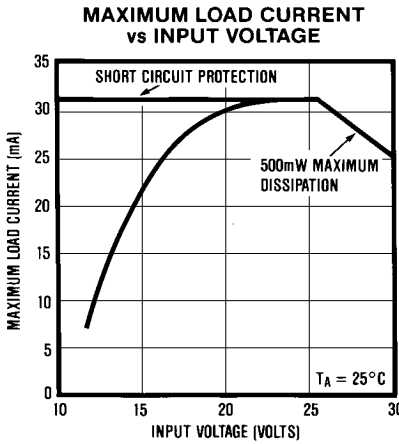
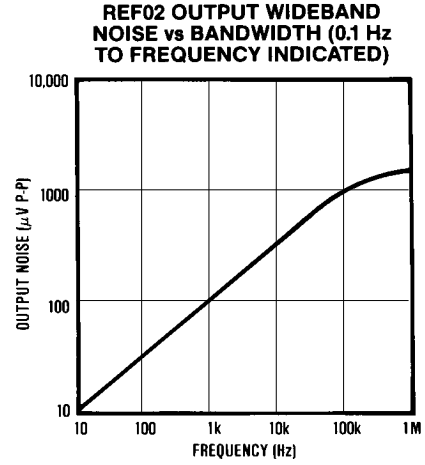
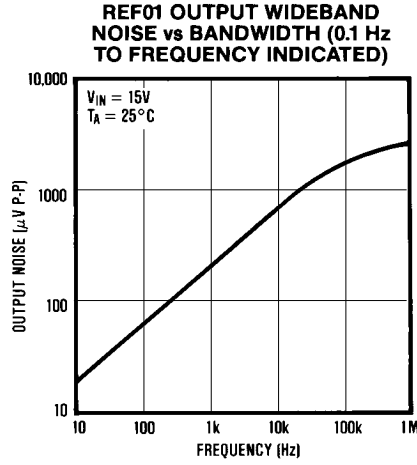
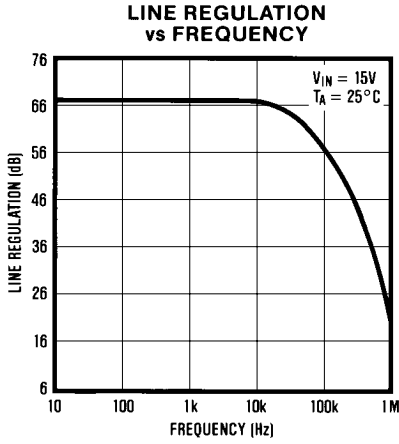


Figure 2. REF02 Temperature/Voltage Output vs. Temperature

# +5V, +10V Precision Voltage References

**REF01/REF02**

## Typical Operating Characteristics



# +5V, +10V Precision Voltage References

## Typical Applications

**REF01/REF02**

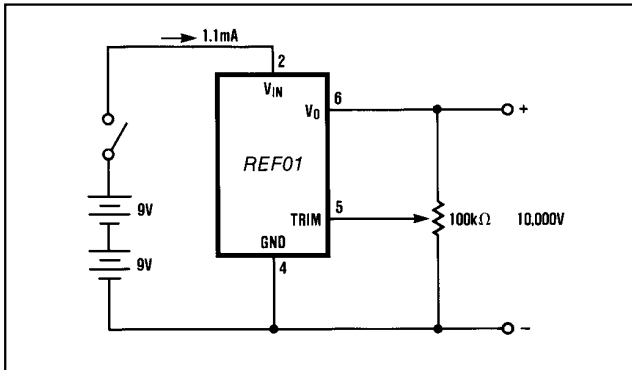


Figure 3. Precision Calibration Standard

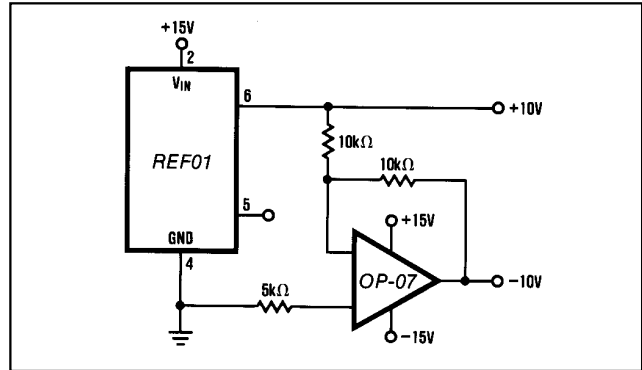


Figure 4. ±10V Reference

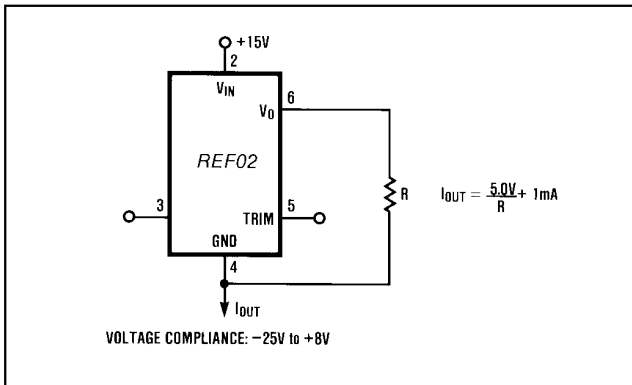


Figure 5. Current Source

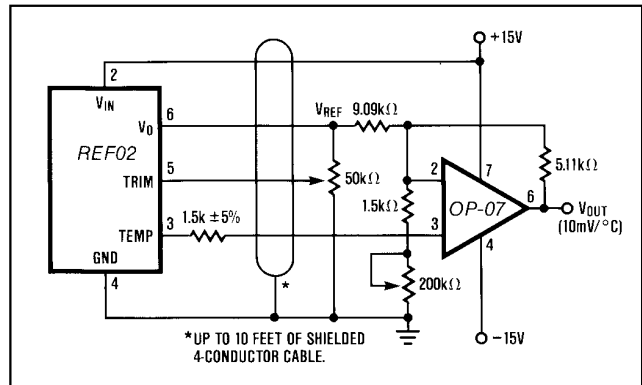
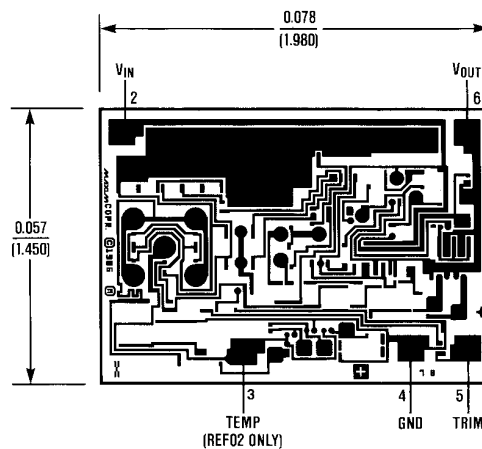


Figure 6. Precision Temperature Transducer with Remote Sensor

## Chip Topography



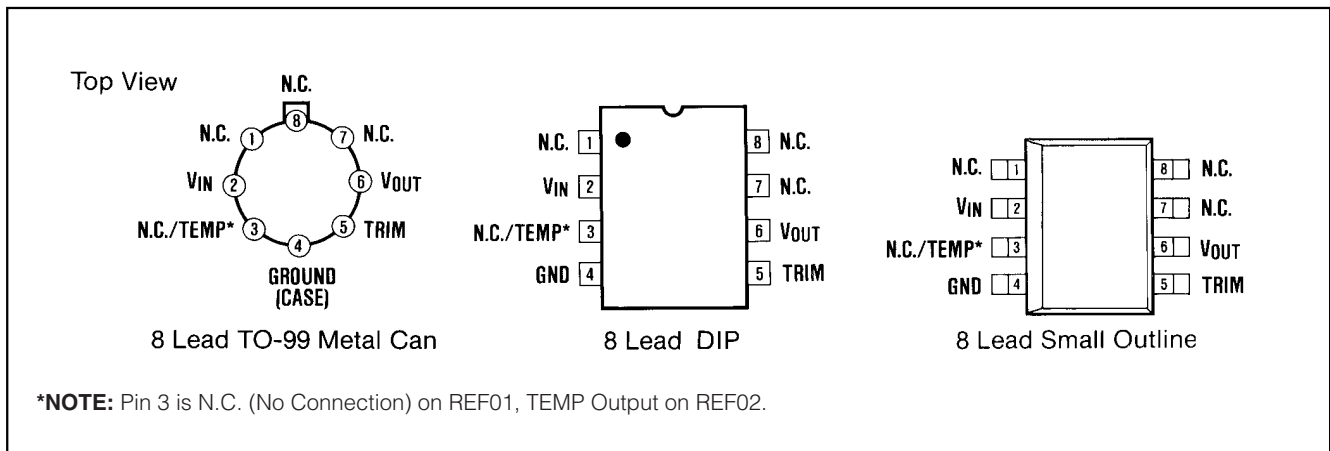
# +5V, +10V Precision Voltage References

## Ordering Information (continued)

PART	TEMP. RANGE	MAX. TEMPCO (ppm/°C)	INITIAL ERROR (mV)	PIN-PACKAGE
REF01EJ*	0°C to +70°C	8.5	±30	8 TO-99
REF01HF*	0°C to +70°C	25	±50	8 TO-99
REF01CJ*	0°C to +70°C	65	±100	8 TO-99
REF01HZ*	0°C to +70°C	25	±50	8 Hermetic DIP
REF01CP-2*	0°C to +70°C	65	±100	8 Plastic DIP
REF01AJ*	-55°C to +125°C	8.5	±30	8 TO-99
REF01J*	-55°C to +125°C	25	±50	8 TO-99
REF01AZ*	-55°C to +125°C	8.5	±15	8 Hermetic DIP
REF02EJ*	0°C to +70°C	8.5	±15	8 TO-99
REF02HJ*	0°C to +70°C	25	±25	8 TO-99
REF02CJ*	0°C to +70°C	65	±50	8 TO-99
REF02DJ*	0°C to +70°C	250	±100	8 TO-99
REF02HZ*	0°C to +70°C	25	±25	8 Hermetic DIP
REF02DP*	0°C to +70°C	250	±100	8 Plastic DIP
REF02DSA*	0°C to +70°C	250	±100	8 SO
REF02AJ*	-55°C to +125°C	8.5	±15	8 TO-99
REF02J*	-55°C to +125°C	25	±25	8 TO-99
REF02AZ*	-55°C to +125°C	8.5	±15	8 Hermetic DIP

\*Contact factory for availability.

## Pin Configuration



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