19-0887; Rev 1; 8/99

MAXIM

+5V, +10V Precision Voltage References

General Description

The REF01 and REF02 are precision voltage references that are pretrimmed to within ±3% of +10V and +5V, respectively. Both references feature excellent temperature stability (as low as 8.5 ppm/°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 ±0.3%**
- **Excellent Temperature Stability: 3ppm/°C**
- **Low Noise: 10µVp-p (REF02)**
- **Low Supply Current: 1.4mA max**
- **Short-Circuit Proof**
- **Linear Temperature Transducer O/P (REF02)**

Ordering Information

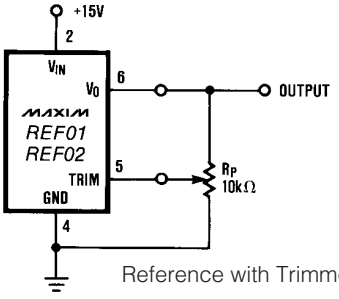
PART	TEMP. RANGE	MAX TEMPCO (ppm/°C)	INITIAL ERROR (mV)	PIN-PACKAGE
REF01EP	0°C to +70°C	8.5	±30	8 Plastic DIP
REF01EZ	0°C to +70°C	8.5	±30	8 CERDIP
REF01HP	0°C to +70°C	25	±50	8 Plastic DIP
REF01HSA	0°C to +70°C	25	±50	8 SO
REF01CP	0°C to +70°C	65	±100	8 Plastic DIP
REF01CSA	0°C to +70°C	65	±100	8 SO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



Reference with Trimmed Output

+5V, +10V Precision Voltage References

ABSOLUTE MAXIMUM RATINGS—REF01

Input Voltage
- REF01, A, E, H, All DICE 40V
- REF01C 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

Output Short-Circuit Duration
- (to ground or V_{IN}) .....Indefinite

Storage Temperature Range .....-65°C to +150°C

Operating Temperature Range
- REF01A, REF01 .....-55°C to +125°C
- REF01E, REF01H, REF01C (except REF01CESA) .....0°C to +70°C
- REF01CESA .....-40°C to +85°C

DICE Junction Temperature (T_j) .....-65°C to +150°C

Lead Temperature (soldering, 60s) .....+300°C

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

PARAMETER	SYMBOL	CONDITIONS	REF01A/E			REF01/H			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	V_O	I_L = 0	9.97	10.00	10.03	9.95	10.00	10.05	V
Output Adjustment Range	ΔV_{trim}	R_p = 10kΩ	±3.0	±3.3	—	±3.0	±3.3	—	%
Output Voltage Noise	e_{np-p}	0.1Hz to 10Hz (Note 5)	—	20	30	—	20	30	μV_{p-p}
Line Regulation (Note 4)		V_{IN} = 13V to 33V	—	0.006	0.010	—	0.006	0.010	%/V
Load Regulation (Note 4)		I_L = 0 to 10mA	—	0.005	0.008	—	0.006	0.010	%/mA
Turn-on Settling Time	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	21	—	10	21	—	mA
Sink Current	I_S		-0.3	-0.5	—	-0.3	-0.5	—	mA
Short-Circuit Current	I_{SC}	V_O = 0	—	30	—	—	30	—	mA

ELECTRICAL CHARACTERISTICS—REF01

(V_{IN} = +15V, -55°C ≤ T_A = +125°C for REF01A and REF01, 0°C ≤ T_A ≤ +70°C for REF01E and REF01H, I_L = 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_{OT}	0°C ≤ T_A ≤ +70°C -55°C ≤ T_A ≤ +125°C	— —	0.02 0.06	0.06 0.15	— —	0.07 0.18	0.17 0.45	%
Output Voltage Temperature Coefficient	TCV_O	(Note 3)	—	3.0	8.5	—	10.0	25.0	ppm/°C
Change in V_O Temperature Coefficient with Output Adjustment		R_p = 10kΩ	—	0.7	—	—	0.7	—	ppm/%
Line Regulation (V_{IN} = 13V to 33V) (Note 4)		0°C ≤ T_A ≤ +70°C -55°C ≤ T_A ≤ +125°C	— —	0.007 0.009	0.012 0.015	— —	0.007 0.009	0.012 0.015	%/V
Load Regulation (I_L = 0 to 8mA) (Note 4)		0°C ≤ T_A ≤ +70°C -55°C ≤ T_A ≤ +125°C	— —	0.006 0.007	0.010 0.012	— —	0.007 0.009	0.012 0.015	%/mA

Note 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 10V:

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

Note 2: ΔV_{OT} specification applies trimmed to +10.000V or untrimmed.
Note 3: TCV_O is defined as ΔV_{OT} divided by the temperature range.
Note 4: Line and Load Regulation specifications include the effect of self heating.
Note 5: Sample tested.

ELECTRICAL CHARACTERISTICS—REF01 (continued)

(V_{IN} = +15V, T_A = +25°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	ΔV_{trim}	R_p = 10kΩ	±2.7	±3.3	—	%
Output Voltage Noise	e_{np-p}	0.1Hz to 10Hz (Note 5)	—	25	35	μV_{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 ±0.1% of final value	—	5	—	µs
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	ΔV_{OT}	(Notes 1 and 2)	—	0.14	0.45	%
Output Voltage Temperature Coefficient	TCV_O	(Note 3)	—	20	65	ppm/°C
Change in V_O Temperature Coefficient with Output Adjustment		R_p = 10kΩ	—	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±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/°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_j) ..... -65°C to +150°C

Output Short-Circuit Duration
- (to Ground or V_{IN}) ..... 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_{IN} = +15V, T_A = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	REF02A/E			REF02/H			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	V_O	I_L = 0	4.985	5.000	5.015	4.975	5.000	5.025	V
Output Adjustment Range	ΔV_{trim}	R_p = 10kΩ	±3	±6	—	±3	±6	—	%
Output Voltage Noise	e_{np-p}	0.1Hz to 10Hz (Note 6)	—	10	15	—	10	15	μV_{p-p}
Line Regulation (Note 1)		V_{IN} = 8V to 33V	—	0.006	0.010	—	0.006	0.010	%/V
Load Regulation (Note 1)		I_L = 0 to 10mA	—	0.005	0.010	—	0.006	0.010	%/mA
Turn-on Settling Time	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	21	—	10	21	—	mA
Sink Current	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	V_T	(Note 2)	—	630	—	—	630	—	mV

ELECTRICAL CHARACTERISTICS—REF01

(V_{IN} = +15V, -55°C ≤ T_A = +125°C for REF02A and REF02, 0°C ≤ T_A ≤ +70°C for REF02E and REF02H, I_L = 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_{OT}	0°C ≤ T_A ≤ +70°C -55°C ≤ T_A ≤ +125°C	— —	0.02 0.06	0.06 0.15	— —	0.07 0.18	0.17 0.45	%
Output Voltage Temperature Coefficient	TCV_O	(Note 5)	—	3	8.5	—	10	25	ppm/°C
Change in V_O Temperature Coefficient with Output Adjustment		R_p = 10kΩ	—	0.7	—	—	0.7	—	ppm/%
Line Regulation (V_{IN} = 8V to 33V)(Note 1)		0°C ≤ T_A ≤ +70°C -55°C ≤ T_A ≤ +125°C	— —	0.007 0.009	0.012 0.015	— —	0.007 0.009	0.012 0.015	%/V
Load Regulation (I_L = 0 to 8mA)(Note 1)		0°C ≤ T_A ≤ +70°C -55°C ≤ T_A ≤ +125°C	— —	0.006 0.007	0.010 0.012	— —	0.007 0.009	0.012 0.015	%/mA
Temperature Voltage Output Temperature Coefficient	TCV_T	(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_{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 5V:

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

Note 4: ΔV_{OT} specification applies trimmed to +5.000V or untrimmed.
Note 5: TCV_O is defined as ΔV_{OT} divided by the temperature range.
Note 6: Sample tested.

ELECTRICAL CHARACTERISTICS—REF02

(V_{IN} = +15V, T_A = +25°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	ΔV_{trim}	R_p = 10kΩ	±2.7	±6.0	—	±2.0	±6.0	—	%
Output Voltage Noise	e_{np-p}	0.1Hz to 10Hz (Note 6)	—	12	18	—	12	—	μV_{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 ±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	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	ΔV_{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/°C
Change in V_O Temperature Coefficient with Output Adjustment		R_p = 10kΩ	—	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/°C

Notes: See previous page.

Output Adjustment

The REF02 trim terminal can be used to adjust the output voltage over a 5V±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/°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/°C (Figure 2).

Output Voltage = 2.1(T + 273)mV
where T = Temperature in °C

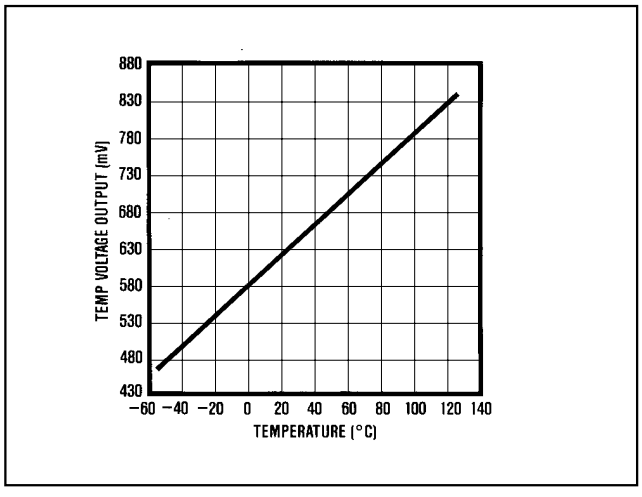
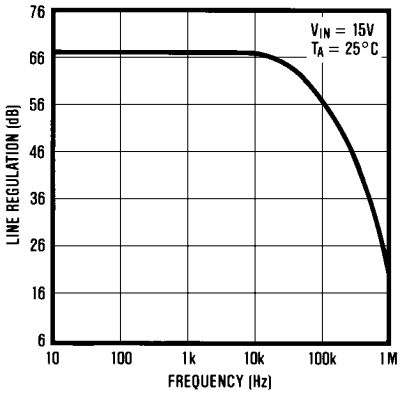


Figure 2. REF02 Temperature/Voltage Output vs. Temperature

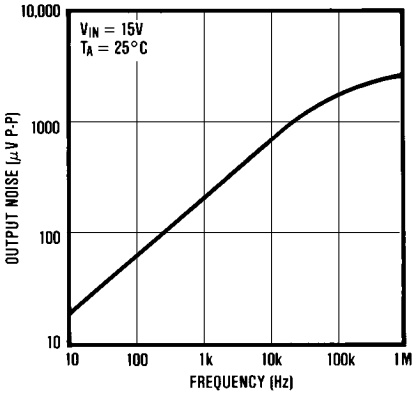
+5V, +10V Precision Voltage References

Typical Operating Characteristics

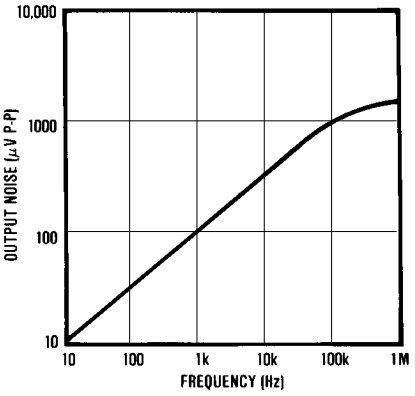
LINE REGULATION vs FREQUENCY



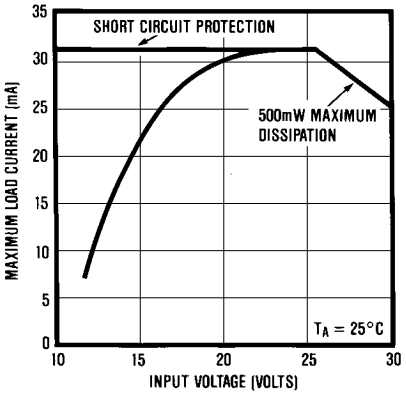
REF01 OUTPUT WIDEBAND NOISE vs BANDWIDTH (0.1 Hz TO FREQUENCY INDICATED)



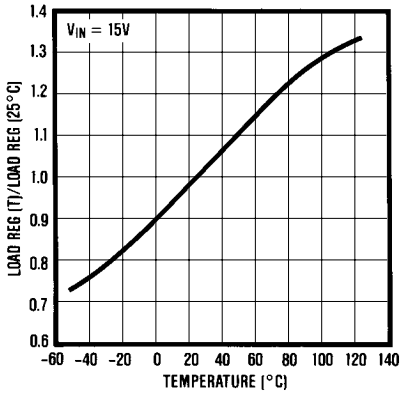
REF02 OUTPUT WIDEBAND NOISE vs BANDWIDTH (0.1 Hz TO FREQUENCY INDICATED)



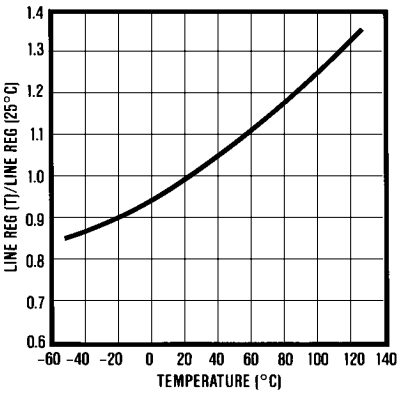
MAXIMUM LOAD CURRENT vs INPUT VOLTAGE



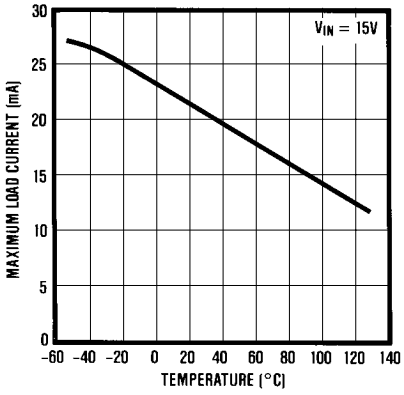
NORMALIZED LOAD REGULATION (ΔI_L = 10 mA) vs TEMPERATURE



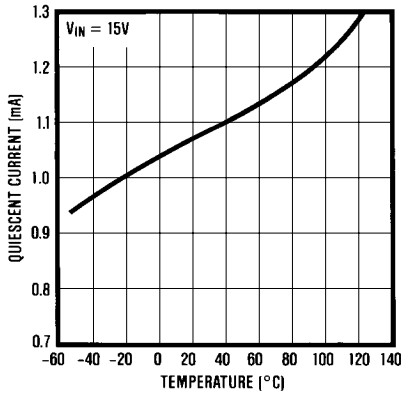
NORMALIZED LINE REGULATION vs TEMPERATURE



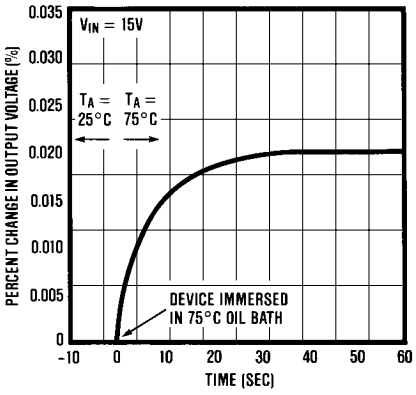
MAXIMUM LOAD CURRENT vs TEMPERATURE



QUIESCENT CURRENT vs TEMPERATURE



OUTPUT CHANGE DUE TO THERMAL SHOCK



Typical Applications

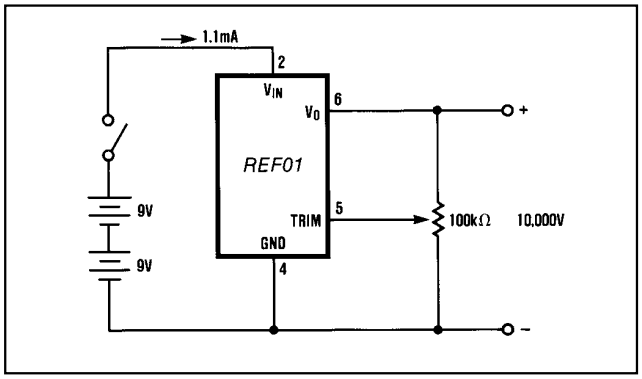


Figure 3. Precision Calibration Standard

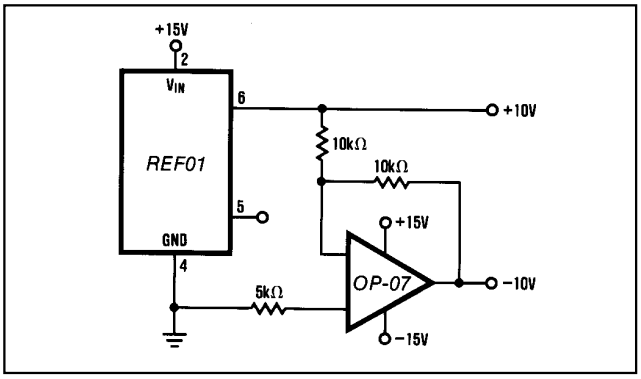


Figure 4. ±10V Reference

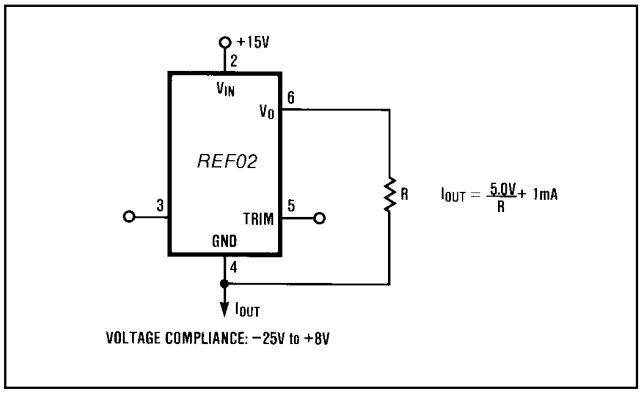


Figure 5. Current Source

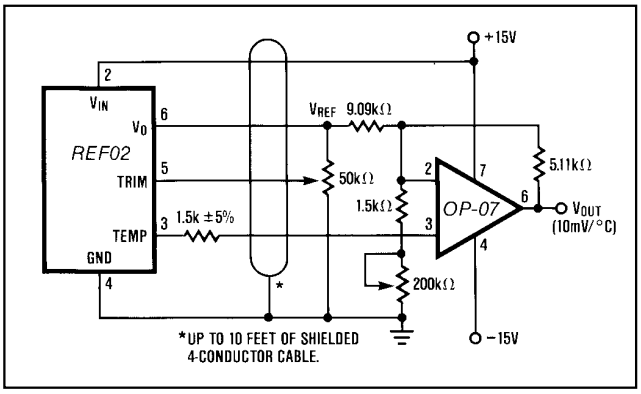
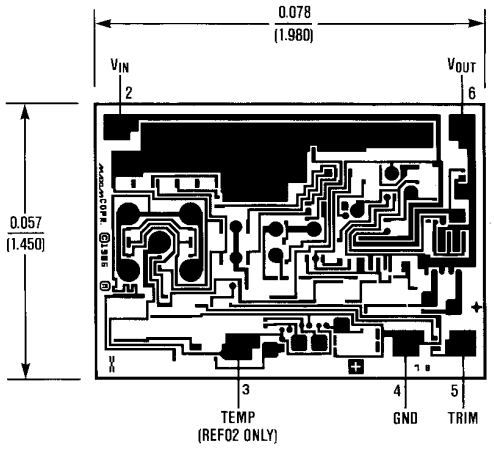


Figure 6. Precision Temperature Transducer with Remote Sensor

Chip Topography



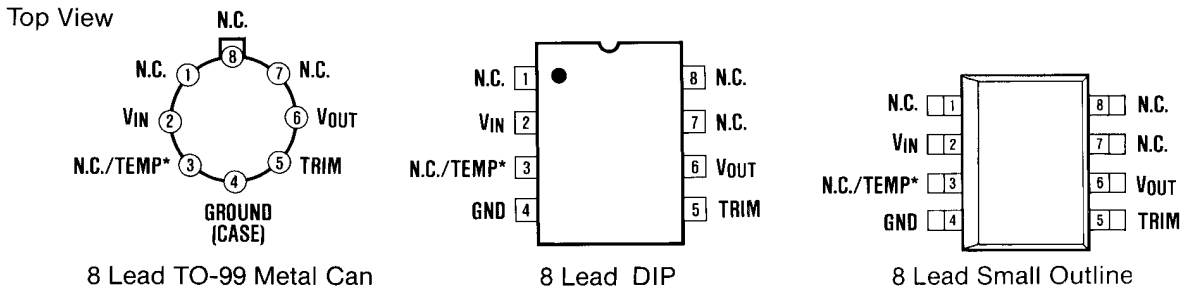
+5V, +10V Precision Voltage References

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



8 Lead TO-99 Metal Can | 8 Lead DIP | 8 Lead Small Outline

***NOTE:** Pin 3 is N.C. (No Connection) on REF01, TEMP Output on REF02.