

# +5V, +10V Precision Voltage References

## ABSOLUTE MAXIMUM RATINGS—REF01

Input Voltage  
 REF01, E, H .....40V  
 REF01C .....30V  
 Continuous Power Dissipation  
 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  
 REF01E, REF01H, REF01C  
 (except REF01CESA) .....0°C to +70°C  
 REF01CESA .....-40°C to +85°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—REF01E/REF01H

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

| PARAMETER                | SYMBOL            | CONDITIONS                            | REF01E    |           |       | REF01H    |           |       | 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  | $\Delta V_{trim}$ | $R_P = 10k\Omega$                     | $\pm 3.0$ | $\pm 6.0$ |       | $\pm 3.0$ | $\pm 6.0$ |       | %             |
| Output Voltage Noise     | $e_{NP-P}$        | 0.1Hz to 10Hz (Note 1)                |           | 20        | 30    |           | 20        | 30    | $\mu V_{P-P}$ |
| Line Regulation          |                   | $V_{IN} = 13V$ to 33V (Note 2)        |           | 0.006     | 0.010 |           | 0.006     | 0.010 | %/V           |
| Load Regulation          |                   | $I_L = 0$ to 10mA (Note 2)            |           | 0.005     | 0.008 |           | 0.006     | 0.010 | %/mA          |
| Turn-On Settling Time    | $t_{ON}$          | To $\pm 0.1\%$ of final value         |           | 400       |       |           | 400       |       | $\mu s$       |
| Quiescent Supply Current | $I_{SY}$          | No load                               |           | 1.0       | 1.4   |           | 1.0       | 1.4   | mA            |
| Load Current             | $I_L$             | To specified output voltage tolerance | 10        | 21        |       | 10        | 21        |       | mA            |
| Sink Current             | $I_S$             | To specified output voltage tolerance | 0.3       | 0.5       |       | 0.3       | 0.5       |       | mA            |
| Short-Circuit Current    | $I_{SC}$          | $V_O = 0V$                            |           | 30        |       |           | 30        |       | mA            |

## ELECTRICAL CHARACTERISTICS—REF01E/REF01H

( $V_{IN} = +15V$ ,  $0^\circ C \leq T_A \leq +70^\circ C$  for REF01E and REF01H,  $I_L = 0mA$ , unless otherwise noted.)

| PARAMETER                                                      | SYMBOL          | CONDITIONS                                     | REF01E |       |       | REF01H |       |       | UNITS  |
|----------------------------------------------------------------|-----------------|------------------------------------------------|--------|-------|-------|--------|-------|-------|--------|
|                                                                |                 |                                                | MIN    | TYP   | MAX   | MIN    | TYP   | MAX   |        |
| Output Voltage Change with Temperature                         | $\Delta V_{OT}$ | $0^\circ C \leq T_A \leq +70^\circ C$ (Note 3) |        | 0.02  | 0.06  |        | 0.07  | 0.17  | %      |
| Output Voltage Temperature Coefficient                         | $TCV_O$         | (Note 4)                                       |        | 3     | 8.5   |        | 10.0  | 25.0  | ppm/°C |
| Change in $V_O$ Temperature Coefficient with Output Adjustment |                 | $R_P = 10k\Omega$                              |        | 0.7   |       |        | 0.7   |       | ppm/%  |
| Line Regulation<br>( $V_{IN} = 13V$ to 33V)                    |                 | $0^\circ C \leq T_A \leq +70^\circ C$ (Note 2) |        | 0.007 | 0.012 |        | 0.007 | 0.012 | %/V    |
| Load Regulation<br>( $I_L = 0$ to 8mA)                         |                 | $0^\circ C \leq T_A \leq +70^\circ C$ (Note 2) |        | 0.006 | 0.010 |        | 0.007 | 0.012 | %/mA   |

# +5V, +10V Precision Voltage References

REF01/REF02

## ELECTRICAL CHARACTERISTICS—REF01C

( $V_{IN} = +15V$ ,  $T_A = +25^\circ C$ ,  $I_L = 0mA$ , 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  | $\Delta V_{trim}$ | $R_P = 10k\Omega$                     | $\pm 2.7$ | $\pm 6.0$ |       | %             |
| Output Voltage Noise     | $e_{nP-P}$        | 0.1Hz to 10Hz (Note 1)                |           | 25        | 35    | $\mu V_{P-P}$ |
| Line Regulation          |                   | $V_{IN} = 13V$ to $30V$ (Note 2)      |           | 0.009     | 0.015 | %/V           |
| Load Regulation (Note 2) |                   | $I_L = 0$ to $8mA$                    |           | 0.006     | 0.015 | %/mA          |
|                          |                   | $I_L = 0$ to $4mA$                    |           | 0.006     | 0.015 |               |
| Turn-On Settling Time    | $t_{ON}$          | To $\pm 0.1\%$ of final value         |           | 400       |       | $\mu s$       |
| Quiescent Supply Current | $I_{SY}$          | No load                               |           | 1.0       | 1.6   | mA            |
| Load Current             | $I_L$             | To specified output voltage tolerance | 8         | 21        |       | mA            |
| Sink Current             | $I_S$             | To specified output voltage tolerance | 0.2       | 0.5       |       | mA            |
| Short-Circuit Current    | $I_{SC}$          | $V_O = 0V$                            |           | 30        |       | mA            |

## ELECTRICAL CHARACTERISTICS—REF01C

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

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

**Note 1:** Guaranteed by design.

**Note 2:** Line and load regulation specifications include the effect of self heating. 100% production tested at  $T_A = +25^\circ C$  and guaranteed by design for  $T_A = T_{MIN}$  to  $T_{MAX}$ , as specified.

**Note 3:**  $\Delta V_{OT}$  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. Guaranteed by design.

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

**Note 4:**  $TCV_O$  is defined as  $\Delta V_{OT}$  divided by the temperature range. Guaranteed by design.

### Output Adjustment

The REF01 trim terminal can be used to adjust the voltage over a  $10V \pm 600mV$  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*).

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, E, H .....40V  
 REF02C .....30V  
 Continuous Power Dissipation  
 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  
 REF02E, REF02H .....0°C to +70°C  
 REF02C (except REF02CESA) .....0°C to +70°C  
 REF02CESA .....-40°C to +85°C  
 Output Short-Circuit Duration  
 (to ground or  $V_{IN}$ ) .....Indefinite  
 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—REF02E/REF02H

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

| PARAMETER                  | SYMBOL            | CONDITIONS                            | REF02E  |         |       | REF02H  |         |       | 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    | $\Delta V_{trim}$ | $R_P = 10k\Omega$                     | $\pm 3$ | $\pm 6$ |       | $\pm 3$ | $\pm 6$ |       | %             |
| Output Voltage Noise       | $e_{nP-P}$        | 0.1Hz to 10Hz (Note 5)                |         | 10      | 15    |         | 10      | 15    | $\mu V_{P-P}$ |
| Line Regulation            |                   | $V_{IN} = 8V$ to 33V (Note 6)         |         | 0.006   | 0.010 |         | 0.006   | 0.010 | %/V           |
| Load Regulation            |                   | $I_L = 0$ to 10mA (Note 6)            |         | 0.005   | 0.010 |         | 0.006   | 0.010 | %/mA          |
| Turn-On Settling Time      | $t_{ON}$          | To $\pm 0.1\%$ of final value         |         | 230     |       |         | 230     |       | $\mu s$       |
| Quiescent Supply Current   | $I_{SY}$          | No load                               |         | 1.0     | 1.4   |         | 1.0     | 1.4   | mA            |
| Load Current               | $I_L$             | To specified output voltage tolerance | 10      | 21      |       | 10      | 21      |       | mA            |
| Sink Current               | $I_S$             | To specified output voltage tolerance | 0.3     | 0.5     |       | 0.3     | 0.5     |       | mA            |
| Short-Circuit Current      | $I_{SC}$          | $V_O = 0V$                            |         | 30      |       |         | 30      |       | mA            |
| Temperature Voltage Output | $V_T$             | (Note 7)                              |         | 630     |       |         | 630     |       | mV            |

## ELECTRICAL CHARACTERISTICS—REF02E/REF02H

( $V_{IN} = +15V$ ,  $0^\circ C \leq T_A \leq +70^\circ C$  for REF02E and REF02H,  $I_L = 0mA$ , unless otherwise noted.)

| PARAMETER                                                      | SYMBOL          | CONDITIONS                                        | REF02E |       |       | REF02H |       |       | UNITS  |
|----------------------------------------------------------------|-----------------|---------------------------------------------------|--------|-------|-------|--------|-------|-------|--------|
|                                                                |                 |                                                   | MIN    | TYP   | MAX   | MIN    | TYP   | MAX   |        |
| Output Voltage Change with Temperature                         | $\Delta V_{OT}$ | $0^\circ C \leq T_A \leq +70^\circ C$<br>(Note 8) |        | 0.02  | 0.06  |        | 0.07  | 0.17  | %      |
| Output Voltage Temperature Coefficient                         | $TCV_O$         | (Note 9)                                          |        | 3     | 8.5   |        | 10    | 25    | ppm/°C |
| Change in $V_O$ Temperature Coefficient with Output Adjustment |                 | $R_P = 10k\Omega$                                 |        | 0.7   |       |        | 0.7   |       | ppm/%  |
| Line Regulation<br>( $V_{IN} = 8V$ to 33V)                     |                 | $0^\circ C \leq T_A \leq +70^\circ C$<br>(Note 6) |        | 0.007 | 0.012 |        | 0.007 | 0.012 | %/V    |
| Load Regulation<br>( $I_L = 0$ to 8mA)                         |                 | $0^\circ C \leq T_A \leq +70^\circ C$<br>(Note 6) |        | 0.006 | 0.010 |        | 0.007 | 0.012 | %/mA   |

# +5V, +10V Precision Voltage References

REF01/REF02

## ELECTRICAL CHARACTERISTICS—REF02E/REF02H (continued)

( $V_{IN} = +15V$ ,  $0^{\circ}C \leq T_A \leq +70^{\circ}C$  for REF02E and REF02H,  $I_L = 0mA$ , unless otherwise noted.)

| PARAMETER                                             | SYMBOL | CONDITIONS | REF02E |     |     | REF02H |     |     | UNITS |
|-------------------------------------------------------|--------|------------|--------|-----|-----|--------|-----|-----|-------|
|                                                       |        |            | MIN    | TYP | MAX | MIN    | TYP | MAX |       |
| Temperature Voltage Output<br>Temperature Coefficient | TCVT   | (Note 7)   |        | 2.1 |     |        | 2.1 |     | mV/°C |

## ELECTRICAL CHARACTERISTICS—REF02C

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

| PARAMETER                  | SYMBOL            | CONDITIONS                            | REF02C    |           |       | UNITS         |
|----------------------------|-------------------|---------------------------------------|-----------|-----------|-------|---------------|
|                            |                   |                                       | MIN       | TYP       | MAX   |               |
| Output Voltage             | $V_O$             | $I_L = 0mA$                           | 4.950     | 5.000     | 5.050 | V             |
| Output Adjustment Range    | $\Delta V_{trim}$ | $R_P = 10k\Omega$                     | $\pm 2.7$ | $\pm 6.0$ |       | %             |
| Output Voltage Noise       | $e_{nP-P}$        | 0.1Hz to 10Hz (Note 5)                |           | 12        | 18    | $\mu V_{P-P}$ |
| Line Regulation            |                   | $V_{IN} = 8V$ to $30V$ (Note 6)       |           | 0.009     | 0.015 | %/V           |
| Load Regulation (Note 6)   |                   | $I_L = 0$ to $8mA$                    |           | 0.006     | 0.015 | %/mA          |
|                            |                   | $I_L = 0$ to $4mA$                    |           |           |       |               |
| Turn-On Settling Time      | $t_{ON}$          | To $\pm 0.1\%$ of final value         |           | 230       |       | $\mu s$       |
| Quiescent Supply Current   | $I_{SY}$          | No load                               |           | 1.0       | 1.6   | mA            |
| Load Current               | $I_L$             | To specified output voltage tolerance | 8         | 21        |       | mA            |
| Sink Current               | $I_S$             | To specified output voltage tolerance | 0.2       | 0.5       |       | mA            |
| Short-Circuit Current      | $I_{SC}$          | $V_O = 0V$                            |           | 30        |       | mA            |
| Temperature Voltage Output | $V_T$             | (Note 7)                              |           | 630       |       | mV            |

## ELECTRICAL CHARACTERISTICS—REF02C

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

| PARAMETER                                                      | SYMBOL          | CONDITIONS                      | REF02C |       |       | UNITS  |
|----------------------------------------------------------------|-----------------|---------------------------------|--------|-------|-------|--------|
|                                                                |                 |                                 | MIN    | TYP   | MAX   |        |
| Output Voltage Change with Temperature                         | $\Delta V_{OT}$ | (Note 8)                        |        | 0.14  | 0.45  | %      |
| Output Voltage Temperature Coefficient                         | TCVO            | (Note 9)                        |        | 20    | 65    | ppm/°C |
| Change in $V_O$ Temperature Coefficient with Output Adjustment |                 | $R_P = 10k\Omega$               |        | 0.7   |       | ppm/%  |
| Line Regulation                                                |                 | $V_{IN} = 8V$ to $30V$ (Note 6) |        | 0.011 | 0.018 | %/V    |
| Load Regulation                                                |                 | $I_L = 0$ to $5mA$ (Note 6)     |        | 0.008 | 0.018 | %/mA   |
| Temperature Voltage Output<br>Temperature Coefficient          | TCVT            | (Note 7)                        |        | 2.1   |       | mV/°C  |

# +5V, +10V Precision Voltage References

## ELECTRICAL CHARACTERISTICS—REF02 (continued)

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

**Note 5:** Guaranteed by design.

**Note 6:** Line and load regulation specifications include the effect of self heating. 100% production tested at  $T_A = +25^\circ C$  and guaranteed by design for  $T_A = T_{MIN}$  to  $T_{MAX}$ , as specified.

**Note 7:** Limit current in or out of pin 3 to 50nA and capacitance on pin 3 to 30pF.

**Note 8:**  $\Delta V_{OT}$  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. Guaranteed by design.

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

**Note 9:**  $TCV_O$  is defined as  $\Delta V_{OT}$  divided by the temperature range. Guaranteed by design.

### 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*).

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 1).

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

where  $T$  = Temperature in  $^\circ C$ .

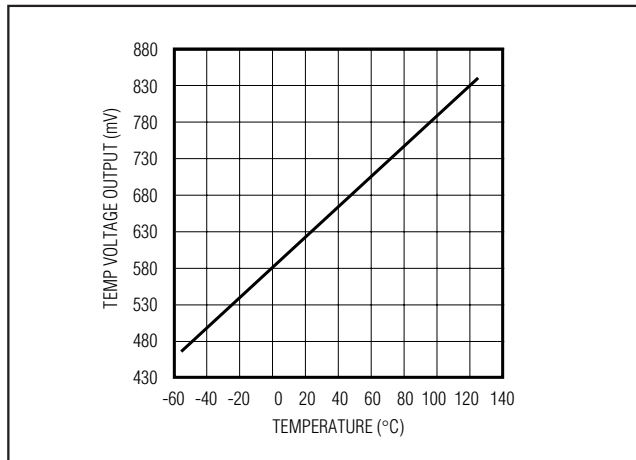


Figure 1. REF02 Temperature/Voltage Output vs. Temperature

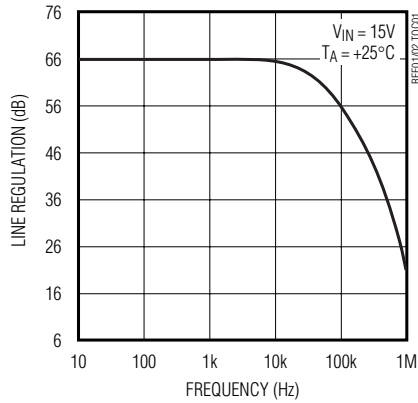
# +5V, +10V Precision Voltage References

## Typical Operating Characteristics

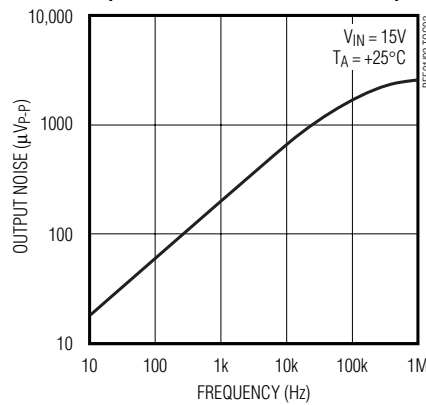
( $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

REF01/REF02

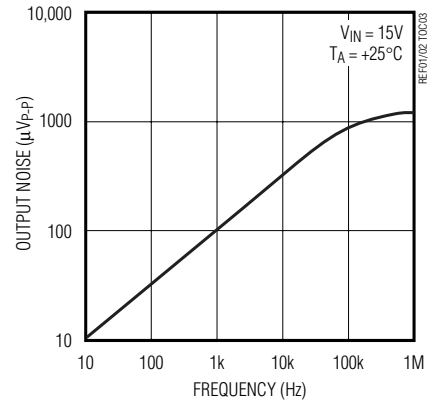
**LINE REGULATION vs. FREQUENCY**



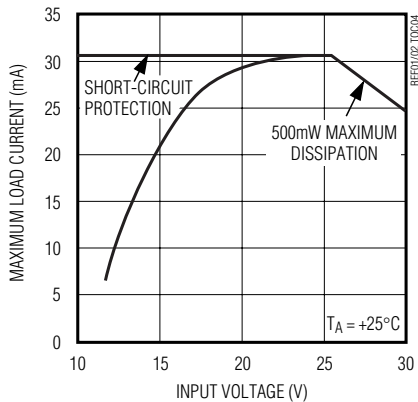
**REF01 OUTPUT WIDEBAND NOISE vs. BANDWIDTH (0.1Hz TO FREQUENCY INDICATED)**



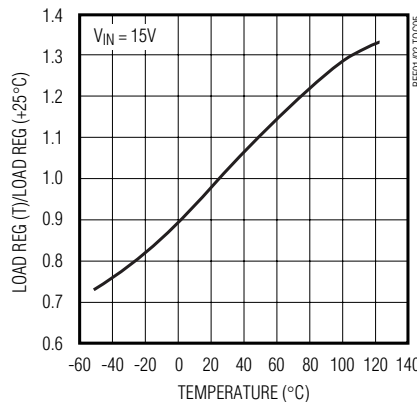
**REF02 OUTPUT WIDEBAND NOISE vs. BANDWIDTH (0.1Hz TO FREQUENCY INDICATED)**



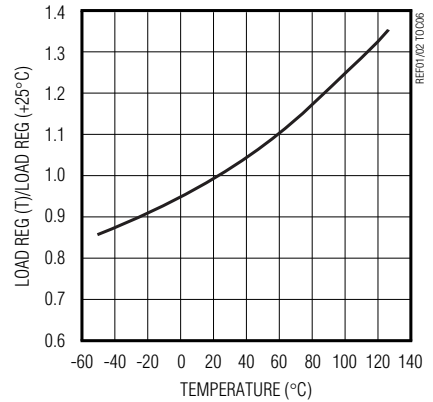
**MAXIMUM LOAD CURRENT vs. INPUT VOLTAGE**



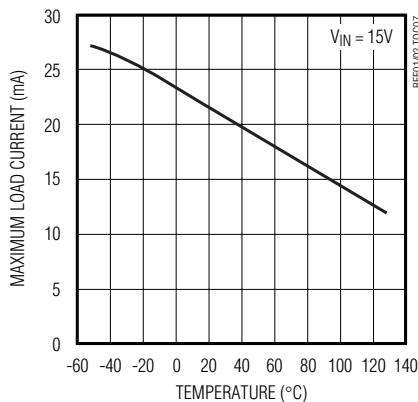
**NORMALIZED LOAD REGULATION ( $\Delta I_L = 10\text{mA}$ ) vs. TEMPERATURE**



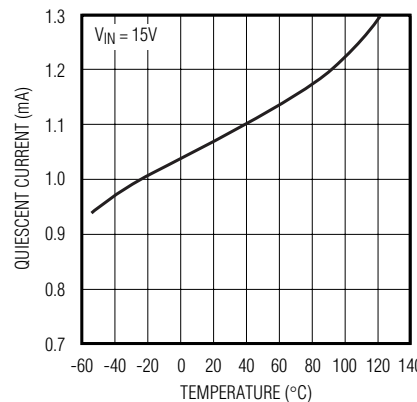
**NORMALIZED LINE REGULATION vs. TEMPERATURE**



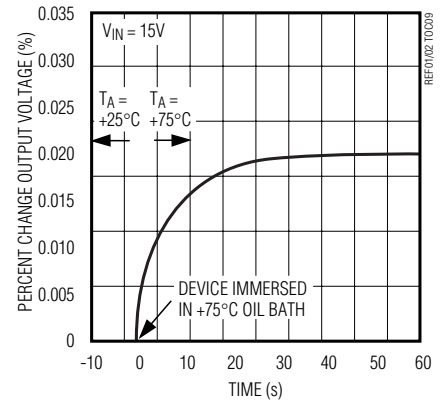
**MAXIMUM LOAD CURRENT vs. TEMPERATURE**



**QUIESCENT CURRENT vs. TEMPERATURE**



**OUTPUT CHANGE DUE TO THERMAL SHOCK**



# +5V, +10V Precision Voltage References

## Typical Applications

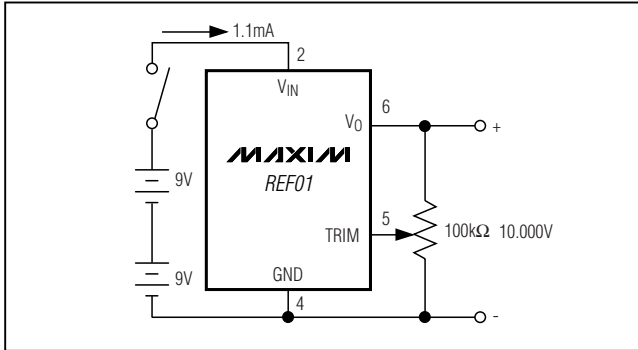


Figure 2. Precision Calibration Standard

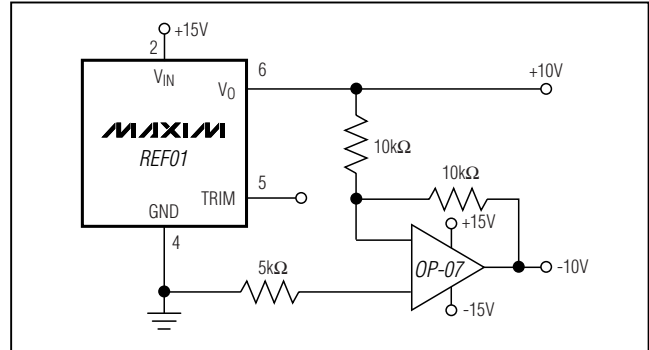


Figure 3. ±10V Reference

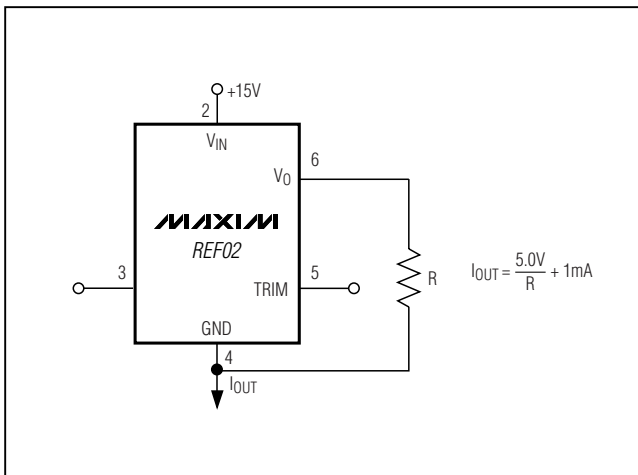


Figure 4. Current Source

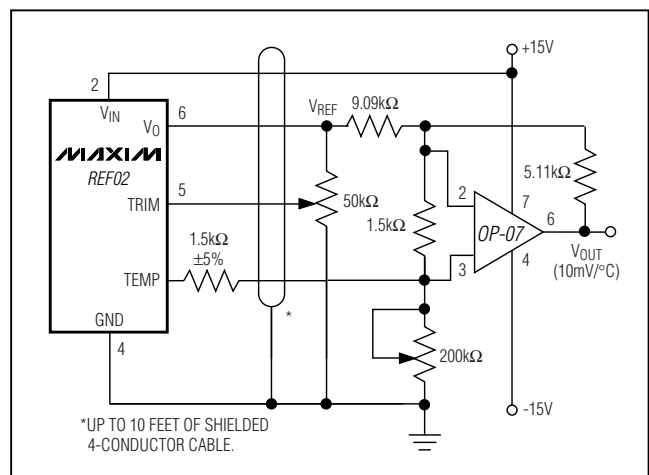


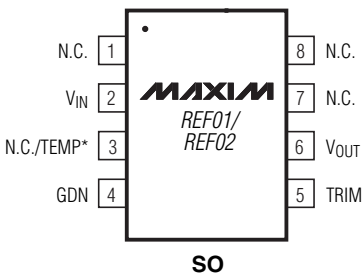
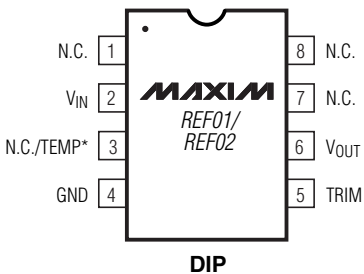
Figure 5. Precision Temperature Transducer with Remote Sensor

# +5V, +10V Precision Voltage References

## Pin Configurations

REF01/REF02

TOP VIEW



\*NOTE: PIN 3 IS N.C. (NO CONNECTION) ON REF01, TEMP OUTPUT ON REF02.

## Ordering Information (continued)

| PART       | TEMP RANGE     | MAX TEMPCO<br>(ppm/°C) | INITIAL ERROR<br>(mV) | PIN-PACKAGE   | PKG<br>CODE |
|------------|----------------|------------------------|-----------------------|---------------|-------------|
| REF02EP    | 0°C to +70°C   | 8.5                    | ±15                   | 8 Plastic DIP | P8-2        |
| REF02EP+   | 0°C to +70°C   | 8.5                    | ±15                   | 8 Plastic DIP | P8-2        |
| REF02HP    | 0°C to +70°C   | 25                     | ±25                   | 8 Plastic DIP | P8-2        |
| REF02HP+   | 0°C to +70°C   | 25                     | ±25                   | 8 Plastic DIP | P8-2        |
| REF02HSA   | 0°C to +70°C   | 25                     | ±25                   | 8 SO          | S8-2        |
| REF02HSA+  | 0°C to +70°C   | 25                     | ±25                   | 8 SO          | S8-2        |
| REF02CP    | 0°C to +70°C   | 65                     | ±50                   | 8 Plastic DIP | P8-2        |
| REF02CP+   | 0°C to +70°C   | 65                     | ±50                   | 8 Plastic DIP | P8-2        |
| REF02CSA   | 0°C to +70°C   | 65                     | ±50                   | 8 SO          | S8-2        |
| REF02CSA+  | 0°C to +70°C   | 65                     | ±50                   | 8 SO          | S8-2        |
| REF02CESA  | -40°C to +85°C | 65                     | ±50                   | 8 SO          | S8-2        |
| REF02CESA+ | -40°C to +85°C | 65                     | ±50                   | 8 SO          | S8-2        |

+Denotes a lead-free package.

## Revision History

Pages changed at Rev 7: 1, 9

## Package Information

For the latest package outline information, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).

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