



# +10V Precision Voltage Reference

## REF-01

### FEATURES

- 10 Volt Output .....  $\pm 0.3\%$  Max
- Adjustment Range .....  $\pm 3\%$  Min
- Excellent Temperature Stability .....  $8.5\text{ppm}/^\circ\text{C}$  Max
- Low Noise .....  $30\mu\text{V}_{\text{p-p}}$  Max
- Low Supply Current .....  $1.4\text{mA}$  Max
- Wide Input Voltage Range ..... 12V to 40V
- High Load-Driving Capability ..... 20mA
- No External Components
- Short-Circuit Proof
- MIL-STD-883 Screening Available
- Available in Die Form

### ORDERING INFORMATION <sup>†</sup>

| $T_A = 25^\circ\text{C}$<br>$\Delta V_{OS}$ MAX<br>(mV) | PACKAGE  |                 |                  |                   | OPERATING<br>TEMPERATURE<br>RANGE |
|---------------------------------------------------------|----------|-----------------|------------------|-------------------|-----------------------------------|
|                                                         | TO-99    | CERDIP<br>8-PIN | PLASTIC<br>8-PIN | LCC<br>20-CONTACT |                                   |
| $\pm 30$                                                | REF01AJ* | REF01AZ*        | —                | —                 | MIL                               |
| $\pm 30$                                                | REF01EJ  | REF01EZ         | —                | —                 | COM                               |
| $\pm 50$                                                | REF01J*  | REF01Z*         | —                | REF01RC/883       | MIL                               |
| $\pm 50$                                                | REF01HJ  | REF01HZ         | REF01HP          | —                 | COM                               |
| $\pm 100$                                               | REF01CJ  | REF01CZ         | —                | —                 | COM                               |
| $\pm 100$                                               | —        | —               | REF01CP          | —                 | XIND                              |
| $\pm 100$                                               | —        | —               | REF01CS††        | —                 | XIND                              |

\* For devices processed in total compliance to MIL-STD-883, add /883 after part number. Consult factory for 883 data sheet.

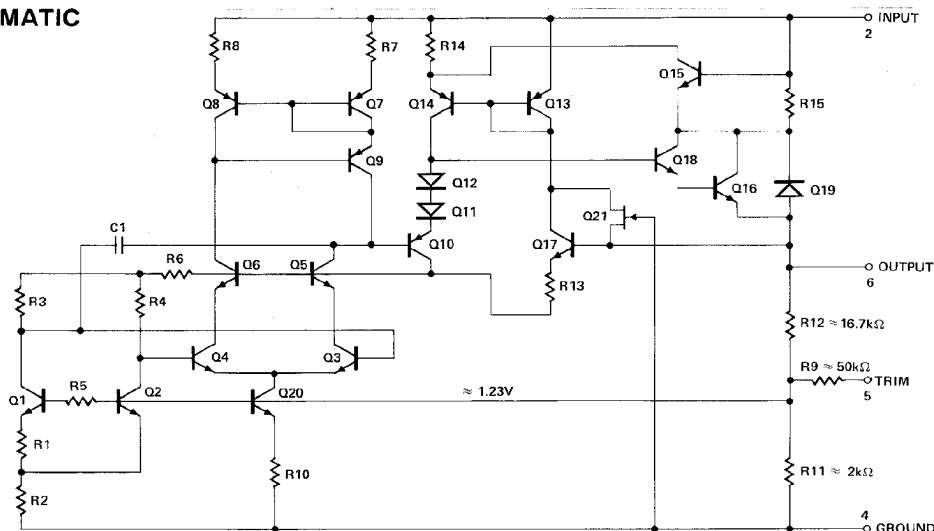
† Burn-in is available on commercial and industrial temperature range parts in CerDIP, plastic DIP, and TO-can packages.

†† For availability and burn-in information on SO and PLCC packages, contact your local sales office.

### GENERAL DESCRIPTION

The REF-01 precision voltage reference provides a stable

### SIMPLIFIED SCHEMATIC

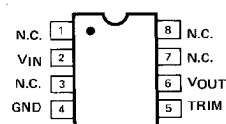
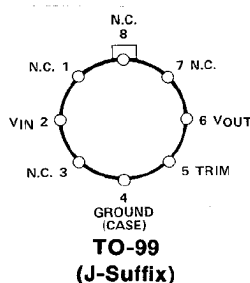


REV. B

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+10V output which can be adjusted over a  $\pm 3\%$  range with minimal effect on temperature stability. Single-supply operation over an input voltage range of 12V to 40V, low current drain of 1mA, and excellent temperature stability are achieved with an improved bandgap design. Low cost, low noise, and low power make the REF-01 an excellent choice whenever a stable voltage reference is required. Applications include D/A and A/D converters, portable instrumentation, and digital voltmeters. Full military temperature range devices with screening to MIL-STD-883 are available. For guaranteed long-term drift see the REF-10 data sheet.

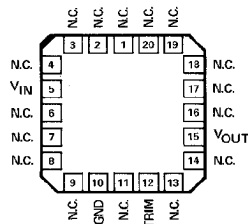
### PIN CONNECTIONS



EPOXY MINI-DIP  
(P-Suffix)

8-PIN HERMETIC DIP  
(Z-Suffix)

8-PIN SO  
(S-Suffix)



REF-01RC/883  
LCC  
(RC-Suffix)

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.  
Tel: 617/329-4700 Fax: 617/326-8703 Twx: 710/394-6577  
Telex: 924491 Cable: ANALOG NORWOODMASS

# REF-01

## ABSOLUTE MAXIMUM RATINGS (Note 1)

|                                                           |                 |
|-----------------------------------------------------------|-----------------|
| Input Voltage                                             |                 |
| REF-01, A, E, H, RC, All DICE                             | 40V             |
| REF-01C                                                   | 30V             |
| Output Short-Circuit Duration<br>(to Ground or $V_{IN}$ ) | Indefinite      |
| Storage Temperature Range                                 |                 |
| J, RC, and Z Packages                                     | -65°C to +150°C |
| P Package                                                 | -65°C to +125°C |
| Operating Temperature Range                               |                 |
| REF-01A, REF-01, REF-01RC                                 | -55°C to +125°C |
| REF-01E, REF-01H,                                         |                 |
| REF-01CJ, REF-01CZ                                        | 0°C to +70°C    |
| REF-01CP, REF-01CS                                        | -40°C to +85°C  |

Junction Temperature ( $T_J$ ) .....-65°C to +150°C  
Lead Temperature (Soldering, 60 sec) .....300°C

| PACKAGE TYPE           | $\theta_{JA}$ (NOTE 2) | $\theta_{JC}$ | UNITS |
|------------------------|------------------------|---------------|-------|
| TO-99 (J)              | 170                    | 24            | °C/W  |
| 8-Pin Hermetic DIP (Z) | 162                    | 26            | °C/W  |
| 8-Pin Plastic DIP (P)  | 110                    | 50            | °C/W  |
| 20-Contact LCC (RC)    | 120                    | 40            | °C/W  |
| 8-Pin SO (S)           | 180                    | 44            | °C/W  |
| 20-Contact PLCC (PC)   | 80                     | 39            | °C/W  |

### NOTES:

1. Absolute maximum ratings apply to both DICE and packaged parts, unless otherwise noted.
2.  $\theta_{JA}$  is specified for worst case mounting conditions, i.e.,  $\theta_{JA}$  is specified for device in socket for TO, CerDIP, P-DIP, and LCC packages;  $\theta_{JA}$  is specified for device soldered to printed circuit board for SO and PLCC packages.

## ELECTRICAL CHARACTERISTICS at $V_{IN} = +15V$ , $T_A = 25^\circ C$ , unless otherwise noted.

| PARAMETER                | SYMBOL            | CONDITIONS                    | REF-01A/E |           |       | REF-01/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  | $\Delta V_{trim}$ | $R_P = 10k\Omega$             | $\pm 3.0$ | $\pm 3.3$ | —     | $\pm 3.0$ | $\pm 3.3$ | —     | %             |
| Output Voltage Noise     | $e_{np-p}$        | 0.1Hz to 10Hz (Note 6)        | —         | 20        | 30    | —         | 20        | 30    | $\mu V_{p-p}$ |
| 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 $\pm 0.1\%$ of final value | —         | 5         | —     | —         | 5         | —     | $\mu s$       |
| 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             | $I_S$             | (Note 7)                      | -0.3      | -0.5      | —     | -0.3      | -0.5      | —     | mA            |
| Short-Circuit Current    | $I_{SC}$          | $V_O = 0$                     | —         | 30        | —     | —         | 30        | —     | mA            |

## ELECTRICAL CHARACTERISTICS at $V_{IN} = +15V$ , $-55^\circ C \leq T_A \leq +125^\circ C$ for REF-01 A/E, and $0^\circ C \leq T_A \leq +70^\circ C$ for REF-01 H and $I_L = 0mA$ , unless otherwise noted.

| PARAMETER                                                      | SYMBOL          | CONDITIONS                                                                        | REF-01A/E |                |                | REF-01/H |                |                | UNITS  |
|----------------------------------------------------------------|-----------------|-----------------------------------------------------------------------------------|-----------|----------------|----------------|----------|----------------|----------------|--------|
|                                                                |                 |                                                                                   | MIN       | TYP            | MAX            | MIN      | TYP            | MAX            |        |
| Output Voltage Change with Temperature (Notes 1, 2)            | $\Delta V_{OT}$ | $0^\circ C \leq T_A \leq +70^\circ C$<br>$-55^\circ C \leq T_A \leq +125^\circ C$ | —         | 0.02<br>0.06   | 0.06<br>0.15   | —        | 0.07<br>0.18   | 0.17<br>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 |                 | $R_P = 10k\Omega$                                                                 | —         | 0.7            | —              | —        | 0.7            | —              | ppm/%  |
| Line Regulation ( $V_{IN} = 13V$ to 33V) (Note 4)              |                 | $0^\circ C \leq T_A \leq +70^\circ C$<br>$-55^\circ C \leq T_A \leq +125^\circ C$ | —         | 0.007<br>0.009 | 0.012<br>0.015 | —        | 0.007<br>0.009 | 0.012<br>0.015 | %/V    |
| Load Regulation ( $I_L = 0$ to 8mA) (Note 4)                   |                 | $0^\circ C \leq T_A \leq +70^\circ C$<br>$-55^\circ C \leq T_A \leq +125^\circ C$ | —         | 0.006<br>0.007 | 0.010<br>0.012 | —        | 0.007<br>0.009 | 0.012<br>0.015 | %/mA   |

### NOTES:

1.  $\Delta V_{OT}$  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:

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

2.  $\Delta V_{OT}$  specification applies trimmed to +10.000V or untrimmed.
3.  $TCV_O$  is defined as  $\Delta V_{OT}$  divided by the temperature range, i.e.,

$$TCV_O (0^\circ \text{ to } +70^\circ C) = \frac{\Delta V_{OT} (0^\circ \text{ to } +70^\circ C)}{70^\circ C}$$

$$\text{and } TCV_O (-55^\circ \text{ to } +125^\circ C) = \frac{\Delta V_{OT} (-55^\circ \text{ to } +125^\circ C)}{180^\circ C}$$

4. Line and Load Regulation specifications include the effect of self heating.
5. Guaranteed by design.
6. Sample tested.
7. During sink current test the device meets the output voltage specified.

**ELECTRICAL CHARACTERISTICS** at  $V_{IN} = +15V$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

| PARAMETER                | SYMBOL            | CONDITIONS                    | REF-01C   |           |       | 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 6)        | —         | 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 $8mA$            | —         | 0.006     | 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             | $I_S$             | (Note 7)                      | -0.3      | -0.5      | —     | mA            |
| Short-Circuit Current    | $I_{SC}$          | $V_O = 0$                     | —         | 30        | —     | mA            |

**ELECTRICAL CHARACTERISTICS** at  $V_{IN} = +15V$ ,  $^\circ C \leq T_A \leq +70^\circ C$  for REF-01CJ, CZ,  $-40^\circ C \leq T_A \leq +85^\circ C$  for REF-01CP, CS, unless otherwise noted.

| PARAMETER                                                      | SYMBOL          | CONDITIONS              | REF-01C |       |       | 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:**

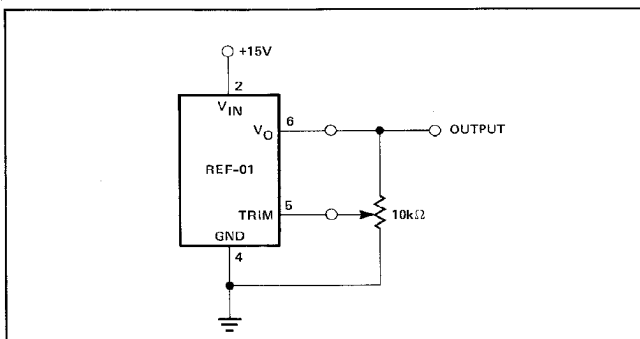
1.  $\Delta V_{OT}$  is defined as the absolute difference between the maximum output voltage and the minimum output voltage over the specified temperature range expressed as a percentage of 10V:

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

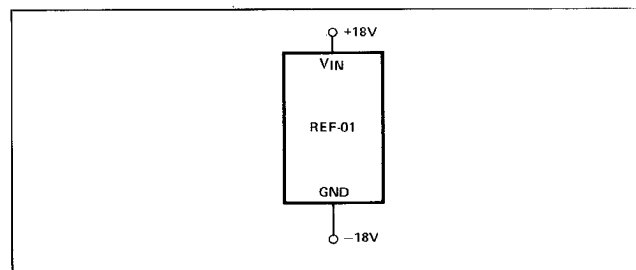
2.  $\Delta V_{OT}$  specification applies trimmed to  $+10.000V$  or untrimmed.  
 3.  $TCV_O$  is defined as  $\Delta V_{OT}$  divided by the temperature range, i.e.,

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

4. Line and Load Regulation specifications include the effect of self heating.  
 5. Guaranteed by design.  
 6. Sample tested.  
 7. During sink current test the device meets the output voltage specified.

**OUTPUT ADJUSTMENT**

The REF-01 trim terminal can be used to adjust the output 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. Of course, the output can

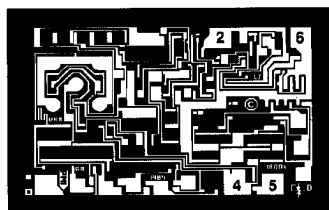
**BURN-IN CIRCUIT**

also be set to exactly 10.000V, or to 10.240V for binary applications.

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

# REF-01

## DICE CHARACTERISTICS (125° C TESTED DICE AVAILABLE)



- 2. INPUT VOLTAGE ( $V_{IN}$ )
- 4. GROUND
- 5. TRIM
- 6. OUTPUT VOLTAGE ( $V_{OUT}$ )

DIE SIZE  $0.074 \times 0.048$  Inch, 3552 sq. mils  
( $1.88 \times 1.22$  mm, 2.29 sq. mm)

**WAFER TEST LIMITS** at  $V_{IN} = +15V$ ,  $T_A = 25^\circ C$  for REF-01N and REF-01G devices;  $T_A = 125^\circ C$  for REF-01NT and REF-01GT devices, unless otherwise noted. (Note 1)

| PARAMETER               | SYMBOL     | CONDITIONS              | REF-01NT<br>LIMIT | REF-01N<br>LIMIT | REF-01GT<br>LIMIT | REF-01G<br>LIMIT | UNITS          |
|-------------------------|------------|-------------------------|-------------------|------------------|-------------------|------------------|----------------|
| Output Voltage          | $V_O$      | $I_L = 0$               | 10.05<br>9.95     | 10.03<br>9.97    | 10.10<br>9.90     | 10.05<br>9.95    | V MAX<br>V MIN |
| Output Adjustment Range | $V_{trim}$ | $R_P = 10k\Omega$       | —                 | $\pm 3.0$        | —                 | $\pm 3.0$        | % MIN          |
| Line Regulation         |            | $V_{IN} = 13V$ to $33V$ | 0.015             | 0.01             | 0.015             | 0.01             | %/V MAX        |

**NOTE:**

Electrical tests are performed at wafer probe to the limits shown. Due to variations in assembly methods and normal yield loss, yield after packaging is not guaranteed for standard product dice. Consult factory to negotiate specifications based on dice lot qualification through sample lot assembly and testing.

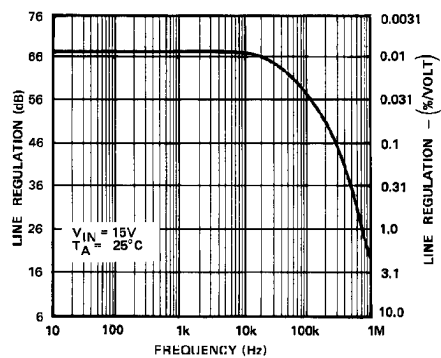
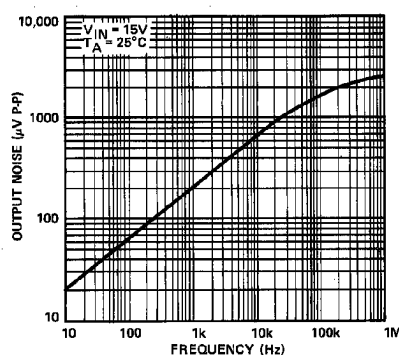
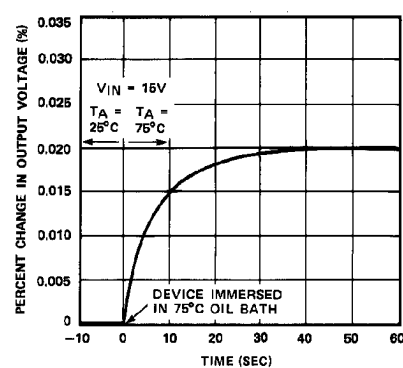
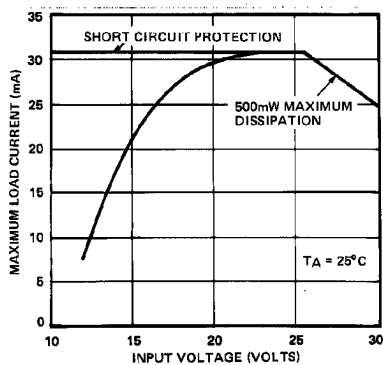
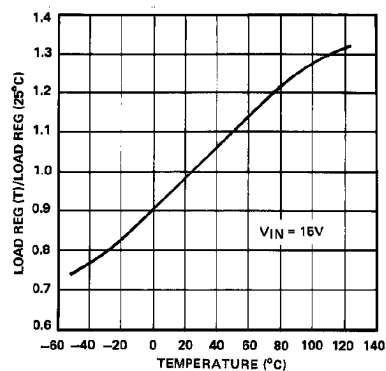
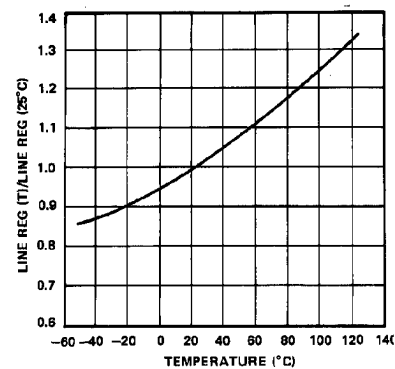
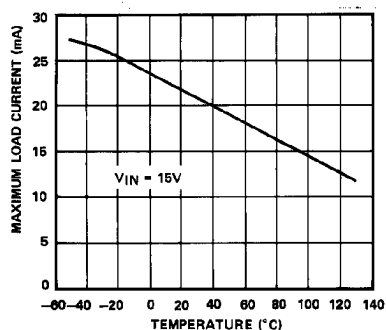
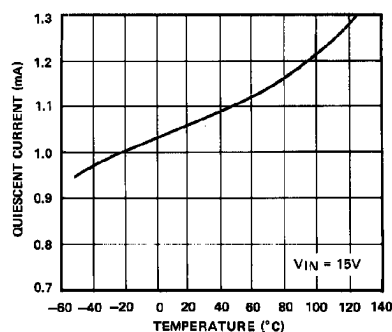
**TYPICAL ELECTRICAL CHARACTERISTICS** at  $V_{IN} = +15V$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

| PARAMETER                              | SYMBOL     | CONDITIONS                                                          | REF-01NT<br>TYPICAL | REF-01N<br>TYPICAL | REF-01GT<br>TYPICAL | REF-01G<br>TYPICAL | UNITS           |
|----------------------------------------|------------|---------------------------------------------------------------------|---------------------|--------------------|---------------------|--------------------|-----------------|
| Load Regulation                        |            | $I_L = 0$ to $10mA$<br>$I_L = 0$ to $8mA$ , NT, GT @ $+125^\circ C$ | 0.007               | 0.005              | 0.009               | 0.006              | %/mA            |
| Output Voltage Noise                   | $e_{np-p}$ | 0.1Hz to 10Hz                                                       | 20                  | 20                 | 20                  | 20                 | $\mu V_{p-p}$   |
| Turn-On Settling Time                  | $t_{ON}$   | To $\pm 0.1\%$ of Final Value<br>NT, GT @ $+125^\circ C$            | 7.5                 | 5.0                | 7.5                 | 5.0                | $\mu s$         |
| Quiescent Current                      | $I_{SY}$   | No Load, NT, GT @ $+125^\circ C$                                    | 1.4                 | 1.0                | 1.4                 | 1.0                | mA              |
| Load Current                           | $I_L$      |                                                                     | 21                  | 21                 | 21                  | 21                 | mA              |
| Sink Current                           | $I_S$      |                                                                     | -0.5                | -0.5               | -0.5                | -0.5               | mA              |
| Short-Circuit Current                  | $I_{SC}$   | $V_O = 0$                                                           | 30                  | 30                 | 30                  | 30                 | mA              |
| Output Voltage Temperature Coefficient | $TCV_O$    |                                                                     | 10                  | 10                 | 10                  | 10                 | ppm/ $^\circ C$ |

**NOTE:**

- For  $+25^\circ C$  specifications of REF-01NT and REF-01GT, see REF-01N and REF-01G respectively.

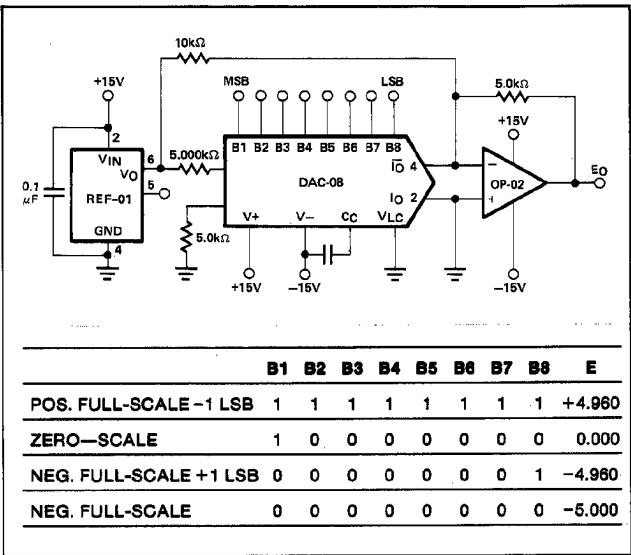
## TYPICAL PERFORMANCE CHARACTERISTICS

LINE REGULATION  
vs FREQUENCYOUTPUT WIDEBAND  
NOISE vs BANDWIDTH (0.1Hz  
TO FREQUENCY INDICATED)OUTPUT CHANGE DUE TO  
THERMAL SHOCKMAXIMUM LOAD CURRENT  
vs INPUT VOLTAGENORMALIZED LOAD  
REGULATION ( $\Delta I_L = 10mA$ )  
vs TEMPERATURENORMALIZED  
LINE REGULATION  
vs TEMPERATUREMAXIMUM LOAD CURRENT  
vs TEMPERATUREQUIESCENT CURRENT  
vs TEMPERATURE

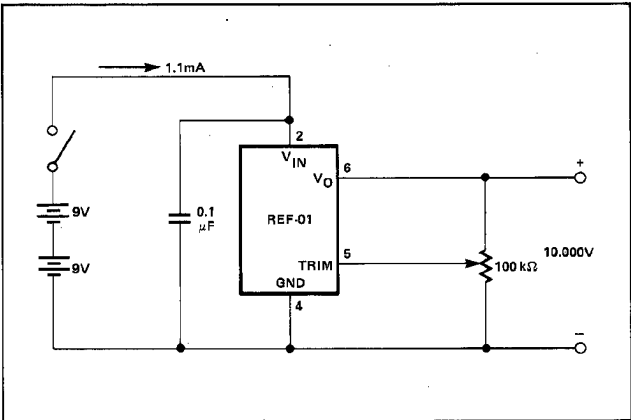
REF-01

TYPICAL APPLICATIONS

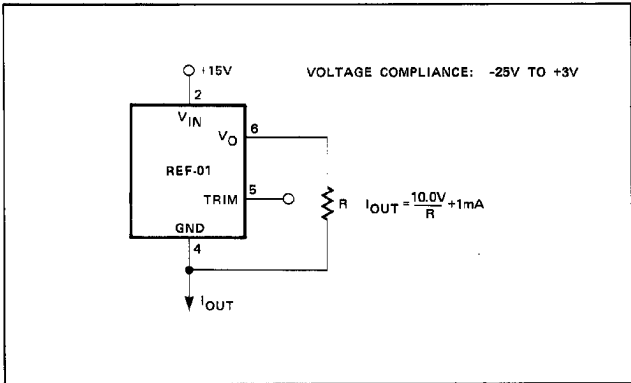
D/A CONVERTER REFERENCE



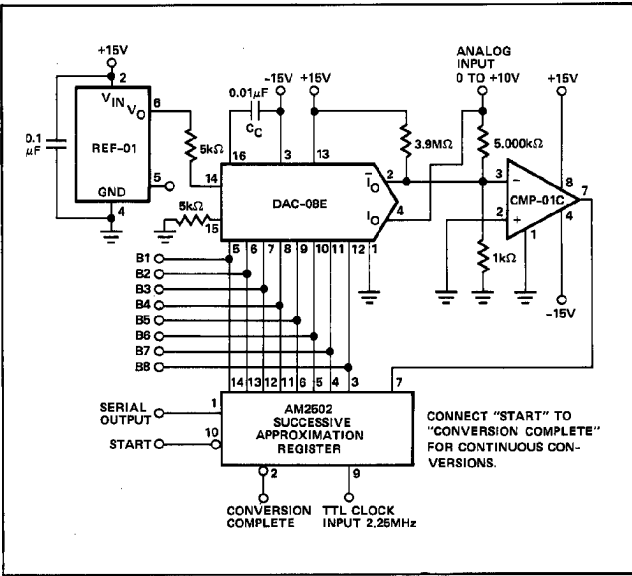
PRECISION CALIBRATION STANDARD



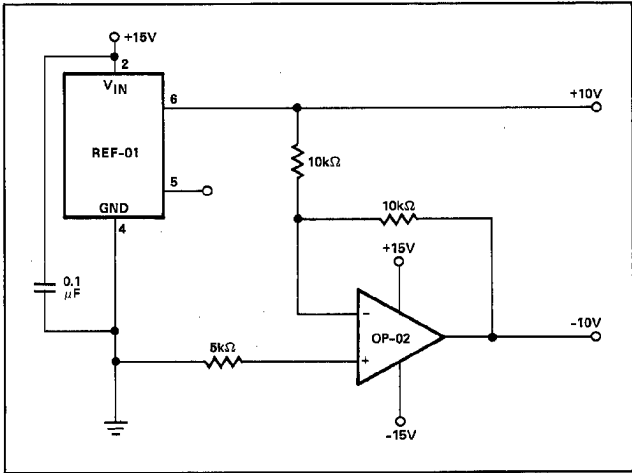
CURRENT SOURCE



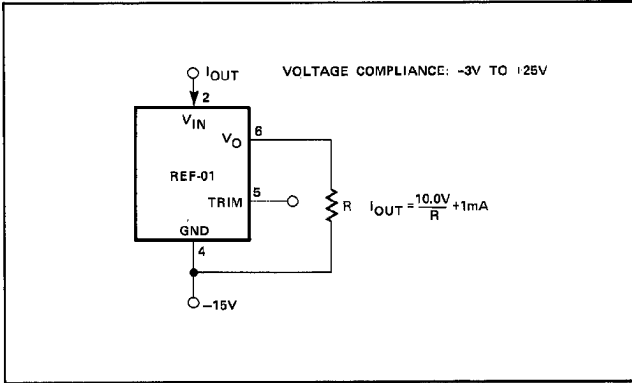
A/D CONVERTER REFERENCE



±10V REFERENCE



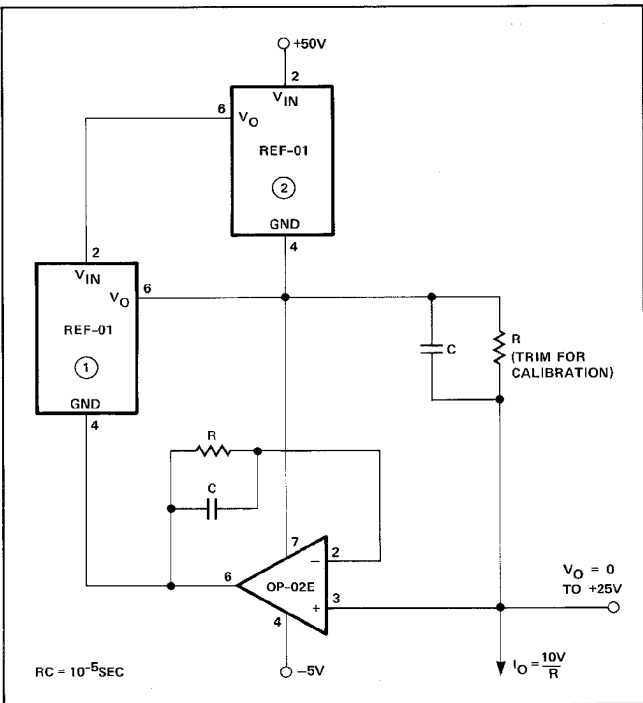
CURRENT SINK



## PRECISION CURRENT SOURCE

A current source with 25V output compliance and excellent output impedance can be obtained using this circuit. REF-01 (2) keeps the line voltage and power dissipation constant in device (1); the only important error consideration at room temperature is the negative supply rejection of the op amp. The typical  $3\mu\text{V/V}$  PSRR of the OP-02E will create an 8ppm change ( $3\mu\text{V/V} \times 25\text{V}/10\text{V}$ ) in output current over a 25V range. For example, a 10mA current source can be built ( $R = 1\text{k}\Omega$ ) with 300M $\Omega$  output impedance.

$$R_O = \frac{25V}{8 \times 10^{-6} \times 10mA}$$



## SUPPLY BYPASSING

For best results, it is recommended that the power supply pin is bypassed with a  $0.1\mu\text{F}$  disc ceramic capacitor.

## REFERENCE STACK WITH EXCELLENT LINE REGULATION

Three REF-01's can be stacked to yield 10.000, 20.000, and 30.000V outputs. An additional advantage is near-perfect line regulation of the 10.0V and 20.0V output. A 32V to 60V input change produces an output change which is less than the noise voltage of the devices. A load bypass resistor ( $R_B$ ) provides a path for the supply current ( $I_{SY}$ ) of the 20.000V regulator.

In general, any number of REF-01's can be stacked this way. For example, ten devices will yield outputs of 10, 20, 30 . . . 100V. The line voltage can range from 105V to 130V. However, care must be taken to ensure that the total load currents do not exceed the maximum usable current (typically 21mA).

