



# REF-01

+10V PRECISION  
VOLTAGE REFERENCE

Precision Monolithics Inc.

## FEATURES

- 10 Volt Output .....  $\pm 0.3\%$  Max
- Adjustment Range .....  $\pm 3\%$  Min
- Excellent Temperature Stability ..... 8.5ppm/ $^{\circ}$ C Max
- Low Noise .....  $30\mu\text{V}_{\text{p-p}}$  Max
- Low Supply Current ..... 1.4mA 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

+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.

## ORDERING INFORMATION <sup>†</sup>

$T_A = 25^{\circ}\text{C}$ $\Delta V_{\text{OS}} \text{ MAX}$ (mV)	PACKAGE				OPERATING TEMPERATURE RANGE
	TO-99	CERDIP 8-PIN	PLASTIC 8-PIN	LCC 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 <sup>††</sup>	—	XIND

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

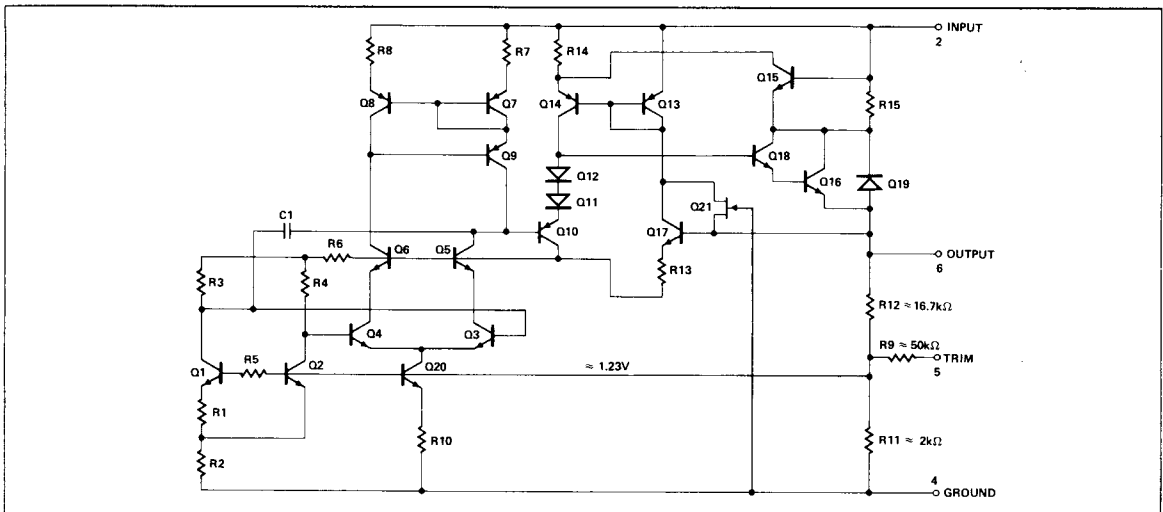
<sup>†</sup> Burn-in is available on commercial and industrial temperature range parts in CerDIP, plastic DIP, and TO-can packages. For ordering information, see 1990/91 Data Book, Section 2.

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

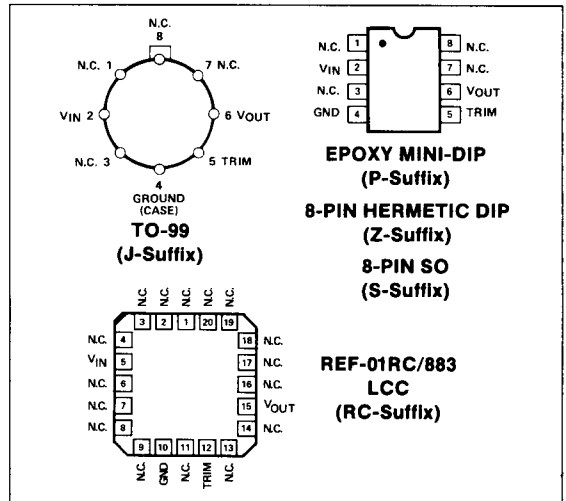
## GENERAL DESCRIPTION

The REF-01 precision voltage reference provides a stable

## SIMPLIFIED SCHEMATIC



## PIN CONNECTIONS



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VOLTAGE REFERENCES

**ABSOLUTE MAXIMUM RATINGS** (Note 1)

Input Voltage	
REF-01, A, E, H, RC, All DICE	40V
REF-01C	30V
Output Short-Circuit Duration (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 +125° 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)	160	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  $V_{IN} = +15V$ ,  $-55^\circ C \leq T_A \leq +125^\circ C$  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)	$\Delta V_{OT}$	$0^\circ C \leq T_A \leq +70^\circ C$ $-55^\circ C \leq T_A \leq +125^\circ C$	—	0.02	0.06	—	0.07	0.17	%
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)		$0^\circ C \leq T_A \leq +70^\circ C$ $-55^\circ C \leq T_A \leq +125^\circ C$	—	0.007	0.012	—	0.007	0.012	%/V
Load Regulation ( $I_L = 0$ to 8mA) (Note 4)		$0^\circ C \leq T_A \leq +70^\circ C$ $-55^\circ C \leq T_A \leq +125^\circ C$	—	0.006	0.010	—	0.007	0.012	%/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  $V_{IN} = +15V \leq T_A \leq +70^\circ C$  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:**

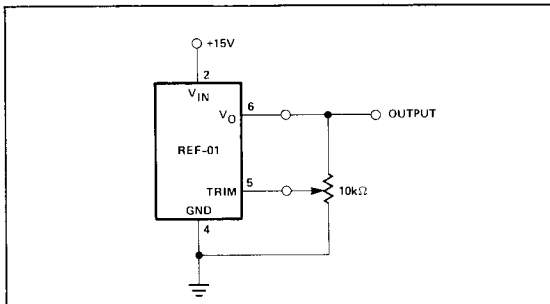
- $\Delta V_{OT}$  is defined as the absolute difference between the maximum output voltage and the minimum output voltage over the specified temperature range expressed as a percentage of 10V:

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

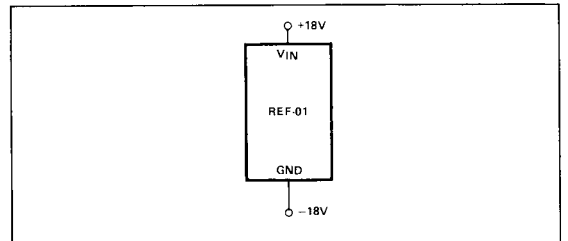
- $\Delta V_{OT}$  specification applies trimmed to  $+10.000V$  or untrimmed.
- $TCV_O$  is defined as  $\Delta V_{OT}$  divided by the temperature range, i.e.,

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

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

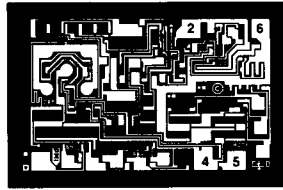
**OUTPUT ADJUSTMENT**


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.

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


DIE SIZE 0.074 × 0.048 inch, 3552 sq. mils  
(1.88 × 1.22 mm, 2.29 sq. mm)

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

For additional DICE ordering information, refer to 1990/91 Data Book, Section 2.

**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 LIMIT	REF-01N LIMIT	REF-01GT LIMIT	REF-01G LIMIT	UNITS
Output Voltage	$V_O$	$I_L = 0$	10.05	10.03	10.10	10.05	V MAX
			9.95	9.97	9.90	9.95	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.

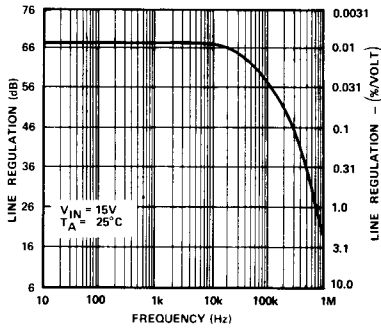
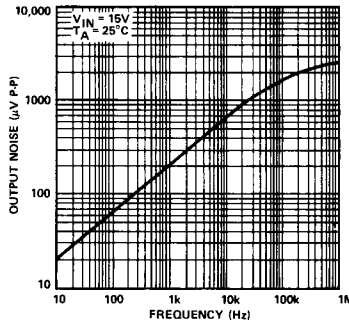
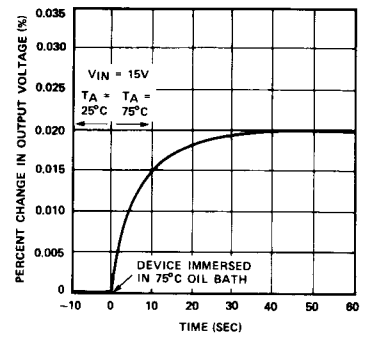
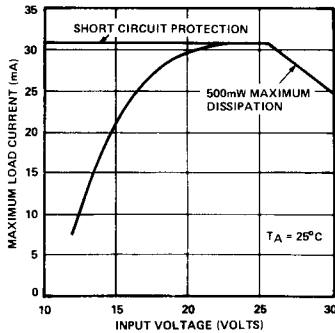
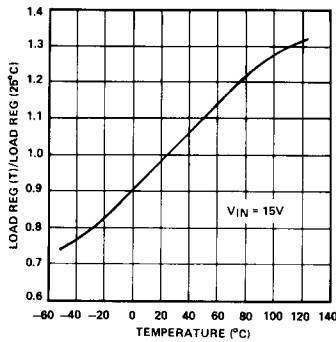
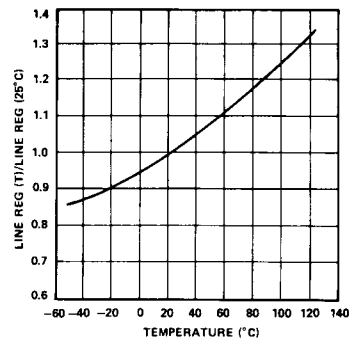
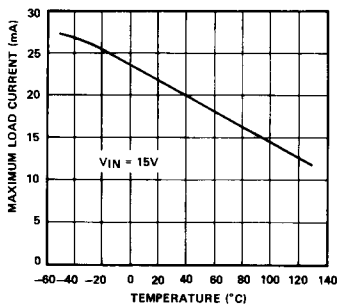
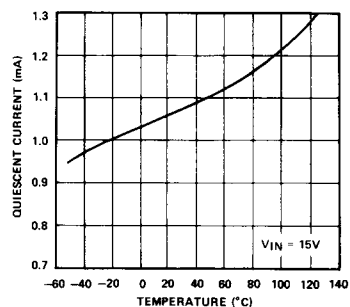
**TYPICAL ELECTRICAL CHARACTERISTICS** at  $V_{IN} = +15V$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

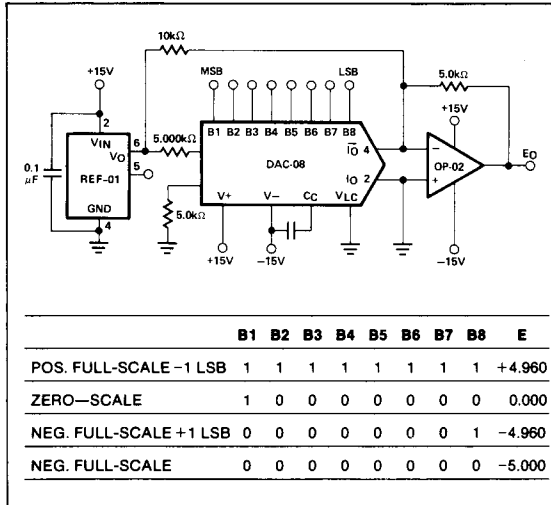
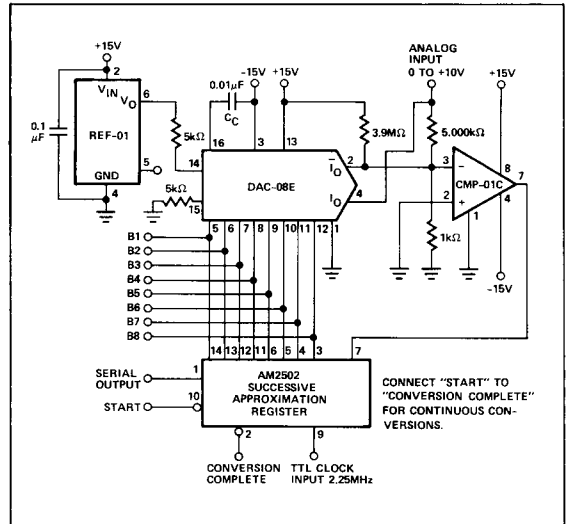
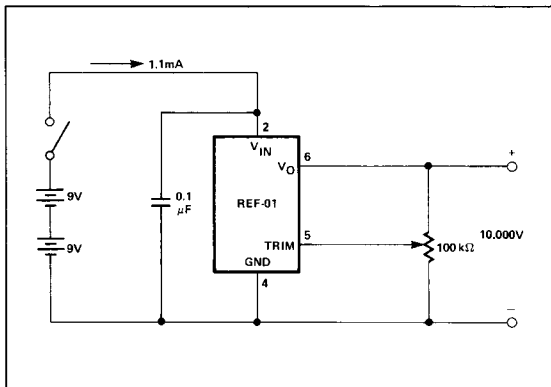
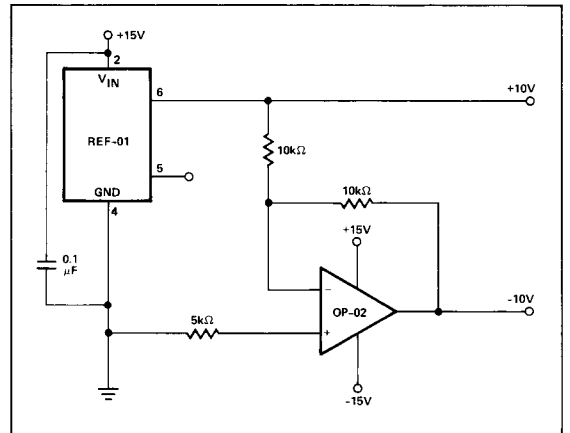
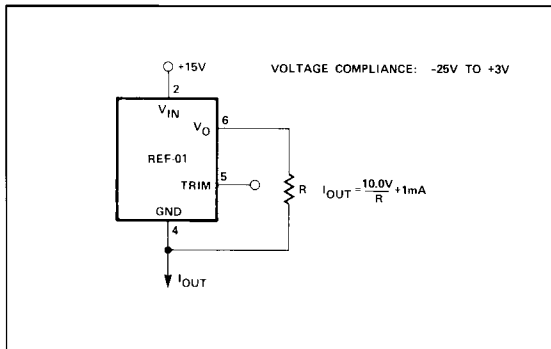
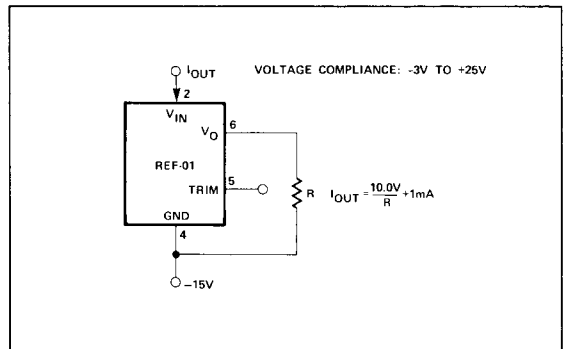
PARAMETER	SYMBOL	CONDITIONS	REF-01NT TYPICAL	REF-01N TYPICAL	REF-01GT TYPICAL	REF-01G TYPICAL	UNITS
Load Regulation		$I_L = 0$ to $10mA$ $I_L = 0$ to $8mA$ , NT, GT @ $+125^\circ C$	0.007	0.005	0.009	0.006	%/mA
Output Voltage Noise	$e_{np-p}$	0.1Hz to 10Hz	20	20	20	20	$\mu V_{p-p}$
Turn-On Settling Time	$t_{ON}$	To $\pm 0.1\%$ of Final Value 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:**

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

## TYPICAL PERFORMANCE CHARACTERISTICS

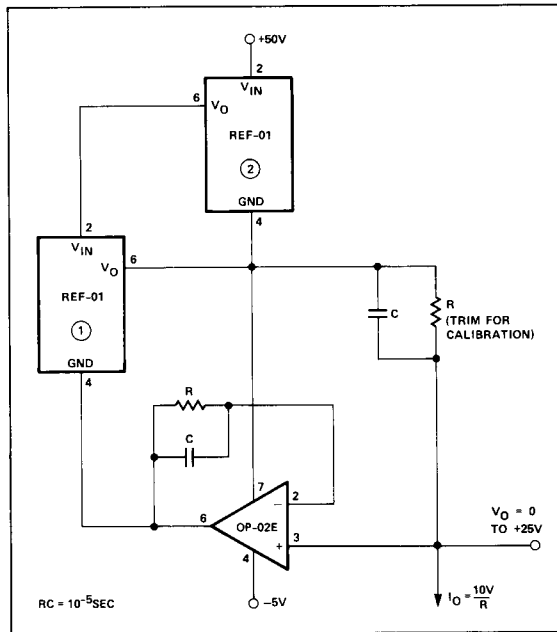
**LINE REGULATION vs FREQUENCY**

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

**OUTPUT CHANGE DUE TO THERMAL SHOCK**

**MAXIMUM LOAD CURRENT vs INPUT VOLTAGE**

**NORMALIZED LOAD REGULATION ( $\Delta I_L = 10mA$ ) vs TEMPERATURE**

**NORMALIZED LINE REGULATION vs TEMPERATURE**

**MAXIMUM LOAD CURRENT vs TEMPERATURE**

**QUIESCENT CURRENT vs TEMPERATURE**


**TYPICAL APPLICATIONS**
**D/A CONVERTER REFERENCE**

**A/D CONVERTER REFERENCE**

**PRECISION CALIBRATION STANDARD**

**±10V REFERENCE**

**CURRENT SOURCE**

**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  $3\mu\text{V}/\text{V}$  PSRR of the OP-02E will create an 8ppm change ( $3\mu\text{V}/\text{V} \times 25\text{V}/10\text{V}$ ) in output current over a 25V range. For example, a 10mA current source can be built ( $R = 1\text{k}\Omega$ ) with  $300\text{M}\Omega$  output impedance.

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



**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).

