# Ultraprecision Operational Amplifier

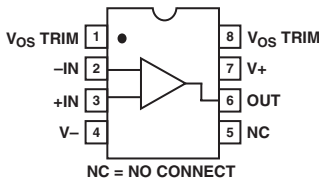
# OP177

**FEATURES**

**Ultralow Offset Voltage:**
**$T_A$ = 25°C: 25 μV Max**
**Outstanding Offset Voltage Drift: 0.1 μV/°C Max**
**Excellent Open-Loop Gain and Gain Linearity:**
**12 V/μV Typ**
**CMRR: 130 dB Min**
**PSRR: 115 dB Min**
**Low Supply Current: 2.0 mA Max**
**Fits Industry Standard Precision Op Amp Sockets (OP07/OP77)**

**PIN CONNECTIONS**

**Epoxy Mini-DIP**
**(P Suffix)**
**8-Pin SO**
**(S-Suffix)**




## GENERAL DESCRIPTION

The OP177 features the highest precision performance of any op amp currently available. Offset voltage of the OP177 is only 25 μV max at room temperature. The ultralow $V_{OS}$ of the OP177 combines with its exceptional offset voltage drift ($TCV_{OS}$) of 0.1 μV/°C max to eliminate the need for external $V_{OS}$ adjustment and increases system accuracy over temperature.

The OP177's open-loop gain of 12 V/μV is maintained over the full ±10 V output range. CMRR of 130 dB min, PSRR of 120 dB min, and maximum supply current of 2 mA are just a few examples of the excellent performance of this operational amplifier. The OP177's combination of outstanding specifications ensures accurate performance in high closed-loop gain applications.

This low noise bipolar input op amp is also a cost effective alternative to chopper-stabilized amplifiers. The OP177 provides chopper-type performance without the usual problems of high noise, low frequency chopper spikes, large physical size, limited common-mode input voltage range, and bulky external storage capacitors.

The OP177 is offered in the –40°C to +85°C extended industrial temperature ranges. This product is available in 8-pin epoxy DIPs, as well as the space saving 8-pin Small-Outline (SO).

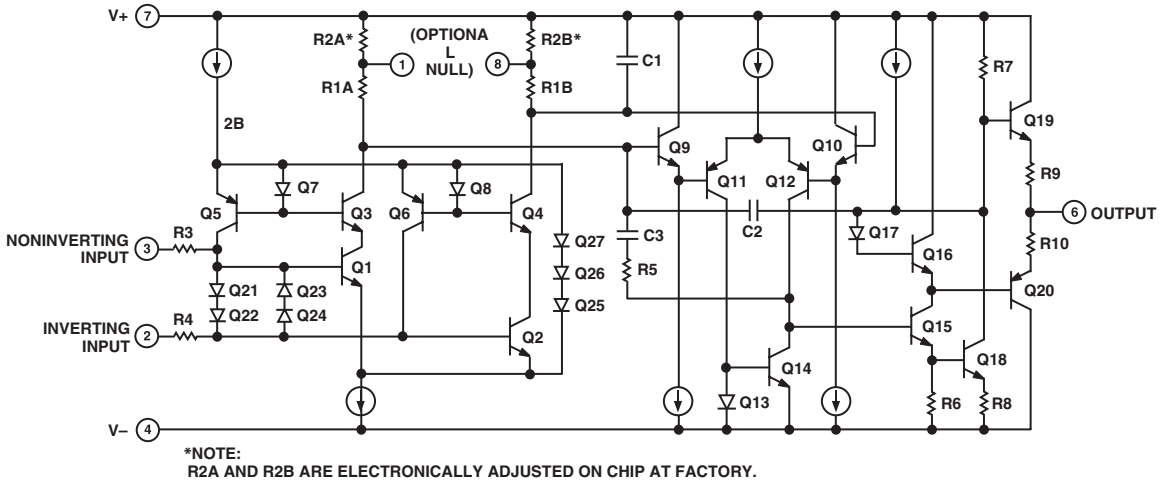



*Figure 1. Simplified Schematic*

REV. C



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## ELECTRICAL CHARACTERISTICS (@ $V_S$ = ±15 V, $T_A$ = 25°C, unless otherwise noted.)

| Parameter | Symbol | Conditions | OP177F Min | OP177F Typ | OP177F Max | OP177G Min | OP177G Typ | OP177G Max | Unit |
|---|---|---|---|---|---|---|---|---|---|
| INPUT OFFSET VOLTAGE | $V_{OS}$ | | | 10 | 25 | | 20 | 60 | µV |
| LONG-TERM INPUT OFFSET Voltage Stability | $\Delta V_{OS}$/Time | | | 0.3 | | | 0.4 | | µV/Mo |
| INPUT OFFSET[1] CURRENT | $I_{OS}$ | | | 0.3 | 1.5 | | 0.3 | 2.8 | nA |
| INPUT BIAS CURRENT | $I_B$ | | –0.2 | 1.2 | 2 | –0.2 | 1.2 | 2.8 | nA |
| INPUT NOISE VOLTAGE | $e_n$ | $f_o$ = 1 Hz to 100 Hz[2] | | 118 | 150 | | 118 | 150 | nV rms |
| INPUT NOISE CURRENT | $i_n$ | $f_o$ = 1 Hz to 100 Hz[2] | | 3 | 8 | | 3 | 8 | pA rms |
| INPUT RESISTANCE Differential-Mode[3] | $R_{IN}$ | | 26 | 45 | | 18.5 | 45 | | MΩ |
| INPUT RESISTANCE COMMON-MODE | $R_{INCM}$ | | | 200 | | | 200 | | GΩ |
| INPUT VOLTAGE RANGE[4] | IVR | | ±13 | ±14 | | ±13 | ±14 | | V |
| COMMON-MODE REJECTION RATIO | CMRR | $V_{CM}$ = ±13 V | 130 | 140 | | 115 | 140 | | dB |
| POWER SUPPLY REJECTION RATIO | PSRR | $V_S$ = ±3 V to ±18 V | | 115 | 125 | | 110 | 120 | dB |
| LARGE SIGNAL VOLTAGE GAIN | $A_{VO}$ | $R_L \geq 2$ kΩ, $V_O$ = 610 V[5] | 5000 | 12000 | | 2000 | 6000 | | V/mV |
| OUTPUT VOLTAGE SWING | $V_O$ | $R_L \geq 10$ kΩ<br>$R_L \geq 2$ kΩ<br>$R_L \geq 1$ kΩ | ±13.5<br>±12.5<br>±12.0 | ±14.0<br>±13.0<br>±12.5 | | ±13.5<br>±12.5<br>±12.0 | ±14.0<br>±13.0<br>±12.5 | | V<br>V<br>V |
| SLEW RATE[2] | SR | $R_L \geq 2$ kΩ | 0.1 | 0.3 | | 0.1 | 0.3 | | V/µs |
| CLOSED-LOOP BANDWIDTH[2] | BW | $A_{VCL}$ = 1 | 0.4 | 0.6 | | 0.4 | 0.6 | | MHz |
| OPEN-LOOP OUTPUT RESISTANCE | $R_O$ | | | 60 | | | 60 | | Ω |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| POWER CONSUMPTION | $P_D$ | $V_S$ = ±15 V, No Load | | 50 | 60 | | 50 | 60 | mW |
| | | Vs = ±3 V, No Load | | 3.5 | 4.5 | | 3.5 | 4.5 | mW |
| SUPPLY CURRENT | $I_{SY}$ | $V_S$ = ±15 V, No Load | | 1.6 | 2 | | 1.6 | 2 | mA |
| OFFSET ADJUSTMENT RANGE | | $R_P$ = 20 kΩ | | ±3 | | | ±3 | | mV |

NOTES

[1]Long-Term Input Offset Voltage Stability refers to the averaged trend line of $V_{OS}$ versus time over extended periods after the first 30 days of operation. Excluding the initial hour of operation, changes in $V_{OS}$ during the first 30 operating days are typically less than 2.0 μV.

[2]Sample tested.

[3]Guaranteed by design.

[4]Guaranteed by CMRR test condition.

[5]To ensure high open-loop gain throughout the ±10 V output range, $A_{VO}$ is tested at $-10\ V \le V_O \le 0\ V$, $0\ V \le V_O \le +10\ V$, and $-10\ V \le V_O \le +10\ V$.

Specifications subject to change without notice.

# OP177–SPECIFICATIONS

## ELECTRICAL CHARACTERISTICS (@ $V_S$ = ±15 V, –40°C ≤ $T_A$ ≤ 85°C, unless otherwise noted.)

| Parameter | Symbol | Conditions | OP177F Min | OP177F Typ | OP177F Max | OP177G Min | OP177G Typ | OP177G Max | Unit |
|---|---|---|---|---|---|---|---|---|---|
| INPUT OFFSET VOLTAGE | $V_{OS}$ | | | 15 | 40 | | 20 | 100 | µV |
| AVERAGE INPUT OFFSET VOLTAGE DRIFT[1] | $TCV_{OS}$ | | | 0.1 | 0.3 | | 0.7 | 1.2 | µV/°C |
| INPUT OFFSET CURRENT | $I_{OS}$ | | | 0.5 | 2.2 | | 0.5 | 4.5 | nA |
| AVERAGE INPUT OFFSET CURRENT DRIFT[2] | $TCI_{OS}$ | | | 1.5 | 40 | | 1.5 | 85 | pA/°C |
| INPUT BIAS CURRENT | $I_B$ | | –0.2 | 2.4 | 4 | | 2.4 | ±6 | nA |
| AVERAGE INPUT BIAS CURRENT DRIFT[2] | $TCI_B$ | | | 8 | 40 | | 15 | 60 | pA/°C |
| INPUT VOLTAGE RANGE[3] | IVR | | ±13 | ±13.5 | | ±13 | ±13.5 | | V |
| COMMON-MODE REJECTION RATIO | CMRR | $V_{CM}$ = ±13 V | 120 | 140 | | 110 | 140 | | dB |
| POWER SUPPLY REJECTION RATIO | PSSR | $V_S$ = ±3 V to ±18 V | 110 | 120 | | 106 | 115 | | dB |
| LARGE-SIGNAL VOLTAGE GAIN[4] | $A_{VO}$ | $R_L$ ≥ 2 kΩ, $V_O$ = 10 V | 2000 | 6000 | | 1000 | 4000 | | V/mV |
| OUTPUT VOLTAGE SWING | $V_O$ | $R_L$ ≥ 2/kΩ | ±12 | ±13 | | ±12 | ±13 | | V |
| POWER CONSUMPTION | $P_D$ | $V_S$ = ±15 V, No Load | | 60 | 75 | | 60 | 75 | mW |
| SUPPLY CURRENT | $I_{SY}$ | $V_S$ = ±15 V, No Load | | 20 | 2.5 | | 2 | 2.5 | mA |

NOTES
[1]$OP177TCV_{OS}$ is sample tested.
[2]Guaranteed by endpoint limits.
[3]Guaranteed by CMRR test condition.
[4]To ensure high open-loop gain throughout the ±10 V output range, $A_{VO}$ is tested at –10 V ≤ $V_O$ ≤ 0 V, 0 V ≤ $V_O$ ≤ +10 V, and –10 V ≤ $V_O$ ≤ +10 V.

Specifications subject to change without notice.

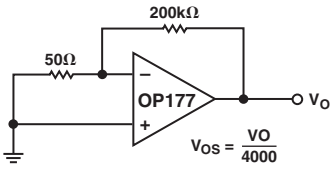



*Figure 2. Typical Offset Voltage Test Circuit*

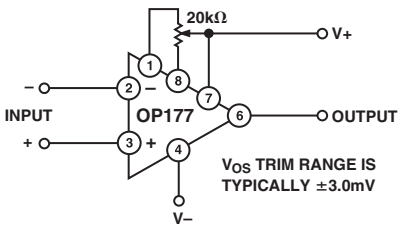



*Figure 3. Optional Offset Nulling Circuit*

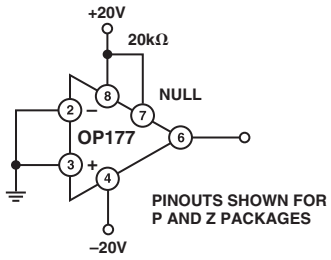



*Figure 4. Burn-In Circuit*

**ABSOLUTE MAXIMUM RATINGS**

Supply Voltage . . . . . ±22 V
Internal Power Dissipation[1] . . . . . 500 mW
Differential Input Voltage . . . . . ±30 V
Input Voltage . . . . . ±22 V
Output Short-Circuit Duration . . . . . Indefinite
Storage Temperature Range
S, P Package . . . . . –65°C to +125°C
Operating Temperature Range
OP177F, OP177G . . . . . –40°C to +85°C
Lead Temperature Range (Soldering, 60 sec) . . . . . 300°C
DICE Junction Temperature ($T_J$) . . . . . –65°C to +150°C

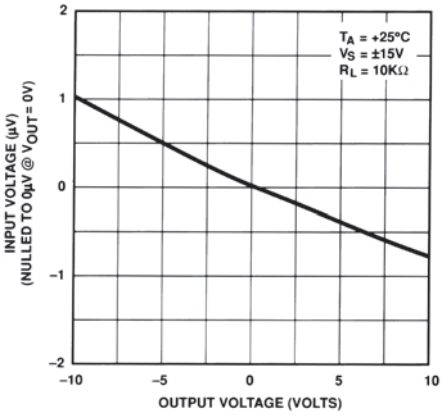
| Package Type | $\theta_{JA}$[2] | $\theta_{JC}$ | Unit |
|---|---|---|---|
| 8-Pin Plastic DIP (P) | 103 | 43 | °C/W |
| 8-Pin SO (S) | 158 | 43 | °C/W |

NOTES
[1]For supply voltages less than ±22 V, the absolute maximum input voltage is equal to the supply voltage.
[2]$\theta_{JA}$ is specified for worst-case mounting conditions, i.e., $\theta_{JA}$ is specified for device in socket for P-DIP; $\theta_{JA}$ is specified for device soldered to printed circuit board for SO package.

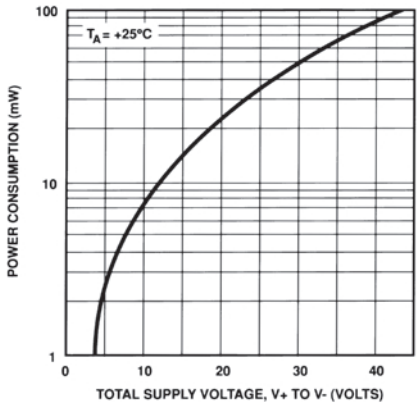
**ORDERING GUIDE**

| Model | Temperature Range | Package Description | Package Option |
|---|---|---|---|
| OP177FP | –40°C to +85°C | 8-Pin Plastic DIP | N-8 |
| OP177GP | –40°C to +85°C | 8-Pin Plastic DIP | N-8 |
| OP177FS | –40°C to +85°C | 8-Pin SO | SO-8 |
| OP177GS | –40°C to +85°C | 8-Pin SO | SO-8 |

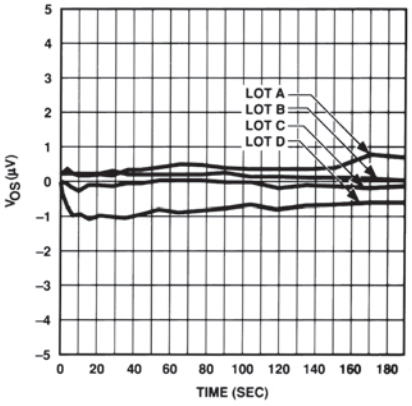
# OP177–Typical Performance Characteristics



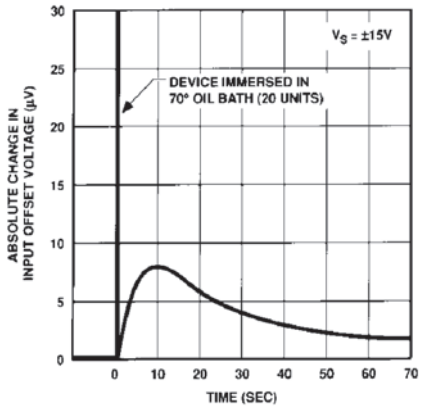

*TPC 1. Gain Linearity (Input Voltage vs. Output Voltage)*



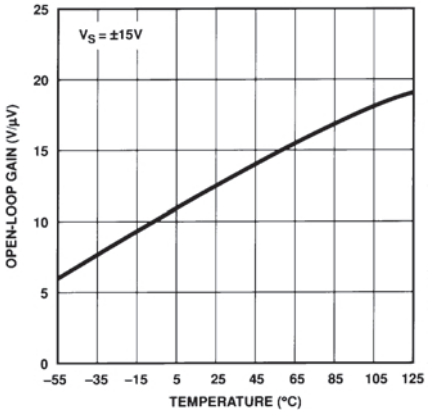

*TPC 2. Power Consumption vs. Power Supply*



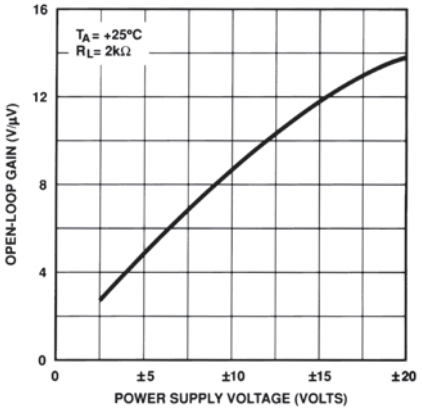

*TPC 3. Warm-Up $V_{OS}$ Drift (Normalized) Z Package*



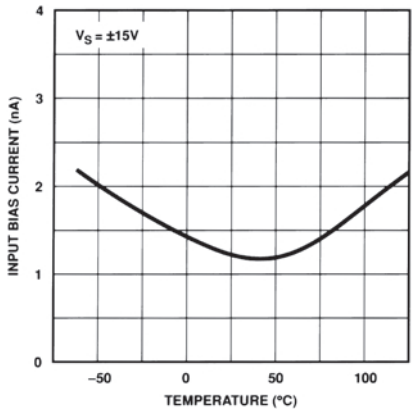

*TPC 4. Offset Voltage Change Due to Thermal Shock*



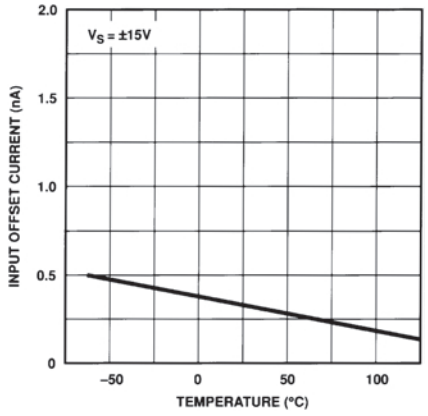

*TPC 5. Open-Loop Gain vs. Temperature*



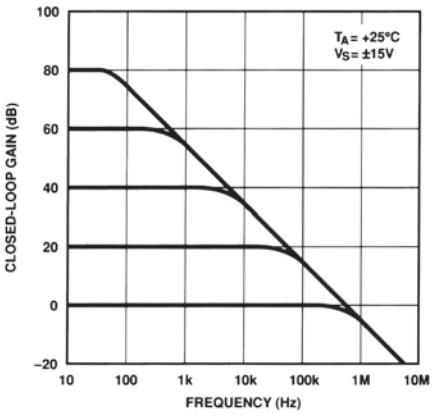

*TPC 6. Open-Loop Gain vs. Power Supply Voltage*



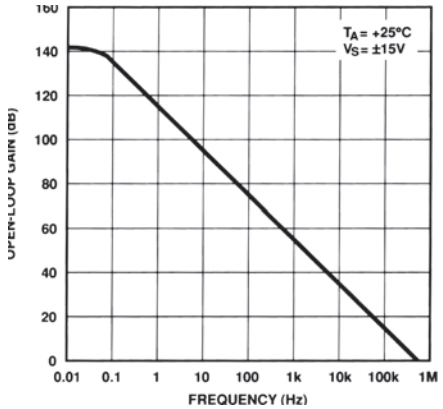

*TPC 7. Input Bias Current vs. Temperature*



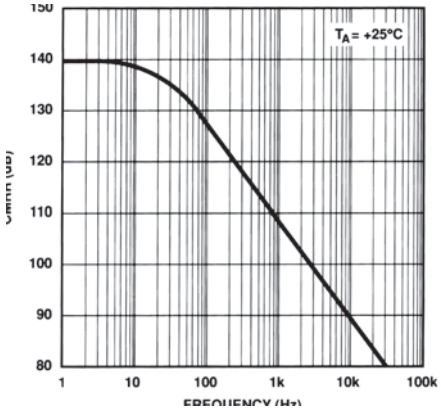

*TPC 8. Input Offset Current vs. Temperature*



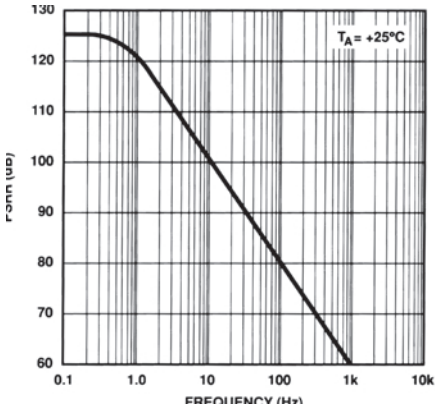

*TPC 9. Closed-Loop Response for Various Gain Configurations*



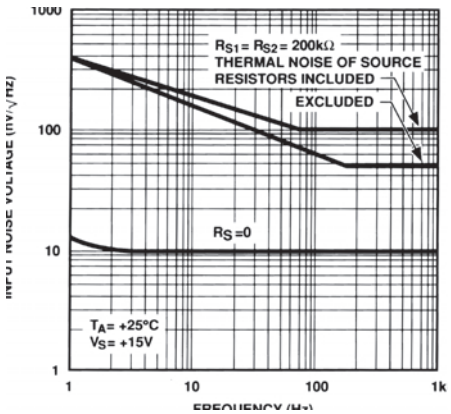

TPC 10. Open-Loop Frequency Response



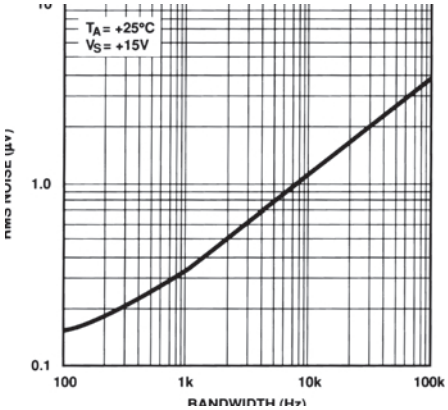

TPC 11. CMRR vs. Frequency



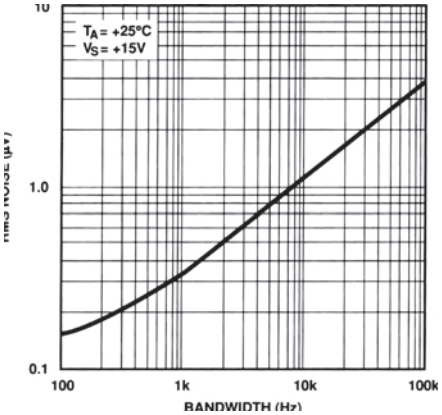

TPC 12. PSRR vs. Frequency



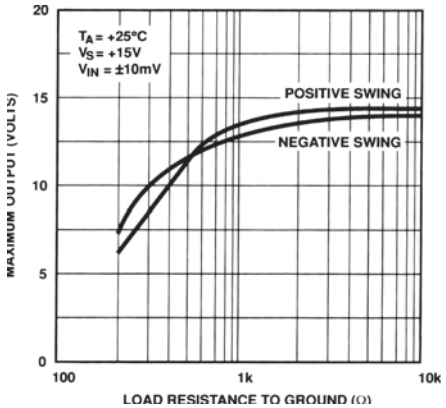

TPC 13. Total Input Noise Voltage vs. Frequency



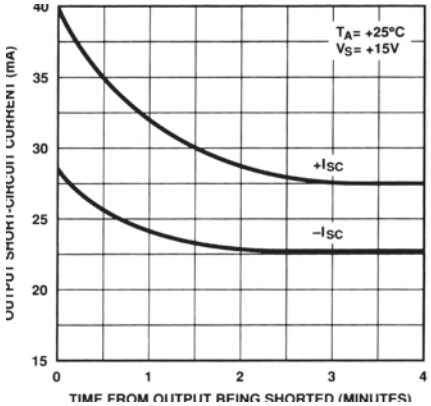

TPC 14. Input Wideband Noise vs. Bandwidth (0.1 Hz to Frequency Indicated)




TPC 15. Maximum Output Swing vs. Frequency




TPC 16. Maximum Output Voltage vs. Load Resistance




TPC 17. Output Short-Circuit Current vs. Time

## APPLICATION INFORMATION

### Gain Linearity

The actual open-loop gain of most monolithic op amps varies at different output voltages. This nonlinearity causes errors in high closed-loop gain circuits.

It is important to know that the manufacturer's $A_{VO}$ specification is only a part of the solution, since all automated testers use endpoint testing and, therefore, show only the average gain. For example, Figure 5 shows a typical precision op amp with a respectable open-loop gain of 650 V/mV. However, the gain is not constant through the output voltage range, causing nonlinear errors. An ideal op amp would show a horizontal scope trace.

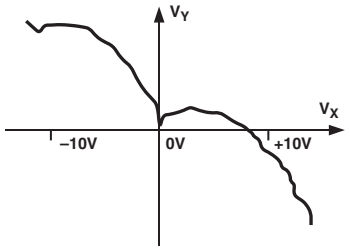



*Figure 5. Typical Precision Op Amp*

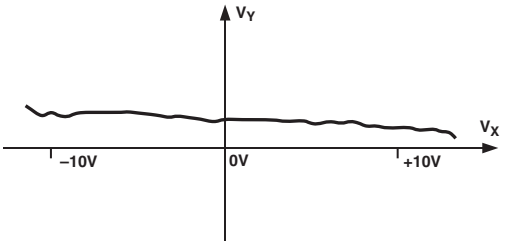



*Figure 6. Output Gain Linearity Trace*

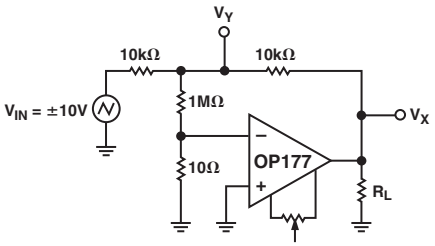



*Figure 7. Open-Loop Gain Linearity Test Circuit*

Figure 6 shows the OP177's output gain linearity trace with its truly impressive average $A_{VO}$ of 12000 V/mV. The output trace is virtually horizontal at all points, assuring extremely high gain accuracy. ADI also performs additional testing to ensure consistent high open-loop gain at various output voltages.

Figure 7 is a simple open-loop gain test circuit for your own evaluation.

## THERMOCOUPLE AMPLIFIER WITH COLD-JUNCTION COMPENSATION

An example of a precision circuit is a thermocouple amplifier that must amplify very low level signals accurately without introducing linearity and offset errors to the circuit. In this circuit, an S-type thermocouple, which has a Seebeck coefficient of 10.3 μV/°C, produces 10.3 mV of output voltage at a temperature of 1000°C. The amplifier gain is set at 973.16. Thus, it will produce an output voltage of 10.024 V. Extended temperature ranges to beyond 1500°C can be accomplished by reducing the amplifier gain. The circuit uses a low-cost diode to sense the temperature at the terminating junctions and, in turn, compensates for any ambient temperature change. The OP177, with its high open-loop gain, plus low offset voltage and drift combines to yield a very precision temperature sensing circuit. Circuit values for other thermocouple types are shown in Table I.

**Table I.**

| Thermocouple Type | Seebeck Coefficient | R1 | R2 | R7 | R9 |
|---|---|---|---|---|---|
| K | 39.2 μV/°C | 110 Ω | 5.76 kΩ | 102 kΩ | 269 kΩ |
| J | 50.2 μV/°C | 100 Ω | 4.02 kΩ | 80.6 kΩ | 200 kΩ |
| S | 10.3 μV/°C | 100 Ω | 20.5 kΩ | 392 kΩ | 1.07 MΩ |

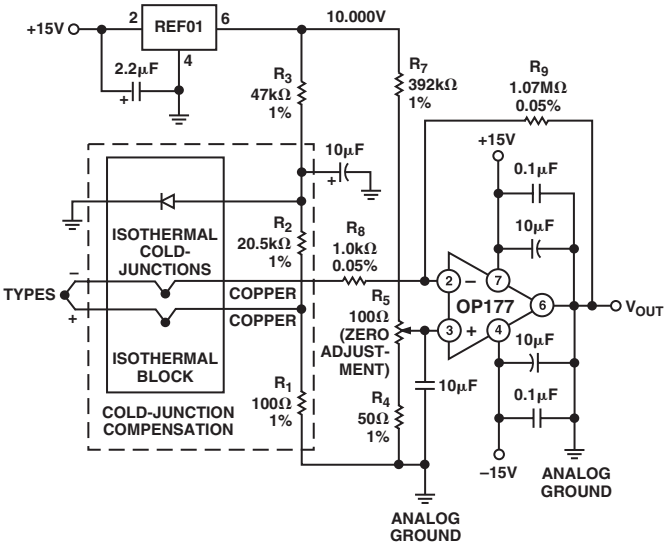



*Figure 8. Thermocouple Amplifier with Cold Junction Compensation*

## PRECISION HIGH GAIN DIFFERENTIAL AMPLIFIER

The high gain, gain linearity, CMRR, and low $TCV_{OS}$ of the OP177 make it possible to obtain performance not previously available in single stage, very high gain amplifier applications. See Figure 9.

For best CMR, $\frac{R1}{R2}$ must equal $\frac{R3}{R4}$. In this example, with a 10 mV differential signal, the maximum errors are as listed in Table II.

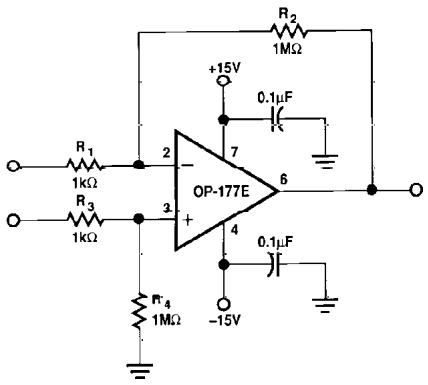



*Figure 9. Precision High Gain Differential Amplifier*

**Table II. High Gain Differential Amp Performance**

| Type | Amount |
|---|---|
| Common-Mode Voltage | 0.1%/V |
| Gain Linearity, Worst Case | 0.02% |
| $TCV_{OS}$ | 0.0003%/°C |
| $TCI_{OS}$ | 0.008%/°C |

**ISOLATING LARGE CAPACITIVE LOADS**

The circuit in Figure 10 reduces maximum slew rate but allows driving capacitive loads of any size without instability. Because the 100 Ω resistor is inside the feedback loop, its effect on output impedance is reduced to insignificance by the high open-loop gain of the OP177.

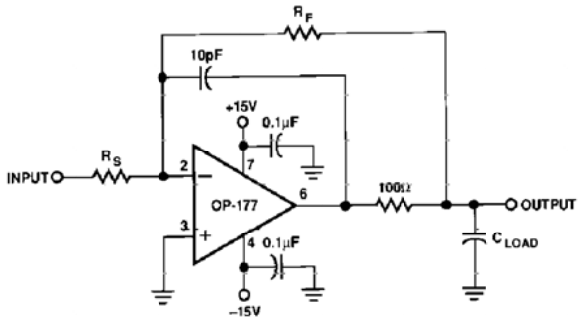



*Figure 10. Isolating Capacitive Loads*

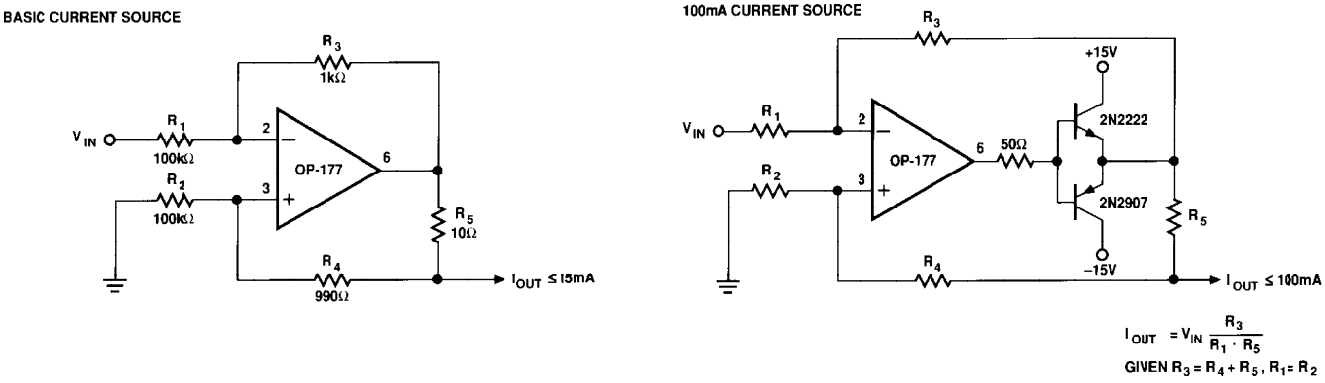



*Figure 11. Bilateral Current Source*

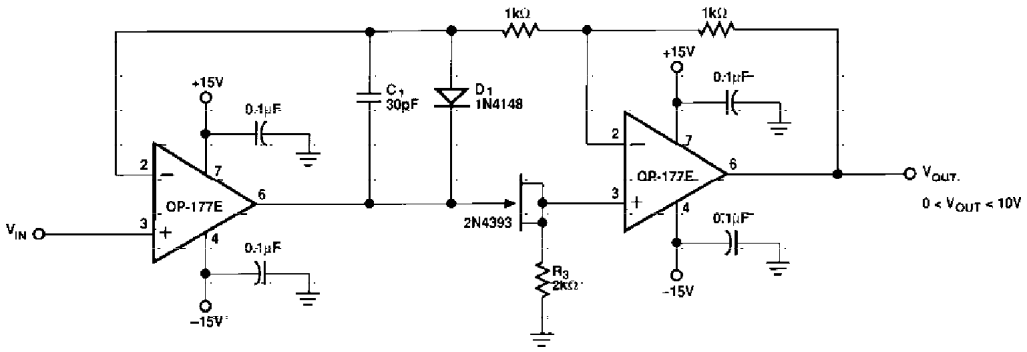



*Figure 12. Precision Absolute Value Amplifier*

**BILATERAL CURRENT SOURCE**

The current sources shown in Figure 11 will supply both positive and negative current into a grounded load.

Note that $Z_O = \dfrac{R5\left(\dfrac{R4}{R2}+1\right)}{\dfrac{R5+R4}{R2}-\dfrac{R3}{R1}}$

and that for $Z_O$ to be infinite,

$$\frac{R5+R4}{R2} \text{ must} = \frac{R3}{R1}$$

**PRECISION ABSOLUTE VALUE AMPLIFIER**

The high gain and low $TCV_{OS}$ assure accurate operation with inputs from microvolts to volts. In this circuit, the signal always appears as a common-mode signal to the op amps. See Figure 12.

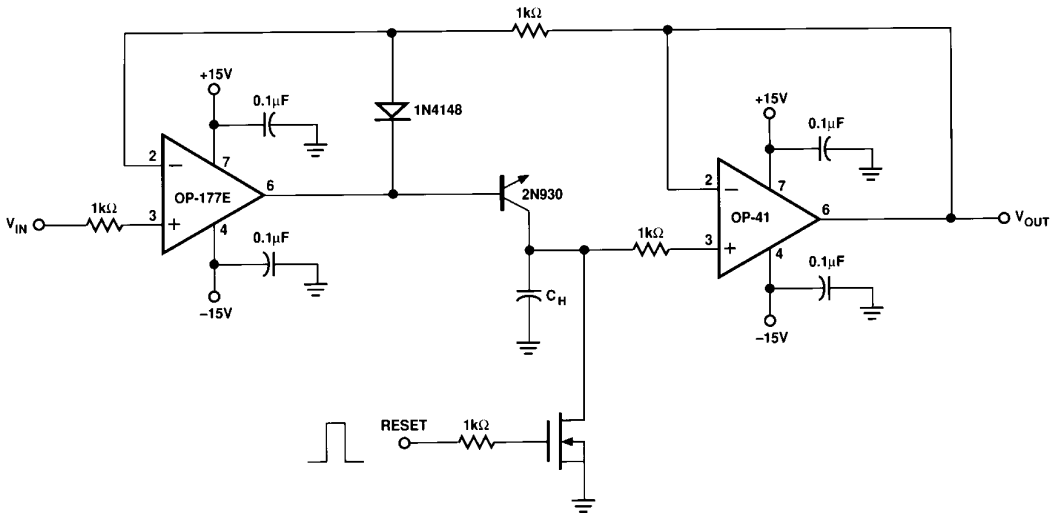



*Figure 13. Precision Positive Peak Detector*

**PRECISION POSITIVE PEAK DETECTOR**

In Figure 13, the $C_H$ must be of polystyrene, Teflon,* or polyethylene to minimize dielectric absorption and leakage. The droop rate is determined by the size of $C_H$ and the bias current of the OP41.

**PRECISION THRESHOLD DETECTOR/AMPLIFIER**

In Figure 14, when $V_{IN} < V_{TH}$, amplifier output swings negative, reverse biasing diode $D_1$. $V_{OUT} = V_{TH}$ if $R_L = \infty$. When $V_{IN} \geq V_{TH}$, the loop closes,

$$V_{OUT} = V_{TH} + \left(V_{IN} - V_{TH}\right)\left(1+\frac{R_F}{R_S}\right)$$

$C_C$ is selected to smooth the response of the loop.

*Teflon is a registered trademark of DuPont.

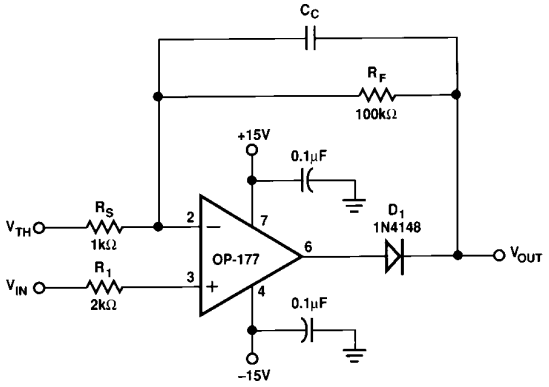
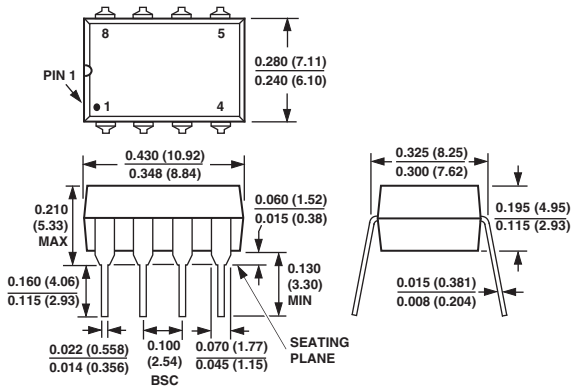



*Figure 14. Precision Threshold Detector/Amplifier*

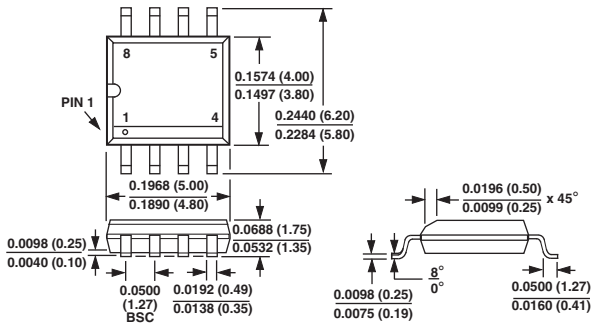
## OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

### 8-Pin Plastic DIP
### (N-8)




### 8-Pin SO
### (SO-08)




# Revision History

| Location | Page |
|---|---|

**01/30—Data Sheet changed from REV. B to REV. C.**

C00289-0-2/02(C)

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