



# High-Gain Instrumentation Operational Amplifier

**OP-06**

## FEATURES

- Very High Voltage Gain ..... 1,000V/mV Min
- Low Offset Voltage and Offset Current
- Low Drift vs. Temperature (TCV<sub>OS</sub>) ..... 0.8μV/°C Max
- Low Input Voltage and Current Noise
- Low Offset Voltage Drift with Time
- High Common-Mode Rejection ..... 120dB Typ
- High Power Supply Rejection ..... 2μV/V Max
- Wide Supply Range ..... ±3.0V to ±22V
- MIL-STD-883 Processing Available
- Slew Rate to ..... 100V/μs
- Available in Die Form

## ORDERING INFORMATION <sup>†</sup>

| T <sub>A</sub> = 25°C<br>V <sub>OS</sub> MAX<br>(mV) | PACKAGE        |                 | OPERATING<br>TEMPERATURE<br>RANGE |
|------------------------------------------------------|----------------|-----------------|-----------------------------------|
|                                                      | TO-99<br>8-PIN | CERDIP<br>8-PIN |                                   |
| 0.2                                                  | OP06AJ*        | —               | MIL                               |
| 0.5                                                  | OP06FJ         | —               | COM                               |
| 0.5                                                  | OP06BJ         | —               | MIL                               |
| 1.3                                                  | OP06GJ         | OP06GZ          | COM                               |

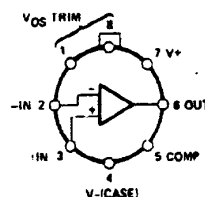
\* For devices processed in total compliance to MIL-STD-883, add /883 after part number. Consult factory for 883 data sheet.

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

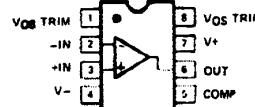
Superior DC input characteristics include very low offset voltage and current, extremely high open-loop gain, low 1/f and wideband noise, and low "popcorn" noise. Low offset voltage drift is improved by a nulling technique that optimizes TCV<sub>OS</sub> performance when V<sub>OS</sub> is nulled to zero. Very high common-mode and power supply rejection enable accurate performance in noisy environments.

Flexible external compensation provides wide-bandwidth and high slew rate operation in high closed-loop gain applications. Excellent long-term stability, and compatibility with MIL-STD-883 processing, make the OP-06 an excellent choice for high-reliability applications; including strain gauge and thermocouple amplifiers, low-noise audio amplifiers, and instrumentation amplifiers. The OP-06 is a direct replacement for all 725 types providing superior DC and noise performance plus the unique feature of complete input differential voltage and output short-circuit protection.

## PIN CONNECTIONS



TO-99 (J-Suffix)

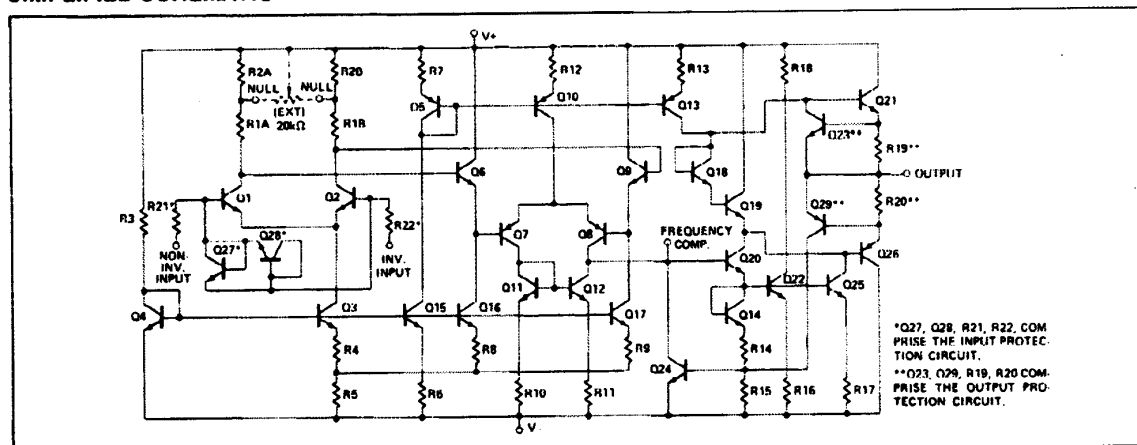


8-PIN HERMETIC DIP (Z-Suffix)

## GENERAL DESCRIPTION

The OP-06 monolithic instrumentation operational amplifier is designed for accurate high-gain amplification of low level signals. High common-mode rejection reduces signal degradation when large common-mode voltages are present.

## SIMPLIFIED SCHEMATIC



## OP-06

### ABSOLUTE MAXIMUM RATINGS (Note 3)

|                                                  |                 |
|--------------------------------------------------|-----------------|
| Supply Voltage .....                             | ±22V            |
| Differential Input Voltage .....                 | ±30V            |
| Input Voltage (Note 1) .....                     | ±22V            |
| Output Short-Circuit Duration .....              | Indefinite      |
| Storage Temperature Range .....                  | -65°C to +150°C |
| Operating Temperature Range                      |                 |
| OP-06A, OP-06B .....                             | -65°C to +125°C |
| OP-06F, OP-06G .....                             | 0°C to +70°C    |
| Lead Temperature Range (Soldering, 60 sec) ..... | +300°C          |
| Junction Temperature .....                       | -65°C to +150°C |

| PACKAGE TYPE           | $\theta_{JA}$ (NOTE 2) | $\theta_{JC}$ | UNITS |
|------------------------|------------------------|---------------|-------|
| TO-99 (J)              | 150                    | 18            | °C/W  |
| 8-Pin Hermetic DIP (Z) | 148                    | 16            | °C/W  |

#### NOTES:

- For supply voltages less than ±22V, the absolute maximum input voltage is equal to the supply voltage.
- $\theta_{JA}$  is specified for worst case mounting conditions, i.e.,  $\theta_{JA}$  is specified for device in socket for TO and CerDIP packages.
- Absolute ratings apply to both DICE and packaged parts, unless otherwise noted.

### ELECTRICAL CHARACTERISTICS at $V_S = \pm 15V$ , $T_A = 25^\circ C$ , unless otherwise noted.

| PARAMETER                    | SYMBOL   | CONDITIONS                                          | OP-06A |       |      | OP-06B/F |       |      | OP-06G |       |      | UNITS                 |
|------------------------------|----------|-----------------------------------------------------|--------|-------|------|----------|-------|------|--------|-------|------|-----------------------|
|                              |          |                                                     | MIN    | TYP   | MAX  | MIN      | TYP   | MAX  | MIN    | TYP   | MAX  |                       |
| Input Offset Voltage         | $V_{OS}$ | $R_S \leq 20k\Omega$ (Note 2)                       | —      | 0.06  | 0.2  | —        | 0.2   | 0.5  | —      | 0.4   | 1.3  | mV                    |
| Input Offset Current         | $I_{OS}$ |                                                     | —      | 0.3   | 2.0  | —        | 0.75  | 5.0  | —      | 2     | 13   | nA                    |
| Input Bias Current           | $I_B$    |                                                     | —      | 30    | 70   | —        | 30    | 80   | —      | 40    | 110  | nA                    |
| Input Noise Voltage Density  | $e_n$    | $f_O = 10\text{Hz}$ (Note 1)                        | —      | 9.0   | 15.0 | —        | 9.0   | 15.0 | —      | 9.0   | 15.0 | $nV/\sqrt{\text{Hz}}$ |
|                              |          | $f_O = 100\text{Hz}$ (Note 1)                       | —      | 8.0   | 9.0  | —        | 8.0   | 9.0  | —      | 8.0   | 9.0  |                       |
|                              |          | $f_O = 1000\text{Hz}$ (Note 1)                      | —      | 7.0   | 7.5  | —        | 7.0   | 7.5  | —      | 7.0   | 7.5  |                       |
| Input Noise Current Density  | $i_n$    | $f_O = 10\text{Hz}$ (Note 1)                        | —      | 0.5   | 1.2  | —        | 0.5   | 1.2  | —      | 0.6   | 1.4  | $pA/\sqrt{\text{Hz}}$ |
|                              |          | $f_O = 100\text{Hz}$ (Note 1)                       | —      | 0.25  | 0.6  | —        | 0.25  | 0.6  | —      | 0.3   | 0.7  |                       |
|                              |          | $f_O = 1000\text{Hz}$ (Note 1)                      | —      | 0.15  | 0.25 | —        | 0.15  | 0.25 | —      | 0.2   | 0.3  |                       |
| Input Resistance             | $R_{IN}$ | (Note 3)                                            | 0.8    | 1.8   | —    | 0.7      | 1.8   | —    | 0.5    | 1.5   | —    | M $\Omega$            |
| Large-Signal Voltage Gain    | $A_{VO}$ | $R_L \geq 2k\Omega$ ,<br>$V_O = \pm 10V$            | 1,000  | 3,000 | —    | 1,000    | 3,000 | —    | 500    | 3,000 | —    | V/mV                  |
| Output Voltage Swing         | $V_O$    | $R_L \geq 10k\Omega$                                | ±12.5  | ±13.0 | —    | ±12.5    | ±13.0 | —    | ±12.0  | ±13.0 | —    | V                     |
|                              |          | $R_L \geq 2k\Omega$                                 | ±12.0  | ±12.8 | —    | ±12.0    | ±12.8 | —    | ±11.5  | ±12.8 | —    |                       |
|                              |          | $R_L \geq 1k\Omega$                                 | ±11.0  | ±12.5 | —    | ±11.0    | ±12.5 | —    | —      | ±12.0 | —    |                       |
| Input Voltage Range          | IVR      |                                                     | ±13.5  | ±14.0 | —    | ±13.5    | ±14.0 | —    | ±13.5  | ±14.0 | —    | V                     |
| Common-Mode Rejection Ratio  | CMRR     | $V_{CM} = \pm 13.5V$<br>$R_S \leq 20k\Omega$        | 114    | 120   | —    | 114      | 120   | —    | 110    | 115   | —    | dB                    |
| Power Supply Rejection Ratio | PSRR     | $V_S = \pm 3V$ to $\pm 18V$<br>$R_S \leq 20k\Omega$ | —      | 0.5   | 2.0  | —        | 1.0   | 5.0  | —      | 2.0   | 10   | $\mu V/V$             |
| Power Consumption            | $P_d$    |                                                     | —      | 90    | 120  | —        | 90    | 120  | —      | 110   | 150  | mW                    |
| Large-Signal Voltage Gain    | $A_{VO}$ | $R_L \geq 500\Omega$ , (Note 3)                     | 100    | 600   | —    | 100      | 600   | —    | 60     | 600   | —    | V/mV                  |
|                              |          | $V_O = \pm 0.5V$                                    |        |       |      |          |       |      |        |       |      |                       |
|                              |          | $V_S = \pm 3V$                                      |        |       |      |          |       |      |        |       |      |                       |
| Power Consumption            | $P_d$    | $V_S = \pm 3V$                                      | —      | 4     | 8    | —        | 4     | 8    | —      | 4     | 8    | mW                    |

#### NOTES:

- Sample tested.
- Thermoelectric voltages generated by dissimilar metals at the contacts to the input terminals can degrade drift performance. Both sides of the contacts should be kept at approximately the same temperature. All temperature gradients should be minimized.
- Guaranteed by design.

**ELECTRICAL CHARACTERISTICS** at  $V_S = \pm 15V$ ,  $-55^\circ C \leq T_A \leq +125^\circ C$ , unless otherwise noted.

| PARAMETER                                                          | SYMBOL      | CONDITIONS                                                      | OP-06A       |                |            | OP-06B       |                |             | UNITS            |
|--------------------------------------------------------------------|-------------|-----------------------------------------------------------------|--------------|----------------|------------|--------------|----------------|-------------|------------------|
|                                                                    |             |                                                                 | MIN          | TYP            | MAX        | MIN          | TYP            | MAX         |                  |
| Input Offset Voltage<br>(Without external trim)                    | $V_{OS}$    | $R_S \leq 20k\Omega$ (Note 2)                                   | —            | 0.06           | 0.28       | —            | 0.3            | 0.7         | mV               |
| Average Input Offset<br>Voltage Drift (With-<br>out external trim) | $TCV_{OS}$  | $R_S = 50\Omega$ (Notes 1, 2)                                   | —            | 0.3            | 0.8        | —            | 0.7            | 2.0         | $\mu V/^\circ C$ |
| Average Input Offset<br>Voltage Drift (With<br>external trim)      | $TCV_{OSn}$ | $R_S = 50\Omega$ (Notes 2, 3)<br>$R_P = 20k\Omega$              | —            | 0.2            | 0.6        | —            | 0.28           | 1.0         | $\mu V/^\circ C$ |
| Input Offset Current                                               | $I_{OS}$    | $T_A$ MAX<br>$T_A$ MIN                                          | —            | 0.25<br>0.8    | 1.0<br>4.0 | —            | 0.6<br>2.0     | 4.0<br>18.0 | nA               |
| Average Input Offset<br>Current Drift                              | $TCI_{OS}$  | (Note 1)                                                        | —            | 3              | 20         | —            | 8              | 90          | $pA/^\circ C$    |
| Input Bias Current                                                 | $I_B$       | $T_A$ MAX<br>$T_A$ MIN                                          | —            | 22<br>40       | 60<br>120  | —            | 25<br>45       | 70<br>180   | nA               |
| Common-Mode<br>Rejection Ratio                                     | CMRR        | $V_{CM} = +13.5V$<br>$R_S \leq 20k\Omega$                       | 109          | 112            | —          | 109          | 112            | —           | dB               |
| Power Supply<br>Rejection Ratio                                    | PSRR        | $V_S = \pm 3V$ to $\pm 18V$<br>$R_S \leq 20k\Omega$             | —            | 1              | 5          | —            | 2              | 8           | $\mu V/V$        |
| Large-Signal<br>Voltage Gain                                       | $A_{VO}$    | $V_O = \pm 10V$ ; $R_L \geq 2k\Omega$<br>$T_A$ MAX<br>$T_A$ MIN | 1,000<br>700 | 3,500<br>2,000 | —          | 1,000<br>700 | 3,500<br>1,800 | —           | V/mV             |
| Output Voltage<br>Swing                                            | $V_O$       | $R_L \geq 2k\Omega$                                             | $\pm 12.0$   | $\pm 12.6$     | —          | $\pm 12.0$   | $\pm 12.6$     | —           | V                |

**ELECTRICAL CHARACTERISTICS** at  $V_S = \pm 15V$ ,  $0^\circ C \leq T_A \leq 70^\circ C$ , unless otherwise noted.

| PARAMETER                                                          | SYMBOL      | CONDITIONS                                                      | OP-06F       |                |             | OP-06G     |                |            | UNITS            |
|--------------------------------------------------------------------|-------------|-----------------------------------------------------------------|--------------|----------------|-------------|------------|----------------|------------|------------------|
|                                                                    |             |                                                                 | MIN          | TYP            | MAX         | MIN        | TYP            | MAX        |                  |
| Input Offset Voltage<br>(Without external trim)                    | $V_{OS}$    | $R_S \leq 20k\Omega$ (Note 2)                                   | —            | 0.25           | 0.8         | —          | 0.5            | 1.8        | mV               |
| Average Input Offset<br>Voltage Drift (With-<br>out external trim) | $TCV_{OS}$  | $R_S = 50\Omega$ (Notes 1, 2)                                   | —            | 0.7            | 2.0         | —          | 1.4            | 4.5        | $\mu V/^\circ C$ |
| Average Input Offset<br>Voltage Drift (With<br>external trim)      | $TCV_{OSn}$ | $R_S = 50\Omega$ (Notes 2, 3)<br>$R_P = 20k\Omega$              | —            | 0.28           | 1.0         | —          | 0.5            | 1.5        | $\mu V/^\circ C$ |
| Input Offset Current                                               | $I_{OS}$    | $T_A$ MAX<br>$T_A$ MIN                                          | —            | 0.85<br>2.0    | 5.0<br>18.0 | —          | 2.0<br>3.0     | 15<br>25   | nA               |
| Average Input Offset<br>Current Drift                              | $TCI_{OS}$  | (Note 1)                                                        | —            | 8              | 90          | —          | 14             | 150        | $pA/^\circ C$    |
| Input Bias Current                                                 | $I_B$       | $T_A$ MAX<br>$T_A$ MIN                                          | —            | 30<br>45       | 80<br>180   | —          | 35<br>45       | 110<br>180 | nA               |
| Common-Mode<br>Rejection Ratio                                     | CMRR        | $V_{CM} = \pm 13.5V$<br>$R_S \leq 20k\Omega$                    | 109          | 112            | —           | 95         | 110            | —          | dB               |
| Power Supply<br>Rejection Ratio                                    | PSRR        | $V_S = \pm 3V$ to $\pm 18V$<br>$R_S \leq 20k\Omega$             | —            | 1.5            | 7.0         | —          | 3.0            | 15         | $\mu V/V$        |
| Large-Signal<br>Voltage Gain                                       | $A_{VO}$    | $V_O = \pm 10V$ ; $R_L \geq 2k\Omega$<br>$T_A$ MAX<br>$T_A$ MIN | 1,000<br>800 | 3,500<br>1,800 | —           | 400<br>300 | 3,200<br>1,700 | —          | V/mV             |
| Output Voltage<br>Swing                                            | $V_O$       | $R_L \geq 2k\Omega$                                             | $\pm 12.0$   | $\pm 12.6$     | —           | $\pm 11.0$ | $\pm 12.6$     | —          | V                |

**NOTES:**

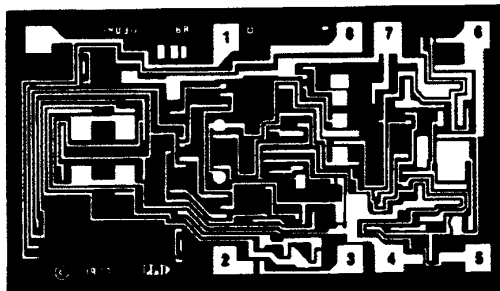
1. Sample tested.
2. Thermoelectric voltages generated by dissimilar metals at the contacts to the input terminals can degrade drift performance. Both sides of the

contacts should be kept at approximately the same temperature. All temperature gradients should be minimized.

3. Guaranteed by input bias current.

# OP-06

## DICE CHARACTERISTICS



1. NULL
2. INVERTING INPUT
3. NONINVERTING INPUT
4. V-
5. COMPENSATION
6. OUTPUT
7. V+
8. NULL

DIE SIZE 0.095 × 0.051 inch, 4845 sq. mils  
(2.41 × 1.30 mm, 3.13 sq. mm)

**WAFER TEST LIMITS** at  $V_S = \pm 15V$ ,  $T_A = 25^\circ C$  for OP-06N, OP-06G and OP-06GR devices;  $T_A = 125^\circ C$  for OP-06NT and OP-06GT devices, unless otherwise noted. (Note 2)

| PARAMETER                               | SYMBOL   | CONDITIONS                                          | OP-06NT<br>LIMIT | OP-06N<br>LIMIT | OP-06GT<br>LIMIT | OP-06G<br>LIMIT | OP-06GR<br>LIMIT | UNITS    |
|-----------------------------------------|----------|-----------------------------------------------------|------------------|-----------------|------------------|-----------------|------------------|----------|
| Input Offset Voltage                    | $V_{OS}$ | $R_S \leq 20k\Omega$                                | 0.3              | 0.2             | 0.7              | 0.5             | 1.3              | mV MAX   |
| Input Offset Current                    | $I_{OS}$ |                                                     | 1                | 2               | 4                | 5               | 13               | nA MAX   |
| Input Bias Current                      | $I_B$    |                                                     | 60               | 70              | 70               | 80              | 110              | nA MAX   |
| Input Resistance<br>Differential Mode   | $R_{IN}$ | (Note 1)                                            | —                | 0.8             | —                | 0.7             | 0.5              | MΩ MIN   |
| Input Voltage Range                     | IVR      |                                                     | ±13.0            | ±13.5           | ±13.0            | ±13.5           | ±13.5            | V MIN    |
| Common-Mode<br>Rejection Ratio          | CMRR     | $V_{CM} = \pm 13.5$<br>$R_S \leq 20k\Omega$         | 108              | 114             | 108              | 114             | 110              | dB MIN   |
| Power Supply<br>Rejection Ratio         | PSRR     | $V_S = \pm 3V$ to $\pm 18V$<br>$R_S \leq 20k\Omega$ | 6                | 2               | 8                | 5               | 10               | μV/V MAX |
| Output Voltage Swing                    | $V_O$    | $R_L \geq 10k\Omega$                                | —                | ±12.5           | —                | ±12.5           | ±12.0            | V MIN    |
|                                         |          | $R_L \geq 2k\Omega$                                 | ±12.0            | ±12.0           | ±12.0            | ±12.0           | ±11.5            |          |
|                                         |          | $R_L \geq 1k\Omega$                                 | —                | ±11.0           | —                | ±11.0           | —                |          |
| Large-Signal<br>Voltage Gain            | $A_{VO}$ | $R_L \geq 2k\Omega$<br>$V_O = \pm 10V$              | 1000             | 1000            | 800              | 1000            | 500              | V/mV MIN |
| Differential Input<br>Voltage           |          |                                                     | ±30              | ±30             | ±30              | ±30             | ±30              | V MAX    |
| Power Consumption<br>( $V_{OUT} = 0V$ ) | $P_d$    |                                                     | —                | 120             | —                | 120             | 150              | mW 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.

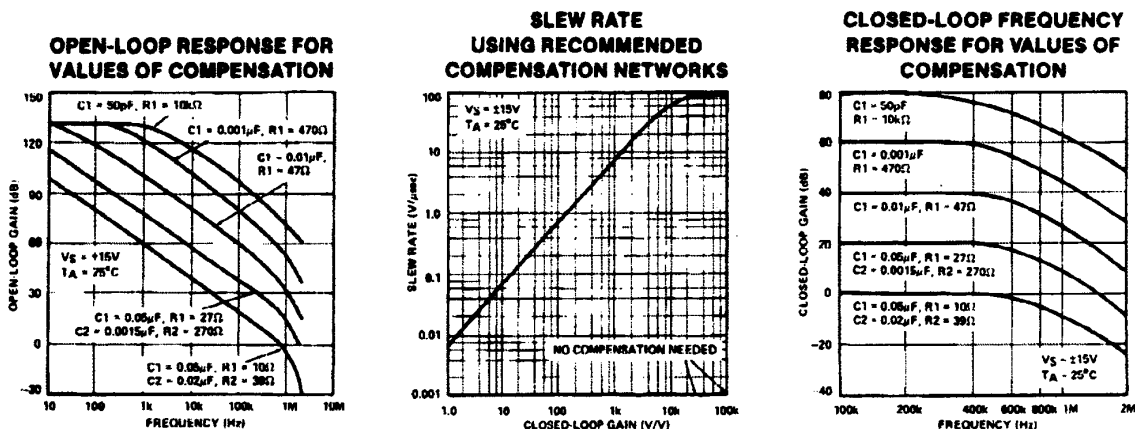
**TYPICAL ELECTRICAL CHARACTERISTICS** at  $V_S = \pm 15V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.

| PARAMETER                               | SYMBOL      | CONDITIONS                                | OP-06NT<br>TYPICAL | OP-06N<br>TYPICAL | OP-06GT<br>TYPICAL | OP-06G<br>TYPICAL | OP-06GR<br>TYPICAL | UNITS |
|-----------------------------------------|-------------|-------------------------------------------|--------------------|-------------------|--------------------|-------------------|--------------------|-------|
| Average Input Offset<br>voltage Drift   | $TCV_{OS}$  | $R_S \leq 50\Omega$                       | 0.3                | 0.3               | 0.7                | 0.7               | 1.4                | μV/°C |
| Nullified Input Offset<br>voltage Drift | $TCV_{OSn}$ | $R_S \leq 50k\Omega$<br>$R_P = 20k\Omega$ | 0.2                | 0.2               | 0.28               | 0.28              | 0.5                | μV/°C |
| Average Input Offset<br>Current Drift   | $TCI_{OS}$  |                                           | 3                  | 3                 | 8                  | 8                 | 14                 | pA/°C |

### NOTES:

1. Guaranteed by input bias current.
2. For  $+25^\circ C$  specifications of OP-06NT and OP-06GT, see OP-06N and OP-06G respectively.

# TYPICAL PERFORMANCE CHARACTERISTICS

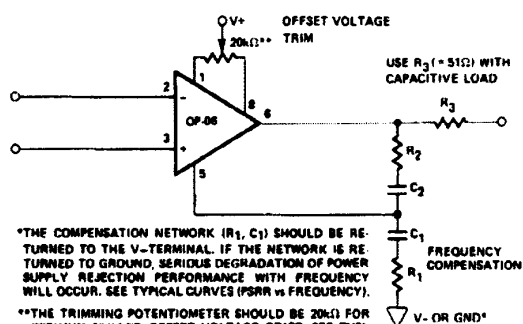


## FREQUENCY COMPENSATION

### COMPENSATION VALUES

| $A_{vcl}$ | $R_1$<br>( $\Omega$ ) | $C_1$<br>( $\mu F$ ) | $R_2$<br>( $\Omega$ ) | $C_2$<br>( $\mu F$ ) |
|-----------|-----------------------|----------------------|-----------------------|----------------------|
| 10000     | 10k                   | 50pF                 | —                     | —                    |
| 1000      | 470                   | 0.001                | —                     | —                    |
| 100       | 47                    | 0.01                 | —                     | —                    |
| 10        | 27                    | 0.05                 | 270                   | 0.0015               |
| 1         | 10                    | 0.05                 | 39                    | 0.02                 |

### COMPENSATION CIRCUIT (J or Z PACKAGE)



\*THE COMPENSATION NETWORK ( $R_1, C_1$ ) SHOULD BE RETURNED TO THE V-TERMINAL. IF THE NETWORK IS RETURNED TO GROUND, SERIOUS DEGRADATION OF POWER SUPPLY REJECTION PERFORMANCE WITH FREQUENCY WILL OCCUR. SEE TYPICAL CURVES (PSRR vs FREQUENCY).

\*\*THE TRIMMING POTENTIOMETER SHOULD BE 20k $\Omega$  FOR OPTIMUM TRIMMED OFFSET VOLTAGE DRIFT. SEE TYPICAL CURVES (TRIMMED OFFSET VOLTAGE DRIFT AS A FUNCTION OF TRIMMING POTENTIOMETER).