

## FEATURES

- *Guaranteed max.  $0.5\mu\text{V}/^\circ\text{C}$  Drift*
- *Guaranteed max.  $0.6\mu\text{V}$  pk-pk Noise*
- *Guaranteed max.  $2\text{nA}$  Bias Current*
- *Guaranteed minimum 114dB CMRR*

## APPLICATIONS

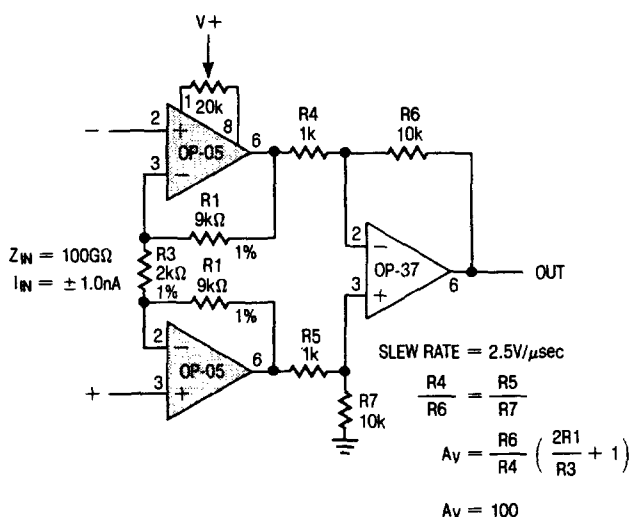
- Strain Gauges
- Thermocouple Amplifiers
- Instrumentation Amplifiers
- Medical Instruments

## DESCRIPTION

The OP-05 is an internally compensated op-amp which provides excellent input offset voltage, low bias current, very high common mode rejection, and low offset voltage drift with temperature when the input offset voltage is externally trimmed to zero. Direct replacement of similar devices in existing systems can result in significant system performance improvement without redesign. The OP-05 is particularly well suited for instrumentation and low signal level applications where precision and stability over time and temperature are important. Internal frequency compensation enhances the OP-05's versatility for a wide variety of precision op-amp uses. Linear's advanced design, process and test techniques ensure device performance as well as reliability. An instrumentation amplifier application is shown below. For higher performance requirements see the LT1001 single precision op amp and the LT1002 dual matched precision op amp series.

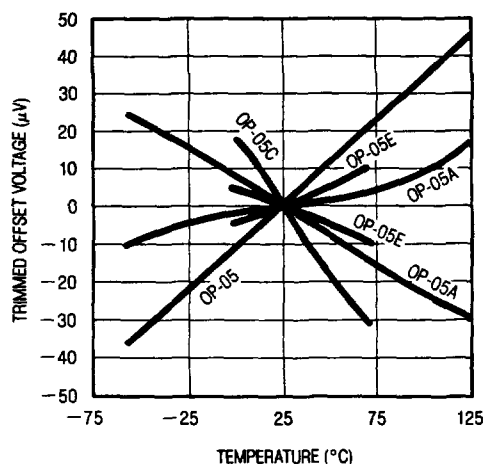
2

Instrumentation Amplifier



Trimmed Offset Voltage with Temperature of Six Representative Units

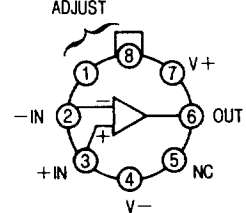
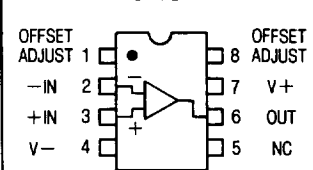
(Offset Trimmed to Zero at  $25^\circ\text{C}$  with  $20\text{k}\Omega$  Pot)



## ABSOLUTE MAXIMUM RATINGS

|                                       |                                  |
|---------------------------------------|----------------------------------|
| Supply Voltage                        | $\pm 22V$                        |
| Differential Input Voltage            | $\pm 30V$                        |
| Input Voltage Equal to Supply Voltage |                                  |
| Output Short Circuit Duration         | Indefinite                       |
| Operating Temperature Range           |                                  |
| OP-05/OP-05A                          | $-55^{\circ}C$ to $125^{\circ}C$ |
| OP-05E/OP-05C                         | $0^{\circ}C$ to $70^{\circ}C$    |
| Storage Temperature Range             |                                  |
| All Devices                           | $-65^{\circ}C$ to $150^{\circ}C$ |
| Lead Temperature (Soldering, 10 sec.) | $300^{\circ}C$                   |

## PACKAGE/ORDER INFORMATION

| TOP VIEW<br>OFFSET<br>ADJUST                                                                                                        | ORDER PART NO.                                                      | OFFSET<br>VOLTAGE<br>MAX                            |
|-------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|-----------------------------------------------------|
| <br>METAL CAN H PACKAGE                           | OP-05AH<br>OP-05H<br>OP-05EH<br>OP-05CH                             | 0.15mV<br>0.5mV<br>0.5mV<br>1.3mV                   |
| <br>HERMETIC J8 PACKAGE<br>PLASTIC DIP N8 PACKAGE | OP-05AJ8<br>OP-05J8<br>OP-05EJ8<br>OP-05CJ8<br>OP-05EN8<br>OP-05CN8 | 0.15mV<br>0.5mV<br>0.5mV<br>1.3mV<br>0.5mV<br>1.3mV |

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

| SYMBOL                                     | PARAMETER                                | CONDITIONS                                                                                                  | MIN                                    | OP-05A<br>TYP                          | MAX                  | MIN                                    | OP-05<br>TYP                           | MAX                  | UNITS                 |
|--------------------------------------------|------------------------------------------|-------------------------------------------------------------------------------------------------------------|----------------------------------------|----------------------------------------|----------------------|----------------------------------------|----------------------------------------|----------------------|-----------------------|
| $V_{OS}$                                   | Input Offset Voltage                     |                                                                                                             |                                        | 0.07                                   | 0.15                 |                                        | 0.2                                    | 0.5                  | mV                    |
| $\frac{\Delta V_{OS}}{\Delta \text{Time}}$ | Long Term Input Offset Voltage Stability | (Notes 1 and 2)                                                                                             |                                        | 0.2                                    | 1.0                  |                                        | 0.2                                    | 1.0                  | $\mu V/\text{Month}$  |
| $I_{OS}$                                   | Input Offset Current                     |                                                                                                             |                                        | 0.7                                    | 2.0                  |                                        | 1.0                                    | 2.8                  | nA                    |
| $I_B$                                      | Input Bias Current                       |                                                                                                             |                                        | $\pm 0.7$                              | $\pm 2.0$            |                                        | $\pm 1.0$                              | $\pm 3.0$            | nA                    |
| $e_n$                                      | Input Noise Voltage                      | 0.1Hz to 10Hz (Note 2)                                                                                      |                                        | 0.35                                   | 0.6                  |                                        | 0.35                                   | 0.6                  | $\mu V_{p-p}$         |
|                                            | Input Noise Voltage Density              | $f_o = 10\text{Hz}$<br>$f_o = 100\text{Hz}$ (Note 2)<br>$f_o = 1000\text{Hz}$                               |                                        | 10.3<br>10.0<br>9.6                    | 18.0<br>13.0<br>11.0 |                                        | 10.3<br>10.0<br>9.6                    | 18.0<br>13.0<br>11.0 | $nV/\sqrt{\text{Hz}}$ |
| $i_n$                                      | Input Noise Current                      | 0.1Hz to 10Hz (Note 2)                                                                                      |                                        | 14                                     | 30                   |                                        | 14                                     | 30                   | $pA_{p-p}$            |
|                                            | Input Noise Current Density              | $f_o = 10\text{Hz}$<br>$f_o = 100\text{Hz}$ (Note 2)<br>$f_o = 1000\text{Hz}$                               |                                        | 0.32<br>0.14<br>0.12                   | 0.80<br>0.23<br>0.17 |                                        | 0.32<br>0.14<br>0.12                   | 0.80<br>0.23<br>0.17 | $pA/\sqrt{\text{Hz}}$ |
| $R_{in}$                                   | Input Resistance Differential Mode       | (Note 3)                                                                                                    | 30                                     | 80                                     |                      | 20                                     | 60                                     |                      | M $\Omega$            |
|                                            | Input Resistance Common Mode             |                                                                                                             |                                        | 200                                    |                      |                                        | 200                                    |                      | G $\Omega$            |
|                                            | Input Voltage Range                      |                                                                                                             | $\pm 13.5$                             | $\pm 14.0$                             |                      | $\pm 13.5$                             | $\pm 14.0$                             |                      | V                     |
| CMRR                                       | Common Mode Rejection Ratio              | $V_{CM} = \pm 13.5V$                                                                                        | 114                                    | 126                                    |                      | 114                                    | 126                                    |                      | dB                    |
| PSRR                                       | Power Supply Rejection Ratio             | $V_S = \pm 3V$ to $\pm 18V$                                                                                 | 100                                    | 108                                    |                      | 100                                    | 108                                    |                      | dB                    |
| $A_{VOL}$                                  | Large Signal Voltage Gain                | $R_L \geq 2k\Omega$ , $V_o = \pm 10V$<br>$R_L \geq 500\Omega$ , $V_o = \pm 0.5V$<br>$V_S = \pm 3V$ (Note 3) | 300<br>150                             | 500<br>500                             |                      | 200<br>150                             | 500<br>500                             |                      | V/mV                  |
| $V_{OUT}$                                  | Maximum Output Voltage Swing             | $R_L \geq 10k\Omega$<br>$R_L \geq 2k\Omega$<br>$R_L \geq 1k\Omega$                                          | $\pm 12.5$<br>$\pm 12.0$<br>$\pm 10.5$ | $\pm 13.0$<br>$\pm 12.8$<br>$\pm 12.0$ |                      | $\pm 12.5$<br>$\pm 12.0$<br>$\pm 10.5$ | $\pm 13.0$<br>$\pm 12.8$<br>$\pm 12.0$ |                      | V                     |
| SR                                         | Slew Rate                                | $R_L \geq 2k\Omega$ (Note 2)                                                                                | 0.1                                    | 0.3                                    |                      | 0.1                                    | 0.3                                    |                      | V/ $\mu S$            |
| GBW                                        | Closed Loop Bandwidth                    | $A_{VCL} = +1$ (Note 2)                                                                                     | 0.4                                    | 0.6                                    |                      | 0.4                                    | 0.6                                    |                      | MHz                   |
| $Z_o$                                      | Open Loop Output Impedance               | $V_o = 0$ , $I_o = 0$ , $f = 10\text{Hz}$                                                                   |                                        | 60                                     |                      |                                        | 60                                     |                      | $\Omega$              |
| $P_d$                                      | Power Dissipation                        | No load<br>$V_S = \pm 3V$ , No load                                                                         |                                        | 90<br>4                                | 120<br>6             |                                        | 90<br>4                                | 120<br>6             | mW                    |
|                                            | Offset Adjustment Range                  | Null Pot = $20k\Omega$                                                                                      |                                        | $\pm 4$                                |                      |                                        | $\pm 4$                                |                      | mV                    |

See Notes on page 2-324

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

| SYMBOL                              | PARAMETER                                                                         | CONDITIONS                         | MIN    | OP-05A<br>TYP | MAX        | MIN | OP-05<br>TYP | MAX        | UNITS            |
|-------------------------------------|-----------------------------------------------------------------------------------|------------------------------------|--------|---------------|------------|-----|--------------|------------|------------------|
| $V_{OS}$                            | Input Offset Voltage                                                              |                                    | ●      | 0.10          | 0.24       |     | 0.3          | 0.7        | mV               |
| $\frac{\Delta V_{OS}}{\Delta Temp}$ | Average Input Offset Voltage Drift<br>Without External Trim<br>With External Trim | Null Pot = 20k $\Omega$ (Note 2)   | ●<br>● | 0.3<br>0.2    | 0.9<br>0.5 |     | 0.7<br>0.3   | 2.0<br>1.0 | $\mu V/^\circ C$ |
| $I_{OS}$                            | Input Offset Current                                                              |                                    | ●      | 1.0           | 4.0        |     | 1.8          | 5.6        | nA               |
| $\frac{\Delta I_{OS}}{\Delta Temp}$ | Average Input Offset Current Drift                                                | (Note 2)                           | ●      | 5             | 25         |     | 8            | 50         | pA/°C            |
| $I_B$                               | Input Bias Current                                                                |                                    | ●      | $\pm 1.0$     | $\pm 4.0$  |     | $\pm 2.0$    | $\pm 6.0$  | nA               |
| $\frac{\Delta I_B}{\Delta Temp}$    | Average Input Bias Current Drift                                                  | (Note 2)                           | ●      | 8             | 25         |     | 13           | 50         | pA/°C            |
|                                     | Input Voltage Range                                                               |                                    | ●      | $\pm 13.0$    | $\pm 13.5$ |     | $\pm 13.0$   | $\pm 13.5$ | V                |
| CMRR                                | Common Mode Rejection Ratio                                                       | $V_{CM} = \pm 13V$                 | ●      | 110           | 123        |     | 110          | 123        | dB               |
| PSRR                                | Power Supply Rejection Ratio                                                      | $V_S = \pm 3V$ to $\pm 18V$        | ●      | 94            | 106        |     | 94           | 106        | dB               |
| $A_{VOL}$                           | Large Signal Voltage Gain                                                         | $R_L \geq 2k\Omega, V_O = \pm 10V$ | ●      | 200           | 400        |     | 150          | 400        | V/mV             |
| $V_{OUT}$                           | Output Voltage Swing                                                              | $R_L \geq 2k\Omega$                | ●      | $\pm 12.0$    | $\pm 12.6$ |     | $\pm 12.0$   | $\pm 12.6$ | V                |

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

| SYMBOL                              | PARAMETER                                | CONDITIONS                                                                                            | MIN                                    | OP-05E<br>TYP                          | MAX                  | MIN                      | OP-05C<br>TYP                          | MAX                  | UNITS           |
|-------------------------------------|------------------------------------------|-------------------------------------------------------------------------------------------------------|----------------------------------------|----------------------------------------|----------------------|--------------------------|----------------------------------------|----------------------|-----------------|
| $V_{OS}$                            | Input Offset Voltage                     |                                                                                                       |                                        | 0.2                                    | 0.5                  |                          | 0.3                                    | 1.3                  | mV              |
| $\frac{\Delta V_{OS}}{\Delta Time}$ | Long Term Input Offset Voltage Stability | (Notes 1 and 2)                                                                                       |                                        | 0.3                                    | 1.5                  |                          | 0.4                                    | 2.0                  | $\mu V/Month$   |
| $I_{OS}$                            | Input Offset Current                     |                                                                                                       |                                        | 1.2                                    | 3.8                  |                          | 1.8                                    | 6.0                  | nA              |
| $I_B$                               | Input Bias Current                       |                                                                                                       |                                        | $\pm 1.2$                              | $\pm 4.0$            |                          | $\pm 1.8$                              | $\pm 7.0$            | nA              |
| $e_n$                               | Input Noise Voltage                      | 0.1Hz to 10Hz (Note 2)                                                                                |                                        | 0.35                                   | 0.6                  |                          | 0.38                                   | 0.65                 | $\mu V_{p-p}$   |
|                                     | Input Noise Voltage Density              | $f_o = 10Hz$<br>$f_o = 100Hz$ (Note 2)<br>$f_o = 1000Hz$                                              |                                        | 10.3<br>10.0<br>9.6                    | 18.0<br>13.0<br>11.0 |                          | 10.5<br>10.2<br>9.8                    | 20.0<br>13.5<br>11.5 | nV/ $\sqrt{Hz}$ |
| $i_n$                               | Input Noise Current                      | 0.1Hz to 10Hz (Note 2)                                                                                |                                        | 14                                     | 30                   |                          | 15                                     | 35                   | pA $_{p-p}$     |
|                                     | Input Noise Current Density              | $f_o = 10Hz$<br>$f_o = 100Hz$ (Note 2)<br>$f_o = 1000Hz$                                              |                                        | 0.32<br>0.14<br>0.12                   | 0.80<br>0.23<br>0.17 |                          | 0.35<br>0.15<br>0.13                   | 0.90<br>0.27<br>0.18 | pA/ $\sqrt{Hz}$ |
| $R_{in}$                            | Input Resistance Differential Mode       | (Note 3)                                                                                              | 15                                     | 50                                     |                      | 8                        | 33                                     |                      | M $\Omega$      |
|                                     | Input Resistance Common Mode             |                                                                                                       |                                        | 160                                    |                      |                          | 120                                    |                      | G $\Omega$      |
|                                     | Input Voltage Range                      |                                                                                                       | $\pm 13.5$                             | $\pm 14.0$                             |                      | $\pm 13.5$               | $\pm 14.0$                             |                      | V               |
| CMRR                                | Common Mode Rejection Ratio              | $V_{CM} = \pm 13.5V$                                                                                  | 110                                    | 123                                    |                      | 100                      | 120                                    |                      | dB              |
| PSRR                                | Power Supply Rejection Ratio             | $V_S = \pm 3V$ to $\pm 18V$                                                                           | 94                                     | 106                                    |                      | 90                       | 104                                    |                      | dB              |
| $A_{VOL}$                           | Large Signal Voltage Gain                | $R_L \geq 2k\Omega, V_O = \pm 10V$<br>$R_L \geq 500\Omega, V_O = \pm 0.5V$<br>$V_S = \pm 3V$ (Note 3) | 200<br>150                             | 500<br>500                             |                      | 120<br>100               | 400<br>400                             |                      | V/mV            |
| $V_{OUT}$                           | Maximum Output Voltage Swing             | $R_L \geq 10k\Omega$<br>$R_L \geq 2k\Omega$<br>$R_L \geq 1k\Omega$                                    | $\pm 12.5$<br>$\pm 12.0$<br>$\pm 10.5$ | $\pm 13.0$<br>$\pm 12.8$<br>$\pm 12.0$ |                      | $\pm 12.0$<br>$\pm 11.5$ | $\pm 13.0$<br>$\pm 12.8$<br>$\pm 12.0$ |                      | V               |
| SR                                  | Slew Rate                                | $R_L \geq 2k\Omega$ (Note 2)                                                                          | 0.1                                    | 0.3                                    |                      | 0.1                      | 0.3                                    |                      | V/ $\mu S$      |
| GBW                                 | Closed Loop Bandwidth                    | $A_{VCL} = +1$ (Note 2)                                                                               | 0.4                                    | 0.6                                    |                      | 0.4                      | 0.6                                    |                      | MHz             |
| $Z_o$                               | Open Loop Output Impedance               | $V_O = 0, I_O = 0, f = 10Hz$                                                                          |                                        | 60                                     |                      |                          | 60                                     |                      | $\Omega$        |
| $P_d$                               | Power Dissipation                        | No load<br>$V_S = \pm 3V$ , No load                                                                   |                                        | 90<br>4                                | 120<br>6             |                          | 95<br>4                                | 150<br>8             | mW              |
|                                     | Offset Adjustment Range                  | Null Pot = 20k $\Omega$                                                                               |                                        | $\pm 4$                                |                      |                          | $\pm 4$                                |                      | mW              |

See Notes on page 2-324

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

| SYMBOL                              | PARAMETER                                                                         | CONDITIONS                            |        | OP-05E     |            |            | OP-05C     |            |            | UNITS            |
|-------------------------------------|-----------------------------------------------------------------------------------|---------------------------------------|--------|------------|------------|------------|------------|------------|------------|------------------|
|                                     |                                                                                   |                                       |        | MIN        | TYP        | MAX        | MIN        | TYP        | MAX        |                  |
| $V_{OS}$                            | Input Offset Voltage                                                              |                                       | ●      |            | 0.25       | 0.6        |            | 0.35       | 1.6        | mV               |
| $\frac{\Delta V_{OS}}{\Delta Temp}$ | Average Input Offset Voltage Drift<br>Without External Trim<br>With External Trim | Null Pot = 20k $\Omega$ (Note 2)      | ●<br>● |            | 0.7<br>0.2 | 2.0<br>0.6 |            | 1.3<br>0.4 | 4.5<br>1.5 | $\mu V/^\circ C$ |
| $I_{OS}$                            | Input Offset Current                                                              |                                       | ●      |            | 1.4        | 5.3        |            | 2.0        | 8.0        | nA               |
| $\frac{\Delta I_{OS}}{\Delta Temp}$ | Average Input Offset Current Drift                                                | (Note 2)                              | ●      |            | 8          | 35         |            | 12         | 50         | pA/°C            |
| $I_B$                               | Input Bias Current                                                                |                                       | ●      |            | $\pm 1.5$  | $\pm 5.5$  |            | $\pm 2.2$  | $\pm 9.0$  | nA               |
| $\frac{\Delta I_B}{\Delta Temp}$    | Average Input Bias Current Drift                                                  | (Note 2)                              | ●      |            | 13         | 35         |            | 18         | 50         | pA/°C            |
|                                     | Input Voltage Range                                                               |                                       | ●      | $\pm 13.0$ | $\pm 13.5$ |            | $\pm 13.0$ | $\pm 13.5$ |            | V                |
| CMRR                                | Common Mode Rejection Ratio                                                       | $V_{CM} = \pm 13V$                    | ●      | 107        | 123        |            | 97         | 120        |            | dB               |
| PSRR                                | Power Supply Rejection Ratio                                                      | $V_S = \pm 3V$ to $\pm 18V$           | ●      | 90         | 103        |            | 86         | 100        |            | dB               |
| $A_{VOL}$                           | Large Signal Voltage Gain                                                         | $R_L \geq 2k\Omega$ , $V_o = \pm 10V$ | ●      | 180        | 450        |            | 100        | 400        |            | V/mV             |
| $V_{OUT}$                           | Output Voltage Swing                                                              | $R_L \geq 2k\Omega$                   | ●      | $\pm 12.0$ | $\pm 12.6$ |            | $\pm 11.0$ | $\pm 12.6$ |            | V                |

The ● denotes the specifications which apply over the full operating temperature range.

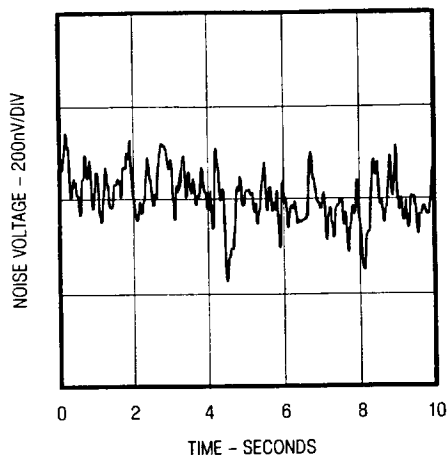
**Note 1:** Long term offset voltage stability is the average value of offset voltage vs. time plotted over extended periods following 30 days of operation. Values for time under 30 days of operation are typically 2.5 $\mu V$  following the first hour of operation.

**Note 2:** This parameter is sample tested.

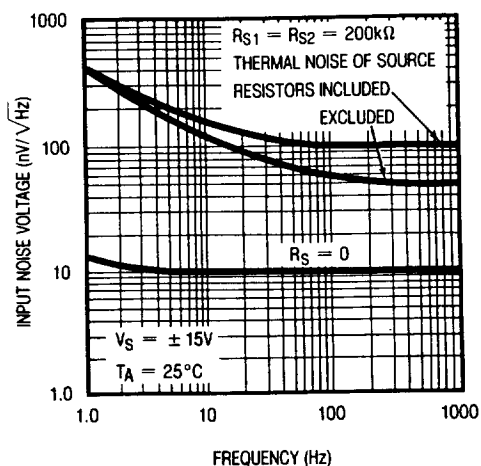
**Note 3:** This parameter is guaranteed by design.

# TYPICAL PERFORMANCE CHARACTERISTICS

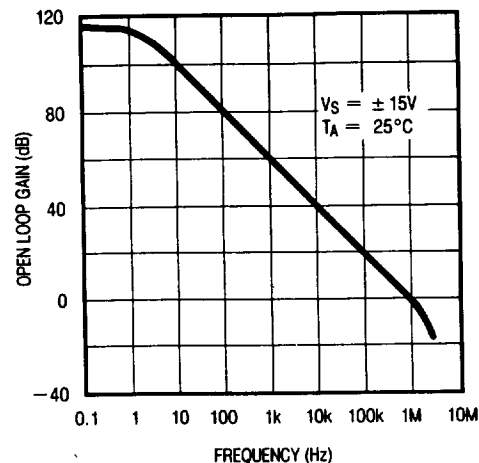
**Low Frequency Noise**  
(Closed Loop Gain = 25,000)



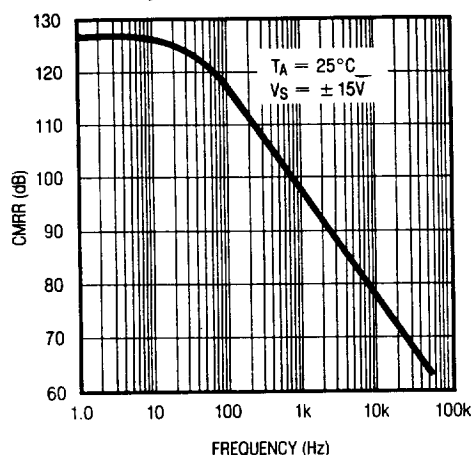
**Total Input Noise Voltage vs Frequency**



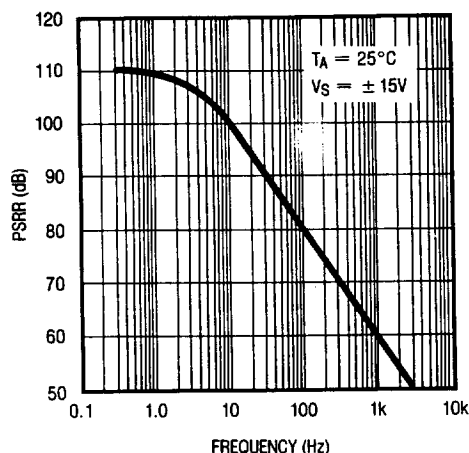
**Open-Loop Frequency Response**



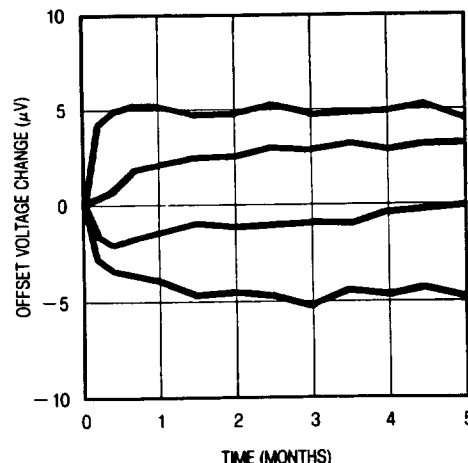
**Common Mode Rejection Ratio vs Frequency**



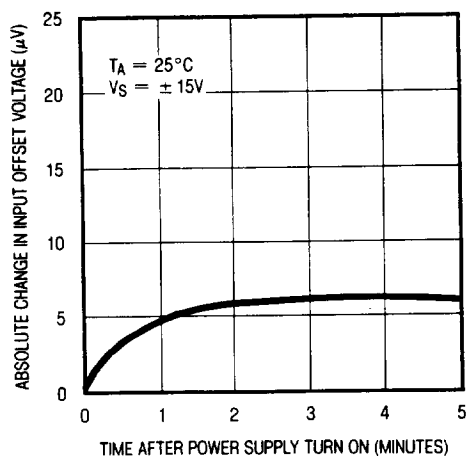
**Power Supply Rejection Ratio vs Frequency**



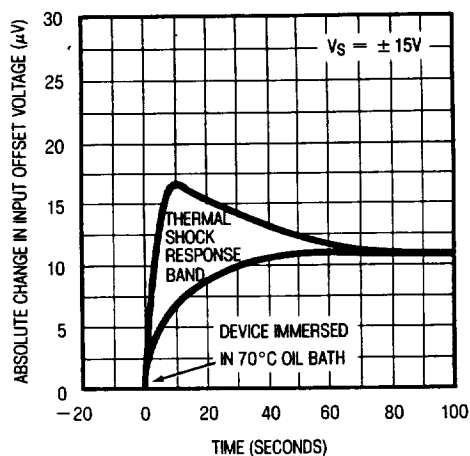
**Long Term Stability of Four Representative Units**



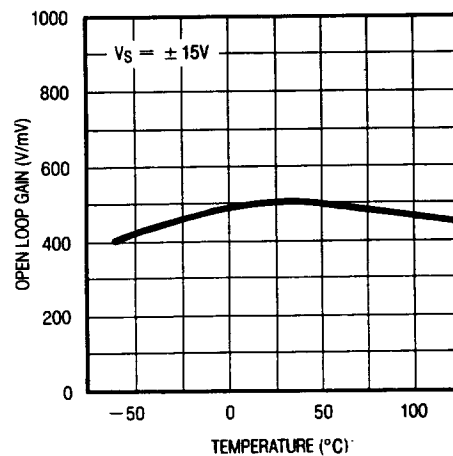
**Warm-Up Drift**



**Offset Voltage Change Due to Thermal Shock**

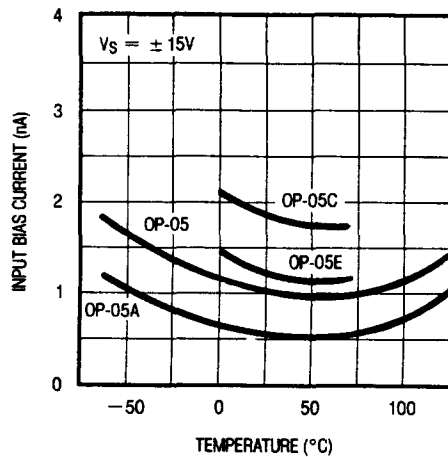


**Open-Loop Gain vs Temperature**

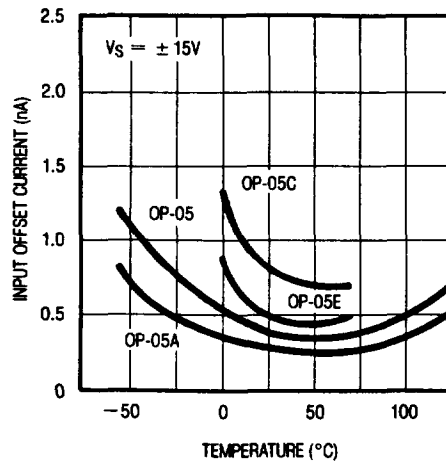


## TYPICAL PERFORMANCE CHARACTERISTICS

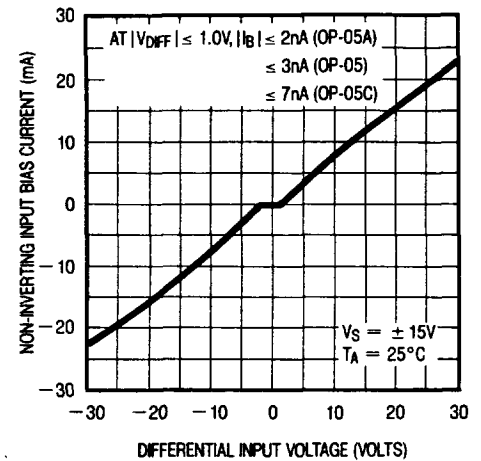
Input Bias Current vs Temperature



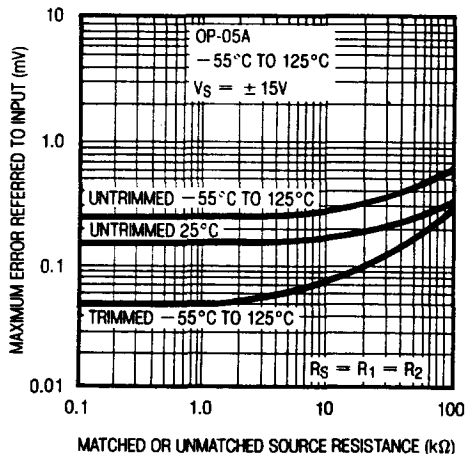
Input Offset Current vs Temperature



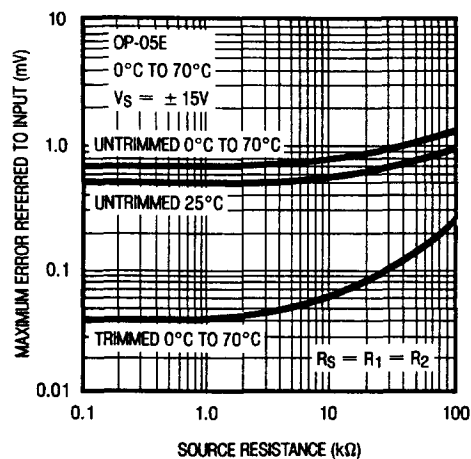
Input Bias Current vs Differential Input Voltage



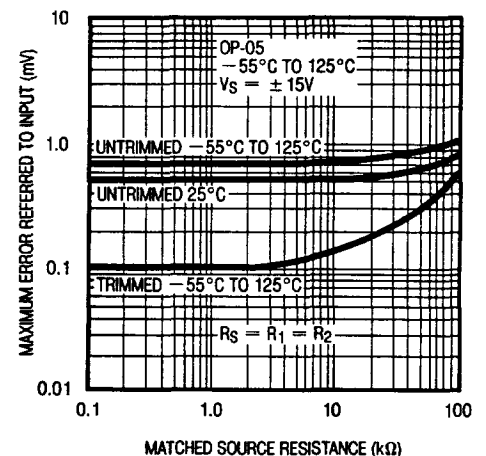
Maximum Error vs Source Resistance



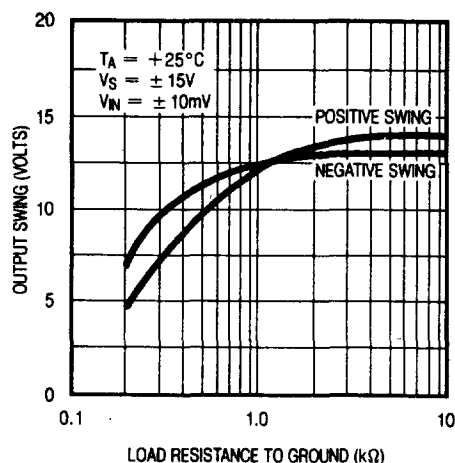
Maximum Error vs Source Resistance



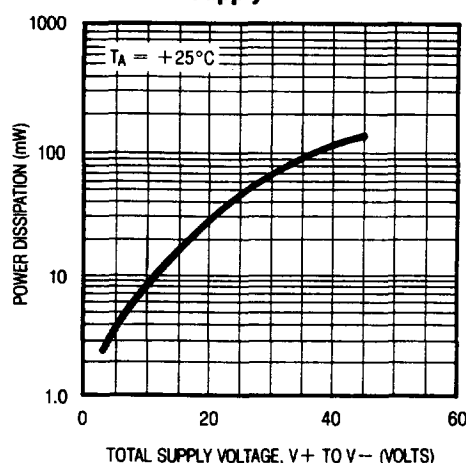
Maximum Error vs Source Resistance



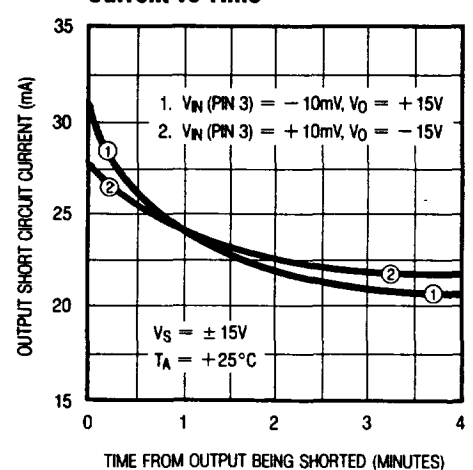
Output Voltage vs Load Resistance



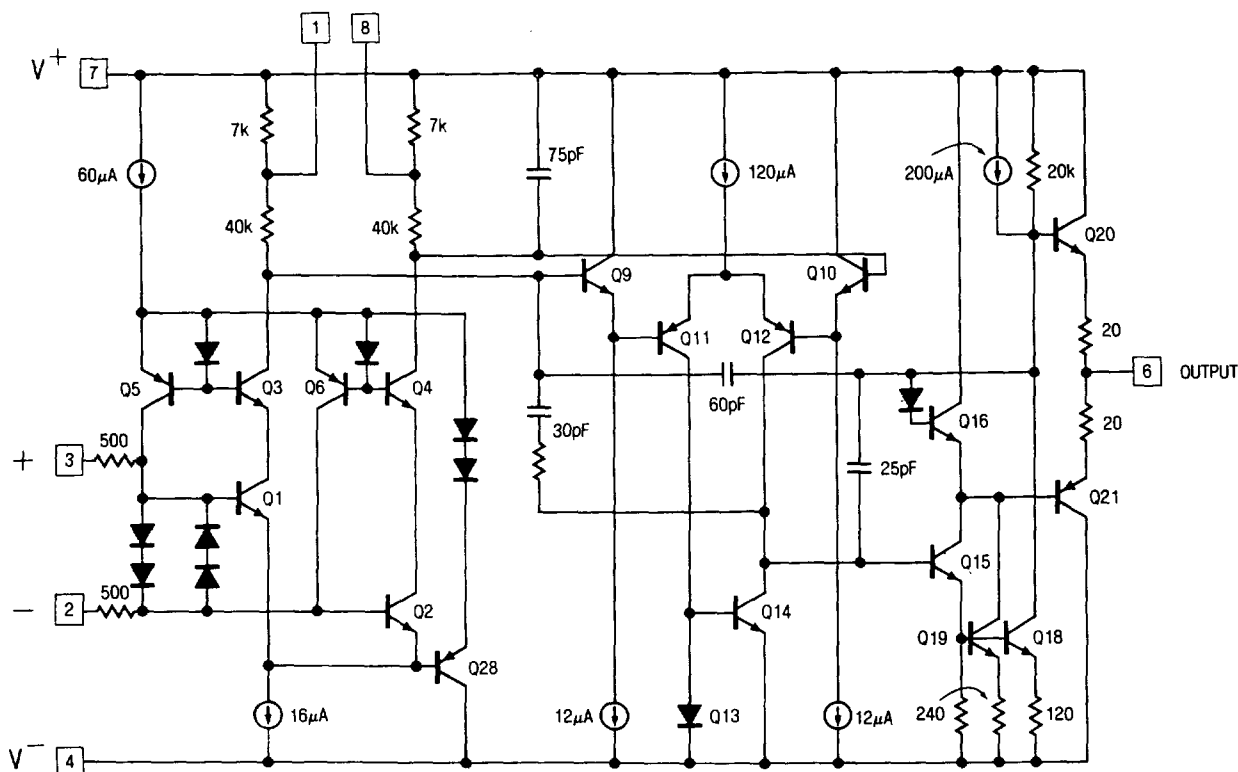
Power Consumption vs Power Supply



Output Short-Circuit Current vs Time



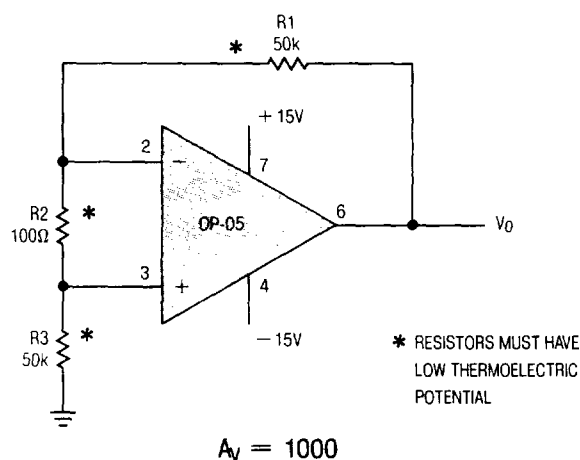
## SCHEMATIC DIAGRAM



2

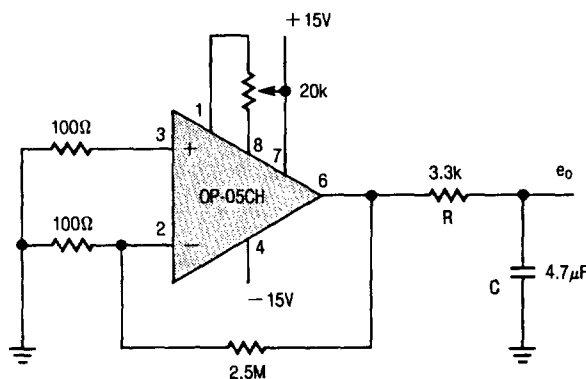
## TEST CIRCUIT DIAGRAMS

Offset Voltage Test Circuit †



$$A_V = 1000$$

Offset Nulling and Low Frequency Noise Test Circuit



NOTES:

- 1) RC APPROXIMATELY 10Hz FILTER
- 2) OBSERVE OUTPUT FOR 10 SECONDS

$$A_V = 25000$$

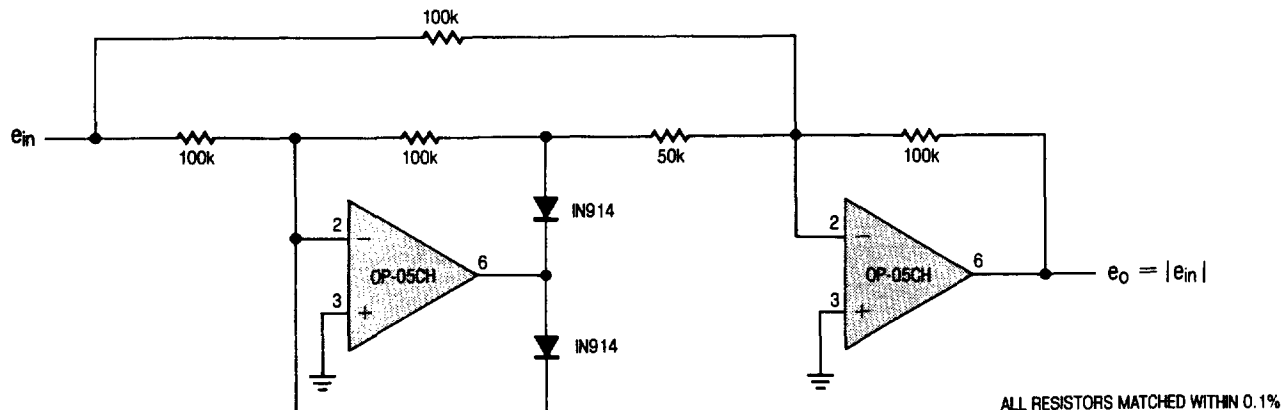
Application Tip

When the OP-05 is used as a replacement in 725, 108/108A, 308/308A applications, removal of external compensation is optional. For conventionally nulled 741 type applications, external trimming should be removed. Care should be taken to avoid thermocouple voltages caused by temperature variations between the input terminals or dissimilar metals.

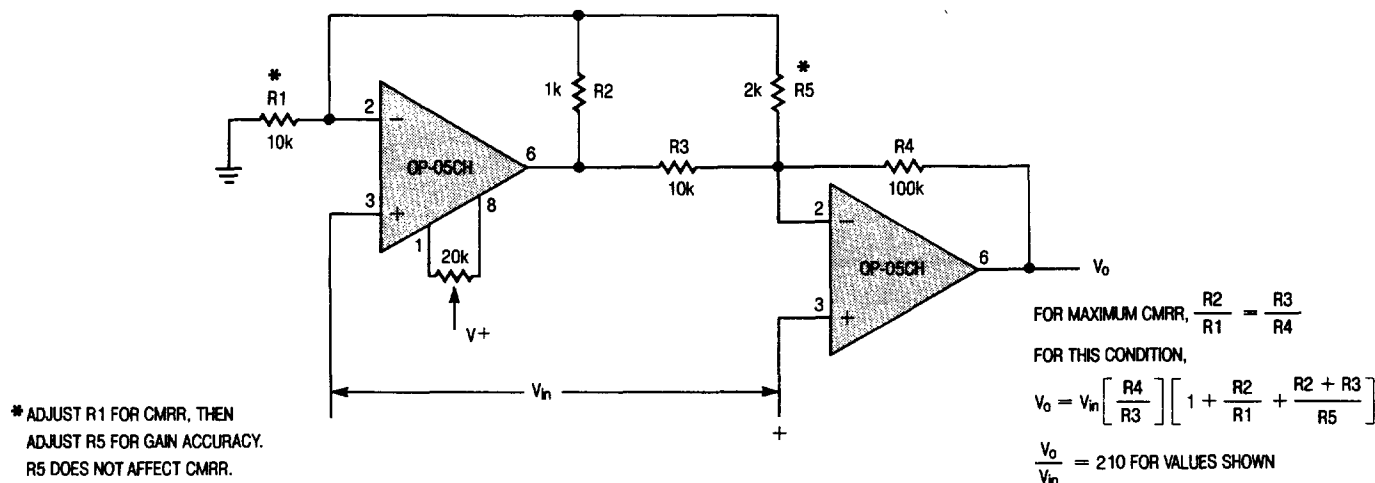
† This circuit is also used as the burn-in configuration with supply voltages changed to  $\pm 20V$ ,  $R1 = R3 = 10k$ ,  $R2 = 200\Omega$ ,  $A_V = 100$ .

# TYPICAL APPLICATIONS

Precision Absolute Value Circuit

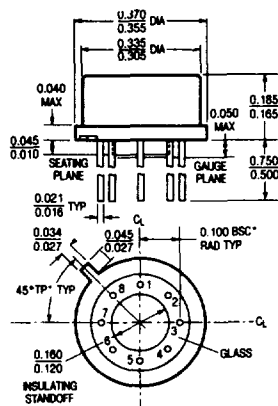


Two Op-Amp Instrumentation Amplifier



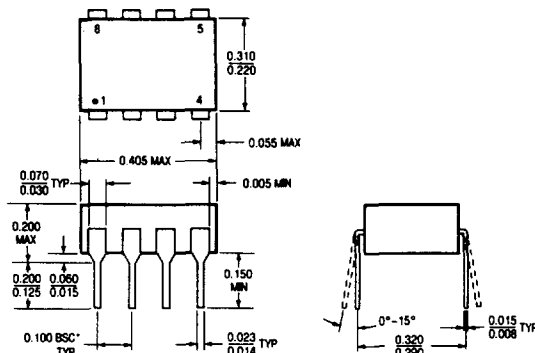
## PACKAGE DESCRIPTION

H Package  
Metal Can



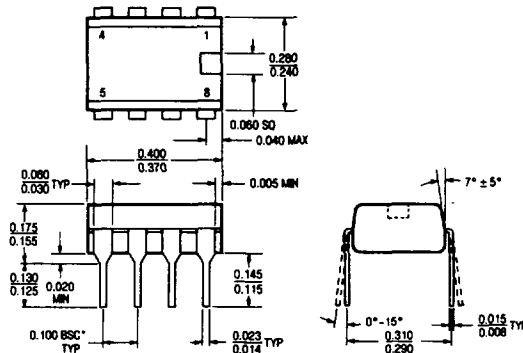
| $T_j$ max | $\theta_{ja}$ | $\theta_{jc}$ |
|-----------|---------------|---------------|
| 150°C     | 150°C/W       | 45°C/W        |

J8 Package  
8 Lead Hermetic Dip



| $T_j$ max | $\theta_{ja}$ |
|-----------|---------------|
| 150°C     | 100°C/W       |

N8 Package  
8 Lead Plastic



| $T_j$ max | $\theta_{ja}$ |
|-----------|---------------|
| 100°C     | 130°C/W       |