

### FEATURES

- Excellent DC Specifications
- Low Noise .....  $0.65 \mu V_{p-p}$  Typ
- Low Drift ( $TCV_{OS}$ ) .....  $8 \mu V/^{\circ}C$  Max
- Silicon-Nitride Passivation
- $125^{\circ}C$  Tested Dice Available
- "Premium" 741 Replacement
- Available in Die Form

### ORDERING INFORMATION <sup>†</sup>

| $T_A = +25^{\circ}C$<br>$V_{OS}$ MAX<br>(mV) | PACKAGE   |                 |                  | OPERATING<br>TEMPERATURE<br>RANGE |
|----------------------------------------------|-----------|-----------------|------------------|-----------------------------------|
|                                              | TO-99     | CERDIP<br>8-PIN | PLASTIC<br>8-PIN |                                   |
| 0.5                                          | OP02AJ*   | OP02AZ*         | —                | MIL                               |
| 2.0                                          | OP02J/883 | OP02Z           | —                | MIL                               |
| 2.0                                          | OP02CJ    | OP02CZ          | OP02CP           | COM                               |
| 5.0                                          | —         | —               | OP02DP           | COM                               |

\* 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.

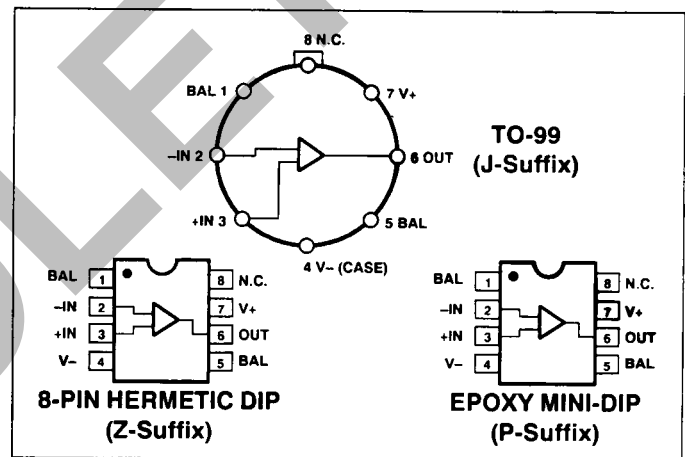
### GENERAL DESCRIPTION

This high-performance general-purpose operational amplifier provides significant improvements over industry-standard and "premium" 741 types while maintaining pin-for-pin

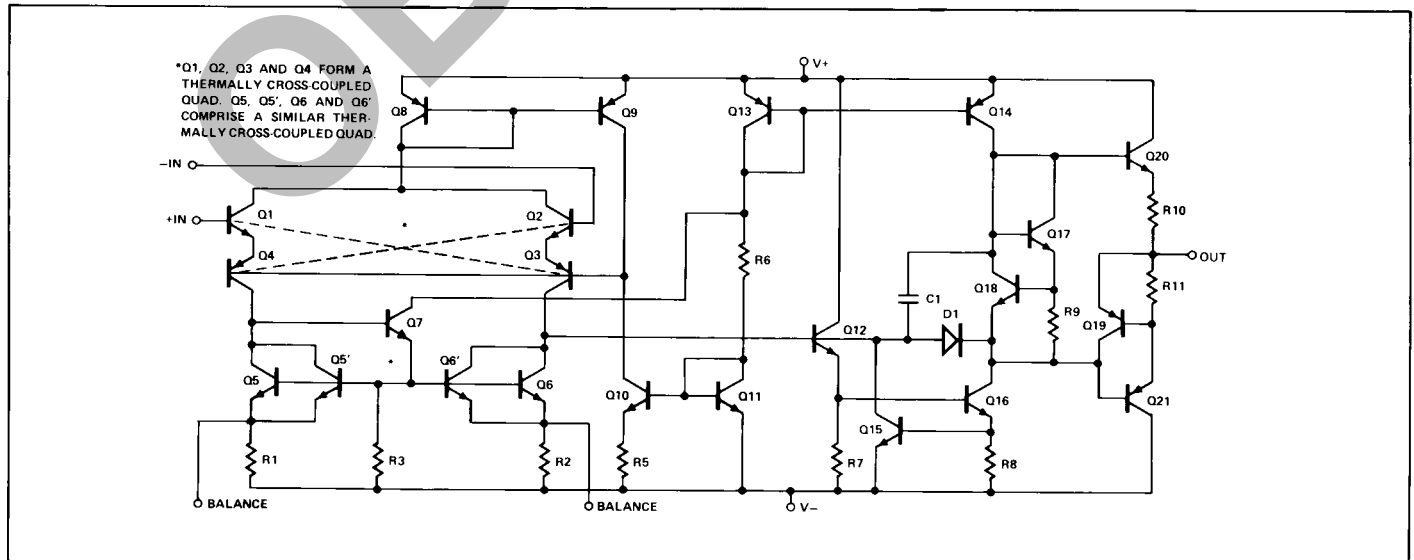
compatibility, ease of application, and low cost. Key specifications, such as  $V_{OS}$ ,  $I_{OS}$ ,  $I_B$ , CMRR, PSRR, and  $A_{VO}$  are guaranteed over the full operating temperature range. Precision Monolithics' exclusive Silicon-Nitride "Triple Passivation" process reduces "popcorn noise." A thermally-symmetrical input-stage design provides low input offset voltage drift and insensitivity to output load conditions.

The OP-02 is a direct replacement for the 741. It is ideal for upgrading existing designs where accuracy improvements are required and for eliminating special low-drift or low-noise selected types.

### PIN CONNECTIONS



### SIMPLIFIED SCHEMATIC



# OP-02

## ABSOLUTE MAXIMUM RATINGS (Note 1)

|                                              |                 |
|----------------------------------------------|-----------------|
| Supply Voltage .....                         | ±22V            |
| Differential Input Voltage .....             | ±30V            |
| Input Voltage .....                          | Supply Voltage  |
| Output Short-Circuit Duration .....          | Indefinite      |
| Operating Temperature Range                  |                 |
| OP-02A, OP-02 .....                          | −55°C to +125°C |
| OP-02C, OP-02D .....                         | 0°C to +70°C    |
| Storage Temperature Range .....              | −65°C to +150°C |
| Lead Temperature (Soldering, 60 sec) .....   | 300°C           |
| Junction Temperature (T <sub>J</sub> ) ..... | −65°C to +150°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  |

### 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 and P-DIP packages.

## ELECTRICAL CHARACTERISTICS at V<sub>S</sub> = ±15V, T<sub>A</sub> = 25°C, unless otherwise noted.

| PARAMETER                          | SYMBOL            | CONDITIONS                                               | OP-02A |      |     | OP-02C |      |     | OP-02D |      |     | UNITS             |
|------------------------------------|-------------------|----------------------------------------------------------|--------|------|-----|--------|------|-----|--------|------|-----|-------------------|
|                                    |                   |                                                          | MIN    | TYP  | MAX | MIN    | TYP  | MAX | MIN    | TYP  | MAX |                   |
| Input Offset Voltage               | V <sub>OS</sub>   | R <sub>S</sub> ≤ 20kΩ                                    | —      | 0.3  | 0.5 | —      | 1    | 2   | —      | 3    | 5   | mV                |
| Input Offset Current               | I <sub>OS</sub>   |                                                          | —      | 0.5  | 2   | —      | 1    | 5   | —      | 5    | 25  | nA                |
| Input Bias Current                 | I <sub>B</sub>    |                                                          | —      | 18   | 30  | —      | 20   | 50  | —      | 30   | 100 | nA                |
| Input Resistance-Differential-Mode | R <sub>IN</sub>   | (Note 2)                                                 | 3.4    | 5.7  | —   | 2.0    | 5.2  | —   | 1      | 3.5  | —   | MΩ                |
| Input Voltage Range                | IVR               |                                                          | ±10    | ±13  | —   | ±10    | ±13  | —   | ±10    | ±13  | —   | V                 |
| Common-Mode Rejection Ratio        | CMRR              | V <sub>CM</sub> = ±10V<br>R <sub>S</sub> ≤ 20kΩ          | 85     | 100  | —   | 80     | 95   | —   | 70     | 85   | —   | dB                |
| Power Supply Rejection Ratio       | PSRR              | V <sub>S</sub> = ±5 to ±20V<br>R <sub>S</sub> ≤ 20kΩ     | —      | 10   | 60  | —      | 30   | 100 | —      | 100  | 150 | μV/V              |
| Output Voltage Swing               | V <sub>O</sub>    | R <sub>L</sub> ≥ 2kΩ                                     | ±12    | ±13  | —   | ±12    | ±13  | —   | ±12    | ±13  | —   | V                 |
| Large-Signal Voltage Gain          | A <sub>VO</sub>   | R <sub>L</sub> ≥ 2kΩ<br>V <sub>O</sub> = ±10V            | 100    | 250  | —   | 50     | 200  | —   | 25     | 150  | —   | V/mV              |
| Power Consumption                  | P <sub>d</sub>    | V <sub>O</sub> = 0V                                      | —      | 40   | 70  | —      | 50   | 90  | —      | 50   | 90  | mW                |
| Input Noise Voltage                | e <sub>np-p</sub> | 0.1Hz to 10Hz                                            | —      | 0.65 | —   | —      | 0.65 | —   | —      | 0.65 | —   | μV <sub>p-p</sub> |
| Input Noise Voltage Density        | e <sub>n</sub>    | f <sub>O</sub> = 10Hz                                    | —      | 25   | —   | —      | 25   | —   | —      | 25   | —   | nV/√Hz            |
|                                    |                   | f <sub>O</sub> = 100Hz                                   | —      | 22   | —   | —      | 22   | —   | —      | 22   | —   |                   |
|                                    |                   | f <sub>O</sub> = 1000Hz                                  | —      | 21   | —   | —      | 21   | —   | —      | 21   | —   |                   |
| Input Noise Current                | i <sub>np-p</sub> | 0.1Hz to 10Hz                                            | —      | 12.8 | —   | —      | 12.8 | —   | —      | 12.8 | —   | pA <sub>p-p</sub> |
| Input Noise Current Density        | i <sub>n</sub>    | f <sub>O</sub> = 10Hz                                    | —      | 1.4  | —   | —      | 1.4  | —   | —      | 1.4  | —   | pA/√Hz            |
|                                    |                   | f <sub>O</sub> = 100Hz                                   | —      | 0.7  | —   | —      | 0.7  | —   | —      | 0.7  | —   |                   |
|                                    |                   | f <sub>O</sub> = 1000Hz                                  | —      | 0.4  | —   | —      | 0.4  | —   | —      | 0.4  | —   |                   |
| Slew Rate                          | SR                | (Note 1)                                                 | 0.25   | 0.5  | —   | 0.25   | 0.5  | —   | 0.25   | 0.5  | —   | V/μs              |
| Large-Signal Bandwidth             |                   | V <sub>O</sub> = 20V <sub>p-p</sub><br>(Notes 1, 4)      | 4      | 8    | —   | 4      | 8    | —   | 4      | 8    | —   | kHz               |
| Closed-Loop Bandwidth              | BW                | A <sub>VCL</sub> = +1<br>(Note 3)                        | 1      | 1.3  | —   | 1      | 1.3  | —   | 1      | 1.3  | —   | MHz               |
| Risetime                           | t <sub>r</sub>    | A <sub>VCL</sub> = +1<br>V <sub>IN</sub> = 50mV (Note 1) | —      | 200  | 350 | —      | 200  | 350 | —      | 200  | 350 | ns                |
| Overshoot                          | OS                | (Note 1)                                                 | —      | 5    | 10  | —      | 5    | 10  | —      | 5    | 10  | %                 |

### NOTES:

1. Sample tested.
2. Guaranteed by input bias current.
3. Guaranteed by maximum risetime.
4. Guaranteed by minimum slew rate.

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

| PARAMETER                                   | SYMBOL     | CONDITIONS                                          | OP-02A   |          |     | OP-02    |          |     | UNITS            |
|---------------------------------------------|------------|-----------------------------------------------------|----------|----------|-----|----------|----------|-----|------------------|
|                                             |            |                                                     | MIN      | TYP      | MAX | MIN      | TYP      | MAX |                  |
| Input Offset Voltage                        | $V_{OS}$   | $R_S \leq 20k\Omega$                                | —        | 0.5      | 1   | —        | 1.4      | 3   | mV               |
| Average Input Offset Voltage Drift (Note 1) | $TCV_{OS}$ | $R_S = 50\Omega$                                    | —        | 2        | 8   | —        | 4        | 10  | $\mu V/^\circ C$ |
| Input Offset Current                        | $I_{OS}$   |                                                     | —        | 1        | 5   | —        | 2        | 10  | nA               |
| Average Input Offset Current Drift (Note 1) | $TCI_{OS}$ |                                                     | —        | 7.5      | 75  | —        | 15       | 150 | $pA/^\circ C$    |
| Input Bias Current                          | $I_B$      |                                                     | —        | 30       | 60  | —        | 40       | 100 | nA               |
| Input Voltage Range                         | IVR        |                                                     | $\pm 10$ | $\pm 13$ | —   | $\pm 10$ | $\pm 13$ | —   | V                |
| Common-Mode Rejection Ratio                 | CMRR       | $V_{CM} = \pm 10V$<br>$R_S \leq 20k\Omega$          | 80       | 95       | —   | 80       | 95       | —   | dB               |
| Power Supply Rejection Ratio                | PSRR       | $V_S = \pm 5V$ to $\pm 20V$<br>$R_S \leq 20k\Omega$ | —        | 10       | 60  | —        | 30       | 100 | $\mu V/V$        |
| Large-Signal Voltage Gain                   | $A_{VO}$   | $R_L \geq 2k\Omega$<br>$V_O = \pm 10V$              | 50       | 100      | —   | 25       | 60       | —   | V/mV             |
| Output Voltage Swing                        | $V_O$      | $R_L \geq 2k\Omega$                                 | $\pm 12$ | $\pm 13$ | —   | $\pm 12$ | $\pm 13$ | —   | V                |

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

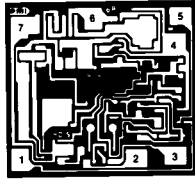
| PARAMETER                                   | SYMBOL     | CONDITIONS                                         | OP-02C   |          |     | OP-02D   |          |     | UNITS            |
|---------------------------------------------|------------|----------------------------------------------------|----------|----------|-----|----------|----------|-----|------------------|
|                                             |            |                                                    | MIN      | TYP      | MAX | MIN      | TYP      | MAX |                  |
| Input Offset Voltage                        | $V_{OS}$   | $R_S \leq 20k\Omega$                               | —        | 1.2      | 3   | —        | 3        | 6   | mV               |
| Average Input Offset Voltage Drift (Note 1) | $TCV_{OS}$ | $R_S = 50\Omega$                                   | —        | 4        | 10  | —        | 8        | 20  | $\mu V/^\circ C$ |
| Input Offset Current                        | $I_{OS}$   |                                                    | —        | 1.4      | 10  | —        | 5        | 50  | nA               |
| Average Input Offset Current Drift (Note 1) | $TCI_{OS}$ |                                                    | —        | 15       | 250 | —        | 70       | 500 | $pA/^\circ C$    |
| Input Bias Current                          | $I_B$      |                                                    | —        | 25       | 100 | —        | 50       | 200 | nA               |
| Input Voltage Range                         | IVR        |                                                    | $\pm 10$ | $\pm 13$ | —   | $\pm 10$ | $\pm 13$ | —   | V                |
| Common-Mode Rejection Ratio                 | CMRR       | $V_{CM} = \pm 10V$<br>$R_S \leq 20k\Omega$         | 80       | 90       | —   | 70       | 85       | —   | dB               |
| Power Supply Rejection Ratio                | PSRR       | $V_S = \pm 5$ to $\pm 20V$<br>$R_S \leq 20k\Omega$ | —        | 30       | 100 | —        | 100      | 150 | $\mu V/V$        |
| Large-Signal Voltage Gain                   | $A_{VO}$   | $R_L \geq 2k\Omega$<br>$V_O = \pm 10V$             | 25       | 60       | —   | 15       | 25       | —   | V/mV             |
| Output Voltage Swing                        | $V_O$      | $R_L \geq 2k\Omega$                                | $\pm 12$ | $\pm 13$ | —   | $\pm 10$ | $\pm 13$ | —   | V                |

**NOTE:**

1. Sample tested.

# OP-02

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



DIE SIZE 0.047 × 0.043 inch, 2021 sq. mils  
(1.19 × 1.09 mm, 1.30 sq. mm)

1. NULL
2. INVERTING INPUT
3. NONINVERTING INPUT
4. V<sub>-</sub>
5. NULL
6. OUTPUT
7. V<sub>+</sub>

**WAFER TEST LIMITS** at V<sub>S</sub> = ±15V, T<sub>A</sub> = 25°C for OP-02N, OP-02G and OP-02GR devices; T<sub>A</sub> = 125°C for OP-02NT and OP-02GT devices, unless otherwise noted.

| PARAMETER                       | SYMBOL          | CONDITIONS                                            | OP-02NT<br>LIMIT | OP-02N<br>LIMIT | OP-02GT<br>LIMIT | OP-02G<br>LIMIT | OP-02GR<br>LIMIT | UNITS    |
|---------------------------------|-----------------|-------------------------------------------------------|------------------|-----------------|------------------|-----------------|------------------|----------|
| Input Offset Voltage            | V <sub>OS</sub> | R <sub>S</sub> ≤ 20kΩ                                 | 1                | 0.5             | 3                | 2               | 5                | mV MAX   |
| Input Offset Current            | I <sub>OS</sub> |                                                       | 5                | 3               | 6                | 5               | 25               | nA MAX   |
| Input Bias Current              | I <sub>B</sub>  |                                                       | 50               | 30              | 60               | 50              | 200              | nA MAX   |
| Input Voltage Range             | IVR             |                                                       | ±13              | ±13             | ±13              | ±13             | ±13              | V MIN    |
| Common-Mode<br>Rejection Ratio  | CMRR            | V <sub>CM</sub> = ±10V<br>R <sub>S</sub> ≤ 20kΩ       | 80               | 85              | 80               | 80              | 70               | dB MIN   |
| Power Supply<br>Rejection Ratio | PSRR            | V <sub>S</sub> = ±5V to ±20V<br>R <sub>S</sub> ≤ 20kΩ | 60               | 60              | 100              | 100             | 150              | μV/V MAX |
| Output Voltage Swing            | V <sub>O</sub>  | R <sub>L</sub> ≥ 2kΩ                                  | ±12              | ±12             | ±12              | ±12             | ±12              | V MIN    |
| Large-Signal<br>Voltage Gain    | A <sub>VO</sub> | R <sub>L</sub> ≥ 2kΩ<br>V <sub>O</sub> = ±10V         | 50               | 100             | 25               | 50              | 25               | V/mV MIN |
| Power Consumption               | P <sub>d</sub>  | V <sub>O</sub> = 0V                                   | —                | 90              | —                | 90              | 90               | mW MAX   |

### NOTE:

For 25°C characteristics of NT and GT devices, see N and G characteristics, respectively.

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.

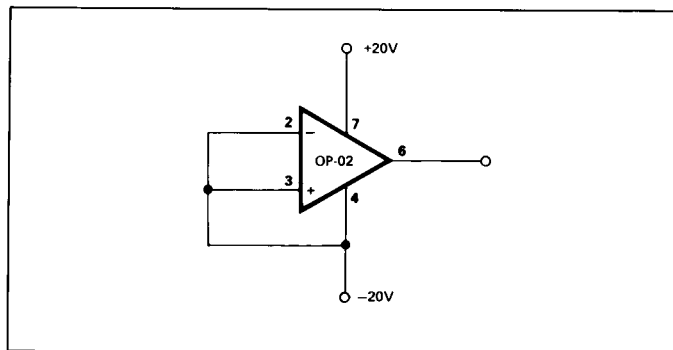
## TYPICAL ELECTRICAL CHARACTERISTICS at V<sub>S</sub> = ±15V, T<sub>A</sub> = 25°C, unless otherwise noted.

| PARAMETER                             | SYMBOL            | CONDITIONS                                                                 | OP-02NT<br>OP-02N<br>TYPICAL | OP-02GT<br>OP-02G<br>TYPICAL | OP-02GR<br>TYPICAL | UNITS             |
|---------------------------------------|-------------------|----------------------------------------------------------------------------|------------------------------|------------------------------|--------------------|-------------------|
| Input Resistance<br>Differential-Mode | R <sub>IN</sub>   |                                                                            | 5.7                          | 5.2                          | 3.5                | MΩ                |
| Input Noise Voltage                   | e <sub>np-p</sub> | 0.1Hz to 10Hz                                                              | 0.65                         | 0.65                         | 0.65               | μV <sub>p-p</sub> |
| Input Noise<br>Voltage Density        | e <sub>n</sub>    | f <sub>O</sub> = 10Hz<br>f <sub>O</sub> = 100Hz<br>f <sub>O</sub> = 1000Hz | 25<br>22<br>21               | 25<br>22<br>21               | 25<br>22<br>21     | nV/√Hz            |
| Input Noise Current                   | I <sub>np-p</sub> | 0.1Hz to 10Hz                                                              | 12.8                         | 12.8                         | 12.8               | pA <sub>p-p</sub> |
| Input Noise<br>Current Density        | i <sub>n</sub>    | f <sub>O</sub> = 10Hz<br>f <sub>O</sub> = 100Hz<br>f <sub>O</sub> = 1000Hz | 1.4<br>0.7<br>0.4            | 1.4<br>0.7<br>0.4            | 1.4<br>0.7<br>0.4  | pA/√Hz            |
| Slew Rate                             | SR                |                                                                            | 0.5                          | 0.5                          | 0.5                | V/μs              |
| Large-Signal<br>Bandwidth             |                   | V <sub>O</sub> = 20V <sub>p-p</sub>                                        | 8                            | 8                            | 8                  | kHz               |
| Closed-Loop<br>Bandwidth              | BW                | A <sub>VCL</sub> = +1                                                      | 1.3                          | 1.3                          | 1.3                | MHz               |
| Risetime                              | t <sub>r</sub>    | A <sub>V</sub> = +1<br>V <sub>IN</sub> = 50mV                              | 200                          | 200                          | 200                | ns                |
| Overshoot                             | OS                |                                                                            | 15                           | 15                           | 15                 | %                 |
| Average Input Offset<br>Voltage Drift | TCV <sub>OS</sub> | R <sub>S</sub> = 500Ω<br>(Note 1)                                          | 2                            | 4                            | 8                  | μV/°C             |
| Average Input Offset<br>Current Drift | TCI <sub>OS</sub> |                                                                            | 7.5                          | 15                           | 30                 | pA/°C             |

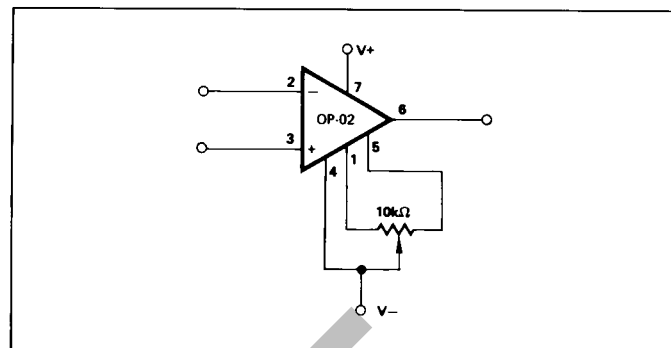
### NOTE:

1. Sample tested.

### BURN-IN CIRCUIT

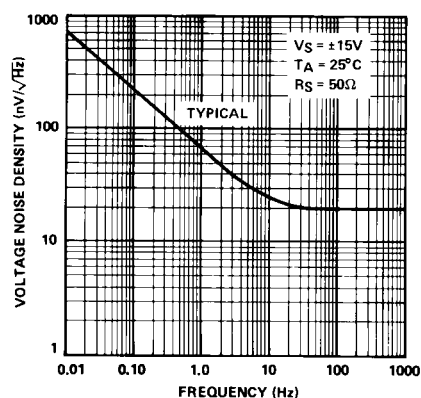


### OFFSET NULLING CIRCUIT

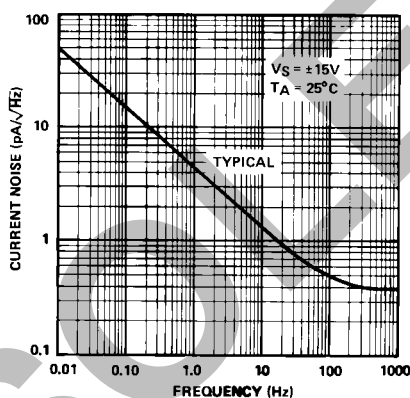


### TYPICAL PERFORMANCE CHARACTERISTICS

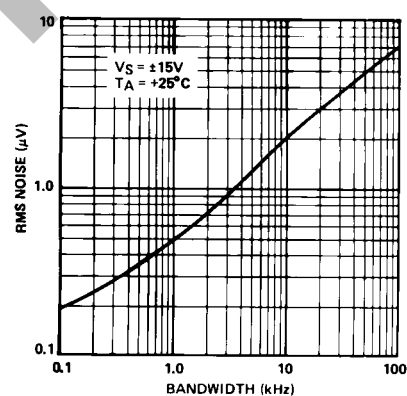
**INPUT SPOT NOISE  
VOLTAGE vs FREQUENCY**



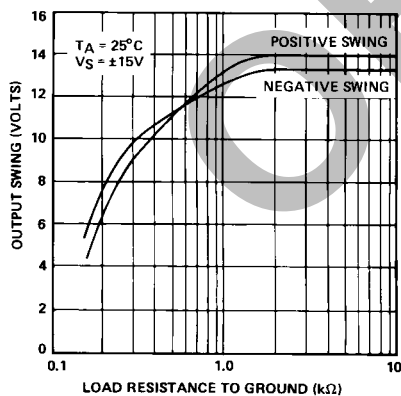
**INPUT SPOT NOISE  
CURRENT vs FREQUENCY**



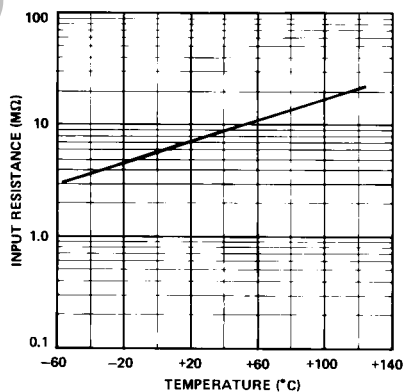
**INPUT WIDEBAND NOISE vs  
BANDWIDTH (0.1Hz TO  
FREQUENCY INDICATED)**



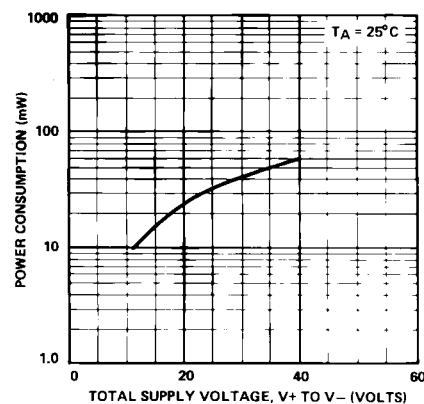
**OUTPUT VOLTAGE vs  
LOAD RESISTANCE**



**DIFFERENTIAL  
INPUT RESISTANCE  
vs TEMPERATURE**



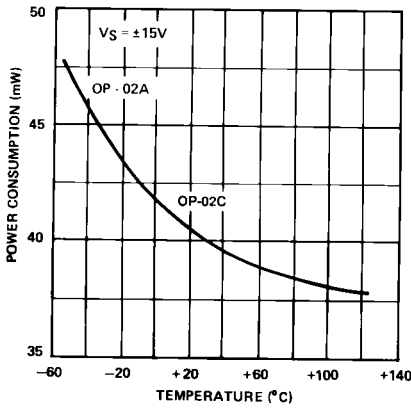
**POWER CONSUMPTION  
vs POWER SUPPLY**



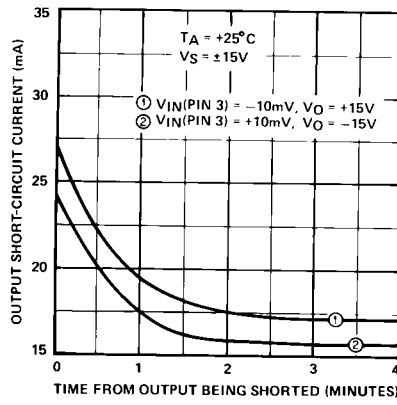
# OP-02

## TYPICAL PERFORMANCE CHARACTERISTICS

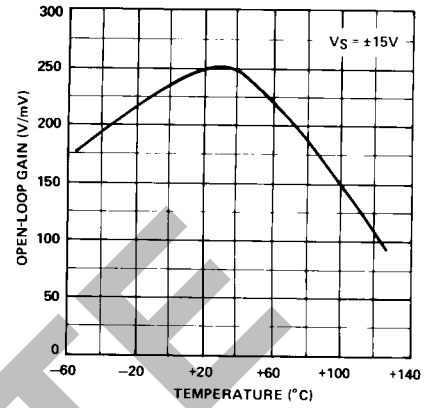
**POWER CONSUMPTION vs TEMPERATURE**



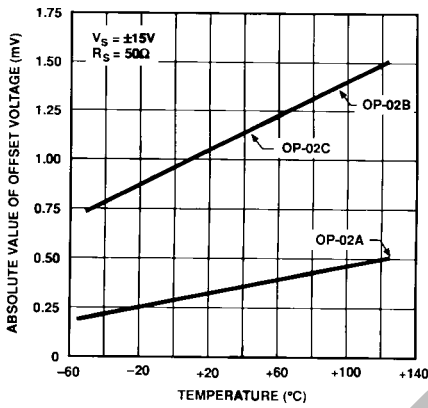
**OUTPUT SHORT-CIRCUIT CURRENT vs TIME**



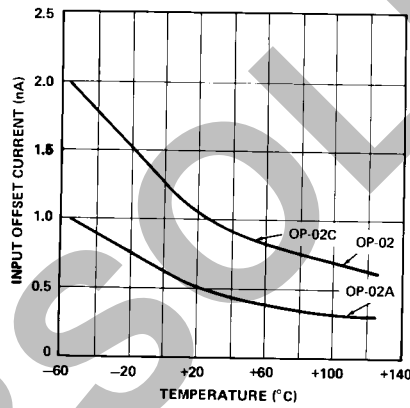
**OPEN-LOOP GAIN vs TEMPERATURE**



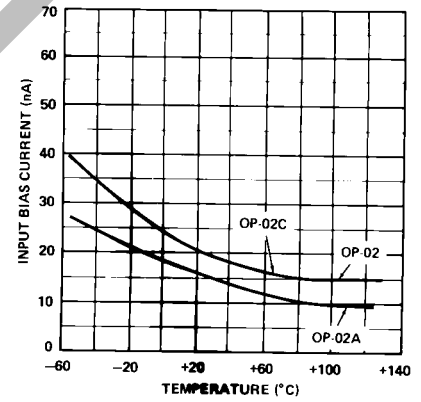
**UNTRIMMED OFFSET VOLTAGE vs TEMPERATURE**



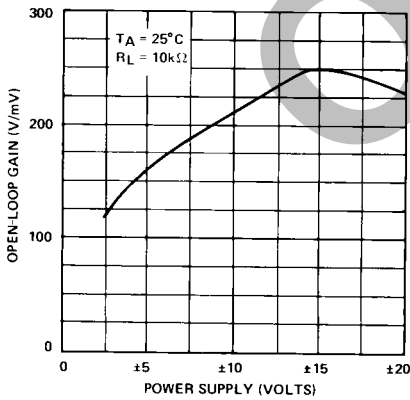
**INPUT OFFSET CURRENT vs TEMPERATURE**



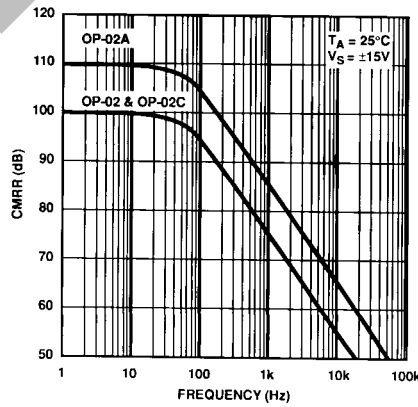
**INPUT BIAS CURRENT vs TEMPERATURE**



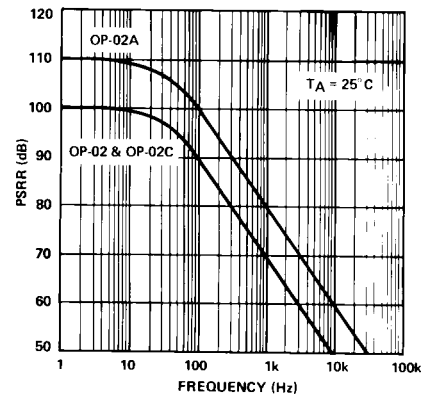
**OPEN-LOOP GAIN vs POWER SUPPLY VOLTAGE**



**CMRR vs FREQUENCY**

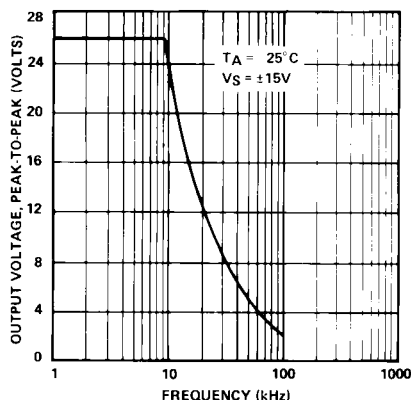


**PSRR vs FREQUENCY**

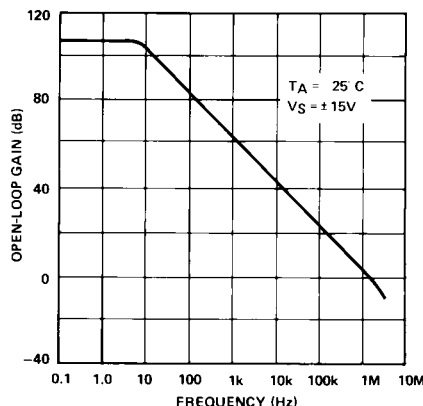


## TYPICAL PERFORMANCE CHARACTERISTICS

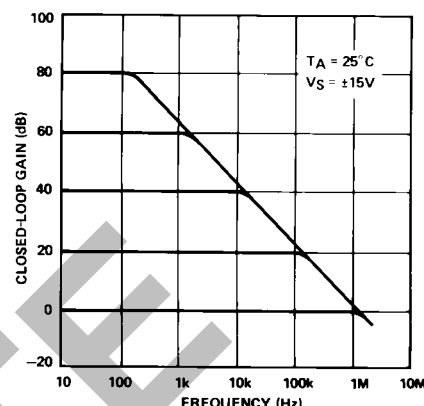
**MAXIMUM UNDISTORTED  
OUTPUT vs FREQUENCY**



**OPEN-LOOP  
FREQUENCY RESPONSE**

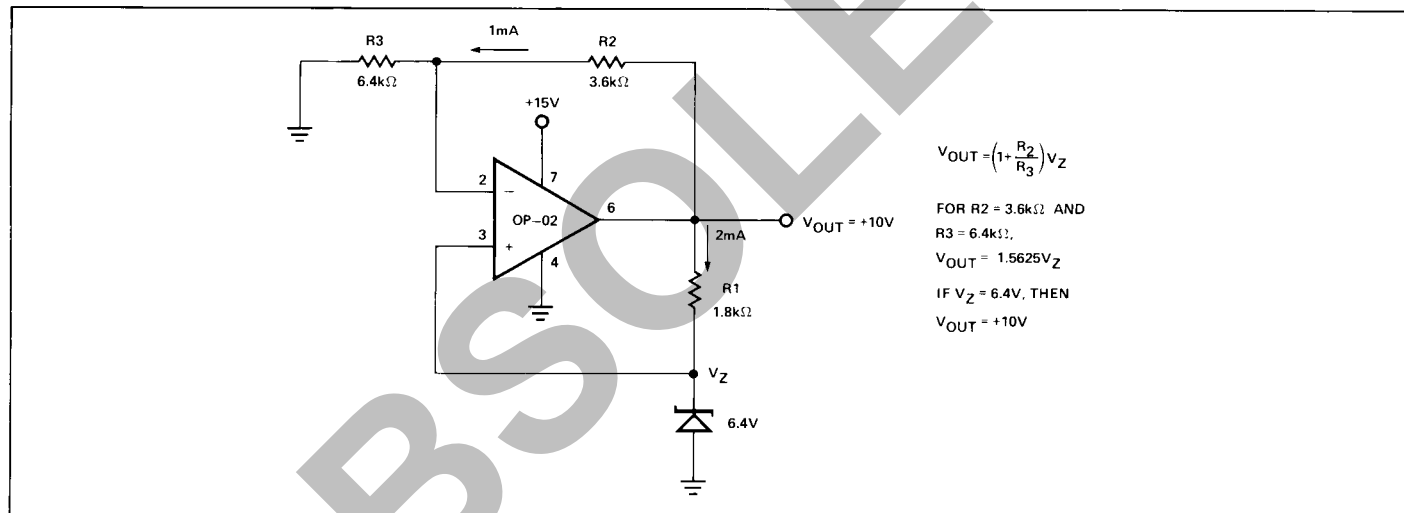


**CLOSED-LOOP RESPONSE  
FOR VARIOUS GAIN  
CONFIGURATIONS**

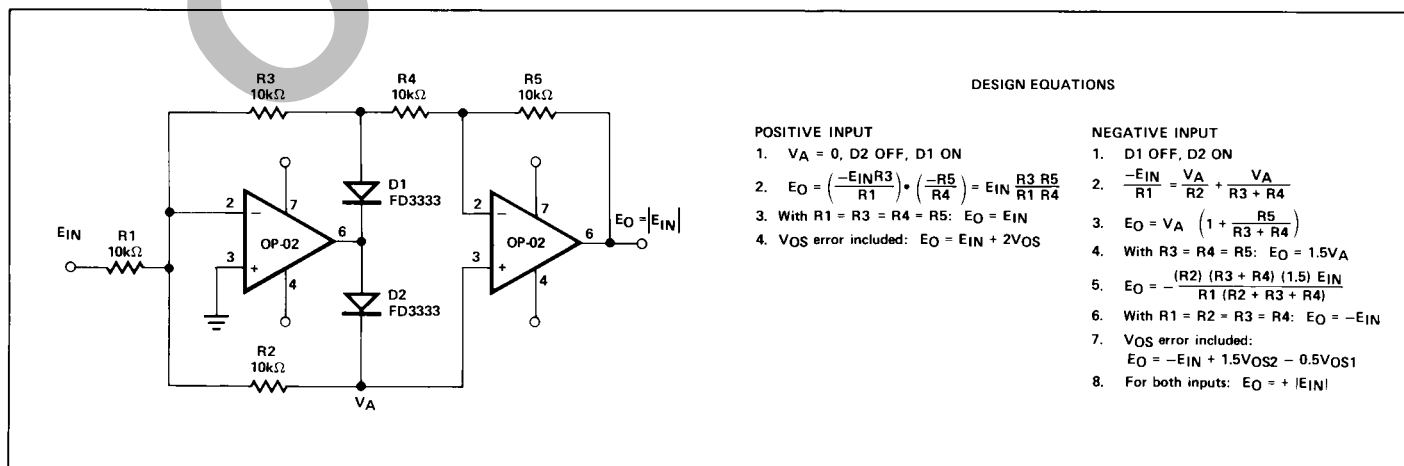


## TYPICAL APPLICATIONS

### HIGH-STABILITY VOLTAGE REFERENCE



### ABSOLUTE VALUE CIRCUIT



OP-02

TYPICAL APPLICATIONS

DAC-08 OUTPUT AMPLIFIER

