



Quad Low-Offset, Low-Power Operational Amplifier

OP400

FEATURES

Low Input Offset Voltage 150 μV Max
Low Offset Voltage Drift, Over -55°C to $+125^{\circ}\text{C}$
1.2 $\mu\text{V}/^{\circ}\text{C}$ Max
Low Supply Current (Per Amplifier) 725 μA Max
High Open-Loop Gain 5000 V/mV Min
Input Bias Current 3 nA Max
Low Noise Voltage Density 11 $\text{nV}/\sqrt{\text{Hz}}$ at 1 kHz
Stable With Large Capacitive Loads 10 nF Typ
Pin Compatible to LM148, HA4741, RM4156, and LT1014
with Improved Performance
Available in Die Form

GENERAL DESCRIPTION

The OP400 is the first monolithic quad operational amplifier that features OP77 type performance. Precision performance no longer has to be sacrificed to obtain the space and cost savings offered by quad amplifiers.

The OP400 features an extremely low input offset voltage of less than 150 μV with a drift of under 1.2 $\mu\text{V}/^{\circ}\text{C}$, guaranteed over the full military temperature range. Open-loop gain of the OP400 is over 5,000,000 into a 10 k Ω load, input bias current is under 3 nA, CMR is above 120 dB, and PSRR is below 1.8 $\mu\text{V}/\text{V}$. On-chip zener-zap trimming is used to achieve the low input offset voltage of the OP400 and eliminates the need for offset nulling. The OP400 conforms to the industry-standard quad pinout which does not have null terminals.

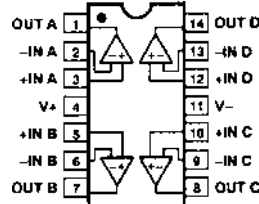
PIN CONNECTIONS

14-PIN HERMETIC DIP

(Y-Suffix)

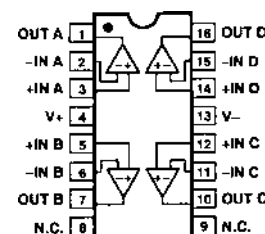
14-PIN PLASTIC DIP

(P-Suffix)



16-PIN SOL

(S-Suffix)



The OP400 features low power consumption, drawing less than 725 μA per amplifier. The total current drawn by this quad amplifier is less than that of a single OP07, yet the OP400 offers significant improvements over this industry standard op amp. Voltage noise density of the OP400 is a low 11 $\text{nV}/\sqrt{\text{Hz}}$ at 10 Hz, which is half that of most competitive devices.

The OP400 is pin-compatible with the LM148, HA4741, RM4156, and LT1014 operational amplifiers and can be used to upgrade systems using these devices. The OP400 is an ideal choice for applications requiring multiple precision operational amplifiers and where low power consumption is critical.

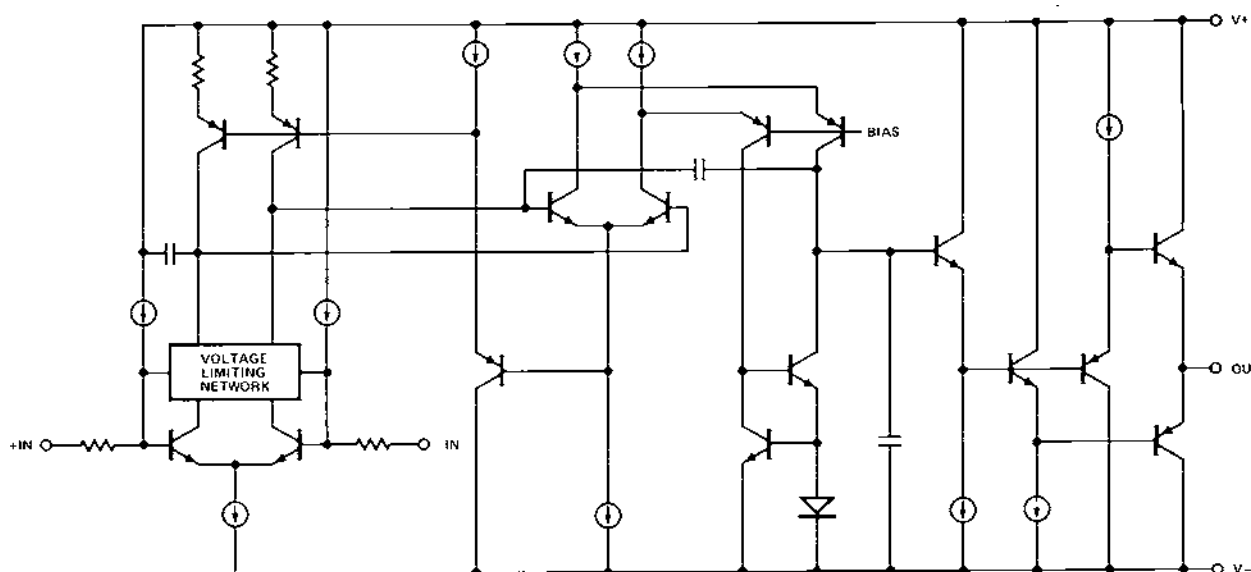


Figure 1. Simplified Schematic (One of Four Amplifiers is Shown)

REV. A

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OP400—SPECIFICATIONS

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

| Parameter | Symbol | Conditions | OP400A/E | | | OP400F | | | OP400G/H | | | Unit |
|--|--------------------|--|----------------------|--------------------------|-----|----------------------|--------------------------|-----|----------------------|--------------------------|-----|------------------------------|
| | | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | V_{OS} | | 40 | 150 | | 60 | 230 | | 80 | 300 | | μV |
| Long-Term Input Voltage Stability | | | 0.1 | | | 0.1 | | | 0.1 | | | $\mu\text{V}/\text{mo}$ |
| Input Offset Current | I_{OS} | $V_{CM} = 0\text{ V}$ | 0.1 | 1.0 | | 0.1 | 2.0 | | 0.1 | 3.5 | | nA |
| Input Bias Current | I_B | $V_{CM} = 0\text{ V}$ | 0.75 | 3.0 | | 0.75 | 6.0 | | 0.75 | 7.0 | | nA |
| Input Noise Voltage | $e_{n\text{ p-p}}$ | 0.1 Hz to 10 Hz | 0.5 | | | 0.5 | | | 0.5 | | | $\mu\text{V p-p}$ |
| Input Noise Voltage Density ¹ | e_n | $f_O = 10\text{ Hz}^1$ $f_O = 1000\text{ Hz}^1$ | 22 11 | 36 18 | | 22 11 | 36 18 | | 22 11 | | | $\text{nV}/\sqrt{\text{Hz}}$ |
| Input Noise Current | $i_{n\text{ p-p}}$ | 0.1 Hz to 10 Hz | 15 | | | 15 | | | 15 | | | pA p-p |
| Input Noise Current Density | i_n | $f_O = 10\text{ Hz}$ | 0.6 | | | 0.6 | | | 0.6 | | | $\text{pA}/\sqrt{\text{Hz}}$ |
| Input Resistance Differential Mode | R_{IN} | | 10 | | | 10 | | | 10 | | | $\text{M}\Omega$ |
| Input Resistance Common Mode | R_{INCM} | | 200 | | | 200 | | | 200 | | | $\text{G}\Omega$ |
| Large Signal Voltage Gain | A_{VO} | $V_O = \pm 10\text{ V}$ $R_L = 10\text{ k}\Omega$ $R_L = 2\text{ k}\Omega$ | 5000 2000 | 12000 3500 | | 3000 1500 | 7000 3000 | | 3000 1500 | 7000 3000 | | V/mV |
| Input Voltage Range ³ | IVR | | ± 12 | ± 13 | | ± 12 | ± 13 | | ± 12 | ± 13 | | V |
| Common Mode Rejection | CMR | $V_{CM} = 12\text{ V}$ | 120 | 140 | | 115 | 140 | | 110 | 135 | | dB |
| Power Supply Rejection Ratio | PSRR | $V_S = 3\text{ V}$ to 18 V | 0.1 | 1.8 | | 0.1 | 3.2 | | 0.2 | 5.6 | | $\mu\text{V}/\text{V}$ |
| Output Voltage Swing | V_O | $R_L = 10\text{ k}\Omega$ $R_L = 2\text{ k}\Omega$ | ± 12 ± 11 | ± 12.6 ± 12.2 | | ± 12 ± 11 | ± 12.6 ± 12.2 | | ± 12 ± 11 | ± 12.6 ± 12.2 | | V |
| Supply Current Per Amplifier | I_{SY} | No Load | 600 | 725 | | 600 | 725 | | 600 | 725 | | μA |
| Slew Rate | SR | | 0.1 | 0.15 | | 0.1 | 0.15 | | 0.1 | 0.15 | | $\text{V}/\mu\text{s}$ |
| Gain Bandwidth Product | GBWP | $A_V = 1$ | 500 | | | 500 | | | 500 | | | kHz |
| Channel Separation | CS | $V_O = 20\text{ V p-p}$ $f_O = 10\text{ Hz}^2$ | 123 | 135 | | 123 | 135 | | 123 | 135 | | dB |
| Input Capacitance | C_{IN} | | 3.2 | | | 3.2 | | | 3.2 | | | pF |
| Capacitive Load Stability | | $A_V = 1$ No Oscillations | 10 | | | 10 | | | 10 | | | nF |

NOTES

¹Sample tested

²Guaranteed but not 100% tested.

³Guaranteed by CMR test

SPECIFICATIONS (continued)

ELECTRICAL CHARACTERISTICS (@ $V_S = 15\text{ V}$, $-55^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$ for OP400A, unless otherwise noted.)

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|------------------------------------|-------------------|---|----------------------|------------------------|-----|------------------------------|
| Input Offset Voltage | V_{OS} | | | 70 | 270 | μV |
| Average Input Offset Voltage Drift | TCV_{OS} | | | 0.3 | 12 | $\mu\text{V}/^\circ\text{C}$ |
| Input Offset Current | I_{OS} | $V_{CM} = 0\text{ V}$ | | 01 | 2.5 | nA |
| Input Bias Current | I_B | $V_{CM} = 0\text{ V}$ | | 1.3 | 5.0 | nA |
| Large Signal Voltage Gain | A_{VO} | $V_O = \pm 10\text{ V}$ $R_L = 10\text{ k}\Omega$ $R_L = 2\text{ k}\Omega$ | 3000 1000 | 9000 2300 | | V/mV |
| Input Voltage Range* | IVR | | ± 12 | ± 12.5 | | V |
| Common Mode Rejection | CMR | $V_{CM} = \pm 12\text{ V}$ | 115 | 130 | | dB |
| Power Supply Rejection Ratio | PSRR | $V_O = 3\text{ V}$ to 18 V | | 0.2 | 3.2 | $\mu\text{V}/\text{V}$ |
| Output Voltage Swing | V_O | $R_L = 10\text{ k}\Omega$ $R_L = 2\text{ k}\Omega$ | ± 12 ± 11 | ± 12.4 ± 12 | | V |
| Supply Current Per Amplifier | I_{SY} | No Load | | 600 | 775 | μA |
| Capacitive Load Stability | | $A_V = 1$ No Oscillations | | 8 | | nF |

NOTE

*Guaranteed by CMR test

ELECTRICAL CHARACTERISTICS (@ $V_S = \pm 15\text{ V}$, $-25^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$ for OP400E/F, $0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$ for OP400G, $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$ for OP400H, unless otherwise noted.)

| Parameter | Symbol | Conditions | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | Unit |
|------------------------------------|-------------------|--|----------------------|------------------------|-----|----------------------|------------------------|-----|----------------------|--------------------------|--------------|------------------------------|
| Input Offset Voltage | V_{OS} | | 60 | | 220 | 80 | | 350 | 110 | | 400 | μV |
| Average Input Offset Voltage Drift | TCV_{OS} | | 0.3 | | 1.2 | 0.3 | | 2.0 | 0.6 | | 2.5 | $\mu\text{V}/^\circ\text{C}$ |
| Input Offset Current | I_{OS} | $V_{CM} = 0\text{ V}$ E, F, G Grades H Grade | 0.1 | | 2.5 | 0.1 | | 3.5 | 0.2 0.2 | | 6.0 12.0 | nA |
| Input Bias Current | I_B | $V_{CM} = 0\text{ V}$ E, F, G Grades H Grade | 0.1 | | 2.5 | 0.1 | | 3.5 | 1.0 1.0 | | 12.0 20.0 | nA |
| Large-Signal Voltage Gain | A_{VO} | $V_{CM} = 0\text{ V}$ $R_L = 10\text{ k}\Omega$ $R_L = 2\text{ k}\Omega$ | 3000 1500 | 10000 2700 | | 2000 1000 | 5000 2000 | | 2000 1000 | 5000 2000 | | V/mv |
| Input Voltage Range | IVR | * | ± 12 | ± 12.5 | | ± 12 | ± 12.5 | | ± 12 | ± 12.5 | | V |
| Common-Mode Rejection | CMR | $V_{CM} = \pm 12\text{ V}$ | 115 | 135 | | 110 | 135 | | 105 | 130 | | dB |
| Power Supply Rejection Ratio | PSRR | $V_S = \pm 3\text{ V}$ to $\pm 18\text{ V}$ | 0.15 | 3.2 | | 0.15 | 5.6 | | 0.3 | 10.0 | | $\mu\text{V}/\text{V}$ |
| Output Voltage Swing | V_O | $R_L = 10\text{ k}\Omega$ $R_L = 2\text{ k}\Omega$ | ± 12 ± 11 | ± 12.4 ± 12 | | ± 12 ± 11 | ± 12.4 ± 12 | | ± 12 ± 11 | ± 12.6 ± 12.2 | | V |
| Supply Current Per Amplifier | I_{SY} | No Load | 600 | | 775 | 600 | | 775 | 600 | | 775 | μA |
| Capacitive Load Stability | | No Oscillations | 10 | | | 10 | | | 10 | | | nF |

NOTE

*Guaranteed by CMR test.

OP400

ORDERING INFORMATION

| $T_A = 25^\circ\text{C}$ $V_{OS} \text{ Max}$ (mV) | Package | | Operating Temperature Range |
|--|-------------------|---------|-----------------------------------|
| | CerDIP 14-Lead | Plastic | |
| 150 | OP400AY | | MIL |
| 150 | OP400EY | | IND |
| 230 | OP400FY | | IND |
| 300 | | OP400GP | COM |
| 300 | | OP400GS | COM |
| 300 | | OP400HP | XIND |
| 300 | | OP400HS | XIND |

NOTES

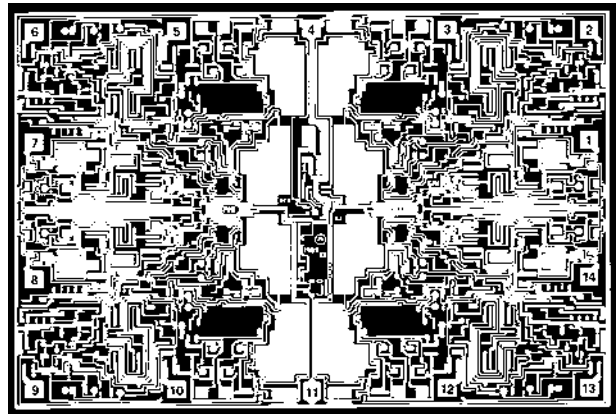
¹For devices processed in total compliance to MIL-STD-883, add/883 after part number. Consult factory for 883 data sheet.

²Burn-in is available on commercial and industrial temperature range parts in CerDIP, plastic DIP, and TO-can packages.

For Military processed devices, please refer to the standard microcircuit drawing (SMD) available at www.dscc.dla.mil/programs/milspec/default.asp

| SMD Part Number | ADI Equivalent |
|-----------------|----------------|
| 5962-8777101M3A | OP400ATCMDA |
| 5962-8777101MCA | OP400AYMDA |

DICE CHARACTERISTICS



DIE SIZE 0.181 × 0.123 inch, 22,263 sq. mils
(4.60 × 3.12 mm, 14.35 sq. mm)

- | | |
|----------|-----------|
| 1. OUT A | 8. OUT C |
| 2. -IN A | 9. -IN C |
| 3. +IN A | 10. +IN C |
| 4. V+ | 11. V- |
| 5. +IN B | 12. +IN D |
| 6. -IN B | 13. -IN D |
| 7. OUT B | 14. OUT D |

WAFER TEST LIMITS (@ $V_S = \pm 15 \text{ V}$, $T_A = 25^\circ\text{C}$, unless otherwise noted.)

| Parameter | Symbol | Conditions | OP400GBC Limit | Unit |
|------------------------------|----------|---|-------------------|---------------------|
| Input Offset Voltage | V_{OS} | | 230 | μA Max |
| Input Offset Current | V_{OS} | $V_{CM} = 0 \text{ V}$ | 2 | nA Max |
| Input Bias Current | I_B | $V_{CM} = 0 \text{ V}$ | 6 | nA Max |
| Large Signal Voltage Gain | A_{VO} | $V_O = \pm 10 \text{ V}$ $R_L = 10 \text{ k}\Omega$ Rig 2 k Ω | 3000 1500 | V/mV Min |
| Input Voltage Range* | IVR | * | ± 12 | V Min |
| Common Mode Rejection | CMR | $V_{CM} = \pm 12 \text{ V}$ | 115 | dB Min |
| Power Supply Rejection Ratio | PSRR | $V_S = \pm 3 \text{ V}$ to $\pm 18 \text{ V}$ | 3.2 | $\mu\text{V/V}$ Max |
| Output Voltage Swing | V_O | $R_L = 10 \text{ k}\Omega$ $R_L = 2 \text{ k}\Omega$ | ± 12 | V Min |
| Supply Current Per Amplifier | I_{SY} | No Load | 725 | μA Max |

NOTE

*Guaranteed by CMR test.

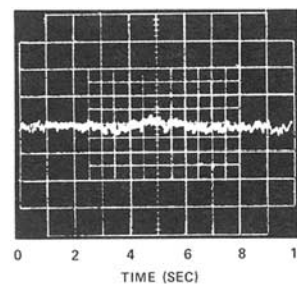
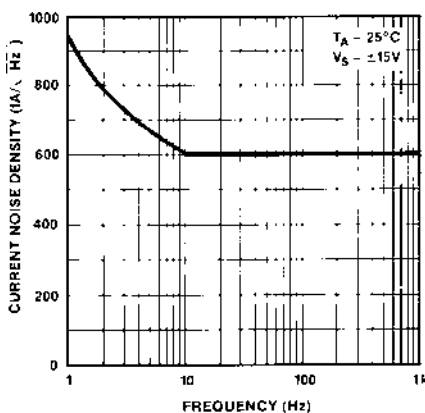
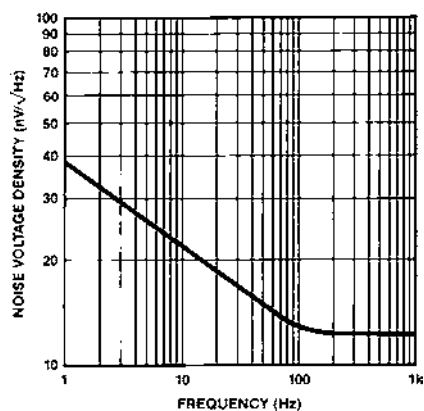
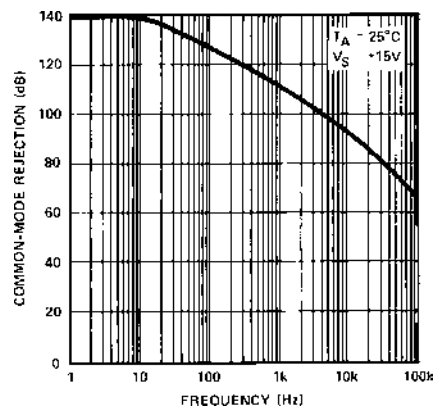
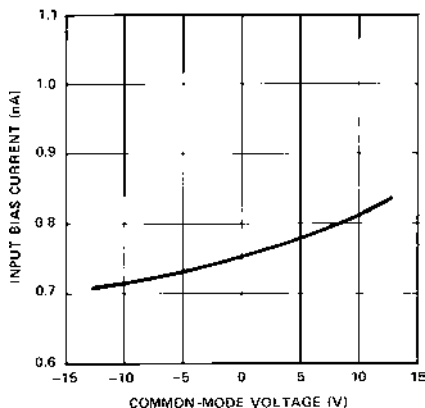
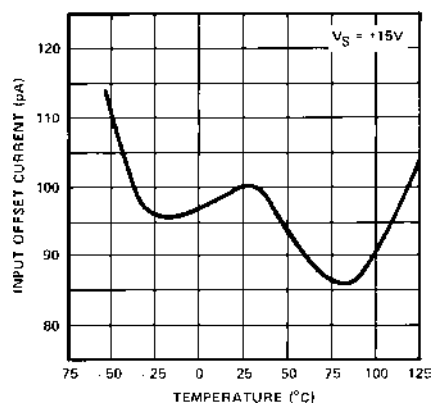
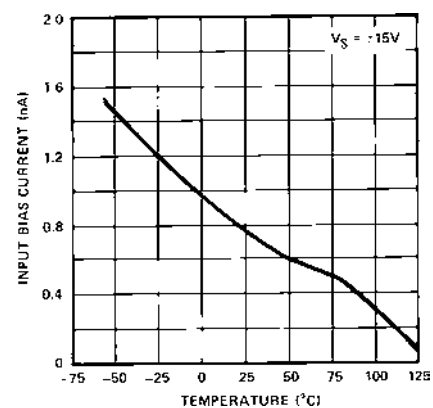
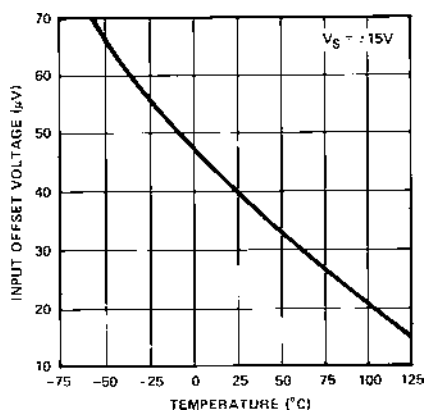
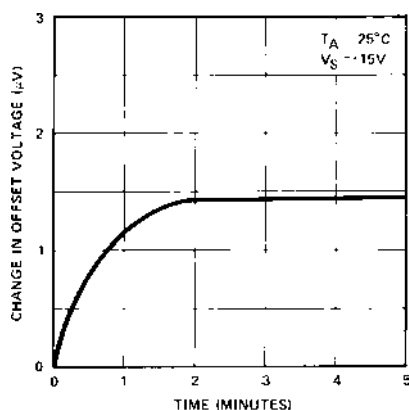
Electrical tests are performed at wafer probe to the limits shown. Due to variations in assembly methods and normal yield loss, yield after packaging is not guaranteed for standard product dice. Consult factory to negotiate specifications based on dice lot qualification through sample lot assembly and testing.

CAUTION

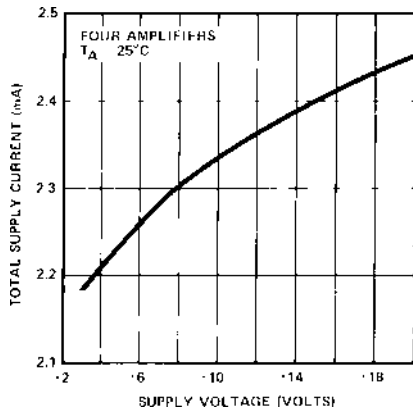
ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the OP400 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high-energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.



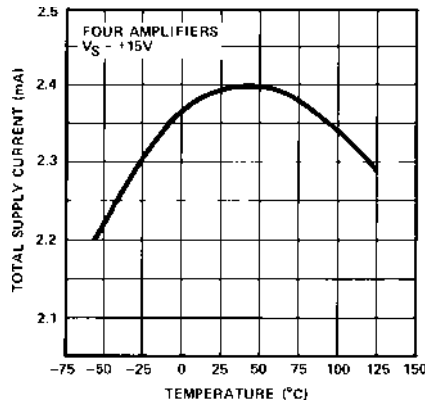
Typical Performance Characteristics—OP400



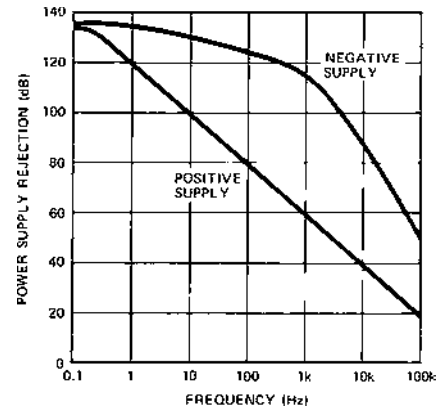
OP400



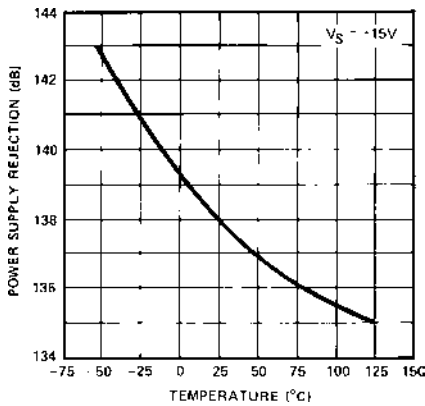
TPC 10. Total Supply Current vs. Supply Voltage



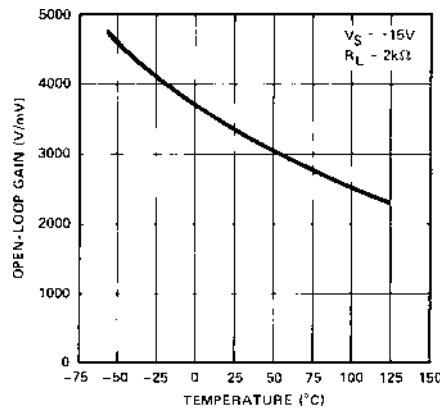
TPC 11. Total Supply Current vs. Temperature



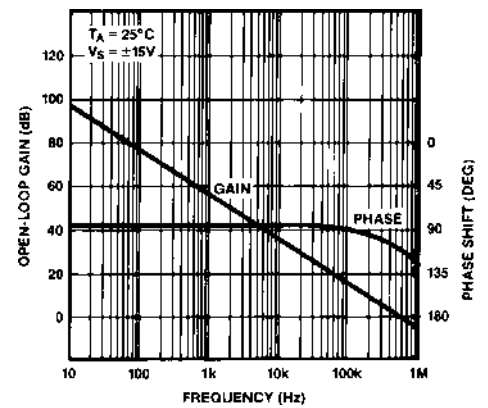
TPC 12. Power Supply Rejection vs. Frequency



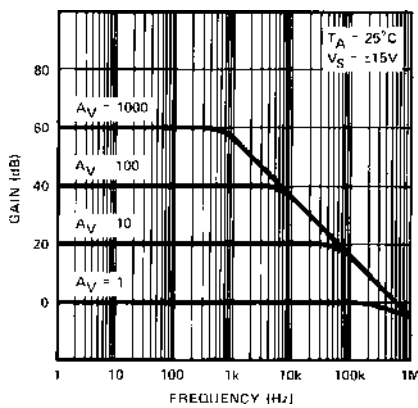
TPC 13. Power Supply Rejection vs. Temperature



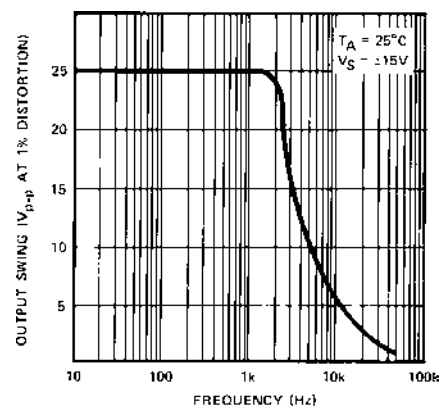
TPC 14. Open-Loop Gain vs. Temperature



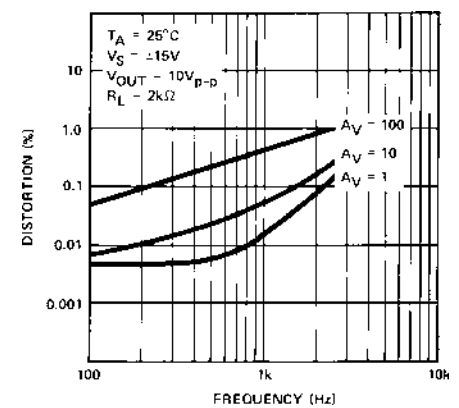
TPC 15. Open-Loop Gain and Phase Shift vs. Frequency



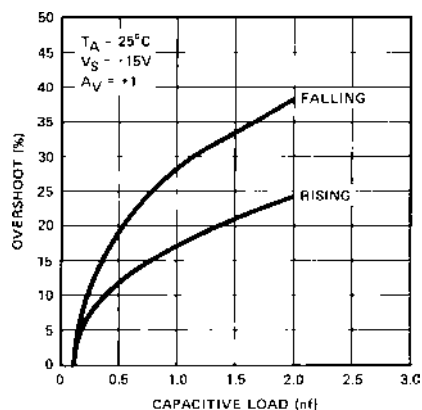
TPC 16. Closed-Loop Gain vs. Frequency



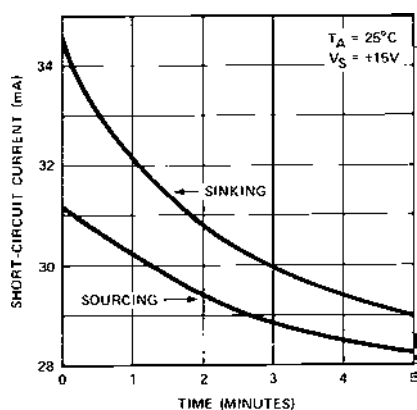
TPC 17. Maximum Output Swing Frequency



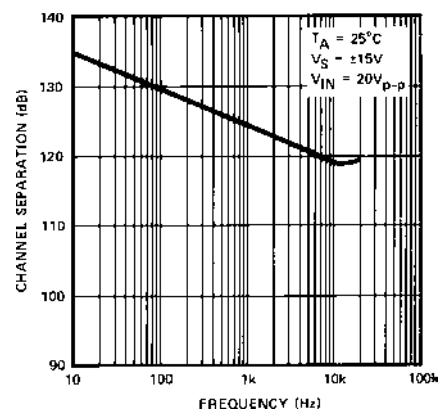
TPC 18. Total Harmonic Distortion vs. Frequency



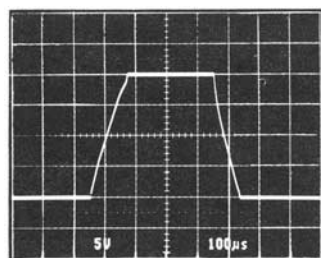
TPC 19. Overshoot vs. Capacitive Load



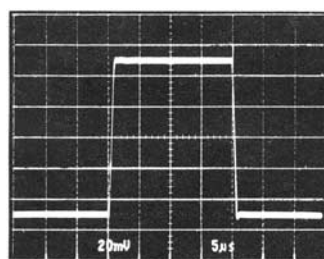
TPC 20. Short Circuit vs. Time



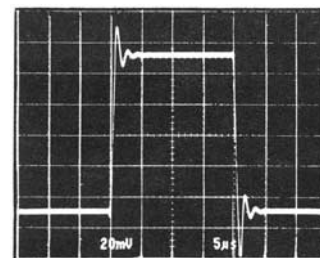
TPC 21. Channel Separation vs. Frequency



TPC 22. Large-Signal Transient Response



TPC 23. Small-Signal Transient Response



TPC 24. Small-Signal Transient Response $C_{LOAD} = 1nF$

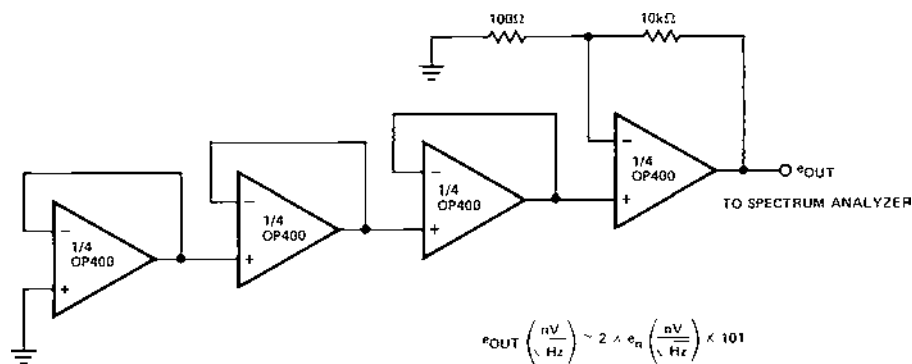


Figure 2. Noise Test Schematic

OP400

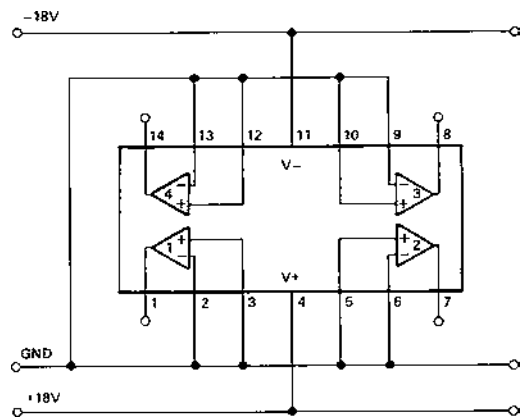


Figure 3. Burn-In Circuit

APPLICATIONS INFORMATION

The OP400 is inherently stable at all gains and is capable of driving large capacitive loads without oscillating. Nonetheless, good supply decoupling is highly recommended. Proper supply decoupling reduces problems caused by supply line noise and improves the capacitive load driving capability of the OP400.

Total supply current can be reduced by connecting the inputs of an unused amplifier to $-V$. This turns the amplifier off, lowering the total supply current.

APPLICATIONS

Dual Low-Power Instrumentation Amplifier

A dual instrumentation amplifier that consumes less than 33 mW of power per channel is shown in Figure 1. The linearity of the instrumentation amplifier exceeds 16 bits in gains of 5 to 200 and is better than 14 bits in gains from 200 to 1000. CMRR is above 115 dB ($G = 1000$). Offset voltage drift is typically $0.4 \mu\text{V}/^\circ\text{C}$ over the military temperature range which is comparable to the best monolithic instrumentation amplifiers. The bandwidth of the low-power instrumentation amplifier is a function of gain and is shown in Table I.

Table I. Gain Bandwidth

| Gain | Bandwidth |
|------|-----------|
| 5 | 150 kHz |
| 10 | 67 kHz |
| 100 | 7.5 kHz |
| 1000 | 500 Hz |

The output signal is specified with respect to the reference input, which is normally connected to analog ground. The reference input can be used to offset the output from -10 V to $+10 \text{ V}$ if required.

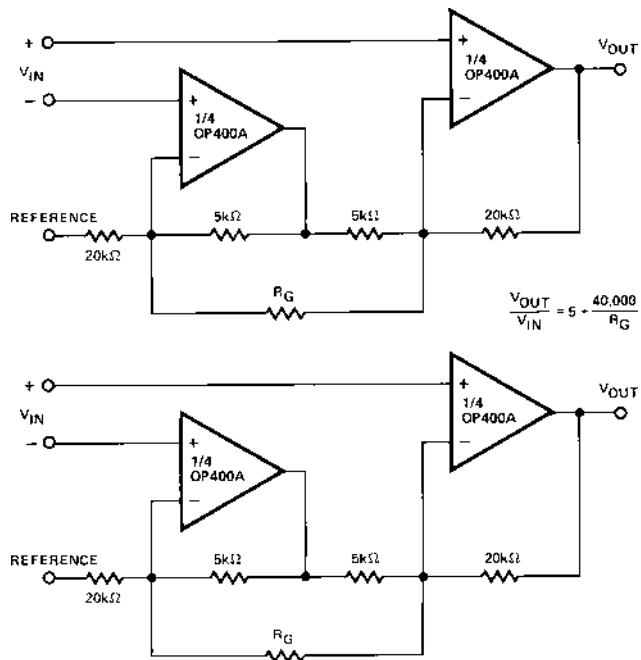


Figure 4. Dual Low-Power Instrumentation Amplifier

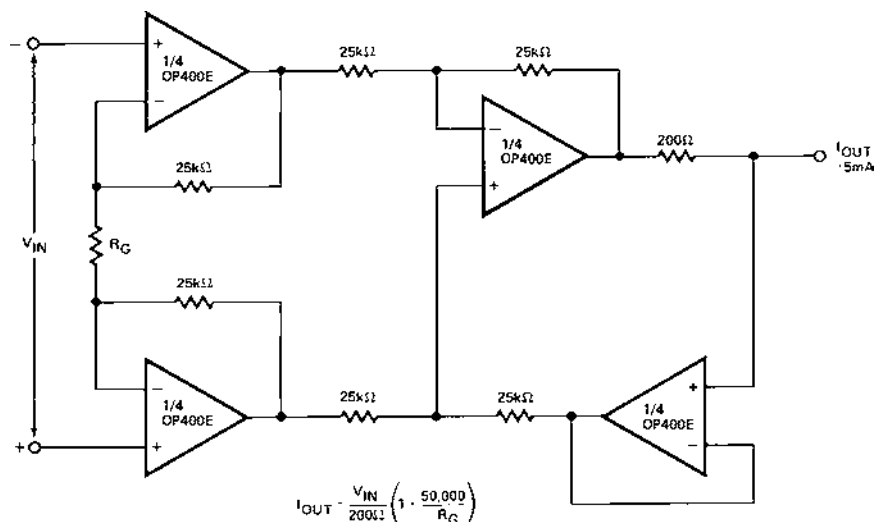


Figure 5. Bipolar Current Transmitter

BIPOLAR CURRENT TRANSMITTER

In the circuit of Figure 5, which is an extension of the standard three op amp instrumentation amplifier, the output current is proportional to the differential input voltage. Maximum output current is ± 5 mA with voltage compliance equal to ± 10 V when using ± 15 V supplies. Output impedance of the current transmitter exceeds $3 \text{ M}\Omega$ and linearity is better than 16 bits with gain set for a full scale input of $\pm 100 \text{ }\mu\text{V}$.

DIFFERENTIAL OUTPUT INSTRUMENTATION AMPLIFIER

The output voltage swing of a single-ended instrumentation amplifier is limited by the supplies, normally at ± 15 V, to a maximum of 24 V p-p. The differential output instrumentation amplifier of Figure 6 can provide an output voltage swing of 48 V p-p when operated with ± 15 V supplies. The extended output swing is due to the opposite polarity of the outputs. Both outputs will swing 24 V p-p but with opposite polarity, for a total output voltage swing of 48 V p-p. The reference input can be used to set a common-mode output voltage over the range ± 10 V. PSRR of the amplifier is less than $1 \text{ }\mu\text{V/V}$ with CMRR ($G = 1000$) better than 115 dB. Offset voltage drift is typically $0.4 \text{ }\mu\text{V/}^\circ\text{C}$ over the military temperature range.

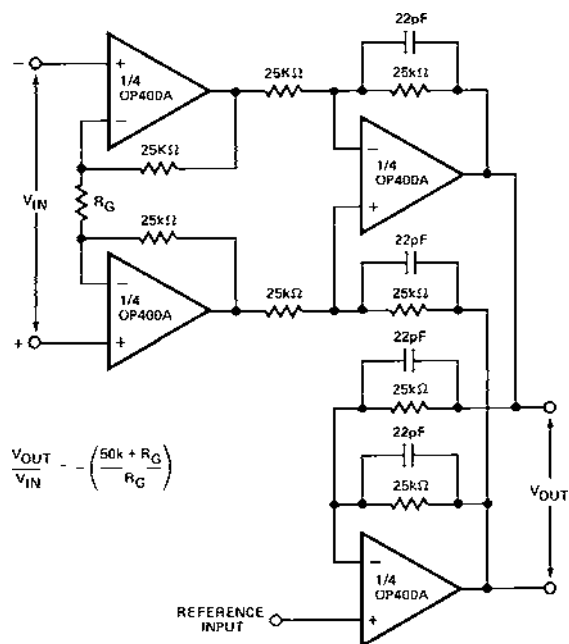
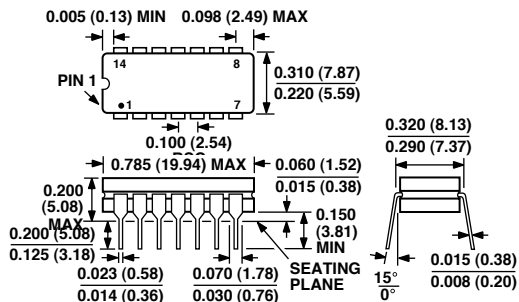


Figure 6. Differential Output Instrumentation Amplifier

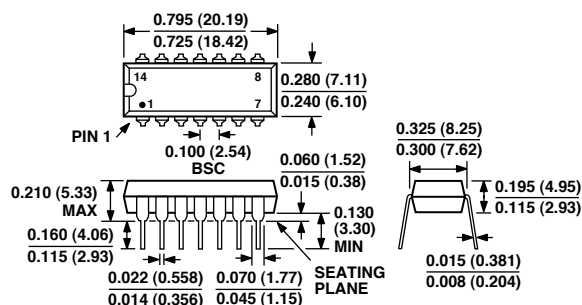
OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

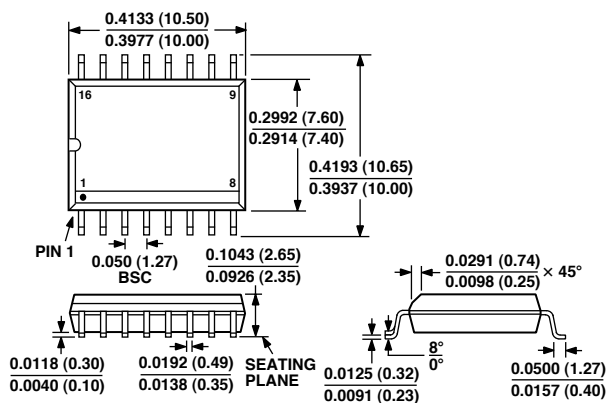
14-Lead Hermetic DIP Package (Y-Suffix)



14-Lead Plastic DIP Package (P-Suffix)



16-Lead SOL Package (S-Suffix)



Revision History

| Location | Page |
|---|------|
| Data Sheet changed from REV. 0 to REV. A. | |
| Edits to FEATURES | 1 |
| Edits to ORDERING INFORMATION | 1 |
| Edits to PIN CONNECTIONS | 1 |
| Edits to GENERAL DESCRIPTIONS | 1, 2 |
| Edits to PACKAGE TYPE | 2 |

