# Quad Low Offset, Low Power Operational Amplifier

# OP400

## FEATURES

**Low input offset voltage: 150 µV maximum**
**Low offset voltage drift over –55°C to +125°C: 1.2 pV/°C maximum**
**Low supply current (per amplifier): 725 µA maximum**
**High open-loop gain: 5000 V/mV minimum**
**Input bias current: 3 nA maximum**
**Low noise voltage density: 11 nV/√Hz at 1 kHz**
**Stable with large capacitive loads: 10 nF typical**
**Pin-compatible to LM148, HA4741, RM4156, and LT1014, with improved performance**
**Available in die form**

## FUNCTIONAL BLOCK DIAGRAMS

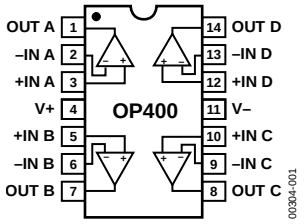


*Figure 1. 14-Pin Ceramic DIP (Y-Suffix) and 14-Pin Plastic DIP (P-Suffix)*

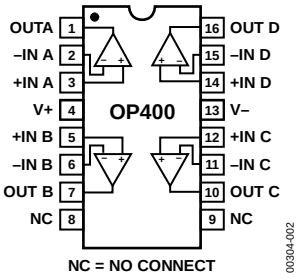


*Figure 2. 16-Pin SOIC (S-Suffix)*

## GENERAL DESCRIPTION

The OP400 is the first monolithic quad operational amplifier that features OP77-type performance. Precision performance is not sacrificed with the OP400 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 less than 1.2 µV/°C, guaranteed over the full military temperature range. Open-loop gain of the OP400 is more than 5 million into a 10 kΩ load, input bias current is less than 3 nA, CMR is more than 120 dB, and PSRR is less than 1.8 µV/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.

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 nV/√Hz at 10 Hz, 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 having these devices. The OP400 is an ideal choice for applications requiring multiple precision operational amplifiers and where low power consumption is critical.

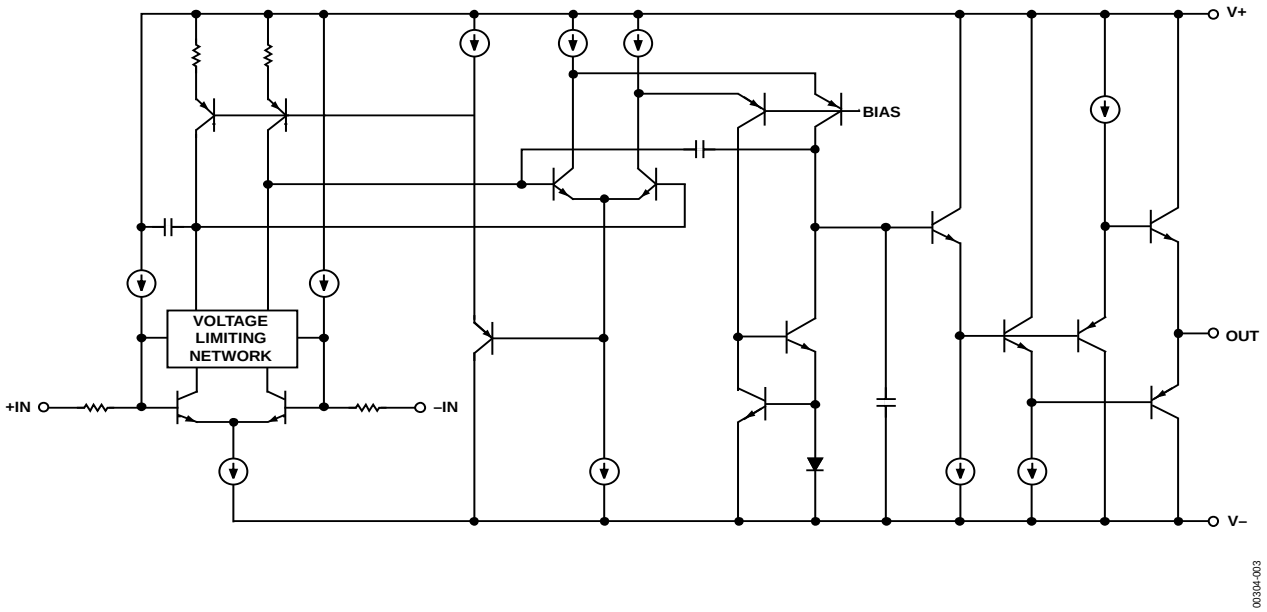


*Figure 3. Simplified Schematic (One of Four Amplifiers Is Shown)*

**Rev. G**



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# TABLE OF CONTENTS



## REVISION HISTORY

**2/11—Rev. F to Rev. G**

Added S Package to Storage Temperature Range in Table 4 ..... 5
Updated Outline Dimensions ..... 15

**12/08—Rev. E to Rev. F**

Added New Figure 28, Renumbered Sequentially ..... 10
Updated Outline Dimensions ..... 15

**1/07—Rev. D to Rev. E**

Updated Format ..... Universal
Changes to Figure 1 and Figure 2 ..... 1
Removed Figure 4 ..... 4
Changes to Table 3 ..... 4
Changes to Figure 16 through Figure 19, Figure 21 ..... 8
Changes to Figure 27 ..... 9
Changes to Figure 28 ..... 10
Changes to Figure 33 ..... 13
Updated Outline Dimensions ..... 14

**3/06—Rev. C to Rev. D**

Updated Format ..... Universal
Deleted Wafer Test Limits Table ..... 4
New Package Drawing: R-14 ..... 15
Updated Outline Dimensions ..... 15
Changes to Ordering Guide ..... 16

**6/03—Rev. B to Rev. C**

Edits to Specifications ..... 2

**10/02—Rev. A to Rev. B**

Addition of Absolute Maximum Ratings ..... 5
Edits to Outline Dimensions ..... 12

**4/02—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

# SPECIFICATIONS

## ELECTRICAL CHARACTERISTICS

@ $V_S$ = ±15 V, $T_A$ = +25°C, unless otherwise noted.

**Table 1.**

| | | | OP400A/E | | | OP400F | | | OP400G/H | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Symbol** | **Conditions** | **Min** | **Typ** | **Max** | **Min** | **Typ** | **Max** | **Min** | **Typ** | **Max** | **Unit** |
| INPUT CHARACTERISTICS | | | | | | | | | | | | |
| Input Offset Voltage | $V_{OS}$ | | | 40 | 150 | | 60 | 230 | | 80 | 300 | µV |
| Long-Term Input Voltage Stability | | | | 0.1 | | | 0.1 | | | 0.1 | | µV/mo |
| Input Offset Current | $I_{OS}$ | $V_{CM}$ = 0 V | | 0.1 | 1.0 | | 0.1 | 2.0 | | 0.1 | 3.5 | nA |
| Input Bias Current | $I_B$ | $V_{CM}$ = 0 V | | 0.75 | 3.0 | | 0.75 | 6.0 | | 0.75 | 7.0 | nA |
| Input Noise Voltage | $e_{n\ p\text{-}p}$ | 0.1 Hz to 10 Hz | | 0.5 | | | 0.5 | | | 0.5 | | µV p-p |
| Input Resistance Differential Mode | $R_{IN}$ | | | 10 | | | 10 | | | 10 | | MΩ |
| Input Resistance Common Mode | $R_{INCM}$ | | | 200 | | | 200 | | | 200 | | GΩ |
| Large Signal Voltage Gain | $A_{VO}$ | $V_O$ = ±10 V | | | | | | | | | | |
| | | $R_L$ = 10 kΩ | 5000 | 12,000 | | 3000 | 7000 | | 3000 | 7000 | | V/mV |
| | | $R_L$ = 2 kΩ | 2000 | 3500 | | 1500 | 3000 | | 1500 | 3000 | | V/mV |
| Input Voltage Range[1] | IVR | | ±12 | ±13 | | ±12 | ±13 | | ±12 | ±13 | | V |
| Common-Mode Rejection | CMR | $V_{CM}$ = 12 V | 120 | 140 | | 115 | 140 | | 110 | 135 | | dB |
| Input Capacitance | $C_{IN}$ | | | 3.2 | | | 3.2 | | | 3.2 | | pF |
| OUTPUT CHARACTERISTICS | | | | | | | | | | | | |
| Output Voltage Swing | $V_O$ | $R_L$ = 10 kΩ | ±12 | ±12.6 | | ±12 | ±12.6 | | ±12 | ±12.6 | | V |
| POWER SUPPLY | | | | | | | | | | | | |
| Power Supply Rejection Ratio | PSRR | $V_S$ = 3 V to 18 V | | 0.1 | 1.8 | | 0.1 | 3.2 | | 0.2 | 5.6 | µV/V |
| Supply Current per Amplifier | $I_{SY}$ | No load | | 600 | 725 | | 600 | 725 | | 600 | 725 | µA |
| DYNAMIC PERFORMANCE | | | | | | | | | | | | |
| Slew Rate | SR | | 0.1 | 0.15 | | 0.1 | 0.15 | | 0.1 | 0.15 | | V/µs |
| Gain Bandwidth Product | GBWP | $A_V$ = 1 | | 500 | | | 500 | | | 500 | | kHz |
| Channel Separation | CS | $V_O$ = 20 V p-p, $f_O$ = 10 Hz[2] | 123 | 135 | | 123 | 135 | | 123 | 135 | | dB |
| Capacitive Load Stability | | $A_V$ = 1, no oscillations | | 10 | | | 10 | | | 10 | | nF |
| NOISE PERFORMANCE | | | | | | | | | | | | |
| Input Noise Voltage | $e_n$ | $f_O$ = 10 Hz[3] | | 22 | 36 | | 22 | 36 | | 22 | | nV/√Hz |
| Density[3] | | $f_O$ = 1000 Hz[3] | | 11 | 18 | | 11 | 18 | | 11 | | nV/√Hz |
| Input Noise Current | $i_{n\ p\text{-}p}$ | 0.1 Hz to 10 Hz | | 15 | | | 15 | | | 15 | | pA p-p |
| Input Noise Current Density | $i_n$ | $f_O$ = 10 Hz | | 0.6 | | | 0.6 | | | 0.6 | | pA/√Hz |

[1] Guaranteed by CMR test.
[2] Guaranteed but not 100% tested.
[3] Sample tested.

@ $V_S$ = ±15 V, −55°C ≤ $T_A$ ≤ +125°C for OP400A, unless otherwise noted.

**Table 2.**

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| INPUT CHARACTERISTICS | | | | | | |
| Input Offset Voltage | $V_{OS}$ | | | 70 | 270 | µV |
| Average Input Offset Voltage Drift | $TCV_{OS}$ | | | 0.3 | 1.2 | µV/°C |
| Input Offset Current | $I_{OS}$ | $V_{CM}$ = 0 V | | 0.1 | 2.5 | nA |
| Input Bias Current | $I_B$ | $V_{CM}$ = 0 V | | 1.3 | 5.0 | nA |
| Large Signal Voltage Gain | $A_{VO}$ | $V_O$ = ±10 V, $R_L$ = 10 kΩ | 3000 | 9000 | | V/mV |
| | | $R_L$ = 2 kΩ | 1000 | 2300 | | |
| Input Voltage Range[1] | IVR | | ±12 | ±12.5 | | V |
| Common-Mode Rejection | CMR | $V_{CM}$ = ±12 V | | 115 | 130 | dB |
| OUTPUT CHARACTERISTICS | | | | | | |
| Output Voltage Swing | $V_O$ | $R_L$ = 10 kΩ | ±12 | ±12.4 | | |
| POWER SUPPLY | | | | | | |
| Power Supply Rejection Ratio | PSRR | $V_O$ = 3 V to 18 V | | 0.2 | 3.2 | µV/V |
| Supply Current per Amplifier | $I_{SY}$ | No load | | 600 | 775 | µA |
| DYNAMIC PERFORMANCE | | | | | | |
| Capacitive Load Stability | | $A_V$ = 1, no oscillations | | 8 | | nF |

[1] Guaranteed by CMR test.

@ $V_S$ = ±15 V, −25°C≤ $T_A$ ≤ +85°C for OP400E/F, 0°C ≤ $T_A$ ≤ 70°C for OP400G, −40°C≤ $T_A$ ≤ +85°C for OP400H, unless otherwise noted.

**Table 3.**

| | | | OP400E | | | OP400F | | | OP400G/H | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Symbol | Conditions | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | Unit |
| INPUT CHARACTERISTICS | | | | | | | | | | | | |
| 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 | µV/°C |
| Input Offset Current | $I_{OS}$ | $V_{CM}$ = 0 V | | | | | | | | | | |
| | | E, F, G grades | | 0.1 | 2.5 | | 0.1 | 3.5 | | 0.2 | 6.0 | nA |
| | | H grade | | | | | | | | 0.2 | 12.0 | nA |
| Input Bias Current | $I_B$ | $V_{CM}$ = 0 V | | | | | | | | | | |
| | | E, F, G grades | | 0.9 | 5.0 | | 0.9 | 10.0 | | 1.0 | 12.0 | nA |
| | | H grade | | | | | | | | 1.0 | 20.0 | nA |
| Large-Signal Voltage Gain | $A_{VO}$ | $V_{CM}$ = 0 V | | | | | | | | | | |
| | | $R_L$ = 10 kΩ | 3000 | 10,000 | | 2000 | 5000 | | 2000 | 5000 | | V/mV |
| | | $R_L$ = 2 kΩ | 1500 | 2700 | | 1000 | 2000 | | 1000 | 2000 | | V/mV |
| Input Voltage Range[1] | IVR | | ±12 | ±12.5 | | ±12 | ±12.5 | | ±12 | ±12.5 | | V |
| Common-Mode Rejection | CMR | $V_{CM}$ = ±12 V | 115 | 135 | | 110 | 135 | | 105 | 130 | | dB |
| OUTPUT CHARACTERISTICS | | | | | | | | | | | | |
| Output Voltage Swing | $V_O$ | $R_L$ = 10 kΩ | ±12 | ±12.4 | | ±12 | ±12.4 | | ±12 | ±12.6 | | V |
| | | $R_L$ = 2 kΩ | ±11 | ±12 | | ±11 | ±12 | | ±11 | ±12.2 | | V |
| POWER SUPPLY | | | | | | | | | | | | |
| Power Supply Rejection Ratio | PSRR | $V_S$ = ±3 V to ±18 V | | 0.15 | 3.2 | | 0.15 | 5.6 | | 0.3 | 10.0 | µV/V |
| Supply Current per Amplifier | $I_{SY}$ | No load | | 600 | 775 | | 600 | 775 | | 600 | 775 | µA |
| DYNAMIC PERFORMANCE | | | | | | | | | | | | |
| Capacitive Load Stability | | No oscillations | | 10 | | | 10 | | | 10 | | nF |

[1] Guaranteed by CMR test.

# ABSOLUTE MAXIMUM RATINGS

**Table 4.**

| Parameter | Rating |
|---|---|
| Supply Voltage | ±20 V |
| Differential Input Voltage | ±30 V |
| Input Voltage | Supply voltage |
| Output Short-Circuit Duration | Continuous |
| Storage Temperature Range | |
| P, Y, S Packages | −65°C to +150°C |
| Lead Temperature (Soldering 60 sec) | 300°C |
| Junction Temperature ($T_J$) Range | −65°C to +150°C |
| Operating Temperature Range | |
| OP400A | −55°C to +125°C |
| OP400E, OP400F | −25°C to +85°C |
| OP400G | 0°C to 70°C |
| OP400H | −40°C to +85°C |

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Absolute maximum ratings apply to both dice and packaged parts, unless otherwise noted.

## THERMAL RESISTANCE

$\theta_{JA}$ is specified for worst-case mounting conditions, that is, $\theta_{JA}$ is specified for device in socket for CERDIP and PDIP packages; $\theta_{JA}$ is specified for device soldered to printed circuit board for SOIC package.

**Table 5. Thermal Resistance**

| Package Type | $\theta_{JA}$ | $\theta_{JC}$ | Unit |
|---|---|---|---|
| 14-Pin Ceramic DIP (Y) | 94 | 10 | °C/W |
| 14-Pin Plastic DIP (P) | 76 | 33 | °C/W |
| 16-Pin SOIC (S) | 88 | 23 | °C/W |

## ESD CAUTION

**ESD (electrostatic discharge) sensitive device.** Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

# TYPICAL PERFORMANCE CHARACTERISTICS

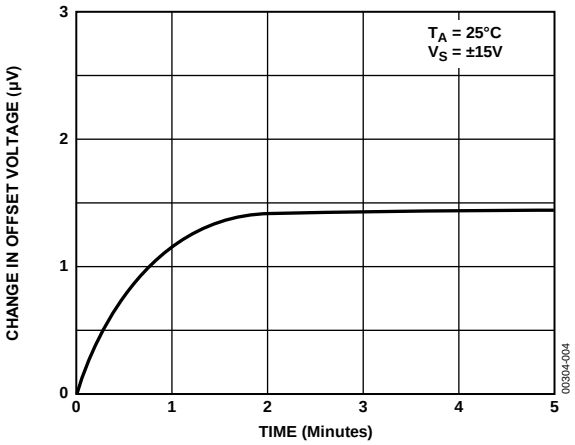



*Figure 4. Warmup Drift*

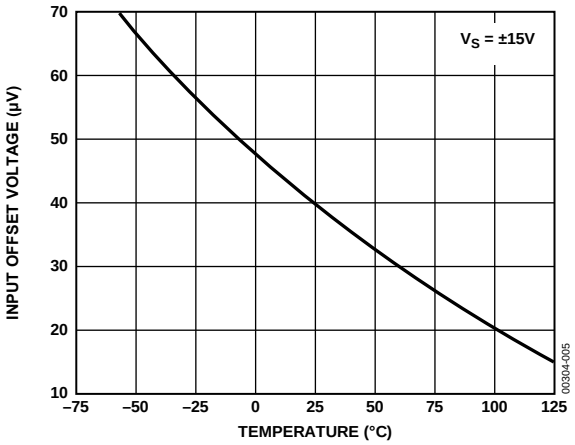



*Figure 5. Input Offset Voltage vs. Temperature*

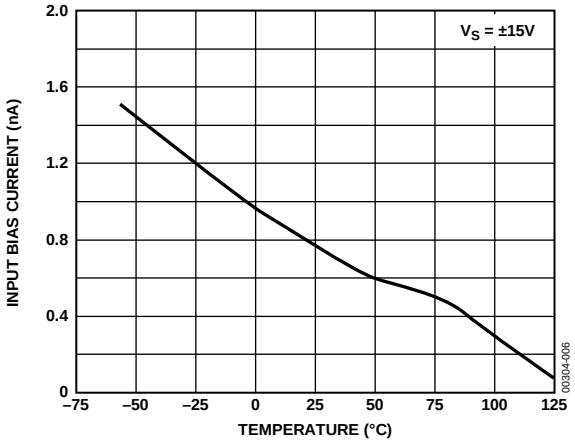



*Figure 6. Input Bias Current vs. Temperature*

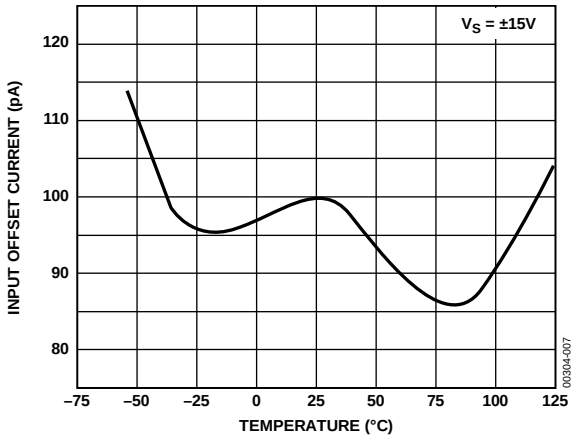



*Figure 7. Input Offset Current vs. Temperature*

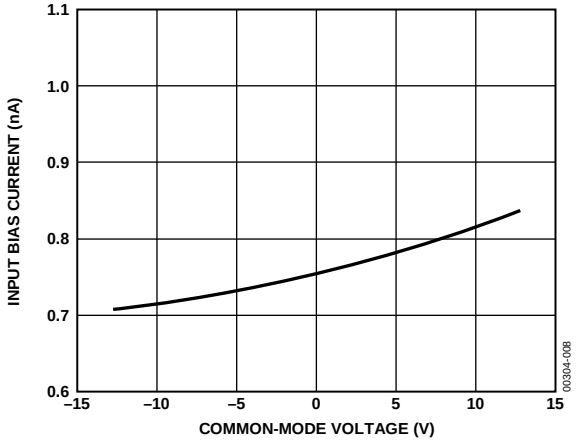



*Figure 8. Input Bias Current vs. Common-Mode Voltage*

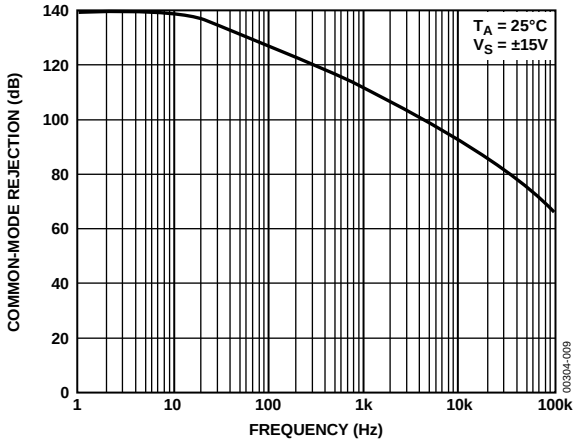



*Figure 9. Common-Mode Rejection vs. Frequency*

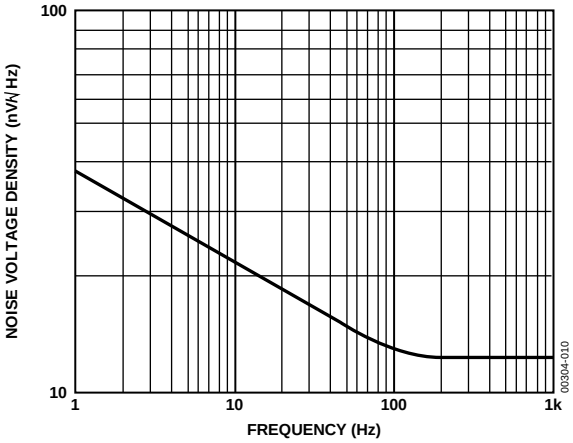



Figure 10. Noise Voltage Density vs. Frequency

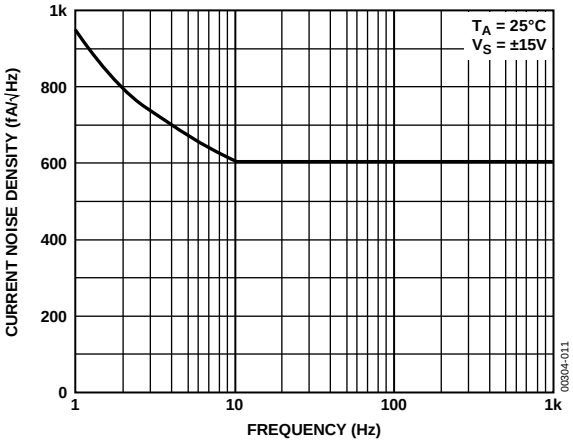



Figure 11. Current Noise Density vs. Frequency

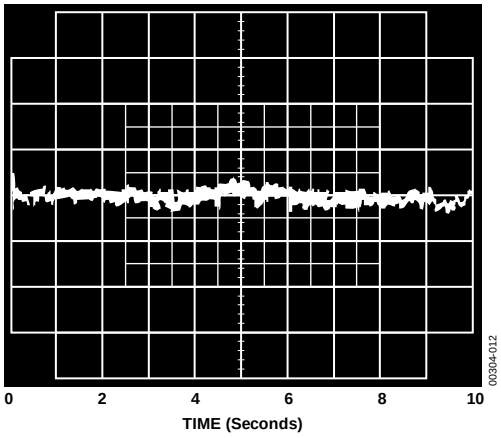



Figure 12. 0.1 Hz to 10 Hz Noise

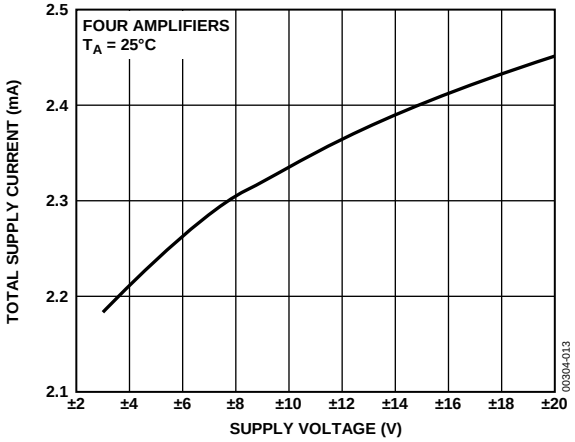



Figure 13. Total Supply Current vs. Supply Voltage

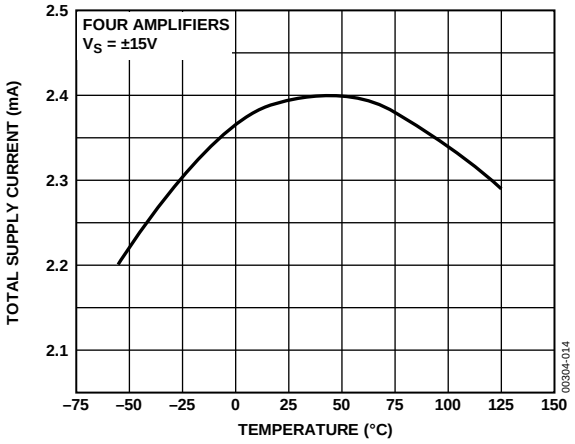



Figure 14. Total Supply Current vs. Temperature

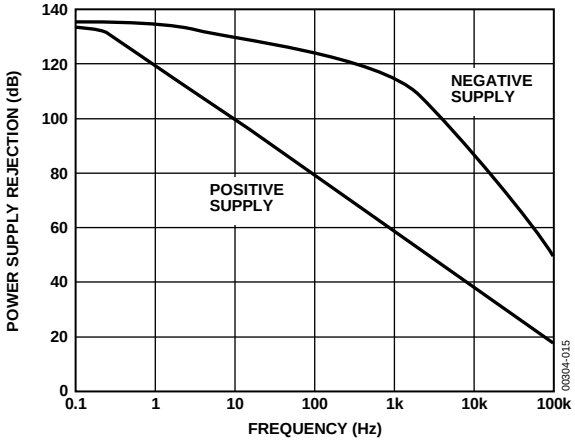



Figure 15. Power Supply Rejection vs. Frequency

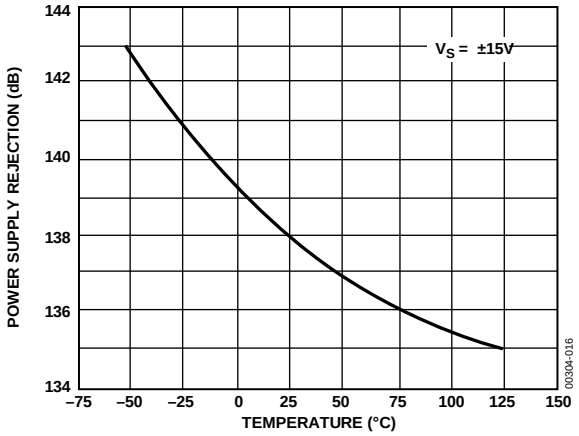



*Figure 16. Power Supply Rejection vs. Temperature*

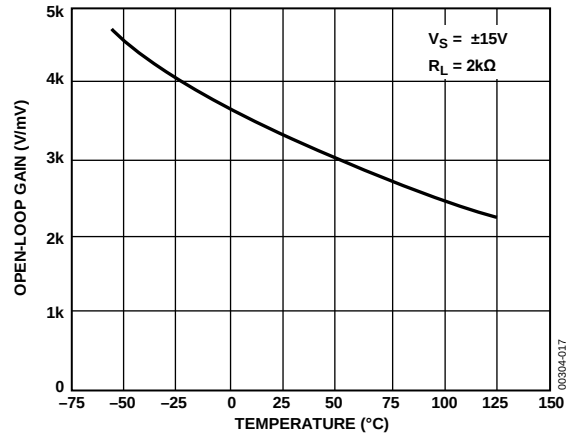



*Figure 17. Open-Loop Gain vs. Temperature*

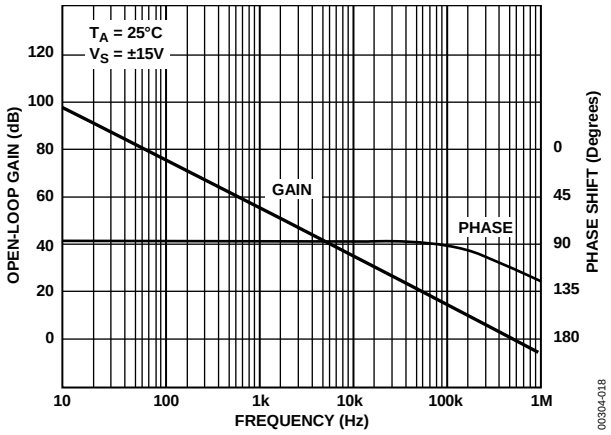



*Figure 18. Open-Loop Gain and Phase Shift vs. Frequency*

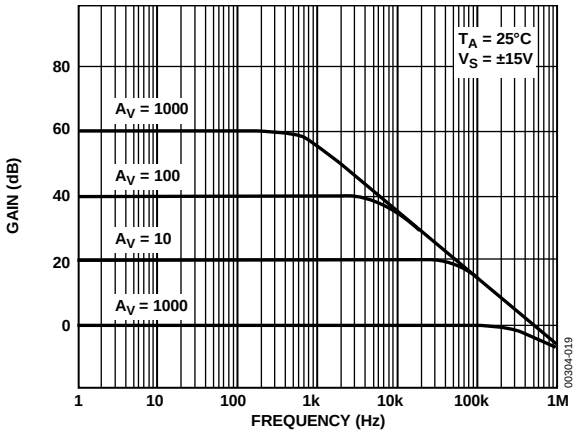



*Figure 19. Closed-Loop Gain vs. Frequency*

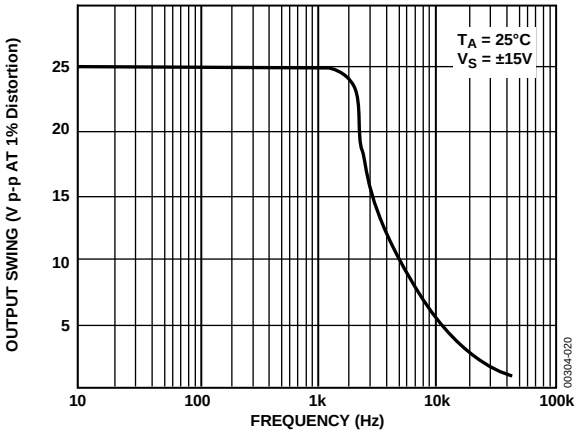



*Figure 20. Maximum Output Swing Frequency*

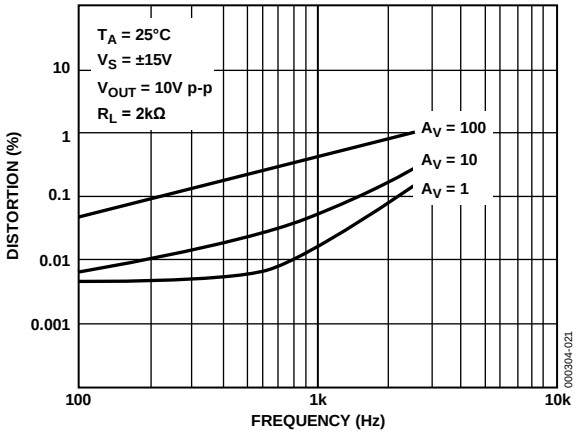



*Figure 21. Total Harmonic Distortion vs. Frequency*

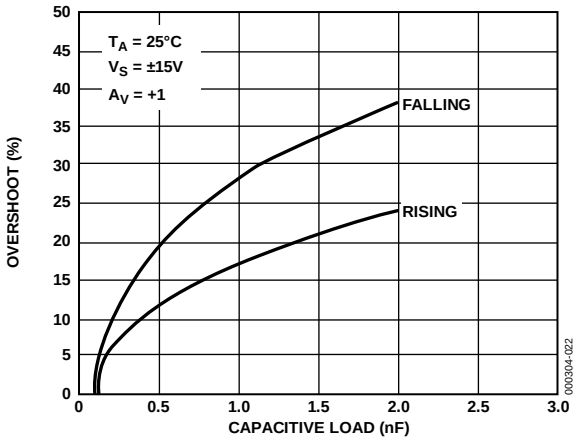



Figure 22. Overshoot vs. Capacitive Load

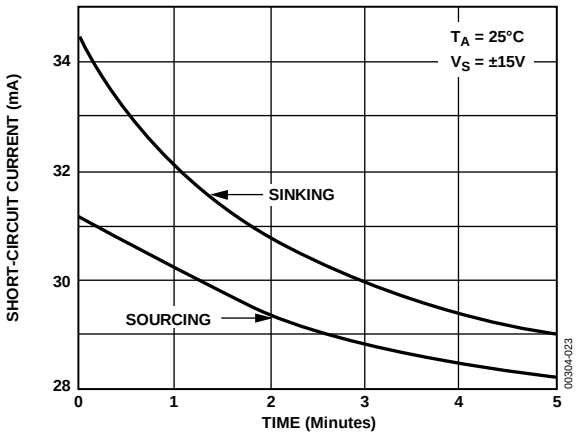



Figure 23. Short Circuit vs. Time

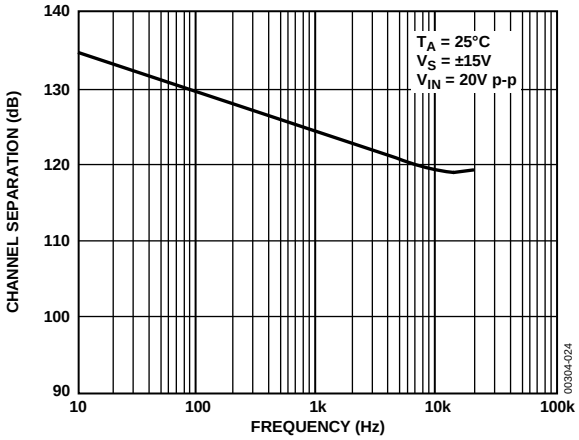



Figure 24. Channel Separation vs. Frequency

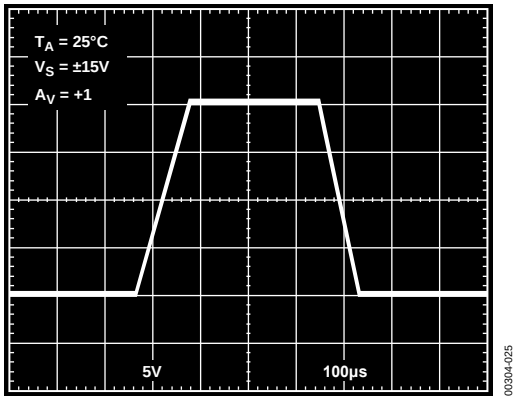



Figure 25. Large Signal Transient Response

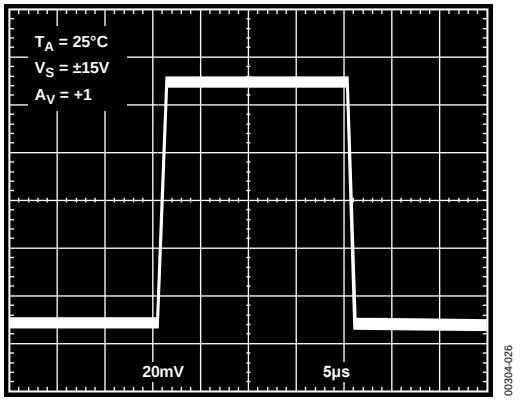



Figure 26. Small Signal Transient Response

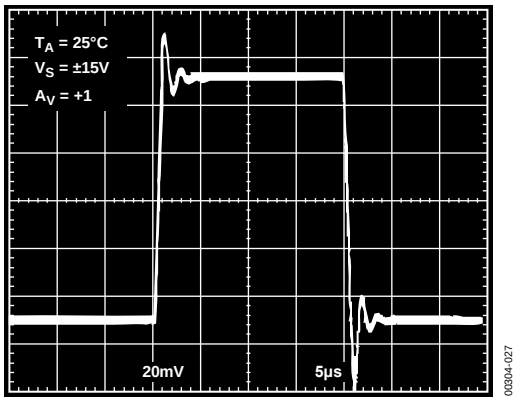



Figure 27. Small Signal Transient Response, $C_{LOAD}$ = 1 nF

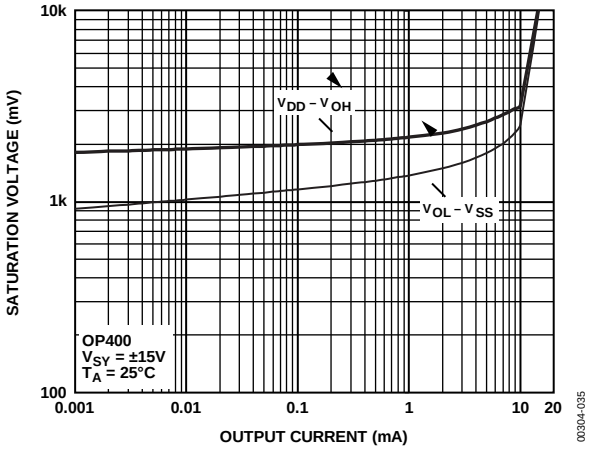



*Figure 28. Saturation Voltage vs. Output Current*

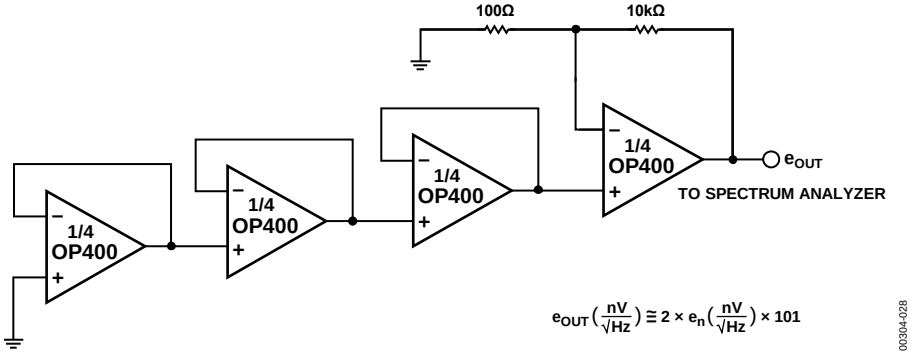



*Figure 29. Noise Test Schematic*

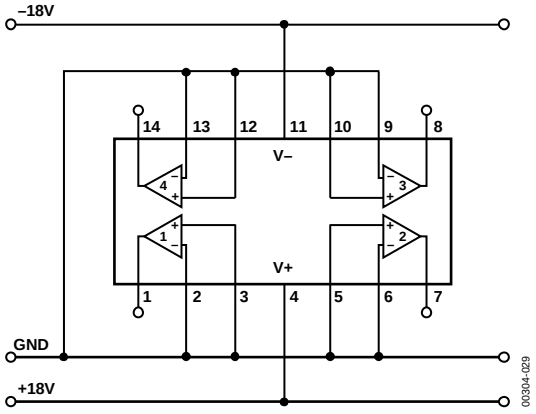



*Figure 30. Burn-In Circuit*

# APPLICATIONS

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.

## DUAL LOW POWER INSTRUMENTATION AMPLIFIER

A dual instrumentation amplifier that consumes less than 33 mW of power per channel is shown in Figure 31. 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 µV/°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 6.

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 V if required.

**Table 6. Gain Bandwidth**

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

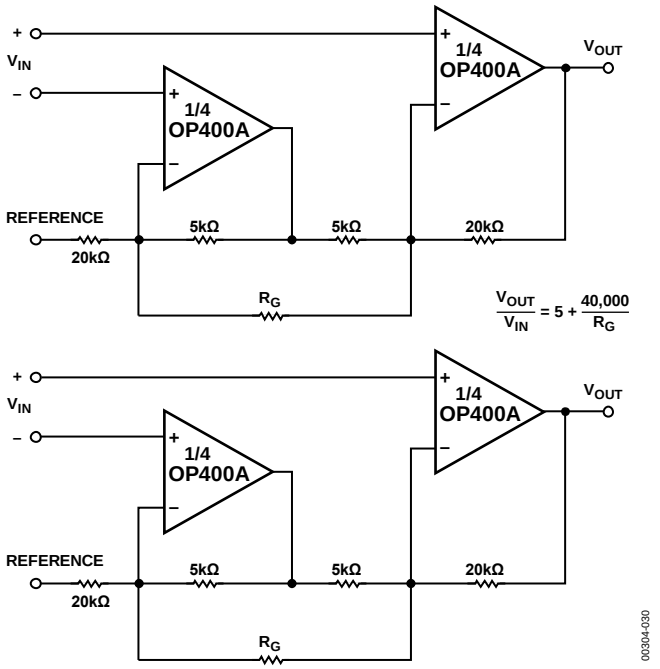



*Figure 31. Dual Low Power Instrumentation Amplifier*

## BIPOLAR CURRENT TRANSMITTER

In the circuit of Figure 32, 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 MΩ, and linearity is better than 16 bits with gain set for a full-scale input of ±100 μV.

## 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 shown in Figure 33 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 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. The PSRR of the amplifier is less than 1 μV/V with CMRR (G = 1000) better than 115 dB. Offset voltage drift is typically 0.4 μV/°C over the military temperature range.

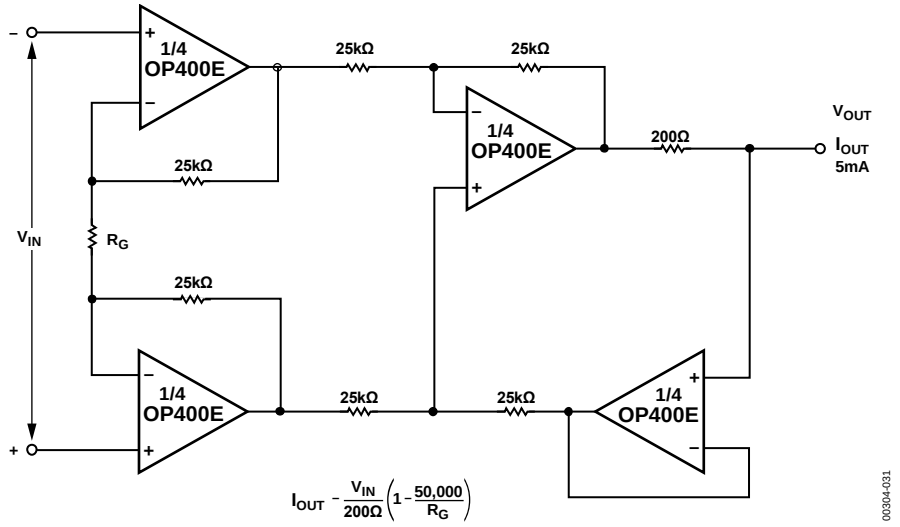



*Figure 32. Bipolar Current Transmitter*

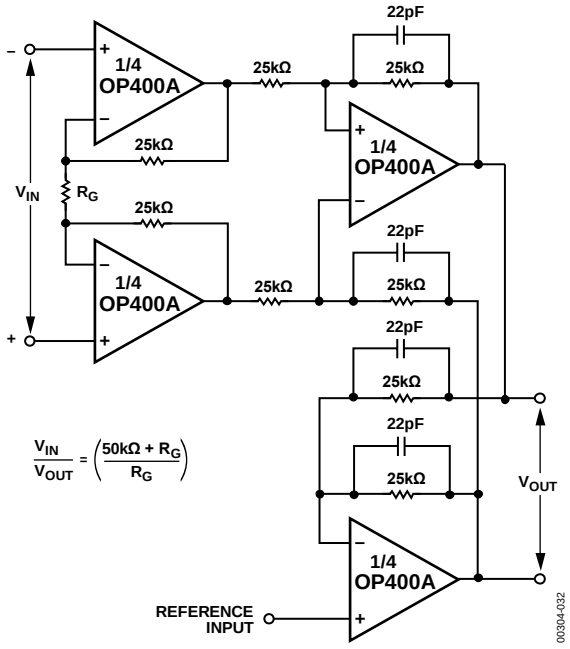



*Figure 33. Differential Output Instrumentation Amplifier*

## MULTIPLE OUTPUT TRACKING VOLTAGE REFERENCE

Figure 34 shows a circuit that provides outputs of 10 V, 7.5 V, 5 V, and 2.5 V for use as a system voltage reference. Maximum output current from each reference is 5 mA with load regulation under 25 µV/mA. Line regulation is better than 15 µV/V, and output voltage drift is under 20 µV/°C. Output voltage noise from 0.1 Hz to 10 Hz is typically 75 µV p-p from the 10 V output and proportionately less from the 7.5 V, 5 V, and 2.5 V outputs.

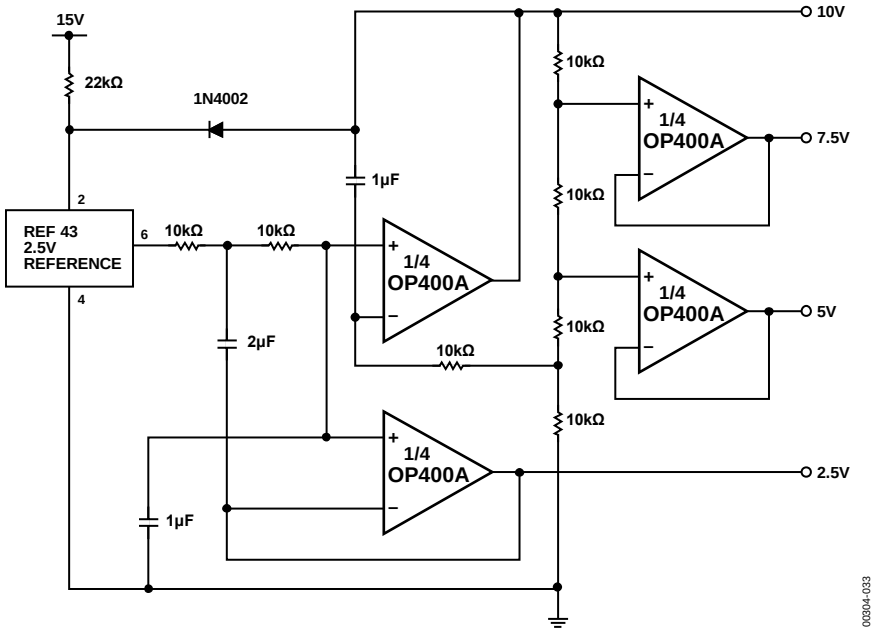
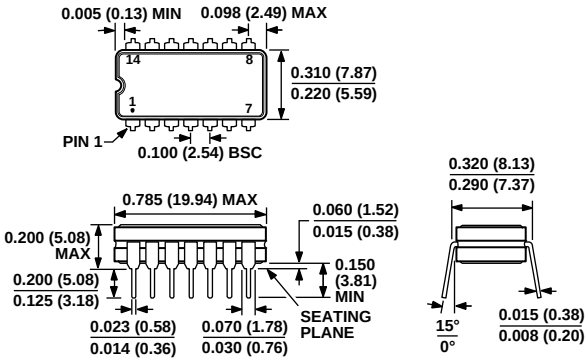


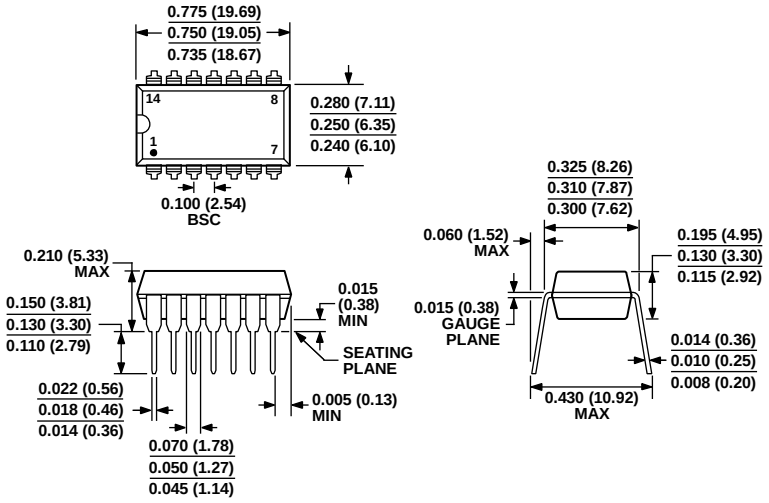

*Figure 34. Multiple Output Tracking Voltage Reference*

# OUTLINE DIMENSIONS




CONTROLLING DIMENSIONS ARE IN INCHES; MILLIMETER DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF INCH EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN.

*Figure 35. 14-Lead Ceramic Dual In-Line Package [CERDIP]*
*(Q-14)*
*[Y-Suffix]*
*Dimensions shown in inches and (millimeters)*




COMPLIANT TO JEDEC STANDARDS MS-001

CONTROLLING DIMENSIONS ARE IN INCHES; MILLIMETER DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF INCH EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN.
CORNER LEADS MAY BE CONFIGURED AS WHOLE OR HALF LEADS.

07.06.06-A

*Figure 36. 14-Lead Plastic Dual In-Line Package [PDIP]*
*(N-14)*
*[P-Suffix]*
*Dimensions shown in inches and (millimeters)*

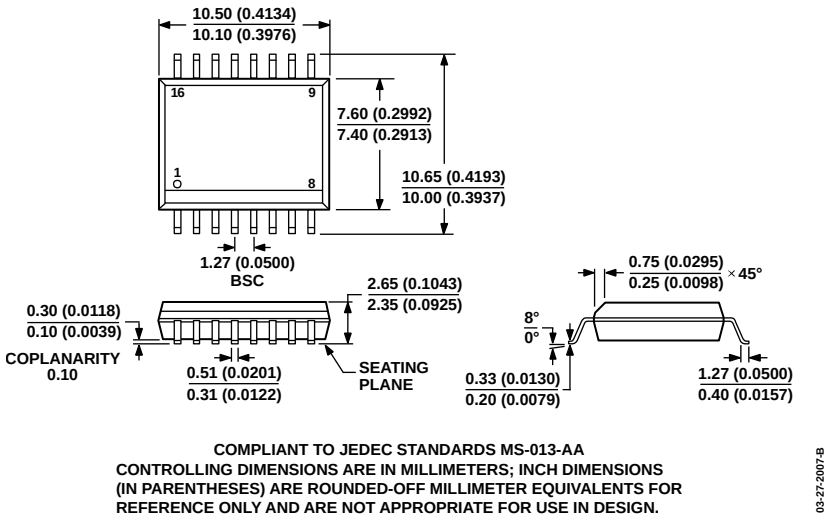



*Figure 37. 16-Lead Standard Small Outline Package [SOIC_W]*
*Wide Body (RW-16)*
*[S-Suffix]*
*Dimensions shown in millimeters and (inches)*

## ORDERING GUIDE

| Model[1] | Temperature Range | Package Description | Package Option |
|---|---|---|---|
| OP400AY | −55°C to +125°C | 14-Lead CERDIP | Y-Suffix (Q-14) |
| OP400EY | −25°C to +85°C | 14-Lead CERDIP | Y-Suffix (Q-14) |
| OP400FY | −25°C to +85°C | 14-Lead CERDIP | Y-Suffix (Q-14) |
| OP400GP | 0°C to +70°C | 14-Lead PDIP | P-Suffix (N-14) |
| OP400GPZ | 0°C to +70°C | 14-Lead PDIP | P-Suffix (N-14) |
| OP400HP | −40°C to +85°C | 14-Lead PDIP | P-Suffix (N-14) |
| OP400HPZ | −40°C to +85°C | 14-Lead PDIP | P-Suffix (N-14) |
| OP400GS | 0°C to +70°C | 16-Lead SOIC_W | S-Suffix (RW-16) |
| OP400GS-REEL | 0°C to +70°C | 16-Lead SOIC_W | S-Suffix (RW-16) |
| OP400GSZ | 0°C to +70°C | 16-Lead SOIC_W | S-Suffix (RW-16) |
| OP400GSZ-REEL | 0°C to +70°C | 16-Lead SOIC_W | S-Suffix (RW-16) |
| OP400HS | −40°C to +85°C | 16-Lead SOIC_W | S-Suffix (RW-16) |
| OP400HS-REEL | −40°C to +85°C | 16-Lead SOIC_W | S-Suffix (RW-16) |
| OP400HSZ | −40°C to +85°C | 16-Lead SOIC_W | S-Suffix (RW-16) |
| OP400HSZ-REEL | −40°C to +85°C | 16-Lead SOIC_W | S-Suffix (RW-16) |
| OP400GBC | | Die | |

[1] Z = RoHS Compliant Part.

## SMD PARTS AND EQUIVALENTS

| SMD Part Number[1] | Analog Devices Equivalent |
|---|---|
| 5962-8777101M3A | OP400ATCMDA |
| 5962-8777101MCA | OP400AYMDA |

[1] For military processed devices, please refer to the standard microcircuit drawing (SMD) available at the Defense Supply Center Columbus website.

## NOTES


D00304-0-2/11(G)