# Dual Picoampere Input Current Bipolar Op Amp

# AD706

**FEATURE**

**HIGH DC PRECISION**
**50 μV max Offset Voltage**
**0.6 μV/°C max Offset Drift**
**110 pA max Input Bias Current**

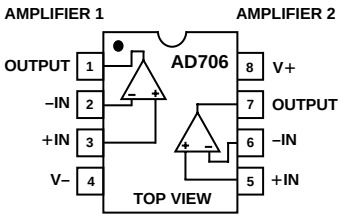
**LOW NOISE**
**0.5 μV p-p Voltage Noise, 0.1 Hz to 10 Hz**

**LOW POWER**
**750 μA Supply Current**
**Available in 8-Lead Plastic Mini-DIP, Hermetic Cerdip and Surface Mount (SOIC) Packages**
**Available in Tape and Reel in Accordance with EIA-481A Standard**
**Single Version: AD705, Quad Version: AD704**

**PRIMARY APPLICATIONS**
**Low Frequency Active Filters**
**Precision Instrumentation**
**Precision Integrators**

**CONNECTION DIAGRAM**

**Plastic Mini-DIP (N)**
**Cerdip (Q) and**
**Plastic SOIC (R) Packages**




The AD706 is offered in three varieties of an 8-lead package: plastic mini-DIP, hermetic cerdip and surface mount (SOIC). "J" grade chips are also available.

**PRODUCT DESCRIPTION**

The AD706 is a dual, low power, bipolar op amp that has the low input bias current of a BiFET amplifier, but which offers a significantly lower $I_B$ drift over temperature. It utilizes superbeta bipolar input transistors to achieve picoampere input bias current levels (similar to FET input amplifiers at room temperature), while its $I_B$ typically only increases by 5× at 125°C (unlike a BiFET amp, for which $I_B$ doubles every 10°C for a 1000× increase at 125°C). The AD706 also achieves the microvolt offset voltage and low noise characteristics of a precision bipolar input amplifier.

Since it has only 1/20 the input bias current of an OP07, the AD706 does not require the commonly used "balancing" resistor. Furthermore, the current noise is 1/5 that of the OP07, which makes this amplifier usable with much higher source impedances. At 1/6 the supply current (per amplifier) of the OP07, the AD706 is better suited for today's higher density boards.

The AD706 is an excellent choice for use in low frequency active filters in 12- and 14-bit data acquisition systems, in precision instrumentation and as a high quality integrator. The AD706 is internally compensated for unity gain and is available in five performance grades. The AD706J and AD706K are rated over the commercial temperature range of 0°C to +70°C. The AD706A and AD706B are rated over the industrial temperature range of –40°C to +85°C.

**PRODUCT HIGHLIGHTS**

1. The AD706 is a dual low drift op amp that offers BiFET level input bias currents, yet has the low $I_B$ drift of a bipolar amplifier. It may be used in circuits using dual op amps such as the LT1024.
2. The AD706 provides both low drift and high dc precision.
3. The AD706 can be used in applications where a chopper amplifier would normally be required but without the chopper's inherent noise.

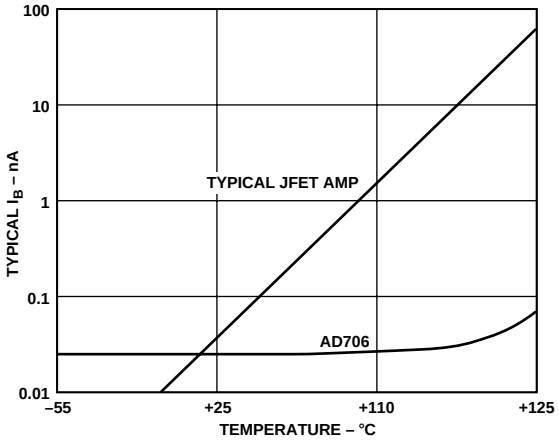



*Figure 1. Input Bias Current vs. Temperature*

REV. C



**One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.**
**Tel: 781/329-4700 World Wide Web Site: http://www.analog.com**
**Fax: 781/326-8703**

# AD706—SPECIFICATIONS (@ $T_A$ = +25°C, $V_{CM}$ = 0 V and ±15 V dc, unless otherwise noted)

| Parameter | Conditions | AD706J/A Min | AD706J/A Typ | AD706J/A Max | AD706K/B Min | AD706K/B Typ | AD706K/B Max | Units |
|---|---|---|---|---|---|---|---|---|
| INPUT OFFSET VOLTAGE | | | | | | | | |
| Initial Offset | | | 30 | 100 | | 10 | 50 | µV |
| Offset | $T_{MIN}$ to $T_{MAX}$ | | 40 | 150 | | 25 | 100 | µV |
| vs. Temp, Average TC | | | 0.2 | 1.5 | | 0.2 | 0.6 | µV/°C |
| vs. Supply (PSRR) | $V_S$ = ±2 V to ±18 V | 110 | 132 | | 112 | 132 | | dB |
| $T_{MIN}$ to $T_{MAX}$ | $V_S$ = ±2.5 V to ±18 V | 106 | 126 | | 108 | 126 | | dB |
| Long Term Stability | | | 0.3 | | | 0.3 | | µV/Month |
| INPUT BIAS CURRENT[1] | | | | | | | | |
| | $V_{CM}$ = 0 V | | 50 | 200 | | 30 | 110 | pA |
| | $V_{CM}$ = ±13.5 V | | | 250 | | | 160 | pA |
| vs. Temp, Average TC | | | 0.3 | | | 0.2 | | pA/°C |
| $T_{MIN}$ to $T_{MAX}$ | $V_{CM}$ = 0 V | | | 300 | | | 200 | pA |
| $T_{MIN}$ to $T_{MAX}$ | $V_{CM}$ = ±13.5 V | | | 400 | | | 300 | pA |
| INPUT OFFSET CURRENT | $V_{CM}$ = 0 V | | 30 | 150 | | 30 | 100 | pA |
| | $V_{CM}$ = ±13.5 V | | | 250 | | | 200 | pA |
| vs. Temp, Average TC | | | 0.6 | | | 0.4 | | pA/°C |
| $T_{MIN}$ to $T_{MAX}$ | $V_{CM}$ = 0 V | | 80 | 250 | | 80 | 200 | pA |
| $T_{MIN}$ to $T_{MAX}$ | $V_{CM}$ = ±13.5 V | | 80 | 350 | | 80 | 300 | pA |
| MATCHING CHARACTERISTICS | | | | | | | | |
| Offset Voltage | | | | 150 | | | 75 | µV |
| | $T_{MIN}$ to $T_{MAX}$ | | | 250 | | | 150 | µV |
| Input Bias Current[2] | | | | 300 | | | 150 | pA |
| | $T_{MIN}$ to $T_{MAX}$ | | | 500 | | | 250 | pA |
| Common-Mode Rejection | | 106 | | | 110 | | | dB |
| | $T_{MIN}$ to $T_{MAX}$ | 106 | | | 108 | | | dB |
| Power Supply Rejection | | 106 | | | 110 | | | dB |
| | $T_{MIN}$ to $T_{MAX}$ | 104 | | | 106 | | | dB |
| Crosstalk | @ f = 10 Hz | | | | | | | |
| (Figure 19a) | $R_L$ = 2 kΩ | | 150 | | | 150 | | dB |
| FREQUENCY RESPONSE | | | | | | | | |
| Unity Gain Crossover | | | | | | | | |
| Frequency | | | 0.8 | | | 0.8 | | MHz |
| Slew Rate | G = –1 | | 0.15 | | | 0.15 | | V/µs |
| | $T_{MIN}$ to $T_{MAX}$ | | 0.15 | | | 0.15 | | V/µs |
| INPUT IMPEDANCE | | | | | | | | |
| Differential | | | 40‖2 | | | 40‖2 | | MΩ‖pF |
| Common Mode | | | 300‖2 | | | 300‖2 | | GΩ‖pF |
| INPUT VOLTAGE RANGE | | | | | | | | |
| Common-Mode Voltage | | ±13.5 | ±14 | | ±13.5 | ±14 | | V |
| Common-Mode Rejection | | | | | | | | |
| Ratio | $V_{CM}$ = ±13.5 V | 110 | 132 | | 114 | 132 | | dB |
| | $T_{MIN}$ to $T_{MAX}$ | 108 | 128 | | 108 | 128 | | dB |
| INPUT CURRENT NOISE | 0.1 Hz to 10 Hz | | 3 | | | 3 | | pA p-p |
| | f = 10 Hz | | 50 | | | 50 | | fA/√Hz |
| INPUT VOLTAGE NOISE | 0.1 Hz to 10 Hz | | 0.5 | | | 0.5 | 1.0 | µV p-p |
| | f = 10 Hz | | 17 | | | 17 | | nV/√Hz |
| | f = 1 kHz | | 15 | 22 | | 15 | 22 | nV/√Hz |
| OPEN-LOOP GAIN | $V_O$ = ±12 V | | | | | | | |
| | $R_{LOAD}$ = 10 kΩ | 200 | 2000 | | 400 | 2000 | | V/mV |
| | $T_{MIN}$ to $T_{MAX}$ | 150 | 1500 | | 300 | 1500 | | V/mV |
| | $V_O$ = ±10 V | | | | | | | |
| | $R_{LOAD}$ = 2 kΩ | 200 | 1000 | | 300 | 1000 | | V/mV |
| | $T_{MIN}$ to $T_{MAX}$ | 150 | 1000 | | 200 | 1000 | | V/mV |
| OUTPUT CHARACTERISTICS | | | | | | | | |
| Voltage Swing | $R_{LOAD}$ = 10 kΩ | ±13 | ±14 | | ±13 | ±14 | | V |
| | $T_{MIN}$ to $T_{MAX}$ | ±13 | ±14 | | ±13 | ±14 | | V |
| Current | Short Circuit | | ±15 | | | ±15 | | mA |
| Capacitive Load | | | | | | | | |
| Drive Capability | Gain = +1 | | 10,000 | | | 10,000 | | pF |

| Parameter | Conditions | AD706J/A Min | AD706J/A Typ | AD706J/A Max | AD706K/B Min | AD706K/B Typ | AD706K/B Max | Units |
|---|---|---|---|---|---|---|---|---|
| POWER SUPPLY | | | | | | | | |
| Rated Performance | | | ±15 | | | ±15 | | V |
| Operating Range | | ±2.0 | | ±18 | ±2.0 | | ±18 | V |
| Quiescent Current, Total | | | 0.75 | 1.2 | | 0.75 | 1.2 | mA |
| | $T_{MIN}$ to $T_{MAX}$ | | 0.8 | 1.4 | | 0.8 | 1.4 | mA |
| TRANSISTOR COUNT | # of Transistors | | 90 | | | 90 | | |

NOTES
[1]Bias current specifications are guaranteed maximum at either input.
[2]Input bias current match is the difference between corresponding inputs ($I_B$ of –IN of Amplifier #1 minus $I_B$ of –IN of Amplifier #2).

CMRR match is the difference between $\frac{\Delta V_{OS}\ \#1}{\Delta V_{CM}}$ for amplifier #1 and $\frac{\Delta V_{OS}\ \#2}{\Delta V_{CM}}$ for amplifier #2 expressed in dB.

PSRR match is the difference between $\frac{\Delta V_{OS}\ \#1}{\Delta V_{SUPPLY}}$ for amplifier #l and $\frac{\Delta V_{OS}\ \#2}{\Delta V_{SUPPLY}}$ for amplifier #2 expressed in dB.

All min and max specifications are guaranteed.
Specifications subject to change without notice.

## ABSOLUTE MAXIMUM RATINGS[1]

Supply Voltage . . . . . ±18 V
Internal Power Dissipation
(Total: Both Amplifiers)[2] . . . . . 650 mW
Input Voltage . . . . . $\pm V_S$
Differential Input Voltage[3] . . . . . +0.7 Volts
Output Short Circuit Duration . . . . . Indefinite
Storage Temperature Range (Q) . . . . . –65°C to +150°C
Storage Temperature Range (N, R) . . . . . –65°C to +125°C
Operating Temperature Range
AD706J/K . . . . . 0°C to +70°C
AD706A/B . . . . . –40°C to +85°C
Lead Temperature (Soldering 10 secs) . . . . . +300°C

NOTES
[1]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.
[2]Specification is for device in free air:
8-Lead Plastic Package: $\theta_{JA}$ = 100°C/Watt
8-Lead Cerdip Package: $\theta_{JA}$ = 110°C/Watt
8-Lead Small Outline Package: $\theta_{JA}$ = 155°C/Watt
[3]The input pins of this amplifier are protected by back-to-back diodes. If the differential voltage exceeds ±0.7 volts, external series protection resistors should be added to limit the input current to less than 25 mA.

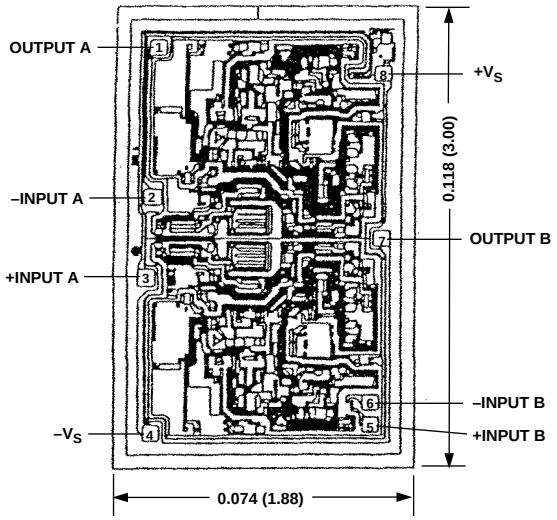
## ORDERING GUIDE

| Model | Temperature Range | Description | Package Option* |
|---|---|---|---|
| AD706AN | –40°C to +85°C | Plastic DIP | N-8 |
| AD706JN | 0°C to +70°C | Plastic DIP | N-8 |
| AD706KN | 0°C to +70°C | Plastic DIP | N-8 |
| AD706JR | 0°C to +70°C | SOIC | R-8 |
| AD706JR-REEL | 0°C to +70°C | Tape and Reel | |
| AD706AQ | –40°C to +85°C | Cerdip | Q-8 |
| AD706BQ | –40°C to +85°C | Cerdip | Q-8 |
| AD706AR | –40°C to +85°C | SOIC | R-8 |
| AD706AR-REEL | –40°C to +85°C | Tape and Reel | |

*N = Plastic DIP; Q = Cerdip, R = Small Outline Package.

## METALIZATION PHOTOGRAPH

Dimensions shown in inches and (mm).
Contact factory for latest dimensions.




## 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 AD706 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.

# AD706–Typical Characteristics (@ +25°C, $V_S$ = ±15 V, unless otherwise noted)

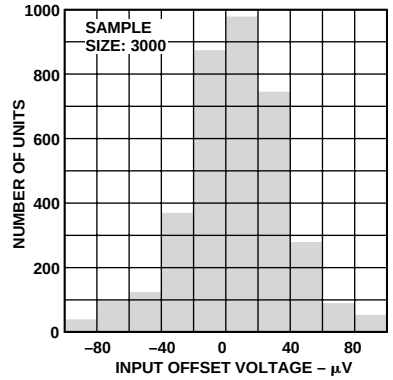



*Figure 2. Typical Distribution of Input Offset Voltage*

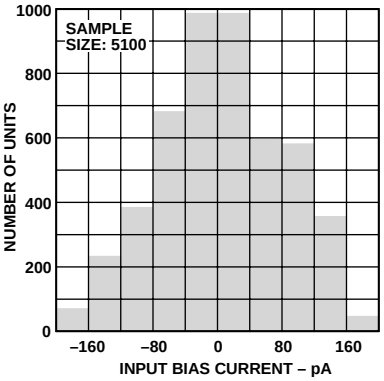



*Figure 3. Typical Distribution of Input Bias Current*

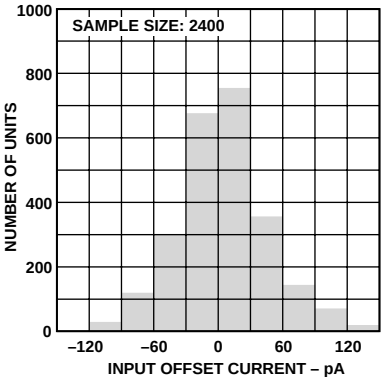



*Figure 4. Typical Distribution of Input Offset Current*

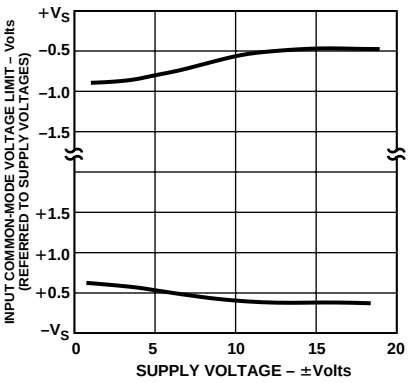



*Figure 5. Input Common-Mode Voltage Range vs. Supply Voltage*

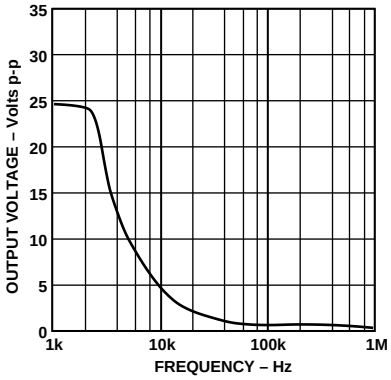



*Figure 6. Large Signal Frequency Response*

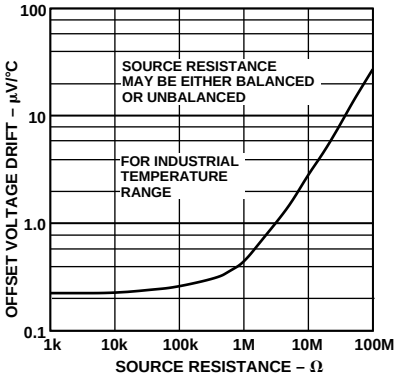



*Figure 7. Offset Voltage Drift vs. Source Resistance*

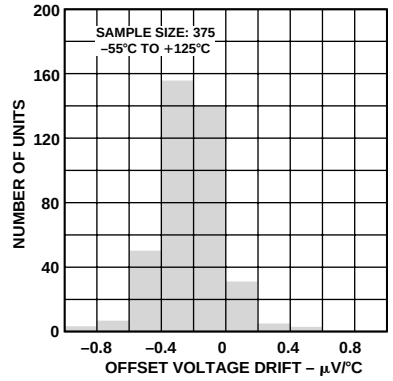



*Figure 8. Typical Distribution of Offset Voltage Drift*

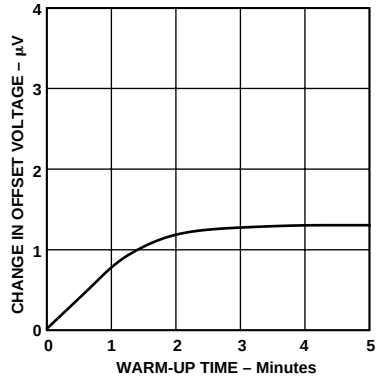



*Figure 9. Change in Input Offset Voltage vs. Warm-Up Time*

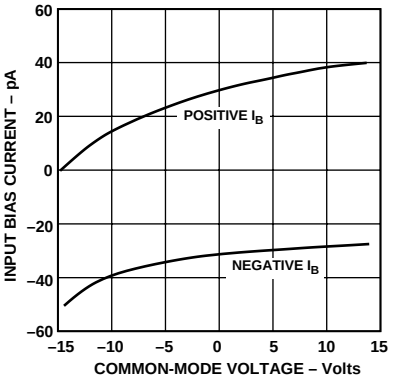



*Figure 10. Input Bias Current vs. Common-Mode Voltage*

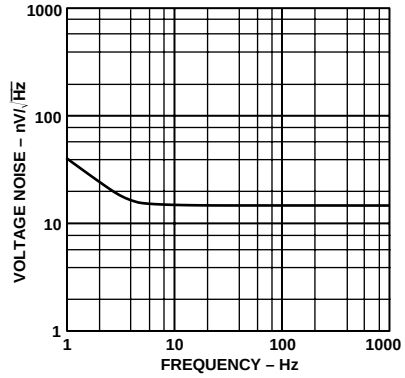



*Figure 11. Input Noise Voltage Spectral Density*

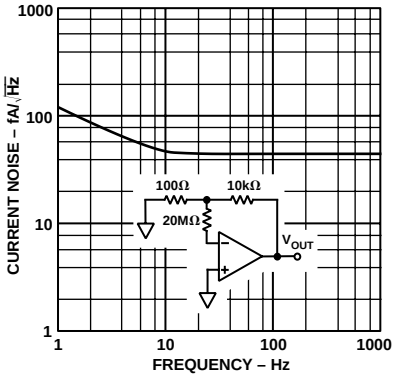



*Figure 12. Input Noise Current Spectral Density*

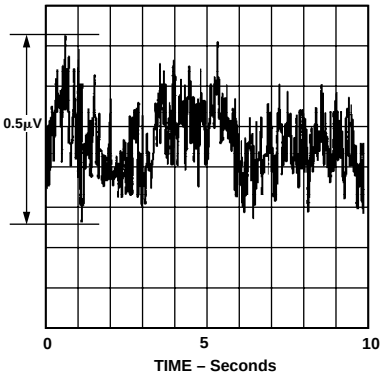



*Figure 13. 0.1 Hz to 10 Hz Noise Voltage*

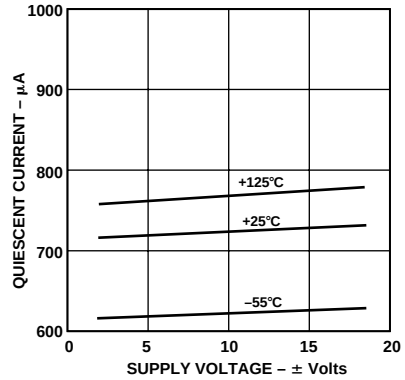



*Figure 14. Quiescent Supply Current vs. Supply Voltage*

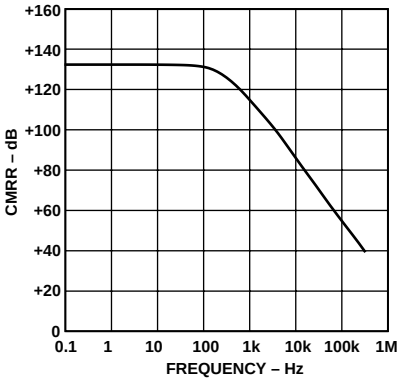



*Figure 15. Common-Mode Rejection Ratio vs. Frequency*

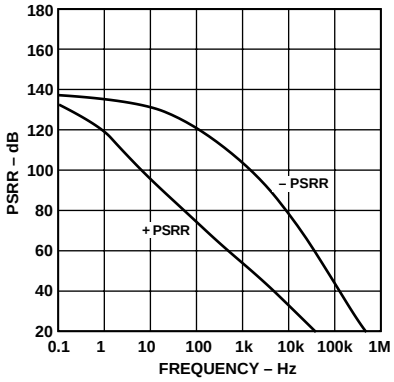



*Figure 16. Power Supply Rejection Ratio vs. Frequency*

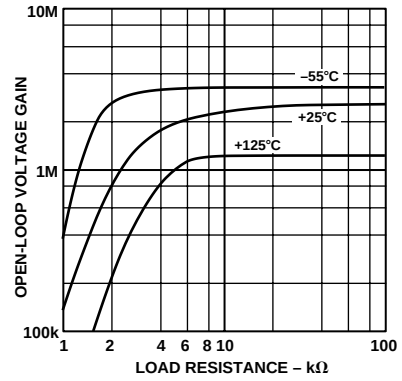



*Figure 17. Open-Loop Gain vs. Load Resistance vs. Load Resistance*

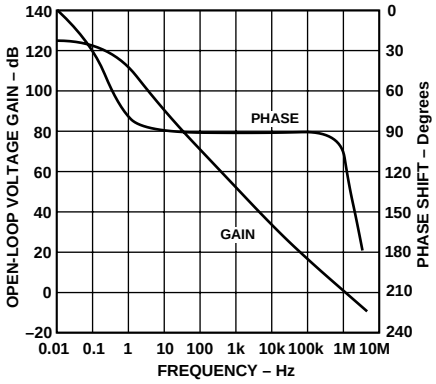



*Figure 18. Open-Loop Gain and Phase Shift vs. Frequency*

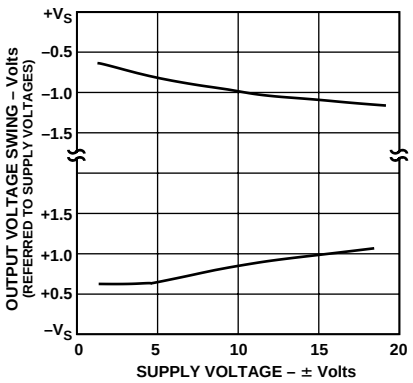



*Figure 19. Output Voltage Swing vs. Supply Voltage*

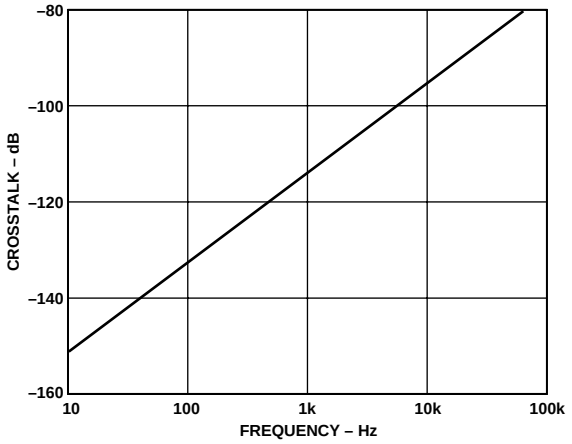



*Figure 20a. Crosstalk vs. Frequency*

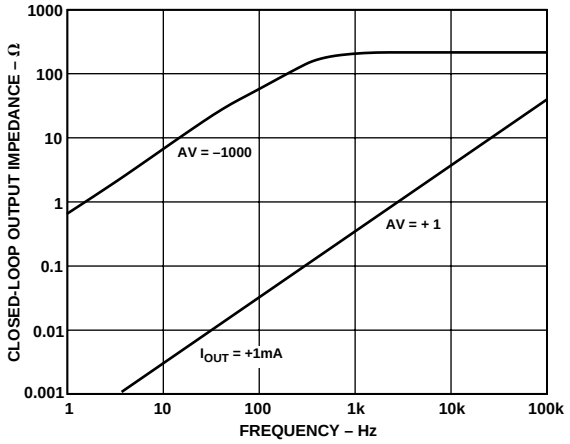



*Figure 21. Magnitude of Closed-Loop Output Impedance vs. Frequency*

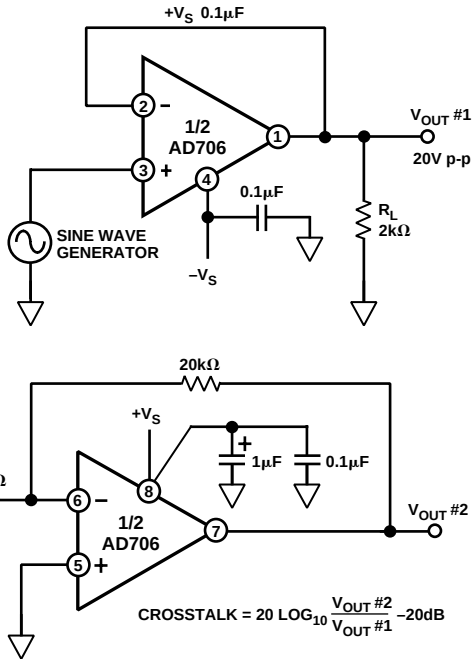



*Figure 20b. Crosstalk Test Circuit*

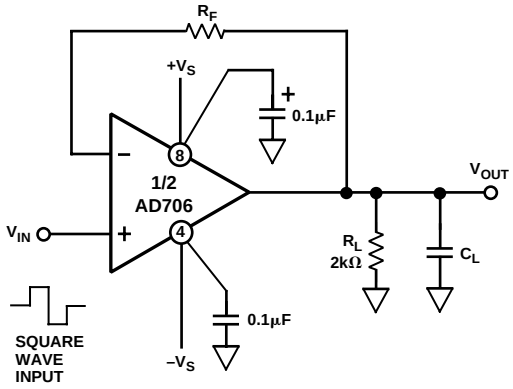



*Figure 22a. Unity Gain Follower (For Large Signal Applications, Resistor $R_F$ Limits the Current Through the Input Protection Diodes)*

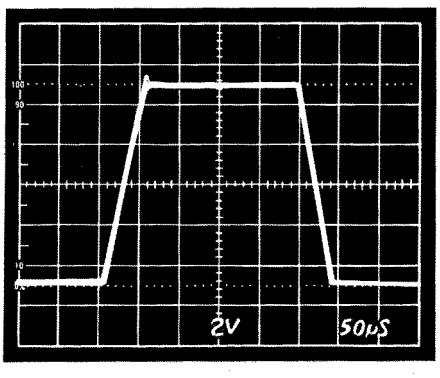



*Figure 22b. Unity Gain Follower Large Signal Pulse Response, $R_F$ = 10 kΩ, $C_L$ = 1,000 pF*

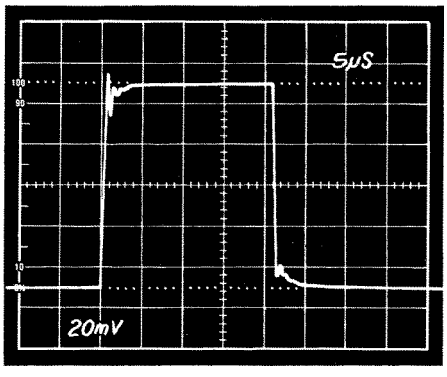



*Figure 22c. Unity Gain Follower Small Signal Pulse Response, $R_F$ = 0 Ω, $C_L$ = 100 pF*

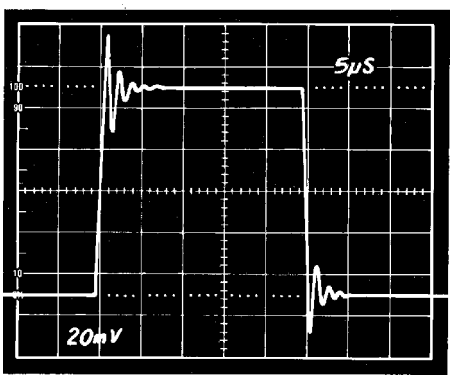



*Figure 22d. Unity Gain Follower Small Signal Pulse Response, $R_F$ = 0 Ω, $C_L$ = 1000 pF*

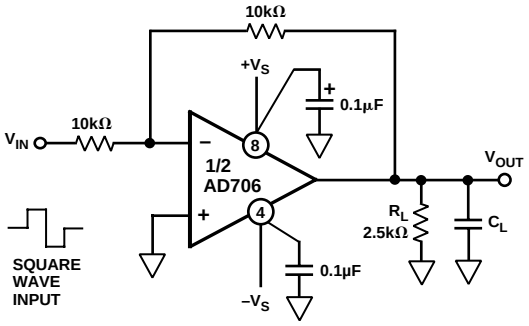



*Figure 23a. Unity Gain Inverter Connection*

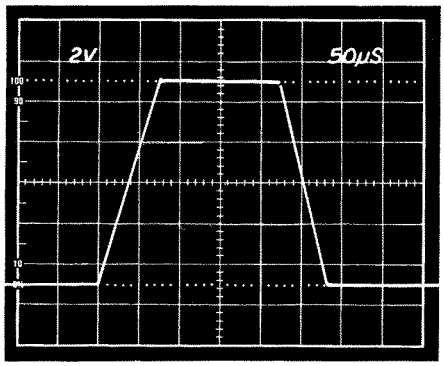



*Figure 23b. Unity Gain Inverter Large Signal Pulse Response, $C_L$ = 1,000 pF*

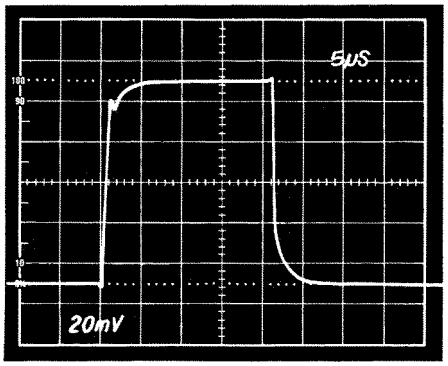



*Figure 23c. Unity Gain Inverter Small Signal Pulse Response, $C_L$ = 100 pF*

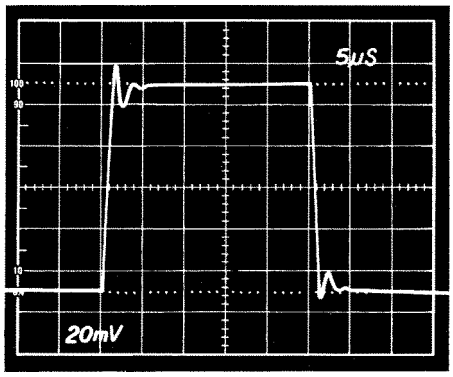


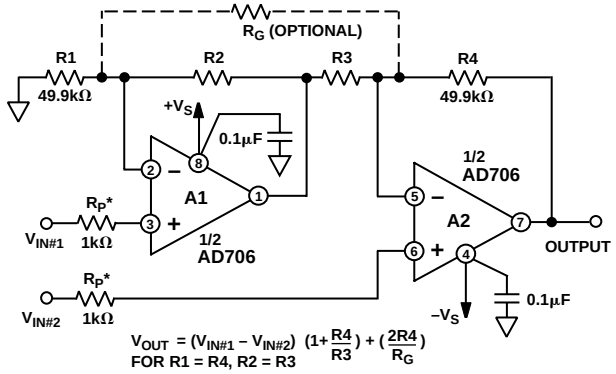

*Figure 23d. Unity Gain Inverter Small Signal Pulse Response, $C_L$ = 1000 pF*

Figure 24 shows an in-amp circuit that has the obvious advantage of requiring only one AD706, rather than three op amps, with subsequent savings in cost and power consumption. The transfer function of this circuit (without $R_G$) is:

$$V_{OUT} = (V_{IN\#1} - V_{IN\#2})\left(1+\frac{R4}{R3}\right)$$

*for R1 = R4 and R2 = R3*

Input resistance is high, thus permitting the signal source to have an unbalanced output impedance.




*OPTIONAL INPUT PROTECTION RESISTOR FOR GAINS GREATER THAN 100 OR INPUT VOLTAGES EXCEEDING THE SUPPLY VOLTAGE.

*Figure 24. A Two Op-Amp Instrumentation Amplifier*

Furthermore, the circuit gain may be fine trimmed using an optional trim resistor, $R_G$. Like the three op-amp circuit, CMR increases with gain, once initial trimming is accomplished—but CMR is still dependent upon the ratio matching of Resistors R1 through R4. Resistor values for this circuit, using the optional gain resistor, $R_G$, can be calculated using:

$$R1 = R4 = 49.9\,k\Omega$$

$$R2 = R3 = \frac{49.9\,k\Omega}{0.9\,G - 1}$$

$$R_G = \frac{99.8\,k\Omega}{0.06\,G}$$

*where G = Desired Circuit Gain*

Table I provides practical 1% resistance values. (Note that without resistor $R_G$, R2 and R3 = 49.9 kΩ/G–1.)

**Table I. Operating Gains of Amplifiers A1 and A2 and Practical 1% Resistor Values for the Circuit of Figure 24**

| Circuit Gain | Gain of A1 | Gain of A2 | R2, R3 | R1, R4 |
|---|---|---|---|---|
| 1.10 | 11.00 | 1.10 | 499 kΩ | 49.9 kΩ |
| 1.33 | 4.01 | 1.33 | 150 kΩ | 49.9 kΩ |
| 1.50 | 3.00 | 1.50 | 100 kΩ | 49.9 kΩ |
| 2.00 | 2.00 | 2.00 | 49.9 kΩ | 49.9 kΩ |
| 10.1 | 1.11 | 10.10 | 5.49 kΩ | 49.9 kΩ |
| 101.0 | 1.01 | 101.0 | 499 Ω | 49.9 kΩ |
| 1001 | 1.001 | 1001 | 49.9 Ω | 49.9 kΩ |

For a much more comprehensive discussion of in-amp applications, refer to the *Instrumentation Amplifier Applications Guide*—available free from Analog Devices, Inc.

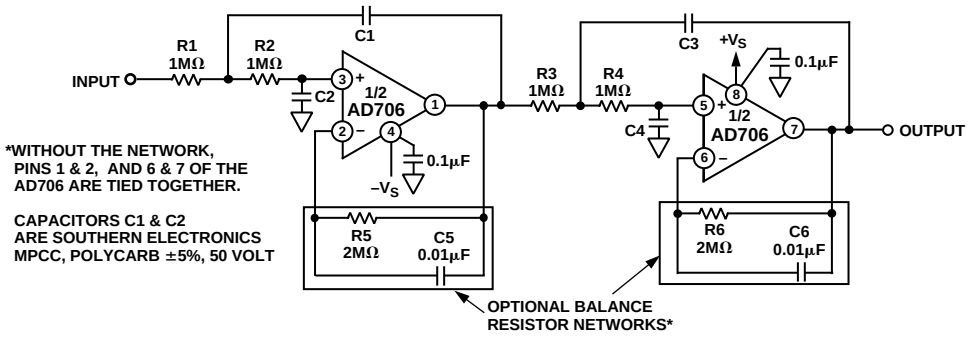



*Figure 25. A 1 Hz, 4-Pole Active Filter*

**A 1 Hz, 4-Pole, Active Filter**

Figure 25 shows the AD706 in an active filter application. An important characteristic of the AD706 is that both the input bias current, input offset current and their drift remain low over most of the op amp's rated temperature range. Therefore, for most applications, there is no need to use the normal balancing resistor. Adding the balancing resistor enhances performance at high temperatures, as shown by Figure 26.

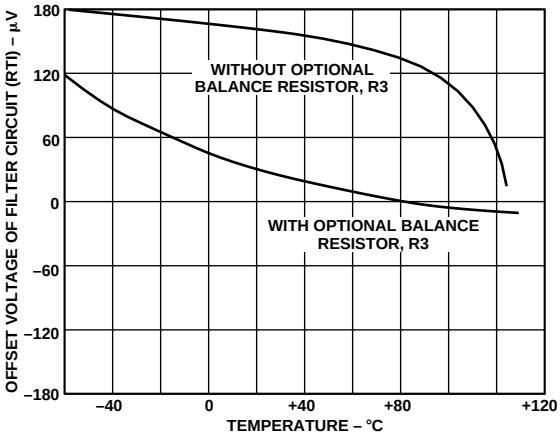



*Figure 26. $V_{OS}$ vs. Temperature Performance of the 1 Hz Filter*

**Table II. 1 Hz, 4-Pole, Low Pass Filter Recommended Component Values**

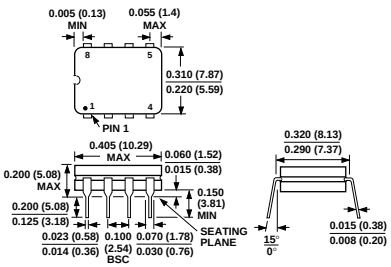
| Desired Low Pass Response | Section 1 Frequency (Hz) | Q | Section 2 Frequency (Hz) | Q | C1 (μF) | C2 (μF) | C3 (μF) | C4 (μF) |
|---|---|---|---|---|---|---|---|---|
| Bessel | 1.43 | 0.522 | 1.60 | 0.806 | 0.116 | 0.107 | 0.160 | 0.0616 |
| Butterworth | 1.00 | 0.541 | 1.00 | 1.31 | 0.172 | 0.147 | 0.416 | 0.0609 |
| 0.1 dB Chebychev | 0.648 | 0.619 | 0.948 | 2.18 | 0.304 | 0.198 | 0.733 | 0.0385 |
| 0.2 dB Chebychev | 0.603 | 0.646 | 0.941 | 2.44 | 0.341 | 0.204 | 0.823 | 0.0347 |
| 0.5 dB Chebychev | 0.540 | 0.705 | 0.932 | 2.94 | 0.416 | 0.209 | 1.00 | 0.0290 |
| 1.0 dB Chebychev | 0.492 | 0.785 | 0.925 | 3.56 | 0.508 | 0.206 | 1.23 | 0.0242 |

NOTE
Specified Values are for a –3 dB point of 1.0 Hz. For other frequencies simply scale capacitors C1 through C4 directly, i.e.: for 3 Hz Bessel response, C1 = 0.0387 μF, C2 = 0.0357 μF, C3 = 0.0533 μF, C4 = 0.0205 μF.

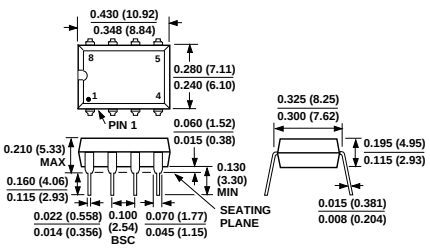
## OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

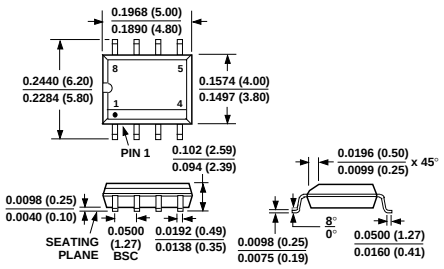
**Cerdip (Q-8)**




**Plastic Mini-DIP (N-8)**




**SOIC (R-8)**








C1429b–2–12/97

PRINTED IN U.S.A.