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ANALOG DEVICES

Dual Picoampere Input Current Bipolar Op Amp

AD706

FEATURES

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-Pin Plastic Mini-DIP, Hermetic Cerdip and Surface Mount (SOIC) Packages
- Available in Tape and Reel in Accordance with EIA-481A Standard
- MIL-STD-883B Processing Available
- Single Version: AD705, Quad Version (AD704)

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

PRODUCT DESCRIPTION

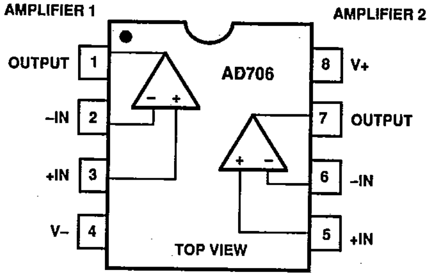
The AD706 is a dual, low power, bipolar op amp that has the low input bias current of a BiFET amplifier but which offers a significantly lower I_B drift over temperature. It utilizes superbeta bipolar input transistors to achieve picoampere input bias current levels (similar to FET input amplifiers at 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 OP-07, the AD706 does not require the commonly used "balancing" resistor. Furthermore, the current noise is 1/5 that of the OP-07 which makes this amplifier usable with much higher source impedances. At 1/6 the supply current (per amplifier) of the OP-07, 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. The AD706T is rated over the military temperature range of −55°C to +125°C and is available processed to MIL-STD-883B, Rev. C.

CONNECTION DIAGRAM

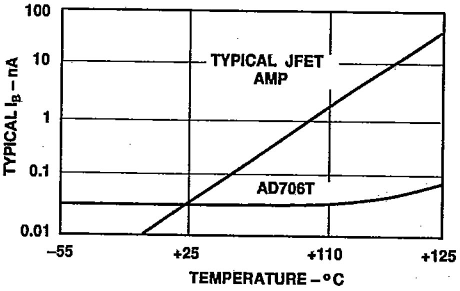
Plastic Mini-DIP (N)
Cerdip (Q) and
Plastic SOIC (R) Packages



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

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.



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

Parameter	Conditions	AD706J/A			AD706K/B			AD706T			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
INPUT OFFSET VOLTAGE											
Initial Offset			30	100		10	50		10	50	µV
Offset	T_{min} to T_{max}		40	150		25	100		25	100	µV
vs. Temp, Average TC			0.2	1.5		0.2	0.6		0.2	0.6	µV/°C
vs. Supply (PSRR)	V_S = ±2 V to ±18 V	110	132		112	132		112	132		dB
T_{min} to T_{max}	V_S = ±2.5 V to ±18 V	106	126		108	126		108	126		dB
Long Term Stability			0.3			0.3			0.3		µV/month
INPUT BIAS CURRENT[1]											
	V_{CM} = 0 V		50	200		30	110		30	120	pA
	V_{CM} = ±13.5 V			250			160			170	pA
vs. Temp, Average TC			0.3			0.2			0.2		pA/°C
T_{min} to T_{max}	V_{CM} = 0 V			300			200			400	pA
T_{min} to T_{max}	V_{CM} = ±13.5 V			400			300			600	pA
INPUT OFFSET CURRENT	V_{CM} = 0 V		30	150		30	100		30	100	pA
	V_{CM} = ±13.5 V			250			200			200	pA
vs. Temp, Average TC			0.6			0.4			0.4		pA/°C
T_{min} to T_{max}	V_{CM} = 0 V		80	250		80	200		80	300	pA
T_{min} to T_{max}	V_{CM} = ±13.5 V		80	350		80	300		80	450	pA
MATCHING CHARACTERISTICS											
Offset Voltage				150			75			75	µV
	T_{min} to T_{max}			250			150			200	µV
Input Bias Current[2]				300			150			200	pA
	T_{min} to T_{max}			500			250			400	pA
Common-Mode Rejection		106			110			110			dB
	T_{min} to T_{max}	106			108			108			dB
Power Supply Rejection		106			110			110			dB
	T_{min} to T_{max}	104			106			106			dB
Crosstalk (Figure 19a)	@ f = 10 Hz R_L = 2 kΩ		150			150			150		dB
FREQUENCY RESPONSE											
Unity Gain Crossover Frequency			0.8			0.8			0.8		MHz
Slew Rate	G = −1		0.15			0.15			0.15		V/µs
	T_{min} to T_{max}		0.15			0.15			0.15		V/µs
INPUT IMPEDANCE											
Differential			40//2			40//2			40//2		MΩ//pF
Common Mode			300//2			300//2			300//2		GΩ//pF
INPUT VOLTAGE RANGE											
Common-Mode Voltage		±13.5	±14		±13.5	±14		±13.5	±14		V
Common-Mode Rejection Ratio	V_{CM} = ±13.5 V	110	132		114	132		114	132		dB
	T_{min} to T_{max}	108	128		108	128		108	128		dB
INPUT CURRENT NOISE	0.1 Hz to 10 Hz		3			3			3		pA p–p
	f = 10 Hz		50			50			50		fA/$\sqrt{Hz}$
INPUT VOLTAGE NOISE	0.1 Hz to 10 Hz		0.5			0.5	1.0		0.5	1.0	µV p–p
	f = 10 Hz		17			17			17		nV/$\sqrt{Hz}$
	f = 1 kHz		15	22		15	22		15	22	nV/$\sqrt{Hz}$
OPEN-LOOP GAIN	V_O = ±12 V R_{LOAD} = 10 kΩ	200	2000		400	2000		400	2000		V/mV
	T_{min} to T_{max}	150	1500		300	1500		300	1500		V/mV
	V_O = ±10 V R_{LOAD} = 2 kΩ	200	1000		300	1000		200	1000		V/mV
	T_{min} to T_{max}	150	1000		200	1000		100	1000		V/mV
OUTPUT CHARACTERISTICS											
Voltage Swing	R_{LOAD} = 10 kΩ	±13	±14		±13	±14		±13	±14		V
	T_{min} to T_{max}	±13	±14		±13	±14		±13	±14		V
Current	Short Circuit		±15			±15			±15		mA
Capacitive Load Drive Capability	Gain = +1		10,000			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	AD706T Min	AD706T Typ	AD706T Max	Units
POWER SUPPLY											
Rated Performance			±15			±15			±15		V
Operating Range		±2.0		±18	±2.0		±18	±2.0		±18	V
Quiescent Current, Total			0.75	1.2		0.75	1.2		0.75	1.2	mA
	T_{min} to T_{max}		0.8	1.4		0.8	1.4		0.8	1.6	mA
TRANSISTOR COUNT	# of Transistors		90			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 #1 and $\frac{\Delta V_{OS}\#2}{\Delta V_{SUPPLY}}$ for amplifier #2 expressed in dB.

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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
AD706T	−55°C to +125°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 and 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-Pin Plastic Package: θ_{JA} = 100°C/Watt
8-Pin Cerdip Package: θ_{JA} = 110°C/Watt
8-Pin Small Outline Package: θ_{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.

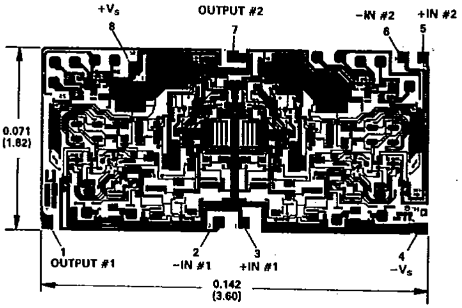
ORDERING GUIDE

Model	Temperature Range	Description	Package Option*
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 & 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 & Reel	
AD706TQ	−55°C to +125°C	Cerdip	Q-8

*For outline information see Package Information section.

METALIZATION PHOTOGRAPH

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



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

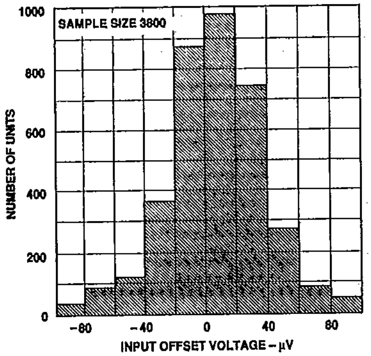

Figure 1. Typical Distribution of Input Offset Voltage

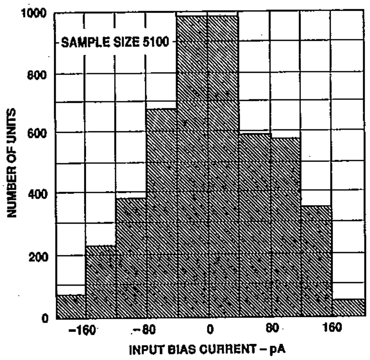

Figure 2. Typical Distribution of Input Bias Current

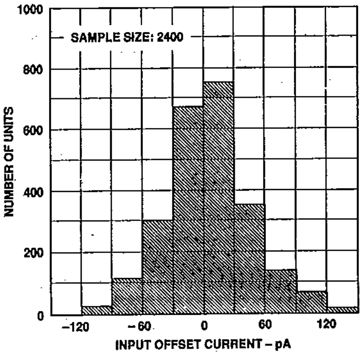

Figure 3. Typical Distribution of Input Offset Current

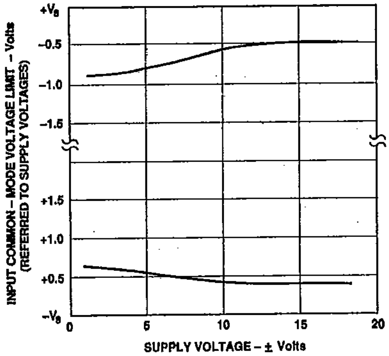

Figure 4. Input Common-Mode Voltage Range vs. Supply Voltage

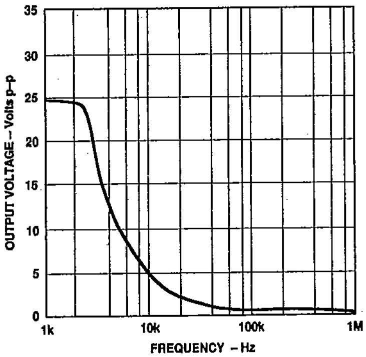

Figure 5. Large Signal Frequency Response

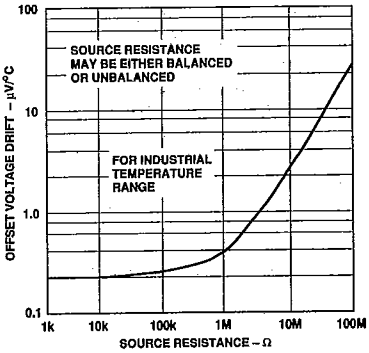

Figure 6. Offset Voltage Drift vs. Source Resistance

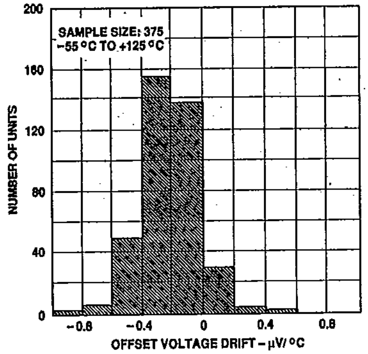

Figure 7. Typical Distribution of Offset Voltage Drift

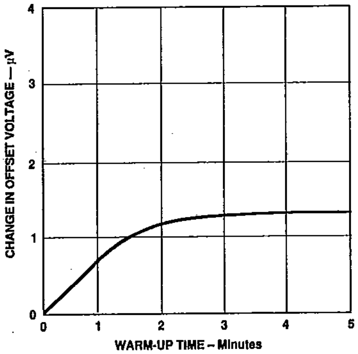

Figure 8. Change in Input Offset Voltage vs. Warm-up Time

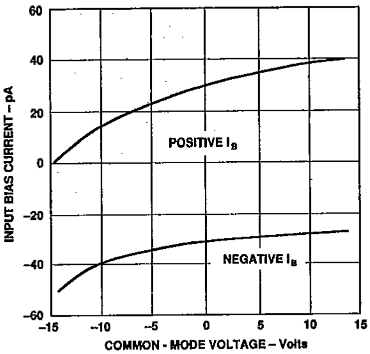

Figure 9. Input Bias Current vs. Common-Mode Voltage

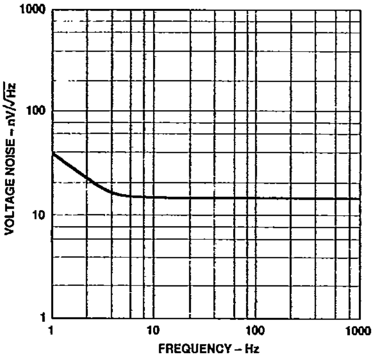

Figure 10. Input Noise Voltage Spectral Density

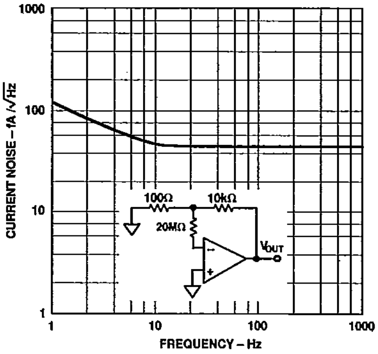

Figure 11. Input Noise Current Spectral Density

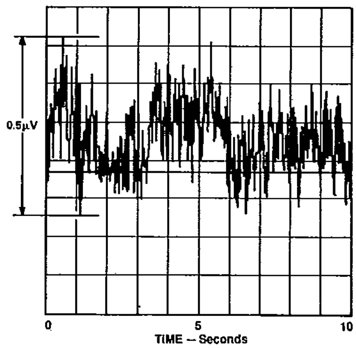

Figure 12. 0.1 Hz to 10 Hz Noise Voltage

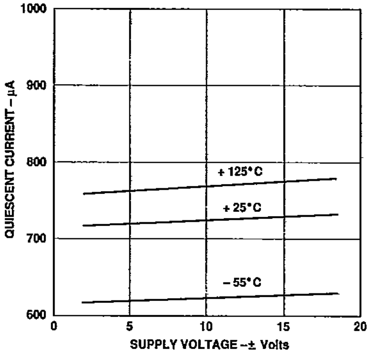

Figure 13. Quiescent Supply Current vs. Supply Voltage

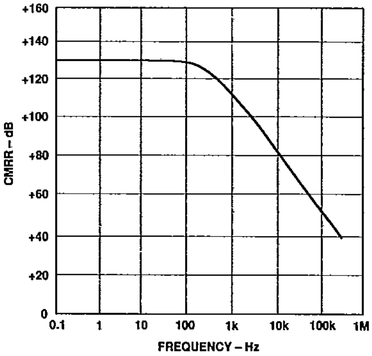

Figure 14. Common-Mode Rejection Ratio vs. Frequency

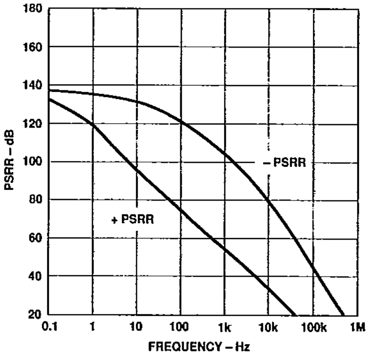

Figure 15. Power Supply Rejection Ratio vs. Frequency

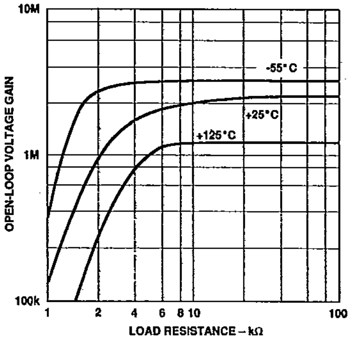

Figure 16. Open-Loop Gain vs. Load Resistance vs. Temperature

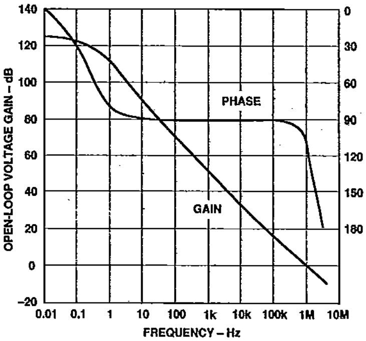

Figure 17. Open-Loop Gain and Phase Shift vs. Frequency

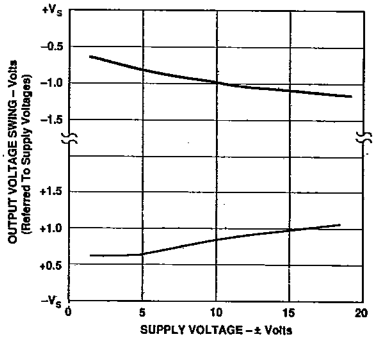

Figure 18. Output Voltage Swing vs. Supply Voltage

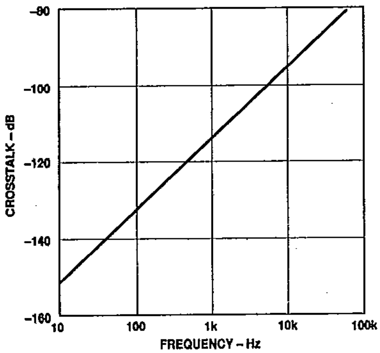

Figure 19a. Crosstalk vs. Frequency

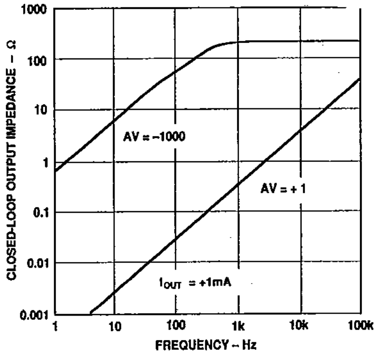

Figure 20. Magnitude of Closed-Loop Output Impedance vs. Frequency

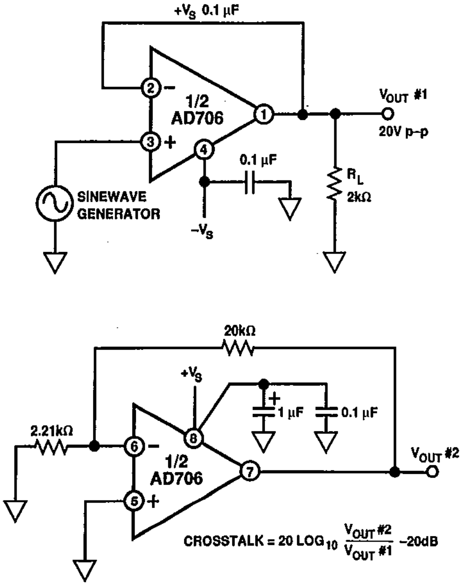

Figure 19b. Crosstalk Test Circuit

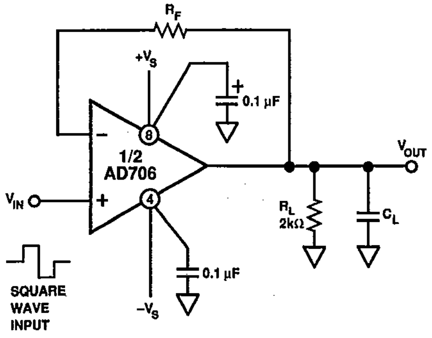

Figure 21a. Unity Gain Follower (For Large Signal Applications, Resistor R_F Limits the Current Through the Input Protection Diodes.)

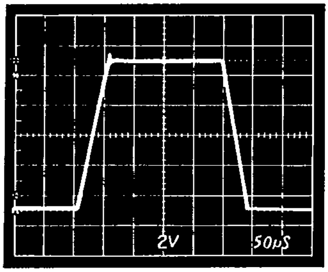

Figure 21b. Unity Gain Follower Large Signal Pulse Response R_F = 10 kΩ, C_L = 1,000 pF

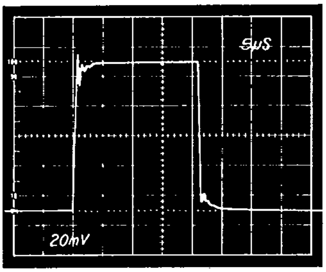

Figure 21c. Unity Gain Follower Small Signal Pulse Response R_F = 0 Ω, C_L = 100 pF

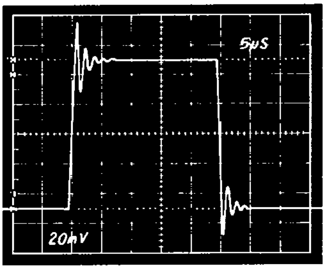

Figure 21d. Unity Gain Follower Small Signal Pulse Response R_F = 0 Ω, C_L = 1000 pF

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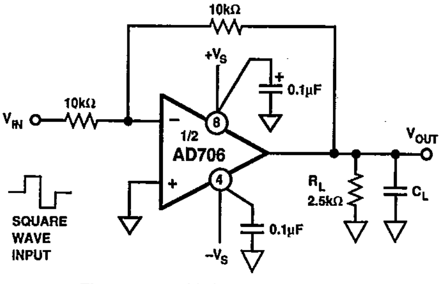


Figure 22a. Unity Gain Inverter Connection

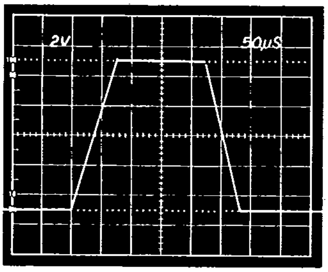


Figure 22b. Unity Gain Inverter Large Signal Pulse Response C_L = 1,000 pF

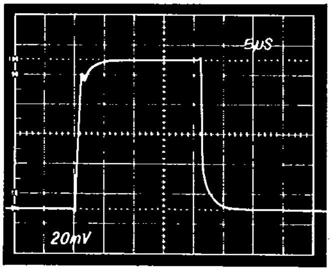


Figure 22c. Unity Gain Inverter Small Signal Pulse Response C_L = 100 pF

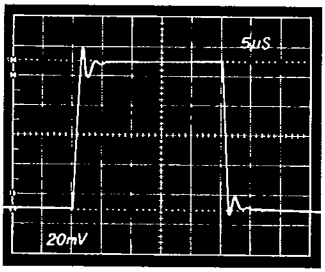


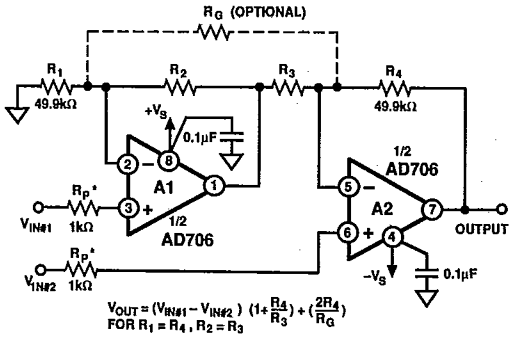
Figure 22d. Unity Gain Inverter Small Signal Pulse Response C_L = 1000 pF

Figure 23 shows an in-amp circuit which 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:

$$V_{OUT} = (V_{IN\#1} - V_{IN\#2}) \left(1 + \frac{R_4}{R_3}\right)$$

$$\textit{for } R_1 = R_4 \textit{ and } R_2 = R_3$$

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



$$V_{OUT} = (V_{IN\#1} - V_{IN\#2})\ (1 + \frac{R_4}{R_3}) + (\frac{2R_4}{R_G})$$
FOR $R_1 = R_4$, $R_2 = R_3$

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

Figure 23. 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 R_1 through R_4. Resistor values for this circuit using the optional gain resistor, R_G, can be calculated using:

$$R_1 = R_4 = 49.9\ k\Omega$$

$$R_2 = R_3 = \frac{49.9\ k\Omega}{0.9\ G-1}$$

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

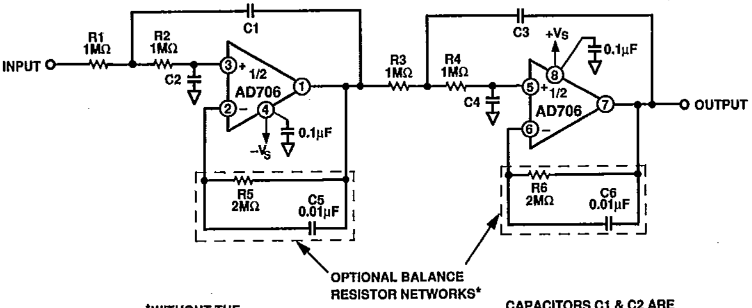
$$\textit{where } G = \textit{Desired Circuit Gain}$$

Table I provides practical 1% resistance values. (Note that without resistor R_G, R_2 and R_3 = 49.9 kΩ/G−1.)

Table 1. Operating Gains of Amplifiers A1 and A2 and Practical 1% Resistor Values for the Circuit of Figure 23

Circuit Gain	Gain of A1	Gain of A2	R_2, R_3	R_1, R_4
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 Application Guide*—available free from Analog Devices, Inc.



*WITHOUT THE NETWORK, PINS 1 & 2, AND 6 & 7 OF THE AD706 ARE TIED TOGETHER.

CAPACITORS C1 & C2 ARE SOUTHERN ELECTRONICS MPCC, POLYCARB ±5%, 50 VOLT

Figure 24. A 1 Hz, 4-Pole Active Filter

A 1 Hz, 4-Pole, Active Filter

Figure 24 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 25.

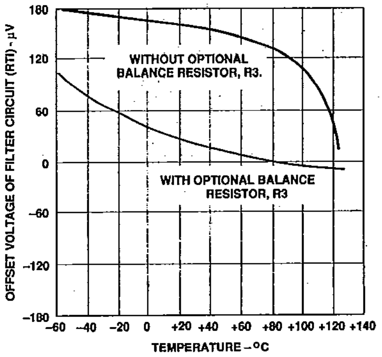


Figure 25. V_{OS} vs. Temperature Performance of the 1 Hz Filter

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 = 0.0357µF, C3 = 0.0533 µF, C4 = 0.0205 µF.