DESCRIPTION

The Model 144 FET Operational Amplifier was specifically designed to trade-off high performance in order to achieve the lowest possible cost. As such, the Model 144 is ideal for most general purpose applications, specifically where the bias current, input impedance and/or frequency response of transistor input op amps is not adequate. Analog Devices offers a broad line of other FET op amps for specialized and high performance applications which offer tighter specifications on key parameters. Examples are: low voltage drift (Model 146), high common mode rejection (Model 143), ultra fast response (Models 148/149), and miniature hybrid construction (Model P501).

The Model 144 presents an economically attractive alternative for engineers who are now using IC op amps preceded by an FET pair. Additionally, the performance of the Model 144 exceeds that of most "IC plus FET" designs, and unlike many in-house designs, performance is guaranteed by testing.

Frequency response, slewing rate and noise characteristics are outstanding features of the Model 144. Two versions of the Model 144 are designated A and K. The Model 144K has improved voltage drift of $30\mu V/^{\circ}C$ (max.).

WHERE TO USE THE MODEL 144

FET op amps are usually the best choice when the amplifier is to be driven from a high-impedance source, where an extremely high-input impedance is desired to minimize loading of the driving circuitry, or for the measurement of very small currents. The benefits of FET op amps in these applications manifest themselves in two ways:

1. The input impedances (differential and common mode) are extremely high. The common mode impedance is particularly important for "buffer" amplifiers (noninverting connection), as this largely determines the input impedance in this configuration.

2. Bias currents (the small currents flowing into or out of the input terminals of all differential amplifiers) are extremely low. This allows high-accuracy measurement of very small currents. It is also important because bias currents develop equivalent voltage offset errors across the resistance "seen" by each input with respect to ground. This is usually the input resistor in inverters, or the source impedance in noninverting buffer applications. This means that bias currents must be low for use with high-value resistances in order that the equivalent voltage offsets remain within reasonable limits. Another area of application in which low bias currents are required is capacitor charge circuits. These include integrators, differentiators, sample-and-hold circuits, etc. The accuracy of this class of circuits is dependent on the magnitude of bias current.

SOME DISADVANTAGES

FET amplifiers like the Model 144 do have certain limitations. Among these is CMRR which is usually compromised in low-cost FET op amps as compared to bipolar transistor types. This is not at all important when the amplifier is to be connected as an inverter. However, when connected as a noninverter the amplifier will exhibit a common mode error which is inversely proportional to the specified CMRR.

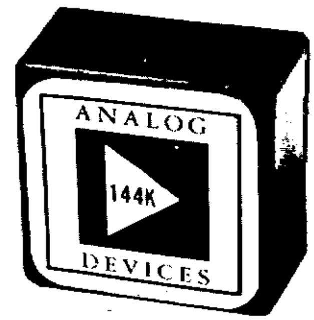
Another compromise generally made in low-cost FET op amps is in the voltage drift specifications. Typically, voltage drift of FET types exceeds that of bipolar transistor amplifiers. This can usually be tolerated because, in high-impedance circuits, the equivalent voltage drift due to bias current is the major factor in overall drift performance.

MODEL 144A/K
GENERAL PURPOSE
LOW COST FET OP–AMP

FEATURES

Bias Current	100pA max
Bandwidth	4MHz
Slew Rate	$6V/\mu sec$
Low Noise	$3\mu V$ rms

Model 144 A (1—24) £ 9/–/–.
Model 144 K (1—24) £ 4 /–/–.
Socket AC 1003 £ 1/2/6.



APPLICATIONS

- High-Impedance Buffer Amplifiers
- Precision Integrators
- Sample-and-Hold Circuits
- Pico-Amp Current Measurements

ANALOG
DEVICES

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221 Fifth Street
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Kingston-upon-Thames Surrey
Tel. 01-546 6636/01-549 0811/
01-549 1277 Telex: 27383

MODEL 144A/K

GENERAL PURPOSE LOW COST FET OP-AMP

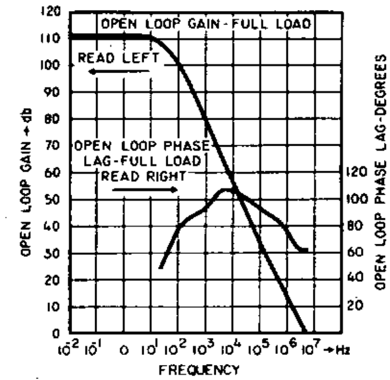
SPECIFICATIONS (typical @ 25°C and ±15VDC unless otherwise noted)

MODEL	144A	144K
OPEN LOOP GAIN		
dc rated load, min	5×10^4	*
RATED OUTPUT		
Voltage, min	±10V	*
Current, min	±5mA	*
Load capacitance range	.01μF	*
FREQUENCY RESPONSE		
Unity gain, small signal	4MHz	*
Full power response, min	100kHz	*
Slewing rate, min	6V/μsec	*
Overload recovery	100μsec	*
INPUT OFFSET VOLTAGE		
External trim pot	500Ω	*
Initial offset, 25°C	±2mV (adj to 0)	*
Avg. vs. temp (−25 to +85°C) max	±100μV/°C	±30μV/°C
vs. supply voltage	±100μV/%	*
vs. time	±250μV/month	*
INPUT BIAS CURRENT		
Initial bias, 25°C, max	(0,−) 100pA	*
Avg. vs. temp	doubles every +10°C	*
vs. supply voltage	±1pA/%	*
INPUT DIFFERENCE CURRENT		
Initial difference, 25°C	±25pA	*
Avg. vs. temp	doubles every +10°C	*
INPUT IMPEDANCE		
Differential	$10^{11}\Omega \parallel 3.5pF$	*
Common mode	$10^{11}\Omega \parallel 3.5pF$	*
INPUT NOISE		
Voltage, .01 to 1Hz, p-p	3μV	*
5Hz to 50kHz, rms	3μV	*
Current, .01 to 1Hz, p-p	.1pA	*
INPUT VOLTAGE RANGE		
Common mode voltage, min	+7, −10V	*
Common mode rejection @ ±5V	60dB	*
Max. safe differential voltage	±15V	*
POWER SUPPLY		
Voltage, rated specification	±15V	*
Voltage, derated specification	±(12 to 18)V	*
Current, quiescent, typ	±4.5mA	*
TEMPERATURE RANGE		
Operating, rated specifications	−25°C to +85°C	+10°C to +60°C
Storage	−55°C to +125°C	*
MECHANICAL		
Case style - pin configuration	M−1	*
Mating socket	AC1003	*
Weight	.52oz.	*

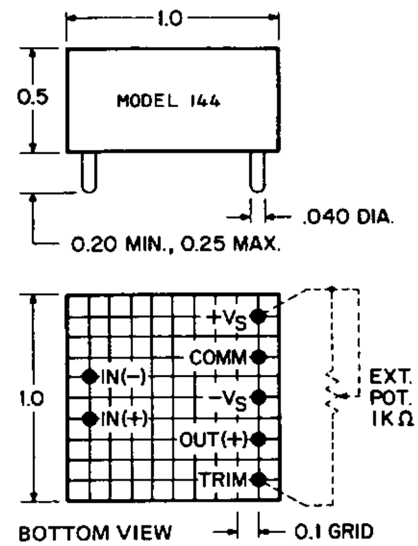
* Specifications same as for Model 144A.

Specifications subject to change without notice.

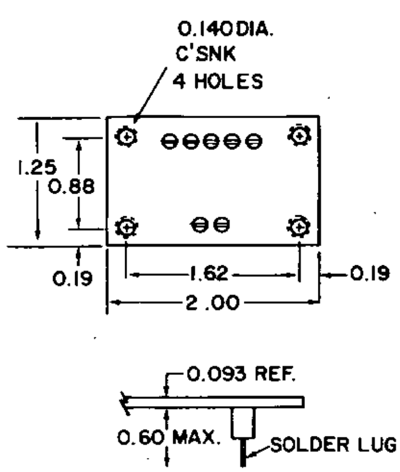
OPEN LOOP RESPONSE AND PHASE LAG



OUTLINE DIMENSIONS



MATING SOCKET AC 1003



NOISE

The Model 144 has exceptionally low noise characteristics. As with other operational amplifiers, the noise content at the output is influenced by the signal source impedance, and is distributed with frequency. Graphical data is presented below to aid in circuit design for low noise.

Specifically, the noise versus source resistance curves show that voltage noise is the predominant noise influence at low source impedances (left side of graph). Moving to the right, current noise predominates and rises in proportion to the increasing source impedance.

This is explained by the following conceptualization: The amplifier's input stages have both voltage and current type noise generators in series and parallel respectively with the input impedance. Therefore, the voltage noise of the amplifier is independent of impedance level, but above a certain impedance (see the noise/source impedance curves), current noise contribution to the total noise output increases directly with higher input impedance.

For further information on Noise in Operational Amplifier circuits, see Analog Dialogue Vol. 3 No. 1.

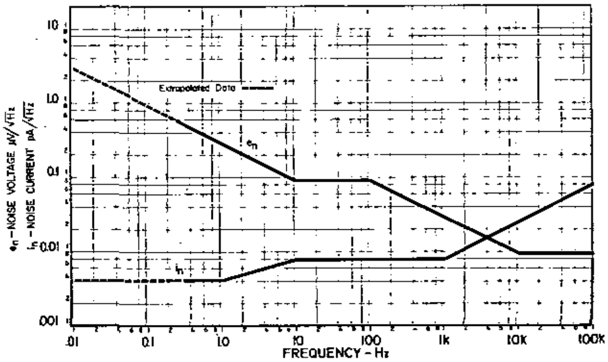


FIGURE 1. VOLTAGE AND CURRENT NOISE PER ROOT Hz OF BANDWIDTH

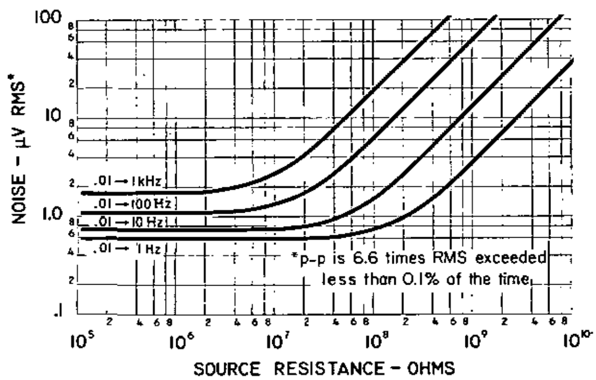


FIGURE 2. VOLTAGE NOISE VS. SOURCE RESISTANCE FOR CONSTANT BANDWIDTH

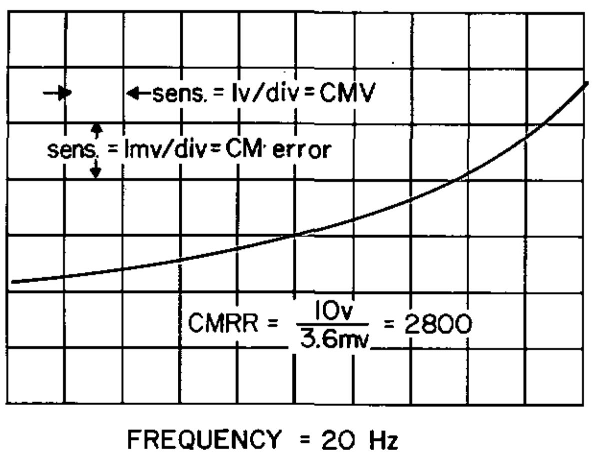


FIGURE 3. COMMON MODE VOLTAGE VS. COMMON MODE ERROR

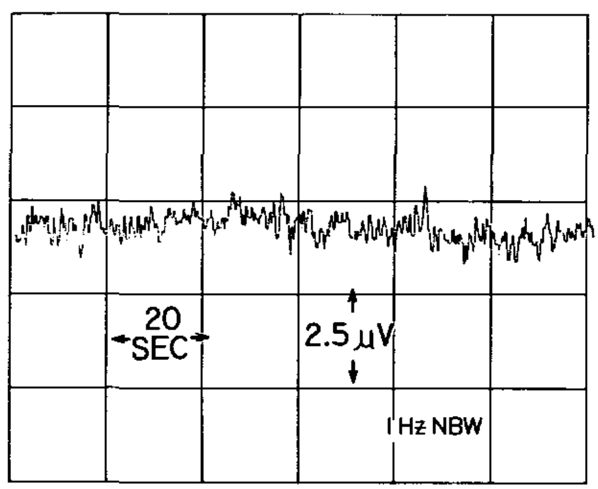


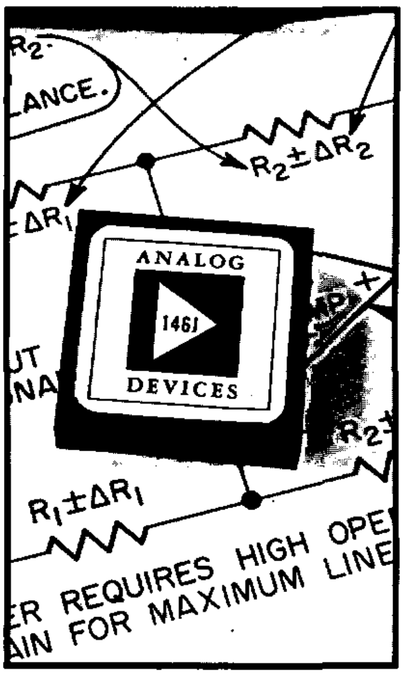
FIGURE 4. VOLTAGE NOISE FOR MODEL 144

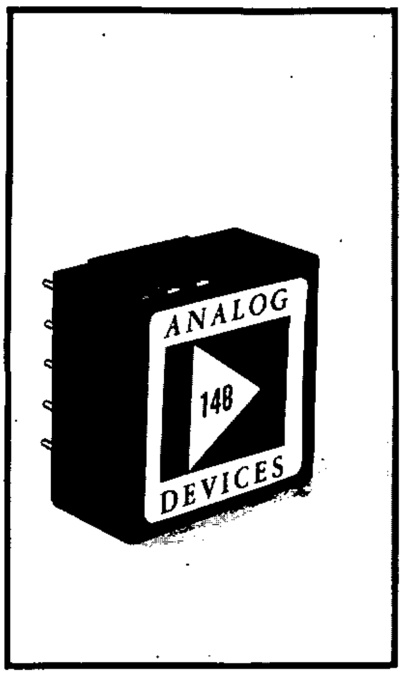
FET INPUT OPERATIONAL AMPLIFIERS

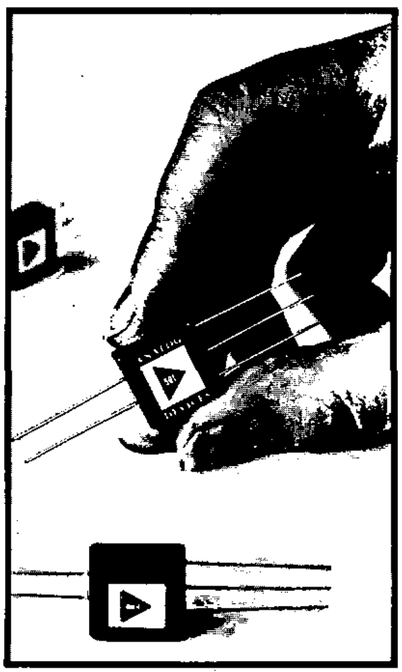
Analog Devices manufactures one of the most complete lines of operational amplifiers in the industry. Other FET op amps in the 140 series include the new Model 146 which boasts a low voltage drift of 2μV/°C, 10V/μsec slew rate, 20mA output, and an 80dB CMRR.

Choose the 148 FET op amp for wideband operation (10MHz), fast settling times (.01% in 1μsec), and high slew rates (50V/μsec).

Finally, consider the microcircuit hybrid Model P501, one of our interesting newer amplifiers. The P501 boasts wide bandwidth (4MHz), –10pA input bias current (P501B), and CMRR of 10,000 (@±5V CMV). All non-essential connections to the P501, such as power supply common, have been eliminated so that just five pin connections remain, and the P501 will not use up valuable PC card "floor space" with frequency compensation components as with IC op amps. The P501 is internally compensated and is packaged in a unique miniature epoxy case measuring .6" square x .25" high.







	LOW DRIFT 2μV/°C MODEL 146J/K	FAST SETTLING .01% in 1μsec MODEL 148A/C	HYBRID MICROCIRCUIT MODEL P501A/B
Open Loop Gain, min.	100k	30k	25k
Rated Output, min.	±10V @ 20mA	±10V @ 20mA	±10V @ 5mA
Bias Current, max.	±30/20pA	±50/25pA	±25/10pA
Voltage Drift, max.	±7/2μV/°C	±50/15μV/°C	±75/25μV/°C
Unity Bandwidth	5MHz	10MHz	4MHz
Slew Rate, min.	10V/μsec	50V/μsec	3V/μsec
Common Mode Rejection	10,000	2,000	10,000

DESCRIPTION

The new Model 146 is the latest in a series of third generation FET input operational amplifiers which offer outstanding performance at new low prices. The 146 is a premium quality amplifier which incorporates special new design techniques to overcome inherent shortcomings of conventional FET designs (CMRR and voltage drift), yet still retains the superior input impedance and bias current characteristics for which FETunits are most often chosen. The 146 is a moderately fast amplifier (5MHz small-signal-open-loop bandwidth; 10V/μsec slewing rate) with substantial output capability (±10V, 20mA). It is encapsulated in a rugged epoxy module of "Low Profile" design (just 0.4" high) and is priced for the OEM.

TWO MODELS AVAILABLE

Two models are available in the 146 series, differing only in input characteristics and price. Model 146J is least expensive, offers 7μV/°C voltage drift, and 30pA initial bias current. Where still higher performance is required, the 146K is available. Voltage drift is just 2μV/°C and bias current is specified at 20pA max. The two models are otherwise identical.

ABOUT FET AMPLIFIERS

FET amplifiers are primarily characterized by superior input bias current characteristics. (The 146, for example, is specified at just 20pA max). Input bias current (the tiny currents which flow into and out of the amplifier input terminals) may be important in many applications. It contributes to error in two ways: 1) In current measuring configurations, the bias current limits the resolution of a current signal and 2) the bias current produces a voltage offset which is proportional to the input resistor (in the case of an inverting configuration) or the source impedance (when the non-inverting "buffer" connection is used). FET amplifiers, therefore, are of interest where tiny currents are to be measured or when low voltage drift is necessary despite large values of source resistance.

Unfortunately, most conventional FET amplifier types are limited in application because of their generally poor common mode characteristics (1000:1 is not untypical) and relatively large temperature drift compared to bipolar-input amplifiers. As we have mentioned, the 146 utilizes special circuitry and physical design techniques to all but eliminate these shortcomings. Common mode rejection of 80dB specified for the 146 is comparable to CMR of most bipolar transistor input amplifiers and 2μV/°C (146K) almost rivals voltage drift performance of chopper stabilized amplifiers.

WHERE TO USE THE 146

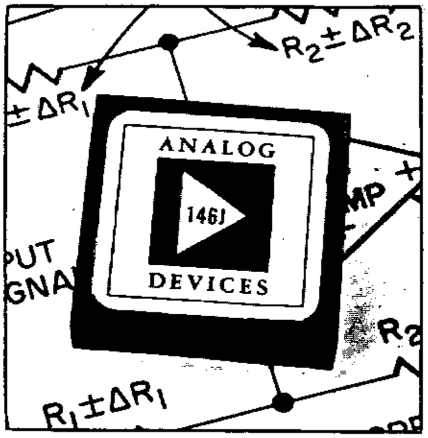
The combination of FET input characteristics (20pA bias current) and low voltage drift (2μV/°C) makes the 146 applicable to a very large number of circuit requirements. It is particularly useful where both voltage drift and current drift must be minimized. Although chopper stabilized amplifiers are also useful in this class of circuits, they are typically larger, more expensive, and generally suffer somewhat higher noise levels than the 146. In addition, most chopper stabilized types are inherently limited to the inverting configuration. The 146 is recommended where high accuracy is required from high impedance sources (particularly bridge circuits which require differential inputs) or where pA current levels are to be measured. For source (or input) resistances below 10k, a bipolar-type "chopperless differential" amplifier (Model 180 or 183) may be a better choice. Further, when femtoamp (10^{-15}A) resolution is necessary or for input resistances above 10 megohms, a varactor bridge amplifier (Analog Devices' Model 310 or 311) is recommended. Between these extremes the 146 will be found to have wide application flexibility where premium performance is required.

MODEL 146J/K

HIGH PERFORMANCE DIFFERENTIAL FET OP AMP

FEATURES

Voltage Drift	2μV/°C
Low Bias Current	20pA
Low Profile	0.4" Height
Output Current	20mA
Price (1-24) £ 28. 3. 3 (146J)	



APPLICATIONS

Picoamp Measurements
High Impedance Buffers
Differential Detectors
High Accuracy Bridge Amplifier

ANALOG DEVICES

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Printed in Switzerland

MODEL 146J/K

HIGH PERFORMANCE DIFFERENTIAL FET OP AMP

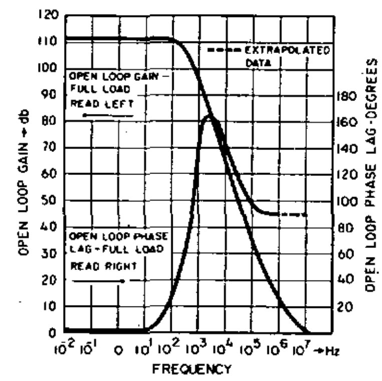
SPECIFICATIONS (typical @ 25°C and ±15VDC unless otherwise noted)

MODEL	J	K
OPEN LOOP GAIN		
dc rated load, min	10^5	*
RATED OUTPUT		
Voltage, min	±10V	*
Current, min	20mA	*
Load capacitance range	1000pf	*
FREQUENCY RESPONSE		
Unity gain, small signal	5MHz	*
Full power response, min	150kHz	*
Slewing rate, min	10V/μsec	*
Overload recovery	1.5msec	*
INPUT OFFSET VOLTAGE		
Initial offset, 25°C	±0.7mV Adj. to 0[1,2]	*
Avg. vs. temp (+10° to +60°C) max	±7μV/°C	±2μV/°C
vs. supply voltage	±15μV/°C	*
vs. time	±100μV/month	*
INPUT BIAS CURRENT		
Initial bias, 25°C, max	30pA	20pA
Avg. vs. temp (+10° to +60°C)	doubles every 10°C	*
vs. supply voltage	±0.75pA/%	*
INPUT DIFFERENCE CURRENT		
Initial difference, 25°C, max	±10pA	*
Avg. vs. temp (+10° to +60°C)	doubles every 10°C	*
INPUT IMPEDANCE		
Differential	$10^{11}\Omega \parallel 3.5$pf	*
Common mode	$10^{11}\Omega \parallel 3.5$pf	*
INPUT NOISE Voltage, .01 to 1Hz, p-p	6μV	*
Voltage, 5Hz to 50kHz, rms	16μV	*
Current, 0.01 to 1.0Hz, p-p	0.1pA	*
INPUT VOLTAGE RANGE		
Common mode voltage, min	±10V	*
Common mode rejection	80dB @ +5, −10V	*
Max. safe differential voltage	±15V	*
POWER SUPPLY		
Voltage, rated specification	±15V	*
Voltage, derated specification	±(12 to 18)V	*
Current, quiescent	±5mA	*
TEMPERATURE RANGE		
Operating, rated specifications	+10°C to +60°C	*
Storage	−55°C to +125°C	*
MECHANICAL		
Case style - pin configuration	F−1	*
Mating socket	AC1010	*
Weight	1 oz.	*

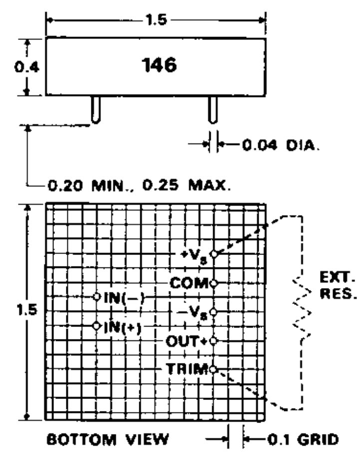
1. Special biasing techniques required. See Application notes Page 3.
2. Model J: Use 499 ohm, 1% metal-film trim resistor. Model K: Trim resistor supplied.

*Specifications same as for Model J.
Specifications subject to change without notice.

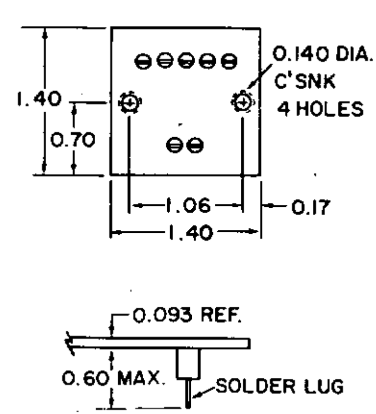
OPEN LOOP RESPONSE AND PHASE LAG



OUTLINE DIMENSIONS



MATING SOCKET AC1010



APPLICATION NOTES FOR MODEL 146

INITIAL OFFSET VOLTAGE

Most differential operational amplifiers have provisions for adjusting initial offset to zero with an external trim pot. It is not usually realized that there is a second order increase in voltage drift which accompanies the change in offset caused by the initial offset adjustment. This increased voltage drift can be safely ignored in conventional amplifiers since it is a small fraction of the specified voltage drift. But the voltage drift of the Model 146 is so small that this effect cannot be ignored. For example, if a 1k pot were used to balance the initial offset voltage of the 146, voltage drift over the range of adjustment could change by as much as 21μV/°C. This error is in addition to the normal drift specification of 7 and 2μV/°C. This trimming error may be minimized by using the circuits shown in Fig. 1-3 as outlined below.

The voltage drift of the Model 146 is measured and guaranteed when using a selected trim resistor. This resistor is supplied with the 146K and the value for this resistor is marked on the unit. The specified voltage drift holds only when this value of resistance is externally connected between the amplifier's TRIM terminal and +15V. In this case initial offset voltage is guaranteed to be less than the specified value at +25°C. The 146 can also be supplied on special order with the trim resistor connected internally. For further information, consult your local Analog Devices representative or the factory directly.

INITIAL OFFSET ADJUSTMENTS

If, for a given application, it is desirable to zero the initial offset of the amplifier, an external bias network is recommended to accomplish this purpose without increasing voltage drift of the 146. For the inverting configuration in Figure 1, the amplifier can be easily zeroed by summing an additional bias voltage (E_b) which is set equal to the initial offset of the amplifier, so as to bring the output to zero.

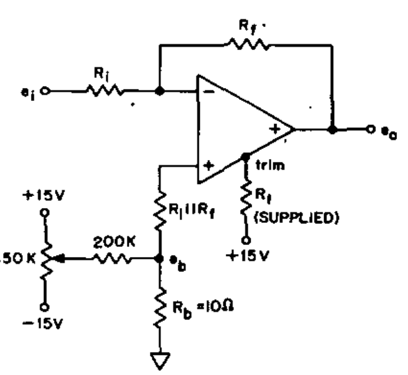


FIGURE 1. BIASING CIRCUIT FOR INVERTING CONFIGURATION

The stability of the components or the ±15V bias voltages is only moderately critical. For example, a change in value of components or supply voltages as large as 1% would cause an additional 7.5μV change of offset voltage (where R_b equals ten ohms).

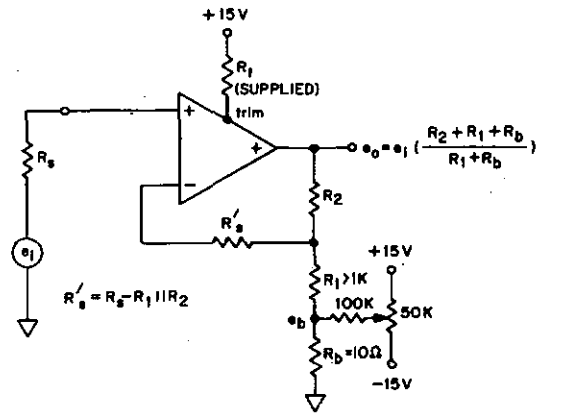


FIGURE 2. BIASING CIRCUIT FOR NONINVERTING CONFIGURATION

Figure 2 shows a biasing circuit which can be used for the noninverting configuration.

A large value for R_1 as compared to R_b is only necessary for low closed loop gains (less than 10) to prevent the gain from changing as a function of the bias adjust setting voltage. For gains greater than 10, the minimum value for R_1 can be reduced proportional to gain.

Of course, the circuit in Figure 2 will not work for unity gain. For this case, to avoid such complicated and costly schemes as a diode in series with a current source, a 1k ohm pot may be substituted for R_t to zero the amplifier. But it must be realized that the voltage drift will be increased to as much as 28μV/°C under the worst conditions.

A similar circuit to Figure 2 can be used to bias differential configurations, as shown in Figure 3.

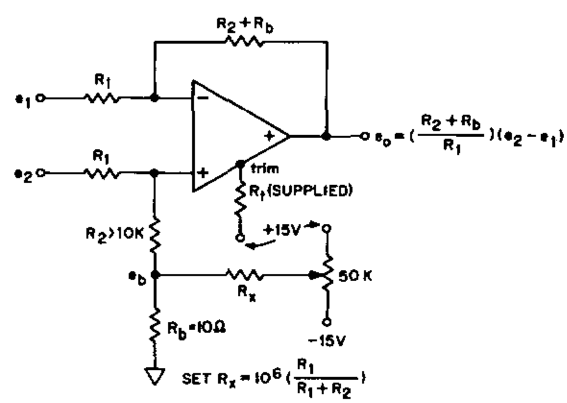


FIGURE 3. BIASING CIRCUIT FOR DIFFERENTIAL CONFIGURATION

For very large gains (R_2/R_1) it may be necessary to use a larger value of R_b in the bias circuit in order to make the offset voltage adjustment more effective.

NOISE

The Model 146 has exceptionally low noise. As with other operational amplifiers, the noise content at the output is influenced by the signal source impedance, and varies with frequency. Therefore, meaningful low noise circuit design must account for all these factors by properly applying the graphical data presented below.

Specifically, the noise versus source resistance curves show that voltage noise is the predominant noise influence at low source impedances (left side of graph, Figure 6). Moving to the right, equivalent noise voltage due to current noise predominates and increases in proportion to source impedance.

VOLTAGE AND CURRENT NOISE

The amplifier's input stages have independent random voltage and current noise generators in series and parallel respectively with the input impedance. The voltage noise of the amplifier, being in series, is independent of impedance level, but the voltage drift across the input impedance caused by current noise, effectively adds to voltage noise, and, above a given impedance level, becomes dominant.

For more complete information on the treatment of amplifier noise, see "Noise and Operational Amplifier Circuits," in Vol. 3 No. 1 of Analog Dialogue, available upon request.

OTHER FETS AVAILABLE FROM ANALOG DEVICES

The 146 FET op amp is complemented by other low bias amplifiers in the 140 FET series. These include the new Model 144, a high speed, low noise differential op amp. Models 141, 142, and 143 span the performance gap between the 144 and the top of the FET line, the Model 147. The 147 displays 10MHz bandwidth, low 2μV/°C voltage drift and a common mode rejection of 300,000. Additionally, the 148 and 149 op amps offer high speed, fast settling (1-1.5μsec to 0.01%) operation.

The tiny (0.6" square x 0.25" high) Model P501 rivals "IC plus FET" (and frequency compensation components) combinations in size and performance. It is a completely self-contained hybrid microcircuit unit having low bias currents typical of FET inputs (5pA), excellent bandwidth (4MHz), and 80dB CMRR (@ CMV from −10V to +5V).

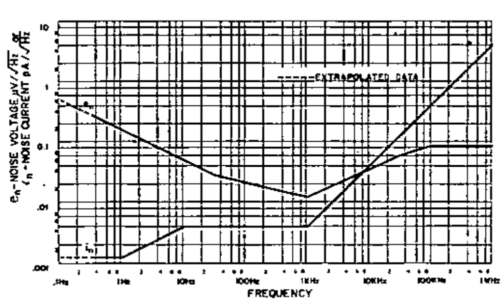


FIGURE 4. VOLTAGE AND CURRENT NOISE PER ROOT Hz OF BANDWIDTH

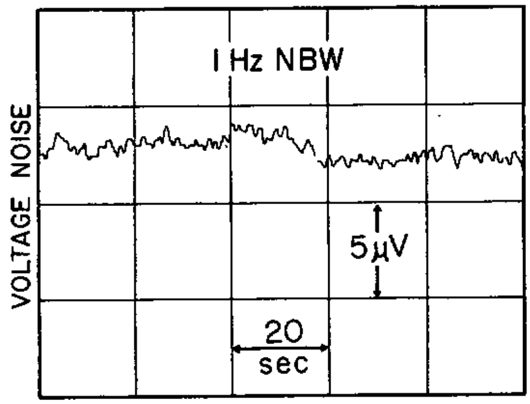


FIGURE 5. VOLTAGE NOISE FOR MODEL 146

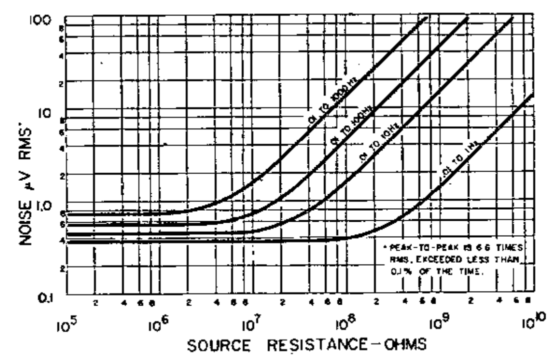


FIGURE 6. VOLTAGE NOISE VS. SOURCE RESISTANCE FOR CONSTANT BANDWIDTH

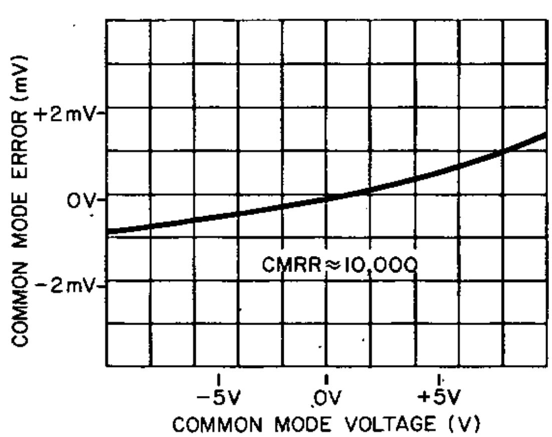


FIGURE 7. COMMON MODE VOLTAGE VS. COMMON MODE ERROR

MODEL 147 A/B/C

ULTRA LOW DRIFT FET DIFFERENTIAL OPERATIONAL AMPLIFIER

DESCRIPTION

Most FET operational amplifiers offer advantages of high input impedance and low input current but sacrifice other specifications — usually voltage drift and common mode rejection (CMR). The Model 147 is the first general purpose FET op amp which excels in every major performance category. For minimizing errors the 147 provides low current and voltage drift, low noise and high common mode rejection; for circuit stability the 147 provides high open loop gain; and, for application flexibility the 147 provides high slewing rate, high output current, fast settling time, wide bandwidth and good overload recovery.

THREE MODELS

A selection of the models A, B, and C is offered, which differ only in their voltage drift and input bias current specifications. Model A has 30pA maximum bias current and $15\mu V/°C$ voltage drift. Model B and C have 15pA (max) bias current while drift is respectively $5\mu V/°C$ and $2\mu V/°C$ over the temperature range from 10 to 60°C. The voltage drift of only $2\mu V/°C$ (Model C) and input bias current of 15 pA (max) approach the performance of chopper stabilized amplifiers and, for many applications the 147 offers comparative advantages of small size, lower price, lower noise and the versatility of differential inputs. Special circuit techniques are used to overcome inherently poor common mode rejection characteristics of FET s. CMRR of 300,000 for the Model 147 is an order of magnitude higher than most FET amplifiers.

Open loop gain of 10^6, input impedance of 10^{12} ohms and output rating of ± 10 volts and 10mA round out the specifications of an almost ideal operational amplifier which will satisfy high performance requirements on several parameters simultaneously.

FAST RESPONSE

In addition to exceptional voltage drift, bias current and CMR specifications, the Model 147 also offers fast response on both the inverting and non-inverting inputs. Unity gain bandwidth is 10MHz, while full power response and slewing rate are respectively 150kHz and $10V/\mu sec$. Thus the 147 is ideally suited for such applications as A to D and D to A converters, sample and hold amplifiers as well as wideband, high impedance voltage followers.

HIGH INPUT IMPEDANCE

In the non-inverting configuration, input impedance is greater than 10^{12} ohms and input capacitance is only 3 pf. When amplifying signals from large source impedances, the 147 provides better accuracy than operational amplifiers now available since every source of error—voltage drift, bias current and CMR — has been minimized.

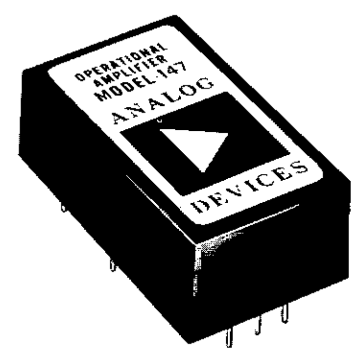
COMMON MODE REJECTION

The high common mode rejection ratio of 300,000 minimizes the output error in differential and non-inverting circuits. For example, a 10 volt common mode signal applied to the 147 would result in a maximum error of only $30\mu V$ (10V/300,000).

www.Electrojumble.org.uk

FEATURES

Bias Current	15 pa. max.
Voltage Drift	$2\mu v/°C$ max.
Common Mode Rejection	300,000
Input Impedance	10^{12} ohms, C.M.
Open Loop Gain	10^6 min.
Slewing Rate	$10v/\mu$ sec
Bandwidth	10mHz
Price (1-9)	\$ 95. (A) \$115. (B) \$135. (C)



APPLICATIONS

Precision Integrators

A to D Converters

D to A Converters

Sample and Hold Amplifiers

Picoamp Current Measurements

High Impedance Buffers

ANALOG DEVICES
221 FIFTH STREET
CAMBRIDGE, MASS. 02142
PHONE: 617/492-6000

C027-10-7/69 PRINTED IN U.S.A.

MODEL 147 A/B/C

ULTRA LOW DRIFT FET DIFFERENTIAL OPERATIONAL AMPLIFIER

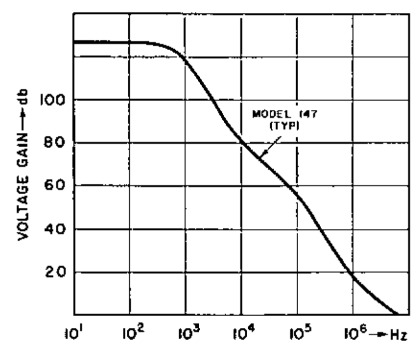
SPECIFICATIONS (typical @ 25°C and ±15VDC unless otherwise noted)

OPEN LOOP GAIN			
dc, rated load, min.	10^6		
RATED OUTPUT			
Voltage, min.	±10V		
Current, min.	±10mA		
FREQUENCY RESPONSE			
Unity gain, small signal	10MHz		
Full power response, min.	150kHz		
Slewing rate, min.	10V/μsec		
Overload recovery	400μsec		
INPUT OFFSET VOLTAGE			
Initial offset, 25°C, max.	±1mV		
Avg. vs. temp.	Model A	Model B	Model C
(10 to 60°C) max.	±15μV/°C	±5μV/°C	±2μV/°C
(−25 to 85°C) max.	±15μV/°C	±10μV/°C	±5μV/°C
vs. supply voltage	±30μV/%	±30μV/%	±30μV/%
vs. time (after warm-up)	±25μV/day	±25μV/day	±25μV/day
INPUT BIAS CURRENT			
Initial bias, 25°C, max.	(0,−) 30pA*	(0,−) 15pA*	(0,−) 15pA*
Avg. vs. temp. @ 25°C	±2pA/°C*	±1pA/°C*	±1pA/°C*
vs. supply voltage	.01pA/%	.01pA/%	.01pA/%
INPUT DIFFERENCE CURRENT			
Initial difference, 25°C	±10pA*	±3pA*	±3pA*
@ 85°C	±1nA	±300pA	±300pA
Avg. vs. temp. @ 25°C	±1pA/°C*	±0.5pA/°C*	±0.5pA/°C*
INPUT IMPEDANCE			
Between inputs	$10^{11}\Omega$ || 3pf		
Common Mode	$10^{12}\Omega$ || 3pf		
INPUT NOISE			
Voltage, .01 to 1Hz, p−p	3μV		
5Hz to 50kHz, rms	12μV		
Current, .01 to 1Hz, p−p	0.1pA		
COMMON MODE CHARACTERISTICS			
Common mode rejection	300,000		
Max. Common mode voltage	±9V (±10V on request)		
Max. Voltage between inputs	±15V		
POWER SUPPLY			
Voltage, rated specification	±(15 to 16)V		
Voltage, derated specifications	±(10 to 17)V		
Current, quiescent	22mA		
TEMPERATURE RANGE			
Operating, rated specifications	−25 to 85°C		
Operating, derated specifications	−55 to 85°C		
Storage	−65 to 125°C		
PRICE	Model A	Model B	Model C
(1-9)	$95.00	$115.00	$135.00
(10-24)	$90.00	$109.00	$128.00

*doubles each 10°C

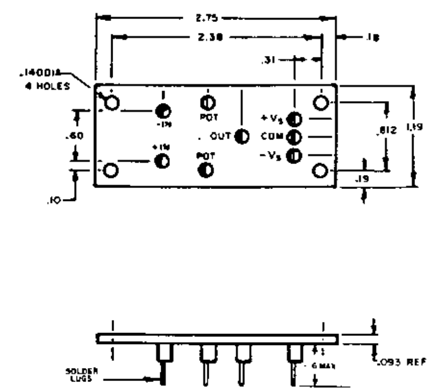
Specifications subject to change without notice

OPEN LOOP RESPONSE

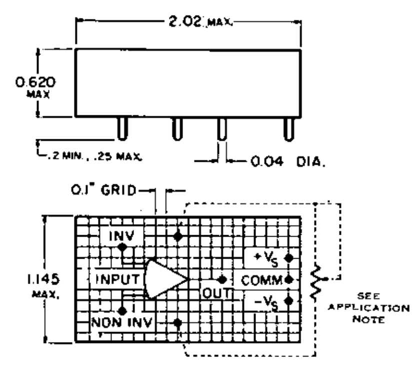


MATING SOCKET AC1001

(PRICE: $3.00)



OUTLINE DIMENSIONS



BOTTOM VIEW

APPLICATION NOTES FOR MODELS 147 A/B/C

INITIAL OFFSET VOLTAGE

Most differential operational amplifiers have provisions for adjusting initial offset to zero with an external trim pot. It is not usually realized that there is a second order increase in voltage drift which accompanies the initial offset adjustment. The increased voltage drift due to balancing the amplifier can be safely ignored in conventional amplifiers since it is a small percentage of the specified voltage drift. But the voltage drift of the B and C units is so small that this effect cannot be ignored. For example, if a 10K pot were used to balance the initial offset voltage, voltage drift could change by as much as $\pm 4\mu V/°C$ and thus voltage drift would exceed the specification by a large measure.

The voltage drift of the B and C units is measured and guaranteed when using a selected trim resistor. In the case of the C units this resistor is supplied with the amplifier and the value of the resistor is inscribed on the side of the unit. For the B units a 4.99k ohm resistor is used, while a 5k ohm resistor is used for the A units. The specified voltage drift holds only when these values of resistance are externally connected between the trim balance terminals of these amplifiers as shown in the outline dimension drawing. The 147 can also be supplied, on special order, with the trim resistor connected internally.

INITIAL OFFSET ADJUSTMENTS

A 10k ohm potentiometer may be used to zero the initial offset voltage of the A units, but an external biasing network is required to zero the B and C units.

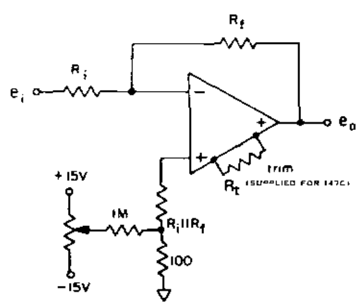


FIGURE 1. BIASING CIRCUIT FOR INVERTING CONFIGURATION

EXTERNAL BIASING NETWORK

An external biasing network is required to balance the initial offset of the B and C units of the Model 147. For the inverting configuration in Figure 1, the amplifier can be easily zeroed by summing an additional bias voltage as shown.

The stability of the components or the $\pm 15V$ bias voltages are not particularly critical. For example a 1% change of components or supply voltages would cause only about a $15\mu V$ change of offset voltage and likewise a 0.1% control of these values will maintain a $1.5\mu V$ offset. This circuit also zeroes the offset due to initial offset current.

Figure 2 shows a biasing circuit which can be used for the non-inverting configuration.

A large value for R_i as compared to 10 ohms is only necessary for low closed loop gains (less than 10) to prevent the bias voltage, e_b, from changing as a function of the input voltage. For gains greater than 10, the minimum value for R_i can be reduced proportional to gain.

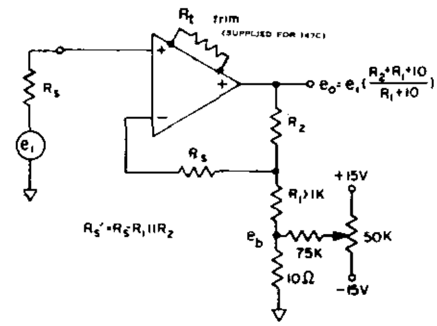


FIGURE 2. BIASING CIRCUIT FOR NON-INVERTING CONFIGURATION

Of course, the circuit in Figure 2 will not work for unity gain. For this case a 10K ohm pot may be substituted for R_t to zero the amplifier. But it must be realized that the voltage drift will be increased by as much as $4\mu V/°C$ under the worst conditions.

A similar circuit to Figure 2 can be used to bias the differential configuration of Figure 3.

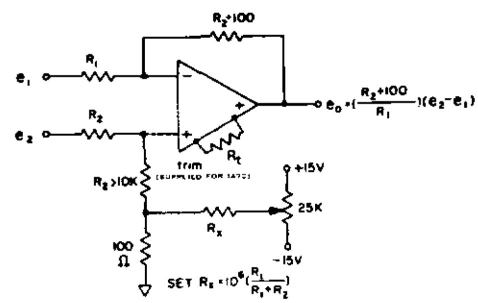


FIGURE 3. BIASING CIRCUIT FOR DIFFERENTIAL CONFIGURATION

For very large gains (R_2/R_1) it may be necessary to use larger than 100 ohms in the bias circuit in order not to load the bias voltage supplies.

CLOSED LOOP STABILITY

A feedback capacitor, C_f, is generally required across the feedback resistor, as shown in Figure 4, to provide proper phase margin for stability and to improve transient response. In the case of inverting circuits employing large feedback resistors, greater than one megohm, the feedback capacitor is very necessary but results in limiting the bandwidth. Typically a one megohm feedback resistor requires a 3pf capacitor. As shown in Figure 4, capacitance loads of 500pf or more can be isolated to improve stability by inserting the resistor R_1 which generally has values between 20 and 100 ohms.

Empirically, the optimum value of C_f for any closed loop gain and feedback resistance can be readily selected by feeding a square wave into the closed loop amplifier circuit and adjusting a variable capacitor to produce the desired transient response.

The non-inverting circuit of Figure 5 is a better choice when both high input impedance and fast response is required, since smaller values can be used for R_f and therefore C_f will not limit the bandwidth. For large source impedances, greater than one megohm, it may be necessary to add a capacitor (C_i) of a few pf across the source as shown in Figure 5. If capacitance loads greater than 500pf are used it may be necessary to add resistor R_1 to isolate the load capacitance and therefore improve stability.

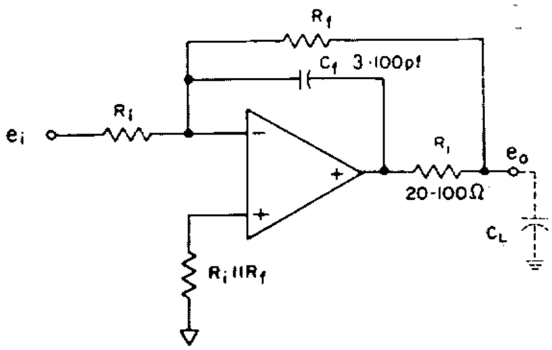


FIGURE 4. IMPROVING CLOSED LOOP STABILITY

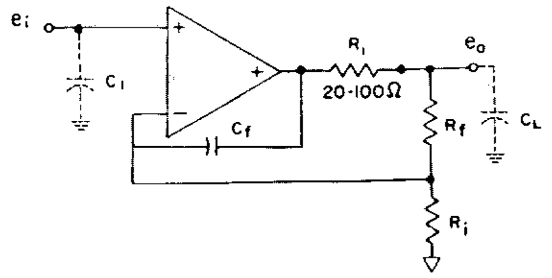


FIGURE 5. ISOLATING CAPACITIVE LOADS

SELECTION GUIDELINES

The 147 versus Chopper Amplifiers

The 147 has equivalent current drift but slightly higher voltage drift specifications than chopper stabilized amplifiers in the same price range. Also the 147C's current noise performance is a hundred fold better than most chopper amplifiers and has lower 1/f voltage noise from D.C. to 10Hz. A prime advantage of the 147 is its ability to be used in noninverting and differential configurations as compared to chopper amplifiers whose single ended inputs limit them to only the inverting configuration. The 147 also offers higher input impedance and lower input capacitance in the inverting configuration. Thus the Model 147 offers not only an excellent alternative to chopper amplifiers where low offset and drift are required, but is also suited to many applications which are impractical for chopper amplifiers.

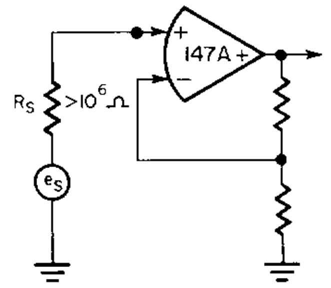
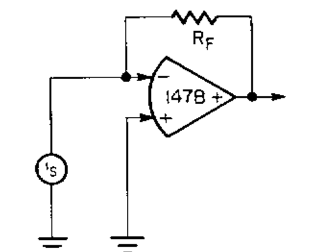
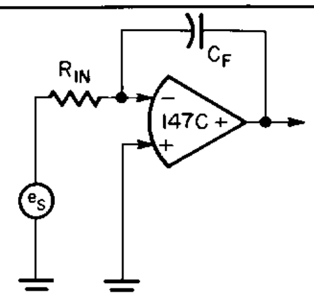
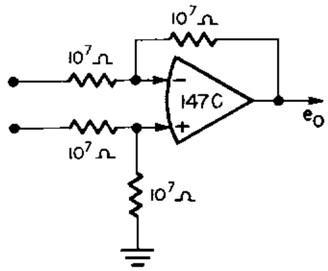
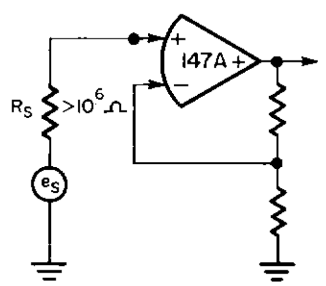
The 147 versus the 301

Where the utmost sensitivity for low level current signals is required, the Model 301 (varactor bridge amplifier) achieves better current drift and noise performance than the 147. However the 301 costs more and has higher voltage drift than the 147C. Since for a given temperature range, source or input resistance determines whether current drift or voltage drift is the predominant error source, there is a crossover point where the 147 is a better choice than the 301. In fact for input resistance below 50 megohms the 147 is the best choice. This is true since the 50μV/°C voltage drift figure of the 301 exceeds 1pa/°C$\times R_{in}$ of the 147 only below 50 megohms.

The 147 versus the 180

The Model 180 offers lower voltage drift and noise but higher current drift and noise than the Model 147. Therefore the 180 is best used for low impedance while the 147 is better for higher impedance. Specifically, for input impedances less than 10k ohms the 180 is the best choice. This follows since the current drift of the 180, (.2na/°C), multiplied by R_{in} or R_s is higher than the 2μV/°C voltage drift of the 147 for input resistance values above 10k ohms.

TO SUMMARIZE — The 147 is the best choice when compared to the 180 and 301 when the input resistance is greater than 10k ohms but less than 50 megohms.

APPLICATION	APPLICABLE AMPLIFIER SPECIFICATION
 HIGH INPUT IMPEDANCE	*a) Very High Z_{in} — $10^{12}\Omega$ || 3pf* *b) Fast Response — 10MHz* *c) Low CMR Error — .003%* *d) Low Drift — 15μV/°C & 2pA/°C*
 CURRENT TO VOLTAGE CONVERTER	*a) Low Current Noise — .1pA, p-p* *b) Low Current Drift — 1pA/°C* *c) Low Initial Bias Current — 15pA* *d) High Output Current — 10mA*
 INTEGRATOR	*a) Low Current Drift — 1pA/°C* *b) High Gain — 10^6* *c) High Differential Impedance — $10^{11}\Omega$* *d) Low Voltage Drift — 2μV/°C*
 DIFFERENTIAL	*a) Low Current Drift — 1pA/°C* *b) Low Voltage Noise — 3μV, p-p* *c) Low Voltage Drift — 2μV/°C* *d) High CMR — .003%*
 SAMPLE AND HOLD	*a) Very High Z_{in} — $10^{12}\Omega$ || 3pf* *b) Fast Response — 10MHz* *c) Low CMR Error — .003%* *d) Low Drift — 15μV/°C & 2pA/°C* *e) Fast Settling Time — 5μsec (to .1%)*

ANALOG DEVICES, Inc.
221 FIFTH STREET
CAMBRIDGE, MASS. 02142
PHONE: 617/492-6000
TWX 710/320-0326

DESCRIPTION

The new generation chopperless 153 optimally combines many of the most desired features of operational amplifiers in an inexpensive, low profile modular package. While specifically designed for portable and low power applications, the Model 153 displays an across-the-board set of exemplary characteristics. This performance is achieved by using proven circuitry throughout, with careful attention paid to the drift compensation design of the input stages.

Other important features are: low drift, low noise, choice of differential operation, low profile size and minimal cost. Since no single operational amplifier can solve all application problems simultaneously, certain compromises must be made in some parameters as "trade-offs" to achieve superior performance in other selected key parameters. Therefore, while the 153 performs very successfully in most moderate performance applications, it should not be recommended where wide bandwidth, high slewing rates, or fast settling times are required. Additionally, in applications involving extremely high input source resistances (above, say, 100kΩ), which necessitate very low bias currents, the Model 153 again would not be considered the best choice. The user encountering such application problems will be well-advised to refer to Analog Devices' complete line of extremely fast amplifiers and the wide variety of FET input and varactor bridge amplifiers available.

The 153 achieves its superior voltage drift with isothermal shielding of the selected dual chip input transistor. This produces very close V_{be} tracking, resulting in ultra low drift. This simplified direct approach to achieving low drift differs from the more complicated chopper solution. The chopperless 153 approaches voltage drift specs of choppers, but without the noise and the inherent limitation of single-ended inputs of chopper types.

PORTABLE OPERATION

The Model 153 combines several essential features of a portable environment amplifier, such as operation off of ±2.7V batteries and extremely low quiescent current drain. But battery voltages are unregulated and vary with temperature and other environmental factors. Their increasing internal impedances tend to loosen an amplifier's specs. The 153 anticipates deterioration of rated specifications due to battery operation and portable environments by including tighter temperature compensation, and a remarkable power supply voltage operating range. In addition, ΔVs rejection is high, placing less reliance on constancy of supply voltages and greater reliance on the basic circuit integrity of the 153.

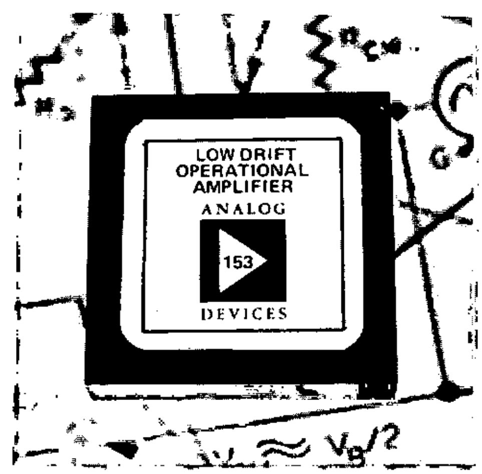
PERFORMANCE VS. SUPPLY VOLTAGE

DC SUPPLY ±V	OUTPUT VOLTAGE ±V(MIN)	OUTPUT CURRENT ±mA(MIN)	OPEN LOOP VOLTAGE GAIN FULL LOAD (MIN)	POWER SUPPLY QUIESCENT CURRENT ±µA	FULL OUTPUT PEAK FREQUENCY RESPONSE kHz(MIN)
2.7	1	1	50k	70	5
4.5	2	2	75k	90	5
6	3	3	100k	100	5
9	5	4	200k	130	5
12	8	4	300k	150	5
15	10	4	400k	170	5

MODEL 153J/K
BATTERY POWERED CHOPPERLESS DIFFERENTIAL LOW DRIFT OPERATIONAL AMPLIFIER

FEATURES

Battery Powered – ±2.7V to ±15V
Low Current Drain – 70µA @ ±2.7V
Low Voltage Drift – 2µV/°C, max
Low Profile Size – 0.4" Height



APPLICATIONS

Portable Instrumentation
Remote Preamplifier
Isolated Null Detector
High Impedance Buffer

ANALOG DEVICES
59 EDEN STREET
KINGSTON-UPON-THAMES
SURREY, ENGLAND
TEL: 01-546-6636

MODEL 153J/K — BATTERY POWERED OP-AMP

SPECIFICATIONS (typical @ 25°C and ±2.7VDC unless otherwise noted)

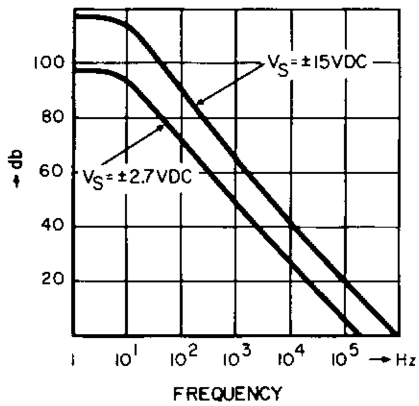
MODEL	J	K
OPEN LOOP GAIN		
dc rated load, min	5×10^4 [4]	*
RATED OUTPUT		
Voltage, min	±1V[4]	*
Current, min	1mA[4]	*
Load capacitance range	1000pF	*
FREQUENCY RESPONSE		
Unity gain, small signal	150kHz	*
Full power response, min	5kHz(peak)	*
Slewing rate, min	.02V/µsec	*
Overload recovery	2msec	*
INPUT OFFSET VOLTAGE		
Initial offset, 25°C, max	±1mV[1]	±250µV[1]
Avg. vs. temp (10° to 60°C) max[2]	±5µV/°C	±2µV/°C
vs. supply voltage	±1µV/%	*
vs. time	±5µV/month	*
Warm-up drift	less than 1µV	*
INPUT BIAS CURRENT		
Initial bias, 25°C, max	±3nA	*
Avg. vs. temp (10° to 60°C) max[2]	±0.1nA/°C	*
vs. supply voltage	±0.1nA/%	*
INPUT DIFFERENCE CURRENT		
Initial difference, 25°C, max	±3nA	*
Avg. vs. temp (10° to 60°C)[2]	±0.05nA/°C	*
INPUT IMPEDANCE		
Differential	1MΩ	*
Common mode	200MΩ	*
INPUT NOISE		
Voltage, .01 to 1Hz, p-p	1µV	*
5Hz to 10kHz, rms	2µV	*
Current, .01 to 1Hz, p-p	10pA	*
.01 to 100Hz, p-p	15pA	*
INPUT VOLTAGE RANGE		
Common mode voltage, min[3]	±1V	*
Common mode rejection @ ±1V	50,000	*
Max. safe differential voltage	±10V	*
POWER SUPPLY		
Voltage, rated specification	±2.7V[4]	*
Voltage, derated specification	±(2.5 to 18)V	*
Current, quiescent	±70µA	*
TEMPERATURE RANGE		
Operating, rated specifications[2]	+10°C to +60°C	*
Storage	−55°C to +125°C	*
MECHANICAL		
Case style - pin configuration	F−1	*
Mating socket	AC1010	*

1. Refer to the Application Notes for adjustment of zero offset.
2. Models also available for operation from −25 to +85°C.
3. ±Common mode voltage range equals rated output voltage range.
4. See Page 1 for specifications at higher power supply voltages.

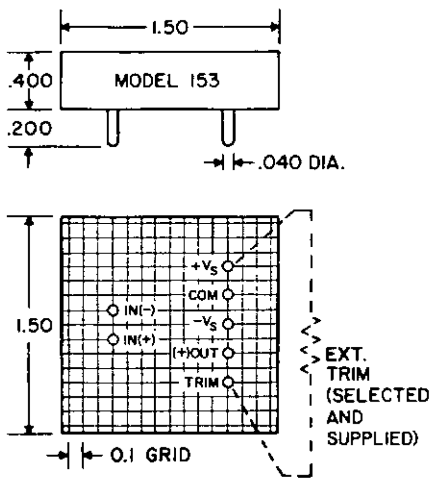
* Specifications same as for Model J.

Specifications subject to change without notice.

OPEN LOOP RESPONSE

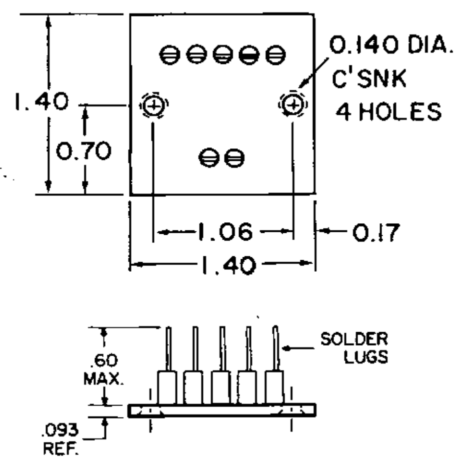


OUTLINE DIMENSIONS



BOTTOM VIEW WEIGHT: 8.9oz.

MATING SOCKET
AC 1010
PRICE (1–9)



APPLICATION NOTES FOR MODEL 153

INITIAL OFFSET VOLTAGE

Most differential operational amplifiers have provisions for adjusting initial offset to zero with an external trim pot. It is not usually realized that there is a second order increase in voltage drift which accompanies the initial offset adjustment. The increased voltage drift due to balancing the amplifier can be safely ignored in conventional amplifiers since it is a small percentage of the specified voltage drift. But the voltage drift of the Model 153 is so small that this effect cannot be ignored. For example, if a 100k pot were used to balance the initial offset voltage of the 153J (1mV initial offset), voltage drift could change by as much as ±3μV/°C and thus would nearly double the rated drift of 5μV/°C.

The voltage drift of the Model 153 is measured and guaranteed when using a selected trim resistor. This resistor is supplied with the amplifier and the value for this resistor is inscribed on the unit. The specified voltage drift holds only when this value of resistance is externally connected between the amplifier's TRIM terminal and +2.7V. In this case, initial offset voltage is guaranteed to be less than the specified value at +25°C. Model 153K guarantees initial offset voltage to be less than ±250μV. In this case, an external 100k trim pot used to zero initial offset will not degrade voltage drift by more than ±.75μV/°C. The 153 can also be supplied on special order with the trim resistor connected internally.

INITIAL OFFSET ADJUSTMENTS

In some applications it may be desirable to zero the initial offset of the amplifier and an external bias network is recommended which will accomplish this purpose and allow the 153 to obtain lowest voltage drift. For the inverting configuration in Figure 1, the amplifier can be easily zeroed by summing an additional bias voltage (e_b) which is set equal to the initial offset of the amplifier.

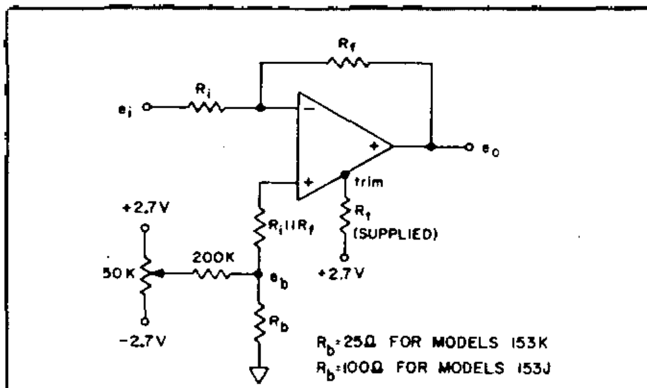


FIGURE 1. BIASING CIRCUIT FOR INVERTING CONFIGURATION

The stability of the components or the ±2.7V bias voltages is only moderately critical. For example: a 1% change of components or supply voltages would cause an offset voltage change of less than 3μV when R_b equals 25Ω, and likewise a 0.1% control of these values will maintain a .3μV offset. These figures should be multiplied by a factor of 4 for the case where R_b equals 100Ω. This circuit will also zero the offset due to initial difference current for values of R_1 up to about 20kΩ. For larger values of R_1 the value of R_b may have to be increased with the resultant higher susceptibility of offset to supply voltage changes.

Figure 2 shows a biasing circuit which can be used for the non-inverting configuration.

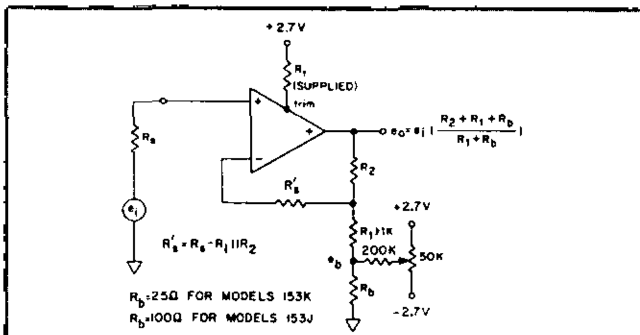


FIGURE 2. BIASING CIRCUIT FOR NONINVERTING CONFIGURATION

A large value for R_l as compared to R_b is only necessary for low closed loop gains (less than 10) to prevent the bias voltage, e_b, from changing as a function of the input voltage. For gains greater than 10, the minimum value for R_l can be reduced proportional to gain.

Of course, the circuit in Figure 2 will not work for unity gain. For this case a 100kΩ pot may be substituted for R_t to zero the amplifier. But it must be realized that the voltage drift will be increased by as much as 3μV/°C for the 153J under the worst conditions.

A similar circuit to Figure 2 can be used to bias the differential configuration of Figure 3.

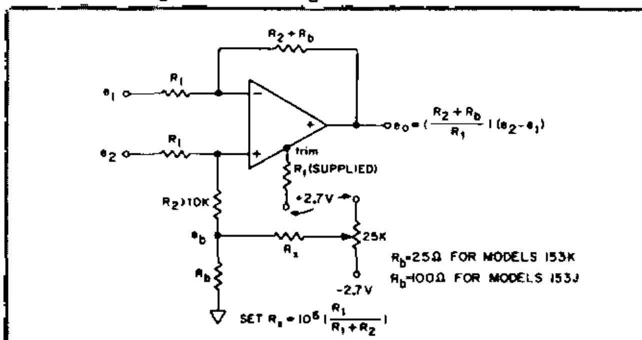


FIGURE 3. BIASING CIRCUIT FOR DIFFERENTIAL CONFIGURATION

For very large gains (R_2/R_1), it may be necessary to use a larger value of R_x in the bias circuit in order not to load the bias voltage supplies.

TEMPERATURE GRADIENTS

Most differential operational amplifiers are critically sensitive to thermal gradients. The dual input transistor used in the Model 153 together with careful design and layout greatly reduces the unit's sensitivity to thermal gradients. The graph in Figure 4 shows the transient offset voltage (referred to the input) resulting from a thermal shock when the amplifier's temperature is abruptly changed from 25°C to 50°C by dipping it into a hot silicone oil bath. This very severe test is rarely encountered in practice but it does illustrate the amplifier's performance under worst conditions.

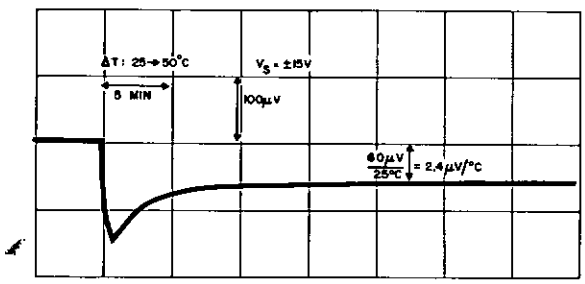


FIGURE 4. TRANSIENT OFFSET VOLTAGE RESPONSE TO THERMAL SHOCK

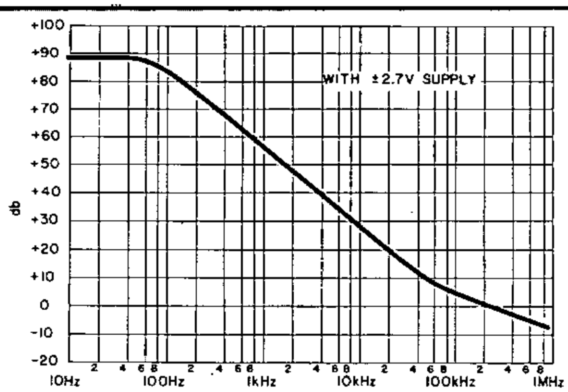


FIGURE 5. CMRR VS. FREQUENCY

LOW NOISE

Voltage noise of the 153 is extremely low for a transistor input amplifier. Low frequency or "flicker" noise is less than 1μV p-p, over a bandwidth of .01Hz to 1Hz. This is contrasted with 5-20 μV p-p for chopper types. Additionally chopper amplifiers often exhibit high peak to peak values of chopper noise at and around the chopper frequency. This "spike" noise is, of course, absent in the chopperless 153. The accompanying graphs represent actual data taken on the 153 showing .01 Hz to 1 Hz noise, total voltage and current noise as a function of input resistance, and a plot of voltage and current noise per root cycle of bandwidth.

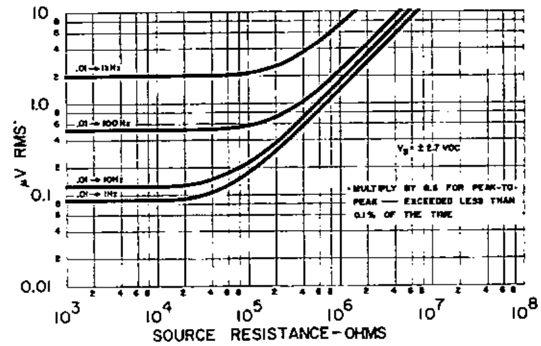


FIGURE 6. EQUIVALENT NOISE AS A FUNCTION OF INPUT RESISTANCE FOR CONSTANT BANDWIDTH

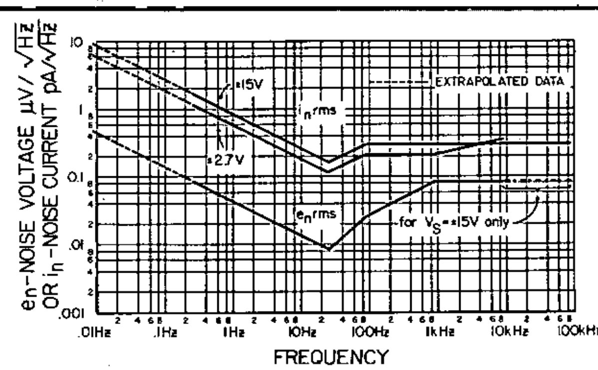


FIGURE 7. VOLTAGE AND CURRENT NOISE PER ROOT Hz OF BANDWIDTH

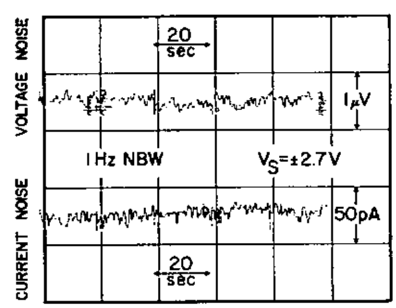


FIGURE 8. TYP. VOLTAGE AND CURRENT NOISE .01Hz to 1Hz

ABOUT BATTERIES

Four 1.35V mercury "D" cells will power a 153 at full output continuously for over 3 years! Further calculations may be made with the information below.

Mallory No.	Volts	Milliamp-Hours	Size	Wt. Oz.	Remarks
TR152R	2.7	350	.47"dia. x 1.125	0.42	"Button cell": use 2 per 153
RM42R	1.35	14000	1.2" dia. x 2.375	5.9	"D" cell: use 4 per 153

ANALOG DEVICES, INC.
221 FIFTH STREET
CAMBRIDGE, MASS. 02142
TEL: 617/492-6000
TWX: 710/320-0326

MODEL 180A/B/J/K
CHOPPERLESS DIFFERENTIAL
OPERATIONAL AMPLIFIER

DESCRIPTION

Based on considerable production experience, performance of the now familiar Model 180 operational amplifier series has been improved, and simultaneously, cost has been reduced. Drift of only 0.5μV/°C makes the Model 180 the highest performance differential input chopperless op amp currently available. While chopper stabilized types still offer the ultimate in voltage drift performance, certain limitations are inherent in their application.

Specifically, since chopper stabilized amplifiers are nearly always single ended devices, they are limited to inverting applications. Since many applications require access to the non-inverting input, (high impedance followers, differential bridge circuits, etc) the 180 is of wide interest. Furthermore, it has additional advantages in smaller size, less weight, and lower cost than most chopper types. "Flicker" noise, common to choppers, is lower in the 180 and chopper "spikes" are, of course, totally absent.

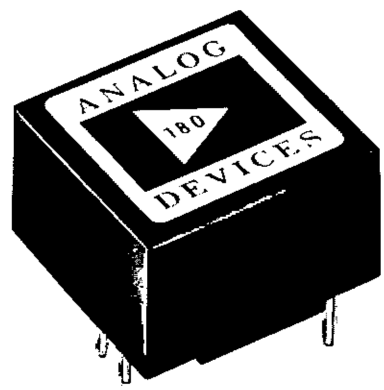
WHERE TO USE THE 180

Because no single operational amplifier can solve all problems simultaneously, certain compromises must be made as "trade-offs" for superior performance in other key parameters. In this regard it will be found that the 180 is not the best amplifier for use in applications requiring high speed (i.e. wide bandwidth, high slew rates, fast settling time, etc). Additionally, where extremely high source resistances (above, say, 100kΩ) require the consideration of very low bias currents the 180 should not be considered the best choice. Analog Devices manufactures a wide variety of extremely fast amplifiers and has a very complete collection of FET and varactor bridge types for these specialized applications.

The 180 series is the best choice where very small signal levels (less than 1mV), from moderate source impedances (below 100kΩ), with modest frequency requirements (DC-5kHz) must be observed, measured or manipulated. Also in this group are larger signal levels that must be operated upon with a very high degree of accuracy, e.g. 1 volt to .01% accuracy. Low voltage drift and noise specifications are the prime requisites for proper solution to this class of op-amp application problems. Another application is the low drift/high input impedance buffer amplifier.

FEATURES

- Voltage Drift - 0.5μV/°C max
- Long Term Drift - 5μV/month
- Initial Offset Voltage - 100μV
- Warm-up Drift - 5μV
- Common Mode Rejection - 100,000
- Bias Current Drift - 0.05nA/°C
- Price - £37. to £55.



APPLICATIONS

- High Impedance Buffer
- Bridge Amplifier
- Stable Voltage Source
- Low Level Amplifier

ANALOG
DEVICES
38-40 FIFE ROAD
KINGSTON-ON-THAMES
SURREY
01-546-6636
01-549-0811

Printed in England by Impacol Limited

CHOPPERLESS DIFFERENTIAL OPERATIONAL AMPLIFIER

SPECIFICATIONS (typical @ 25°C unless otherwise noted)

MODEL	180A	180B	180J	180K
OPEN LOOP GAIN, rated load, min	300,000			
RATED OUTPUT				
Voltage, min	±10V			
Current, min	±2.5mA			
Load capacitance range	1000pf			
FREQUENCY RESPONSE				
Unity gain, small signal	1.0MHz			
Full power response, min	10kHz			
Slewing rate, min	0.6V/µs			
Overload recovery	2ms			
INPUT OFFSET VOLTAGE				
Initial offset 25°C, max*	±1mV**	±100µV	±250µV	±100µV
Avg. vs. temp(10 to 60°C)	–	–	±1.5µV/°C	±0.5µV/°C
vs. temp(-25 to 25 to 85°C)	±1.5µV/°C	±0.5µV/°C	–	–
vs. supply voltage	±2µV/%			
vs. time	±5µV/month			
Warm up drift (5 min)	5µV			
INPUT BIAS CURRENT				
Initial bias, 25°C, max	±4nA			
Avg. vs. temp(10 to 60°C)max	–	–	±0.1nA/°C	±0.05nA/°C
vs. temp(-25 to 85°C)max	±0.2nA/°C	±0.2nA/°C	–	–
vs. supply voltage	±0.2nA/%			
INPUT DIFFERENCE CURRENT				
Initial difference, 25°C	±1nA			
Avg. vs. temp(10 to 60°C)	–	–	±0.02nA/°C	±0.02nA/°C
Avg. vs. temp(-25 to 85°C)	±0.05nA/°C	±0.05nA/°C	–	–
INPUT IMPEDANCE				
Differential	2MΩ			
Common mode	1,000MΩ			
INPUT NOISE				
Voltage, .01 to 1Hz, p-p	1µV			
.01 to 100Hz, p-p	2µV			
5Hz to 50kHz, rms	4µV			
Current, .01 to 1Hz, p-p	50pA			
.01 to 100Hz, p-p	100pA			
INPUT VOLTAGE RANGE				
Common mode voltage, min	±10V			
Common mode rejection @ ±10V	100,000			
Max. safe differential voltage	±15V			
POWER SUPPLY				
Voltage, rated specification	±(15 to 16V)			
Voltage, derated specification	±(10 to 18V)			
Quiescent current, max	6mA			
Quiescent current	5.5mA			
TEMPERATURE RANGE				
Operating, rated specification	-25 to +85°C	-25 to +85°C	10 to 60°C	10 to 60°C
Operating, derated specifications	-55 to +85°C			
Storage	-55 to +85°C			
MECHANICAL				
Case Style · Pin Configuration	Q1			
Mating Socket	AC1003			
Weight	.85oz.			
PRICE				
1-24	£40.0.0.	£55.0.0.	£37.0.0.	£47.0.0.

*External resistor supplied.
**±250µV max; add £2.10.0. and specify 180A0
Specifications subject to change without notice.

CHOPPERLESS DIFFERENTIAL AMPLIFIERS

Until the advent of the new generation chopperless-differential op amps (pioneered by the Analog Devices Model 180), design engineers had been forced to either compromise their requirements and use existing differential amplifiers or apply the more costly chopper stabilized types, not without encountering certain other difficulties. The 180 is contrasted with these alternative approaches below.

VERSUS CHOPPER TYPES

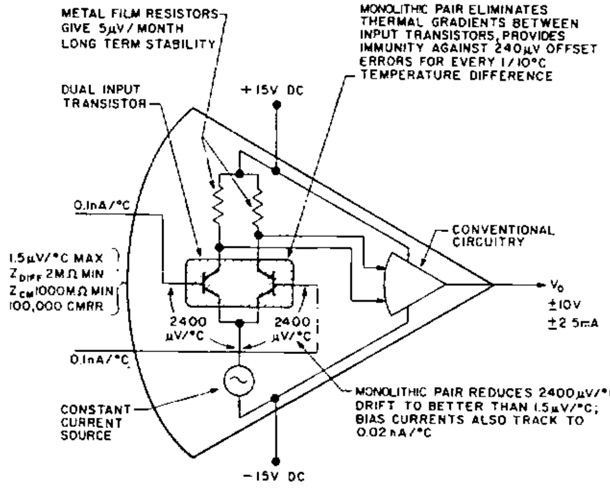
HIGH INPUT IMPEDANCE—Chopper amplifiers, while exceptionally good for low voltage drift, are generally single-ended input devices, and are only applicable as inverting amplifiers. The chopperless 180 provides the flexibility of true differential inputs and hence may be connected in the noninverting configuration. This connection "bootstraps" input impedance to 1000MΩ (the common mode impedance). Most chopper amplifiers can achieve input impedances of only a few megohms. The 180 can also be connected in all other op-amp configurations requiring differential inputs.

LOW NOISE—The 180 is specified at 1μV p-p noise level in a bandwidth of .01Hz to 1Hz, an order of magnitude less than the "flicker noise" of most chopper types. Additionally, chopper amplifiers have high level "spikes" at the chopping frequency which are, of course, totally absent in the chopperless 180.

VERSUS CONVENTIONAL DIFF AMPS

THERMAL GRADIENTS—The superior drift and noise performance of the 180 is based on the use of special dual monolithic input transistors and proprietary thermal design techniques. One of the major limitations of previously available differential amplifiers has been their acute sensitivity to drift and noise errors introduced by thermal gradients. This means that while these amplifiers might be specified with 5μV/°C drift coefficients, it is implied in this specification that the amplifier is subjected to a totally isothermal environment. In practice, however, this is rarely the case. Installation of the amplifier near cooling fans, transformers, power transistors, or other active devices will almost always produce a temperature difference between opposite sides of the amplifier and therefore, a thermal gradient across it. Since differential amplifiers depend on cancellation of V_{BE} voltages for their drift performance, this results in offset errors (and low frequency noise) far in excess of the published specifications and the designer's expectations. The aforementioned attention to special monolithic transistors and thermal design reduce this effect in the 180 by at least an order of magnitude.

LONG TERM AND WARM-UP DRIFT—Special high stability metal film resistors are used at critical points in the design of the 180. Since resistor aging is the major cause of long term drift in operational amplifiers, the 180 specification of 20μV/year is several times better than amplifiers designed with carbon composition resistors (most low-cost op amps). Further, the combination of special components and thermal design limit warm-up drift to less than 5μV, two orders of magnitude less than is found in most conventional differential op amps.



HOW THE MODEL 180 WORKS

The advanced performance of the Model 180 is based on a proprietary technique for closely matching the dual input transistors together with refined circuit design which minimizes every possible source of drift. Since the voltage offset of differential amplifiers depends on cancellation of the 2,400μV/°C drift of each input transistor, a very small temperature difference between the junctions of the input pair caused by thermal gradients can cause a significant offset error. In the 180, the use of a monolithic pair at the amplifier input greatly reduces this source of error. As an illustration, an abrupt temperature shock from 25 to 50°C generates a transient offset voltage of less than 100μV, which is an order-of-magnitude improvement over conventional differential amplifiers.

TEMPERATURE GRADIENTS

Most differential operational amplifiers are critically sensitive to thermal gradients. The dual input transistor used in the Model 180 together with careful design and layout greatly reduces the unit's sensitivity to thermal gradients. The graph in Figure 4 shows the transient offset voltage (referred to the input) resulting from a thermal shock when the amplifier's temperature is abruptly changed from 25°C to 50°C by dipping it into a hot silicon oil bath. This very severe test is rarely encountered in practice but it does illustrate the amplifier's performance under worst conditions.

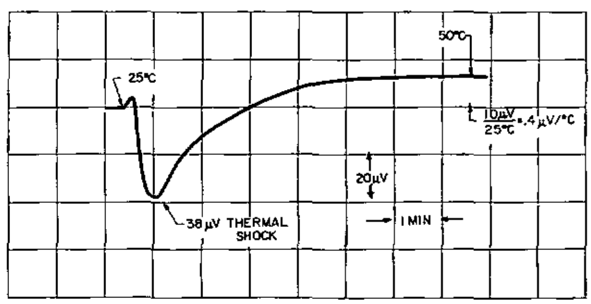


FIG. 4 TRANSIENT OFFSET VOLTAGE RESPONSE TO THERMAL SHOCK

WARM-UP DRIFT

The amplifier has exceptionally low warm up drift following the application of power supply voltage. Initial warm up drift is typically less than 5µV over a period of 5 to 10 minutes.

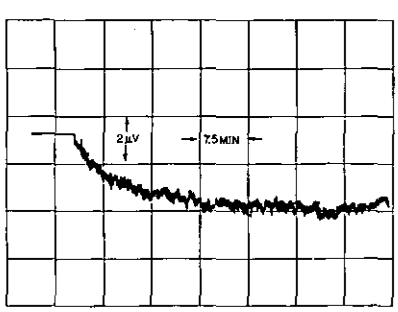


FIG. 5 TYPICAL WARM-UP DRIFT

LOW NOISE

Voltage noise of the 180 is extremely low for a transistor input amplifier. Low frequency or "flicker" noise is less than 1µV p-p, over a bandwidth of .01Hz to 1Hz. This is contrasted with 5-20µV p-p for chopper types. Additionally chopper amplifiers often exhibit high peak to peak values of chopper noise at and around the chopper frequency. This "spike" noise is, of course, absent in the chopperless 180. The accompanying graphs represent actual data taken on the 180 showing .01Hz to 1Hz noise, total voltage and current noise as a function of input resistance (Fig. 6) and a plot of voltage and current noise per root cycle of bandwidth (Fig. 7).

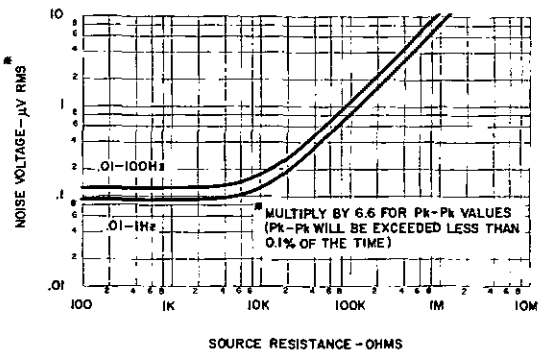


FIG. 6 EQUIVALENT VOLTAGE NOISE AS A FUNCTION OF INPUT RESISTANCE FOR CONSTANT BANDWIDTH

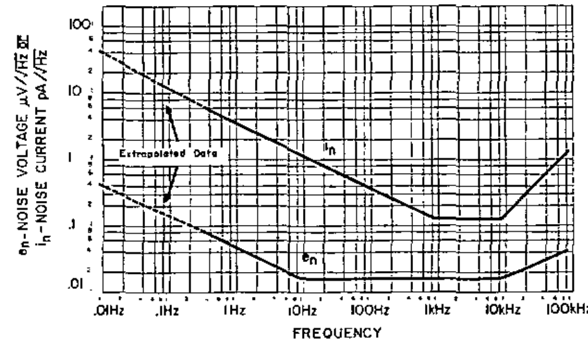


FIG. 7 VOLTAGE AND CURRENT NOISE PER ROOT CYCLE BANDWIDTH

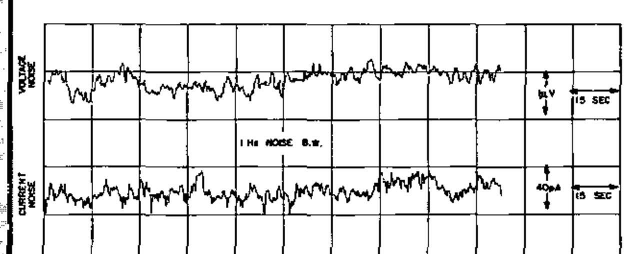


FIG. 8 TYPICAL VOLTAGE AND CURRENT NOISE .01Hz to 1Hz

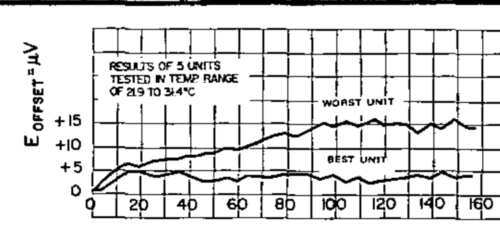


FIG. 9 LONG TERM STABILITY

INITIAL OFFSET VOLTAGE

Most differential operational amplifiers have provisions for adjusting initial offset to zero with an external trim pot. It is not usually realized that there is a second order increase in voltage drift which accompanies the initial offset adjustment. The increased voltage drift due to balancing the amplifier can be safely ignored in conventional amplifiers since it is a small percentage of the specified voltage drift. But the voltage drift of the Model 180 is so small that this effect cannot be ignored. For example if a 100k pot were used to balance the initial offset voltage of the 180A (1mV initial offset), voltage drift could change by as much as $\pm 3\mu V/^\circ C$ and thus would exceed the specification.

The voltage drift of the Model 180 is measured and guaranteed when using a selected trim resistor. This resistor is supplied with the amplifier and the value for this resistor is inscribed on the unit. The specified voltage drift holds only when this value of resistance is externally connected between the amplifier's TRIM terminal and +15V. In this case initial offset voltage is guaranteed to be less than the specified value at +25°C. Models 180B and K guarantee initial offset voltage to be less than $\pm 100\mu V$ ($\pm 250\mu V$ for 180J). In this case an external 100k trim pot used to zero initial offset will not degrade voltage drift by more than ± 0.3 and $0.75\mu V/^\circ C$ respectively. The 180 can also be supplied on special order with the trim resistor connected internally.

INITIAL OFFSET ADJUSTMENTS

In some applications it may be desirable to zero the initial offset of the amplifier and an external bias network is recommended which will accomplish this purpose and allow the 180 to obtain lowest voltage drift. For the inverting configuration in Figure 1, the amplifier can be easily zeroed by summing an additional bias voltage (e_b) which is set equal to the initial offset of the amplifier.

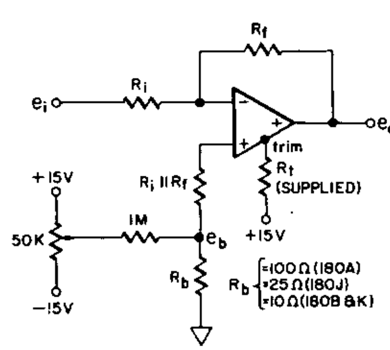


FIG. 1 BIASING CIRCUIT FOR INVERTING CONFIGURATION

The stability of the components or the ±15V bias voltages is only moderately critical. For example: a 1% change of components or supply voltages would cause only about a $1.5\mu V$ change of offset voltage (where R_b equals ten ohms) and likewise a 0.1% control of these values will maintain a $.15\mu V$ offset. These figures should be multiplied by a factor of 2.5 and 10 for $R_b = 25$ and 100Ω respectively.

This circuit will also zero the offset due to initial difference current for values of R_i up to about 100k ohms. For larger values of R_i the value of R_b may have to be increased. Figure 2 shows a biasing circuit which can be used for the noninverting configuration.

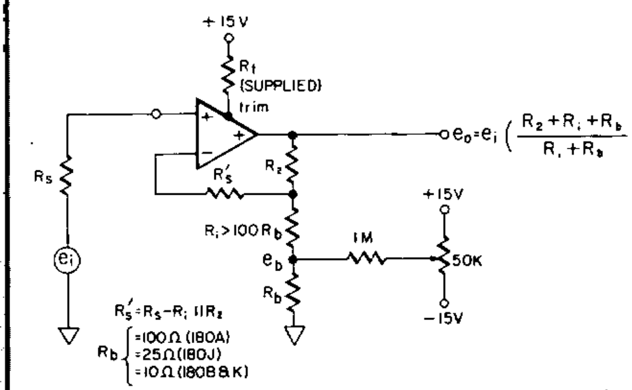


FIG. 2 BIASING CIRCUIT FOR NON-INVERTING CONFIGURATION

A large value for R_i as compared to R_b is only necessary for low closed loop gains (less than 10) to prevent the bias voltage, e_b, from changing as a function of the input voltage. For gains greater than 10, the minimum value for R_i can be reduced proportional to gain.

Of course, the circuit in Figure 2 will not work for unity gain. For this case a 100k ohm pot may be substituted for R_T to zero the amplifier. But it must be realized that the voltage drift will be increased by as much as $3\mu V/^\circ C$ for the 180A under the worst conditions. Alternatively, it is recommended that the Model 180B, J, or K be ordered with lower initial offset voltage ($\pm 100\mu V$ B or K, $\pm 250\mu V$ J) in which case the degradation due to zeroing with R_T will be one fourth to one tenth less. A similar circuit to Figure 2 can be used to bias the differential configuration of Figure 3.

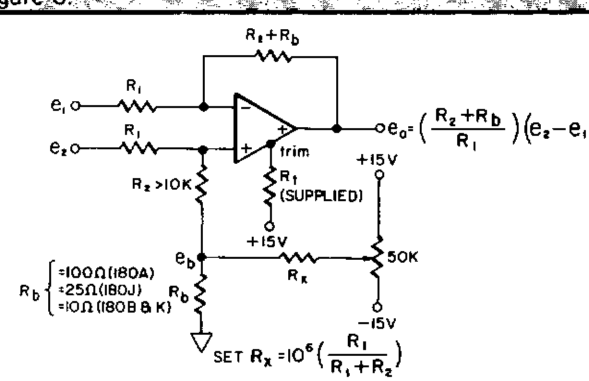
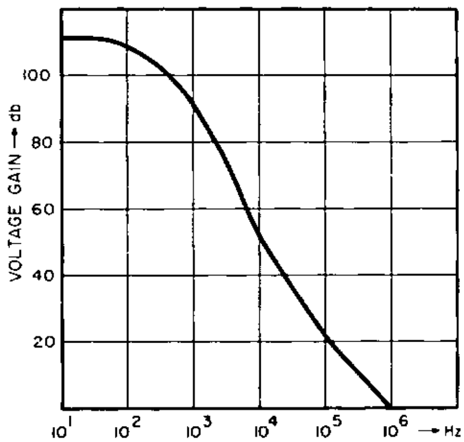


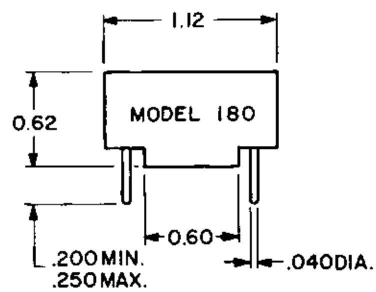
FIG. 3 BIASING CIRCUIT FOR DIFFERENTIAL CONFIGURATION

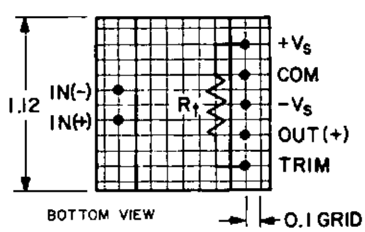
For very large gains (R_2/R_1) it may be necessary to use a larger value of R_b in the bias circuit in order not to load the bias voltage supplies.

OPEN LOOP RESPONSE



OUTLINE DIMENSIONS

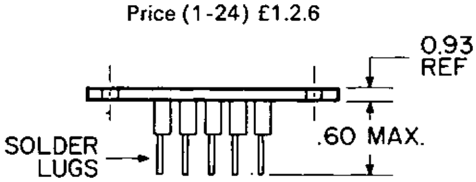


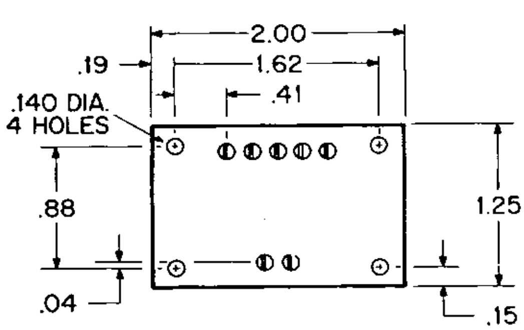


MATING SOCKET

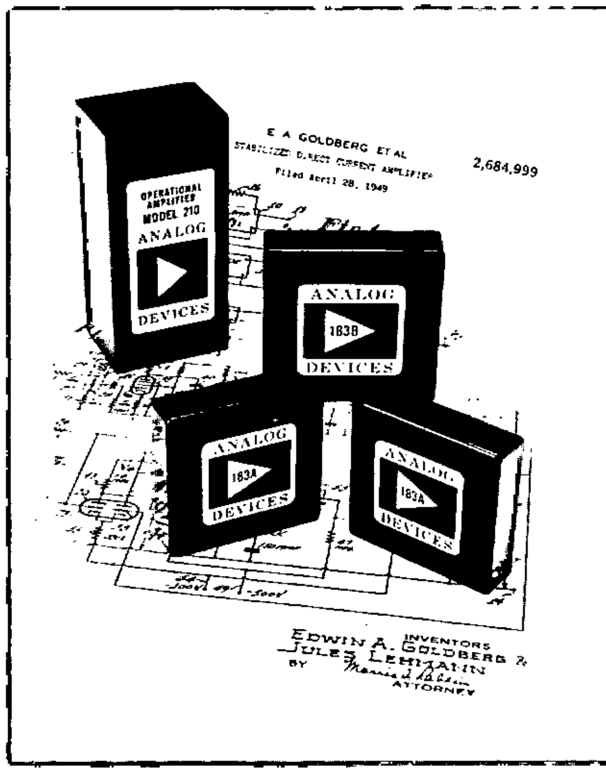
AC1003

Price (1-24) £1.2.6





OTHER LOW DRIFT AMPLIFIERS



A number of additional low drift amplifiers are available from Analog Devices. Among these is a complete line of chopper stabilized types including Models 230 (0.1μV/°C, 0.5pA/°C, $139 unit quantities) and Model 210 (0.5μV/°C, 1.0pA/°C, $157).

For high impedance applications where ultra low bias current is required, Models 141, 142, 143, 147 and 501 feature FET inputs. Models 301, 302, 310 and 311 are varactor bridge types with femto-amp bias currents.

The Model 183 is a chopperless differential amplifier similar to the 180 series with somewhat relaxed specifications and reduced cost.

ANALOG DEVICES, LTD.
38-40 FIFE ROAD
KINGSTON-ON-THAMES
SURREY
01-546-6636
01-549-0811

DESCRIPTION

The Model 184 is a third generation improvement in a series of ultra low drift, chopperless, differential input operational amplifiers from Analog Devices. By using new design techniques and improved components, performance has been upgraded and drift reduced to only 0.25μV/°C. Combining this with an initial offset voltage of only 100μV and input difference current drift of 0.02na/°C, the Model 184L achieves the best drift performance of any differential input op amp currently available. Prices, however, have been reduced to a point where the Model 184 will be an attractive solution for many low level, high accuracy instrumentation applications.

WHERE TO USE THE MODEL 184

While chopper stabilized amplifiers, such as Models 232 and 233, still offer the very lowest levels of voltage and current drift, their range of possible applications is limited by their single-ended input design. By contrast, owing to its differential inputs, the Model 184 may be connected as a non-inverting amplifier with input impedance of 10^9 ohms, or as a bridge circuit differential amplifier. In addition, flicker noise (often observed in chopper amplifiers) is reduced, and chopping spikes are, of course, totally absent.

The Model 184 is the best choice where small signal levels, less than 1 millivolt, from source impedances up to 100k ohms, must be observed, measured, or manipulated. Other applications include large signals which must be buffered with extremely high accuracy, such as 1 volt with 0.01% accuracy.

LONG TERM STABILITY

Special attention has been paid to minimizing the long term aging drift of the Model 184. Since little industry data is available on long term drift, the circuits and components of the Model 184's predecessor have been tested and monitored for more than one year to verify their aging and stability characteristics. The remarkable long-term stability of the dual monolithic transistors and other input stage components used in the Model 184 is illustrated by actual data taken on a group of similar amplifiers, as shown in Fig. 6.

OFFSET AND DRIFT

Initial offset voltage is adjusted and fixed at less than 100μV to remove any possibility of disturbing the drift characteristics of the amplifier due to second order effects of standard external trim operations. If desired, the remaining offset may be reduced to zero by external bias networks, as shown on page 3. Warmup drift and offsets caused by dissipation and thermal gradients are essentially negligible. The Model 184 embodies the most exotic low-drift performance ever achieved in differential op-amps and represents the culmination of over four years of intensive research and development in this area of amplifier design.

MODEL 184J/K/L
ULTRA LOW DRIFT
CHOPPERLESS DIFFERENTIAL
OPERATIONAL AMPLIFIER

FEATURES

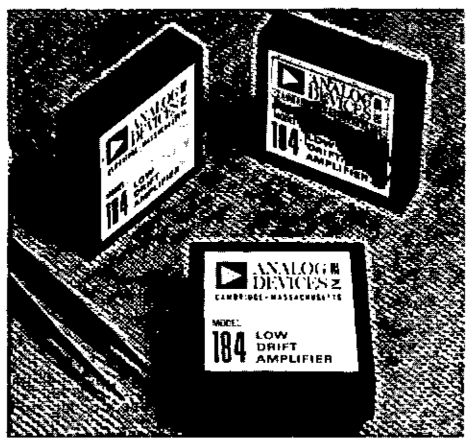
Initial Offset—under 100μV

Voltage Drift— .25μV/°C max

Long Term Drift—3μV/month,
10μV/year

Common Mode Z—2000 Megohms

Difference Current Drift—.02 nA/°C



APPLICATIONS

High Impedance Buffer

Bridge Amplifier

Stable Voltage Source

Low Level Preamplifier

Precision Voltage Comparator

ANALOG DEVICES INC
PASTORIZA DIVISION
59 Eden Street, Kingston-on-Thames
Surrey, ENGLAND
Telephones
01-546 6636 01-549 0811 01-549 1277/8

Printed in Switzerland

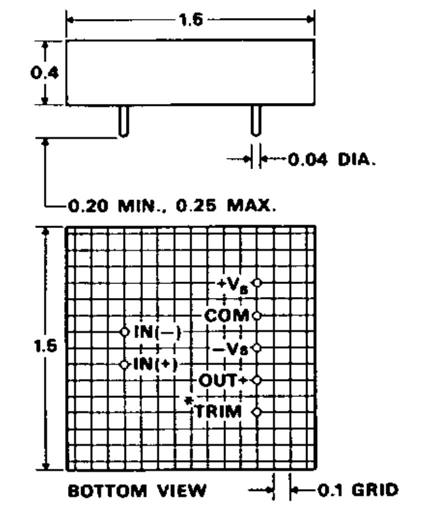
MODEL: 184 ELECTRICAL SPECIFICATIONS

SPECIFICATIONS (typical @25°C and ±15VDC unless otherwise noted)

MODEL	184J	184K	184L
OPEN LOOP GAIN			
with 2kΩ dc load, min	300,000	*	*
with 10kΩ dc load	1,000,000	*	*
RATED OUTPUT			
Voltage, min	±10V	*	*
Current, min	±5mA	*	*
Load capacitance range	0 to 1000pF	*	*
FREQUENCY RESPONSE			
Unity gain, small signal	1.0MHz	*	*
Full power response, min	5kHz	*	*
Slewing rate, min	0.3V/μsec	*	*
INPUT OFFSET VOLTAGE			
Initial offset, 25°C, max	±250μV	±100μV	±100μV
vs. temp (+10° to +60°C)max	±1.5μV/°C	±0.5μV/°C	±0.25μV/°C
vs. supply voltage	±5μV/%	*	*
vs. time	±3μV/month	*	*
Warm-up drift 20 minutes	±10μV	*	*
INPUT BIAS CURRENT			
Initial bias, 25°C, max	(0, +) 25nA	*	*
vs. temp (rated temp. range) max.	(0, -) 0.25nA/°C	*	*
vs. supply voltage	+0.1nA/%	*	*
INPUT DIFFERENCE CURRENT			
Initial difference, 25°C	±2nA	*	*
Avg. vs. temp, rated temp. range	±0.02nA/°C	*	*
INPUT IMPEDANCE			
Differential	4MΩ ‖ 4pF	*	*
Common mode	2000MΩ ‖ 4pF	*	*
INPUT NOISE			
Voltage, .01 to 1Hz, p-p	1μV	*	*
5Hz to 10kHz, rms	3μV	*	*
Current, .01 to 1Hz, p-p	10pA	*	*
INPUT VOLTAGE RANGE			
Common mode rejection ratio at ±10VDC	100dB	*	*
Max. safe differential voltage	±15V	*	*
POWER SUPPLY			
Voltage, rated specification	±15V	*	*
Voltage, derated specification	±(10 to 18)V	*	*
Current, quiescent	±9mA	*	*
TEMPERATURE RANGE			
Operating, rated performance	+10 to +60°C	*	*
Operating	-55 to +85°C	*	*
Storage	-55 to +125°C	*	*
MECHANICAL			
Mating socket	AC 1010	*	*
Weight	0.9 oz.	*	*
PRICE			
1-24	£23.0.0	£30.0.0	£37.0.0

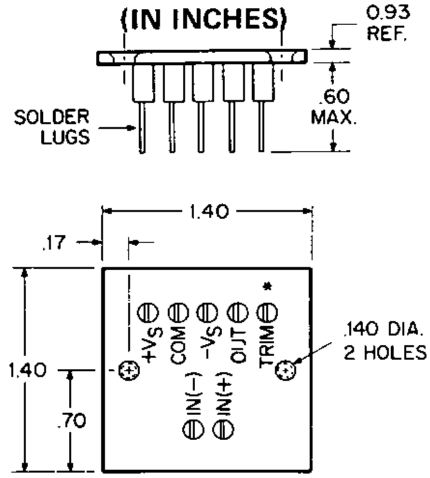
*Specifications same as for Model 184J.
Specifications subject to change without notice.

Models 184A and 184B are identical to Models 184J and 184K respectively, except that listed specifications are met over the extended temperature range of −25°C to +85°C. Offset voltage drift is based on 3 point measurement: −25°C to +25°C and +25°C to +85°C.



*TRIM CONNECTION — the amplifier is internally trimmed as explained on page 3. It requires no external trim connection. Though the TRIM terminal is brought out, no connection should be made to it.

OUTLINE DIMENSIONS
(IN INCHES)



*See note above

MATING SOCKET AC1010

Ultra-low drift chopper stabilized amplifiers with 0.1μV/°C voltage drift and 50pA input current — Analog models 230, 231, 232, 233, 260, for both inverting and non-inverting applications are available at low cost.

INITIAL OFFSET VOLTAGE COMPENSATION

Most differential input operational amplifiers have provisions for compensating initial offset voltage to zero using an external trim potentimeter. It is not usually realized that there is a second order increase in voltage drift which accompanies the initial offset adjustment, since perfect trim normally requires unbalanced collector load resistances in the first differential stage. This second order drift can be ignored in most operational amplifiers, since it is only a small percentage of the total drift. In the Model 184, however, the basic drift is so low that this additional component could be significant. Therefore, initial offset voltage at 25°C has been internally trimmed to the lowest practical level during production of the Model 184, and the amplifier's "trim" connection must NOT be used. For many applications, the initial offset of the amplifier is indeed so low that the expense and inconvenience of an external trim is not necessary. In some applications, however, it may be desired to reduce the remaining initial offset voltage to zero. For the inverting configuration, Figure 1 illustrates the technique for providing an additional bias voltage (E_b) to reduce the initial offset to zero.

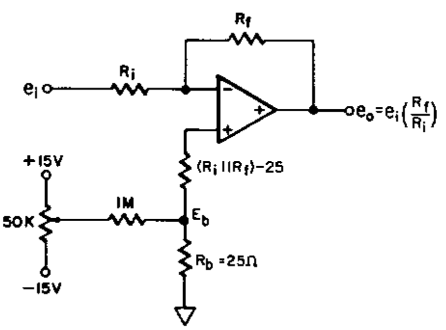


Fig.1 Biasing Circuit for Inverting Configuration

The stability required of the trim components and of the ±15 volt supply is only moderately critical. For example, a 1% change on the ±15V supply would only result in a 4.0μV shift of offset voltage, and likewise, a 0.1% change in the circuit values will maintain a 0.40μV offset limit. This circuit may also be used to zero the net offset resulting from initial input difference current. Figures 2 and 3 show similar circuits for zeroing the offset voltage, for both the non-inverting and differential configurations.

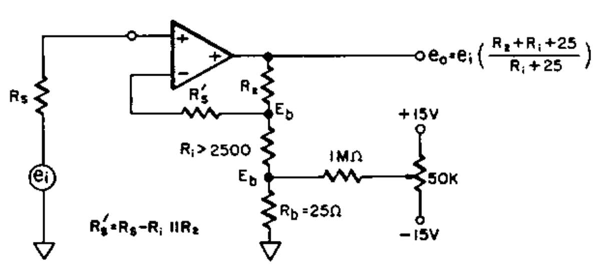


Fig.2 Biasing Circuit for Non-Inverting Configuration

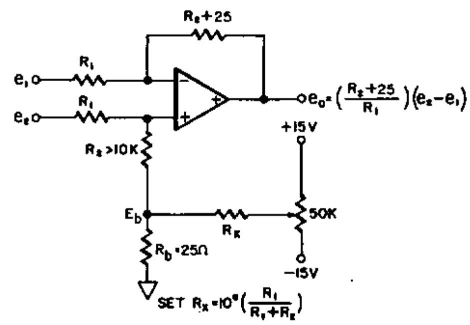
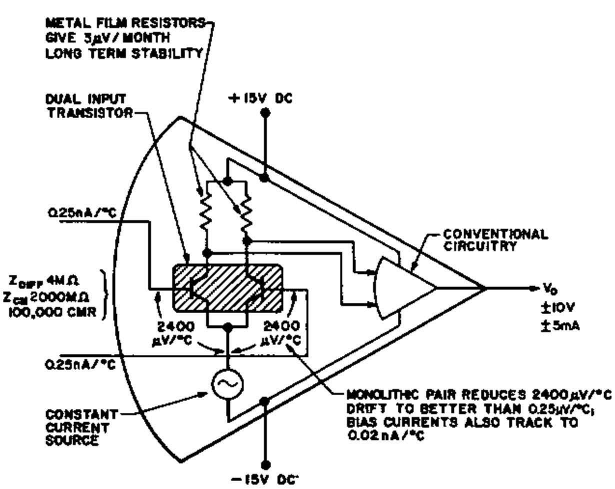


Fig.3 Biasing Circuit for Differential Configuration

HOW THE MODEL 184 ACHIEVES ULTRA LOW DRIFT

The advanced performance of the Model 184 is based on the use of a dual monolithic input transistor in a highly-refined circuit design utilizing extensive matching and selection to minimize every possible source of drift. Since the stability vs. temperature of the Model 184 depends critically on the cancellation of the 2400μV/°C drift at each of the base-emitter junctions in the differential input stage, an extremely small thermal gradient between these junctions can cause a significant drift error. The special dual input transistor and proprietory design techniques reduce the resultant drift of the 184 to a level previously unobtainable with chopperless amplifiers.



HOW THE MODEL 184 WORKS

TEMPERATURE GRADIENTS

Most differential operational amplifiers are critically sensitive to thermal gradients. The dual monolithic input transistor used in the Model 184 (together with careful design and layout) greatly reduces the unit's sensitivity to thermal gradients. The graph in Figure 4 shows the transient offset voltage (referred to the input) resulting from a thermal shock when the amplifier's temperature is abruptly changed from 25°C to 50°C by dipping it into a hot silicone oil bath. This very severe test is rarely encountered in practice but it does illustrate the amplifier's performance with violent temperature changes.

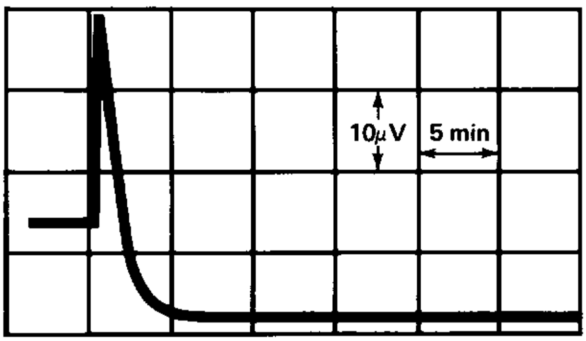


Fig.4 25°C Thermal Shock for Model 184J

WARM-UP DRIFT

The amplifier has exceptionally low warm up drift following the application of power supply voltage. Initial warm up drift is typically less than 10μV over a period of 10 minutes.

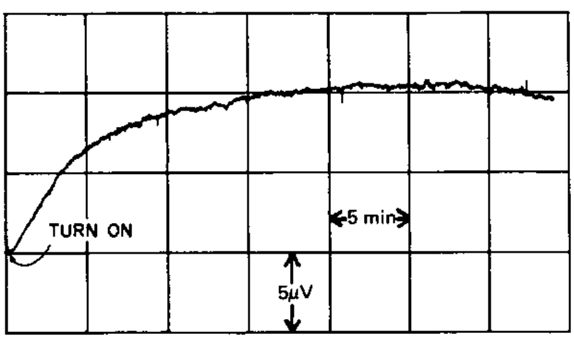


Fig.5 Typical Warm-Up Drift

LOW NOISE

Voltage noise of the 184 is extremely low for a transistor input amplifier. Low frequency or "flicker" noise is less than 1μV p-p, over a bandwidth of .01Hz to 1Hz. This is contrasted with 2-6μV p-p for chopper types. Additionally, chopper amplifiers often exhibit high peak-to-peak values of chopper noise in the vicinity of the chopper frequency and its harmonics. This "spike" noise is, of course, absent in the chopperless 184.

LONG TERM DRIFT

Life tests run on Models 180 and 183, the predecessors of the 184, have shown that long term drift over a year will be only 10μV. The performance of the Model 184 should equal or improve on this data. Figure 6 shows data taken on a group of Model 183 amplifiers over a one year period.

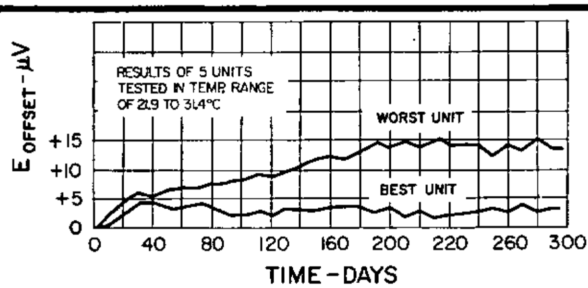


Fig.6 Long Term Stability

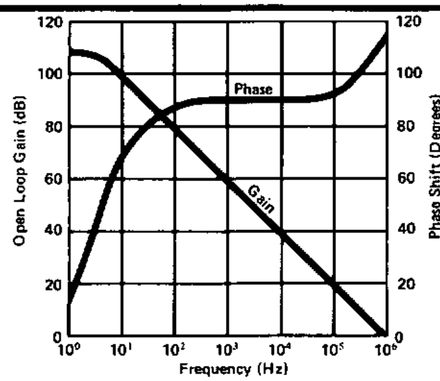


Fig.7 Frequency and Phase Response of Model 184

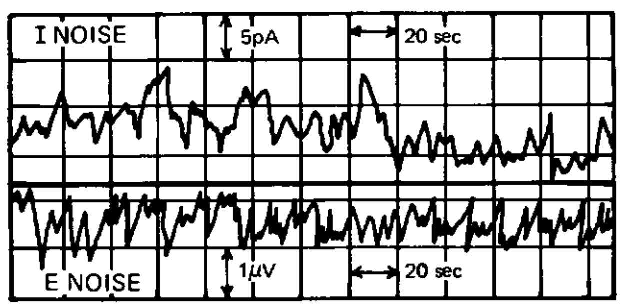


Fig.8 Voltage and Current Noise 0.01–1 Hz

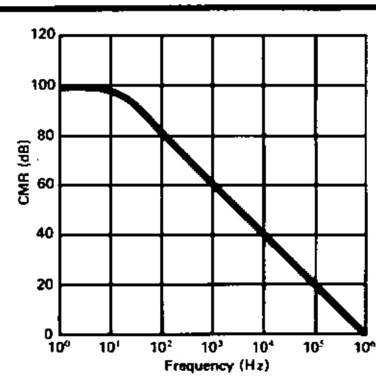


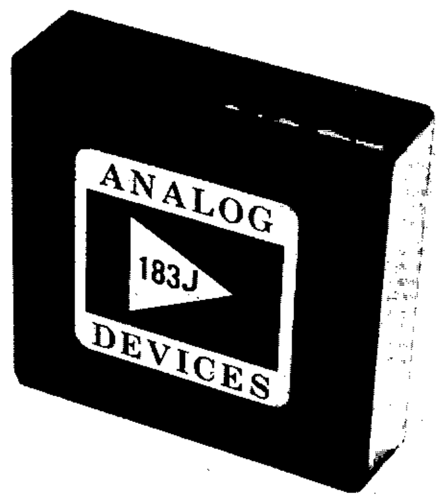
Fig.9 CMR vs. Frequency

Model 183 J/K/L

LOW COST / LOW DRIFT CHOPPERLESS DIFFERENTIAL OPERATIONAL AMPLIFIER

FEATURES

Voltage Drift	1.5μV/°C
Input Impedance	1000MΩ
Low Noise	1μV P-P
Low Profile	.4" Height
Price (1-9)	\$35 (J)
	\$45 (K)
	\$65 (L)



APPLICATIONS

Low Level Signal Conditioning
Precision Voltage Comparators
Microvolt DC Amplifier
High Impedance Buffers

DESCRIPTION

The new generation chopperless 183 series operational amplifiers are designed to solve application problems where low drift, low noise, small size and low cost are primary design considerations. Because no single operational amplifier can solve all problems simultaneously, certain compromises must be made as "trade-offs" for superior performance in other key parameters. In this regard it will be found that the 183 is not the best amplifier for use in applications requiring high speed (i.e., wide bandwidth, high slew rates, fast settling times, etc.). Additionally, where extremely high source resistances (above, say, 100KΩ) require the consideration of very low bias currents the 183 should not be considered the best choice. Analog Devices manufactures a wide variety of extremely fast amplifiers and has a very complete collection of FET and varactor bridge types for these specialized applications.

WHERE TO USE THE 183

The 183 series is the best choice where very small signal levels (less than 1mV), from moderate source impedances (below 100KΩ), with modest frequency requirements (DC-5KHz) must be observed, measured or manipulated. Also in this group are larger signal levels that must be operated upon with a very high degree of accuracy, e.g., 1 volt to .01% accuracy. Low voltage drift and noise specifications are the prime requisites for proper solution to this class of op-amp application problems. Another application is the low drift/high input impedance buffer amplifier.

Until the advent of the new generation chopperless-differential op amps (pioneered by the Analog Devices Model 180), design engineers have been forced to either compromise their requirements and use existing differential amplifiers or apply the more costly chopper stabilized types, not without encountering certain other difficulties. The 183 is contrasted with these alternative approaches below.

VERSUS CHOPPER TYPES

HIGH INPUT IMPEDANCE — Chopper amplifiers, while exceptionally good for low voltage drift, generally single-ended input devices, and are only applicable as inverting amplifiers. The chopperless 183 provides the flexibility of true differential inputs and hence may be connected in the noninverting configuration. This connection "bootstraps" input impedance to 1000MΩ (the common mode impedance). Most chopper amplifiers can achieve input impedances of only a few megohms. The 183 can also be connected in all other op-amp configurations requiring differential inputs.

LOW NOISE — The 183 is specified at 1μV p-p noise level in a bandwidth of .01Hz to 1Hz, an order of magnitude less than the "flicker noise" of most chopper types. Additionally, chopper amplifiers have high level "spikes" at the chopping frequency which are, of course, totally absent in the chopperless 183.

LOW COST AND SIZE —The high performance of the 183 is available at a fraction of the cost of most chopper stabilized op amps. The .4" height also allows the 183 to be designed in where large and heavy chopper types could not be considered.

VERSUS CONVENTIONAL DIFF AMPS

THERMAL GRADIENTS — The superior drift and noise performance of the 183 is based on the use of special dual input transistors and proprietary thermal design techniques. One of the major limitations of previously available differential amplifiers has been their acute sensitivity to drift and noise errors introduced by thermal gradients. This means that while these amplifiers might be specified with 5μV/°C drift coefficients, it is implied in this specification that the amplifier is subjected to a totally isothermal environment. In practice, however, this is rarely the case. Installation of the amplifier near cooling fans, transformers, power transistors, or other active devices will almost always produce a temperature difference between opposite sides of the amplifier and therefore, a thermal gradient across it. Since differential amplifiers depend on cancellation of V_{BE} voltages for their drift performance, this results in offset errors (and low frequency noise) far in excess of the published specifications and the designer's expectations. The aforementioned attention to special transistors and thermal design reduce this effect in the 183 by at least an order of magnitude.

BIAS AND DIFFERENTIAL CURRENT ERRORS — All differential amplifiers are subject to an equivalent voltage error developed by the bias current across the input resistance (in the case of the inverting connection), or the source impedance (for the noninverting configuration). It is not always realized that the + and — bias currents tend to "track" one another and by balancing the impedances "seen" (with respect to ground) by the + and — inputs, the equivalent voltage offset may be calculated on the basis of the difference current (I_d) specified for the amplifier. The 183 difference current is specified with a guaranteed maximum value of .05nA/°C. The engineer who employs the above technique by means of a compensating resistor may confidently predict drift performance of his design. The 10 to 1 improvement of difference current over bias current means that the maximum allowable impedance (to remain within any given limit of error) may be extended by a full decade of resistance.

LONG TERM AND WARM-UP DRIFT—Special high stability metal film resistors are used at critical points in the design of the 183. Since resistor aging is the major cause of long-term drift in operational amplifiers, the 183 specification of 100μV/ year is several times better than amplifiers designed with carbon composition resistors (most low-cost op amps). Further, the combination of special components and thermal design limit warm-up drift to less than 20μV, an order of magnitude less than is found in most convential differential op amps.

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CAMBRIDGE, MASS. 02142
PHONE: 617/492-6000
TWX: 710/320-0326

C043a-10-12/69 PRINTED IN U.S.A.

Model 183 J/K/L

LOW COST / LOW DRIFT CHOPPERLESS DIFFERENTIAL OPERATIONAL AMPLIFIER

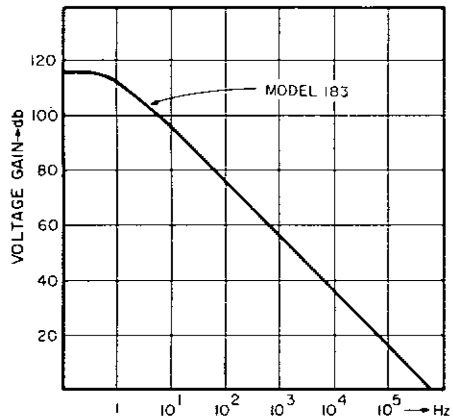
SPECIFICATIONS (typical @ 25°C unless noted)

OPEN LOOP GAIN			
dc rated load, min.	2×10^5		
RATED OUTPUT			
Voltage, min.	±10V		
Current, min.	5mA		
FREQUENCY RESPONSE			
Unity gain, small signal	0.5MHz		
Full power response, min.	5kHz		
Slewing rate, min.	0.3V/μsec		
Overload recovery	2msec		
INPUT OFFSET VOLTAGE	Model J	Model K	Model L
Initial offset, 25°C max.	±3mV	±.5mV	±.5mV
Avg. vs. temp. max.*	±5μV/°C	±3μV/°C	±1.5μV/°C
vs. supply voltage	±10μV/%	±10μV/%	±10μV/%
vs. time	±10μV/day	±10μV/day	±10μV/day
INPUT BIAS CURRENT			
Initial bias, 25°C max.	(0, +) 40nA		
Avg. vs. temp. max.*	±0.5nA/°C		
vs. supply voltage	±0.2nA/%		
INPUT DIFFERENCE CURRENT			
Initial difference, 25°C, max.	±4nA		
Avg. vs. temp. max.*	.05nA/°C		
INPUT IMPEDANCE			
Differential	2MΩ		
Common mode	1000MΩ		
INPUT NOISE			
Voltage, .01 to 1Hz, p-p	1μV		
.01 to 100Hz, p-p	2μV		
5Hz to 50kHz, rms	12μV		
Current, .01 to 1 Hz, p-p	50pA		
.01 to 100Hz, p-p	75pA		
INPUT VOLTAGE RANGE			
Common mode voltage, min.	±10V		
Common mode rejection	100,000		
Max. safe differential voltage	±15V		
POWER SUPPLY			
Voltage, rated specification	± (15 to 16) V		
Voltage, derated specification	± (10 to 18) V		
Current, quiescent, max.	± 10mA		
TEMPERATURE RANGE			
Operating, best performance*	−25 to 85°C		
Operating, derated performance	−55 to 85°C		
Storage	−55 to 125°C		
PRICE	Model J	Model K	Model L
(1-9)	$35.00	$45.00	$65.00
(10-24)	$33.00	$43.00	$62.00

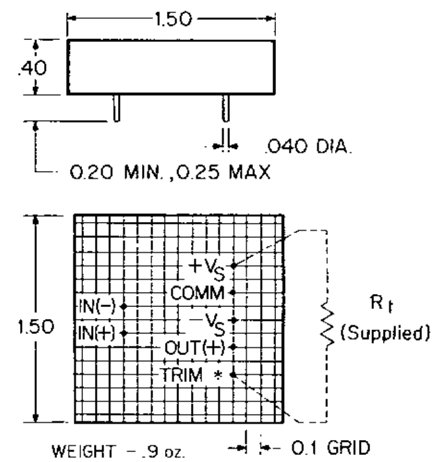
*Models J, K, L are tested for operation from +10°C to +60°C.
For operation from −25°C to +85°C specify models A, B, C (respectively) and add $5 each.

Specifications subject to change without notice.

www.Electrojumble.org.uk

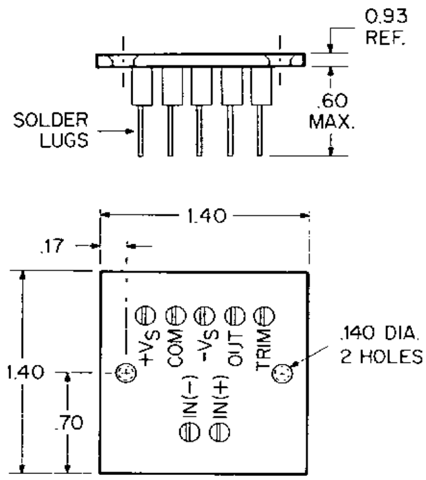


OPEN LOOP RESPONSE



*There must be an electrical connection between this terminal and +15V supply for proper operation.

OUTLINE DIMENSIONS



Price — $3.00 (1-9)

MATING SOCKET AC1010

APPLICATION NOTES FOR MODEL 183

INITIAL OFFSET VOLTAGE

Most differential operational amplifiers have provisions for adjusting initial offset to zero with an external trim pot. It is not usually realized that there is a second order increase in voltage drift which accompanies the initial offset adjustment. The increased voltage drift due to balancing the amplifier can be safely ignored in conventional amplifiers since it is a small percentage of the specified voltage drift. But the voltage drift of the Model 183 is so small that this effect cannot be ignored. For example if a 100K pot were used to balance the initial offset voltage of the 183J (3mV initial offset), voltage drift could change by as much as $\pm 9\mu V/^{\circ}C$ and thus would exceed the specification by a large measure.

The voltage drift of the Model 183 is measured and guaranteed when using a selected trim resistor. This resistor is supplied with the amplifier and the value for this resistor is inscribed on the unit. The specified voltage drift holds only when this value of resistance is externally connected between the amplifier's TRIM terminal and +15V. In this case initial offset voltage is guaranteed to be less than the specified value at $+25^{\circ}C$. Models 183K and 183L guarantee initial offset voltage to be less than $\pm 500\mu V$. In this case, an external 100K trim pot used to zero initial offset will not degrade voltage drift by more than $\pm 2\mu V/^{\circ}C$. The 183 can also be supplied on special order with the trim resistor connected internally.

INITIAL OFFSET ADJUSTMENTS

In some applications it may be desirable to zero the initial offset of the amplifier and an external bias network is recommended which will accomplish this purpose and allow the 183 to obtain lowest voltage drift. For the inverting configuration in Figure 1, the amplifier can be easily zeroed by summing an additional bias voltage (e_b) which is set equal to the initial offset of the amplifier.

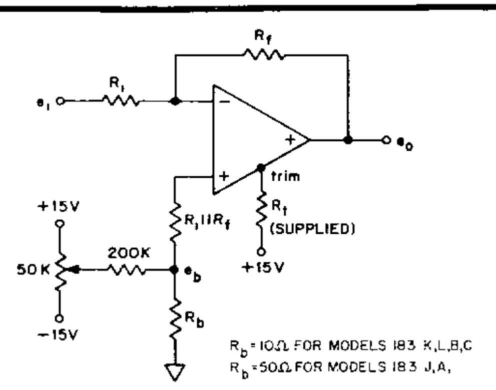


FIGURE 1. BIASING CIRCUIT FOR INVERTING CONFIGURATION

The stability of the components or the ±15V bias voltages is only moderately critical. For example: a 1% change of components or supply voltages would cause only about a $7.5\mu V$ change of offset voltage (where R_b equals ten ohms) and likewise a 0.1% control of these values will maintain a $.75\mu V$ offset. These figures should be multiplied by a factor of five for the case where R_b equals 50 ohms. This value is necessary to balance the 183K and 183A. This circuit will also zero the offset due to initial difference current for values of R_1 up to about 100K ohms. For larger values of R_1 the value of R_b may have to be increased.

Figure 2 shows a biasing circuit which can be used for the noninverting configuration.

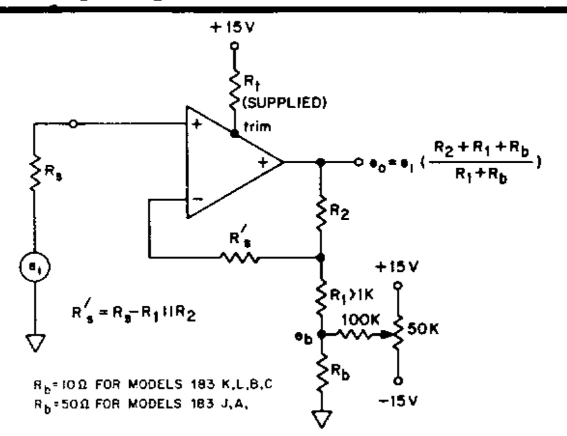


FIGURE 2. BIASING CIRCUIT FOR NONINVERTING CONFIGURATION

A large value for R_1 as compared to R_b is only necessary for low closed loop gains (less than 10) to prevent the bias voltage, e_b, from changing as a function of the input voltage. For gains greater than 10, the minimum value for R_1 can be reduced proportional to gain.

Of course, the circuit in Figure 2 will not work for unity gain. For this case a 100K ohm pot may be substituted for R_1 to zero the amplifier. But it must be realized that the voltage drift will be increased by as much as $9\mu V/^{\circ}C$ for the 183-J under the worst conditions. Alternatively, it is recommended that the Model 183-K or 183-L be ordered with lower initial offset voltage ($\pm 500\mu V$) in which case the degradation due to zeroing with R_1 will be six times less.

A similar circuit to Figure 2 can be used to bias the differential configuration of Figure 3.

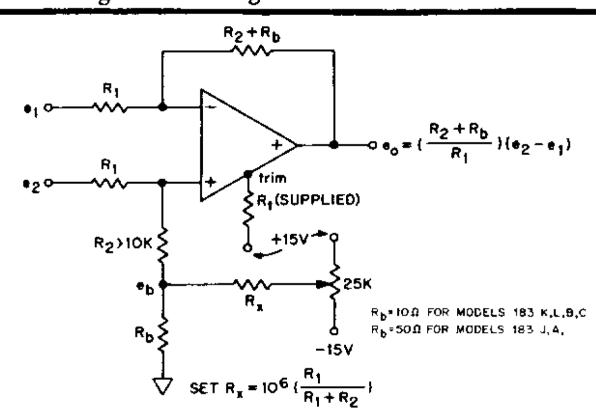


FIGURE 3. BIASING CIRCUIT FOR DIFFERENTIAL CONFIGURATION

For very large gains (R_2/R_1) it may be necessary to use a larger value of R_b in the bias circuit in order not to load the bias voltage supplies.

TEMPERATURE GRADIENTS

Most differential operational amplifiers are critically sensitive to thermal gradients. The dual input transistor used in the Model 183 together with careful design and layout greatly reduces the unit's sensitivity to thermal gradients. The graph in Figure 4 shows the transient offset voltage (referred to the input) resulting from a thermal shock when the amplifier's temperature is abruptly changed from 25°C to 50°C by dipping it into a hot silicon oil bath. This very severe test is rarely encountered in practice but it does illustrate the amplifier's performance under worst conditions.

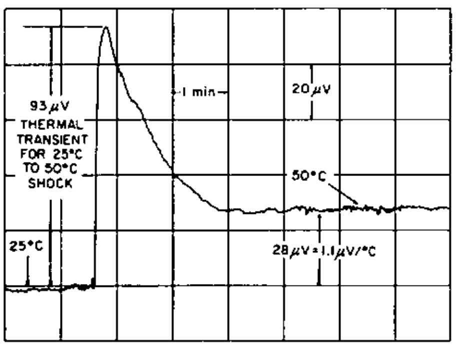


FIGURE 4. TRANSIENT OFFSET VOLTAGE RESPONSE TO THERMAL SHOCK

WARM-UP DRIFT

The amplifier has exceptionally low warm up drift following the application of power supply voltage. Initial warm up drift is typically less than 20μV over a period of 10 to 20 minutes.

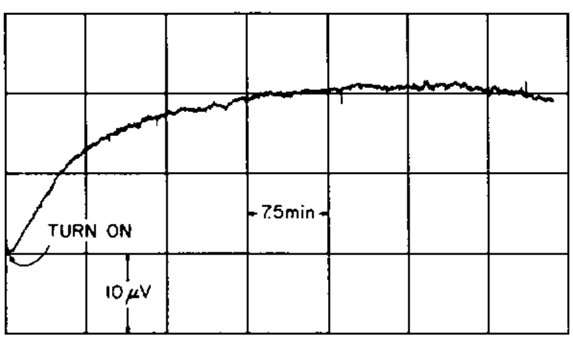


FIGURE 5. TYPICAL WARM-UP DRIFT

LOW NOISE

Voltage noise of the 183 is extremely low for a transistor input amplifier. Low frequency or "flicker" noise is less than 1μV p-p, over a bandwidth of .01Hz to 1 Hz. This is contrasted with 5-20μV p-p for chopper types. Additionally chopper amplifiers often exhibit high peak to peak values of chopper noise at and around the chopper frequency. This "spike" noise is, of course, absent in the chopperless 183. The accompanying graphs represent actual data taken on the 183 showing .01 Hz to 1 Hz noise, total voltage and current noise as a function of input resistance, and a plot of voltage and current noise per root cycle of bandwidth.

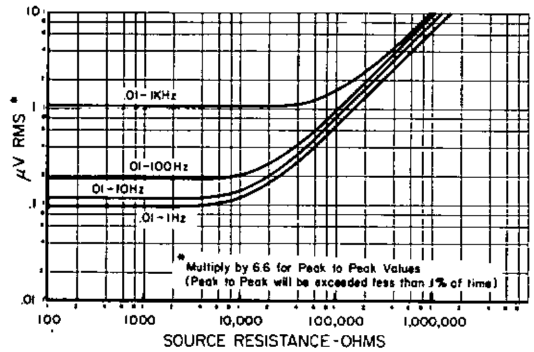


FIGURE 6. EQUIVALENT VOLTAGE NOISE AS A FUNCTION OF INPUT RESISTANCE FOR CONSTANT BANDWIDTH

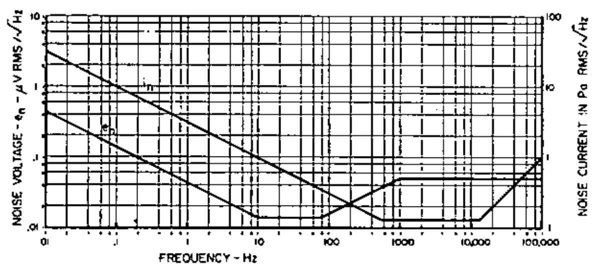


FIGURE 7. VOLTAGE AND CURRENT NOISE PER ROOT CYCLE BANDWIDTH

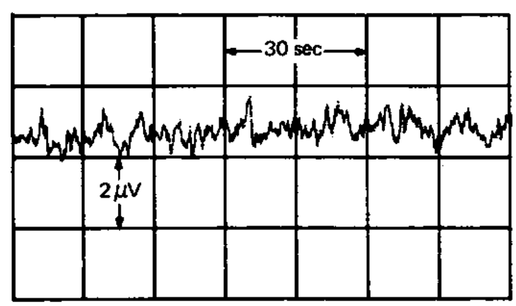


FIGURE 8. TYPICAL VOLTAGE NOISE .01Hz to 1Hz

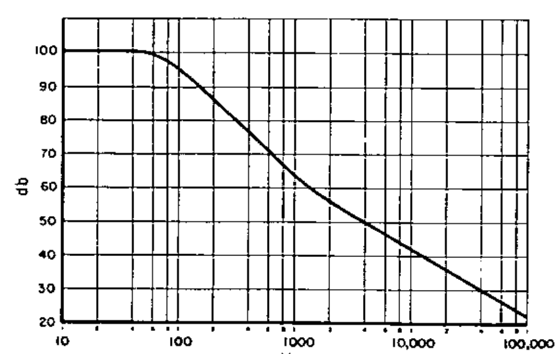


FIGURE 9. CMRR VS. FREQUENCY