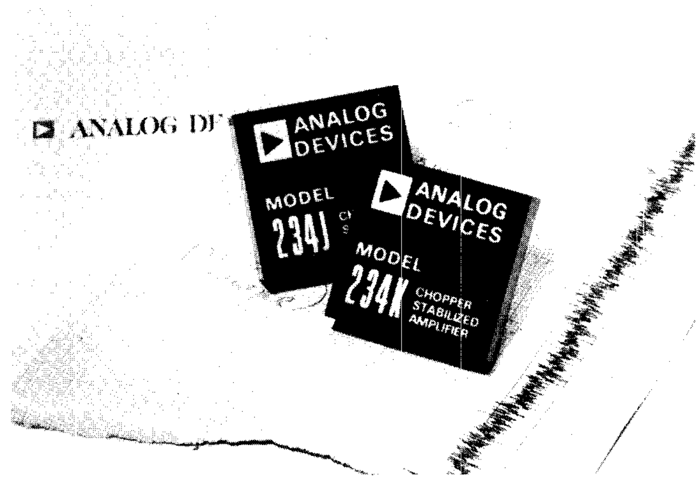
ANALOG DEVICES

Low Noise-Wideband Chopper Stabilized Amplifier

MODEL 234

FEATURES
- Low Drift: 0.1μV/°C, 1pA/°C (Model 234L)
- Offset Stability: 2μV per month
- Submicrovolt Noise: 0.7μV p-p (0.01 to 1Hz B.W.)
- Fast Response: 2.5MHz B.W., 4μs settling (0.01%)
- Low Cost Module
- Small Size: 1½" x 1½" x 0.4"

APPLICATIONS
- Precision Wideband Amplification
- Current and Voltage Summation
- High Speed Integration
- Reference Buffering
- Controlled Current Source
- Bridge Amplifier



GENERAL DESCRIPTION
Analog Devices' model 234 is a high performance chopper stabilized op amp which significantly improves on the noise and bandwidth performance of previous designs. Available with drift of 0.1μV/°C, the model 234 features 0.7μV p-p input noise and 2.5MHz unity gain bandwidth to satisfy many demanding requirements for a premium amplifier at less than premium prices.

Incorporating MOSFET choppers and discrete components (vs. IC op amps) for the main and stabilizing amplifier channels, this inverting design is virtually free of input chopper spikes and offers reduced modulation ripple for quieter wideband performance. These characteristics are especially desirable when operating from high source impedances (above 100kΩ) at wide bandwidths. To illustrate the improvements in noise and bandwidth performance, over previous Analog Devices' designs, comparative data is set forth in the following sections comparing models 232 and 233 with 234.

Other model 234 specifications include: gains of 10^7 V/V, 4μs settling time to 0.01% (20kΩ load, 10V) and three selections for voltage drift: 1μV/°C (234J), 0.3μV/°C (234K), and 0.1μV/°C (234L). Available in a compact plug-in module (1½" x 1½" x 0.4"), model 234 is competitively priced for new OEM designs and is recommended as a pin compatible replacement for upgrading the performance of most existing designs. The use of premium discrete components throughout assures repeatable unit-to-unit performance for best results at lower costs.

APPLICATIONS
In general, the model 234 inverting amplifier should be considered where long term stability of offset voltage must be maintained with time and temperature for precision designs, or wherever carefree operation of instruments and remote circuits is essential. Typical applications include low drift amplification of wideband microvolt signals, integration of low duty-cycle pulse trains and fast analog computing for general purpose designs. Low input noise and stable offset voltages also make model 234 an ideal preamp for precision low frequency applications such as DVM's, 12 to 16 bit A to D converters, and for error amplifiers in servo and null detector systems.

IMPROVED NOISE AND BANDWIDTH PERFORMANCE
The improved performance of model 234 accrues from the use of discrete components throughout, coupled with low noise front-end circuits, all carefully packaged and shielded to minimize pickup and intermodulation effects. Chopper modulation ripple, as shown in Figure 1, is significantly reduced over an earlier design, model 232, for most wideband applications.

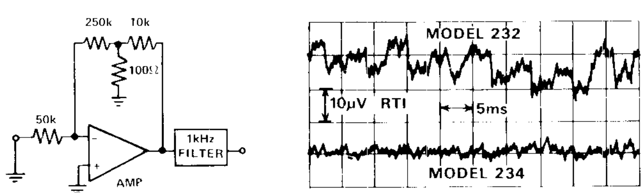


Figure 1. Comparative Input Noise (RTI) Performance in a dc to 1kHz Bandwidth

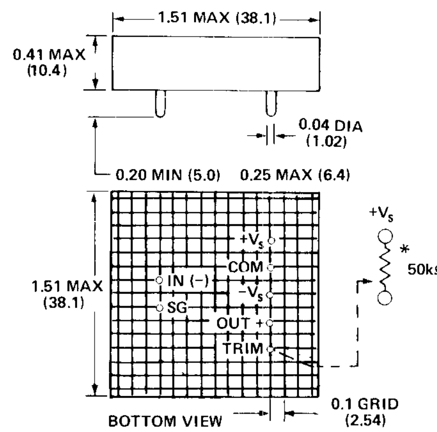
SPECIFICATIONS (typical @ +25°C and ±15V unless otherwise noted)

MODEL	234J	234K	234L
OPEN LOOP GAIN			
DC, 2k ohm load	10^7 V/V min	*	*
RATED OUTPUT			
Voltage	±10V min	*	*
Current	±5mA min	*	*
Load Capacitance Range	0-1000pF min	*	*
FREQUENCY			
Unity Gain, Small Signal	2.5MHz	*	*
Full Power Response	500kHz min	*	*
Slew Rate	30V/μs	*	*
SETTLING TIME to 0.01%			
20kΩ load, 10V step (Figure 2)	4μs	*	*
INPUT OFFSET VOLTAGE			
Initial Offset[1] @ +25°C	±50μV max	±20μV max	±20μV max
vs. Temp, 0 to +70°C	±1.0μV/°C max	±0.3μV/°C max	±0.1μV/°C max
vs. Supply Voltage	±0.2μV/%	*	*
vs. Time	±2μV/month	*	*
vs. Turn On, 10 sec to 10 min	±3μV	*	*
INPUT BIAS CURRENT			
Initial, @ +25°C	±100pA max	*	*
vs. Temp, 0 to +70°C	±4pA/°C max	±2pA/°C max	±1pA/°C max
vs. Supply Voltage	±0.5pA/%	*	*
INPUT IMPEDANCE			
Inverting Input to Signal Ground	300k ohms	*	*
INPUT NOISE			
Voltage, 0.01 to 1Hz	0.7μV p-p	*	*
0.1 to 10Hz	1.5μV p-p	*	*
10Hz to 10kHz	2μV rms	*	*
Current, 0.01 to 1Hz	2pA p-p	*	*
0.1 to 10Hz	4pA p-p	*	*
INPUT VOLTAGE RANGE			
(-) Input to Signal Ground	±15V max	*	*
POWER SUPPLY (V dc)[2]			
Rated Performance	±15V @ 5mA	*	*
Operating	±(12 to 18)V	*	*
TEMPERATURE RANGE			
Rated Specifications	0 to +70°C	*	*
Operating	-25°C to +85°C	*	*
Storage	-25°C to +100°C	*	*

*Specifications same as model 234J.
[1] Externally adjustable to zero.
[2] Recommended power supply, Analog Devices model 904, ±15V @ 50mA
Specifications subject to change without notice.

OUTLINE DIMENSIONS

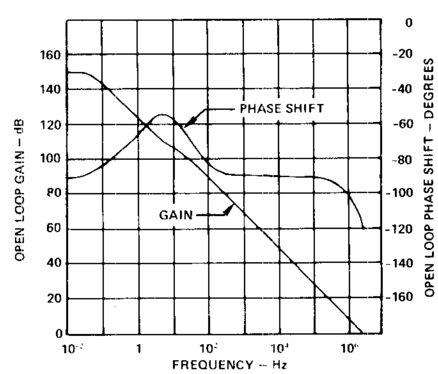
Dimensions shown in inches and (mm).



NOTES:
*Optional Trim Pot Analog Devices Model 79PR50k
Connect Trim Terminal to Common if Trim Pot is not used.

1. SG (SIGNAL GROUND) Tied to Common.
2. Mating Socket AC1010
3. Weight: 27 grm

OPEN LOOP GAIN AND PHASE SHIFT



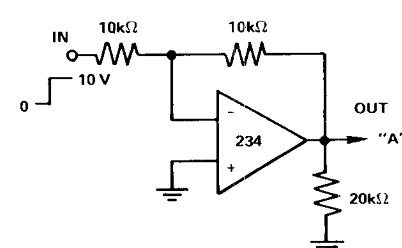


Figure 2. Settling Time Test Circuit Using Scope Comparator Preamp at "A"

Shown below are plots of typical input voltage and input current noise over the frequency range of 0.01Hz to 10Hz. Particular care has been exercised in the design of this amplifier to reduce the noise level to that commensurate with the low drift performance obtained by chopper stabilization.

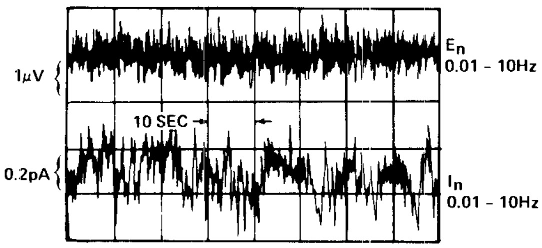


Figure 3. Model 234 Voltage and Current Noise

INPUT IMPEDANCE CONSIDERATIONS

The maximum input impedance for inverting amplifiers of all types is limited by bias current, bias current drift, and noise current. These currents flowing through the source impedance will increase the total error and noise when the input impedance exceeds E/I, where E is a given type of voltage error and I is the corresponding current error. Figure 4 is a plot of total offset voltage, total voltage drift and total noise vs. input resistance for the model 234. Up to 100,000 ohms, the model 234 provides relatively constant levels of offset, noise, and drift. Above this resistance level, the bias current effects become more predominant.

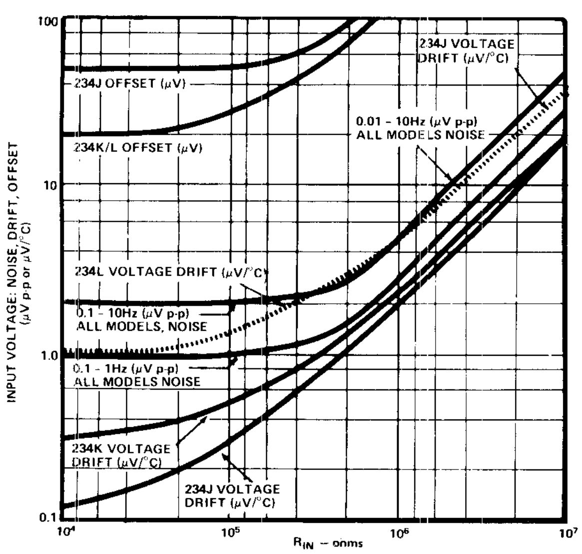


Figure 4. Uncompensated Offset, Drift and Noise vs. R_{in}

INITIAL OFFSET ADJUSTMENT

A valuable characteristic of the model 234 is the low offset voltage without external trim. The specification is 50μV maximum for the model 234J, and 20μV maximum for the models 234K and 234L. In many applications there will be no need to zero the offset since it is so low. In such cases the trim terminal may either be left open, or grounded, whichever is more convenient for the user. If voltage offset adjustment is desired, it may be done with a potentiometer or selected fixed resistor network, as shown in the outline drawing on previous page.

Input bias current flowing through the input resistor(s) creates additional voltage offset, particularly with input resistances exceeding 500,000 ohms. For circuits where the total input and source resistance remain relatively constant, the entire offset may be zeroed out with the voltage offset adjustment. No additional drift will occur with the model 234 when voltage trimming is used to compensate for the offset effects of input bias current.

The circuit of Figure 5 should be used to compensate for bias current offsets when using the model 234 as a current to volt-voltage converter. The potentiometer-resistor network provides a compensating bias current to cancel the amplifier's own input bias current. The offset voltage trim may be used but is not necessary when using this technique.

When the amplifier is used with a widely varying input resistance and minimum offset is desired, the voltage and current trim potentiometers should be used. The voltage offset should be zeroed with a low value (e.g. 1k ohm) resistor connected from the inverting input to ground. The offset current adjustment should be made with the maximum expected value of R_i connected between the input and ground.

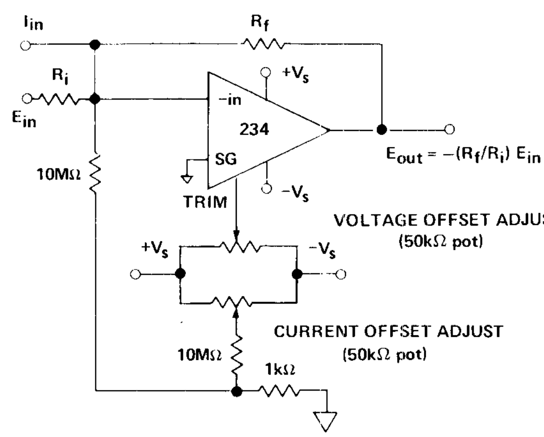


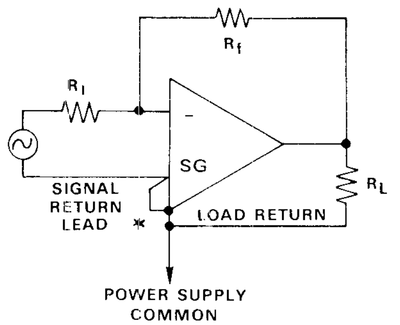
Figure 5. Offset Current Voltage Cancellation

INVERTING OPERATION

The model 234 is designed for use in the inverting mode. It is important that the SG (equivalent to +in) terminal be kept at the same potential as the amplifier's "common" terminal. Any voltage difference between these points is similar to a common mode voltage, and performance cannot be guaranteed under such conditions. The model 234 is also an excellent amplifier for measurement and conversion of low level current sources to proportionate voltages. With offset current externally zeroed, input currents of ten to twenty picoamperes can be amplified and converted to a voltage source for further processing.

SHIELDING, PICKUP AND GROUNDS

A special feature of the model 234 is the internal electrostatic static shield. This prevents not only pickup of extraneous signals by the module but also prevents radiation of chopper noise by the module. One precaution is to insure that noise sources are shielded from the inverting input. The user should also insure that ground loops do not occur which can add extraneous signals when amplifying from microvolt or millivolt sources. Figure 6 illustrates the proper connections to avoid ground loops.



* SIGNAL RETURN AND LOAD RETURN SHOULD BE CONNECTED TO POWER COMMON AS CLOSE TO AMPLIFIER PINS AS POSSIBLE

Figure 6. Ground Connection

INTERMODULATION CONSIDERATIONS

If noise at medium frequencies (to 400Hz) finds its way into the input circuits of carrier amplifiers (chopper amplifiers and the chopper-stabilizing portions of chopper-stabilized amplifiers), it tends to "beat" with the chopper frequency and produce sum and difference frequencies. The "sum" frequencies are unimportant, because they are usually filtered out; the noise frequency is usually unimportant because it, too, is filtered out. But the difference frequencies (which can include dc) usually interfere directly with the low-level low-frequency signal information.

There are precautions that can be taken by the manufacturer to minimize such interference occurring within the devices themselves; but the user must also be aware of the need for precautions, especially in performing low-level measurements in the presence of:

1. input signals containing high-frequency normal-mode noise components (such as unfiltered carrier from a measuring device)
2. ripple coupled in from power supplies
3. stray electromagnetic radiation at line frequencies, especially if it is rich in harmonics.

This noise may be introduced to the amplifier at either improperly guarded input leads or at the power supply terminals. These effects may be minimized by using shielded supplies which have low ripple and low source impedances at the line harmonics. Properly shielding the input leads, as well as locating the amplifier as far from sources of 60Hz (or 50Hz) magnetic fields, is also recommended for best performance. Mechanical orientation of the amplifier package and layout of signal grounds may also be used to minimize EMI effects.

If a "beat" does occur, it usually manifests itself as a slowly varying offset signal at the output of the amplifier, usually below 20Hz. To examine the extent of this equivalent offset noise voltage in a system, an oscilloscope should be used to monitor the amplifier output with the input signal point shorted to ground. As another test, a low level signal may be applied at the input of the final circuit configuration to determine the intermodulation rejection capability of the design. In this test, the signal frequency should be swept through the modulation frequency point to observe output signal peaking. A low pass output filter, at approximately 40Hz, should be used when making these tests.

THE "T" NETWORK

High gains and high input impedance to an inverting amplifier normally require excessively large feedback resistors. For example, an input impedance of 1,000,000 ohms and a gain of 100 require a feedback resistor of 100 Megohms. Such a resistor is relatively expensive, particularly for low tolerance units. Furthermore, one picofarad of stray capacitance across this single resistor would reduce 3dB bandwidth to 1590Hz, and resistive leakage across PC boards may become a problem. The "T" network in Figure 7 is a means of minimizing these problems. If the ratio R_f/R_i is at least 5 to 1, there will be no measurable change in other performance characteristics. If the ratio is lower, for instance, 1 to 1, the effective drift and noise gain will be doubled, compared to the signal gain. A general rule is to make the ratio R_f/R_i approximately equal to the ratio R_2/R_1. This normally results in reasonable values of resistance for R_f, and a minimal increase in noise and drift gains compared to the standard two resistor circuit. An additional advantage of the "T" network is variable gain without the necessity of connecting a switch or potentiometer directly to the highly sensitive inverting input terminal. This avoids serious noise pickup problems. In such a hookup, R_1 is the variable element.

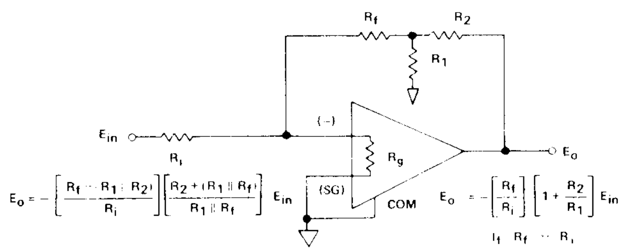


Figure 7. "T" Network

OVERLOAD RECOVERY

The overload recovery circuit shown in Figure 8 will prevent the input circuitry from becoming saturated. This circuit, connected externally, will allow the amplifier to recover from overload in less than 0.5µs. Without this circuit overload recovery will require up to 5 seconds.

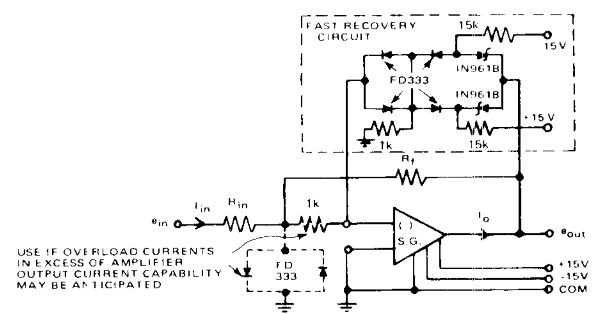


Figure 8. Overload Recovery Circuit

HIGH SOURCE IMPEDANCE CIRCUITS

When required to operate from source impedances above 100kΩ, the model 234, with inherently lower input current noise and spikes, offers dramatic improvements over previous designs. (See Figure 9)

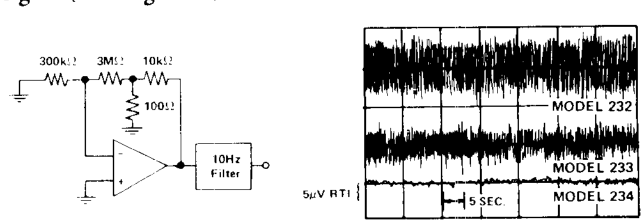


Figure 9. Comparative Input Noise (RTI) Performance in a dc to 10Hz Bandwidth