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ANALOG MODULES, INC.

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Specialists in Analog and Laser Electronics

MODEL 312A/712A SERIES AMPLIFIERS
APPLICATION/OPERATING NOTES

CIRCUIT DESCRIPTION

The Model 312A Series of low-noise amplifier comprise three stages:

1. A transimpedance virtual ground preamplifier, DC coupled
2. A non-inverting second stage amplifier
3. An AC coupled output stage to drive a 50Ω load.

Each stage has negative feedback to ensure accuracy. This arrangement is ideal for converting a pulse current source such as a photodetector into an amplifier voltage output.

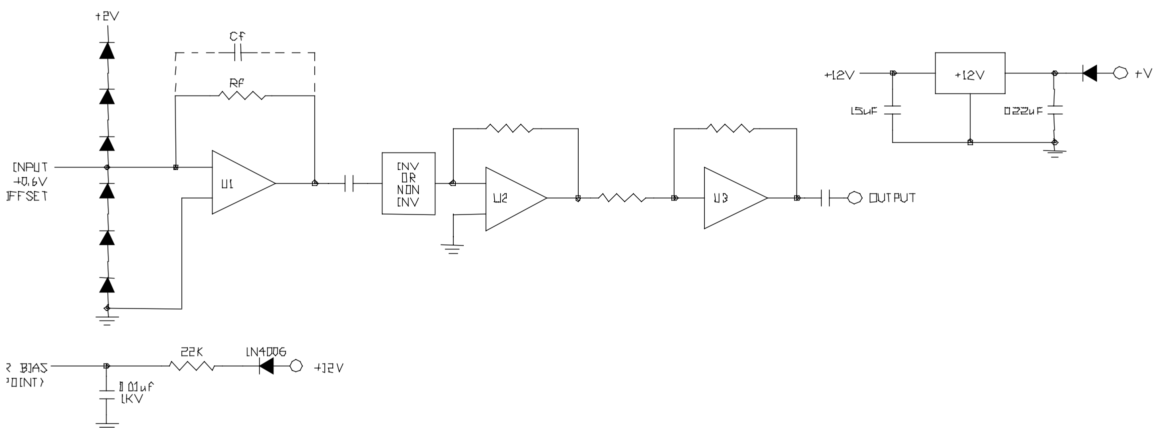

Figure 1. Block Diagram

The input stage is dc coupled with an input offset of about +1V. Feedback resistor R_f is 100K for all models. DC input coupling allows leakage or background DC photocurrents of about 10μA respectively to flow before preamplifier saturation. The high feedback resistors are necessary for low thermal (Johnson) noise.

The second stage is AC coupled and can be configured as inverting or non-inverting. This selection is made at the time of ordering and is normally determined by the polarity of input signal. Conventionally, most people prefer a positive output pulse and so when the detector is biased from a positive supply, non-inverting is usually selected. Some sources or detectors need a negative supply, and here an inverting configuration may be specified. A gain of times three is set in the second stage.

The output stage also has a gain of three and uses complementary drive to give both positive and negative swings centered on a quiescent 6V. The output is AC coupled with a polarized 33μF, 10V capacitor to reference the output swing from 0V baseline.

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POWER

A single +15V supply is recommended with a common ground return connected to the ground lug at the power input pin/filter. The power leads should be lightly twisted from the amplifier to the power supply. Series diodes are used to protect the electronics from reversed power connections. No current will be drawn in such as event.

If a lower voltage power supply is applied, generally the amplifier will work, but with reduced output swing. The regulator will saturate resulting in less rejection of noise from the power lines. High supply voltages result in increased regulator dissipation inside the amplifier box and may result in a thermal shutdown. The simplest solution is to add 15V pre-regulators to power the amplifier or to fit series diodes/resistors. Typical power consumption is 60mA.

INPUT

These amplifiers are designed to be used with current inputs. It is possible to convert them into a voltage amplifier by adding a series resistor to the input. Generally, lower noise will be achieved from voltage sources by selecting the 321A or 351A range of amplifiers. Input connections are critical to the performance of any ampler and useful hints are published in our Application Note 300-1. The main problems concerning current input amplifiers are those of capacitance and source leakage.

INPUT CAPACITANCE

Capacitance across the input of these virtual ground amplifiers causes a mid-band frequency boost and loss of bandwidth. The frequency boost can be canceled by adding a small capacitor C_f across the feedback resistor of U1, R_f. The noise also increases at high frequencies due to current flow in the input capacitance caused by the input voltage noise of the amplifier. It is very important to minimize lead length and input capacitance for the best performance and AMI fits a low-capacitance input feed through pin as standard. BNC or SMA connectors may be fitted on request at the time of ordering, but add about 5pF to the input capacitance. Graphs of noise and bandwidth performance versus input capacitance are given on the data sheet.

INPUT DC CURRENT

The leakage or DC-current flow of the source affects the interfacing of the amplifier input. As the input stage is DC coupled, the maximum input current is the peak preamplifier output voltage swing divided by the transimpedance gain in ohms. Exceeding this current will cause saturation of the preamplifier. Possible solutions to this problem are to reduce the gain of the preamplifier, set by R_f, or to draw current away from the input (to reduce the input current to the amplifier). This may be done with a high value resistor to a voltage source (Figure 2a) or with an active current source (Figure 2b).

Using high value resistors results in less thermal (Johnson) current noise, at the expense of dissipation and a higher voltage reference. Metal film type resistors should be used with a quiet and well-decoupled voltage reference. Active current sources may be made from a transistor with emitter resistor. The current is set by the base voltage. Low-noise, low-capacitance devices are necessary with the highest possible emitter normally only feasible for relatively constant background DC currents close to the preamplifier's handling capability. For greater input currents or input current variations, a 1μF 50V blocking capacitor is recommended. Current sources with biasing arrangements which provide a bias current return and do not exceed ± 50V may be connected to the 312A via this capacitor (Figure 2c). Higher voltages require the input capacitor rating be increased and care taken not to apply fast high voltage transients to the input.

If a photo conductive photodiode with DC leakage or background light is connected to the input without a bias current return, the blocking capacitor will charge up and gradually reduce the bias across the detector.

Where these higher leakage or light-induced currents are present, then an input capacitor is necessary and shunt resistor must be fitted to prevent the capacitor from charging up thus de-biasing the detector. This resistor is normally fitted between the input pin and the input ground pin (Figure 2d). Its value is set by:

$$R = \frac{\text{maximum acceptable loss of bias volts}}{\text{maximum leakage DC light current}}$$

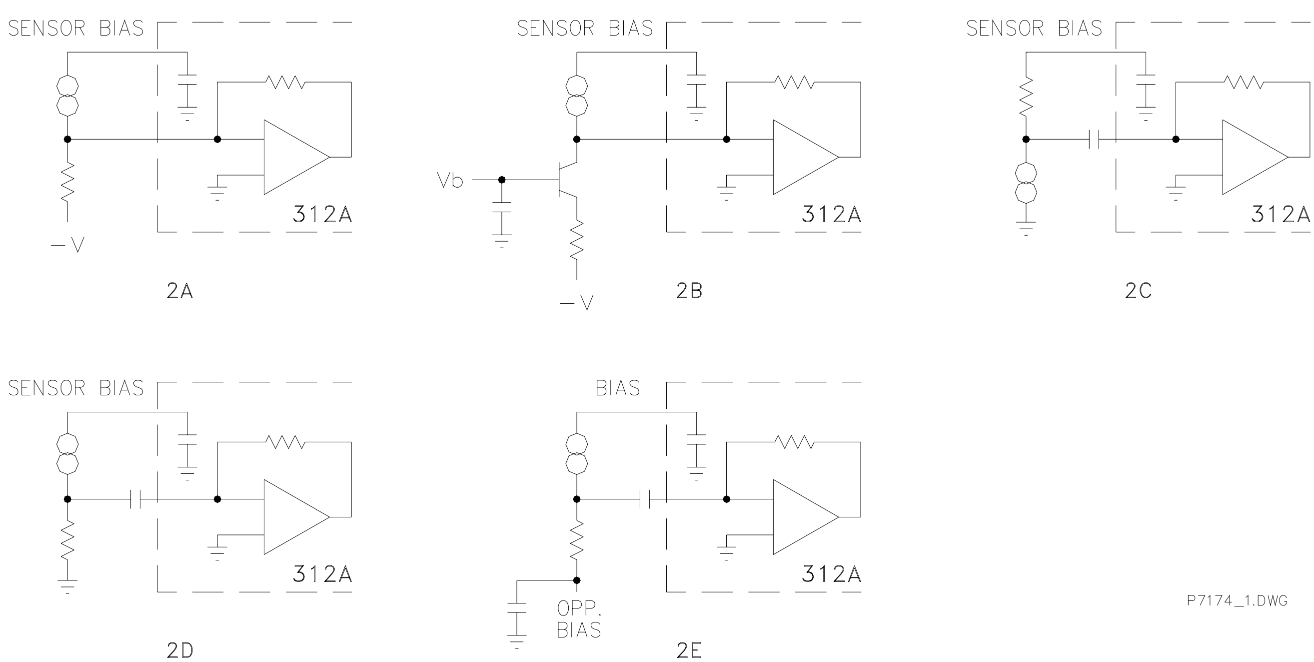

FIGURE 2

The noise will be increased by two times if a 3k and 33k is used to parallel the inputs of the 312A-2 through -4 respectively. Lower values may be necessary for high DC current flow in the detector. Shot noise caused by this flow will also be a factor. Low-noise metal film resistors should be used. One way to reduce the extra noise is to increase the value of R and return R to a voltage opposite in polarity to the bias voltage (Figure 2e). Care should be taken to avoid fast high voltage transients on the input or exceeding the capacitor voltage rating.

SENSOR BIAS PIN

The AC component of the input current must be returned to the amplifier input reference ground, especially if the sensor or detector has any capacitance. The sensor bias pin is available as a tie point with a 0.01μF 1000V ceramic capacitor to the input ground. In a typical application, the bias is applied via a decoupling resistor to the bias decouple pin (see reverse of Model 312A data sheet).

A low impedance output driver stage is designed to drive loads of 50Ω or greater impedance. When longer shielded cables are used, it is essential to correctly terminate the cable to avoid line reflections causing signal distortion. Unterminated lines may cause oscillation. With long lines (i.e., >10 meters), it may be desirable, in addition, to add a resistor value equal to the line impedance in series with the amplifier output. This will cause a gain loss of 6dB, but will reverse-terminate the line to minimize reflections. Do not short circuit the output as large currents will flow possibly damaging the output stage. Keep the output leads as short as possible and away from the input. Avoid an output ground loop to the input wires or sensor as this may cause oscillation.

DYNAMIC RANGE

The dynamic range of the amplifier is usually specified in dBs as peak output voltage divided by rms noise at the output. Clearly, low noise and large output swing is desirable to maximize dynamic range. The higher the gain of the amplifier, the less the dynamic range since the output noise is greater.

A good rule is to set the amplifier gain so that output noise is just at the minimum of the working range of the instrument or device following the amplifier. Dynamic range can also be increased by limiting the amplifier bandwidth to that required since the noise is reduced by the square root of the bandwidth. A 50Ω series output resistor, followed by a capacitor to ground is one way to achieve this. Models 312A-2 and -3 have an internal frequency response reduction capacitor.