

MP227A

Precision Isolation Amplifier

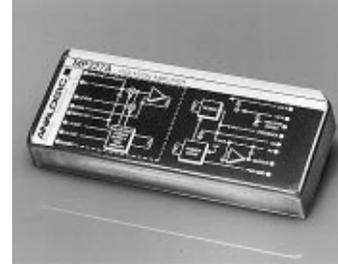
Replaces Relays and Filter Elements in Multichannel DASs

Introduction

The Analogic MP227A is a precision isolation amplifier that provides an unparalleled cost-effective combination of linearity, stability, and isolation. It is designed primarily to replace relays and filter elements in multichannel data acquisition systems. However, its unique features make it attractive wherever low-level, low frequency signals must be applied in the presence of severe common mode interference.

The MP227A offers user-selectable gains from 10 to 1000, input full-scale voltage ranges from ± 10 mV to ± 1 V, 3-pole (60 dB/decade) filtering from 5 Hz, extremely good linearity, superb common-mode rejection, and very low drift. All parameters are commensurate with A/D conversion at levels up to 13 bits.

The MP227A includes an internal power oscillator and isolated supply so that no external drivers are needed. The isolated power (± 4 V nominal) can be used for open thermocouple indication or offsetting strain gauge inputs.



Features

- High Common Mode Rejection—170 dB
- Excellent Linearity—0.0075%
- Selectable Input Range— ± 10 mV FS to ± 1 V FS
- Low Noise— < 0.5 μ V RMS
- Low Drift—3.0 μ V RTI per Month
- Built-in 3-pole Filtering
- Built-in Oscillator/Driver

Applications

- Thermocouple Temperature Measurement
- Weighing Systems
- Strain Gauge Measurements
- Remote Data Acquisition and Precision Telemetry Systems
- Microvolt and Millivolt Level Measurements
- Replacement for Classical Instrumentation Amplifier

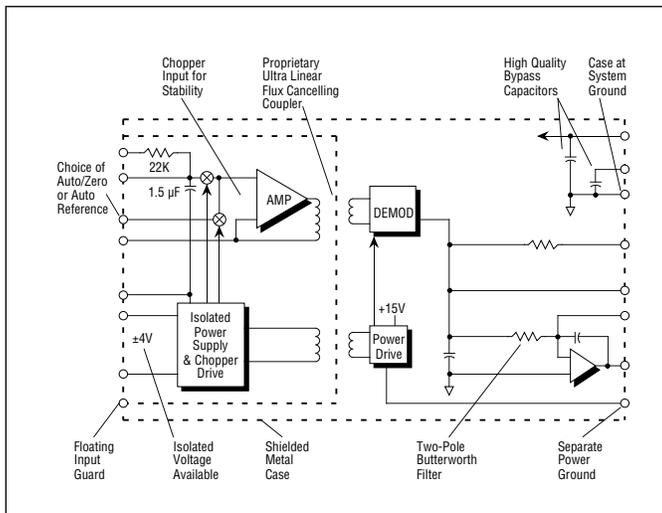


Figure 1. MP227A Block Diagram.

MP227A

Specifications

All specifications guaranteed at 25°C unless otherwise noted.

ANALOG INPUT

Gain Range

10 to 1000, Non-inverting, Resistor Programmable; Optimized for Gains of 50 to 500

Non-linearity

±0.0075% FSR Max. at G = 50 to 500
±0.01% FSR Max. at G = 1000
±0.05% FSR Max. at G = 10

Input Amplifier Type

Isolated Chopper

Linear Differential Input Voltage Range

±10 mV to ±1V Full Scale

Maximum Safe Differential Input Voltage

16V RMS Continuous, without Damage

Common Mode Isolation Voltage

1000 VDC, 750V RMS Max.

Common Mode Rejection Ratio

At DC, with G = 100 & 1000, 166 dB Min.; 1 kΩ Source Unbalance
At 60 Hz, with G = 100 & 1000, 176 dB Typ., 160 dB Min.; 1 kΩ Source Unbalance

Common Mode Impedance

10,000 MΩ // 80 pF

Differential Input Impedance

At DC, 10 MΩ Min.; at AC, Low-pass Filter of 22 kΩ and 1.5 μF

Overload Input Impedance

22 kΩ, at 50/60 Hz

Input Bias Current

0.5 nA Typ., 3.0 nA Max.; Bias Current Increases if Open Input Indicator Circuit Used

Offset Voltage

At G = 10, ±1 mV Typ., ±5 mV Max.; at G = 1000, ±150 μV Max.; all Referred to Input (RTI); Offset Voltage may be Determined by Interpolation for Other Gain Values

Voltage Noise (0.01 to 5 Hz)

At G = 10, 1.5 μV RMS Max.; at G = 100 and 1000, 0.5 μV RMS Max.; RTI

Bandwidth¹

DC to 5 Hz Nom.; 6 dB Down at 5 Hz

Overall Filtering²

3-pole, 60 dB/Decade Roll-off (-60 dB at 50 Hz)

Input Filter

1-pole RC, 3 dB Cut-off at 5 Hz

Output Filter

2-pole Butterworth, 3 dB Cut-off at 5 Hz

ANALOG OUTPUT

Voltage Range

±10V Full Scale

Output Impedance at DC

0.1Ω

Maximum Load

±5 mA and 500 pF

Output Protection

Continuous Short Circuit to Ground

Output Chopper Noise (1 MHz BW)

±1 mV p-p Spike at Approximately 10 kHz³

STABILITY

Gain Tempco

At G = 10 and 100, ±25 ppm FSR/°C Max.; at G = 1000, ±35 ppm FSR/°C Max.; Exclusive of External Gain Setting Resistor

Offset Voltage Tempco

At G = 10, ±5.0 μV/°C Max.
At G = 100, ±1.7 μV/°C Max.;
At G = 1000, ±0.5 μV/°C Max.;
All RTI

Bias Current Tempco

100 pA/°C Max., at 25°C;
Doubles Every 10°C Max.

Power Supply Sensitivity

At G = 1000, ±2.0 μV/%;
at G = 10, ±10 μV/% Max.; RTI

Warm-up Drift (5 Minutes)

Within 2 μV RTI Typ. at G = 1000

Long Term Drift

3.0 μV RTI/Month Typ.

ISOLATED POWER SUPPLY OUTPUT

Voltage

±4 VDC Nom., with respect to INPUT LO

Current

±3 mA Full Load

Regulation

12%, No Load to Full Load

Ripple

60 mV p-p at 10 kHz

INPUT POWER SUPPLY REQUIREMENTS

+15V, ±3%

3 mA, No Load

-15V, ±3%

5 mA, No Load

ENVIRONMENTAL AND MECHANICAL

Operating Temperature Range

0°C to +70°C

Storage Temperature Range

-55°C to +85°C

Relative Humidity

0 to 85% Non-condensing up to 40°C

Dimensions

1.2" x 2.8" x 0.5"
(30 mm x 70 mm x 12 mm)

Shielding

RFI: 6 Sides; EMI: 5 Sides

NOTES:

1. Modifications for bandwidths from DC to 100 Hz, or optimized for specific settling times are available on special order. Please contact factory.
2. Filter nodes are externally accessible to allow modification of characteristics.
3. Output Chopper noise can be reduced to negligible level by suggested output multiplexer circuit.

Specifications subject to change without notice.

OPERATION DATA

Application

The MP227A was designed as an economically competitive and functionally superior alternative to the relay multiplexing circuits traditionally used in multichannel data acquisition systems. In a typical thermocouple system, the MP227A replaces three functional blocks for each channel – the input filter and a dual relay, as well as the common channel high gain amplifier – and permits high-level, solid-state multiplexing to be used for low cost and high reliability.

The MP227A provides significantly better isolation and common-mode rejection than low-level relays and it puts the gain at a point in the system where the bandwidth is lowest (prior to multiplexing), thereby reducing total system noise. Even where multiplexing is not used, the unusual combination of performance and price makes the MP227A attractive for a wide variety of industrial applications.

When many MP227As are used in a system, a high-speed, high-level analog multiplexer switches the MP227A outputs to a common analog output bus for subsequent A/D conversion. Any high precision isolation amplifier/filter used in such a configuration has an inherent error source of sizable magnitude that is often overlooked, ignored, or simply unknown; that is, dumped charge effects. This Application Note discusses the problem, the solution, and the fringe benefits.

Dumped Charge

Figure 2 shows the apparently straightforward connection of multiple amplifiers/filters and multiplexer to a common A/D converter.

Each time the multiplexer in Figure 2 switches channels, for instance, from Channel 1 to Channel 2, the

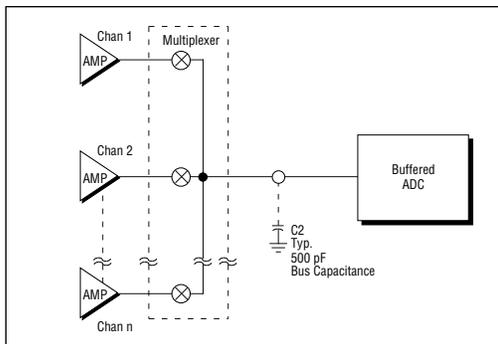


Figure 2. Multiplexing Amplifier Outputs.

Channel 1 output appears across C2, the capacitance of the output bus. The output stage of Channel 2 must absorb that dumped charge before it can reach a true final value dependent only on its input. The exact magnitude of the dumped charge is not important; what is significant is that the Channel 2 amplifier may be forced to deliver a peak instantaneous current beyond its design specifications.

The dumped charge (Q) is defined as, $Q = idt$,

where $i = C dv/dt$

In a typical example, the outputs of the two channels could be at the extreme ends of the range.

Channel 1 output = +10V.

Channel 2 output = -10V.

This makes the voltage difference (dv).

$dv = 20$ volts.

Assume that the capacitance of the output bus C2 is about 500 pF, and a reasonable turn-on time for an analog switch is 100 ns, or,

$$C = 500 (10^{-12})$$

$$dt = 100 (10^{-9})$$

Solving first for the current and then the dumped charge, gives:

$$i = C (dv/dt) = \frac{500(10^{-12})}{100 (10^{-9})} 20 = 100 \text{ mA}$$

$$Q = idt = (100)(10^{-3})(100)(10^{-9}) = 10,000 \text{ pico Coulomb}$$

Under these conditions, IC op amps, such as the popular 741, have been found to have full-scale current excursion lasting as long as a microsecond.

If the design factors allow a conventional IC output stage to drive the multiplexer instead of a high precision amplifier with an output/filter stage, no real harm is done by the dumped charge. The amplifier eventually recovers and C2 charges to the new value. The recovery time constant is the ON resistance of the multiplexer switch and C2

$$\text{for } R_{on} = 300\Omega$$

$$C2 = 500 \text{ pF}$$

$$T = (300)(500) 10^{-12} = 0.15 \mu\text{s}$$

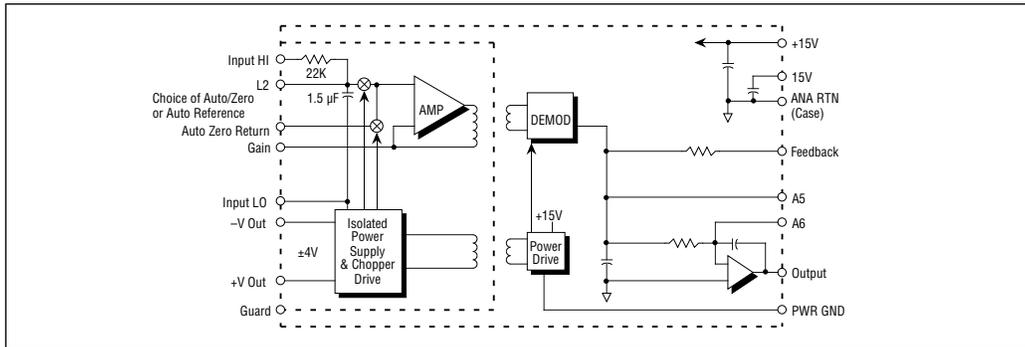


Figure 3. MP227A Isolation Amplifier Functional Block Diagram.

In high resolution systems, ten time constants should be allowed to reach a voltage within 0.005% of final value. Therefore, the actual time should be 1.5 μ s.

The 1.5 μ s settling time required in this example is usually less than the settling time of the conventional buffer amplifier at the multiplexer output, and the dumped charge effect can be safely ignored. The dumped charge cannot be ignored, however, when high precision amplifiers employing output filters are required.

The Problem

Many isolation and/or instrumentation amplifiers do not include an output filter. On the other hand, the MP227A has an integral two-pole Butterworth filter in the output stage. The feedback element of the MP227A is a capacitor, and a sudden voltage step at the amplifier output, such as the dumped charge, presents a problem.

The dumped charge demands excessive current in too short a time and causes the amplifier to momentarily open-loop. The summing node changes to a large voltage, inducing current flow in the input resistor and causing an extraneous charge on the feedback capacitor.

This error source has produced observed errors as large as 0.05% in typical applications.

The Solution

Figure 4 shows the addition of a single-pole filter (R1,C1) at the output of each MP227A and ahead of the multiplexer. C1 of the succeeding channel now absorbs the charge accumulated on C2 from the preceding channel. The MP227A no longer sees a step but a well controlled exponential change, well within its capabilities. Hence, the output stage in the MP227A does

not open-loop, and no spurious charge is placed on the feedback capacitor.

The best results are obtained with a time constant between 0.25 and 0.5 μ s. This must be short for two reasons: 1) a settling time of up to 10RC does not significantly add to multiplexer settling time; and 2) the recovery time is sufficiently short for final values that are independent of the duty cycle involved in reading a channel.

R1 should be between 50 and 270 Ω ; this value is kept intentionally low to reduce voltage divider error (R1 + Ron relative to Rin of the follower at the multiplexer output) to an insignificant level. These values of R1 yield values for C1 between 10,000 pF and 1,000 pF which is an acceptable range for C1. In the capacitive voltage divider, formed by C1 and the bus capacitance C2, as C1 decreases in size relative to C2, the initial voltage transferred to C1 by a succeeding channel approaches its final value and leaves a smaller exponential rise portion.

R1, C1 MUST BE INCLUDED FOR ALL HIGH RESOLUTION (>12 BITS) APPLICATIONS OF THE MP227A.

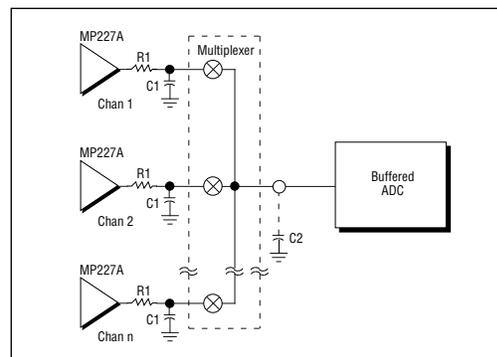


Figure 4. MP227A with Output Filters Added.

Fringe Benefits

Noise spikes inherent in the design of high performance isolation amplifiers are attenuated by 10 dB or more by the R1 C1 output filter.

The superior isolation of the MP227A is provided by transformer coupling. A modulator/demodulator is used in the analog signal path and is driven by an integral chopper/power driver. It is impossible to avoid some stray capacitance between the driver circuitry and the output. Careful design and layout of the MP227A has reduced the resulting output noise spikes caused by stray capacitance to 1 mV p-p, which is 0.01% relative to 10V FS, when measured over a bandwidth of 1 MHz. The noise spikes repeat at 20 kHz, or twice the nominal 10 kHz frequency of the MP227A chopper driver.

If the output filter time constant (R1 C1) is equal to 0.5 μ s, then:

$$f_c = 1/2\pi RC$$

$$= 333 \text{ kHz}$$

This low cut-off frequency ensures that the output spikes, over an effective bandwidth in excess of 1 MHz, are attenuated 10 dB or more, which is enough to reduce this error source from .01% to a negligible level.

USING THE MP227A

Offset Adjustment

Provision is made for offset adjustment on the MP227A Precision Isolation Amplifier by connecting a

25k or 50 k Ω (100 ppm/ $^{\circ}$ C or better) multi-turn potentiometer (R2) with a 1 M Ω resistor as shown in Figure 5. To adjust, momentarily short INPUT HI, INPUT LO, and AZ RTN to the output ANA RTN and set the offset potentiometer for zero output at the OUTPUT terminal.

Setting the MP227A Gain

The gain of the MP227A may be set to any value from 10 to 1000 by connecting an external resistor (RG) between the GAIN and INPUT LO terminals as shown in Figure 5.

$$\text{Gain} = \frac{10.375 \times 10^3}{R_G \Omega}$$

An RN55E or better resistor is recommended for temperature stability. Untrimmed, the absolute gain will be within +2% and -3% of the calculated value.

Gain Trimming

The gain may be deliberately fine-trimmed, if desired, by connecting a 500 Ω (100 ppm/ $^{\circ}$ C or better) potentiometer (R1) between the FEEDBACK and OUTPUT terminals as shown in Figure 5. R1 compensates for the tolerance of RG plus the unit-to-unit gain variability (3%) between multiple MP227As. This also allows standardization of the outputs of multiple MP227As to a common full-scale range. For volume production where cost is a factor, the trimpot may be replaced with a fixed resistor selected during final testing.

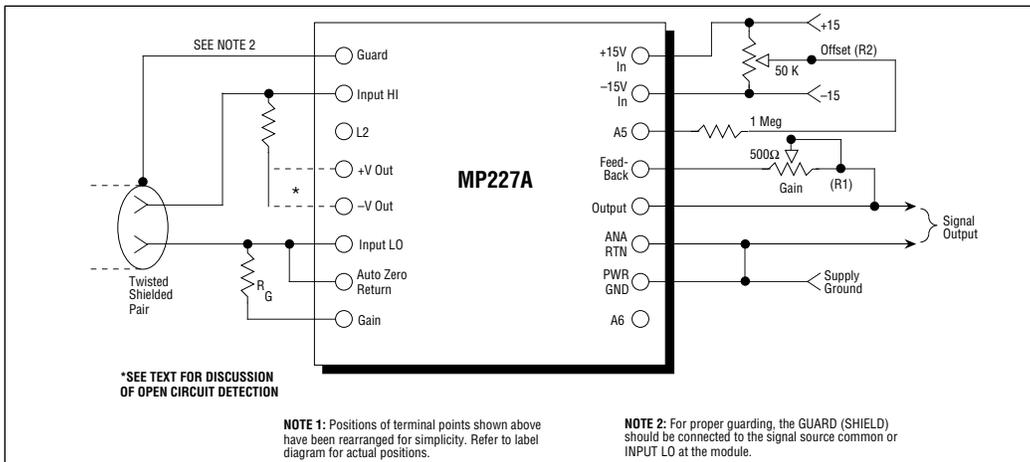


Figure 5. Typical External Connections – MP227A

Auto-Zero Return

The signal that is amplified by the MP227A is actually the difference between the INPUT LO and the Auto-Zero (AZ) voltages. For normal operation, tie the AZ terminal directly to the INPUT LO terminals. In some applications, it may be convenient to offset the input deliberately by an amount that exceeds the range of the OFFSET trimpot (for example, to obtain expanded scale operation or to cancel out the initial or "tare" output of a load cell). To do this, connect the AZ terminal to a source of voltage equal to the desired offset, with noise performance and stability at least as good as the signal source.

Observe that both the INPUT HI signal and the AZ signal (if any) are measured with respect to the INPUT LO terminal. For best linearity, each signal must be within $\pm 1V$ of INPUT LO.

Open Input Indication

The user-accessible isolated power supply voltages make it possible to use a simple open input indication network. Connect a resistor on the order of $180 M\Omega$ to the INPUT HI and either the +4V or -4V isolated power output terminal. This network produces a bleeder current of approximately 20 nA through the input source circuitry. If the source should open, this bleeder current will drive the MP227A output into a saturated state. The speed of this response is a function of the MP227A gain setting and input time constant.

Multiplexing MP227As

The outputs of multiple MP227As may be multiplexed to a common analog line as indicated in Figure 4. A single RC filter ahead of each MUX is suggested.

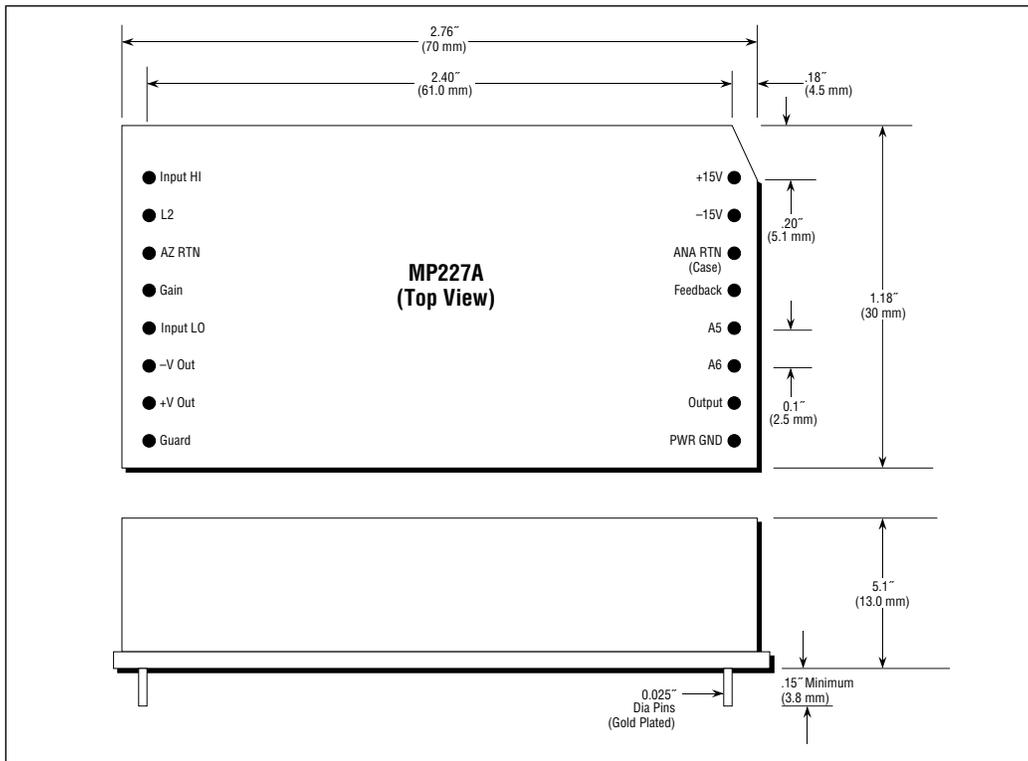


Figure 6. MP227A Mechanical & Pinout.

Ordering Guide

Specify
MP227A