

Key Circuits in Sensor Signal Conditioning

In sensor technology, accurate signal conditioning is crucial for reliable data analysis. Amplification, phase control, and noise reduction are key aspects of this process. This application note explores five essential amplifier circuits at the core of sensor signal conditioning. From inverting and non-inverting amplifiers to precision instrumentation amplifiers and versatile difference amplifiers, each circuit uniquely enhances sensor data.

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1. Inverting Amplifier

The inverting amplifier is a foundational circuit in sensor signal conditioning, employing operational amplifiers (op-amps) and feedback networks. Its operation revolves around two key aspects: signal inversion and amplification. The input signal from the sensor is connected to the inverting (-) input of the op-amp. The degree of amplification is governed by the ratio of the feedback resistor ( $R_F$ ) to the gain resistor ( $R_G$ ). This setup results in an output signal that is an inverted (180-degree phase-shifted) version of the input. The inverting amplifier is crucial when both signal amplification and phase inversion are necessary, a common occurrence when dealing with sensors that generate signals of varying polarities.

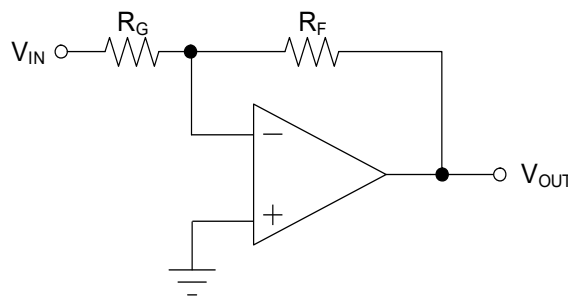


Figure 1. Inverting Amplifier

## 2. Non-Inverting Amplifier

The non-inverting amplifier, another essential component in sensor signal conditioning, is built upon op-amps and feedback resistors. It diverges from the inverting amplifier by preserving the phase and polarity of the input signal. The input signal of the sensor is applied to the non-inverting (+) terminal of the op-amp. The degree of amplification is determined by the relationship between the feedback resistor ( $R_F$ ) and the gain resistor ( $R_G$ ). In contrast to the inverting amplifier, the non-inverting amplifier retains the original phase of the input signal while achieving amplification. It finds its niche in applications where signal amplification is required without the requirement for phase inversion, which is crucial when maintaining the signal phase of the sensor.

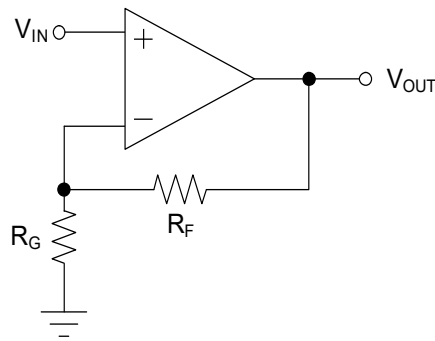


Figure 2. Non-Inverting Amplifier

## 3. Difference Amplifier

Difference amplifiers, often referred to as subtractors or differential amplifiers, are pivotal in sensor signal conditioning for measuring the voltage difference between two input signals. These circuits are centered around op-amps and excel in providing precision differential measurements. The two sensor input signals are differentially connected to the amplifier, creating a contrast between them. The gain of the difference amplifier is intricately linked to the ratio of the feedback resistor ( $R_F$ ) to the gain resistor ( $R_G$ ). Often, unity gain is employed for highly accurate differential measurements. Difference amplifiers are indispensable in applications demanding precise amplification and comparison of two sensor outputs, frequently found in scenarios involving strain gauges and bridge-based sensors.

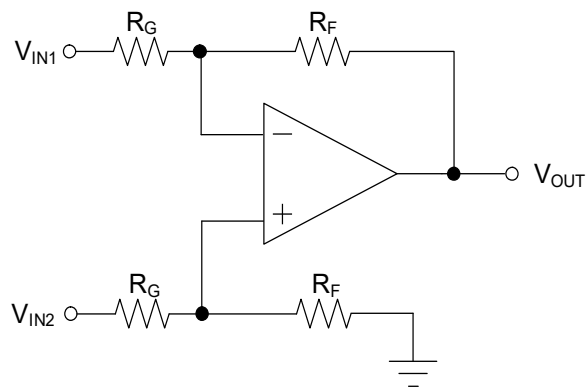


Figure 3. Difference Amplifier

## 4. Two Instrumentation Amplifiers

The two-op-amp instrumentation amplifier represents a meticulously engineered circuit that represents precision and resilience in mitigating common-mode noise. Comprising two op-amps in conjunction with precision resistors, this circuit facilitates differential amplification while suppressing common-mode noise. This design amplifies the disparity between  $V_{IN1}$  and  $V_{IN2}$ , yielding a single-ended output signal, while maintaining steadfast rejection of common-mode voltage interference. Importantly, note that the gain within this amplifier can be seamlessly adjusted by manipulation resistor values. Also, the linear operation of an instrumentation amplifier relies on the linear performance of its primary building block, the op-amp. An op-amp exhibits linear behavior when the input and output signals conform to the defined input common-mode and output swing ranges of the device. These pivotal operational ranges are intricately defined by the supply voltages that energize the op-amps. Such versatility renders the two-op-amp instrumentation amplifier an instrument of choice in applications where exacting precision in signal conditioning and resolute noise attenuation are imperative, including demanding industrial environments and critical medical devices where precision measurements are significant.

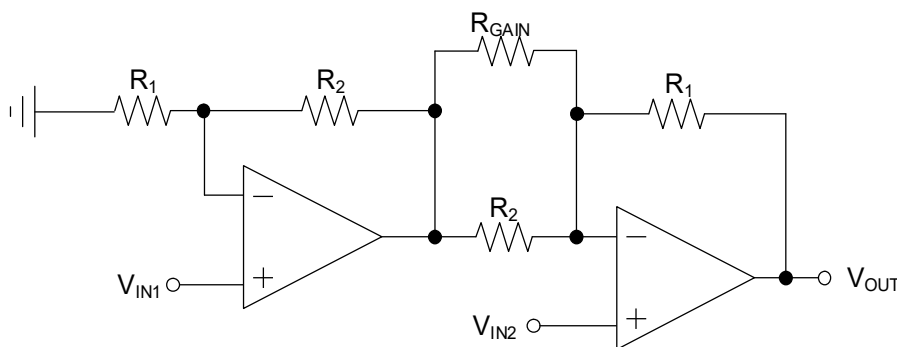


Figure 4. Two Instrumentation Amplifier

## 5. Three Instrumentation Amplifiers

The three-op-amp instrumentation amplifier epitomizes precision and sophistication in signal conditioning. By leveraging three op-amps, this discrete circuit enhances differential signals while converting them into single-ended outputs. Its operation centers on amplifying the difference between two input signals,  $V_{IN1}$  and  $V_{IN2}$ , with remarkable linearity. This linear behavior hinges on the ability of the op-amps to operate within specific input common-mode and output swing ranges, dictated by precise supply voltage control. Renowned for its precision and immunity to common-mode noise, this amplifier is designed for applications that demand precise measurements such as medical instrumentation for scientific research and advanced data acquisition systems. It is an essential tool for engineers and scientists, ensuring accurate and reliable data acquisition across diverse applications.

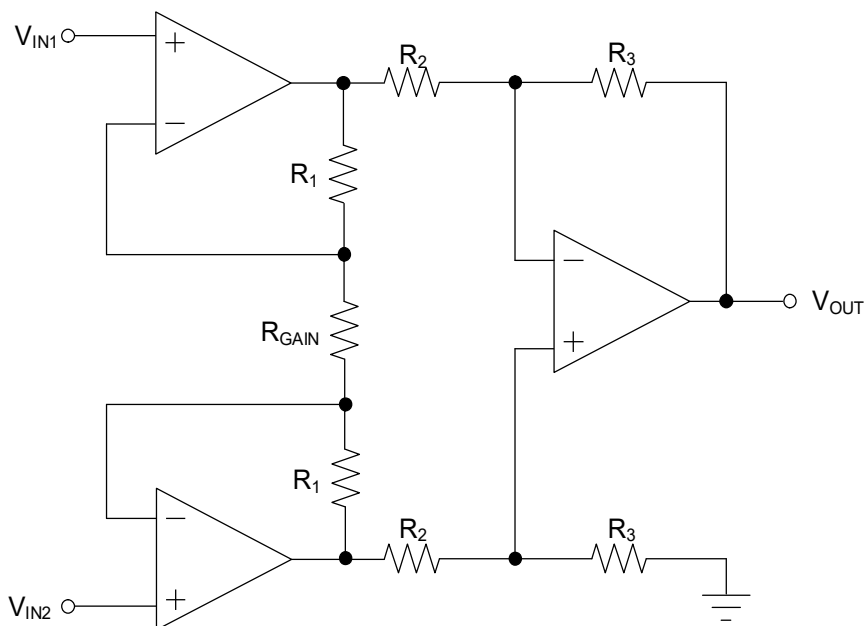


Figure 5. Three Instrumentation Amplifier

## 6. Revision History

Revision	Date	Description
1.00	Dec 18, 2023	Initial release.

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