Many industrial and medical applications use instrumentation amplifiers (INA) to condition small signals in the presence of large common-mode voltages and DC potentials.

The three op amp INA architecture can perform this function, with the input stage providing a high input impedance and the output stage filtering out the common mode voltage and delivering the differential voltage. High impedance, coupled with high common mode rejection (CMR), is key to many sensor and biometric applications.

The input offset voltage of all amplifiers, regardless of process technology and architecture, will vary over temperature and time. Manufacturers specify input offset drift over temperature in terms of volts per degree Celsius. Traditional amplifiers will specify this limit as tens of µV/°C.

Offset drift can be problematic in high precision applications and cannot be calibrated out during initial manufacturing. In addition to drift over temperature, an amplifier’s input offset voltage can drift over time and can create significant errors over the life of the product. For obvious reasons, this drift is not specified in datasheets.

Zero drift amplifiers inherently minimise drift over temperature and time by continually self correcting the offset voltage. Some zero drift amplifiers correct the offset at rates of up to 10kHz. Input offset voltage (Vos) is a critical parameter and a source of DC error encountered when using instrumentation amplifiers (INA) to measure sensor signals. Zero drift amplifiers, like the ISL2853x and ISL2863x, can deliver offset drifts as low as 5nV/°C.

Zero drift amplifiers also eliminate 1/f, or flicker noise; a low frequency phenomenon caused by irregularities in the conduction path and noise due to currents within the transistors. This makes zero-drift amplifiers ideal for low frequency input signals near DC, such as outputs from strain gauges, pressure sensors and thermocouples.

Consider that the zero drift amplifier’s sample and hold function turns it into a sampled data system, making it prone to aliasing and foldback effects due to subtraction errors, which cause the wideband components to fold back into the baseband. However, at low frequencies, noise changes slowly, so the subtraction of the two consecutive noise samples results in true cancellation.

**Monitoring of sensor health**

The ability to monitor changes to the sensor over time can help with the robustness and accuracy of the measurement system. Direct measurements across the sensor will more than likely corrupt the readings. A solution is to use the INAs input amplifiers as a high impedance buffer. The ISL2853x and ISL2863x give the user access to the output of the input amplifiers for this purpose. VA+ is referenced to the non-inverting input of the difference amplifier, while VA- is referenced to the inverting input. These buffered pins can be used for measuring the input common mode voltage for sensor feedback and health monitoring. By tying two resistors across VA+ and VA-, the buffered input common mode voltage is extracted at the midpoint of the resistors (see fig 1). This voltage can be sent to an A/D converter for sensor monitoring or feedback control, thus improving precision and accuracy over time.

**Advantages of a PGA**

It is widely accepted that you cannot build a precision differential amplifier using discrete parts and obtain good CMR performance or gain accuracy. This is due to the matching of the four external resistors used to configure the op amp into a differential amplifier. An analysis shows that resistor tolerances can cause the CMR to range from as high as the limits of the op amp to as low as -24.17dB.

While integrated solutions improve on-chip resistor matching, there remains a problem with absolute matching to the external resistors used to set amplifier gain. This is
because the tolerance between on-chip precision resistor values and external resistor values can vary by up to 30%. Another source of error is the difference in thermal performance between internal and external resistors; it is possible for the internal and external resistors to have opposite temperature coefficients.

A PGA solves this problem by having all the resistors on board. The gain error for this type of amplifier can be less than 1%, while offering typical trim capabilities of the order of ±0.05% and ±0.4% maximum across temperature.

The ISL2853x and ISL2863x families offer single ended and differential outputs with three different gain sets. Each gain set has nine settings, with the gain sets determined for specific applications.

Sensor health monitor
A bridge type sensor uses four matched resistive elements to create a balanced differential circuit. The bridge can be a combination of discrete resistors and resistive sensors for quarter, half and full bridge applications. The bridge is driven by a low noise, high accuracy voltage reference on two legs. The other two legs are the differential signal, whose output voltage change is analogous to changes in the sensed environment.

In a bridge circuit, the common mode voltage of the differential signal is the ‘midpoint’ potential voltage of the bridge excitation source. For example, in a single supply system using a +5V reference for excitation, the common mode voltage is ±2.5V.

The concept of sensor health monitoring is to keep track of the bridge impedance within the data acquisition system. Changes in the environment, degradation over time or a faulty bridge resistive element will cause measurement errors. Since the bridge differential output common mode voltage is half the excitation voltage, you can use this to monitor the sensor’s impedance health (see fig 2). Monitoring the bridge’s common mode voltage gives an indication of the sensor’s health.

Active shield guard drive
Sensors at a distance from signal conditioning circuits are subject to noise that reduces the signal to noise ratio into an amplifier. Reducing the noise that the INA cannot reject (high frequency noise or common mode voltage levels beyond supply rail) improves measuring accuracy.

Shielded cables offer excellent rejection of noise coupling into signal lines, but cable impedance mismatch can result in a common mode error into the amplifier. Driving the cable shield to a low impedance potential reduces this mismatch.

The cable shield is usually tied to chassis ground as it is easily accessible. While this works well in dual supply applications, it may not be the best potential voltage to which to tie the shield for single supply amps.

In certain data acquisition systems, the sensor signal amplifiers are powered with dual supplies (±2.5V). Tying the shield to analogue ground (0V) places the shield’s common mode voltage right at the middle of the supply bias, where the best CMR performance is obtained. With single supply amplifiers (5V) becoming more popular for sensor amplification, tying the shield at 0V is at the amplifier’s lower power supply rail, which is typically where CMR performance degrades. Tying the shield at common mode voltage of mid supply results in the best CMR.

An alternative solution is to use the VA+ and VA- pins of the ISL2853x and ISL2863x for sensing common mode and driving the shield to this voltage. This reduces cable impedance mismatch and improves CMR performance in single supply sensor applications. For further buffering of the shield driver, the additional unused op amp on ISL2853x devices can be used, reducing the need for an external amplifier.

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