

LMP8358

*Going Beyond the Front End (Zero-Drift, Programmable Instrumentation
Amplifier with Diagnostics)*



Literature Number: SNOA867

Going Beyond the Front End

— By Soufiane Bendaoud, Technical Engineer

Introduction

The premise of instrumentation amplifiers is to amplify small signals in the presence of large common-mode voltages. By the same token, instrumentation amplifiers (in amps) need to reject these common-mode voltages. In amps, as they are commonly called, find home in many applications across various markets from motor control, thermocouples, and bridge sensors to current sensing and medical instrumentation applications such as ECG and EEG.

In amps have come a long way since the classic two- and three-operational amplifier (op amp) in amps or the simple Difference Differential Amplifier (DDA). They are designed with different topologies to address the broad requirements for a variety of applications.

Traditionally, In amps have been designed on bipolar process and JFET to provide a wide dynamic range and good signal-to-noise ratio. Today, however, with signals being digitized in virtually any application and data converters using lower voltages, much progress and improvements have been made on the CMOS process in the realm of in amps.

In amps built on the CMOS process offer advantages over their bipolar and JFET counterparts. CMOS in amps enjoy the benefit of very low input bias currents over bipolar input devices and are easy to combine with on-chip logic functions to interface with ADCs. That said, they also have shortcomings. A major one is the noise associated with CMOS, which is typically much higher than that of a bipolar or JFET ICs, especially in the low frequency range which is dominated mostly by flicker or 1/f noise.

Clever designs, however, can overcome such a problem and provide the best combination of noise, power consumption, and speed for the optimal choice. One way to overcome the disadvantage is to combine CMOS in amps with dynamic offset compensation techniques like chopping and auto-zeroing.

Difference Between Auto-Zeroing and Chopping

One of the key differences between chopping and auto-zeroing is that chopping is a modulation technique, which creates substantial amounts of chopper noise at the chopping frequency, while auto-zeroing is a sampling technique that increases the observed white noise at low frequencies due to noise folding. The strength of combining the two techniques lies in the fact that the increased low frequency noise associated with auto-zeroing is modulated to higher frequencies by chopping the amplifier, while auto-zeroing reduces the chopper noise associated with chopping.

An example of this combined topology is National Semiconductor's LMP8358 instrumentation amplifier (**Figure 1**), which provides glitch-free transitions between gain settings through an SPI compatible serial interface or in parallel mode (from 10 to 1000). However because of the small remaining ripple of the auto-zeroing and chopping technique, it is a good idea to consider using active filtering for anti-aliasing when interfacing it with high-resolution data converters.

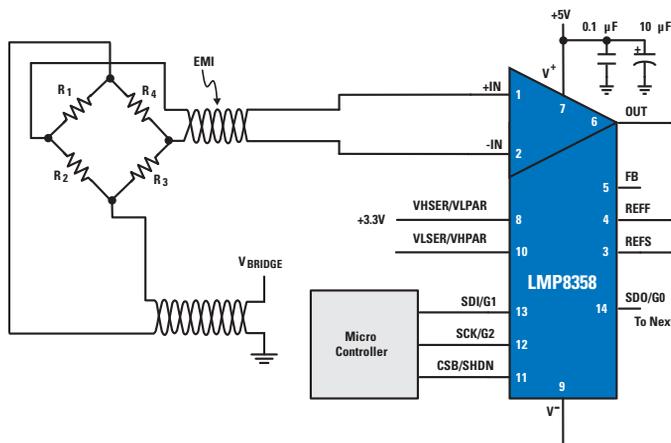
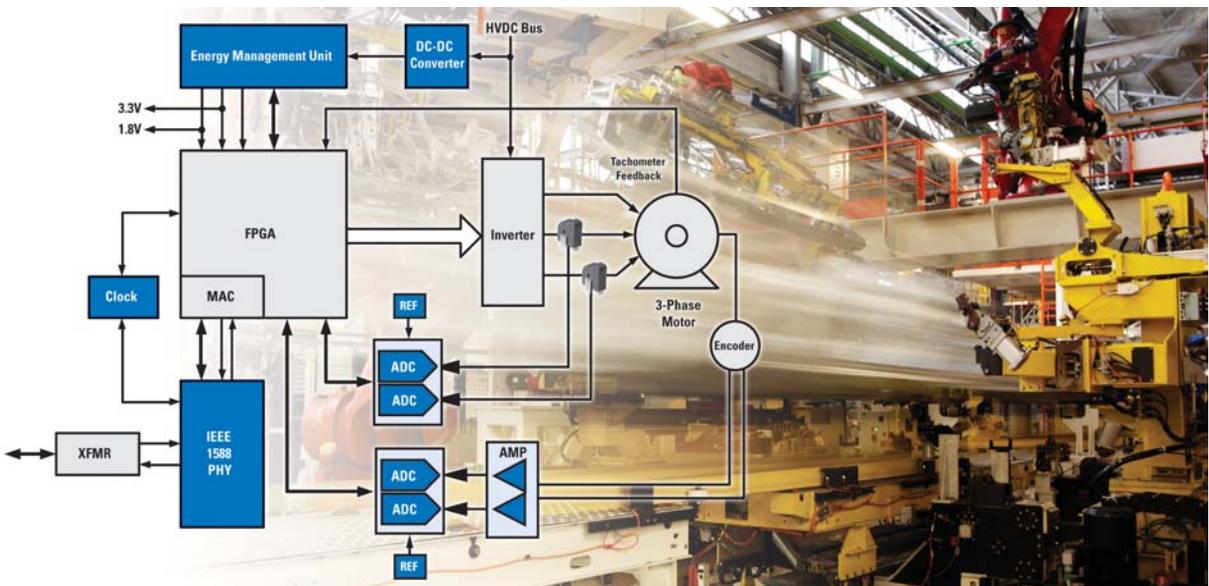


Figure 1. Industry's first zero-drift, programmable instrumentation amplifier with on-chip diagnostics

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Shown: Servo Motor Control Application Diagram

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Going Beyond the Front End

The Best of Both Worlds

Chopper amplifiers combined with auto-zeroing offer a great advantage in applications where accuracy, low noise, and high gains are desirable. One example is the popular strain bridge in which small differential signals must be amplified with small, full-scale voltages. The low offset voltage and low voltage noise of the in amp contribute very little to the overall error and help maintain system accuracy.

A high open-loop gain helps maintain a low gain error which allows the in amp to be used in the front-end interface to the sensor without having to use expensive precision amplifiers in subsequent stages.

Different Topologies for Different Requirements

The internal architecture of in amps varies depending on the end goal for the application and the intended use of the in amp. Each has its advantages and disadvantages relative to others. For example, the classic three-op amp in amp limits the common-mode voltage range and is not suitable for ground sensing applications. Its Common-Mode Rejection Ratio (CMRR) is limited by resistor matching.

Current feedback topologies, on the other hand, offer a CMRR that is independent of resistor mismatch and can have ground sensing capability without the addition of charge pumps which can add substantial noise. A current feedback topology combined with auto-zeroing and chopping, such as the one incorporated in the LMP8358, offers great benefits in applications that require precise measurements. An example is EEG or electro encephalography (the detection of brain wave activity), a critical measurement especially during life threatening procedures (**Figure 2**). In this application, very small signals need to be amplified, conditioned, and processed digitally with high-resolution data

converters at very low frequencies. A lower noise floor will have a lesser impact on the resolution and provide a higher bit count, ultimately resulting in a cleaner conditioned signal.

Going Beyond the Front End

With growing demand for automation in electronic systems, engineers expect ICs to provide functions that were historically implemented by external circuitry.

Contemporary electronic systems are often used in close proximity, leading to serious interference problems, and engineers can be faced with challenging tasks to get the desired results. Factory floors in process control and operating rooms in hospitals are prime examples of areas where many instruments are used in the same space and often at the same time. From two-way radios to the doctor's pager and the ubiquitous portable telephone, electronic systems can produce unforeseen anomalies.

Preventive measures can be taken by implementing additional circuitry or choosing the appropriate device that solves the problem before it even occurs. To address these interference issues, the LMP8358 includes EMI suppression filters that reject RF interference up to 60 dB while maintaining a noise floor of only 27 nV/ $\sqrt{\text{Hz}}$ with a programmable bandwidth. It also gives users the capability to diagnose a system by detecting accidentally shorted inputs, degraded sources, or inputs shorted to either supply with the flexibility of programmability via SPI interface or in parallel mode. The chip's DC specifications make it a suitable solution for precision measurements across a wide spectrum of applications.

Note: The author would like to thank Frerik Witte for his useful insights.

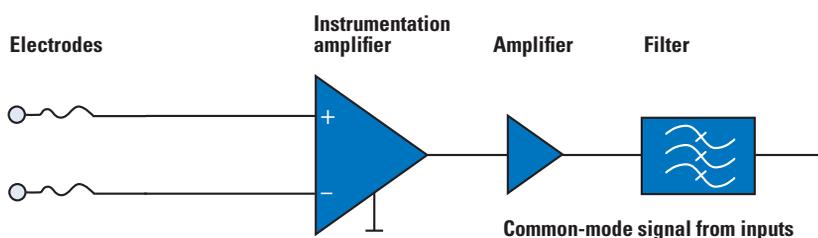
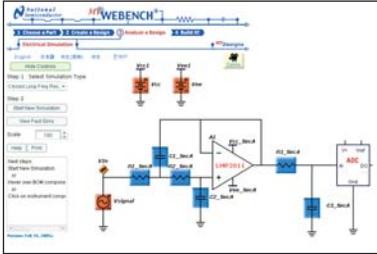


Figure 2. EEG machines benefit from auto-zero and chopper in amps due to low frequency noise

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