Application Brief

How to Select Amplifiers for Pressure Transmitter Applications

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Introduction

Pressure transmitters are used to monitor weight, level, force and flow in industrial process control systems. The primary challenges encountered when designing pressure transmitters are nonlinearities and temperature dependence. Overcoming these challenges requires the proper implementation of an appropriate operational amplifier (op amp) and a deep understanding of, the precision, voltage range, and drive characteristics of the op amp.

Pressure Sensors

The four most common types of pressure sensors used in pressure transmitter applications are: Resistive, Capacitive, Silicon, and Linear Variable Differential Transformer (LVDT) with resistive strain gauges being the most commonplace. These four variants all use similar paths in the pressure transmitter signal chain. Figure 1 illustrates a block diagram of a typical pressure transmitter signal path.

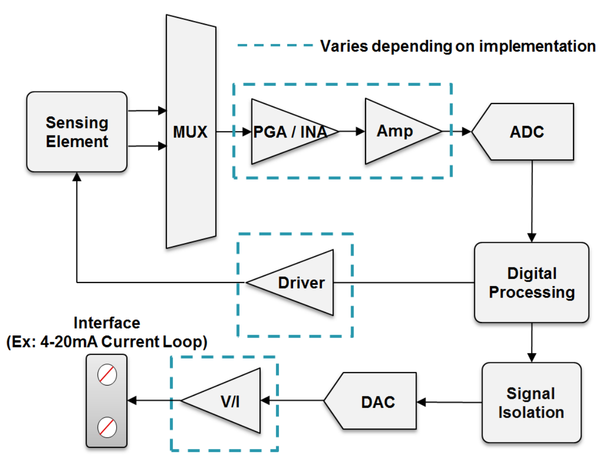

Figure 1. Common Pressure Transmitter Block Diagram

Various sensors and interfaces call for diverse device implementations.

- Instrumentation amplifiers, also known as INAs, are used to amplify small differential signals in the presence of larger or noisy common-mode signals
- Programmable-gain amplifiers, also known as PGAs, can provide higher gain accuracy using selectable gain steps
- Capacitive, LVDT and silicon sensors require implementation of a driver amplifier, which provides the excitation required for the sensor to capture changes in pressure or displacement.
- Voltage-to-current (V/I) converters are used to interface with commonly used 4-20 mA current loops.

Instrumentation Amplifiers

The output signal from the sensing element will require amplification prior to digital conversion as sensor signals are typically very small and can commonly be in the low single millivolt range. Instrumentation amplifiers provide the necessary amplification of differential signals while ensuring low noise and good rejection of the common-mode signals.

The INA823 instrumentation amplifier with Super beta input transistors provides exceptionally low input offset, offset drift, noise, and input bias current to help maintain signal accuracy when interfacing sensing elements. In addition, the wide supply (2.7 V to 36 V), below ground input voltage range, and input overvoltage protection up to 60 V beyond the supplies enables a wide variety of sensing elements.

Programmable Gain Amplifiers

Sensing elements typically output a nonlinear signal over temperature and pressure changes. A programmable gain amplifier with linearization circuitry, such as the PGA309, can be used to adjust for nonlinearities. The PGA309 is a programmable analog signal conditioner designed specifically for bridge sensors. The output of the PGA309 is sufficient to drive any 5 V analog-to-digital converter (ADC). Any higher-voltage ADC must be buffered by a low-noise, low-offset voltage and low-drift op amp to extend the output signal and make use of the ADC's full dynamic range. The OPA189 is a good option for a buffer amplifier, given its wide voltage range up to 36 V, zero-drift and low-noise (5.8 nV/√Hz) performance.

Driver Amplifiers

Capacitive-, LVDT- and Silicon-based sensing elements require excitation by an op amp with sufficient drive characteristics necessary to enable the sensing element to capture minute changes in pressure and displacement. The important design parameters for these op amps are output current and capacitive load drive. The OPA196 op amp offers sufficient output current (65 mA) and high capacitive load drive (1 nF) capability making it a good choice for this application.

Table 1. Instrumentation Amplifier/PGA Device Selection

INA/PGA	Key Benefits
INA823	Low power (250 µA), wide supply (2.7 V to 36 V), precision (100 µV), instrumentation amplifier input overvoltage protection and below ground input range.
INA333	Ultra-low power (50 µA), high precision (25 µV, 0.1 µV/°C), zero-drift instrumentation amplifier
PGA309	Programmable gain amplifier offering design versatility while mitigating pressure and temperature nonlinearities through highly integrated linearization circuit, fault monitoring and digital temperature compensation.

Table 2. ADC Buffer Device Selection

ADC Buffer	Key Benefits
OPA2182	Industry leading precision (0.012 µV/°C, 4 µV max), low-noise (5.7 nV/√Hz), zero-drift op amp with Mux-Friendly inputs
OPA210	Ultra-low noise (2.2 nV/√Hz), wide-bandwidth (14 MHz), high-precision, Super beta op amp
THP210	High-precision (40 µV, 0.1µV/°C), high-voltage (36 V), low-noise (3.7 nV/√Hz), fully-differential amp and ADC driver

Table 3. Driver Amplifier Device Selection

Driver Amplifier	Key Benefits
OPA202	Low noise (0.2 µVPP, 9 nV/√Hz), heavy capacitive drive (25 nF), super beta, precision op amp
OPA196	High capacitive load drive (1 nF) and high output current (65 mA) enables capacitive sensor excitation.

Table 4. Voltage-to-Current (Integrated) Device Selection

Voltage-to-Current (Integrated)	Key Benefits
XTR115 XTR116	Integrated solutions for 4-20 mA loops provide low nonlinearity error and the convenience of an on-chip 5-V voltage regulator and a precision VREF.
XTR111	Cost effective 4-20 mA driver provides an integrated device with low nonlinearity, good accuracy, wide supply and output error flag.
XTR300 XTR305	Integrated 4-20 mA loop solution: output can be configured as current or voltage without external shunt resistor and provides error flags and monitor pins for fault detection (XTR305 is a cost effective version)

Table 5. Voltage-to-Current (Op Amp) Device Selection

Voltage-to-Current (Op Amps)	Key Benefits
OPA187	Low-power and zero-drift architecture reduces power consumption and ensures high precision over the full industrial temperature range.
OPA391	Micro-power (24 µA), high-precision, wide bandwidth, RRIO op amp with e-Trim™

Voltage-to-Current Converters

A common interface in pressure transmitter applications is the 4-20 mA current loop, which uses a precision, low-power op amp to create a measurable current range from a voltage range. The requisites of the op amp in this application are low power and high precision. The OPA391, an e-Trim op amp, features 45 µV maximum offset and 24 µA of quiescent current, making it a good candidate for such requirements.

An integrated solution can also be implemented using an XTR115, XTR300, or XTR305, which are precision current output converters designed to provide signal conditioning of low level signals and translation of them to a robust, noise-immune 4-20 mA transmission.

Temperature, Power, and Nonlinearities

In a real application environment, changes in temperature can affect the behavior of key device specifications, such as input offset voltage and input bias current. This impact can be mitigated by selecting zero-drift opp amps.

For applications with power constraints such as battery powered sensors or 4-20 mA loops with many sensor nodes, low-power devices that maintain high precision are available.

Nonlinearities in sensor output over pressure or temperature can be corrected by adjusting the excitation of the sensor. This function can be implemented through digital processing or integrated linearization circuitry.

Summary

The implementation of amplifiers in pressure transmitters will vary depending on sensing elements and interfaces. Issues with wide temperature drifts and nonlinearities can be mitigated through the proper use of instrumentation amplifiers, programmable gain amplifiers and op amps. Table 6 outlines some devices that are commonly used in pressure and field transmitter applications.

Table 6. Related Articles and Resources

Media	Title
Technical Guide	TI Field Transmitter Solutions Guide
Application Brief	Offset Correction Methods
Application Report	Selecting an A/D Converter
Application Brief	Zero-drift Amplifiers: Features, and Benefits