A matter of scale

Integrated device eases industrial signal scaling issues. By **Carine Alberti**.

In an industrial environment, the control of machinery or processes is often done using programmable logic controllers and distributed control systems. Both have monitoring and controlling functions, with analogue I/O modules that can receive inputs from sensors and transmit outputs to actuators.

The analogue input voltage and current ranges used in industrial control modules include: ±10V, ±5V, 0 to 5V, 0 to 10V, 0 to 20mA and 4 to 20mA. The common problem is the need to build a signal conditioning circuit that can accept a ±10V input operating signal and scale it to match the full scale input range of the single supply a/d converter. The traditional method to implement the signal path requires discrete components such as resistors, switches, digital potentiometer, instrumentation amplifiers and operational amplifiers to scale and level shift the signal.

The LMP7312 provides an integrated solution to this problem. It has been designed to provide a minimum parts count solution to the issue of interfacing higher voltage input signals with lower voltage a/d converters.

A typical industrial control module is shown in Figure 1. The sensors considered could be pressure, temperature, flow or weight. It is possible that the I/O module provides a mV input for unconditioned sensors, such as thermocouples.

The interface with a thermocouple (see fig 2) is implemented with the LMP8358, a precision instrumentation amplifier. Its gain can be programmed to preset values between 10 and 1000 using an SPI compatible serial interface or a parallel interface. Alternatively, gain can be set to an arbitrary value using two external resistors. The LMP8358 uses patented techniques to measure and continuously correct its input offset voltage, eliminating offset drift over time and temperature and the effect of $1/f_{noise}$.

These dc performances (Vos (max) 10µV, TCVos (max) 50nV/°C) make it suitable to interface with sensors having millivolt output ranges. Along with fault detection circuitry, open and shorted inputs can be detected, as well as a degrading connection to the signal source.

When attenuation is required

If the input signal range is ±10V, attenuation will be required so the analogue signal matches the full range of the low power single supply a/d converter. Figure 3 shows the signal path solution using the LMP7312 and one way of realising the design with a more traditional discrete solution. The discrete solution could, for example, be implemented using a digital potentiometer or resistor arrays and switches to adjust the gain and the biasing. Another way is to use a voltage divider by 10 to attenuate the signal and readjust it later.

The LMP7312 is a digitally programmable variable gain amplifier block with differential output to drive differential input a/d converters. The LMP7312 provides CM input range capability of ±15V (absolute) and ±10V (operative) from a 5V single supply. It is suitable for interfacing standard industrial analogue bus voltages and includes a common mode input pin to centre the conversion input voltage range of the a/d converter. The result is a conversion environment which is not degraded by loss of conversion codes near the bottom rail of single supply systems.

The amplifier provides fractional gain values, designed to provide a minimum parts count solution to the problem of interfacing higher voltage input signals with lower voltage a/d converters, including the elimination of external passive resistors needed for level shifting. The gain values for the level shift mode (inputs $+V_{IN}$ and $-V_{IN}$) are 0.096, 0.192, 0.384 and 0.768V/V. For the current loop mode, they are 1 and 2V/V.

The LMP7312 can be used in single ended and fully differential output modes, allowing interfacing of fully differential and single ended input a/d converters.

Fig 1: System block diagram

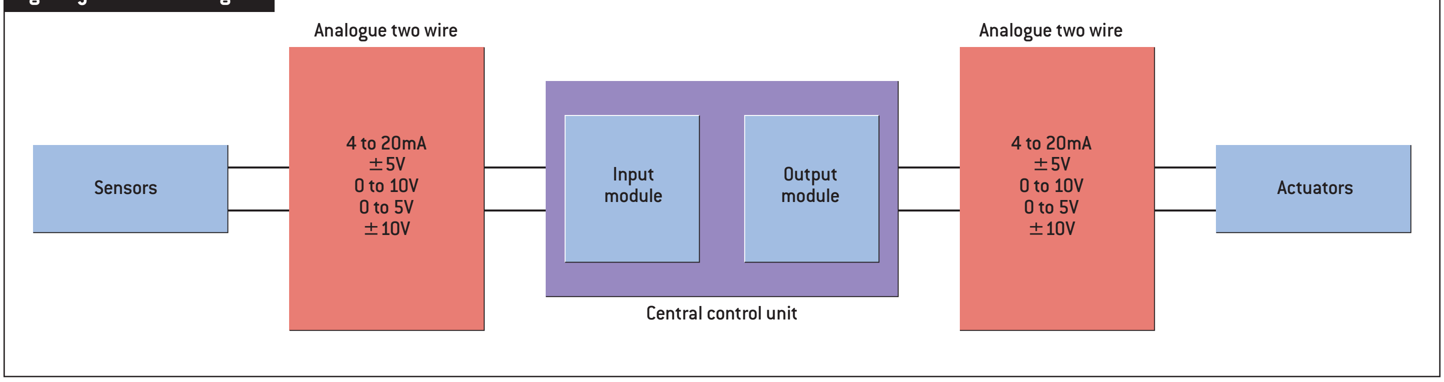
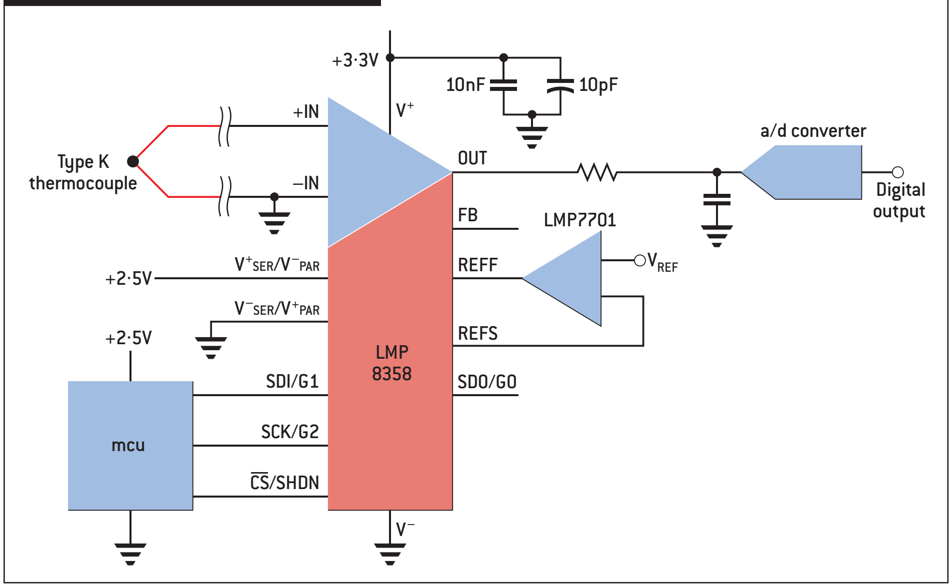


Fig 2: Thermocouple signal conditioning



Using a fully differential output mode has two advantages – it eliminates missing codes found in single ended systems near the bottom rail and it doubles the voltage conversion range presented to the a/d converter, thus increasing signal/noise ratio and, ultimately, bit error rate. A 5V differential system has the effective conversion range of a 10V single ended system.

The LMP7312 is suitable for driving the ADC161S626 a/d converter, a 16bit SAR device with a maximum sampling rate of 250ksample/s. The converter, which features a differential analogue input with a common mode signal rejection ratio of 85dB, is suitable for noisy environments.

Error budget consideration

As gain, offset and common mode rejection errors can be removed by a system calibration; they will not be considered in the error budget calculation.

The system has the following operating conditions:

- Input voltage range: 10V p-p
- System gain: 0.384
- Temperature variation: 50°C
- Signal bandwidth: 100kHz

The errors, related to temperature drift and noise, assume the worse case conditions.

The maximum offset drift (input referred) given in the datasheet is 14.4μV/°C, leading to an error of 72ppm. The gain drift maximal is 5ppm/°C, therefore 250ppm can be considered.

The voltage noise contribution can be calculated, by separating high frequency and low frequency noise, with the current noise contribution neglected. The high frequency noise calculation is pretty straightforward: the broadband noise of 91nV/√Hz is given in the datasheet for the complete LMP7312, while the noise from 10kHz to 100kHz is around 204μVpp. For low frequency noise (from 0.1Hz to 10kHz), the datasheet provides the voltage of the core op amp, so the thermal noise of the resistors has to be estimated as well. For a differential amplifier configuration, the thermal noise is:

$$E_{thermal}(f) = \sqrt{[\int 8kTR2(1+(R2/R1))df]}$$

When the LMP7312's internal resistors R1 and R2 are 104k and 40k respectively, the resultant thermal noise is 32μV p-p. T is temperature and k is Boltzmann's constant.

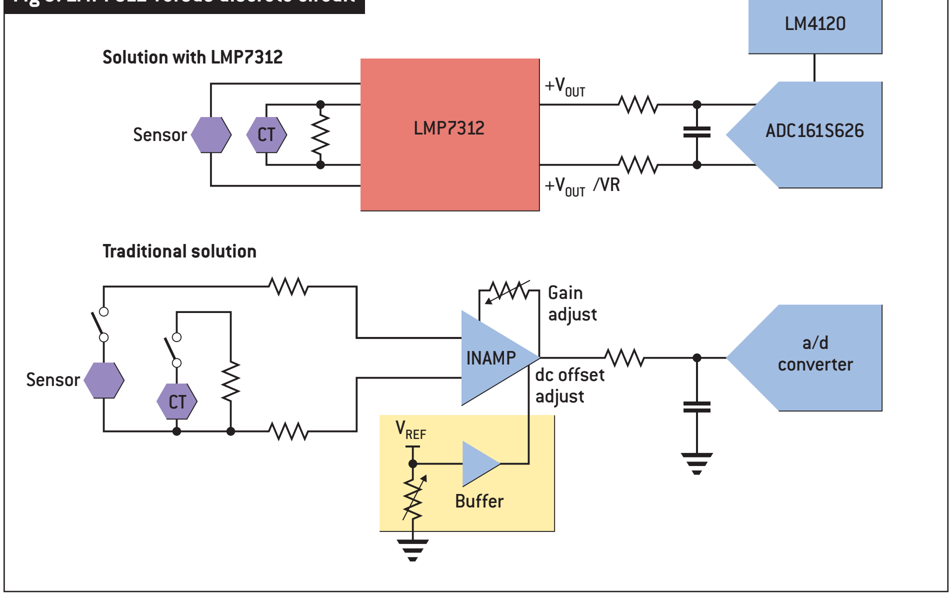
The voltage noise of the core op amp also needs to be included in the low frequency noise calculation. To start, the datasheet indicates a noise in the range from 0.1Hz to 10Hz noise of 3μV p-p. In addition, we need to calculate the 1/f noise from 10Hz to 10kHz, using the equation

$$En_{1/f\ region(f)} = k1/f^{k2} = 7\mu V\ p\text{-}p$$

where k1 and k2 are constants derived from the voltage noise at two frequencies.

Finally, the total noise is the square root of the sum of squares of the various noises. With a total noise contribution of 207μV p-p, this corresponds to 21ppm. The LMP7312 is a prime choice for applications requiring high accuracy such as data acquisition systems for I/O modules. The high integration allows designers to decrease the component count therefore reducing the bills of material, qualification and the various quality issues associated with using discrete components.

Fig 3: LMP7312 versus discrete circuit



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