Group Four Transducers Inc

The secret to designing high-resolution load cell electronics.

A common problem with weighing applications is that the vessel that holds the product you are trying to weigh (dead load), substantially outweighs the product itself (live load). An example of this is when a fruit processor is trying to weigh a hopper full of blueberries. The hopper weighs several hundred pounds but the blueberries weigh less than 20 lb. Of course, the more accurately we can weigh the hopper, the more precisely we can fill containers of blueberries.

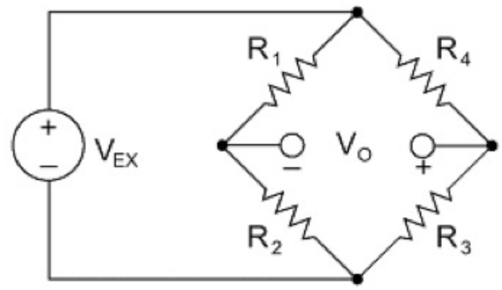
To process the load cell signal, the electronics in this measuring chain must be very fast and very stable. Why are the Group Four electronics solutions superior to other manufacturers? What makes them more stable in this application? There are many reasons and each component must be optimized for best performance. However, Group-4 has taken a different approach toward optimizing the electronic performance by using AC excitation rather than DC.

Load cell electronics wizard *Michael Bach* explains these details in the following paper:

Load cell excitation, AC vs. DC

The Wheatstone bridge configuration used in strain gage load cells is shown in figure 1. When all four gauges have the same resistance the bridge is in balance and the resulting output voltage (Vo) is zero.

Figure 1



If the gauges are arranged so that R1 and R3 are elongated and R2 and R4 are compressed while the load is applied then the applied load will result in a positive output voltage (Vo). The output voltage can be expressed as:

Figure 2

$$Vo = \frac{Actual\ load}{Rated\ load}\ k\ V_{EX}$$

In Figure 2 VEX is the supply voltage to the bridge. k is the sensitivity of the load cell and is expressed in mV/V. The k-values for most load cells are between 1 mv/v and 3mV/V and a typical value for VEX is 5V. The result is a full-scale output voltage between 5 and 15mV. To obtain 1g resolution when using a 10kg, 2mV/V load cell the input signal to the electronics will be 10mV / 10,000 = 1µV/g. Obtaining stable and reliable measuring results from signals so minute is a challenge for circuit designers. The contributing factors are described below.

Input offset voltage

One of the many sources of measurement error in a strain gage amplifier is the offset voltage, which results from the variation in the components that make up the amplifier. The offset is totally random and varies with temperature. All DC amplifiers have the effect and ultimately it is impossible to differentiate between the measured value and the influence of this DC offset. The advantage of AC excitation is this DC offset is not amplified.

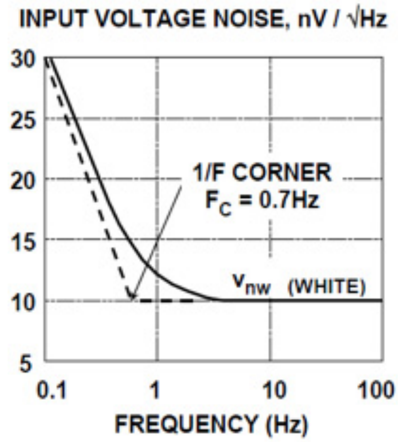
Thermal EMF's

When two metals are joined together a thermocouple junction is formed and results in the creation of DC offset voltage. Once again this DC voltage is random and cannot be differentiated from the measurement voltage. The advantage of AC excitation is this DC offset is not amplified.

Internally Generated Electrical Noise

All amplifier circuits generate electrical noise. The noise distribution for a typical amplifier used for strain gauge applications is shown in figure 3.

Figure 3



From Analog Devices tutorial MT-048

In figure 3 the noise increases with decreasing frequency - The high frequency noise can easily be eliminated using various filter techniques (As explained in the following paper - http://www.groupfourtransducers.com/filters-for-load-cell-applications.php)

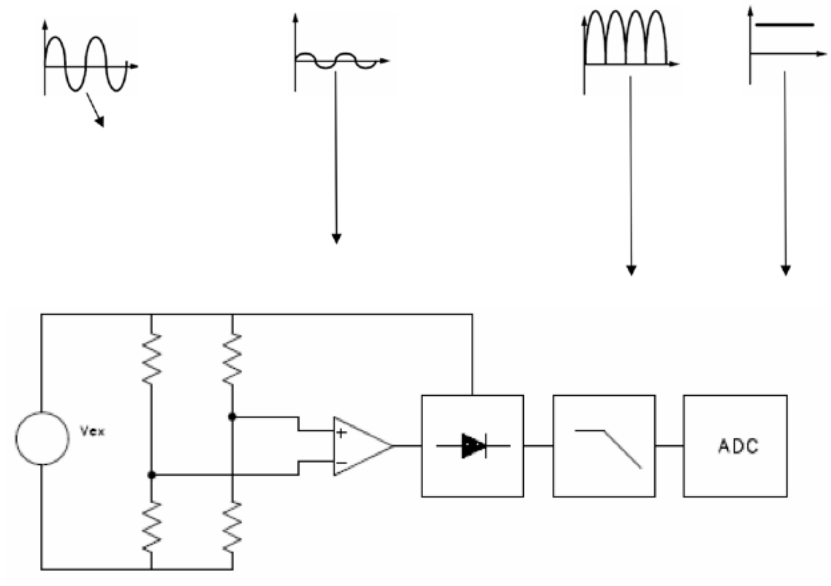
The lower frequency noise components is a severe problem when trying to make DC measurements.

The solutions

If the DC voltage supply VEX is replaced with sine wave generator, the output voltage from the bridge (Vo) will also be a sine wave. With the AC circuit it is easy to block any DC voltage and apply amplification to the AC component only and in this way eliminate errors caused by DC instability.

The AC signal is amplified, filtered, rectified and finally averaged into a DC voltage representing the original low level signal as shown in figure 4.

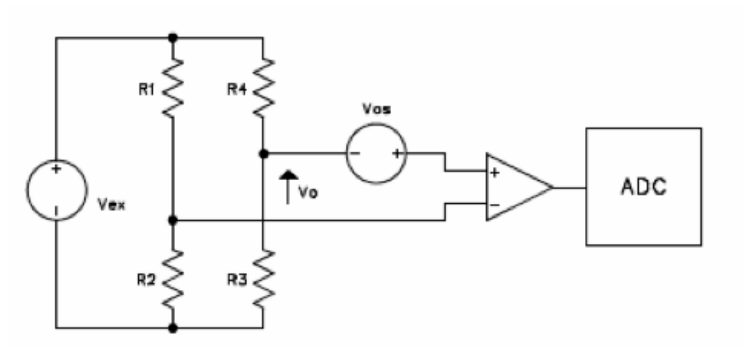
Figure 4



Modern AC solutions

Faster A to D converters and highly integrated logic circuits has simplified AC circuit designs.

Figure 5



Higher quality load cells use PCB's and flex circuits with "solder mask" which helps to protect the wiring from the effects of moisture induced lower insulation resistance.

The schematic in figure 5 illustrates a bridge with a a positive excitation voltage resulting in a positive output signal (Vo). The ADC will then measure a voltage VADC = A (Vo + Vos), where A is the gain factor of the input amplifier. If the excitaion voltage (VEX) can be reversed, e.g. through a switch network, the polarity of Vo will change but the polarity of Vos will remain constant. By subtracting two subsequent measurements with oposite excitaion polarity the effect of the offset voltage can be cancelled.

$$VADC = A\ (Vo + Vos) - A\ (-Vo + Vos) = A\ 2\ Vo$$

Circuits using this technique are lower cost than circuits using the sine wave principle and they will still cancel thermal EMF's in the load cell wiring and reduce 1/f noise in the input amplifier stage. An example of a device using this technique is the GLDU 69.1 from Group-4 making the use of instrumentation with nearly laboratory performance realistic at the factory floor.