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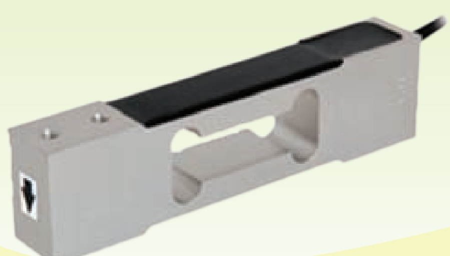
Load-Cell Testing in Practice



Application Note

Anticipate ___Accelerate ___Achieve

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WHAT IS A LOAD-CELL?

A load-cell is a device that is used to measure high compression, tensile force, high pressure, and weight. Load-cells take many forms in order to accommodate a variety of uses in research and industry applications. Most current designs use a strain gauge as the sensing element because it is able to measure tension, compression, and shear forces.

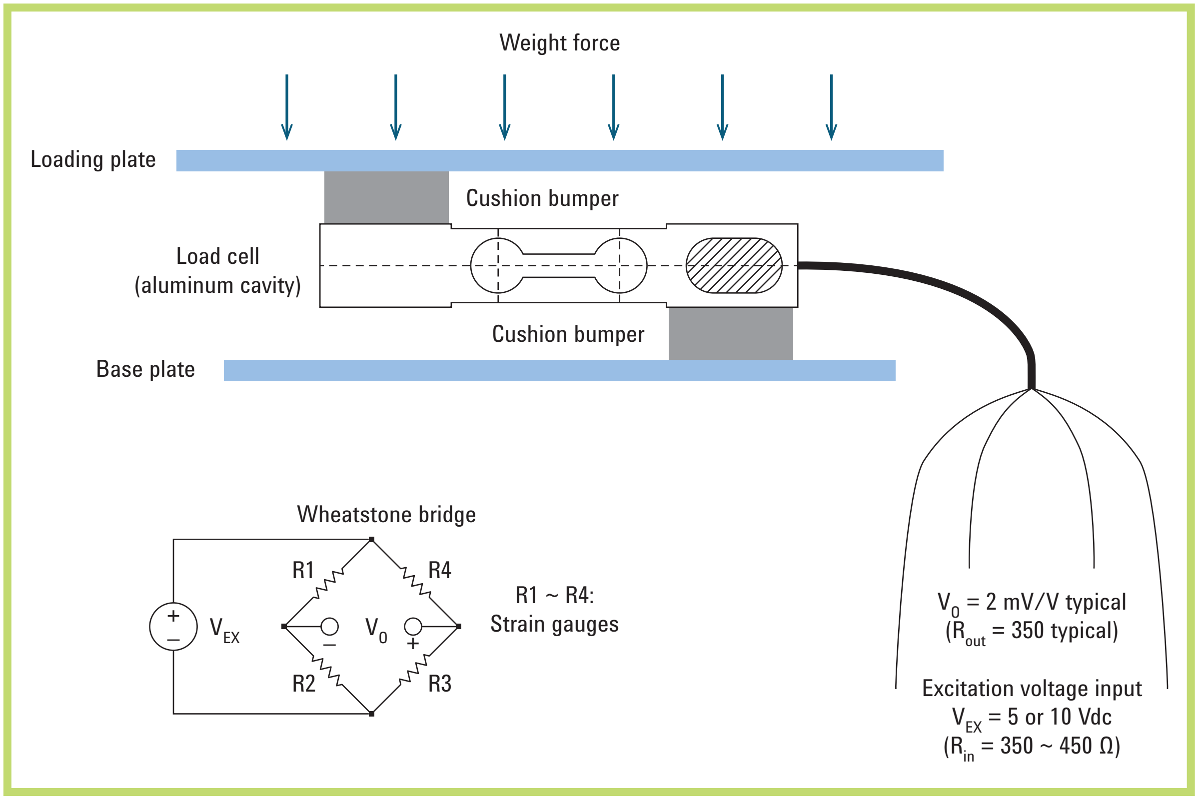
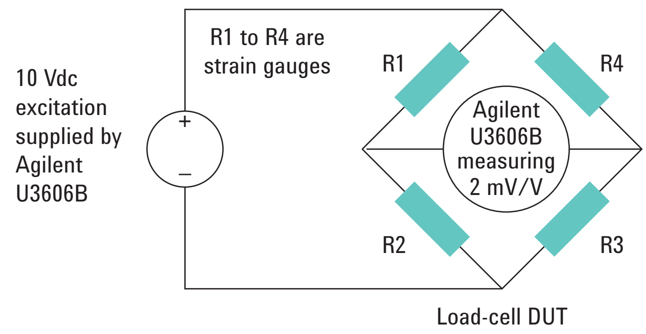


Figure 1. A weight indicator using a load-cell structure

The load-cell is a simple device that changes a mechanical force into an electrical signal; for example, a force transducer. The device is made of a piece of metal that was tempered and therefore functions as a spring. At least four strain gauges are bonded to the inner surface to form a configuration similar to a Wheatstone bridge (see Figure 1). The strain gauge mimics the Wheatstone bridge configuration to convert a certain amount of strain or force into electrical output. Each gauge has the same resistance value. All four gauges would remain the same when no stress is applied to the load-cell. When stress is applied to the load-cell, two of the gauges will be slightly stretched and increase in resistance. The other two gauges will be compressed and decrease in resistance.

Applying stress causes the bridge to be slightly out of balance. The unbalanced resistance effect is proportional to the amount of stress applied. Most modern weight indicators provide "excitation voltage" to supply power to the load-cell. The voltage is applied to the strain gauges through calibration resistors throughout the load-cells. This is a method of calibrating the load-cell to deliver a specific signal for its rated capacity. It amounts to a stress point that is repeatable, so that the load-cell can return to its original state. Usually, load-cells are sealed during production and cannot be serviced.

A regulated voltage is supplied to the load-cell, usually 10 V. A small output signal rated in “mV/V” (millivolts per volt) from the cell is generated (see Figure 2). This means that when voltage is supplied while the cell is stressed to its capacity, it will return a known output voltage. Normally, the output voltage would be approximately 2 to 3 mV/V. In reality, the output voltage is much less than the value given in Figure 2. Furthermore, all scales have dead-load values. A dead-load value is the amount of load permanently applied and constantly acting on a load-cell. This is the amount of load that is equal to the platform or to any other constant weight not applied by the user.



The output voltage of the bridge, V_0 is equal to:

$$V_0 = \left(\frac{R3}{R3 + R4} - \frac{R2}{R1 + R2}\right) \cdot V_{EX}$$

Figure 2. Testing a load-cell using the Agilent U3606B

EXAMPLE...

The following example shows how to make load-cell measurement, assuming that a truck weight indicator has a deck weight of 20,000 lbs. (see Figure 3). That weight is applied to a group of load-cells with a combined capacity of up to 520,000 lbs. That’s eight 65,000-lb.-capacity cells. The load-cells are connected to “summing boards”, while the output is connected to the indicator. The resulting signal is about 1.154 mV. The actual rated capacity of the scale would likely be 200,000 lbs. A force of 200,000 lbs. will cause 11.538 mV of signal change. Include the 1.154 mV of dead-load, and the resulting signal is 12.692 mV. Now, the scale weighs in 20 lb. divisions. That means the full-capacity signal divided by 10,000 divisions (200,000/20) equals 0.00115 mV, which is 1.15 µV.

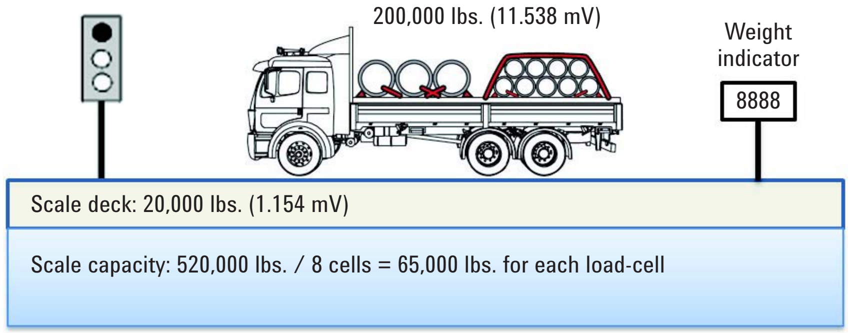


Figure 3. A measurement example of a truck weighing station

As the example shows (from Figure 3), the resulting signal for one division is very small in value. Our example did not include any loss of signal caused by the cable or the summing boards that the individual load-cells are connected to. This phenomenon can easily amount to a 10% loss of signal. There are scales that have up to 14 load-cells at that same capacity if a longer scale is required. Their signal might well be less than the 1 µV value. To cope with this, the Agilent U3606B Multimeter|DC Power Supply meets the required specification with 0.001 mV resolution. The U3606B can also be used to check the excitation voltage, as well as indicating power supply voltages under 5 V, or up to ±15 in range for analog signal. Apart from that, the U3606B can also clear up to 180 V DC for certain displays and backlighting, which is well covered within the DC voltage range.

Figure 4. Agilent U3606B Min/Max function

Another important area to focus on is measuring leakage. This is a common problem with weight indicators that are exposed to weather, placed in an area with very high humidity, or washed with any liquid substance. If a cable develops wear and tear, or if water seeps into the summing box, this can cause a slight leakage of the excitation voltage, particularly to the signal connections or earth ground. The leakage is tested by measuring the resistance of any bridge wires to earth ground, or in actual practice to the case of the load-cell or frame of the weight indicator. Moisture is present when there is a measurement reading. The cables also have a shield that creates virtual connection in the load-cell. It should also show no leakage to the bridge connections or to earth ground. A clear resistance in the 50 MΩ to 100 MΩ range can cause instability or non-repeatability of the load-cell signal. The U3606B can measure up to 100 MΩ to indicate the leakage.

You also may need to measure the resistance on the bridge, also known as the resistance of the strain gauges. They can be tested in several ways. To measure the resistance of the excitation connections, the signal connection is tested for cell balance. This would involve four measurements: + sig to + ex and +sig to – ex. The measurements should have the same value.

Likewise, –sig to + and – ex and should also have the same value. Typically, the signal resistance is 350 Ω or 700 Ω. Some signal can go as low as 240 Ω or as high as 2000 Ω. The excitation value is usually close to if not higher than the resistance caused by the calibration resistors.

Occasionally, the load-cells will have some intermittence caused by poor connections and corrosion in the cell or cable. When observed, the weight indicator will either be unstable or non-repeatable. The easiest way to test for this is to connect a meter to the signal with the cell powered while tapping it with a small hammer at a spot that will not cause damage, such as an end. If the signal changes, it could mean that the cell has a bad internal connection or a strain gauge is cracked. The same tap test can be done when measuring resistance instead of voltage. If a calibration resistor has become intermittent due to over-voltage (such as from lightning), it is very difficult to test for a signal change unless a large load is placed on the cell. A load-cell would provide a measurement of 0.000 mV without load in an ideal condition. In summary, if the actual voltage to the stain gauges varies wildly with no force on the cell, no measurement will be read. The Min/Max functions on the U3606B are very useful when finding intermittent problems.

CONCLUSION

When measuring load-cells, design and test engineers should take note that the output signals of the load-cells have very small voltage range. Another thing to note is that the output signal is sensitive to the force applied, and the measured readings are easily influenced by poor connections in the load-cell itself. Leakage of the excitation voltage due to poor weather or moisture might also occur. A stable bridge-resistance measurement is important to ensure that resistance is balanced in the excitation connections between the cells.

The Agilent U3606B provides not only the AC/DC power supply to perform tests on load-cells, but also has DMM functionality to provide stable low-voltage and resistance measurements, high resolution in low-voltage ranges, and the built-in math functions (Min/Max/AVG) to eliminate noisy measurements in finding intermittent load-cells and poor wiring connections.

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