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APPLICATION NOTE 5278

Why Honest Weigh Scales Are Application Specific

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Abstract: Current laws and regulations require honesty, tolerance, and accuracy in weigh scales. The most commonly used weight-measurement element is the strain gauge. This application note explains how strain gauges are useful in multiple applications that must measure stress and pressure and their effects. The electronics of honest weigh scales are varied, and can provide the resolution and accuracy that each application demands.

“Dust on the Scales”

Recently the electronics industry has lost some great men. A twentieth century song, “Dust in the Wind,”[1] laments the difficulty of honoring heroes and great men. “All they are is dust in the wind.” Yet our social sensibilities make us yearn to remember and honor their accomplishments. So they may be dust in the wind, but still far more than that to fellow engineers.

Dust is an interesting metaphor here. With regards to measurement, a particle of dust is usually considered as “nothing.” Ancient writings describe something insignificant as “the film of dust on the scales.”[2] Logically, we must balance the magnitude of an item that we are weighing or calibrating against the significance of measurement error. Weighing a spec of dust is far different than weighing a large truck, a chemical, or a molecule. In short, weighing is application specific.

Current laws and regulations require scale honesty, tolerance, and accuracy. Hence, our focus on honest weigh scales. The most commonly used weight-measurement element is the strain gauge. Strain gauges are also useful in multiple applications that must measure stress and pressure and their effects. The electronics of honest weigh scales are varied, and can provide the resolution and accuracy that each application demands.

Versatile Role of Strain Gauges for Weight Measurement

The most commonly used weight measurement element is the strain gauge. Strain gauges are also useful for monitoring stress in almost any device or structure; for building earthquake improvements in architecture; for managing the effects of traffic loading in bridges; and for predicting structural repair and failure prevention in aircraft. Pressure measurements, whether of the atmosphere, liquids, gases, or steam can also be performed by strain gauges. The two most common types of strain gauges are the metal-foil type and the semiconductor-based peizoresistive transducers. Piezoresistive transducers are more sensitive and have better linearity than metal-foil-type transducers, but they require special care to handle initial voltage and temperature dependence.

A strain gauge measures a change in resistance when the applied force is varied. The strain gauge then converts pressure or stress into an electrical signal. A load cell is one or more strain gauges, that is, active resistive elements packaged in a convenient container. Inside the scale or measurement system, the strain gauges are typically connected in a Wheatstone bridge configuration to produce a differential output voltage. The balanced bridge was invented by Charles Wheatstone in 1843[3] and expanded upon by William Thomson (known as Lord Kelvin after 1892) in 1856. The great improvement that made strain gauges practical, however, was the invention of amplifiers, which can increase the small changes in voltage from mechanical stress.

The late Karl Hoffmann placed 30 years of his knowledge in a very well written book, “An Introduction to Measurements using Strain Gages.” A free copy is available courtesy of Hottinger Baldwin Messtechnik (HBM) GmbH, Darmstadt.[4] The book is more than 250 pages of detailed strain-gauge information. The subjects covered include strain gauge types, selection criteria, environmental influences, mounting materials, a Wheatstone bridge circuit, calibration, multiwire circuits, Hook’s Law, and measurement accuracy.

Today the Wheatstone bridge is ubiquitous and comes in many forms, each with advantages and disadvantages. We do not have the space to review all facets of this subject. Instead, we will just point to the relevant information already covered in other application notes. Links to “Resistive Bridge Basics: Part One and Two”[5,6] cover Wheatstone bridges and their variants. Sensor interfaces, amplifiers, and filters are referenced below.[7 to 12] A tutorial on Kelvin force sense and guarding is contained in the MAX4554 data sheet as are examples of 3-, 5-, 8-, and 12-wire sense, guards, and switching.

Summary

A speck of dust is small when we weigh a truck and big when we weigh a molecule—it truly is application specific. The electronics are just as varied and can provide the resolution and accuracy the each application demands.

Appendix: Laws and Regulations for Scale Honesty, Tolerance and Accuracy

Since the earliest socialized tribes, accurate scales have involved serious consideration. Trade between people likely resulted in the first rules and laws dictating accurate and impartial scales. Dishonest people could manipulate scales fraudulently by using inaccurate weights. They could multiply the trickery by using one set of weights for buying and another for selling. In early Biblical times this practice was condemned by Jewish tradition.[13] “Cheating” scales could also be rigged or made inaccurate by making the arm lengths unequal; they could be rendered less sensitive by making the beam thicker and heavier or by having the arms relatively short.

Our English word “pecuniary” comes from the Latin root *pecus* which means cattle.[14] Cattle were likely the first barter currency for the Romans, much as cattle still are in many parts of the world today. The Bible[15] relates that barter, or exchanging cattle and goods as payment, was resorted to by Egypt and

Canaan during the severe famine of the eighteenth century BCE.

In the Code of Hammurabi[16] c. 1780 BCE (i.e., the Babylonian era), “many immoral acts, such as the use of false weights, lying…are severely denounced…as likely to bring the offender into ‘the hand of God’ as opposed to ‘the hand of the king.’”

Mc Clintock and Strong Cyclopaedia, while discussing Exodus 3:13 “the shekel of the sanctuary,” write “Here the shekel is evidently a weight, and a special system of which the standard examples were probably kept by the priests.”[17]

On March 2, 1799, the first United States federal weights and measures law was signed by President John Adams. The federal agency, the National Institute of Standards & Technology (NIST), began in 1901 as the National Bureau of Standards. All of the nation's weighing and measuring standards can be traced back to this body. The State of California passed legislation in 1911 establishing a County Department of Weights and Measures. The hierarchy of the U.S. government in descending order is typically federal, state, county, and city.

We will quote the department of Weights and Measures of Santa Clara County[18] in the Silicon Valley. Its “mission is to protect the buyer and seller in all monetary transactions that use weight, measure, or count.” A few of the devices that they inspect are “gasoline pumps, scales, and other similar devices for accuracy so that consumers will be charged the correct price.” To that end, the tare, or tare weight, is the weight of packaging, wrapping, or any material not considered product or part of the net weight. Tare weight plus net weight equal gross weight. Selling by gross weight or measure is a misdemeanor in California (California Business & Professions Code 12023). It is interesting that a law forbidding gross weight sales is still required in the twenty-first century. Clearly this issue dates back to the earliest tribal rules codifying fair treatment for all.

To make tare weight removal simple, many products include an internal microprocessor which can aid testing. For example, a weight scale can compensate for the weight of the product package, such as a syringe, plastic bag, or glass jar. Subtracting the weight of the package (tare weight) from the gross weight is necessary to accurately measure the net weight of the material on the scale. Because the weight of the package may change over time due to manufacturing variation or a change of vendors, it is desirable to update the tare or container weight from time to time. A local hardware store sells nails by weight, one first places the container (a paper bag in this case) and pushes the tare button. The bag weight is calibrated out and the scale registers zero, ready for one to add the nails.

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