Tech Lesson:

All That Shines is Not Gold

By Boon Lim

If you're a scale technician, especially if you're new to the profession, this article can give you some insight into the differences between cheap retail scales and industrial-type scales. When an industry customer asks you what kind of bathroom scale they should buy, you'll have the knowledge to advise them on what to watch out for. This information could also be useful to B2B customers looking to purchase a lab balance online; you'll be able to warn them, "buyer beware."

Weighing sensors from bathroom to truck scales commonly utilize 350-, 700-, and 1000-ohm strain gages. These thin wires measure changes in resistance due to compression or tension. Four primary materials are used: stamped metal, aluminum, alloy steel, and stainless steel.

Bathroom scales and low-cost shipping scales often use single 1000-ohm stamped metal load cells with one strain gauge per cell, as they are the most affordable but are not accurate or temperature compensated. Two strain gages per cell are used in lower-cost luggage and fishing scales, often made of aluminum.

Overhead hanging scales typically use either an S-type shear beam or bending beam strain-gage load cell, or single plate blind hole shear beam designs to measure the beams' bending or shear stress. For scales with capacities under 500 pounds, aluminum moment insensitive load cells (MILC) are often used, typically 350 ohms full bridge or four gages per cell with temperature compensation resistors. For capacities over 500 pounds, alloy steel or stainless-steel designs, such as blind hole shear beam load cells, are used. Truck scales employ compression, tension, single-ended, or double-ended shear load cells.

Analog load cells can output 1mV/V, 2mV/V, or 3mV/V. This output signal from the indicator, usually ranging from 1.5 VDC to 15 VDC, is used to power the load cell, with the return signal in millivolts. The higher the mV/V, the higher the signal, which leads to higher resolution because the indicator has a higher voltage from the load cell(s) to convert to digital weight signals. However, the higher output also means more bends or flexes on the beams, leading to longer travel, delayed settling time, and a shorter life span. Most load cells are tested to half a million complete cycles, while some manufacturers test up to one million cycles, enhancing the life span of the weighing devices. Lower output voltages like 1mV/V have less travel and faster response, but the output voltage is also much smaller and cannot provide the same resolution.

The signals from the load cells are in the millivolt signal, and the resolutions are in microvolt (one million of a volt). For the analog-to-digital (AD) processor to read the microvolt signals, it is necessary to expand the shallow analog signal to a higher level, known as front-end expand electronics. The AD processor then converts the higher voltage signals into digital signals, known in industry terms as internal counts. Since the signals are originally very small, there's a lot of electrical noise in the circuitry inside the AD processor. The cost of an AD processor for kitchen and postal scales can range from 0.10 to 0.28 cents, while the processor for balances and high-end counting scales can range from six to 12 dollars each. There are 12, 18, 21, 24, and even 32-bit AD processors, which can reach up to billions of counts when multiplied 1x2x2x2 up to 32 times. A good processor will give higher speed and more stable internal counts. Unfiltered counts are the raw counts in millions or even billions, but they are very unstable due to electrical noise. To reduce this noise, the first part of the scale software filters them into lower resolution counts, usually between one and five million internal counts. This is why, during calibration, one might see 123,456 digital numbers when the scale is zero and 890,123 when weight is applied.

The software will determine a filtered raw count of 123,456 with a balanced platter and sub-platter as zero, such as 0.00 gram. If the balance is 3,000 grams x 0.01 grams and then 3,000 grams is placed on the balance, the internal count goes to 890,123, which the software will recognize as FS or Full Scale at 3,000 grams. This same logic applies to counting scales, tank scales, floor scales, and even truck scales.

Subtracting 123,456 from 890,123 yields 766,667 internal filtered raw counts. With a balance of 3000 grams and 0.01grams divisions, this equates to 300,000 divisions. Dividing 766,667 by 300,000 yields

2.5 internal counts per division, which the weighing industry requires to be at least 10 for stable weight. Lower cost balances, using 0.10-0.28 cents AD processors, tend to be relatively unstable due to the high electrical noise in the AD processor. Generally, 0.28 cents AD processors are suitable for 3,000 to 10,000 division non-approved scales, while 0.10 cents are suitable for low-cost kitchen scales. Unfortunately, some manufacturers use kitchen scale components to sell as industrial high precision balances on the internet due to cost pressures.

When looking at the internal raw counts of an analog scale, the counts are never stable, so if the "zero" range is set to a very small window (e.g., 123,456 ± 10 counts), the scale may not appear to be accurate, whereas if the window is set very high (e.g., 123,456 ± 50 counts), the display may seem stable. However, in reality, it is NOT because the "gut" inside is still unstable. The unstableness also applies to displaying the weights at 100, 200, 500 grams, one, two, and three kilograms for a 3,000 × 0.01 grams balance. Low-cost manufacturers use a "wider window" on these capacities to display the weight we want to see because they know that end users with little knowledge of weighing will not have test weights to check the linearity of the balance or scale. Hence, a low-end 3,000 × 0.01 grams balance with kitchen scale components can accurately display 0.00, 100.00, 200.00, 500.00, 1000.00, 2000.00, and 3000.00 grams; however, if one starts placing 100 grams + 2 deci or 100.02 grams on the balance, or 500 grams + 3 deci or 500.03 grams, it will still display 100.00 and 500.00 grams, respectively.

A balance that lacks sufficient internal filtered raw counts will be unable to display 1 deci changes in weight, such as displaying 100.00, 100.03, 100.04, 100.09, and 100.12 instead of a continuous weight increment. A comparison can be made to illustrate this concept by using a measuring tape. For example, if an 11, 15, 16, 21, and 26-inch marking were missing from a ruler, it could only read to the nearest number. Would this be satisfactory? Visualizing this concept with a comparison between weight and length, would you accept that a measuring tape would have "wider" markings on 0, 5, 10, 12, 20, and 24 inches? Using this weird ruler would mean that nine inches would be read as 10 inches. Similarly, if 100 grams of test weight is placed on a balance, it displays 100.00 grams, but when 100.02 grams is placed, it still reads 100.00 grams, and when 0.03 grams more is added, it still shows 100.00 grams.

Do you think this constitutes deceptive marketing? No laws exist prohibiting it, so it is important to educate customers on how to purchase reliable balances and scales. Additionally, consider other factors that impact weighing accuracy, including temperature compensation, hysteresis, creep, and software. If you have ideas on ensuring customers get the best scales for their investments, please feel free to contact us at boon@lwmeasurements.com.