



3-pt Mobile Scale Systems

Design, Installation & Testing Guidelines

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Design, Installation, & Testing Guidelines for 3-pt Mobile Scale Systems

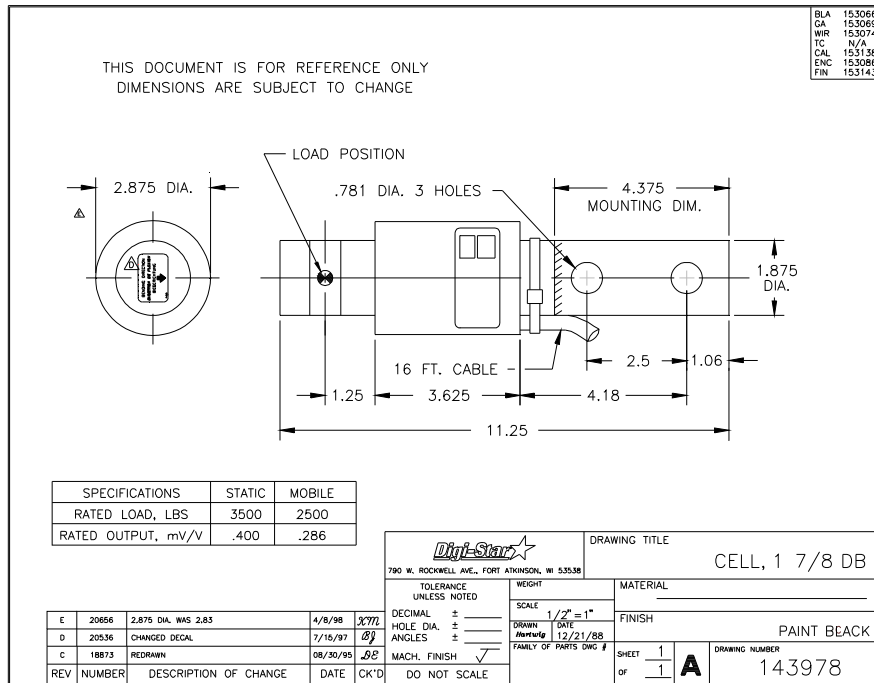
Introduction

Every effort is made by Digi-Star to ensure that all load cells are properly calibrated. By using standards traceable to the National Institute of Standards and Technology (NIST), Digi-Star pre-calibrates all its load cells to be matched to within +/- 0.5%. Some load cells are matched even tighter to within +/- 0.1%.

Even though Digi-Star load cells are precisely calibrated, many factors can affect their accuracy. This document is written to offer the OEM guidelines for reducing errors and maximizing reliability of their 3-pt mobile scale system using two axle load cells and a hitch bar load cell.

Sales Drawings

Every Digi-Star load cell has a sales drawing that is available upon request. This drawing details the load cell's dimensions, rated loads, and nominal outputs. For example...



Mount Design: General

Each load cell sales drawing contains information known as the “mounting dimension”. This dimension shows the exact location for the edge of the load cell’s mounting tube. It is where Digi-Star supports each load cell during the calibration process. This dimension should be maintained as closely as possible and should never deviate more than +/- .031”

Along with providing proper calibration, the mounting dimension also provides clearance for the load cell’s cable. Without this clearance, the cable may need to bend too sharply to exit the area

resulting in an encapsulation failure. Encapsulation is the material / process used to protect the electronics from the environment (moisture, dust, etc.).

Mounts for Digi-Star load cells are generally heavy-walled round tubing with an inside diameter larger than the nominal load cell diameter. Gussets should be used to counteract the large bending moments that result from the cantilever beam design.

Digi-Star differential load cells are categorized by the nominal steel diameter. The tolerances of the steel are such that it is never oversized and may be undersized by a few thousandths of an inch depending on the nominal diameter (e.g. 1.875" +.000"/-.006" vs. 2.875 +.000"/-.007"). If the load cell is painted, then the bar may be a few thousandths of an inch oversized.

Mounting tubes should be oversized to allow easy installation (and replacement, if necessary), but not so large as to provide excessive movement. A mobile system should have mounting tubes that are .010" to .015" oversized. Anything smaller may result in installation difficulties if the tubes warp during welding. Anything larger may increase the shock loads as a result of motion.

Mounting tubes for stationary systems can be much more loosely controlled because they are not subjected to motion. For these systems, the ID of the mounting tube can range between .010" and .062" over the nominal bar dimension. Tighter is better, but by making them larger, fabrication and installation will be easier. This looseness in diameter should not be confused with the mounting dimension. As mentioned earlier, the mounting dimension should not deviate more than +/- .031".

Rated Output

Rated output defines the electrical signal generated at the rated load. Not all styles and types of Digi-Star load cells are compatible with one another. In general, the following table describes which load cells can be used together in the same system. Load cells in the same column (e.g. system "A") are compatible with one another. Load cells in two different columns (e.g. system "A" and system "B") are not compatible with one another.

A	B	C	D	E	F	G
1 DB	1-1/2 DB	2 SA	10K CT	30K CT	SW 3300	SW 6600
1 DBTC	1-7/8 DB	2-1/8 DB				
	1-7/8 DBTC	2-1/8 DBTC				
	1-7/8 DA	2-1/2 DB				
	2 DA	2-1/2 DBTC				
		2-1/2 DA				
		2-7/8 DB				
		2-7/8 DA				
		2-7/8 SA				
		3-3/4 SB				
		3-3/4 SA				
		50K CT				

The preceding load cell groupings define, in general terms, which load cells can be used together in the same system. However, there are some exceptions that have been excluded for simplicity. In order to know for sure whether or not two load cells are electrically compatible, the following procedure can be used.

First, obtain the rated loads and outputs for the load cells in question. If the two load cells have the same rated load and output, they are compatible. If the two load cells have the same rated load with different outputs (or vice versa) they are not compatible. If the rated loads and outputs are both different then use the following equation...

$$(\text{Rated Output of cell \#1}) \times (\text{Rated Load of cell \#2}) / (\text{Rated Load of cell \#1})$$

If the result of this equation is equal to the rated output of load cell #2, then the two load cells are compatible and can be used in the same system. If not, they are not compatible and should not be used in the same system. For example...

A mixer is designed to use a pair of 2-1/8 DA spindles (0.571 mV/V @ 5,000 lbs). Which of the following hitch bars can be used to complete the scale system?

Hitch Bar "A"...2-1/8 DB...0.300 mV/V @ 6,000 lbs

$$(0.571 \text{ mV/V}) \times (6,000 \text{ lbs}) / (5,000 \text{ lbs}) = 0.685 \text{ mV/V @ 6,000 lbs...not compatible}$$

Hitch Bar "B"...1-7/8 DB...0.286 mV/V @ 2,500 lbs

$$(0.571 \text{ mV/V}) \times (2,500 \text{ lbs}) / (5,000 \text{ lbs}) = 0.286 \text{ mV/V @ 2,500 lbs...compatible}$$

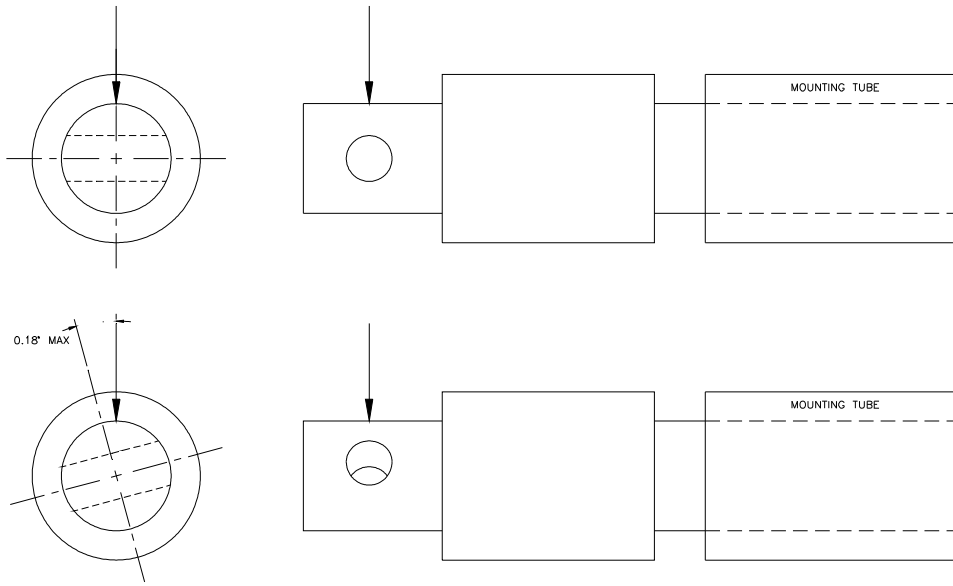
Rated Load

Each load cell has a rated load that describes the maximum operating load allowable. Unless specifically designed for a mobile system, each load cell will have both static and mobile ratings. The static rating pertains to stationary applications such as bulk bins, deck scales, etc, while the mobile rating refers to applications such as feed mixers, grain carts, etc.

Most load cell drawings specify a "load position". The rated load is based on a load at this position. Loading the bar at any other position will affect its rating. For example, if the load cell is made longer by the addition of a clevis, the rated load will decrease. If not sure about the proper load cell for a given application, Digi-Star can help answer any questions.

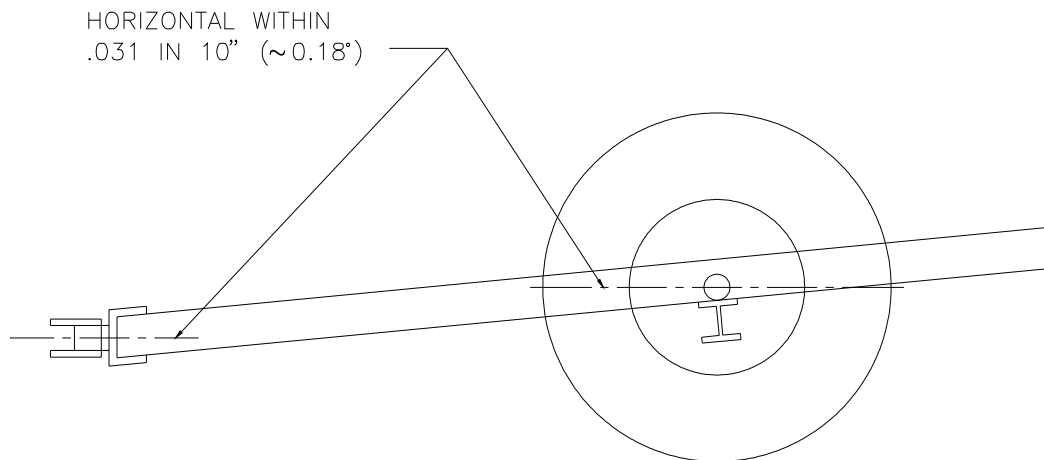
Mount Design: Load Cell Orientation

Proper angular orientation plays an important role in load cell output. Any angular deviation from the ideal orientation will result in reduced output due to weight and increased output due to side loads and/or axial loads. The following sketch describes angular orientation. The accompanying table describes the magnitude of the errors that could result.



Mis-Alignment (degrees)	Weighing Error (%)	Amount of Side Load Recorded as Weight (%)
0	0.00	0.00
1	-0.02	1.75
2	-0.06	3.49
3	-0.14	5.23
4	-0.24	6.98
5	-0.38	8.72
10	-1.52	17.36
15	-3.41	25.88
20	-6.03	34.20

Each Digi-Star load cell (CT's excluded) is equipped with either a horizontal or a vertical mounting hole. It is the designer's responsibility to ensure that the load cells are oriented properly during normal weighing operation. Care should be used when considering details such as frame orientation, tractor height, etc. Orientation errors can be seen in the preceding table for various angles. With proper tooling and fixtures, it should be reasonable to maintain a proper orientation of .031" in 10" (~0.18°).



To assist the installer, each Digi-Star load cell is equipped with either a “TOP” decal or a “LOAD DIRECTION” decal. These decals will prevent gross installation errors caused by a load cell being installed up side down.

Mount Design: Extraneous Loads

In order for a Digi-Star scale system to weigh correctly, the load cells must be the only structural objects that support the weight. In other words, there should be no load paths from the structure being weighed to the base that bypass the load cells.

This fact may seem straight forward, but care should be given to minimize all possible load paths. Weighing errors can result from seemingly minor flaws. For example, a PTO shaft that is not perfectly horizontal, a stiff hydraulic hose that connects the structure being weighed to the structure supporting the load cells, or a rock that gets wedged into a protective shroud are all potential problems that can result in incorrect and erratic weight readings.

There may be instances where side loads are significant enough to require structural support in the horizontal direction. Mobile mixers and animal chutes are examples of this type of situation.

Whenever side load checking is built into a scale, the most important guideline to remember is that the structure should support horizontal loads only. If rods (or beams) are used for side load checking they should be oriented horizontally and pinned loosely at each end. If a chain or cable is used, it too should be oriented horizontally.

Be careful to minimize the effects of friction in the vertical direction. Two pieces of steel in contact with each other as the result of a side load can support significant load in the vertical direction. A threaded bolt (vertical) pushed up against the edge of a clearance hole is an example of friction that may cause problems.

Axle Load Cells: Wheel Alignment

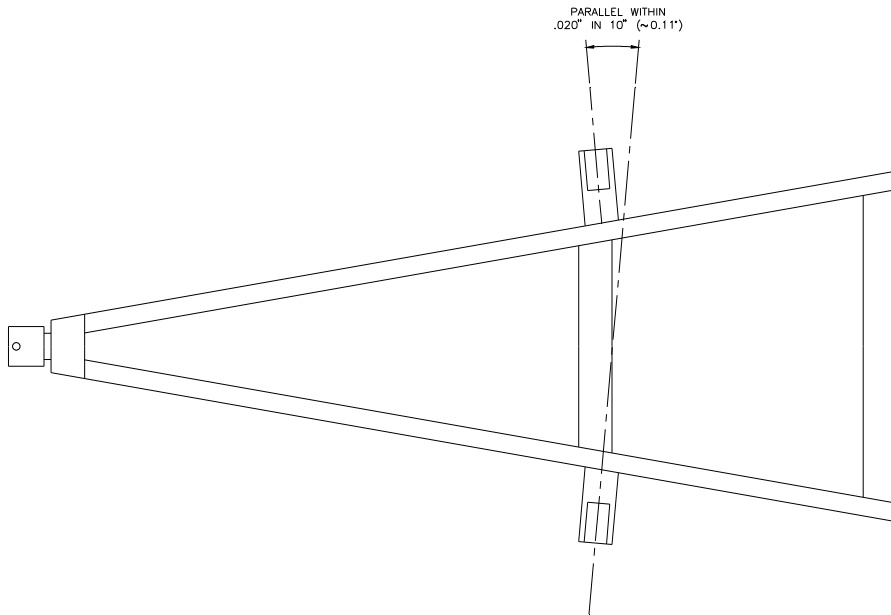
The main load bearing structure of 3-pt axle scale systems are the two axle load cells. All of the information previously discussed pertains to these load cells. In addition, there is another factor that needs special attention.

Toe-in / toe-out is a phenomenon uniquely associated with axle load cells. If not accounted for, the scale may exhibit erratic behavior when moved. Please note that some fluctuation in the scale reading is natural when moving on bumpy terrain.

Toe-in / toe-out scale problems occur when the two tires are not parallel with each other. Toe-in defines a scale where the direction of motion of the two tires crosses in front of the scale, while toe-out has the direction of motion crossing in back of the scale. In either case, an unwanted bending moment is applied to the load cell that may cause erroneous readings.

In order to diagnose a toe-in / toe-out problem, a simple test must be performed. First of all balance the indicator. On a smooth surface (if possible), move the machine forward approximately one tire rotation and record the indicator reading. If the indicated weight increases or decreases significantly (50 to 500 lbs), you may have a toe-in / toe-out problem. Move the machine backward to its original location. If the indicated weight returns approximately to zero, you definitely have a toe-in / toe-out problem. Moving the machine one tire rotation in the opposite direction should change the indicated reading by about the same amount as the forward motion, but in the opposite direction.

In order to minimize the effects of toe-in / toe-out, axle load cells need to be installed properly. This is easily accomplished by using weld fixtures during the assembly process. As seen below, fixtures should be utilized to ensure the axle's mounting tubes are parallel within .020" in 10" (~0.11°).



Toe-in / toe-out is unpredictable and cannot be summarized in a table like orientation errors. Many factors contribute to the phenomena including the type of load cell installed, the amount of misalignment, the test surface, etc. As mentioned above, the best method for minimizing its effects is using proper fixtures.

Hitch Bar Load Cells: Clevis Considerations

Hitch bar load cells are the remaining structural elements of a 3-pt scale system. Although they generally carry less weight than the axles (~10% of the total weight), they are no less important. With the exception of toe-in / toe-out, hitch bars need to follow all the same rules of installation as discussed previously.

The load end of the hitch bar load cell is less defined than that of an axle load cell with its precision bearing races. This allows the OEM more flexibility in its application including the use of various clevis designs.

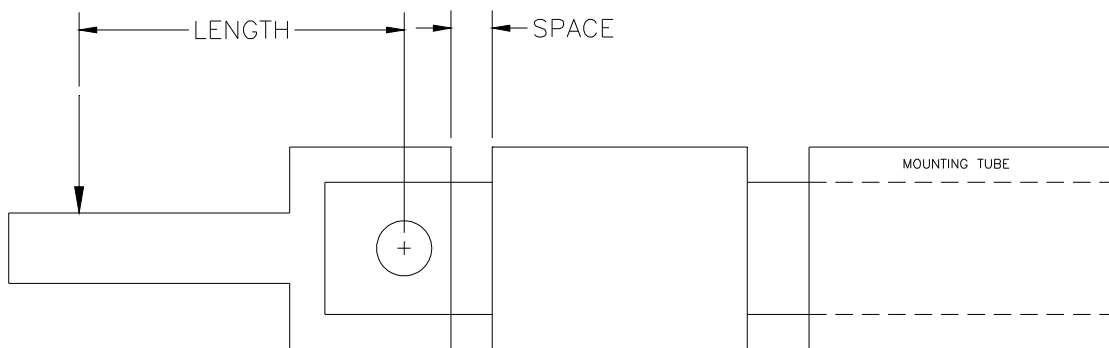
Digi-Star load cells are designed to be very forgiving to load location. This includes the extension of a load beyond the end of the bar by use of a clevis. However, if the design of the clevis is such that a concentrated load is positioned too close to the strain gages, large weighing errors can occur.

Although not explicitly mentioned on the hitch bar sales drawing, the edge of a clevis should not be positioned right next to the encapsulation cover. First of all, if the clevis actually contacts the encapsulation cover, the electronics may be damaged. Secondly, as mentioned above, weighing errors could occur that are many times the normal load cell tolerance of 0.5%.

When designing a clevis for use with a Digi-Star load cell, the following information should be considered:

Always make the clevis “LENGTH” as short as possible. A long clevis decreases the load cells capacity by increasing the bending moment on the bar for the same applied load. In addition, a long clevis results in large concentrated loads on the bar itself that may influence the strain sensing components.

Always keep the “SPACE” between the clevis and the encapsulation cover as large as possible. This prevents physical damage to the electronics and minimizes the effects of the concentrated loads mentioned above.



When testing a new 3-pt scale system, it is common to “walk the corners” by standing over each load cell. If, during this test, there are noticeable weight differences between the hitch bar readings and the axle readings, adjusting the clevis may help the situation. As mentioned earlier, shortening the “LENGTH” or increasing the “SPACE” may be all that is required.

Finally, it should be stated that Digi-Star is here to help in the design, installation, and testing of new and existing scale systems. The best time to ask for assistance is during the design phase, before problems can arise. With proper guidance, we at Digi-Star can help the OEM provide their customers with a reliable and easy-to-maintain Digi-Star scale system.