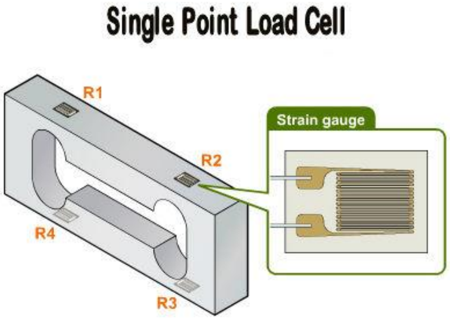
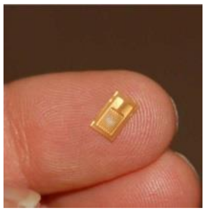
Getting to Know Load Cell Weighing

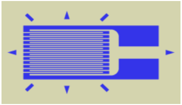
Can you use a load cell in your application? Sure. Whether you want to measure compression or tension, there is a load cell that will fill the bill. Load cells can be mounted, suspended, submersed, and mobile. Load cells can be built large enough to measure thousands of tons or small enough for grams. Whether your use is clinical, industrial, construction, marine, aerospace, or environmental, there is a load cell that will work for you.



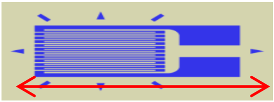
What is a Load Cell?



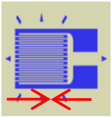
A load cell consists of a metal element that is introduced to a change through tension (pulling apart) or compression (pushing together) forces, and interior strain gages that sense this change, which is sometimes referred to as deflection. Strain gages consist of a thin, continuous, compact, metallic foil pattern, insulated and mounted to the interior of the load cell with proprietary adhesives. This foil wire has a specific resistance that is directly proportional to its length and width. As the load cell bends or stretches, the strain gages move with it. When a strain gage is



A strain gage at rest



A strain gage while a tension load is being applied (horizontal dimension exaggerated)



A strain gage while a compression load is being applied

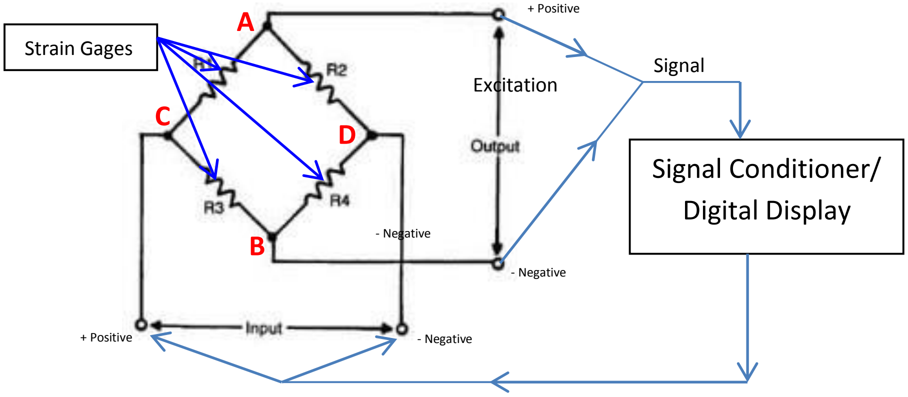
Tension causes the gage to lengthen thus increasing its resistance; compression shortens the gage, decreasing its resistance.

stretched, the path the current must travel lengthens, while its cross section narrows, increasing the resistance. The opposite occurs when the strain gage is compressed.

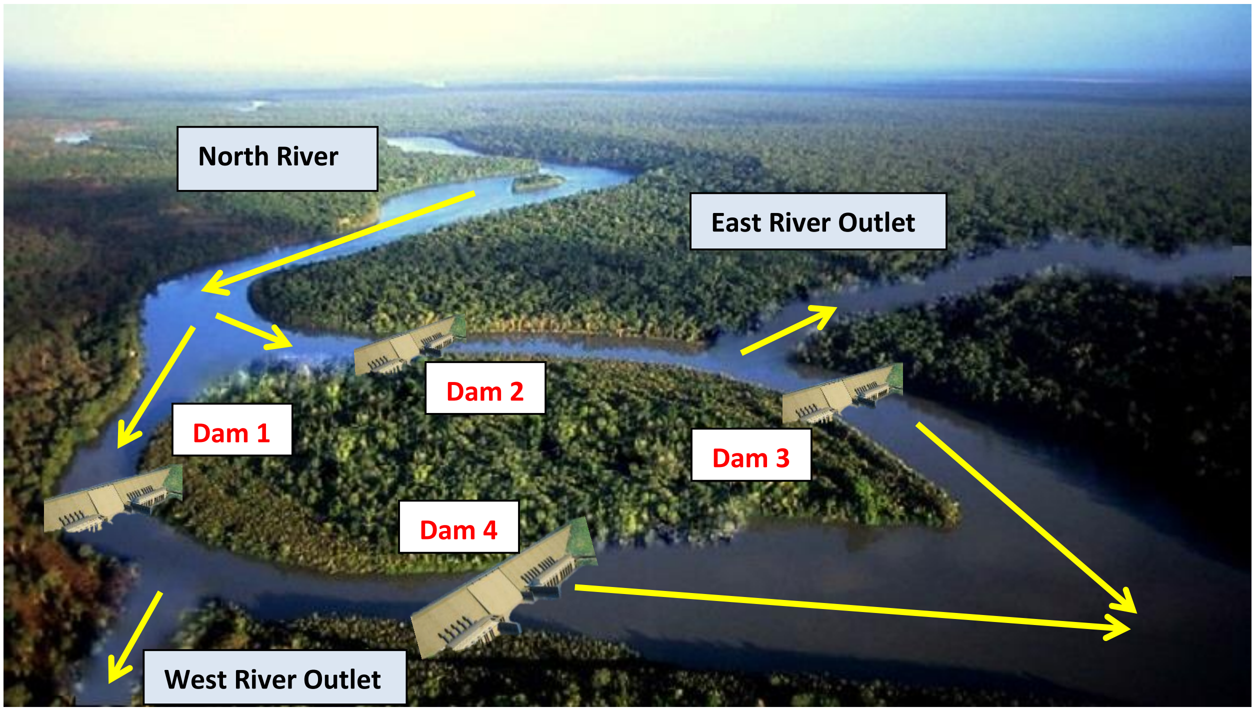
Understanding the Wheatstone Bridge

In order for a load cell to work, there must be a way to measure the resistance of the strain gages. These strain gage resistors are configured in a Wheatstone bridge circuit. For the purpose of this discussion, we will assume this load cell has four internal strain gages. The input voltage (excitation) which is supplied by a signal conditioner or digital display, is attached to two opposite corners of the bridge (**C** and **D** in the diagram) while the output voltage is measured by attaching the other two corners of the bridge (**A** and **B**) to the “signal” side of the indicator. The circuit is said to be “balanced” when the output voltage is zero when no load is being applied to the load cell. When force is applied, the strain gages configured in the Wheatstone bridge will flex, increasing or decreasing resistance, therefore altering the voltage through the branches of the bridge. Hence, the output voltage across the two corners of the bridges (**A** and **B** in the diagram) will change and the signal conditioner or display will register this signal as weight.

Wheatstone Bridge Circuit



As an analogy, imagine a river flowing south and splitting into two channels. Each channel has one outlet point, one in the east and one in the west. If each branch of the channel has a dam, and all these dams are set to the same flow resistance, the flow of water would be consistent between the east and west outlets. If two of these dams were opened or closed more than the other two, the flow of water to the outlets would increase or decrease, creating a measurable variation in the volume of water passing through the outlets.

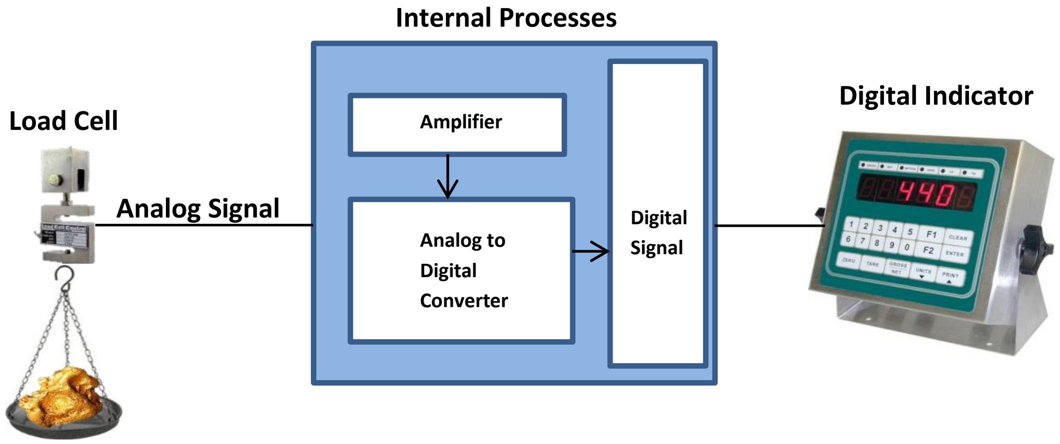


As the North River flows south, it passes through four dams. If all four dams are set at the same flow restriction, the amount of water emptying at the West River outlet and the East River outlet will be the same. If, for example, you further open the spillways of Dam 2 and Dam 4, the flow of water to the West River will be diminished in comparison to the flow to the East River.

Utilizing the Data from Your Load Cell

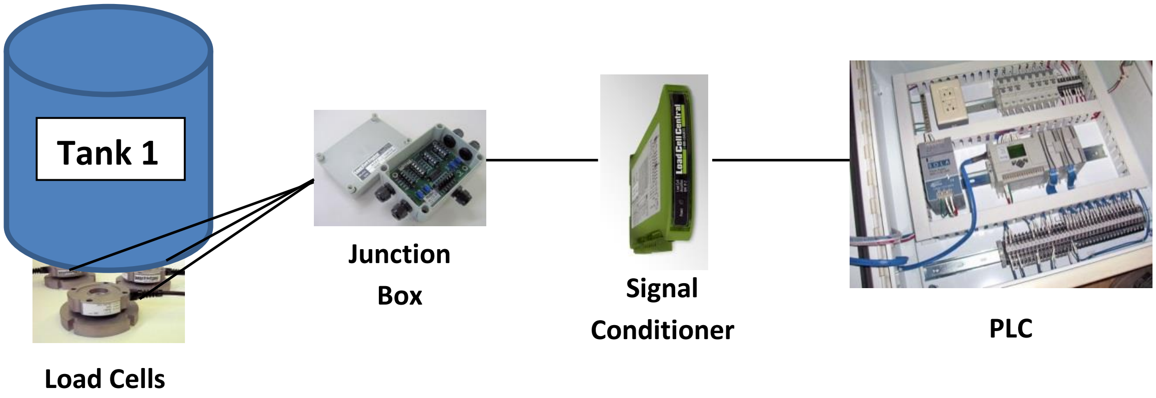
The output of the Wheatstone Bridge is an analog signal, usually expressed in millivolts per volt of excitation. In order to convert millivolts to a language that we can understand, the load cell's signal leads are wired to a device that can interpret and convert the signal to a digital format. The signal from a strain gage has to be "conditioned" before it can be utilized. A signal conditioner can be a separate device or, in the case of a digital display, an internal component. The complexity of your weighing application dictates what devices you require to interpret your load cell signal.

Load cell systems can be as basic as weighing one piece of material or as complex as monitoring individual ingredients as they are added to a hopper in a batch weighing system.

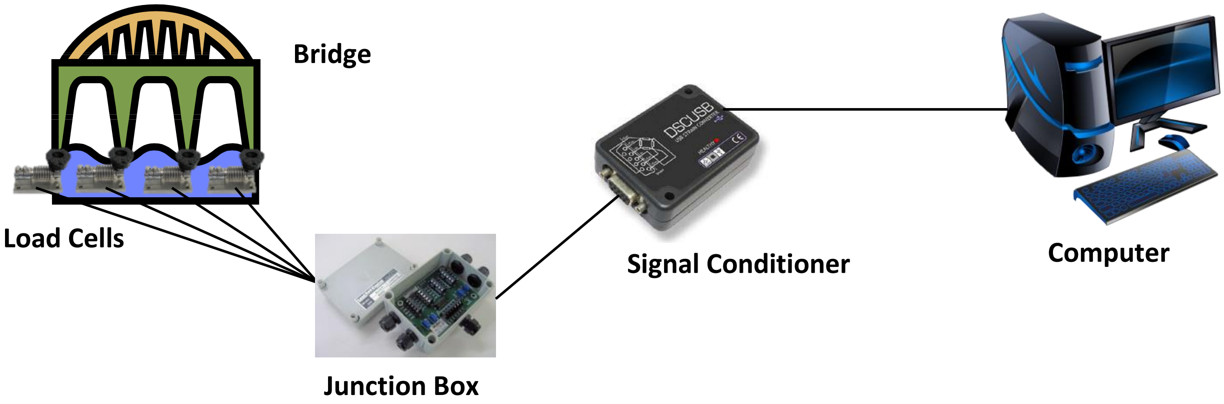


Consider a system for weighing gold nuggets. You would require a load cell, a vessel to hold the nugget and a digital display to show the detected weight. In this example, the display is connected to the load cell and the signal conditioning is all done as an internal function of the display. A signal conditioner amplifies the millivolt signal to the voltage requirement of the analog to digital converter. The signal is then converted from analog to digital, and can be seen as a numeric weight.

In a complex batch weighing system such as a concrete blending operation, a load cell, or multiple load cells can be wired into a signal conditioner and then to a computer or PLC (programmable logic controller). In this example the signal conditioner is a separate device that prepares the signal for further processing. The PLC can use the output of the signal conditioner to move a conveyor, start filling a tank, stop filling a tank or switch ingredients in a batch.

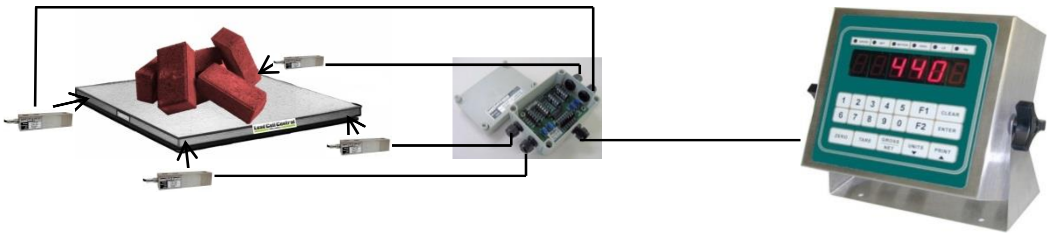


Applications may require data to be recorded at specific intervals or in a continuous stream. Let’s assume you are evaluating the traffic load on a bridge. In this example you would connect your load cells to a signal conditioner and then to a computer with Datalogging software that allows you to view your recorded data and make analyses from this information. You would be able to determine when the load was heaviest and what the maximum load was on the bridge. Once your load cell can communicate with your computer or PLC, the possibilities are endless.



The Importance of a Junction Box

Another essential component of a weighing system is the junction box. A junction box ensures that the mV/V outputs of all the load cells in a system are “matched.” Because the manufacturing process is not perfect, each cell will exhibit a slightly different output in mV/V. The millivolts per volt output of the cells in this diagram have a nominal output of 3mV/V; from the factory, the output typically can vary from 2.9 to 3.1mV/V.



In this example, there are four internal load cells in this floor scale. When the load cells are calibrated, they are each “trimmed” within the junction box to return virtually the same mV/V output when a known test weight is introduced. This ensures that a 500lb weight will read consistently regardless of load placement or orientation in a multi-cell system - imperative in an application that weighs products that aren’t self-leveling (dirt, flour, concrete, etc.).

The junction box also performs a “summing” function that combines the outputs of the individual load cells in such a way as to appear to the digital indicator to be one load cell bearing the load. The combined signal is proportional in millivolts to the combined mV/V output of the cells.

This is an example of a typical calibration press.

Calibration of a Weighing System

Calibration of a weighing system is extremely important to convert the voltage from each load cell to a user-defined value. In other words, the display or data processing components of a weighing system have to be shown how many mV/V are equal to a pound. During a calibration, it is the job of the calibration technician to program the indicator or signal conditioner to know what amount of force a load cell is sensing. We have already established that a load cell produces an analog signal, expressed in millivolts per volt. All load cells manufactured have a slightly different mV/V output at “full scale” or 100% of the cell’s capacity. Essentially, two or more points are used, typically at 0% and 100% of full capacity, to scale the output of the load cell to the desired displayed value on the indicator.

A weighing system is introduced to a known weight either through actual force provided by a calibration press or a simulated weight provided by a load cell simulator. For this discussion, we have a 1000 lb. load cell that produces 3.0040 mV/V output at “full scale” - when 1000 lbs. of force is applied. Because we know this, we can “tell” the indicator or signal conditioner that when 3.0040 mV/V output is registered, that *is* 1000 lbs. We have now calibrated the system. The indicator will now interpret 1.502 mV/V output as 500 lbs. and so forth. Any weight that is introduced to this load cell will produce a linear (i.e., proportional) millivolt per volt output that the indicator can now “understand” and convert to pounds or kilograms.

It’s important periodically to recalibrate your weighing system. We recommend once a year; however specific industries may have stricter guidelines for measurement testing. Load Cells can become inaccurate over time. A number of things can adversely affect a weighing system: extreme conditions, exposure to weather, buildup of particulates from daily use, possible overload, degradation of instruments and cables or mechanical failure. Even normal use can cause the accuracy of a weighing system to degrade over time.

A certified calibration center is equipped with “standard” load cells in various capacities that have been tested by an outside accredited agency to ensure their accuracy. All calibrations should be NIST (National Institute of Standards and Technology) traceable, and include a certificate of calibration.

Choosing a Load Cell

There a many variables to consider when choosing the load cell for your application. A load cell technician can help you narrow down or expand this list to find your perfect system.

- ☐ Environment
    - ☐ Temperature - Hot/Cold? Will it experience extreme climate changes?
    - ☐ Wet or Dry? Does it need to be submersible? Is it in a wash-down area? Pollution or salt air?
    - ☐ Hazardous conditions? Does the load cell need to be intrinsically safe?
    - ☐ Are there size constraints? Does the load cell need to fit in a specific area?

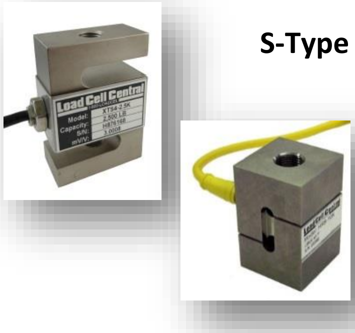
- ☐ Capacity
    - ☐ What is the weight or force you are measuring?
    - ☐ Are there any additional weights that need to be figured in? Hooks, Vessels, Preloads?
    - ☐ What degree of accuracy do you need to maintain?

- ☐ Tension or Compression?
    - ☐ Do you need the load cell to measure a pulling or a pushing force? Or both?
    - ☐ How will it be installed? In a mount? Suspended? Under a tank? Single ended, double ended?

Types of Load Cells

Now that you've seen some of the variables to consider when choosing a load cell, let’s look at some of the different kinds of load cells. Load cell designs vary according to application. Understanding some of the different configurations can aid you in choosing the load cell that is right for you.

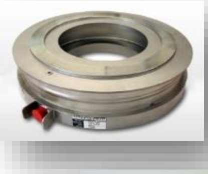
Beam Load Cell – These load cells can be found in vessel/tank weighing and floor scales. They can be either single-ended or double-ended. The single-ended model is mounted on one end and force is applied to the opposite end. The double-ended cell is mounted on both ends and force is applied to the middle of the load cell. The double-ended design is intended primarily for higher capacities, for example truck scales and silo weighing.



S-Type Load Cell – These Load cells are typically found in hanging scales or suspended vessel weighing and can be used in either tension or compression applications. They can be suspended from shackles and pulled in tension or mounted between two items via the top and bottom threads and compressed.

Shear Web Load Cell – These load cells are often seen in a manufacturing environment. They are used to measure durability and product failure limits in destructive testing. They are also ideal for verifying force measurement in press applications. These cells can be sandwiched between two components for compression, or used in tension via the threaded holes.

Canister Load Cell – The canister load cell is the earliest load cell design. This configuration is best suited to higher capacities. They work well in heavy duty applications for truck scales and railroad scales. Canister load cells are available in compression only or tension and compression. As with the Shear Web load cells, some are designed with threads for pulling applications.



Thru-Hole Load Cell – These load cells are well suited for anchor and fastener testing and boat mooring tests. This extremely versatile load cell is utilized in tension or compression. It can be installed between two parts to measure compression or pulled from opposite directions like the link in a chain to measure tension. They can also be threaded onto a part, such as a bolting mechanism, to measure force.

Single Point Load Cell – These compression load cells are a lower capacity load cell. They are perfectly designed for deli scales, bench scales and check weighing applications as they are moment compensated load cells. The cell body is modified and the gages arranged such that they allow for load placement anywhere on a scale platform and they will return an accurate value.

Tension Link Load Cell – These versatile load cells have numerous applications. The capacity of these load cells is customizable for extremely heavy applications. Tension links are used for mooring and submersible testing, crane scales and towing/pull force measurement.

The Terminology

Here is a list of basic terms used in reference to load cell weighing applications. Having an understanding of these terms will make it easier to design a load cell system that is right for you.

Accuracy – Normally quoted as either a percentage of full scale output or a percentage of the applied load. The accuracy figure is the combined error caused by non-linearity, repeatability and hysteresis error values in the load cell.

Axial Load – A load applied along the primary axis.

Calibration – The comparison of load cell output against standard test loads.

Capacity – The maximum axial load a load cell is designed to measure within its specifications.

Combined Error – The maximum deviation of the calibration curve from the straight line drawn between minimum load output and maximum load output, normally expressed in units of %FS. Both ascending and descending curves are considered.

Creep – The change in load cell signal occurring with time, while under constant load, and with all environmental conditions and other variables remaining constant; usually measured with rated load applied and expressed as a percent of rated output over a specific period of time.

Deflection – The change in length along the primary axis of the load cell between no-load and rated load conditions.

Eccentric Load – Any load applied parallel to but not concentric with the primary axis.

Excitation – The voltage or current applied to the input terminals of the load cell. The voltage needs to be sourced from a very stable power supply otherwise it will impact the signal return. Common excitation voltages are between 5-10 VDC.

Full Scale or FS – The output corresponding to maximum load in any specific test or application.

Hysteresis – When a load cell is taken from zero to full load and back to zero, the mV output for a given load value will be slightly different when the load is ascending versus when the load is descending. The maximum difference is called hysteresis. Measurements should be taken as rapidly as possible to minimize the effect of creep.

Input Resistance – The resistance of the load cell circuit measured at the excitation terminals with no load applied and with the output terminals open-circuited.

Insulation Resistance – Normally measured at 50VDC, this is the minimum resistance between the metal body of the load cell and any of its electrical connections. Sometimes resistance is measured between the electrical connections also.

Non-Linearity – The algebraic difference between output at a specific load and the corresponding point on the straight line drawn between minimum load and maximum load. Normally expressed in units of %FS. It is common to characterize by measuring it at 40-60 %FS.

Non-Repeatability – The maximum difference between output readings for repeated loadings under identical loading and environmental conditions.

Output Resistance – The resistance of the load cell circuit measured at the signal terminals with no load applied and with the excitation terminals open-circuited.

Primary Axis – The axis along which the load cell is designed to be loaded.

Rated Capacity – The maximum load over which the load cell will operate within its specifications.

Rated Output – The nominal mV/V output of the load cell.

Repeatability – A measure of the ability of the load cell to consistently give the same output for the same load under the same conditions. The error is normally quoted as a percentage of full load.

Resolution – The smallest change in load which produces a detectable change in the signal.

Side Load – Any load at the point of axial load application acting at 90° to the primary axis.

Zero Balance – The output of the load cell at no load, normally quoted as a percentage of full scale. Also known as zero offset.

We hope this article is informative and provides you with some basic insight into load cell system weighing. Load cell systems are surprisingly versatile. If you're thinking load cells might fit into your application for weighing or force measurement, chances are, you're right. In every industry on the planet, under the water and in the sky above us, load cells are used to measure our world.

Load Cell Central is here for all your weighing needs. If you have questions, need technical assistance, or you are looking for a new system, call us. We will provide you the answers you require to get your job done. We look forward to doing business with you!