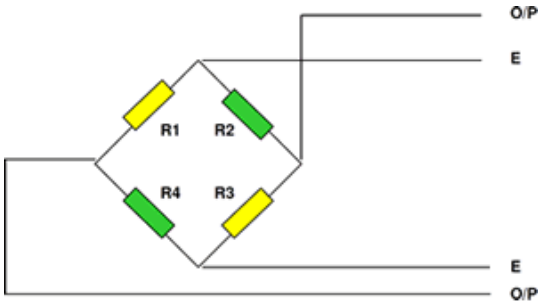
Applied Measurements — Load Cells Explained

A load cell – sometimes referred to as a ‘force’, ‘weigh’ or ‘weight’ cell – is a transducer that converts the load acting on it into a measurable (analogue or digital) output. The output is proportional to the force or load applied.

The conversion is achieved by the physical deformation of strain gauges, which are bonded onto the load cell structure. The strain gauges are connected into a Wheatstone Bridge circuit with four strain gauges (full bridge), two gauges (half bridge) or one gauge (quarter bridge). With half and quarter bridges, the bridge is completed using precision monitors.

Additional bondable resistors are configured within the bridge circuit to compensate for the effects of temperature on the zero or no-load signal and the sensitivity (output due to applied load, plus a further resistor to enable the bridge to be nulled at no load).

The completed Wheatstone Bridge requires a stable DC supply to excite the circuit. This is usually 5Vdc or 10Vdc, but can be any value from 1Vdc up to 18Vdc.



The Wheatstone Bridge Circuit

As stress is applied to the bonded strain gauges, a resistive change takes place which unbalances the Wheatstone Bridge. This provides an output signal that is linearly proportional to the stress value. The value of this signal, which is also proportional to the excitation voltage, is typically a few millivolts.

These low level millivolts signals are compatible with a vast range of bespoke strain gauge instrumentation. These instruments include digital displays, analogue and digital amplifiers. Typical analogue amplifiers will generate a higher level voltage (0-5Vdc, 0-10Vdc) or current (0-20mA, 4-20mA) for onward processing.

Digital amplifiers typically provide an RS232, RS422 or RS485 output using either the common ASCII protocol or one of a host of more specialised, industry-specific protocols that have been developed such as CANbus or Modbus. Both the analogue and digital instrumentation have been reduced in size (miniaturised) sufficiently to enable the item to be fitted within the body of a load cell or force sensor.

Load cell designs are either distinguished by the type of output signal they generate (pneumatic, hydraulic or electrical) or by the method in which they detect the load or weight (bending, shear, compression, tension, etc).

To cater for the huge variety of uses within R&D and industrial applications, a load cell can take many forms. However, the majority of today’s designs utilise strain gauges as the sensing element, where a foil or semiconductor is used.

Foil gauges provide the widest choice of load cell designs and so tend to be the most commonly used. Strain gauge patterns offer measurement of tension, compression and shear forces.

Semiconductor strain gauges are available in a smaller range of patterns, but offer the advantages of being smaller and provide large gauge factors, resulting in much larger outputs for the same given stress. Due to these properties, they tend to be used for miniature load cell designs. Proving rings

are used for load measurement, using a calibrated metal ring, the movement of which is measured with a precision displacement transducer.

Load Cell Operating Principle

Strain gauge load cells convert the load acting on them into electrical signals. The gauges themselves are bonded onto a beam or structural member that deforms when force is applied. In most cases, four strain gauges are used to obtain maximum sensitivity and temperature compensation. Two of the gauges are usually in tension, and two in compression, and are wired with compensation adjustments. When a load is applied, the strain changes the electrical resistance of the gauges in proportion to the load. Other load cells are becoming less popular as strain gauge versions continue to increase their accuracy whilst reducing unit costs.

The early load cell designs simply use a strain gauge to measure the direct stress, which is introduced into a metal element when it is subjected to a tensile or compressive force. A bending beam type design uses strain gauges to monitor the stress in the sensing element when subjected to a bending force. More recently, the measurement of shear stress has been adopted as a more efficient method of load determination, as this method is less dependent on the direction in which the force is applied to the load cell.

Other types of load cell used include hydraulic (or hydrostatic), pneumatic, piezo-electric and vibrating wire load cells.

Load Cell Designs

Compression Load Cells
Compression load cells often have an integral button design. These are ideal for mounting where space is restricted and they offer excellent long-term stability.

Tension Load Cells
Products specific to this group include ‘S’ and ‘Z’ beams, lift links, canister tension cells, tensile links, submersible canister types, non-contact tension measurement, clamp-on and toggle models.

Compression/Tension Load Cells
Compression/tension load cells can be used for applications where the load can go from tension to compression and vice versa. They are ideal for space-restricted environments. Threaded ends facilitate easy installation.

Load Measuring Pins
Products specific to this group include load pins, force pins, custom pins, shackle pins, sheave pins, clevis pins. Load pins are often a convenient way of measuring force by replacing an existing pin with a strain gauged version that is able to provide an electrical signal proportional to the applied force.

Link Load Cells
Normally, this type of tension link is used in lifting applications on cranes and winches. The cells can be self-indicating links, remote display by wire links or remote display by telemetry links. They are also useful for measuring forces in vertical or horizontal tension frames and marine mooring applications.

S-Beam or Z-Beam Load Cells
Derived from their shape, S-beam and Z-beam load cells are usually relatively simple designs in which the structure is shaped as an 'S' or 'Z', with strain gauges bonded to the central sensing area in the form of a Wheatstone bridge. S-Beam load cells can provide an output if under tension or compression and provide superior side-load rejection. Applications include tank level, hoppers and

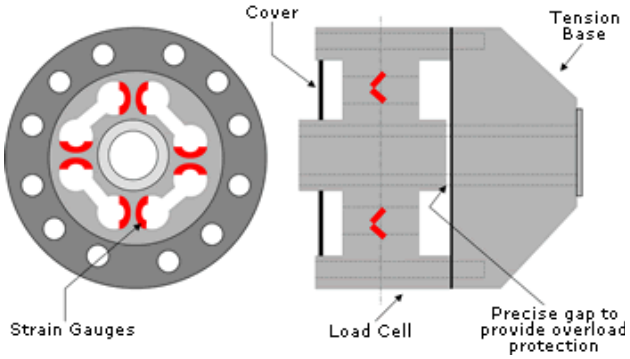
truck scales.

Bending Beam Load Cells
Bending beam load cells incorporate strain gauges that are bonded on the flat upper and lower sections of the load cell at points of maximum strain. These types of load cells are often used in multiple load cell applications, including tank or vessel weighing and for industrial process control systems. The load cells have a low profile design for easy integration into restricted spaces. These types of load cells are often used for low capacity applications and perform with excellent linearity. One drawback of this design is that it must be loaded correctly to obtain consistent results.

Shear Beam Load Cells
In this design, in order to maximise the shear effect, the strain gauges are bonded to a reduced part of the cross-section of the beam. The strain gauges are bonded at 45 degrees on either side of the beam in order to measure the shear strains. Used for medium-to-large capacities, the load cell has good linearity and is not as susceptible to extraneous loading, in particular to side loads.

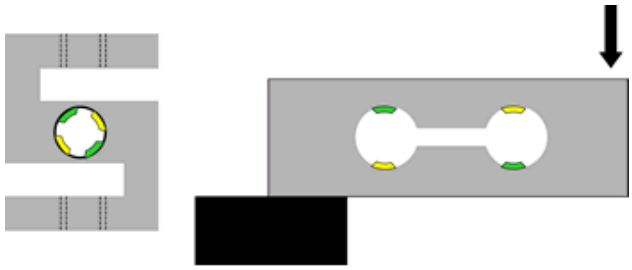
The popular pancake type load cell is configured to operate in shear, offering a very low profile in a design that is easily environmentally sealed and is largely insensitive to off-axis loads.

The Pancake Load Cell Design



For high reliability applications, the pancake style load cell also easily accommodates dual, electrically separated strain bridges. The high stiffness tension-base enables the measurement of tensile forces, which stiffens the load cell structure in compression and allows the incorporation of over-range limiting stops for compression applications.

Platform and Single Point Load Cells (Dual Beam)
This type of load cell is used in commercial and industrial weighing systems. Single point load cells provide accurate readings regardless of the position of the load on the platform.



The Dual-Beam Load Cell Design

Canister Load Cells
Canister load cells are used for single and multiple weighing applications. Many canister designs incorporate an all-stainless steel construction and are hermetically sealed to withstand frequent wash down or damp/wet conditions.

Low Profile Load Cells
Low profile load cells can be compression or tension/compression type designs. Mounting holes and female threads are provided for easy installation. These types are often used in weighing research and development activities and for in line force monitoring.

Often, low profile multiple-bending designs incorporate four spokes at 90-degree intervals, where strain gauges are wired to cancel out off-axis moment-induced strains.

Miniature Load Cells
Due to their compact size, miniature load cells normally use semiconductor strain gauges as the sensing element. The designs come in many different configurations for both tension and compression force measurement. Miniature load cells offer good performance with high outputs and high overload capability for protection.

Load Cell Applications

Potential applications for load cells includes the weighing of silos, vessels, crane safety monitoring, weighing of tanks, vessels and conveyors, lifting, fatigue testing, R&D testing, quality control, industrial weighing scales, weigh platforms, Weighbridges, Underhook scales, tensile testing machines and dynamometers. The marine sector also uses waterproof, submersible or sea water load cells.

Other load cell designs include special, custom-designed cells, including battery-powered versions, aluminium or stainless steel, robust outdoor weatherproof units, universal, multi-axis versions and waterproof or submersible load cell designs.