Getting Started with Load Cells

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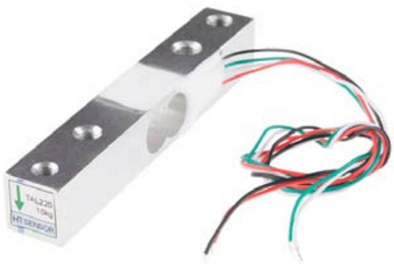
Introduction

Have you ever wanted to know the weight of something? How about knowing the change in weight over time? Do you want your project to sense the presence of something by measuring strain or a load on some surface. If so, you're in the right place. This tutorial is here to help you get started in the world of load cells and their variants.



One of many kinds of load cells.

Suggested readings:

Before jumping into load cells and all of their awesomeness, we suggest you familiarize yourself with some basic concepts if you haven't already:

- Voltage, Current, Resistance, and Ohm's Law
- Series and Parallel Circuits
- Resistors
- Voltage Dividers
- How to Read a Schematic

Load Cell Basics

Types of Load Cells

A load cell is a physical element (or transducer if you want to be technical) that can translate pressure (force) into an electrical signal.

So what does that mean? There are three main ways a load cell can translate an applied force into a measurable reading.

Hydraulic Load Cells

Hydraulic load cells use a conventional piston and cylinder arrangement to convey a change in pressure by the movement of the piston and a diaphragm arrangement which produces a change in the pressure on a Bourdon tube connected with the load cells.

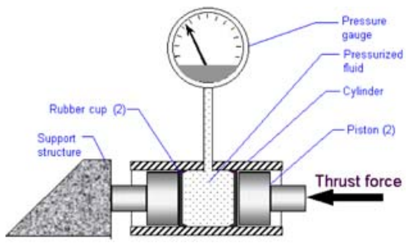


Diagram of a Hydraulic Load Cell from Nikka's Rocketry

Pneumatic Load Cells

Pneumatic load cells use air pressure applied to one end of a diaphragm, and it escapes through the nozzle placed at the bottom of the load cell, which has a pressure gauge inside of the cell.

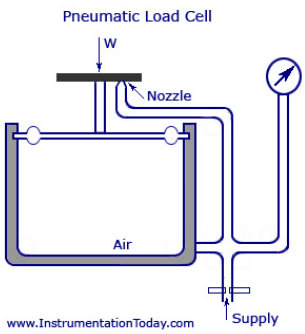
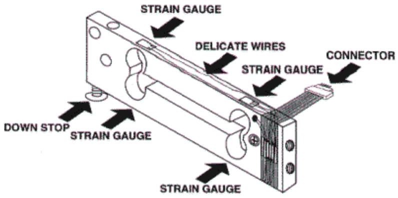


Diagram of a pneumatic load cell from Instrumentation Today

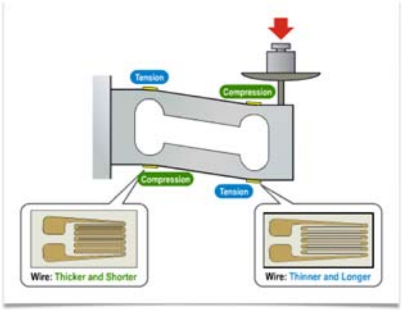
Strain Gauge Load Cells

And lastly (though there are many other less common load cell set ups), there is a strain gauge load cell, which is a mechanical element of which the force is being sensed by the deformation of a (or several) strain gauge(s) on the element.



Strain gauge load cell diagram from Scalenet.com

In bar strain gauge load cells, the cell is set up in a “Z” formations so that torque is applied to the bar and the four strain gauges on the cell will measure the bending distortion, two measuring compression and two tension. When these four strain gauges are set up in a wheatctone bridge formation, it is easy to accurately measure the small changes in resistance from the strain gauges.



More in depth diagram of strain gauges on bar load cells when force is applied

In this tutorial we will be focusing on strain gauge load cells like the ones SparkFun carries:

Load Cell - 200kg, Disc (TAS606)
SEN-13332
$56.96
2

Load Cell - 50kg, Disc (TAS606)
SEN-13331
$56.96

Load Cell - 10kg, Straight Bar (TAL220)
SEN-13329
$6.96
3

Load Cell - 10kg, Wide Bar (TAL201)
SEN-13330
$11.95

Most strain gauge load cells work in very similar ways, but may vary in size, material, and mechanical setup, which can lead to each cell having different max loads and sensitivities that they can handle.

Strain Gauge Basics

A strain gauge is a device that measures electrical resistance changes in response to, and proportional of, strain (or pressure or force or whatever you so desire to call it) applied to the device. The most common strain gauge is made up of very fine wire, or foil, set up in a grid pattern in such a way that there is a linear change in electrical resistance when strain is applied in one specific direction, most commonly found with a base resistance of 120Ω, 350Ω, and 1,000Ω.

Each strain gauge has a different sensitivity to strain, which is expressed quantitatively as the gauge factor (GF). The gauge factor is defined as the ratio of fractional change in electrical resistance to the fractional change in length (strain).

(The gauge factor for metallic strain gauges is typically around 2.)

We set up a stain gauge load cell and measure that change in resistance and all is good, right? Not so fast. Strain measurements rarely involve quantities larger than a few millistrain $(e \cdot 10^{-3})$ (fancy units for strain, but still very small). So lets take an example: suppose you put a strain of 500me. A strain gauge with a gage factor of 2 will have a change in electrical resistance of only

$$2 * (500x10 - 6) = 0.1$$

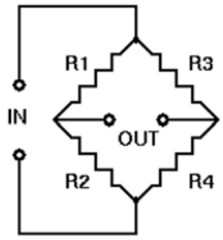
For a 120Ω gauge, this is a change of only 0.12Ω.

0.12Ω is a very small change, and, for most devices, couldn't actually be detected, let alone detected accurately. So we are going to need another device that can either accurately measure super small changes in resistance (spoiler: they are very expensive) or a device that can take that very small change in resistance and turn it into something that we can measure accurately.

This is where an amplifier, such as the HX711 comes in handy.

SparkFun's HX711 Amplifier breakout board

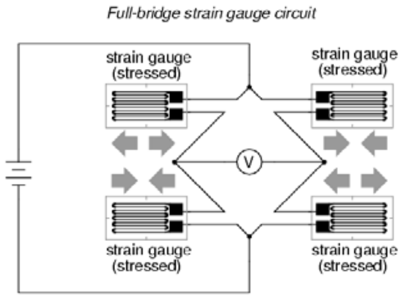
A good way of taking small changes in resistance and turning it into something more measurable is using a wheatstone bridge. A wheatstone bridge is a configuration of four resistors with a known voltage applied like this:



where Vin is a known constant voltage, and the resulting Vout is measured. If $R1/R2 = R3/R4$ then Vout is 0, but if there is a change to the value of one of the resistors, Vout will have a resulting change that can be measured and is governed by the following equation using ohms law:

$$Vout = [(R3/(R3 + R4) - R2/(R1 + R2))] * Vin$$

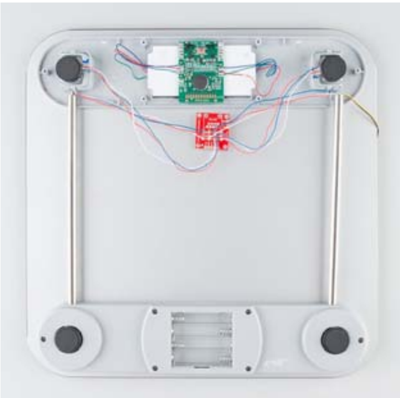
By replacing one of the resistors in a wheatstone bridge with a strain gauge, we can easily measure the change in Vout and use that to assess the force applied.



Bar load cell wheatstone bridge example From All About Circuits

Combinator Basics

Now that you have a load cell with a strain gauges hooked up to an amplifier, you can now measure force applied to your cell. For more information about how to hook up strain gauges, load cells, and amplifiers go to our hookup guide.



Bathroom scale using the Load Sensor Combinator to combine twelve wires into one wheatstone bridge

But what happens when you don't have a load cell with four strain gauges? Or you want to measure something really heavy on something scale like?

You can combine four single strain gauge load cells (sometimes referred to as Load sensors)! Using the same wheatstone bridge principle, you can use a combinator to combine the single strain gauge load cells into a wheatstone bridge configuration where the force applied to all four single strain gauge load cells is added to give you a higher maximum load, and better accuracy than just one, and then the combinator can be hooked up to the same amplifier for easier measuring.

For more information on hooking up load sensors go to our hookup guide.

This is the same layout that you would find in say your home scale. There would be four strain gauge load cells hooked up to a combinator and an amplifier to give you your weight reading.

Resources and Going Further

For more information about setting up load cells and how to integrate them into your next project, check out our HX711 hook up guide: Want to know more? Check out this tutorial if you haven't already:

Load Cell Amplifier HX711 Breakout Hookup Guide

JULY 22, 2016

A hookup guide for the HX711 load cell amplifier breakout board

You may also be interested in learning about the OpenScale.

OpenScale Applications and Hookup Guide

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OpenScale allows you to have a permanent scale for industrial and biological applications. Learn how to use the OpenScale board to read and configure load cells.

Need even more? Check out this awesome article wheatstone bridges and load cell types.

For some inspiration, check out the SparkFun IoT Beehive:

- The Internet of Bees: Adding Sensors to Monitor Hive Health

And stay up to date with the OpenScale by following it on GitHub:

- Internet of Bees GitHub Repository

Can't get enough about how load cells work? Check out this article for more in depth information.