VIDEO#33: Electronic Basics #33: Strain Gauge/Load Cell and how to use them to measure weight

Strain Gauge and Load Cells

Introduction

Over the past year, I have been working on improving my electric longboard by implementing a new power switch, remotes, and control circuits. A key innovation in my design is a weight-measuring system that ensures safety by detecting the absence of a rider and automatically engaging the brakes. The fundamental component behind this system is a **strain gauge**, which is securely attached under a protective silicon layer.

What is a Strain Gauge?

A **strain gauge** is a flexible piece of plastic with a zig-zag pattern of resistance wire. By soldering two thin wires to its contacts and measuring resistance, we can determine force or weight applied to an object. Standard resistance values for strain gauges include **120Ω, 350Ω, 700Ω, and 1000Ω**. Different strain gauge variations exist, including smaller designs and different resistance patterns.

How Strain Gauges Work

The working principle of a strain gauge is based on **resistance variation due to strain**. When the strain gauge is stretched or compressed, the resistance of the wire pattern changes proportionally to the applied force. This means that by measuring the resistance, we can determine the weight or force acting on the strain gauge. However, small forces only produce minimal resistance changes, making direct measurement difficult.

The Wheatstone Bridge

To accurately measure small resistance changes, a **Wheatstone bridge circuit** is used. By replacing **one resistor with a strain gauge** and using precise 120Ω resistors for the remaining three resistors, a balanced bridge is created. When no force is applied, the voltage difference across the circuit is **zero volts**. When force is applied, the output voltage varies proportionally, allowing for accurate force measurement.

Signal Amplification

Since the output voltage of a Wheatstone bridge is small, we use a **differential operational amplifier (op-amp)** to amplify the signal. For example, a gain of **196** can be applied before measuring the signal using the **analog-to-digital converter (ADC)** of a microcontroller.

Temperature Sensitivity

Strain gauges are **temperature-sensitive**, which can lead to inaccurate readings. To counteract this, instead of using a **quarter-bridge (one strain gauge)**, a **half-bridge (two strain gauges)** or a **full-bridge (four strain gauges)** setup is used. A half-bridge setup compensates for temperature variations, while a full-bridge setup minimizes all unwanted forces, providing higher accuracy.

Adjusting Resistance Values

To ensure accurate readings, **ten-turn trimmers** are used to fine-tune the resistance values of the Wheatstone bridge. Once properly adjusted, the ADC outputs a voltage between **supply voltage and ground**, allowing for consistent weight measurement.

Load Cells

For a more convenient approach, **load cells** can be used. These are **aluminum profiles with a built-in Wheatstone bridge**. By simply connecting the red wire to **5V**, black wire to **ground**, and measuring the voltage difference between the **white and green wires**, force or weight can be determined.

Using a Load Cell as a Scale

By mounting a load cell between two pieces of wood with **M4 spacers and screws**, the setup can function as a **crude scale**. The amplified signal can be measured using an ADC, similar to the strain gauge method.

HX711 Breakout Board

For a **simpler solution**, we can use an **HX711 breakout board**, which is a **24-bit ADC with an integrated amplifier** offering a gain of **128**. The HX711 connects to an **Arduino** as follows:

- **Data pin to Arduino pin 7**
- **Clock pin to Arduino pin 8**
- **Power to 5V and ground**

- **Load cell wires to A+ and A-**

Using the **HX711 Arduino library from SparkFun**, the serial monitor outputs precise readings, detecting even tiny weight changes.

Resolution Comparison

A standard **10-bit ADC** (e.g., **ATmega328P**) has **1024 steps**, corresponding to a **4.9mV resolution per step**. The **HX711's 24-bit ADC**, however, has **16,777,216 steps**, achieving a much finer resolution of **0.298µV per step**. Although this increased resolution introduces more noise, it allows for detecting significantly smaller forces.

With this knowledge, we can now use **strain gauges and load cells** to measure force and weight accurately. This principle can be applied to a variety of engineering projects, including **electric longboards, weighing scales, and industrial force measurement systems**.