## Objectives:

1. Sensor selection (Accuracy)
2. Control Units  
   Assembly
3. Calibration, Safety cutoffs
4. Software Development for data acquisition and visualisation
5. Testing/Validation

## Outcome:

1. Measuring thrust, torque, RPM, voltage supplied, current consumed
2. Deriving powers and efficiencies
3. Building a thrust bench that can be scaled up to different load specifications

## Temperature Sensors

Thermocouple:  
  
A thermocouple is a temperature sensor that generates an electrical voltage when there is a temperature difference between two of its junctions. It operates based on the principle of the Seebeck effect, discovered by Thomas Johann Seebeck in 1821.

A thermocouple consists of two different metal wires or alloys joined together at one end to form two junctions: the hot junction and the cold junction. The hot junction is exposed to the temperature being measured, while the cold junction is typically kept at a reference temperature.

When there is a temperature difference between the two junctions, an electromotive force (EMF) is generated along the length of the thermocouple. The magnitude of the EMF depends on the temperature difference and the specific characteristics of the thermocouple materials.

Each type of thermocouple uses a different combination of metals or alloys for the wires, and these combinations are given specific letter designations. For example, the most common type is the Type K thermocouple, which uses chromel (an alloy of nickel and chromium) for one wire and alumel (an alloy of nickel, manganese, aluminum, and silicon) for the other wire.

The generated voltage can be measured using a voltmeter or connected to a temperature measurement device known as a thermocouple thermometer or pyrometer. By knowing the properties of the thermocouple materials and the relationship between temperature and voltage for the specific thermocouple type, the temperature at the hot junction can be determined.

It's important to note that thermocouples are nonlinear devices, meaning that the relationship between the measured voltage and temperature is not a simple linear equation. Therefore, calibration tables or mathematical equations are used to accurately convert the voltage readings into temperature values.

The generation of an electromotive force (EMF) in a thermocouple occurs due to a phenomenon known as the Seebeck effect. The Seebeck effect states that when two dissimilar metals or alloys are joined at two different temperatures, a voltage potential is produced across the junctions.

This effect arises from the difference in electron densities and energy levels between the two metals or alloys. When there is a temperature gradient along the length of the thermocouple, the electrons in the metal with the higher temperature gain more thermal energy and become more energetic compared to the electrons in the metal at the lower temperature. This leads to a flow of electrons from the hot junction to the cold junction, creating a voltage difference.

The magnitude of the generated EMF depends on several factors, including the specific characteristics of the metals or alloys used in the thermocouple, the temperature difference between the junctions, and the properties of the junctions themselves. Each type of thermocouple has a unique combination of materials, and these combinations are carefully selected to generate a suitable voltage range for temperature measurement.

The key principle behind the Seebeck effect is the conversion of thermal energy into electrical energy. The temperature difference acts as a driving force that causes the movement of charge carriers (electrons) across the thermocouple junctions, resulting in the generation of an EMF. By measuring this voltage, it is possible to infer the temperature at the hot junction based on the characteristics of the specific thermocouple type.

Resistance Temperature Detectors (RTDs), also known as platinum resistance thermometers, are temperature sensors that utilize the principle of electrical resistance to measure temperature. Here's how RTDs work:

Basic Principle: RTDs are based on the concept that the electrical resistance of a conductor changes with temperature. Most RTDs use platinum as the sensing element due to its stability and linear resistance-temperature relationship.

Platinum Wire: The sensing element of an RTD is typically a fine coil or wire made of pure platinum. The wire's electrical resistance increases or decreases with temperature changes, providing a measurable indication of the temperature.

Resistance-Temperature Relationship: Platinum RTDs follow the Callendar-Van Dusen equation, which describes the relationship between resistance and temperature. The equation is typically calibrated by the manufacturer to provide accurate temperature measurements.

Measurement Circuit: The RTD is connected in a measurement circuit, usually a Wheatstone bridge configuration. The Wheatstone bridge circuit compensates for the resistance variations in the connecting wires and provides an accurate measurement of the RTD's resistance.

Excitation Current: A constant current source is used to pass a known current through the RTD. This current generates a voltage drop across the RTD, which is proportional to its resistance.

Voltage Measurement: The voltage across the RTD is measured using a precision analog-to-digital converter or a bridge circuit. The measured voltage is then converted into a temperature reading using the calibration data specific to the RTD being used.

Accuracy and Calibration: RTDs are known for their high accuracy and stability over a wide temperature range. However, calibration is necessary to account for any slight deviations or nonlinearities in the resistance-temperature relationship. Calibration coefficients or lookup tables are used to convert the measured resistance into an accurate temperature reading.

Signal Conditioning: In some applications, signal conditioning circuits may be employed to amplify, filter, or linearize the RTD output signal for further processing or control purposes.

RTDs offer several advantages, including high accuracy, stability, and linearity. They can be used in various industries and applications where precise temperature measurement is required. However, RTDs are generally more expensive than other temperature sensors like thermocouples or thermistors, making them suitable for applications that demand higher accuracy and stability.

|  | Thermocouple | RTD | Thermistor |
| --- | --- | --- | --- |
| Accuracy | Average | Highest | Low but sufficient |
| Temperature Range | Highest, can measure extremely high temperatures | Upto a few hundred degree celsius | Limited temperature range, but they can be designed for specific ranges. |
| Response Time | Slowest | slower | Fastest |
| Cost | Average | Most expensive | Economical |
| Range |  |  |  |
| Least Count |  |  |  |

References:

1. <https://www.omega.co.uk/temperature/z/thermocouple-rtd.html>
2. <https://instrumentationtools.com/difference-between-rtd-thermocuples-and-thermistors/>

Hall Sensors:

1. <https://youtu.be/On9jgL5pAB0>
2. <https://www.mouser.com/pdfdocs/Selecting-Hall-Effect-for-DC-Brushless-Motors.pdf>
3. <https://www.precisionmicrodrives.com/ab-021>
4. <https://www.bldcmotor.org/how-hall-sensor-works-in-brushless-dc-motor.html>

## Load cells

Chosen type -

Parallelogram Bending beam load cell

References:

1. [Load cell working principle | Wheatstone Bridge | how to use them to measure weight | Electrical](https://youtu.be/SfFPgbSqoSA)
2. [Electronic Basics #33: Strain Gauge/Load Cell and how to use them to measure weight](https://youtu.be/lWFiKMSB_4M)
3. [Type of Load Cell](https://youtu.be/6NgJ1L4rATY) Data Acquisition System

References:

1. [Data Acquisition System](https://youtu.be/zv5NXbl00GQ)
2. [What is a data acquisition system? (DAQ System)](https://youtu.be/-0LzMfhoSts)
3. [Sensor Fundamentals Data Acquisition Basics and Terminology](https://youtu.be/Xc8dP0PdC_4)
4. <https://www.edn.com/7-data-acquisition-systems-attach-directly-to-sensors/>

Examples:

1. <https://in.mathworks.com/products/data-acquisition.html>
2. <https://youtu.be/kZ5uGLfvnwA>
3. <https://www.tytorobotics.com/pages/rcbenchmark-software>
4. <https://dewesoft.com/products/dewesoftx>
5. <https://in.mathworks.com/products/data-acquisition.html#sensors>
6. Sigview