
# Measurements, Sensors and Data Logging Course

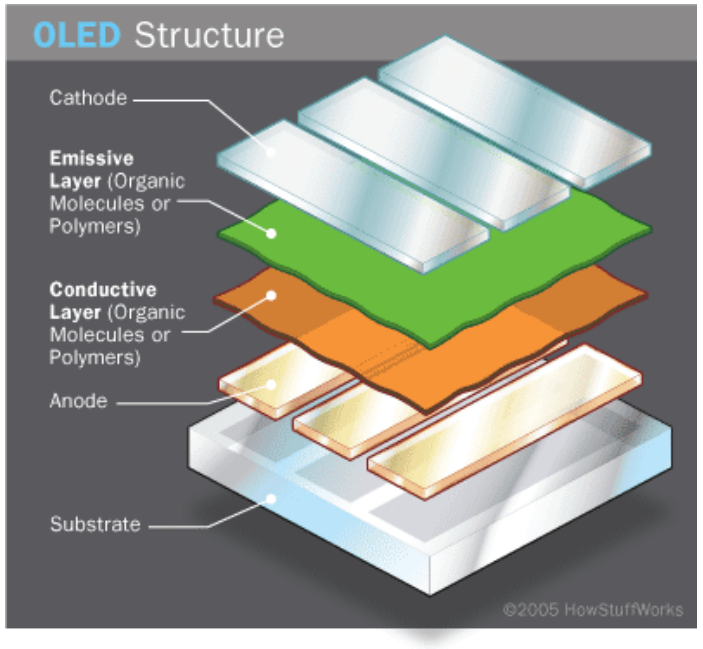
Week 6

# Display

Use the OLED Display to provide information to the user.

# Organic Light Emitting Diodes

## Lesson 12: Display




- Organic Light Emitting Diodes (OLED)
  - Series of organic thin films between two conductors.
  - When electrical current is applied, light is emitted
  - Flexible and transparent options
- Relative to LCD
  - Lower power consumption.
  - Improved image quality - better contrast, higher brightness, fuller viewing angle, a wider color range and much faster refresh rates.
  - Simpler design that enables ultra-thin, flexible, foldable and transparent displays
  - Better durability - OLEDs are very durable and can operate in a broader temperature range

https://www.oled-info.com/oled-introduction#:~:text=OLED%20(Organic%20Light%20Emitting%20Diodes,a%20bright%20light%20is%20emitted
https://electronics.howstuffworks.com/oled1.htm

# Hardware

## Lesson 12: Display

- What hardware will we need for this Lesson?
  - Grove Temperature and Humidity Module on pin D3
  - Grove Light Sensor on pin A6
  - Grove Temp & Humidity Sensor I2C
  - Seeeduino Lotus (Arduino Uno compatible board)

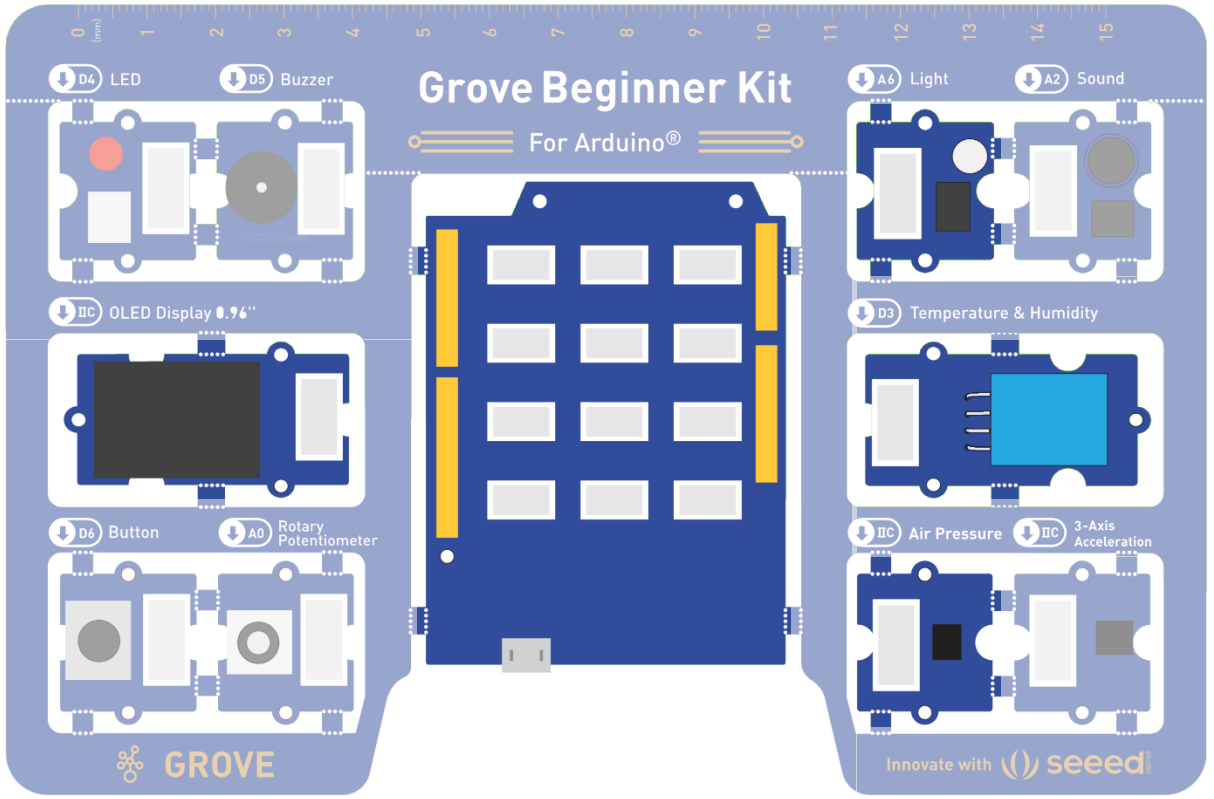



Image modified from https://files.seeedstudio.com/wiki/Grove-Beginner-Kit-For-Arduino/res/Grove-Beginner-Kit-For-ArduinoPDF.pdf

# Library for Air Pressure Sensor

## Lesson 12: Display

- Library to use: Seeed BMP280
  - Search for ***Seeed_BMP280*** in the library manager and install it.
  - There are multiple variants available for the BMP280 air pressure sensor.

```
#include <Seeed_BMP280.h>
bmp280.init();

float temperatureBMP = bmp280.getTemperature();  //gets the temp
float pressure = bmp280.getPressure();    //gets the pressure
```

- More Information:
  - https://github.com/Seeed-Studio/Grove_BMP280

# Library for Display

## Lesson 12: Display

- Library to use: U8x8lib
  - Search for ***U8g2*** in the library manager and install it.

```
#include <U8x8lib.h>
U8X8_SSD1306_128X64_ALT0_HW_I2C Display(U8X8_PIN_NONE);
Display.begin();
Display.setFlipMode(1);
Display.setFont(u8x8_font_chroma48medium8_r);

Display.setCursor(0, 0);
Display.print("some text here");
```

- More Information:
  - https://github.com/olikraus/u8g2/wiki

# Open and Upload Sketch

## Lesson 12: Display

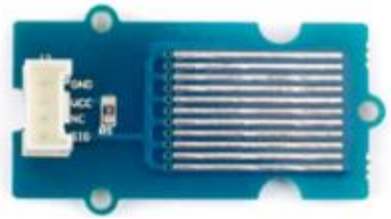
1. Open Simple Datalogger Sketch
   - **File** > **Sketchbook > FRSEF_Crash_Course > Week_6 > L12_OLED.ino**
2. Upload the sketch to your Arduino by clicking the Upload Button.
   - The sketch should compile, and then upload to your Arduino.
3. The OLED will display the time, temperature, humidity, pressure and light values from the sensors.

# Sensor Calibration
# +
# Water Sensor

# Moisture Sensors

## Sensor Calibration + Moisture Sensor

- How it works: uses the conductivity of water to “short” between GND and the signal input
  - Digital Input: water is present or not
  - Analog Input: level of water present
    - Voltage divider with pullup resistor and water between the signal and ground lines.

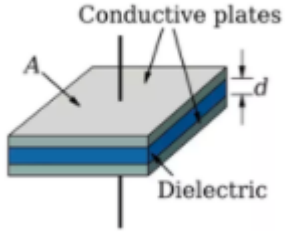


# Soil Moisture Types

## Sensor Calibration + Water Sensor

- Common Types
  - Resistive
    - Two probes
    - Current passes through the soil and the resistance value is calculated to measure soil moisture content.
    - Problems: sensor corrodes and resistance continually increases, fertilizer and nutrients can affect resistance
    - Quantitative measurement.
  - Capacitive
    - Single probe, soil contact with electrodes not required (less corrosion)
    - Soil + water form a dialectric, similar to a capacitor
      - Capacity of soil change with change of moisture content
    - Quantitative measurement

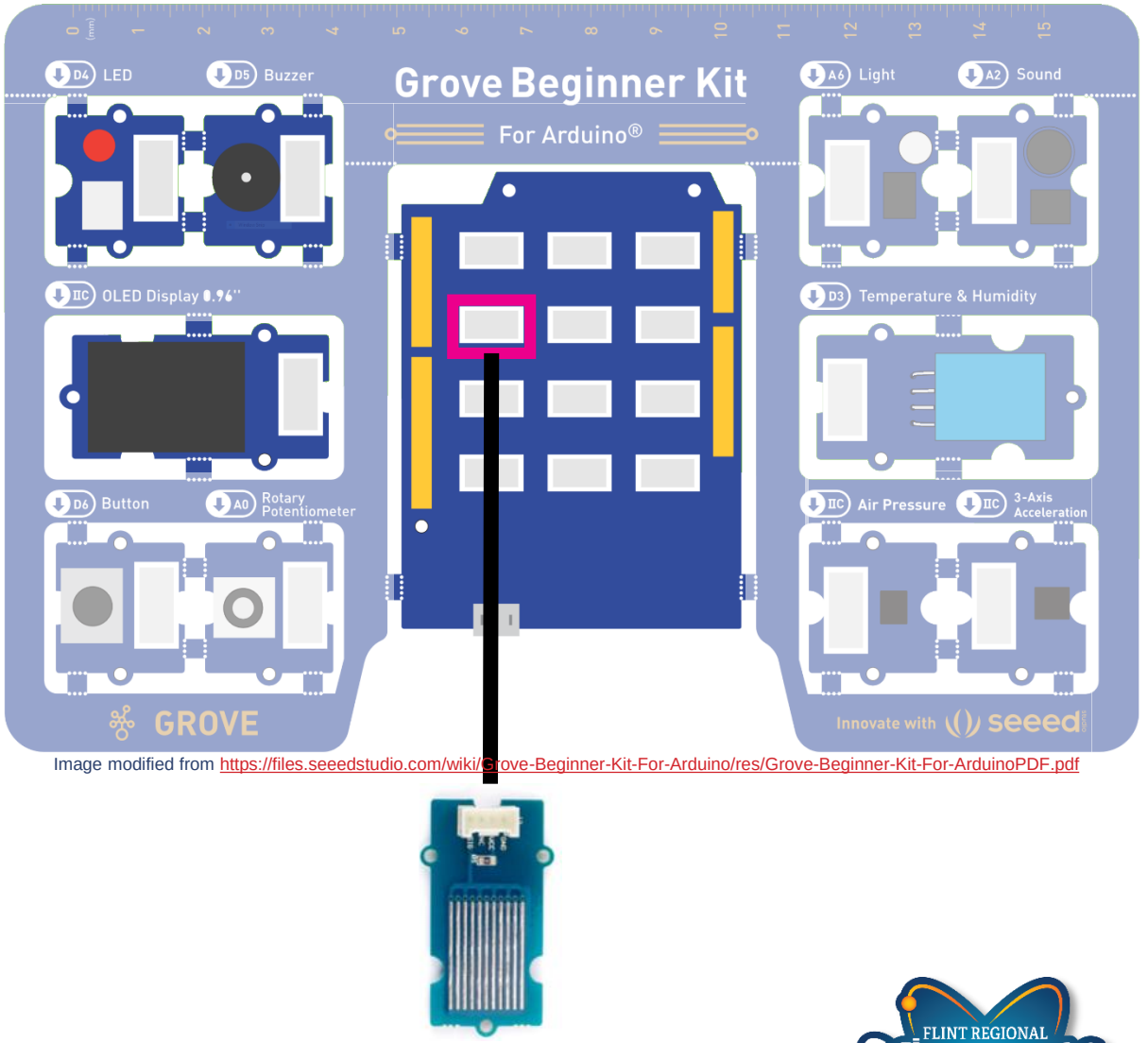
https://ucanr.edu/sites/CE_San_Joaquin/files/35895.pdf



# Hardware

## Sensor Calibration + Water Sensor

- What hardware will we need for this Lesson?
  - Grove LED, Buzzer and Display
  - Seeeduino Lotus (Arduino Uno compatible board)
  - Grove Water Sensor
    - Connect to D2 Header
    - Use the provided cable

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# Open and Upload Sketch

## Sensor Calibration + Water Sensor

1. Open Simple Datalogger Sketch
   - **File** > **Sketchbook > FRSEF_Crash_Course > Week_6 > L13_Water_Alert.ino**
2. Upload the sketch to your Arduino by clicking the Upload Button.
   - The sketch should compile, and then upload to your Arduino, assuming you have the correct
3. Touch the water sensor, see what happens.
   - What happens if you place a drop of water on the sensor or dip the sensor into a cup of water?

# Agriculture Applications

## Sensor Calibration + Water Sensor

- What can we measure for agriculture applications?
  - Small scale - individual plants, gardens
  - Large scale - farms

# Agriculture Applications

## Sensor Calibration + Water Sensor

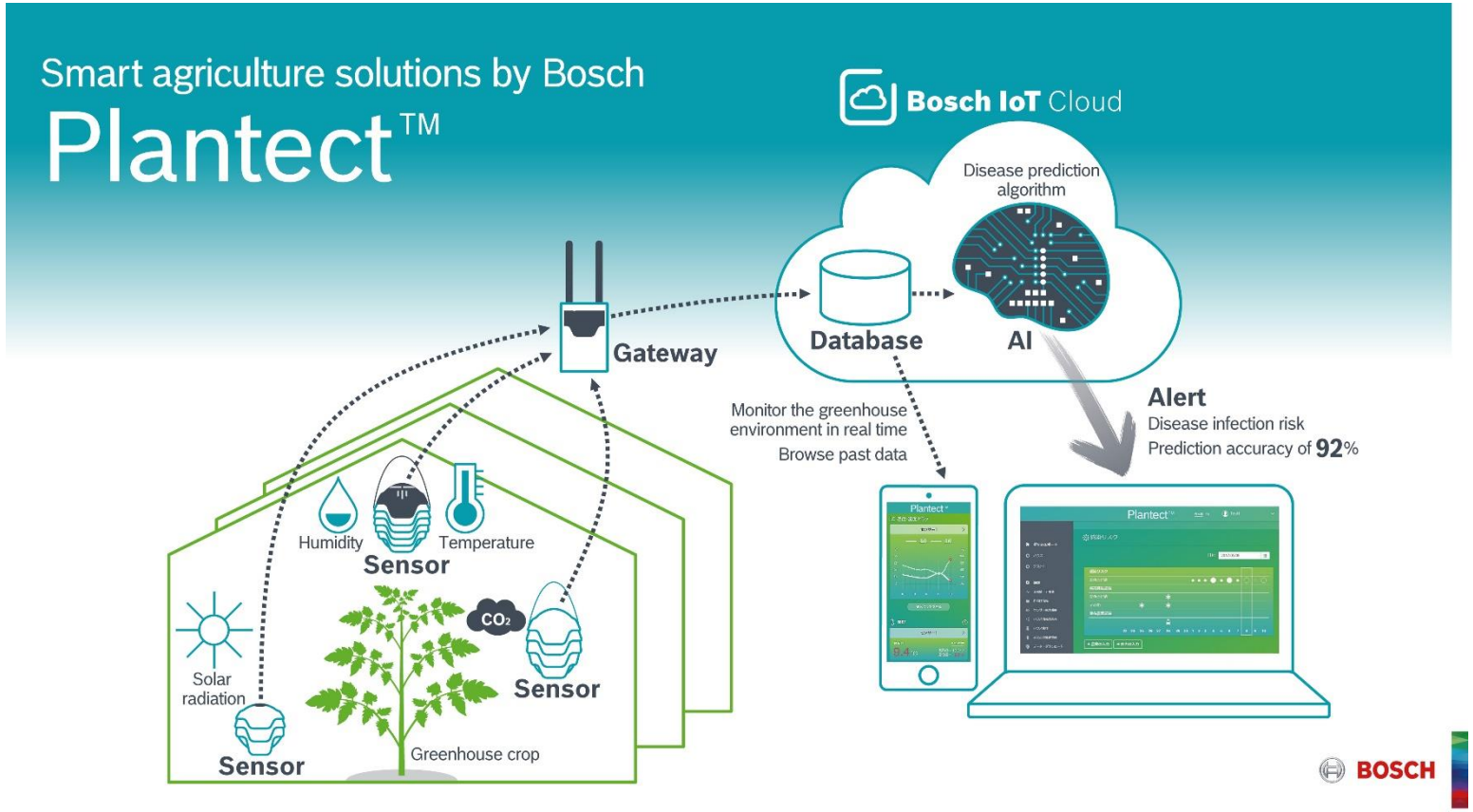
- What can we measure for agriculture applications?
  - Individual plants
    - Environment
      - Temperature
      - Air Quality
      - Air Content: CO, CO2, Oxygen
      - Humidity
    - Soil: moisture, temperature
    - Fertilizer
    - Plant Height
  - Large Scale: entire fields
    - Optical (soil reflectance, color, height)
    - Cameras (identify weeds, where plants are growing)


https://cropwatch.unl.edu/ssm/sensing
https://www.mouser.com/applications/smart-agriculture-sensors/
https://www.wespeakiot.com/robust-sensors-and-the-power-of-the-cloud-the-perfect-recipe-for-smart-farming/

# Agriculture Applications + Livestock

## Sensor Calibration + Water Sensor

https://www.bosch-presse.de/pressportal/de/en/smart-agriculture-101824.html




# Agriculture Applications + Livestock

## Sensor Calibration + Water Sensor

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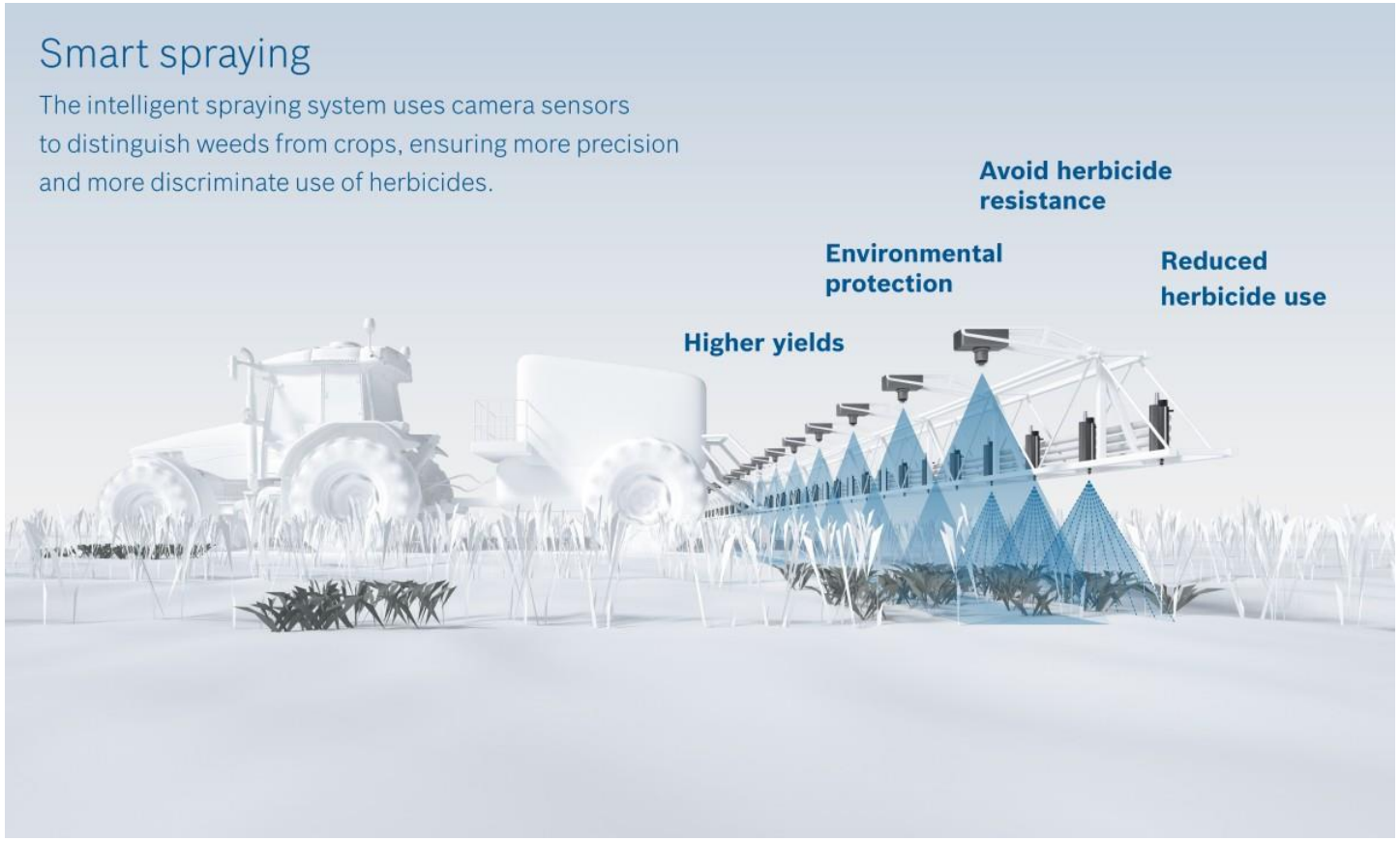
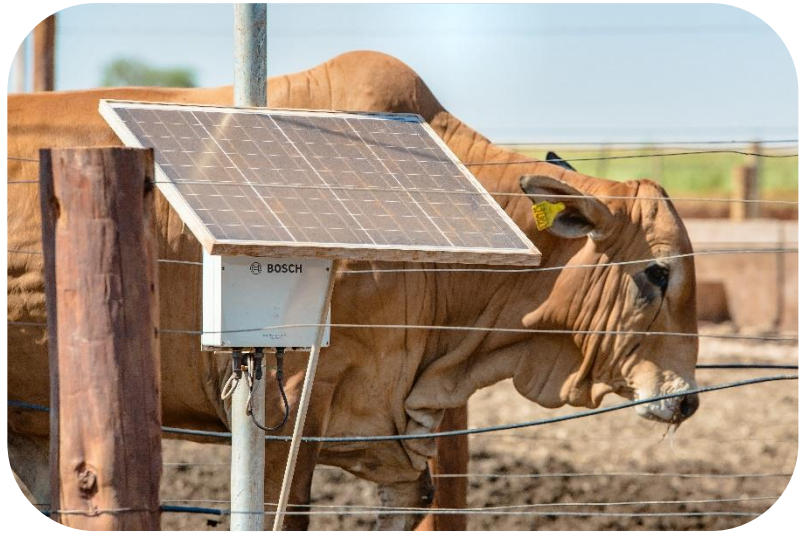


# Livestock Applications

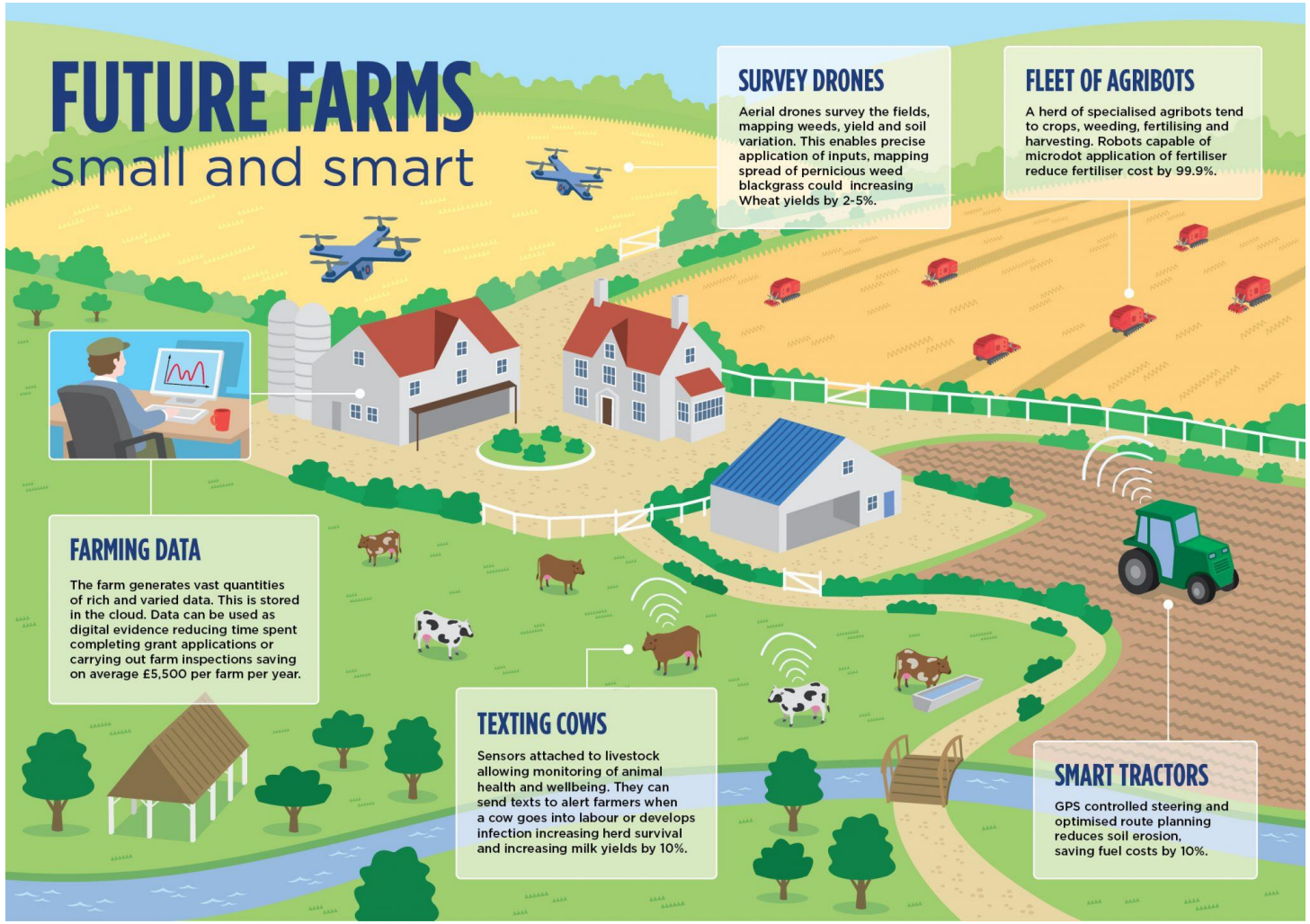
## Sensor Calibration + Water Sensor

- Livestock Applications
  - Location
    - GPS
    - Near-Field (near feed bunk, water)
  - Health
    - Temp
    - Pulse-Ox
    - Accel
  - Calving (birth)
  - Weight

https://www.moovement.com.au/farm-management-platform/

# Agriculture Applications

## Sensor Calibration + Water Sensor



# Two Point Calibration

# Calibration

## Sensor Calibration

- What is calibration?
  - Calibration establishes a known relationship between a measurement (ex. voltage) and a standard (ex. temperature, position).
- What types of calibration are there?
  - Offset (add or subtract out error)
  - Slope [Sensitivity] (multiply by a correction factor)
  - Slope and Offset (combination of prior two, think $y = mx + b$)
  - Two Point (linear interpolation between two known points)
  - Best Fit Equation [Characteristic Equation] (algebraic equation of line of best fit)
  - Look Up Table [LUT or Characteristic Curve] (linear interpolation between point on the table)
- More information:
  - https://learn.adafruit.com/calibrating-sensors?view=all
  - https://us.flukecal.com/literature/about-calibration

# Open and Upload Sketch – At Home

## Sensor Calibration

1. Open Calibration Sketch
   - **File** > **Sketchbook > FRSEF_Crash_Course > Week_6 > L14_Calibration.ino**
2. Upload the sketch to your Arduino by clicking the Upload Button.
   - The sketch should compile, and then upload to your Arduino

# Two Point Calibration of the Potentiometer

## Sensor Calibration

- Activity:
  1. Adjust the potentiometer such that the slot in the knob is vertical. Record at the raw value.
  2. Rotate the knob by 180° (half turn) and record the raw value.
  3. Update **`deg90Count`** and **`deg270Count`** values and re-upload.
  4. Note how the Degrees output is now much closer to the actual rotational value.

- When setting up logging – record the new calibration value and the raw value off of the sensor.
- Calibration can also be done during data analysis.

# Code Analysis: `map()` function

## Sensor Calibration

```
map(potValueRaw, deg90Count, deg270Count, 90, 270);
```

- Linearly interpolate **`potValueRaw`** between points defined by **`deg90Count`**, **`deg270Count`**, **`90`**, and **`270`**.

- Re-maps a number from one range to another.
  - A value of **`fromLow`** would get mapped to **`toLow`**,
  - A value of **`fromHigh`** to **`toHigh`**,
  - Values in-between to values in-between, etc.
- Syntax:

```
map(value, fromLow, fromHigh, toLow, toHigh)
```

  - **`value`**: number to map or interpolate
  - **`fromLow`**: lower bound of input range (range of value)
  - **`fromHigh`**: upper bound of input range (range of value)
  - **`toLow`**: lower bound of the output range (range of calibrated value)
  - **`toHigh`**: upper bound of the output range (range of calibrated value)
- More information:
  - https://www.arduino.cc/reference/en/language/functions/math/map/

# Open and Upload Sketch – At Home

## Sensor Calibration + Water Sensor

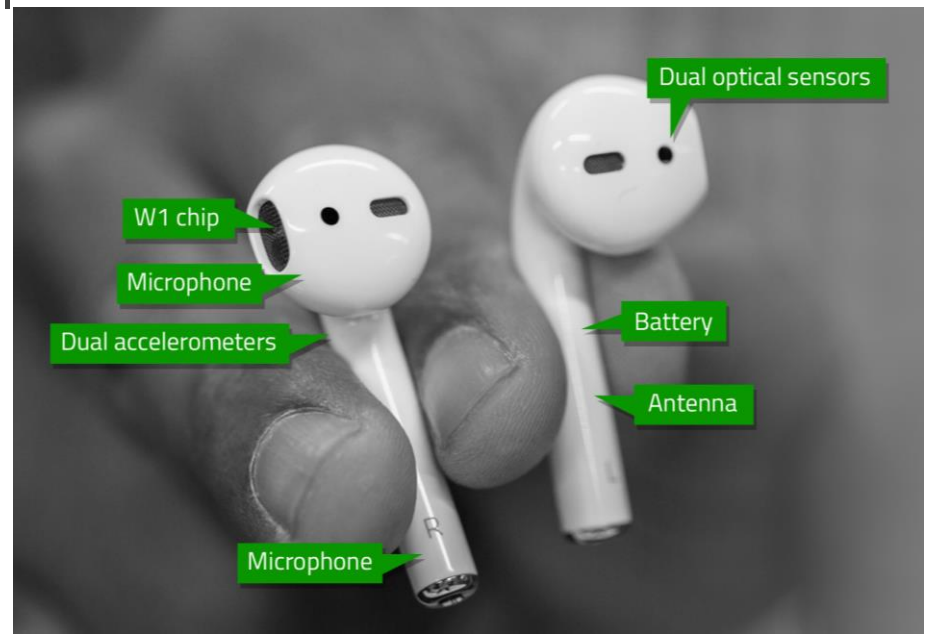
1. Connect to A2 header with the capacitive soil moisture sensor.
2. Break out the sound sensor.
3. Open Simple Datalogger Sketch
   - **File > Sketchbook > FRSEF_Crash_Course > Week_6 > L14_SoilMoisture.ino**
4. Upload the sketch to your Arduino by clicking the Upload Button.
   - The sketch should compile, and then upload to your Arduino, assuming you have the correct
5. Place the probe in soil, add water to measure the difference

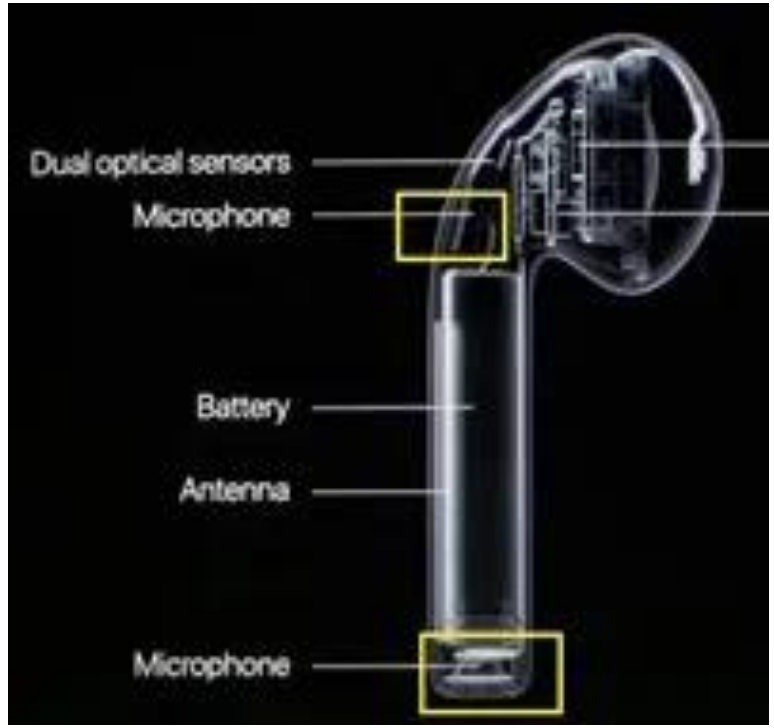
   How do we know what it actually relates to?
6. Update the calibration values!

# Sensors & Applications

# Sensors & Applications - Airpods

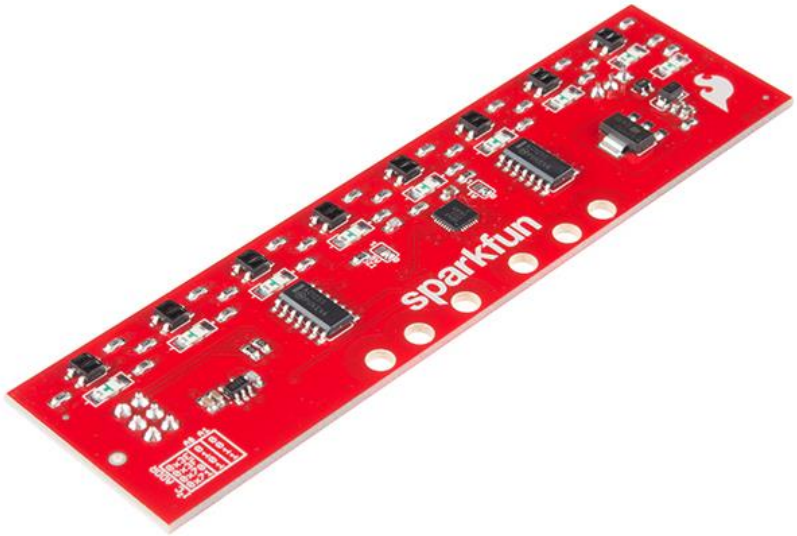
- Airpods
  - Optical sensors
    - Installed in ear
  - Accelerometer
    - Gestures and control



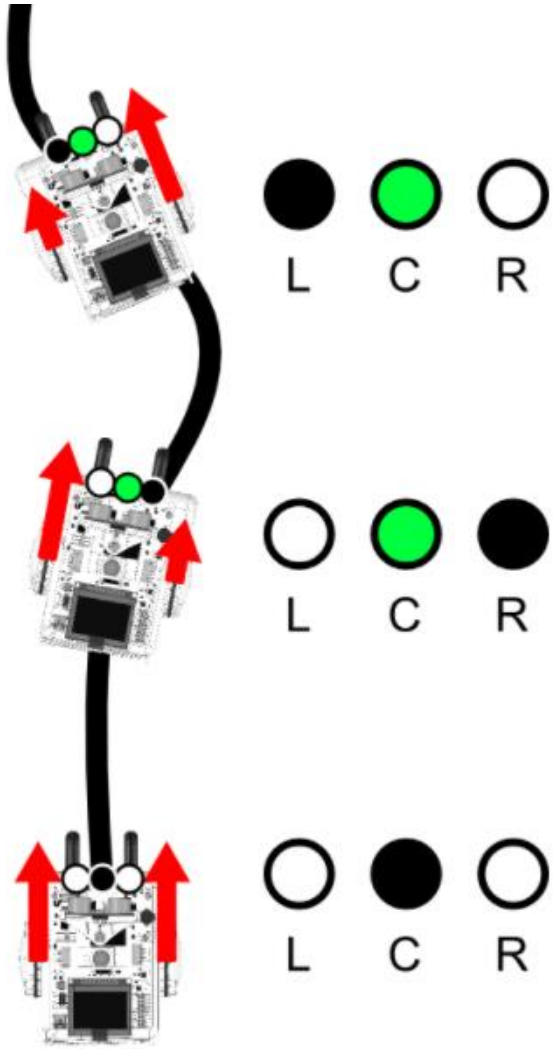
# Sensors & Applications – Line Following Sensors

- Typically utilize IR (InfraRed) sensors
  - IR sensor consists of an LED and phototransistor
    - LED emits an IR light (humans an unable to see this)
    - Phototransistor is measuring IR light that is reflected back
      - White surface: reflects light back to the phototransistor
      - Black surface: absorbs light



# Sensors & Applications – Line Following Sensors

- In-Use



# Sensors & Applications – EEG, ECG EMG

- Measures of biopotential, the electrical output of human activity
  - Electroencephalogram (EEG)
    - Monitors brain activity
    - Measurements at forehead, top of head (potentially) and ears
  - Electrocardiogram (EKG)
    - Measures heart activity
    - Measurements at torso, arms and legs
  - Electromyography (EMG)
    - Electrical activity of muscles
    - Common test is to measure muscle response relative to stimulation of the muscle, measure a specific muscle

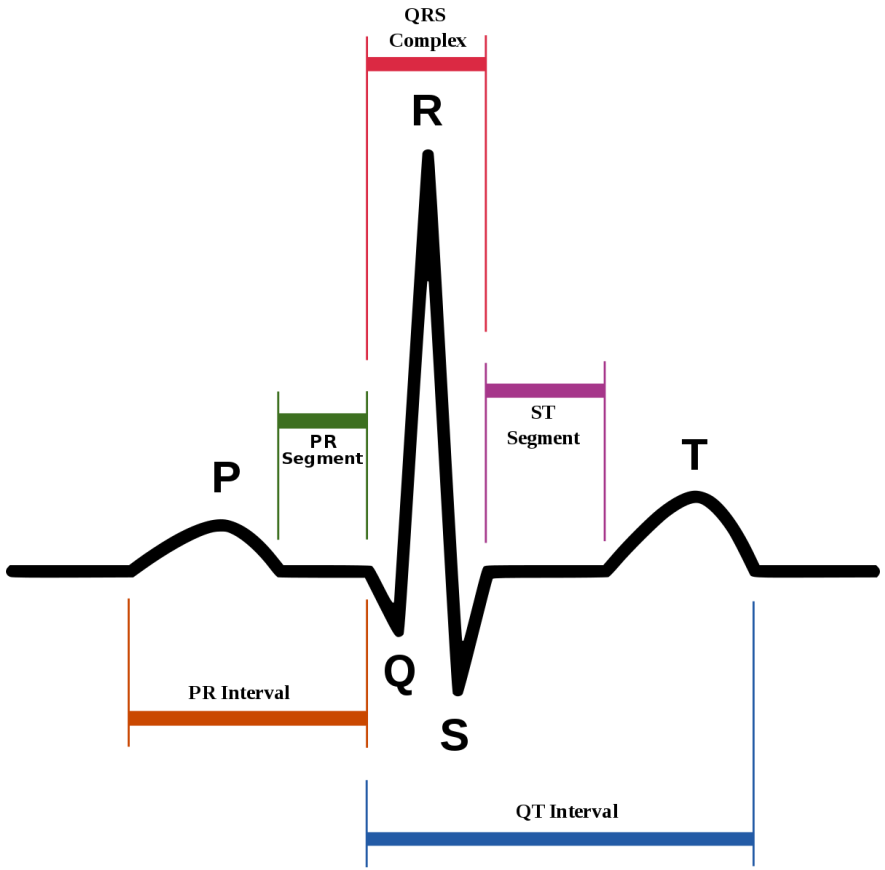
https://www.sensortips.com/featured/what-is-the-difference-between-an-ecg-eeg-emg-and-eog/
https://www.withings.com/de/en/health-insights/about-ecg-ekg-electrocardiogram

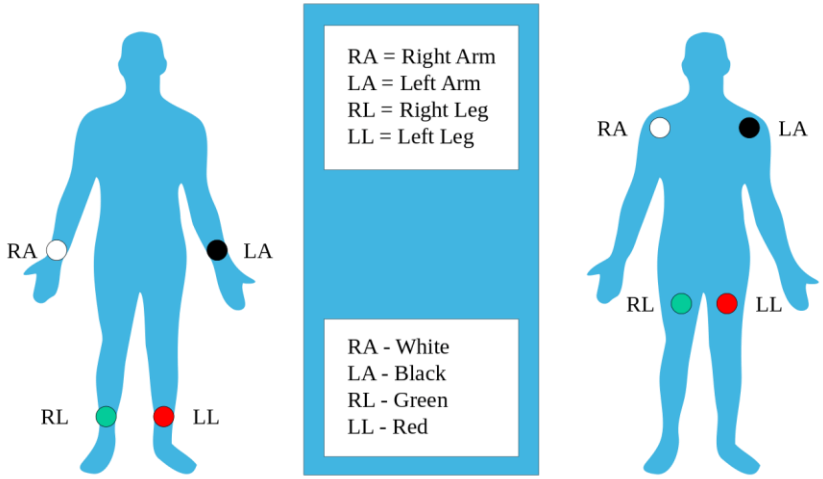
# Sensors & Applications – EEG, ECG EMG

- Measuring
  - Amplifier is required (very lower voltages)
  - Electrodes used to “pick up” the voltages

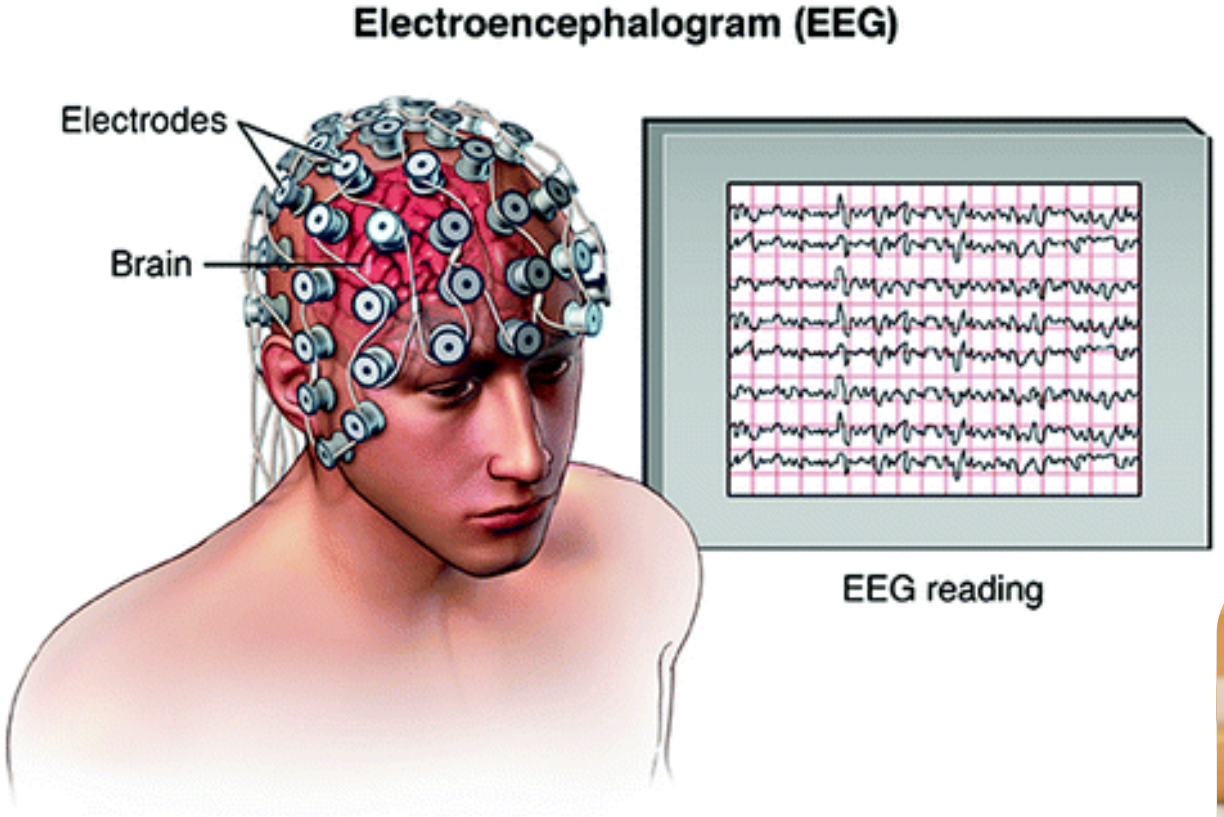
| Source | Amplitude (mV) | Bandwidth (Hz) |
|---|---|---|
| ECG | 1-5 | 0.05-100 |
| EEG | 0.001-0.01 | 0.5-40 |
| EMG | 1-10 | 20-2000 |
| EOG | 0.01-0.1 | dc-10 |

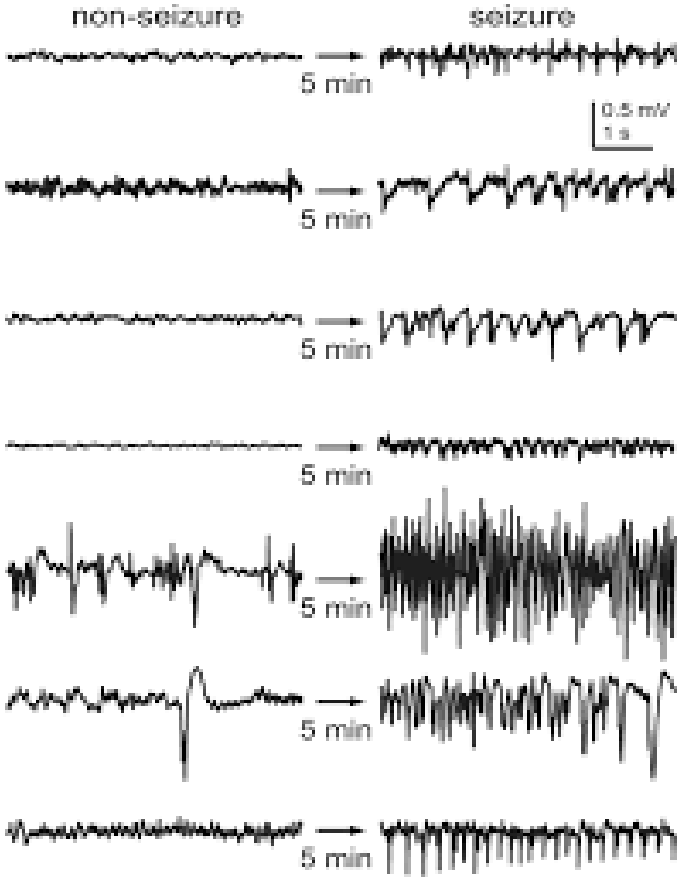
# Sensors & Applications – EKG



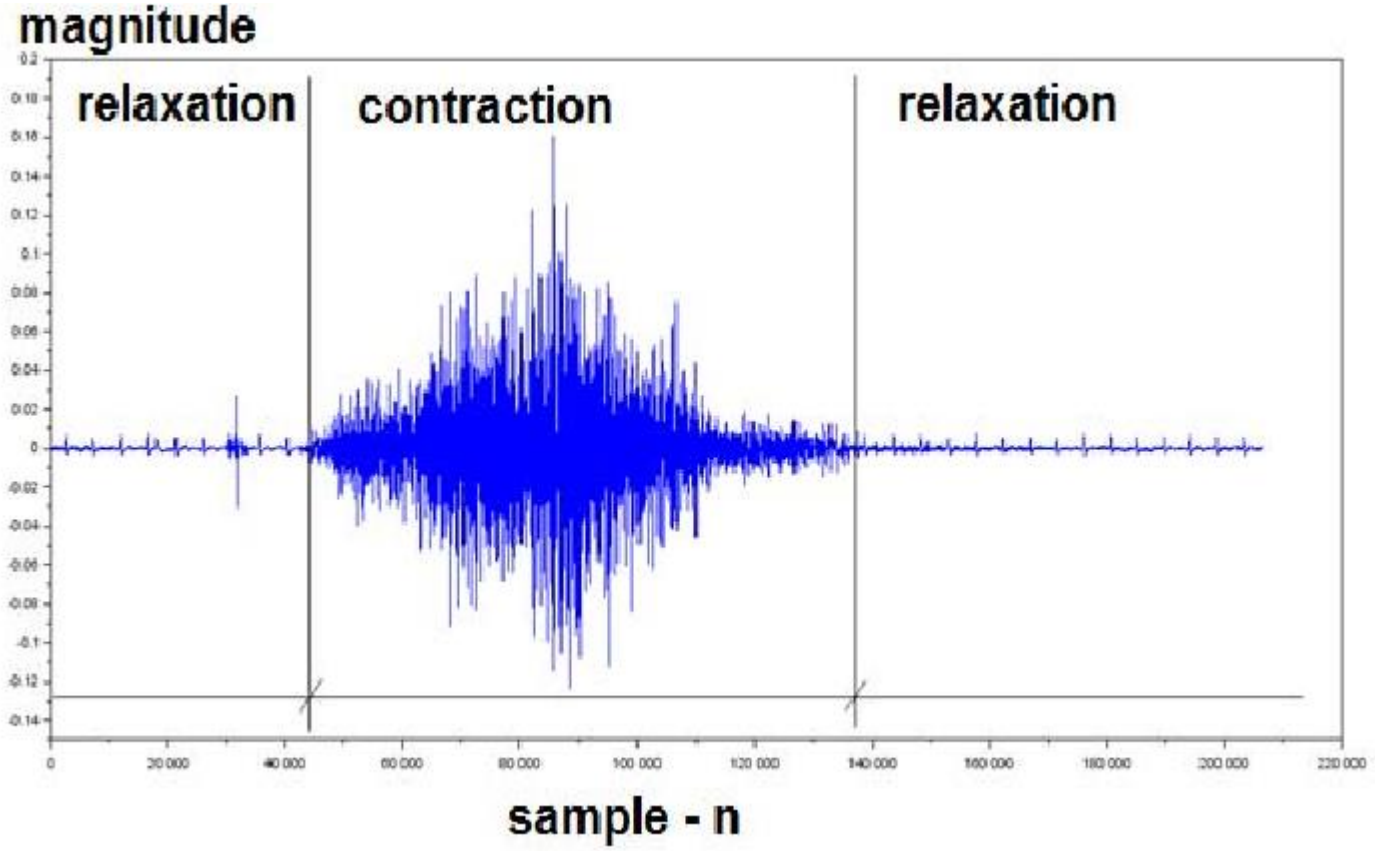



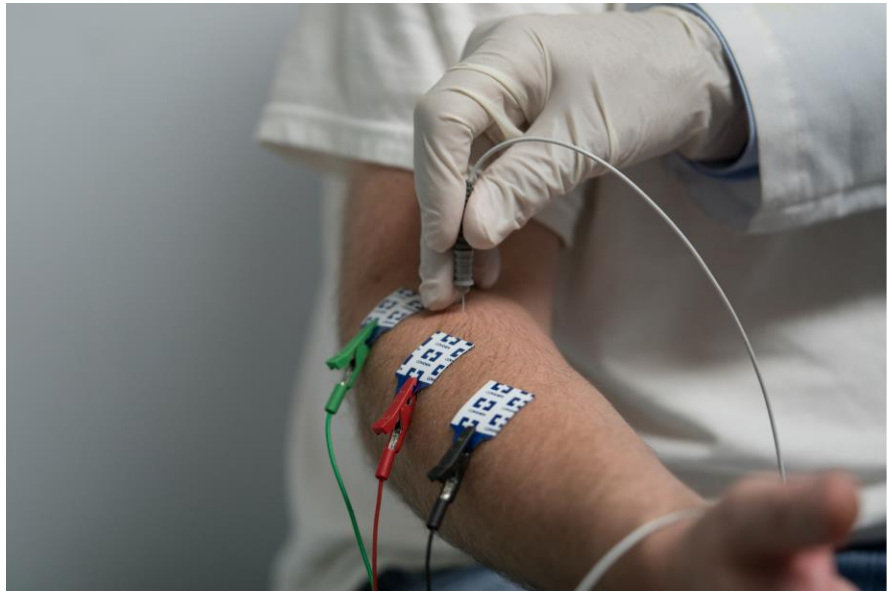

# Sensors & Applications – EEG



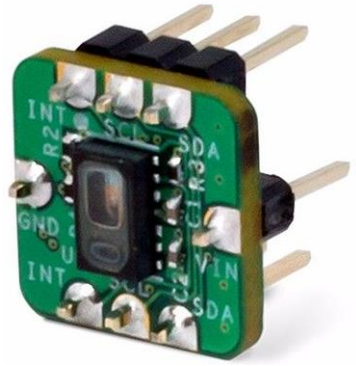



# Sensors & Applications – EMG



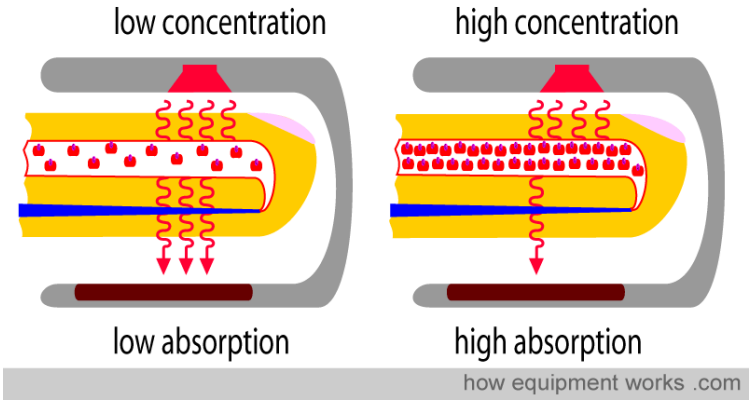



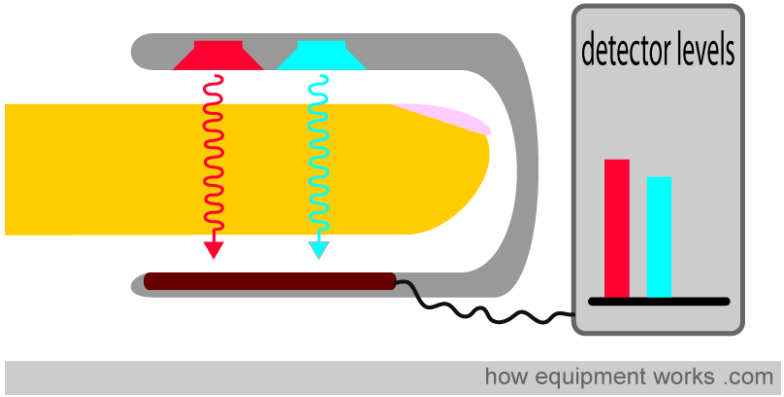
# Sensors & Applications – Pulse Ox

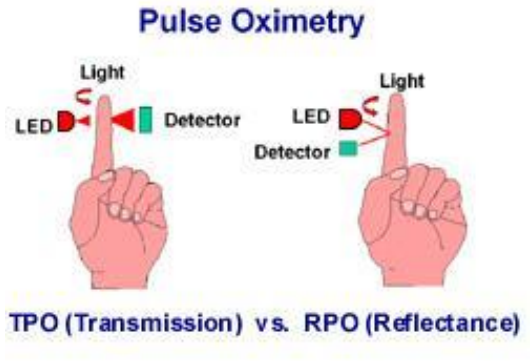


- Pulse-Oximetry
  - Measure blood oxygen saturation (Sp02) and calculate heart rate
    - Oxygen molecules attach to hemoglobin
    - Types: Transmission and Reflectance
    - Hemoglobin with and without oxygen absorbs light differently (wavelength of light differs)
      - Oxy Hb absorbs more infrared light than red light
      - Deoxy Hb absorbs more red light than infrared light

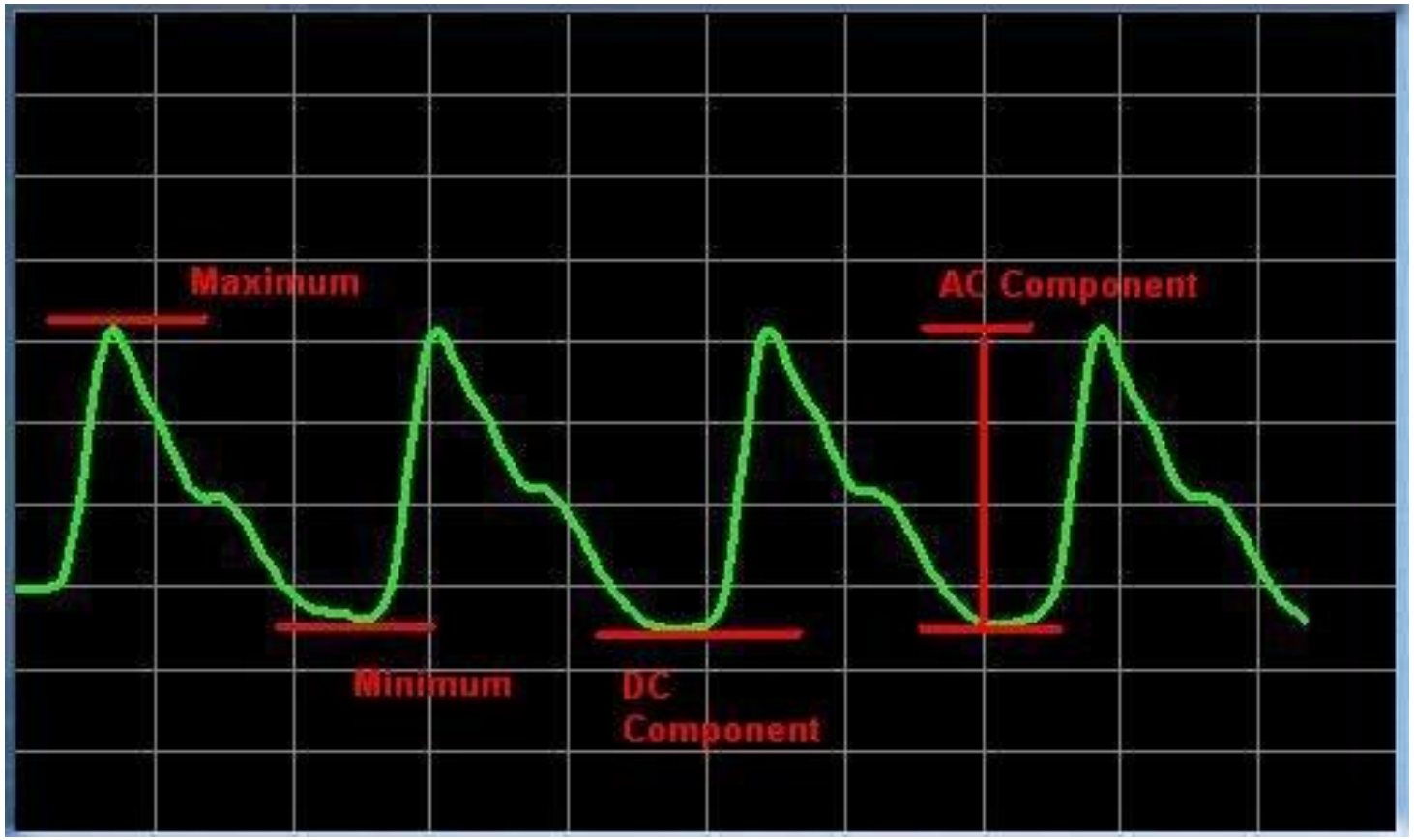
https://www.howequipmentworks.com/pulse_oximeter/



# Sensors & Applications – Pulse Ox




# FRSEF

# Putting It All Together

## FRSEF

- What are we trying to measuring? (our outcome)
  - Are there multiple ways we can measure it?
- What affects it? (our variables; independent, dependent and controlled)
  - Can we measure this?
- How fast will we measure and record it?
  - Are we limited by our equipment?
- How will we analyze it?
- How will we present our data?

# Putting It All Together – Improved Helmet

## FRSEF

- Engineering Goal: *Design a Helmet to reduce concussions in football.*
- What are we trying to measuring? *Impact to brain.*
  - *G Force's via accelerometer*
- What affects it? (our variables; independent, dependent and controlled)
  - Helmet Design (padding, shape, etc)
  - Drop Height
  - Environmental Factors? (temp, etc....)
  - Temp of padding, etc?
- How fast will we measure and record it?
- How will we analyze it?
- How will we present our data?

# Putting It All Together – Best Fertilizer

## FRSEF

- Hypothesis: *Scott's Fertilizer will produce the highest yield of tomatoes.*
- What are we trying to measuring? Yield of tomatoes – quantity, mass
- What affects it? (our variables; independent, dependent and controlled)
  - Fertilizer brand
  - Amount of applied fertilizer
  - Environmental Factors (temp, sunlight, soil moisture, water quantity)
  - Soil pH
- How fast will we measure and record it?
- How will we analyze it?
- How will we present our data?

# Upcoming Activities
## FRSEF

- Crash Course: Data Analysis
  - February
- 2021 Virtual Science Fair
  - Registering
    - www.flintsciencefair.org
  - Format, Resources and Templates
    - https://www.flintsciencefair.org/important-stuff/virtual-fair-information/
  - Senior Fair (9-12)
    - March 7: Registration Deadline + Upload of Project Materials
    - March 20: Judging Interviews (online via Zoom or similar)
  - Junior Fair (6-8) + Elementary Fair (4-5)
    - April 3: Registration Deadline + Upload of Project Materials
    - April 17: Judging Interviews (online via Zoom or similar)

# Why Participate?
## FRSEF

- Open to science, engineering, math and computer science projects
- Great learning experience
- Interact and communicate with local professionals
- Prizes!
  - Over $10,000 in cash prizes
  - Scholarships to Kettering and UM-Flint
  - 4 students advance to International Science and Engineering Fair (Senior category)
  - 15-20 students advance to Broadcom MASTERS (Junior category)

# Resources

## FRSEF

- Interactive Project Guide
  - Part 1: Starting a Project
  - Part 2: Experimentation and Communicating Results
- Educator Grants
- Student Project Grants

# Thank you!

Chris

Tracy

John

Nick

Ivan

Clare

MSU St. Andrews