EMG Workshop w/ IEEE

Neurotech

Computational NeuroSCience Society

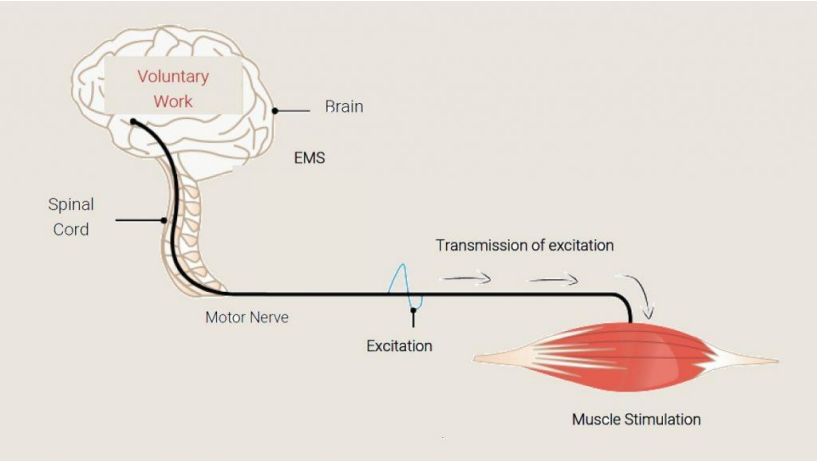
IEEE

Goals:

- Successfully measure electrical activity of a muscle using Arduino and electrodes to introduce biofeedback
- Relate the context of the workshop into the realm of Neurotechnology and emerging technologies (BCI, etc.)

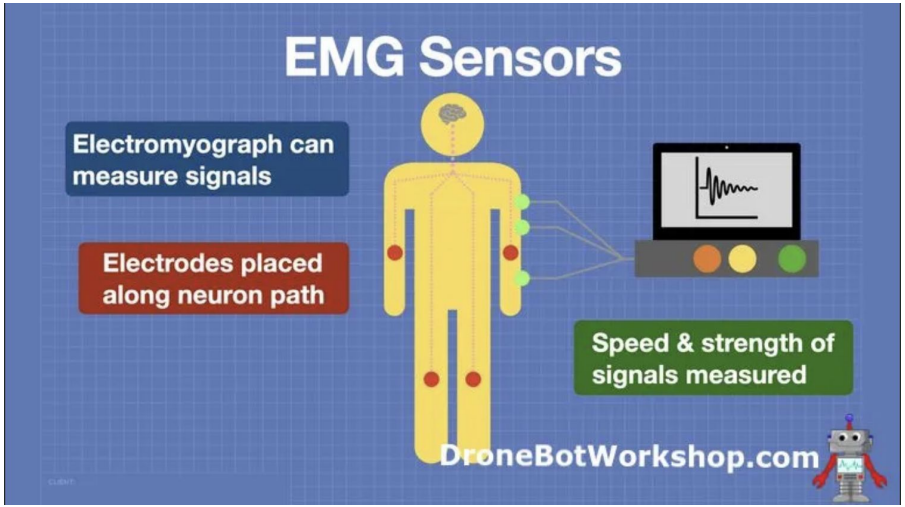
Anatomy

- Neurons in the brain communicate through electrical activity (voltage)
  - Muscles communicate the same way
- Motor Neurons in the brain send signals to peripheral muscles through electrical signal
  - Electrical signal causes muscle to contract



Role of EMG

- Electromyography:
  - Process of sensing electrical activity produced by skeletal muscles
- Electromyograph (EMG):
  - Instrument that performs electromyography
  - Measures faint electrical signals
- How?
  - Sensors placed along path of neurons picking up speed and strength of signals



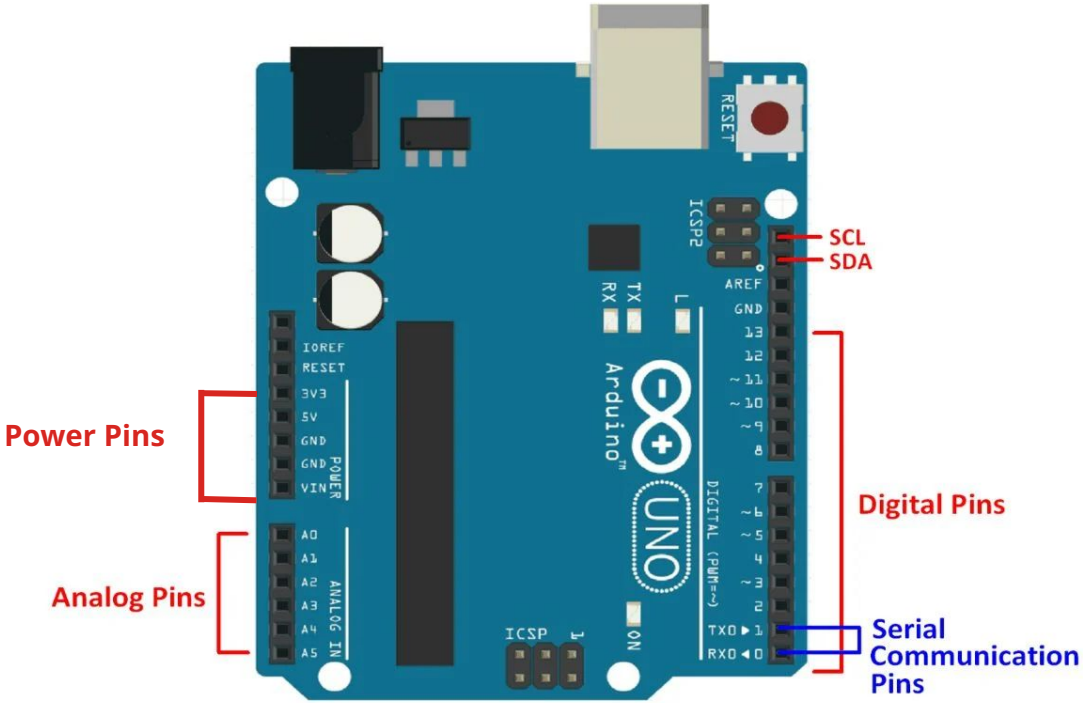
A note about Safety

- Recording electrodes only and NOT stimulating electrodes
- Muscle sensor is only for sensory purposes and does not transmit any electricity to the electrodes
    - Works opposite with electricity flow from body to the sensor due to path of least resistance

Electrical Circuit Basics

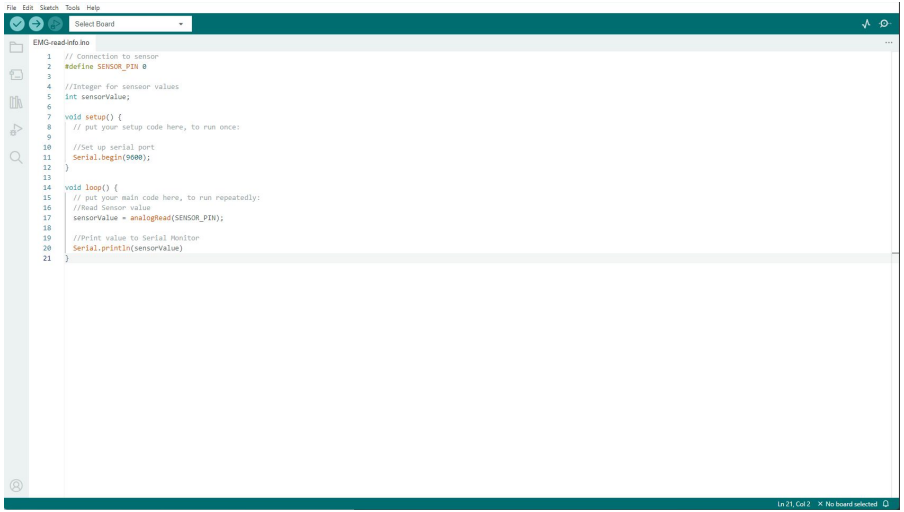
- Voltage – potential difference, always measured between two points
- There has to be a voltage reference, GND in this case
- Analog vs digital signals
  - Analog can take any value in a range - eg. 0-5V
  - Digital can only take distinct, defined values - 0V or 1V
- Positive and negative voltage
  - Voltage can be positive or negative (this is in relation to the reference point)
- Connections between pins allow the flow of current and transmission of changes in voltage → voltage changes over time → EMG signals

Arduino - An intro



Arduino IDE

- Written in C++
- Special libraries for Arduino setup/usage
- Make sure you have it downloaded
    - Only one person in each group needs it
- Create a new Sketch (code)
    - Tells the arduino what to do



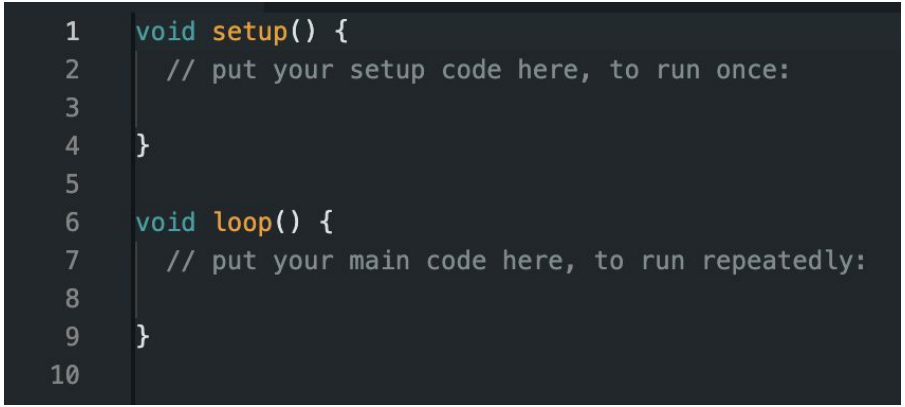
Organization of the Sketch

Setup():

- Initialize variables, pin modes, libraries (e.g. serial communication, setting pin modes (I vs O), etc.)
- Runs once

Loop():

- Instructions (e.g. reading sensors, controlling outputs, logic, etc.)
- Runs repeatedly, after setup()



```
1   void setup() {
2     // put your setup code here, to run once:
3
4   }
5
6   void loop() {
7     // put your main code here, to run repeatedly:
8
9   }
10
```

Functions to be used:

Serial.begin(value);

- Initializes serial communication on the Arduino board
  - Through baud specification (rate of data transfer in bits per second; we are using 9600)

analogRead(value);

- Reads voltage values from the analog pins on the board (A0, A1...)
  - Converts analog voltage and provides a corresponding digital value (ADC)
  - Range of conversion:
    - 0 -1023 (10 bit); 0 = 0 volts, 1023 = reference voltage

Code:

Copy from github:

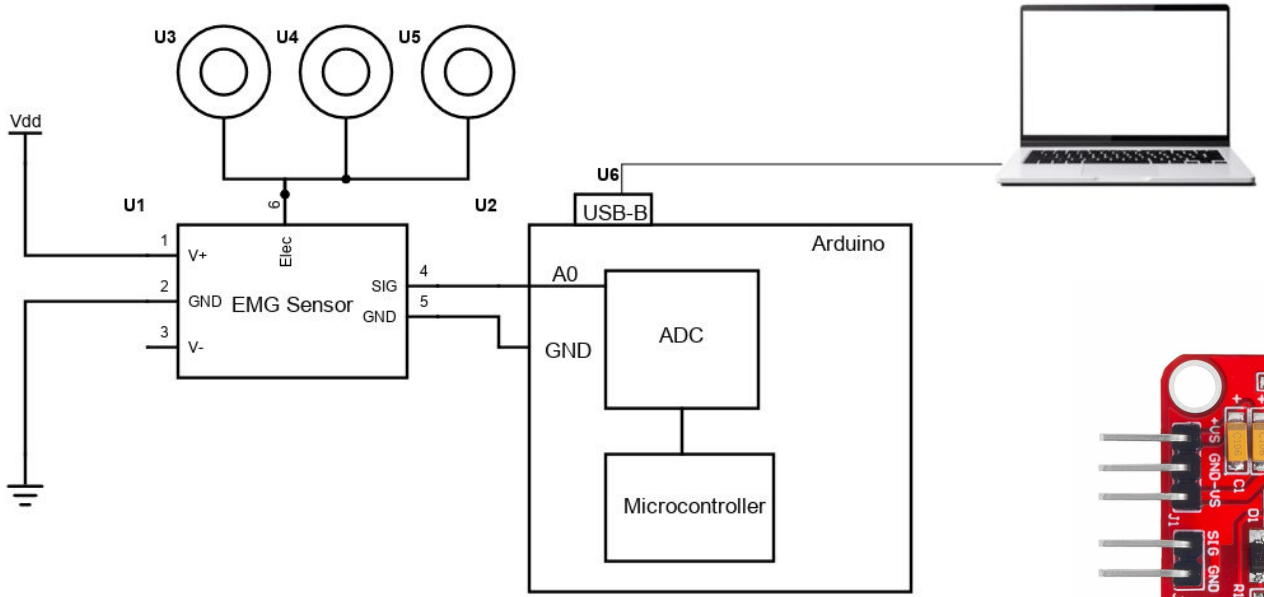
- https://github.com/rskdmr/emg_sketch_code/blob/main/read-info

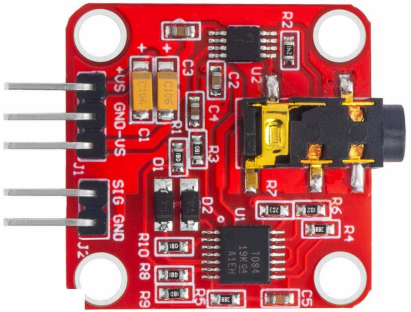
- Or: Github.com → Search “rskdmr” → Users → Repositories → emg_sketch_code → read-info

EMG.ino

```
// Connection to Myoware sensor
#define SENSOR_PIN 0

// Integer for sensor value
int sensorValue;


void setup() {

  // Set up serial port
  Serial.begin(9600);
}

void loop() {

  // Read sensor value
  sensorValue = analogRead(SENSOR_PIN);

  // Print value to Serial Monitor
  Serial.println(sensorValue);
}
```

Hardware





Schematic of EMG Circuit

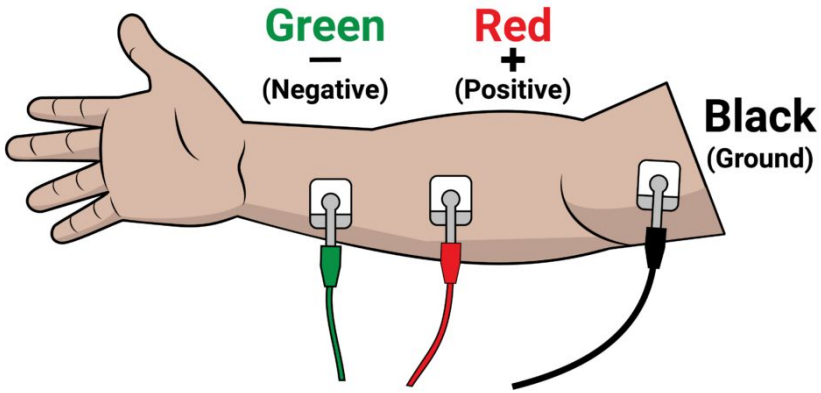
Hardware Setup

1. Connect the arduino to your laptop using the USB-A to USB-B cable. If required, use a USB-C to USB-A adapter.
2. Wire the EMG sensor to the arduino **GND** and **A0** pins. Use M-F jumper wires.
3. Connect the EMG sensor to the power supply via the breadboard. Use M-F jumper wires.
4. Connect the electrodes to the EMG sensor.
5. Start up the Arduino IDE and connect to the Arduino board.
6. Attach the electrodes to the muscle. One for ground and two to measure the potential difference.
7. Put your code in the IDE and upload it to the Arduino.
8. Open the serial monitor or serial plotter to visualize the sensor readings.

Electrode Placement

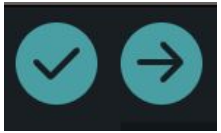
3 electrodes:

- 1 GND (Yellow)
  - Boney part of the body
    - As a reference to muscle voltage
- 2 on muscle pathway for potential difference (Red/Green)*
  - Forearm muscle
  - Bicep brachii
    - Green in front of red



*Ensure same muscle for both electrodes

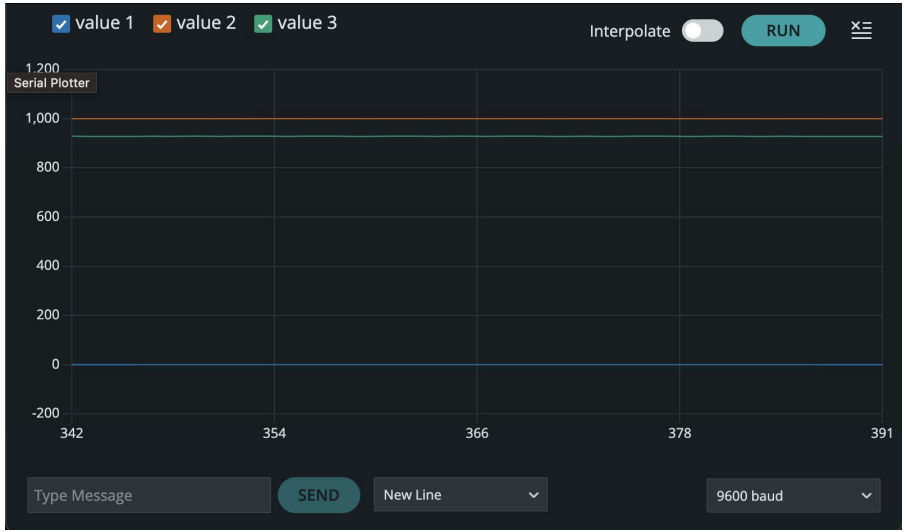
Output:



- After pressing run, open serial plotter or monitor
- Before flexing muscle, let the sensor sit to adjust to the voltage of the muscle.
  - It won't be exactly stable (due to noise)
- Look at the y-axis
  - What do you notice?

Output - Define Limits

- In order to view the measured output of the sensor, we need to view the info in a set point of reference.
- Do this by defining two constant Serial values, 1 and 2.



Code - Define Limits

- Add two bounds:
  - One lower
  - One upper
- Use the “Serial.print(#)” function
  - Creates constant “limit” on serial monitor
- Change the numbers according to your data
  - Anywhere between 300-900 range

```
// Add "fake" plots to stabilize Y axis
Serial.print(0); // To freeze the lower limit
Serial.print(" ");
Serial.print(1000); // To freeze the upper limit
Serial.print(" ");
```

Refining Signal

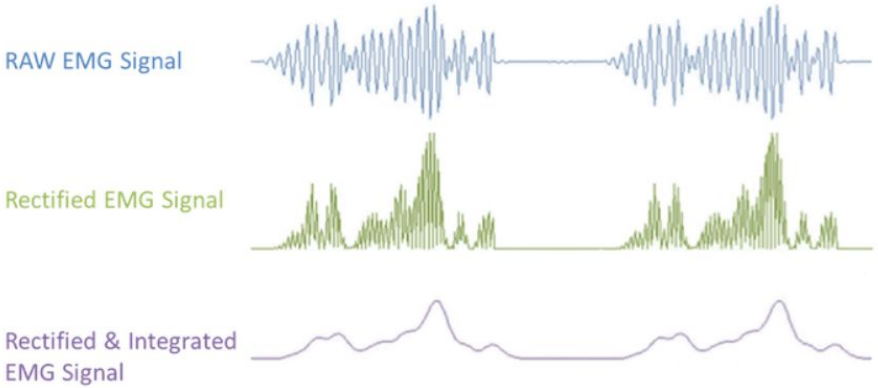
Rectified EMG signal:

- Applied ReLU (ramp function)
  - Holds positives, converts negative to 0
  - Remove negative polarity to simplify data

Integration

- Envelope Detection
  - Calculates areas under rectified curve
  - Captures general trend/energy content

Varies by application

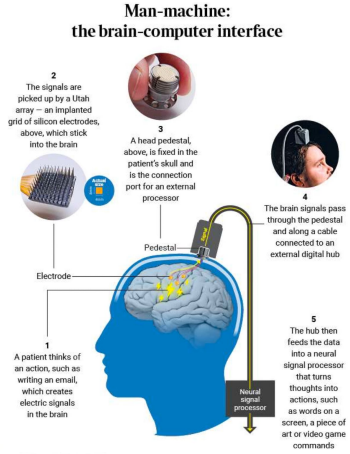


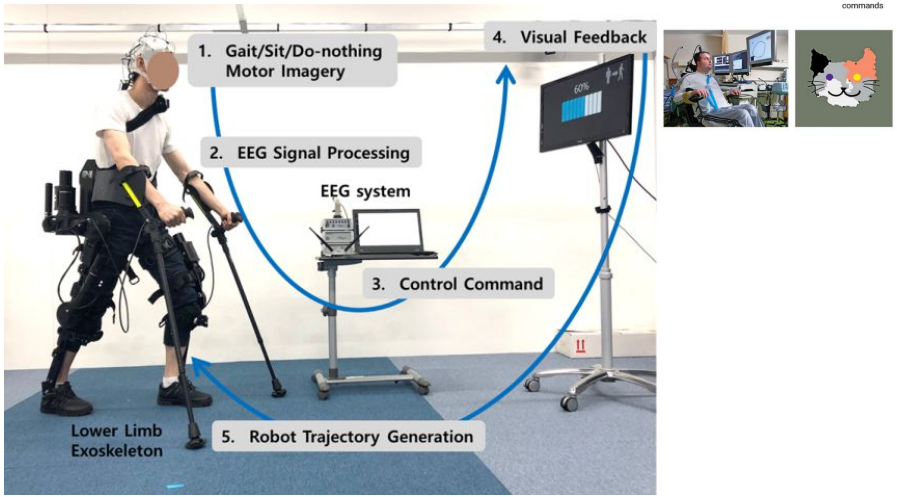
So What?

- Numbers on a graph are only interesting for so long

Neurotechnology Applications

- Emerging neurotechnologies rely on the principles performed today, just more complex
  - Locate Signal
  - Record
  - Read/visualize data in an coherent way
  - Use data to manipulate external system
- Technologies including:
  - BCI
    - Communication, limb/muscle control, everyday interaction, etc.
  - EEG
    - Understanding brain waves (Neurbale and focus state)





Need for Diverse Studies within Neurotechnology

- **Electrical Engineers:**
  - Circuitry design, transferring electrical signal from body into computer data, etc.
- **Biomedical Engineers/Neuroscientists:**
  - Understanding of nervous system to implement technologies in an effective/safe manner
- **Data/Computer Scientists:**
  - Extract and decode data in a readable manner to use with external systems like prosthetics
- **And Others!**