Tishk International University
Mechatronics Engineering Department
Special Topics in Mechatronics
Code: ME 374
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# Electromyogram Monitoring System Design

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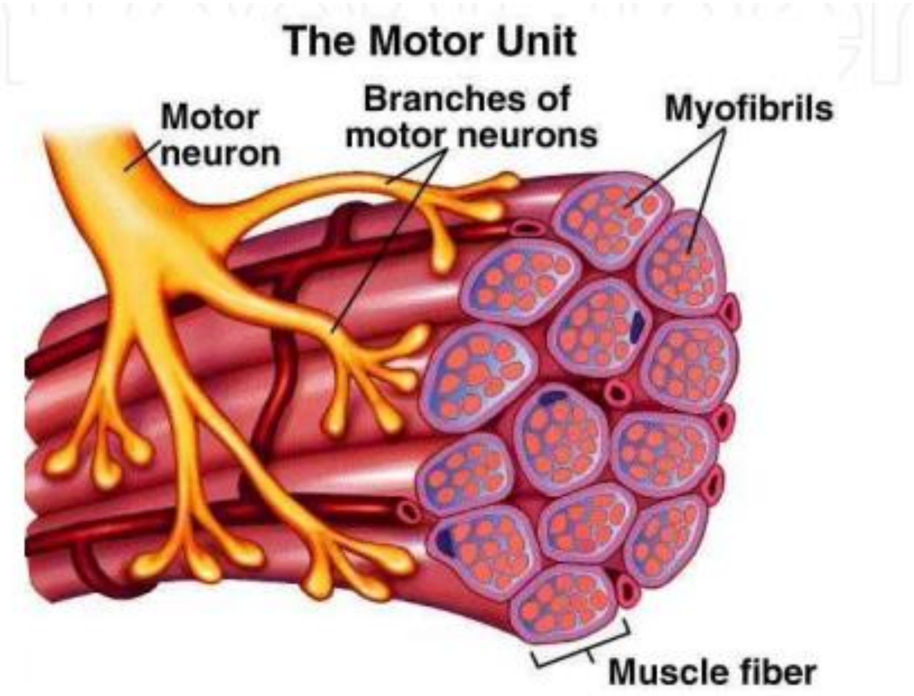
# Lecture 3 Outline:

- Electromyography
- Designing an Arduino-based EMG monitor
- EMG Muscular Signal Sensor
  - Components and Circuit diagram
  - Circuit connections
  - Arduino sketch
  - The result

# Electromyography

- Measuring muscle activation via electric potential, referred to as electromyography (EMG), has traditionally been used for medical research and diagnosis of neuromuscular disorders.
- However, with the advent of ever shrinking yet more powerful microcontrollers and integrated circuits, EMG circuits and sensors have found their way into prosthetics, robotics and other control systems under the umbrella of Biomechatronics.
- Electromyography (EMG) is a diagnostic procedure that evaluates the health condition of muscles and the nerve cells that control them. These nerve cells are known as motor neurons. They transmit electrical signals that cause muscles to contract and relax.




- The electric signal produced during muscle activation, known as the myoelectric signal, is produced from small electrical currents generated by the exchange of ions across the muscle membranes and detected with the help of electrodes.
- Electromyography is used to evaluate and record the electrical activity produced by muscles of a human body. The instrument from which we obtain the EMG signal is known as **electromyograph** and the resultant record obtained is known as **electromyogram**.
- An EMG module translates these signals into graphs or numbers, helping doctors to make a diagnosis and engineers to design solutions .

# Electromyograph

- A doctor will usually order an EMG when someone is showing symptoms of a muscle or nerve disorder. These symptoms may include: tingling, numbness and unexplained weakness in the limbs.
- EMG results can help in diagnosing muscle disorders, nerve disorders, and disorders affecting the connection between nerves and muscles.
- It's important to notify the doctor about any prescription medications that the patient may be taking, if there is any bleeding disorder, or in case of having a pacemaker or implantable defibrillator. Under any of these condition the patient may not be able to have an EMG test.
- If the patient able to have an EMG, the following steps are important beforehand:

  - Avoid smoking for at least three hours before the procedure.
  - Bathe or take a shower to remove any oils from the skin. Don't apply any lotions or creams after washing.
  - Wear comfortable clothing that doesn't obstruct the area that your doctor will be evaluating.

# EMG electrodes and its types

- The bioelectrical activity inside the muscle of a human body is detected with the help of EMG electrodes. There are two main types of EMG electrodes: surface (or skin electrodes) and inserted electrodes. Inserted electrodes have further two types: needle and fine wire electrodes.

  - **Needle electrodes**

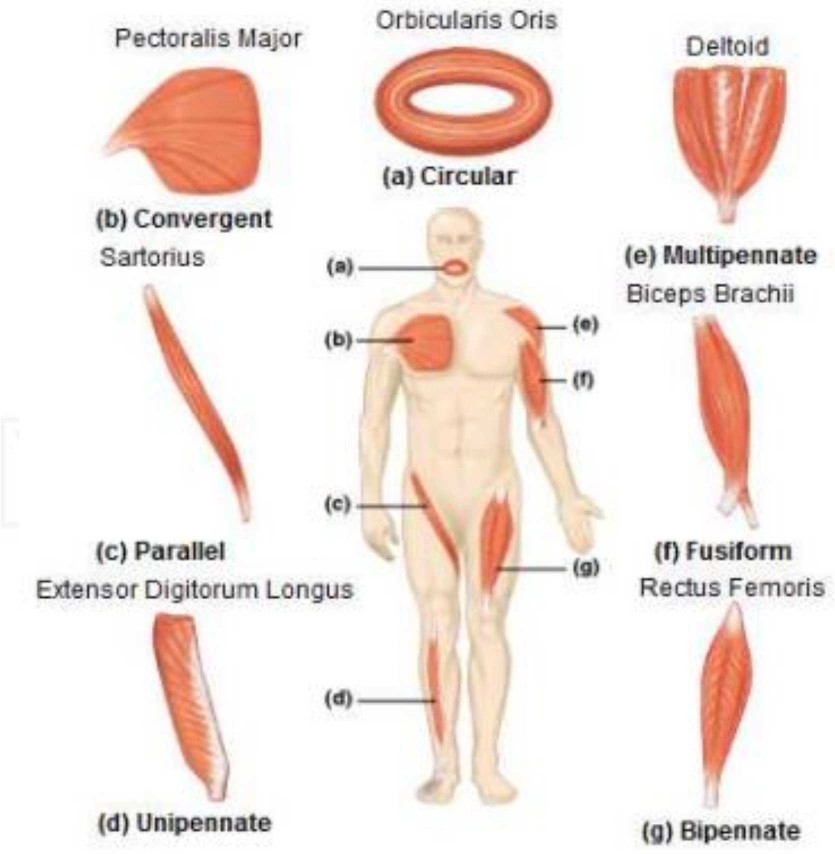

  - **Fine wire electrodes**

  - **Surface EMG electrode**

Gelled EMG Electrodes

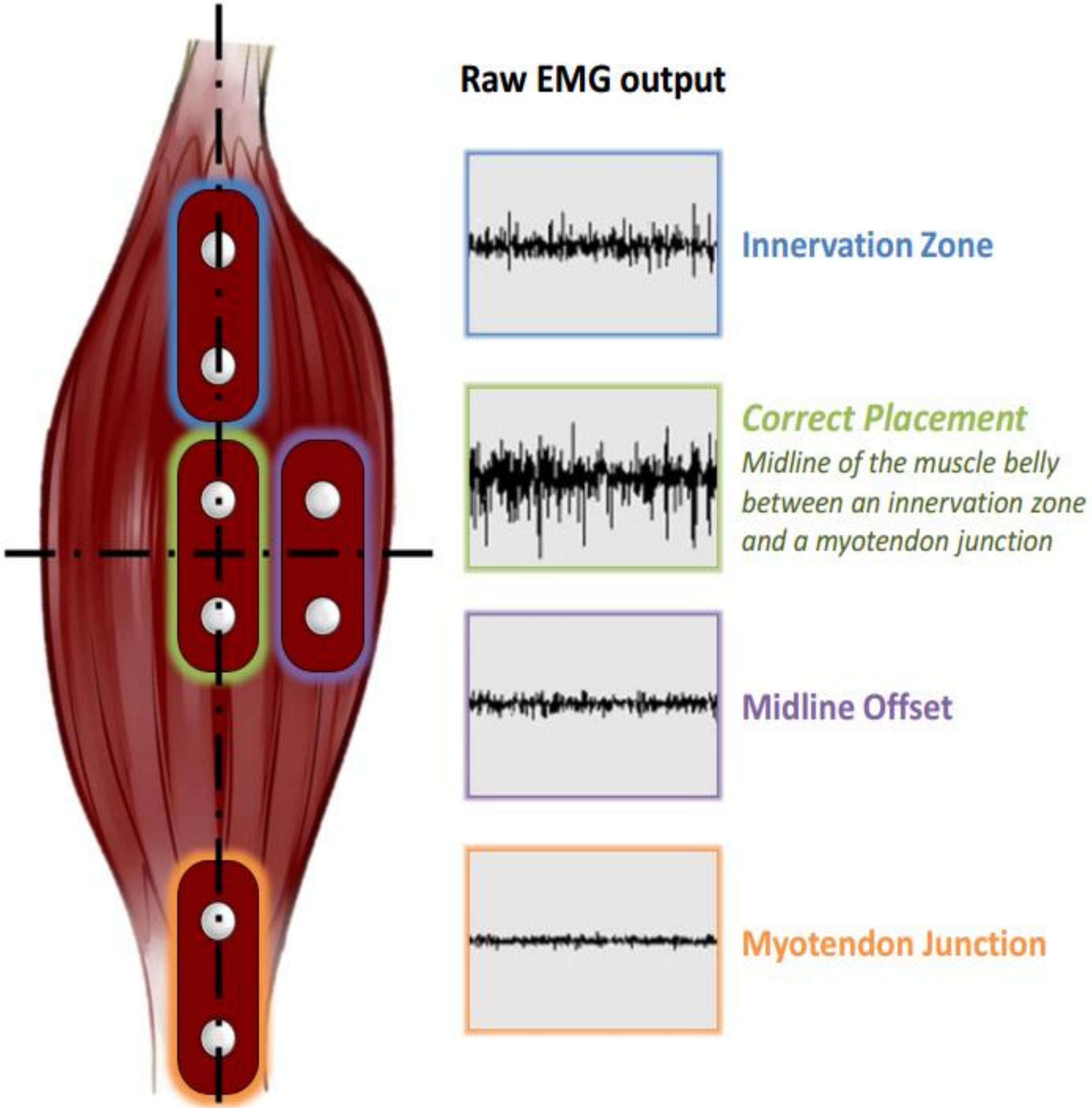
Dry EMG electrodes

- **Overview of muscle architecture**
- Skeletal muscle architecture is defined in terms of "the arrangement of muscle fibers relative to the axis of force generation." The skeletal muscle arrangement as well as their activity reveals striking organization at the macroscopic level.
- The functional properties of the skeletal muscle depend strongly on their architecture.



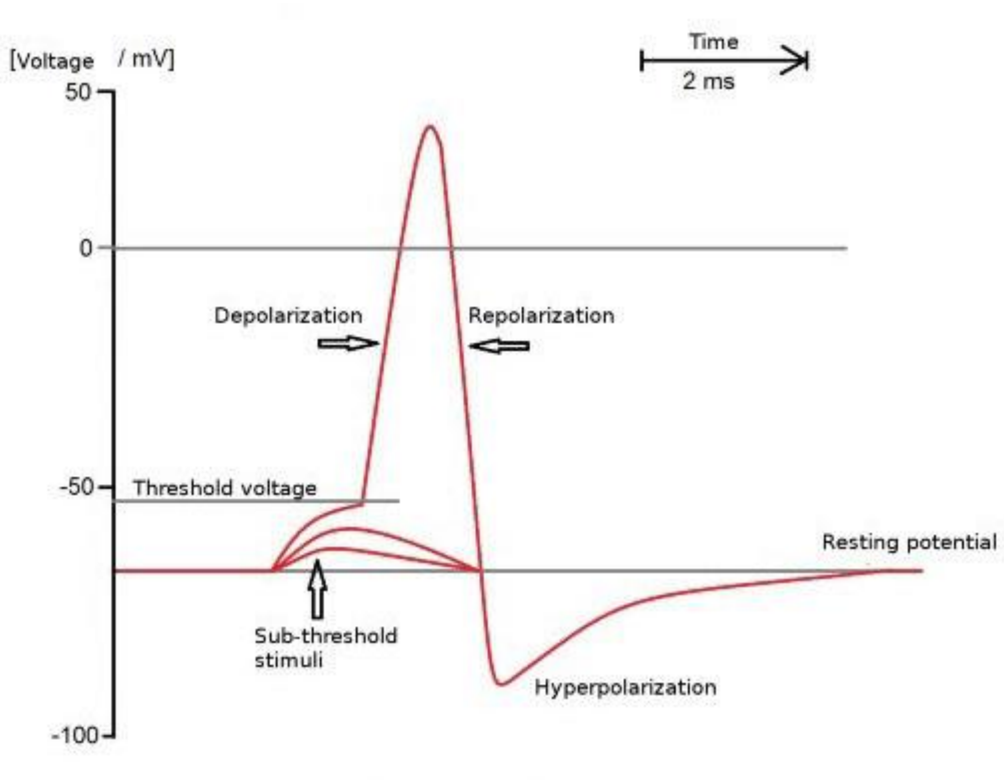
# EMG electrode placement

- Position and orientation of the muscle sensor electrodes has a vast effect on the strength of the signal.
- The electrodes should be place in the middle of the muscle body and should be aligned with the orientation of the muscle fibers.
- Placing the sensor in other locations will reduce the strength and quality of the sensor's signal due to a reduction of the number of motor units measured and interference attributed to crosstalk.

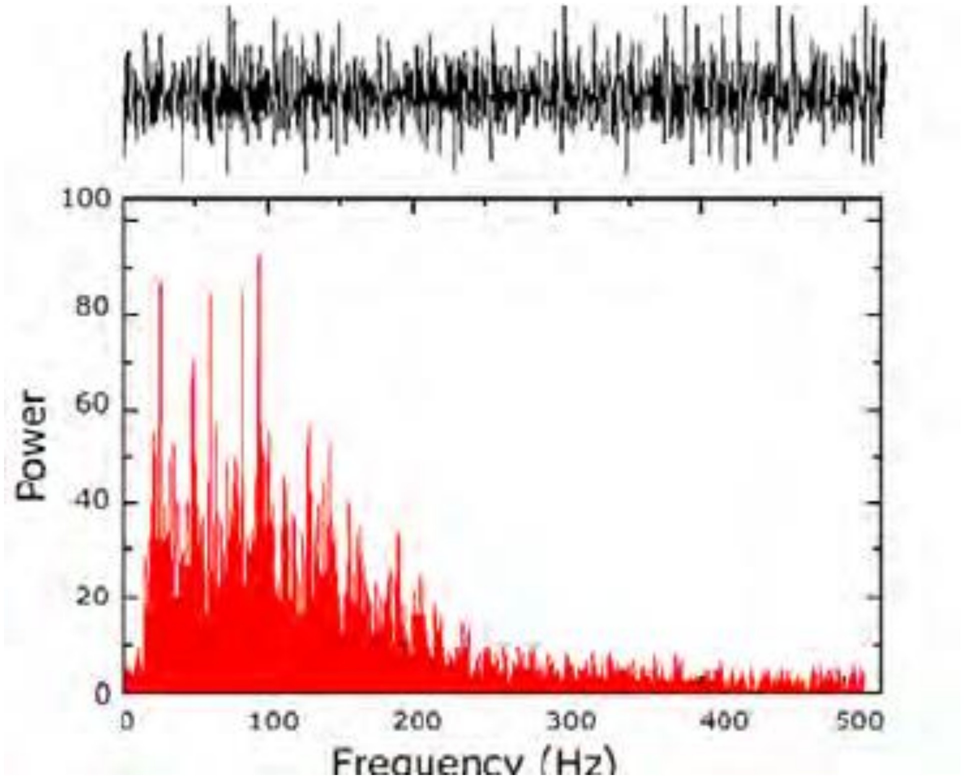


# Normal Rang For EMG Signal

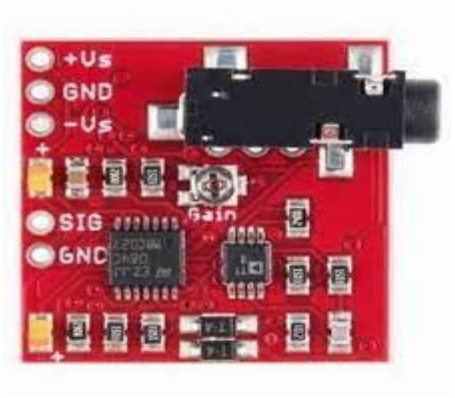
The EMG signal's amplitude lies in between 1-10 mV, making it a considerably weak signal. The signal lies in the frequency range from **0-500 Hz** and most dominant in between 50-150 Hz.



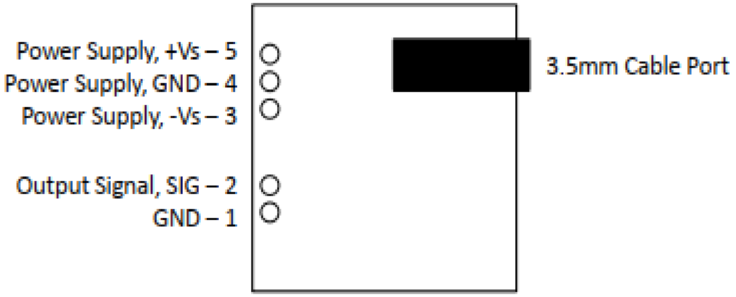

Action potential



- **MyoWare™ AD8226-based EMG sensor**

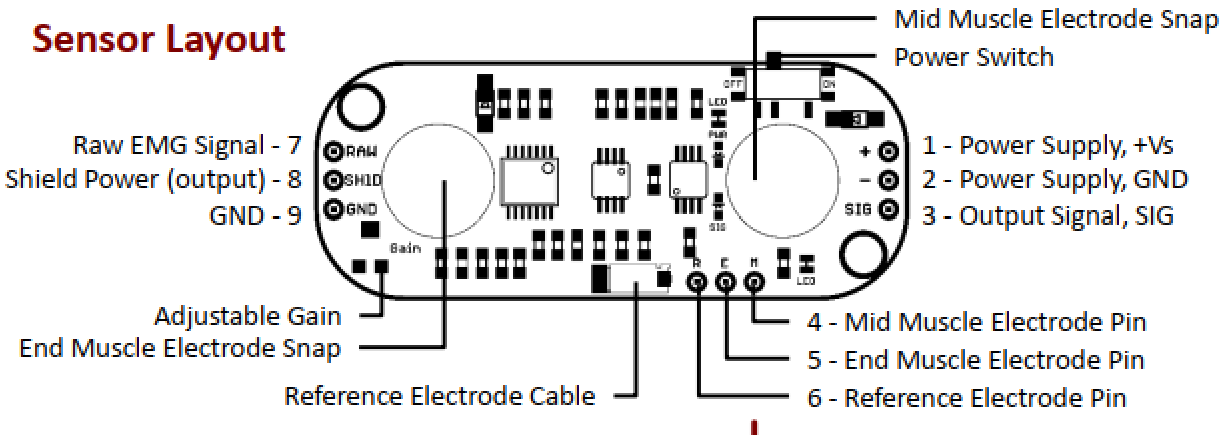



PIN LAYOUT




- **MyoWare™ Muscle Sensor (AT-04-001)**


Sensor Layout



# Designing an Arduino-based EMG monitor

- Beside that the EMG sensor utilize for diagnosis , it also used in muscle controlled electronic applications such as for controlling a servo motor or robotic arm by using muscle-like movements.
- An EMG sensor use to plot an EMG graph with the help of Arduino. It is an instrumentation amplifier that's widely used to design sensors. It provides gains from 1 to 1000. It's also widely used in medical instrumentations, bridge amplifiers, industrial process control, and portable data-acquisition systems.
- The EMG sensor can be used to measure the activation of any group of muscles, including biceps, quads, calves, etc.

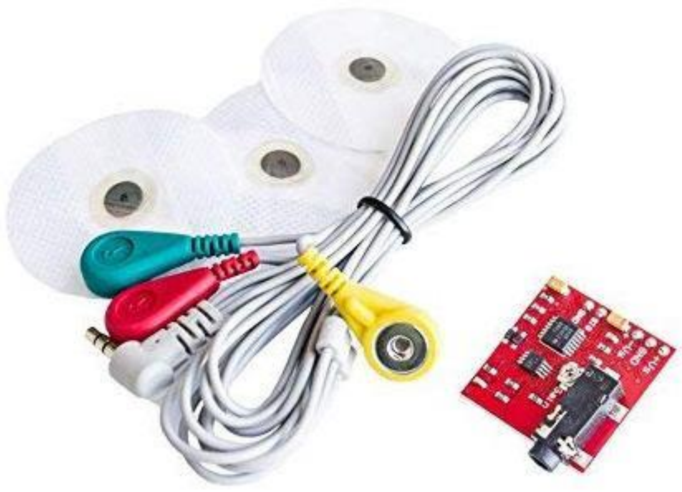
# EMG Muscular Signal Sensor

In medical research, measuring the activity, contraction and expansion of muscles is important. The EMG muscle sensor measures the muscle activity and produces a signal to show the amount of expansion and contraction. Therefore, the output depends on the amount of activity in the selected muscle.

Three Green, red and yellow electrodes connect to the module for transmitting electrical signals from the muscle motion.

## Features:

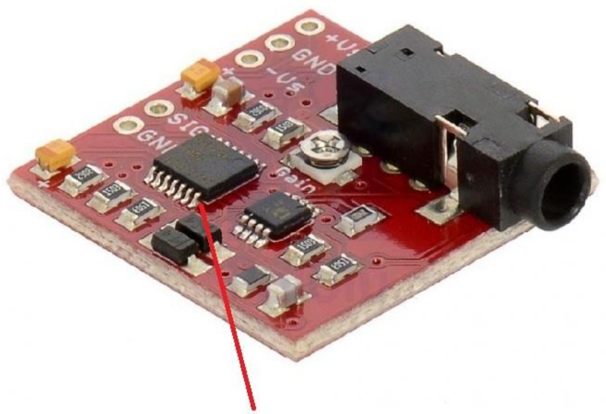
- Small Form Factor
- Specially Designed for Microcontrollers
- Adjustable Gain using onboard potentiometer
- 5mm Connector



## Applications:

- Video games
- Robotics /Medical equipment
- Wearable/Mobile Electronics
- Powered Exoskeleton suits

- The board is powered by DC voltage that ranges from +/-3.5 to +/-18V. The output signal voltage can range to 0V.
- The sensor board uses an AD8226 instrumentation amplifier. It requires only one external resistor to set the gain from 1 to 1000. The amplifier operates on supplies, ranging between +/-1.35 to +/-18V (for dual supplies) and 2.2 to 36V (for a single supply).
- It's can also handle voltages beyond its rail-to-rail voltage. For example, even with a 5V supply, the IC can withstand up to +/-35V.



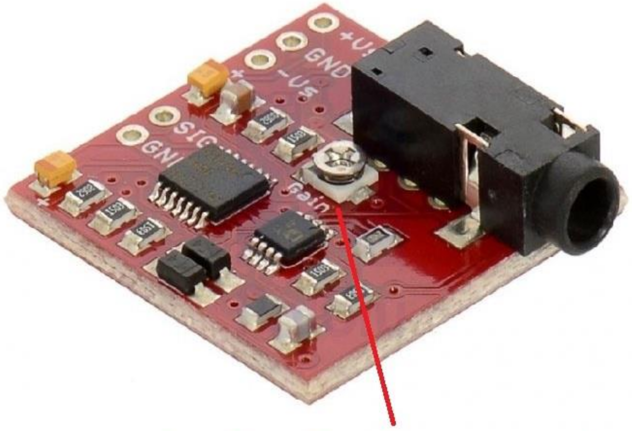

AD8226 Instrumentation Amplifier

# Adjusting the gain

- **The default gain setting should be appropriate for most applications.**

  To adjust the gain, locate the gain potentiometer in the lower left corner of the sensor marked as “GAIN”. Using a Phillips screwdriver, turn the potentiometer counterclockwise to increase the output gain; turn the potentiometer clockwise to reduce the gain.

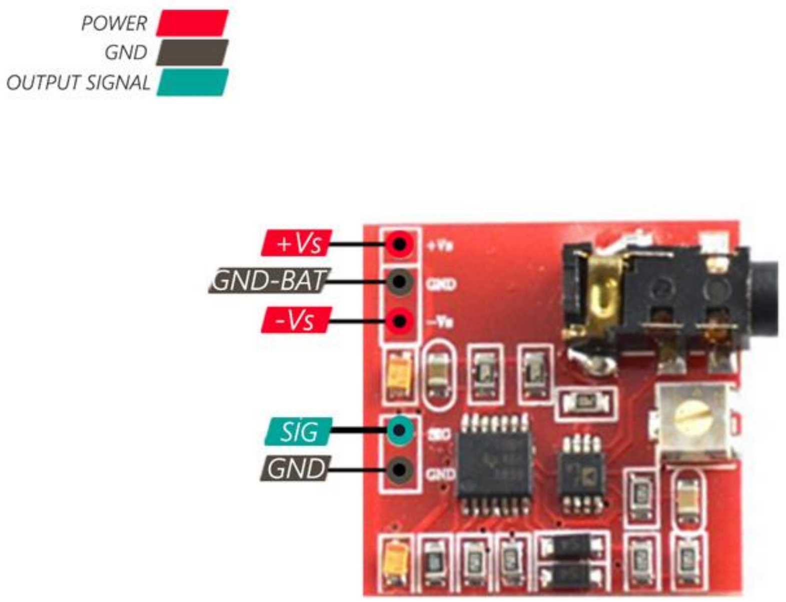
- The sensor’s gain can be changed using an onboard potentiometer, which can be adjusted between 0.002 for 0.01Ω to 20,700 for 100KΩ on the pot. The output differential signal can vary from 0mV to the supply voltage/gain.

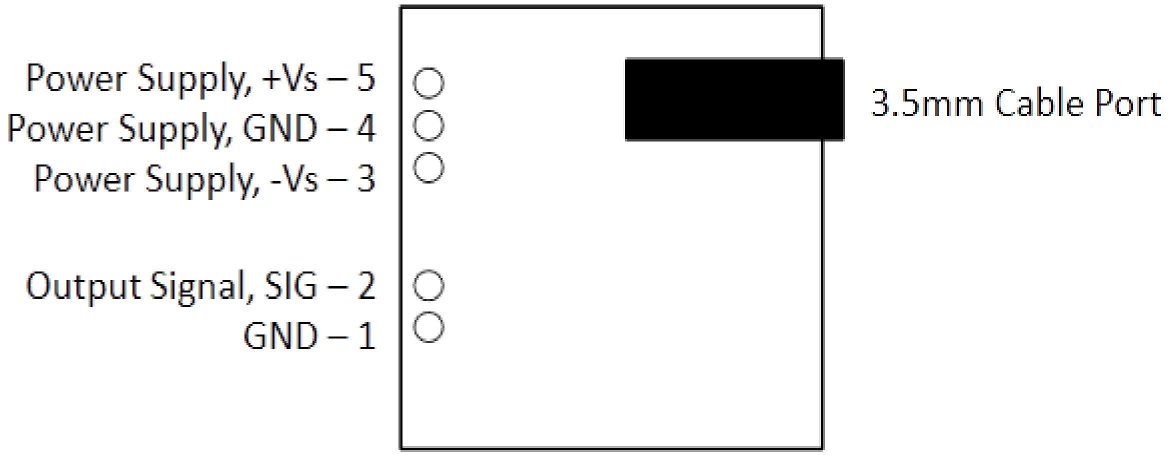



Pot for adjusting sensor gain

# Setup Configurations

- The EMG device is a 3-lead differential muscle/electromyography sensor. It comes with an onboard, 3.5mm cable port that can be used to attach regular EMG/ECG electrodes.
- The sensor board has this pin configuration:



# Setup Instructions

- Thoroughly clean the intended area with soap to remove dirt and oil
- Snap electrodes to the sensor's snap connectors

  **Note**: While you can snap the sensor to the electrodes after they've been placed on the muscle, we do not recommend doing so due to the possibility of excessive force being applied and bruising the skin.)

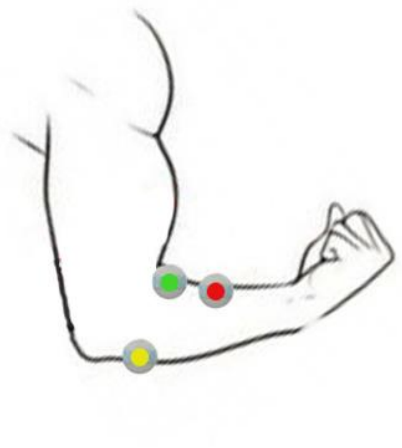
- Place the sensor on the desired muscle
  - After determining which muscle group you want to target (e.g. bicep, forearm, calf), clean the skin thoroughly
  - Place the sensor so one of the connected electrodes is in the middle of the muscle body. The other electrode should line up in the direction of the muscle length
  - Peel off the backs of the electrodes to expose the adhesive and apply them to the skin
  - Place the reference electrode on a bony or nonadjacent muscular part of your body near the targeted muscle
- Connect to a development board (e.g. Arduino, RaspberryPi), microcontroller.

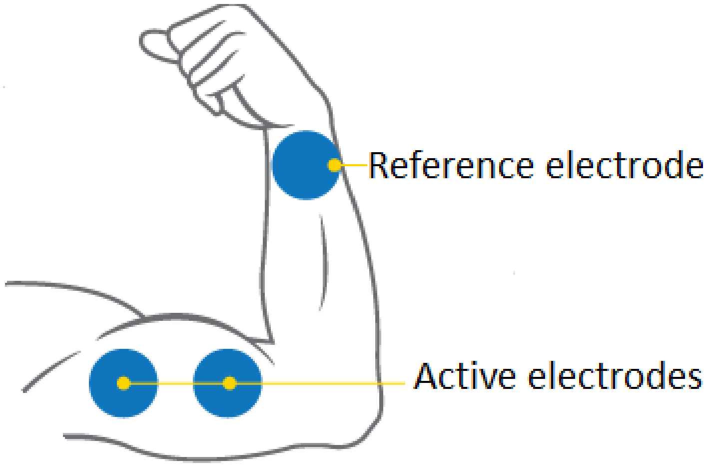
# Electrodes Setup Instructions

**Middle Connect (green electrode),** this pad to the cable leading to an electrode placed in the middle of the muscle body.

**End Connect (red electrode),** this to the cable leading to an electrode placed adjacent to the middle electrode towards the end of the muscle body.

**Ref Connect (yellow),** this to the reference electrode. The reference electrode should be placed on an separate section of the body, such as the bony portion of the elbow or a nonadjacent muscle





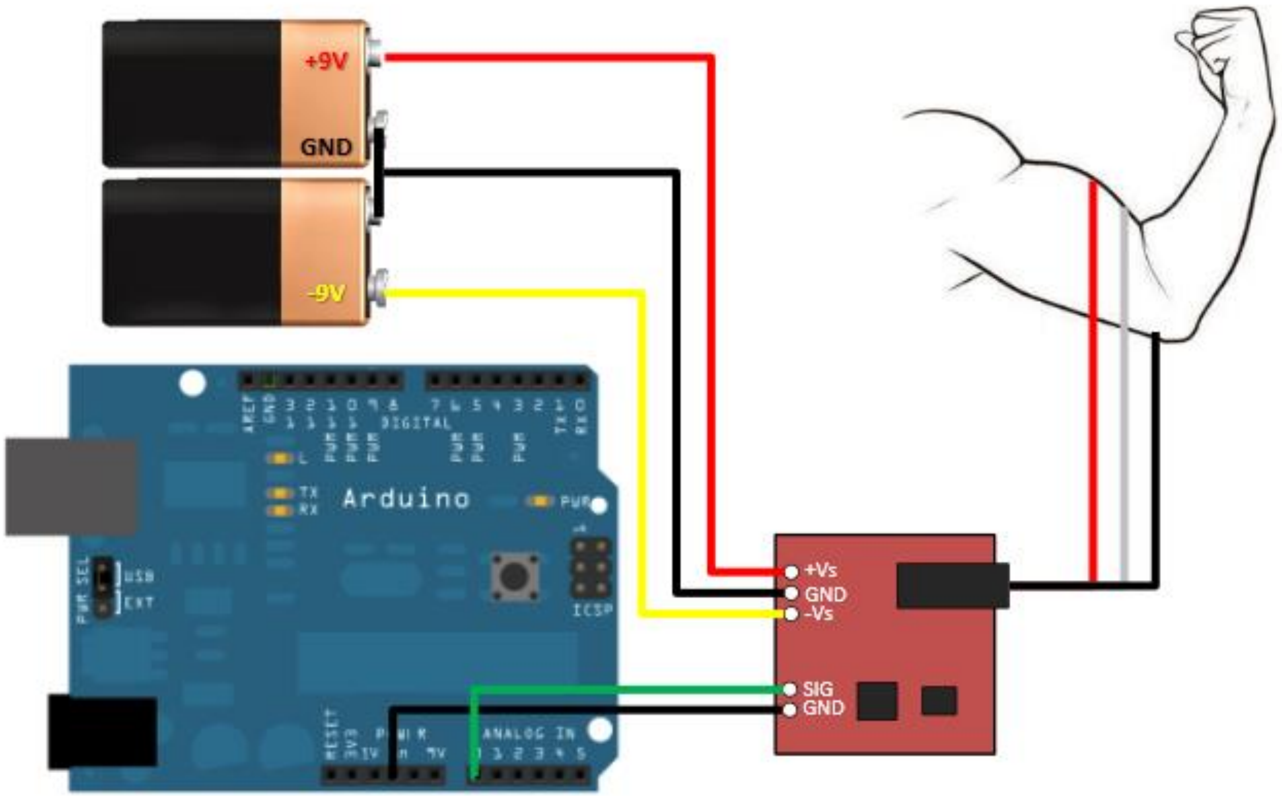
# Getting Started Using Two 9V Batteries

1) Connect the power supply (two 9V batteries)

a. Connect the positive terminal of the first 9V battery to the +Vs pin on your sensor.

b. Connect the negative terminal of the first 9V battery to the positive terminal of the second 9V battery. Then connect to the GND pin on your sensor.

c. Connect the negative terminal of the second 9V battery to the –Vs pin of your sensor.



## 2) Connect the electrodes

a. After determining which muscle group you want to target (e.g. bicep, forearm, calf), clean the skin thoroughly.

b. Place one electrode in the middle of the muscle body, connect this electrode to the RED Cable’s snap connector.

c. Place a second electrode at one end of the muscle body, connect this electrode to the Blue Cable’s snap connector.

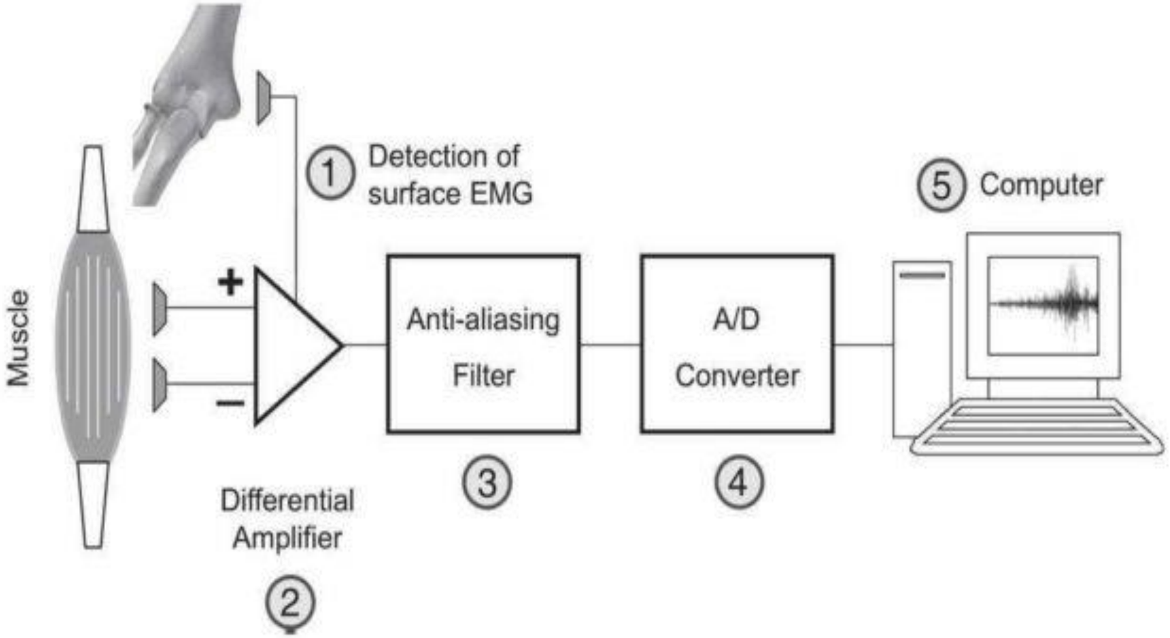
d. Place a third electrode on a bony or non-muscular part of your body near the targeted muscle, connect this electrode to the Black Cable’s snap connector.

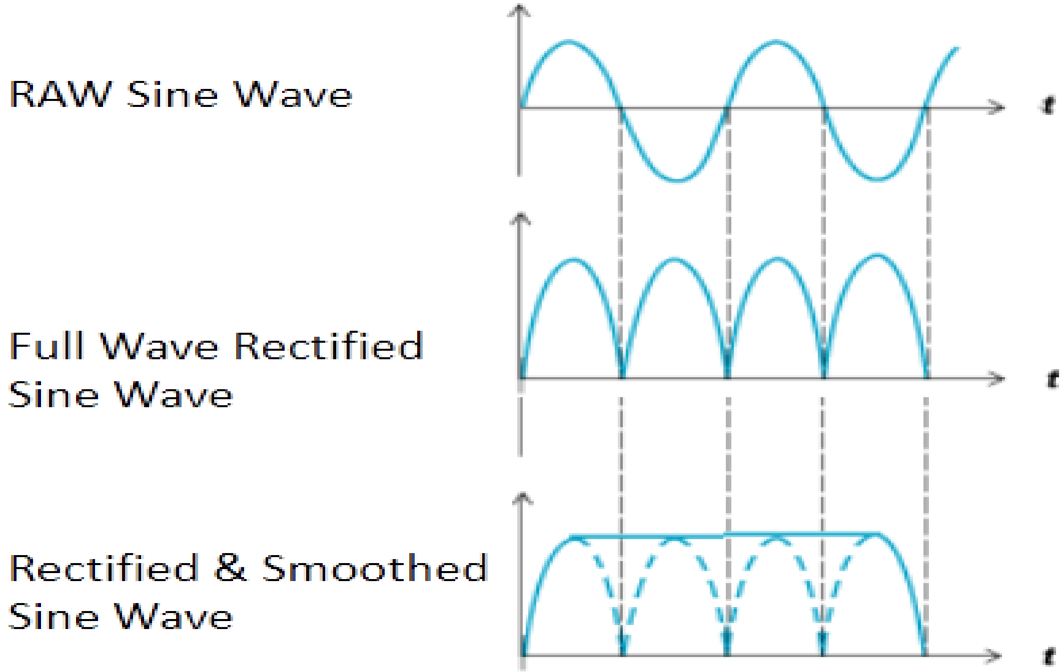
## 3) Connect to a Microcontroller (e.g. Arduino)

a. Connect the SIG pin of the sensor to an analog pin on the Arduino (e.g. A0)

b. Connect the GND pin of the sensor to a GND pin on the Arduino.

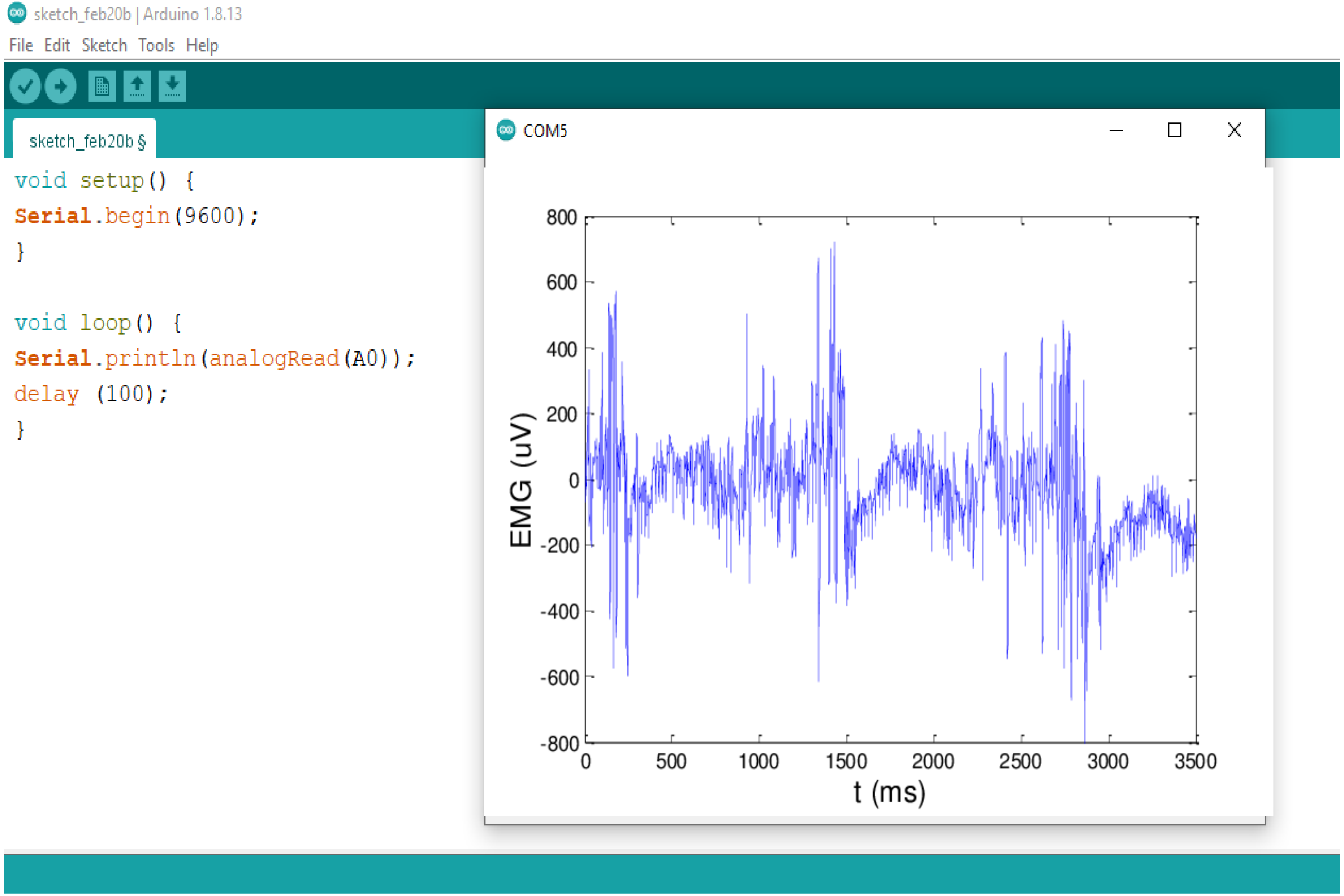
The sensor is ideal for use with microcontrollers. Unlike industry-grade medical sensors, however, it does not output raw EMG signals. Rather, an amplified, rectified, and smooth signal is delivered that can be read at Arduino’s analog input pin (or any other microcontroller).



# Arduino sketch

```
/*
 EMG-Muscular-Signal-Sensor
*/
void setup() {
Serial.begin(9600);
}
void loop() {
Serial.println(analogRead(A0));
}
```



# Arduino sketch

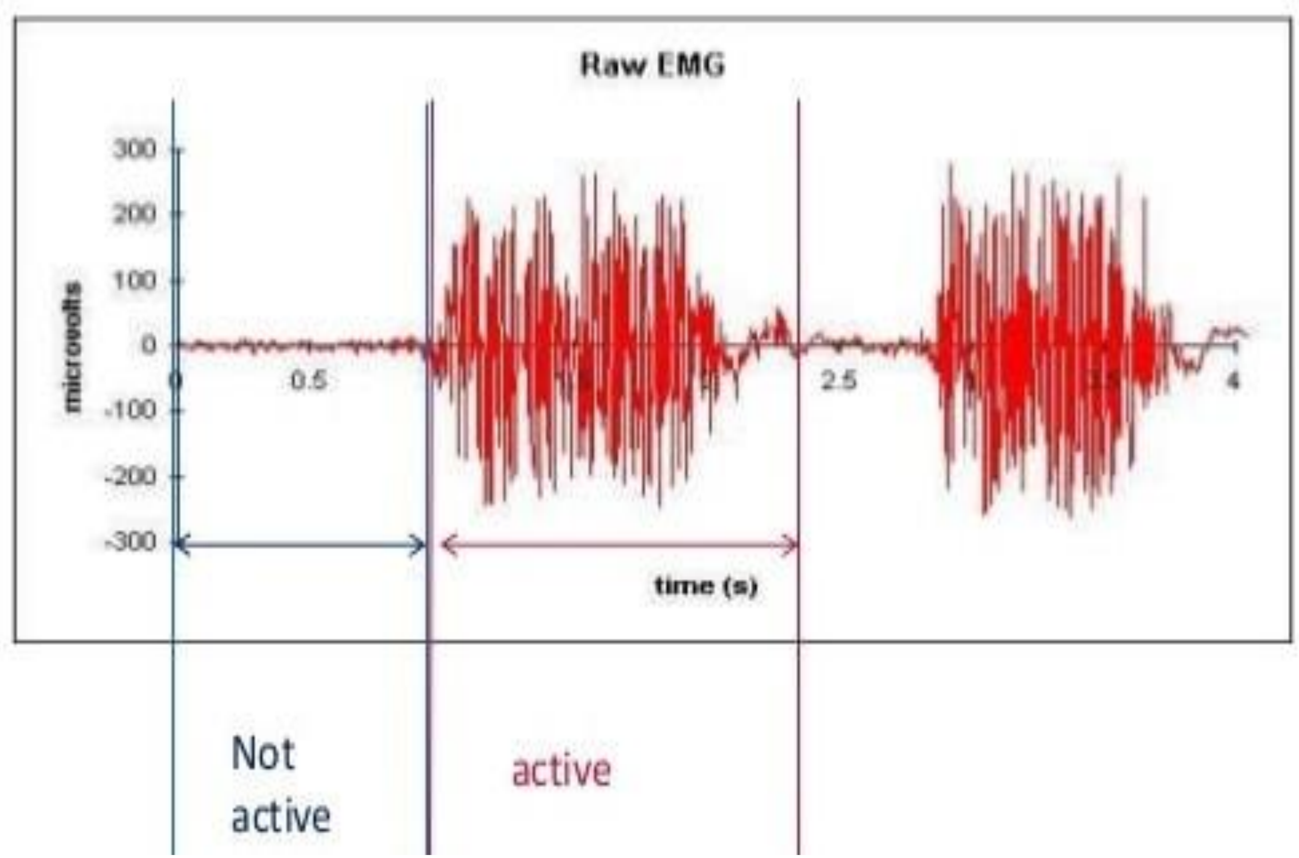
```
int EMGPin = A1;
int EMGVal = 0;


void setup()
{
Serial.begin(115200);
}


void loop()
{
EMGVal = analogRead(EMGPin);
Serial.println(EMGVal);
}
```

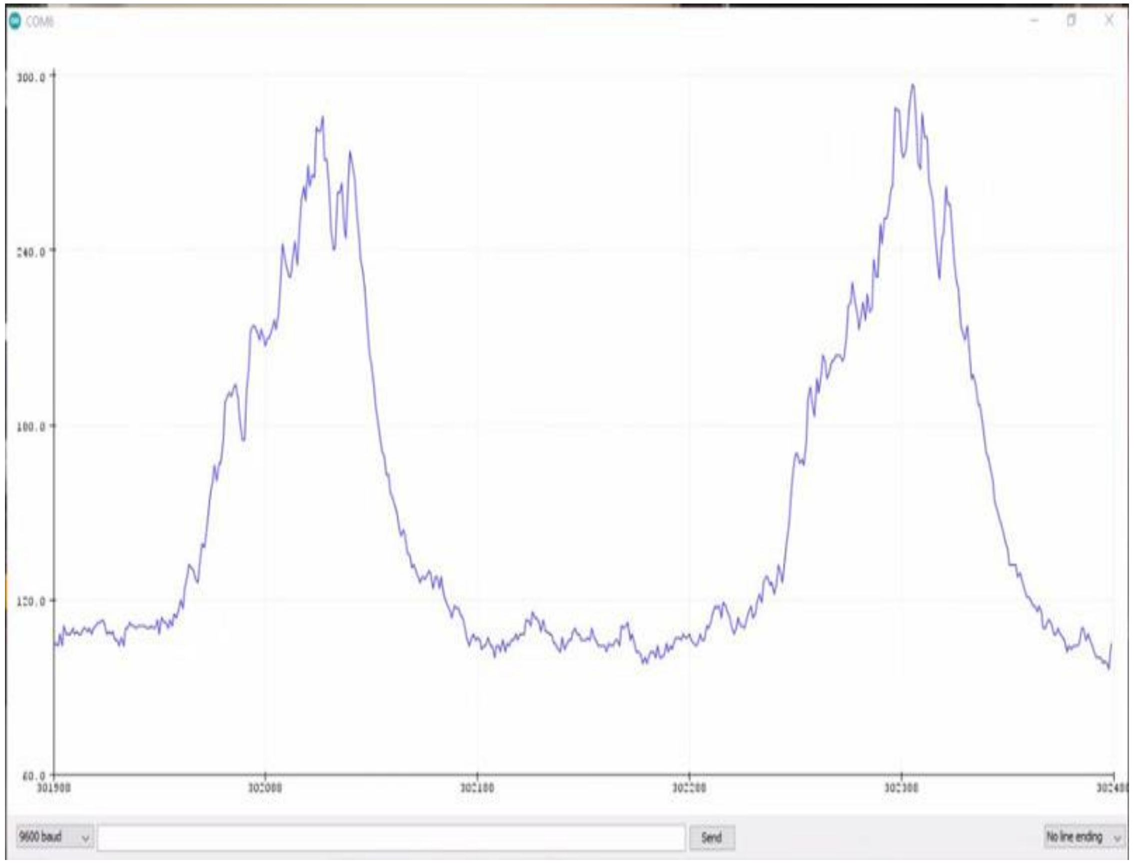
**The code:**

- The sketch begins by assigning A1 as the pin to read the EMG sensor's analog signals.
- A variable 'EMGVal' is declared to store the analog values that are received from the sensor.
- In the setup() function, the baud rate for serial communication is set to 115200 to get more data.
- In the loop() function, the sensor's analog voltages are read and stored in the 'EMGVal' variable.
- The analog readings are printed to the serial port, where they can be monitored on Arduino IDE's serial monitor or serial plotter.

## The results

- To observe the changes in analog output signal of the module as the forearm muscle expands and contracts. To do this, open the Serial Plotter and see the output signal.
- The image below shows the output changes.



# Groups and Projects

1. Make Robotic figure using Arduino

2. Aid for Visually Impaired- Haptic Feedback

3. Forehead Non- contact Temperature Gun for Covid-19

4. Pulse Oximeter for COVID-19

5. Real-Time Breath Monitoring system

6. IOT Based EMG Monitoring Using Nodemcu

7. CT and 3D Scanner based Arduino