# EMG-Based Human Machine Interface System

Senior Project Proposal

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12/07/2016

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## 1. Introduction

Electromyogram (EMG) signals are generated by muscles when activated by the nervous system which generates electric potential. Surface EMG electrodes (sEMG) assess muscle function by reading the muscle activity from the surface above the desired muscle. Another technique, intramuscular, can be used for reading these type of muscle signals. A fine needle is inserted into the muscle of the subject to measure the generated electric potential. Intramuscular technique is used in research and kinesiology predominantly. EMG signals can be useful for developing systems that can help the disabled by developing prosthetics. The medical field has benefited from intensive research in EMG signal analysis in the past couple decades. This research has improved the ability of living for those with psychomotor skill disabilities.

This project aims to develop an EMG-based human machine interface system which is used for in home assistance for disabled people. A wearable WiFi board and sensor board is used to record sEMG signals and send out wireless control commands. A wheeled robot is controlled wirelessly and equipped with feedback vision system. The video monitoring system assists the user for navigation of the robot. The system has potential applications in improving the quality of life for those with physical disabilities.

## 2. Standards and Patents

**Standards:** All wires and soldering are done with care so there are no shorts in the circuitry and all wires are covered to ensure that there is no chance of electrocution. Also all connections to power are secured for the safety of the user. The EMG pads are put on the sensor when it is not attached to the skin to avoid bruising. All testing will also be done only on people who are working directly with this project to ensure that there is no outside human testing done that could be hazardous. The mobile platform also does not reach a speed at which it can cause any damage to the user or the system. Finally there are no hazardous materials or chemicals used in this project that could cause physical hard or endanger someone's safety

## 3. System Block Diagram, Specifications and Subsystems

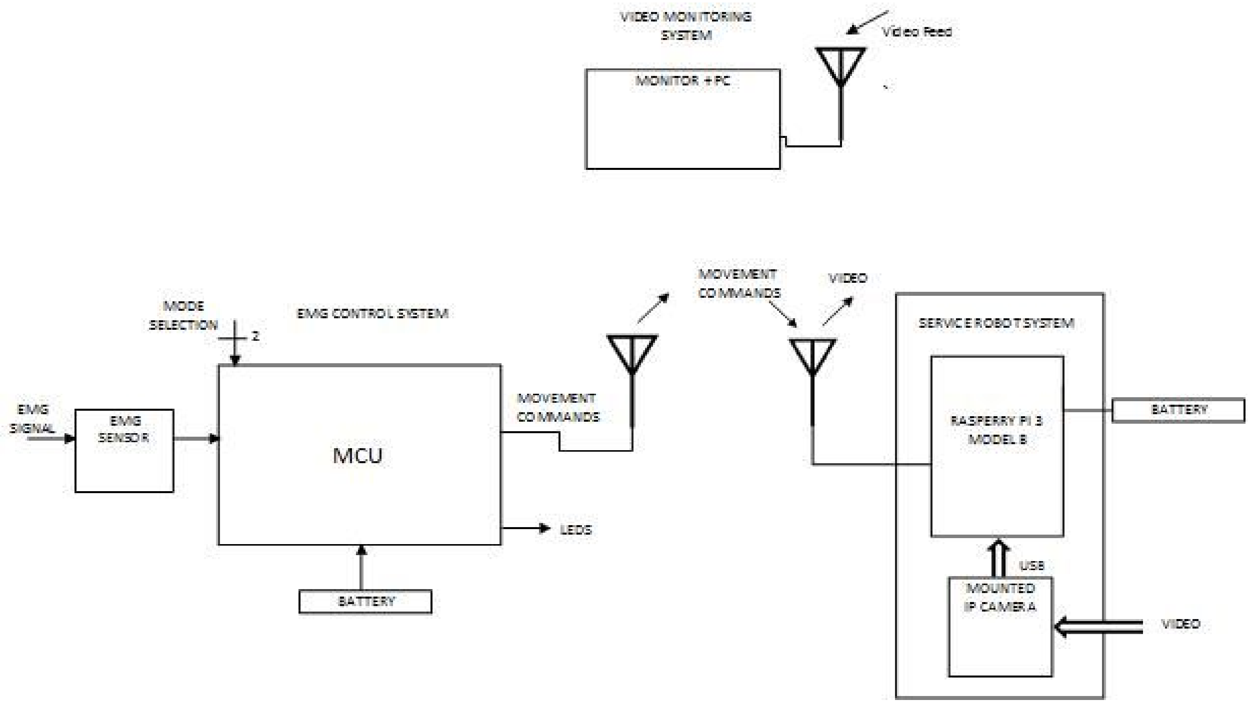



Figure 1. System Block Diagram

Figure 1 displays the project's system block diagram. The system includes three subsystems. They are EMG control subsystem, service robot subsystem, and video monitoring subsystem. Communication within subsystems will be through Wifi.

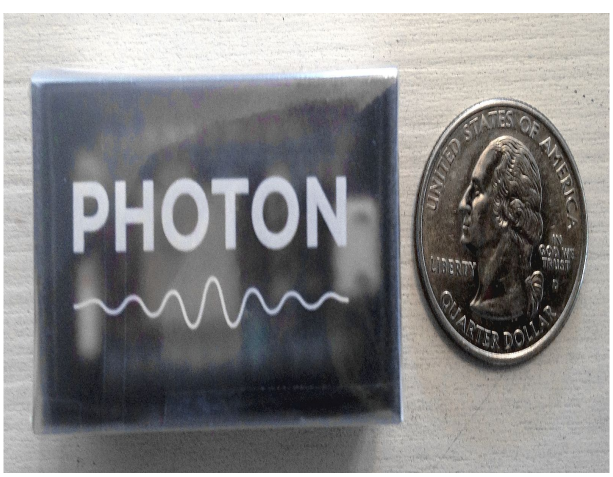



Figure 2. Size of Particle Photon

Figure 3. MyoWare Sensor Board [2]

While researching similar projects there were many that utilize small microcontrollers however larger muscle sensor board which prevented the subsystem to be wearable. The Particle Photon along with the Myoware Muscle Sensor board ensured that the EMG control subsystem would be wearable for the user with the least amount of space taken up on the arm. Figure 2 shows a comparison of size between a microcontroller and a quarter. Along with the perfect size for this project it also has the software required to make this project successful. It has an on board WiFi module with data transfer rate of 65 Mbits/s. The board also has a 12 bit analog-to-digital ADC converter with a 30 MHz serial clock.

## 3.1 EMG Control Subsystem

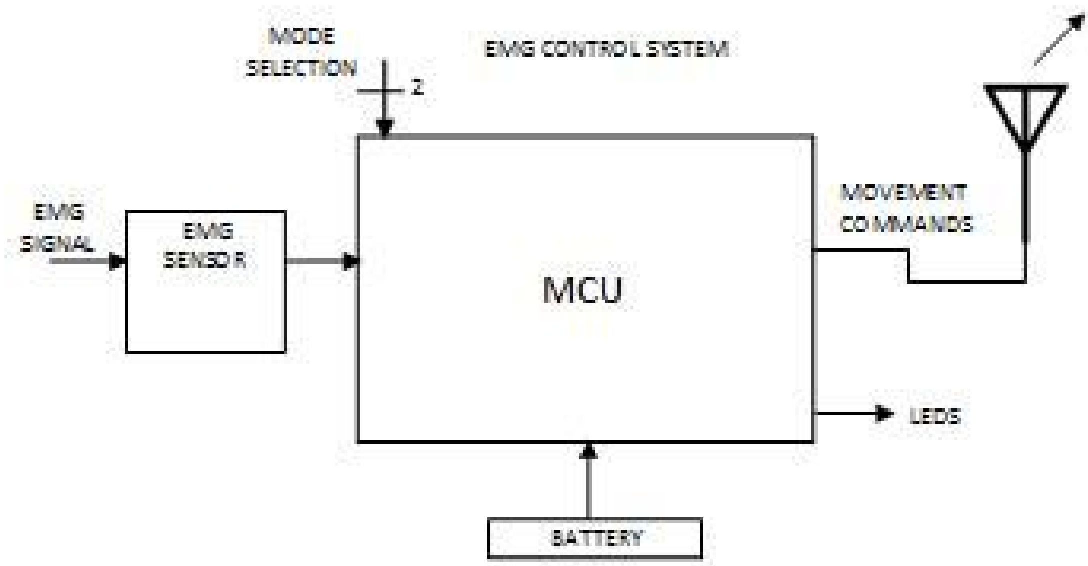



Figure 4. EMG Control Subsystem

In the EMG control subsystem, a low-cost embedded system acquires EMG signals generated by the user's physiological muscle fibers.The subsystem will then determine what movement the user is doing and categorize these into commands, which include f*orward, left turn, right turn* and *halt.* The commands are sent out through wireless communication to remotely control a service robot. For system status information the subsystem's data will be sent to the video monitoring system. This subsystem will be powered by a battery source which will also power the muscle sensor board

1. Inputs
    a. EMG signals from muscle sensors
    b. Mode selection switch
    c. Power switch (ON/OFF)
    d. Power source from Particle Photon

2. Outputs
    a. Movement commands
    b. System status information

## 3.2 Service Robot Subsystem

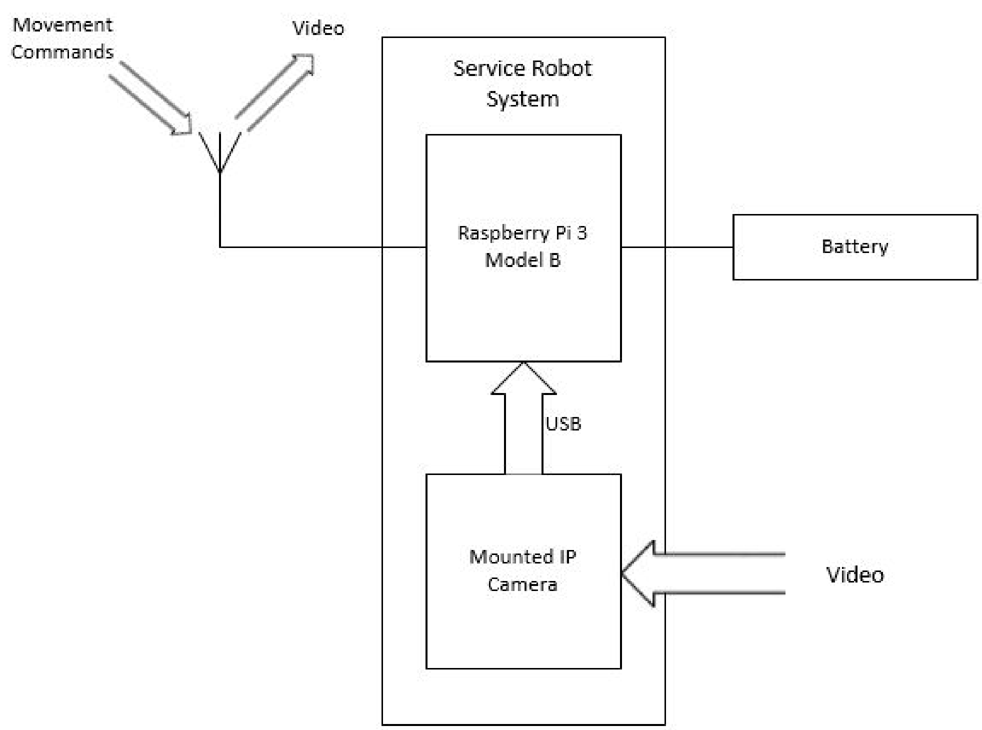



Figure 5. Service Robot Subsystem

In the service robot system, an embedded system will be mounted on the wheel robot to able to communicate and receive one of four commands from the EMG control system. Once the commands are received the service robot will generate pwm signals for motor control. The subsystem will have one set speed for the service robot. In addition, the service robot system will also be equipped with a web camera for navigational purposes for the user. The video monitoring system will access the video feed from the web camera via internet which will help the user better control the robot within their homes. The service robot system will have LEDs that will indicate system status information such as diagnostics codes and commands received. The embedded system will be powered by a battery pack while the wheel robot itself will have its own rechargeable battery system.

Note: Collision avoidance of the robot is not considered in this project.

1. Inputs
    a. Movement commands from the EMG control system
    b. Video feed from Logitech Webcam
    c. Power switch (ON/OFF)
    d. Power source battery expansion pack

2. Outputs
    a. Video feed transmitted through internet to the video monitoring system
    b. PWM signals

## 3.3 Video Monitoring Subsystem

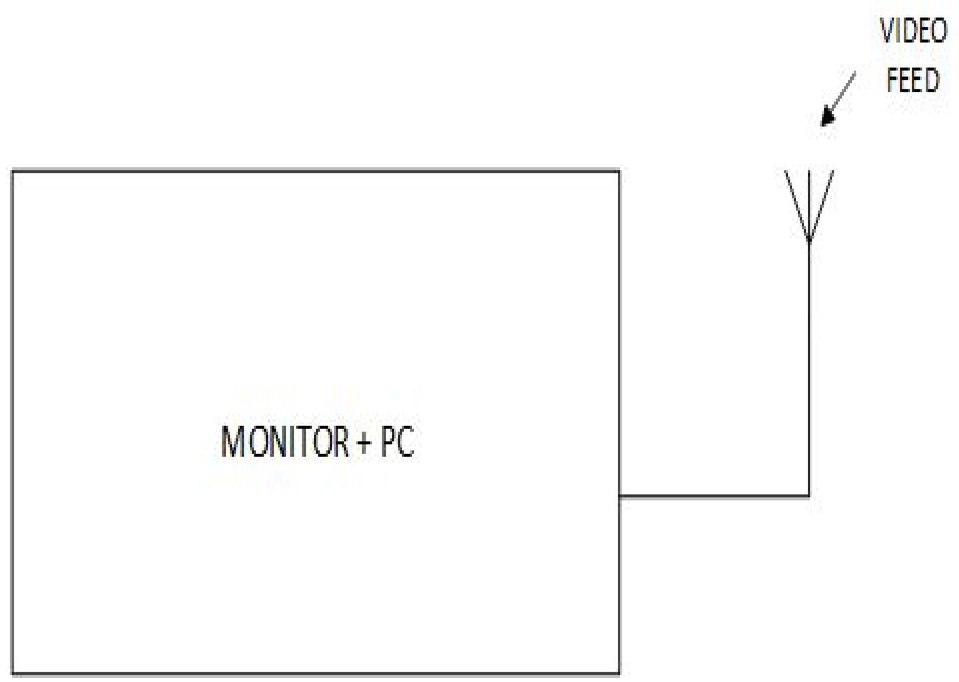



Figure 6. Video Monitoring Subsystem

The video monitoring system will help the user with robot navigation. The subsystem receives live video feed from a webcam sent from the service robot platform via wifi. The video will then be displayed onto a monitor. This subsystem will also display mode selection options for the user along with system diagnostics of the EMG control subsystem.

1. Inputs
   a. Video feed
   b. Power switch (ON/OFF)

2. Outputs
   a. Video (monitor display for the user)
   b. Mode of operation
   c. Diagnostics

# 4. Software and Network Flow Charts

## 4.1 Mode Selection

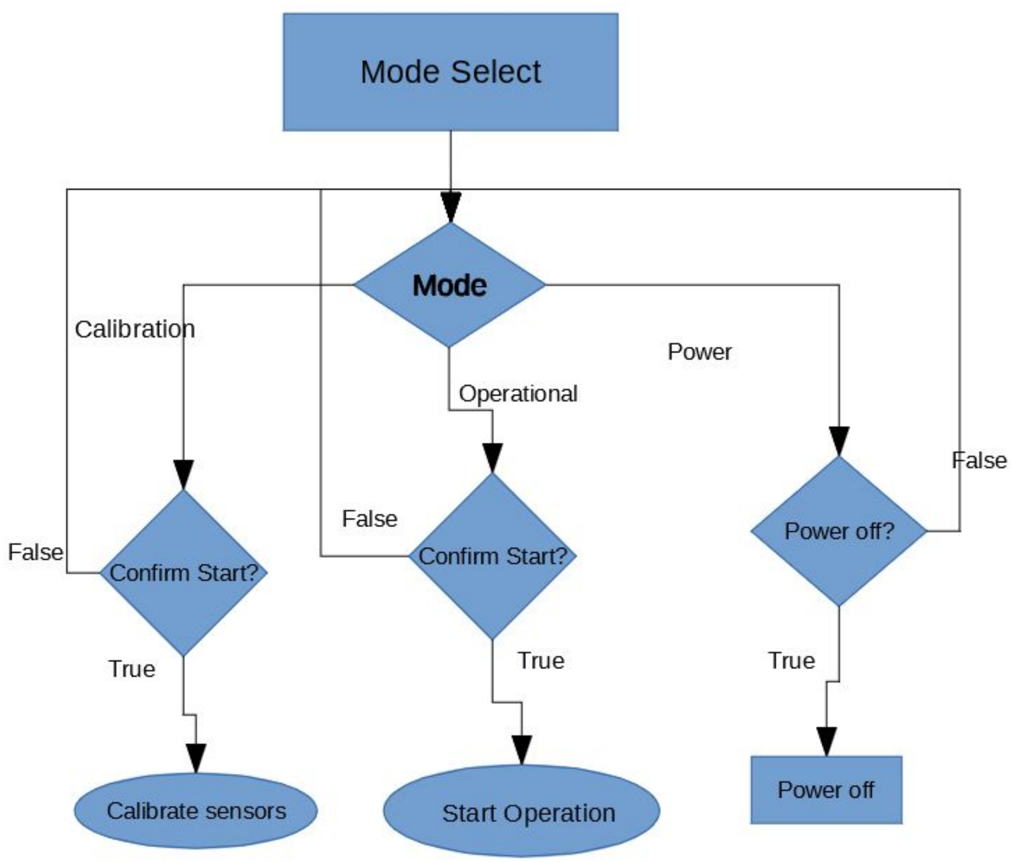



Figure 7. Mode Selection Flow Chart

**Mode Selection Description:**

The mode selection screen will be the basic menu and the user interface. There will be a monitor that will present the user with three different options: Calibration, Operational, and Power. The calibration and operational modes will serve as the two main modes of usage.

**Calibration:** The calibration mode is designed to get multiple samples of the user's actions and save them as commands so that the system will translate muscle movement to commands. First, the screen will prompt the user to do a physical motion, such as move a finger, to represent moving forward. The user will then complete this motion a few times to get a range of samples for that motion. After the first action is completed the system will then move onto the next command and movement and complete the process stated before. During the process of calibrating, if any errors occur, the system will alert the user then revert back to the original mode selection screen. Alternatively if a signal was not received or there was an issue with the sample the system will prompt the user to complete the action again so a valid sample can be collected. Once the system has cycled through every movement successfully and gathered enough data to operate, it will alert the user that the calibration has been complete. At this point the user will be able to select the operational mode.

**Operational:** The operational mode of the system is where the user is able to successfully tell the service robot what movements to make based on the EMG signals measured from the user's muscles. This mode can only be accessed once the calibration is complete. Calibration must be completed first because everyone is going to generate different EMG signals. In the operational mode the user's EMG recordings will have been optimized which will ensure that service robot moves properly.

**Overall:** At every point during this process there will be an option to exit the current mode and return to the mode selection screen on the video monitoring system. If the user choses to do so they will be asked to confirm if they wish to exit the current mode, this will assure that there will be no accidental exiting the operational or calibration modes. Also from the main mode selection screen there will be an option to power off the system so the user has a safe way to exit.

## 4.2 Wireless Communication Network

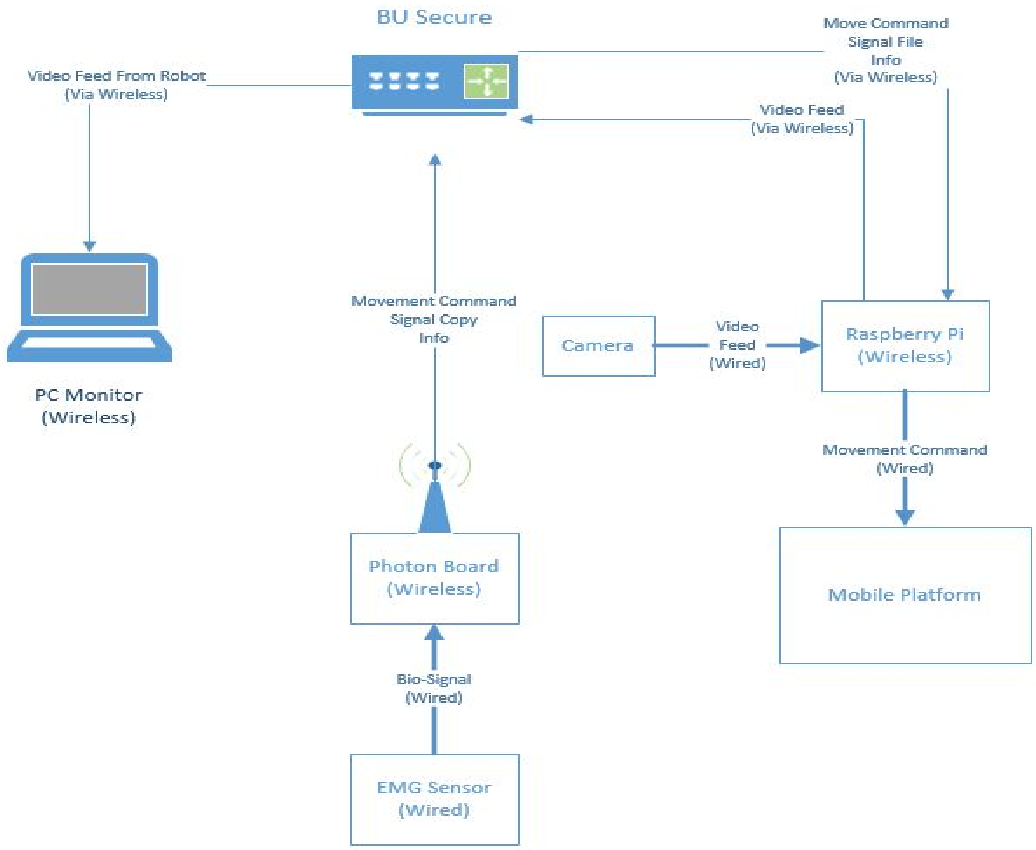



Figure 8. Wireless Communication Flow Chart

Above in figure 6 is pictured a flow chart for all the wireless communication used for this project. There are three components in this project that make up the communication network, Particle Photon, PC, and Raspberry Pi. All three components connect to Bradley University's network to communicate via WiFi.

## 5. Parts List

| Description | Quantity | Price($) | Price Ext. ($) |
|---|---|---|---|
| Particle Photon Wi-Fi Board | 1 | 20.19 | 20.19 |
| Multiple Function Sensor Development Tools MyoWare Muscle Sensor | 2 | 37.95 | 75.90 |
| Raspberry Pi 3 Model B Motherboard | 1 | 35.70 | 35.70 |
| 3M Red Dot Multi-Purpose Monitoring Electrode, Foam, 50/bg | 2 | 13.30 | 26.60 |
| Battery Packs Lithium Ion Battery 3.7v 2000mAh | 1 | 21.99 | 21.99 |
| Logitech C270 Laptop Webcam | 1 | 18.99 | 18.99 |
| Processor Accessories KIT eZDSP55XX battery PACK | 1 | 28.13 | 28.13 |
| Note: Freshman robot or existing robot platform is used as the service robot. | **Total** | | **227.50** |

Table 1. Bill of Materials

## 6. <u>Preliminary Results</u>

The preliminary results for the project so far has focused on configuring the position of the MyoWare sensor board's electrodes and analysis of the signal.

In order to determine where to place the sEMG electrodes there had to be extensive research in kinesiology. A thesis paper *RELATING FOREARM MUSCLE ELECTRICAL ACTIVITY TO FINGER FORCES* had an in depth research on placement of sEMG and how much electric potential each configuration produced.

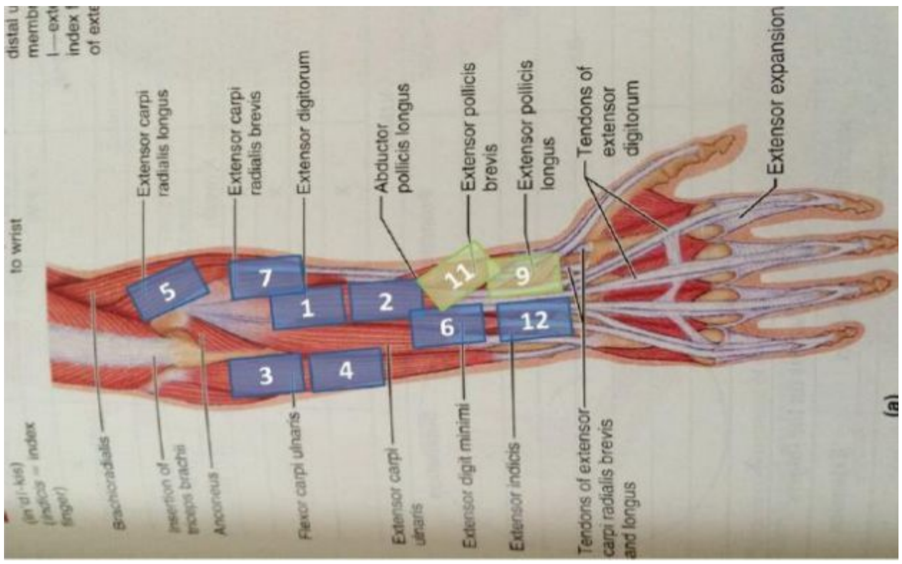
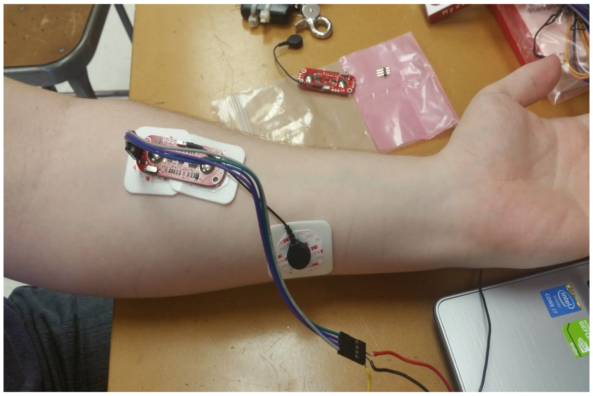


Figure 9. Placement of Electrodes [1]

As one can see there were twelve different placements of sEMG in figure 1. The thesis paper stated that she observed the most accurate results of EMG signals by placing sEMG electrodes on position one and two. These locations will be used for proper placement of muscle sensor board in this project.

In lab, the MyoWare sensor board has been placed in two different configurations focusing on changing the positioning of the reference electrode. As shown in figure 10 (configuration 1) the reference electrode is placed on the inner elbow while in figure 11 (configuration 2) the reference electrode is placed on the inner forearm. These positions were chosen for the reference electrode, because it is necessary to place the electrode on a non adjacent muscle to provide a clear and accurate signal.



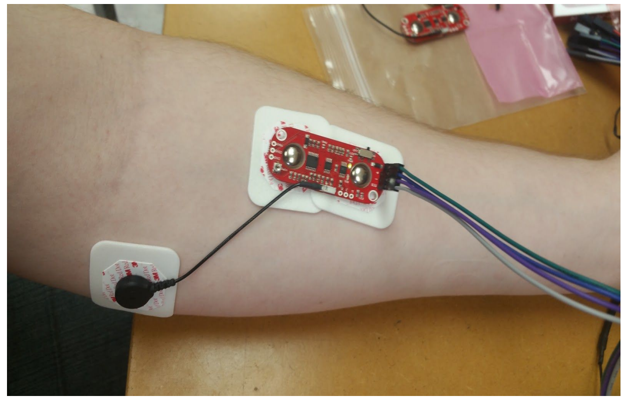


Figure 10. Myoware Sensor Configuration 1 Figure 11. Myoware Sensor Configuration 2

Based on lab results shown in the configuration 2 results, figures 13-16, the index finger and ring finger signals were shown to be too similar to distinguish the two, both within the range of .2 V. Therefore we have found configuration 1 better suited for our application.

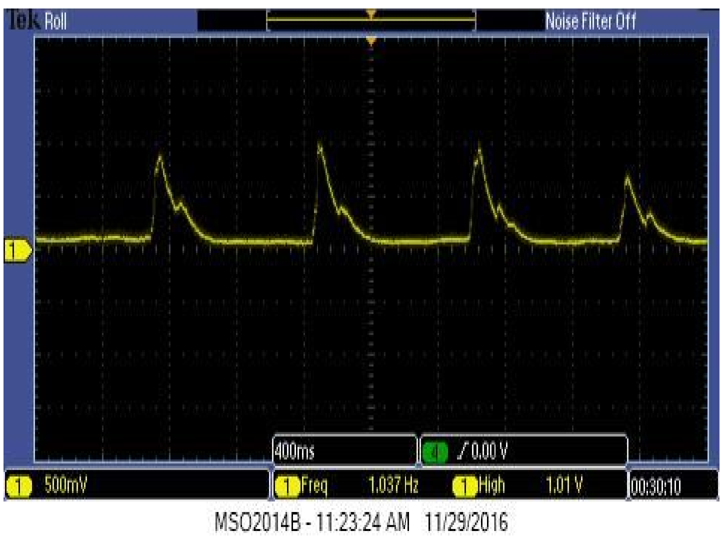



Figure 12. Configuration 1 Closed Fist-Stop

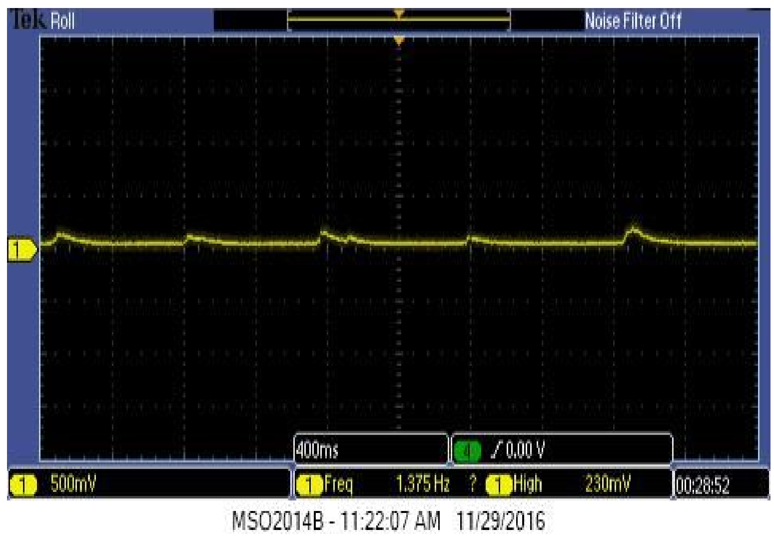
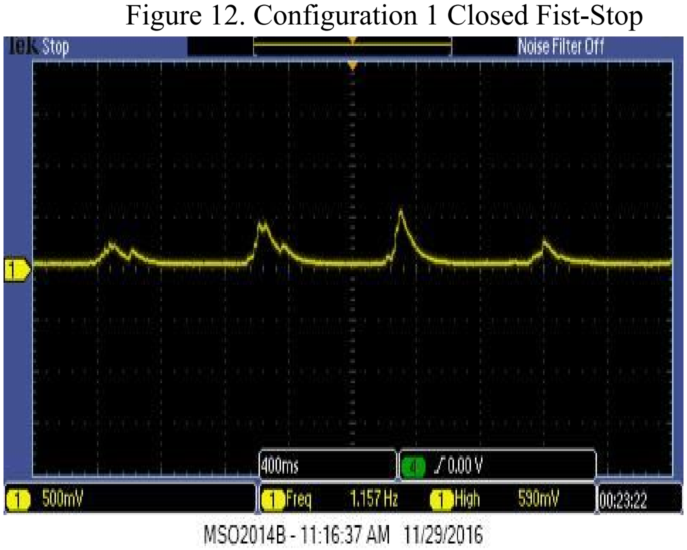



Figure 13. Configuration 1 Index Finger-Left



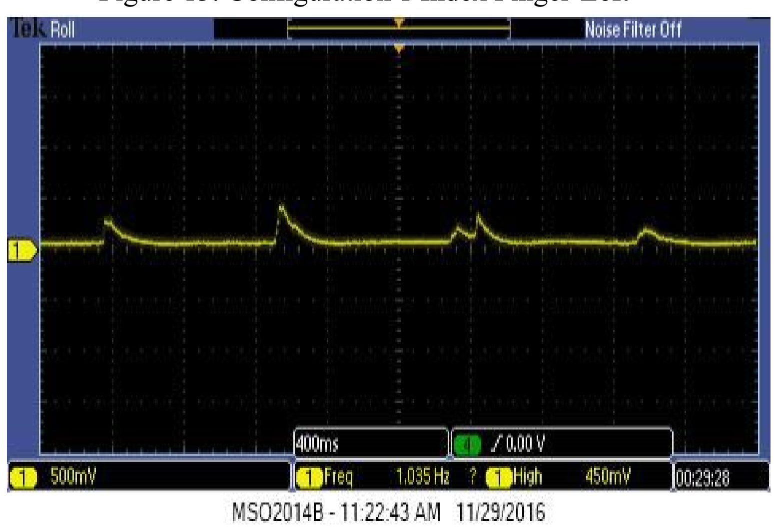
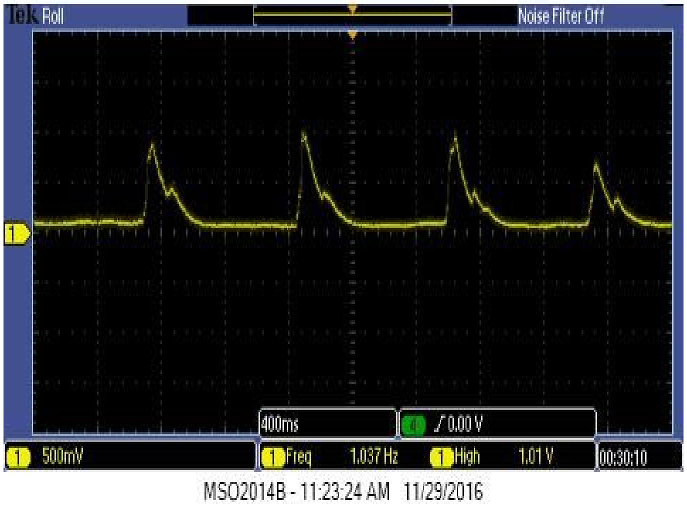



Figure 14. Configuration 1 Middle Finger-Forward

Figure 15. Configuration 1 Ring Finger-Right



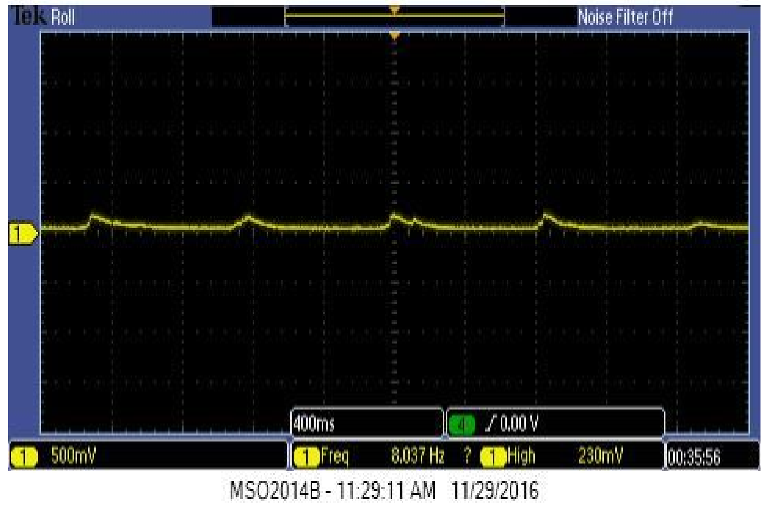
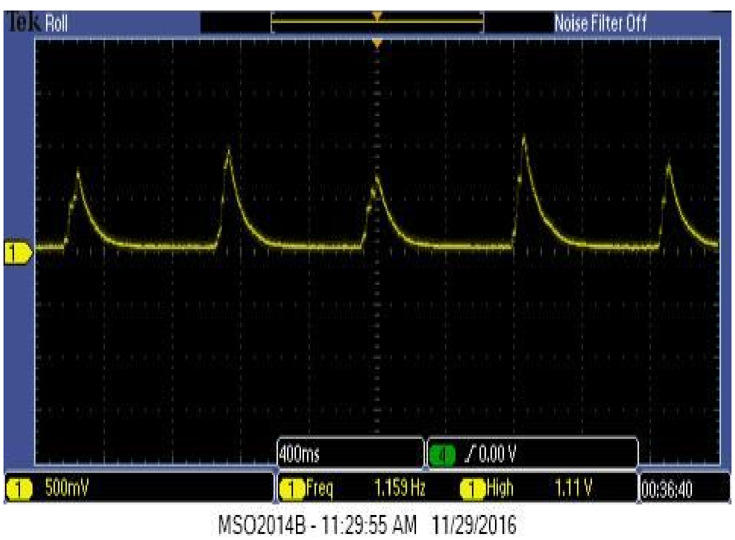




Figure 16. Configuration 2 Closed Fist-Stop

FIgure 17. Configuration 2 Index Finger-Left



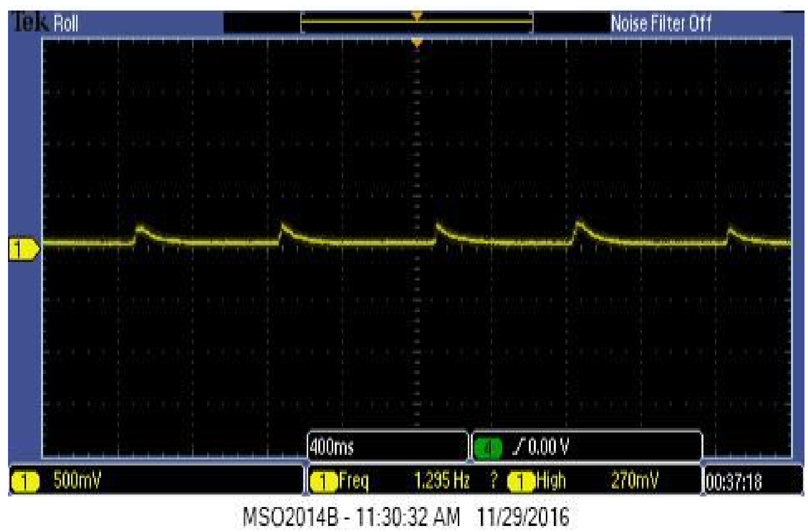




Figure 18. Configuration 2 Middle Finger-Forward

Figure 19. Configuration 2 Ring Finger-Right

After the Myoware Sensor board has integrated, rectified, and amplified the signal the resulting EMG signal is in the range of 0v to Vref of 3.3v. These results indicate that the individual movement commands will be within a range of .5v to 1.5v assuming 80% contraction of muscle observed in lab. As seen above, different motions yield different signals depending on the placement of the sensors and the user. Based on these observations the calibration system will need to be able to handle great variation with each movement signal. Further research and lab work will be needed to determine the variation of signals for different users as well as the feasibility of using different configurations depending on voltage levels output.

## 7. Project Management

This division of labor will make sure that all team members have an adequate amount of work and contribute to the system's completion equally. The EMG-Control subsystem was viewed as the subsystem with the most software design along with other peripherals so therefore it was necessary to distribute work among team members.

**Jon Morón**

1. Service Robot subsystem
2. Video Monitoring System
    a. Sending video feed from Service Robot System

**John Cochrane**

1. EMG-Control subsystem
    a. Calibration Mode
    b. System diagnostics
2. Video Monitoring System
    a. User Interface

**Thomas DiProva**

1. EMG-Control System
    a. EMG DSP
    b. Operation mode
    c. Wireless Communication

## **Project Schedule**

The team will like to work on the following during winter break and end of fall semester:

1. Complete analysis of EMG signals and classify finger movements.
2. Get computations for data rate and other formulas.
3. Receive live video feedback on video monitoring system.
4. Design software and start working with Particle Photon.

Table 2 is next semester's schedule. The purpose of diagnostic testing on the schedule is for the team to try to implement individual team member's parts. For example on the first diagnostic day the team would like to send one of four movement commands and make the service robot move on specified command. The overall system will be completed the week before or after spring break.

| | WEEK 1 | WEEK 2 | WEEK 3 | WEEK 4 | WEEK 5 | WEEK 6 | WEEK 7 | WEEK 8 | WEEk 9-14 |
|---|---|---|---|---|---|---|---|---|---|
| **Agenda** | Work on implementation of DSP system to get a clear digital output of the EMG signal. Also work connecting raspberry pi to service robot. Work on getting communications up between the systems. | Continue last week's agenda. Run systems check to see if the subsystems correctly work together. | Depending on Diagnostics test work to fix any connection issues. Begin working on mapping emg signal frequencies to our commands. | Continue mapping digital signal to commands in both subsystems. Run test to determine progress of each subsystem. | Service Robot subsystem work on translating incoming commands to pwm for the robot's movement. Start work on different operations within the user subsystem. | Continue work and Run test to determine subsystems progress. | Fix any issues with either subsystem from test. Begin setting up ip camera system. | Finish ip camera system setup. Finish any tweaks to subsystems and run a complete system check. | Complete ECE 499 Deliverables. |
| | | **Diagnostic Test** | | **Diagnostic Test** | | **Diagnostic Test** | **Diagnostic Test** | **Complete Project** | |

Table 2. Spring Semester Schedule

## 8. Project Deliverables and Discussion

The following deliverables will be completed after week 8.

1. Final Project Report
2. Final Project Presentation
3. Final Project Demo
4. Industry Advisory Board Poster Presentation
5. Bradley Student
6. Scholarship Expo

Future Directions for this project can include a mobile phone platform, user speed control of the service robot, and working to apply this technology to larger platforms. The mobile platform will give the users the option to receive video feedback and system status on their phones instead of a computer. The purpose of a mobile platform of the video monitoring system is to provide greater freedoms to the user and to shrink the size of the video monitoring system as a whole. Another Add on for user would be the ability to control the speed of the service robot platform; this could be performed through the initial setup of the system or a sequence of commands to change the speed mid operation. The purpose of the user speed control is to allow users greater control of the vehicle service platform. In the future this application can be applied to greater applications such as wheel chair control for disabled patients, allowing greater control of movement with less physical stress on the user.

## 9. References

[1] Keating, Jennifer. "Relating Forearm Muscle Electrical Activity To Finger Forces." (n.d.): Worcester Polytechnic Institute, May 2014.

[2] #790956, Member, and Member #556548. "MyoWare Muscle Sensor." *SEN-13723 - SparkFun Electronics*. SparkFun Electronics, n.d. Web. 11 Dec. 2016.