Senior Design 2018/2019

Notorious EMG

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DR 1.1 Docs

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Executive Summary

For those who have experienced physical therapy, they know it is painful and at times, an inconvenience. Physical therapy helps to take care of patients in all phases of healing, from initial diagnosis to a final preventative stage of recovery. By doing what the therapist prescribes, and properly triggering the target muscles, we can often avoid any delays to the rehabilitation process.

Surface electromyography (SEMG) provides therapists vast amounts of information on measurable patient data. Only 35% of patients in physical therapy will completely follow through on their routine, both in and out of the clinic. This already low number drops significantly upon discovering that only 30% of all patients who receive outpatient services attend the entirety of their sessions. Taking both statistics into consideration, it becomes plain to see why a significant number of patients, roughly 70% overall, physical therapy with the intended results for recovery.

The goal is to determine a way to encourage those recovering from long-term musculoskeletal injuries to follow through on their physical therapy and to see it through to the end. We would go about this by creating the Muscle Guide: a device that alerts patients to when they are not firing the proper muscles, as set by their therapist. Muscle use would be monitored by electromyography, or EMG sensors, and that information would be relayed back to a microcontroller. Based on set parameters, the Muscle Guide will pinpoint when muscles are being fired incorrectly and alert the user.

Our highest risk path is, by far, successfully integrating the EMG sensor with the microcontroller and having the data processed in real-time. This is because the signal must be picked up by the electrodes, conditioned, and then sent to the MCU where the signal will be sent wirelessly to the terminal. As a result, by the end of the quarter, we intend to not only become familiar with EMG, but also to integrate it with the microcontroller entirely. Finally, the device needs to be able to process at least one set of incoming data from the EMG sensors.

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Figure of Concept

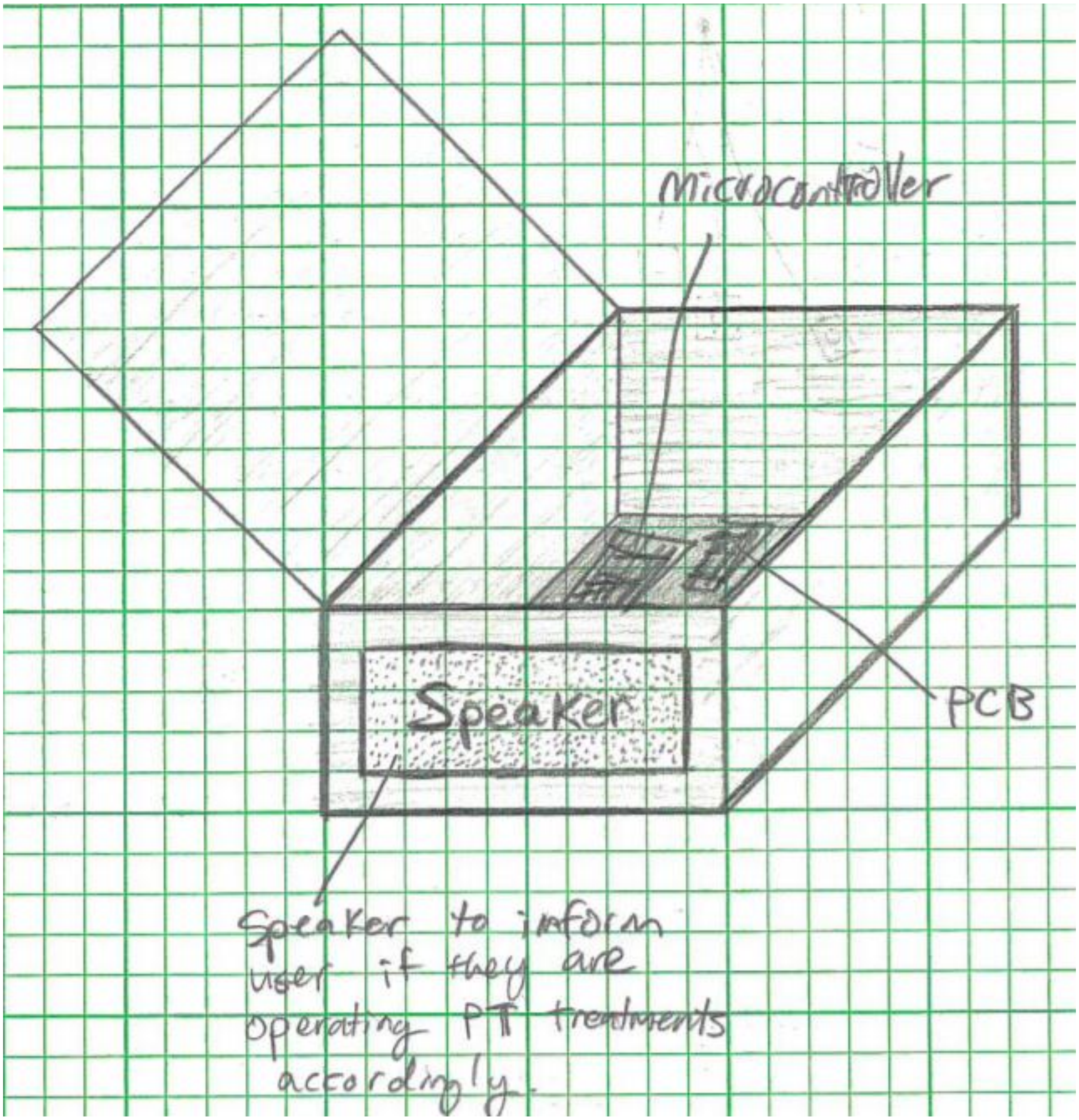

Figure 1 - Concept of RRP1 and RRP2

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Quad Chart

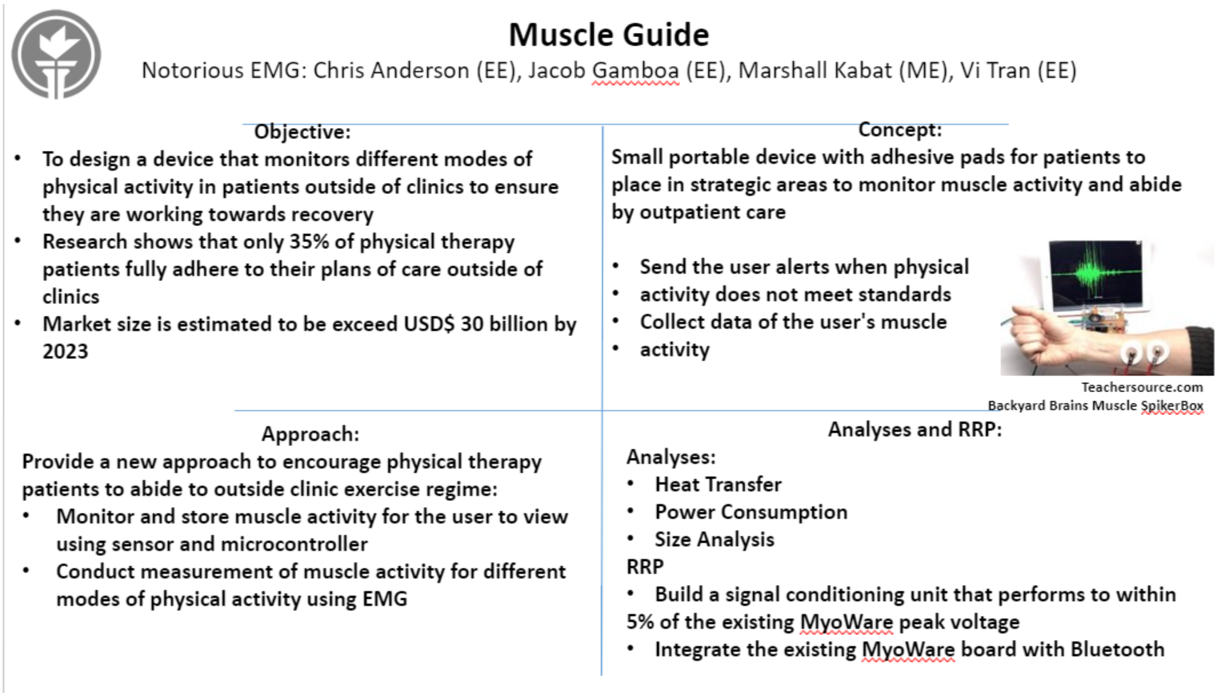

Figure 2 - Quad Chart

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Introduction and Overview

When prescribed physical therapy plans cause patients pain and/or discomfort the remedial course-of-action is to modify the motion so that it doesn't hurt. These modifications could lead to additional injuries or damage to the affected area and prolong treatment plans. By utilizing SEMG and a signal conditioning unit, we hope to alleviate this problem by creating a device that can detect muscle movement and store the data so that patient and therapist can review progress and adjust as needed for a more effective rehabilitation plan.

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Research Summary

Ryan Klepps, PT's article entitled "7 Thought-Provoking Facts About Physical Therapy You Can't Ignore" to express the obstacles within physical therapy. According to his study, every year nearly half of all Americans are affected by a muscle injury, yet only about 10% of these individuals seek physical therapy. Yet within that 10%, only 35% follow the recommended exercise regime and complete their therapy. The average number of physical therapy sessions in America are ten sessions, yet there is a reoccurring pattern of patients not only abandoning their treatment as soon as they begin to slightly recover, but they also fail to continue treatment outside of clinics. Patients usually only interact with PTs during session, therefore it is difficult for therapists to monitor a patient's activity outside of sessions and alert the patient if they are not adhering to outpatient physical therapy practices.

Insights, a company that reports on business solutions, published an article explaining how devices like the Muscle Guide is impacting the physical therapy industry. Written by Taylor Holland, the article entitled "next Step for Remote Patient Monitoring: Virtual Physical Therapy" discusses this pivotal technology. Starting in 2016, there has been an increase in remote patient monitoring used by healthcare providers. These devices allowed providers to gather and track biometric data as well as monitoring a patient's medicine intake. This rise is due to traditional physical therapy being too expensive and inconvenient. Therefore, patients now prefer to work towards recovery through these remote and cheaper options. While the devices on the market are cost efficient and convenient for patients, remote patient monitoring is in its initial stages and can benefit from more innovative features in the future.

While physical therapy sessions with PTs heavily influence a patient's road to recovery, the responsibility falls on the patient and their ability to commit their course of care outside of clinics. Physical therapists Ian Ford researches trends within physical therapist patients' behaviors in his journal "Journal of Sport Rehabilitation: Anterior Cruciate Ligament Injuries". Amount Due to lack of Ian has seen a trend where lack of self-motivation shows that many physical therapists are not confident in their patients' ability to continue their treatment on their own, thus creating an additional obstacle in the recovery process.

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Project Summary

Physical Therapy patients recover by adhering to prescribed rehabilitation plans, but research has shown that patients will often shy away from the prescribed exercise regime required outside of the PT clinic. The goal of this device, the Muscle Guide, is to help patients comply with prescribed rehabilitation plans by alerting the user to when they their actions do no coincide with what their physical therapist called for. Additionally, the Muscle Guide will be storing the data for review by the patient's therapist so that treatment can continue to improve towards a positive outcome.

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System Design/System Block Diagram

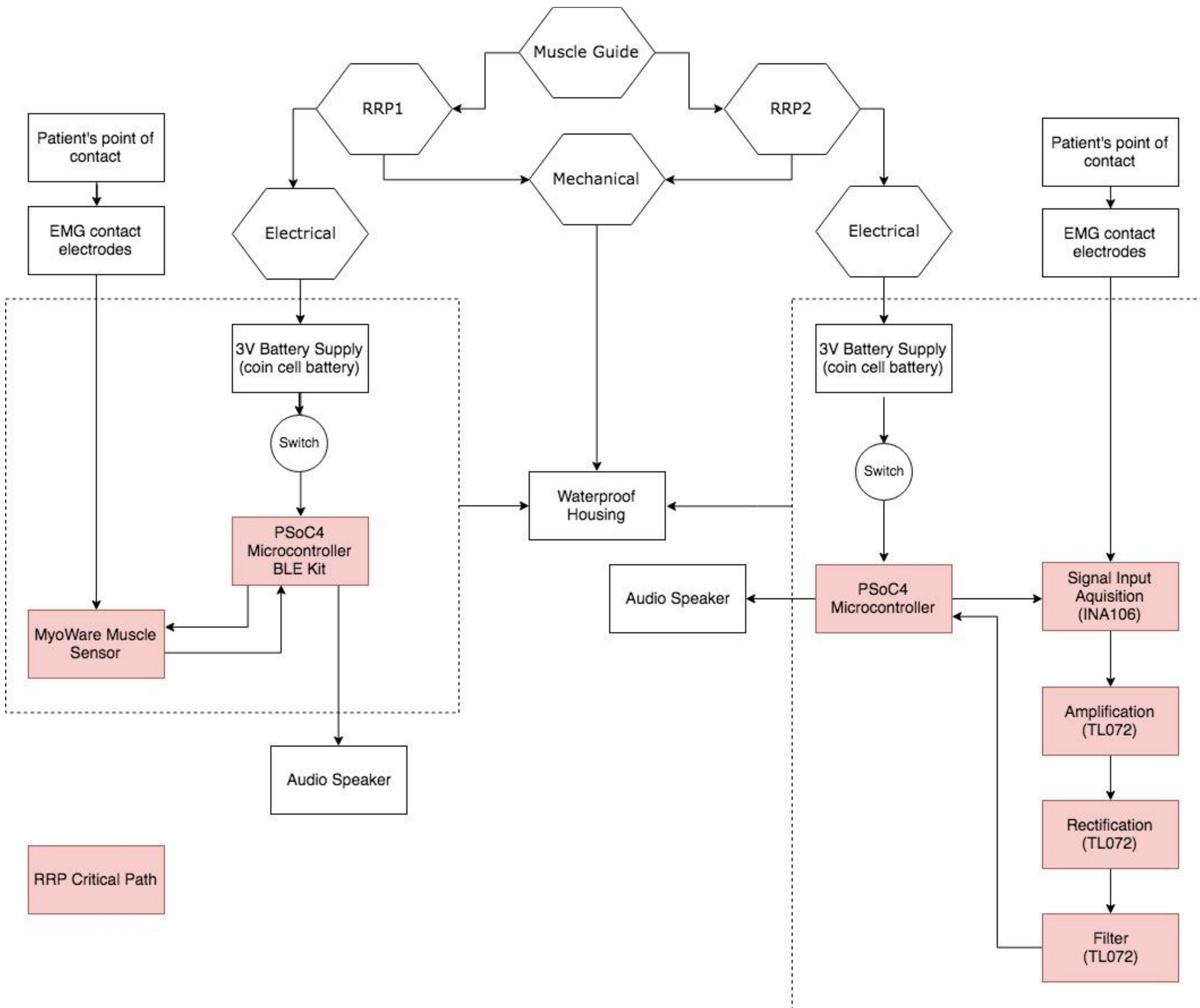

Figure 3 – Block Diagram for RRP1/2

The critical path of RRP1 includes the MyoWare Muscle Sensor to the PSoC4 BLE Microcontroller Kit. The challenges associated with this is the ability to correctly code the appropriate GPIO pin needed to communicate the MyoWare Sensor's output muscle signal to the input of the MCU. Additionally, the code to be written to save the data to eventually use for the audio alert function will also propose a challenge.

The critical path of RRP2 includes the overall signal conditioning unit and interfacing with the MCU. The conditioning unit includes three crucial elements, the data acquisition, amplifier, and filter for the signals output form the EMG electrodes. Because the initial muscle signals are both noisy and of a microvolt amplitude, the filter and the amplifier are crucial to attain a workable output signal. The filter design must be design with the appropriate frequency cut off and must output a signal like the MyoWare Muscle Sensor’s amplitude.

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Engineering Analysis List

- **Heat Dissipation:** Because this is a box that will be attached to the wearer, the device will burn the user from the heat generated from the electronics. Hence, the plan for Heat Transfer analysis. The result we obtain will instruct us to possibly implement a heat sink.
- **Power Consumption:** The maximum power consumed by the microcontroller and the electrodes based on the processor speed of the microprocessor and the current draw of the electrodes must be calculated. This will yield the smallest power source needed for the device to function and to make the device more user friendly and portable.
- **Safety Analysis:** The EMG electrodes are a passive element that allows electrical current to run through the user to communicate with the MCU. The device must avoid the risk of shocking the patient. Therefore, FDA Compliance research much be done to ensure that the amount of contact the user has with electrical current is safe and allowed.
- **Weight & Size Analysis:** Because this device is to be portable, small, and lightweight for the user to use while exercising, a weight and size analysis must be done to ensure that this device is not inconvenient for the user or makes their exercise regime towards recovery more difficult. The vision for this device is to be similar to the size and weight of a typical cell phone.
- **Data Rate Analysis:** The data sampled by the EMG electrodes must have a data rate to successfully store in the PSoC4 and trigger the parameters of the alert system. This alert system must be accurate in real time so that the user knows when and what action took place when something was done incorrectly and what to improve.
- **Data Storage Analysis:** The device will story activity data from the user to be reviewed later with a physical therapist. The data sampled from both the MyoWare Muscle Sensor and the signal conditioning unit will need to store this data directly to the MCU. The amount of Random-Access Memory, RAM on the MCU will need to be looked at an analyzed. If necessary, to accommodate the amount of data sampled and needed to be store, an alternative MCU with larger RAM will be considered.

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Risk Reduction Prototype Specs

RRP 1:

- EMG001: EMG Integration: **The EMG electrodes will be read through a MyoWare Muscle Sensor and integrated with a PSoC4 microcontroller to read and store data.** *Through direct contact, the electrodes will successfully detect a voltage signal and then transmit the data to the PSoC4 to be written to memory.*

EMG002: PSOC4 - EMG Communication: **The PSoC4 shall illuminate an LED when the muscle activity detected by the MyoWare exceeds 8 mV (peak-to-peak). The PSoC4 should illuminate an LED when the detected activity exceeds 5 mV (peak-to-peak).** *By successfully detecting a set parameter, we will demonstrate that the PSOC4 successfully communicates with the EMG sensor.*

- EMG003: Wireless Data Acquisition: **The PSoC4 shall receive detected muscle activity from the MyoWare wirelessly from 20 feet. The PSoC4 should detect muscle activity from the MyoWare wirelessly from 30 feet.** *Wireless capability will make the device more user friendly, and it will also decrease the chance of damaging the device by entanglement of loose wires.*

- EMG004: Data Processing & Reporting: **The microcontroller will be able to correctly process one set of incoming data and output the results correctly and continuously.** *The purpose of this device is to alert people to when they are not firing the proper muscles, so correctly processing the incoming data is a necessity. By detecting data points outside of the parameters we set, we will be able to implement this alert system.*

- EMG005: Wireless Data Rate: **The system shall have a Bluetooth radio system (EMG005) that transfers data at Bluetooth standard 4.1 rates. The system should have a Bluetooth radio system that transfers data at Bluetooth standard 4.2 B.L.E. rates.** *Current availability of Bluetooth devices with low power consumption make the PSoC4 Bluetooth capable devices a suitable option. With the ability to integrate with the PSoC4 creator, the IDE we are familiar with, the likelihood of meeting final specifications is increased by utilizing this standard. Verification will be accomplished by way of the datasheet.*

Spec ID	**Requirement**	**Threshold (Shall)**	**Objective (Should)**	**Validation Method**	**Notes**
EMG001	EMG Integration	MyoWare integrated with PSoC4	N/A	Output measured by oscilloscope, peak values	

				printed to terminal	
EMG002	PSoC4 – EMG Communication	8 mV (peak-to-peak)	5 mV (peak-to-peak)	Display no LED when user is stationary, LED when in motion	
EMG003	Wireless Data Acquisition	20 feet	30 feet	Increase distance while monitoring output signal until the signal is no longer received	
EMG004	Data Processing & Reporting	Correctly output one set of incoming data	N/A	Compare output signal of electrodes from MyoWare Muscle Sensor with signal from oscilloscope	
EMG005	Wireless Data Rate	Compliant with Bluetooth 4.1	Compliant with Bluetooth 4.2	Datasheet, Experimental Data Capture	Throughput = Payload size/ Time for single transaction

Table 1 – RRP1 Specifications

RRP 2:

- CU001: EMG Integration: **The EMG electrodes will be read through a signal conditioning unit and integrated with a PSoC4 microcontroller to read and store data.** *Through direct contact, the electrodes will successfully detect a voltage signal and then transmit the data to the PSoC4 to be written to memory.*

- CU002: PSOC4 - EMG Communication: **The PSoC4 shall illuminate an LED when the muscle activity detected by the signal conditioning unit exceeds 8 mV (peak-to-peak). The PSoC4 should illuminate an LED when the muscle activity detected by the signal conditioning unit exceeds 5 mV (peak-to-peak.** *By successfully detecting a set parameter, we will demonstrate that the PSOC4 successfully communicates with the EMG sensor.*

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- CU003: Signal Conditioning Unit: **The signal conditioning unit will output a noise-reduced, amplified, and accurate muscle signal that is within 5% of the peak voltage of the signal received from an open source board.** *Using the output from the MyoWare Muscle Sensor as the standard, the signal conditioning unit we build will output a cleaner signal with significant noise reduction when compared to the characteristics of an unconditioned EMG signal.*

- CU004: Data Processing & Reporting: **The microcontroller will be able to correctly process one set of incoming data and output the results correctly and continuously.** *The purpose of this device is to alert people to when they are not firing the proper muscles, so correctly processing the incoming data is a necessity. By detecting data points outside of established parameters we will be able to implement this alert system.*

Spec ID	**Requirement**	**Threshold (Shall)**	**Objective (Should)**	**Validation Method**	**Notes**
CU001	EMG Integration	Signal conditioning unit integrated with PSoC4	N/A	Output measured by oscilloscope, peak values printed to terminal	
CU002	PSOC4 – EMG Communication	8 mV (peak-to-peak)	5 mV (peak-to-peak)	Display no LED when user is stationary, LED when in motion	
CU003	Signal Conditioning Unit	Peak voltage of signal from conditioning unit will be within 5% of MyoWare Sensor's peak voltage	N/A	Compare the signal from signal conditioning unit with the signal from the MyoWare Muscle Sensor	
CU004	Data Processing & Reporting	Correctly output one set of incoming data	N/A	Compare output signal of electrodes from MyoWare Muscle Sensor with signal from oscilloscope	

Table 2 – RRP2 Specifications

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Risk Reduction Prototype Description

The RRP that we intend to build prior to the end of the quarter will be an EMG circuit consisting of electrodes and a signal conditioning unit interfaced with a PSOC4 microcontroller. The microcontroller will process the signals sent from the electrodes and report results so that we may analyze the motion of the detected movement. To ensure accuracy of RRP1 (within 5%), the conditioned output signal will be compared to the MyoWare Muscle Sensor output signal.

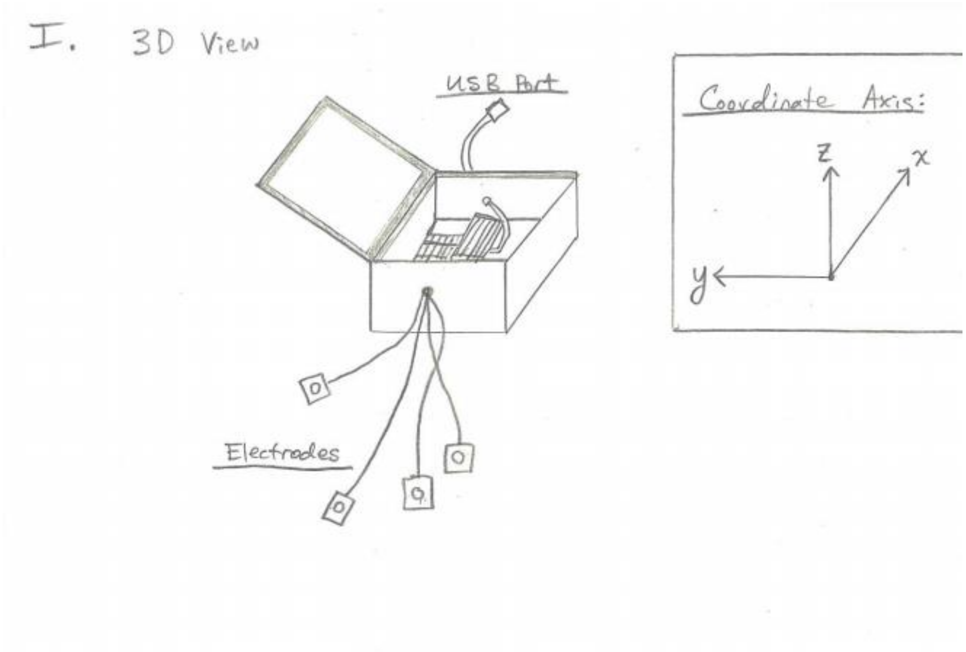

Figure 4 – RRP1 & RRP2 concept (3D view)

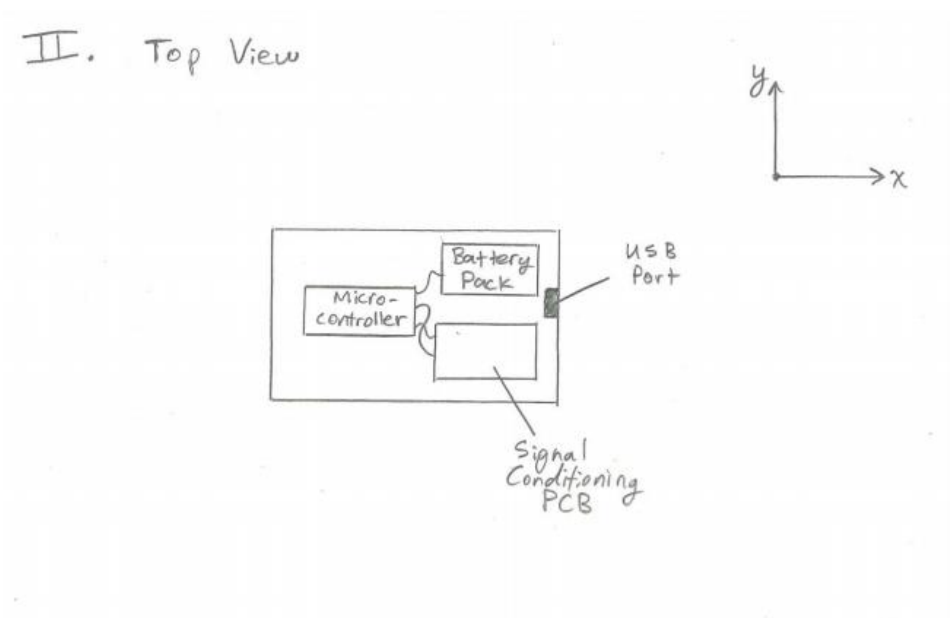

Figure 5 – RRP1 & RRP2 concept (Top view)

RRP Block Diagram

RRP1

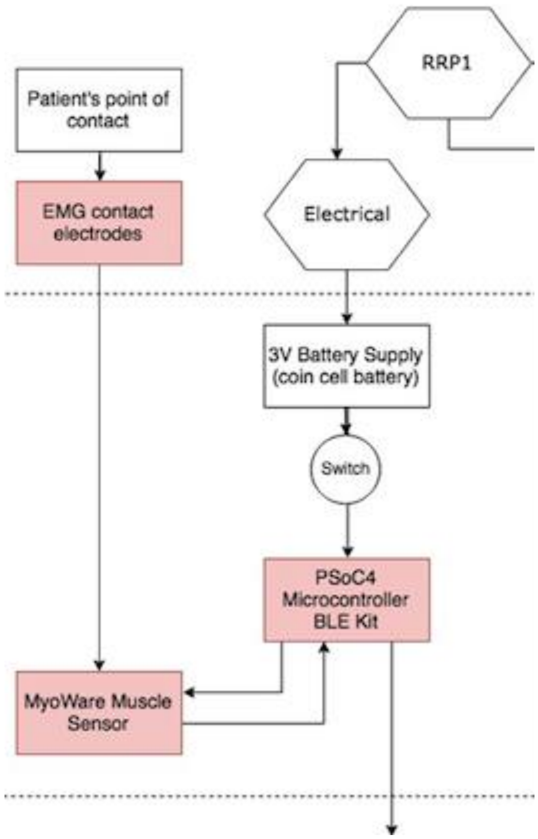

Figure 6 – RRP1 Block Diagram

RRP2

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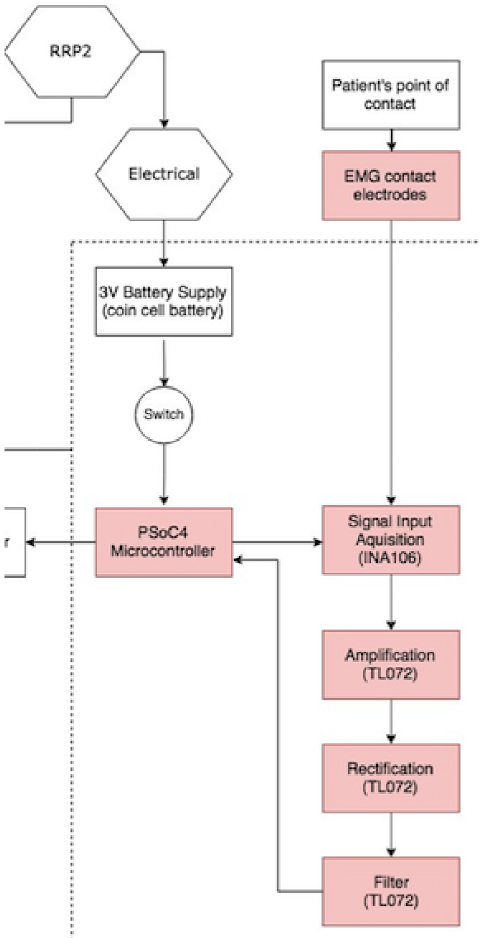

Figure 7 – RRP2 Block Diagram

Bill of Materials

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RRP Bill of Materials (BOM)			
Item	**Quantity**	**Vendor**	**Price**
TL072	3	Texas Instruments	$0.71
INA106	1	Texas Instruments	$12.00
EMG Cables	1	BioMedical Instruments	$22.50
EMG Electrodes	6	Adafruit.com	$4.95
9V Battery	2	Duracell	$8.98
9V Battery Clips	2	Keystone Electronics	$1.82
1 microFarad Tantalum Capacitor	2	Jameco Electronics	$0.78
01 microFarad Ceramic Disc Capacit	1	Jameco Electronics	$0.12
1 microFarad Ceramic Disc Capacitor	1	Digi-Key Electronics	$0.47
150 kOhm 1% Resistor	3	Digi-Key Electronics	$0.30
1 Mohm 1% Resistor	2	Digi-Key Electronics	$0.20
80.6 kOhm 1% Resistor	2	Digi-Key Electronics	$0.20
10 kOhm 1% Resistor	6	Digi-Key Electronics	$0.60
100 kOhm Trimpot Resistor	1	Allied Electronics & Automation	$1.27
1 kOhm 1% Resistor	1	Digi-Key Electronics	$0.10
1N148 Diode	2	Digi-Key Electronics	$0.20
Jumper Wires	60	Amazon.com	$8.65
Alligator Clips	10	Amazon.com	$5.93
PSoC 4 Pioneer Board	1	Cypress Semiconductor Corporation	$30.00
MyoWare Muscle Sensor	1	Adafruit.com	$37.95
		Total:	$137.73

Table 3 – Bill of Materials

Code Summary

```
int voltageMinEMG = 250;        //Minimum muscle read from EMG before alerting user
int voltageMinMC = 200;         ////Minimum muscle read from MC before alerting user
int infile(data);               //File to read data input
int outfile(data);

//Constantly read the user's muscle activity
void read(){
        EMG.infile();   //Read in EMG data
        MC.infile();    //Read in MC data
        outfile(EMG.infile);    //Write the data from the EMG sensor to an output file
        outfile(MC.infile);     //Write the data from the EMG sensor to an output file
        if(EMG.infile() < voltageMinEMG){
                //Alert the user
                cout << "LOW MUSCLE ACIVITY";   //Notes there was low muscle read
        }
        if(MC.infile() < voltageMinMC){
                //Alert the user
                cout << "INCORRECT MUSCLE ACTIVITY";    //Notes that there was incorrect muscle read
        }
}
```


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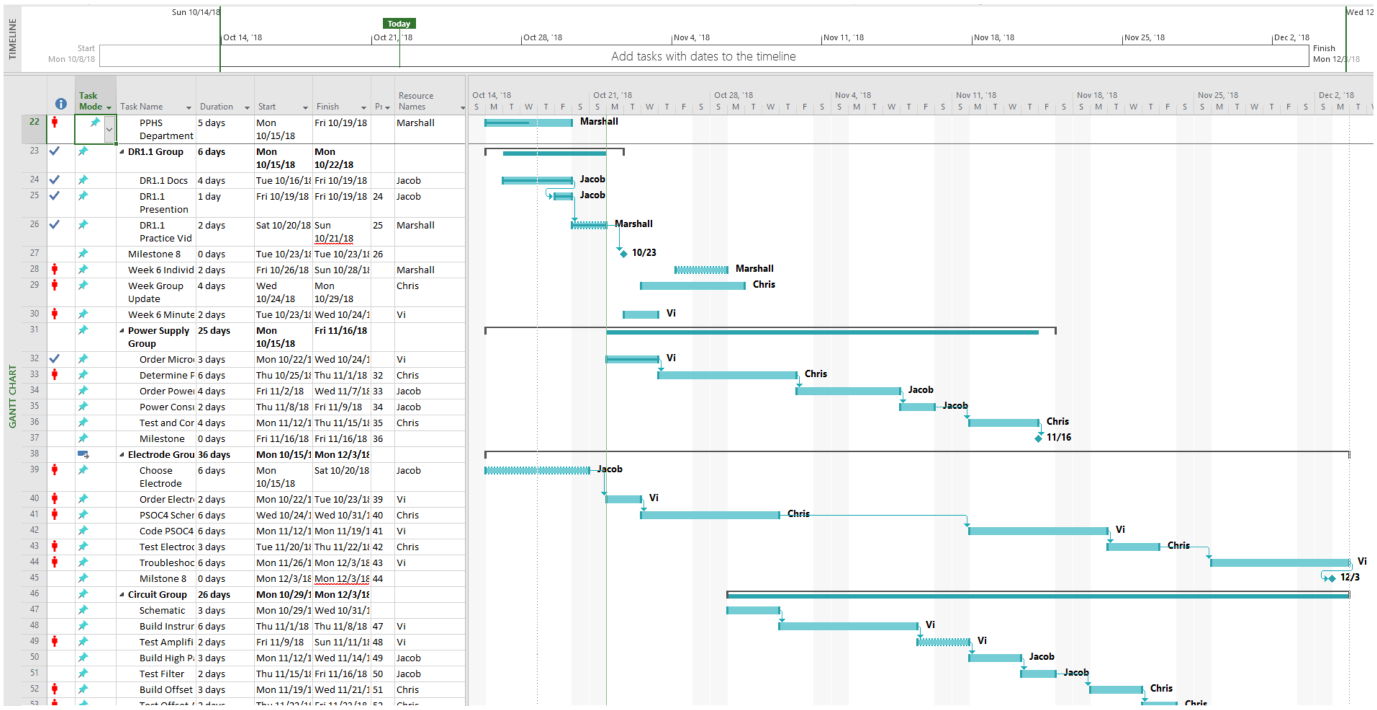
Detailed Schedule



The main concern and potential aspect that would put us behind schedule is the ability to interface a PSOC4 microcontroller with the EMG and MC sensors we intend to use to track muscle activity of the user. Therefore, researching and determining the appropriate sensors is the initial task before we begin assembly the sensor circuit and programming the PSOC4. By doing so, we can plan according and ensure that the rest of the project will be well integrated in the end.

References

Holland, Taylor Mallory. The Next Step in Remote Patient Monitoring: Virtual Physical Therapy. *Samsung Business Insights*, 17 Jan. 2017, insights.samsung.com/2017/01/17/next-step-for-remote-patient-monitoring-virtual-physical-therapy/.

Klepps, Ryan. Thought-Provoking Facts About Physical Therapy You Can't Ignore. *WebPT*, 19 Feb. 2015, www.webpt.com/blog/post/7-thought-provoking-facts-about-physical-therapy-you-cant-ignore.

Ford, Ian W, and Sandy Gordon. *Journal of Sport Rehabilitation: Anterior Cruciate Ligament Injuries*. Human Kinetics Publishers, 1997.

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Appendix

Christopher A. Anderson

Chris is the Electrical Lead for Notorious EMG. He is currently working toward his bachelor's degree in electrical engineering from Seattle Pacific University in Seattle, Washington, USA and is planning to graduate in the spring of 2019.

He started working on power generation and distribution systems as a Facilities Maintenance Technician in the military, and, over 11 years, assumed the roles of Facilities Maintenance Team Chief and Facilities Maintenance Instructor. At the start of June 2018, he began working as a Network Service Engineering Intern at Seattle City Light in Seattle, WA.

Jacob A. Gamboa

Jacob is the coordinator and bookkeeper for Notorious EMG. He is currently working toward his bachelor's degree in electrical engineering from Seattle Pacific University in Seattle, Washington, and is anticipating to graduate in the spring of 2019.

He previously interned at the Cal OES telecommunication division in Sacramento, California from the start of June 2017 through the end of August 2017 as an Assistant to the Senior Engineer.

Marshall Kabat

Marshall is the Recorder and Mechanical Lead of Notorious EMG. He is currently working toward his bachelor's degree in mechanical engineering at Seattle Pacific University in Seattle, Washington anticipating to graduate in the spring of 2019.

He recently interned at UV SYSTEMS Incorporation as a Test Engineer in Renton, Washington from June 2018 to the end of August 2018.

Vi C. Tran

Vi is the leader and facilitator of Notorious EMG. She is currently working toward her bachelor's degrees in electrical engineering from Seattle Pacific University in Seattle, Washington anticipating to graduate in the spring of 2019.

She is currently an Electrical Engineering Intern at Puget Sound Energy in Bellevue, Washington and previously interned at the Seattle Department of Transportation in Seattle as an Engineering Intern, Washington from October 2017 to June 2018.

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Team Mission & Vision

Mission: To develop a device that encourages physical therapy patients to continue monitoring their muscle activity and rehabilitation even after they have left therapy.

Vision: Physical therapy that assists and encourages physical activity, relieve pain, and stimulate muscles for patients on their journey towards recovery.

Team Contract

A. Commitments:

As a project team, we will:

1. See the project through to completion.
2. Respect each other
3. Effectively communicate and actively listen to each other's inputs and ideas
4. Work together to ensure that every team member has a clear understanding of every aspect of the project

B. Team Meeting Ground Rules: Participation

We will:

1. Be open to new approaches and listen to new ideas.
2. Avoid placing blame when things go wrong. Instead, we will discuss the process and explore how it can be improved.
3. We will meet every Wednesday at 4:30 PM for team meetings.
4. If necessary, we will meet on Tuesday at 2PM as an extra meeting time.
5. Always be responsive outside of class and meeting times
6. Be accountable to every team member's work

C. Team Meeting Ground Rules: Communication

We will:

1. Seek first to understand, then to be understood
2. Listen and respect other team members input and ideas
3. Always address conflict with tenacity
4. Create an environment where all team members are comfortable

D. Team Meeting Ground Rules: Problem Solving

We will:

1. Encourage everyone to participate.

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2. Bounce ideas off each other whenever we are stuck
3. Be transparent
4. Not be afraid to ask the group for help
5. Take breaks!

E. Team Meeting Ground Rules: Decision Making

We will:

1. Get input from the entire team before a decision is made.
2. Discuss concerns with other team members during the team meetings or privately rather than with non-team members in inappropriate ways.
3. Document any ideas that would help make the decision
4. Consider the quality of product over the ease of product

F. Team Meeting Ground Rules: Handling Conflict

We will:

1. Choose an appropriate time and place to discuss and explore the conflict.
2. Listen openly to other points of view.
3. State our points of view and our interests in a non-judgmental and non-attacking manner.
4. Be objective
5. Focus on solutions
6. Be constructive, rather than critical

G. Meeting Guidelines:

1. Regular meetings will be held at least once a week
2. Meetings can be called by anyone on the team.
3. Someone will be in charge of meeting minutes
4. Everyone must participate during team meetings
5. Be ready and enthusiastic coming into the meetings
6. Have a fun atmosphere
7. Keep tangents short

H. Meeting Procedures:

1. Meetings will begin and end on time.
2. Meetings will be recorded using the memorandum format provided
3. Team members will come to meetings prepared.
4. We will prepare and have an agenda before every meeting
5. Outline the points of the meeting in the beginning
6. Complete what needs to be completed, regardless of time

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AGREED TO:

NAME (Signed and printed): Vi Tran
Vi Tran
DATE: 10/03/2018

NAME (Signed and printed): Chris Anderson
Chris Anderson
DATE: 10/03/2018l

NAME (Signed and printed): Jacob Gamboa
Jacob Gamboa
DATE: 10/03/2018

NAME (Signed and printed): Marshall Kabat
Marshall Kabat
DATE: 10/03/2018

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