BME 484 - Capstone Design

Department of Electrical, Computer and Biomedical Engineering

University of Rhode Island, Kingston, RI 02881

Electromyogram Based Controls Acting on Lego Mindstorm Car

Design Progress Report – 5, November, 2012

Instructor:

Dr. Ying Sun

Assistants:

Brian Ramos

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Project Engineers:

Kaitlin Abbate

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Abstract:

This project will focus on creating a functioning electromyogram, controlled by human muscle contractions, to power a Lego Mindstorm NXT 2.0® car. The ability to move a small electronic device will be translated to moving something larger and more beneficial, such as a wheelchair. This will eventually lead to aiding paraplegic patients succumbed to a wheelchair lifestyle. If this person can now control their own wheelchair, more independence is gained.

Introduction:

Approximately 250,000 Americans have a spinal cord injury, with 11,000 new injuries occurring each year. Therefore, there is a growing need for assisting these patients, paraplegics specifically. Today, the most commonly used aiding device is the power wheelchair. However, this requires complete usage of arms/hands, and some injured patients are not capable of this. This electromyogram project will allow patients to control a wheelchair through simple muscle contraction. Specifically to this project, the forearm flexor muscles will be used to control a Lego Mindstorm car.

Methods:

- Utilize previously existing hardware setup for ECG - including breadboard, PCB, electrodes, and oscilloscope connection.
- Adjust previously developed MOBD and ECG algorithms to create new software that can read muscle activity.
- Add additional software that will recognize direction and force of muscle movement, and output appropriate action onto Lego car.
- Import new software from utilized coding program into the Lego MindStorm's controlling program.

Probable Goal:

Reasonably, an analog system will be developed, triggered by muscle activity, to control the acceleration and direction of the movement of a Lego MindStorm car. The acceleration of the car will be determined by the amount of force the muscle contraction produces. For example, a stronger muscle contraction leads to a faster acceleration. Also, this system will be able to differentiate between channel 1 and 2 (arms 1 and 2) and detect muscle stimulation patterns to signal direction of the car.

Ideal Outcome:

Through the course of the semester, the proposed final outcome will be to create a "stand alone" system that uses muscle activity of an individual's arms to control the movement and direction of a Lego Mindstorm car. This will be accomplished through the use of Bluetooth, i.e. there will be no computer directly connected to the Lego car.

Design:

Origin of Problem:

Approximately 11,000 spinal cord injuries occur each year, leaving victims with little or no motor and sensor functionality in their lower extremities. 47% of spinal cord injuries cause quadriplegia. In this case individuals lose the ability to move or feel any limbs, as well as the torso. Either case is certainly tragic, and today drastically reduces quality of life after such an accident. With the overwhelming majority of spinal cord injuries occurring before the age of 30, assistive devices and methods are becoming more significant in helping individuals continue on with their lives.

The motivation behind this research comes from the following five facts:

1. There is a large population of individuals in the US (25 million people) with spinal cord injuries

2. Spinal cord injuries generally occur at an early age, often leaving patients otherwise healthy, but constricted to a wheelchair.

3. Some spinal cord injuries leave an individual with the inability to manually move a wheelchair. Quadriplegics are unable to move even power chairs triggered by a joystick.

4. The electrical signal in a muscle is strong, and very easy to capture.

5. Individuals with paraplegia and quadriplegia still have many working muscles activated by electrical signals.

The Biomedical Engineering program at the University of Rhode Island has been closely associated with electronics and electrical engineering from its inception. Therefore, this project requires skills from electrical engineering classes we have taken, and incorporates engineering problems in medicine. Students in the program have also, in earlier semesters, been asked to create their own electrocardiogram, so we have a strong background in sensing internal electrical signals. The project was realized last year, and has been passed down each year, so as to investigate further the uses of an electromyographic input in robotics.

Realistic Constraints:

> *an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability. - ABET*

Economic: The products and systems that were used and tested met the economic constrains. Much of the supplies were donated to us from previous people trying to design the electromyogram before us. Laboratory supplies were also given to us to construct the breadboard and printed circuit board.

Environmental: The electromyogram meets the environmental constrains. The manufacturing of parts such as the PIC18F452 and Lego MindStorm met with the standards of RoHS which are environmentally conscious, restricting the usage of specific harmful chemicals.

Social: There are no clear social restrictions with this project.

Political: There are no clear political restrictions with this project.

Ethical: The ethical constraints of this project are met with the basic standards of manufacturing and distribution of the supplies used and tested.

Health and Safety: All of the products that we are using and testing require certain protocol in ordered to be manufactured. These protocols are standards for the health and safety of others and are recognized by many organizations as being a top priority.

Manufacturability: The Manufacturability constrains are not distressful. Much of the major parts combined for the project are already manufactured reasonably economical. The finished products of the printed circuit board and bread board could be easily manufactured.

Sustainability: The maintenance constrains are unknown since the final product has not been constructed. The products previously developed that we are incorporating in the project have low maintenance such as the Lego MindStorm NXT® which are made for child's play.

Engineering Standards:

In engineering, business and manufacturing it is essential for the suppliers, customers and users of the product to come to an agreement on requirements for the transaction. Most requirements are standards with specific targets and tolerances. Standards can range anywhere from the procedures, balance or consensus. Specifications may be written by government agencies, standards organizations (IEC, RoHS, ANSI, AAMI, etc.), trade associations, corporations, and others. The specifications ensure that such products can use worldwide; the idea such that if a people who own cameras can go anywhere and purchase film needed. These standards ensure that the characteristics and quality of products are consistent, that people should use the same definitions and terms, and that products are tested the same way.

The engineering standards that are applied to the Electromyogram being tested at the University of Rhode Island follow the basic safety and essential performances of medical equipment and systems. The ANSI/AAMI EC 11 describes the safety and performance requirements for the basic electrocardiograph. This same cardiograph we converted into detecting electric impulses on the muscles, just by changing the sampling frequency but still following the safety requirements. In the standards required by the IEC 60601-11 describes the safety and essential performance of medical electrical equipment and systems. The project does not modify the equipment but modifies programs ideally that will control the Lego MindStorm car so the equipment still follows the basic safety produced by the manufacturer. We also follow the basic RoHS (Restriction of Use of Hazardous Substances) regulations limits or bans of specific substances - lead, cadmium, polybrominated biphenyl (PBB), mercury, hexavalent chromium, and polybrominated diphenyl ether (PBDE) flame retardants - in new electronic and electric equipment. The restricted materials are hazardous to the environment and pollute landfills, and are dangerous in occupational exposure during manufacturing and recycling. The manufacturer followed these regulations therefor by default, our research did as well because we did not modify the equipment. Our PIC18F452 is also verified if it is RoHS compliant in the

references listed below.

In conclusion, the importance of restrictions and standards is evident. For many products and systems there are parts which are important that they are interchangeable to make that product last longer and worth the money of the investor; this is ensured by procedure standards. These products and systems should represent the manufacturer with the quality of safety of the product. With new technology evolving everyday the standards can keep waste down to minimum and the safety of everyone the main priority.

Results:

Current Results:

The electrocardiogram that was previously constructed in BME 361 has been successfully converted to an electromyogram. There are three electrodes that are placed on a participant's forearm (two on forearm muscle, and one near elbow to act as ground), and the oscilloscope shows the contractions as the participant clenches fist to engage forearm muscle. Also, we have successfully connected the Lego Mindstorm software to a C coding software so we can input actions for the Mindtsorm car to carry out. Right now, we have code for the car to beep.

Eventual Results:

Probable Goal: Reasonably, an analog system will be developed, triggered by muscle activity, to control the acceleration and direction of the movement of a Lego MindStorm car. The acceleration of the car will be determined by the amount of force the muscle contraction produces. For example, a stronger muscle contraction leads to a faster acceleration. Also, this system will be able to differentiate between channel 1 and 2 (arms 1 and 2) and detect muscle stimulation patterns to signal direction of the car.

Ideal Outcome: Through the course of the semester, the proposed final outcome will be to create a "stand alone" system that uses muscle activity of an individual's arms to control the movement and direction of a Lego Mindstorm car. This will be accomplished through the use of Bluetooth, i.e. there will be no computer involved in the system.The electromyogram that acts upon the forearm muscle will control the Lego Mindstorm car through C coding that we have connected to the Mindstorm software.

Discussion:

Since the current results do not match the desired results, we are continuing to work our way to reach this eventual goal.

References:

Erik Simpanen: Worked on EMG over summer 2012 (erik_simpanen@my.uri.edu)

Brian Ramos: TA (brian_ramos@my.uri.edu)

Dr. Ying Sun: professor (sun@ele.uri.edu)

BME 361 Lab Manual

IRBNet.org

http://www.sci-info-pages.com/facts.html

http://www.rohsguide.com

http://www.mouser.com/Search/include/RoHSCompliant.aspx?qs=k25gaGAYTGryDXfQRQZdDw==

http://en.wikipedia.org/wiki/Paraplegia

http://en.wikipedia.org/wiki/Quadriplegia

http://en.wikipedia.org/wiki/Wheelchair

http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=45605

http://www.techstreet.com/cgi-bin/detail?doc_no=aami%7Cec11_1991_r_2007;product_id=1642246

Appendices:

Appendix A: IRB Application Form (Note: some unnecessary pages have been omitted from original IRB Application document)

University of Rhode Island

Institutional Review Board (IRB)

Instructions and Checklists for IRB Application Submission

This application form is to seek initial IRB approval for a research study.

There are three levels of IRB review (Full Board, Expedited and Exempt), determined by the nature of the project, level of potential risk to human subjects, and the subject population. It is the principal investigator's responsibility to request the type of review he or she believes is appropriate for the study, but the IRB will make the final decision. Regardless of the type of review, all applications use the same submission form.

As required, read the linked URI IRB policies and procedures manual, where you will find guidance as to which level of review to request.

Following are three separate checklists and instructions for submission for each of the three levels of IRB review: Exempt, Expedited and Full Board. One checklist must be completed and submitted with your IRB application form, located immediately following the checklists.

Be certain to answer all questions thoroughly and attach all necessary documentation to avoid delays in the review of your IRB application.

All documents must be submitted electronically as attachments to the project package on IRBNet. The IRB cannot review any project unless the documents are submitted as a single package. For instructions on using IRBNet, please see Instructions for IRBNet Online Submissions.

Graduate students must submit an original hard copy of their Thesis/Dissertation Proposal Approval Sheet to the Office of Research Compliance after submitting IRBNet package electronically. A PDF version of the form should also be included with the IRBNet package.

If you have any questions, please contact the Office of Research Compliance at (401)874-4328 or compliance@ds.uri.edu.

University of Rhode Island - Institutional Review Board
Instructions and Checklists for IRB Application Submission

EXPEDITED REVIEW – Submit one original or copy of each document

If you are unsure which level of review to request, review the URI IRB policies and procedures manual for guidance, using this link:
www.uri.edu/research/tro/offices/compliance

In making the request for expedited review, complete and submit this Checklist with your application, attaching all required documents to your IRBNet package:

☒Y ☐N/A	Submit one completed research proposal (ex. thesis, dissertation, or sponsored research grant proposal) less any appended material not necessary to an understanding of the project. Student proposals must include the original Thesis/Dissertation Approval Sheet.
☒Y ☐N/A	Submit one completed IRB Application Form using the latest version from our website. *The application form is revised regularly. Please check our website for the current version.*
☒Y ☐N/A	Ensure that all parties named on the Assurance (final page of the Application) sign the package **electronically** via IRBNet. Directions for registering with IRBNet and signing a package can be obtained here.
☒Y ☐N/A	Submit one copy of any survey, questionnaire, sample interview questions, and flyers or advertisements.
☐Y ☒N/A	Submit one copy of all informed consent documents to be used written using language no higher than the eighth-grade reading level. If applicable, include online consent request or scripts that are to be used as part of consent process.
☐Y ☒N/A	If the research involves a cooperating agency, institution, school district, etc., a letter of agreement to participate in the research (on letterhead, submitted as a PDF) is required. If the cooperating agency has an IRB, a copy of that agency's IRB approval is required. Research that is to be conducted in foreign countries requires a letter of agreement from an appropriate official or cooperating institution. Use of secondary data that is not publicly available needs a prior IRB approval number or a letter from a person in authority granting permission to use the data.
☒Y ☐N/A	Documentation of CITI Program Training in the Protection of Human Subjects for all key personnel. Comparable training certification from another credible source will be considered by Office of Research Compliance staff.

University of Rhode Island

Institutional Review Board (IRB)
IRB Application Form

IRB ID No. _____(Internal Use Only)

Part 1. Project Identification

1.1 Review Requested – Choose One: (See URI IRB Policy and Procedures for guidance)

a☐Full Board b. ☒Expedited Review c. ☐Exempt Review - Category #_____

1.2 Project Title (Project title must match grant title. If different, also provide grant title):

Electromyogram Based Robotics

1.3 Project Duration:

Start Date: 9/10/12	**End Date:** 5/10/13

1.4 Principal Investigator (PI)

EVERY SUBMISSION REQUIRES A PI. THE PI CANNOT BE A STUDENT.
PI NAME MUST BE THE SAME ON THIS FORM AND IRBNet SUBMISSION

Name: Ying Sun	
Mailing Address: Kelley Hall, Room 206 University of Rhode Island Kingston, RI 02881	**Phone Number:** 401-874-2515
Email: sun@ele.uri.edu	**Fax:** 401-782-6422
University Department: Department of Electrical, Biomedical, and Computer Engineering	**College:** University of Rhode Island
Occupational Position at URI: X Faculty Staff Other: ____	

1.5 Co-Investigator (Students cannot be co-investigators):

Name: N/A	
Mailing Address:	**Phone Number:**
Email:	**Fax:**
University Department:	**College:**
Occupational Position at URI: Faculty Staff Other: _____	

1.6 Student Investigator

Name Kaitlin Abbate	
Local Mailing Address 25 Spring Brook Rd, Narrgansett, RI 02882	**Phone Number:** (401)487-2458
Permanent Mailing Address (if different) 7 Streamview Dr, Cumberland, RI 02864	**Fax:**
Email: kaitlin_abbate@my.uri.edu	
University Department: Department of Electrical, Biomedical, & Computer Engineering	**College:** University of Rhode Island
Dissertation/Thesis Proposal: Yes ☒ No ☐ **IF YES, please submit thesis or dissertation proposal with this IRB Application Form!!(?)**	

1.7 Key Personnel - Other people engaged in the study who have access to identifiable information about subjects (i.e. enroll participants, conduct consent process, collect or review identifiable information, or conduct intervention activities):

Name	Position	Role on study
Thomas Franklin	Biomedical Engineering Student	Software Engineer
Morgan Rosenberger	Biomedical Engineering Student	Hardware Engineer
Brian Ramos	Teaching Assistant	Assistance/reference

1.8 Training in Responsible Conduct of Research With Human Subjects

Have all study investigators and other key personnel completed training in the responsible conduct of research with human subjects within the past three years?

YES ☒
NO ☐

If NO, it is the principal investigator's responsibility to ensure that all key personnel complete responsible conduct of research with human subjects training and to provide documentation to the Office of Research Compliance in order to receive IRB approval. Use the following link to access URI's training program, the CITI Program: https://www.citiprogram.org/default.asp

CITI CERTIFICATES MUST BE SUBMITTED WITH YOUR IRBNET SUBMISSION

1.9 Funding

A. Will this be an externally funded project?

YES ☐
NO ☒

If yes, please answer the following:

Funding source:
Is the funding source PHS?

C. URI Log Number:

1.10 Collaborating Institutions and Investigators

A. Does the research involve a collaborating agency, institution, school district or other organization (entity)?

YES ☐
NO ☒

IF YES, please complete the following:

A1. List all collaborating entities.

A2. Does each collaborating entity have a Federalwide Assurance?

YES ☐
NO ☐

A3. If yes, please provide the Federalwide Assurance Number(s) of each collaborating entity:

A4. For each collaborating entity, a copy of a letter of agreement to participate in the research (on letterhead) is required. If the collaborating entity has an IRB, a copy of that

entity's IRB approval is required. Please include all necessary documentation with the submission of this IRB APPLICATION form.

B. Does the project involve one or more independent investigators who are not formally affiliated with the URI or another institution with a Federalwide Assurance (FWA)?

YES ☐
NO ☒

If YES, the independent investigator(s) must sign a formal written agreement of commitment to follow the human subject protection policies of URI.

Part 2. Summary of Activities

You may copy and paste information from your proposal or consent, if appropriate, in response to any of these questions.

2.1 Briefly describe the research study design, providing a short overview using layman's terms:

This EMG based robotics project will serve as a stepping stone to later projects that will be more beneficial to human welfare. The current goal is to connect a robotic car with the electrical signal of a human's muscle contraction. Ideally, signals in both arms will control movement in the right/left direction, and the strength of the signal will control acceleration in the car.

The proposed human subjects study will investigate the electromyography of ten anonymous subjects. Electrodes will be placed on the subjects, in an attempt to measure the amplitude and frequencies of the electrical signals from their muscle contractions. With this data, algorithms can be written to read a large range of electromyogram signals. This will allow for a working system for all subjects in the future.

2.2 Describe the tasks research subjects will be asked to perform. Attach surveys, instruments, interview questions, focus group questions, etc. Describe the frequency and duration of procedures, tests, and experiments.

Research subjects will have three electrodes attached to their forearm. Two will be placed one inch apart on their flexor muscles, reading electrical signals. The third will be placed around the elbow; This will be used as a ground comparison. The electrodes will be connected to a voltage amplifier, followed by an oscilloscope.

Subjects will be asked to flex the muscles in their forearm by clenching their fists. This will be repeated 5-10 times, at three different levels of strength of contraction, for a total of 15-30 events. Subjects may be asked to repeat on their other arm in an investigation to see the degree of variability between either arm of a single subject. All contractions will be shown on an oscilloscope, and saved to an external hard drive.

2.3 Provide a full description of risks and measures to minimize risks. Include risk of psychosocial harm (emotional distress, embarrassment), economic harm (e.g., loss of employment or insurability, loss of professional standing or reputation, loss of standing within a community), and legal jeopardy. Describe what will be done to minimize those risks.

This study will be requiring its subjects to clench his/her rists with a reasonable number of iterations. Thus, no risks or dicomfort are anticipated.

2.4 Describe any potential for direct benefit to individual subjects, as well as the benefit to society based on scientific knowledge to be gained; these should be clearly distinguished. Monetary payment or other compensation is not considered a benefit.

The individual subjects will have no direct benefits.

Society, however will most definitely benefit. This study will serve as a significant step forward in the assisted movement of paraplegics. By measuring the electrical signals of a number of human subjects, there will be good indication of the range of signal strength (ultimately correlating to acceleration of the robotics). Likewise, if overwhelming variability in electrical signal strength between test subjects is found, the algorithms may be written to calibrate a subject, in order to better differentiate between their own signal strenths. Ultimately, this study will provide evidence on how best to proceed in processing signals to output to the robot.

2.5 Does the research involve (Check all that apply):

- ☐ **Use of private records (e.g. medical, educational financial)**
- ☐ **Possible invasion of privacy of subject or subject's family**
- ☐ **Deception**
- ☐ **Deprivation of physiological requirements such as sleep or food**
- ☐ **Surveys requesting disclosure of sensitive information or illegal activities**
- ☐ **Diet and exercise interventions**
- ☐ **Presentations of materials that might cause stress to a particular population**
- ☐ **Infectious or hazardous materials**
- ☐ **Risks to job security or financial stability**
- ☐ **Invasive medical procedures other than blood draws**
- ☐ **Blood draws**
- ☐ **Investigational New Drug**
- ☐ **Investigational New Device**

Other (please describe)

Part 3. Characteristics of the Subject Population and Location of Study

3.1 Expected total maximum number of subjects:

Must be an exact number – cannot be a range.

10 subjects

Note: You may not exceed the number of subjects approved by the IRB. If you wish to enroll more subjects, you must first submit a request to the Office of Research Compliance.

3.2 Expected age range of subjects:

Subjects will be between the ages of 18 to 25.

3.3 Briefly describe the subject population. Specify number, sex, ethnicity, race and age. Justify exclusion of any group, especially by criteria based on gender, ethnicity, race or age.

The human subjects will be University of Rhode Island students. The study will be volunteer-based. No groups will be excluded from the study.

3.4 Vulnerable populations to be recruited for this project (Check all that apply):

☐Children (17 or under)	☒URI Students	☐Decisionally impaired
☐Prisoners	☐URI employees	☐Frail elderly
☐Pregnant Women	☐Employees of Researcher	☐Other:_____

3.5 Describe the location(s) where subject recruitment will take place (e.g. university, agency, hospital, shopping mall)?

University of Rhode Island, both dormatory and academic buildings

(Private settings require an authorization letter.)

Part 4. Recruitment and Informed Consent Process

4.1 Describe the recruitment process, being sure to explain who will approach potential subjects and how the privacy of potential subjects will be protected. Describe any incentives or inducements that will be offered. List all recruitment materials to be used (e.g. advertisements, bulletin board notices, emails, letters, phone scripts, or URLs) and attach copies to this form:

The potential subjects of this study will be all URI students. That is, bulletin board notices and fliers will be displayed in random dorms and academic buildings. Subjects will be strictly volunteers; There will be no incentives or inducements for students involved in the study.

4.2 Principal investigators are responsible to see that reasonable steps are taken to ensure that subjects are fully informed and understand the study. Considering that consent involves a process of communication in addition to use of a consent form, describe how you plan to consent your subjects.

All subjects will be given a copy of the project proposal. The purpose of this human study within the scope of the project will be explained. The study will be communicated in full detail, and a full demonstration of the study will be shown.

4.3 If any potential participants could have limited decision-making capacity, language barriers or hearing difficulty, describe how capacity to consent will be assessed.

We do not anticipate and language barriers, or other factors that may limit a subjects understanding of the study.

4.4 If your study population includes a substantial number of people who speak a foreign language, a consent form should be provided in translation. Please provide the name/credentials of the person who will do the translations.

We do not anticipate a substantial number of non-English speaking subjects.

If translated by the PI, a second fluent translator should also review the translation.

4.5 Parent/Guardian Consent and Assent – If enrolling children, describe how parent(s) or guardian(s) will provide consent and how child will provide assent.

Subjects must be older than 18 years of age to participate in the study.

4.6 Waiver or alteration of consent: The IRB may approve waiver or alteration of one or more of the elements of consent in some minimal risk studies. Do you plan to request one of the following:

X **Waiver of signed consent form**
Alteration of consent (i.e. deception)
Waiver of any other elements of informed consent , or entire consent

If so, please explain why the study is considered to be of minimal risk and why the waiver would be necessary to conduct the research:

This study is both anonymous and contains no risk. Patients will be required to clench their fists a maximum of 30 times, each with an estimated half-second duration. This simple task, even with a high level of repititions is not believed to cause any discomfort to the subjects.

A waiver would be necessary in order to expedite both the IRB review of the study, as well as the study itself. This data is pressing; Moving forward with the EMG based robotics project is dependent on the results of this human subjects study, and any time saved will be used in more valuable ways.

****The consent form(s) to be used for this study must be included with the submission of this IRB APPLICATION form. Use the following link to access recommended consent form templates: www.uri.edu/research/tro/offices/compliance**

Part 5. Privacy and Confidentiality

5.1 Describe any links between data collected and subject identity. Examples of links include names, addresses, telephone numbers, etc.

This study will be anonymous. No personal information will be recorded. Subject number will have no correlation with that subjects name, number, address, etc.

5.2 Describe the provisions made to maintain anonymity and/or confidentiality of data collected, including assignment of identification numbers, coding systems, etc.

Subjects will be assigned a number 1 through 10, and will not be asked to disclose any personal information.

5.3 Where, how long, and in what format (such as paper, digital or electronic media, video, audio, or photographic) will data be kept? Include details about where data will be stored (address), how it will be secured and who will have access to the data. For example, storage and security methods can include such methods as locked cabinets, password protection, encryption, firewalls, etc.

Exported oscilloscope data and images will be filed on a password protected external hard drive, solely used for this EMG human subject testing. PI Dr. Ying Sun, as well as student investigators Thomas Franklin, Kaitlin Abbate, and Morgan Rosenberger will have access to the hard drive, and will be given the password. The hard drive containing the human subjects data will be held in a locked cabinet in the Biomedical Engineering lab in room 206 of Kelly Hall.

5.4 Is Investigator requesting authorization for use and disclosure of Protected Health Information (PHI) from a covered entity? (Ex. Hospital, pharmacy, physician office)

YES ☐
NO ☒

5.5 Is Investigator requesting waiver of authorization for use and disclosure of PHI?

YES ☒ -- Fill out and submit Waiver of Authorization
NO ☐

5.6 Describe how the results of this research will be publicly disseminated (e.g. thesis, dissertation, publication, presentation that is not internal):

The results of the study will be used in algorithm design. The project will end in a publication. Algorithms and study images will most likely be described in the publication. Anonymity will be protected.

Part 6. Conflict of Interest

A conflict of interest may exist whenever financial considerations or publication rights have the potential to compromise or have the appearance of compromising one's professional judgment and independence in the design, conduct or publication of research.

The IRB considers the investigator's financial interests when evaluating the protection of human subjects. If a financial interest is reported, the IRB will assess the investigator's objectivity in:

- Communicating risks
- Promoting informed consent
- Selecting subjects
- Gathering, analyzing and reporting data

6.1 In the space below, identify whether you (including your spouse or dependent child) or any key person affiliated with the project has any financial interest, financial relationship, governance or administrative affiliation with any entity that is providing funds for or which has rights to intellectual property resulting from this study.

No individuals affiliated with this project, nor their families have any financial interest in this study.

6.2 Does this study evaluate a drug, a device, a test for disease, or a product?

YES ☐
NO ☒

IF YES, please answer the following two questions:

A. Do you (or any member of your immediate family) own stock, shares, or have other investments in the product or company owning, manufacturing, or developing the drug, device, test, or product exceeding $10,000 or 5% ownership during the conduct of the research or within one year of the termination of the research study?

YES ☐ - Complete the *Conflict of Interest Disclosure Form*
NO ☒

B. Do you receive any remuneration from the manufacturer, developer or owner of the device, drug, test, or product being evaluated?

YES ☐ - Complete the *Conflict of Interest Disclosure Form*
NO ☒

6.3 Are you serving as a paid consultant or speaker on behalf of the sponsor of your research?

YES ☐ - Complete the *Conflict of Interest Disclosure Form*
NO ☒

If any changes affect your answers to any of the questions in Part 6, it is your responsibility to report these changes to the Office of Research Compliance promptly.

Part 7. Assurance Statement

Required Electronic Signatures on IRBNet to complete your assurance:

Principal Investigator
Co-investigator(s) if applicable
Student investigator(s) if applicable (sign as team member)
Department Chair or Dean

Submission of the fully signed IRBNet package will serve as your assurance that the following statements are true:

I CERTIFY as follows concerning the above named research proposal:

I have read and am familiar with the University of Rhode Island's "Policies and Procedures Manual for Human Subject Protection."

The rights and welfare of the subjects will be adequately protected.

Risks or discomfort (if any) to subject(s) have been clearly indicated and it has been shown how they are outweighed by potential benefits to the subject or by the importance of the knowledge to be gained.

The informed consent of subjects will be obtained by appropriate methods that meet the requirements of the University's general assurance procedures.

Any proposed changes in research activity will be reported to the IRB. Those changes may not be initiated without IRB review and approval except where necessary to eliminate apparent immediate hazard to the subjects. Any changes relating to Part 6, Conflict of Interest, will be reported immediately to the Office of Research Compliance.

Any unanticipated problems involving risks to human subjects or others will be reported to the IRB immediately.

The Principal Investigator certifies that he/she has reviewed this IRB Application and ensured that all materials follow the instructions and checklists (see Pages 1-4) developed by the University of Rhode Island Institutional Review Board. The Principal Investigator acknowledges responsibility for the work of student investigators that he/she supervises.

Kaitlin Abbate
Morgan Rosenberger
Thomas Franklin
Ying Sun

Appendix B: HIPAA Waiver Form

University of Rhode Island
Institutional Review Board

WAIVER

OF AUTHORIZATION (CONSENT) FOR USE OF PROTECTED HEALTH INFORMATION IN RESEARCH

Title of Project: Electromyogram Based Controls

Duration of Project: September 2012 - February 2013

1. Is there any plan to review records of individuals who are not being asked to sign an authorization? ☐ yes ☒ no

2. Will the waiver adversely affect privacy rights and welfare of the research subjects?
☐ yes ☒ no

3. Could the research practicably be conducted without this waiver of the requirement to obtain research subject authorization? ☒ yes ☐ no

IF NO, please explain:

4. Could the research be practicably conducted without access to and use of the personal health information? ☒ yes ☐ no

IF NO, please explain:

5. Are the risks to the privacy of the research subjects whose personal health information is being used, reasonable in relation to the anticipated benefits, if any, to the individuals and the importance of the knowledge that is reasonably expected to result from the research?
☒ yes ☐ no.

6. Describe the plan to protect the identifiers from improper use and disclosure.
There will be supervision of all individuals participating in project.

7. Is there a plan to destroy identifiers at the earliest opportunity consistent with the conduct of the research? ☒ yes ☐ no

IF NO, please explain the research or legal justification for retaining identifiers.

PI Signature: ___ King Sun

Appendix C: Flyer Template

University of Rhode Island – STUDENT VOLUNTEERS NEEDED

Date:	TBD
Class:	Biomedical Capstone Design Project - Electromyogram

Looking for volunteers to help in our Capstone design project! Participants will be asked to contract forearms 15-30 times with varying strength and duration while connected to 3 electrodes – this will aid in our ability to electrically detect muscle activity.

Email: Kaitlin Abbate at kaitlin_abbate@my.uri.edu if interested!

Kaitlin Abbate
Thomas Franklin
Morgan Rosenberger

(Project Engineers)

Appendix D: CITI Completion Forms:

CITI Collaborative Institutional Training Initiative

Human Subject Research Curriculum Completion Report
Printed on 4/1/2011

Learner: Brian Ramos (username: brian_ramos)
Institution: University of Rhode Island
Contact Information Upper College Rd.
Kingston, RI 02881 United States
Department: Electrical and Biomedical Engineering
Phone: 1-401-874-1000
Email: brian_ramos@my.uri.edu

Group 1 (Basic Course):

Stage 1. Basic Course Passed on 03/28/11 (Ref # 5722284)

Elective Modules	Date Completed	Score
Belmont Report and CITI Course Introduction	03/21/11	3/3 (100%)
History and Ethical Principles - SBR	03/21/11	4/4 (100%)
Basic Institutional Review Board (IRB) Regulations and Review Process	03/22/11	5/5 (100%)
Informed Consent - SBR	03/22/11	5/5 (100%)
Privacy and Confidentiality - SBR	03/28/11	5/5 (100%)
Research With Protected Populations - Vulnerable Subjects: An Overview	03/28/11	4/4 (100%)
Conflicts of Interest in Research Involving Human Subjects	03/28/11	2/2 (100%)
University of Rhode Island	03/28/11	no quiz

For this Completion Report to be valid, the learner listed above must be affiliated with a CITI participating institution. Falsified information and unauthorized use of the CITI course site is unethical, and may be considered scientific misconduct by your institution.

Paul Braunschweiger Ph.D.
Professor, University of Miami
Director Office of Research Education
CITI Course Coordinator

Return

CITI Collaborative Institutional Training Initiative

Human Subject Research Curriculum Completion Report
Printed on 9/29/2011

Learner: Ying Sun (username: sun@ele.uri.edu)
Institution: University of Rhode Island
Contact Information University of Rhode Island
Dept. of Electrical, Computer and Biomedical Eng.
4 E AlumniAve
Kingston, RI 02881 USA
Department: Electrical, Computer and Biomedical Engineering
Phone: 401 874 2515
Email: sun@ele.uri.edu

Group 1 (Basic Course):

Stage 1. Basic Course Passed on 09/29/11 (Ref # 6793796)

Elective Modules	Date Completed	Score
Belmont Report and CITI Course Introduction	09/29/11	3/3 (100%)
History and Ethical Principles - SBR	09/29/11	4/4 (100%)
Basic Institutional Review Board (IRB) Regulations and Review Process	09/29/11	5/5 (100%)
Informed Consent - SBR	09/29/11	5/5 (100%)
Privacy and Confidentiality - SBR	09/29/11	4/5 (80%)
Research With Protected Populations - Vulnerable Subjects: An Overview	09/29/11	4/4 (100%)
Conflicts of Interest in Research Involving Human Subjects	09/29/11	5/5 (100%)
University of Rhode Island	09/29/11	no quiz

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Director Office of Research Education
CITI Course Coordinator

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Human Subject Research Curriculum Completion Report
Printed on 10/1/2012

Learner: Kaitlin Abbate (username: kabbate)
Institution: University of Rhode Island
Contact Information 7 Streamview Drive
Department: Biomedical Engineering
Phone: 401-874-5439
Email: kaitlin_abbate@my.uri.edu

Group 1 (Basic Course):

Stage 1. Basic Course Passed on 05/08/12 (Ref # 7898030)

Elective Modules	Date Completed	Score
Belmont Report and CITI Course Introduction	05/08/12	3/3 (100%)
History and Ethical Principles - SBR	05/08/12	4/4 (100%)
Basic Institutional Review Board (IRB) Regulations and Review Process	05/08/12	5/5 (100%)
Informed Consent - SBR	05/08/12	4/5 (80%)
Privacy and Confidentiality - SBR	05/08/12	3/5 (60%)
Research With Protected Populations - Vulnerable Subjects: An Overview	05/08/12	3/4 (75%)
Conflicts of Interest in Research Involving Human Subjects	05/08/12	4/5 (80%)
University of Rhode Island	05/08/12	no quiz

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Human Subject Research Curriculum Completion Report
Printed on 10/1/2012

Learner: Thomas Franklin (username: tomfrnk5)
Institution: University of Rhode Island
Contact Information 50 Lower College Rd, Kingston RI
Department: Department of Biomedical, Electrical, and Computer Engineering
Phone: 4018745439
Email: franklintr@gmail.com

Group 1 (Basic Course):

Stage 1. Basic Course Passed on 09/17/12 (Ref # 8775904)

Elective Modules	Date Completed	Score
Belmont Report and CITI Course Introduction	09/17/12	3/3 (100%)
History and Ethical Principles - SBR	09/17/12	5/5 (100%)
Basic Institutional Review Board (IRB) Regulations and Review Process	09/17/12	5/5 (100%)
Informed Consent - SBR	09/17/12	5/5 (100%)
Privacy and Confidentiality - SBR	09/17/12	5/5 (100%)
Research With Protected Populations - Vulnerable Subjects: An Overview	09/17/12	4/4 (100%)
Conflicts of Interest in Research Involving Human Subjects	09/17/12	5/5 (100%)
University of Rhode Island	09/17/12	no quiz

For this Completion Report to be valid, the learner listed above must be affiliated with a CITI participating institution. Falsified information and unauthorized use of the CITI course site is unethical, and may be considered scientific misconduct by your institution.

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Director Office of Research Education
CITI Course Coordinator

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CITI Collaborative Institutional Training Initiative

Human Subject Research Curriculum Completion Report
Printed on 10/1/2012

Learner: morgan rosenberger (username: mrosenberger)
Institution: University of Rhode Island
Contact Information 26 barrington Dr Gansevoort NY 12831
Department: Biomedical Engineering
Phone: 5187469824
Email: mrosenberger@my.uri.edu

Group 1 (Basic Course):

Stage 1. Basic Course Passed on 09/21/12 (Ref # 8813525)

Elective Modules	Date Completed	Score
Belmont Report and CITI Course Introduction	09/21/12	3/3 (100%)
History and Ethical Principles - SBR	09/21/12	5/5 (100%)
Basic Institutional Review Board (IRB) Regulations and Review Process	09/21/12	5/5 (100%)
Informed Consent - SBR	09/21/12	5/5 (100%)
Privacy and Confidentiality - SBR	09/21/12	5/5 (100%)
Research With Protected Populations - Vulnerable Subjects: An Overview	09/21/12	4/4 (100%)
Conflicts of Interest in Research Involving Human Subjects	09/21/12	4/5 (80%)
University of Rhode Island	09/21/12	no quiz

For this Completion Report to be valid, the learner listed above must be affiliated with a CITI participating institution. Falsified information and unauthorized use of the CITI course site is unethical, and may be considered scientific misconduct by your institution.

Paul Braunschweiger Ph.D.
Professor, University of Miami
Director Office of Research Education
CITI Course Coordinator

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Appendix E: BME 361 Final Lab (Software):

```
/
*************************************************************************
*********************/

/* BME 361 Biomeasurement Laboratory:  FINAL DEMO
                          */

/* Instructors: Prof. Ying Sun, Dr. John DiCecco
                       */

/* Assembled by: Ryan Andrews
                       */

/* Last update: June 29, 2011
                            */

/
*************************************************************************
*********************/



/******************************** Specify the chip that we are using
*****************************/

#pragma chip PIC18f452



/********************************** Define Prototype Functions
*********************************/

void _highPriorityInt(void);

void delay_ms(unsigned char x);



/************************************** Global variables
************************************/

unsigned char function, buttondelay0, buttondelay1;               // Switch
between demo functions

unsigned char variable;
      // LAB 1 - BINARY COUNTER

unsigned char ad_input, mode, counter, output;                    // LAB 2 -
ECG SIMULATION

uns16 timer_count;

unsigned char data0, data1;
      // LAB 3 - ECHO & DERIVATIVE

int16 dumb, dumber;
```

```
unsigned char data2, pres, next, buffer, sorted[9], stuffed[9];
      // LAB 6 - LP, HP, 60Hz, MEDIAN FILTERS

unsigned char a, i, j;



bit LCD_update, buttflag, new_data, display;                        // Flags
for buttons, filters, and LCD



#pragma origin 0x8

interrupt  highPriorityInterrupt(void){

      _highPriorityInt();     // 8 code words available including call and
RETFIE

      // Restore W, STATUS and BSR from shadow registers:

      #pragma fastMode

}

unsigned char ReadADC(){                          /********* start A/D, read
from an A/D channel ************/

unsigned char ADC_VALUE;

      GO = 1;                                                       // Start
the AD conversion

      while(!ADIF) continue;                              // Wait until AD
conversion is complete

      ADC_VALUE = ADRESH;                                       // Return the
highest 8 bits of the 10-bit AD conversion

      return ADC_VALUE;

}

void _highPriorityInt(void){              /******** High Priority Interrupt
Service Routine *********/

checkflags:

      if(TMR0IF == 1) {                                   // When there is a
timer0 overflow, this loop runs

            TMR0IE = 0;                                         // Disable
interrupt

            TMR0IF = 0;                                         // Reset timer 0
interrupt flag to 0

            if (buttondelay0 != 0)buttondelay0--;     // Delay to debounce
pushbutton
```

```
            if (buttondelay1 != 0)buttondelay1--;     // Delay to debounce
pushbutton

            switch (function) {

            case 0:                                          // LAB 1 - BINARY
COUNTER

                  TMR0H  =0xFC;                              // Reset timer
count: high-order and low-order bytes

                  TMR0L = 0x17;                              // $FFFF - $FC17
= $03E8 = 1000 (decimal) => ~ 1ms

                  break;

            case 1:                                          // LAB 2 - ECG
SIMULATION

                  ad_input = ReadADC();               // Bonus Section -
Variable Heartrate

                  timer_count = (uns16)ad_input;      // Casting ad_input as
16 bits

                  timer_count = timer_count*4;  // Convert timer_count from
0V-5V input

                  timer_count += 500;                        // to 500-1500
digital range => 48bpm-138bpm (approx)

                  timer_count = 0xFFFF - timer_count;

                  TMR0H = timer_count >> 8;           // Load upper 8 bits to
TMR0H

                  TMR0L = timer_count - TMR0H;  // Load lower 8 bits to TMR0L

                  switch(mode){

                  case 0:                                                // P wave up

                        counter++;

                        output++;

                        if(counter == 30) mode++;

                        break;

                  case 1:                                                // P wave
flat

                        counter--;

                        if(counter == 0) mode++;

                        break;
```

```
                case 2:                                         // P wave
down
                      counter++;
                      output--;
                      if(counter == 30){
                            mode++;
                            counter = 0;
                      }
                      break;
                case 3:                                         // PQ
segment
                      counter++;
                      if(counter == 70) {
                            mode++;
                            counter = 0;
                      }
                      break;
                case 4:                                         // Q wave
down
                      counter++;
                      output-=3;
                      if(counter == 5){
                            mode++;
                            counter = 0;
                      }
                      break;
                case 5:                                         // R wave up
                      counter++;
                      output+=5;
                      if(counter == 44){
                            mode++;
                            counter = 0;
```

```
                        }
                        break;
                  case 6:                                          // R wave
down
                        counter++;
                        output-=5;
                        if(counter == 51){
                              mode++;
                              counter = 0;
                        }
                        break;
                  case 7:                                          // S wave up
                        counter++;
                        output+=5;
                        if(counter == 10){
                              mode++;
                              counter = 0;
                        }
                        break;
                  case 8:                                          // ST
segment
                        counter++;
                        if(counter == 89){
                              mode++;
                              counter = 0;
                        }
                        break;
                  case 9:                                          // T wave up
                        counter++;
                        output++;
                        if(counter == 55) mode++;
```

```
                        break;
                  case 10:                                    // T wave flat
                        counter--;
                        if(counter == 0) mode++;
                        break;
                  case 11:                                    // T wave down
                        counter++;
                        output--;
                        if(counter == 55){
                              mode++;
                              counter =0 ;
                        }
                        break;
                  case 12:                                    // End of
heartbeat - wait 255 counts
                        counter++;
                        if(counter == 255){
                              mode = 0;
                              counter = 0;
                        }
                        break;
                  }
                  break;
            case 2:                                           // LAB 3 - ECHO
                  TMR0H  =0xEF;                               // Reset timer
count: high-order and low-order bytes
                  TMR0L = 0xB8;                               // 0xFFFF-0xEFB8
= $1047 = 4167 => 4.167 ms => 240 Hz
                  output = ReadADC();                         // Read A/D and
send it to output
                  break;
            case 3:                                           // LAB 3 -
DERIVATIVE
```

```
                TMR0H  =0xEF;                                   // Reset timer
count: high-order and low-order bytes

                TMR0L = 0xB8;                                   // 0xFFFF-0xEFB8
= $1047 = 4167 => 4.167 ms => 240 Hz

                data1 = data0;                                  // Save the
previous sample in data1

                data0 = ReadADC();                              // Read ADC and
save the present sample in data0

                dumb = data0;

                dumb -= data1;                                  // Backward
difference: data0 - data1

                dumb += 128;                                    // Shift baseline
up

                if (dumb > 255) dumb = 255;

                if (dumb < 0) dumb = 0;

                output = dumb;

                break;

            case 4:                                             // LAB 6 -
LOWPASS FILTER

                TMR0H  =0xEF;                                   // Reset timer
count: high-order and low-order bytes

                TMR0L = 0xB8;                                   // 0xFFFF-0xEFB8
= $1047 = 4167 => 4.167 ms => 240 Hz

                data2 = data1;                                  // Save the
previous-previous in data2

                data1 = data0;                                  // Save the
previous sample in data1

                data0 = ReadADC();                              // Read ADC and
save the present sample in data0

                dumb = data0;

                dumb += data1;

                dumb += data1;

                dumb += data2;

                dumb = dumb >> 2;                       // y[n]=(x[n]+2x[n-1]
+x[n-2])/4

                output = dumb;
```

```
                break;

            case 5:                                     // LAB 6 - HIGH-
FREQUENCY ENCHANCED FILTER

                TMR0H  =0xEF;                           // Reset timer
count: high-order and low-order bytes

                TMR0L = 0xB8;                           // 0xFFFF-0xEFB8
= $1047 = 4167 => 4.167 ms => 240 Hz

                data2 = data1;                          // Save the
previous-previous in data2

                data1 = data0;                          // Save the
previous sample in data1

                data0 = ReadADC();                      // Read ADC and
save the present sample in data0

                dumb = data0;                           // Calculates the
LPF component...

                dumb += data1;

                dumb += data1;

                dumb += data2;

                dumb = dumb >> 2;

                dumber = data0;

                dumber += data0;

                dumber -= dumb;                         // y[n]=2x[n]-
((x[n]+2x[n-1]+x[n-2])/4)

                if (dumber > 255) dumber = 255;

                if (dumber < 0) dumber = 0;

                output = dumber;

                break;

            case 6:                                     // LAB 6 - 60 Hz
NOTCH FILTER

                TMR0H  =0xEF;                           // Reset timer
count: high-order and low-order bytes

                TMR0L = 0xB8;                           // 0xFFFF-0xEFB8
= $1047 = 4167 => 4.167 ms => 240 Hz

                data2 = data1;                          // Save the
previous-previous in data2
```

```
                data1 = data0;                          // Save the
previous sample in data1}

                data0 = ReadADC();                      // Read ADC and
save the present sample in data0

                dumb = data0;

                dumb += data2;

                dumb = dumb >> 1;               // y[n]=(x[n]+x[n-2])/2

                output = dumb;

                break;

            case 7:                                     // LAB 6 - MEDIAN
FILTER

                TMR0H  =0xEF;                           // Reset timer
count: high-order and low-order bytes

                TMR0L = 0xB8;                           // 0xFFFF-0xEFB8
= $1047 = 4167 => 4.167 ms => 240 Hz

                ad_input = ReadADC();           // Read ADC and save
the present sample in ad_input

                new_data = 1;                           // Set new_data
flag

                break;


            PORTD = output;                     // Output to the D/A via the
parallel port D

            TMR0IE = 1;                         // Enable timer interrupt

            GO = 1;                                 // Starts ADC conversion

      }

      if (INT0IF == 1){                         // Interrupt for (-) button
(pin 33/RB0/INT0)

            INT0IE = 0;                             // Disable interrupt

            INT0IF = 0;                             // Reset interrupt flag

            if (buttondelay0 == 0){             // If buttondelay0 is not 0,
it's a switch bounce

                function--;                         // DECREMENT the
function mode

                if (buttflag == 1){
```

```
                        buttflag = PORTB = 0;   // Reset flag and turn off
binary counter LEDs
                        function = 8;                // Return to QRS
DETECTION
                  }
                  if (function == 7) PORTB.3 = 0;     // MEDIAN FILTER: Turn
off buzzer/LED
                  if (function == 1){                       // ECG SIMULATION
                        output = 50;
                        mode = counter = 0;                 // Initialize
variables for ECG Simulation and
                        variable = 0;                       // Binary Counter
                  }
                  if (function == 0) buttflag = 1;// Set flag to return to
QRS DETECTION if (-) button
                                                                  // is
pushed while doing BINARY COUNTER
                  LCD_update = 1;               // Signal the main program to
update LCD
                  buttondelay0 = 100;           // Delay by 100 timer periods
to debounce switch
            }
            INT0IE = 1;                         // Enable interrupt
            goto checkflags;              // Check again in case there is a
timer interrupt
      }
      if (INT1IF == 1){                         // Interrupt for (+) button
(pin 34/RB1/INT1)
            INT1IE = 0;                         // Disable interrupt
            INT1IF = 0;                         // Reset interrupt flag
            if (buttondelay1 == 0){       // If buttondelay1 is not 0, it's a
switch bounce
                  function++;                   // INCREMENT the function mode
                  buttflag = 0;                 // Reset flag
                  if (function == 1){           // ECG SIMULATION: Turn off
binary counter LEDs
```

```
                        PORTB = 0;
                  }
                  if (function == 9){
                        function = 0;     // Back to BINARY COUNTER
                        variable = 0;           // Initialize variables for
Binary Counter
                        output = 50;            // and ECG Simulation
                        mode = counter = 0;
                        PORTB.3 = 0;            // Turn off LED/Buzzer
                        buttflag = 1;           // Set flag to return to QRS
DETECTION if (-) button is pushed
                  }                                   // while doing BINARY
COUNTER
                  LCD_update = 1;               // Signal the main program to
update LCD
                  buttondelay1 = 100;           // Delay by 100 timer periods
to debounce switch
            }
            INT1IE = 1;                         // Enable interrupt
            goto checkflags;              // Check again in case there is a
timer interrupt
      }
  }
}
void Transmit(uns8 value){                  /************* Send an ASCII
Character to USART ***************/
      while(!TXIF) continue;                // Wait until USART is ready
      TXREG = value;                              // Send the data
      while (!TXIF) continue;               // Wait until USART is ready
      delay_ms (2);                               // Wait for 2 ms
}
void ClearScreen(){                         /******************** Clear LCD
Screen ************************/
      Transmit(254);                              // See datasheets for Serial
LCD and HD44780
```

```
      Transmit(0x01);                           // Available on our course
webpage

}

void backlight(uns8 state){         /**************** Turn LCD Backlight on/
off ******************/

      Transmit(124);

      if (state) Transmit(0x9D);          // If state == 1, backlight on

      else Transmit(0x81);                // otherwise, backlight off

}

void SetPosition(uns8 position){    /****************** Set LCD Cursor
Position  ******************/

      Transmit(254);

      Transmit(128 + position);

}

void PrintLine(const * string, uns8 numChars){ /******** Print character
string ******************/

      uns8 count;

      for (count=0; count<numChars; count++) Transmit(string[count]);

}

void PrintNum(uns8 value, uns8 position){ /*********** Print number at
position ******************/

uns8 units, tens, hundreds;

      SetPosition(position);                          // Set at the present
position

      hundreds = value / 100;                         // Get the hundreds
digit, convert to ASCII and send

      if(hundreds != 0)Transmit(hundreds + 48);

      else Transmit(20);                                    // If hundreds =
0, display a space

      tens = value - hundreds * 100;                  // Get the tens digit

      tens /= 10;

      Transmit(tens + 48);                            // Convert to ASCII and
send

      units = value - hundreds * 100;                 // Get the units digit

      units -= tens * 10;
```

```
      Transmit(units + 48);                          // Convert to ASCII and
send

}

void SetupSerial(){                        /****** Set up the USART
Asynchronous Transmit (pin 25) *******/

      TRISC = 0x80;                                          // Transmit and
receive, 0xC0 if transmit only

      SPBRG = 25;                                            // 9600 BAUD at
4MHz: 4,000,000/(16x9600) - 1 = 25.04

      TXEN = 1;                                              // Transmit enable

      SYNC = 0;                                              // Asynchronous
mode

      CREN = 1;                                              // Continuous
receive (receiver enabled)

      SPEN = 1;                                              // Serial Port
Enable

      BRGH = 1;                                              // High speed
baud rate

}

void SetupADC(unsigned char channel){     /*********** Configure A/D and Set
the Channel ************/

      TRISA = 0b.1111.1111;                          // Set all of Port A as
input

      // ADCON1 Setup

      // bit 7: Left justify result of AD (Lowest 6bits of ADRESL are 0's)

      // bit 6: Set to Fosc/8

      // bit 5-4: Unimplemented

      // bit 3-0: Configuration of 8 AD ports (Set all 8 inputs to Analog)

      ADCON1      = 0b.0000.0000;

      // ADCON0 Setup

      // bit 7,6 = 1,0: Set to Fosc/8

      // bits 5-3 = Channel select

      // bit 2: GO Bit (Starts Conversion when = 1)

      // bit 1: Unimplemented

      // bit 0: AD Po-wer On
```

```
	ADCON0 = (channel << 3) + 0b.0100.0001;

	ADIE = 0;		// Turn off the AD interrupt

	ADIF = 0;		// Reset the AD interrupt flag

}

void delay_ms(unsigned char x){		/**** Generate a delay for x ms,
assuming 4 MHz clock *****/

unsigned char y;

	for(;x > 0; x--) for(y=0; y< 165;y++);

}


/************************************* MAIN PROGRAM
*****************************************/

void main(){

	// Initial Global Variables

	function = variable = mode = counter = 0;

	buttondelay0 = buttondelay1 = 0;

	display = new_data =  0;

	buttflag = 1;

	output = 50;

	LCD_update = 1;

	TRISD = 0b.0000.0000;				// Set all Port D pins
as outputs (connected to D/A)

	TRISB = 0b.0000.0011;				// RB0 and RB1 as input
for pushbutton, others outputs

	SetupADC(0);					// Call SetupADC()
to set up Channel 0, AN0 (pin 2)

	SetupSerial();					// Set up USART
Asynchronous Transmit for LCD

	for (a=0; a<4; a++) delay_ms(250);	// Take a deep breath...allow
LCD to initialize

	for (a=0; a<2; a++) delay_ms(250);	//

	backlight(1);					// Turn backlight
on

	ClearScreen();					// Clear screen
and
```

```
      SetPosition(1);                                    // Set cursor to
first position

      PrintLine("BME 361 2012 :)", 14);

      SetPosition(68);                                   // Go to beginning of
Line 2

      PrintLine("Enter Team Name", 15);         // Put your trademark here

      for (a=0; a<4; a++) delay_ms(250);

      T0CON = 0b.1000.1000;                              // Setup the timer
control register for interrupt

      // bit 7 = GIE - global interrupt enable

      // bit 5 = TMROIE - Timer 0 overflow interrupt enable

      // bit 2 = TMR0IF - Timer 0 interrupt flag

      INTCON = 0b.1010.0000;

      INTEDG0 = 0;                                       // Enable pin 33
(RB0/INT0) for pushbutton interrupt

      INT0IE = 1;                                        // Enable INT0
interrupt

      INTEDG1 = 0;                                       // Enable pin 34
(RB1/INT1) for pushbutton interrupt

      INT1IE = 1;                                        // Enable INT1
interrupt

      while (1){

            if (LCD_update){

                  LCD_update = 0;

                  ClearScreen();

                  SetPosition(1);

                  PrintLine("Function: ", 10);  // Print funtion number

                  PrintNum(function, 11);

                  SetPosition(65);

                  switch (function){                     // Display
current function name on Line 2

                  case 0:

                        PrintLine("Binary Counter", 14);

                        break;
```

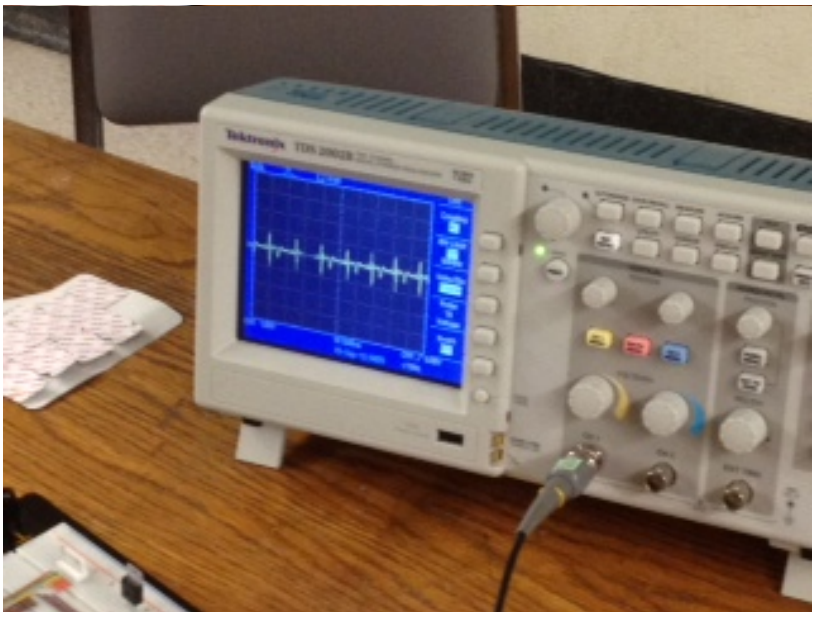
```
                case 1:
                      PrintLine("ECG Simulation", 14);
                      break;
                case 2:
                      PrintLine("Echo", 4);
                      break;
                case 3:
                      PrintLine("Derivative", 10);
                      break;
                case 4:
                      PrintLine("LP Filter", 9);
                      break;
                case 5:
                      PrintLine("HFE Filter", 10);
                      break;
                case 6:
                      PrintLine("60Hz Notch", 10);
                      break;
                case 7:
                      PrintLine("Median Filter", 13);
                      break;
                }
          }
          if(function == 0){                                    // LAB 1 -
BINARY COUNTER
                variable++;                                           //
Unsigned 8-bit variable increments by one
                if(variable <= 15){
                      variable = (variable << 4);               // Move
lower 4 bits to upper 4 bits (LEDs)
                      PORTB = variable;                         // Output
to Port B
```

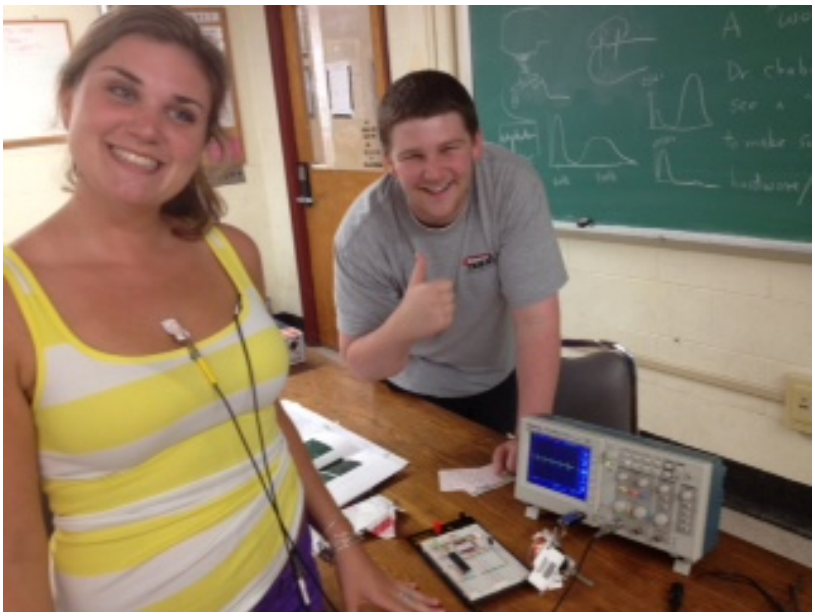
```
                        delay_ms(250);                                  //
Least significant bit toggles at 2Hz

                        delay_ms(250);

                        variable = (variable >> 4);             // Return
to lower 4 bits

                        if(variable == 15){

                              variable = 0;

                              PORTB = variable;

                              delay_ms(250);

                              delay_ms(250);

                        }

                  }

            }

            if(function == 7){

                                    if (new_data){

                        new_data = 0;                                   //
Reset new_data flag

                        TMR0IE = 0;                                     //
Disable timer interrupt



                        for(i=8; i>=1; i--){

                              buffer = stuffed[i-1];            // Previous
sample is shifted into next place

                              stuffed[i] = buffer;                      //
Stores 9 consecutive values in array

                              sorted[i] = buffer;

                        }

                        stuffed[0]=ad_input;

                        sorted[0]=ad_input;

                        for(i=0; i<=4; i++){                    // Bubble
Sort: places first 5 values in order

                              for(j=i+1; j<=8; j++){            // of
magnitude

                              pres = sorted[i];
```

```
                                    next = sorted[j];
                                          if(pres<next){
                                                sorted[i] = next;
                                                sorted[j] = pres;
                                          }
                                    }
                              }
                        }
                        output = sorted[4];                                 // Median =
middle value, i.e. array[4]
                        TMR0IE = 1;                     // LAB 6 - MEDIAN FILTER
                                                        // Enable timer interrupt
                  }
            }
}                                                                           /
******************** END MAIN ************************/
```

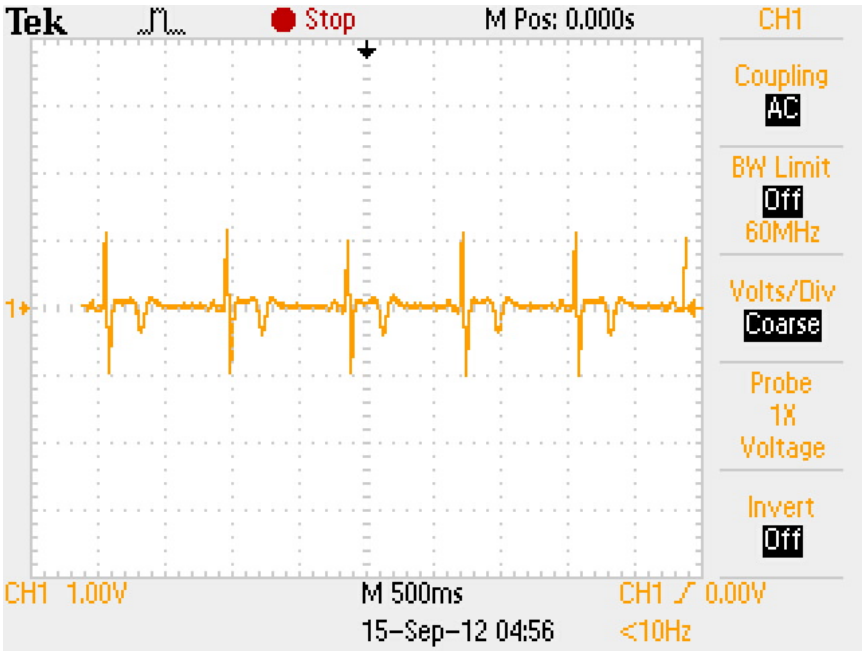
Appendix F: Images of Ongoing Research

ECG Simulation Successful:

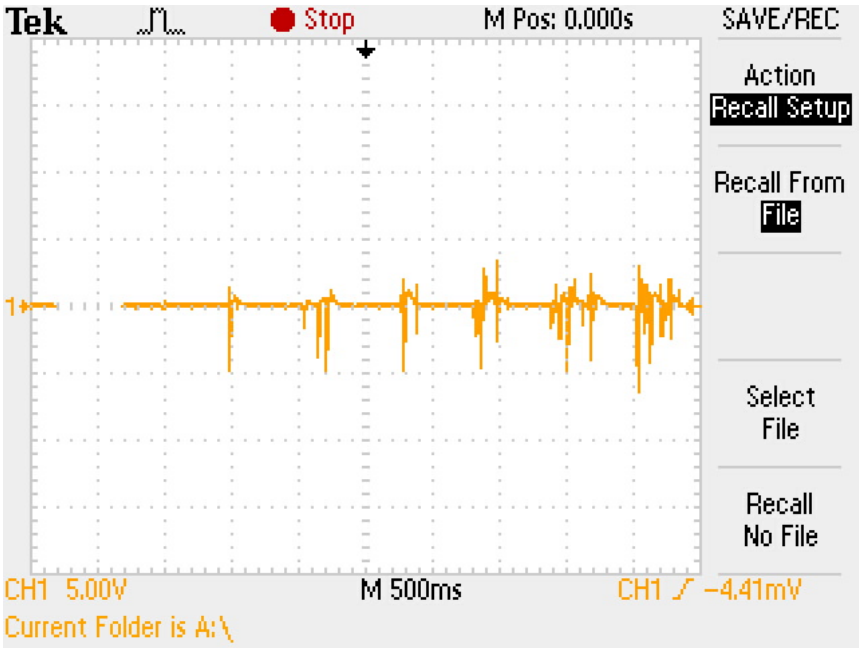




EMG Simulation Successful:



Light, Medium, Hard Forearm Contractions:


Tek
Stop
M Pos: 0.000s
SAVE/REC
Action
Recall Setup
Recall From
File
Select
File
Recall
No File
1
CH1 5.00V
M 500ms
CH1 ∕ −4.41mV
Current Folder is A:\