End of Project Documentation

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EEE 193B – Senior Design

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***Abstract* – Communicable diseases are a leading cause of health problems throughout the world. When an individual becomes infected with a communicable disease, they should isolate themselves from other non-infected people to prevent the spread of the disease. Complete isolation is not typically possible if the infected person requires treatment. Our goal through this project is to provide affordable and effective healthcare technology to the containment of communicable diseases. This document provides a brief background and overview of communicable diseases, current efforts in place to prevent spread, and future efforts being taken.**

I. Introduction

A communicable disease is a disease that is transmitted through direct contact with an infected individual or indirectly through a vector. This document focuses on two categories of communicable diseases: Airborne and Contact Diseases.

Airborne diseases are transmitted from an infected person by coughing, sneezing, laughing and close personal contact. The disease is caused by a pathogenic microbe that is small enough to be suspended in the air on dust particles, respiratory and water droplets.

Common Airborne Diseases:

- Tuberculosis
- Influenza (flu)
- Measles
- Chicken Pox
- Mumps
- Meningitis

Contact diseases are transmitted from direct bodily contact between an infected and uninfected person.

Common Direct Contact Diseases:

- Anthrax
- Coronavirus
- Legionellosis
- Meningococcal disease
- MRSA
- Plague
- Strep pneumoniae
- SARS

People with communicable diseases usually seek treatment from a health care professional at a health care facility. Often times, the health care professional is at risk for becoming infected with the communicable disease that the patient is being treated for. There are many steps currently in place to reduce this risk, but there are still cases of the health care professionals becoming infected.

As a case study, Tony Lewis of Natomas went to the hospital for a broken femur and 8 day later died from Clostridium difficile (C. diff), a completely unrelated disease. 200,000 Californians are diagnosed annually with C. diff (CA Healthcare Foundation, 2013).

All patients in the health care facility are also put at risk for becoming infected with communicable diseases. Even with proper isolation between infected patients, the health care professional or their physical tools can act as the transporter of the disease. 90% of physicians' and 79% of nurses' stethoscopes are contaminated with an infectious disease. (Global Industry Analytics, 2011). Stethoscopes are a major culprit in the spread of infectious diseases.

There are devices, such as a wireless stethoscope, which are being employed for various reasons. Some reasons that a wireless stethoscope may be used are:

- Increase the volume of the heart sound
- Create a recording of the heart sound
- Increase the distance between the patient and doctor

A wireless stethoscope also provides other benefits with the ability to perform digital signal processing. Noise cancellation is one particular application of signal processing.

II. Problem

In order to treat communicable diseases, health care professionals must put themselves at risk of becoming infected.

State of the art medical devices can be created which reduce the risk of health care professionals becoming infected from their patients. Reducing the rate of health care professionals becoming infected also reduces the rate of other uninfected patients becoming infected.

"Communicable diseases are a major threat within healthcare; the industry is anxious for solutions such as Safe Scope." *– Bruce Jobe M.D., Hospitalist at Kaiser Permanente*

III. Current Efforts

In the professional world of health care in hospitals there are certain standards to follow for nurses and doctors. Practice standards for registered nurse and nurse practitioners by *College of registered nurses of British Columbia* state principles which are to be followed/help nurses reduce the risk of communicable diseases by preventing nurse to client transmission.

1. Understand the principles in "routine practices and standard precautions" applying in their practice to any infection they have, from a cold to Hepatitis B (HBV).

2. If nurses have influenza symptoms, such as fever or chills, they must stay home.

3. Be vigilant about the hand washing after contact with client or potentially contaminated articles and before contact with another client. Using sanitizers is the most effective way of protecting clients.

4. Keeping immunization up to date to protect themselves and their colleagues.

5. A nurse with an infection that could put clients at risk needs to seek confidential advice

from an infectious disease expert about treatment options and about disclosing information to colleagues.

6. On chronic infection that affects your ability to practice safely, work with manager to arrange appropriate retraining opportunities and/or alternative placements.

In addition, according to the communicable disease control and prevention San Francisco Department of Public Health they state eight health habits to keep public safe from spreading these diseases

1. Handle & Prepare Food Safely
2. Wash Hands Often
3. Clean & Disinfect Commonly Used Surfaces
4. Cough & Sneeze Into Your Sleeve
5. Don't Share Personal Items
6. Get Vaccinated
7. Avoid Touching Wild Animals
8. Stay Home When Sick

IV. Future Efforts

Scenario planning can be used to help plan out how to fight diseases. Scenario planning involves illustrating the future and thinking and about what needs to be done when a particular situation occurs. Asia-Pacific Economic Corporation (APEC) members attended a scenario workshop about emerging infectious diseases. Four scenarios were developed as the outcomes of the workshop to reflect how the experts anticipate the possible futures regarding the development of emerging infectious diseases and their impacts. This idea helps organizations analyze alternative futures that might occur so the organizations can make better decisions for developing a proper strategic guidance. From the scenario workshops, experts highlighted key technological domains in the areas of modeling, tracking and vaccine development.

The center for disease control and prevention (CDC) has developed a framework for preventing infectious diseases. They focused on three key elements which are strong public health fundamentals, high impact interventions, and sound health policies. The first element seeks out to strengthen public health fundamentals. This can be done by expanding the role of public health and clinical laboratories in disease control and preventions. The second element seeks to identify and implement high-impact public health interventions to reduce disease. Effective tools and new ones can be used to reduce disease. The third element involves solid data to develop cost-effective policies. These policies can improve prevention, detection and control of infectious diseases; increase community and individual engagement to prevent disease; strengthen global efforts to find and react to outbreaks.

An example of the CDC framework being taken into consideration can be found in the work of Naveen Verma, an assistant professor of electrical engineering at Princeton University. The proposed project includes a wearable or implantable electronic devices that monitors brain or heart signals to prevent acute problems and perform long-term assessments in patients with chronic illnesses such as heart disease and epilepsy.

Intractable diseases are hard to cure because diagnosing the problem is difficult. There are also problems with curing unclassified diseases.

This approach supports users for thinking new criteria for the unclassified diseases. This system involves the user choosing disease names that have similar effects, then the user makes them into a group. This system can find criteria that is not considered by medical doctors. If the user alternates the group name, then the user states why the user has alternated it. The result ends up being new criteria to classify unclassified diseases.

Modern technology continues to grow and allow development of devices which can reduce the risk of health care professionals becoming infected with communicable diseases while treating infected patients. Reducing the spread of infection to health care professionals also reduces the spread of infections between patients. Preventing spread between patients is very critical, because often uninfected patients are more susceptible to the most severe consequences of the disease.

V. Funding Proposals

Daniel Forer entered the team into the 2014 CSU I-Corps Student Challenge hosted by California State University Program for Education and Research in Biotechnology. Daniel was awarded a $2500 microgrant. Daniel Forer and Prem Bhaskara participated in the student challenge and the team was awarded the crowd favorite award. Due to the teams' success at the 27th Biotechnology Symposium in Santa Clara, the team was offered the opportunity to compete in a NSF competition and a grant of $50,000 to continue their research and product development.

Prem Bhaskara and Daniel Forer also entered the team into The Pitch business competition hosted by SACE. The team won 2nd place and was awarded $500.

The team is also entered in the Future Four competition hosted by CSU Chico and the Big Bang business competition hosted by UC Davis.

VI. Work Breakdown Structure

Hardware Tasks - Sensor Module

The Sensor Module contains the sensors that will be placed on the patient. There are two types of sensors:

1. ECG
2. Audio Stethoscope

Level 1	Level 2	Level 3
Choose ECG sensor		
	Design ECG amplifier and filter circuit	
		Simulate circuit in SPICE
Choose audio stethoscope sensor		
	Design audio stethoscope amplifier and filter circuit	
		Simulate circuit in SPICE
Create prototype		
	Test and revise prototype	
Finalize design		

Hardware Tasks - Transmit Module

The Transmit Module contains the hardware that interfaces with the sensor module, the processing of the sensor data, and the ability to send the data wirelessly.

Level 1	Level 2	Level 3
Choose microcontroller		
	Test programming microcontroller	
Choose wireless data module		
	Test wireless data module	
Choose wireless audio module		
	Test wireless audio module	
Design power circuit		
	Simulate power circuit in SPICE	
		Create and test power circuit
Design transmit module circuit		
	Simulate transmit module circuit in SPICE	
		Create and test transmit module circuit
Create full prototype		
	Test and revise prototype	
Finalize design		

Software Tasks - Transmit Module

The Transmit Module software has the ability to sample the ECG signal, determine heartbeats per minute, send ECG data wirelessly, and configure the wireless audio module.

Level 1	Level 2	Level 3
Hardware Startup		
	Clock and power setup	
	Pin configuration	
Operating System		
	Process Scheduling	
	Hardware Drivers	
		UART
		A2D
ECG Processing		
	Detect beats per minute	
Wireless Data		
	Package data into packets	
	Configure data module	
		Pair with Android device
		Send data to and from Android device
Wireless Audio Configure		
	Configure audio module	
		Pair with wireless headphones

Android Application

This is an application for the table which lets the doctors see the ECG signal.

Level 1	Level 2	Level 3
Layout design		
	User friendly Design	
Display ECG signal		
	plotting BPM	
Connecting to wireless		

Project Management

Project management contains the tasks required to manage the project. This includes all assignments required by the Senior Design course.

Level 1	Level 2	Level 3
Project Timeline		
	Continuously update timeline	
Breadboard Proof		
Midterm Technical Review		
Prototype Demonstration and Review		
Problem Statement Revision		
Device Test Plan		
Market Review		
Midterm Progress Review		
Feature Presentation and Report		
Deployable Prototype Review		
End of Project Documentation		
Deployable Prototype Presentation		

Packaging

The table below shows the structure of various parts needed for Sensor module which is on the patients.

Common junction is the node where the data from all the sensors is collected and transmitted to transmit module via a wired communication.

Transmit module it consists of electronics necessary for processing incoming data and transmitting it to the table and the audio device.

Level 1	Level 2	Level 3
Sensor Module		
	ECG Leads	
		Filter circuits
	Microphone	
		Filter circuits
Common junction		
	Wired communication to transmit module	
Transmit Module		
	Case for all the electronics	

Funding

The table below shows the structure of the funding schedule and corresponding reports.

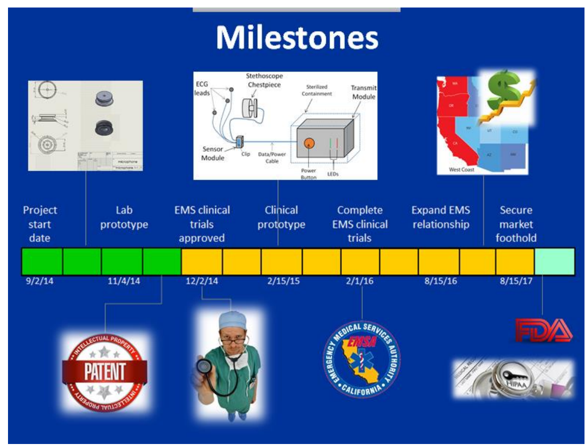
Level 1	Level 2	Level 3
Obtain microgrant		
	File application	
		Get faculty mentor, industry mentor, business student
CSUPERB bi-weekly conference		
	bi-weekly homework assignments	
CSUPERB documentation		
	business model	
		revise business model
	summary documentation	
		revise summary documentation
	final roster	
	presentation documentation	
CSU Biotechnology Symposium		
	finalize presentation slides/initial presentation	
		revise presentation slides
	presentation competition	
CSUPERB follow-up documentation		
	post competition write-up	

Testing

The table below shows the structure of the device testing schedule.

Level 1	Level 2	Level 3
Breadboard Proof		
	ECG signal verification	
		psuedo ECG signal
Lab prototype		
	sensor module running	
		sub-stage verification
Deployable Prototype		
	Interconnection between sensor and transmit module	
		receive and display data on android

Milestones



VII. Risk Assessment and Mitigation

Probability	5 (High	Minor Software				
	4				Major Software	
	3	Graphical User	Bluetooth audio		Mathematical	Instrumentation
	2		Insufficient	Bluetooth audio	Android app	MCU demo
	1 (Low				Losing a team	Disaster at
		1 (Least Impact)	2	3	4	5 (Most Impact)
		Impact				

VIII. Task Assignments

Tasks In Process

test circuit protection (clamping diodes)

Dan: Done 2/6/15

SOLUTION: clamping diodes do not work when wired as in analog circuit example, low priority for me so will be skipped for now. Someone else should pick this task up and complete.

will also need this working for the analog audio output

test microphone and design amplifier circuit (if necessary)

see Mic & Amp Circuit diagram, need to order OP177 op-amp , OP177 datasheet

target specs

Max voltage = 500 mV

Dan: Circuit Designed 3/20/15

order wireless RF audio headset and test/integrate into system

Dan: Done 3/20/15

Tx/Rx verified for audio connected to known source 3mm jack (phone)

assemble transmit and sensor modules

Dan: In process 2/2/15

test to see if raw ECG signal can be detected through RJ-45 cable and jacks (Rj-45 pinout is same order for both jacks) - Yes 2/6/15

can not send voltage down same line that is directly connected to a person, NOT SAFE!!

if we have to then only send 3.3V, not 9V

want to move as much circuitry as possible from the sensor module to the transmit

SOLUTION: raw ECG signal can be detected through RJ-45 cable and jacks, move all circuitry to Transmit Module

only circuitry in Sensor Module is wiring from individual sensors to RJ-45

test to see if 2 voltage regulator circuits in parallel can run off of 1 9V battery instead of 2 independent circuits - No simple way to do this 2/6/15

if so then can use a single DPST switch to control the entire system

SOLUTION: use 2 9V batteries for +/- VCC, need to order TPST switch

assemble circuit cards and test

3D printing for chassis parts bypassed

ECG Analog circuit integration and validation

Dan: Done 3/20/15

Tasks Completed

reduce HPF -3 dB cutoff frequency and test (use 0.1 Hz instead of 1 Hz)

Dan: Done 2/6/15

SOLUTION: change R to 150k for both HPF, new f-3dB=0.1061 Hz

design rechargeable battery and select part

Dan: Done 2/3/15

test rechargeable battery system

find proper circuit isolation

Dan: Done 2/20/15

design AGC and select part

Dan: Done 2/18/15

no AGC used, signal not centered in dynamic range - high potential for failure

dynamic range verified

DC offset verified

Riverside 3001

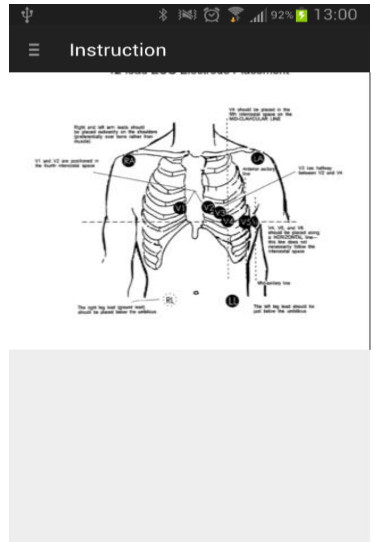
Outdoor Alley between Riverside and Santa Clara halls

design final specs for sensor and transmit module cases

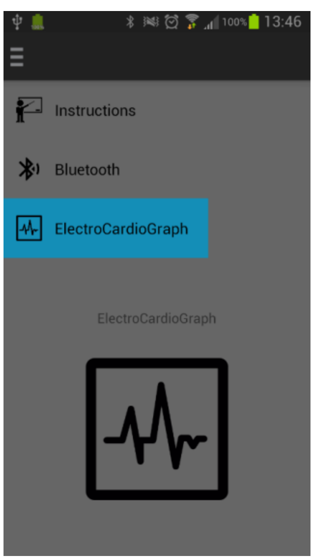
Dan/Prem: Done 2/25/15

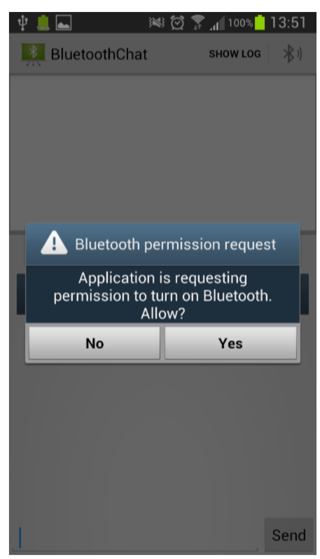
update all documentation to reflect design changes

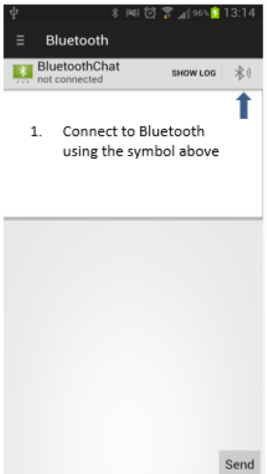
Dan: Done 2/25/15

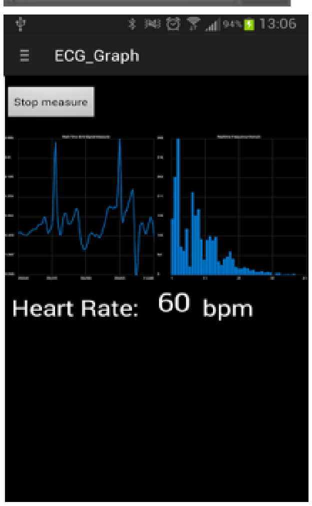


IX. User Manual









X. Design Documentation

Components:

- Microcontroller – ARM Cortex M3 (NXP LPC1769)
- Bluetooth Data Module – Microchip RN42
- DigitAL HIFI Dynamic Wireless Tx/Rx
    - Tx: Operating Frequency (72~74 MHz), DC 9 V (500 mA), Max Input 500 mV
    - Rx: Operating Frequency (71~76 MHz), DC 3 V, SNR > 50 dB

Interfaces:

- UART – Universal Asynchronous Receiver Transmitter
- ADC – Analog Digital Converter. 10-bit, 1000 samples/sec.
- Bluetooth Classic

Software:

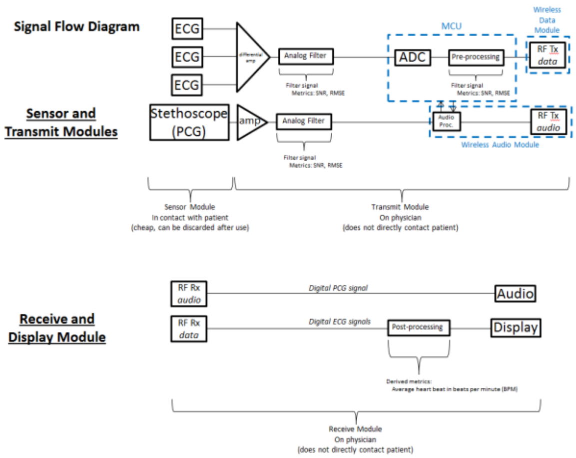
- FreeRTOS – Market leading real time operating system. Ported to many devices
- CLI – Command Line Interface

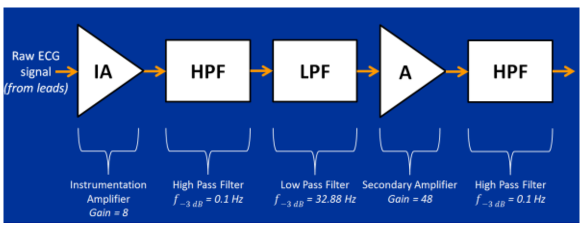
Power:

- 2000 mAH Li-ion, 3.3 V
- Combines the high level of integration and low power consumption of the LPC1769

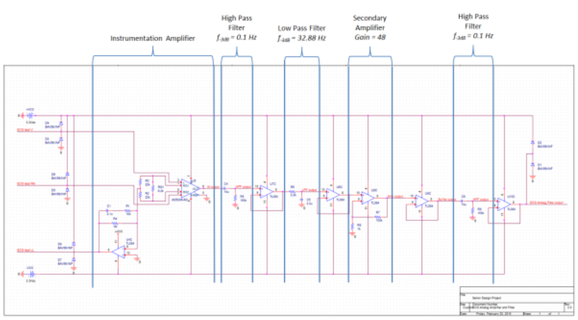
XI. Hardware

a. Block Diagram



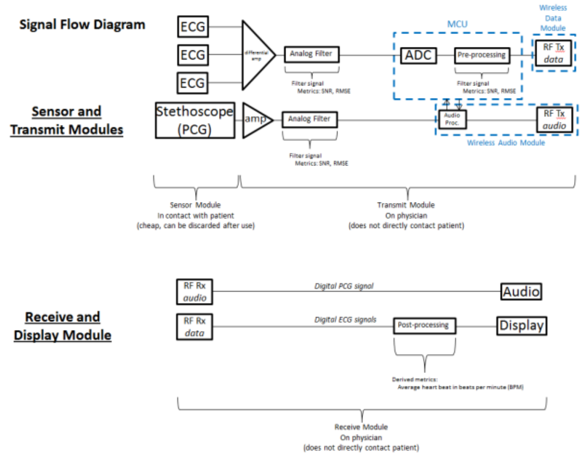


b. Schematics

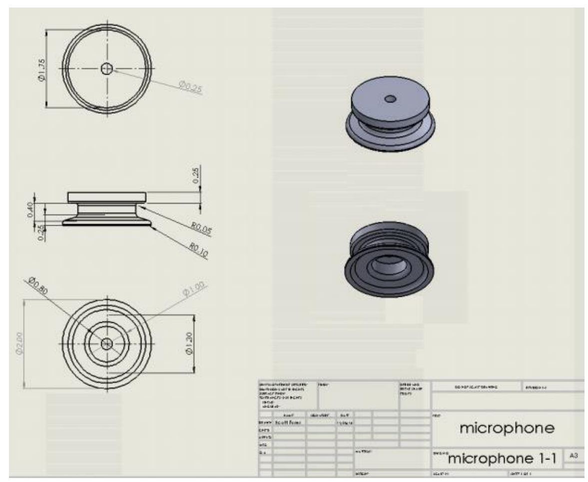


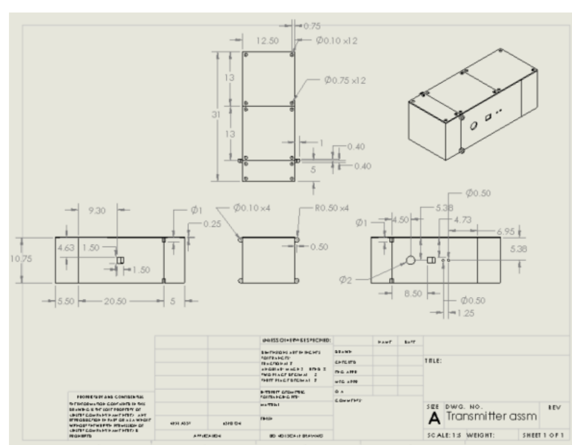
XII. Software

a. Flowcharts



XIII. Mechanical





XIV. Hardware Test Plan

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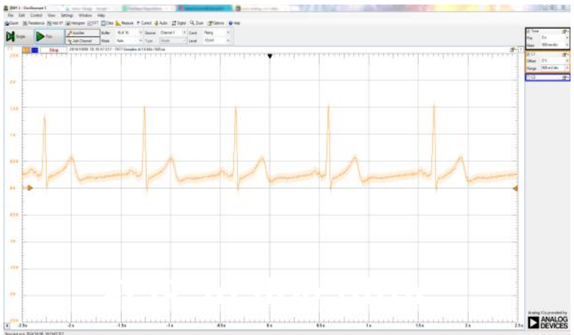

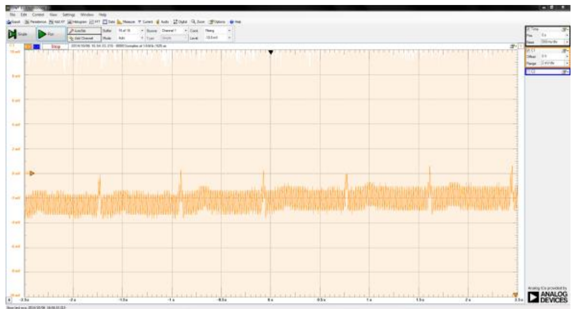

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XV. Software Test Plan

- ARM Cortex-M3 processor
    - Industry standard NXP LPC1768 MCU
    - Pin compatible package with NXP LPC4xxx MCU Cortex-M4 family
- Scalable and minimalistic FreeRTOS real time operating system
- Preemptive microkernel

- Minimal ROM/RAM footprint
- Compatibility with Memory Protection Unit
- Abundance of middleware providers
    - TCP/IP stack
    - USB stack

“Developed in partnership with the world's leading chip companies over a 12 year period, FreeRTOS is the market leading real time operating system (or RTOS), and the de-facto standard solution for microcontrollers and small microprocessors.”-*freertos.com*

XVI. Task Distribution

Task Distribution

• Brandon Ortiz - Microprocessor programming, install of device drivers, serial communication to MCU, integration of wireless modules, mobile device software programming

• Daniel Forer - Operational amplifier design, digital/analog filter design, digital signal pre/post-processing, MATLAB modeling of biomedical signals, entrepreneurial lead, mobile device software programming

• Prem Bhaskara - Operational amplifier design, analog filter design, PCB assembly, power sources, charging circuit design, mobile device software programming, support with CSUPERB

• George Medina Jr. - Support with MATLAB modeling of signals, analog circuitry design, equipment purchasing, power sources, microprocessor programming, serial communication to MCU

System Verification

We can validate our system as we progress through the development stages. We will use a signal analyzer, oscilloscope, and a network analyzer to verify the output of our analog signals (both ECG and PCG). It is important to characterize these signals, especially the ECG signal, so that we know what to look for when we enter the pre-processing stage. We will use a serial interface to communicate with the MCU. In this stage we can analyze the output of our ADC as well the pre-processor. We can also verify that the signal is ready to transmit and are wireless transmit modules are operating correctly within the MCU. On the receive and display side we can verify that our signals are indeed being received and are being displayed properly without latency or distortion. Distortion can be monitor by following the SNR and RMSE metrics from the pre- and post-processing stages.

XVII. Conclusion

This report introduces the future design layout of a wireless stethoscope. We presented the information on how the design would be, that is by introducing modularity in the design. It consists of two major parts, one that can easily be replaced and is also cheap. The other part is always with the doctor, which contains the transmitter and the necessary electronics to amplify/filter/convert the incoming analog signal. Information passed over from the transmission module is heard by the wireless headset and the ECG of the patient is displayed on the tablet. Hence solving the issue with communicable diseases and preventing the spread.

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