Emergency Vitals Monitor

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ECE445 Project Proposal - Spring 2020
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1. Introduction

1.1 Objective

Problem: Administering first aid in disaster situations is an extremely stressful task, that is prone to error if not done by a very well trained professional. Under circumstances with multiple injuries (gunshot, heat/fire related, earthquake, etc.), with limited bystanders available, treatment for these injuries are typically left for emergency response personnel. According to an article by H. K. Bakke et. al. that looked into the role of the bystander in trauma response, only 35% of those bystanders who assisted the injured had first aid training. Furthermore, it is estimated that 6-20% of trauma victims who die prior to making it to the hospital could have been saved if bystanders had acted to assist them.

Solution: A uniquely colored automated blood pressure cuff with extending rod for taking temperature, which doubles as the alignment for the pressure cuff's microphone. This simplifies the use as much as possible so that only a few people can attach them to as large a group as necessary in as little time needed. After activation, the blood pressure cuff will automatically take readings of blood pressure, heart rate, and temperature every thirty seconds. The blood pressure and heart rate can be used to determine an individual's 'shock index', which would set up a triage system automatically. This data is collated on a device for the user so as to see the ranking of each cuff in use in terms of who needs attention first, and gives first aid advice on how to treat the conditions detected. This improves the likelihood of an individual performing effective first aid, as well as ensuring that bystanders are able to perform first aid on those who need it most if first responders are limited.

1.2 Background

There is a similar product named QardioArm[1] that supports blood pressure monitoring for multiple users. This product requires to be paired with other mobile devices before displaying its measurements and it’s mostly used in daily life instead of in emergency situations that it lacks the ability to rank the priority of different patients. Our project ranks the severity of patients depending on MSI (modified shock index)[2] and improves first aid capabilities in untrained bystanders by providing methods to assist injured individuals.

1.3 Physical Design

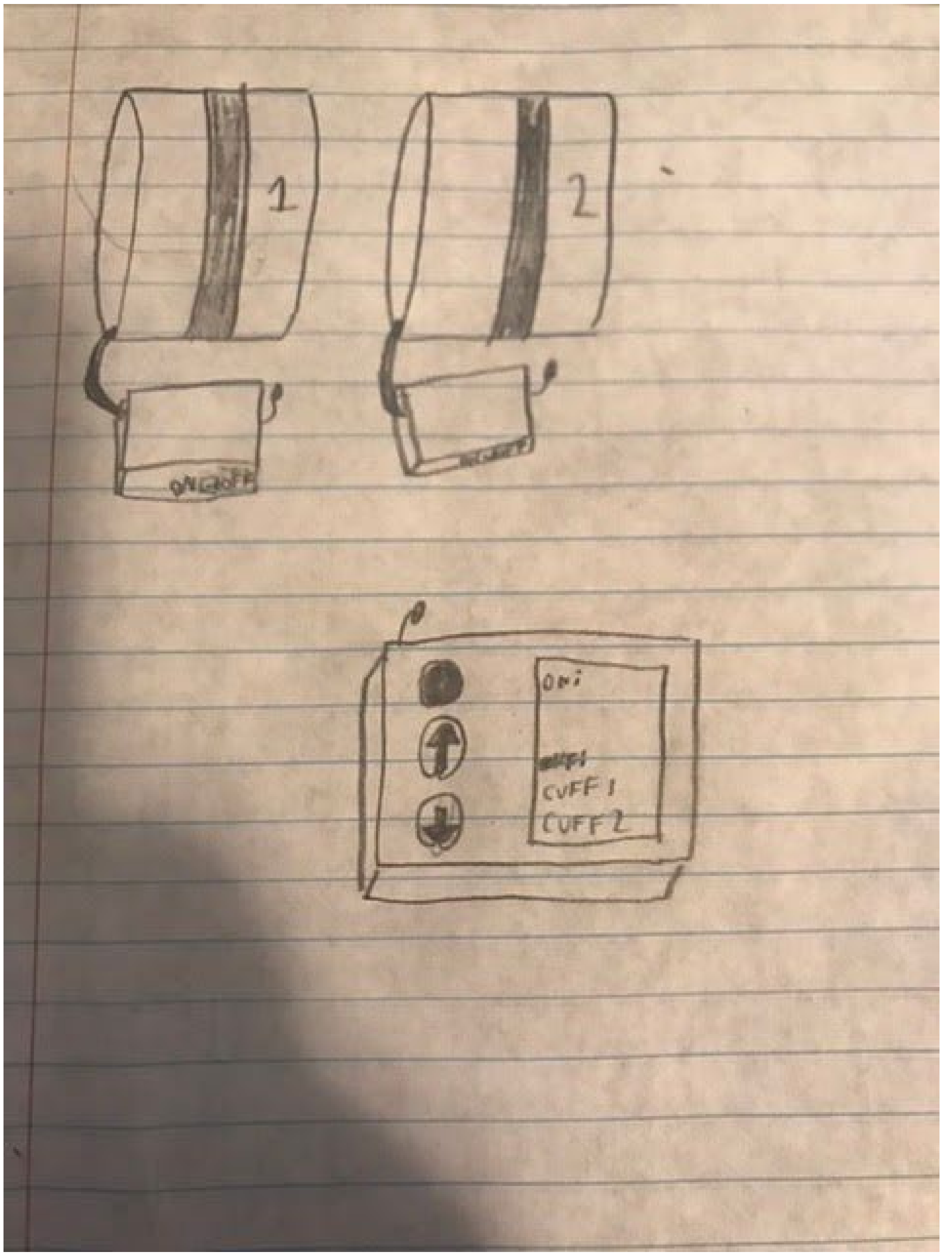

Figure 1. Physical Design High-Level

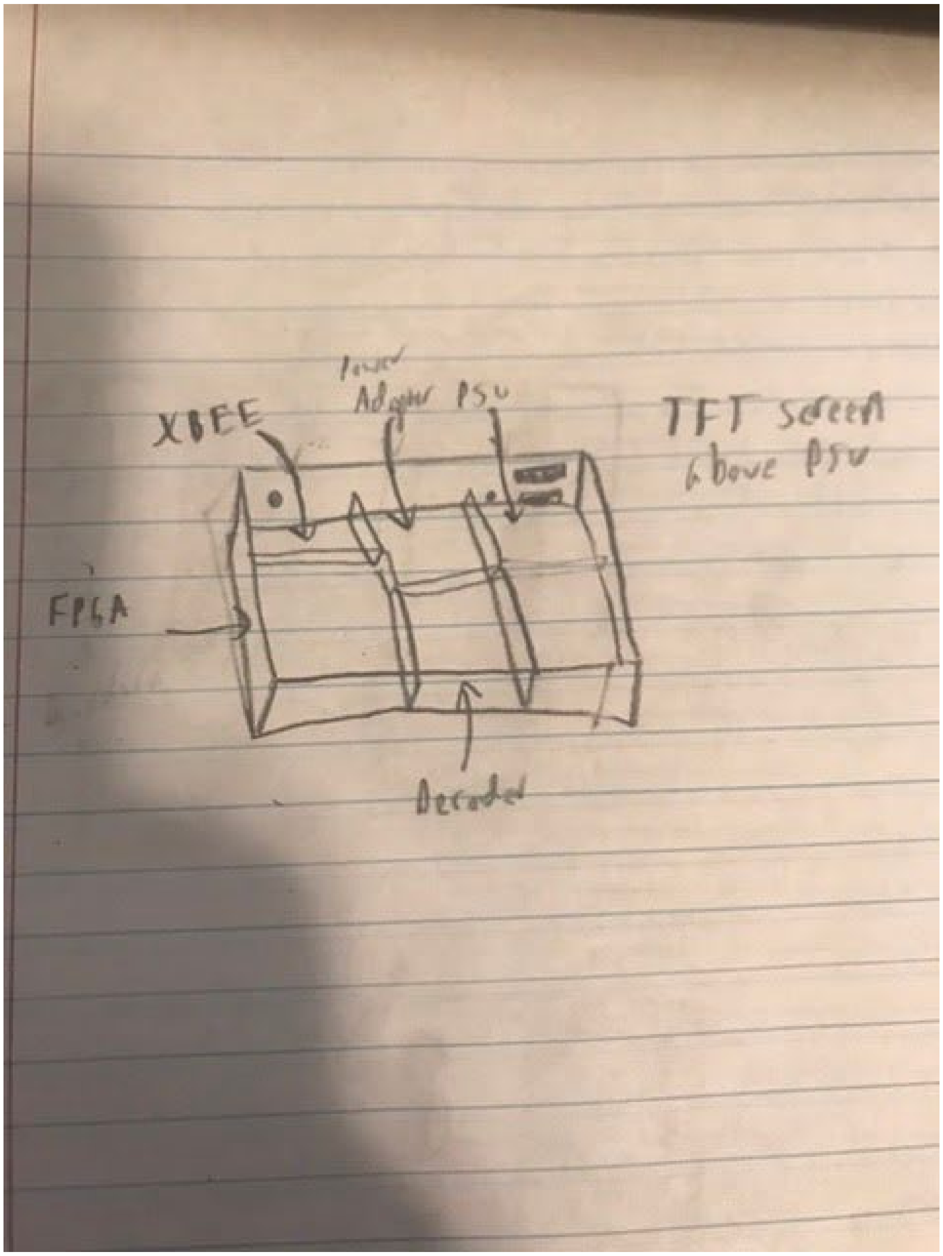

Figure 2. Display Box Layout

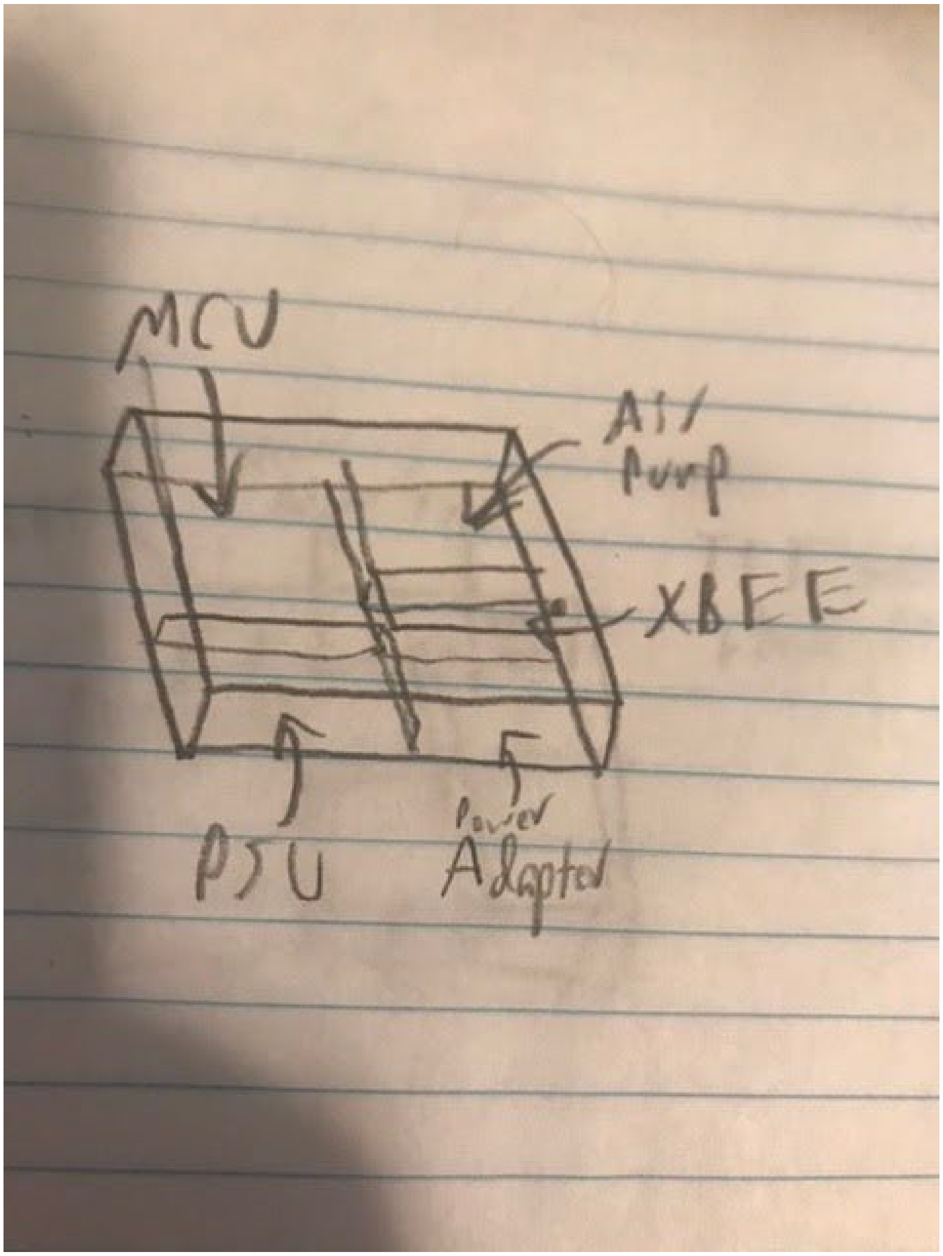

Figure 3. Measurement Unit Box Layout

1.4 High-Level Requirements

- Automatic blood pressure cuffs must operate every one to two minutes, sending vital readings to display device for triage ranking
- Display Device must be able to handle more than one cuff being used at a time
- Display Device doubles as a guide for first aid, with topics prioritized based off of the vital readings of the active blood pressure cuffs.

2. Design

2.1 Block Diagram

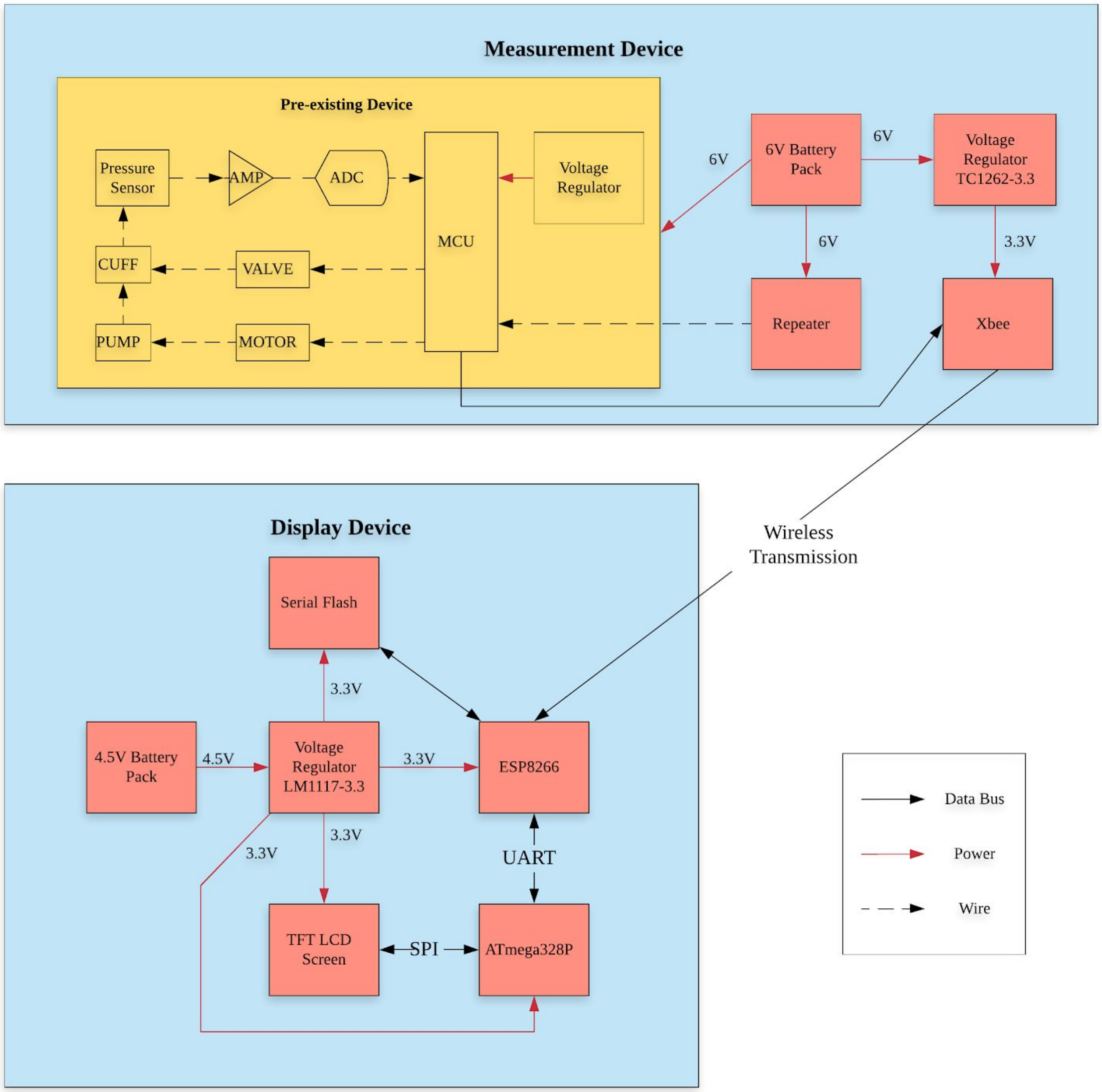

Figure 4. Block Diagram

2.2 Functional Overview and Block Requirements

2.2.1 Power Unit

Using the integrated power supply from our sphygmomanometer, we'll power our cuff and data communication device. Our measurement device will use 6V EBL rechargeable battery pack and our display device will use 4.5V EBL rechargeable battery pack.

Voltage Regulator

TC1262-3.3(for measurement device)

Requirement	Verification
1. Provides 3.3V +/- 5% and 5V +/- 5% from a 6V source. 2. Can draw 500 mA output. 3. Maintains thermal stability below 125 degree Celsius.	1-2. A. Using the circuit schematic in figure 5., we connect 6V battery supply to the input and regulate 3.3V and 5V. B. Measure the output voltageVREG3.3V using an oscilloscope, ensuring that the voltage stays within 5% of 3.3V. 3. A. Use an IR thermometer to ensure that the temperature of ICs stays below 125 degree celsius during the above steps.

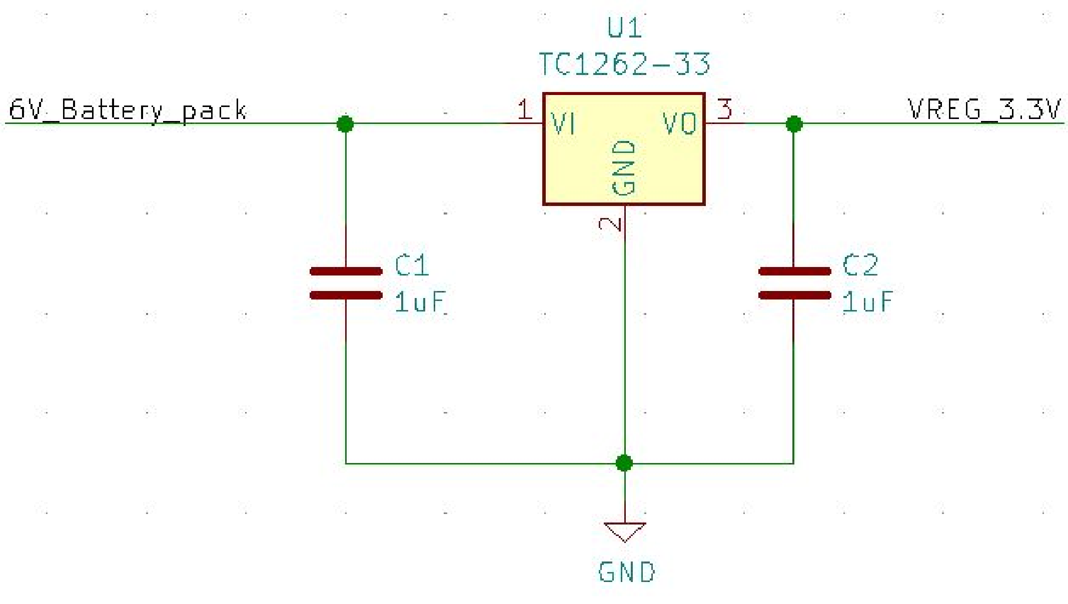

Figure 5. TC1262-3.3 Circuit Schematics

LM1117-3.3(for display device)

Requirement	Verification
1. Provides 3.3V +/- 5% and 5V +/- 5% from a 4.5V-12V source. 2. Can draw 800 mA output. 3. Maintains thermal stability below 125 degree Celsius.	1-2. C. Using the circuit schematic in figure 6., we connect 4.5V battery supply to the input and regulate 3.3V and 5V. D. Measure the output voltageVREG3.3V

	using an oscilloscope, ensuring that the voltage stays within 5% of 3.3V. 3. B. Use an IR thermometer to ensure that the temperature of ICs stays below 125 degree celsius during the above steps.

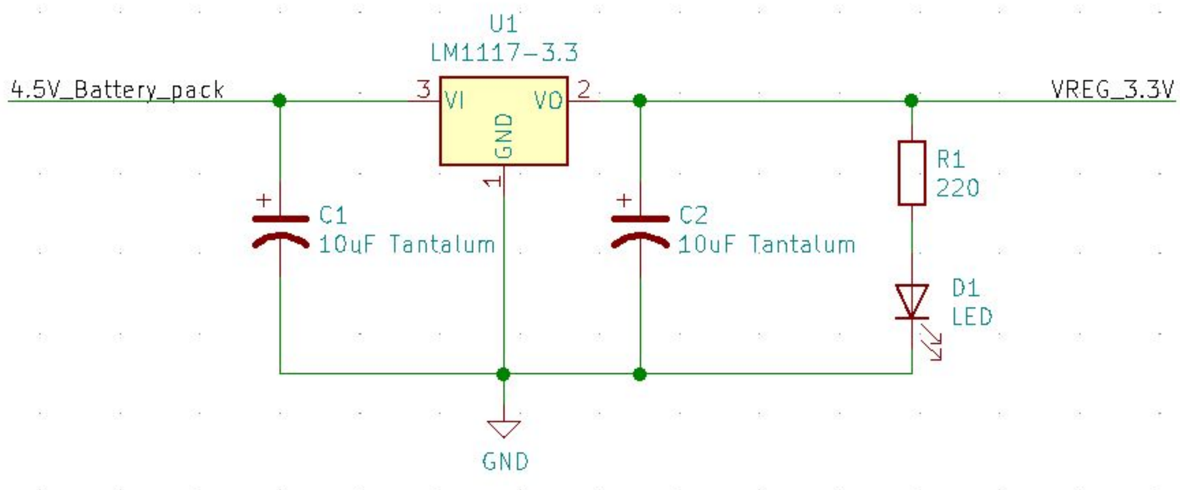

Figure 6. LM1117-3.3 Circuit Schematics

2.2.2 Measurement Unit

A measurement unit reads the vitals of the individual it's attached to. It measures blood pressure, heart rate, and temperature, sending this data to the processing unit through the wifi module (ESP-8266).

Blood Pressure Cuff

A sphygmomanometer, contains an air pump and pressure sensor to determine the Diastolic and Systolic blood pressures, as well as the heart rate through the impulses of pressure that come through.

Requirement	Verification
1. The cuff must be able to read Diastolic blood pressures as low as 60 mmHg consistently with readings taken every 1-2 minutes.	1. A. Measure blood pressure every 3.5 minutes, at recommended delay between readings. Record average Diastolic/Systolic blood pressures. Take blood pressure readings every 1

2. Cuff must be able to operate in at least a minimum of 32 degrees Fahrenheit weather.	minute. If readings deviate, compensate at FPGA calculations. 2. B. Measure blood pressure every 3.5 minutes, at room temperature. Record average Diastolic/Systolic blood pressures. Take blood pressure readings in a freezing environment. If readings deviate, installation of an ambient temperature sensor may be necessary to compensate pressure readings at FPGA calculations.

2.2.3 Data Communication

For our initial prototype, we'll be using a Wi-Fi module and XBee to send and receive data from our cuff to the control unit. The power supply is shared between the blood pressure cuff and the cuff's transmitter.

XBee

One XBee RF module receives data from the cuff/measurement unit. It then transmits cuff readings through a data bus to ESP8266 Wi-Fi module. We will use XBee along with ESP-8266 to set up a mesh network to allow data communication between modules.

Requirement	Verification
1. Must be connected to a 5V/3.3V power supply. 2. Xbee can communicate to ESP-8266 3. Xbee can receive serial data from MCU(more specifically, MSP430 microcontroller)	1. A. Use the constant-current circuit in the Fig.3 connecting the output of the voltage regulator to "VDD" in the image, and draw 300mA B. Measure the output voltage using an oscilloscope, ensuring that the output voltage stays within 5% of 3.3V. 2. A. Configure Xbee using XCTU software B. Connect Xbee to the network setup by ESP-8266 C. Test if Xbee can send message to or receive message from ESP-8266 3. A. Configure Xbee using XCTU software B. Use code in [3] as an example to

	program MSP430 and build serial communication between MSP430 and Xbee C. Test if Xbee can receive serial data from MSP430 by showing data received on XCTU terminal

ESP-8266 Wi-Fi Module

ESP-8266 can perform as a standalone system to interface with other systems to provide Wi-Fi through SPI/SDIO[4]. We will use ESP-8266 Wi-Fi module to set up a mesh network along with XBee to enable devices to talk to each other. ESP-8266 will receive cuff readings collected by XBee and periodically send readings to the control unit.

Requirement	Verification
1. ESP-8266 must be able to communicate over IEEE 802.11b/g/n at 4.5Mbps with a 50Ω nominal RF connecton. 2. It must be able to communicate over both SPI and UART.	1. A. Assemble WiFi IC on PCB as specified in the datasheet as the basic application schematic. B. Note default WiFi network on a mobile device 2. A. Connect to the ESP8266's UART port with an FT232 UART bridge, as per the FT232 reference diagram, and a computer. This can be done on a through-hole breadboard with an ESP-8266 module. B. Program 4.5Mbit HTML page (large photo) to SPI flash (program memory). C. Connect to default network with a mobile device, navigate to webpage from step 4 D. Time loading process, ensure that it is less than one second

Serial flash

The serial flash is connected to ESP-8266 by SPI, and it stores the program used by ESP-8266 WiFi module. The memory size is 1MB and is subject to change as program size varies.

Requirement	Verification
1. Operates consistently at 80 MHz (depends on real purchased product) 2. Size must be >= 1MB to store program	1. A. Operates the serial flash at 80MHz, and WiFi module is able to read a simple program (send strings) B. Receive correct strings as expected 2. A. Store 1MB memory of program/real-time data B. Read expected data from serial monitor in arduino IDE

Wi-Fi Reset button

The button is connected to ESP-8266's reset pin. It only resets network connection and does not affect any other embedded program/unit.

Requirement	Verification
Must be a pressable button with Wi-Fi RESET label	Press the button and ensure Wi-Fi connection is refreshed by looking at the Wi-Fi signal on LED screen

2.2.4 Control Unit

ATmega328

ATmega328 is used to build a standalone Arduino on PCB. It is used for the purpose of setting up serial communication with ESP8266 and transmitting data to the LCD screen. We also need a breakout board (SparkFun USB to Serial Breakout - FT232RL) to program ATmega328 and use a lm1117-3.3 voltage regulator to provide power supply.

Requirement	Verification
Operation voltage is 3.3V and input voltage is recommended to be 7-12V.	A. Use the constant-current circuit in the Fig.4 connecting the output of the voltage regulator to "VDD" in the

	image, and draw 300mA B. Measure the output voltage using an oscilloscope, ensuring that the output voltage stays within 5% of 5V.

MCU (Pre-existing)

The MCU built into the blood pressure cuff. A black box in terms of operation. It outputs blood pressure and heart rate into a serial read/write IC. Extending the connection to a parallel read/write IC allows for a connection to the XBee.

Requirement	Verification
Limit voltage to 6V +/- 1V.	Measure the output voltage using an oscilloscope, ensuring that the output voltage stays within 5% of 6V.

HD44780U LCD module

16*2 LCD module displays a 4bit cuff reading fetched by XBee from sphygmomanometer, with a button/dial to swap between readings and triage ranking. It interfaces with AVR (ATMega328). Though it has a wide range of display driver power, we will limit voltage supply to 2.7V-5.5V to support low power operation.

Requirement	Verification
1. Limit voltage supply to 2.7-5.5V. 2. LCD must read digital input pins for each new data point collected, collecting information such as cuff sending data, blood pressure, and heart rate, and calculate the MSI/change in MSI since last read.	1. A. Measure the output voltage using an oscilloscope, ensuring that the output voltage stays within 5% of 5V. 2. A. Read data in a proper range of value and can inspect a 3-digit data/triage priority on screen. B. MSI is properly calculated, as confirmed by hand. Rate of change of MSI is stored to factor into their triage ranking.

Button/dial
A button/dial on device to swap between readings and triage ranking.

Requirement	Verification
A pressable button/dial with label.	Press button and check if reading on screen changes as expected.

2.3 Server

The server design will consist of a Raspberry Pi to set up a webpage demonstrating real time data (both for testing and demo purposes). However, it is not in the scope of this class, but we consider it as a necessity to communicate with the outside world (rescue team, etc.).

2.4 Case

Figure 1, 2, and 3 are drafts of the cases for respective devices.

2.5 Protocol

We use UDP protocol to transmit data between communication modules (ESP8266, XBee). Since we have verification mechanisms within our design, it is suitable to use UDP as error checking and correction are not necessary. UDP effectively reduces the complexity of routing protocol.

2.6 Tolerances Analysis

Analysis of battery life
Measurement Device:

Components	Current Consumption
Pre-existing Measurement Device	The entire device consumes 1Ah according to its market description[?]
Repeater(NE555)	Uses 10ma * 1h = 10 mAh
Voltage Regulator TC1262-3.3	The regulator takes 500mA * 1h = 500 mAh

Table 1.Power Analysis of measurement device

We are using 4 EBL AA batteries as our power supply and each of the AA batteries has a capacity of 2800mAh.
Total current consumption = 10+500+1000 = 1510 mAh
Battery life = 2800mAh/1510mAh = 111 minutes

Display Device:
Since all components in the display device are operating at 3.3V regulated from the voltage regulator, we would only consider current consumption of the voltage regulator consisting current consumption of other units. Current consumption of each individual unit is listed after the voltage regulator as a reference.

Components	Current Consumption
Voltage Regulator LM1117	Uses 800mA * 1h = 800mAh
ATmega328	Uses 200mA * 1h = 200mAh
TFT LCD screen	Uses 25mA * 1h = 25mAh
ESP8266	Uses 300mA * 1h = 300mAh
Serial Flash	Uses 30 mA * 1h = 30mAh

Table 2.Power Analysis of display device

Total current consumption = 800 mAh
Battery life = 2800mAh/800mAh = 3.5 hours

Since our design is mostly used under emergency situations that it may be used no longer than one hour before the emergency personnel arrives, although the measurement device lasts less than 2 hours in operating mode and the display device lasts for 3.5 hours, this should be fine in our design. The EBL batteries devote to low self-discharge technology, hold 75% after three years and the batteries in the kit should be recharged on safety purpose after each usage.

2.7 Schematics

DATA COMMUNICATION

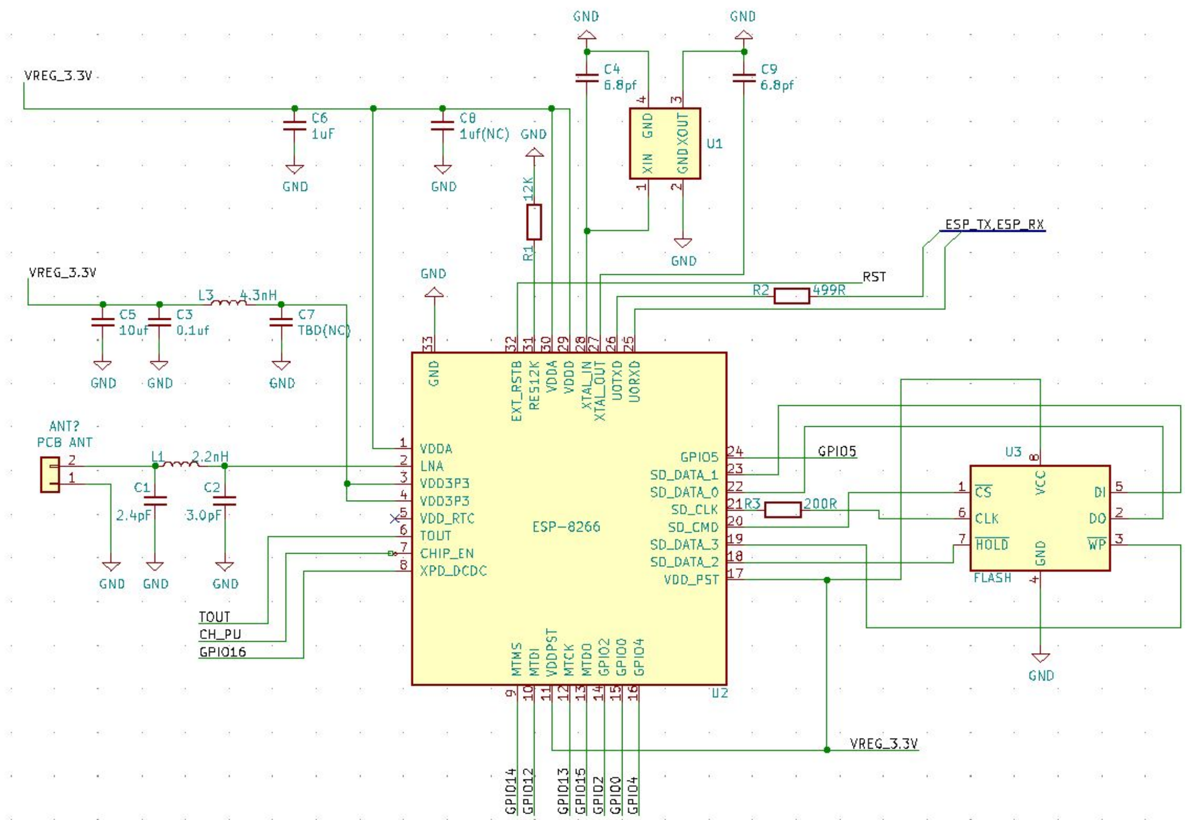

Figure 7. ESP-8266 Schematic with SPI [5]

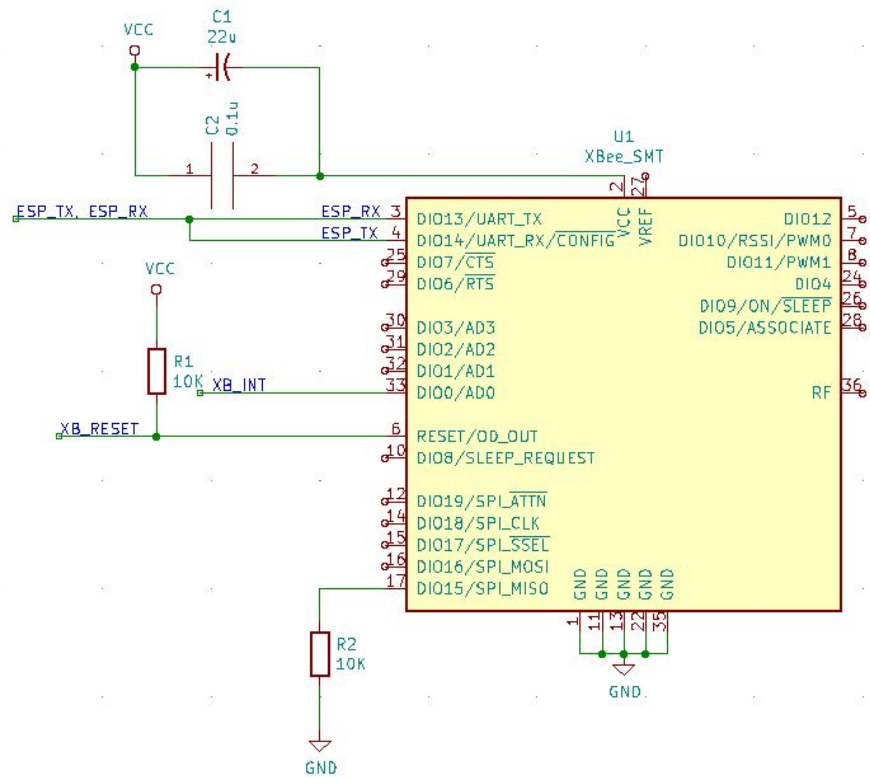

Figure 8. XBee (XB_INT is the serial input from MCU)

CONTROL UNIT

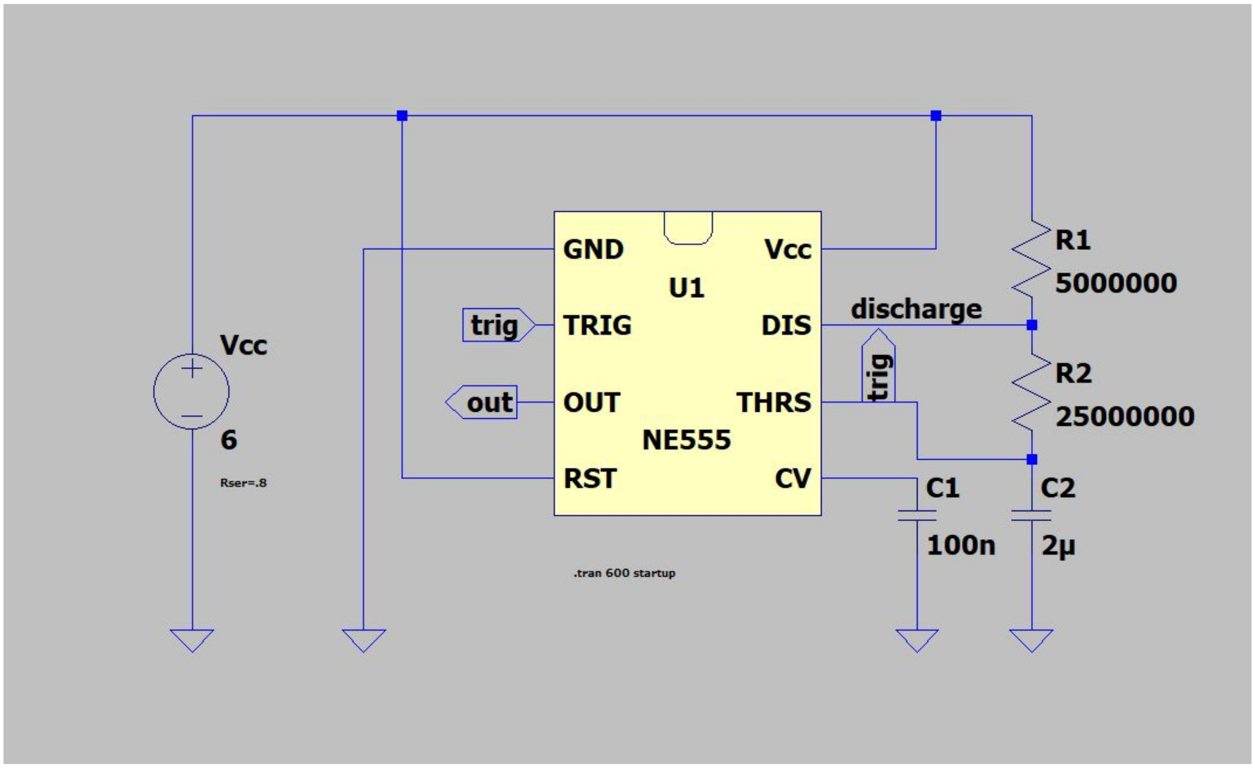

Figure 9. Repeater Circuit Diagram (Blood Pressure Cuff Activator)

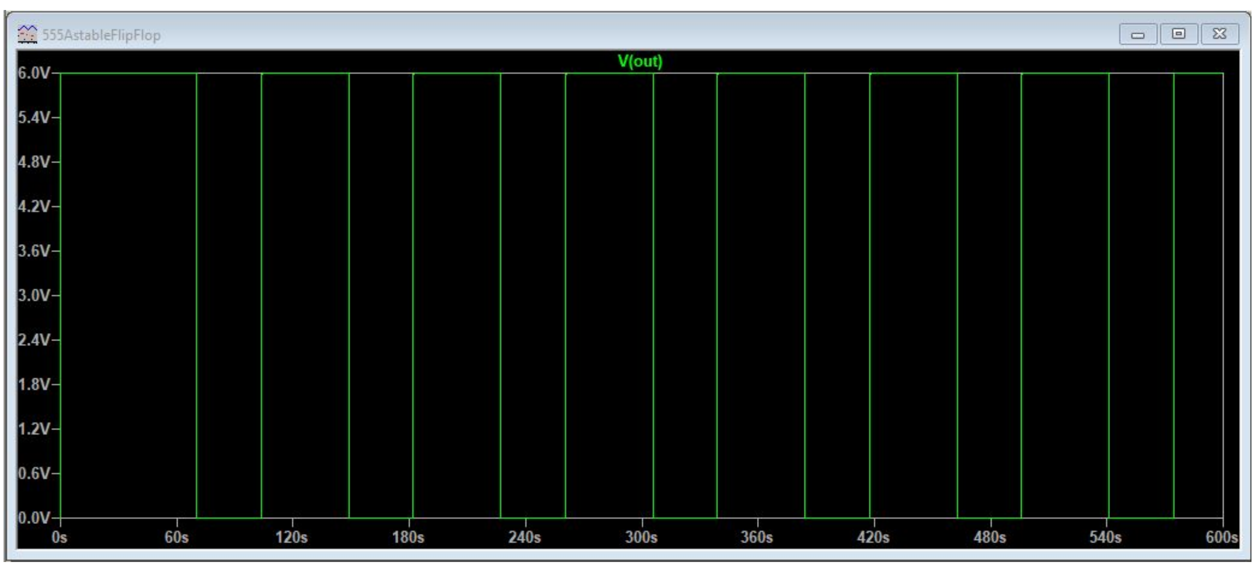

Figure 10. Repeater Circuit Simulation (Blood Pressure Cuff Activator)

Repeater Circuit Calculations:

$f = 1.38/(R_1 + 2R_2)C_2$ Hz, from NE555 data sheet

$R_1 = 5M\Omega$

$R_2 = 25M\Omega$

$C_2 = 2\mu F$

$f = 0.012077\ Hz$

$P = 1/f = 82.8\ seconds$

$Duty\ Cycle = (R_1 + R_2)/(R_1 + 2R_2)$

$Duty\ Cycle = 86\%$

2.8 Risk Analysis

Of our blocks, the piece that will pose the greatest problem will be the Data Communication block. Being able to handle a multitude of blood pressure cuffs requires either a set of unique receivers, or for means to 'mute' each cuff selectively so that only one cuff transmits data at a time, as one of our goals is to handle at least 6 cuffs, and ideally go past 6 into 16 or more simultaneous cuffs. Furthermore, if the wireless communication is unreliable, then data transferal may result in misconstrued readings, which could either manifest as extremely abnormal blood pressure, and thus inaccurately rank them in the triage list, or prevent it from communicating at all - preventing the individual from being considered in the triage list.

3. Cost and Schedule

3.1 Cost Analysis

Fix cost is estimated to be $40/hr, 10hr/week for three people.

3*$40/hr*10 hrs/wk*16 wks*2.5 = $48000

Part	Cost (Prototype)
ESP-8266 (Expressif)	$15.0
XBee*2	$44.0
Cuff*2	$40.0
PCB	$5.0
TFT Screen	$20

ATmega328P	$2.08
EBL rechargeable battery pack	$20
Resistors, Voltage Regulator ICs, capacitors, LEDs, sockets, other adaptors	$20
Total	$166.08

Since we build 2 measurement boxes and 1 display box, this yields to a total cost of $48166.08.

3.2 Schedule

Week	Brandon	Songtao	Zihong
2/24/20	Design control system for blood pressure monitor	Begin on version1 wifi-module regulator schematics	Begin on version1 voltage regulator schematics
3/2/20	Design and test serial-to-parallel read for sensor/RF module connection	Setup ESP-8266 Wi-Fi module and test its functionality with serial monitor in Arduino IDE	Test functionality of voltage regulators
3/9/20	Program ATmega328P and TFT LCD Screen communication.	Set up XBee and a mesh network along with ESP-8266, ensure communication between modules	Setup ESP-8266 Wifi network and test communication between ESP-8266 and Xbee
3/16/20	Version 1 PCB Design	Version 1 PCB Design	Version 1 PCB Design
3/23/20	Attempt ATmega328P replacement with PCB/Modify ATmega328P as needed, based off of results from 3/16/20	Attempt ATmega328P replacement with PCB/Modify ATmega328P as needed, based off of results from 3/16/20	Work on data communication between ESP8266 and ATmega328P replacement with PCB
3/30/20	Version 2 PCB Design	Version 2 PCB Design	Version 2 PCB Design
4/6/20	Power tests	Assemble modules to create final product	Continue to work on data communication between ESP8266 and FPGA
4/13/20	Power sources/boxes	Collect samples to create	Bugfix on problems

	modifications	a data chart	occurred during transmission between Xbee, ESP8266, ATmega328P
4/20/20	Demo day	Demo day	Demo day
4/27/20	Demo day	Demo day	Demo day

4. Ethics and Safety

Any and all electrical components/wires on the blood pressure cuff must be fully contained inside a box/shell, as the testing will not emulate the hectic nature of the wake of a disaster, and any free wires will pose a safety concern, even if insulated. While assembling the device, the maximum voltage provided will be 6V, and the power supply will only be connected during testing to limit the probability of burning out the batteries on our skin. Working in the electronics labs carries its own challenge. We will strictly follow the guidelines in the laboratory safety training to work in pairs allowing for one individual to provide emergency response if something goes wrong. During the unit testing, we would also use an IR thermometer to ensure that the temperature of the ICs stays within safety range. We are also using an oscilloscope to monitor the output voltage from the voltage regulator to avoid burning other chips in our circuit caused by potential voltage spikes. Our testing and debugging techniques follow the IEEE code of ethics, "to avoid injuring others, their property, reputation, or employment by false or malicious action"[6]. Before using the blood pressure cuff, consulting a medical professional about the safety of an automated blood pressure cuff, as there have been reports of side-effects to their use. The delay between each reading will be done based off of this medical advice. By alternating which partner tests the blood pressure cuff on themselves, we'll further limit the chances of damaging our arm through repeated use.

Furthermore, in accordance with FDA, commercial use of this product will require adherence to SP10 regulations, involving clinical trials, advertised variability, as well as graphical analysis of the data for the user. Not using any sterile components, none of them need to be listed. The product is not legally allowed to be used as a medical device until SP10 regulations have cleared it as a blood pressure cuff.

5. Citations

- Useful IoT Resources from CS 498 IoT, Professor Matthew Caesar

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  J. Rhysider. “XBee S2 Quick Reference Guide/Cheat Sheet and Video Tutorials to Getting Started.” TunnelsUp.com. https://www.tunnelsup.com/xbee-guide/ (accessed Feb. 12, 2020)

- Useful readings on measuring blood pressure (including non-invasive approach in development)
  [1] “QARDIOARM Smart Blood Pressure Monitor.” QARDIO. https://www.getqardio.com/qardioarm-blood-pressure-monitor-iphone-android/ (accessed Feb. 13, 2020)

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R. Nugent. “Building an Arduino on a Breadboard.” Arduino. Accessed: Mar. 3, 2020. [Online]. Available: https://www.arduino.cc/en/Main/Standalone