Firefighter Life Monitor

Team 27 - Mary Bucki, Nick Lau, Seth Groharing
ECE 445 Project Proposal - Spring 2017
TA: Kexin Hui

Introduction:

Objective:

According to the National Fire Protection Association approximately 59% of injuries for firefighters are a result of overexertion, stress, and medical difficulties compared to other injuries such as crashes, getting hit by objects, or falling [1]. The goal is to create a device that can monitor heart rate, temperature, and motion of firefighters in the field and send the information to a display in another location. The device would be attached to the arm under the firefighter's uniform. This would allow a response team to take appropriate actions if a firefighter was in danger.

Background:

Previous projects for firefighters have involved hazard detection and wireless heart rate transmission [2]. Our project would be different in that we are focusing on more than just heart rate. We would also monitor the temperature of the firefighter and whether they are moving or not. A distress signal will be sent if no motion is detected after a short while. This device could also be adapted for more than just firefighters in the future.

High Level Requirements:

- The life monitor must be able to sense heart rate, movement, and temperature of the firefighter
- The life monitor must detect when the values taken indicate abnormal heart rate, motionless, or hyperthermia and send a distress signal
- The life monitor must work in at least 140° F environments and moist conditions inside a firefighter's bunker gear

Design:

The firefighter life monitor has three main functions: movement detection, temperature reading, and heart rate monitoring. This is accomplished with a four part modular design consisting of a power supply, control unit, sensor unit and RF display. Sensors will obtain the necessary data and and the control unit will process this data and wirelessly transmit it to a display.

Block Diagram:

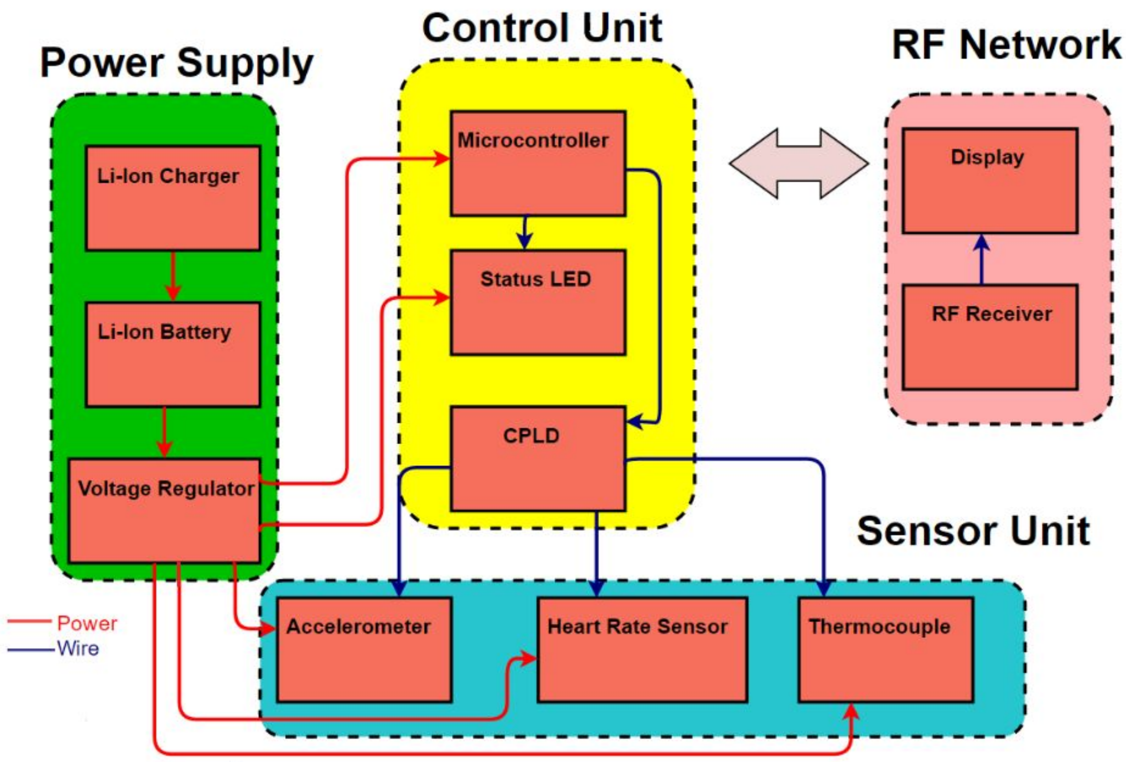

Figure 1: Block Diagram

Physical Design:

The circuitry must be contained in a light weight, easy to put on and remove armband. Velcro will be used in order to attach the device to the user's arm. The circuitry will be housed in a fire resistant fabric. This fabric will most likely be nomex which is one of the materials used in firefighters' suits.

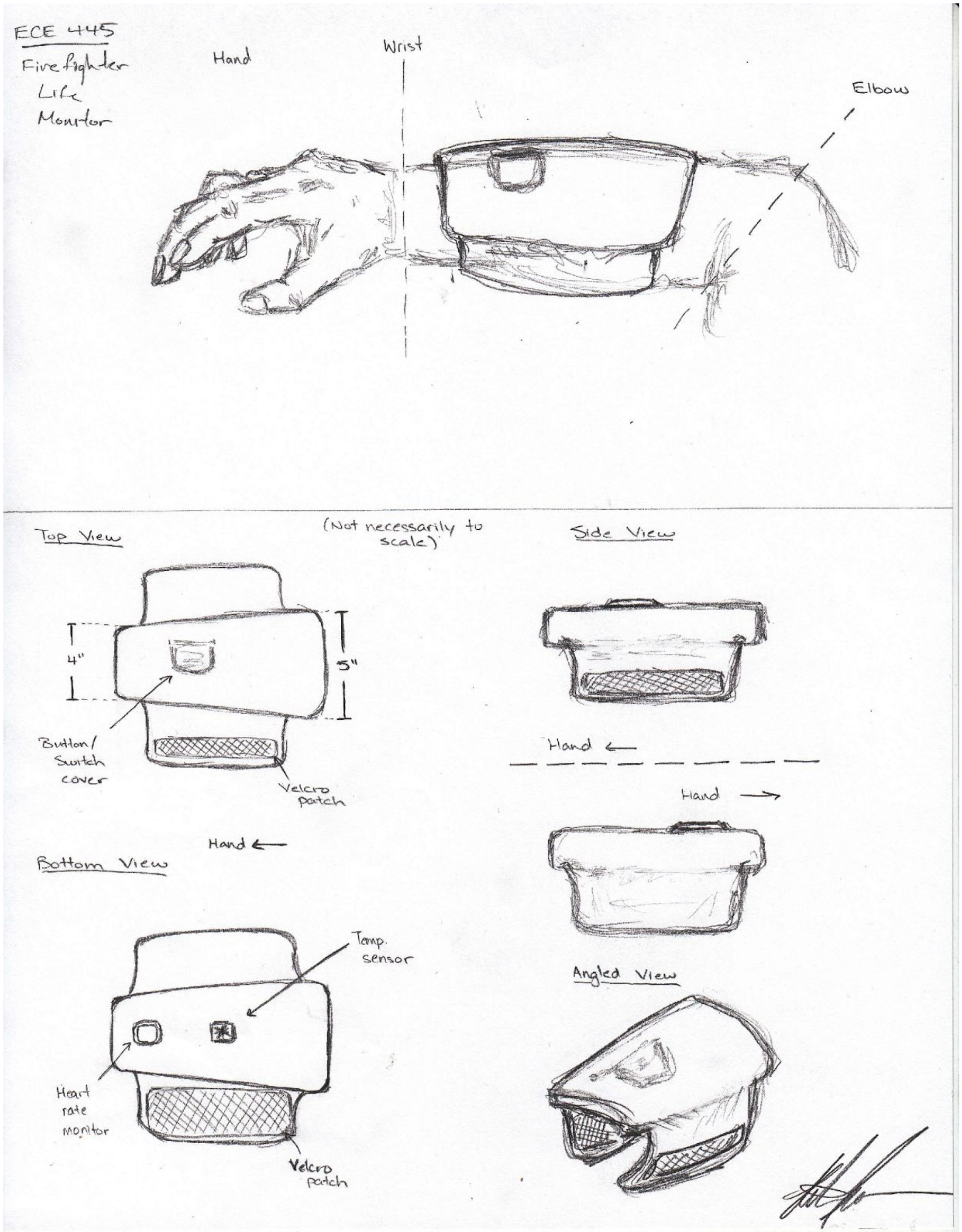

Figure 2: Physical Design

Functional Overview:

1. ***Power Supply***

A power supply is required to keep the life monitor operable. Power will come from a rechargeable lithium-ion battery. Through the use numerous voltage regulators, the microcontroller and sensor circuits will be powered.

1.1 Lithium-Ion Battery Charger

The battery will be charged via a charging IC. There are three phases for charging the battery. First, there is a preconditioning charge, a constant-current fast charge, and finally a constant-voltage trickle charge to keep the battery topped.

Requirement 1: Must be able to charge a battery at a rate of 2 amps or less
Requirement 2: Charge a lithium-ion battery of 3.6-3.7 volts
Requirement 3: Able to be charged from a 5V± USB source

1.2 Lithium-Ion Battery

A lithium-ion battery will power the microcontroller, the CPLD, and each individual circuit that connects to the sensors. The battery should be able to keep the circuit continuously powered until switched off.

Requirement: Battery should have a voltage of 3.6-3.7V and a minimum capacity of 1000mAh

1.3 Voltage Regulators

Multiple voltage regulators will be used to step down voltage from the battery.

Requirement: 3.3V, 2.5V, and 1.8V voltage regulators; all with a maximum of 5% fluctuation

2. ***Control Unit***

The control unit will manage the signals in the circuit and manage data transmission to the display. It will be made up of a microcontroller, CPLD, and an LED to indicate the status of the sensors.

2.1 Microcontroller

The microcontroller will accept all the signals from the sensors and transmit this data using radio frequency.

Requirement 1: Must be compatible with I2C.
Requirement 2: Be able to transmit via 27MHz or 49MHz frequency ranges.

2.2 CPLD (Complex Programmable Logic Device)
A CPLD will be used to collect data from the sensors and be programmed to send necessary data to the microcontroller on which actions to take.

Requirement 1: 3.3V supply voltage
Requirement 2: Has at least 32 macrocells

2.3 Status LEDs
An array of LEDs will be used to assure that each sensor is operating.

Requirement: Must be small and consume small amounts of power.

3. ***Sensor Unit***

The sensor unit will collect all data necessary that we need to monitor the firefighters. Three sensors will be used along with appropriate circuitry to process the data and send it to the control unit.

3.1 Accelerometers
An accelerometer array will be implemented in order to detect movement of the wearer's arm. We will use four accelerometers which will communicate with the cpld using I2C.

Requirement 1: Accelerometer array must be able to accurately detect even slight movement. Multiple accelerometers are used for accuracy.
Requirement 2: 2.5V supply voltage

3.2 Heart Rate Sensor
A small heart rate sensor will be placed on the bottom of the device to monitor heart rate just like most fitness devices. It will communicate with the microcontroller using I2C.

Requirement 1: Must take accurate heart rate data at an appropriate time interval.
Requirement 2: 1.8V supply voltage

3.3 Temperature Sensor
A small thermocouple or a thermistor will be placed near the skin of the forearm. Temperature of the suit may affect the the signal.

Requirement: Must be able to take extreme temperature readings. It would need to be up to at least 212° F but the thermocouple will be able to read much higher temperatures than that.

4. ***Display Unit***

The display unit will receive data sent from the control unit and output the data on a small screen.

4.1 Display
The display will be a small LCD display that will simply show the data being sent from the wearable device.

Requirement: powered by 3.6-5V battery.

4.2 RF Receiver
Receives data from microcontroller so that it can be displayed.

Requirement: Operates in the 27MHz or 49MHz frequency range.

Risk Analysis:

The riskiest part to the completion of the project is powering the device with a battery. The battery unit has the most destructive failure risk. Overheating the unit may cause fire and the unit may explode [3]. A circuit must be incorporated to prevent the battery cell voltage from decaying below 3.0 V cell or exceeding 4.2 V cell. Also, the temperature inside the firefighter's suit should be maximum 60-75°C for the Li-Ion battery to not overheat and become damaged - leading to fires or explosions [3].

Ethics and Safety:

The firefighter life monitor is a device that is designed to detect the warning signs of a firefighter experiencing danger and stress and increase the likelihood of a firefighter surviving, however there are safety risks.

IEEE code one is “to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment”[4]. The Li-ion battery must not be overcharged, a circuit must be incorporated to prevent the battery cell voltage from decaying below 3.0 V cell or exceeding 4.2 V cell---or buy a commercially available charger.

The battery cannot be exposed to excess heat , however the Li-ion batteries can work in temperatures around 60-75°C . Due to IEEE code “ to be honest and realistic in stating claims or estimates based on available data”, we must disclose temperature inside the firefighter suit when it is made known, and if it is not within the acceptable range for the battery (see IEEE code #1)--we must pick another battery or find another way to power our circuits [4]. The hazard of the battery overheating then catching on fire is too high if the temperature inside the suit proves to overload the circuit [3].

As an electrical device that will be inside the firefighter's bunker gear, sweat moisture could cause damage to the nodes leading to short-circuits. The case will need to adhere to IP66 guidelines, which is protection from water projected in powerful jets from a nozzle with a 12.5mm diameter opening in any direction. The fire hose spray could accidentally seep through the protective layers of the bunker gear and induce a moist environment for the life monitor. Although this is unlikely, it is still a possibility so IP66 guidelines will work.

Lastly, the Rf frequency on the field test model might interfere with other emergency signals, endangering more lives than saving lives. We must designate a frequency that is unused or is firefighter specific to reduce the risks of RF interference and noisy signals.

References:

[1] nfpa.org, "Firefighter fatalities in the United States", 2016. [Online]. Available: http://www.nfpa.org/news-and-research/fire-statistics-and-reports/fire-statistics/the-fire-service/fatalities-and-injuries/firefighter-fatalities-in-the-united-states. [Accessed: 7- Feb- 2017]

[2] engineering.illinois.edu, "Corvae making wireless heart monitoring possible", 2015. [Online]. Available: http://engineering.illinois.edu/news/article/11001. [Accessed: 7- Feb- 2017]

[3] http://batteryuniversity.com "Lithium-ion Safety Concerns", 2017. [Online]. Available: http://batteryuniversity.com/learn/archive/lithium_ion_safety_concerns. [Accessed: 8- Feb- 2017]

[4] Ieee.org, "IEEE Code of Ethics", 2017. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 7- Feb- 2017]