Stun Gun Self Defense Ring and Bracelet

ECE4871 Senior Design Project

Section L01, Team Sweet Dreams

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Executive Summary

The world is a dangerous place, especially for women, as one in five women are sexually assaulted during their time at college [1]. This is a major problem that Sweet Dreams has decided to find a solution to. Sweet Dreams' Self Defense Jewelry is a bracelet and ring combo made to protect the user while looking fashionable and unassuming. The main goal of this product is to protect the user from a variety of dangerous situations. With that goal in mind, Sweet Dream strived to find a solution that no one would suspect to be a weapon, would be hard for the user to lose, and be effective in defense. In the end, it was agreed upon to create the jewelry set.

The bracelet component holds a majority of the electronic components such as the battery, GPS, Bluetooth, heart rate monitor, and circuitry for a stun gun. All of these would be assembled using integrated circuits on a PCB inside the bracelet. The bracelet then connects to the ring through an optic cable. The ring contains electrodes, so when the user punches an attacker, it triggers the stun gun circuit in the bracelet, which sends the charge through the cable out the electrodes and shocks the attacker on contact. The design will cost $47 to produce.

The design works such that when the user feels unsafe, she can press a button on the side of the bracelet, which would charge the stun gun circuit and notify her five prechosen contacts that she feels unsafe. Then when she punches an attacker, this will cause the stun gun circuit to discharge, shocking the attacker and notifying the police. Also, if the user's heart rate drops below a given threshold (i.e., she has been knocked out), the product will notify her contacts as well. The design stands apart from competitors as other products only focus on one feature or the other, those features being defense or notifying loved ones, while Sweet Dreams' product does both. The product is set to be sold for $100, but the lives it will save are priceless.

1. Introduction

Sweet Dreams is a team requesting $301,000 in funding to develop a self-defense ring and bracelet set. Today, it is normal for women to be hyperaware of their surroundings as they navigate unpresuming lives. It has also become customary for women to buy pepper spray, pocketknife, brass knuckles, and more to keep themselves safe. However, all these products are hard to use, clanky and evident to the attacker, and are often not allowed into public events, a place where tools like this would be important. Our product is designed to shock the attacker while being discrete and stylish for the user. The bracelet ring combo will have the main components of the ability to shock the perpetrator, track the location of the user and device through GPS, and monitor the user's heart rate to identify if the user is alive. In addition to the technical requirements, the final product will be discrete, affordable, durable, easy to use, and adjustable for users. The product will consist of a conductive nanocircuit with a Bluetooth network and power usage and consumption capabilities. There will be an external USB-C port for recharging. The technical challenges that will be faced are the small size that the electronics will have to be lightweight for the customer, wearable electronics codes and standards [2], and weapons regulations at events.

The primary desired solution is the one described with the bracelet and ring combo acting as a stun gun. The successful completion of this design will be demonstrated by a successful current discharge from the ring's electrocution after meeting all the right conditions/triggers. This will be measured by either having a multimeter measure the current discharge or asking for a volunteer to pretend to be the attacker. However, there are many technical obstacles between now and the successful completion of the product; therefore, a backup solution would be to make the ring into a flashlight instead of a stun gun. Therefore, the ring will emit a bright light blinding the attacker.

This will be easier to implement as concerns about insulation will become obsolete, and no physical contact between the user and attacker will be needed.

The rest of the document will go into more detail about the specific design and goals. Then it will become more technical as the technical specifications are explained and how they fit in the design. The design description will explore the justification, engineering analysis, and codes and standards affecting the project. Then the document takes another shift by focusing more on the logistics such as scheduling, marketing, and cost analysis. The document then wraps up with a brief description of the project's status and the delegated leadership roles.

2. Project Description, Customer Requirements, and Goals

The user will be able to monitor their heart rate and GPS location in an accompanying app that can hold emergency contacts to contact in case of use of the weapon.

The requirements for the customers are that the product has/is:

- concealable,
- GPS tracking,
- long battery life.
- low cost,
- comfortable while aesthetically pleasing,
- durable,
- user friendly,
- and, shocks the perpetrator.

All the requirements for the customers align with the hopes of the company and steps will be taken to ensure that all the requirements are met.

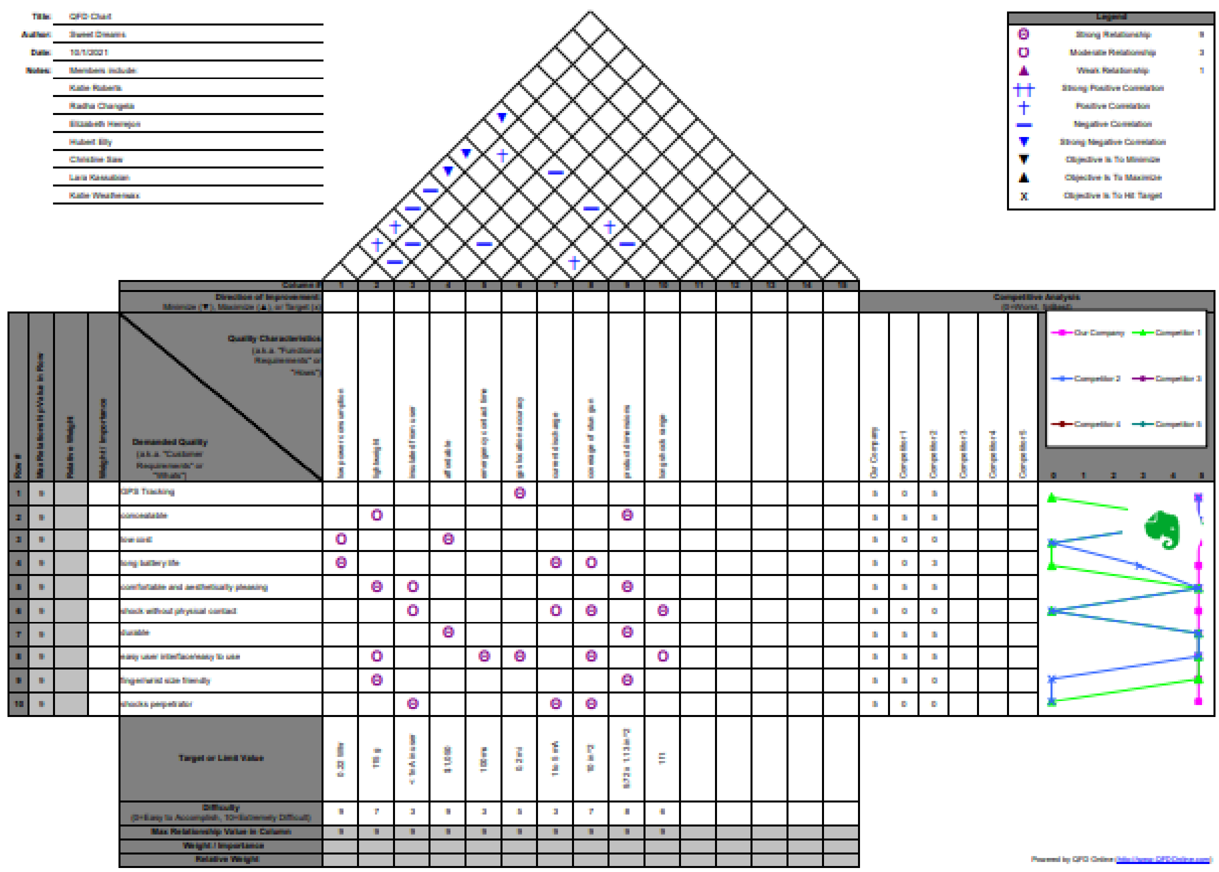

Figure 1. A QFD aligning customer requirements, design elements, and competitor analysis.

3. Technical Specifications

Table 1 contains the specific engineering requirement that will be used to determine the final product design.

Table 1. Engineering Requirements

Technical Requirement	**Target/Limits**	**Reasoning**
Low Power Consumption	0.22 Watt-hours	Longer lasting battery life so that users are protected for an extended period of time.
Lightweight	115 g	Not cumbersome for the user to wear so they are more likely to wear it for protection.

Insulated from User	<1 nA in user	Insulation is important to protect the user from accidental electrocution or shocking.
Affordable	<$1050 production costs	To expand product outreach, the product should be reasonably priced so that more women can afford it as a self defense object.
Emergency Contact Time	100 ms	Contacts should be notified as soon as possible so that help can reach the user quickly.
GPS Location Accuracy	0.2 mi	A higher location accuracy can guarantee higher chances of the user's emergency contacts and the police locating them.
Current Discharge	1 mA - 3 mA	The higher the current discharge, the more damage the attacker receives. However, current cannot be too high to cause permanent damage to the attacker.
Coverage of Stun Gun	10 in^2	The wider the coverage of the stun gun, the more pain the attacker will feel, which should reduce chances of the attacker attacking a second time.
Product Dimension	9.72 x 1.13 in^2	The product dimension needs to be small and compact so that it is not bulky for the user to wear. Also, the smaller it is the less likely the attacker will identify it as a weapon.

4. Design Approach

4.1 Design Concept Ideation, Constraints, Alternatives, and Tradeoffs

There are two main components to the device: the ring and the bracelet. The bracelet, inspired by Fitbit, will draw upon many open-source circuits and software. The primary purpose of the bracelet is to hold most of the electrical components such as the power supply, GPS, Bluetooth, heart rate monitor, and the stun gun circuitry. The bracelet will have most of the components since it will have the most space to work with. It will be modeled after a Fitbit with added circuitry for the stun gun.

The stun gun/shocking circuit's main component is a high voltage capacitor. The circuit has a switch in it that remains open for regular operation. However, there is a button on the side of the bracelet that the user can press when feeling unsafe. This causes the switch to close, and the capacitor begins charging. The pressing of the button also triggers the software to notify the five prechosen emergency contacts that the user feels unsafe. The bracelet connects to the ring through a PTFE dielectric coaxial cable. The ring acts as the shocking device, having the main "gemstone" area being the contact point between the circuit and the attacker. As soon as the user punches the attacker applying force to the "gemstone" area of the ring, another switch activates in the stun gun circuitry. This causes the switch to open, allowing the capacitor to discharge and carry the current through a cable to the ring. The current then exits from the electrodes on the ring, shocking the attacker.

The idea of stun gun jewelry has many constraints in the form of predefined codes and standards. For example, great care must be taken into setting the output current as it must remain between one to three milliamps. Also, the design must implement specific insulation guidelines to protect the user from getting shocked when punching the attacker.

Due to these constraints and many technical concerns, the team has decided on a backup plan. The alternative solution is to implement a bright "flash" device to blind the attacker temporarily instead of shocking them. This design would have fewer standards and safety concerns to deal with and would not require as much insulation. However, the jewelry becomes less focused on self-defense and more focused on prevention. Through plenty of research, it was determined that the shocking device would be the most lightweight and affordable solution.

4.2 Preliminary Concept Selection and Justification

At the beginning of the semester, many ideas were discussed on the topic of self-defense jewelry. For example, the first design solution was to have the ring acting as a chainsaw to help women break out if they were tied up. However, the technical obstacles (and the unrealistic design) were soon scrapped. The next idea explored was of a taser ring with electrodes shooting out of the ring allowing the user to attack from a distance. This idea was favored for a while, but after research, it was discovered that there were too many complicated laws and policies regarding tasers. This, along with the technical obstacle of having electrodes shoot out of the ring, made the group reject the idea.

It was then decided to take the taser idea and simplify it to a stun gun as stun guns had fewer legal concerns, more straightforward technical requirements, and would ultimately work out for the user better. The idea of a stun-gun ring with a GPS tracker bracelet worked well for our customer requirements listed in the table below.

Table 2 contains the demanded quality or customer requirements that will be implemented into the final design of the product.

Table 2. Customer Requirements

Customer Requirements	Reasoning
GPS Tracking	Allow users to get help when in emergency situations. This feature is currently present in similar products.
Concealable	Product should not look like a weapon so that users can wear it all day without perpetrators identifying it as a weapon.
Low Cost	The goal is to equip as many women as possible so that they can be safer; therefore, it needs to be reasonably priced to expand product outreach.

Long Battery Life	Allows users to use the product in emergency situations for an extended period of time without worrying about product running out of battery.
Comfortable and Aesthetically Pleasing	Product is meant to be worn and seen all day.
Durable	Allows users to use product for a long time.
Easy User Interface/ Easy to Use	Allows users of any technical background to use the product in emergency situations without confusion.
Finger/ Wrist Size Friendly	Allows all users to use and wear the product comfortably.
Shocks Perpetrator	Allows users to fight off perpetrator when being attacked.

After discussing and researching stun guns and wearable jewelry, the solution of a stun gun self-defense ring and bracelet set was the best course of action. This solution not only defends the customer and meets all customer requirements but also has obtainable technical specifications that would be easier to implement.

4.3 Engineering Analyses and Experiment

Research on modern technologies such as heart-rate monitors and prank gum proves that functional heart rate circuits and shock circuits are entirely possible. The heart rate circuit exists in Fitbits and open-source forums, while the shock circuit exists in prank gum and stun guns. No experiments have been completed at the time of this proposal to determine the reliability of these circuits. However, due to the popularity and reviews of Fitbits, it is predicted that using a similar heart rate monitor circuit will function as well. Similarly, with the shock circuit, stun guns and prank gum are widely used and functional. Applying the shock circuit technology of these modern contraptions into the stun gun jewelry device is possible. Other parts of the device like the GPS tracker will also be based on currently available products.

To ensure the prototype meets specifications and functions as designed, the following tests will be conducted:

1. Testing the shock circuit:
    a. The voltage and current will be measured across the electrodes when a button is pressed to close the circuit.
2. Testing the heart rate monitor:
    a. Person A will wear the device prototype while Person B counts Person A's heart rate using their fingers and a stopwatch. The prototype's display should match up to the calculated heart rate. Another method includes Person A wearing the device prototype while staying connected to a heart rate monitor and comparing both devices' final heart rate values, checking if they match.
3. Testing the GPS:
    a. Person A will move the prototype to various locations and ask Person B if the GPS display shows the correct locations. Another method includes Person A comparing their location displayed from the prototype with another smartphone's GPS map tracking their location.
4. Testing the alert system:
    a. Person B will enter their phone number into the software. Person A will press the alert button on the prototype circuit and Person B will verify that they received an alert message.

As of this proposal, no tests have been conducted as there are no prototypes. Tests will be conducted as soon as the prototypes have been created.

4.4 Codes and Standards

IEEE P360 - IEEE Draft Standard for Wearable Consumer Electronic Devices - Overview and Architecture

The IEEE Standard for Wearable Consumer Electronic Devices is significant to our project as it outlines the specific technological requirements to make wearable devices secure and suitable for wear. The code affects our design as it defines technical requirements and testing methods that we will have to follow to make the device safe [3].

IEC 60335-2-76 Ed 2.1 Household and similar electrical appliances – Safety

The International Electrotechnical Commission (IEC) household and similar electrical appliances standard is important to our project as it sets the safety requirements for electroshock devices. This standard affects our design as it sets a limitation on the maximum rated voltage of our stun gun [4].

IEC 60479-1 & 2 Effects of current on human beings and livestock

The International Electrotechnical Commission (IEC) Effects of Current on Human Beings and Livestock is significant to our project as it explains the thresholds and limits of current that can pass through the human body. With these standards, it explores the safety concerns with each range of current and consequences with as mild as a tingling sensation and as severe as death [5]. Since our jewelry has a stun gun, we will be passing a current and a large voltage into a human being and thus our electrical components must be fine-tuned to meet the standards and not cause unnecessary harm. These standards will affect our decisions in purchasing components such as capacitors as they must have the correct voltage rating to produce the correct range of current. Measurements that will affect these decisions will be the average resistance of the human body (provided within the standards documentation) and the current range the device will operate at.

IEC 60601-1 Medical Design Standards for Power Supplies

IEC 60601-1 is a series of technical standards for the safety and effectiveness of medical electrical equipment [6]. It is significant to our project as it addresses the basic safety and essential performance requirements of medical electrical equipment. Our project revolves around a self-defense wearable that may collect heart rate data. The standards give us guidance on the product requirements such as isolation, creepage and insulation clearance to ensure the device is safe for the user. However, not all countries comply with the same requirements. For example, China and Taiwan have only adopted the 2nd edition of the standard but the United States, Canada, and Europe have already fully adopted the 4th edition requirements [6]. Therefore, when making design decisions, we must take additional consideration into our market to ease the compliance process.

UL 69 Standard for Electric-Fence Controllers

The UL 69 standard may be meant for electric-fence controllers used only for the control of animals but is still used to verify the safety for Conducted Electrical Weapons (CEW) [7]. During two IEEE conferences, papers were released detailing how the safety of certain CEWs relates to relevant standards, “Electrical safety of conducted electrical weapons relative to requirements of relevant electrical standards” [8] and “New conducted electrical weapons: Electrical safety relative to relevant standards” [9]. Both papers consider the UL 69 standard as it covers portable electric-fence controllers with peak-discharge or sinusoidal-discharge output for battery circuits of 42.4 V or less. Our team is creating a non-lethal weapon; therefore, this standard should be used to verify the safety of our device. These standards detail load requirements and a current vs. impulse duration graph [7]; too high of a current or a long impulse can have fatal or harmful effects. This will affect our circuit design for the CEW portion of our final product; it is needed to ensure that the final device is safe to use.

5. Project Demonstration

5.1 Stun Gun Demonstration

To demonstrate the stun gun wearable jewelry, two tests will be conducted. The first test will not involve any person to test the technical requirements. The stun gun jewelry will be placed on a lab bench with the ring's electrodes connected to a digital multimeter. We will then go through the correct sequence of events to trigger the stun gun circuit as follows:

1. Press the safety button. This button triggers the software to start charging the stun gun circuit and notify the emergency contacts the user is feeling unsafe.
    a. During the demonstration, we will show the notifications sent to the emergency contacts.
2. Apply pressure to the ring (substitute to actual event of the user punching the attacker).
    b. This will trigger the stun gun circuitry and release the charge.

With the multimeter attached to the electrodes the current/ discharge will be measured and shown to be in the determined range of 1 to 3 mA. For the next test, two people will demonstrate the stun gun with the following procedure:

1. Person A will equip the device securing the bracelet around the wrist and the ring on any finger of their choosing. After adjusting the fit securely, the user will press the safety button triggering the above sequence of events.

    a. The first step is to demonstrate the wearable as a lightweight, easy to use device with a comfortable fit, as noted under the customer requirements.
    b. The notification of emergency contacts will be redemonstrated again.
2. Person B will wear rubber, non-conducting gloves. Person A will then punch Person B on the gloves.
    a. The second test will be a real-life demonstration of the product working in an attack while also showing its ease of use. This test will also demonstrate successful insulation when Person A does not feel pain or tingling.

5.2 GPS and Alert System Demonstration

Two people will demonstrate the GPS and alert system with the following procedure:

1. Person A will equip the device in their hand and press the safety button.
2. Person B will hold a phone with the GPS application installed.
3. Person B will enter their phone number into the emergency contacts list.
4. Person A will press the ring onto a hard surface to activate the device.

To verify that the GPS is functioning correctly, Person B will check that their device map shows the user's location within 20 feet of them. To verify the alert system, Person B will receive a text message alert to their phone number.

6. Schedule, Tasks, and Milestones

The Gantt chart in **Appendix A** displays the tasks that must be finalized to complete the device. Each task has an allotted time that is estimated for completion to stay on track. Each sub-team has broken down the necessary steps to complete their portion of the project.

7. Marketing and Cost Analysis

7.1 Marketing Analysis

In the United States, 50% of women feel unsafe walking alone at night, and as a result, 34% and 12% of women carry pepper spray and an alarm, respectively [10]. Wearable and concealable self-defense devices and weapons are not a new concept in the current market for this reason. However, each option typically focuses on one distinct feature. The two current products on the market with the same deliverable feature as the proposed are invisaWear and Defender Ring. InvisaWear is designed as a necklace or bracelet with a button that sends the user's location to emergency dispatchers and their friends and family during an emergency [11]. Defender Ring is a ring with a small hidden blade that can be used during an emergency [12]. These products lack the ability to fight off a perpetrator while notifying emergency dispatchers, including friends and family.

7.2 Cost Analysis

The total development cost for a prototype of the Stun Gun Ring is approximately $100.00. **Tables 3** [13] and **4** [14] below shows a breakdown of the material costs of different components of the prototype. The costliest equipment is the wristband material and custom design built PCB board, intended to minimize cost and optimize functionality at such a small scale.

Table 3. Parts for Teardown: Fitbit Flex

Item	Manufacturer	Quantity	Cost
2-Shot Injection Molded Polycarbonate & Silicone Rubber	Healthy Metrics Research Inc.	1	$20.00
MCU, 32-Bit, ARM Cortex-M3, 32 MHz, 128KB Flash, 16KB SRAM, 24 Channel x 12-Bit ADC	ST MICROELECTRONICS	1	$6.44
Bluetooth, Single-Chip, V4.0LE	NORDIC SEMICONDUCTOR ASA	1	$5.61
Bluetooth USB Dongle	RoHS - TP link	1	$9.99
USB Cables / IEEE 1394 Cables USB Cable, Type A Plug to Type C Plug, USB 2.0, 28 AWG	CUI Devices	1	$5.82
Accelerometer, 3-Axis, ±2g/±4g/±8g/±16g, I2C/SPI digital output interface	ST MICROELECTRONICS	1	$9.97
Lithium Ion Polymer Battery Ideal For Feathers - 3.7V 400mAh	Adafruit Industries LLC	1	$6.95
Vibration Motor, Coin Type, w/ 2 Discrete Insulated Wires	Adafruit Industries LLC	1	$1.95
			$66.73

Table 4. Parts for Stun Gun Circuit on PCB

Item	Price	Quantity	Cost
2SD965 NPN Transistor	0.34	1	$0.34
Fly back Transformer	3.81	1	$3.81
Push button	0.47	1	$0.47
LED	0.61	2	$0.61
PCB	4.00	1	$4.00
Terminal Block 2 pin	1.14	3	$3.42
Resistor 150k	0.15	1	$0.15
Resistor 1k	0.31	3	$0.93
Capacitor 1nF/3KV	0.90	2	$1.80
Capacitor 1000uF	0.99	1	$0.99
Capacitor 470nF/400V	1.68	1	$1.68
Capacitor 105/3KV	0.56	1	$0.56
Power Supply 3v-12v - Battery	1.32	1	$1.32
1N4007 Diode	0.22	7	$1.54
Zenner diode 5.1v	0.22	1	$0.22
On/off switch	0.95	1	$0.95
			$22.79

The development costs shown in **Table 5** were determined with an assumed production cost of $46,000. Overhead costs were factored into the higher costs, specifically with Total Cost/Year, and thus, would affect the Total Cost of Year 1 Adjusted Cost and the Cost/Unit. With a total of $-20,312.50 in Total Profit/Year, it is not until more years go by that we see a steady decrease in Cost/Unit and an increase in Total Profit/Year. The most laborious process will be the assembly of the product as it is predicted to cost $10,000 in its first year.

Table 5. Development Costs

Project Component	Base Cost Year 1 (USD)	Total Cost Year 1 (USD)
Production		
Parts	17.00	$17,000.00
PC Board	8.00	$8,000.00
Assembly	10.00	$10,000.00
Packaging	1.00	$1,000.00
Testing	10.00	$10,000.00
Packaging		
Per/Unit	1.00	$10,000.00
Marketing		
Non-Engineering	30,000.00	$2,500.00
Sales		
Non-Engineering	30,000.00	2,500.00
Distribution		
Shipping Per/Unit	1.50	$1,500.00
Shipping		
Non-Engineering	30,000.00	$2,500.00

Using the overheard as 150% of material and labor, the total development cost for the ring stun gun product is $300,781.25, as shown below in **Table 6**.

Table 6. Total Development Costs

	Base Cost Year 1 (USD)	Total Cost Year 1 (USD)
Parts	$89.52	$120,312.50
Overhead	$47.00	$180,468.75
Adjusted Cost		$300,781.25
Cost/Unit		$120.31
Total Profit/Year		$-20,312.50
Total Profit		$373,137.50

The production run will consist of 1000 units sold over a 5-year period at a price of $100.00 per unit. A group of seven engineers will be employed to work a total of $65,000.00 in the first base year. Sales expense, or marketing and advertising, will make up 6% of the final selling price. With the current prediction of the unit price, the expected revenue is $373,137.50.

8. Current Status

The major features and technical specifications of the device have been determined. Research into the stun gun circuitry and the GPS has already begun. Research so far has mainly been focused on miniaturizing the stun gun circuitry. The electrical components have mostly been decided on for the bracelet, but the stun gun electrical components can still change. Also, research on assembly and how the software and hardware interact still needs to be conducted.

9. Leadership Roles

To better organize the project, each member of the team has been assigned a leadership role. While all members will collaborate to accomplish the tasks of each role, the leader of each role will be held accountable should the tasks assigned to their role fail to be accomplished on time. The current leadership roles and the corresponding tasks are assigned as follows:

- Webmaster (Hubert Elly): creating and designing the product and contact information website
- Expo Coordinator (Katie Weatherwax): organizing and coordinating the end-of-term exposition
- Documentation (Radha Changela): documenting project progress and results
- Electrical Lead (Katie Roberts): designing circuits and assembling electrical components
- Mechanical Lead (Lara Kassabian): device packaging design
- Software Lead (Christine Saw): GPS software design
- Leadership Coordinator (Elizabeth Herrejon): keeping track of the project deadlines and making sure all team members are doing their job

10. References

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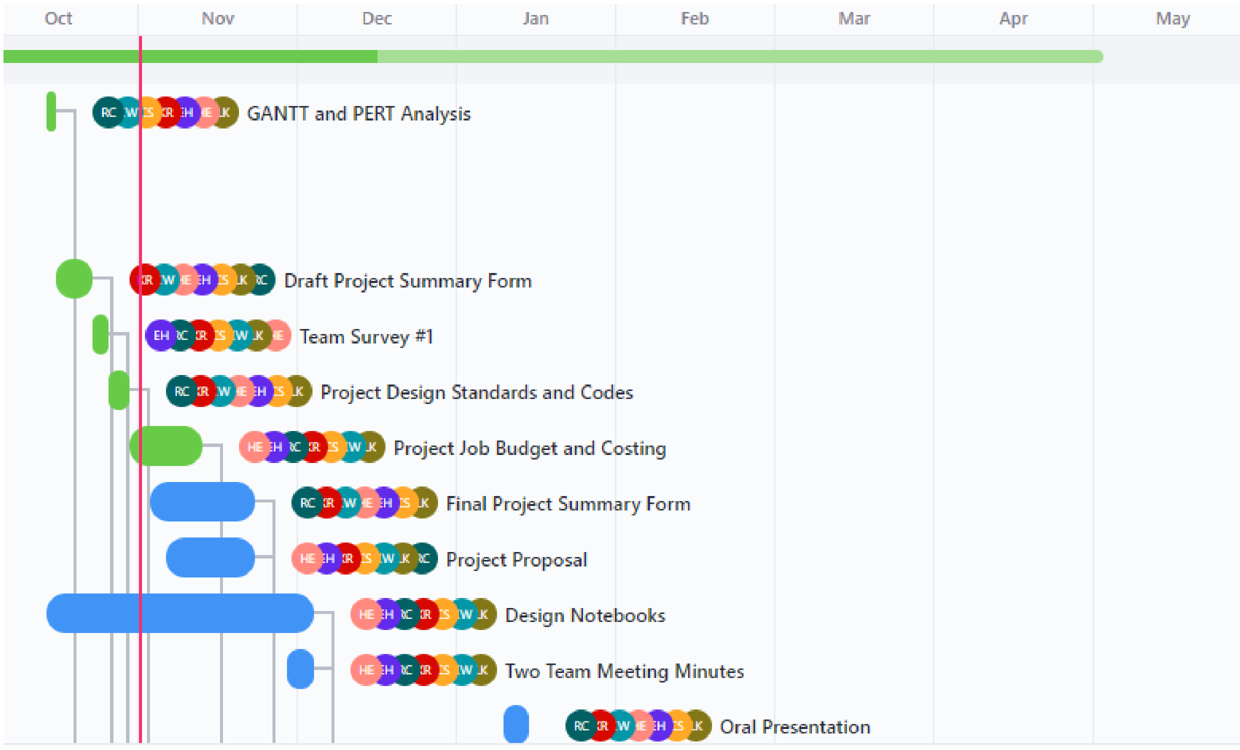
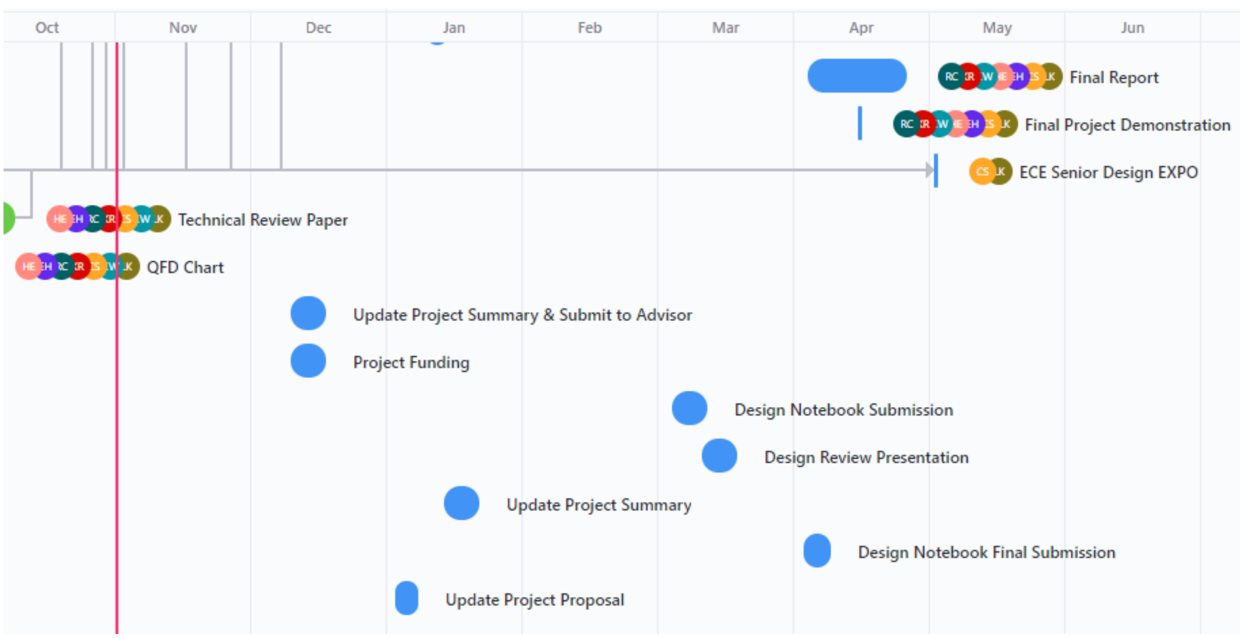
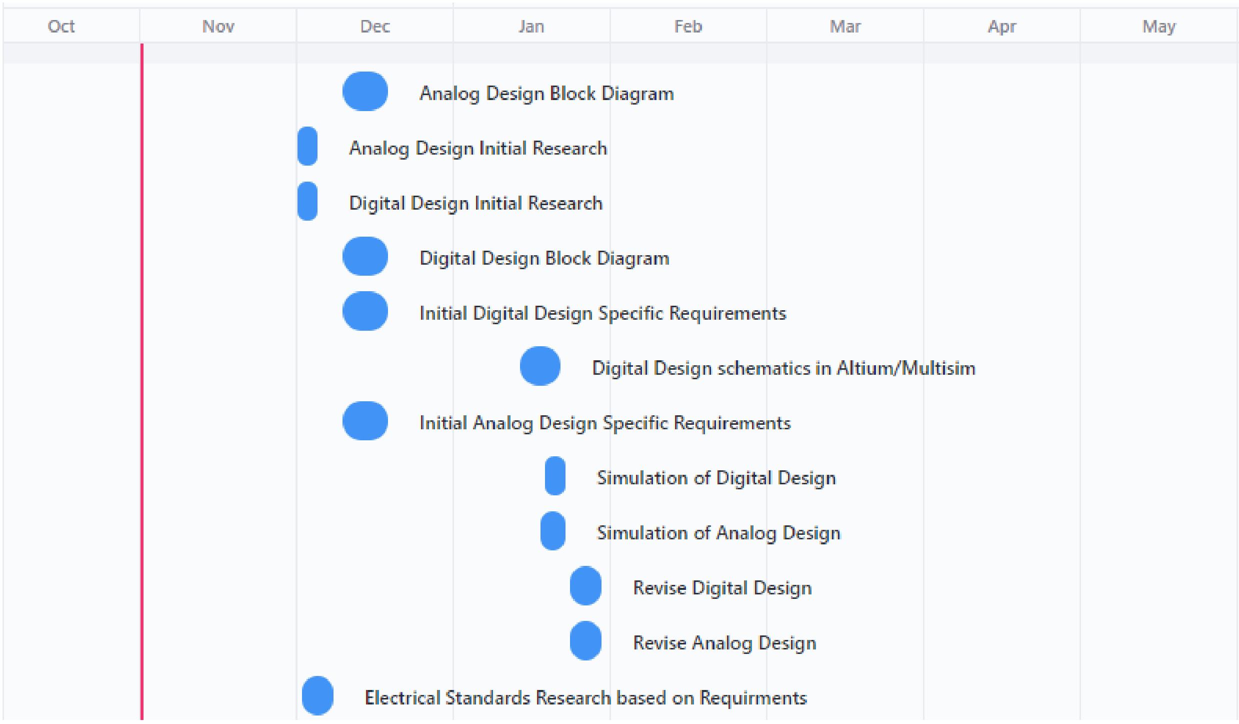
Appendix A: Gantt Chart







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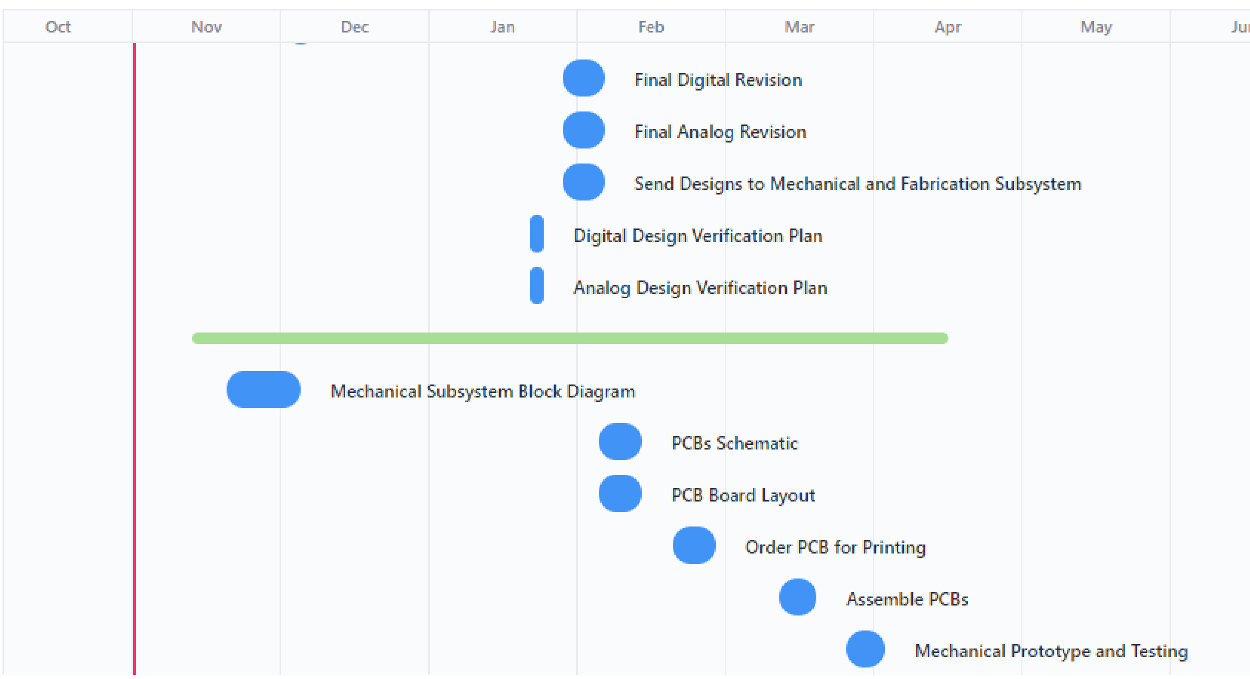
Analog Design Block Diagram
Analog Design Initial Research
Digital Design Initial Research
Digital Design Block Diagram
Initial Digital Design Specific Requirements
Digital Design schematics in Altium/Multisim
Initial Analog Design Specific Requirements
Simulation of Digital Design
Simulation of Analog Design
Revise Digital Design
Revise Analog Design
Electrical Standards Research based on Requirments



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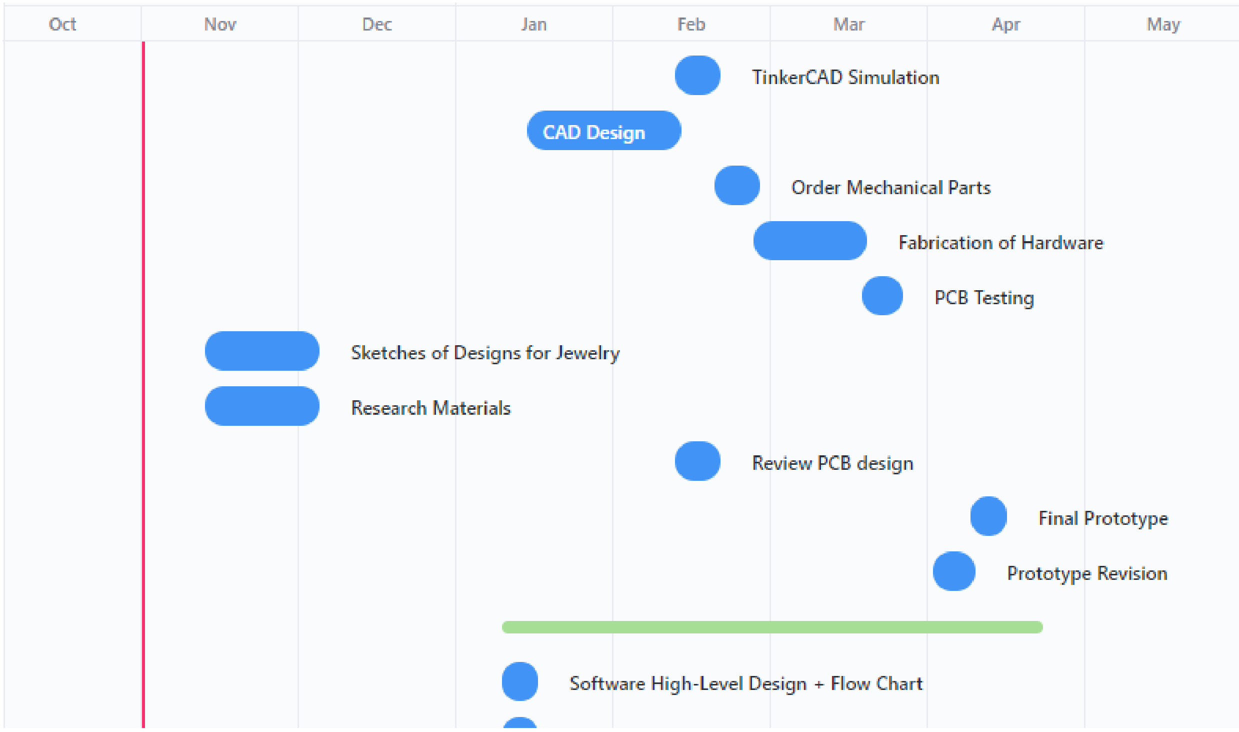
Final Digital Revision
Final Analog Revision
Send Designs to Mechanical and Fabrication Subsystem
Digital Design Verification Plan
Analog Design Verification Plan
Mechanical Subsystem Block Diagram
PCBs Schematic
PCB Board Layout
Order PCB for Printing
Assemble PCBs
Mechanical Prototype and Testing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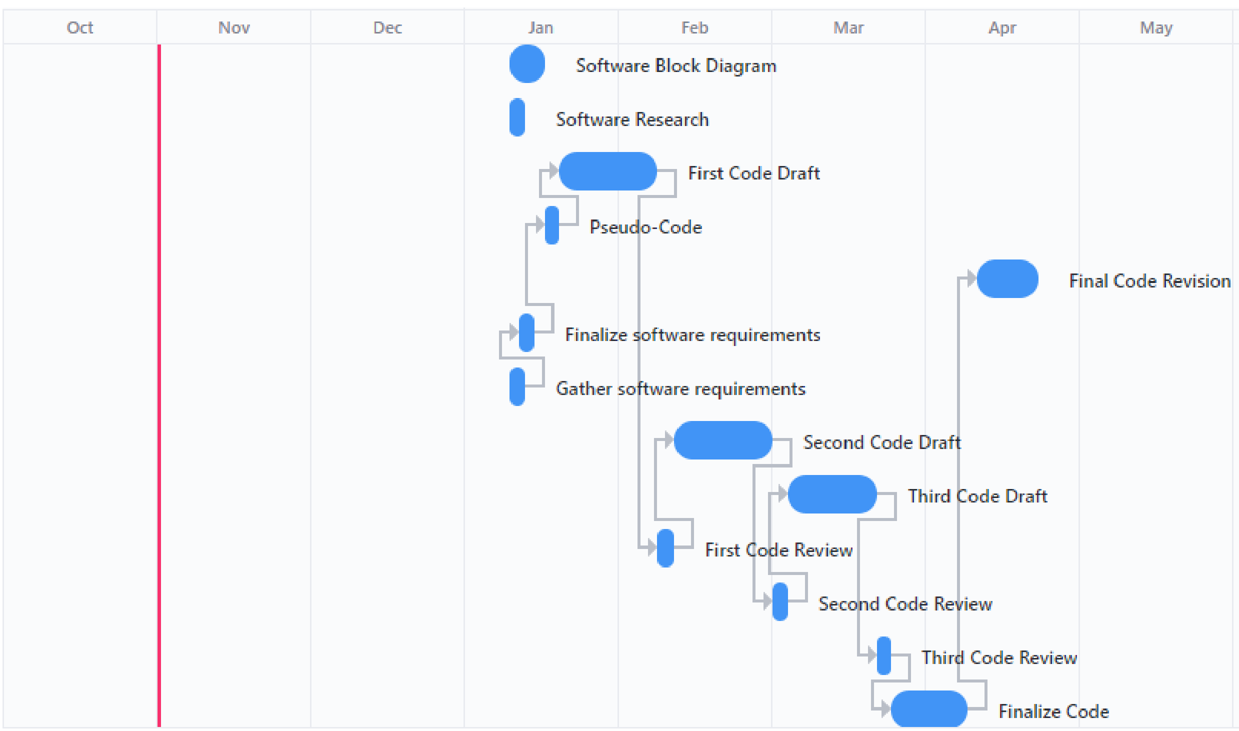
TinkerCAD Simulation
CAD Design
Order Mechanical Parts
Fabrication of Hardware
PCB Testing
Sketches of Designs for Jewelry
Research Materials
Review PCB design
Final Prototype
Prototype Revision
Software High-Level Design + Flow Chart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Software Block Diagram
Software Research
First Code Draft
Pseudo-Code
Final Code Revision
Finalize software requirements
Gather software requirements
Second Code Draft
Third Code Draft
First Code Review
Second Code Review
Third Code Review
Finalize Code