PET THREAT DETECTOR
FINAL REPORT

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Abstract

In the course ECE 445 Senior Design Laboratory administered by University of Illinois at Urbana-Champaign, electrical and computer engineering students design and build projects based on a variety of problems conceived by the students themselves. Circumstances outside of the control of the university and students led to the reformatting of the course for the Spring 2020 semester and including a secondary project which solves the problem of a prior ECE 445 team project. This document reflects the findings and implementations of Team 45 for the ECE 445 course. Much of this document reviews the design of the secondary project which is known as the Pet Threat Detector. This system is designed to solve the problem of pets encountering danger when left unattended outside. First, the project motivation is examined through an overview of the problem and solution. Additionally, the original and revised designs are compared and contrasted. To summarize the project goals, the high level requirements for the project are stated. Each of the modules are introduced with an explanation of their primary function and purpose. From this discussion, the objectives and goals of this project should become clear. Afterward an analysis on the projects implementation thus far is conducted. This includes simulations, Eagle schematics and flowcharts to further explain how the components and design chosen solves the original problem while demonstrating the progress made in the design thus far. Conclusions are then drawn from the findings of this study as well as the remaining uncertainties. Statements will also be made about how the project could be improved in the future. To conclude the document, the first Team 45 project, Touchless Proximity Lock, is introduced by discussing the progress completed since the development of its Design Document.

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1 Project Motivation

During the second half of the semester, students in ECE 445 were tasked with revising a project from a previous team. For this project, Team 45 selected to work on the Pet Pest Detector project from Team 8 of the Fall 2019 semester. The Team 45 students had a wealth of ideas on how to improve the original design using the experience gained from the first project. By incorporating these improvements, the revised design protects the pet from several dangerous situations beyond just pests.

1.1 Problem Statement

For many households around the world, pets are treated like family members and their safety is considered a high priority. Pets need to go outside to get exercise and many are left unattended while they roam the yard. This can lead to pets finding themselves in a variety of dangerous situations. Some common examples of danger that pets can encounter include finding a wild animal, becoming injured or wandering far from home. While owners eventually discover the danger their pet was in, this usually happens after the pet has been harmed.

Pet safety technology is a relatively new and unexplored field. The most prominent and commonly used electronic technology for pet safety are microchips using passive integrated transponders (PIT). This development was originally introduced in 1984 to study the migration patterns of fish. PIT devices are injected into the animal and contain a radio frequency identification (RFID) number to track which animal is which. Little has changed with this technology since its inception and it has most frequently been used as a method of identifying a lost animal that someone has found [1]. However, PIT microchips do not feature Global Positioning Services (GPS) technology and do not track the exact location of a pet in real time. Real time GPS tracking is a feature included in various collars. These devices use global positioning and an accelerometer to detect an animal's motion and current position. GPS tracking collars were invented in 2014 by Terrie Williams, Christopher Wilmers and Gabriel Elkaim to track large wild cats [2]. While these devices do monitor the animals' behavior using an accelerometer, the device is not made with the intention of detecting hazards to the animal. These devices have been refined and commercialized for pets as well with some even including cameras to record what the pet does on a day to day basis. Other devices are designed to track the location of hunting dogs so that the owner can locate their dog and game [3]. While many microchips and GPS collars exist, these devices only notify the owner of where the pet is located and not of any other existing danger they might have encountered [4].

1.2 Solution Overview

While Team 8 provided an adequate solution for protecting a pet from wild pests, the students of Team 45 recognized a multitude of adjustments which could be made to the design so that the pet is protected from a wider variety of threats. The device Team 8 developed was a collar which could protect a pet by detecting the motion of a pest through a Passive Infrared (PIR) sensor which uses temperature detection technology and infrared light to identify if the pet has encountered a threatening animal or person [5]. While the device accomplishes the task of detecting danger from other animals or humans in close proximity to the pet, there are many other forms of danger that would go unnoticed by the PIR sensor. Moreover, the original design functionality is hindered if the owner has multiple pets because there is no way to distinguish from the notification alone whether the pet has encountered a threat or a friendly pet or human.

In order to ensure the improvement of Team 8's design and provide a more thorough solution than a simple GPS tracker, the problem statement is solved with a focus on tracking the condition of the pet rather than the danger itself. To determine whether or not the animal is in danger, a variety of sensors and a camera will be attached to a harness that the animal will wear while outside. When these sensors detect a change in the pet's behavior or current state, the owner will receive a notification on their mobile device through a software application. These notifications will include information about the type of danger that the pet is potentially experiencing. The type of notification and when each alert occurs can be seen in Table 1 in Appendix A.

The sensors being used are a camera (ZM 0.3 Megapixel), an accelerometer (ADXL363) and a heart rate monitor (SEN-11574). The accelerometer and heart rate monitor track the pet's current state by detecting an elevated heart rate and checking the pet's movement. With this information, the integrated software in the ESP32 microcontroller decides if a notification should be sent and what information the notification should contain. Whenever a notification is sent, a picture is captured by the camera and sent to the owner, which can be viewed in the software application. This provides the owner with an added level of information about the type of danger the pet might be in.

Applying these sensors along with traditional GPS tracking technology and a mobile notification system produces a solution which provides comprehensive information on the pet and improves owner response time for handling the imminent threat to their pet's safety. This solution can also be safely used with several pets to monitor their safety simultaneously.

1.3 High Level Requirements

- HLR-1: The owner shall be notified through the Pet Threat Detector whether or not a pet is in danger in under 10 seconds of the pet encountering a threat with a failure rate of 5% or lower.
- HLR-2: The Pet Threat Detector shall send a notification to the owner's mobile device when the pet is in danger through the Communication Module with failure rate of 5% or lower.
- HLR-3: The Pet Threat Detector shall track the longitudinal and latitudinal coordinates of a pet within a 20 meter radius of its actual location and display these results to the owner as long as communication between the mobile device and harness is maintained.

1.4 Visual Aid

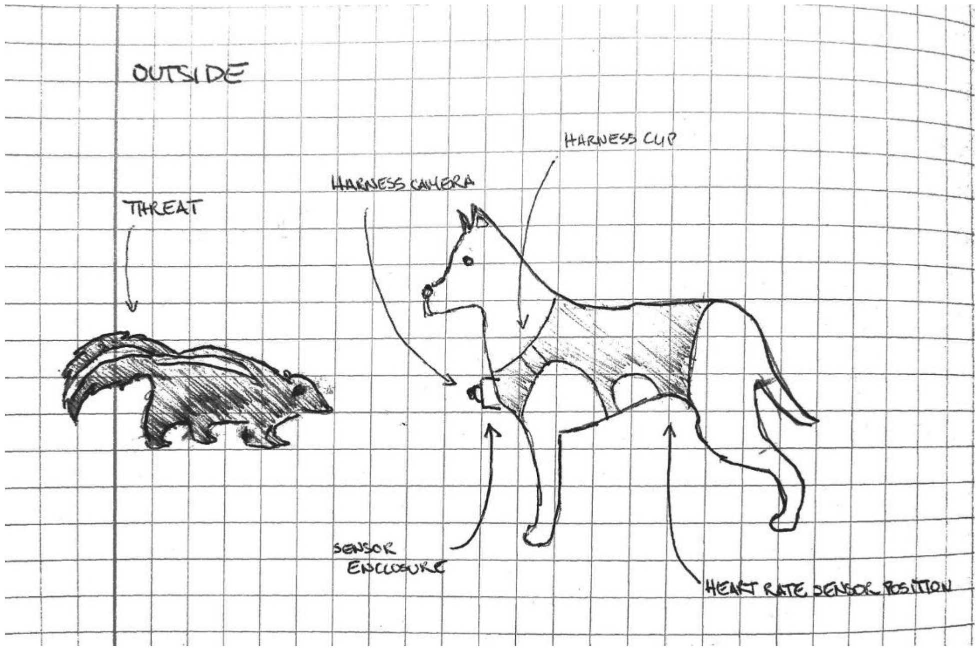

Figure 1: Initial sketch of the harness design with all sensors and their positions. This figure also demonstrates how the camera would capture an image of the potential threat.

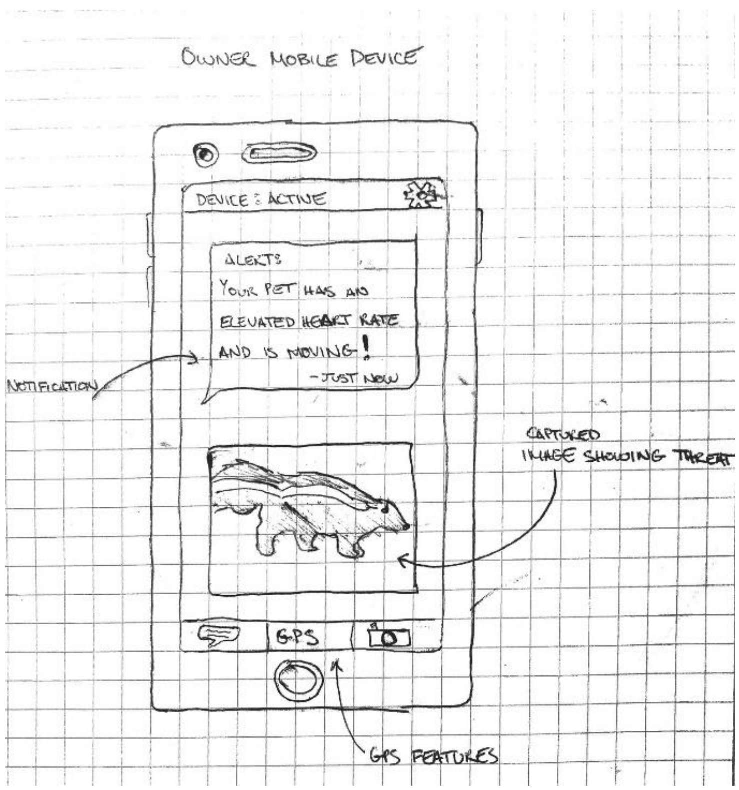

Figure 2: Sketch of the software application GUI and example of a notification and a picture sent to the owner.

1.5 Block Diagram

To complete the task of notifying a pet owner quickly of any possible danger, the design requires interaction between two electronic devices: a modified pet harness, which is designed specifically for this application, as well as an Android mobile device such as a smartphone or tablet. Harnesses are commonly used as a training mechanism and should not cause the pet any discomfort during use while still providing a platform to include each of the desired features. The mobile device operates a student-developed software application which will receive the notifications.

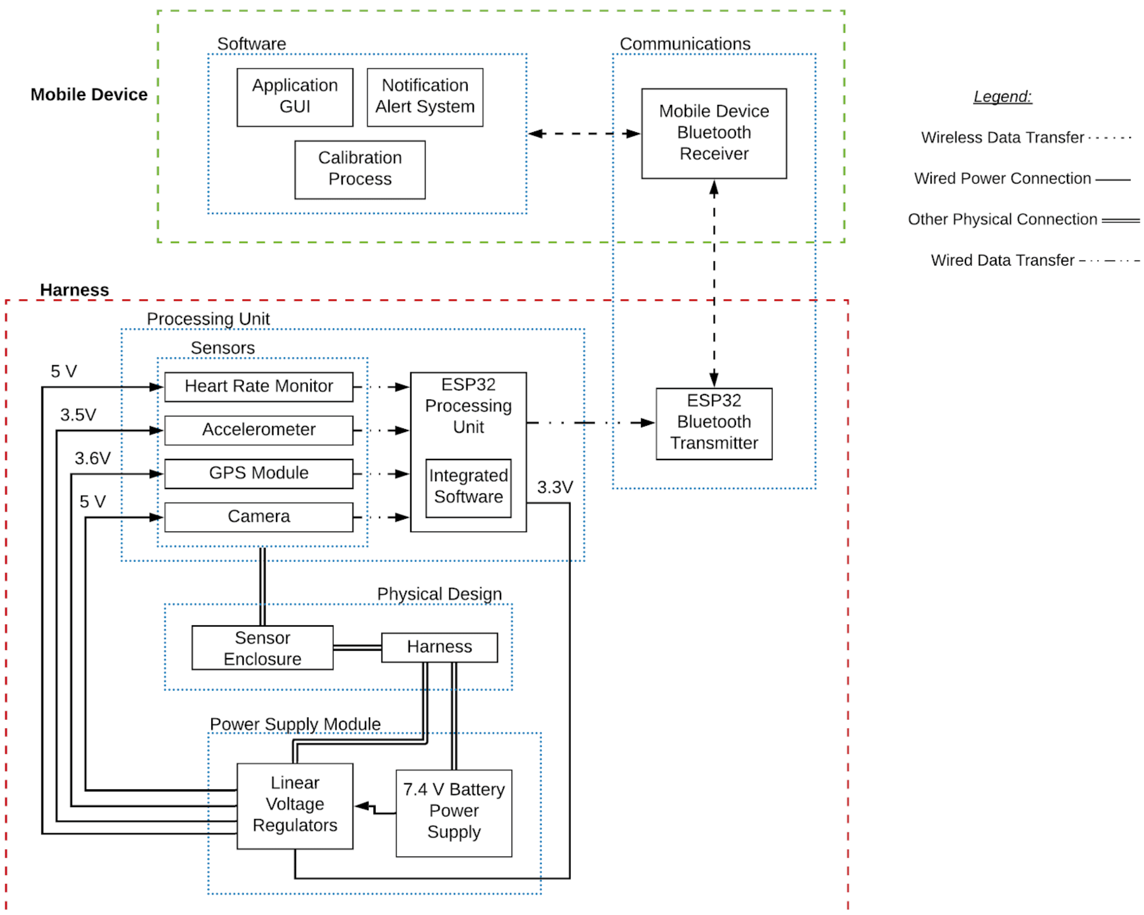

Figure 3: Block diagram for entire project showing modules, devices and components and their interfaces.

Design organization is subdivided into five modules: a Power Supply Module, a Physical Design Module, a Processing Unit Module, a Communication Module and a Software Module. The primary task of the Power Supply Module is to ensure each component is supplied with the appropriate power required for operation. This includes the battery supply, power wire routing and a small network of linear voltage regulators. The Physical Design Module diminishes the challenges associated with mounting electronics on a living animal. While this module does not include any electrical components, it is still an integral module for keeping the animal safe when the device is in use. All of the sensors for monitoring the pet's physical condition are contained within the Processing Unit Module as well as a ESP32 which collects the data to be sent through Bluetooth with the Communication Module. The Processing Unit Module also contains an integrated software component developed on the Arduino Integrated Development Environment (IDE) which is used to interpret what data to send through the Communication Module. The software that the pet owner interacts with is contained in the Software Module. This includes an application developed for Android devices for the user to calibrate the electronic harness to their pet's vital conditions and receive notifications about the pet's well-being.

2 Project Implementation

Due to limited resources and delayed shipping times as a result of the COVID-19 pandemic, implementation for this system was limited to simulated analysis, pseudocode development and updating the bill of material as more components are added or removed from the system. For system implementation, work was concentrated on physical components and simulation. Many of the software requirements demand significant progress in the development of both the integrated microcontroller program and mobile application. While implementation of functional software was deemed unreasonable for the time and resources available, a pseudocode was created for the integrated software of the microcontroller.

2.1 Linear Voltage Regulator Testing

Focus was put on collecting data for the Power Supply Module due to the large amount of technical information which could be investigated. To demonstrate this, schematics were created in Eagle and simulations were conducted using LTSpice. The results of this simulation were used to improve the Eagle schematic, PCB layout and update expectations for the components necessary for a successful system.

2.1.1 Schematic and PCB Development

The schematic design was built from the components discussed in the Design Document. The ESP32 microcontroller is shown in Figure 4 in the center of the schematic to clearly present the necessary connections for processing the signals from each of the other components. The development kit was used since it contains the necessary capacitors and resistors to operate the device in the simplest manner. Each sensor connection to the microcontroller was determined from their respective datasheets.

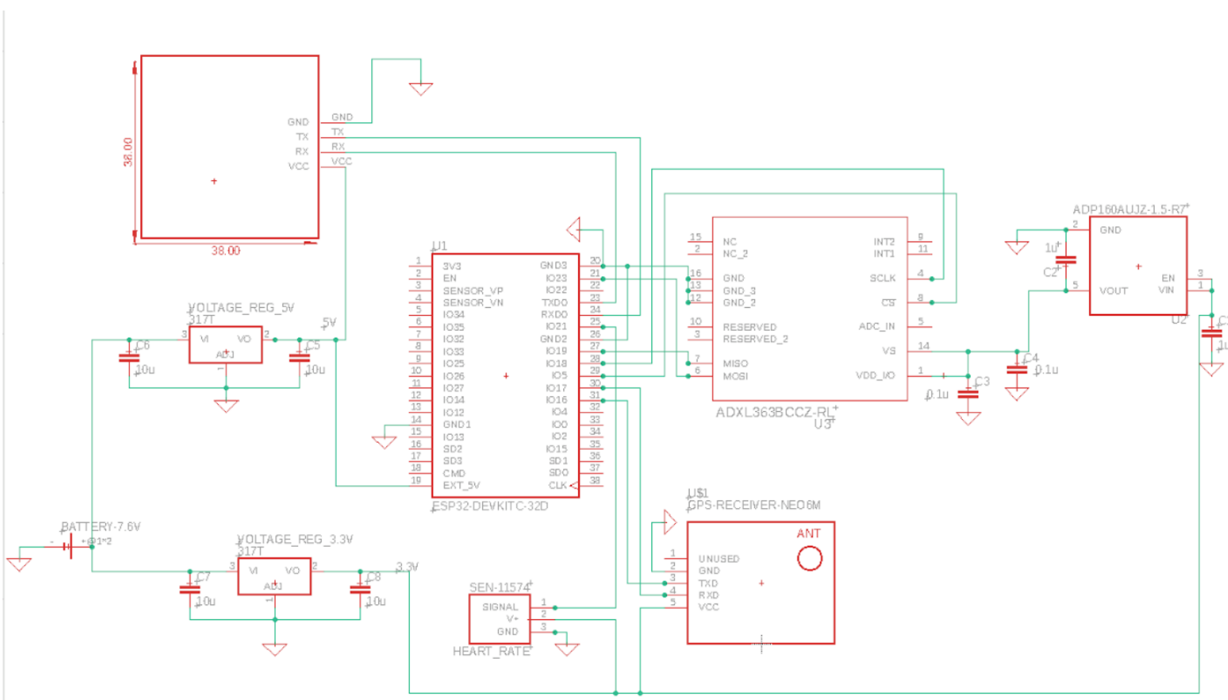

Figure 4: Schematic of the harness' components including the ESP32, camera, accelerometer, heart rate monitor, GPS and linear voltage regulators with capacitors.

The PCB layouts were then generated from the Eagle schematic and both the boards designed are shown in Appendix A as Figures 5 and 6. Some of the components are located in different areas of the modified harness and not all of them need a dedicated board to function. Therefore, the only components that had a dedicated PCB were the battery and ESP32 together and the accelerometer.

2.1.2 Simulations

Students in Team 45 conducted simulations on the linear voltage regulators using the software LTspice to ensure the circuit configuration chosen produces the desired voltage values. While Eagle contains ngspice, an integrated open source spice simulation feature, the difficulty of finding model files (.mdl extension) for the chosen linear voltage regulators led to obstacles in conducting the simulation in this manner. Instead, similar voltage regulator models were used within the included LTspice libraries along with the components which would be used if the system were constructed. While the design of this project used the MIC29300-3.3WT, MIC29310-5.0WT and ADP160 voltage regulators, these were respectively substituted by the LT1763-3.3, LT1763-5 and ADP150-2.8 in the simulations. These linear regulators are used in the design to step down the 7.6 V from the battery to 3.3 V, 5V, and 2.8 V respectively, depending on the voltage requirement of the component.

The results of the simulation incited additional thoughts about what resistors and capacitors to use for this application, especially when it comes to smoothing fluctuations in and out of the voltage regulators. Also, special attention was given to the linear voltage regulators that were connected to the accelerometer. Given that this component's bypass capacitors needed to be discharged whenever the harness battery depleted, an extra linear voltage regulator with a shutdown discharge feature was added. This second device was recommended by the accelerometer's datasheet and needed to have an input voltage of 2.2 V to 5 V, thus requiring the 7.6 V from the battery to be stepped down to 3.3 V before passing into the second linear voltage regulator serially.

At first glance, simulating this system in LTSpice yielded no direct option for a 2.8 V output, so the LT162-2.5 regulator with an output of 2.5 V was used instead. The replacement device, however, generated unexpected and undesired results and modifying the control resistor caused insignificant changes in the output voltage even though the range of input voltages for the LT162-2.5 includes 3.3 V. To test the cause of this problem, the input to the 2.5 V regulator was replaced with a voltage source. This source was tested with various voltages, including 3.3 V and 5 V. The results of this test led to choosing the ADP150-2.8 regulator for the simulation, produced by the same manufacturer as the ADP160, that has an output of 2.8 V. The designed system then produced the predicted results, and a similar behavior is expected from the regulator chosen for the system assembly. Figure 7 shows the schematic used and Figure 8 the described simulation. The results of the remaining simulations are shown in Appendix A as Figures 9 through 12.

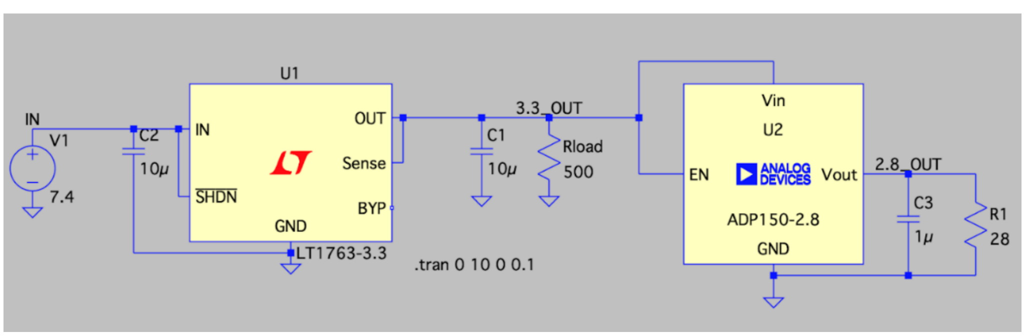

Figure 7: Simulation schematic of 7.4 V battery step down to 3.3 V with LT1763-3.3 linear voltage regulator, then step down to 2.8 V with ADP150-2.8.

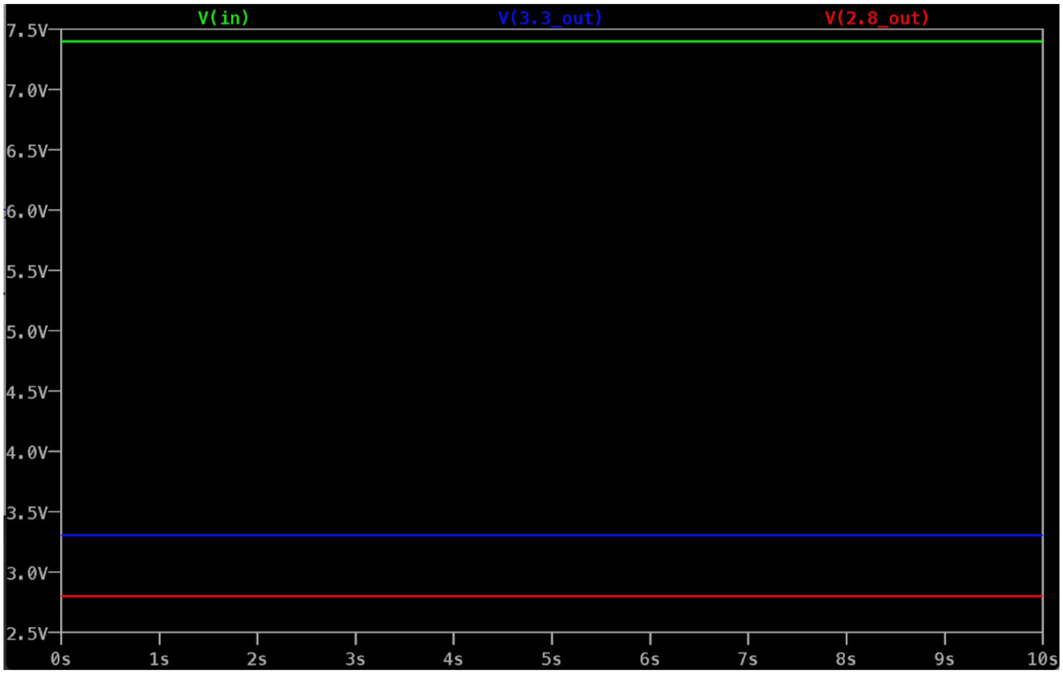

Figure 8 - x-axis is time transpired (s) and y axis is voltage level (V). Vin (green - top) is the supply of 7.4 V, V(3.3_out) (blue - middle) is the voltage level after going through LT1763-3.3, stepping the supply down to 3.3 V and V(2.8_out) (red – bottom) is the voltage level after going through the ADP150-2.8, stepping the supply down to 2.8 V.

2.2 Integrated Software Pseudocode

Despite not realizing the full implementation of the integrated software for the ESP32 microcontroller, pseudocode was developed to determine the logic of how the ESP32 would gather data and decide when a notification would be sent, based on Table 1. The success of the high level requirements is largely dependent on this process because this procedure is how the system gathers and handles information about the safety of the pet. A flowchart illustrating the associated logic can be seen in Appendix A Figure 13.

Because the process for checking the heart rate of the pet takes a significant amount of time when the animal is excited, the software first checks if the user is requesting the GPS location of the pet. This requires an input control bit from the mobile device software which is transferred via the Communication Module to the ESP32. While this process currently only checks this at the start of the logic in the pseudocode, the implementation of this operation as an interrupt is also being considered. Doing so results in many tradeoffs. For example, interrupting the sensors as they gather information on the pet to collect the GPS location gives the owner faster access to the location of the pet if the owner suspects that the pet is in danger. However, this interruption would also prevent the owner from receiving a notification because the process is interrupted before completion. As the device stands, the GPS request does not interrupt the sensors.

In the scenario when the owner is not requesting the coordinates of the pet using the GPS features, the algorithm enters a conditional statement which determines whether or not a notification has been sent from the ESP32 in the past two minutes. This prevents the mobile device from constantly receiving notifications every few seconds if the pet has an elevated heart rate. If there have not been any notifications in the past two minutes, the accelerometer begins taking data on the acceleration of the animal for a period of two seconds. If each of the data points obtained is under an acceleration of |1.5 g|, then the current heart rate reading from the sensor is captured. This heart rate is compared with a value in memory representing the boundary of the pet's elevated heart rate. If the detected heart rate is greater than the value stored in memory the pet is assumed to be in danger. An additional two seconds is taken to collect data from the accelerometer. If all of the observed data points are less than |1.5 g|, then a bit corresponding to the notification type is set to equal 0. If any of the data points observed has a value greater than |1.5 g| then the notification bit is set to equal 1. A notification bit equal to 0 corresponds to sending a notification stating, "your pet has an elevated heart rate and is moving" and a notification bit equal to 1 corresponds to a notification stating, "your pet has an elevated heart rate and is not moving." Next, a JPEG image is captured by the harness camera and the image and notification bit are sent to the mobile device by the Communication Module. If no notification is sent, the camera does not capture an image and the process loops back to the start.

2.3 Bill of Materials

Table 2 - Parts required for the project and their respective manufacturers, quantities required, and costs.

Description	Manufacturer	Quantity	Cost
Pet Harness	Idepet	1	$15.99
LiPo 7.4V Battery	Ovonic	1	$18.99
MIC4576 Voltage Regulator	Microchip Technology	6	$26.46
NEO-6 u-blox GPS Module	52Pi Technology	1	$25.99
0.3M Pixel Serial JPEG Camera Module	DFRobot	1	$45.00
ADXL363	Analog Devices	1	$10.29
SEN-11574	Sparkfun	1	$24.95
ESP32 Microprocessor	Espressif Systems	1	$10.95
Waterproof Case	uxcell	1	$7.63
MIC29300-3.3WT	Microchip Technology	1	$3.48
MIC29310-5.0WT	Microchip Technology	1	$2.48
ADP160	Analog Devices	1	$1.12
10 Microfarad Capacitor	TDK	4	$4.92
1 Microfarad Capacitor	Jameco Valuepro	2	$0.50
0.1 Microfarad Capacitor	AVX	1	$0.25

The Bill of Materials (BOM) composed for the Design Document was expanded upon for the implementation component of the final report. Specific voltage regulators were chosen for each sensor with the MIC29310-5.0WT providing 5 V, the MIC29300-3.3WT providing 3.3 V and the ADP160 providing 2.8 V. These voltage regulators step down the 7.4 V battery voltage to the appropriate values for various components. Capacitors were also added to the BOM for their utility in dampening noise in the voltage regulator's input and output.

Altogether, the estimated cost of all the aforementioned components is $199.00. The cost of the materials without the additional components listed was $186.29. Thus, there was a $12.71 increase in cost with the revised BOM.

The initial cost of the entire project was $43,536.29. With the new components added to this design, the revised total cost of the project will be $43,549.00.

3 Project Conclusions

Progression in the implementation of this design assisted the engineering students of Team 45 in drawing conclusions and determining how to improve the design moving forward. This is done by summarizing the findings of implementation research, expressing what is still unknown, overviewing the ethical considerations made for composing the design and discussing what would be done to improve the project.

3.1 Implementation Summary

The battery supply is an essential part of the Pet Threat Detector, since it powers all the components that are needed for the project to function. Each of the sensors has a different input voltage requirement, with the highest being 5 V. Given the choice of a Lithium Polymer battery for its rechargeable and lightweight characteristics, a limited range of voltage output values were commercially available which would be applicable for this design, namely at 3.7 V and 7.4 V. The battery included on the harness featured the latter voltage value which means the voltage must be stepped down for the other components. Thus, it is essential to simulate the voltage levels and ensure they would be correctly transformed through the voltage regulators.

3.2 Unknowns and Uncertainties

Given the current pandemic, the inaccessibility of the Senior Design Laboratory and time constraints, the majority of the project was not fully realized in implementation. Significant progress was made on the design and simulations, however, unit testing each device would be one of the most crucial parts of this assignment.

For unit testing to be possible, all the necessary components would need to be ordered and shipped including the sensors, the microcontroller and battery. While those are available for purchase online, the delivery time, especially considering the delays caused by the pandemic, would surpass the two weeks since it was announced that implementation would be a mandatory component of the project and final report. Moreover, even if those components were available to use, the Senior Design Laboratory would be needed to test the linear voltage regulators through an oscilloscope, which is one of the first steps for the implementation of this project.

Under the current circumstances, both the integrated software and the mobile application can be developed without needing the laboratory or additional resources. However, given the complexity of the software design, it was not viable to implement the software in a functional capacity in the allotted time. Moreover, the inability to test its Bluetooth functionality with the microcontroller would make the creation of this application insignificant for the verification of the software and high level requirements.

3.3 Ethical Considerations

The IEEE Code of Ethics was used as a reference to make design decisions for this project. In particular, the nature of the design required the team to heavily focus on policy numbers one, three, seven and nine. The first code referenced in the IEEE Code of Ethics states that this design should “hold paramount the safety, health and welfare of the public, to strive to comply with ethical design and sustainable practices, and promptly disclose any factors that might endanger the public or environment [6].” When working with any electrical or non-electrical device, the safety of the user is a primary concern, especially when the intention of the design is to promote the safety of individuals and their pets. Code number three directly references the honesty and realism of the experiment being conducted [3]. This was an important criterion for developing this design largely due to the importance of receiving accurate data from the sensors and interpreting it correctly. For example, a variety of sensors are used in this design along with the camera to provide the owner with honest measurements of the pet's condition by attempting to be as comprehensive as possible. As a revision of a previous year's project, it was also important to consider the effects of IEEE 7.8 Safety and Ethics #7 which covers accepting criticism of technical work, identifying and amending errors and crediting sources which contribute to the work performed [6]. With this design, Team 45 seeks not only to revise the design of Team 8 from the Fall 2019 semester but improve on the concepts it introduced to create technological advancements in the field of animal health and science. Furthermore, any contributions derived from the previous project's design architecture were carefully cited to ensure the intentions and originality of various components of this design are clear and all parties are credited for their respective work. The ninth code referenced by the IEEE Code of Ethics pertains to avoiding injuring or harming others "by false or malicious action [6]." Similarly to codes one and seven, this incentivizes honesty and transparency in development to avoid injuring other parties both physically and in reputation. Due to safety being a primary concern in the development of this technology, this requirement was carefully followed.

All of the other codes were also carefully adhered to but many were followed naturally by the guidelines given for the project and by consequence of other design decisions made. For example, IEEE 7.8 Safety and Ethics Code #4 refers to rejecting bribery in all forms which is irrelevant to this design considering there is no manufacturing that will occur and there are no plans to commercialize the device. Another example of this can be seen in Code #2 which states that conflicts with other parties will be avoided and no conflicts of interest will occur. Because the only other parties involved with this design are the sources used for the development of its architecture there should be no other conflicts of interests that would occur outside of ensuring each source is cited properly. Following this standard is a result of closely following IEEE Codes #7 and #9.

Though for the most part, the pet threat detector is based on providing an added layer of security for pets, there still are some potential hazards that are present. One of the biggest concerns is how the electromagnetic radiation could harm the pets while the device is in use. High frequency electromagnetic radiation can have a harmful effect on biological tissue [7], which could potentially cause more harm than good for the pet wearing the device. This concern pertains to the safety of the public and must be considered in adherence to the first policy of the IEEE Code of Ethics [6]. Despite these concerns, the actual device specifications do not actually call for the use of signals that would be different than that of a cell phone signal. Both humans and animals are frequently exposed to signals of similar magnitude by using electronic devices in close proximity. While the impact from this is non-zero it also has a comparatively insignificant impact on the lifetime of the pet and would provide greater benefits to its safety than detriments. If this product were to be commercialized, the product packaging would include a disclaimer about this impact and its effects on pets.

Another concern is largely related to the use of attaching a battery-using device to a pet in order to operate the device. Different environmental factors such as excessive heat or precipitation could cause the battery to catch on fire, explode, or leak its contents, which would be detrimental to the health of a pet. In accordance with this, different preventative measures mentioned previously on the Power Supply Module and on the risk analysis will be taken such that the risks are as low as possible. One of these measures is to conceal the battery in an enclosure and have that inside the physical harness itself, covered by a high durability fabric such as polyester. Another environmental risk occurs from the electronics becoming exposed to liquids and shorting connections in the process. Everyday waterproof materials were selected for the harness and electrical project box to prevent harm to the animal during use in rainy weather conditions. Despite this, everyday waterproof materials are not designed to be submerged and doing so could risk damaging the device or harming the animal. Therefore, if this product were to be manufactured, a label would be included on the packaging as a disclaimer and warning to not use the system under water. Consequences associated with misusing the product would also be made clear, notifying the owner that incorrect use could cause severe harm to the device or their beloved pet.

The ethics of using various collars and harnesses as a means of restraining animals has been called into question before, especially with dogs. Several varieties of collars cause physical pain, stress and anxiety for dogs when used to restrain them. This would be in violation of the first policy of the IEEE Code of Ethics [6]. For this reason, considerations were taken in the design process to avoid harming pets in use. The non-profit organization People for the Ethical Treatment of Animals (PETA) recommends the use of harnesses to alleviate tension in the neck and to avoid spinal cord injury while in use. For this reason, dogs should be relatively safe when using this device. PETA's harness and collar safety guidelines were also used as a baseline for determining how devices should be protected to provide the safest environment for the pet [8].

3.4 Project Improvements

Many aspects of this project could not plausibly be implemented in just a few weeks by the team, even without the current pandemic transpiring. To commercialize this product, the team would allocate more resources and time to research how to best prepare the product for the market. One improvement would be to provide different sizes of harnesses or create a "one-size-fits-all" harness. The placement of the sensors would only change slightly in the former case, since the design would simply be scaled to meet the different sizes. The latter case would require the sensors to be in a range where they would fit any animal, which necessitates more research on this matter.

Many of the components of this device contribute to a potentially costly final price for the buyer. Although the value of a pet's safety, which is considered a part of the family for many, cannot explicitly be measured, inexpensive products are always welcomed on the market. With more time and resources, the team would research the prices of alternative components to create a more economical model of the product. Hence, the overall price of the harness would be more affordable for customers and would make this product more consumer-friendly.

Lastly, but arguably the most important improvement is to have a network of harnesses, with which notifications could become more accurate. This network would consist of many pets wearing the harness, and, if one encounters the other, both owners would get a notification that their own pet found another friendly pet (no information about the pet would be shared with the other user). Moreover, with a network, it would be possible to track pets farther away. Much like the Tile [9], a tracking device that people can attach to their belongings, each mobile device with the software application would detect other harnesses on the network through a Bluetooth connection. This can be useful if the original owner has a pet that has run away, and their mobile device is no longer paired with their pet's harness. The Bluetooth connection established by other users of the software application would anonymously locate the owner's pet and send its GPS coordinates to the owner. Therefore, if a pet runs away, an owner can get its exact location even if the animal is across town. This last improvement would require more software integration, which would take significantly more time to develop, but it is a feature that would set this product apart from competitors.

4 Original Project Progress

The team's first project for ECE 445 was a Touchless Proximity Lock. Upon completion of the design review, the members designed a schematic and PCB for the Bluetooth Key Transmitter Module. Those can be both seen in Appendix B as Figures 14 and 15.

The electronic key needed to be compact to meet requirement MLM-1 (Table 3 in Appendix B), which said the key shall be small enough to fit into a pocket of 6 in x 4 in x 2 in, or, equivalently, 152.4 mm x 101.6 mm x 50.8 mm. That was achieved with careful consideration of the placement of each component. The final PCB measurements were 55.8 mm by 48.26 mm with an estimated height of 20 mm, considering the battery diameter and the HC-05 module. The PCB design consisted of a mock Arduino Uno, with the ATMEGA286 microcontroller, a 16MHz crystal clock and an LED that indicates if the key is on. Also, on the PCB were the HC-05 for Bluetooth communication, a series of battery-indicating LEDs and positive and negative terminals for the battery.

The power supply used for this component was decided to be 3 AAA batteries in series. With a voltage of 4.5 V, all components would be powered on the board, the batteries' size was ideal to meet the size requirement mentioned earlier and its current output was sufficient for this module. The use of these batteries, however, was subject to change, and for this reason the footprint included on the PCB for the battery is simply a positive and a negative terminal to which a battery holder would be connected. Therefore, even though the PCB and schematic marks the battery pad as 9 V, the symbol and footprint were only used because they fit what was needed, and not because 9 V would be used.

A simple battery indicator was also designed, in which 5 LEDs are connected in series, and resistors are connected in between each of them. This would make it possible for the LEDs to light up according to the battery voltage, i.e., the more LEDs on, the more voltage the battery has. The lights would be visible through the key enclosure, which had been discussed with the ECE Machine Shop.

The Bluetooth component of this project was going to be accomplished with two HC-05 devices, which were also programmed and tested. The team was able to pair them with each other, having one as master and one as slave, and test its range by leaving the master on one side of a 55 m hallway inside the Electrical and Computer Engineering Building and the slave on the other, in which case they maintained connection. The team also simulated the Faraday Cage designed in the project, which would block the signal from inside the door, such that the user would not unlock the door from behind by walking past it. This was accomplished by approaching the elevator, which is made of metal and is a good simulation of a Faraday Cage, with the slave and leaving the master inside the Senior Design Laboratory. When the team neared the elevator, the connection was broken between the two modules. However, as soon as the team was out of reach of the elevator, the two modules reconnected automatically. This was a tremendous accomplishment, since it demonstrated HLR-3 and implemented the beginning of HLR-2, as seen in Table 4 in Appendix B.

References

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Appendix A

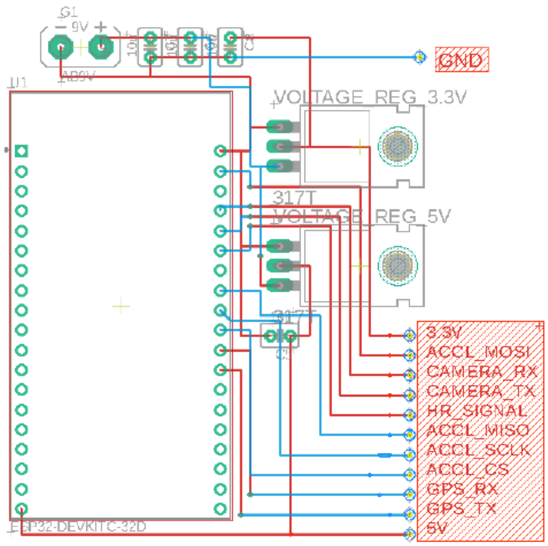

Figure 5 - PCB design for ESP32 and battery.

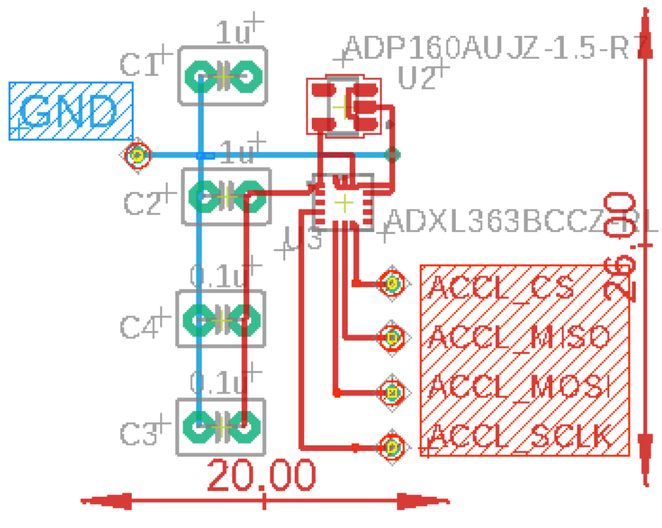

Figure 6: PCB design for accelerometer and ADP160.

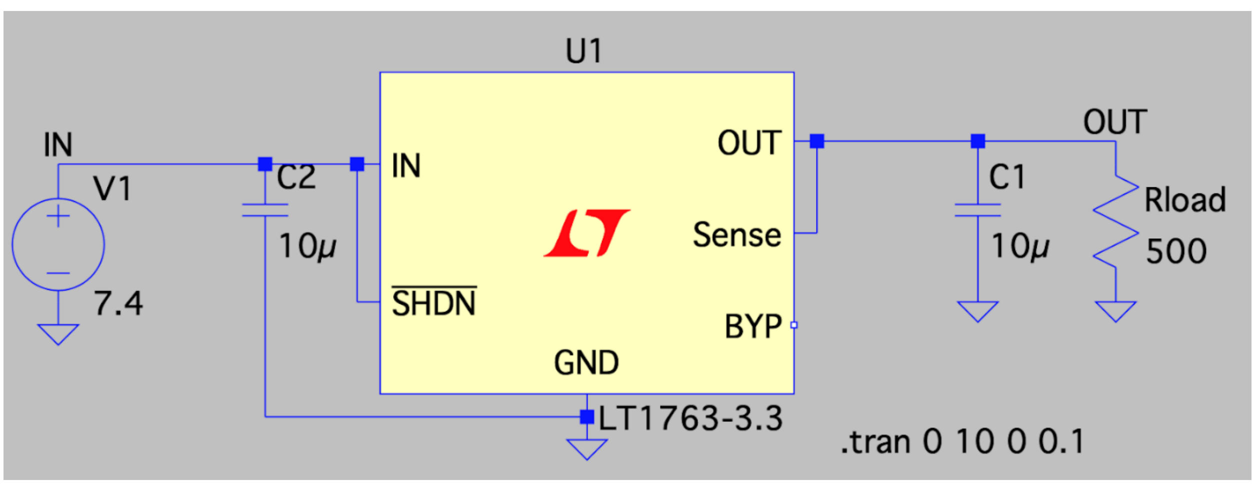

Figure 9: Simulation schematic of 7.4 V battery step down to 3.3 V with LT1763-3.3 linear voltage regulator.

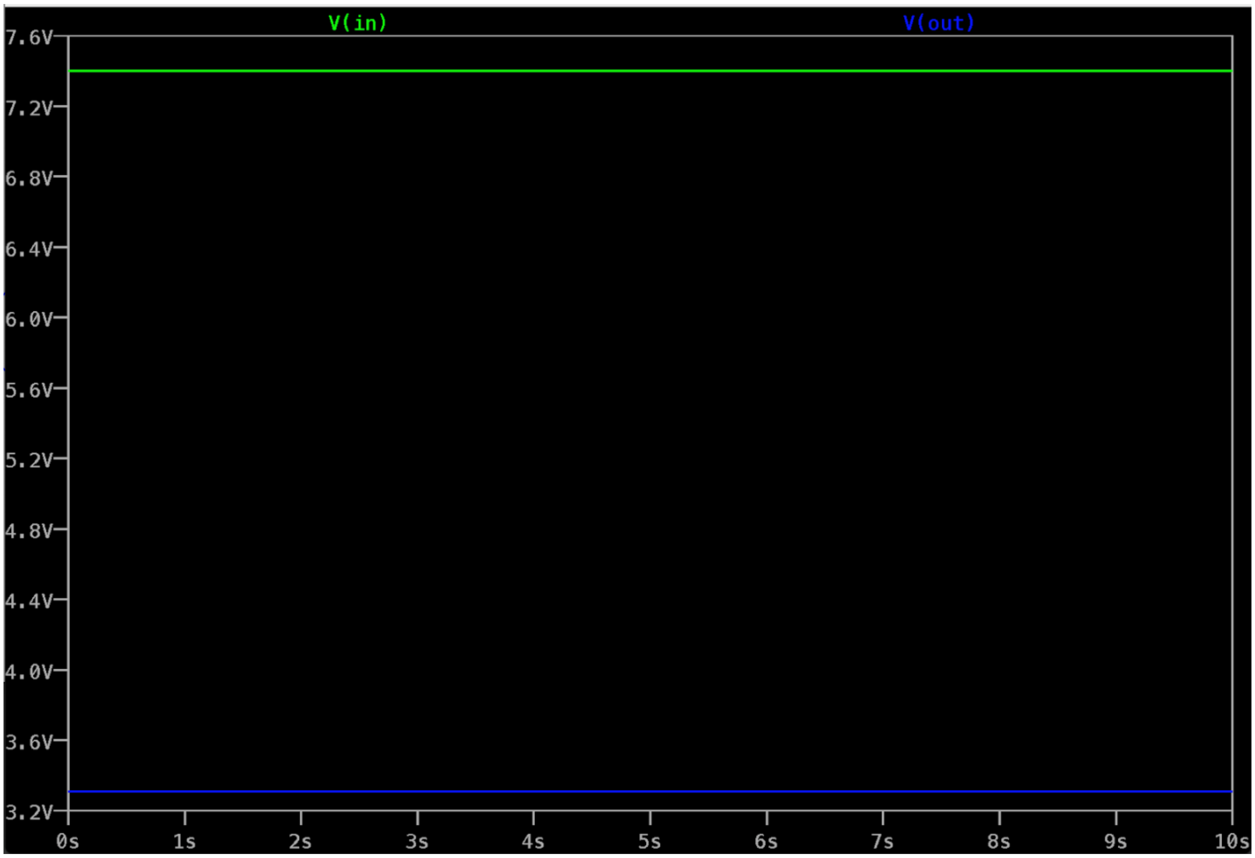

Figure 10 - x-axis is time transpired (s) and y axis is voltage level (V). Vin (green - top) is the supply of 7.4 V, V(out) (blue - bottom) is the voltage level after going through LT1763-3.3, stepping the supply down to 3.3 V (referring to schematic in Figure 8).

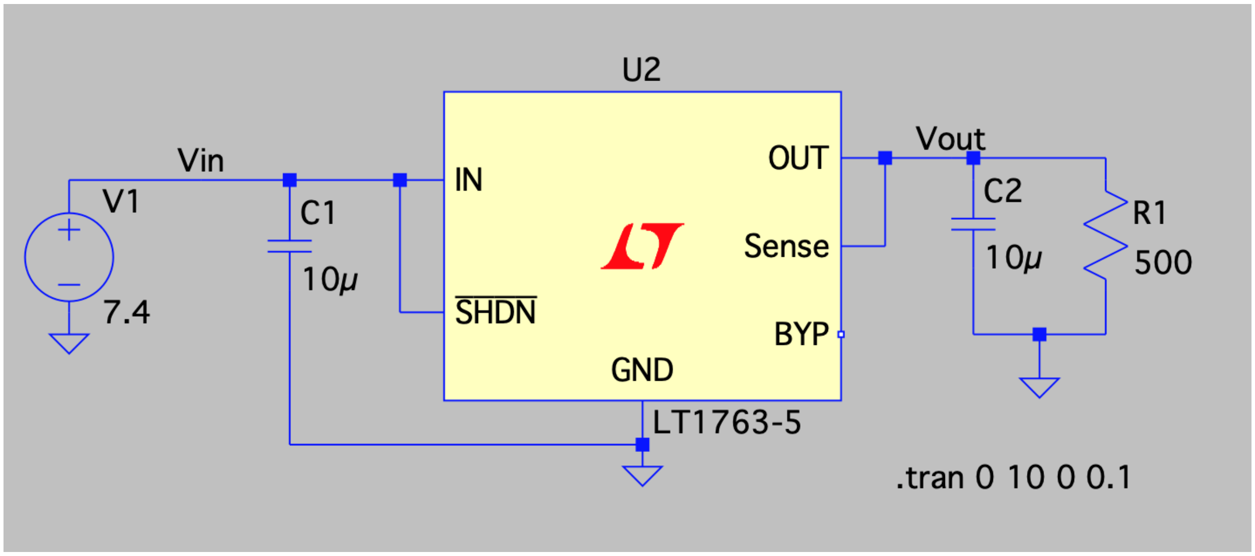

Figure 11 - Simulation schematic of 7.4 V battery step down to 5 V with LT1763-5 linear voltage regulator.

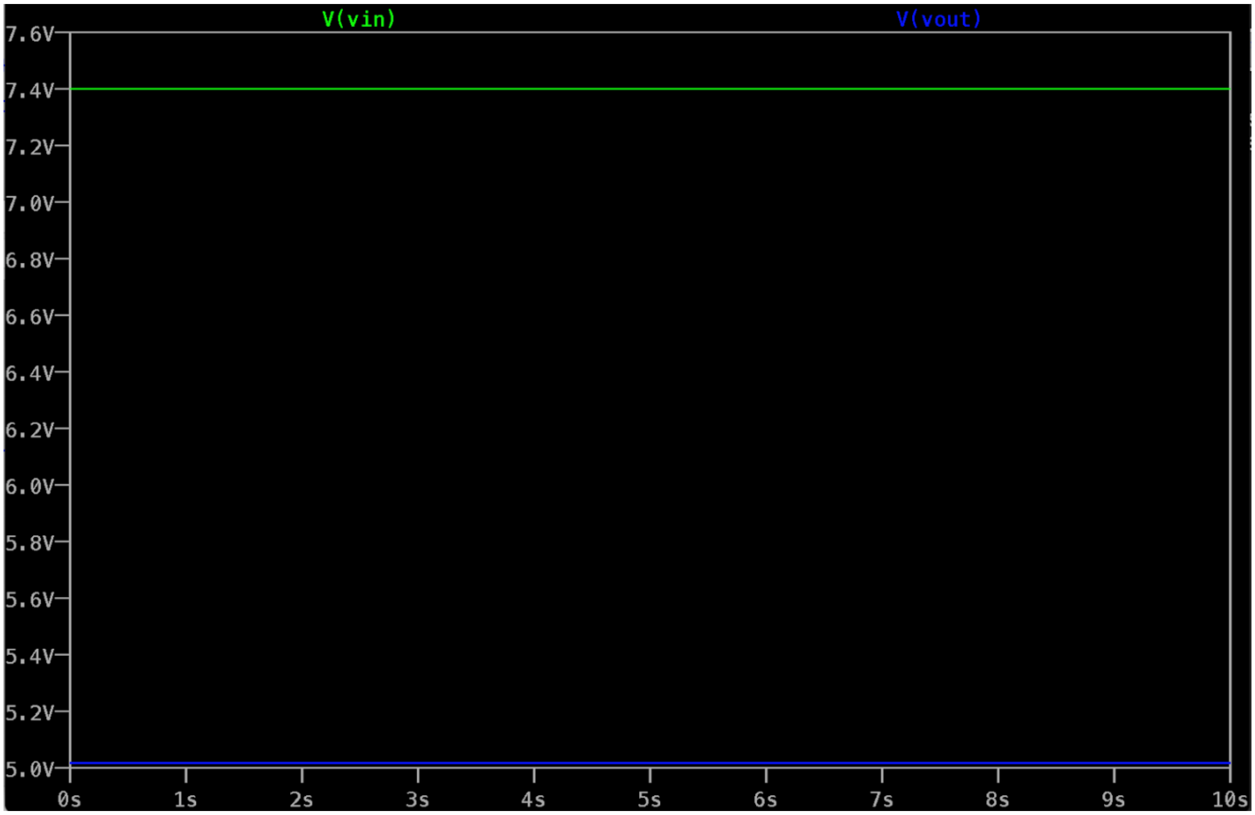

Figure 12: x-axis is time transpired (s) and y axis is voltage level (V). V(vin) (green - top) is the supply of 7.4 V, V(vout) (blue - bottom) is the voltage level after going through LT1763-5, stepping the supply down to 5 V (referring to schematic in Figure 10)

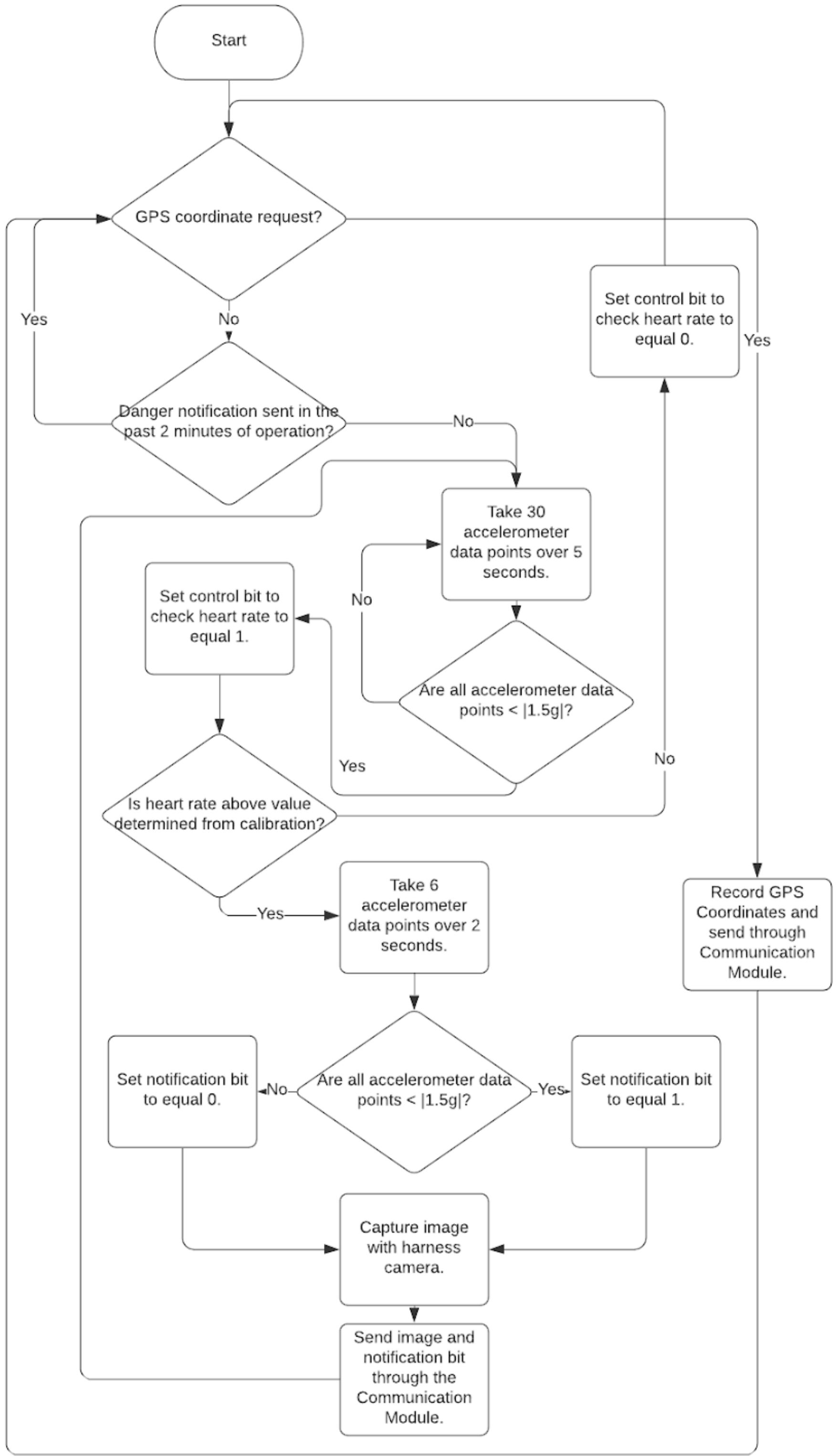

Figure 13 - Integrated software pseudocode flowchart describing how the ESP32 microcontroller processes information to be sent by the Communication Module.

Table 1 - Simplified notification type truth table based on a combination of different signals.

Accelerometer Reading- (before heart rate is captured)	Heart Rate Captured-	Accelerometer Reading- (3 seconds after heart rate reading)	Camera - is a picture taken?	Notification Type-
Reading < $\lvert 1.5 g \rvert$ (still or small movements)	"Normal"	Not measured	No	No notification sent. Heart rate monitor indicates the pet is safe.
Reading < $\lvert 1.5 g \rvert$ (still or small movements)	"Elevated"	Reading > or = $\lvert 1.5 g \rvert$ (a lot of movement)	Yes	"Your pet has an elevated heart rate and is moving." (Notification type 0)
Reading < $\lvert 1.5 g \rvert$ (still or small movements)	"Elevated"	Reading < or = $\lvert 1.5 g \rvert$ (still or small movements)	Yes	"Your pet has an elevated heart rate and is not moving." (Notification type 1)
Reading > or = $\lvert 1.5 g \rvert$ (a lot of movement)	Not measured	Not measured	No	No notification sent. No accurate heart rate captured.

Appendix B

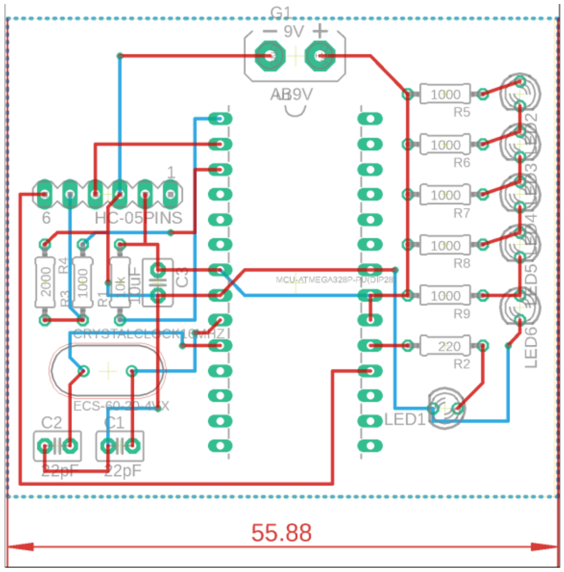

Figure 14 - PCB design of electronic key for first project.

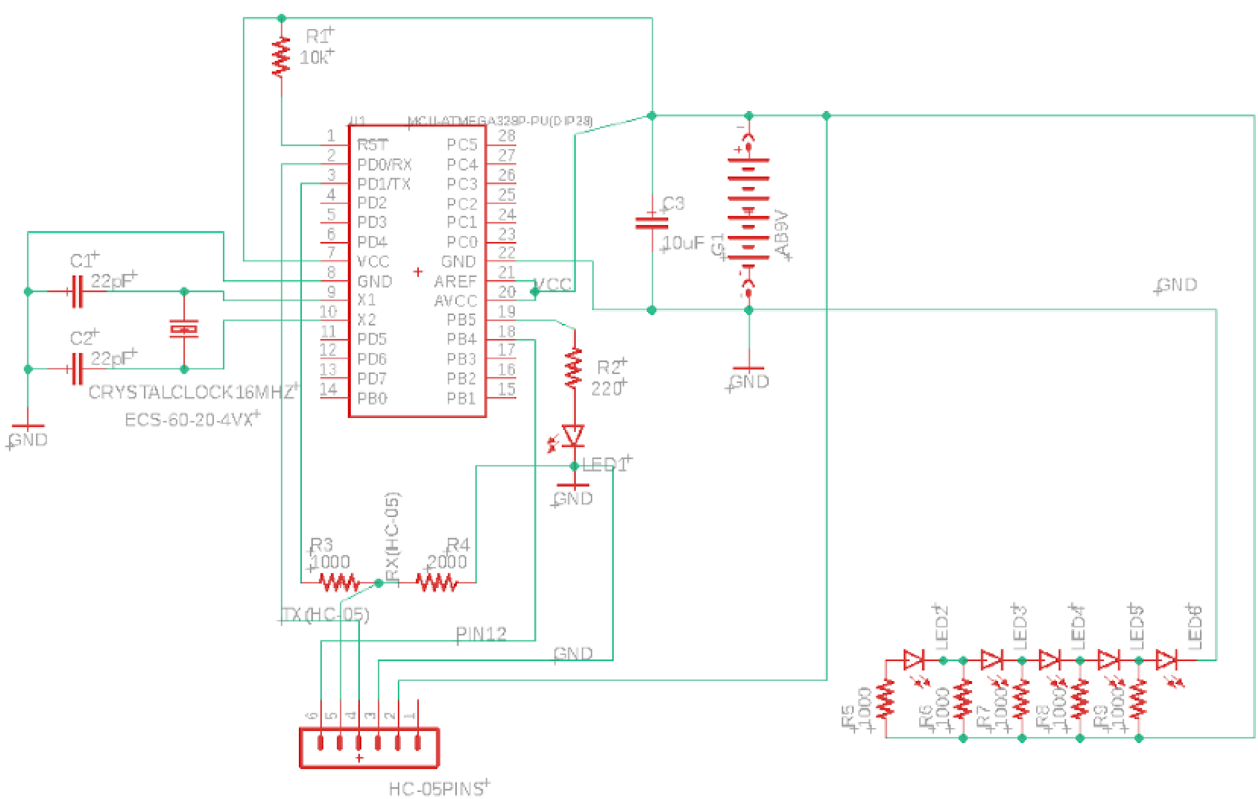

Figure 15 - Schematic of electronic key for first project.

Table 3: Requirements and verification for the Mechanical Locking Module in regards to the key enclosure of the first project.

Requirements	Verification
MLM-1: The key enclosure’s size shall be small enough to fit into a pocket or purse and shall be considered a priority in its design.	A. The project box chosen shall be smaller than 6 in X 4 in X 2 in. B. The project box will be put into the user’s pocket during testing and demonstration to prove hands free operation.

Table 4 - High level requirements of the first project.

Requirement	Description
HLR-1	The security system shall unlock and lock without the user needing to pick up, hold or manually operate the key device in their hands.
HLR-2	The security system shall unlock when the key is located within a distance of ten feet while directly in front of the locking unit.
HLR-3	The security system shall not be unlocked unintentionally by a passing user behind the locking unit within a distance of two feet.