

ECE Senior Capstone Project

# GPS Dog Tracker

ECE Project Document  
ECE 44x

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# 1 Overview

## 1.1 Executive Summary

The GPS dog tracker is a 3"x4" device that is attached to a backpack/harness. The tracker box is equipped with a GPS module that will acquire the GPS location of the tracker every 2 minutes and store this in a data log for examination by the user when the tracker is charging. The GPS module will be used to obtain the current date and time as well as the longitude and latitude. The tracker uses a micro-controller to encode the date, time, location using the Automatic position reporting system (APRS) protocol. This encoded message will be transmitted over radio-frequency (RF) on 144.39Mhz under a FCC granted amateur radio license. The owner will use a receiver module to decode the RF transmission from the tracker unit. The user will be able to display the GPS coordinates on their mobile device to display the trackers location relative to their location. The tracker unit must transmit for at least 8 hour and have a transmit range of at least 1 mile. The goal is for this GPS Dog Tracker to be a possible alternative to commercial GPS do collar's that use cellular networks and require a yearly subscription for their services.

### 1.1.1 Problem Statement

We are living in a the world where every day, even every moment, pets get lost. Pets have a special meaning to us, they are like friends and family to us. This GPS collar allows users to remotely track their pets' geographic location and movement in real time on their cell phones. Whether you are traveling with your dog, or your dog is active, or you are just worried about your dog getting lost, this GPS collar is a great way to prevent your pet from getting lost.

### 1.1.2 Proposed solution

One solution such as designing a GPS collar that connects via Bluetooth and can track the dog's geographic location and movement in real time. The user would be able to know the geographic location and movement of the dog, as well as the battery level of the device, from our mobile application. The user is also able to switch the collar on and off remotely. The collar will update and send the dog's geographic location every few minutes.

## 1.2 Team Protocols and Standards

### 1.2.1 Team Contact information:

Project Point of contact: Declan O'Hara: [oharad@oregonstate.edu](mailto:oharad@oregonstate.edu)

Project Point of Contact: Declan O'Hara <a href="mailto:oharad@oreonstate.edu">oharad@oreonstate.edu</a>		
Team Meber	Project Role	Email
Declan O'Hara	Project Team Lead	<a href="mailto:oharad@oregonstate.edu">oharad@oregonstate.edu</a>
Francisco (Junior) Velasco	Project Co-Lead	<a href="mailto:velascfr@oregonstate.edu">velascfr@oregonstate.edu</a>

Table 1: A table of team's contact information

### 1.2.2 Communication Analysis

- The main method of communication will be a private Discord server containing all members of the group.
- A secondary method of contact will be through email.
- All group members have no restrictions on when they are available for contacting.

### 1.2.3 Roles and Expected Contributions

- Declan O'Hara: Project Team Lead & Project Partner. Responsible for overall goal and objectives planning for the team and timeline management. Also responsible for primary requirements and definition of the GPS Dog Collar. Declan will also develop and test the microcontroller and transmitter on the collar itself.
- Francisco (Junior) Velasco: Project Co-Lead. Responsible for supporting objectives planning and timeline management. Also responsible for development and testing of the GPS module. Junior will also be responsible for the USB-UART block and will also develop the system's PCB.

All group members contained herein are responsible for the timeliness of the development of their blocks and meeting deadline requirements placed by the project partner.

<i>Protocol</i>	<i>Standard</i>	<i>Team Signatures</i>
Full participation during weekly meeting (reflect on the previous week's progress for each member and questions)	Team members should agree and find times to meet at least once a week, for at least an hour.	Declan O'Hara Junior Velasco
Sharing Ideas during a meeting or via a message	Team members should encourage others to voice their ideas regarding an aspect of the project.	Declan O'Hara Junior Velasco
Setbacks Occurring regarding team progress	Team members should not be afraid to admit setbacks or troubles when dealing with their own blocks or parts of the project.	Declan O'Hara Junior Velasco
Team Communication in a group setting and interpersonal experiences	Team members should not be afraid to communicate on anything. Team members should spend at least one hour a week communicating about the project's development in order to ensure that every member understands the project plan. If someone does not understand, the team should reconsider continuing further and should focus on making sure the individual is up to speed.	Declan O'Hara Junior Velasco
Code (commenting, structure, readability)	Members should comment their code well enough for another member to understand. (Does not have to be every line, but maybe each section or function headers).	Declan O'Hara Junior Velasco
Member availability and communication etiquette for tardiness and absence.	Members should communicate at least 24 hours before if they cannot meet a commitment (meeting/lecture/etc).	Declan O'Hara Junior Velasco
Respectfulness and Inclusion in all settings (group or interpersonal)	Members will all be treated with respect when communicating and in-general and will always be included in all tasks in order to be a better team.	Declan O'Hara Junior Velasco
Discord Communication	Members will strive to check the discord server at least once a day. When a meeting is scheduled, members will either react to a message or respond to ensure acknowledgement.	Declan O'Hara Junior Velasco
Punctuality	Members should comply with their agreements to submit their work on-time and will communicate if that deadline cannot be met. It would be best to have work done before the deadline.	Declan O'Hara Junior Velasco
Task Management	Members will regularly check the team Trello board to see what needs to be done at least 3 times a week. All work will be uploaded to the team Google Drive.	Declan O'Hara Junior Velasco
Personal Matters and Outstanding Circumstances	A team member should notify the team of anything personal that might affect progress. Identifying these issues quickly can help the team develop good solutions to solve the matter at hand. Other group members should be considerate of that group member and give help or advice.	Declan O'Hara Junior Velasco
Team Environment and Conflict	A team member should not be afraid to address any issues they feel are not being dealt with, such as work loads, work quality, or even the work environment itself. If a group member feels that the current workload or difficulty is too high, they can ask for help from other group members.	Declan O'Hara Junior Velasco

Table 2: Team standards

## **1.3 Gap Analysis**

### **1.3.1 Motivation behind development**

The GPS dog collar project was proposed to fill a market hole to provide free instant tracking tracking of the users pet. There are commercially available GPS dog collars that use cellular networks to send GPS data to user. Our GPS dog collar will transmit the pet's GPS coordinates over radio frequency to provide real time tracking capabilities for the user without monthly fees. Our GPS Collar will be able to fill the whole the the market for local free live pet tracking to help locating them when they have run away from home.

## **1.4 Assumptions made**

Our team is assuming that the end user has a pet that is running away from home and has no current electronic GPS tracker. We are also assuming that the owner is frugal and does not want to pay a monthly fee for the service.

## **1.5 Market Research**

### **1.5.1 Surveyed Potential Client 1**

We surveyed a potential client that has a dog that digs out of their fenced yard and runs away. They reported to us that they are too frugal to purchase a commercial GPS dog collar and have been looking for a free alternative. Our GPS dog collar would be an excellent choice to meet this customers need to track and locate their runaway pet.

### **1.5.2 The importance of GPS dog collars to prevent dogs from being lost**

According to statistics, one third of all pets will be lost during their lifetime, and approximately 10 million pets are lost each year. That's why it's essential to purchase a GPS collar. No matter how well your dog is trained, lost accidents can still happen, and if your dog usually likes to run around, a GPS collar is even more important. If you just take your dog out for a trip, it's also easy to get lost when the dog is separated from its acquaintances in an unfamiliar area. Walking in the snow can also cause a dog to get lost, even if it is on a road that is normally very familiar. If your dog has impaired hearing due to age or other reasons, a GPS collar can also play an important role in preventing your dog from getting lost [1].

## **1.6 Who is the end user?**

Our end user is a pet owner who's pet runs away and wants a method of easily locating the pet with the aid of GPS coordinates.

## 1.7 Timeline/Proposed Timeline

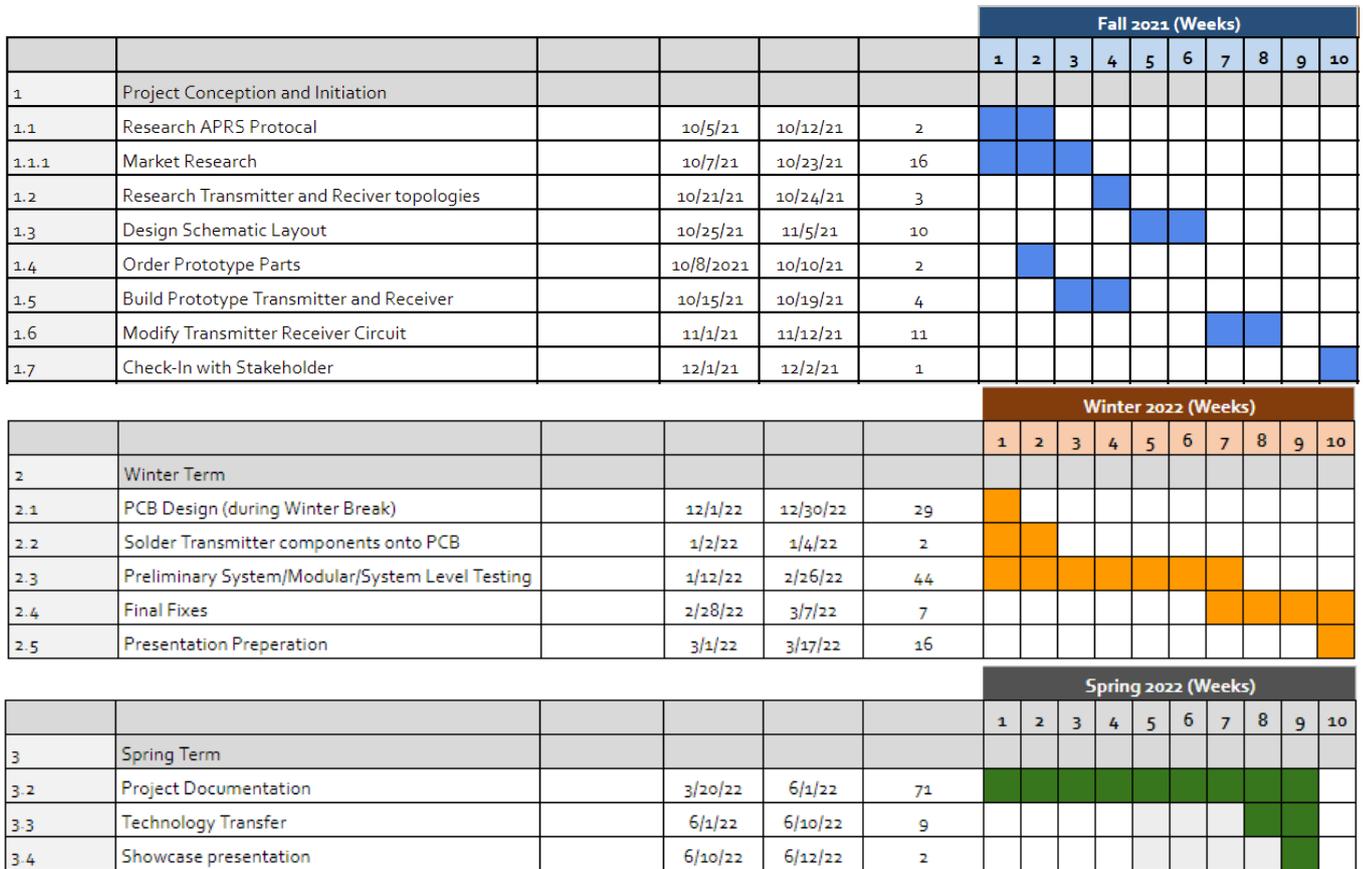


Figure 1: The proposed timeline for the project.

## 1.8 References and File Links

“Setting team standards,” Google. [Online]. Available: <https://tinyurl.com/7dtjpx3> [Accessed:22-Oct-2021]

[1] P. Permenter and J. Bigley, “Should I buy a GPS dog collar?,” DogTipper. [Online]. Available: <https://www.dogtipper.com/tip/2019/10/gps-dog-collar.html> . [Accessed: 03-Dec-2021].

## 1.9 Revision Table

Date	Responsible Member	Revision Made
01/12/2022	Declan O’Hara	Removed ex-team member’s names and small amount of content they added.
11/10/2021	Junior Velasco	Revised Timeline.
11/10/2021	Junior Velasco	Added in table captions and revised small section of executive summary.
11/06/2021	Declan O’Hara	Added in team contact information table
11/06/2021	Declan O’Hara	Rewrote executive summary.
10/28/2021	Junior Velasco	Fixed timeline image.
10/21/2021	Declan O’Hara	Fixed spacing problems with team standards table.
10/21/2021	Junior Velasco	Added Timeline and team protocols table.
10/21/2021	Declan O’Hara	Added Gap Analysis.
10/21/2021	Declan O’Hara	Added Executive summary.
10/12/2021	Junior Velasco	Created Initial document.

Table 3: The revision table for section 1.

## 2 Requirements, Impacts and Risks

### 2.1 Requirements

#### 2.1.1 Transmitter to send GPS data over radio-frequency

**PPR:** The tracker must use RF in Amateur Radio Bands.

**ER:** The system will detect pet location data within +/- 150 feet.

1. User will power on tracker unit
2. User will turn on Kenwood TH-72D handheld radio to receive data packets
3. User will wait for GPS fix on both the tracker and the handheld radio and the tracker unit then continue
4. User will compare TH72D's position to the position coordinates of the dog tracker unit location. The TH72D will auto calculate the distance between the handheld radio and the tracker.
5. Verify that the dog trackers GPS coordinates are within +/- 150 feet.

#### 2.1.2 Display satellite fix

**PPR:** Indicate satellite fix status to user.

**ER:** The system will indicate when satellite fix has been obtained.

**Verification:**

1. User will turn on system.
2. User will insure that a power light is on.
3. User will monitor the satellite fix status LED.
4. User will verify that the satellite fix status changes to "ON" (blinking once every 15 seconds is in the "ON" state) and the LED is ignited.

#### 2.1.3 Monitor Battery Level

**PPR:** The device's battery level must be displayed to the user.

**ER:** The system will notify users of low power (below 10%).

**Verification:**

1. User will tun on the system and wait until the system begins to transmit data packets.
2. User will monitor the battery level from the mobile device receiving the data packets.

#### 2.1.4 Frequency of Updating Location

**PPR:** The location of the pet will be transmitted at a set interval.

**ER:** The system will transmit the pet's location data at a minimum of every 5 minutes

**Verification:**

1. User will power on the tracker unit.
2. User will connect to tracker unit with Bluetooth device.
3. User will change interval time from within the bluetooth app and verify that the interval LEDS on the tracker unit change to their respective indication.

### 2.1.5 Tracker Run Time

**PPR:** The dog's location must be transmitted for 8 hours

**ER:** The system will operate normally for at least 8 hours on one full charge.

**Verification:**

1. User will charge battery until full.
2. User will measure full battery voltage.
3. User will plug in battery to dog tracker unit.
4. User will power on dog tracker unit.
5. User will run tracker for 20 minutes.
6. User will measure voltage level of battery after the 20 minutes of run time.
7. User will take the full voltage and subtract voltage after 20 minutes of running to calculate how much power was used in 20 minutes
8. Multiply the above result by 24 to get 8 hour run time estimate for power usage
9. Verify that the battery has 5% battery capacity above 8 hour estimated run consumption

### 2.1.6 Display GPS data on mobile device

**PPR:** The display of data must be data that can be put into a Map viewer like Google Maps.

**ER:** The system will display data in a way that is easy to interpret for 9/10 users.

**Verification:** 9/10 users take a survey after interacting with the app and say it is understandable.

1. User will power on tracker unit
2. User will turn on Kenwood TH-72D handheld radio to receive data packets
3. User will wait for GPS fix on both the tracker and the handheld radio and the tracker unit then continue
4. User will review GPS coordinates of tracker on TH-72D
5. User will monitor distance and bearing to tracker unit on TH-72D

### 2.1.7 Weatherproof design with a rugged enclosure that protects the device from environmental damage

**PPR:** The inner circuitry of the board is fully enclosed and there are no exposed connections

**ER:** The system will (rated IP22) withstand water splashing against the enclosure from any direction shall have no harmful effect. It must also withstand an ingress of dust (some dust entering the system is not prevented) and must still operate normally.

**Verification:**

1. User will verify that the tracker unit is inside an enclosure.

### 2.1.8 Range of tracker transmitter

**PPR:** Must be able to locate dog at least one mile away from owner

**ER:** The system operate normally with a range of at least 1 mile.

**Verification:**

1. User will power on dog tracer unit and place outside
2. User will take receiver unit at minimum one mile away
3. User will verify that they are receiving dog trackers location over RF and displayed on the mobile device at a distance of at least one mile.

## 2.2 Design Impact Statement

### 2.2.1 Public Health, Safety and Welfare Impacts

Depending on the frequencies used, it is possible for negative health impacts to be a result of being exposed to said frequencies. According to a study from the ICNIRP (International Commission for Non-Ionizing Radiation Protection), the “heating of cells and tissues from RF exposure might have benign or adverse biologic effects” [1]. It may be possible that the severity of the frequencies can have very negative effects on people. The possible effects are something that can affect someone with underlying health conditions. Exposure to RF can be something that can be detrimental, depending on the circumstance. However, it is very rare for someone to be exposed to strong enough frequencies for it to be unsafe. This is due to the fact that there is no conclusive evidence that RF has dramatic effects on people, as it is very rare and difficult to come to a final diagnosis. Referring to the study above, the “results of these studies to date give no consistent or convincing evidence of a causal relation between RF exposure and any adverse health effect” [1]. Addressing this risk is of high importance as it is clear that there is some ambiguity with the effects of exposure. The first step to avoid health hazards is to ensure that the frequencies being used are safe and proven to be adequate for daily use. Although there is no set frequency for the project, there will be sufficient research to what frequencies will be used in order to ensure that it is safe and effective in sending the location of the pet.

There is a concern that the system requires an adequate battery that can last a considerable amount of time, while still operating as expected. The battery has substantial effects on the performance of the device and the quality of data that is produced. When using a GPS Module, the “data quality issues related to the accuracy of the receiver unit, and quantity depended on data storage capacity within the span of battery life” [2]. In a GPS system, the battery is the most important part of the system as the quality and quantity of data is what determines the accuracy of the location of the pet. If there is poor battery life, there is a risk in lowering the quality of data and performance of the system and that can ultimately lead to a more difficult time in finding the pet.

In order to mitigate the effects of the battery life, the implication of this process includes a considerable amount of research that will ensure that the battery that is supplying the necessary power for normal operation. This process will require the battery to be sufficient in power, but also must be a reasonable size to implement into the system. There will be discussions and research done in order to find the best possible solution for the best performance, while not sacrificing the overall size of the battery as it will need to be comfortably affixed to a pet for a long period of time.

### 2.2.2 Cultural and Social Impacts

As any product is perceived by the public and intended crowd, there can be a stigma around GPS collars based on assumptions or the performance of competing products. Seeing another product not perform as expected can tarnish how someone perceives the capabilities of a GPS collar. Therefore, the general performance of a GPS collar can have a negative social impact as audience perception is something that has the potential to reduce the number of people who are interested in buying a product. On average, the “error of uncorrected data from Global Positioning System (GPS) collars range from 45.5 to 65.5 m “ [3]. The accuracy of the location being used will have profound effects on the ability to physically find a pet. Even the smallest amount of error can be the difference between losing the pet and easily detecting the most accurate location. If the performance is as expected and the location is accurate, the social perception of the product can be widely accepted or the opposite can be true if the error in data is too high and leads to inconsistent performance. In order to mitigate the severity of the error in data, there will need to be an awareness of where this GPS module is being used and plan accordingly. If it is known that the product will be used in forest-dense areas, a higher quality GPS Module is one way to help lessen the error and performance. In the end, the general reception from the intended crowd resides in the accuracy of the data.

In regards to cultural impacts, the collar can give insight to how animals behave and gives more insight into what the different culture there is between types of animals (specifically dogs). In a study that was conducted with GPS dog collars with free-ranging and more domesticated dogs to see how they interact. After the study was conducted, it was found “that the dog-owner bond indeed influences roaming behavior in dogs. This highlights the necessity of wildlife management strategies considering the cultural context” [4]. Understanding the culture with different types of dogs was found to be drastically different, all with data that was collected using a GPS dog collar. The impact that this type of project can have is profound as the data that is collected from the device is something that can be interpreted, portrayed and analyzed in a specialized and meaningful way, like understanding how it can help better understand the social and cultural practices of animals.

### 2.2.3 Environmental Impacts

When working with GPS signals, the working environment where the signals are being transmitted can have a profound effect on the performance of a GPS tracking device. More specifically, working in Oregon is something that will make someone consider the fact that this is a state full of natural flora and fauna, which can lead to the skewing of the data being collected. In a study that was conducted to better understand the performance of a GPS collar in a forest environment, it was found that “the obstruction of GPS signals by trees is a problem. The problem was greatest when the trees were tall and GPS performance decreased as tree height increased” [5]. The success of the GPS functionality relies upon an open environment (not very tree dense) and the overall performance of the GPS module can greatly vary depending on the working environment. Therefore, in order to be transparent with the intended audience, it will be prefaced that the impacts of the working environment can affect the performance of the collar as it is something that is still affecting the success of GPS. The design implications of this mainly affect the priority of the components being used in the implementation. Besides the battery, the GPS module is the component that would likely need to be prioritized to ensure that natural impact like the working environment has less impacts on the operation of the system.

However, there are actions that can be taken in order to help lessen the error of a GPS module in order to avoid possible negative outcomes. The first thing that has already been discussed is finding a GPS module that is able to work well with the main microcontroller for the system (ESP 32) and has proven to have success in some implementations. Knowing and understanding the capabilities of the GPS Module is something that requires significant research on different models and variants of the module and finding the one that is known to have the most consistent and efficient performance in order to help the quality of the data. With an increased quality in the data, the overall system performance can help the social and cultural perspective of the need for a GPS collar.

Not only may RF be a possible health hazard for humans, but it also has the potential of having profound change on the earth’s environment and function. In a recent study, researchers have found that “Radio Frequency exposure may particularly alter the receptor organs to orient in the magnetic field of the earth” [6]. Similar to the possible health risk involved with using radio frequencies, it is largely unknown if there is a true risk involved, however there are some signs pointing to there being true risk. However, the uncertainty that surrounds the effects of using RF is something that is a possible risk that may be something that deters a possible client because they may be concerned about possible environmental damage. Mitigating this possible impact is again using safe frequencies (after doing extensive research on what is considered safe in practice) and ensuring that there is a lower chance of any negative environmental impacts.

### 2.2.4 Economic Factors

A GPS collar can be something that can quickly become quite expensive depending on the application that it is being used in. In most cases, there are commercially available collars that are relatively low-cost and can accommodate the needs of the owner. However, these products are not likely to be as reliable due to the quality of parts being used. The downfall of a GPS collar can be narrowed down to a few common causes, the most common being “collar design, the GPS, VHF and timed-release components, and unforeseen costs in retrieving and refurbishing collars” [7]. The cost of the product is something that will either make or break the success of the product as it will need to be accessible to most people and be competitive with market competition. However, this can be addressed by making tradeoffs, which comes down to the design, the parts being used and overall cost after manufacturing. Although maximum performance is the goal for a design, aspects like “maximum accuracy, storage capacity, and battery life are expensive and lead to a much higher cost” [8]. Using quality components exponentially increases the overall cost of the product. One of the first pieces of information that a possible client looks at is the cost and that can be an immediate turn off if it is high (in comparison to comparable products). On the other hand, finding the least expensive parts can lead to unreliable performance and reliability issues.

Mitigating the overall cost of the product requires a level of compromise where the possible client is being considered in the design. This process requires extensive knowledge of each component being used and understanding the relationship between cost and performance when selecting certain parts. These decisions can be the most difficult part of the design process and a lack of awareness can lead to an unsuccessful outcome. However, an extra level of thought during the design process has the potential to not only make the current design efficient and affordable, but also the mass manufacturing and availability of the product to a broader audience.

### 2.2.5 References

[1] A. Ahlbom, “Epidemiology of Health Effects of Radio Frequency Exposure,” National Institute

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- [8] A. Matthews, "The success of GPS collar deployments on mammals in Australia," CSIRO PUBLISHING, 04-Feb-2013. [Online]. Available:  
<https://www.publish.csiro.au/AM/AM12021>. [Accessed: 02-Dec-2021].

## 2.3 Risks

Risk ID	Risk Description	Risk Category	Risk Probability	Risk Impact
R1	GPS Accuracy	Technical	15%	H
R2	Dog Health	Owner/Dog Safety	5%	H
R3	Loss of Personnel	Team Function	25%	H
R4	Public Health	Owner Safety	5%	H
R5	Effect of temperature on device	Environment Risks	20%	H
R6	Dog collar comfort	external risk	10%	H
R7	Delay of Manufacturing/Shipping	Timeline	25%	H
R8	Shared Information Across Radio	Owner/Dog Safety	10%	M
R9	Collar Falls off Dog	Owner/Dog Safety	25%	M
R10	RF transmission interfering with nearby electronic devices	Public Safety	10%	L
R11	Environmental impact of discarded batteries	Environment problem	20 %	M
R12	Battery dies when pet has run away and owner can not locate lost pet	Dog safety	15%	M

Table 4: A table of the Risk Assessment regarding the project (1/2).

Risk ID	Performance Indicator	Responsible Party	Action Plan
R1	The system can report the correct area of the collar	Junior V.	Improve the accuracy of equipment positioning
R2	System can no longer power on and function	Junior V.	Use a hard enough enclosure.
R3	Delay of Project Development	Junior V.	Be proactive and communicate with all members.
R4	Frequencies are unsafe for User	Junior V.	Understand the risk and use certain frequencies to work at.
R5	Device can work in non-extreme temperature conditions	Wang	Use a material with good heat dissipation as housing
R6	Dog willing to wear the collar	Wang	Find softer and more comfortable materials for the collar
R7	Delay of Project Development	Aaron C.	Picking parts that are not delayed, or ordering ahead.
R8	Receiving data from other devices	Aaron C.	Broadcasting a password that is unique to owner.
R9	Collar breaks and falls easily when dog moves or walks	Aaron C.	Creating a sturdy and sealed case for the collar.
R10	Monitor RF transmission frequency and see if it is in use.	Declan O.	Choose unused frequency
R11	Test exposing a battery to water and monitor the battery for hazards	Declan O.	Verify that enclosure is indeed water proof
R12	What is battery life on the transmitter	Declan O.	Monitor battery usage for 2hrs and extrapolate battery life

Table 5: A table of the Risk Assessment regarding the project (2/2).

## 2.4 References and File Links

No references or file links to display yet.

## 2.5 Revision Table

<b>Date</b>	<b>Responsible Member</b>	<b>Revision Made</b>
5/6/2022	Junior Velasco	Added Design Impact Statement
11/29/2021	Junior Velasco	Revised Engineering Requirements
11/28/2021	Declan O'Hara	Added verification steps to all requirements
11/27/2021	Junior Velasco	Revised Engineering Requirements and Verification
11/12/2021	Declan O'Hara	Added requirements 2.4-2.7
11/12/2021	Junior Velasco	Added Requirements 2.1-2.3
10/28/2021	Junior Velasco	Added requirements R1-R4.
10/28/2021	Declan O'Hara	Added requirements R10,R11,R12.
10/27/2021	Junior Velasco	Created Initial section.

Table 6: The revision table for Section 2.

### 3 Top-Level Architecture

#### 3.1 Block Diagram

##### 3.1.1 Black Box Diagram



Figure 2: Black Box Block Diagram

##### 3.1.2 Block Diagram

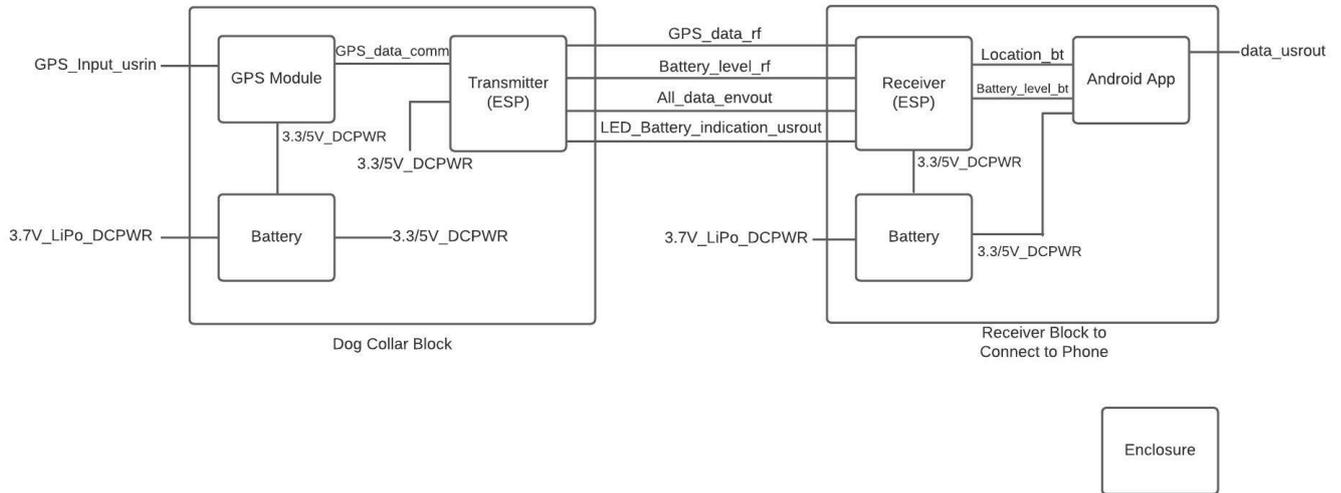


Figure 3: Top-level Block Diagram

### 3.2 Block Descriptions

#### 3.2.1 GPS

The GPS module is one of the most critical blocks of this project as it receives the latitude, longitude as well as the date and time from the GPS satellites. This information will be sent to the micro controller in the transmitter block for packaging and compiling. The location and time data will also be stored locally to keep a hard backup of the trackers position.

#### 3.2.2 Power supply

The power supply will be using a LiPO battery using a MCP73812T-420I/OT: Lithium Ion/Polymer charge controller and a MCP1642B-50I/MC: Fixed 5V output boost converter. The power supply must supply power for 8-12hours. The power supply must charge the LiPO battery and then when not charging the boost converter must be enabled to supply 5v to the transmitter and receiver units.

#### 3.2.3 Transmitter

The transmitter block will use an ESP32-WROOM micro controller acting as the brain of the tracker. The ESP32 will interface with the GPS module to package the latitude, longitude, and the data and time received from the GPS module. The transmitter’s micro controller will send this packaged data out over radio

frequency. The transmitter will have a battery monitoring system to monitor and display the on board battery level.

### **3.2.4 Receiver**

The receiver block will also use an ESP32 microcontroller which will act as the central unit for the receiver and bluetooth adapter. The ESP32 will receive all data from the transmitter, decode and transform the data, and then transmit the data out via the bluetooth adapter to the phone. As stated in the transmitter block description, the data will include a battery monitoring system to display the on board battery level of the collar, the location of the pet, and the timestamp of the last received packet.

### **3.2.5 Android Application**

Since our Arduino board has a Bluetooth module and uses APRS, this Android application will use Bluetooth and APRS to connect and monitor the collar. Also, to improve the accuracy of GPS tracking, this system will improve the interface with the receiver. For now, each leash has a separate identifier or something in case we track down another dog that is also using the collar.

### **3.2.6 Enclosure**

The enclosure is one of the most important parts of the project. It will keep the components inside and protect them from impact forces and weather. The enclosure will be made out of plastic or thin metal.

### 3.3 Interface Definitions

Block Name	Item Name	Property 1	Property 2
Transmitter	ACPWR	$V_{nominal}$	120VAC
Transmitter	COMM	$V_{max}$	5V
Transmitter	ENVOUT	Transmits data over RF	Time, Location and LED Indication.
Transmitter	GPS_data_rf	300mW	APRS protocol
Transmitter	Battery_level_rf	Battery status and health	Remote battery monitoring
Transmitter	LED_Battery_indication_usrout	LED battery level	Red,Green, yellow LEDs

Table 7: The revision table for Section 2.

Block Name	Item Name	Property 1	Property 2
GPS	ACPWR	$V_{nominal}$	120VAC
GPS	DCPWR	$V_{nominal}$	24 V
GPS	USRIN	Location & time data	Received from satellite
GPS	COMM	Data recorded from the input	Sends data to Receiver

Table 8: The revision table for Section 2.

Block Name	Item Name	Property 1	Property 2
Battery	DCPWR	3.7 V LiPo Battery	System Input voltage
Battery	DCPWR	3.3/5V output	Boosted output to micro-controller

Table 9: The revision table for Section 2.

Block Name	Item Name	Property 1	Property 2
Receiver	DCPWR	$V_{nominal}$	5V
Receiver	DCPWR	$V_{max}$	12V
Receiver	ENVOUT	Transmits data over RF	Time, Location and LED Indication.
Receiver	GPS_data_rf	300mW	APRS protocol
Receiver	Battery_level_rf	Battery status and health	Remote battery monitoring
Receiver	LED_Battery_indication_usrout	LED battery level	Red,Green, yellow LEDs
Receiver	Location_bt	Data transmitted over bluetooth	Location and Timestamp of received data.
Receiver	Battery_level_bt	Data transmitted over bluetooth	Battery level of the dog collar.

Table 10: The revision table for Section 2.

### 3.4 References and File Links

#### 3.4.1 References

[1] Espressif Systems, "ESP32-WROOM-32D & ESP32-WROOM-32U Datasheet," ESP32 Datasheet Version 2.2, Nov. 2017 [Revised Aug. 2021].

#### 3.4.2 File Links

No team files or artifacts to display yet.

### 3.5 Revision Table

<b>Date</b>	<b>Responsible Member</b>	<b>Revision Made</b>
11/19/2021	Junior Velasco	Added Battery block descriptions.
11/19/2021	Declan O'Hara	Added GPS and transmitter block descriptions.
11/19/2021	Junior Velasco	Revised Interface table layout.
11/19/2021	Declan O'Hara	Added revision table.

Table 11: The revision table for Section 3.



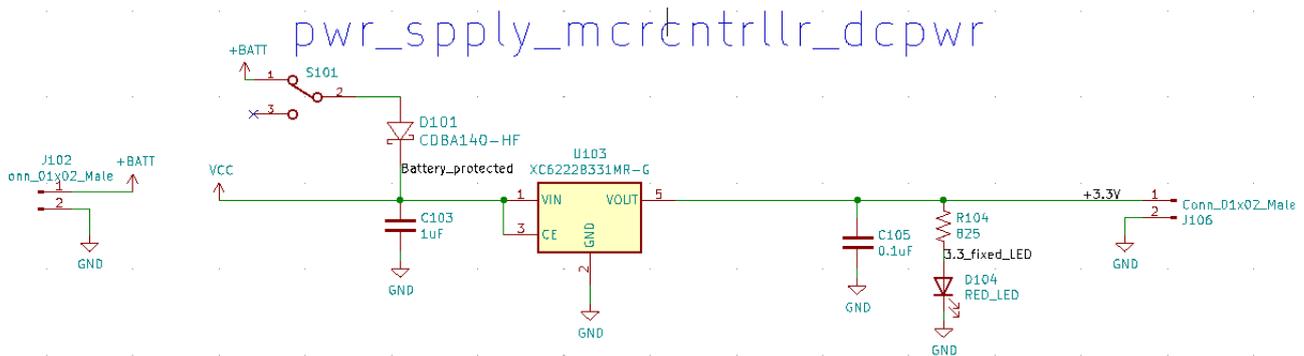


Figure 6: pwr\_sply\_mcrntllr\_dcpwr

## pwr\_sply\_trnsmtr\_hx1\_dcpwr

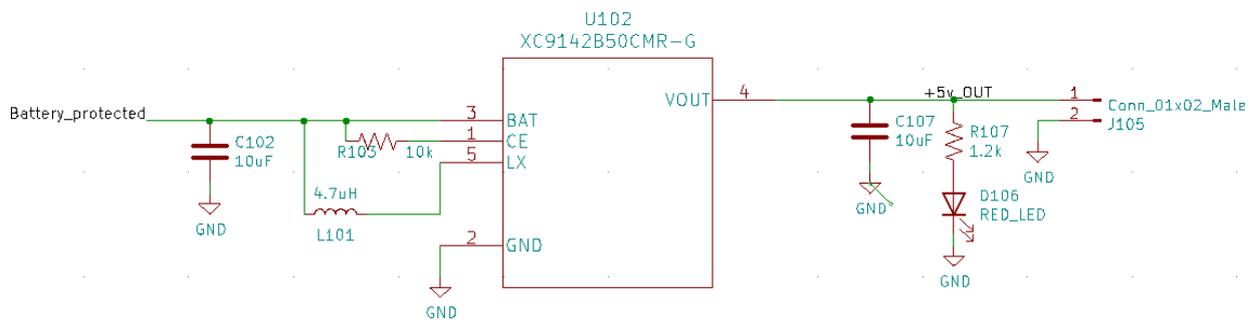


Figure 7: pwr\_sply\_trnsmtr\_hx1\_dcpwr

### 4.1.3 Block General Validation

The power supply block fits the needs and requirements to power all components on the PCB with 5 volts or 3.3 volts. The boost converter producing 5 volts output is rated over 3 times the nominal current draw of the transmitter during transmit. Having a larger margin has no negative impact to the function if the product but potentially the component will cost more. The 3.3 volt low drop out converter has a 500mA rating which will cover the

The USB-to-TTL converter CP2102 has a maximum current draw of 26mA.

In this section describe why your design details fit the needs of the system with respect to what the block is supposed to do. Including reasoning related to concerns like cost, availability of parts, understanding, engineering time, technical performance, interaction with other blocks, size, project partner needs, etc. . . This is the only section that should have paragraphs and look like an essay. Write one sentence about how this design validation might affect the design impact statement from fall term.

#### 4.1.4 Block Interface Validation

Vmax: 5.1v	This is the highest voltage we expect on our USB supply input	This value was pulled from the example 5v usb values given from the course
Vmin: 4.9V	This is the lowest voltage we expect on our USB supply input	This value was pulled from the example 5v usb min voltage given from the course
Inominal: 150mA	This was derived by working back from the current used by the transmitter module during transmit	With an expected peak output current of 200mA Nominal @ 5V (1W) and a worst-case efficiency of 60% (XC9142B50CMR-G, page 7) input current peak at 1W at 3.4V input = 38mA peak. Note this is when the boost converter is in active mode, not powered down.
Ipeak: 800mA	The peak current value was calculated by adding 25% to the current draw.	With an expected peak output current of 200mA+25% Nominal @ 5V (1.25W) and a worst-case efficiency of 60% (XC9142B50CMR-G, page 7) input current peak at 1.25W at 3.4V input = 48mA peak. Note this is when the boost converter is in active mode, not powered down.

Table 12: usbrt\_pwr\_sply\_dcpwr

Vmax:5.10v	This is the highest voltage we expect on our LiPo battery	The boost converter XC914B50CMR-G: Datasheet on page 7, has a max output voltage of 1.03 *Vout. which comes out to be 5.15 volts.
Vmin: 4.85V	This is the lowest voltage we expect on our LiPo battery	The boost converter XC914B50CMR-G: Datasheet on page 7, has a max output voltage of 0.97 *Vout. which comes out to be 4.65 volts.
Inominal: 94mA	This was derived by working back from the current used by the transmitter module during transmit	With an expected peak output current of 200mA Nominal @ 5V (1W) and a worst-case efficiency of 60% (XC9142B50CMR-G, page 7) input current peak at 1.6W at 3.7V input = 432mA peak. Note this is when the boost converter is in active mode, not powered down.
Ipeak: 140mA	The peak current value was calculated by adding 25% to the current draw.	With an expected peak output current of 200mA+25% Nominal @ 5V (1.25W) and a worst-case efficiency of 60% (XC9142B50CMR-G, page 7) input current peak at 1.8W at 3.7V input = 486mA peak. Note this is when the boost converter is in active mode, not powered down.

Table 13: pwr\_sply\_trnsmttr\_hx1\_dcpwr

Vmax: 3.33v	This is the lowest voltage out from the low drop out linear regulator from torex: XC6222B331MR-G <a href="#">Data sheet</a>	Page 4 of the data sheet explains the output voltage tolerance being 1%
Vmin: 3.0V	This is the lowest voltage out from the low drop out linear regulator from torex: XC6222B331MR-G battery	Page 4 of the data sheet explains the output voltage tolerance being 1%
Inominal:50mA	This is calculated by adding the USB-to-TTL IC(CP2102)'s typical current draw of 20mA to the estimated 140mA draw of the ESP32 during Bluetooth transmit and driving an I/O pin	With an expected nominal output current of 160mA Nominal @ 3.3 (66mW) and a efficiency of 90% projects an estimated Inominal of 180mA current draw on the 3.3v rail.
Ipeak: 75mA	The peak current value was calculated by adding 25% of the nominal current draw that is projected to be on the 3.3v rail.	200mA @ 3.3V (66mW) and a worst-case efficiency of 85% is approx 205mA.

Table 14: pwr\_sply\_mrcntrlr\_dcpwr

#### 4.1.5 Block Testing Process

##### Test LiPO Charge Controller

1. Supply 5v DC input power to simulate a USB connector plugged in.
2. Measure the output of the LiPO charge controller to verify 4.2 volts output that will charge the battery
3. Decrease input voltage to below LiPO voltage to test automatic shutdown of LiPO charger.

##### Test 3.3v LDO

1. Make sure only battery is plugged in and USB is unplugged.
2. Test 3.3v output and verify stability of output within 3.0v to 3.6v
3. Unplug battery and plug in 5v input supply to simulate USB power.
4. Test 3.3v output to verify that 3.3 volts is output regardless of being supplied with a USB 5 volts or a LiPO battery's 3.7 volts

##### Test 5.0v Boost converter

1. Make sure only battery is plugged in and USB is unplugged.
2. Test 5v output and verify that 5v +/- 200mV is being supplied.
3. Unplug battery and plug in 5v input supply to simulate USB power.
4. Test the 5v output to verify that 5v volts is output regardless of being supplied with a USB 5 volts or a LiPO battery's 3.7 volts

#### 4.1.6 References and File Links:

##### Datasheets

LiPO Charger IC: [MCP73830T-2AAI<sub>M</sub>YY](#)

pwr\_spplly\_mrcntrllr\_dcpwr: [XC6222B331MR-G](#)

pwr\_spplly\_trnsmtrr\_hx1\_dcpwr: [XC6222B331MR-G](#)

Micro controller datasheet: [Arduino Nano Datasheet](#)

#### 4.1.7 Revision Table

Date	Responsible Member	Revision Made
2/25/2020	Declan O'Hara	
2/15/2020	Declan O'Hara	Added in arduino datasheet and updated block properties due to change in micro controller
2/17/2022	Declan O'Hara	Changed schematic and block diagram images to match most up to date design
1/20/2020	Declan O'Hara	Made modifications given by don regarding schematic names being interface names
1/20/2022	Declan O'Hara	Added figure captions
1/06/2022	Declan O'Hara	Added schematics, testing steps, interface explanations
1/05/2022	Declan O'Hara	Block creation and added first information to each block section

Table 15: The revision table for Declan's Block:Power Supply

## 4.2 Micro-Controller

### 4.2.1 Block Overview

Block Champion: Declan O'Hara

The micro-controller will be the brains of the whole tracker. This block is responsible for taking in the GPS data and compiling a AX.25 APRS packet. The built AX.25 packet will be transmitted using the onboard PWM output pin or DAC. The APRS protocol uses 1200Hz and 2200Hz frequency shift keying to encode the data packet over RF. The micro-controller will also be responsible for monitoring the battery using an onboard ADC, the ESP32 is powered by 3.3v and only accepts 3.3v max on the input pins thus a resistor divider network will be used to limit the input voltage on the I/O pin. The ESP32-WROOM micro-controller will output TTL logic levels and the H1X transmitter by radiometrix requires a 5v logic level and thus the Nexperia USA Inc.: Voltage Level Translator, This will shift the ESP's 3.3-volt logic into 5v level. The ESP32-WROOM also has onboard Wifi and Bluetooth capabilities that can provide wireless access to setup tracker features.

### 4.2.2 Block Design

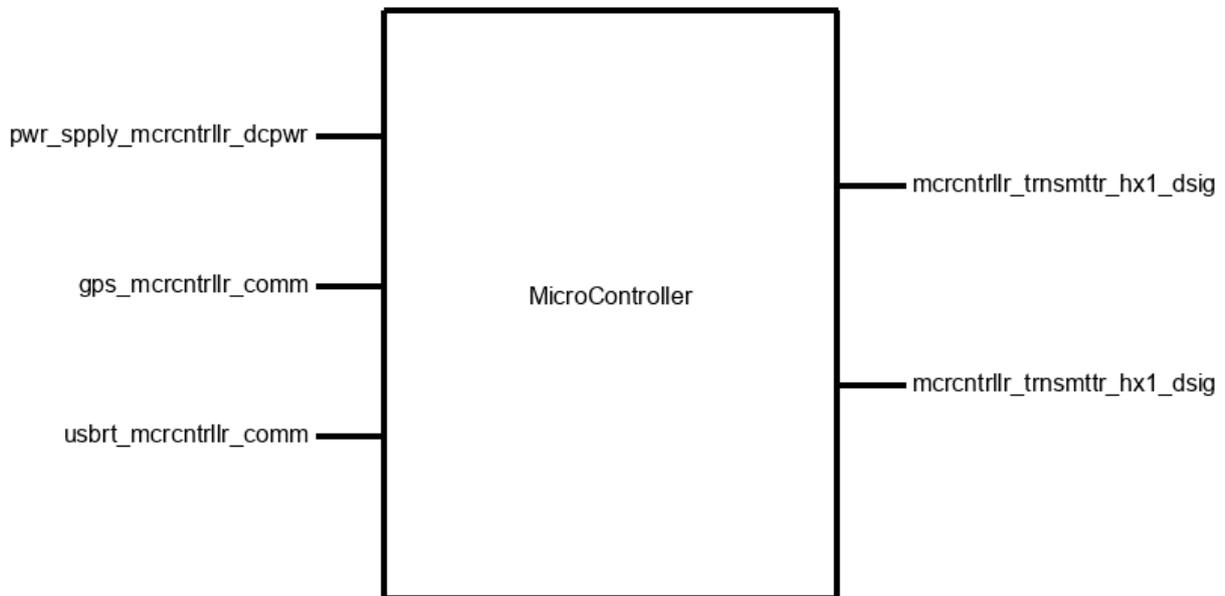


Figure 8: Micro-Controller Overall block diagram

### 4.2.3 Block General Validation

The ESP32-WROOM micro-controller will be compiling the GPS data from Junior's block into a AX.25 APRS packet to be transmitted using a PWM output to create 1200Hz and 2200Hz tones. These two tones are used to encode the AX.25 packet for transmission over 144.390Mhz, 2 meter amateur radio band. The micro controller is the brains of the whole project.

# uController

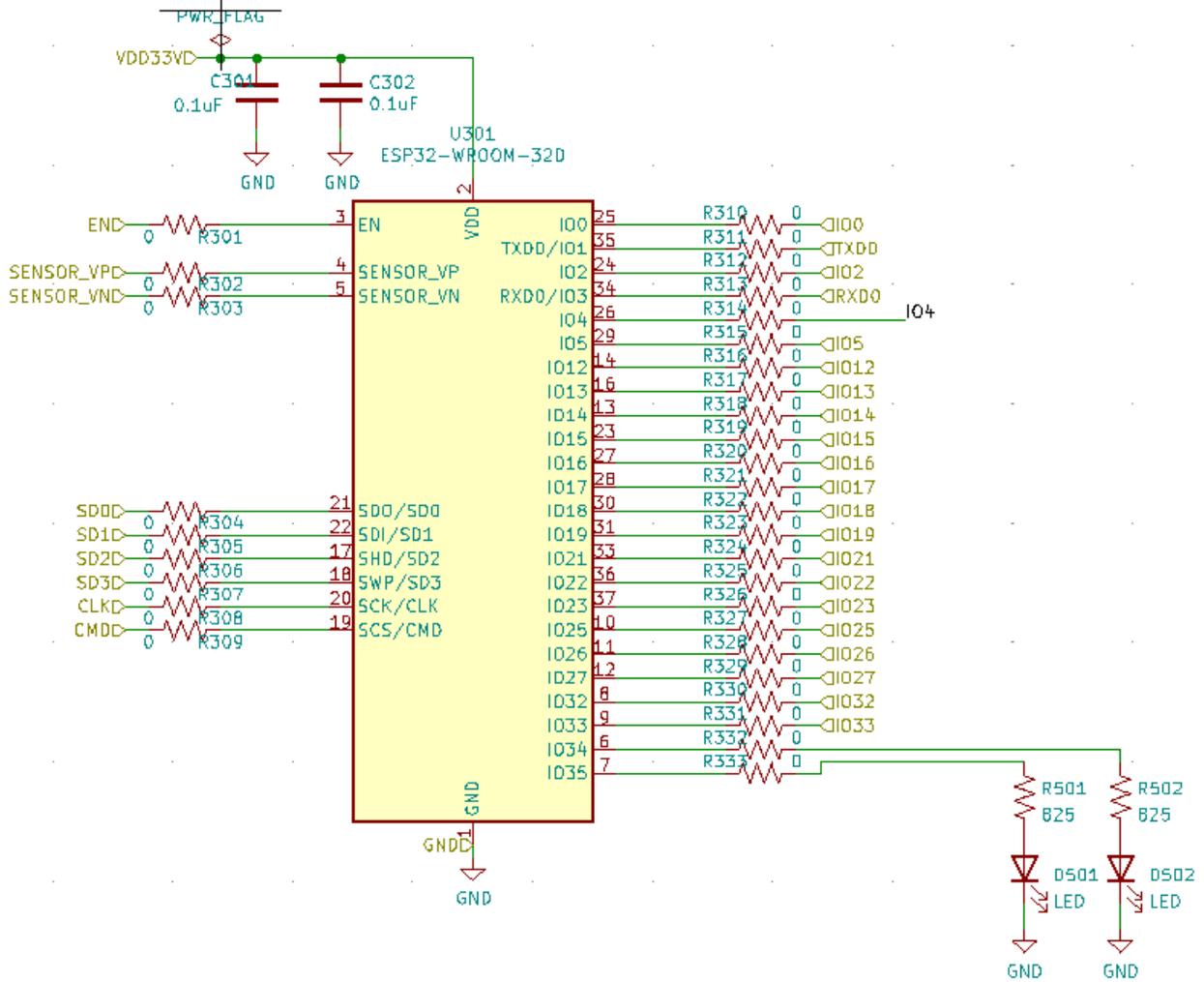


Figure 9: Micro-Controller Schematic

# Transmitter

X401  
H1X\_transmitter

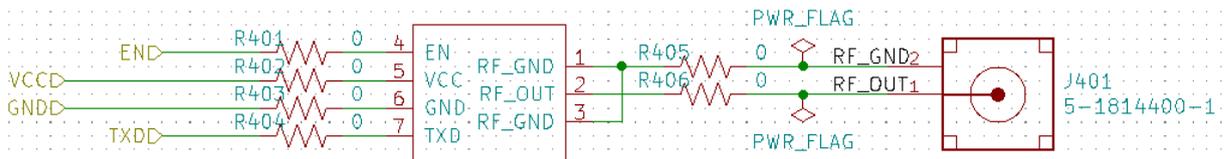


Figure 10: Transmitter Schematic

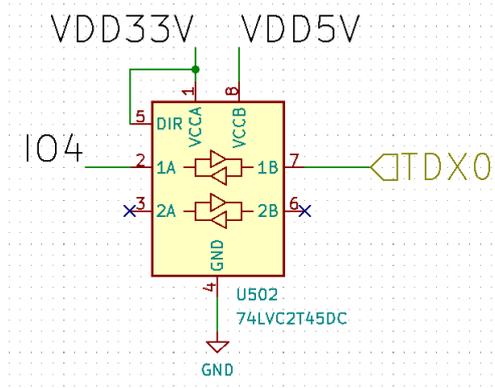


Figure 11: Level Shift Schematic

#### 4.2.4 Block Interface Validation

Vmax:3.31v	The ESP32-WROOM runs on 3.3v for the input voltage.	The 3.3V LDO: XC6222B331MR-G has a max output voltage speced at 3.31v
Vmin:3.29v	The ESP32-WROOM runs on 3.3v for the input voltage.	The 3.3V LDO: XC6222B331MR-G has a min output voltage speced at 3.29v
Vnominal: 3.30	The ESP32-WROOM runs on 3.3v for the input voltage.	The 3.3V LDO: XC6222B331MR-G has a nominal output voltage speced at 3.30v
Inominal: 140mA	The H1X transmitters data sheet shows 140mA typical current draw during transmit	The power supply took a 160mA current draw into consideration when building the power supply. The 5v regulator will supply the transmit power for the transmission.
Ipeak:168mA	The peak current draw is 20% above the nominal peak draw. Because the transmitter is not transmitting constant it will redce the current draw on the system	The power supply calculations planned for 170mA draw to over protect the power system.

Table 16: pwr\_spply\_mrcntrllr\_dcpwr

Logic Level:CMOS	The H1X transmitter datasheet states that the transmitter uses 5v input logic.	The 74LVC2T45DC,125 level shifter will shift the 3.3v output from the micro-controller to be 5v logic and intern enable the H1X transmitter
Vmax:5v	H1X transmitter specs the logic HIGH input voltage at 5v	Because using an ESP32-WROOM which only outputs 3.3v from it's I/O pins, a level shifter will be required.
Vmin:0v	The H1X datasheet lists the input voltage for a logic LOW "0" is typically 0v	The micro controller will send an enable signal to the H1X transmitter through the level shifter. The level shifter converst 3.3v to 5v logic. Refer to 74LVC2T45DC,125 datasheet and level shifter schematic.

Table 17: micntrllr\_trnsmttr\_hx1\_dsig 1

Vmax:	The H1X transmitter datasheet states that the transmitter uses 5v input logic.	The 74LVC2T45DC,125 level shifter will shift the 3.3v output from the micro-controller to be 5v logic and intern enable the H1X transmitter
Vmin:0v	The H1X datasheet lists the input voltage for a logic LOW "0" is typically 0v	The micro controller will send an enable signal to the H1X transmitter through the level shifter. The level shifter converts 3.3v to 5v logic. Refer to 74LVC2T45DC,125 datasheet and level shifter schematic.
Max Frequency: 2200Hz	This is the max frequency tone that is needed for AX.25 encoding. For APRS it is 1200Hz and 2200Hz	The ESP32 has a PWM that has a configurable frequency output up to 78KHz

Table 18: micrcntrlr\_trnsmtr\_hx1\_dsig 2

Protocol: Data is downloaded via NMEA 0183	This is what the Adafruit Ultimate GPS Breakout Board requires.	The Adafruit GPS Library states that the protocol that this board uses is NMEA 0183, which is what the GPS data looks like in the serial monitor (in the Arduino IDE) as a sentence that begins with \$GPRMC.
Voltage Level: 3.3 V	This is what the Adafruit Ultimate GPS Breakout Board requires for Tx and Rx.	Product Specifications, under the Breakout Serial Data Pins. The typical logic level voltage will be 3.3V.
Data rate:9600:	This is the standard baud rate for programming a microcontroller.	Product Specifications, under the Breakout Serial Data Pins. This is the expected baud rate.

Table 19: gps\_micrcntrlr\_comm

Protocol: logic-level UART Connection	This is what the Adafruit Ultimate GPS Breakout Board requires.	The Adafruit GPS Library states that the protocol that this board uses is NMEA 0183, which is what the GPS data looks like in the serial monitor (in the Arduino IDE) as a sentence that begins with \$GPRMC.
Voltage Level: 3.3V	This is what the Adafruit Ultimate GPS Breakout Board requires for Tx and Rx.	Product Specifications, under the Breakout Serial Data Pins. The typical logic level voltage will be 3.3V.
Data rate:9600:	This is the standard baud rate for programming a microcontroller.	See product Specifications, under the Breakout Serial Data Pins. This is the expected baud rate.

Table 20: usbtr\_micrcntrlr\_comm

#### 4.2.5 Block Testing Process

##### Test micrcntrlr\_trnsmtr\_hx1\_dsig 1

1. Power on ESP32-WROOM development board
2. Program with test code
3. Hook output I/O PWM pin to O-scope and measure Px frequency
4. Verify that 1200Hz output, 0v to 5v logic
5. Hook output I/O PWM pin to O-scope and measure Pxx frequency
6. Verify that 2200Hz output, 0v to 5v logic

##### Test micrcntrlr\_trnsmtr\_hx1\_dsig 2

1. Power on ESP32-WROOM development board
2. Program with test code

3. verify that LED turns on and off.
4. Verify 5v at output.

#### 4.2.6 References and File Links

1. [https://www.espressif.com/sites/default/files/documentation/esp32-wroom-32\\_datasheet\\_en.pdf](https://www.espressif.com/sites/default/files/documentation/esp32-wroom-32_datasheet_en.pdf)
2. <http://www.radiometrix.com/files/additional/hx1.pdf>
3. [https://assets.nexperia.com/documents/data-sheet/74LVC\\_LVCH2T45.pdf](https://assets.nexperia.com/documents/data-sheet/74LVC_LVCH2T45.pdf)
4. <https://learn.adafruit.com/adafruit-ultimate-gps/arduino-wiring>
5. <https://circuitpython.readthedocs.io/projects/gps/en/3.8.0/>

#### 4.2.7 Revision Table

<b>Date</b>	<b>Responsible Member</b>	<b>Revision Made</b>
1/15/2022	Declan O'Hara	Block creation and added first each section for this block

Table 21: The revision table for Declan's Block:Power Supply

## 4.3 USB/UART

### 4.3.1 Block Overview

Block Champion: Junior Velasco

This block will focus on the function of programming the microcontroller (ESP-WROOM-32). The construction of this block will be based on a typical implementation from a CP2102 device datasheet. The design will be adjusted to have USB-C, instead of micro-USB. The implementation for the USB-C is based on a typical schematic implementation for a USB-C Receptacle Breakout Board. The 0 Ohm resistors are placed to provide flexibility during testing that will allow for testing of smaller cases and specific components, without relying on the correct functionality of the entire circuit. The Schottky diode is placed on the VBUS line to avoid any reverse current that may harm the rest of the circuit. The two LEDs are also added with the intent to indicate that the correct voltages are being output from the circuit (3.3V and 5V).

### 4.3.2 Block Design

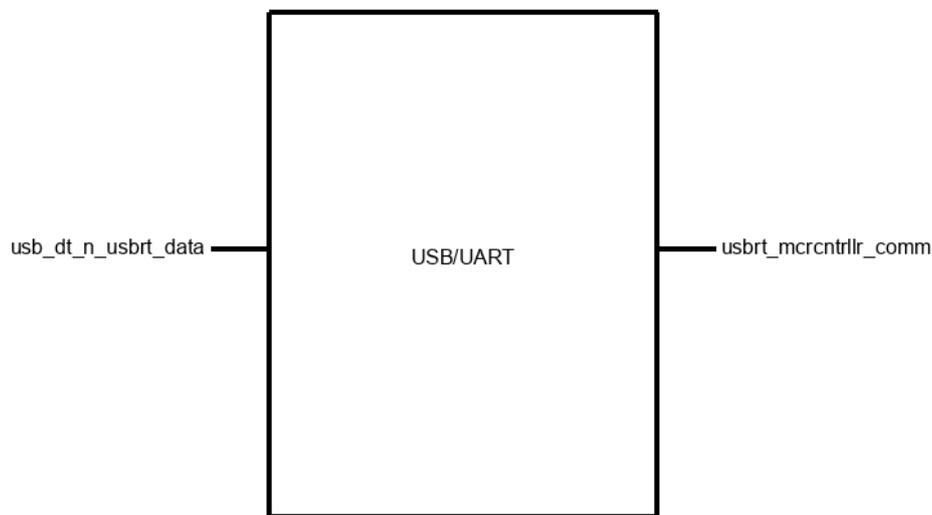


Figure 12: USB/UART block diagram

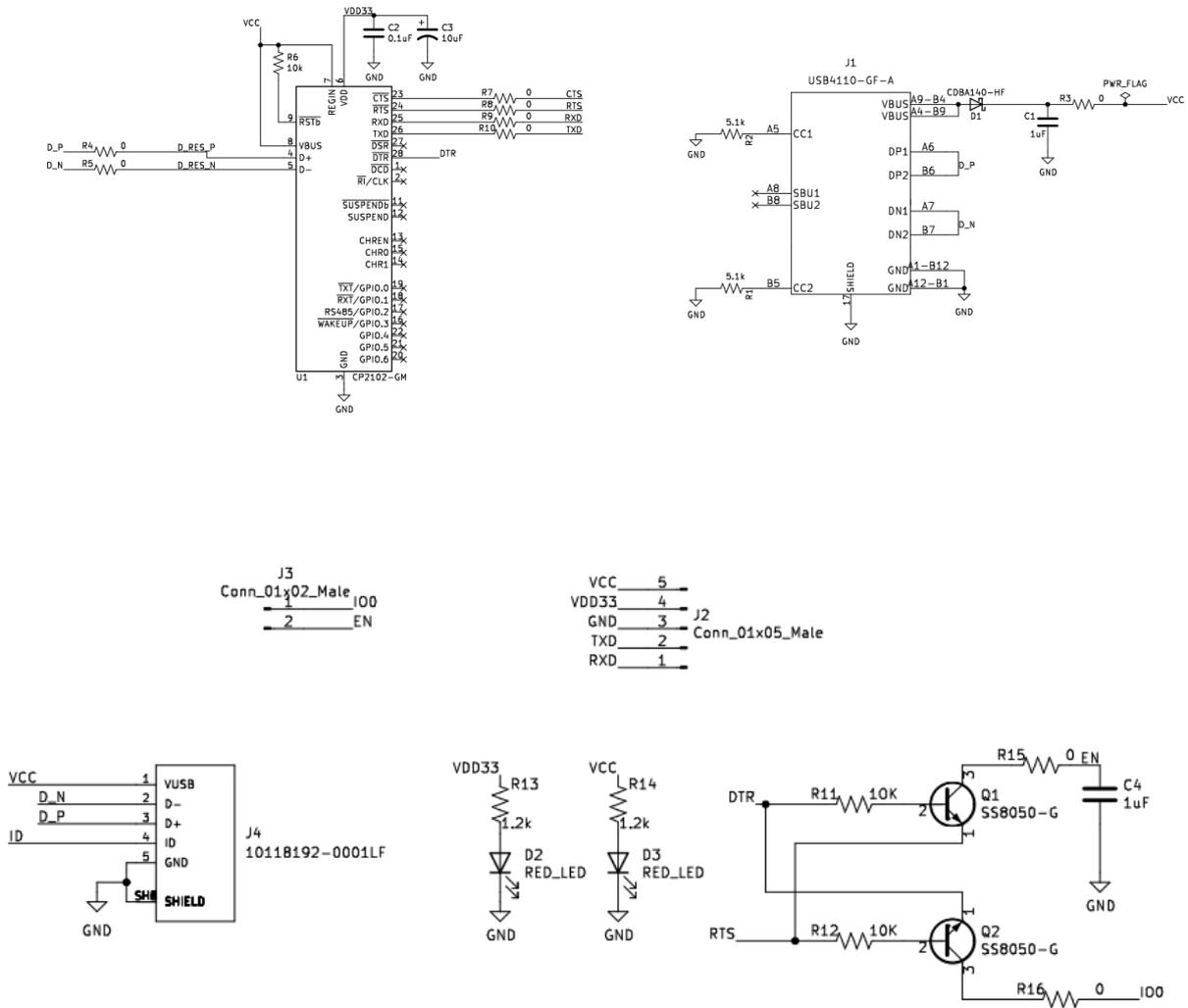


Figure 13: USB/UART block Schematic

### 4.3.3 Block General Validation

Based on the above design, the details were chosen based on the main function of the block. The inclusion of the CP2102 chip is the main chip that will allow for the ESP-WROOM-32 microcontroller to be programmed. Therefore, the function of this block is something that the microcontroller block will be heavily reliant upon in order to program the microcontroller with the intended program. Another detail that was described above is the substitution of USB-C instead of micro-USB. Moving towards USB-C was chosen to help modernize a past design and include a more common cable used today. Some of these parts (USB-C Receptacle, Schottky Diode) were chosen based on a compromise between availability and cost. There were many more options that were more available, however they were typically double the price. Therefore, the decision was made to pursue the path that wasn't as expensive and was still generally available (1000+ components in-stock on Digikey). As for engineering time, this block is something that will open the opportunity to test a smaller part of the entire system that will later be combined into a larger PCB for the entire system. The idea is to test this block thoroughly to ensure that there is less time spent incorporating it into the main PCB later on, as it provides vital functions of the circuit (power, programmability).

#### 4.3.4 Block Interface Validation

Datarate: 9600 baud	This is the standard baud rate for programming a microcontroller.	CP2102 Datasheet, page 10, the baud rate cannot be selected to be 1152000.
Messages: An arbitrary message typed in a PuttY terminal	This is a method to verify that serial data is converted over UART.	Using a feedback loop can prove that the CP2102 chip is sending data as expected.
Other: Powered by USB-C at input.	This is an included receptacle on the PCB.	This will power the board using a different receptacle than other designs.
Other: Code: Blink program will be used to program a Microcontroller.	This is an arbitrary sketch that will send data to a microcontroller.	The data sent from the Tx and Rx lines from the board will be sent to the respective pins on a microcontroller and program it.

Table 22: pwrscopy\_usb-t-ttl\_dcpwr : Input

Messages: The input will be echoed.	Local echo shows that the input from the user is not from local line editing and is from the Tx/Rx lines of the board.	This is what proves that the CP2102 is functioning by repeating the input from the user.
Other: Code: "Blink" Arduino sketch sent from USB/UART Tx/Rx lines program a microcontroller.	This proves that the CP2102 can properly program another chip.	The data sent from the USB/UART will be sent properly to the microcontroller and it will be programmed accordingly.
Protocol: Code/Data is downloaded via a logic-level UART Connection.	This is the main function of the CP2102 chip.	The Tx/Rx lines of USB-UART board are the means of transportation for the data being sent via UART.

Table 23: pwrscopy\_usb-t-ttl\_dcpwr : Input

#### 4.3.5 Block Testing Process

##### Test Tx and Rx (usb\_dt\_n\_usbprt\_data and usbprt\_mrcntrllr\_comm)

1. Connect the PCB board to power through USB-C and check if the LED for VDD is ON when the chip is connected to USB-C.
2. Create a feedback Loop by connecting a Jumper cable between Tx and Rx on the USB/UART board.
3. Open Putty and use the Serial Testing Feature and use the correct COM Port as according to the Device Manager.
4. Ensure that Local Echo is turned on under "Serial" Setting.
5. Open Terminal within Putty and type an Arbitrary message.
6. The message should be "echoed" by every letter being repeated twice (i.e. only an "l" is entered, but an "ll" appears in the terminal).
7. Connect the Tx/Rx outputs of the CP2102 in opposite order to an Arduino's Tx/Rx inputs.
8. Use Serial program that programs the Arduino to Blink an LED.
9. Check that the LED is blinking as according to the Arduino Sketch.

### 4.3.6 References and File Links

1. <https://www.cmd-ltd.com/advice-centre/usb-chargers-and-power-modules/usb-and-power-module-product-help/usb-charger-faqs/>
2. <https://www.silabs.com/documents/public/data-sheets/CP2102-9.pdf>
3. <https://www.sparkfun.com/products/15100>
4. [https://docs.ai-thinker.com/\\_media/esp32/docs/nodemcu-32s\\_\\_product\\_\\_specification.pdf](https://docs.ai-thinker.com/_media/esp32/docs/nodemcu-32s__product__specification.pdf)
5. [https://www.espressif.com/sites/default/files/documentation/esp32-wroom-32\\_\\_datasheet\\_\\_en.pdf](https://www.espressif.com/sites/default/files/documentation/esp32-wroom-32__datasheet__en.pdf)

### 4.3.7 Revision Table

Date	Responsible Member	Revision Made
3/5/2022	Declan O'Hara	Reordered revision table to match format of most recent revision at the top of table
2/18/2022	Junior Velasco	Updated Schematic Notes.
2/17/2022	Junior Velasco	Updated Interface Properties and Schematic.
2/17/2022	Junior Velasco	Updated Block Image.
1/7/2022	Junior Velasco	Updated References and the Interface Validation.
1/6/2022	Junior Velasco	Wrote the Verification Plan
1/5/2022	Junior Velasco	Filled out General and Interface Validation.
1/4/2022	Junior Velasco	Included Black Box Diagram and Schematic.
1/5/2022	Junior Velasco	Updated References and Description.
1/4/2022	Junior Velasco	Created initial document

Table 24: The revision table for Junior's Block:GPS

## 4.4 GPS

### 4.4.1 Block Overview

Block Champion: Junior Velasco

This block will focus on the function of the GPS Module in the system. The makeup of this block consists of an Adafruit Ultimate GPS Breakout Board. The outputs of the breakout board will be sent to a microcontroller of choice and will be programmed accordingly. The construction of this block will be based on a typical implementation of a GPS Breakout Board module and will use a pre-manufactured board to test functionality of the GPS module. The design will have no adjustments from the reference design and it will be used as the design was intended. There is an on-board voltage regulator that outputs 3.3V (from the 3.3V pin), if 5V are applied to the VIN pin. This aspect of the design may be used in other blocks of the system, as some components require 3.3V for an input voltage for power. The two LEDs that are on the board indicate whether the board is on and if a fix has been acquired. Each of these LEDs will both demonstrate its functionality during testing (further discussed in Section 5 below).

### 4.4.2 Block Design

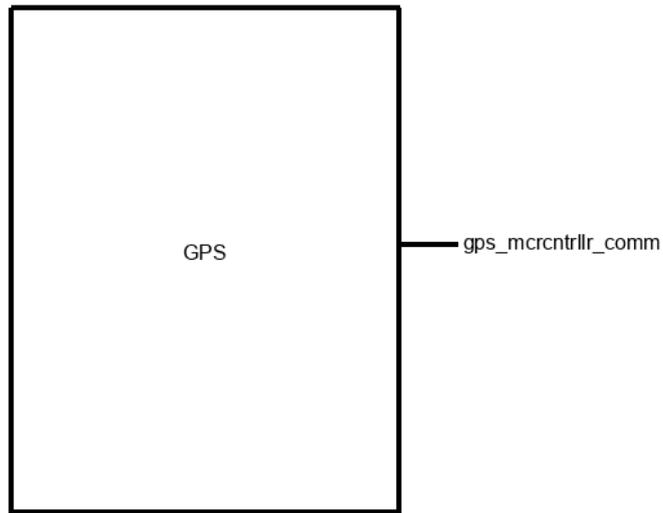


Figure 14: GPS block diagram

Vin: pwr\_spply\_gps\_dcpwr

Tx/Rx: gps\_mrcntrlr\_comm

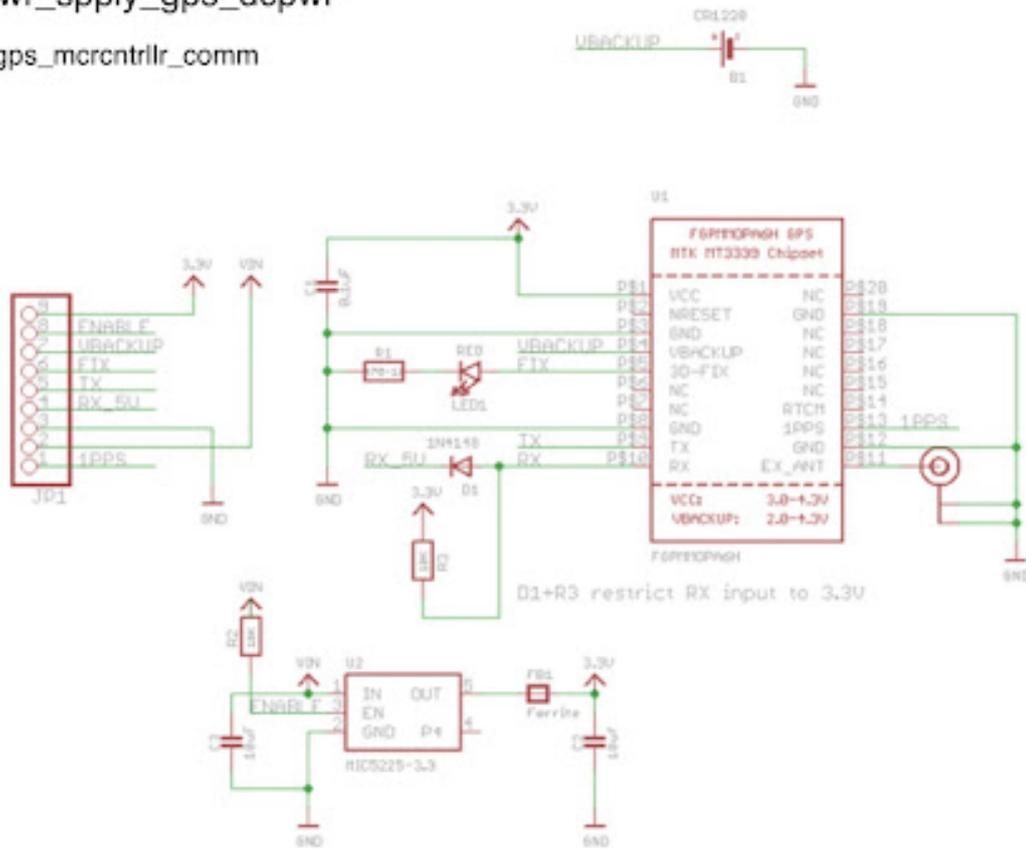


Figure 15: GPS block Schematic

#### 4.4.3 Block General Validation

Based on the above design, the breakout board was chosen based on the main function of the block. The inclusion of the MTK3329 chip is the main chip that will allow for GPS functionality. GPS is one of the most vital features of the entire system and the functionality of this board will determine the location of the tracker. This breakout board will be used in conjunction with a microcontroller (Arduino will be used for testing purposes). This will be programmed using a “blank program” that will allow the GPS data to be directly connected to the USB/Serial Chip converter on an Arduino to get the raw NMEA sentence data in

terms of \$GPRMC, as outlined in the Product Overview. Another detail that was briefly described above is the on-board voltage regulator can be something that can be used as an interface, if needed. This aspect of the system is not vital to performance of the MTK3329 chip, however it is another feature that provides flexibility within the system as there are other components that require 3.3V for power and this may be a source of voltage. The whole board was acquired with the intent to find a GPS breakout board that would both work with a microcontroller (Arduino/ESP-32) and also still be at an affordable price. There were many more options that were more available, however other versions of editions of the board from different manufacturers cost either double the price or more. Therefore, the decision was made to pursue the path that was most beneficial to the system, while still not overspending on a component with similar functionality. As for engineering time, this block is something that saves a considerable amount of time as it already arrives fully manufactured. The idea is to test this block thoroughly to ensure that there is less time spent incorporating it into the main PCB later on, as it provides vital functions of the circuit (GPS coordinates and output power if needed).

#### 4.4.4 Block Interface Validation

Vmax = 5V	This is the highest voltage we expect the board to operate under.	Vin can range anywhere from 3 V to 5 V (referring to the specification from the Product Overview, however we are going to apply the maximum of 5V to ensure that the board still functions (powers on/programs).
Vmin = 3V	This is the lowest voltage we expect the board to operate under.	The minimum voltage of the system is 3 V (according to the Product Overview), we expect to apply 3.3V to this in the system implementation, therefore the minimum will be tested and should work as expected (powers on/programs).
Inomial = 20mA	This is the current draw that we expect from the breakout board.	The Product Overview of the GPS Module states that there is only a 20 mA current draw.

Table 25: pwrsply\_usb-t-ttl\_dcpwr : Input

Protocol: NMEA 0183	This is what the Adafruit Ultimate GPS Breakout Board requires.	The Adafruit GPS Library states that the protocol that this board uses is NMEA 0183, which is what the GPS data looks like in the serial monitor (in the Arduino IDE) as a sentence that begins with \$GPRMC.
Voltage Level: 3.3 V	This is what the Adafruit Ultimate GPS Breakout Board requires for Tx and Rx.	Product Specifications, under the Breakout Serial Data Pins. The typical logic level voltage will be 3.3V.
Baud Rate: 9600	This is the current draw that we expect from the breakout board.	The power supply took a 160mA current draw into consideration when building the power supply. The Product Overview of the GPS Module states that there is only a 20 mA current draw.

Table 26: gps\_mrcntrllr\_comm : Output

#### 4.4.5 Block Testing Process

##### Test Input Power and Wired Communication (pwrsply\_usb-t-ttl\_dcpwr and gps\_mrcntrllr\_comm)

1. Apply a varying power supply to the Vin of the GPS breakout board.
2. Apply a voltage of 3V and verify that the power indicator LED is on.
3. Apply a varying load and set to 20 mA to ensure that the proper current is being drawn from the block.
4. Connect the Tx/Rx outputs from the GPS breakout board into the inputs of Tx/Rx on an Arduino.
5. Change the Baud Rate in the Arduino IDE to 9600.
6. Run a test program to ensure that the module gets a fix and the proper coordinates are output to the Serial Monitor of the Arduino IDE.
7. Repeat steps 3-6 by increasing or decreasing the voltage by 1V and ensuring that the outcomes of 4V/5V are as expected (GPS Module has LED indicator ON, and the correct coordinates are output to Serial Monitor with a 9600 baud rate after a fix has been found).

#### 4.4.6 References and File Links

1. <https://learn.adafruit.com/adafruit-ultimate-gps/downloads>.
2. <https://learn.adafruit.com/adafruit-ultimate-gps>.
3. <https://circuitpython.readthedocs.io/projects/gps/en/3.8.0/>

#### 4.4.7 Revision Table

Date	Responsible Member	Revision Made
3/5/2022	Declan O'Hara	Reordered revision table to have most recent revision at the top
1/21/2022	Junior Velasco	Revised the Verification Plan and fixed typo.
1/21/2022	Junior Velasco	Updated Interface Validation.
1/21/2022	Junior Velasco	Updated verbiage in General Validation.
1/19/2022	Junior Velasco	Updated References and the Interface Validation.
1/19/2022	Junior Velasco	Filled out General and Interface Validation.
1/19/2022	Junior Velasco	Included Black Box Diagram and Schematic.
1/19/2022	Junior Velasco	Updated References and Description.
1/19/2022	Junior Velasco	Created initial document
1/19/2022	Junior Velasco	Wrote the Verification Plan

Table 27: The revision table for Junior's Block:GPS

## 5 System Verification Evidence

### 5.1 Universal Constraints

#### 5.1.1 The system may not include a breadboard

The system will not include a breadboard during either of the System Verification Checkoffs. We have a prototyping board that has our two custom PCB's solder down with the rest of the project components.

#### 5.1.2 The final system must contain both of the following: a student designed PCB and a custom Android/PC/Cloud application

The final system will contain a student designed PCB that will hold all components. Due to component failure and assembly problems we have gone back to using version 1 of the design which uses two custom PCBs mounted to protoboard for the final checkoff.

The custom Android application's function is used for a requirement that will be demonstrated during spring 2022 system verification

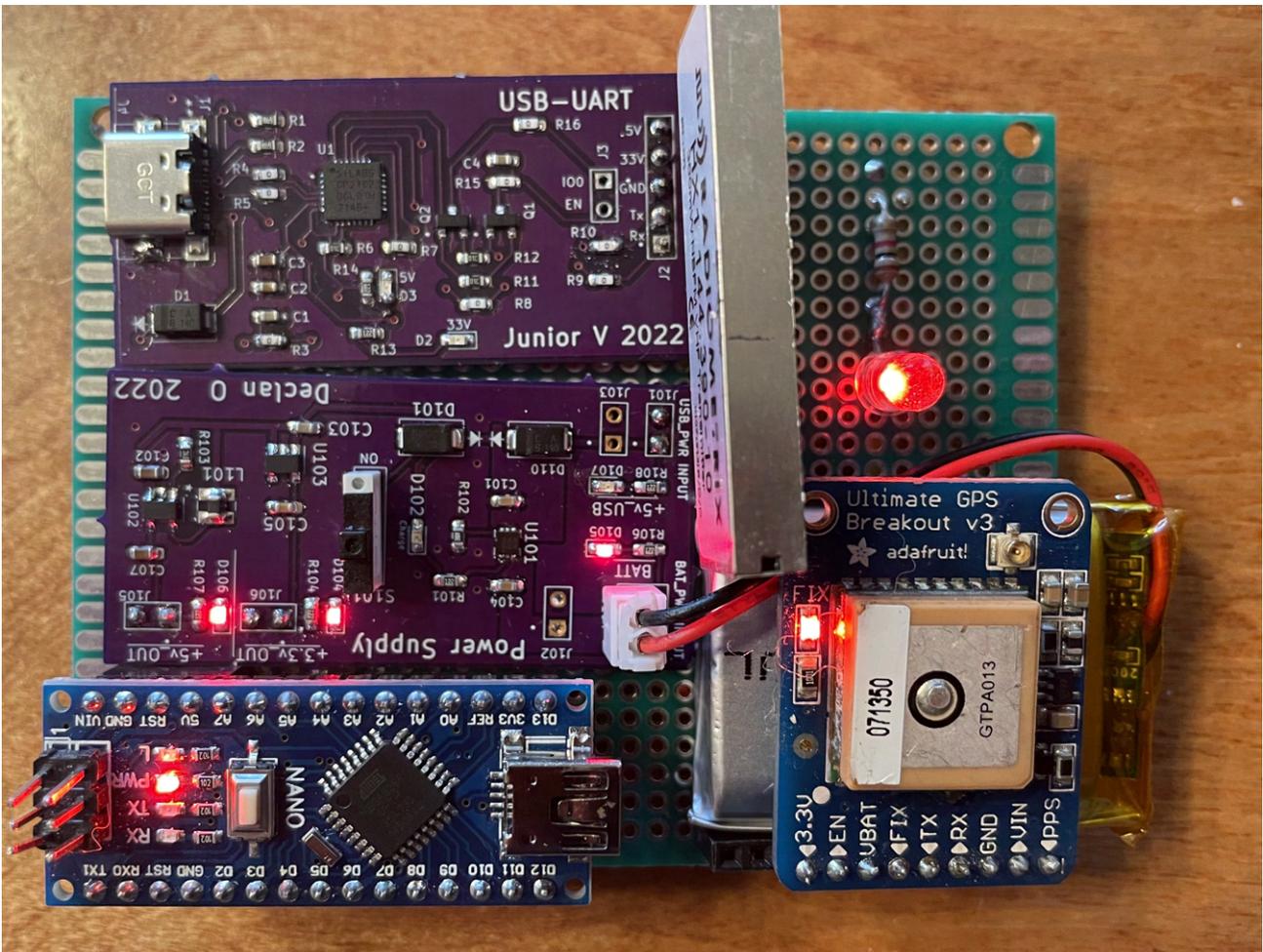


Figure 16: The completed PCB, with the custom PCBs

#### 5.1.3 If an enclosure is present, the contents must be ruggedly enclosed/mounted as evaluated by the course instructor

Our project has a 3-D printed enclosure that holds all the projects circuitry.

#### 5.1.4 If present, all wire connections to PCBs and going through an enclosure (entering or leaving) must use connectors

Our system has no wires leaving the enclosure and therefore this constraint is not impacting our project.

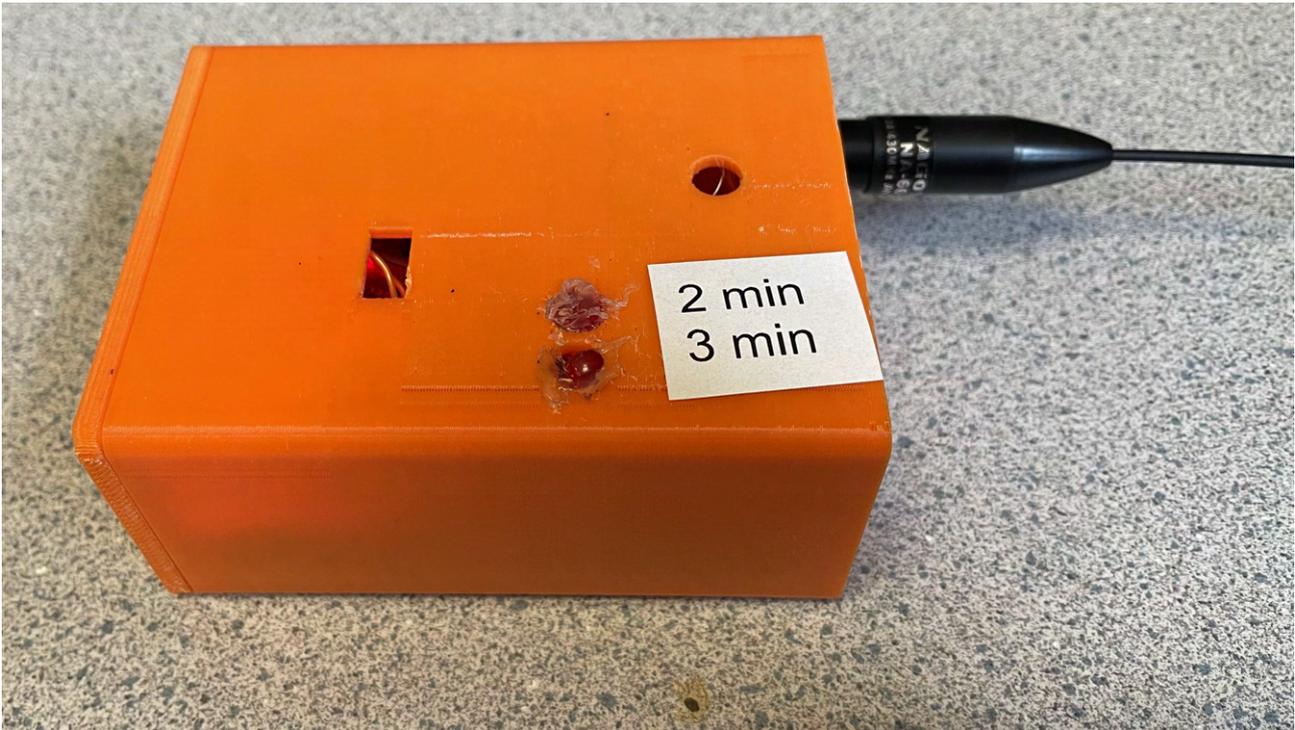


Figure 17: Enclosure of System

#### 5.1.5 All power supplies in the system must be at least 65% efficient

The power supply used in the `pwr_sply_trnsmttr_hx1_dcpwr` has a 86 to 80% efficiency rating according to their [XC9142B50CMR-G Datasheet](#) on page 7. The power supply used in `pwr_sply_mrcntrllr_dcpwr` circuit the XC6222B331MR-G 3.3 linear voltage regulator has a 95% efficiency according to the [XC6222B331MR-G Datasheet](#)

#### 5.1.6 The system may be no more than 50% built from purchased modules

The system will not include over 50% pre-built purchased modules during System Verification. Our system has 3 out of 5 blocks custom built, the GPS and Transmitter are pre-purchased modules.

### 5.2 Transmitter to send GPS data over radio-frequency

#### 5.2.1 Requirement

The system will detect pet location data within +/- 150 feet.

#### 5.2.2 Testing Processes

1. User will power on tracker unit
2. User will turn on Kenwood TH-72D handheld radio to receive data packets
3. User will wait for GPS fix on both the tracker and the handheld radio and the tracker unit then continue
4. User will compare TH72D's position to the position coordinates of the dog tracker unit location. The TH72D will auto calculate the distance between the handheld radio and the tracker.
5. Verify that the dog trackers GPS coordinates are within +/- 150 feet.

#### 5.2.3 Testing Evidence

[Testing Evidence Video](#)

## **5.3 Display satellite fix**

### **5.3.1 Requirement**

The system will indicate when satellite fix has been obtained.

### **5.3.2 Testing Processes**

1. User will turn on system.
2. User will insure that a power light is on.
3. User will monitor the satellite fix status LED.
4. User will verify that the satellite fix status changes to "ON" (blinking once every 15 seconds is in the "ON" state) and the LED is ignited.

### **5.3.3 Testing Evidence**

[Testing Evidence Video](#)

## **5.4 Monitor Battery Level**

### **5.4.1 Requirement**

The system will allow the user to monitor the battery level

### **5.4.2 Testing Processes**

1. User will tun on the system and wait until the system begins to transmit data packets.
2. User will monitor the battery level from the mobile device receiving the data packets.

### **5.4.3 Testing Evidence**

[Testing Evidence Video for requirement 5.4](#)

## **5.5 Frequency of Updating Location**

### **5.5.1 Requirement**

The system will transmit the pet's location at a set interval.

### **5.5.2 Testing Processes**

1. User will power on the tracker unit.
2. User will connect to tracker unit with Bluetooth device.
3. User will change interval time from within the bluetooth app and verify that the interval LEDS on the tracker unit change to their respective indication.

### **5.5.3 Testing Evidence**

[Testing evidence for requirement 5.5](#)

## **5.6 Tracker Run Time**

### **5.6.1 Requirement**

The system must able to transmit the pet's location data for 8 hours

### **5.6.2 Testing Processes**

1. User will charge battery until full.
2. User will measure full battery voltage.
3. User will plug in battery to dog tracker unit.
4. User will power on dog tracker unit.
5. User will run tracker for 20 minutes.
6. User will measure voltage level of battery after the 20 minutes of run time.
7. User will take the full voltage and subtract voltage after 20 minutes of running to calculate how much power was used in 20 minutes
8. Multiply the above result by 24 to get 8 hour run time estimate for power usage
9. Verify that the battery has 5% battery capacity above 8 hour estimated run consumption

### **5.6.3 Testing Evidence**

[Testing evidence for requirement 5.6](#)

## **5.7 Display GPS data on mobile device**

### **5.7.1 Requirement**

The system will display GPS data on a mobile device.

### **5.7.2 Testing Processes**

1. User will power on tracker unit
2. User will turn on Kenwood TH-72D handheld radio to receive data packets
3. User will wait for GPS fix on both the tracker and the handheld radio and the tracker unit then continue
4. User will review GPS coordinates of tracker on TH-72D
5. User will monitor distance and bearing to tracker unit on TH-72D

### **5.7.3 Testing Evidence**

[Testing evidence for requirement 5.7](#)

## **5.8 Rugged enclosure that protects the device from environmental damage**

### **5.8.1 Requirement**

The system must have an enclosure.

### **5.8.2 Testing Processes**

1. User will verify that the tracker unit is inside an enclosure.

### **5.8.3 Testing Evidence**

[Testing evidence for requirement 5.9](#)

## **5.9 Range of tracker transmitter**

### **5.9.1 Requirement**

The system must have a transmit range of at least 1 mile.

### 5.9.2 Testing Processes

1. User will power on dog tracer unit and place outside
2. User will take receiver unit at minimum one mile away
3. User will verify that they are receiving dog trackers location over RF and displayed on the mobile device at a distance of at least one mile.

### 5.9.3 Testing Evidence

[Testing evidence for requirement 5.9](#)

### 5.10 References and File Links

1. <https://www.torexsemi.com/file/xc9141/XC9141-XC9142.pdf>
2. <https://media.digikey.com/pdf/Data%20Sheets/Torex/XC6222.pdf>

### 5.11 Revision Table

Date	Responsible Member	Revision Made
5/4/2022	Declan O'Hara	Updated Section 5 with minor touches
4/22/2022	Declan O'Hara	Updated Section 5.4 through 5.9 with details for system verification 2.
3/5/2022	Junior Velasco	Updated Section 5.3 to match the requirement in Section 2.
3/2/2022	Junior Velasco	Updated Universal Constraint section
3/2/2022	Declan O'Hara	Added Universal Constraint section outline
3/2/2022	Declan O'Hara	Created outline for section 5 of project document

Table 28: Section 5 revision table

## 6 Project Closing

### 6.1 Future Recommendations

#### 6.1.1 Technical Recommendations

Our first technical recommendation is trying to source a microcontroller IC to fit on the Printed Circuit Board instead of using an entire development board. Our group chose to use an entire Arduino Nano development board on our final PCB, due to the chip shortage during our project. If it is possible, using an IC like the ATmega 168p, the ATmega 328p, ESP-32 or any older chip that has similar functionalities is something that our group recommends doing in the future. Using a standalone IC is recommended because it can save a considerable amount of space on the Printed Circuit Board itself and that can lead to a more affordable manufactured board. Our team recommends reaching out the instructors and asking if they have leftover microcontroller ICs from the Fall Term Tech Demo. If neither of those suggestions work, it is also possible to remove the ATmega 168p or ATmega 328p directly off of an Arduino development board with a heat gun carefully and then placing that IC onto the PCB. According to an article from Bain, "removing nonessential features underpinned by unavailable chips, minimizing product customization, qualifying parts from multiple suppliers, or creating new products that rely on available chips" [1] is an approach that can combat the chip shortage and also address the design changes as mentioned previously.

The next recommendation is to expand the project to use LORA capabilities to transmit the GPS data through RF. The LORA protocol is something that some companies use in industry and getting the experience to work closely with it during a nine-month process can be very beneficial to the group and would be a good thing to mention during an interview or on a resume. One of the reasons that our group recommends using LORA is for the range-capabilities as it was designed to transmit data within a mile of the system (using the Ax.25 protocol) and with LORA, it is possible to greatly extend the usable range that data can be transmitted from. Due to the specifications and design of the Dog Collar to be battery operated, LORA could be very useful as it "permits data transmission over long distances with a low power consumption rate. Unlike other GPS devices, the LoRa GPS enables data transmission at a slower rate over long ranges. This makes the LoRa GPS an ideal tracker for battery-operated applications" [2]. For a project like this, it would be beneficial to make this project more practical in long-distance applications as it would be most useful for the owner to know where their pet is inside a larger radius than 1 mile.

Another recommendation is to use an alternative Transmitter for this project. One of the issues that our group encountered to the end was transmitting the GPS Data of the system. This was an issue towards the end of the project as we thought that the Transmitter was "stuck" in transmit mode which would not allow us to decode the packet that was being sent (which included all of the vital information of the project). With that issue, we thought that we may have needed to replace the transmitter, the only issue was that it costed nearly \$70 and it was also not readily available. Therefore, using the prior recommendation of using LORA above, our team recommends using the LORA E5 module as it is a module that includes the transmitter and is much more affordable (less than \$10 depending on the manufacturer). Attached is the data sheet of the LORA E5 Module for more information, compatibility and specifications [3].

The final recommendation that we have is to have a more weatherproof enclosure. Our current enclosure had holes at the top of the box to include lights that would show the Transmission time lights, the GPS fix light, and also access to the switch that would power the system. This design could be improved by including different LEDs that would be more practical for the design instead of smaller surface mount LEDs and instead have possibly through-hole LEDs that would be covered by a protective shield to protect it from any water damage/environmental damage. Also, instead of using a switch that is mounted to the PCB, we recommend having either an external switch or button that ensures that there are no exposed holes in the enclosure to have better coverage of the main internal system and components. Incorporating a more protective standard like IP64 would be something that this project should have in the future to have better protection of the system for a more practical application of mounting the system onto a harness/collar. In order to provide better coverage, we recommend to review the different IP ratings from Rainford Solutions [4] and choosing a rating of at least IP64 for the system and its enclosure.

#### 6.1.2 Global Impact Recommendations

The first recommendation our team has is that our tracker unit used RF in the amateur radio bands to transmit the location and tracker data to the owner. When we started this project we read multiple research studies that exposed negative effects that RF can do to human bodies and pets. Although our team determined we could mitigate the effects of RF by creating a reflector on the collar to help shield direct RF radiating into the dogs skin never the less it is still an import impact. We recommend looking into using cellular to transmit the data as it is orders of magnitude smaller transmit power. Not only does the reduced

transmit power help protect the animal from the effective radiated power but also helps prolong battery life and shrink the device's overall size. Even though using cellular connection still uses RF its power output is less in situations and the wavelength might be less harmful to humans and animals [5].

The final recommendation is that we acknowledge that there may be some privacy concerns with using amateur radio licensed frequencies. Due to the the non-encrypted communication through amateur radio, it is possible that someone else may get access of the data of the tracker. In order to mitigate this concern, we recommend either using Cellular networks to have more possibilities to encrypt or using different frequencies that are public (915 MHz in the US may be a good frequency to consider for this) so that the data being sent in the packets can be encrypted and only the owner of the dog can have access to the location that is being sent from the Tracker. For further information of different methods of encrypting information through RF, we recommend reading this article that outlines the different methods to encrypt and protect data using keys [6].

### 6.1.3 Teamwork Recommendations

Our first recommendation for future teams is to define and set strong team standard. We found during our experience that team members who failed to follow the team standards ended up letting the team down ultimately resulting in a team split. We recommend the whole team sitting down at the begging of the project during week 1 and brainstorming standards that the whole team can agree upon. Holding each teammate accountable and to team standards is crucial to having a strong team that is productive and successful. Please reference standards of Performance for the Work of Your Team for helpful tips on managing a team [7].

Our second recommendation is ensuring that all team members are interested in the project and its success. When team members are not equally invested in the success of the project it hinders progress. We suggest surveying team members on their interest areas and having each member choose a block of the project that they are interested in working on. When team members are interested in what they are working on they strive to do their best work and want to give it their all, as outlined in this article from Adecco that provides methods to motivate team members [8].

Our third recommendation is to set early deadlines! Setting project goals building a timeline is extremely important with any project in school. For senior capstone this proved to be especially true. We recommend analyzing all the project deadlines and moving them up by 2-3 weeks to account for unusable setbacks such as part failures and rework. We also suggest that you try and have the first PCB prototype built over winter break. This last year we experienced extensive chip shortages and sourcing IC's so ordering your parts as fast as possible is the best of attack and when you see a part in stock you should immediately order it because when you check back again the part will be out of stock. For further suggestions, we recommend referring to this article that gives suggestions on project timelines [9].

Our fourth recommendation that we have for future teams is to keep in regular communication with all team members and the instructors is important. We found that some team members struggled keeping the other team members informed of emergencies, task status and updates. This communication break down impacts the whole team and progress. This circles around to our first recommendation of setting team standards and one of them should be a communication standard for all the team member. There is an excellent book that Declan's mentor from Electro Scientific Industries gave his called "Crucial Conversations Tools for Talking When Stakes Are High" which gives great advice, tips and tricks to navigate tricky conversations. We have included a link to an Amazon page with the book that we recommend reading during the early stages of the project [10].

### 6.1.4 References

- [1] P. Hanbury, A. Hoecker, and M. Schallehn, "A chip shortage recovery guide," Bain, 28-Apr-2022. [Online]. Available: <https://www.bain.com/insights/a-chip-shortage-recovery-guide/>. [Accessed: 06-May-2022].
- [2] MokoLORA, "Lora GPS: All the information you want to know," LoRaWAN IoT Technology for Your Projects, 19-Jan-2022. [Online]. Available: <https://www.mokolora.com/all-you-need-to-know-about-lora-gps/>. [Accessed: 06-May-2022].
- [3] Mouser, "Lora-E5 - Mouser.com," Mouser Electronics. [Online]. Available: [https://www.mouser.com/datasheet/2/744/LoRa\\_E5\\_module\\_datasheet\\_V1\\_0-2488126.pdf](https://www.mouser.com/datasheet/2/744/LoRa_E5_module_datasheet_V1_0-2488126.pdf). [Accessed: 06-May-2022].
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- [10] K. Patterson, "Crucial conversations: Tools for talking when stakes are high, Second edition," Amazon, 2012. [Online]. Available: <https://www.amazon.com/Crucial-Conversations-Talking-Stakes-Second/dp/1469266822>. [Accessed: 06-May-2022].

## 6.2 Project Artifact Summary with Links

### 6.2.1 Code

A GitHub link to our public repository with all of the code necessary for the project: [Github](#)

### 6.2.2 User Guides

#### User Guide

1. User will power on the tracker unit via the switch on the system.
2. User will turn on Kenwood TH-72D handheld radio to receive data packets
3. User will wait for GPS fix on both the tracker (LED will blink once every 15 seconds when fix is acquired) and the handheld radio and the tracker unit then continue
4. User will review GPS coordinates of the tracker on TH-72D on a map like Google Maps to verify the proper location.
5. User will monitor distance and bearing to tracker unit on TH-72D
6. User will connect to the system via Bluetooth and use the application to change the transmit time (if desired).

Figure 18: The user guide for the recommended way to use system.

### 6.2.3 Schematics

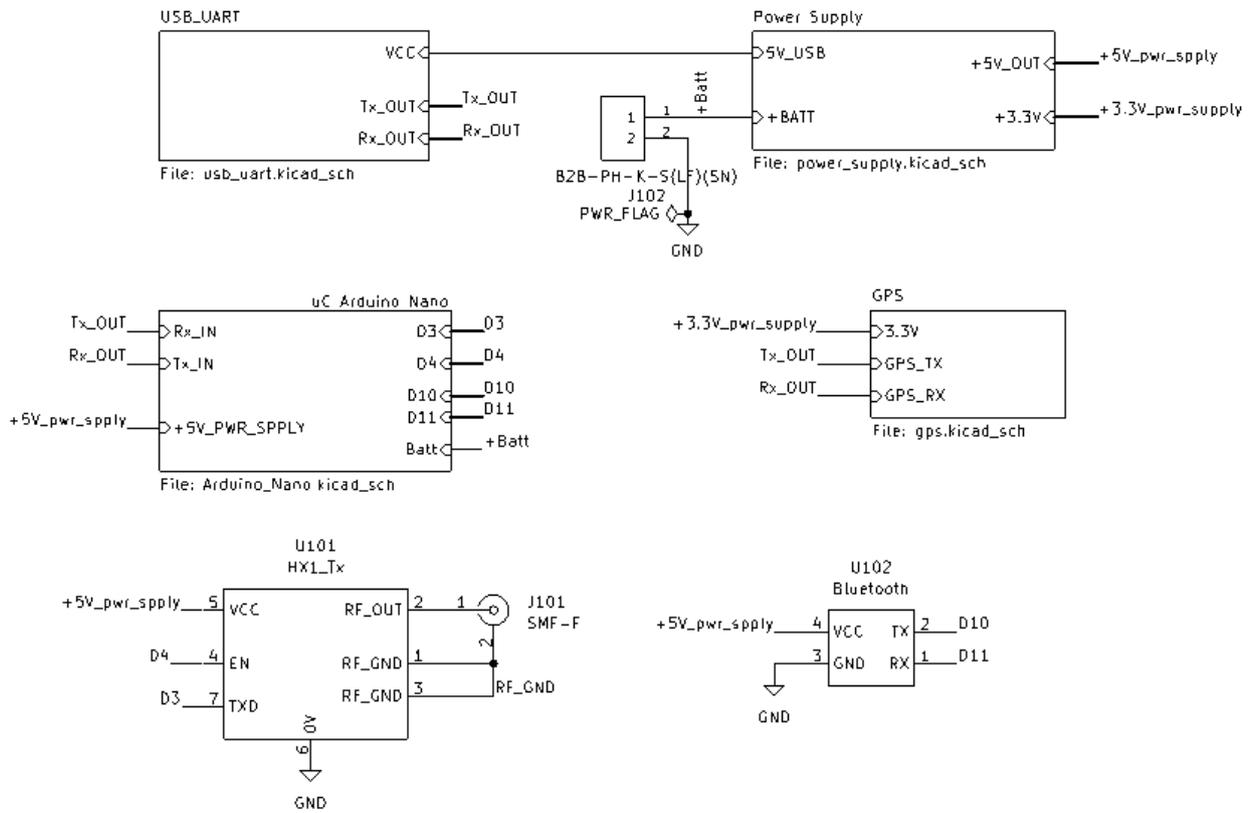
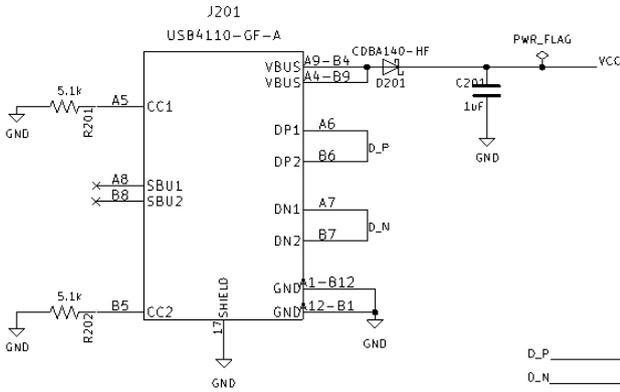


Figure 19: The top-level schematic of the entire system.

# USB



# CP2102

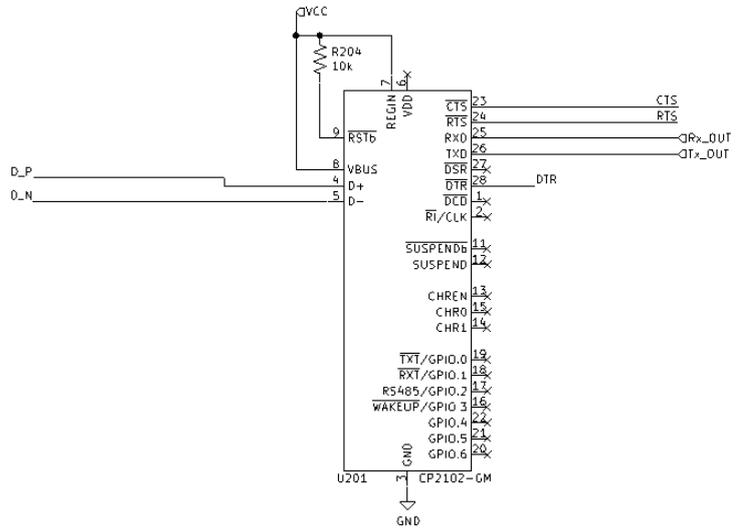


Figure 20: The schematic for the USB-UART schematic of the system.

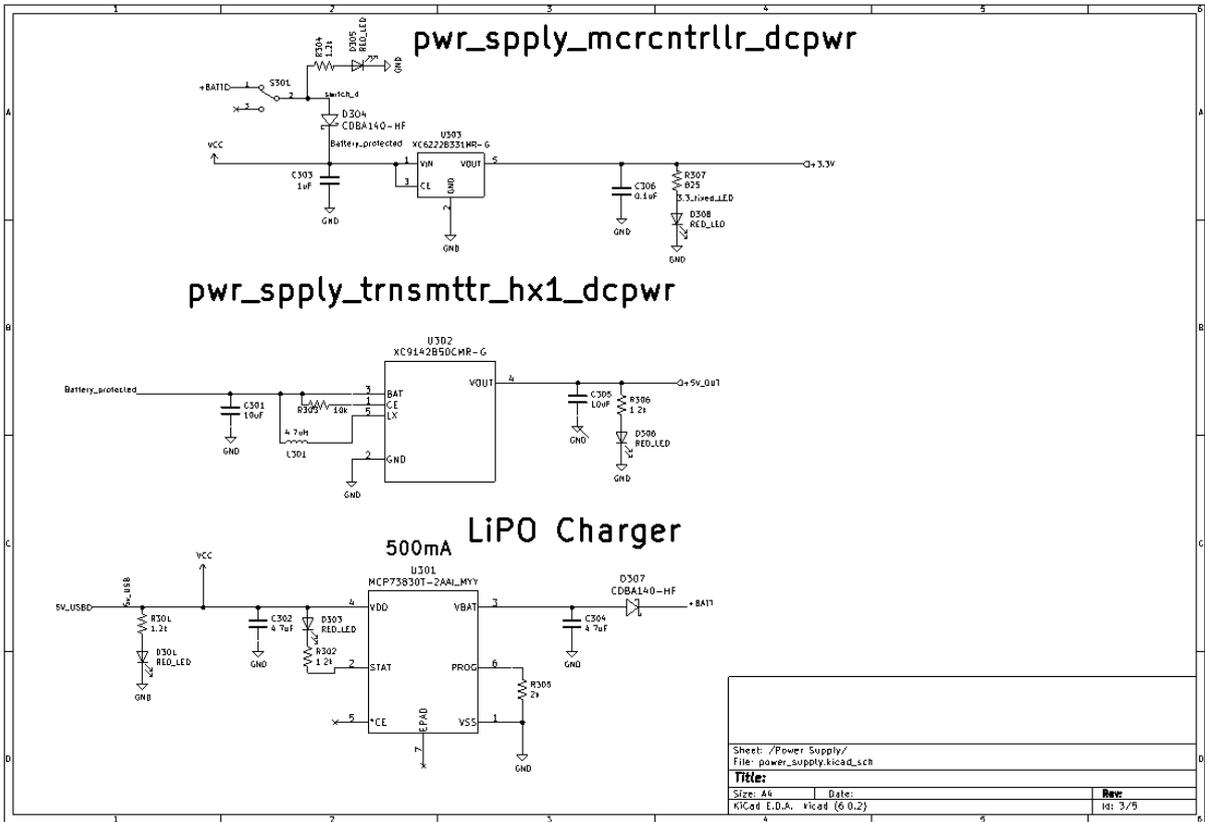


Figure 21: The schematic for the power supply of the system.

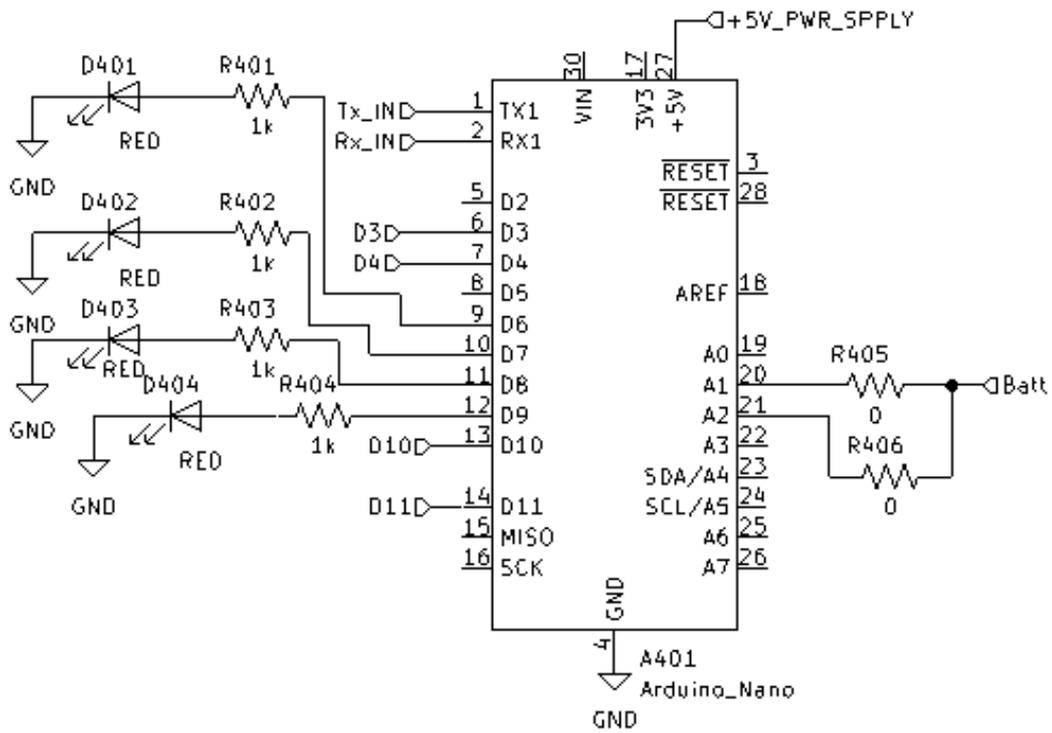


Figure 22: The schematic for the microcontroller used in the system.

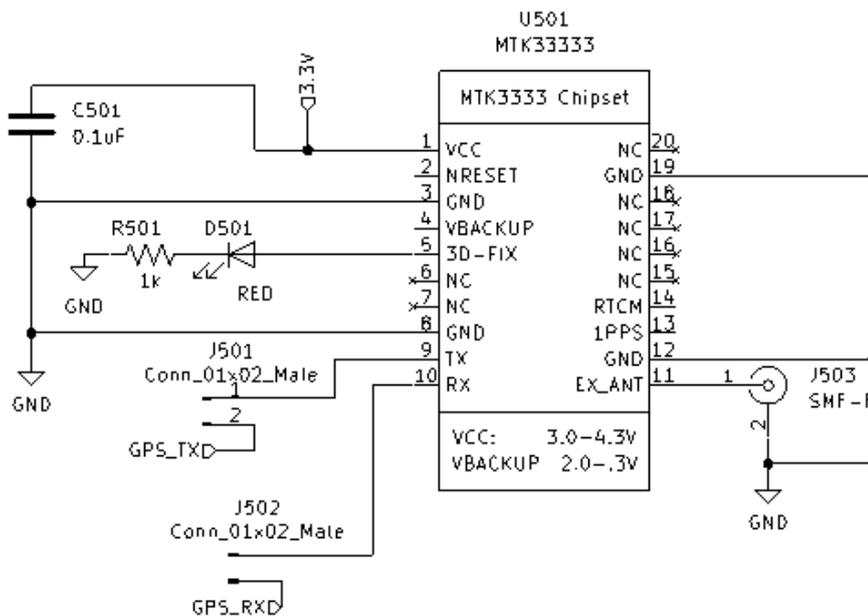


Figure 23: The schematic for the GPS in the system.

## 6.3 Presentation Materials

**COLLEGE OF ENGINEERING**
**Electrical Engineering and Computer Science**
**ECE.32**

### SYSTEM OVERVIEW

The GPS dog tracker is a 2.5"x3" device that is attached to collar. The tracker unit uses a GPS module to acquire the GPS location of the pet wearing the unit at a user defined interval. The GPS module will be used to obtain the current date and time as well as the longitude and latitude. The tracker uses a micro-controller to encode the date, time, location, battery voltage level using the AX.25 protocol. This encoded message will be transmitted over radio-frequency (RF) on the 2-meter Amateur radio ham bands.

### KEY FEATURES

- 10 hour run time
- 1-mile radius
- Rechargeable LIPO battery
- 300 mW Transmitter
- Bluetooth Connectivity
- AX.25 Protocol
- User selectable TX Interval
- 1 to 10 Hz GPS Refresh rate



Figure 2: A Block Diagram of the system.



# GPS DOG COLLAR

## RF Location Device

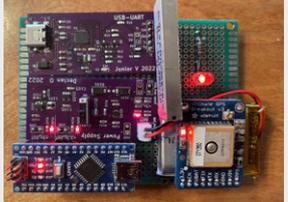



Figure 2: An Image of the first prototype of the system. Figure 3: An Image of the system inside the Enclosure.

### WHY RF?

RF was chosen during this project as it is an alternative to the typical GPS Dog Collar on the Market. Other competitors are known to use Cellular Data to send the tracker's location. Therefore, RF can provide some advantages over Cellular that sets this project apart from other implementations. Using RF can be more stable over Cellular, as it is possible for Cellular Lines to go down which can cause the system to fail.

The GPS dog collar uses the AX.25 protocol and packet radio to package the data before transmitting over RF. AX.25 transmits its data in small packets called frames, the frame construction is displayed in Figure 4. Packet radio uses 1200Hz and 2200Hz tones to represent 0's and 1's being fed into the transmitters input.

Flag	Address	Control	PID	Info	FCS	Flag
01111110	112/224 Bits	8/16 Bits	8 Bits	N*8 Bits	16 Bits	01111110

Figure 4: Information frame construction

### FUTURE REVISIONS

- Incorporate an ESP-32 chip instead of an entire Arduino Nano Development Board.
- Point-to-point Encryption of Location Data.
- Include a smaller antenna, possibly built-in.
- Expand project to use LORA.
- Condense size of PCB for a sleeker and more compact design.
- Find a cheaper alternative for the transmitter to cut down costs.
- Use a more efficient GPS Module to avoid the need to include an external antenna.

### ENGINEERING REQUIREMENTS

- **Location:** The system will detect the pet's location data within +/- 150 feet.
- **Satellite Fix:** The system will indicate when satellite fix has been obtained.
- **Battery:** The system will notify users of battery level.
- **Frequency of Location Data:** The system will transmit the pet's location data at a minimum of every 5 minutes.
- **Transmit Time:** The system will operate normally for at least 8 hours on one full charge.
- **Displaying GPS Data:** The system will display data in a way that is easy to interpret for 9/10 users.
- **Weatherproof Design:** The system will (rated IP22) withstand water splashing against the enclosure from any direction shall have no harmful effect.
- **Range of Tracker:** The system operate normally with a range of at least 1 mile.

### MEET THE TEAM



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Responsibilities:

- GPS Module
- USB-Serial Converter
- PCB Design



Declan O'Hara  
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Responsibilities:

- Power Supply
- Enclosure Design
- Microcontroller




Figure 24: The poster that is going to be presented at the Engineering Expo.

## 6.4 Revision Table

Date	Responsible Member	Revision Made
5/5/2022	Declan O'Hara	Modified formatting.
5/5/2022	Declan O'Hara	Added code.
5/5/2022	Junior Velasco	Added all Schematics.
5/5/2022	Junior Velasco	Added Presentation Materials.
5/5/2022	Junior/Declan	Wrote the Global Impact recommendations section.
5/5/2022	Junior Velasco	Wrote the Technical recommendations section.
5/5/2022	Declan O'Hara	Wrote the Teamwork recommendation section.
5/4/2022	Junior Velasco	Created Section 6 and outline for section 6 of project document

Table 29: Section 6 revision table