Design Document
Mesh Network Positioning System

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1. Introduction

1.1 Background

Spaceshot from the Illinois Space Society is working towards being one of the first collegiate teams to build and launch a completely student designed vehicle 100 kilometers to the edge of space; Also known as the Kármán line. Besides physically getting to space, a critical challenge is being able to prove that you reached space. Many commercial systems like Global Positioning Systems (GPS) are not operable in those extreme conditions. Suitable internal inertial navigation systems are cost prohibitive for amateur applications, and for mission critical applications multiple novel redundant methods are highly prefered. Therefore, a new method to reliably track objects and resolve their position in these extreme applications is needed.

(Spaceshot recently broke the University's 7-year standing altitude record in June of 2024, and is looking to do so again in the summer of 2025. Kairos II Launch)

1.2 Solution

This project aims to create a novel off grid radio positioning system that can be used to track objects with the only limitation being link budget. Due to the practicality of testing to 100 km, this system will focus on creating the foundational hardware and software to track objects needed to track objects at long ranges at a cheaper price than available professional alternatives. However, for demonstration purposes the scope will be over much shorter ranges. In the future better antennas could be used to drastically extend range. Depending on progress this system may be flight tested at a launch in April.

1.2.1 Overview

There are two primary system components. Anchor nodes are stationary position reference nodes that then communicate with Rover nodes to resolve a Rover node's position. By timing the round trip call and response of a radio signal, the distance between transceivers can be calculated with the known speed of light constant. Using at minimum 3 ground based Anchor nodes with known positions, a moving Rover node can be sequentially pinged and its position calculated through trilateration. Rover nodes would be attached to the desired tracking assets of unknown position. Anchor nodes must also have synchronized time to allow for Time Division Multiple Access (TDMA) communication with an asynchronous Rover node.

1.2.2 Additional Applications

- Drone tracking
- Warehouse asset & robotics tracking
- Car tracking

1.3 Visual

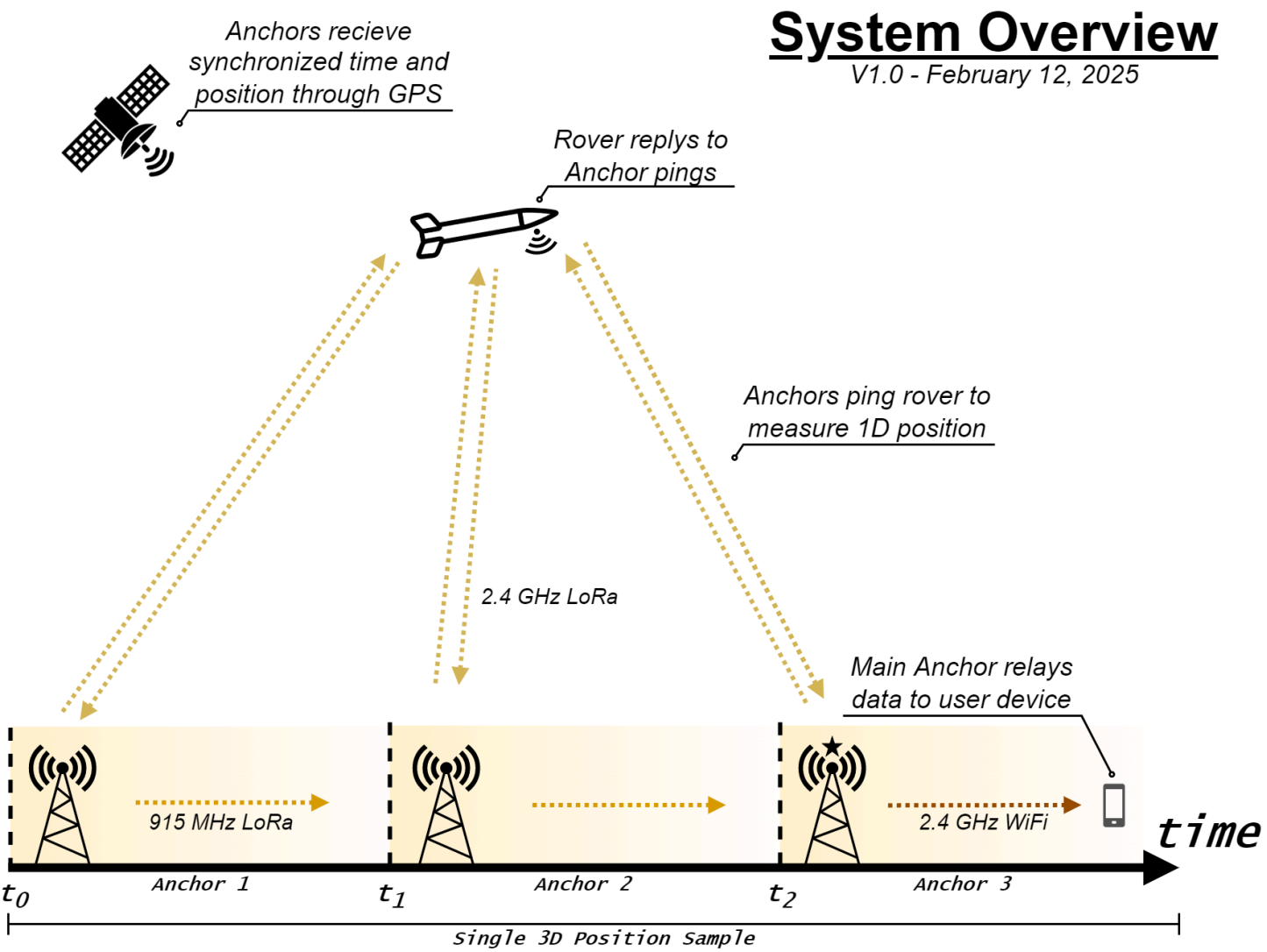


Figure 1. System Overview

1.4 High Level Requirements

1. Perform 3D trilateration of a Rover node at a minimum distance of 20 meters from at least one anchor node with a sample rate of at most 2 second. Sample rate is defined as the time period a position reading is resolved.

2. Relay barometer, GNSS, and at minimum one other data point to another node in the network with a latency of less than 2 seconds. Latency is defined as the time from an initial sensor reading to reception by another member of the network.

3. Publish position data to a local WiFi network in at most 5 seconds delay between receiving initial sensor or calculated data to receiving on WiFi.

2. System Design

2.1 Block Diagrams Detailed

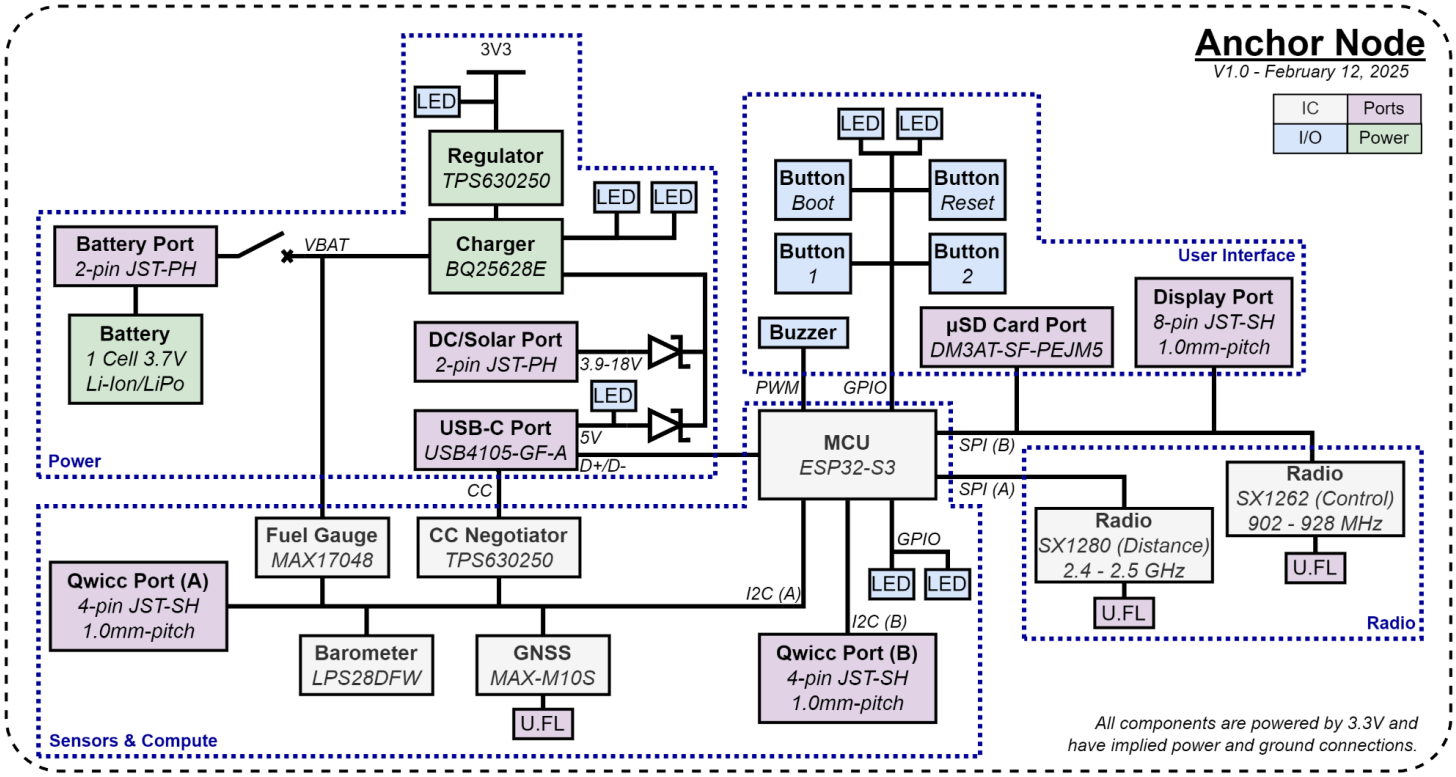


Figure 2. Anchor Node Detailed Diagram

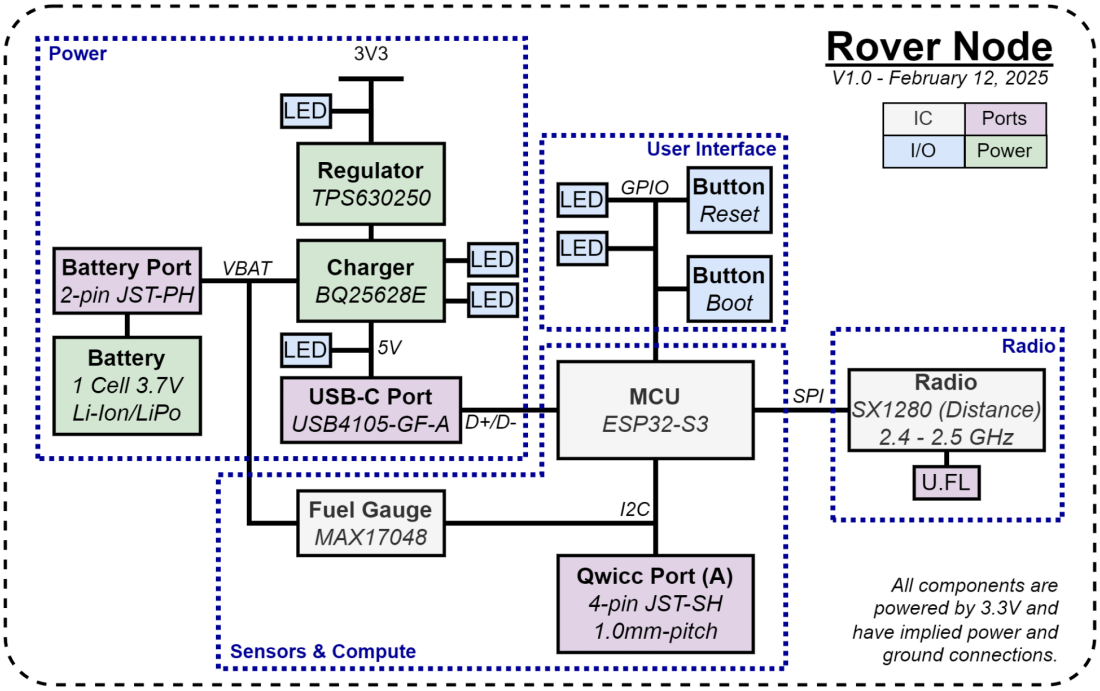


Figure 3. Rover Node Detailed Diagram

2.2 Block Descriptions

2.2.1 Anchor

Anchors are reference nodes with synchronized time and fixed positions. Schematics can be found in the appendix sections.

- *Requirement 1: Anchor nodes must have synchronized time with less than 200 ms offset*
- *Requirement 2: Anchor must be able to receive GPS transmissions at least once every two seconds*
- *Requirement 3: Anchor must have at least two status LEDs and at least one I2C expansion port*
- *Requirement 4: Anchor must be able to operate from 4.2V battery*
- *Requirement 5: Anchor must be able to determine altitude from two or more means (GPS & Barometer)*

2.2.2 Rover

Rovers are roaming nodes with unknown position or time attached to a tracking asset. Schematics can be found in the appendix sections.

- *Requirement 1: Nodes must automatically respond to Anchor ping requests in less than 500µs.*
- *Requirement 2: Rover must have at least two status LEDs and at least one I2C expansion port*
- *Requirement 3: Rover must be able to operate from ~3.3V battery*

2.2.3 Power

Each node is battery operated with the option to charge and power the device through a USB-C port. The BQ25628E controls power switching and battery charging. A thermistor is used to ensure the battery does not overheat during charging. For Anchor nodes an additional generic DC input port is available that can be used for solar panels or other power sources. It's able to optimize voltage draw for near maximum power draw and employs a buck-boost convert to ensure it outputs at most 4.5V. The TPS630250 regulates the input voltage to a stable 3.3V for all system components. Additionally a few debug LEDs for 3.3V, 5V, Power Good, and Charging are connected to these circuits. The goal is to enable portable deployments with seamless charging or extended usage in fixed locations.

- *Requirement 1: Voltage regulator must output 3.3V and supply 2A at maximum*
- *Requirement 2: Battery charger must be configurable with GPIO and resistors, or I2C*
- *Requirement 3: Battery charger must accept 1S 3.7V LiPo batteries and automatically switch between USB and battery power sources.*

2.2.4 Radios

Each node contains an SX1280 which has a built in ranging engine that is able to ping another radio and calculate the distance. This is then telegraphed over SPI to the user without the need for extensive timing and tuning of the radio front end. The SX1280's ease of use for ranging is what directly enables this project to maintain a focused and achievable scope. Anchor nodes also contain an SX1262 which serves as a command and control backbone for anchor nodes to share data while not congesting the primary ranging radios. The SX1280 uses 2.4 GHz LoRa and the SX1262 uses 915 MHz LoRa. LoRa enables low power usage yet longer ranges.

- *Requirement 1: Radio systems must use seperate frequency bands to avoid congestion*

- *Requirement 2: Radios must occupy ISM bands for license free operation*
- *Requirement 3: Radios must use SPI or I2C for communication with MCU*

2.2.5 User Interface

Anchor and Rover nodes each contain boot and reset buttons for programming the microcontroller (MCU). However, Anchors which are not at a premium for space have additional buttons and a buzzer for the user to interact with and configure the devices. An optional display can also be added via the display port. Anchors feature a MicroSD card port to allow for long term data logging. Each node also has debug LEDs that are user programmable.

- *Requirement 1: MCU must have SPST buttons to enable programming*
- *Requirement 2: MicroSD card must interface with at most 32GB FAT32 cards over SPI*

2.2.6 Sensors & Compute

Each node has an ESP32-S3 MCU as the core control unit. These MCUs feature WiFi/Bluetooth connectivity for additional user interaction. Anchor nodes feature a GPS module for precise synchronized timing and deducing their own position and a fuel gauge to measure battery charge over time. A water resistant barometer is used to further resolve their vertical position. Anchors have a USB-C Configuration Channel (CC) negotiator to ensure proper USB power delivery.

- *Requirement 1: All sensors must communicate over at least one of the following protocols – SPI, I2C, PWM – and draw 3.3V.*
- *Requirement 2: Barometer must output a resolution of at least 1 meter*
- *Requirement 3: GPS module must output 1 Hz time pulse and position within 3 meters*
- *Requirement 4: Fuel gauge must read cell voltage and communicate over at least one of the following protocols – SPI, I2C, PWM*
- *Requirement 4: MCU have a clock speed greater than 100 MHz and communicate over all of the following protocols – SPI, I2C, PWM – to interface with all modules.*

2.2.7 Antennas

Rover nodes only have one antenna that will require a U.FL connector. Depending on their space constraints patch antennas will most likely be the optimal solution. Anchor nodes also have three U.FL connectors. An internal active patch GPS antenna will be mounted inside the case, while two U.FL to SMA bulkhead adapters will be mounted through the case wall. This will enable the user to switch antennas for their specific needs.

In regular usage omnidirectional antennas for the 915 MHz and 2.4 GHz LoRa radios can be used, but if long range usage is required more directional antennas may be used. The MCU's have an embedded antenna for WiFi/Bluetooth connectivity.

2.3 Tolerance Analysis

One key aspect of our design is ensuring 1D ranging accuracy provided by each SX1280 module. There are a multitude of ways ranging could be degraded such as multipath reflections and doppler shift caused by high velocity tracking assets. However, calibration of the SX1280 to account for different RF front ends is the most prevalent for mitigating error and the focus of this tolerance analysis.

2.3.1 Calibration

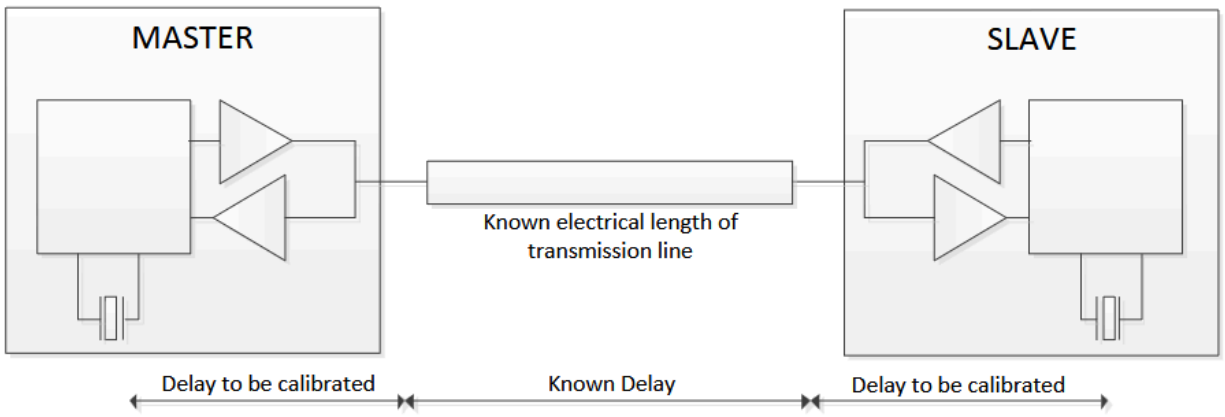


Figure 4. [6] Semtech, Ranging Calibration Setup

Using a coax cable of known length the system delay can be isolated to just the RF front end of the ranging devices. This offset would then be applied to future ranging measurements.

$$D_{uncalibrated} = (RangeResult \times D_{LSB})/2$$
$$D_{calibrated} = (D_{uncalibrated} - D_{cable})/2$$
$$Calibration = D_{calibrated}/D_{LSB}$$

Additionally, outdoor line of sight measurements can be conducted when the nodes are separated at known fixed distances. Their measured vs actual error can be calculated and then applied as a linear offset. More advanced offsets could also be used if you take into account alternate frequencies and LoRa parameters.

2.3.2 Manufacturer Testing

Semtech, the manufacturer of the SX1280, conducted outdoor 1D range testing after calibration at a distance of 170 meters with an estimated error of less than 4 meters for single sample pings, and less than 1 meter accuracy for larger sample ping sizes of 70.

2.3.3 External Testing

Additional 1D testing conducted by Stuart Robinson has revealed an error rate of about 0.2% at 40.65 kilometers [16]. Robinson was also able to achieve a measured ground distance of 89.237 km [16] with a small directional antenna; Further suggesting this system's potential for ranges in excess of 100 km.

2.3.4 Tolerance Expectations

Ultimately, the team expects to achieve relatively high positional accuracy. However without the ability to test the system they are hesitant to guarantee a specific error tolerance. External testing has revealed the SX1280 can be highly accurate, but it is to be seen if similar accuracy can scale down to shorter distances of around 25 meters for the purposes of a demonstration. With this in mind, the team is expecting less than a 10% 1D distance error.

Expected Accuracy		
Semtech Test	**Robinson Test**	**Expected**
170 m	40.65 km	30 m
2.23%	0.20%	10%

Table 1. Expected Accuracy From Tolerance Analysis

3. Board Design

3.1 Anchor Layout

Anchors were designed with all parts to be on the front side to allow for quicker assembly and reduce pick and place costs for machine assembled orders. All user I/O is located near the edges to be easily accessed in a case. The RF section is also spaced from the power regulators to try and mitigate noise. The back layer is used as a vertical bridge to connect the MCU to the upper section of the board.

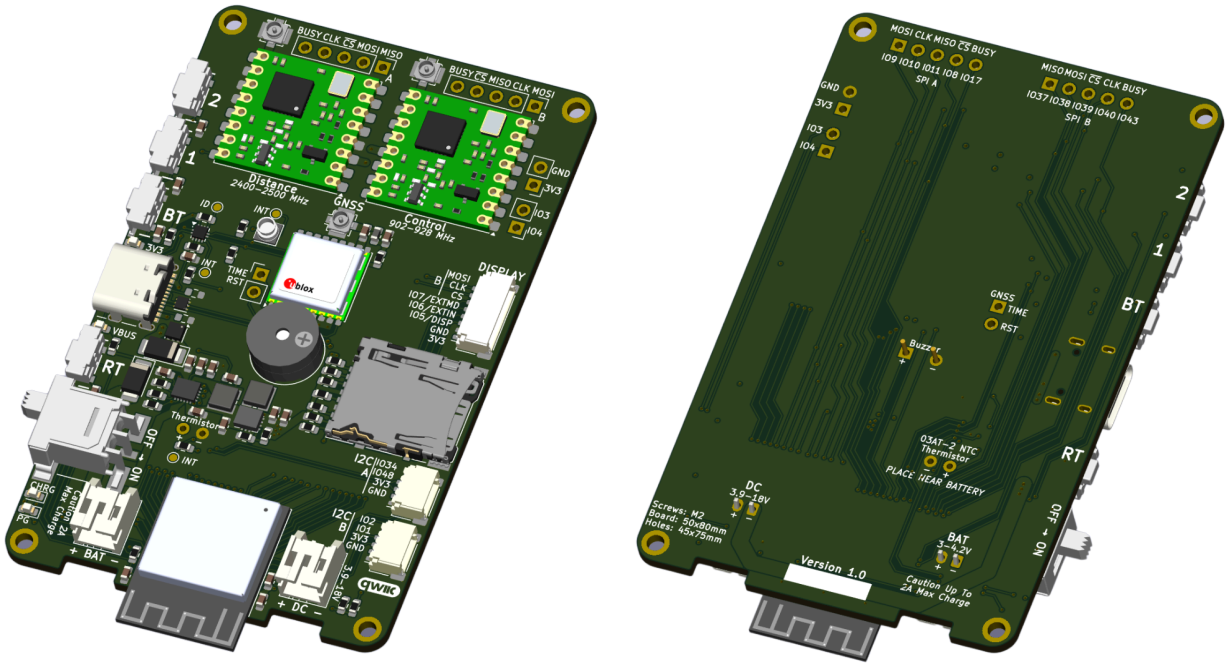


Figure 5. Anchor Node 3D View (Front: L Back: R)

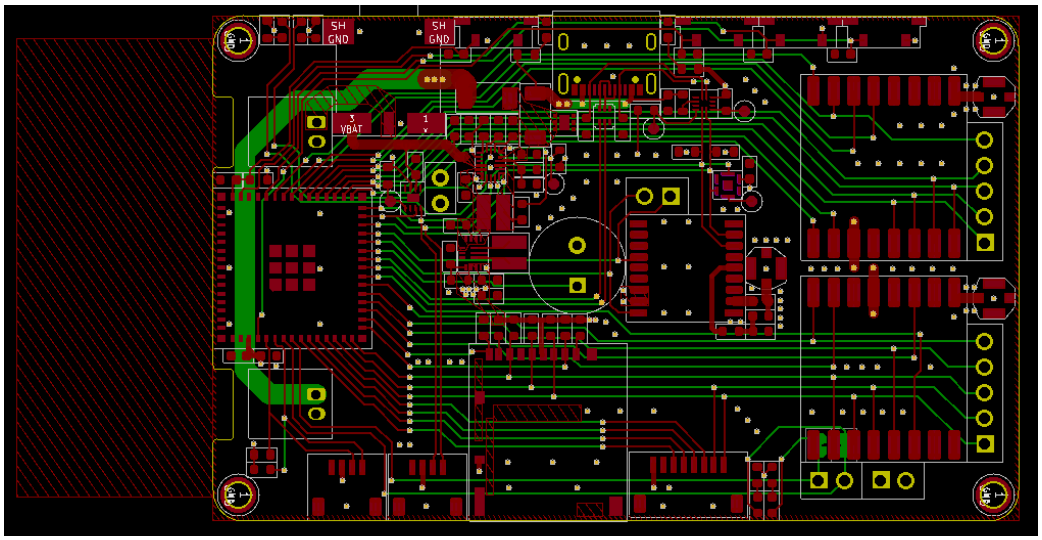


Figure 6. Anchor Routing

3.2 Rover Layout

Unlike Anchors, Rovers are extremely space constrained to optimize their placement on tracking assets. Therefore, they have parts on both sides. Only two screw holes are used to save space since the boards have little mass. Similarly user I/O is located near the edges

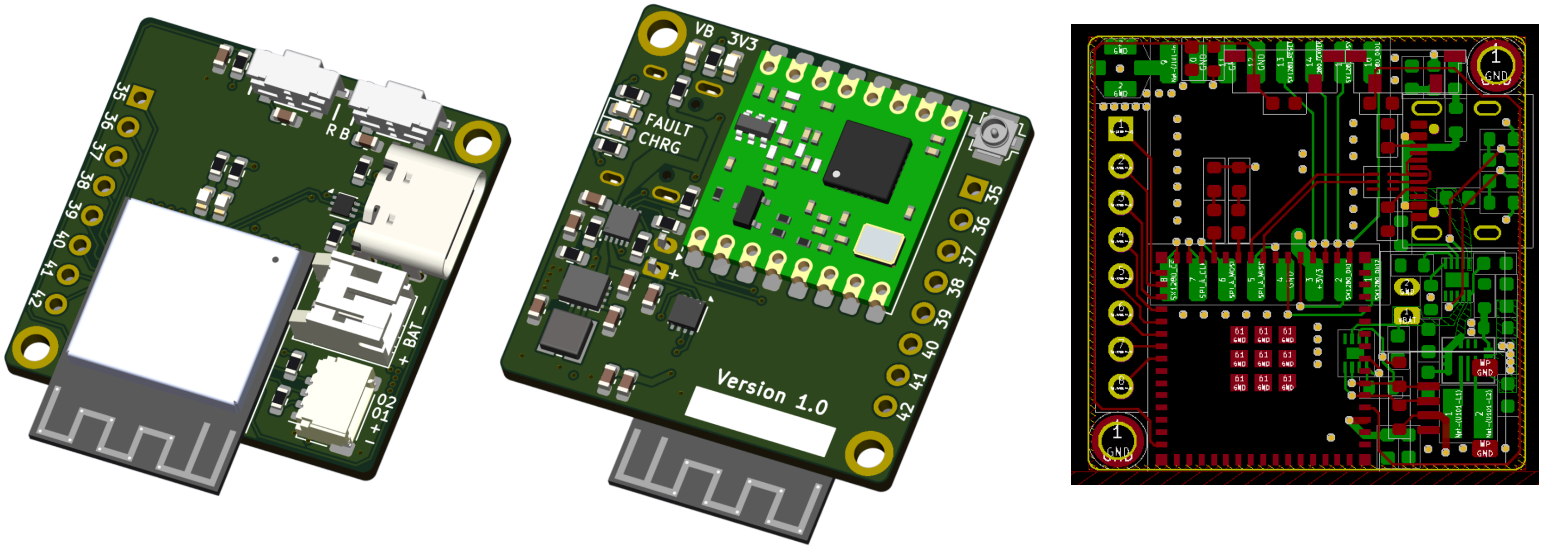


Figure 7. Rover 3D View (Front: L Back: C) & Routing (Right)

3.3 General Layout

Each board is four layers and follows a similar stackup plan. The front and back layers are used primarily for data signal (SIG) traces, and the inner layers are reserved for power. The only difference is the location of the ground (GND) plane which is immediately underneath the layer with RF traces. Anchors have all RF components on the front while Rovers have all RF traces on the back. This allows for 50Ω impedance controlled boards with specific trace widths.

Board Layer Stack		
Layer	**Anchor**	**Rover**
F.Cu	GND	GND
In1.Cu	GND	+3.3V
In2.Cu	+3.3V	GND
B.Cu	GND	GND

Table 2. Board Layers

4. Mechanical Design

All mechanical design is focused on Anchor nodes as Rover nodes will be mounted to the tracking asset while Anchor nodes are free standing across the tracking area.

Board Dimensions *(mm)*		
Layer	**Anchor**	**Rover**
Edges (W x L)	50 x 80	30 x 30
M2 Holes (W x L)	45 x 75	26 x 26

Table 3. Board Dimensions

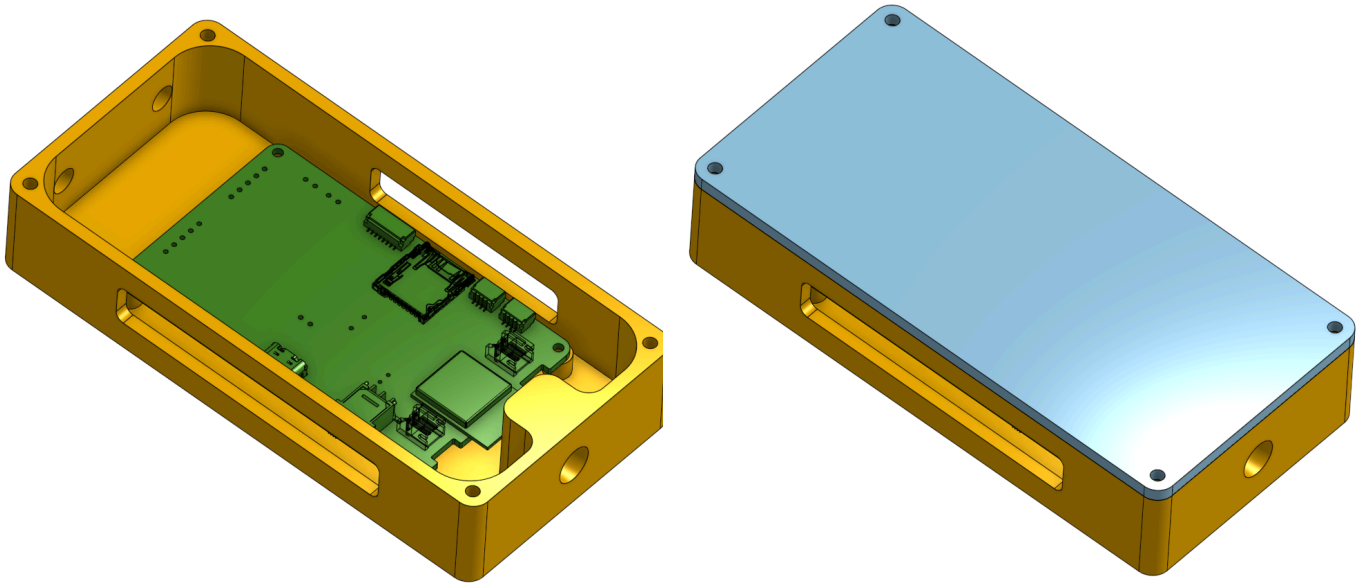


Figure 8. Anchor Case and Lid

The Anchors and a flat cell battery will sit inside of a 3D printed case to protect them from the outdoors while still allowing access for the user I/O. There will be rubber covers around the ports which are not depicted. More importantly these cases also act as a strain relief on the SMA cables used to attach the two radio antennas. The GPS antenna will be placed inside the case. Additionally, each case will have a tripod mounting hole to allow for easy setup in the field.

Figure 9. Tripod Stand

5. Cost Analysis

5.1 Engineering Labor

Engineering Labor Cost				
Engineers	**Hours/Week**	**Wage/Hour**	**Weeks**	**Total**
2	2	$33	12	$1,584

Table 4. Engineering Labor Cost

5.2 Bill of Materials

A more detailed cost breakdown per board can be found in the appendix section. These prices are strictly for a single node.

Node Cost	
Anchor	**Rover**
$74.0597	$21.2389
Assumes MOQ part price but only counts consumed parts.	

Table 5. Node Cost

5.3 Current Expenditures

With all the parts needed to assemble three Anchors and one Rover node not many expenditures are expected unless soldering issues are encountered. The only remaining orders include parts to mount the Anchor nodes into their mechanical enclosures with a total of $150 estimated for M2 screws, M2 heat inserts, TPU filament, and tripods.

Current Expenditures		
Type	**Cost**	**Description**
Amazon	$73.20	Development Board
LCSC	$129.27	PCB Parts 1st Round
Mouser	$81.88	PCB Parts 1st Round
Digi-Key	$31.20	PCB Parts 1st Round
Digi-Key	$75.27	PCB Parts 2nd Round
Data Alliance	$96.13	RF Adapters & Antennas
Total	**$486.95**	

Table 6. Current Expenditures

6. Ethics

6.1 FCC Regulations

We will follow all FCC regulations that concern the ISM Band, provided here: [eCFR :: 47 CFR Part 18 -- Industrial, Scientific, and Medical Equipment][18][19][20], as they relate to our RF equipment such as general practices and spectrum usage.

6.2 Tracking Assets

All assets being tracked will be owned by the team and not another individual without their explicit consent.

6.3 Feedback

As this is an experimental project we plan to maintain an open mind when creating this novel system by listening to ideas given from mentors, course staff, students, and others throughout the project. We will take notes in their lab notebook on any feedback received to ensure it is properly documented and considered.

7. Safety

7.1 Batteries

Following the *Safe Practice for Lead Acid and Lithium Batteries* guidelines all batteries will be charged in their recommended conditions, and stored in a flammables cabinet when not in use. When handling batteries they will be treated with care and monitored for degradation. If disposal is needed batteries will be left in the battery cabinet until proper disposal is available.

8. Citations and References

[1] IEEE, "IEEE Code of Ethics," IEEE, [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html, Accessed: Feb. 10, 2025.

[2] ACM, "ACM Code of Ethics and Professional Conduct," ACM, [Online]. Available: https://www.acm.org/code-of-ethics, Accessed: Feb. 10, 2025.

[3] Semtech, "AN1200.29 Introduction to Ranging with the SX1280 Transceiver", Semtech, [Online]. Available: https://semtech.my.salesforce.com/sfc/p/#E0000000JelG/a/3n000000l9OZ/Kw7ZeYZuAZW3Q4A3R_IUjhYCQEJxkuLrUgl_GNNhuUo, Accessed: Feb. 11, 2025.

[4] Semtech, "AN1200.80 LoRa Doppler Immunity", Semtech, [Online]. Available: https://semtech.my.salesforce.com/sfc/p/#E0000000JelG/a/3n000000l9JA/FoIjLVxAx4xpf3Wh5xvvX3B9PWTw.S7R.YPZHazMzBo, Accessed: Feb. 11, 2025.

[5] Semtech, "AN1200.50 SX1280 Ranging Protocol and Result Processing", Semtech, [Online]. Available: https://semtech.my.salesforce.com/sfc/p/#E0000000JelG/a/2R000000UypY/5mprGH6TIzeLnfosUgj1xK5ftoqDpoCnRk_dzY_jAx4, Accessed: Feb. 11, 2025.

[6] Semtech, "Introduction to Ranging with the SX1280 Transceiver", Semtech, [Online]. Available: https://semtech.my.salesforce.com/sfc/p/#E0000000JelG/a/44000000MDiH/OF02Lve2RzM6pUw9gNgSJXbDNaQJ_NtQ555rLzY3UvY, Accessed: Feb. 11, 2025.

[7] Jamie Smith, "The Lightspeed Rangefinder," EngrXiv Preprints, Accessed: Feb. 11, 2025. [Online]. Available: https://engrxiv.org/preprint/download/1655/version/2524/3401/2512

[8] u-blox, "MAX-M10S Data sheet," u-blox, Apr. 8, 2024. [Online]. Available: https://content.u-blox.com/sites/default/files/MAX-M10S_DataSheet_UBX-20035208.pdf, Accessed: Feb. 11, 2025.

[9] Espressif Systems, "ESP32-S3-MINI-1 & ESP32-S3-MINI-1U Datasheet," Version 1.3, Espressif Systems, Mar. 7, 2023. [Online]. Available: https://www.espressif.com/sites/default/files/documentation/esp32-s3-mini-1_mini-1u_datasheet_en.pdf, Accessed: Feb. 11, 2025.

[10] Texas Instruments, "BQ25628E I2C Controlled 1-Cell, 2A, Maximum 18V Input, Buck Battery Charger with NVDC Power Path Management," BQ25628E datasheet, Jul. 2023. [Online]. Available: https://www.ti.com/lit/ds/symlink/bq25628e.pdf, Accessed: Feb. 11, 2025.

[11] Texas Instruments, "TPS630250: High-Efficiency Buck-Boost Converter," Texas Instruments, [Online]. Available: https://www.ti.com/product/TPS630250, Accessed: Feb. 15, 2025.

[12] Semtech, "SX1261/2 Datasheet", Semtech, [Online]. Available: https://semtech.my.salesforce.com/sfc/p/#E0000000JelG/a/2R000000Un7F/yT.fKdAr9ZAo3cJLc4F2cBdUsMftpT2vsOICP7NmvMo, Accessed: Feb. 11, 2025.

[13] STMicroelectronics, "LPS28DFW - Dual full-scale, 1260 hPa and 4060 hPa, absolute digital output barometer with water-resistant package," LPS28DFW datasheet, Dec. 2021. [Online]. Available: https://www.st.com/resource/en/datasheet/lps28dfw.pdf, Accessed: Feb. 11, 2025.

[14] Analog Devices, "MAX17048/MAX17049 3µA 1-Cell/2-Cell Fuel Gauge with ModelGauge m3," MAX17048/MAX17049 datasheet, Rev. 5, Jan. 2023. [Online]. Available: https://www.analog.com/media/en/technical-documentation/data-sheets/MAX17048-MAX17049.pdf, Accessed: Feb. 11, 2025.

[15] Texas Instruments, "TUSB320LAI, TUSB320HAI USB Type-C Configuration Channel Logic and Port Control," TUSB320LAI datasheet, May 2017. [Online]. Available: https://www.ti.com/lit/ds/symlink/tusb320lai.pdf, Accessed: Feb. 11, 2025.

[16] Robinson, S. (GW7HPW), "SX1280_Testing: Semtech SX1280 2.4ghz LoRa Ranging Transceivers," GitHub repository, Apr. 2019. [Online]. Available: https://github.com/StuartsProjects/SX1280_Testing, Accessed: Feb. 11, 2025.

[17] ECE 445 Course Staff, "Safe Practice for Lead Acid and Lithium Batteries," University of Illinois, ECE 445: Senior Design Project Laboratory, Rev. D, Apr. 13, 2016. [Online]. Available: https://courses.grainger.illinois.edu/ece445/documents/GeneralBatterySafety.pdf, Accessed: Feb. 11, 2025.

[18] Federal Communication Commission, "The Federal Register," Code of Federal Regulations, Title 47, Chapter I, Subchapter A, Part 18, Subpart C, Section 18.111. [Online]. Available: https://www.ecfr.gov/current/title-47/chapter-I/subchapter-A/part-18/subpart-C/section-18.111. Accessed: Mar. 6, 2025.

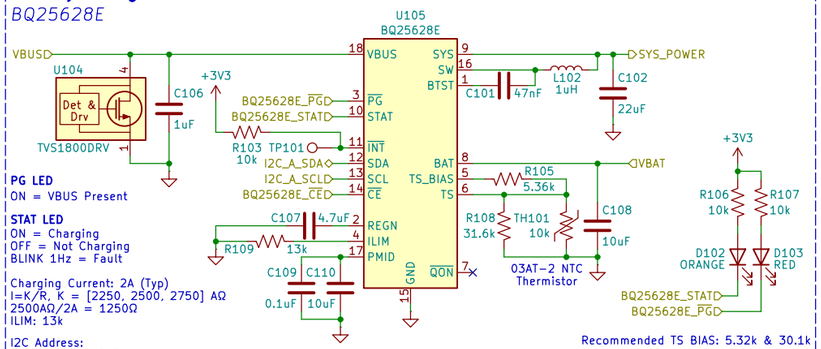
[19] Federal Communication Commission, "The Federal Register," Code of Federal Regulations, Title 47, Chapter I, Subchapter A, Part 18, Subpart C, Section 18.301. [Online]. Available: https://www.ecfr.gov/current/title-47/chapter-I/subchapter-A/part-18/subpart-C/section-18.301. Accessed: Mar. 6, 2025.

[20] Federal Communication Commission, "The Federal Register," Code of Federal Regulations, Title 47, Chapter I, Subchapter A, Part 18, Subpart C, Section 18.311. [Online]. Available: https://www.ecfr.gov/current/title-47/chapter-I/subchapter-A/part-18/subpart-C/section-18.311. Accessed: Mar. 6, 2025.

Appendix A: Schematics

Battery Charger

BQ25628E



PG LED
ON = VBUS Present

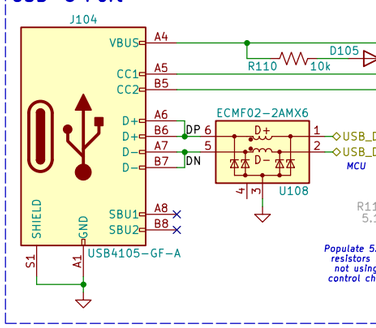
STAT LED
ON = Charging
OFF = Not Charging
BLINK 1Hz = Fault

Charging Current: 2A (Typ)
I=K/R, K = [2250, 2500, 2750] AΩ
2500AΩ/2A = 1250Ω
ILIM: 13k

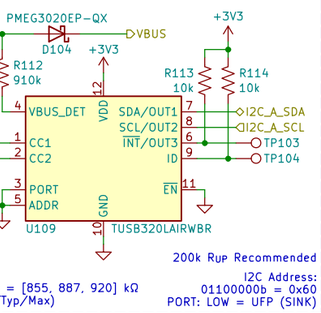
I2C Address:
01101010b = 0x6A

Recommended TS BIAS: 5.32k & 30.1k
Use 10k resistor to bypass TH101

USB-C Port



USB-C Configuration Channel



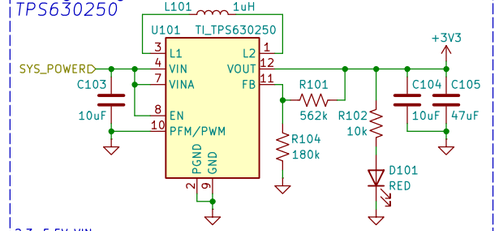
200k Rup Recommended

RVBUS = [855, 887, 920] kΩ
(Min/Typ/Max)

I2C Address:
01100000b = 0x60
PORT: LOW = UFP (SINK)

Voltage Regulator

TPS630250

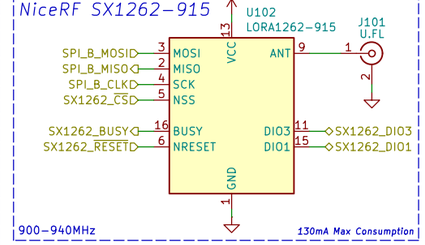


2.3-5.5V VIN
2A OUT MAX

PFM/PWM auto power saving mode enabled low

Radio Control

NiceRF SX1262-915

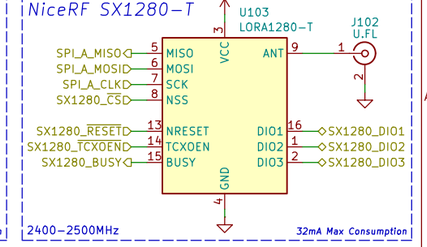


900-940MHz

130mA Max Consumption

Radio Distance

NiceRF SX1280-T

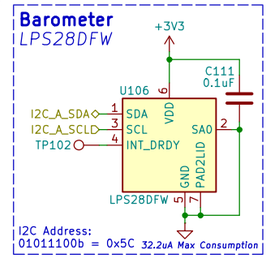


2400-2500MHz

32mA Max Consumption

Barometer

LPS28DFW

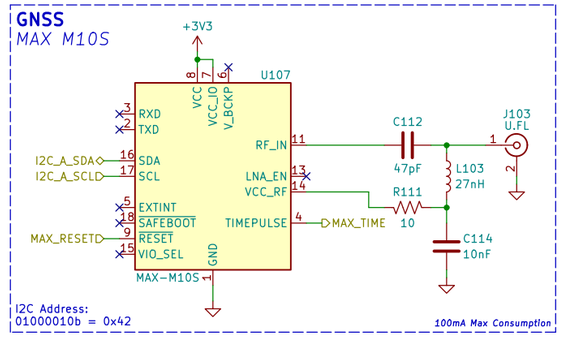


I2C Address:
01011100b = 0x5C

32.2uA Max Consumption

GNSS

MAX M10S

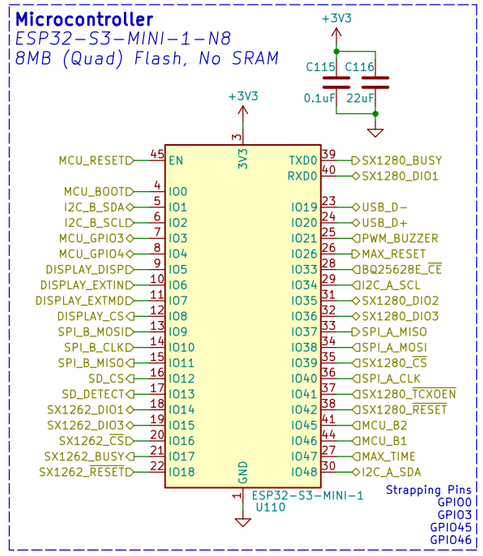


I2C Address:
01000010b = 0x42

100mA Max Consumption

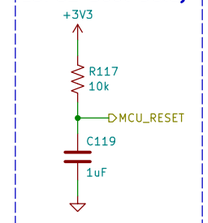
Microcontroller

ESP32-S3-MINI-1-N8
8MB (Quad) Flash, No SRAM



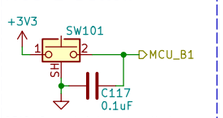
Strapping Pins
GPIO0
GPIO3
GPIO45
GPIO46

ESP32 Boot Delay



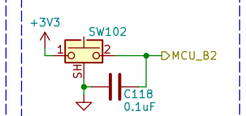
Minimum of 50us delay for stable power up

MCU 1 Button



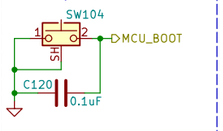
GPIO46 weak internal pull down

MCU 2 Button



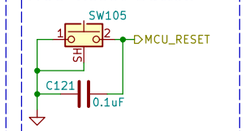
GPIO45 weak internal pull down

MCU 0/Boot Button



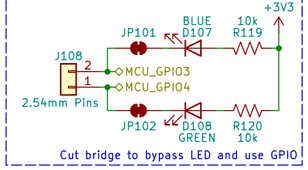
GPIO0 weak internal pull up

MCU Reset Button



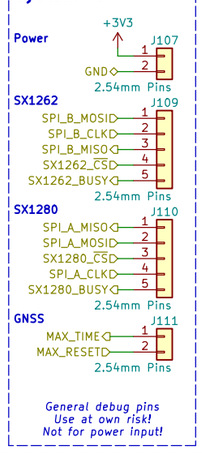
External pull up

MCU LEDs & GPIO



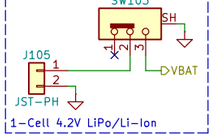
Cut bridge to bypass LED and use GPIO

System IO



General debug pins
Use at own risk!
Not for power input!

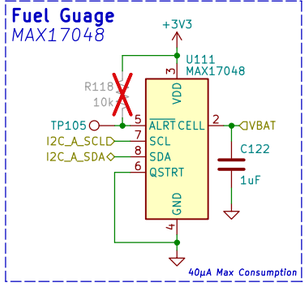
Battery Input



1-Cell 4.2V LiPo/Li-Ion

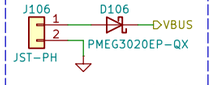
Fuel Guage

MAX17048



40μA Max Consumption

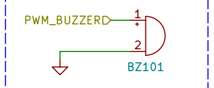
DC/Solar Input



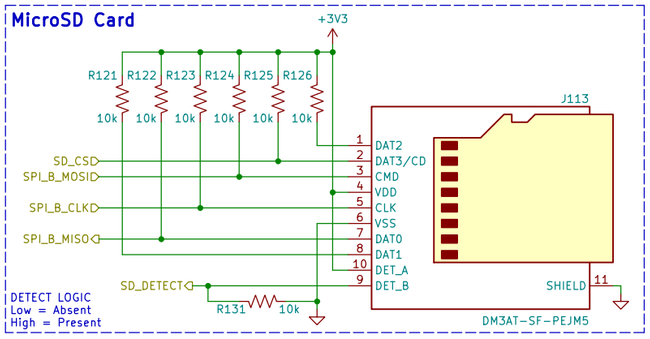
3.9-18V Input, 100mA (Min)

PIEZO BUZZER

AT-0927-TT-6-R

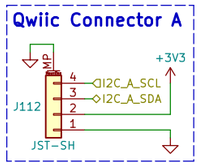


MicroSD Card

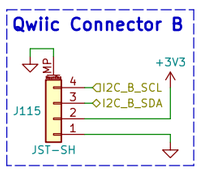


DETECT LOGIC
Low = Absent
High = Present

Qwiic Connector A

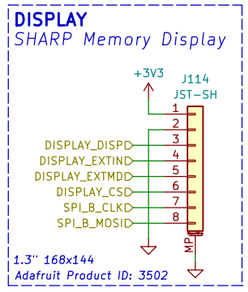


Qwiic Connector B



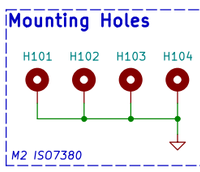
DISPLAY

SHARP Memory Display



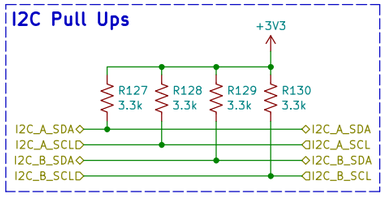
1.3" 168x144
Adafruit Product ID: 3502

Mounting Holes



M2 ISO7380

I2C Pull Ups



Author: Peter Giannetos

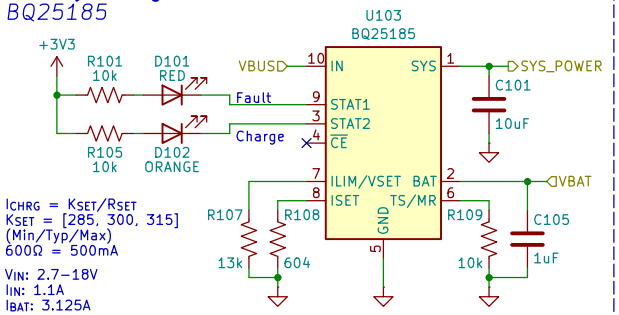
Sheet: /
File: Anchor.kicad_sch

Title: Anchor Node

Size: A3	Date: 2025-01-28	Rev: A
KiCad E.D.A. 8.0.7		Id: 1/1

Battery Charger

BQ25185

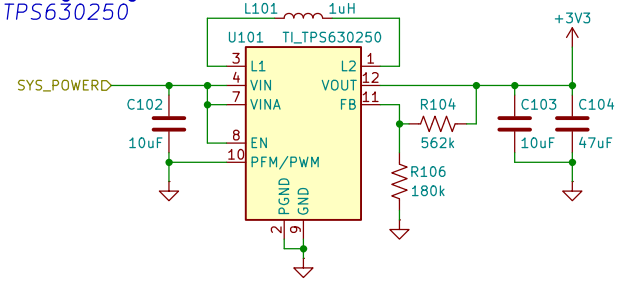


ICHRG = KSET/RSET
KSET = [285, 300, 315]
(Min/Typ/Max)
600Ω = 500mA

VIN: 2.7–18V
IIN: 1.1A
IBAT: 3.125A

Voltage Regulator

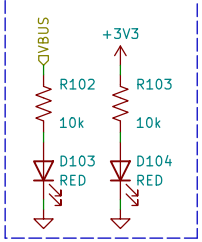
TPS630250



2.3–5.5V VIN
2A OUT MAX

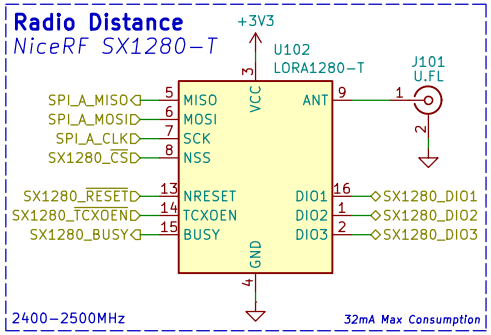
PFM/PWM auto power saving mode enabled low

Power LEDs



Radio Distance

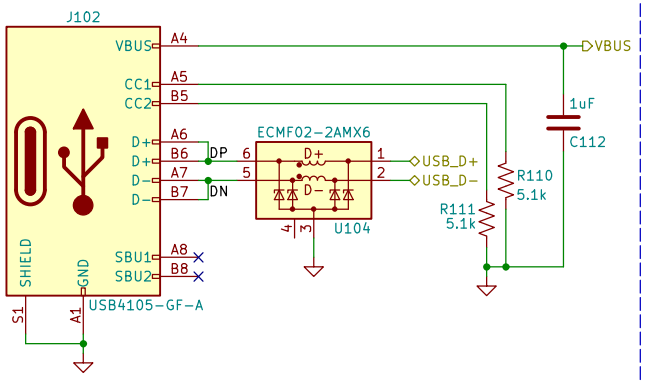
NiceRF SX1280–T



2400–2500MHz

32mA Max Consumption

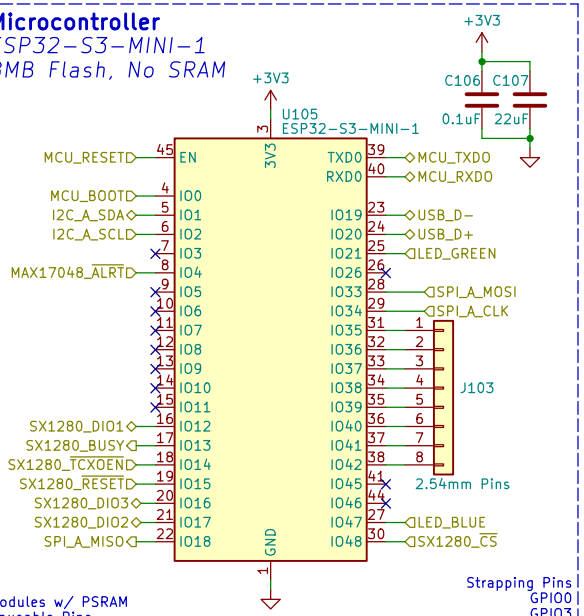
USB–C Port



Microcontroller

ESP32–S3–MINI–1

8MB Flash, No SRAM

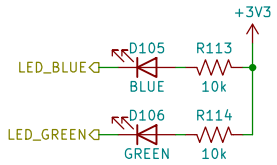


Modules w/ PSRAM
Unusable Pins
GPIO35
GPIO36
GPIO37

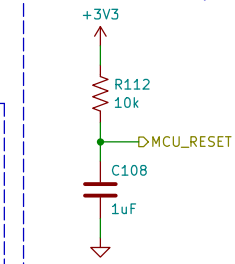
Strapping Pins
GPIO0
GPIO3
GPIO45
GPIO46

500mA Max Consumption

MCU LEDs



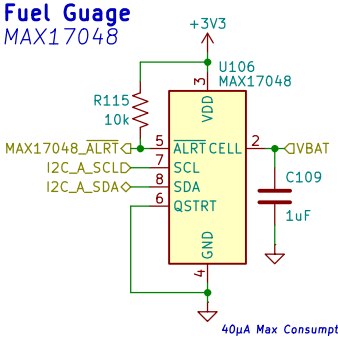
MCU Boot Delay



Minimum of 50us delay
for stable power up

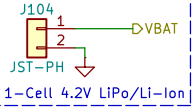
Fuel Guage

MAX17048



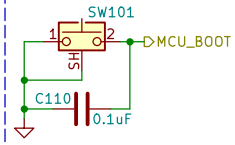
40µA Max Consumption

Battery Input



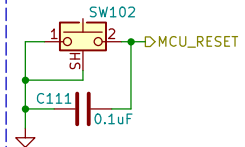
1–Cell 4.2V LiPo/Li–Ion

MCU 0/Boot Button



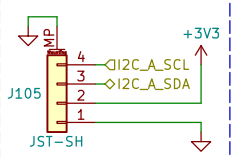
GPIO0 weak internal pull up

MCU Reset Button

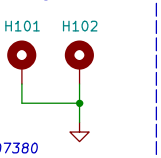


External pull up

Qwiic Connector A

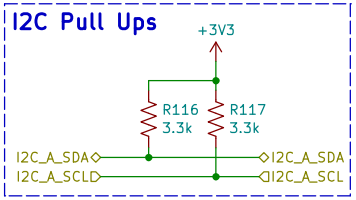


Mounting Holes



M2 ISO7380

I2C Pull Ups



Author: Peter Giannetos

Sheet: /
File: Rover.kicad_sch

Title: Rover Node

Size: A4	Date: 2025–01–28	Rev: A
KiCad E.D.A. 8.0.7		Id: 1/1

Appendix B: BOM Cost Analysis

Reference (A)	Reference (R)	Value	Qty (A)	Qty (R)	MPN	Link	MOQ	Cost	Distributor	DPN
BZ101		Buzzer	1		AT-0927-TT-6-R	https://w	1	$0.8700	Mouser	665-AT0927TT6R
C101		47nF	1		CGA0603X7R473J500JT	https://w	100	$0.0029	LCSC	C36911405
C102, C116	C107	22uF	2	1	CL10A226MQ8NRNC	https://w	20	$0.0074	LCSC	C59461
C103, C104, C108, C110	C101, C102, C103	10uF	4	3	CGA0603X5R106M250JT	https://w	50	$0.0144	LCSC	C6119874
C105	C104	47uF	1	1	CL10A476MQ8QRNC	https://w	10	$0.0438	LCSC	C730416
C106, C113, C119, C122	C105, C108, C109, C112	1uF	4	4	CGA0603X5R105K250JT	https://w	100	$0.0035	LCSC	C6119818
C107		4.7uF	1		CL10A475KQ8NNNC	https://w	50	$0.0037	LCSC	C8032
C109, C111, C115, C117, C118, C120, C121	C106, C110, C111	0.1uF	7	3	TCC0603X7R104J500CT	https://w	100	$0.0030	LCSC	C282518
C112		47pF	1		FN18N470J500PSG	https://w	100	$0.0023	LCSC	C525253
C114		10nF	1		CC0603JRX7R8BB103	https://w	100	$0.0037	LCSC	C519510
D101, D103, D105	D101, D103, D104	RED	3	3	XL-1608SURC-06	https://w	100	$0.0029	LCSC	C965799
D102	D102	ORANGE	1	1	YLED0603O	https://w	100	$0.0053	LCSC	C19273153
D104, D106		PMEG3020EP-QX	2		PMEG3020EP-QX	https://w	1	$0.4500	Mouser	771-PMEG3020EP-QX
D107	D105	BLUE	1	1	NCD0603B1	https://w	50	$0.0142	LCSC	C84266
D108	D106	GREEN	1	1	PSC-1608U52GC-G4	https://w	50	$0.0078	LCSC	C22371297
J101, J102, J103	J101	U.FL	3	1	734120110	https://w	1	$0.3463	LCSC	C434806
J104	J102	USB4105-GF-A	1	1	USB4105-GF-A	https://w	1	$0.7400	Mouser	640-USB4105-GF-A
J105, J106	J104	JST-PH	2	1	S2B-PH-K-S	https://w	1	$0.1000	Digi-Key	455-1719-ND
J112, J115	J105	JST-SH	2	1	SM04B-SRSS-TB(LF)(SN)	https://w	5	$0.1685	LCSC	C160404
J113		DM3AT-SF-PEJM5	1		DM3AT-SF-PEJM5	https://w	1	$2.6600	Mouser	798-DM3AT-SF-PEJM5
J114		JST-SH	1		SM08B-SRSS-TB(LF)(SN)	https://w	5	$0.2351	LCSC	C160407
L101, L102	L101	1uH	2	1	74438336010HT	https://w	1	$1.4600	Digi-Key	732-74438336010HTCT-ND
L103		27nH	1		LQG18HN27NJ00D	https://w	10	$0.0492	LCSC	C162550
R101	R104	562k	1	1	FRC0603F5623TS	https://w	100	$0.0009	LCSC	C2933238
R102, R103, R106, R107, R110, R113, R114, R117, R119, R120, R121, R122, R123, R124, R125, R126, R131	R101, R102, R103, R105, R109, R112, R113, R114, R115	10k	17	9	FRC0603F1002TS	https://w	100	$0.0008	LCSC	C2906982
R104	R106	180k	1	1	FRC0603F1803TS	https://w	100	$0.0008	LCSC	C2906999
R105		5.36k	1		FRC0603F5361TS	https://w	100	$0.0009	LCSC	C2930112
R108		31.6k	1		FRC0603F3162TS	https://w	100	$0.0009	LCSC	C2933196
	R108	604		1	FRC0603F6040TS	https://w	100	$0.0009	LCSC	C2930123
R109	R107	13k	1	1	FRC0603F1302TS	https://w	100	$0.0009	LCSC	C2906992
R111		10	1		RTT0310R0FTP	https://w	100	$0.0009	LCSC	C103222
R112		910k	1		SCR0603J910K	https://w	100	$0.0008	LCSC	C3017672
	R110, R111	5.1k		2	SCR0603F5K1	https://w	100	$0.0005	LCSC	C3016319
R127, R128, R129, R130	R116, R117	3.3k	4	2	SCR0603F3K3	https://w	100	$0.0005	LCSC	C3016312
SW101, SW102, SW104, SW105	SW101, SW102	SW_Push_Shielded	4	2	TL3330AF260QG	https://w	1	$0.3600	Mouser	612-TL3330AF260QG
SW103		Slide Switch SPDT	1		500ASSP1SM6QE	https://w	1	$5.1600	Mouser	612-500ASSP1SM6QE
TH101		10k	1		103AT-2	https://w	1	$0.5800	Digi-Key	4316-103AT-2-ND
U101	U101	TI_TPS630250	1	1	TPS630250RNCR	https://w	1	$2.2800	Digi-Key	296-47380-1-ND
U102		LORA1262-915	1		LORA1262-915TCXO	https://w	1	$10.0000	Tindie	Lora1262-915
U103	U102	LORA1280-T	1	1	LORA1280-TCXO	https://w	1	$8.7054	LCSC	C19632391
U104		TVS1800DRV	1		TVS1800DRVR	https://w	1	$0.5500	Mouser	595-TVS1800DRVR
U105		BQ25628E	1		BQ25628ERYKR	https://w	1	$2.8000	Mouser	595-BQ25628ERYKR
	U103	BQ25185		1	BQ25185DLHR	https://w	1	$1.8000	Mouser	595-BQ25185DLHR
U106		LPS28DFW	1		LPS28DFWTR	https://w	1	$4.8100	Mouser	511-LPS28DFWTR
U107		MAX-M10S	1		MAX-M10S-00B	https://w	1	$21.0000	Mouser	377-MAX-M10S-00B
U108	U104	ECMF02-2AMX6	1	1	ECMF02-2AMX6	https://w	1	$0.5300	Mouser	511-ECMF02-2AMX6
U109		TUSB320LAIRWBR	1		TUSB320LAIRWBR	https://w	1	$1.8100	Mouser	595-TUSB320LAIRWBR
U110	U105	ESP32-S3-MINI-1	1	1	ESP32-S3-MINI-1-N8	https://w	1	$3.1000	Mouser	356-ESP32-S3-MINI1N8
U111	U106	MAX17048	1	1	MAX17048G+T10	https://w	1	$1.1226	LCSC	C2682616