Smart Sensor

A device that communicates with a sensor and camera to understand its surroundings

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<u>Work Allocation</u>

Shyamal Patel: Budget, updated table of contents, and researched for the parts price, model number, Software testing, final and Software Design.

Shaikh Haque: Task Allocation and Timeline, data sheet

Akhil Nair: Abstract and User Manual Part 1, updated table of contents, needs and objective statements

Harith Hussien: User Manual Part 2, updated Table of contents, data sheet, Preliminar designs, Final Design, Final hardware design, and researched for the parts price and model number

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Abstract

It is a human right to be able to walk around freely without fear of getting attacked. Despite there being a larger police presence in many places, the rate of muggings and robberies haven't declined. So, in an attempt to add an extra layer of security for lone walkers everywhere, the Smart Crew have been working on a device called the Smart Sensor. This product will clip onto the back of commuters and will enable them to react accordingly to situations that take place behind them. It gives them time to react by outputting audio and haptic feedback in different intervals depending on the distance someone is approaching them while also keeping track of their last known location and taking an image of their pursuer. A mobile application will be used in conjunction with the product to track location, display the stored images, as well as have hot buttons to contact the authorities. A user survey was conducted so as to help with creating design and the marketing and engineering requirements.

Overview:

Project Goals

One of the goals we have for our project is to have the smart sensor be able to detect individuals nearby at different distance intervals. This will be possible by having the LIDAR sensor detect the distance vector of the object/individuals. The next part is to have audio/vibrational feedback to the user once the LIDAR sensor detects an individual nearby. We will create a feedback system that takes the distance vector from the LIDAR sensor and translates that data into 1-5 different audio/vibrational notifications. Lastly, we will add a small camera to the sensor that will take a snapshot image in 20 µs intervals when the LIDAR sensor scans an individual. The snapshot image will be one of the following types: JPEG (or JPG), PNG – Portable Network Graphics (.png), WebP (.webp), TIFF – Tagged Image File (.tiff), PSD. We will have the image stored in the database where the user is able to access them with a timestamp when the image was taken.

Needs Statement

Many people don't feel safe walking alone on the street as the crime rate has increased in the US. According to Gallup News, less than 4 in 10 adults in the U.S (37%)feel that there is an area within a mile of where they live that is not safe to walk alone. On top of that, we frequently hear about people getting attacked while walking alone at night. According to our user survey, the majority of users (85%) stated that they lived in the city and would avoid walking alone at night. Although there are phone apps like WalkSafe, Life360, etc. that can track a person's location, none of them give the user a fast enough reaction time. Our device adds this extra level of reaction time that other apps do not, bringing not only an extra layer of security but also a second sense.

Objective Statement

The objective of this project is to design a sensor that will be able to enable the user to have a sense of safety while walking at night by allowing them to have a quick enough reaction time. This will be achieved by providing haptic and audio feedback for the user when being approached from behind while keeping track of their last known location and taking a picture of the person pursuing the user. When the user receives this feedback, they will have enough time to act appropriately.

Background

Research:

In this article, the autonomous vehicles were using the LIDAR sensors and cameras to understand the environment while the vehicle was being used. They studied the security performance of LIDAR Sensor based on perception in Av setting and that was highly recommended, but it was not explored enough because they were blindly applying LIDAR sensor which is insufficient to achieve the goal due to the machine learning algorithm based on object detection process [3]. The LIDAR sensor and camera will get the position vector of the object upon the detection and take image data with specific types such as PNG or JPG to analyze and identify the object to give the user a feedback signal with either an audio or vibration to alert if the object is crossing the user's personal space. We need to be conscious of the machine learning algorithms because that could save a lot of the bugging time if we know the algorithms beforehand. Machine learning algorithms will help to identify the object with the help of the image data that will be provided from the camera module and convert that data into RGB pixel numbers to compare them with sampling databases to get accurate feedback to the user. The purpose of this article was to use a LIDAR sensor for indoor localization and activity monitoring in an industrial environment with useful knowledge about signal processing to gather the data from the LIDAR Sensor to track the picking orders. This article is related to our project because in our device our purpose is the same as it uses LIDAR sensor and camera to transfer information to the Arduino chip [4]. The purpose of this conference is to show the different ways of the approach to achieve interoperability such as hosting a web service that challenges the battery life, bandwidth, and processing power constraints of low power sensor nodes. They also provided how their system enables sensors and disables the assistant of entering into sleep mode algorithm and using high-level languages. As the conference is discussing the usage of the battery life and bandwidth for the devices our project is also required to determine the usage of the power and bandwidth to store the data to the Arduino chip [5].

Relevant Patents

This patent was about a focusing device that uses the camera lens including the LIDAR sensor and controller coupled to the LIDAR sensor and the camera interface. The controller receives the raw data from the LIDAR sensor with help from the user interface. To get a good image, the device uses the LIDAR sensor and the camera lens with help of the target selection via the user interface and also to determine the focusing setting using the LIDAR data [6].

Current Competitors

The current competitors are Ouster (OUST), Velodyne LIDAR (VLDR), Luminar Technologies (LAZR), AEVA Technologies (AEVA), SPAC CF Finance Acquisition Corp III (CFAC), and Sony using indirect ToF technology [7].

Basic Theory and Concept

LIDAR stands for light detection and ranging. Originally intended for satellite tracking, it was first used in terms of meteorology. It shoots laser beams out which are used to create a 3D representation of the environment by essentially shooting a laser pulse and then calculates the time it takes to get back. This information can then be used to map a 3D environment [4]. The main idea of the SmartSensor device is to use the LIDAR sensor to detect if an incoming object is following someone. The Arduino board will integrate the LIDAR and a camera together and if someone is closing in on the user, a snapshot will be taken while the vibration frequency increases. The camera will then be used to try to identify what exactly the object that is getting closer to the person is doing. The picture and last location of the user are stored on the phone. When all these tools come together, it will act as a type of second sense so that the user can react accordingly [4].

Current Methods/Technologies

Currently, LIDAR is being used to make high-resolution maps to aid with surveying amongst other things. It is also used on driverless cars and even on everyday mobile devices to take 3d scans of objects or even rooms. This technology, while it has existed for a long time, has finally become more consumer-friendly [7].

Current Limitation

There are a few limitations of LIDAR, with its biggest being its inability to properly measure distance in adverse conditions such as snow or rain.

Comparing Concept and Current System

Similarities are using cameras, LIDAR sensors, Arduino modules, and lenses. Differences are our device is more advanced in the design, wearable aspect and our concept of using LIDAR sensors and camera are more toward able to find the distance of the object that coming in the contact of the LIDAR sensor and camera lens then the Arduino will trigger to send a signal to the buzzer [6].

User survey

We have more than 25 surveys of UIC students who said that walking in the city is far scarier and dangerous. Most people were comfortable walking alone at night in the suburbs. Also, 9.4% of survey takers know someone in their family circle who uses some sort of help visualizing their surroundings [Appendix A]. Our survey data shows that people will buy our device for their loved ones for their safety. With this knowledge, we were able to decide that the device should primarily be a security device catered towards a younger generation.

Marketing Requirements:

In *Table 1* we address the customer's needs on what the device is capable of doing by focusing on the user's safety, functionality, reliability, affordability, and ease of use.

Table 1: Marketing Requirements

Number#:	Requirements
1	The device should be portable
2	The device should be reliable
3	The device should have a longer battery life
4	The device can be easy to use
5	The device should be able to detect objects and immediate process everything
6	The device should be affordable
7	The device should trigger everything upon LIDAR sense the object
8	The device should only be detected in a 5-meters radius

Objective Tree:

Objective tree for an Arduino Sensor Device to be used by anyone for safety purposes. The weights reflect the relative importance of needs at each level in the hierarchy.

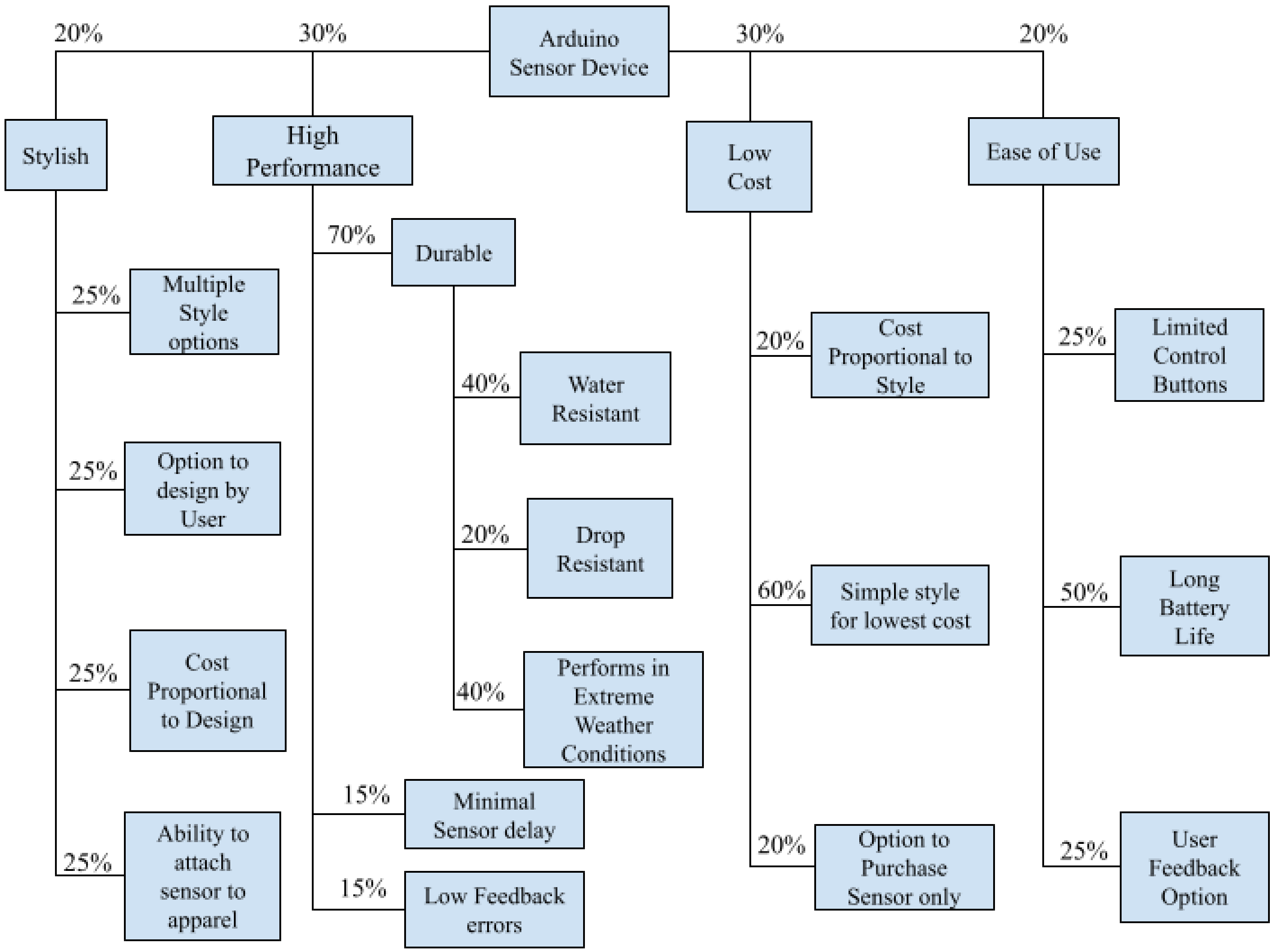

Figure 1: Objective Tree

Project Updates:

In this subsection, we will discuss the project updates. We made some changes to the Marketing Requirements. We had to revise the requirements so we can make some changes to get the desired results. First, we were waiting for the correct parts to be delivered within the dates we requested. The department tried best to get their hands on the fastest availability of parts but product companies somehow shipped it late. Along with that we wanted to test our prototype almost a month before the expo but as we worked on it we faced new challenges. Another challenge we faced was the portability of the device. The housing we made was getting too hot because of different parts used and their sizes. So reliability and portability were the major challenges for us.

Another challenge we faced was changing the document. Mainly the objective tree was the focus because anytime we made change to our plans we had to change objective tree accordingly. The ideas that we couldn’t implement were the durability, weather conditions and the response rate of the sensor.

Engineering Requirements:

The Engineering Requirements in *Table 2* are statements that will give us a rough idea about the device's limitations with help of the abstract, verifiable, unambiguous and traceable.

Table 2: Engineering Requirements

Marketing Requirements	Engineering Requirements	Justification	Applicable Standards	Categories
8,5	The device should be able to detect a person from 5 meters away and capture an image.	A cap of 5 meters allows us to process less data for a faster and more accurate response while alerting the user.	(IEEE Std 802.3aq-2006)	Functionality
6,3	The device's cost of production with power supply, as well as selling price, should be less than $75	An affordable device will be easily accessible to everyone while also being inexpensive to manufacture while still profiting.	(IEEE Std 739-1984)	Economic, Manufacturability, Energy/Power
4	The device should be able to be used by people age 12 and older.	Focused on that age group since 12-year-olds and upstart being independent.	(IEEE Std P2089/D3)	Usability
7,2,1	The device can capture the user's last location based on their phone's location and stores in the phone app	Gives the user a sense of safety no matter where they're located or how visible their surroundings are.	(IEEE Std P1847/D1)	Health and Safety
7	The device should be able to provide haptic/audio and phone alert feedback through the app.	The haptic and audio feedback allows those who have trouble seeing to react appropriately.	(IEEE Std C63.19-2011)	Functionality

Updates on Engineering Requirements:

Red = Unable to complete

Table 3: Engineering Requirements

Marketing Requirements	Engineering Requirements	Justification	Applicable Standards	Categories
8,5	The device should be able to detect a person from 5 meters away and capture an image.	A cap of 5 meters allows us to process less data for a faster and more accurate response while alerting the user.	(IEEE Std 802.3aq-2006)	Functionality
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7	The device should be able to provide haptic/audio and phone alert feedback through the app.	The haptic and audio feedback allows those who have trouble seeing to react appropriately.	(IEEE Std C63.19-2011)	Functionality

Engineering Design Alternatives:

In the Design Alternatives, we have shown three different types of the design with different arrays of components in order to help determine the best design amongst the kinds of combinations.

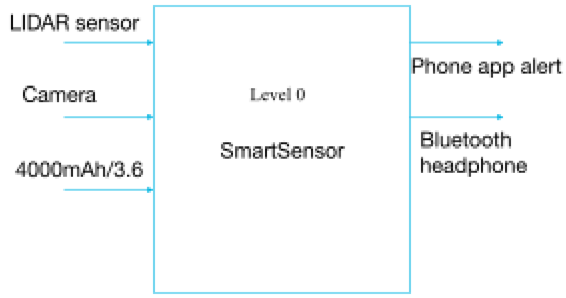


Figure 2: Design 1

Table 4: Concept Map

Connection type	Charging type	MCU	Motion Detection	Image recognition	Navigation	Type of housing material	Software
Phone app	Wire Cord	Arduino with wifi/Bluetooth	LIDAR sensor	IMX219-200 wide angle camera (3280x2464) resolution	Smart sensor GPS	PLA	OpenCV Single Shot Detection
Bluetooth connection	Wireless Coil	Jetson nano 2gb-4gb GPU	Ultrasonic sensor	IMX219-160 IR-cut infrared camera (3280x2464) resolution	Smartphone GPS	Nylon	TensorFlow
Buzzer	Magnetic contacts	Tiva-C	PIR with Ultrasonic sensor	IMX219-200 wide angle camera (3280x2464) resolution			Image classification using convolutional neural networks (CNNs)
		Raspberry pi 4 with Wifi/Bluetooth					

As shown in the design 1 concept map, this design revolves around the Jetson nano board and the LIDAR sensor. LIDAR is designed for detecting individuals nearby and is also equipped with a camera for image recognition. The smart sensor is equipped with a 4000mAh/3.6V internal battery for extended usage. It has an app designated for collecting and processing data coming from the LIDAR sensor and camera and is able to have a Bluetooth connection with the user's smartphone. The sensor will rely on the smartphone's GPS signal to accurately pinpoint the location of each scan. The housing will be 3-D printed from nylon material; as it's durable, flexible, and has a quality finish. This design has different options for power supply capacity and types of material for 3-D printing, the selected options for these two categories are interchangeable based on the cost of the material.

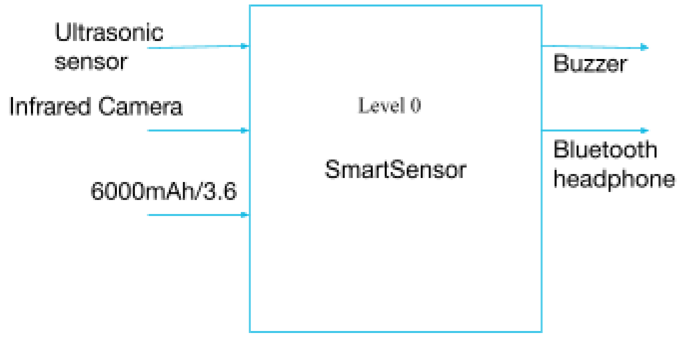


Figure 3: Design 2

Table 5: Concept Map

Connection type	**Charging type**	**MCU**	**Motion Detection**	**Image recognition**	**Navigation**	**Type of housing material**	**Software**
Phone app	Wire Cord	Arduino with wifi/Bluetooth	LIDAR sensor	IMX219-200 wide angle camera (3280x2464) resolution	Smart sensor GPS	PLA	OpenCV Single Shot Detection
Bluetooth connection	Wireless Coil	Jetson nano 2gb-4gb GPU	Ultrasonic sensor	IMX219-160 IR-cut infrared camera (3280x2464) resolution	Smartphone GPS	Nylon	TensorFlow
Buzzer	Magnetic contacts	Tiva-C	PIR with Ultrasonic sensor	IMX219-200 wide angle camera (3280x2464) resolution			Image classification using convolutional neural networks (CNNs)
		Raspberry pi 4 with Wifi/Bluetooth					

As shown in the design 2 concept map, this design revolves around Raspberry pi with wifi/Bluetooth and an Ultrasonic sensor. The sensor is designed for detecting individuals nearby; however, it doesn't have the ability to detect all the details of curvatures when compared to LIDAR. It is also equipped with an infrared camera for detecting individuals nearby. The smart sensor is equipped with a 6000mAh/3.6V internal battery for extended usage, far more than design 1. The Smart sensor is connected to the user's device via Bluetooth. The sensor will rely on the internal programming of the Raspberry pi to process the data collected from the camera and sensor. The tradeoff of using a raspberry pi 4 vs. arduino board is we are able to have more processing power using the raspberry pi, essentially making it a mini computer. While the arduino board has limitations, as it mainly works as a controller with very limited amount or RAM. This design has GPS installed in its internal hardware, enabling it to accurately pinpoint the user's location. The housing will be 3-D printed from nylon material; as it's durable, flexible, and has a quality finish. This design has different options for power supply capacity and types of material for 3-D printing, the selected options for these two categories are interchangeable based on the cost of the material.

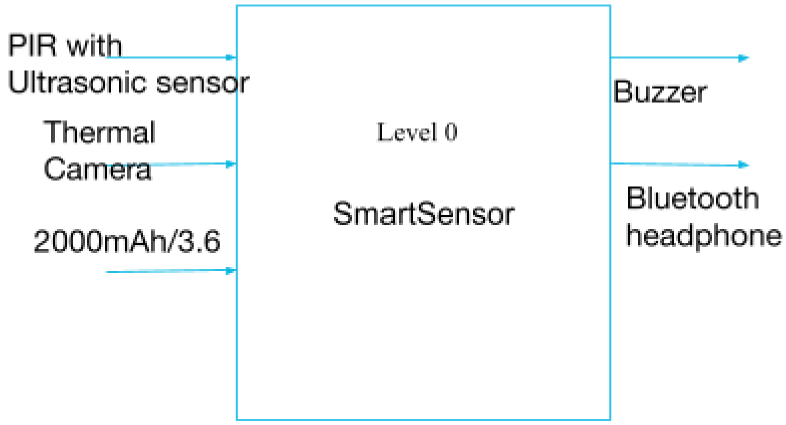


Figure 4: Design 3

Table 6: Concept Map

Connection type	**Charging type**	**MCU**	**Motion Detection**	**Image recognition**	**Navigation**	**Type of housing material**	**Software**
Phone app	Wire Cord	Arduino with wifi/ Bluetooth	LIDAR sensor	IMX219-200 wide angle camera (3280x2464) resolution	Smart sensor GPS	PLA	OpenCV Single Shot Detection
Bluetooth connection	Wireless Coil	Jetson nano 2gb-4gb gpu	Ultrasonic sensor	IMX219-160 IR-cut infrared camera (3280x2464) resolution	Smartphone GPS	Nylon	TensorFlow
Buzzer	Magnetic contacts	Tiva-C	PIR with Ultrasonic sensor	IMX219-200 wide angle camera (3280x2464) resolution			Image classification using convolutional neural networks (CNNs)
		Raspberry pi 4 with Wifi/ Bluetooth					

As shown in the design 3 concept map, this design revolves around Tiva-C and PIR with an Ultrasonic sensor. The sensor is designed for detecting individuals nearby with infrared motion. It is also equipped with a Thermal camera for detecting individuals nearby with heat signals. The smart sensor is equipped with a 2000mAh/3.6V internal battery for efficiency. The Smart sensor is connected to the user's device via Bluetooth. The sensor will rely on the internal programming of the Tiva-C to process the data collected from the Thermal camera and PIR with an Ultrasonic sensor. This design will use smartphone GPS to accurately pinpoint the user's location. This design has GPS installed in its internal hardware, enabling it to accurately pinpoint the user's location. The housing will be 3-D printed from PLA material; as it's durable, flexible, and has a quality finish. This design has different options for power supply capacity and types of material for 3-D printing, the selected options for these two categories are interchangeable based on the cost of the material.

Design Comparisons:

Table 7: Comparison of designs

Similarities	● All designs must have a portable battery, Camera, sensor, and GPS signal. ● Design 2, 3 had Bluetooth for an audio response, Buzzer for the user's alert with vibration, and a GPS module as inbuilt.
Differences	● All Designs will have different forms of recharging the battery. Design 1 utilizes a basic wire cord for more reliability and can recharge the battery fastest for the device with a straight connection to an outlet. Design 2 utilizes a wireless connection with the device for anywhere usage and ease to recharge and no need to find the outlet or carry the wire cord. Design 3 utilizes magnetic contacts connected to the magnetic charger cord to the device. ● As a device is used on a daily basis the user has the ability to get alerts beforehand and has full control to report any incident. The user will be guided on how to use and how to connect everything with the phone or Bluetooth headphones. There will be more features in the phone app for users' safety and to take quick action in a difficult situation. Design 1 uses a LIDAR sensor to keep the distance of the object to trigger the camera to take the image of the object and then the data transfer to an Arduino chip will keep updating the user with audio and vibration feedback throughout the phone app or Bluetooth headphone. This is the same with Design 2, but instead, it uses an Ultrasonic sensor, Infrared camera, and Raspberry Pi to communicate with users and other modules. This is the same as Design 3, but instead, it uses a PIR with an Ultrasonic sensor, a Thermal camera, uses PLA material for device housing, and Tiva-C to communicate with users and other modules.

Design Alternative Evaluation Criteria

Selection criteria:

For the selected criteria, we chose the following criterias that we felt were important. People would want to buy a product that is developed and designed nicely; so keeping in mind the design alternatives, our group examined each alternative that fits into the criterion.

Table 8: The selected criteria

Criteria	Justify
Cost to consumer	The price is important, if the price is too high, the consumer will not purchase the product thereby losing potential customers.
Your groups' technical knowledge about the design alternative	The teammates should have knowledge about the design alternatives such as the components of the device, and the functionality of parts that can be used to come up with a different prototype in a limited time.
The time needed to complete design and development	The time taken to complete the design and development will determine the complexity of the project and also how to price out the final product.
Suitability for demo for 397	The demo that will be presented in 397 will be the most effective and competent one out of all our design plans.
Ease of product use	Users should be able to operate this device with a simple instruction manual

Pair-wise comparison of criteria:

1 = equal, 3 = moderate, and 5 = strong, 7 = very strong, 9 = extreme.

Table 9: Pairwise Comparison

	Cost to consumer	Your groups' technical knowledge about the design alternative	The time needed to complete design and development	Suitability for demo for 397	Ease of product use	Geometric Mean	Weights
Cost to consumer	1	4	0.89	2.08	4.50	2.02	0.34
Your groups' technical knowledge about the design alternative	0.25	1	0.94	3.10	5.50	1.32	0.22
The time needed to complete design and development	1.13	1.06	1	3.50	4.50	1.80	0.31
Suitability for demo for 397	0.48	0.32	0.29	1	5	0.74	0.13
Ease of product use	0.22	0.18	0.22	0.20	1	0.28	0.05

Selection of Design Alternative & Justification

Design alternative relative to the criteria:

As a team, rate each alternative relative to the criteria. This section, including the final list of ratings. Use the scale presented in the lecture: 1 = does not meet the criterion, 3 = partially meets the criterion, and 5 = completely meets the criterion.

Table 10: Design Alternatives Criteria

	Cost to consumer	Your groups' technical knowledge about the design alternative	The time needed to complete design and development	Suitability for demo for 397	Ease of product use
Design 1	5	1	5	3	5
Design 2	1	3	1	5	3
Design 3	3	1	5	3	5

Decision Matrix:

Present the final decision matrix, which includes a list of the alternatives, final list of criteria, weights for each criterion, and the final score for each alternative.

Table 11: Decision Matrix

Decision Matrix		Design 1	Design 2	Design 3
Cost to consumer	0.34	5	1	3
Your groups' technical knowledge about the design alternative	0.22	1	3	1
The time needed to complete design and development	0.31	5	1	5
Suitability for demo for 397	0.13	3	5	3
Ease of product use	0.05	5	3	5
Score		4.11	2.11	3.43

Final Decision:

Based on the information we got from the decision matrix, we noticed that Design 2 and 3 scored lower than Design 1. In terms of time to complete design and ease of product use, all three designs scored the same but when it came to our technical knowledge Design 1 had the best rating. On top of that, Design 1 had the maximum rating for all categories except cost to consumer in which it only partially met the criteria.

Preliminary Design:

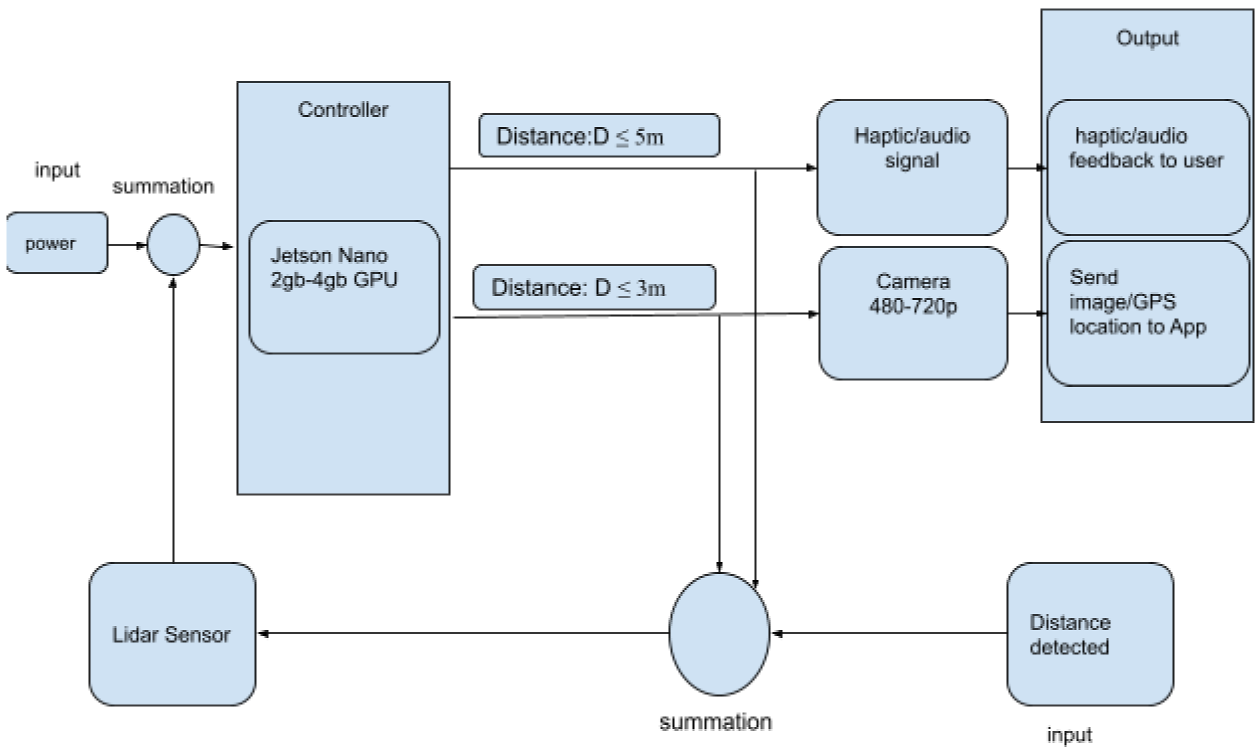


Figure 5: Initial Hardware Design

<u>Circuit design</u>:

Draw a detailed schematic diagram for every circuit that you intend to build. Label component values, IC pin numbers. In an appendix, include datasheets for each integrated circuit and semiconductor device used in your circuit.

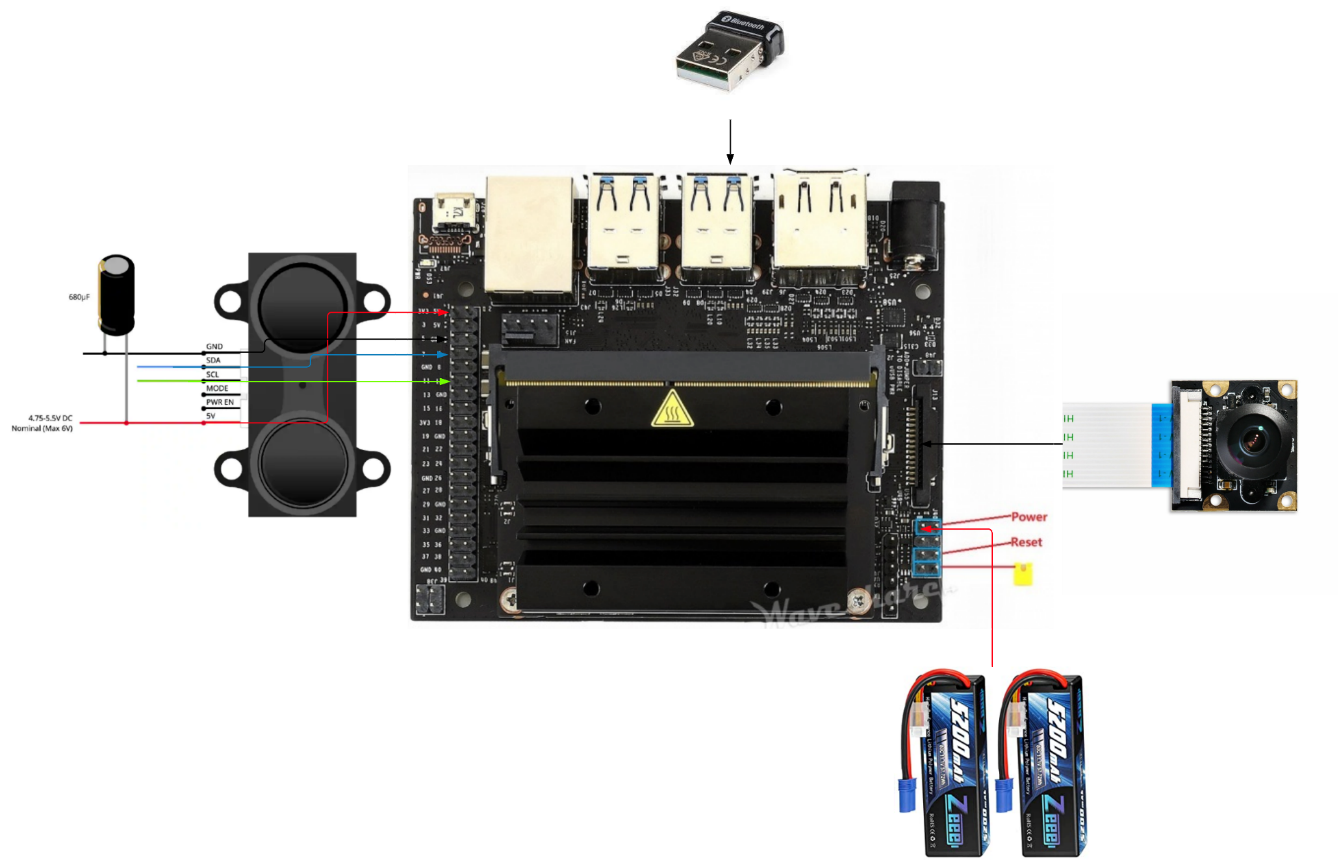


Figure 6: Circuit Design

Software design:

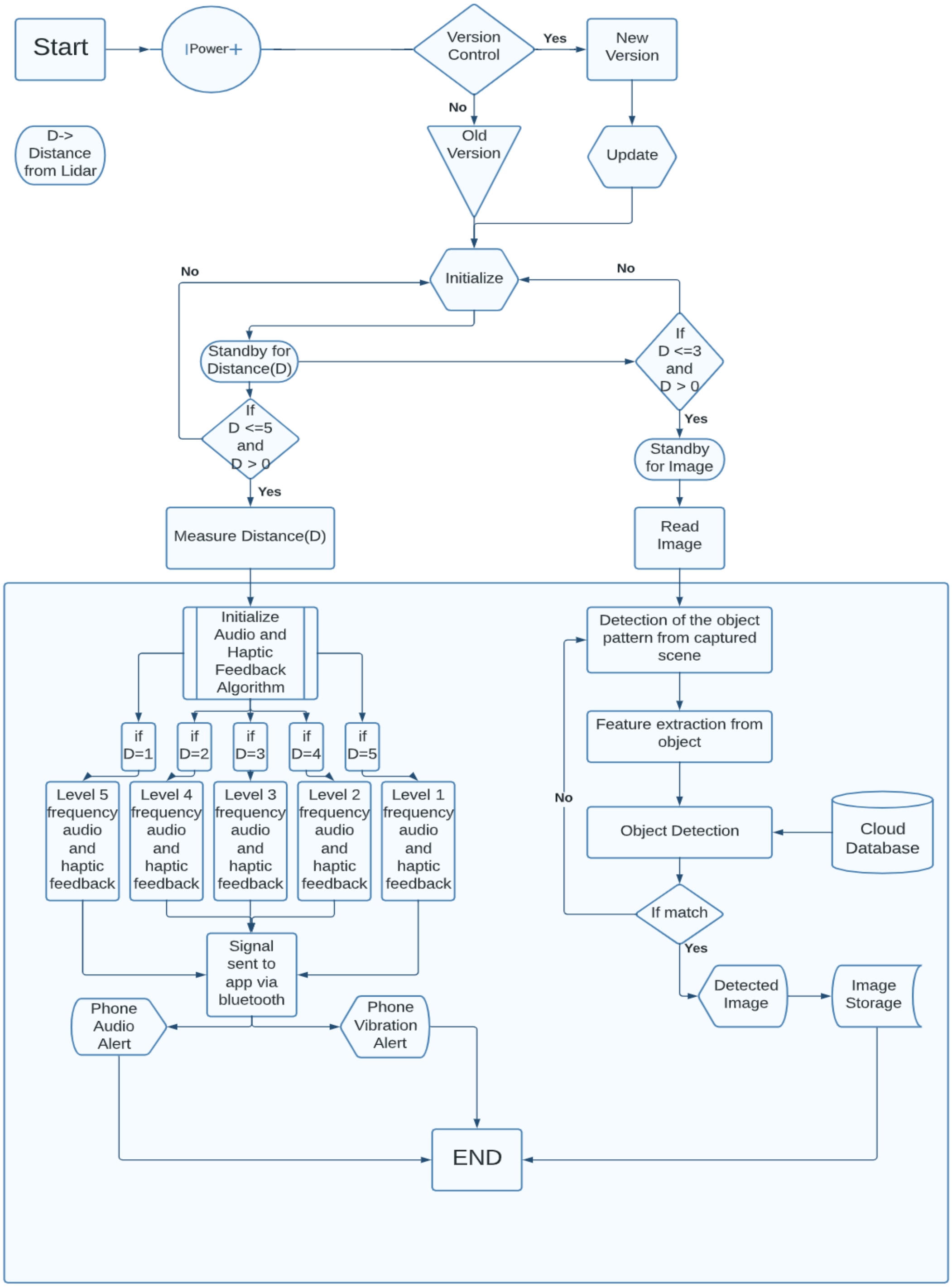


Figure 7: Software Design

Differing frequencies will go up to the maximum phone volume, but will be in increments of 5dB starting at 0. It's labeled as Level 1-5 because each phone is different.

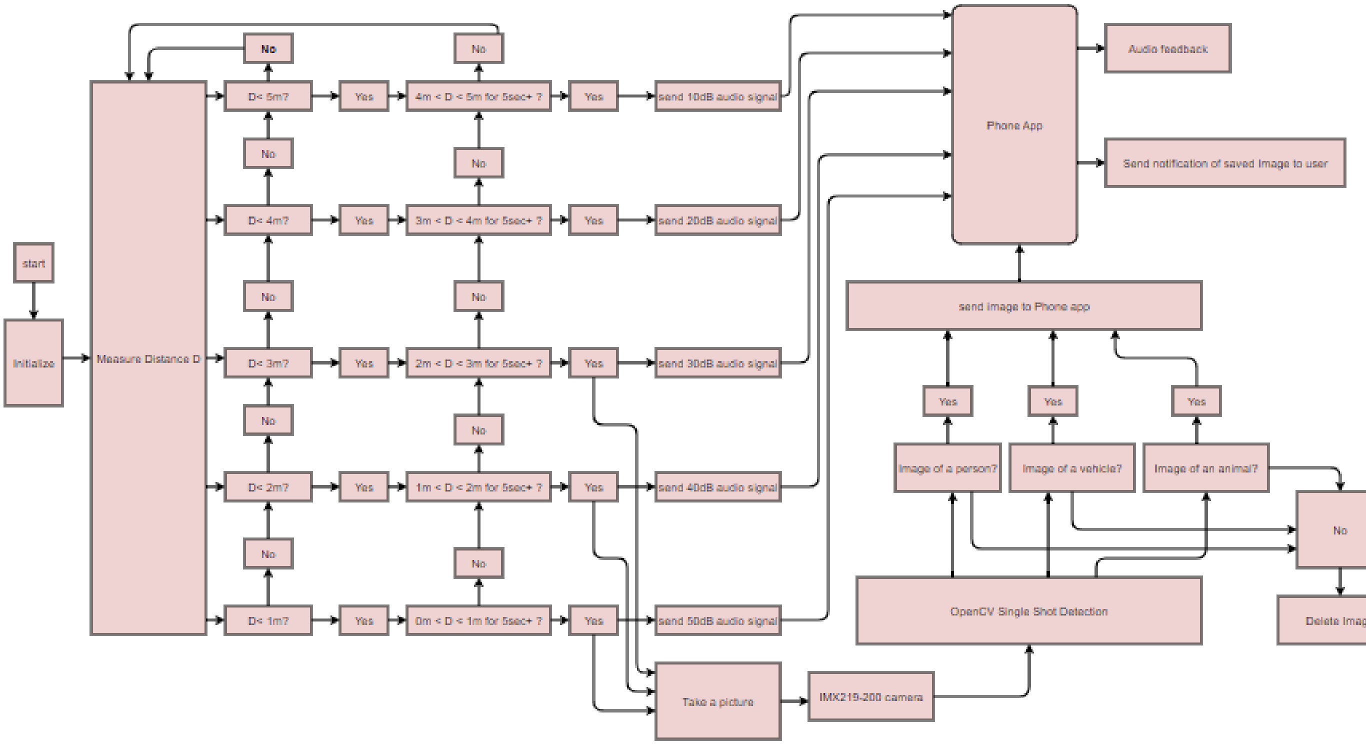


Figure 8: Software Design Distance Parameters

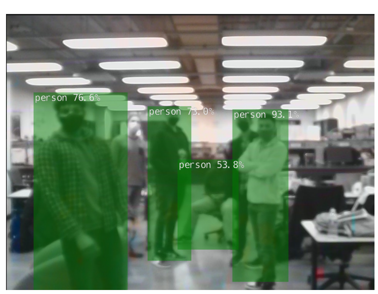
Testing:

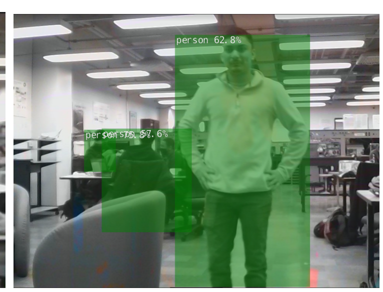
LIDAR

There were multiple stages of testing due to there being many different components coming in at different times. Thus, we tested each component separately. First off, there was the **LIDAR**, which due to many different issues we needed to wait for the Jetson Nano to test. First, we tested the LIDAR in a controlled setting. This to us, was the senior design lab. First we set it up on a stable surface and measured the distance as we walked closer and further. The numbers were given in centimeters and were accurate as measured by a yardstick. Next, we had to test what the result would be like on an uneven surface. Basically, while the LIDAR was laid flat, sideways, or upside down we recorded data. We noticed that in situations when the LIDAR was upside down there were some discrepancies with the data. Finally, the last phase of LIDAR testing included actually sitting on the back of the user. This would include jumping, running, and also testing it out in adverse visual conditions. While jumping and running, we noticed that as long as the LIDAR was not violently shaking around it was still able to hold the connections and produce accurate data. This was while there was a target immediately behind the person. We don't expect this to be used in situations where people are jumping or running.

Machine Learning

Next up in testing was the machine learning aspect of it. In a basic sense, the pedestrian network we chose initially was very helpful in giving a basis for detecting pedestrians. Unfortunately, this network was unable to properly detect masks so we had to feed it test data that basically had all of us stand in different variations with masks on. Now that the network had mask recognition, we needed to make sure it was able to pass the same tests that the LIDAR was able to. Unfortunately for us, we were issued a faulty camera. Luckily this was good enough for us to test blurry vision and it worked like a charm. Not only did the algorithm detect everyone in the room, it detected them with an extreme level of out of focus.





We increased the number of pedestrians it could detect by reducing the threshold and thus was able to detect a max total of 10 pedestrians behind the user. Finally, we tested it out when connected to the user and while they were doing a large amount of activity. Surprisingly enough it was able to detect people with a greater than 65% confidence level while the user was running and jumping around.

Application

Testing Steps:

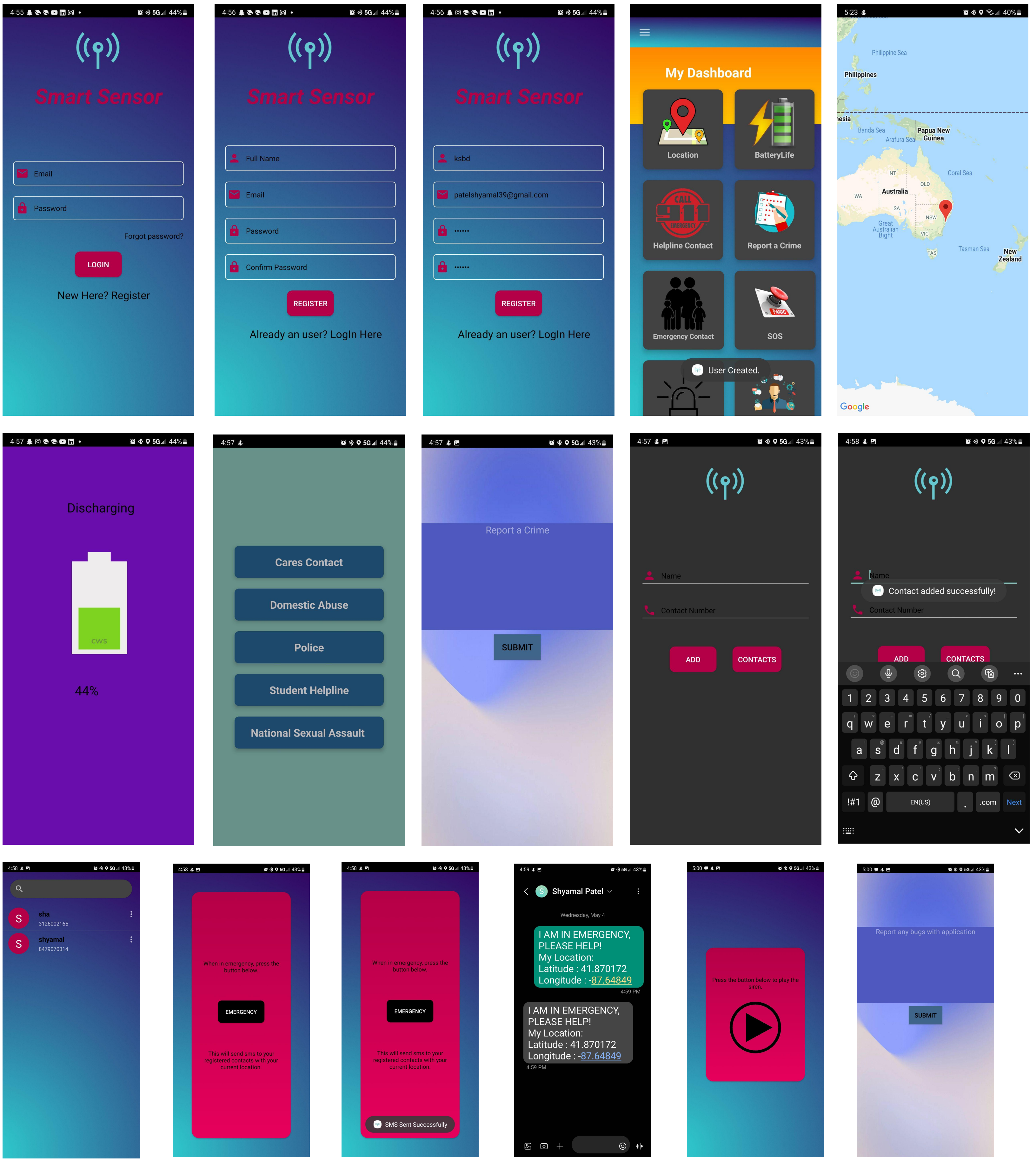
A. Does the login and register page work perfectly
B. After successfully login into the user's account the user is able to click on any buttons without crashing the application.
C. Does the 8 cool feature functional work correctly such as Location detector, Battery Life checker, user can able to add emergency contact to use in emergency sistution via pressing the panic button, helpline contact(cares contact, and etc), fake siren, support and report crime.
D. The main purpose of this application is that the user is able to receive images with detection of a person from Jetson Nano via firebase.
E. Profile and settings page were not able to complete due to time constraints.
F. Does user can able to logout successfully

Variables Tested:

A. Functional of the application
B. Communication between Jetson Nano and application via firebase for images and login & registration.
C. Application responsiveness and Crash reports

Results:

Results are outlined below with images.



Final Design:

To begin, we have created the final design for our device described in design alternatives. The final design contains level 1 schematic of the device, the circuit schematic of the hardware components and fully detailed application with functional block diagram.

The preliminary design had some issues with connecting the jetson nano board to the camera and lidar sensor. Originally, we ordered all the necessary components to build the preliminary design; however, the jetson nano board was not delivered due to backorder issues with the supplier. As a result, we requested a loaner jetson nano board from a graduate student working under the advisor of our project. The loaner jetson nano board was an older model and it had some issues with connecting to the components we ordered.

The initial lidar sensor had some connection issues when it was wired to the jetson nano, as the lidar sensor would not give any type of feedback. The jetson nano also couldn't recognize the ordered camera and therefore was unable to establish a link internally.

We decided as a team to interchange the components that were not connecting properly. As a result, the camera, lidar sensor, power supply, and the bluetooth adapter had to be interchanged. The camera and lidar sensor couldn't be connected to the loaner board, this caused us to use a USB connected camera as a replacement and also use a different type of lidar sensor in order to function properly. Furthermore, we needed to use an Arduino Uno board as the connection between the lidar sensor and the jetson nano board.

Below are the final block diagram, circuit schematic for the jetson nano, and the circuit schematic for the arduino uno connection with the lidar sensor.

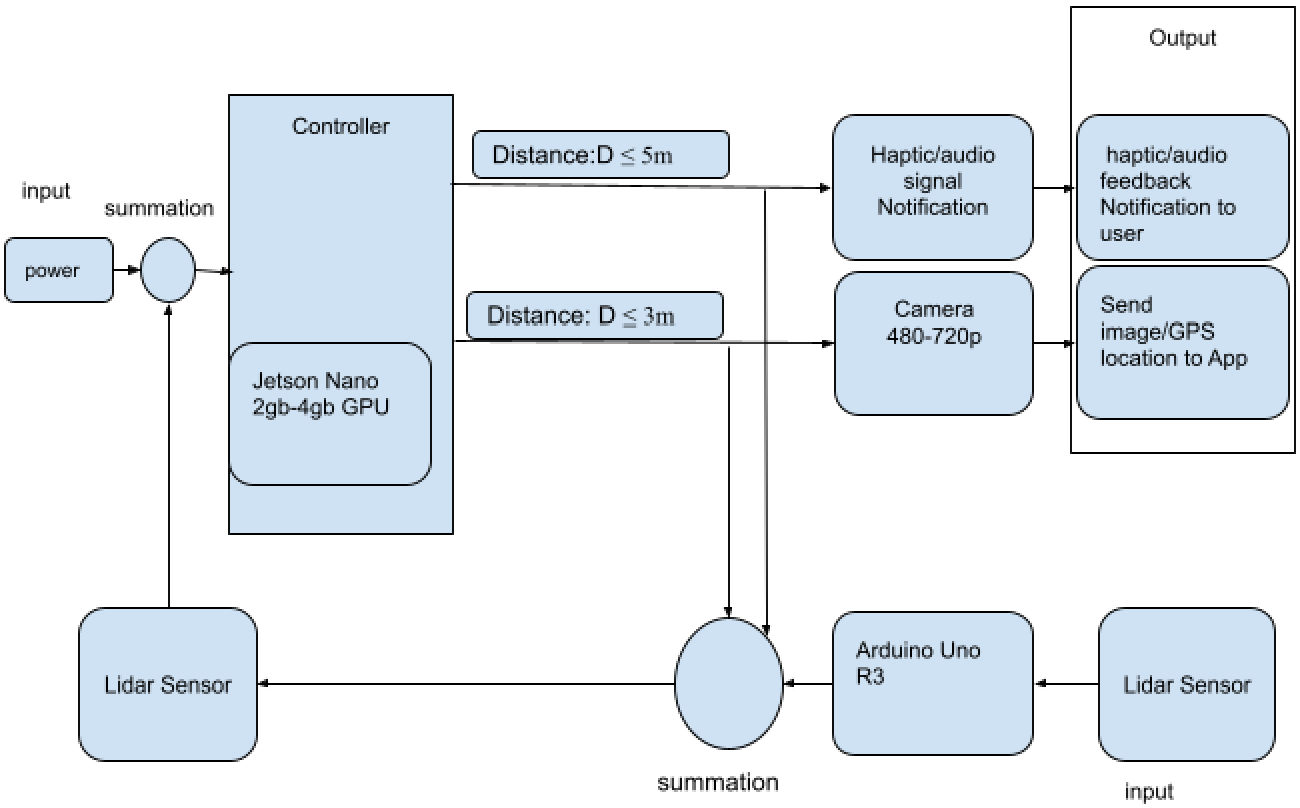


Figure 9: Final Hardware Design Distance Parameters

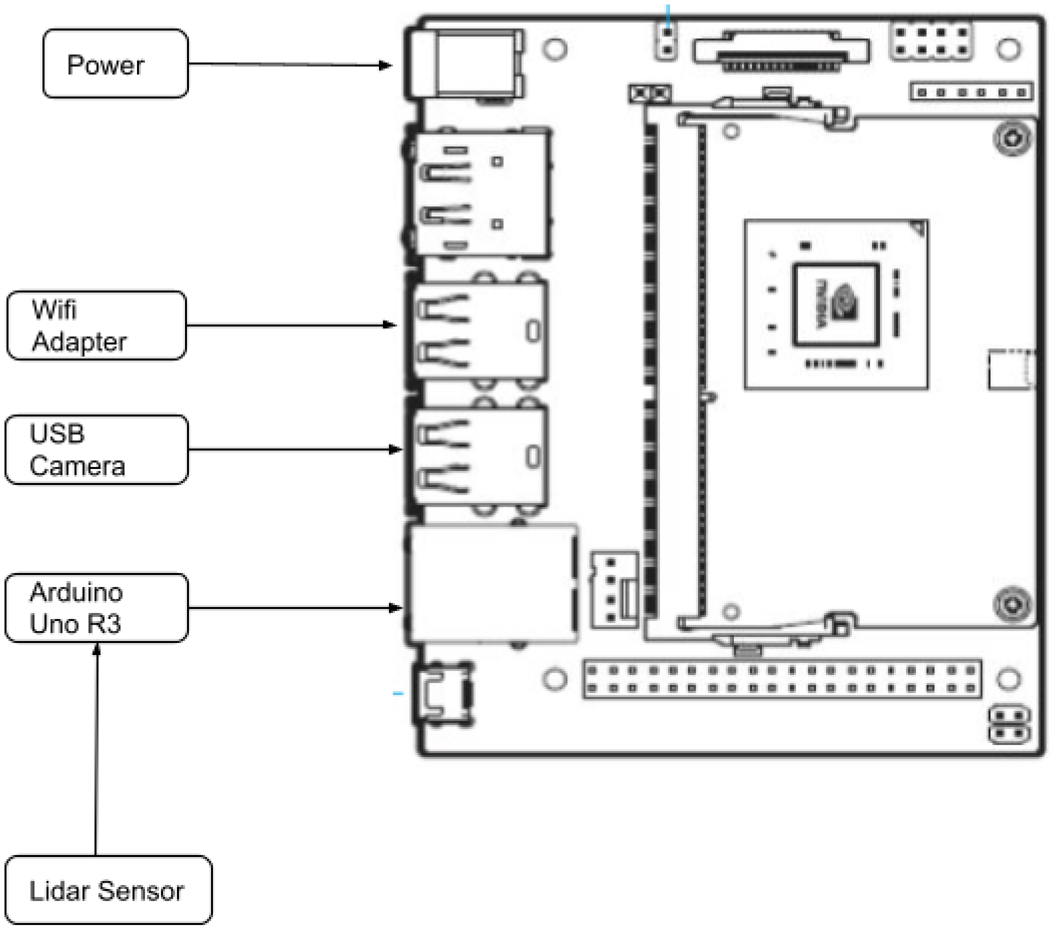


Figure 10: Final Hardware Schematic Design

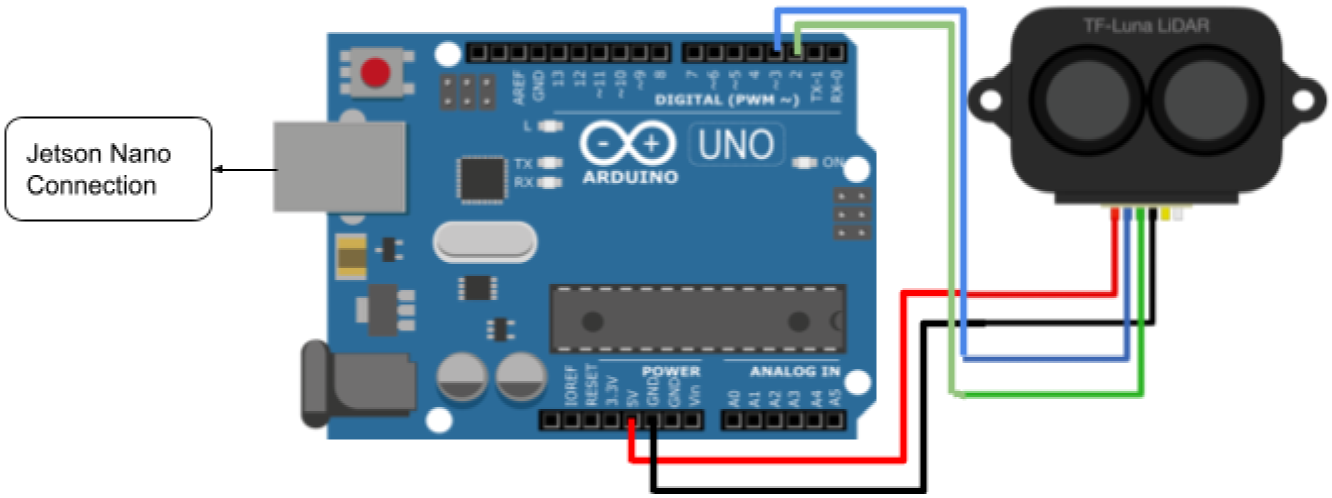


Figure 11: Final Hardware Schematic (Arduino Board)

Bill of Materials

Table 12: Bill of Materials

S.No	Item	Price without tax
1	Nvidia Jetson Nano	$59.00
2	Arduino Uno R3	$33.99
3	TF-Luna Lidar Sensor	$24.90
4	USB Camera	39.99
	Total	**157.88**

Software design

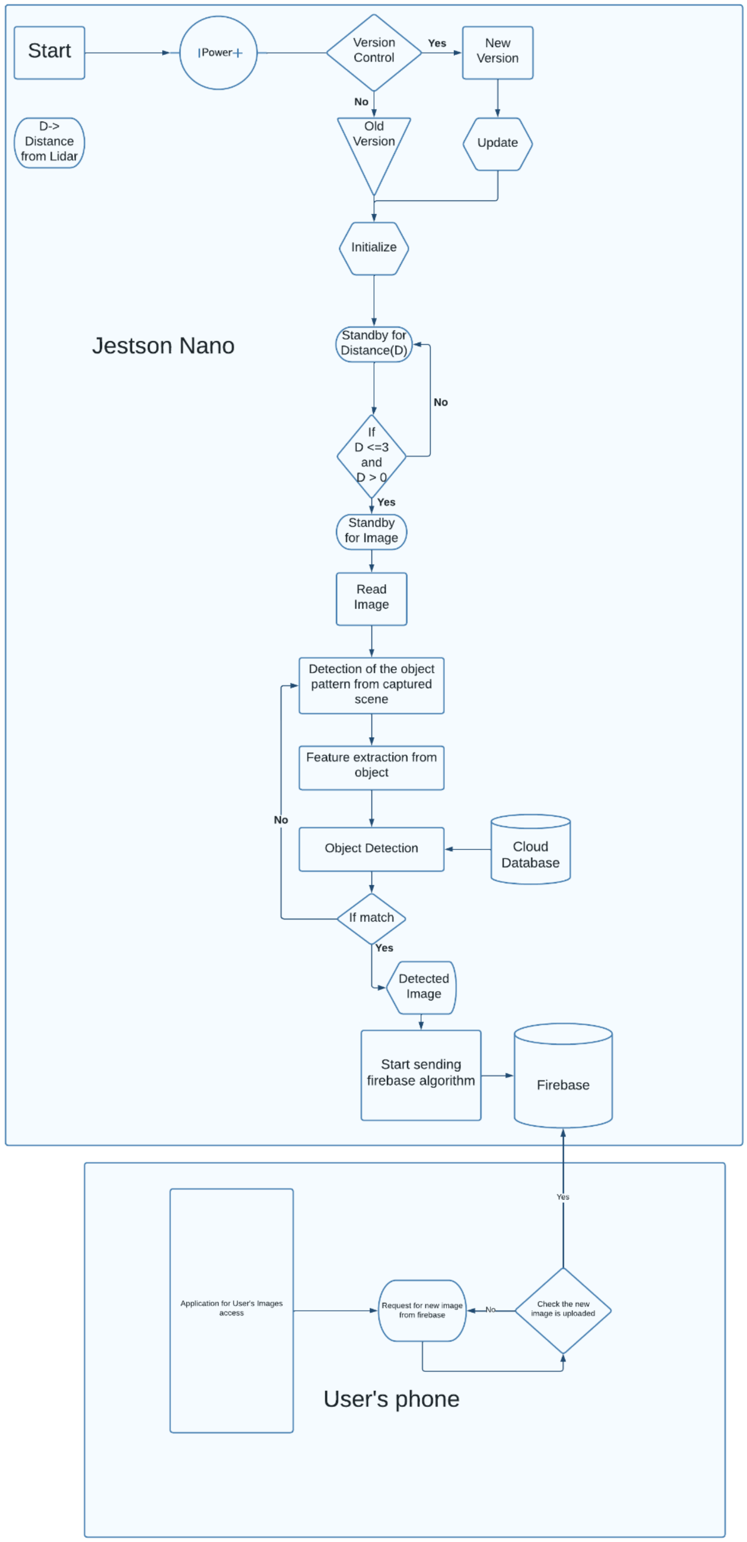


Figure 12: Final Software Schematic Design

Task Allocation and Timeline

Product Cost Analysis and Budget:

Anticipated Budget: $250

Table 13: Budget

Part Name	Quantity	Cost	Total Cost
Lithium Ion Battery	2	$19.95	$39.9
Lidar sensor	1	$ 59.95	$59.95
Bluetooth Adapter	1	$26.25	$26.25
Camera	1	$30	$30
Jetson nano board	1	$73.75	$73.75
Resistors(4.7k, 470, 1k) *	3	$0.00	$0.00
Capacitor	1	$0.00	$0.00
LED Light	4	$0.00	$0.00
Push Button	5	$0.85	$4.25
		Total:	$234.10

Note: The price as of December 08, 2021

Table 14: Task Allocation

Start Date	Finish By	Week	Team Lead	Task	Description
1/10/2022	1/14/2022	1	Shyamal	Planning Begins	Set the schedule and revise dates
1/10/2022	1/14/2022	1	Akhil	Faculty Advisor	Discuss upcoming weeks in detail
1/17/2022	1/21/2022	2	Shaikh	Parts Ordering	Order parts from the parts list
1/22/2022	1/28/2022	3	Harith	Faculty Advisor Meetup	Discuss Resources
1/24/2022	1/28/2022	3	Shyamal	Resources Collected	Use and Implement useful data and information
1/24/2022	1/28/2022	3	Akhil	Faculty Advisor	Discuss C language implementation
2/1/2022	2/4/2022	4	Shaikh	Programming Starts	Start on software build
2/7/2022	2/11/2022	5	Harith	Faculty Advisor Meetup	Discuss parts and hardware
2/14/2022	2/18/2022	6	Shyamal	Hardware Assembling	Start on hardware side of prototype
2/21/2022	2/25/2022	7	Akhil	Faculty Advisor Meetup	Revise programming code
3/1/2022	3/4/2022	8	Shaikh	Testing C	Finalize program
3/7/2022	3/11/2022	9	Harith	Final Faculty Advisor Meeting	Discuss final code and hardware
3/14/2022	3/18/2022	10	Shyamal	Build Start with Programming	Hardware and program discussion
3/19/2022	3/25/2022	11	Akhil	Faculty Advisor Meetup	Discuss progress altogether
3/21/2022	3/25/2022	11	Shaikh	Conditional Release	All four partners meet to share progress and report

3/26/2022	4/1/2022	12	Harith	Faculty Advisor Meetup	Plan prototype last details
3/26/2022	4/1/2022	12	Shyamal	Test prototype	First test on prototype
4/2/2022	4/8/2022	13	Akhil	Faculty Advisor Meetup	Discuss progress
4/9/2022	4/15/2022	14	Shaikh	Check Prototype	Other member of group tests prototype
4/16/2022	4/22/2022	15	Harith	Final Touch Ups	Main hardware member checks any last minute hardware details/errors
4/23/2022	4/29/2022	16	Shyamal	Final Presentation	Smart Crew presents the working prototype

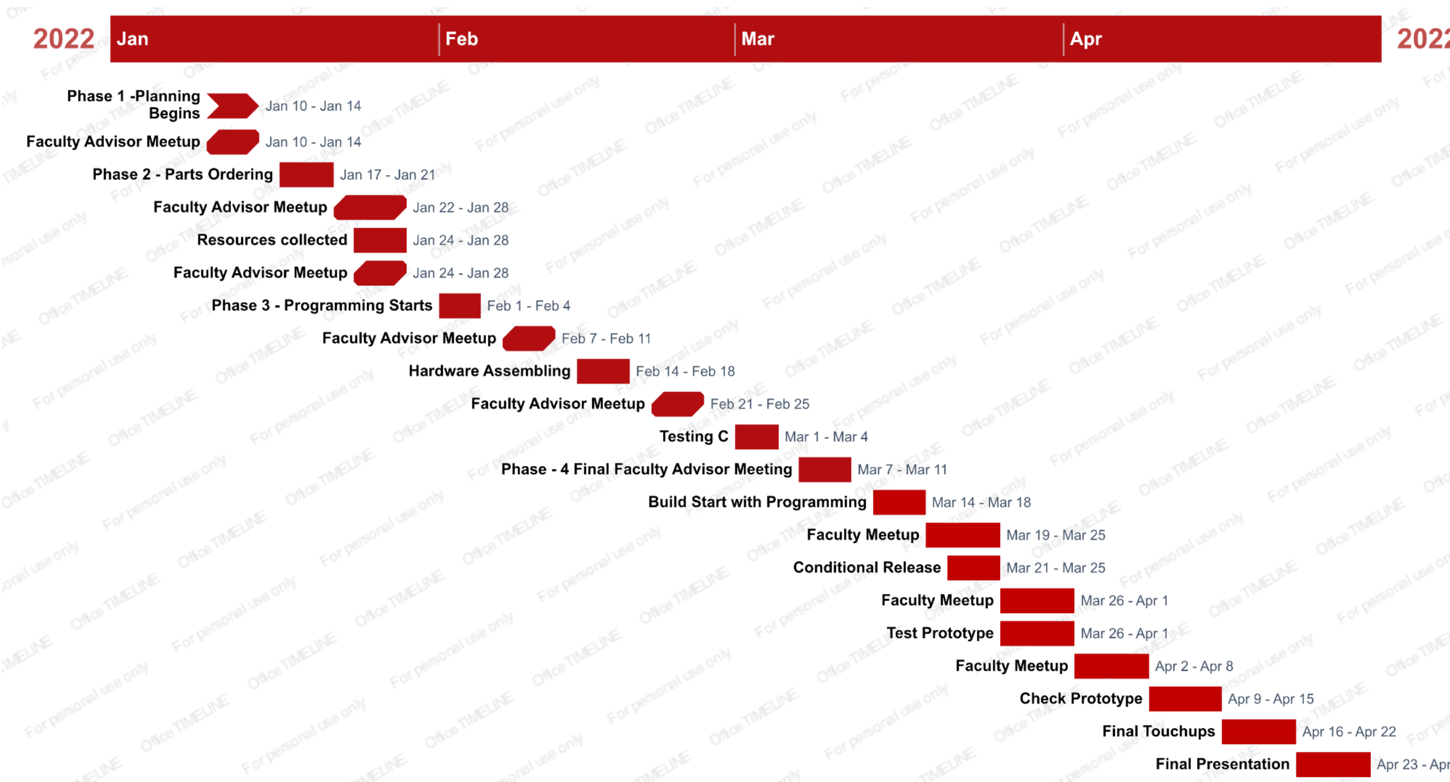


Figure 13: Timeline

Contribution:

Shaikh Haque:

In ECE 396, we distributed some tasks amongst ourselves and me and Harith were hardware side so we discussed what guidelines we are going to follow. Initially, there were issues with parts in the beginning so we didn't know what to divide between us. Finally we decided and we mostly worked alongside on the wiring of the device. I told my group about the design and structure of the parts. I was in constant touch with our TAs and Guadalupe Loza for the parts. The timeline that I made in 396 was hard to follow but I made sure that we were following deadlines.

Akhil Nair:

We split the tasks up by software and hardware. I focused primarily on the machine learning aspect of the project. This meant that I was researching and figuring out how to implement it with the LIDAR sensor. Unfortunately, due to issues we had we bounced back and forth between the microcontrollers. Once we finalized on the Jetson Nano, I got to work on researching and was lucky to find that the Jetson Nano itself had a very nice machine learning library for us to use. I took that and then built off of it so that it would work with our project. I also worked with Harry, our go to for hardware, to connect the LIDAR sensor with the Jetson Nano's machine learning that took a screenshot when someone was in close proximity to the user. This information was then passed on, pushed to the cloud and then would be displayed on the application that Shyamal created. Originally, it was meant to be sent via bluetooth but the Linux distro had a bluetooth box that would not close. I also work on the 3D housing for the Jetson Nano but unfortunately due to time constraints a proper design wasn't able to be made. Finally, we all contributed to the core assignments of the class.

Shyamal Patel:

From ECE 396, I started by researching ideas to store images that were captured from the camera that is connected to the Jetson Nano. The idea was to keep our device portable strapped around the user's body on the back and the camera facing away from the user's body with the Lidar Sensor that will detect the object within the range of 5 meters and also it should be able to last long with lithium batteries. As I was searching through many thoughts, I came up with the idea that was to create an application that will be able to connect directly to the Jetson Nano via bluetooth to retrieve the Detected image from Akhil's algorithm. I also worked with Akhil to understand his algorithm of detecting humans in the image and then figure out how to send images directly to the application via bluetooth. We were able to send images directly to the application with detection, but we came across an issue that was we were not able to close the dialog box automatically of the bluetooth in the Jetson Nano's OS until we manually close the bluetooth dialog box with the mouse. After that problem we came up with a solution that was able to resolve all the concerns. It was to move everything from bluetooth to wifi. The idea was to send the images to the firebase to store the images. After that the application will reach out to the firebase data storage to retrieve the images and show the user the proper Date and Time of the image was captured. Also, we could not able to accomplish the haptic and audio feedback for alerting the user with different level of frequency due to the time delay on the parts, so I added some cool features that could help user in emergency situation such as live location, Batterylife, Emergency helpline contacts, Report a crime, able to add Emergency contact to send sos message with panic button, Fake siren to scare the strange in emergency situation, and support to report any bugs to the application.

Harith Hussien:

I worked mainly on the hardware design of the project and also took the lead working on the Lidar Sensor portion of the project. I allocated time towards researching the lidar sensor and troubleshooting the errors that were occuring with it. I performed multiple testing of the lidar sensor and used the user manual as a guide to troubleshoot the different types of errors that were occurring. I tested the lidar sensor with the Jetson nano initially but that didn’t produce any results, even after the troubleshooting. I then replaced the Jetson nano with a Raspberry pi that was loaned from the ECE department to test out the functionality of the lidar sensor, as the lidar sensor is compatible with the Raspberry pi. That also gave inconsistent data, and the errors were still present. After more research about the Garmen lidar sensor, I concluded the lidar sensor as defective, due to the inconsistent results and the connection issues present when attempting to connect to the microcontroller.

The next step I took was acquiring a new sensor, the TF-Luna Lidar sensor. This sensor needed to be connected to an Arduino Uno board in order to function, as the sensor had compatibility issues with different microcontrollers. I acquired an Elegoo Uno R3 board to be used as the connection between the newly acquired lidar sensor and the jetson nano. I then collaborated with Akhil and Shyamal to design the layout of how the lidar sensor will scan. I provided the necessary code to read the data collected from the lidar sensor scans; while akhil took the initiative to help create the loop for scanning and also set up the threshold triggers sending the necessary data to the cloud once the minimum distance from the lidar is scanned and recorded.

Lessons Learned:

Shaikh Haque:

This project taught me a lot of important virtues. First of all time management was an important lesson gained throughout the course. It would be tough to complete the assignment before the deadline if you didn't have good time management abilities. The courses at UIC were very helpful in this regard because all courses emphasized time management skills. Having good time management skills was beneficial in keeping things on track. In the future, time management training will assist in ensuring that all potential jobs are accomplished within the stated deadline. Another thing was the parts ordering and planning so what I learned is one has to be prepared for changes in the planned timeline.

Akhil Nair:

One thing I was most excited about this class was the ability to work on a tech project outside of the boundaries of a grading scale and other classroom criteria. I definitely got that and in doing so was able to learn a lot more than I would have otherwise. It was also really nice working with 3 other students and having material dependent on their progress as well. It had a very real industry feel that I really enjoyed. On top of that, we went from essentially not knowing each other at all to becoming close friends and partners which I think is equally as important as the rest of the project. I also learnt a ton of the things that will also apply to the workforce, such as dealing with unwanted hitches such as parts coming in later. Due to also having many other classes, time management was another thing I garnered from this project since it involved long hours of troubleshooting and meeting deadlines. Finally, it was very nice to work with everyone else on this project. Just from spending hours trying to get one piece working to asking random TAs questions to help, the whole environment felt very collaborative and nice to be a part of.

Shyamal Patel:

As I was taking other courses in pervious , I have heard that Senior Design course will be very hard to finish from so many friends that already were done and some of them were taking it, so from that time I have started my research to accomplish the idea that we came up with, but as looking back that same memories I have learned that this class teaches the same experience and environment that will be in the real job after graduating. I have also learnt tons of cool things in the software and also hardware sides. I learn how to create an idea and then assemble that idea into hardware and software to help our society in emergency situations. I have got experience in hands-on work with hardware components that I really did not have a clue on before this course such as Lidar sensor, Jetson Nano. I also got exposed to machine learning and I was very interested in it. This is the second application I have built, but this one was a different type of environment because I have never used Android studio to create an application, so it was a very good experience.

Harith Hussien:

Through the research and testing I did on the Lidar sensor, I learned a lot about how different types of sensors scan and operate with different microcontrollers. Learning how the quality of the sensor and the type can determine the run time of the component and also the space it needs to function without overheating.

I also learned how to diagnose and troubleshoot errors more efficiently thanks to some of the graduate students present at the Senior design lab and also what to look for when encountering a new issue in the hardware.

Learning from my teammates was crucial to the success of the project; as Akhil's knowledge of various coding languages helped me understand more about how to implement the lidar sensor code into the jetson nano. This gave me insight on how to create the proper layout of how the lidar should scan for our project. Shyamal's knowledge of the process of creating an app gave me insights on the different parts that go into creating an app, which helped me provide shyamal with more details on how the app should look and function based on his knowledge.

During these 2 semesters of working as a team, I learned many things from my teammates, I learned the importance of knowing different types of coding languages from Akhil and also what steps to take for building an app from Shyamal. Lastly, I learned how to take the ideas of my teammates and my own, then implement them into the overall project. This allowed more collaboration with each other and prevented possible hurdles that might arise from disagreements.

Conclusion:

Overall this project made us a team. We didn't know each other well before the start of 396/397, now as we end our semester, we consider ourselves fortunate enough to be partners and friends. This project was quite a challenge because we faced a number of challenges in ordering parts and when the parts were delivered they were either not working or working properly. Sometimes when we needed help, Hongyi Pan loaned us parts and guided us. ECE 397 was one of the important classes in all of our college lives as we had other classes too and had different weekly schedules. So we learned how to arrange and change our schedules accordingly.

Our smart device has all the machine learning and hardware aspects to it, so learning and implementing new research was challenging. Unfortunately, we were unable to fully create the project as we intended it and this is shown in our modified engineering requirements. Time constraints and lack of ordered parts were the foundation of many of our issues and if we could have an environment without these we would've had a finished product.

In the end we can say that we are proud of what we built and the challenges we faced in the shape of time scheduling, parts, meetings, and advising. We learned a lot from this class.

References:

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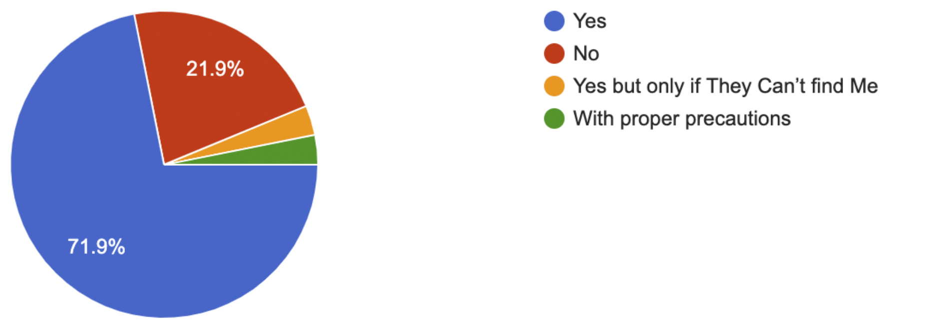
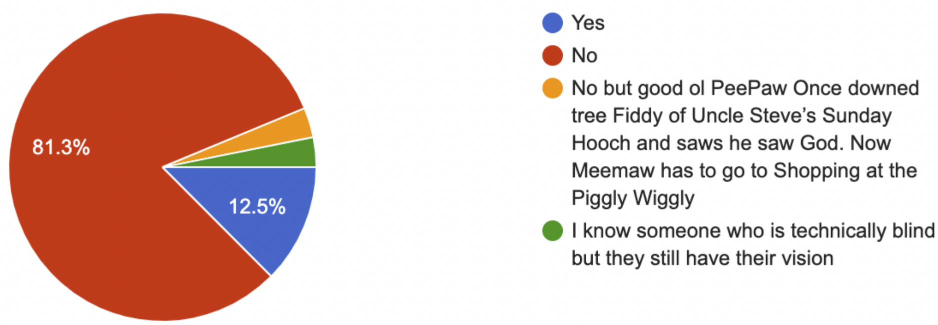
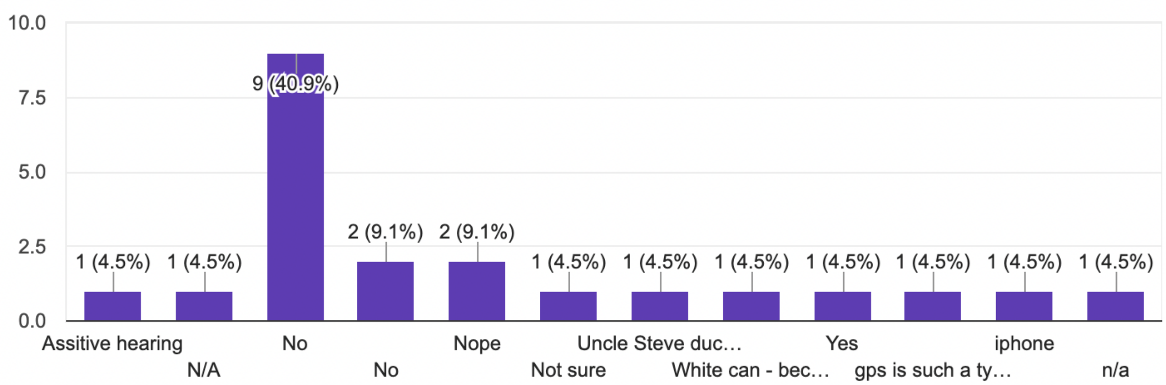
Appendix A:

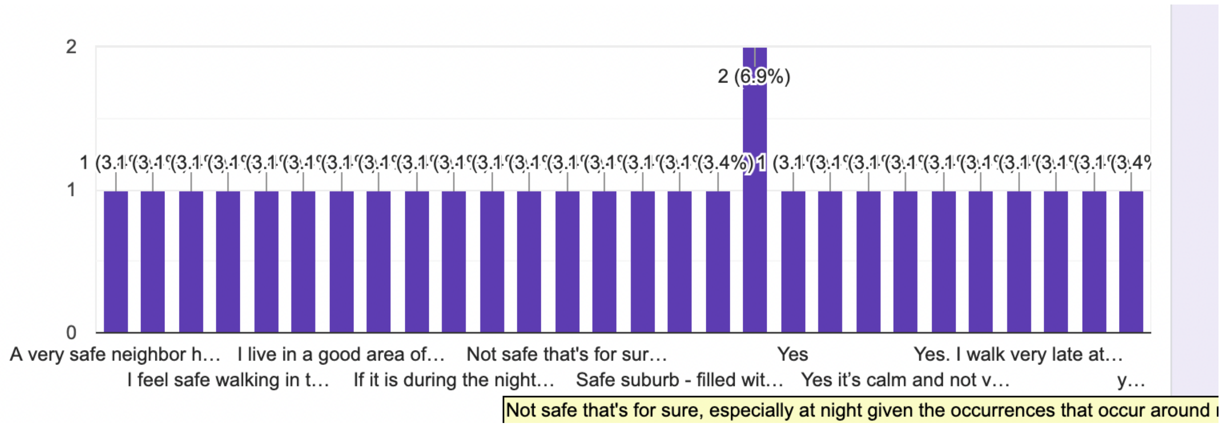
User Survey Results



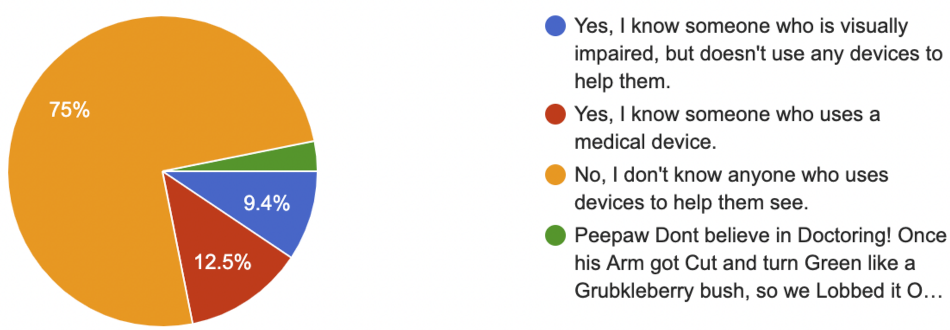


22 responses

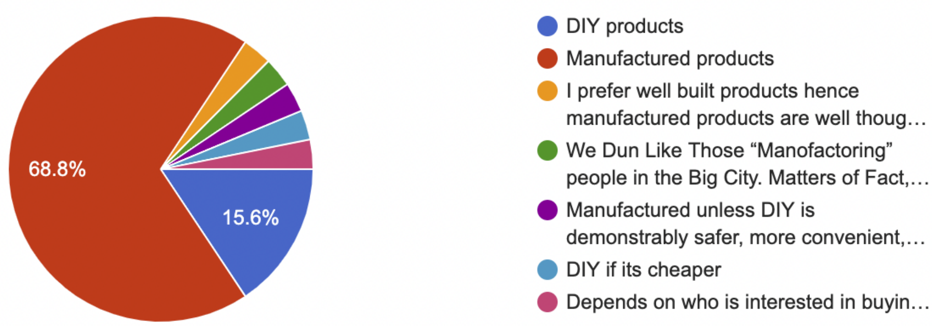




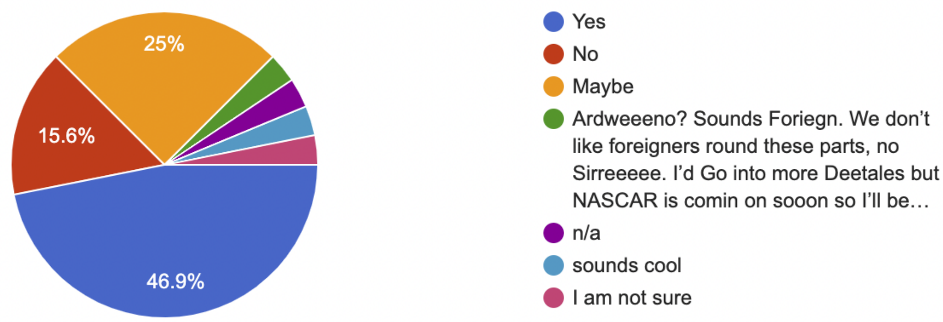
32 responses



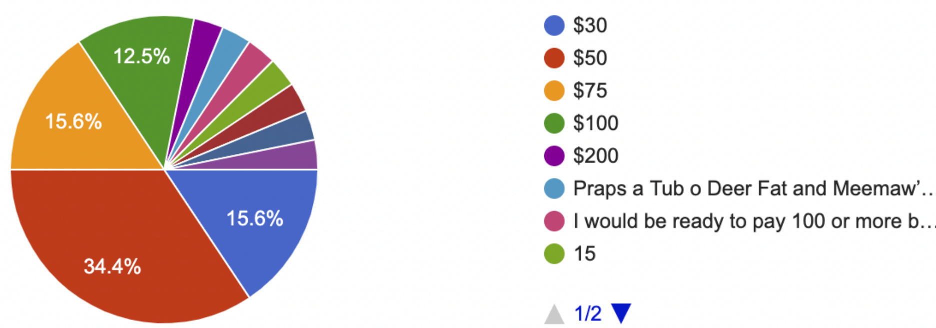
32 responses



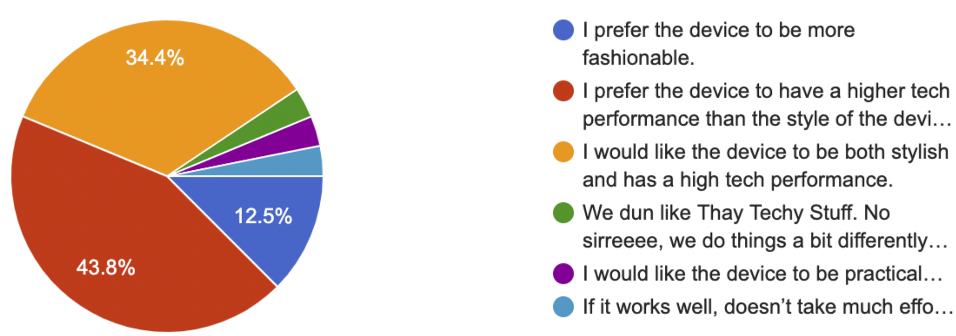
32 responses



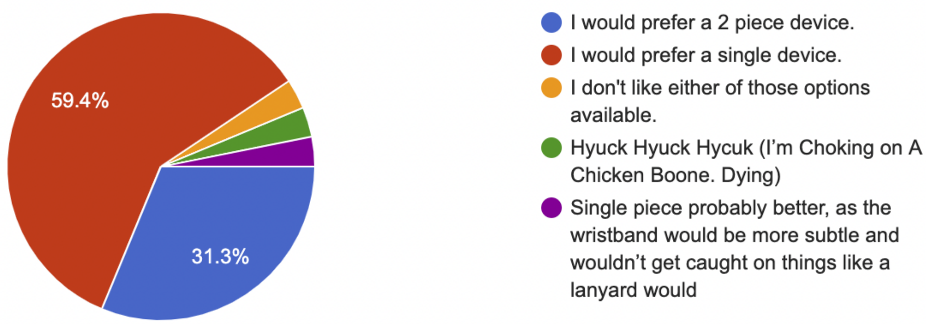
32 responses



32 responses

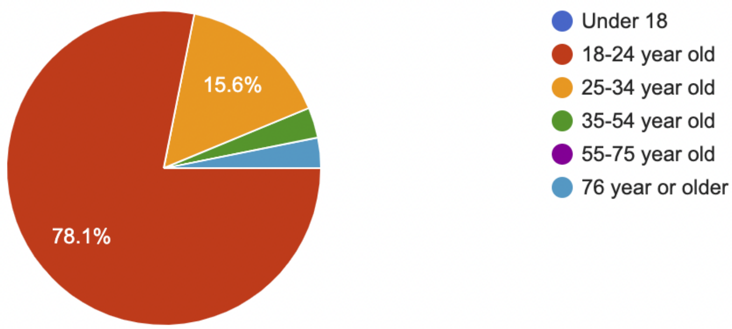


32 responses



How old are you?

32 responses



Appendix B:

Table 15: Concept Map

Connection type	**Charging type**	**MCU**	**Motion Detection**	**Image recognition**	**Navigation**	**Type of housing material**	**Software**
Phone app	Wire Cord	Arduino with wifi/ Bluetooth	LIDAR sensor	IMX219-200 wide angle camera (3280x2464) resolution	Smart sensor GPS	PLA	OpenCV Single Shot Detection
Bluetooth connection	Wireless Coil	Jetson nano 2gb-4gb gpu	Ultrasonic sensor	IMX219-160 IR-cut infrared camera (3280x2464) resolution	Smartphone GPS	Nylon	TensorFlow
Buzzer	Magnetic contacts	Tiva-C	PIR with Ultrasonic sensor	IMX219-200 wide angle camera (3280x2464) resolution			Image classification using convolutional neural networks (CNNs)
		Raspberry pi 4 with Wifi/ Bluetooth					

Individual Pairwise Comparison of Criteria

Table 16: Individual Pairwise 1

Shyamal	Cost to consum er	Your groups' technical knowledge about the design alternative	The time needed to complete design and development	Suitability for demo for 397	Ease of product use
Cost to consumer	1	5	1/9	5	5
Your groups' technical knowledge about the design alternative	1/5	1	1/3	1/5	7
The time needed to complete design and development	9	3	1	1	3
Suitability for demo for 397	1/3	5	1	1	5
Ease of product use	1/5	1/7	1/3	1/5	1

Table 17: Individual Pairwise 2

Shaikh	Cost to consumer	Your groups' technical knowledge about the design alternative	The time needed to complete design and development	Suitability for demo for 397	Ease of product use
Cost to consumer	1	3	3	1/9	7
Your groups' technical knowledge about the design alternative	1/3	1	1/9	7	5
The time needed to complete design and development	1/3	9	1	7	7
Suitability for demo for 397	9	1/7	1/7	1	3
Ease of product use	1/7	1/5	1/7	1/3	1

Table 18: Individual Pairwise 3

Harith	Cost to consumer	Your groups' technical knowledge about the design alternative	The time needed to complete design and development	Suitabilit y for demo for 397	Ease of product use
Cost to consumer	1	5	1/3	1/5	5
Your groups' technical knowledge about the design alternative	1/5	1	3	5	3
The time needed to complete design and development	3	1/3	1	5	5
Suitability for demo for 397	5	1/5	1/5	1	3
Ease of product use	1/5	1/3	1/5	1/3	1

Table 19: Individual Pairwise 4

Akhil	Cost to consumer	Your groups' technical knowledge about the design alternative	The time needed to complete design and development	Suitability for demo for 397	Ease of product use
Cost to consumer	1	3	1/9	3	1
Your groups' technical knowledge about the design alternative	1/3	1	1/3	1/5	7
The time needed to complete design and development	9	3	1	1	3
Suitability for demo for 397	1/3	1/7	1	1	9
Ease of product use	1	1/7	1/3	1/9	1

Table 20: Datasheets

Name	**Part No:**
Lidar Sensor	SEN-13680
Camera	114992265
Jetson nano	DEV-17244
Bluetooth	WRL-17598
Power Supply	B07ZNW8N1W

Appendix C:

User Manual:

I. Installation
   A. Attach the clip of the housing onto two areas of the backpack so the camera is facing outwards and stable.

II. Powering on the Device
   A. Check to make sure that the battery LED is green, indicating that the battery is fully charged. The different LED battery indicators are listed below.
      1. Green: 100-65%
      2. Yellow: 64-35%
      3. Red: 34-1%
   B. After the device is fully charged, Press the power button to turn on the device.
   C. Once the device is turned on, it will attempt to initialize.
   D. Once the device has fully initialized, the LED will turn green indicating all systems are active.
   E. To turn off the device, press and hold the power button for 3 seconds.
   F. Once the device is turned off, a solid red LED will turn on for 3 seconds, indicating that the device has been turned off.

III. Pairing Mode
   A. Press the button with the bluetooth logo once and wait for a blue blinking LED to appear.
   B. The blue blinking LED indicates the device is in pairing mode.
   C. Access bluetooth settings on the mobile device and click “Scan” to search for the Smart Sensor.
   D. Once the device name “Smart Sensor” is visible on the bluetooth visible devices tab, click on it to attempt pairing.
   E. Once the two devices are connected, the blue blinking LED will turn a solid blue indicating a stable connection. The LED light will then turn off 5 seconds after pairing.

IV. Wifi Connection

   A. Purchase a dongle that is compatible with the Jetson Nano
   B. Set up the Wifi driver on the Jetson Nano and then establish a connection to the internet by clicking the three bars on the top left of the screen

V. Using the Smart Sensor

   A. Once the device has been physically set up, turned on, and connected to a mobile device running the Smart Sensor app, it will run until the battery is dead, physically turned off, or shutdown using the smart phone app.

VI. Using the Smart Sensor App

   A. Upon starting the app, a check will be done to see if the Smart Sensor is connected to the app.
      1. If the Smart Sensor is not connected, the user will be directed to the bluetooth settings where connection can be established.
   B. The pictures taken by the Smart Sensor will be stored in the gallery section of the app with a timestamp as well as the last known location.
   C. Settings can be found in the gear icon located on the top left corner of every page
      1. Volume settings, location settings, and as well as privacy settings can all be accessed on this page.
      2. A complete reset button can also be found on this page which will immediately remove all data stored on the device and the cloud.

VII. Troubleshooting

   A. Symptoms
      1. Smart Sensor not connected to the user's mobile device
         a) Check to see if both the Smart Sensor and the mobile device are in pairing mode.
         b) Turn off the Smart Sensor and then turn it back on. Then redo the pairing steps listed in the previous page.
      2. Smart Sensor camera not storing pictures onto mobile device

a) Check to see if the Smart Sensor is connected via bluetooth to the mobile device and see if the Smart Sensor app recognizes the Smart Sensor

b) Check mobile device storage settings to see if there is space to store images

3. Smart Sensor is picking up unwanted information during poor weather conditions

    a) In the case of adverse weather conditions such as rain or snow, proceed to the settings tab in the Smart Sensor app and deactivate the LIDAR sensor. This will reduce the input information received by the Smart Sensor device.

4. GPS signal lost

    a) If the Smart Sensor app is unable to retrieve last known location when taking a picture, it will default to the previous last known location before losing signal. The app will alert the user that image location is not accurate.

VIII. For any other issues, please contact technical support.

Appendix D:

Jetson nano board

NVIDIA JETSON NANO 2GB DEVELOPER KIT
GET HANDS ON WITH AI AND ROBOTICS.

Small Size. Small Price. Big AI Discoveries.

Discover the power of AI and robotics with NVIDIA® Jetson Nano™ 2GB Developer Kit. It's small, powerful, and priced for everyone at $59*. This means educators, students, and other enthusiasts can now easily create projects with fast and efficient AI using the entire GPU-accelerated NVIDIA software stack.

Learning by doing is key for anyone new to AI and robotics, and the Jetson Nano 2GB Developer Kit is ideal for hands-on teaching and learning. Unlike online-only learning, you'll see your work on the developer kit perceive and interact with the world around you in real time.

Thousands of Jetson Nano developers actively contribute videos, how-tos, and open-source projects in addition to the free and comprehensive tutorials offered by NVIDIA. These start with an introductory "Hello AI World," continue to robotics projects such as the open-source NVIDIA JetBot AI robot platform, and lead to the next level of robotics development with NVIDIA Isaac™.

All these resources are enabled by NVIDIA JetPack™, which brings to each Jetson developer the same CUDA-X™ software and tools used by professionals around the world. JetPack includes a familiar Linux environment and simplifies the development process with support for cloud-native technologies such as containerization and orchestration.

The Jetson Nano 2GB Developer Kit delivers incredible AI performance at a low price. It makes the world of AI and robotics accessible to everyone with the exact same software and tools used to create breakthrough AI products across all industries. There's no better way to start.

KEY FEATURES

NVIDIA Jetson Nano 2GB Developer Kit
- 128-core NVIDIA Maxwell™ GPU
- Quad-core ARM® A57 CPU
- 2 GB 64-bit LPDDR4

Power options
- USB-C 5V ⎓ 3A

I/O
- USB 3.0 Type A
- USB 2.0 Type A
- USB 2.0 Micro-B (device mode)
- MIPI CSI-2 camera connector
- Gigabit Ethernet
- 40-pin header (GPIOs, I2C, I2S, SPI, UART)
- HDMI
- Fan header†

Kit Contents
- NVIDIA Jetson module and reference carrier board
- Quick Start / Support Guide
- 802.11ac wireless adapter and extension cable†

* Local pricing will vary due to currency and taxes | † Not initially available in all regions

NVIDIA JETSON NANO 2GB DEVELOPER KIT | DATA SHEET | SEP20

NVIDIA JETSON NANO 2GB DEVELOPER KIT
TECHNICAL SPECIFICATIONS

GPU	128-core NVIDIA Maxwell
CPU	Quad-core ARM A57 @ 1.43 GHz
Memory	2 GB 64-bit LPDDR4 25.6 GB/s
Storage	microSD (Card not included)
Video Encode	4Kp30 | 4x 1080p30 | 9x 720p30 (H.264/H.265)
Video Decode	4Kp60 | 2x 4Kp30 | 8x 1080p30 | 18x 720p30 (H.264/H.265)
Connectivity	Gigabit Ethernet 802.11ac wireless†
Camera	1x MIPI CSI-2 connector
Display	HDMI
USB	1x USB 3.0 Type A, 2x USB 2.0 Type A, 1x USB 2.0 Micro-B
Others	40-pin header (GPIO, I^2C, I^2S, SPI, UART) 12-pin header (Power and related signals, UART) 4-pin Fan header†
Mechanical	100 mm x 80 mm x 29 mm

† Not initially available in all regions

Learn more at **www.nvidia.com/JetsonNano2GB**

Bluetooth USB Adapter

EDIMAX
NETWORKING PEOPLE TOGETHER

Bluetooth® 5.0
BQB Certified

Bluetooth 5.0 Nano USB Adapter

BT-8500

FEATURES

- **Bluetooth 5.0 BQB Certified + EDR**: Max speed up to 3Mbps
- **Small, Stylish Design:** World's smallest Bluetooth 5.0 Adapter.
- **Single-chip Bluetooth 5 controller**, combines a BT Protocol Stack (LM, LL, L2CAP, GATT, RFCOMM, SPP, and LE), BT Baseband, modem, and BT RF in a single chip
- **Supports dual mode (BR/EDR + LE Controllers)**, compatible with previous versions, including v2.1 + LE
- **Supports Bluetooth Low Energy (BLE)** - multiple Low Energy states
- **Supports Bluetooth classic (BDR/EDR)**
- **Supports Windows 8.1/10, Linux:** Kernel 2.6.32 - 5.3 or above (support Fedora & Ubuntu only)

OVERVIEW

The real Bluetooth 5.0 BT-8500 with BQB certification is a Nano USB adapter supports the dual mode (BR/EDR + LE). BT-8500 with EDR supports maximum 3 Mbps data rate and can be connected up to the distance of 40 meters (4 times Bluetooth 4.2).

The BT-8500 is a portable ultra-small design USB adapter, you can plug into any USB port and enjoy incredible high-speed Bluetooth 5.0, no matter when you are travelling or at home. This is for sure the trendiest piece of upgrade you can make to your Bluetooth devices.

Bluetooth 5.0 BQB Certified

The new Bluetooth 5.0 BQB certified with EDR allows the data rate to operate at 3 Mbps and thus enables higher data rates than Bluetooth 4. And the range for Bluetooth 5 for a maximum of around 40 meters which is up to four times the range of Bluetooth 4.2. You can add Bluetooth to your Windows or Linux computer to enjoy your Bluetooth speakers, headphones, keyboards, along with Bluetooth mice, keyboards and more. As the IoT expands, Bluetooth 5.0 will continue to expand across the different devices that we use day to day.

Huge Compatibility

Enables Bluetooth connectivity on devices that don't have it built in, and can pair your computer with multiple Bluetooth compatible devices, such as, Bluetooth headphones, speakers, game controllers, Bluetooth keyboard & mouse, printer, smartphone, tablet, etc..

Compact Size

The ultra-small design BT-8500 USB adapter present a compact size are ideal for any users. It is suitable for traveling or working from home.

Dual Mode

The dual mode BT-8500 Bluetooth 5.0 USB adapter is a fully integrated Bluetooth® BR/EDR and Low Energy (BLE) adapter. It is compatible with previous versions, including v2.1 + LE. For BR/EDR, it allows multiple active links in either slave mode or master mode.

Bluetooth 5.0 Nano USB Adapter

BT-8500

SPECIFICATIONS

HARDWARE	
Interface	1 x USB 2.0 Type A
Antenna	Internal PiFa Antennas x 1
Dimensions	7.1 (H) x 14.9 (W) x 17.4 (D) mm
Weight	2g
BLUETOOTH	
Standard	Bluetooth 5 specification compliant
Frequency Band	2402~2480MHz
Maximum Data Speed	3Mbps (class BT-BR/EDR) : 2Mbps(BLE)
Output Power	8dB (max.)
Receiver Sensitivity	-94dBm (2Mbps EDR) -87dBm (3Mbps EDR) -98dBm (BLE) -106dBm (125K BLE long range)
OTHERS	
Certification	CE, FCC, NCC, BSMI, BQB
Environmental Condition	• Operating Temperature: 32~104°F (0~40°C) • Storage Temperature: -4~140°F (-20~60°C) • Operating Humidity: 10~90% (NonCondensing) • Storage Humidity: Max. 95% (NonCondensing)
System Requirement	• Windows 8.1/10 32bit/64bit or above • Linux: Kernel 2.6.32 - 5.3 or above (support Fedora & Ubuntu only)
Installation	Easy setup wizard with auto run configuration
Package Content	• Bluetooth 5.0 USB Adapter • Quick Installation Guide

Bluetooth Performance

	Bluetooth **5.0 + EDR**	Bluetooth **4.2**
3X Data Rate	3 Mbps	1 Mbps
4X The Range	40 Meters	10 Meters

*Range and speed may differ depending on the testing environment.

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Email : sales@edimax.com

Wifi dongle

EDIMAX
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AC1200 MU-MIMO USB Adapter
EW-7822ULC

SPECIFICATIONS

EW-7822ULC AC1200 Dual-Band MU-MIMO USB Adapter

HARDWARE	
Interface	• 1 x USB 2.0 Type A • 1 x Link/Activity LED
Antenna	• Internal Antennas x 2 (2T2R)
Dimensions	• 7.1 (H) x 14.9 (W) x 20 (D) mm
Weight	• 2g
WIRELESS	
Standards	• 2.4GHz: IEEE 802.11b, 802.11g, 802.11n • 5GHz: IEEE 802.11ac, 802.11a, 802.11n
Frequency	• 2.4000 - 2.4835GHz* • 5.150 - 5.825GHz* FCC: Band 1: 5.150~5.250(GHz) Band 4: 5.745~5.850(GHz) CE: Band 1: 5.150~5.250(GHz) *Subject to local regulations
Output Power	• 2.4GHz: 11b(11M): 8±1.5dBm 11g(54M): 7±1.5dBm 11n(20MHz, MCS7): 6±1.5dBm 11n(40MHz, MCS7): 6±1.5dBm • 5GHz: 11a(54M): 7±1.5 dBm 11n(20MHz, MCS7): 6±1.5 dBm 11n(40MHz, MCS7): 6±1.5dBm 11ac(80MHz, VHTMCS9): 4±1.5dBm
Operating Range	• 11a: 6/9/12/24/36/48/54Mbps • 11b: 1/2/5.5/11Mbps; 11g: 6/9/12/24/36/48/54Mbps • 11n (20MHz): MCS0-07, up to 144Mbps • 11n (40MHz): MCS0-07, up to 300Mbps • 11ac (80MHz): VHTMCS0-9, up to 867Mbps
Security	• WEP 64/128-bit, WPA , WPA2 and WPA3 • Software WPS Configuration
OTHERS	
Certification	• CE, FCC, RoHS
Environment	• Operating Temperature: 32~104˚F (0~40˚C) • Storage Temperature: -4~140˚F (-20~60˚C) • Operating Humidity: 0~90% (NonCondensing) • Storage Humidity: Max. 95% (NonCondensing)
System Requirement	• Windows 7/ 8/ 8.1/ 10 • Mac OS 10.9 ~ 10.15 • Linux: Kernel 2.6.24 ~ 5.8 * Additional version information will be announced on the EDIMAX website download section.
Package Content	• Quick Installation Guide • CD (Multi-Language Quick Installation Guide & Setup Wizard)

*Maximum performance, actual data rates, and coverage will vary depending on network conditions and environmental factors. Product specifications and design are subject to change without notice.

Parameters	Command	Response	Remark	Default setting
Obtain firmware version	5A 04 01 5F	5A 07 01 V1 V2 V3 SU	Version V3.V2.V1	
System reset	5A 04 02 60	5A 05 02 00 60	Succeeded	/
		5A 05 02 01 61	Failed	/
Frame rate	5A 06 03 LL HH SU	5A 06 03 LL HH SU	1-250Hz①	100Hz
Trigger detection	5A 04 04 62	Data frame	After setting the frame rate to 0, detection can be triggered with this command	
Output format	5A 05 05 01 65	5A 05 05 01 65	Standard 9 bytes(cm)	√
	5A 05 05 02 66	5A 05 05 02 66	Pixhawk	/
	5A 05 05 06 6A	5A 05 05 06 6A	Standard 9 bytes (mm)	/
Baud rate	5A 08 06 H1 H2 H3 H4 SU	5A 08 06 H1 H2 H3 H4 SU	Set baud rate②	115200
Enable/Disable output	5A 05 07 00 66	5A 05 07 00 66	Disable data output	/
	5A 05 07 01 67	5A 05 07 01 67	Enable data output	√
Obtain Data Frame	5A 05 00 01 60	Data Frame(9bytes-cm)	Only works in I2C mode	/
	5A 05 00 06 65	Date Frame(9bytes-mm)		
Restore factory settings	5A 04 10 6E	5A 05 10 00 6E	Succeeded	
		5A 05 10 01 6F	Failed	
Save settings	5A 04 11 6F③	5A 05 11 00 6F	Succeeded	
		5A 05 11 01 70	Failed	

Note:Bytes with yellow undertone represents checksum.

5 Line Sequence and Data Communication Protocol

5.1 Description about Line Sequence and Connection

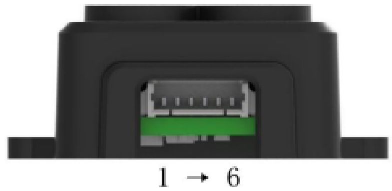


Table 5: The Function and Connection Description of each pin

No.	Function	Comment
1	+5V	Power supply
2	RXD/SDA	Receiving/Data
3	TXD/SCL	Transmitting/Clock
4	GND	Ground
5	\	
6	\	

5.2 Serial port Communication Protocol

TF-Luna adopts the serial port data communication protocol, as given in *Table 6*.

Table 6: Data Communication Protocol of TF-Luna

Communication interface	UART
Default baud rate	115200
Data bit	8
Stop bit	1
Parity check	None

5.3 Data Output Format of Serial port

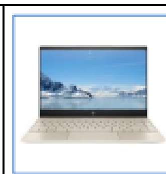
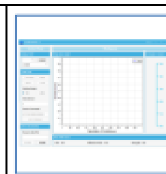
TF-Luna is available with two formats of data output, namely, the standard data output format and the character string data format, both of which are switchable with command.

- **Standard data output format (default):**

Data structure: each data frame contains 9 bytes, including the distance value, signal strength, temperature of chip and data check byte (Checksum), etc. Data format is hexadecimal (HEX). Data

6 Quick Test

6.1 Required Tools of Product Test

					
TF-Luna	Data wire	TTL - USB converter	USB cable	PC	PC software

6.2 Test Procedures

① Download the Test software

Please download the Test software of TF-Luna at our official website (en.benewake.com).

Caution: please shut down any anti-virus software before uncompressing the PC software. Otherwise, maybe the software is deleted as virus. The software is only runnable under Windows environment for the time being. Please refer to Attachment 1 - Product manual of TF Test software.

② Connection of the hardware

Figure 4 Schematic Diagram of Correct Connection

Connect "TF-Luna", "TTL - USB board" and "USB cable" as shown in *Figure 4*. Make sure there is no loose connection. Then connect "USB cable" with "PC".

③ Connection to the Test software and data output

Open the PC software and select "①TF-Luna" and select automatically recognized occupied serial port (here it is "② COM9"), as shown in Figure 7

Then click "CONNECT". Upon successful connection, The continuous images of the output data will be displayed in area "④ TIME LINE CHART" on the right. Besides, the real-time data of the Current measure

Troubleshooting: please use such value as the trigger signal of some unreliable data, and it will ensure that your system can use other reliable data for further assessment and decision-making if there are some unreliable data.

(2) Significant error between the output distant value of LiDAR and actual distance

Cause ①: Incorrect interpretation of the data communication protocol of TF-Luna.

Troubleshooting: check data communication interpretation means. In case of such error, please check the data format to adjust interpretation means.

Cause ②: Due to the physical principles of TF-Luna, the above phenomenon is likely to occur if the detection object is the material with high reflectivity (such as mirror, smooth floor tile, etc.) or transparent substance (such as glass and water, etc.)

Troubleshooting: Please avoid use of this product under such circumstance in practice.

Cause ③: The IR-pass filters are blocked.

Troubleshooting: please use dry dust-free cloth to gently remove the foreign matter

(3) No data output

Cause: The product will be strictly inspected before leaving our factory, ensuring that all the shipped products can work normally. However, some abnormal working matters maybe still occur because of incidents during the transportation or use.

Troubleshooting: Check whether the power supply is normal; check whether the voltage is within rated voltage range. If power supply is normal, there will be a red light inside the transmitting lens of TF-Luna.

Check TF-Luna with correct connection sequence and reliable connection.

Check whether the data interpretation is correct. Please carry out the interpretation as per the data format specified herein.

If the problem persists, please contact our technical support.

(4) There is no data output when LiDAR is connected to PC software.

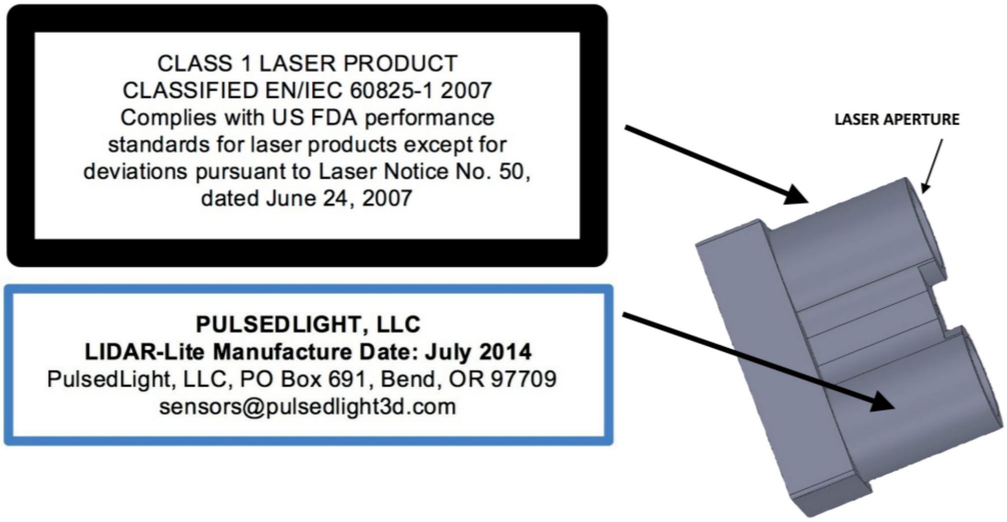
Cause ①: The PC software only supports the Windows operation system for the time being

LIDAR-Lite v2 Overview

LIDAR-Lite Specifications

General	Technical Specifications
Power	4.75-5.5V DC Nominal, Maximum 6V DC
Weight	PCB 4.5 grams, Module 22 grams with optics and housing
Size	PCB 44.5 X 16.5mm (1.75” by .65”)
Housing	20 X 48 X 40mm (.8” X 1.9” X 1.6”)
Current Consumption	<2mA @ 1Hz (shutdown between measurements), <100mA (continuous operation)
Max Operating Temp.	70° C
External Trigger	3.3V logic, high-low edge triggered
PWM Range Output	PWM (Pulse Width Modulation) signal proportional to range, 1msec/meter, 10μsec step size
I2C Machine Interface	100Kb – Fixed, 0xC4 slave address. Internal register access & control.
Supported I2C Commands	Single distance measurement, velocity, signal strength
Mode Control	Busy status using I2C, External Trigger input / PWM outputs
Max Range under typical conditions	~40m
Accuracy	+/- 2.5cm, or +/- ~1"
Default Rep Rate	~50 Hz.

Laser Safety



LIDAR-Lite is a laser rangefinder that emits laser radiation. This Laser Product is designated Class 1 during all procedures of operation. This means that the laser is safe to look at with the unaided eye. However, it is very advisable to avoid looking into the beam and power the module off when not in use.

No regular maintenance is required for LIDAR-Lite. In the event that the unit becomes damaged or is inoperable, repair or service of LIDAR-Lite is only to be handled by authorized, factory-trained technicians. No service of LIDAR-Lite by the user is allowed. Attempting to repair or service the unit on your own can result in direct exposure to laser radiation and the risk of permanent eye damage. For repair or service please contact PulsedLight directly for a return authorization.

No user should modify LIDAR-Lite or operate it without its housing or optics. The operation of LIDAR-Lite without a housing and optics or modification of the housing or optics that exposes the laser source may result in direct exposure to laser radiation and the risk of permanent eye damage. Removal or modification of the diffuser in front of the laser optic may result in the risk of permanent eye damage.

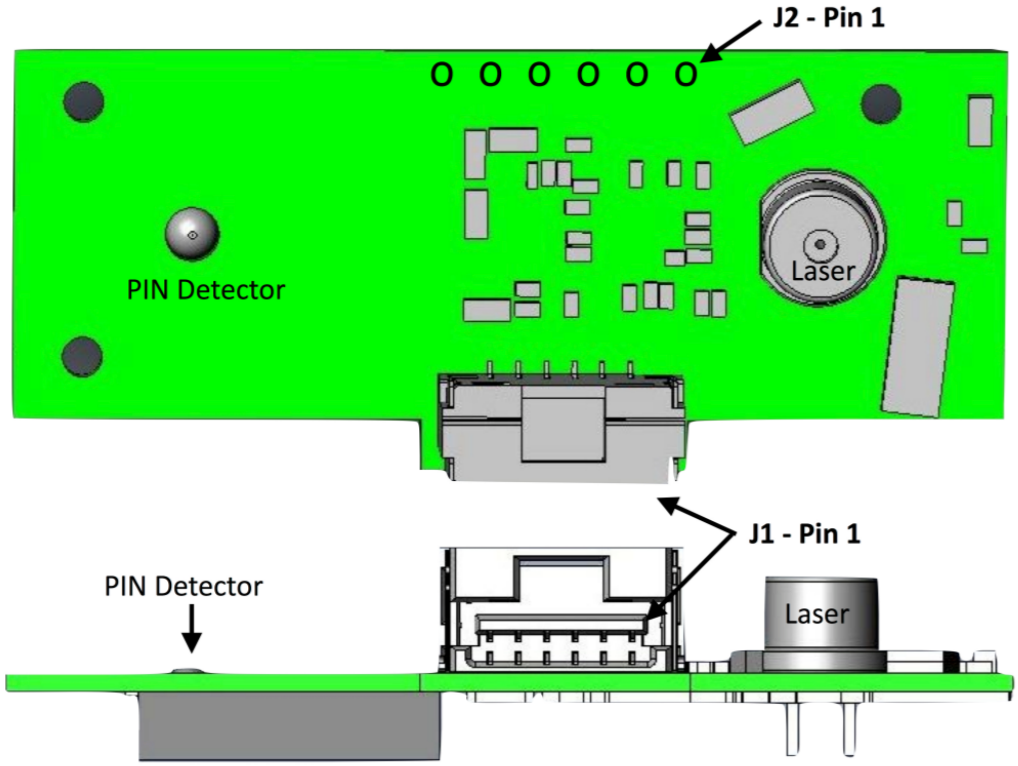
Caution – Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure. PulsedLight is not responsible for injuries caused through the improper use or operation of this product.

Class 1 Laser Product

This Laser Product is designated Class 1 during all procedures of operation.

Parameters	**Laser Value**
Wavelength	905nm (nominal)
Total Laser Power - Peak	1.3Watts
Mode of operation	Pulsed (max pulse train 256 pulses)
Pulse Width	0.5μSec (50% duty Cycle)
Pulse Repetition Frequency	10-20KHz nominal
Energy per Pulse	<280nJ
Beam Diameter at laser aperture	12mm x 2mm
Divergence	4mRadian x 2mRadian (Approx)

LIDAR-Lite Signal & Power Interface Definitions



J1 - Primary interface

Board Connector: Molex part #5023860670 (DigiKey Part #: WM3917CT-ND)

Mating Connector: Molex # 5023800600 PLUG HSG 6POS (DigiKey Part #: WM2271-ND)

Pin	Description
PIN1	POWER_IN – 4.75-5.5V DC Nominal, Maximum 6V DC. Peak current draw from this input (which occurs during acquisition period) is typically < 100 mA over a duration from 4 to 20ms depending on received signal strength. Unless you use power management, the unit will draw 80 mA between acquisition times.
PIN2	POWER_EN - Active high, enables operation of the 3.3V micro-controller regulator. Low puts board to sleep, draws <40 µA. (Internal 100K pull-up)
PIN3	Mode Select – Provides trigger (high-low edge) PWM out (high)
PIN4	I2C Clock (SCL)

PIN5	I2C Data (SDA)
PIN6	Signal/power ground.

J2 - Secondary signal/power - .1” spacing Molex style through hole (Factory Option Only)

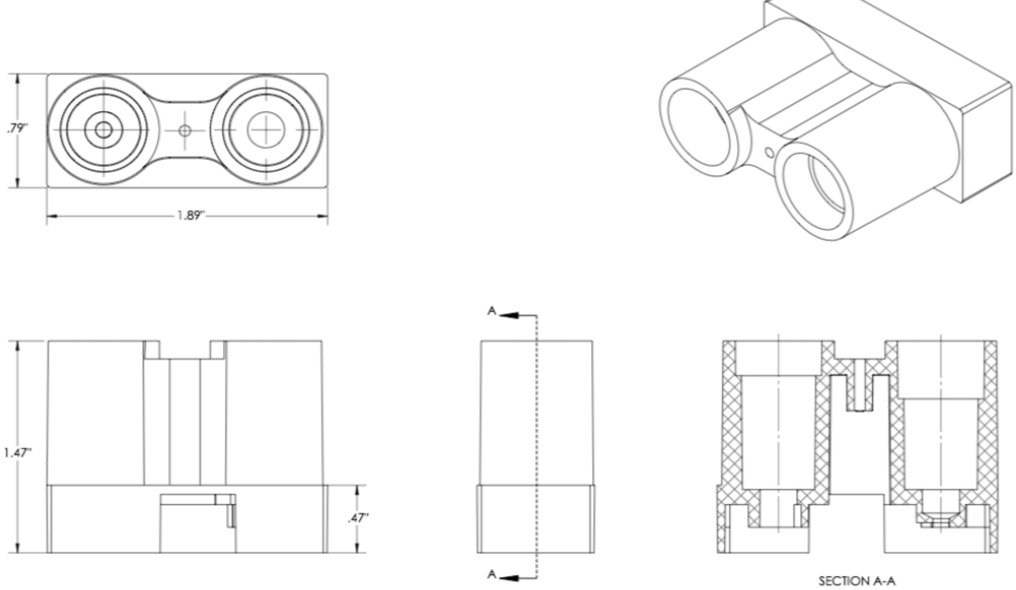
Pin	Description
PIN1	Laser Bypass 5-20V max (nominally connected to pin 2 through inductor L8 – removed for external power)
PIN2	POWER_IN – 4.75-5.5V DC Nominal, Maximum 6V DC
PIN3	POWER_EN - Active high
PIN4	External reference clock input (Factory Option – Consult Factory)
PIN5	Signal/power ground.
PIN6	Detector bias – up to 25V external bias for PIN, external bias input 200V for APD (consult factory)

Module Mechanical Drawings & Dimensions

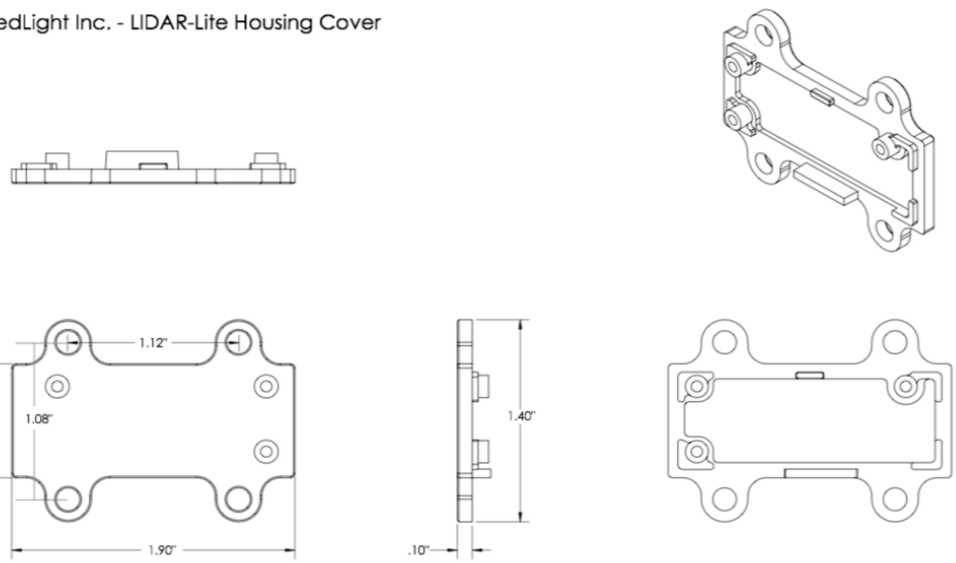
Download Housing and Cover in PNG, STL, STEP and SLDPRT formats on GitHub

LIDAR-Lite Housing

PulsedLight, Inc. - LIDAR-Lite Housing



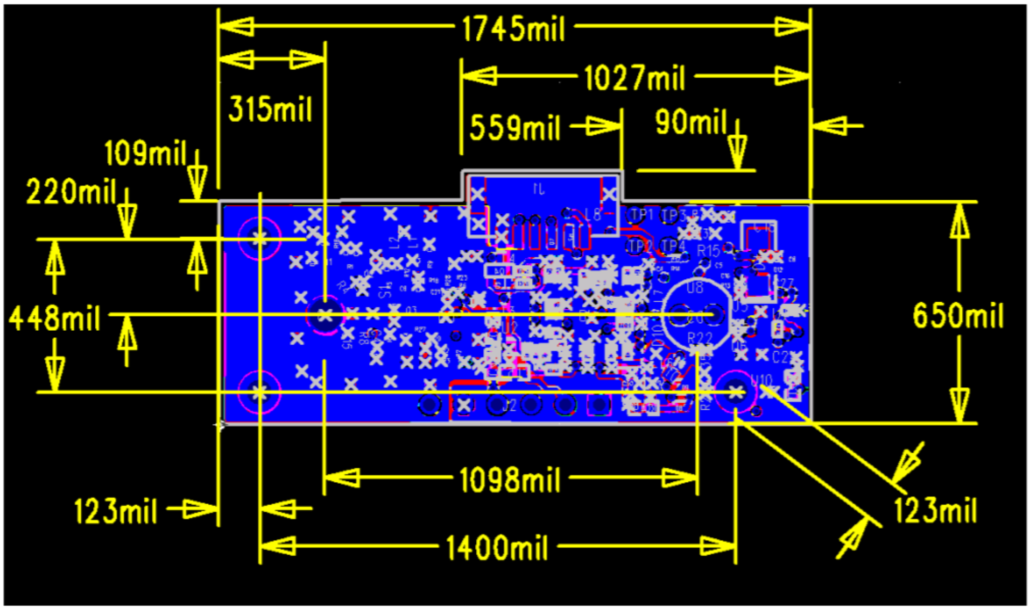
PulsedLight Inc. - LIDAR-Lite Housing Cover



Notes: - The hole diameters at their smallest are 0.15" or 0.385 cm with a little rounding erring small

PCB Dimensions

Backside viewed through board



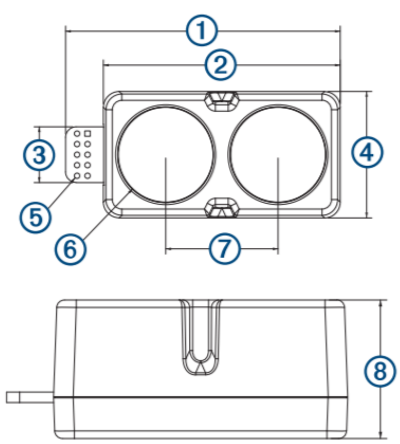
GARMIN.

LIDAR-LITE V4 LED OPERATION MANUAL AND TECHNICAL SPECIFICATIONS

Specifications

Specification	Measurement
Unit dimensions (L × W × H) **NOTE:** Measurements do not include an attached connector.	52.2 x 24 x 21.2 mm (2.1 x 0.9 x 0.8 in.)
Weight	14.6 g (0.5 oz.)
Operating temperature	-20 to 60°C (-4 to 140°F)
Storage temperature	-40 to 85°C (-40 to 185°F)
Power (operating voltage)	4.75 to 5.25 Vdc
Current consumption	2 mA idle 85 mA during an acquisition
Input voltage (VIN)	3.3 V Max
Range	5 cm (1.97 in.) to 10 m (32.8 ft.)
Resolution	1 cm (0.4 in.)
Beam divergence	4.77 degrees
LED wavelength	940 nm
Optical aperture	14.9 mm
Update rate	I2C: Greater than 200 Hz typical ANT: Up to 200 Hz to a 90% reflective target indoors at 2 m in normal operating mode
Interface	I2C or ANT® Configurable for SPI with user applications
Measurement repeatability **NOTE:** As measured indoors to a 90% reflective target; 1 cm is equivalent to 1 standard deviation. Measurements were obtained using high accuracy mode.	± 1 cm to 2 m ± 2 cm to 4 m ± 5 cm to 10 m

Device Dimensions



①	52.17 mm (2.05 in.)
②	44.98 mm (1.77 in.)
③	10.6 mm (0.42 in.)
④	24.03 mm (0.95 in.)
⑤	1 mm (0.04 in.)
⑥	18 mm (0.71 in.)
⑦	21.35 mm (0.84 in.)
⑧	21.2 mm (0.83 in.)

Mounting Options

Cable tie: You can secure the device to your application using a 3.6 mm (0.14 in.) wide cable tie. You should route the cable tie through the channel in the center of the device.

Double-sided tape: You can secure the bottom of the device to your application using double-sided tape. For best results, you should select a tape that has a high-strength bond.

Labeling Requirements

The LIDAR-Lite v4 LED device is an FCC-certified transmitter. If you are integrating the device with another product, you must ensure the FCC ID is visible from the outside of your product. You are responsible for meeting any other labeling requirements imposed by the FCC rules and any rules related to the compliance of your end product.

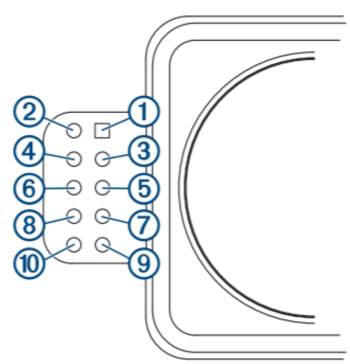
Connections

LIDAR-Lite v4 LED Connection Diagram

The through-holes on the LIDAR-Lite v4 LED device are arranged in 2 rows of 5 holes each, with a 2 mm pitch between each connection.

NOTICE

The LIDAR-Lite v4 LED maximum signal level is 3.3 V. A signal greater than 3.3 V will damage the device.



Pin	Pin Name	Function	V Max
①	VIN	5 V Power	5 V
②	GND	Ground	--
③	I2C SDA	I2C Data	3.3 V
④	I2C SCL	I2C Clock	3.3 V

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190-02533-00_0A

Pin	Pin Name	Function	V Max
⑤	GPIOA	General Purpose I/O	3.3 V
⑥	GPIOB	General Purpose I/O	3.3 V
⑦	VRETURN	nRF52840 DBG	3.3 V
⑧	nRESET	nRF52840 DBG	3.3 V
⑨	SWCLK	nRF52840 DBG	3.3 V
⑩	SWDIO	nRF52840 DBG	3.3 V

Operational Information

Technology

This device measures distance by calculating the time delay between the transmission of a near-infrared light and its reception after reflecting off of a target, using the known speed of light.

The LIDAR-Lite v4 LED contains an nRF52840 SoC from Nordic Semiconductor. This SoC pairs an ARM Cortex-M4 processor with 1 MB of flash memory and 256 KB of RAM. The included 2.4GHz multiprotocol radio and S340 SoftDevice support Ultra Low Power (ULP) wireless technologies, including ANT and Bluetooth® 5 LE.

The LIDAR-Lite v4 LED comes preloaded with an application that allows the developer to communicate with the device using several methods. An I2C interface allows the device to be connected to an external micro-controller, or it can be controlled and operated wirelessly using the ANT wireless protocol in accordance with the ANT Ranging Profile.

The LIDAR-Lite v4 LED also comes preloaded with a Bluetooth LE secure DFU bootloader, which enables wireless software updates using a Bluetooth LE capable device.

Theory of Operation

When the device takes a measurement, it first performs a receiver adjustment routine, correcting for changing ambient light levels and allowing maximum sensitivity.

The device sends a reference signal directly from the transmitter to the receiver. It stores the transmit signature, sets the time delay for "zero" distance, and recalculates this delay periodically after several measurements.

Next, the device initiates a measurement by performing a series of acquisitions. Each acquisition is a transmission of the main light signal while recording the return signal at the receiver. If there is a signal match, the result is stored in memory as a correlation record. The next acquisition is summed with the previous result. When an object at a certain distance reflects the light signal back to the device, these repeated acquisitions cause a peak to emerge, out of the noise, at the corresponding distance location in the correlation record.

The device integrates acquisitions until the signal peak in the correlation record reaches a maximum value. If the returned signal is not strong enough for this to occur, the device stops at a predetermined maximum acquisition count.

Signal strength is calculated from the magnitude of the signal record peak and a valid signal threshold is calculated from the noise floor. If the peak is above this threshold, the measurement is considered valid and the device will calculate the distance. If the peak is not above the threshold, it will report 1 cm. When beginning the next measurement, the device clears the signal record and starts the sequence again.

Interface

Initialization

When you turn on or reset the device, it performs a self-test sequence and initializes all registers with default values. After roughly 22 ms, you can take distance measurements using the I2C interface, the mode control pin, or a wireless ANT connection.

I2C Interface

This device has a 2-wire, I2C-compatible serial interface. It can be connected to an I2C bus as a slave device, under the control of an I2C master device. It supports 400 kHz Fast Mode data transfer.

The I2C bus operates internally at 3.3 Vdc. Internal 13 kiloohm pull-up resistors ensure this functionality and allow for a simple connection to the I2C host.

The device has a 7-bit slave address with a default value of 0x62. The effective 8-bit I2C address is 0xC4 write and 0xC5 read. The device does not respond to a general call. Support is not provided for 10-bit addressing. The device auto-increments the register address with successive reads or writes within an I2C block transfer. This is commonly used to read the two bytes of a 16-bit value within one transfer. See *Obtaining Measurements from the I2C Interface*, page 2.

For a list of all available control registers, see *Control Register List*, page 5.

For more information about the I2C protocol, see *I2C Protocol Information*, page 4.

Obtaining Measurements from the I2C Interface

You can obtain measurement results from the I2C interface.

1. Write 0x04 to register 0x00.
2. Read register 0x01.
3. Repeat step 2 until bit 0 (LSB) goes low.
4. Read two bytes from 0x10 (low byte 0x10 then high byte 0x11) to obtain the 16-bit measured distance in centimeters.

Settings

You can configure the device with alternate parameters for the distance measurement algorithm. You can use this algorithm to customize performance by enabling configurations that allow speed, range, and sensitivity options. See the full control register list (*Control Register List*, page 5) for additional settings.

Configurable I2C Address

You can change the I2C address from its default to any 7-bit value. Before you can configure the secondary I2C address, you must first enable flash storage (0xEA). After you configure the secondary I2C address, the address persists if you turn off the device. You can use this process to run multiple devices on a single bus by enabling a device, changing its address, and then enabling the next device. Before you can change the I2C address, the I2C communications bus must read the UNIT_ID and write it back to the device in a single five-data-byte transaction with the new I2C address as the fifth byte. Software template functions for configuring the I2C address are available at https://github.com/garmin/.

Mode Control Pins

The mode control pins can be used to trigger distance measurements and check the status of the LIDAR-Lite v4 LED. These connections are not required. These pins can provide a simpler and faster method of controlling the device, and they are intended to be used in conjunction with the I2C interface. For more information, go to https://github.com/garmin/.

Pin	Description	Functionality	Details
GPIO A	TRIGGER	LIDAR-Lite v4 LED measurement trigger input	Toggle to start a distance measurement. The LIDAR-Lite v4 LED starts a distance measurement on either the rising or falling edge. If a distance measurement is triggered while the device is busy, the requested measurement is ignored.
GPIO B	MONITOR	LIDAR-Lite v4 LED BUSY status output	Indicates when the LIDAR-Lite v4 LED is busy. If low, the device is idle and is ready to start a distance measurement. If high, the device is busy taking a distance measurement. Wait for the signal to drop before you toggle GPIO A to trigger a distance measurement.

Triggering and Reading Distance Measurements

1. Toggle the TRIGGER pin.
2. Wait for the MONITOR pin to go low.
3. Read two bytes from 0x10 (low byte 0x10, then high byte 0x11) to obtain the 16-bit measured distance in centimeters.

   NOTE: If you need to take distance measurements as quickly as possible, you can reverse steps 2 and 3 so the LIDAR-Lite v4 LED device takes a distance measurement while performing the I2C register read. When this occurs, the LIDAR-Lite v4 LED device is in the process of measuring the distance while the registers are read. The distance returned is the previously triggered measurement.

ANT

ANT is a practical wireless network protocol running in the 2.4 GHz ISM band. Designed for ultra-low power, ease of use, efficiency, and scalability, ANT easily handles peer-to-peer, star, tree, and mesh topologies. Other ANT capable devices can connect to the LIDAR-Lite v4 LED to control it, receive data from it, and configure it wirelessly. ANT messages are sent and received from the LIDAR-Lite v4 LED in accordance to the ANT ranging profile.

For more details about the ANT ranging profile and the capabilities and workings of the ANT wireless protocol, see *ANT Ranging Profile* and *ANT Message Protocol and Usage* at https://github.com/garmin/.

Connecting Wirelessly Using ANT

Before you can connect to the LIDAR-Lite v4 LED using ANT, you must complete these tasks.

- Install Windows 7 Service Pack 1 or higher on your PC
- Install .Net Framework 4.5 or higher on your PC
- Install Visual C++ 2008 SP1 Redistributable Package or higher on your PC
- Purchase a Garmin® ANT USB-m stick

1. Connect the USB ANT stick to your computer.
2. Download and install the Garmin ANT demo PC application on your computer (https://github.com/garmin/) .
3. Configure and connect the PC application to the LIDAR-Lite v4 LED device as specified in the readme file that is included with the Garmin ANT demo PC application.

Activating the Bluetooth LE Bootloader

NOTE: If you are installing a custom unsigned application to the LIDAR-Lite v4 LED, you should first test and debug the custom application using a J-Link debugging probe before you perform wireless updates.

The LIDAR-Lite v4 LED device comes preloaded with a Bluetooth LE bootloader that allows you to update the device software wirelessly. You can use the Nordic Secure DFU bootloader to install an official update signed by Garmin, or a developer can use that bootloader to install a custom, unsigned application.

1. Disconnect power from the LIDAR-Lite v4 LED device.
2. Ground the boot pin (GPIO B).
3. Connect power to the LIDAR-Lite v4 LED device.

The Bluetooth LE bootloader starts advertising as "LLV4 DFU Mode."

Updating the Firmware Using the Bluetooth LE Bootloader

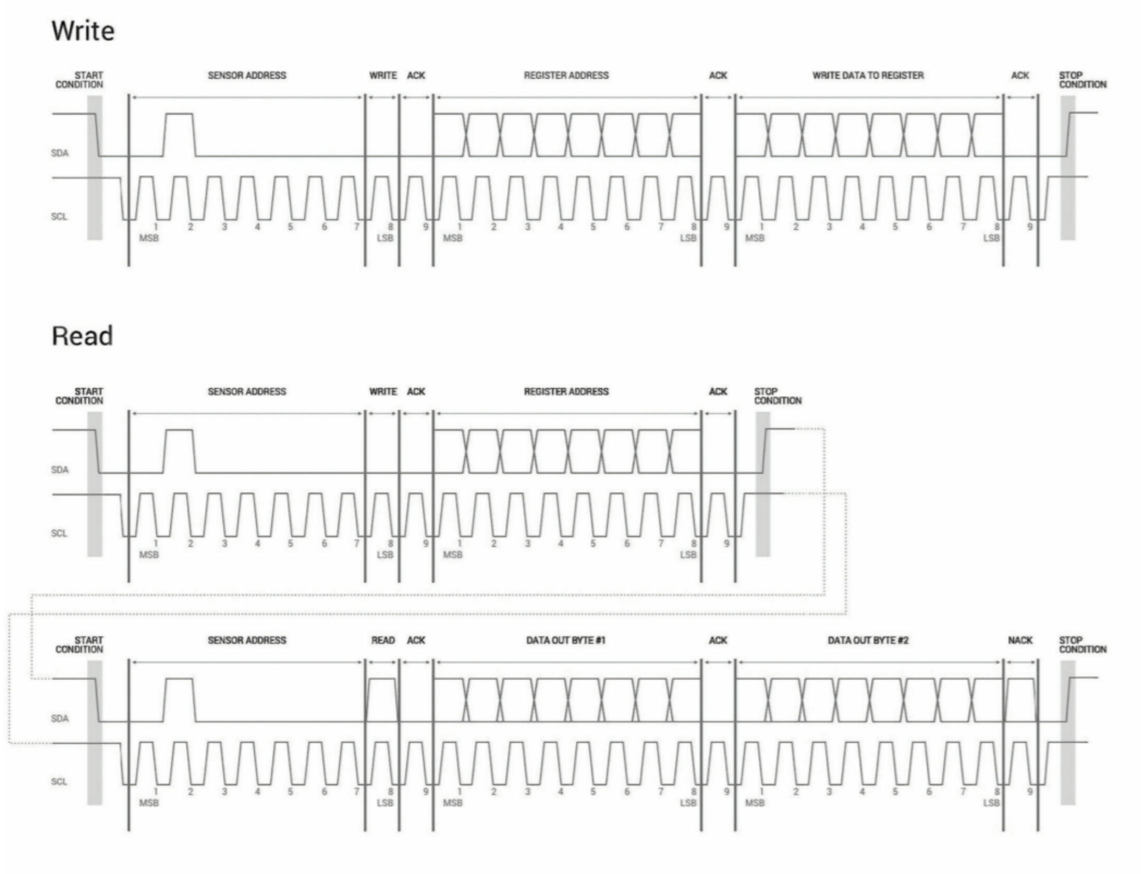
You can use the Bluetooth bootloader to update the LIDAR-Lite v4 LED firmware using a smartphone equipped with Bluetooth LE or a PC equipped with an nRF52 DK or nRF52840 dongle. The firmware is contained in a file called DFU.zip.

1. Copy the DFU.zip file to a smartphone or PC.

   NOTE: You can use the DFU.zip file provided by Garmin or a custom DFU.zip file.
2. Using the nRF Connect or nRF Toolbox app, start the firmware upgrade using the DFU.zip file you copied.
3. After the DFU process reaches 100%, verify the new application runs correctly.

For more information about how to update the nRF52840 using the Nordic secure DFU bootloader, go to https://github.com/garmin/.

I2C Protocol Information



The sensor module has a 7-bit slave address with a default value of 0x62 in hexadecimal notation. The effective 8 bit I2C address is 0xC4 write, 0xC5 read. The device will not respond to a general call.

The last NACK in the read is optional, but the formal I2C protocol states that the master shall not acknowledge the last byte.

I2C Protocol Operation

This protocol description uses the term **master** to refer to the host controller, and the term **LIDAR device** to refer to the LIDAR-Lite v4 LED device acting as a slave on the I2C bus.

When working with the I2C serial bus protocol, the LIDAR device operates as follows.

1. The master initiates data transfer by establishing a start condition, which consists of a high-to-low transition on the SDA line while SCL is high.
2. The master sends an address byte, which consists of the 7-bit slave address.
3. The master sends a read/write bit with a zero state, which indicates a write request. A write operation is used as the initial stage of both read and write transfers.
4. If the slave address corresponds to the LIDAR device address, the LIDAR device responds by pulling SDA low during the ninth clock pulse. This operation is considered the acknowledge bit. At this stage, all other devices on the bus remain idle while the selected LIDAR device waits for data to be written to or read from its shift register.
5. Data transmits over the serial bus in sequences of nine clock pulses (eight data bits followed by an acknowledge bit). These transmissions must occur on the SDA line during the low period of SCL and remain stable during the high period of SCL.
6. The master sends an 8-bit data byte following the slave address, which loads the I2C control register on the LIDAR device with the address of the first control register to be accessed.
7. The master requests a read operation from the LIDAR device or sends a write operation to the LIDAR device.

Read Operation

After the master establishes communication with the LIDAR device, you can obtain a reading from the LIDAR device.

1. The first data frame sets the address of the desired read register.
2. The master sends a stop bit at the completion of the first data frame.
3. The master initiates a new start condition, which consists of the slave I2C device address with the read bit set (one state).
4. The LIDAR device sends an acknowledge bit to the master when it receives a valid address.

5 The master reads one or more data bytes in succession. The internal device address pointer auto increments with each byte access.
6 The master strobes the acknowledge bit following each data byte except for the final byte in the transfer before sending the stop condition.
7 After the read cycle is done, the master sends a stop condition to complete the operation.

Write Operation

After the master establishes communication with the LIDAR device, writing to the LIDAR device operates as follows.

1 The master sends one or more 8-bit data blocks to the LIDAR device. The internal device address pointer auto increments with each byte access.
2 The LIDAR device sends an acknowledge bit to the master when it receives and writes a valid data byte.
3 After the write cycle is done, the master sends a stop condition to complete the operation.

Control Register List

NOTE: Unless otherwise noted, all registers contain one byte and are read and write.

Address	R/W	Name	Description	Initial Value	Details
0x00	W	ACQ_COMMANDS	Device command	--	0x00, page 5
0x01	R	STATUS	System status	--	0x01, page 5
0x05	R/W	ACQUISITION_COUNT	Maximum acquisition count	0xFF	0x05, page 6
0x10	R	FULL_DELAY_LOW	Distance measurement low byte	--	0x10, page 6
0x11	R	FULL_DELAY_HIGH	Distance measurement high byte	--	0x11, page 6
0x16	R	UNIT_ID_0	Unit ID, byte 0	--	0x16, page 6
0x16	W	UNIT_ID_0_UNLOCK	Write unit ID 0 for I2C address unlock	--	0x16, page 6
0x17	R	UNIT_ID_1	Unit ID, byte 1	--	0x17, page 6
0x17	W	UNIT_ID_1_UNLOCK	Write unit ID 1 for I2C address unlock	--	0x17, page 6
0x18	R	UNIT_ID_2	Unit ID, byte 2	--	0x18, page 6
0x18	W	UNIT_ID_2_UNLOCK	Write unit ID 2 for I2C address unlock	--	0x18, page 6
0x19	R	UNIT_ID_3	Unit ID, byte 3	--	0x19, page 6
0x19	W	UNIT_ID_3_UNLOCK	Write unit ID 3 for I2C address unlock	--	0x19, page 6
0x1A	R/W	I2C_SEC_ADDR	Write new I2C address after unlock	--	0x1A, page 6
0x1B	W	I2C_CONFIG	Default address response control	0x00	0x1B, page 6
0x1C	R/W	DETECTION_SENSITIVITY	Peak detection threshold bypass	0x00	0x1C, page 6
0x30	R	LIB_VERSION	Read Garmin software library version string	--	0x30, page 7
0x52	R/W	CORR_DATA	Correlation record data control	--	0x52, page 7
0x72	R	CP_VER_LO	Coprocessor firmware version low byte	--	0x72, page 7
0x73	R	CP_VER_HI	Coprocessor firmware version high byte	--	0x73, page 7
0xE0	R	BOARD_TEMPERATURE	Board temperature	--	0xE0, page 7
0xE1	R	HARDWARE_VERSION	Board hardware version	--	0xE1, page 7
0xE2	R/W	POWER_MODE	Power state control	0xFF	0xE2, page 7
0xE3	R/W	MEASUREMENT_INTERVAL	Automatic measurement rate	0xFF	0xE3, page 7
0xE4	W	FACTORY_RESET	Reset default settings	--	0xE4, page 7
0xE5	R/W	QUICK_TERMINATION	Quick acquisition termination	0x08	0xE5, page 7
0xE6	W	START_BOOTLOADER	Start secure Bluetooth LE bootloader	--	0xE6, page 7
0xEA	R/W	ENABLE_FLASH_STORAGE	Store register settings	0x00	0xEA, page 7
0xEB	R/W	HIGH_ACCURACY_MODE	Improved accuracy setting	0x14	0xEB, page 8
0xEC	R	SOC_TEMPERATURE	SoC temperature	--	0xEC, page 8

0x00

R/W	Name	Description	Initial Value
W	ACQ_COMMANDS	Device command	--

Bit	Function
7:0	Write 0x03: Take distance measurement without receiver bias correction Write 0x04: Take distance measurement with receiver bias correction

0x01

R/W	Name	Description	Initial Value
R	STATUS	System status	--

Bit	Function
5	DC error flag 0: No error detected 1: An error was detected in correcting DC noise bias, and distance measurements are expected to be inaccurate
4	DC bias done flag 0: The device is performing automatic DC noise bias corrections 1: DC noise is within tolerance, and the automatic DC noise bias corrections are currently idle
3	Low power flag 0: Device is powered on. I2C commands can be issued at a normal rate. 1: The device is in low power mode. To allow the device to power on and perform the I2C command, a 10ms delay after each command is recommended.

Bit	Function
2	Reference overflow flag 0: Reference data has not overflowed 1: Reference data in correlation record has reached the maximum value before overflow (this occurs when taking measurements with biasing enabled)
1	Signal overflow flag 0: Signal data has not overflowed 1: Signal data in correlation record has reached the maximum value before overflow (this occurs with a strong received signal strength)
0	Busy flag 0: Device is ready for a new command 1: Device is busy taking a measurement or powering on

0x05

R/W	Name	Description	Initial Value
R/W	ACQUISITION_COUNT	Maximum acquisition count	0xFF

Bit	Function
7:0	Maximum number of acquisitions during measurement

0x10

R/W	Name	Description	Initial Value
R	FULL_DELAY_LOW	Distance measurement low byte	--

Bit	Function
7:0	Distance measurement result in centimeters, low byte.

0x11

R/W	Name	Description	Initial Value
R	FULL_DELAY_HIGH	Distance measurement high byte	--

Bit	Function
7:0	Distance measurement result in centimeters, high byte.

0x16

R/W	Name	Description	Initial Value
R	UNIT_ID_0	Unit ID, byte 0	--
W	UNIT_ID_0_UNLOCK	Write unit ID 0 for I2C address unlock	--

Bit	Function
7:0	Read byte zero (LSB) of the unit ID Write the value in UNIT_ID_0 here as part of enabling a non-default I2C address. See I2C_SEC_ADDR (*0x1A*, page 6).

0x17

R/W	Name	Description	Initial Value
R	UNIT_ID_LOW	Unit ID, byte 1	--
W	UNIT_ID_1_UNLOCK	Write unit ID 1 for I2C address unlock	--

Bit	Function
7:0	Read byte one of the unit ID Write the value in UNIT_ID_1 here as part of enabling a non-default I2C address. See I2C_SEC_ADDR (*0x1A*, page 6).

0x18

R/W	Name	Description	Initial Value
R	UNIT_ID_2	Unit ID, byte 2	--
W	UNIT_ID_2_UNLOCK	Write unit ID 2 for I2C address unlock	--

Bit	Function
7:0	Read byte two of the unit ID Write the value in UNIT_ID_2 here as part of enabling a non-default I2C address. See I2C_SEC_ADDR (*0x1A*, page 6).

0x19

R/W	Name	Description	Initial Value
R	UNIT_ID_3	Unit ID, byte 3	--
W	UNIT_ID_3_UNLOCK	Write unit ID 3 for I2C address unlock	--

Bit	Function
7:0	Read byte three (MSB) of the unit ID. Write the value in UNIT_ID_3 here as part of enabling a non-default I2C address. See I2C_SEC_ADDR (*0x1A*, page 6).

0x1A

R/W	Name	Description	Initial Value
R/W	I2C_SEC_ADDR	Write new I2C address after unlock	--

Bit	Function
7:0	Non-default I2C address. Available addresses are any non-zero 7-bit values. The five byte sequence is composed of the four byte UNIT_ID and the one byte slave address. The UNIT_ID must be entered with the least significant byte first. UNIT_ID_0_UNLOCK (*0x16*, page 6), UNIT_ID_1_UNLOCK (*0x17*, page 6), UNIT_ID_2_UNLOCK (*0x18*, page 6), and UNIT_ID_3_UNLOCK (*0x19*, page 6) must have the correct value for the device to respond to the non-default I2C address. Example: UNIT_ID = 0x01020304, (LSB = 04, MSB = 01) Example write starting at 0x16: 0x0403020155, would match on UNIT_ID and set slave address to 0x55 (The effective 8-bit secondary I2C address would be 0xAA write and 0xAB read) **NOTE:** You must enable ENABLE_FLASH_STORAGE before configuring the secondary I2C address (*0xEA*, page 7).

0x1B

R/W	Name	Description	Initial Value
W	I2C_CONFIG	Default address response control	0x00

Bit	Function
7:0	0x00: Use the default address only (0x62). 0x01: Use the secondary I2C address only. This requires the address to be configured using write command I2C_SEC_ADDR (*0x1A*, page 6). 0x02: Use both addresses.

0x1C

R/W	Name	Description	Initial Value
R/W	DETECTION_SENSITIVITY	Peak detection threshold bypass	0x00

Bit	Function
7:0	0x00: Use default valid measurement detection algorithm based on the peak value, signal strength, and noise in the correlation record. 0x01 to 0xFF: Set simple threshold for valid measurement detection. Values 0x20 to 0x60 generally perform well.

0x30

R/W	Name	Description	Initial Value
R	LIB_VERSION	Read Garmin software library version string	--

Bit	Function
7:0	Read 11 consecutive bytes in one I2C read for the full library version string. Each byte represents a character using ASCII encoding.

0x52

R/W	Name	Description	Initial Value
R/W	CORR_DATA	Correlation record data control	--

Bit	Function
7:0	Read two consecutive bytes to retrieve correlation record data as a 16-bit, two's complement value. The memory index is incremented automatically, and successive two-byte reads produce sequential data. Write 0x00: Reset correlation internal pointer to zero.

0x72

R/W	Name	Description	Initial Value
R	CP_VER_LO	Coprocessor firmware version low byte.	--

Bit	Function
7:0	Coprocessor firmware version low byte.

0x73

R/W	Name	Description	Initial Value
R	CP_VER_HI	Coprocessor firmware verison high byte	--

Bit	Function
7:0	Coprocessor firmware version high byte.

0xE0

R/W	Name	Description	Initial Value
R	BOARD_TEMPERATURE	Board temperature	--

Bit	Function
7:0	Returns the board's temperature as an 8-bit, two's complement value in Celsius.

0xE1

R/W	Name	Description	Initial Value
R	HARDWARE_VERSION	Board hardware version	--

Bit	Function
7:0	Board hardware version

0xE2

R/W	Name	Description	Initial Value
R/W	POWER_MODE	Power state control	0xFF

Bit	Function
7:0	0x00: **Asynchronous Mode**. The coprocessor is always OFF unless a distance measurement is requested or a register access is required 0x01: **Synchronous Mode**. Distance measurement is tied to the ANT channel period. The coprocessor is turned on and off as required. 0xFF: **Always on**. The coprocessor is not turned off, allowing for the fastest measurements possible. **NOTE:** You must disable HIGH_ACCURACY_MODE before you adjust the power mode.

0xE3

R/W	Name	Description	Initial Value
R/W	MEASUREMENT_INTERVAL	Automatic measurement rate	0xFF

Bit	Function
7:0	This register is used in conjunction with **Synchronous Mode** (*0xE2*, page 7). 0x00 and 0xFF: Trigger a distance measurement for every ANT message 0x01 to 0xFE: The number of ANT channel periods to wait before triggering a distance measurement, effectively reducing the automatic measurement rate. HIGH_ACCURACY_MODE must be disabled before adjusting the measurement interval (*0xEB*, page 8).

0xE4

R/W	Name	Description	Initial Value
W	FACTORY_RESET	Reset default settings	--

Bit	Function
7:0	0x01 to 0xFE: Resets the NVM/Flash storage information back to default settings and executes a SoftDevice reset.

0xE5

R/W	Name	Description	Initial Value
R/W	QUICK_TERMINATION	Quick acquisition termination	0x08

Bit	Function
7:0	0x00: Enable measurement quick termination. The device terminates the distance measurement early if it anticipates the signal peak in the correlation record will reach the maximum value. 0x08: Disable measurement quick termination.

0xE6

R/W	Name	Description	Initial Value
W	START_BOOTLOADER	Start secure Bluetooth LE bootloader.	--

Bit	Function
7:0	0x01 to 0xFE: Restarts the device and launches the Bluetooth LE advertiser. All other functionality is disabled while using the Bluetooth LE bootloader.

0xEA

R/W	Name	Description	Initial Value
R/W	ENABLE_FLASH_STORAGE	Store register settings	0x00

Bit	Function
7:0	0x00: Use RAM storage only. 0x11: Use FLASH/NVM storage. Any register that supports both read and write operations is stored in NVM and persists over power cycles. **NOTE:** Use caution when enabling flash storage. The total number of writes and erases is limited to 10,000.

0xEB

R/W	Name	Description	Initial Value
R/W	HIGH_ACCURACY_MODE	Improved accuracy setting	0x14

Bit	Function
7:0	0x00: Disable high accuracy mode. While high accuracy mode is disabled, you can adjust the POWER_MODE to **Asynchronous Mode** or **Synchronous Mode** if required (*0xE2*, page 7). 0x01 to 0xFF: Enable high accuracy mode. The value is used as the number of distance measurements to accumulate and average before returning them to the user. You must set the POWER_MODE to **Always On** before you adjust to a non-zero value.

0xEC

R/W	Name	Description	Initial Value
R	SOC_TEMPERATURE	SoC temperature	--

Bit	Function
7:0	Returns the temperature of the nRF SoC as an 8-bit, two's complement value in Celsius.

Appendix

Reprogramming the nRF52840 SoC

NOTICE

Reprogramming the nRF52840 System on Chip (SoC) removes all pre-programmed factory software. The device comes preprogrammed with a unique ANT ID to ensure each device can be uniquely identified over the ANT wireless protocol. When reprogramming the device, special precautions should be taken to preserve the ANT ID value. See https://github.com/garmin/ for information about accessing and retaining the ANT ID value.

The LIDAR-Lite v4 LED device comes preprogrammed from the factory with a Bluetooth LE secure DFU bootloader for receiving wireless software updates. When reprogramming the nRF52840, the bootloader is removed. If you require a bootloader after reprogramming the device, you can follow the Bluetooth LE Secure DFU Bootloader reference design in the Nordic nRF5 SDK. If a boot pin is required, you should configure it to one of the exposed GPIOs (*LIDAR-Lite v4 LED Connection Diagram*, page 1).

Before you can reprogram the device, you must connect it to a compatible debugging probe.

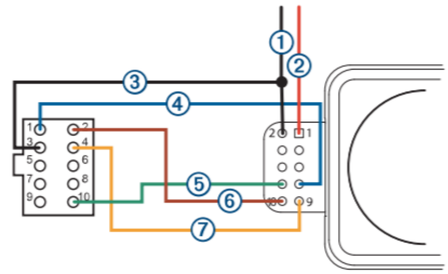
The header on the LIDAR-Lite v4 LED device provides access to the nRF52840 SoC. You can reprogram the nRF52840 SoC to suit the individual needs of your project. Software development should be completed using the C programming language and the Nordic nRF5 SDK. For more information about the capabilities of the nRF52840, go to www.nordicsemi.com/nrf52840.

- For information about setting up a LIDAR-Lite v4 LED development environment, go to https://github.com/garmin/.
- For support in using the nRF5 SDK and reprogramming the nRF52840 SoC, go to https://devzone.nordicsemi.com/.

10-pin J-Link Wiring

You should connect the 10-pin J-Link debugging probe to the LIDAR-Lite v4 LED device as shown in the diagram and table below.

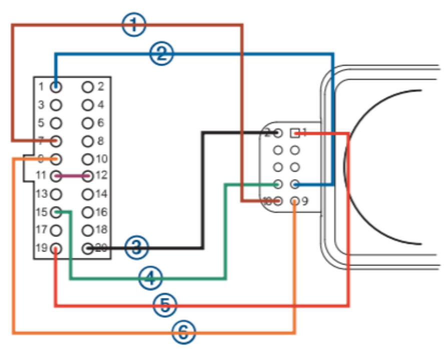
NOTE: A 10-pin J-link debugging probe cannot supply power to the LIDAR-Lite v4 LED device. Connections 1 and 2 are connected to the device from an external power supply. The power supply and debugging probe should share a common ground at pin 2 on the LIDAR-Lite v4 LED device.



Connection	10-Pin J-Link Debugging Probe Pin	LIDAR-Lite v4 LED Pin
①	--	2 (GND) to common ground
②	--	1 (VIN) to power source
③	3 (GND) to common ground	--
④	1 (VCC)	7 (VRETURN)
⑤	10 (nRESET)	8 (nRESET)
⑥	2 (SWDIO)	10 (SWDIO)
⑦	4 (SWCLK)	9 (SWCLK)

20-pin J-Link Wiring

You should connect the 20-pin J-Link debugging probe to the LIDAR-Lite v4 LED as shown in the diagram and table below.



Connection	20-Pin J-Link Debugging Probe Pin	LIDAR-Lite v4 LED Pin
①	7 (SWDIO)	10 (SWDIO)
②	1 (VCC)	7 (VRETURN)
③	20 (GND)	2 (GND)
④	15 (nRESET)	8 (nRESET)
⑤	19 (5V Supply)	1 (5V)
⑥	9 (SWCLK)	9 (SWCLK)
⑦	Short 11 to 12	Not applicable

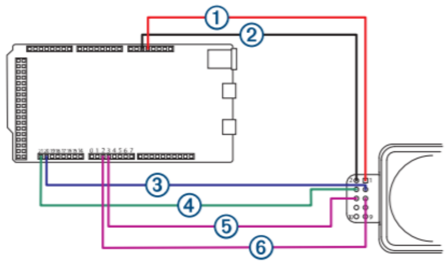
Standard Arduino® DUE I2C Wiring

NOTICE

The LIDAR-Lite v4 LED maximum signal level is 3.3 V. A signal greater than 3.3 V will damage the device.

You should connect the Arduino DUE and the LIDAR-Lite v4 LED as shown in the diagram and table.

NOTE: You must splice the ground wires so all components share a common ground. These components include the power supply, the programmer, the microcontroller operating I2C, and any GPIOs.



Item	Arduino DUE	LIDAR-Lite v4 LED	V Max
①	5V	1 (5 V)	5 V
②	GND	2 (GND)	--
③	SDA 20	3 (SDA)	3.3 V
④	SCL 21	4 (SCL)	3.3 V
⑤	PWM 3	6 (GPIOB)	3.3 V
⑥	PWM 2	5 (GPIOA)	3.3 V

Troubleshooting

Product Support

Contact your authorized Garmin Reseller for troubleshooting information related to your device and its specific application.

Go to support.garmin.com for general help and information, such as product manuals, specifications, and frequently asked questions.

The I2C is not responsive while the device is powered on

GPIO B is used as a boot pin to start the LIDAR-Lite v4 LED Bluetooth LE bootloader. If GPIO B is grounded when the device is powered on, the bootloader is enabled and I2C and ANT functionality are disabled.

Verify GPIO B is not grounded.

I cannot connect my device to the Garmin PC simulator

- Ensure the ANT network key is configured correctly.
  - If the LIDAR-Lite v4 LED device still has the default application installed from the factory, verify that you have the Garmin developer key selected.
  - If you have reprogrammed the device and you are using the public network key, verify that you have the public network key selected.
- Verify that you have the same RF frequency selected on both the LIDAR-Lite v4 LED device and the Garmin PC simulator.
- Verify that you have the correct channel parameters selected.

  TIP: You can set wildcards for the channel parameters to connect to any device. On the PC simulator, if you set the device number and transmission type to zero, the Garmin PC simulator connects to a device with any device number and transmission type.

Can I use a microcontroller with 5 V signaling?

The LIDAR-Lite v4 LED device is tolerant to only 3.3 V. If you need to use a 5 V system, such as the Arduino Uno, you must use a logic level converter to protect the I/O drivers in the LIDAR-Lite v4 LED device. Garmin does not endorse or recommend using a microcontroller with 5 V signaling.

RB-Dfr-448
Mini Push Button (5pk)

Miniature Single Pole Single Throw switches. These are high quality Omron type B3F momentary on switches. Perfect as a tactile reset switch. Mounts directly into standard bread boards also prototype shield. Rated up to 50mA.

Specifications

- Maximum ratings: DC 12V 50mA
- Operation temperature range: -25~70℃(normal humidity, normal press)
- Storage temperature range: -30~80℃(normal humidity, normal press)
- Size: 6 x 6.5 x 7mm

SHENZHEN PKCELL BATTERY CO., LTD

PKCELL

Polymer Li-ion Battery Technology Specification

Model：ICR18650 4400mAh 3.7V

Customer confirmation	Corporate name	adafruit industries
	Checked	Limor Fried
	Approved	8.18.14 MUST USE GENUINE JST BRAND CONNECTORS
	Corporate seal	

Signed: MJungman

Drafted by:____________

Signed by: Mary Jungman

Document No.: **QA.S.0221** Edit：**A/0**

SHENZHEN PKCELL BATTERY CO., LTD
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E-mail：pkcell@pkcell.net Website：http://www.pkcell.net

(If manufacturer want to modify the product technology specification, we won't inform you additionally)

PKCELL BATTERY	Document	**Technical Specification ICR18650 4400mAh 3.7V**	Edition	A/0
			Valid Date	2014-07-28
			Drafted by	Xiao li
	Number	QA.S. 0221	Signed by	Zhijiang Li

1. SCOPE

This document describes the performance characteristics and testing methods for Polymer Lithium-ion batteries produced by shenzhen pkcell battery Co., Limited.

2.SPECIFICATION

No.	Item	Characteristics	Remarks
1	Nominal Capacity	Minimum:4180mAh Typical: 4400mAh	Standard discharge（$0.2C_5A$) after Standard charge
2	Nominal Voltage	3.7V	—
3	Charging Cut-off Voltage	4.2V	—
4	Discharge Cut-off Voltage	3.0V	—
5	Standard Charge	Constant Current $0.5C_5A$ Constant Voltage 4.2V 0.01 C_5A cut-off	Charge Time : Approx 4.0h
6	Maximum Constant Charging Current	4400mA（1.0C）	—
7	Standard Discharge	Discharge at 0.2 C_5A to 3.0V	—
8	Maximum Continuous Discharging Current	8800mA（2.0C）	—
9	Operating Temperature	Charge 0～45℃ Discharge –20～60℃	—
10	Storage Temperature	-20～45℃ for 1Month -20～35℃ for 6Months	—
11	Storage Voltage	3.7-3.9V	—
12	Environmental request	RoHS	If the materials of the product and packaging accord with RoHS standard，there will be a RoHS Id on the box.

3. Dimensions

Please refer the drawing in appendix.

4. Appearance

No scratches, dirt, defect, leakage of electrolyte or gassing should be observed as a new product.

5. Standard Testing Environment

Temperature : 25±2℃

Relative humidity : 65±20%（unless specially requested）

6. Characteristics

6.1 Electrochemical performance characteristics

No.	Item	Testing Method	Requirements
1	Fully Charged State	CCCV or Constant current charge to 4.2V @1C follow by a constant voltage holding at 4.2V until current drops below 22±3mA.	—
2	Rated Capacity	CCCV at 4.2V (per 6.1.1) at room temp. (20±5C), rest for 1-2 hrs then discharge at a constant current of 0.2C to 3.0V, testing will be terminated by either 5 cycles or any one discharge time exceeds 5 hrs	≥4180mAh
3	Cycle Life @25℃	Discharge to 3.0V @1C, then CCCV charge to 4.2V, rest for 10 min. discharge @ 1C to 3.0V and rest for 10 min. Continue the charge/discharge cycles until discharge capacity lower than 70% of rated capacity.	Cycle life ≥500
4	Internal Impedance	Internal impedance is measured on a 50% charged battery at 1KHz AC at ambient temperature（20±2）℃	—
5	Capacity Retention	Fully charge cells per 6.1.1, store them at (20±2)℃ for 28 days, then discharge the cells to 3.0V at 0.2C.	Discharge Capacity≥3520mAh
6	High Temperature Characteristics	Fully charge cells per 6.1.1, store them at (55±2)℃ for 2 hours, then discharge the cells to 3.0V at 0.2C.	Discharge Capacity≥3520mAh
7	Low Temperature Characteristics	Fully charge cells per 6.1.1, store them at (-10±2)℃ for 16~24 hours, then discharge the cells to 3.0V at 0.2C.	Discharge Capacity≥2640mAh
8	Cell Voltage during Transportation	Check open circuit voltage (OCV) of cells prior to the delivery to customers	≥3.7V

6.2 Safety characteristic

No.	Item	Test Method	Requirements
1	Over charge	Discharge cells to 3.0V at 1C, then charge to 14.4V at 3C and rest for 8 hours.	No fire No explosion No leakage
2	Overdischarge	Fully charge cells per 6.1.1, then discharge the battery to 3.0V with 0.2CmA at room temperature, connect with external load of 30Ω for 24 hours.	No fire No explosion No leakage
3	Hot Oven Test	Put a fully charged battery in a forced air oven and raise the temperature at 5±2℃/min. to130±2℃ Rest for10 minutes.	No fire No explosion No leakage

6.3 Reliability

No.	Item	Test Method	Requirements
1	High Temperature Test	Fully charged per 6.1.1,then rest at 60±2℃ for 2 hours.	Electrochemical performance、visual test not changed
2	Low Temperature Test	Fully charge cells per 6.1.1, rest at -20±2℃ for 2 hours. Then the cells are placed at room temperature for 3 hours.	No appreciable alternation electrochemically and visually
3	Humidity Test	Fully charge cells per 6.1.1, rest at 40±2℃ with 90%～95RH% for 48 hours. Then the cells are placed at room temperature to “dry out” for 2 hours.	No appreciable alternation electrochemically and visually
4	Vibration Test	After standard charged, fixed the cell to vibration table and subjected to vibration cycling that the frequency is to be varied at the rate of 1Hz per minute between 10Hz an 55Hz, the excursion of the vibration is 1.6mm. The cell shall be vibrated for 30 minutes per axis of XYZ axes.	No fire No explosion No leakage
5	Drop Test	The cell is to be dropped from a height of 1 meter twice onto concrete ground.	No fire No explosion No leakage
6	Collisions	After the vibration test, according to X.Y.Z each battery average three vertical pulse peak acceleration, the setting for the 100m/s2, every minute, 40 ~ 80 collision frequency, pulse duration 16ms collision frequency ± 10 thousand.	No fire No explosion No leakage
7	Crush (Fresh, Fully charged)	Crush between two flat plates. Applied force is about 13kN(1.72Mpa) for 30min.	No fire No explosion No leakage
8	Short Circuit	This test will be placed the battery electric dipole in the fume hood, short-circuit the anode (total resistance is not more than 50mΩ lines), monitor temperature changes, when the battery is low temperature dropped to about 10 degrees than peak, the end of experiment.	No explosion, No fire The temperature of the surface of the Cells≤150℃
9	Impact(Fresh, Fully charged)	A 56mm diameter bar is inlayed into the bottom of a 10kg weight. And the weight is to be dropped from a height of 1m onto a sample battery and then the bar will be across the center of the sample.	No fire No explosion No leakage

10	Thermal shock(Fresh, Fully charged)	Batteries in hot box Temperature in 5℃±2℃/min，rising to 50℃±2℃ keep 30min	No fire No explosion No leakage
11	Constant damp performance	Standard after the battery, Will a battery into 40℃±2℃, Relative humidity90%～95% At constant temperature and humidity box after 48h Battery will in environmental temperature 20±5℃ Aside 2h, $0.2C_5A$ to terminate discharge current voltage,	No obvious deformation, hands rust, smoke, explosion, discharge time ≥36 min

7. Warranty

Warranty period for this product is 6 months starting from the date when the products left the door of manufacturer.

8. Liability

The user has to operate the products according to the instructions printed on the battery label or follow the advices described in this "Product Specification for Lithium Ion Batteries published by shenzhen pkcell battery Co., Limited. In case the battery were overheated or even catch fire or explosion caused by mishandling of the user side, shenzhen pkcell battery Co., Limited. will not be liable for the lose caused by any of such mishandling. shenzhen pkcell battery Co., Limited. will notify the users in written form if any modifications in specification, raw material, production process control.

9. Battery Packing Label

The following warnings should be indicated on the battery pack labels.

- Use a specified charger.
- Do not throw the battery into fire, or heat.
- Do not short-circuit the battery terminals.
- Do not disassemble the battery.

10. Warnings and Cautions in Handling the Lithium-ion Battery

To prevent potential leaking, overheating or explosion of batteries please be advised to take following precautions:

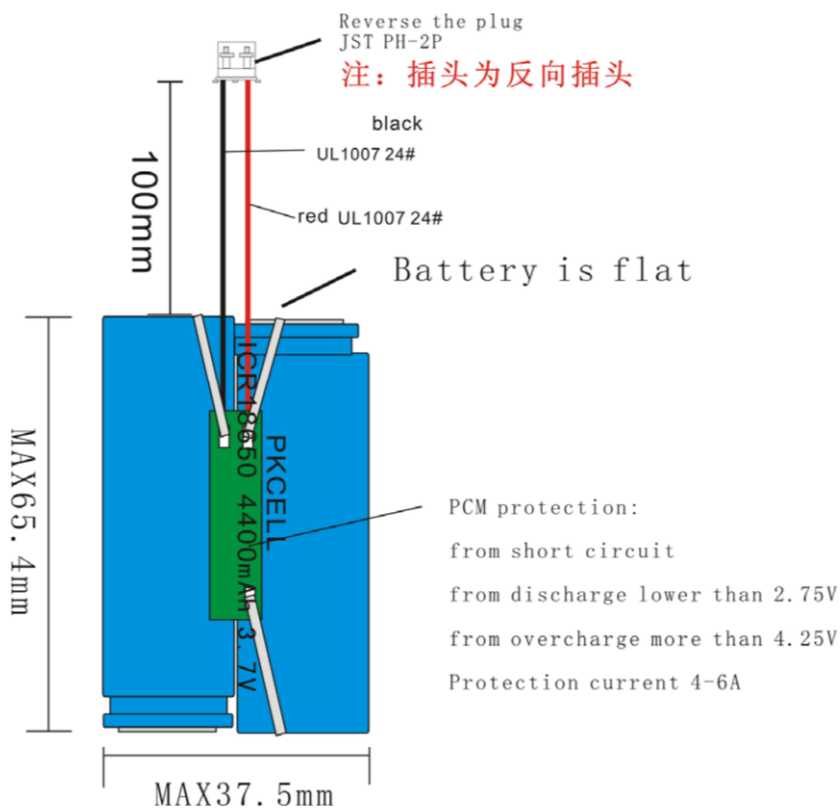
WARNINGS!

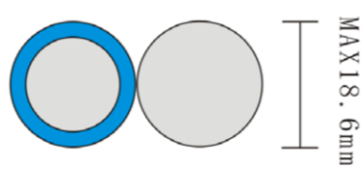
- Do not immerse the battery in water or seawater, and keep the battery in a cool dry environment during stands by period.
- Do not use or leave the battery near a heat source such as fire or heater.
- When recharging, use the battery charger specifically for that purpose.
- Do not reverse the position (+) and negative (-) terminals.
- Do not connect the battery to an electrical outlet.
- Do not dispose the battery in fire or heat.
- Do not short-circuit the battery by directly connecting the positive (+) and negative (-) terminal with metal objects such as wire.
- Do not transport or store the battery together with metal objects such as necklaces, hairpins etc.
- Do not strike or throw the battery against hard surface.
- Do not directly solder the battery and pierce the battery with a nail or other sharp object.
- Outer metal conduct can not contact the aluminum layer in AL laminate film, especially with electrification ,which will be “black spot ”and swelling easily.
- Do not use sharp things to hit the battery.

CAUTIONS!

- Do not use or leave the battery at very high temperature (for example, at strong direct sunlight or in a vehicle in extremely hot weather). Otherwise, it can overheat or fire or its performance will be degenerate and its service life will be shortened.
- Do not use it in a location where static electricity is rich, otherwise, the safety devices may be damaged, causing a harmful situation.
- In case the electrolyte get into the eyes due to the leakage of battery, do not rub the eyes! Rinse the eyes with clean running water, and seek medical attention immediately. Otherwise, it may injure eyes or cause a loss of sight.
- If the battery gives off an odor, generates heat, becomes discolored or deformed, or in any way appear abnormal during use, recharging or storage, immediately remove it from the device or battery charger and place it in a contained vessel such as a metal box.
- In case the battery terminals are contaminated, clean the terminals with a dry cloth before use. Otherwise power failure or charge failure may occur due to the poor connection between the battery and the electronic circuitry of the instrument.
- Be aware discarded batteries may cause fire, tape the battery terminals to insulate them before disposal.

12. Dimensions


Reverse the plug
JST PH-2P
注：插头为反向插头
black
UL1007 24#
red UL1007 24#
100mm
Battery is flat
ICR18650 4400mAh 3.7V
PKCELL
PCM protection:
from short circuit
from discharge lower than 2.75V
from overcharge more than 4.25V
Protection current 4-6A
MAX65.4mm
MAX37.5mm


MAX18.6mm

........END........