Team 6 - Dormice
ECE 212 Project Report

Cause it's lit yo

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Executive Summary

Lit is a turn/brake system for bicyclists that makes sharing the road with cars and pedestrians safer. It consists of two components:

- A handlebar-mounted device with a tactile switch, brake sensors and front lights.
- A wearable backpack with rear lights paired with the handlebar via Bluetooth.

Lit relies on tactile feedback with a three way switch and brake sensors to avoid distracting the rider. It is easy to install and remove for charging and is expected to operate for 12-24 hours one a single charge. It is water-resistant and can be used in most conditions. Lit has a small screen on the handlebar that indicates device charge, speed and mileage. Bluetooth communication between the two devices helps minimize wiring and maximize portability.

Lit is marketable to bicyclists and the growing market of electric devices for pedestrian commuting. Lit offers good value for its cost.

Motivation

Need

A safe way to signal turning and stopping using a bicycle or similar form of transportation that is visible in all conditions and communicates the user's intent clearly.

Problem definition

Create a system of devices that is portable, weather-resistant, easy to use, affordable, and communicates the user’s intent to turn and to stop. The device has to clearly communicate the user’s intent using LEDs and easy-to-use switching mechanisms. The system has to be safer than using hand signals and clearly visible to others from the front and the back. For the system to be marketable to the user, it has to be usable by various types of cyclists (road, commuter, mountain biker) and other similar forms of transportation like scooters.

Project selection

The most important factor in selecting the project was practical application and usefulness of the product. A bicycle turn light system helps ensure road safety by clearly showing the cyclist’s intent to brake and/or turn. Lit provides a clear way to communicate the cyclist’s intent to drivers and pedestrians. The device may also alleviate concerns of the danger of commuting by bicycle and encourage wider use of bicycles, leading to lower greenhouse emissions.

From the perspective of the team's personal interest, the project provides opportunities to expand our technical skill set by using technologies like bluetooth, new types of sensing equipment, and using microcontrollers to design output responses based on input devices. The project met the team's expectations of budget and time requirements for a 4-sprint product development timeline. The project is complex enough to be challenging and interesting. The team possesses most of the necessary components and the ones remaining to be acquired are low cost.

Project Description

Functional decomposition: this part describes project functionality by the L0 and L1 functional decomposition.

L0 decomposition

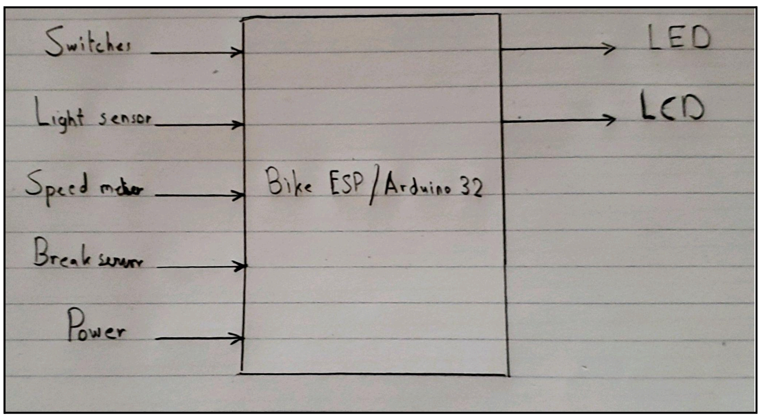


Figure 1: This figure represents the L0 functional decomposition of the project.

In figure 1, a level 0 functional decomposition sketch represents a simplified version of 'lit' with esp32, inputs and outputs. Inputs include: the brake switches, turn signal switch, the accelerometer/gyrometer(speedometer), and the ESP32 monitoring the batteries charge. The speedometer is going to be used to measure the speed and calculate total miles traveled. The speed, mileage and battery charge are to be displayed on the LCD (output). Switches are used to control the turn signal LEDs and the breaking LEDs. Five banks of LEDs are used to indicate intent, two for the right and left turning and one for the braking. Switches will be used to power the devices on/off.

L1 decomposition

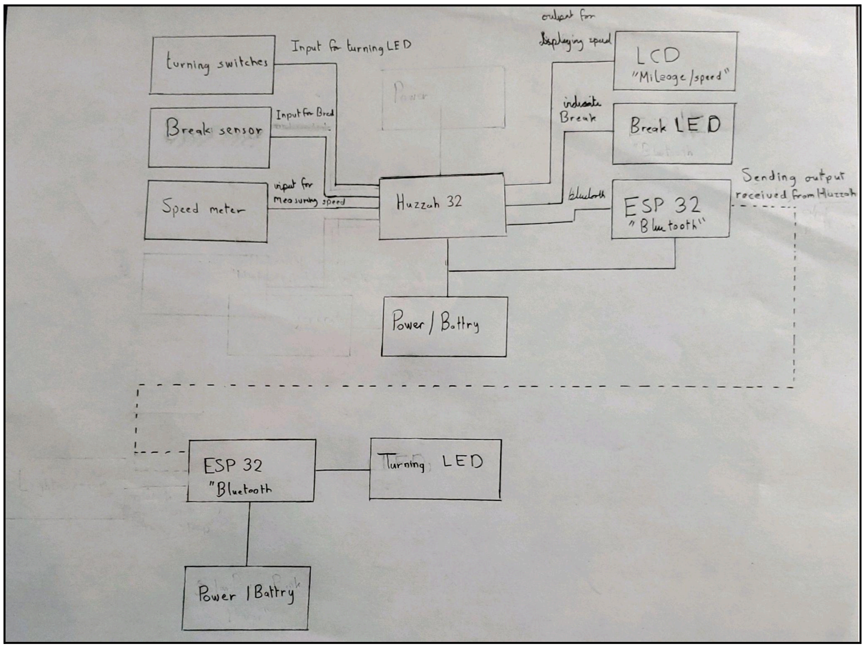


Figure 2: This figure represents the L1 functional decomposition of the project.

Figure 2 shows the level 1 functional decomposition of the project in more detail compared to the L0 functional decomposition. L1 shows that both esp32's are powered by rechargeable batteries, three inputs (brake switch, speedometer and turn light switch) and three outputs (an LCD, LEDs and esp32). The speedometer is used to measure and communicate the speed to the esp32, which then displays mileage and speed on the LCD. Two switches are used to turn on the LEDs that represent the right and left directions. The brake switches are used to send an input to the esp32 whenever the user applies either the front or the back brake. When the input is received from the brake sensor, the brake LED will flash. A rechargeable battery is connected to a power generator which converts the mechanical energy of the cyclist to electrical energy to extend use between full charges (stretch goal).

The second part of decomposition displays the vest design for rear turn and brake lights. Mainframe esp32 will send turn and brake data to the vest esp32 via bluetooth. A solar power bank is used to extend use time between charges(stretch goal).

Functions

- The handlebar esp32 shall send signals to the other esp32 to turn on rear LEDs.
- LCD shall display mileage and speed from the speed sensor.
- If the brake switch is applied, the brake lights shall light up.
- If a turn signal switch is applied, the turn lights will light up for the indicated direction.
- The battery shall be rechargeable.

Performance

- The cyclist's intent shall be clear to other users of the road in most weather and lighting conditions.
- The operator shall safely navigate the road without being distracted with the operation of the device.
- The switches shall control the LEDs with the least time delay possible.

Requirements/constraints for the project

- Operable without distracting the operator from riding safely and paying attention to the road.
- Intention/lights visible to people ahead and behind up to 15 feet away in most weather and lighting conditions.
- Rider not physically connected to the bike with wires. Using bluetooth for the wearable component.
- All portions of the electrical circuitry are weather resistant with a custom-designed case and backpack.
- 12 to 24 hours of continuous operation on a single charge to allow 2-3 days between charges.
- Small, easily storable vest.

The most important requirement is safety. Here are the highest priority requirements:

- Operator safety is the number one concern. If the product is not safe to use while riding on the roads (a distraction from safe riding), it is a failed product.
- Intentions of the operator are clear to all people sharing the road. If the device does not properly convey the intention of the operator, the product is not useful and would be considered a failure.

Project planning

Organization

We followed the class standard SCRUM format. We decided to change from in-person only meetings to a mix of remote and in-person meetings. Monday and Wednesday meetings were in-person. Friday and weekend meetings were done remotely. We used Discord to communicate and facilitate remote meetings.

Timelines Planned vs. Actual

Overall the initial timeline was followed with only minor changes to individual tasks when roadblocks were encountered like programming and testing two different accelerometers to obtain best results or ordering an incorrect board with pins to mount the display. The team

addressed such setbacks at the time they occurred and came up with adjustments on how to continue working on the project to mitigate any delays and stay on track for the overall due date. The parts of the timeline that got updated are highlighted in the Gantt charts below:
Original timeline:
https://drive.google.com/file/d/1EIRxFP1MPzAlhqVgtI43euD-aIGfgdHk/view?usp=sharing
Final timeline:
https://drive.google.com/file/d/1tWtFAT2yWsuYYCFBUhLiUWjy7gnLHaeE/view?usp=sharing

Team Member Specializations

- Dimitrii Fotin: Programming
- Elan Redmon: Circuit Design
- Hobie Topping: Physical Design - Handlebar device
- Mohamed Ashkanani: Physical Design - Vest

Sprint Breakdown

We broke the four sprints into manageable and incremental tasks to fulfill the needs of our project defined by our product features and requirements. Spring 1 encompassed the preliminary research, acquisition and purchasing of components and circuit design and programming for the basic functionality of turn/brake input and LED output. Sprint 2 encompassed final design choices for the handlebar and vest, programming for the screen and accelerometer, and adding each component to the circuit toward building an initial prototype. Sprint 3 encompassed prototyping and initial testing of the circuit.
Sprint 4 encompassed finishing the final prototype for presentation and testing the prototype to ensure it works as desired.

- Sprint 1 Goal: Complete the basic circuit capable of receiving user inputs for braking and turning, communicating the signals to the vest circuit via bluetooth and lighting up the mainframe and vest LEDs for received inputs. Additionally, research features planned for implementation in further sprints.
- Sprint 2 Goal: Determine the final mainframe and vest physical designs, finalize the circuit design and implement the display and accelerometer in code.
- Sprint 3 Goal: Assemble a working prototype and perform initial testing to ensure that the core features are working together. Determine any issues in circuit and code.
- Sprint 4 Goal: Address the issues in circuit and code, solder custom PCBs and assemble all components in final physical designs.

Planning Review

The project went according to plan with the exception of minor setbacks with ordering incorrect components and refining accelerometer code. Project goals were met and adjusted as needed when any issues were encountered that led to timeline changes. We effectively used Trello to facilitate our planning and implementation. We used SCRUM's flexibility to incrementally complete our project. The use of Gantt charts allowed us to track our overall progress. The Gantt chart provided a solid outline of our sprints for us to plan with.

Prototype Implementation

The project was broken down into four major areas: physical designs for the handlebar and vest devices, coding and circuit design.
The handlebar consists for a custom case with a custom PCB that includes an ESP32 Feather microcontroller, an Adafruit OLED FeatherWing display, a three-way switch, two braking sensors and an MPU 6050 accelerometer, various LEDs and a 3.7V 820mAh Lithium-ion polymer battery.
The vest consists of an ESP32 Feather microcontroller, various LEDs and a 3.7V 820mAh Lithium-ion polymer battery.
The overall device composition is displayed below.

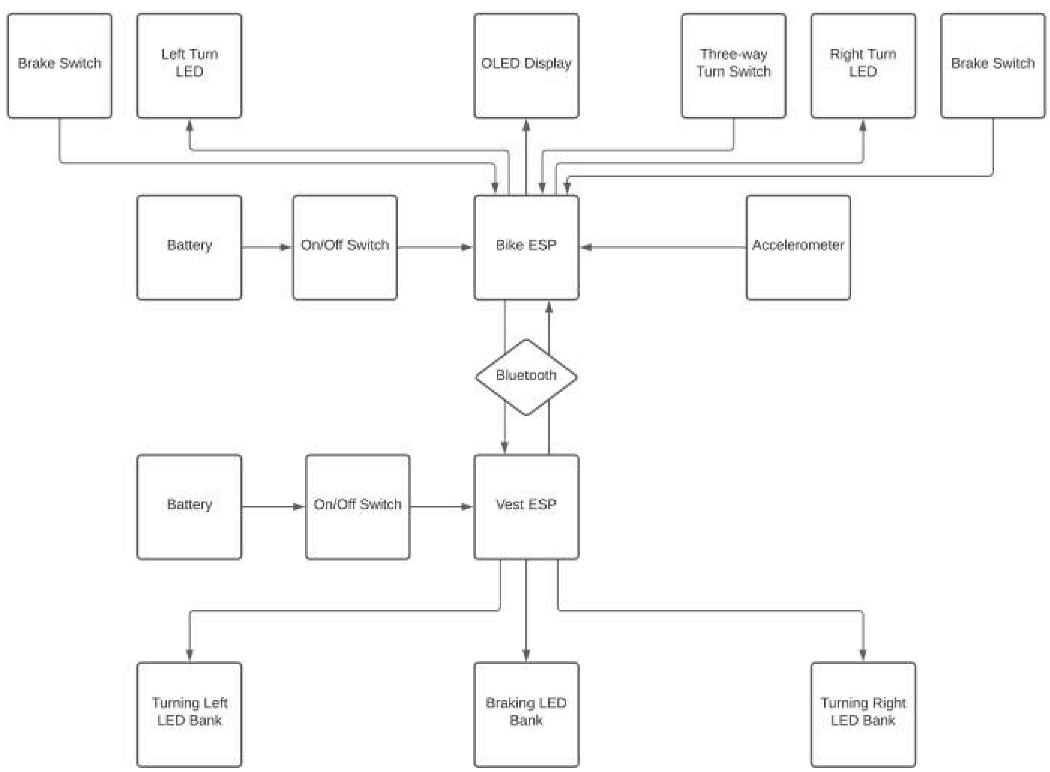


Figure 3: Block diagram of LIT.

ESP32 Feather was the microcontroller of choice for this project due to its small size compared to a standard ESP32 and its support of bluetooth. It also ships in a package with pre-installed pins that allows mounting an Adafruit OLED FeatherWing display right on top of it. Size was an important consideration for the project, a smaller microcontroller would help keep the size of the product compact making the product less susceptible to changing position while riding a bike.

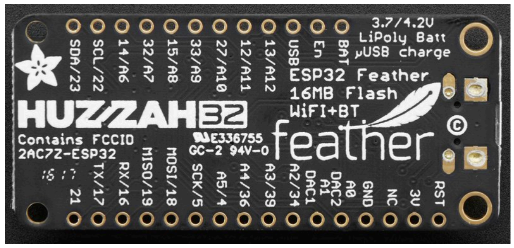


Figure 4:ESP32 Feather.

Adafruit OLED FeatherWing display was selected for its easy integration with ESP32 Feather and low power consumption. The purpose of the device was to function on battery power and this display provided all needed functionality with minimal drain.

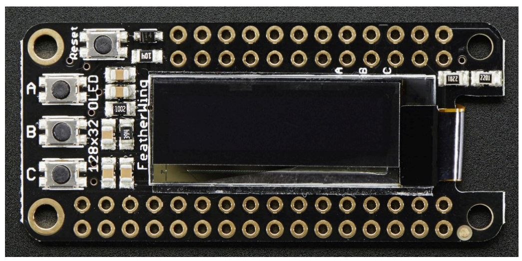


Figure 5: Adafruit OLED FeatherWing display.

A three-way switch was selected in lieu of buttons for the turn signal to allow for tactile feedback to the user and minimize distraction due to operation while riding a bike.

Figure 6: 3-way switch with extender.

A brake sensor selected is a switch with a long handle for easy integration with standard bicycle brake handles.

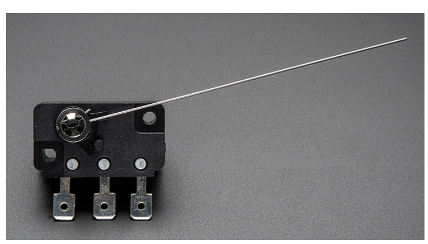


Figure 7: Brake sensor/Micro-switch.

MPU 6050 3-axis accelerometer was selected to track device acceleration and calculate average speed with rotational component in mind. This component was selected due to its small size and easy integration with the microcontroller as it could be placed directly within the case ensuring weather-resistance as opposed to a reed sensor that would need to be mounted on a wheel and would make the product less user-friendly due to more wires, extra installation and higher risk of malfunctioning in wet conditions. In the course of testing it was determined that the sensor tends to accumulate error very quickly over time and is not a reliable way to track speed. The issue can be resolved by adding GPS.

Figure 8: MPU 6050 3-axis accelerometer.

A 3.7V 820mAh battery was selected for both the handlebar and the vest based on calculations for the current needed for all components including the LEDs and the 12-24 hours of operation on a single charge.

Figure 9: 3.7V 820mAh battery.

Final prototype

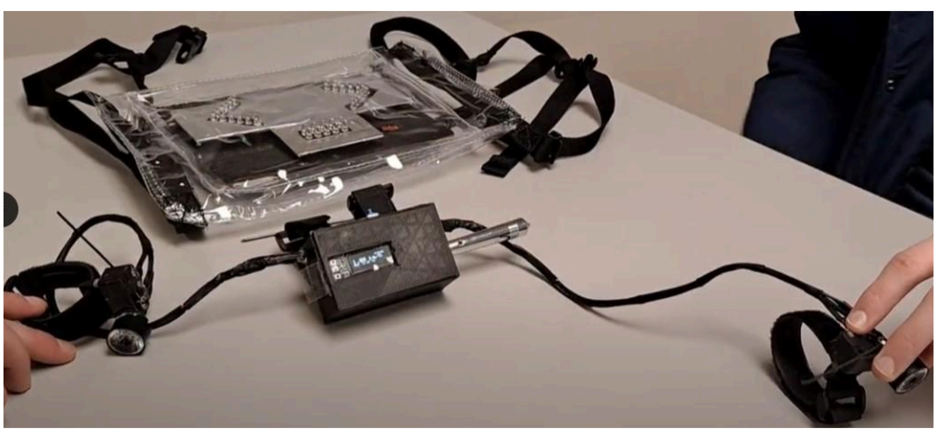
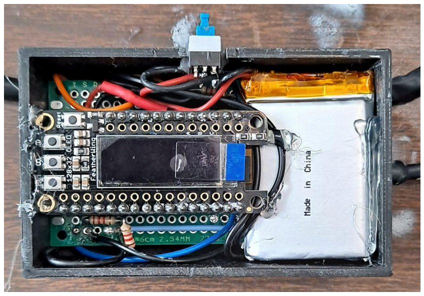
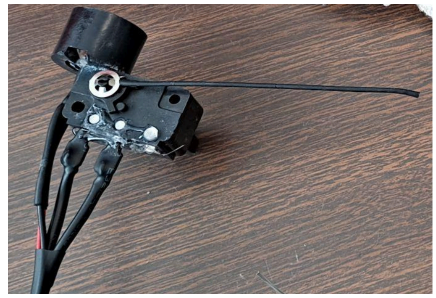


Figure 10: Final prototype during testing.





Figures 11 and 12: Handlebar device interior before case sealed and close up of the front right turn signal LED housing and braking switch.

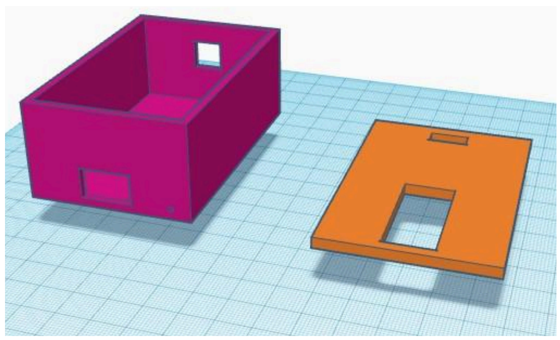


Figure 13: TinkerCAD design for handlebar case.

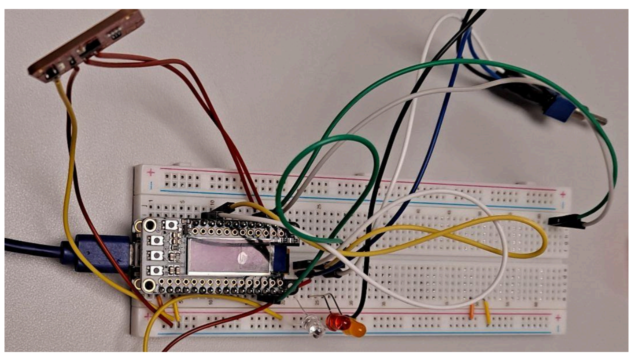
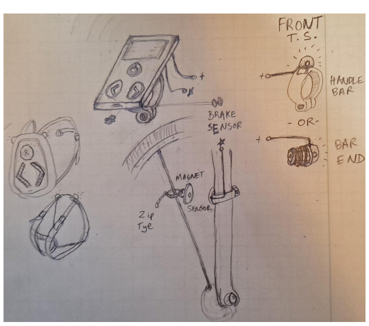
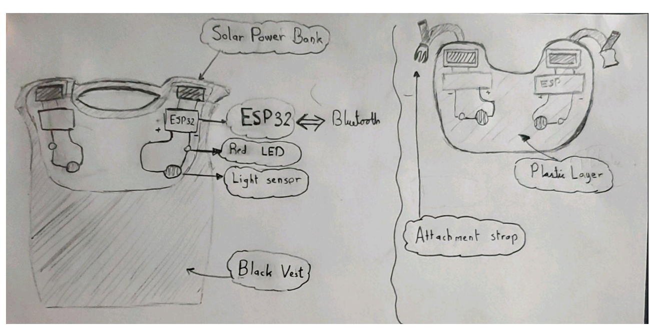


Figure 14: Initial Prototype for handlebar device.





Figures 15 and 16: Initial concept design for the handlebar device and the vest.

Figure 17: Final vest design.

Components

- Handlebar device
  - ESP32 Feather
  - Two braking switches (Adafruit microswitches)
  - One 3-way switch for indicating turning.
  - Two banks of LEDs (single LED in a reflective housing)
  - Adafruit 3045 Assembled FeatherWing OLED screen
  - MPU-6050 3 Axis Accelerometer Gyroscope Module
  - 3D printed custom case.
- Vest Device
  - ESP32 Feather
  - Red and Yellow LEDs
  - On/off switch
  - Lithium Ion battery - 3.7v 2000mAh
  - Vest (including a small case, straps, a cardboard and a button)

User Guide

Quick Start Guide:

1. Charge each unit's battery using a micro-USB cable (note: we would provide a short one for the user). Standard charging time is approximately 4 hours.

2. Attach the handlebar case to the handlebar within reach of your right thumb while holding the grip.

3. Attach each braking switch/front LED signal so that the brake switch can be used while applying the brake lever with the LED housing facing forward.

4. Power on the vest device first to make sure it's available for bluetooth pairing. Then power on the handlebar unit.

5. Put the vest on with the LEDs facing to your rear. Adjust the straps for comfort.

6. Ride LIT!

Prototype Testing

Testing was performed incrementally as each component was added or code was implemented.

The 3d case was printed and the major components were tested for proper fit, tolerances. The board and switches fit within the case. The LEDs were tested to see if they fit within the purchased housings.

We tested our prototype by applying the inputs to see if we had the required outputs. We applied the brake switches and the turn signals separately and together to see if the correct LEDs lit up and blinked (rear). We applied these tests at each stage of prototyping and construction to ensure the major functionality worked. The final stage of this test was attaching the devices to a bicycle and a user to see if they work per our user stories. We tested the speedometer during this test.
The speedometer worked initially but as it was used it became increasingly incorrect. The speedometer reported speeds well outside of the possible range of speeds for a cyclist, 0-to 29kph (0-18mph).

Test	Result Worked y/n
Right brake switch applied	y
Left brake switch applied	y
Turn signal left	y
Turn signal right	y
Turn signals and brakes all four combinations	y
Power switch handlebar device on/off	y
Power switch vest device on/off	y
Handlebar(HB) device fits on bicycle	y
HB device removable	y
HB device water resistant	y
Speedometer reporting speed	y
Screen battery charge display	y
Screen speed display	y
Screen mileage display	y
Mileage data saved between device on/off sessions	y
Bluetooth pairing	y
Bluetooth signal transmission	y

Table 1: Tests with results.

Technical Summary

Lit is portable, water-resistant and easy to use. It features wireless communication between the user interface and the vest using bluetooth, a powerful feature of the ESP32. Lit is rechargeable and easy to remove for charging. It offers an easy way to safely indicate your braking and turning, especially at night when visibility is an issue. Once the issues surrounding the speed are addressed, Lit offers some features that are not available in current similar products. Adding GPS along with the accelerometer can help eliminate error and improve speed and mileage accuracy. The ESP32 offers many features that could be exploited to further improve Lit's functionality.

The stretch goals for power saving and recharging using the sun or the rider's energy would further improve the marketability of Lit.

Teamwork Discussion

Team Member Contribution and Strengths

Hobie researched and purchased the components (screen, battery, circuit board blanks, accelerometer) required for the handlebar device. Hobie designed the case to house the front circuit and made design choices surrounding switches and the front banks of LEDs. Hobie assembled the final prototype of the handlebar device with assistance from the team. Hobie added waterproofing to the front device.

Elan designed the overall layout of the circuit, assembled the initial circuit and subsequent circuit iterations, soldered final circuit connections, and tested the circuit iterations at all stages of the project. Elan worked with Mohamed and Hobie for the final handlebar unit construction.

Dmitrii programmed the input/output paths for the sensors and LEDs, bluetooth communication between the vest and the handlebar, the screen speed, mileage and battery charge data display and the accelerometer data parsing.

Mohamed researched and purchased the components (battery, LEDs, PCB boards, waterproof material for the vest) required for the vest. Mohamed designed the vest according to group members' suggestions as the team had a strong and positive impact on the design. Circuit assembly for the vest was done using tapes, superglue and cardboard to put inside the vest.

Collaboration

We worked within our defined roles to allow us to work as efficiently as possible. We talked about who had an interest in working on which aspect of design. Elan chose to work on the circuit design. Hobie chose to do the case design. Mohamed chose to work on the vest design. Dmitrii chose to work on the coding. We discussed the roles as a group and used them to divide up the task per sprint and per team member.

The design process was a solid collaboration. We all contributed ideas and worked with each other to establish the best solutions for each task. As a group we picked the best fits for case design, vest design and circuit design. We discussed the necessary coding requirements and worked out solutions that we implemented as part of our sprint tasks.

The hybrid nature of the class worked well. When the reporting was required, we worked remotely as it is easier to work as a team on a document using remote tools. Toward the end of sprint 3 and through sprint 4, we met outside of our regular meeting times to work on and test our physical prototypes.

Teamwork Review

We had very strong communication throughout the process. We divided the work among our team fairly evenly. We used Trello to maintain transparency and to update each other as to what tasks were in process, in need of review, done and not done. We had one small issue with communication surrounding the leads from the handlebar circuit to the front LEDs/brake but we were able to work together to address the issue. We wired the LEDs with two output wires and not to the ground. We worked on re-soldering the leads as a group and fixed it quickly. We did not lose much time to the mistake. Overall, we worked great as a team. The meetings were enjoyable and productive.

Lessons learned

Lit was fun to work on. We all learned some new skills. Coding the two ESP32's to pass input signals from one to the other was a particular accomplishment we are proud of. The project truly highlighted how important transparency and communication are when working as a team. SCRUM's flexibility and iterative approach allowed us to deliver testable results at the end of each sprint. It allowed us to work through the project on time and held us accountable for our efforts. We all learned how to solder. Using the EPL for 3D printing was an excellent experience and will be used again in the future. The process of design choice and selecting the correct components for the project was a learning experience. It is very important to read the datasheets and do research surrounding each choice before settling on the final choice or ordering components.

We had several major hurdles that we overcame and a couple we did not. During sprint 3 we purchased an ESP32 and not an ESP32 Feather which made the code incompatible with the circuit. This pushed our timeline back while we waited for the component. We worked as a team to overcome this setback.

We burned three boards due to a manufacturing issue with the battery for the handlebar device. The manufacturer had switched the polarity of the battery connection for the ESP32. The boards almost immediately spat smoke and one had a chipset component pop. We had to remove the clip and re-solder it to the battery in the correct orientation.

We did not overcome the issues with the accelerometer-gyroscope acting as our speedometer and source for mileage information. We need to add GPS to the design or implement speed tracking using a mechanical sensor.

Next time, we would start the prototyping for the vest and handlebar case sooner. We (Adafruit)would improve how the product looks. We would work on making our leads short for easier final construction.

We recommend to the teams next year to choose a project that works with your overall schedule. It is good to be ambitious but with some restraint. We did this fairly well and would pass this lesson on. Don't reinvent the wheel, use existing technologies whenever possible. Don't forget to cover how to turn it on and off. Be very mindful of your voltage, current and power requirements.

"All team members have contributed to this report, read it and agree with its contents.

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Accessed March 17, 2022

Appendix

BoM

Item	Qty	Unit Cost $	Total Cost $
3045 Assembled FeatherWing OLED screen	1	15.99	15.99
3-way toggle switch	1	0.69	.69
EEMB 3.7V 820mAh 653042 Lipo Battery Rechargeable	2	11.99	23.98
MPU-6050 MPU6050 3 Axis Accelerometer Gyroscope	1	3.33	3.33
Acrylic Lens with Black Holder Bracket	2	0.45	0.90
Double Sided PCB Board 4x6cm	1	0.32	0.32
Black Fastening Cable Straps 0.8”x6”	4	0.41	1.64
Micro Switch w/Wire - Three Terminals	2	2.95	5.90
3d printed Case	1	6.14	6.14
ESP32 Feather	2	15.00	30.00
Super Bright Yellow 5mm LED	22	0.39	8.58
Super Bright Red 5mm LED	10	0.64	6.40
On/Off Switch	1	0.47	0.47
Double Sided PCB Board 5x7cm	2	0.32	0.64
Double Sided PCB Board 7x9cm	2	0.32	0.64
Backpack chest straps	1	7.49	7.49
Straps with adjustable buckles	2	2.99	5.99
Vest	1	28.00	28.00
Total			147.10

Table 2: Bill of Materials.