# BicycLED

Team members:
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## 1 Customer

Cyclists who wish to improve safety with little extra effort.

## 2 Value

Cycling is a significant source of accidents in the US [1]. Our product increases visibility of the cyclist with LEDs, detects passing vehicles from behind, and alerts both the cyclist and driver.

Similar products exist on the market [2]. Ours is more convenient as the cyclist has two options: They can control the LEDs either by raising their arm, or by activating a switch near the handlebars. The LEDs can be mounted under the bicycle saddle, on the front tube, or fastened to cycling apparel. They can light up in different patterns (e.g. blink left, blink right, and brake) to alert vehicles of the cyclist's existence and motion, thus improving cyclists' safety.

Our product can also detect vehicles approaching the cyclist from behind. When the cyclist is at risk, it activates the buzzer to alert the cyclist and the driver.

## 3 Approach

The BicycLED consists of two hubs: front and back. The front hub is to be installed on the handlebar, and the back hub may be mounted below the bicycle saddle facing backward, or attached to the cyclist's back with Velcro. Each hub has a microcontroller and an XBee module, with which they communicate to ensure consistent output.

A special thing about the MCUs is that they run the exact same firmware. As such, we designed a rudimentary symmetric network protocol. Every time a hub needs to toggle an output, the following communication happens over XBee:

- Hub A reports its output state to Hub B

- Hub B remembers the state of Hub A
- Hub B sends an ACK message with its own state
- Hub A remembers the state of Hub B

Then, each hub would combine the two states and set the output to the state with higher priority. For example, the "BUZZER_HORN" state triggered with the button has higher priority than the "BUZZER_WARNING" state triggered by the radar, which means the user always has control over the horn.

We also implemented a keep-alive feature. Each hub emits a keep-alive message every two seconds. If it does not receive the message from its peer for 10 consecutive seconds, it "forgets" about the peer, and operates standalone. This may happen if one of the two hubs runs out of battery on a long trip.

Apart from the MCU and the XBee, our product has the following functional components:

- Switch: an e-bike switch with left/right and horn buttons.
- Accelerometers: a pair of accelerometers attached to cyclist's sleeves, connected to MCU via $I^2C$.
- Radar: a doppler radar sensor that detects direction of moving objects.
- LEDs: red and yellow LED strips, PWM-driven with transistors at 12V.
- Buzzer: a piezoelectric buzzer, also PWM-driven with transistors at 12V.
- Light sensor: a photoresistor, in order to adjust the LED brightness (i.e. duty cycle) dynamically.

We designed a PCB, laser-cut acrylic and 3D-printed enclosures for BicycLED. They provide mechanical support and mitigate electrical contact issues on a constantly vibrating bicycle.

## 4 Development Roadmap

Checkpoint 1:

- Blink LEDs based on switch input
- Drive buzzer
- Transfer data with XBee

Checkpoint 2:

- Detect arm position from accelerometer, control blinkers
- Use PWM to adjust LED brightness based on light sensor
- 3D print enclosure for two hubs

Final product:
- Detect deceleration from accelerometer, control brake light
- Honk when doppler radar senses approaching object
- Design & solder protoboards, and later PCBs
- Fit in enclosure & connect wires

## 5 Essential System Components

### 5.1 Controller & Wireless
- Nucleo-L432KC (2x, front + back, stock)
- XBee breakout board (2x, stock)

### 5.2 Input / sensors
- LIS3DSH Accelerometer module (2x, one for each arm, order) [4]
- E-bike turn signal switch (front only, order) [5]
- BGT60LTR11AIP Radar Shield2Go (back only, order) [6]
- Photoresistors (2x)

### 5.3 Output
- LED strips (order, red and yellow) [9]
- Buzzer (order)
- BJTs / MOSFETs (we used 2N3904 NPNs in our protoboard version and Si2302CDS NFETs on the PCB)

### 5.4 Connector
- Dupont sockets (stock)

### 5.5 Power supply
- 12V/5V battery pack (2x, stock)

## 6 Technical Difficulties

On March 17, we spent more than two hours trying to talk to the I²C accelerometer we had bought. After trial and error involving a CubeIDE project from scratch on another Nucleo, we found that the read/write bit is reversed; the standard states that 1 = read, while on the device, 1 = write. We had to handle I²C differently for the accelerometers.

We planned to make a PCB early on, but failed to design it in time, causing a painful amount of protoboard soldering.

## 7 Complexity

| **Task** | **Complexity** |
|---|---|
| Accelerometers for both arms | 0.67 |
| Light sensor | 0.25 |
| Doppler radar | 0.25 |
| XBee | 0.50 |
| Synchronization protocol | 0.50 |
| PWM + Transistor | 0.25 |
| PCF8574P/AP I2C GPIO expanders | 0.50 |
| Designing boxes mounted on bike (3D printing and laser cutting) | 0.50 |
| PCB design & protoboard soldering | 0.67 |
| *Total* | *4.09* |

## 8 Team Member Contribution

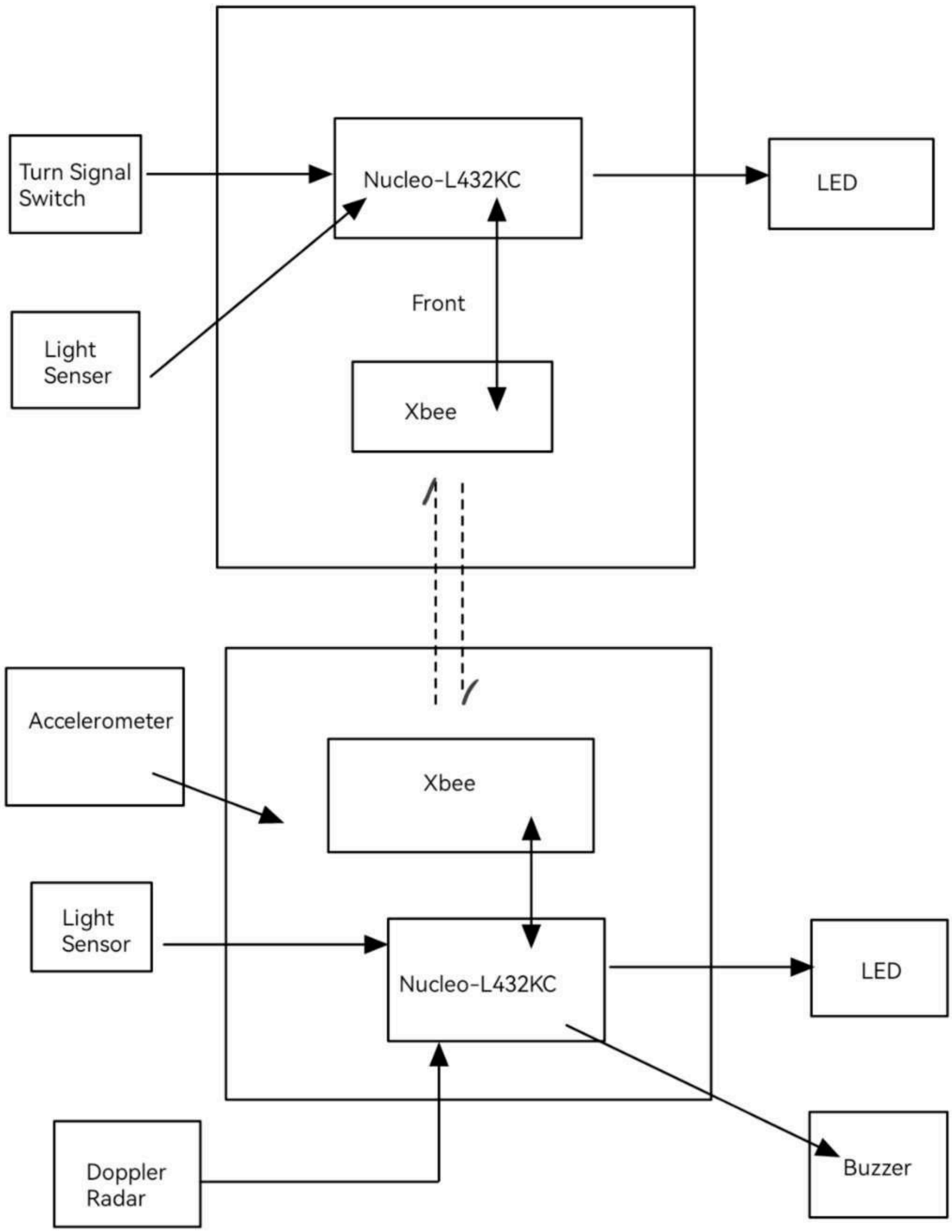
Yi Wen Jiang: 20%. Realized the feature of adjusting LED intensity based on light intensity of the environment. Contributed to LED blinking controlled by switch.
Duo Xu: 20%. Applied GPIO expander to the project and contributed to parts of project.
Yihang Yin: 30%. Implemented wireless communication and synchronization, transistor-based relay mechanism, proposed a physical layout of the product, and designed PCB.
Xiaomi Zhou: 30%. Be responsible for 3D printing and contribute to part of the project such as accelerometer, buzzer, and radar.

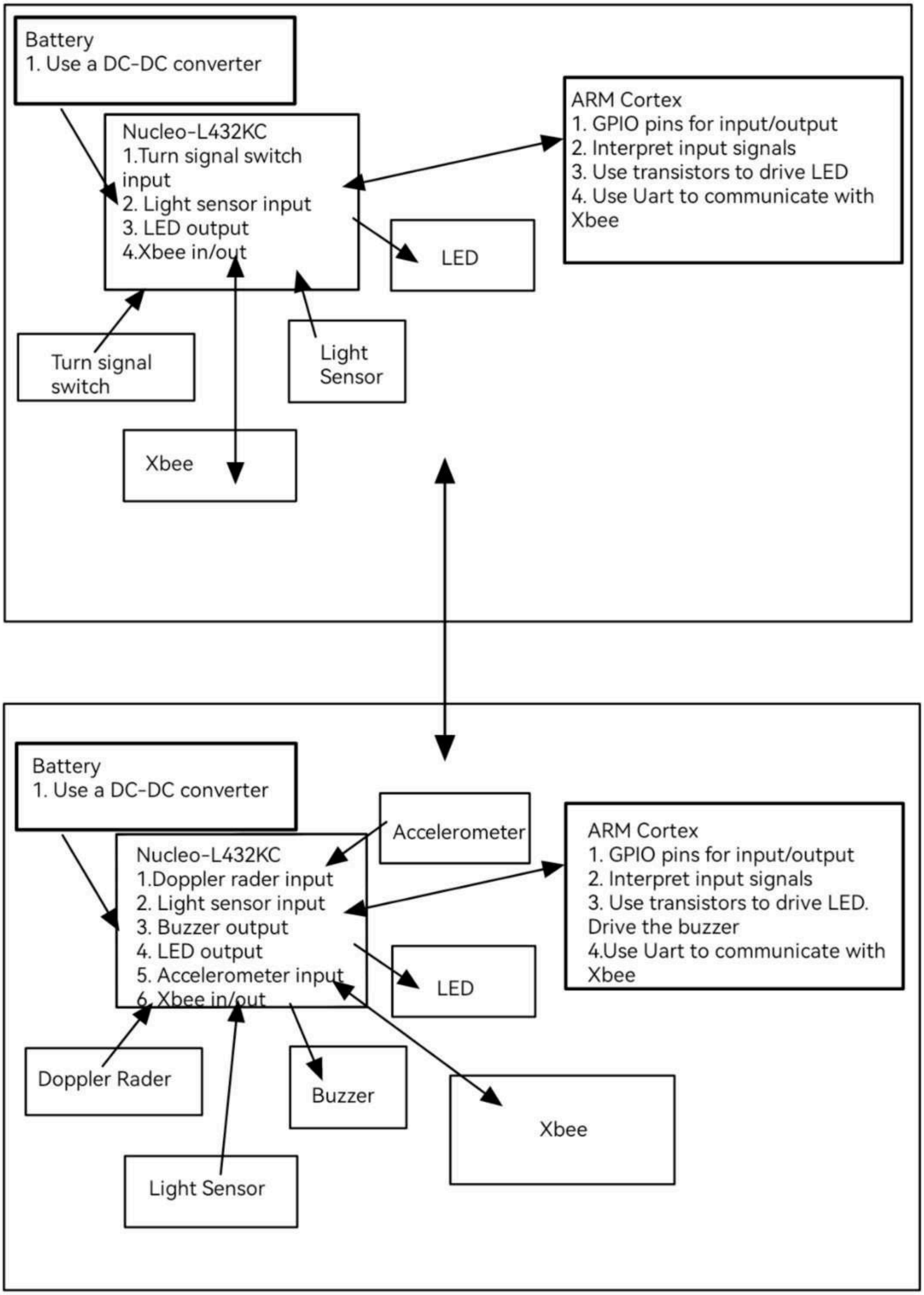
## Design Material and Code

https://drive.google.com/drive/folders/1yums9XRzRqo6GhQJK58j7t1VLEED-wFN?usp=drive_link

## References


[1] https://www.cdc.gov/transportationsafety/bicycle/index.html
[2] https://www.amazon.com/dp/B0C27FGHMW
[3] https://mou.sr/3QhFiMZ
[4] https://www.amazon.com/dp/B082W63MWL
[5] https://www.amazon.com/dp/B09TBGLY7N
[6] https://mou.sr/3HQwgRr
[7]https://www.mouser.com/ProductDetail/SparkFun/BOB-08688?qs=WyAARYrbSnZU5nftx3HY3Q%3D%3D
[8] https://www.amazon.com/dp/B01MYUFVEW/
[9] https://www.amazon.com//dp/B0B4NJCVRF


Turn Signal Switch
Nucleo-L432KC
LED
Light Senser
Front
Xbee
Accelerometer
Xbee
Light Sensor
Nucleo-L432KC
LED
Doppler Radar
Buzzer


Battery
1. Use a DC-DC converter
Nucleo-L432KC
1.Turn signal switch input
2. Light sensor input
3. LED output
4.Xbee in/out
ARM Cortex
1. GPIO pins for input/output
2. Interpret input signals
3. Use transistors to drive LED
4. Use Uart to communicate with Xbee
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4.Use Uart to communicate with Xbee
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Doppler Rader
Buzzer
Xbee
Light Sensor

# EECS 373: Introduction to Embedded System Design

# BicycLED

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## Project Usage: Assisting Device for Cycling to Enhance Safety of Cyclists

### Problem:

- Cyclists cannot signal turning/braking except by raising their arms.
- Cyclists are not warned when cars approaching fast from behind.

### Solution:

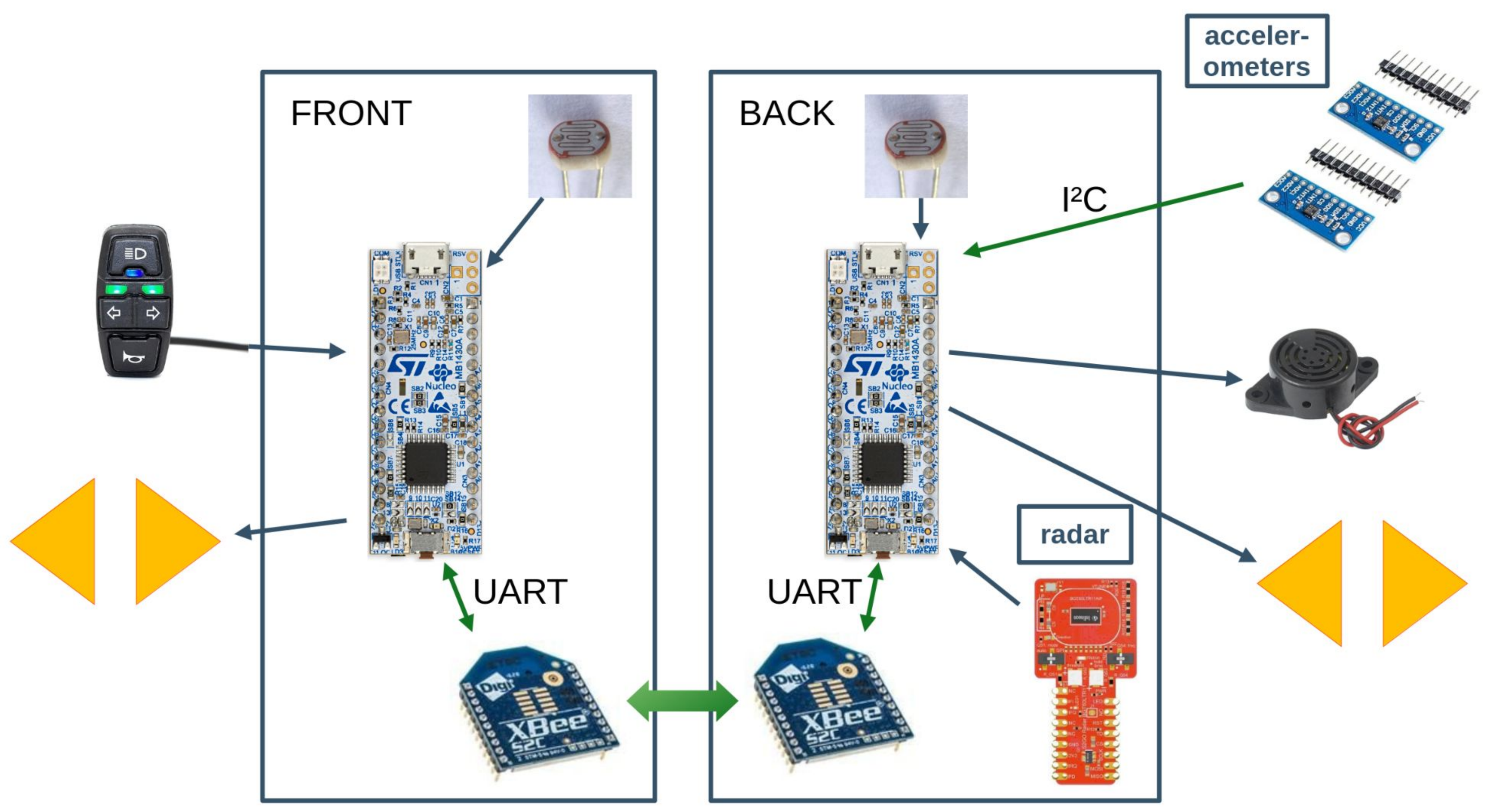
- LEDs to display turning/braking signals, triggered by switch or lifting of the arm in the direction of turning.
- Buzzer to warn the cyclists of fast-approaching cars behind and honk by pressing the button on the switch.

## Project Description: Embedded wearable system based on STM32

- Two boxes — one on the front (mounted on bike)
  — one on the back (stick to the jacket to wear or mounted on bike)
- Arm bands — on which to mount accelerometers; worn on both arms
- Modular design — Switch, accelerometer, radar, LED modules

## Component Teardown

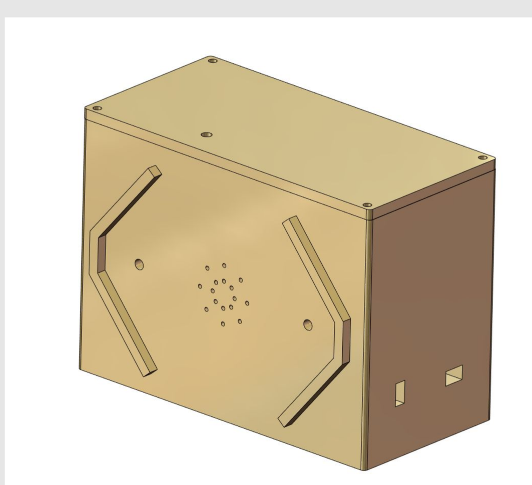
### Our design:



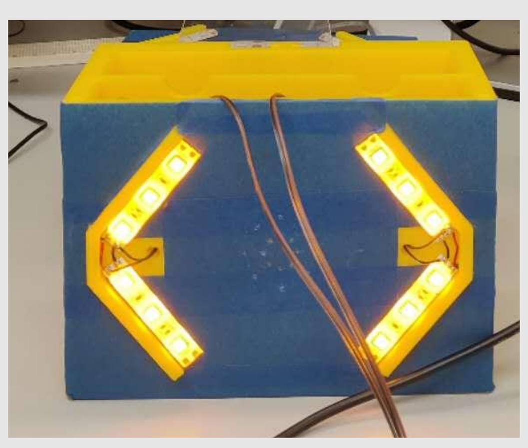

- Use XBee to transfer data between two boxes
- Use light sensor to detect sunlight and adjust the lightness of LED
- Use doppler radar to detect fast-moving vehicles to sound the buzzer
- Use accelerometer to detect the movement of cyclist's arm
- UART for XBee, I²C for accelerometer, PWM for buzzer and light sensor, GPIO expander for switch and doppler radar

## Prototyping, Testing, & Issues

3D model design



3D printed part



Assembled product

PCB design (too late)