UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

# Secure Illini

## Electrical & Computer Engineering

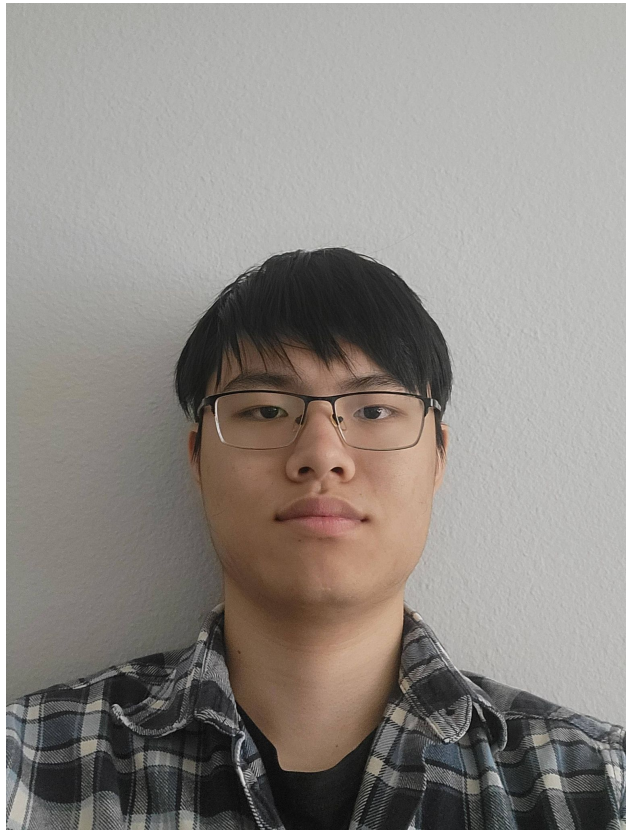
Group 61: Andrew Ruiz, Bowen Cui, Sebastian Sovailescu

May 6th 2025

# Secure Illini Team

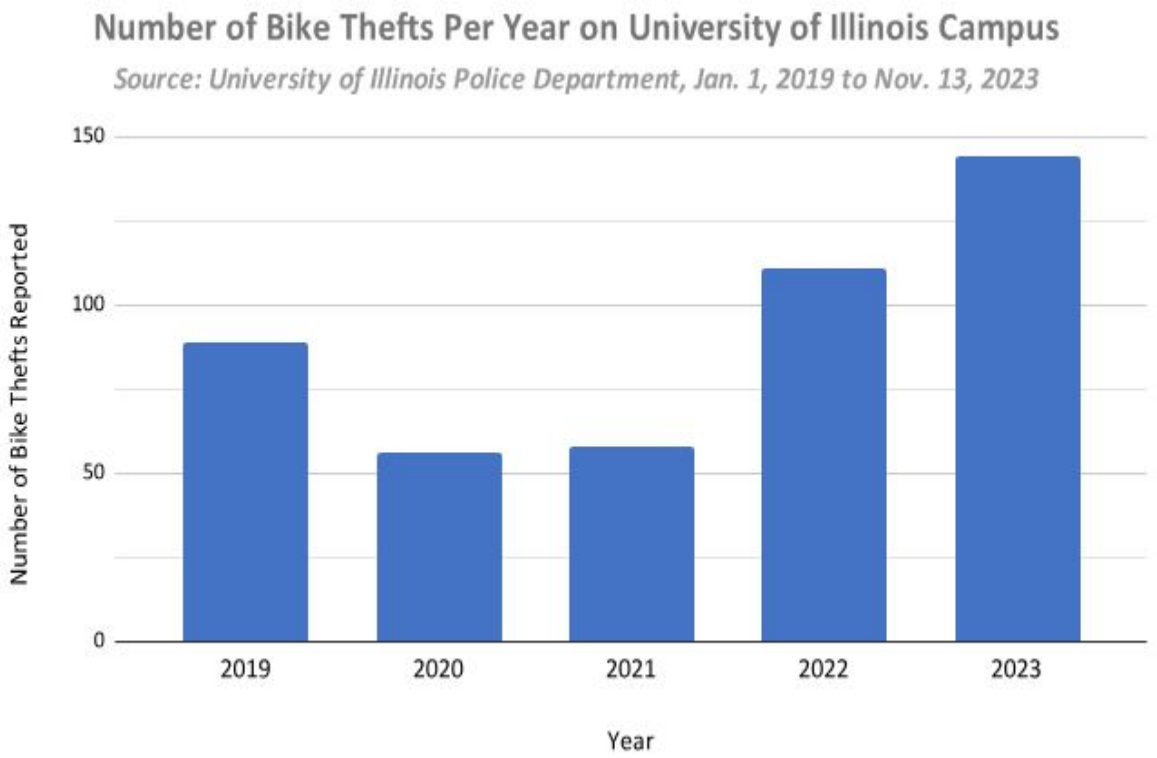
Andrew Ruiz- BSEE.

Sebastian Sovailescu - BSCE



Bowen Cui - BSCE

# Bike Thefts




## Problem

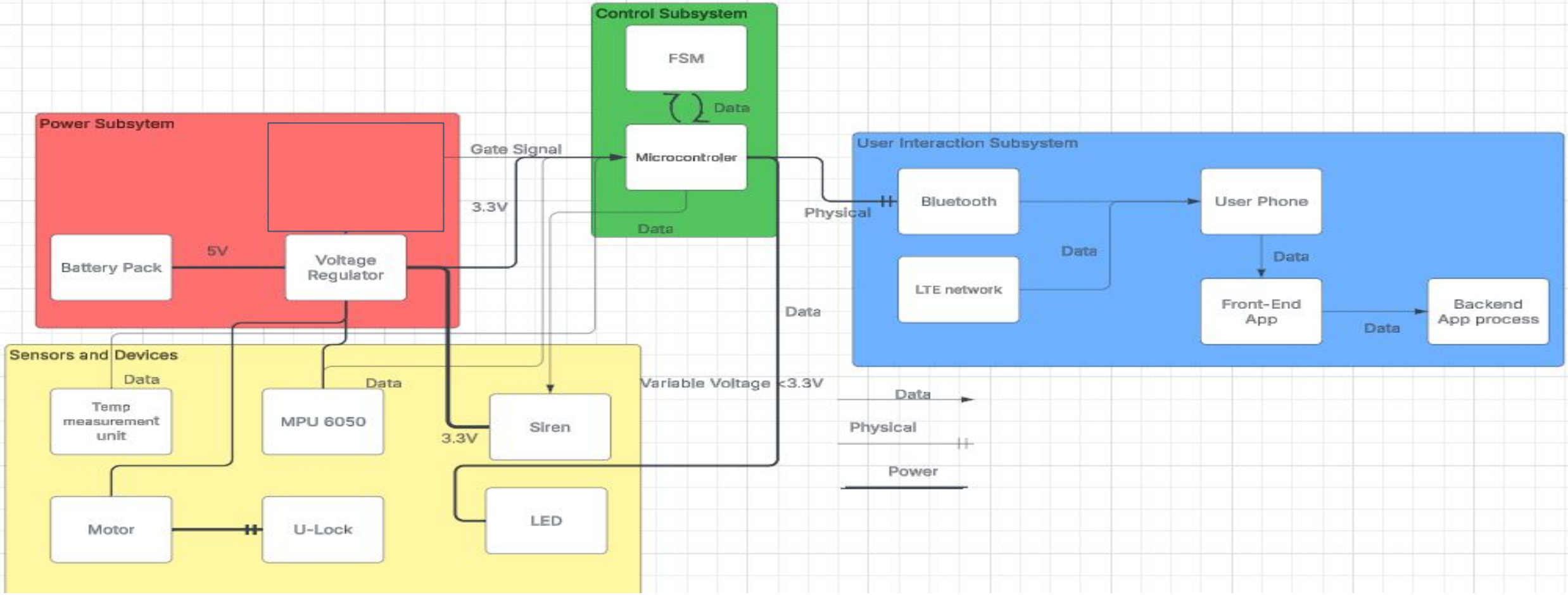
- There were over 100 bike thefts reported in 2022 and 2023.
- Even properly secured U-bar lock are not impervious to being stolen
- “5-10% of bike theft reports get solved”
- Bike theft is often a low priority for police due to limited evidence or lead
- Victims face direct costs (replacing the bike) and indirect costs (transportation delays, lost work time).

# Smart Bike Lock

## Solution

- Real Time alerts over WiFi of disturbances
- Remote Control over Bluetooth for keyless capabilities
- Advanced materials and electronic locking mechanisms resist common theft tools.
- Records when the lock was used, aiding in theft investigations.
- Siren to deter thieves when tampering is detected

# Design




Block Diagram of original design

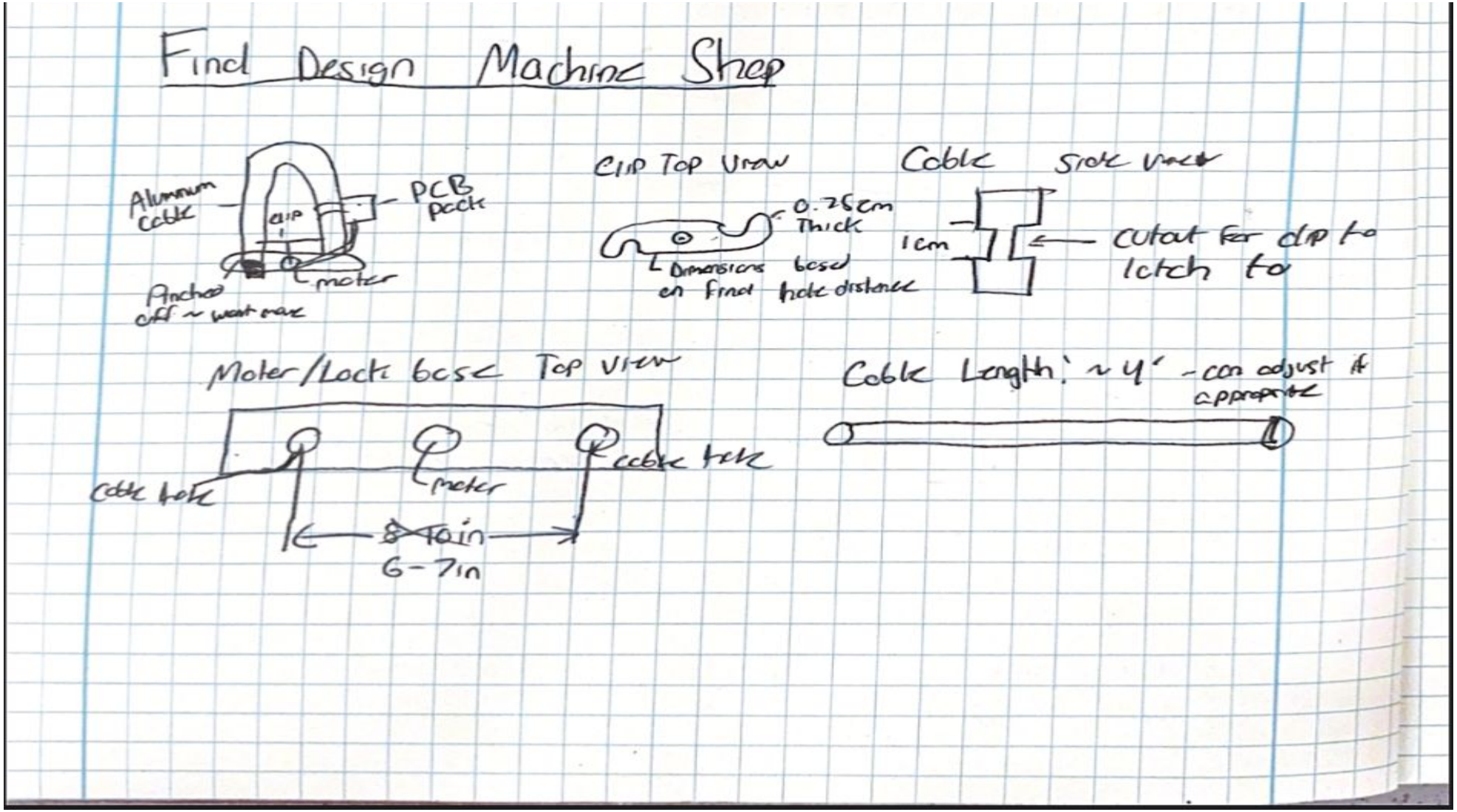
## Overview of each functional block requirements

1. Electronic locking system that can be manually overridden with master key (or override code) that can withstand over 1000 lbs of force.
2. A 90 dB siren will sound for 10 seconds when our anti-theft algorithm detects suspicious activity within a locked state. Theft attempts will be determined when excessive movement is detected which sensitivity will be experimented with.
3. Can send and receive real-time alerts, commands, or temperature readings over WiFi and/or Bluetooth using a custom built web application. All communications will be safe.
4. 3.3V Indicator LEDs to indicate the lock's current state as well as power level.

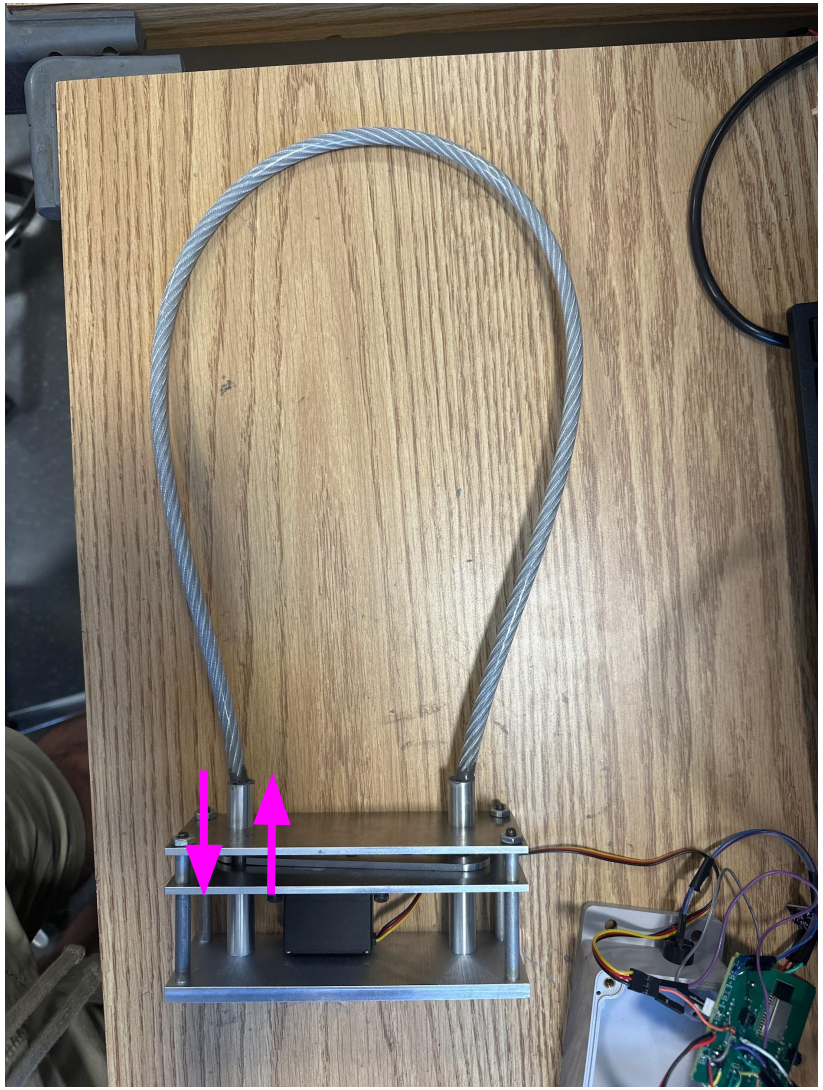
## High level requirements

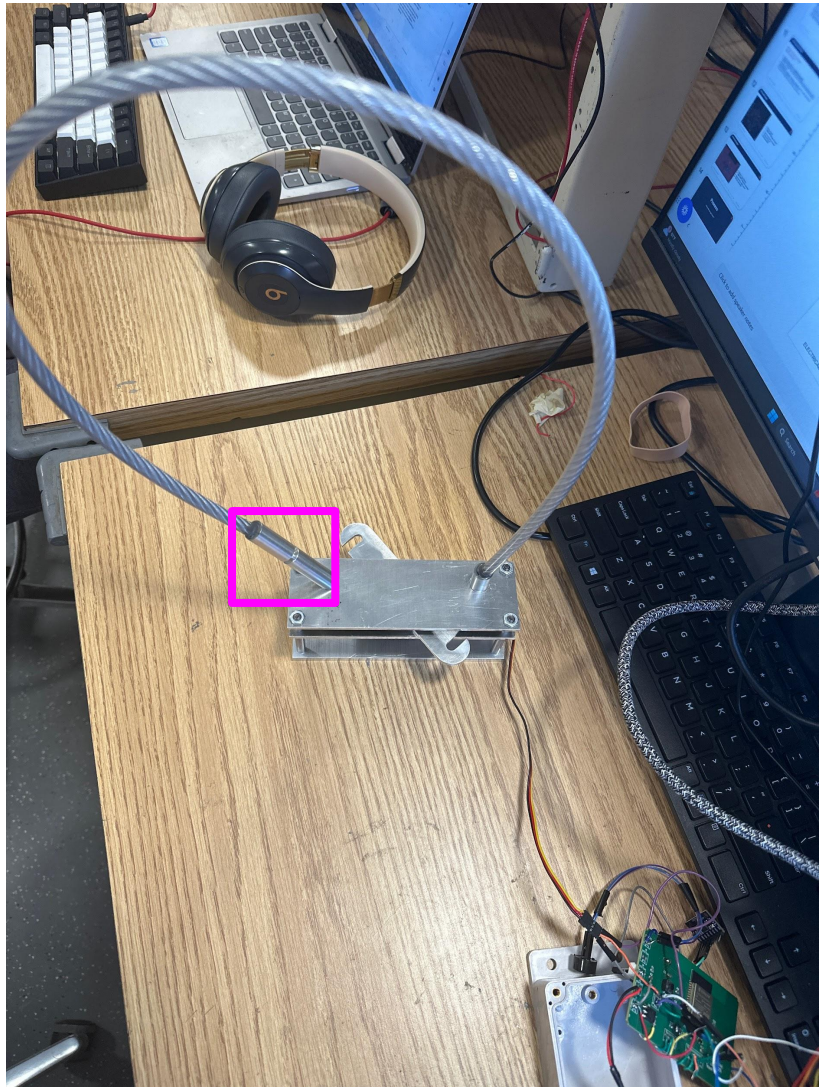
1. Electronic locking system that can be **controlled with Bluetooth** ~~manually overridden with master key (or override code) that can withstand over 1000 lbs of force.~~
2. A **60 dB buzzer** will sound for 10 seconds when our anti-theft algorithm detects suspicious activity within a locked state. Theft attempts will be determined when excessive movement is detected which sensitivity will be experimented with.
3. Can send and receive real-time alerts, or temperature readings over WiFi ~~and/or Bluetooth~~ using a **ThingSpeak dashboard**. All communications will be safe.
4. 3.3V Indicator LEDs to indicate the lock's current state ~~as well as power level~~.

# Physical Design

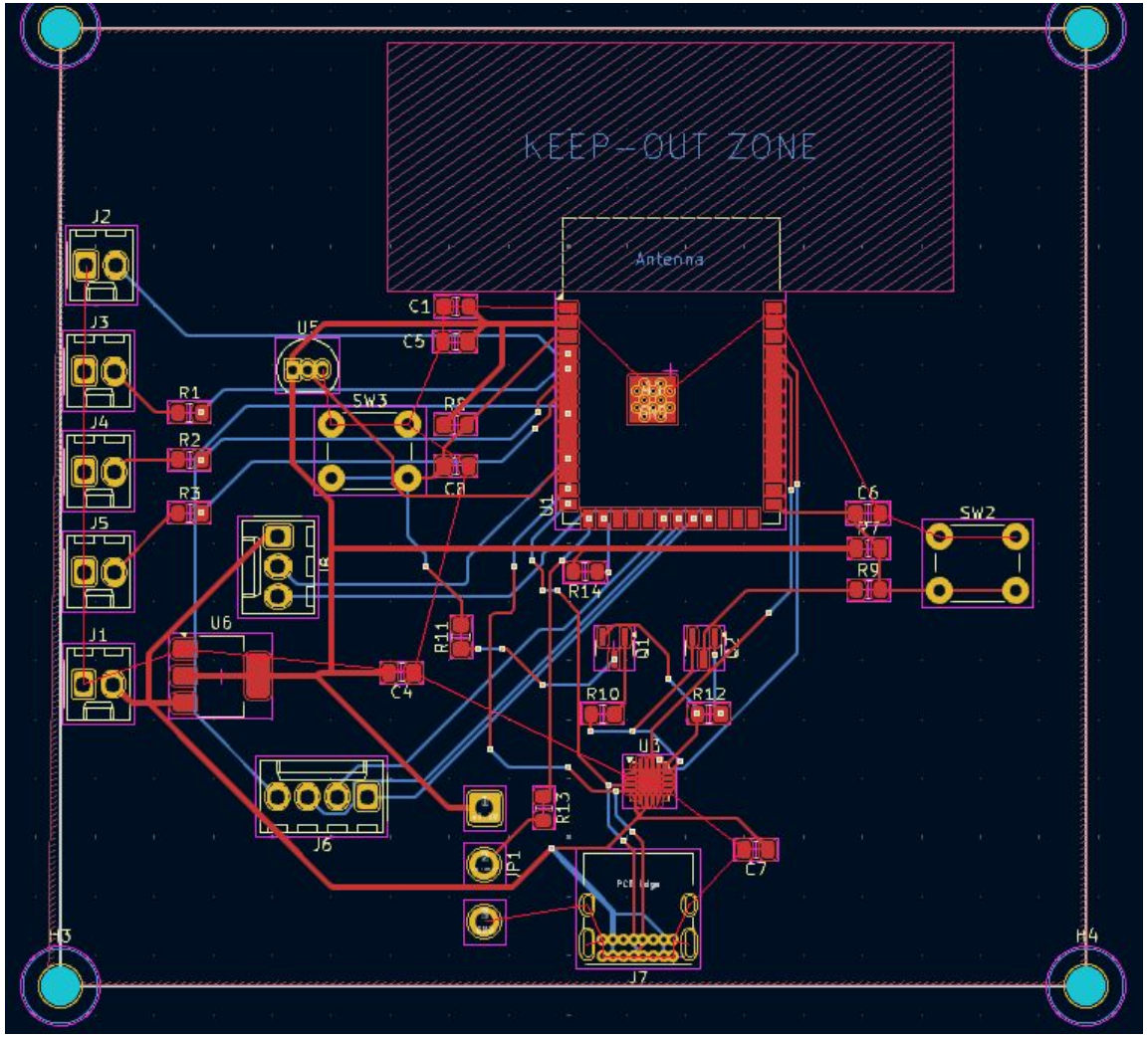


# Physical Design





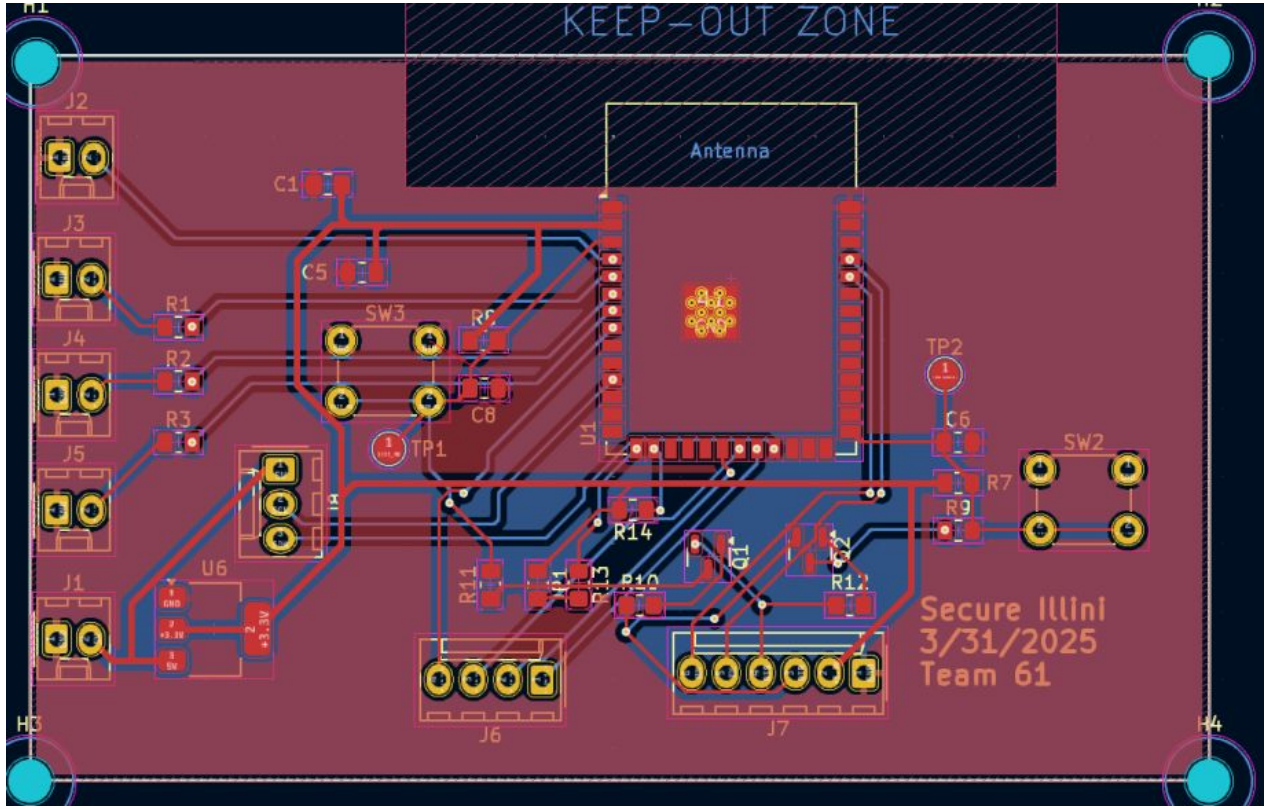
# PCB Initial Design




## Problems

- Messy Traces
- USB-UART Bridge on board
- Extra unnecessary sensors
- Oversized board
- No Ground Net

# PCB Final Design




## Improvements

- Cleaner Trace Design
- USB-UART bridge pins provided
- Significantly smaller board
- Test pins provided

## Over of functional blocks

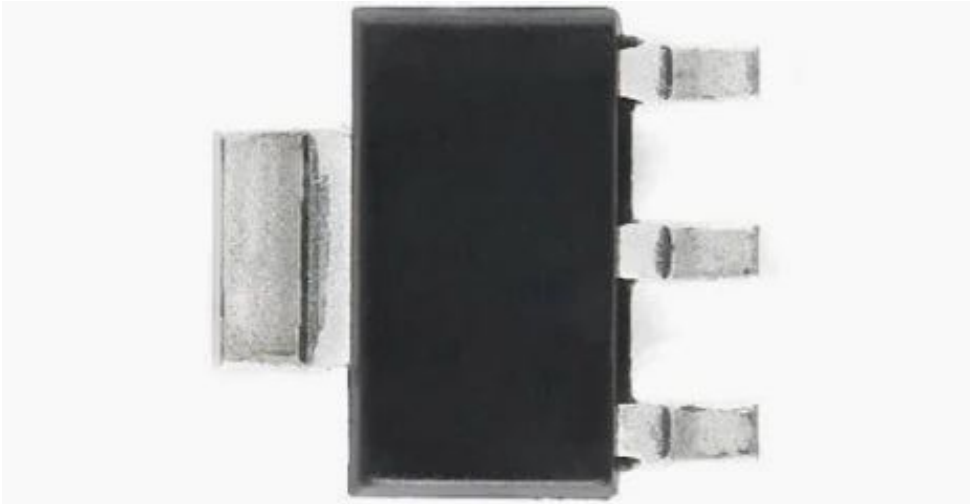
**Power**
- 4.7V 2Ah rechargeable battery
- Voltage regulator
- Battery life of ~2.4days

**Locking Mechanism**
- Bluetooth controlled servo
- LED state

**Alarm**
- Anti-theft detection
- Buzzer plays for 10 seconds
- Trigger alert

**WiFi**
- Real-time alerts
- IMU and temperature readings
- ThingSpeak dashboard

# Power

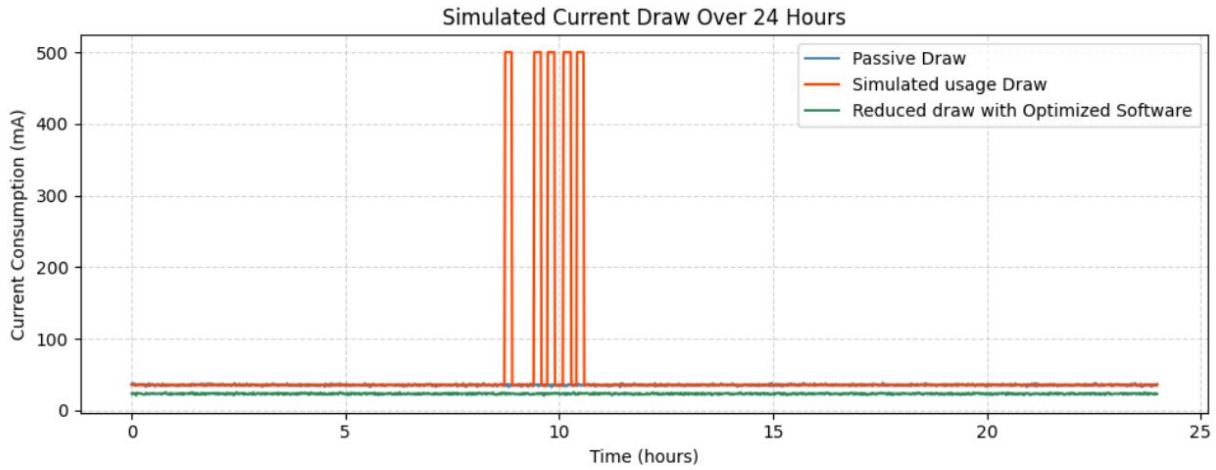
## Components

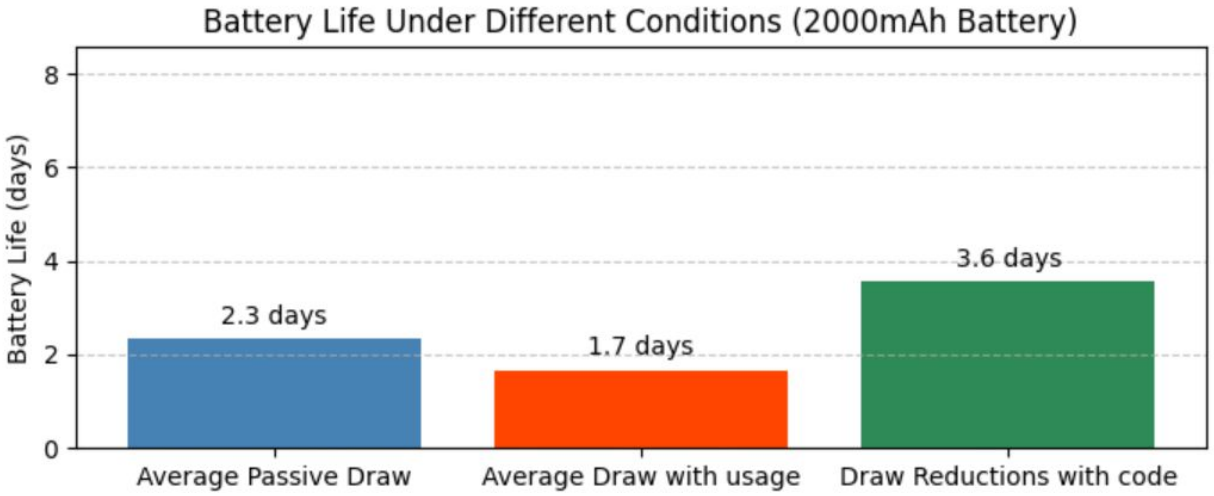
- Tenergy Rechargeable Battery (4.8V 2000mAh)
- LM1117 3.3V Regulator
- Several 0.1uF-10uF stability capacitors

## Power

- 4.8V Rail from Battery
  - IMU
  - SERVO
- 3.3V
  - ESP
  - Programing

# Battery Life Testing




## Testing

- No Manual Battery Life test obtained
- Current Consumption Passive:
  - ESP: 20mA
  - IMU: 3.9mA
  - LED: 4mA
  - SERVO: 7.7mA
  - SIREN: 0mA
- 2000mAH /(35.6mA * 24H) = 2.34Days
- Peak Values
  - ESP: 300mA
  - IMU:3.9mA
  - LED:4mA
  - SERVO: 200mA
  - SIREN: 0.1mA

# R&V Table

| Requirement | Verification Method | Result |
|---|---|---|
| The lock shall secure within 2 seconds of command. | Measure time from Bluetooth command to movement with stopwatch | Lock secured within 1.5s |
| Lock shall unlock only after valid authentication | Test it doesn't open with invalid commands | Only opened and closed on proper commands |
| The lock shall detect and alert on tampering | Simulate tampering (e.g., vibrational or mechanical force) and check alert response. | IMU properly detected movement and signaled the siren. |
| There shall be a mechanical override. | Try to mechanically override lock | Successful test |
| Siren will trigger 90dB siren within 1 sec of tampering | Simulate tampering and time response time | Siren only capable of 70dB but successful timing |
| The electronic locking system shall be able to withstand at least 1000 lbs of pulling force without mechanical failure. | Apply increasing force with with force gauge until failure | Unsuccessful, motor was displaced from force well below 1000lbs |
| The device shall send real-time alerts and receive commands over WiFi and/or Bluetooth using the custom web app | Confirm and demonstrate wifi communication with web app | Successful Test |
| 3.3V Indicator LEDs shall show lock state (Locked/Unlocked) and battery status (e.g., Good, Low, Critical). | Demonstrate LED with different lock states and battery level | Successful Alarm status LED, due to design limitations with housing, Unsuccessful battery status LED |
| The system shall measure and report temperature data to the web application in real time. | Vary the temperature environment and verify reported values | Successful Test |
| The siren shall sound for 10 seconds once activated. | Trigger alarm and use a timer to verify siren duration. | Design choice led to a shorter duration than 10 sec, Unsuccessful test |
| Battery life can last up to 7 days | Leave plugged in and running for 7 days | Ran out of time to test but mathematically unsuccessful based on assumed average current draw. |

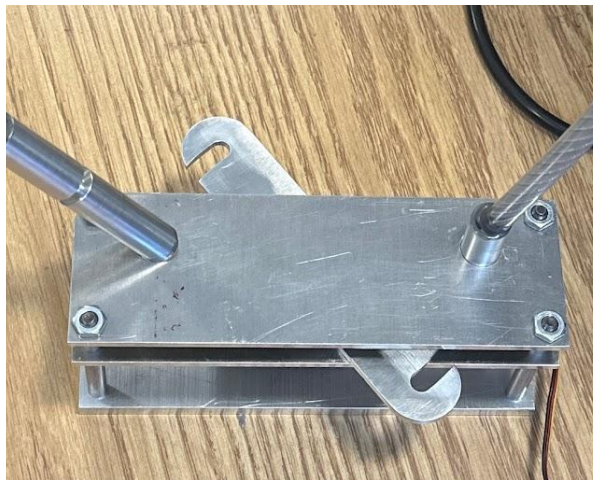
# Locking Mechanism

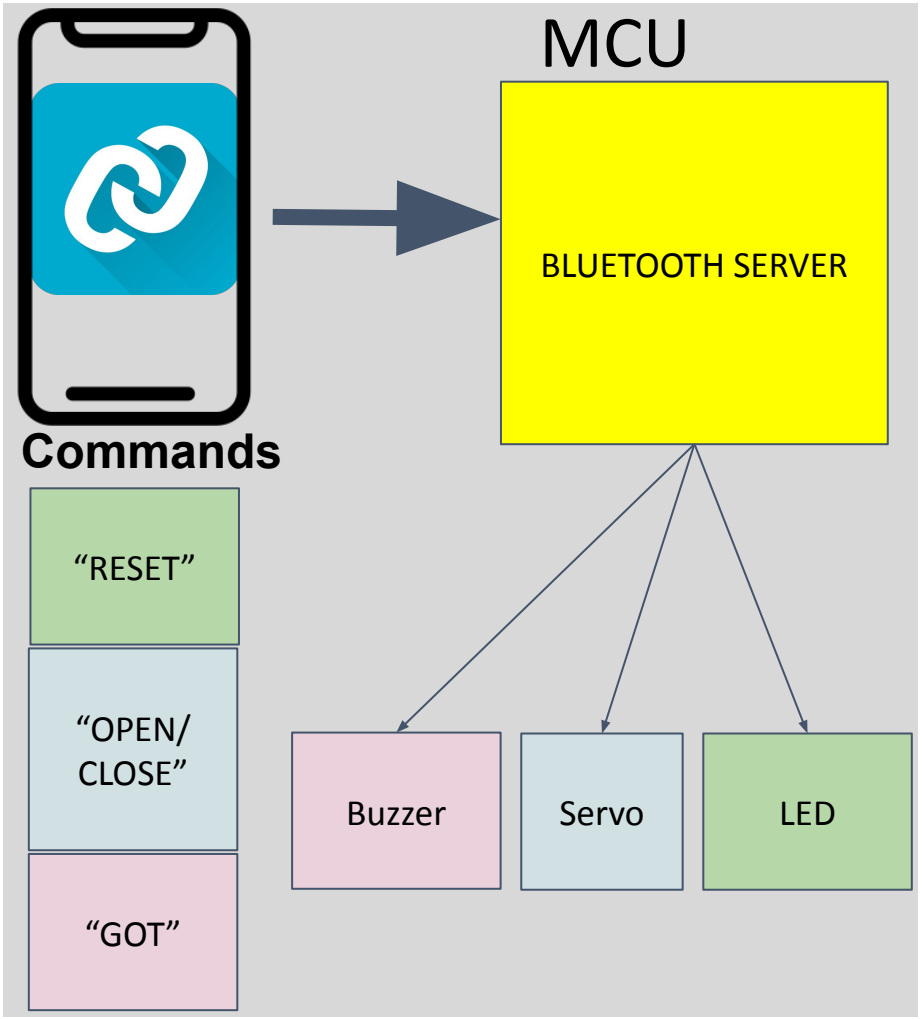
## Bluetooth

- MCU as Server
- nRF Connect app
- Commands over terminal

## Servo

- ESP32Servo library
- Machine shop modification
- Latch modification



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# Alarm

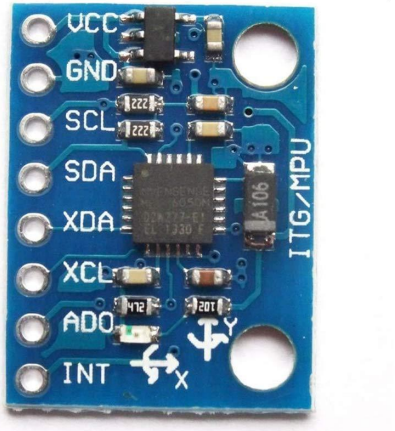



Figure 1 MPU6050 module

$$|v| = \sqrt{x^2 + y^2 + z^2}$$

Figure 2 Acceleration magnitude formula for tampering detection

## Alarm

- Anti-theft detection
- Buzzer plays for 10 seconds
- Trigger alert

## Problem

- Only 60dB
- ESP: Low output Voltage (3.3)

## Solution

- H-Bridge
- ESP to Switch to Battery

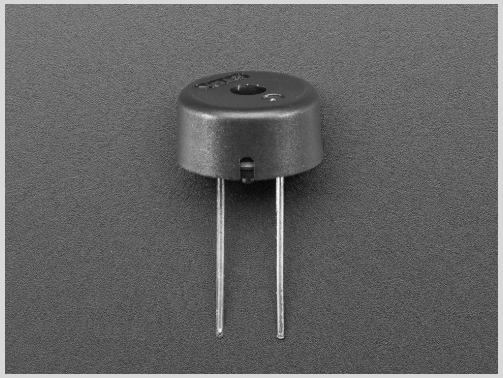
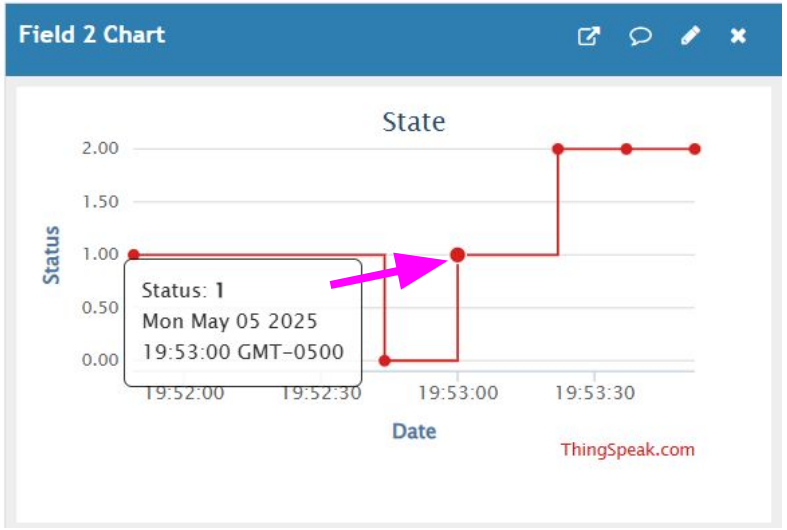
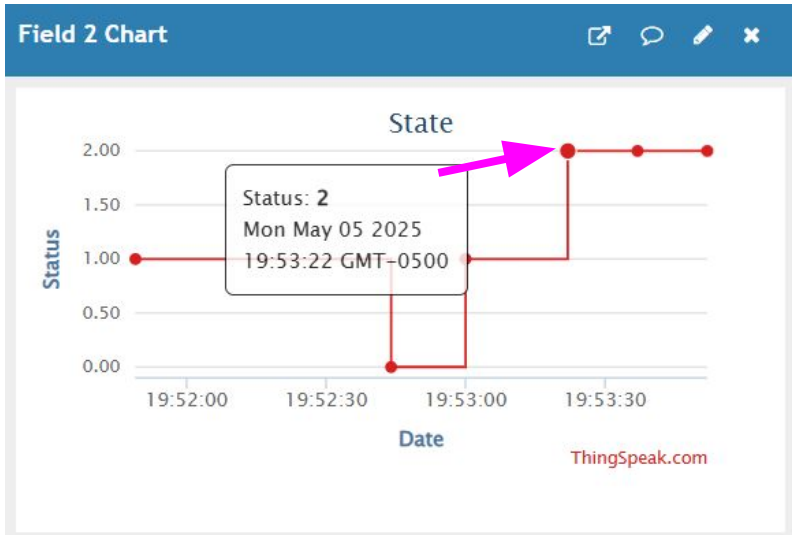


Figure 3 Adafruit piezo buzzer PS1240

# Alarm Tests




## Testing

- Update
- Accurate data
- LED pattern to communicate

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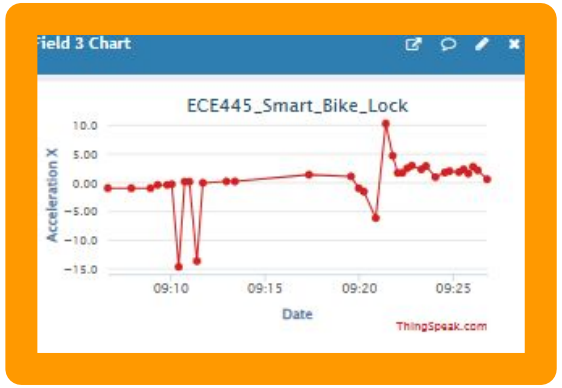
## WiFi

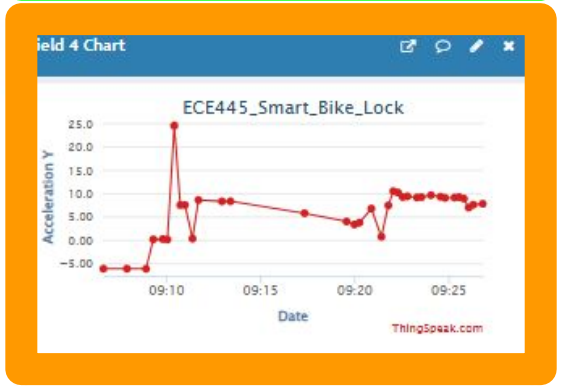
- Used WiFi.h library
- Registered device with MAC
- Generated API for ThingSpeak

## ThingSpeak

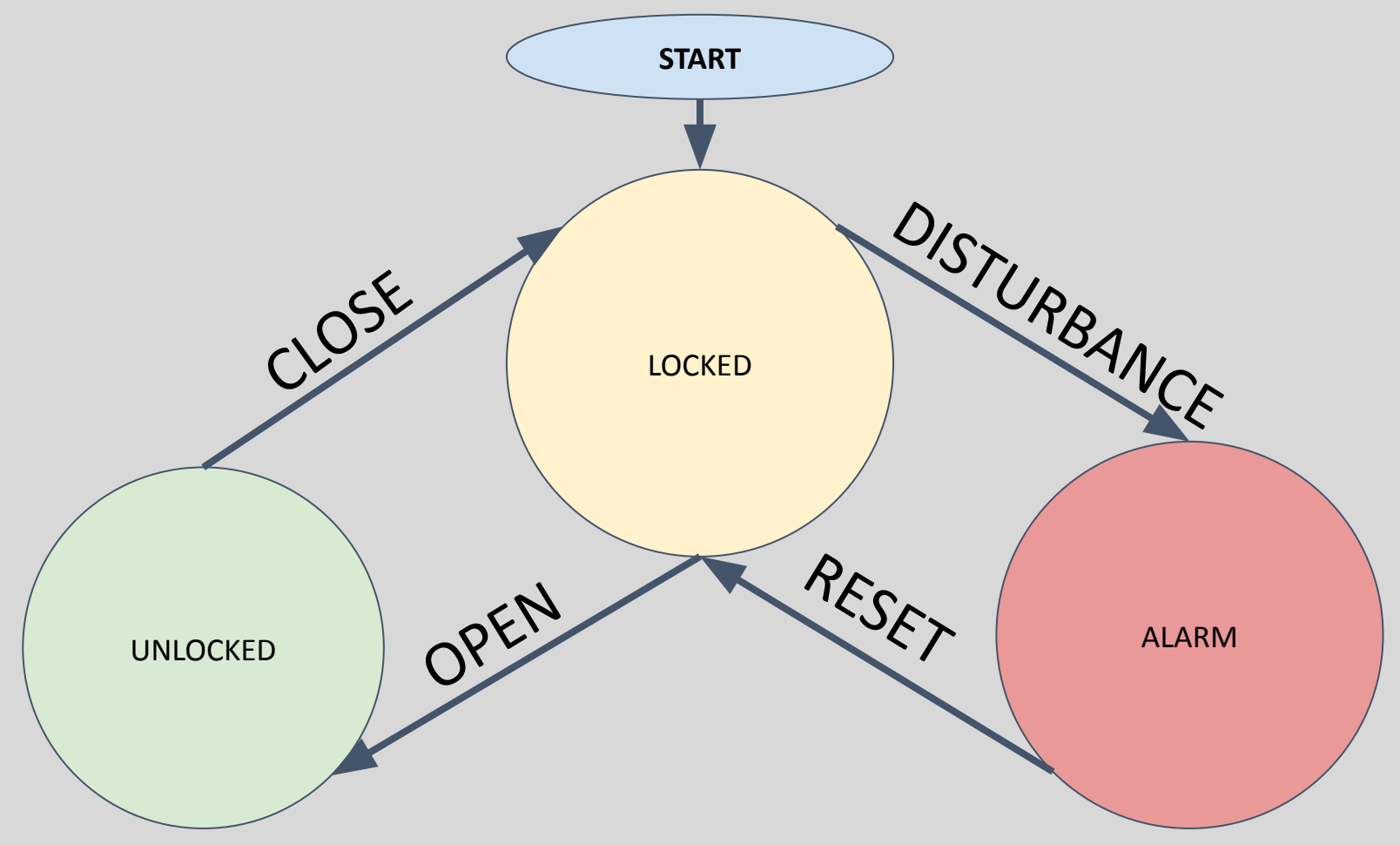
- POST HTTP Request
  - X,Y, and Z acceleration (m/s^2)
  - Temperature (°C)
  - State (UNLOCKED/LOCKED/ALARM)






# System FSM




Finite State Machine

# FSM

| State | Signals |
| --- | --- |
| **UNLOCKED** | Motion Detection OFF<br>BUZZER OFF<br>Ping ThingSpeak on state change |
| **LOCKED** | Motion Detection ON<br>BUZZER OFF |
| **ALARM** | Motion Detection OFF<br>BUZZER ON<br>Ping ThingSpeak on state change and every 15 sec until reset |

Finite State Machine

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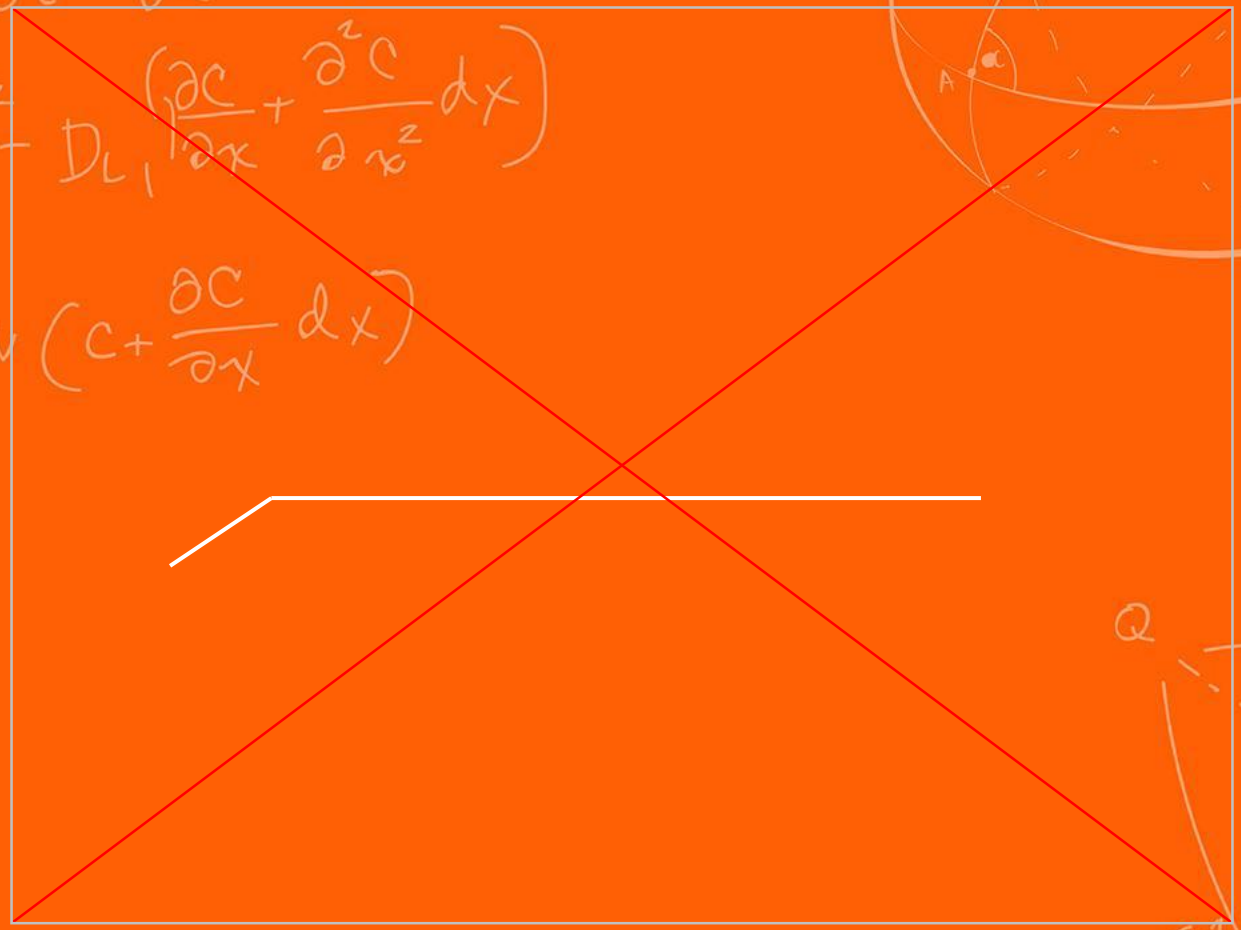
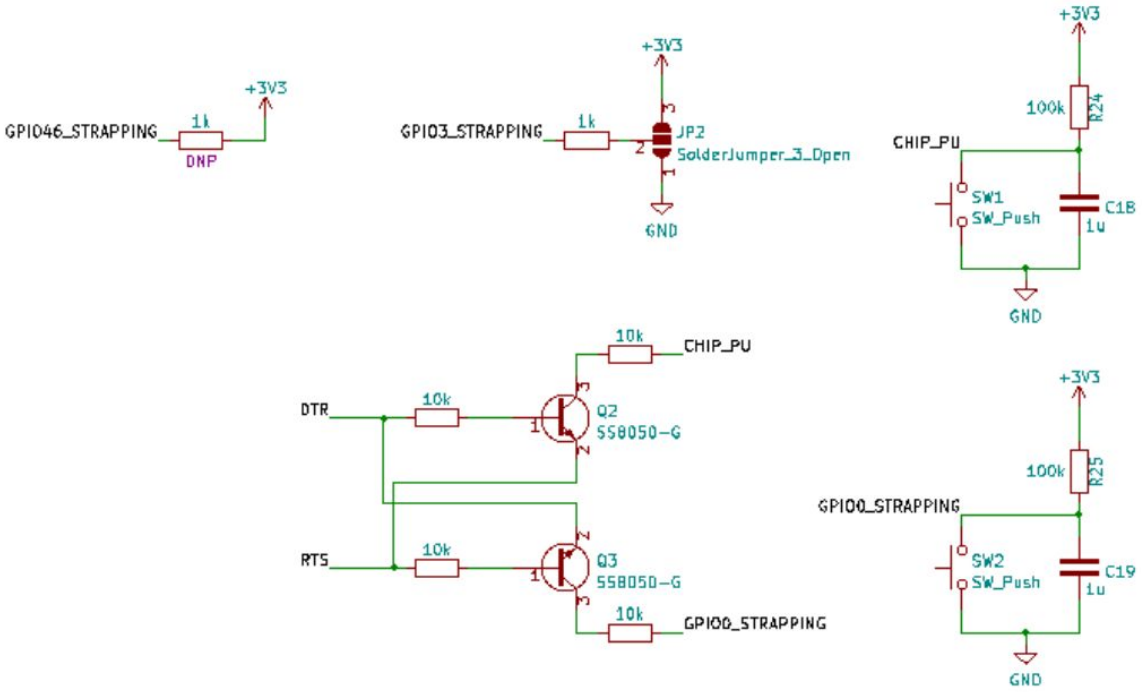


# Demo

# Process

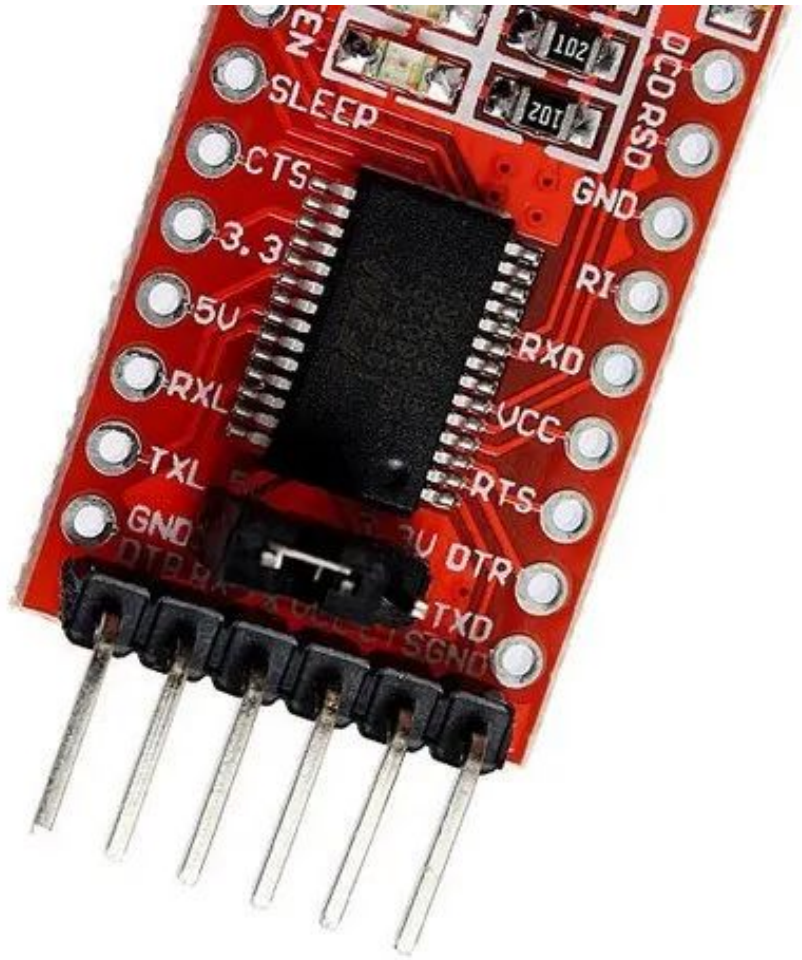
How did we get here?

# Challenges




## Challenges

- Programming Circuit wouldn’t upload
- Stepper Motor Unidirectional
- Multiple PCB Designs with no USB Bridge connections
- Delayed testing process
- Bridged contacts underneath the ESP32



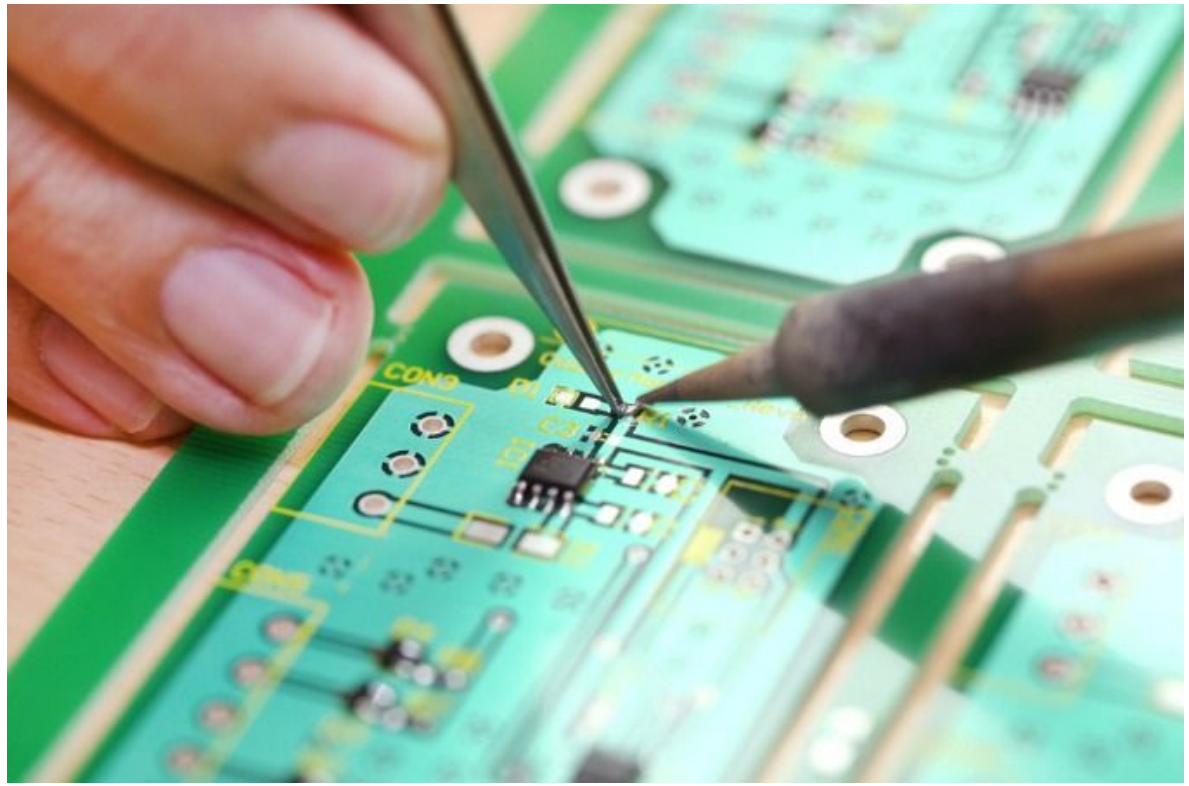

## Solutions

- Swapped CTS  and RTS pins
- Switched to Servo - Updated Lock Design
- 3rd PCB print  was successful
- Had to speed up testing and Validation to makeup time
- Careful alignment of the ESP and longer baking time

# Conclusion

What have we learned?

# Conclusions



## Things we learned

1. Circuit/PCB design using kicad
2. Circuit manufacturing process
3. The iterative process for product development

## Things we would do differently

1. Pick components more carefully
2. Allow GPS tracking of the lock
3. Redesigning the lock to be physically stronger

# Recommendations

What should be done going forward?

## Smart attachment Vs Full Lock Design

- Safe and Secure Electronic Locking mechanism is expensive and hard to make secure
- Most physical locks already provide good physical protection
    - Lack external safety solutions

### Develop Smart Attachment box

- Most of design could be condensed into attachment
- Attach either to bike or lock itself
- Cheap solution to improve security of products already on the market

# Thank You
# Questions?

# References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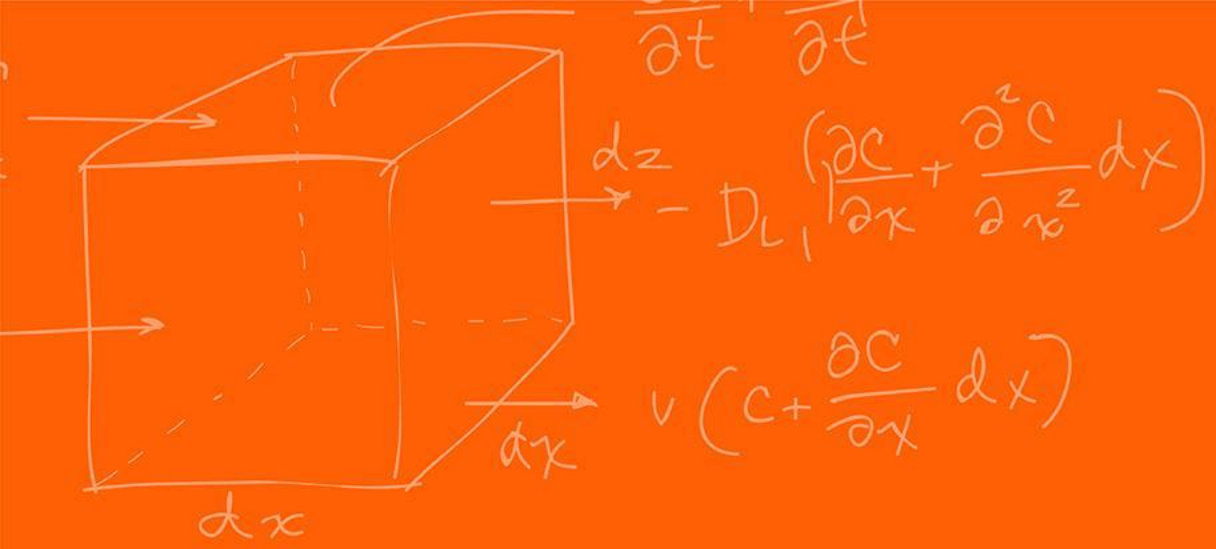

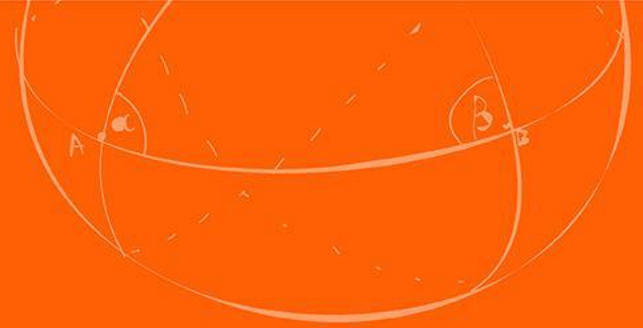

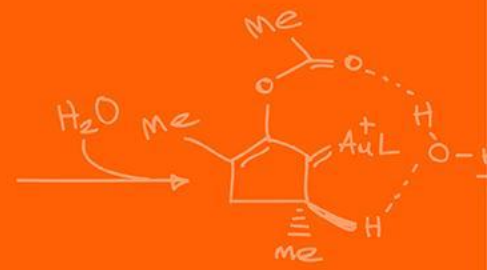

# The Grainger College of Engineering

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