E-Bike Crash Detection and Safety

ECE 445

Group 6

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Introduction: Problems with E-bike Safety

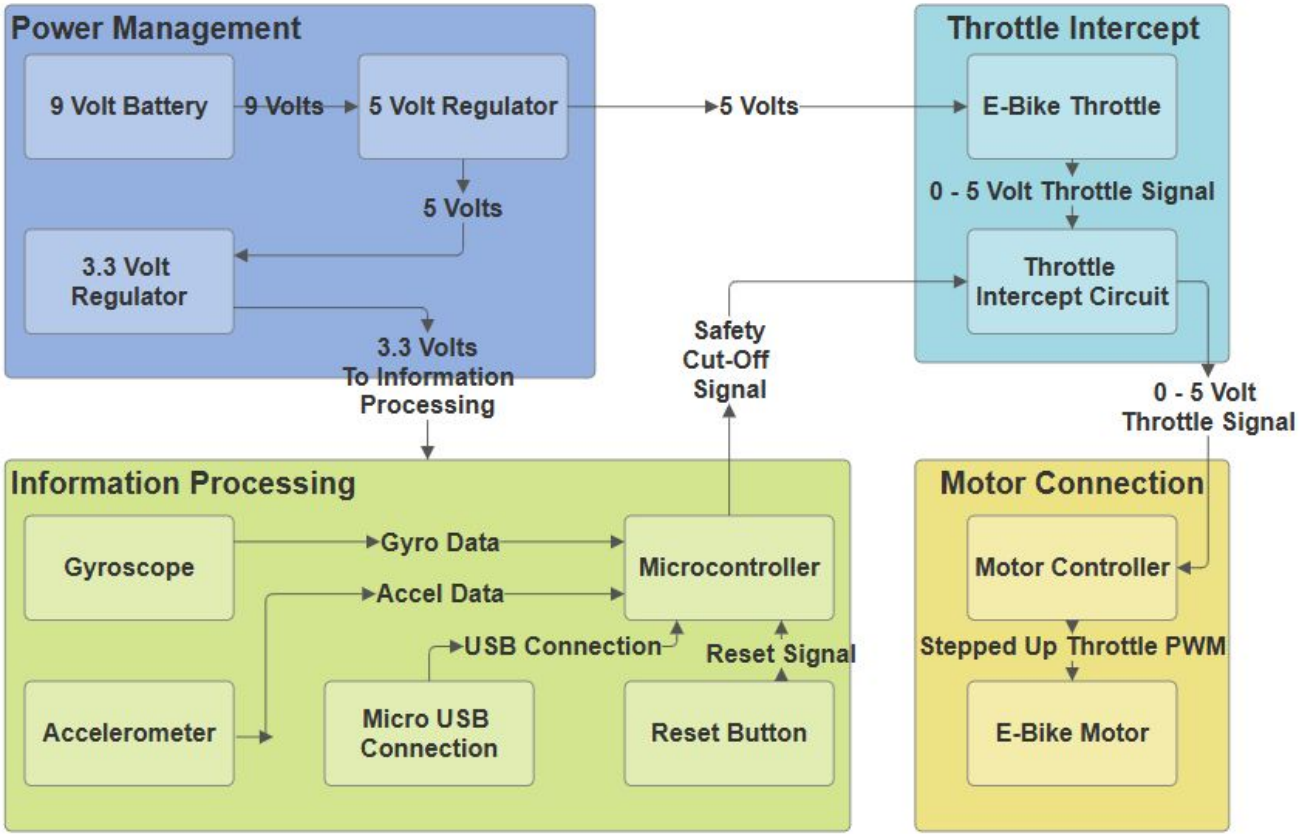
- ➔ Rapid growth in e-bike usage
- ➔ Increase in crash-related injuries
- ➔ Motors may remain active after impact
- ➔ No built-in crash detection or automatic cutoff

Solution: E-Bike Crash Detection and Safety System

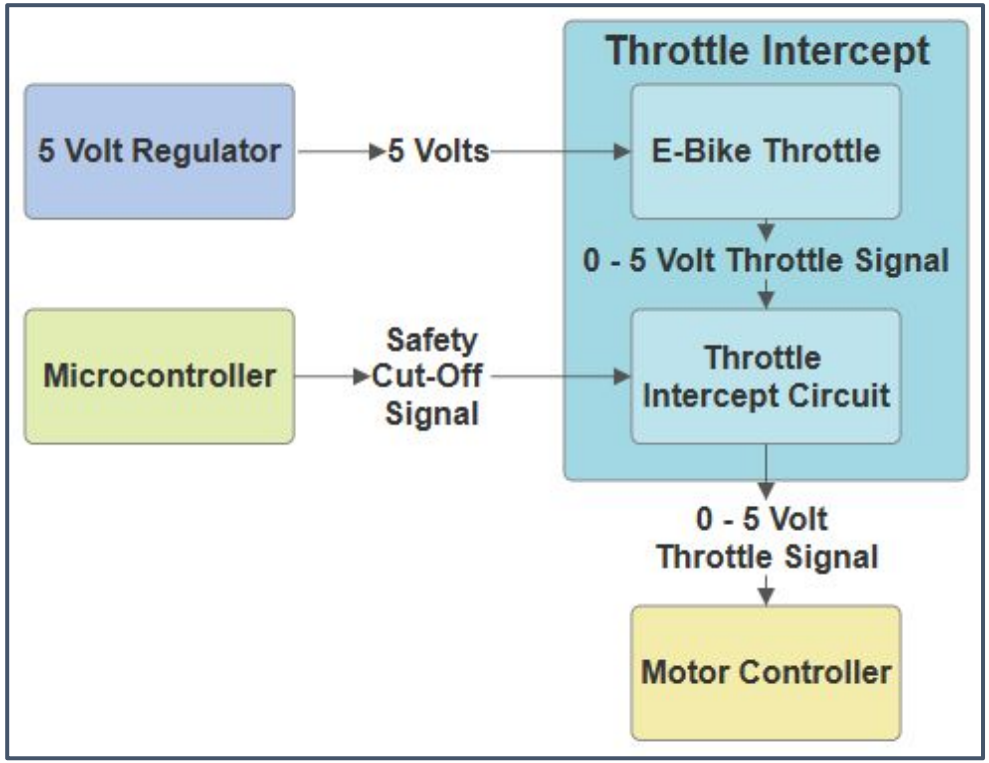
An embedded safety system that detects crashes in real time and automatically disables motor power.

- ➔ **Detects front, side, and rear collisions without triggering during normal riding**
- ➔ **Rollover detection**
- ➔ **Manual rider reset after safety confirmation**

Block Diagram



Designing Throttle Interception Circuit

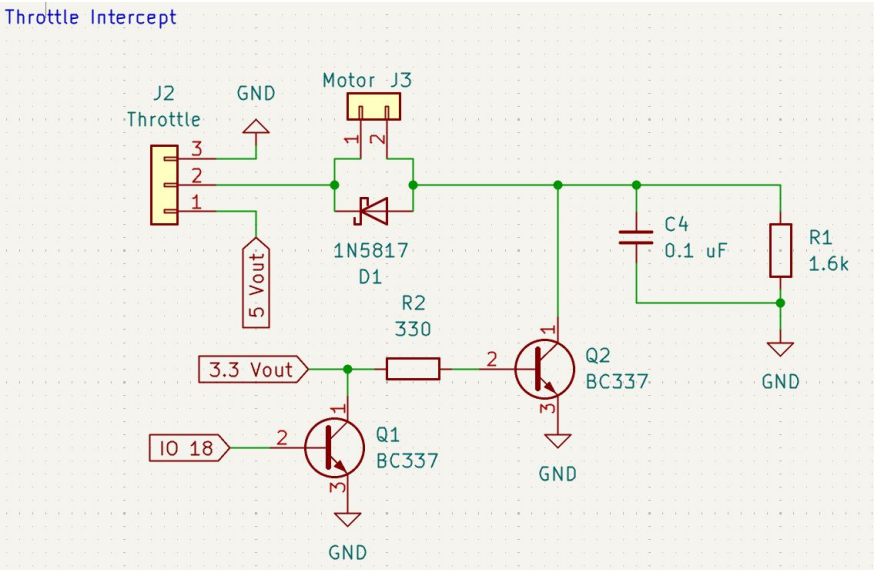


Throttle Intercept Subsystem Block Diagram with Inputs and Outputs

Requirements & Constraints

- **Safely Stop Power to an E-Bike Motor**
- **Ensure compatibility with typical E-Bike Throttles**
- **Avoid distorting the throttle signal**
- **Safely Clamp Throttle Signal**

Final Throttle Interception Circuit

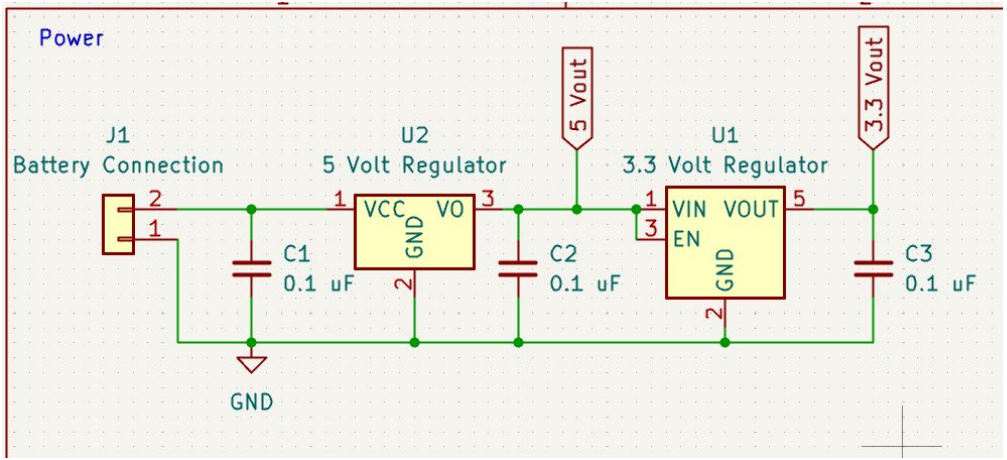


Final Throttle Intercept Circuit

Multimeter Voltage Across Motor With Safety Signal Low

Multimeter Voltage Across Motor With Safety Signal High

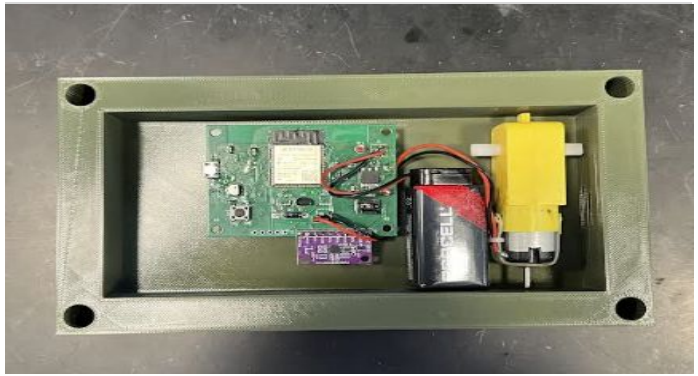
Power Management Subsystem

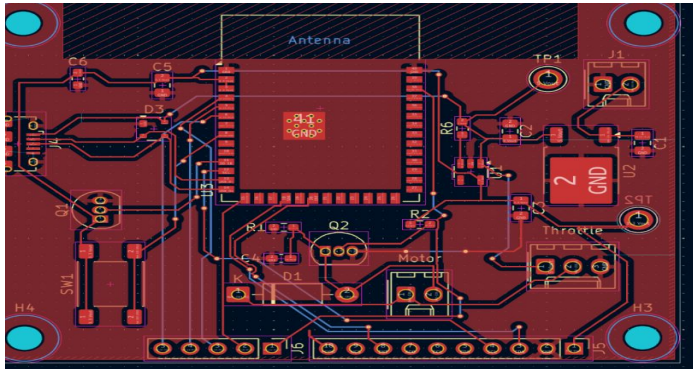


PCB Power Subsystem Schematic

Component	Requirement
5 Volt Regulator	Outputs 5 ± 0.2 Volts with ≥ 200 mA of Current
3.3 Volt Regulator	Outputs 3.3 ± 0.2 Volts with ≥ 300 mA of Current

Final Design





3d-Printed Enclosure

- Custom encasing to fit our PCB, test motor and 9 volt battery

PCB Layout

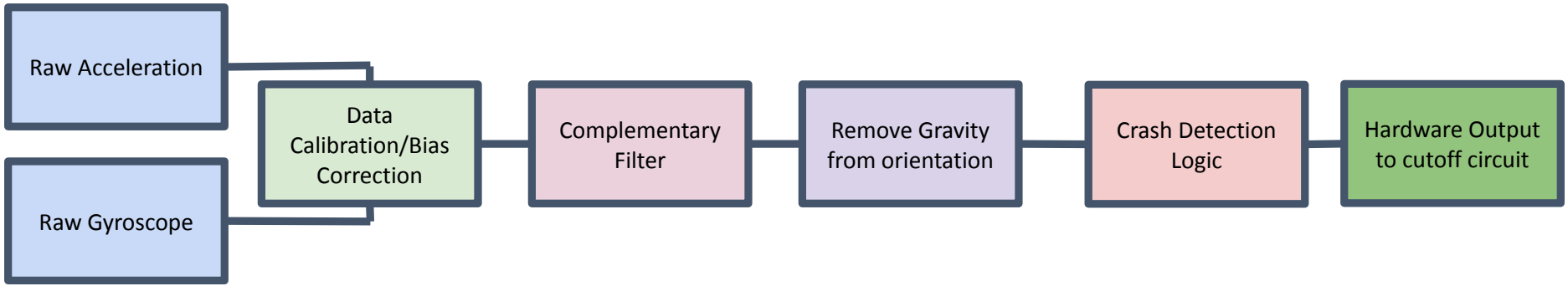
- Final routed design with connections for our IMU, Throttle Input and Motor Controller Output
- Failsafes for voltage spikes and vibrations from everyday riding
- Includes microcontroller connections, our full throttle intercept circuit and power management subsystem

Device On a Bicycle

Calibration of IMU

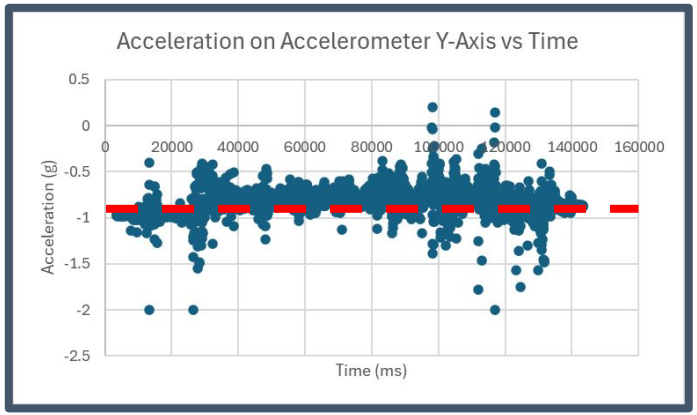
- Gyroscope bias calibration (500-sample average while bike is still)
- Accelerometer gravity-based tilt initialization
- Linear acceleration bias estimation in world frame
- Complementary filter to fuse gyro + accel, update every 500 samples. Removes noise
- Result: stable roll/pitch estimates & reduced drift

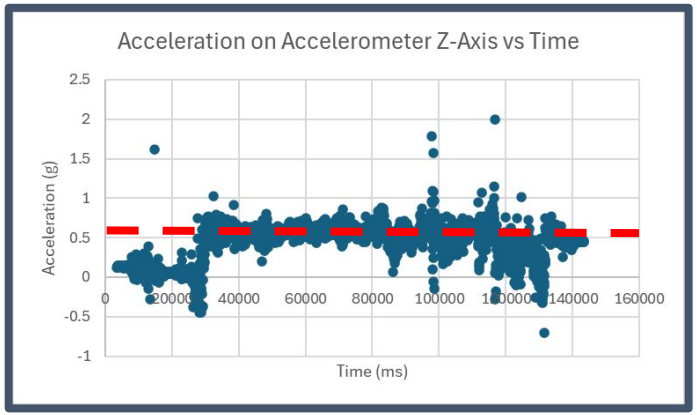
Code Diagram



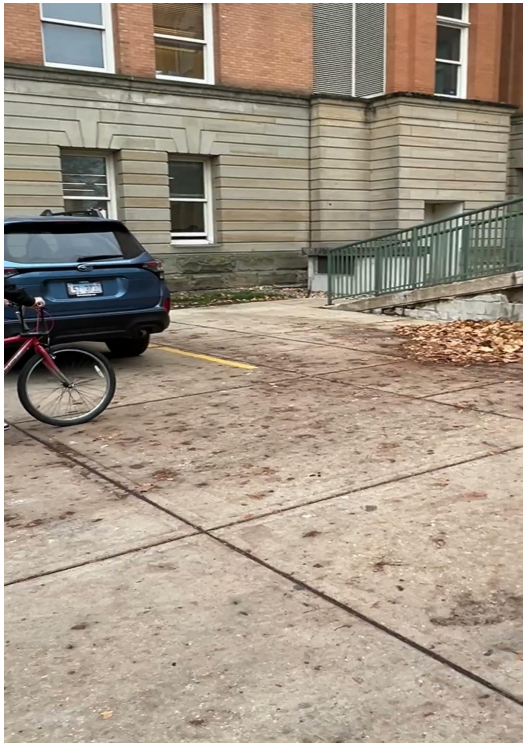
Why Did We Need to Account for World Frame?

Pre Calibration Accelerometer Force Data

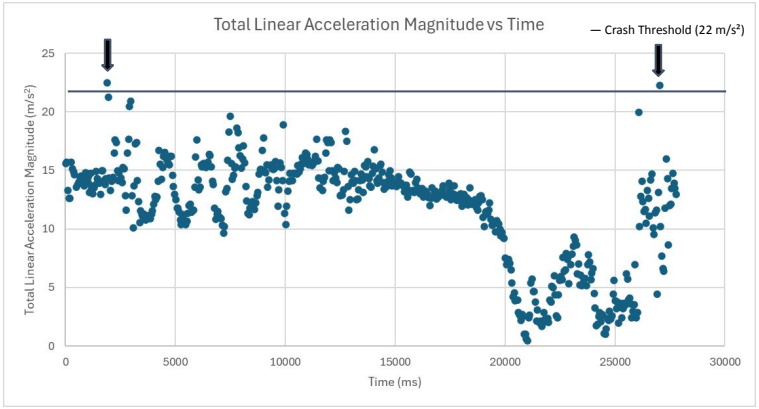


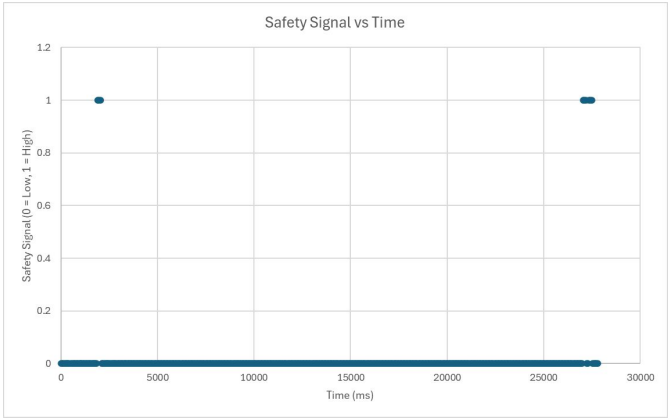


Crash Detection Example



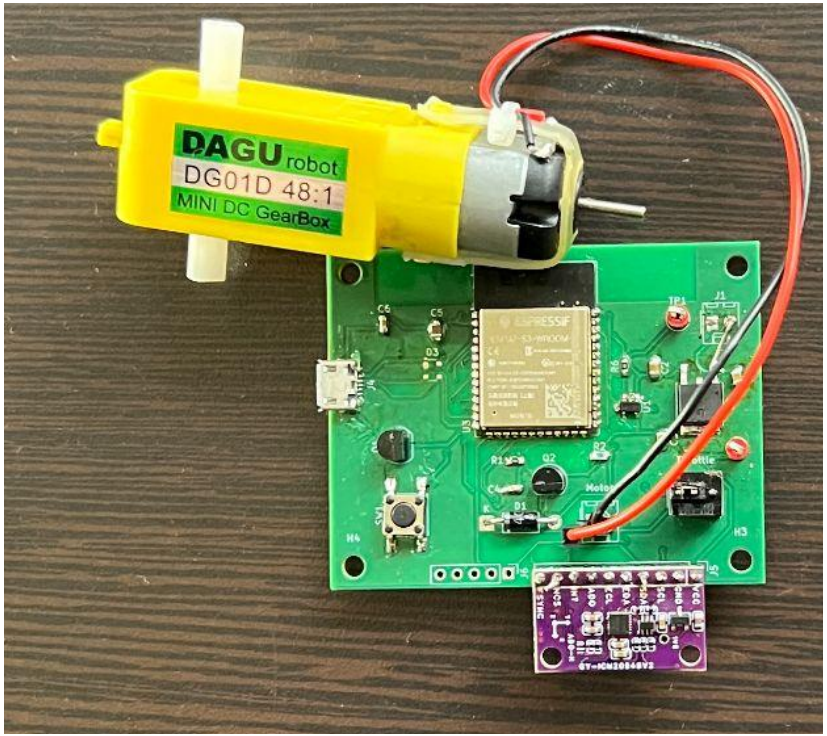
Video Of Front End Collision





Challenges Faced During Testing

- **Crash testing was challenging due to safety constraints**
- **Overvoltage during early testing damaged our initial development kit**
- **ESD event damaged the final PCB**



What We Learned

- **ESD Protection is critical for preventing permanent damage to microcontroller systems**
- **Power validation must be completed before full system integration to avoid cascading hardware failure**
- **Incremental subsystem testing significantly improves debugging efficiency and fault isolation**
- **Real-world safety affect how electronics can be tested and validated**

High-Level Requirement Successes

Successfully Demonstrated Requirements

- ➔ Detected a rollover / tip over event above 60°
- ➔ Verified reset and calibration functionality
- ➔ Detected front end collisions, side swipes and rear end collisions

Future of Project:

- ➔ Attach fully validated device to a real E-Bike
- ➔ Add wireless reporting using ESP32-S3 Bluetooth for app-based alerts

Ethics

- Prioritize rider safety by ensuring the system shuts off the motor during dangerous crash conditions, following IEEE Code of Ethics #1.
- Minimize false triggers to avoid unexpected motor cutoff, reducing harm and inconvenience to the rider.
- All testing is done in controlled environments to ensure no risk to the person or bystanders.

Thank You!
Questions?