ECE 445 - Fall 2025

Senior Design Project Proposal

E-Bike Crash Detection and Safety

Team 6

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1. Introduction

1.1. Problem:

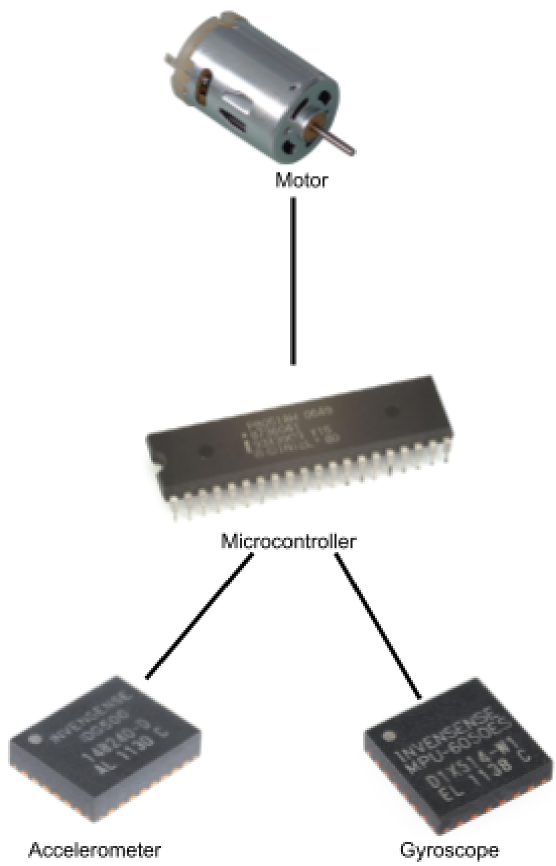
E-bikes are becoming a more popular mode of sustainable transportation, offering greater efficiency and accessibility compared to traditional bicycles. However, the increasing number of e-bikes has introduced new rider safety concerns. One of the most significant risks occurs during a crash: while the rider may be incapacitated or thrown off the bike, the motor and electrical system often remain active. This can drag the rider, cause additional collisions, or worsen injuries. The safety features in e-bikes and similar devices primarily focus on post-crash actions such as sending alerts or contacting emergency services. While these services are useful, they do not prevent the immediate danger that occurs during the crash itself. It would be more effective to detect accidents in real time and disable the motor to stop further harm to e-bike users.

1.2. Solution:

Our proposed solution is a crash detection and automatic motor cutoff system for e-bikes. The device will use an accelerometer and gyroscope, along with motor current and voltage measurements, to identify crash conditions such as head-on impacts or rollovers. Once a crash is detected, the system will immediately disable the motor either by signaling the controller or by cutting off electrical power through a dedicated cutoff circuit. To improve reliability, the system will fuse data from multiple signals rather than relying on a single trigger, reducing false positives during normal events like bumps or hard braking. A manual override and reset switch will allow the rider to safely restore motor function after a false detection. This system provides an added layer of protection to help prevent further injury or damage in the event of an accident.

1.3. Visual Aid

We will use an accelerometer and a gyroscope as an input to our microcontroller to detect potential crashes. The output of the microcontroller will cut-off the motors.



1.4. High-Level Requirements

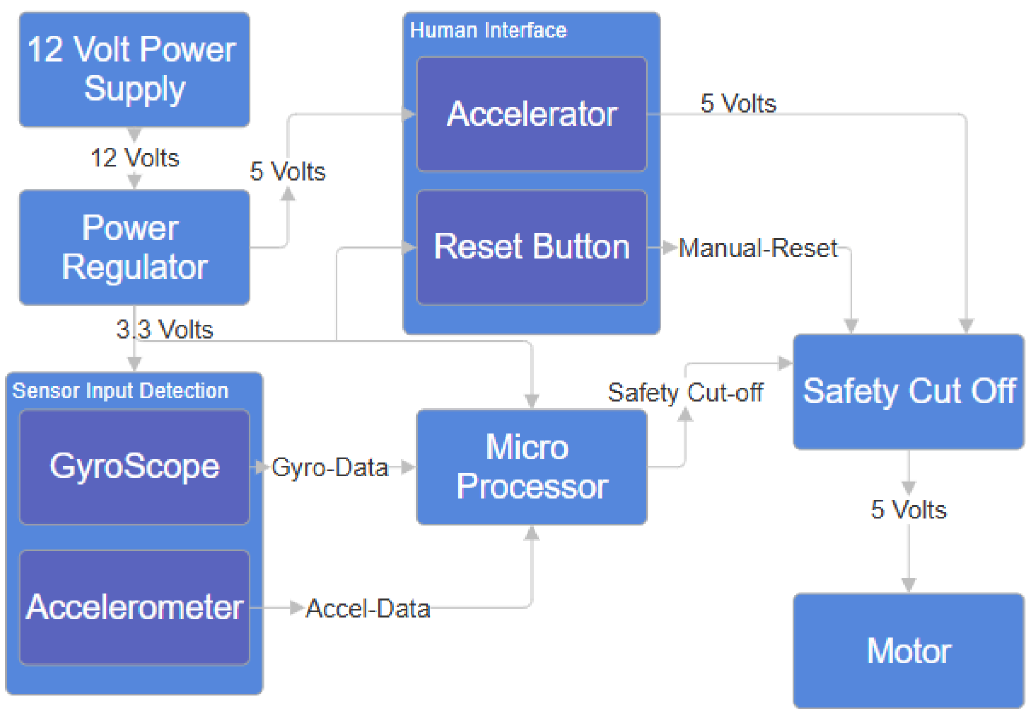
- Motor Impact Cutoff: The system must detect a head-on collision from rapid changes in acceleration and disable motor power within 200 ms to prevent the bike from moving forward after impact.

❖ Flip/Rollover Cutoff: The system must detect a rollover or tip-over event by monitoring tilt and angular velocity and disable motor power within 200 ms to stop wheel movement while the bike is on its side.

❖ Reset Functionality: A manual reset switch must allow the rider to clear the cutoff signal and restore motor power after a crash or false trigger, ensuring safe continuation without restarting the device.

2. Design

2.1. BlockDiagram



2.2. Subsystem Overview

Power Supply:

The power supply will be the primary DC source for all of our other subsystems. We will be using a 12 volt battery as our power supply that we can change, or recharge. The 12 volt power supply will be able to handle the current and voltage needed for several sensors, our microprocessor and the motor.

Power Regulator:

Our power regulator will step voltage down to a lower voltage that is safe for several of our subsystems. This subsystem receives the full 12 volts from our power supply. It will bring the 12 volts down to 3.3 Volts and 5 volts. The 3.3 volts will be delivered to the input sensor detection subsystem, micro-processor, and the manual reset switch. The 5 volts will go to the accelerator to be later delivered to the motor.

Sensor Input Data

This subsystem consists of a gyroscope and an accelerometer. It will receive 3.3 volts from the power regulator, and then communicate with the microprocessor by sending two different signals. These signals are gyro-data and accel-data.

Human Interface

This subsystem will give the person operating the e-bike control of our entire system. This subsystem will receive two different voltages. One is 3.3 volts, and it is connected to a button that will send a signal to the safety cut-off system to reset the safety switch. The second voltage is 5.5 volts. This will go to an accelerator that will be used to determine how much power will be given to the motor if the safety switch has not been triggered.

Micro-Processor

This subsystem is powered by 3.3 volts from the power regulator. The micro-processor subsystem receives gyro-data and accel-data. Using this data, it will send a signal to the safety cut-off called “Safety cut-off” in order to cut power to the motor.

Safety Cut-Off

The safety cut-off subsystem is required to turn off and on the power to the motor. It is supposed to take 5 volts from the accelerometer, and deliver it to the motor. When the “safety cut-off” signal is sent to it, it will disable this power. If disabled, it can then receive a “manual reset” signal from the human interface to reset this safety feature and return power to the motor.

Motor

The motor subsystem is a 5 volt motor that will work as a proof of concept. It will be used to visually detect if the safety features work and if the human interface works as well.

2.3. Subsystem Requirements

Power Supply:

- Must provide 12 V DC under a full load
- Be able to continuously provide current to all other subsystems
- Must be a swappable battery

Power Regulator:

- Convert 12 volts to 5 volts +/- 5% and 3.3 volts +/- 5%
- The efficiency should be above 80% to avoid unnecessary heat and power loss
- Over current and short circuit protection

Sensor Input Data

- Operate between 3.0 volts and 3.6 volts
- Output rate above 100 Hz to accurately send data to microprocessor
- Gyrometer must have a full range

Human Interface

- Debounced button for the reset that sends one time logic
- Accelerator must be able to send 1 to 5 volts, in proportion to throttle position on analog device

Micro-Processor

- Must read data from input detection subsystem and determine cutoff within 100 ms.

Safety Cut-Off

- Switch the 5 volt motor off instantly after receiving a “safety cut-off” signal.
- Reset the safety cut-off upon receiving “manual-reset” signal.

Motor

- Operate on 5 volts
- Produce visual rotation for proof of concept testing

2.4 Rough Parts List:

PART	**MODEL**	**INFO**
Microcontroller	ESP32-S3 module / STM32F401RBT6	3.3V logic MCUs. ESP32-S3 adds Wi-Fi/BLE + strong I²C support; STM32F401 offers bare-metal Cortex-M4 with FPU. Both have timers and interrupts needed for ≤200 ms cutoff logic.
Gyroscope	NOT FOUND ON ESHOP	NOT FOUND IN ESHOP
Motion Sensor	3D Magnetometer and Accelerometer LSM303DLHCTR	3-axis accelerometer + 3-axis magnetometer (I²C). Use ±16 g range for crash detection; compute tilt for rollover events.
5V Regulator	LM2931AZ-5	Automotive-style 5V LDO regulator, tolerant to load

		dump, ~100 mA output for logic/low-power circuits.
3.3V Regulator	LM317T (adjustable)	Adjustable linear regulator set to 3.3V. Supplies MCU + LSM303. Requires resistor divider.
Motor Driver / Cutoff	L298N	Dual H-bridge driver for DC motors, relays, solenoids. Use EN pin for MCU-controlled cutoff. Suited for 5V demo motor.
Isolation (optional)	4N25 / 4N35 Optocoupler	Provides electrical isolation between MCU and motor driver signals. Improves noise immunity.
Input Protection	1.5KE300CA (TVS Diode)	Absorbs voltage spikes on 12V input, protecting regulators and MCU.
Reverse/Flyback Protection	1N5820 / 1N5822 Schottky Diode	Prevents reverse polarity connection; also used across motor or relay coil to absorb

		flyback energy.
Fuse	Fuse Holder + appropriate fuse	Protects wiring and circuits from overcurrent on 12V input.
Reset Switch	TP11J81ZQE22 (momentary pushbutton)	Rider-resettable cutoff clear switch. Sends logic input to MCU to re-enable motor after event.
Arm/Disarm Switch	Generic Toggle Switch	Manual override; allows rider to arm/disarm the cutoff system.
Status Indicator	SSF-LXH25780GD LED (Green)	Indicates system status (armed, cutoff triggered, etc.).
Alert (optional)	MCP320B2 Piezo Buzzer	Audible feedback when cutoff triggered.
Connectors	1715721 Terminal Block + headers	Wire-to-board connection for power/motor lines and modular hookup of subsystems.

2.5. Tolerance Analysis

A critical parameter in our design is the reaction time of the crash detection system. The motor must cut off within 200 ms of a collision event. If this timing extends much beyond 200 ms, the rider risks being dragged by the bike. If it is too fast or too sensitive, the system could trigger false positives on normal bumps. To manage this, we will set thresholds such that linear acceleration above ~80 m/s^2 or angular velocity above about 300 degrees/s reliably indicates a crash condition.

The power subsystem also has strict tolerance requirements. The microcontroller and IMU require 3.3 V ± 5%, while the cutoff driver requires 5 V ± 5%. Any voltage droop outside these ranges risks missed detections or unstable operation. Our regulator efficiency must stay above 80% to minimize heat and maintain stable supply.

<u>Calculation Example:</u>

At a wheel radius of 0.35 m and a cutoff delay of 0.2 s, a bike traveling at 5 m/s (≈18 km/h) will move:

Distance = velocity × delay = 5 m/s × 0.2 s = 1.0 m

This means the rider could be dragged roughly one meter after a crash before power cuts. Any delay beyond this distance would significantly increase risk, making our 200 ms tolerance essential for safety.

3. Ethics and Safety

3.1 IEEE Code of Ethics #1: Safety

We will prioritize the safety of the rider and surrounding environment at all times. Our system will be tested under controlled conditions to avoid endangering the user during development. Sensors and electronics will be securely mounted to the bicycle to prevent loose components from interfering with normal operation. Since the system interacts directly with the e-bike motor, we will implement fail-safes that default to motor cutoff in case of malfunction, ensuring that the system does not create a hazard. Proper electrical safety measures will be taken, including protection against short circuits, overcurrent, and overheating of components.

3.2 IEEE Code of Ethics #5: Avoid Harmful Effects

We will avoid creating false crash detections that could cause unnecessary motor cutoffs while riding. To address this, we will carefully calibrate our accelerometer and gyroscope thresholds to distinguish between normal bumps and genuine crash events. This reduces the chance of the system causing harm or inconvenience to the rider.

3.3 IEEE Code of Ethics #9: Privacy and Security

If the system includes smartphone notifications, we will ensure that only the intended rider and their designated contacts can receive crash alerts. We will not collect or store unnecessary personal data. Any wireless communication between the microcontroller and external devices will use secure protocols to prevent unauthorized access.

3.4 ACM Code of Ethics 2.5: Fairness and Non-Discrimination

Our system will be designed to work with a wide variety of e-bikes and riders. We will ensure that our design choices do not unfairly disadvantage users based on the type of bike or equipment they own.

3.5 Risk Awareness and Handling

The lithium-ion batteries and motor circuitry used in the system have potential risks such as overheating or fire. We will follow proper battery safety guidelines, use appropriate fuses and regulators, and conduct thorough testing to minimize these risks. Crash detection testing will be done in safe, low-speed, and controlled environments.

4. References

University of Illinois ECE Shop, Student Self-Help Parts Drawers Inventory (2025).

IEEE, IEEE Code of Ethics: https://www.ieee.org/about/corporate/governance/p7-8.html