Regenerative Braking in Electric Bike Conversion Kit

ECE 445 Project Proposal

Team 38

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1. Introduction

1.1. Problem

Though electric bikes are a greener alternative to gas-powered cars and faster than traditional bikes, electric bikes' limited range can discourage some to make the switch. An average electric bike has a range of 20-40 miles [1]. For some, this range is simply too low to justify purchasing something on the order of $1000 to $2000, especially when that price tag reflects that of an entry-level electric bike [2].

Conventional electric bikes also suffer from the same brake wear as a traditional bike. It is suggested that traditional cyclists replace their brake pads every 500-1000 miles [3]. Since electric bikes use the same braking system as manual bikes, the same advice more or less applies. For those who cycle frequently, brake maintenance may be seen as an undesirable chore.

1.2. Solution

To solve these problems, we would like to create a kit that transforms a traditional bike into an electric bike that is capable of regenerative braking. The regenerative braking aspect would both provide a range boost to the user, as well as preserve the manual brakes such that brake maintenance would not need to be conducted as often as with both a traditional bike and more conventional electric bikes.

This kit would contain all of the components of a traditional electric bike, including motor, battery, and user controls. Completing the assembly would result in a friction drive, throttle-assist electric bike. The kit would also include the necessary control unit to not only provide the traditional function of supplying power to the motor, but also to supply power to the battery during regenerative braking. The end result is that the user would be able to convert their bike into an electric bike capable of regenerative braking. Riders will be able to use a regenerative braking control that is separate from the manual brake lever, slowing them down. The use of this system will both recharge the battery and reduce manual brake wear.

1.3. Visual Aid

The regenerative braking feature will be best utilized when coming to a stop for traffic signs, or when trying to slow down while biking down a hill. It will help recapture kinetic energy that would otherwise be lost to friction due to traditional brakes.

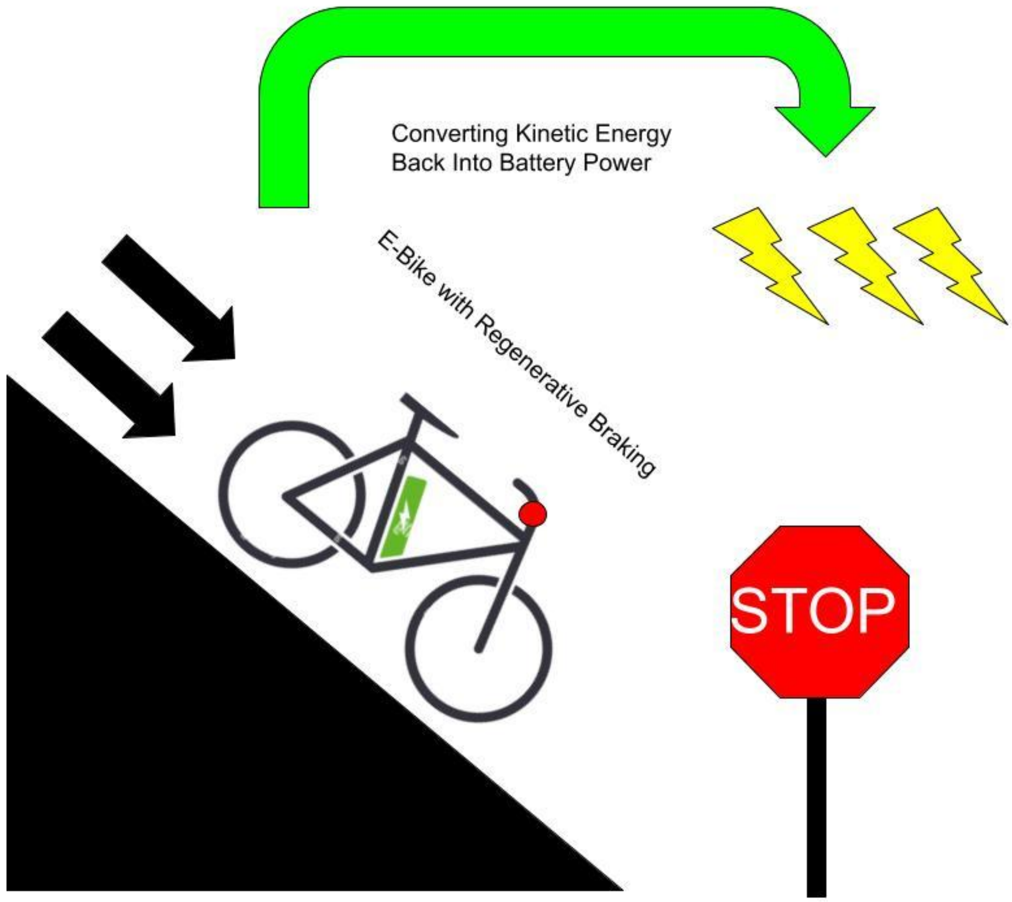

Fig 1: Example of Regenerative Braking Application

1.4. High-Level Requirements

- Regenerative braking must be utilized to recharge the battery to some extent. Data will be collected to demonstrate this.
- Pressing a button or switch on the bike must initiate regenerative braking. The braking should be strong enough to stop the bike at 15 mph within 100 yards. Regenerative braking should not be relied on for emergency stops.
- There will be an emergency shutoff switch that disconnects everything from the battery.

2. Design

2.1. Block Diagram

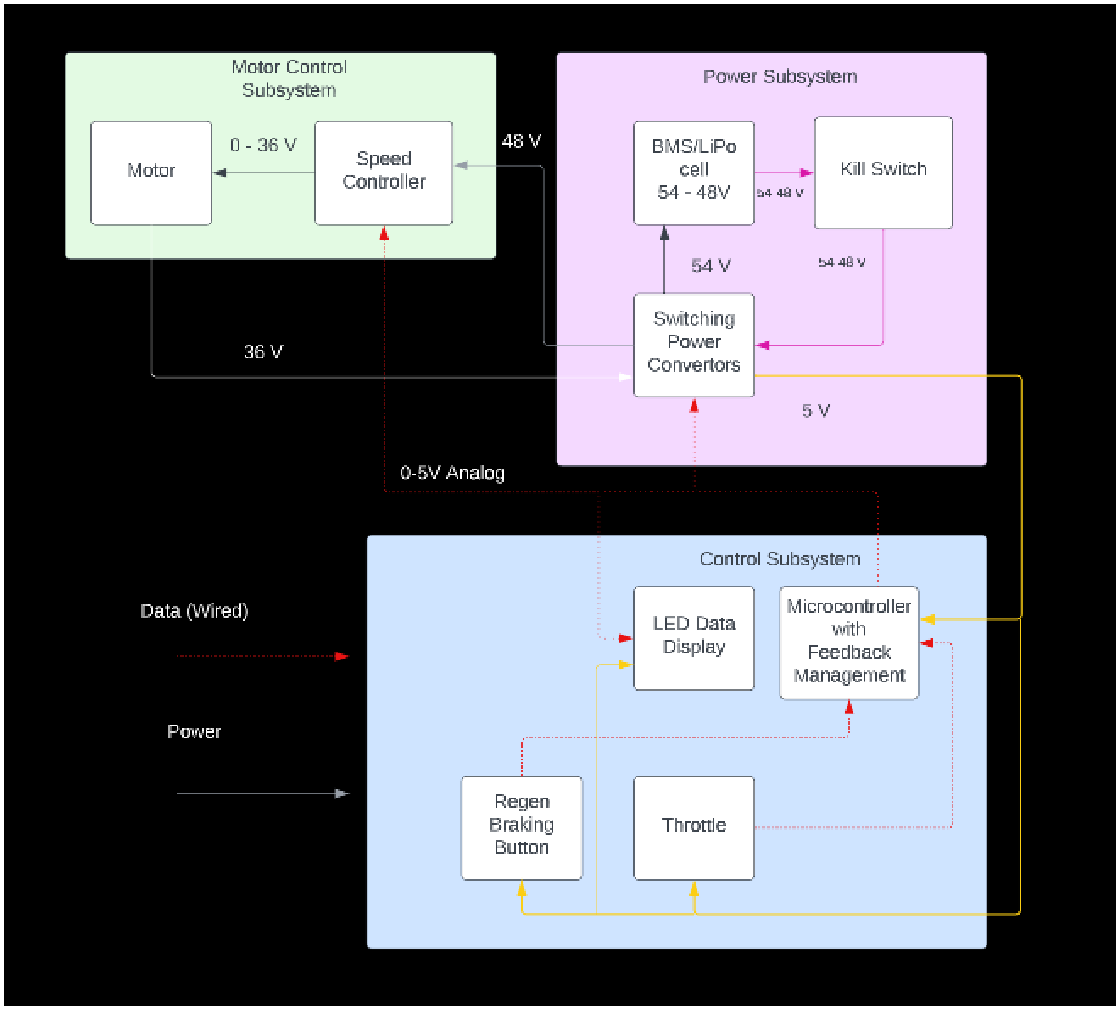

Figure 2: Block Diagram

2.2. Subsystem Overview

2.2.1. Motor Control

The motor control unit will modulate the DC voltage going to the motor to adjust the torque output. This could be done using a pot in a voltage divider. Another option would be to use a pot and an opamp to create an analog voltage multiplier. The output voltage will be a multiple of pot and a resistor.

2.2.2. Power System

The power system is meant to build upon the integrated BMS for our battery. It will measure the voltage of the battery and relay it to the control system in order to measure remaining capacity. It will manage whether or not the battery is charging or discharging based on control signals from the control unit. It will regulate the voltage output for the motor and the control unit. It will dissipate any excess power such that the battery isn't damaged by overcharging.

2.2.3. Control Unit

The control unit is primarily responsible for generating control signals for the motor control and power subsystems. The user inputs are the throttle and the regenerative braking signal. The control unit converts the throttle signal into a speed signal for the motor controller. It also takes the regenerative braking input and uses it to generate a switching signal for the BMS MOS portion of this project. The control unit takes care of data management, saving relevant information for testing. This would include a measurement of how much energy is returned to the battery. Finally, if the project has progressed enough, the control unit will supply data and power, possibly, to the displays on the electric bike.

2.3. Subsystem Requirements

2.3.1. Motor Control

Motor control aims to change a constant voltage into a voltage that can be varied by the user. Changing the voltage will increase the energizing current provided to the motor. Increasing the energizing current will increase the torque output to the motor in turn increasing acceleration. This is an important system to allow the user to engage the system in a throttle like manner.

2.3.2. Power System

Provides 36V ± 1 to the motor at up to 18A ± 5%. Cuts off flow of current into the battery when 54V is reached. Cuts off the flow of current out of the battery when 38V is reached. Provides 5V ± 5% to the control unit.

2.3.3. Control Unit

The control unit must supply an analog 0-5V signal to the motor controller indicating desired speed. It must do this using the throttle signal generated by the user. Pressing the regenerative braking switch must also trigger the control unit to switch the buck/boost function of the DC/DC converter. These signals would depend on the current function of the battery. On signals would be the on voltage of the MOS devices used, likely slightly higher than the on voltage, ± 5%. This number will be better known when those devices are selected.

2.4. Tolerance Analysis

An important aspect of our e-bike will be the conversions between voltages from the battery, the motor, and the supply board. To ensure success, we must ensure these conversions are done efficiently. Using information from previous classes, we designed a simple op amp voltage regulator. We created a simple model in falstad. However, we quickly realized how inefficient this design would be. Using this design, our 48V-36V DC-DC conversion would consume 188.6W. Based on this poor efficiency, we have decided to purchase, rather than design our voltage regulators.

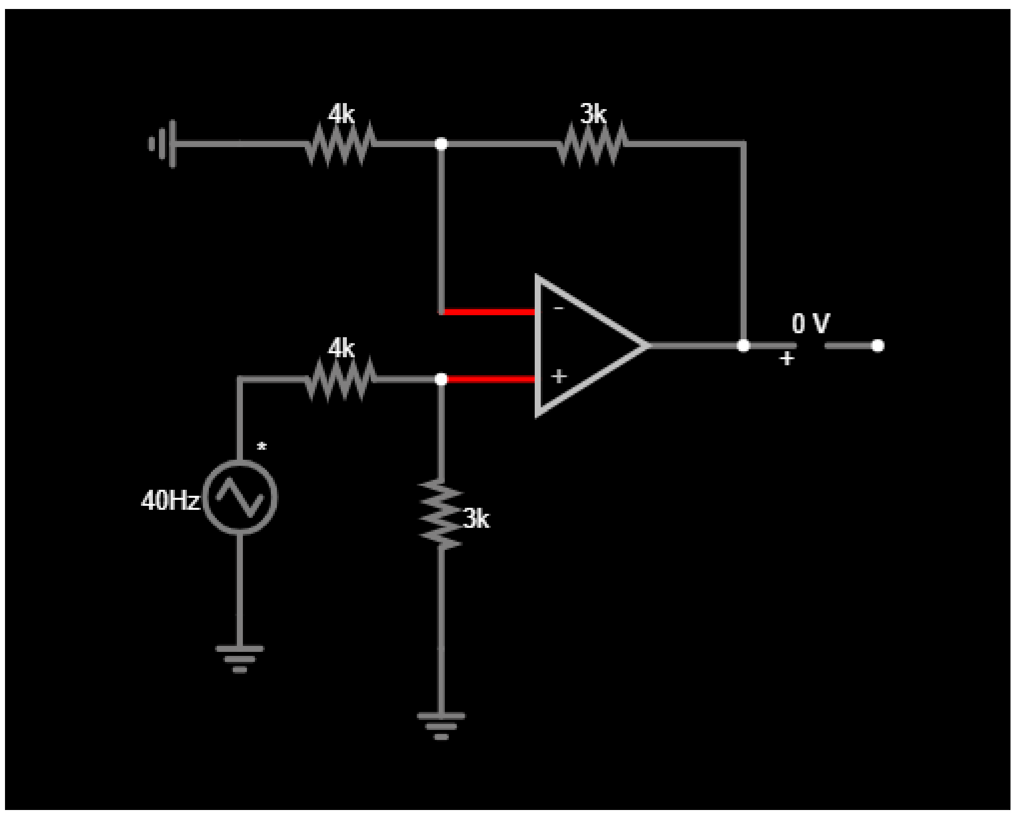

Figure 3. Proposed 48-36 DC-DC Voltage Converter

3. Ethics and Safety

Due to the potential risks associated with the battery being used for this project, we as a team must take care to minimize those risks, as stated in Section I.1 of the IEEE Code of Ethics [4]. We will take care to ensure that the batteries do not receive more charge than they can hold. We will also make protections against any unsafe battery conditions, such as overcurrent, overvoltage, short circuiting. During assembly, we must also take care not to drop or damage the battery in any way, as this can be unsafe to users. Charging at cold temperatures and ensuring that the battery does not operate above its rated temperature will also be important considerations. Charging below 0C will also be a consideration for the end user [5]. There will also be an emergency shutoff switch to prevent any unsafe conditions with the battery.

Another important consideration for our project is that our regenerative braking system must function to a satisfactory degree. The user must be able to slow the bike to a stop during typical use using our braking system. Design considerations will be made to have the bike slow to a stop in a reasonable distance. A manual braking system will also be included in the final design to ensure that the user can stop the bike at all times, especially during emergency situations.

We are not responsible for the user riding the finished project in any way that is not in accordance with the traffic laws in their area. Safe riding practices must be determined and followed by the user. Helmets and protective eyewear are recommended while riding an electric bike.

References

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[3] “Do bike brake pads get old?,” *Cycling Vitality*, 07-Aug-2022. [Online]. Available: https://cyclingvitality.com/do-bike-brake-pads-get-old. [Accessed: 08-Feb-2023].

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