E-bike Speed Controller with Regenerative Braking

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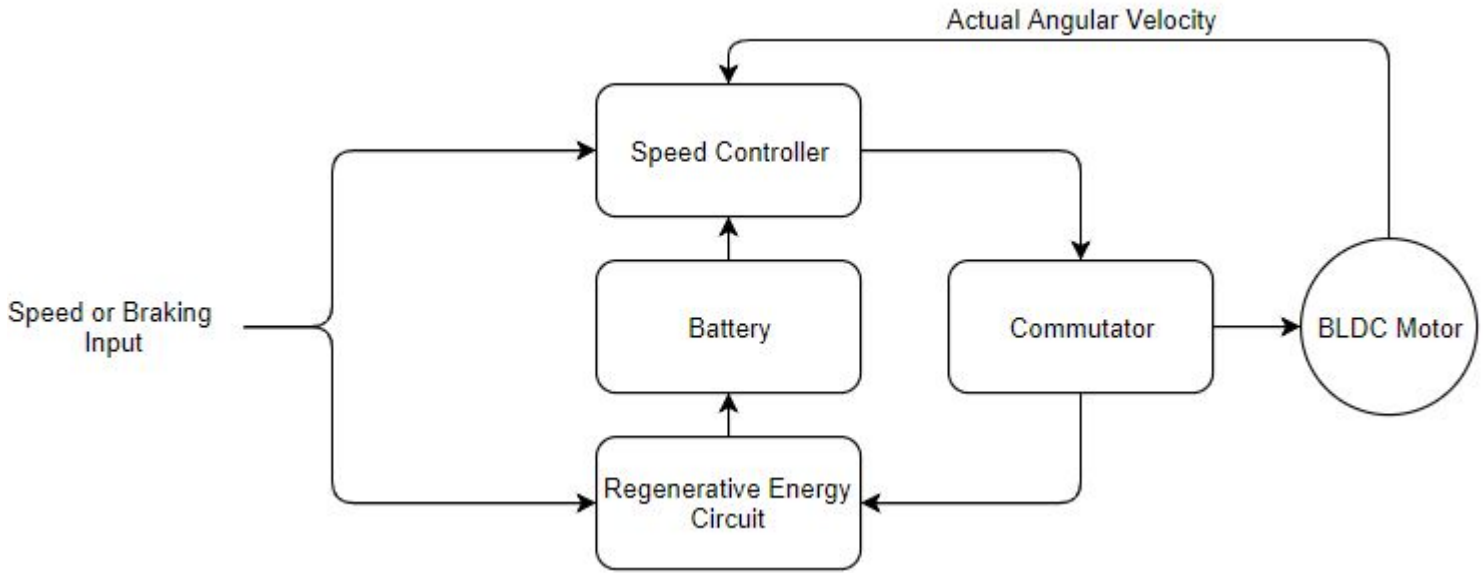
Project Goal

We will be designing a **speed controller** for an **electric bicycle** motor with **regenerative braking**.

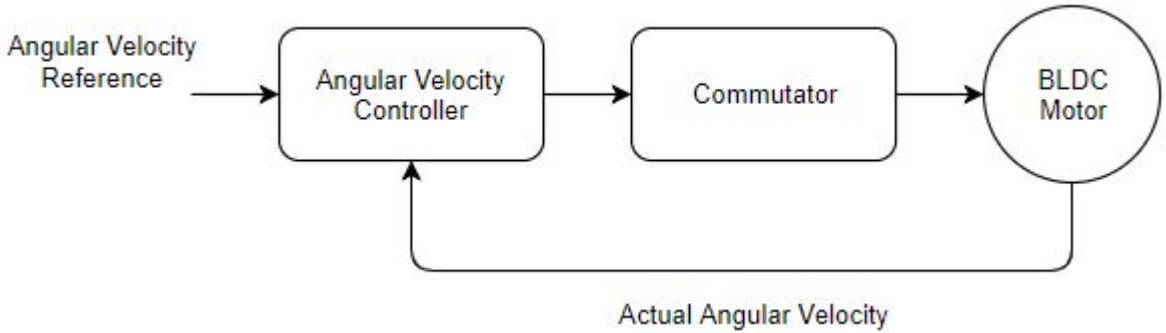
The rider will be able to set the desired bicycle speed.

The battery will recharge during braking.

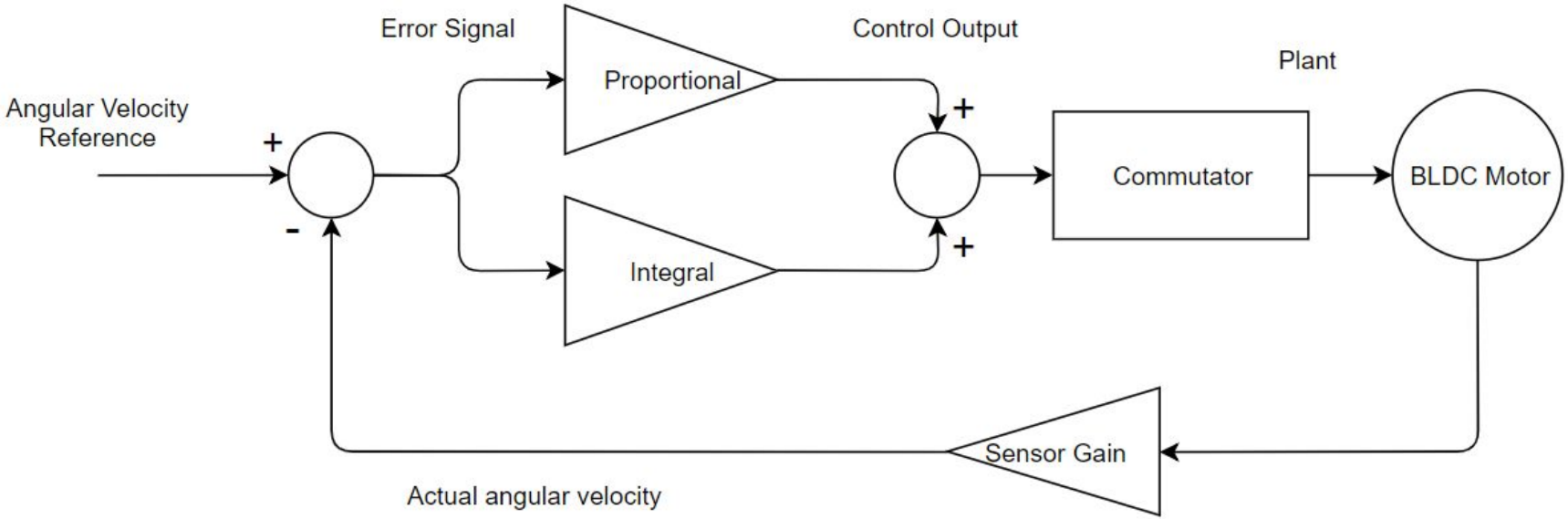
System Overview



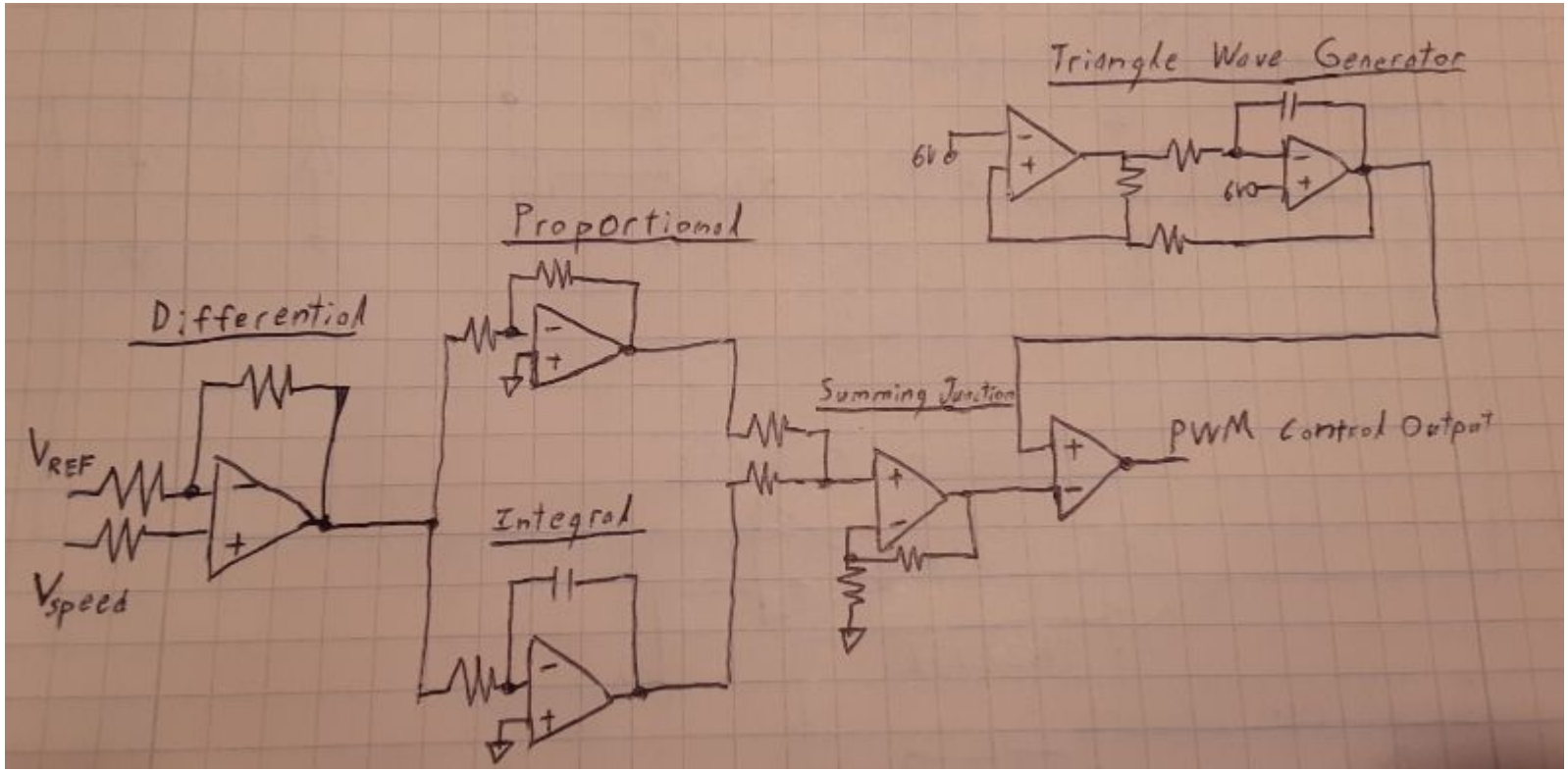
Speed Controller

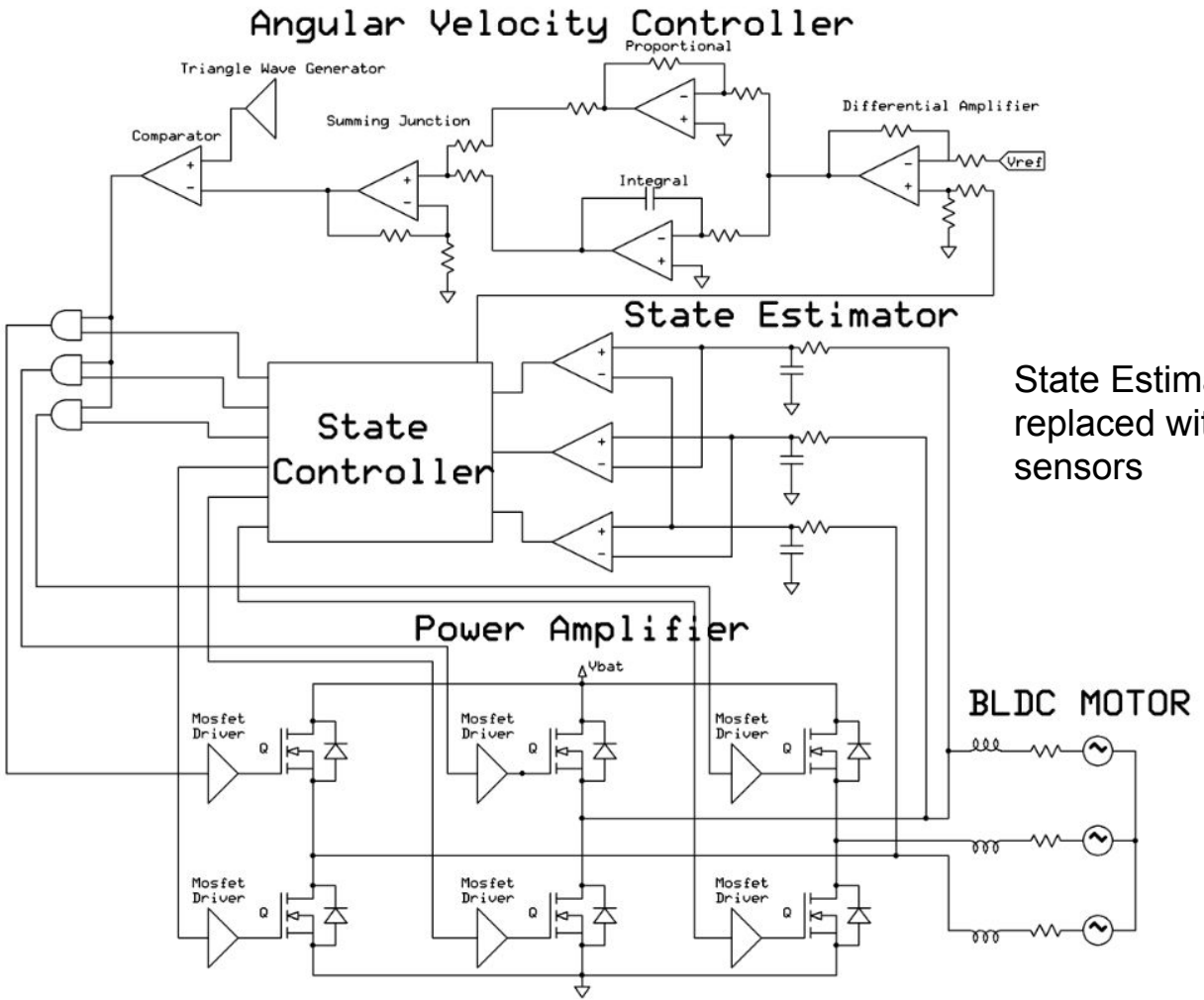


Speed Controller Again



Speed Controller Circuit



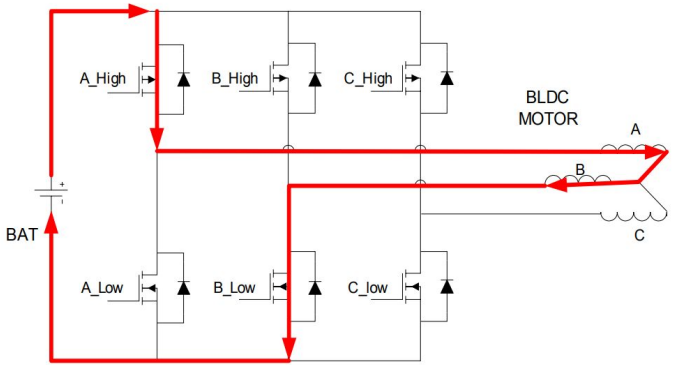


State Estimator can be replaced with hall sensors

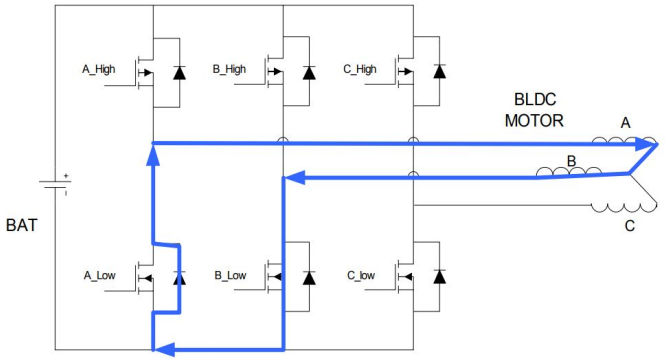
Driving the BLDC Motor

For one particular motor state:

When A_High is closed, current is supplied to the motor.



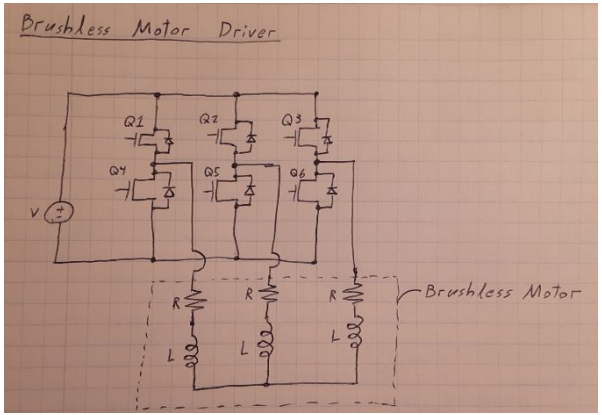
When A_High is open, the motor coasts.

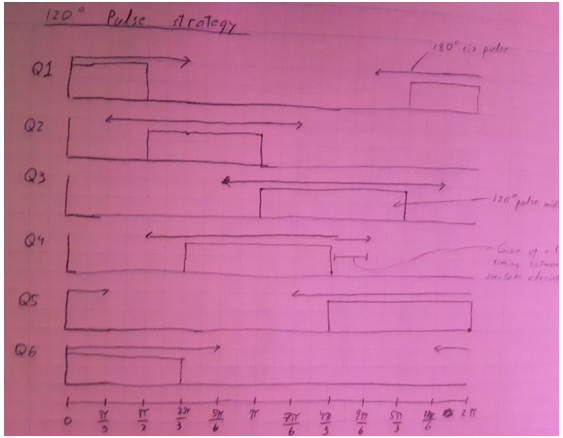


By switching between these two paths using a PWM signal, we can control the speed of the motor.

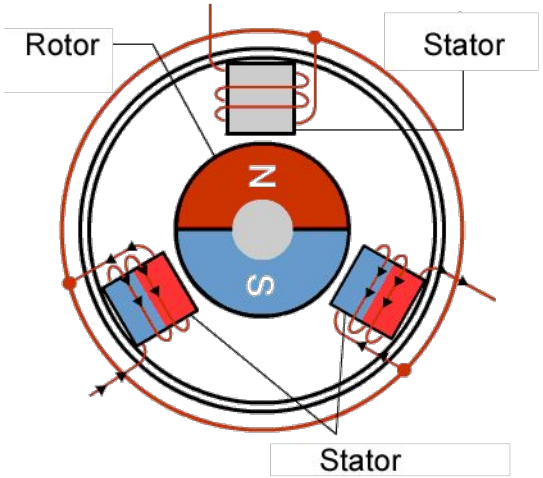
Source: “REGENERATIVE BRAKING IN AN ELECTRIC VEHICLE “, Cody et. al., University of South Australia

Commutator



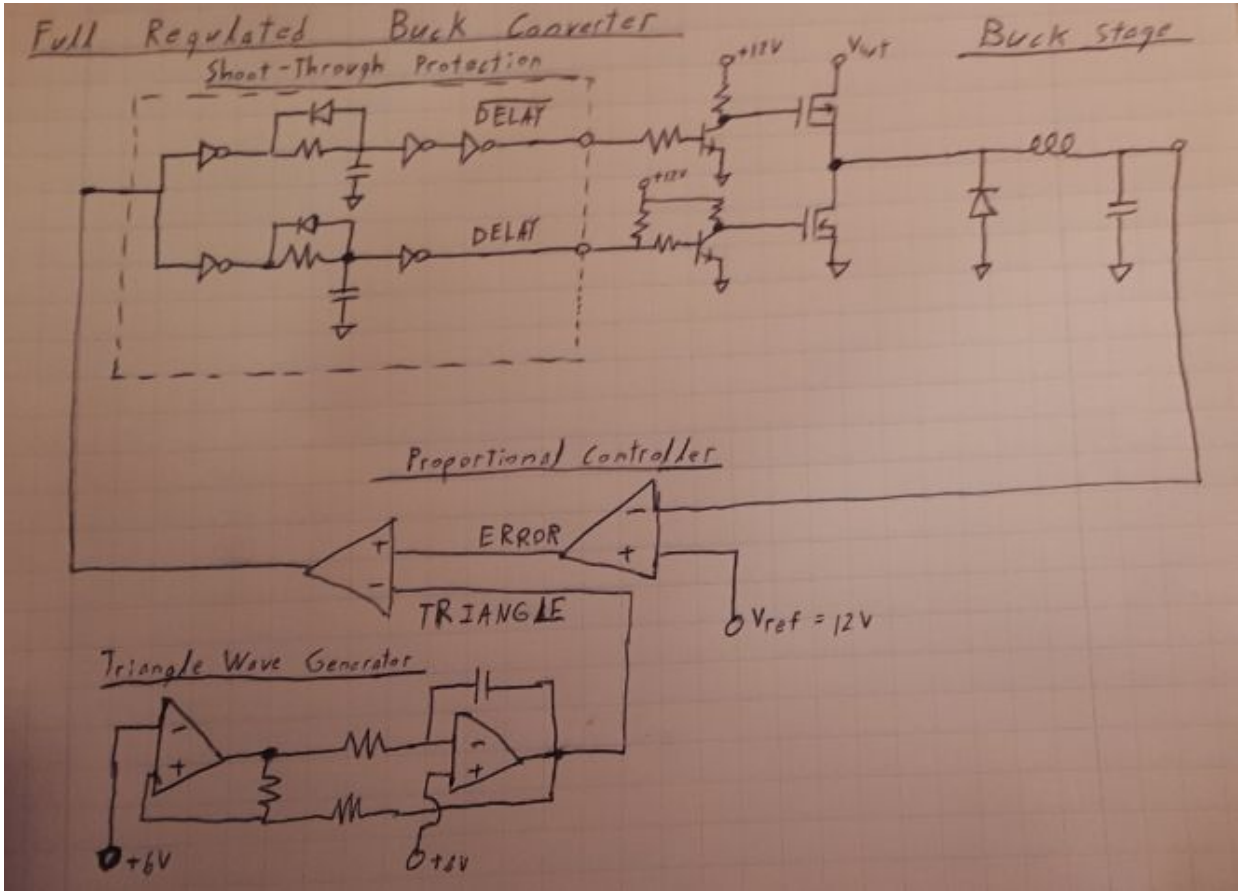


Motor is rotated by running currents through wire loops in a series of six states.



https://www.renesas.com/in/en/support/technical-resources/engineer-school/brushless-dc-motor-01-overview.html

Regulated Buck Converter



Regenerative Circuit

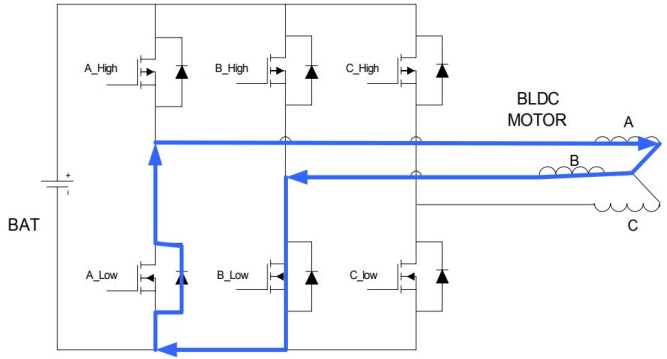
- We will design a circuit to return energy from the motor to the battery when the bicycle is braking. This is known as **regenerative braking**.

- By controlling which MOSFETs are closed during a given motor state, we can redirect current back in to the battery.

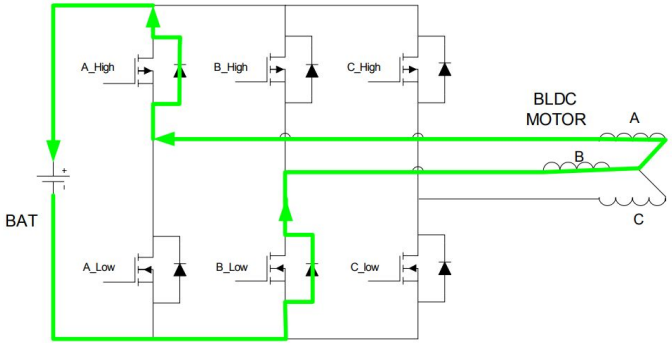
Regenerative Circuit

For one particular motor state:

If MOSFET A_Low is closed, current will not reach battery.



If all MOSFETs are open, current will be redirected to battery.



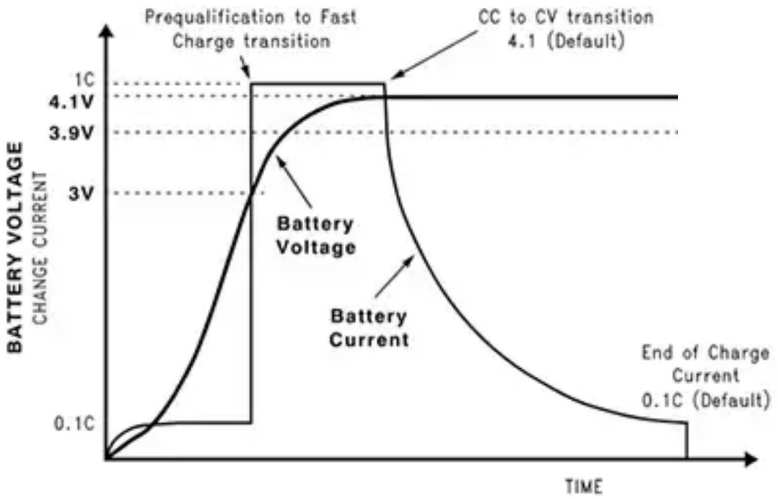
By applying a PWM wave to switch between these two configurations, we can control the level of current being supplied to the battery.

Source: “REGENERATIVE BRAKING IN AN ELECTRIC VEHICLE “, Cody et. al., University of South Australia

LiPo Battery Charging

The proper way to charge a LiPo battery is in two stages:

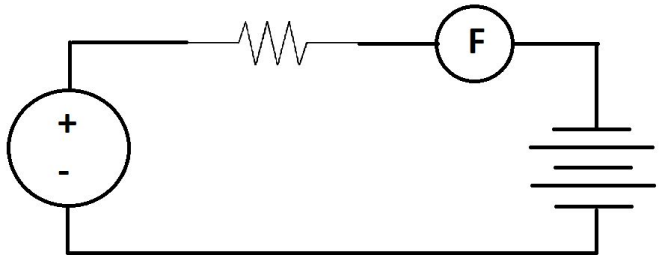
- Apply a **constant current** until the battery has reached a certain voltage.
- Switch to applying a **constant voltage** until the current the battery draws has decreased to a certain level.



Battery Charging Circuit

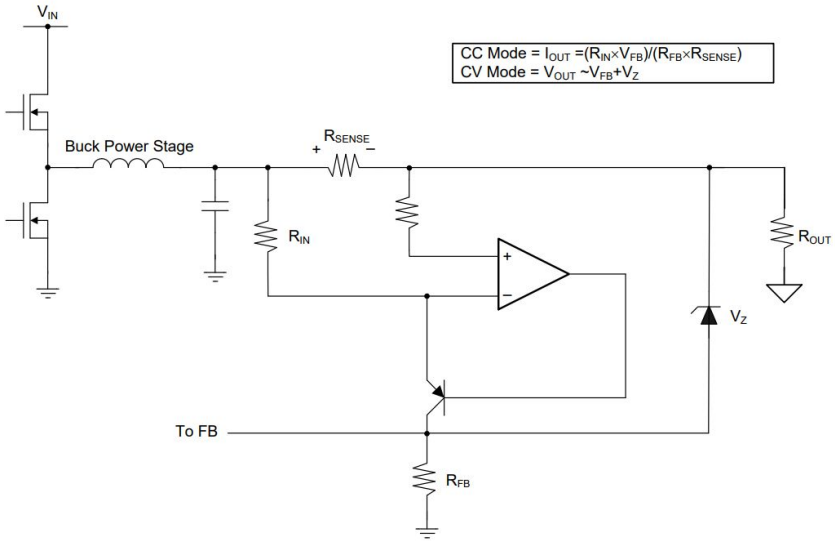
A simple battery charging circuit may consist of applying a constant voltage (using a buck converter) behind a resistor in series to the battery.

The resistor will limit the current being supplied to the battery (and a fuse will ensure this current is not exceeded)



Battery Charging Circuit

For **more efficient** charging, we may implement a circuit that **switches between constant voltage and constant current**, such as the the one shown to the right described in a TI document.



Source: http://www.ti.com/lit/an/snva829/snva829.pdf

Timeline

April 23-27:

- Design PCBs on KiCAD
- Prototype BLDC circuit and analyze return currents from motor.

April 28:

- Place PCB Order

May 5:

- Show live demo.