UMassAmherst

Mellivora: A Battery Experiment

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Overview

- Team Introduction
- Problem
- Our Approach
- Technological Innovations
- Design Alternatives
- Design Specifications
- Block Diagram
- Individual Subsystems
- MDR Deliverables
- Questions

Team Introduction

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EE

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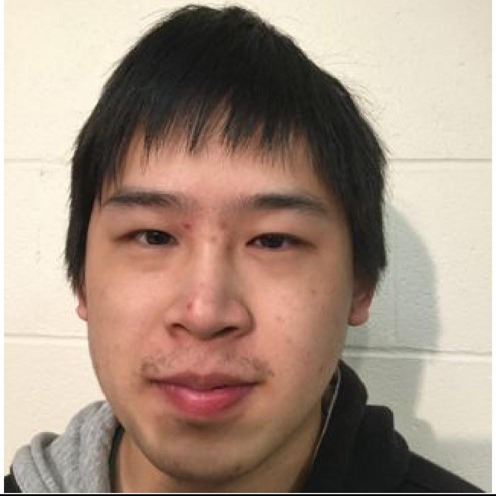

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CSE

The Problem

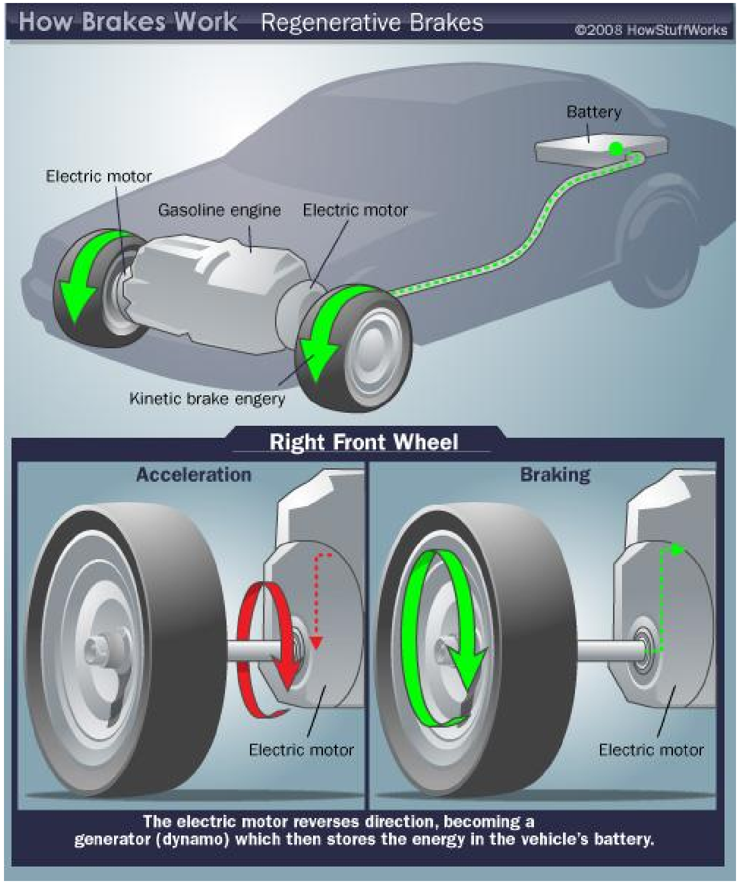
- Inefficiencies of conventional cars
- Lost power from braking
- Long charge times
- Chemical batteries are not environmentally friendly

Our Approach

- Demonstrate effectiveness of supercapacitor technology
- Demonstrate recharging capabilities with regenerative braking
- Use Brushless DC motor to turn a single wheel
- Physical wheel controls to accelerator and brake wheel
- Android App that displays RPM, Speed, and Capacitor Bank Charge Level

Regenerative Braking

- Recover kinetic energy from braking instead of converting to heat
- Back EMF slows motor
- Braking speed is controlled via brake pedal input



Why Supercapacitors?

- Advantages
  - Rapid charge/discharge cycles
  - No degradation over vehicle life
  - Future technology will drastically reduce cost, size, and weight while significantly increasing charge density
- Disadvantages
  - Advanced technology not yet commercially released
  - High discharge rate requires special cautions and consideration
  - Fewer applications in the automotive industry compared to batteries, need custom solutions

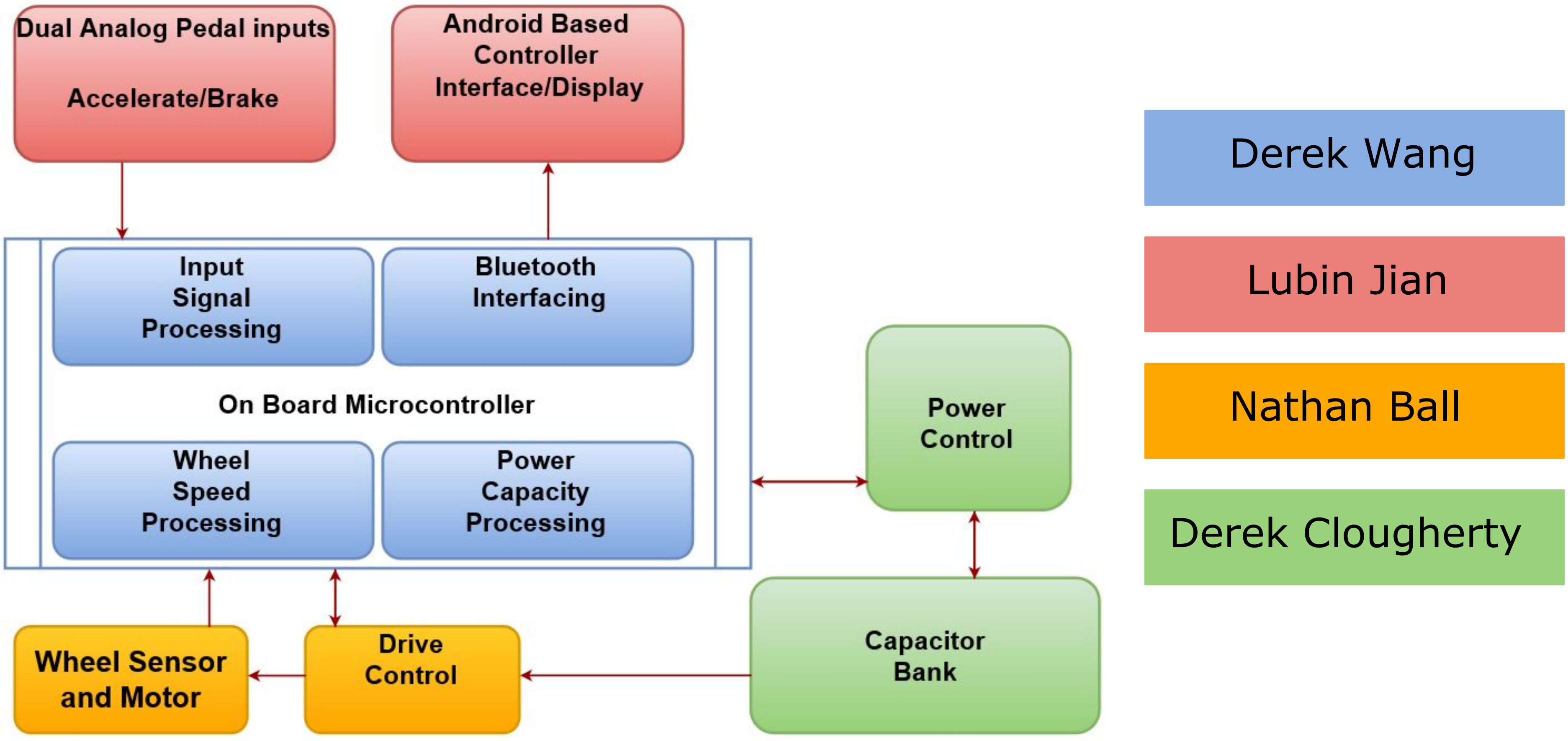
Capacitor Banks Usages

- Regulates reactive power (AC power correction)
  - Computers, buses, trains, cars, generators, transformers, etc.
- Can supply huge bursts of current
  - Pulsed lasers, fusion research, particle accelerators, nuclear detonators, railguns etc.
- As a power supply
  - Due to size, weight, cost, and charge density issues, has not been done
  - Tesla has expressed interest in this technology
  - EEstor claimed in 2007 to have created a car battery equivalent capacitor bank. Has not demonstrated it.

Final Product and Specification

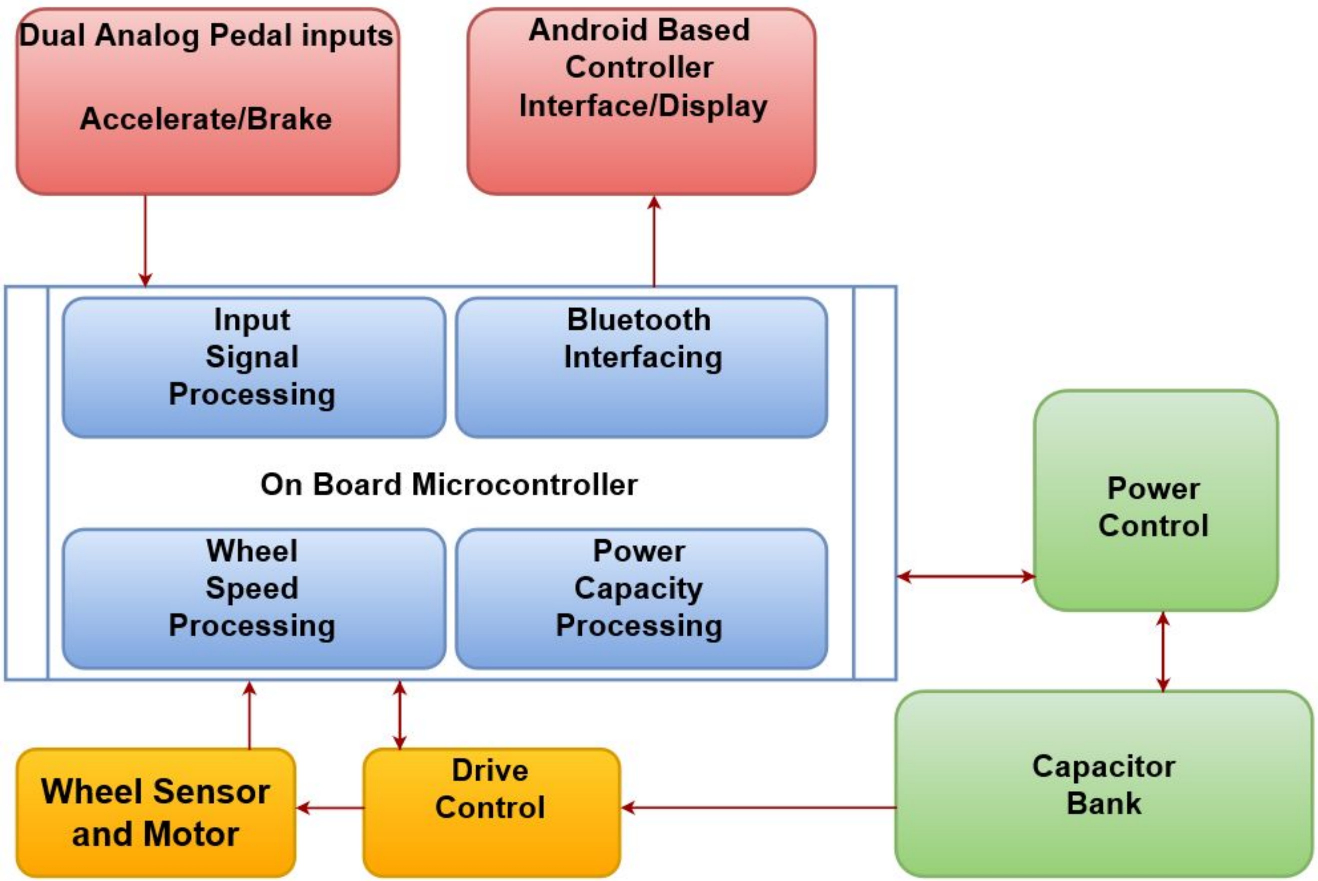
- One wheel concept to show advantages of capacitor bank power technology
  - Accelerated charging capabilities with capacitor bank power supply
  - On board Central Control Module program
  - Controlled with multiple inputs - Pedals, Android App
- Requirements
  - Top speed of 30MPH
  - Efficiency of system must be above 70%
  - Full stop from 30 MPH within 3 seconds

Block Diagram



Central Control Module

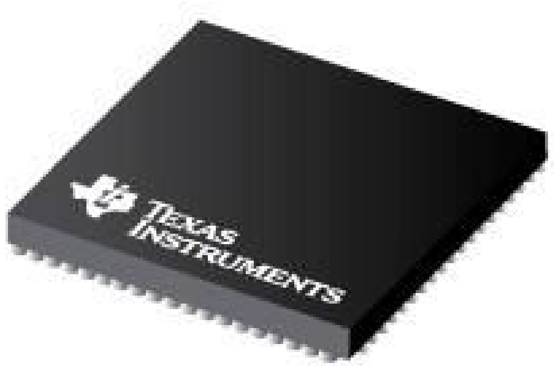
- Derek Wang



Central Control Module (CCM)

- Microprocessor: TI Sitara ARM Cortex A9 MPU

Main Tasks
- Input processing
- Android App Interfacing
- Power Control
- Drive Control



- Also deals with error handling
  - Ex. Braking and accelerating simultaneously.

Input Processing

- By Gamepad Pedal
  - Interpret gamepad voltage signals as wheel speed demands and power mode changes
  - A/D Converter

- By Android App
  - Interpret bluetooth signals from Android app to modulate wheel speed

Sensor Data and Android App Interfacing

- Processes Sensor Data
  - Hall Sensor feedback in wheel
  - Power supply voltage from Power Control
  - Current and voltage to and from power supply
  - Power mode (drive, braking, freewheel, and charging)
- Sends Sensor Data to Android App via Bluetooth
  - Wheel speed and RPM
  - Power remaining in power supply
  - Rate of power consumption and generation
  - Power control mode
- Communicates via bluetooth

Power Control and Drive Control

- Power Control
  - Mode changes (Drive, braking, freewheel, and charging)
- Drive Control
  - Control variable motor speed using pulsed signal
  - Control variable regenerative braking with pulsed signal
  - Select forward/backward using directional signal
  - Calculate what pulsed signal is needed based on gamepad pedal or Android input and wheel speed sensor data

MDR Deliverables

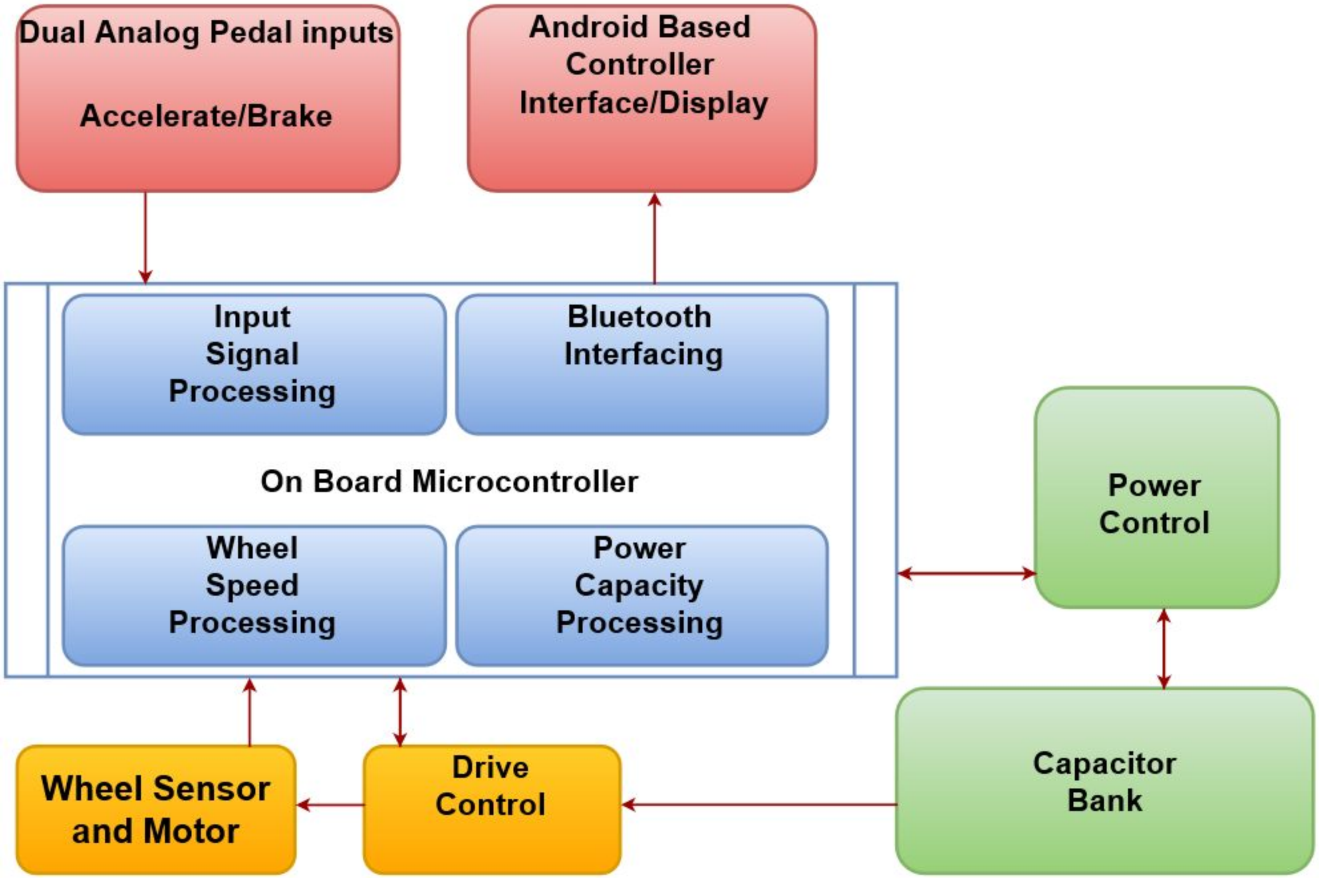
- CCM program calls correct functions in simulation and outputs correct dummy signals based on simulated inputs

Challenges:

- Get microprocessor mounted and with a working program
- CCM on chip can recognise and give the correct output to signals from gamepad pedal input

Controller Inputs and Display

- Lubin Jian



Pedals as Analog Inputs

Drive Pedals

- In order to replicate a real driving experience
- Adapt gaming pedals in order to connect to CCM
- Simplifies android application

Android Application Display

Android Display

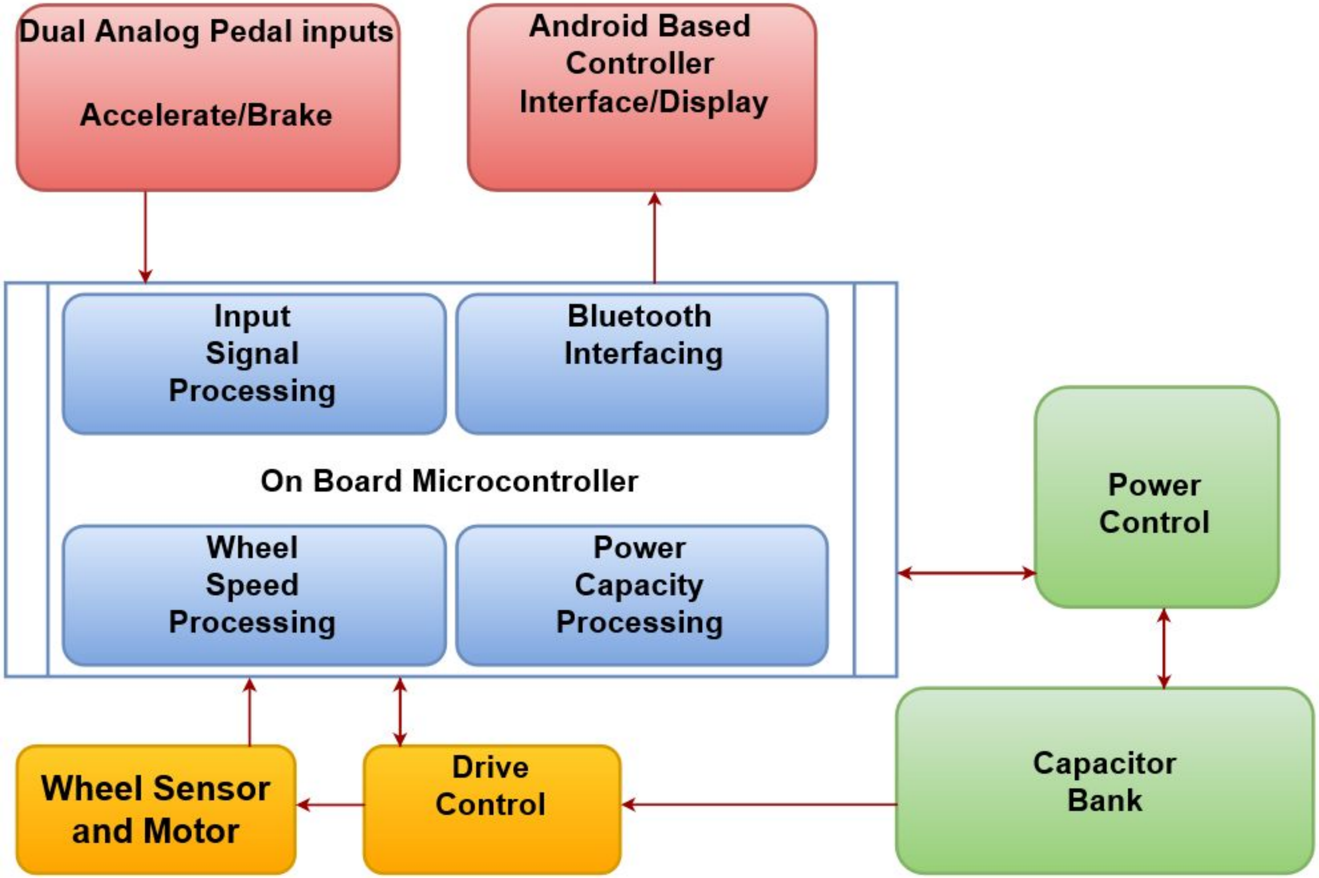
- Takes in an input from the CCM
- Displays valuable information the summarizes the current state of the system
  - Wheel speed
  - Power being drawn from capacitor bank
  - How much power is left in the capacitor bank
- We will be able to visualize the regenerative braking in real time
- Eventually implement controls to move the wheel from the android application

MDR Deliverables

- Deliverables
  - Working pedals that can interface with the CCM
  - User-friendly application that displays the information in a clear concise way
- Challenges
  - Adapting the pedals from whatever system it was made for

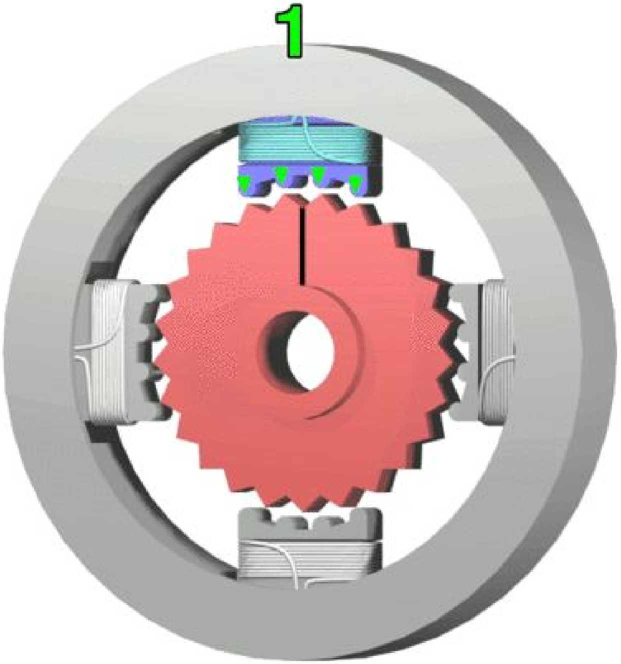
Drive Module

- Nathan Ball



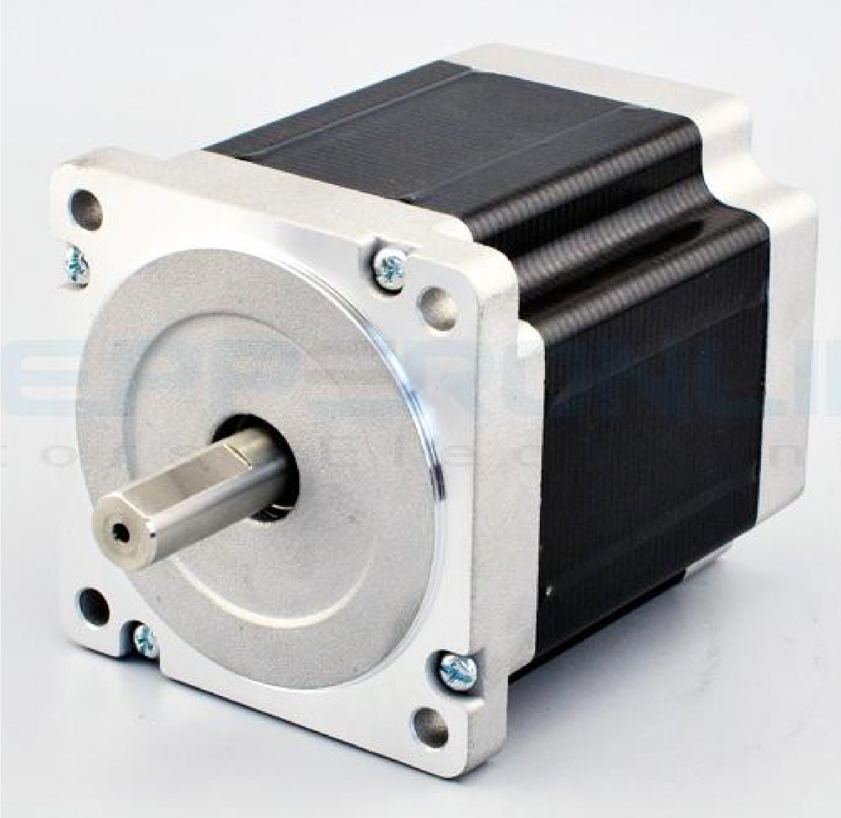
Stepper Motor

- Permanent magnets on rotor
- Teeth offset between rotor and stator
- Energize electromagnets to turn rotor



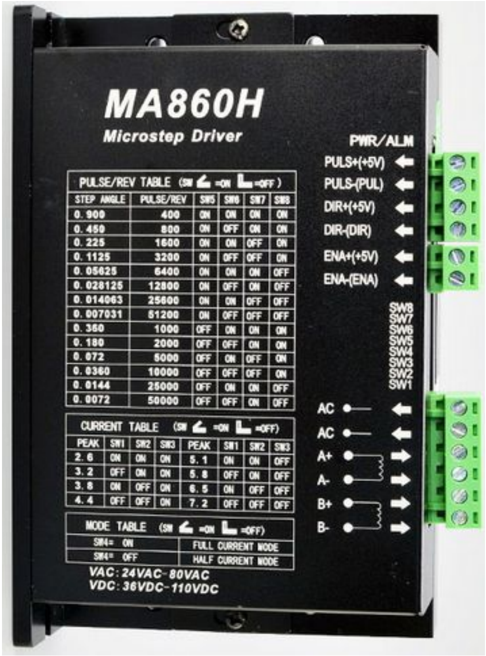
Motor

- 8 Wire NEMA 34 Stepper Motor
- 5 Nm holding Torque
- $45



Motor Driver

- Converts signal from controller to motor pulses
  - MA860H Driver
- Control regenerative braking
  - Full wave rectifier to convert AC to DC current
- Feedback
  - 3 Hall Sensors



MDR Deliverables & Challenges

- MDR Deliverables
  - Demonstrate working drive module from test signals
  - Hall sensors for wheel speed
- Challenges
  - Providing clean power with regenerative braking

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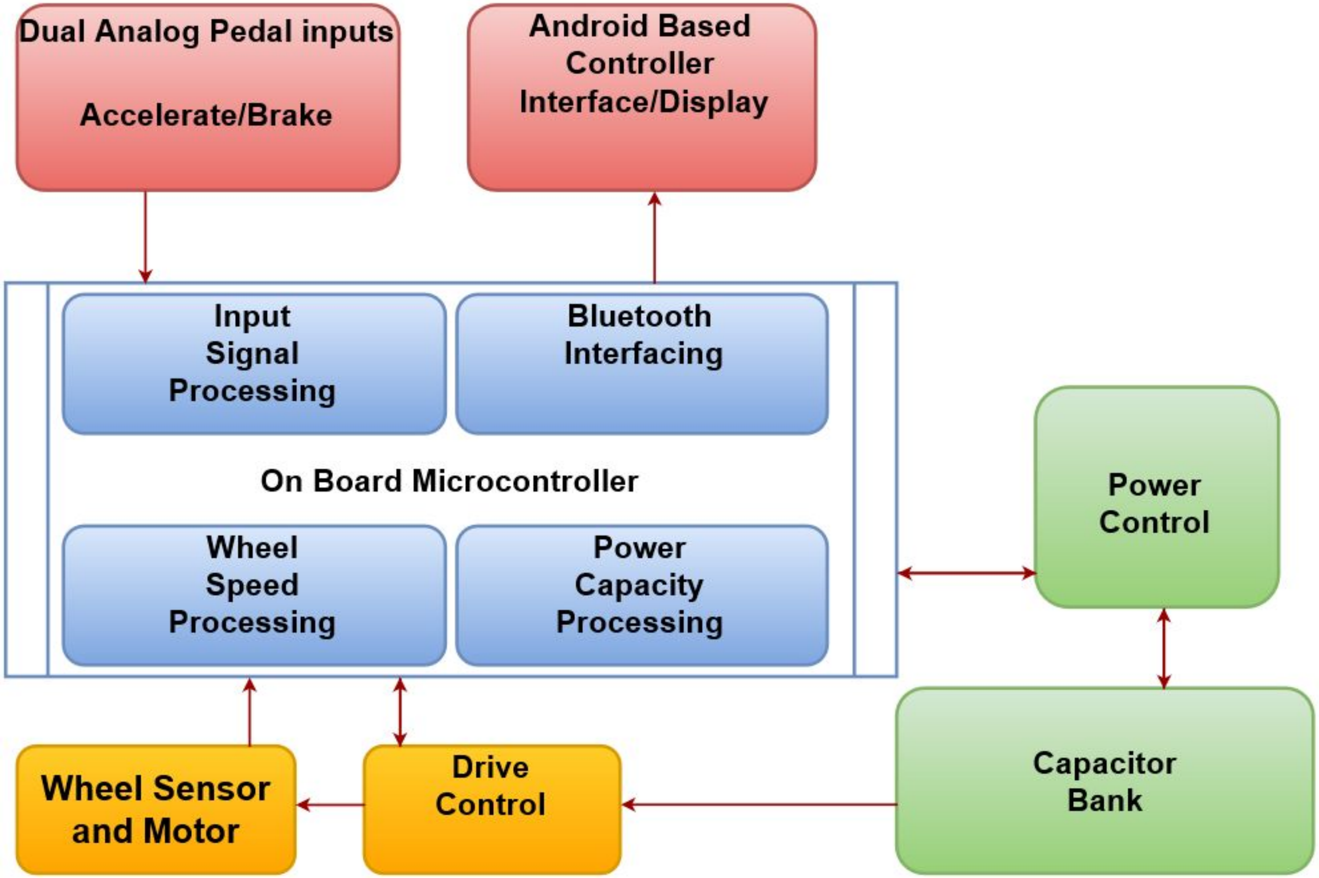
Power Supply

- Derek Clougherty



Power Supply and Charge Controller Requirements

- Support 3-5 minute runtime
- Monitors cell voltages for fault detection and overvoltage conditions
- Charge cells from 120V AC power supply or drive motors while in regenerative braking mode
- Communicate with CCM for charge level display and for switching between power and regenerative braking mode

Supercapacitor Power Supply

Capacitor

Maxwell BCAP0350 in 6x2 series-parallel array

2.7V 350F 170A (max)

Power for supercapacitor array

2[((116.7F*16.2V^2)/2)/(1Wh/3600J)] = 4.25 Wh

Motor

OMC 34HS38-3008S

36V 2A 5Nm 3500RPM

Runtime

36V*2A = 72W

[4.25WHr/72W]*60 = 3.5 minute continuous runtime

MDR Deliverables & Challenges

- MDR Deliverables
  - Circuit layout designed and prototyped
  - Demonstrate switching between power and charging modes
- Challenge
  - Providing clean power to capacitor bank during regenerative braking
  - Producing a suitably sized power supply that fits within the budget

Conclusion

- Problem
- Our Approach
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Questions?

Research Questions

- Energy in our wheels (Joules of KE) at different speeds?
- Energy is only dependent on mass of wheel if we pick a desired lateral velocity
- $KE = Iw^2$
- $I_{Wheel} = ½ M (R^2_{inner}+R^2_{Outer})$

Research Questions

- Braking force of regenerative braking (how fast can we stop?)
- Need Physical testing, braking speed does not decrease regenerative efficiency (within reason, excessively long braking distances will have additional friction losses compared to faster stops)

Research Questions

- Efficiency of battery/ capacitor bank in charge/discharge from current input?
- Battery seems to be between 10-20% loss

Research Questions

- Motor Efficiency, how many joules can we get out if we put in X amount of electric joules
- 3k or 3.5k RPM on standard

Capacitor Bank Equations

$Q = CV^2/2$

1 Wh = 3600 J

Capacitance for one string of 6 capacitors in series

$1/[(1/350\ F)6] = 58.3\ F$

Capacitance for two strings of six capacitors in parallel

$58.3\ F + 58.3\ F = 116.7\ F$

Voltage for one string of 6 capacitors in series

$6(2.7\ V) = 16.2\ V$

$Q = [116.7\ F \times (16.2\ V)^2] \div 2 = 15{,}309\ J$

$(1\ Wh / 3600\ J)(15{,}309\ J) = 4.25\ Wh$

Wheel Speed Calculations

7.75” radius to tread of wheel

Circumference of wheel = 2πr

2 × π × 7.75 = 48.7”

Wheel speed to achieve 30MPH

Speed (MPH) × 1 Hr/60 min × 63360 in/mile ÷ circumference of wheel = RPM

30MPH × 1 Hr/60 min × 6360 in/mi ÷ 48.7 in/revolution = 65.3 RPM

Reduction ratio

Motor speed ÷ wheel speed

3500 RPM ÷ 65.3 RPM = 53.8:1

Torque delivered to the wheel

Motor torque × Reduction ratio

5Nm × 53.8 = 269 Nm

Motor Conections