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Mellivora:

Supercapacitor Power Supply Project

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Overview

- Team Introduction
- Project Overview
- System Requirements
- Block Diagram
- Individual Subsystems
- CDR Deliverables
- Gantt Chart
- Demonstrations
- Questions

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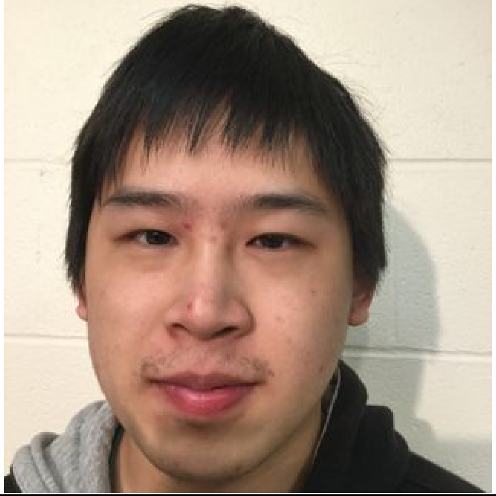
Team Introduction

Nathan Ball
EE

Derek Clougherty
EE

Lubin Jian
EE



Derek Wang
CSE

What is Mellivora?

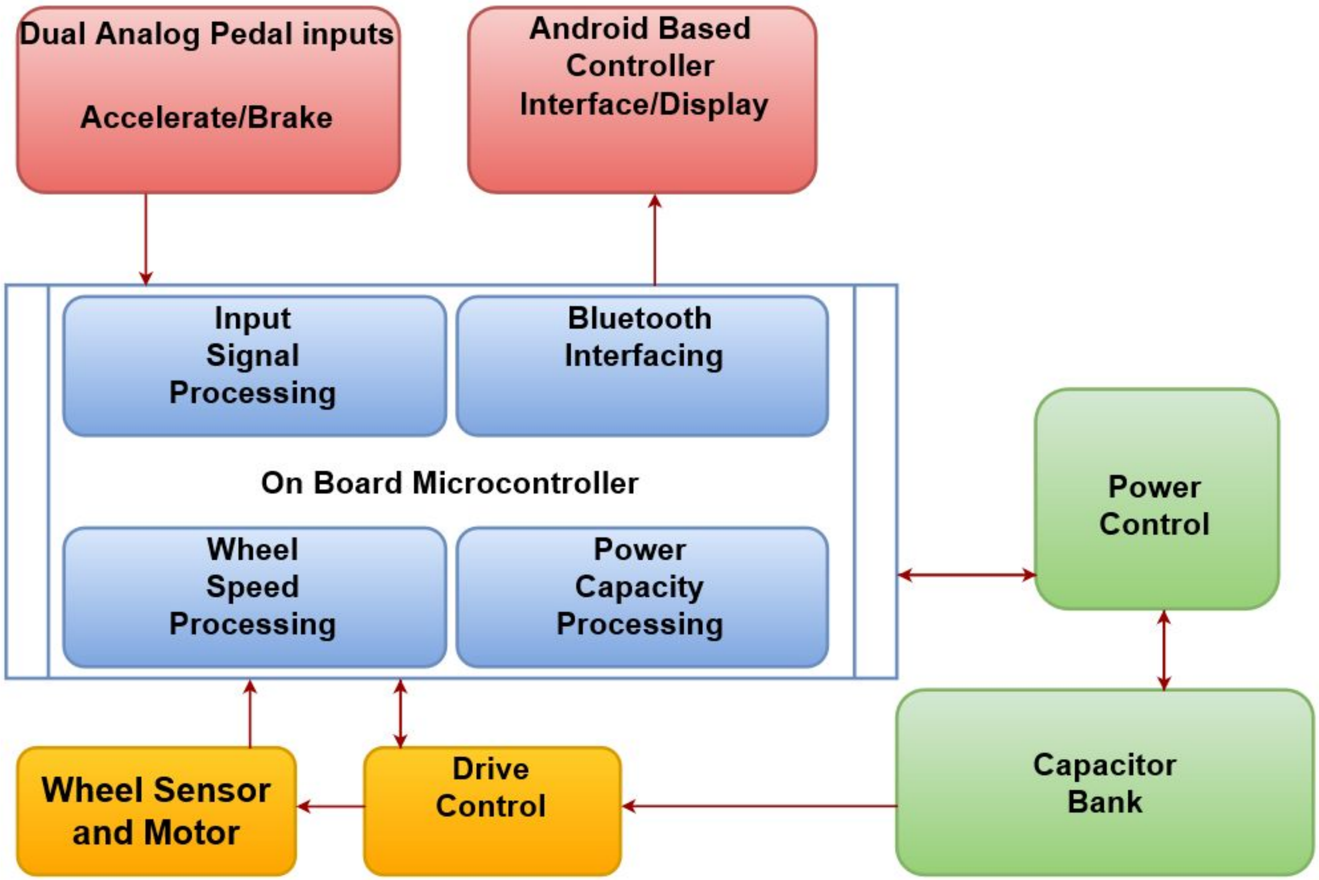
- Demonstrate the effectiveness of supercapacitors as a power supply
- Use supercapacitor power supply to drive a single motor load
- Recharging capabilities of supercapacitor
- Android App that displays RPM, Speed, and Capacitor Bank Charge Level

Final Product and Specification

- One wheel concept to show advantages of supercapacitor powerbank technology
  - Accelerated charging capabilities with supercapacitor power supply
  - Reduced drivetrain losses due to direct drive wheel hub motors
  - Power supply charge/discharge rate not a limiting factor for sizing requirements, no need to oversize power supply to meet maximum current demand.
- Requirements
  - Efficiency of system must surpass efficiency when powered from lithium battery bank (typical 86%)
  - Full stop from max speed (18MPH) within 7.25 revolutions*
  - Recharge rate must be higher than lithium battery bank

*NHTSA req of 19ft braking distance from 20MPH for passenger vehicles

Block Diagram



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Nathan Ball

Derek Clougherty

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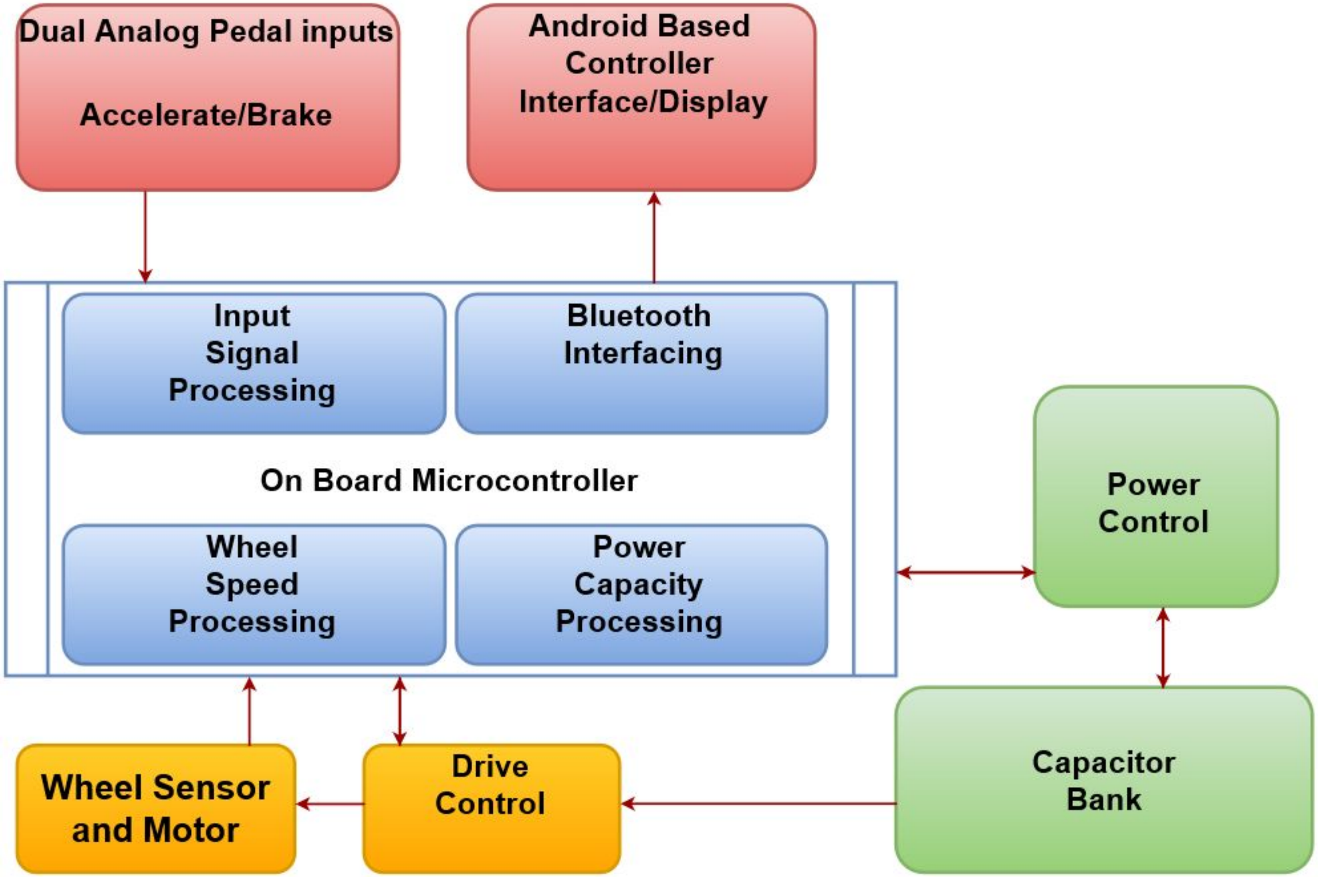
Central Control Module

- Derek Wang



What Is My Role?

The Central Control Module

- Run on a microprocessor

Main Tasks

- I/O processing
- Connecting all other systems together
- Bluetooth connection to Android App
- Flexibility to adapt to new tasks

Secondary Tasks

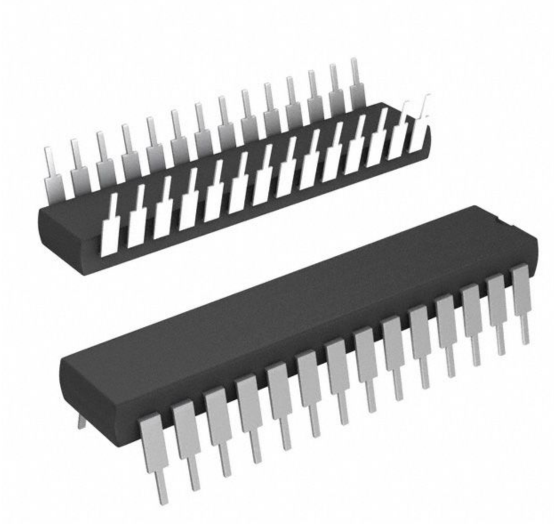
- Safety and error checking
- Recording run data

What Has Changed?

The Processor
- First: DE2i-150 Development Board
- Then: TI Sitara ARM Cortex A9 MPU
- Now: PIC16F886-I/SP (8bit, 14kb Flash)

The Simulator
- Simulates all systems in real time
- Responds to CCM commands

The Display (separate from simulator)
- Updates in real time



What Did I Promise? What Did I Deliver?

MDR Deliverable

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

Delivered

- CCM is capable of issuing orders to the simulator
- Simulator reads and reacts to input in real time
- Display can read record and display simulated data in real time

Software Points of Interest

- Around 500 Lines of Code in C
- Linux Distribution using Cygwin and gcc
- Makefile for easy compilation

Core: (73 lines)

- Uses nonblocking FIFO pipe to issue orders

Simulator: (386 lines)

- Calculates friction
- Easy to change variables
- 5 Modes simulated
- Updates an output file

Display: (78 lines)

- Can read output file as it is updated

CDR Deliverables

- Mount program onto microprocessor
- Communicate with Android over Bluetooth
- Interface with pedals, power control, and drive module

Extra:

- Integrate power control tasks into CCM which may require a more powerful processor
- Ensure battery to be compared with capacitor bank works with system

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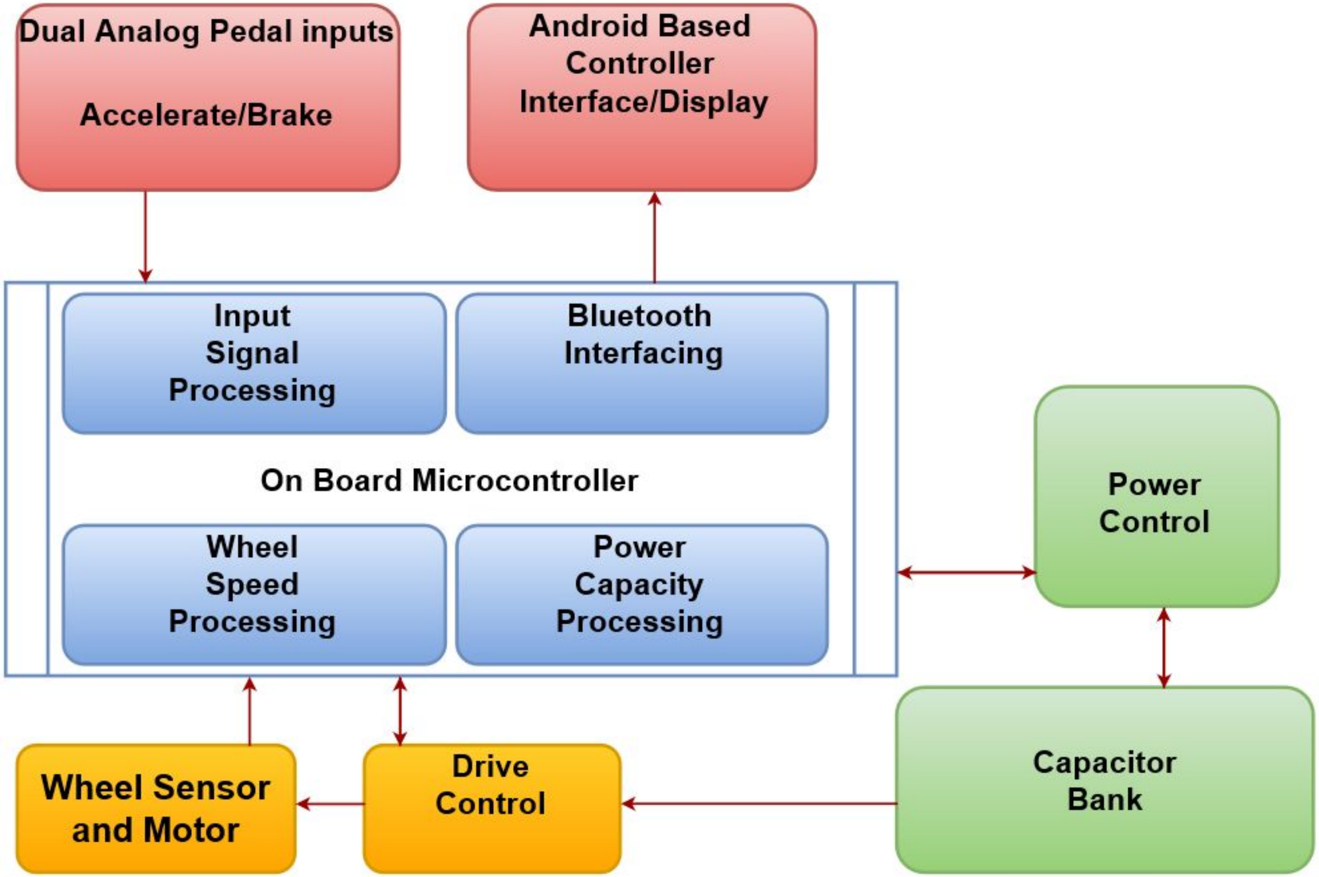
Controller Inputs and Display

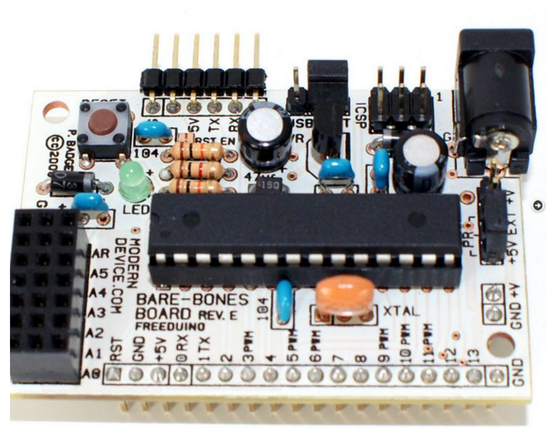
- Lubin Jian

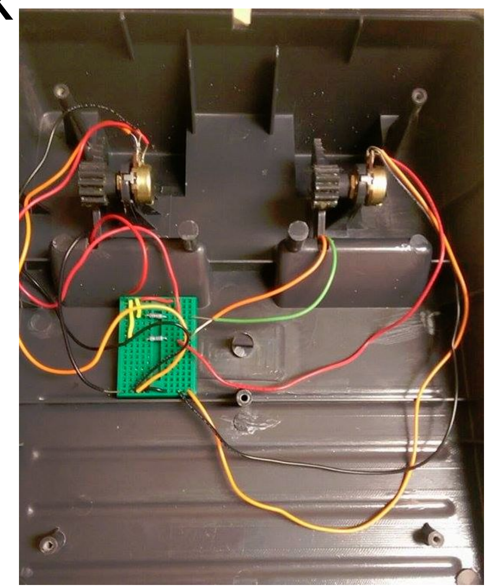


Pedals as Analog Inputs

Drive Pedals

- Originally had 2 potentiometers attached to a barebones Arduino (Shown Below)
- Removed Arduino
- Added a voltage divider 5V → 1V Max
- Mostly integration with CCM

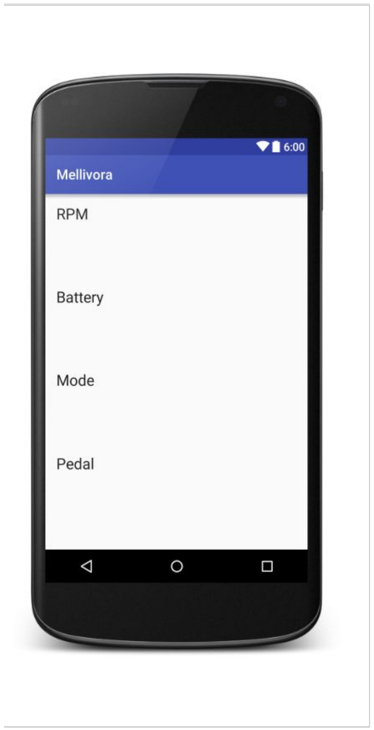




Android Application Display

Android User Interface

- To make thing easier, started by splitting the project into two parts:
  - 1. Design of user view (Shown Right)
  - 2. Processing of data



Creating a User Interface (UI)

- Android applications are coded in Java
- Must be written and designed in an environment
  - Android Studio
  - Eclipse
- For the UI, graphics and layouts are easier in Android Studio
  - Most things can be dragged and dropped
  - Has a convenient output image
  - Interfaces well with android devices (easy to get the program onto the actual phone)
  - However, a lot of cluster in the environment

Android Functionality

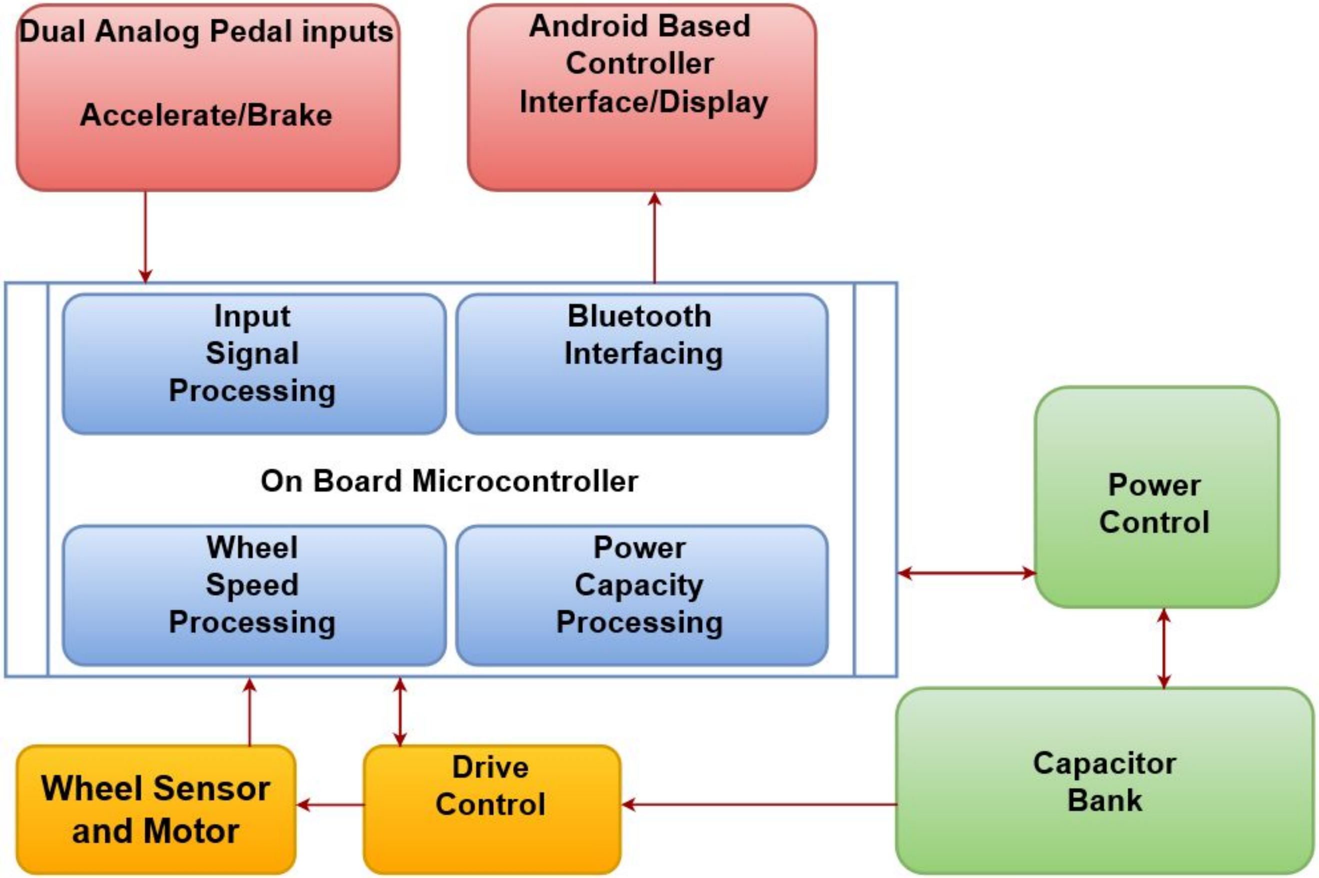
- As mentioned above, Android Studio is crowded with unnecessary features
  - A lot of formalities
  - All Packages are created when starting the project
- So, for the logistics, use Eclipse
  - Choose the packages that are needed
  - The program is simple without Android formalities
- Program
  - Takes a .txt file that simulates input from CCM
  - Separates the string and identifies each input

CDR Deliverables

- Finish Android graphics interface
- Integrate pedals with CCM
- Develop Bluetooth between CCM and Android app

Drive Module

- Nathan Ball

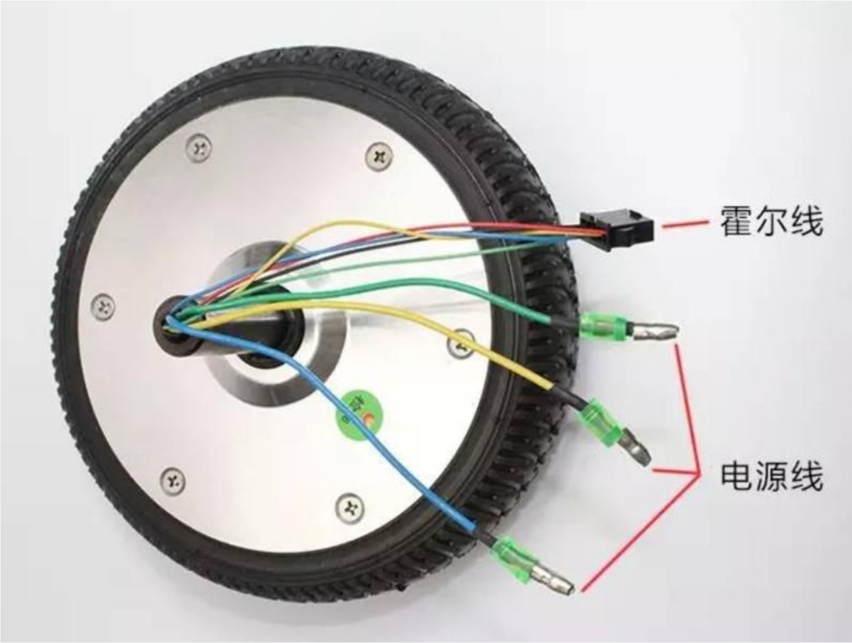


Motor Control

- Accept signals from the CCM to drive motor
- Three Modes: Acceleration, Coasting, Regenerative Braking
- Proposed MDR Deliverable:
  - Working drive controller without regenerative braking
  - Hall Sensor
- MDR Deliverable:
  - Working drive controller without regenerative braking
  - Simulated Hall Sensor input

Motor

- 36V 4A Brushless DC wheel hub motor
- 3 Phase
- Built in Hall Sensors
- Simulated motor load



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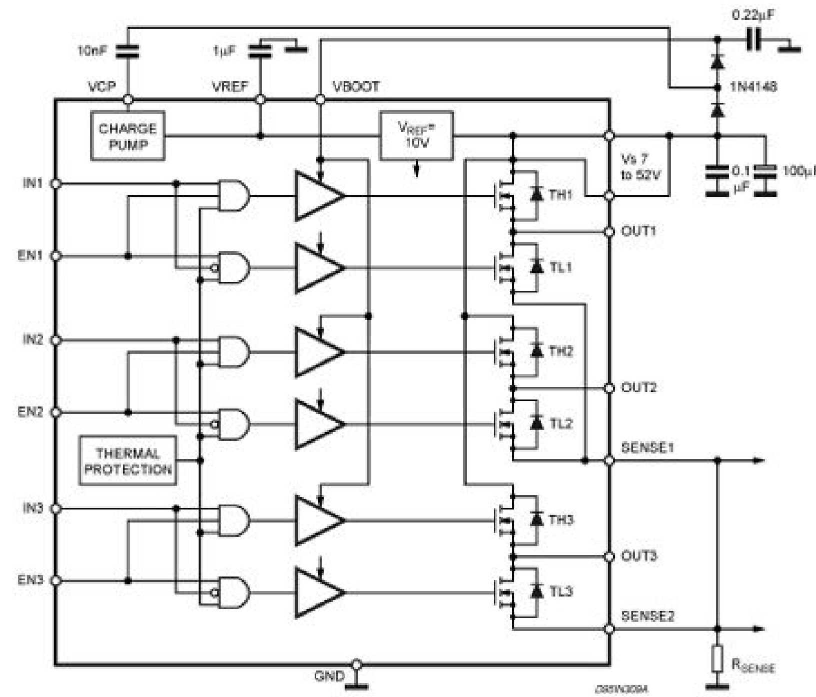
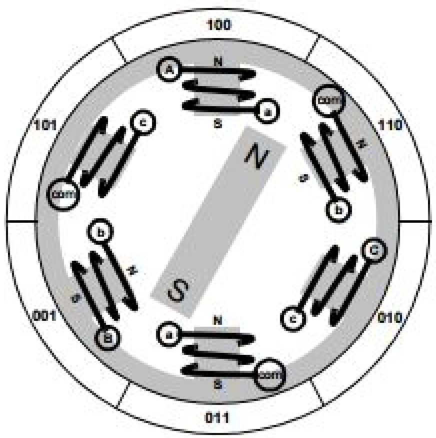
ST Microelectronics L6234

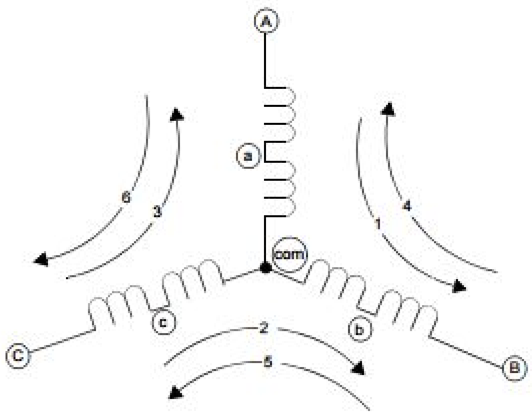
- Triple Half Bridge Driver
- 52 V Load and 5A Supply
- Switching frequency up to 150kHz
- Input & Enable signals

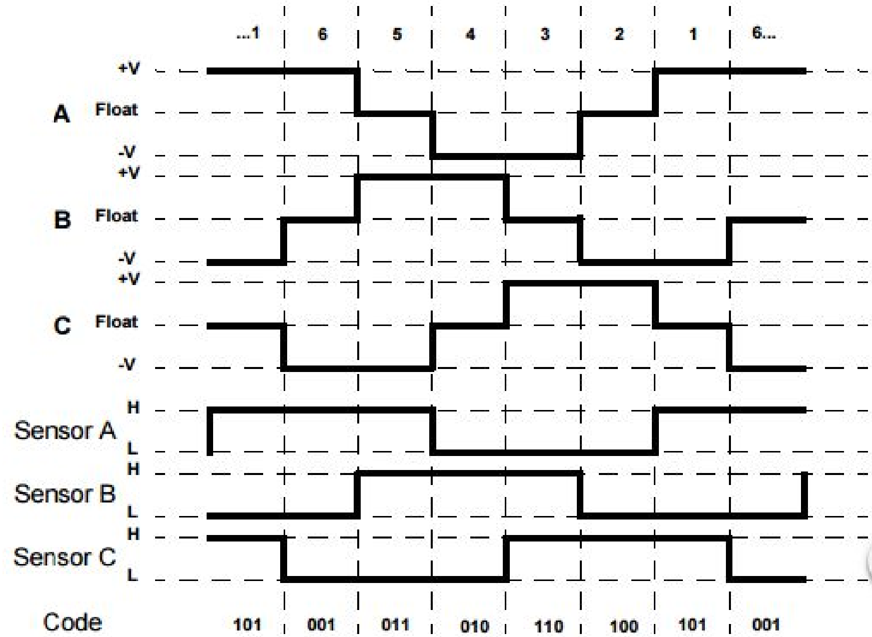


Arduino Code

- Input: Hall Sensor Data
- Output: Enable & Input Signals
- Translates hall sensor data into motor states





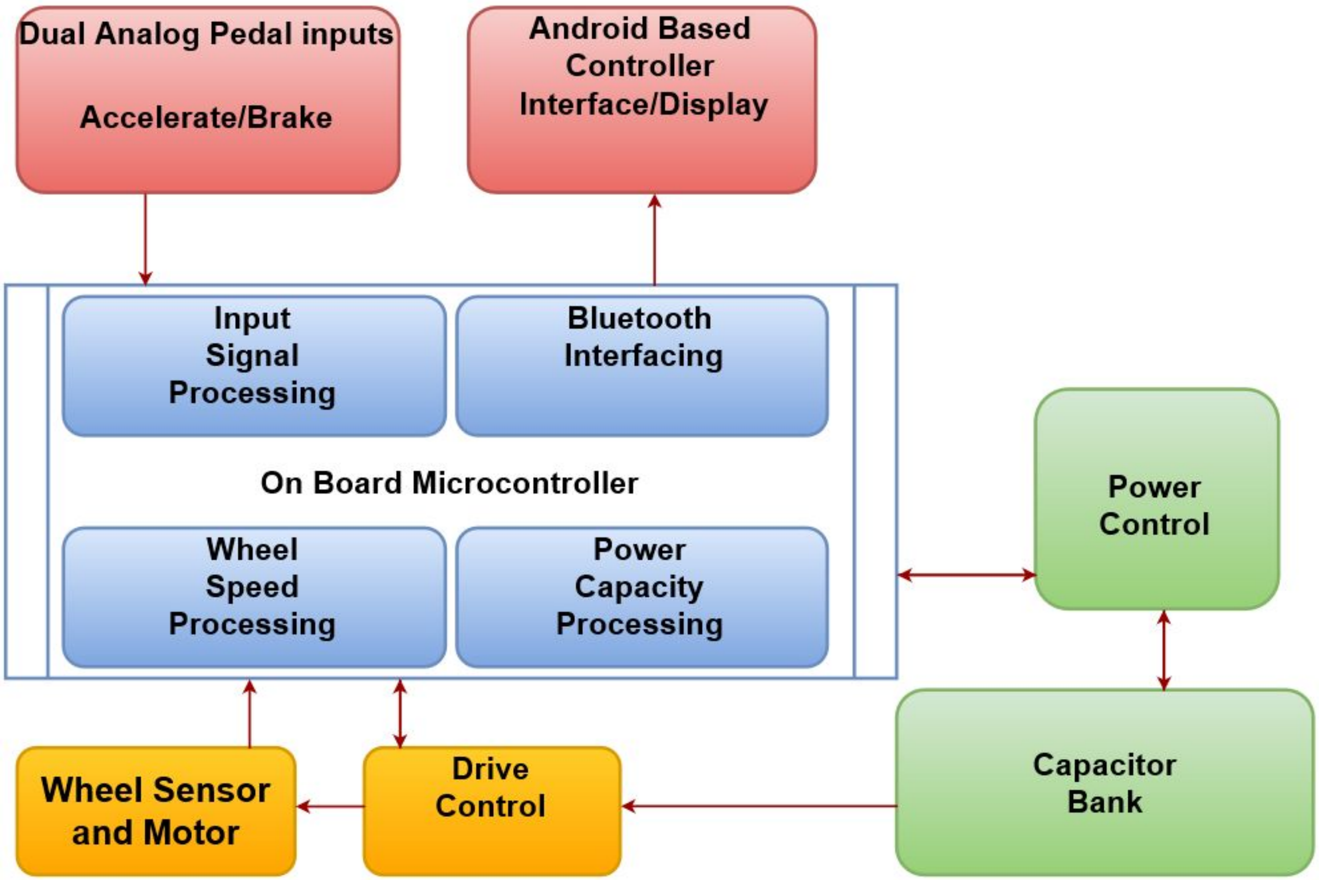


CDR Deliverables

- Deliverables
  - Motor Integration
  - Regenerative Braking
  - Integration with Power Supply

Power Supply

- Derek Clougherty



Power Supply and Charge Controller Requirements

- Support a minimum 10 minute runtime
- Monitors cells for 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

Capacitor Selection

CAMKAP 2.7V 3000F supercapacitors

ESR: .26mΩ

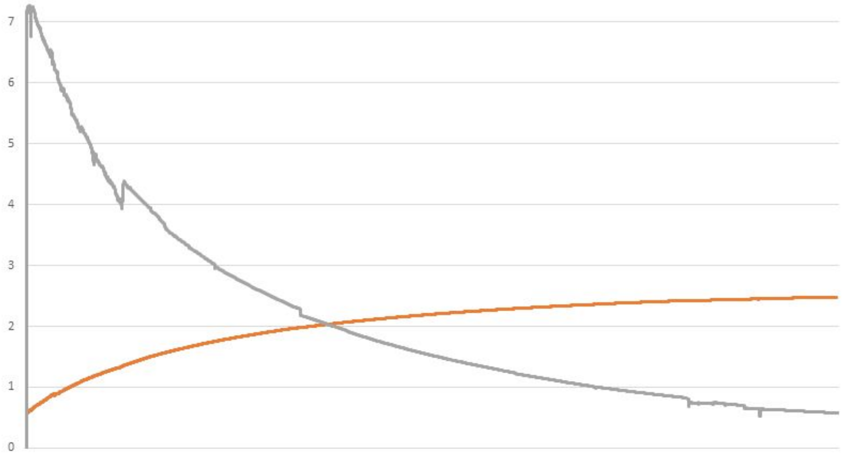
Max energy: 3WHr

Energy density: 12kW/kg

Expected lifetime: 1,000,000 cycles

<4X change in ESR

<30% change in capacitance



Power Bank

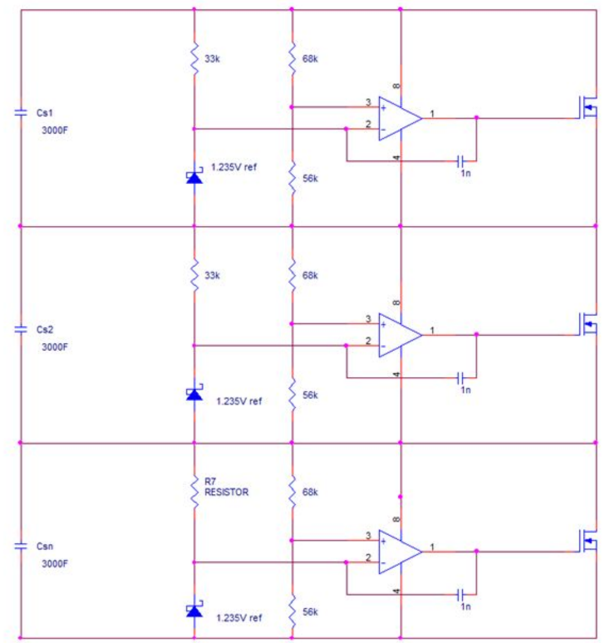
24 series connected 3000F supercapacitors

Total Capacitance: 125F

Max Energy: 75.6WHr

Useable Energy: 65.6 WHr (cutoff at 1V per cell)

15 minute runtime with 300W motor



Active load balancing prevents overcharging cells

Current shunted around fully charged cells

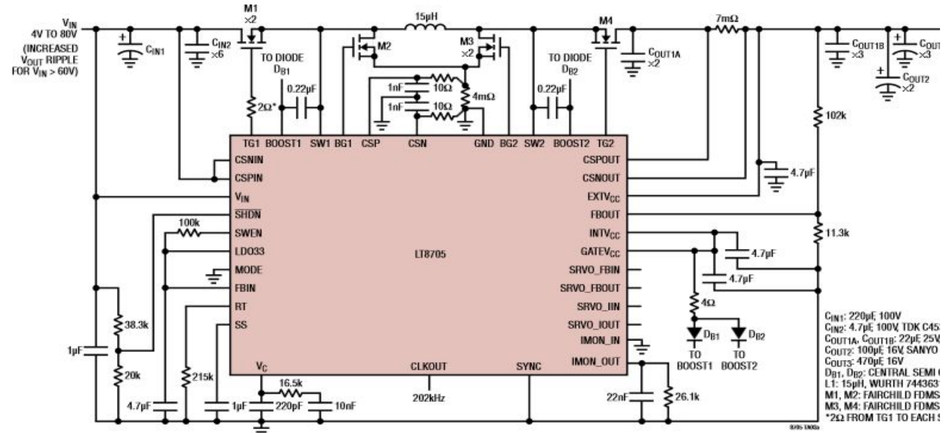
Approximately 1.2mA current draw while balancing circuit active (during charging and regenerative braking only)

DC/DC Converter

Linear Technology LT8750

Synchronous Buck-Boost DC/DC Controller

- Input voltage range: 2.8V to 80V
- Output voltage range: 1.3V to 80V
- Up to 98% efficiency
- Input/Output current limiting capability
- Low voltage cutoff
- Energy Consumption: 2.65mA to 4.2mA



Typical layout; varying input, fixed output

Motoring Converter Configuration

- 24V to 66V input
- 36V output
- 24V low voltage cutoff (1V per cell)
- 6A output limit (4A full load motor current)

Regenerative Braking Configuration

- 2.8V to 36V input
- 66V output
- Current limiting and low voltage cutoff not utilized to maximize regenerative braking capability

Proposed MDR Deliverables

Circuit layout designed and prototyped

- Charge balancer designed, parts ordered, PCB Gerber file created
- DC/DC converters designed, parts order compiled, alternate converter design to be tested during winter break

Demonstrate switching between converter modes

- Alternate design prototyping and testing dependant on parts that have not yet arrived, testing to occur during first half of winter break
- Design will be finalized, parts ordered, and PCB fabbed before the end of winter break

Demonstrate ability to power motor from supercapacitor

- Demonstration in progress

Proposed CDR Deliverables

Power Supply

- PCBs fabricated, assembled, and tested for charge balancer, DC/DC converter, and supercapacitor interconnects
- Power supply subsystems integrated and fully functional
- Be in the initial stages of integrating the power supply with the rest of the system

CDR Deliverables

- Fully functioning supercapacitor driven motor with regenerative braking implemented
- Central Control Program on microprocessor
- Working bluetooth connection between phone and CCM

Gantt Chart

	December	January	February	March	April
Derek C.	Buck boost converter	Balancing circuit	PCB Fab	Charging Circuit	
Derek W.		Microprocessor integration	Bluetooth Integration	Controller & Power Integration	Battery Comparison
Lubin		App on phone		Pedal Integration	
Nathan		Motor Integration	Regenerative Braking		
Integration			Supercapacitor & Motor Integration	Motor & Controller Integration	

Transition ot Demonstrations

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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