SDP21 - Let’s Ride CDR

Team #23
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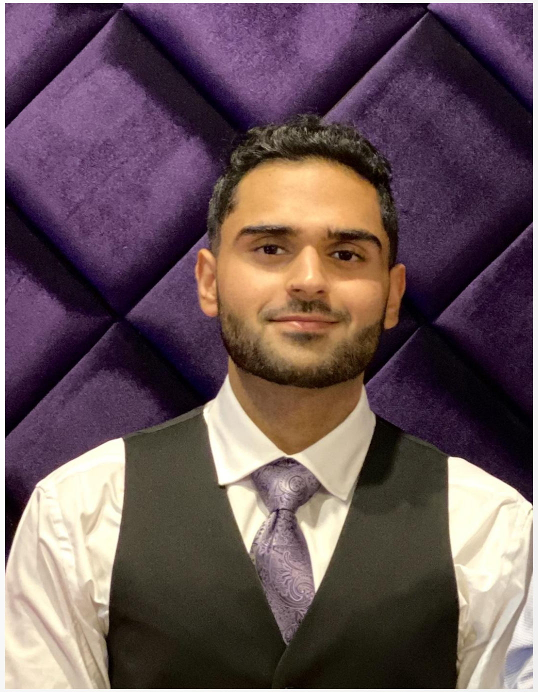
University of Massachusetts Amherst
BE REVOLUTIONARY™

Team #23

Advised by Professor Baird Soules

Ali Abdel-Maksoud EE
Altium Lead

Xavier Farrell EE
Team Coordinator



Syed Ali CompE
Team Secretary

Ben Ledoux CompE
Team Treasurer

Problem Statement

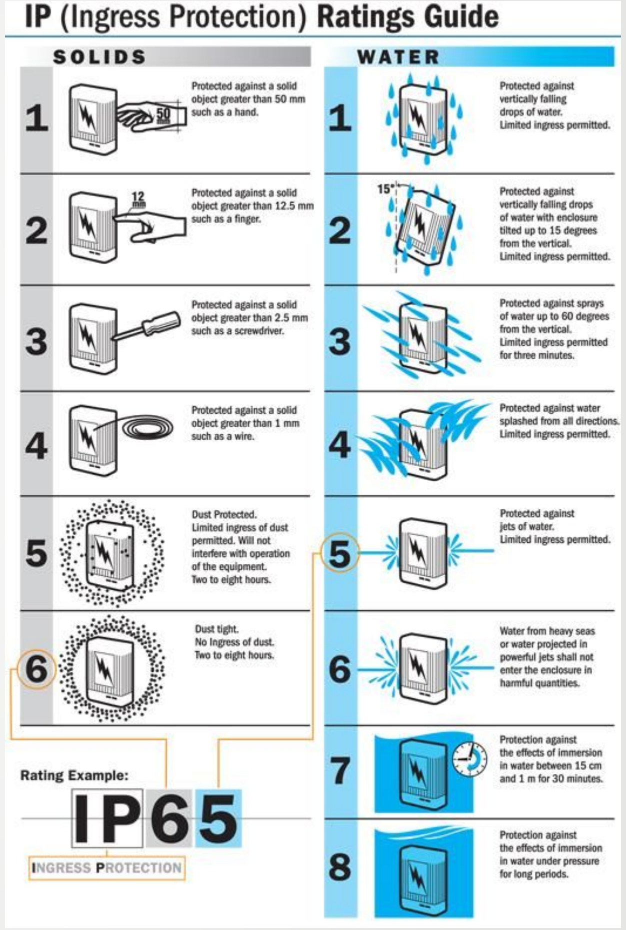
As Covid-19 continues to shutdown or limit gyms many workout enthusiasts are turning to working out at home. Peloton and other internet connected stationary bikes have seen huge success by allowing users to connect and workout with others virtually while tracking their workouts and progress. The problem with the currently available solutions is that they are expensive, difficult to move or transport, and cannot bring their experience to the outdoors. Our product Let's Ride solves these problems by providing a cheap system that can be easily installed on a user's own bike to communicate live ride data to an iOS app. Let's Ride allows users to workout with others virtually either inside on a stationary bike stand or outdoors on any terrain.

System Specifications: User Experience

- **Rider experience**
  - Passively receive real-time information on place via RGB light
  - Set up the physical system in <1 hour (one time installation on bike)
  - On bike system in water resistant enclosure that can be used in rain
  - Automatically connect via Bluetooth Low Energy >90% of the time
- **Application**
  - Store and track data in a user profile using Google Firebase Authentication and database
  - Opt into or create ride events matches based on skill level
  - Invite friends to created events or match with random players

System Specifications: Power, Sensor, Computation

- **Power System**
  - Generates usable electric power at speeds > 3.2 m/s (~7 mph)
  - Meet the above specification in moderately rainy/wet conditions
  - Power system > 8 hrs
- **Sensor/Computation System**
  - Track distance travelled to error bar of ± 0.6m
  - Track amplitude change to error bar of ± 0.5m
  - Relay measurements to mobile devices in real-time
- **Physical Elements**
  - Max weight < 2lbs
  - Does not impair the natural cycling motion of the user
  - Removable and water resistant (IP34)



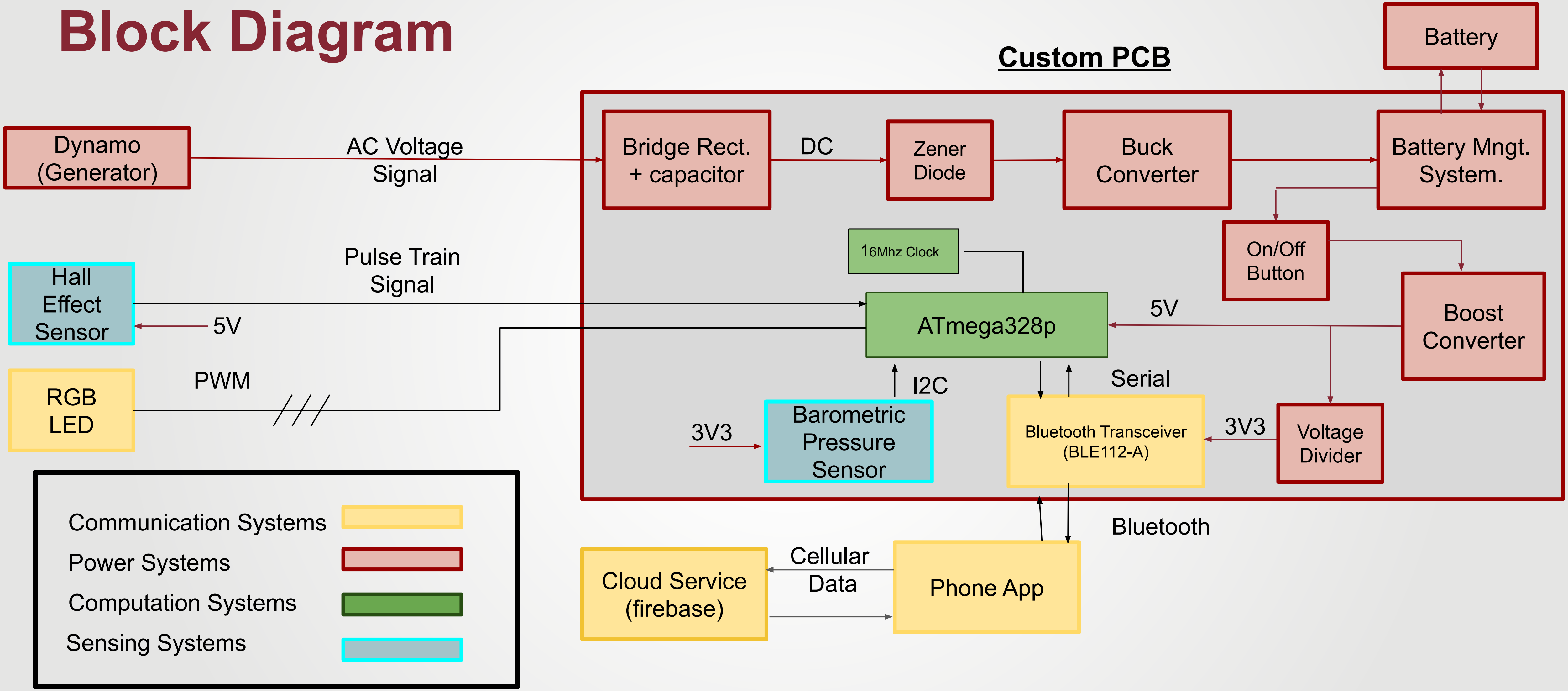
Normalized Unit of Measurement

- Required a way to measure "effort" comparatively
- Ranks by largest amount of ride points acquired
- Subjective solution to rewarding riders facing inclines.

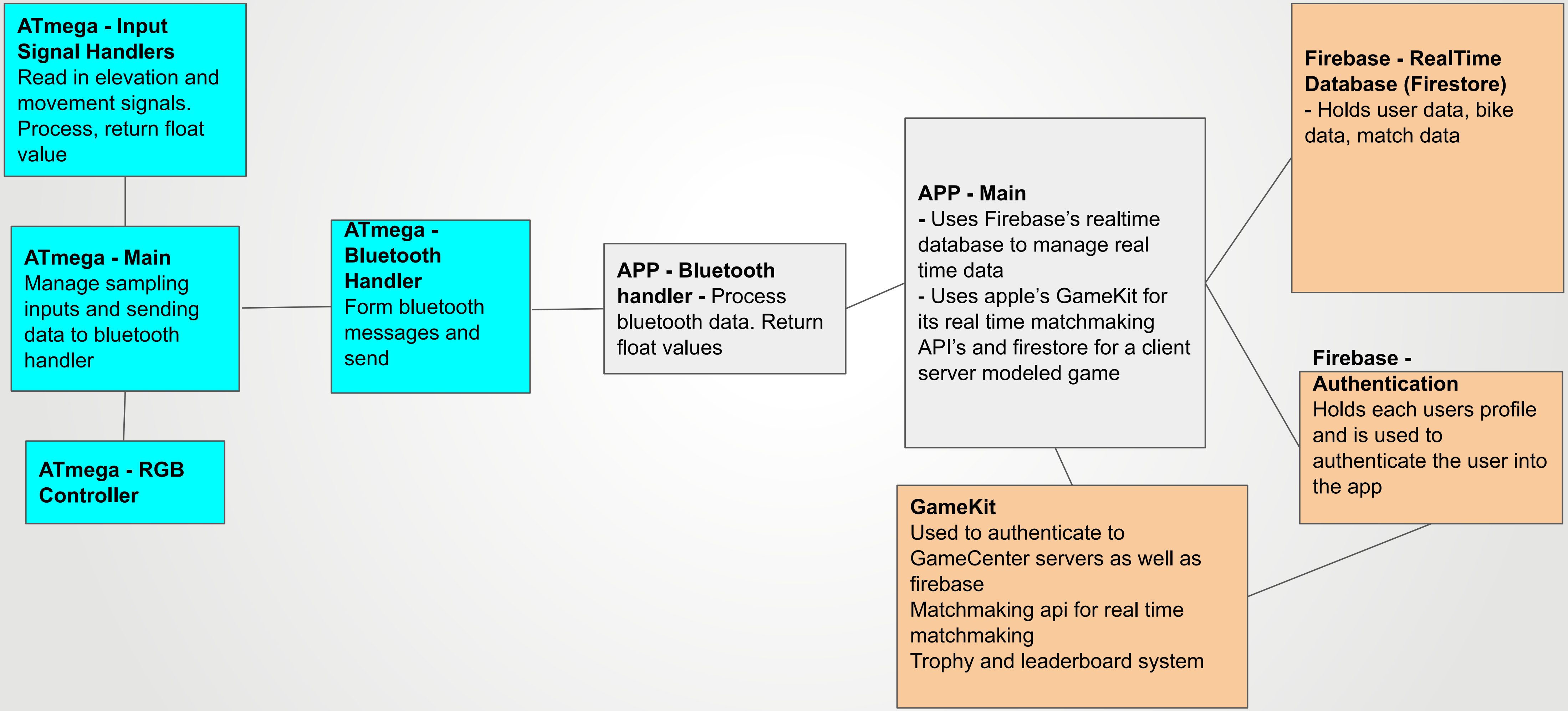
ΔD = change in distance, ΔA = change in altitude

$$Ride\ Point = \Delta D(m) * (1 + |\Delta A(m)|)^{\left(\frac{\Delta A}{|\Delta A|}\right)}$$

Block Diagram



Software Design



Current Prototype

- Microcontroller, sensors, power system on solderless breadboards mounted to back of bicycle
- Bike dynamo, hall effect sensor mounted to back wheel
- Status LED mounted to middle of handlebar
- Can be taken for a ride as intended, not yet water/weather proof

Current Prototype

iOS App

- start a game with a stranger or invite a friend through their GameCenter account, which can also send a text message invite to any imessage user
- Riders can currently choose 1 minute, 5 minute, 10 minute races. We can easily configure the race times by setting some configuration parameters
- App also displays a end of Ride summary of your race which includes the users score, the opponents score, Position placed, total distance and altitude traveled

Hardware and Software Used up to CDR

Power System

- 1 Tung Lin 4 pole Dynamo
- 1 Buck Converter (LM2596)
- 1 Chenbo Battery Charging Board (8205A)
- 1 Boost Converter (TPS63060)
- 1 Switch
- 1 Full Bridge Rectifier (KBP2005G)
- 1 Zener Diode 24V 5W (GA 5358B 1352)
- 1 Li-Ion Battery (EBL 18650)
- 1 Capacitor 50V 4700mF (1823)
- Assorted resistors to model system power demands

Sensor System

- 1 Hall effect sensor (US5881LUA)
- 1 Barometric pressure sensor (BMP 388)
- 6 Magnets (neodymium)

Hardware and Software Used up to CDR

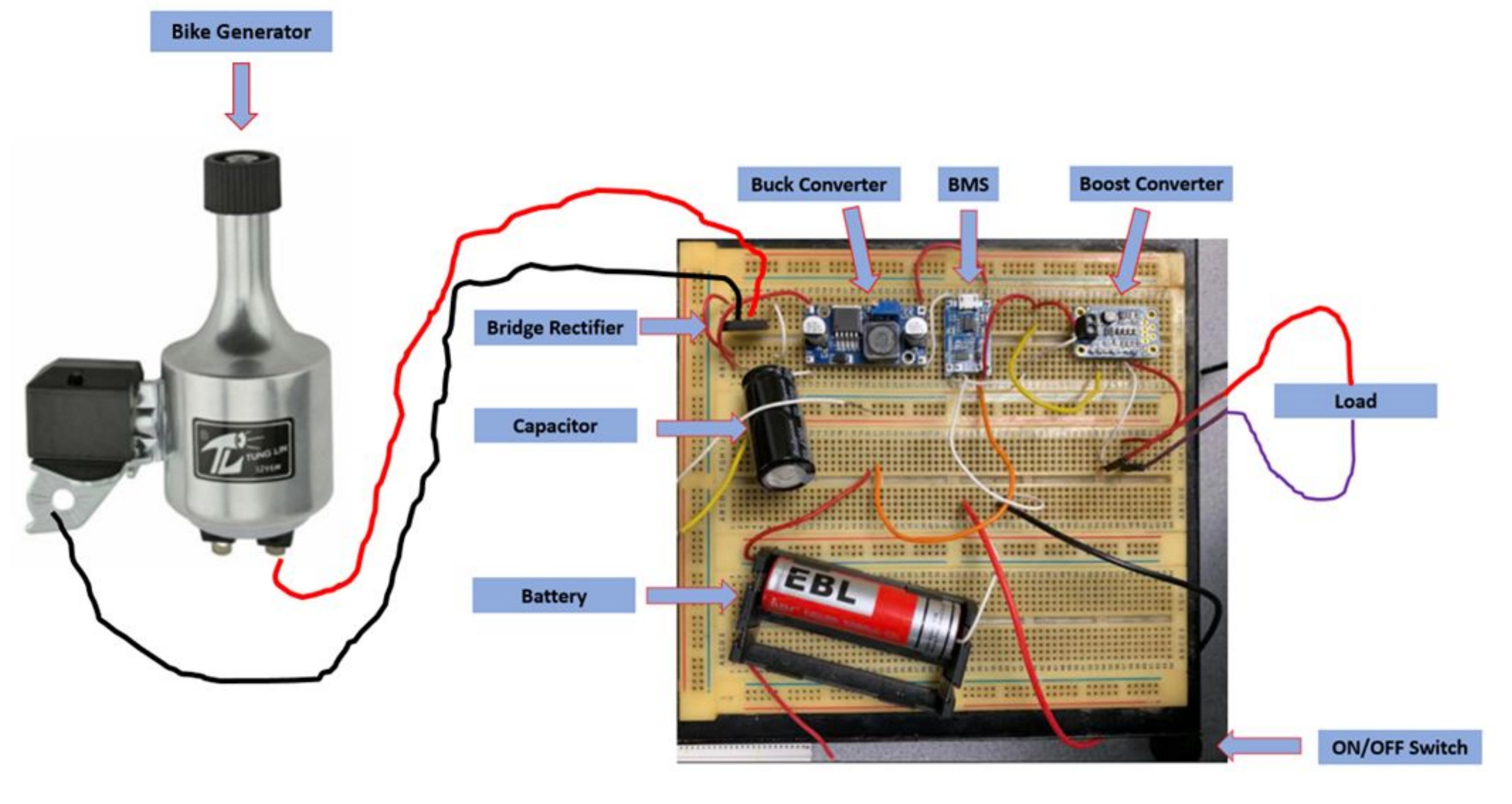
On Bike Microcontroller

- Hardware
  - ATmega328p Microcontroller
  - HC-08 Bluetooth Low Energy module
- Software
  - IDE: Microchip Studio
  - Language: C++

iOS App

- Backend
  - Google Firebase
  - Apple GameKit
- Development
  - IDE: XCode
  - Language: Swift (Apple's development language based on Objective C)

Power System Hardware



Demos

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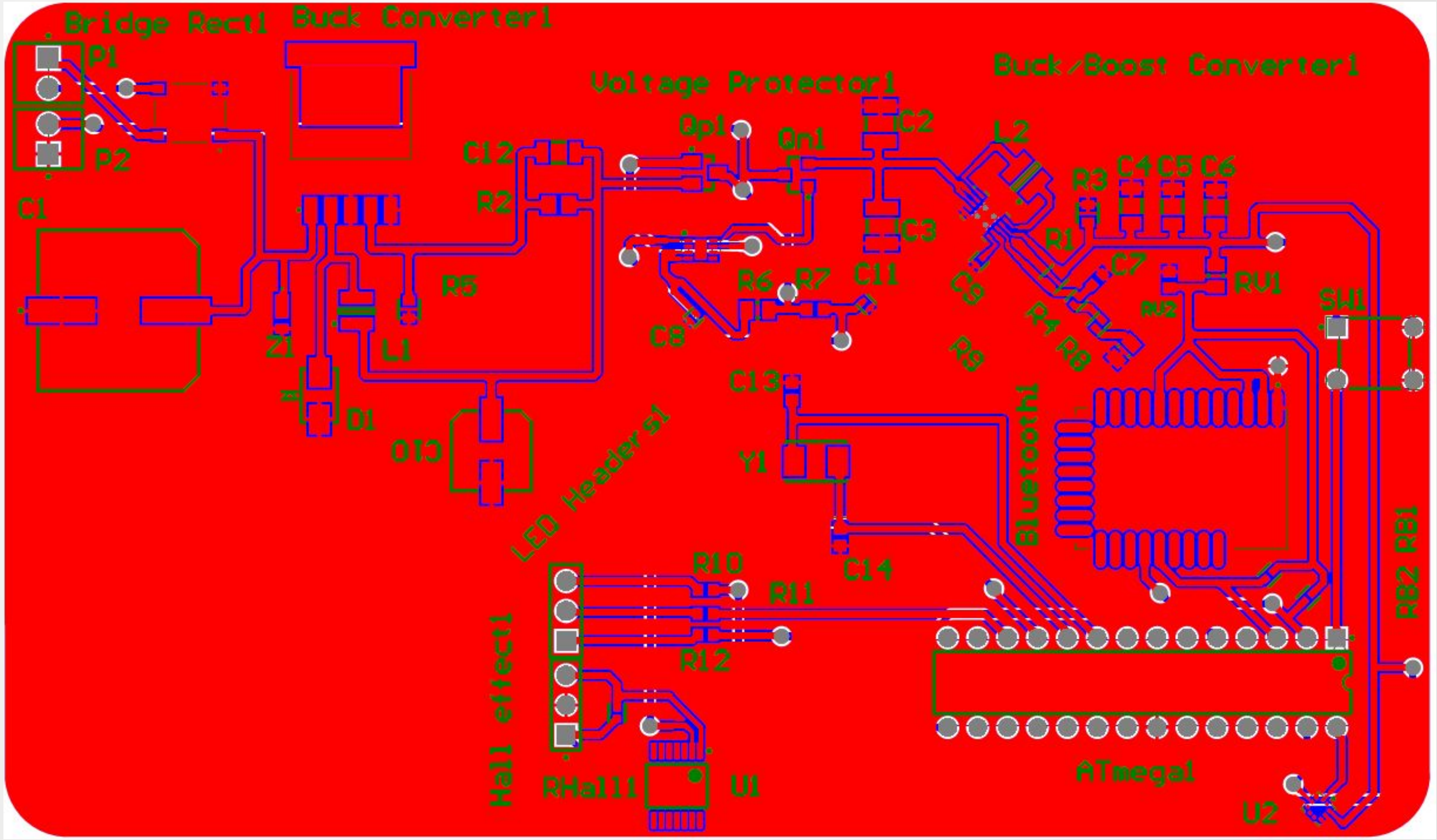
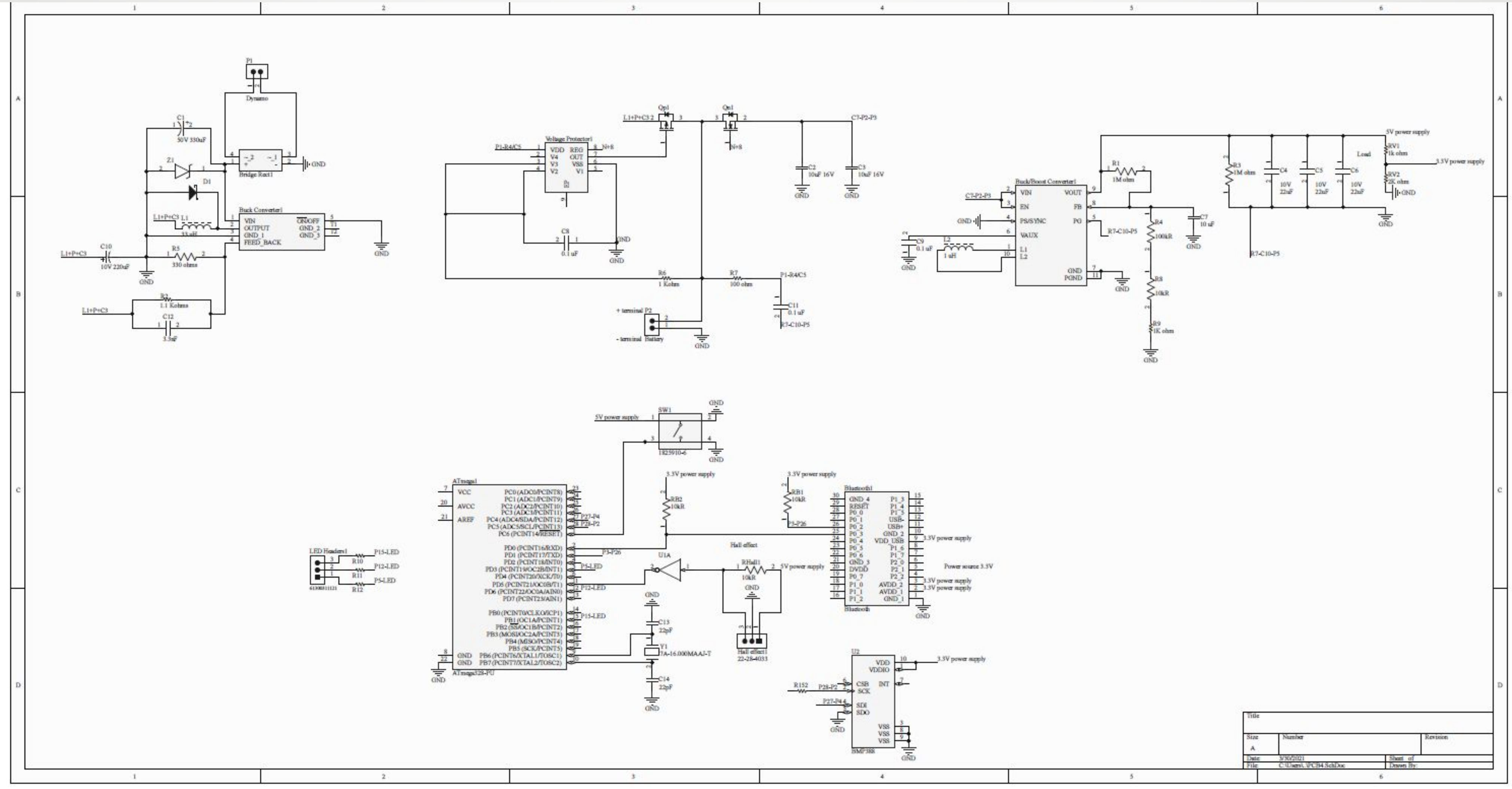
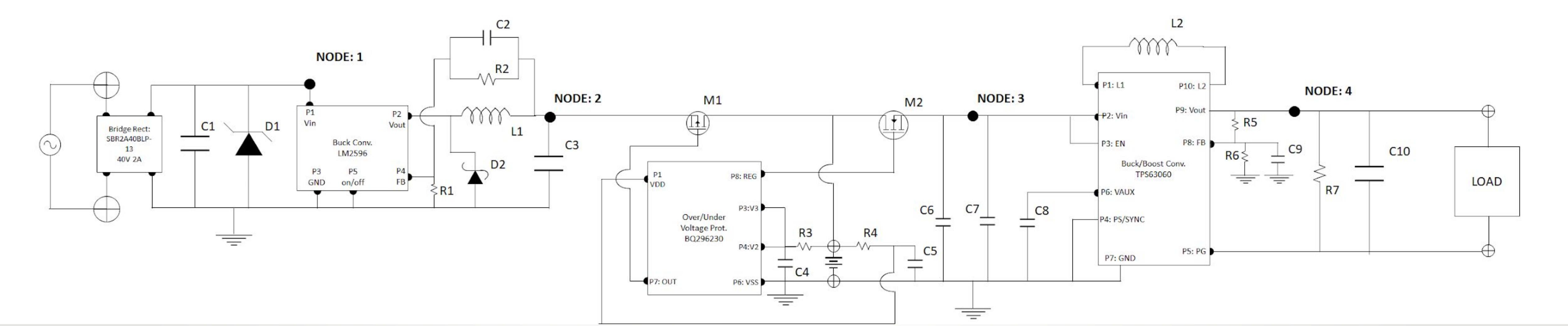
Board Layout



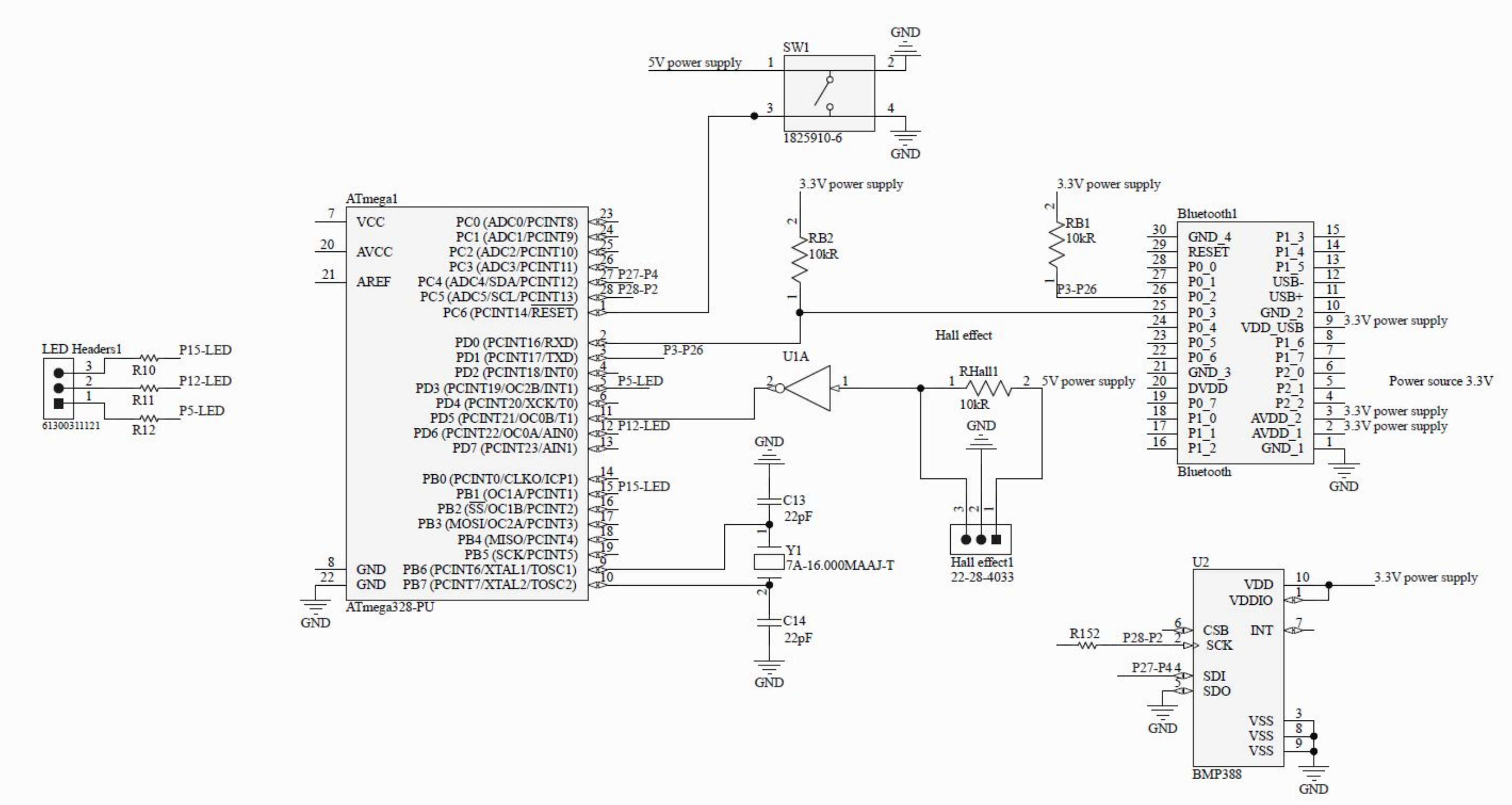
PCB Schematic



Power System PCB Design



Microcontroller PCB Design



CDR Deliverables - Xavier

Promised at MDR	**Delivered at CDR**
Combine both power system stages to produce stable 5V DC output from dynamo✓	The power system outputs 5.3V DC from battery and dynamo which is within the input voltage tolerance of the microcontroller
Complete power system PCB layout design✓	PCB layout completed and implemented in Altium by Altium Lead
Supply power to the entire system in operation ✓	Supplied power to other systems simultaneously under normal operating conditions

CDR Deliverables - Ben

Promised at MDR	**Delivered at CDR**
Send data from microcontroller to iOS app via Bluetooth Low Energy ✓	Microcontroller and iOS app can fully communicate back and forth via the Bluetooth module
Control RGB lights based on opponent data ✓	Status LED changes every second depending on user's score as compared to other riders
Transition from Arduino Uno to AVR ✓	Now using standalone ATmega328p microcontroller programmed with Atmel ICE
Transition from solderless breadboard to PCB ✓	Blank PCB in hand

CDR Deliverables - Syed

Promised at MDR:	Delivered for CDR:
• Inviting and joining games with friends ✓	- invite and joining games with friends through Apple's GameKit api's that they provide - Send invites to players they are already friends with or an invite as a text message link to the recipients imessage
• Display players stats along with leaderboard ✓	● end of ride shows a players stats page
• Ability to specify the type of game they're looking to play ✓	● Can specify the length of game they want to choose ● currently set at 1 min, 5 minute, 10 minute for testing (longer intervals can be added with minimal code change)
• Display live game details ✓	● Displays Users current score which is updated about every second, also shows opponent data (set to show the score of the user with the highest score) ● Displays a timer counting down till end of game

CDR Deliverables - Ali

Promised at MDR	**Delivered for CDR**
● Design of mounting devices for magnets and hall effect ✓	○ Was able to purchased spoke clips that were outfitted to hold magnets in place at correct orientation for the hall effect. ○ Currently using zip ties for hall effect mounting
● Custom PCB design ✓	○ First iteration is complete and ready to have parts soldered with revisions for a second already underway.
● Enclosure design ✓	○ Exterior enclosure is a waterproof cycling pouch and in process of ensuring a battery safe environment.

Testing plan and changes between now and FPR

iOS App:

- **Features**
  - Adding more achievements and trophies
  - Support for multiple friends (mostly already implemented but needs to be enabled in UI and tested further with some additional changes required)
  - Adding a game starting countdown timer which gets triggered once all players have hit ready to ride button.
- **Testing Plan**
  - Test rides with apps over cellular data - going through different levels of cellular reception and seeing how the app handles poor/intermittent connection.

Testing plan and changes between now and FPR

Microcontroller and Bluetooth:

- **Features**
  - Add error correction for messages sent between iOS app and microcontroller
- **Testing Plan**
  - Test connecting to the device many times in different locations (inside, outdoors)
  - Test connection over the course of rides - examine iOS app log files to check for missing or corrupt messages and check for disconnections

Testing plan and changes between now and FPR

Power System:

Features	Testing Plan
Portable	Size, weight, mountable/detachable
Safe	Physical, electrical, functional protections
Ride Variation Insensitive	Ride durations, ride speeds, weather conditions
Durable	Drop tests, water exposure
Reusable	Number of rides

Testing plan and changes between now and FPR

Sensor System Test Plan

1. Test the stationary capabilities of the magnet mounting system
   a. vary speeds
   b. take it on an actual ride and see if any of them get knocked out of place
2. Insuring consistent and real time data readout of the hall effect over many different durations of activity
   a. cycling characterization
3. Test the effectiveness of the BMP in inducing intended reward using the Ride points formula.

FPR Demo Plan

For live demo - 2 bikes in different locations on stationary bike stands riding with each other live

Will include video of a ride outside between 2 bikes

Project Expenditure

Prototyping

Item	Quantity	Item Price	Total Price
SC-HC-08 BLE	2	$6.50	$13.00
Schmitt Trigger 74HC04	1	$6.70	$6.70
Baromtric Sensor BMP388	3	$9.95	$29.85
Hall Effect Sensor US5881LUA	5	$2	$10
10 pcs Neodyium Magnets	5	$2.15	$10.75
Buck Boost Cnvtr.	2	$9.95	$19.90
Bike Dynamo	1	$33.75	$33.75
		Total	**$123.95**

PCB and Components

Item	Quantity	Item Price	Total Price
BLE 112A Surface Mount	3	$7.75	$23.25
ATmega328p surface mount	3	$1.90	$5.70
BMP 388 Surface Mount	3	$3.47	$10.41
74HC04 Surface Mount	3	$0.40	$1.20
Full Bridge Rectifier (RDBF310-13 smd)	5	0.6	3
Zener Diode 27V (MM5Z5V1T5G)	3	0.23	0.69
Zener Diode 5V (BZX84B10VLYFHT116)	10	0.37	3.7
Cycling pouch	1	$11	$11
Buck Converter (LM2596)	2	5.73	11.46
tp63060	2	2.34	4.68
Blank PCB	10	$2.00	$20.00
		Total	**$95.09**

Gantt Chart

Task	Feb				March	CDR				April		FPR
On-Bike Controller	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12
Control led to alert user of position			Ben									
Transition to AVR				Ben								
Design controller PCB portion						Ben, Ali						
Test and finalize mounting position								Ben				
iOS App												
Invite friends to races			Syed									
Display player stats and leaderboards					Syed							
Allow specific race details							Syed					
Display game details live											Syed, Ben	
Power System												
Analyze buck converter PCB schemetic				Xavier								
Altium Training		Xavier										
Design power system PCB in Altium							Xavier, Ali					
Integrate into first basic system						Xavier						
Real tests on bike ride								Xavier				
Final PCB design												Xavier
Sensor System												
Design sensor system PCB in Altium				Ali								
Test hall effect mounting design							Ali					
Final ride, IP, druability testing												Ali, Ben

Project Management

Team Responsibilities:

- **Budget Leader - Ben**
- **Team Secretary - Syed**
- **Team Coordinator - Xavier**
- **Altium Lead - Ali**

Technical Responsibilities:

- **Power System - Xavier**
- **Sensing System - Ali**
- **Cloud Infrastructure - Syed**
- **Embedded System - Ben**
- **iOS App - Syed/Ben**

QUESTIONS?

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Backup

University of Massachusetts Amherst

Custom PCB - Hardware Plan for FPR

Sensors

- Barometric pressure (BMP 388)

Microcontroller

- ATmega328p
- Bluetooth receiver (BLE112A)

Power Systems

- Buck Converter (LM2596)
- Buck Boost Converter (tp63060)
- AC to DC converter (RDBF310-13)
- Zener diode 27V 5W (BZX84B10VLYFHT116)
- Zener diode 5V 1W (MM5Z5V1T5G)

Power System Schedule to FPR

Week 1

- Test functionality of PCB
- Revise PCB Design and share with Altium Lead
- Secondary Testing

Week 2

- Design and create off site charger
- Implement slippage reduction scheme for rain

Week 3

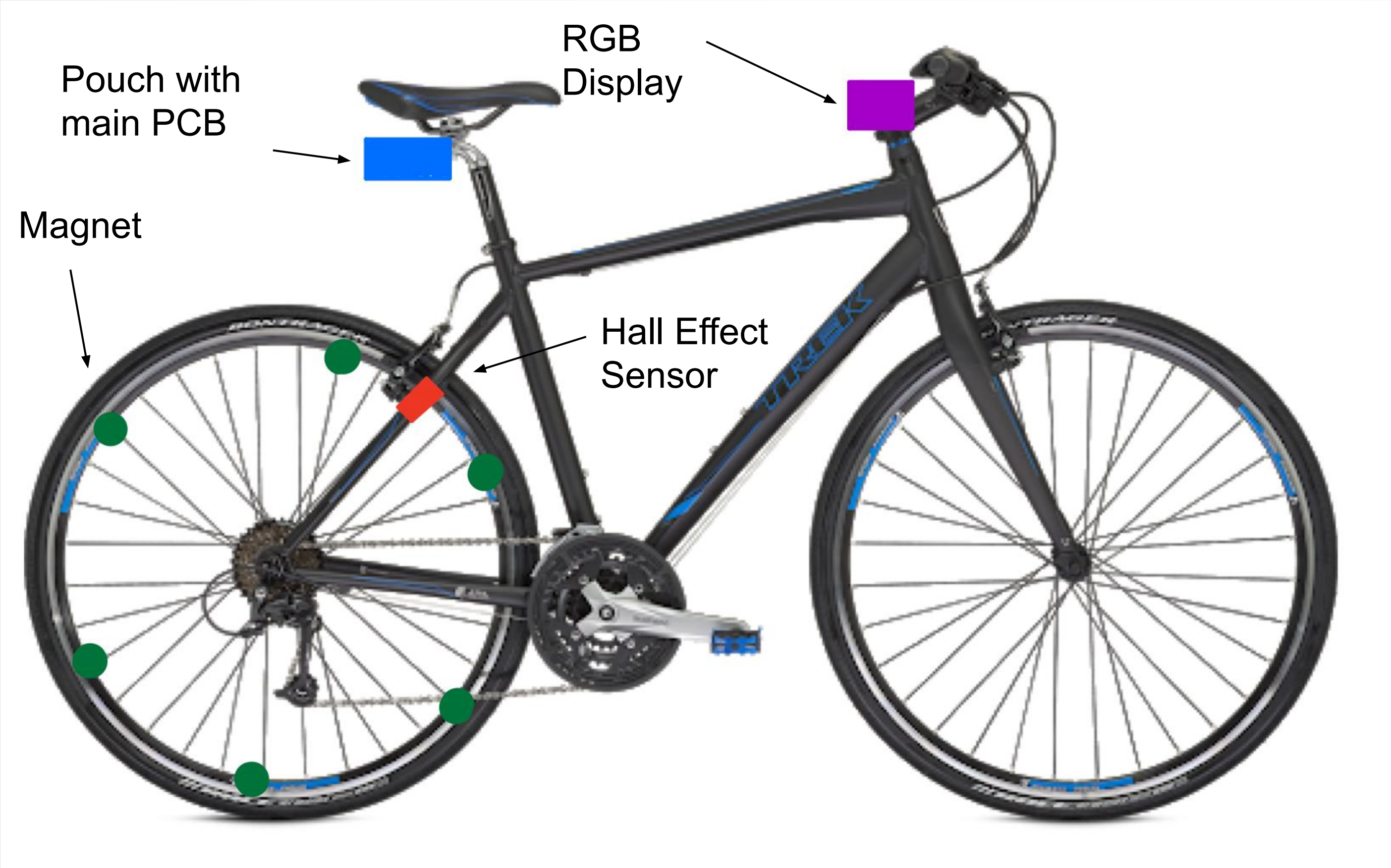
- Support final enclosure Design
- Estimate reusability

MDR Accomplishments - Power System (Xavier)

- **Proposed MDR Deliverables**
  - Produce a steady DC output signal from the voltage conditioning circuit using a signal generator: **Achieved**
  - Charge a battery from 0% to 100% using a voltage conditioning system and a signal generator: **Achieved**
  - Produce a Speed vs Output Power plot for Bike Dynamo: **Partially Achieved**

- **Accomplishments**
  - Total System Power Demands: ~300mW
    - Power System Produced ~1.7W @ 13mph (simulated)
  - System Current Demands: ~60mA
    - Power System Produced ~ 400mA @ 13mph (simulated)
  - System Voltage Demands: ~6V
    - Power System Produced ~ 24V Open Circuit @ 13mph (simulated)

Mounting Plan

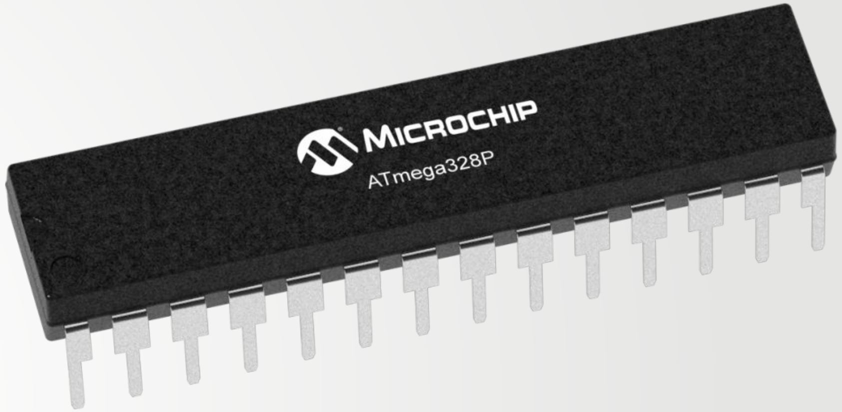


PCB in plastic enclosure which will be placed inside of cycling pouch

Wires to RGB display and hall effect sensor secured with velcro straps

On-Bike Microcontroller

- **ATmega328**
  - Low power
  - Computes distance travelled
  - Receives and transmits information via bluetooth
  - Encodes race placement and programs LEDs
- **HC-05 Bluetooth Module**
  - Low cost
  - Reliable
  - Serial Port Protocol Profile
  - Bluetooth V2.0+Enhanced Data Rate (3Mbps), 30m range
- **Schmitt Trigger**
  - Convert analog signal to digital



CDR Deliverables - Power System

- **Functional Deliverables**
  - Use dynamo, lithium-ion battery and two stage stabilization circuit to meet voltage and current demands of all other system components (5V and ~60-80mA). This should be achieved at speeds $\geq$ 6 mph (~9.5 km/h)
  - Complete schematic circuit diagram and parts list
- **PCB Design* Deliverables**
  - Implement rectifier, stabilization, buck, boost, short-circuit and overvoltage protection functions in PCB design.
  - Finalize component list to achieve specified functionalities and construct schematic in PCB designer software
  - Purchase and acquire PCB
- **Stretch Goal**
  - Mount dynamo on the bike and achieve the functional deliverables by rotating the bike pedal.

***Note: Team #23 plans to use 1 PCB. This slide only includes pcb design deliverables related to the Power System. All other references to a pcb design can be assumed to coexist on the same pcb.**

MDR Deliverables

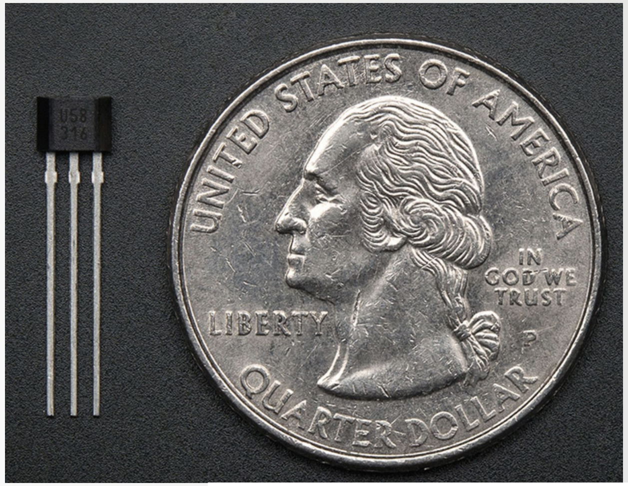
- **Power System**
  - Produce a Speed vs Output Power plot for Bike Dynamo
  - Produce a steady DC output signal from the voltage conditioning circuit using a signal generator
  - Charge a battery from 0% to 100% using a voltage conditioning system and a signal generator
- **Magnetic Sensor**
  - Capture output of sensor in response to magnetic excitation
  - Optimize resolution

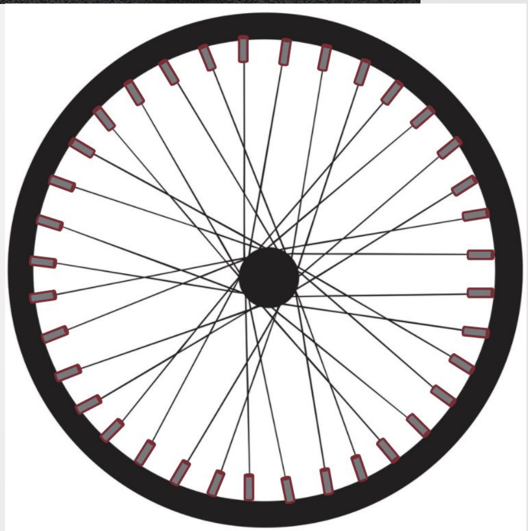
Power System

- **Layout**
  - Power Supply: Bike Dynamo (generator)
  - Voltage Conditioning Circuit
  - Rechargeable Battery
- **Bike Dynamo Specs**
  - Outputs an AC signal
  - Max Voltage Rating = 6V
  - Max Power Rating = 3W
- **Voltage Conditioning Circuit**
  - AC to DC converter
  - Buck-Booster Design
  - Voltage Regulator
- **Battery**
  - Natural waste heat management
  - Meet voltage demands for sensor, microcontroller, LED, and bluetooth system

Sensor System - Magnetic Sensor

- **Spokes**
  - All spokes evenly spaced
  - Magnetic material placed on spokes
- **Bike Fork**
  - Hall effect sensor
  - Sensed change will indicate certain passage of distance





5%	Presentation & Demo
15%	Documentation of the Current Prototype
45%	Integrated System
15%	Custom PCB
15%	FPR Plan
5%	Project Management Plan

Presentation & Demo	
5%	
• Presentation must include **Problem Statement & System Specifications**	
• Includes the list of CDR deliverables (as submitted in ECE 415)	
• Begins on time, has been practiced & rehearsed	
• Teamliness and professionalism	

Rubric
(4.0) The presentation and demo were excellent.
(3.0) The presentation and demo were good.
(2.0) The presentation and demo were fair.
(1.0) The presentation and demo were unsatisfactory.

Documentation of the Current Prototype
15%
• Describes the **current prototype**
• Includes diagrams & lists for hardware & software
• Includes any other relevant documentation

Rubric
(4.0) Documentation of the current prototype is excellent (clear and complete).
(3.0) Documentation of the current prototype is good (mostly complete, but some details are missing or unclear).
(2.0) Documentation of the current prototype is fair (missing or unclear on significant portions).
(1.0) Documentation of the current prototype is unsatisfactory.

Integrated System
45%
• Demonstration of the integrated system
• Meets the milestones set by the CDR deliverables
• Discusses which system specifications are currently satisfied by the current prototype and which are yet to be met

Rubric
(4.0) A demonstration of a fully functioning, integrated system (team is on schedule to FPR).
(3.0) A demonstration of a mostly functioning, integrated system (team is slightly behind schedule to FPR).
(2.0) A demonstration of a partly functioning, integrated system (team is significantly behind schedule to FPR).
(1.0) The demonstration was unsatisfactory (the evaluators have major concerns about the team's progress towards FPR).

Custom PCB
15%
• Populated or blank PCB in hand
• Schematic and board layout are shown and explained

Rubric
(4.0) The custom PCB (fabricated) is in the possession of the team.
(3.0) The custom PCB was ordered, but has not yet arrived.
(2.0) The custom PCB has not yet been ordered.
(1.0) The custom PCB design progress is not satisfactory.

FPR Plan

15%

- Describes the **planned FPR version of the system.** Highlight changes between current and FPR versions
- Plan for testing the project for compliance to system specifications
- Plan for hardening the prototype
- Plan for FPR demonstration

Rubric
(4.0) Plan for FPR is excellent (clear and complete).
(3.0) Plan for FPR is good (mostly complete, but some details are missing or unclear).
(2.0) Plan for FPR is fair (missing or unclear on significant portions).
(1.0) Plan for FPR is unsatisfactory.

Project Management Plan
5%
• Gantt chart from CDR to FPR
• Expenditures (current & projected)
• State team member responsibilities from CDR to FPR

Rubric
(4.0) Project management plan is excellent (clear and complete).
(3.0) Project management plan is good (mostly complete, but some details are missing or unclear).
(2.0) Project management plan is fair (missing or unclear on significant portions).
(1.0) Project management plan is unsatisfactory.

Updated Design