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Smart Bike: Automatically Shifting Bicycle with Other Embedded Features

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Outline

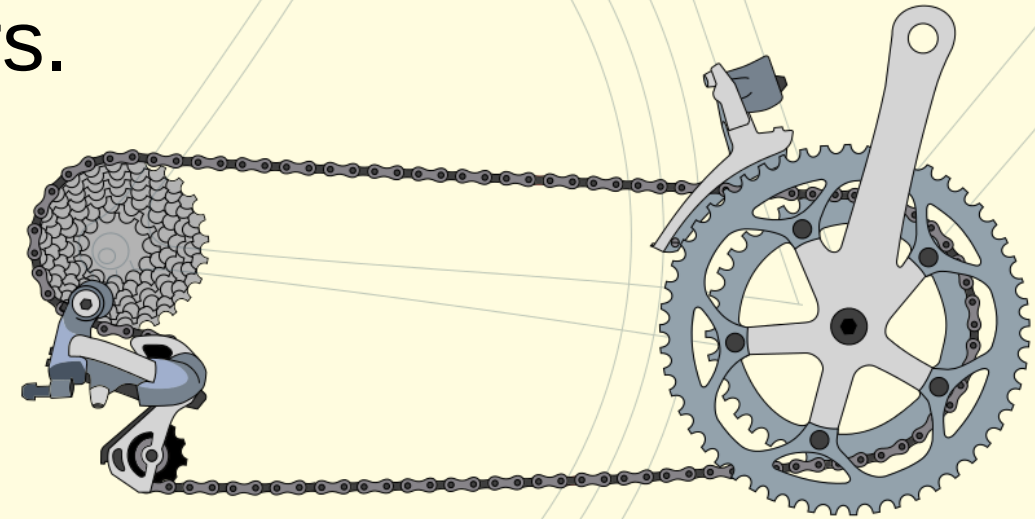
- Background
- Project Goal
- Constraints
- Components
- Design
- Results

Background

- Single-Speed vs. Multispeed Bicycles
  - Single-speed bicycles offer excellent reliability, but they are not well-suited to differences in altitude nor custom user preferences.
  - Multi-speed bicycles allow the user to adjust the bike's gear ratio to suit their needs.

Background

- How do multi-speed bikes work?
  - Multi-speed bikes use derailleurs which moves the bike chain across the various gears.



Project Goal

- Automate the derailleur shifting process so cyclists can better enjoy their ride.
  - Bicycle should maintain a user-defined cadence (pedaling rpm).
- Create a manual electronic shifting mechanism for experienced riders.
- Create a self-powered unit
- Display ride statistics to the cyclist to keep them informed of speed, cadence, current gear ratio and to display warning messages.

Constraints

- Time
- Money
- Safety
- Mechanical constraints
  - Servo brackets
  - Electronic to Mechanical Motion
  - Component Placement
- Electrical Constraints
  - Power Consumption/Generation
  - Servo Torque
  - MCU Resource Management

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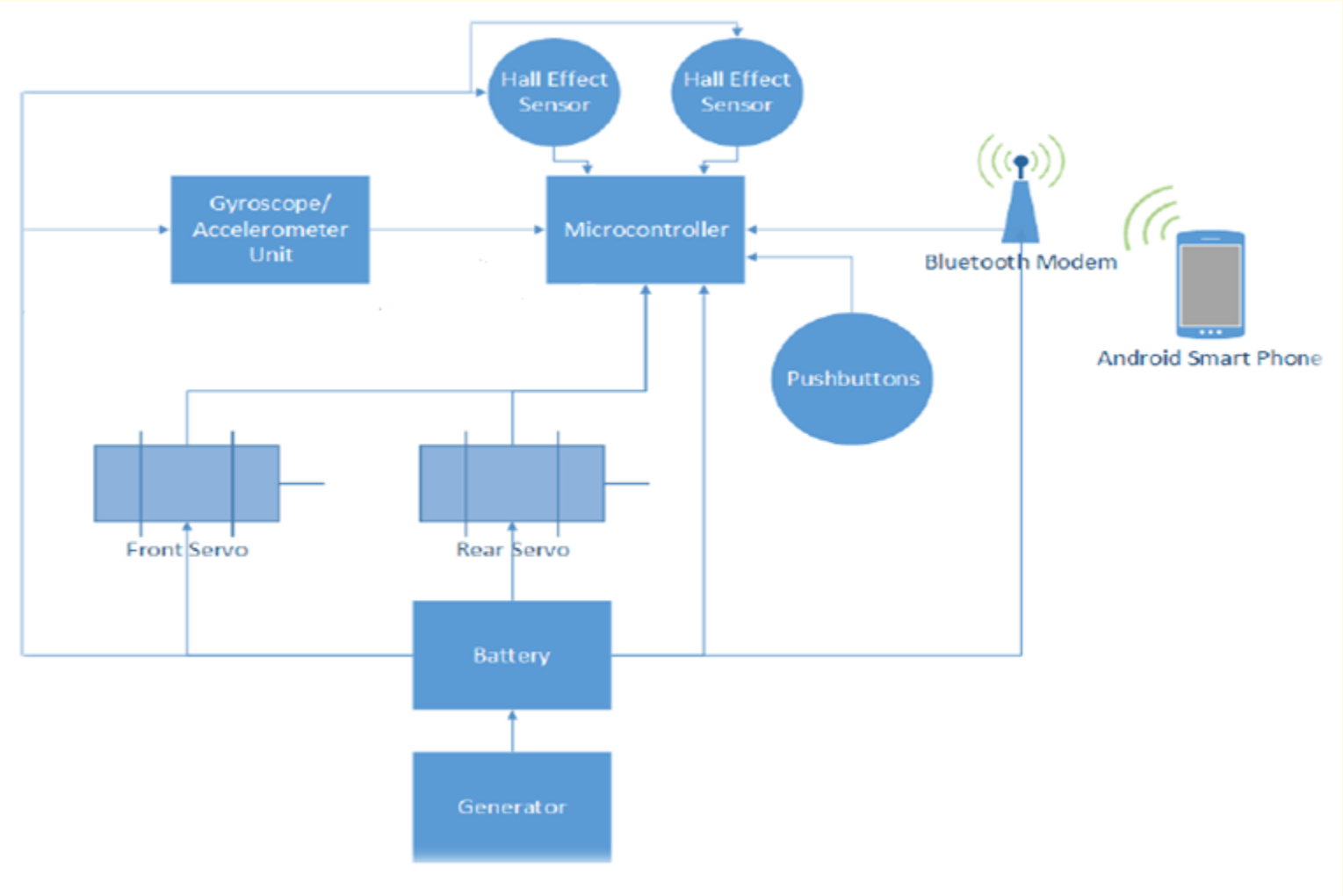
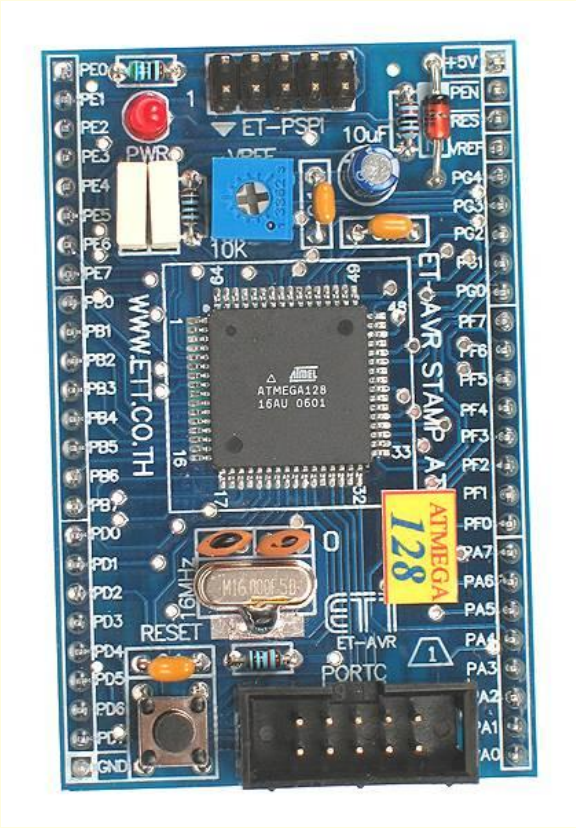
Components



Components

- Microcontroller
  - ATMega128
    - Futurlec ET-AVR Stamp
    - 53 Programmable I/O lines
    - 128Kb program memory
    - 4Kb EEPROM
    - Two 16-bit Timer/Counters
    - TWI (I^2C), UART



Components

- Inertial measurement unit
  - Invensense MPU-6050
    - 6-axis measurement
      - 3-axis Gyroscope
      - 3-axis Accelerometer
    - Thermometer
    - Digital Motion Processor
      - Performs complex mathematical operations on raw data
    - Communicates over I^2C

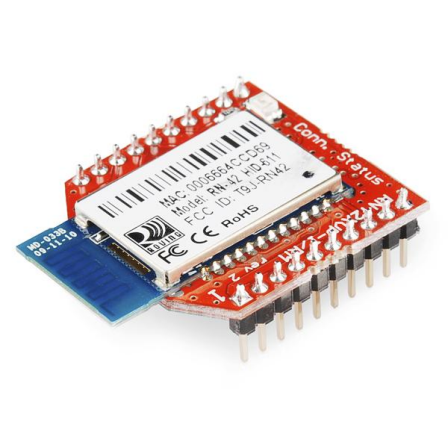
Components

- Servos
  - Sunkee Tower Pro MG995
    - Metal Geared
    - 15 kg-cm Stall Torque @ 6V
    - 0.13 sec/60º @6V with no load
    - Used for rear derailleur
  - SMAKN MG996R
    - Metal Geared
    - 15 kg-cm Stall Torque @ 6V
    - 0.14 sec/60º @6V with no load
    - Used for front derailleur

Components

- Servo Controller
  - Pololu Micro Maestro
    - 6-channel Servo Controller
    - Allows us to control up to 6 servos over one serial bus (UART)
      - This allows us to reserve the ATMega128's16-bit timer/counters for other purposes.
      - We can easily move the servos without worrying about PWM merely by specifying a desired angle.

Components



- Bluetooth Module
  - Microchip RN42-XV
    - Supports up to Bluetooth 2.1
    - Low power consumption
    - PCB antenna
    - Two modes of operation: Bluetooth Module or Command Mode
      - Bluetooth mode allows us to send data over UART without worrying about Bluetooth protocol commands.

Components

- Hall-Effect Sensors
  - OPTEK OH090U
    - Digital Hall-effect sensor
      - Produces a digital output (as opposed to analog) in the presence of a magnetic field
        - Signal from sensor remains a logic 1 until a magnet passes by. Then the signal goes low until the magnet leaves its vicinity.

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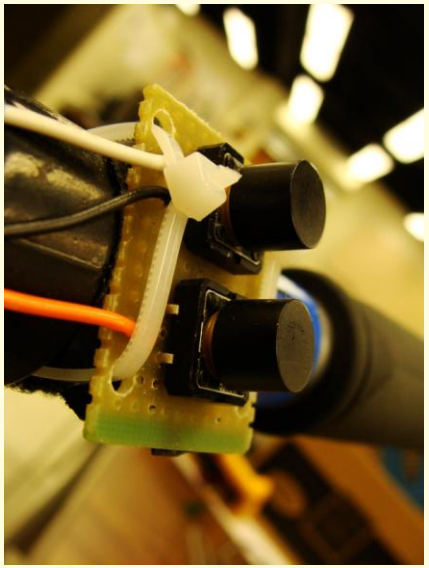
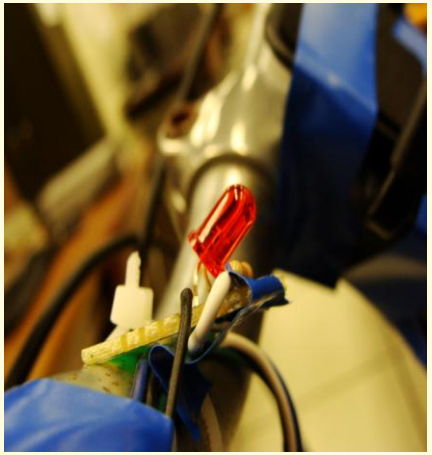
Components

- Push Button
  - Two sets of two pushbuttons located on the handlebars.
  - Utilizing button combinations, the perform 7 actions with just 4 buttons.
- LED
  - Used as feedback for the rider
  - Used to indicate mode
    - On = Automatic
    - Off = Manual





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Components

- Android Application
  - Connects to the system over Bluetooth.
  - Displays ride statistics to the cyclist
    - Cadence
    - Speed
    - Temperature
    - Current Gear Ratio
    - Warning Messages

Components

- Bottle Dynamo / Generator
  - Generates 12V 6W of power
  - Generally used to power head and tail lights for bicycles, the power coming out is AC
  - Voltage is bridge-rectified and converted to DC
  - Used to charge the battery below.

- Universal Non-Spillable Lead-Acid battery (UB645)
  - Provides 6V for adequate operation
  - Supplied 4.5 Ah of charge
  - Used to power the entire electrical system.
  - On/Off switch used to control power to system

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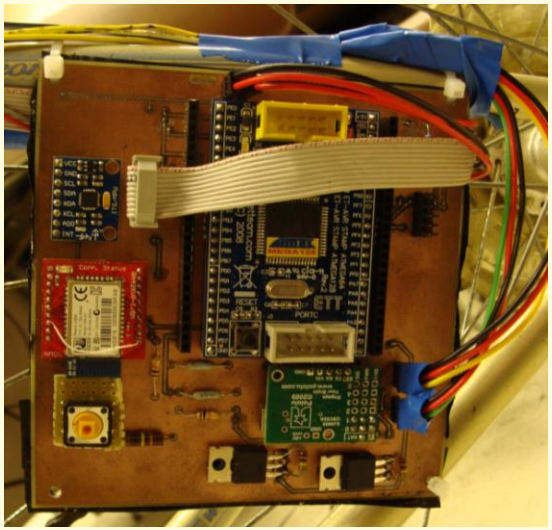
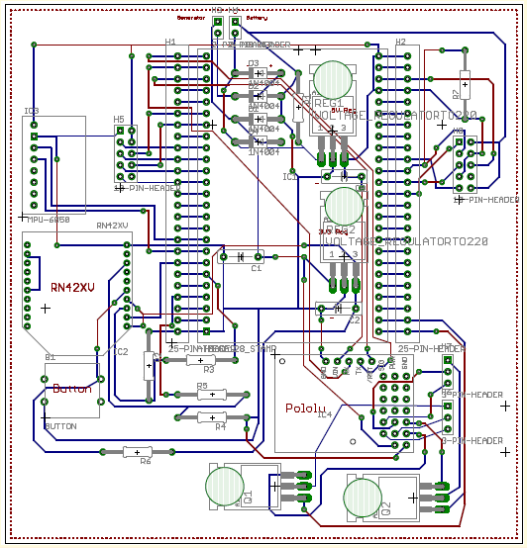
PCB

- Printed Circuit Board
  - •Designed using CadSoft EAGLE
  - • Provides a compact, portable alternative to a breadboard.
  - • Male and Female headers allow access to outside components





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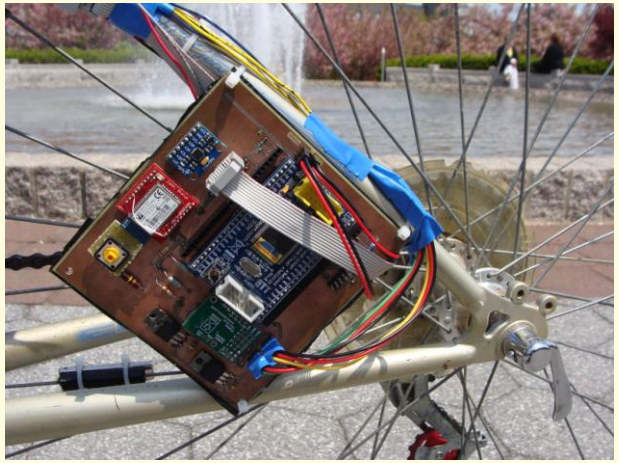
Final Design

- Component Placement
  - PCB
  - Hall-effect sensors & magnets
  - Servos
  - Buttons & LED
  - Generator
  - Battery & power switch
  - Android smartphone
- Wiring
  - Taped to secure lose wires
  - Held tight to frame with cable ties
  - Minimized with short wires and ribbon cables



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User Control

- User Controlled Inputs
  - Manual Mode
    - Shift Up/Down in Rear/Front
    - Hill Incoming mode
    - Switch to Automatic
    - Shutdown
  - Automatic Mode
    - Switch to Manual
    - Hill Incoming mode
    - Shutdown

Results

- The bicycle works as intended, allowing for complete manual electronic shifting as well as full automatic shifting based on speed.
- Shifting is as easy and quick as a button press.
- Shifting is smooth and efficient.
- Android app keeps tally of ride statistics

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Results

- Electronic shifting is still somewhat error prone
  - Less holding force.
  - Need to disengage servos for protection and power consumption
- Failed Shifts
  - Occasionally it fails to shift into proper gear
    - Occurs mostly on the front gear set.
- Rider error in manual mode
  - Cross chaining
  - Abrupt changes in cadence