High Level Design Document

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SmartCycle

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1. Introduction

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2. Problem Statement and Proposed Solution

Stationary exercise bicycles are one of the greatest modern luxuries of our time. The user gets some healthy and productive cardiovascular exercise rather easily, and, in smarter systems, can view several personal health and mobility statistics while remaining in the comfort of their own home. However, with current technology, these two benefits come as a package deal, and some people would rather enjoy the info presented by stationary bicycles while enjoying the great outdoors. Smart watches can provide an outdoor user these benefits, but they also tend to be rather expensive and require an LTE connection to track the user’s location and speed. Speaking of expensive, stationary exercise bicycles are usually a non-worthwhile investment for those of low/average income: high-quality exercise bikes such as Peloton and SoulCycle range in price from $1,500 to $2,500, and average/lower quality bikes are less likely to provide as much useful data [1,2]. Finally, not everyone has room for a stationary exercise bike in their house as they can take up quite a bit of space.

Our project, the SmartCycle, seeks to resolve all of these issues: it would provide the user with heart rate, calorie, distance, and velocity data while enjoying the benefits of biking outside, and it would provide a cheaper and more easily storable alternative to a stationary bicycle. Essentially, this device would serve as a modification to an existing outdoor bicycle, saving even more money for those who want to own both because of the different benefits. Using a central board, a collection of sensors, and an LCD screen, this system should be able to convert mechanical movement into useful electrical signals. It would also use bluetooth capabilities to connect to an application on the user’s smartphone, providing easy data storage and a more user-friendly interface. Overall, this system would effectively serve any cyclist, casual or otherwise, who wishes to get the most out of their commute and/or cardio-exercise routine.

3. System Requirements

3.1. General Requirements
- 3.1.1. The system shall integrate with a general use bicycle without interfering with normal function
- 3.1.2. The system shall not introduce any additional hazards to the cyclist
- 3.1.3. The installation shall require no advanced tools
- 3.1.4. The installation time shall be under 20 minutes
- 3.1.5. The weight of the system shall not exceed 2.25kg so as to not unbalance the bicycle's weight distribution
- 3.1.6. The board shall be encased in a 3D printed box that connects to the LCD panel on the handlebars
- 3.1.7. The wiring and sensors shall be encased in insulated material

3.2. Hardware Requirements
- 3.2.1. The system shall measure data on bike speed to within 0.2 mph
- 3.2.2. The system shall measure data on pedal speed to within 0.1 rps
- 3.2.3. The system shall measure data on bike incline to within 5 degrees
- 3.2.4. The system shall measure heart rate of the user to within 10 bpm
- 3.2.5. The system shall contain an LCD display
- 3.2.6. The system shall contain sufficient buttons to be able to fully control the LCD display
- 3.2.7. The LCD panel shall be sufficiently large to display:
  - A. Total distance traveled
  - B. Average speed
  - C. Heart Rate
  - D. Time Elapsed
  - E. Calories Burned
  - F. Previous Mile Split
  - G. Device Battery Level

3.3. Software Requirements
- 3.3.1. The microprocessor shall regularly command measurement updates from hardware
- 3.3.2. The microprocessor shall save off sufficient data to calculate:
  - A. Total distance traveled
  - B. Average speed
  - C. Heart Rate
  - D. Time Elapsed
  - E. Calories Burned
  - F. Previous Mile Split
- 3.3.3. The microprocessor shall be able to connect via bluetooth to a single cellular phone to push data to it (within a range of 10m)

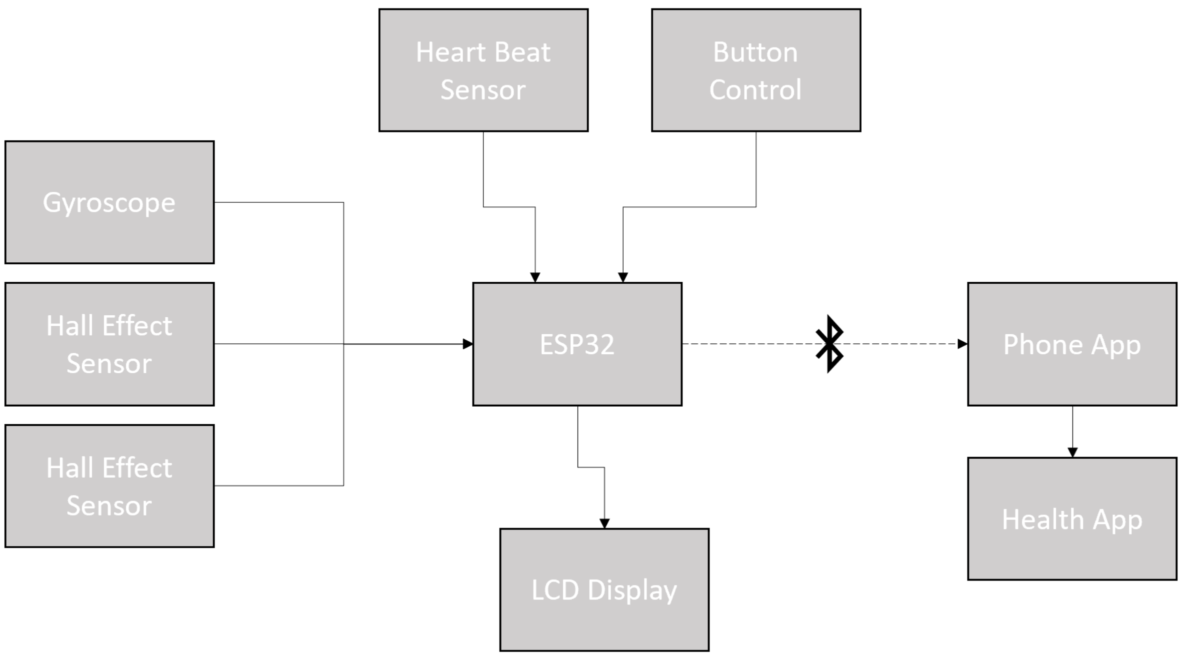
3.4. Environmental Factors
- 3.4.1. The system shall operate unimpeded in temperatures from 32°F to 100°F
- 3.4.2. The system shall operate in rainy weather

3.5. Power Requirements
- 3.5.1. The device shall be powered using a 2Ah, 3.7 LiPo rechargeable battery

3.5.2. The device shall be powered continuously for at minimum 8 hours
3.5.3. The device shall be able to be turned off when not in use
3.5.4. The device shall be able to be charged via a USB C charger

4. System Block Diagram

4.1. Overall System:



4.2. Sensors-Board Subsystem Requirements:

In order to accurately display the heart rate, distance, and velocity data, the system will need several sensors connected to its central board which will then process the signals sent from the sensors and display the necessary data on the also-connected LCD screen. For the different datasets, we have chosen different types of sensors believed to be optimal for each.

To measure the distance traveled as well as instantaneous speed, we will attach a Hall effect sensor to the part of the frame near the front wheel, and on one of the spokes on the front wheel we will attach a magnet. When the magnet passes the sensor, it will induce a current, and based on this current spike we can determine both the rpm of the wheel (and thus the speed with an input of wheel radius) and the distance traveled as the system will also contain a timer that starts at the beginning of a ride. Similarly, a second Hall effect sensor will be attached to the metal crossbar connecting the front and back wheels, in close proximity to the pedal. The corresponding magnet will be placed on the pedal to determine how fast the pedals are turning. This will aid in data collection for calories burned. A gyroscope would also be attached to this subsystem to measure tilt which will help determine rider effort and thereby the number of calories burned.

4.3. Heart Rate Monitor Subsystem Requirements:

To measure the rider's heart rate, we will need to create a small board with a variety of components, most notably an infrared emitter that will measure blood flow in the palm. This will create another electrical signal to send to the board. The display will be set to update at least every couple of seconds.

4.4. LCD Display Subsystem Requirements:

All of these signals' data will be displayed on an LCD screen attached to the handlebars, also connected to the central board. The screen will also have a button panel in its interface that can be used to change between the different screen layouts.

4.5. App Interface Requirements:

The app will read in data from the gyroscope and Hall effect sensors to create a set of workout data from the activity. This data will include heart rate measurements, total distance traveled, gear, incline, calories burned, and mile split times. This data can then be processed to the iPhone health app via bluetooth.

4.6. Future Enhancement Requirements:

A number of features could be added to this device using software. For example, the device could be able to classify workout intensity or give more specific data/statistics on workout performance. The feature of choosing workout intensity or workout specifications could be added, which would involve more analysis on how data from the heart rate monitor, gyroscope, Hall effect sensors, and gear shift works in conjunction to determine intensity of the workout.

Another obvious feature that could be added would be to add a physical gear shifter and another sensor to determine what gear the bike is in, and to automatically change the bike gear depending on how difficult the terrain is.

5. High Level Design Decisions

5.1. General Decisions

For controls and communication, we are planning to use an ESP 32 for its Bluetooth capabilities (it has the capability to connect to at least one device), its ability to interface through I2C to our two Hall effect sensors, gyroscope, and heart rate sensor, and our familiarity with it.

For power, we are planning to use the Adafruit 2.7Ah 3.7 V lithium-polymer rechargeable battery because it meets the system requirements for amp hours, battery type, and recharging ability [3]. This battery has also been selected for its lower price, and the Seeed Technology LiPo Rider Plus USB C Interface has been selected to allow for recharging to occur [4].

5.2. Sensors-Board Subsystem Decisions

A gyroscope will be used to measure tilt in order to help calculate calories burned. This option has over 90,000 in stock. The gyroscope can also use I2C or SPI comms [5].

We will need another sensor to detect the distance the bike has traveled. Our idea for this is to use a Hall effect sensor. We will attach a magnet to one of the spokes on the front wheel, and put the sensor attached to the frame on the front wheel, and the magnetic field spike when the magnet is next to the sensor can give us an rpm of the wheel, which using the circumference of the wheel can be converted into distance [6]. This will allow us to collect and then send distance and speed data to the LCD through the microcontroller. We are planning to use I2C communication to gather data from our Hall effect sensors.

5.3. Heart Rate Monitor Subsystem Decisions

To make the heart rate monitor, we are planning to create a small board loosely using the instruction guide from Jameco [7]. This would be attached to the handlebars to measure heart rate in the palm. We are planning to use I2C communication to gather data from this heart rate monitor.

The list of items we would need for this is as follows:

- LM324N quad channel op amp
- 2N3904 general purpose NPN transistor
- 1 μF capacitor
- .1μF capacitor
- 470kΩ resistor
- 68kΩ resistor
- 39kΩ resistor
- 8.2kΩ resistor
- 1kΩ resistor
- 1.8kΩ resistor
- 220Ω resistor
- 880nm, 5mm infrared emitter LED
- 5mm phototransistor

5.4. LCD Display Subsystem Decisions

The LCD panel will sit on the handlebars of the bike and be able to display exercise information for the user in real-time. This serves as the immediate user interface to the bike rider during exercise. The Pervasive Displays LCD panel has dimensions of 81mm x 47mm, which should allow for plenty of display area to show the required data. This option also has 61 currently in stock and can ship immediately, which also factored into choosing this part [8].

5.5. App Interface Decisions

We plan to implement bluetooth via the chip already built into the board. The app will have a menu where you can select pages with different statistics the rider has built up over the course of their ride (average heart rate, average speed, total distance, ride time, those same statistics saved from the last couple of rides). The app will be designed using Unity Engine.

6. Open Questions

Our current idea is to upload the workout data set from our device into the health app on iPhones or an equivalent health app. This process is something we are currently unsure of how to do, and will need to do further research before deciding if it is a feasible feature of our device.

Another issue that may come up with our design is building the heart rate sensor. We have a tutorial on how to build a small board that we are hoping will work, but we are unsure given our current knowledge on the topic if we can get it to work and function properly on our device.

In order to track speed and distance of the ride, we plan to employ two Hall effect sensors that we can use to read data. Using these sensors will require more research, and well some trial and error once we put the device together to make sure they function accurately.

In order to have accurate health data, we intend to include a measure of calories burned. On many current fitness apps and devices, this data point tends to be fairly inaccurate, often overestimating calories burned. Next semester, we will have to do more research to develop a formula for computing calories burned using the data we collect, including speed, distance, and pedal gear, along with data inputted by the user such as height, weight, age, and gender. As we refine our calorie formula, we may need to add additional user inputs or data measurements to achieve an accurate result.

7. Major Component Costs

Our project does not have any significant costs above $20, besides the board cost. This leaves us a significant amount of wiggle room in case components don't work. At the South Bend Bike Garage, if you volunteer six hours you are eligible to obtain a free bike. We plan to do this, which helps significantly lower our costs.

Component	**Cost**
Gyroscope (1)	$4.67
Hall Effect Sensor (2)	$2.14
Heart Rate Sensor (1)	$3.00
LCD Panel (1)	$17.85
Battery (1)	$12.50
USB C Interface (1)	$4.90
Bike (1)	$0
Board (1)	$50
Total	**$98.06**

8. Conclusions

References

[1] Peloton Bike. Dick's Sporting Goods.
[2] Peloton Bike+. Dick's Sporting Goods.
[3] Adafruit LiPo Battery. Digikey.
[4] Speed Technology USB C Interface. Digikey.
[5] Gyroscope. Digikey.
[6] Hall Effect Sensor. Digikey.
[7] Heart Rate Sensor Tutorial. Jameco.
[8] LCD Panel. Digikey.