The Bike System

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***Abstract* — The objective of this project was to provide bicycle riders useful metrics while they ride, while providing an alternative to more expensive solutions. The Bike System will provide speed, distance, and ambient temperature measurements; which will be displayed on an LCD. The Bike System will be powered by two sources, a dynamo generator, and a battery, and will have a seamless transition between the two during operation. This project was chosen because of the diverse hardware and coding requirements that provided a good opportunity to demonstrate electrical and computer engineering principals.**

***Index Terms* — Bicycles, Energy harvesting, Hybrid power systems, Lighting, Microcontrollers, RFID tags, Servomotors.**

I. Introduction

The bicycle is a vital form of transportation for millions of people around the world today. Many security systems already exist to secure bicycles to bicycle racks or fixed objects, but they are not always sufficient. Additionally, bicycle owners who do not own or choose not to wear a smartwatch, such as an Apple Watch or Fitbit, have no way to track metrics such as calories burned, distance traveled, or the speed at which they are traveling when they are cycling. The solution to this need is the Bike System.

The Bike System will be designed to maximize portability, such that it will fit most, if not all, popular bicycle designs. The Bike System also aims to maximize on convenience for its users. By maximizing convenience, the user will save time every time they want to lock or unlock their bicycle. In order to achieve this design goal, an RFID (Radio Frequency IDentification) scanner will be available so that the user can swipe an RFID card across an RFID reader to have the locking mechanism lock or unlock in seconds – much faster than traditional bicycle locking systems already on the market. Metrics such as calories burned, distance traveled, and speed for the current trip will be displayed continuously on the LCD (Liquid Crystal Display) display once the bicycle is unlocked and in motion.

This Bike System also includes the addition of lights as a safety measure that will be mounted on the bike frame itself. If the user chooses to ride his/her bicycle at night, he/she would need to be visible to both pedestrian and motor traffic. With lights mounted to the bike frame itself, the bicycle will be visible from hundreds of feet away. The system will also be battery powered and will emphasize long lasting battery life by making the circuitry as energy efficient as possible.

The implementation of an alternate power source allows for the on-board battery to be charged while the user is cycling. The alternate power source would be a generator that will generate power from the mechanical energy transferred from the user. If the battery is fully charged, the power from the generator could be used to take over the most power draining features such as the lights mounted on the bicycle frame or the LCD display. This alternate power source will allow the user to go for longer periods of time without having to remove and charge the battery. Ideally, the battery, in conjunction with the alternate power source, should last for weeks at a time without needing to be charged via an external charger.

The project was self-funded by the group, with a target budget was $600. This budget was to include all the research and building materials required for the Bike System.

II. System Components Overview

The Bike System is comprised of 4 major subsystems. These subsystems are the Power, RFID/Locking, Lighting, and Microcontroller subsystems. In this section, an overview of these subsystems will be provided to give a better understanding of how the Bike System will operate.

A. Power Subsystem

The power subsystem is used to provide power to the Bike System's various other subsystems and components. The power subsystem is powered by three separate sources, a dynamo generator, a Li-Ion battery (Lithium Ion), and power via an external power source. While the bike is in motion, power is generated by the dynamo by the spinning of the bike's tire to power the Bike System and charge its battery. The battery is there to ensure that the Bike System has a continuous source of power, even when the bike is not in motion. A LED (Light Emitting Diode) is illuminated when the battery is in use to indicate to the rider that the battery is currently being drained. The external power source is used to charge the battery and power the system when the bike is not in motion, such as after a long period of storage. The external source has also been designed to charge the battery more quickly than the dynamo when the bike is in motion. The transition between the two sources will happen automatically and seamlessly. The outputs of the power subsystem are 3.3V and 5V. It is made up of an input stage, switching circuit, battery circuit and output stage. Refer to Fig. 1 for a block diagram of the power subsystem.

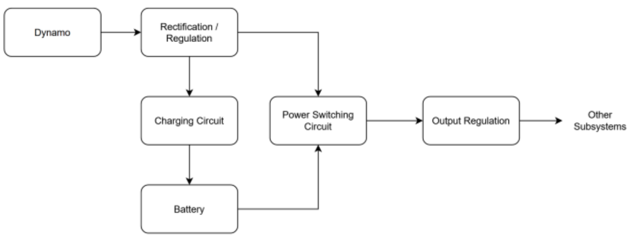


Fig. 1. Block diagram of the Bike System's Power subsystem

The input stage consists of the is used to rectify, filter, and regulate the power provided by the dynamo generator. This is done to ensure that the power provided by the dynamo is stable and will not cause any issues with other subsystems and components down the line.

The switching circuit is where the two power sources are switch between that will later feed into the output stage. This circuit detects when the voltage supplied by the dynamo fall below a certain level, then switches to using the battery as a source of power for the Bike System.

The battery circuit contains the battery and the circuitry necessary to charge the battery when it is not in use. This circuit also incorporates the connector that allows for external power and charging of the system and battery, respectively. When being charged from an external source, there is circuitry that allows for the battery to charge more quickly as compared when it is being charged by the dynamo.

The output stage is used to take the selected source from the switching circuit and provide a regulated output of 3.3V and 5V. These voltages are then used by the rest of the Bike System's other subsections and components for operation.

B. RFID and Locking Subsystem

The RFID and locking components are paired together in this single subsystem because they are used in conjunction with one another to act as the method of securing the Bike System to another object (such as a bike rack or pole). This is done by scanning a RFID tag by an antenna attached to the Bike System's enclosure and the locking tab that is used to secure the bike is locked/unlocked. See Fig. 2 for the location of the locking tab.

The bike is secured to objects by a strap on an inertia reel system. This allows for the length of the strap to return back into the encloser when not in use, and put tension on the strap when it is secured to the object. The bike will be secured by the user where the user will pull out the locking tab, wrap the strap around a secure object, then put the locking tab into the locking slot into the Bike System's enclosure (shown as a white bar on the enclosure in Fig. 2).

An RFID circuit was designed that will read an RFID tag via the antenna and interface with the Bike System's microcontroller by sending a control signal to the microcontroller. The microcontroller will check to see if the ID is valid, and if so, actuate a servomotor to engage/disengage the lock for the locking tab.

C. Lighting Subsystem

The lighting subsystem will provide a source of light for the rider as well as acting as a deterrent from motor vehicles. The light generated will be resourced appropriately to conserve energy by implementing an auto-dimming feature. An optical sensor will be used in conjunction with the dimming feature to set the threshold to signal the lights to turn on.

The light system will reach its brightest luminance when the relative light of the area is at its minimum. This is done by having a light sensor interface with a microcontroller to turn the LEDs on and off, and a photoresistor is used to set the brightness levels of the LEDs.

D. Microcontroller Subsystem

The microcontroller subsystem is comprised of the microcontroller, the LCD module, and other sensors and components that were not covered in the previous subsystems. These sensors are the reed switch and temperature sensor.

The reed switch is used to count the rotations of the bike tire by sending a pulse to the microcontroller whenever a magnet that is attached to the bike's tire actuates the reed switch, see Fig. 2. This is used to determine the speed and distance traveled for the bike.

The temperature sensor is used to measure the ambient temperature of the air around the Bike System. This is used to provide the rider an idea of the current temperature outside. The temperature sensor does this be generating a voltage that is proportional to its current temperature. This is measured by the microcontroller and is given a temperature value for the measured voltage level by the microcontroller.

The LCD module is used to display the information calculated by the microcontroller (speed, distance, and temperature) to the rider. These serve as metrics to the rider to enhance the rider's experience and serve as a fitness tool. The rider passively interacts with the LCD module by simply viewing the outputted metrics. The touchscreen capabilities were not enabled in this application as a measure to reduce any forms of distraction in an effort to increase safety for the rider.

III. System Overview

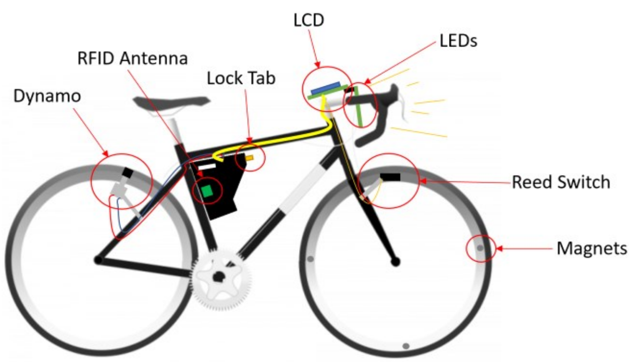


Fig. 2. Diagram of Bike System with some key features highlighted.

The Bike System will be constructed as shown in Fig. 2. There will be a main PCB (Printed Circuit Board) that will contain the power, RFID, and microcontroller circuitry. This PCB board will be located in an enclosure mounted in the center of the bike, as shown in Fig 2. In addition to the main PCB board, the enclosure will house the hardware for the locking mechanism and have an antenna mounted on it so that the RFID tag can be scanned and processed by the main PCB board. There will be a slot for the locking tab (represented as a white bar on the enclosure in Fig. 2) where the locking tab will be inserted and secured to lock the bike.

The dynamo generator will be mounted on the rear wheel of the bike and will have connections that run to the power circuitry on the main PCB board housed in the enclosure. This will route the generated electricity generated by the dynamo to the power circuitry on the main PCB board. On the front bike wheel, the reed which will be mounted along with magnets attached to the rim of the front bike tire.

The LCD, temperature sensor, lighting circuitry, and the battery-in-use indicator will be installed on a secondary PCB board mounted on the bike's handlebars. This is shown as the red circle labeled "LCD" in Fig. 2. This allows for easy viewing of the LCD for the rider, as well as providing access to what the sensors are meant to be sensing. There the temperature sensor has access to the ambient air, and the light sensor and photoresistor have access to the surrounding lighting conditions. Power and data connections are routed from the main PCB located in the enclosure, and ran along the frame of the bike to the secondary PCB board, as shown as the yellow wire in Fig. 2.

The LEDs will be mounted on their own separate board that will plug into the LCD board via a right-angle connector, represented as a black rectangle between the LCD and LED boards in Fig. 2. This will allow for the LEDs mounted on the LED board to face forward of the bike and direct the light generated by the LEDs towards the front of the bike. The power for the LEDs is controlled by the light circuitry on the LCD board, and routed through the LCD board back to the power circuitry on the main board located in the Bike System's enclosure.

IV. Hardware Design and Detailed Breakdown

The hardware design of the bike system entailed the design of each subsystem then working to integrate all the various subsystems together so that they would work in concert so that the Bike System would operate as intended. This section will give a detailed explanation of the design and hardware aspects of the subsystems discussed in Section II, and broken up in a similar fashion.

A. Power Subsystem Detailed Description

The input power stage will consist of the rectification and regulation of the input power. Additionally, there is a reverse voltage protection provided by a diode. Input power will be provided by a dynamo that generates power from the spinning of the bike tire. This type of power generation results in an alternating current (AC) voltage.

The AC voltage generated from the dynamo is not useable with most electronics, which usually require a direct current (DC) voltage. A full-wave rectifier was implemented in the power subsystem circuit. Capacitors placed right after this rectifier serve to smooth out the ripple voltage from the rectification process, so that the voltage is relatively stable when it arrives at the regulation stage. Two electrolytic capacitors with relatively large capacitance values to help filter out the dynamo's relatively low AC output frequency (about 100 Hz), while the other capacitors are ceramic capacitors there to filter out the higher frequency components from noise and interference.

Voltage regulation is needed to deal with the remaining voltage ripple from the input voltage, as well as the variations in the voltage level as the bike tire's rotational speed changes.

Due to the varying nature of the voltage generated from the dynamo the input of the rectifier needed to support a wide range of input voltages. Regulating the input voltage to 5V was decided based on the characteristics of charging a Li-ion battery. While a Li-ion battery nominally provides a voltage of 3.7V, the voltage required to charge the battery is 4.2V. To accommodate this need, a regulator was chosen to output a voltage of 5V.

The reverse voltage protection diode serves to prevent the power provided from the USB connection to feed back into the 5V regulator, but allows power to flow to the to the rest of the Bike System when the USB is not providing power. The penalty of this is the small voltage drop across the diode; however, this voltage drop was minimalized by utilizing a Schottky diode, which has a lower voltage drop than a traditional PN junction diode.

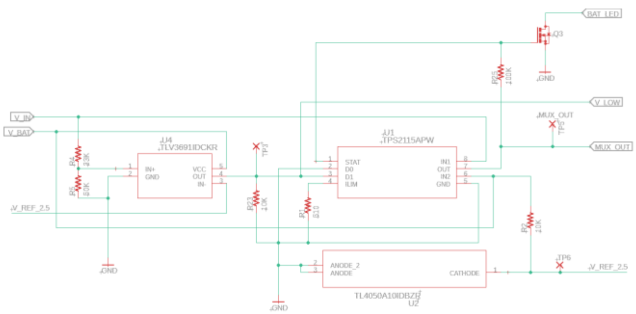


Fig. 3. The power subsystem’s switching circuit.

The power switching stage is very import in the successful operation of the Bike System. This is because it is at this stage that the two power sources, from the dynamo and the battery, are switched between. This is determined by a comparator circuit, discussed later this section. The power switching stage is comprised of the power mux IC (Integrated Circuit) and the push-pull comparator (U1 and U4 in Fig. 3, respectively). In the schematic, the power mux has two input pins (IN1 and IN2) where the two power sources are fed to (represented as V_IN and V_BAT in Fig. 3). The power from one of these two input pins this then routed to the output pin of the mux (OUT) to be fed to the following stages (represented as MUX_OUT in Fig. 3).

There is functional pin (ILIM) that sets the maximum current that can pass through the mux. In the current configuration a 500Ω resistor is put between this pin and ground. This resistance value sets a max current of 1A at the output, which is the same max current specified for the voltage regulator in the input stage. The STAT pin is used to determine the mode of operation of the power mux, whether it is routing power at the IN1 pin, or the power at the IN2 pin to the output pin OUT.

The STAT pin gets pulled low when pin IN1 is routed to the output pin, and is “Hi-Z” when IN2 is routed to the output pin. “Hi-Z” means high impedance, and can usually be treated as an “open” or no connection. Effectively, the STAT pin either acts as a ground or as an open wire. Referencing the schematic in Fig. 3, resistor R25, MOSFET Q3 and a LED (represented as the BAT_LED signal in Fig. 3) create a circuit that serves to indicate when the battery is in use (IN2 routed to the output). Resistor R25 serves as a pull-up resistor and pulls the gate of the Q3 up when the STAT pin goes to “Hi-Z”, which causes Q3 to act like a closed switch. This causes the LED connected between the drain of Q3 and the 3.3V rail (not shown in Fig. 3) to illuminate, indicating to the user that the battery is in use. When IN1 is routed to the output, meaning STAT is pulled low, the voltage at the gate of Q3 will be low and Q3 will act as an open switch. This means that the LED will not be lit, indicating the battery is not in use.

What determines which input is routed to the output pin is determined by selection control line pins (D0 and D1). Table 28 shows the logic table for how the inputs pins are routed.

TABLE I
POWER MUX LOGIC TABLE

D0	D1	OUT
Low	High	IN1
Low	Low	IN2

“High” and “low” are defined as TTL values, so a “high” signal is any voltage over 2V, and a “low” signal is any voltage under 0.7V. To achieve a low the control line pin can simply be tied to ground. Since pin D0 is low for either operation, the D0 pin is permanently tied to ground to always keep it low. Pin D1 is pulled either low or high via the push-pull comparator, represented by the U4 in Fig. 3.

A push-pull comparator either outputs high (whatever the comparator’s positive supply voltage is) or low (whatever the comparator’s negative supply voltage is, here it’s ground). The comparator outputs high when the voltage at noninverting terminal (denoted by a “+”) is higher than the inverting terminal (denoted by a “–”). A voltage reference, represented as V_REF_2.5 in Fig. 3, sets a voltage of 2.5V and applies that voltage to the inverting terminal of the comparator. The voltage divider at the noninverting terminal of the comparator sets the voltage at the noninverting terminal to 2.5V when 4.15V is reached by the dynamo’s regulated output. What this does is set the threshold for triggering the comparator to go low when 4.15V is reached at the dynamo’s input line. Thus, when the dynamo’s input line goes below 4.15V, the voltage at the noninverting terminal of the comparator goes below 2.5V (lower than the inverting terminal) and causes the output of the comparator to go low. This switches the output of the mux to be that of IN2.

One concern is the issue of oscillations of a comparator’s output due to noise on the signals at the inputs of the comparator. The solution is the use of hysteresis. The comparator chosen has a 17mV hysteresis value built in, which address this issue in the Bike System's power subsystem and prevents unwanted oscillations at the output of the comparator.

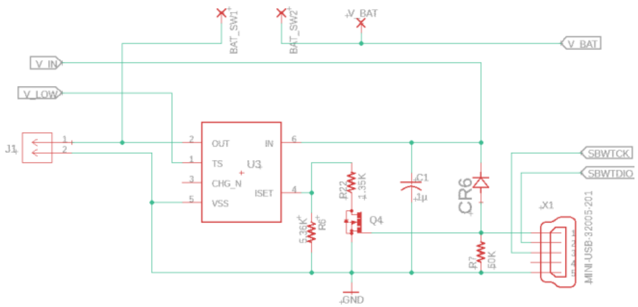


Fig. 4. The power subsystem's input voltage regulation circuit.

Referencing the schematic shown in Fig. 4, the battery and the battery charging stage of the power subsystem are comprised of the battery charging circuit and the battery. In Fig. 4, the battery is represented by J1 (the jack that the battery will plug into). The charger's output to the battery is represented by V_BAT in Fig. 4. The BAT_SW connections are used for a switch that will be used to disconnect the battery from the rest of the circuit.

The battery charging circuit consist of the battery charging IC (U2 in Fig. 4), the necessary passive components, a USB mini connector for external power, and a circuit to allow for faster charging while powered externally. The passive components include a capacitor (C1 in Fig. 4) for some passive filtering of the supply line recommended by the IC's datasheet, CR6 to prevent Q4 from turning on until power is supplied from the USB port, and resistors to set the battery charging current limit (R6 and R22 in Fig. 4).

The resistor value that is used to limit the battery charging current was chosen to be 5.4KΩ to limit the current to 100mA when powered by the dynamo. This calculation was obtained from the battery charging IC's datasheet, shown as equation 1.

$$R_{ISET} = \frac{540}{I_{OUT}} \quad (1)$$

However, when powered via USB, Q4's gate is high which makes Q4 act as a closed switch. This puts the resistors R6 and R22 effectively in parallel to give a new resistance value of about 1KΩ. Using equation 1, it can be found that the new input current is limited to about 500mA. This allows for the battery to charge much quicker.

For the temperature sense (TS) pin on the battery charging IC it serves two functions. First, the datasheet specified to use a 10KΩ when the battery does not support temperature sense, such as the one used in the Bike System's design. Second, the TS pin serves as an output enable. When the TS pin is pulled low, the charging IC is disabled. This function can be used to turn of the charging IC to when the regulated input voltage from the dynamo is not sufficient to power the rest of the Bike System. This is done to help prevent the charging IC from attempting to charge the battery when there is not enough voltage being generated by the dynamo.

The TS pin can be pulled low by using the comparator, U4 in the circuit shown in Fig. 3. This comparator signal is represented by V_LOW in Fig. 4. This is the same comparator that is used to command the power mux to switch between IN1 and IN2 pins being routed to the OUT pin. This means that when the regulated voltage generated by the dynamo dips below a certain voltage level, the input power is switched to the battery, and the battery charging IC is disabled.

The USB mini connector allows for external power to be applied to the Bike System in order to charge the battery and power the Bike System without needed to actually ride the bike.

The battery is connected directly to the power mux's IN2 pin, which is then routed to the output pin. The battery also directly powers the voltage reference IC (U2 in Fig. 3) and the comparator. The issue that comes from powering devices directly from a battery are the changing voltage levels as the battery is charging and discharging. This is one of the reasons why an output regulator is needed.

However, the voltage reference has been designed to maintain a set voltage over a varying voltage. This is because the voltage reference has a range of current that will guarantee the correct reference voltage. This current is established and maintained by the 10KΩ resistor in series with it. The 10KΩ value was chosen based on the expected voltages at the top of the resistor (in reference to the circuit in Fig. 3), and the current was calculated based on that voltage range. The voltage range is expected to vary from 3.5V (the battery voltage with little charge remaining) to 4.2V (Li-ion battery charging voltage). The resistance is found by using equation 2.

$$R = \frac{V - V_{ref}}{I_{ref}} \quad (2)$$

Where R is the resistance needed to maintain the reference current, V is the voltage seen by the resistor, Vref is the reference voltage, and Iref is the current through the voltage reference. The minimum current threshold to ensure proper operation for this particular part is 65µA, so 100µA was chosen for Iref to accommodate this requirement. Using this value, the minimum expect voltage V of 3.5V, and the reverence voltage Vref of 2.5V, R was shown to be 10KΩ.

Unlike the voltage reference, the comparator function will vary directly proportionally to the supply voltage provided to it. This is because the comparator's high output voltage is essentially the same as the supply voltage. To overcome any issues with this the components connected to the output of the comparator had be selected carefully. The voltage supplied to the comparator is expected to vary from 3.5V – 4.2V. This means that the high output from the comparator will vary by the same voltage, and the components connected to the comparator output need to be able to use this voltage. The components connected to the comparator's output are the control lines for the power mux and the TS pin of the charging IC.

The datasheets for the power mux and charger IC specify TTL voltage thresholds for the control lines, which has a minimum voltage of 2V to read high. This means that the minimum voltage that the comparator voltage high would satisfy this requirement.

The power output stage consists of the 3.3V and 5V voltage regulators. The need for these output regulators is twofold. First, the voltage outputted by the power mux (MUX_OUT) will either be the 5V from the regulated output from the dynamo, or the nominal 3.7V from the battery. Since the voltage varies so widely there is a need to regulate this voltage to a stable output that can be used by other electronics. The second reason is that even if the power mux is running exclusively from the battery, the voltage from the battery is not completely stable. This is because as the charge state of the battery changes, the voltage from the battery will change as well. The is another reason for regulation. The voltage generated from the dynamo is already regulated, so it would be a usable voltage. However, this voltage is not as reliable as the battery (the bike needs to be in motion with sufficient speed to generate the power), it needs to be fed into another regulator to ensure that it gets stepped down to the 3.3V regulated output voltage or boosted up to 5V again.

B. RFID and Locking Detailed Description

The primary IC used to drive the RFID system is the MFRC522, manufactured by NXP Semiconductors. The MFRC522 IC generates a signal with a frequency at 13.56 MHz that radiates from the antenna. The following circuitry subsystems describe the architecture of the RFID system: antenna, damping resistor, EMC cutoff filter, matching network, and receiver circuit.

The first step in designing the RFID system was to design an antenna with characteristics suitable for the MFRC522 IC. It is recommended in [1] to design an antenna with an estimated inductance between 300nH and 3μH and a resistance between 0.3 and 8Ω. As such, a 3-turn coil (antenna) embedded on a printed circuit board was designed and manufactured. Upon testing the antenna, it was recorded that the antenna had an inductance of 1.951μH at 13.56 MHz, a resistance of 2.6Ω, and an assumed capacitance of 0.1pF at 13.56 MHz. The next step was to calculate the value of a damping resistor needed to decrease the Q-factor of the antenna to a value between 30 and 35. According to equation 3, the resistance value of 1.47Ω was chosen.

$$R_Q = 0.5 * \left(\frac{\omega * L_a}{35} - R_a\right) \qquad (3)$$

Where L_a and R_a are the series inductance and resistance of the antenna, respectively. Next, was to calculate the values of the capacitors that would be used to match the input impedance of the antenna to the output impedance of the TX1 and TX2 pins on the MFRC522 IC using equations 4 and 5.

$$C_1 \approx \frac{1}{\omega\left(\sqrt{\frac{R_{tr}R_{pa}}{4}} + \frac{X_{tr}}{2}\right)} \qquad (4)$$

$$C_1 \approx \frac{1}{\omega^2 \frac{L_{pa}}{2}} - \frac{1}{\omega\sqrt{\frac{R_{tr}R_{pa}}{4}}} - 2C_{pa} \qquad (5)$$

After the values for C_1 and C_2 were solved, the EMC cutoff filter, matching network, damping resistor, and antenna series equivalent circuits were simulated using RFSim99, a free open-source software suggested by NXP Semiconductors, and an S_{11} port measurement was taken with the center of the Smith Chart normalized to 50Ω. The results shown in Fig. 5 were obtained.

The electromagnetic compatibility (EMC) cutoff filter was designed to have a cutoff frequency of 14.5 MHz as this is the frequency past which the amplitude of the output signal decreases by 3 dB. It is recommended in [1] that the EMC cutoff frequency be between 14.1 and 14.5 MHz as this will ensure that reception bandwidth is maximized.

The last circuit to be designed was the receiver circuit because its parameters depend on the component values in the EMC cutoff filter, matching network, damping resistor, and antenna. The two capacitor values, CVMID and CRX, were predefined in [1] as 100nF and 1nF, respectively. The two resistor values form a voltage divider and depend on the voltage level across one of the capacitors in the EMC cutoff filter with respect to ground.

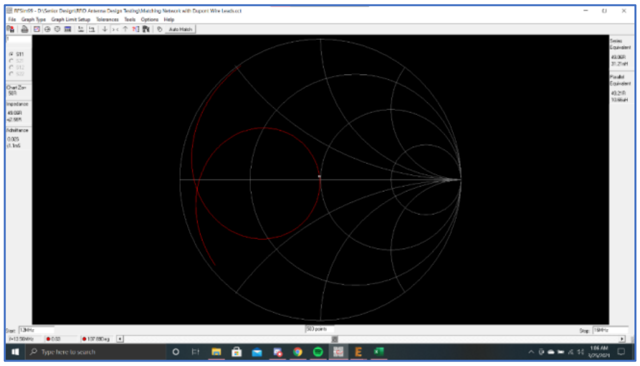


Fig. 5. Smith Chart for simulated circuit using RFSim99.

C. Lighting Subsystem Detailed Description

The lighting subsystem will be comprised of the LEDs in front of the bike, as well as a dimming circuit to automatically dim according to the ambient light.

The dimming of the LEDs will be done with a differential amplifier circuit in combination with a photoresistor. This type of amplifier was used because the luminous intensity of the sun at its greatest, results in a low resistance within the photoresistor. A voltage divider was implemented as the solution for the necessary inversion. The rate at which the lighting system will increase from lowest luminance to greatest luminance is dependent on the gain resistors used for the amplifier.

Referencing Fig. 6, this circuit works by comparing the voltage at the inverting terminal, determined by the voltage divider created by the 115KΩ resistor and the photoresistor. The higher the voltage at the inverting terminal (lower photoresistor resistance) the more current the op amp will supply to the LEDs, and vice versa with lower voltage.

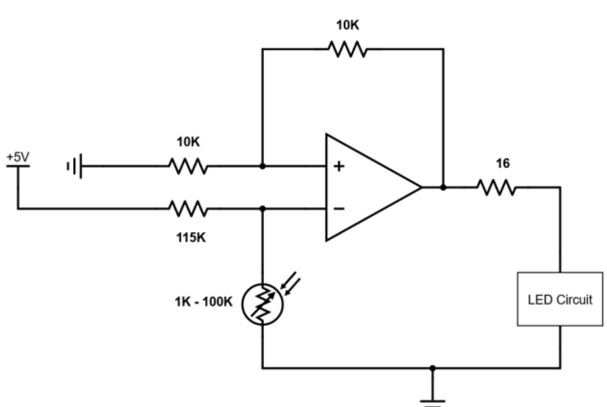


Fig. 6. LED dimming Circuit.

D. Microcontroller Subsystem Detailed Description

The main component of this subsystem is the Texas Instrument's MSP430G2553 microcontroller. The operating voltage of this device is in the range of 1.8 V to 3.6 V. This was a particularly crucial factor since the power subsystem was designed to supply 3.3 V. This microcontroller has a memory capacity of 16 KB flash memory and 512 B SRAM. A microcontroller with larger memory was not chosen since it was deemed not necessary. The calculations in the code that were not computationally heavy. The Code Composer Studio (CCS) Integrated Development Environment (IDE) was chosen to compile, develop and debug the code that was programmed on this microcontroller.

The reed switch and temperature sensors work connected to the microcontroller so that their signals could be read and interpretated. The reed switches simply switch the 3.3V to the microcontroller pin as a pulse to be read when the magnate passes the reed switch. The temperature sensor outputs a voltage that is proportional to the current temperature and is interpreted by the microcontroller's ADC to be displayed on the LCD board.

V. Software Detail

This section provides a detailed description of the software used to implement the Bike System.

A. System Firmware

The software that is running on this Bike System is written in the C programming language. This decision was made based off the chosen MSP430G2553 microcontroller. The C programming language was also the only language that the entire group had the most experience with and was the most comfortable with. Besides the main() C file that hosts the calculation and RFID interaction functions, there were ten other header and auxiliary C files that hosts supporting C functions that implement the Graphical User Interface (GUI) portion of the software.

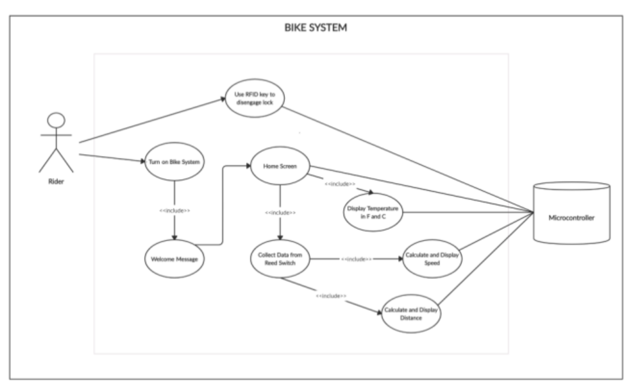


Fig. 7. The Bike System's use case diagram.

B. Software Functionality

Fig. 7 shows the use case diagram which visualizes the expected behaviors of the Bike System software and what the intended relationships between the system and the users are. This type of UML (Unified Modeling Language) diagram does not seek to explain or specify the exact process of how these tasks will be or are done – it is purely behavioral. The actor (which is the rider) has two actions that they can perform: (1) use their RFID key to disengage the locking mechanism and, (2) turn on or power on the Bike System. Powering on the Bike System automatically triggers the software to start executing. The welcome and home screen messages are displayed in that respective order with a small delay in between. The next and final screen displays the metrics discussed in this paper continuously until the rider turns off the Bike System.

C. Algorithm Description

The algorithm of the Bike System software is broken down into three main subsections: (1) initialization of ports and reading inputs, (2) computing the calculations (speed, distance, temperature) and listening for the RFID to unlock/lock, and (3) outputting the metrics to the LCD module for viewing by the rider. For this application, the size of the wheel on the bicycle being used was stored as a constant value for the speed and distance calculations.

Inputs are taken from the reed switches, TMP 235 temperature sensor, RFID module and the lights. The metrics such as the average speed, average distance and ambient temperature are continuously displayed or outputted to the LCD by a draw_string function that takes 4 inputs: the x position on the screen, the y position on the screen, the font size, and the string to be printed to the screen. An auxiliary set_color function is used to set the font color before the desired string can be drawn. Functions such as clear_screen, which clears the entire screen, and draw_string of the exact string is drawn over in the background color to mimic the clear_screen function.

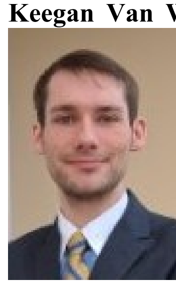
VII. Conclusion

Through the course of completing the two-semester long Bike System project, the team has learned many valuable lessons and were able to leverage the skills and knowledge learned in the pursuit of their degrees.

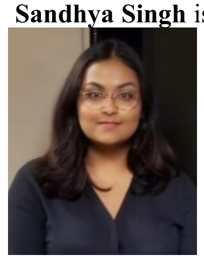
References

[1] Antenna Design Guide for MFRC52x, PN51x and PN53x, AN1445, Rev. 1.2, NXP Semiconductors, 2010.

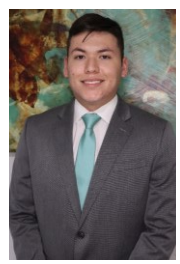
Group 21 Design Team



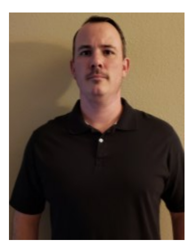
Keegan Van Wyk is an Electrical Engineering Student who previously served in the Air Force as an Avionics Technician. Keegan is taking a full-time position as an Electrical Engineer at Lockheed Martin's Missiles and Fire Control facility in Orlando, Florida.



Sandhya Singh is a senior Computer Engineering student in the College of Engineering and Computer Science at the University of Central Florida. She is a Cohort B5 Scholar in the National Science Foundation (NSF) Flit-Path program. After graduation, she has plans to pursue a working career in the engineering industry as a Systems Engineer.



Benjamin Tamayo is an Electrical Engineering Student who is a first-generation scholar. After graduation, Benjamin is taking a position at Lockheed Martin's Missiles and Fire Control facility, located in Orlando, Florida, as an Electrical Engineer.



Daniel Birath is a senior Electrical Engineering student minoring in Computer Science as part of the College of Engineering and Computer Science at the University of Central Florida. He is an Air Force veteran who performed as an aerospace maintenance technician on C-130 aircraft. Daniel will be employed after graduation with Electrical Design Associates who design and implement power for water/wastewater utility companies.