ENKIDU BICYCLE LOCK

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Abstract

This report includes introduction, detailed designs of our project, verifications for our designs, costs of project and conclusion. The goal of our project is to design an anti-theft bike lock. A backup lock will automatically lock the bicycle and an alarm will be activated when a thief breaks the regular lock of the bike. After the backup lock is locked, the user can unlock the bicycle by entering the correct password on the mobile application.

Contents

1. Introduction

The bicycle was invented in motion due to a volcanic eruption two hundred years ago. It has become a popular individual means of transportation that represents quality of life for healthier living and more environmentally friendly cities. Nowadays, when the transportation technology developed, the bicycle still takes an important role in urban areas [1]. From 1992 to 2006, bicycle sales increased from 15.3 million to 18.2 million per year in the United States. According to National Crime Victim Survey (NCVS), approximately 1.3 million bicycles stolen are reported to the police. However, the actual stolen bicycles might be four or more times greater than this number. That said, there is at least a total of 6.5 million bicycles stolen in 2006 in the United States [2]. More specifically, on our campus, there were 373 bicycle thefts reported to the University of Illinois Police Department (UIPD) between August 4, 2011 and March 9, 2016. This is an average of 82 reported bicycle lost a year, and we believe this number is a low estimate [3].

Thus, our goal is to reduce the bicycle stolen rate. Instead of using traditional locks, we will use the Enkidu Bike Locker, which is an anti-theft device. When the regular lock is broken by a thief violently, the alarm will be sent to the owner and meanwhile, a backup lock will be automatically locked. The only way to unlock the backup lock is to use password on the phone or the computer so that only the owner can connect to the device wirelessly using Bluetooth.

The whole device is divided into three subsystems: detecting system, locking system and unlocking system. Detecting system detects the lock-breaking action and activates the alarm when the action is detected. It also sends a signal to notify the locking system. The locking system, as its name indicates, is a lock that can lock itself when it receives the signal from the detecting system. The unlocking system communicates with the user's devices, such as phones and computers, and sends a signal to unlock the backup lock when the password is correct.

2 Design

Our project consists of four subsystems: the power supply, the detecting system, the locking system and the unlocking system. The overall objective of our design is to make it function as an emergency backup lock which will prevent the bike from getting stolen. When the regular lock in the detecting system is cut, the backup lock will automatically lock itself and the alarm will get activated to stop the thief from stealing the bike. The backup lock can be manually unlocked when the password is entered in the mobile app correctly. Figure 1 is the block diagram of our project.

Both the detecting system and the locking system will be implemented on the same tire of the bicycle. To prevent the thief from cutting the wire or uninstalling the battery, we protect all components, except the mechanical Backup lock, with a metal shell. The battery and alarm can be taken out with keys for replacements. Figure 2 is the overall physical design of the device when it is implemented on a bicycle.

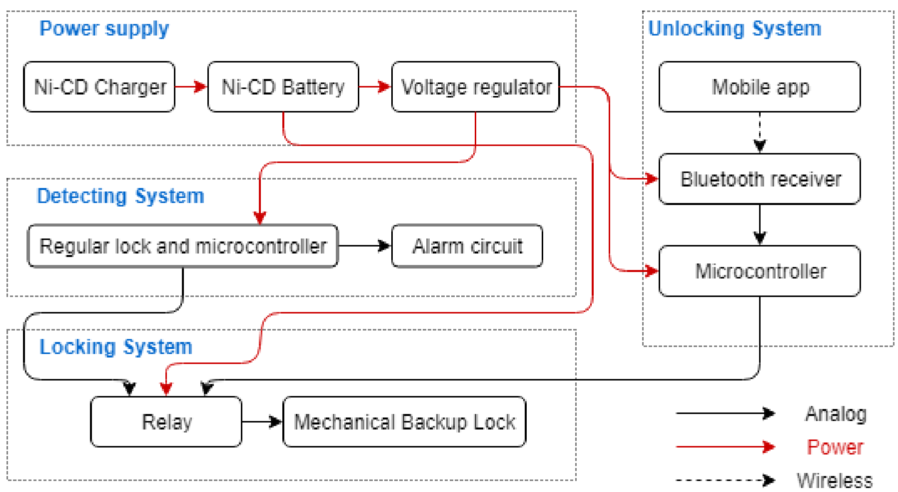

Figure 1 Block Diagram

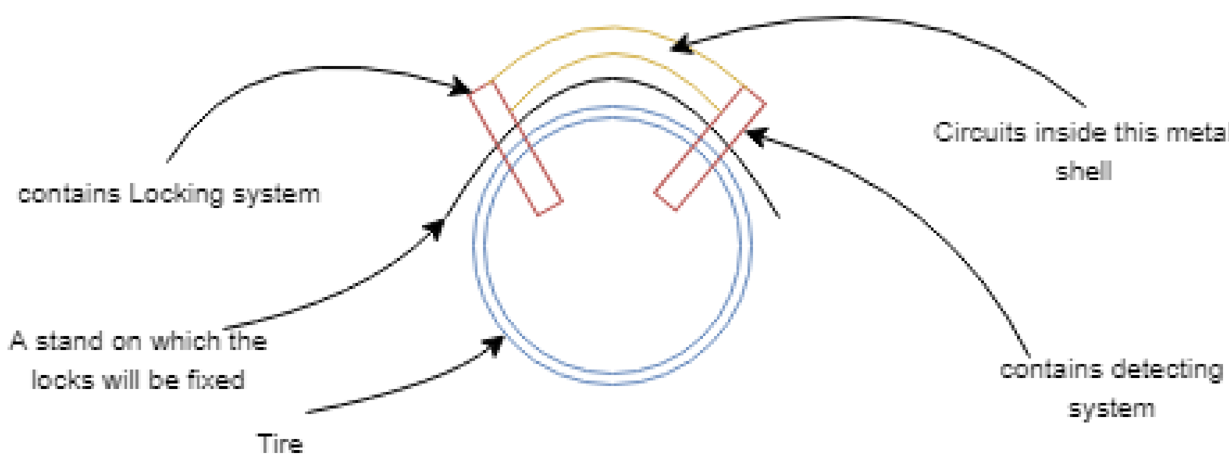

Figure 2 Overall physical design

2.1 Power Supply

A power supply is required to make the whole system work when needed. Power is delivered from a Ni-CD battery which is rechargeable. The battery has 18 V output. Some parts of our project need to have 5 V input voltage, so a voltage regulator is used to regulate the voltage to 5V for these parts. The rest uses 18 V directly.

2.1.1 Ni-CD charger

The charger will charge the Ni-CD battery [4]. The charger is powered by wall power outlet of 120 V and output a constant voltage of 18 V. The charger can fully charge our battery within about 40 minutes.

Figure 3 Ni-CD charger

2.1.2 Ni-CD battery

We use DC9096 Ni-CD battery as the power source for our whole system [5]. The output voltage of the battery is 18 V and the capacity is 1500 mAh.

Figure 4 18 V Ni-CD battery

2.1.3 Voltage regulator

For some parts of the sub-systems, we need voltage supply to be 5 V. Thus, we use voltage regulator MC7805ACTG ON semiconductor to regulate the voltage from 18 V to 5 V [6].

2.2 Detecting System

The detecting system consists of a regular lock, a microcontroller and an alarm circuit. The regular lock is used for daily purpose. We insert a long wire inside the regular lock, so once the regular lock is broken, this wire is cut. We simulate this situation using a switch. The physical design of the regular lock is shown in figure 5 below. Normally, the switch is closed. Once a thieve breaks the regular lock, the switch becomes open. As long as the switch opens, a 10-second pulse should be sent to the alarm circuit, which would activate the alarm during the pulse period. Another 1-second pulse should be output to the locking system.

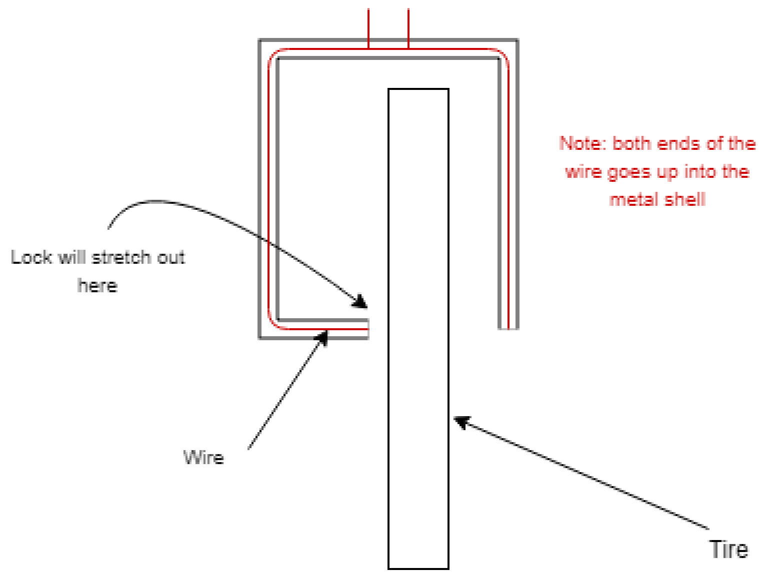

Figure 5 Physical Design of the regular lock

2.2.1 Microcontroller

Microcontroller is a programmable chip. We chose ATMEGA328P chip to achieve the purpose [7]. We used three pins in this sub-module: one input pin and two output pins. The input pin is connected to the long wire that is inserted in the regular lock. It detects whether the wire is cut or not. Normally, the wire is connected, so the input would have high voltage of 5 V, which is the VCC for the whole microcontroller. Once the input drops to 0 V, which means the wire is being cut, two outputs should output different pulses. One is a 10-second pulse, which goes into the alarm circuit, and the other is a 1-second pulse which goes to the locking system.

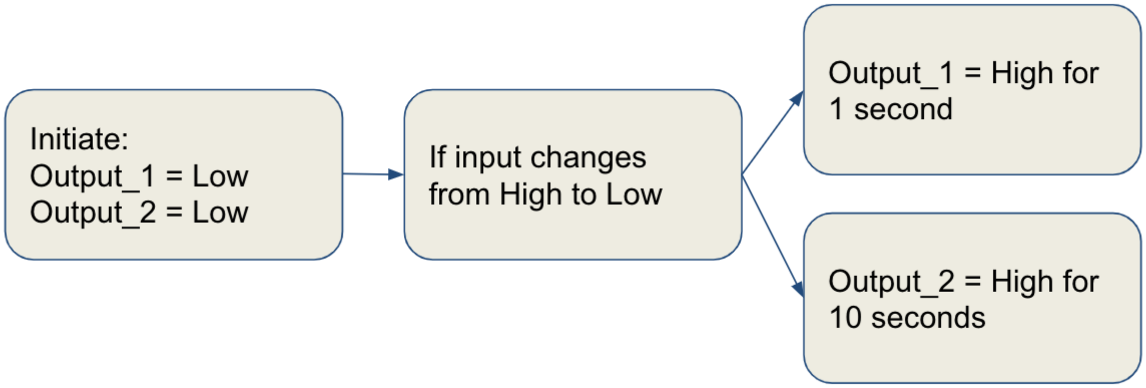

Figure 6 Flow chart of algorithm inside microcontroller

2.2.2 Alarm circuit

Alarm circuit is a circuit that takes 5 V DC signal as input, and transfers to 5 V AC signal across the speaker. The speaker we used is CEM-1203 [8]. This is a small 12mm round speaker that operates around the audible 2kHz range.

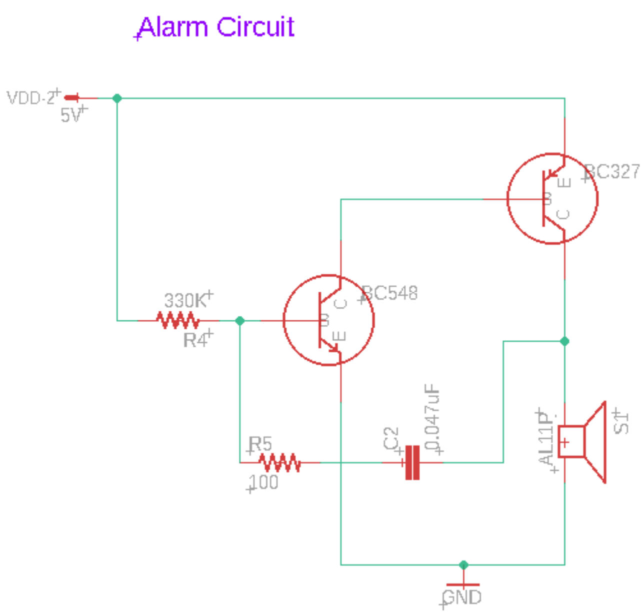

Figure 7 Alarm circuit schematic

2.3 Locking System

The locking system consists of a 5 V relay and a mechanical backup lock. The relay functions as a switch and receives the output voltage pulses from both the detecting system and the unlocking system. When the relay receives the 1-second voltage pulse from the detecting system, the mechanical lock immediately locks itself. When the relay receives the 5-second voltage pulse (which will be talked about later in section 2.4) from the unlocking system, the mechanical lock will be free to be unlocked manually within 5 seconds.

2.3.1 Relay

The mechanical backup lock we implemented needs at least 1.6 A current to function properly. However, the current passing through our PCB cannot exceed 200 mA due to the current limitations of some components, such as the 7805ACT voltage regulator [6]. In order to have enough current passing through the mechanical backup lock, we need a relay to function as a switch driven by the voltage pulses from the detecting system and the unlocking system [9].

Figure 8 is a diagram of the relay we use in our project. The normally-closed pin (NC) is open. The normally-open pin (NO) is connected to the lock. C is connected to the battery. The inductor is connected to the output from both the detecting system and the unlocking system. Our lock does not consume any power when it is not receiving any signal since NC is open. When a voltage pulse is received, the switch is turned on. The current from the battery goes into NO and through the mechanical backup lock. When the voltage pulse halt, the switch is turned off again. No current passes through the lock and the lock will stay in its current state.

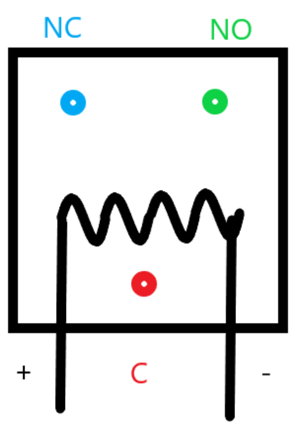

Figure 8 Relay Diagram

2.3.2 Mechanical Backup Lock

The Mechanical Backup Lock is made up using aluminum for economical purpose since aluminum is one of the cheapest and most corrosive-resistant metal we can find on market. If it is not locked, the backup lock should automatically lock itself when it receives the signal from the detecting system. If it is locked, the backup lock should be free to be unlocked manually within 5 seconds when it receives the voltage pulse from the unlocking system.

The Backup Lock consists of a spring, a solenoid and an aluminum plug. Figure 9-1, figure 9-2 and figure 9-3 present the mechanical design of the backup lock as well as a clear demonstration of the entire locking process. In figure 9-1, the solenoid receives no signal and the lock remains locked. The spring is compressed, and the aluminum plug is not pushed out. In figure 9-2, the solenoid receives the voltage pulse. When the solenoid gets pulled up, the spring starts pushing out the metal plug. When the voltage pulse halts, as demonstrated in figure 9-3, the solenoid gets pushed down into the rut on the metal plug.

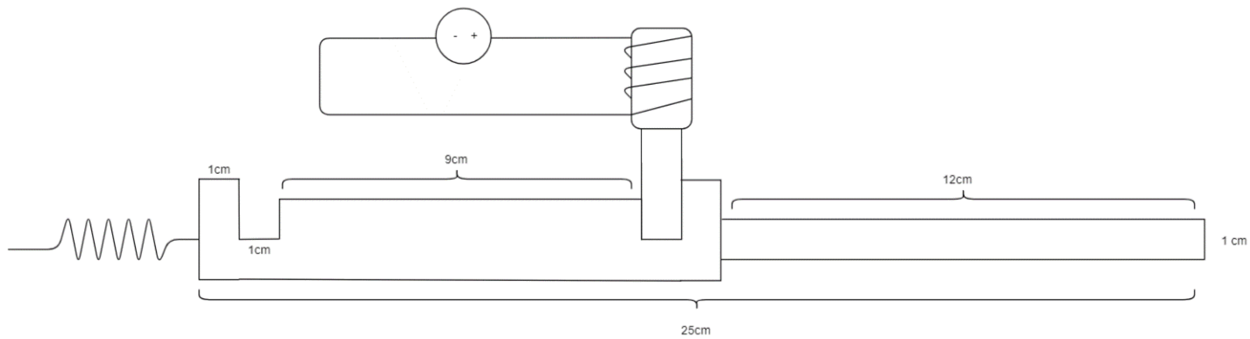

Figure 9-1 Not locked

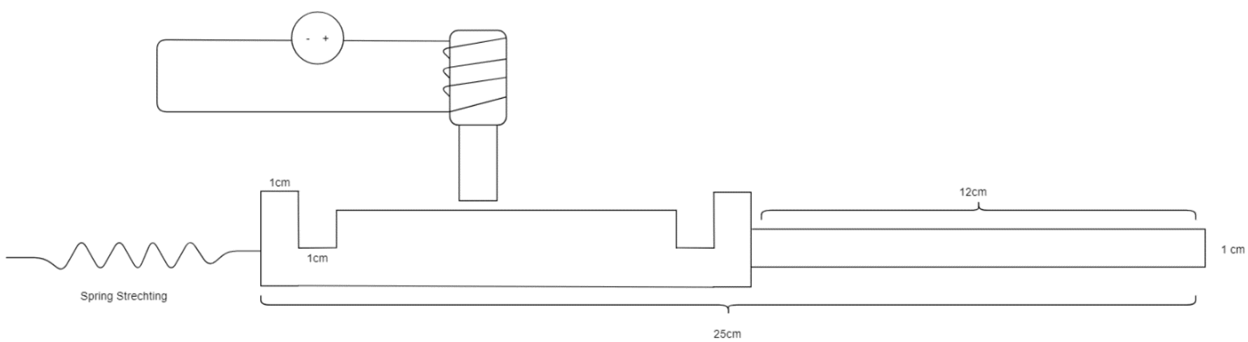

Figure 9-2 Locking

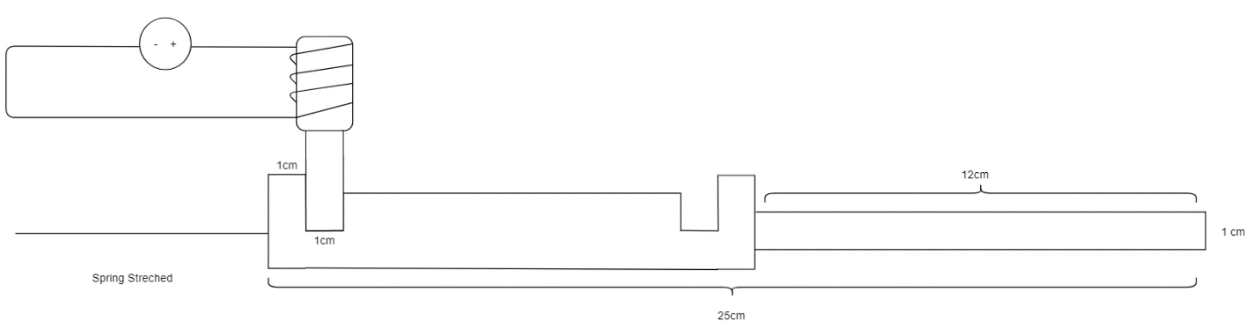

Figure 9-3 Locked

Additionally, we made some improvements on the design to enhance its feasibility. We made the plug hollow and put the spring inside the plug to save space. We also made the plug round to eliminate potential vibrational influence. Figure 10 shows both the side view and the top view of the plug.

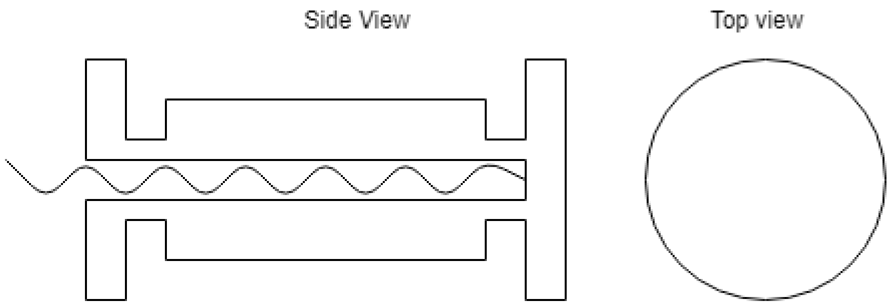

Figure 10 Feasibility enhancements

2.4 Unlocking System

The unlocking system consists of a Bluetooth module and a microcontroller. The Bluetooth receives password from mobile application then passes it to microcontroller. Microcontroller will determine whether the password is correct or not. If password is correct, microcontroller will send out a 5-second pulse to unlock the lock.

2.4.1 Bluetooth

The Bluetooth module we used is HC-05. 5 V is needed to drive this module. We used 4 pins of it, which are TX, RX, VCC and GND [9].

2.4.2 Microcontroller

Microcontroller is a programmable chip. We chose ATMEGA328T chip to achieve the purpose [7]. We used three pins in this sub-module: one TX pin, one RX pin and one output pin. The TX pin connects to Bluetooth's RX, and the RX pin connects to Bluetooth's TX. The algorithm programmed inside the microcontroller is indicated below.

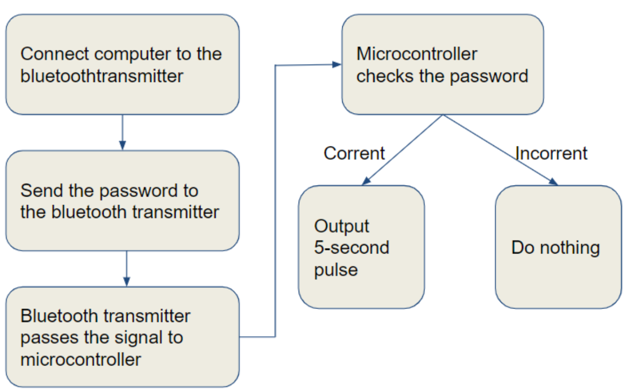

Figure 11 Flow chart of algorithm inside microcontroller

3. Design Verification

The expected functionality of our original design is perfectly achieved. When we cut the wire, which represents the regular lock, the backup lock automatically locks itself and the alarm sounds for 10 seconds. When we enter the password on our mobile application, the backup lock will be free to be manually unlocked within 5 seconds. The verifications of each subsystem are discussed below.

3.1 Power Supply

It needs to be verified that the power supply meets all the requirements that we need.

3.1.1 Ni-CD charger

Ni-CD charger should be able to charge our Ni-CD DC9096 battery within 40 minutes. To verify this, we first used all the energy in our DC9096 battery. After that, we use the charger to charge our battery. The battery is fully charged after about 35 minutes.

3.1.2 Ni-CD battery

Ni-CD battery has an output voltage of 18 V and capacity of 1500 mAh. To test the output voltage, we just simply connect the battery to a DC voltmeter. The measured voltage is 19 V, which falls into the acceptable voltage range. To test the capacity, we connect the battery to a 200-ohms resistor to make the current to be about 0.1 A. The current did not decrease after 15 hours, which indicates that the capacity is at least 1400 mAh.

3.2 Detecting System

The whole detecting system is functional in the condition that if the wire inside the regular lock is cut, a 1-second voltage pulse of 5 V is output and alarm sounds for 10 seconds. Below are the verification steps for each sub-component.

3.2.1 Microcontroller

We connected a wire between 5 V voltage supply and the input pin of the microcontroller. The two output pins are connected to the oscilloscope. Once the wire is cut, we captured the signal on the oscilloscope. One signal is a 5 V 1-second pulse and the other is a 5 V 10-second pulse.

3.2.2 Alarm circuit

To verify the alarm circuit, we apply a 5 V input for the circuit and make sure the alarm can sound with an acceptable loudness.

3.3 Locking System

If the locking system is not locked, it automatically locks itself when it receives the voltage pulse signal from the detecting system. If the locking system is locked, it is free to be unlocked manually within 5 seconds when it receives the voltage pulse from the unlocking system. The locking system of our design meets the requirements and functions perfectly. Below are the verification steps for each sub-component.

3.3.1 Relay

We connect C to the battery, the inductor to the power supply, NO to the multimeter and leave NC open. We first measure if the output of NO is 0 with the multimeter when the inductor of the relay is not receiving any signal. Then we input a 5 V voltage to the inductor and measure the output of NO to see if it matches the voltage of the battery, which is 18 V.

3.3.2 Mechanical Backup Lock

We manually connect the battery to the input of the mechanical backup lock.

To verify the locking process, we first manually pull up the solenoid and adjust the position of the lock so that it is not locked. We then let the battery and the lock stay connected for 1 second to see if the lock can successfully lock itself.

To verify the unlocking process, we first manually push down the solenoid into the left rut of the metal plug so that it is locked. We then let the battery and the lock stay connected for 5 second to see if the lock can be manually unlocked within 5 seconds.

3.4 Unlocking System

The whole unlocking system is functional except the Bluetooth cannot support iOS system due to the old version of Bluetooth module. We use computer to instead of iPhone. Below are the verification steps for each sub-component.

3.4.1 Bluetooth

To verify the Bluetooth function, we connect Bluetooth with computer 5 meters away, and write a program to test whether Bluetooth can receive the password, once Bluetooth receive the password, it will give a signal back to computer, which will show a text of what password that Bluetooth received.

3.4.2 Microcontroller

To verify the microcontroller, we first connect tested Bluetooth module to microcontroller. Bluetooth’s RX pin connected to microcontroller’s TX pin, Bluetooth’s TX pin connected to microcontroller’s RX pin and microcontroller’s output pin connected to oscilloscope. Once the Bluetooth receive the password, microcontroller will determine whether the password correct or not. If password correct, a 5 V 5-second pulse will generate from the output pin. Otherwise, nothing will happen.

4. Costs and Schedule

4.1 Parts

Table 1 Parts Costs

Part	Manufacturer	Retail Cost ($)	Bulk Purchase Cost ($)	Actual Cost ($)
Ni-CD battery [5]	DeWalt	28.95	14.99	28.95
Ni-CD charger [4]	DeWalt	28.99	19.99	28.99
Voltage Regulator [6]	STMicroelectronics	0.52	0.21	0.52
Arduino Uno [10]	RoboGets	22.00	16.90	22.00
Mini-speaker [8]	CUI Inc.	1.95	0.39	1.95
HC-05 Bluetooth [9]	HiLetgo®	8.49	4.99	8.49
Solinoid [11]	Amazon	7.49	1.80	7.49
Total		**98.39**	**59.27**	**98.39**

4.2 Labor

Our fixed development labor costs are estimated to be $30/hour, 10 hours/week and 16 weeks for three people.

$$3 * \frac{\$15}{\text{hour}} * \frac{10\text{ hours}}{\text{week}} * 16\text{ weeks} * 2.5 = \$18000$$

4.3 Schedule

Table 2 Schedule

Week	All group members	Shijie He	Jiahao Chen	Zhengyu Ji
2/18/2019	Design schematics and PCB and Write design document	Design schematics and PCB and Write design document	Design schematics and PCB and Write design document	Design schematics and PCB and Write design document
2/25/2019	Finalize schematics design	Program the unlocking system	Run final simulations	Contact the machine shop and draw CAD
3/4/2019	Finalize PCB design and get the PCB board	Buy the microcontroller	Buy the bluetooth equipments	Buy the electromagnet and spring
3/11/2019	Solder PCB board with all parts implemented	Soldering	Soldering	Soldering

3/18/2019	Program the microcontroller	Test the utility of microcontroller and unlocking system	Circuitry modulo testing and debugging	Test the utility of electromagnet and spring
3/25/2019	Design the prototype case	Modulo test and debug	Modulo test and debug	Contact the machine shop and finalize CAD
4/1/2019	Connect all the parts with PCB and power	Final test and debug	Final test and debug	Test the utility of the lock sub-system
4/8/2019	Product stability and weather condition testing	Test the waterproof quality of the device	Test the stability of the device	Connect the lock sub-system to PCB
4/15/2019	Prepare demonstration	Prepare demonstration	Prepare demonstration	Prepare demonstration
4/22/2019	Prepare final presentation	Prepare final presentation	Prepare final presentation	Prepare final presentation
4/29/2019	Write final report	Write final report	Write final report	Write final report

5. Conclusion

5.1 Accomplishments

We almost complete all the functionalities as we expected. Once the wire inside the regular lock is cut, two pulses are correctly generated, and can successfully drive the lock and alarm circuit. The Bluetooth module inside the device can be successfully connected by the computer and correctly receive the serial signal sent by the computer. The microcontroller can determine whether the password is correct or not and perform correct action in each case.

The only part that is not functional is that the Bluetooth module is not compatible with IOS devices, such as iPhones. Thus, we can only use computers to connect to the device to unlock the backup lock for now.

The overall looking of the project is not quite good now since we did not have enough time to make things neat and put everything into a whole metal box.

5.2 Uncertainties

We might consider developing some alternative approaches to unlock our project, like a fingerprint or facial recognition system. Although fingerprint and facial recognition system are safer compared to simply passcode unlocking, the two approaches can be unreliable due to other factors, like hand sweat and environmental conditions. We are not sure if we can develop a safer and reliable unlocking method to better our bike lock.

Also, the lock will be exposed to the environment when it is implemented on a bicycle. We are not sure if it can endure severe weather conditions, like rains or snows. We need to take the waterproof quality of our device into consideration.

5.3 Ethical considerations

As we discussed above, we might consider using facial recognition or fingerprint tests when we further develop our unlocking system. We then need to run huge amounts of facial recognition or fingerprint tests. These data may be an invasion of other's privacy, so we need to be careful about ethical issues when picking those samples.

Also, when a company publicizes their product, the level of credential is the problem. These results are not honest and realistic during product publicity, which violates the #8 of the IEEE Code of Ethics, "to be honest and realistic in stating claims or estimates based on available data" [12]. We plan to encrypt every face data we used to prevent the data divulge. We will open our data sources to the public as the proof of our honesty.

5.4 Future work

Although the functionalities of the project are mostly achieved, there are still some improvements that we can make our project better. First, the backup lock is about 30 cm long and a little heavy. To make it more compact, we could try some different materials to build it. What's more, to insert the spring into the lock bolt and make the lock into a round shape could help decrease its dimension.

Secondly, we can improve the appearance of the electric part. Now, there are wires across different boards and different parts of the system. We could design a larger PCB that includes all the components. Also, we need a waterproofed metal shell all around our device since bicycles are sometimes used in rainy weather.

Lastly, since the Bluetooth module we are using in this device is not compatible with IOS devices, we will need a more universal one instead. We hope the new Bluetooth module can connected with all different phones, computers and even other smart devices, such as apple watches.

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Appendix A Requirement and Verification Table

Table 3 Requirements and Verifications

Requirement	Verification	Verification status (Y or N)
1. The detection circuit should output two voltage pulse signal of 1-second (to the backup lock) and 10-second (to the alarm circuit) when the regular lock is opened.	1. Simulate the circuit on LTSPICE to make sure that the simulation gives us the correct result. Measure the output of the circuit after it is implemented.	Y
2. The backup-lock will be locked once it receives the 1-second signal.	2. Input a 1-second voltage pulse to the relay and observe the result. The spring should push out the metal stick for around 10 cm as indicated by the physical design.	Y
3. The alarm should sound 10 seconds when it receives the 10-second signal.	3. Alarm can be correctly activated when the pulse starts.	Y
4. The Bluetooth module can be found and connected successfully by phone or computer. The Bluetooth signal transmission can be achieved within 5 meters.	4. Search for Bluetooth receiver on the phone and make sure it can connect successfully. Walk away from the receiver at least 5 meters and test if the Bluetooth still works by sending a test signal.	Y
5. Microcontroller can receive the serial signal from Bluetooth and output a 5-second pulse.	5. Connect microcontroller to a Bluetooth receiver and send code to the Bluetooth receiver. Make sure the microcontroller receives the same code we sent and output a pulse of 5 seconds.	Y
6. The backup-lock will be free to be unlocked manually for 5 seconds once the relay receives a 5-second signal.	6. Input a 5-second voltage pulse to the relay and observe the result. The solenoid should be pushed up and the metal stick should be free to move backwards within 5 seconds.	Y