# Multipurpose Key Chain with Lock Device

ECE 445 | Senior Design Project

# Design Review

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# Introduction

Despite the improvement in the variety of locking devices available in the market, including electronic keycards and fingerprint recognition, mechanical locks still play a significant role in our everyday life. Such locks inevitably create problems to lots of people. More than often, one always tries to remember whether he or she locks the door when leaving the apartment. You have to either go back to check it or just live with the anxiety. Remember the time when you stand outside of your office or laboratory with a bunch of similar or identical ones, from which you have to find the correct one? Or the time you try to recall where you leave the keys in your room? Such trivial but annoying problems will not just go away without getting rid of all the mechanical locks. We aim to solve these problems with a key chain that is easy to carry and use.

## Objectives

The key chain that we are going to implement will be a working prototype of any possible extensions. It will carry 8 keys with LEDs attached to each of them. Every lock is installed with a corresponding device as well. Whenever the status of a certain lock (locked or unlocked) changes in range, the information will be updated to the key chain via Bluetooth and stored. This information can be triggered to be displayed anytime from anywhere with the RGB LED indicators. When someone is near a door, by pressing a button on the door, the key chain could identify the right key for it by lighting up the LED corresponding to it. A small buzzer (speaker) will be installed on the key chain that can be triggered by any door device if in range for one to trace where it is. Last but not lease, via internet, with a smart phone or any device that has a browser, locks can be remotely locked with the help of a servo motor.

### *Benefits*

- Instantaneous access to lock information and able to remotely control them.
- Save time and troubles by detecting corresponding key to the nearest lock.
- Able to track keys within range of a registered lock.

### *Features*

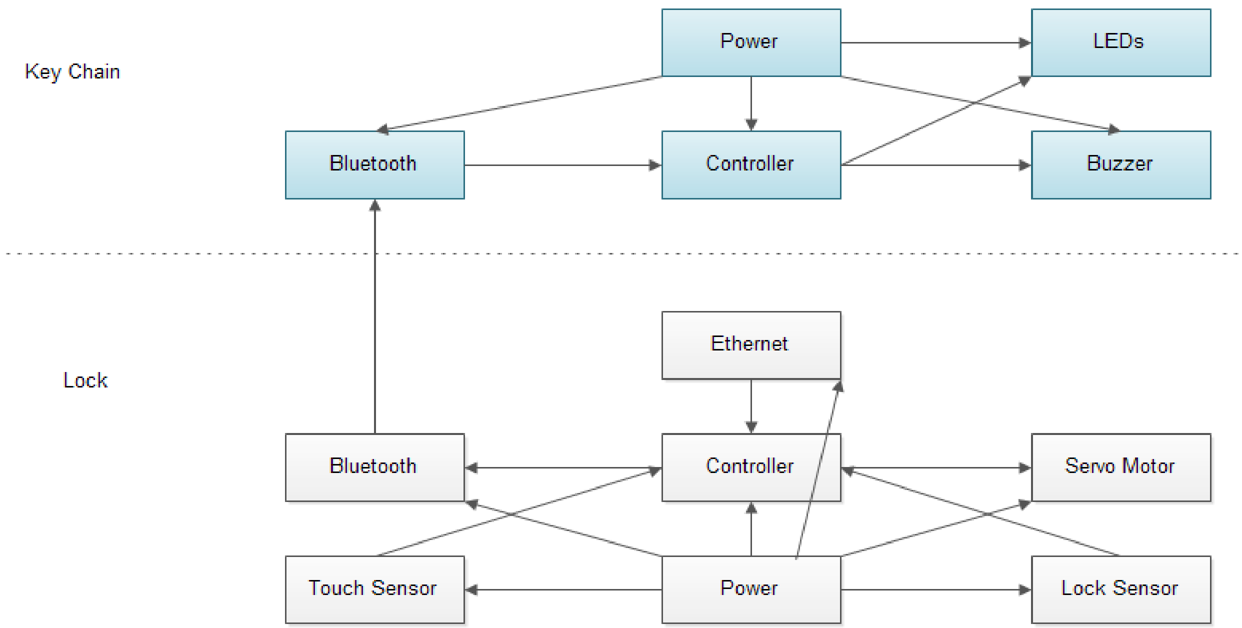
- Light, portable, easy to carry and easy to use.
- Bluetooth communication interface.
- LED indicators.
- Long battery lifetime and easy to change battery.

- Easy to setup or add new keys and locks.
- Reliable and accurate detection.

# Design

The design in this project involves two components, the key chain and the lock device. Both devices are designed separately with wireless communication enabled between the two.

## Block Diagram




## Block Descriptions

### *Power Supply (Key Chain):*

We will be using a 9V alkaline battery with a power regulator. Majority of the circuit will require a 3.3V voltage input and 9V battery is the easiest one to obtain on market and it has the best voltage to size ratio. It supplies power to the entire circuit in the keychain including the controller, the LEDs, the wireless communication interface and etc. For miniaturization considerations, we might change the battery to be used later on in the process and make sure the input voltage will just be maintained at 3.3V.

### *Power Supply (Lock):*

On the lock side, miniaturization will not be as much as a big issue as compared to the key chain. A 9V battery will still be used the same way as described above. The battery is going to supply power to the entire circuit in the lock device.

### *Controller (Key Chain):*

The controller will make use of a Atmel ATmega328 microcontroller chip. It is going to be loaded with the Arduino UNO boot loader and will be programmed using the Arduino programming environment with the help of the FT232RL USB to serial breakout board. It is responsible of processing all information received via Bluetooth or user control via button presses. Also, it will process information and send out signals to light up corresponding LEDs or sound the buzzer.

### *Controller (Lock):*

The controller on the lock device side will perform almost the same way except that there is going to be no LEDs or speakers there. We are still going to be using the same chip here. It is going to output its control signals to the servo motor which is responsible for locking the lock. The inputs to this controller include information obtained through Bluetooth and Ethernet as well as button presses.

### *LEDs:*

Since these LEDs are used as indicators for users to know the status of each lock at anytime. It needs to be able to display different information with different colors. We are going to use 8 Bi-Color LEDs in this case. Three PWM outputs from the microcontroller will be directed to the red, blue and green inputs of these LEDs and with the help of a multiplexer, we are able to light up the right LED with the right color based on stored information.

### *Buzzer:*

The speaker is responsible for letting the user track the location of the key chain by producing sound. A small PCB speaker or buzzer will be used.

### *Lock Sensor:*

The lock sensor will be self built to detect whether a door is being locked or unlocked at a time. It will be mounted on existing locks. The circuit has metal ends at the end of the lock's latch as well as the inside surface of the lock's socket. It produces signals about whether the metal surfaces are in contact; hence indicating whether or not it is locked.

### *Touch Sensor:*

The touch sensor will be installed outside of a door (lock) and it will be activated when a touch is performed by a user. It will trigger the lock's Bluetooth module to send out information, in this case, the specific ID number associated to the lock. This will be received by the key chain so as to know which key it is to this particular lock.

### *Servo Motor:*

The motor here is used to automatically lock or unlock a lock when remotely controlled via Ethernet. We choose a DC servo motor here because it perfectly fits our need. To lock or unlock a door, the knob is turned clockwise or counter-clockwise by a certain angle and this can be easily implemented by using a servo motor.

### *Bluetooth (Key Chain):*

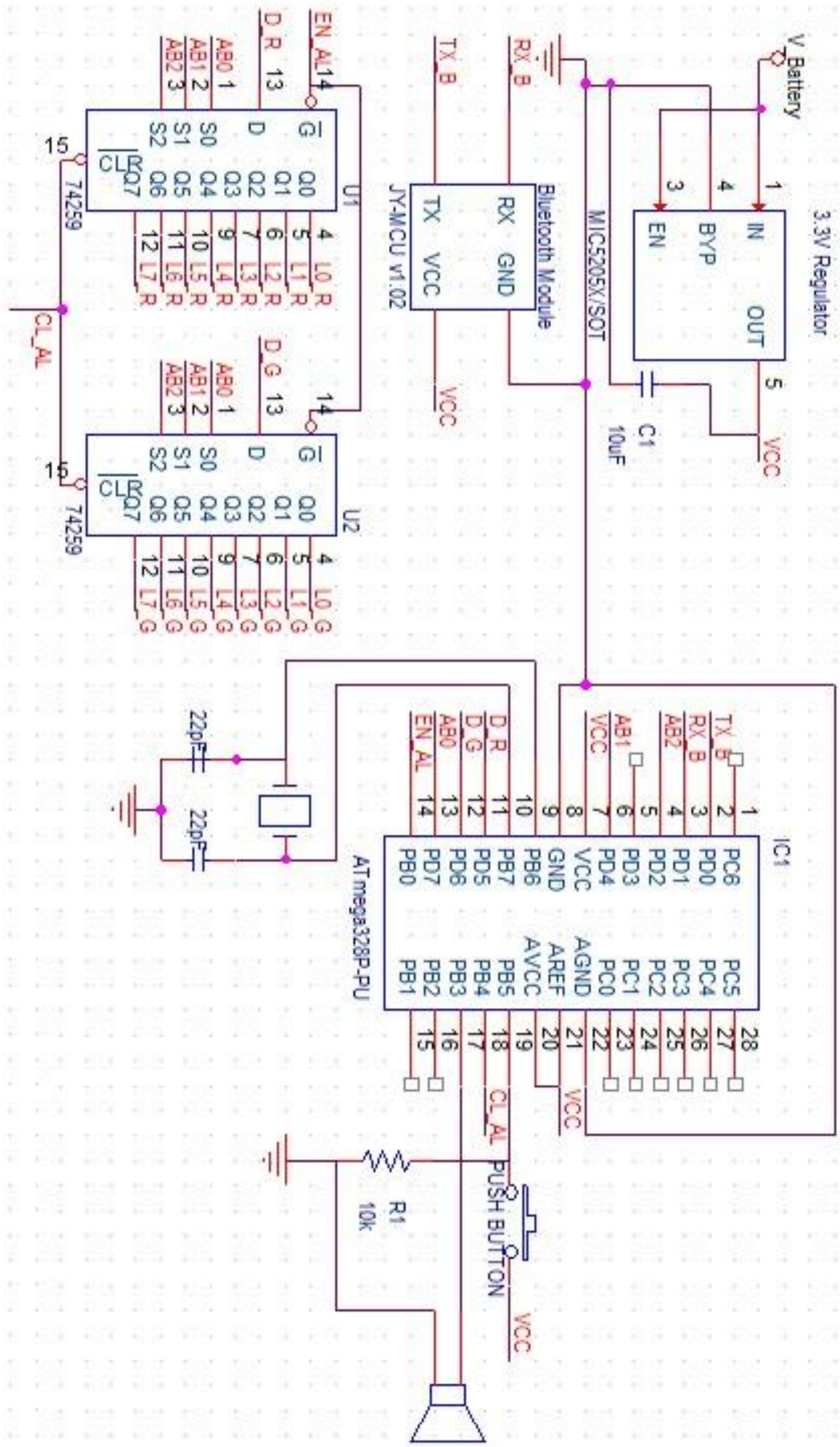
The Bluetooth block is the most crucial and important one in the entire design. On the key chain side, an Arduino Bluetooth transceiver RS232 will be installed on the key chain so that it is going to be able to receive information from the locks. Every time one locks or unlocks a door, signals will be sent via Bluetooth to update current status of the locks in the keychain. It is also responsible for receiving lock ID numbers from the lock when the touch sensor is activated so that the key chain will know which key is the right one.

### *Wireless Communication (Lock):*

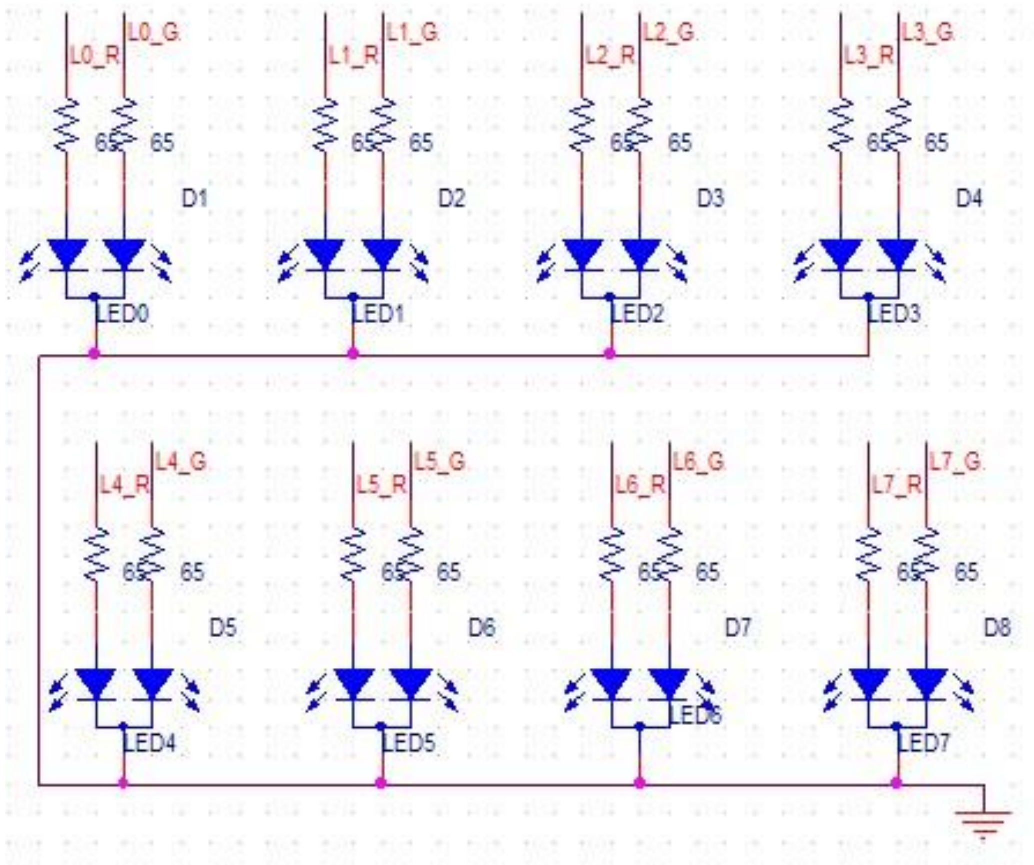
On the lock side, there is also going to be a same Bluetooth transceiver installed on the lock device to send and receive information with the key chain. It is responsible for sending out status and ID numbers associated with this lock. Other than that, communication is also enabled with a Microchip ENC28J60 Ethernet controller. This is connected using an Ethernet cable so that information can be sent using any device with an internet browser from anywhere.

## Schematics

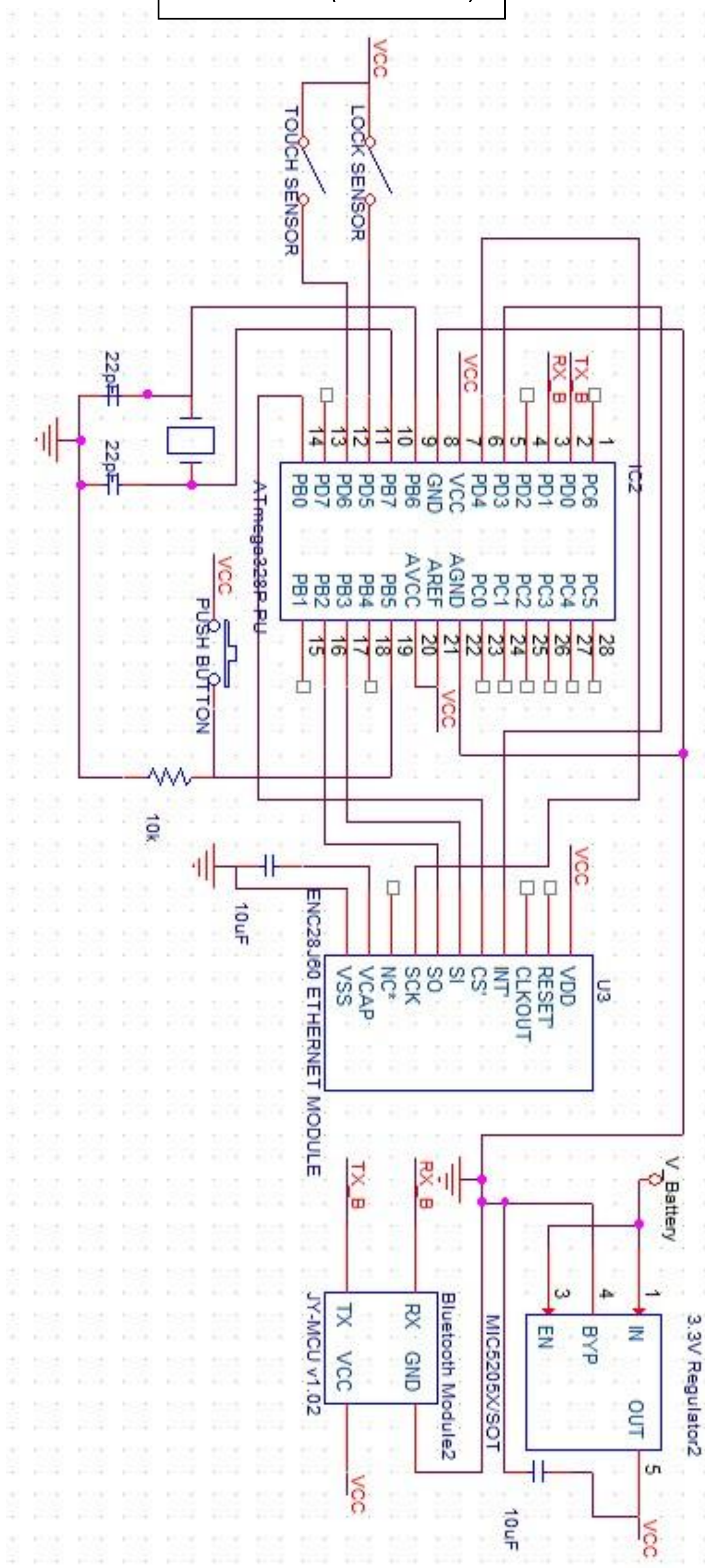
Schematics 1 (Key Chain, Except LEDs)



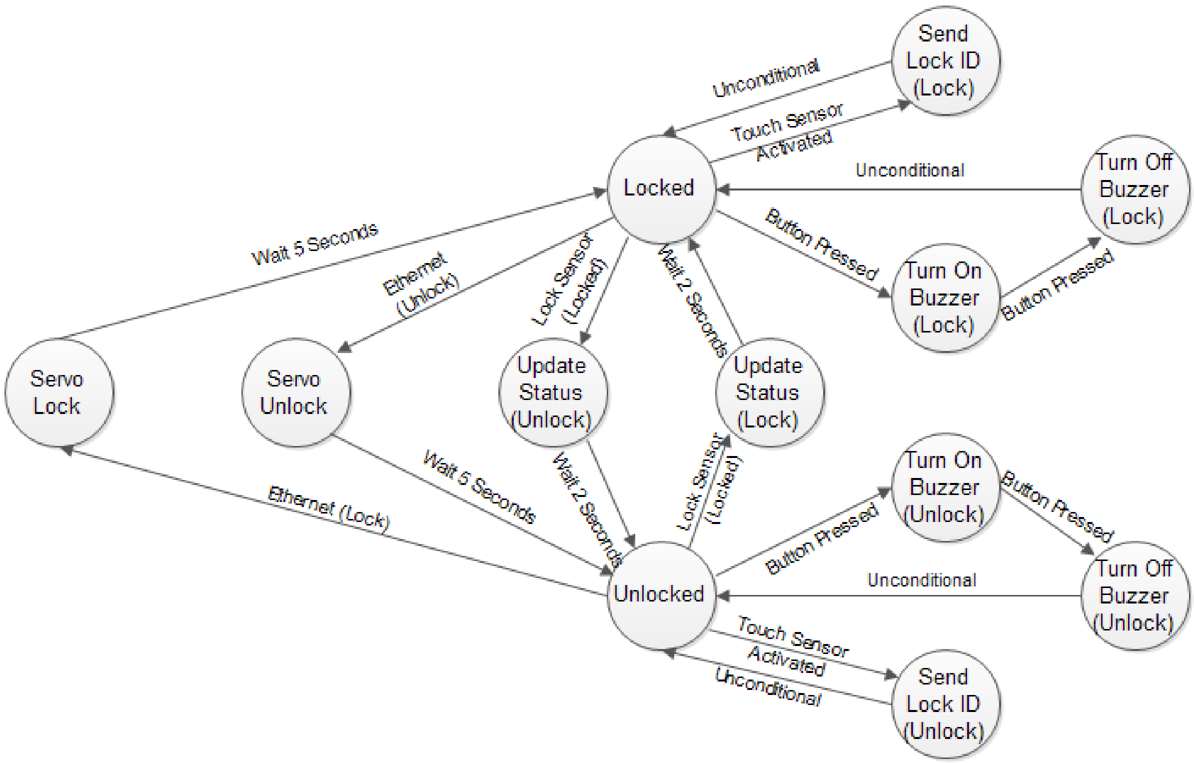
Schematics 2 (LEDs)



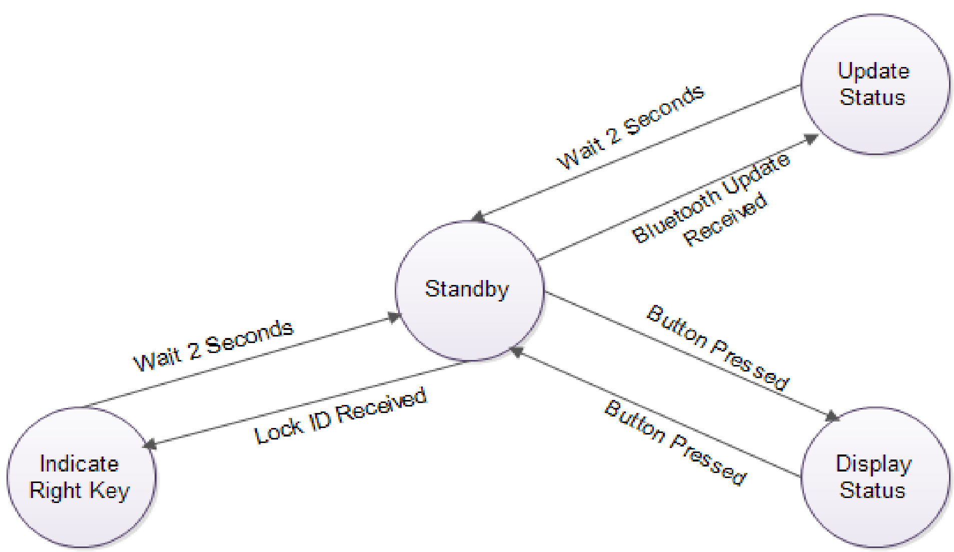
Schematics 3 (Lock Device)



## Control Flow




State Diagram for Lock Device




State Diagram for Key Chain

## Calculations

Some calculations are performed in the design stage to produce results that are relevant and helpful in determining certain parameters to meet design specifications.

First of them is the calculations regarding the LEDs. The LEDs to be used have an operating current of 20mA and voltage of 2V. To meet this requirement, resistors have to be placed in series with the LEDs in order to ensure the right current value.

The voltage output will be 3.3V and the voltage across the LEDs will be 2V. Therefore, the resistor will have 1.3V voltage across it. The resistance value is then calculated by

$$V_R = \frac{3.3 - 2}{2 \times 10^{-3}} = 65\ \Omega$$

The other value to be determined is the current output to the device. There are a few situations involved, including when the buzzer is turned on, when the LEDs are on, when the Bluetooth is working, when the servo motor is on and etc. Some of the components do not have clear datasheets included. We put together the current output from all devices when they are in standby mode and it ends up being around 100mA for both devices. Further measurements and calculations will be performed with the actual parts.

# Test and Verification

## Requirements and Verifications

In order to have this project working, both the lock device and the key chain have to be able to complete their own functionalities and they should reliably communicate with each other. All these involve the proper operations of all modules listed above in the block description part. In the table below, the requirements and verification procedures are listed for each individual module consisting of sub-requirements to be verified and tested.

| Module | Requirements | Verification Procedures |
| --- | --- | --- |
| Power Supply (Key Chain) | 1. Supply steady 3.3V output voltage.<br>a) Able to provide 3.3V output voltage at various output current.<br><br>2. Able to last for a considerable amount of time (45 days).<br>a) The worst case scenario is tested assuming all components are consuming maximum amount of power.<br>b) The average case is examined with reasonable estimates and calculations. | 1. a)<br>- A test circuit will be built using the voltage output from the voltage regulator with different values of resistors<br>- Based on preliminary calculations, the current output for standby mode is around 100mA and will not exceed 300mA with all components active.<br>- Tests will be performed from 50mA to 300mA with 10mA intervals.<br>- Values of resistors are controlled to obtain the current values.<br>- The voltage across resistor will be measured using a multi-meter and recorded.<br>**Expected Results:** At all current values, the voltages measured should fall within the range of 3.25V to 3.35V.<br><br>2. (This step is calculated, instead of tested using bench equipment because it is not possible to monitor the battery for a long time over months. However, with reasonable assumptions, the calculated results should give a brief idea of the power consumption of the devices.)<br>a) Assuming all modules are |

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| | | consuming maximum power, calculate the time it is going to take before the battery drains. This should give us a brief idea of how long the device could last at least.<br>b) Estimate that an average user uses the key chain 6 times a day and each time the LEDs light up for 5 seconds. Also assume that the buzzer is used once every 3 days with duration of 15 seconds each time. Under these circumstances, calculate the operating current together with devices that continuously draws power. The result needs to be more than 45 days. |
| Power Supply (Lock) | 1. Supply steady 3.3V output voltage for entire circuit except the servo motor.<br>a) Able to provide 3.3V output voltage at various output current.<br>b) Supply required voltage for servo motor.<br><br>2. Same as "2." from Power Supply (Key Chain) section. | 1. a) Same as "1. a)" in Power Supply (Key Chain) section.<br>b)<br>- The servo motor operates best between 4.8V and 6V.<br>- The test will be set up using power supply from the 3.3V voltage output.<br>- The current through the servo motor will be measured using a multi-meter.<br>- The operation behavior will be monitored too.<br>**Expected Results:** If the current falls within the normal range suggested by the data sheet and the operation behavior of the servo motor is not abnormal, 3.3V will be used. If not, a different circuit will be used to provide power to the servo motor.<br><br>2. Same as "2." from Power Supply (Key Chain) section except with different estimations. The servo motor together with the Ethernet module is estimated to operate once every 6 days. The corresponding result should be |

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| | | more than 45 days. |
| LEDs | 1. The LEDs should be able to light up two distinguishably different colors. | 1.<br>- The test circuit will be set up using the bi-color LEDs with each input connected to a 65 Ohm resistor.<br>- 3.3V voltage will be applied to each pin of each LED.<br>**Expected Results:** The LED should light up red with input to the red pin and green with input to the green pin. These colors should match the intended color and should be easily distinguishable. |
| Buzzer | 1. Able to produce sound to be heard under variety of circumstances.<br>a) Able to hear sound within 15 meters in clear distance.<br>b) Able to hear sound within 10 meters in a separate room.<br>c) Able to hear sound within 10 meters with buzzer places in closed objects, such as drawers and boxes. | 1. a)<br>- The buzzer will be placed on a bread board with 3.3V input voltage.<br>- It will be triggered by one of the group members at 15 meters away from the rest.<br>**Expected Results:** The other two people have to be able to clearly hear the buzzer and determine its location.<br><br>b)<br>- The same buzzer circuit from part (a) will be triggered inside one of the rooms in Everitt Lab 10 meters away from where the other two members stand.<br>**Expected Results:** Both members have to be able to hear the sound clearly and determine which room it is in.<br><br>c)<br>- The same buzzer circuit will be triggered inside a drawer at home with two members standing 10 meters away.<br>**Expected Results:** Both members have to be able to hear the sound clearly and locate the buzzer. |
| Bluetooth Transceiver | 1. The Bluetooth module on the key chain should be able to receive data | 1. a) b)<br>- The Bluetooth transceiver will be |

| | | |
|---|---|---|
| (Key Chain) | reliably and quickly from the sender.<br>a) The Bluetooth module should receive data from sender without errors at distance between 0.1m to 15m.<br>b) The Bluetooth module should receive data without errors within closed objects or rooms.<br>c) No data is lost when the time interval between sending is short. | connected to an Arduino Uno board.<br>- The Arduino will be programmed to send 300 sets of data with 2 second intervals.<br>- The computer enabled with Bluetooth will be the receiver and all data received will be monitored on the screen.<br>**Expected Results:** All data should arrive and be displayed on the screen with no single error.<br><br>c)<br>- This is the same setup as described above.<br>- The Arduino will be sending 100 sets of data with 0.5 second interval.<br>**Expected Results:** All data should arrive and be displayed on the screen without losing any single one. |
| Bluetooth Transceiver (Lock) | 1. The Bluetooth module on the lock should be able to send data reliably and quickly from the sender.<br>a) The Bluetooth module should send data that is passed from the controller without errors.<br>b) No data is lost when the time interval between sending is short. | 1. a)<br>- The sender will be the same circuit above with the receiver being another Bluetooth module connected to an ATmega328 chip.<br>- 300 sets of data will be sent and the received data will be monitored on the screen.<br>**Expected Results:** All data should arrive and be displayed on the screen with no single error.<br><br>c)<br>- This is the same setup as described above.<br>- The Arduino will be sending 100 sets of data with 0.5 second interval.<br>**Expected Results:** All data should arrive and be displayed on the screen without losing any single one. |
| Servo | 1. Able to rotate a specified angle | 1. |

| | | |
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| Motor | correctly.<br><br>2. Able to turn lock's knob to perform lock and unlock. | - The servo motor will be connected with PWM output from the ATmega328 chip.<br>- The ATmega is programmed to send out a series of control command involving roting 10 to 180 degrees clockwise with 10 degree interval.<br>- The servo needs to return to its original position 5 seconds after each rotation.<br>- A protractor will be used to measure the angle turned and all measurements will be recorded.<br>- The same test is then performed with the servo motor rotating counter-clockwise.<br>**Expected Results:** All recorded data should be within 1degree tolerance range of the intended rotation.<br><br>2.<br>- The servo will be connected to a mechanical lock.<br>- The angle to be turned in order to lock and unlock the lock is recorded.<br>- The servo will receive command from the ATmega328 chip to turn the predetermined angle in order to lock and unlock the lock.<br>- 10 locks and 10 unlocks are performed and results are recorded.<br>**Expected Results:** All 20 operations should be completed with no failures meaning that each time the lock needs to be locked or unlocked matching the intentions. |
| Lock Sensor | 1. Should output correctly when the status of lock changes.<br><br>2. Should keep track of the status of lock with fast change of state, meaning | 1<br>- The sensor will be installed on a mechanical lock.<br>- The lock will be manually locked and unlocked 100 times each. |

| | | |
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| | when lock and unlock are performed with very short time interval. | - The output is observed on an oscilloscope.<br>**Expected Results:** The waveform on the oscilloscope should match correctly to the operations without a single error.<br><br>2.<br>- The same setup from part 1 will be used.<br>- The door will be manually locked but at a very fast speed by a group member.<br>- One other member will count the number of times locks and unlocks occurred.<br>**Expected Results:** The waveform on the oscilloscope should not miss any of the operations. |
| Ethernet Module | 1. Correctly receive information based on controls sent via computers or smart phones. | 1.<br>- The Ethernet module will be connected to the ATmega328 chip.<br>- 10 Sets of commands will be sent from an iPhone, an Android phone, an iPad and a computer each.<br>- The received command is decoded and displayed on screen.<br>**Expected Results:** All data on screen should match that sent from all devices without any error. |
| Controller (Key Chain) | 1. Detects button presses correctly.<br>a) Button needs to be debounced and respond correctly to fast pressings.<br><br>2. Able to display correct information by lighting up correct LEDs.<br>a) Correctly indicates the right key given the lock ID.<br>b) Correctly light up all LEDs based on stored information of lock status.<br><br>3. Able to store or output correct information | 1. a)<br>- The button will have one side being connected to a 3.3V voltage source and the other to an ATmega328 chip.<br>- The ATmega controller is preprogrammed with a debounce function and the output to an oscilloscope is high when button is pressed.<br>- The button will be manually pressed 100 times as fast as possible.<br>**Expected Results:** The output on the oscilloscope should indicate 100 |

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| | | presses.<br>2. a)<br>- The controller will be connected to a Bluetooth module.<br>- A total of 100 signals indicating lock IDs will be sent.<br>- The controller will generate signals light up the correct LED based on the ID.<br>- The generated signal will be monitored using an oscilloscope.<br>**Expected Results:** The output signal should match the intended output to the correct LED.<br><br>b)<br>- 10 sets of different combinations of the locks' status will be written into the microcontroller.<br>- The LEDs are going to be attached to the microcontroller as indicated in schematics 2 in page 8.<br>- The behavior of all 8 LEDs will be monitored and recorded.<br>**Expected Results:** The LEDs should exactly match the pre-written information about the locks for all 10 times.<br><br>3.<br>- Without the Bluetooth module attached, an input pin will be used to simulate the data input from the Bluetooth module.<br>- 20 different Commands including triggering buzzer and update information will passed to the controller.<br>- The controller will generate different output based on different information received. |

| | | |
|---|---|---|
| | | **Expected Results:** The output should match the commands without single error. |
| Controller (Lock) | 1. Same as "1." from Controller (Key Chain) section.<br><br>2. Correctly generates output signals to be sent via Bluetooth and Ethernet.<br>a) Correctly generate output for updating status.<br>b) Correctly generate lock ID.<br>c) Correctly generate signal to trigger buzzer.<br>d) Lock or unlock. | 1. Same as "1." from Controller (Key Chain) section.<br><br>2. a) b) c)<br>- A function generator will be used to generate square wave simulating the lock sensor and touch sensor.<br>- The output from the microcontroller will be monitored on a computer.<br>**Expected Results:** The output needs to show the exact command to be generated based on the input from different sensors without a single error. |

## Tolerance Analysis

The controller will be considered as the most important part of the entire design. The major job of our design is to make the controller modules on door and keychain working reliably and efficiently. More specifically, our controller module on the door should generate the correct output signal immediately when the door status changes. And the door status in the system can be updated quickly at a real-time.

For testing the module on the door, we lock and unlock the door with one second stop between each status change. And we expect the module can receive the signal and generate to change the door status in the system instantaneously within 0.5s time delay. When we watch through the testing result by demonstrating the signal received on PC, so we should see the door status change continuously.

Also for controller to ask the servo motor to rotate a specific degree, the accuracy should within 5 degree as our expectation. And the operation should be accomplished within a short time, we expect the door can lock and unlock in 2 sec. We plan to test this by successfully operating lock and unlock door 5 times continuously with one second between each time.

For the keychain, we want to make sure that no data is lost or misread after received by the Bluetooth receiver. Specifically, we want the status to be continuously updated even with data coming in at a very fast rate, for example, 0.5s intervals. Also the buzzer will start or stop to play sound as soon as we press the button on the door or keychain side. Last but not least, the controller can determine the right the key to light up its BLUE LED without disturbing the other key status according to the sent signal.

In conclusion, this project consists of a number of small constituent modules and they have to coordinate well by the control of the microcontrollers to achieve efficient, precise and accurate operation and functions.

# Ethics Considerations

When working on this project, we will comply strictly to the IEEE Code of Ethics as well as the moral standards set among the members. We will make sure that the process of development and the final product will not violate any rules, regulations or moral principles. The following table illustrates all relevant ethical issues corresponding to the IEEE Code of Ethics.

| Relevant IEEE Code of Ethics | Relevance in Project |
|---|---|
| 1. to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment; | The keychain that we are going to develop is going to integrate a battery as the power supply. We will make sure that the battery makes stable performance at all times so that it does not create potential harm to others. As we are dealing with doors and locks, we will make sure that the device to be develop does not pose any safety or security issues on society. |
| 3. to be honest and realistic in stating claims or estimates based on available data; | We will make sure that all experimental data and calculations illustrated in all related documents in the process of this project are honest and real. |
| 6. to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations; | We will not embark on producing or marketing devices made in this course unless after qualified training and approval. |
| 7. to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others; | Our group will listen and accept all constructive advice and suggestions from people around us and will acknowledge any contribution towards the eventual result of this project. |
| 10. to assist colleagues and co-workers in their professional development and to support them in following this code of ethics. | All group members will keep the code of ethics on our mind and remind ourselves and group mates throughout the process. We all are responsible and accountable for this project. |

# Cost Analysis

## Parts

| Module | Part | Unit Cost | Number | Subtotal |
|---|---|---|---|---|
| Power Supply (Key Chain) | Energizer 522BP-2 9V Alkaline Battery | 3.99 | 1 | 3.99 |
| | MIC5205-3.3BM5 Voltage Regulator | 1.05 | 1 | 1.05 |
| Power Supply (Lock) | Energizer 522BP-2 9V Alkaline Battery | 3.99 | 1 | 3.99 |
| | MIC5205-3.3BM5 Voltage Regulator | 1.05 | 1 | 1.05 |
| Bluetooth (Key Chain) | Arduino Bluetooth Transceiver Module RS232 | 8.39 | 1 | 8.39 |
| Bluetooth (Lock) | Arduino Bluetooth Transceiver Module RS232 | 8.39 | 1 | 8.39 |
| Ethernet | Microchip ENC28J60 Ethernet Module | 4.39 | 1 | 4.39 |
| | 6 ft Ethernet Cable | 0.99 | 1 | 0.99 |
| LEDs | Bi-Color LED – Common Cathode, Pack of 10 | 2.00 | 1 | 2.00 |
| Buzzer | PCB Tone Alarm Buzzer | 0.15 | 1 | 0.15 |
| Motor | Hitec HS-322HD Standard Heavy Duty Servo | 9.99 | 1 | 9.99 |
| Controller (Key Chain) | Atmel ATmega328P-PU Microcontroller with Bootloader | 5.50 | 1 | 5.50 |
| | **USB to UART Bridge – FT232RL*** | **10.95** | **1** | **10.95** |
| Controller (Lock) | Atmel ATmega328P-PU Microcontroller with Bootloader | 5.50 | 1 | 5.50 |
| Misc. | Resistors, Capacitors, Wires, PCB and so on | 10.00 (Esti-mate) | 1 | 10.00 |
| | | | Total | 76.33 **(65.38)** |

* This breakout board will only be used for programming and configuring the controller chip, hence does not contribute to the total cost in the device because it is not included.

## Labor

| Members | $/Hour | Hours/Week | Number of Weeks | Total/Person | *Multiplier (2.5) |
|---|---|---|---|---|---|
| Junting Lou | 30 | 15 | 12 | 5400 | 13500 |
| Yaming Tang | 30 | 15 | 12 | 5400 | 13500 |
| Lida Zhu | 30 | 15 | 12 | 5400 | 13500 |
| | | | | Total | 40500 |

## Total Cost

The total cost including labor and parts is 40576.33

# Schedule

| Week | Tasks | Person in Charge |
|---|---|---|
| 9/16 | Finalize project idea and write up proposal | Junting Lou |
| | Research for microcontroller ICs and their operations | Lida Zhu |
| 9/23 | Sign up and prepare for Design Review | All |
| | Research for power management and wireless modules | Yaming Tang |
| | Finalize and order parts | Lida Zhu |
| 9/30 | Build basic Bluetooth communication circuits and verify | Yaming Tang |
| | Test Bluetooth circuit's reliability and performance | Junting Lou |
| 10/7 | Test and verify controller modules with the integration of wireless modules | Lida Zhu |
| | Build sensor circuit and test its operation, then integrate with controller module | Junting Lou |
| 10/14 | Finalize motor selection and verify its operation | Junting Lou |
| | Build basic circuit involving Ethernet module | Yaming Tang |
| 10/21 | Prepare for individual Report | All |
| | Finalize PCB design | Lida Zhu |
| 10/28 | Build basic speaker circuit and test it together with the Bluetooth module | Lida Zhu |
| | Test reliable status updates | Yaming Tang |
| 11/4 | Integrate entire circuit and build working prototype on bread board | Junting Lou |
| 11/11 | Identify existing problems and debugging. | Yaming Tang |
| 11/18 | Finalize design of actual devices | Lida Zhu |
| | Start working on final paper and presentation | Junting Lou |
| 11/25 | Construct final device and test all components with possible improvements. | Yaming Tang |
| | Sign up for Demo and presentation | All |

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