5-2022

Electronic Fingerprint Safe

Bryton Flecker
Trinity University, bflecker@trinity.edu

Carlos Bucheli
Trinity University, cbucheli@trinity.edu

Tristan Arias
Trinity University, tnorton@trinity.edu

Final Report
Electronic Fingerprint Safe

Bryton Flecker, Carlos Bucheli, Tristan Arias
Project Group 4

ENGR-4367 Mechatronics | Trinity University
May 16, 2022

Table of Contents

I. Design Summary

The objective for this project was to create a lockbox storage solution which used a fingerprint sensor (3) as the mechanism for locking and unlocking the device. A user of the device would have the ability to add or remove up to four fingerprints from the device while it is unlocked. As a backup measure for the event that a fingerprint is no longer recognized, the lockbox will have a preprogrammed PIN assigned to the device which the user can enter to unlock it. User input was implemented via a series of buttons (5) on the front panel of the lockbox. Then, to display information about the state of the lockbox and communicate any other UI information, an LCD display (4) was included on the front of the device. A stepper motor (1) positioned under the lid was also used as the mechanism for both opening and closing the lid of the lockbox via a connected lifting arm while a solenoid latch (2) also positioned inside the box was used to lock it. A buzzer will sound an alarm should a tilt sensor detect movement of the box above a certain predefined threshold.

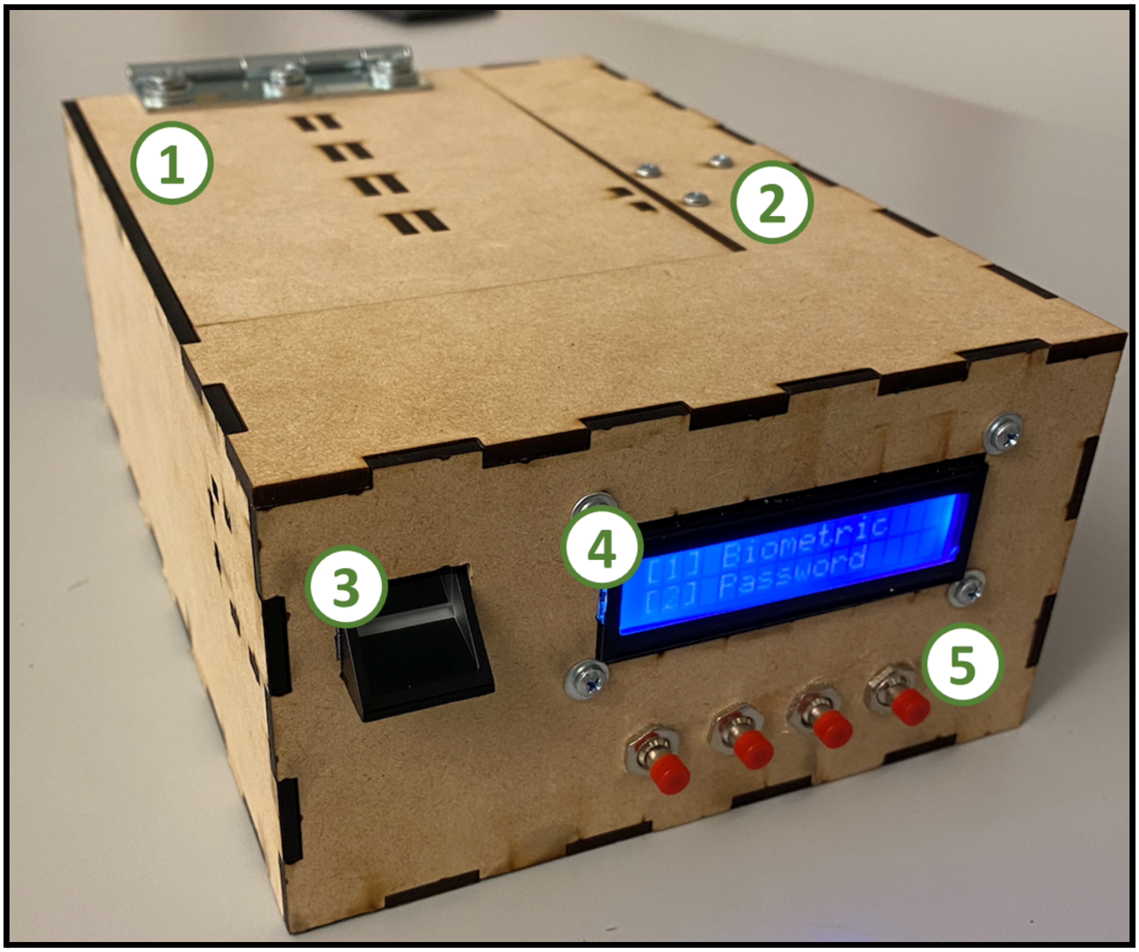

Figure 1. Labeled Final Prototype

II. System Details

In order to implement the design described in the previous section, the team created an initial hardware sketch as seen in Figure 2. This schematic shows the general placement and distribution of key features of the lockbox.

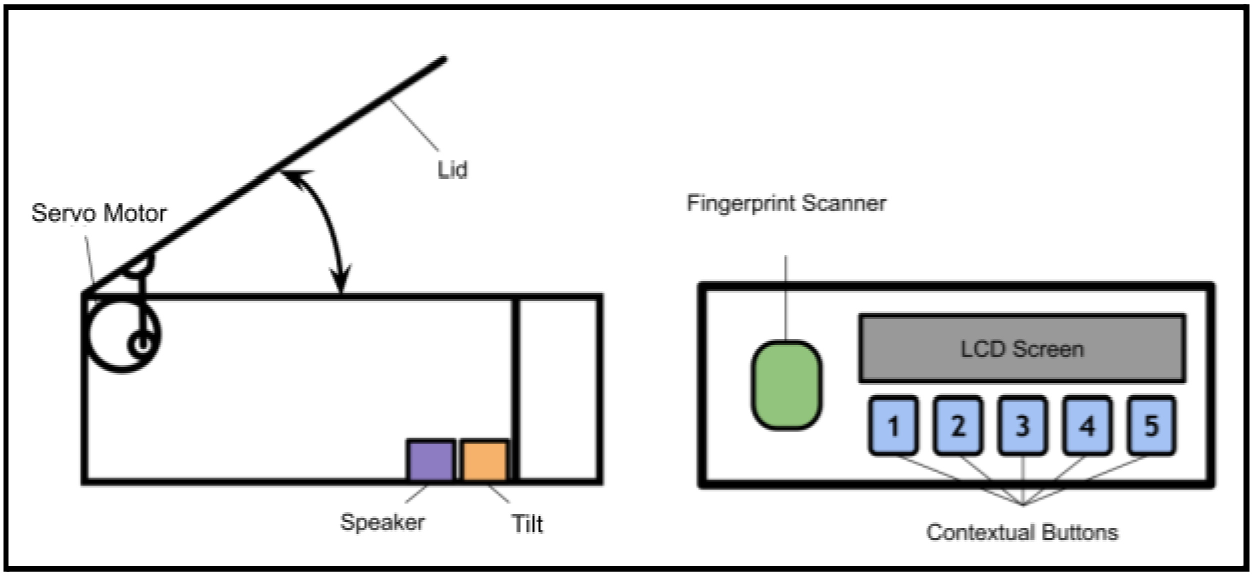

Figure 2. Initial Hardware Sketch

The primary structural features of the lockbox were made out of medium-density fibreboard (MDF) wood due to material availability, ability to be laser-cut, and structural stability. The MDF was laser-cut and glued into an interlocking assembly providing the overall structure to exterior faces, allowing for securement holes for the various electronic components, the support and securement for the fingerprint scanner, and the stops and latch for the lid. The higher-stress components of the brackets for the servo motor and servo horn extension arm were laser-cut from ⅛” thick black acrylic. A simple hinge was used to allow for lid rotation, and a small brass tube with masking tape stops pinned the lid slot to the servo horn arm extension.

As the first step to start programming the box, a software flowchart was created and can be seen in Figure 3.

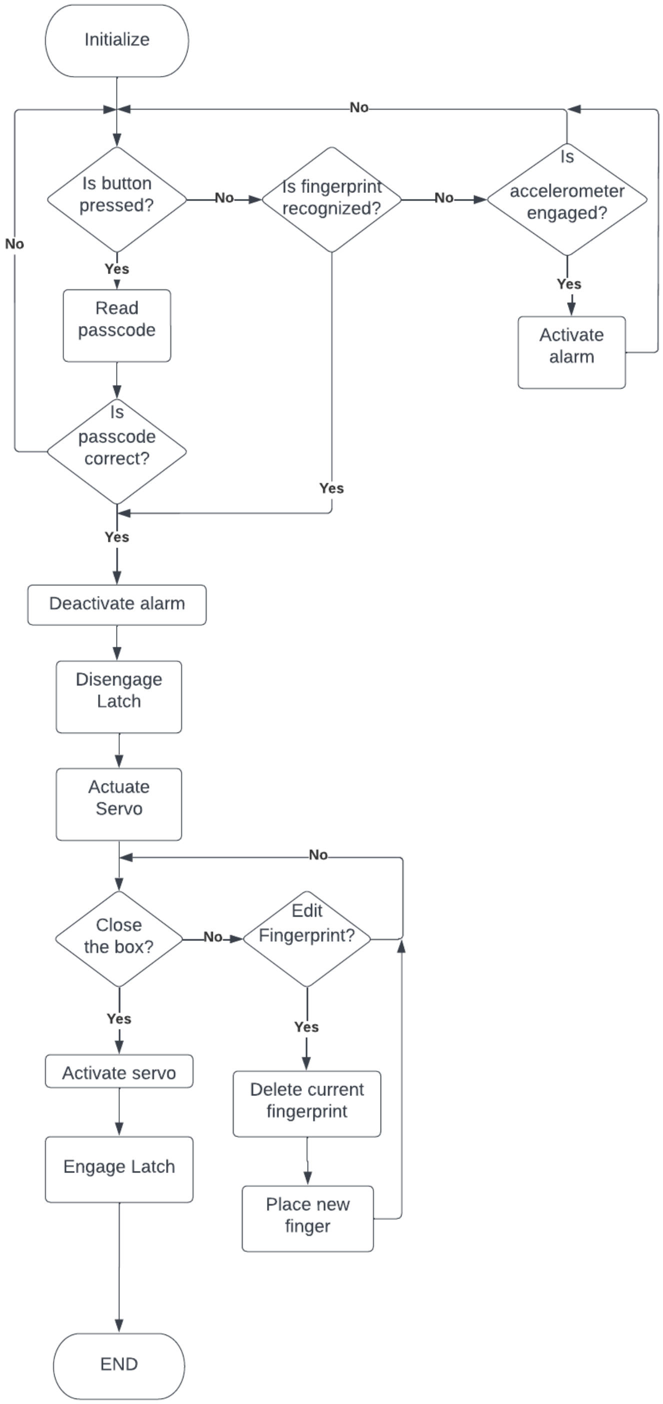

Figure 3. Software Flowchart

Additionally, a wiring schematic showing all components and their respective connections can be seen in Figure 4. The team chose to use a PIC microcontroller as well as an Arduino UNO to implement the lockbox code.

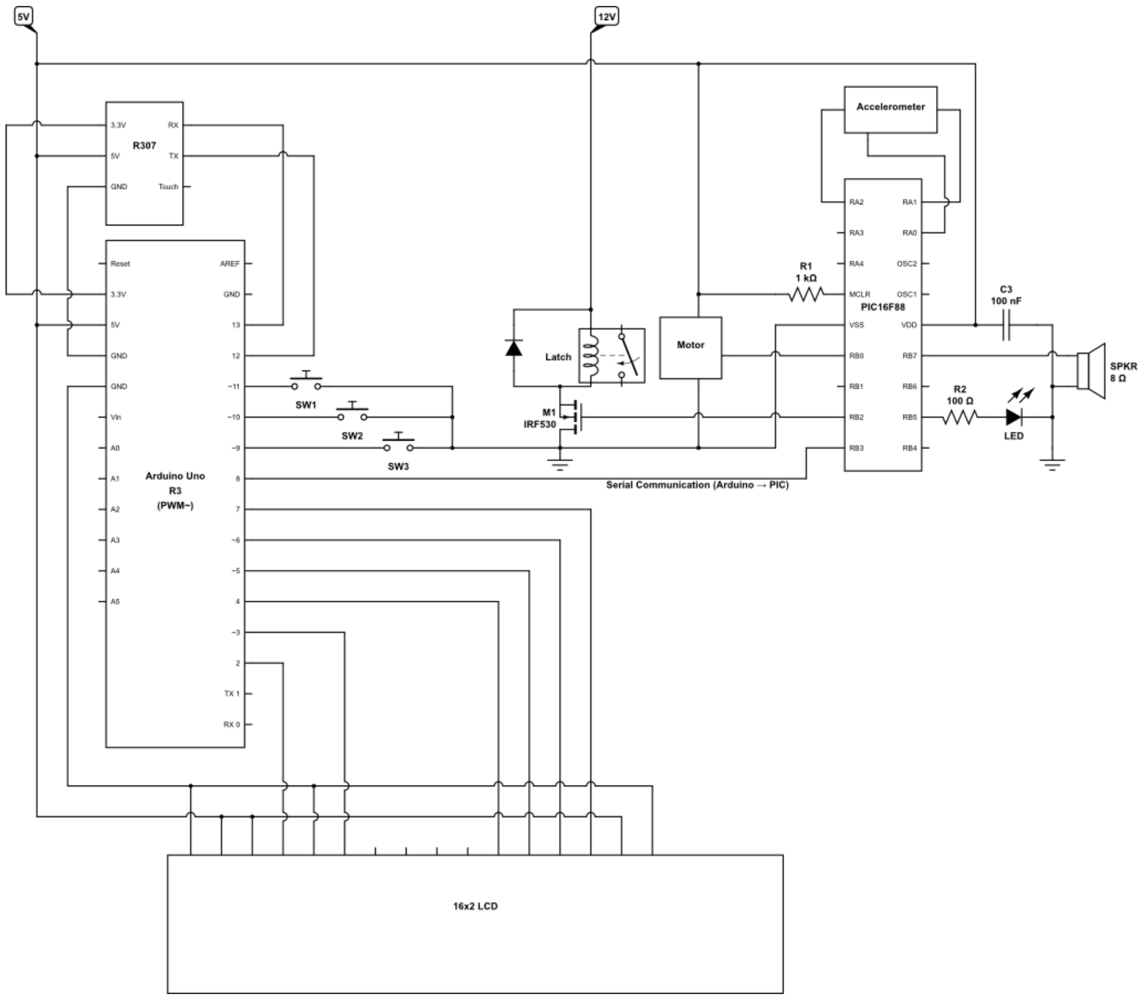

Figure 4. Circuit Schematic

III. Design Evaluation

Output Display Device

The output display device used in this project was an LCD Display using I2C communication. Although it worked smoothly once configured, the task of making it functional required a significant amount of research to set up properly as it was not covered in any of the course materials. We eventually managed to find a library for the Arduino which supported I2C communication with an LCD display, but it was poorly documented and required a non-trivial amount of trial and error to determine how it functioned. However, once set up it was relatively simple to use as it was designed to imitate the API for a traditional LCD display and thus this category likely scores as a [15/20] on the design evaluation scale.

Audio Output Device

A buzzer was used as the audio output device for this project as we simply needed a loud alarm for the case that the lockbox detected suspicious movement. It did require some minimal research to determine why it seemed to work in some circuit configurations and not others, however it was minimal as we rather quickly discovered that the buzzer we selected was directional and simply needed to have the connection pins oriented properly for it to function as we intended, thus resulting in a [10/20] on the evaluation scale.

Manual User Input

There were two methods for manual data input used in this project, the first were four simple push-buttons while the second was an optical fingerprint scanner. Although the push-buttons required practically no research to implement, the fingerprint scanner was quite complicated and required extensive research to determine what model to purchase, how to interface with it, and many additional hours to implement the code required to have it interact with the remainder of the system. In summary, the final implementation of the scanner included authenticating up to four separate users, adding/editing user fingerprints, and removing user fingerprints from the database. A combination of factors including debugging hardware failure mean that this category should likely score a [20/20].

Automatic Sensor

The automatic sensor in this project was a tilt sensor which did not require considerable research to implement as the output could simply be interpreted as either a high or low signal by the PIC processor. However, there was some difficulty implementing the device as the sensor actuation wasn't initially detected by the PIC. We eventually discovered that it wouldn't register an activation without the addition of a pull-down resistor, however as this took only minimal research to discover, this category should only score a [10/20].

Actuators, Mechanisms and Hardware

The actuators used in this project were a solenoid latch and a servo motor. Implementing these devices took additional time and research than the audio and tilt sensors mentioned previously as there were several challenges we encountered when attempting to get them functional. One of the major issues that we encountered was the power consumption required to get them operational. We originally believed that all our systems could be powered either directly from a 12 volt battery or the 5 volt power supply from an Arduino, however it was discovered that when we needed to activate the solenoid latch and servo simultaneously, there was enough power draw to starve the Arduino of energy and force it to restart. We were eventually able to circumvent this issue by creating a separate power supply circuit, but the amount of time invested in making these systems function properly would likely score a [15/20] on the rating scale.

The mechanisms and hardware could largely refer to the mechanical design of the lockbox itself. The design of the lockbox proved robust, clean, and reliable, with the only apparent flaw in the design being the poor spacing for the 12 volt battery, resulting from a lack of account for the battery's flex in the middle of its height. The box's design was begun early, and in such a way as to allow for adaptability in the position and size of components placed within it. This provided the team the flexibility to adjust component position to optimize cable routing and interface intuitiveness. The space taken by the various planned components was also mocked up during the design process to ensure proper fits and margins. The combination of these considerations resulted in minimal redesigns after initial print and assembly. Only one redesign was performed, to add an on/off switch for box power, and reprints were made of the servo brackets and servo horn arm extension due to breakage and subsequent replacement with stronger material. Due to the final quality of the build, lack of connection to available textbook and lecture information, and the degree of effort expended in precise measurement and robust and adaptable design, this category would likely score a [15/20]. This does not score higher because the design did not require much research apart from part schematic retrieval for proper dimensioning and it possessed a flaw in the dimensions of the battery slot.

Logic, Processing, and Control

This project was very logic and processing intensive despite not having any form of traditional feedback control system. Implementing the functionality of the fingerprint scanner alone was a significant challenge given the limitations of the user interface. Designing an LCD interface to instruct the user how they should interact with the lockbox was difficult due to the limited number of characters that can be shown on a 16x2 display. Furthermore, ensuring that button presses were properly debounced so they didn't trigger multiple events was surprisingly difficult to get working consistently. Surprisingly, the code for the fingerprint scanner was not as challenging to get working as the user interface and menu logic once I found an Adafruit library to interface with the device, however, finding the library took a considerable amount of time since the original library that we attempted to use, never managed to let us login to the scanner. Overall, due to the challenge and extensive research required to get these systems functional, I would say that this category deserves [20/20] on the rating scale.

IV. Partial Parts List

- Fingerprint Scanner: R307 Optical Fingerprint Module
  This component integrates a fingerprint algorithm chip with functions such as fingerprint input, image processing, feature extraction, template generation, template storage, fingerprint comparison and fingerprint search. It had a cost of $22.59.

- Latch: Electromagnetic Solenoid Lock
  This component was used as a latch mechanism, it uses 12 VDC and is normally closed. It had a cost of $7.99.

- Actuator: Metal Gear Servo Motor
  This component is a high torque motor with 270 degree control angle. It had a cost of $21.99.

V. Lessons Learned

One of the major difficulties in finishing this project was burnout. We originally anticipated that this project would require a considerable amount of time to complete and tried to factor that into the project schedule, but there were even more issues that came up than we originally accounted for which included partial redesigns of the system, needing to reorder parts due to the hardware failure, team members falling ill, amongst other problems. This culminated in a rush to complete the project which ended up requiring a non-trivial amount of time past the original deadline which naturally resulted in fatigue and burnout amongst the team.

Part of the reason for this was caused by a lack of realization about which parts of the project could bottleneck progression and thus, when certain problems occurred, they had a more dramatic impact on progress than was originally anticipated. One good instance of this occurring was with the fingerprint scanner. A full day was spent attempting to get the device working before it was realized that a small connection had failed in the scanner's power supply that we were unable to repair. As a result, a considerable amount of the programming and testing and assembly was delayed for several days as we waited for a replacement to arrive. Furthermore, due to the time frame, we were unable to order from a reputable supplier and were thus unsure whether the new device would even be functional, which was a non-trivial concern since any additional sensors we purchased would likely arrive only days before the project deadline if they were required. As it turned out, the new scanner arrived in good condition and due to the extensive amount of time spent trying to get the first scanner to work, it was not too difficult to verify that the second one worked as we expected.

In hindsight, there were parts of the project related to coding that could have probably been completed during this downtime, but due to the time pressure and other assignments that required attention at the point in the semester when this occurred, nobody realized that these options were available. We would thus make several recommendations in terms of planning any future projects.

First, try to test hardware as soon as possible, and thus, order parts as soon as possible. It is probably best to assume that the first and perhaps second part that you order of each component will be defective so that you have time to react and aren't pressured by any component failures as they have been accounted for in the schedule.

Second, we would have wanted to integrate all project components into a final assembly at least two weeks before the project deadline for something on this scale. Our group and other groups found that although their project components worked fine individually, that they interfered with each other in ways that were not accounted for. These issues were largely related to voltage regulation and power supplies and required multiple days of intensive effort to try to fix. In our case, we found that our solenoid latch was somehow drawing almost half an amp of current even though we were under the impression that it shouldn't have any current draw while engaged and ended up needing to design a completely new circuit to use as a power regulator so that our the power requirements wouldn't exceed the amount that our Arduino could provide.

Finally, it would have been much better to determine what systems we could implement simultaneously to improve work efficiency. We simply didn't anticipate how difficult it would be to reprioritize tasks towards the later end of the project. There was much more time available to discuss options earlier on in the process which could have been leveraged much more effectively. It was overly optimistic to assume that we could determine how to handle these issues while also trying to balance out work for other courses towards the later part of a semester and dealing with burnout due to the workload.

VI. Appendix

No appendices are provided with this report.