CENG 3010 - Design Activity: Digital Controller for a Programmable Locking Safe

Luka Aitken, Toma Aitken, and Brandon Breithaupt
Thompson Rivers University, Kamloops, B.C. Canada

1. Introduction

Every year, there are about on average 2.5 million burglaries that occur around the world, with 66% of these being break-ins. Of that, homes without any security system are more likely to be targeted 3 times more than homes with a security system [1]. To prevent important and valuable items from being taken, using a safe is beneficial but issues can occur. These types of issues of safes can range from how reliable the safe can be, the ease of use, and the type of security options the safe contains. Most safes are reliable enough to keep items safe but can tend to wear down over time every time the safe is used to store items. When the safe becomes unusable, it can cause items to be easily stolen or trapped due to the safe breaking down, and would cost more money to pay to replace the safe. With each safe being able to keep items safe, the safe itself should be easy to use, but many people use older safes to save money which can lead to these users not knowing how to operate the safe. This can eventually make the person want to not use the safe or make them waste more money on a different safe. Finally, with safes having limited reliability and ease to use, each safe has different security measures that can be both beneficial but also disadvantageous. These disadvantages can be from the safe only having one combination that is easy to break, no countermeasures such as one-time use codes and a limited number of tries, and a timer to either keep the safe open for a duration or to be only used during a certain time period in a day [2]. With all these flaws that can lead to break-ins and loss of items, using a programmable safe is the key to preventing this and that's where our programmable safe comes in.

To begin with our programmable locking safe, we will come up with different possible solutions that will require minimal effort and ease of use for users, while following the project requirements and constraints. The task was to come up with a solution that is programmable to have enhanced security features for users' personal items that they want to keep safe. The safe should be interactive with the user allowing the users to perform measures to keep belongings safe.

Through this report, we will discuss the problems we faced with the designing and building of the programmable locking safe. We will also discuss other solutions that weren't used and how they inspired the final solution. Additionally, the environmental, societal, safety and economic considerations are other key factors that will be discussed throughout this report.

2. Design Problem

Problem Definition

According to security expert, R. Edwards, the average loss from a robbery of homes is worth about $3000, which can include cash and expensive items. With that, about 50% of stolen goods are irreplaceable or have sentimental value towards the owner which can cause emotional and mental stress [3]. Programmable safes can provide protection over sentimental items and prevent items from being either damaged or stolen, reduce the need for more security, prevent sentimental items from being damaged by fire, and give relief to the item's owner by reducing the stress of the owner [4].

Design Requirements

Functions

•The system should allow users to open the door on keypad or/and remote device.
•The system should use the 7-segment display to display information when the safe is being used.
•The system should have a reset function for inputting a new password. The time limit on how long it will sit idle for will be based off a clock.
•If the system goes over 3 attempts when entering an incorrect password, an alarm will go off. Alarm will also go off if the door is open for too long.
•The door should lock when it is either closed, the lock button has been pressed on a remote device or after the time limit.
•The door should unlock when a correct password has been implemented.

Objectives

•The system should be easy to use for new users.
•The system should be able to keep the user's items safe.
•The system should use a sequential machine to run all possible outcomes.
•The system should be able to change password when needed to.
•The system should be cost effective.

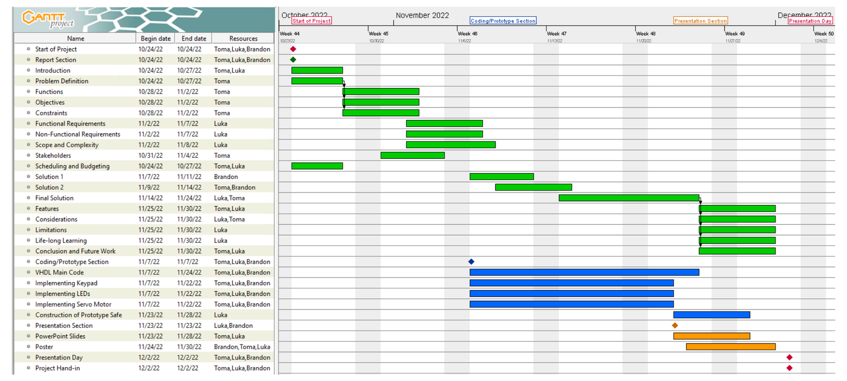
Constraints

•The door of the safe should only open when the correct password is entered.
•The safe should automatically lock after a certain time frame.
•The safe should use one or more sequential machines.
•The Safe should be cost-effective.

3. Stakeholders

Table 4.3.2 - Budgeting List		
Item Name	Quantity Used	Cost
FPGA board [5]	1	~$242.00 (Given by Lab Technician)
Pmod KYPD: 16-Button Keypad [6]	1	~$25.00 (Given by Lab Technician)
Pmod ESP32 bluetooth adapter [7]	1	~$47.00 (Given by Lab Technician)
Scrap Cardboard	~3	Free

4. Scheduling & Budgeting



Stakeholders	Required Needs
User / Owner of the safe	•To keep important and valuable items safe from unwanted users or environments. Such as unwanted guests, burglars and house fires.
Programmers creating the code	•To create a code that can prevent break-ins into the safe. •To create a code that can't be hacked easily.
Programmable Safe Company	•To generate money from users who require a safe to protect and keep important or valuable items safe. •To generate money from users to improve the programmable safe.

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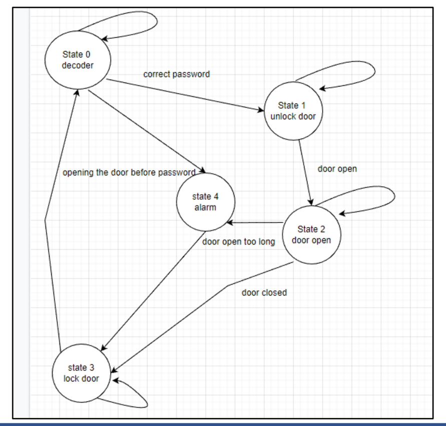
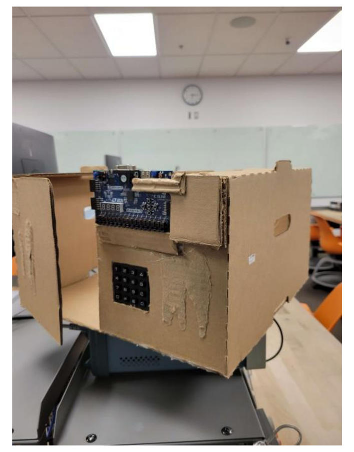
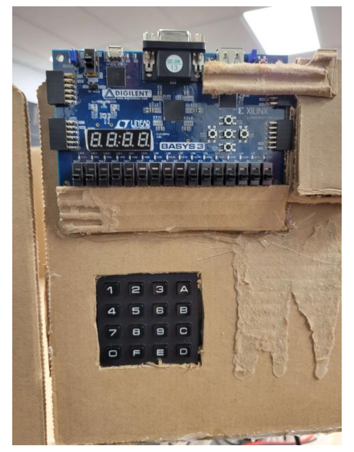
5. Final Solution

For our final solution, we came up with a design where the user would enter the password using a keypad connected to the FPGA board. Our system displays 1 digit at a time. When the user needs to change the other digits, they would use two switches indicating from digit 1 to digit 4. Our program used cases to allow the system to easily change from one digit to another such as 11, 10, 01, and 00. If the user tries to open the door without entering a password or with an incorrect password, the safe will turn on an alarm meaning that the password is wrong or someone was tampering with the safe. If the user enters the password correctly, the program will allow the user to open the safe and once they do, a timer is started. The timer has a set duration until an alarm is started due to the safe being open for too long, which can lead to items being taken away. If the user closes the door before the timer is up, the system will go back to its original state asking for a password. With each state, there are LEDs indicating if the password is correct, the door is open and the alarm is triggered.

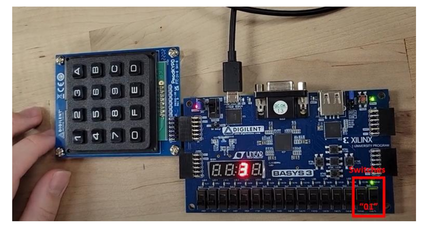






6. Features

For our features, the programmable locking safe will use a keypad to allow users to enter a password. To enter a password, a user must use the two most right switches on the FPGA board. These two switches can be represented in binary digits for choosing which display you will be starting on with the 4 digit 7 segment display. The leftmost 7 segment displays the "11" case, next it would be "10", then "01", and the right most digit would be "00". When users are entering a password, any button located on the keypad can be used as an input for the password. To prevent other unwanted users from viewing your password, we have an **enhanced security measure** that will only allow users to view one digit at a time for optimal security. When the user has correctly entered a password, the door will be unlocked which will be represented as the third most right LED on the FPGA board. If the door is open for more than five seconds, the timer in the program will cause the fifth most right LED to start blinking. This indicates that the safe is in the alarm state and that the user needs to close the door with the third-most right switch. If a user tries to open the door with the incorrect password, the alarm state will be set off and cause the fifth-most right LED to start blinking.



7. Limitations

When building and developing our programmable locking safe, there are always limitations. Many of our limitations were due to time constraints. This is because we spent a lot of time figuring out and trying to understand how the keypad functions and how we can save a user's input value in our program. Due to these time constraints, we were unable to do a test bench to test the different input and output values within our program. If there was more time, we would be able to use a test bench to see all possible inputs and outputs. There were also other features that we wanted to perform such as the user resetting the password to their choosing. Additionally, we wanted to use external colour LEDs to represent different states within our program such as when the door is locked or unlocked. With the door, we wanted to use a servo motor to act as the locking mechanism that would display our physical prototype locking instead of an LED. With our physical prototype safe, the safe itself was made out of cardboard which is not a realistic safe and is easily accessible to break-ins. For our design purposes, environmental considerations, and cardboard being easily accessible, we used cardboard as our main safe structure.

8. Lifelong Learning

When building the program for our programmable locking safe, we learn a lot of information on how to create a decoder for the PMod keypad. When first learning about the PMod keypad, we had to figure out how our keypad works and how it connects with the Basys 3 FPGA board. This took a while as most examples of how to decode the keypad were using Verilog rather than VHDL. Once we figured out a way to decode it, we integrated it into our system which allows us to use any button on the keypad, and it would convert it into binary code that can work with the seven-segment display. After getting these numbers, we were able to compare them with a decode value that can take it as a 4-bit binary number such as "0010" which represents '2' on the keypad.

9. Conclusion & Future Work

In conclusion, we achieved many considerable designs on how to create a programmable locking safe that can keep valuable items safe from unwanted people. First off, we came up with a couple of solutions that could be used to make the best possible programmable locking safe, while following all the constraints. Our objective was to build a program that is easy to use and keeps items safe by using sequential machines.

From our research, the biggest challenges for safes are the things that could go wrong. Some such incidents could be home intrusions and break-ins that can lead to normal safes from being broken into and losing valuable items. With a higher frequency of these possible events, one in every six homes is targeted every year. Furthermore, as these events occur, the results can lead to the loss of important items and damages in homes that can cost lots of money to repair or replace [9].

With the help of programmable locking safes, it can reduce the number of unpleasant incidents when using programmable locking safes. Using these types of safes, can reduce the chance of home intrusions and break-ins as well as overall improve the security of important items. Also, it can save money by reducing the chances of important items being taken from unwanted people and preventing the item's owner from being replaced [9] [10].

For recommendations on how the process will continue in the future of improving the programmable locking safe, we would include more security when operating the safe. This can be such as whenever a user entered the password wrong three times in a row, which could trigger the alarm and a buzzer to indicate the alarm instead of an LED. Also, we would want to implement a BlueTooth device to allow the user to control the safe's functionality on a phone app for easier access or to change the settings of the safe. Some such functions could be opening and closing the safe door, notifications of the safe's activities, and changing the password of the safe in case unwanted people know the password.

10. References

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