MazEscape

ECE 445 Design Document - Spring 2025

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1. Introduction

1.1 Problem

Modern-day theme park immersive games have become stale and predictable, so we wanted to make them more entertaining by seeing if it is possible to mix some of them. So, we devised a fun idea for a mix between a maze and an escape room where the participants will enter a labyrinth and answer questions to move onto the next level or to the next room and complete the game.

1.2 Solution

To tackle this challenge, we have decided that there will be a set of four smart lock systems, two of which will have an LCD screen along with a keypad with which the user will be able to interact with the whole system, and the other two will be the emergency escape lock system. Each set of smart lock systems will be attached to a door that will open up to the next part of the maze or the next level or to a door that will take them out of the maze and back to the starting point. The questions that will be asked on each of the smart locks will be related to small puzzles or general knowledge questions that they will get one chance to answer, as all the questions displayed will be multiple-choice. The players will answer the questions using the keypad by selecting one of four choices: A, B, C, or D.

There will be a total of two levels: an entry-level or the first level, which will be the first instance where the player will be asked to answer a question, and upon successfully answering the question, the system will unlock the gate and the player will be able to move onto the next level and which will be the second or the final level. The player will then again be asked to answer a question, and if they get the correct answer, they exit the maze and claim their prize. If, however, in any of the two levels, the player selects the wrong answer, then the smart lock will send a signal automatically to the escape smart lock system, which will be put on an escape gate to unlock the gate so that the player can leave the game and go back to the starting point. Each of the two smart locks, which will have an LCD screen, will also have a motion sensor so that the smart lock can automatically detect if a player has approached it, and then it can display its question.

The smart lock systems that ask questions will also be able to communicate with each other so that the user is not introduced to the same question. The player will also have an additional option to leave the game by pressing a leave button on the keypad, upon which the smart lock system will send the escape lock system a signal to unlock the gate.

1.3 Visual Aid

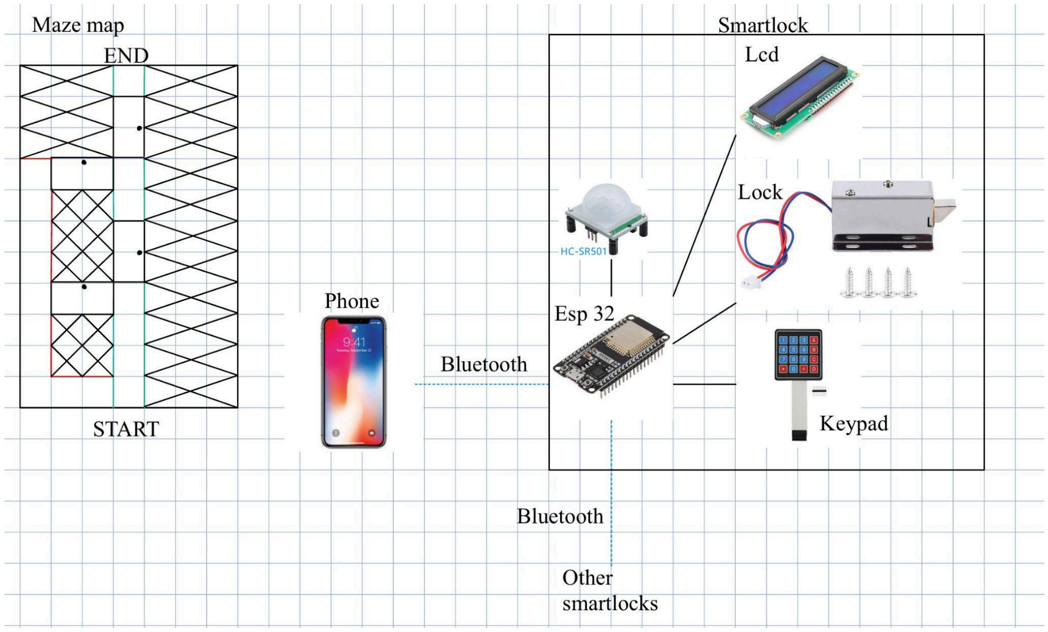

Figure 1. Visual Aid for MazEscape

1.4 High-level requirements list

- The system shall unlock the door within 2 seconds of receiving correct input from the participant to ensure a smooth and engaging user experience.
- The motion sensor must detect an approaching participant within 3-5 meters and trigger the display of the quiz question within 1 second to facilitate prompt interaction.
- The Bluetooth module integrated within the smart lock systems shall reliably exchange data—specifically transmitting quiz questions and lock/unlock commands.

2. Design

2.1 Physical Design

Our physical design comprises six parts: the solenoid lock, the infrared sensors, the keypad, the LCD screen, the microcontroller, and the power supply. We plan to have all components in a single lock box for seamless integration. The user can see the screen, the keypad, the sensor, and the lock. The Microcontroller and the power supply will be hidden from the user. The user only intends to interact with the screen and keypad, as the screen will display the question and the keypad will be used to answer the question.

2.2 Block Diagram

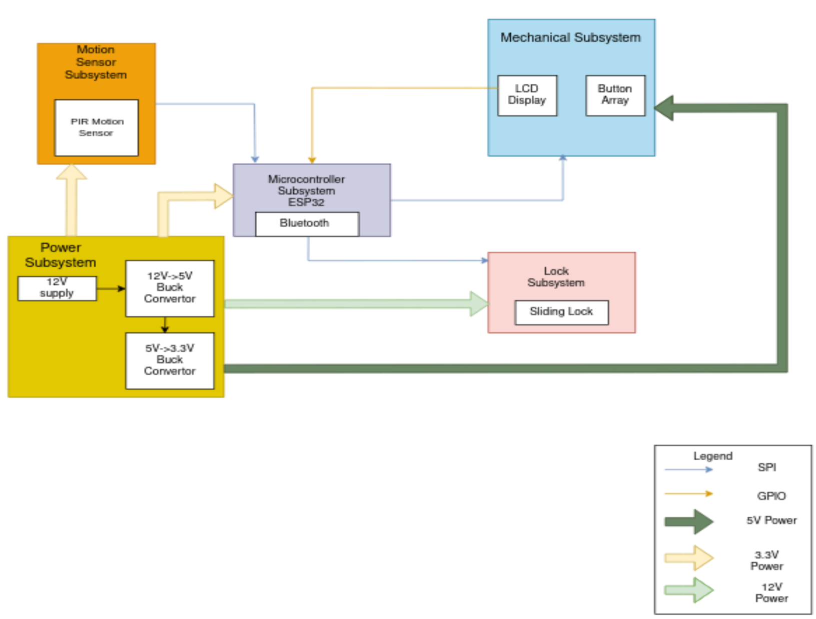

Figure 2. Block Diagram for the project

2.3 Mechanical Subsystem:

We will use a 1602 LCD Display Module to display the problems the user will solve and a Numeric Keypad to input their answers. The LCD module will be very important for the user interface as all the information the user will need to use the device properly will be available on the LCD display. The user will be able to navigate the different functionalities using the keypad. The LCD module and the keypad will communicate via the SPI protocol with the microcontroller.

Requirements	**Verifications**
• The LCD display must update content reliably at ≥60 Hz. • The keypad must accurately capture and transmit inputs within 0.5 seconds. • The SPI communication channel must operate at least 8 MHz without data loss.	• Implement a software timer system to record the duration between subsequent screen refreshes. • Access an external tool that can timestamp both the physical press and the system's input reception. • Use an oscilloscope to monitor SPI clock and data lines.

2.4 Microcontroller Subsystem:

The ESP32 microcontroller will have different types of questions organized into various questions (MC questions about trivia and general knowledge questions answered with pressing buttons).

Requirements	Verifications
• The microcontroller, ESP32, must be able to interpret the status of the user input • 3.3±0.5V must supply the microcontroller	• Record the behavior of the DC solenoid lock in response to each command using an oscilloscope. • Use a multimeter to measure the voltage of the microcontroller • Ensure voltage readings are within 3.3±0.5V for each microcontroller.

2.5 WiFi/Bluetooth Subsystem:

We will use the ESP32 Microcontroller as a Wifi/Bluetooth module to connect all the LCD screens. The Bluetooth module will also allow the smart lock system to signal the escape lock system in case the player gets the question wrong or wants to leave the game.

Requirements	Verifications
• Provide stable and responsive (<100ms input lag) Bluetooth connection • It must interface seamlessly at 3.3V logic levels with the ESP32 microcontroller to relay commands accurately.	• For stability, tests should be performed in an environment crowded with Bluetooth (ECEB) and range tests. • Test the amount of time it takes to receive the updates. • Ensure voltage readings are within 3.3±0.5V for each microcontroller.

2.6 Motion Sensor Subsystem:

To have a unique and interactive experience, we will implement an HC-SR501 Infrared PIR Motion Sensor Module that will interact with the user by detecting them, and then once the user is detected, it will prompt them with a question to unlock the system.

Requirements	Verifications
• When there is no human present, the PIR sensor module should output Logic Low (0 V)	• Use a multimeter to measure the voltage of all sensors • Ensure voltage readings are within

• The PIR sensor module should output 3.3±0.5V digital pulse when a human is detected • The output signal must be at a 3.3V logic level to be compatible with the microcontroller's digital inputs.	3.3±0.5V for each sensor • Have a person walk before the sensor and observe a logic high pulse on the analyzer, with a parallel voltmeter reading about 3.3 V (±0.3 V). Repeat this procedure 10 times and confirm the expected behavior occurs at least 9 out of the 10 trials.

2.7 Lock Subsystem:

We will use a sliding solenoid lock when the questions are answered. It will unlock the door, and it will lock after the user closes the door. When the questions are fully answered, the sliding lock will be in the form of a rod and operated by a motor on command. The lock will be connected to an IRL40S212 power Mosfet which will be connected to the microcontroller so that we may be able to reliably control it.

Requirements	**Verifications**

• The digital control interface must reliably receive 3.3V logic-level commands from the microcontroller.	• Use a multimeter to measure the voltage of the microcontroller • Ensure voltage readings are within 3.3±0.5V for each microcontroller.

2.8 Power Subsystem:

We will be using a standard 12V battery source,the 12 Volt power source itself will be used to power the solenoid lock, and in order to ensure that we can power all our other subsystems we will be making use of two buck converters.

The first buck converter will be making use of the LM2575-12BT buck converter that will be stepping down the 12V power source to a 5V power supply which will be used to power the mechanical subsystem.

We will then be using a second buck converter to step down the 5V power source to a 3.3V power source to supply the microcontroller and the motion sensor subsystem, for the 5V to 3.3V buck converter we will be using the LM2575-3.3BT. These converters will ensure a fixed and steady supply of power that will also ensure that all our components are working within their recommended parameters.

Requirements	**Verifications**
• The 12 V to 5 V buck converter must provide a regulated 5 V±0.5V output	• Connect the Buck converter to a 12 V

under the maximum operational load of the mechanical subsystem. ● The 5 V to 3.3V buck converter must provide a regulated 5 V±0.5V output under the maximum operational load of the mechanical subsystem.	battery and measure its 5 V output while varying the load from 25% to 100% of the mechanical subsystem's maximum current. The output must remain between 4.5 V and 5.5 V during all load conditions ● Connect the Buck converter to a 5 V battery and measure its 3.3V output while varying the load from 25% to 100% of the mechanical subsystem's maximum current. The output must remain between 3.8 V and 2.8 V during all load conditions ●

2.8 Tolerance Analysis

One of the most important components of this project is the lock subsystem, and its reliable operation so that we may be able to lock and unlock the doors by operating a solenoid connected to the lock. The lock subsystem must operate in different load conditions, this is also our foremost safety concern as if a situation arises where the participant must leave the maze, reliable operation of the lock ensures that the participant is safe at all times within the maze. We are using a 12V 0.4 Amp electromagnetic solenoid lock as our reference lock for this proposal [1]. We will need a current of 0.4Ampere and 12 volt DC source to ensure that our lock is able to operate at all times. And as the ESP32 can only operate at a maximum level of 3.3 Volts we will be using a MOSFET to control the solenoid and connect it to the microcontroller [2]. Which means we will need a power MOSFET that will be able to operate within the following restrictions:

$$VDS \geq 12\,Volts$$

$$VGS < 3.3Volts$$

$$IDS \geq 0.4Amperes$$

And comparing these values to those of our power MOSFET:

$$VDSmax = 40\,Volts$$

$$VGSmin = 1\,Volts$$

$$IDSmax = 195\,Amperes$$

We see that our MOSFET can operate under these restrictions [3].

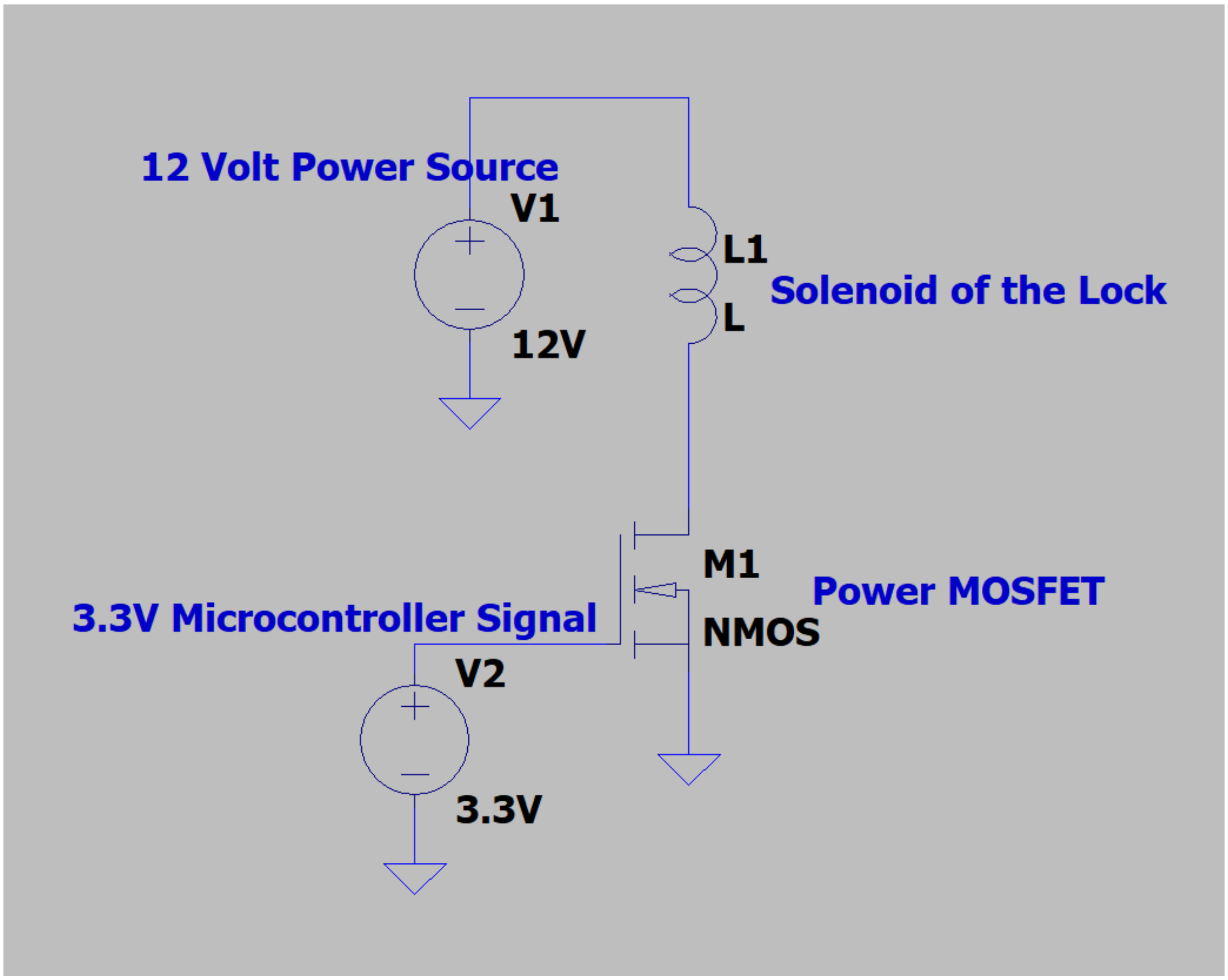

Figure 3: Schematic for the Lock Subsystem

3.Cost and Schedule

3.1 Cost Analysis

The total cost for all parts as seen in the table below is **$109.16**. We can expect a salary of $35/hr x 2.5 hr x 60 = $5250 per team member. Since our group consists of 3 members, we must multiply this value by the number of members, $5250 x 3 = $15,750 in labor cost. Adding the labor cost to the cost of all components, we get a final project cost of **$15859.16**

Component	Part #	Quantity	Price per unit	Total Price	Source:
Solenoid Lock	Electromagnetic Lock	4	7.98	31.92	Amazon Zopcs Shop
LCD Screen	LCD1602	2	1.82	3.64	ECE 445 Inventory/20 70 Lab
Microcontroller	ESP32-S3-WROOM-1	4	3.35	13.4	ECE 445 Inventory/20 70 Lab
Microcontroller Development Board	ESP32-S3-WROOM	1	16.53	16.53	ECE Electronic Shop
Keypad	Uxcell 3*4 matrix	2	11.19	22.38	ECE 445 Inventory/2070 Lab

Buck converter 5-3.3	LM2575-3.3BT	1	1.085	1.085	Octopart
Buck converter 12-5	LM2575-12BT	1	1.085	1.085	Octopart
Power Mosfet	IRL40S212	4	2.4	9.6	Octopart
Resistor	1k Ohm	48	0.02	0.96	ECE 445 Inventory/20 70 Lab
Resistor	3.09k Ohm	6	0.03	0.18	ECE 445 Inventory/20 70 Lab
Resistor	1.68k Ohm	4	0.03	0.12	ECE 445 Inventory/20 70 Lab
Resistor	5k Ohm	4	0.03	0.12	ECE 445 Inventory/20 70 Lab
Capacitor	100uF	8	0.14	1.12	ECE 445 Inventory/20 70 Lab
Capacitor	330 uF	15	0.14	2.1	ECE 445 Inventory/20 70 Lab
Capacitor	0.1 uF	4	0.14	0.56	ECE 445 Inventory/20 70 Lab
Inductor	330 uH	10	0.22	2.2	ECE 445 Inventory/20 70 Lab
Diode	IN5822	6	0.28	1.68	ECE 445 Inventory/20 70 Lab
Diode	SBR1U400P1	4	0.12	0.48	ECE 445 Inventory/20 70 Lab
TOTAL COST				**109.16**	

3.2 Schedule

Week	Tasks	Person
March 3rd	PCB Design; Breadboard Design	Group
March 10th	Integrate the Solenoid Lock, Send out the PCB order	Jayanto and Will, Group
March 17th	Integrate the Motion Sensor	Will and Jatin
March 24th	Testing and Debugging(if any)	Group
March 31st	Get the bluetooth operational(SPI Protocol), Place order for PCB, Individual Progress Report	Jatin, Group, Group
April 7th	Integrate the LCD and Button Array(GPIO protocol), PCB Order	Jatin and Jayanto, Group
April 14th	Testing and Debugging(if any), Team contract assessment	Group, Group
April 21th	Mock Demo	Group
April 28th	Final Demo, Mock Presentation	Group, Group
May 5th	Final Presentation, Final Papers	Group, Group

4. Ethics and Safety

Our project is designed firmly committed to ethical integrity and user safety, fully aligning with IEEE and ACM ethical guidelines.

1) While we currently do not foresee any ethical dilemmas in the design and construction of this project, we will ensure that we do not collect any data without the approval and knowledge of our participants.
2) Additionally, we will conduct regular testing and maintenance of all our components and subsystems to ensure that they operate safely within their parameters, per the ACM Code of Ethics 2.1, striving to achieve a high quality in work [4].
3) One safety issue that we do foresee is: when a participant is in the middle of the maze and is forced to leave due to an unforeseen emergency, in such a scenario we will have the microcontroller send in a signal to unlock all the doors so that any participant may leave in a safe and organised manner. This is following the IEEE code of ethics 7.8.I.1 [5].
4) Another safety issue that we foresee is the power aspect of the project and keeping the voltage contained accordingly to our project and not damaging anything. We have come to the conclusion of using buck converters. This is following the IEEE code of ethics 7.8.I.1 [5].

5. References

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[4] “ACM Code of Ethics”, *acm.org*. [Online].

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[5]”IEEE Code of Ethics”, *ieee.org*. [Online].

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