Smart Grid Integrated Digital License Plate

Detail Design and Integration Testing Report

Team Members:

Abdul Bhutta - 100785884

Yussef Elzein - 100641407

Emran Soltani - 100618333

Kumail Syed - 100661596

Walid Ayub - 100695612

This report is submitted in partial fulfillment for the final year Capstone Project in the Faculty of Engineering and Applied Science.

Project Advisor: Dr. Tarlochan Sidhu, P.Eng.

Capstone Coordinator: Dr. Vijay K. Sood, P.Eng., ECSE

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Abstract

In recent years, it has become evident that traditional license plates have many flaws such as security, durability, and functionality. Current license plates have proven time and time again that it is time for an update. The world is quickly going digital as technological advancements are being made every day. License plates have not yet caught up to the times. A smart digital license plate would be a tremendous upgrade moving into this electric and digital world. Current technologies such as displays, communications, and electric vehicles have created a possibility for revolutionary smart digital license plates with features such as theft detection, renewal updates, smart grid integration, and web information access. The following capstone project report is a follow-up of report 1. It includes all the design aspects of the smart grid-integrated digital license plate. It contains all the test cases that will be conducted to ensure the proper function and safety of the product. Furthermore, during the concept generation, we found it feasible to program the digital license plate on a Raspberry Pi. It was also found logical to power the system using a rechargeable power bank. The system will also utilize a GPS module alongside a RFID tag and reader to support anti-theft measures. Moreover, the assembly of the product will be enclosed in a 3D-printed case designed using SolidWorks. Finally, the integration of a website will be included to manage all the features. According to the Gantt chart, the product is currently on track to be fully established by April 2023.

Dedication

We would like to dedicate this report to each of our group members’ families who have continuously supported us throughout the university in both moral and material needs. Moreover, we would like to dedicate this report to all our professors, peers, and friends for their consistent encouragement and motivation.

Acknowledgments

We would like to express our gratitude to our supervisor Dr. Tarlochan Sidhu who made this project possible. With his guidance, we were able to get a thorough understanding of the project and how to execute our ideas. His continuous support fed our ambition to take this project above and beyond.

We would also like to acknowledge our capstone coordinator Dr. Vijay Sood. He was able to give us a strong detailed understanding of producing reports and how to have a complete presentation on our project.

Our sincere appreciation to Dr. Sheldon Williamson for offering his knowledge and guidance with this project. In our first meeting, he provided us with many ideas on smart grid technology and possible recommendations on how to implement them.

Lastly, we would like to thank our friends and family for their continued support and encouragement throughout our final year.t

We will be forever grateful for this capstone project as it has not only challenged us but helped us understand the process of designing, testing, building, and implementing a product from start to finish.

Table of Contents

List of Figures

List of Tables

List of Acronyms Used

Acronym	Meaning
12V	12-Volt
3.3V	3.3 Volt
3D	3-Dimensional
BMS	Battery Management System
CICD	Continuous Integration and Continuous Deployment/Delivery
EV	Electric Vehicle
GND	Ground
GPIO	General-Purpose Input/Output
GPS	Global Positioning System
HDMI	High-Definition Multimedia Interface
IT	Integration Test
LCD	Liquid Crystal Display
LTE	Long-Term Evolution
MISO	Master Input Slave Output
MOSI	Master Output Slave Input
RFID	Radio-Frequency Identification
RST	Reset
SCK	Serial Clock
SDA	Serial Data
UML	Unified modelling language
USB-A	Universal Serial Bus Type A
USB-C	Universal Serial Bus Type C

1 Introduction

This capstone project aims to create a smart digital license plate that will present an innovative design for displaying all the requirements needed for a traditional license plate on a digital screen with the integration of smart grid and various other improvements. Given current technological advancements, it is highly possible to add features that allow clients to be kept updated on all current information and alerts such as theft, battery life, plate renewal, etc., all while being visually appealing. The digital license plate will be used to display the characters needed for a legal license plate, clearly for any law enforcement to read and customize in any way of the owner's choosing. A website is available for all the services a user might need, such as fulfilling the requirements to renew a vehicle owner's license plate, tracking where the license plate is and whether it has been removed/stolen.

This report will include a concept analysis to show the required key components for our prototype and some viable options we can eliminate. A system design will be provided to clearly outline the software aspect of the project, with diagrams explaining how everything will operate and coordinate for the system to run. Furthermore, visuals for a website example, using a wireframe, will show how the actual website will look and specify how a user can navigate around the services. An electrical design will give a visual representation of how the license plate circuit will operate and the connections it has with every component, along with other circuit diagrams of how the plate features will work. Multiple integration testing will be done to explain where the software aspects can be logically integrated and tested. The test will describe the scenario, and procedures being taken, alongside the expected result. A cost breakdown will also be provided with information on all parts.

Problem Statement

Many advancements have been made in technology and there is no reason for vehicles today not to be equipped with smart license plates. The current license plates endure issues such as peeling, theft, and readability. Moreover, the province of Ontario had recently updated its plates to blue ones with a new slogan. The goal was to refresh the plates and solve the peeling issue but, instead, it made matters worse as law authorities found it difficult to see the plates at night as they were not reflective. These new plates cost the province about 1 million dollars and shortly after were discontinued [1]. Introducing a smart digital license plate would automatically eliminate all the problems with the current license plates. Furthermore, designing, integrating, and implementing digital license plates would not only save the province issues like legibility at night, but also create cost-effective solutions for plate updates in the future.

Overview of the Report

This report's remaining sections are organized as follows: Section 2 will outline the detailed design of the different aspects of our license plate prototype including the final software, final electrical, and casing design of the prototype which is modeled in SolidWorks. Section 3 covers the completed integration testing demonstrating how our product operates properly and how we expected. Finally, sections 4 and 5 will outline our updated project plan and contribution to this report, respectively. The Gantt Chart and the deliverables have also been updated for this semester accordingly.

2 Detailed Design

2.1 Final Software Design

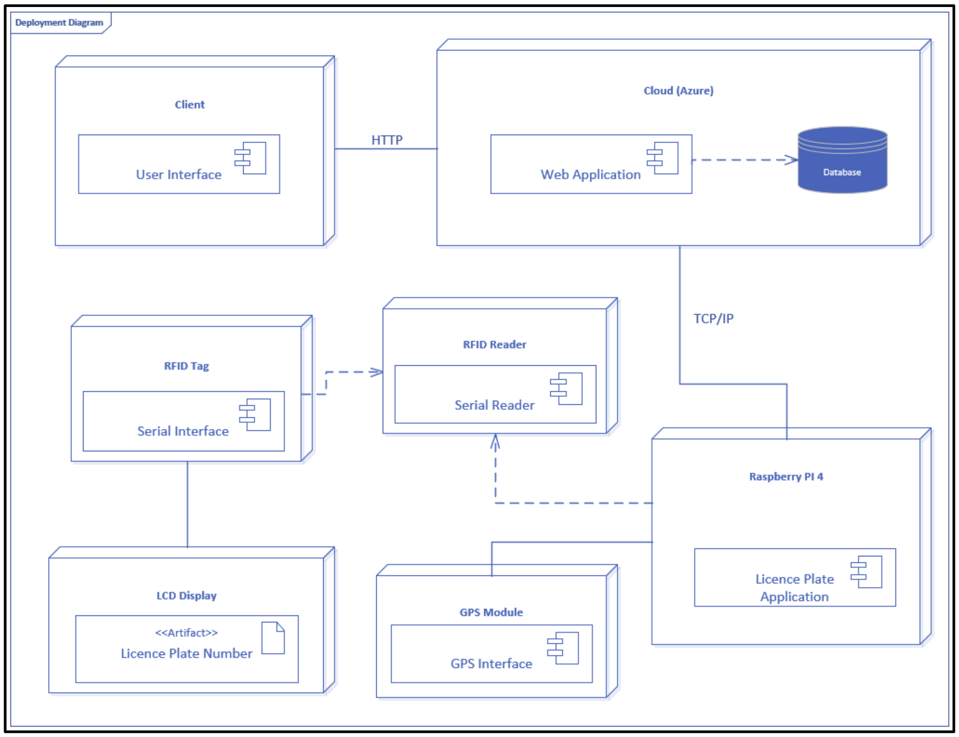


Figure 1: Deployment Diagram

The following is a visual diagram displaying the current process our group has implemented. It follows CICD practice which is deployed using GitHub and Microsoft Azure. The website is live with access to only the homepage. Our group is integrating additional features, which will be deployed once they pass the acceptance tests. These updates will be deployed without any downtime (99.8% Availability).

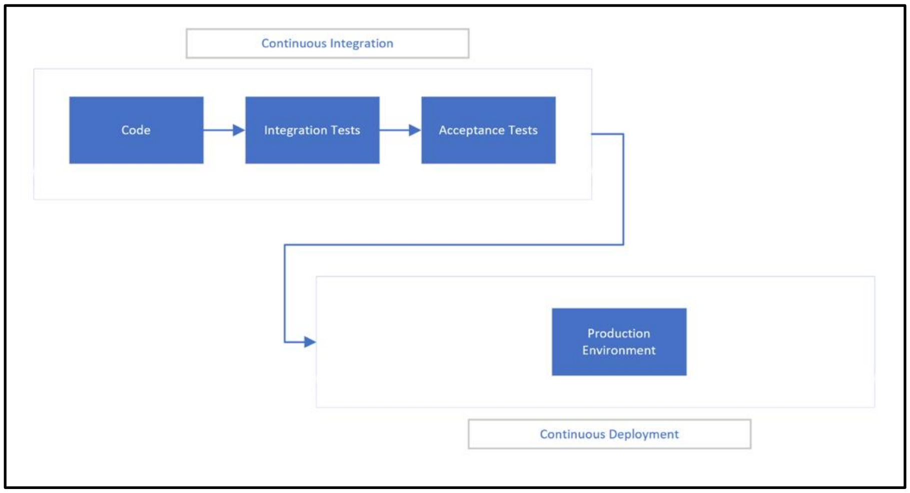


Figure 2: CICD pipeline through GitHub/Azure Diagram

2.1.1 UML Sequence Diagrams

The following is a sequence diagram displaying the various modules communicating with each other to update the outstanding balance for the energy consumed.

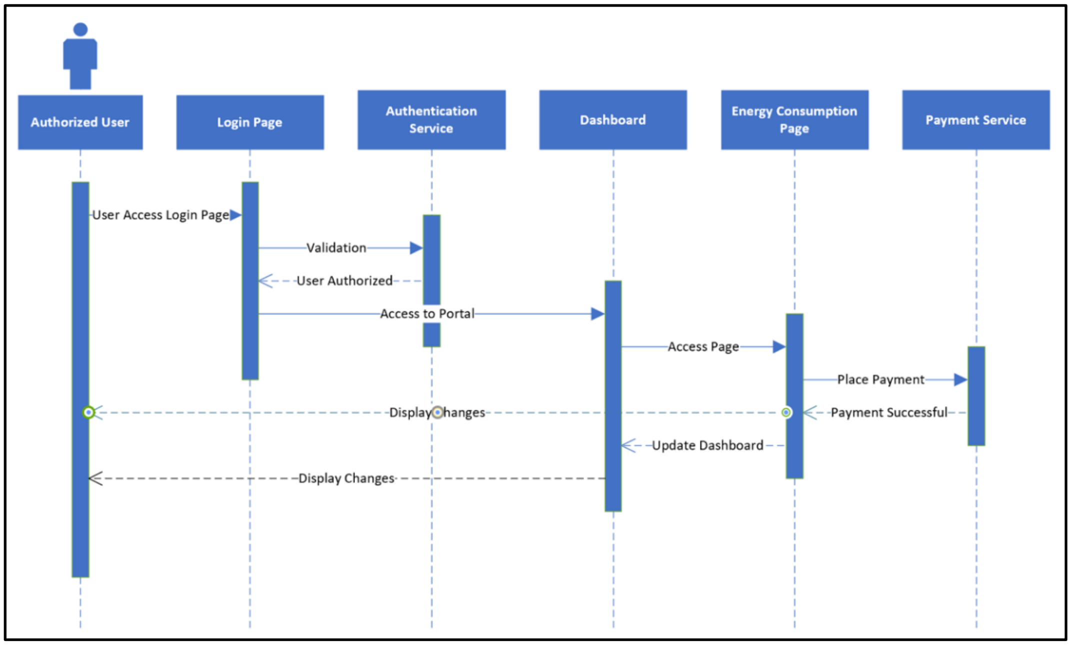


Figure 3: Sequence Diagram for Energy Consumed Payment

The following is a sequence diagram displaying the various modules communicating with each other to renew the licence plate for an authorized user.

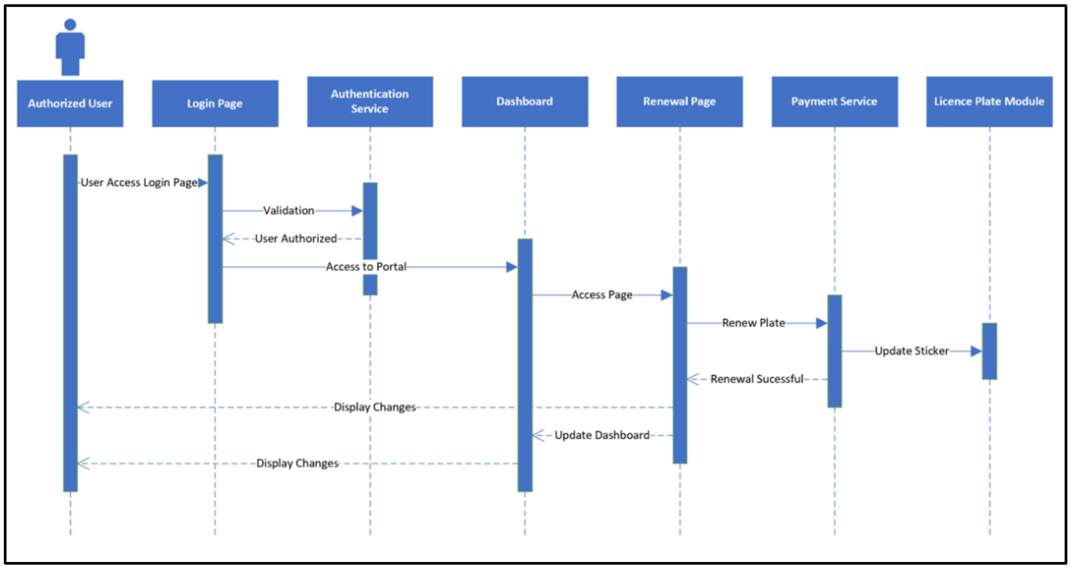


Figure 4: Sequence Diagram for Renewing a Licence Plate

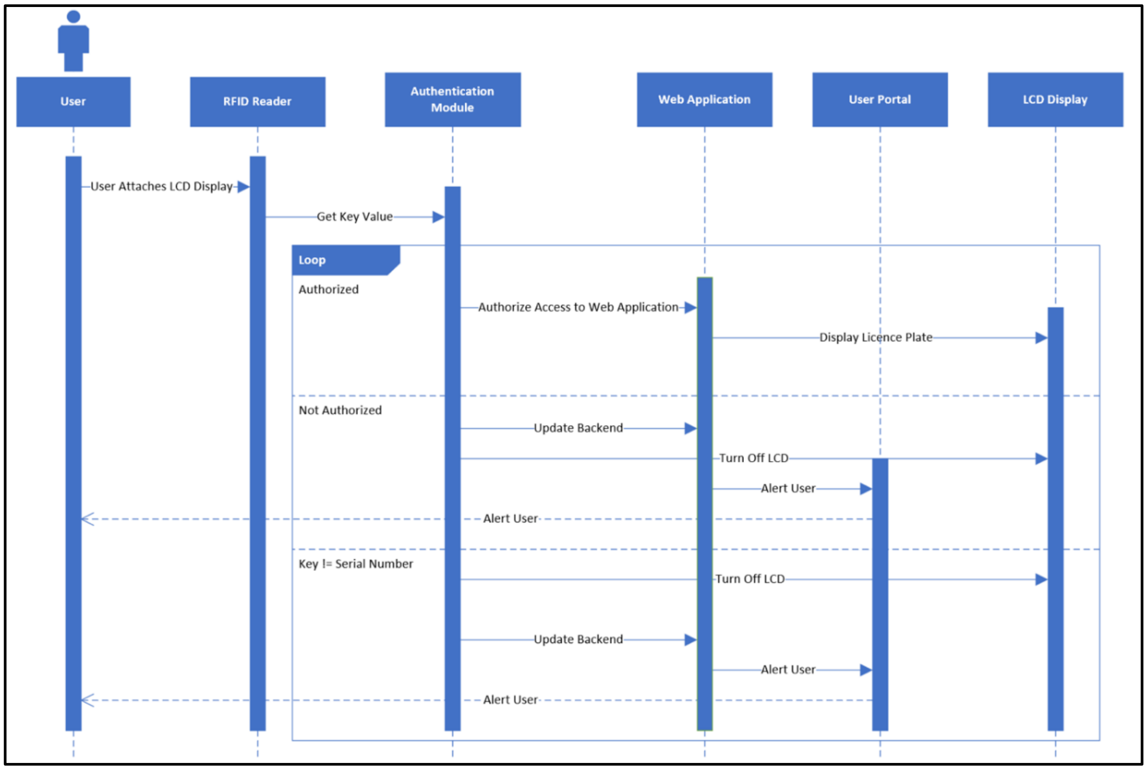


Figure 5: Interaction between RFID Reader and LCD Display

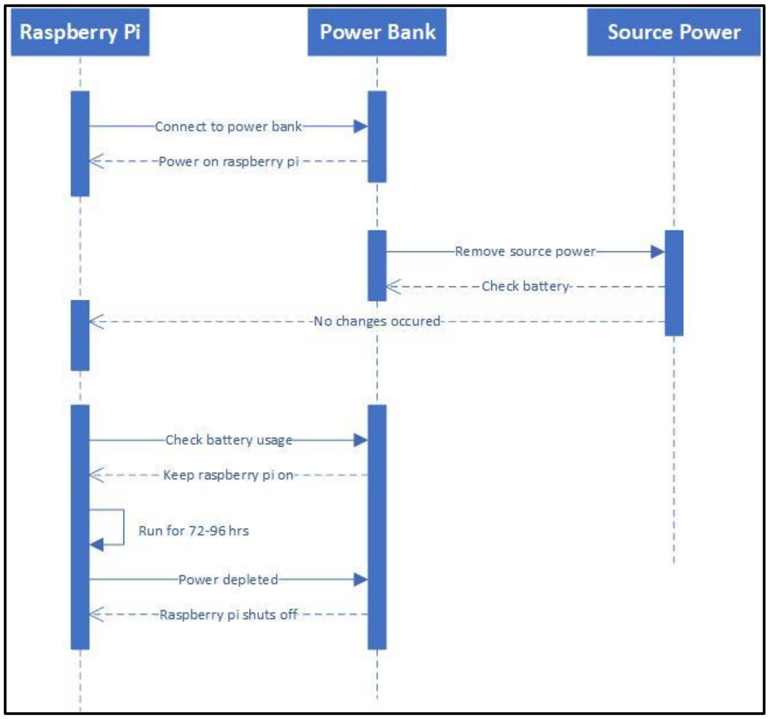


Figure 6: Interaction Between Consumed Energy & Payment Module

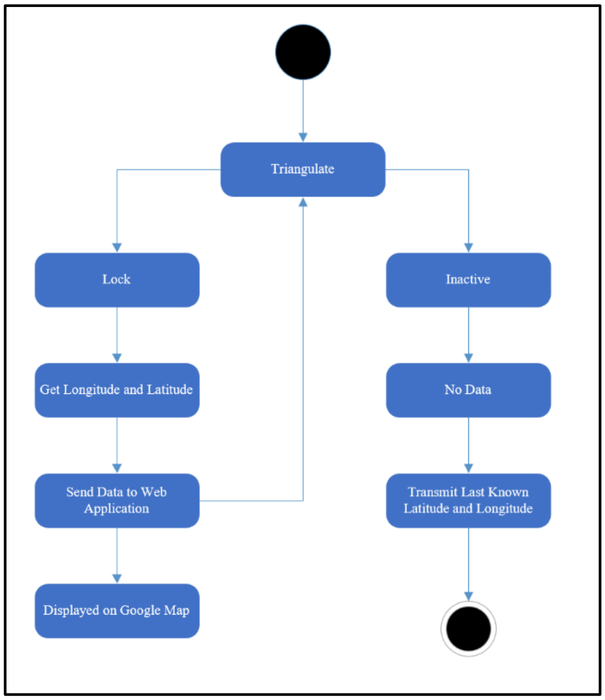

Triangulate
Lock
Inactive
Get Longitude and Latitude
No Data
Send Data to Web Application
Transmit Last Known Latitude and Longitude
Displayed on Google Map

Figure 7: State Diagram for GPS Module

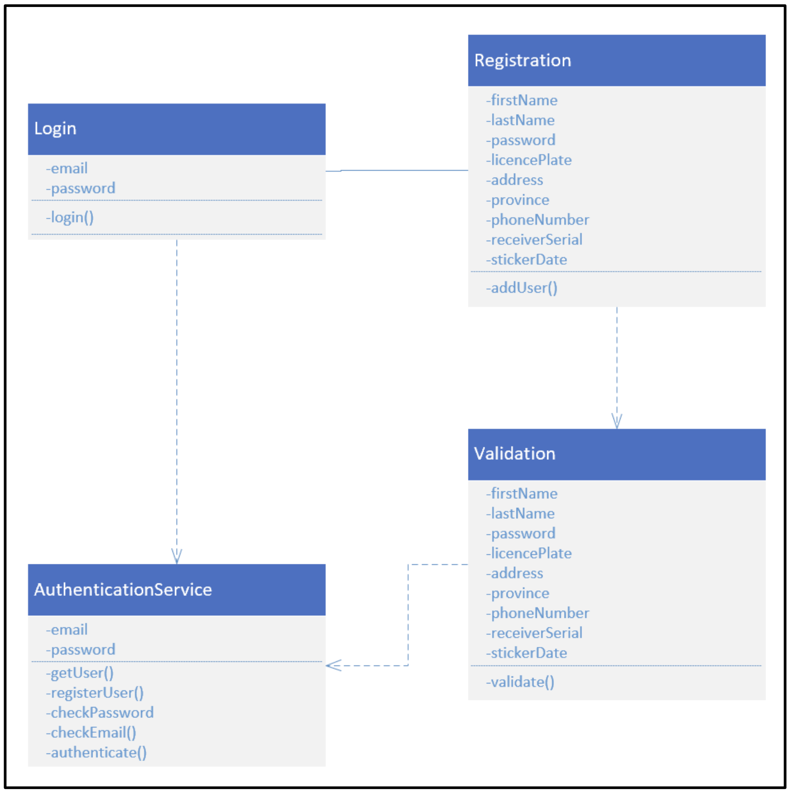


Figure 8: UML Class Diagram for Login Module

2.1.2 Scripts

Table 2.1 below lists the scripts and their descriptions for all programmed scripts currently being used to run our prototype.

Table 2.1: Current Functional Scripts

Scripts	Description
Writer.py	The script is executed to overwrite the current KEY value on the RFID tag.
Authorization.py	The main script allows access to an authorized LCD with an RFID tag while information the authorized user of an illicit user.
Reader.py	The script is executed to test the communication between the RFID reader and tag
GPS.py	The script is executed to get current location for the device using the GPS module

2.2 Final Electrical Design

The following figure is a complete and final diagram of the physical connections used for our smart license plate. As can be seen from the figure, there are 3 major connection classifications we have defined for the electrical design: Power (blue), Security (green) and EV (red).

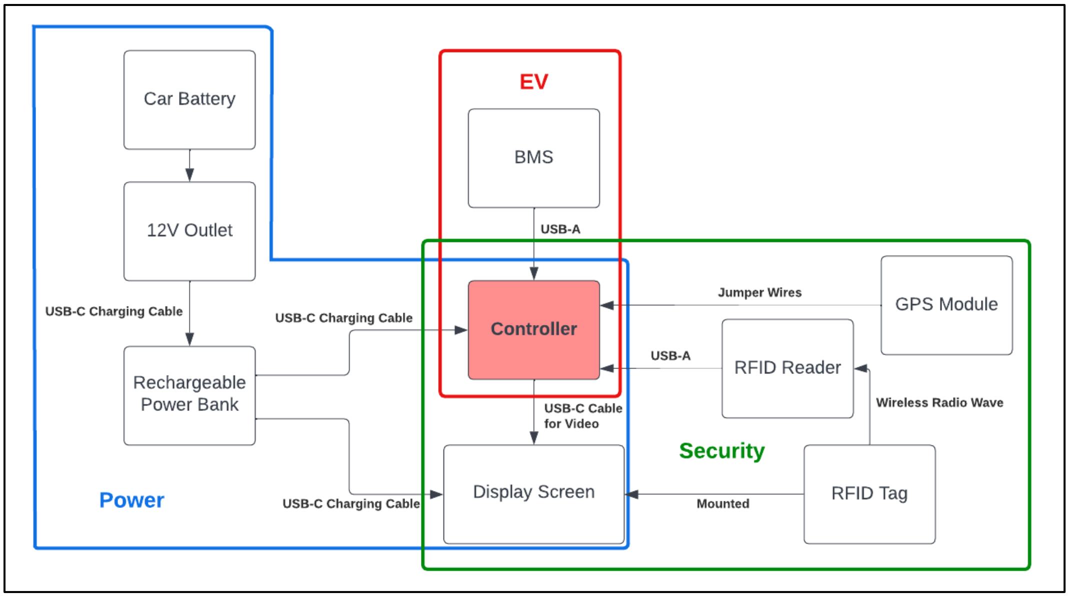


Figure 9: Complete Electrical Connection Diagram

2.3.1 Power & Display Connection Diagram

The figure below shows the detailed outline of the how the plate's display and power are connected to the main controller. The rechargeable power bank will be continuously recharged via a 12V outlet in the vehicle when the vehicle is turned on. The power bank will then power the controller and display screen via USB-C charging cables. Smaller devices like the RFID reader and GPS module will then draw power from the directly from their connections to controller (not shown).

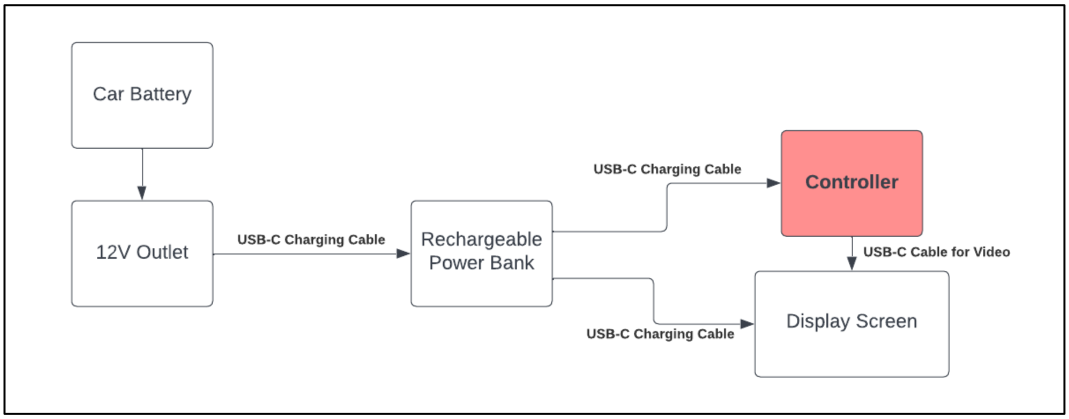


Figure 10: Power & Display Connection Diagram

2.3.2 Security Connection Diagram

The connections for the security devices are shown in **Figure 11** below. Both the GPS module and RFID reader will be connected to the Raspberry Pi controller via jumper wires. The RFID tag, which is attached to the back of the display screen, will wirelessly and continuously send a signal to the RFID reader when it is in close proximity. Once this signal is broken, due to the display being removed, an alarm will be triggered notifying the user of the removal of the plate. If the plate is then reconnected, it will show as "stolen" until the user resets via the website.

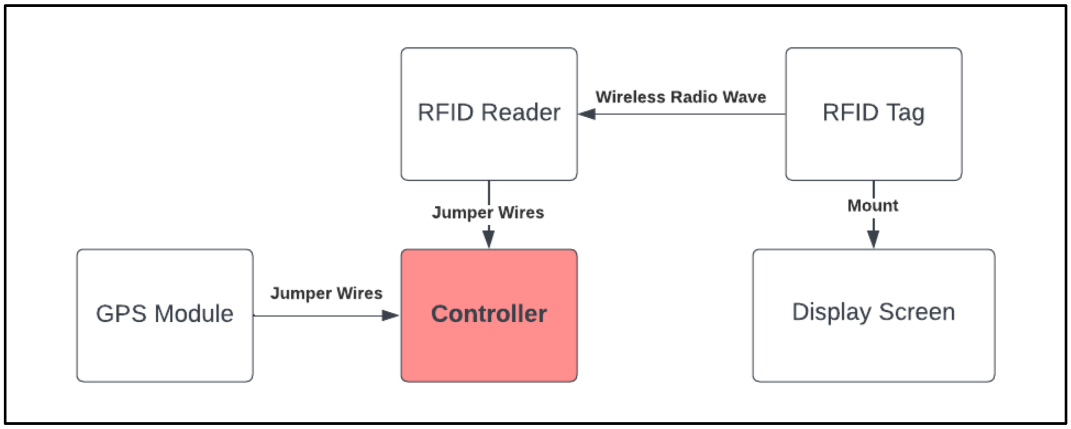


Figure 11: Plate Security Connection Diagram

2.3.2.1 RFID Reader

The RFID reader will have 7 jumped connections to the controller. All connections are outlined in the table below.

Table 2.2: List of RFID Reader to Raspberry Pi Pin Connections [2]

Connection #	RFID Reader Connection	Raspberry Pi Pin #
1	SDA	24
2	SCK	23
3	MOSI	19
4	MISO	21
5	GND	6
6	RST	22
7	3.3v	1

The following figure visually shows how the RIFD reader will connect to the Raspberry Pi through a breadboard.

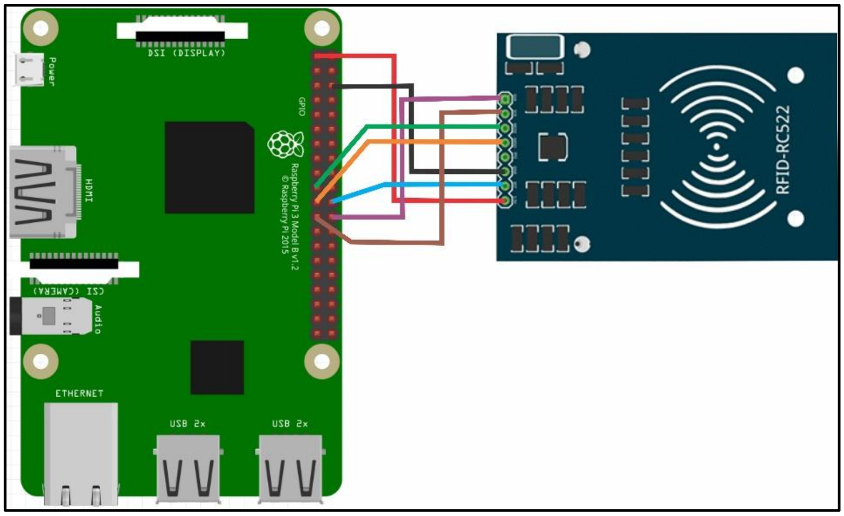
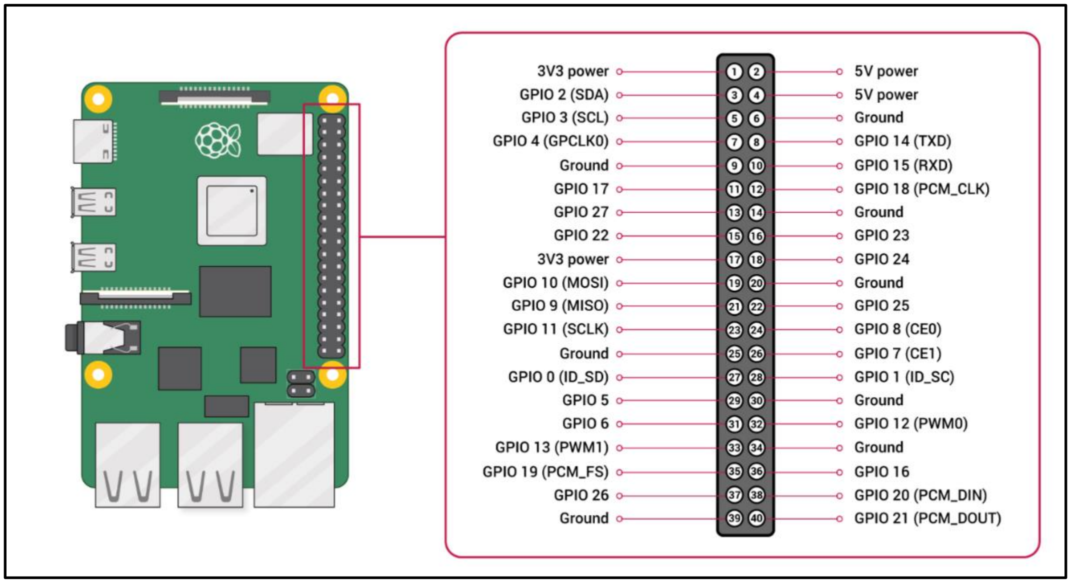


Figure 12: RFID Reader Connections to Raspberry Pi 4 [2]

Figure # outlines the Raspberry Pi’s pin numbers as well as their names.



3V3 power	1	2	5V power
GPIO 2 (SDA)	3	4	5V power
GPIO 3 (SCL)	5	6	Ground
GPIO 4 (GPCLK0)	7	8	GPIO 14 (TXD)
Ground	9	10	GPIO 15 (RXD)
GPIO 17	11	12	GPIO 18 (PCM_CLK)
GPIO 27	13	14	Ground
GPIO 22	15	16	GPIO 23
3V3 power	17	18	GPIO 24
GPIO 10 (MOSI)	19	20	Ground
GPIO 9 (MISO)	21	22	GPIO 25
GPIO 11 (SCLK)	23	24	GPIO 8 (CE0)
Ground	25	26	GPIO 7 (CE1)
GPIO 0 (ID_SD)	27	28	GPIO 1 (ID_SC)
GPIO 5	29	30	Ground
GPIO 6	31	32	GPIO 12 (PWM0)
GPIO 13 (PWM1)	33	34	Ground
GPIO 19 (PCM_FS)	35	36	GPIO 16
GPIO 26	37	38	GPIO 20 (PCM_DIN)
Ground	39	40	GPIO 21 (PCM_DOUT)

Figure 13: Raspberry Pi Pins [3]

2.3.2.2 GPS Module

The GPS Module will have 3 jumped connections to the controller. The connections are outlined in the table below.

Table 2.3: List of GPS Module to Raspberry Pi Pin Connections [2]

Connection #	GPS Module Connection	Raspberry Pi Pin #
1	GND	6
2	TX	10
3	UCC	2

The following is an image showing how the GPS module connects to the main controller (Raspberry Pi).

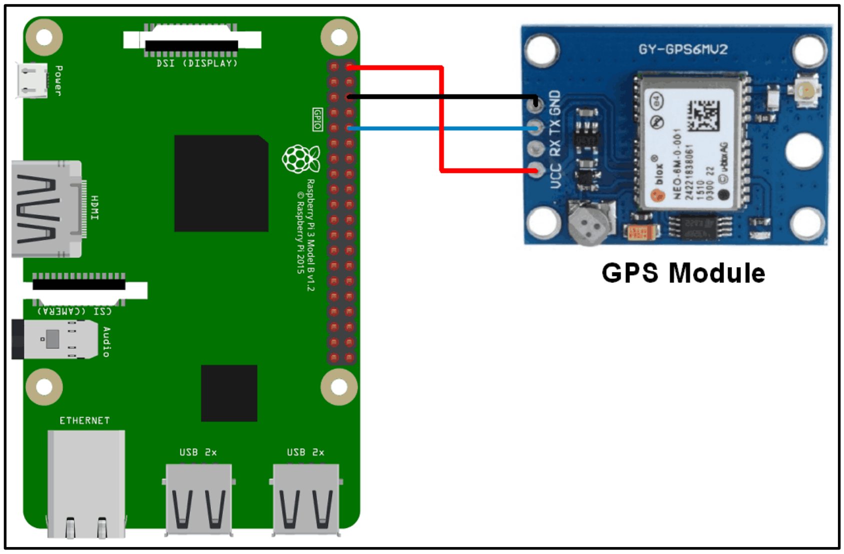


Figure 14: GPS Module Connections to Raspberry Pi 4 [4]

2.3.3 EV Connection Diagram

This diagram depicts the EV connectivity to the controller and cloud storage.

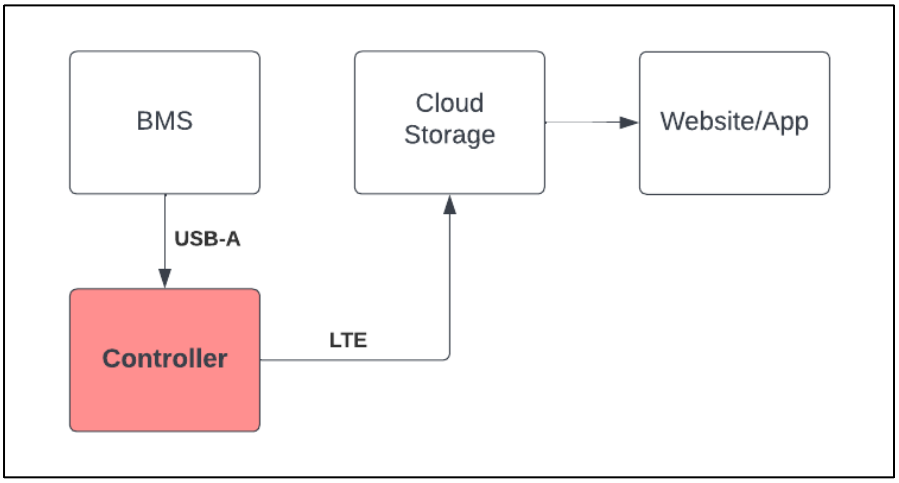


Figure 15: EV Connection Diagram

Figure 15 demonstrates the smart grid electrical setup for electric vehicles. The EV's battery management system, or BMS for short, is connected to the controller through a USB-A input. The BMS will provide real-time battery data and pass it to the controller. The controller will then communicate the data to our cloud storage system using an LTE connection and ergo to our website. The website will be available to users who want to check their vehicle's electrical consumption data along with its battery health and state information. Note that this circuit can only be implemented into EV vehicles.

2.4 Casing Design

This section consists of the casing design, measurements, and 3D modeling. Our prototype's housing will be separated into two separate pieces. The rear housing will be mounted to the vehicle using mounting screws similar to how regular plates are mounted. The front housing will slide over the rear housing securely locking it into place.

2.4.1 Front Housing Drawing

2.4.1.1 Front Housing 3D Renderings

The figures below are various 3D renderings of the front housing that will contain the screen and front protective plexiglass. This housing will tightly slide over the rear housing to secure the LCD display in place.

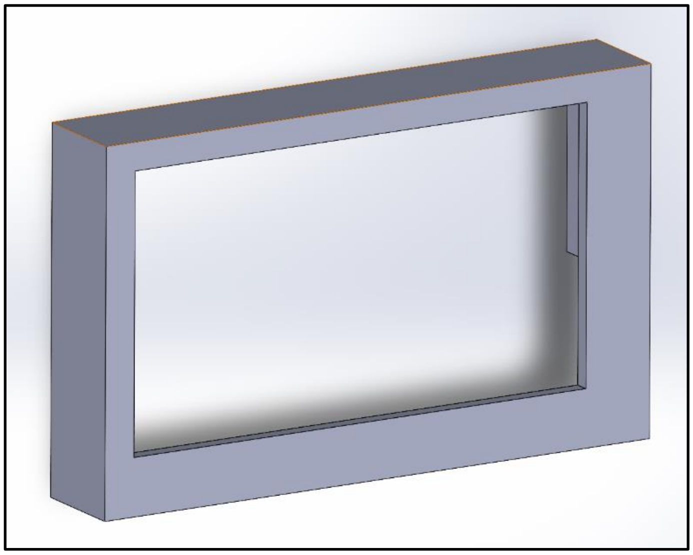


Figure 16: Front Housing 3D Rendering - Front View

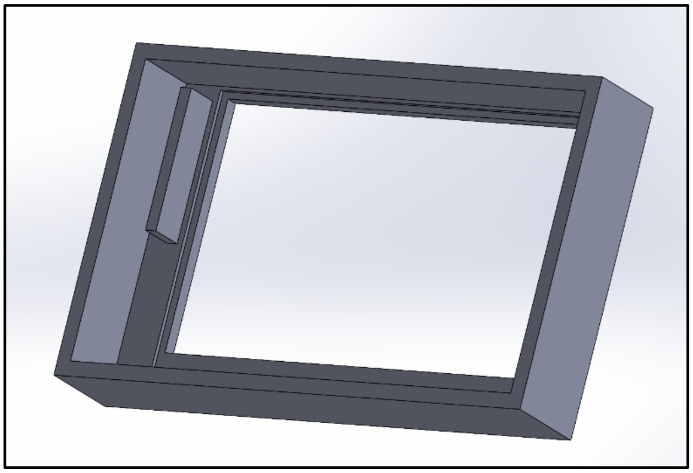


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Figure 17: Front Housing 3D Rendering – Rear View

2.4.1.2 Front Housing Front View

The schematic below is the front view of the front housing with all the respective measurements.

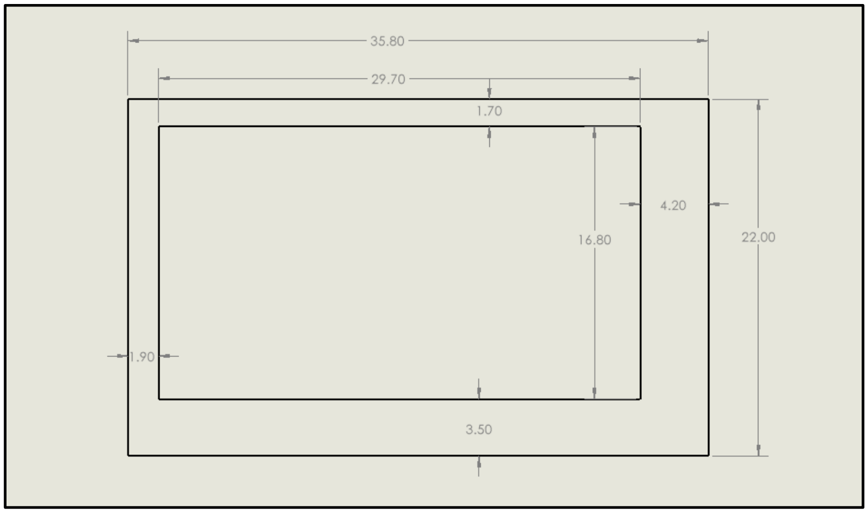


Figure 18: Front Housing Front View Drawing

2.4.1.3 Front Housing Rear View

The schematic below is the rear view of the front housing with all the respective measurements.

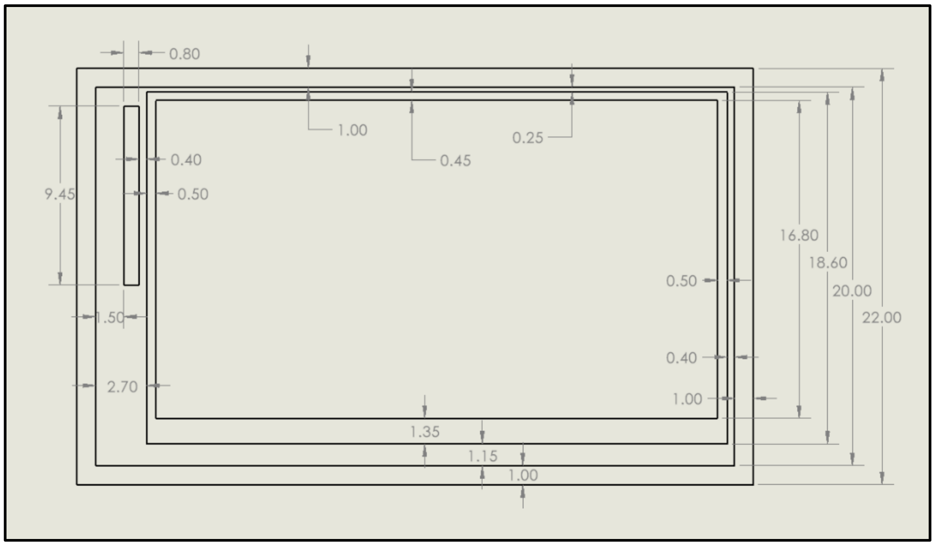


Figure 19: Front Housing Rear View Drawing

2.4.1.4 Front Housing Side View

The schematic below is the side view of the front housing with all the respective measurements.

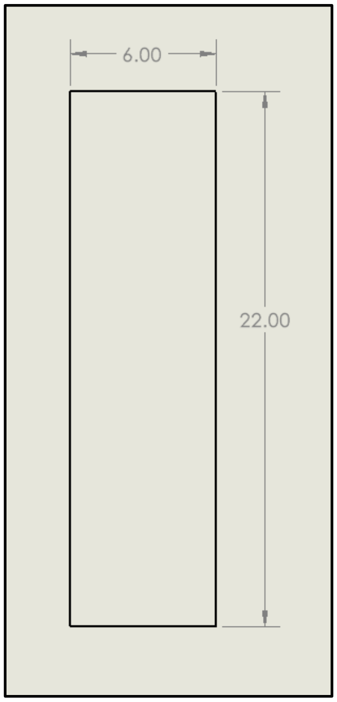


Figure 20: Front Housing Side View Drawing

2.4.1.5 Front Housing Top/Bottom View

The schematic below is the top/bottom view of the front housing with all the respective measurements.

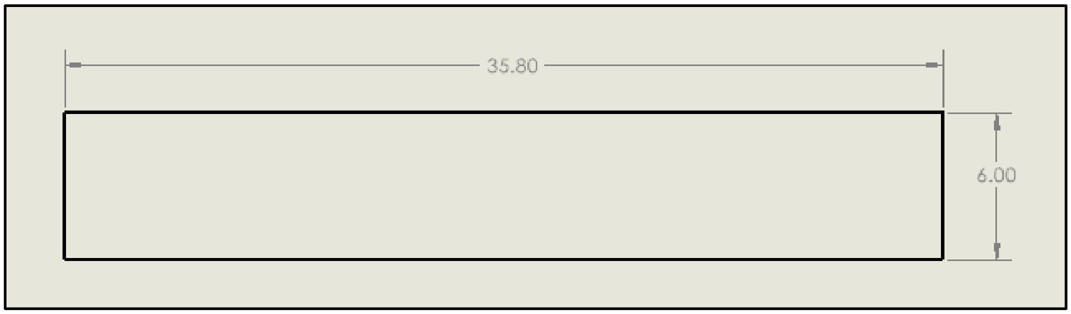


Figure 21: Front Housing Top/Bottom View Drawing

2.4.2 Rear Housing Drawings

2.4.2.1 Rear Housing 3D Renderings

The following is a 3D rendering of the rear housing. This housing will enclose the power bank, RFID reader, and GPS module. As can be seen from the picture below it has cut-outs to secure all devices within. There are two holes above passing through the housing in order for screws to be used to secure the housing to the vehicle. The large cut-out on the right side, seen on the right side in **Figure 22**, provides a space for the earlier mentioned retaining wall to pass as well as space for cables and other connections to pass through.

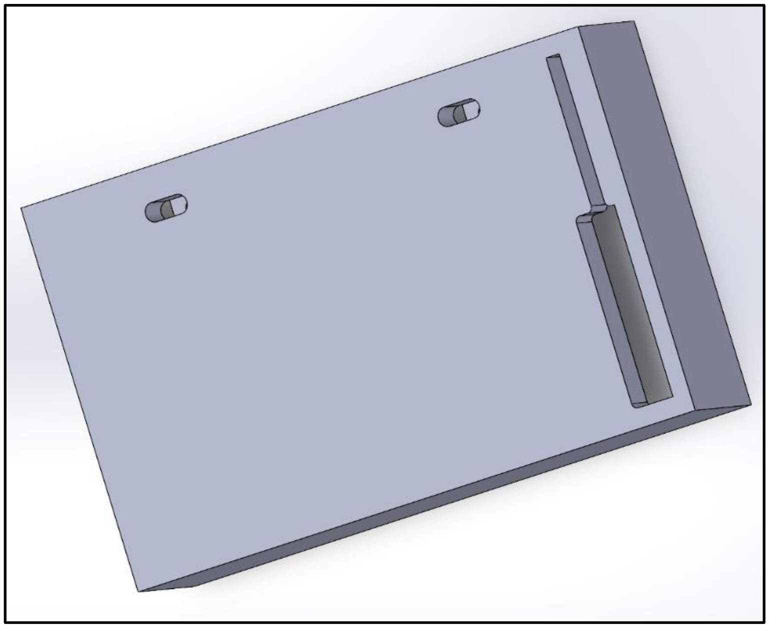


Figure 22: Rear Housing 3D Rendering – Front View

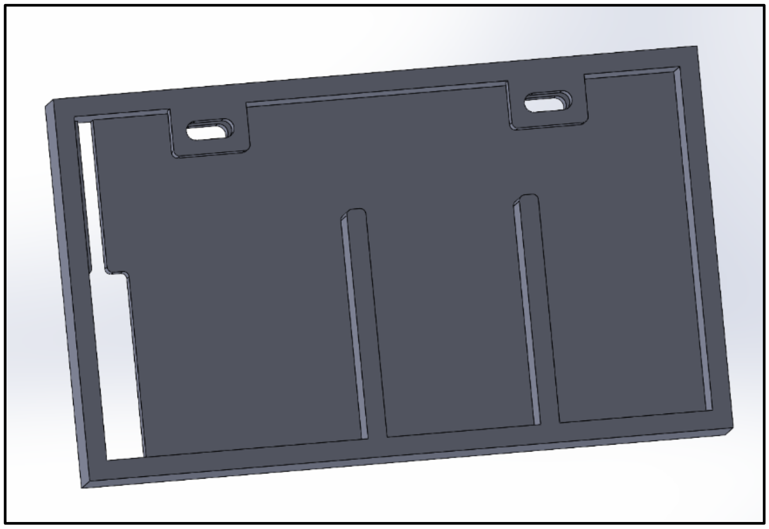


Figure 23: Rear Housing 3D Rendering – Rear View

2.4.2.2 Rear Housing Front View

The schematic below is the front view of the rear housing with all the respective measurements.

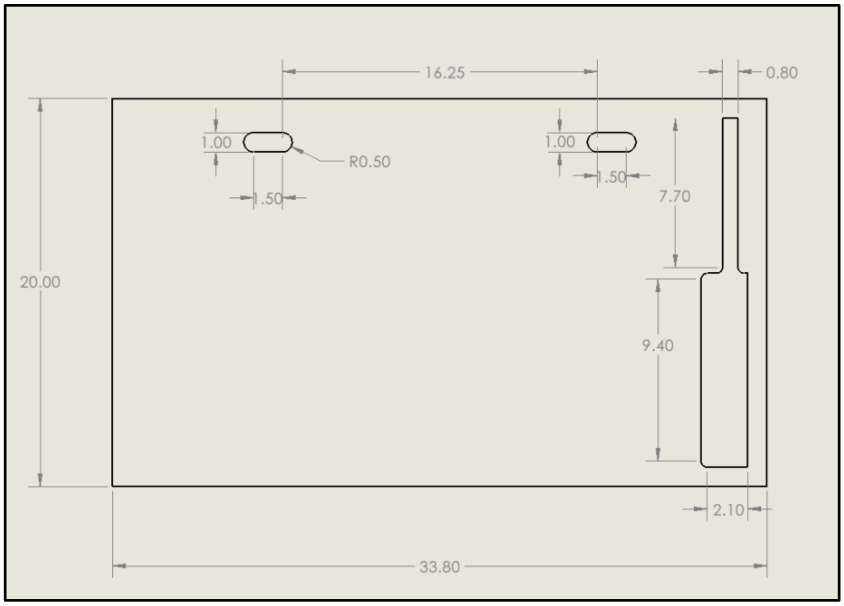


Figure 24: Rear Housing Front View Drawing

2.4.2.3 Rear Housing Rear View

The schematic below is the rear view of the rear housing with all the respective measurements.

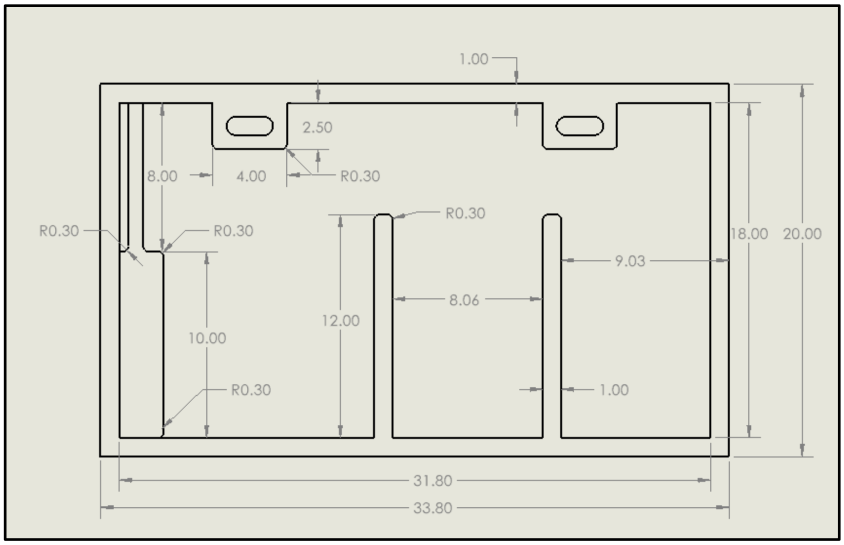


Figure 25: Rear Housing Rear View Drawing

2.4.2.4 Rear Housing Side View

The schematic below is the side view of the rear housing with all the respective measurements.

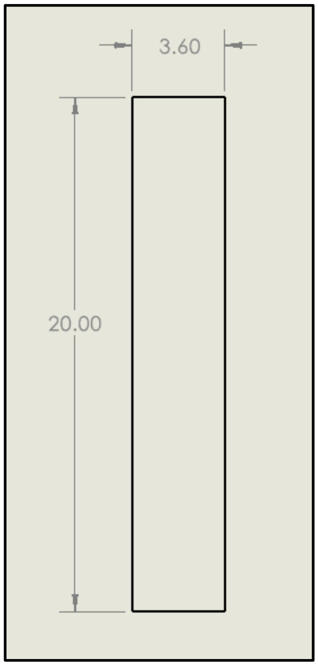


Figure 26: Rear Housing Side View Drawing

2.4.2.5 Rear Housing Top/Bottom View

The schematic below is the top/bottom view of the rear housing with all the respective measurements.

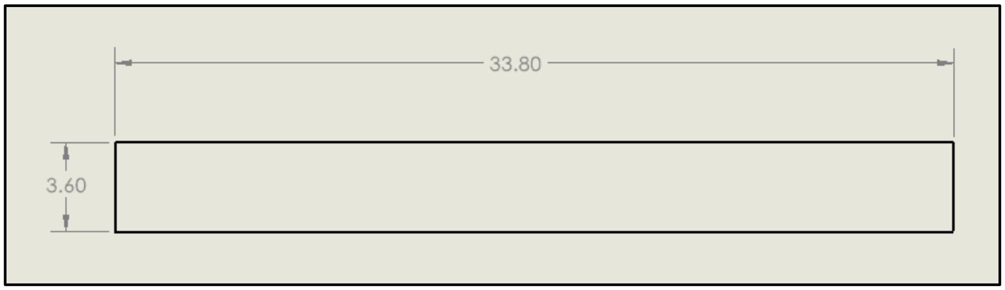


Figure 27: Rear Housing Top/Bottom View Drawing

3 Integration Tests

3.1 List of Integration Tests

Below, **Table 3.0** lists the integration test cases that will be described in the next section.

Table 3.0: List of Integration Tests

Integration Test Case Name	Test ID	Description
IT #1	Plate-IT-01	Test the interface link between the login and the portal module
IT #2	Plate-IT-02	Test the interaction between the RFID tag and Raspberry Pi 4
IT #3	Plate-IT-03	Test interaction between LCD display and Raspberry Pi 4
IT #4	Plate-IT-04	Test the interaction between the LCD display and renewal module.
IT #5	Plate-IT-05	Test the interaction between Raspberry PI and power bank.
IT #6	Plate-IT-06	Test the interaction between energy consumed and payment module.
IT #7	Plate-IT-07	Test the writing module with the Raspberry PI serial to the RFID tag and verify output
IT #8	Plate-IT-08	Test the interaction between the RFID reader and unauthorized LCD

3.2 Completed Integration Tests

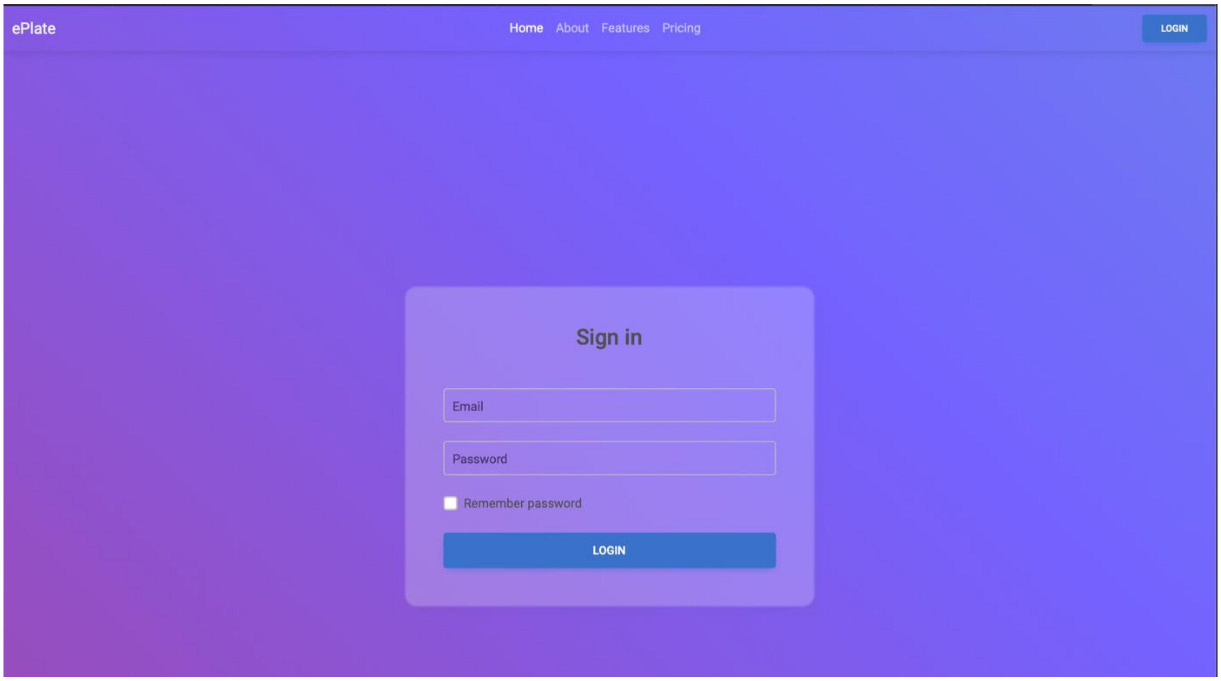
Table 3.1: Completed Integration Test Case #1

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #1	**Test ID:**	Plate-IT-01
Description:	Test the interface link between the login and the portal module	**Type:**	Black Box: ✓ White Box: □
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	02/14/2023
Hardware Version:	V1.0	**Time:**	8:10 PM
Setup:	The user accessing the login page must be within the database.		

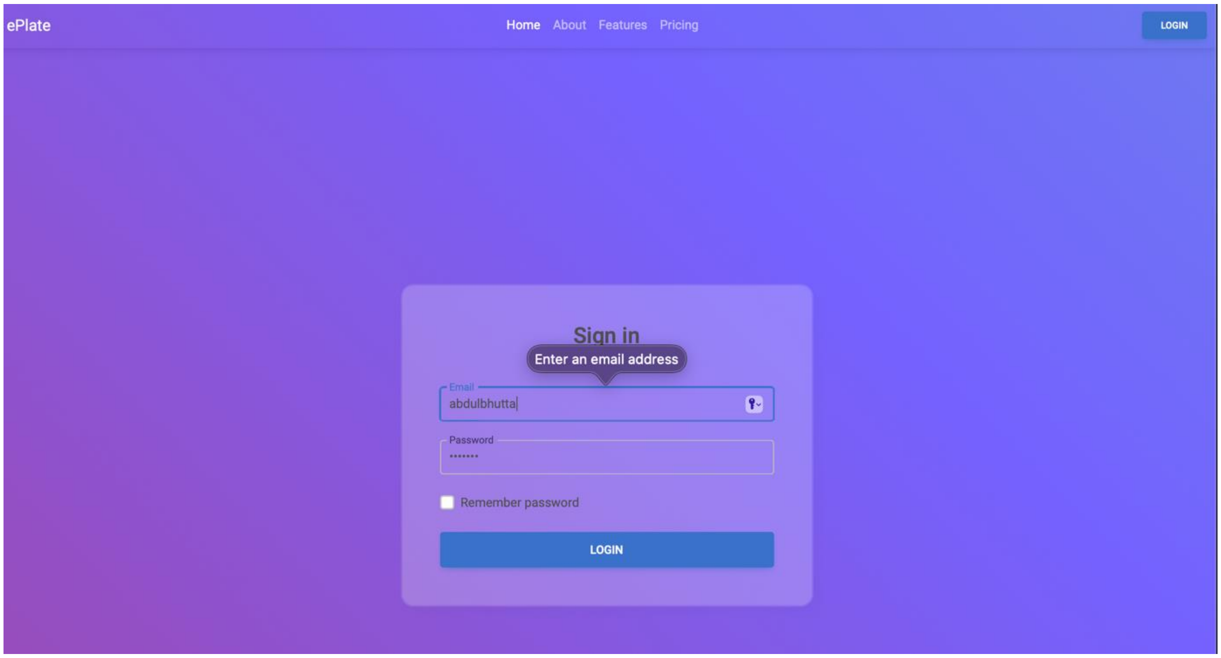
Step	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Access the login page	The user shall be prompted with credential request	✓			
2	Validate user enters an email	If user enters an incorrect format, an error message should be displayed	✓			
3	User enters authorized credentials	User should not expect to see any error	✓			
4	User clicks on login button	The user shall be redirected to a portal page	✓			
Test Result:			**PASS**			

Plate-IT-01 Results

Step 1: Access Login page



Step 2: Validate user enters an email

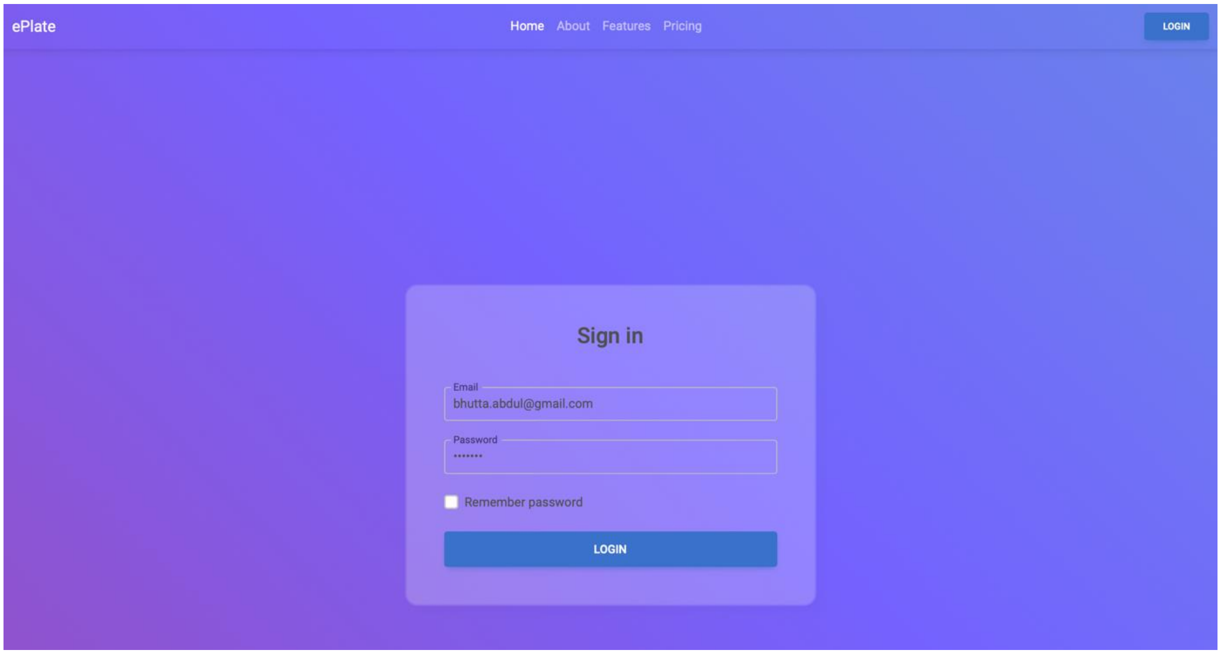


Enter an email address

Email: abdulbhutta

Password: •••••••

Step 3: Users enters authorized credentials



Sign in

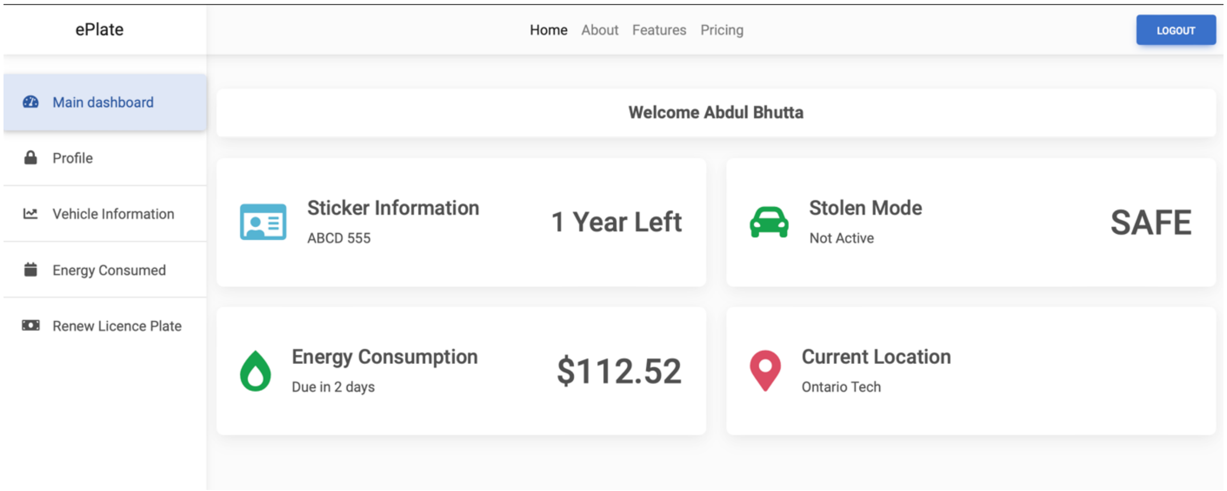
Email: bhutta.abdul@gmail.com

Password: •••••••

□ Remember password

LOGIN

Step 4: Users clicks on login button



Welcome Abdul Bhutta

Sticker Information	ABCD 555	1 Year Left
Stolen Mode	Not Active	SAFE
Energy Consumption	Due in 2 days	$112.52
Current Location	Ontario Tech	

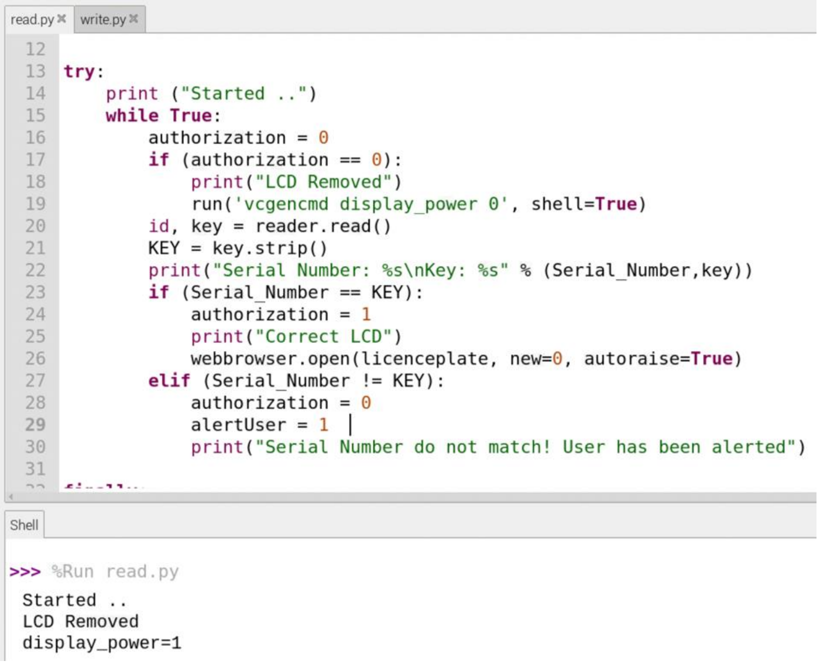
Table 3.2: Completed Integration Test Case #2

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #2	**Test ID:**	Plate-IT-02
Description:	Test the interaction between the RFID tag and Raspberry Pi 4	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	-
Hardware Version:	V1.0	**Time:**	-
Setup:	The Raspberry Pi 4 must have the RFID unique ID authorized within the microcontroller. The RFID reader must be installed and running on the Raspberry Pi.		

Step	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Verify the output	Initially, the lcd should be in sleep mode.	✓			
2	Connect the LCD (RFID tag) to the case (RFID Reader)	The microcontroller should grant access	✓			
3	Remove the LCD from the case	The RFID reader should detect the LCD has been removed	✓			
4	Verify LCD has been turned off				✓	Needs to be tested with the LCD. Currently working on the Raspberry Pi
Test Result:			**Pass**			

PLATE-IT-02 Results

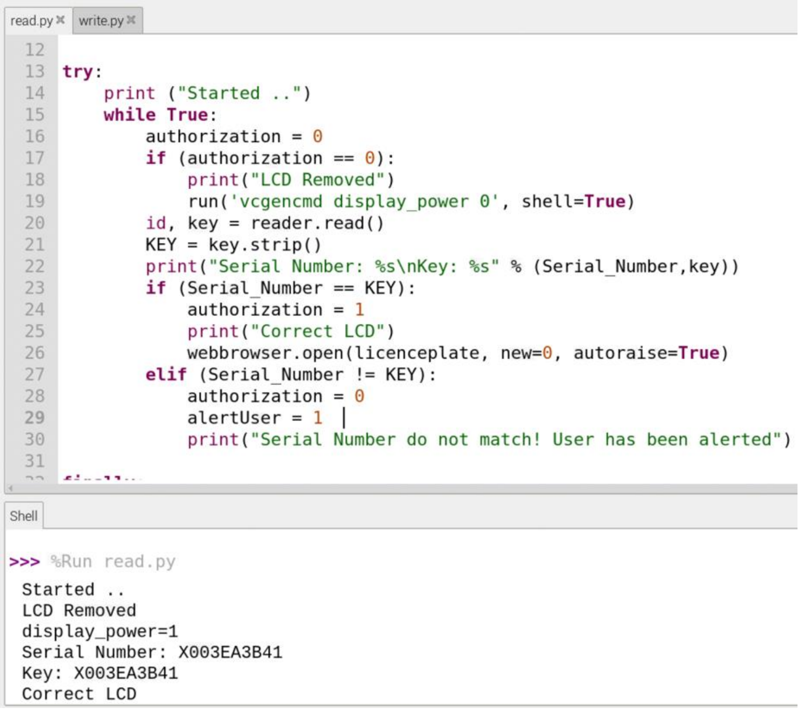
Step 1: Verify the output



```
try:
    print ("Started ..")
    while True:
        authorization = 0
        if (authorization == 0):
            print("LCD Removed")
            run('vcgencmd display_power 0', shell=True)
        id, key = reader.read()
        KEY = key.strip()
        print("Serial Number: %s\nKey: %s" % (Serial_Number,key))
        if (Serial_Number == KEY):
            authorization = 1
            print("Correct LCD")
            webbrowser.open(licenceplate, new=0, autoraise=True)
        elif (Serial_Number != KEY):
            authorization = 0
            alertUser = 1
            print("Serial Number do not match! User has been alerted")
```

```
>>> %Run read.py
 Started ..
 LCD Removed
 display_power=1
```

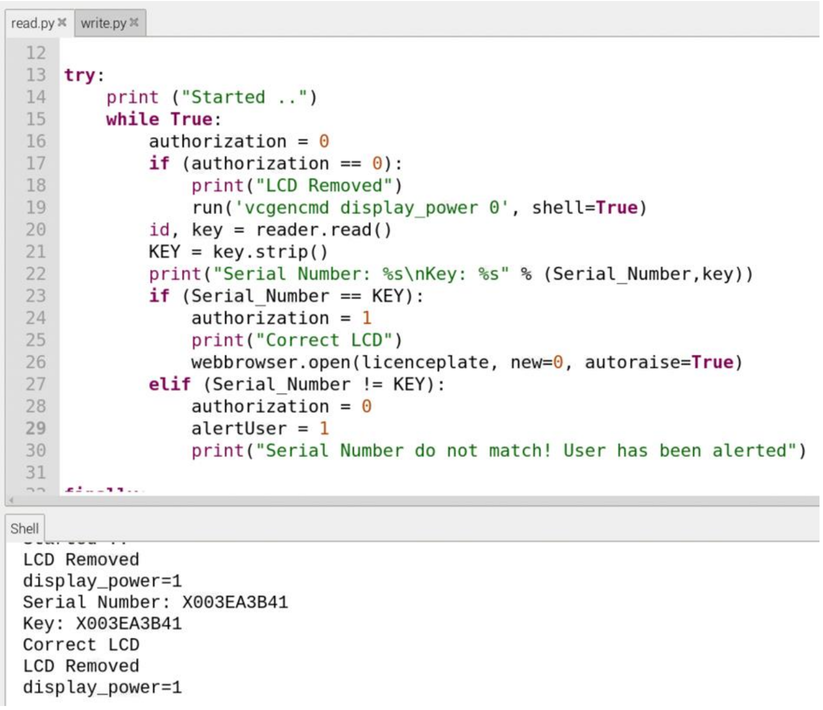
Step 2: Connect the LCD (RFID tag) to the case (RFID Reader)



```
try:
    print ("Started ..")
    while True:
        authorization = 0
        if (authorization == 0):
            print("LCD Removed")
            run('vcgencmd display_power 0', shell=True)
        id, key = reader.read()
        KEY = key.strip()
        print("Serial Number: %s\nKey: %s" % (Serial_Number,key))
        if (Serial_Number == KEY):
            authorization = 1
            print("Correct LCD")
            webbrowser.open(licenceplate, new=0, autoraise=True)
        elif (Serial_Number != KEY):
            authorization = 0
            alertUser = 1
            print("Serial Number do not match! User has been alerted")
```

```
>>> %Run read.py
 Started ..
 LCD Removed
 display_power=1
 Serial Number: X003EA3B41
 Key: X003EA3B41
 Correct LCD
```

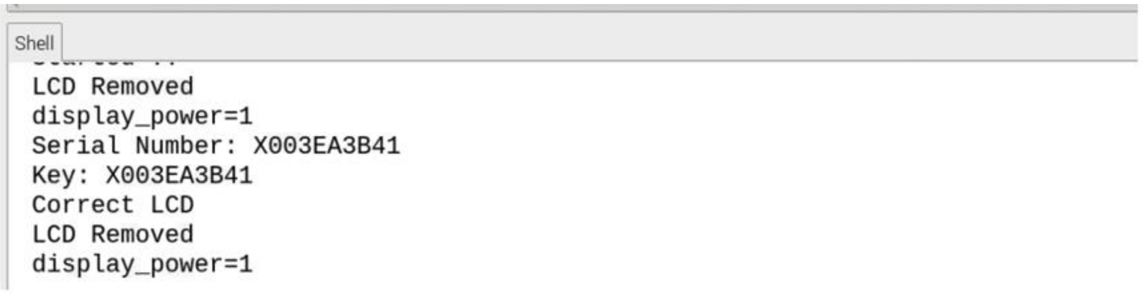
Step 3: Remove the LCD from the case



```
try:
    print ("Started ..")
    while True:
        authorization = 0
        if (authorization == 0):
            print("LCD Removed")
            run('vcgencmd display_power 0', shell=True)
        id, key = reader.read()
        KEY = key.strip()
        print("Serial Number: %s\nKey: %s" % (Serial_Number,key))
        if (Serial_Number == KEY):
            authorization = 1
            print("Correct LCD")
            webbrowser.open(licenceplate, new=0, autoraise=True)
        elif (Serial_Number != KEY):
            authorization = 0
            alertUser = 1
            print("Serial Number do not match! User has been alerted")

```

```
LCD Removed
display_power=1
Serial Number: X003EA3B41
Key: X003EA3B41
Correct LCD
LCD Removed
display_power=1
```

Step 4: Verify LCD has been turned off



```
LCD Removed
display_power=1
Serial Number: X003EA3B41
Key: X003EA3B41
Correct LCD
LCD Removed
display_power=1
```

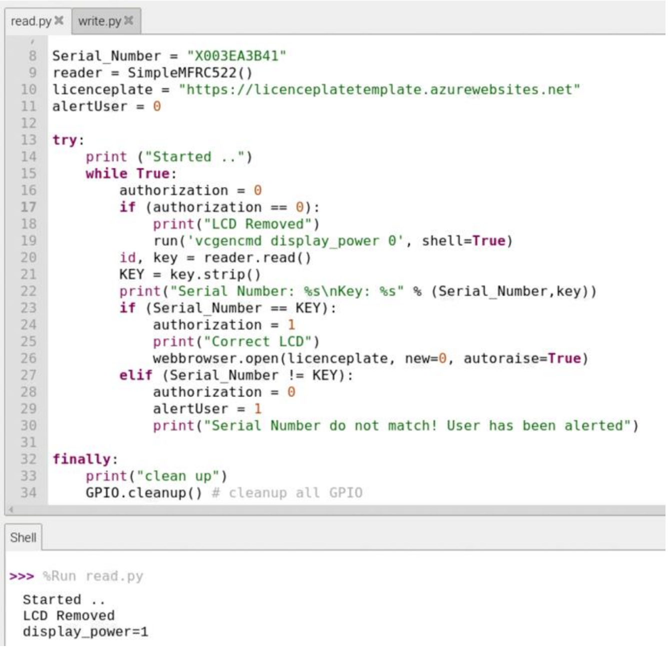
Table 3.3: Completed Integration Test Case #3

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #3	**Test ID:**	Plate-IT-03
Description:	Test interaction between LCD display and Raspberry Pi 4	**Type:**	Black Box: ✓ White Box: □
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	02/12/2023
Hardware Version:	V1.0	**Time:**	1:15 AM
Setup:	The Raspberry Pi 4 must have the RFID unique ID authorized within the microcontroller. The RFID reader must be installed and running on the Raspberry Pi.		

Step	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Verify the display is turned off	The LCD screen should not display any information and should be off.	✓			
2	Attach the LCD onto the case	Raspberry Pi should turn on and validate LCD display	✓			
3	Verify output on the LCD	The LCD will display the linked licence plate number	✓			Note: Browser needs to open in full screen mode
4						
Test Result:			**Pass**			

Plate-IT-03 Results

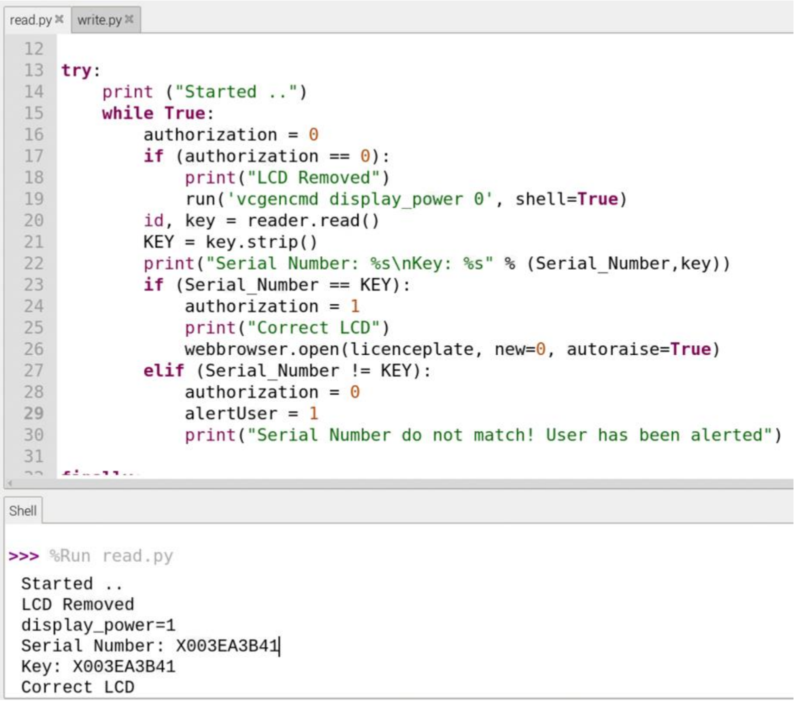
Step 1: Verify the display is turned off (display_power=1)



```
Serial_Number = "X003EA3B41"
reader = SimpleMFRC522()
licenceplate = "https://licenceplatetemplate.azurewebsites.net"
alertUser = 0

try:
    print ("Started ..")
    while True:
        authorization = 0
        if (authorization == 0):
            print("LCD Removed")
            run('vcgencmd display_power 0', shell=True)
        id, key = reader.read()
        KEY = key.strip()
        print("Serial Number: %s\nKey: %s" % (Serial_Number,key))
        if (Serial_Number == KEY):
            authorization = 1
            print("Correct LCD")
            webbrowser.open(licenceplate, new=0, autoraise=True)
        elif (Serial_Number != KEY):
            authorization = 0
            alertUser = 1
            print("Serial Number do not match! User has been alerted")

finally:
    print("clean up")
    GPIO.cleanup() # cleanup all GPIO
```

```
>>> %Run read.py
 Started ..
 LCD Removed
 display_power=1
```

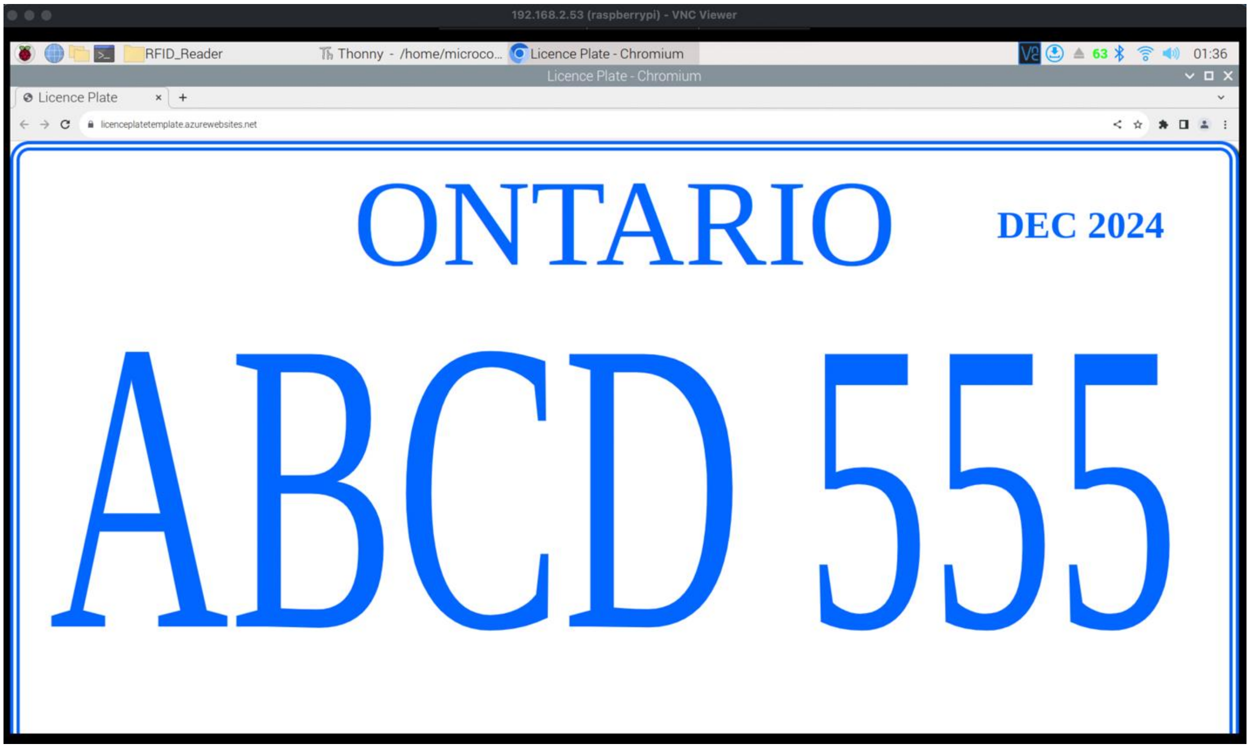
Step 2: Attach the LCD onto the case



```

try:
    print ("Started ..")
    while True:
        authorization = 0
        if (authorization == 0):
            print("LCD Removed")
            run('vcgencmd display_power 0', shell=True)
        id, key = reader.read()
        KEY = key.strip()
        print("Serial Number: %s\nKey: %s" % (Serial_Number,key))
        if (Serial_Number == KEY):
            authorization = 1
            print("Correct LCD")
            webbrowser.open(licenceplate, new=0, autoraise=True)
        elif (Serial_Number != KEY):
            authorization = 0
            alertUser = 1
            print("Serial Number do not match! User has been alerted")

```

```
>>> %Run read.py
 Started ..
 LCD Removed
 display_power=1
 Serial Number: X003EA3B41
 Key: X003EA3B41
 Correct LCD
```

Step 3: Verify output on the LCD screen


192.168.2.53 (raspberrypi) - VNC Viewer
RFID_Reader
Thonny - /home/microco...
Licence Plate - Chromium
63
01:36
Licence Plate - Chromium
Licence Plate
licenceplatetemplate.azurewebsites.net
ONTARIO
DEC 2024
ABCD 555

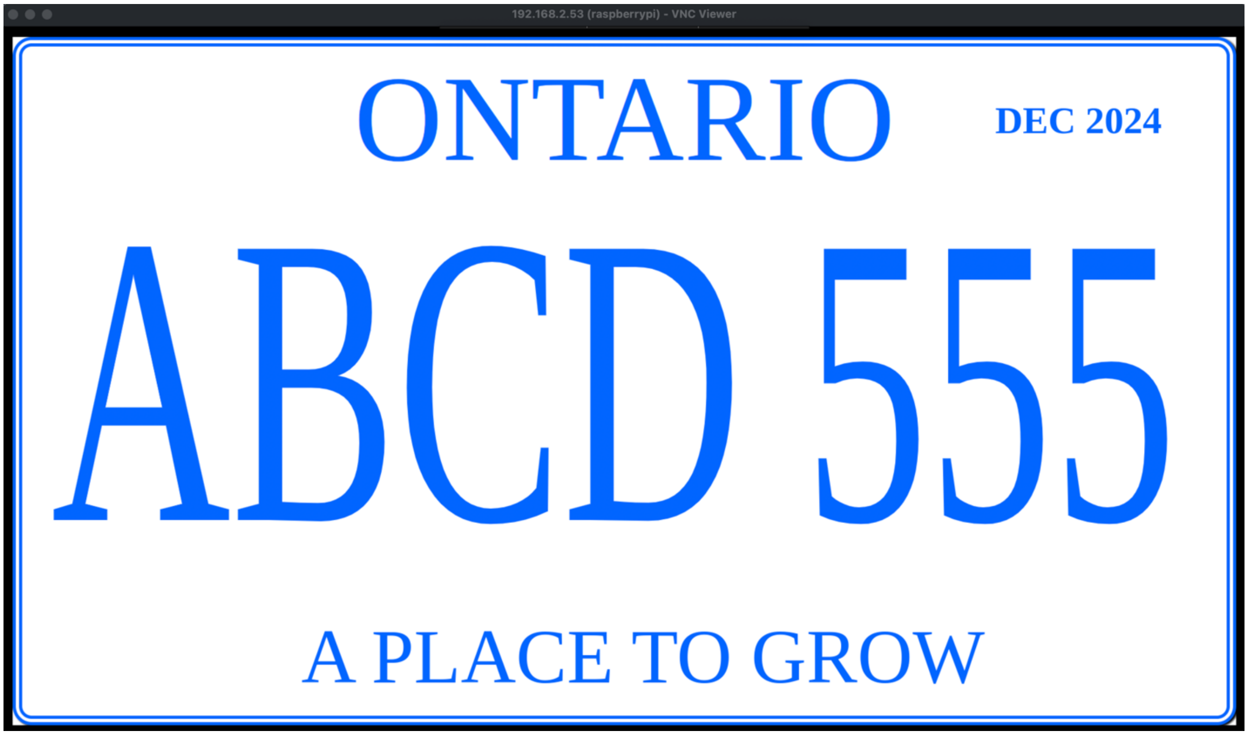

192.168.2.53 (raspberrypi) - VNC Viewer
ONTARIO
DEC 2024
ABCD 555
A PLACE TO GROW

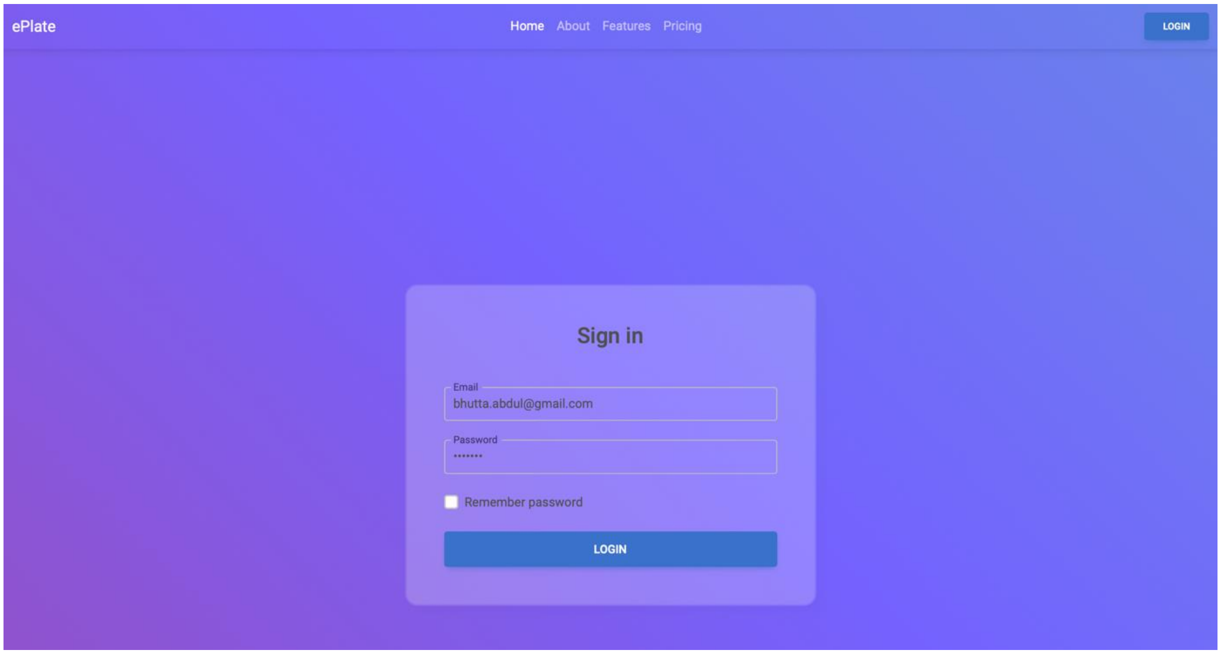
Table 3.4: Completed Integration Test Case #4

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #4	**Test ID:**	Plate-IT-04
Description:	Test the interaction between the LCD display and renewal module.	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	02/10/2023
Hardware Version:	V1.0	**Time:**	1:30 PM
Setup:	The Raspberry Pi must be running the application and the RFID unique ID should be authorized to access the microcontroller. The Raspberry Pi must be connected to a reliable Wi-Fi network.		

Step	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Login as an authorized user to access the portal	The user shall be redirected to a personalized portal	✓			
2	Verify portal page	Verify it displays the correct information	✓			
3	Access renewal plate	The webpage will be updated to the renewal page while allowing the user to pay the fee	✓			
4	Verify output on licence plate	The current expiry date should appear on the licence plate	✓			
5	Pay the amount	Payment should be processed	✓			Simulated credit card and no actual payment module
6	Verify payment has been processed	The portal page should be updated with the correct value	✓			
7	Verify updated sticker	The expiry date on the sticker will be updated	✓			
Test Result:			**Pass**			

Plate-IT-04 Results

Step 1: Use an authorized user to access the portal

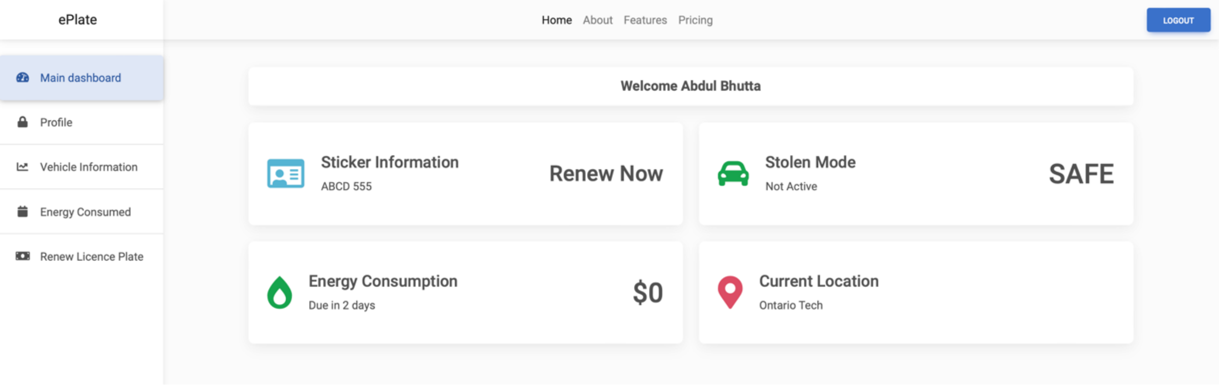


Sign in

Email: bhutta.abdul@gmail.com

Password: •••••••

Step 2: Verify portal page



Welcome Abdul Bhutta

Sticker Information — ABCD 555 — Renew Now

Stolen Mode — Not Active — SAFE

Energy Consumption — Due in 2 days — $0

Current Location — Ontario Tech

Step 3: Access Renewal page

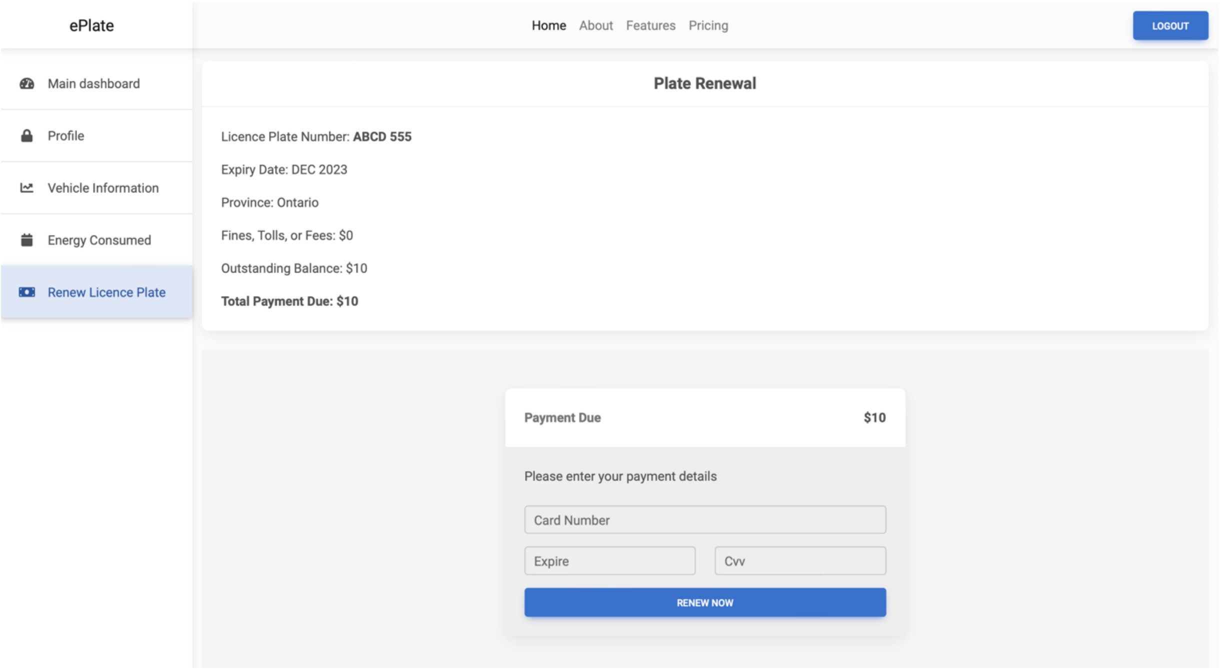


Plate Renewal

Licence Plate Number: **ABCD 555**

Expiry Date: DEC 2023

Province: Ontario

Fines, Tolls, or Fees: $0

Outstanding Balance: $10

Total Payment Due: $10

Payment Due **$10**

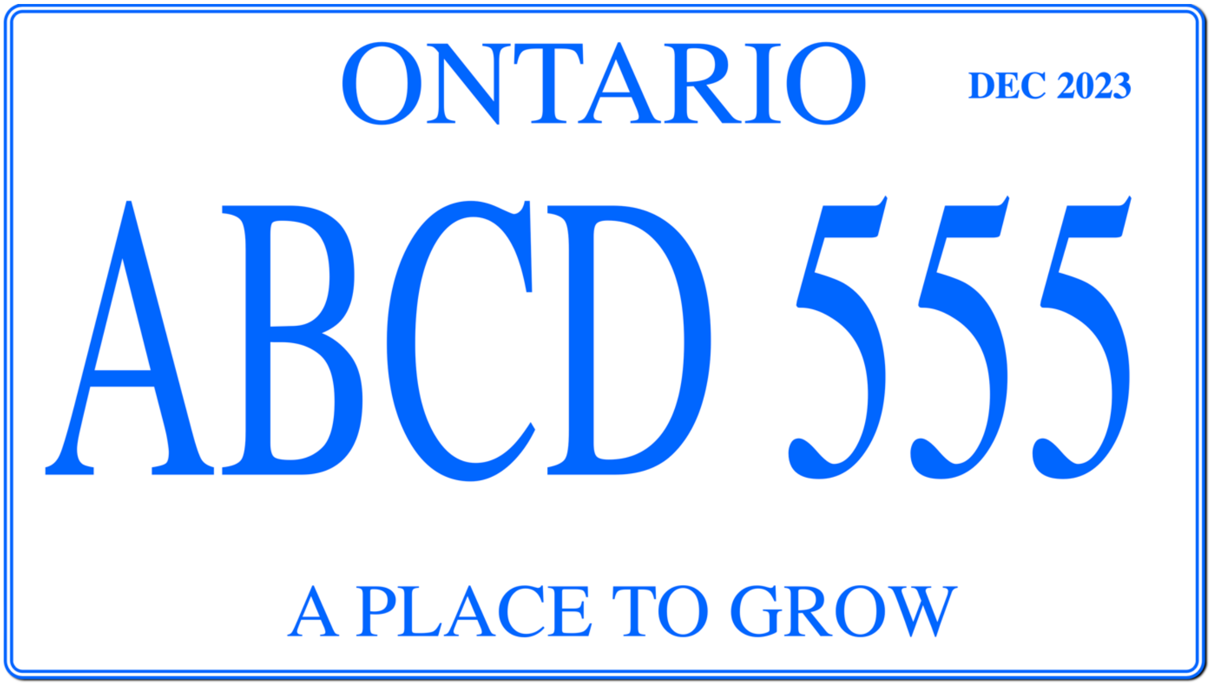
Please enter your payment details

Card Number

Expire

Cvv

Step 4: Verify output on licence plate



Step 5: Pay the amount (Simulated credit card and no actual payment module)

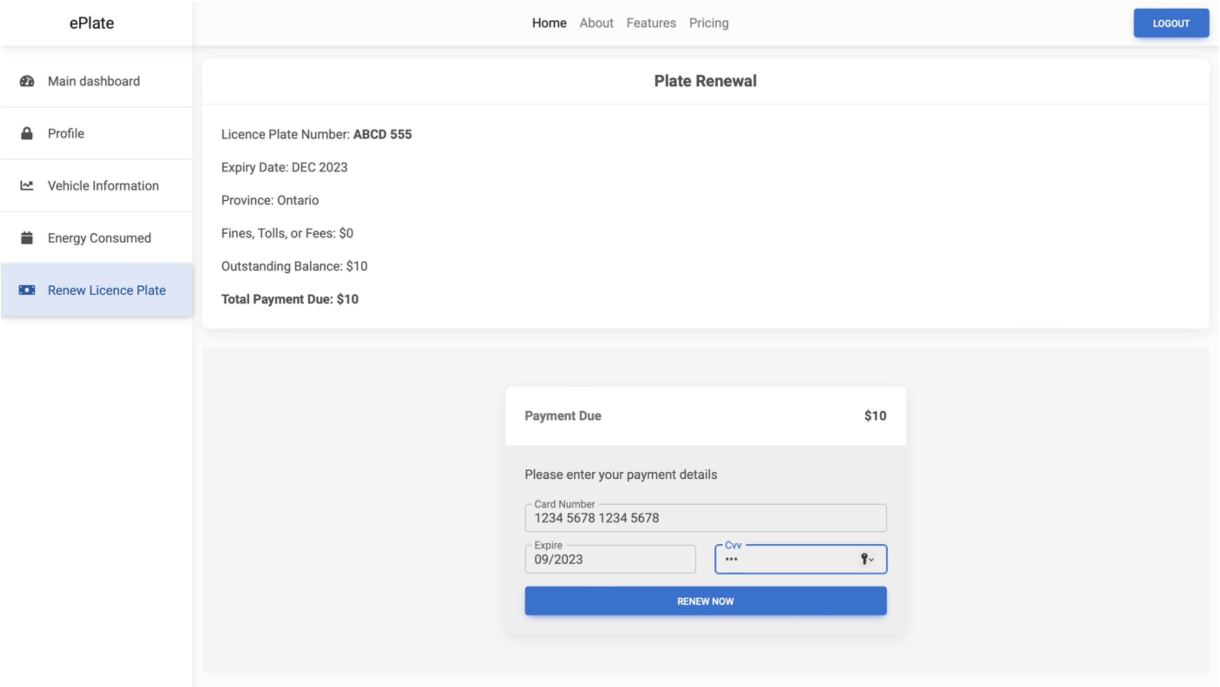


Plate Renewal

Licence Plate Number: **ABCD 555**

Expiry Date: DEC 2023

Province: Ontario

Fines, Tolls, or Fees: $0

Outstanding Balance: $10

Total Payment Due: $10

Payment Due **$10**

Please enter your payment details

Card Number: 1234 5678 1234 5678

Expire: 09/2023

Cvv: •••

Step 6: Verify payment has been processed

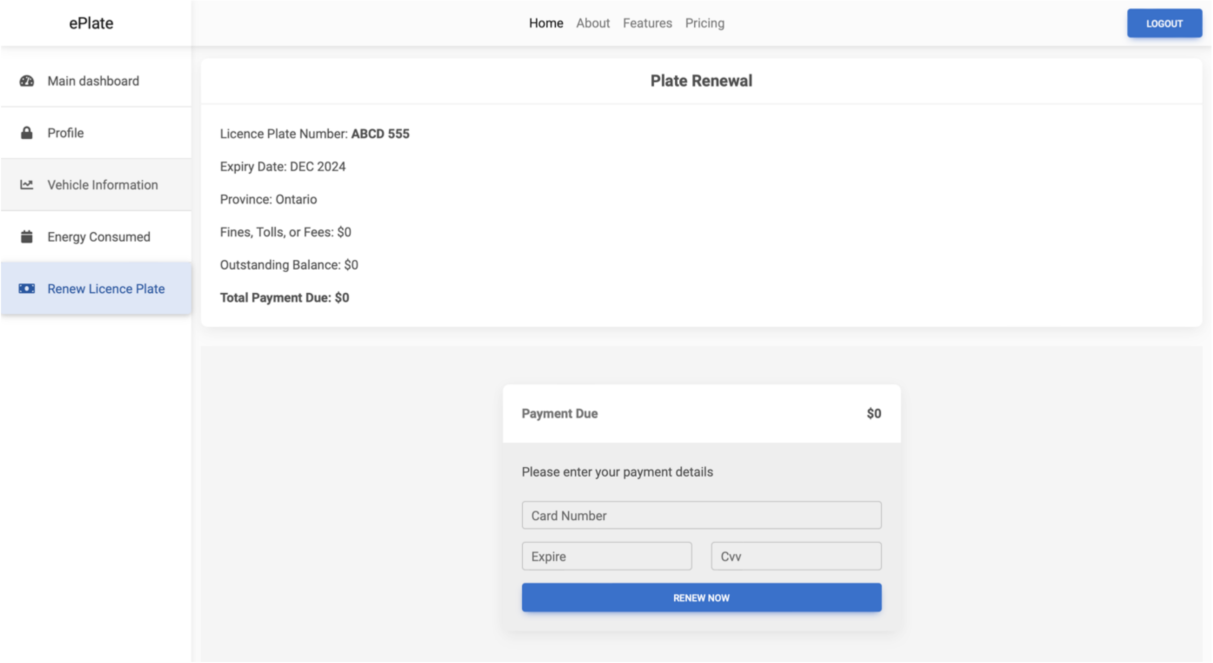


Plate Renewal

Licence Plate Number: **ABCD 555**

Expiry Date: DEC 2024

Province: Ontario

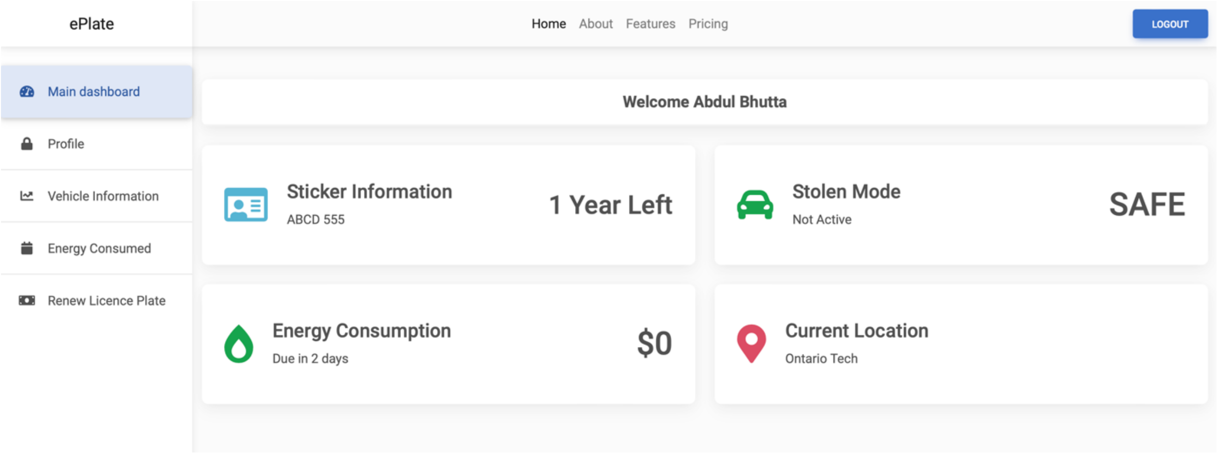
Fines, Tolls, or Fees: $0

Outstanding Balance: $0

Total Payment Due: $0

Payment Due **$0**

Please enter your payment details



ePlate

Home About Features Pricing

LOGOUT

- Main dashboard
- Profile
- Vehicle Information
- Energy Consumed
- Renew Licence Plate

Welcome Abdul Bhutta

Sticker Information
ABCD 555
1 Year Left

Stolen Mode
Not Active
SAFE

Energy Consumption
Due in 2 days
$0

Current Location
Ontario Tech

Step 7: Verify Licence Plate

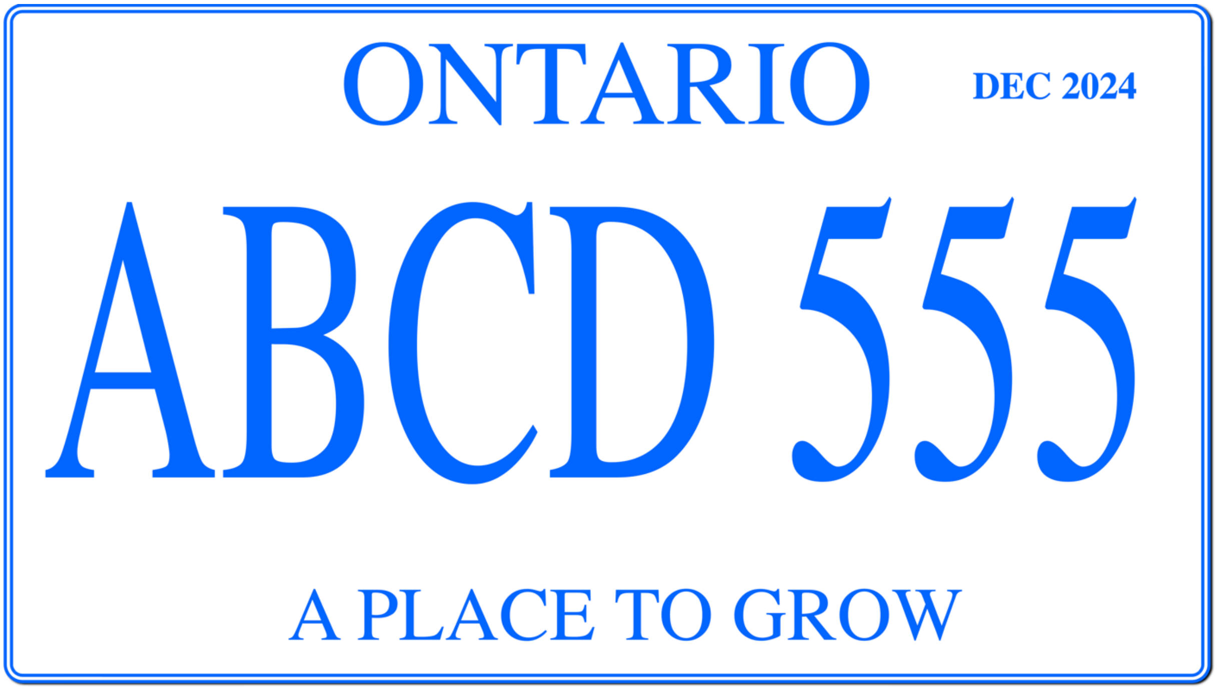


Table 3.5: Completed Integration Test Case #5

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein					
Test Case Name:	IT #5				**Test ID:**	Plate-IT-05
Description:	Test the interaction between Raspberry Pi and power bank.				**Type:**	Black Box: ✓ White Box: □
Tester Information						
Tester Name(s):	Abdul Bhutta, Walid Ayub				**Date:**	02/15/2023
Hardware Version:	V1.0				**Time:**	12:00pm
Setup:						
Step	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Connect the Raspberry PI to the power bank	The Raspberry Pi should be powered on.	✓			
2	Remove source power	No change on the Raspberry Pi and power bank.	✓			
3	Verify battery usage	The Raspberry Pi should stay powered on for at least 72 hours.	✓			Power bank successfully powered Raspberry Pi for 72 hours.
Test Result:			**Pass**			

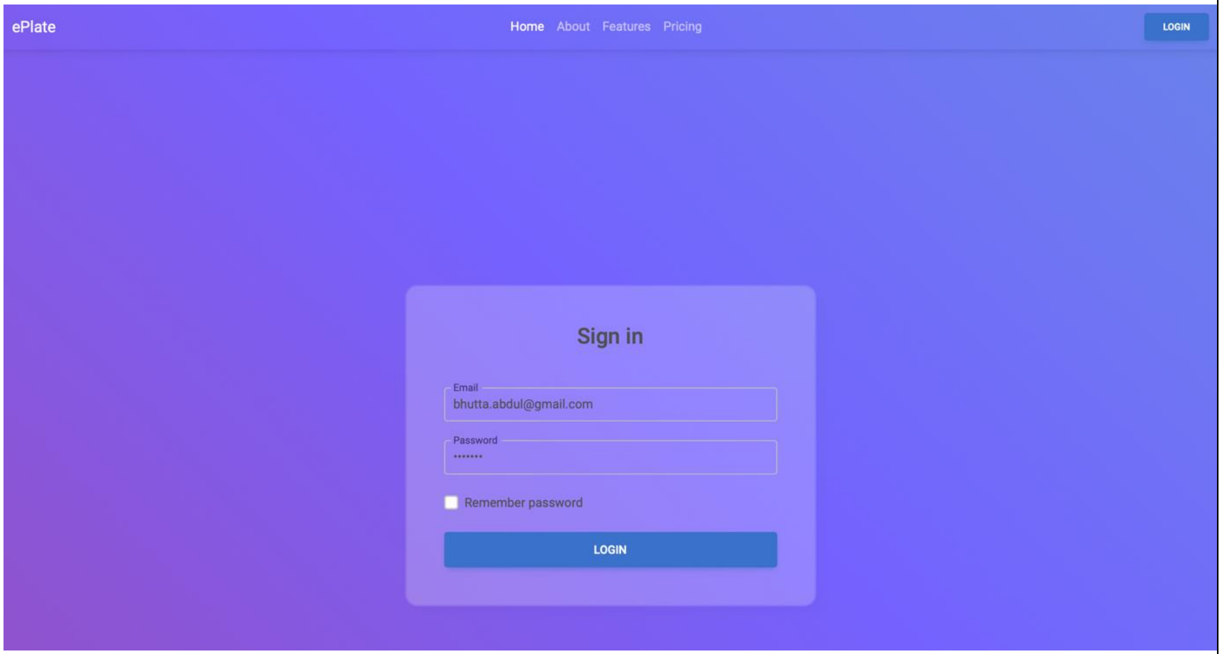
Table 3.6: Completed Integration Test Case #6

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #6	**Test ID:**	Plate-IT-06
Description:	Test the interaction between energy consumed and payment module.	**Type:**	Black Box: ✓ White Box: ☐
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	02/17/2023
Hardware Version:	V1.0	**Time:**	2:00pm
Setup:	The user must exist within the database and have an outstanding balance.		

Step	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Login as an authorized user	The webpage will display the personal portal.	✓			
2	Access the Energy Consumption page	The webpage will display the outstanding payment.	✓			
3	Enter payment information	The webpage will be redirected to the payment page.	✓			Dummy credit card and no actual payment module
4	Submit Payment Information	Information for payment will be received.	✓			
5	Verify payment	The portal page should display the correct cost.	✓			
Test Result:			**Pass**			

Plate-IT-06 Results

Step 1: Login as an authorized user



Sign in

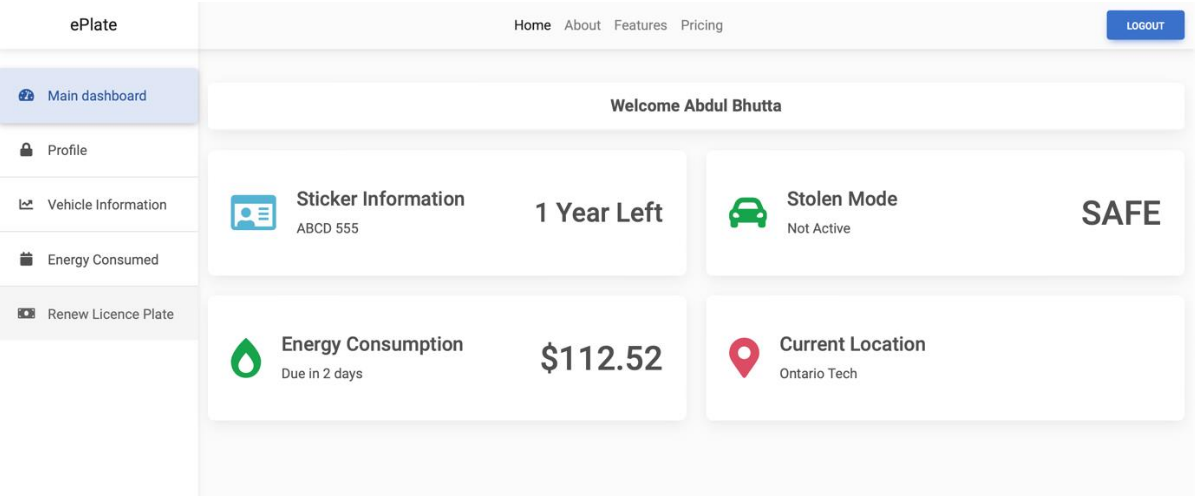
Email: bhutta.abdul@gmail.com

Password: •••••••

☐ Remember password

LOGIN

Step 2: Access the Energy Consumption page



Welcome Abdul Bhutta

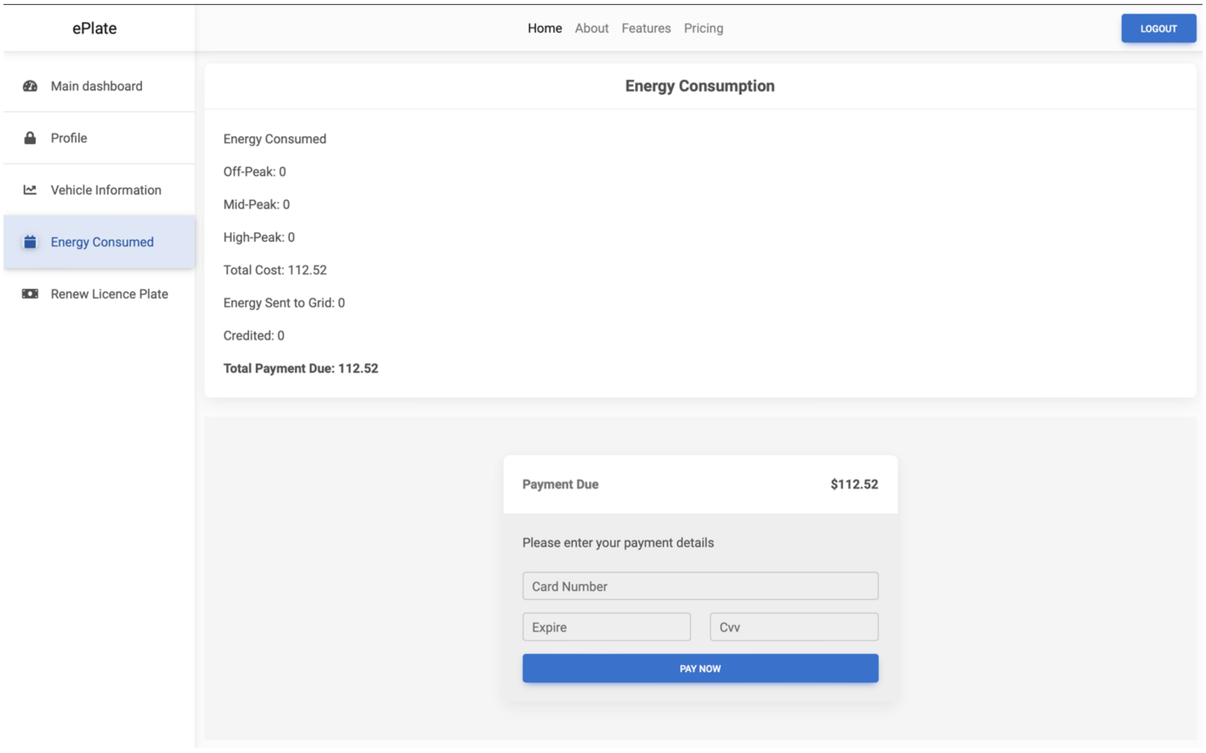
Sticker Information
ABCD 555
1 Year Left

Stolen Mode
Not Active
SAFE

Energy Consumption
Due in 2 days
$112.52

Current Location
Ontario Tech

Step 3: Enter payment information (Dummy credit card and no actual payment module)



Energy Consumption

Energy Consumed

Off-Peak: 0

Mid-Peak: 0

High-Peak: 0

Total Cost: 112.52

Energy Sent to Grid: 0

Credited: 0

Total Payment Due: 112.52

Payment Due **$112.52**

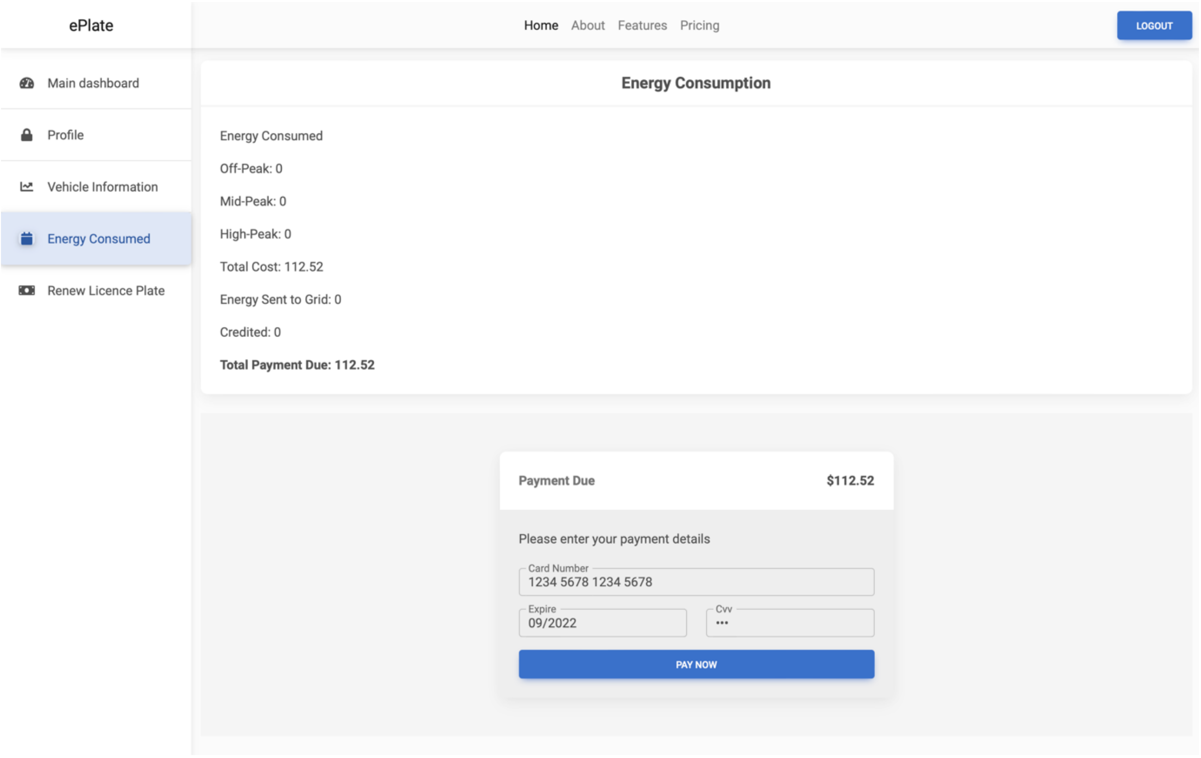
Please enter your payment details

Card Number

Expire

Cvv

Step 4: Submit Payment Information



Energy Consumption

Energy Consumed

Off-Peak: 0

Mid-Peak: 0

High-Peak: 0

Total Cost: 112.52

Energy Sent to Grid: 0

Credited: 0

Total Payment Due: 112.52

Payment Due **$112.52**

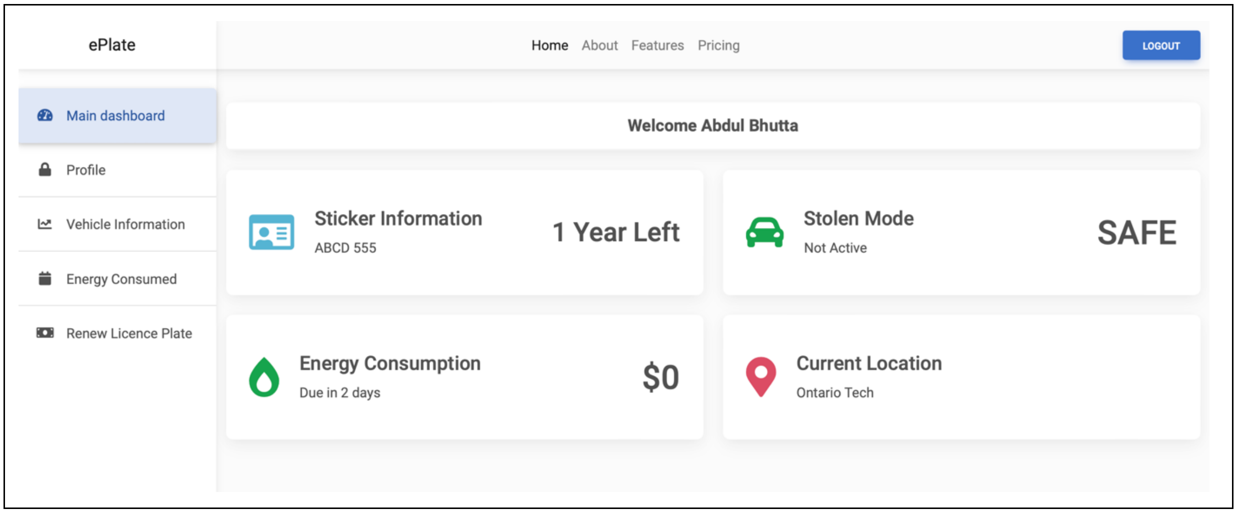
Please enter your payment details

Card Number: 1234 5678 1234 5678

Expire: 09/2022

Cvv: •••

Step 5: Verify on portal



Welcome Abdul Bhutta

Sticker Information
ABCD 555
1 Year Left

Stolen Mode
Not Active
SAFE

Energy Consumption
Due in 2 days
$0

Current Location
Ontario Tech

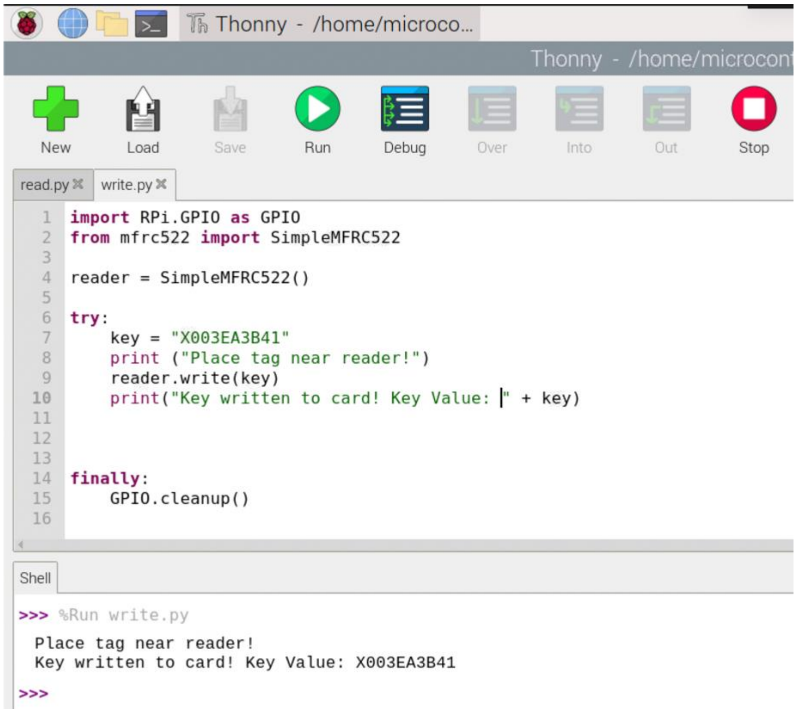
Table 3.7: Completed Integration Test Case #7

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #7	**Test ID:**	Plate-IT-07
Description:	Test the writing module with the Raspberry PI serial to the RFID tag and verify output	**Type:**	Black Box: ✓ White Box: □
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	02/16/2023
Hardware Version:	V1.0	**Time:**	4:30 PM
Setup:	The user must have one tag to program the current key		

Step	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Place a tag near the RFID reader	The RFID reader should read the key value from the tag.	✓			
2	Verify the output key	The serial number and the key should match	✓			
3			✓			
4			✓			
5			✓			
Test Result:			**Pass**			

Plate-IT-07 Result

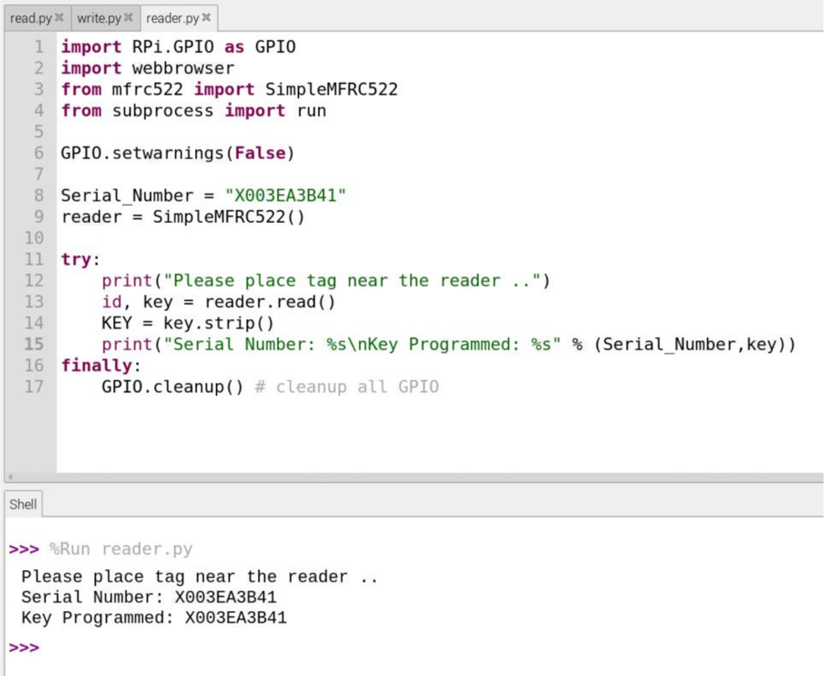
Step 1: Place tag near the reader



```python
import RPi.GPIO as GPIO
from mfrc522 import SimpleMFRC522

reader = SimpleMFRC522()

try:
    key = "X003EA3B41"
    print ("Place tag near reader!")
    reader.write(key)
    print("Key written to card! Key Value: " + key)



finally:
    GPIO.cleanup()

```

```
>>> %Run write.py
 Place tag near reader!
 Key written to card! Key Value: X003EA3B41
>>>
```

Step 2: Verify card has been programmed



```python
import RPi.GPIO as GPIO
import webbrowser
from mfrc522 import SimpleMFRC522
from subprocess import run

GPIO.setwarnings(False)

Serial_Number = "X003EA3B41"
reader = SimpleMFRC522()

try:
    print("Please place tag near the reader ..")
    id, key = reader.read()
    KEY = key.strip()
    print("Serial Number: %s\nKey Programmed: %s" % (Serial_Number,key))
finally:
    GPIO.cleanup() # cleanup all GPIO
```

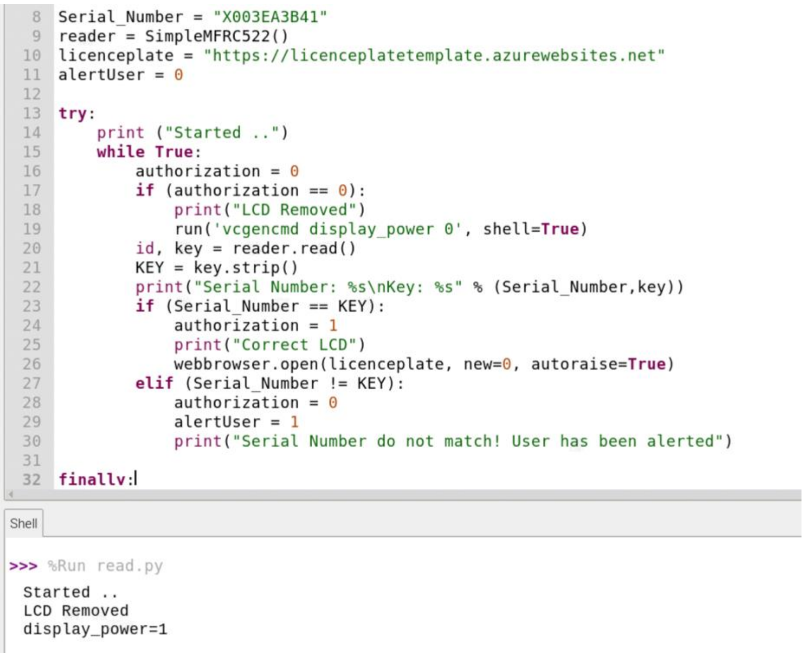
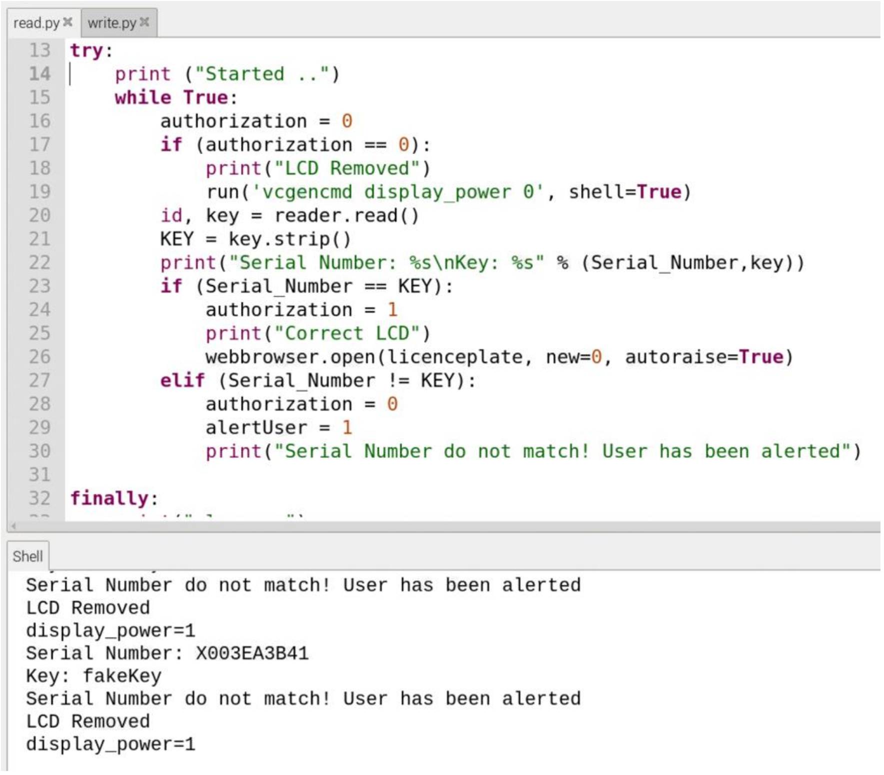
```
>>> %Run reader.py
 Please place tag near the reader ..
 Serial Number: X003EA3B41
 Key Programmed: X003EA3B41
>>>
```

Table 3.8: Completed Integration Test Case #8

Test Writer(s):	Abdul Bhutta, Emran Soltani, Kumail Syed, Walid Ayub, Yussef Elzein		
Test Case Name:	IT #8	**Test ID:**	Plate-IT-08
Description:	Test the interaction between the RFID reader and unauthorized LCD	**Type:**	Black Box: ✓ White Box: □
Tester Information			
Tester Name(s):	Abdul Bhutta, Walid Ayub	**Date:**	01/25/2023
Hardware Version:	V1.0	**Time:**	1:30 PM
Setup:	The user must have one authorized and unauthorized RFID tag		

Step	**Action**	**Expected Results**	**Pass**	**Fail**	**N/A**	**Comments**
1	Verify the LCD is turned off	The LCD should display no content	✓			Display_power = 1 should be displayed as it does not allow any hdmi output
2	Use an unauthorized RFID tag with the reader	The display should not be turned on and the user should be alerted	✓			
3	Use an authorized user tag with the reader	The display will turn on and licence plate should appear	✓			
4						
5						
Test Result:			**Pass**			

Plate-IT-08 Result

Step 1: Verify the LCD is turned off

Step 2: Use an unauthorized RFID tag with the reader


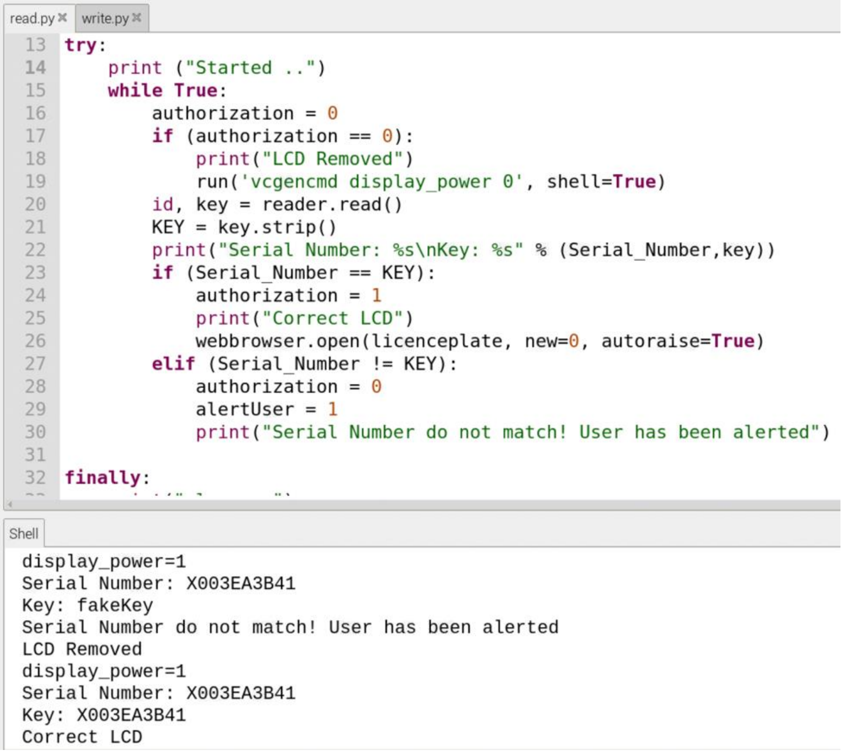
```
Serial_Number = "X003EA3B41"
reader = SimpleMFRC522()
licenceplate = "https://licenceplatetemplate.azurewebsites.net"
alertUser = 0

try:
    print ("Started ..")
    while True:
        authorization = 0
        if (authorization == 0):
            print("LCD Removed")
            run('vcgencmd display_power 0', shell=True)
        id, key = reader.read()
        KEY = key.strip()
        print("Serial Number: %s\nKey: %s" % (Serial_Number,key))
        if (Serial_Number == KEY):
            authorization = 1
            print("Correct LCD")
            webbrowser.open(licenceplate, new=0, autoraise=True)
        elif (Serial_Number != KEY):
            authorization = 0
            alertUser = 1
            print("Serial Number do not match! User has been alerted")

finally:
```

```
>>> %Run read.py
 Started ..
 LCD Removed
 display_power=1
```

```
try:
    print ("Started ..")
    while True:
        authorization = 0
        if (authorization == 0):
            print("LCD Removed")
            run('vcgencmd display_power 0', shell=True)
        id, key = reader.read()
        KEY = key.strip()
        print("Serial Number: %s\nKey: %s" % (Serial_Number,key))
        if (Serial_Number == KEY):
            authorization = 1
            print("Correct LCD")
            webbrowser.open(licenceplate, new=0, autoraise=True)
        elif (Serial_Number != KEY):
            authorization = 0
            alertUser = 1
            print("Serial Number do not match! User has been alerted")

finally:
```

```
Serial Number do not match! User has been alerted
LCD Removed
display_power=1
Serial Number: X003EA3B41
Key: fakeKey
Serial Number do not match! User has been alerted
LCD Removed
display_power=1
```

Step 3: Use an authorized user tag with the reader



```python
try:
    print ("Started ..")
    while True:
        authorization = 0
        if (authorization == 0):
            print("LCD Removed")
            run('vcgencmd display_power 0', shell=True)
        id, key = reader.read()
        KEY = key.strip()
        print("Serial Number: %s\nKey: %s" % (Serial_Number,key))
        if (Serial_Number == KEY):
            authorization = 1
            print("Correct LCD")
            webbrowser.open(licenceplate, new=0, autoraise=True)
        elif (Serial_Number != KEY):
            authorization = 0
            alertUser = 1
            print("Serial Number do not match! User has been alerted")

finally:
```

```
display_power=1
Serial Number: X003EA3B41
Key: fakeKey
Serial Number do not match! User has been alerted
LCD Removed
display_power=1
Serial Number: X003EA3B41
Key: X003EA3B41
Correct LCD
```

4 Project Plan

4.1 Updated Winter Semester Deliverable Breakdown

Below is the updated deliverable breakdown for the Winter semester.

Table 4.0: Winter Semester Deliverable Breakdown

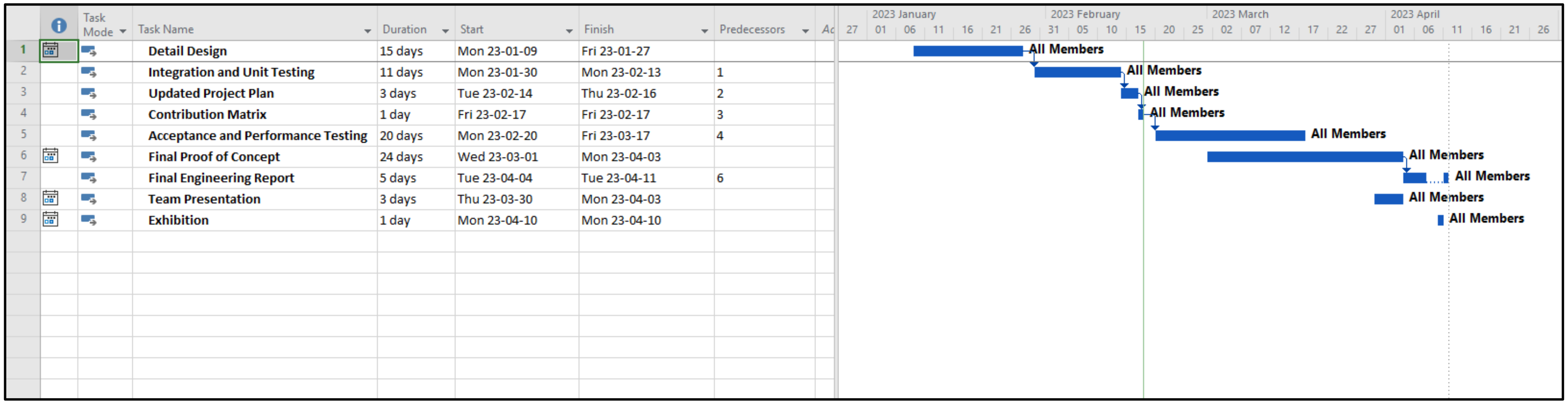
Deliverable	Report Section Name	Section Deliverables	Assigned Team Member(s)	Duration (Days)
Detail Design & Integration Testing Report	**Report Introduction**	Abstract, Dedication, Acknowledgements, Report Introduction	All Members	2
Detail Design & Integration Testing Report	**Detail Design**	Diagram Creation Design Analysis Detailed Schematics	All Members	15
Detail Design & Integration Testing Report	**Integration Testing / Unit Testing**	Refine Integration Tests Complete Integration Tests	All Members	10
Detail Design & Integration Testing Report	**Project Plan**	Updated Task Breakdown Update Gantt Chart	Abdul Yussef	2
Detail Design & Integration Testing Report	**Contribution Matrix**	Matrix Creation and Completion	Yussef	1
Detail Design & Integration Testing Report	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	2
Detail Design & Integration Testing Report	**Report Formatting**	Format Report Organizing Tables & Figures Table of Contents	Yussef	1
Detail Design & Integration Testing Report	**Report Submission**	Submission to Capstone Advisor	Yussef	>1
Acceptance Test Demonstration Report	**Acceptance Testing**	Complete Acceptance /Performance Testing Refine Acceptance Tests	All Members	3
Acceptance Test Demonstration Report	**Demonstration Rehearsals**	Assign Sections for Presentation Practice Presenting	All Members	2
Acceptance Test Demonstration Report	**Acceptance Test Demonstration**	Present to Capstone Advisor	All Members	>1

Acceptance Test Demonstration Report	**Report Introduction**	Abstract, Dedication, Acknowledgements, Report Introduction	All Members	2
Acceptance Test Demonstration Report	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	2
Acceptance Test Demonstration Report	**Report Formatting**	Format Report Organizing Tables & Figures Table of Contents	Yussef	1
Acceptance Test Demonstration Report	**Report Submission**	Submission to Capstone Advisor	Yussef	>1
Final Engineering Report	**Report Introduction**	Title Page, Abstract, Dedication, Acknowledgements, Report Introduction Executive Summary	All Members	3
Final Engineering Report	**Addition of Previous Reports**	Add Report #1 Add Report #2	Yussef	1
Final Engineering Report	**Revised Design Report**	Revise Designs	All Members	4
Final Engineering Report	**Ethical Considerations**	Comments of Ethical Considerations of Project	All Members	3
Final Engineering Report	**Safety Considerations**	Comments of Safety Considerations of Project	All Members	3
Final Engineering Report	**Report Conclusion**	Write Project's Closing Remarks	All Members	1
Final Engineering Report	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	2
Final Engineering Report	**Report Formatting**	Format Report Organizing Tables & Figures Table of Contents	Yussef	1
Final Engineering Report	**Report Submission**	Submission to Capstone Advisor	Yussef	>1
Team Presentation & Video Clip	**Presentation Assembly**	Construction of Presentation	All Members	5

Team Presentation & Video Clip	**Presentation Rehearsals**	Assign Sections for Presentation Practice Presenting	All Members	2
Team Presentation & Video Clip	**In-Class Final Presentation**	Present to Class / Faculty Advisors	All Members	>1
Team Presentation & Video Clip	**Video Clip Planning**	Writing of Script Review of Script Overall Plan of Video	All Members	4
Team Presentation & Video Clip	**Video Clip Filming**	Filming of Prototype Clips	Yussef	2
Team Presentation & Video Clip	**Video Clip Editing**	Assemble Clips Overall Video Editing	Yussef	4
Team Presentation & Video Clip	**Video Compilation & Review**	Finalize Video Review Final Video	Yussef	2
Capstone Design Annual Exhibition	**Presentation Assembly**	Construction of Presentation	All Members	5
Capstone Design Annual Exhibition	**Presentation Rehearsals**	Assign Sections for Presentation Practice Presenting	All Members	3
Capstone Design Annual Exhibition	**Poster Creation**	Design of Poster Assembly of Poster	All Members	5
Capstone Design Annual Exhibition	**Preparation of Final Prototype**	Test Final Prototype Ensure All Parts Assembled	Yussef	2
Team Retrospective Report	**Report Preparation**	Write Team Report	All Members	10
Team Retrospective Report	**Report Corrections**	Proofreading Consistency Check General Flow Check	Emran Kumail	2
Team Retrospective Report	**Report Formatting**	Format Report Naming/Organizing Tables Table of Contents	Yussef	1
Team Retrospective Report	**Report Submission**	Submission to Capstone Coordinator	Yussef	>1
END OF WINTER SEMESTER				

4.2 Winter Semester Gantt Chart

Figure 28 below shows a Gantt chart demonstrating the project plan deliverables throughout to the end of the project and a timeframe for their completion.



	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		**Detail Design**	15 days	Mon 23-01-09	Fri 23-01-27	
2		**Integration and Unit Testing**	11 days	Mon 23-01-30	Mon 23-02-13	1
3		**Updated Project Plan**	3 days	Tue 23-02-14	Thu 23-02-16	2
4		**Contribution Matrix**	1 day	Fri 23-02-17	Fri 23-02-17	3
5		**Acceptance and Performance Testing**	20 days	Mon 23-02-20	Fri 23-03-17	4
6		**Final Proof of Concept**	24 days	Wed 23-03-01	Mon 23-04-03	
7		**Final Engineering Report**	5 days	Tue 23-04-04	Tue 23-04-11	6
8		**Team Presentation**	3 days	Thu 23-03-30	Mon 23-04-03	
9		**Exhibition**	1 day	Mon 23-04-10	Mon 23-04-10	

Figure 28: Smart Grid Integrated Digital License Plate Project Gantt Chart

5 Contribution Matrix

The contribution matrix in the table below displays how the work this report was divided.

Table 5.0: Detail Design & Integration Testing Report Contribution Matrix

	Group Members				
Report #2 Sections	**Abdul Bhutta**	**Yussef Elzein**	**Emran Soltani**	**Kumail Syed**	**Walid Ayub**
Section 1: Introduction					
	✓	✓	✓	✓	✓
Section 2: Concept Generation & Analysis					
Final Software Design	✓	✓	✓	✓	✓
Final Electrical Design	✓	✓	✓	✓	
Casing Design – Front Housing		✓	✓		
Casing Design – Rear Housing		✓	✓		
Section 3: Integration Tests					
List of Integration Tests	✓				✓
Completion of Integration Test Cases	✓	✓			✓
Section 4: Project Plan					
Updated Winter Deliverable Breakdown		✓			
Gantt Chart				✓	
Section 5: Contribution Matrix					
Contribution Matrix		✓			
Other:					
Report Formatting	✓	✓			
Report Corrections		✓	✓	✓	✓

References

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2. Gus, “How to setup a raspberry pi RFID RC522 chip,” Pi My Life Up, 28-Oct-2022. [Online]. Available: https://pimylifeup.com/raspberry-pi-rfid-rc522/. [Accessed: 04-Jan-2023].

3. “Introduction to the raspberry pi GPIO and physical computing,” Introduction to the Raspberry Pi GPIO andPhysicalComputing-SparkFunLearn.[Online]. Available: https://learn.sparkfun.com/tutorials/ introduction-to-the-raspberry-pi-gpio-and-physical-computing/gpio-pins-overview. [Accessed: 02-Jan-2023].

4. “GPS module interfacing with Raspberry Pi: Raspberry Pi,” ElectronicWings. [Online]. Available: https://www.electronicwings.com/raspberry-pi/gps-module-interfacing-with-raspberry-pi. [Accessed: 18-Dec-2022].