UNIVERSITY OF BENIN

A STUDY AND DESIGN FOR THE PRODUCTION OF EXAMINATION GUARD TERMINAL

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CERTIFICATION

This is to formally acknowledge that this project was completed by **Eboka Confidence Onyebuchi**, **Duebo Promise Erhiga**, **Braimoh Prince Omeyimi**, **Chukwudi Stephen Obinna**, **Molokwu Solomon Ogechi**, and **Ayo Godwin Otinomoh** of the Department of Mechatronics Engineering, Faculty of Engineering, University of Benin, Benin City. This work fulfills the academic requirements for the award of the Bachelor of Engineering (B.Eng) degree in Mechatronics Engineering.

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Lastly, we express our profound thanks to our project supervisor, **Professor D.I IGBINOMWANHIA**, for his invaluable direction, patience, and dedication. His guidance made this research process seamless and greatly enhanced the quality of our work. Thank you very much, sir.

ABSTRACT

The conventional manual method to taking record of examination attendance in academic institutions like the University of Benin (UNIBEN) has some issues like impersonation, human error, and manipulation. The Examination Guard Terminal (EGT), which is biometric-based, was developed to solve the problems of the traditional approach to recording examination attendance.

The methodology was used to establish the functional requirements of the EGT. The EGT was to be portable, enable real-time fingerprint verification, and enable recording of attendance. The hardware components was selected based on its performance, cost, and availability. The ESP32 DevKit-C microcontroller was selected because of its dual-core processor and Wi-Fi capabilities. The AS608 Optical Fingerprint Module was selected because of its fast reaction time and easy use. The 2.8-inch TFT LCD was selected because of its clear display. Conceptual and detailed design for the circuits was developed, making use of the UART protocol for the fingerprint sensor and the SPI protocol for the display and data logging for the SD card. The software that was used for the project was based on the Arduino platform and consist of two modes for efficient functionality: one for Enrollment (Access Point Captive Mode) and another for Verification (Wi-Fi Mode).

Testing and analysis for efficiency were done in a simulated examination environment with 30 students. This helped in understanding the efficiency of the prototype. The project showed high efficiency in terms of average student verification in 2.44 seconds. Most importantly, the project showed a Zero False Acceptance Rate (FAR) and Zero False Rejection Rate (FRR), which confirms the EGT's basic reliability and accuracy in terms of identity verification. In conclusion, the project successfully developed a functional prototype for the Examination Guard Terminal. Recommendations for further improvement: Upgrading the system

to a multi-biometric system and using a faster processor like Raspberry Pi 5.to enhance speed and security further.

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Abbreviations and Keywords

Abbreviation	Full Meaning
EGT	Examination Guard Terminal
UNIBEN	University of Benin
ESP32	Espressif Systems 32-bit Microcontroller (Wi-Fi and Bluetooth enabled)
UART	Universal Asynchronous Receiver/Transmitter
SPI	Serial Peripheral Interface
TFT LCD	Thin-Film Transistor Liquid Crystal Display
SD	Secure Digital (used for memory/storage cards)
CS	Chip Select
GPIO	General Purpose Input/Output
VCC	Voltage Common Collector (positive power supply voltage)
GND	Ground (reference point in an electrical circuit)
TX2/RX2	Transmit Pin 2 / Receive Pin 2 (used for UART communication)
VIN	Voltage Input
MOSI	Master Out Slave In (SPI data line for sending data from master)
MISO	Master In Slave Out (SPI data line for receiving data from slave)
SCK	Serial Clock (used in SPI communication)
SW1–SW4	Switch 1 to Switch 4 (push buttons for control inputs)
LED	Light Emitting Diode
CAD	Computer-Aided Design
BT1	Battery 1 (label for the battery in circuit diagrams)
U4	Boost Converter Component Label
DC/RS	Data/Command Register Select (display control

	signal)
ID	Identification (as in ID cards)
IJRPR	International Journal of Research and Publication Review

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND TO THE WORK

Time goes on, and in its course, some issues do not move along with it. One of such issues in the context of UNIBEN examinations is as basic an issue as that of recording the presence of people. One would expect that recording the attendance of people present in an examination hall is an easy task. However, in the course of years, it has proven to be more than that: it has proven to be an area that has revealed gaps that cannot be ignored anymore.

The traditional method that has been in use all these years, passing an attendance sheet around the examination hall and calling out the names of people present in the examination hall one after the other, is not without its own problems. Issues like impersonation, human error, wrong marking of people's names on the attendance sheet, and some people not even being marked on the attendance sheet in the first place have continued to plague the system. These problems have continued to persist in the context of large numbers of people in an examination hall.

To solve some of these problems that have continued to persist in the context of examination attendance in the University of Benin, I came up with an idea of developing a system called the Examination Guard Terminal (EGT). This is a biometric-based system that makes use of fingerprints to verify people present in an examination hall. Once a student is verified by the system, the system automatically records the attendance of that particular student. Therefore, there is no need to worry about issues of impersonation because the system has completely eliminated that possibility.

The system has made it possible for only authorized students to enter the examination hall. Therefore, the examination attendance in the context of the University of Benin has become not only more secure but also more efficient.

1.2 STATEMENT OF THE PROBLEM

In most Nigerian universities, including UNIBEN, the exam attendance is done manually, mostly by the use of a list or by checking the students' ID cards. These practices lead to a lot of problems, including mistakes, impersonations, missing names, misplaced ID cards, and a lot of stress for the exam supervisors. In some cases, the exam does not even start on time due to the problems experienced during the attendance. The problems keep recurring with each exam session, and the need for a quicker and more reliable system to identify the students correctly and keep a record of their attendance without relying too much on the manual process.

1.3 AIM AND OBJECTIVES

1.3.1 AIM

The primary goal of undertaking this project is to design and implement a biometric-based Examination Guard Terminal (EGT) system that uses fingerprint technology to facilitate automated and precise attendance during exams. In order to achieve this objective, it was necessary to undertake a review of similar projects, design both the hardware and software, implement a working prototype, and finally test it to ascertain its level of performance

1.3.2 OBJECTIVES

In order to attain this aim, the project was conducted with the following objectives:

1. Feasibility studies and literature review on the use of biometric attendance systems.

2. Designing the hardware and software components of the EGT.

3. Developing a functional prototype incorporating fingerprint sensors, display units, and data storage facilities.

4. Testing the system and assessing its accuracy, efficiency, and reliability in use.

1.4 SCOPE OF THE WORK

This project is primarily concerned with developing a simple biometric terminal that can identify students using their fingerprints and also record their attendance during examinations. It entails the selection of the required hardware, the development of the software that controls the identification process, and finally, the testing of the project in a controlled environment. The project does not include the implementation in the entire university and the integration of the system with big server systems, as that requires more resources than were allocated for the project.

1.5 RELEVANCE OF STUDY

This study is significant because it provides an approach that can help eliminate impersonations and mistakes that usually occur in the process of manual attendance during exams. Through the use of fingerprints, students are able to confirm their identities without relying on their signatures and identity cards. The system also assists the exam officers in their work, allowing them to do so efficiently and without many mistakes. The project also contributes to the overall shift towards digital and automated systems in universities, which is becoming necessary due to the increasing number of students.

CHAPTER TWO

LITERATURE REVIEW

2.1 TRADITIONAL ATTENDANCE SYSTEM AND THEIR LIMITATIONS

In most universities, the traditional system of taking attendance was done using paper-based methods. These included sign sheets, roll calls, or ID card checks. Even though the traditional system was cheap and easy to implement, it was plagued by many problems. For instance, the traditional system was time-consuming, error-prone, and allowed for impersonation. In some instances, a student who presented themselves for the exam was marked absent. The traditional system of taking attendance was also characterized by difficulties in getting quick updates. Due to the many limitations of the traditional system of taking attendance, schools began to seek a reliable system.

2.2 EMERGENCE OF BIOMETRIC ATTENDANCE SYSTEMS

The use of biometric systems was made possible because of the uniqueness of the characteristics used. For instance, fingerprint characteristics or face recognition cannot be duplicated. In most parts of the world, universities have adopted the use of biometric systems for the purpose of enhancing the reliability of the attendance system. In Bangladesh, for instance, universities have implemented the fingerprint system successfully. Fingerprint recognition has been found to be the most viable system because it is affordable, relatively accurate, and easy to implement.

2.3 INTEGRATION WITH EXAMINATION PROCESSES

While biometrics are used in most schools for normal class attendance, the use of biometrics in examination processes is still in its developmental stages. Examinations require even higher levels of security since impersonation can occur. Some schools have reported a marked improvement in terms of accountability in the exam entry process after the introduction of the biometric system. The EGT uses the same idea of concentrating on the examination process.

2.4 CHALLENGES IN IMPLEMENTING BIOMETRIC SYSTEMS

Though the use of the biometric system has its advantages, there are a few challenges associated with the use of the system. The system can be expensive, especially in large-scale use. There has been a lot of debate about the use of the system in terms of the storage of sensitive information. There can also be a few technical problems, such as incorrect matching or failure of recognition. There should also be a constant power supply for the system to function properly.

2.5 THE EXAMINATION GUARD TERMINAL APPROACH

The EGT uses the idea of biometrics for the examination process. The system can store the details of the students or can directly upload the information. The system can then help the exam supervisor keep a tab on the students' attendance. The EGT uses the idea of biometrics specifically for the examination process.

2.6 CASE STUDIES OF BIOMETRIC APPLICATIONS

Several institutions have successfully implemented similar biometric systems to what the EGT is trying to achieve:

1. Simprints Project in Zambia: Fingerprint scanning was implemented in eight rural schools to monitor teacher and student attendance. This improved accuracy by 14 to 20 percent and saw a significant reduction in absenteeism.

2. LUISS Guido Carli University in Italy: The university employed facial biometrics in online exams to ensure identity under the COVID-19 lockdown restrictions.

3. Lagos State University in Nigeria: Fingerprint scanning was employed to improve attendance verification. This saw the verification period fall from 18 seconds to 4 seconds per student, with a 94% success rate.

4. Universities in India and Tanzania: These universities developed an innovative system that employed the use of QR codes coupled with fingerprints to improve verification in examination rooms.

5. WAEC (West African Examinations Council): Fingerprint identification was piloted to improve the credibility of examinations administered to millions of students across the region to prevent impersonation.

2.7 EVOLUTION OF EXAMINATION ATTENDANCE AND MONITORING

The exam attendance system has evolved over time. Initially, the system was done manually. However, with the growth of ICT in the world, schools began to use ID cards, barcodes, and magnetic stripes. However, impersonation was still possible. The next big step in exam attendance was the use of biometrics. This was because biometrics use physical characteristics for recognition. Today, many institutions have adopted the use of biometrics in the general management system.

From the reviewed studies, it is evident that the use of biometric exam attendance systems has advantages in terms of accuracy, speed, and security. However, many schools need a system that is portable and can function without the use of complex technology. The EGT aims to provide a portable fingerprint system for exam attendance.

CHAPTER THREE

METHODOLOGY

3.1 SYSTEM REQUIREMENTS

Before constructing the system, the group established what the Examination Guard Terminal needed to accomplish and the conditions that it needed to meet. These requirements were categorized into functional and non-functional requirements.

3.1.1 FUNCTIONAL REQUIREMENTS

The Examination Guard Terminal needed to check fingerprints in real-time, store students' data safely, work even when connected to a battery source, connect to the network when necessary, and also ensure that it provided feedback to users via the terminal's screen. It also needed to ensure that students were authenticated in real-time so that long queues were not established.

3.1.2NON-FUNCTIONAL REQUIREMENTS

Apart from the functional requirements, the Examination Guard Terminal also needed to ensure that it was portable, durable, and safe to use during long periods of exams. It also needed to ensure that it complied with the basic regulations regarding biometric data, that it could be upgraded in the future, and that it could be operated even by those without advanced training in using such systems.

3.2 SYSTEM SPECIFICATION

Once these requirements were established, they were converted into design parameters that could be measured. These were the type of sensor to use, the type of microcontroller, the type of display, the type of power system, and the type of data communication system to use. These were chosen based on their performance, price, and availability in the country since sourcing these in the country is always a problem for students.

3.3 SELECTION OF COMPONENTS

3.3.1 BIOMETRIC SENSOR: THE AS608 OPTICAL FINGERPRINT MODULE

After evaluating and comparing various options, we finally selected the AS608 Optical Fingerprint Sensor module due to its balance of accuracy, price, and ease of integration. Unlike other sensors such as the capacitive sensor, which is harder to work with due to the increased complexity of the driver and the power required, the AS608 Optical Fingerprint Sensor module is easier to work with since it already has image processing and storage capabilities, which reduced the amount of coding required.

We also considered other modules such as the R305 and FPM10A, but after conducting thorough research and testing, they were slower and larger in size, which is not suitable for the EGT since it is designed to be compact and portable.

Key reasons for selection:

1. Fast recognition, taking less than 1 second.
2. Internal storage for 150 fingerprints.
3. Simple UART communication with ESP32.
4. Cost-effective and easily available locally.
5. Low power consumption, suitable for battery operation.

3.3.1.1 Display – 2.8-Inch TFT LCD

The EGT makes use of a 2.8-Inch TFT LCD as the display screen. The screen is colorful and user-friendly for invigilators and students alike. The use of this screen has been chosen over the use of monochrome LCD and small OLED displays due to its ability to show text and icons in a more readable manner, thus making the system more user-friendly.

The main use of the screen will be to show real-time visual feedback to invigilators and students during the entire process of identity verification and the exam session. The use of fonts, layout, and icons makes the system very user-friendly, even for those who are new to the use of digital technology. The screen size provides more space to show the icons and text in an organized manner. The TFT screen allows the display of the following key information in a visually structured format:

a. Authentication Results: “Check-In Successful” or “ID Mismatch”.
b. Student Information: Full name, matriculation number, and seat number.
c. Exam Session Status: Countdown timer, active session alerts.
d. System Messages: Errors, warnings, or confirmation prompts.

Fig. 1: Illustration of Proposed Screen display

3.3.2 ADVANTAGES OF TFT DISPLAY FOR THE EGT

1 **.Compact Size for Portability:** The 2.8-inch TFT has a compact size, which can fit inside a compact case made using 3D printing technology without making the EGT too bulky, thus meeting the portability requirement specified by the EGT.

2. **Adequate Resolution for Clear Feedback:** The 2.8-inch TFT has an adequate resolution of 240 x 320, thus ensuring the EGT can clearly show the results and feedback to the exam operators.

3. **Power Consumption:** The TFT has relatively low power consumption, thus meeting the requirement for the EGT to have uninterrupted operation in case of a power outage, as the TFT can be easily powered by a battery.

4. **Full Color and Good Visibility**: The 2.8-inch TFT has a full color display, thus ensuring the exam operators can easily read the results and feedback from the EGT.

5. **Cost-Effective and Widely Available:** The 2.8-inch TFT is relatively cheaper compared to the 3.5-inch TFT, thus making the EGT cost-effective and easily available in the market, as the ESP32 microcontroller is easily available and can be used to drive the 2.8-inch TFT.

6. **Interface Compatibility:** The 2.8-inch TFT has an interface with the ESP32 microcontroller, TFT uses the SPI interface, thus allowing the display to interface with the ESP32 microcontroller.

7. Durability in Exam Environments: Designed for embedded applications, they can withstand repeated use, slight handling stress, and typical indoor lighting conditions found in exam halls.

3.3.3 ALTERNATIVE DISPLAY OPTIONS CONSIDERED

1. **1.8-Inch OLED Screens:** The possibility of using OLED technology was explored however the small screen resolution and size of the 1.8-inch OLED screen modules limited the potential of the system to show complex menus, different states of the user interface, and student images. In addition, the potential for image retention on the OLED screen, especially with the interface elements such as the timer and text, was also a concern.

2. **Smaller OLED Modules (0.96-inch, 1.3-inch):** The small OLED modules were initially considered but the small screen resolution and the limited screen area made the modules unsuitable for the quantity of text and icons needed in the terminal's user interface. For instance, the simultaneous display of student name, ID, scan result, time, and navigation prompts is impossible on these small OLED modules.

3. Nokia 5110 LCD: This monochrome LCD was dismissed early in the evaluation due to its low resolution, limited character rendering capability, and outdated PCD8544 driver, which complicates integration with modern microcontrollers. The inability to display colored or dynamic content also conflicted with the project’s goal of delivering a modern, intuitive user interface.

4. **E-Paper Displays**: These modules were also explored but their low refresh rates and lack of support for real-time updates made them unsuitable for our application. Additionally, their inability to show bright colors was also a drawback.

In summary, the 2.8-inch TFT display offers a promising solution that not only makes the EGT a cost-effective solution but also makes it a user-friendly device that increases the overall efficiency of the EGT.

3.3.4 POWER SYSTEM

Exams can last for hours without a guaranteed power supply. Hence, it was necessary to ensure that the EGT could function independently. We tested AA batteries, 9V batteries, Li-Po batteries, and Li-ion batteries before finally settling on a single 18650 Lithium-ion battery rated at 3.7V and 3400mAh.

The 18650 battery was ideal because it:

1. Provides stable voltage and long runtime.
2. Is rechargeable and easily replaceable.
3. Has built-in protection against overcharging and short circuits.

A TP4056 charging module was added to allow safe USB charging, and a boost converter steps up the 3.7V to 5V required by the ESP32 and other components. This setup allows the terminal to operate for 3–5 hours continuously enough for a full examination session.

3.3.5 MICROCONTROLLER (ESP32 DevKit-C)

The ESP32 DevKit-C was chosen as the core controller for the EGT. We evaluated several alternatives (Arduino Uno, Raspberry Pi Pico, and STM32) but selected ESP32 for its excellent combination of power, built-in Wi-Fi, and Bluetooth connectivity.

Reasons for choice:

1. Dual-core processor allows multitasking (fingerprint + display + data logging).
2. Integrated Wi-Fi enables cloud synchronization or local data upload.
3. Plenty of GPIO pins to handle multiple modules.
4. Low cost and excellent online documentation.
5. Works seamlessly with Arduino IDE, which simplified our programming.

Although boards like Raspberry Pi 4 are more powerful, they were too expensive and required operating system support. The ESP32 offered everything needed at a student-friendly cost.

3.4 PROGRAMMING AND SOFTWARE

The ESP32 was programmed using Arduino IDE, mainly because of its simplicity and wide library support for both the AS608 fingerprint sensor and the TFT display.

The code structure included:

1. Setup section: initializes components, Wi-Fi, and display interface.
2. Main loop: continuously listens for fingerprint scans and handles attendance logic.
3. Interrupts: used for push buttons to navigate menus or reset the device quickly.

During development, we carried out step-by-step testing for each component before combining everything to avoid complex debugging later.

3.5 CONCEPTUAL DESIGNS

Prior to the physical design, there were conceptual models that were considered and various trade-offs in complexity, portability, and user interaction features.

1. Conceptual Alternative A: Desktop/Countertop Model:

This design features a large angled horizontal casing meant for placement on a desk or countertop. While it offers enhanced data entry capabilities (useful for tasks like matriculation number searches or setup), its bulkiness and complexity make it less portable and more expensive to produce, conflicting with the project's goals of portability and affordability**.**

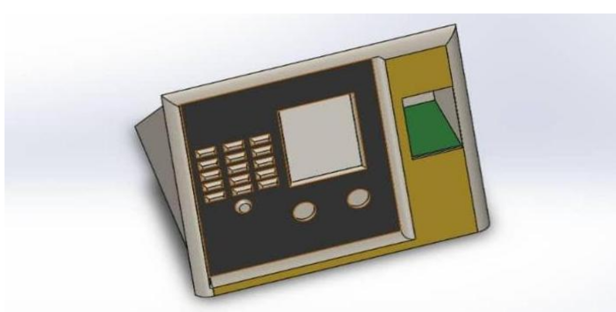

Figure 2: Alternative Design A

2. Conceptual Alternative B: Vertical Stand/Kiosk Model

This design features a tall, sleek kiosk-like structure with a large vertical display and a compact base housing the fingerprint sensor and status LED. It offers high screen visibility and a space-saving form, but its upright orientation may be unstable on examination desks. Additionally, the minimal interaction area limits input options for invigilators, making the system heavily dependent on screen-based prompts.

Figure 3: Alternative Design B

3. Conceptual Alternative C: Brick/Handheld Model

Thus design is a compact, portable unit offering easy mobility and tactile input via a keypad. However, the keypad limits internal space for key components like the battery, boost converter, and ESP32, while also reducing screen size, which can diminish user experience when displaying detailed feedback.

Figure 4: Alternative Design C

4. Selected Design: Small Handheld Terminal

The last selected design for the Examination Guard Terminal (EGT) is a thin, compact rectangular case, minimized for small desktop space and use. It was selected because it maximizes the essentials: Large rectangular opening at the top-left corner for the 2.4-inch TFT LCD monitor. Four tiny, circular openings below the monitor, maximized for the necessary navigation push buttons (SW1-SW4). A cutaway rectangular recessed on the right-hand side, measured to fit the AS608 Optical Fingerprint Module.

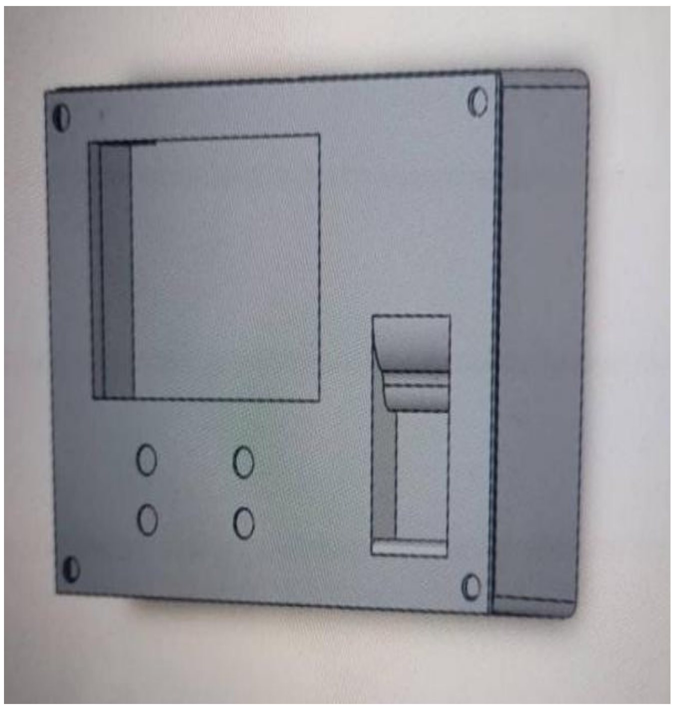

Figure 5: Selected Design

3.6 DETAILED DESIGN

This phase translated the conceptual architecture into definitive hardware schematics and precise mechanical models.

3.6.1 CIRCUITRY DESIGN AND CONNECTIONS

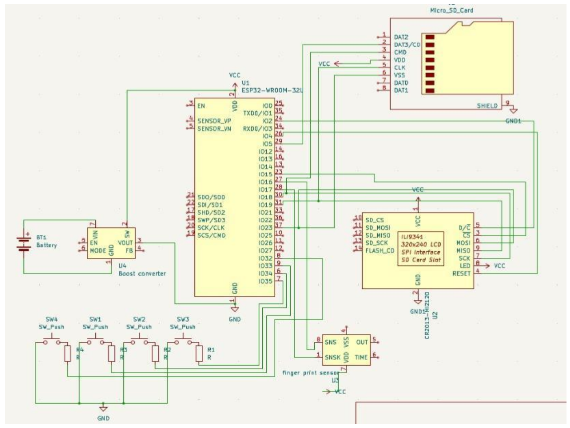

Figure 6: Circuit Design of the System

1. **Power System Architecture:** The schematic displays the 3.7V Battery (BT1) feeds the Boost Converter (U4) which steps up the voltage to a stable 5V (VCC) necessary for the ESP32 VIN, Fingerprint Sensor, and display logic.

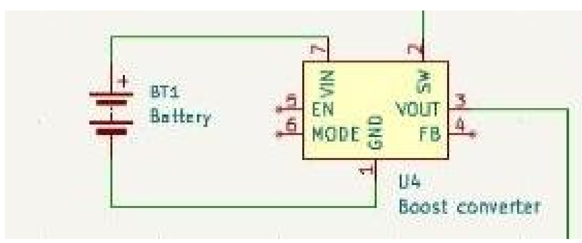

Figure 7: Power System

2. **Universal Asynchronous Receiver-Transmitter (UART):** The AS608 fingerprint sensor communicates with the ESP32 through dedicated hardware serial ports (TX2/RX2 – IO17/IO16) to ensure fast and reliable data transfer. Using hardware UART prevents data collisions and latency issues, which could occur if software serial were used while the ESP32 handles multiple tasks, thereby supporting the system's rapid verification performance.

Sensor Pin	ESP32 Pin	Description
VCC	5V	Power supply
GND	GND	Common ground
TX	GPIO 16 (RX2)	Sensor data output to ESP32
RX	GPIO 17 (TX2)	Data input from ESP32

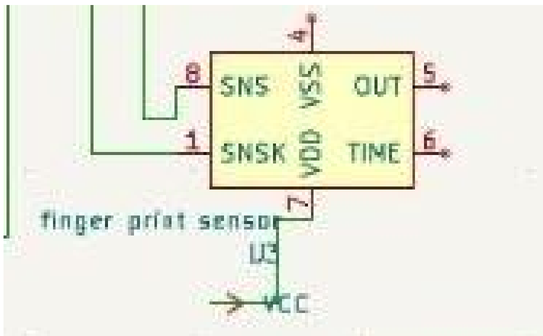

Figure 8: Finger Print Sensor

3. **SPI (Display and Storage):** The TFT LCD Display and the Micro SD Card Module utilize the SPI protocol .These devices share the main SPI bus lines but are differentiated using independent Chip Select (CS) pins. The TFT uses CS pin IO 15, while the SD card uses CS pin IO 5. This configuration is resource-efficient but requires firmware logic to manage bus access, preventing data overlap between the UI updates and the data logging process.

TFT Pin	ESP32 Pin	Description
VCC	3.3V	Power supply for the display
GND	GND	Common ground
CS	GPIO 15	Chip Select for TFT
RESET	GPIO 4	Hardware reset pin
DC/RS	GPIO 2	Data/Command control pin
SDI (MOSI)	GPIO 23	SPI data output from ESP32
SDO (MISO)	GPIO 19	SPI data input to ESP32
SCK	GPIO 18	SPI clock

LED	3.3V	Backlight

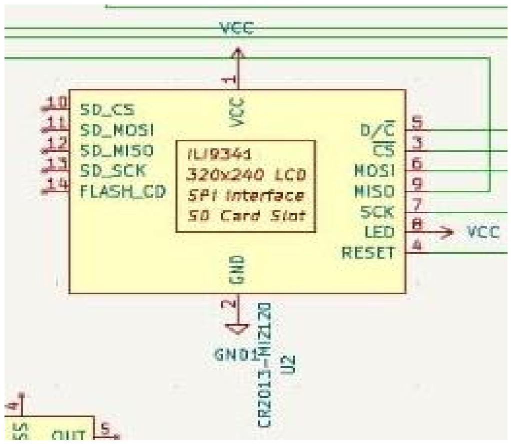

Figure 9: Display

SD Pin	ESP32 Pin	Description
VCC	3.3V	Power supply
GND	GND	Common ground
CS	GPIO 5	Chip Select for SD card
MOSI	GPIO 23	Shared SPI line
MISO	GPIO 19	Shared SPI line
SCK	GPIO 18	Shared SPI clock

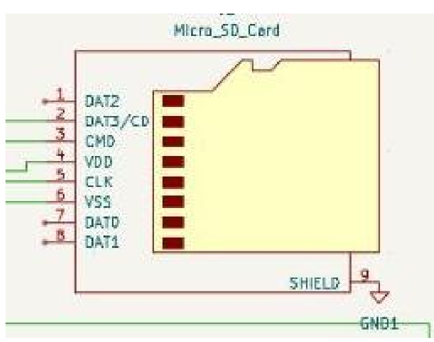

Figure 10: SD card

4. **Control Inputs:** Four tactile Push Buttons (SW1-SW4) are connected to discrete Digital GPIO pins (e.g., IO 32, IO 33, IO 25, IO 26)

Button Function	ESP32 Pin	Connection Type
Enter	GPIO 32	Active LOW, internal pull-up enabled
Up	GPIO 33	Active LOW, internal pull-up enabled
Down	GPIO 25	Active LOW, internal pull-up enabled
Back	GPIO 26	Active LOW, internal pull-up enabled

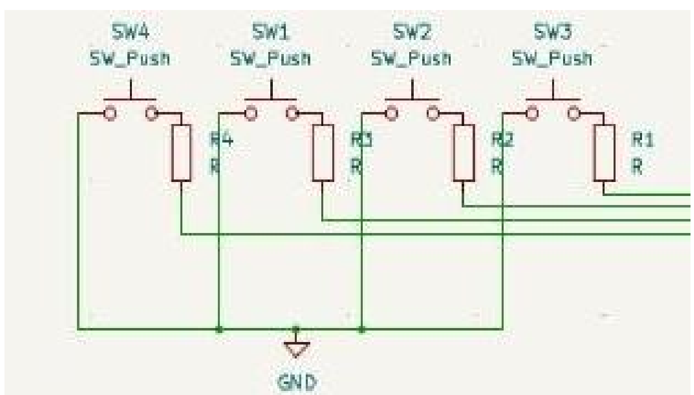

Figure 11: Control Inputs

3.7 EGT CIRCUIT FUNCTION AND COMPONENT INTERACTION

1. Battery System and BMS: The EGT uses a set of Lithium-ion batteries, specifically two connected in a parallel configuration of type 18650. The batteries are connected in a parallel configuration to optimize the available current for the device. The external charger circuit acts as a Battery Management System regulator.

2. Charging Safety: The charging system regulates the input from the battery, providing a precise input of 5V externally. When the batteries have a maximum charging capacity of 4.2V, the blue light turns on. The charging system cuts off the charging process until the voltage drops.

3. System Voltage Distribution: The charging system regulates the voltage supplied to the main ESP32 processor. The voltage supplied should not exceed 5V to avoid a hardware "blow-up." The ESP32 processor receives a voltage of 5V. However, the processor operates at a maximum of 3.3V. The TFT-LCD monitor and the AS608 fingerprint processor operate at a maximum of 3.3V. The voltage is supplied through the ESP32 GPIO pins.

4. Display Communication via SPI (Serial Peripheral Interface):
The TFT-LCD display with an ILI9341 driver uses the high-speed SPI protocol to facilitate the transmission of graphical data in an efficient manner. The SPI protocol is a slave-master protocol. In the EGT system, the ESP32 acts as the Master, while the TFT display acts as the Slave. The display is used to render the graphical output of the system. In the SPI protocol, the Master Out-Slave In (MOSI), Master Out-Slave Out (MISO), and the clock signals are used. However, in the EGT system, only the MOSI and clock signals are used to send the pixel data to the display screen.

5. The ESP32 microcontroller:
It acts as the brain of the system that governs all activities from verification to user interface management.

6. Code Loop Execution: When the EGT system is powered on using the start button, the ESP32 immediately executes the code loop. This is the core function of the ESP32 microcontroller.

7. Interrupt-Driven Input (Push Buttons): The user input is provided by four push buttons labeled SW1 to SW4. These buttons act as interrupts to the ESP32 microcontroller.1 When any of the buttons is pressed, it immediately interrupts the code loop to execute the specific command before executing the main code loop.

Figure12: Couple hardware

3.8 PHYSICAL ENCLOSURE AND CAD MODELING

1. Overall Enclosure Face-plate Dimensions: The primary outer dimensions for the enclosure front plate are a width of 132.00 +/- 0.50 mm and a height of 100.00 +/-0.50 (mm).

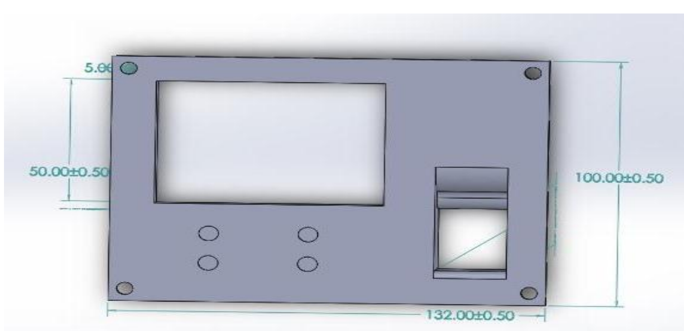

Figure 13: Faceplate Enclosure

2. Base/Side Thickness: The thickness of the main body's base is defined as 7.00 +/-0.50(mm). The outer dimensions for the enclosure base body are a width of 132.00 +/- 0.50 mm and a height of 100.00 +/-0.50 (mm).

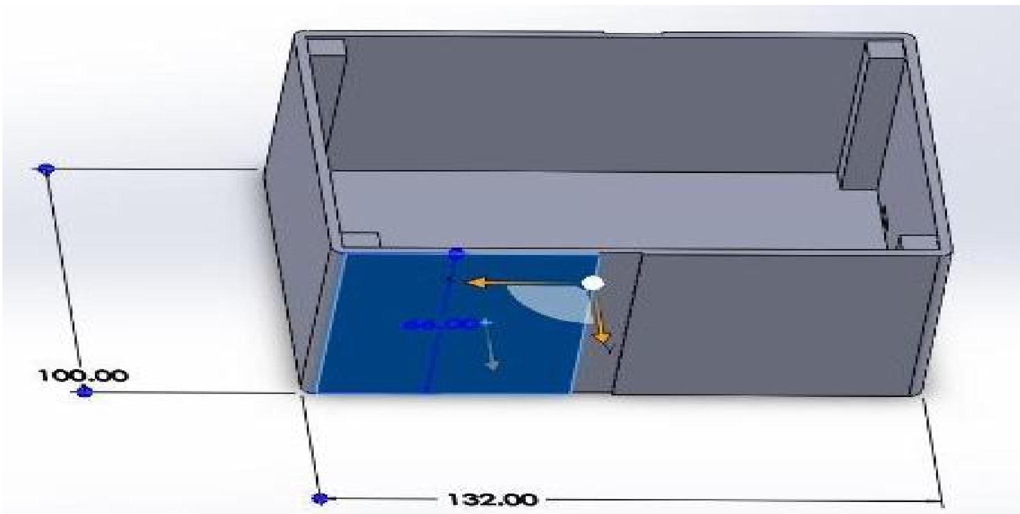

Figure 14: Base/Side

3. Internal Cutout Dimensions: Internal structural cutouts used for component mounting or feature definition show symmetrical dimensions of 24.90 +/- 0.50(mm).

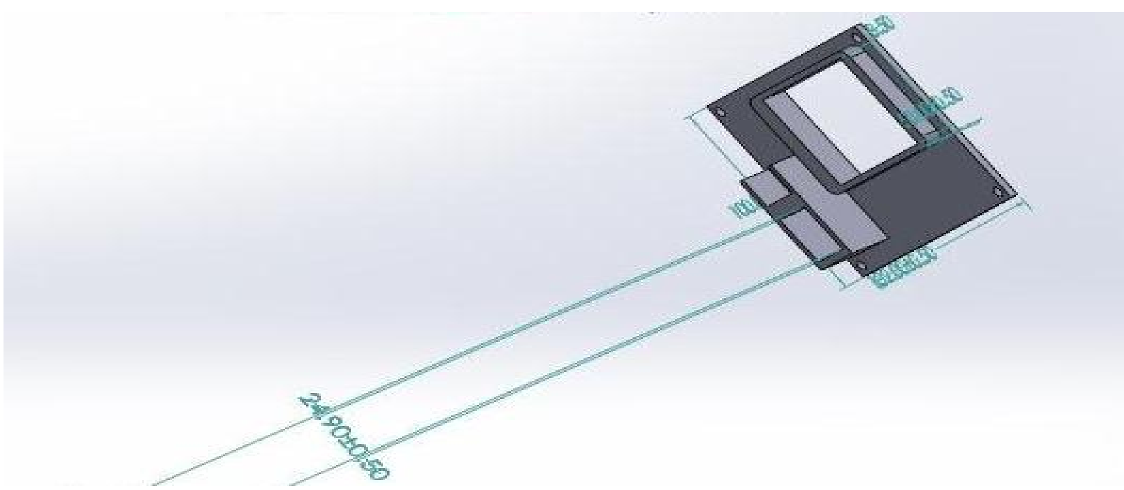

Figure 15: Internal Cutout

3.9 PERIPHERAL COMPONENTS

1. RTC Module:

To ensure that the time stamping of the fingerprint logs is accurate, the system will include a Real-Time Clock module. The DS1302 module is chosen due to its ability to retain the time even when the system is turned off using its internal battery backup. This is an essential requirement since the system is designed to work even in the absence of an Internet connection.

Although the highly accurate DS3231 module is also available, it is not chosen since the system does not require such high accuracy in its application. The DS1302 module is accurate enough and also consumes slightly less power than the DS3231 module. Another option that could have been chosen is the Network-based approach using the NTP protocol. However, this approach also requires Internet connectivity, which is not always guaranteed in many scenarios such as access point scenarios

2. SD Card Module: In the design of the EGT, reliable data storage is essential for ensuring that user records are preserved, especially in situations where internet access is intermittent or unavailable. For this reason, an SD card module will be incorporated into the system. The inclusion of this module provides a local, non-volatile storage solution that allows the device to record fingerprint scans, timestamps and user IDs.

3. Pushbuttons and Switch: Pushbuttons provide manual input for navigation or control. Also useful for system reset or triggering manual data export.

4. Jumper Wires: Used to connect and prototype the components on a breadboard or PCB such as wiring the fingerprint sensor, TFT, SD card module, RTC and microcontroller pins together during assembly and testing phases.

5. 3D Modelling Filament: Material for 3D printing the enclosure and mechanical parts of the EGT. Allows you to create a custom, ergonomic, and protective casing to house the components securely and provide proper finger placement guides.

3.9.1 COMMUNICATION INTERFACE SUMMARY

Interface Type	Peripheral	Protocol Used	Pins Utilized
Display + SD Card	TFT, SD Card	SPI	GPIO 18, 19, 23, CS(15/5)
Fingerprint Sensor	R307/AS608	UART	GPIO 16 (RX2), 17 (TX2)
Control Inputs	Buttons	Digital GPIO	25, 26, 32, 33
Network	Wi-Fi	Wireless	Handled internally by ESP32
Feedback	Buzzer	Digital GPIO	GPIO 27

CHAPTER 4

SYSTEM IMPLEMENTATION AND RESULTS

Arduino IDE was used as the programming environment for the programming of the ESP32.

4.1 FIRMWARE STRUCTURE

The main software modules used in the programming of the Examination Guard Terminal are;

1. Biometric Logic: The code handling communication with the AS608 (UART) for enrollment is; """

```
if (cnt == 0) {
server.send(400, "text/html", "<h3>Select at least 1 course</h3><a href='/student'>Back</a>");
return;
}
server.send(200, "text/html", "<h3>Place finger on sensor...</h3>");
uint16_t fid = enrollFingerprint();
if (fid == 0) {
   server.send(200, "text/html", "<h3>Fingerprint failed. <a href='/student'>Retry</a></h3>");

   return;
}
```

""" The code handling communication with the AS608 (UART) for real time verification is;

""""""

```
void fingerprintAttendance() {
uint8_t p = finger.getImage();
if (p != FINGERPRINT_OK) return;
p = finger.image2Tz();
if (p != FINGERPRINT_OK) return;
p = finger.fingerFastSearch();
if (p != FINGERPRINT_OK) { showStatus("No match", ILI9341_RED); return; }"""""
```

2. User Interface (UI) Logic: The code managing the display on the TFT LCD (SPI) and handling navigation via the push buttons (SW1-SW4) is;

```
"""
void setup() {
Serial.begin(115200);
Serial.println("\nBIOREG v4.1 – Starting in AP Mode");
pinMode(BTN_UP, INPUT_PULLUP);
pinMode(BTN_DOWN, INPUT_PULLUP);
pinMode(BTN_ENTER, INPUT_PULLUP);
pinMode(BTN_BACK, INPUT_PULLUP);
pinMode(BUZZER, OUTPUT);

tft.begin();
tft.setRotation(1);
tft.fillScreen(ILI9341_BLACK);

fingerSerial.begin(57600, SERIAL_8N1, FINGERPRINT_RX, FINGERPRINT_TX);
if (!finger.verifyPassword()) {
tft.setTextSize(2);
tft.setTextColor(ILI9341_RED);
tft.setCursor(40, 100);
tft.println("FP SENSOR ERROR");
while (1) delay(1000);
}
"""
```

3. Data Logging and Synchronization: The routines for securely logging data are;

```
""" void saveCourses() {
prefs.begin("bioreg", false);
prefs.putUShort("cCount", courseCount);
for (uint8_t i = 0; i < courseCount; i++) {
prefs.putString(("c" + String(i)).c_str(), courseList[i]);
```

```
}
prefs.end();
}
void loadCourses() {
prefs.begin("bioreg", true); courseCount = prefs.getUShort("cCount", 0);
if (courseCount > MAX_COURSES) courseCount = MAX_COURSES;
for (uint8_t i = 0; i < courseCount; i++) {
courseList[i] = prefs.getString(("c" + String(i)).c_str(), "");
}
prefs.end();
}
void saveStudents() {
prefs.begin("bioreg", false);
prefs.putUShort("sCount", studentCount);
prefs.putBytes("students", students, sizeof(Student) * studentCount);
prefs.end();
}
void loadStudents() {
prefs.begin("bioreg", true); studentCount = prefs.getUShort("sCount", 0);
if (studentCount > MAX_STUDENTS) studentCount = 0;
prefs.getBytes("students", students, sizeof(Student) * studentCount);
prefs.end();
}
void clearAllData() {
prefs.begin("bioreg", false);
prefs.clear();
prefs.end();
}

void clearAllData() {
prefs.begin("bioreg", false);
```

```
prefs.clear();
prefs.end();
studentCount = 0; courseCount = 0;
finger.emptyDatabase();
}
```
""""""

4.1.1 OPERATIONAL MODE IMPLEMENTATION

The programming steps taken to implement the Examination Guard Terminal's dual mode operational framework include;

1. Enrollment (Access Point Captive Mode): When the device is powered on and switched to configuration mode, it automatically creates its own dedicated Wi-Fi hotspot. Any device that connects to this hotspot is instantly redirected to a secure captive-portal interface hosted on the EGT, allowing controlled access to the setup and enrollment environment.

a. **Student Registration Interface:** Students authenticate and register for their scheduled courses. This ensures that only pre-verified candidates are associated with specific examination sessions.

b. **Administrative Management Interface**: The system provides administrators with a comprehensive set of tools for managing examination data. This includes the ability to create, modify, and organize course lists, monitor real-time student enrollment statistics, and access detailed student information, such as name, matriculation number, and academic level.

The code is;

""""""

```
// === CAPTIVE PORTAL ===
const char* AP_SSID = "BIOREG-Setup"; const char* AP_PASS = "bioreg123";
#define MAX_STUDENTS 200
#define MAX_COURSES 50
#define MAX_SEL_COURSES 10

struct Student {
```

```
char name[32];
char matric[16];
char dept[24];
char level[10];
uint16_t fingerID;
 uint8_t courses[MAX_SEL_COURSES];
uint8_t courseCount;
};

Student students[MAX_STUDENTS];
uint16_t studentCount = 0;
String courseList[MAX_COURSES];
uint8_t courseCount = 0;

const char* ADMIN_USER = "Admin";
const char* ADMIN_PASS = "Engineering";
const char* ADMIN_TOKEN = "bioreg_secure_2025";

enum Mode { MENU, ATTENDANCE };
Mode currentMode = MENU;
bool inAPMode = true; // Tracks current Wi-Fi mode
uint8_t selectedCourse = 0;

// Start in AP Mode
WiFi.softAP(AP_SSID, AP_PASS);
IPAddress IP = WiFi.softAPIP();
Serial.print("AP IP: "); Serial.println(IP);
dnsServer.start(53, "*", IP);

// Web routes
server.on("/", HTTP_GET, handleRoot)
```

```
server.on("/student", HTTP_GET, handleStudentGet);
server.on("/student", HTTP_POST, handleStudentPost);
server.on("/admin", HTTP_GET, handleAdminGet);
server.on("/admin", HTTP_POST, handleAdminPost);
server.on("/admin/dashboard", HTTP_GET, handleAdminDashboard);
server.on("/admin/addcourse", HTTP_POST, handleAddCourse);
server.on("/admin/remcourse", HTTP_POST, handleRemCourse);
server.on("/admin/delstudent", HTTP_POST, handleDelStudent);
server.on("/admin/clearall", HTTP_POST, handleClearAll);
server.onNotFound(handleNotFound);

 server.begin();
drawMenu();
}

void loop() {
  if (inAPMode) {
  dnsServer.processNextRequest();
  server.handleClient();
}
yield();

""""
```

2. Verification (Wi-Fi Mode):

The EGT connects to an externally provided Wi-Fi network to enable cloud or local network communication for data transmission.

a. Biometric Authentication Process: The system captures the student's fingerprint and compares it against stored biometric templates from the enrollment phase to confirm identity authenticity.

b. **Real-Time Attendance Processing:** Once verification is successful, the system immediately logs the student's attendance details including identity, time-stamp, and verification status. The data is automatically formatted and synchronized to the designated storage host (e.g., spreadsheet on the connected device).

This is the code for connecting the Examination Guard Terminal to an external network and performing the real-time biometric comparison and logging process:

```
void connectToWiFi() {
  tft.fillScreen(ILI9341_BLACK);
  tft.setTextColor(ILI9341_YELLOW);
  tft.setTextSize(1);
  tft.setCursor(20, 100);
  tft.println("Connecting to:");
  tft.println(STATION_SSID);
  Serial.println("Switching to Station Mode..."); stopAP();
  WiFi.mode(WIFI_STA);
  WiFi.begin(STATION_SSID, STATION_PASS);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
}
Serial.println("\nConnected to Wi-Fi!");
inAPMode = false;
}""""
```

4.2 TESTING AND PERFORMANCE ANALYSIS

4.2.1 Test Environment

Testing was carried out in a controlled setting in the Mechatronics laboratory with a number of 30 students in order to simulate examination conditions.

4.2.2 Functional Testing

This tested the enrollment speed, verification speed, enrollment capacity and reliability of the Examination Guard Terminal.

S/N	NAME	MATRIC NUMBER	ENROLLMENT TIME (seconds)	VERIFICATION TIME (seconds)
1	Anger Smith	ENG2025001	6.07	2.48
2	Ado Brown	ENG2025002	5.43	2.57
3	Justin James	ENG2025003	5.47	2.83
4	Santa Clara	ENG2025004	5.77	2.46
5	Kassim Osagie	ENG2025005	5.36	1.98
6	Ayo Godwin	ENG2025006	5.40	2.66
7	Mofokuku Solomon	ENG2025007	5.22	2.63
8	Chukwudi Stephen	ENG2025008	5.52	1.93
9	Bamiloi Prince	ENG2025009	5.47	2.79
10	Diego Proluse	ENG2025010	5.42	2.87
11	Captain Okoro	ENG2025011	5.39	2.21
12	Judith Oyele	ENG2025012	5.54	2.68
13	Jesse Ikumag	ENG2025013	5.18	2.19
14	James King	ENG2025014	5.22	2.88
15	Reece James	ENG2025015	5.11	2.63
16	Victor Osimhen	ENG2025016	5.00	2.12

17	Timothy John	ENG2025017	5.37	2.34
18	Uche Mbachu	ENG2025018	5.62	2.25
19	Chris Wilfred	ENG2025019	5.39	2.54
20	Jessica Owarisi	ENG2025020	5.34	2.39
21	Ariane Jeffery	ENG2025021	5.39	1.94
22	Ariane James	ENG2025022	5.39	2.00
23	Israel Israel	ENG2025023	5.22	2.74
24	Chibuikem Abraham	ENG2025024	5.36	2.79
25	Agahundu Henry	ENG2025025	5.21	2.76
26	Ekem Henry	ENG2025026	5.37	1.85
27	Bryan Testimony	ENG2025027	5.08	2.31
28	Chidinma Johnson	ENG2025028	5.49	2.17
29	Precious Osaigbovo	ENG2025029	5.36	2.63
30	Johanna Peace	ENG2025030	5.38	2.66

From testing;

1. The average enrollment speed is calculated to be 5.39 seconds.
2. The average verification speed is calculated to be 2.44 seconds.

The test covered a range of 30 students which is 15% of the total enrollment capacity of 200 students of the Examination Guard Terminal. The device showed no heating or drop from the average performance. There was no instance of False Acceptance or False Rejection therefore the False Acceptance Rate and False Rejection Rate are 0.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The project was successful in producing a reliable and efficient Examination Guard Terminal (EGT) prototype. Conceptual designs and detailed design for the hardware schematic were produced. The Examination Guard Terminal (EGT) prototype was constructed based on the detailed design and specifications for both hardware and software. Functional tests were carried out in a simulated examination environment and produced satisfactory results that fully aligned with the objectives and proposed parameters for the project. That is;

1. An average student verification speed of 2.44 seconds, ensuring high speed verification at examination entry points.
2. The system demonstrated zero False Acceptance Rates (FAR) and zero False Rejection Rates (FRR) across the test sample, validating its core reliability and ability to secure academic integrity.

5.2 LIMITATIONS OF THE SYSTEM

The developed Examination Guard Terminal (EGT) system has a number of limitations that provide room for further development and highlight existing dependencies:

1. **Impact on Scale:** This requirement presents a significant logistical and administrative challenge in using this system for very large student numbers. This process is tedious and time-consuming for administrators in getting the system ready for use.

2. **Fingerprint Sensor Sensitivity and Accuracy:** The operational accuracy and efficiency of the system are highly dependent on the quality of the fingerprint image captured by the optical sensor. The AS608 optical sensor, while efficient, is sensitive to external factors. Fingerprints that are excessively dry, oily, scarred, or covered in dirt or moisture may sometimes fail to read on the first attempt, leading to a temporary increase in the False Reject Rate (FRR).

3. **Component Reliability:** The system is also vulnerable to the brown-out situation documented in the power subsystem, where momentary peak current draw by components like the TFT-LCD can destabilize the 3.3V operating voltage, potentially causing temporary functionality failures.

4. **Security and Redundancy:** This reliance limits the system's security and redundancy. If a student's enrolled finger cannot be successfully scanned due to injury or environmental factors (Limitation 2), there is no immediate, alternative biometric method for verification.

5.3 RECOMMENDATIONS

To maximize the efficiency and longevity of the Examination Guard Terminal (EGT) and ensure its continued successful operation without hindrances, the following recommendations for usage protocols must be strictly adhered to:

1. The device's battery must be charged for at least an hour and thirty minutes to be at full functioning capacity.
2. The device must be stored in a dry environment in order to prevent equipment failure due to short circuit.
3. Routine maintenance is to be carried out on the TFT-LCD monitor and the AS608 fingerprint sensor after use with an alcohol solution and clean cloth to remove oils and grime.

To improve and extend the system future works, the following recommendations are advised:

1. Multi-Biometric System Upgrade
2. Mobile Application Integration
3. Enhanced Security Features:
4. Adopt Raspberry Pi 5 for Higher Processing Speed

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