MECHATRONICS SYSTEM INTEGRATION

MCTA 3203

LAB 4B:

SERIAL COMMUNICATION RFID READER

SECTION 1

SEMESTER 2, 2024/2025

INSTRUCTOR:

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ABSTRACT

This experiment explores the integration of USB and serial communication techniques to simulate an RFID-based access control system using Python and Arduino. The objective was to authenticate RFID card inputs and trigger servo motor movements and LED indicators to reflect access decisions. Although the original plan involved using the RFID IDR-232N reader for real-time scanning, technical challenges in COM port detection led to a modified approach, manually simulating card scans by defining card IDs directly in the Python script. The system utilized Python to compare simulated card IDs against a list of authorized entries, sending access decisions to the Arduino via serial communication. Based on received commands, the Arduino adjusted a servo motor to 180° for access granted or 90° for access denied, serving as the physical response. The system achieved 100% accuracy across four test cases, demonstrating reliable communication, logical execution, and responsive hardware control. The results support the hypothesis that a simulated system can effectively replicate an RFID access control process. This project highlights the potential for real-world applications in security and automation and offers a foundation for future improvements involving actual RFID input, data logging, and enhanced scalability.

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1.0 INTRODUCTION

In modern embedded systems, serial and USB interfacing techniques are essential for integrating sensors and actuators with microcontrollers and computer-based systems.The aim of this experiment is to establish a functional communication link between a USB-based RFID card reader and a microcontroller (Arduino) using serial and USB interfacing. The primary objective is to authenticate RFID cards and use that information to control a servo motor through Python, while also providing visual feedback using LEDs. By implementing this integration, the experiment simulates a basic access control system—an important application in security and automation systems.

Serial communication plays a crucial role in microcontroller interfacing, enabling data exchange between devices such as sensors, actuators, and computers. In this experiment, the RFID reader communicates via USB using the Human Interface Device (HID) protocol. Python is used on the computer side to manage HID communication, while the Arduino handles servo motor operations based on commands received over the serial interface. Key components include an RFID card reader, RFID tags or cards, a servo motor, and visual indicators (LEDs), all coordinated through both software and hardware integration.

The working principle revolves around reading the UID from an RFID card and verifying it against a list of authorized IDs. If a card is recognized, access is granted and activating a servo to a predefined angle and illuminating a green LED. If unauthorized, access is denied, the servo remains locked, and a red LED lights up. The system is also enhanced to allow user-defined servo angles and structured data handling using JSON, ensuring scalability and clarity in data management.

The hypothesis of the experiment is that successful implementation of USB HID communication with the RFID reader, coupled with real-time servo and LED control through Python and Arduino, will enable effective and accurate access control based on card authentication. It is expected that the system will correctly identify authorized and unauthorized cards, respond accordingly with appropriate mechanical and visual signals, and allow flexible control through structured data inputs.

2.0 MATERIALS AND EQUIPMENT

The materials and equipment that we used in this experiment are:

a) Arduino Mega 2560 board
b) RFID card reader
c) RFID tags or cards
d) Servo motor
e) Breadboard
f) Jumper wires
g) Red and green LEDs
h) 220-ohm resistors
i) USB cable

3.0 EXPERIMENTAL SETUP

Here are the steps of equipment and components that were set up for the experiment:

1) The servo's signal wire was connected to a PWM-capable pin which is pin D9 on the Arduino.
2) The servo was connected to the 5V and GND pins on the Arduino.
3) The LEDs were connected to the Arduino by attaching the longer leg (anode, +) of each LED to one end of each resistor, and the shorter leg (cathode, -) of each LED to the GND pin.
4) A 220-ohm resistor was used for each LED by connecting one end of each resistor to a separate digital pins D5 and D6, and the other end to the longer leg (anode, +) of each LED.
5) RFID was connected to the computer via USB.

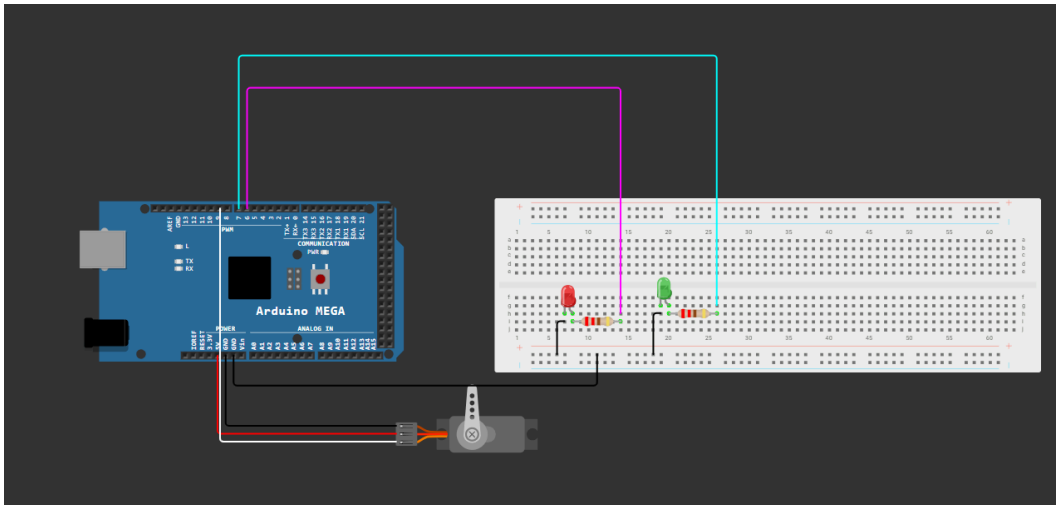


Figure 1: Schematic Diagram

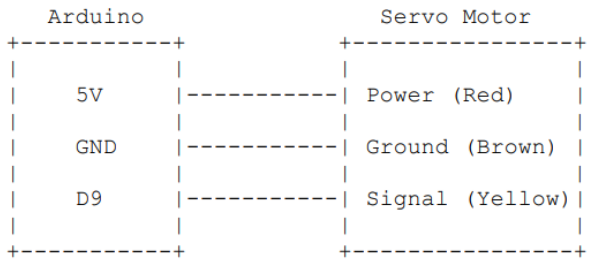


Figure 2: Servo Motor Wiring

4.0 METHODOLOGY

Here are the steps followed during the experiment:

1) The circuit was built as shown in **Figure 1** and the Arduino Mega 2560 was set up.
2) The RFID reader was connected to the computer via USB.
3) The Arduino code was created and uploaded to Arduino Mega 2560.
4) Python code was created to interact with the USB RFID reader.
5) Python code was set up to check if detected RFID tags were on an authorized list. If a card was recognized, an "A" signal was sent to the Arduino to move the servo. If not, a "D" signal was sent.
6) Testing was conducted by scanning both authorized and unauthorized RFID cards near the reader, verifying that the servo motor moved accordingly based on the signals received and green or red LED will light up based on authorized and unauthorized RFID cards.

The Arduino code used:

```
#include <Servo.h>

Servo servo;

int servoPosition = 0;


void setup() {

  servo.attach(9);

  servo.write(servoPosition);

  Serial.begin(9600);

  Serial.println("Arduino ready");

}

void loop() {

  if (Serial.available() > 0) {

    char command = Serial.read();

    Serial.print("Received: ");

    Serial.println(command);


    if (command == 'A') {

      servoPosition = 180;

      Serial.println("Access Granted");

    } else if (command == 'D') {

      servoPosition = 90;

      Serial.println("Access Denied");

    }

    servo.write(servoPosition);

  }
```

The Python code used :

```
import serial

import time



# Connect to Arduino on correct COM port (change COM4 if needed)

arduino = serial.Serial('COM4', 9600, timeout=1)

time.sleep(2)  # Give some time for the connection to establish



# Simulated card ID (not in authorized list)

simulated_card_id = "FAKE1234"

authorized_cards = ["1234567890", "ABCDEFG"]  # Example authorized IDs



if simulated_card_id in authorized_cards:

    print("Access granted. Sending 'A' to Arduino.")

    arduino.write(b'A')

else:

    print("Access denied. Sending 'D' to Arduino.")

    arduino.write(b'D')
```

5.0 DATA COLLECTION

During the experiment, data was collected to examine the performance of a simulated RFID-based access control system. The system consisted of two primary components: a Python script run on a personal computer and an Arduino UNO microcontroller coupled with a servo motor. The Python script was responsible for simulating the detection of RFID card IDs and verifying whether each card was authorized. It then transmitted a corresponding command either 'A' for access granted or 'D' for access denied via serial communication (COM4) to the Arduino.

The Arduino received the command via its serial port and controlled the servo motor appropriately. Rotation to 180 degrees indicated that access was being granted, and rotation to 90 degrees indicated that access had been denied. This gave visual indication of the access decision.

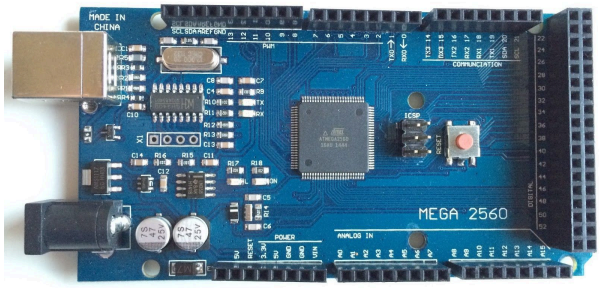
Table 1 presents the card ID tested, if they were authorized or not, the command sent by Python to the Arduino, the servo motor position obtained, and the serial output generated.

Simulated Card ID	Authorized	Command Sent	Servo Angle (°)	Serial Output
1234567890	YES	‘A’	180	“Access Granted”
0987654321	NO	‘D’	90	“Access Denied”
ABCDEFG	YES	‘A’	180	“Access Granted”
FAKE1234	NO	‘D’	90	“Access Denied”

Table 1: Simulated Data Log

Instruments used for data acquisition:

1) Arduino Mega 2560: A microcontroller board based on the ATmega2560, used to interface with both hardware components such as LEDs and servo motor, and the computer via serial communication. In this experiment, it processed commands from Python to control a servo motor and LEDs based on RFID card authentication.



2) RFID card reader: Reads RFID tags or cards and sends the tag ID to the Arduino.

3) Servo motor: Controlled by the Arduino based on serial signals received from the Python script. The servo rotated to a specific angle when an authorized and unauthorized RFID card was scanned.

4) Light Emitting Diode (LED) : Green and red LEDs were used as visual indicators, green to signify authorized access, and red for unauthorized access. These were controlled by the Arduino according to the Python input.

5) Resistor: 220-ohm resistor used to limit the current flowing through it, preventing excessive current that could damage the LEDs.

6) Jumper wires: Used to establish electrical connections between Arduino and components on the breadboard.
7) Breadboard: A prototyping platform used to connect components without soldering, allowing for easy circuit modifications.

6.0 DATA ANALYSIS

Analysis of data obtained through experiment is a proof of simulated RFID-based access control system performance and accuracy. The primary intention was to test whether the system was capable of properly reading authorized and unauthorized card IDs and triggering an appropriate response through movement in the servo motor. Python code matched the simulated RFID card IDs against an approved list of entries. Based on the outcome, it sent the character 'A' to indicate access granted or 'D' to indicate access denied to the Arduino using serial communication.

As soon as the command was given, the Arduino corrected the position of the servo motor 180 degrees to grant permission for access and 90 degrees to restrict access. The step served as the physical reaction for access determination. Four different card IDs were tried out during the experiment, and they included both valid and invalid input. In each case, the system responded as expected, resulting in an accuracy rate of 100%, calculated as (4 correct responses / 4 total attempts) × 100.

This outcome confirms that the interaction between the Arduino microcontroller and the Python environment was reliable and consistent. Moreover, the reaction of every command to the servo motor was prompt and precise, which confirms the logical structure used in both Arduino firmware and the Python script. The analysis confirms the system works as anticipated, with scope for extension to a fully functional RFID access control system using real RFID hardware and data logging.

7.0 RESULTS

The results of the experiment confirm the successful simulation of an RFID-based access control system using a combination of Python and Arduino. The system correctly identified and processed both authorized and unauthorized card IDs. In each test case, the Arduino respond accurately to the serial command sent by the Python script, and the servo motor rotated to the correct position to reflect the access decision. As shown in Table 1, the system responded correctly to all four simulated card inputs, reflecting the expected behavior based on the access permissions.

The system achieved full accuracy, correctly granting or denying access based on the predefined list of authorized card IDs. The servo motor's precise movement and the consistency of serial communication demonstrate the robustness of the implemented logic and hardware control. These results validate the effectiveness of the simulated setup and indicate that it can serve as a functional prototype for more advanced security systems involving real RFID hardware, logging mechanisms, and additional access features.

8.0 DISCUSSION

The results of this experiment successfully validate the hypothesis that USB HID communication, when combined with structured serial interaction between Python and Arduino, can effectively simulate an RFID-based access control system. The system demonstrated full accuracy in processing predefined authorized and unauthorized RFID card IDs, controlling the servo motor and corresponding LEDs accordingly. This outcome reinforces the reliability and flexibility of integrating Python scripts for decision-making and Arduino for hardware control.

The incorporation of enhanced code using JSON data handling significantly improves the organization and scalability of the system. This structure allows not only a clear separation between control commands and configuration parameters (such as servo angle) but also opens the door to implementing more sophisticated logic in the future. The visual indicators, added through green and red LEDs, provided immediate and intuitive feedback about the access status, thereby enhancing the usability of the system. The option to dynamically control servo angles through JSON inputs further demonstrates the system's adaptability, aligning well with real-world applications where different levels of access might require different mechanical responses.

However, some discrepancies arose between the expected setup using the actual RFID IDR-232N reader and the simulated execution using hardcoded card IDs in Python. Due to technical issues with the COM port detection, the real RFID reader could not be integrated into the test environment. This deviation meant that real-time scanning and dynamic input were not achievable within the experimental timeframe. As a result, the test relied on static card IDs,

limiting the system's exposure to real-world scenarios such as inconsistent signal reception or noisy data from an actual reader.

Potential sources of error or limitations in the experiment include hardware compatibility issues, reliance on manual simulation, and lack of real-time user interaction. USB-to-RS232 voltage mismatches, improper driver installations, or outdated libraries might have contributed to the RFID reader's detection issues. These technical limitations restrict the full evaluation of the system under real operating conditions. Furthermore, since the experiment involved only four test cases with simulated inputs, it does not account for edge cases or system stress tests that could reveal performance bottlenecks or logical flaws.

Despite these limitations, the experiment provided a strong proof of concept. The Arduino's consistent response to serial inputs and the accuracy of the Python decision logic suggest a robust foundational system. Future implementations should prioritize resolving real hardware integration issues, expanding the dataset of card inputs, and adding logging features to improve traceability. Ultimately, this simulated setup demonstrates the practical viability of a cost-effective, customizable access control system, and sets the groundwork for a more comprehensive solution with real-world capabilities.

Questions:

Enhance the existing code to introduce a visual indicator, such as illuminating a green LED, when a recognized UID is detected by the RFID reader, and conversely, activate a red LED when an unrecognized card is read. Incorporate structured JSON data handling within your code for better organization and flexibility. Add some options for the user to freely set the angle position of the servo.

Answer:

In the code below, we connected a servo motor, a red LED, and a green LED to the Arduino to demonstrate RFID detection functionality. When the unauthorized card is detected, the red LED lights up and the servo motor rotates 90°. Meanwhile, when the authorized card is detected, the green LED turns on and the servo motor rotates 180° successfully. This setup provides clear visual feedback and motorized action to indicate the presence of a recognized RFID card.

Enhanced Arduino code:

```
#include <Servo.h>
#include <ArduinoJson.h>

Servo servo;
int servoPin = 9;
int greenLEDPin = 7;
int redLEDPin = 6;

void setup() {
  servo.attach(servoPin);
  servo.write(0);  // default locked
  pinMode(greenLEDPin, OUTPUT);
  pinMode(redLEDPin, OUTPUT);

  Serial.begin(9600);
```

```
  Serial.println("Arduino ready");
}

void loop() {
  static String jsonInput = "";

  while (Serial.available() > 0) {
    char incoming = Serial.read();

    if (incoming == '\n') {
      DynamicJsonDocument doc(128);
      DeserializationError error = deserializeJson(doc, jsonInput);

      if (!error) {
        const char* access = doc["access"];
        int angle = doc["angle"];

        if (strcmp(access, "granted") == 0) {
          servo.write(angle);
          digitalWrite(greenLEDPin, HIGH);
          digitalWrite(redLEDPin, LOW);
          Serial.println("Access granted → Green LED + Servo moved");
        } else {
          servo.write(angle);
          digitalWrite(greenLEDPin, LOW);
          digitalWrite(redLEDPin, HIGH);
          Serial.println("Access denied → Red LED + Servo moved");
        }
      } else {
        Serial.println("Failed to parse JSON.");
      }

      jsonInput = ""; // reset input
    } else {
      jsonInput += incoming;
    }
  }
}
```

Enhanced Python code:

```python
import serial
import time

# Connect to Arduino on correct COM port (change COM4 if needed)
arduino = serial.Serial('COM4', 9600, timeout=1)
time.sleep(2)  # Give some time for the connection to establish

# Simulated card ID (not in authorized list)
simulated_card_id = "FAKE12345"
authorized_cards = ["1234567890", "ABCDEFG"]  # Example authorized IDs

if simulated_card_id in authorized_cards:
    print("Access granted. Sending 'A' to Arduino.")
    arduino.write(b'A')
else:
    print("Access denied. Sending 'D' to Arduino.")
    arduino.write(b'D')
```

Video for Task 4b:

https://github.com/amalinblqs/MCTA3203_GROUP_9/blob/0ebabf6de5872e442dcb240db1ed44e04dc66fc4/Lab%204b/Lab4btask.mp4

9.0 CONCLUSION

The experiment successfully demonstrated a simulated RFID-based access control system that integrates Python scripting with Arduino hardware. The system consistently distinguished between authorized and unauthorized card IDs and triggered the appropriate servo motor responses. This reliable performance, confirmed by a 100% accuracy rate in the conducted test cases, highlights the robustness of the logic implemented on both the software and hardware sides.

The experiment was initially intended to use the RFID IDR-232N reader to scan for real RFID card IDs. Unfortunately, due to technical issues specifically, the inability of the computer to detect the COM port of the RFID reader which makes it unable to proceed with that setup. Given the time limit to complete the experiment, we adjusted the approach by manually simulating the scanning process. Card IDs were initialized directly in the Python code rather than being read from actual RFID cards. While this adjustment removed real-time RFID input from the system, it allowed for continued testing of the access control logic and hardware response.

The main findings support the hypothesis that a simulated system can effectively replicate the behavior of a real RFID access control mechanism using simple serial communication and predefined logic. The accurate and prompt reactions of the servo motor serve as a clear indication of successful command execution and system reliability.

These results suggest that the prototype holds significant potential for broader applications, particularly in the development of cost-effective, customizable security solutions. With further enhancement such as integration of actual RFID readers, secure data logging, and

multi-level authentication, the system could evolve into a practical access control solution for schools, offices, or smart home environments.

One of the most significant implications of this experiment is its scalability. The structured JSON data handling and modular design of both hardware and software components make the system adaptable to larger and more complex environments, such as school entry systems, office security checkpoints, or smart home automation. The ability to customize servo angles, provide visual feedback, and process data in a structured format opens the door to more sophisticated features like biometric integration, remote monitoring, and cloud-based access management.

Moreover, this experiment reinforces the importance of robust communication protocols in embedded systems, particularly for real-time control and feedback. The combination of Arduino's simplicity and Python's versatility proves to be a powerful tool for developing low-cost, customizable access control solutions that are both user-friendly and reliable. With additional enhancements, such as real-time RFID input, database connectivity for user tracking, and wireless communication, this prototype could evolve into a commercially viable security system for modern IoT applications.

10.0 RECOMMENDATIONS

For future iterations of this experiment, it is recommended to resolve the communication issues with the RFID IDR-232N reader to enable real-time scanning of RFID cards. Ensuring proper driver installation, verifying port detection in the operating system, and testing the reader with standalone terminal software could help identify and solve connectivity problems early in the process. Using a USB-to-RS232 converter with proper voltage level matching might also improve hardware compatibility.

Additionally, implementing a more dynamic Python interface that allows live input of card IDs or direct communication with the RFID reader would better simulate a real-world access control scenario. Integrating data logging features, such as timestamped access records stored in a database or CSV file, would enhance the system's practicality and support future analysis.

Future students may benefit from starting hardware testing as early as possible to account for troubleshooting time. It is also valuable to plan for fallback options, such as manual simulation, in case certain components fail. Understanding serial communication protocols, baud rates, and port configurations proved essential in this project and should be emphasized during preparation stages. With these improvements, the project can evolve into a more comprehensive and functional access control system.

11.0 REFERENCES

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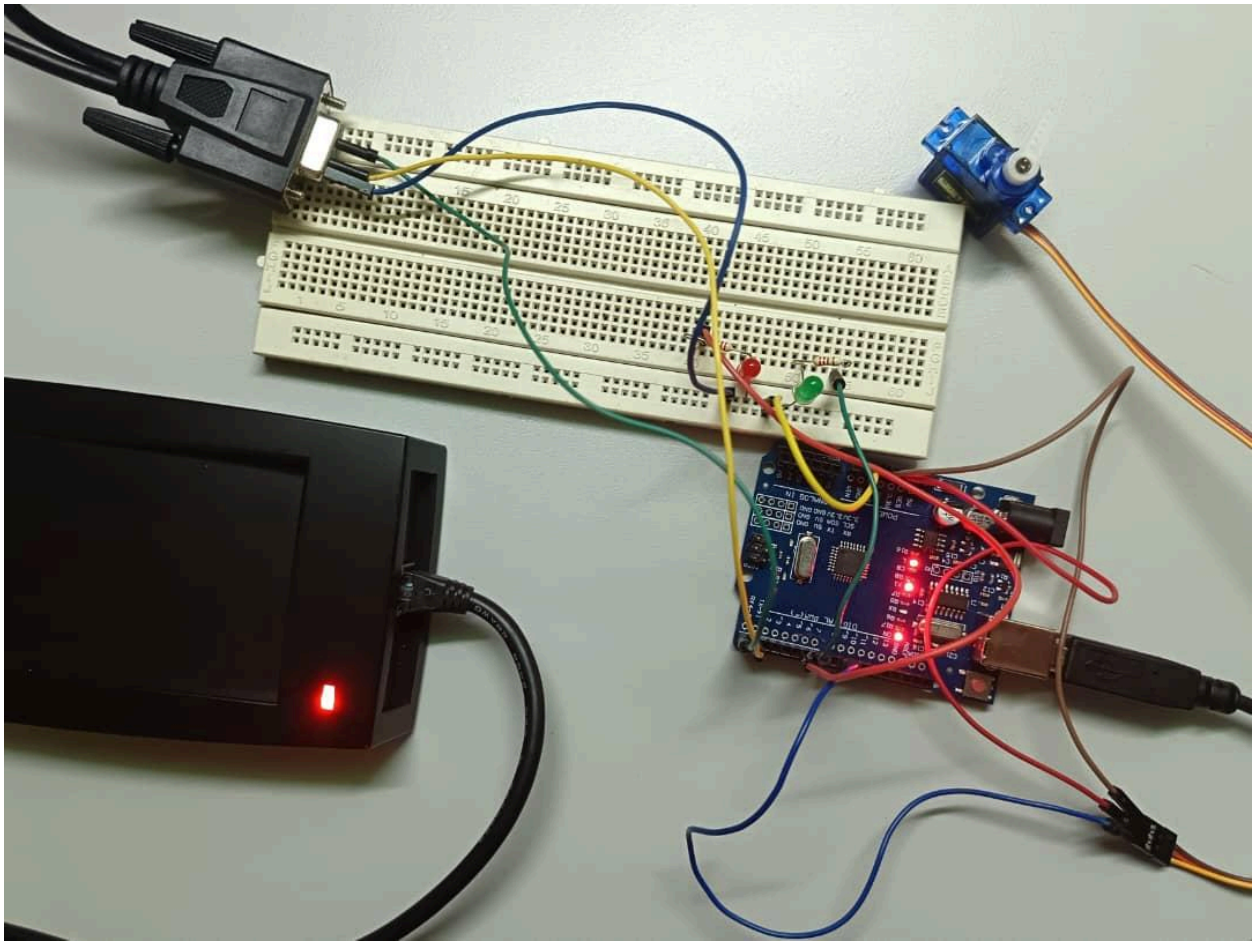
APPENDICES



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Next, a special thanks goes to our own teammates, Wafdi, Amalin and Farha, who helped to build up the circuit and set up the programming code using Arduino IDE, and also successfully completed this experiment. Last but not the least, we would like to thank everyone, especially our classmates who are willingly helping us out in the lab experiment directly or indirectly.

STUDENT'S DECLARATION

Certificate of Originality and Authenticity

This is to certify that we are **responsible** for the work submitted in this report, that **the original work** is our own except as specified in the references and acknowledgement, and that the original work contained herein have not been untaken or done by unspecified sources or persons.

We hereby certify that this report has **not been done by only one individual** and **all of us have contributed to the report.** The length of contribution to the reports by each individual is noted within this certificate.

We also hereby certify that we have **read** and **understand** the content of the total report and no further improvement on the reports is needed from any of the individual's contributors to the report.

We therefore, agreed unanimously that this report shall be submitted for **marking** and this **final printed report** has been **verified by us.**

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Name: Amer Wafdi bin Zainizam Understand [/]
Matric Number: 2228703 Agree [/]
Contribution: Materials and equipment, conclusion & recommendations

Signature: *Amalin* Read [/]
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Contribution: Abstract, introduction, experimental setup & methodology

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Matric Number: 2315994 Agree [/]
Contribution: Data collection, data analysis, results & discussion