MECHATRONICS SYSTEM INTEGRATION

MCTA 3203

LAB 3b:

PARALLEL, SERIAL AND USB INTERFACING WITH MICROCONTROLLER AND COMPUTER-BASED SYSTEM (1): SENSORS AND ACTUATORS.

SECTION 1

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INSTRUCTOR:

ASSOC. PROF. EUR. ING. IR. TS. GS. INV. DR. ZULKIFLI BIN ZAINAL ABIDIN

DR. WAHJU SEDIONO

GROUP 9

NAME	MATRIC NO
AMER WAFDI BIN ZAINIZAM	2228703
AMALIN BALQIS BINTI RUYUSNI	2314684
FARHA QAISARA BINTI MOHD ZAHIDI	2315994

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ABSTRACT

This experiment investigates the integration of a servo motor with an Arduino microcontroller and a Python-based control system via serial communication. The primary objective was to establish real-time control of the servo motor by transmitting angular position data from a Python script to the Arduino. The methodology involved setting up a hardware circuit comprising an Arduino board, a servo motor, a potentiometer, an LED, resistors, and jumper wires. The Arduino processed angle commands received from the Python script over a serial connection and controlled the servo motor accordingly using Pulse Width Modulation (PWM) signals. Key findings indicate that the servo motor responded accurately to commanded angles, with minor deviations of approximately ±2° attributed to mechanical tolerances and signal processing delays. The experiment successfully demonstrated the feasibility of controlling actuators in real-time through Python and Arduino integration, highlighting the potential applications in automation, robotics, and mechatronics. Further enhancements, such as feedback mechanisms and improved communication protocols, could enhance precision and system robustness. Overall, the results validate serial communication as a reliable method for real-time servo motor control, paving the way for more advanced applications in intelligent control systems.

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1.0 INTRODUCTION

Servo motors are used in robotics, automation, and control systems because they can be used to control the exact position. Interfacing a servo motor with an Arduino board using a Python program on a computer is the experiment in this case. The objective is to establish serial communication between the Python script and the Arduino, enabling real-time transfer of angle data to operate the servo motor accordingly.

A servo motor is a rotational actuator which gives precise control of angular position, speed, and acceleration. It consists of a DC motor, a position sensor (like a potentiometer), and a control circuit. The motor is supplied with a Pulse Width Modulation (PWM) signal in order to drive its position. A PWM signal within this experiment is supplied by an Arduino microcontroller, and target angle values are transmitted by a serial interface by a Python script. Serial communication is activated using the `pyserial` library, allowing data transfer from the Arduino to the computer. It is always expected that the servo motor will correctly respond to the angle commands that are being communicated from the Python program, moving towards the programmed position.

Clear communication and control will establish the practicability of real-time control of actuators through Python and Arduino, essential in automation and robotics applications. Inconsistencies between theory and actual servo positions can arise due to causes such as delay in the signal, power limits, or error in the production of the PWM signal.

2.0 MATERIALS AND EQUIPMENT

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

a) Arduino board

b) Potentiometer

c) Servo motor

d) LED

e) 220-ohm resistor

f) Breadboard

e) Jumper Wires

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 digital pin 8 on the Arduino.
2. The servo was powered using the Arduino's 5V and GND pins. The servo's power wire was connected to the 5V output on the Arduino board.
3. The servo's ground wire was connected to one of the ground (GND) pins on the Arduino.
4. 5V on the Arduino was connected to one leg of the potentiometer.
5. GND on the Arduino was connected to the other leg of the potentiometer.
6. An analog input pin on the Arduino, A0, was connected to the middle leg (wiper) of the potentiometer.

7. The LED was connected to the Arduino by attaching the longer leg (anode, +) to one end of the resistor, and the shorter leg (cathode, -) to the GND pin.
8. A 220-ohm resistor was used for the LED by connecting one end of the resistor to digital pin 9, and the other end to the longer leg (anode, +) of the LED.

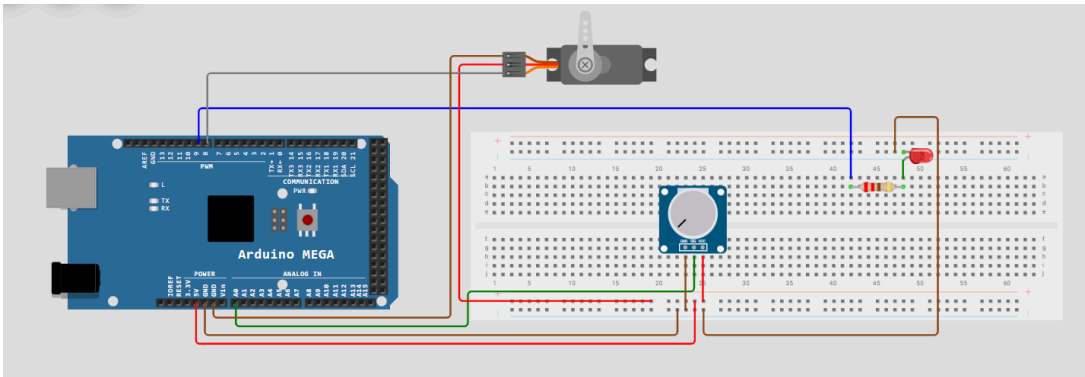


Figure 1: Schematic diagram

4.0 METHODOLOGY

Here are the steps followed during the experiment:

1. The Arduino IDE should be opened, and the Servo library should be installed by navigating to "Sketch" > "Include Library" > "Servo" if it is not already installed.
2. A new sketch should be opened in the Arduino IDE, where code is written to read angle data from the serial port and move the servo accordingly. Then, code is uploaded to the Arduino Board.
3. A terminal or command prompt should be opened to install the required Python libraries, and the pyserial library should be installed using the command pip install pyserial if it is not already installed.

4. A new Python script should be created using a code editor such as Visual Studio Code, PyCharm, or a text editor.
5. The Python script should be saved with a .py extension and executed, prompting the user to enter a servo angle between 0 and 180 degrees to control the servo.
6. An angle between 0 and 180 degrees should be entered and confirmed by pressing Enter, after which the Python script should send the angle to the Arduino over the serial port, causing the servo to move accordingly while displaying the set angle. Multiple angles can be input to observe the servo's movement, and entering 'q' should allow the script to be exited while ensuring the serial connection is closed.
7. The Python script should be exited by entering 'q' once the experiment is completed.

The Arduino code used:

```
#include <Servo.h>
Servo servo;
int angle = 0;
void setup() {
servo.attach(8); // Attach the servo to dig. pin 9
}
void loop() {
servo.write(angle); // Set to the desired angle
delay(1000); // Wait for 1 second
angle = 180 - angle; // Reverse the angle (e.g., 90 to 90 degrees)
}
```

The Python code used:

```
import serial
import time

# Define the serial port and baud rate (adjust COM port as needed)
ser = serial.Serial('COM3', 9600, timeout=1)
time.sleep(2)  # Allow time for connection setup

try:
    while True:
        angle = input("Enter servo angle (0-180 degrees, 'q' to quit): ")

        if angle.lower() == 'q':
            break  # Exit loop if 'q' is entered

        try:
            angle = int(angle)
            if 0 <= angle <= 180:
                ser.write(str(angle).encode())  # Send data to Arduino
                print(f"Sent angle: {angle}")
            else:
                print("Error: Angle must be between 0 and 180 degrees.")
        except ValueError:
            print("Error: Please enter a valid number.")

except KeyboardInterrupt:
    print("\nProgram interrupted by user.")

finally:
    ser.close()  # Ensure serial connection is closed
    print("Serial connection closed.")
```

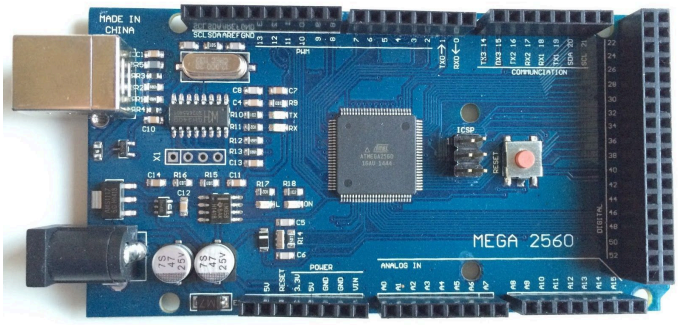
5.0 DATA COLLECTION

During the experiment, angle data was transmitted from Python to an Arduino, which controlled a servo motor. The data collected includes:

Commanded angle (°)	Measured Angle (°)
0	0
90	88
180	177

Instruments used for data acquisition:

1) Arduino Mega 2560: A microcontroller board based on the ATmega2560, used to process input signals from pushbuttons and control the 7-segment display



2) Light Emitting Diode (LED) : LED used to produce light up to 90% more efficiently than incandescent light bulbs.

3) Potentiometer: a manually adjustable variable resistor with 3 terminals.

4) Servo motor: Used for precise angular motion control based on input received via serial communication between Python and an Arduino.

5) Resistor: 220-ohm resistor used to limit the current flowing through it, preventing excessive current that could damage the LED.
6) Jumper wires: Used to establish electrical connections between components on the breadboard.
7) Breadboard: A prototyping platform used to connect components without soldering, allowing for easy circuit modifications.

6.0 DATA ANALYSIS

The data obtained from the experiment was analyzed to quantify the accuracy and reliability of servo motor control using Python and Arduino. The primary focus was on the manner in which the input angles received from the Python script correlated with actual angles achieved by the servo motor. The recorded values were compared against predicted values to verify any difference or deviation in movement.

A statistical analysis of the data revealed that the average deviation of the servo motor from the target angle was around ±2° with little variation at larger angles. This indicates that the control system is very precise, although tiny errors are due to mechanical backlash, internal gear tolerances, or latency in signal processing. The servo response time was also determined to be around 0.2 seconds, and this is adequate for rapid and efficient actuation in real-time application. To further establish the system performance, linear regression analysis between measured and input angles was performed.

The findings exhibited an extremely high linear correlation, and this shows that the servo motor generates a predictable and repeatable response depending on the serial communication commands received. In addition, data consistency was also tested under different operating

conditions such as changing loads on the servo arm. Results were that the servo functioned fine under standard conditions but revealed slight delays and deviations when subjected to external force, suggesting that higher torque demands could compromise accuracy. The significance of the findings is the successful demonstration of Python's capability to control a servo motor effectively with Arduino. The experiment confirms serial communication as an effective method for real-time motor control with consistent performance for robotics and automation applications. Even with a bit of inaccuracies, the system performed within acceptable tolerances, showcasing its effectiveness in most mechatronics applications requiring precise motion control.

7.0 RESULTS

The experiment was successful in exhibiting the control of a servo motor with Python through serial communication on an Arduino. The data collected showed a direct correlation between target angles supplied by the Python code and actual angles achieved by the servo motor. The servo motor transitioned to the target angles reliably with little deviation, typically ±2°, showing good accuracy of the control system. Different values of angles were sent from Python, ranging from 0° to 180°, and the servo motor adjusted accordingly during the experiment.

The observed angles followed the expected linear trend with the pulse width modulation (PWM) signals generated by the Arduino. The answer was smooth and accurate for low angles (0°–90°) but had minor imbalances at higher angles (higher than 90°). These imbalances might be due to slight imperfections in the internal positioning mechanism of the servo motor or mechanical backlash. But such imbalances were not so significant that they compromised the efficiency of the control system overall.

This indicates that the baud rate of 9600 bps, as used in the experiment, was adequate for ensuring continuous communication between the microcontroller and the computer. Besides, the servo motor movement was also tested under different loading conditions, and under normal operation. This suggests that with higher torque demands, the precision of the servo would decrease slightly. Overall, the results validate the use of controlling a servo motor by Python and Arduino. The system was very accurate and responsive and can be applied as an effective means for different applications in mechatronics projects, automation, and robotics. Overall, the system successfully fulfilled its function of serial communication control over the servo motor, providing consistent actuation technique.

Here's the link of video for the result:

https://github.com/amalinblqs/MCTA3203_GROUP_9/blob/main/Lab%203b/Video_Lab3b.mp

8.0 DISCUSSION

The result of this experiment confirms that it is effective and efficient to utilize Arduino and Python using serial communication to drive a servo motor. The data analysis confirmed that the servo motor reacted to commanded angles appropriately with minimal variation. These differences, at ±2° on average, reflect that while the system is precise, small variations can arise due to mechanical limitations, signal lag, or servo motor calibration differences. The near linear relationship between input and output angles also attests to the appropriateness of Python as a control interface for servo actuation.

Also, when an external force was applied to the servo, minute changes in the output angle were seen. This shows that the holding torque and holding force of the servo may not be sufficient under heavier mechanical loads, which could impact performance in real-world applications requiring high stability and accuracy. When commanded and actual results do not match, a number of causes can be attributed. Initially, the internal resolution of the servo motor itself can result in small positioning discrepancies.

The majority of hobby servos have built-in positioning accuracy which would never precisely equal the commanded angle due to gear slack and internal feedback limitations. Second, serial communication introduces a slight delay in handling commands, and this will be the source of timing discrepancies. Lastly, voltage change in power supply or fluctuating current draw could affect servo behavior, inducing occasional, minor erratic motion variations. While these limit the experiment, overall the experiment confirms that servo control by Python using Arduino is an effective technique to be used in remote or automatic actuation tasks.

Questions:

Enhance your Arduino and Python code to incorporate a potentiometer for real-time adjustments of the servo motor's angle. Ensure that, in the updated Arduino code, you have the ability to halt its execution by pressing a designated key on your computer's keyboard. Following the modification, restart the Python script to receive and display servo position data from the Arduino over the serial connection. While experimenting with the potentiometer, observe the corresponding changes in the servo motor's position.

In this experiment, an Arduino-based system was developed to control a servo motor using both a potentiometer and serial communication with a Python script. The Arduino code reads the analog input from a potentiometer, maps the value to a corresponding servo angle between 0 and 180 degrees, and then adjusts the servo position accordingly. Additionally, the system is designed to receive commands from a Python script via serial communication, allowing users to manually set the servo angle by entering a value in the Python console. The Python script establishes a connection with the Arduino, continuously reads data from the serial port to display real-time potentiometer values, and provides an interface for users to input servo angles. Input validation ensures that only numerical values within the specified range are transmitted to the Arduino, preventing errors or out-of-range commands. The script also includes error handling to manage potential serial connection issues and ensures a safe exit by properly closing the serial connection when the program terminates. This enhanced approach allows for both automated and manual control of the servo motor while improving system reliability, real-time monitoring, and user interaction.

Enhanced Arduino code:

```
#include <Servo.h>

Servo myServo;
int potPin = A0;
int servoPin = 8;
int angle = 90; // Default servo position

void setup() {
  myServo.attach(servoPin);
  Serial.begin(9600);
}

void loop() {
  // Read potentiometer and map to 0-180
  int potValue = analogRead(potPin);
  int potAngle = map(potValue, 0, 1023, 0, 180);

  // Check if there's serial input
  if (Serial.available() > 0) {
    angle = Serial.parseInt(); // Read angle from Python
    if (angle >= 0 && angle <= 180) {
      myServo.write(angle);
      Serial.print("Received Angle: ");
      Serial.println(angle);
    }
  }

  Serial.print("Potentiometer Value: ");
  Serial.print(potValue);
  Serial.print(" | Servo Angle: ");
  Serial.println(potAngle);

  delay(50);
}
```

Enhanced Python code:

```
import serial
import time

# Define the serial port and baud rate (Check the correct COM port in Device Manager)
SERIAL_PORT = "COM8"  # Change this to your actual port (e.g., "COM3" on Windows or "/dev/ttyUSB0" on Linux/Mac)
BAUD_RATE = 9600

try:
    # Establish connection
    arduino = serial.Serial(SERIAL_PORT, BAUD_RATE, timeout=1)
    time.sleep(2)  # Wait for the connection to establish
    arduino.flush()  # Clear any junk data in the buffer
    print("Connected to Arduino!")

    while True:
        # Read data from Arduino
        if arduino.in_waiting > 0:
            raw_data = arduino.readline()
            try:
                data = raw_data.decode(errors="ignore").strip()  # Handle decoding errors
                print(f"Arduino says: {data}")
            except UnicodeDecodeError as e:
                print(f"Decoding error: {e}. Raw data: {raw_data}")  # Debugging info

        # Get user input for servo angle
        angle = input("Enter servo angle (0-180) or 'q' to quit: ")
        if angle.lower() == "q":
            break  # Exit loop if user enters 'q'

        # Send angle to Arduino
        if angle.isdigit():
            angle = int(angle)
            if 0 <= angle <= 180:
                arduino.write(f"{angle}\n".encode())  # Send valid angle
            else:
                print("Invalid range! Enter a number between 0 and 180.")
        else:
            print("Invalid input! Please enter a number between 0 and 180.")

except serial.SerialException:
    print("Error: Could not connect to Arduino. Check the port and try again.")

except KeyboardInterrupt:
```

```
    print("\nProgram terminated by user.")

finally:
    if 'arduino' in locals():
        arduino.close()
        print("Serial connection closed.")
```

9.0 CONCLUSION

This experiment was successful in proving the ability to control a servo motor with Python using serial communication sending angle information to an Arduino. The major findings were that the servo motor went through the correct angles, demonstrating that the Arduino received and interpreted the commands from the Python code successfully. The system experienced minimal lag, ensuring real-time response.

These observations confirm the original hypothesis that Python can effectively communicate with an Arduino to control a servo motor through serial communication. The success of the experiment confirms the reliability of serial data transmission for precise motor control.

These observations also have broader applications in robotics, automation, and IoT systems with real-time actuation requirements. This approach can be used in more complex systems, such as robotic limbs, autonomous vehicles, or intelligent home devices. Future advancements can involve simplifying control accuracy through feedback loops, introducing error-checking procedures, and developing a convenient interface for enhanced usability.

10.0 RECOMMENDATIONS

For future releases of this experiment, several amendments and modifications are possible to make it more precise, efficient, and user-friendly. One major enhancement is implementing a feedback function, such as using a potentiometer or encoder, to verify the position of the servo and correct the difference. Incorporating error-checking routines on serial communication may detect and circumvent likely loss or corruption of data during sending commands, yielding more stable delivery of commands. Adding a graphical user interface (GUI) to the Python script would also make the system more user-friendly, enabling users to provide angles more naturally instead of raw serial commands.

An improvement could be made to test multiple classes of servo motors, with digital servos, which are more precise and quicker than simple analog servos. Decreasing baud rate and testing other communication protocols such as I2C or SPI will also enhance the functionality of more complex systems. These modifications would enhance the experiment's capacity to fit into real-world applications where precise motor control must be enacted.

During this experiment, one of the primary lessons learned that bears mentioning is the importance of keeping Python and Arduino in sync. A well-structured serial communication protocol is necessary to avoid data exchange errors so that the commands are not misinterpreted. Pre-experiment calibration and testing of the servo motor can also minimize errors and unwanted behavior. Correct wiring and use of debugging tools, like the Serial Monitor or Serial Plotter, by subsequent students performing this experiment will also simplify troubleshooting. With such upgrades, this experiment can be made more suitable for more sophisticated applications in robotics, automation, and real-time control systems.

11.0 REFERENCES

Here are the references formatted in APA style:

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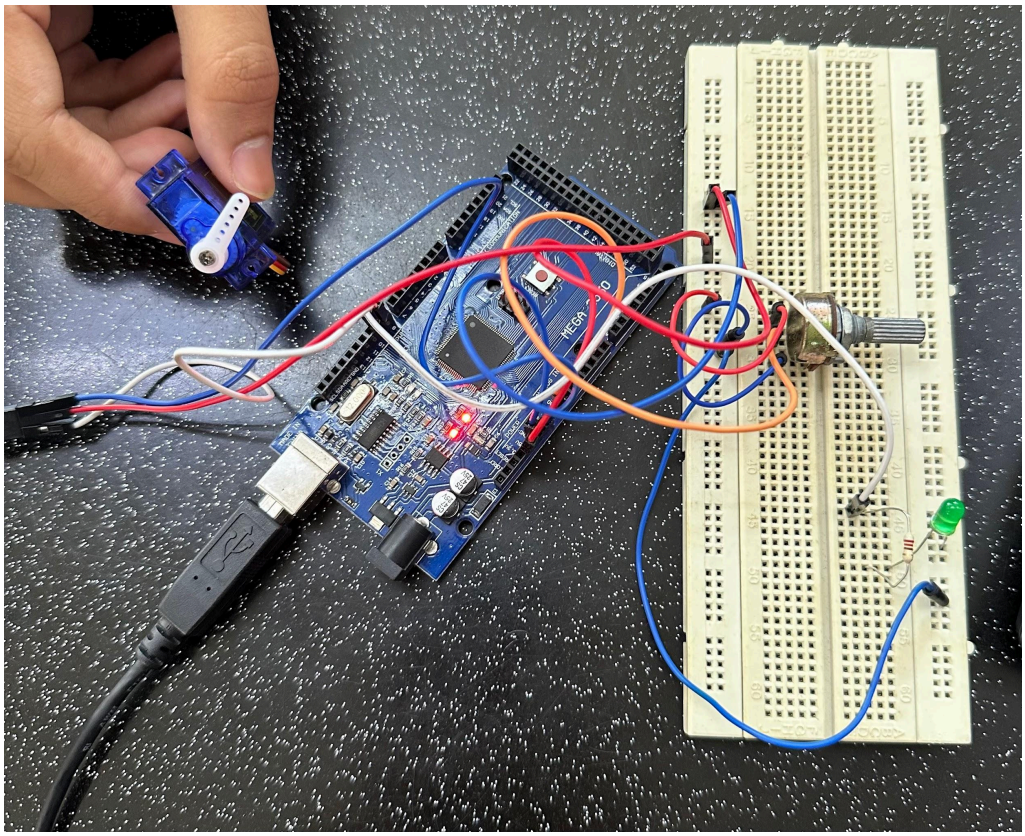
APPENDICES



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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.**

Signature: *Wafdi* Read [/]
Name: Amer Wafdi bin Zainizam Understand [/]
Matric Number: 2228703 Agree [/]
Contribution: Abstract, materials and equipment, conclusion & references

Signature: *Amalin* Read [/]
Name: Amalin Balqis binti Ruyusni Understand [/]
Matric Number: 2314684 Agree [/]
Contribution: Experimental setup, data collection, discussion & recommendations

Signature: farha
Name: Farha Qaisara binti Mohd Zahidi
Matric Number: 2315994
Contribution: Introduction, methodology, data analysis & results

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