ARM ROBOT

[HEXABOT]

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DIPLOMA TECHNOLOGY

ELECTRONIC

KOLEJ VOKASIONAL SLIM RIVER

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This project has been a valuable experience that enhanced my practical knowledge in robotics, electronics, and automation systems.

ABSTRACT

This project presents the development of a **4-Degree of Freedom (DOF) robotic arm** controlled manually using **10kΩ potentiometers**. The robotic arm utilizes **Arduino UNO** as the main controller and **MG995 servo motors** as actuators. The system demonstrates the basic concept of pick and place automation, where the arm is capable of lifting and transferring light objects within its workspace. The arm structure is powered by battery supply and USB connection, showcasing a simple yet effective control mechanism suitable for educational and exhibition purposes.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO PROJECT

In the field of industrial automation, robotic arms play an essential role in increasing production efficiency and precision. This project aims to design and build a **DIY robotic arm** that can perform pick and place operations. The project focuses on implementing a **manual control system** using potentiometers to control the movement of each joint.

The robotic arm demonstrates fundamental robotic principles such as kinematics, servo control, and motion coordination, serving as an educational prototype to understand how industrial robots function.

1.2 BACKGROUND OF STUDY

The rapid advancement in **automation and robotics** has significantly transformed modern industrial sectors. One of the most essential components in automation systems is the **robotic arm**, which performs repetitive tasks such as lifting, moving, and arranging objects with high precision and efficiency. The use of robotic arms helps to increase productivity, reduce human error, and save both time and labor costs.

A robotic arm is designed to mimic the movement of a human hand through several **Degrees of Freedom (DOF)**, allowing it to move in multiple directions. In this project, a **4-DOF robotic arm** is developed using an **Arduino UNO** microcontroller as the main controller. The system is **manually operated** using **10kΩ potentiometers**, which control the rotation angles of four **MG995 servo motors**. Each servo motor is responsible for controlling the base, shoulder, elbow, and wrist joints, enabling the arm to perform precise **pick and place** operations.

This project also serves as an educational prototype that introduces students to the fundamental concepts of **mechanical design, electronics, and control systems** in robotics. It demonstrates how analog input data from potentiometers can be converted into actual motion through microcontroller processing. Although simple in design, the system operates based on the same principles used in industrial robots for manufacturing, component assembly, and material handling.

Overall, this project strengthens students’ understanding of robotic control principles and encourages the development of **intelligent automation systems** that can be applied in various engineering and technological fields.

1.3 PROBLEM STATEMENT

In many educational environments, students often learn about automation and robotics through theory without hands-on experience in building and controlling real systems. As a result, understanding how a robotic arm functions in real-world applications becomes limited.

Moreover, industrial robotic systems are usually expensive and complex, making them less accessible for student learning and small-scale exhibitions. Therefore, there is a need to design a **low-cost, easy-to-build robotic arm** that can demonstrate the fundamental concept of **pick and place operation** while using simple and affordable components such as the Arduino UNO and potentiometers.

1.4 OBJECTIVE OF THE PROJECT

The objectives of this project are:

i. To design and construct a **4-DOF robotic arm** using Arduino UNO and MG995 servo motors.
ii. To develop a **manual control system** using potentiometers to control the movement of each servo.
iii. To demonstrate the **pick and place** operation using servo-based control
iv. To create a **low-cost educational prototype** for exhibition and learning purposes.

1.5 SCOPE OF THE PROJECT

The scope of this project focuses on developing a **manual-controlled robotic arm** with four degrees of freedom. The project involves both **hardware and software** development using Arduino UNO as the main microcontroller.

The scope includes:

i. Designing and assembling the arm using four MG995 servo motors.
ii. Using 10kΩ potentiometers as input devices to manually control servo angles.
iii. Implementing Arduino code to map potentiometer input values to servo positions.
iv. Demonstrating the arm's ability to perform **pick and place operations** within a small working area.
v. Powering the system using a **battery supply** (for servos) and **USB connection** (for Arduino).

The project does **not include** automatic control, wireless communication, or sensor-based object detection, as it focuses purely on the manual control mechanism and movement demonstration for exhibition purposes.

1.6 SIGNIFICANCE OF THE PROJECT

This project provides several important benefits, particularly in the fields of **education and automation**:

i. **Educational Value:**
   Students can gain practical experience in electronics, programming, and mechanical design, which are crucial elements in robotics.
ii. **Cost-Effective Prototype:**
   The robotic arm uses affordable components, making it suitable for classroom learning, workshops, and exhibitions without the need for expensive industrial robots.
iii. **Understanding of Motion Control:**
   The project demonstrates how analog signals from potentiometers can control servo movements, allowing students to understand the relationship between input and mechanical motion.
iv. **Foundation for Future Development:**
   The prototype can be further improved with additional features such as automation, sensors, or wireless control, serving as a foundation for more advanced robotic applications.
v. **Promotes Interest in Robotics:**
   The simplicity and interactivity of the system make it an engaging project that encourages creativity and innovation among students interested in robotics and engineering.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discusses the previous studies and fundamental concepts related to the design and development of robotic arms. The review covers the principles of robotic arm systems, Arduino microcontrollers, servo motor operation, and the use of potentiometers for manual control. The purpose of this chapter is to provide theoretical understanding that supports the design and implementation of the 4-DOF robotic arm project.

2.2 ROBOTIC ARM SYSTEM

A robotic arm is a type of mechanical manipulator designed to perform movements similar to the human arm. It typically consists of several joints, each providing a **Degree of Freedom (DOF)** that allows the arm to move in different directions. The number of DOFs determines how flexible and capable the arm is in performing tasks such as picking, placing, rotating, or assembling objects.

In industrial applications, robotic arms are widely used in **manufacturing**, **assembly lines**, **packaging**, and **material handling** processes. However, industrial robots are often expensive and complex. Therefore, educational robotic arms are developed as **low-cost prototypes** to demonstrate basic robotic movements and control principles.

The 4-DOF robotic arm in this project includes four joints:

i. **Base rotation** – allows horizontal rotation of the arm.
ii. **Shoulder joint** – provides vertical lifting motion.
iii. **Elbow joint** – controls the middle segment movement.
iv. **Wrist joint** – allows fine adjustment for gripping objects.

These joints enable the arm to perform the **pick and place** operation effectively within a limited working area.

Figure 2.1: Example arm robot pick and place

2.3 ARDUINO UNO MICROCONTROLLER

Arduino UNO is an open-source microcontroller board based on the **ATmega328P** chip. It is widely used in education and research due to its simplicity, affordability, and flexibility. The board provides **14 digital input/output pins**, **6 analog inputs**, and supports **Pulse Width Modulation (PWM)**, which is essential for controlling servo motors.

Arduino can be programmed using the **Arduino IDE** with a simple C/C++-based syntax. In this project, Arduino UNO reads analog values from potentiometers and maps them to servo positions. The ease of hardware interfacing and availability of libraries make Arduino UNO an ideal platform for robotic applications.

Table 2.1: Spesification Arduino UNO

MICROCONTROLLER	**ARDUINO UNO**
Voltage Operation	5V
Voltage Input suggested	7-12V
Input voltage limit	6-20V
I/O digital pin	14(6 di antaranya menyediakan keluaran PWM)
Input analog pin	6
Current DC each pin I/O	40mA
Current DC for pin 3.3V	50mA
Memory Flash	32 KB (ATmega328),sekitar 0.5 KB digunakan oleh bootloader
RAM	2 KB (ATmega328)
EEP ROM	1 KB (ATmega328)
Clock speed	16 MHz

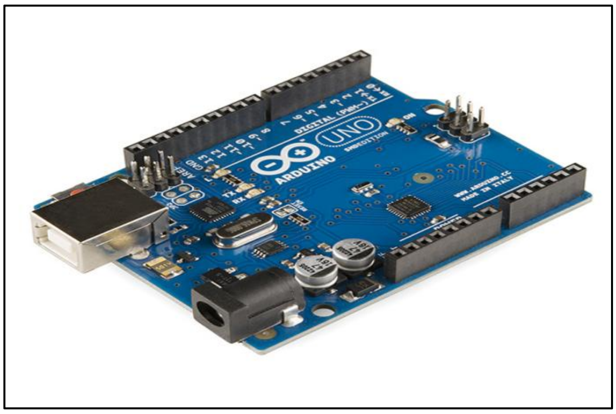

Figure 2.2: Arduino UNO Microcontroller

2.4 SERVO MOTOR (MG995)

Servo motors are crucial components in robotic arms because they allow precise control of angular movement. The **MG995 servo motor** is a high-torque DC motor with a built-in feedback system and control circuitry. It can rotate between 0° and 180°, depending on the control signal received through its PWM input.

The MG995 is commonly used in robotic applications due to its strength, reliability, and ability to handle heavier loads compared to small standard servos. Each servo in this project is responsible for controlling one joint of the arm. The servo's position is determined by the analog signal generated from the corresponding potentiometer, allowing smooth and accurate joint movement.

Table 2.2: Spesification Servo Motor SG-995

SKU:	FS995MG
Dimensions:	23.2 x 12.5 x 22mm
Weight:	14 g
Operating Speed:	0.12 sec / 60 degree (4.8v) 0.10 sec / 60 degree (6v)
Stall Torque:	1.5 kg.cm /20.87oz in (4.8v) 1.8 kg.cm/25.04oz in (6v)
Operating Voltage:	4.8v-6v
Control System:	Analog
Direction:	CCW
Operating Angle:	120degree
Required Pulse:	900us-1200us
Bearing Type:	None
Gear Type:	Metal
Motor Type:	Metal
Connector Wire length:	20cm

Figure 2.3: Servo Motor MG-995

2.5 POTENTIOMETER AS MANUAL CONTROLLER

A **potentiometer** is an analog input device that functions as a variable resistor. It produces different voltage levels based on its rotation angle, which can be read by the Arduino's analog input pins. In this project, **10kΩ potentiometers** are used as manual controllers to adjust servo positions.

Each potentiometer controls one joint of the robotic arm. When the potentiometer is turned, the Arduino reads the voltage change (ranging from 0 to 5V) and maps it to a corresponding servo angle (0° to 180°). This allows the user to manually control the arm's motion in real time, creating a simple and interactive control system.

Table 2.3: Spesification Potentiometer

Parameter	**Specification**
Component Type	Rotary Potentiometer
Resistance Value	10 kΩ (10,000 ohms)
Tolerance	±10%
Power Rating	0.25 W (¼ W)
Adjustment Type	Rotary knob (manual)
Rotation Angle	Approximately 300°
Mounting Type	Through hole / Panel mount
Material	Carbon film resistive track
Operating Voltage	Up to 50 V DC (typical)
Operating Temperature Range	-10°C to +70°C

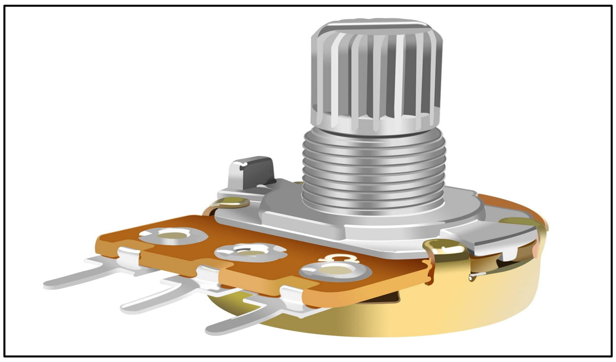

Figure 2.4: Potentiometer 10kΩ

2.6 PICK AND PLACE OPERATION

The **pick and place** mechanism is a fundamental task in robotics where an object is lifted from one location and placed in another. Industrial robots perform this task repeatedly with high precision in manufacturing lines. The concept involves several coordinated movements between the robotic arm's joints.

In this project, the robotic arm performs a simplified version of the pick and place operation using manual potentiometer control. The user adjusts each joint to grab and move lightweight objects within the arm's reach. Although it lacks automation, this manual control effectively demonstrates the mechanical and control principles behind real industrial robots.

Figure 2.5: Robot pick and place in industry

2.7 RELATED WORKS

Previous studies and projects on robotic arms have shown various approaches in terms of design, control, and functionality. For example:

i. Researchers have developed **automated robotic arms** using sensors and computer vision for object detection and placement.
ii. Some educational prototypes use **Bluetooth or Wi-Fi control**, enabling wireless operation through mobile apps.
iii. However, for beginner-level learning, **manual potentiometer-based systems** remain the most suitable because they are simpler, cheaper, and easier to understand.

This project builds upon those studies by focusing on **low-cost implementation** and **manual control** suitable for educational and exhibition purposes.

2.8 SUMMARY

In conclusion, the literature review highlights the essential components and principles involved in designing a robotic arm. The use of **Arduino UNO**, **MG995 servo motors**, and **potentiometers** forms a solid foundation for developing a functional manual robotic arm system. The knowledge from past research and existing technologies supports the implementation of the 4-DOF robotic arm for pick and place operation in this project.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter explains the methods and procedures used to design and implement the **4-DOF Robotic Arm (Pick and Place System)**. It includes the overall system design, hardware and software development, wiring configuration, and operational flow. The methodology ensures that each stage of the project is systematically planned and executed to achieve the intended objectives.

3.2 SYSTEM OVERVIEW

The proposed system consists of four main parts:

i. **Input Section:** Four 10kΩ potentiometers are used as input devices to control the angular position of each servo motor.
ii. **Control Section:** The **Arduino UNO** acts as the main controller, processing the analog input signals and generating PWM output signals.
iii. **Output Section:** Four **MG995 servo motors** that drive the robotic arm joints (base, shoulder, elbow, and wrist).
iv. **Power Supply Section:** The system is powered using a combination of USB power for Arduino and a battery pack for the servo motors.

The system performs manual **pick and place operations**, where each potentiometer directly controls one joint of the robotic arm.

3.3 SYSTEM DESIGN

3.3.1 BLOCK DIAGRAM

Each potentiometer sends an analog signal to the Arduino. The Arduino processes the input and sends corresponding PWM signals to control each servo's position.

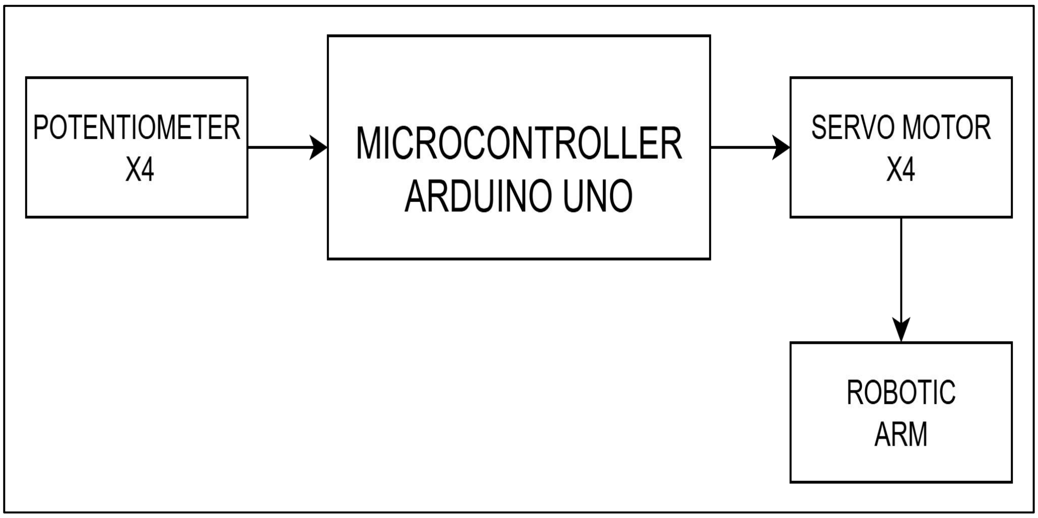

Figure 3.1: Block Diagram for arm robot

3.3.2 SCHEMATIC CIRCUIT

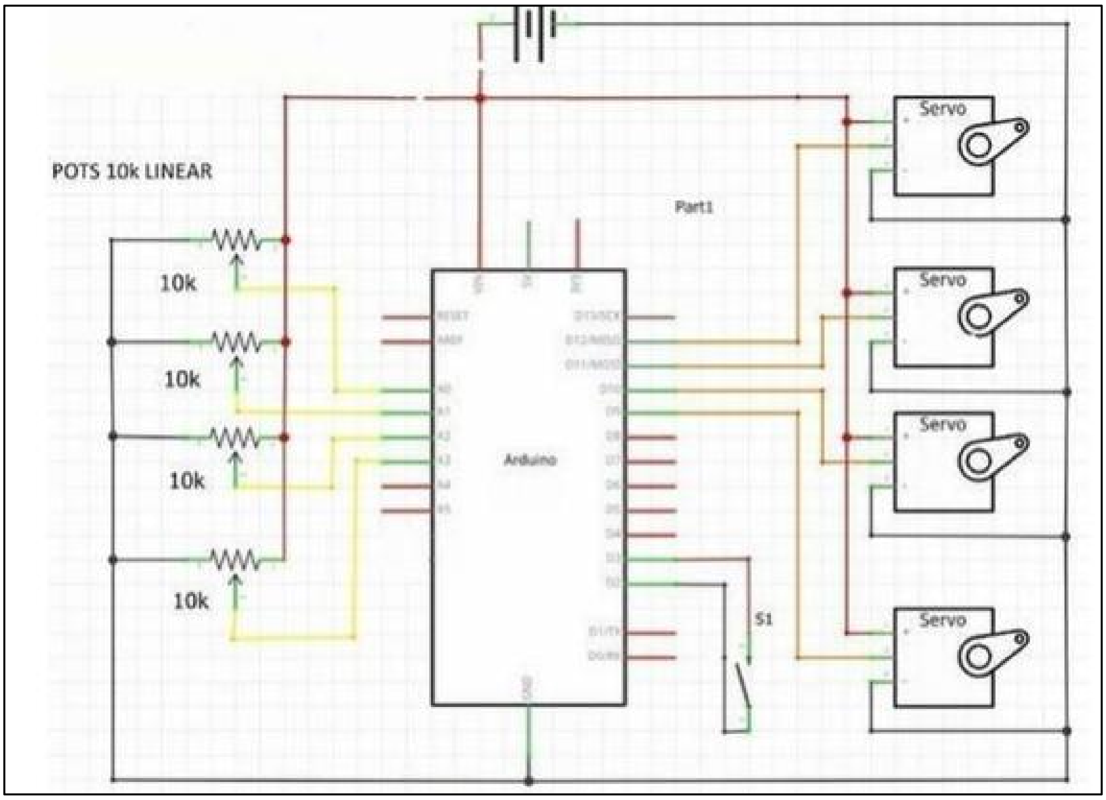

Figure 3.2: Schematic Circuit for arm robot

The circuit connects:

Potentiometers to Arduino analog pins A0–A3.

Servos to digital PWM pins D9, D10, D11, and D12.

Common Ground between the Arduino, battery, and all components.

The **battery pack** powers two servos to reduce the load on the Arduino's 5V supply, while the **USB cable** powers the Arduino and the remaining servos. This configuration ensures stable operation and prevents voltage drops.

3.4 HARDWARE DEVELOPMENT

3.4.1 COMPONENT USED

Table 3.1: List of component used

No.	Component	Quantity	Function
1	Arduino UNO	1	Main microcontroller
2	MG995 Servo Motor	4	Provides motion for each joint
3	Potentiometer 10kΩ	4	Manual input for servo control
4	Battery Pack	1	Powers servo motors
5	USB Cable	1	Powers Arduino board
6	Jumper Wires	Several	For electrical connections
7	PVC Foam / Acrylic	–	Arm body structure
8	LED Indicator (optional)	1	Shows power status

3.4.2 MECHANICAL DESIGN

The robotic arm is designed with **four degrees of freedom (4-DOF)**:

i) **Base rotation** (horizontal movement)

-The base can rotate for 360 degree

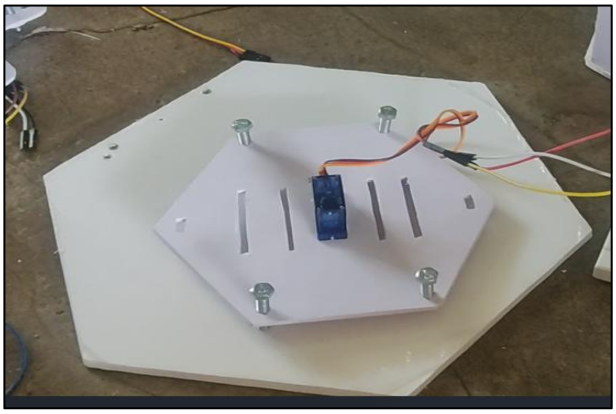

Figure 3.3: Base for arm robot

ii) **Shoulder joint** (up and down motion)

- The robot arm is capable of lifting a load up to a height of 30 cm.

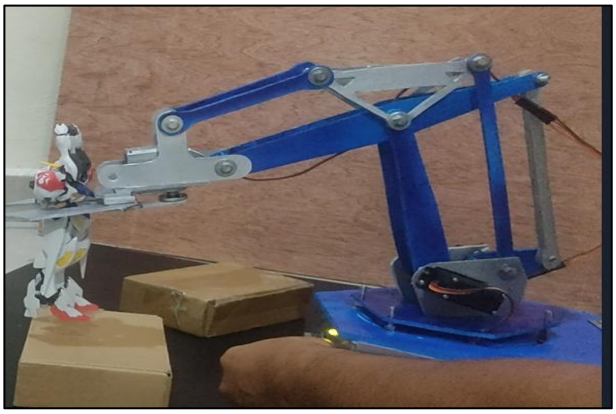

Figure 3.4: Shoulder joint for arm robot

iii) **Elbow joint** (bending motion)

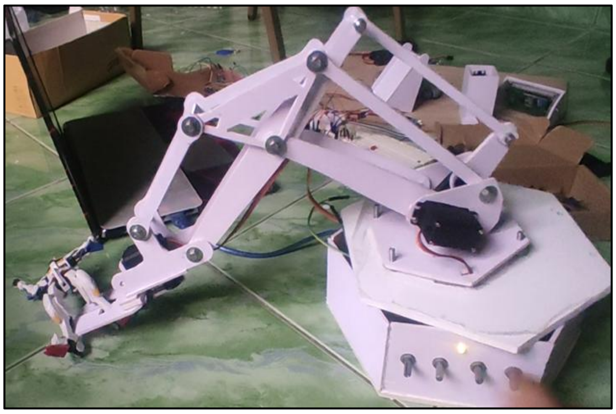

Figure 3.5: Elbow joint for arm robot

iv) **End of effector** (fine movement for gripping or placing)

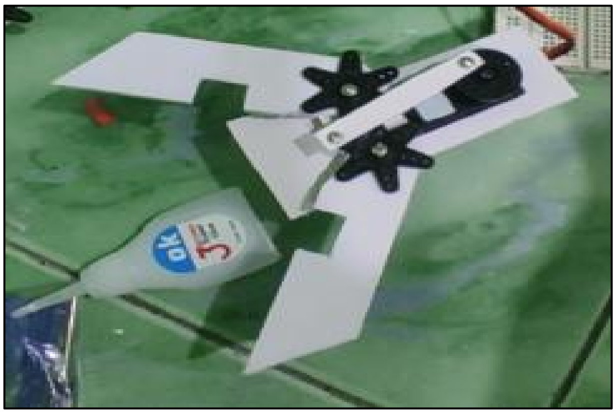

Figure 3.6: End of effector for arm robot

The frame is built using **PVC foam** because it is lightweight, easy to cut, and affordable. Servo motors are fixed at each joint using screws and brackets to ensure strong mechanical stability.

3.5 SOFTWARE DEVELOPMENT

3.5.1 PROGRAMMING ENVIRONMENT

The system is programmed using the **Arduino IDE**. The Arduino reads the analog signals from each potentiometer (ranging from 0 to 1023) and maps them to servo angles (0°–180°).

3.5.2 FLOW CHART OF OPERATION

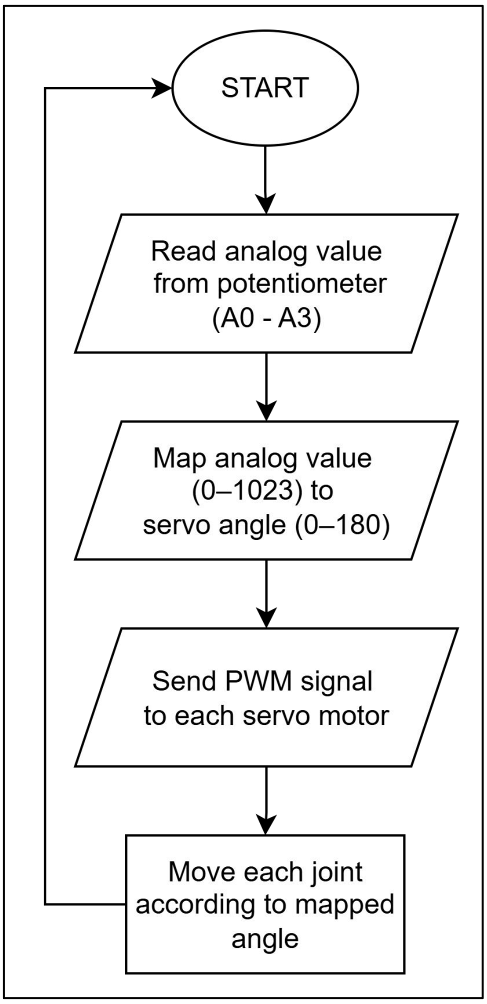

Figure 3.7: Flow chart for operation system

3.5.3 ARDUINO PROGRAM

```
#include <Servo.h>

Servo base, shoulder, elbow, wrist;
int pot1 = A0, pot2 = A1, pot3 = A2, pot4 = A3;

void setup() {
  base.attach(3);
  shoulder.attach(5);
  elbow.attach(6);
  wrist.attach(9);
}

void loop() {
  base.write(map(analogRead(pot1), 0, 1023, 0, 180));
  shoulder.write(map(analogRead(pot2), 0, 1023, 0, 180));
  elbow.write(map(analogRead(pot3), 0, 1023, 0, 180));
  wrist.write(map(analogRead(pot4), 0, 1023, 0, 180));
  delay(15);
}
```

Figure 3.8: Source code for arm robot

3.6 SYSTEM TESTING PROCEDURE

i. **Connection Verification** – Ensure all potentiometers and servos are connected correctly.
ii. **Power Supply Test** – Verify stable voltage from battery and USB.
iii. **Input Reading Test** – Check Arduino Serial Monitor to confirm correct analog readings.
iv. **Servo Movement Test** – Rotate potentiometers and observe corresponding servo movement.
v. **Pick and Place Demonstration** – Test the robotic arm by lifting and placing lightweight objects.

3.7 SUMMARY

In conclusion, this chapter explains the overall development process of the robotic arm, including both hardware and software design. The system combines Arduino-based control, servo actuation, and manual input through potentiometers to perform simple pick and place operations. The methodology ensures that each component works together efficiently to achieve the desired motion control.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

After completing the assembly and wiring of the 4-DOF robotic arm, each servo motor was tested and successfully controlled through its corresponding 10 kΩ potentiometer connected to the Arduino UNO. The potentiometers acted as manual input devices that varied the servo angles, allowing smooth and precise control for every joint of the arm.

During testing, the **MG995 servo motors** produced sufficient torque to lift and place small lightweight objects such as plastic cubes and nuts. Each joint—including the **base rotation**, **shoulder**, **elbow**, and **gripper**—performed the expected movements accurately. The user could manipulate all four degrees of freedom manually by turning the potentiometers to achieve coordinated motion of the arm for **pick-and-place** operations.

The robotic arm was powered using two sources:

USB cable from the computer for the Arduino UNO

External battery for the servo motors

This configuration provided stable voltage and reduced power fluctuations. However, minor jerky movements were observed when multiple servos operated simultaneously, which were caused by current drops in the battery. The issue was minimized by ensuring proper grounding and using separate power lines for logic and actuation.

Overall, the testing demonstrated that manual control through potentiometers is a simple yet effective method for learning robotic motion and servo actuation. The robotic arm successfully carried out the desired pick-and-place task with satisfactory accuracy and response time. The project also highlighted the importance of power management and calibration when controlling multiple servos.

In summary, the developed robotic arm system met the intended objectives of demonstrating a functional 4-DOF manual control robotic arm suitable for educational and exhibition purposes. The design effectively showcased the integration of electronic components, mechanical design, and programming control using Arduino.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The development of the 4-DOF robotic arm using **Arduino UNO**, **MG995 servo motors**, and **10k potentiometers** has successfully achieved the project objectives. The robotic arm was able to perform **pick and place** operations effectively through manual control. Each joint of the arm functioned smoothly, and the movement could be adjusted precisely using potentiometers.

This project demonstrated the basic principles of **robotic motion control**, **servo operation**, and **microcontroller programming**. It also provided a practical understanding of how electrical, mechanical, and software components work together in an automation system.

Despite minor power fluctuations when operating multiple servos, the system performed reliably after power separation between the Arduino and servo supply. Overall, the project successfully met its goal of building a functional, low-cost, and educational robotic arm system suitable for exhibitions and learning environments.

5.2 RECOMMENDATION

For future improvements, several enhancements can be made to increase the performance and functionality of the robotic arm:

i. **Automation and Sensors** – Integrate sensors such as ultrasonic or infrared to allow the arm to detect objects automatically without manual control.
ii. **Wireless Control** – Use Bluetooth or Wi-Fi modules to control the arm remotely via smartphone or computer interface.
iii. **Improved Power System** – Use a higher-capacity power supply or voltage regulator to ensure stable current delivery for all servo motors.
iv. **Software Optimization** – Add programming logic for smoother motion and automatic sequencing for repetitive tasks.
v. **Mechanical Design** – Replace PVC components with lightweight aluminum or 3D-printed parts to increase durability and precision.

With these improvements, the robotic arm could evolve from a manually operated system into a more advanced, semi-automated, or fully automated robotic solution suitable for industrial or academic applications.

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ATTACHMENT

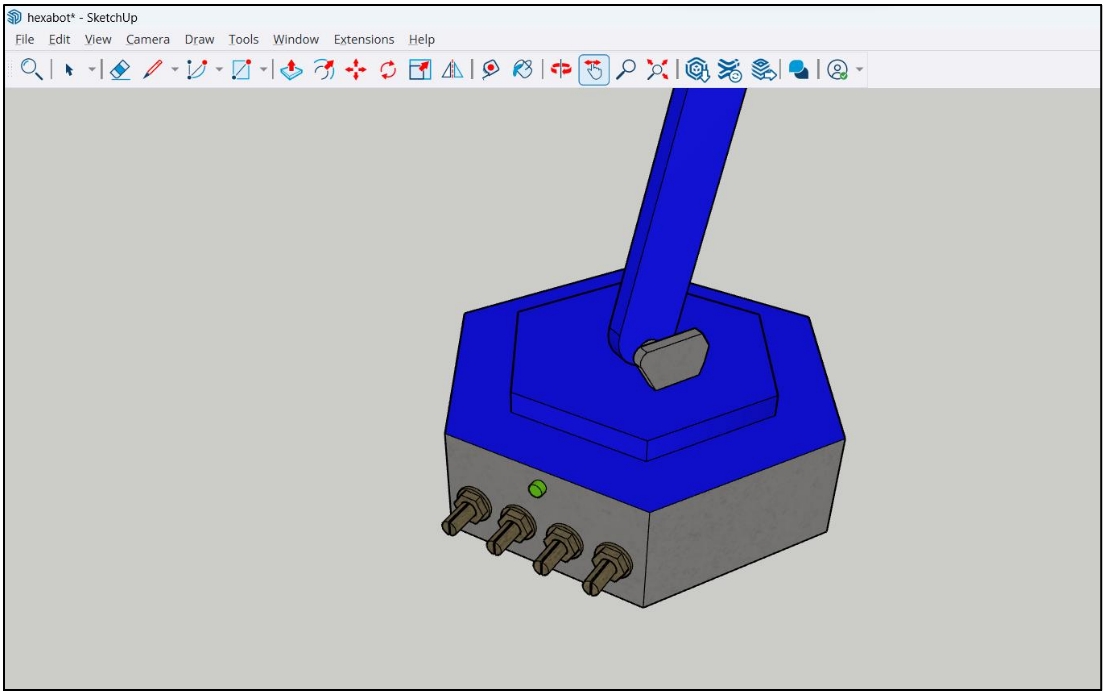

Figure 1: Base design in SketchUp

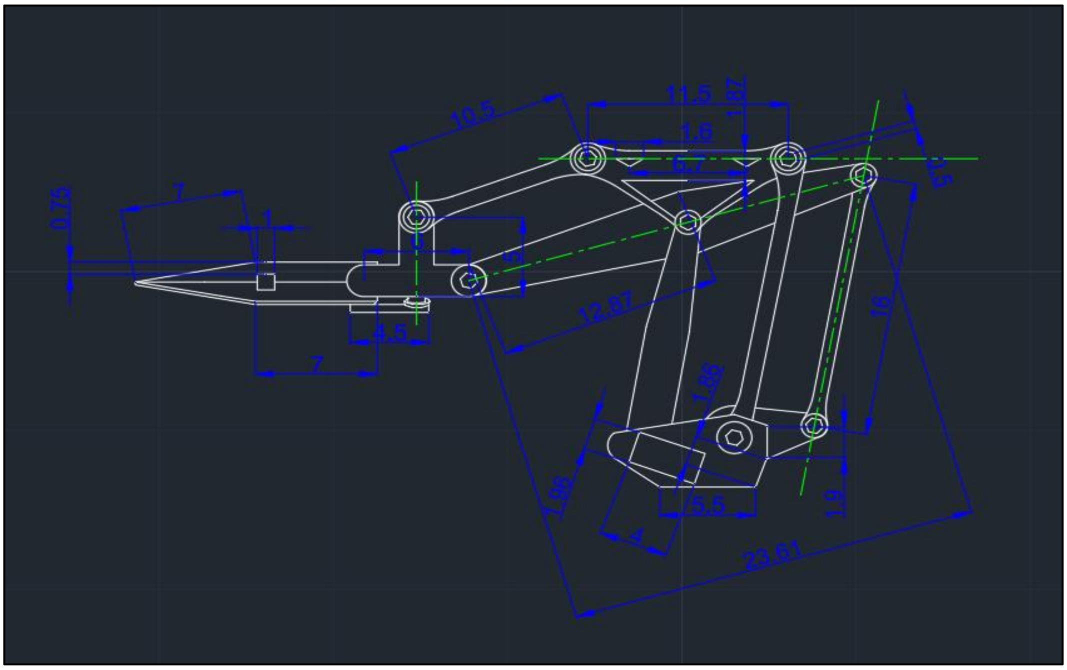

Figure 2: Joint 2, joint 3 and end of effector desing in AutoCAD

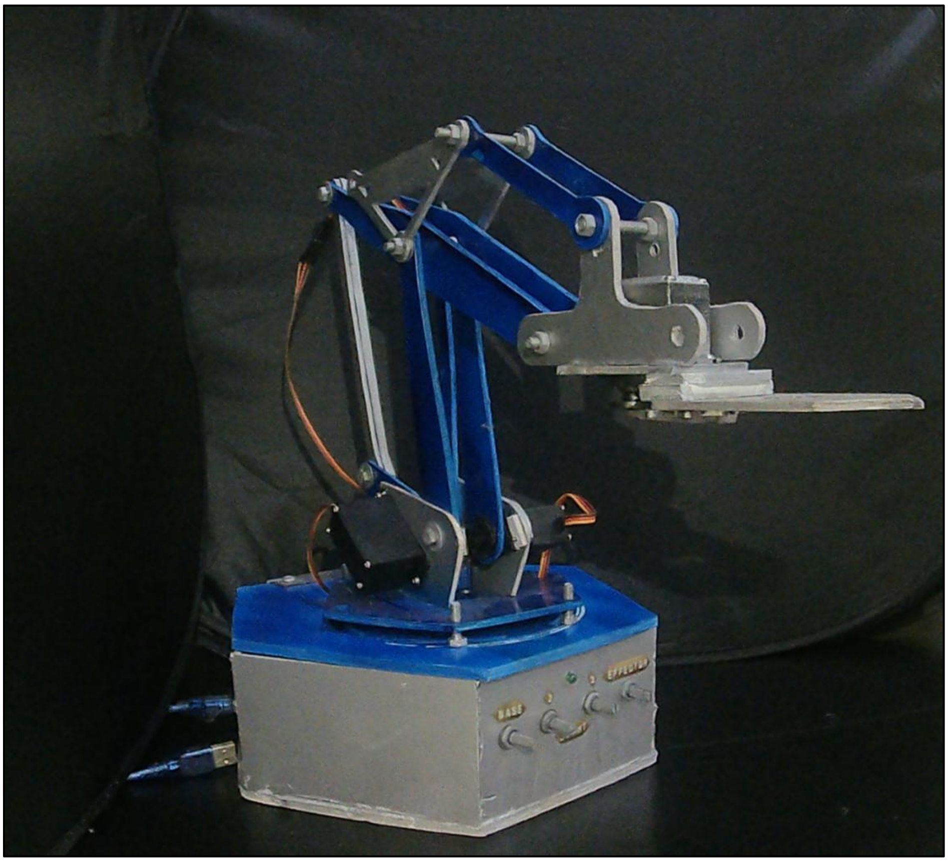

Figure 3: Side of Final design of Arm Robot

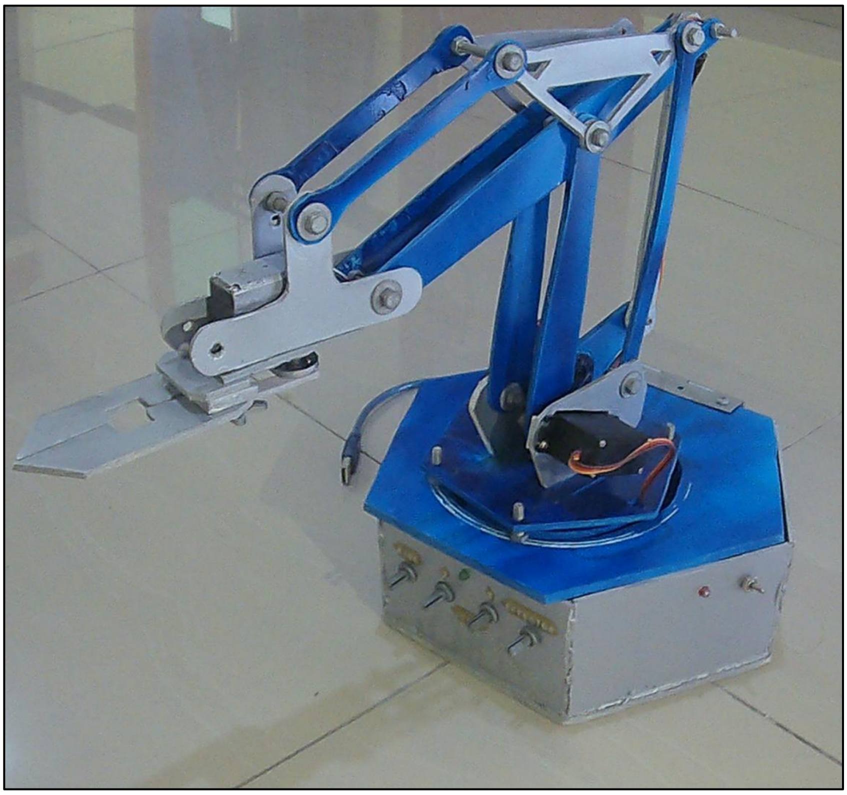

Figure 4: Front view of final design of Arm Robot