Department of Electronics &
Instrumentation Engineering

A Project Report on

Hand Motion Controlled Robotic Arm

Submitted in partial fulfillment of the requirements for the award of the degree of

Bachelor of Engineering

in

Electronics & Instrumentation Engineering

By

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Department of
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Engineering

CERTIFICATE

This is to certify that the dissertation work entitled **"Hand Motion Controlled Robotic Arm"** is carried out by Mr. Hamza Mohammad (1MS19EI021), Mr. Imran Ahmed Khan (1MS19EI026), Mr. Mohammad Ayyan Anees (1MS19EI035), Mr. Ravi Chaturvedi (1MS19EI042), bonafide students of **Ramaiah Institute of Technology, Bengaluru** in partial fulfillment of the requirements for the award of the degree Bachelor of Engineering **in Electronics and Instrumentation Engineering** of Visvesvaraya Technological University, Belagavi during the year **2022-23**. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the report deposited in the department library. The project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the said degree.

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DECLARATION

I hereby declare that the project work entitled "**Hand Motion Controlled Robotic Arm**" has been carried out by us under the supervision of **Dr. M.D. Nandeesh**, Assistant Professor, Department of Electronics and Instrumentation Engineering, Bengaluru and submitted in partial fulfillment of the requirements of the award of Bachelor of Engineering **in Electronics and Instrumentation Engineering,** of Ramaiah Institute of Technology, autonomous institute affiliated to Visvesvaraya Technological University, Belagavi during the academic year 2022-23.

This work has not been submitted in part or full for the award of any other degree/ diploma in this university or any other university.

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ABSTRACT

As robotics is one of the emerging technologies this project presents the design and development of a hand motion controlled robotic arm using flex sensors and an MPU6050 sensor the system allows for intuitive control of robotic arm using hand movement enabling more natural and efficient interaction with the robot.

The flex sensor is used to detect the bending of the fingers whereas the MPU6050 detects the orientation and movement of the hand these movements are translated into the movements of the robotic arm. Studies have shown this technique of controlling the robotic arm has potential to be used in various application such as medical rehabilitation manufacturing assembly line processes military and defence or even entertainment.

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1.1 Introduction

With the rapid pace of technological advancements, human effort has been significantly reduced across a range of fields. The use of hand gestures to control robots and applications has emerged as an innovative approach, replacing traditional methods such as switches or remotes. Hand gesture-controlled robots detect finger and hand movements via an accelerometer in the transmitting device. The signals are then processed by a Microcontroller that translates the gestures into commands for the robot. This type of wireless technology has numerous applications and can save time while also increasing productivity, efficiency, reliability, and reducing costs. The impact of robotics on various industries is immense, and it plays a vital role in achieving faster results, enhancing productivity, and improving safety in hazardous work environments. As such, the development of hand gesture-controlled robots represents a significant advancement in the field of robotics, enabling a more intuitive and efficient approach to control systems.

Robotic Arm

A robotic arm is a robot manipulator and a mechanical arm, usually programmable, with similar functions to a human arm. The links of such a manipulator are connected by joints allowing either rotational motion (such as in an articulated robot) or translational (linear) displacement. The links of the manipulator can be considered to form a kinematic chain. The business end of the kinematic chain of the manipulator is called the end effector and it is analogous to the human hand. The end effectors can be designed to perform any desired task such as welding, gripping, spinning, etc., depending on the application. The robot arms can be autonomous or controlled manually and can be used to perform a variety of tasks with great accuracy. The robotic arm can be fixed or mobile (i.e., wheeled) and can be designed for industrial or home applications.

1.2 Literature Survey

1. This paper describes a smart mobile robotic arm controlled by hand gestures. The arm is designed to be intuitive and easy to use, allowing users to control the arm's movements with simple hand gestures. An Arduino UNO board and an MPU-6050 sensor were used to detect the user's gestures, and a servo motor to control the arm's movements. The robotic arm was tested and found to be successful in performing various tasks such as picking up and moving objects. [1]
2. This paper describes a robotic hand controlled by a glove equipped with flex sensors. The glove sends signals wirelessly to the robotic hand, allowing the user to control the hand's movements with their hand movements. It uses Arduino boards and RF modules for wireless communication. The robotic hand was able to perform tasks such as grasping objects and moving them. [2]
3. This paper presents the research on using the MPU6050 measuring system for determining angular velocities and linear accelerations. The authors used the MPU6050 sensor to measure the movements of an object in three dimensions and then used mathematical algorithms to calculate the angular velocities and linear accelerations. The research has applications in various fields, including robotics, motion tracking, and virtual reality.[3]
4. The paper describes the use of flex sensors and MPU6050 sensors in a smart glove for sign language translation. A smart glove was developed that detects hand gestures using flex sensors and tracks hand movements using the MPU6050 sensor. The glove was able to accurately translate sign language gestures into text and speech. [4]
5. This paper describes the development of a wireless robotic arm controlled by hand gestures. It uses an NRF24L01 transceiver for wireless communication and an Arduino board to control the arm's movements. The robotic arm was able to perform various tasks such as picking up and moving objects. [5]
6. A 5-degree of freedom (DOF) wireless hand motion-controlled robotic arm was designed. An Arduino board, RF module, and servo motors were used to develop a robotic arm that can be controlled wirelessly using hand gestures. The robotic arm was tested and found to be successful in performing various tasks.[6]
7. Research-based on the responses of flex sensors and MPU6050 sensors in a smart glove for sign language translation had been done. A smart glove that uses flex sensors and

MPU6050 sensors was developed to detect hand movements and translate sign language gestures into text and speech. The glove was tested and found to be successful in accurately translating sign language gestures.[7]

8. A multi-DOF mobile robotic helping hand designed for paralyzed patients was designed. Using an Arduino board and servo motors to develop the robotic hand, is controlled by a joystick. The hand was able to perform various tasks such as holding objects and picking them up. [8]
9. This paper presents a review of resistive flex sensors, which are used to detect bending or flexing in a variety of applications. The paper discusses the types of flex sensors available, their construction, and their use in various industries such as automotive, medical, and robotics. It also discusses the advantages and limitations of resistive flex sensors. [9]
10. This paper proposes a control interface for unmanned aerial vehicles (UAVs) using a smart glove and hand gestures. The paper presents a system that uses a flex sensor-based smart glove to detect hand movements and translates them into commands for controlling the UAV. The authors describe the hardware and software components of the system, as well as the experimental results. [10]
11. This paper describes the design and development of a wearable glove that uses flex sensors to control robotic grippers. It presents a prototype of a glove that can detect finger movements using flex sensors and transmit this information wirelessly to control a robotic gripper. The paper includes details of the glove's construction, as well as experimental results. [11]
12. This paper presents a design for a data glove that uses flex sensors to track finger movements. The paper describes the construction of the glove, the placement of the flex sensors, and the software used to process the sensor data. The authors also present experimental results demonstrating the accuracy of the glove in tracking finger movements. [12]
13. This paper presents a design for a robotic glove and arm that can be controlled using hand gestures. The authors describe the hardware and software components of the system, which uses flex sensors to detect hand movements and transmit this information wirelessly to control a robotic arm. The paper also includes details of an automatic alert system that can detect changes in the environment and trigger the robotic arm to take action. [13]

14. This paper describes the design and development of a wireless robotic hand that can be controlled remotely using flex sensors. The authors present a prototype of the robotic hand, which uses flex sensors to detect finger movements and transmits this information wirelessly to a control system. The paper includes details of the hand's construction, as well as experimental results demonstrating its functionality. [14]

1.3 Problem Statement

Human arms can indeed do plenty work at a time but it always involves the risk of injury during work involving lifting of heavy items and picking of radioactive substances. Moreover, the medical industryneeds an arm for people who lost it in accidents. Also, it is seen that the efficiency of a person decreases as his age advances due to which one involved in rough work becomes unproductive and inefficient.

In the manufacturing industry and nuclear industry, a large fraction of the work is repetitive and judicious application of automation will most certainly result in the optimum utilization of machines and manpower. A pneumatic `Pick and Place' Robot has been developed to achieve automation in applications where great sophistication is not needed and simple tasks like picking up small parts at one location and placing them at another location can be done with great ease of programming.

This robot is a mechanical arm, a manipulator designed to perform many different tasks and capable of performing its assigned tasks, the robot moves parts, objects, tools, and special devices employing programmed motions and points. The robotic arm performs motions in space. Its function is to transfer objects or tools from point to point, as instructed by the controller.

A robotic arm is an asset for those people who are involved in the nuclear industry as by robotic arms, picking up the radio substances can be done by the instructions given by them and they do not have to physically go to the site and pick these harmful substances. Also, in the manufacturing industry risk of injury is prevented as now these robotic arms are involved in doing repetitive work and people of all ages can control it without any loss in efficiency.

1.4 Objectives

- To design and build a sophisticated robotic arm that can replicate the movements of a human hand.
- Construction of a 5-degree-of-freedom (DOF) robotic arm and integrating it with a glove module that incorporates flex sensors, an accelerometer, and a gyroscope.
- To develop a system that can accurately translate the movements of the user's hand into corresponding movements of the robotic arm, enabling precise control and manipulation of objects in real time.

Chapter 2: Methodology

2.1 Introduction

This project involves the development of a Hand Gesture Controlled Robotic Arm using a Microcontroller, MPU6050, and Flex Sensors. The primary objective of the project is to develop a user-friendly and intuitive way of controlling a robotic arm. The system is designed in such a way that the user wears a hand glove that is fitted with an MPU6050 accelerometer and two flex sensors. The position of the hand glove determines the position of the robotic arm. The Microcontroller is used to process the sensor data and control the robotic arm.

The robotic arm in this project consists of five motors, three of which are controlled by the MPU6050 accelerometer and two of which are controlled by the flex sensors. The flex sensors are used to control the motion of the robotic arm, while the MPU6050 accelerometer is used to control the movement of the robotic hand. The MPU6050 accelerometer and flex sensors are mounted onto a hand glove, which is worn by the user. The user moves their hand to control the position of the robotic arm.

The Microcontroller used in this project is the STM32 Nucleo F401RE, which is powered by a regulated 5V supply. The motors in the robotic arm are powered by a 12V supply, which is stepped down to 5V using an LM2596 voltage regulator. The communication between the MPU6050 accelerometer and the Microcontroller is done using the I2C protocol, while the communication between the flex sensors and the Microcontroller is done using the ADC module. Overall, this project combines various technologies such as sensors, microcontrollers, and motors to create a functional and intuitive hand gesture-controlled robotic arm.

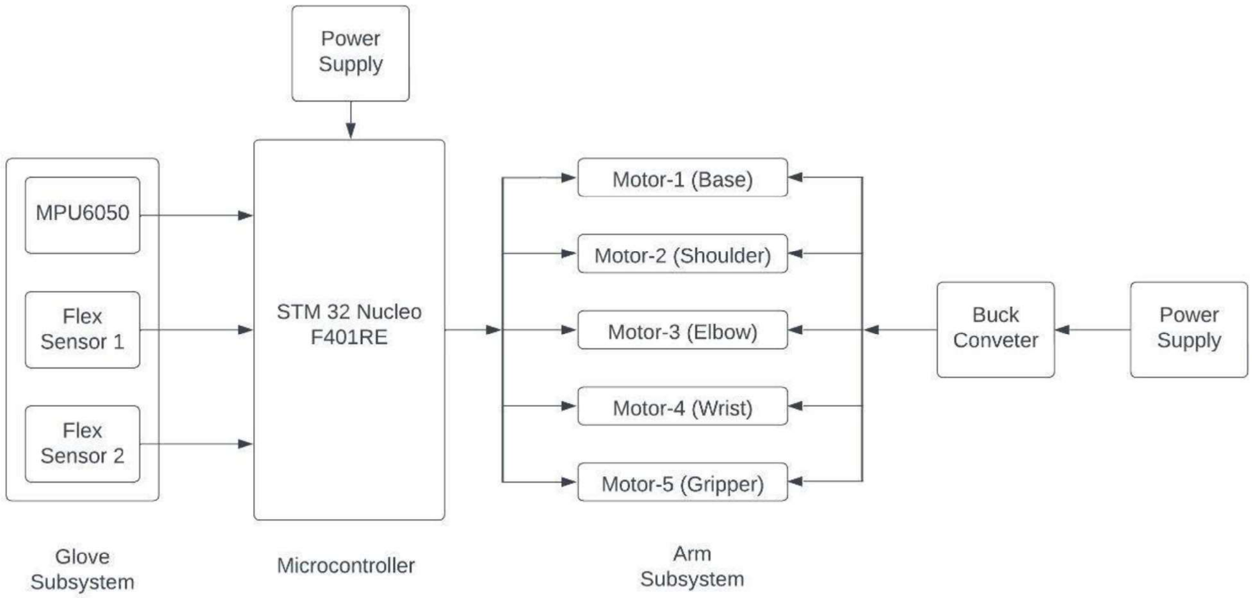

Figure 2.1: Block diagram of the system

2.2 Block Diagram

This project involves the creation of a robotic arm controlled by a glove equipped with flex sensors and an MPU-6050 sensor. The glove subsystem as seen in Fig 2.1 consists of two flex sensors and an MPU-6050 sensor that detects the orientation and acceleration of the hand. The movement of the hand is translated into control signals that are sent to the robotic arm. The robotic arm consists of five motors, of which two are controlled by the flex sensors and three by the MPU-6050 sensor.

The flex sensors are used to control the motors responsible for opening and closing the gripper of the robotic arm. The flex sensors change their resistance in response to the bending of the fingers, which is detected by the microcontroller (STM Nucleo F401RE). The microcontroller then generates the appropriate control signals to control the motors. The motors used for this purpose are SG90 and MG966R.

The MPU-6050 sensor is used to control the movement of the rest of the robotic arm. The sensor detects the orientation and acceleration of the hand and sends this information to the microcontroller. The microcontroller then generates the control signals for the three motors responsible for controlling the motion of the robotic arm. The motors used for this purpose are MG966R.

The microcontroller used in this project is STM Nucleo F401RE. It is a powerful microcontroller that is capable of handling multiple sensors and motors simultaneously. It is powered by 6V, while the motors require 12V to operate. An LM2596 voltage regulator is used to step down the voltage from 12V to 5V to power the motors.

In summary, this project involves the creation of a robotic arm controlled by a glove equipped with flex sensors and an MPU-6050 sensor. The flex sensors are used to control the gripper of the robotic arm, while the MPU-6050 sensor is used to control the movement of the rest of the robotic arm. The microcontroller used in this project is STM Nucleo F401RE, and the motors used are SG90 and MG966R.

2.3 Glove Subsystem

The glove subsystem plays a crucial role in this project as it is responsible for capturing the motion of the user's hand using the flex sensors and mpu6050 sensor. The flex sensors are positioned on the user's fingers to detect the amount of bending and hence, the motion of the fingers. The mpu6050 sensor, on the other hand, is placed on the back of the hand to detect the orientation and motion of the hand in 3D space. These sensors send analog signals to the microcontroller, which processes the signals and translates them into digital signals to control the motors of the robotic arm.

2.3.1 MPU6050

The mpu6050 sensor is a highly precise sensor that combines a 3-axis gyroscope and a 3-axis accelerometer in a single chip. It provides accurate and stable measurements of the orientation and motion of the hand in real-time. The sensor uses an I2C interface to communicate with the microcontroller, making it easy to integrate into the system. The mpu6050 sensor's ability to detect the orientation and motion of the hand is critical in ensuring that the movements of the robotic arm are smooth and precise. This sensor is an excellent choice for this project as it provides reliable and accurate measurements of the hand's position and orientation.

2.3.2Flexsensor

The flex sensors, on the other hand, play a crucial role in detecting the finger movements of the user. These sensors are bendable and change resistance when they are bent. The microcontroller reads the resistance changes to determine the degree of finger bending, which is then used to control the motors of the robotic arm. The flex sensors are lightweight, inexpensive, and highly reliable, making them an ideal choice for this project. Additionally, the sensors are highly flexible, which allows them to be easily integrated into the glove subsystem. Overall, the flex sensors' ability to detect finger movements in real-time is critical in ensuring that the robotic arm mimics the hand's movements accurately.

2.4 Robotic arm subsystem

The 5 DOF (Degree of Freedom) Robotic Arm is the main subsystem of this project. It consists of five different parts: base, shoulder, wrist, elbow, and gripper as shown in Fig 2.2, each of which is controlled by a specific servo motor. The base is fixed to the surface on which the arm is placed and the shouldermotor controls the motion of the arm in the horizontal direction. The elbow motor controls the vertical movement of the arm, while the wrist motor controls the rotational movement of the arm.The gripper motor is used to open and close the gripper of the robotic arm. All these motors areconnected to the microcontroller for control.

The three MG966R servo motors are used for the base, shoulder, and elbow, while the two SG90 servo motors are used for the wrist and gripper. These servo motors are suitable for this project as they are small, lightweight, easy to use, and have high torque and precision. Additionally, they are widely used in robotics projects due to their reliability and affordability. The control signals for these motors are generated by the microcontroller and sent to the servo motors, which then rotate to the desired position. Overall, the 5 DOF robotic arm subsystem plays a crucial role in the project, allowing for precise and accurate movements controlled by the flex sensors and MPU6050 accelerometer.

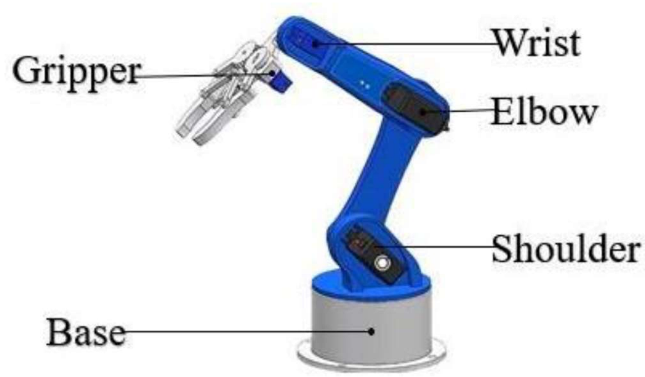

Figure 2.2: Parts of a robotic arm offering 5 DOF

2.5 Hardware selection

3D-Printed Pick and Place Robotic Arm is an emerging sector in the field of both robotics and mechatronics. 3D printed parts have a lighter weight as compared to the current state of the art in industries and hence require less power to operate. The 5 DOF Robotic Arm is the most versatile selection for pick and place application due to its large operating area. Table 1 and Table 2 elaborate on the specification and parameters of the robot subsystem.

2.5.1 Specification of the robotic arm

Table 1 : Specifications of the robotic arm

Specification	Value
Number of Axes	5
Degrees of Freedom	5
Horizontal Reach	150mm
Vertical reach	240mm
Drives	5 servo motors
Configuration	Jointed Arm (Articulated)
Work Envelope Base	Base Rotation: 360 Shoulder Rotation: 180° Elbow Rotation: 180° Wrist Rotation: 180° Gripper Rotation: 60°

2.5.2 D-H parameters

Table 2: D-H Parameters of the robotic arm

Joint i	Name	αi (deg)	ai(mm)	di(mm)	θi(mm)
1	Base	0	0	86	θ1
2	Shoulder	90	0	0	θ2
3	Elbow	0	96	0	θ3
4	Wrist	0	96	0	θ4
5	Gripper	90	0	60	θ5

2.5.3 Circuit components

STM32 Nucleo F401RE

Powerful Cortex-M4 microcontroller with 84 MHz clock speed and 512 KB of flash memory, providing ample processing power and storage space for this project. Integrated ST-LINK/V2-1 debugger and programmer for easy development and debugging. Arduino compatible headers for easy expansion and compatibility with a wide range of sensors and actuators.

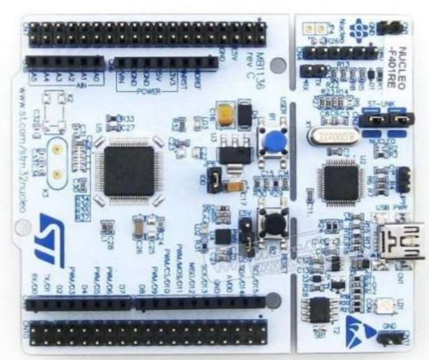

Figure 2.3 : STM 32 Nucleo F401RE microcontroller

SG90 servo motor

TowerPro SG90 is a tiny lightweight servo motor with high power output. It is used in low-torque joints such as the wrist, gripper, etc.

Figure 2.4 : SG90 servo motor

MG996R Hi Torque Servo Motor:

TowerPro MG996R Digital High Torque Servo Motor is used for joints that are under heavy loads such as the shoulder, elbow, and base.

Figure 2.5 : MG996R Servo Motor

Flex sensor

A flex sensor (Fig 2.6) is a type of sensor that changes resistance when it is bent or flexed. It can detect thedegree of bending or flexing, making it useful in measuring motion and position. The resistance of a flex sensor typically ranges from around 10k ohms to 50k ohms and is being used to control the motion of two of the five motors in the robotic arm.

Figure 2.6 : Flex sensor

MPU6050 accelerometer and gyroscope:

High accuracy and precision, with 16-bit ADCs and 3-axis sensing for accurate and precise measurements of motion and orientation. Low power consumption and small form factor, making it suitable for use in battery-powered and space-constrained applications. It is being used to control the motion of three of the five motors in the robotic arm.

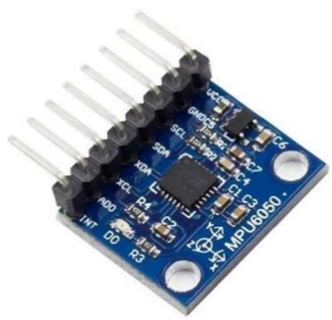

Figure 2.7: MPU6050 module

LM2596 voltage regulator:

Wide input voltage range (4-40V) and high efficiency (up to 92%), making it ideal for regulating the voltage from a variety of power sources. Adjustable output voltage and current, making it versatile and adaptable to different requirements and loads. It steps down 12v supply to 5v and provides it to the motors.

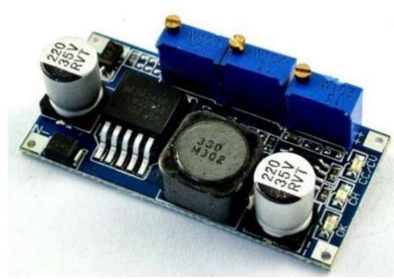

Figure 2.8 : LM2596 voltage regulator

Chapter 3: Implementation

3.1 Interfacing MPU6050 with STM32 Nucleo F401RE:

Robotic arms have been extensively used in various fields such as manufacturing, healthcare, and the military to perform tasks requiring high precision and accuracy. Controlling a robotic arm through hand motion has gained popularity in recent years. This article delves into the implementation of I2C communication between the MPU-6050 sensor and the STM Nucleo F401RE microcontroller to achieve hand motion control for a robotic arm.

I2C Protocol

The I2C protocol is a two-wire communication protocol that facilitates multiple devices to communicate using a single pair of wires. In the project at hand, the STM Nucleo F401RE microcontroller serves as the master device, while the MPU-6050 sensor acts as the slave device. The I2C protocol allows the microcontroller to obtain data from the MPU-6050, such as the angular velocity and acceleration values, which are then used to control the motors of the robotic arm. The protocol also enables the microcontroller to calibrate and configure the MPU-6050, ensuring precise and reliable data is received.

Hardware Setup

The hardware setup comprises of an MPU-6050 sensor and an STM Nucleo F401RE microcontroller. The I2C pins connect the MPU-6050 sensor to the microcontroller as seen in Fig. 3.1. The I2C module on the microcontroller is configured through the STM32CubeIDE. The clock speed, data,and clock pins are configured, and the I2C module is enabled.

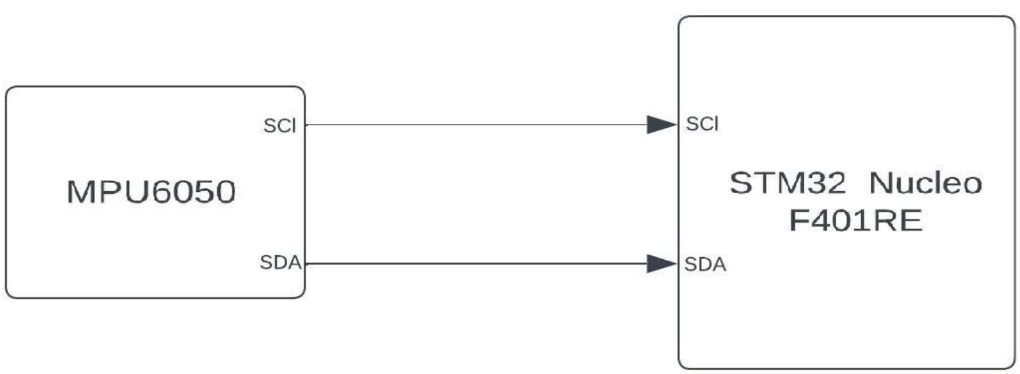

Figure 3.1 : MPU6050 Interface with microcontroller

Sensor Initialization

To initialize the MPU-6050 sensor, the microcontroller writes to its registers using the I2C protocol. The sample rate, filter settings, and sensitivity of the accelerometer and gyroscope are set as per the datasheet. The MPU-6050 sensor provides accurate data on the orientation of the hand, which is critical for controlling the robotic arm.

Data Reading and Processing

The I2C read function is utilized to read the accelerometer and gyroscope data separately from the MPU-6050 registers. The data is then combined to obtain the orientation of the hand. The orientation data is sent to the control algorithm, which generates control signals for the robotic arm. The PID control algorithm is used to convert the orientation data from the MPU-6050 into control signals for the robotic arm. The control signals are implemented on the robotic arm using servo motors. The servo motors allow for precise control of the robotic arm's movements. Fig 3.2 show cases the sample outputs obtained during the experimental analysis.

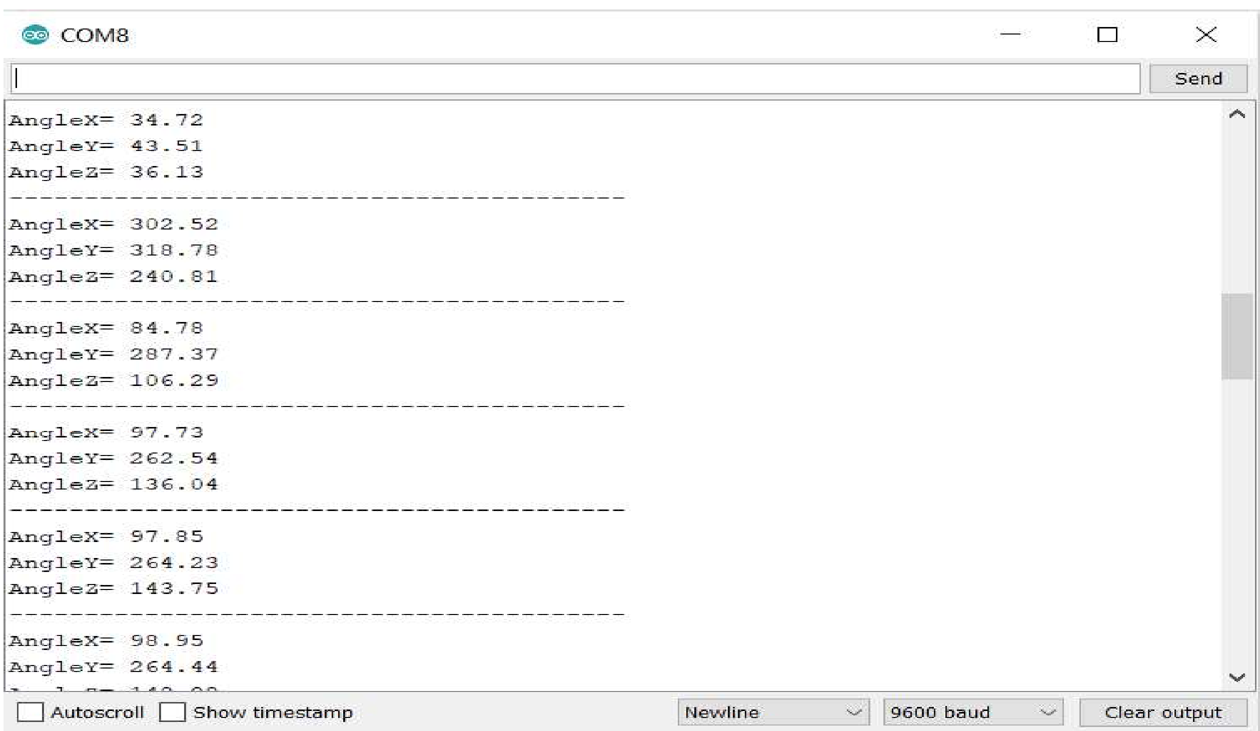

Figure 3.2 : MPU6050 Data Readings

Output

The implementation of I2C communication between the MPU-6050 and the STM Nucleo F401RE microcontroller was successful. The robotic arm moved in the desired direction based on the motion of the hand. The PID control algorithm accurately controlled the position and orientation of the robotic arm. The system demonstrates that I2C communication can be used to control the motion of a robotic arm using hand motion.

3.2 Flex Sensor Interface with STM32 Nucleo F401RE

Analog to Digital Conversion (ADC) is a common technique used in electronic systems to convert analog signals into digital signals that can be processed by a digital system such as a microcontroller. In this project, we explored how the flex sensors are connected to the STM32 Nucleo F401RE board and how the ADC module is used to convert the analog signals from the flex sensors into digital values that can be processed by the microcontroller. The digital values are then used to control the motors connected to the microcontroller.

Flex Sensors

Flex sensors are analog sensors that output a voltage proportional to the degree of bend. They are commonly used in applications where it is necessary to measure the degree of bend in a particular object or component. In our project, we will be using flex sensors to measure the degree of bend in a human hand. The flex sensors are connected to the STM32 Nucleo F401RE board through analog input pins. The analog voltage output by the flex sensors is then read by the microcontroller.

ADC Module

The STM32 Nucleo F401RE board has a built-in ADC module that converts the analog voltage output by the flex sensors into a digital value. The ADC module is a peripheral device that interfaces between the analog world and the digital world. It consists of a sample and hold circuit, a voltage comparator, and a successive approximation register. The ADC module is capable of sampling the analog input signal at a high rate and converting it to a digital value with a high degree of accuracy.

Working

The ADC module is configured to read the analog voltage output by the flex sensors connected to the analog input pins. The analog voltage is sampled and held by the sample and hold circuit of the ADC module. The voltage comparator then compares the held voltage with a reference voltage and generates a digital value based on the comparison. The successive approximation register then processes the digital value and stores it in a register within the microcontroller.

The microcontroller then processes the digital value and uses it to control the motors connected to it. The digital value corresponds to the degree of bend in the flex sensors. By mapping the digital value to a particular motor speed and direction, the microcontroller can control the motors in a precise and accurate manner.

In addition to using the ADC module to interface with the flex sensors, we also implemented a voltage divider circuit to ensure the voltage output from the flex sensors was within the range that the ADC module can read.

A voltage divider circuit is a simple circuit that allows us to lower the voltage level of a signal to a level that can be read by the ADC module. The circuit consists of two resistors connected in series between the power supply and ground as seen in Fig 3.3, with the signal being read from the point where the two resistors are connected.

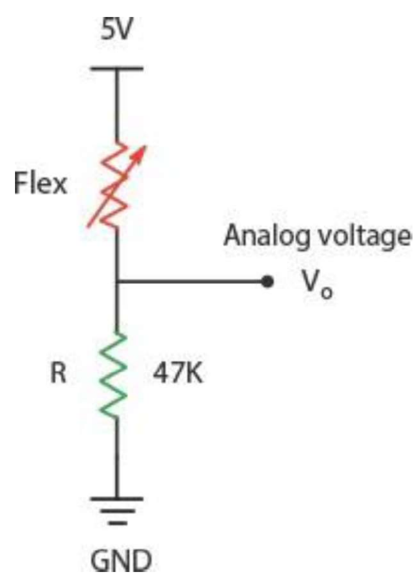

Figure 3.3: Voltage divider circuit

For our project, we used a 10k ohm resistor and a flex sensor as the two resistors in the voltage divider circuit. The flex sensor output voltage ranges from 0 to 5V, which is too high for the ADC module to read. The 10k ohm resistor acted as a fixed reference voltage, while the flex sensor acted as a variable resistor. The voltage at the point where the two resistors are connected is equal to the output voltage of the flex sensor divided by the sum of the two resistors.

We can use this equation to calculate output voltage (Vo):

$$V_0 = V_{CC}\frac{R}{R + R_{Flex}}$$

With different value of R_{flex}, we get the following degrees of bending:

Table 3: Flex sensor resistance values for degree of bend

ADC FLEX	RESISTANCE	BEND
340 (3.6v)	19K	2°
320 (3.8v)	23K	10°
290 (3.9v)	28K	30°
235 (4.2)	33K	73°
213 (4.5)	38K	89°

By using a voltage divider circuit, we were able to lower the voltage output of the flex sensors to a level that the ADC module could read, thus allowing us to accurately measure the degree of bend in the flex sensors and control the motors accordingly.

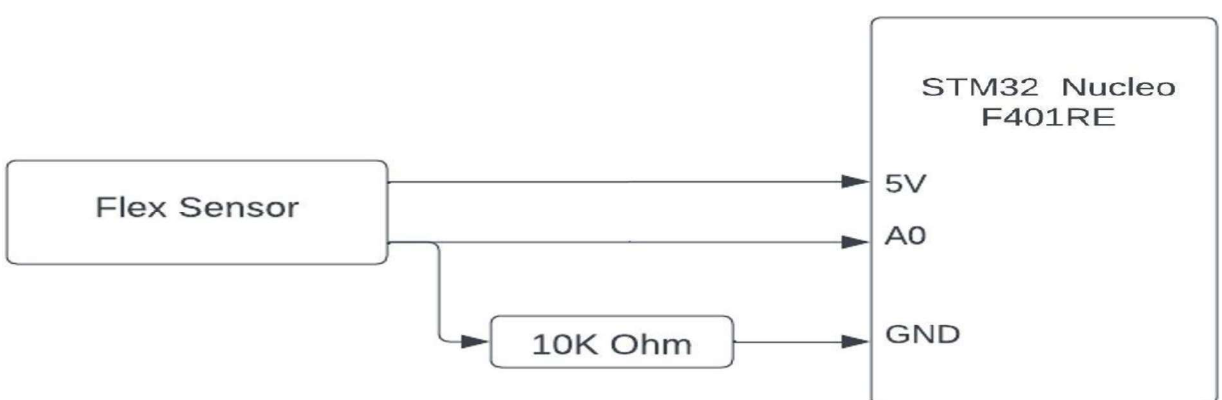

Figure 3.4 : Flex Sensor Interface

```
COM19

-------------------------------------------------------------------------
angleflex1: 160
angleflex2: 183
-------------------------------------------------------------------------
angleflex1: 229
angleflex2: 199
-------------------------------------------------------------------------
angleflex1: 229
angleflex2: 171
-------------------------------------------------------------------------
angleflex1: 217
angleflex2: 272
-------------------------------------------------------------------------
angleflex1: 243
angleflex2: 186
-------------------------------------------------------------------------
angleflex1: 235
angleflex2: 245
-------------------------------------------------------------------------
angleflex1: 178
angleflex2: 241
-------------------------------------------------------------------------
angleflex1: 244
angleflex2: 157
-------------------------------------------------------------------------
angleflex1: 151
angleflex2: 203
-------------------------------------------------------------------------
angleflex1: 158
angleflex2: 244
-------------------------------------------------------------------------
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Figure 3.5 : Flex Sensors raw output values

Output

The use of ADC in the communication between the flex sensors and the microcontroller enables the microcontroller to accurately measure the degree of bend in the flex sensors and control the motors accordingly. The ADC module is a powerful tool that allows analog signals to be converted into digital values that can be processed by digital systems such as microcontrollers. The use of ADC in our project provides a simple and efficient way to control the motors connected to the microcontroller using the flex sensors.

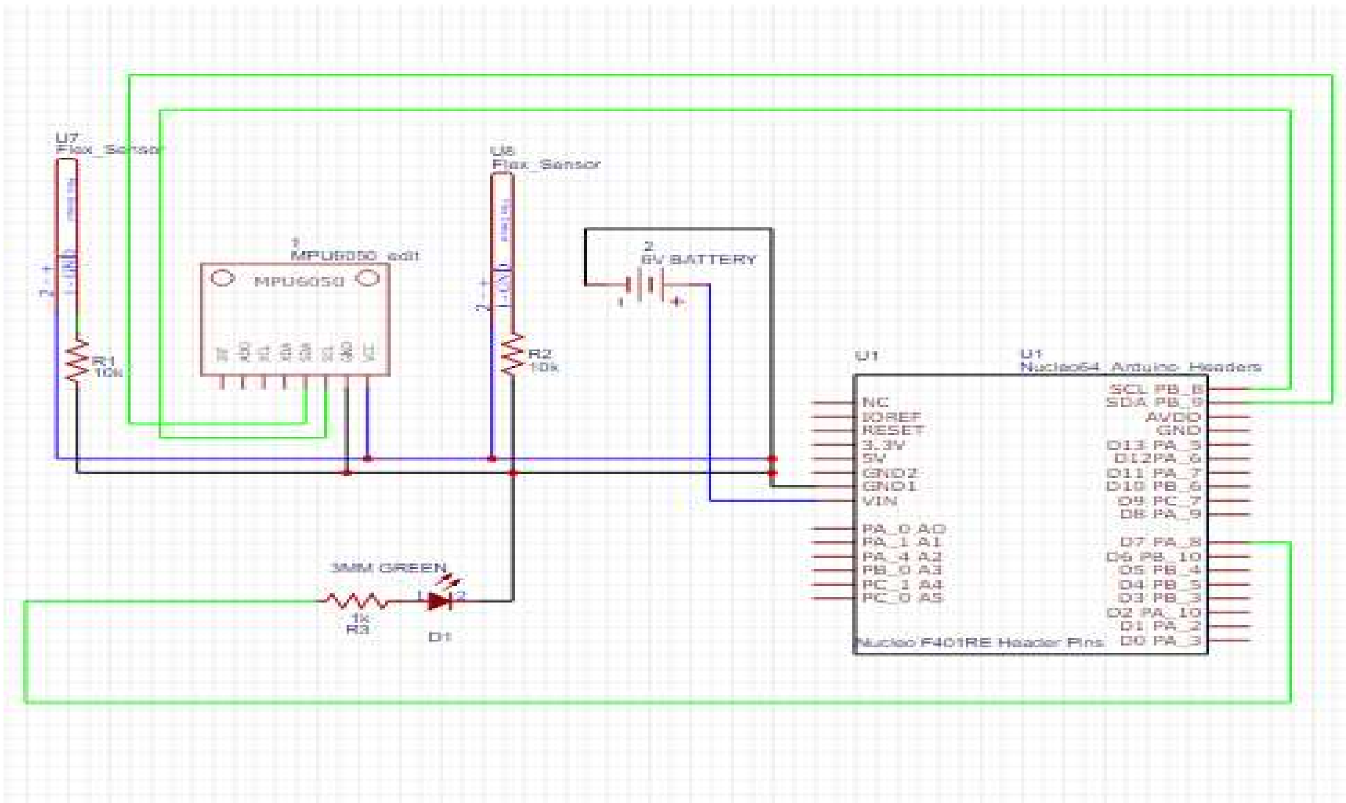

Figure 3.6 : Glove module circuit diagram

3.3 Connecting Servo Motors to STM32 Nucleo F401RE:

In this part, we will describe how we connected the servo motors (MG996R and SG90) to our microcontroller board (STM32 Nucleo F401RE) to cause actuation (motion)

Servos

Servos are commonly used in robotics and automation applications. They are electromechanical devices that are capable of rotating to a specific angle. The rotation angle of the servo can be controlled by sending a PWM (Pulse Width Modulation) signal to it. The PWM signal determines the position of the servo. In our project, we will be using three MG 996R and two SG90 servos to control the robotic arm.

Connecting Servos to STM32 Nucleo F401RE

The servos are connected to the STM32 Nucleo F401RE board using PWM output pins. The PWM output pins generate the PWM signal that controls the position of the servos. The MG 996R servos require a higher voltage and current than the SG90 servos. Therefore, they are connected to an external power source, while the SG90 servos are powered directly by the STM32 Nucleo F401RE board.

One of the challenges we faced during the project was the power supply to the servos. The servos require a high current and voltage to operate, which is beyond the capability of the microcontroller's output pins. Therefore, we used a buck converter to control the power supply given to the motors. A buck converter is a type of DC-to-DC converter that steps down the voltage while increasing the current. By using a buck converter, we were able to provide a stable and reliable power supply to the servos.

The MG996R servos were used for the base, shoulder and elbow while the SG90 servos were used for the gripper and wrist. The MG996R servos have a higher torque and can rotate up to 180 degrees, while the SG90 servos have a lower torque and can rotate up to 90 degrees. The servos

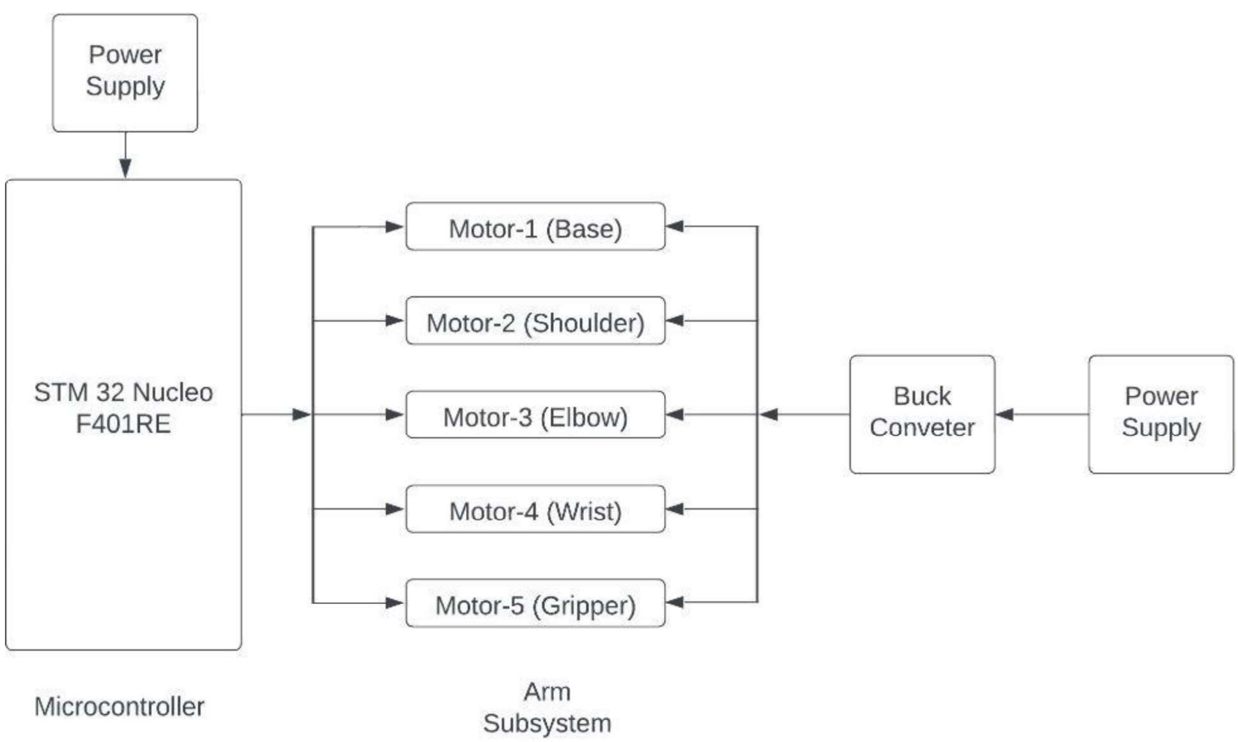

Figure 3.7 : Block diagram for robotic arm subsystem

were connected to the microcontroller board through PWM pins and were controlled using the servo library in the Arduino IDE.

Output

In this project, we have explored how to connect and control five servos - three MG 996R and two SG90 - using an STM32 Nucleo F401RE microcontroller. The servos are used to control a hand motion-controlled robotic arm. The robotic arm is controlled using a glove with flex sensors and MPU6050. The flex sensors and MPU6050 provide data that is used to control the servos, enabling the robotic arm to move in a precise and accurate manner. The project demonstrates the use of microcontrollers and sensors in creating complex and dynamic robotic systems.

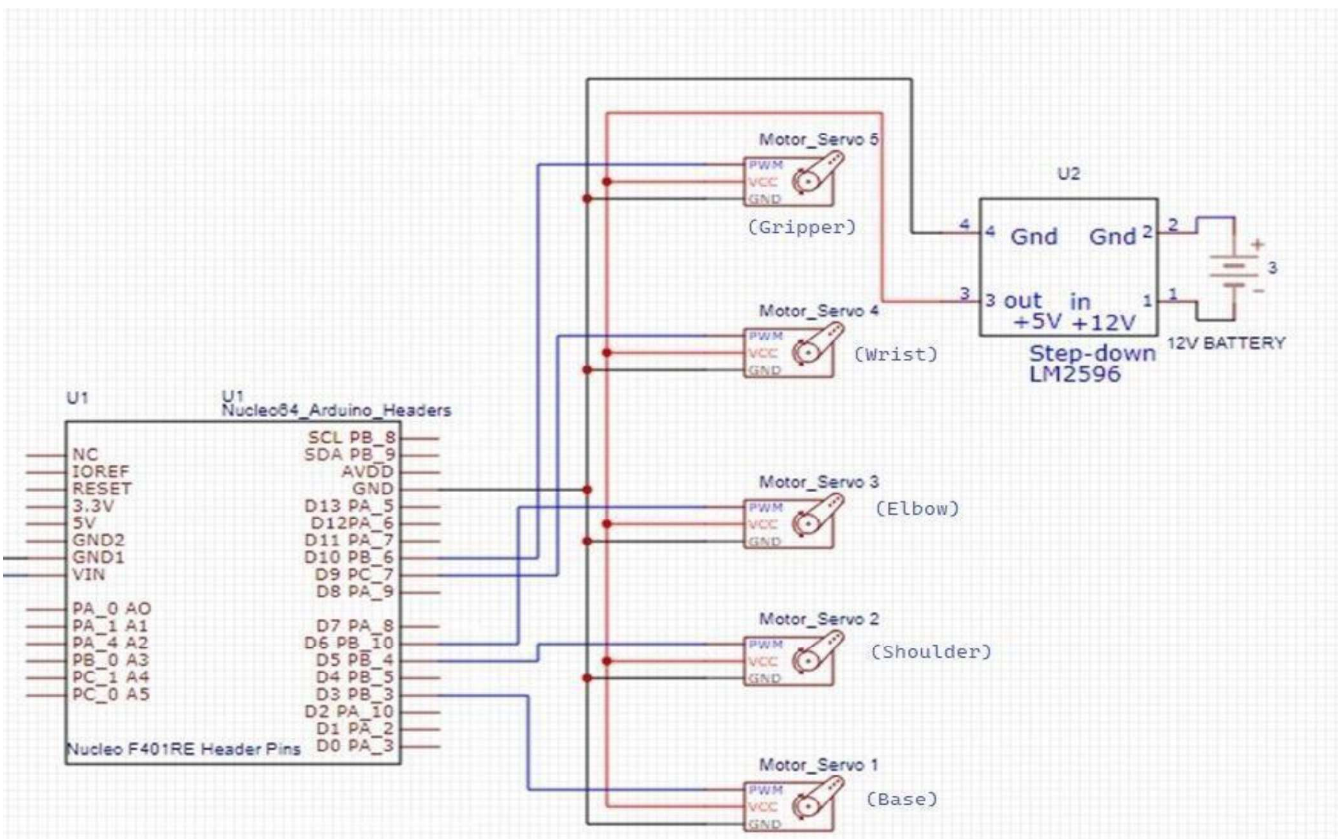

Figure 3.8 : Robotic Arm Circuit Diagram

Chapter 4: Result

Initialization

The table presented below details the initial positions allotted to each motor of the robotic arm subsystem. The movement of each motor with respect to the flex sensor and MPU6050 sensor is also indicated. These initial positions were pre-defined to ensure that every time the system is powered on, the robotic arm subsystem always begins from a fixed starting position relative to the initial position of the glove subsystem. This design feature enables more precise and accurate movements of the robotic arm during operation. The assigned positions were calibrated based on the angular displacement values of the flex sensor and the MPU6050 sensor in conjunction with the movement requirements of each motor. The resulting positions were fine-tuned to optimize the overall performance of the system.

Table 4: Initialization Angles

Servo Motor	**Initial Position**
Servo Motor -1 (Base)	$\theta = 160°$
Servo Motor -2 (Shoulder)	$\theta = 90°$
Servo Motor -3 (Elbow)	$\theta = 120°$
Servo Motor -4 (Wrist)	$\theta = 60°$
Servo Motor -5 (Gripper)	$\theta = 30°$

The figures captured during the testing of the Hand Gesture Controlled Robotic Arm project show the effectiveness of the glove subsystem in controlling the movements of the robotic arm. The data captured through various experiments indicate that the position of the robotic arm can be effectively controlled by the hand gestures made while wearing the glove subsystem. The movements of the robotic arm, including base rotation, shoulder rotation, elbow rotation, wrist rotation, and gripper movement, are synchronized with the gestures made by the user, enabling precise control of the robotic arm. These figures visually demonstrate the interdependence between the motion of the glove subsystem and the corresponding movement of the robotic arm.

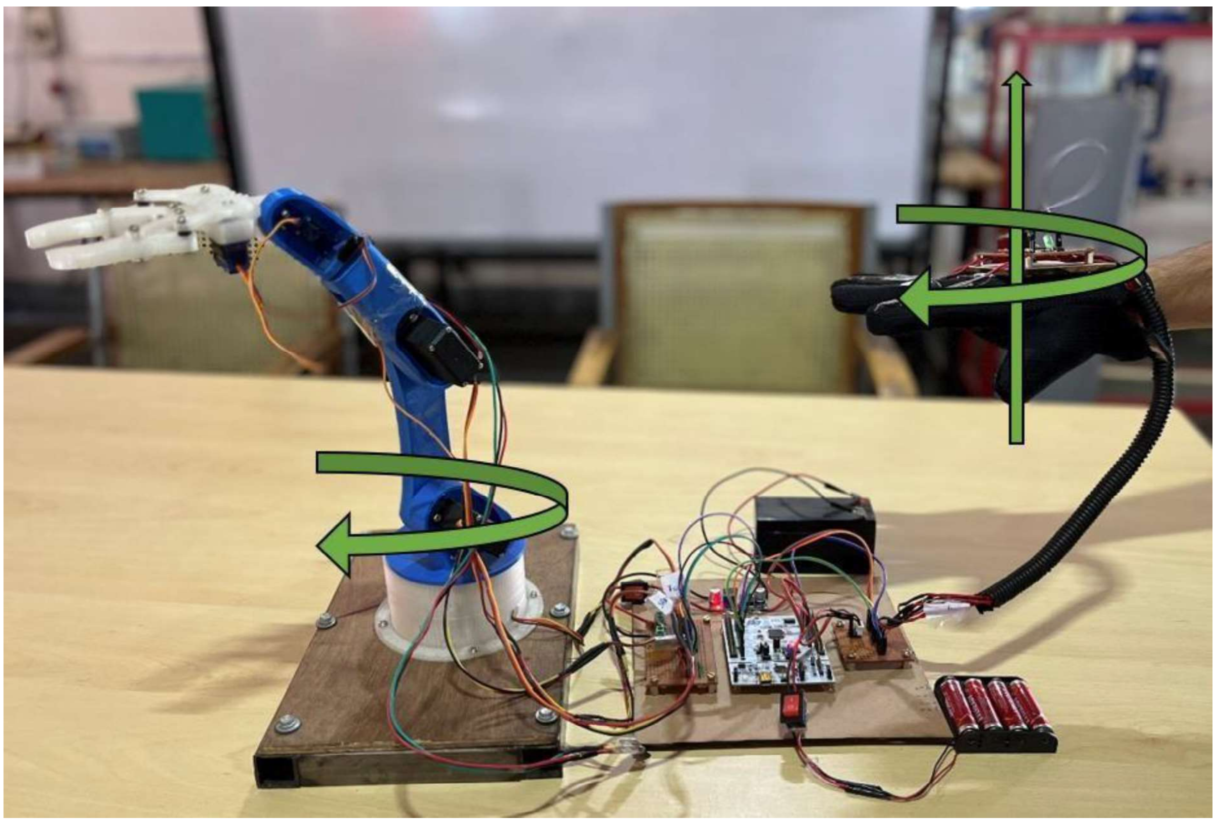

Figure 4.1: Motor 1 initial position

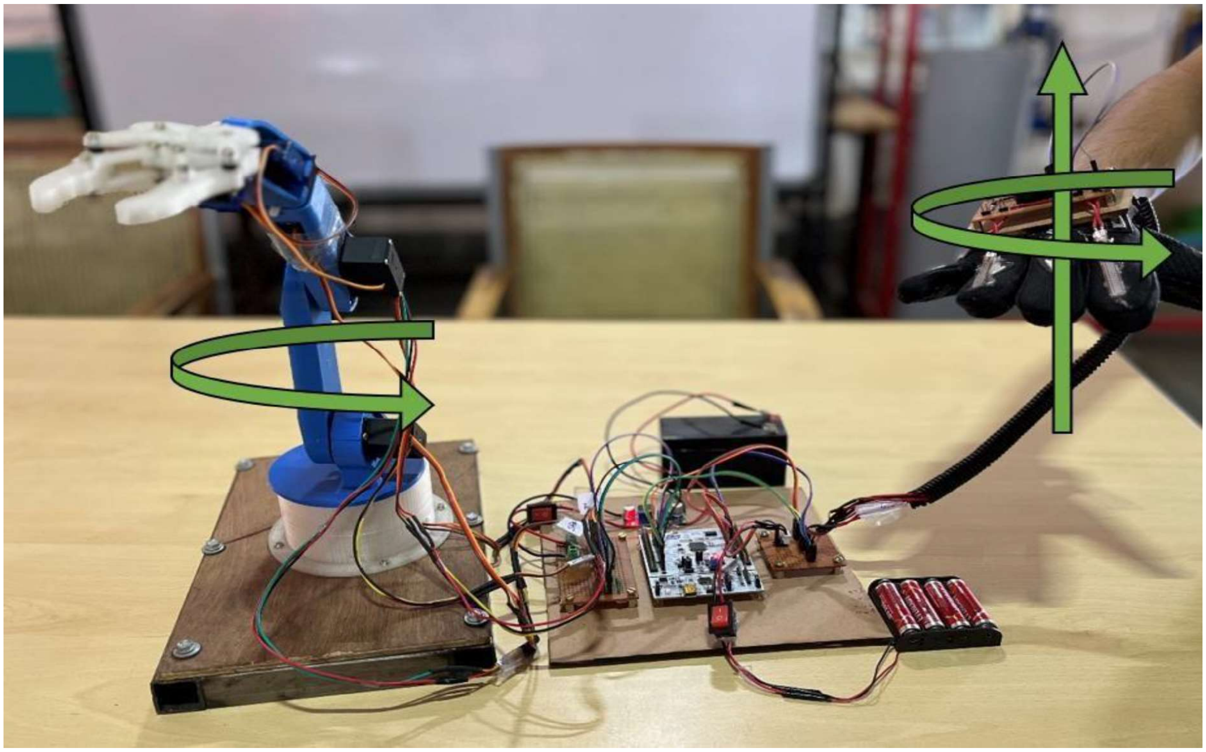

Figure 4.1: Motor 1 final position

Figures 4.1 and 4.2 exhibit the rotational movement of the robotic arm's base, with the directional arrows denoting the corresponding displacement of the MPU6050 sensor on the Z-plane. Figure 4.1 denotes the starting position of the arm with respect to Angle Z being 0 on the glove, at an angle (theta) of 0. On the other hand, Figure 4.2 displays the maximum rotation of the motor, at an angle of 160 degrees with respect to Angle Z being 60. A maximum rotation of 160 degrees was selected so that the wires would not get intertwined.

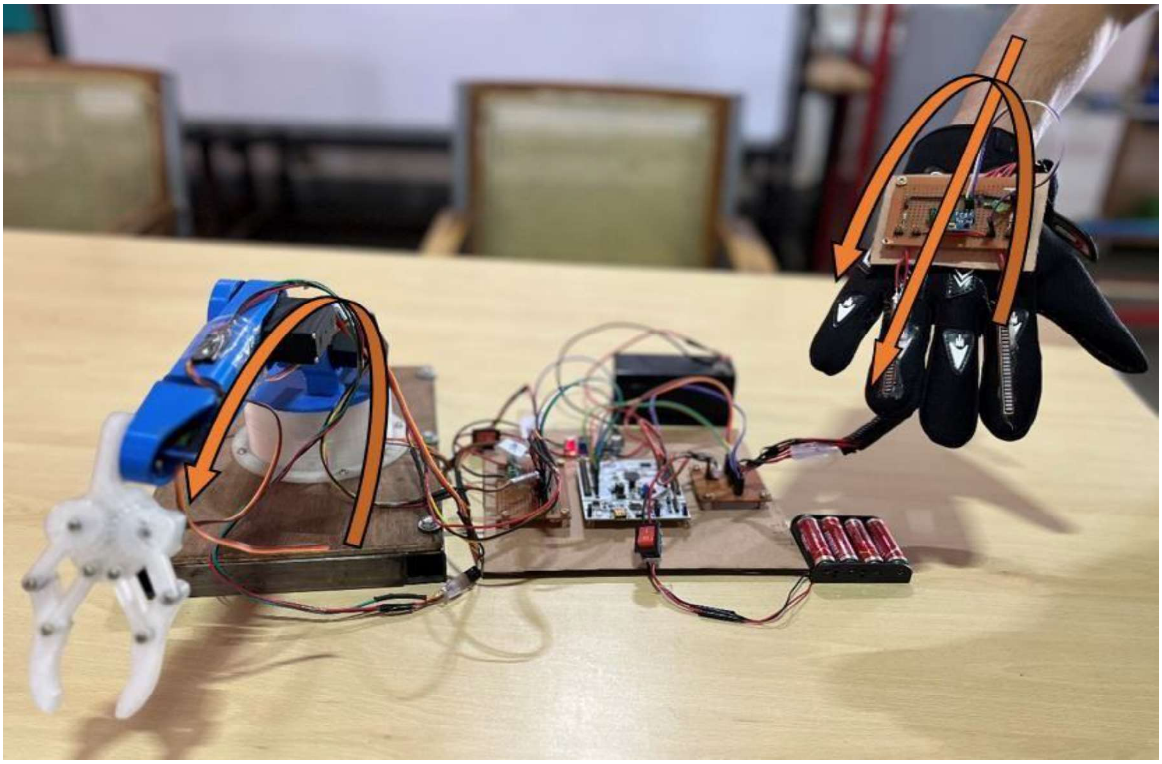

Figure 4.3 : Motor 2 final position

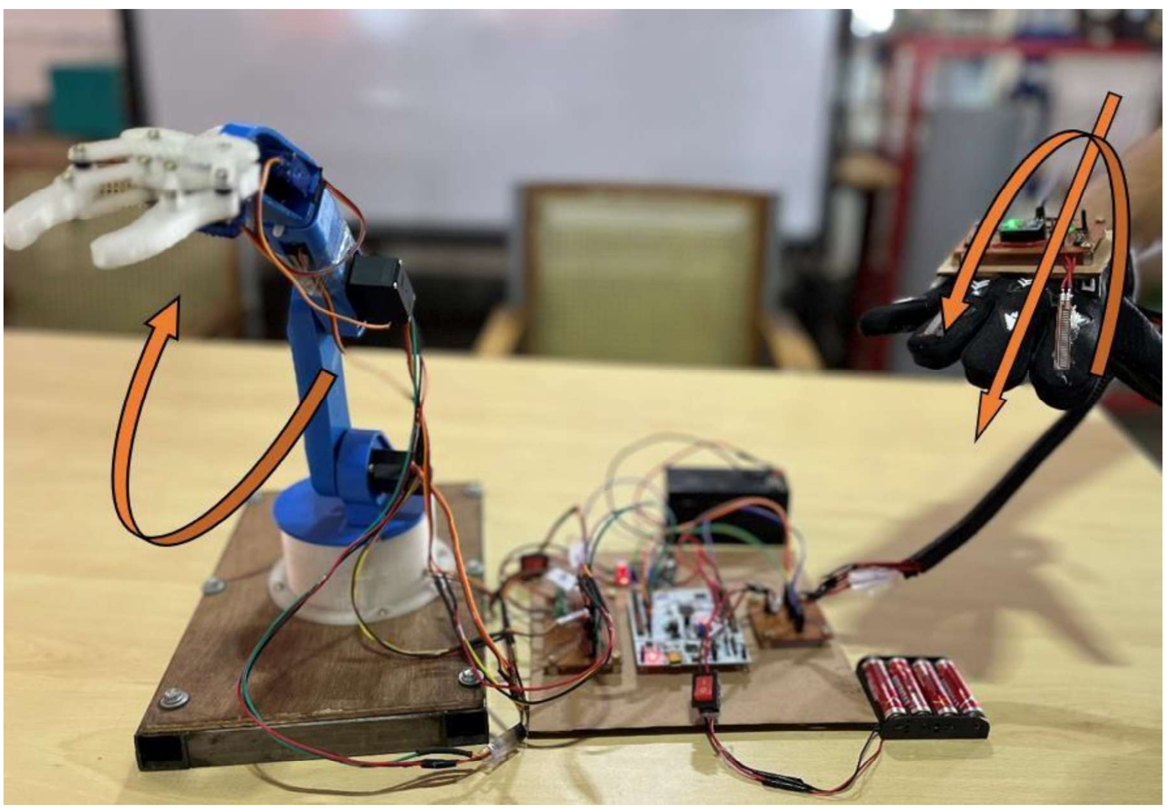

Figure 4.4 : Motor 2 final position

Figures 4.3 and 4.4 demonstrate the shoulder rotation of the robotic arm, where the directional arrows indicate the displacement of the MPU6050 sensor on the Y-plane. Figure 4.3 represents thestarting position of the shoulder at an angle (theta) of 0, with respect to Angle Y being 0. On the other hand, Figure 4.4 displays the maximum rotation of the motor at an angle of 90 degrees withrespect to Angle Y being 60. A maximum movement of 90 degrees was set, as upon greater degreeof movement collision between base and shoulder was observed.

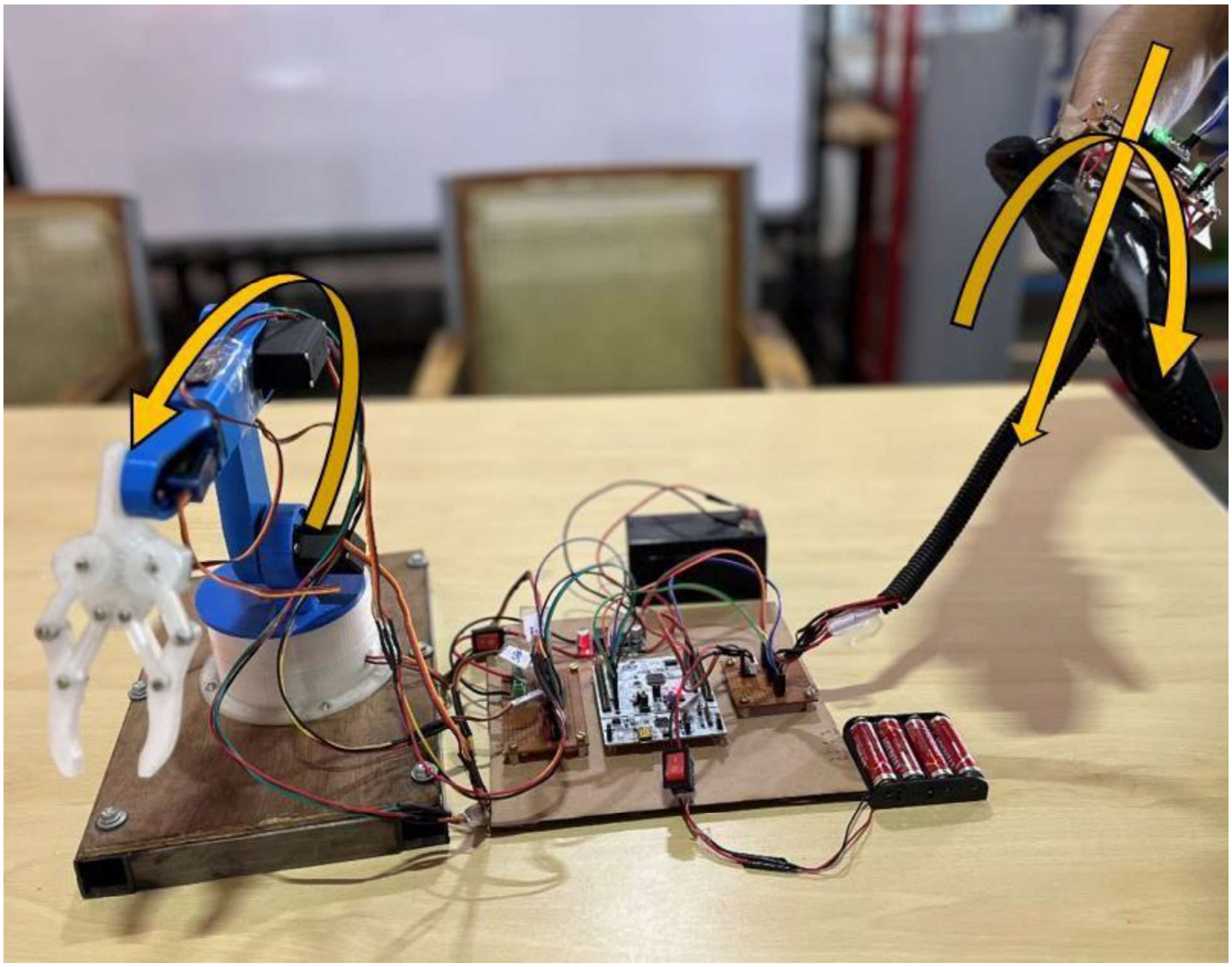

Figure 4.5 : Motor 3 initial position

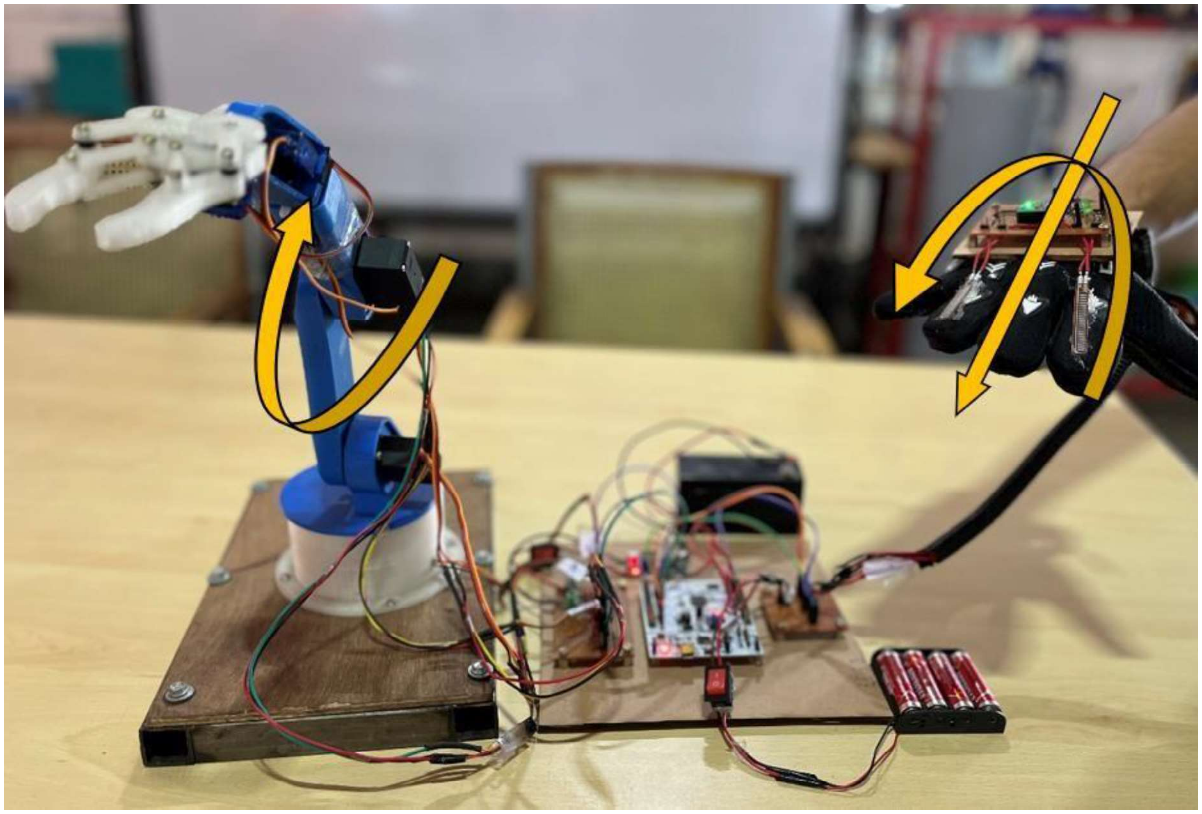

Figure 4.6 : Motor 3 final position

The movements of the elbow rotation of the robotic arm are showcased in Figures 4.5 and 4.6, where the directional arrows represent the displacement of the MPU6050 sensor on the X-plane. Figure 4.5 illustrates the starting position of the shoulder at an angle (theta) of 90, with respect toAngle X being -60. In contrast, Figure 4.6 exhibits the maximum rotation of the motor at an angleof 180 degrees with respect to Angle Y being 0.

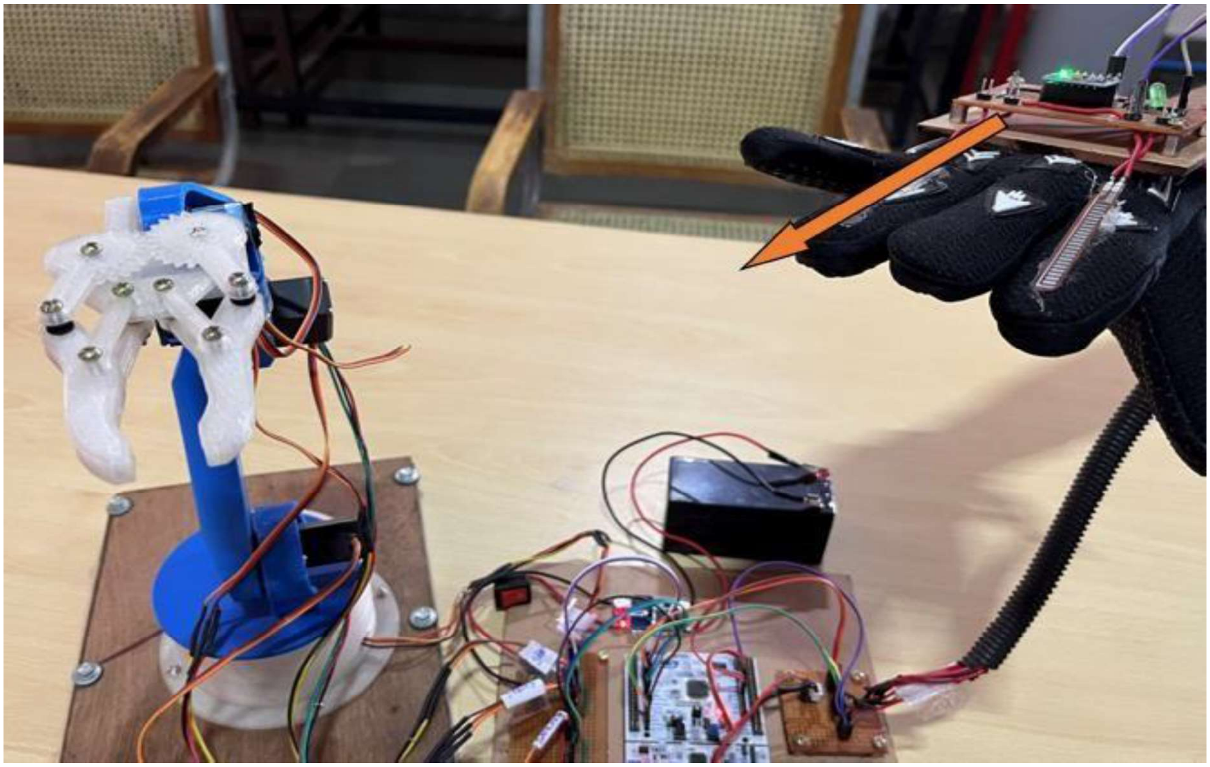

Figure 4.7 : Motor 4 initial position

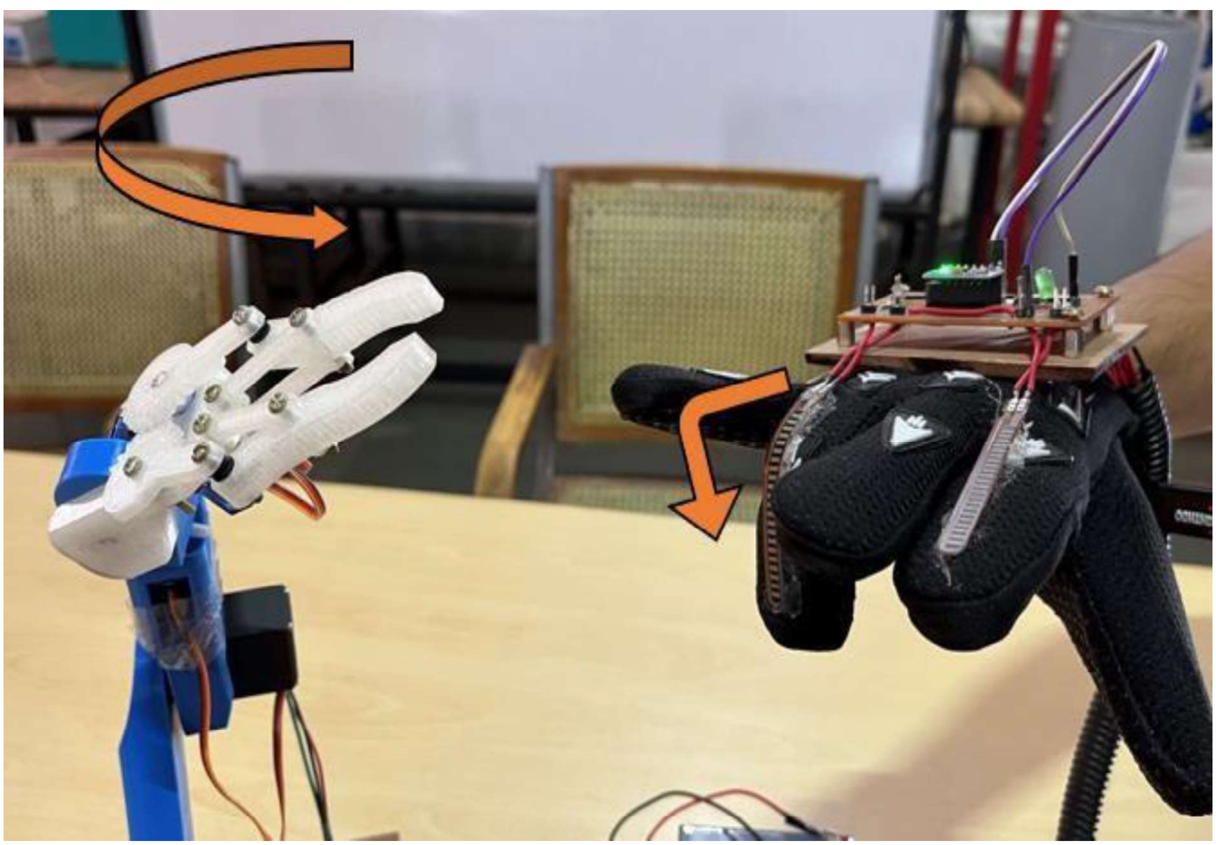

Figure 4.8 : Motor 4 final position

Figures 4.7 and 4.8 depict the movements of the wrist rotation of the robotic arm, with the directional arrows representing the displacement of the flex sensor. Figure 4.7 displays the initial position of the wrist, set at an angle (theta) of 60 degrees, with respect to Angle of bend being 0. Conversely, Figure 4.8 exhibits the maximum rotation of the motor, set at an angle of 180 degrees at maximum angle of bend. It is worth noting that due to the difficulty in maintaining a fixed position of the flex sensor, the motor can only be displaced at these two positions. Any deviation from these positions could lead to jittering of the motor.

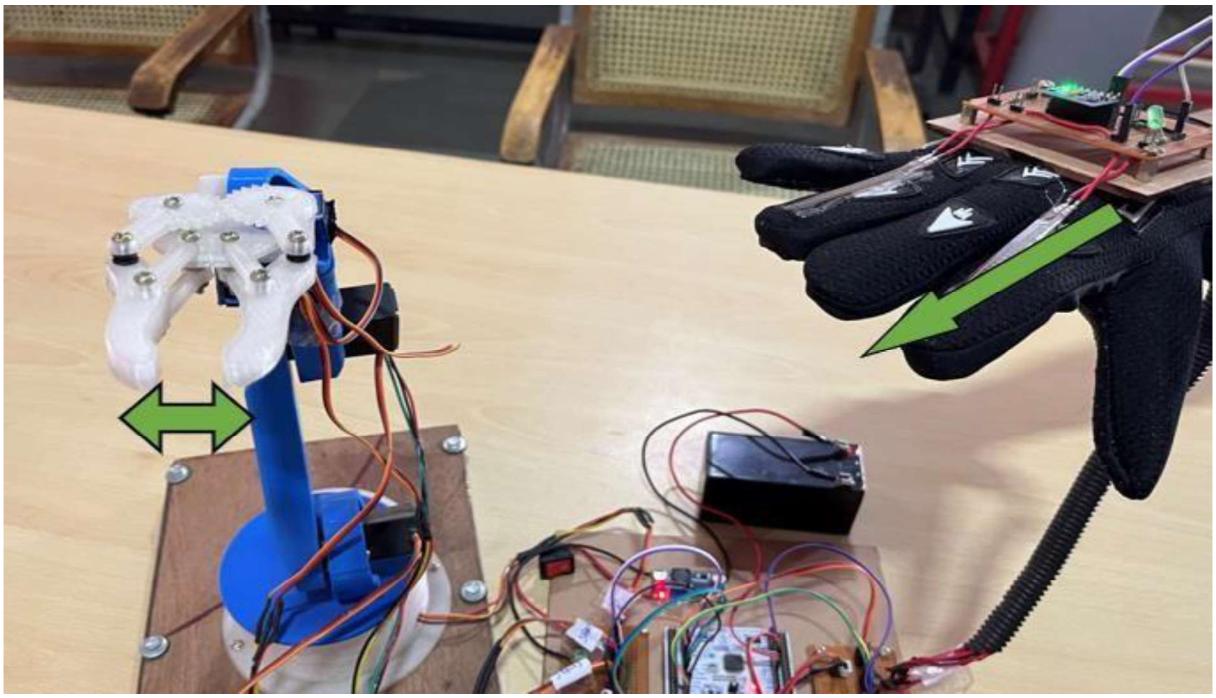

Figure 4.9 : Motor 5 initial position

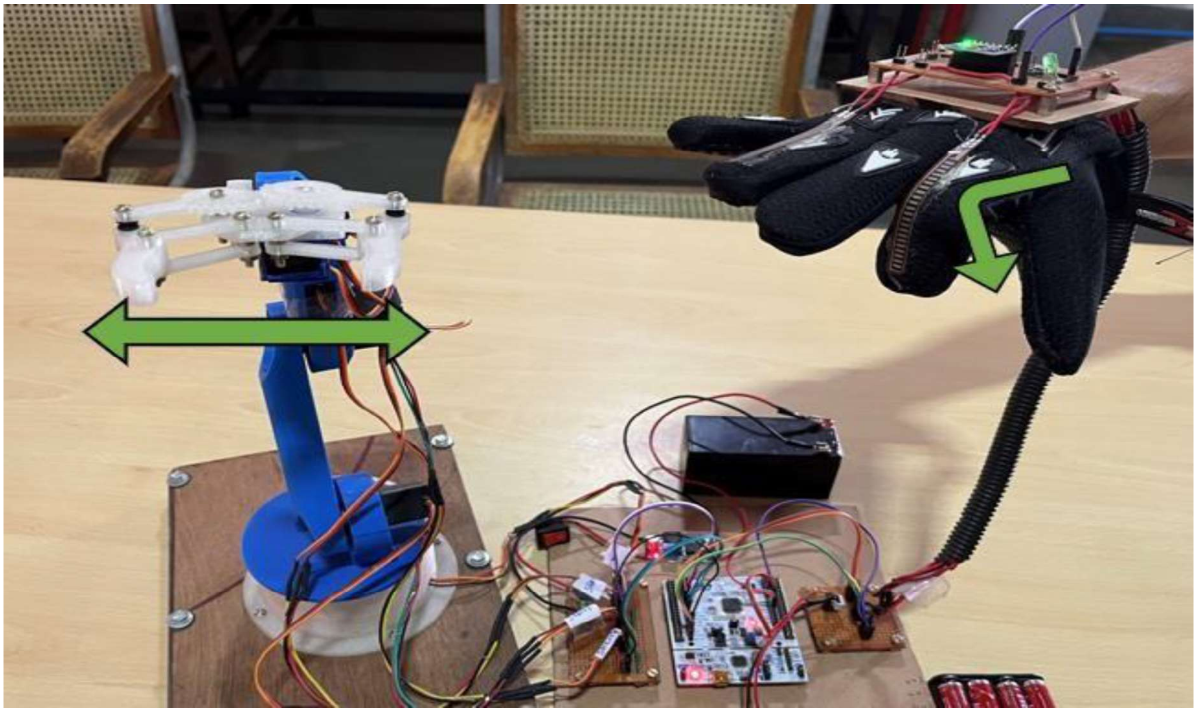

Figure 4.10 : Motor 5 final position

Figures 4.9 and 4.10 illustrate the gripper rotation movements of the robotic arm, where the flex sensor displacement is represented by directional arrows. In Figure 4.9, the gripper is positioned at an initial angle (theta) of 30 degrees, with Angle of bend being 0. In contrast, Figure 4.10 displays the maximum motor rotation at an angle of 180 degrees, corresponding to the maximum angle of bend. It is worth noting that the gripper's initial position is set at 30 degrees to prevent constant locking of the servo motor, which would occur if the initial angle was set to zero.

The applications of this project are diverse and span across multiple industries. One of the most significant applications is in the field of healthcare, where this technology can be used to help patients with disabilities or limited mobility. Patients can perform tasks that were previously impossible or extremely difficult for them. By implementing this technology, manufacturers can increase productivity and efficiency while also ensuring the safety of their workers. Furthermore, this project has potential applications in the field of education, where it can be used as a tool for teaching robotics and programming. Overall, the potential applications of this project are vast and can revolutionize various industries.

Conclusion

In conclusion, we have successfully implemented a hand motion controlled robotic arm using an STM32 Nucleo F401RE microcontroller, 3 MG996R and 2 SG90 servos, a MPU6050 accelerometer and gyroscope, and flex sensors.

We used the I2C protocol to communicate with the MPU6050, allowing us to receive data on angular velocity and acceleration which were then used to control the servos. We also used ADC to interface with the flex sensors, allowing us to accurately measure the degree of bend in the sensors and control the servos accordingly.

To power the servos, we used a buck converter to provide a stable voltage output. The buck converter allowed us to regulate the voltage level supplied to the servos, ensuring that they operate within their rated voltage range.

Overall, the implementation of the hand motion controlled robotic arm was successful, with the system accurately responding to the movements of the user's hand. The use of the flex sensors allowed for intuitive control of the robotic arm, while the MPU6050 provided additional data to improve the accuracy of the arm's movement.

Possible future improvements could include implementing PID control for more precise control of the servos, adding additional sensors for improved accuracy and control, and exploring different control interfaces for the robotic arm.