A Major Project Phase-II Report

On

“DESIGN AND FABRICATION OF A LOW-COST HUMAN BODY LOWER LIMB EXOSKELETON WITH EMG”

SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE AWARD OF DEGREE OF

BACHELOR OF ENGINEERING

IN

ELECTRONICS & COMMUNICATION ENGINEERING

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2023-2024

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Certificate

This is to certify that the Major Project Phase-II report entitled **"Design and Fabrication of A Low-Cost Human Body Lower Limb Exoskeleton With EMG"** being submitted by **Ms.K.AKSHITHA (1608-20-735-012), Ms.V.SAI PRIYA (1608-20-735-035) and Mr.N.TARUN KUMAR (1608-20-735-042)** in partial fulfilment for the award of the Degree of Bachelor of Engineering in Electronics and Communication Engineering of the Osmania University, Hyderabad, during 2023-24, is a record of Bonafide work carried out under our guidance and supervision.

The results presented in this project report have not been submitted to any other University or Institute for the award of any Degree or Diploma.

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DECLARATION

This is to declare that the work submitted in the present project work report titled **“DESIGN AND FABRICATION OF A LOW-COST HUMAN BODY LOWER LIMB EXOSKELETON WITH EMG”** is a record of bonafide work done by me in the Department of Electronics & Communication Engineering, Matrusri Engineering College, Saidabad, Hyderabad.

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ACKNOWLEDGEMENT

We want to formally express our gratitude to several individuals without whom this project would not have come to fruition. While it's challenging to acknowledge everyone, it's essential to recognize some key individuals. We extend our heartfelt appreciation to our project guide, **Dr. PALLAVI KHARE**, Associate Professor, for her unwavering support, invaluable guidance, and continuous encouragement.Her insightful suggestions have been instrumental in shaping this project. We sincerely thank her for her consistent motivation and assistance throughout the project duration.

We would like to express our deep gratitude to the Head of Department **Dr. N SRINIVASA RAO** and Project Coordinators **Dr.M.NARESH and Mr.V. KARUNAKAR REDDY** for their timely cooperation while carrying the project. It is their friendliness that made me feel free and learn more from them.

Last but not least we would thank to all those people associated directly or indirectly with the project.

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ABSTRACT

The Low-Cost Human Body Lower Limb Exoskeleton with EMG marks a groundbreaking advance in addressing impaired mobility, especially for individuals recovering from accidents with weakened muscles. By integrating EMG sensors at strategic muscle points, the system captures and amplifies muscle signals, enabling precise control of servo motors. This integration facilitates naturalistic gait movements by optimizing leg mobility through specific joint angles, tailoring the rehabilitation experience to individual users. The innovative fusion of EMG technology and servo motors provides a cost-effective yet sophisticated solution, enhancing accessibility to assistive technology. Ultimately, this advancement contributes to a more inclusive and empowering future for individuals with mobility impairments, ensuring they can regain independence and mobility with greater ease and efficiency.

The exoskeleton's ability to capture muscle signals and translate them into precise movements not only aids in rehabilitation but also opens avenues for personalized therapy and long-term mobility support. This breakthrough technology represents a significant step towards democratizing assistive devices, making them more accessible to those in need and improving their quality of life.

Keywords: Electromyography, Arduino Nano, Servo Motor, Muscle Mobility, Exoskeleton.

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Chapter 1

INTRODUCTION

1.1 Introduction

In recent years, there have been incredible strides in the field of wearable robotics, particularly in the creation of exoskeletons aimed at boosting human capabilities and assisting those with mobility challenges. One standout area of progress is in lower limb exoskeletons, which offer support and rehabilitation for individuals facing lower limb disabilities. However, the cost of these exoskeletons often puts them out of reach for many, especially in areas with limited resources.

This project seeks to tackle that obstacle by focusing on designing and building a lower-cost lower limb exoskeleton that incorporates Electromyography (EMG) technology. EMG, which involves recording and analyzing the electrical signals produced by muscles, is a powerful tool for real-time monitoring and control in exoskeleton systems. By combining EMG with an affordable exoskeleton design, the goal is to create a solution that not only fits within budget constraints but also effectively enhances lower limb functionality.

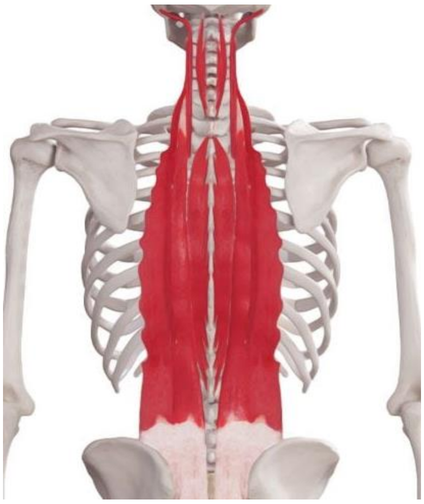
The integration of EMG technology allows the exoskeleton to adjust its support levels based on the user's muscle activity, offering personalized assistance and improving user comfort and efficiency. Moreover, the affordability of the proposed design makes it suitable for broader deployment, especially in healthcare facilities and rehabilitation centers where financial limitations often restrict access to advanced assistive technologies.

Through careful attention to design and fabrication processes, this project aims to strike a balance between affordability, functionality, and ease of use, ensuring that the resulting exoskeleton system meets the diverse needs of its users. By making lower limb assistive technology more accessible, this initiative has the potential to significantly enhance the quality of life for individuals with mobility impairments, promoting independence and fostering inclusion within society.

Here's a table outlining different muscle groups, their healthy EMG (Electromyography) value range, and the side effects of unhealthy EMG readings. This table provides an overview of different muscle groups, their healthy EMG (Electromyography) value ranges, and the potential side effects associated with unhealthy EMG readings. EMG values reflect muscle activity, with deviations from the healthy range indicating potential issues such as weakness, pain, or reduced mobility. Understanding these ranges can aid in assessing muscle health and identifying potential issues affecting various parts of the body.

Table 1.1 EMG for Muscle Groups

Muscle Group	Image of muscle	Healthy EMG Value Range (in micro volts)	Unhealthy EMG Value Side Effects
Quadriceps (Thigh)		0-100 µV	Reduced strength, pain, difficulty walkingor standing
Biceps (Upper arm)		0-150 µV	Weakness, limited range of motion, muscle atrophy
Deltoids (Shoulder)		0-120 µV	Impaired shoulder movement,

			instability, rotator cuff injury
Erector Spinae (Back)		0-80 µV	Back pain, reduced spinal stability, poor posture
Gastrocnemius (Calf)		0-130 µV	Difficulty walking, calf pain, decreased ankle mobility

1.2 Problem Statement

In the current scenario, conventional prosthetic leg arrangements require individuals to adapt to rigid designs, limiting user efficiency. This adaptation challenge, coupled with the high cost of existing solutions, hampers accessibility and affordability.

1.3 Objective

The aim of our project is to develop an affordable lower limb exoskeleton integrated with Electromyography (EMG) technology, with the goal of improving mobility and accessibility for individuals facing lower limb impairments. By harnessing EMG for real-time monitoring of muscle activity and adjusting assistance levels accordingly, our exoskeleton system is designed to offer personalized support tailored to each user's specific needs.Through streamlined design and fabrication processes, we aim to create a scalable solution that addresses the cost and accessibility barriers often encountered with current exoskeleton technologies. We'll thoroughly evaluate the performance and reliability of the exoskeleton system, as well as gather feedback on user satisfaction, to ensure its effectiveness in real-world scenarios.

1.4 Methodology

The methodology involves literature review for insight, followed by conceptualization and modeling of the exoskeleton. Fabrication utilizes cost-effective materials and techniques, with integration of EMG sensors and signal processing modules. Rigorous testing evaluates mechanical performance, ergonomics, and user feedback iteratively. Documentation of the validated exoskeleton system enables future research and development.

1.5 Motivation

The motivation behind undertaking this project stems from a profound desire to address the pressing challenges faced by individuals with lower limb disabilities, particularly in accessing affordable and effective assistive technologies. Witnessing the limitations imposed by high costs and limited accessibility of existing lower limb exoskeletons, coupled with the transformative potential of Electromyography (EMG) technology, sparked the inspiration to develop a novel solution. By combining low-cost design principles with EMG integration, the project endeavors to democratize access to assistive technologies, empowering individuals with lower limb impairments to regain mobility and independence Additionally, the prospect of contributing to advancements in wearable robotics and promoting inclusivity in society serves as a driving force, motivating the team to pursue innovative solutions that have a tangible impact on people's lives coupled with the transformative potential of Electromyography (EMG) technology,empowering individuals with lower limb impairments to regain mobility and independence.

1.6 Layout of the thesis

The thesis explains the implementation of “Design And Fabrication Of A Low-Cost Human Body Lower Limb Exoskeleton With EMG”.

Chapter 1: Presents introduction to the overall thesis and the overview of the project.

Chapter 2: Literature survey on different existing methods and systems for energy harvesting.

Chapter 3: It deals with the problem specification of the project and explains the necessary block diagram.

Chapter 4: It deals with Hardware implementation.

Chapter 5: It explains the implementation of the project using ARDUINO IDE Studio Compiler software.

Chapter 6: It explains the integration and testing of project.

Chapter 7: This chapter contains results of prototype with required graphs.

Chapter 8: This chapter contain Conclusion and future scope of project.

Chapter 2
LITERATURE SURVEY

2.1 Introduction

Our literature survey provides an extensive review of past research on lower limb exoskeletons, emphasizing the incorporation of electromyography (EMG) technology for enhanced mobility in individuals with muscle weakness. By identifying gaps and challenges in existing methodologies, our survey sets the stage for innovative approaches in designing and fabricating a low-cost exoskeleton system.

2.2 Literature Study

[1] Design of a Lower Limb Exoskeleton: Robust Control, Simulation and Experimental Results by E. Anyuli Alvarez Salcido, Daniel Centeno-Barreda.[1]

The paper details the creation of a lightweight exoskeleton targeting knee and ankle joint rehabilitation, notably focusing on ACL injuries. With rotary actuators providing four degrees of freedom, it enables a broad range of motion crucial for effective exercises. The design's adaptability allows customization for individual patients, boosting its efficacy. A robust control algorithm based on terminal high-order sliding mode control ensures precise trajectory tracking, promoting efficient and safe rehabilitation as in Fig 2.1. This mechanism ensures swift convergence, minimal tracking errors, and avoids singularities. Overall, the study emphasizes personalized customization, enhancing the exoskeleton's effectiveness in ACL injury rehabilitation and other lower limb conditions.

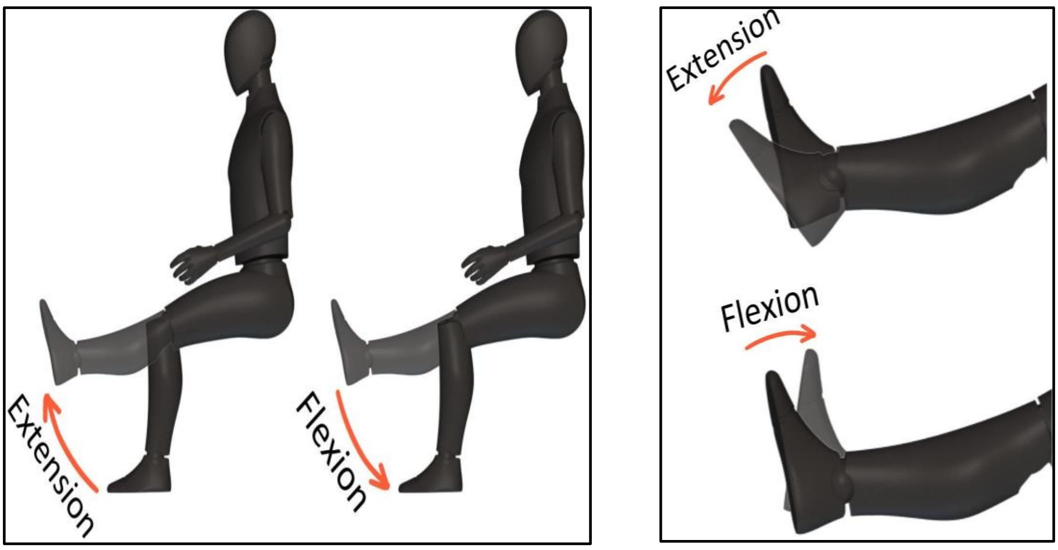


Fig. 2.1 Flexion and Extension

[2] Design and Simulation of Low-Cost Lower Limb Exoskeleton for Rehabilitation Exercise by **Nilam Abdullah,S. Ramesh.**[2]

This paper presents the design and simulation of a low-cost lower limb exoskeleton for rehabilitation exercises, aimed at aiding stroke patients in regaining mobility and independence. The design prioritizes simplicity, affordability, and safety, addressing the limitations of expensive exoskeletons currently available in the market. Through Finite Element Analysis (FEA), stress analysis ensures the exoskeleton's structural integrity, validating its suitability for supporting the user's weight during rehabilitation activities. The paper focuses on the development and functionalities of a Remotely Operated Underwater Vehicle (ROV). The authors discuss the design, construction, and operation of the ROV, highlighting its capabilities and potential applications in underwater exploration and surveillance.

[3] Design of a Low-Cost Lower Limb Rehabilitation Exoskeleton System by **Ullas U and Rajendrakumar P K.**[3]

This project focuses on the development of an affordable active exoskeleton for lower limb rehabilitation, addressing the urgent need for accessible walking assistance devices, especially in underserved regions like rural India. The exoskeleton is designed to be adaptable to the diverse anthropometric measurements of the Indian population while remaining cost-effective. The design emphasizes adjustability and modularity to efficiently meet the individual needs of patients as in Fig 2.2. By leveraging electric linear actuators and prioritizing adaptability, this exoskeleton system aims to overcome the barriers of cost, availability, and customization commonly associated with existing rehabilitation devices, thereby enhancing the quality of life for individuals with walking disabilities.

Fig. 2.2 Exoskeleton System Assembly

[4] Design and Analysis of Lower Body Exoskeleton by **Manoj M. Jadhav, Komal C. Kale.**[4]

Exoskeletons, wearable mechanical devices that amplify human strength and endurance, have become essential in industries where workers face the risk of injuries from heavy lifting and repetitive tasks as in Fig 2.3. The primary need in industries is to support the lower half of the body and alleviate fatigue and strain caused by bending and lifting. By redistributing weight and burden forces from the body to external actuators, exoskeletons can prevent fatigue and stress among workers, thereby improving productivity and reducing the risk of musculoskeletal disorders. The significance of exoskeletons lies in their ability to enhance worker strength and endurance, allowing them to handle more physical tasks safely and efficiently.

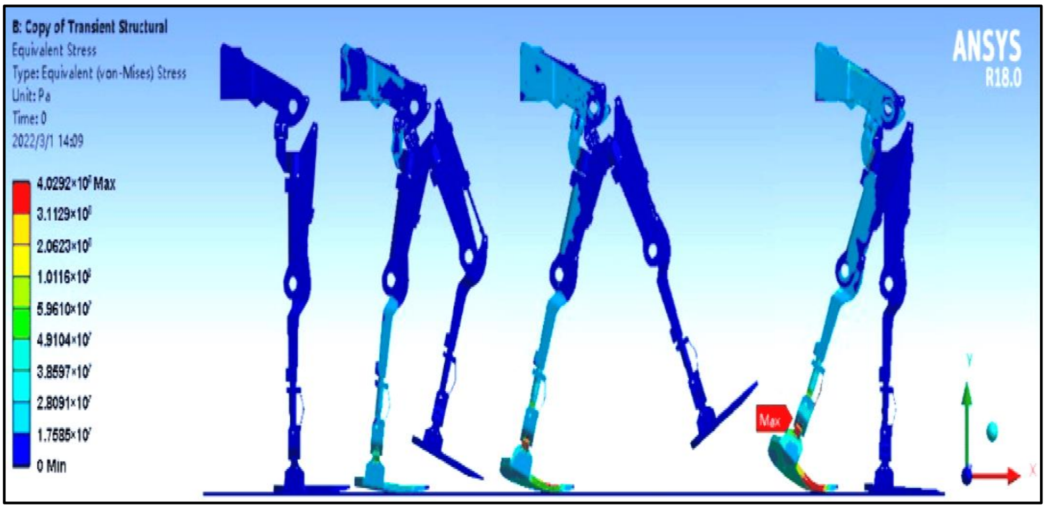


Fig. 2.3 ANSYS Analysis

[5] Design and Fabrication of Lower Limb Exoskeleton by **Rakesh. . C, Harish Kumar Yadav.**[5]

This study aims to create a portable exoskeleton device providing knee-joint assistance during walking without external power, proposing an "energy-neutral" solution. By employing a passive wearable device with pneumatic damping, the hypothesis suggests a reduction in metabolic activity by recycling knee joint mechanical work during the walking cycle. Prioritizing lightweight, durable, and portable design, the exoskeleton aims to mimic natural joint movement patterns and recycle energy from the pneumatic damper. Exoskeletons, versatile anthropomorphic devices, hold potential in enhancing performance and aiding mobility for individuals with disabilities. With applications ranging from rehabilitation gait trainers to autonomous force-augmenting exoskeletons, they offer hope for reducing metabolic costs and expanding mobility, particularly beneficial for those with spinal cord injuries as in Fig 2.4.

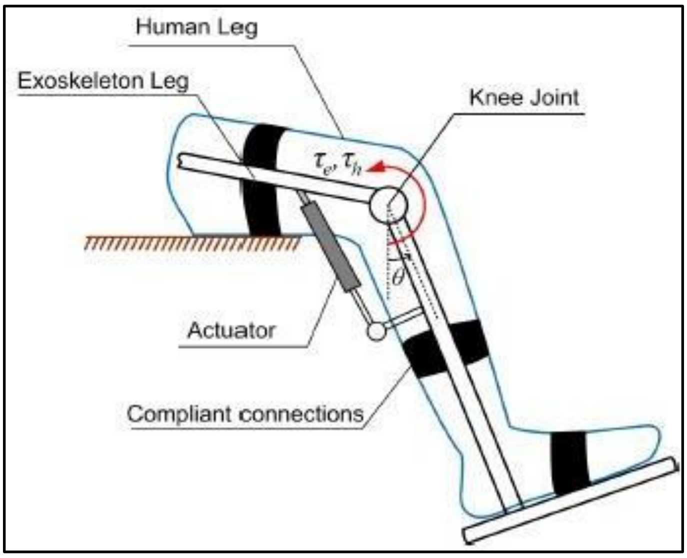


Fig. 2.4 Support Structure for Leg

[6] Improvement of energy consumption for a lower limb exoskeleton through verticalization time optimization by **Sergey Jatsun, Sergei Savin.[6]**

This paper focuses on addressing the challenge of improving the energy efficiency of a lower limb exoskeleton during the sit-to-stand motion, also known as verticalization. The proposed approach suggests optimizing the time allocated for the verticalization motion as a means to enhance energy efficiency. The study demonstrates that the optimal duration of verticalization is dependent on the initial position of the exoskeleton, and this relationship can be approximated by a polynomial function. The paper provides an analysis of the obtained results and offers practical suggestions for their implementation. In the introduction, the significance of exoskeletons in extending human functional capabilities across various domains, including medicine, rehabilitation, and industrial applications, is highlighted.

[7] Lower limb rehabilitation exoskeleton robot: A review by **Jinman Zhou, Shuo Yang.[7]**

This paper outlines the advancements in Lower Limb Rehabilitation Exoskeleton Robots (LLRERs), pivotal in aiding patients with lower limb disorders. LLRERs integrate artificial intelligence and mechanical power devices to facilitate lower limb movement, enhancing muscle vitality and compensating for physical dysfunction. Various LLRER prototypes and products are summarized, showcasing their potential to improve stability, reduce metabolic consumption, and enhance patient self-care abilities as in Fig 2.5,2.6. Commercial devices like LOKOMAT and Ekso

Bionics are highlighted for their role in rehabilitation, with EksoNR receiving FDA clearance for medical applications. The paper underscores LLRERs' positive impact on lower limb rehabilitation while advocating for further research to refine designs and validate effectiveness through clinical trials.

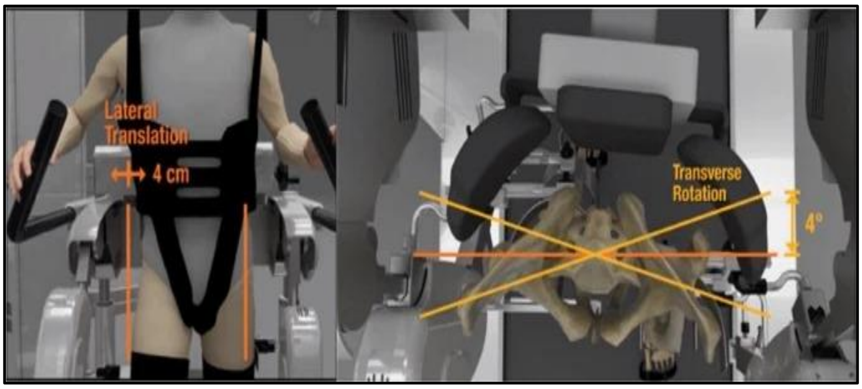


Fig. 2.5 Lateral Translation and Transverse Rotation

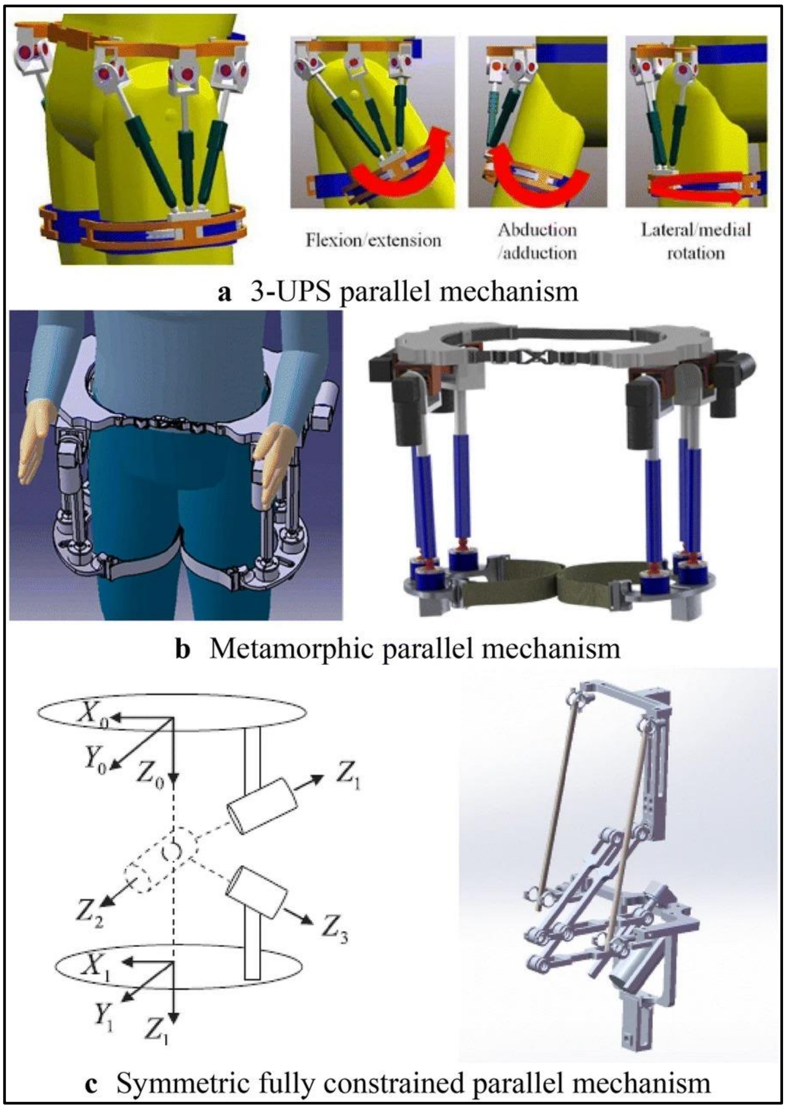


Fig. 2.6 Types of Parallel Mechanisms

[8] Design and Manufacturing of A Lower Limb Exoskeleton by **Praseeda Prabhu, Prathmesh Pawar.[8]**

Exoskeletons, versatile in industry, space, and healthcare, are pivotal for aiding those imagined to be confined to wheelchairs. Our focus lies in creating a low-cost lower limb exoskeleton for paraplegic patients, utilizing a linear actuator within a cage design for mobility. With a significant population facing disabilities, particularly in India, where medical equipment imports dominate, local manufacturing becomes crucial. Various exoskeleton types exist, with some like the HAL series aiding movement for paraplegics. Our project aims to provide torque and power for knee joint movement, fostering independence in therapy.

[9] Design and Experimental Evaluation of a Lower-Limb Exoskeleton for Assisting Workers With Motorized Tuning of Squat Heights by **Yao Tu, Aibin Zhu.[9]**

This paper presents the E-LEG, a semi-passive lower-limb exoskeleton designed to aid workers in squatting tasks, featuring motorized height adjustment for enhanced usability. Through systematic experimental evaluation involving human subjects, the study assessed muscular activity during prolonged static squatting. Evaluation metrics encompassed leg muscle activity, plantar pressure fluctuation, plantar pressure center fluctuation, and gait angles. Results indicate a decrease in muscular strain during squatting without significant alterations to normal gait, suggesting the potential efficacy of the E-LEG exoskeleton in alleviating muscular fatigue during extended squatting tasks.

[10] Review of Hybrid Exoskeletons to Restore Gait Following Spinal Cord Injury Antonio J. del-Ama.[10]

Addressd gait impairment in spinal cord injury (SCI) patients involves various methods like passive orthoses, functional electrical stimulation (FES), and robotic exoskeletons. However, drawbacks such as energy demands and muscle fatigue exist in each approach. Hybridizing FES with exoskeletons presents a promising solution to overcome these limitations. This article provides an overview of hybrid lower-limb exoskeletons, focusing on technologies, control systems, and functional assessment in SCI individuals.SCI-induced paraplegia significantly hampers mobility, with gait impairment being particularly challenging. Recent studies emphasize the importance of restoring walking ability in SCI patients. Different approaches, including orthotic gait, FES, and hybrid FES-based methods, are explored for gait restoration.

Chapter 3

PROBLEM SPECIFICATION

3.1 Introduction

The introduction to the block diagram description of the Design and Fabrication of a Low-Cost Human Body Lower Limb Exoskeleton with EMG provides an overview of the key components and their interactions within the system. It outlines the integration of electromyography (EMG) sensors, servo motors, and control algorithms to achieve precise control over joint angles and facilitate naturalistic gait patterns during rehabilitation. This section aims to establish a foundational understanding of the system architecture.

3.2 Block Diagram

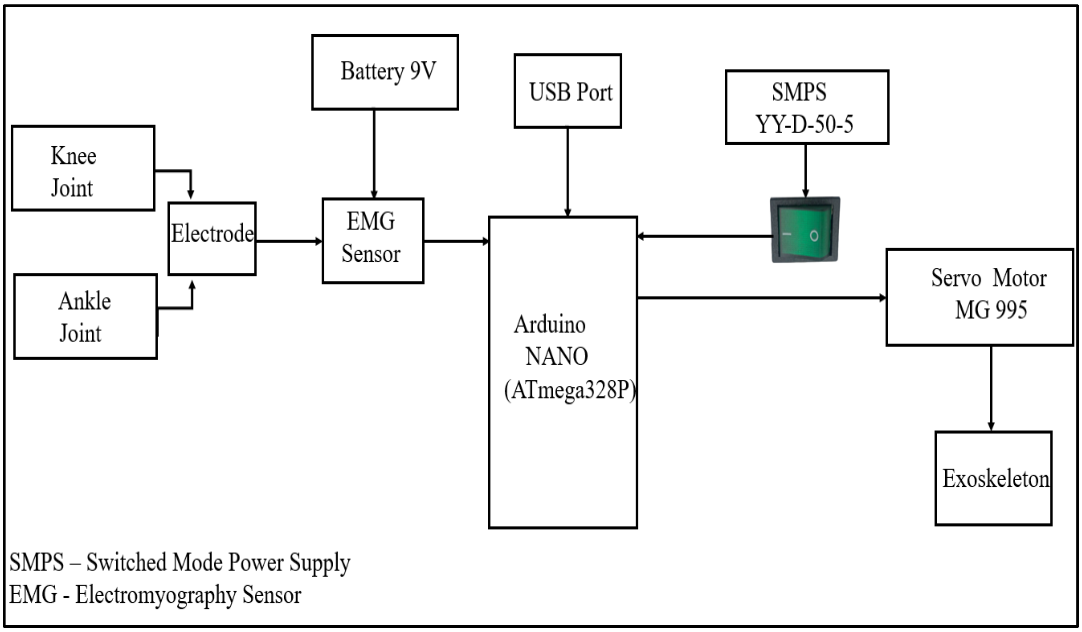
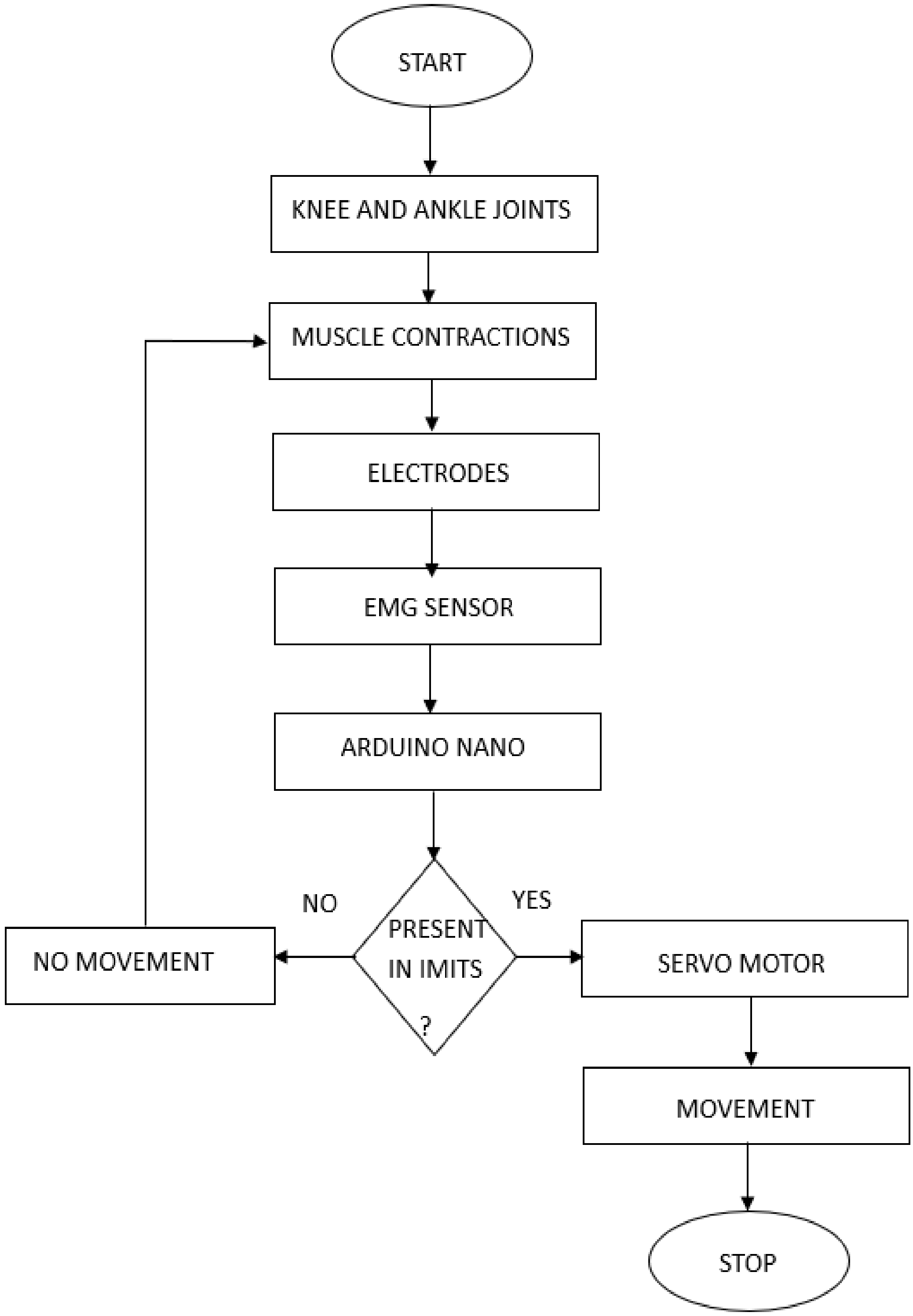


Fig. 3.1 Block Diagram

The above block diagram in Fig.3.1 explains the working of the exoskeleton. In this setup, muscle contractions are monitored using EMG sensors placed on specific muscle groups around the knee or ankle joints. Each muscle group requires one EMG sensor, powered by two lithium-ion batteries. As the muscles contract, electrical signals are detected by the electrodes of the EMG sensors and transmitted to an Arduino Nano for processing. The Arduino Nano displays the EMG signals as a graph on the serial plotter. When the EMG values fall within pre-programmed peak limits set by the user, indicating the desired muscle activity level, a signal is sent to a servo motor. This servo motor, powered by an SMPS, then initiates movement in the corresponding muscle when the switch is turned on this acts as an interface between SMPS and NANO, effectively translating the electrical signals into physical motion. This integrated system enables real-time monitoring and control of muscle activity, facilitating applications such as rehabilitation or assistive devices.

3.3 Flowchart



The "Design and Fabrication of Low-Cost Human Body Lower Limb Exoskeleton" involves a comprehensive process to enable movement assistance for individuals with lower limb disabilities. At its core are the knee and ankle joints, essential for mimicking natural lower limb movements. These joints are pivotal for providing support and enabling activities like walking.

To initiate movement, the system detects muscle contractions using electrodes placed on the user's skin. These contractions are sensed by an Electromyography (EMG) sensor, which translates them into electrical signals. The Arduino Nano microcontroller serves as the central processing unit, receiving input from the EMG sensor and controlling the exoskeleton's operation accordingly.

A critical step in the process is determining whether the detected muscle contractions fall within predefined limits. This ensures that the exoskeleton responds only to intentional movements, avoiding unintended actions. If the contractions are within limits, the movement is given to servo motors to activate the movement in exoskeleton.

Servo motors play a crucial role in actuating the movement of the exoskeleton's joints, specifically the knee and ankle joints. They translate the electrical signals from the Arduino Nano into mechanical movement, facilitating walking or other desired lower limb movements. However, if the contractions do not meet the predetermined criteria, or if the presence of limits is not confirmed, the exoskeleton remains stationary, and no movement is initiated.

This detailed process highlights the integration of joint mechanisms, muscle detection, sensor technology, microcontroller programming, and motor control in the design and fabrication of the low-cost human body lower limb exoskeleton. By following these steps, the exoskeleton can effectively assist individuals with lower limb disabilities in regaining mobility and enhancing their quality of life.

The flowchart outlines a systematic approach for the design and fabrication of a low-cost human body lower limb exoskeleton. By incorporating knee and ankle joints, muscle detection technology, EMG sensors, Arduino Nano microcontrollers, and servo motors, the exoskeleton aims to assist individuals with lower limb disabilities in regaining mobility. The process ensures that movements are initiated only when muscle contractions fall within predetermined limits, enhancing safety and reliability and the quality of life for users by providing efficient and affordable support for lower limb mobility.

3.4 Hardware Selection

3.4.1 Arduino Nano

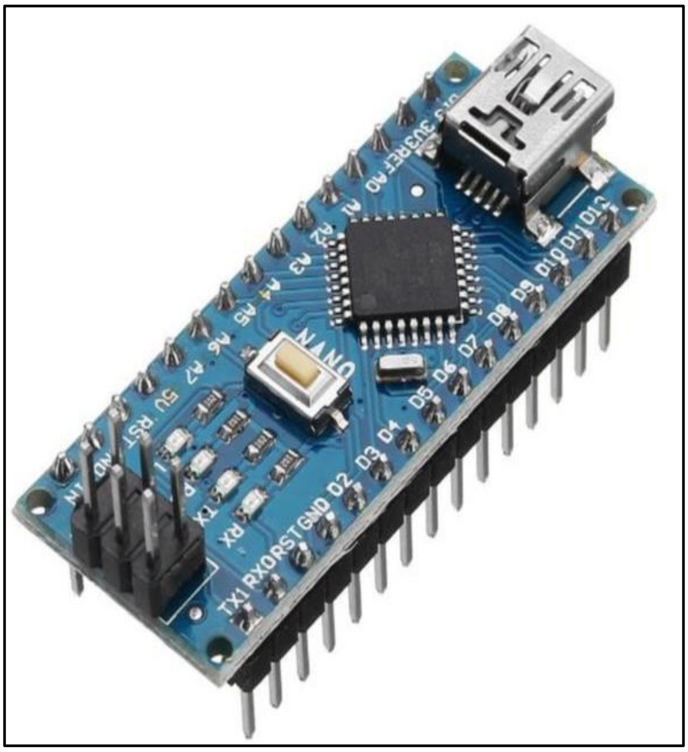


Fig 3.2 Arduino Nano

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328P microcontroller. It's similar to the Arduino Uno but with a smaller form factor, making it ideal for compact projects as shown in Fig.3.2.

Specifications:

- Microcontroller: ATmega328P
- Operating Voltage: 5V
- Input Voltage (recommended): 7-12V
- Input Voltage (limit): 6-20V
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- Analog Input Pins: 8
- DC Current per I/O Pin: 40 mA
- Flash Memory: 32 KB (ATmega328P) of which 2 KB used by bootloader
- SRAM: 2 KB (ATmega328P)
- EEPROM: 1 KB (ATmega328P)
- Clock Speed: 16 MHz
- Dimensions: 18 x 45 mm

- USB Mini-B Connector: Used for power and programming.
- ICSP Header: Used for programming the firmware on the microcontroller.
- Reset Button: For restarting the program running on the microcontroller.

The Arduino Nano can be powered via the USB connection or with an external power supply. The power source is selected automatically. The external power supply can come from an AC-to-DC adapter or a battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the GND and VIN pin headers of the POWER connector.

The Arduino Nano can be programmed with the Arduino software (IDE). Select "Arduino Nano" from the Tools > Board menu (according to the microcontroller on your board). The ATmega328 on the Arduino Nano comes pre-burned with a bootloader that allows you to upload new code without the use of an external hardware programmer.

The Arduino Nano has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). The Arduino Software (IDE) includes a serial monitor which allows simple textual data to be sent to and from the Arduino board.

Each of the 14 digital pins on the Nano can be used as an input or output, using `pinMode()`, `digitalWrite()`, and `digitalRead()` functions. They operate at 5V. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms.

3.4.2 EMG Sensor

Electromyography (EMG) sensors detect and record muscle electrical activity, operating through surface or intramuscular placement. They find applications in healthcare, sports, and rehabilitation, aiding in muscle function assessment and neuromuscular disorder diagnosis. Proper sensor positioning is critical for accurate signal detection, tailored to the muscles under study as shown in Fig.3.3. EMG signals are processed with specialized software to extract muscle activity patterns and other relevant information. Despite limitations like signal noise, EMG sensors offer real-time insights into muscle function, proving valuable in various fields. They are utilized across healthcare, sports, and rehabilitation fields, assisting in evaluating muscle function and diagnosing neuromuscular disorders.

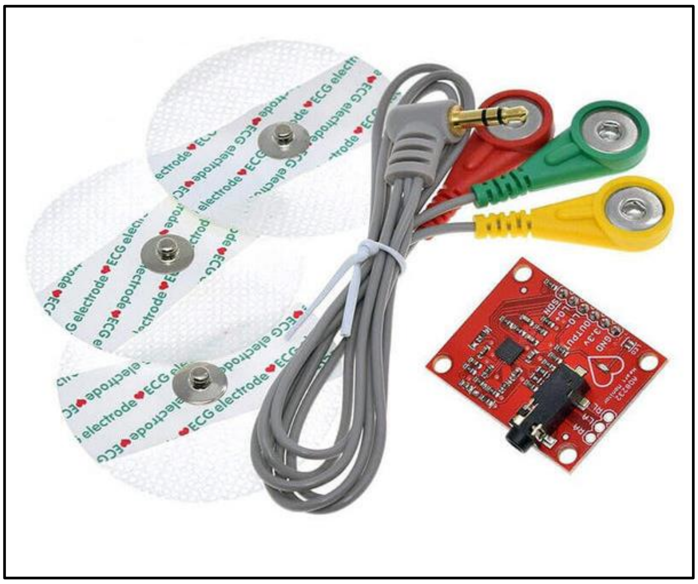


Fig 3.3 EMG Sensor

Table 3.1 EMG Sensor Specifications

Parameters	Value/Range
Electrode pad diameter	52mm
Operating voltage	5 volts
Dimension of module	33.5×26×12mm
Power supply	±9V dual power supply
Weight	30g
Cable length	2.5 meters

Working

An EMG (Electromyography) sensor functions by detecting and measuring the electrical activity generated by muscles during contraction and relaxation. Typically, electrodes are placed on the skin surface above the muscles of interest, where they pick up electromyographic signals. These signals are initially weak and susceptible to noise, so the sensor amplifies and filters them to enhance their detectability and accuracy. After this preprocessing, analog-to-digital conversion converts the signals into a digital format for further processing. The processed signals can then be displayed in real-time on a screen or transmitted wirelessly to other devices for analysis or control. EMG sensors play a crucial role in various applications, including medical diagnostics, rehabilitation, prosthetics, and sports science, providing insights into muscle function, movement patterns, and motor control. By monitoring electromyographic signals, EMG sensors contribute to understanding muscle activity, facilitating personalized rehabilitation programs, improving prosthetic limb functionality, and enhancing performance optimization in sports and physical therapy.

3.4.3 MG995 Servo Motor

Servo motors, vital for precise position, velocity, and acceleration control, consist of a motor, feedback sensor, and control circuit, making them ideal for accuracy-demanding fields like robotics and aerospace as shown in Fig.3.4. They encompass types like DC, AC, and brushless servo motors, each tailored for specific applications. Servo motors rely on feedback systems such as encoders to ensure accurate positioning. Controlled through methods like PWM or digital communication protocols, they find extensive use in industrial automation, robotics, remote-controlled vehicles, camera stabilization systems, and beyond.

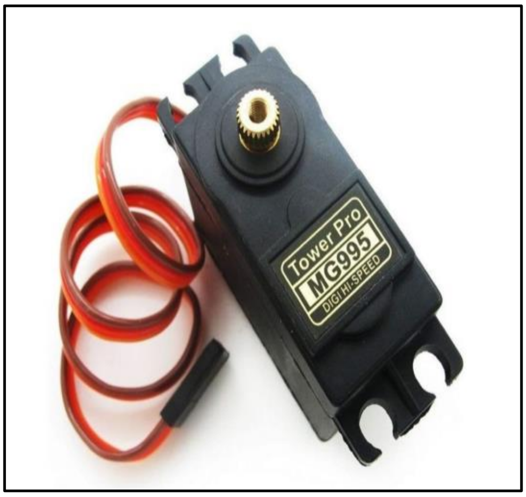


Fig 3.4 MG995 Servo Motor

Specifications

- Voltage : 4.8V – 6.6V
- RPM : 0.2s/60 degrees (4.8v),0.16s/60 degrees(6v)
- Torque : 9.4kg/cm(4.8v) – 11kg/cm(6v)
- Angle:180 degrees
- Dimensions : 40mm x 20mm x 43mm
- Weight : 55g

Working

The MG995 servo motor operates by translating electrical signals into precise mechanical movement. Within its compact housing, it houses a DC motor coupled with a gearbox, which reduces speed while increasing torque for accurate motion. It relies on a control signal, often in the form of pulse-width modulation (PWM), to dictate its position. This signal, typically generated by a microcontroller like Arduino, specifies the desired angle or position for the servo motor's output shaft. Crucially, the MG995 incorporates a feedback mechanism, usually a potentiometer, providing positional feedback for enhanced accuracy and stability. Upon receiving the control signal, the servo's internal circuitry adjusts the motor's speed and direction, ensuring the output shaft moves to the commanded position with precision. With its moderate load-handling capability, the MG995 finds applications in robotics, remote-controlled vehicles, model airplanes, and animatronics, offering reliable and controlled movement for a diverse array of projects.

3.4.4 SMPS YY-D-50-5

The SMPS YY-D-50-5 is a Switch Mode Power Supply (SMPS) module designed for various electronic applications requiring a stable and efficient power source as shown in Fig 3.5. With a model number indicating its specifications, it likely delivers an output of 5 volts with a maximum current capacity of 50 amps. These modules typically feature compact designs, high efficiency, and protection features such as overcurrent and overvoltage protection. They are commonly used in industrial, commercial, and DIY projects where reliable power conversion is essential.

Fig 3.5 SMPS YY-D-50-5

Specifications

- Output voltage: 5 Vdc
- Input voltage

- range: 85-264VAC
- Output current: 10 Amps
- Efficiency: 89%
- Input voltage: 230 VAC

Working

The SMPS YY-D-50-5, a Switched Mode Power Supply, operates through a sophisticated process to efficiently convert high-voltage AC power from a mains power source into low-voltage DC power suitable for electronic devices. Its functionality involves several key stages. Initially, the AC input voltage is rectified and smoothed to produce a high-voltage DC signal. This signal is then fed into a high-frequency switching circuit, where it undergoes rapid switching on and off. Through this process, the voltage is converted into a high-frequency AC signal. Subsequently, this high-frequency AC signal is passed through a transformer, which steps down the voltage to the desired level and isolates the output from the input, ensuring safety and reducing electrical noise. Following the transformer, the signal is rectified once again to convert it back into DC form. Finally, the output is filtered to remove any remaining AC ripple and noise, resulting in a stable and clean DC output voltage. The SMPS YY-D-50-5's efficiency and compact design make it suitable for various applications, including powering electronic devices, telecommunications equipment, and industrial machinery, where reliability and performance are paramount.

3.4.5 Battery BF22

The BF22 9V battery is a common rectangular-shaped battery commonly used in various electronic devices such as smoke alarms, remote controls, and small electronic gadgets. It typically consists of six cylindrical cells connected in series, providing a total voltage of 9 volts. These batteries are known for their reliability and long-lasting power, making them suitable for applications requiring a stable power source. They are widely available and can be found in most stores that sell batteries as in Fig 3.6.

Specifications

- Model Name/Number: BF22
- Usage/Application: Transistor Radio and General Purpose
- Nominal Voltage: 9 V
- Battery Cell Composition: Lithium Ion

- Weight: 350 Grams
- Dimensions: 10 x 4 x 5 Centimeters
- Battery Weight: 36 Grams

Fig 3.6 Battery BF22

3.4.6 Aluminium Frame

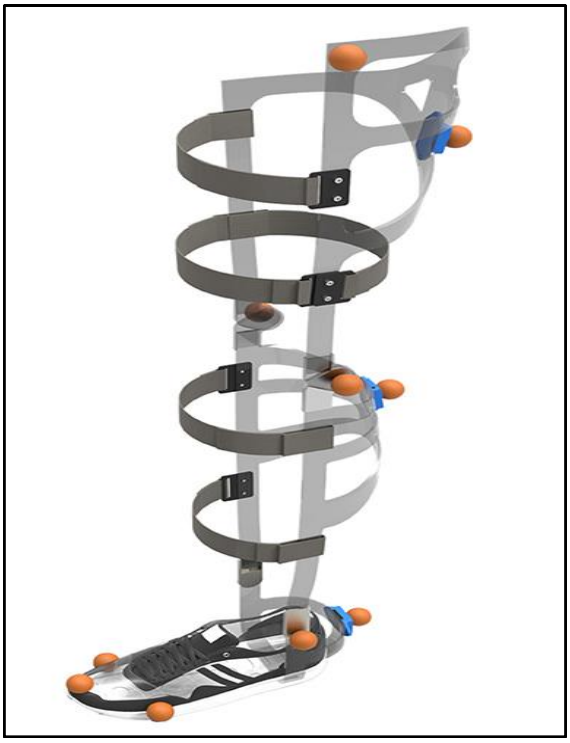


Fig 3.7 Aluminium Frame

The aluminum frame of an exoskeleton functions as its structural backbone,offering essential support, stability, and attachment points for various components. Aluminum is favored for exoskeleton frames due to its strength, durability, and lightweight nature, crucial for minimizing weight while maintaining robustness. These frames are designed to efficiently distribute loads and provide necessary rigidity to support users and additional components like actuators and sensors. Various geometries such as tubular, truss, or lattice structures are employed based on the exoskeleton's requirements as shown in Fig.3.7. Customization is key, with frames adjustable to fit users' body dimensions and mobility needs, often featuring modular designs for its versatility.

3.4.7 Velcro Band

Fig 3.8 Velcro Band

Velcro bands, also known as hook and loop straps, are versatile fastening solutions widely used for bundling and securing items. Comprising hooks and loops, they form a robust and reversible bond when pressed together as shown in Fig.3.8. Available in various widths, lengths, and colors, they serve diverse applications like cable organization and object attachment. Notably, their reusability sets them apart, allowing multiple uses without compromising grip strength, unlike traditional tapes or zip ties. Additionally, their adjustable nature permits users to customize tightness, accommodating objects of different sizes with ease.

3.4.8 Switch

Fig 3.9 Switch

The Double Pole Canal R Series Rocker Switch, identified by its green color, is a robust electrical switch capable of handling up to 20A of current as in Fig 3.9. Designed for various applications, it features a double pole conFiguration, allowing it to control two separate circuits simultaneously, making it ideal for high-power uses such as household appliances, industrial equipment, and automotive systems. The switch typically operates at 120V or 240V AC and may include an integrated LED indicator for illumination. It has a compact design suitable for panel mounting, with durable plastic housing and secure quick-connect or screw terminals. When toggled, the switch connects or disconnects both sets of contacts, ensuring reliable and safe operation. The Canal R Series Rocker Switch is known for its sturdy construction and dependable performance, making it a preferred choice for applications requiring simultaneous control of two circuits.

3.5 Mapping of the design into hardware and software

In the process of mapping the design into hardware and software components, several key elements come into play. On the hardware side, components such as the exoskeleton itself, the SMPS YY-D-50-5 power supply unit, servo motor MG995, EMG sensor, Velcro bands for securing the exoskeleton, and the BF22 battery are integral to the system's functionality. The exoskeleton serves as the physical framework for the device, while the SMPS YY-D-50-5 provides the necessary power supply to drive the system. The servo motor MG995 facilitates precise movement control, essential for mimicking naturalistic gait patterns. Additionally, the EMG sensor captures muscle signals, enabling the user to control the exoskeleton effectively. Velcro bands ensure proper attachment and stability of the exoskeleton to the user's body. The BF22 battery powers the entire system, ensuring mobility and independence. On the software side, the Arduino Nano board serves as the central processing unit, executing the programmed algorithms and controlling the hardware components. The Arduino IDE (Integrated Development Environment) provides a user-friendly platform for writing, compiling, and uploading code to the Arduino Nano board, enabling seamless integration of software and hardware components for optimal exoskeleton operation.

Chapter 4

HARDWARE IMPLEMENTATION

4.1 Introduction

In the hardware implementation section, we will explore the tangible components vital to our system's functionality. This includes EMG sensors for muscle monitoring, Arduino Nano as the central processing unit, servo motors for translating signals into motion, and power supply units ensuring seamless operation. Through this discussion, we aim to understand how these components work together to achieve our system's objectives, whether in rehabilitation, assistive devices, or advancing our understanding of human movement.

4.2 Hardware Implementation

The hardware setup for this project involves careful integration of several key components. The EMG sensor has five wires: the first three are for the battery, with +VS connecting to +9V, GND to GND, and -VS to -9V of the BF22 battery. The other two connections involve the signal wire connecting to the A0 pin and the ground wire connecting to the GND pin of the Arduino Nano. This conFiguration allows the EMG sensor to send muscle activity data to the Arduino for processing.

For the servo motor MG 995, there are three essential wire connections. The 5V wire connects to the 5V output of the SMPS YY-D-50-5, ensuring the servo receives adequate power. The ground wire is connected to the ground terminal of the SMPS to complete the circuit, and the signal wire is connected to the D8 pin of the Arduino Nano. This setup enables the Arduino to control the servo motor's position based on the EMG sensor's input, allowing precise movement control for the exoskeleton.

Additionally, the system includes two green double pole switches, which are crucial for managing the power supply to the Arduino Nano and its components. The positive and negative wires from the SMPS are connected to each switch, and then from each switch to the Arduino Nano. This setup is duplicated for both switches, corresponding to the knee and ankle mechanisms of the exoskeleton. The double pole switches ensure that power can be controlled independently for each section, providing flexibility and safety during operation.

The operational workflow begins by checking the threshold limits for the knee and ankle without turning on the SMPS. These limits are observed using the Arduino Nano code and recorded. The predefined limits are then entered into the Arduino code.

Depending on the requirements, the switch for the knee, ankle, or both is turned on, followed by turning on the SMPS supply. When the EMG sensor values fall within the predefined limits, the corresponding movement in the exoskeleton is triggered. This ensures that the exoskeleton only moves when appropriate muscle signals are detected, providing precise and responsive assistance.

4.2.1 Electromyography (EMG) Sensor Setup

The EMG sensor system is meticulously conFigured to ensure precise and reliable monitoring of muscle activity. Two 9V batteries are strategically arranged to power the EMG sensor, following a sequence of +9V, 0V, and -9V and they are respectively connected to +Vs ,GND and -Vs of EMG sensor. This conFiguration is crucial for stabilizing the sensor's performance, providing a consistent power supply that is essential for accurate readings of muscle signals. By adhering to this specific power arrangement, the EMG sensor can effectively capture and transmit muscle activity data without interference or fluctuations.

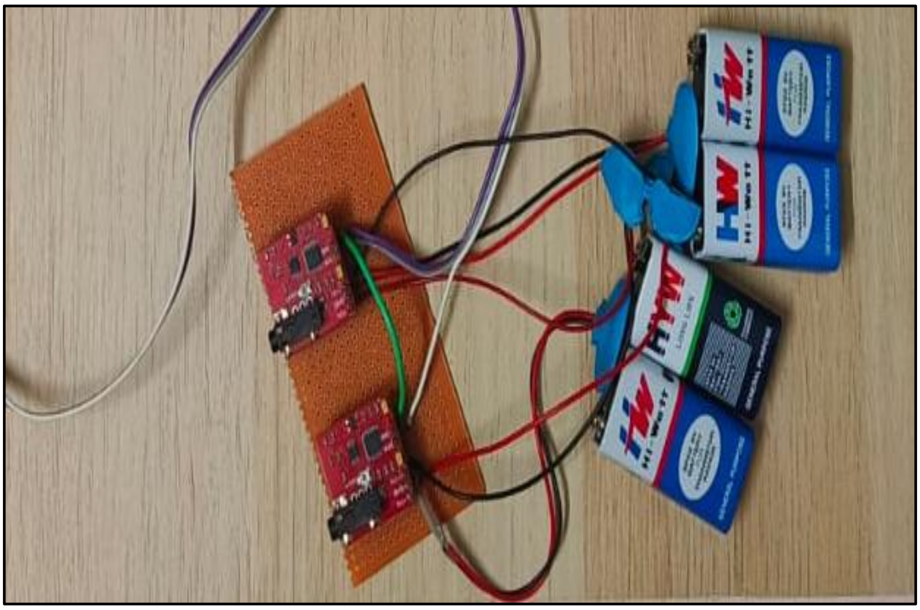


Fig 4.1 EMG Sensor and battery connection

Upon power stabilization, the EMG sensor is meticulously connected to an Arduino Nano board, establishing a vital link for data acquisition and processing. The connection process involves carefully linking the ground pin of the Arduino to the corresponding ground pin of the EMG sensor. This step ensures a common reference point for signal measurement, mitigating potential noise and ensuring accurate interpretation of muscle activity signals. Furthermore, the signal pin of the EMG sensor is precisely routed to analog pin A0 of the Arduino and GND pin to GND pin of Nano. This connection facilitates the seamless capture of analog signals from the EMG sensor, enabling precise analysis and interpretation of muscle activity levels as in Fig 4.1 and 4.2 .

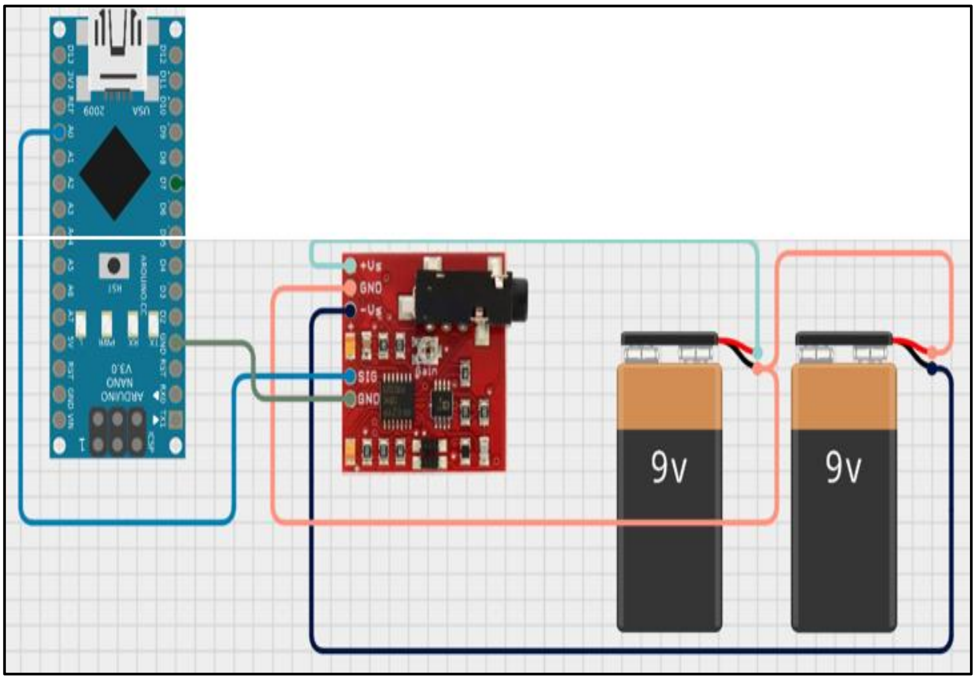


Fig 4.2 Arduino Nano integration with EMG

4.2.2 SMPS, Arduino Nano and Servo Integration

Power management is a critical aspect of the hardware setup, and it is meticulously addressed through the integration of a switching mode power supply (SMPS) model YY-D-50-5. This SMPS model is carefully selected for its efficiency and reliability in providing stable power output to the Arduino Nano board. Combined with the power supplied via the USB port of a desktop computer, this integrated power system ensures uninterrupted operation of the Arduino board, essential for continuous data acquisition and processing.

The Arduino Nano board, powered by the integrated power system, serves as the central control unit for the entire hardware setup. Its versatility and robustness make it an ideal choice for interfacing with various components, including the EMG sensor and servo motors. The integration process involves meticulous attention to detail, ensuring secure connections and optimal performance. Specifically, connections for controlling the servo motor (MG995) responsible for knee movement are established with precision. This includes linking the 5V and ground pins of the SMPS to the corresponding pins of the servo motor, providing stable power delivery. Additionally, the signal pin of the servo motor for knee and ankle movement is tactically connected to digital pin D8 of the Nano, enabling precise control and synchronization with the Arduino as in Fig 4.3.

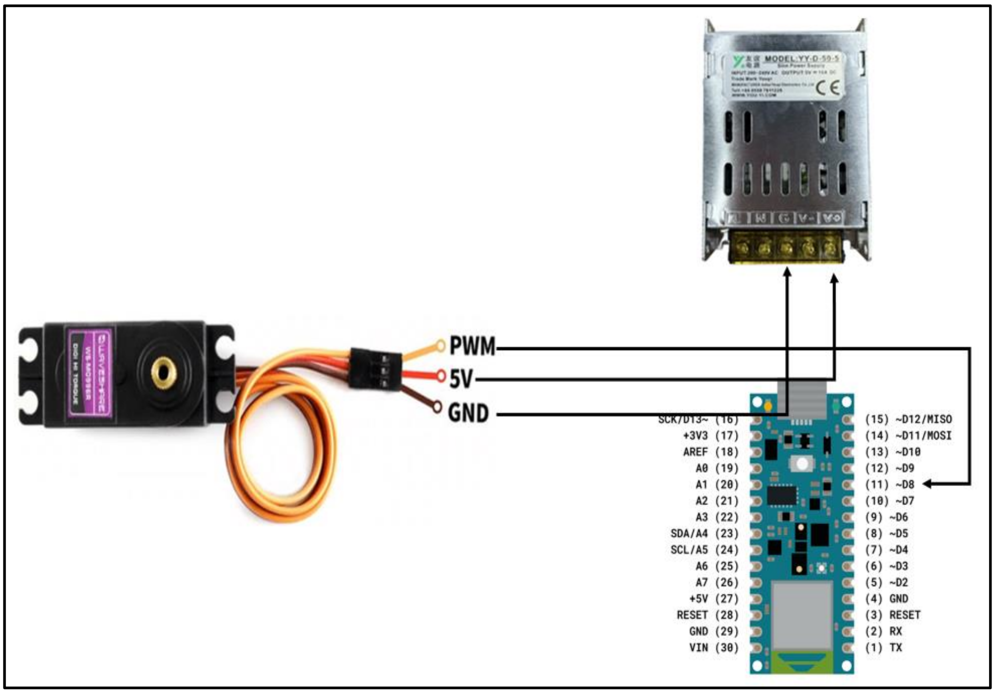


Fig 4.3 SMPS, Arduino Nano and servo integration

4.2.3 Threshold Testing and Calibration

Before activating the switching mode power supply (SMPS) and initiating movement, thorough threshold testing and calibration are essential. This crucial step involves setting and validating threshold limits for both knee and ankle joints within the Arduino code. The threshold limits serve as reference points for accurately detecting and interpreting muscle activity signals, ensuring precise control of movement. By meticulously calibrating these threshold limits, the system can effectively differentiate between intended movements and noise, enhancing overall performance and reliability.

4.2.4 Mild Movement Testing

With threshold calibration complete and the Arduino code uploaded, the system is ready for testing. Now, we have to unplug the USB cable of NANO and switch on the Green buttons for knee and ankle movement according to our requirements.This green switch is interface between SMPS and NANO.Mild movements of the knee and ankle joints are carefully observed after switching on the green switch and the SMPS Supply, allowing for real-time assessment of the system's responsiveness and accuracy. The exoskeleton demonstrates a smooth range of motion, reaching approximately 55 degrees at the knee and 65 degrees at ankle joints.

Chapter 5

SOFTWARE IMPLEMENTATION

5.1 Introduction

To monitor the components connected to Arduino used a software i.e., Arduino IDE. Through Arduino IDE we implemented the EMG Sensor readings and conditions for movement of exoskeleton.

5.2 Arduino IDE

Arduino IDE is an open-source software that is mainly used for writing and compiling code into the Arduino Module. It is an official Arduino software, making code compilation so easy that even a common person with no prior technical knowledge can get their feet wet with the learning process. It is easily available for operating systems like MAC, Windows, Linux and runs on the Java Platform that comes with inbuilt functions and commands that play a vital role for debugging, editing, and compiling the code in the environment.

IDE stands for "Integrated Development Environment: it is an official software introduced by Arduino.cc, that is mainly used for editing, compiling, and uploading the code in the Arduino Device Almost all Arduino modules are compatible with this software that is an open source and is readily available to install and start compiling the code on the go. A range of Arduino modules is available including Arduino Nano, Arduino Mega, Arduino Leonardo, Arduino Micro and many more. Each of them contains a microcontroller on the board that is programmed and accepts the information in the form of code. The main code, also known as a sketch, created on the IDE platform will ultimately generate a Hex File which is then transferred and uploaded in the controller on the board. The IDE environment mainly contains two basic parts: Editor and Compiler where former is used for writing the required code and later is used for compiling and uploading the code into the given Arduino Module. This environment supports both C and C++ languages.

Installing Arduino on your computer

To program the Arduino board, you must first download the development environment (the IDE) from here: www.arduino.cc/en/Main/Software. The software is available for common operating systems like Linux, Windows, and MAC OS, we selectto download the correct software version that is easily compatible with ouroperating system. Choose the right version for your operating system.

Details on IDE

The IDE environment is mainly distributed into three sections.

- Menu Bar
- Text Editor
- Output Panel

As we download and open the IDE software, it will appear like a Figure-

The bar appearing on the top is called Menu Bar that comes with five different optionsas follows as in Fig.5.1:

- File You can open a new window for writing the code or open an existing one. Edit-Used for copying and pasting the code with further modification for font Sketch-For compiling and programming.
- Tools - Mainly used for testing projects. The Programmer section in this panel is used for burning a bootloader to the new microcontroller.
- Help - In case you are feeling skeptical about software, complete help is available from getting started to troubleshooting.
-

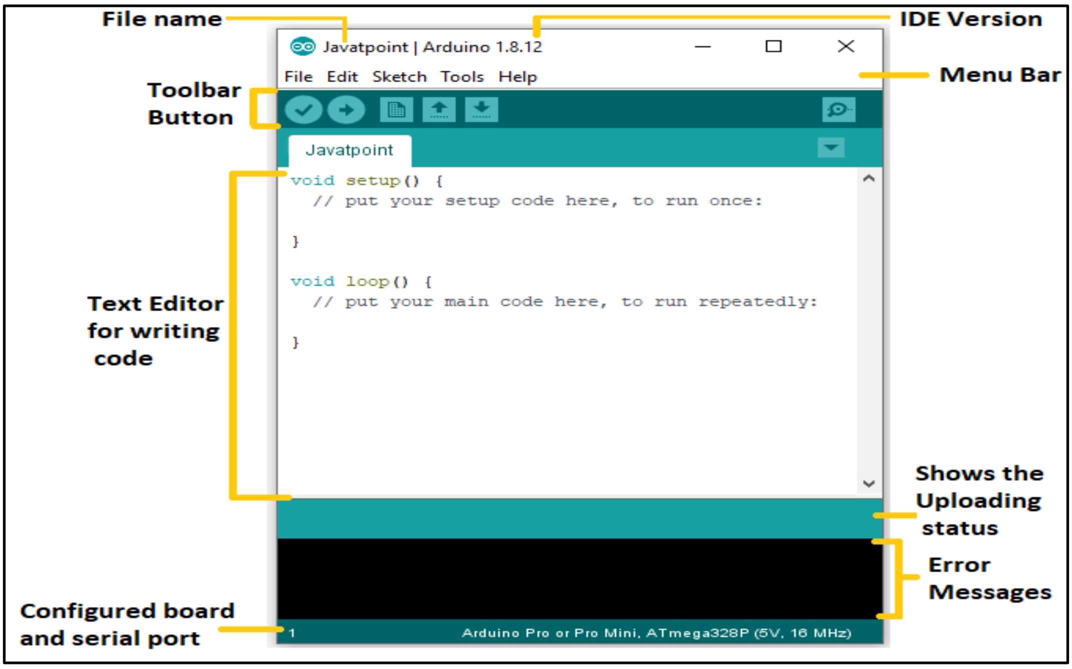


Fig 5.1 Arduino IDE Window

Libraries

Libraries are very useful for adding extra functionality into the Arduino Module There is a list of libraries you can add by clicking the Sketch button in the menu bar and going to the Include Library. Libraries make programming on the Arduino a lot of easier. They simplify and reduce the amount of code required in your program.

Thousands of Arduino libraries are available to download for free, for a range of programming tasks like controlling LCD displays, driving servos, reading sensors,and more.

As you click the Include Library and Add the respective library ie Servo library it will on the top of the sketch with a #include sign as shown in Figure 5.2.

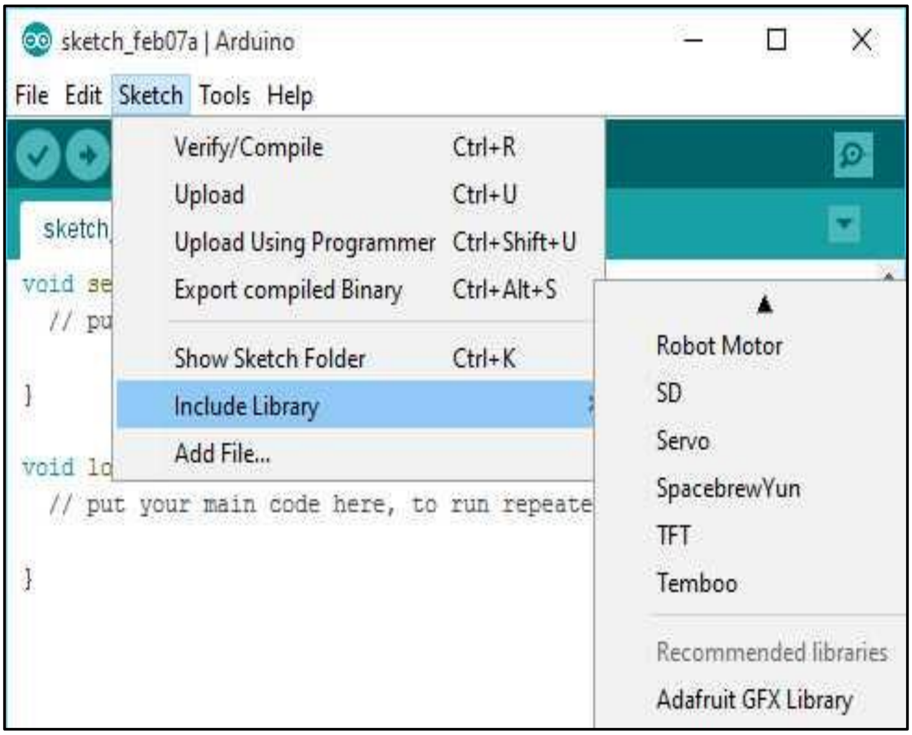


Fig 5.2 Arduino IDE Libraries

The Servo library in the Arduino IDE is a powerful tool for controlling servo motors with ease and precision. Servo motors are widely used in robotics, automation, and various other projects where precise control of angular position or speed is required. The Servo library simplifies the process of controlling these motors by abstracting away the complexities of pulse width modulation (PWM) signals and timing calculations.

At its core, the Servo library provides a set of functions that allow users to create and manipulate servo objects. These objects represent individual servo motors connected to specific pins on the Arduino board. By creating a servo object and attaching it to a pin, users can then control the position of the servo motor by specifying the desired angle using the write() function. The library takes care of generating the appropriate PWM signals to drive the servo motor to the specified position.Additionally, the Servo library offers functionalities for setting the minimum and maximum pulse widths, which can be adjusted to calibrate the servo motor's range of motion. This enables users to fine-tune the behavior of the servo motor to suit their specific application requirements.

Selecting board and port in Arduino

Arduino boards are able to read inputs light on a sensor, a finger on a button, or a Twitter message and turn it into an output activating a motor, turning on an LED, publishing something online. It is to create an accessible way for software developers to enter the world of microcontroller programming. To upload the sketch, we need to select the relevant board we are using and the ports for that operating system. Click on Tools in the menu bar and find the Board row and select Arduino Nano.

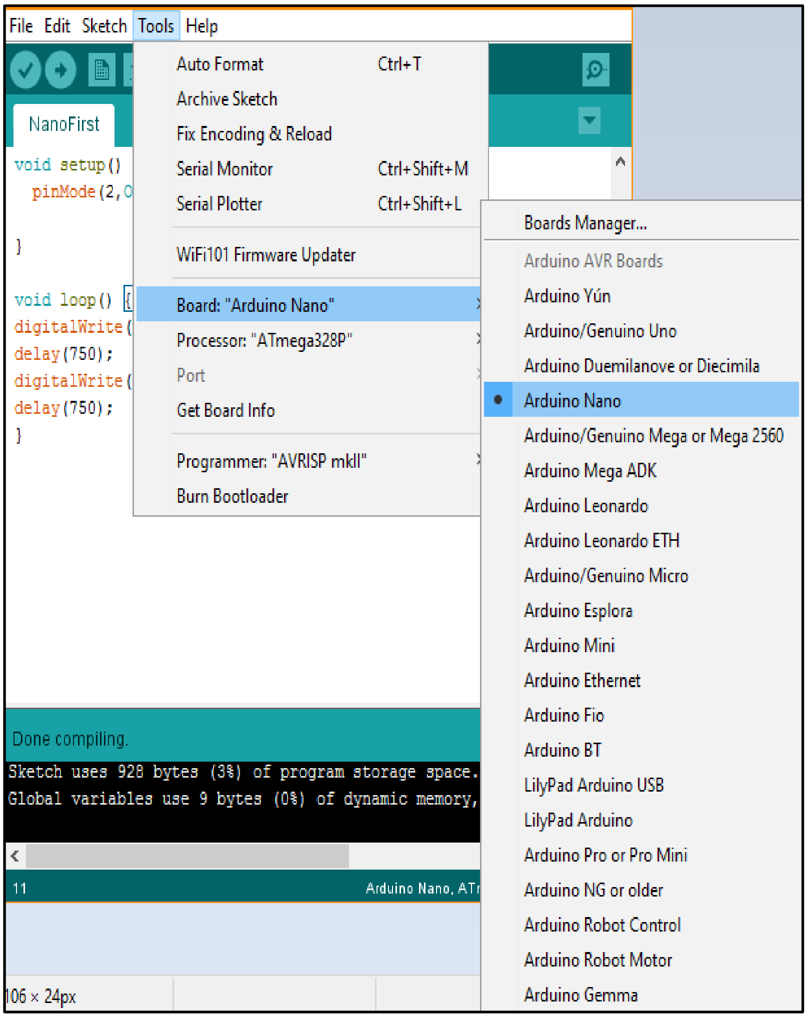


Fig 5.3 Arduino Nano Board Selection

If a board is currently selected it will be displayed here. If you don't know which package to use, or if it's missing from the list see Add a board to Arduino IDE as per shown in Fig 5.3. To add a board to the Arduino IDE, go to Tools in the menu bar and select Board Manager. From there, you can search for the desired board package and install it and make sure that you select correct port before uploading the code.Here, we used COM4. To select,go to tools and click on Port and select COM4 as in Fig 5.4. This process enables software developers to expand their options for microcontroller programming within the Arduino ecosystem.

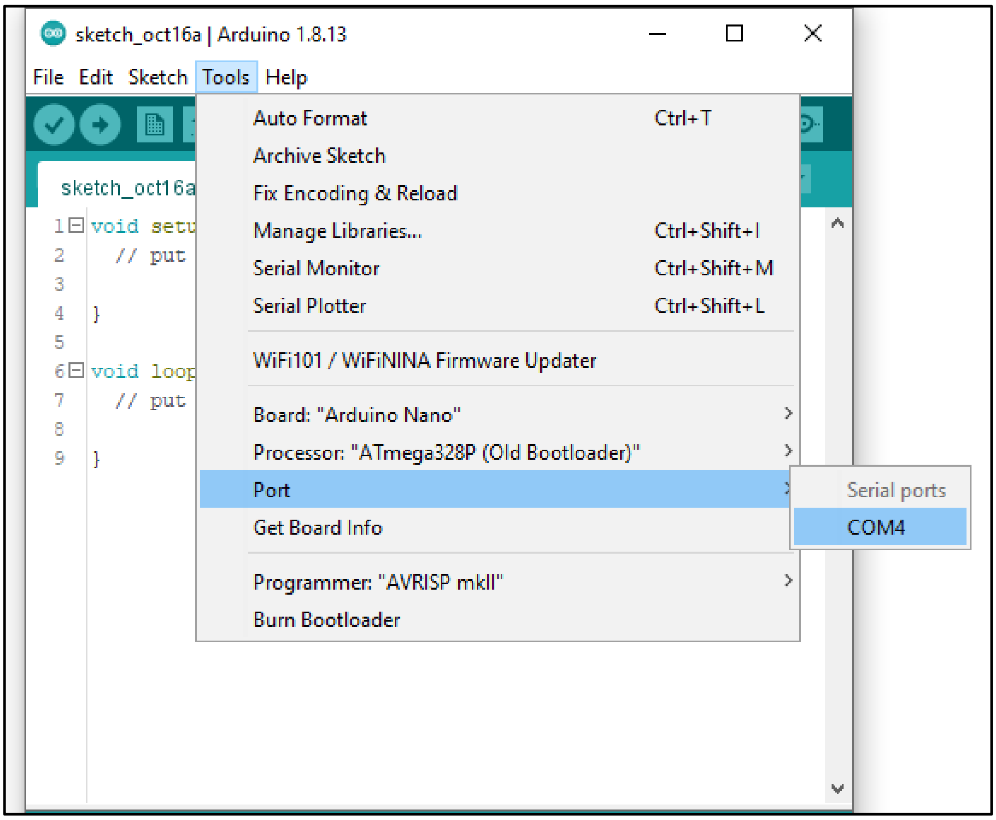


Fig 5.4 Port Selection

Chapter 6

INTEGRATION AND TESTING

6.1 Introduction

In this chapter, we delve into the critical aspects of integration and testing within the electromyography (EMG) controlled exoskeleton project. Integration involves the seamless merging of various components, including EMG sensors, Arduino microcontrollers, servo motors, and power supplies, to create a cohesive and functional system. Testing plays a pivotal role in validating the system's performance, ensuring accurate interpretation of muscle activity signals and precise control of movement. Through meticulous integration and rigorous testing, we aim to refine and optimize the exoskeleton's functionality, paving the way for enhanced mobility and improved quality of life for individuals with mobility impairments.

6.2 Integration and Testing

In our initial phase of integration and testing, our primary focus revolved around verifying the electromyography (EMG) sensor's efficacy in eliciting movement. Placing the EMG sensor on the arm as in Fig 6.1, we meticulously conducted a series of tests in conjunction with the SG90 servo motor. The outcome was promising, as evidenced by a discernible spin—a tangible indication of the sensor's operational functionality. Buoyed by this success, we proceeded to elevate our experimentation by transitioning to the exoskeleton framework, sans external supports. This pivotal transition entailed relocating the EMG sensor to the knee region, marking a crucial juncture in our exploration. Remarkably, the exoskeleton responded with synchronized movement, effectively traversing forward and backward in accordance with our directives.

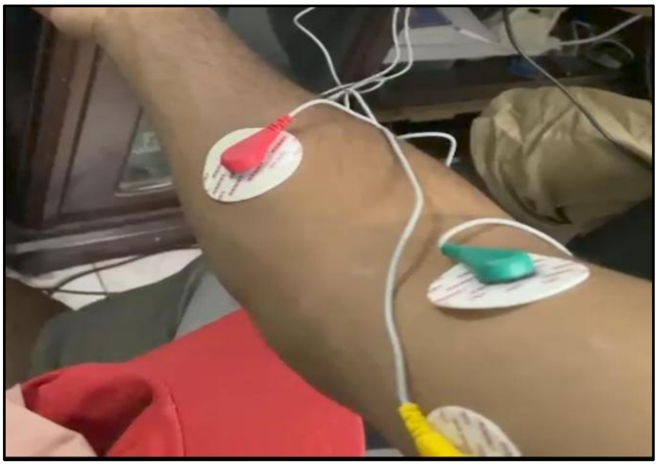


Fig 6.1 EMG testing

Amidst our progress, a significant challenge emerged—the SG90 servo motor exhibited limitations in effectively raising the exoskeleton's leg as in Fig 6.3. Undeterred, we swiftly sought a remedy, opting to replace the SG90 servo motor with the more robust MG995 variant. This critical enhancement proved instrumental as we successfully overcame the obstacle, reaffirming our unwavering commitment to advancing our project. Encouraged by the fruitful outcome of knee movement tests, our exploration progressed further, prompting us to delve into the complexities of ankle movement. This phase necessitated a meticulous reevaluation of the Arduino code to ensure the requisite independence and autonomy of both knee and ankle joints as in Fig 6.2.

Fig 6.2 Arduino Serial Plotter

Through a process of iterative refinement and relentless experimentation, we methodically navigated through the intricacies, steadily advancing towards our overarching objective. Our integration and testing endeavors stand as a testament to resilience, adaptability, and unwavering determination, epitomizing the spirit of scientific inquiry and technological innovation. In conclusion, our journey through the integration and testing phases of the electromyography (EMG) controlled exoskeleton project has been marked by perseverance, adaptability, and significant milestones. From the initial validation of the EMG sensor's functionality on the arm to its successful implementation within the exoskeleton framework, we have navigated through challenges and triumphs alike. The transition from the SG90 to the MG995 servo motor underscored our commitment to overcoming obstacles and achieving optimal performance. Furthermore, our exploration into ankle movement highlighted the intricacies of code refinement and system autonomy as in Fig 6.3.

Fig 6.3 Testing of Exoskeleton

Through meticulous experimentation and iterative refinement, we have laid a solid foundation for the development of a robust and functional EMG-controlled exoskeleton. As we move forward, our journey serves as a testament to the transformative power of scientific inquiry and technological innovation in enhancing mobility and improving quality of life for individuals with mobility impairments.The final outcome of the integration is shown in Fig 6.4 and Fig 6.5.

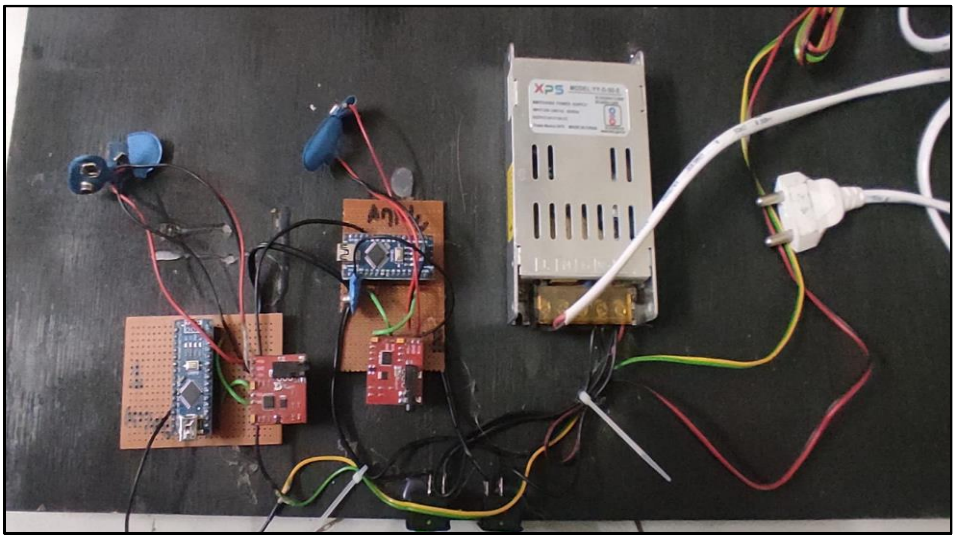


Fig 6.4 Component Integration

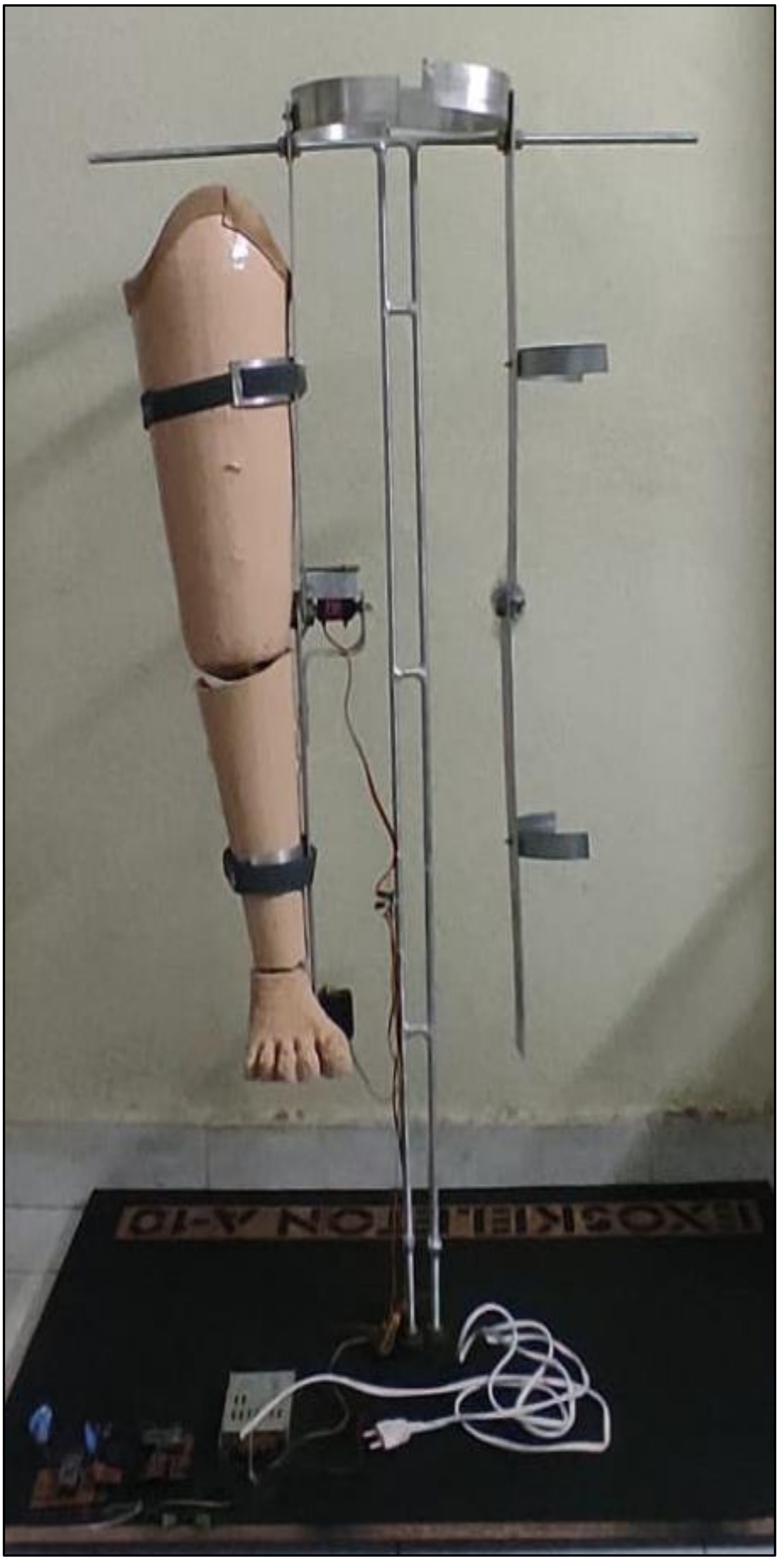


Fig 6.5 Final Exoskeleton

Chapter 7

RESULTS

STEP 1: Put the EMG Sensor patches on the knee you want to move in the exoskeleton. There are coloured EMG Electrode patches red, yellow and green. Make sure to place them correctly as per the user's muscle movement as shown below in Fig 7.1.

Fig 7.1 EMG on Knee joint

STEP 2: Without turning on SMPS, Select the correct port COM4, Arduino NANO board and take the limits of the EMG Sensor on the ankle on the serial monitor by uploading the Arduino code of the respective joint on Arduino IDE and note the limits.

STEP 3: After noting the limits, type the range into the Arduino code and upload it. Unplug the USB cable, switch on the ankle joint's green button, and then plug in the SMPS supply. So, when the EMG detects the movement in the knee then, if the value is in the pre-defined range, the exoskeleton gives movement in the knee then when the knee muscle moves 55 degrees and when there is no movement in muscle , the exoskeleton stays the same with no moment. we can observe the exoskeleton and the serial plotter as shown in Fig 7.2,7.3and 7.4.

Fig 7.2 Normal Position of Knee

Fig 7.3 Knee Position Changed by 55 degrees

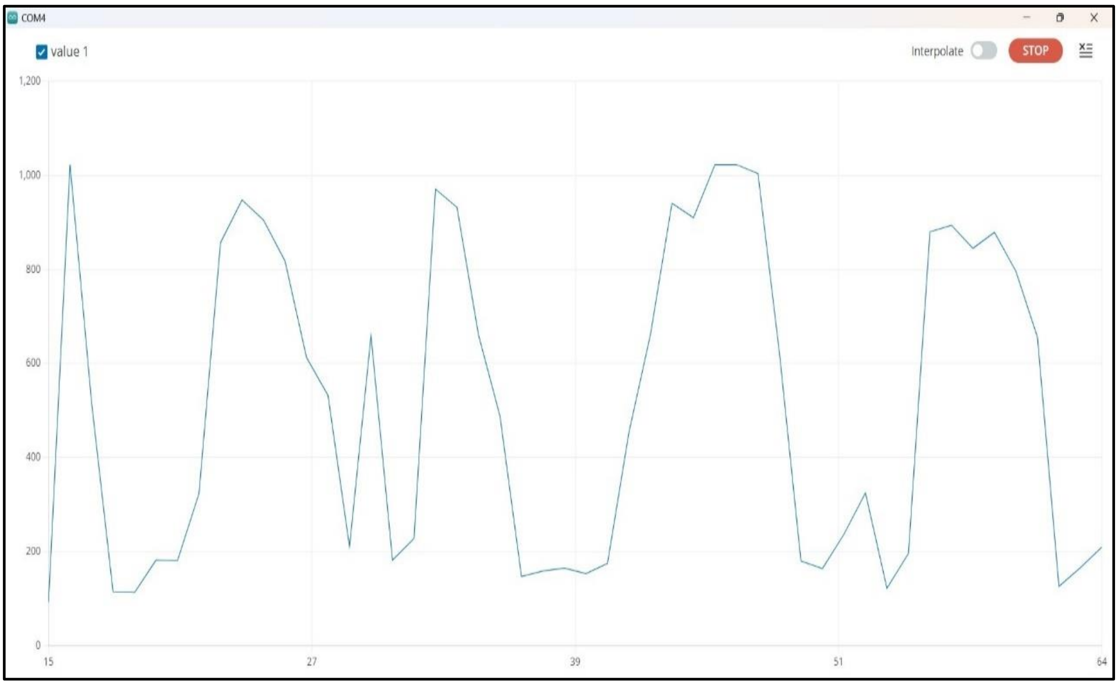


Fig 7.4 Arduino Serial Plotter for Knee

STEP 4: We can do the same for ankle joint which is placing the electrode patches correctly on the ankle joint, know the limits and then upload the limits into the code ,on muscle movement detection ,the exoskeleton at the ankle moves by the required angkle given in the code and observed that it makes an angle of 65 degrees as in Fig 7.5,7.6,7.7 and Fig 7.8.

Fig 7.5 EMG on Ankle joint

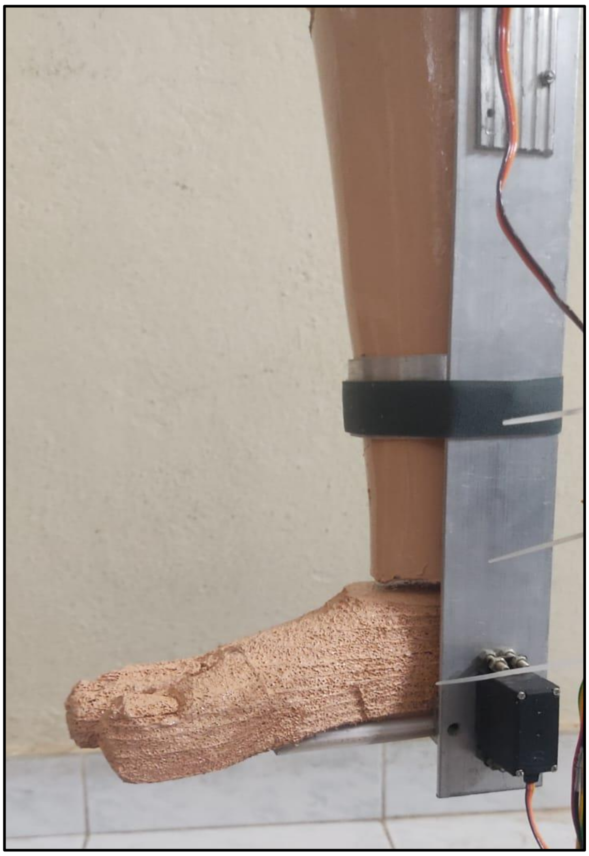


Fig 7.6 Normal Position of Ankle

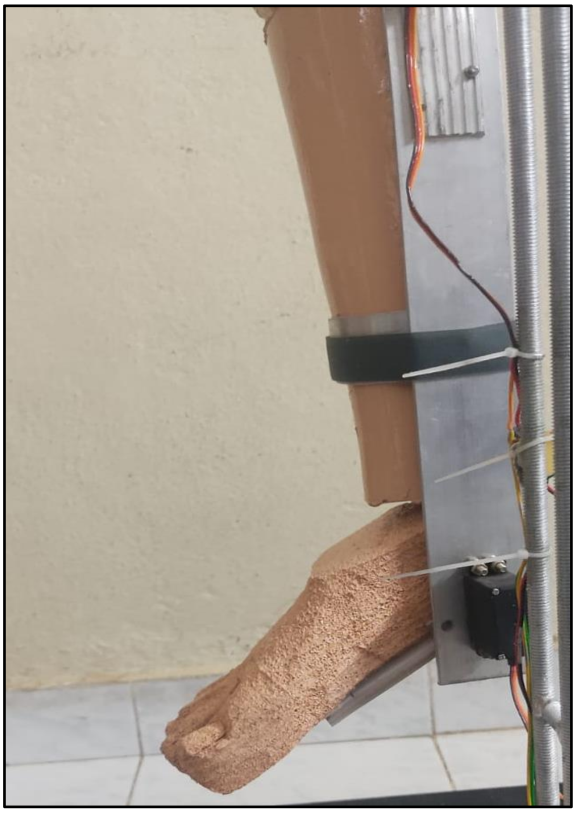


Fig 7.7 Ankle Position Changed by 65 degrees

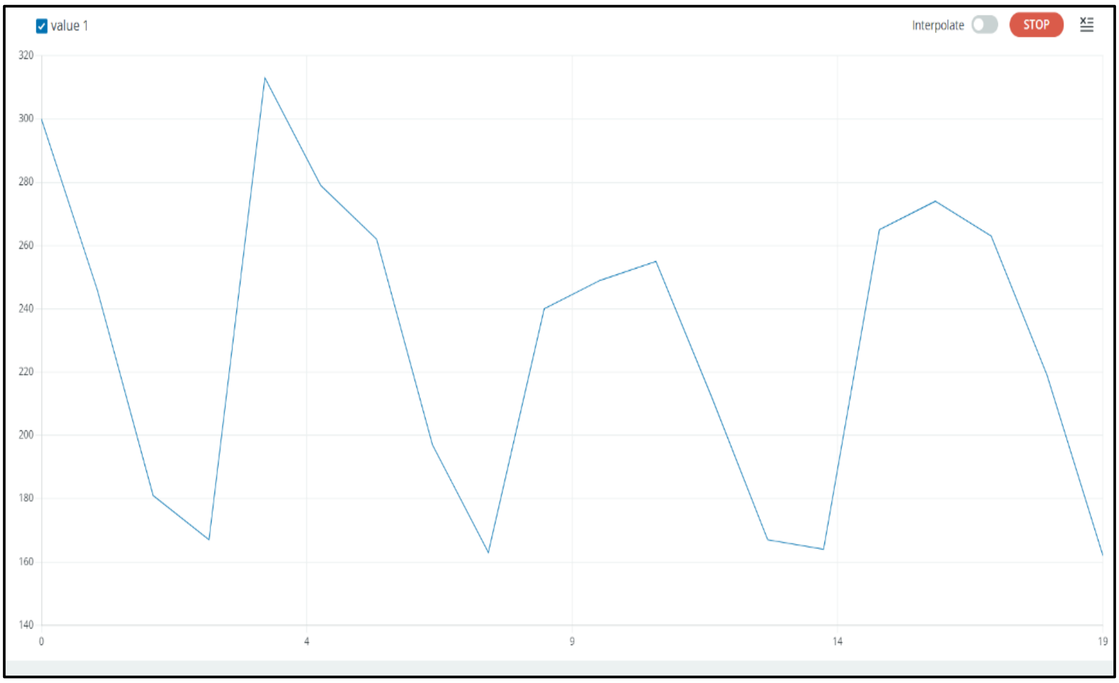


Fig 7.8 Arduino Serial Plotter for Ankle

As for the serial plotter ,we can see the higher and lower limits of EMG changing gradually by the movement of muscles in knee and ankle.

Chapter 8
CONCLUSION

8.1 Conclusion

In conclusion, the manufacturing and designing an inexpensive EMG human body lower limb exoskeleton has been a big step forward in assistive technology for rehabilitation purposes. This innovative system, using electromyography sensors and servo motors, provides control over the angles of joints, making it possible to walk more naturally during rehabilitation. The main focus on cost-effectiveness aims at increasing access to assistive technologies for many more people thus addressing the common problem of limited mobility resulting from muscle weakness.

8.2 Future Scope

The future scope of the "Design and Fabrication of a Low-Cost Human Body Lower Limb Exoskeleton with EMG" project is to include the addition of another leg to the existing single-leg functioning exoskeleton holds immense potential. This augmentation would enable bilateral assistance, enhancing stability and balance for users. Integration of synchronized control algorithms would facilitate coordinated movement between both legs, further optimizing mobility assistance. Additionally, the enhanced exoskeleton can be achieved by using BCI i.e Brain Computer Interface where we can use ECG for leg movements.

APPENDIX-I

PROJECT CODE

Knee Joint Arduino Code:

```
#include <Servo.h>
#define EMG_PIN 0
#define SERVO_PIN1 8
Servo SERVO_1;
void setup()
{
Serial.begin(115200);
SERVO_1.attach(SERVO_PIN1);
SERVO_1.write(25);
}
void loop()
{
int value = analogRead(EMG_PIN);
if(value >500  && value <700)
{
SERVO_1.write(55);
delay(1000);
  }
else
{
SERVO_1.write(25);
delay(500);
}
Serial.println(value);
delay(100);
}
```

Ankle Joint Arduino Code:

```
#include <Servo.h>
#define EMG_PIN 0
#define SERVO_PIN 8
Servo SERVO;
void setup()
{
Serial.begin(115200);
SERVO.attach(SERVO_PIN);
SERVO.write(45);
}
void loop()
{
int value = analogRead(EMG_PIN);
if(value <200&& value >150)
{
SERVO.write(65);
delay(1000);
```

```
}
else
{
SERVO.write(30);
delay(500);
}
Serial.println(value);
delay(100);
}
```

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