DESIGN AND DEVELOPMENT OF ROBOTIC ACTUATOR

A PROJECT REPORT

Submitted by

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In partial fulfillment for the award of the degree of

BACHELOR OF ENGINEERING

in

Electrical Engineering Department

Vishwakarma Government Engineering College Chandkheda, Ahmedabad

Gujarat Technological University, Ahmedabad

[May-2023]

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Vishwakarma Government Engineering College

CERTIFICATE

This is to certify that the internship report submitted along with the internship entitled **"DESIGN AND DEVELOPMENT OF ROBOTIC ACTUATOR"** has been carried out by **VYAS NAMAN KARTIKBHAI** Enrollment number **190170109145** under my guidance in partial fulfillment of the requirement for the subject **Internship (3180901)** of Bachelor of Engineering **Semester 8th Electrical** at Vishwakarma Government Engineering College.

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DECLARATION

I confirm that the Internship report accompanying the Internship program titled "**DESIGN AND DEVELOPMENT OF ROBOTIC ACTUATOR**" which I have submitted to fulfill the requirements for the Bachelor of Engineering degree in the Electrical Department at Vishwakarma Government Engineering College, Chandkheda, affiliated to Gujarat Technological University, Ahmedabad, is a genuine account of my original project work conducted at Tesseract Robotics. I completed this internship under the guidance of Mr. Shail Jadav, and I certify that I have not directly copied any content from any other student's reports or any other sources without providing proper references.

Name of Student	**Sign of Student**
VYAS NAMAN KARTIKBHAI	___________________

ACKNOWLEDGEMENT

I feel fortunate to have had the opportunity to intern at Tesseract Robotics, as it allowed me to gain valuable knowledge and grow professionally. I am grateful for the chance to be a part of such an experience. Additionally, I would like to express my gratitude to my mentors, **Prof. P.J. Purohit** and the Head of the Electrical Engineering Department, **Prof. (Dr.) Saurabh N. Pandya**, for their support, guidance, advice, and encouragement throughout the internship.

I am filled with happiness and gratitude as I express my appreciation to the individuals who assisted me during my internship. I am deeply thankful to **Dr. Nilay N. Bhuptani**, the Principal, for providing me with the necessary resources to complete my internship successfully. I would also like to extend my thanks to the Electrical Department's Professors, including **Prof. Divyesh J. Vaghela**, **Prof. Dilip R. Dobariya**, **Prof. A.T. Mistry**, and **Prof. Hiren Zala**, for their support and constructive feedback that proved invaluable to me.

I extend my heartfelt gratitude to **Assoc. Prof. Harish P. M, Mr. Arpit Sakhareliya and Mr. Shail Jadav,** Co-Founders of Tesseract Robotics, for their valuable input, advice, and guidance, as well as for providing all the necessary resources to make my internship experience more manageable. Furthermore, I am thankful for the opportunity to have met numerous incredible people at Tesseract Robotics and professionals who supported me throughout my internship.

VYAS NAMAN KARTIKBHAI

ABSTRACT

This internship program focuses on developing a comprehensive understanding of the fundamental principles and techniques involved in designing a reliable and efficient actuation system, specifically a Robotic Actuator. It covers various aspects of actuator design, including load analysis, component selection, topology selection, and system integration. The program starts by introducing trainees to the basics of power electronics and the different types of actuator systems available. They will learn about the different components of an actuator, such as prime mover, prime mover controller circuit, batteries, and static switches, and the various topologies of robotic actuator systems. The program emphasizes designing an actuator system from scratch, beginning with load analysis and component selection, with a focus on the significance of load analysis and the various factors that affect it. Trainees will also learn how to select different components of an actuator system based on the load analysis.

Furthermore, the internship program will include an in-depth study of Actuator system control and the principles of feedback control systems. I will gain knowledge on how to design a control system for the Actuator system using various control techniques such as Proportional-Integral-Derivative (PID) control, Fuzzy logic control, and Model Predictive control. Additionally, I will learn about the protection system design for the Actuator system, including short circuit protection, overvoltage protection, and overcurrent protection. The monitoring system design will also be covered, where I will gain insight into how to monitor the Actuator system's performance and condition through various monitoring methods such as voltage and current monitoring, temperature monitoring, and vibration monitoring. Through this program, I will also learn how to troubleshoot and resolve common issues that arise during the design and testing of an Actuator system.

List of figures:

List of Abbreviation

PID	**Proportional Integral Derivative**
CAD	**Computer Aided Design**
CNC	**Computer Numerical Control**
BOM	**Bill Of Material**
DC	**Direct Current**
BLDC	**BrushLess Direct Current**
MCB	**Miniature Circuit Breaker**
MCCB	**Molded Case Circuit Breaker**
PWM	**Pulse Width Modulation**
RPM	**Rotation Per Minute**
DSO	**Digital Storage Oscilloscope**
PCB	**Printed Circuit Board**
PLA	**Poly Lactic Acid**
I2C	**Inter Integrated Circuit**
SPI	**Serial Peripheral Interface**

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CHAPTER-1

INTRODUCTION OF LAB

1.1 ABOUT SYSIDEA ROBOTICS LAB

Nestled within the vibrant campus of the Indian Institute of Technology Gandhinagar (IITGN), the SYSIDEA Robotics Lab stands as a bastion of innovation and exploration in the realm of robotics. Located within the Mechanical Engineering Department, this prestigious lab is at the forefront of cutting-edge research, spanning a diverse array of projects that delve into the intricacies of robotics and related fields.

The SYSIDEA Robotics Lab serves as a melting pot for a multitude of projects, each rooted in fundamental engineering principles. The research spectrum extends from the theoretical realms of dynamics, control theory, and systems theory to the practical domains of computational simulations, table-top experiments, and even human subject studies.

1.2 INCUBATING INNOVATION: STARTUPS

A testament to the entrepreneurial spirit within the lab's ecosystem is the emergence of robotics startups. These ventures, fuelled by Nidhi Prayas grants and incubated by IIT Gandhinagar, exemplify the practical applications and commercial potential of the lab's research.

1.2.1 TESSERACT ROBOTICS

Tesseract Robotics, a product of SYSIDEA's fertile innovation ground, pioneers' advancements in Robotic actuator motor drivers. Leveraging the foundational research of robotics smooth motion from the lab, Tesseract Robotics has secured funding and support to transform theoretical brilliance into market-ready solutions.

The company's commitment to precision and accuracy is evident in the quality of their products, which are designed to meet the rigorous demands of modern robotics applications. The products of Tesseract Robotics include normal DC motor driver, smart DC motor driver combined with ESP32 microprocessor, smart BLDC motor driver, and robotic actuators. These products are designed to provide high performance and reliability, making them suitable for use in various industries, such as manufacturing, healthcare, and logistics.

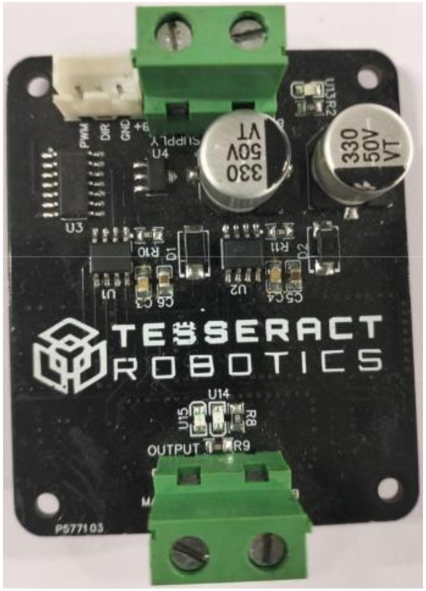

Figure 1: DC MOTOR DRIVER

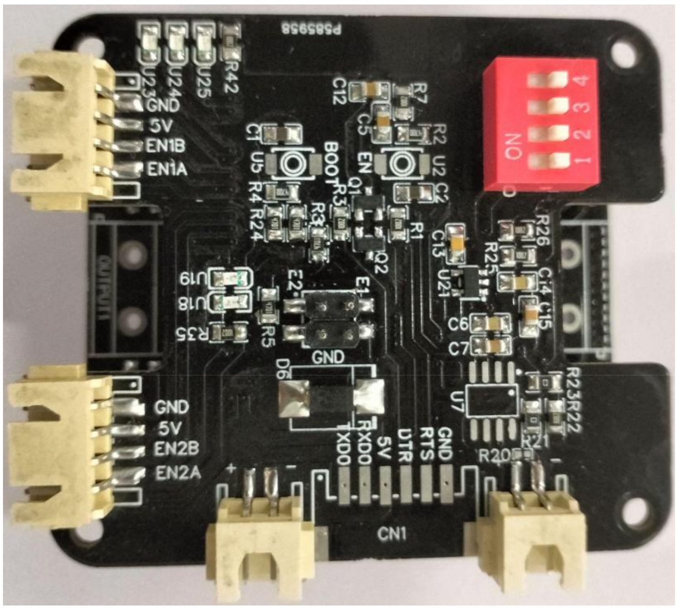

Figure 2: SMART DC MOTOR DRIVER

Operating Voltage: 12/24 v

Rated Current: 30 A

Singal Channel Motor Control

Operating Voltage: 12/24

Rated Current: 30 A

Dual Channel Motor Control

1.2.2 SASTRA INNOVATION LABS

Sastra Innovation Lab, another feather in the cap of SYSIDEA Robotics Lab's entrepreneurial ecosystem, adds smarter solutions to robotic Gripper technologies and related fields . This startup, fostered within the lab, epitomizes the diverse range of innovations springing forth from collaborative research efforts.

1.3 LEADERSHIP

Heading the helm of the SysIDEA Robotics Lab is Professor Harish P. M, serving as the lab's Director and an esteemed Associate Professor in the Mechanical Engineering Department at IIT Gandhinagar. With a versatile expertise encompassing control systems and theory, signal and systems, robotics, mechanism synthesis and analysis, and system identification, Professor Harish is a guiding force steering the lab towards uncharted territories of research and innovation.

In essence, the SysIDEA Robotics Lab transcends the conventional notion of a workplace; it stands as a dynamic ecosystem where theoretical concepts seamlessly metamorphose into practical solutions. It's a breeding ground where collaboration begets innovation, and the fertile soil where the seeds of startups find nourishment to flourish. As we navigate the intricacies of this haven for robotics, we embark on a transformative journey of exploration, discovery, and evolution.

CHAPTER-2

A BRIEF UNDERSTANDING OF AN ACTUATOR

2.1 WHAT IS AN ACTUATOR?

Actuators are an essential component of many mechanical systems, and they are used to create motion or movement in response to a control signal. These control signals can be electrical, hydraulic, pneumatic, or even manual in nature, and the actuator is responsible for converting this signal into motion. In other words, an actuator is a device that transforms energy into motion.

There are various types of actuators available in the market, including hydraulic, pneumatic, and electric actuators. Hydraulic actuators are powered by pressurized fluids, and they are known for their high force capabilities and precision. Pneumatic actuators, on the other hand, are powered by compressed air and are commonly used in industrial automation systems. Electric actuators are driven by electric motors and are ideal for applications that require precise control and accuracy.

Actuators are used in many different industries and applications, including aerospace, automotive, robotics, and medical devices. In aerospace, for example, actuators are used to control the movement of flaps and other control surfaces on an aircraft. In the automotive industry, they are used in power windows, door locks, and seat adjusters. In robotics, they are used to control the movement of robotic arms and grippers, as well as in the actuation of various sensors and other components.

Robotic actuators are a specific type of actuator that is designed for use in robotics applications. They are typically smaller in size and have higher torque capabilities than standard actuators, making them ideal for use in robotic systems. These actuators are designed to provide precise and controlled motion, which is essential for the operation of robotic systems.

There are various types of robotic actuators, including rotary actuators, linear actuators, and even piezoelectric actuators. Rotary actuators are used to produce rotational motion, while linear actuators produce linear motion. Piezoelectric actuators are used to produce precise and rapid movements, and they are commonly used in micro- and nanoscale applications.

2.2 TYPES OF ACTUATORS

There exists a plethora of actuator types available in the market, with each type possessing unique characteristics that make them well-suited for various applications. The most common types include hydraulic, pneumatic, electric, and piezoelectric actuators.

Hydraulic actuators operate by converting hydraulic pressure into linear or rotary motion. This type of actuator is ideal for heavy-duty applications that require high force and torque

Figure 3: HYDRAULIC ACTUATOR

output. On the other hand, pneumatic actuators utilize compressed air to create force and motion, making them suitable for applications that require a clean and quiet operation.

Electric actuators, as the name suggests, use electrical energy to create motion. This type of actuator has the advantage of being more precise and controllable than other types, making them suitable for applications that require accuracy and repeatability. Piezoelectric actuators utilize piezoelectric materials to convert electrical energy into mechanical displacement, making them ideal for applications that require high precision, such as in semiconductor manufacturing.

Ultimately, the choice of actuator depends on the specific application requirements,

Figure 4: ELECTRIC ACTUATOR

including load capacity, accuracy, speed, and environment. The selection process involves considering factors such as cost, efficiency, reliability, and ease of maintenance.

2.3 APPLICATIONS OF ACTUATOR IN ROBOTICS

Actuators play a crucial role in the field of robotics as they provide the necessary motion and force required for robots to perform various tasks.

Robotics applications that use actuators can be found in a wide range of industries, including automotive, aerospace, healthcare, manufacturing, and more.

In automotive manufacturing, robots equipped with actuators are used to perform tasks such as welding, painting, and assembly of components. Aerospace applications use actuators to control the flaps, rudders, and other control surfaces of aircraft.

In healthcare, robotic actuators are used in prosthetics and rehabilitation devices to provide movement to the user. In manufacturing, robotic actuators are used to handle materials, perform cutting and shaping operations, and assemble products.

Actuators are also used in research and development of robotics systems to create more precise and efficient movements. This is particularly important in the development of humanoid robots, where the use of advanced actuators is necessary to achieve natural and lifelike movements.

2.4 TYPES OF ACTUATORS IN ROBOTICS

2.4.1 Electric Actuators:

Electric actuators are the most commonly used actuators in robotics. They are easy to control and provide high accuracy and precision. They include DC motors, stepper motors, and servo motors. Examples of electric actuators in robotics include linear actuators, grippers, and rotary actuators.

There are several types of electric actuators that are used in robotics, including:

Linear Electric Actuators: These actuators are designed to convert rotational motion into linear motion. They are commonly used in pick-and-place operations, packaging, and assembly processes.

Figure 5: LINEAR ELECTRIC ROBOTIC ACTUATOR

Rotary Electric Actuators: These actuators are designed to rotate objects in a precise and controlled manner. They are commonly used in robotics for tasks such as positioning, gripping, and turning objects.

Figure 6: ROTARY ELECTRIC ROBOTIC ACTUATOR

Stepper Motor Actuators: These actuators are designed to move in small and precise steps, making them ideal for tasks that require accuracy and repeatability. They are commonly used in robotics for tasks such as 3D printing, CNC machining, and robotics motion control.

Figure 7: STEPPER MOTOR ACTUATOR

Servo Motor Actuators: These actuators are designed to provide precise control over the position, speed, and torque of a motor. They are commonly used in robotics for tasks that require high accuracy and precision, such as robotics arm movement, camera positioning, and automation.

Figure 8: SERVO MOTOR ACTUATOR

2.4.2 Pneumatic Actuators:

Pneumatic actuators are powered by compressed air and are commonly used in industrial automation applications. They are known for their high force-to-weight ratio and high-speed operation. Examples of pneumatic actuators used in robotics include air muscles, diaphragm actuators, and bellows actuators.

Figure 9: PNEUMATIC ACTUATOR WITH DIRECTION CONTROL VALVE

CHAPTER-3
MECHANICAL DESIGN AND ANALYSIS

The design and analysis of an actuator play a crucial role in the performance and efficiency of a robotic system. The mechanical design of an actuator involves selecting the right prime mover, such as a motor, and deciding on the type of gearbox and gear ratio, if necessary.

In this chapter, we will discuss the mechanical design and analysis of an actuator, with a focus on a DC motor-based actuator designed in SolidWorks.

We will explore the process of designing a part and assembling it, along with the various features of SolidWorks that aid in analysis, such as finite element analysis, motion study, and fatigue test. This chapter will provide a comprehensive overview of the mechanical design process and the key factors to consider when designing an actuator for a robotic system.

To design an actuator, the first step is to choose its prime mover, such as a motor. The type of motor used can vary, and may be AC or DC, with or without a gearbox. If a gearbox is added, the gear ratio must also be considered.

Figure 10: DC BRUSHED MOTOR

Figure 11: DC BRUSHED MOTOR WIRE CONNECTION

After researching various DC or BLDC motors, I decided to start designing with a 775 DC motor. This motor has the following specifications: 12V, rated current of 1.2A, no-load speed of 12,000 RPM, stall torque of 0.1 N.m, and a weight of 350 grams.

Figure 12: ISOMETRIC DC BRUSHED MOTOR

3.1 SOFTWARE USER INTERFACE

To begin the design process, I utilized SolidWorks, a powerful computer-aided design (CAD) software that allows for precise and accurate modeling of mechanical components.

SolidWorks offers a variety of functionalities, including creating parts, assemblies, and drawings.

Figure 13: SOLIDWORKS LOGO

Additionally, the software provides features such as finite element analysis, wire routing, photo rendering, motion study, drop test, and fatigue test, among others.

Figure 14: SOLIDWORKS USER INTERFACE

The SolidWorks interface has three main features: Create Part, Assembly, and Drawing. Each feature has different functionalities that are essential in designing a mechanical actuator.

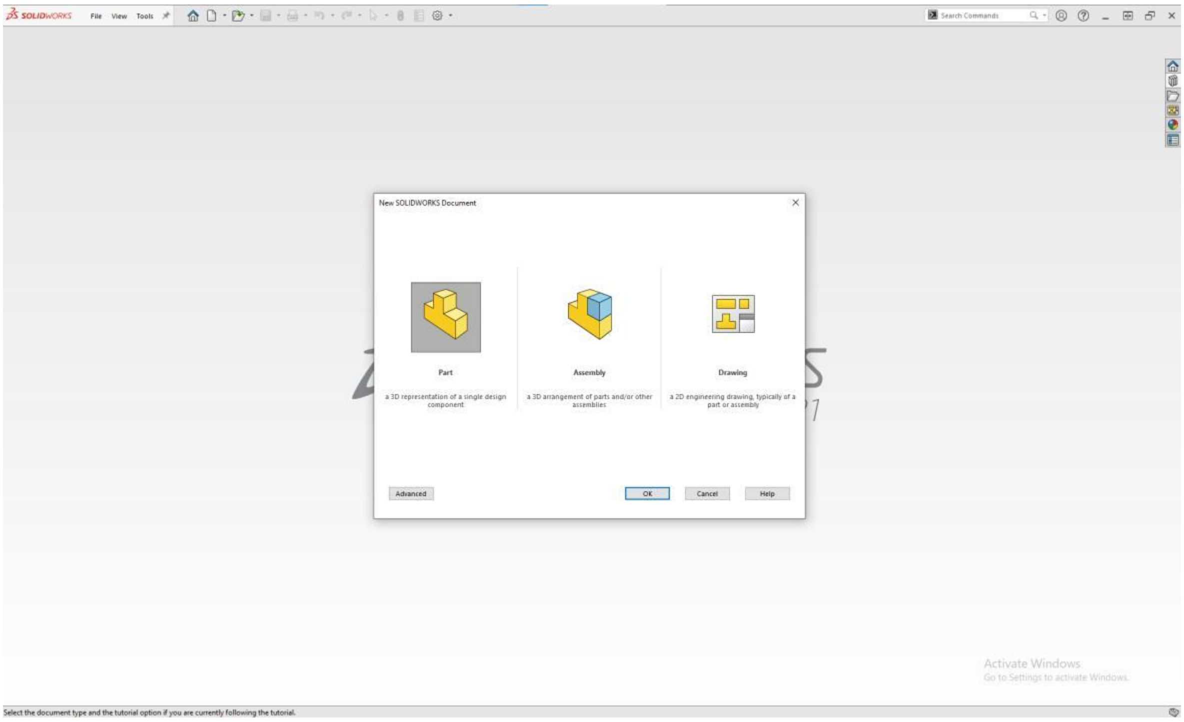

Figure 15: PRIMARY OPTIONS SHOWN IN SOLIDWORKS

Create Part:

This feature provides the facility to sketch in different planes such as the top plane, front plane, and right plane.

It allows the user to create any components with different methods like solid part, hollow, surface finishing, weldments, structure systems, etc.

By selecting the Create Part feature, the user can start designing the parts of the actuator, which will be assembled later in the Assembly feature.

Assembly:

The Assembly feature allows the user to assemble the designed parts to form the complete actuator.

The user can select different parts and components from the Create Part feature and assemble them using mates and constraints to ensure they fit together precisely.

This feature also allows the user to check the interference and clearance between the components, which is essential in ensuring that the actuator functions properly.

Drawing:

The Drawing feature provides the facility to create a technical drawing of the designed actuator.

This feature enables the user to create 2D or 3D views of the actuator, which can be used for manufacturing and assembly purposes.

The user can add dimensions, annotations, and other details to the drawing to ensure that the actuator is manufactured correctly.

In mechanical design, planes are used to create a reference surface that is perpendicular or parallel to an axis.

They help in defining the orientation and position of sketches, features, and components in 3D space. The three main planes used in mechanical design are:

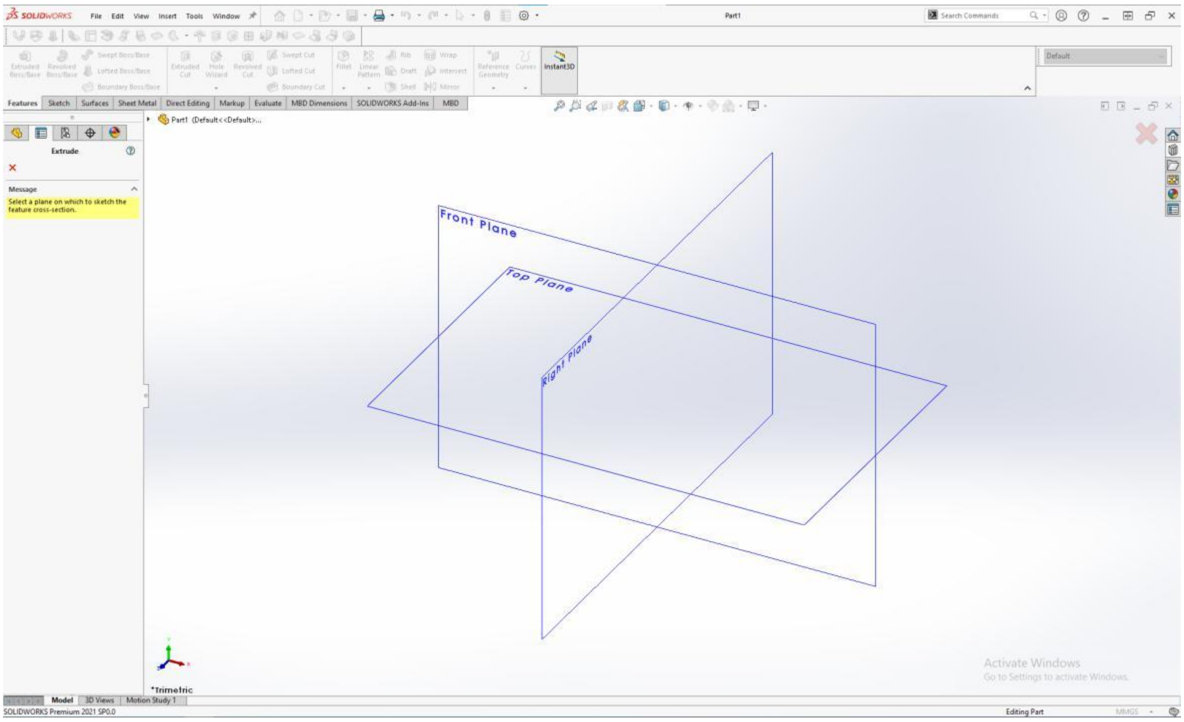

Figure 16: PRIMARY PLANES SHOWN IN SOLIDWORKS

As shown in the figure there are three basic planes in the interface.

1.) Top plane:

This plane is perpendicular to the front and right planes and defines the height of the part or assembly.

It is used to create sketches or features that are parallel to the ground or horizontal to the workspace.

2.) Front Plane:

This plane is perpendicular to the top and right planes and defines the depth of the part or assembly.

It is used to create sketches or features that are facing the user or in the front view of the design.

3.) Right Plane:

This plane is perpendicular to the top and front planes and defines the width of the part or assembly.

It is used to create sketches or features that are perpendicular to the front or top view of the design.

After introducing the concept of planes in mechanical design, you could discuss the various methods of creating components using solid modeling techniques. Some topics to cover could include:

Extruding:

This involves taking a 2D sketch and extending it in a certain direction to create a 3D object. This is useful for creating simple parts such as blocks or shafts.

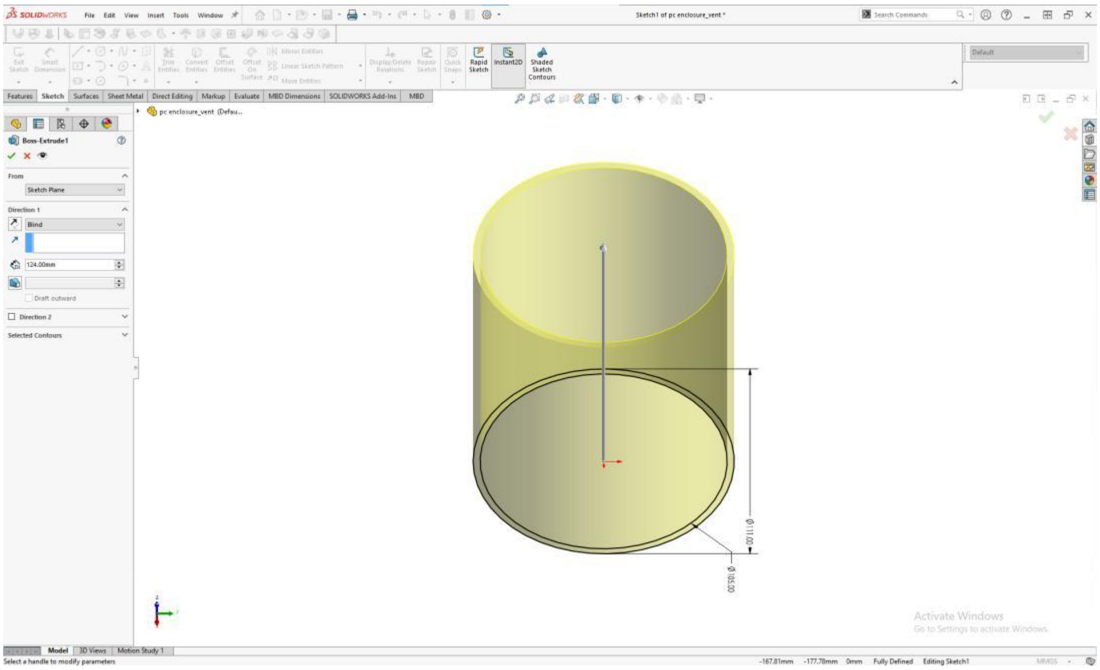

Figure 17: EXTRUDING SHOWN IN SOLIDWORKS

Revolving:

This involves taking a 2D sketch and rotating it around an axis to create a 3D object. This is useful for creating parts with circular symmetry such as wheels or gears.

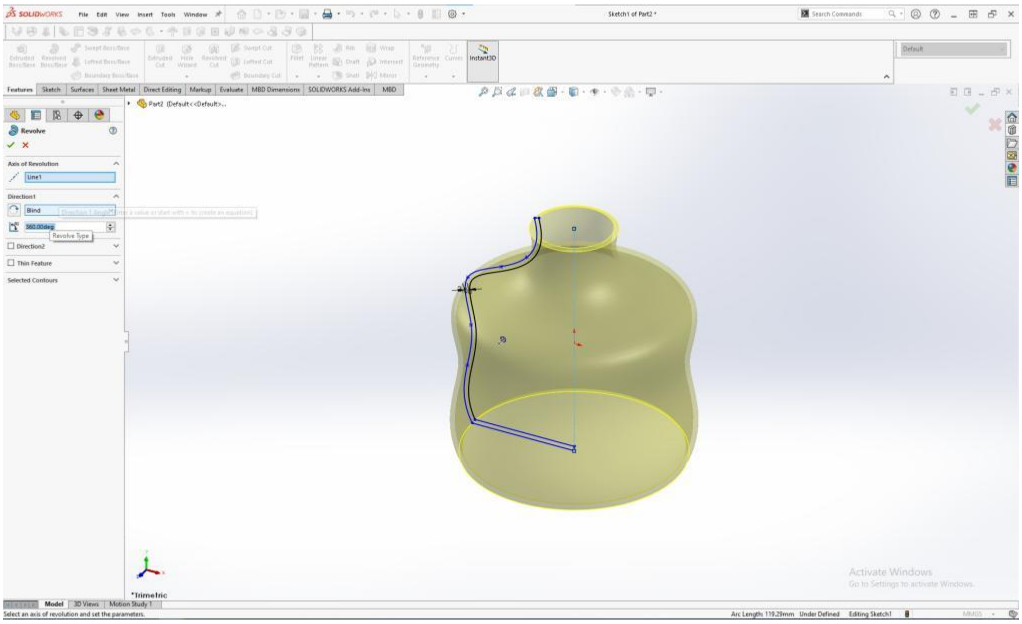

Figure 18: REVOLVING SHOWN IN SOLIDWORKS

Sweeping:

This involves taking a 2D sketch and extruding it along a path to create a 3D object. This is useful for creating parts with complex shapes such as pipes or cables.

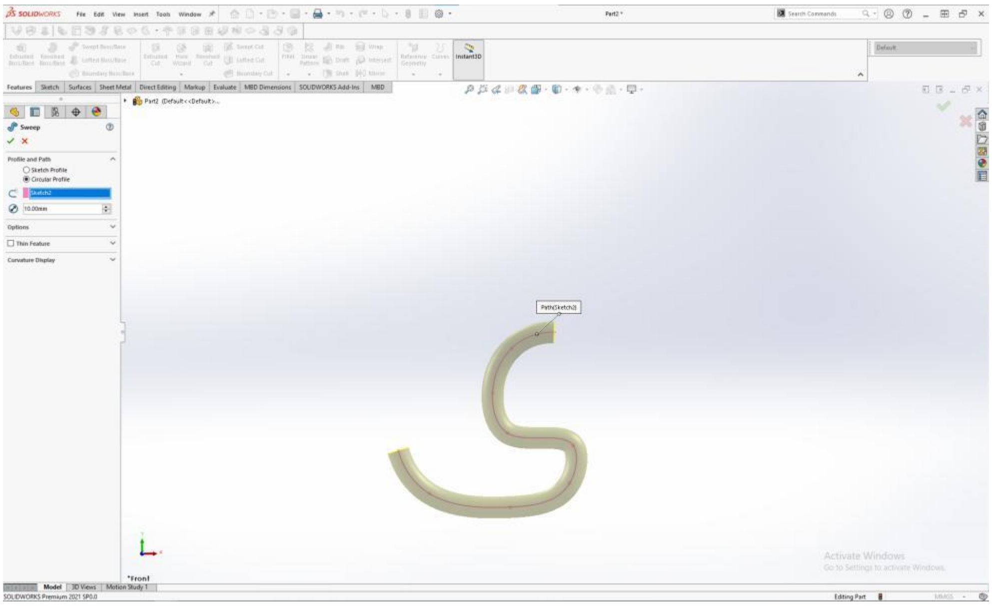

Figure 19: SWEEPING SHOWN IN SOLIDWORKS

Lofting:

This involves creating a shape by interpolating between two or more cross-sections. This is useful for creating complex parts with curved surfaces such as airplane wings or car bodies.

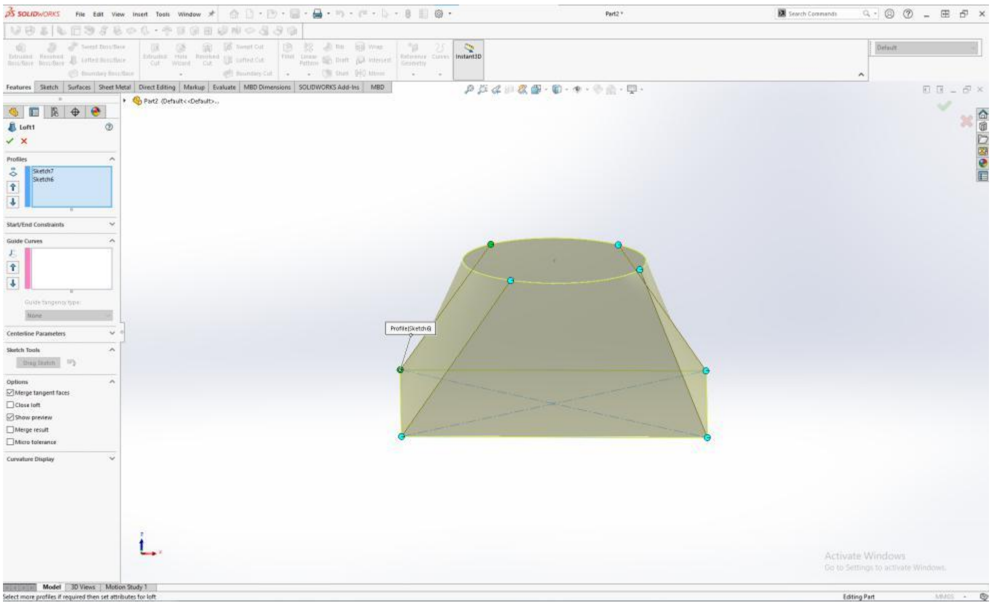

Figure 20: LOFTING SHOWN IN SOLIDWORKS

Filleting :

These are techniques used to add rounded or beveled edges to a part. This is important for improving the strength and durability of a part, as well as its aesthetic appeal.

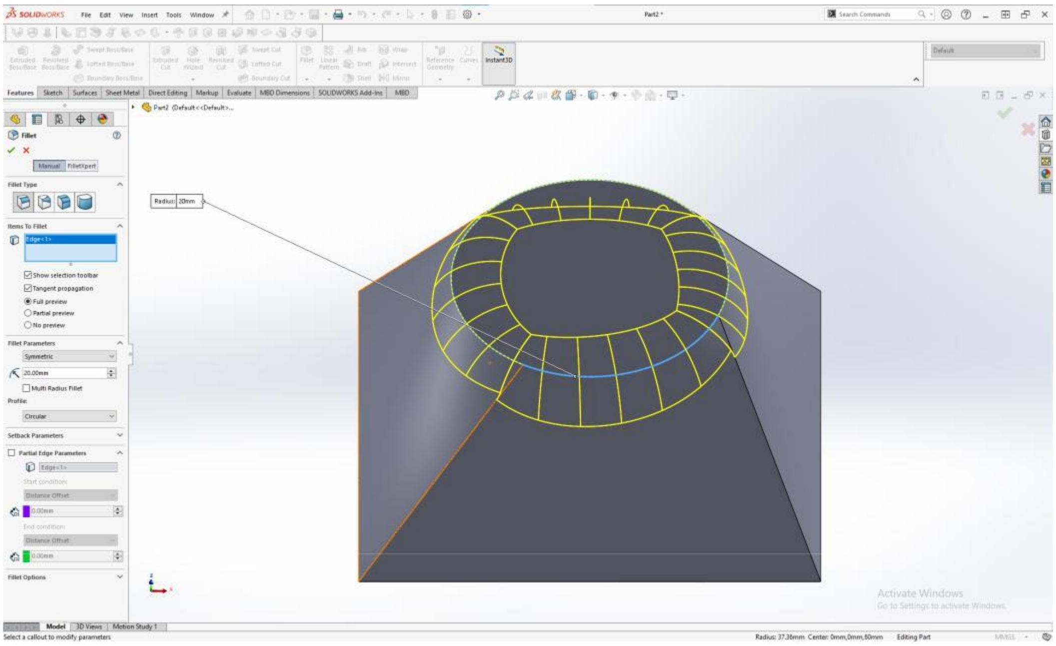

Figure 21: FILET SHOWN IN SOLIDWORKS

Chamfering :

Chamfers are commonly used to improve the appearance of parts and to make them easier to handle or assemble.

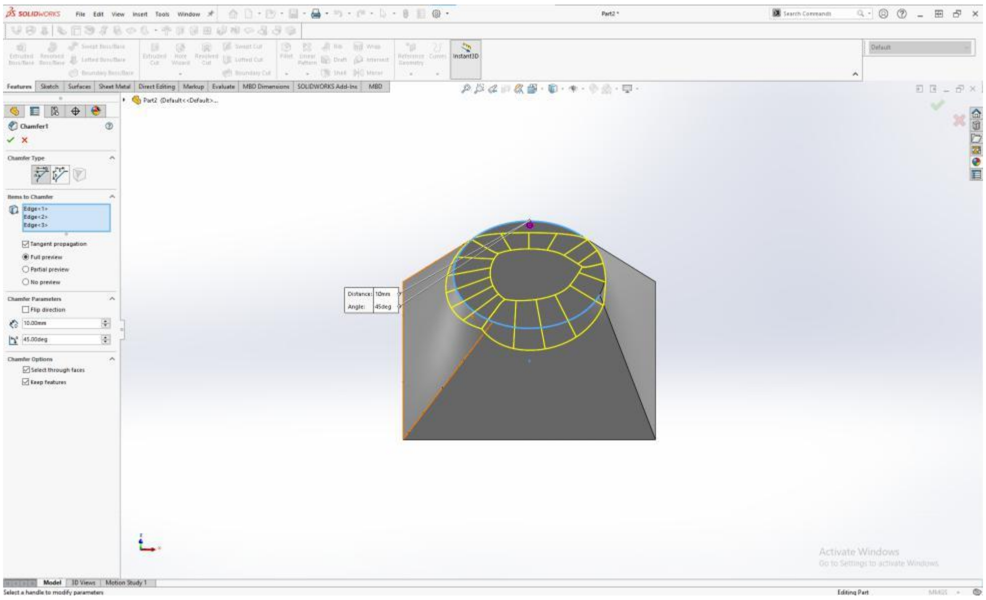

Figure 22: CHAMFER SHOWN IN SOLIDWORKS

3.2 DESIGN ANALYSIS IN SOLIDWORKS SIMULATION

Simulations in SolidWorks provided a virtual representation of the parts, which helped the team to detect and correct any issues with the design before creating physical parts.

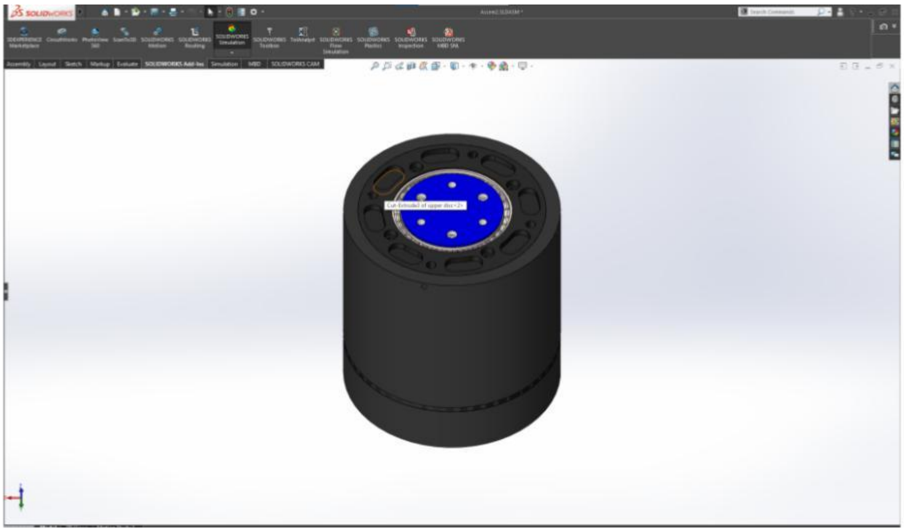

Figure 23: BEFORE SIMULATION

Simulations in SolidWorks provided a virtual representation of the parts, which helped the team to detect and correct any issues with the design before creating physical parts. Simulations in SolidWorks provided a virtual representation of the parts, which helped the team to detect and correct any issues with the design before creating physical parts.

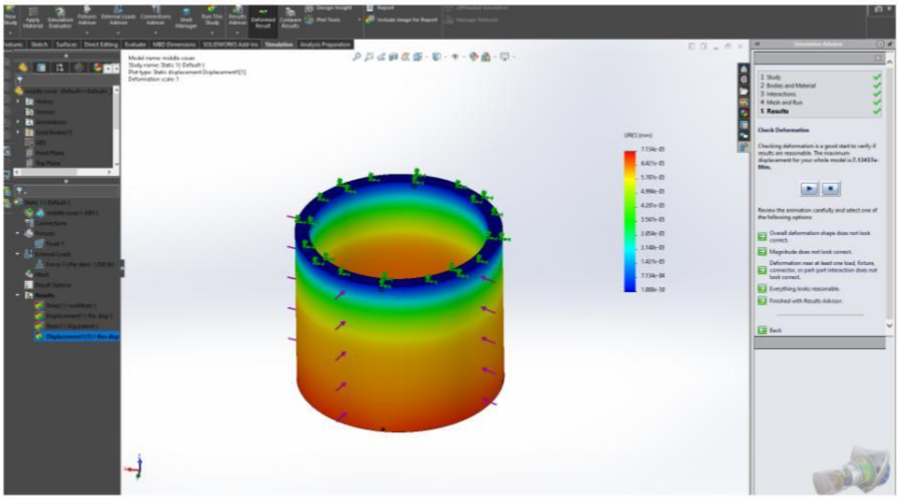

Figure 24: AFTER SIMULATION (STRENGTH CHECK)

This approach also saved time and resources that may have been wasted on trial and error during the physical prototyping process. By utilizing both simulation and 3D printing technologies, the team was able to minimize the risk of errors and increase the accuracy of the final design.

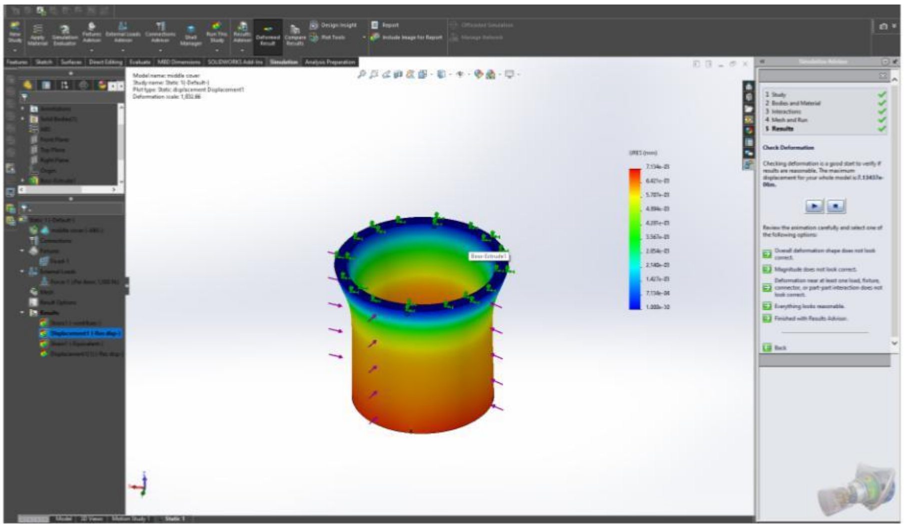

Figure 25: AFTER SIMULATION (STRAIN CHECK)

The combination of these technologies is becoming increasingly common in many industries, as it offers a more efficient and reliable way of testing and validating designs.

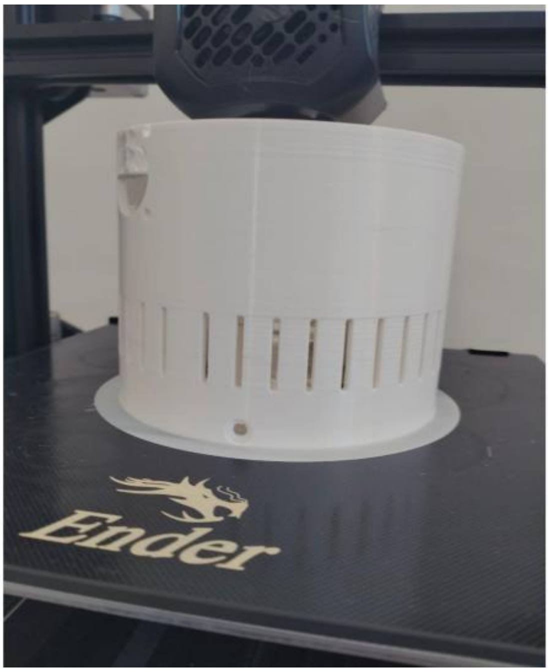

Figure 26: 3D PRINTING OF OUTER CASE

It is common practice to cover the 775 DC motor and 40:1 gear reduction gearbox in parallel to protect them from external factors such as dust, moisture, and other contaminants.

Figure 27: PARALLELY ATTACHED DC MOTOR AND GEARBOX WITH 3D PRINTED PARTS

The cover can also help to reduce the noise level of the motor during operation. The design of the cover should take into consideration the size and shape of the motor and gearbox, as well as any ventilation needs to prevent overheating.

Figure 28: A COMPLETE PROTOTYPE OF THE ACTUATOR

It should also be made of a material that can withstand the environmental conditions and protect the internal components adequately. Overall, using a cover to protect the motor and gearbox can help extend their lifespan and ensure their efficient operation, making it an essential component of the motor and gearbox setup.

CHAPTER-4
ELECTRONICS SELECTION AND PCB MAKING

Now that we have designed the mechanical components of our actuator, it is time to focus on the electronics that will control its movement.

In this chapter, we will discuss the process of selecting the appropriate electronic components for our actuator and designing a printed circuit board (PCB) to control them. The choice of electronic components and the design of the PCB are critical to ensure the reliable and precise operation of the actuator.

We will explore various factors that influence the selection of electronic components, such as voltage and current requirements, signal processing needs, and communication interfaces. Additionally, we will discuss the process of designing a custom PCB using software tools, including schematic capture and PCB layout editors. The resulting PCB will provide a compact and efficient platform to interface with the actuator's sensors and control circuitry.

4.1 PCB MAKING

The process of creating a PCB involves four crucial steps which include selecting suitable components, designing the schematic, routing the design within the desired PCB dimensions, and finally, prototyping.

4.1.1 APPROPRIATE COMPONENT SELECTION:

The first step in designing and making a PCB is to select the appropriate components that will be used in the circuit. This involves identifying the components needed based on the design requirements and selecting components with appropriate specifications such as voltage rating, current rating, package type, etc.

Figure 29: ELECTRONICS COMPONENTS

It is essential to ensure that the components are readily available and affordable. Choosing appropriate components ensures that the circuit operates as intended and reduces the risk of failure.

4.1.2 DESIGN IN SCHEMATIC FORM:

Once the components are selected, the next step is to create a schematic diagram of the circuit. A schematic is a graphical representation of the circuit that shows how the components are connected.

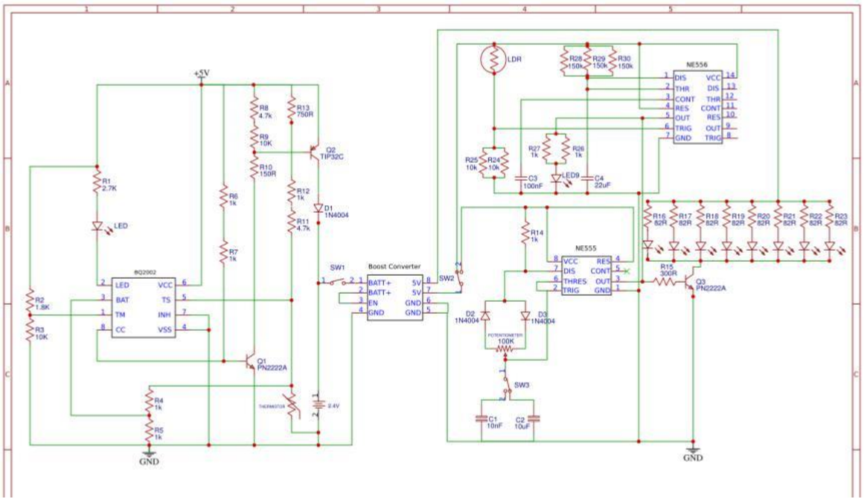

Figure 30: EASYEDA SCHEMATIC

It helps to identify the connections between the components and how they are related to each other. In EasyEDA, this step involves using the schematic editor tool to create a visual representation of the circuit. It is essential to ensure that the schematic is accurate and reflects the intended functionality of the circuit.

4.1.3 Route the schematic design in desired PCB dimensions:

After the schematic is complete, the next step is to design the physical layout of the PCB. This involves routing the connections between the components based on the schematic diagram.

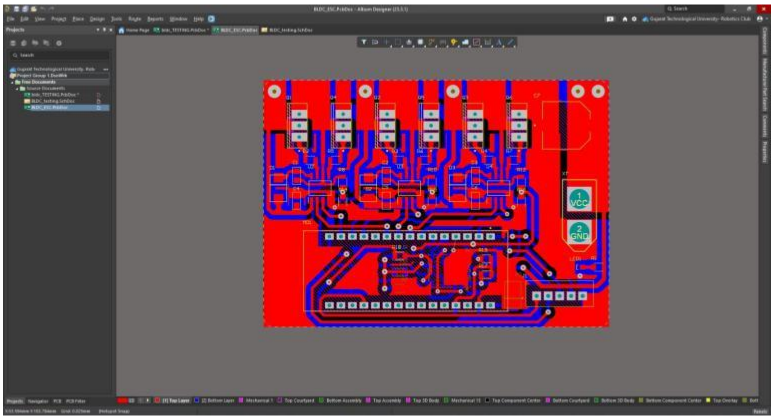

Figure 31: EASYEDA ROUTING TOP LAYER

The routing process involves placing the components on the board and connecting them with copper traces. In EasyEDA, this process is done using the PCB layout editor tool. The designer can specify the dimensions of the board and the spacing between the components. It is essential to ensure that the routing is done correctly to avoid problems such as signal interference or short circuits.

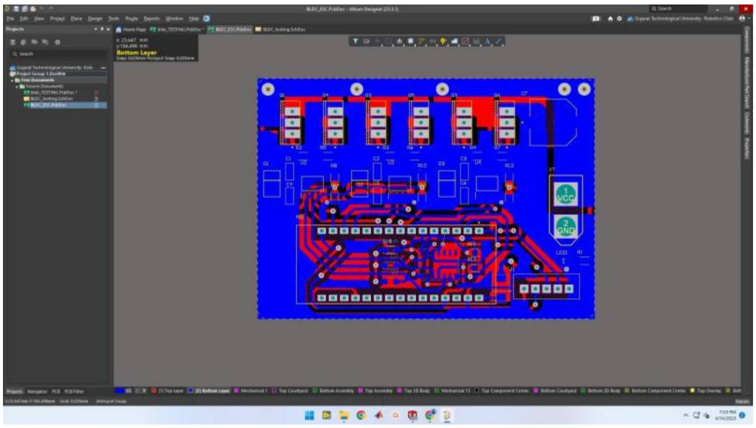

Figure 32: EASYEDA ROUTING BOTTOM LAYER

4.1.4 Prototyping:

The final step in the process is prototyping. This involves creating a physical prototype of the PCB. The prototype can be created using various methods such as etching, milling, or ordering from a PCB manufacturer. It is essential to test the prototype to ensure that it functions correctly and meets the design requirements. Any issues identified during the testing phase should be addressed before finalizing the design.

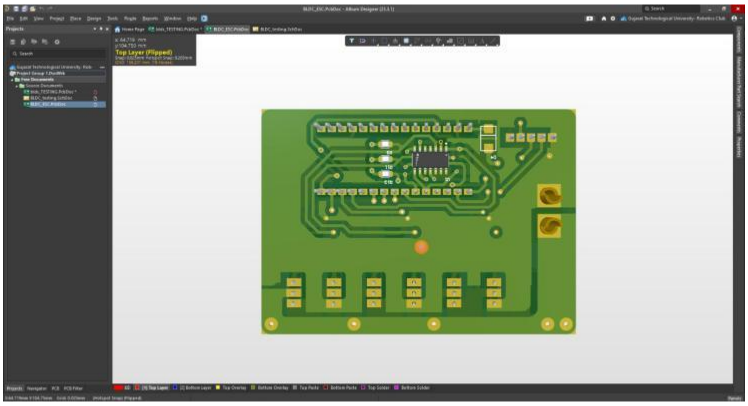

Figure 33: EASYEDA PCB 3D MODEL

During the prototyping phase of the PCB, physical fabrication of the board is necessary to test the design's functionality. This can be achieved through two main methods: PCB milling or PCB printing. In the company where the internship was completed, the facility had a PCB milling machine available for use.

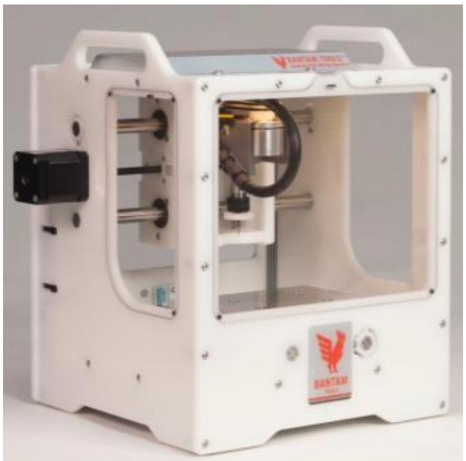

Figure 34: BANTAM PCB MILLING MACHINE

The PCB was milled using a Bantam PCB milling machine, which is a compact and easy-to-use machine. However, during the milling process, a drill bit of 0.05mm broke due to overfeeding of the spindle attached to the motor's shaft.

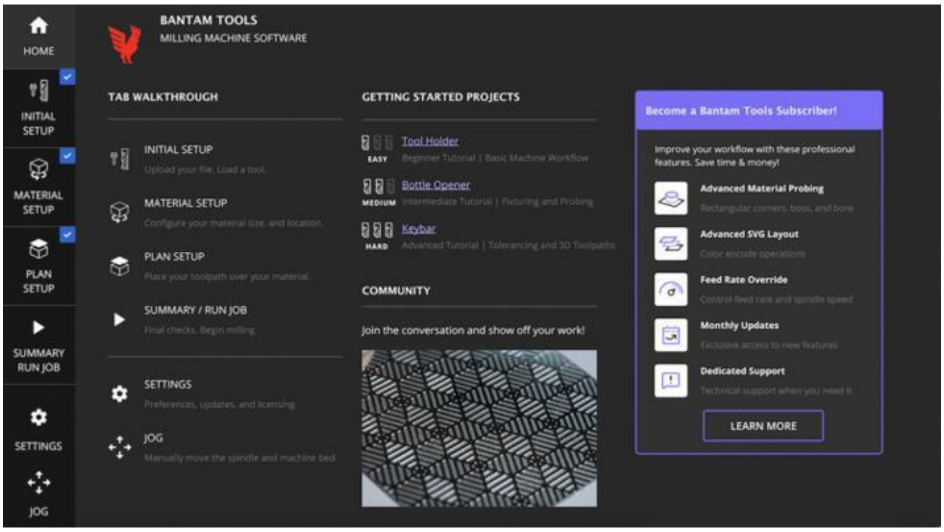

Figure 35: BANTAM SOFTWARE

This highlighted the importance of careful operation of the machine to avoid such issues. To operate the Bantam PCB milling machine, the user must utilize Bantam's custom software. This software provides an easy-to-use interface for designing and milling PCBs, allowing for quick and accurate production.

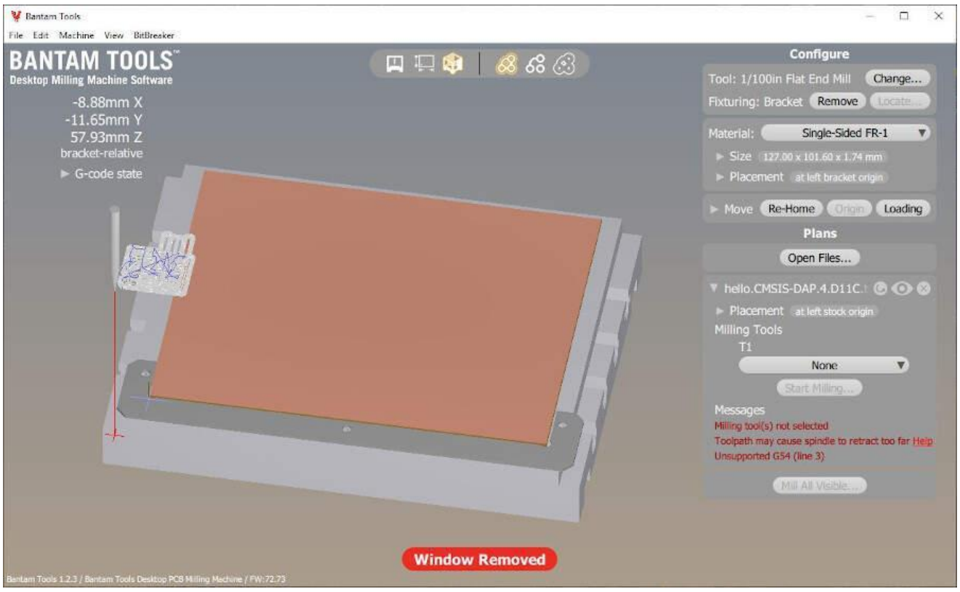

Figure 36: BANTAM SOFTWARE USER INTERFACE

Despite the setback caused by the broken drill bit, the use of the PCB milling machine allowed for the efficient prototyping of the PCB design, ultimately leading to a functional and effective product.

PCB prototyping involves several steps to create a functional printed circuit board. One of the common methods for prototyping a PCB is to use a milling machine.

Here are the steps to follow for PCB prototyping using a Bantam PCB milling machine:
Take a single or double sided copper plate.

Place a double-sided tape on the back of the copper plate.

Mount the copper plate on the bed of the Bantam PCB milling machine.

Generate Gerber files in EasyEDA.

Attach the drilling tool to the spindle of the machine.

Configure the machine. Start the PCB milling process.

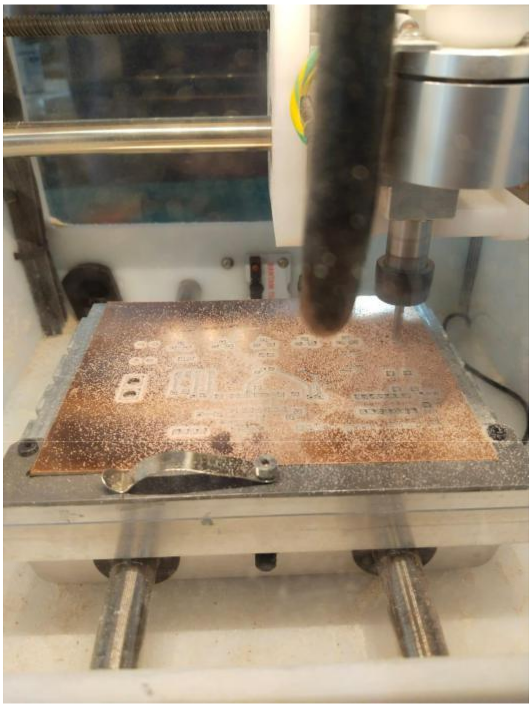

Figure 37: BANTAM MACHINE WITH PCB FIXERS

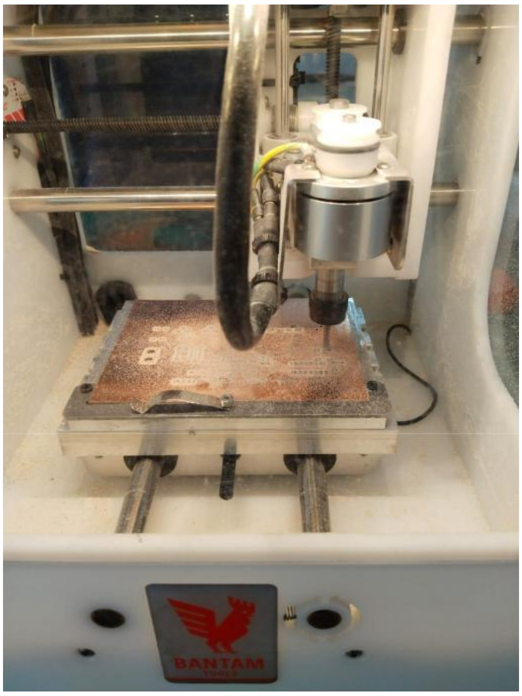

Figure 38: BANTAM MACHINE WITH PCB FIXERS 2

4.2 SOFTWARE USED TO DESIGN PCB

EasyEDA is a user-friendly online software that provides a comprehensive solution for designing printed circuit boards (PCBs).

The platform offers a range of powerful tools to help users create professional-quality PCBs quickly and easily, including schematic capture, PCB layout editor, and a vast library of electronic components.

One of the key advantages of EasyEDA is its intuitive and user-friendly interface, which makes it easy for beginners to get started with PCB design.

Figure 39: EASYEDA

4.3 KEY FEATURES OF EASYEDA

Users can create schematics for their designs using a drag-and-drop interface

Users can select from a vast library of electronic components and connect them using nets

Seamlessly convert it into a PCB layout

provides real-time Design Rule Check (DRC) to ensure that the PCB design meets the required specifications

EasyEDA also provides users with access to a cloud-based storage system

It has extensive range of features and tools make it an ideal choice for beginners and professionals alike

The auto-router feature in EasyEDA makes it easy to route traces and optimize the layout of the PCB

EasyEDA allows users to export their PCB designs in Gerber file format, which is the industry standard for PCB manufacturing

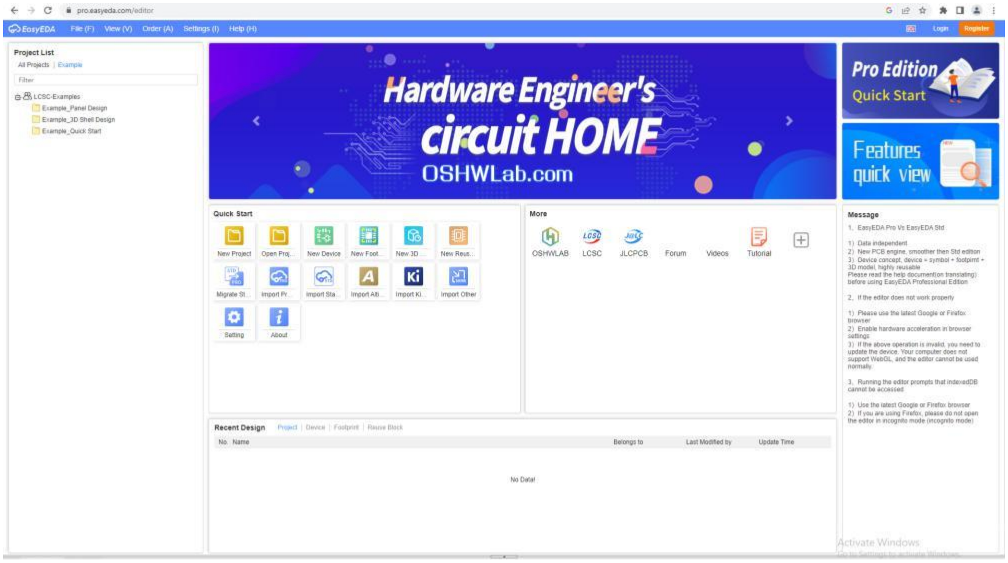

Figure 40: EASYEDA USER INTERFACE

4.4 SELECTION OF ENCODER

The actuator is powered by an RS-775 DC motor with a high nominal speed, which requires a suitable encoder to ensure optimal performance.

After research, the AS5600 12-bit magnetic encoder was found to be the best option for this application.

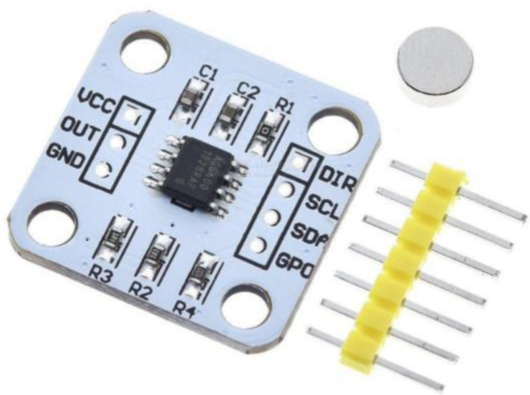

Figure 41: AS5600 MAGNETIC ENCODER WITH MAGNET

Magnetic encoders have several advantages over other types such as optical encoders.
To use the AS5600, a diametrically magnetized magnet that is axially colinear with the encoder sensor is required.
The AS5600 can communicate using I2C communication protocol or with just an analog output of the sensors.

CHAPTER-5

ACTUATOR ASSEMBLY AND TESTING

5.1 ACTUATOR ASSEMBLY INTRODUCTION

In this chapter, we will discuss the process of actuator assembly and testing. The assembly of the actuator involves the integration of all mechanical and electronic components into a single functional unit.

This phase requires careful attention to detail to ensure that all components are properly aligned and connected. Once the assembly is complete, testing is performed to evaluate the performance of the actuator. This includes testing for precision, speed, and accuracy, as well as identifying any potential issues that may need to be addressed.

The goal of this chapter is to provide a comprehensive overview of the assembly and testing process for the actuator, with a focus on ensuring reliable and accurate operation.

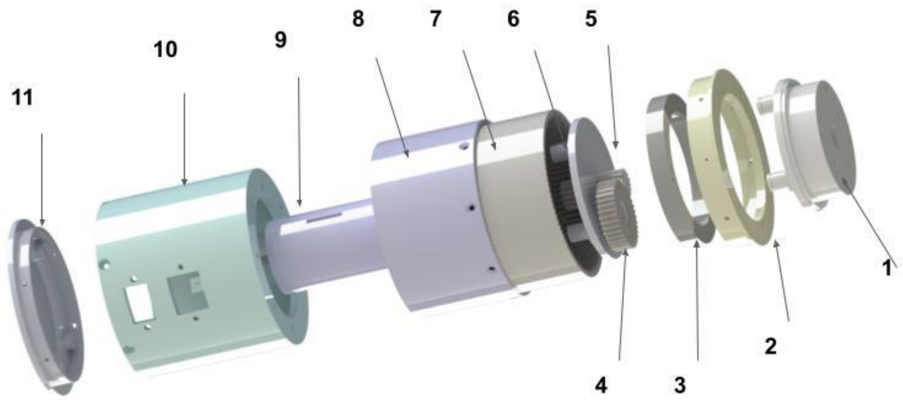

Figure 42: EXPLODED VIEW OF ACTUATOR

Here is the exploded view of Actuator with appropriate annotations:

1. Output Shaft
2. Shaft Holder
3. Output Shaft Bearing
4. Planet Gear
5. Sun Gear
6. Planet Carrier Plate
7. Ring Gear
8. Output Casing of Gearbox
9. RS - 775 DC Motor
10. Body Cover with Connector Slots
11. Back Silk Cover (PCB Attachments)

Now, Let's Discuss the application and functionality of each and every component

Output Shaft

This is the main output shaft of the actuator, which rotates as the motor rotates.

Shaft Holder

This component holds the output shaft in place.

Output Shaft Bearing

This component supports the output shaft and allows it to rotate smoothly.

Planet Gear

This gear meshes with both the sun gear and the ring gear to transmit torque and rotation.

Sun Gear

This gear is located at the center of the planetary gear system and meshes with the planet gears.

Planet Carrier Plate

This component holds the planet gears and is attached to the output shaft.

Ring Gear

This gear is located on the outside of the planetary gear system and meshes with the planet gears to transmit torque and rotation.

Output Casing of Gearbox

This component houses the planetary gear system and supports the output shaft and bearings.

RS - 775 DC Motor

This is the main motor that drives the planetary gear system and output shaft.

Body Cover with Connector Slots

This component covers and protects the internal components of the actuator and provides slots for connecting external wires.

Back Silk Cover (PCB Attachments)

This component attaches to the body cover and provides mounting points for the printed circuit board (PCB) that controls the motor and actuator.

5.2 REAL TIME ASSEMBLY OF ACTUATOR

During the real-time assembly of the actuator, all the manufactured components were used, with many of the parts being produced in-house.

The assembly process was successful as all the parts fit together perfectly according to the expected specifications.

Figure 43: ALL THE COMPONENTS OF ACTUATOR

Here are some of the components's photos:

Figure 44: PLANET CARRIER PLATE WITH SUN GEAR ATTACHED

Figure 45: PLANET CARRIER PLATE WITH PLANET GEAR ATTACHED

Figure 46: HALF ASSEMBLY OF ACTUATOR

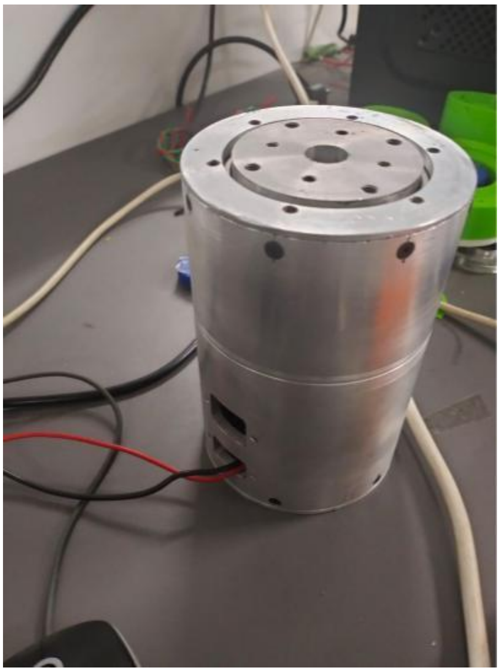

Figure 47: FULL ASSEMBLY OF ACTUATOR

5.3 TESTING OF MOTOR DRIVER

To validate the designed motor driver, a motor testing setup was built. The setup included a DC geared and encoder motor attached to its housing.

The output wire terminals of the motor were connected to the motor driver while the motor driver was powered by a switch mode power supply of 12 volts.

An acrylic-made setup was built to hold the motor and the motor driver in place during testing.

To analyze the waveform nature of the input and output of the power supply, a digital storage oscilloscope (DSO) was connected. The DSO helped in capturing and displaying the electrical waveforms of the input and output signals of the power supply. The motor driver was tested for its various functionalities, such as speed control, direction control, and torque control.

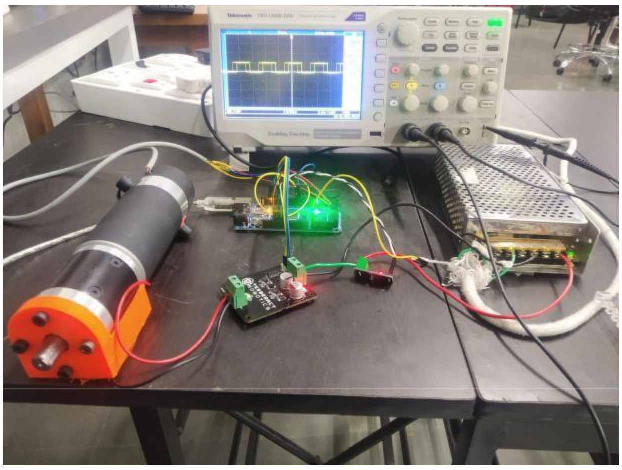

Figure 48: MOTOR TESTING SETUP

The DSO was used to analyse the waveform nature of the output of the motor driver. This helped in validating the performance of the motor driver and ensuring that it met the required specifications.

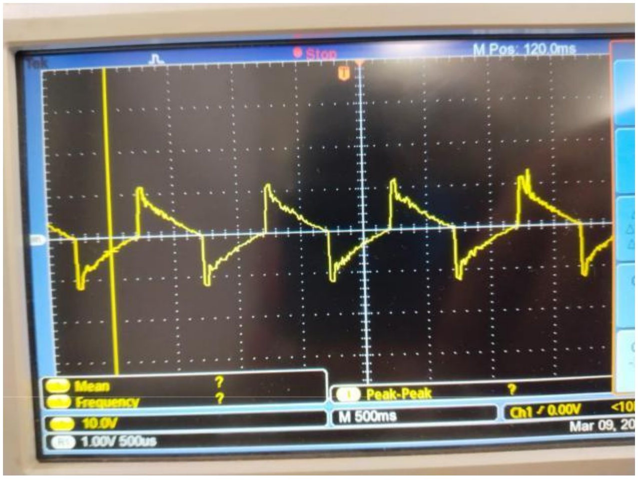

Figure 49: DSO OUTPUT WAVEFORM

Overall, the motor testing setup helped in validating the designed motor driver and ensuring that it was functioning optimally.

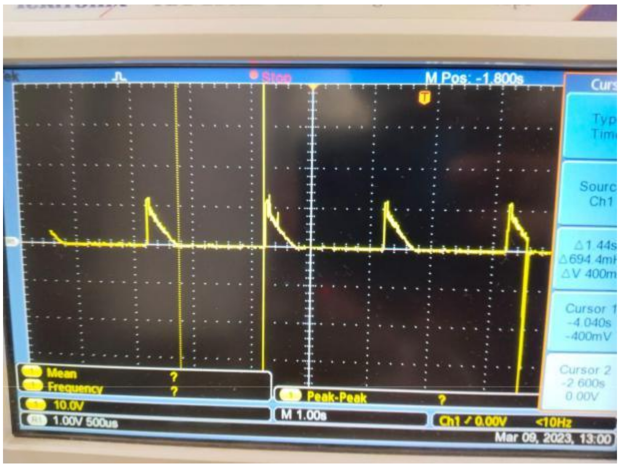

Figure 50: DSO OUTPUT WAVEFORM (TRIANGULAR WAVE)

The triangular waveform observed in the DSO output represents the PWM signal generated by the motor driver. The duty cycle of the PWM signal determines the speed and direction of the motor.

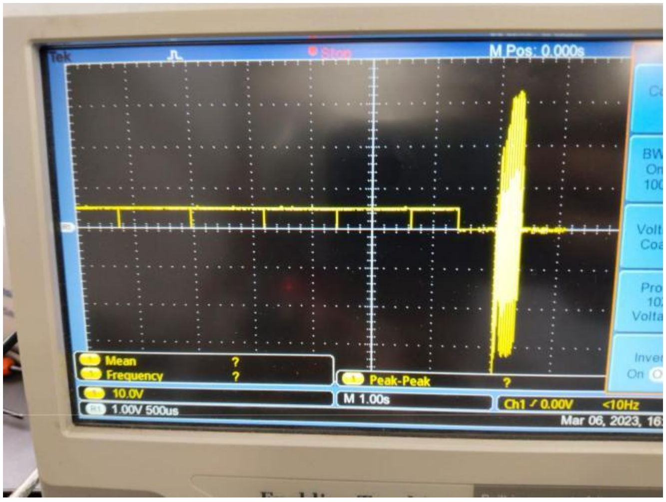

Figure 51: DSO OUTPUT WAVEFORM SHOWING NOISE

By analysing the waveform, the characteristics of the PWM signal can be determined, such as the frequency, duty cycle, and amplitude.

This information can then be used to optimize the motor driver and improve its performance.

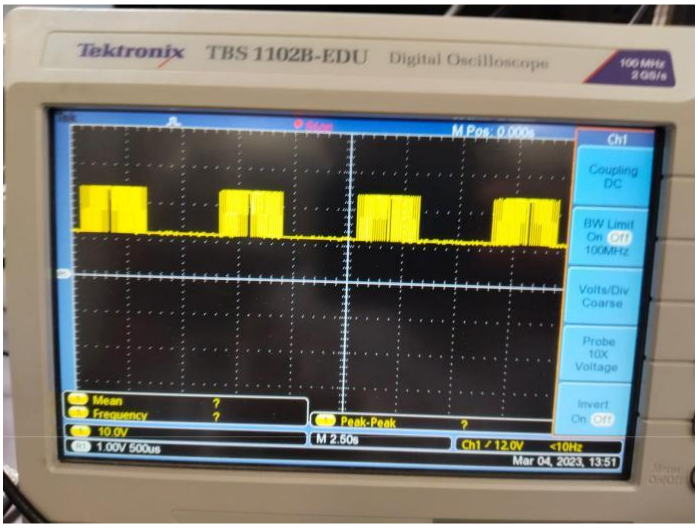

Figure 52: DSO OUTPUT WAVEFORM SHOWING 50% PWM

A 50 percent duty cycle displayed on the DSO indicates that the waveform is equally high and low in duration, which is also known as a square wave commonly used in digital circuits. It can also suggest that the input signal has a frequency that is twice the frequency of the square wave and is periodic.

CHAPTER-6

FUTURE SCOPE: COMPACT DESIGN OF ELECTRIC ACTUATOR

6.1 CURRENT CHALLENGES: SIZE AND WEIGHT

The existing electric actuator, while formidable in its capabilities, falls short when it comes to on-site applications. Its bulkiness and substantial weight limit its practicality in scenarios where portability and space efficiency are paramount. Recognizing this, the focus shifts towards redefining the very architecture of the actuator.

6.2 THE NEW PROPOSED DESING

The revamped electric actuator boasts a compact form factor without sacrificing power. Key specifications include:

- Continuous Output Torque: 6 Nm
- Operating Voltage: 24/36/48
- Continuous Current: 9 A
- Peak Current: 24 A
- Peak Torque: 16 Nm
- RPM at Given Voltage Supply: 230/360/500
- Torque to weight Ratio: 6
- Dimensions:- O.D – 100 mm
  Height – 85 mm

The body of the new design is crafted from high-strength 6 series aluminium alloy, ensuring durability while keeping weight to a minimum. The gears, critical for torque transmission, are engineered from mild steel for optimal strength.

A pivotal shift lies in the adoption of a frameless brushless DC (BLDC) motor. The rotor, featuring neodymium magnets, enhances efficiency and responsiveness. This shift not only contributes to the reduction in size but also brings improvements in overall performance.

6.3 CONCEPT VALIDATION

For the sake of concept validation, 3D-printed components were initially employed. The results have been exceptionally promising, demonstrating the feasibility of the design in real-world applications.

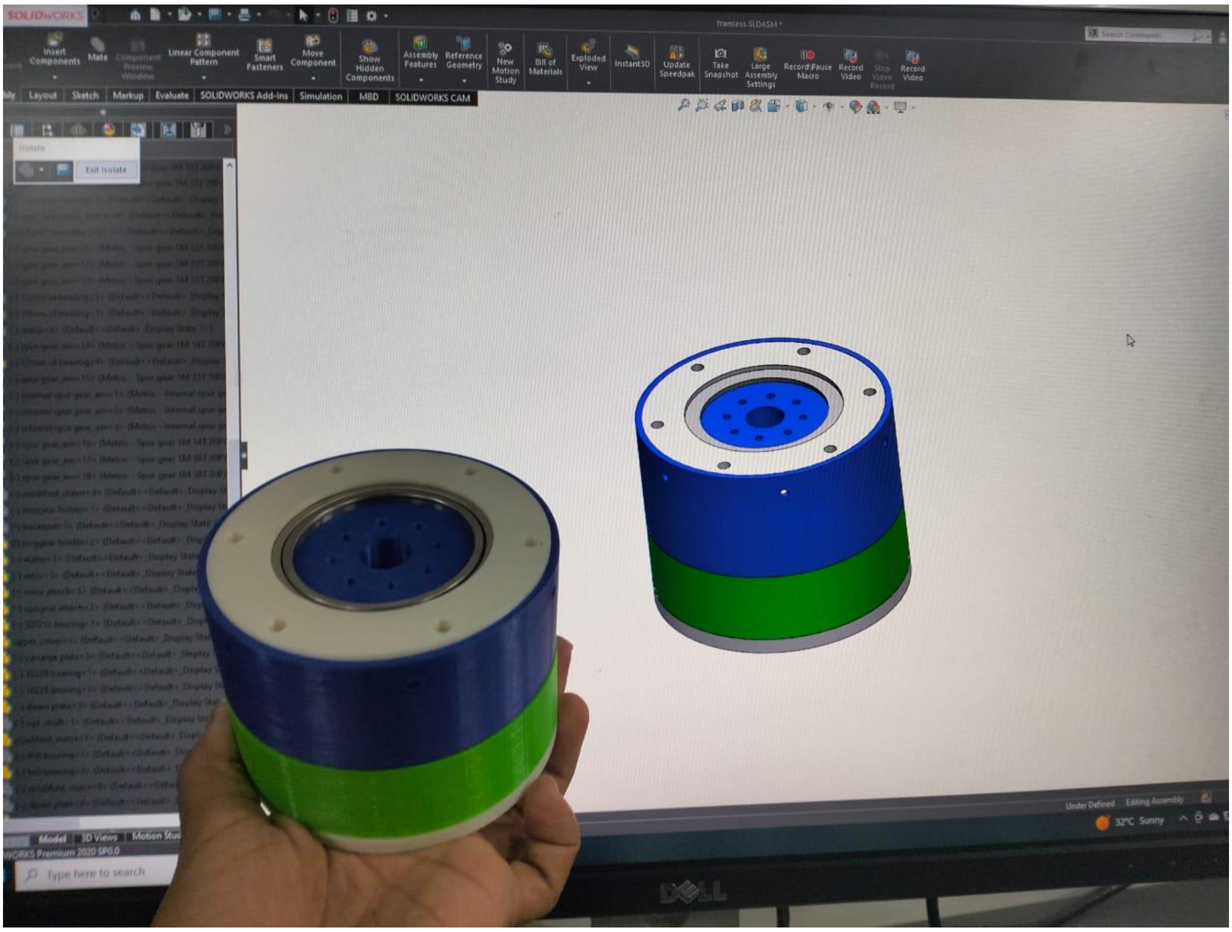

Figure 53: ISOMETRIC VIEW OF 3D PRINTED ACTUATOR

The compact electric actuator holds immense potential across a spectrum of applications, redefining the landscape of various robotic systems.

The compact actuator, with its blend of power and portability, can form the backbone of exoskeletal systems, providing enhanced support and independence to those in need.

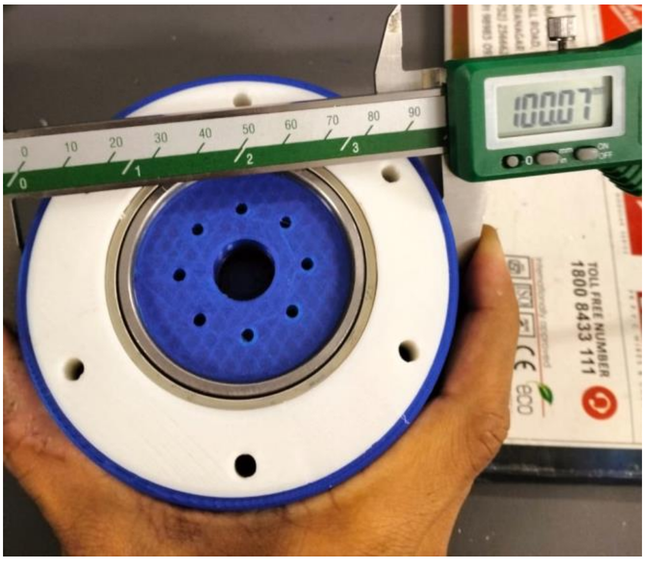

Figure 54: DIAMETER OF ACTUATOR

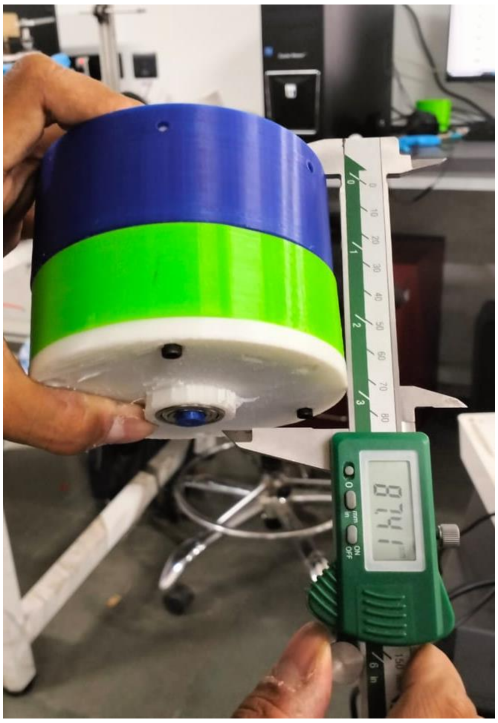

Figure 55: HEIGHT OF ACTUATOR

6.4 CONCLUSION: A LEAP TOWARDS PRACTICALITY

The compact design presented not only addresses the current limitations but also sets the stage for a new era of versatile and efficient actuators. As we transition from conceptualization to realization, the journey unfolds with the promise of enhanced performance within a sleek and lightweight framework.

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