Department of Electronic & Telecommunication Engineering, University of Moratuwa, Sri Lanka.

Pick and Place Robot Arm
Final Report

Discussion Group C
Group 8
Group Members:

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EN2160 Electronic Design Realization

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Contents

1 Abstract

The project aims to revolutionize the electronic component assembly process through the development of a Pick and Place Robot Arm. Focusing on precise assembly, the system targets components like rivets, washers, and transistors. The objectives span multiple engineering domains, incorporating design, mathematical modeling, control systems, and practical skills acquired during university studies. The device architecture includes horizontal and vertical conveyor systems, a gripper mechanism, and a user-friendly controller interface. The research explores solutions from industry leaders, and the proposed system seeks to integrate the best features observed, providing a state-of-the-art solution for H-Bridge component assembly.

2 Progress Report: Development of Industrial Robot Arm for Handling Rivenuts and Washers

2.1 Key Features and Innovations

The development of the industrial robot arm incorporates several key features and innovations. These include multi-axis motion control, customization and integration of grippers, implementation of vision systems for object detection, and advancements in robotic manipulation techniques.

2.2 Research and Literature Review

The investigation includes solutions from ABB, KUKA, and FANUC through YouTube videos and product brochures. Key features such as multi-axis motion control, gripper customization, and integrated vision systems for precision are emphasized. Also Bolt and Washer Insertion solutions were seen as a robotic solution that can be used for this system.

Development Plan

2.3 Our Development Plan

The comprehensive development plan encompasses various elements such as modular robot arm design, utilization of advanced sensing technologies, formulation of control algorithms, rigorous testing and validation procedures, and collaboration with industry partners.

2.4 Proposed Robotic Arm System

2.4.1 Arm configuration and Gripper Design

The system is designed with a gripper arm for picking and assembling electronic components. For this we need a customized gripper to picking up the small object.

2.4.2 Robot Selection

Criteria for selecting appropriate robotic arms include payload capacity, accuracy, speed, and reach. Collaborative robots are considered for safety benefits during human interaction.

2.4.3 Gripper Design

Customized grippers are developed for each component based on size, shape, and material. Vacuum grippers can be used for washers, and parallel grippers for transistors.

2.4.4 Programming and Control

An intuitive programming interface is developed for defining assembly sequences and motion paths. Safety protocols and error handling routines are implemented.

2.4.5 Safety Measures

Emergency stop systems are integrated for robotic arms. A user-friendly interface is provided for monitoring and control.

2.5 Next Steps

The subsequent steps involve the synthesis of the technologies mentioned above, aiming to create a system tailored for the specific tasks outlined in the project.

Combined Project Plan

2.6 Objectives

The primary objectives of the combined project plan revolve around assembling sets of rivets, washers, transistors, and cylindrical heat sinks for the 3-phase H bridge system. The approach involves employing a moving robotic arm system with a slider mechanism for efficient picking and stacking.

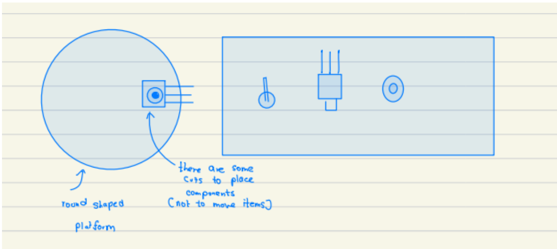


Figure 1: Planned Project Objective

2.7 Action Plan

The action plan encompasses multiple phases, including the development of the robot arm, programming and control implementation, handling of heat sinks, incorporation of the slider system, and thorough testing and validation.

3 Stakeholder Map

A stakeholder map has been created to identify and categorize key stakeholders involved in the project. The map includes:

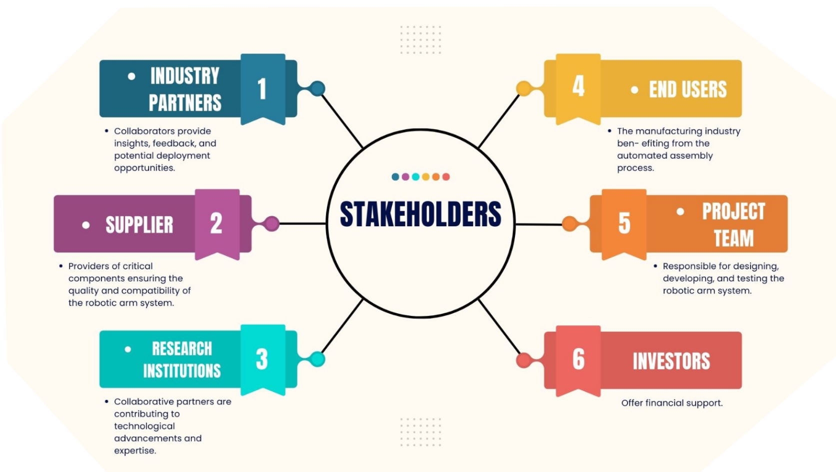


Figure 2: Stake Holder Map

4 Observing User Requirements

User requirements for the project are as follows:

1. Precision in Assembly:

   The system must be capable of precisely assembling H-Bridge components, including rivets, washers, and transistors.

2. Automation and Efficiency:

   The robotic mechanism should automate the assembly process to enhance efficiency and accuracy in electronic component manufacturing.

3. Modular and Customizable Gripper Mechanism:

   The gripper must be adaptable to securely hold and manipulate different electronic components during the assembly process.

4. User-Friendly Controller Interface:

   The system should have an intuitive interface, allowing users to easily control and monitor the robotic arm's operations. This may include physical buttons, touchscreen displays, or a computer interface.

5. Safety Features:

   The robotic mechanism should incorporate safety features to prevent accidents and protect users from harm during operation. This may include emergency stop buttons, motion sensors, and protective barriers.

6. Cost-Effective Design:

   The system should be designed with cost-effectiveness in mind, utilizing affordable components and materials without compromising performance or reliability.

7. Scalability and Flexibility:

   The design should be scalable and adaptable to accommodate future upgrades or modifications based on evolving assembly requirements or technological advancements.

8. Maintenance and Support:

   The system should be easy to maintain and repair, with readily available spare parts and technical support to ensure continuous operation and longevity.

9. Integration with Existing Systems:

   The robotic arm should be compatible with existing manufacturing systems and processes, allowing seamless integration into the production line without significant modifications or disruptions.

5 Review Existing Solutions

The investigation extends to solutions showcased in YouTube videos, covering pick and place mechanisms, screw robots, and innovative approaches like bolt and washer insertion.

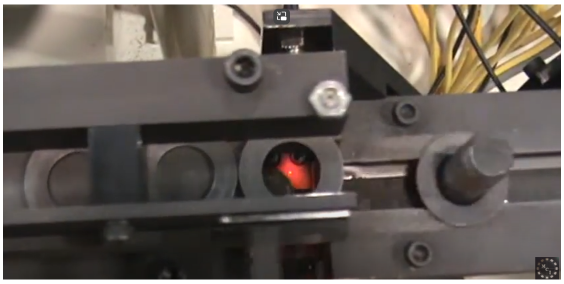


Figure 3: Delivery with Screw and Washer Assembly

Notable technologies, such as Yaskawa Motoman's 3D Vision Picking, are highlighted for advanced manipulation techniques.

This comprehensive review serves as a foundation for the proposed robotic arm system. The project aims to incorporate the best features observed during the research, leveraging the strengths of existing solutions to develop a state-of-the-art robotic arm tailored to the specific requirements of the H-Bridge component assembly process.

6 Need List

a) **High Precision:** The robot arm should be capable of precisely picking up and placing electronic components with accuracy in the micrometer range to ensure proper assembly.

b) **Adaptability:** The system should be adaptable to handle a variety of electronic components of different shapes, sizes, and weights commonly used in electronics manufacturing.

c) **Speed and Efficiency:** The pick and place process should be efficient, with high-speed movements to optimize production throughput.

d) **Reliability:** The system should operate reliably over extended periods without frequent breakdowns, ensuring continuous production without interruptions.

e) **User-Friendly Interface:** The control interface should be intuitive and user-friendly, allowing operators to easily program and operate the robot arm without extensive training.

f) **Safety Features:** Incorporate safety features such as emergency stop mechanisms and protective enclosures to prevent accidents and ensure the safety of operators and nearby personnel.

g) **Integration with Existing Systems:** The robot arm should be compatible with existing production systems and workflows, allowing seamless integration into the manufacturing process.

h) **Cost-Effectiveness:** The overall cost of the system, including initial investment, maintenance, and operational costs, should be reasonable and cost-effective compared to the benefits it provides.

i) **Scalability:** The system should be scalable to accommodate future expansion and changes in production requirements, allowing for flexibility and adaptability to evolving needs.

j) **Documentation and Support:** Provide comprehensive documentation and support resources, including user manuals, troubleshooting guides, and technical support, to assist users in operating and maintaining the system effectively.

k) **Environmental Considerations:** Minimize environmental impact by designing energy-efficient components and using sustainable materials wherever possible.

l) **Compliance with Regulations:** Ensure compliance with relevant regulations and standards governing robotics and manufacturing processes to meet legal requirements and industry best practices.

7 3D Modeled Simulation

We created a Solid Works 3D Model for simulation of the Mechanical Concepts (using mates and etc.)

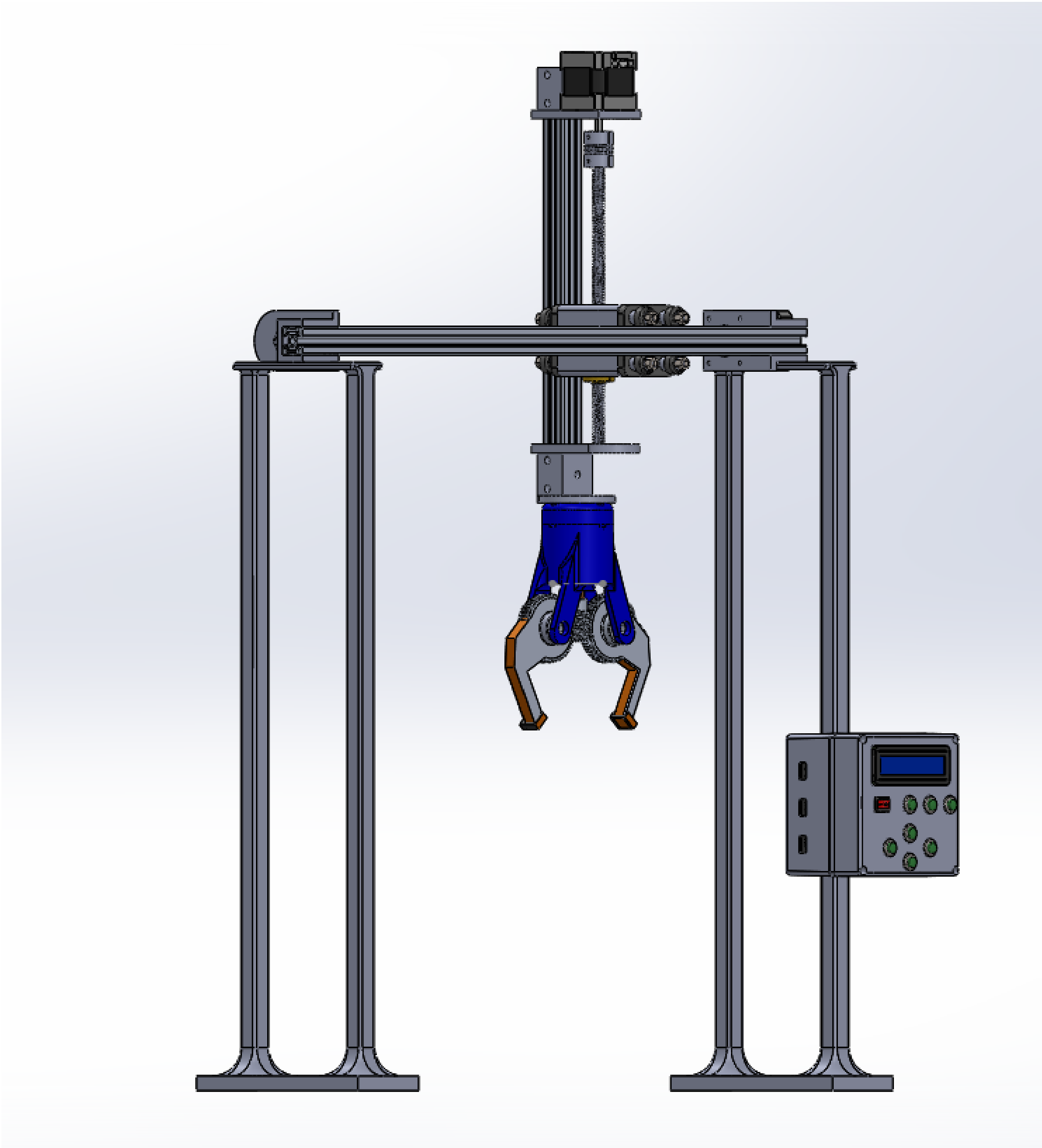


Figure 4: 3D Model

8 Conceptual Design

8.1 Robot Arm Concepts

8.1.1 Multi Axis Robot Arm

A multi-axial robot arm is an advanced robotic design characterized by its ability to move in multiple directions or axes, offering increased degrees of freedom (DOFs) compared to traditional robotic arms. This enhanced flexibility enables the robot to perform complex and intricate tasks with precision and adaptability.

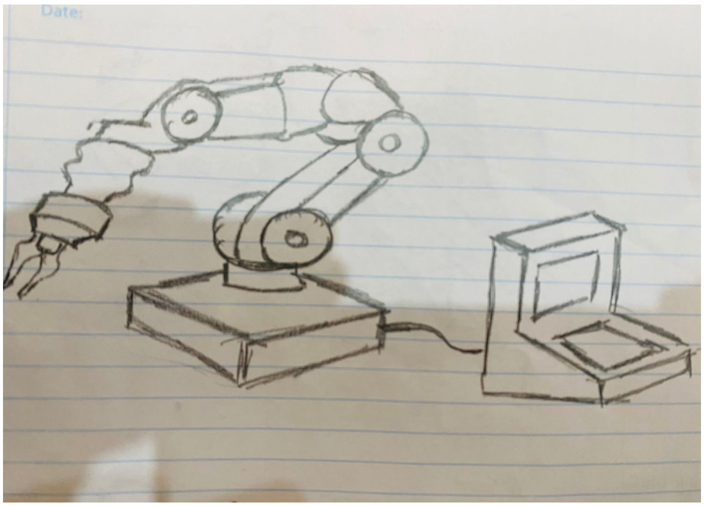


Figure 5: Multi Axial Robot Arm Concept Design

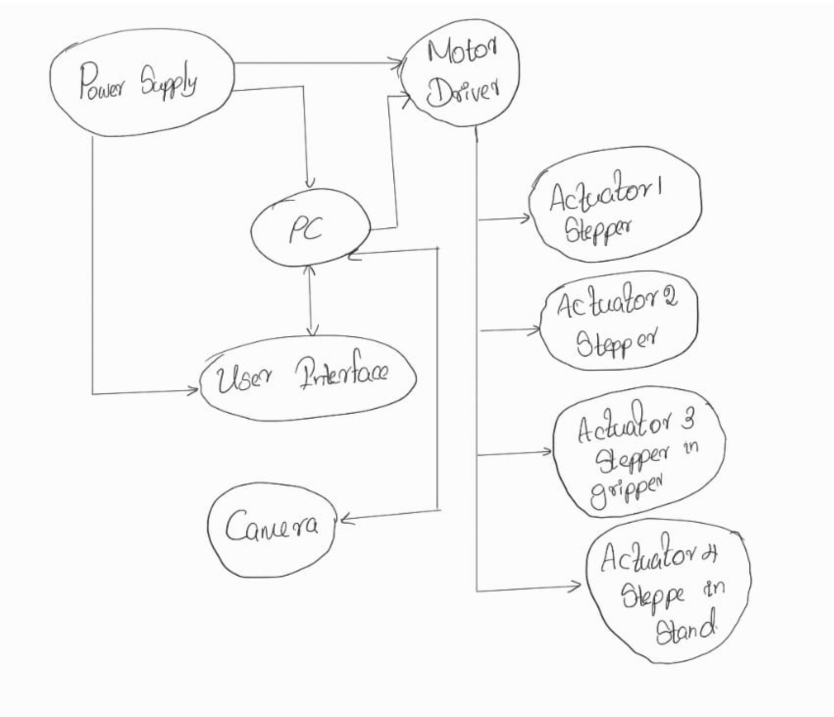


Figure 6: Multi Axial Robot Arm Block Diagram

8.1.2 Screw-Rod Based Robot Arm

A Screw-Rod Based Robot Arm is a specialized robotic design that utilizes a screw or rod mechanism for its motion, enabling it to move vertically and horizontally with precision. This type of robot arm design is particularly effective in applications where linear motion along specific axes is crucial.

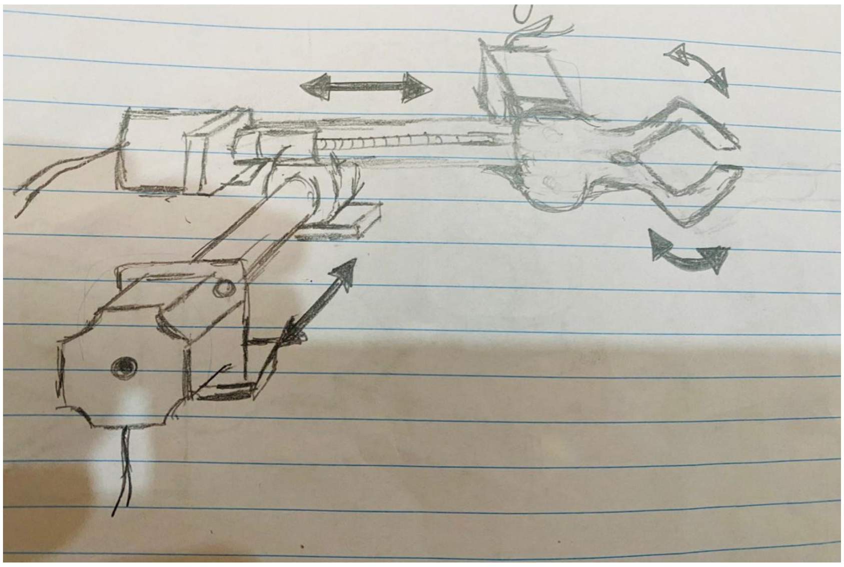


Figure 7: Screw-Rod Based Robot Arm Concept Design

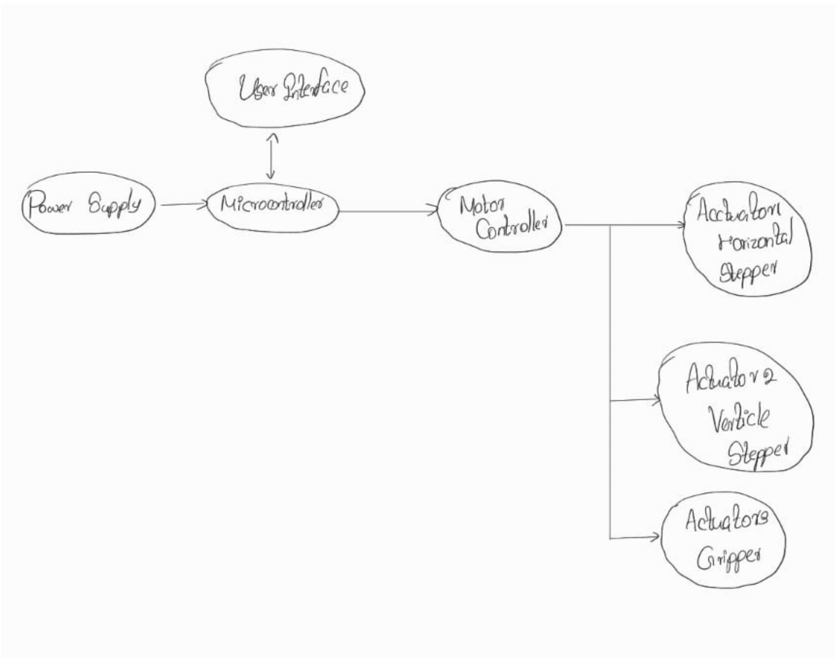


Figure 8: Screw-Rod Based Robot Arm Block Diagram

8.1.3 Feeder Assembler System

A Feeder Assembler System is a sophisticated automation solution designed to efficiently gather components from multiple conveyors and assemble them at a centralized point. This system is widely used in manufacturing and assembly lines to streamline production processes and enhance overall efficiency.

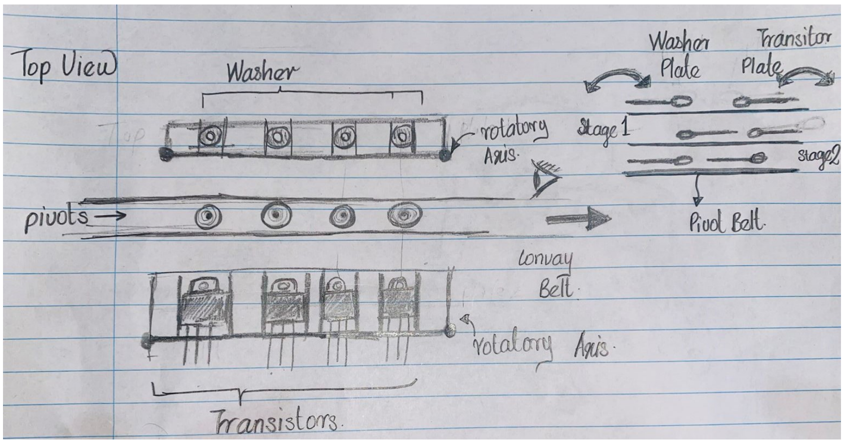


Figure 9: Feeder Assembler System Concept Diagram

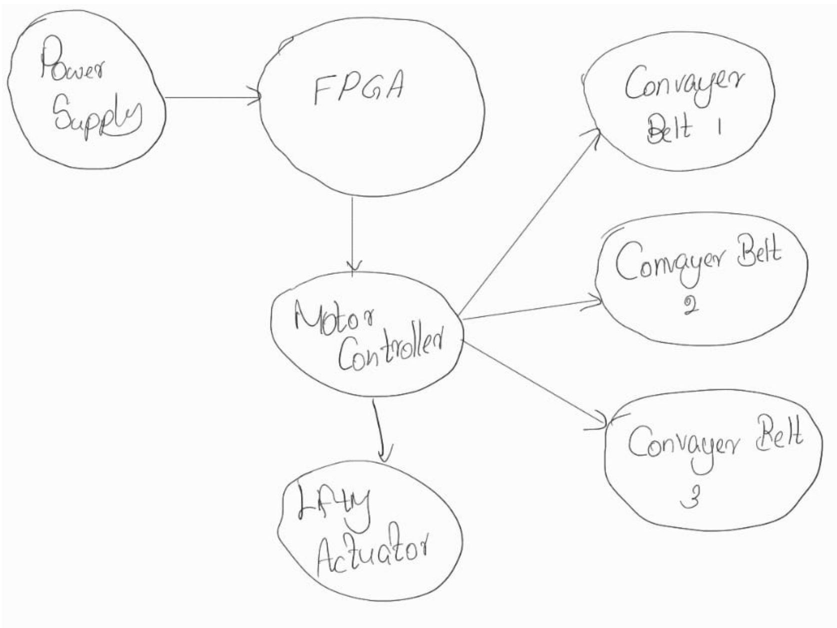


Figure 10: Feeder Assembler System Block Diagram

8.2 Gripper

8.2.1 Mechanical Gripper

This is a concept of the gripper that uses stepper motor and mechanical system for gripping

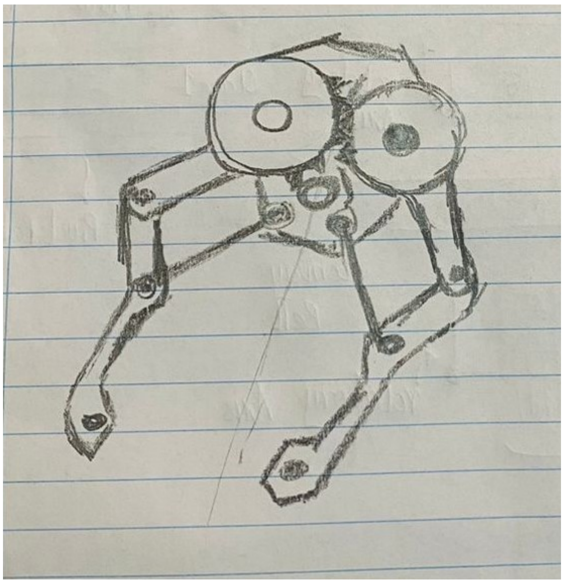


Figure 11: Mechanical Gripper Concept

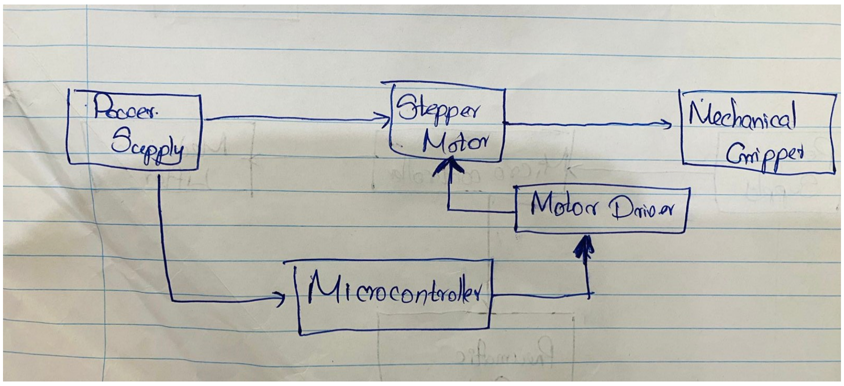


Figure 12: Mechanical Gripper Block Diagram

8.2.2 Suction Gripper

This is a concept of the gripper that uses pneumatic vacuum concepts to suck the components and grip them.

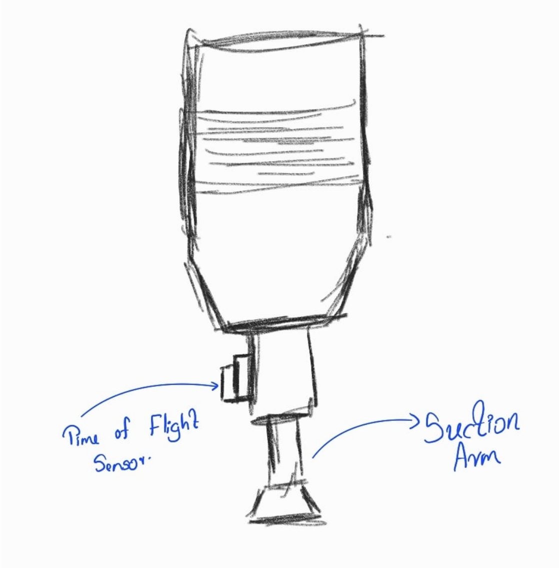


Figure 13: Pneumatic Suction Gripper Concept Diagram

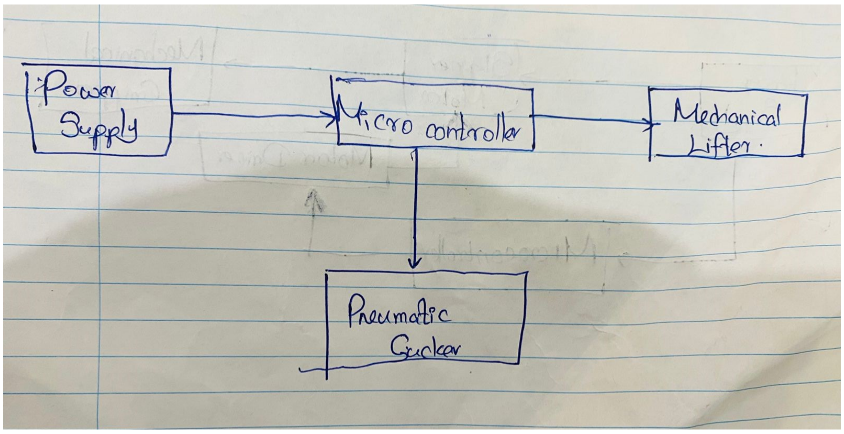


Figure 14: Pneumatic Suction Gripper Block Diagram

8.2.3 Mechanical + Electromagnetic Gripper

After considering some scenarios, we thought of a mechanical gripper using electromagnet to grip one of the stacked washers.

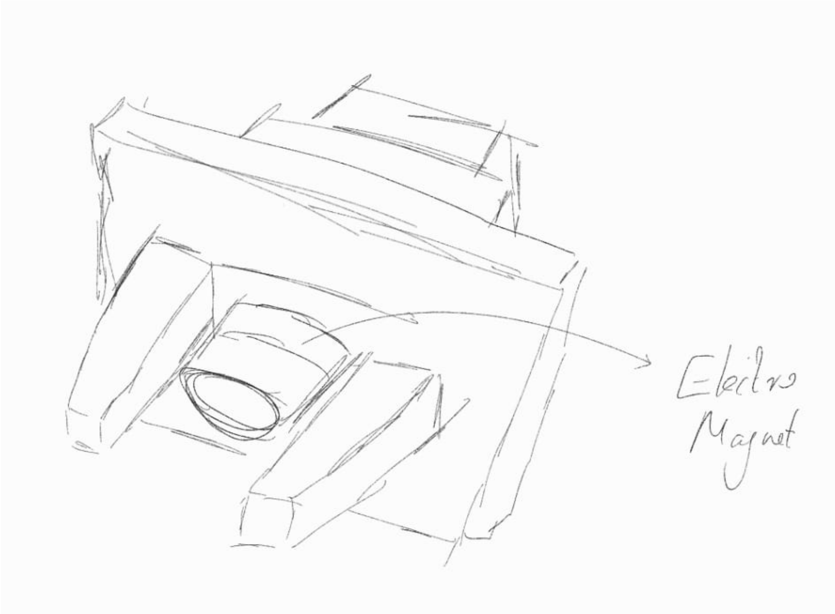


Figure 15: Mechanical + Electromagnetic Based Gripper

8.3 Design Comparison

Concept Number		Concept 1	Concept 2	Concept 3
Newly added features		Multiple degrees of freedom Increased dexterity Vission Camera	Linear motion vertical and horizontal axes, high positional accuracy, simple mechanical design.	Automated component feeding from multiple conveyors centralized assembly point
Envisioned Design		Single axis arm A robotic arm with multiple rotational joints and linkages	A robotic arm using a lead screw or rod mechanisms to achieve linear extension/retraction motions	A system with several feeder conveyors converging to a shared workspace where components are robotically assembled.
Comparison between Mechanical part	Functionality	7	9	7
	Assembly	6	9	7
	Serviceability	5	9	7
	Simplicity	5	9	7
	Durability	8	9	8
	Ergonomics	8	8	8
Comparison between Functional block diagram	Functionality	8	9	7
	User experience	6	9	7
	Feasibility	6	9	6
	Cost(neg.effect)	6	7	5
	Performance	7	8	7
	Power(neg.effect)	6	8	6
Total		78	103	82

Figure 16: Deisgn Concept Comparisopn

9 Selected Design

Based on above concepts, the selected design is a Screw-Rod Based Robot Arm with a Pneumatic Suction Gripper. This design combines the precision and flexibility of a screw-rod mechanism with the gripping efficiency of a pneumatic suction system, offering a comprehensive solution for the assembly of H-Bridge components. The system architecture includes a multi-axis robot arm with vertical and horizontal motion capabilities, a feeder assembler system for component collection, and a user-friendly controller interface for operation and monitoring. The gripper mechanism utilizes a pneumatic vacuum concept to securely hold and manipulate electronic components during the assembly process, ensuring accuracy and efficiency in manufacturing operations.

9.0.1 Screw-Rod Based Robot Arm

A Screw-Rod Based Robot Arm is a specialized robotic design that utilizes a screw or rod mechanism for its motion, enabling it to move vertically and horizontally with precision. This type of robot arm design is particularly effective in applications where linear motion along specific axes is crucial.

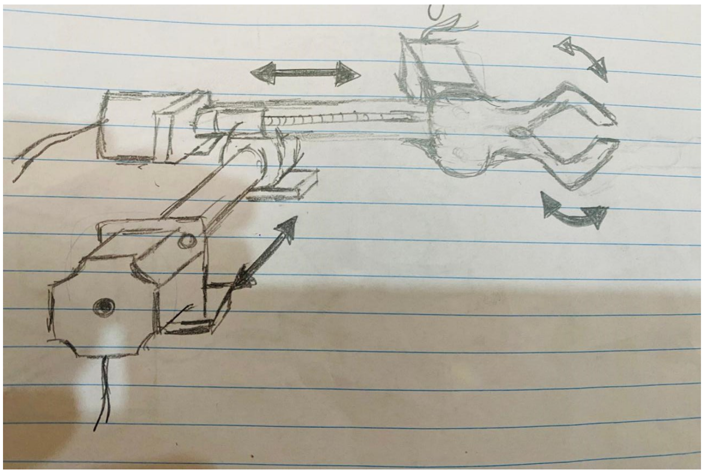


Figure 17: Screw-Rod Based Robot Arm Concept Design

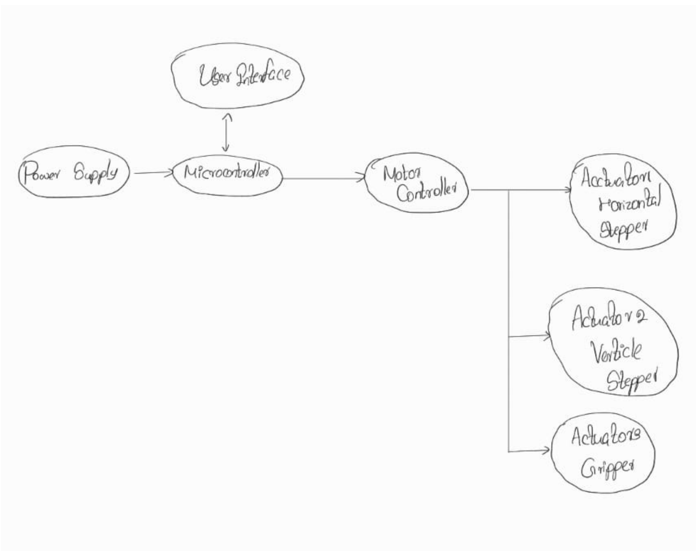
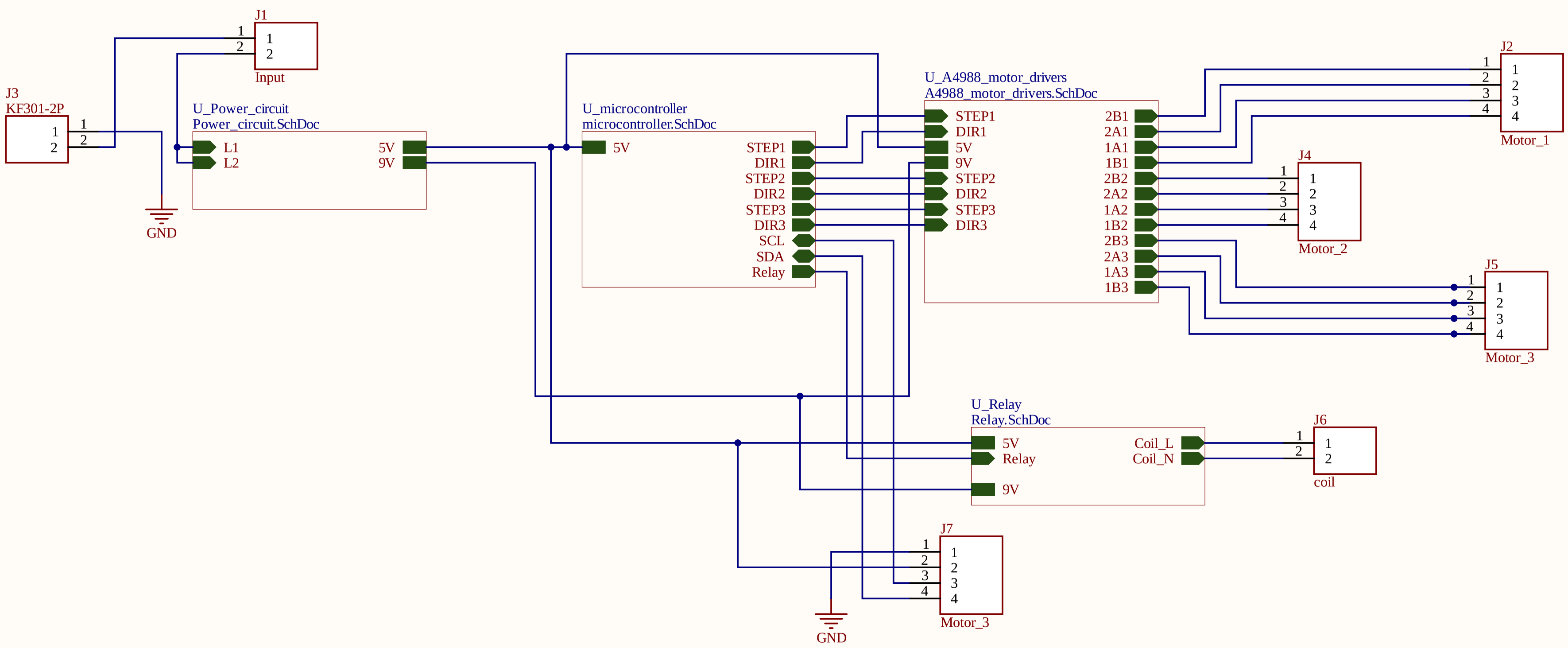


Figure 18: Screw-Rod Based Robot Arm Block Diagram

10 Final schematic and PCB design

Below 6 pages will show the PCB and Schemetic design. we considered about the cost and the efficiency of the design. We have used seven 2 pin JSTs connect switches and one 2 pin JST for electromagnet. We have used four 4 pin JSTs to connect stepper motors to motor drivers. One relay module for get 230 volts to electromagnet. We have used Atmega 328p as our microcontroller. We have planned to get 12V input from power pack and regulate that to 5V and 9V. Also we used flyback diodes to eliminate the damage happen because of the flyback diodes.



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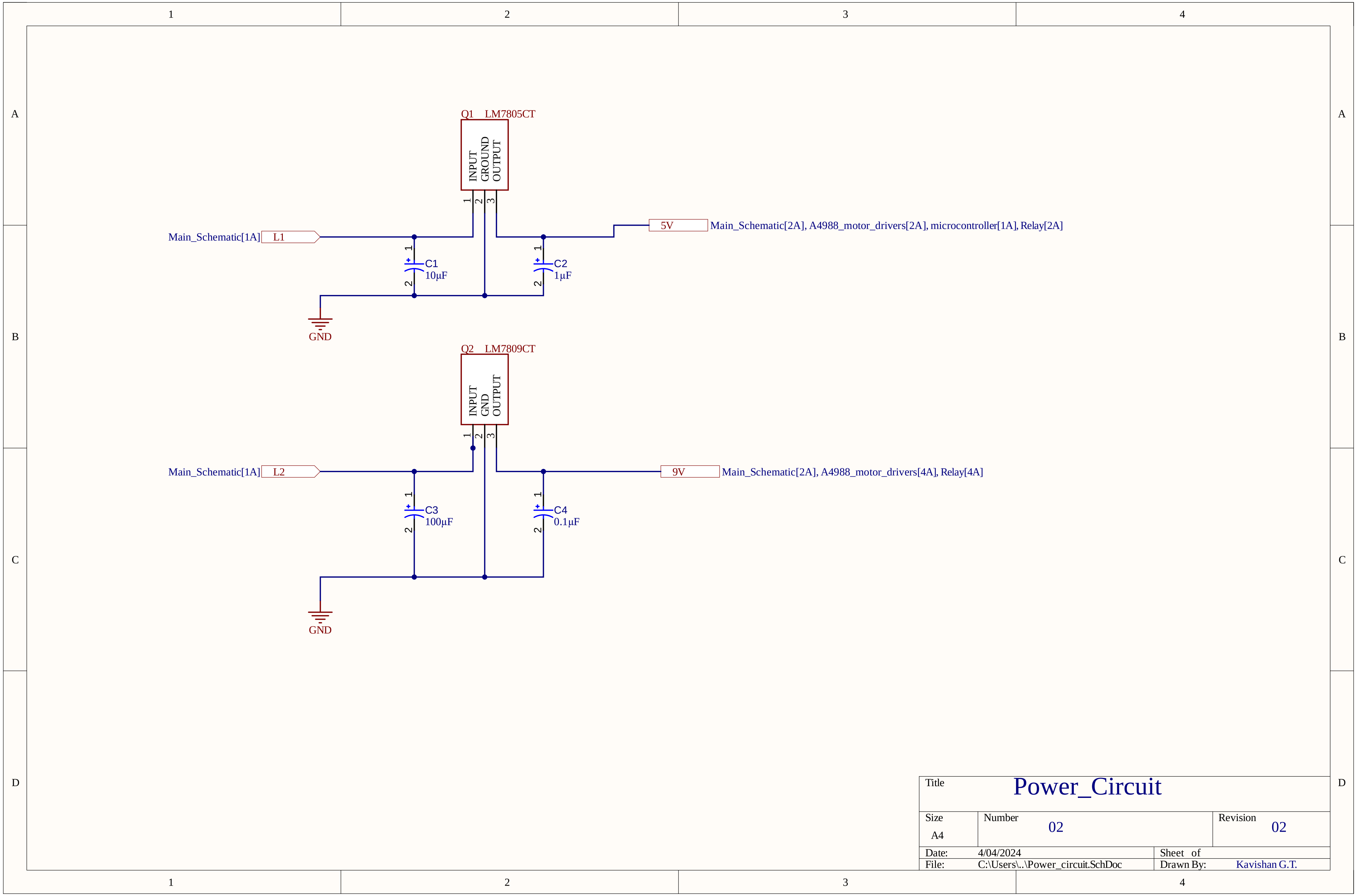
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GROUND
OUTPUT
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L1
5V
Main_Schematic[2A], A4988_motor_drivers[2A], microcontroller[1A], Relay[2A]
C1
10µF
C2
1µF
GND
Q2 LM7809CT
INPUT
GND
OUTPUT
Main_Schematic[1A]
L2
9V
Main_Schematic[2A], A4988_motor_drivers[4A], Relay[4A]
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C4
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Revision
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Date: 4/04/2024
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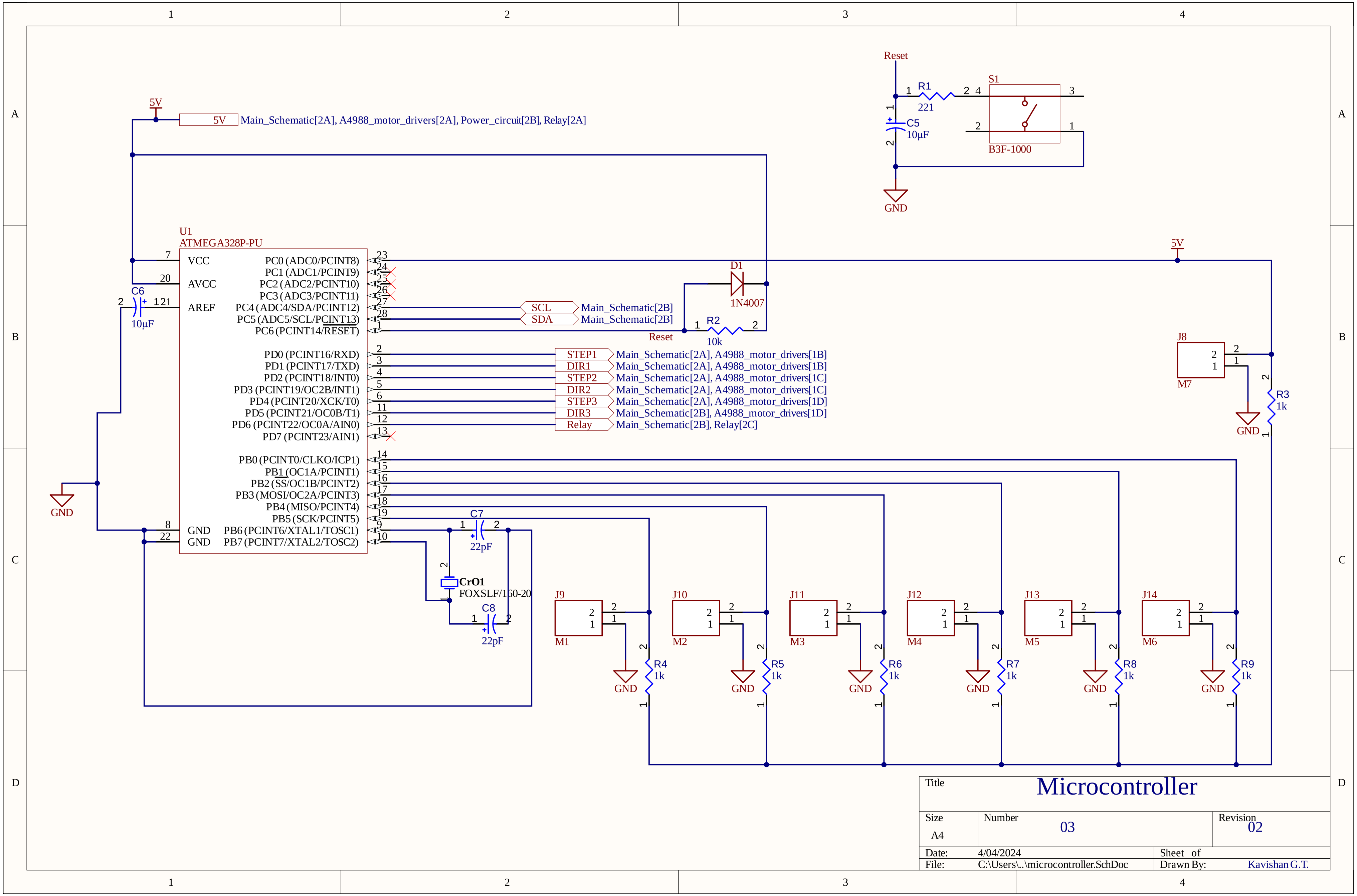
Reset
R1
221
S1
B3F-1000
C5
10µF
GND
5V
5V
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U1
ATMEGA328P-PU
VCC
AVCC
AREF
GND
GND
C6
10µF
PC0 (ADC0/PCINT8)
PC1 (ADC1/PCINT9)
PC2 (ADC2/PCINT10)
PC3 (ADC3/PCINT11)
PC4 (ADC4/SDA/PCINT12)
PC5 (ADC5/SCL/PCINT13)
PC6 (PCINT14/RESET)
PD0 (PCINT16/RXD)
PD1 (PCINT17/TXD)
PD2 (PCINT18/INT0)
PD3 (PCINT19/OC2B/INT1)
PD4 (PCINT20/XCK/T0)
PD5 (PCINT21/OC0B/T1)
PD6 (PCINT22/OC0A/AIN0)
PD7 (PCINT23/AIN1)
PB0 (PCINT0/CLKO/ICP1)
PB1 (OC1A/PCINT1)
PB2 (SS/OC1B/PCINT2)
PB3 (MOSI/OC2A/PCINT3)
PB4 (MISO/PCINT4)
PB5 (SCK/PCINT5)
PB6 (PCINT6/XTAL1/TOSC1)
PB7 (PCINT7/XTAL2/TOSC2)
D1
1N4007
R2
10k
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SDA Main_Schematic[2B]
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DIR1 Main_Schematic[2A], A4988_motor_drivers[1B]
STEP2 Main_Schematic[2A], A4988_motor_drivers[1C]
DIR2 Main_Schematic[2A], A4988_motor_drivers[1C]
STEP3 Main_Schematic[2A], A4988_motor_drivers[1D]
DIR3 Main_Schematic[2B], A4988_motor_drivers[1D]
Relay Main_Schematic[2B], Relay[2C]
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C8
22pF
CrO1
FOXSLF/160-20
J8
M7
R3
1k
J9 M1 R4 1k
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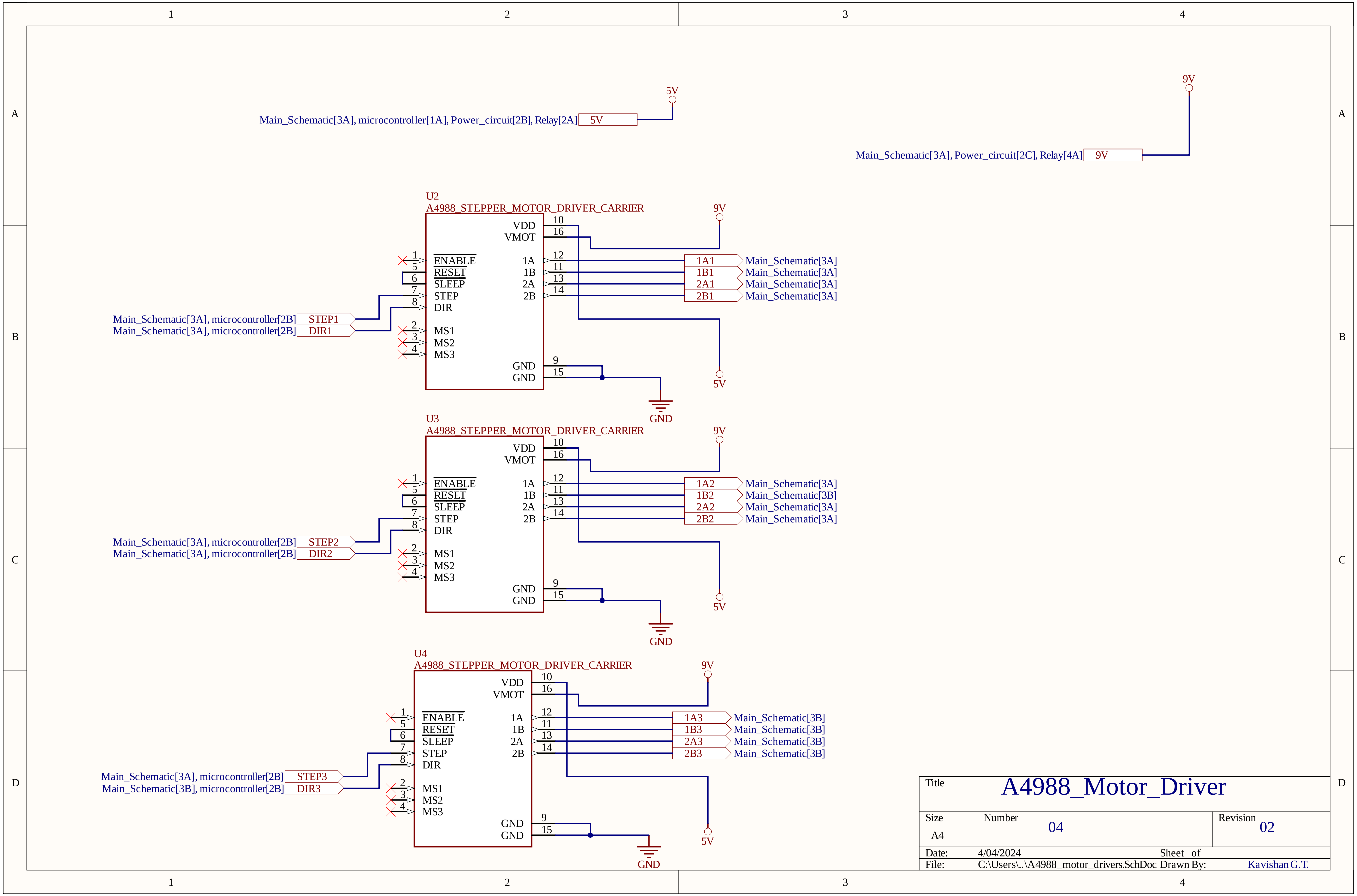
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5V
Main_Schematic[3A], Power_circuit[2C], Relay[4A]
9V
U2
A4988_STEPPER_MOTOR_DRIVER_CARRIER
VDD
VMOT
ENABLE
RESET
SLEEP
STEP
DIR
MS1
MS2
MS3
1A
1B
2A
2B
GND
GND
1A1
1B1
2A1
2B1
Main_Schematic[3A]
Main_Schematic[3A]
Main_Schematic[3A]
Main_Schematic[3A]
Main_Schematic[3A], microcontroller[2B]
STEP1
Main_Schematic[3A], microcontroller[2B]
DIR1
U3
A4988_STEPPER_MOTOR_DRIVER_CARRIER
1A2
1B2
2A2
2B2
Main_Schematic[3A]
Main_Schematic[3B]
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Main_Schematic[3A]
Main_Schematic[3A], microcontroller[2B]
STEP2
Main_Schematic[3A], microcontroller[2B]
DIR2
U4
A4988_STEPPER_MOTOR_DRIVER_CARRIER
1A3
1B3
2A3
2B3
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Main_Schematic[3B]
Main_Schematic[3B]
Main_Schematic[3B]
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04
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4/04/2024
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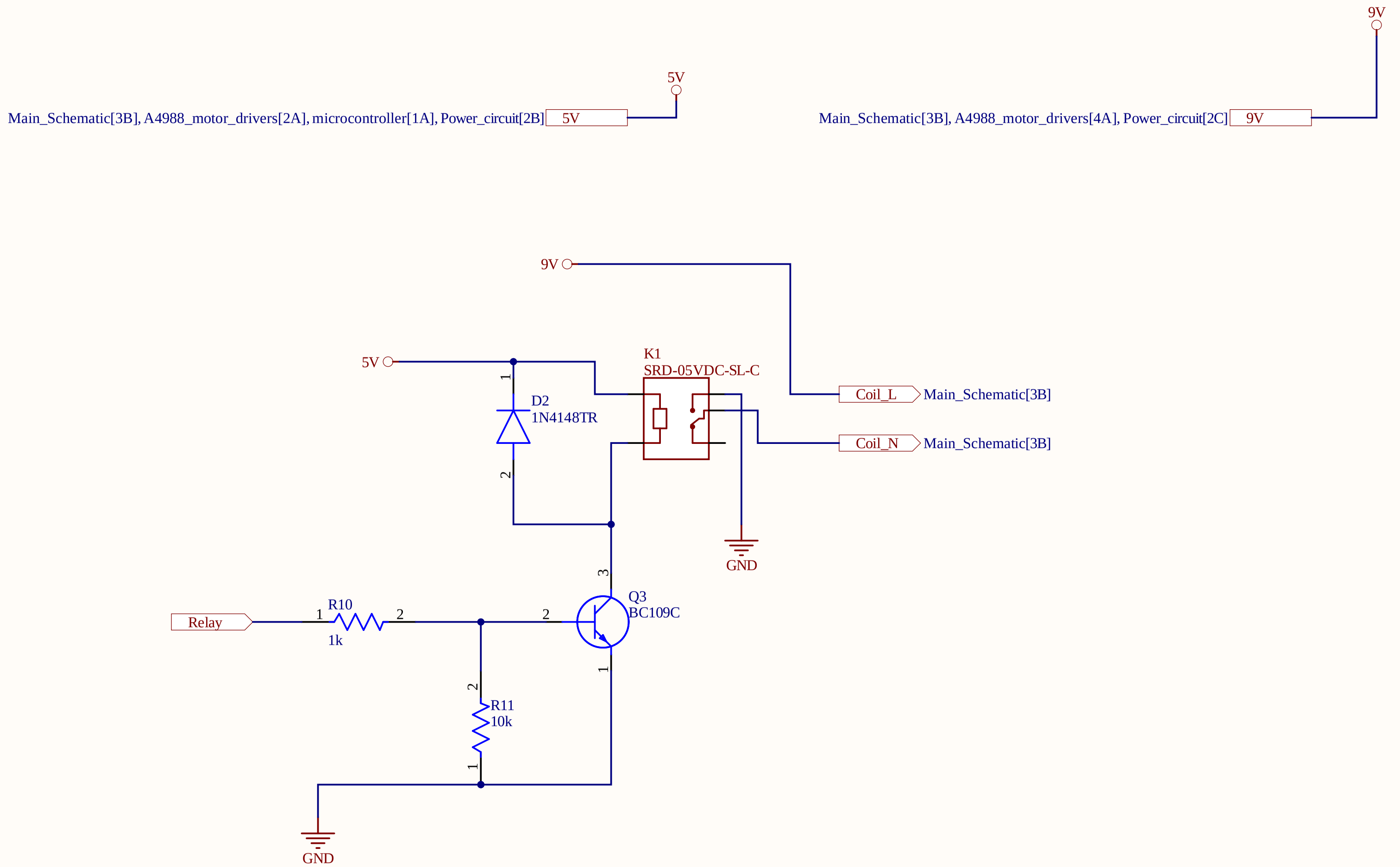
Drawn By:
Kavishan G.T.



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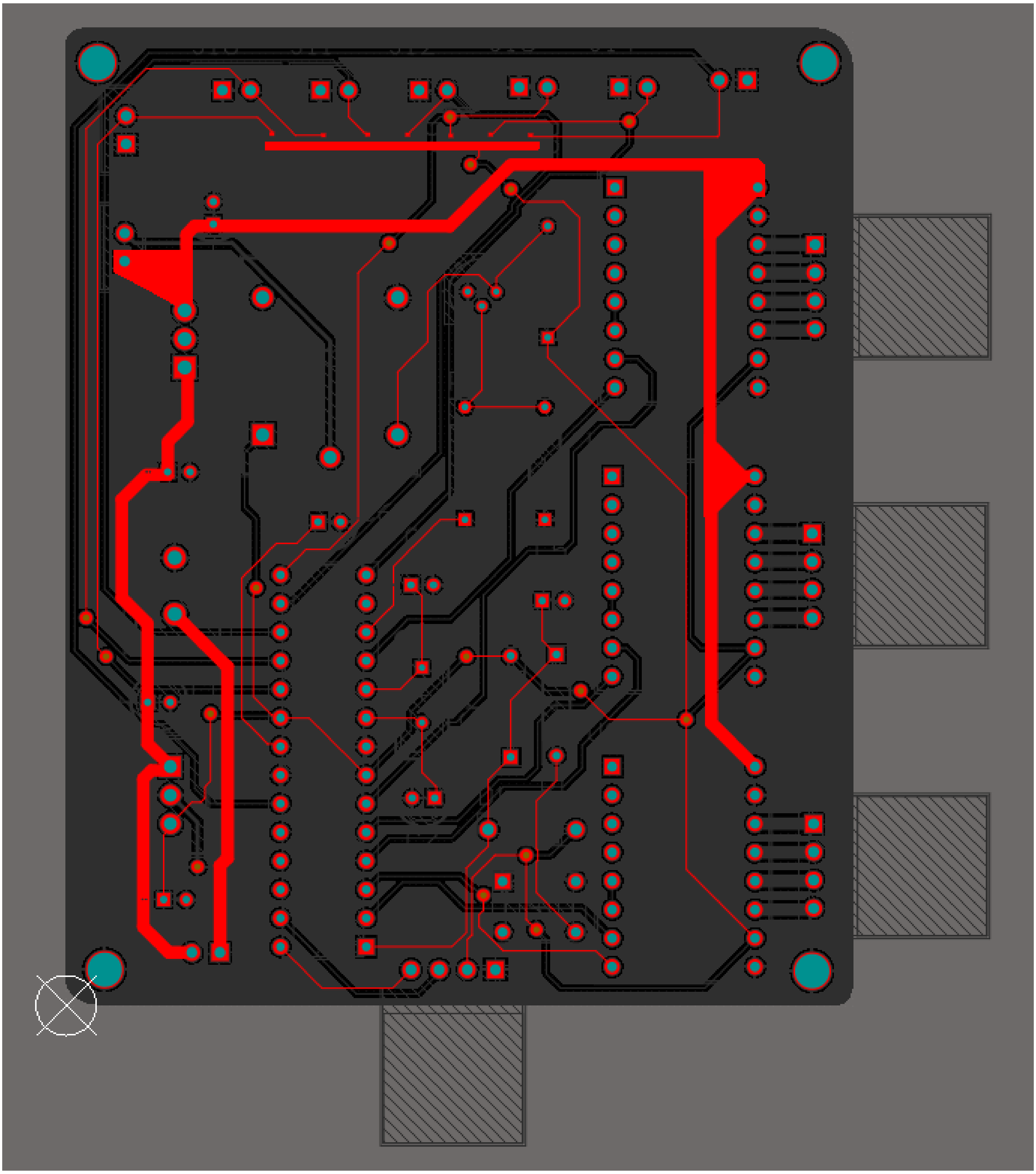


Figure 19: PCB Top Layer

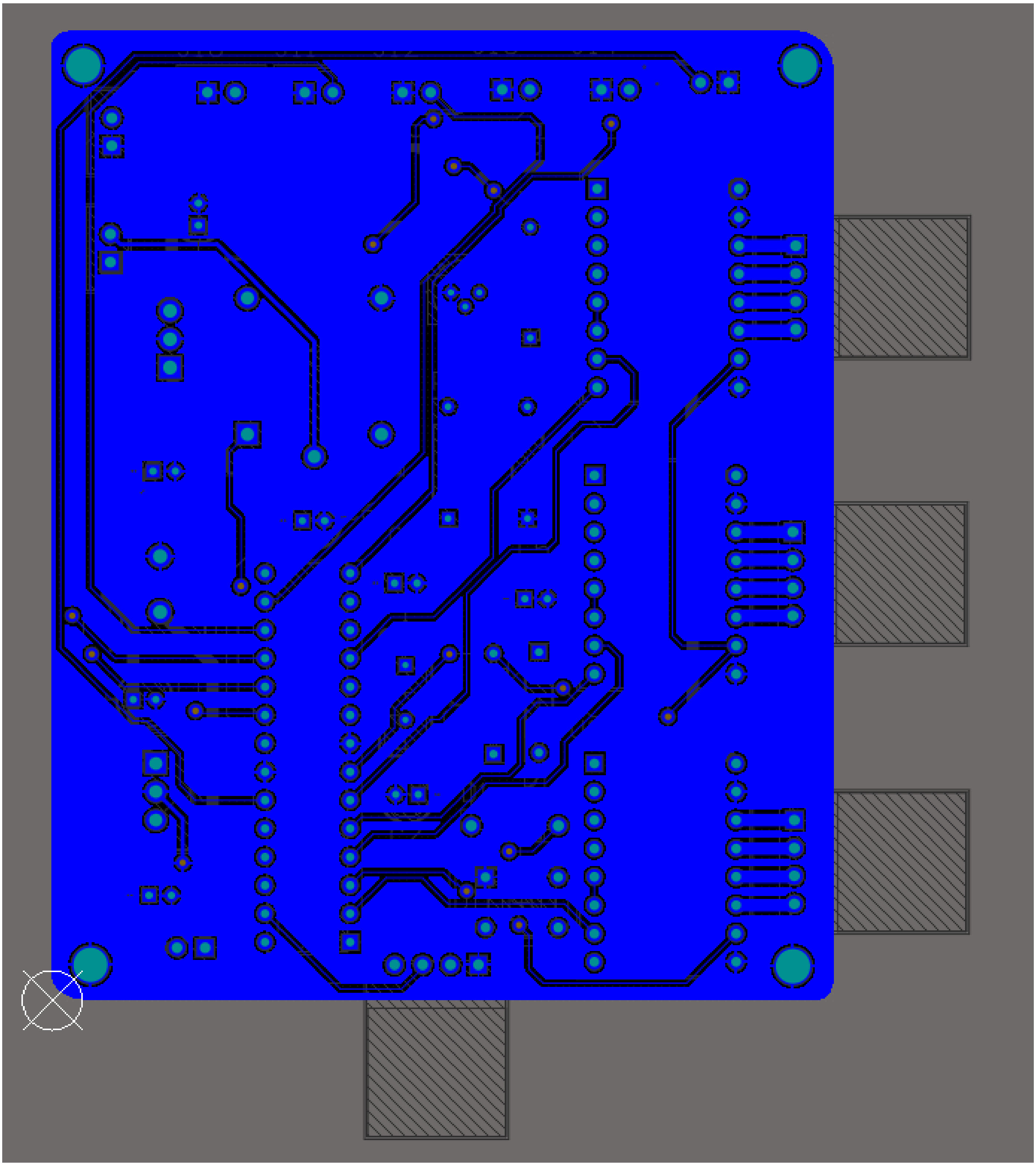


Figure 20: PCB Bottom Layer

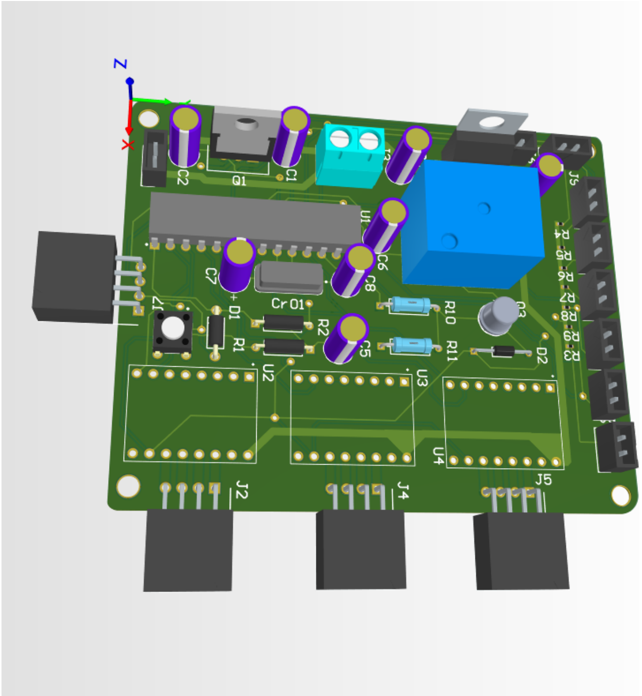


Figure 21: 3D Image of PCB Layout

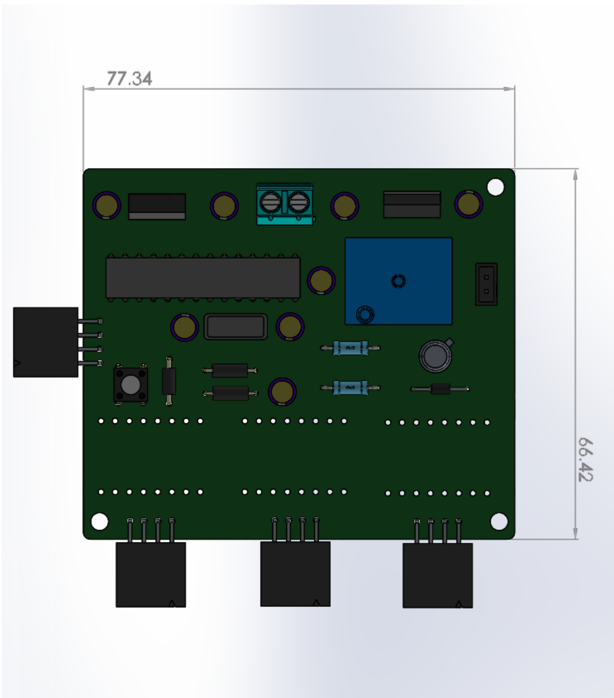


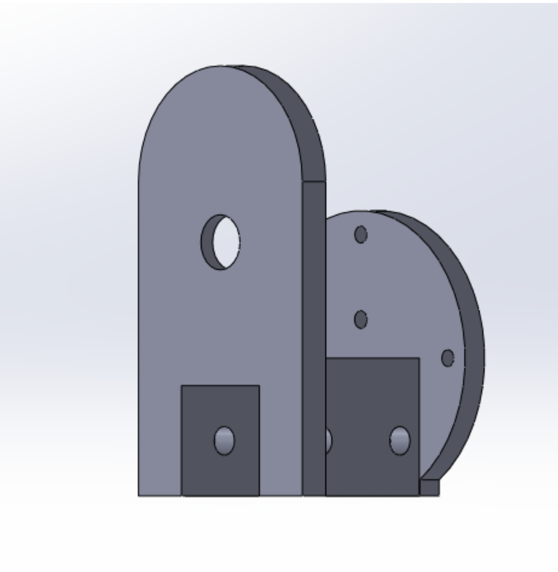
Figure 22: PCB with Dimenssions

11 Final Solidwork Design

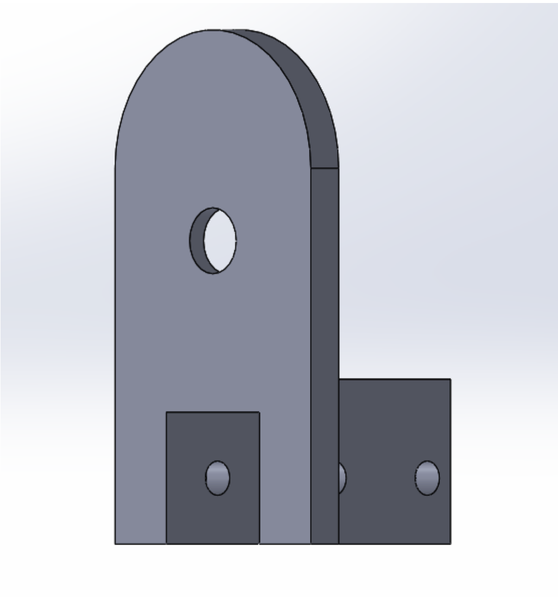
These images show the final SolidWorks design of the enclosure. Ventilation holes are provided to dissipate the heat generated by the components. The design is user-friendly, ensuring easy interaction and operation. The enclosure is durable and robust, capable of withstanding impacts and environmental conditions. The overall design is simple and cost-effective, meeting the functional requirements while providing an aesthetically pleasing appearance. We have added holes to insert buttons to control the stepper motors, electromagnet, display, and other components.

We used parametric design tools in SolidWorks and conducted anti-collapsing tests to ensure structural integrity.

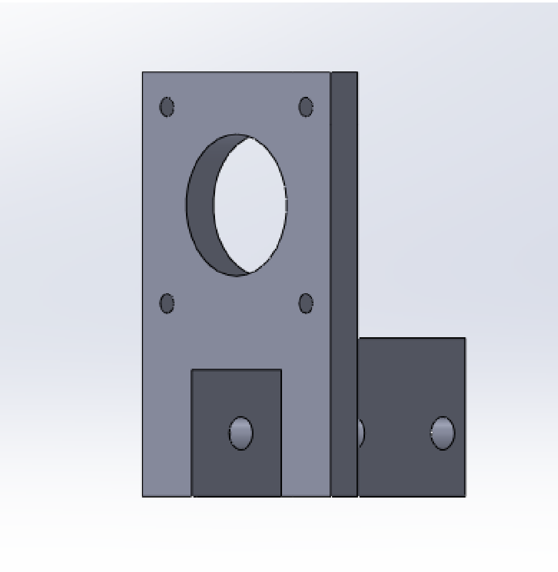
11.1 Connectors



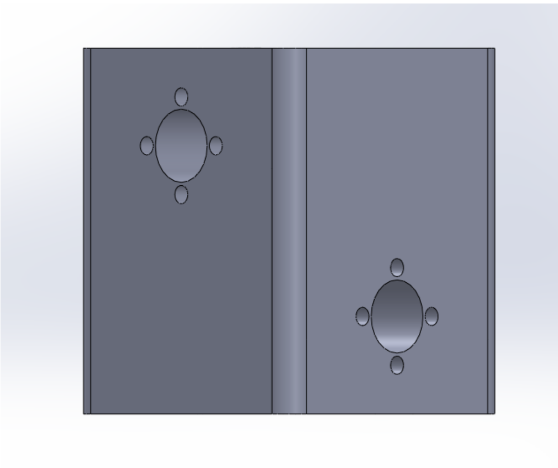
(a) Connector 1 - With Gripper Mount



(b) Connector 2



(c) Connector 3

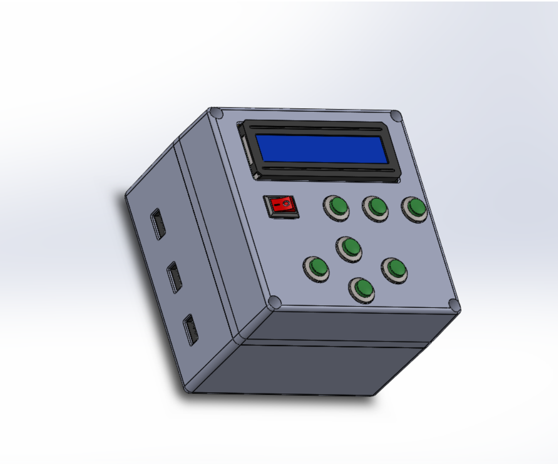


(d) Base Plate

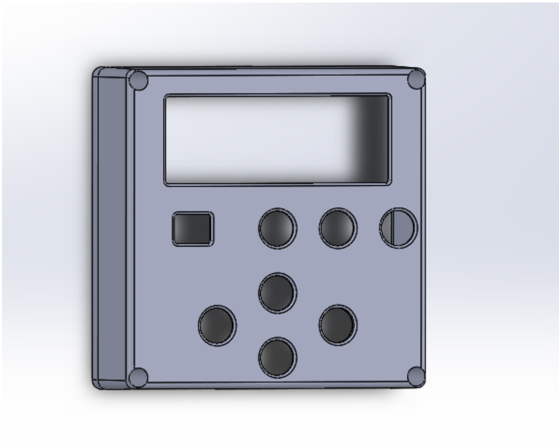
Figure 23: 3D Printed Coupling Parts

11.2 Enclosures

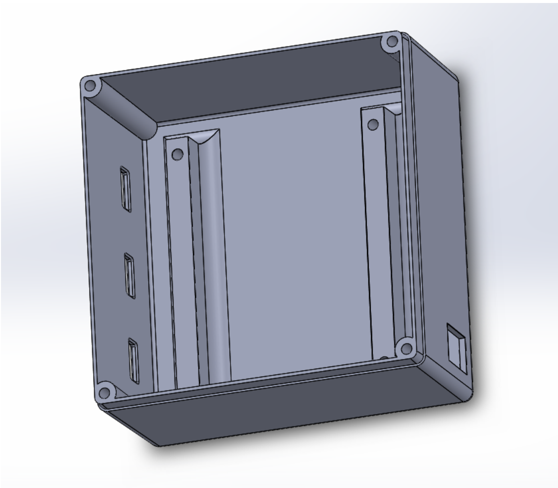
The for the enclosure we are using 3D printing to create the enclosure.



(a) Assembly of the Enclosure



(b) Top Part

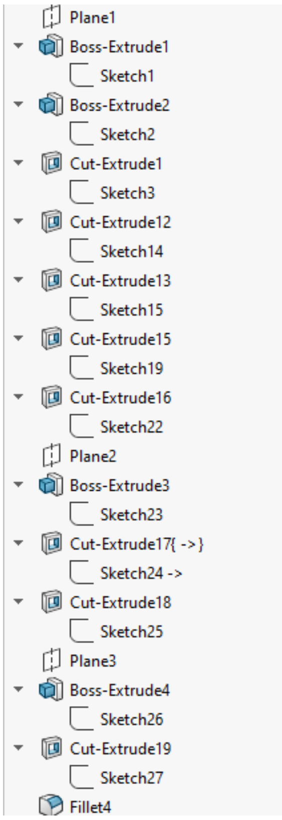


(c) Bottom Part

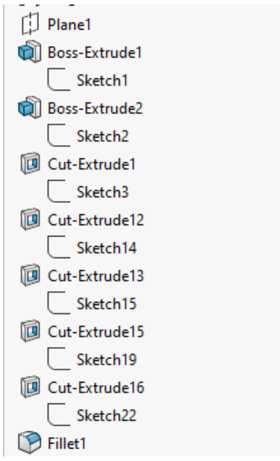
Figure 24: Enclosure Views

To create these plastic enclosures, 3D printing materials such as Nylon PA12 or Nylon PA11 are planned to be used.

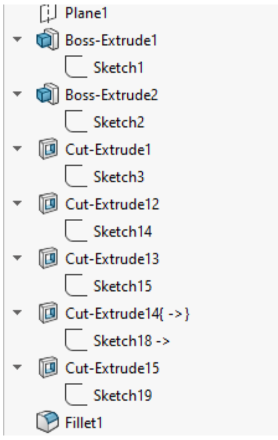
11.3 Solidworks Design Trees



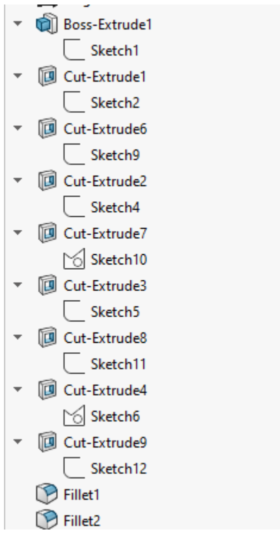
(a) Connector 1 - With Gripper Mount



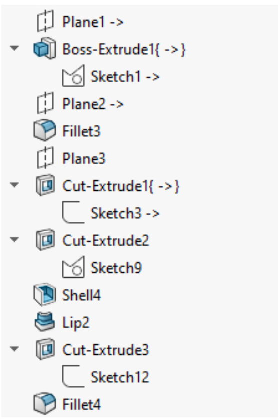
(b) Connector 2



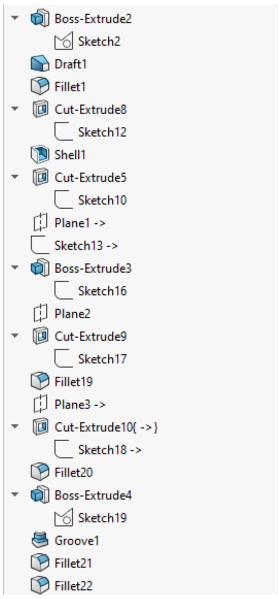
(c) Connector 3



(d) Base Plate



(a) Top Part

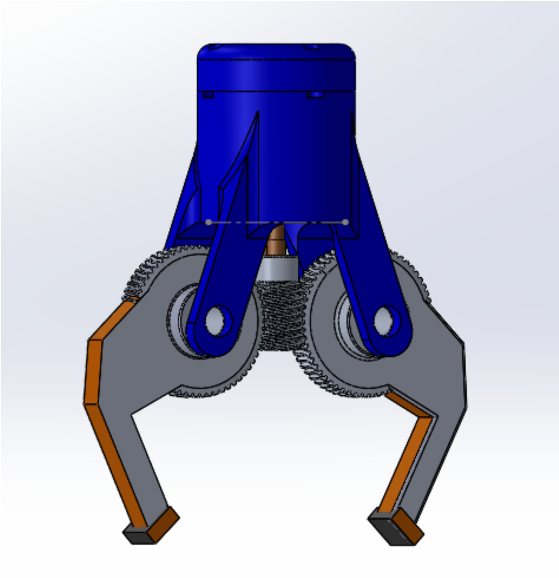


(b) Bottom Part

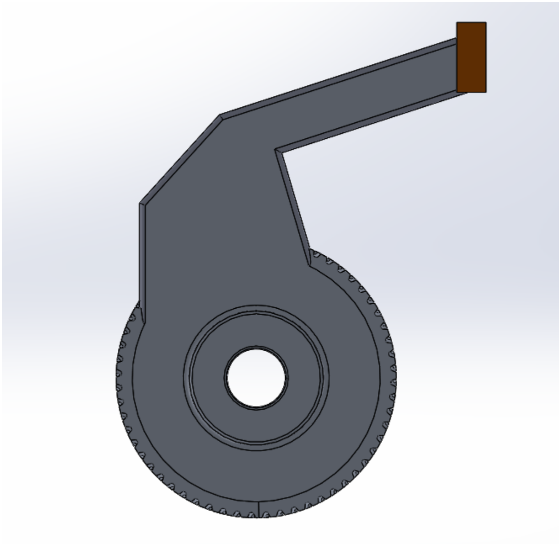
Figure 26: Design Trees

11.4 Mechanical Gripper Mechanism

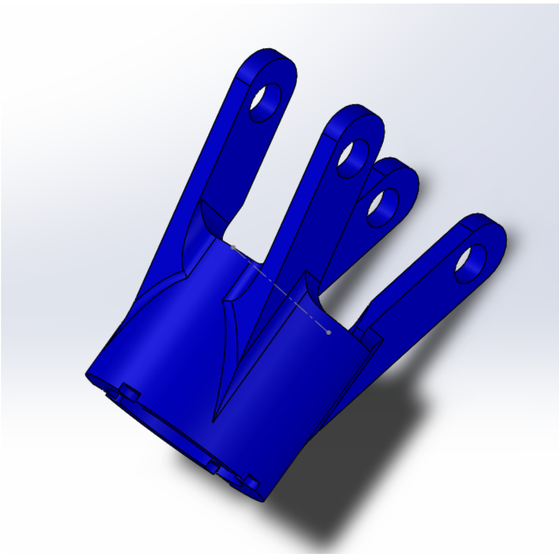
The gripper mechanism is connected to the vertical conveyor system and is responsible for picking up and placing H-Bridge components. It includes:



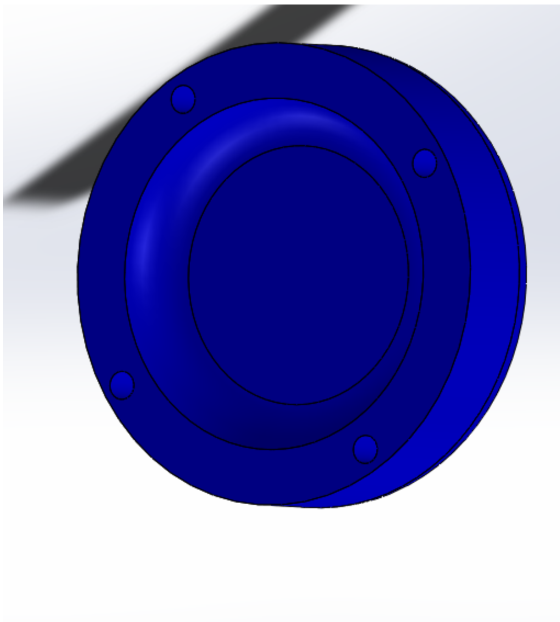
(a) Assembly of the Gripper



(b) Gripper Finger



(c) Stepper Housing 1



(d) Stepper Housing 2

Figure 27: Gripper 3D Model

- **Gripper Module:** The gripper module is designed to securely hold and release electronic components during the pick and place operation. It is attached to the vertical conveyor system to enable controlled vertical movement.
- **Actuation System:** The actuation system within the gripper module allows controlled opening and closing of the gripper, ensuring a secure hold on the components during transportation.

References

[1] Yaskawa Motoman. *Yaskawa Motoman Official Website*. [3D Vision Picking]. Available: https://www.motoman.com/en-us/products/systems/bin-picking

[2] "Pick and Place Robot - Circle Feeder to Press - Bottle Cap Manufacturing." https://www.youtube.com/watch?v=xnze96qM4C0

[3] "Pick and Place - with pneumatic tubings." https://www.youtube.com/watch?v=xnze96qM4C0

[4] "Screw Robot." https://www.youtube.com/watch?v=a5kuUYbLiy0&t=27s

[5] "Flat washer feeder." https://www.youtube.com/watch?v=sB1bOrIo17U

[6] "Bolt and Washer Insertion." https://www.youtube.com/watch?v=YvI_yXXqAw8

[7] "Pick and Place - dual stroke pneumatic cylinder." https://www.youtube.com/watch?v=AA7OIyv2GAc

A Log Entries

A.1 26 February - 3 March

A.1.1 Research Phase

- Conducted research on existing pick and place robots, focusing on products designed to handle nuts, washers, and MOSFET transistors with high accuracy.
- Evaluated industry standards and technologies used in similar projects.
- Decided to design a robot arm based on gathered insights and requirements.

A.2 4 March - 10 March

A.2.1 Conceptualization Phase

- Engaged in brainstorming sessions to generate innovative ideas and methods for the pick and place robot.
- Developed multiple conceptual designs and evaluated them based on criteria such as efficiency, scalability, cost, and technical complexity.
- Analyzed and ranked each conceptual framework, selecting the most promising designs for further development.

A.3 11 March - 17 March

A.3.1 Design Evaluation Phase

- Conducted detailed evaluations of selected conceptual designs, considering factors like technical feasibility, scalability, and alignment with project objectives.
- Developed a structured assessment method to ensure objective evaluation.
- Selected the best conceptual design based on thorough analysis and consensus among team members.

A.4 18 March - 24 March

A.4.1 Gripper Mechanism Selection

- Analyzed various gripper mechanisms for efficiency, precision, and compatibility with the overall robot design.
- Finalized the most suitable gripper mechanism through collaborative discussions and technical assessments.
- Developed a comprehensive project plan, outlining key milestones, tasks, and timelines.
- Defined design specifications, including technical requirements and performance benchmarks.

A.5 25 March - 31 March

A.5.1 Design Phase

- Commenced the design phase by creating a prototype of the pick and place robot using Solidworks software.
- Visualized and validated key features and functionalities of the conceptual design through the prototype.
- Iteratively refined the prototype based on feedback and feasibility assessments to meet performance requirements and address limitations.

A.6 1 April - 7 April

A.6.1 Design Refinement

- Continued iterative refinement of the robot's prototype.
- Incorporated feedback from initial reviews and conducted feasibility assessments to enhance the design.
- Ensured the prototype met all specified performance requirements and addressed any identified limitations.

A.7 8 April - 14 April

A.7.1 Design Finalizing

- Finalized the PCB design and the Solidworks Designs.

A.8 15 April - 21 April

A.8.1 PCB Printing

- Submitted the PCB for printing to JLCPCB.

A.9 22 April - 28 April

A.9.1 Final Design Adjustments

- Finalized the detailed design documentation for the robot.
- Prepared for the upcoming evaluation by reviewing all project elements to ensure completeness and accuracy.
- Ensured that all design elements were aligned with stakeholder requirements and project goals.

A.10 29 April - 5 May

A.10.1 Review and Testing

- Created the prototype
- Conducted internal reviews of the design documentation and prototype.
- Engaged in peer review sessions to gather additional feedback and make necessary adjustments.
- Tested the PCB designed for the robot to ensure it met all operational specifications.

A.11 6 May - 12 May

A.11.1 Controller Enclosure

- FInalized the controller Solidworks and 3D Printed it.

A.12 13 May - 19 May

A.12.1 Final Report Preparation

- Compiled all project documentation, including detailed design reports, test results, and feedback from demonstrations.
- Finalized the project report, ensuring it included comprehensive details about the design process, challenges faced, and solutions implemented.