University of Moratuwa

Faculty of Engineering

Department of Electronic & Telecommunication Engineering

EN2160

Electronic Design Realization

Closed Loop Stepper Motor Driver Design Methodology

Group 32

Group Members

- 210152E - Dulnath W.H.R.
- 210599E - Shamal G.B.A.
- 210600D - Shamika K.A.M.
- 210642G - Thennakoon T.M.K.R.

Table of Contents

Introduction

In the realm of precision motion control, stepper motors have long been the preferred choice for applications demanding accurate and repeatable positioning. Traditionally, stepper motors operate on an open-loop control system, where a fixed number of pulses is sent to the motor, assuming that the desired position is achieved. However, this assumption often leads to inaccuracies, as factors such as mechanical resistance and inertia can cause missed steps. To address these limitations and enhance the precision and reliability of stepper motor systems, our project proposes the development of a stepper motor driver with a closed-loop feedback mechanism.

The proposed driver will incorporate a feedback sensor to continuously monitor the actual position of the stepper motor's shaft. By comparing real-time position data with the desired target position, any discrepancies or errors will be corrected in real-time. This closed-loop feedback system ensures that the motor reaches the exact intended position, significantly improving accuracy and minimizing the risk of missed steps. Such a mechanism is crucial for applications requiring high precision and reliability.

In addition to closed-loop feedback, our driver will utilize micro-stepping technology. Micro-stepping divides each full step of the motor into many finer steps, allowing for smoother and more precise control of the motor's movement. This results in reduced vibration and enhanced torque delivery, particularly at lower speeds, making the system ideal for applications that demand smooth and controlled motion.

The driver will be designed using a dedicated microcontroller unit (MCU) or a field-programmable gate array (FPGA) to handle real-time control and implement advanced control algorithms for both closed-loop feedback and micro-stepping. The power stage will employ an H-bridge configuration using power electronics such as MOSFETs or IGBTs to control current flow to the motor windings. Gate drivers may be used to amplify the MCU's outputs to meet the requirements of the chosen power electronics. The design will prioritize safety, proper heat dissipation, and signal integrity to ensure reliable and high-performance operation.

By integrating closed-loop feedback and micro-stepping technologies, our stepper motor driver aims to deliver enhanced accuracy, smoother movement, and improved performance over traditional open-loop systems. This project not only addresses the limitations of current stepper motor drivers but also pushes the boundaries of precision motion control, making it suitable for a wide range of applications that require exact and reliable positioning.

Review Progress

1. Research on Industrial Stepper Motor Drivers:

- *Research by Universities:*
    - Laurean Bogdan from the University "Lucian Blaga" of Sibiu presented a cost- effective solution utilizing Programmable Logic Controllers (PLCs) for stepper motor control. This approach emphasizes simplicity and ease of configuration via ladder diagrams, offering an alternative to expensive off-the-shelf controllers.
    - Universities such as Huazhong University of Science and Technology and Hangzhou Dianzi University have investigated hybrid stepper motor drives employing single-chip microcontrollers (e.g., STM32), combining the benefits of permanent magnet and variable reluctance motors.
- *Summary of Research Papers:*
    - Microcontrollers are commonly employed for stepper motor control, allowing precise movement through designed sequences. Various microcontroller-based approaches for position and speed control have been explored, often involving custom firmware development and interfacing with external sensors.

2. Commercial Solutions and Challenges:

- Many companies offer specialized stepper motor drivers, ranging from single-axis controllers to multi-axial control versions. However, cost remains a significant factor in adopting these solutions.
- Stepper motors lack built-in feedback, necessitating external commutation by the controller. Despite this limitation, they excel in precise positioning applications.

3. Proposed Solution:

- The project proposes the development of a stepper motor driver with closed-loop feedback, aiming to minimize inaccuracies associated with traditional open-loop systems.
- The driver will integrate micro-stepping technology for smoother movement and finer control over rotational motion, enhancing

performance particularly at lower speeds.Utilizing a dedicated microcontroller unit (MCU) or field-programmable gate array (FPGA) for real-time control, advanced control algorithms will be implemented for closed-loop feedback and micro-stepping.

- The power stage will employ an H-bridge configuration using power electronics like MOSFETs or IGBTs to control current flow to the motor windings, prioritizing safety, heat dissipation, and signal integrity.

The review progress highlights the existing research and commercial solutions in the realm of stepper motor control, emphasizing the need for enhanced accuracy and performance through closed-loop feedback mechanisms. The proposed project aims to bridge these gaps by developing a robust stepper motor driver, integrating advanced control algorithms and micro-stepping technology for precise and reliable operation in industrial applications.

Plan Next Steps

1. **Review Project Scope and Objectives:**
    - Conduct a thorough review to ensure alignment with stakeholders' expectations and industry requirements.
    - Verify that all necessary components and functionalities are adequately addressed.
2. **Establish Timeline and Milestones:**
    - Develop a detailed timeline with specific milestones for each phase of the project.
    - Assign responsibilities to team members and establish deadlines for accountability.
3. **Procurement and Material Acquisition:**
    - Identify and procure all necessary materials, components, and equipment.
    - Ensure materials meet quality standards and project specifications.
4. **Design and Fabrication of Feedback Mechanism:**
    - Initiate the design and fabrication process for the feedback mechanism, considering sensor selection, integration, and calibration.
    - Conduct prototype testing to validate design specifications and functionality.
5. **Microcontroller Programming and Algorithm Development:**

- Begin development of control algorithms and software for real-time feedback control.
- Program the MCU/FPGA to receive feedback data, compare with target positions, and adjust control signals accordingly.

6. **Integration with Power Stage:**
    - Integrate feedback mechanism with the power stage, ensuring compatibility and functionality.
    - Conduct thorough testing to validate performance and reliability.

7. **Testing and Optimization:**
    - Perform rigorous testing to validate accuracy, reliability, and performance under various operating conditions.
    - Iterate on design and software as necessary to optimize performance and address any identified issues.

8. **Documentation and Support:**
    - Create comprehensive documentation, including assembly instructions, operating procedures, and troubleshooting guidelines.
    - Provide ongoing support and assistance to users for successful implementation and operation.

9. **Stakeholder Communication and Feedback:**
    - Maintain regular communication with stakeholders to provide updates on project progress and address any concerns or feedback.
    - Solicit feedback throughout the project lifecycle to ensure alignment with expectations and incorporate necessary adjustments.

10. **Evaluation and Validation:**
    - Evaluate the system's performance against predetermined metrics and objectives. Validate the effectiveness of the closed-loop feedback mechanism in minimizing inaccuracies and improving positioning accuracy.

11. **Future Steps:**
    - Explore opportunities for further enhancements and applications of the developed stepper motor driver technology.
    - Consider potential collaborations with industry partners for real-world testing and implementation.

This plan outlines the next steps for the successful execution of the project, ensuring alignment with project objectives and stakeholder expectations. Each step is essential for achieving the desired outcome of developing a robust stepper motor driver with closed-loop feedback mechanism

Stakeholder Mapping

In the context of developing a stepper motor driver with a closed-loop feedback mechanism, identifying, and understanding key stakeholders is crucial for project success. Stakeholders can include individuals, organizations, or entities directly or indirectly impacted by the project. By mapping stakeholders based on their levels of interest and influence, we can effectively manage relationships, anticipate needs, and ensure alignment with project objectives.

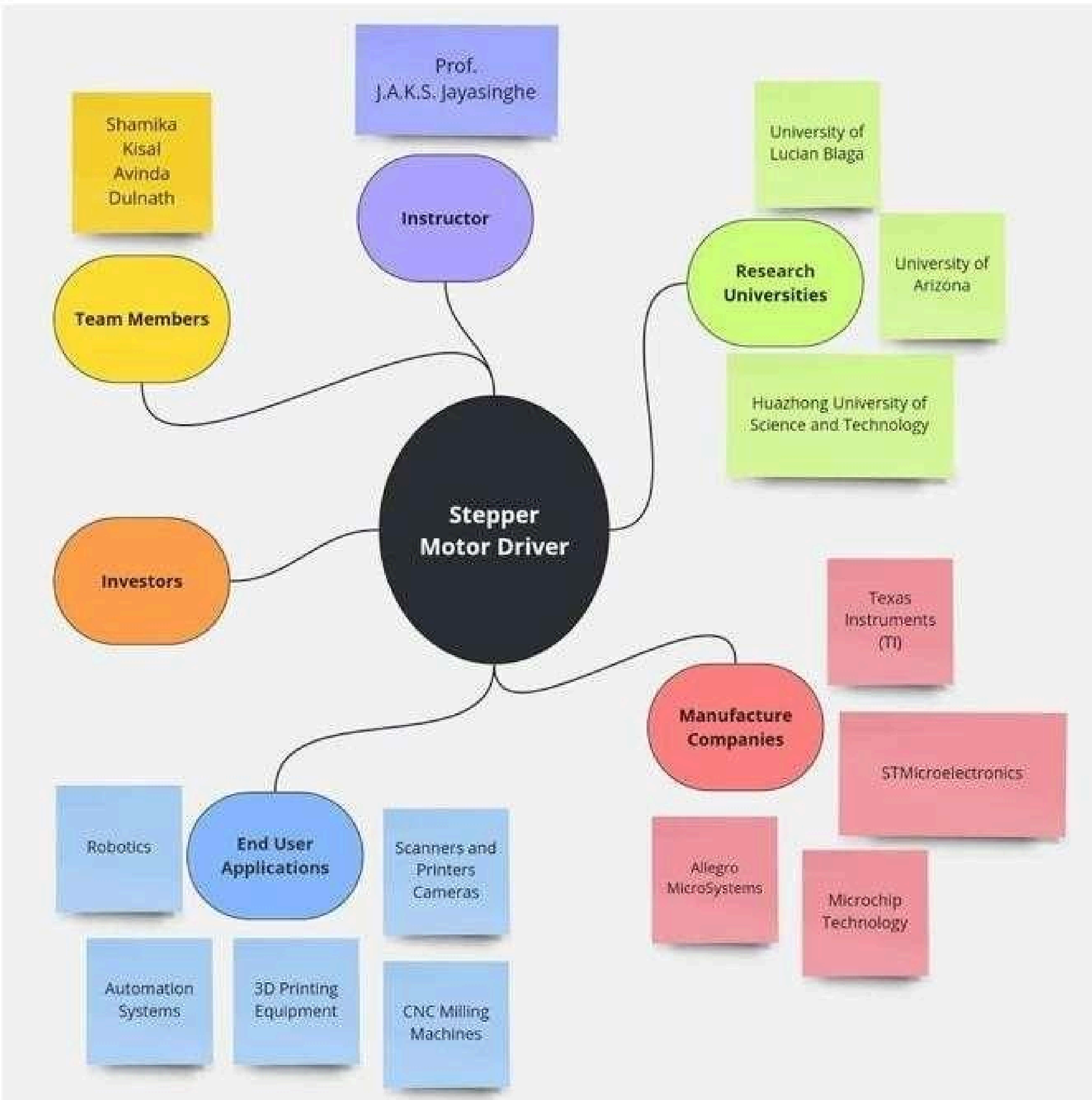
Stakeholder Categories:

1. **Manufacturers and Suppliers**:
    - These stakeholders provide essential components and materials necessary for the fabrication and assembly of the stepper motor driver. Their input and support are critical for ensuring the availability of quality components and timely delivery.
2. **Technology Partners:**
    - Collaborating with technology partners such as microcontroller manufacturers, sensor suppliers, and electronic component distributors is essential for accessing cutting-edge technologies and expertise. Their involvement can influence the selection of components and the overall performance of the driver.
3. **End Users and Customers:**
    - End users and customers, including industries requiring precise motion control systems, are primary stakeholders. Understanding their needs, preferences, and performance expectations is essential for designing a stepper motor driver that meets market demands and delivers value.
4. **Regulatory Authorities:**
    - Regulatory authorities may have oversight or compliance requirements related to motor control systems, particularly in safety-critical industries such as aerospace, automotive, and medical devices. Engaging with regulatory bodies ensures adherence to standards and certifications necessary for market acceptance.
5. **Research Institutions and Academia:**

- Collaboration with research institutions and academia can provide valuable insights, expertise, and resources for advancing motor control technologies. Engaging with academic stakeholders fosters innovation and facilitates knowledge exchange in the field.

By strategically mapping stakeholders based on their levels of interest and influence, we can tailor communication strategies, address concerns, and foster productive collaborations. throughout the project lifecycle. Regular engagement and alignment with stakeholders' expectations contribute to the successful development and adoption of the stepper motor driver with a closed-loop feedback mechanism.

Stakeholder Map



Observe Users

1. User Interface Preferences:

Users prefer an intuitive interface for controlling the stepper motor driver, allowing easy adjustment of parameters like speed, acceleration, and direction.

Clear and readable displays are essential for visibility in busy industrial environments.

2. Motor Interaction and Maintenance:

Operators prioritize a robust and durable motor driver, minimizing maintenance needs.

Ease of access for cleaning and component replacement is crucial for efficient operation.

3. Enclosure Design:

Observations highlight the need for an enclosure offering adequate protection while allowing easy access for maintenance and troubleshooting.

4. Documentation and Support:

Stakeholders emphasize comprehensive documentation and support for assembly, operation, and troubleshooting.

User training programs and ongoing technical support are essential for successful implementation and operation.

User Requirements

Introduction: Stepper motor drivers with feedback mechanisms play a critical role in various industrial applications, requiring a thorough understanding of user requirements to ensure optimal performance and usability. This section outlines the key user requirements associated with the development of such a driver.

Precision and Accuracy:

- *Observation:* Users demand high precision and accuracy in motor control to achieve precise positioning and movement.
- *User Requirement:* The stepper motor driver must maintain accuracy even under challenging conditions, minimizing errors, and ensuring reliable performance. It should be capable of precise micro stepping to achieve smooth motion and accurate positioning, especially in applications requiring intricate movements or fine adjustments.

Speed and Efficiency:

- *Observation:* Efficient motor control necessitates fast response times and high- speed operation to meet the demands of industrial applications.
- *User Requirement:* Users expect the stepper motor driver to deliver rapid and precise motion control, optimizing productivity and minimizing production downtime. It should offer adjustable speed settings to accommodate varying operational requirements and ensure efficient performance across a wide range of applications.

Cost-Effectiveness:

- *Observation:* Cost considerations are crucial for industrial operations, requiring a balance between performance and affordability.
- *User Requirement:* Users seek a stepper motor driver solution that offers cost- effective motor control without compromising on quality or reliability. The driver should provide value for money by delivering efficient performance, minimizing energy consumption, and offering long-term durability to reduce overall operational costs.

Reliability and Maintenance:

- *Observation:* Continuous operation is essential in industrial settings, highlighting the need for a reliable motor driver with minimal downtime.
- *User Requirement:* Users expect the stepper motor driver to exhibit high reliability, with robust hardware components and advanced fault detection mechanisms to minimize the risk of malfunctions. It should offer easy access for maintenance and troubleshooting, allowing quick diagnosis and resolution of issues to ensure uninterrupted operation. Additionally, proactive support from the manufacturer or service provider, including timely availability of spare parts and comprehensive maintenance contracts, is essential to address any potential concerns promptly and effectively.

Understanding and addressing these user requirements will guide the development of a stepper motor driver with a feedback mechanism that meets the diverse needs of users across industrial sectors. By prioritizing precision, speed, cost-effectiveness, reliability, and ease of maintenance, we can create a driver solution that enhances operational efficiency and productivity in industrial automation applications.

Stimulating Ideas

Introduction: In the pursuit of revolutionizing stepper motor control systems, stimulating innovative ideas is pivotal to drive progress and explore new frontiers in motion control technology. This section presents a series of stimulating ideas aimed at enhancing the performance, versatility, and adaptability of stepper motor drivers equipped with closed-loop feedback mechanisms.

1) **Dynamic Torque Compensation Algorithm:**

    Explore the development of a dynamic torque compensation algorithm that adjusts motor current and step rates in real-time based on load variations and environmental conditions.

    By dynamically adapting to changes in load, inertia, and friction, the algorithm ensures consistent torque delivery and optimal motor performance across a wide range of operating conditions.

    This innovative approach enhances motor efficiency, minimizes power consumption, and mitigates the risk of stalling or missed steps, particularly in high-load or variable-load applications.

2) **Intelligent Micro-Stepping Control:**

    Investigate intelligent micro-stepping control algorithms that dynamically adjust micro-step resolutions based on motor speed, load requirements, and positional accuracy criteria.

    By optimizing micro-step resolutions in real-time, the stepper motor driver can achieve smoother motion, reduced vibration, and enhanced positional accuracy, especially at low speeds and during acceleration/deceleration phases.

    This intelligent micro-stepping control mechanism improves motion control precision, minimizes resonance effects, and enhances overall system performance in applications demanding high precision and smooth motion profiles.

3) **Predictive Maintenance and Health Monitoring:**

Implement predictive maintenance algorithms that utilize sensor data and machine learning techniques to anticipate potential motor failures or performance degradation before they occur.

By continuously monitoring motor parameters such as temperature, current, and vibration, the stepper motor driver can detect early signs of wear, misalignment, or overheating, allowing for proactive maintenance interventions.

This proactive approach to maintenance minimizes unplanned downtime, extends motor lifespan, and enhances system reliability, ensuring uninterrupted operation in critical industrial applications.

4) **Adaptive Control Interfaces and User Experience Enhancements:**

Explore the integration of adaptive control interfaces and user experience enhancements to streamline motor setup, configuration, and tuning processes.

Develop intuitive user interfaces that provide real-time feedback on motor status, performance metrics, and diagnostic information, empowering users to optimize motor control parameters effortlessly.

By prioritizing user-friendly design principles and interactive features, the stepper motor driver enhances usability, reduces setup time, and facilitates seamless integration into diverse automation systems and applications.

5) **Interoperability and Integration with Industry 4.0 Technologies:**

Investigate interoperability standards and protocols for seamless integration of stepper motor drivers with Industry 4.0 technologies such as PLCs, HMIs, and industrial IoT platforms.

Enable bidirectional communication and data exchange between the stepper motor driver and other smart factory components, facilitating real-time monitoring, control, and optimization of manufacturing processes

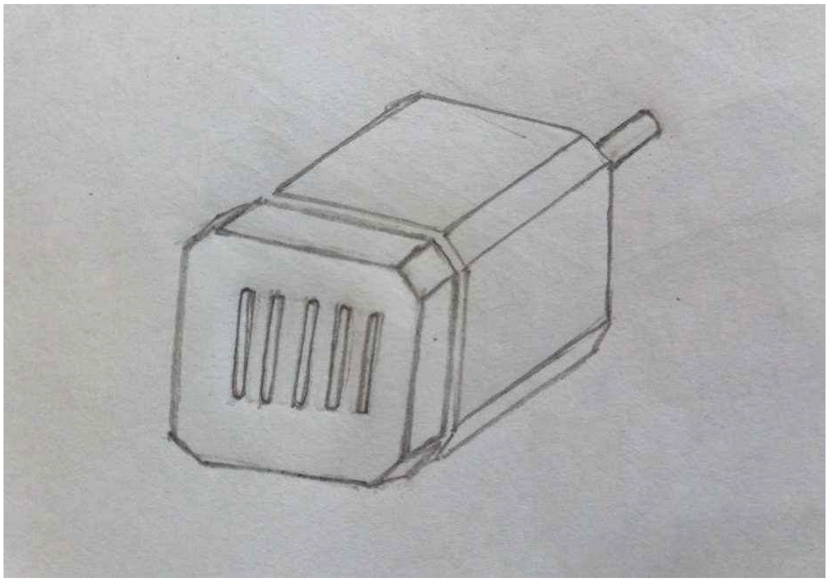
Conceptual Designs

Three specific designs were selected for the review process after a variety of design possibilities were taken into consideration with the goal of finding the best solution.

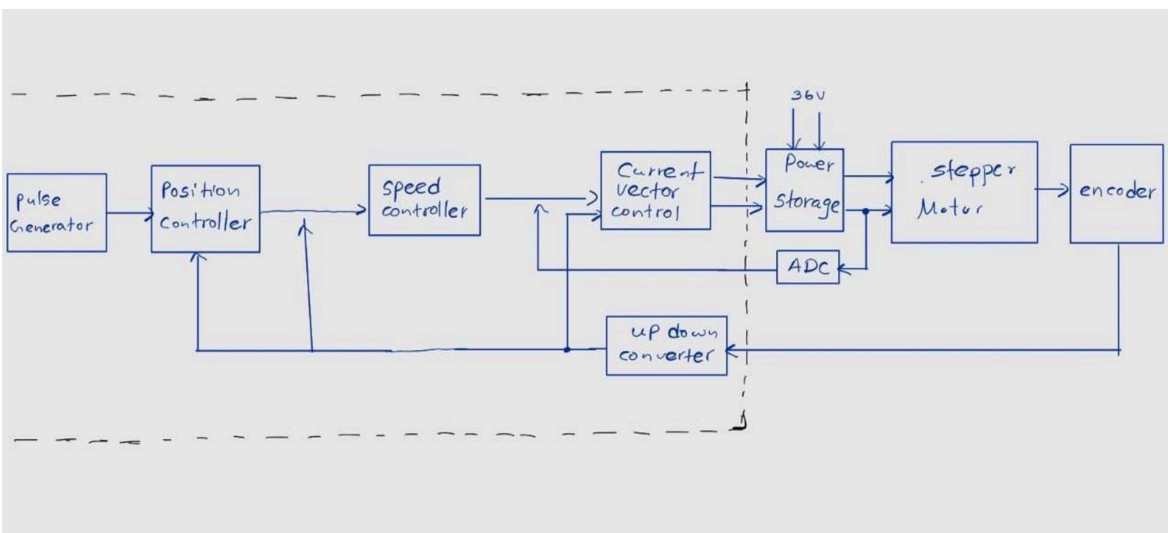
3. Design 1

Conceptual Design 1 is engineered to seamlessly integrate with the stepper motor, serving as an attachable component for streamlined installation. Notably, its compact enclosure and minimalist circuitry distinguish it from alternative designs, offering a space-efficient solution without compromising functionality. Notably, this design's block diagram showcases the utilization of FPGA for carrying out essential calculations required for motor control. By leveraging FPGA technology, the driver achieves efficient processing and execution of tasks, enhancing its overall performance and reliability. This design prioritizes portability and ease of use, catering to users seeking mobility and simplicity in their applications. Its lightweight and user-friendly design make it a versatile option for various stepper motor setups, ensuring hassle-free integration and operation. Conceptual Design 1 embodies a balance of compactness, computational efficiency, and user-centric features, making it an ideal choice for applications where space constraints and ease of use are paramount considerations.

- **Enclosure Design**



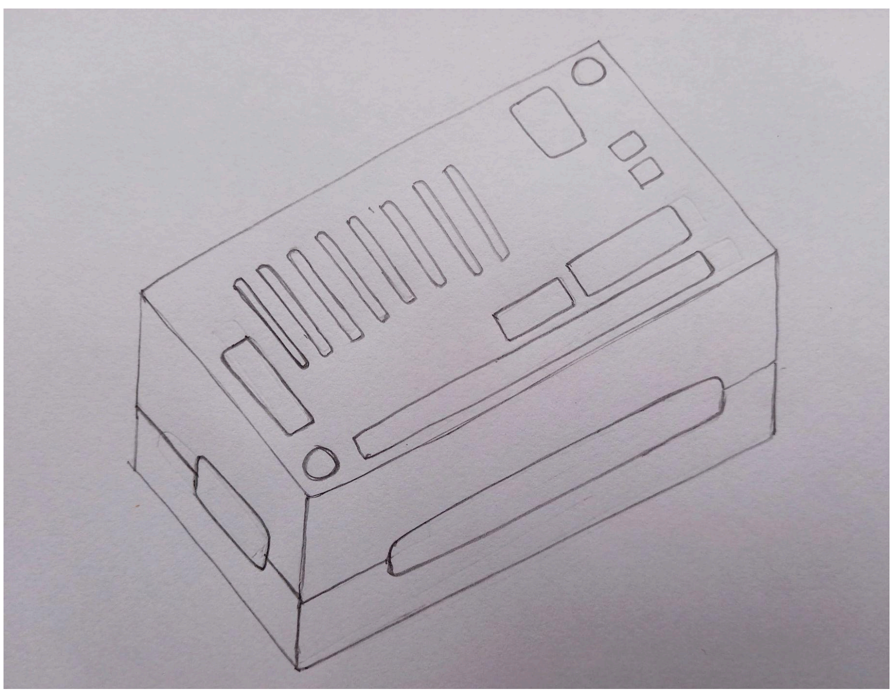
- **Functional Block Diagram**



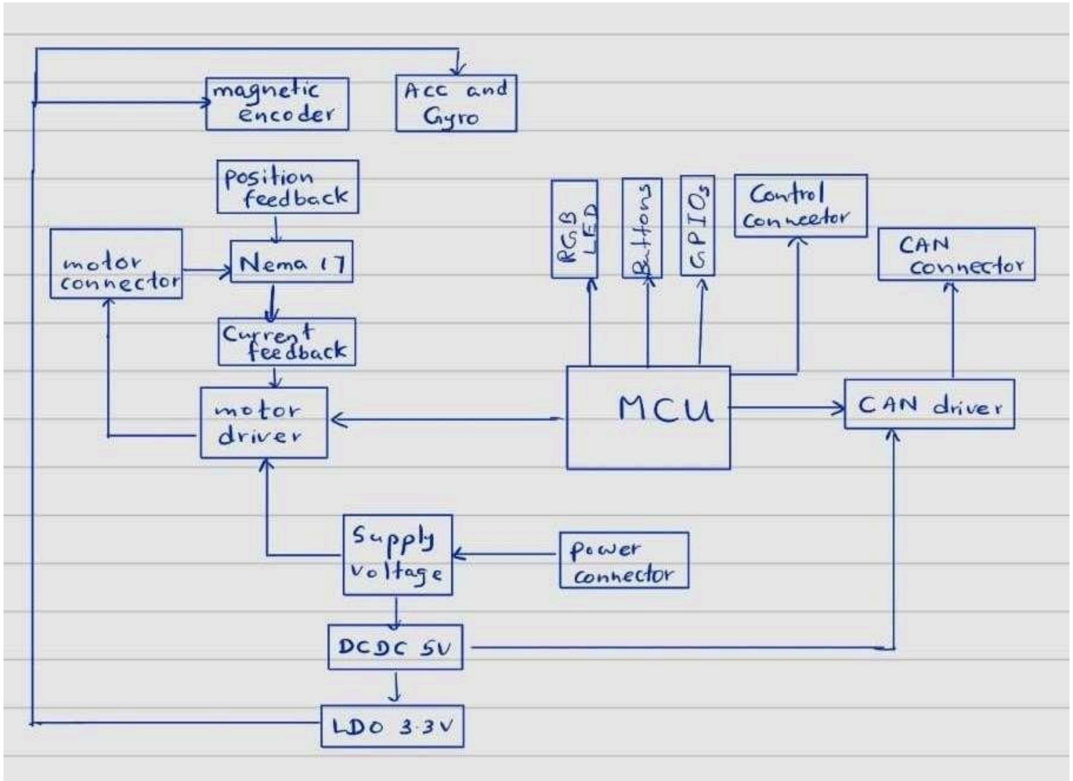
2. Design 2

Conceptual Design 2 represents a closed-loop stepper motor driver equipped with an integrated feedback system, ensuring precise control and movement. The driver incorporates encoder information from the stepper motor to accurately monitor its position, enabling precise stepping actions. Positioned as an external component, it features a spacious enclosure accommodating a wholes for optimal thermal management. A Microcontroller serves as the primary computational unit, efficiently handling essential calculations for motor control. This comprehensive approach to design ensures not only precision in motion control but also addresses thermal considerations and computational efficiency, positioning Conceptual Design 2 as a robust solution for stepper motor applications.

- **Enclosure Design**



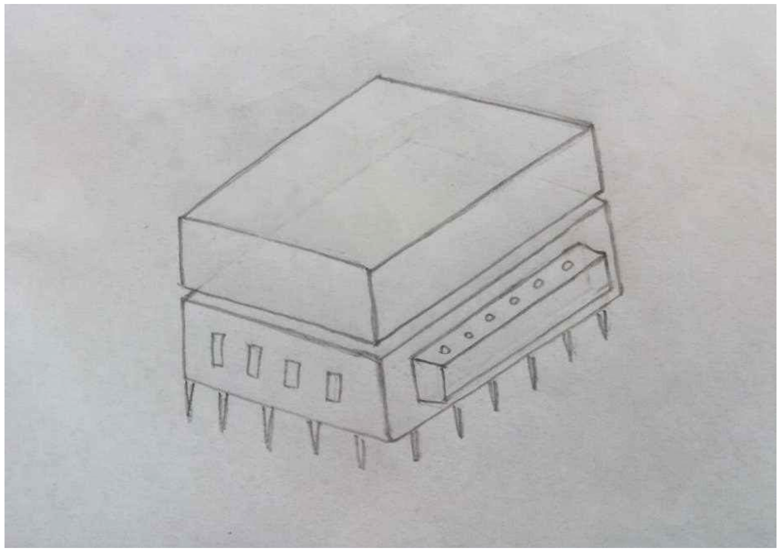
- **Functional Block Diagram**



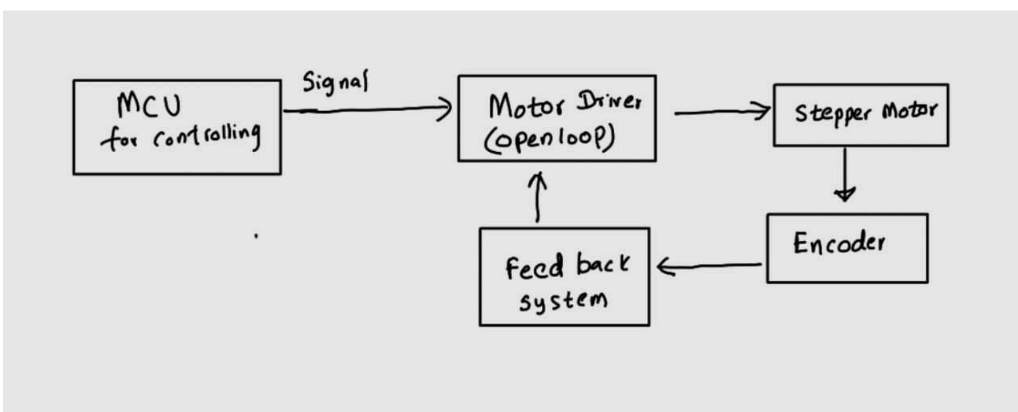
3. Design 3

Design 3 presents a versatile approach by integrating an open-loop stepper motor driver with an external feedback mechanism, positioned independently from the motor drive. This unique configuration offers the flexibility to operate the motor driver in both open and closed-loop modes, catering to a wide range of application requirements. The external feedback mechanism enables precise monitoring of the motor's position, allowing for enhanced control and accuracy when operating in closed-loop mode. Conversely, in open-loop mode, the system operates without feedback, offering simplicity and efficiency for applications where precise control is not necessary. By combining the advantages of both open and closed-loop systems, Design 3 provides users with the adaptability to tailor their motor control strategy according to specific performance needs and operational preferences, making it a versatile and adaptable solution for diverse stepper motor applications.

- **Enclosure Design**



- **Functional Block Diagram**



Evaluation Criteria

Enclosure Design Criteria:

1. Functionality: How well the design supports the main functionalities?
2. Aesthetics: How much eye catching and overall appeal of the user?
3. Heat dissipation: How much heat is generated and how well it has been managed?
4. Assembly and serviceability: How easily do the assembly and disassembly is done?
5. Ergonomics: How well does the design fit in the user's hand and allow easy interaction?
6. Durability: How well does the design withstand impacts and environmental conditions?
7. Simplicity

Functional block diagram criteria:

1. Functionality: How well the circuit design meets functional requirements?
2. User experience: How intuitive and user-friendly is the interaction?
3. Manufacturing feasibility: Evaluate the feasibility of manufacturing the design.
4. Cost: Evaluate the overall cost effectiveness for the provided functionality
5. Performance: Evaluate signal quality, resolution, and bandwidth range?
6. Future proofing: To what extent does the design allow for easy replacement or upgrade ofindividual components?
7. Power Efficiency: How effectively does the device manage power consumption?

Evaluation of the Designs - Selection Matrix

	Criteria	Design 1	Design 2	Design 3
Enclosure design criteria	Functionality	6	8	6
	Aesthetics	7	7	5
	Heat Dissipation	3	8	7
	Assembly And Serviceability	8	6	4
	Ergonomics	8	6	6
	Durability and Reliability	7	8	9
	Simplicity	10	8	5
Functional block diagram criteria	Functionality	6	8	7
	User Experience	8	8	6
	Feasibility	6	8	5
	Cost	7	9	3
	performance	6	7	6
	Future Proofing	7	9	5
	Power Efficiency	6	7	5
	Total	**95**	**107**	**79**

Selected Design

After a thorough evaluation process, Conceptual Design 2 emerged as the optimal choice for our project based on various criteria. Within the framework of our assessment, Conceptual Design 2 consistently outperformed its counterparts across multiple key parameters.

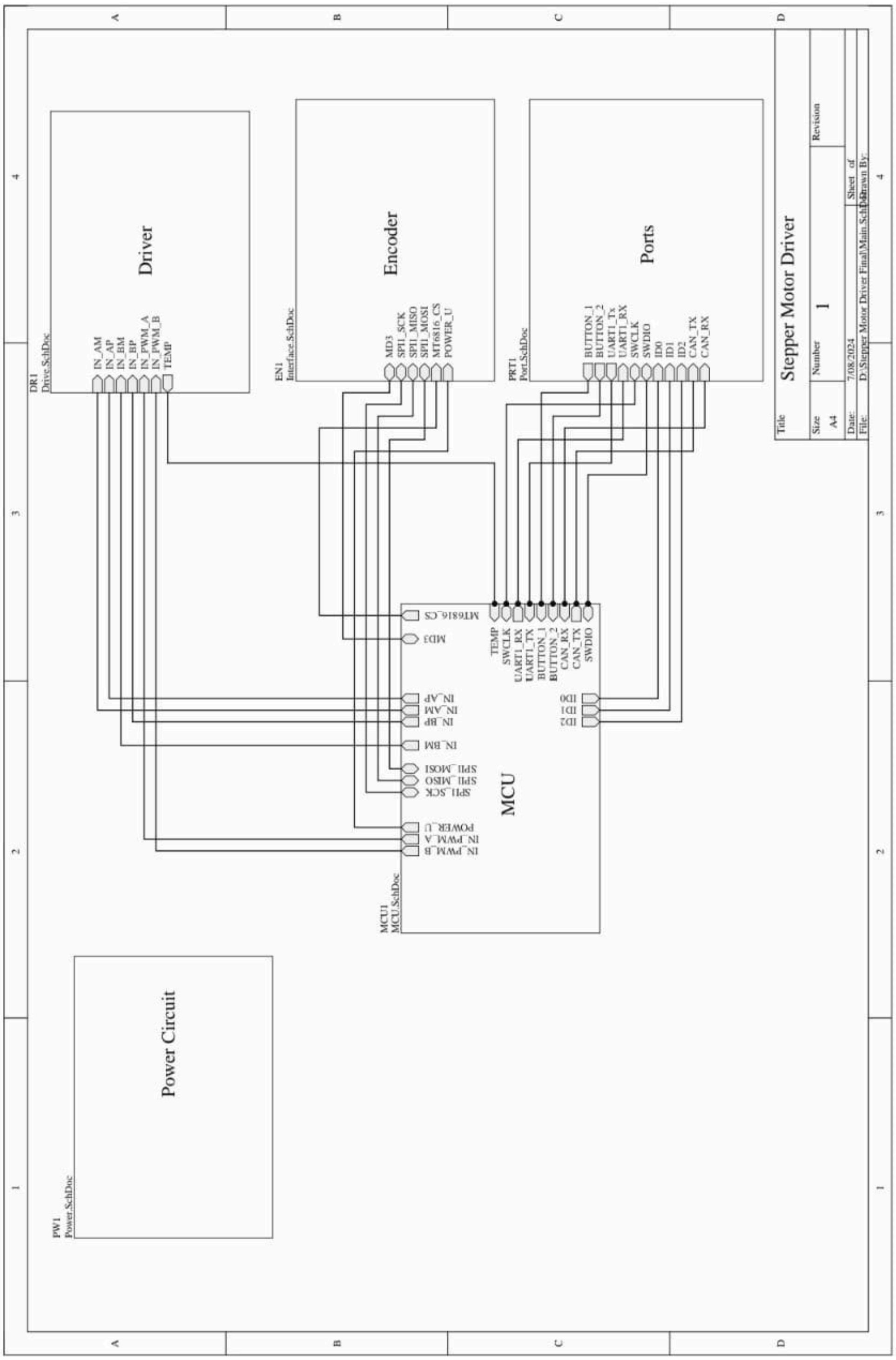
In terms of enclosure design, Conceptual Design 2 excelled due to its user-friendly interface, earning commendations for both simplicity and aesthetics. The ergonomic considerations and attention to user experience garnered higher scores compared to alternative designs.

Furthermore, the block diagram analysis highlighted Conceptual Design 2's superior functionality, showcasing its robust performance capabilities. Notably, this design demonstrated a high degree of cost-effectiveness without compromising on functionality, making it a financially viable option. Additionally, its feasibility was underscored by its adaptability and practicality for implementation.

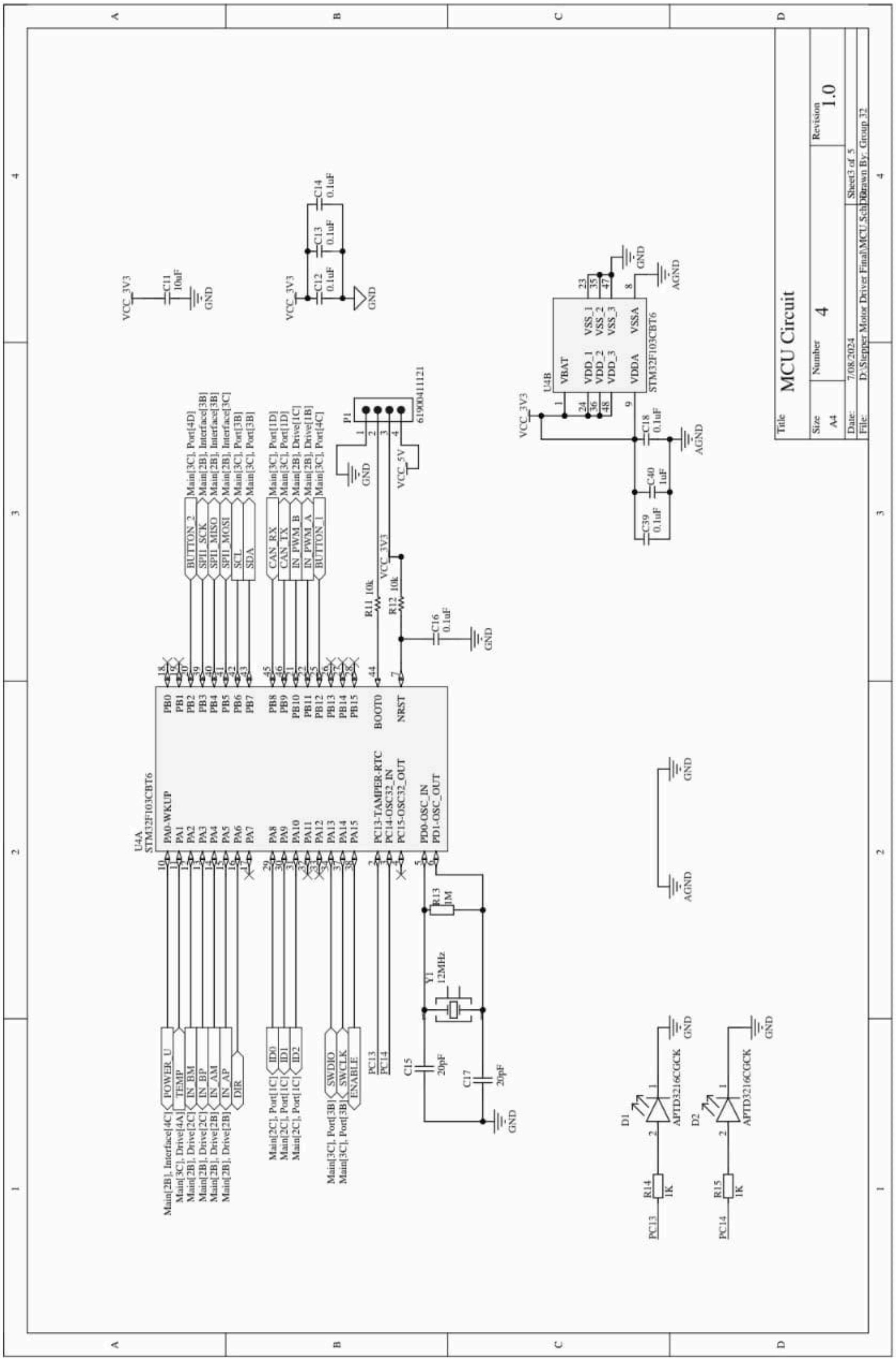
Given the comprehensive evaluation results indicating the superiority of Conceptual Design 2 across multiple metrics, the decision to proceed with its development as our project aligns with our objectives of prioritizing efficiency, usability, and cost- effectiveness.

Final Schematic And PCB Design

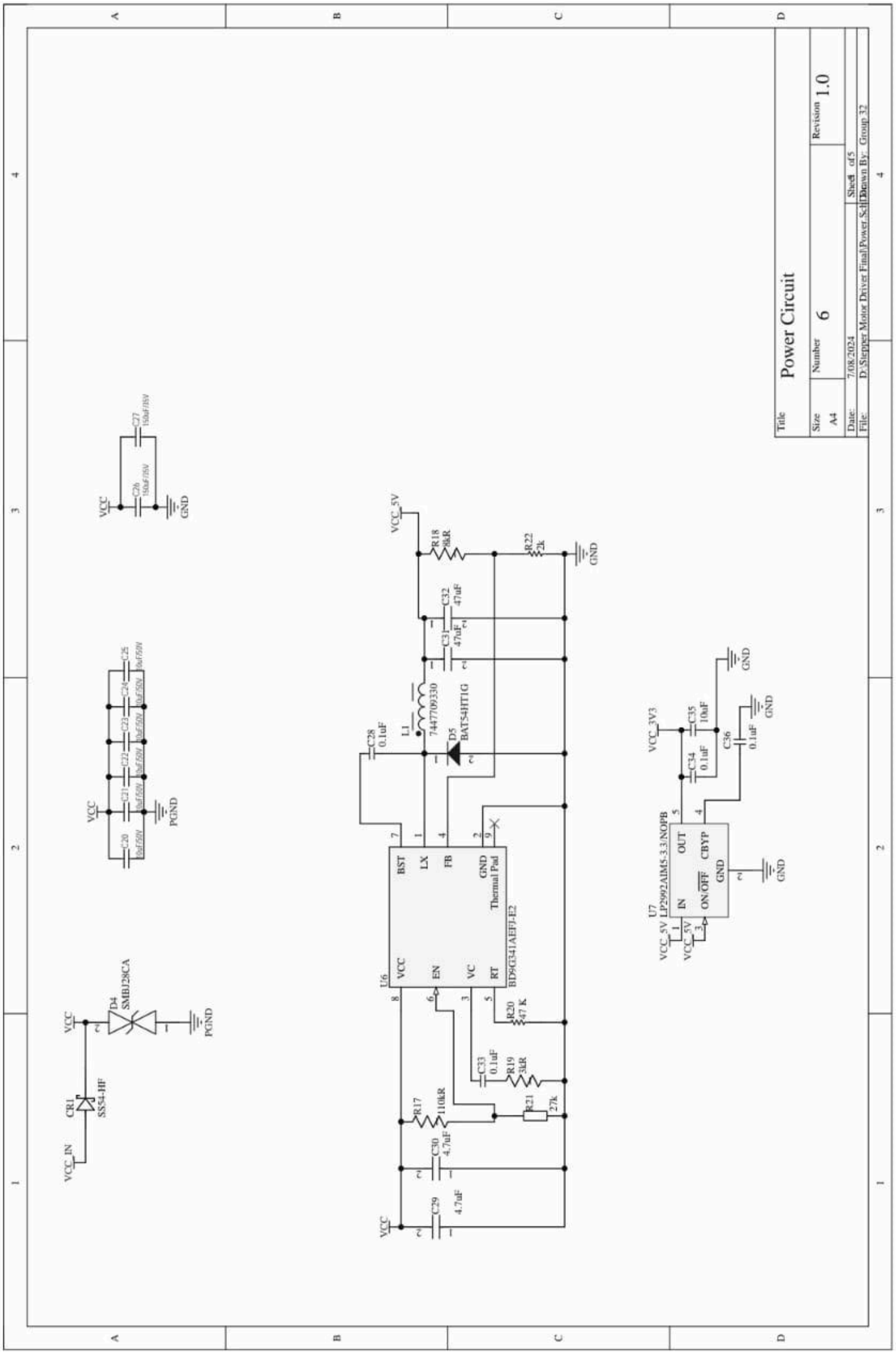
1. Main Block Diagram



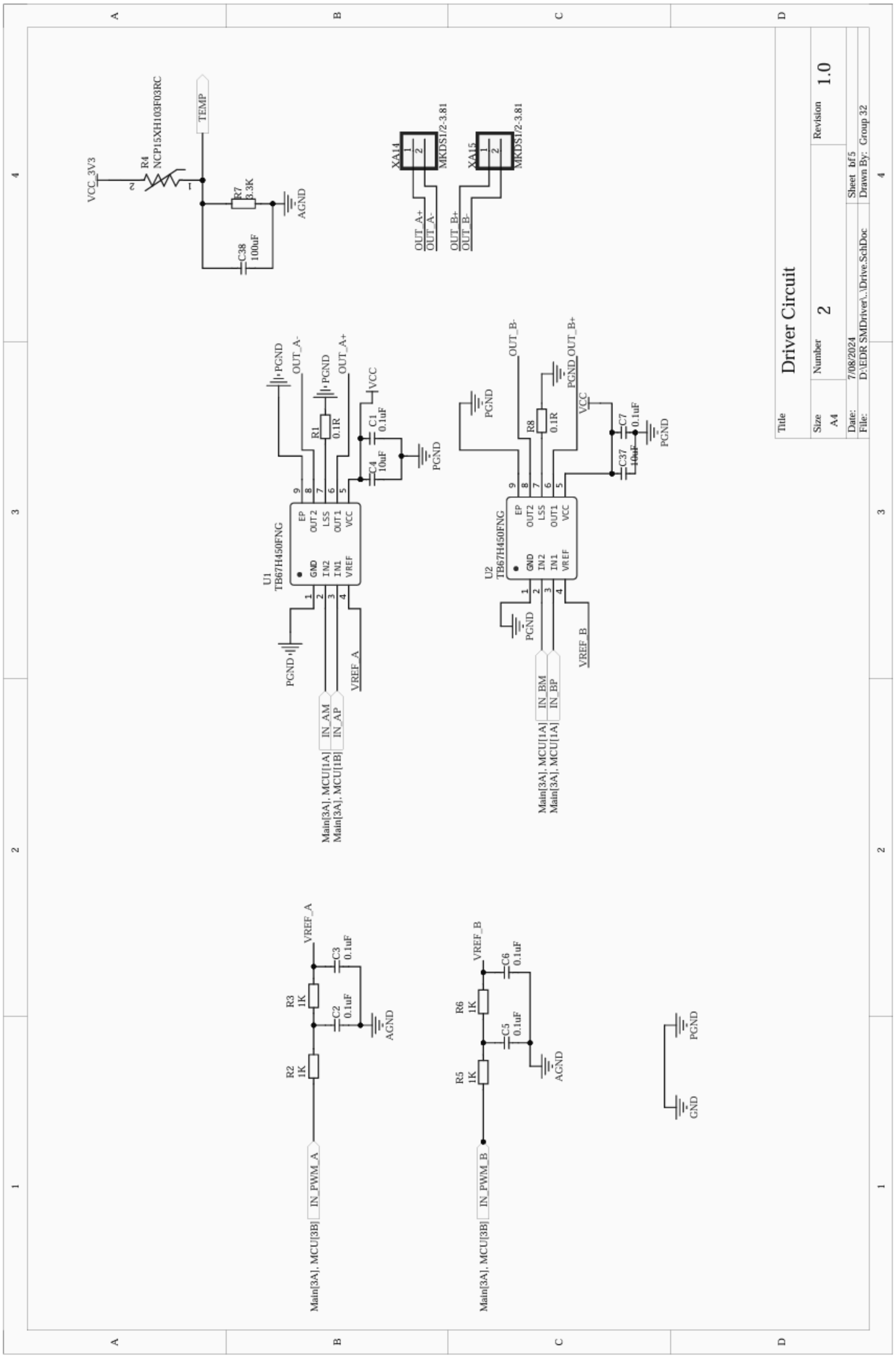
2. Micro Controller



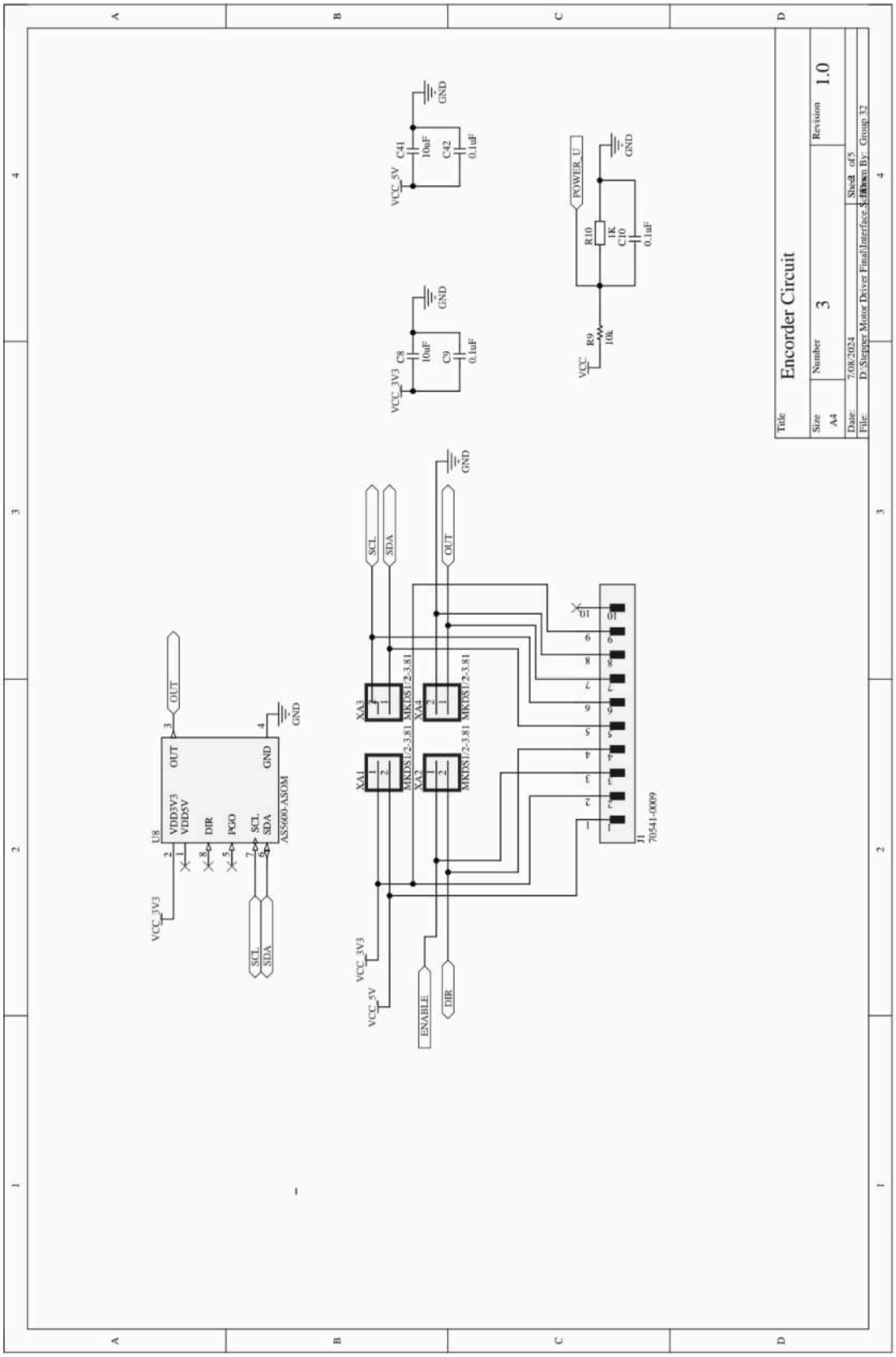
3. Power Supply



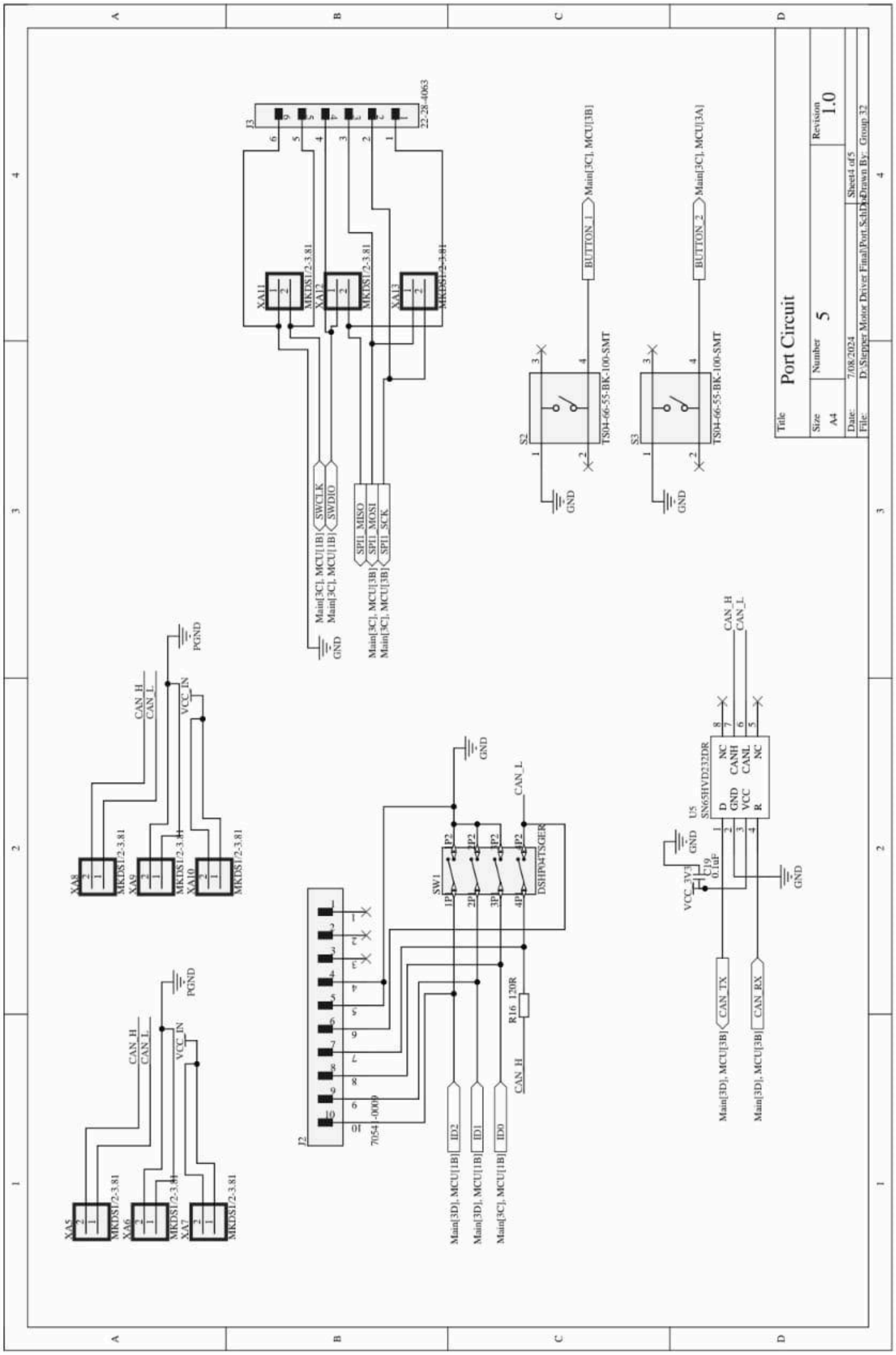
4. Driver Circuit



5. Encoder Circuit

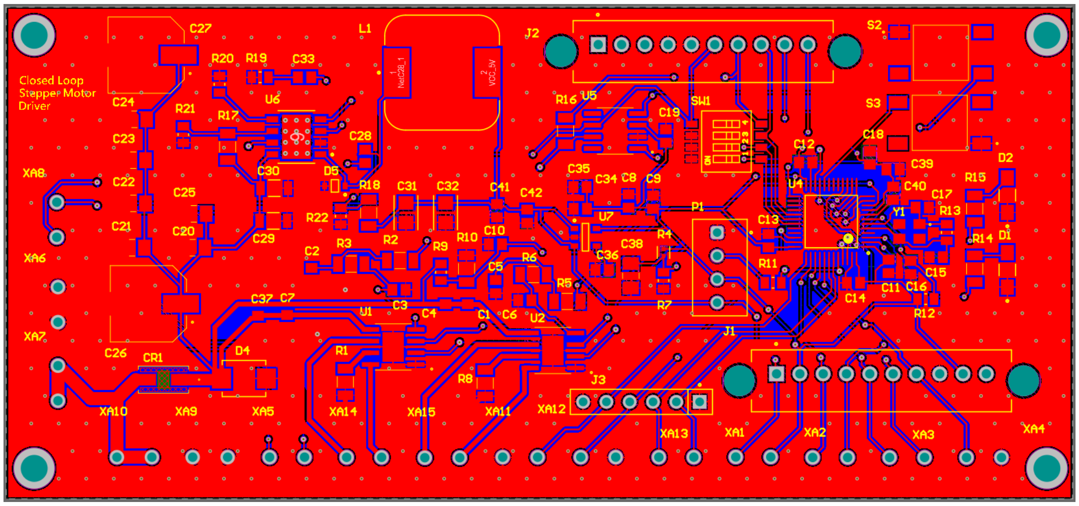


6. Port Circuit

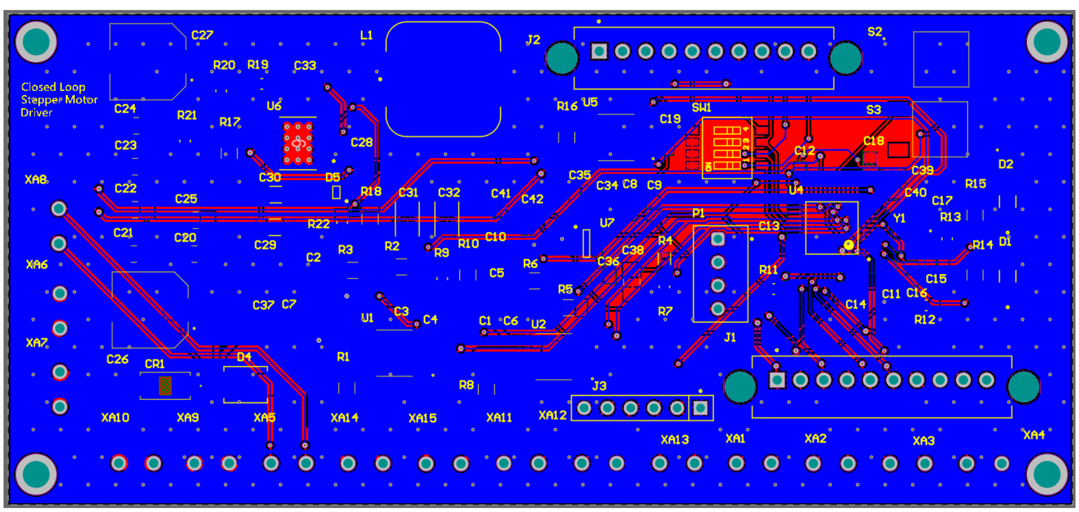


PCB Design and 3D View

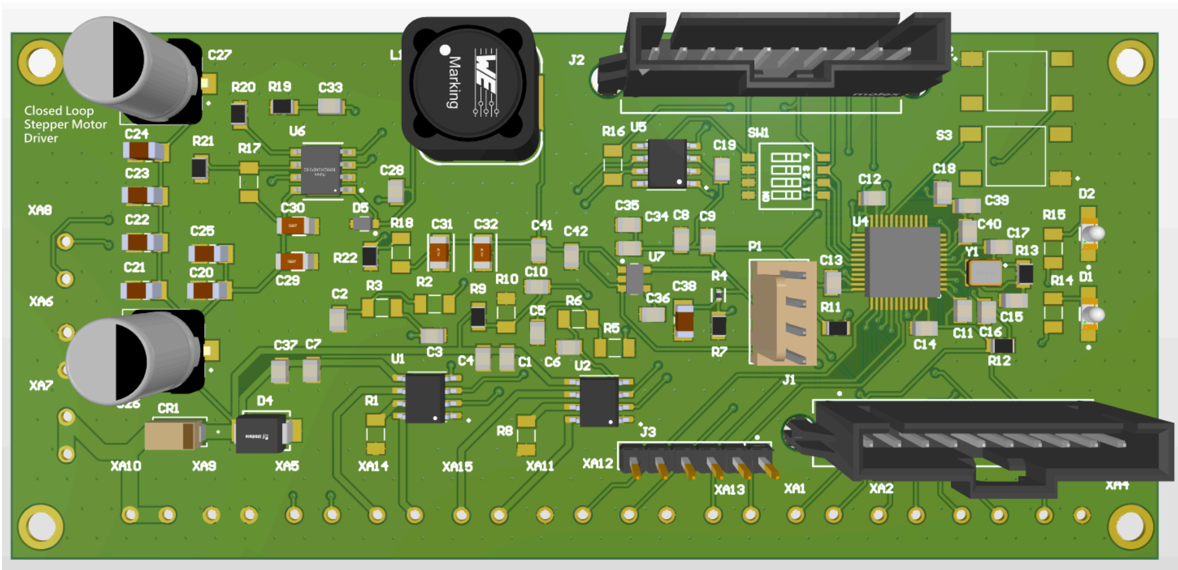
1. Top Layer



2. Bottom Layer

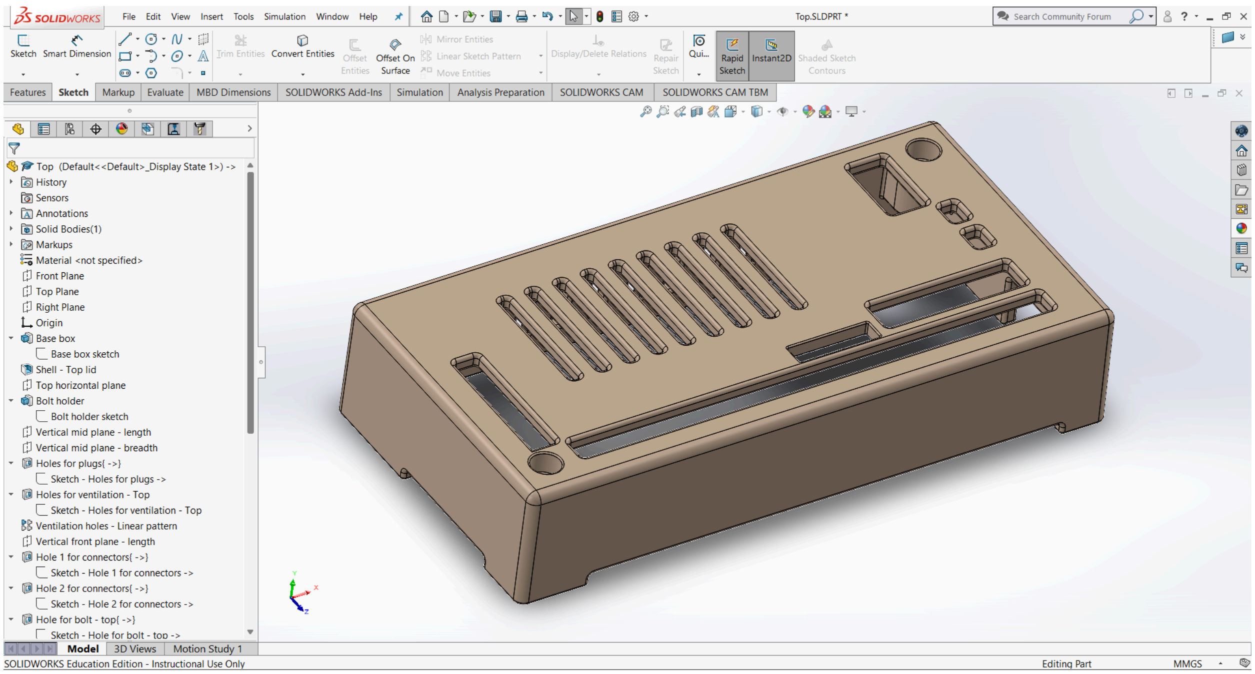


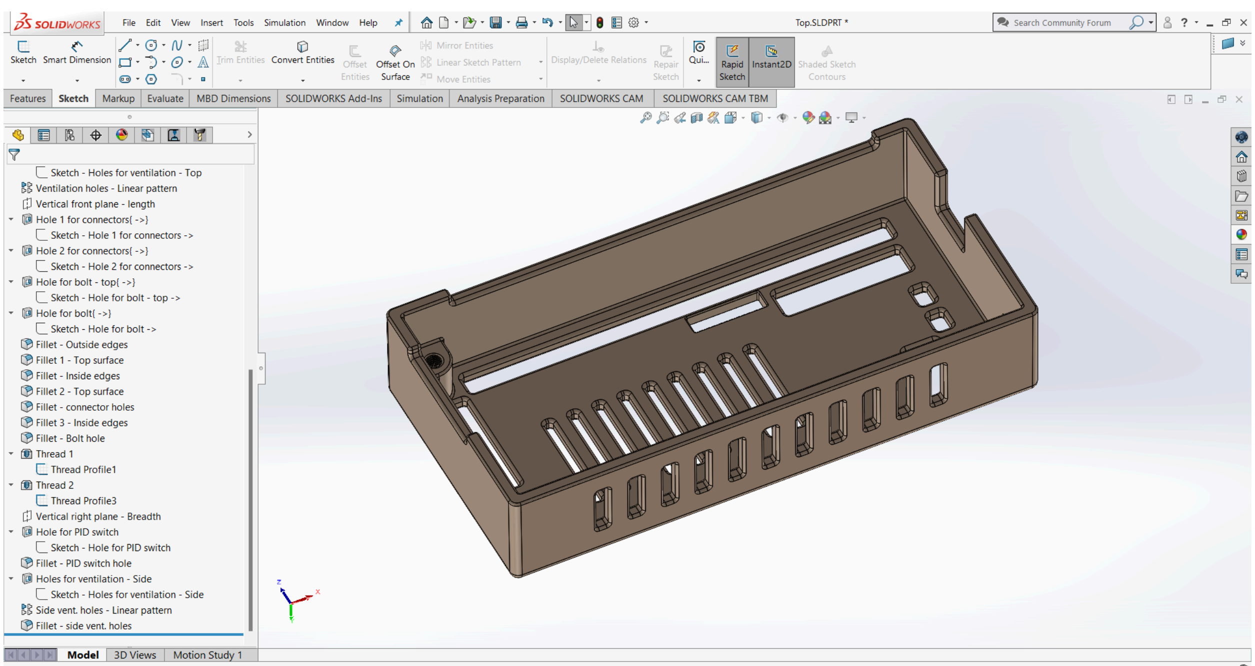
3. 3D View

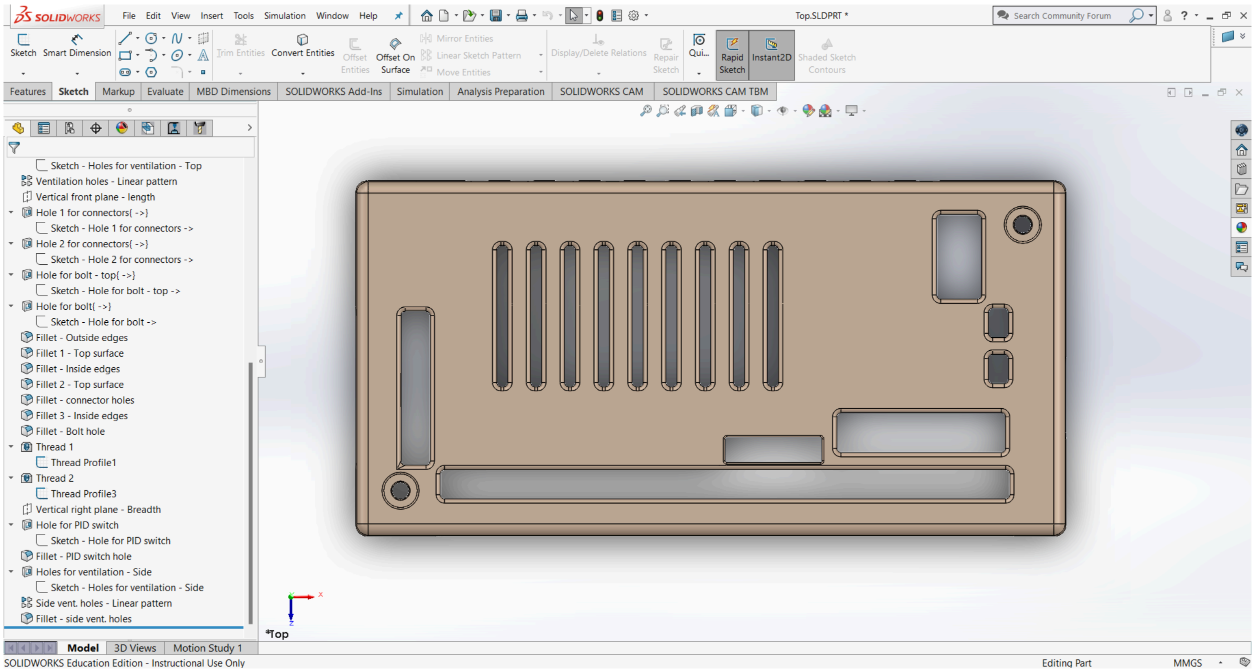

Closed Loop
Stepper Motor
Driver
Marking
C27
R20
R19
C33
U6
R21
R17
C24
C23
C22
C21
C25
C20
C30
C29
C28
D5
R18
C31
C32
R22
R3
R2
R9
R10
C2
C41
C42
C10
C5
R6
R5
C3
C4
C1
C6
C37
C7
U1
U2
R1
R8
CR1
D4
L1
J2
U5
R16
C19
SW1
C35
C34
C8
C9
U7
C36
C38
R4
R7
P1
J1
C13
R11
C12
C18
S3
C39
U4
C40
C17
Y1
R13
R15
D2
R14
D1
C15
C11
C16
C14
R12
J3
XA8
XA6
XA7
XA10
XA9
XA5
XA14
XA15
XA11
XA12
XA13
XA1
XA2

Final SolidWorks Design

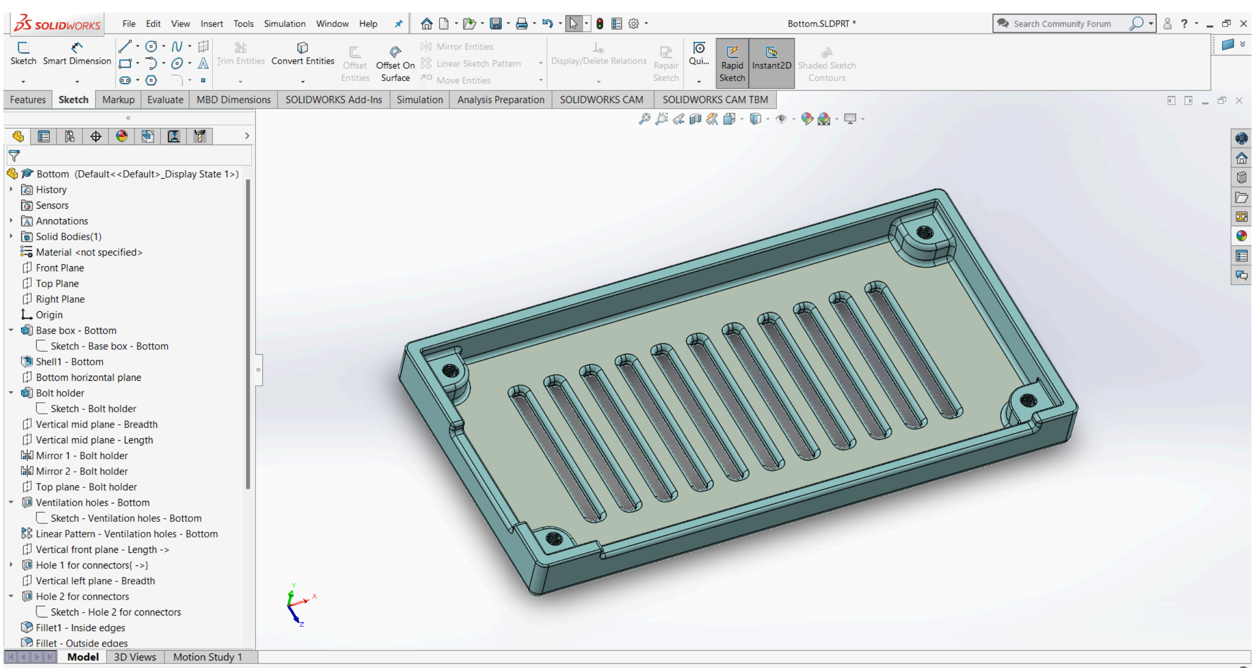
Top Part

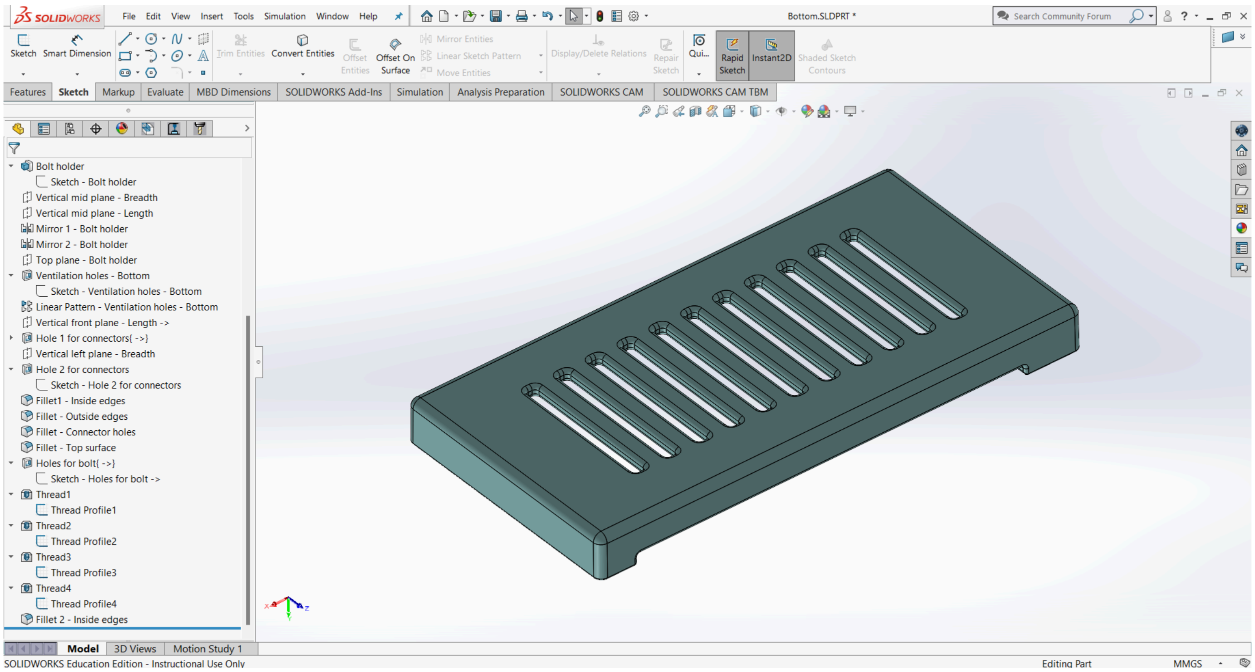


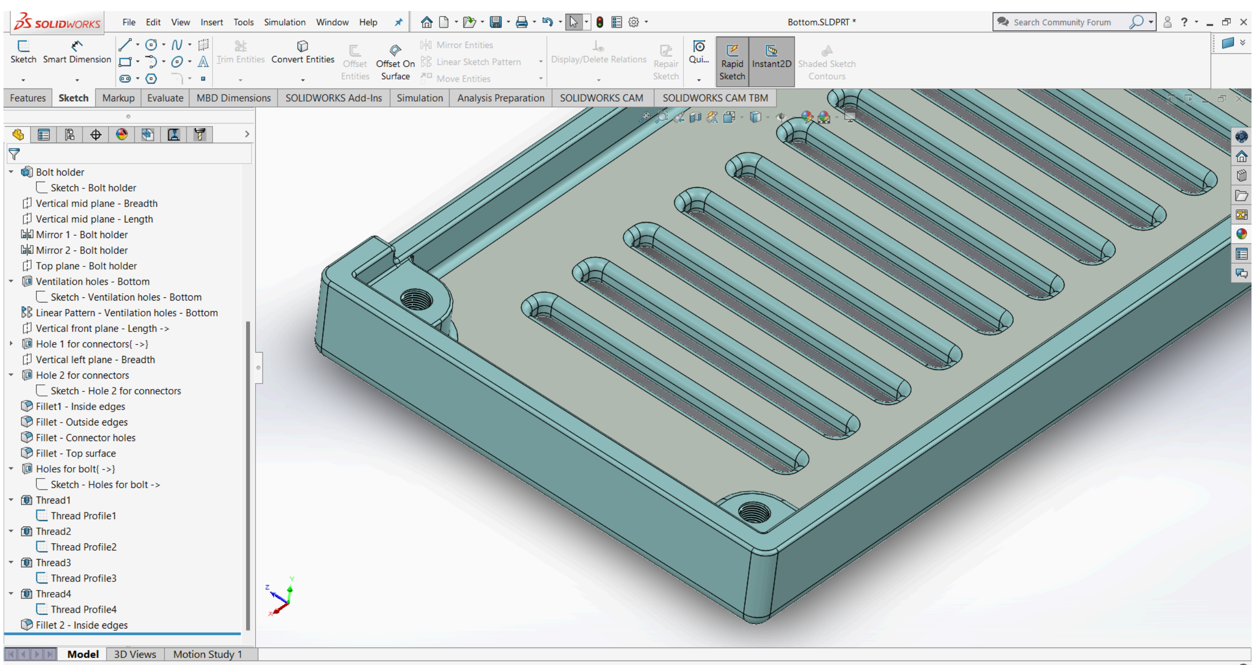



Top.SLDPRT *
Sketch - Holes for ventilation - Top
Ventilation holes - Linear pattern
Vertical front plane - length
Hole 1 for connectors(->)
Sketch - Hole 1 for connectors ->
Hole 2 for connectors(->)
Sketch - Hole 2 for connectors ->
Hole for bolt - top(->)
Sketch - Hole for bolt - top ->
Hole for bolt(->)
Sketch - Hole for bolt ->
Fillet - Outside edges
Fillet 1 - Top surface
Fillet - Inside edges
Fillet 2 - Top surface
Fillet - connector holes
Fillet 3 - Inside edges
Fillet - Bolt hole
Thread 1
Thread Profile1
Thread 2
Thread Profile3
Vertical right plane - Breadth
Hole for PID switch
Sketch - Hole for PID switch
Fillet - PID switch hole
Holes for ventilation - Side
Sketch - Holes for ventilation - Side
Side vent. holes - Linear pattern
Fillet - side vent. holes
*Top
SOLIDWORKS Education Edition - Instructional Use Only

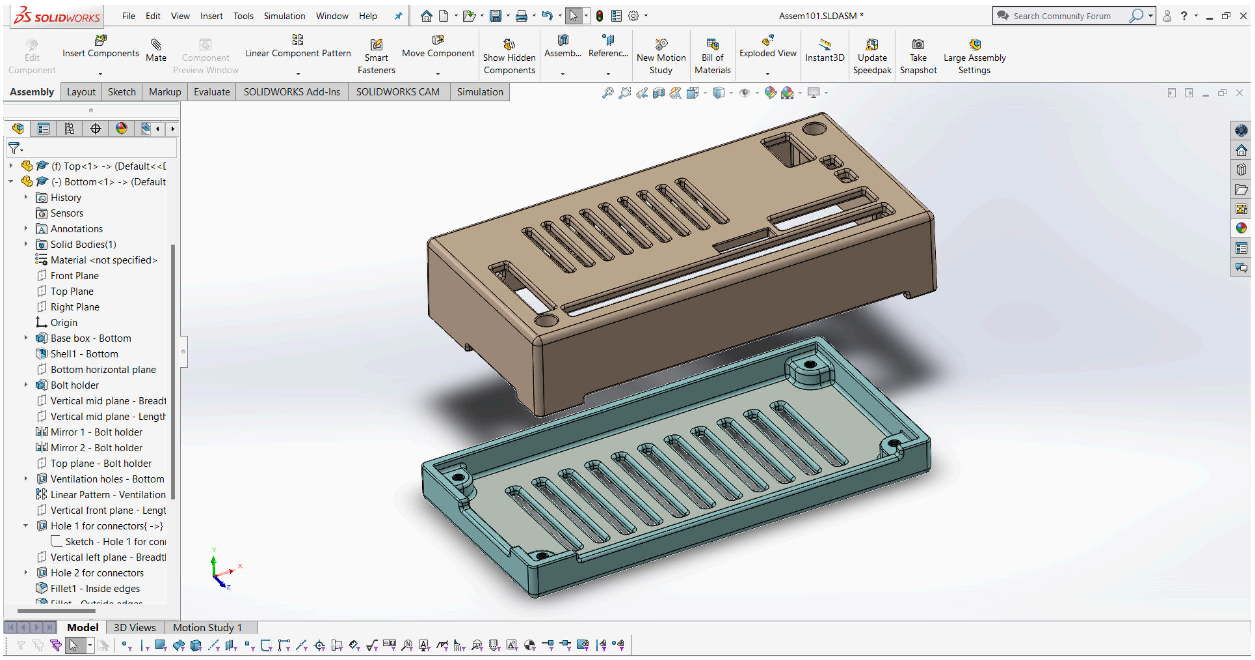
Bottom Part

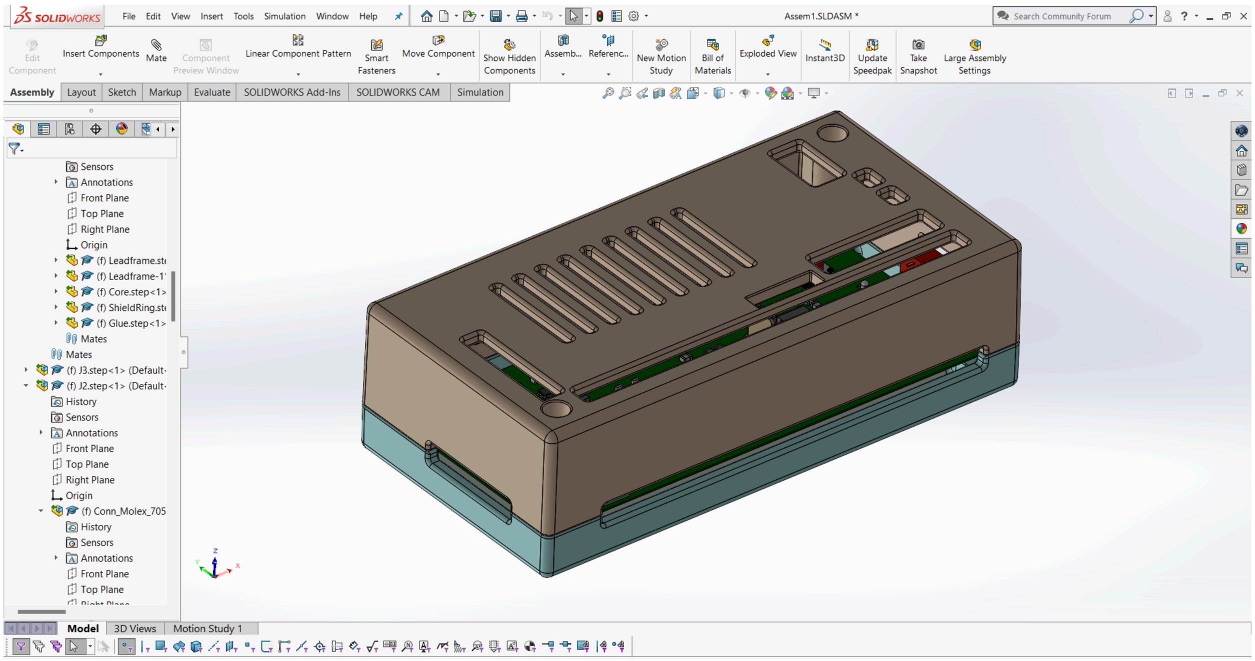

Bottom.SLDPRT *
Bottom (Default<<Default>_Display State 1>)
History
Sensors
Annotations
Solid Bodies(1)
Material <not specified>
Front Plane
Top Plane
Right Plane
Origin
Base box - Bottom
Sketch - Base box - Bottom
Shell1 - Bottom
Bottom horizontal plane
Bolt holder
Sketch - Bolt holder
Vertical mid plane - Breadth
Vertical mid plane - Length
Mirror 1 - Bolt holder
Mirror 2 - Bolt holder
Top plane - Bolt holder
Ventilation holes - Bottom
Sketch - Ventilation holes - Bottom
Linear Pattern - Ventilation holes - Bottom
Vertical front plane - Length ->
Hole 1 for connectors(->)
Vertical left plane - Breadth
Hole 2 for connectors
Sketch - Hole 2 for connectors
Fillet1 - Inside edges
Fillet - Outside edges
SOLIDWORKS Education Edition - Instructional Use Only

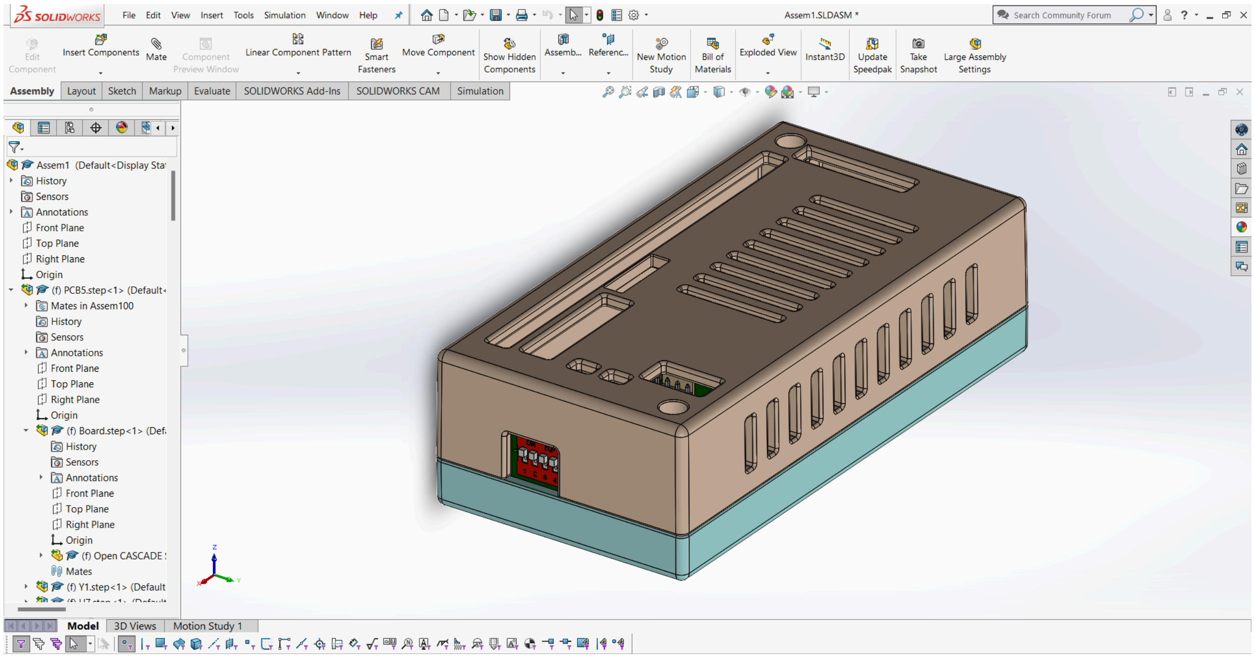

SOLIDWORKS
Bottom.SLDPRT *
Features
Sketch
Markup
Evaluate
MBD Dimensions
SOLIDWORKS Add-Ins
Simulation
Analysis Preparation
SOLIDWORKS CAM
SOLIDWORKS CAM TBM
Bolt holder
Sketch - Bolt holder
Vertical mid plane - Breadth
Vertical mid plane - Length
Mirror 1 - Bolt holder
Mirror 2 - Bolt holder
Top plane - Bolt holder
Ventilation holes - Bottom
Sketch - Ventilation holes - Bottom
Linear Pattern - Ventilation holes - Bottom
Vertical front plane - Length ->
Hole 1 for connectors(->)
Vertical left plane - Breadth
Hole 2 for connectors
Sketch - Hole 2 for connectors
Fillet1 - Inside edges
Fillet - Outside edges
Fillet - Connector holes
Fillet - Top surface
Holes for bolt(->)
Sketch - Holes for bolt ->
Thread1
Thread Profile1
Thread2
Thread Profile2
Thread3
Thread Profile3
Thread4
Thread Profile4
Fillet 2 - Inside edges
Model
3D Views
Motion Study 1
SOLIDWORKS Education Edition - Instructional Use Only
Editing Part
MMGS

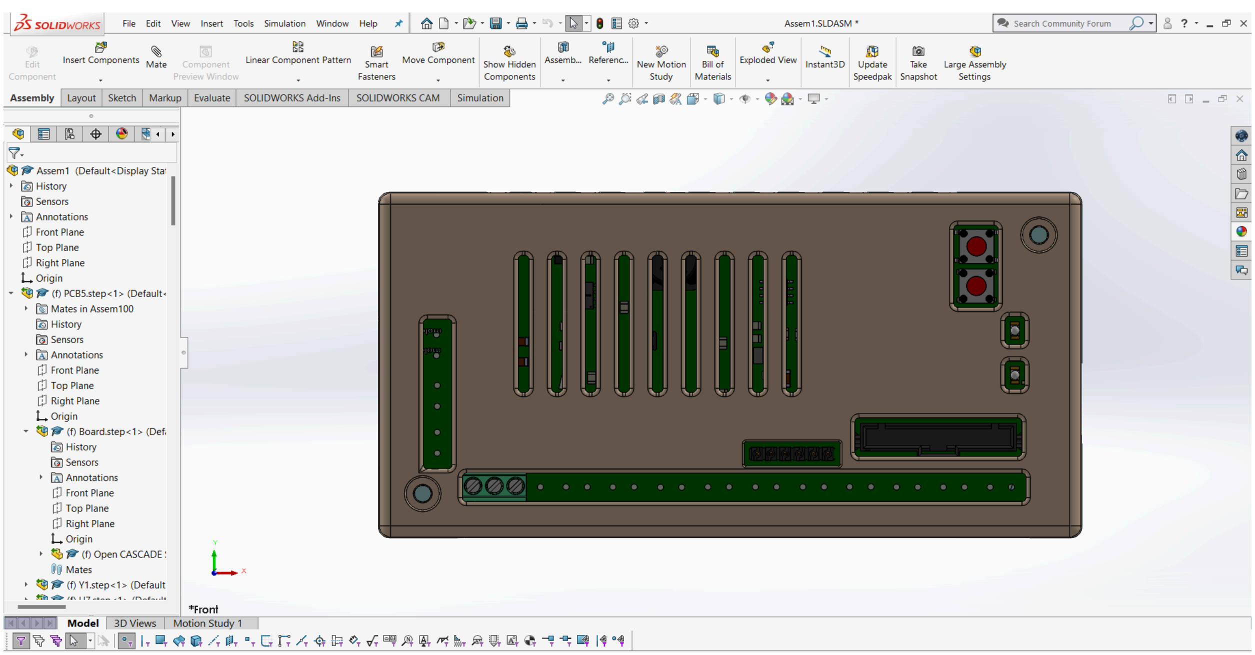

SOLIDWORKS
Bottom.SLDPRT *
Features
Sketch
Markup
Evaluate
MBD Dimensions
SOLIDWORKS Add-Ins
Simulation
Analysis Preparation
SOLIDWORKS CAM
SOLIDWORKS CAM TBM
Bolt holder
Sketch - Bolt holder
Vertical mid plane - Breadth
Vertical mid plane - Length
Mirror 1 - Bolt holder
Mirror 2 - Bolt holder
Top plane - Bolt holder
Ventilation holes - Bottom
Sketch - Ventilation holes - Bottom
Linear Pattern - Ventilation holes - Bottom
Vertical front plane - Length ->
Hole 1 for connectors(->)
Vertical left plane - Breadth
Hole 2 for connectors
Sketch - Hole 2 for connectors
Fillet1 - Inside edges
Fillet - Outside edges
Fillet - Connector holes
Fillet - Top surface
Holes for bolt(->)
Sketch - Holes for bolt ->
Thread1
Thread Profile1
Thread2
Thread Profile2
Thread3
Thread Profile3
Thread4
Thread Profile4
Fillet 2 - Inside edges
Model
3D Views
Motion Study 1
SOLIDWORKS Education Edition - Instructional Use Only
Editing Part
MMGS

Full Enclosure









References

(1) An Introduction to Stepper Motors - University of Arizona.

https://wp.optics.arizona.edu/optomech/wp-content/uploads/sites/53/2016/10/Tutorial_Xinda-Hu.pdf.

(2) PLC AS A DRIVER FOR STEPPER MOTOR CONTROL Laurean Bogdan University
(PDF) PLC AS A DRIVER FOR STEPPER MOTOR CONTROL (researchgate.net)

(3) Design and Realization of Stepping Motor Drive System - Springer.
https://link.springer.com/article/10.1007/s11277-022-09534-z.

(4) Stepper motor driver, Stepper motor drive - All industrial manufacturers.
Stepper motor driver, Stepper motor drive - All industrial manufacturers (directindustry.com)

(5) "Stakeholder Mapping. The Basics | Smaply Blog,"
www.smaply.com.
The basics of Stakeholder Mapping | Smaply Blog

[6] "Concept design process: Overview,"
www.inclusivedesigntoolkit.com.
https://www.inclusivedesigntoolkit.com/GS_overview/overview.html

(7) Wikipedia Contributors, "Stepper motor", Wikipedia, May 25. 2024.
https://en.wikipedia.org/wiki/Stepper_motor