EN2160 - Electronic Design Realization

3D - Scanner Machine

Design Methodology v3.0

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Contents

Project Documentation - 3D Scanner Machine

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I Introduction

Unlock the potential of digital replication and exploration with our cutting-edge mini 3D scanner, meticulously designed for prototyping, model making, research, and beyond. This powerful device leverages laser scanning technology, precision motors, mechanical systems, and an Arduino controller to transform physical objects into detailed 3D models.

Our selected project is to create a 3D scanner machine. It would be capable of scanning the surface of any 3D object and then plot the particular object using the Matplotlib library in Python. Obtaining the actual 3D plot of a certain 3D object is very much useful in many different industries for making their outcomes efficient. To make decisions on a 3D object on an industrial basis, gaining a pointwise knowledge of the particular object is crucial. So our approach in this project is to build and operate a simple yet effective 3D scanner machine using readily available components and basic electronics skills which can be introduced to the market with an affordable price and a considerable accuracy.

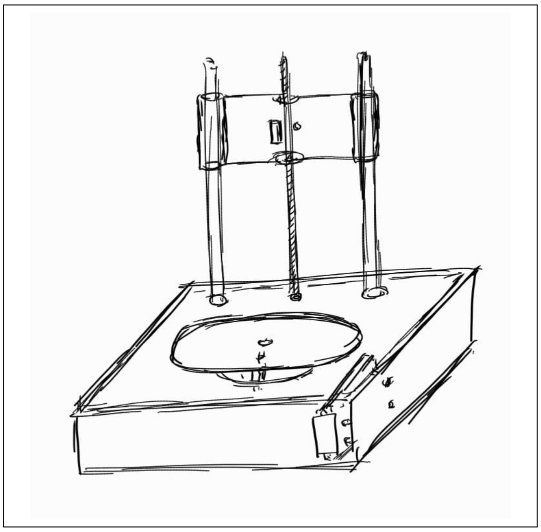


Fig. 1: 3D Scanner Assembled sketch

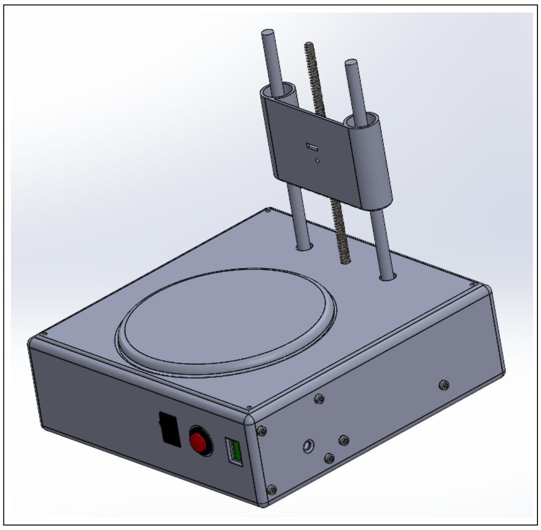


Fig. 2: 3D Scanner Final Assembly

Fig. 3: Final Assembled Product

II Review Progress

Our progress report highlights the final designing and testing phase of our 3D scanner project, focusing on the identification of necessary components, delineation of key system elements, Designing and Printing PCB, and drawing and printing enclosure items.

We have outlined the main components as:

- the rotating disk (Tray), serving as the platform for object scanning,
- The TOF (Time-of-Flight) sensor holder, essential for capturing accurate distance data.
- USB module

Additionally, emphasis has been placed on the development of the control unit, which will orchestrate the synchronized movement of these components to facilitate efficient and precise scanning operations. This progress marks a significant step towards realizing our vision for an innovative and functional 3D scanning solution.

and now, we are in the final testing phase of the 3D scanner with the following tasks:

- Printed and component placed soldered PCB
- Finalizing the code using to take accurate distances for capturing the 3D object point cloud
- 3D printing the main enclosure and other minor parts for the entire assembly

Also, the documentation part has been completed with the Final Report for the product and the Comprehensive Design Details document for our 3D Scanner project.

III Identify Stakeholders

Our stakeholder map identifies key individuals and groups vital to the success of our 3D scanner in the market. From end users like researchers, engineers, and artists to industry partners such as technology manufacturers and distributors, each stakeholder plays a crucial role in driving adoption and market penetration. Engaging with educational institutions, government bodies, and professional associations further enhances our reach and credibility. By cultivating relationships with investors, media influencers, and industry thought leaders, we aim to generate excitement and support for our product, positioning it as the go-to solution for precision 3D scanning needs across various sectors.

- Project Team: The core group responsible for the design, testing, and implementation of the 3D scanner machine.
- University of Moratuwa: Provides guidance, resources, and ensures academic standards are maintained throughout the project.
- Technology Manufacturers and Distributors: Potential industry partners representing practical applications and market needs, ensuring the 3D scanner meets industry standards.
- Material Suppliers: Companies supplying components and materials essential for constructing the 3D scanner, impacting its quality and functionality.
- Classmates and Academic Community: Collaborators and peers who provide feedback, fostering a collaborative learning environment and contributing to the project's iterative improvement.

Users	Those are interested in 3D mapping, printing and prototyping Researchers, Engineers, and artists
Industry partners	Technology manufacturers and distributors
Institutions	Educational institutions, government bodies, and professional associations

Fig. 4: Stakeholder Map

IV Observe Users

Observing users is a crucial step in the design process of our 3D scanner. This phase involves understanding how potential users interact with existing products, identifying pain points, and gathering insights into their workflows and needs. By closely observing and analyzing user behavior, we can ensure that our design is user-centric and addresses real-world challenges effectively.

1 Primary Users

- Researchers: Require precise 3D scans for scientific studies, data collection, and analysis.
- Engineers: Use 3D scans for prototyping, reverse engineering, and quality control.
- Artists: Need detailed scans for digital modeling, animation, and creating physical art pieces.

2 Secondary Users

- Educators and Students: Utilize 3D scanning for educational purposes, projects, and learning advanced technologies.
- Healthcare Professionals: Employ 3D scanning for medical imaging, prosthetics, and customized implants.
- Architects and Construction Professionals: Use 3D scans for designing, modeling, and renovating buildings.
- Manufacturing Professionals: Apply 3D scanning for inspection, design verification, and product development.

3 Applications of 3D Scanners

3D scanners are used in various applications, such as:

- 3D printing: Creating digital models of objects for 3D printing.
- Reverse engineering: Analyzing existing objects to create digital models for redesign or replication.
- Quality control: Inspecting manufactured parts for defects.
- Virtual reality (VR) and augmented reality (AR): Creating 3D models of real-world objects for use in VR/AR applications.
- Healthcare: Creating 3D models of body parts for prosthetics, implants, and surgical planning.

V Need List

To ensure our 3D scanner design meets the diverse needs of all stakeholders, we compiled a comprehensive list of requirements:

- Functional Needs:
  - Accurate and detailed 3D scanning capabilities for various objects.
  - Real-time data processing and transmission to connected devices or software.
  - Flexibility to scan objects of different shapes and sizes without manual adjustments.
- Accessibility Needs:
  - User-friendly interface for easy operation and integration.
  - Comprehensive documentation and support for setup, troubleshooting, and maintenance.
- Usability Needs:
  - Intuitive calibration and operation process.
  - Reliable performance with minimal downtime and high accuracy.
- Technical Needs:
  - Robust and durable hardware capable of withstanding industrial and academic environments.
  - Compatibility with various software platforms and file formats used in 3D modeling and printing.
- Business Needs:
  - Cost-effective design providing significant ROI through enhanced productivity and reduced errors.
  - Scalable solution adaptable for various applications, including education, research, and industrial design.
- Regulatory Needs:
  - Compliance with industry standards for safety and performance.
  - Adherence to environmental regulations to ensure sustainable operation
- Contextual Needs:
  - Effective operation in diverse environments, including varying lighting conditions and space constraints.
  - Seamless integration into existing workflows to enhance productivity without significant disruptions.

By addressing these needs, we aim to develop a 3D scanner that not only meets the technical and functional requirements but also enhances the overall efficiency and reliability of various applications, from education and research to industrial design and prototyping.

VI Stimulate Ideas

In the process of developing a robust and innovative 3D scanner, stimulating ideas from various perspectives is crucial. The ideation phase is foundational to ensure that the final product not only meets technical specifications but also addresses user needs, market demands, and potential future advancements. Here, we delve into the various strategies and thought processes employed to stimulate ideas for our 3D scanner project.

1 Brainstorming Sessions

1) Initial Brainstorming

We initiated our ideation process with several brainstorming sessions, involving all the team members. These sessions were aimed at generating a wide range of ideas without filtering for feasibility at the outset. The focus was on creativity, with team members encouraged to think outside the box and propose innovative solutions and features for the 3D scanner.

2) Focused Brainstorming

After the initial sessions, we conducted more focused brainstorming to refine the raw ideas. We categorized the ideas into themes such as functionality, usability, cost-effectiveness, and technological innovation. This helped us to focus on specific aspects of the design and explore them in more depth.

2 Competitive Analysis

We conducted a thorough competitive analysis to understand the strengths and weaknesses of existing 3D scanners in the market. By studying competitors' products, we identified gaps and opportunities for innovation. Key features from successful products were noted, and potential areas for improvement were highlighted. This analysis served as a benchmark and inspired ideas for new functionalities and enhancements that could set our 3D scanner apart.

3 Technological Exploration

1) Emerging Technologies

Exploring emerging technologies in sensors, imaging, and data processing inspired several innovative ideas. We investigated advancements in Time-of-Flight (ToF) sensors, and image processing algorithms with point clouds. This exploration opened up possibilities for incorporating cutting-edge technology into our design.

2) Cross-Industry Innovations

We looked at technological innovations in adjacent industries and by applying concepts from these fields to our 3D scanner design led to several creative ideas for improving accuracy, speed, and user interface.

4 Design Thinking Approach

1) Empathy and Definition

Using the design thinking methodology, we began by empathizing with users and stakeholders to deeply understand their needs and challenges. Defining clear problem statements based on this empathy phase provided a focused direction for idea generation.

2) Ideation and Prototyping

We moved into the ideation phase with an open-minded approach, generating a broad spectrum of ideas with a broad thinking with three different conceptual design approaches. The comprehensive evaluation of these ideas allowed for quick and accurate decision-making and finalizing the design, ensuring that the concepts developed were user-centric and feasible.

5 Scenario Planning

1) Future Use Cases

We engaged in scenario planning to envision future use cases for our 3D scanner. This exercise helped us think ahead and incorporate features that would be relevant in evolving technological landscapes. By anticipating future trends and user needs, we aimed to create a product that remains relevant and valuable over time by considering the evaluation of our conceptual designs also.

2) Risk Assessment

Identifying potential risks and challenges in the development and deployment of the 3D scanner prompted us to think of innovative solutions to mitigate these risks. This proactive approach ensured that our design was resilient and adaptable. And this criteria was also included by us for the final conceptual design evaluation and were able to come up with the best solution for our product with risk assessment too.

VII Develop Concepts

1 Design Criteria

A new product's success and general efficacy in the market will depend on a number of critical factors that must be considered at all times during the design process. Performance and usefulness should be taken into account first and foremost. Ensuring the product can effectively and consistently achieve its intended goal is of utmost importance in its design. This means that in addition to functioning well in the best of circumstances, the product must also be able to handle any difficulties that may occur when using it.

In addition to the performance, there are several other factors to be considered in the design process of a product. Listed below are some of such criteria to be considered when designing a new product.

- Aesthetics : The design's visual appeal and attractiveness, enhancing the overall user experience and ensuring the product is eye-catching and appealing
- Heat Dissipation : The efficiency with which the design manages and dissipates heat, ensuring optimal performance and longevity of the components.
- Assembly and Serviceability : The ease with which the product can be assembled and maintained, ensuring that parts can be easily accessed, replaced, or repaired as needed.
- Ergonomics : The comfort and ease of use for operators, ensuring that the product is designed to minimize strain and maximize efficiency for users during operation.
- Simplicity : The straightforwardness of the design and assembly process, facilitating easier manufacturing and reducing the potential for errors.
- Durability : The ability to withstand wear, impact, and environmental conditions, ensuring a long-lasting and reliable product.
- User Experience : The overall satisfaction and usability perceived by the end-users, focusing on intuitive design, ease of use, and meeting user needs effectively.
- Manufacturing Feasibility : The practicality of producing with available manufacturing techniques and resources, ensuring the design can be efficiently brought to market.
- Cost : The total expenses associated with the design, production, and maintenance of the product, aiming to balance quality with affordability.
- Power Consumption : The amount of electrical power required to operate efficiently, aiming for energy-efficient design to reduce operational costs and environmental impact.

2 Conceptual Designs

1) Conceptual Design 1

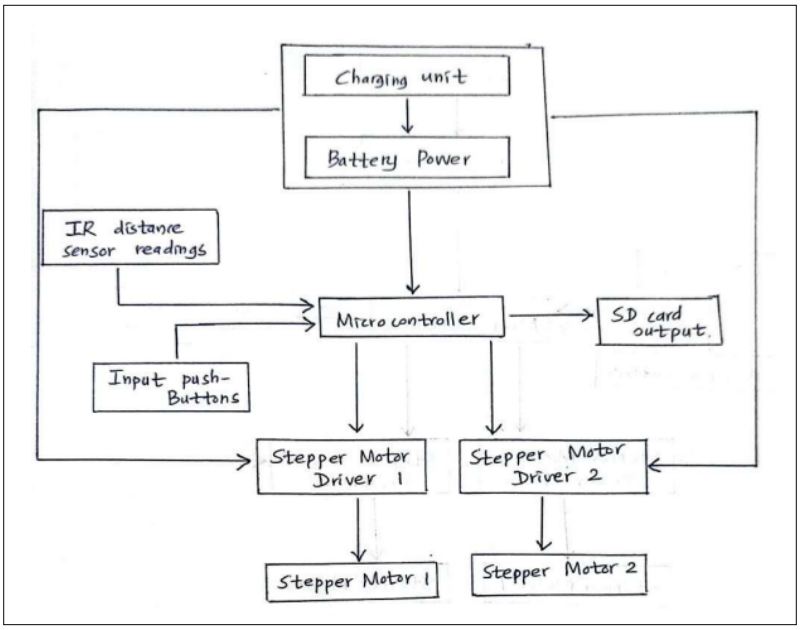


Fig. 5: Concept 1 - Block Diagram

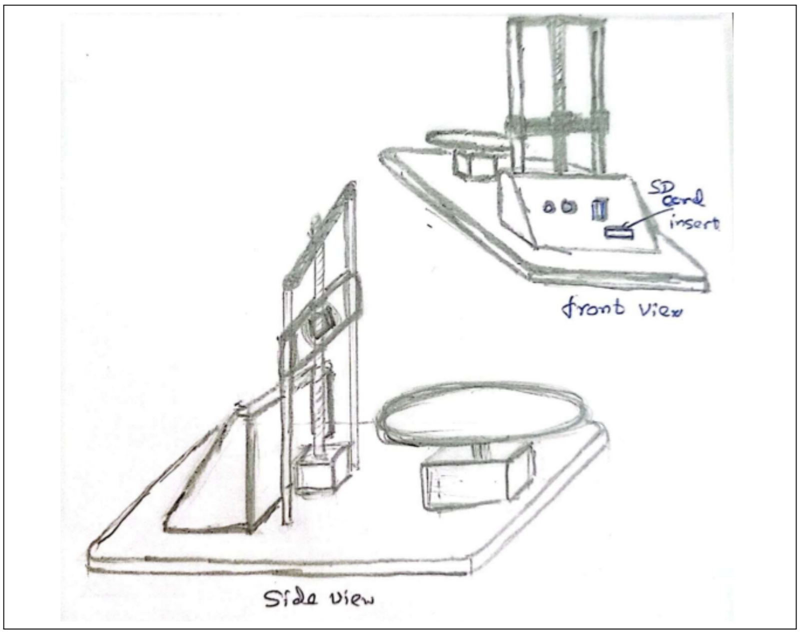


Fig. 6: Concept 1 - Design

2) Conceptual Design 2

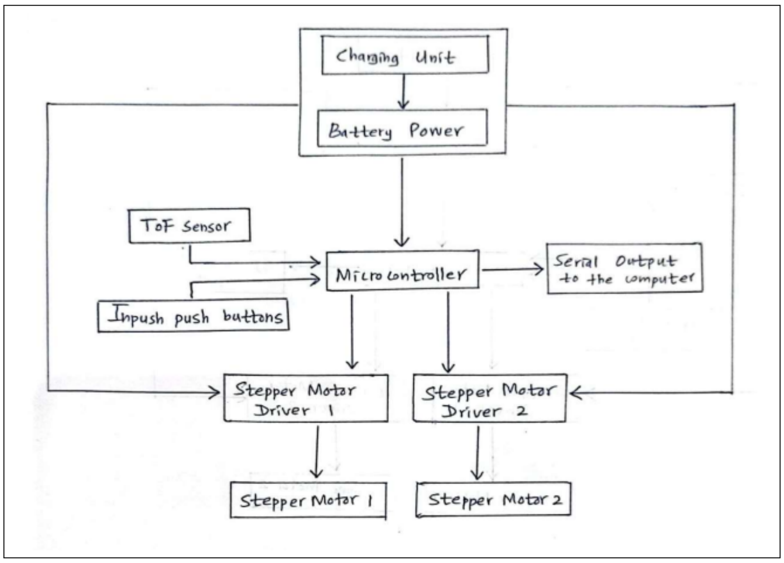


Fig. 7: Concept 2 - Block Diagram

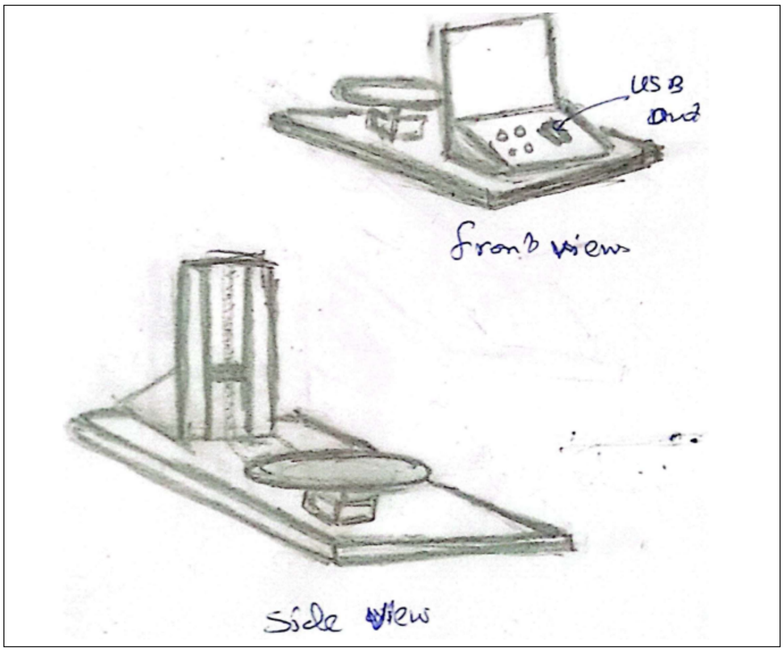


Fig. 8: Concept 2 - Design

3) Conceptual Design 3

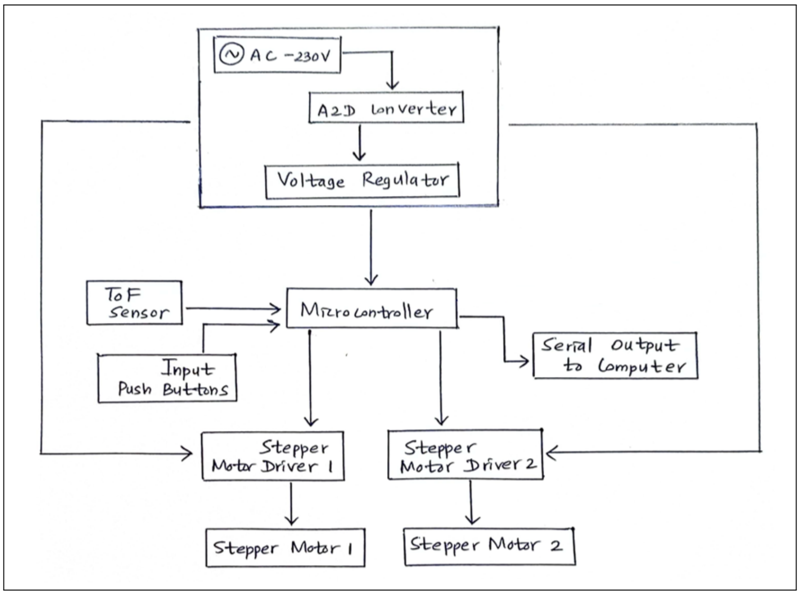


Fig. 9: Concept 3 - Block Diagram

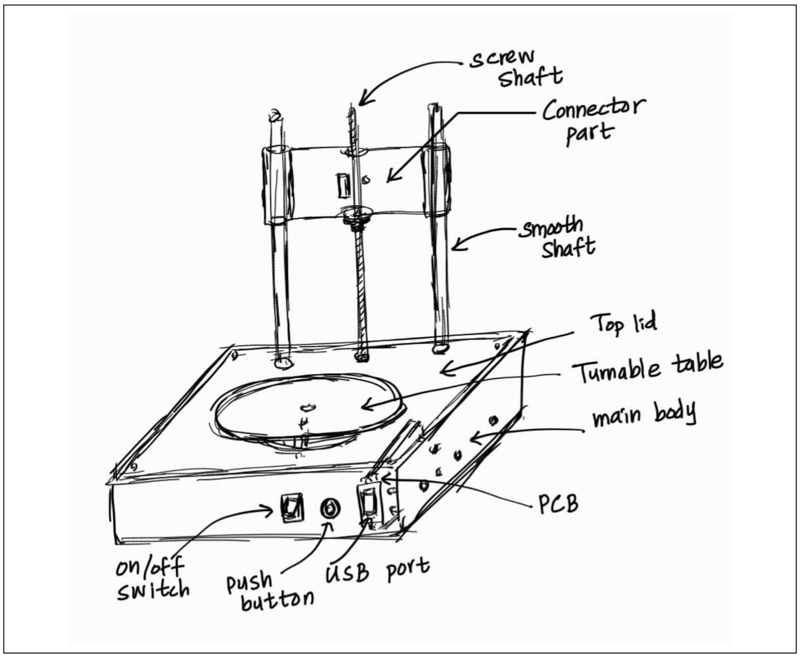


Fig. 10: Concept 3 - Design

VIII Evaluation Criteria

1 Functional Block Diagram Criteria

- Functionality:
  The amount in which the circuit design meets functional requirements.
- User experience:
  How simple and easy to use the interface is.
- Manufacturing feasibility:
  Analyze whether the design is feasible to be manufactured.
- Cost:
  Overall cost-effectiveness for the desired functionality.
- Performance:
  How accurate are the results?
- Power Consumption:
  The amount of power to be consumed by the product with the particular circuit design.

2 Enclosure Design Criteria

- Functionality:
  The way which the design supports the main functionalities.
- Aesthetics:
  How good the overall appeal of the user.
- Heat dissipation:
  The amount of heat generated and the way in which it is managed.
- Assembly and Serviceability:
  How well the design is compatible for easy assembly, maintenance, and troubleshooting with modular components and intuitive interfaces.
- Ergonomics:
  How well the design can prioritize user comfort and efficiency for intuitive interaction and reduced physical strain.
- Simplicity:
  Simplicity of manufacturing and assembling the enclosure.
- Durability:
  How well does the design withstand impacts and environmental conditions.

IX Conceptual Design Evaluation

		Conceptual Design 1	Conceptual Design 2	Conceptual Design 3
Newly Added features		SD card output Charging Circuit	USB Output to PC Serial Output to the computer	USB Output to PC DC power supply
Removed features		Display	SD card output	Battery power supply and charging unit.
Enclosure Design Criteria Comparison	Functionality	8	8	9
	Aesthetics	5	7	9
	Heat Dissipation	9	8	6
	Assembly and Serviceability	9	9	8
	Ergonomics	6	8	9
	Simplicity	9	8	6
	Durability	6	6	9
Functional Block Diagram Idea Comparison	Functionality	7	7	9
	User Experience	6	7	9
	Manufacturing Feasibility	9	8	8
	Cost	9	8	6
	Performance	8	8	9
	Power Consumption	9	9	8
Total		**100**	**101**	**105**

Fig. 11: Conceptual Design Evaluation

Our team thought of proceeding with the third design after careful consideration and thorough discussion sessions. Also according to the comparison, Conceptual Design 3 scores the highest and it would satisfy user requirements easily. It is also safer and more easier to use when compared with the other conceptual designs listed above.

X Schematic Design

1 Block Diagram

Includes all the sub-sections of the pcb schematics as blocks, integrated into one diagram, renamed as the block diagram.

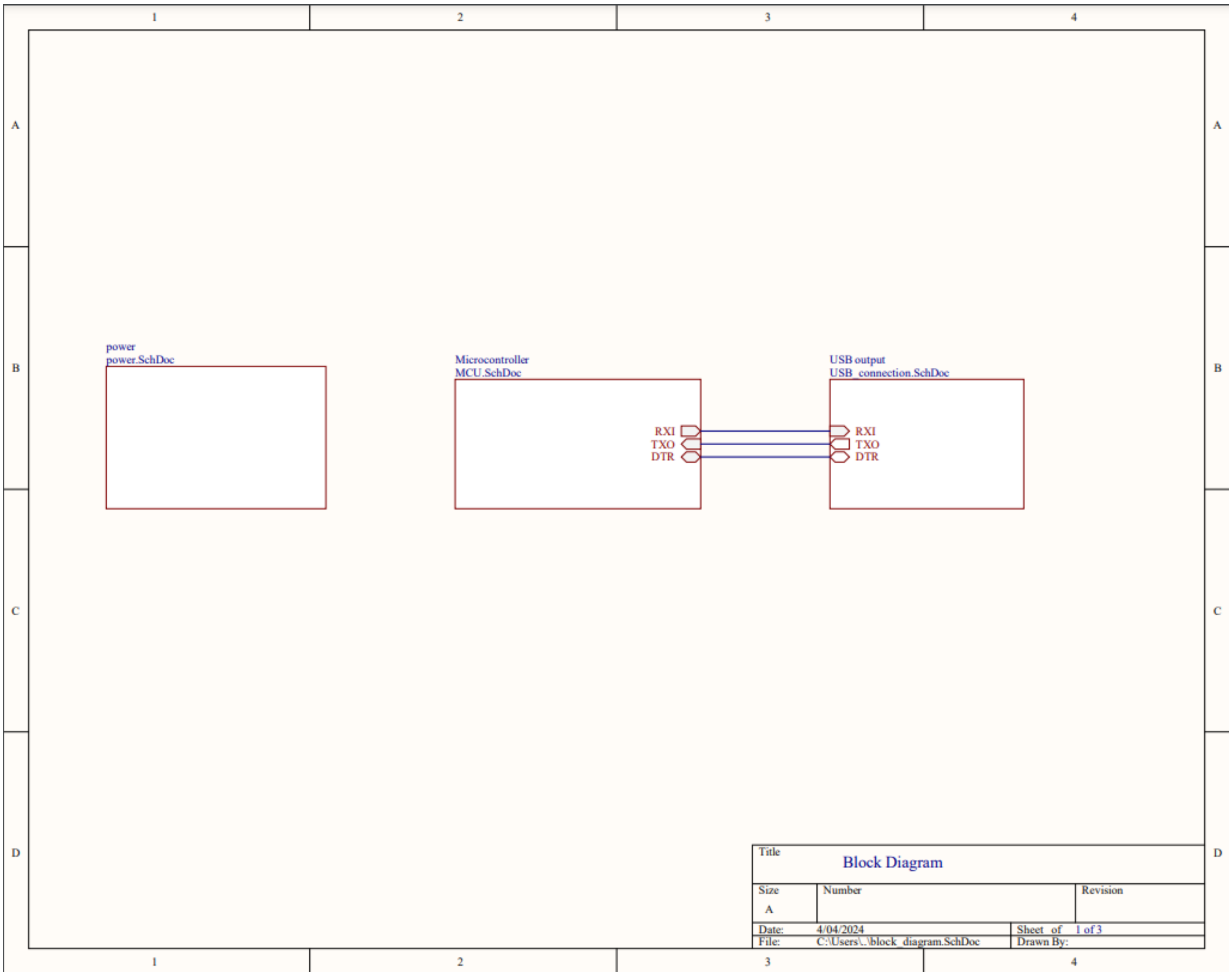


Fig. 12: Overall Block Diagram

2 Micro-controller

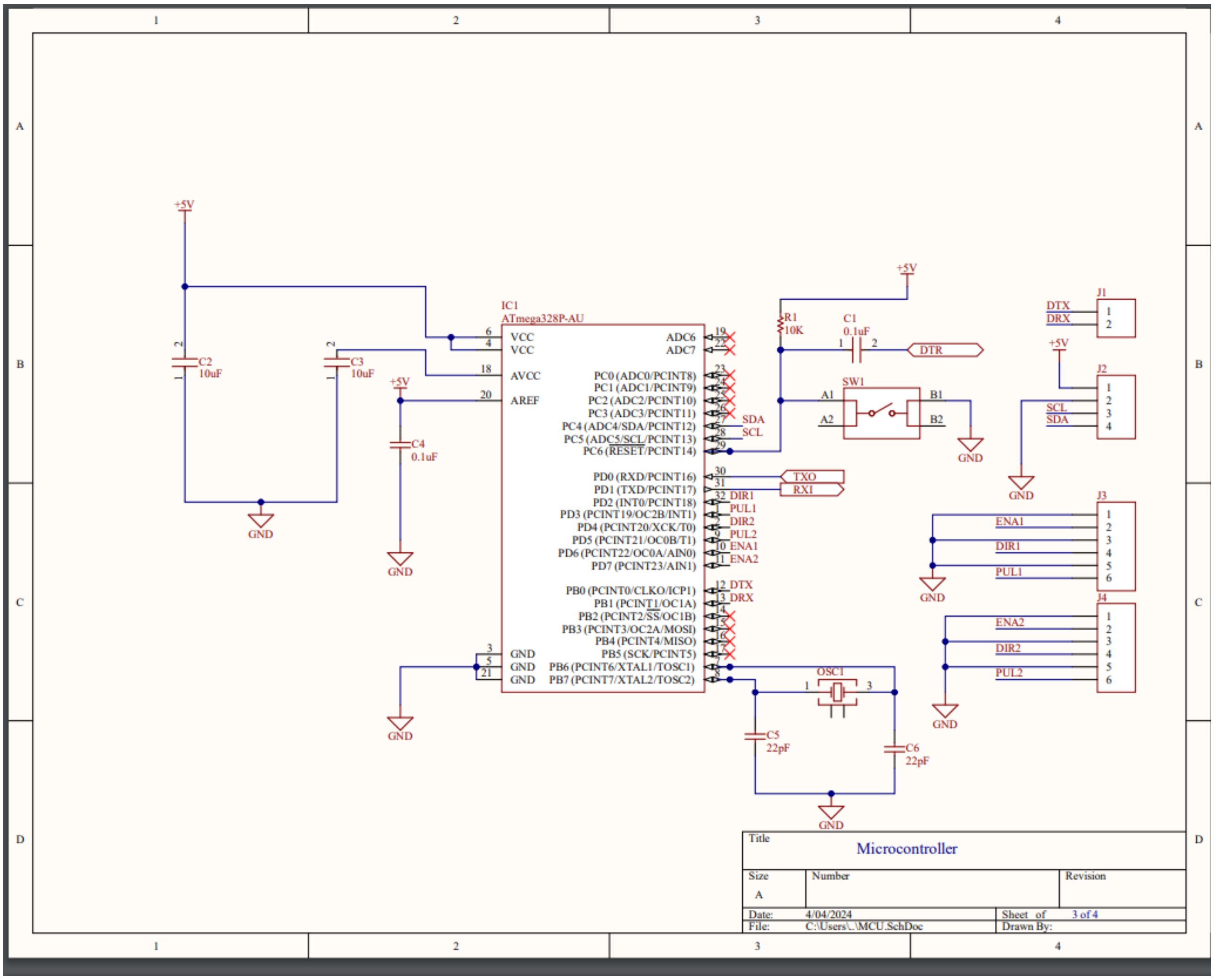


Fig. 13: Micro-controller Diagram

3 Voltage Converter

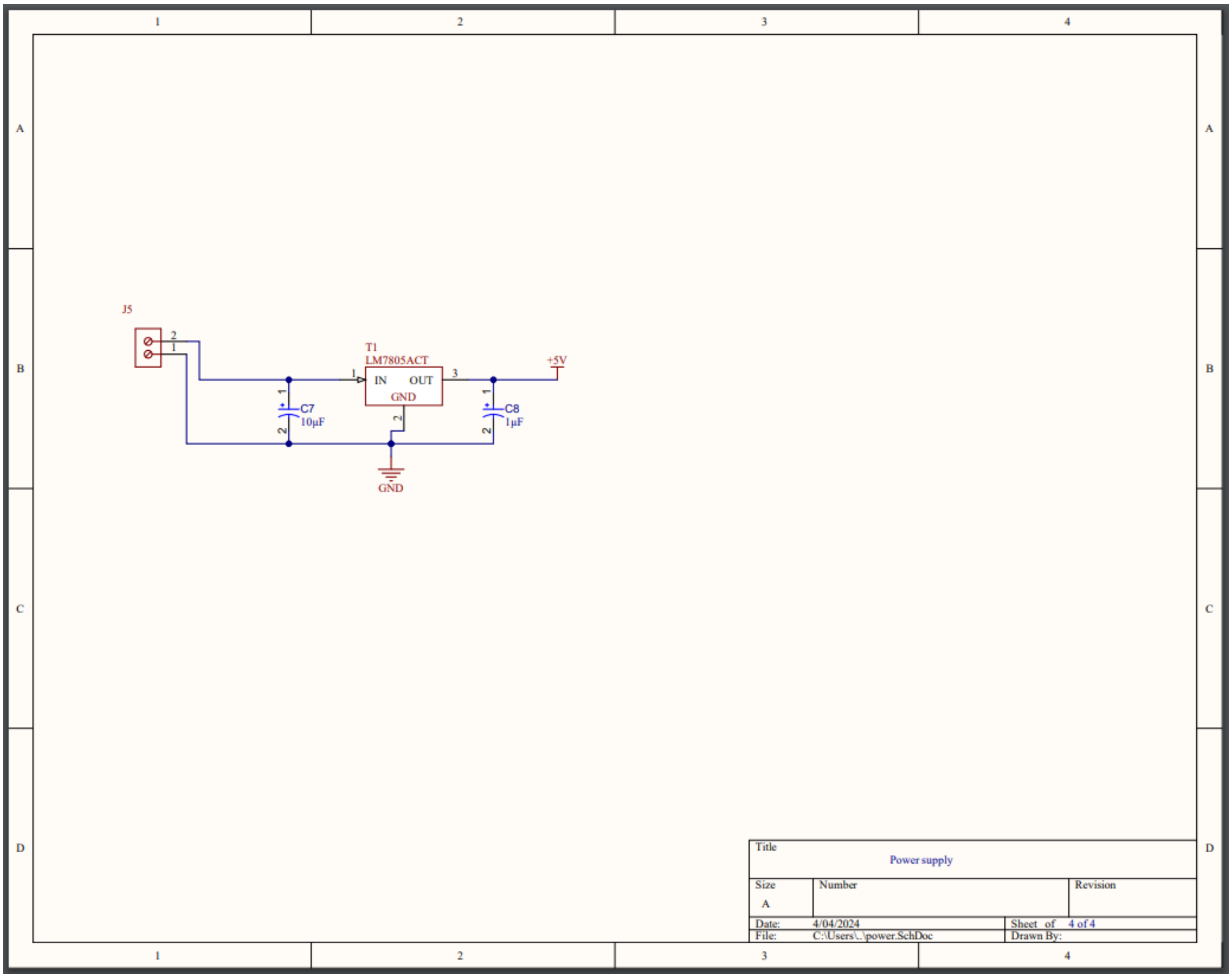


Fig. 14: Voltage Converter Diagram

4 USB Controller

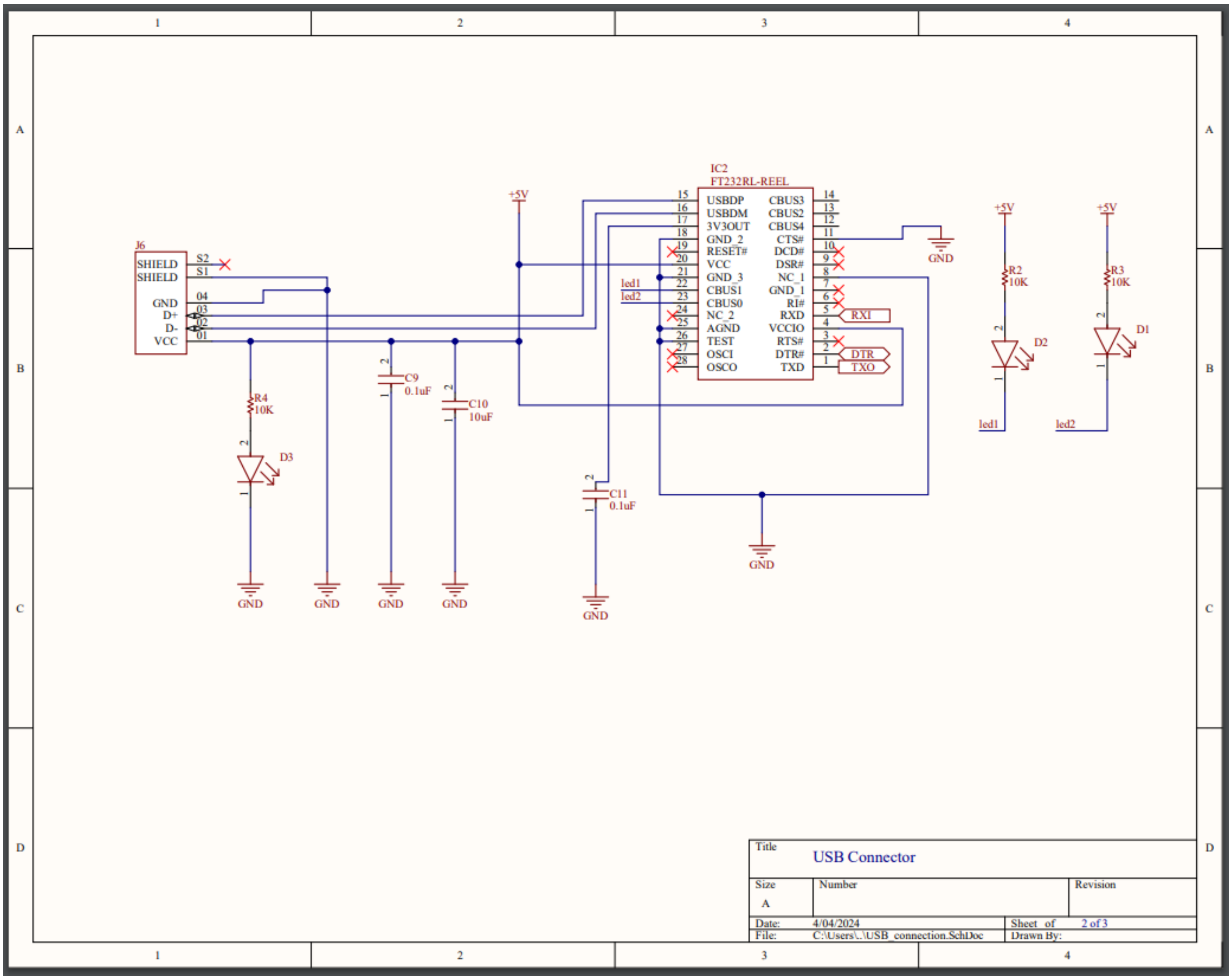


Fig. 15: USB Controller Diagram

XI PCB Design

Designed as a two-layer PCB with both smd and through-hole components.

1 Top Layer

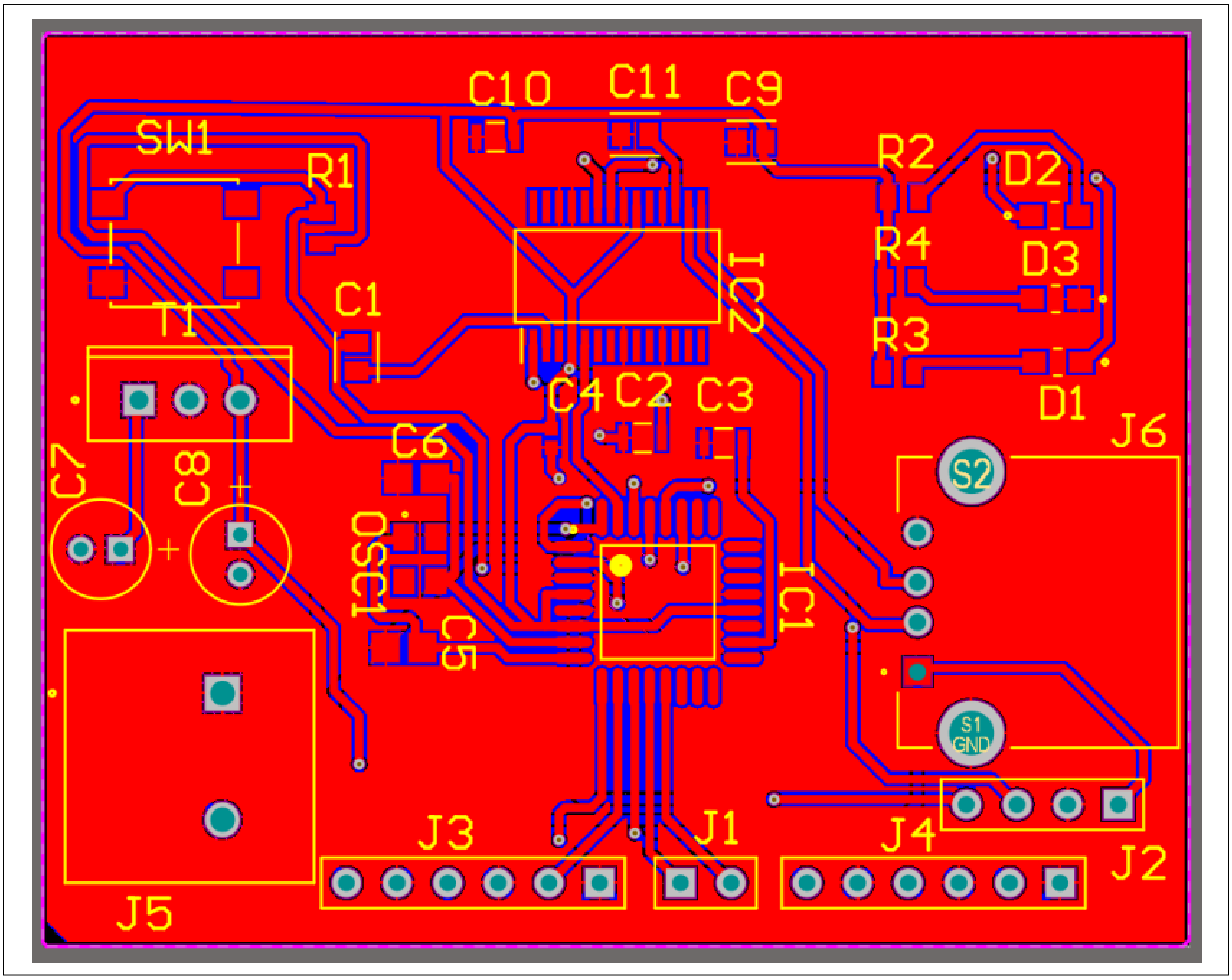


Fig. 16: PCB top layer

2 Bottom Layer

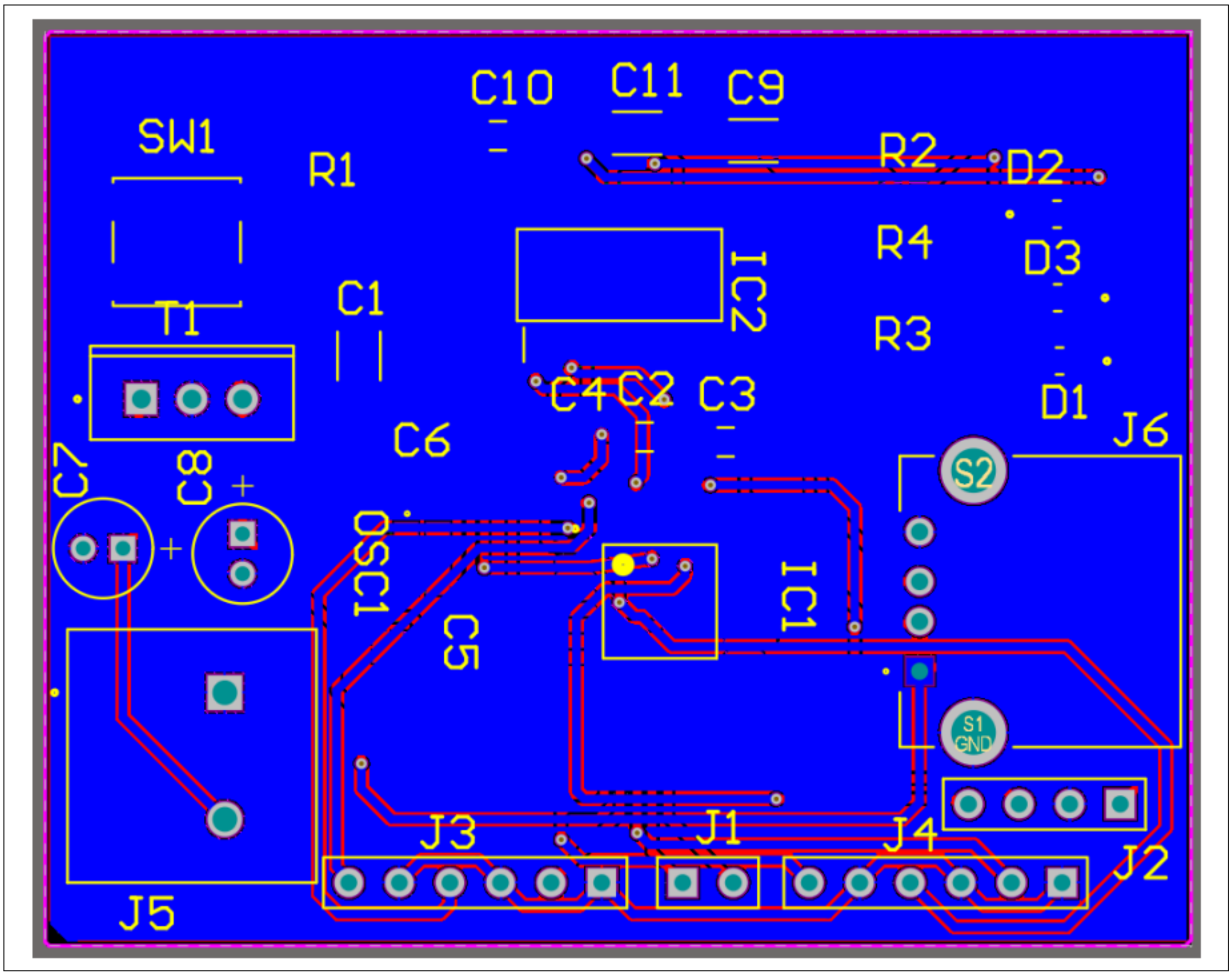


Fig. 17: PCB bottom layer

3 PCB with components

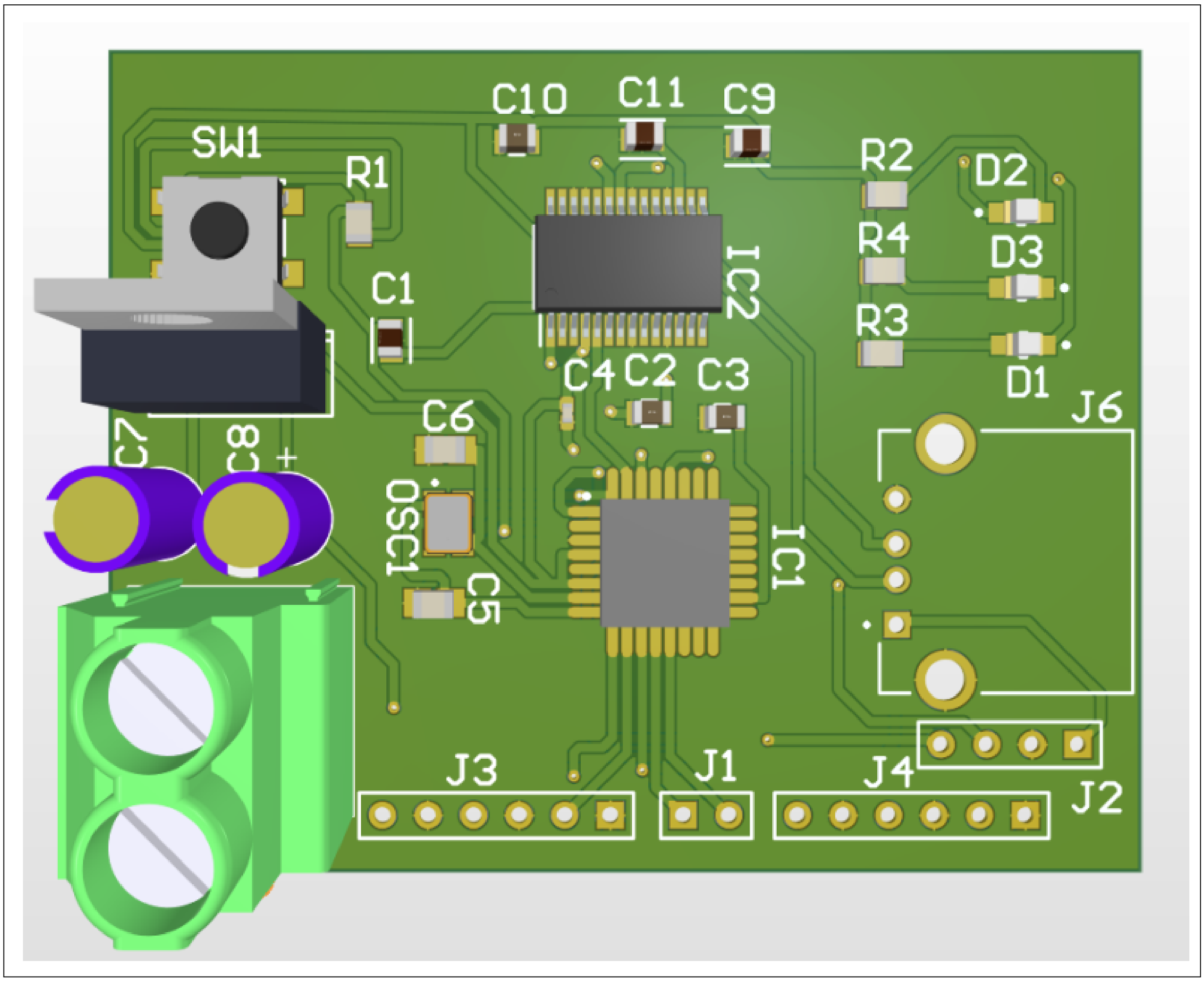


Fig. 18: PCB with components

4 Printed PCB

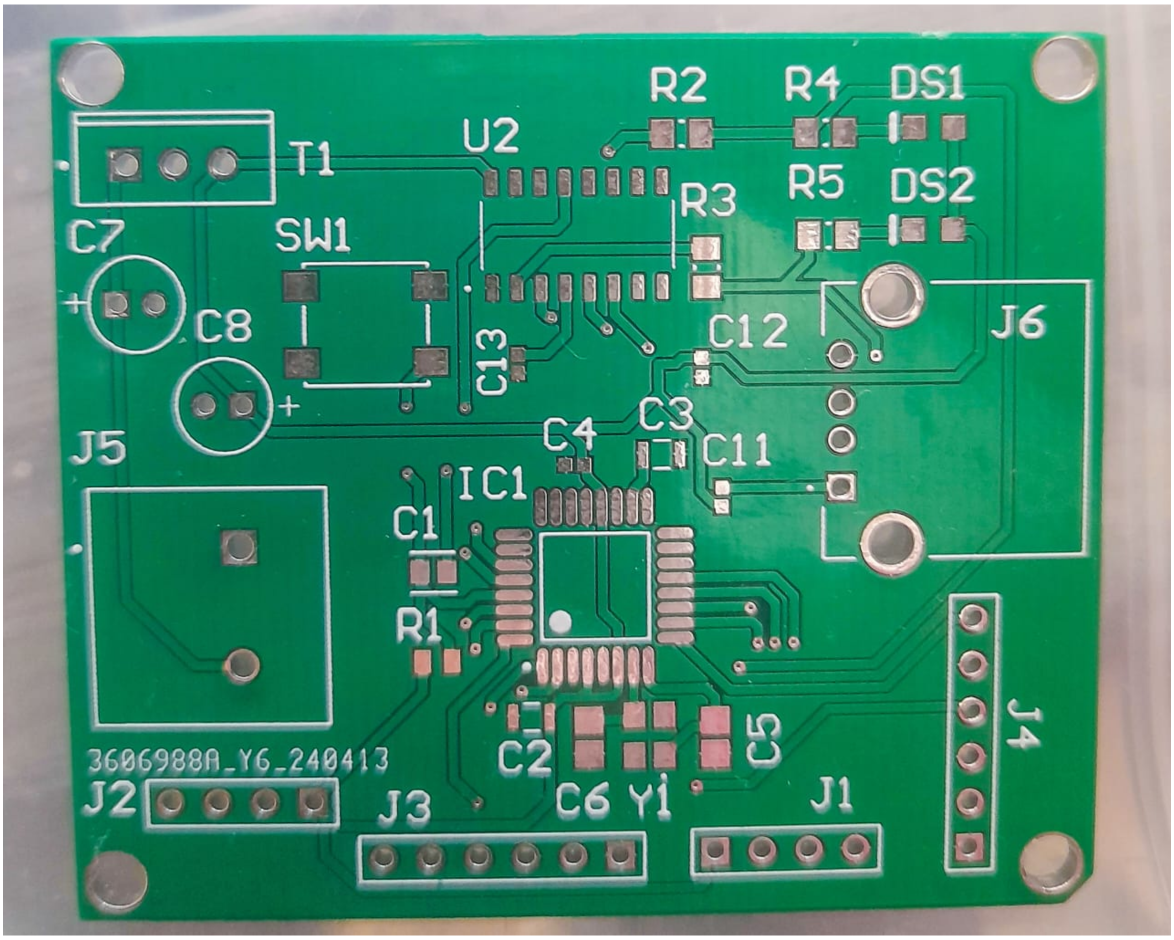


Fig. 19: Printed PCB

5 Soldered PCB

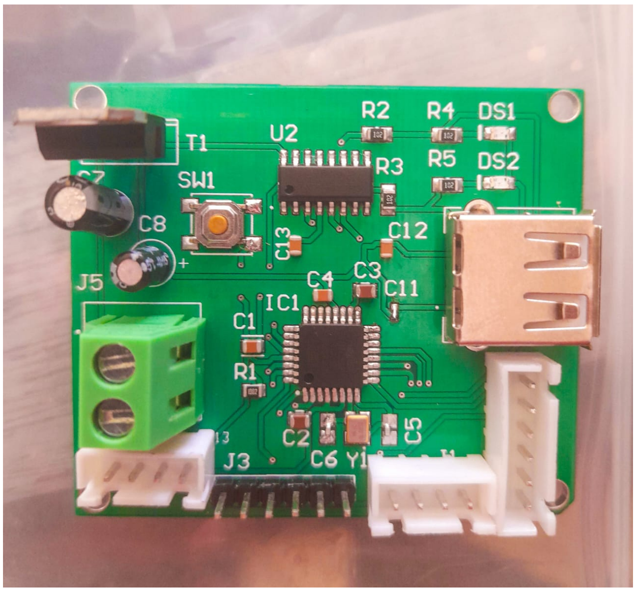


Fig. 20: Soldered PCB

Fig. 21: Soldered PCB

XII PCB Testing

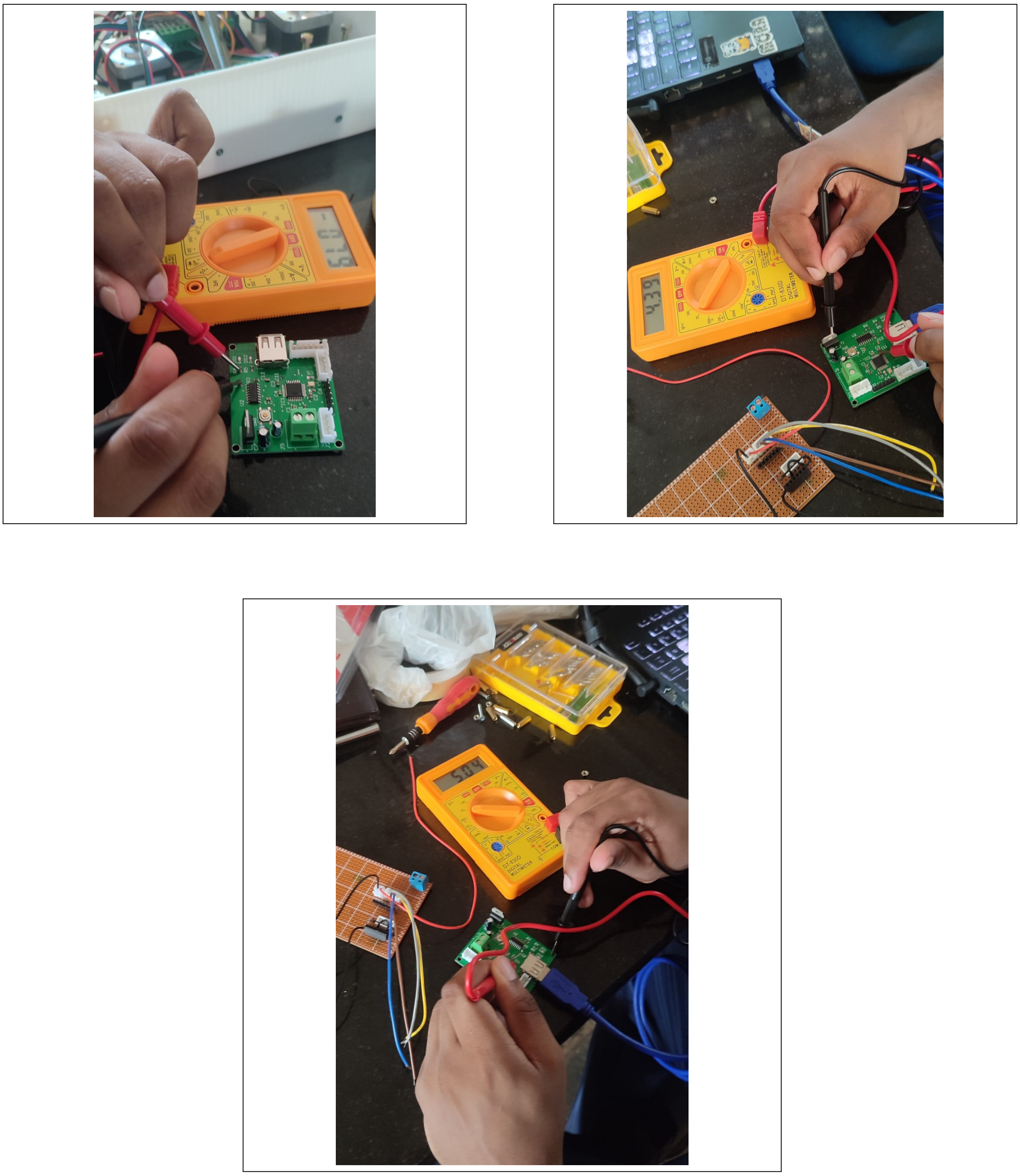


Fig. 22: PCB Testing Images

XIII Solidwork Design

Enclosure design for the 3D Scanner.

1 Finalized enclosure Assemble

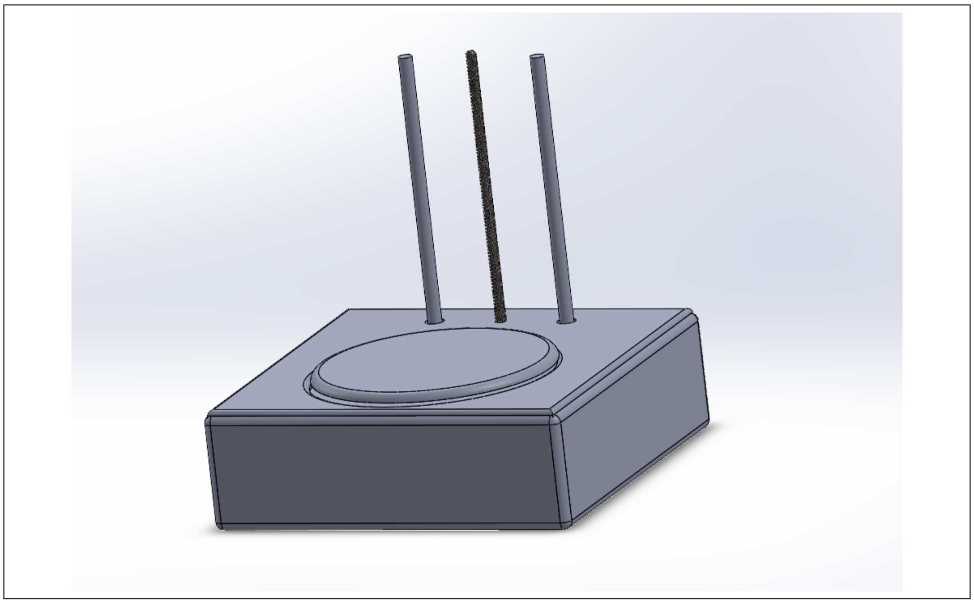


Fig. 23: 3D Scanner Assembled image

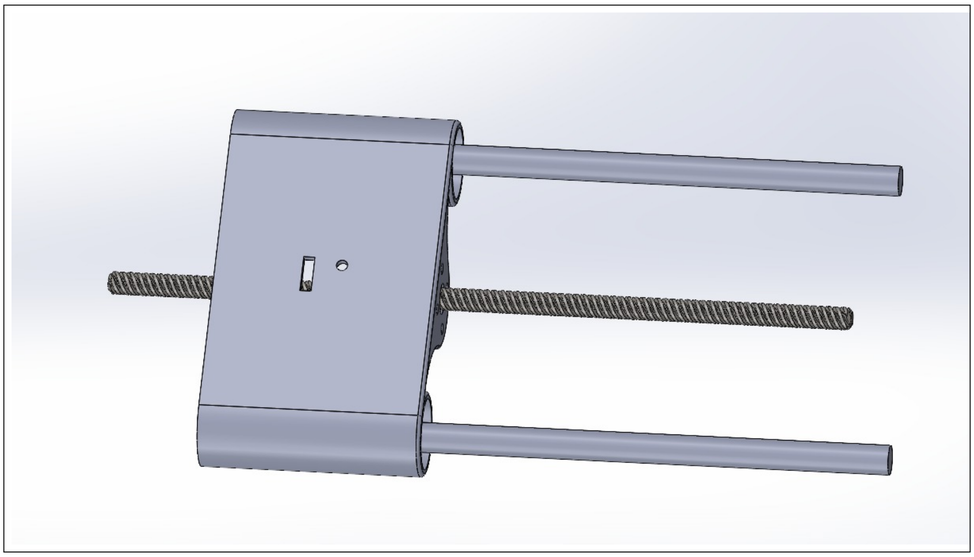


Fig. 24: Connector part with shafts

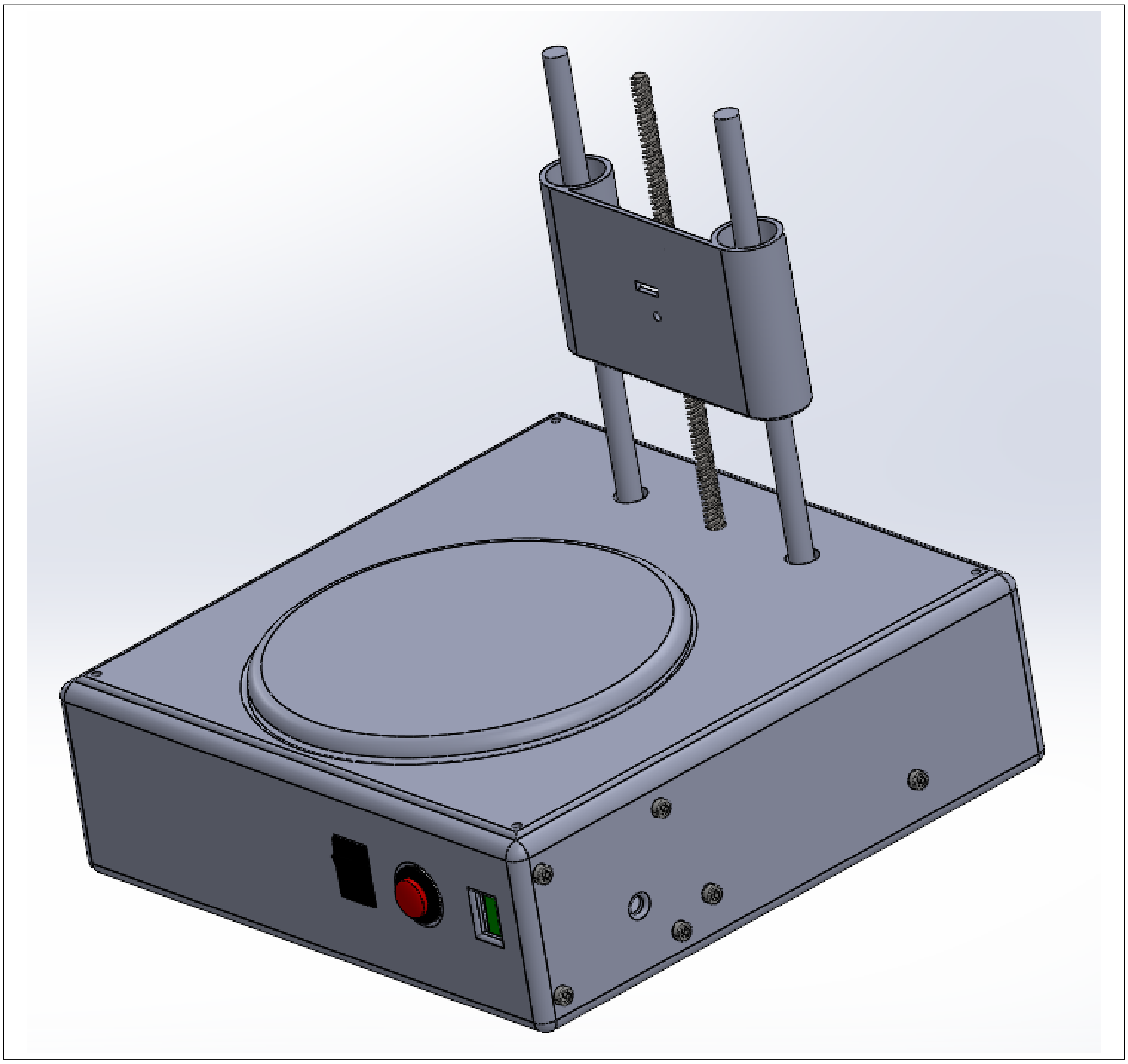


Fig. 25: Finalized Assembly in Solidworks

2 Main Base

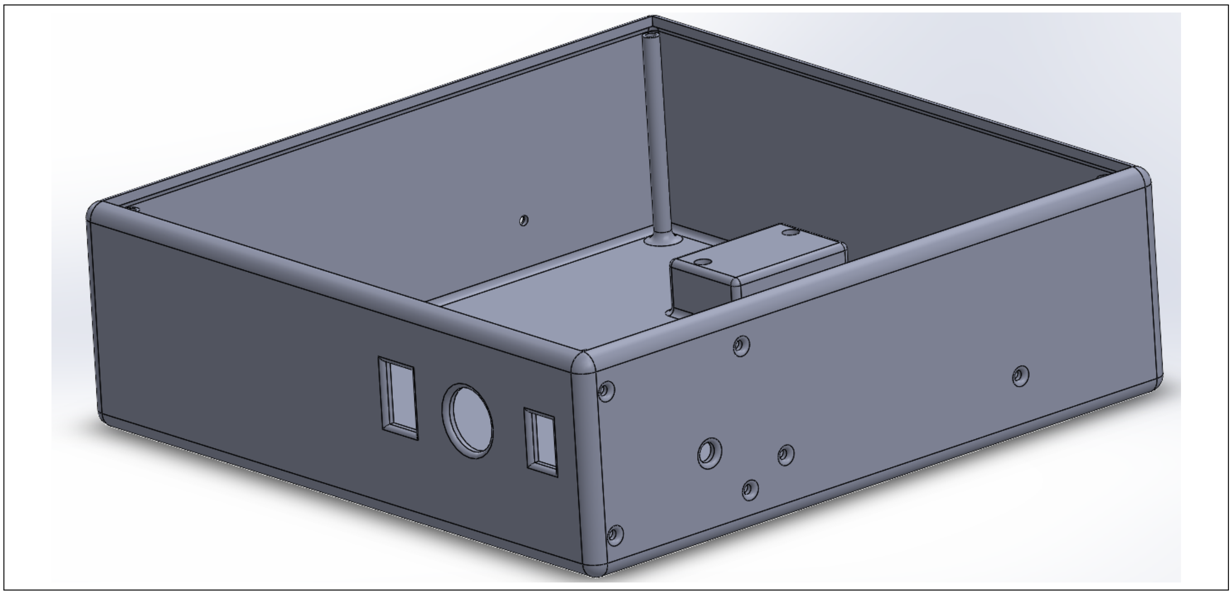


Fig. 26: 3D Scanner Main base

Fig. 27: Main base Design Tree

3 Top Lid

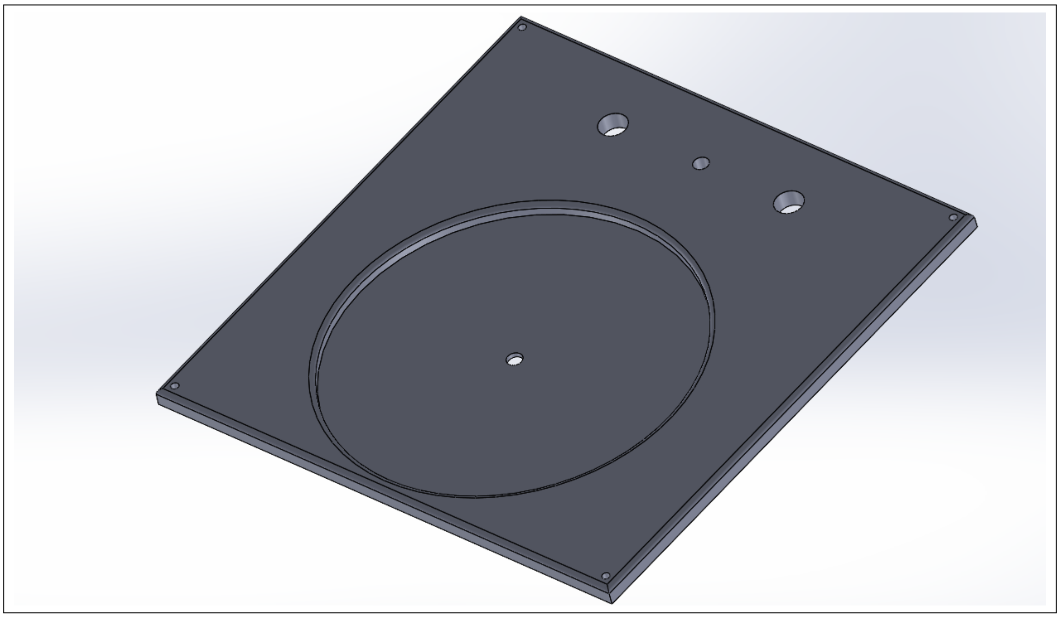


Fig. 28: 3D Scanner Top Lid

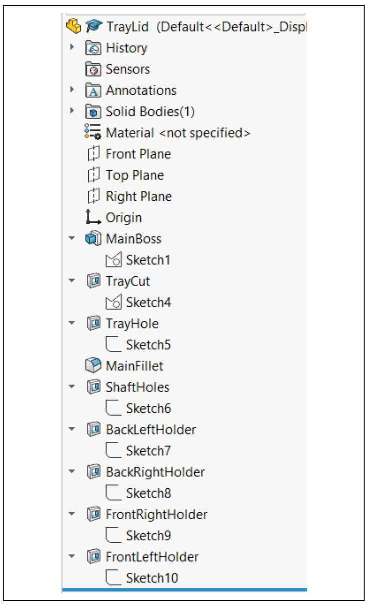


Fig. 29: Design Tree

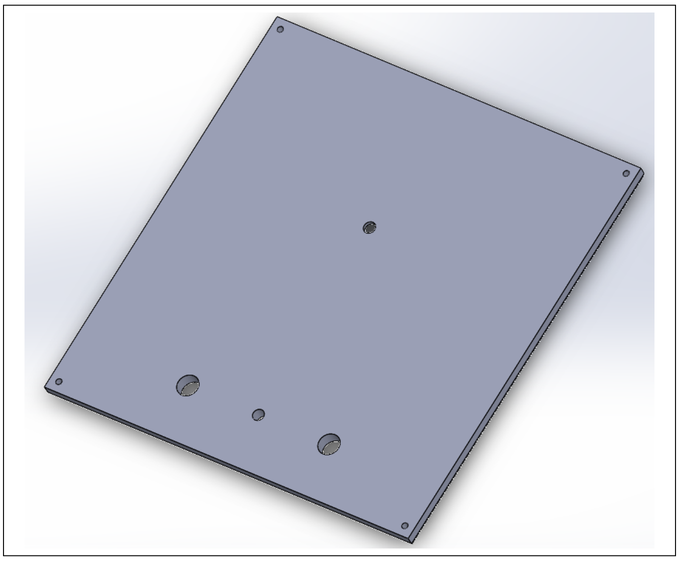


Fig. 30: Lid Bottom

4 Turnable Table

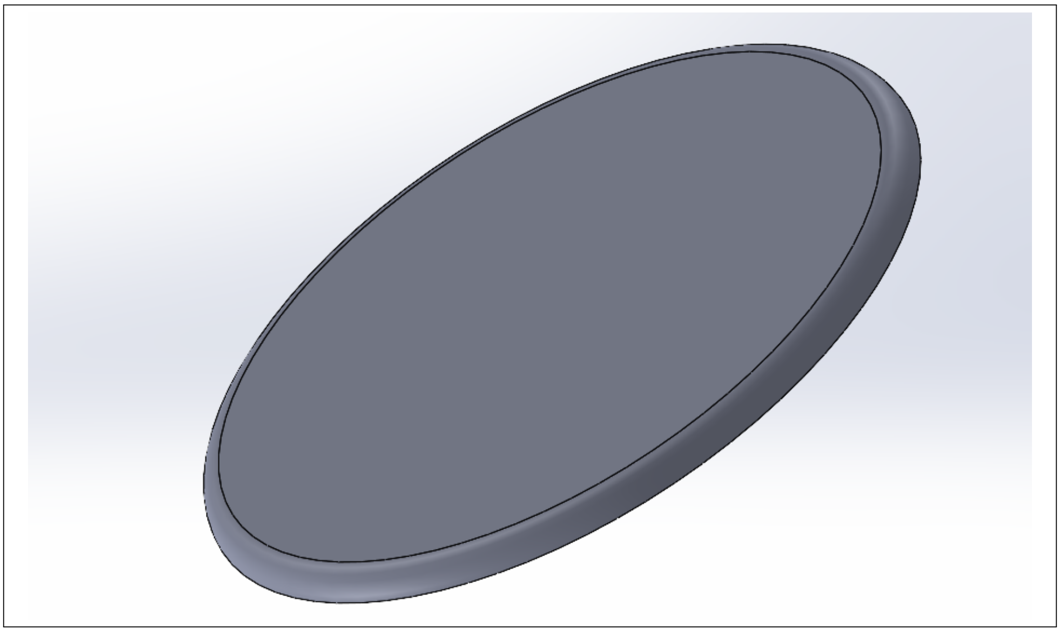


Fig. 31: 3D Scanner Turnable Table top

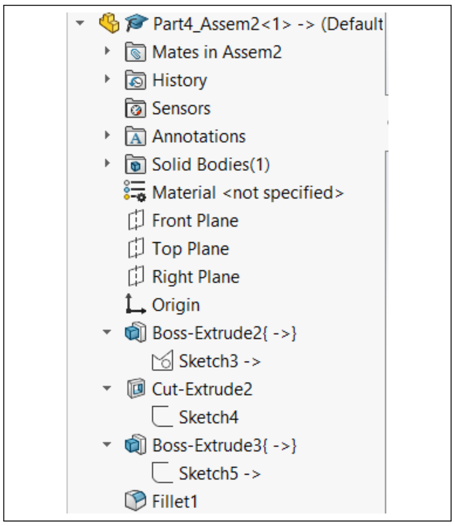


Fig. 32: Design Tree

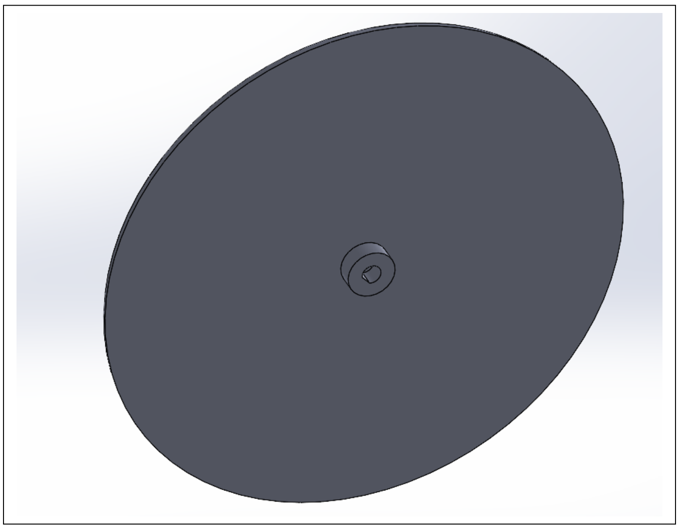


Fig. 33: Tray Bottom

5 Connector part

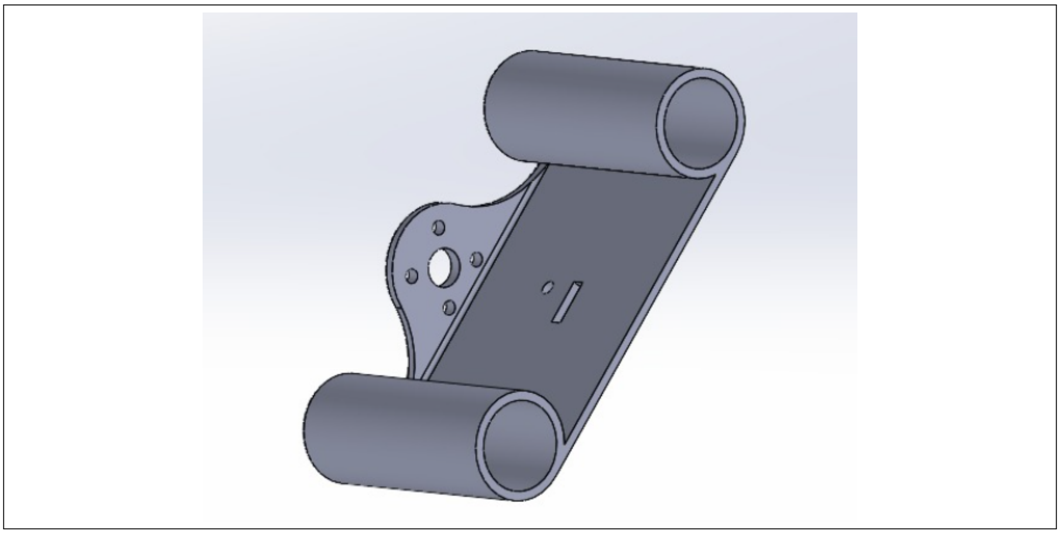


Fig. 34: 3D Scanner Moving Holder

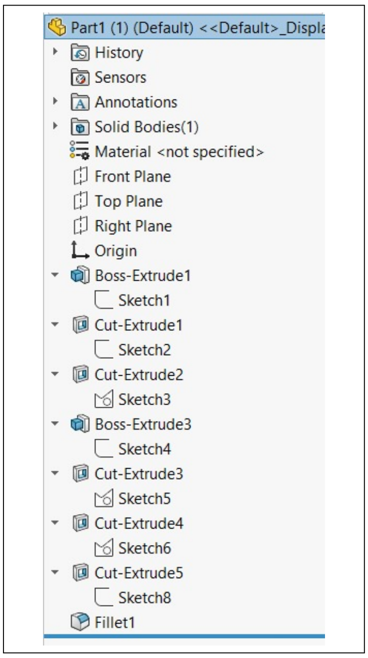


Fig. 35: Design Tree

Fig. 36: Connector part

XIV 3D printed parts

1 Main Base

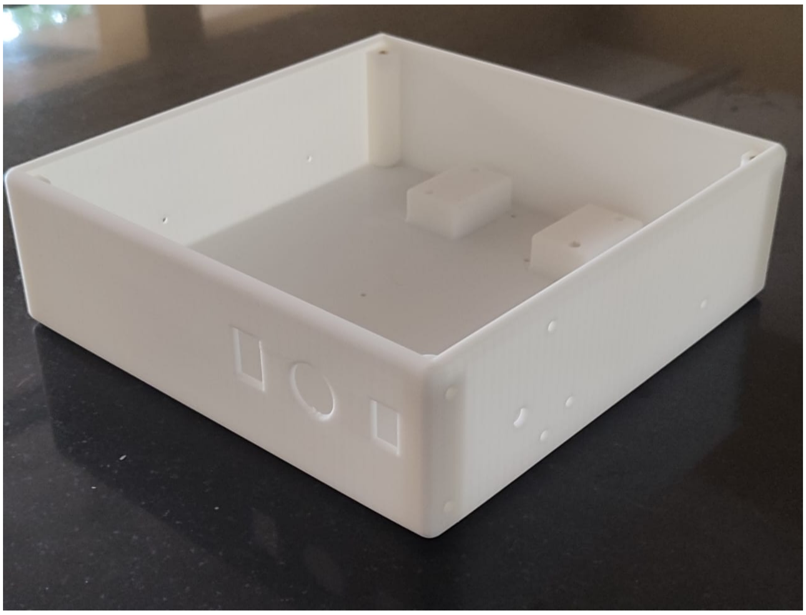


Fig. 37: 3D Scanner Main base

Fig. 38: Main base top

2 Top Lid

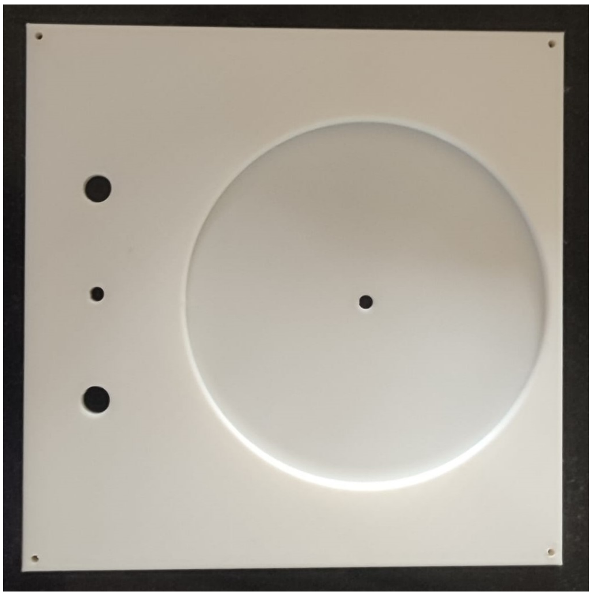


Fig. 39: 3D Scanner Top lid

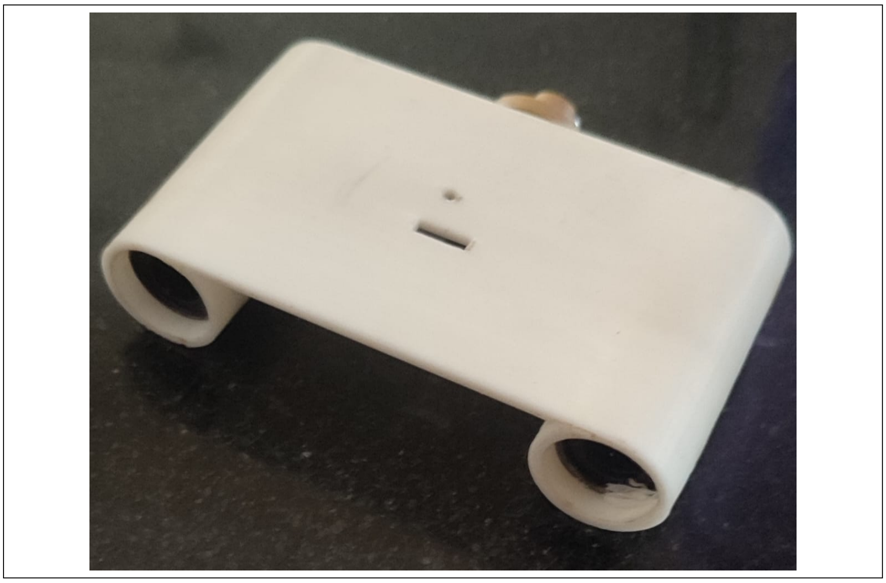
Fig. 40: Top lid bottom

3 Turnable Table

Fig. 41: 3D Scanner Tray

Fig. 42: Tray bottom

4 Connector part



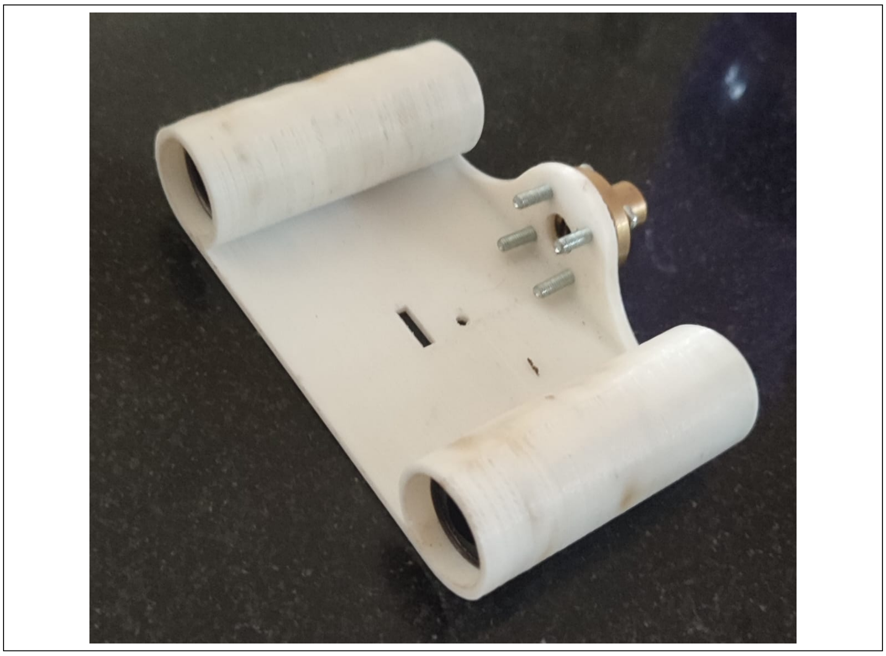


Fig. 43: Shafts Connector

XV System Integration

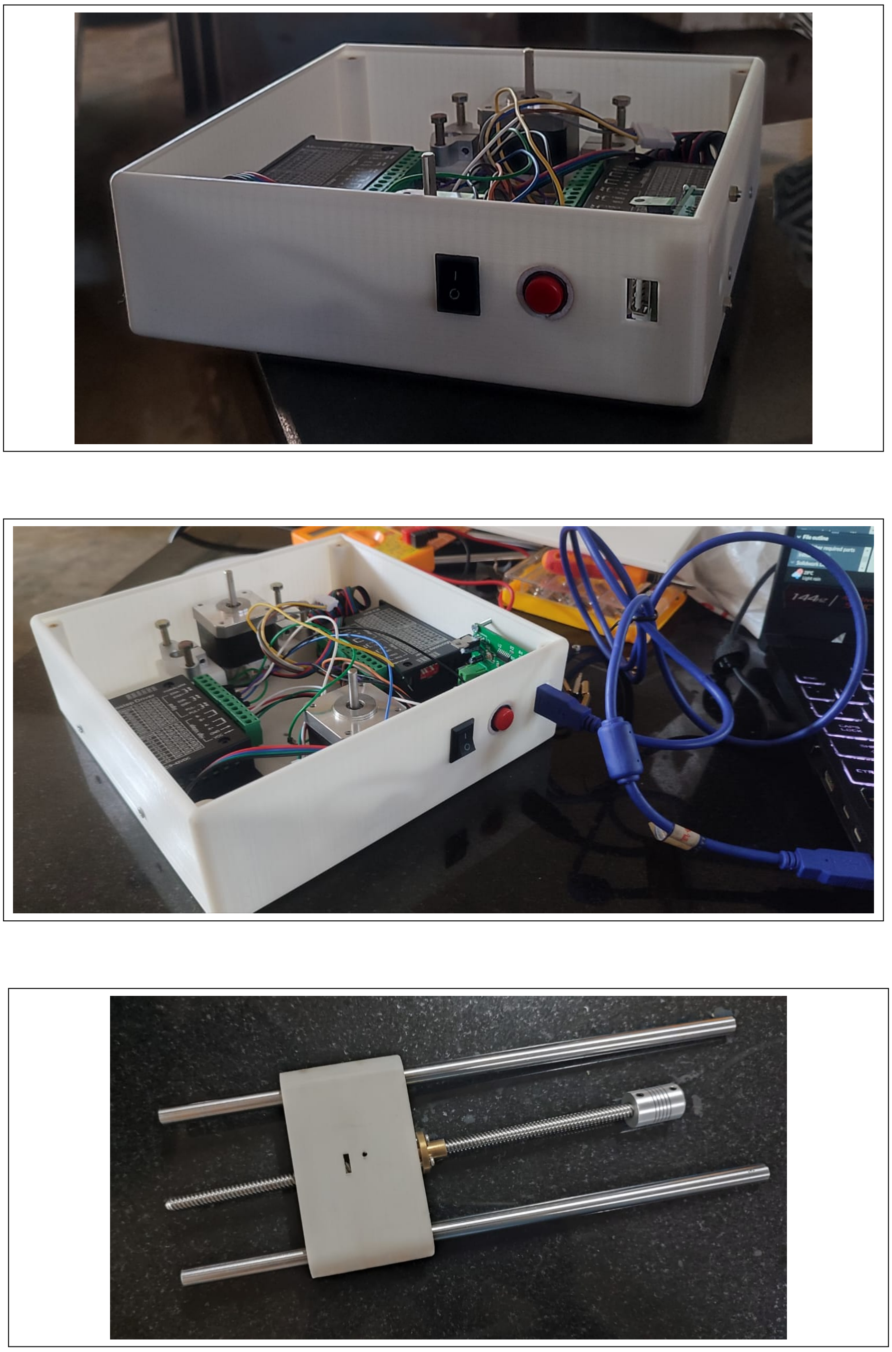


Fig. 44: System Integration

XVI Final Assembly

Fig. 45: Final 3D Scanner Assemble

XVII CONCLUSIONS

In summary, the 3D scanner prototype demonstrates promising capabilities in capturing detailed three-dimensional objects efficiently. Further development and strategic partnerships will be crucial in refining the prototype for widespread adoption and transformative applications across industries.

References

[1] B. Sumetheeprasit, R. R. Martinez, H. Paul, R. Ladig, and K. Shimonomura, “Variable baseline and flexible configuration stereo vision using two aerial robots,” Sensors, vol. 23, no. 3, p. 1134, Jan. 2023, doi: 10.3390/s23031134.

[2] S. May, D. Droeschel, S. Fuchs, D. Holz, and A. Nuchter, “Robust 3D-mapping with time-of-flight cameras,” Robust 3D-Mapping With Time-of-Flight Cameras, Oct. 2009, doi: 10.1109/iros.2009.5354684.

[3] S. May, D. Droeschel, S. Fuchs, D. Holz, and A. Nuchter, “3DReconstruction Using 3D Registration-Based ToF-Stereo Fusion,” 3DReconstruction Using 3D Registration-Based ToF-Stereo Fusion, Oct. 2009, doi: 10.1109/iros.2009.5354684..

XVIII APPENDIX

Cross check by the other team - Depth Camera
we hereby declare that we have reviewed and approved the report of the project 3D Scanner done by Pathirana R.P.S. and Uduwaka S.S.

Index	Name	Signature
210071E	BOTHEJU W.G.W.	
210022G	ADIKARI A.A.S.D.	