Schmalkalden University of Applied Sciences

Master of Mechatronics and Robotics

Project Report on **XY-**

Pen Plotter under the

subject of

Workshop I & II

Submitted by

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Student Declaration

We, Dhanush Muthyala Kanika ,Sejal Dhavale ,Mayank Yogesh Khandelwal, Pranay Pravin Patel hereby declare that this project entitled **“XY PEN PLOTTER”** done by us under the guidance of **PROF. DR. STEFAN ROTH AND PROF. DR.-ING. SILVIO BACHMANN** is not copied and submitted anywhere for the award of any degree.

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PLACE: Schmalkalden, Germany

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Acknowledgement

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Furthermore, we are immensely grateful to all the individuals working in the AKT Lab. Their expertise, collaboration, and assistance were instrumental in the successful completion of our project. Their valuable contributions, coupled with the guidance of Prof. Dr.-Ing. Silvio Bachmann and Prof. Dr. Stefan Roth, have significantly enriched our project's outcomes.

We also extend our thanks to our classmates, whose interactions and inquiries enhanced our understanding of the subject matter. Their active involvement in the learning process has been truly valuable.

Lastly, we would like to thank the faculty, staff, and management for their assistance and provision of necessary resources that enabled us to bring this project to fruition. Their support has been crucial in our journey towards accomplishing our goals.

We express our sincere appreciation to all those who played a part in making this project a reality.

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CHAPTER 1 INTRODUCTION

In an era where technology converges with artistry, the Pen Plotter emerges as an emblematic bridge between the realms of precision and creativity. This project embarks on a captivating journey, wielding the capabilities of a Pen Plotter to intricately draw the Nicolaus House—a venerable architectural masterpiece that stands as both a testament to history and a canvas for the fusion of technological precision and artistic finesse.

As we delve into this Pen Plotter Project, transcending the conventional boundaries of art and engineering, it is not merely about reproducing an architectural marvel on paper. It is a symphony of lines and algorithms, a harmonious interplay between the soul of the Nicolaus House and the digital precision of the Pen Plotter. This project seeks to encapsulate not just the physical dimensions of the Nicolaus House, but also the intangible essence that makes it an enduring piece of architectural history.

Beyond the technicalities of programming and plotting, this project is a tribute to the intersection of creativity and innovation. The Nicolaus House becomes a muse, guiding the Pen Plotter's pen in an intricate dance, transcending the mere representation of bricks and mortar to evoke a sense of time, culture, and artistic intention. In undertaking the challenge of drawing the Nicolaus House with a Pen Plotter, we embark on a voyage through time and technology—a celebration of craftsmanship and an exploration of the symbiotic relationship between human ingenuity and technological prowess.

1.1 BACKGROUND

This Pen Plotter project is pivotal within the study as it serves as a hands-on exploration of precision and technical mastery in digital art, utilizing programming languages to achieve accuracy in replicating the Nicolaus House. Beyond technical expertise, the project transforms the Pen Plotter into a dynamic instrument, seamlessly integrating technical precision with creative nuance. It contributes significantly to education by providing practical insights into programming proficiency and technical problem-solving. Furthermore, the project adds valuable resources to the Pen Plotter art knowledge base by addressing technical challenges and showcasing the device's potential for intricate architectural representation. Symbolically, the Nicolaus House becomes a benchmark for calibrating the Pen Plotter's capabilities, pushing its boundaries. Overall, this interdisciplinary project fosters a nuanced understanding of the symbiotic relationship between technology and artistry within a concise framework.

1.2 AIM

This project aims to highlight the precision of a Pen Plotter in replicating the Nicolaus House, with a focus on achieving accuracy in architectural details. Emphasizing the Pen Plotter's capabilities for nuanced drawing without delving into specific technical challenges, the goal is to showcase its potential for accurate and detailed architectural representation. Additionally, the project seeks to contribute insights to the broader field of Pen Plotter art.

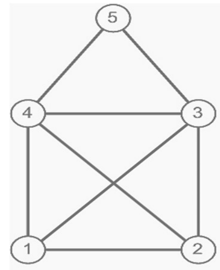


Figure 1 Nicolaus Haus

1.3 ORGANISATIONAL CHART

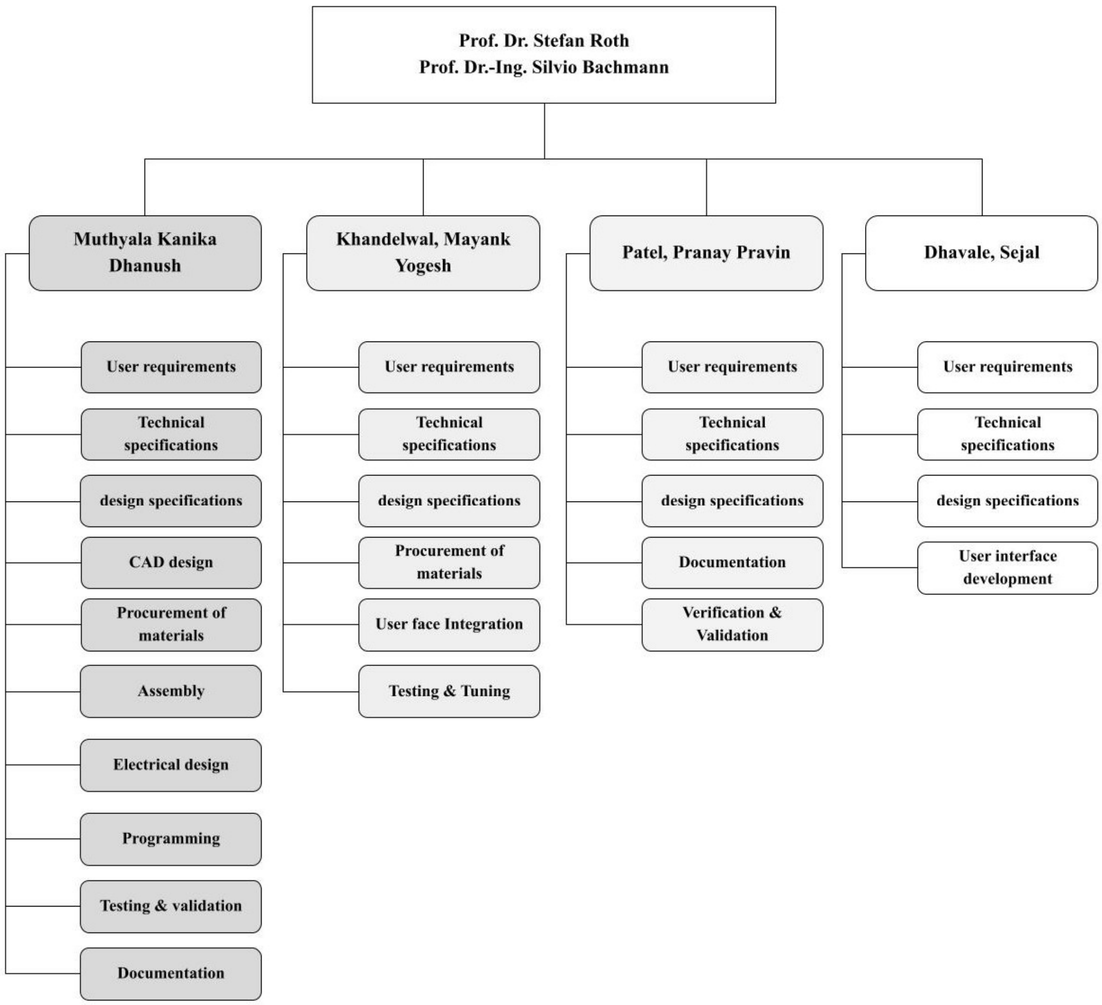


Figure 2 Organisational Chart

CHAPTER 2 PROJECT PLANNING

2.1 METHODOLOGY

2.1.1 PDCA CYCLE

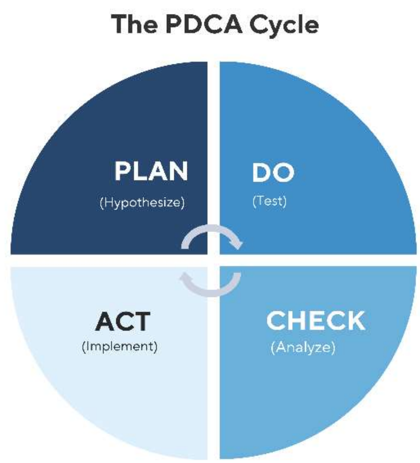


Figure 3 PDCA Cycle

The PDCA (Plan-Do-Check-Act) cycle is integral to the pen plotter project:

Plan: Initial stages involve planning, encompassing design, and validation strategies for the pen plotter.

Do: Execution follows the plan, with the actual creation and implementation of the pen plotter based on the designed strategies.

Check: Rigorous testing and validation protocols assess the pen plotter's performance, ensuring it aligns with predefined criteria.

Act: Findings from testing inform iterative refinements and optimizations, acting as a continuous improvement loop for enhanced pen plotter functionality.

2.2 APPROACH

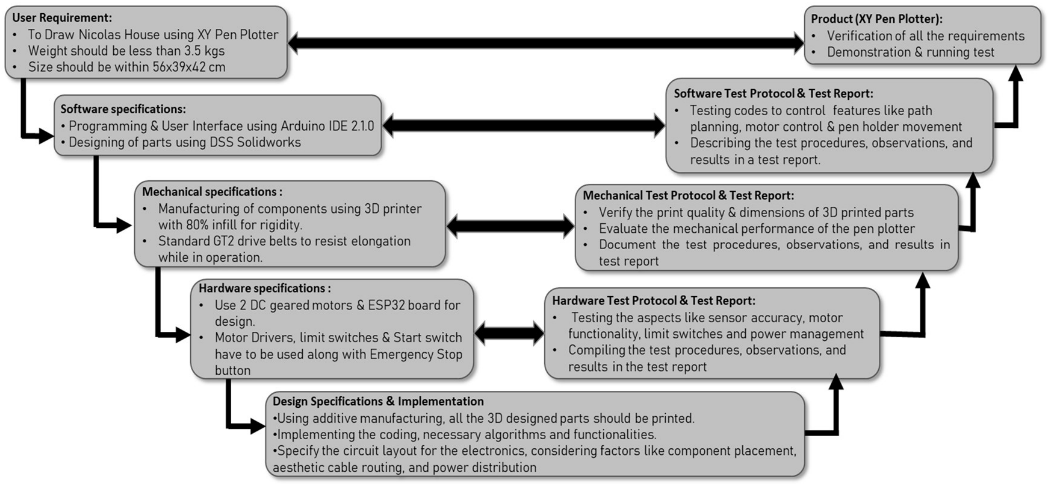


Figure 4 V-Model

Within the V-Model framework, the pen plotter project adopts a methodical approach. Starting with User Requirements, it gathers and documents user needs. Transitioning to Technical Specification, it precisely defines dimensions and specifications. The Software Requirements stage identifies necessary functions and programming needs. Simultaneously, the Mechanical Requirements focus on the physical structure, while the Electrical Requirements delve into essential components. Each stage contributes to a robust development lifecycle, ensuring a comprehensive understanding of the project's intricacies within a structured framework.

2.3 CONCEPT PLAN

The morphological chart for this pen plotter project serves as a comprehensive roadmap, outlining the diverse design options and potential configurations for critical elements such as the pen mechanism, servo motors, and overall system architecture. It facilitates systematic decision-making, guiding the selection of optimal combinations that balance functionality, precision, and efficiency. This visual tool streamlines the design process, fostering innovation and ensuring that the final pen plotter configuration aligns seamlessly with the project's overarching objectives.

Table 1 Morphological Chart

Module	Solution 1		Solution 2		Solution 3	
Cad software	Catia V5		Solidworks		Creo	
Manufacturing	3D Printing		Injection Moulding		Metal	
Power	Dc Adapter		Battery		Solar Powered	
Drive module	Dc Motor		Micro Servo		Dc Stepper	
Micro controller	Esp32 board		Arduino Uno		Rassberry Pi	
Motor Driver Module	Sparkfun QWiiC Motor Driver		L298N		Tb6560	
Limit switches	Micro Limit Switches		Ultrasonic sensor		Optical Sensors	
User interface	MIT Inventor		Blynk		Web Based	
Pen movement	Servo		Manual		DC Motor	
Status indication	LED		O-led screen		Mobile interface	
Paper fixtures	Magnets		Paper Clips		Tape	

Note : Be advised that the solution for our ultimate output has been highlighted in green.

2.4 LIST OF TASKS

- Receive kit
- Develop v model
- Morphological diagram
- Layout selection
- Measuring given parts
- Cad development
- Assembly structure and flow creation
- 3d printing
- Procurement of 3d printed things
- Assembly
- Electrical design
- Wiring
- Check code development
- Main coding
- App development
- User tech design validation verification
- Circuit diagram
- Gannt Chart
- Technical Drawing
- Bill of Materials
- Dossier
- Presentation

2.5 TIMELINE

Table 2 Timeline

MECHATRONICS WORK SHOP- XY PEN PLOTTER-TEAM 22				
		TASKS	Start date	End date
1. PLAN	1.1	planning and allocation of tasks to team members	03-08-2023	14-08-2023
	1.2	recieving kit	15-08-2023	15-08-2023
	1.3	planning layout and model	16-08-2023	25-08-2023
2.DESIGN	2.1	1st phase design	28-08-2023	22-09-2023
	2.1.1	design of model	28-08-2023	07-09-2023
	2.1.2	3d printing of parts	07-09-2023	15-09-2023
	2.1.3	limiation of 3D printer update	15-09-2023	15-09-2023
	2.1.4	design change and resent for print	15-09-2023	15-09-2023
	2.1.5	3d printing of parts	15-09-2023	21-09-2023
	2.1.6	recieveing of 1st design parts	22-09-2023	22-09-2023
	2.2	2nd phase design	22-09-2023	16-10-2023
	2.2.1	design revision	22-09-2023	03-10-2023
	2.2.2	3d prototype	03-10-2023	03-10-2023
	2.2.3	3d printing of part	03-10-2023	09-10-2023
	2.2.4	recieving of part	10-10-2023	10-10-2023
	2.2.5	2nd phase parts 3D print	11-10-2023	11-10-2023
	2.2.6	3d printing of parts	09-10-2023	13-10-2023
	2.2.7	recieving of parts	16-10-2023	16-10-2023
	2.3	3rd phase design	17-10-2023	08-11-2023
	2.3.1	design enhancement	17-10-2023	30-10-2023
	2.3.2	3d printing of part	31-10-2023	07-11-2023
	2.3.3	recieving of parts	08-11-2023	08-11-2023
3.ASSEMBLY	3.1	1st pahse assembly	25-09-2023	28-09-2023
	3.2	2nd pahse assembly	17-10-2023	20-10-2023
	3.3	circuitry	23-10-2023	25-10-2023
	3.4	3rd pahse assembly	08-11-2023	15-11-2023
	3.5	circutry	16-11-2023	20-11-2023
4.PROGRAMMING	4.1	movements coding	23-10-2023	26-10-2023
	4.2	including limit switches	27-10-2023	31-10-2023
	4.3	hall sensor, servo	01-11-2023	03-11-2023
	4.4	emergency stop, LED functions	06-11-2023	08-11-2023
	4.5	fine tuning	09-11-2023	20-11-2023
	4.6	mobile application	23-10-2023	24-11-2023
5. Testing verification and validation			02-11-2023	24-11-2023
6.DOCUMENTATION	6.1	requirements, verification & validation	02-10-2023	13-10-2023
	6.1	circuit diagram	16-10-2023	20-10-2023
	6.1	Bill of Materials	23-10-2023	31-10-2023
	6.1	technical drawings	02-11-2023	24-11-2023
	6.1	time line gantt chart	01-11-2023	03-11-2023
	6.1	dossier	06-11-2023	24-11-2023
	6.1	presentation	27-11-2023	01-12-2023
7. Dossier Submission			04-12-2023	04-12-2023
8. Final presentation & Test Run			05-12-2023	05-12-2023

CHAPTER 3 BUILD UP STAGES

3.1 USER REQUIREMENTS:

- Involves understanding and documenting unique needs and expectations of users.
- Serves as the foundation for subsequent technical specifications and design considerations.
- Provides crucial insights into shaping the project.

3.2 TECHNICAL REQUIREMENTS

- Transitioning from user insights.
- Precisely specifies dimensions, resolution, speed, and accuracy parameters.
- Sets the groundwork for subsequent design and development activities.

3.3 DESIGN SPECIFICATION

- With technical requirements as the focal point, the design specification stage is initiated.
- This stage outlines the detailed architectural and operational blueprint of the pen plotter.
- It encompasses mechanical and electrical components, materials, and design considerations.

3.4 VALIDATION PROTOCOL AND REPORT

- Development and execution of a robust validation protocol.
- Aimed at ensuring the pen plotter aligns with defined user requirements and technical specifications.
- Subsequent report consolidation of findings.
- Highlights areas of success and improvement identified during validation.

3.5 VERIFICATION PROTOCOL AND REPORT

- Following design and validation, rigorous testing ensues in the verification protocol stage.
- The pen plotter undergoes thorough testing against predefined criteria.
- The verification report consolidates results for a comprehensive overview.
- It provides insights into the system's performance and adherence to specifications.

CHAPTER 4 DESIGN AND FABRICATION

4.1 PROTOTYPE

4.1.1 INITIAL CAD DESIGN

In the initial phase, we delve into intricate Computer-Aided Design (CAD), crafting a blueprint for the pen plotter's components. This phase lays the foundation for precision and innovation, outlining the detailed specifications and structure crucial for the project's success. CAD modeling becomes the bridge between concept and reality, setting the stage for the subsequent phases of materialization and testing.

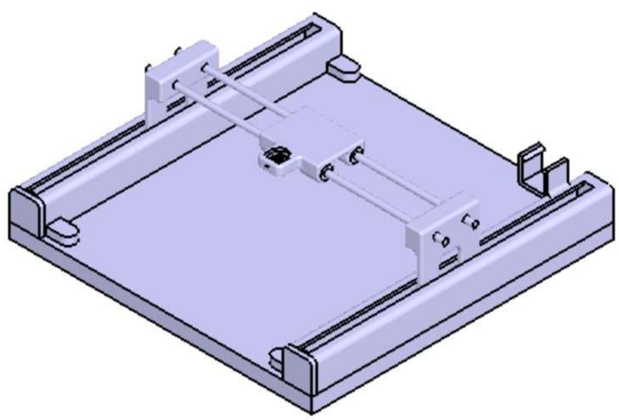


Figure 5 CAD Model of Pen Plotter

4.1.2 PRINTING

We have used CREALITY (Ender-6) 3D-printer with a print precision of ± 0.1mm. 3D Printing is an easy and safe way to manufacture complex components. To manufacture the parts, first we need to convert the file to .STL extension. This file format is supported by many other software packages; it is widely used for rapid prototyping, 3D printing and computer-aided manufacturing. STL files describe only the surface geometry of a three-dimensional object without any representation of colour, texture of other common CAD model attributes.

This printer required a CAD file of STL extension. These files are commonly used for 3D printing and CAD.

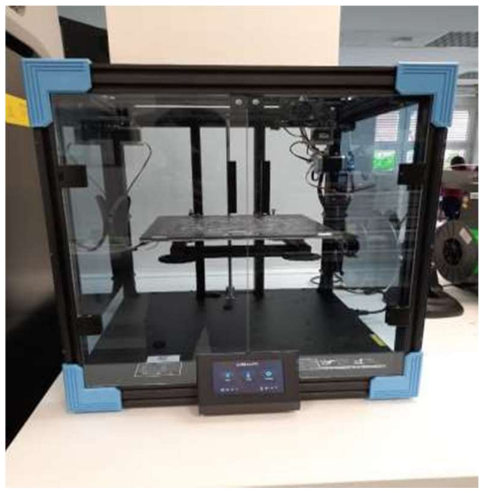


Figure 6 Creality(Ender 6)

4.1.3 CHALLENGES IN PROTOTYPE STAGE

- Structural failures leading to component fractures
- Insufficient stiffness causing deflections
- Deviations from specified dimensions impacting precision in the pen plotter.

Figure 7 Broken Parts

4.2 ENHANCEMENTS

4.2.1 IMPROVE AND ELIMINATE CHALLENGES

- Augmented structural resilience by increasing parts' wall thickness to mitigate the risk of fractures and enhance overall durability.
- Ensured precision in architectural reproduction by meticulously maintaining tight tolerances during fabrication.
- Strengthened the pen plotter's structural integrity by elevating the infill density in3D-printedcomponents.

4.2.2 CHALLENGES IN ENHANCEMENT STAGE

- Balancing Wall Thickness: Achieving increased wall thickness for structural resilience posed challenges in maintaining a balance. Too much thickness could lead to excessive weight, affecting the pen plotter's overall efficiency.
- Tight Tolerance Maintenance: Meticulously maintaining tight tolerances during fabrication demanded precision. Challenges arose in consistently meeting these tight specifications, requiring careful calibration and monitoring.
- Optimizing Infill Density: Elevating infill density in 3D-printed components presented challenges in finding the optimal balance. Excessive density could result in increased material usage and potentially affect the overall weight and functionality of the pen plotter.

These challenges required strategic problem-solving to ensure that the enhancements, while addressing specific goals, did not compromise the overall performance and efficiency of the pen plotter.

4.3 FINALISATION

4.3.1 IMPROVE, ADDITION AND ELIMINATION OF CHALLENGES

- DFM analyses guided the optimization of wall thickness, ensuring structural resilience without compromising efficiency. This solution involved iterative adjustments based on practical considerations.

- DFM principles facilitated precision in fabrication by incorporating allowances for variations. The solution involved refining machining processes and tooling to ensure consistent tight tolerances during manufacturing.
- DFM strategies were employed to optimize infill density in 3D-printed components. The iterative approach ensured a balance between strength and material usage, enhancing structural integrity without relying on simulation tools.
- Also, in enhancement stage we fully integrated electrical system in our pen plotter, encompassing the microcontroller power module, motors, and other essential components. This integration streamlines the overall operation of the device, enhancing its efficiency and reliability. The microcontroller power module ensures stable power delivery to the system, while the motors provide precise and controlled movement of the pen carriage. Together, these electrical components form the backbone of the pen plotter's enhanced capabilities.

4.3.2 3D-PRINTED COMPONENTS

Following are the different CAD models of components used in the pen plotter project

Table 3 CAD Model of Components

 *Figure 8 Bush*	 *Figure 9 Case Fixer Guide Left*	 *Figure 10 Case*

Figure 11 LED Pole

Figure 12 Logo

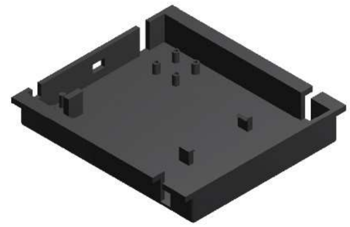


Figure 13 Case

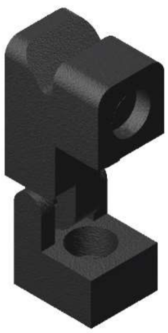


Figure 14 Paper Holder

Figure 15 Pen Mechanism

Figure 16 Pen Rack

Figure 17 X-belt fix plate

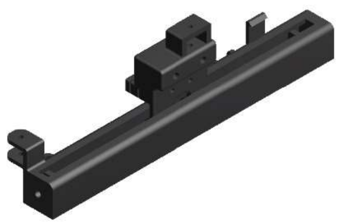


Figure 18 Y-axis left

Figure 19 Y-axis right

Figure 20 Pen Slider

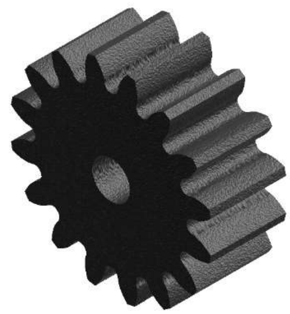


Figure 21 Pinion

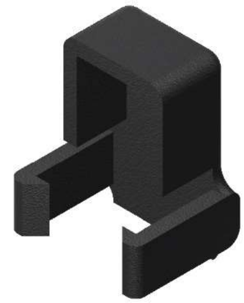


Figure 22 Sensor Cover

Figure 23 Sensor Holder

Figure 24 Sensor Slider Guide

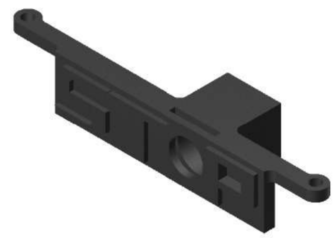


Figure 25 Stop Button Holder

Figure 26 Y-Belt fix plate

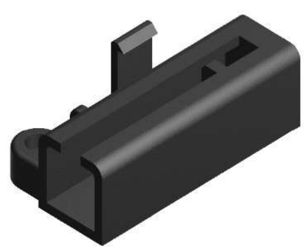


Figure 27 Y shell L0

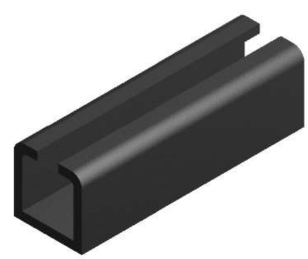


Figure 28 Y shell L1

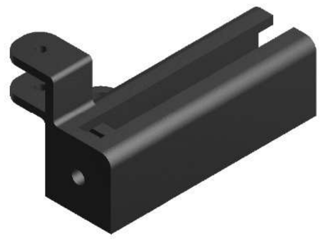


Figure 29 Y-shell L2

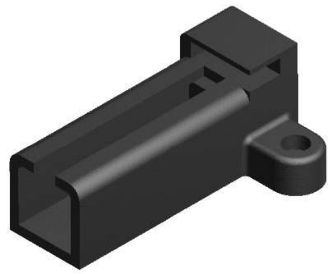


Figure 30 Y-shell R0

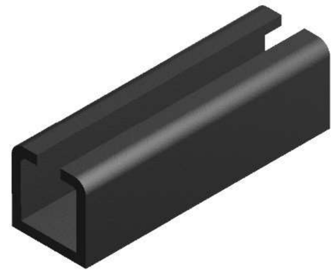


Figure 31 Y-shell R1

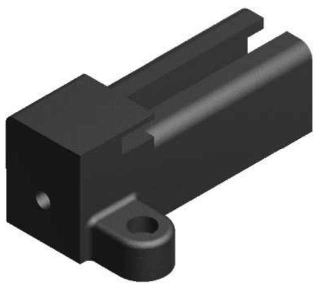


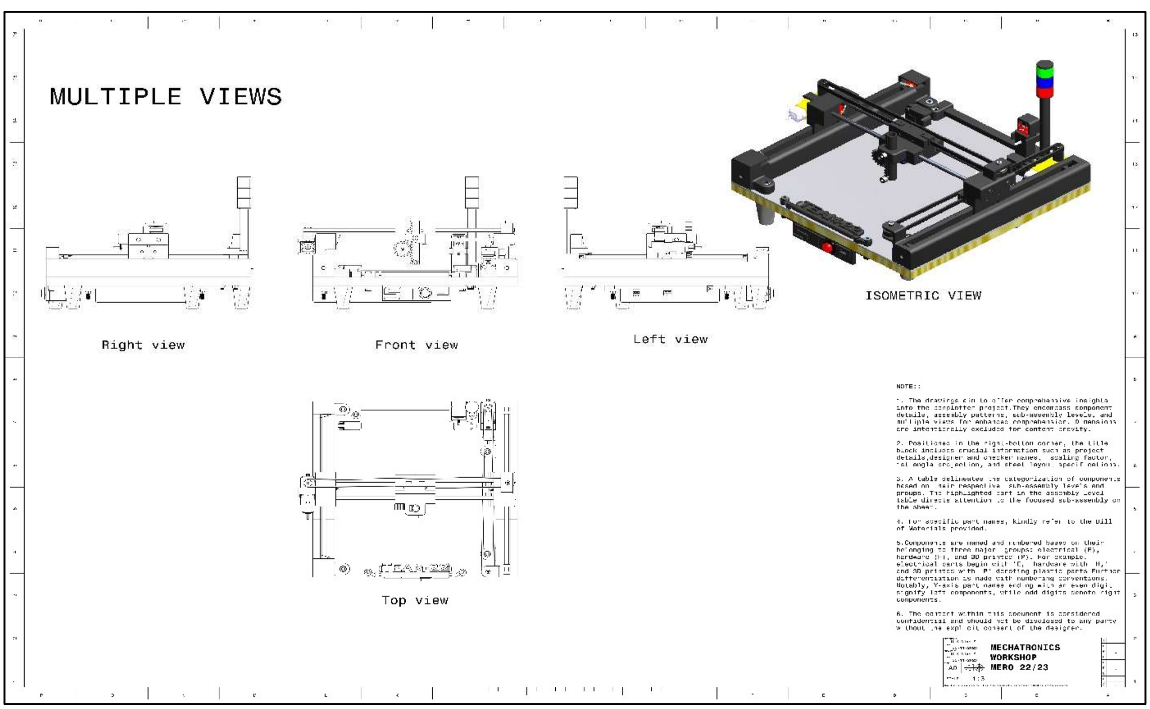
Figure 32 Y-shell R2

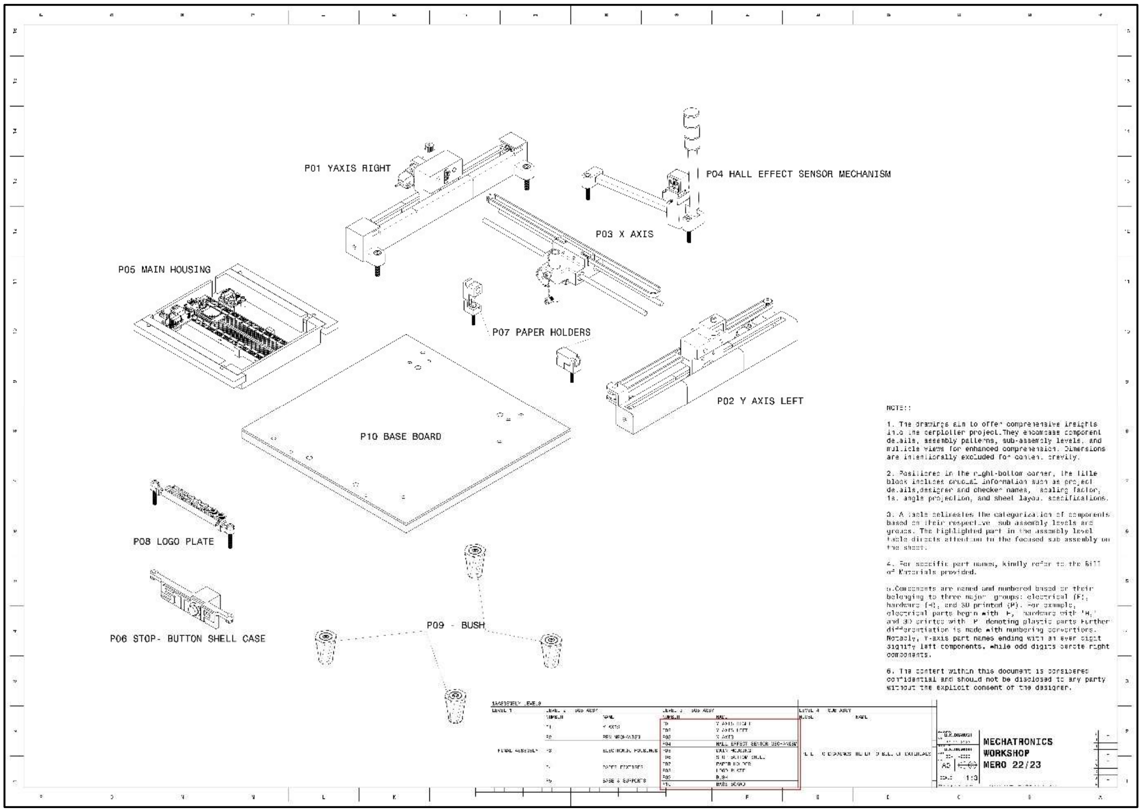
Figure 33 Y support L

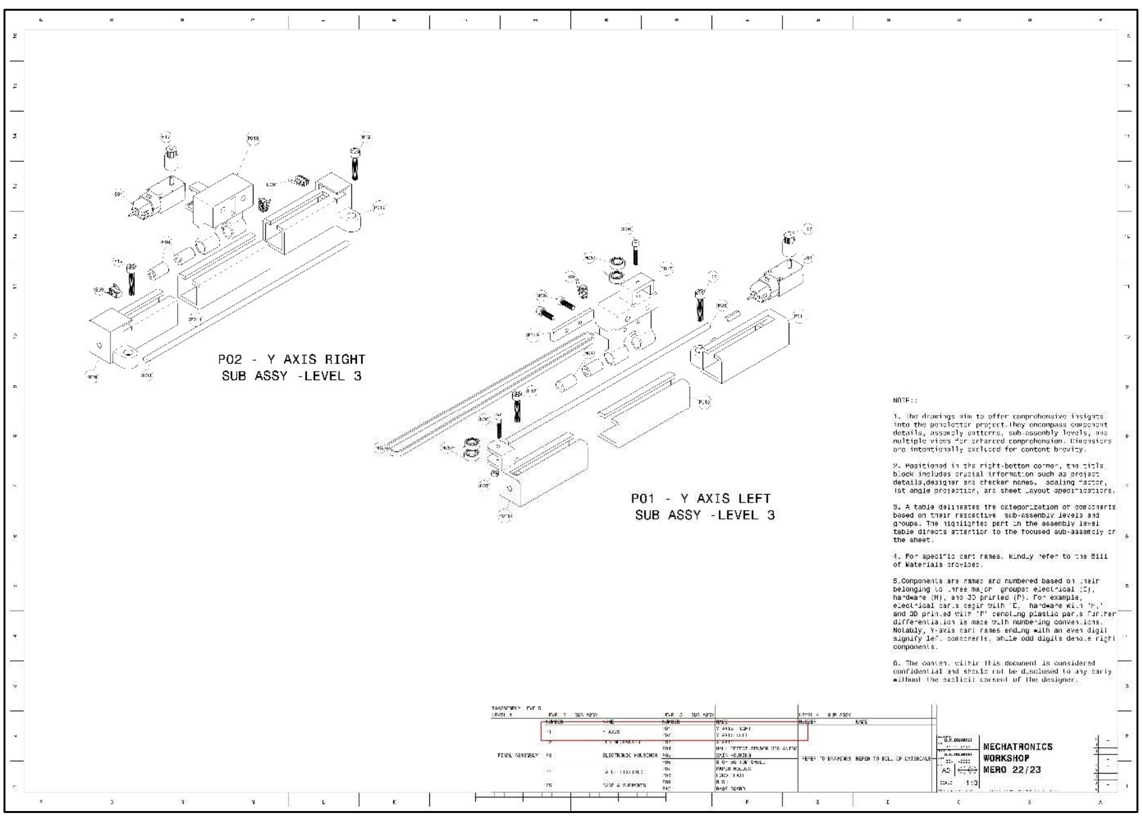
Figure 34 Y support R

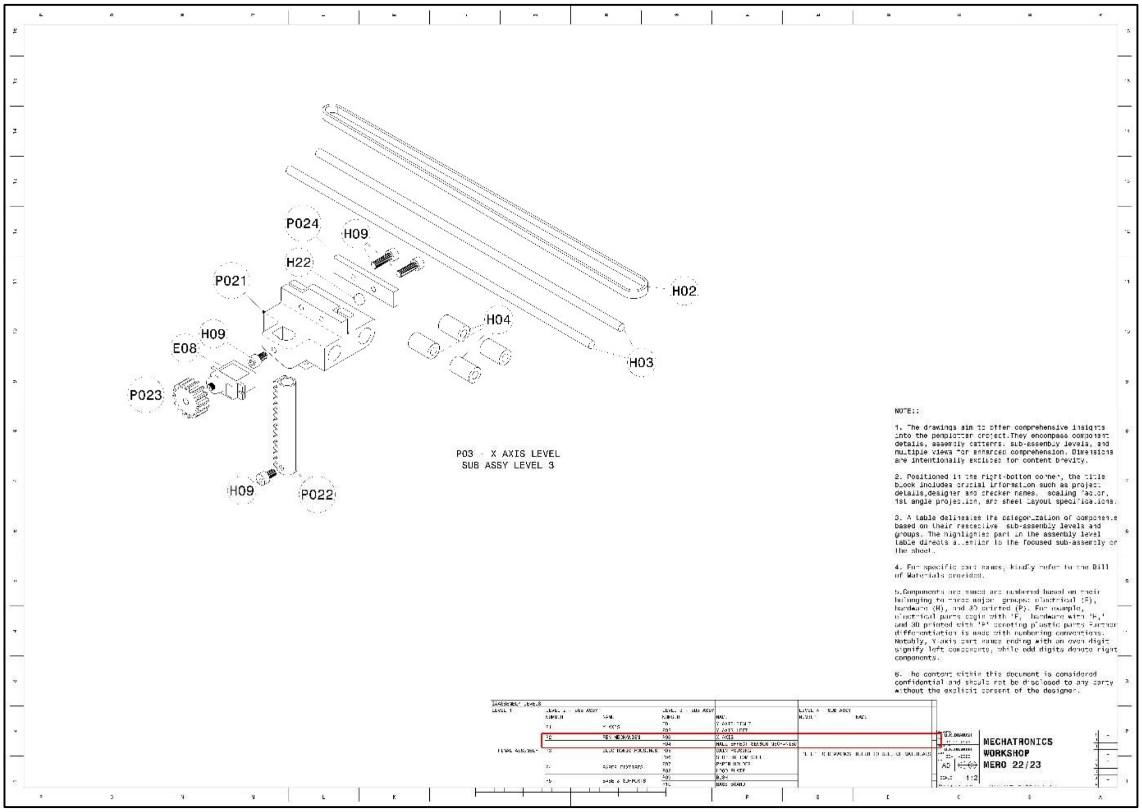
4.4 ASSEMBLY

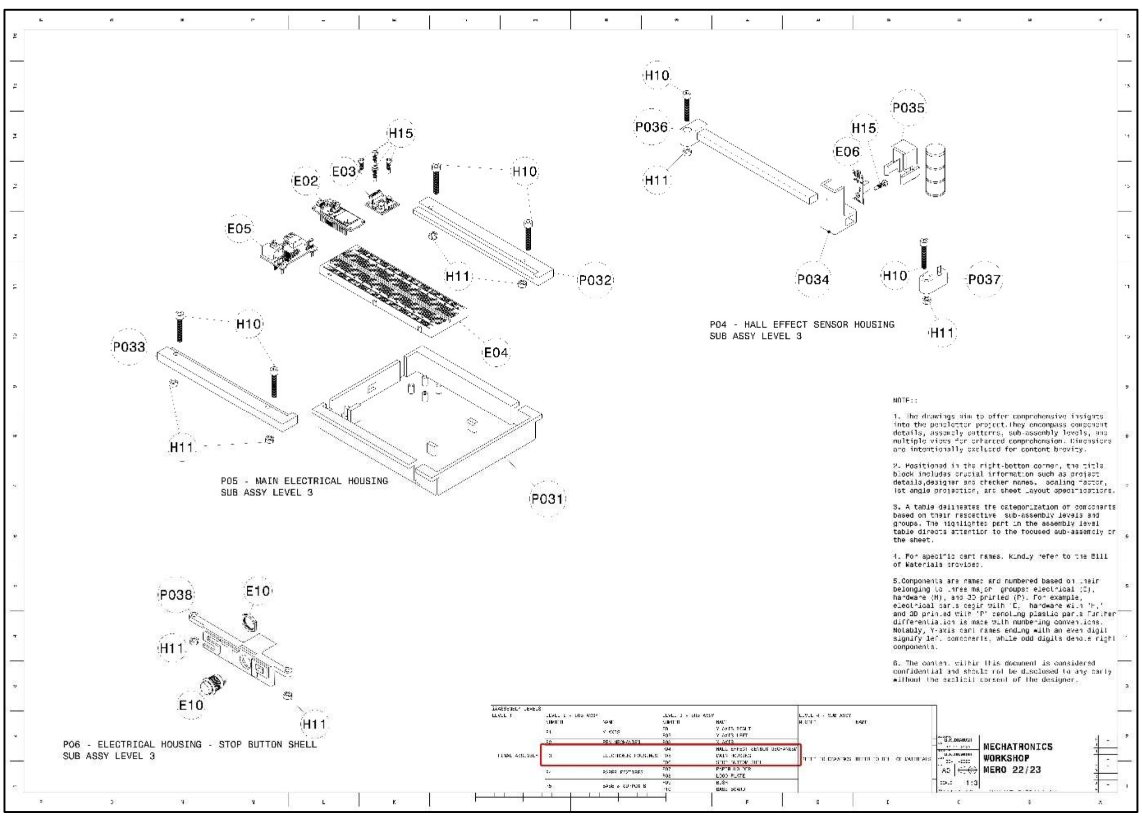
4.4.1 TECH DRAWINGS

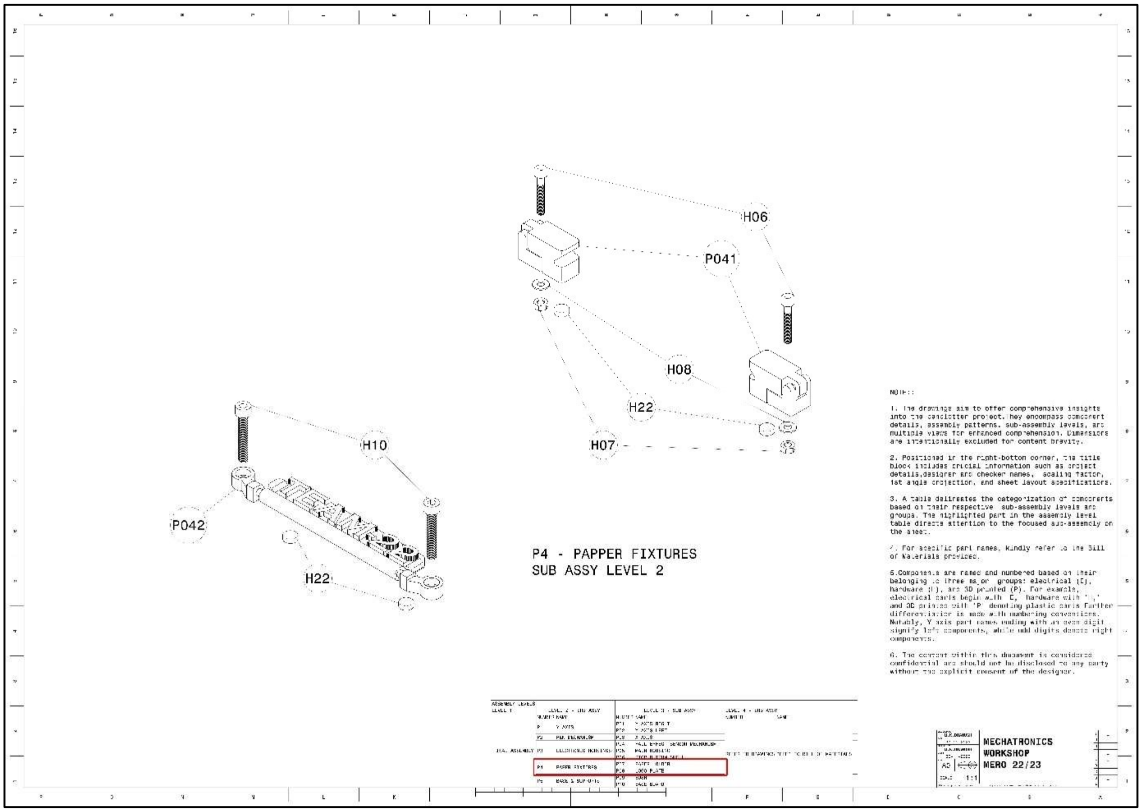



P01 YAXIS RIGHT
P04 HALL EFFECT SENSOR MECHANISM
P03 X AXIS
P05 MAIN HOUSING
P07 PAPER HOLDERS
P02 Y AXIS LEFT
P10 BASE BOARD
P08 LOGO PLATE
P09 - BUSH
P06 STOP- BUTTON SHELL CASE
MECHATRONICS
WORKSHOP
MERO 22/23


P02 - Y AXIS RIGHT
SUB ASSY -LEVEL 3
P01 - Y AXIS LEFT
SUB ASSY -LEVEL 3
MECHATRONICS
WORKSHOP
MERO 22/23


P024
H09
H22
P021
H02
H09
E08
H04
H03
P023
P03 - X AXIS LEVEL
SUB ASSY LEVEL 3
H09
P022
MECHATRONICS
WORKSHOP
MERO 22/23


H10
P035
P036
H15
E06
H15
H11
E02
E03
H10
E05
H11
P032
P034
H10
P037
H10
P033
E04
P04 - HALL EFFECT SENSOR HOUSING
SUB ASSY LEVEL 3
H11
H11
P05 - MAIN ELECTRICAL HOUSING
SUB ASSY LEVEL 3
P031
P038
E10
H11
E10
H11
P06 - ELECTRICAL HOUSING - STOP BUTTON SHELL
SUB ASSY LEVEL 3
MECHATRONICS
WORKSHOP
MERO 22/23



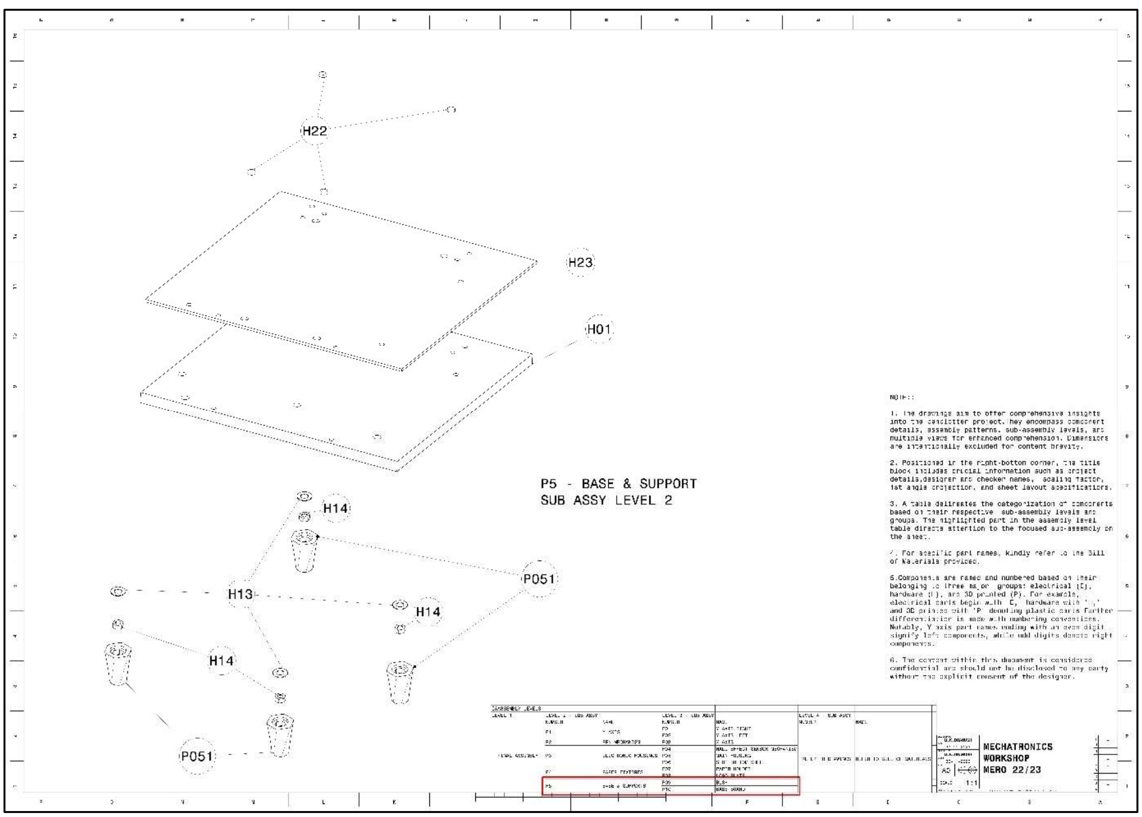


Figure 35 Tech Drawings

4.4.2 CHALLENGES FACED DURING ASSEMBLY

- Component Alignment: Precise alignment of mechanical components poses challenges, affecting movement and overall functionality.
- Wiring Complexity: Managing intricate wiring and cable routing is challenging to prevent tangling and interference.
- Mechanical Interference: Challenges in mitigating mechanical interference between moving parts, affecting smooth operation.
- Testing Complications: Complications during testing phases may arise, necessitating thorough troubleshooting and debugging.

4.4.3 SOLUTIONS

To address the challenges encountered during the assembly of the pen plotter, employing Design for Manufacturability (DFM) and Design for Assembly (DFA) principles can offer effective solutions:

- DFM - Component Alignment: Utilize DFM to optimize component placement and alignment, ensuring ease of assembly and minimizing discrepancies in movement.
- DFA - Wiring Complexity: Implement DFA principles to simplify the wiring layout, minimizing complexity and reducing the likelihood of tangling or interference.
- DFM/DFA - Mechanical Interference: Design components with DFA principles to minimize mechanical interference, ensuring smoother operation during assembly.

4.4.4 FINAL LOOK

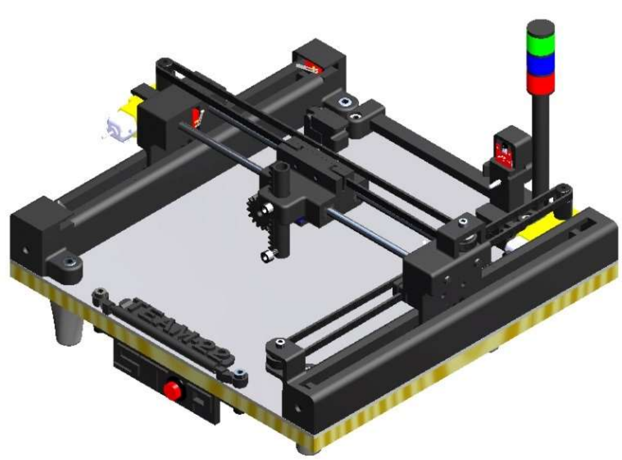


Figure 36 Final Assembly

CHAPTER 5 ELECTRICAL AND CODE

In the Electrical and Code phase, the ESP32 SparkFun microcontroller takes center stage, translating architectural intricacies into executable instructions. The code development process undergoes iterative refinement, addressing scaling challenges for technical precision and aesthetic representation. This collaborative effort optimizes plotter movements and ensures the accurate reproduction of the Nicolaus House. Meticulous documentation facilitates version control, streamlining the creative process within a systematic workflow.

5.1 CIRCUIT DIAGRAM

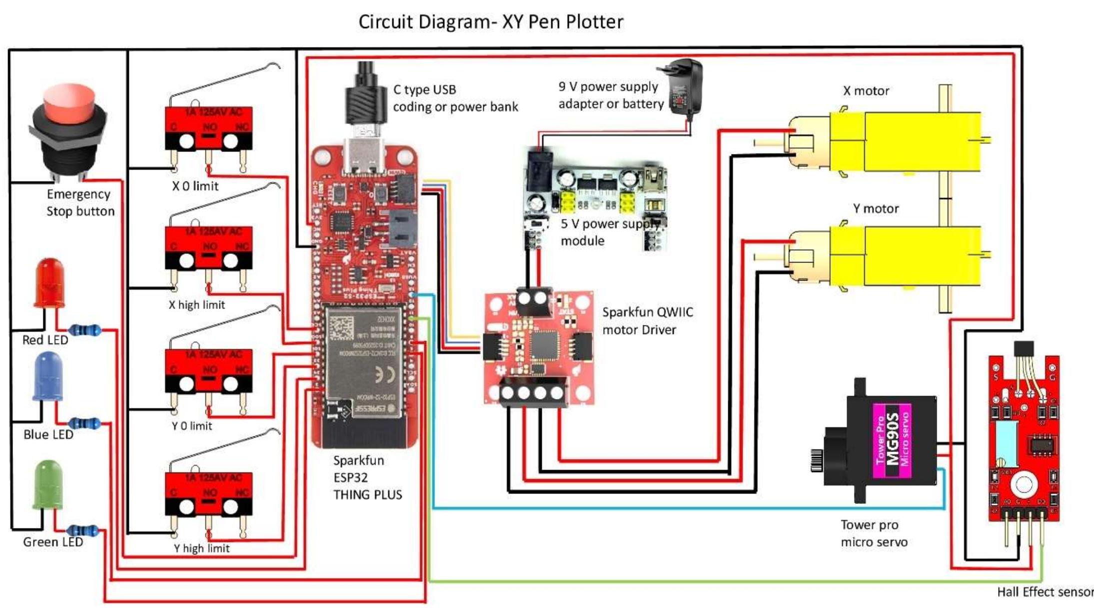


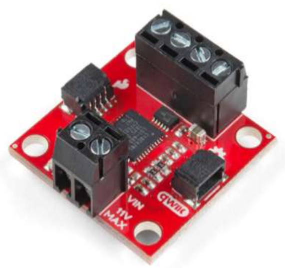
Figure 37 Circuit Diagram

The circuit diagram for the pen plotter project showcases a cohesive integration of essential components with the microcontroller. Limit switches serve as position sensors, ensuring precise control. LEDs offer visual feedback, indicating operational states. The power module provides a stable energy source, while servo motors, intricately connected, enable controlled pen movements. This intricate circuit design forms the foundation of the pen plotter, facilitating seamless communication and coordination among diverse elements for accurate and efficient performance.

5.1.1 ELECTRICAL COMPONENTS

In the pen plotter project, key electrical components, including the ESP32 SparkFun microcontroller, play a pivotal role. The microcontroller serves as the brain, translating architectural intricacies into executable instructions. Additional components contribute to precise movements, ensuring accurate reproduction of the Nicolaus House. This strategic selection and integration of electrical elements form the backbone of the pen plotter, facilitating its functionality and precision.

Table 4 Important Electrical Components used in the project

 *Figure 38 THINGSPARK ESP32*	 *Figure 39 QWIIC Motor Driver*	 *Figure 40 Power Supply Unit (QITA TS 1171*
 *Figure 41 DAGU DG01D Geared Motor*	 *Figure 42 Limit switch*	 *Figure 43 Stop Button*

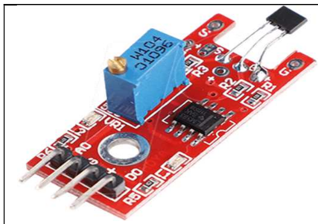


Figure 44 Hall Sensor

Figure 45 LEDs

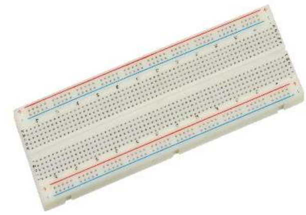


Figure 46 Braid Board

Figure 47 Resistors

Figure 48 Adapter

Figure 49 Servo Motors

Figure 50 Jumper Cables

Figure 51 Battery

5.2 CODE

The code flow chart for the pen plotter project delineates a systematic sequence of operations to translate digital designs into tangible drawings. Starting with initialization, the code establishes connections with essential components. It then progresses to a loop where the microcontroller constantly monitors inputs from limit switches.

Upon detecting input, the code activates servo motors to control the pen's movements. Simultaneously, LEDs provide visual feedback on the system's status. The power module ensures a stable energy supply throughout the process.

The loop continues until the desired drawing is complete, after which the system undergoes a graceful shutdown. This systematic and iterative code flow ensures precision and efficiency in the pen plotter's operation, offering a precise output of Nicolaus Haus.

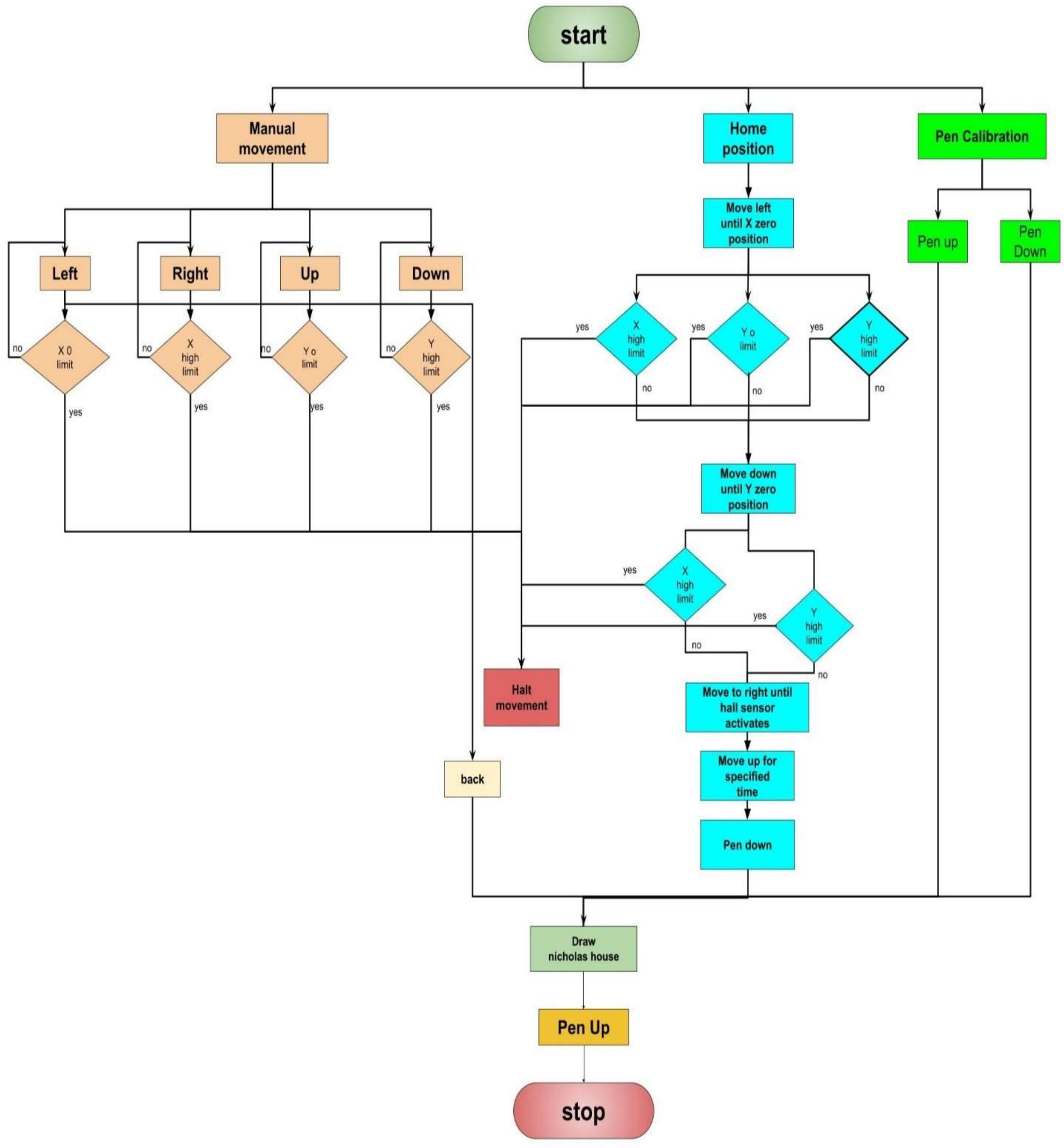


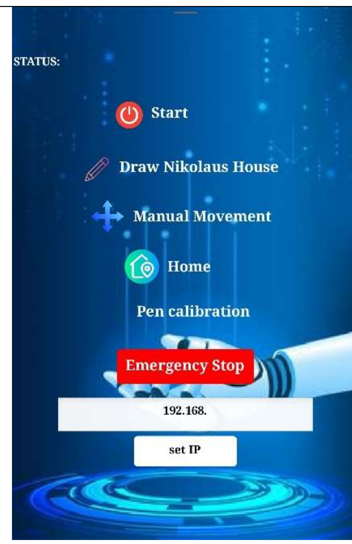
Figure 52 Flowchart

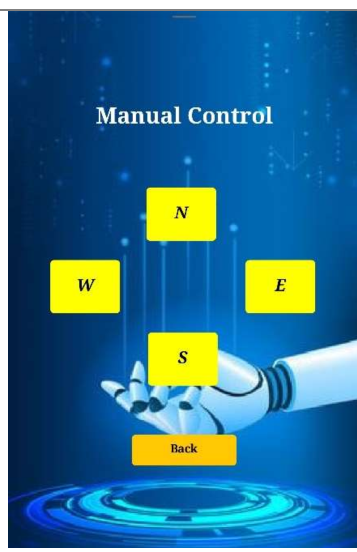
5.3 GUI – INTERFACE OF MOBILE APPLICATION

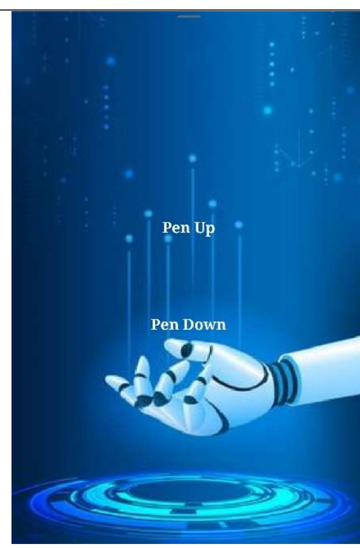
This pivotal section outlines the seamless integration of mobile control for our pen plotter using the MIT Inventor:

Effortlessly enhancing user experience, our pen plotter now boasts mobile control capabilities through the MIT Inventor. This innovative integration allows users to intuitively operate and command the pen plotter directly from their mobile devices. From drawing customization to real-time adjustments, this mobile control feature provides a user-friendly interface, ensuring convenience and flexibility in commanding the pen plotter's precision and creativity. Explore a new dimension of accessibility as the MIT Inventor transforms your mobile device into a powerful tool for artistic expression through our pen plotter project.

Table 5 Mobile interface







CHAPTER 6 TESTING AND OUTPUT

6.1 TESTING OF FUNCTIONS

6.1.1 WORKING OF COMPONENTS

- ESP32 SparkFun Microcontroller: The brain of the pen plotter, the ESP32 SparkFun microcontroller translates architectural intricacies into executable instructions, ensuring precise and accurate reproduction.
- 3D-Printed Components: Crafted through advanced technologies, 3D-printed components contribute to structural resilience. Increased wall thickness and optimized infill density enhance durability while maintaining efficiency.
- Mechanical Components: Components like motors and gears facilitate controlled movements, ensuring the pen plotter's precision. Strategic alignment, guided by Design for Manufacturability (DFM) principles, optimizes their placement for ease of assembly.
- Wiring Layout: Simplified wiring layout, influenced by Design for Assembly (DFA) principles, minimizes complexity. This thoughtful design reduces the likelihood of tangling or interference, enhancing overall efficiency
- Pen Mechanism: The pen's vertical motion, vital for drawing precision, is controlled by servo motors integrated into the mechanical assembly. Guided by the ESP32 SparkFun microcontroller, these motors ensure accurate positioning, contributing to the pen plotter's precision in translating digital designs into real-world drawings.

6.1.2 ACCURACY

Precision is paramount in the pen plotter's operation. Enabled by carefully calibrated servo motors and the ESP32 SparkFun microcontroller, the pen executes movements with exceptional accuracy. This meticulous control ensures that the pen plotter faithfully reproduces intricate digital designs, culminating in the precise depiction of the Nicolaus House on paper. The final output reflects a high degree of precision and detail in its artistic rendering.

6.1.3 MOVEMENTS OF MOTOR

Table 5 Movements of Motor

MOTOR X	MOTOR Y	MOVEMENT
↺	x	→
x	↻	↓
x	↺	↑
↻	x	←
↺	↻	↘
↻	↺	↖
↺	↺	↗
↻	↻	↙

6.2 EXPECTED OUTPUT

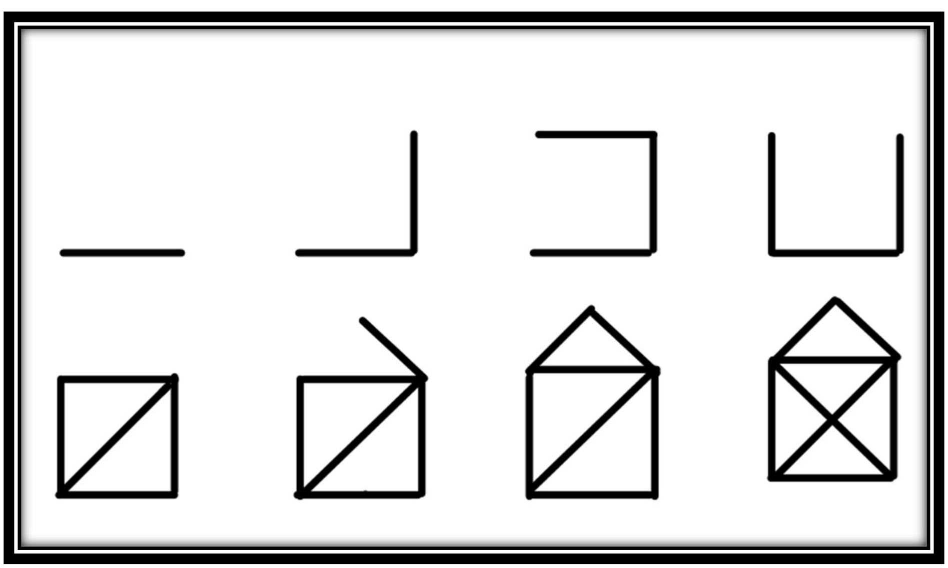
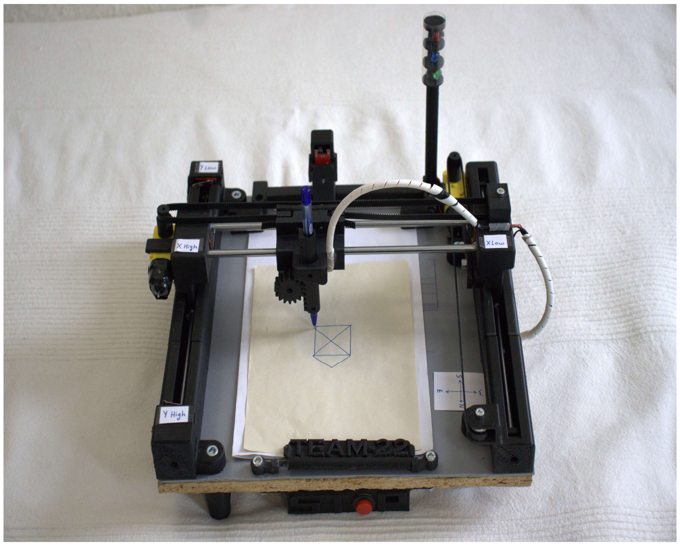


Figure 53 Expected Outcome

6.3 FINAL OUTPUT



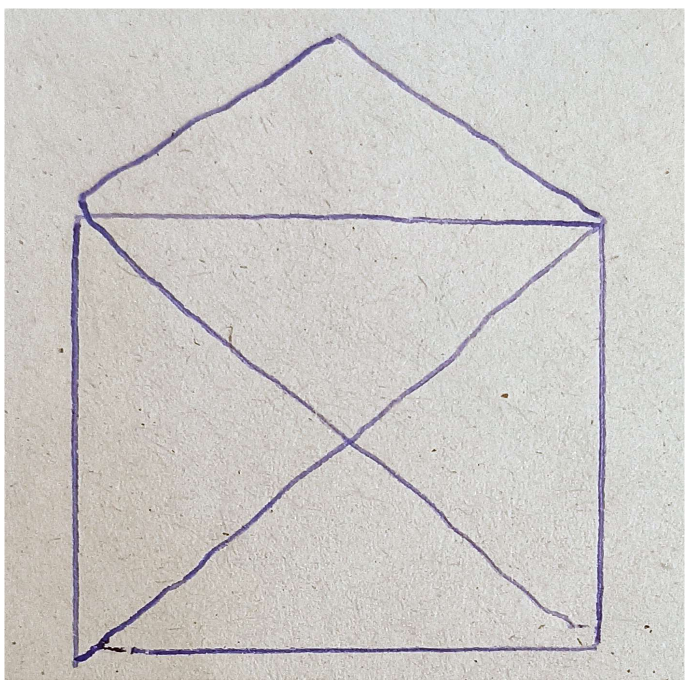


Figure 54 Final Outcome

CHAPTER 7 APPENDICES AND REFERENCES

7.1 FUTURE SCOPE

- Make the pen plotter more versatile so that it can hold several different coloured pens or markers. You may then make colourful drawings and experiment with the potential of colour blending and gradients.
- Use of servo motors with encoder can increase the accuracy and precision of the motion or We can Also implement PID control for smooth control of motion.
- Collaboration with Emerging Technologies: Stay at the forefront of innovation by collaborating with emerging technologies, fostering a symbiotic relationship between the pen plotter and cutting-edge advancements.

7.2 GANTT CHART

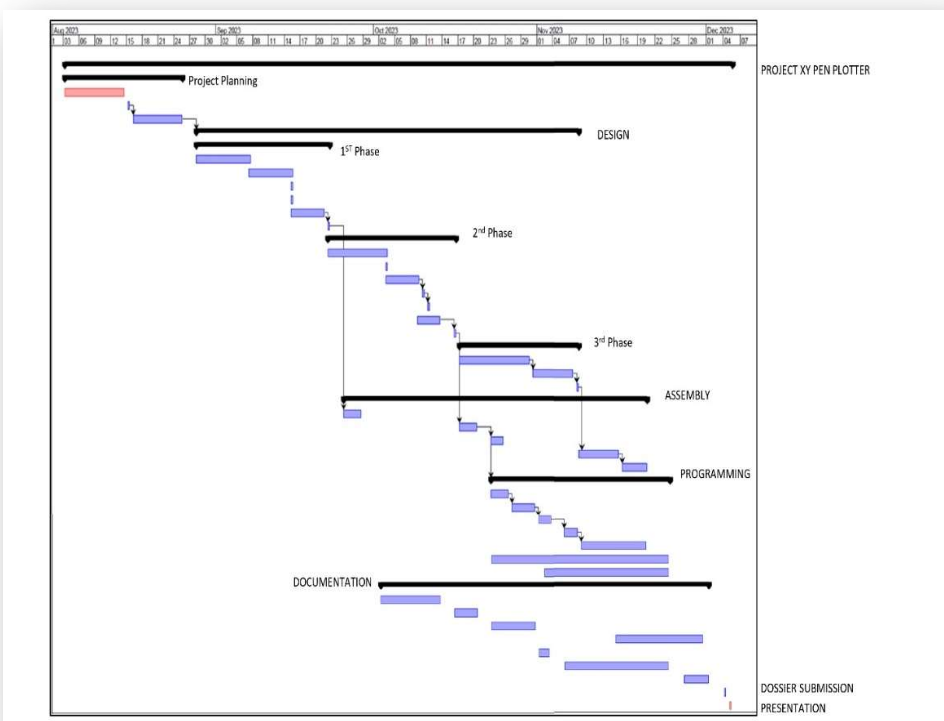


Figure 55 Gannt Chart

7.3 BILL OF MATERIAL

Table 6 Bill of Material

BILL OF MATERIALS						
PART NUMBER	GROUP	PART NAME	SPEC	MATERIAL	QTY	SOURCE
E01	ELECTRICAL COMPONENTS	DC Motor	DAGU - DG01D 48:1 Mini DC GearBox		2	Lab Kit
E02		Micro Controller	SparkFun Thing Plus ESP32 WROOM WRL 173811		1	Lab Kit
E03		Motor Driver	SparkFun Qwiic Motor Driver		1	Lab Kit
E04		Bread board	BoardMB-102 Plug-in board 830 pins603200251		1	Lab Kit
E05		Power Supply module	Breadboard Power Supply TS11711		1	Lab Kit
E06		Hall Effect Sensor	Module magnetic detector 49E LM393TS01451		1	Lab Kit
E07		AC - DC Adapter	variable 3V - 11V		1	Amazon
E08		Micro Servo	Tower Pro SG 90		1	Amazon
E09		Limit Micro Switch	XSS-5GL13		4	Lab Kit
E10		Push Button	15 dia x 24 mm length		1	Lab Kit
E11		LEDs	20 mA 3V		3	Amazon
E12		Li Battery	3.7 V		1	Lab Kit
E13		Resistor	10Ω		3	Amazon
E14		Jumper Cables			65	Lab Kit
E15		Copper wires	5 meter each		3	Amazon
H01	HARDWARE & ASSEMBLY COMPONENTS	Base Board	305mm x 305mm x 15mm	Wood	1	Lab Kit
H02		Timing Belt	2mm pitch, 6mm wide, 2m length	Nylon	1	Lab Kit
H03		Hard steel guide Shaft	6dia x 300mm legth	steel	4	Lab Kit
H04		Linear Ball Bearing	LMU-N6	steel	8	Lab Kit
H05		Ball Bearing		steel	4	Amazon
H06		M4 Bolt	25 mm length	steel	4	Lab Kit
H07		M4 Nut		steel	3	Lab Kit
H08		M4 washer		steel	2	Lab Kit
H09		M5 Bolt	16 mm length	steel	5	Lab Kit
H10		M5 Bolt	30 mm length	steel	8	Lab Kit
H11		M5 Nut		steel	8	Lab Kit
H12		M6 Bolt	30 mm length	steel	4	Lab Kit
H13		M6 washer		steel	4	Lab Kit
H14		M6 Nut		steel	4	Lab Kit
H15		Screw	10 mm tdrx plus M3	steel	5	Amazon
H16		storage box	560mm x 390mm x 280mm	plastic	1	Lab Kit
H17		Motor Gear Pulley		Plastic	2	Lab Kit
H18		Zip tie	2.5mm x 100mm	plastic	2	Amazon
H19		Spiral wiring Sleve	500 mm	plastic	0.5	Amazon
H20		Silicon Grease	Industrial Grade Lubricant		5	Amazon
H21		Super Glue	adhesive		10	Amazon
H22		Magnets	super neodym	magnet	10	Amazon
H23		Base padding	PVC Foam	plastic	1	Amazon
H24		Insulation Tape	10mm wide		1	Amazon

NOTE – Be advised for more detail please refer e-file(BOM)

P011	3D PRINTED COMPONENTS	Y Shell L0	Designed as per technical specification	plastic	1 3D Printed
P013		Y Shell L1	Designed as per technical specification	plastic	1 3D Printed
P015		Y Shell L2	Designed as per technical specification	plastic	1 3D Printed
P017		Y Support L	Designed as per technical specification	plastic	1 3D Printed
P 019		Y Belt Fix Plate	Designed as per technical specification	plastic	1 3D Printed
P012		Y Shell R0	Designed as per technical specification	plastic	1 3D Printed
P014		Y Shell R1	Designed as per technical specification	plastic	1 3D Printed
P016		Y Shell R2	Designed as per technical specification	plastic	1 3D Printed
P018		Y Support R	Designed as per technical specification	plastic	1 3D Printed
P021		Pen Slider	Designed as per technical specification	plastic	1 3D Printed
P022		Pen Carrier Rack	Designed as per technical specification	plastic	1 3D Printed
P023		Pinion	Designed as per technical specification	plastic	1 3D Printed
P024		X Belt Fix Plate	Designed as per technical specification	plastic	1 3D Printed
P031		Main Case	Designed as per technical specification	plastic	1 3D Printed

7.4 REFERENCES

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https://all3dp.com/2/pen-plotters-best-xy-plotters

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https://www.sparkfun.com/products/15451

https://www.sparkfun.com/products/15663

https://us.misumi-ec.com/vona2/detail/110300026540/?HissuCode=LMU-N6