Department of Electronic & Telecommunication Engineering
University of Moratuwa

EN 2160 – Electronic Design Realization

Design Methodology

Group no (O) 41

Project : Verifying the accurate placement of labels on milk packets and rejecting faulty ones.

Team Members

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1. Introduction

Our project aims to develop an automated system capable of detecting misprints on product packaging. The primary objective of this project is to detect instances where critical information such as expiration dates, manufacturing dates, and price tags deviate from the designated white space on the packaging. Upon detection of misprints or deviations from the expected placement of information within the designated white space, the system will trigger a mechanism to reject the affected packaging from the conveyor belt.

2. Review Progress

2.1. Key Stakeholders

- **Manufacturing Companies:** Companies producing milk packets, Motor Manufacturing Companies

- **Internal Quality Control Teams:** Ensuring the accuracy and reliability of the automated label verification system.

- **Plant Managers:** Overseeing the implementation and performance of the automated rejection system on the production line.

- **Production Workers**: Operating the machinery and monitoring the automated rejection process.

- **Maintenance Teams**: Responsible for the upkeep and troubleshooting of the computer vision system and automation equipment.

- **Environmental Conservation Organizations:** Assessing and promoting the sustainability aspects of the automated rejection system.

- **Consumer Advocacy Groups:** Representing the interests of consumers, ensuring that the product meets quality standards.

- **Logistics Teams:** Managing the movement of rejected packets and ensuring proper disposal or recycling.

- **Supply Chain Managers:** Incorporating the automated rejection system into the overall supply chain.

- **Government and Authorities:** National Livestock Development Board (NLDB)

- **Public Relations Teams:** Managing communication strategies, especially if there are changes in packaging or labeling due to the automated rejection system.

- **Marketing Teams:** Incorporating the quality assurance aspect into product marketing.

- **Cost Analysis Teams**: Assessing the cost-effectiveness of the automated rejection solution.

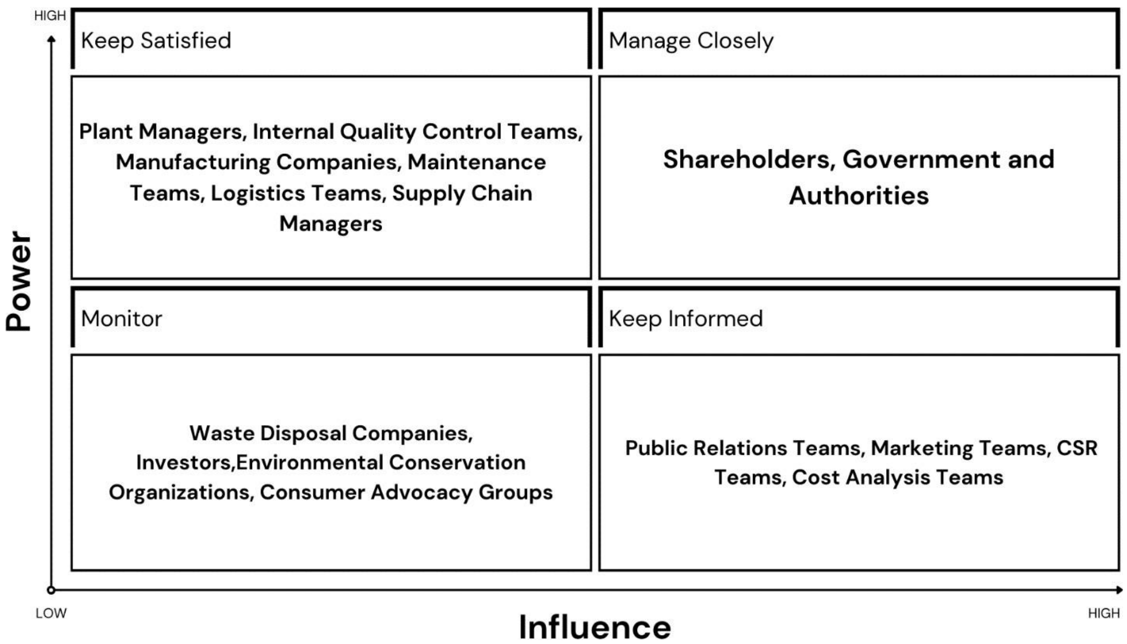
- **Waste Disposal Companies**: Managing the proper disposal or recycling of rejected milk packets.

- **CSR Teams:** Ensuring that the implementation of the automated rejection system aligns with ethical considerations and social responsibility goals.

- **Investors:** Having an interest in the success and sustainability of the project.

- **Shareholders:** Expecting returns and benefits from the implementation of the automated rejection system.

2.2. Stakeholder Map



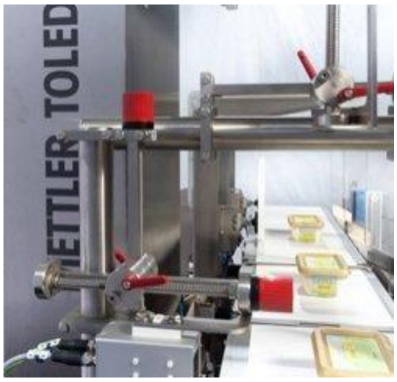
2.3. Work already done by various companies and universities related to this project

1. **In-Sight vision systems – Cognex**

- The In-Sight vision systems by Cognex automates complex applications that are too difficult to deploy with traditional human inspection. These systems solve a range of tasks such as label quality inspection, skewed label inspection, assembly verification and optical character recognition.

  Video URL: https://youtu.be/0Snnn6hp6yQ?si=Jr0CgxiJwqKbZ1Na

2. **Label Check Vision Inspection Systems - METTLER TOLEDO**



- METTLER TOLEDO vision inspection systems automate quality control for product labeling and packaging across various industries, including food production. They detect irregularities, printing errors, and functional flaws on packaging, ensuring accuracy and integrity. These systems verify label accuracy and remove faulty packaging from the production line, enhancing quality assurance.

  Video URL: https://youtu.be/MZnY_bQA19w?si=vN_HoARMkby98fXi

3. **Quality control system Label Checker– SICK Sensor Intelligence**

- The Label Checker by SICK is a compact quality control system designed for complex label inspections. It simultaneously performs multiple inspections, including reading printed texts, barcodes, and 2D codes, while also checking label position, presence of pictograms, and print quality, with advanced tools and features like image filters and segmentation

  Video URL: https://youtu.be/JHJq5wagbHA?si=qZV5JpS1r1Qqa0Va

4. **Optimal approaches to the quality control checking of product labels (Research) - Loughborough University**

- Loughborough University conducted research on label-checking errors in fresh produce packaging facilities. They observed and interviewed workers, finding a lack of formal training in label-checking. In a laboratory task, error detection accuracy was generally high, but individual differences were significant. Shorter response times occurred when errors were missed, suggesting incomplete checking strategies. Those who adopted a systematic approach were more successful in error detection. Interestingly, systematic checking did not correlate with years of experience. Recommendations included explicit training and possibly software assistance for systematic checking.

  Research article URL: https://repository.lboro.ac.uk/articles/journal_contribution/Optimal_approaches_to_the_quality_control_checking_of_product_labels/9613916

2.4. Our Plan

- Our project consists of two main parts and one optional part. The first main part involves image processing and computer vision. We plan to use a webcam for this part, and the processing will be carried out on a personal computer.

- The computer vision plan involves detecting the misprinted labels using Image processing techniques and deep learning techniques.

- The main second part of the project involves pushing out incorrectly aligned printed milk packets from the conveyor belt. We have planned to design a mechanical pushing mechanism for this aspect of the project.

- Our main PCB and the main enclosure is for this controlling part of pushing out mechanism. We are sending the controlling signals from the microcontroller chip in this PCB.

- Then the optional part of this project is to make a conveyor belt. We have planned to make a conveyor belt mechanism using a DC motor.

2.5. Observation Summary

- The diverse stakeholder landscape, spanning manufacturing, quality control, environmental conservation, consumer advocacy, and other sectors, highlights the importance of effective stakeholder engagement and communication. Anticipating the interests and concerns of these stakeholders will be critical as we move forward with project implementation.

- Our project is informed by insights from related research and projects, particularly emphasizing systematic approaches to quality control in labeling. These insights shape our strategy for developing an effective automated label verification and rejection system for milk packets.

- Our project plan aligns with best practices by integrating image processing, computer vision, and mechanical solutions for comprehensive quality control of milk packet labels.

3. User Requirements

The primary users of this product are manufacturing companies that utilize conveyor belt systems for labeling their products. These companies rely heavily on accurate labeling to maintain product integrity and comply with regulatory standards. Therefore, ensuring precise placement and accurate printing of labels is essential for manufacturers to avoid financial losses and uphold their brand reputation.

- **Accurate Detection of Misprints**: The system must accurately detect misprinted expiration dates, manufacturing dates, and price tags on product packaging. It should be capable of identifying deviations from the designated white space and flagging them as anomalies.
- **Real-time Detection**: The system should operate in real-time to detect misprints as the labeled products move along the conveyor belt. This allows for immediate intervention and prevents defective products from progressing further in the production process.

- **Integration with Conveyor Belt Systems**: Seamless integration with existing conveyor belt systems is essential. The system should be compatible with various types of conveyor belts commonly used in manufacturing facilities.
- **Automated Rejection Mechanism**: Upon detection of misprints, the system should trigger an automated mechanism to reject the affected packaging from the conveyor belt. This ensures that defective products are promptly removed from the production line to prevent further processing or distribution.
- **Customizable Settings**: Manufacturers may have specific requirements regarding label placement and detection sensitivity. Therefore, the system should offer customizable settings to accommodate different packaging formats and printing variations.
- User-Friendly Interface: The system should feature an intuitive user interface that allows operators to monitor detection results, adjust settings, and troubleshoot issues easily. This ensures efficient operation and minimizes the need for extensive training.
- **Reliability and Accuracy:** The system must exhibit high reliability and accuracy in detecting misprints to minimize false positives and false negatives. Consistent performance is crucial for maintaining

By addressing these user requirements, the automated misprint detection system aims to enhance quality control processes, minimize production losses, and uphold the reputation of manufacturing companies in delivering high-quality products to consumers

4. Conceptual Designs & Functional Block Diagrams

4.1. Conceptual Designs for Detecting Misprinted Labels on Milk Packets

4.1.1. Design 1 - Using Camera

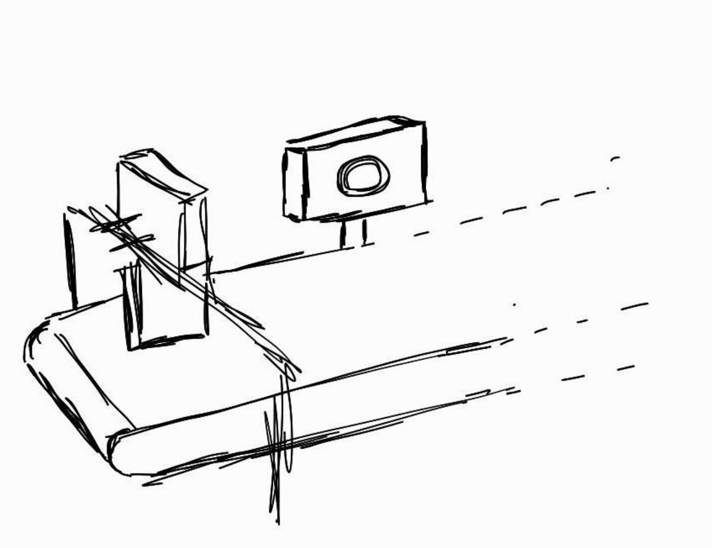


Figure 1: Using camera

4.1.2. Design 2 - Using IR sensor

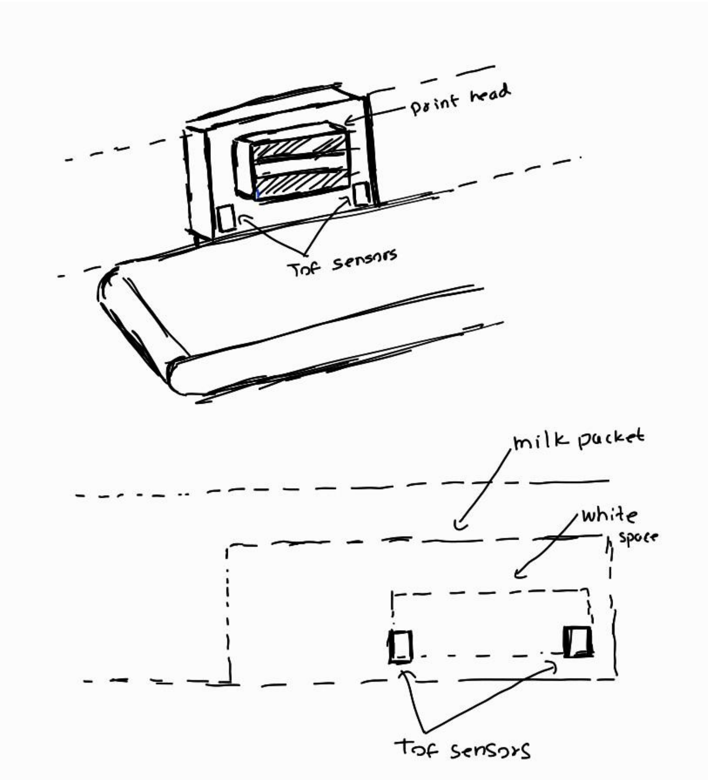


Figure 2: using IR sensors

4.1.3. Design 3 - Using TOF sensors

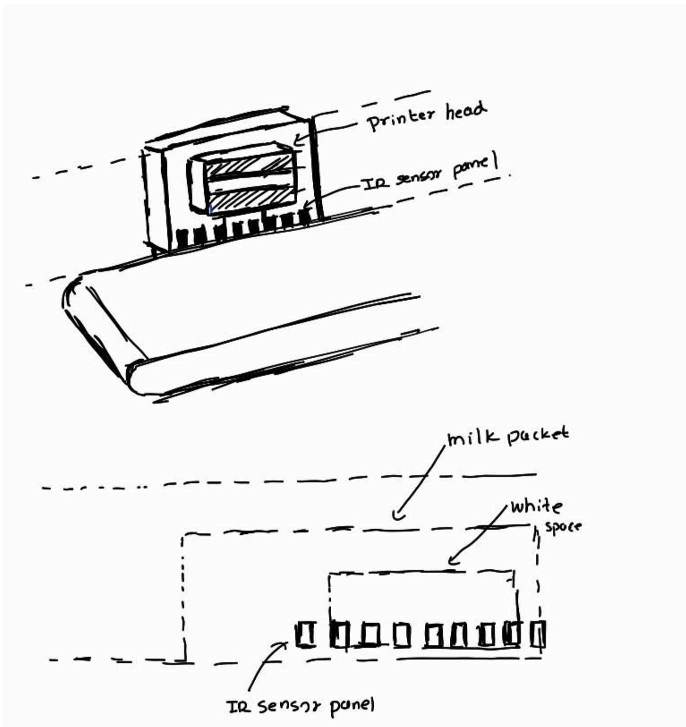


Figure 3: Using TOF sensors

4.2. **Conceptual Designs for Rejecting Faulty Milk packets**

4.2.1. Design 1 - Pushing mechanism

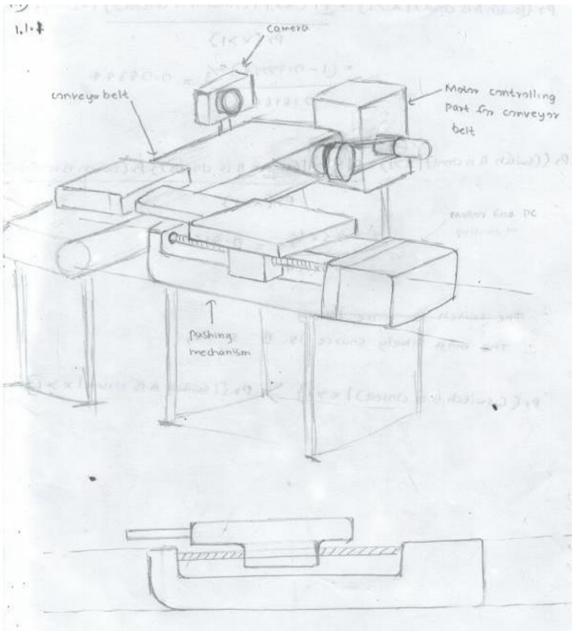


Figure 4: Pushing mechanism I

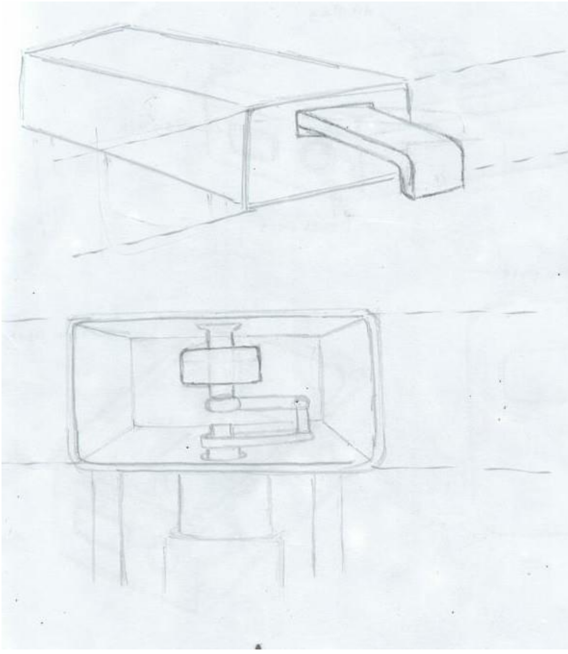


Figure 5: Pushing Mechanism II

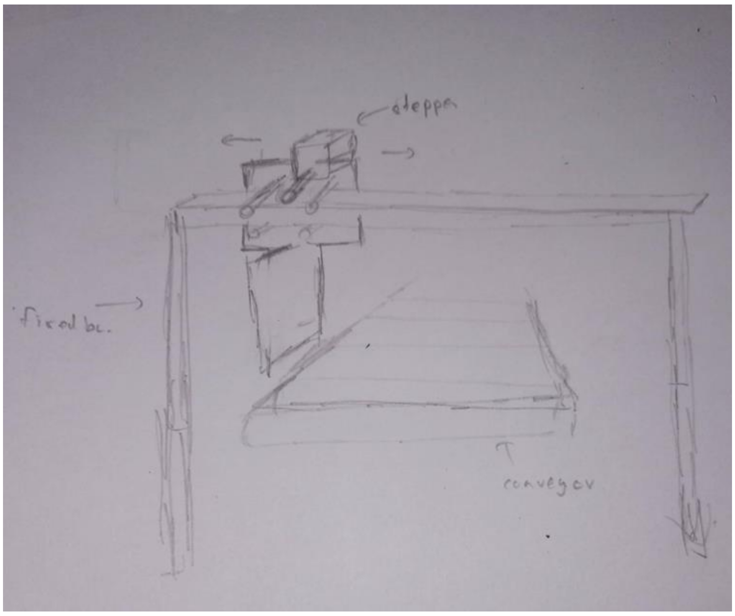


Figure 6: Pushing mechanism III

4.2.2. Design 2 – Conveyor belt controlling mechanism

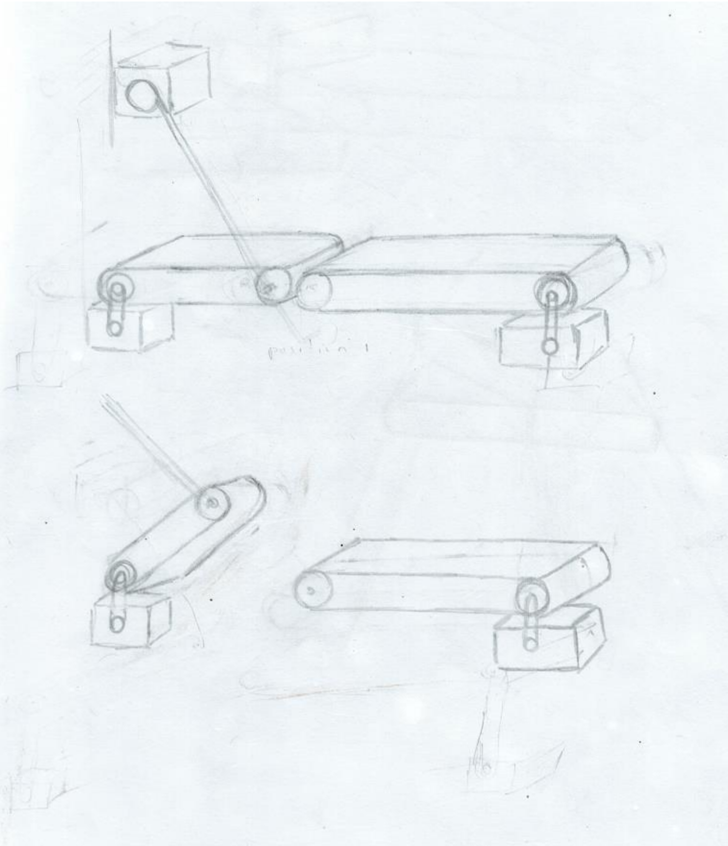


Figure 7: Conveyor belt controlling mechanism

4.2.3. Design 3 – Sorting mechanism on the conveyor bel

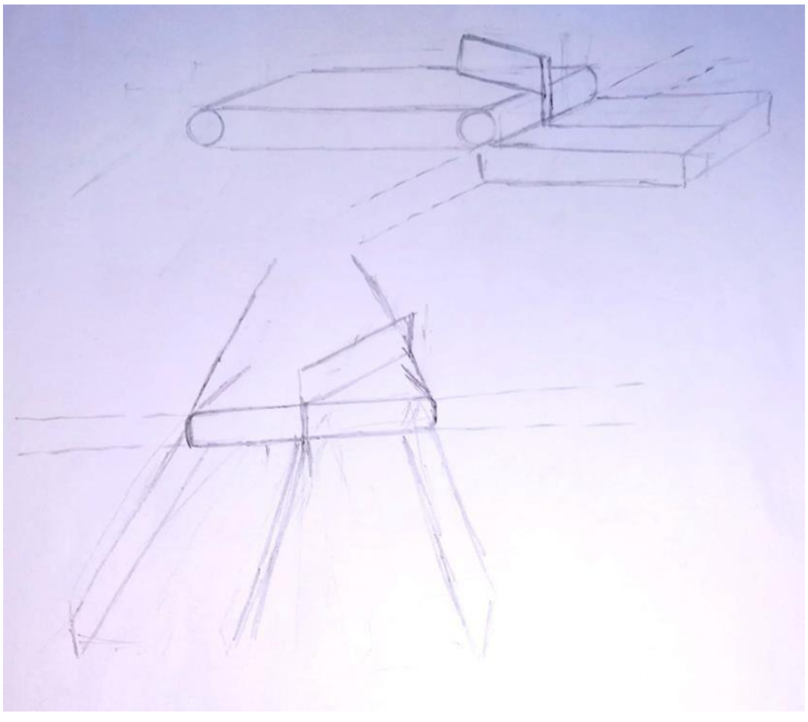


Figure 8: Sorting mechanism on the conveyor belt

4.3. Conceptual designs for PCB Enclosure

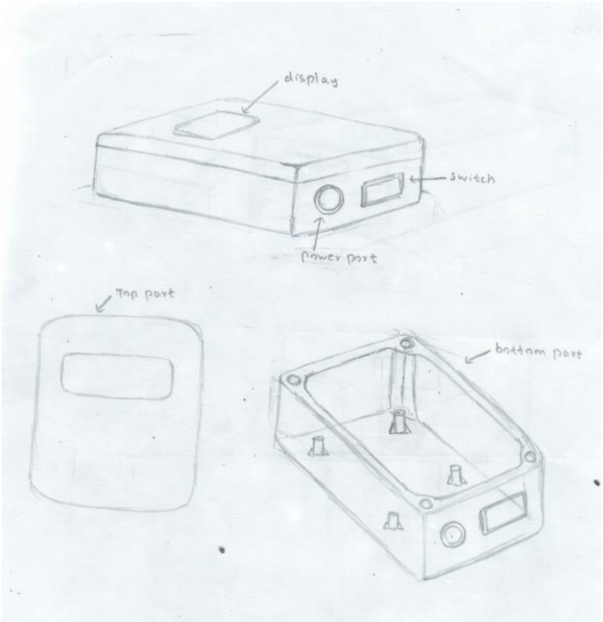


Figure 9: PCB Enclosure Design

4.4. **Functional Block Diagrams**

4.4.1. Functional Block Diagram 1

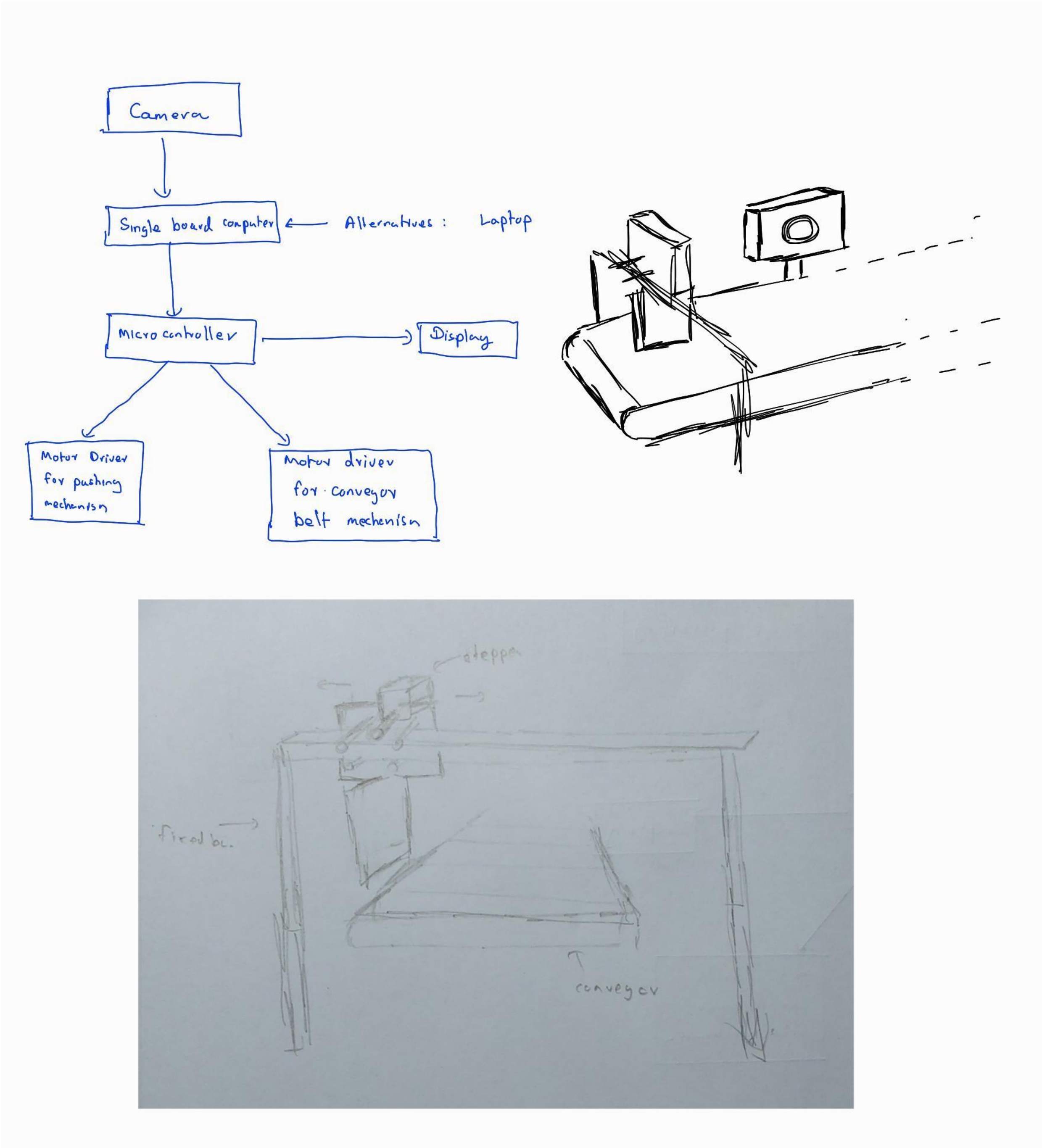


Figure 10: Functional Block Diagram 1

4.4.2. Functional Block Diagram 2

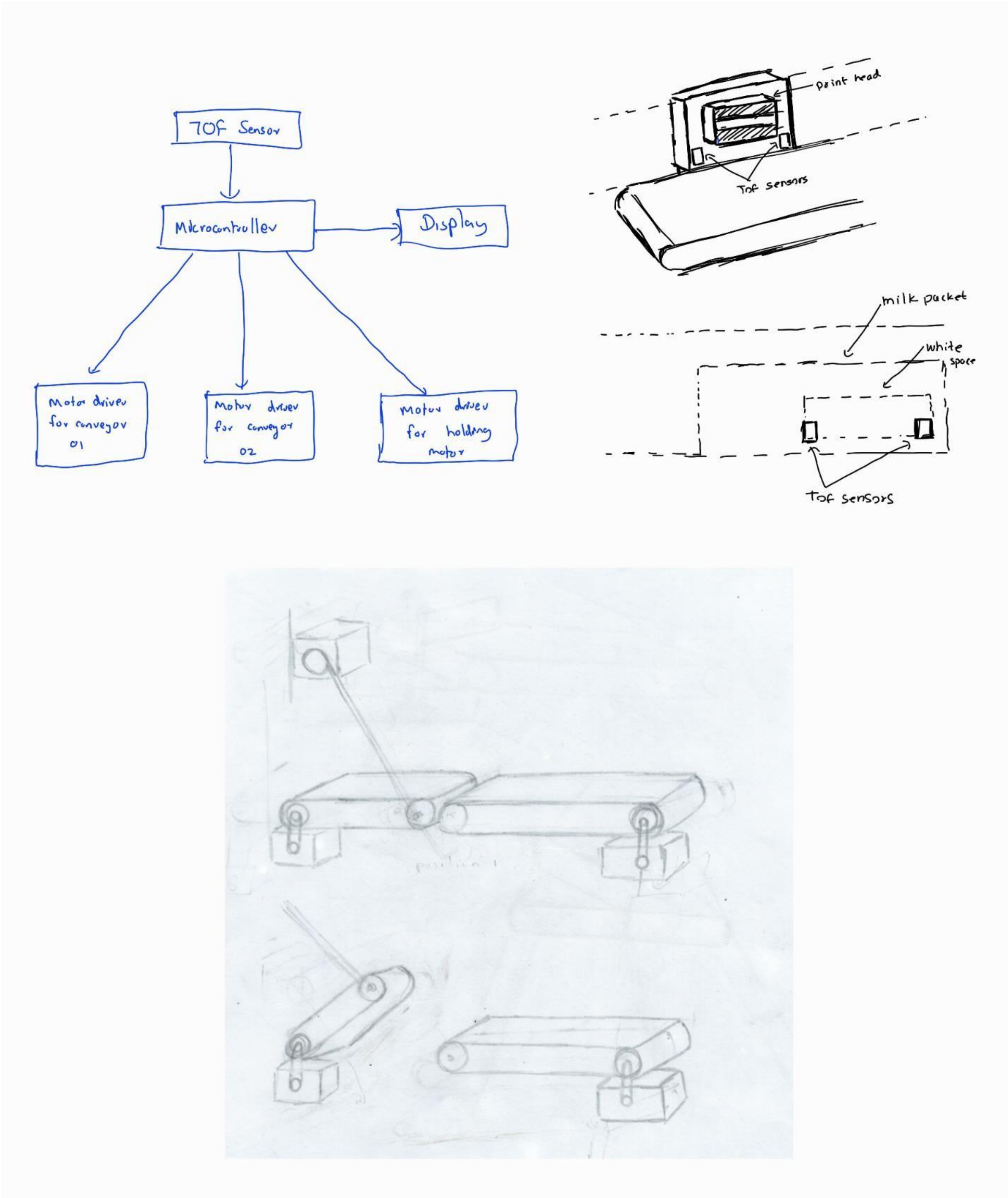


Figure 11: Functional Block Diagram 2

4.4.3. Functional Block Diagram 3

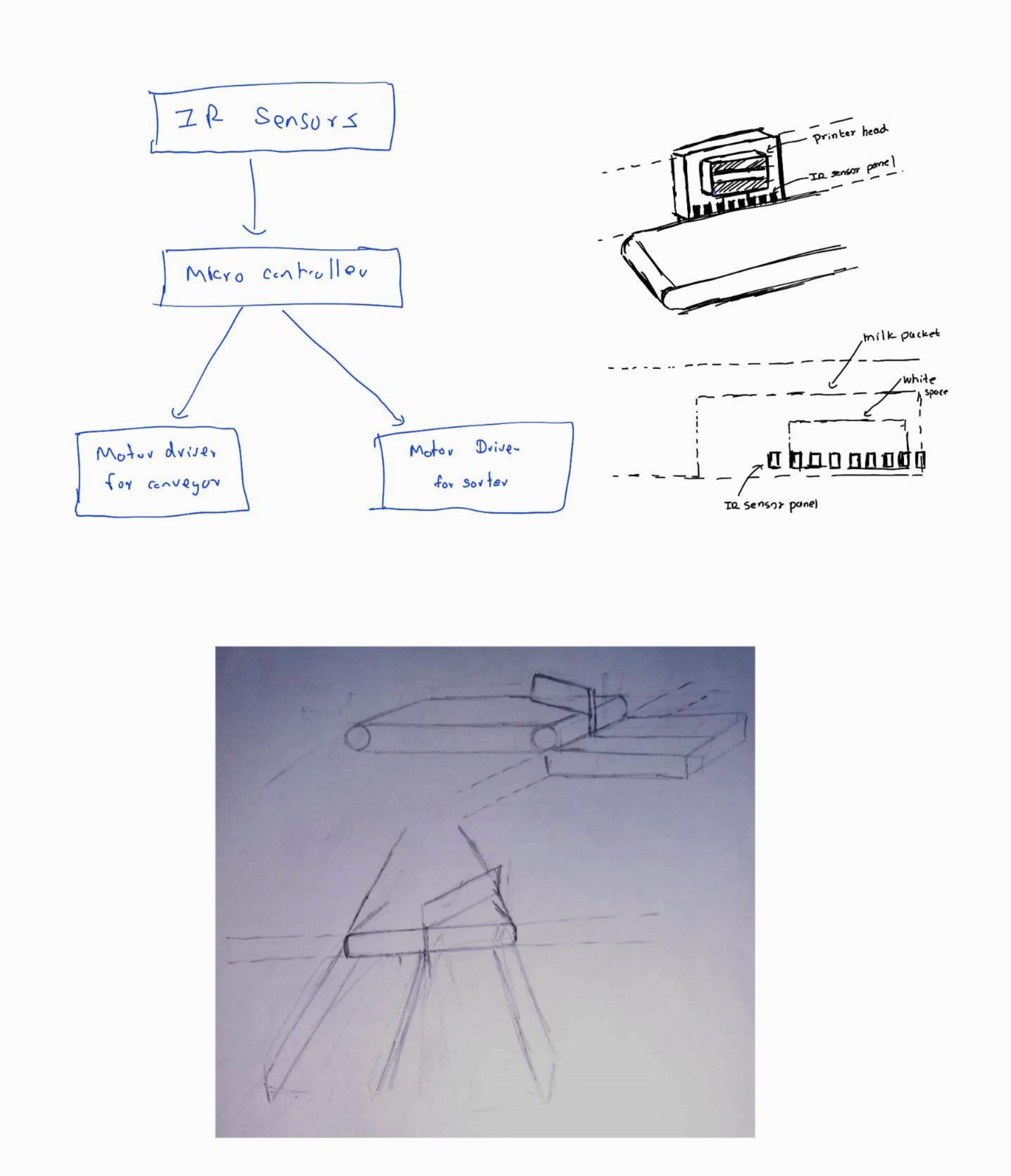


Figure 12: Functional Block Diagram 3

5. Evaluation of the Designs

5.1. Design Comparison - Detecting Misprinted Labels on Milk Packets

Design Criteria	Design 1(Camera)	Design 2(IR sensors)	Design 3(TOF sensors)
Accuracy of Detection	9	7	6
Speed of Detection	8	6	7
Cost	6	7	7
Complexity of Implementation	8	6	6
Space Requirement	8	7	7
Reliability	9	6	8
Total	**48**	**39**	**41**

5.2. Design Comparison – Rejecting Faulty Milk Packets

Design Criteria	Design 4 (Pushing Mechanism 1)	Design 5 (Pushing Mechanism 2)	Design 6 (Pushing Mechanism 3)	Design 7 (Conveyor belt controlling mechanism)	Design 8 (Sorting mechanism)
Accuracy of Rejection	7	8	8	8	7
Speed of Rejection	6	6	9	7	6
Cost	8	7	8	5	4
Complexity of Implementation	7	6	8	6	5
Space Requirement	6	7	8	5	6
Reliability	7	7	8	7	7
Total	**41**	**41**	**49**	**38**	**35**

5.3. Functional Block Diagrams Comparison

Design Criteria	Design 1	Design 2	Design 3
Functionality	8	6	8
Aesthetics	9	6	7
Performance	9	5	8
Power Efficiency	9	5	5
Manufacturing feasibility	8	7	7
Assembly and serviceability	9	7	5
Ergonomics	8	6	8
Durability	9	5	7
Simplicity	9	4	6
Cost effectiveness	9	4	5
Total	**87**	**48**	**66**

5.4. Evaluation criteria for Functional Block Diagrams Comparison

- **Functionality**: How well the design supports the main functionalities?
- **Aesthetics:** How much eye catching and overall appeal of the user?
- **Performance**: Evaluate Processing speed and Accuracy?
- **Power Efficiency**: How effectively does the device manage power consumption?
- **Manufacturing feasibility**: Evaluate the feasibility of manufacturing the design
- **Assembly and serviceability**: How easily do the assembly and disassembly is done?
- **Ergonomics**: How well does the design It in the user's hand and allow easy interaction?
- **Durability**: How well does the design withstand impacts and environmental conditions?
- **Simplicity**
- **Cost effectiveness**

6. Selected Design

Based on the evaluation conducted, Design 1 (Figure 11) has been selected as the final design for our project. The comprehensive explanation of the selected design is detailed below:

6.1. Part 1 - Detecting the misprinted labels on Milk packets

For the detection of misprinted labels on milk packets, a camera-based design employing computer vision (Figure 1) has been chosen. Two options were considered for the computer vision component: Deep learning techniques and only Image processing techniques without involving with the deep learning. Due to challenges in obtaining a more accurate results in without Deep learning techniques, Deep learning were deemed more practical.

For the deep learning segment, a single-board computer is required. Although devices like Raspberry Pi and Jetson Nano are available, the former lacks industrial application while the latter is cost prohibitive. Therefore, a laptop serves as a suitable alternative for demonstration purposes. The process of detecting misprinted labels is outlined as follows:

- A 1080p full HD webcam (Figure 13) is positioned alongside the conveyor belt, while a screen is placed on the opposite side to obscure the background visible to the camera. The webcam is connected to the laptop via a USB cable, and the laptop connects to the PCB (Printed Circuit Board) via USB. Furthermore, USB to serial chip CH340C IC (Figure 14) is employed to facilitate real-time communication between the laptop and the PCB (Printed Circuit Board).

Figure 13: 1080p full HD webcam

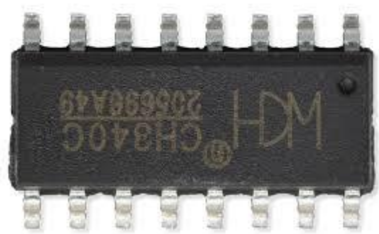


Figure 14 : CH340C IC

6.2. **Part 2 - Rejecting Faulty Milk Packets**

For rejecting faulty milk packets, Pushing Mechanism III (Figure 6), commonly used in CNC machines, has been selected. When a misprinted label is detected, the laptop sends a signal to the PCB to activate the pushing mechanism, thereby rejecting the faulty packets. The pushing mechanism employs NEMA 17 motors (Figure 15) and TB6600 motor controllers (Figure 16), with an ATmega328P (Figure 17) serving as the microcontroller on the PCB.

Figure 15: NEMA 17 motor

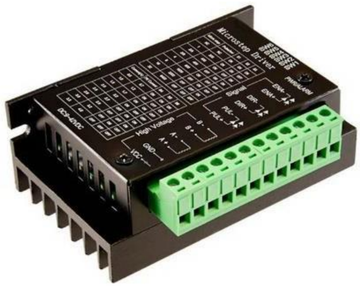


Figure 16: TB6600 motor controller

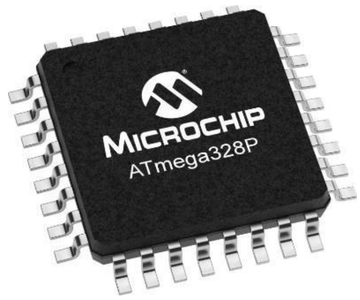


Figure 17: Atmel ATmega328P

7. Final Solid works design

We designed the enclosure using SolidWorks to house the PCB and motor controllers. It consists of two parts: the bottom and the top, with provisions for the power port, USB port, power switch, and signal output for the motors from the motor controllers. However, since the enclosure is not essential, we are not printing the 3D enclosure.

7.1. Top part

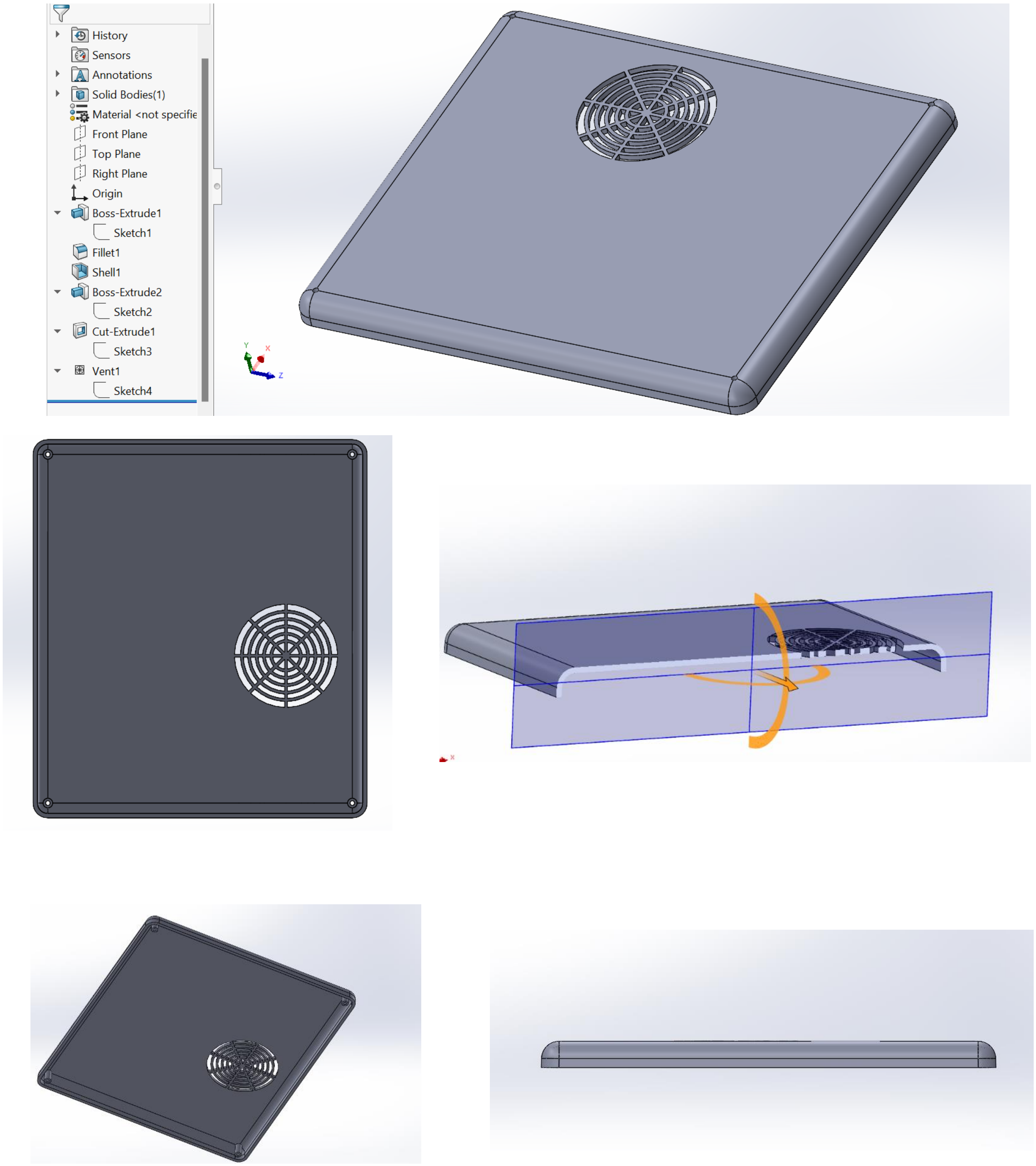


Figure 18: Top part of the enclosure

7.2. Bottom Part

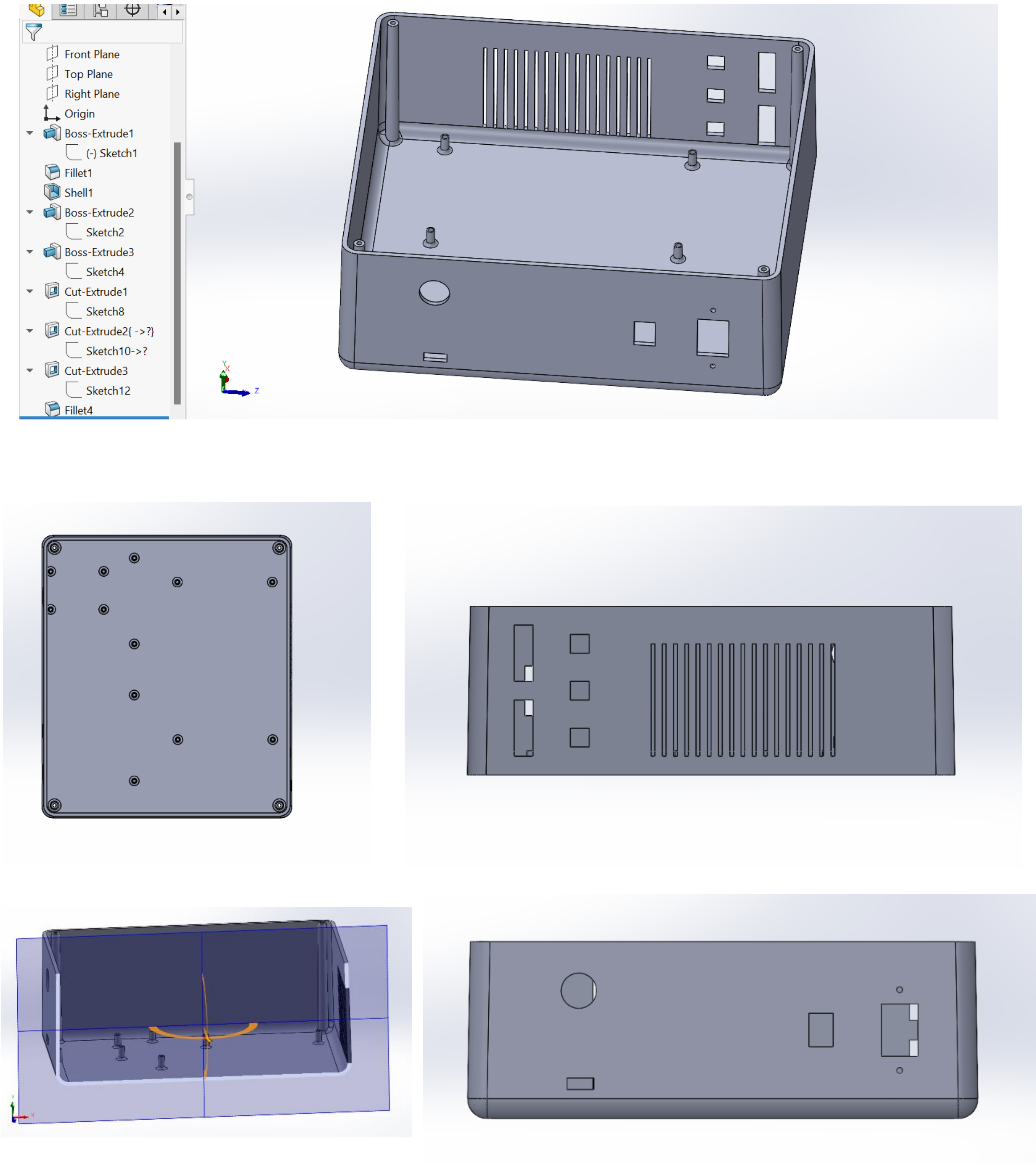


Figure 18: Bottom part of the enclosure

7.3. Assembly

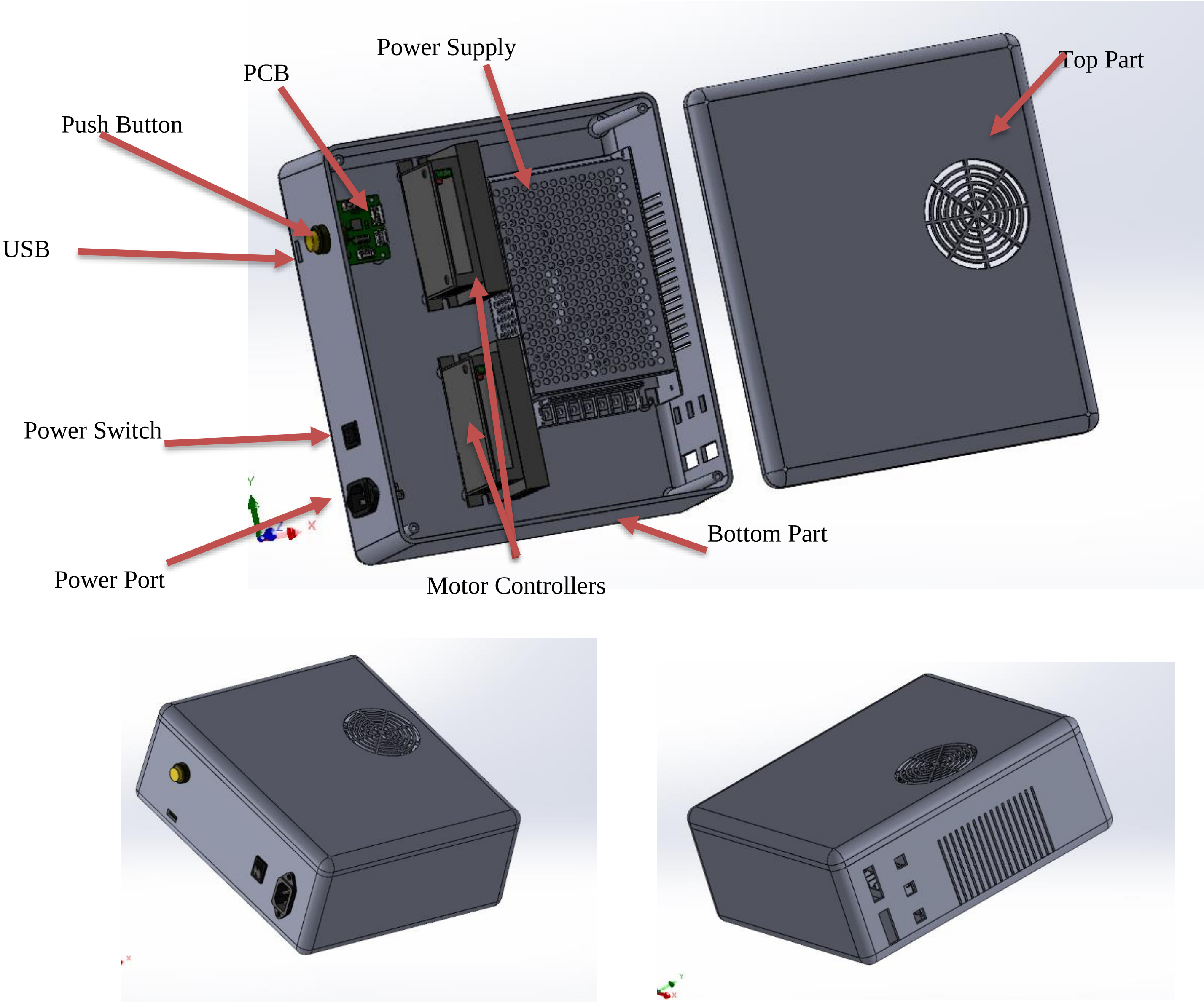


Figure 19: Assembly of the enclosure

8.Final Schematic & PCB Design

8.1. Schematics designs

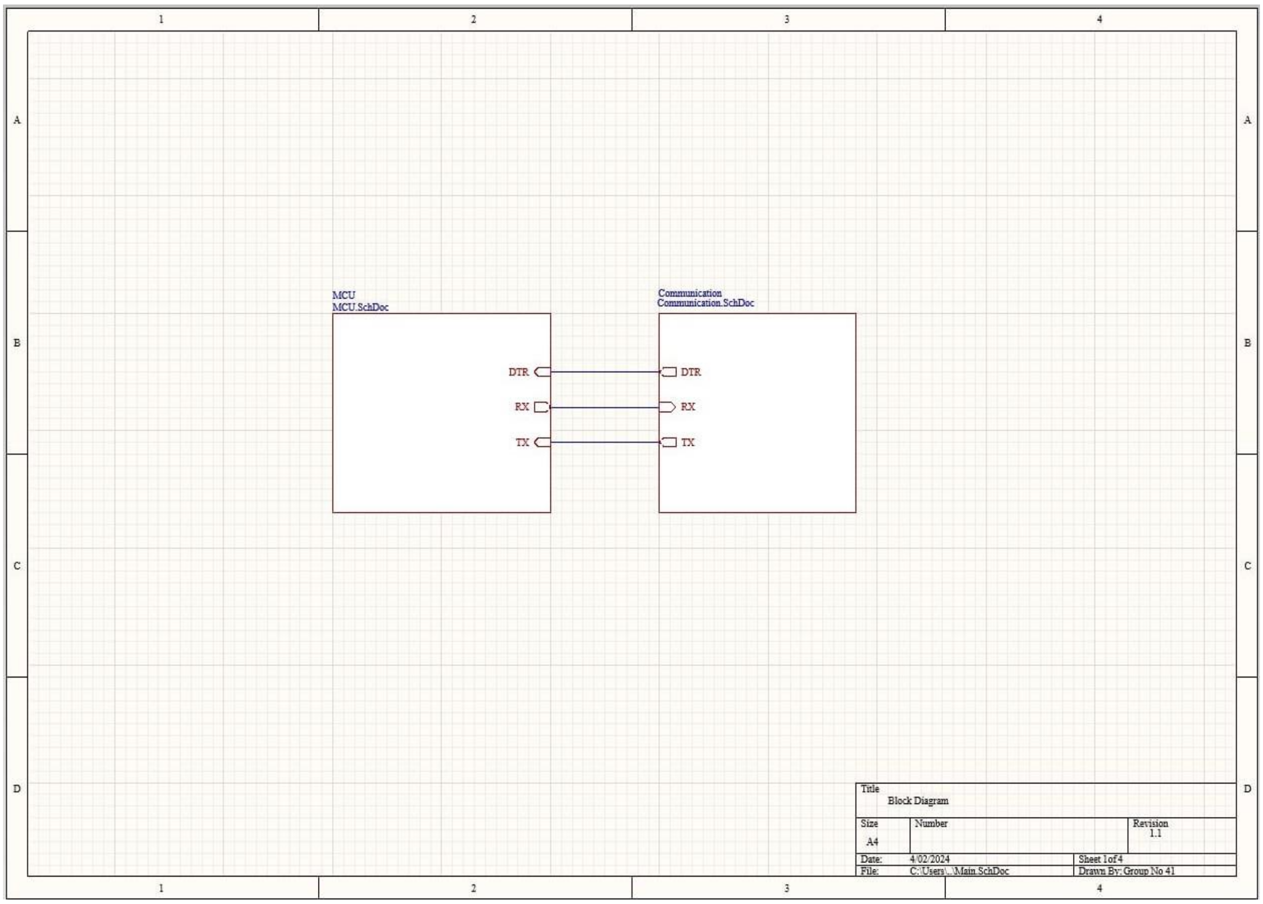


Figure20: Schematic - Block diagram

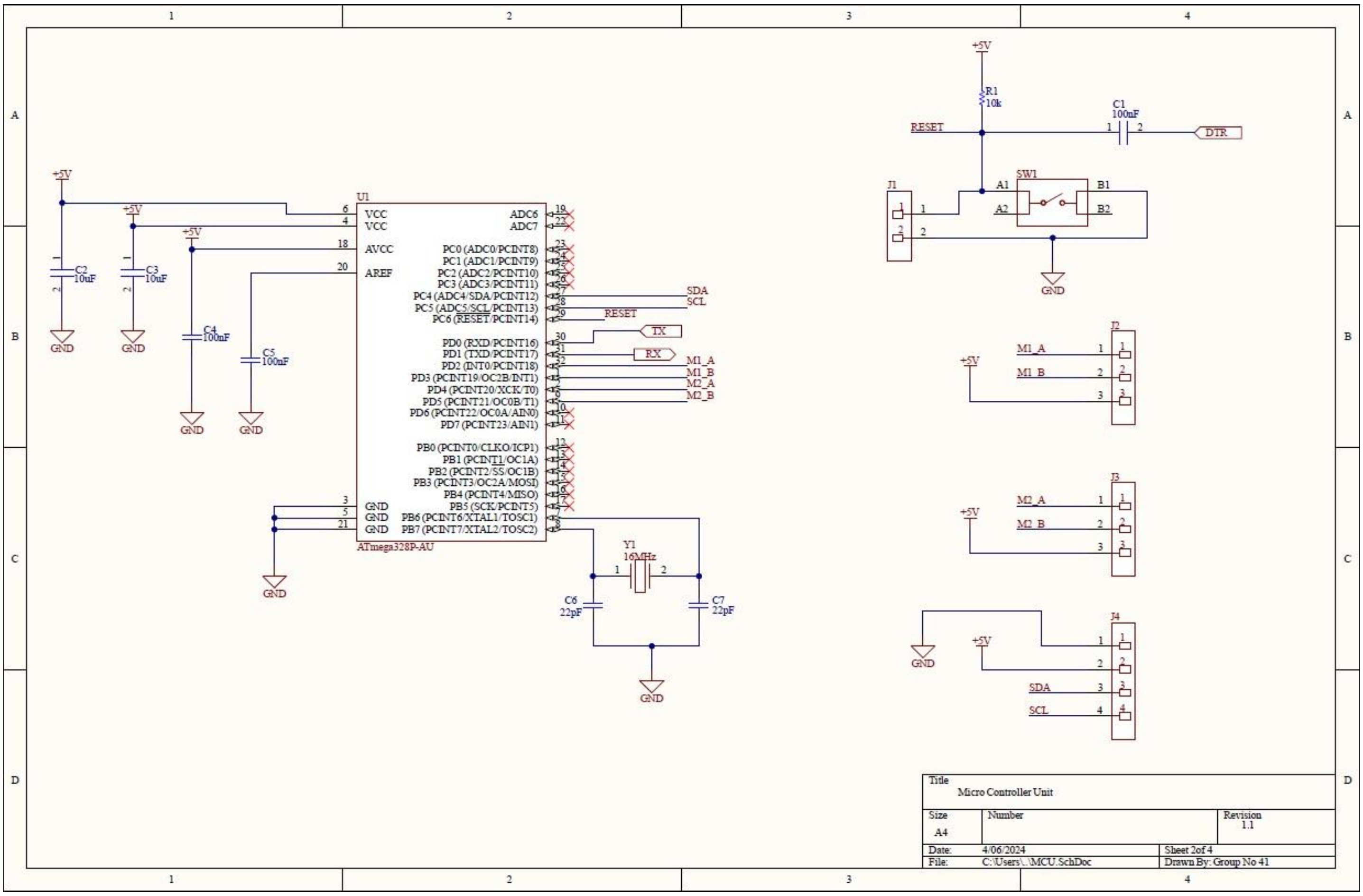


Figure 21: Schematic-Microcontroller Unit

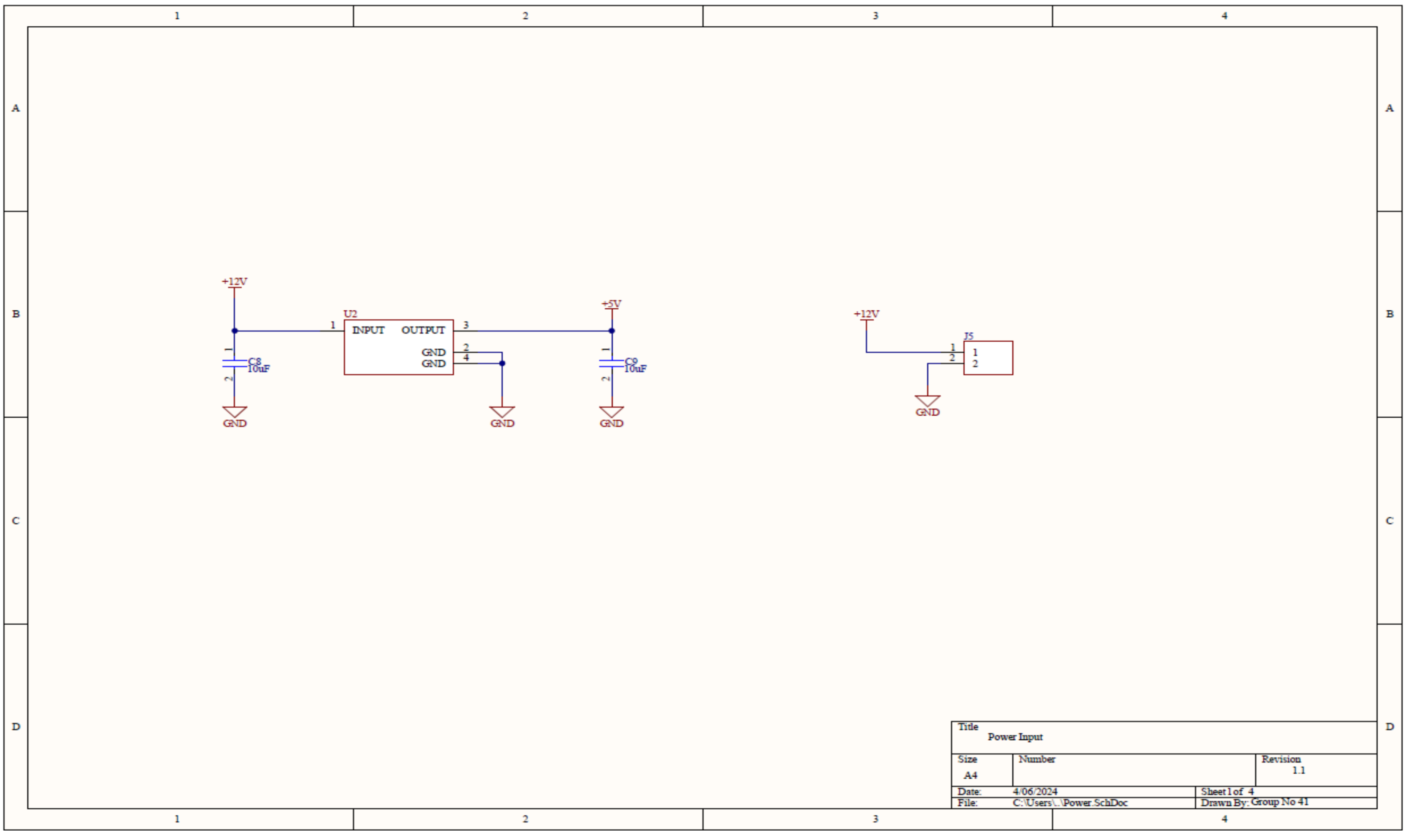


Figure 22: Schematic-Power Input

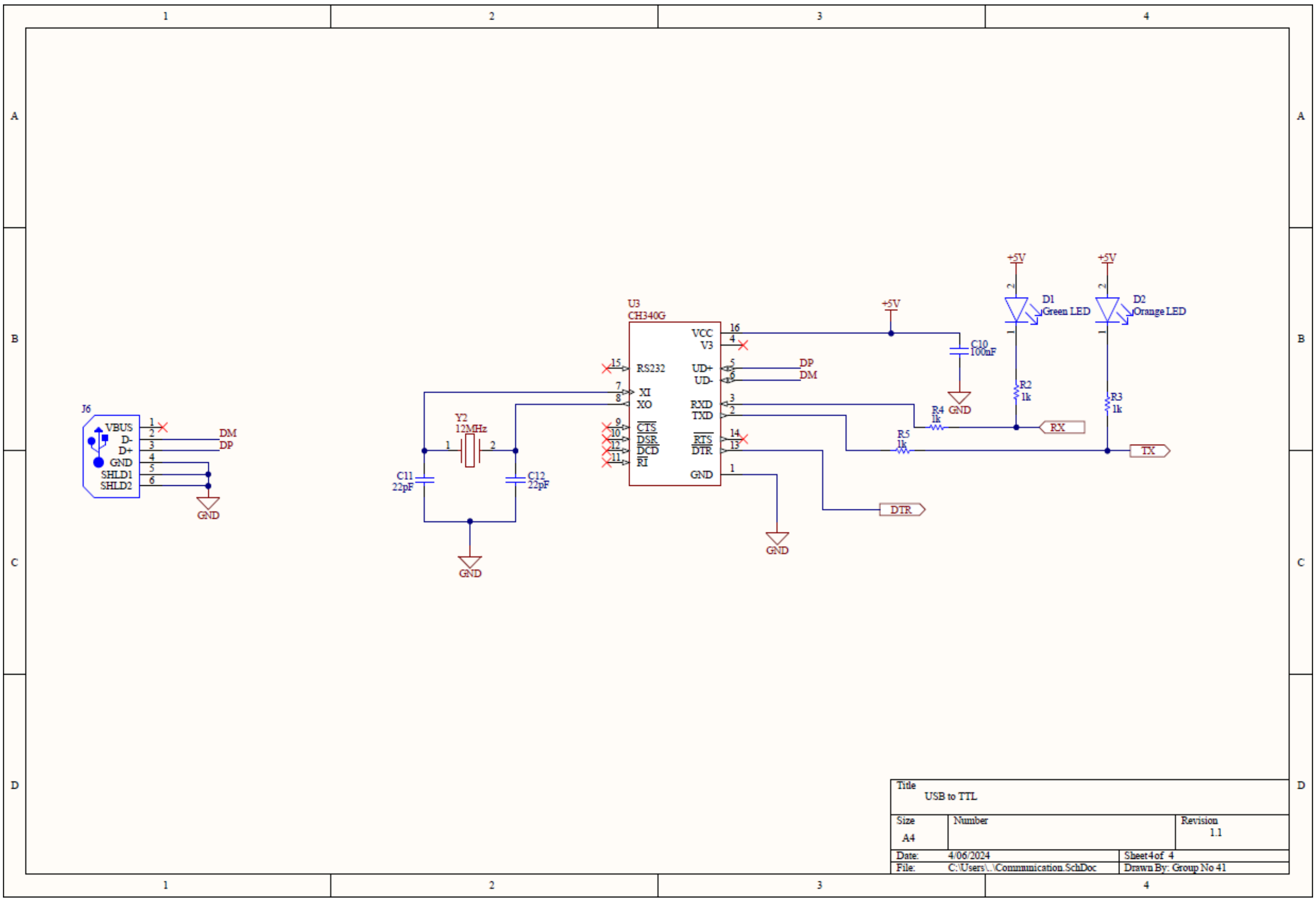


Figure 23: Schematic- USB to TTL

8.2. PCB design

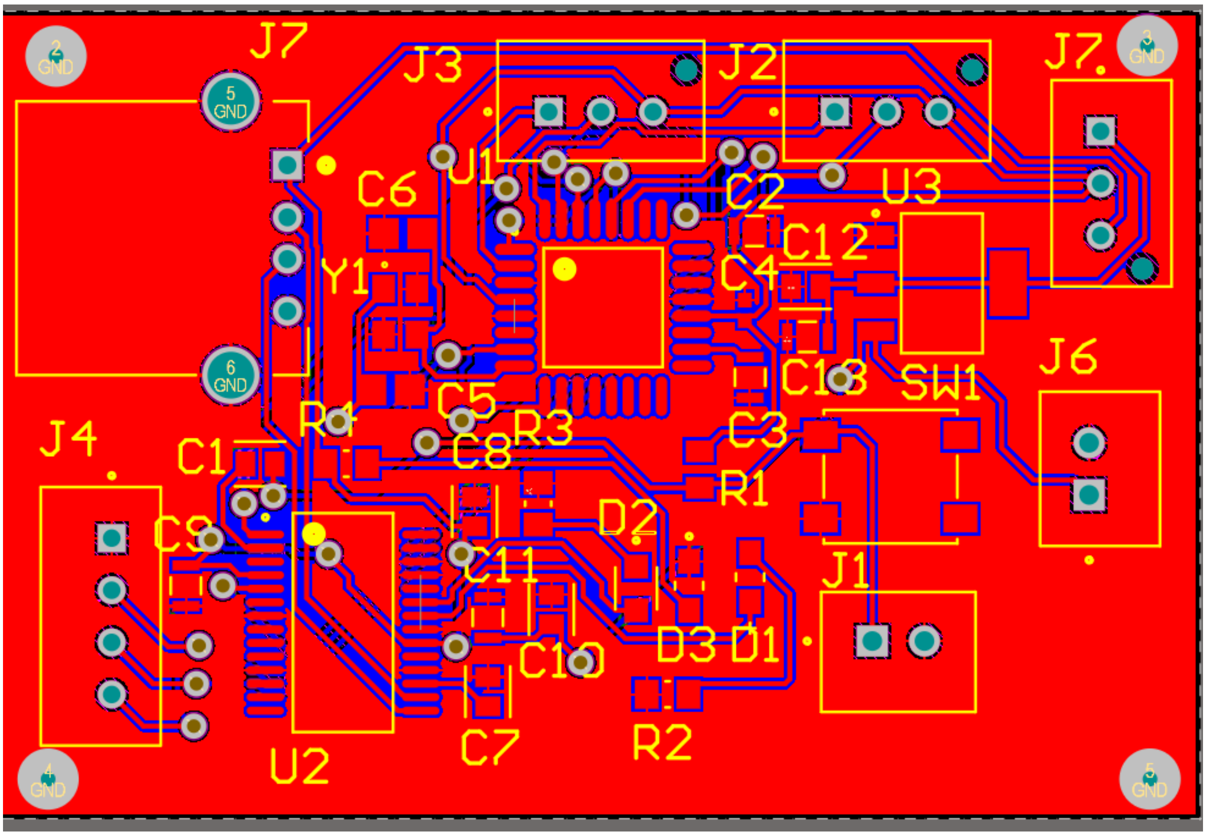


Figure 24: Top Layer of the PCB design

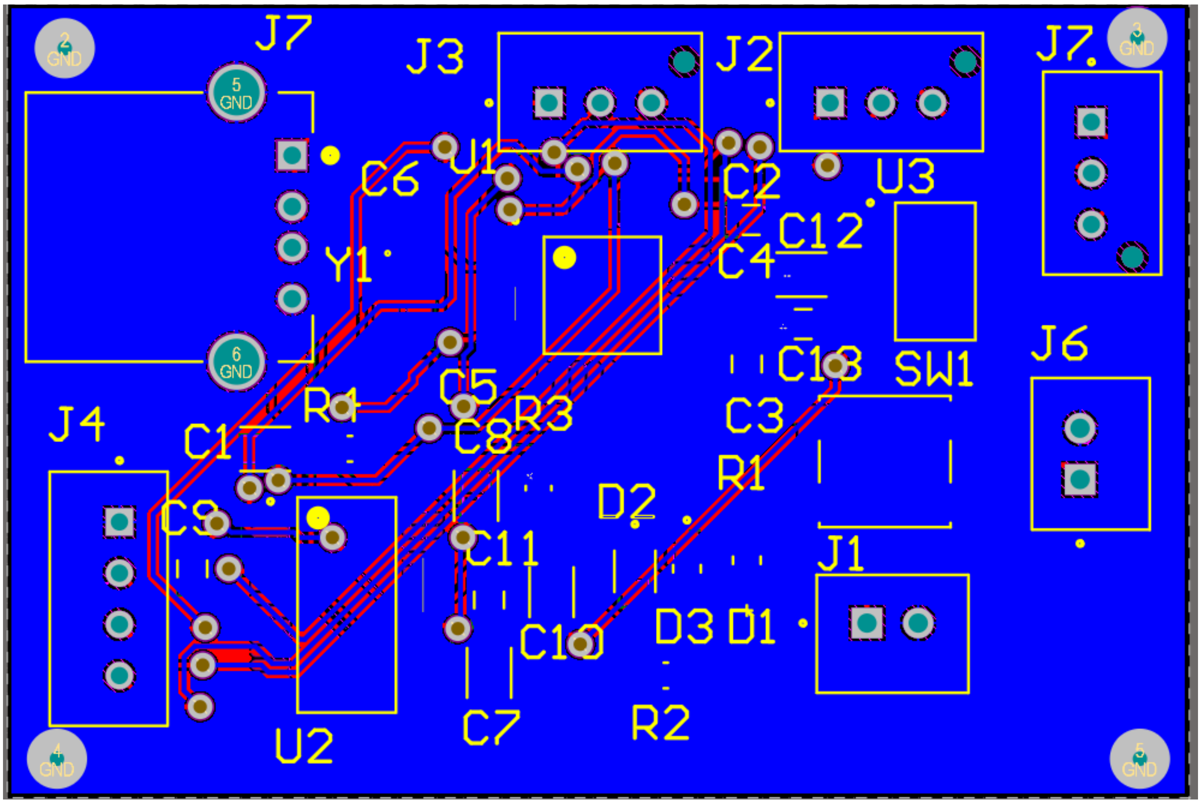


Figure 25: Bottom Layer of the PCB design