Department of Electronic & Telecommunication Engineering

University of Moratuwa, Sri Lanka

Autonomous Mobile Robot
Design Documentation

220701X - Wickramasinghe S.D
220542J - Sadaruwan I.J.M.J
220299T - Kalubowila K.A.T.S
220197E - Gunathilaka K.L
220449F - Pathirana P.N.A
220468L - Perera M.D.R.N
220077L - Budvin M.P.L
220533H - Ravishan B.B.N.
220439B - Pahasara L.P.P
220551K - Samaramanna M.A

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1 Introduction

This project aims to design and develop a cost-effective autonomous mobile robot (AMR) tailored for structured indoor environments. The primary objective is to build a reliable robotic platform capable of performing predefined tasks such as material transport and workspace navigation, using practical and readily available components.

Our design incorporates essential features such as LiDAR-based obstacle detection, closed-loop stepper motor control, and a modular sensor layout to support future upgrades. Emphasis is placed on efficient power management, structured system design, and iterative hardware evaluation to meet project requirements within budget constraints.

This document presents an overview of the project's motivation, design process, component selection, and planned implementation approach.

2 Review Progress

2.1 Existing Products in the Market

To better understand the landscape of Autonomous Mobile Robots (AMRs), we studied key offerings from three leading companies: **Omron**, **MiR**, and **Geek+**. Each has distinct product lines tailored to various industrial and logistics applications. Below is a detailed breakdown and comparison.

2.1.1 Omron

Figure 1: LD Series

Figure 2: MD Series

Figure 3: HD-1500 Series

Omron offers a diverse range of AMRs under its LD, MD, and HD series. These robots are designed to operate collaboratively in dynamic environments. Omron's robots are equipped with onboard obstacle avoidance, mapping, and navigation features that are tightly integrated into the robot's core systems. The standout features include:

- **Series:** LD-60/90, MD-650/900, HD-1500
- **Payload Capacity:** 60 kg to 1500 kg
- **Navigation:** Autonomous Mapping and Navigation with LDMapEdit
- **Software:** Fleet Manager to coordinate up to 100 robots

- **Key Use Cases:** Manufacturing, Semiconductor, Healthcare
- **Safety:** ISO-certified laser scanners, speed control, and E-stop buttons

2.1.2 Mobile Industrial Robots (MiR)

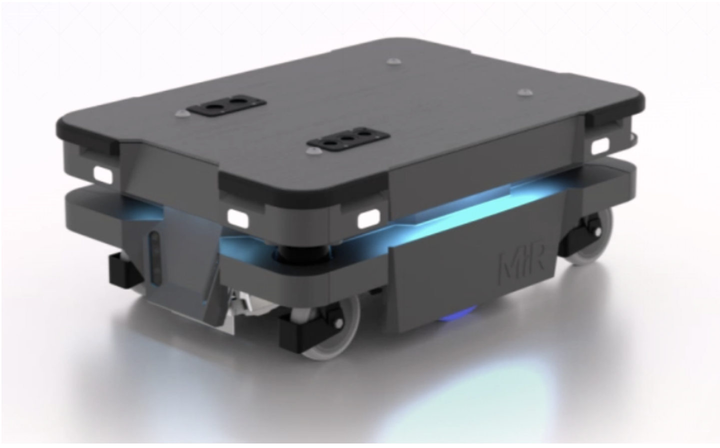

Figure 4: MiR250 AMR

MiR is a pioneer in easy-to-use AMRs, designed for rapid deployment without extensive infrastructure changes. Their robots are ideal for collaborative operations in warehouses and production lines. A strong user interface and third-party integration make MiR a flexible option.

- **Series:** MiR100, MiR250, MiR600, MiR1350
- **Payload Capacity:** 100 kg to 1350 kg
- **Navigation:** Laser-based SLAM, camera fusion
- **Software:** MiR Fleet — centralized fleet coordination
- **Key Use Cases:** Logistics, Warehouse Automation, FMCG
- **Safety:** 360° obstacle detection, dynamic path planning

2.1.3 Geek+

Figure 5: Geek+ P Series AMR

Geek+ offers a wide portfolio of AMRs, including picking, moving, and sorting robots tailored for smart warehouses. Their AI-driven platform optimizes traffic, task scheduling, and energy consumption. Geek+ is widely adopted in large-scale logistics centers.

- **Series:** P-Series (Picking), M-Series (Moving), S-Series (Sorting)
- **Payload Capacity:** 100 kg to 1200 kg+
- **Navigation:** QR code/grid-based and SLAM hybrid
- **Software:** Geek+ Robot Management System (RMS)
- **Key Use Cases:** E-commerce, Apparel, 3PL Warehousing
- **Safety:** Multi-sensor obstacle detection, AI-powered route optimization

2.1.4 Comparison of AMR Offerings

Feature	Omron	MiR	Geek+
Max Payload	1500 kg (HD-1500)	1350 kg (MiR1350)	1200+ kg (M-Series)
Navigation	Onboard laser + SLAM	Laser + Camera SLAM	QR/Grid + SLAM
Fleet Management	Omron Fleet Manager	MiR Fleet	Geek+ RMS
Ease of Use	Moderate	High (plug-and-play)	Moderate-High
Target Market	Industrial manufacturing	General logistics, hospitals	Smart warehouses, e-commerce
Safety Standards	ISO-compliant, advanced LIDARs	Full 360° sensing	AI and sensor fusion
Integration	Tight with Omron PLCs	Open API support	Customizable via SDK

Table 1: Comparison of Leading AMR Products

Conclusion: Each of these companies brings a strong value proposition to the AMR space. Omron provides tight industrial integration and reliability, MiR offers user-friendly plug-and-play solutions, and Geek+ excels in warehouse AI and logistics optimization.

2.2 Selected Reference Model

After a comprehensive evaluation of various commercially available Autonomous Mobile Robots (AMRs), we selected the **Omron LD Series**, specifically the **LD-60 platform**, as our reference design for the development of our AMR controller system.

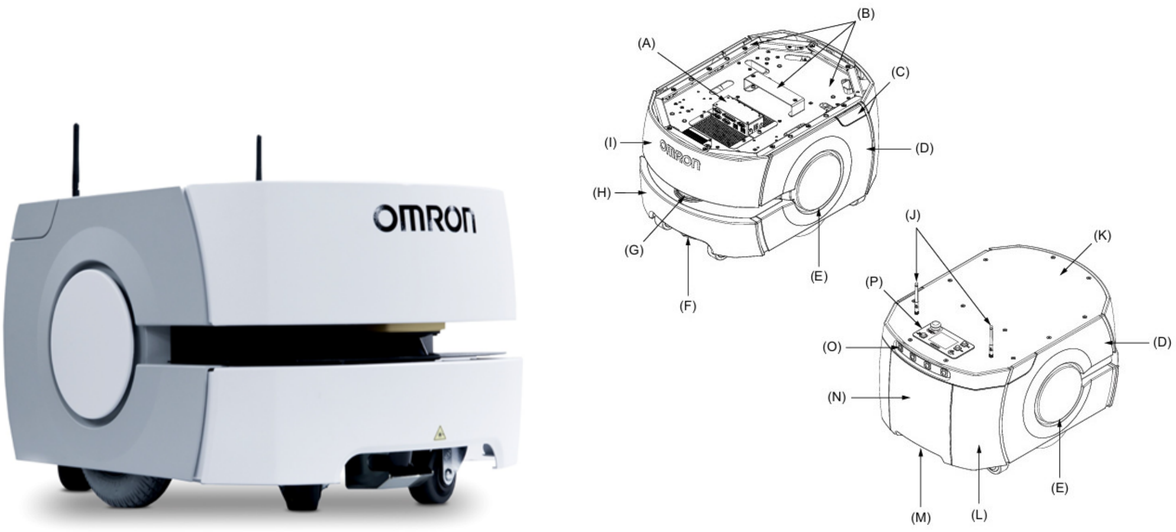

Figure 6: Omron LD-60 Reference AMR Platform

Key Features of Omron LD-60

- **Maximum Payload Capacity:** 60 kg
- **Run Time:** Up to 15 hours (no payload), approximately 12 hours (with full payload)
- **Maximum Translational Speed:** 1800 mm/s
- **Turning Radius:** 354 mm
- **Stop Position Repeatability:**
  - With CAPS: ±12 mm, ±1.0°
  - Without CAPS: up to ±100 mm
- **Navigation:** Autonomous mapping and obstacle avoidance using LIDAR and onboard sensors
- **Footprint:** Compact, enabling navigation in narrow aisles and dynamic industrial environments

Reasons for Selection

- The LD-60 offers a well-documented and industry-proven design, making it a strong foundation for developing and benchmarking our custom controller.
- Its technical specifications align closely with our design goals in terms of speed, payload, and battery endurance.
- The platform integrates effectively with fleet management and safety systems, setting a high standard for scalability.
- CAD models, datasheets, and documentation for the LD-60 are readily available, aiding simulation and mechanical reference.

Conclusion: The Omron LD-60 platform provides a reliable and realistic reference architecture that supports our development efforts while ensuring industrial relevance and performance benchmarking.

3 Identification of Stakeholders

The stakeholder plan for our AMR controller project is developed to systematically identify, engage, and manage the various individuals and organizations involved in the design, development, deployment, and operation of the Autonomous Mobile Robot (AMR). Key stakeholders such as the Developers and Engineers, Maintenance and Support Teams, and End-users play vital roles in ensuring the system's effectiveness, reliability, and user-friendliness.

Industries such as logistics, warehousing, and retail are expected to benefit from integrating our AMR solution into their operations. The AMR is specifically designed to automate material handling and transportation tasks, providing a significant advantage by improving efficiency, reducing manual workload, and enhancing operational safety.

Secondary stakeholders, including Regulatory Bodies, Equipment Suppliers, and Research Institutes, are also recognized for their influence on the project. Our core suppliers provide critical components like motors, sensors, microcontrollers, and batteries—elements essential to the AMR's performance. Collaborating with specialized partners in component manufacturing and research ensures both the technical excellence and long-term sustainability of our solution.

Stakeholders were categorized into four groups—**Manage Closely**, **Keep Satisfied**, **Keep Informed**, and **Monitor**—based on their level of interest and influence. This classification helps prioritize engagement strategies and ensure effective communication throughout the development lifecycle.

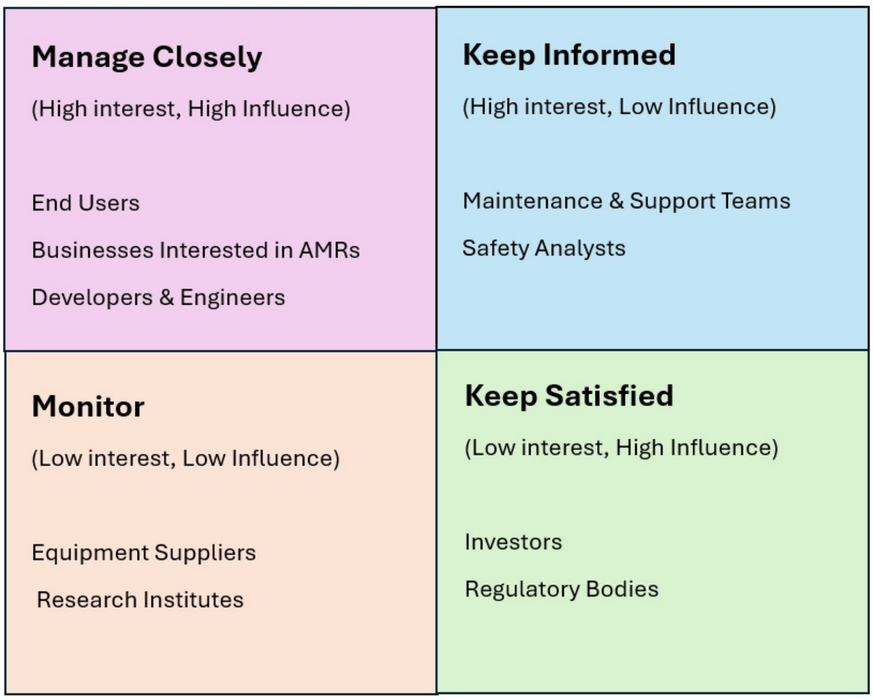

Figure 7: Stakeholder Map

4 Observe Users

Understanding how users interact with Autonomous Mobile Robots (AMRs) in real-world environments is essential for designing an effective and user-friendly system. To explore user preferences and expectations, we conducted a qualitative observation study by analyzing video footage of AMR usage across different industries. The videos were reviewed with sound and subtitles turned off to sharpen our focus on physical interactions, behavioral cues, and system responses. **Videos Analyzed**

- `https://www.youtube.com/watch?v=7BenDNX5ZQU`
- `https://www.youtube.com/watch?v=LfVk2qFgPks`
- `https://www.youtube.com/watch?v=qrlx4PjfpP8`
- `https://www.youtube.com/watch?v=ESA4Cps7v2Q`
- `https://www.youtube.com/watch?v=J70Ump35T8k`
- `https://www.youtube.com/watch?v=EfBUXHnR50w`

Key Observations

- **Simplicity and familiarity:** Users preferred straightforward and familiar interfaces, with minimal manual interaction.
- **Clear feedback and updates:** Real-time notifications and system status indicators enhanced user experience and trust.
- **Autonomous navigation:** Users appreciated AMRs that could autonomously reroute around obstacles without manual input.
- **Emergency control:** Clearly accessible emergency stop buttons and fail-safe recovery mechanisms were seen as essential safety features.
- **System integration:** Compatibility with existing infrastructure, tools, and software was important for smooth operational adoption.

These insights guided several design decisions in our AMR controller, ensuring it aligns with real user needs and practical deployment scenarios.

5 Need List

After thorough evaluation and observation, we compiled a comprehensive list of user needs to ensure that the AMR controller meets the expectations of all stakeholders. These needs span across functional, safety, operational, and integration aspects, supporting the efficient and user-friendly deployment of Autonomous Mobile Robots.

- **Autonomous Navigation in Dynamic Settings:** The AMR should independently navigate and adapt to environments with moving obstacles and dynamic changes.

- **Obstacle Detection & Evasion:** Reliable sensors must detect and avoid obstacles, ensuring safe operations in crowded or shared spaces.
- **Versatile Load Handling:** Capable of transporting loads of varying sizes and weights, providing flexibility across different cargo types.
- **Long-Lasting Power with Simple Charging:** Equipped with a high-capacity battery for extended use and an efficient, user-friendly charging method.
- **Seamless System Integration:** Easy integration with existing infrastructure and management systems like warehouse software for smooth coordination.
- **User-Friendly Interface:** Simple and intuitive user interface for easy control, setup, and operation.
- **Safe Interaction with Humans & Equipment:** Designed for safe operation near humans and other machines, minimizing accident risks.
- **Quiet Operation:** Operates with minimal noise to maintain a comfortable working environment.
- **Effective Diagnostic Capabilities:** Built-in diagnostics tools to detect and report issues, enabling quick maintenance and troubleshooting.
- **Durable Build:** Constructed using tough, wear-resistant materials to enhance lifespan and reduce maintenance.
- **Safety Compliance:** Integrated safety mechanisms such as collision avoidance, emergency stop, and compliance with standards (e.g., ISO 13482).
- **Data Security & Privacy:** Ensures secure data transmission and protection, adhering to privacy and security regulations.
- **Cost-Effective Manufacturing:** Designed to be economical to produce without compromising on performance or quality.
- **Adaptable for Various Applications:** Versatile enough for deployment in different sectors including warehouses, hospitals, retail stores, and factories.
- **Remote Monitoring Capabilities:** Includes software for remote supervision and real-time system updates.
- **Energy Efficiency:** Designed for minimal power consumption to reduce operational costs and environmental impact.
- **Reliability:** High uptime and robust error-handling systems to support uninterrupted operations.
- **Scalability:** Supports coordinated operation of multiple AMRs in large-scale environments without interference or inefficiencies.

6 Component Selection

The component selection for the AMR controller robot was driven by functional requirements, performance efficiency, availability, and cost considerations. Key hardware components were evaluated and finalized after assessing multiple alternatives. Below is a summary of the selected components and their justifications:

6.1 Microcontroller Unit (MCU)

Selected: ATmega32U4

Key Characteristics:

- **Architecture:** 8-bit AVR RISC
- **Clock Speed:** Up to 16 MHz
- **Flash Memory:** 32 KB
- **SRAM:** 2.5 KB
- **EEPROM:** 1 KB
- **GPIOs:** 26 programmable I/O lines
- **Interfaces:** USB 2.0 Full Speed, SPI, I^2C (TWI), USART
- **Analog Inputs:** 12-channel 10-bit ADC
- **Timers:** Four timers (two 8-bit, two 16-bit)
- **Built-in USB Support:** Enables native USB communication without external components

Figure 8: ATmega32U4 Microcontroller

Justification:

- Adequate GPIOs (> 15), USB, I2C, USART, and ADC support
- External interrupt capability
- Well-documented with strong community and SDK support
- Available development boards

Alternatives considered: SAM E70, STM32 F-Series, STM32 H-Series, RP2040

6.2 Single-Board Computer (SBC)

Selected: Jetson Nano
Key Characteristics:

- Quad-core ARM Cortex-A57 @ 1.43 GHz CPU
- 128-core Maxwell GPU
- 4 GB LPDDR4 memory
- Rich I/O (40-pin GPIO, I^2C, SPI, UART)
- Excellent community and development ecosystem via NVIDIA JetPack

Figure 9: Jetson Nano Development Board

Alternatives considered: Jetson AGX Orin, AMD Ryzen V1000, Intel NVC

6.3 LIDAR Selection

Autonomous navigation and obstacle avoidance are core functionalities in any AMR system. Therefore, selecting an appropriate LIDAR sensor is crucial for ensuring precise environmental perception. Key factors considered in this selection include:

Figure 10: Lakibeam 1S LIDAR Sensor

- Measurement range (minimum and maximum distance)
- Accuracy and angular resolution
- Field of view (angle of detection)
- Sampling rate
- Communication interface
- Dimensional capability (2D or 3D)
- Cost and ease of integration

Comparison of Available LIDAR Sensors

LIDAR	Price (USD)	2D/3D	Min Dist. (m)	Max Dist. (m)	Accuracy Score	Angle	Sampling Rate	Interface
LakiBeam 1S	310	2D	0.1	15	9	270°	18000	Ethernet UDP
YDLIDAR T-mini Pro	72	2D	0.12	10	6	360°	5000	UART
STL-19P D500	96	2D	0.03	12	7	360°	5000	UART
Velodyne VLP-16	499	3D	0.1	100	8	360°	300000	Ethernet
LS01B LIDAR Scanner	378	2D	0.1	16	8	360°	14000	UART
RPLIDAR S2P	400	2D	0.2	50	9	360°	18000	UART
VF 2D 360° LIDAR	499	2D	0.1	25	8	360°	20000	UART

Table 2: Comparison of Selected LIDAR Modules

Selected LIDAR Module

After evaluating the listed options based on technical specifications, performance metrics, and interface compatibility, we selected the **Lakibeam 1S** as the LIDAR sensor for our AMR platform.

- **Accuracy:** High, with an accuracy score of 9
- **Field of View:** 270° — ideal for forward-facing obstacle detection
- **Sampling Rate:** 18000 — ensures dense and fast environmental scanning
- **Interface:** Ethernet UDP — fast and robust data communication
- **Min/Max Range:** 0.1 m to 15 m — suitable for indoor dynamic environments
- **Dimensionality:** 2D — sufficient for horizontal floor navigation

Cost of Selected Module: $310 (approximately Rs. 90,600)

The Lakibeam 1S offers a strong balance between cost and performance, and integrates well with our Jetson Nano SBC via Ethernet UDP for high-speed data transmission and real-time processing.

6.4 Motor Selection

6.4.1 Estimated Weight

- Motors = $3.6\,\text{kg} \times 2 = 7.2\,\text{kg}$
- Gears = $0.92\,\text{kg} \times 2 = 1.84\,\text{kg}$
- Payload = $5\,\text{kg}$ (requirement)
- Battery $< 3\,\text{kg}$ (assumption)
- Lidar $\approx 0.4\,\text{kg}$
- Chassis + Enclosure = $5\,\text{kg}$ (estimated)
- Jetson Nano + peripherals = $2\,\text{kg}$

$$\text{Total Estimated Weight} \approx 24.44\,\text{kg} \Rightarrow \textbf{Weight} \approx \boxed{25\,\text{kg}}$$

6.4.2 Minimum Displacement

We consider a wheel diameter of 15 cm (reference design diameter = 20 m). The stepper motor under consideration is the NEMA 24, commonly used in robotics for its balance between torque and precision.

NEMA 24 Stepper Motor Specifications:

- Standard step angle: 1.8° per full step (from manufacturer datasheet)
- Full rotation: 360° = 200 steps
- We chose not to micro-step as it significantly reduces the motor torque output

Minimum Displacement Analysis:

- Without microstepping, minimum angular displacement:

$$\frac{1.8^\circ}{360^\circ} \times 15\,\text{mm/rev} = 0.075\,\text{mm/step}$$

- Resulting linear displacement: $\approx 2.4\,\text{mm}$ per step

LD Series Comparison:

- Assumed stop position repeatability: 10 mm (from datasheet specifications)
- Feasibility assessment: Our motor's minimum displacement capability (2.4 mm per step) is within the required spec
- **Conclusion:** Standard full-stepping is sufficient to achieve the required precision

6.4.3 Torque and Gear Ratio

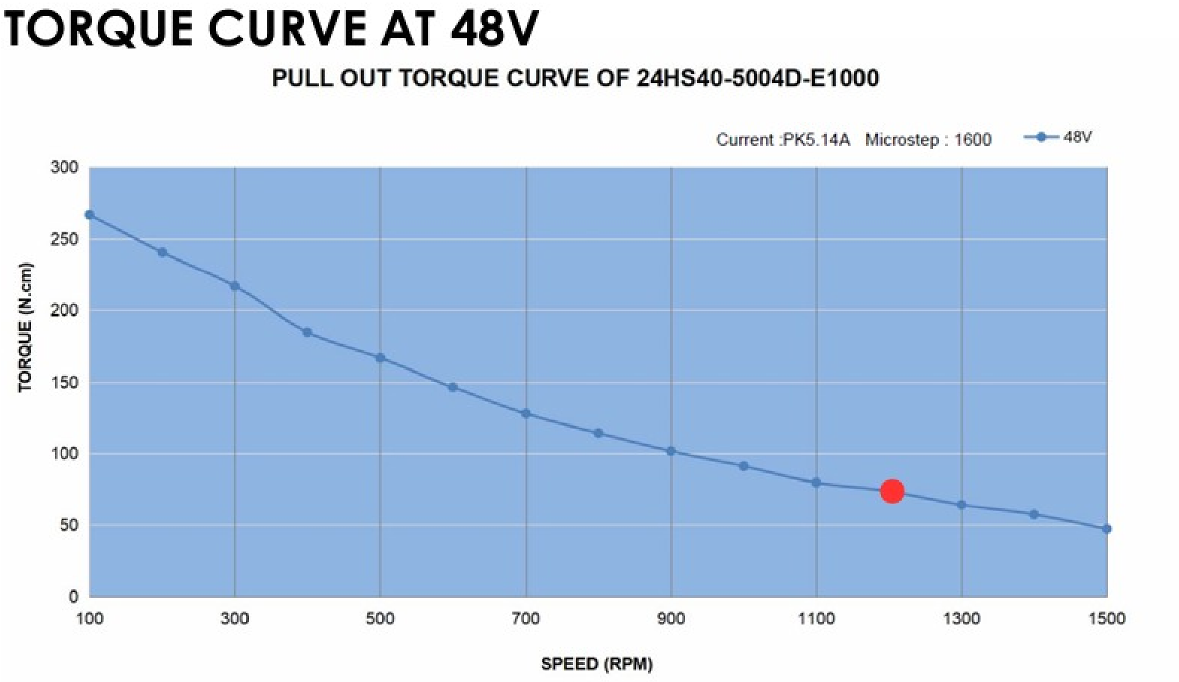

Figure 11: Torque Curve at 48 V

- Gear ratio: 10:1
- To achieve 120 RPM at the wheel, motor must rotate at 1200 RPM
- From the torque curve of NEMA 24 at 48 V and 1200 RPM:

$$\text{Motor torque} \approx 0.75\,\text{Nm}$$

- Output torque after gearing:

$$0.75 \times 10 = 7.5\,\text{Nm}$$

- Considering losses due to friction and gear inefficiencies, conservatively assumed:

$$\boxed{\text{Usable Output Torque} \approx 6.0\,\text{Nm}}$$

6.4.4 Velocity and Acceleration

We compare the torque-limited drive force to the traction limit and take the smaller to find the true maximum acceleration.

$$r = 0.075 \text{ m}, \quad T_{\text{wheel}} = 6.0 \text{ Nm}$$

$$F_{\text{drive}} = 2 \times \frac{T_{\text{wheel}}}{r} = 2 \times \frac{6.0}{0.075} = 160 \text{ N}$$

$$
\begin{aligned}
a_{\text{torque}} &= \frac{F_{\text{drive}}}{m} = \frac{160}{25} = 6.4\ \text{m/s}^2 \\
F_{\text{traction,max}} &= \mu\, m\, g = 0.6 \times 25 \times 9.8 = 147\ \text{N} \\
a_{\text{traction}} &= \frac{F_{\text{traction,max}}}{m} = \frac{147}{25} \approx 5.88\ \text{m/s}^2 \\
a_{\max} &= \min\Big(a_{\text{torque}},\, a_{\text{traction}}\Big) = 5.88\ \text{m/s}^2
\end{aligned}
$$

Since $5.88\,\text{m/s}^2 \gg 0.6\,\text{m/s}^2$, the acceleration target is readily achieved without wheel slip.

6.4.5 Selected Motor Summary

After evaluating motion requirements, weight, torque, precision, and cost constraints, the selected motor for the AMR platform is:

- **Motor Type:** NEMA 24 Closed-Loop Stepper Motor
- **Holding Torque:** 4.0 Nm
- **Operating Voltage:** 24 V to 48 V
- **Driver Type:** Integrated closed-loop driver with encoder feedback
- **Gearbox:** Planetary Gearbox with 10:1 reduction ratio
- **Output Torque (after gearbox):** Approx. 6.0 Nm (conservatively estimated)
- **Weight per motor:** 3.6 kg
- **Gearbox weight:** 0.92 kg

Figure 12: NEMA 24 Closed-Loop Stepper Motor

Reasons for Selection:

- Provides sufficient torque with gear reduction to drive the estimated 25 kg robot with margin.
- Full-step resolution offers displacement accuracy within the required stop position tolerance.
- Closed-loop control ensures accuracy and stability even under varying loads.
- Readily available with good documentation and integration support.

Conclusion: The NEMA 24 closed-loop stepper motor with a 10:1 planetary gearbox meets all key motion and performance requirements of the AMR platform, making it a robust and efficient choice for reliable autonomous operation.

6.5 Inertial Measurement Unit (IMU)

Selected: Bosch BNO055
Key Characteristics:

- Integrated 9-axis sensor: 3-axis accelerometer, 3-axis gyroscope, 3-axis magnetometer
- Onboard Cortex-M0+ microcontroller running sensor fusion algorithms
- Output data: fused orientation (quaternions, Euler angles), linear acceleration, gravity vector
- Interfaces: I^2C, UART, HID-I2C; logic voltage 1.7 V to 3.6 V
- Accelerometer ranges: ±2g, ±4g, ±8g, ±16g
- Gyroscope ranges: ±125°C/s to ±2000°C/s
- Magnetometer typical range: ±1300 µT (X,Y), ±2500 µT (Z)
- Operating voltage: 2.4 V to 3.6 V
- Power modes: Normal, Low Power, Suspend
- Operating temperature: -40C to +85C

Justification:

- Provides fully fused absolute orientation data, reducing processing load on main controller
- Compact and lightweight package suitable for mobile robotics
- Wide operating voltage and temperature range for robustness
- Multiple communication interfaces for flexible integration

- Automatic calibration and self-test features improve reliability

Alternatives considered: MPU-9250, LSM9DS1, ICM-20948
Price: Rs. 3,652.00

Figure 13: Inertial Measurement Unit

Provides accurate orientation data with onboard sensor fusion.

6.6 Communication Module

Selected: Mercusys MW300UH 300Mbps High Gain Wireless USB Adapter
Key Characteristics:

- **Antenna Type:** External high gain antenna
- **Dimensions:**
  - Without antennas: 113.2 × 63.8 × 21.7 mm
  - With vertical antennas: 113.2 × 100.5 × 201.1 mm
- **Signal Rate:**
  - 11n: Up to 300 Mbps (dynamic)
  - 11g: Up to 54 Mbps (dynamic)
  - 11b: Up to 11 Mbps (dynamic)
- **Wireless Standards:** IEEE 802.11n/g/b
- **Frequency Range:** 2.400 - 2.4835 GHz
- **Reception Sensitivity:** Ranges from -68 dBm to -94 dBm depending on data rate
- **Interfaces:** Micro USB 2.0

- **Transmission Power:** $\leq$ 20 dBm (EIRP)
- **Security:** WEP, WPA/WPA2, WPA-PSK/WPA2-PSK
- **Operating Environment:**
  - Temperature: 0C to 40C operating, -40C to 70C storage
  - Humidity: 10% to 90% non-condensing (operating)

Justification:

- Offers reliable wireless communication, critical for remote monitoring and diagnostics.
- Supports high-speed wireless communication up to 300 Mbps suitable for data transfer needs
- External antenna provides extended range and improved signal quality
- Compatible with common operating systems ensuring easy integration
- Compact form factor with standard Micro USB interface simplifies hardware integration

Alternatives considered: TP-Link TL-WN725N, Netgear Nighthawk A7000
Price: Rs. 4,700.00

Figure 14: Communication module

6.7 User Interface

Selected: 7-Inch IPS HDMI-Compatible Touch Screen Display
Key Characteristics:

- **Display Type:** 7-inch IPS LCD with capacitive touch

- **Resolution:** 1024 × 600 pixels
- **Touch Technology:** Capacitive multi-touch
- **Interface:** HDMI input with included HDMI cable
- **Viewing Angles:** Wide viewing angles due to IPS technology
- **System Compatibility:** Supports Raspbian, Ubuntu, Windows, and other OS
- **Package Contents:** Display, HDMI cable, mounting nuts

Justification:

- Provides high-quality visuals with sharp resolution and vibrant colors
- Capacitive touch allows smooth and responsive user interaction
- HDMI compatibility ensures easy connection with Raspberry Pi and other devices
- Compact size fits well for portable and embedded applications in the robot

Price: Rs. 10,890.00

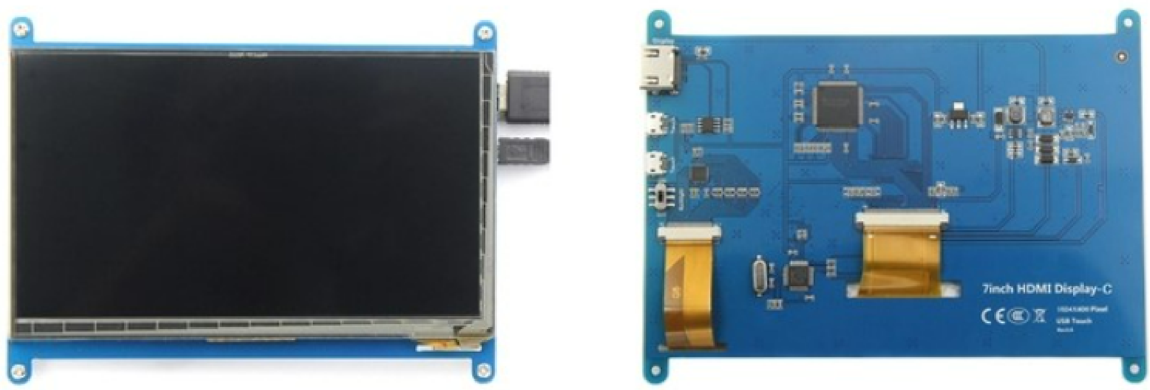

Figure 15: HDMI Touch Screen Display

6.8 Mechanical Components

Driving Wheels: 2 units

- **Type:** Rubber treaded wheels for good traction
- **Diameter:** 20 cm
- **Material:** Rubber with durable aluminium hub
- **Mounting:** Directly connected to motor shafts on each side, positioned at the middle of the chassis
- **Load Capacity:** Suitable for carrying robot payload and weight

- **Justification:**
  - Central placement allows balanced drive force and stable movement
  - Direct drive reduces mechanical losses and improves responsiveness
  - Rubber tread ensures good grip on indoor surfaces for precise navigation

Castor Wheels: 4 units

- **Type:** Swivel castor wheels for multi-directional support
- **Diameter:** 5 cm
- **Material:** Hard plastic or polyurethane for smooth rolling
- **Mounting:** Fixed at four chassis corners
- **Load Capacity:** Designed to stabilize the chassis and support overall weight
- **Justification:**
  - Corner placement ensures maximum stability and balance
  - Swivel design facilitates easy turning and maneuvering
  - Reduces friction during directional changes, preserving floor surfaces

Figure 16: Driving Wheel

Figure 17: Caster Wheeel

7 Power Management Modules

To ensure stable and efficient power delivery to various subsystems within the AMR robot, a set of DC-DC power converters have been incorporated. These modules are responsible for stepping up or stepping down voltages to match the requirements of individual components such as microcontrollers, sensors, computing units, and motor drivers. All selected modules are compact, high-efficiency, and designed to operate reliably under variable load conditions. Two of them feature waterproof enclosures, making them suitable for rugged environments and improving the robot's resilience to external factors like dust and humidity.

24V to 12V Step-Down Converter Module

Step-down (buck) converter designed to convert 24 V DC input to stable 12 V DC output with adjustable current up to 5 A. Features a design suitable for rugged environments and reliable power regulation. This is used to supply the power to the LIDAR.

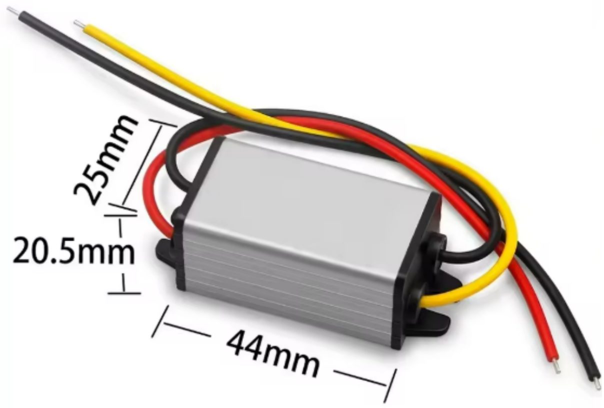

Figure 18: 24V to 12V Step-Down Converter Module

DC-DC Booster- Adjustable Step-Up Converter

High-power boost converter module featuring a wide input range of 10 V to 60 V DC and an adjustable output from 12 V up to 90 V DC. Delivers up to 20 A output current (30 A max input current from 10–30 V or 25 A from 31–60 V).Compact and robust, ideal for high-power applications needing flexible, step-up power regulation. This is used to supply power to the motors.

Figure 19: DC-DC Booster- Adjustable Step-Up Converter

B560C 5A DC-DC Buck Converter Module
High-current buck converter module accepting 5 V to 60 V input voltage, providing adjustable output voltage from 5 V to 20 V with a maximum output current of 5 A. Features low ripple voltage (∼3 mV), suitable for high-performance power regulation. This is used to supply power to the Jetson Nano.

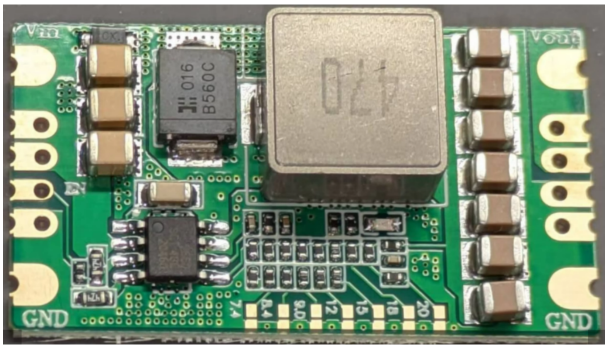

Figure 20: B560C 5A DC-DC Buck Converter Module

DC-DC Step-Down Power Supply Module (7-100V to 5/9/12/24V, 2A)
Wide input voltage range buck converter module accepting 7 V to 100 V DC input, with selectable output voltages of 5 V, 9 V, 12 V, or 24 V DC and maximum output current of 2 A. Suitable for applications requiring wide input voltage adaptability. This is used to supply power to the MCU.

Figure 21: DC-DC Step-Down Power Supply Module

8 Conceptual Design

8.1 Conceptual Designs(Initial Sketches)

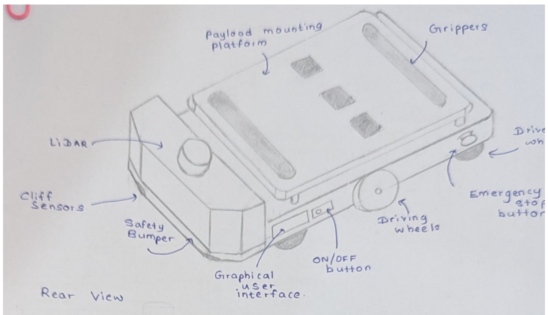

Figure 22: Initial Sketch 1

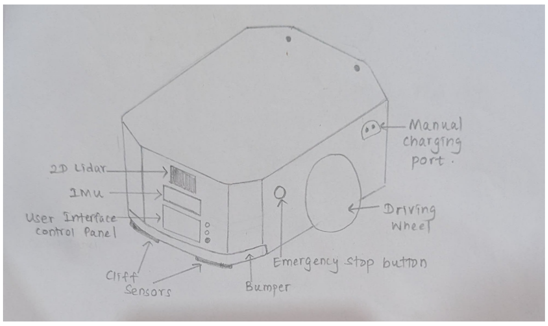

Figure 23: Initial Sketch 2

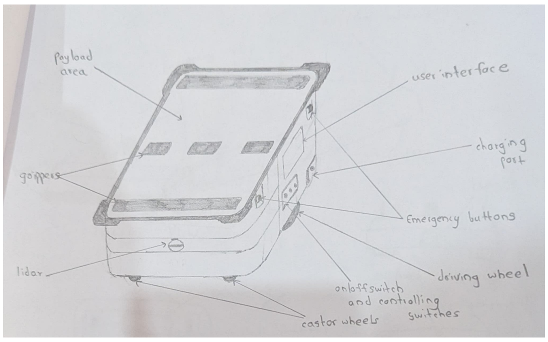

Figure 24: Initial Sketch 3

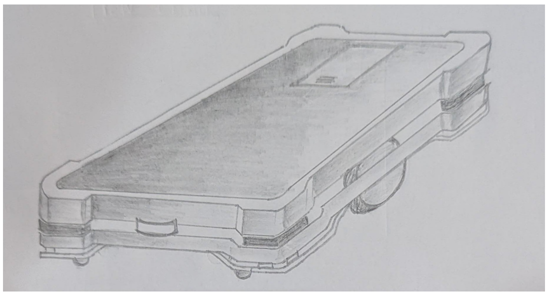

Figure 25: Initial Sketch 4

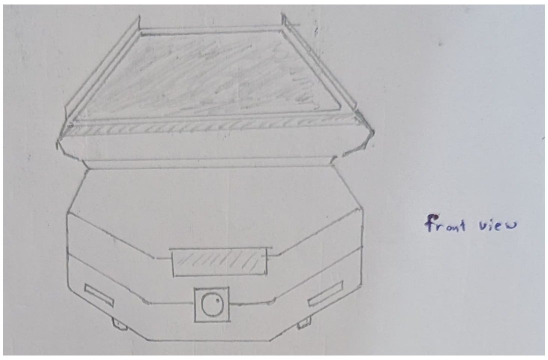

Figure 26: Initial Sketch 5

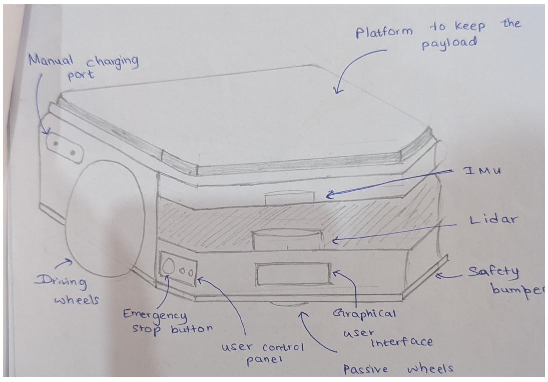

Figure 27: Initial Sketch 6

8.2 FINAL Conceptual Design

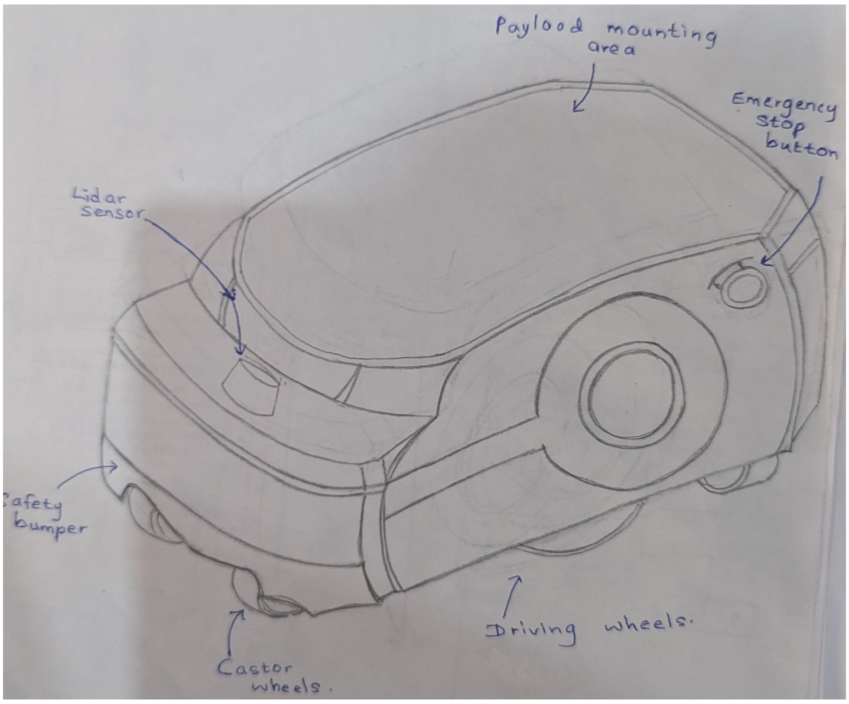

Figure 28: Front View

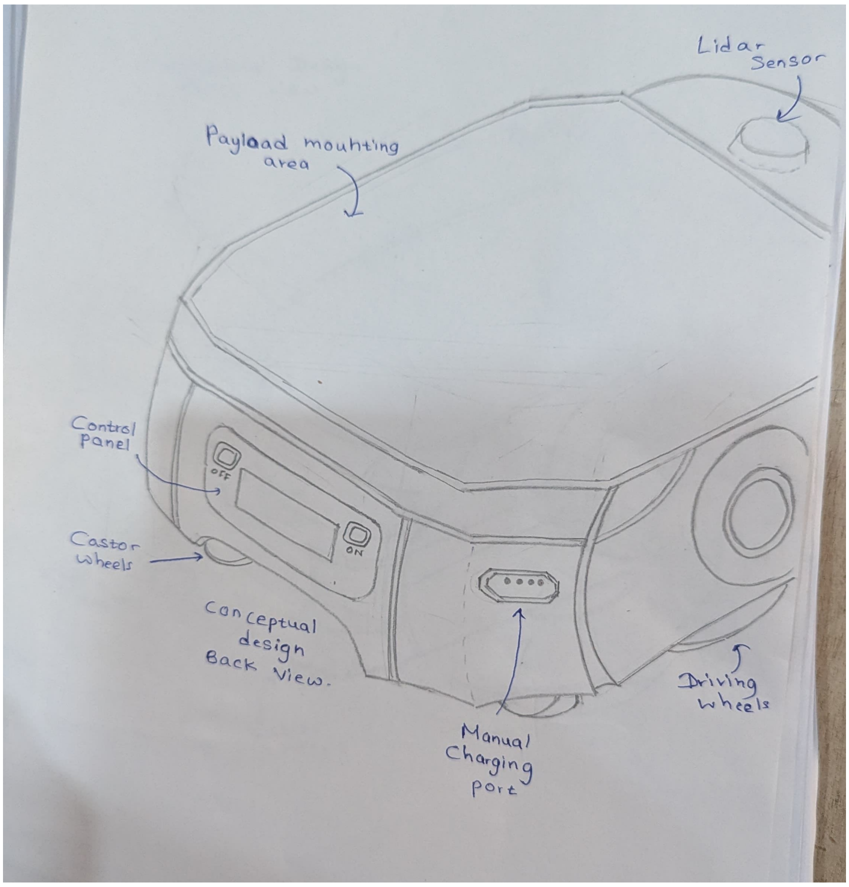

Figure 29: Rear View

9 Block Diagram

9.1 Initial Block Diagrams

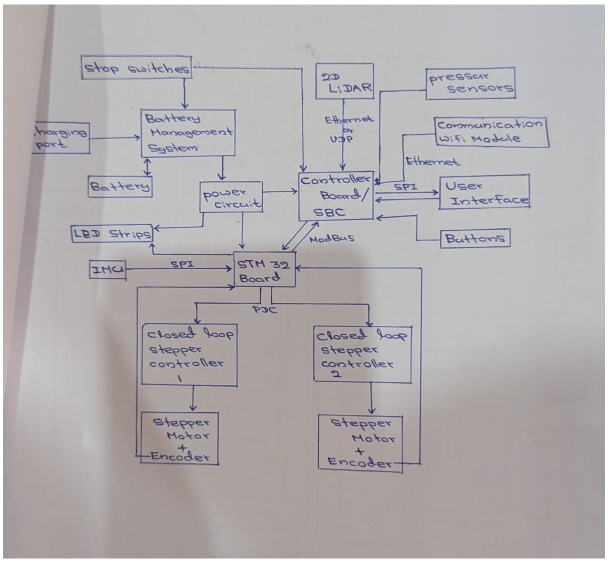

Figure 30: Iteration 1

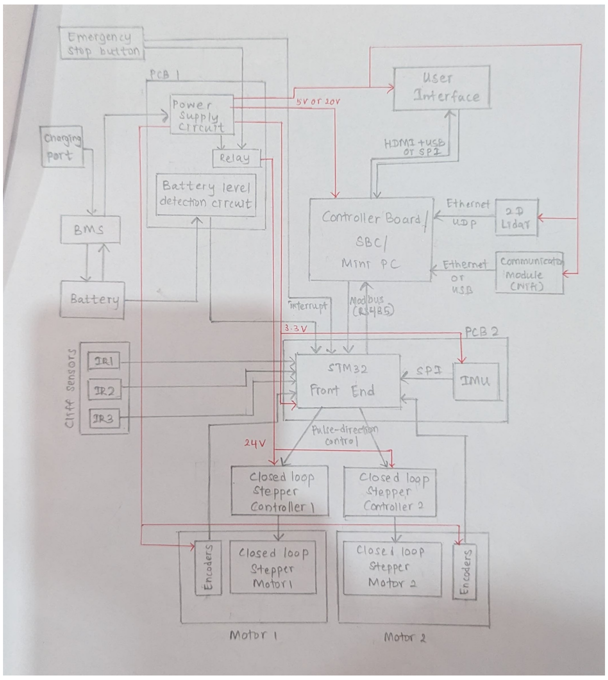

Figure 31: Iteration 2

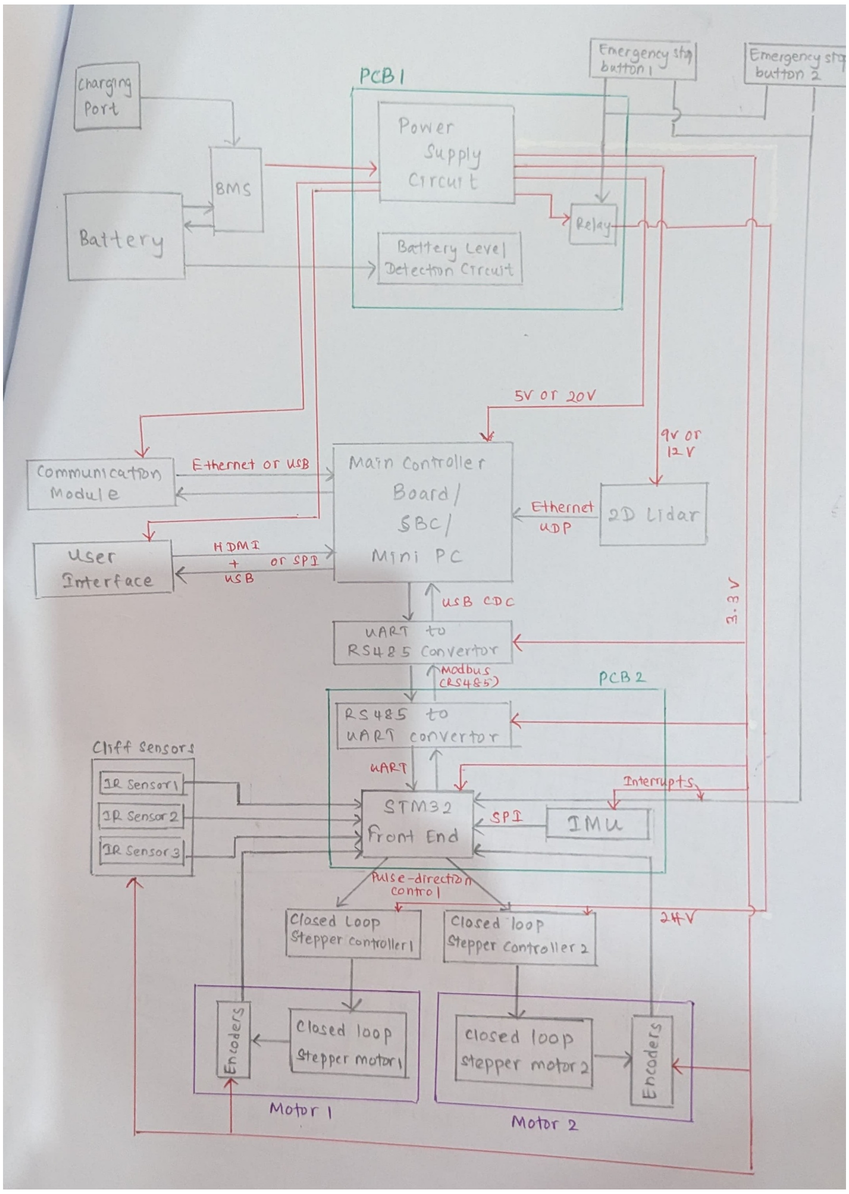

Figure 32: Iteration 3

9.2 Final Block Diagram

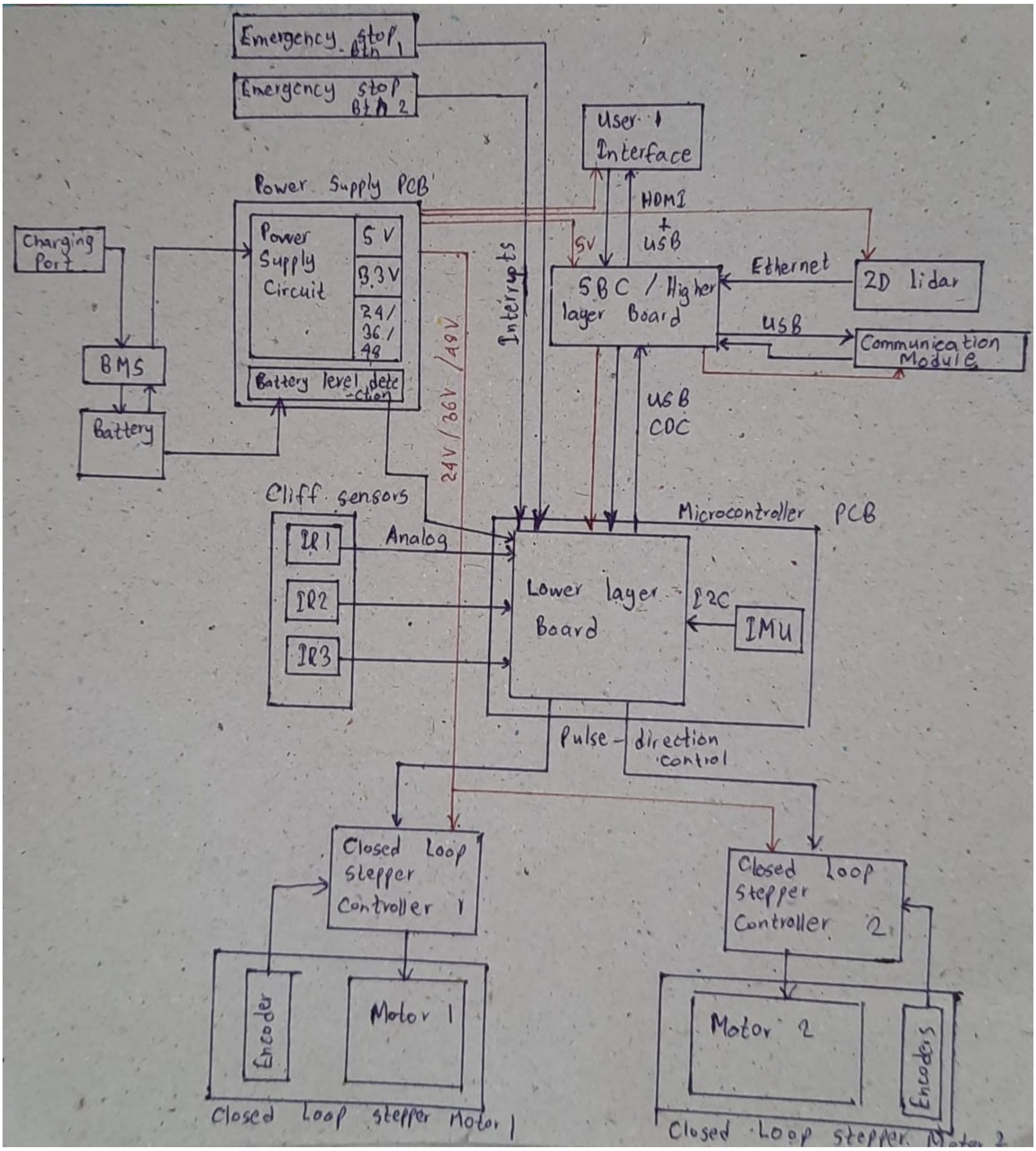

Figure 33: Final Block Diagram

10 Enclosure Design

The enclosure design of our Autonomous Mobile Robot (AMR) has been developed with a strong focus on both functional utility and aesthetic appeal, creating a solution that is not only practical and durable but also visually aligned with modern industrial and commercial expectations. The design achieves a seamless balance between performance and presentation, ensuring the robot can operate reliably in real-world environments while projecting a clean, professional image.

To ensure cost efficiency without compromising on strength and functionality, the structural framework of the robot is based on a lightweight skeleton made from aluminium bars. These aluminium extrusions form the core internal frame of the AMR and are chosen for their excellent strength-to-weight ratio, corrosion resistance, and ease of machining. Aluminium also offers versatility in design and allows for modular construction, enabling easier customization or expansion in future iterations. The frame provides sufficient rigidity to withstand dynamic loads, vibrations, and minor impacts encountered during typical navigation tasks.

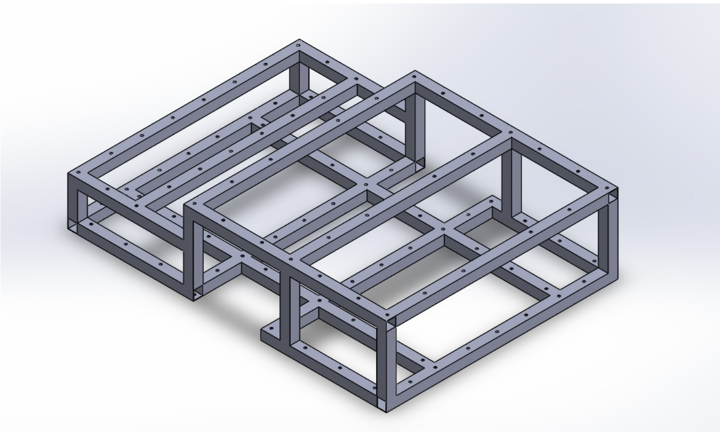

Figure 34: Metal Skeleton

The chassis is made from white steel. The use of steel in the chassis ensures structural stability and durability, capable of withstanding external forces and protecting sensitive electronics housed within the robot.

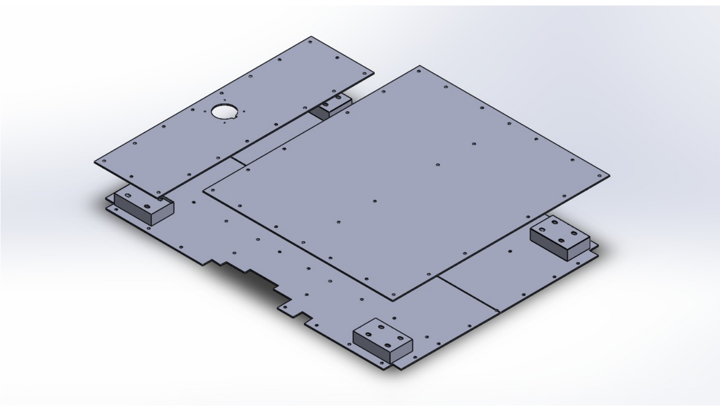

Figure 35: Steel Chassis

A defining feature of the enclosure is its external cover, also fabricated from white-coated steel, which serves several critical purposes. In addition to completing the robot's enclosed form and contributing to its professional aesthetic, this cover functions as the primary payload area. A dedicated mounting section is integrated into the top surface of the cover, enabling secure attachment of payloads or transport containers. The mounting platform is reinforced to handle variable loads while maintaining balance and stability, making the AMR adaptable to a wide range of use cases including material transport, delivery tasks, and modular tool systems. The removable top cover allow technicians to reach internal systems quickly without disassembling major structural elements.

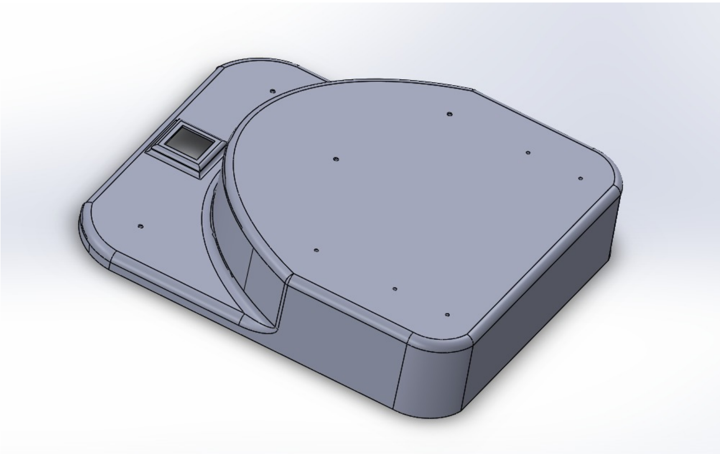

Figure 36: Steel External Cover

Our AMR robot features a differential drive system with two driving wheels positioned centrally on either side of the chassis. This central placement ensures balanced weight distribution and enables smooth rotation around the robot's axis, making it ideal for precise turning and maneuverability in narrow spaces. To support stability and maintain consistent ground contact, four caster wheels are placed at the front and rear corners. These passive wheels reduce tipping and help evenly distribute the robot's weight across the platform. This combination provides a stable yet agile design, ensuring both efficient mobility and the ability to handle varying floor conditions in indoor environments.

From a visual standpoint, the combination of polished aluminium edges, smooth white steel surfaces, and a clean geometric form factor gives the robot a sleek, high-tech appearance. This makes it suitable not only for industrial applications but also for customer-facing environments where design plays a role in user experience. The enclosure reflects attention to detail and engineering discipline, communicating both technological capability and aesthetic sensitivity.

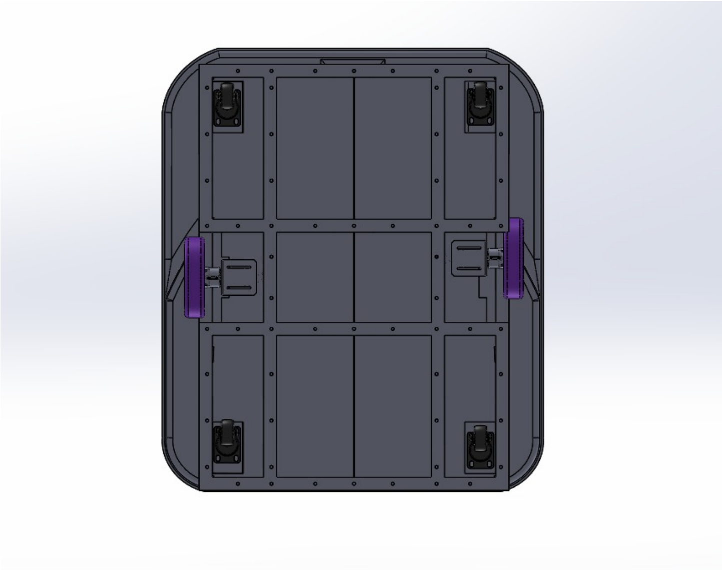

Figure 37: Wheel Placement

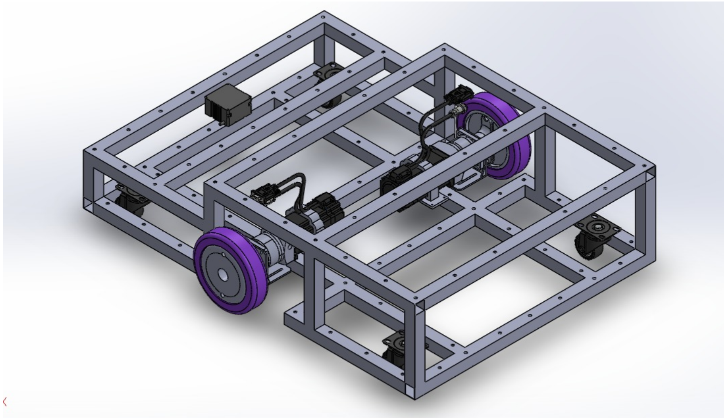

Figure 38: Placement of Motors and Wheels

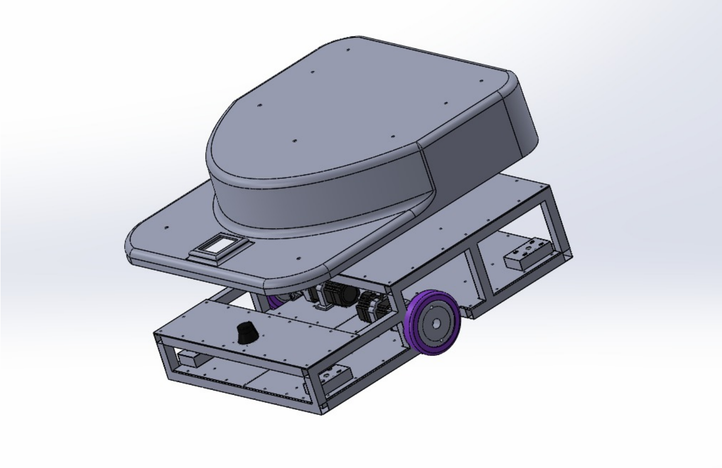

Figure 39: Side View

11 Schematic Design

11.1 Main Micro-controller Unit

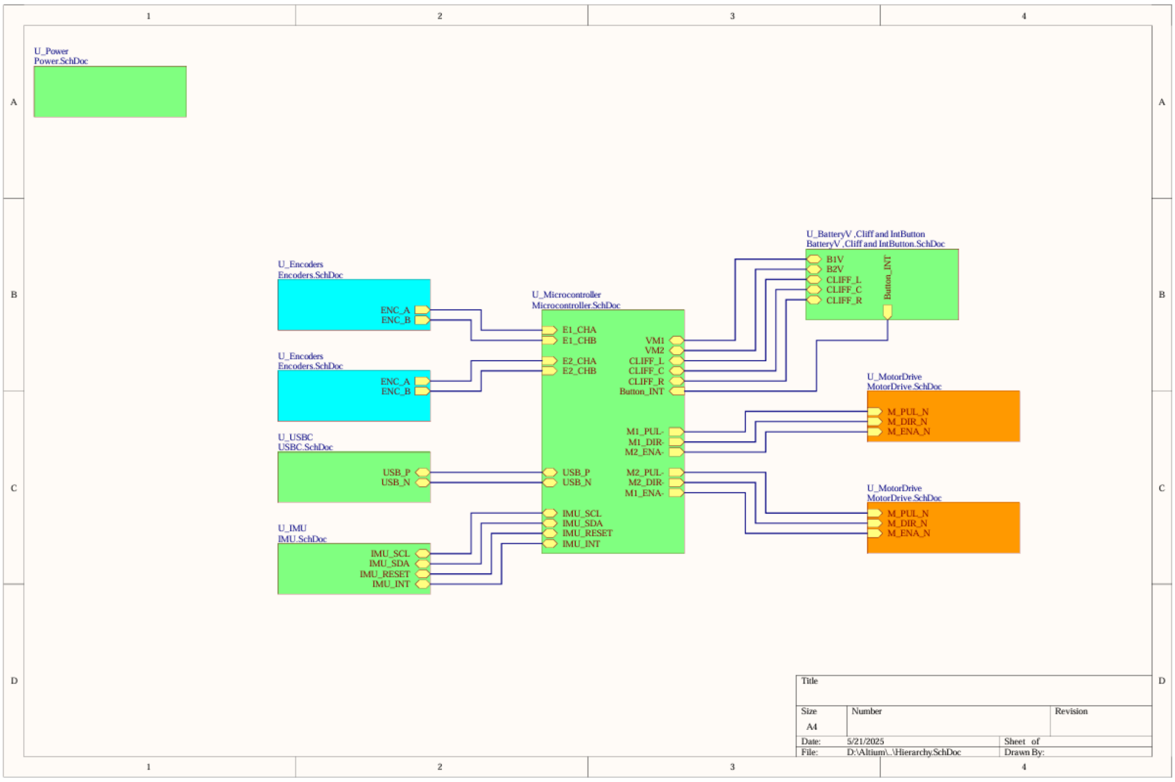

Figure 40: Hierarchical Design

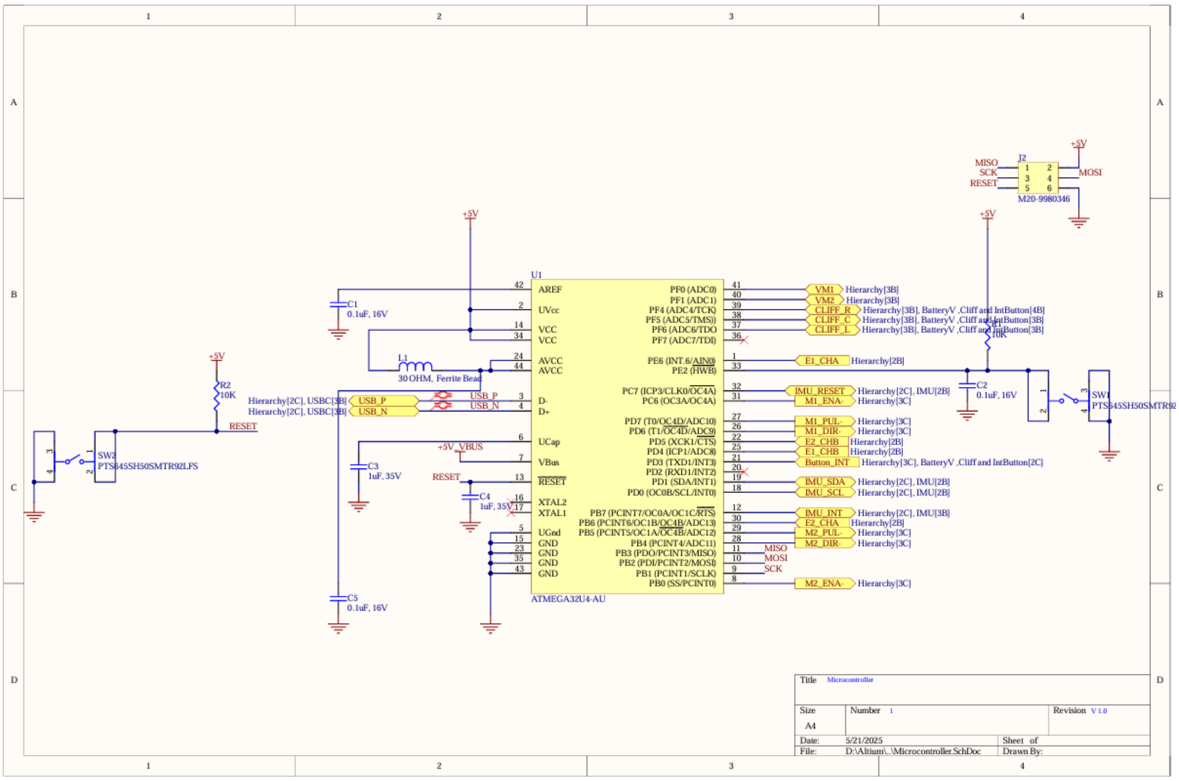

Figure 41: Micro-controller

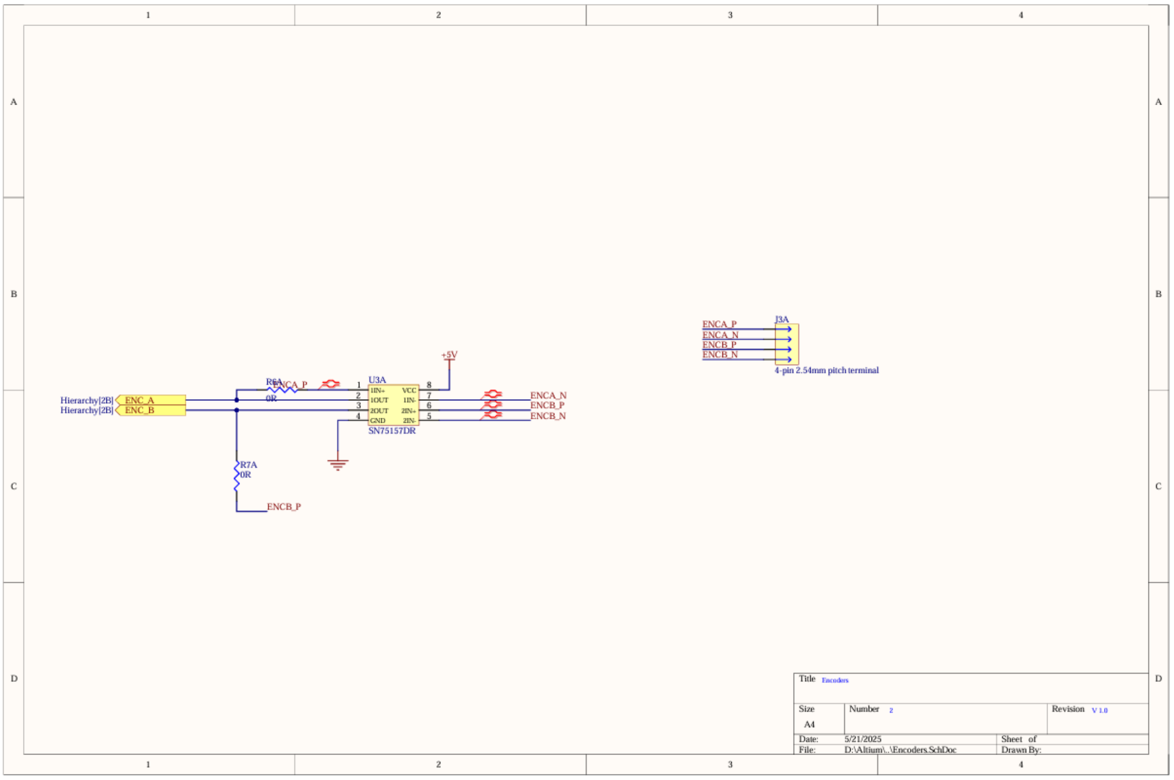

Figure 42: Encoder 1

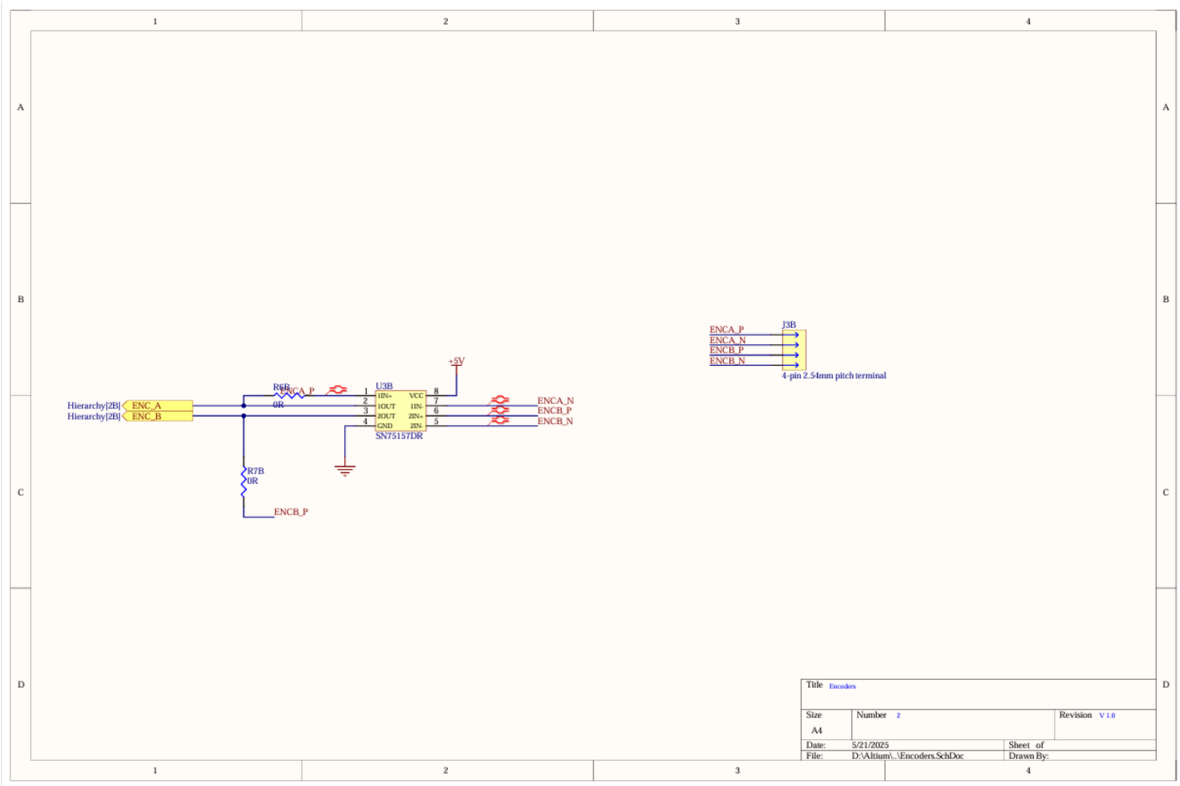

Figure 43: Encoder 2

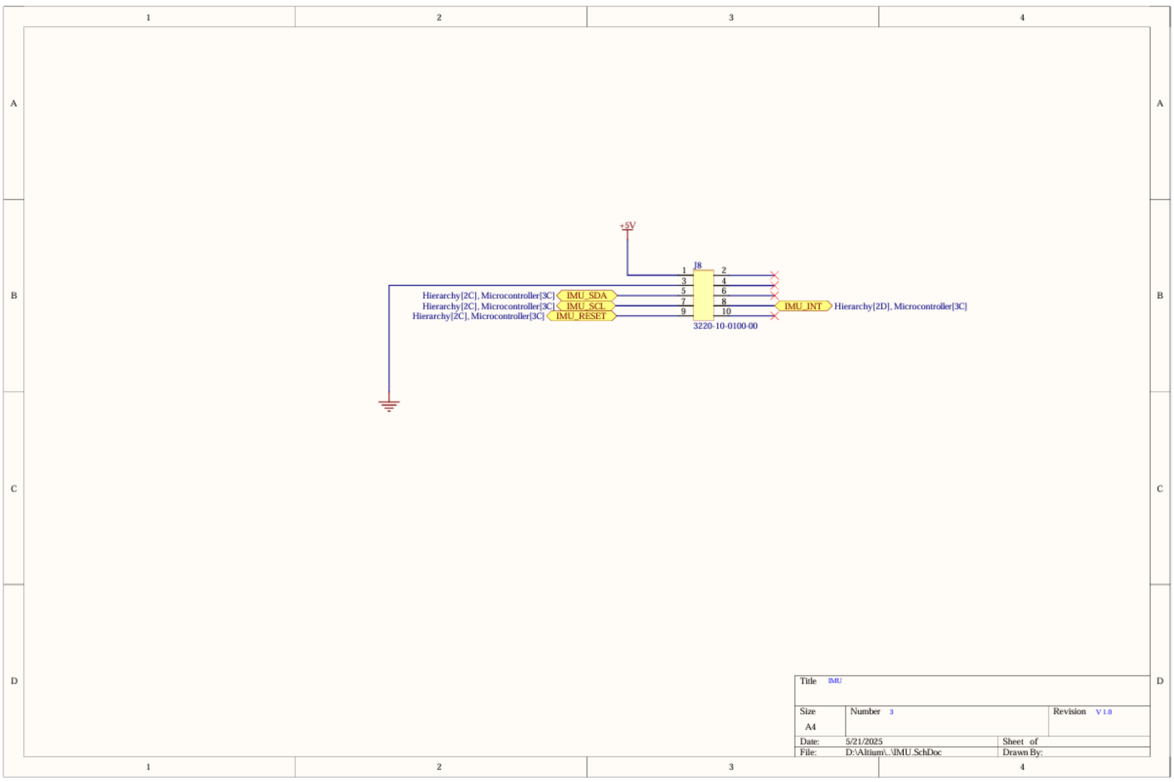

Figure 44: IMU

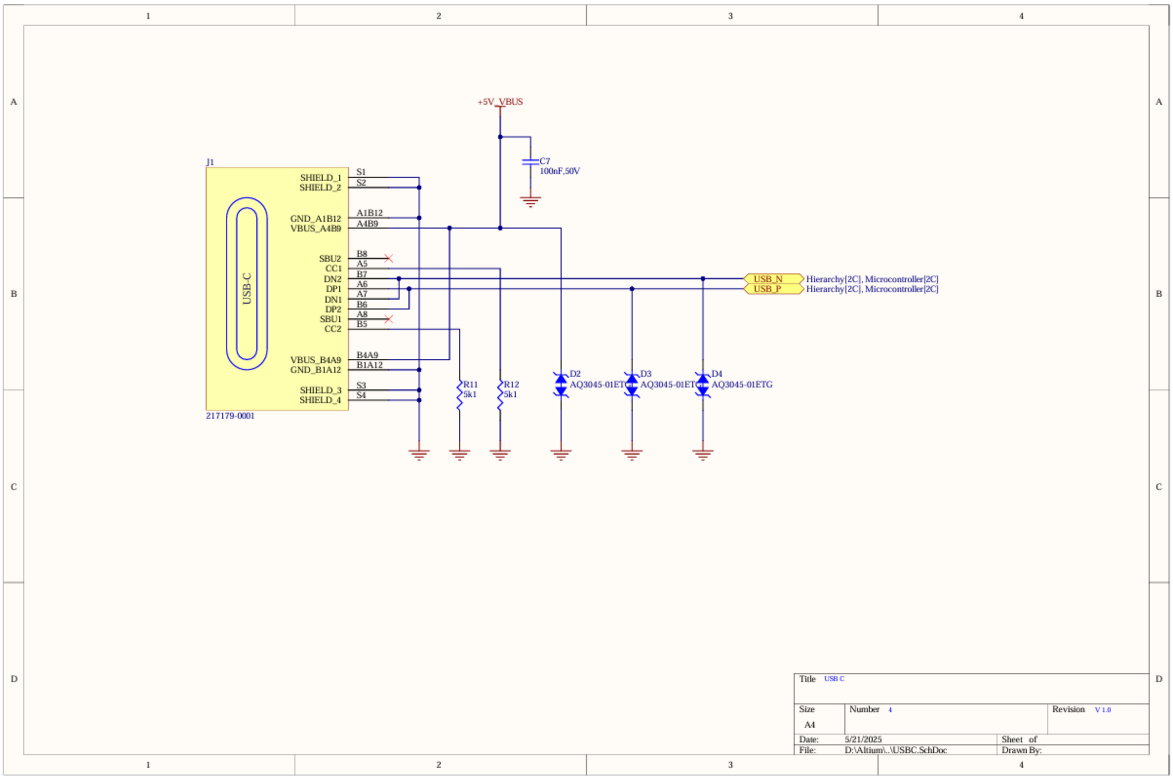

Figure 45: USB-C

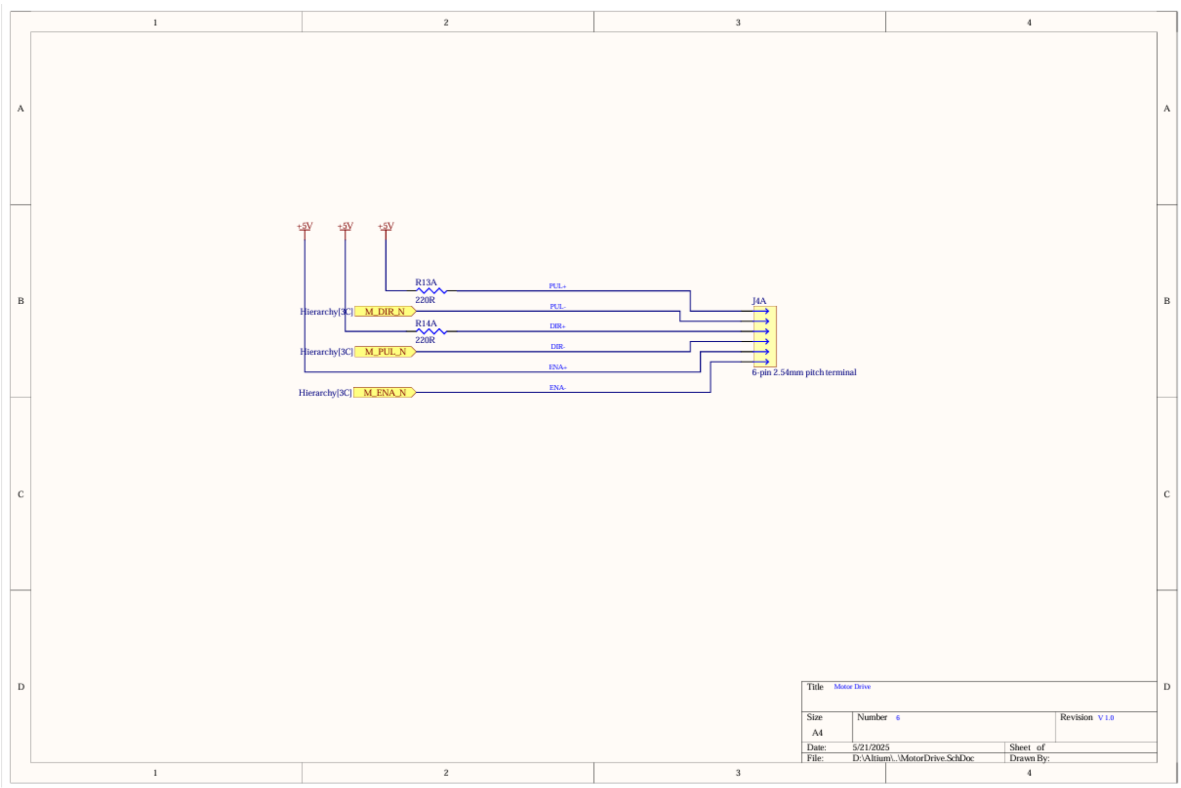

Figure 46: Motor Driver 1

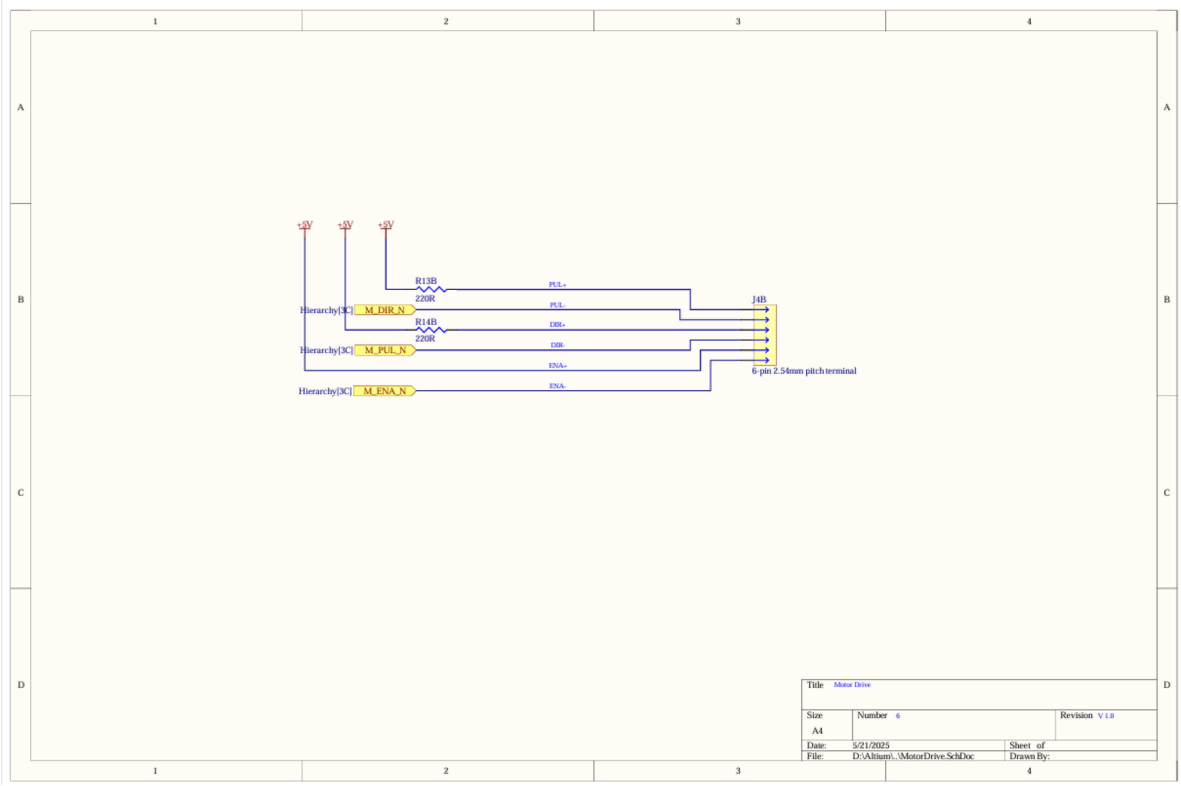

Figure 47: Motor Driver 2

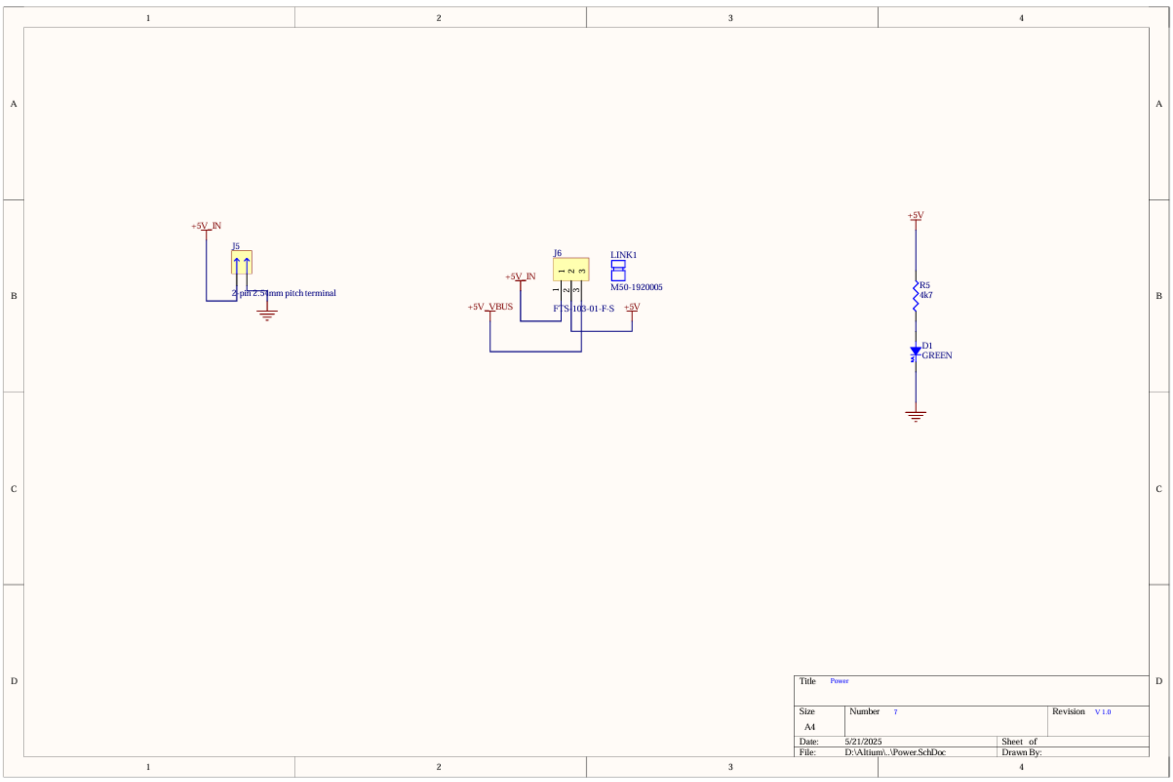

Figure 48: Power

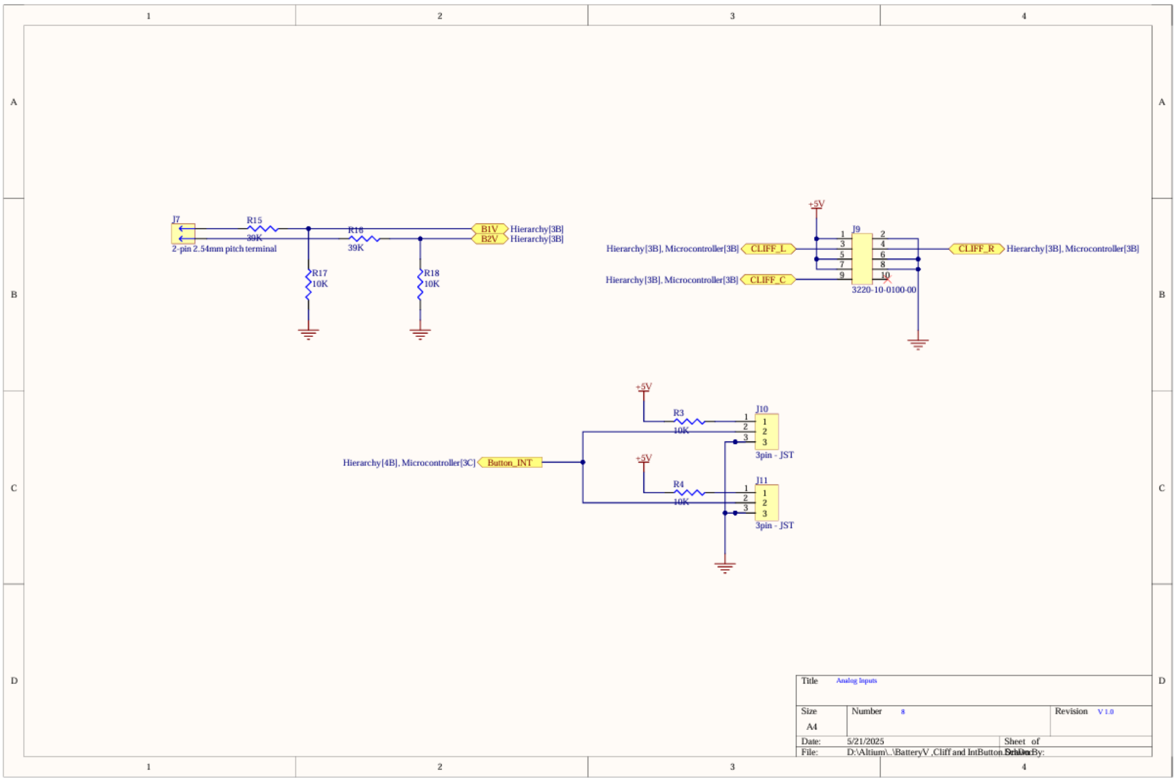

Figure 49: Analog Inputs

11.2 Power Circuit

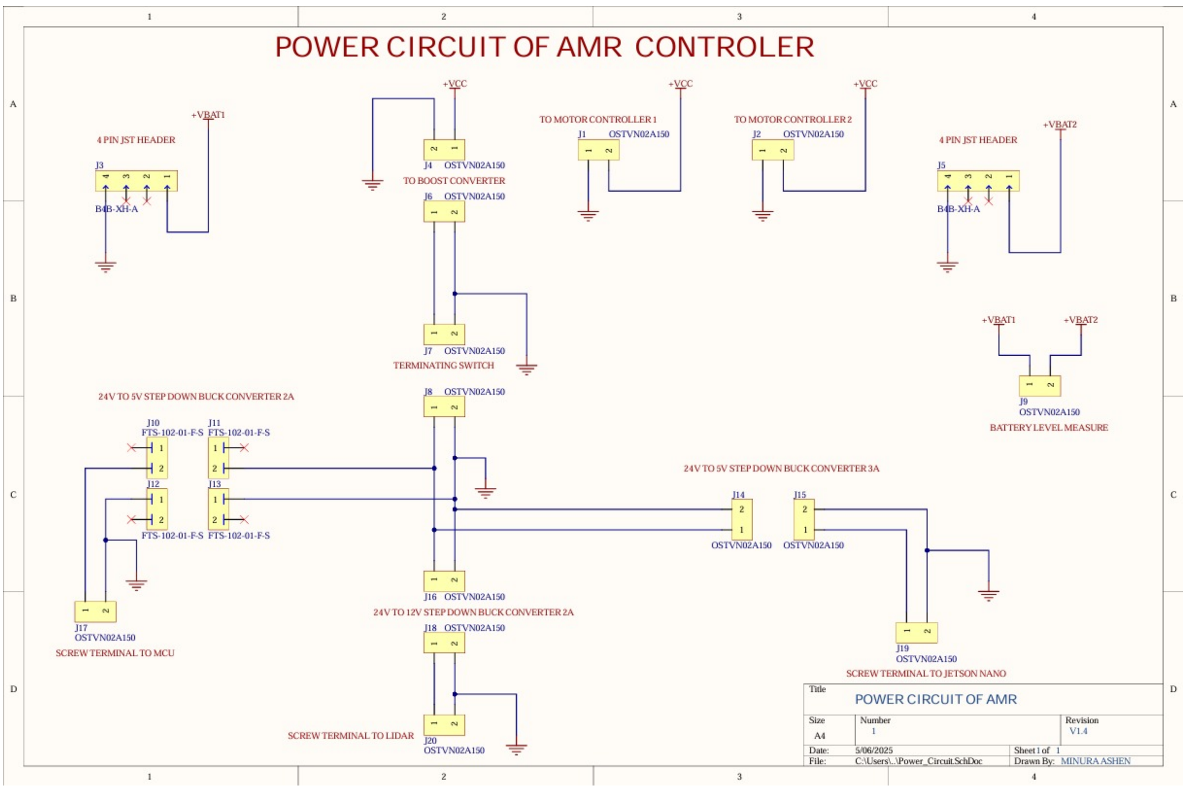

Figure 50: Power Circuit

All power for the control electronics and drive motors is derived from a single 24 V battery input on the PCB. From this bus, a boost converter raises the voltage to 36–40 V and distributes it to each motor driver. Concurrently, a dedicated buck regulator steps the 24 V down to 5 V to power the Jetson Nano, and that same 5 V rail is further tapped off and regulated down for the microcontroller unit. In a separate branch, a second buck converter drops the 24 V to 12 V to feed the LiDAR sensor.

11.3 Buffer Circuit

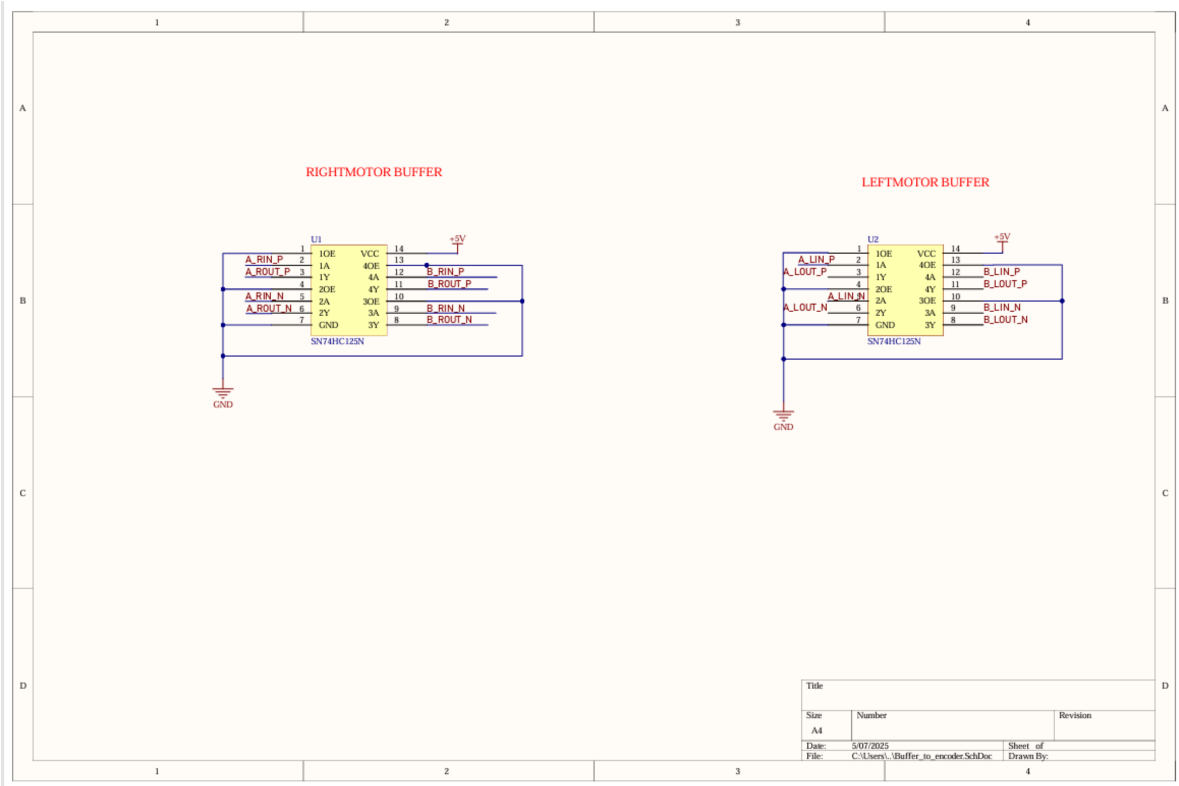

Figure 51: Buffer Circuit

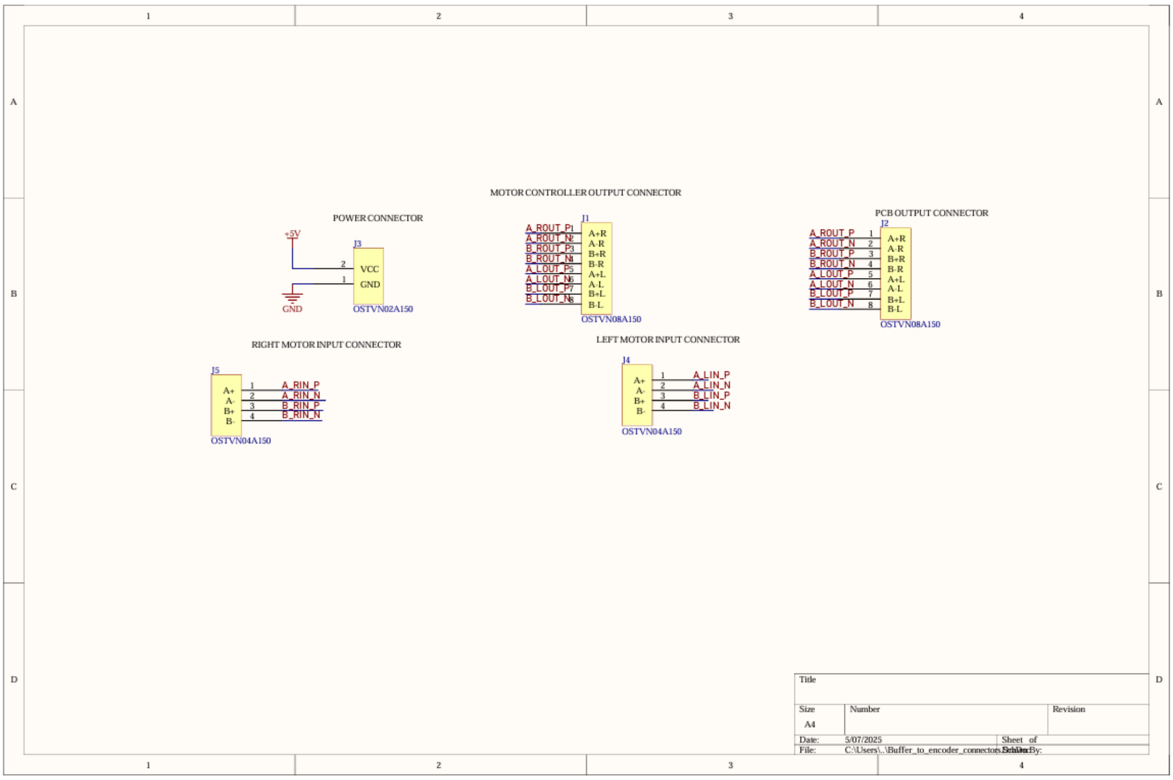

Figure 52: Buffer Circuit

11.4 IMU Circuit

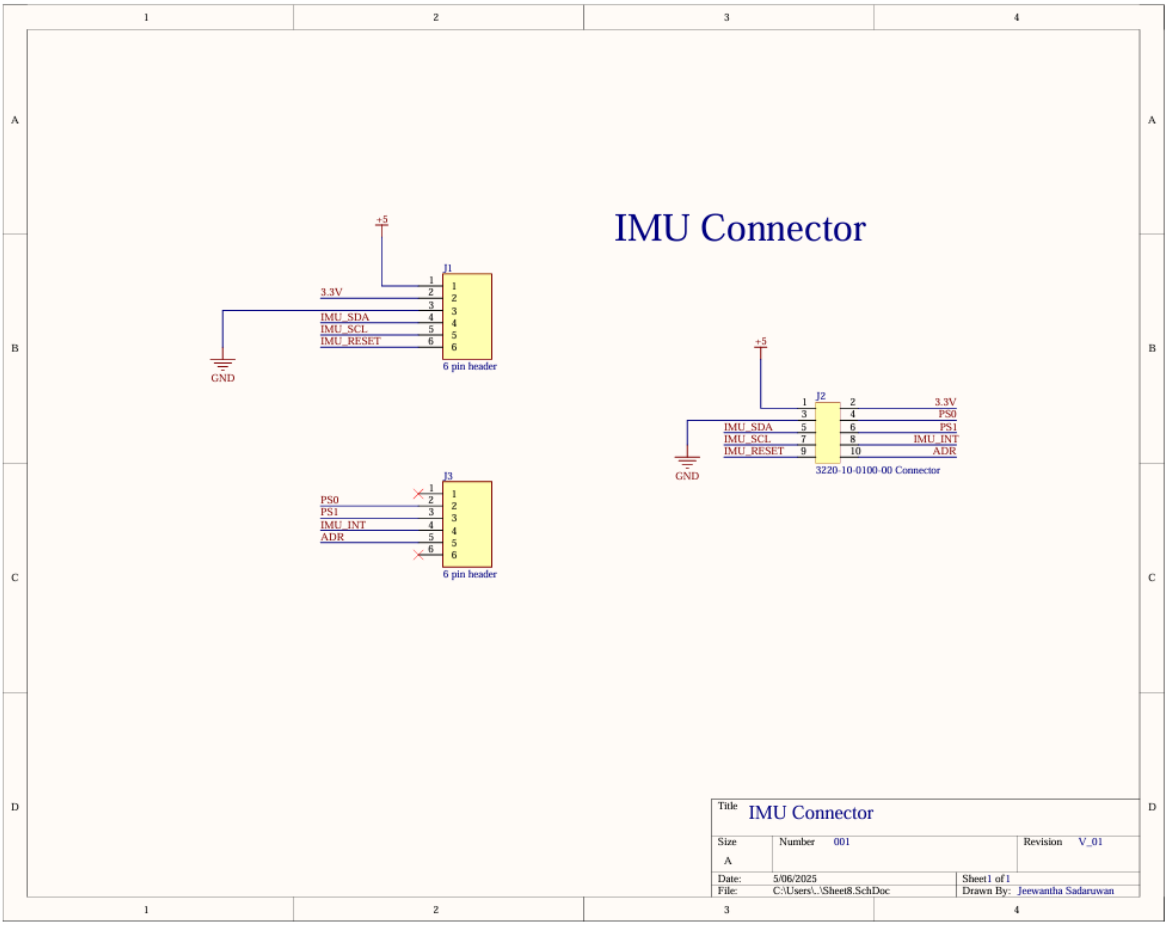

Figure 53: IMU Connector

12 PCB Design

12.1 Main PCB

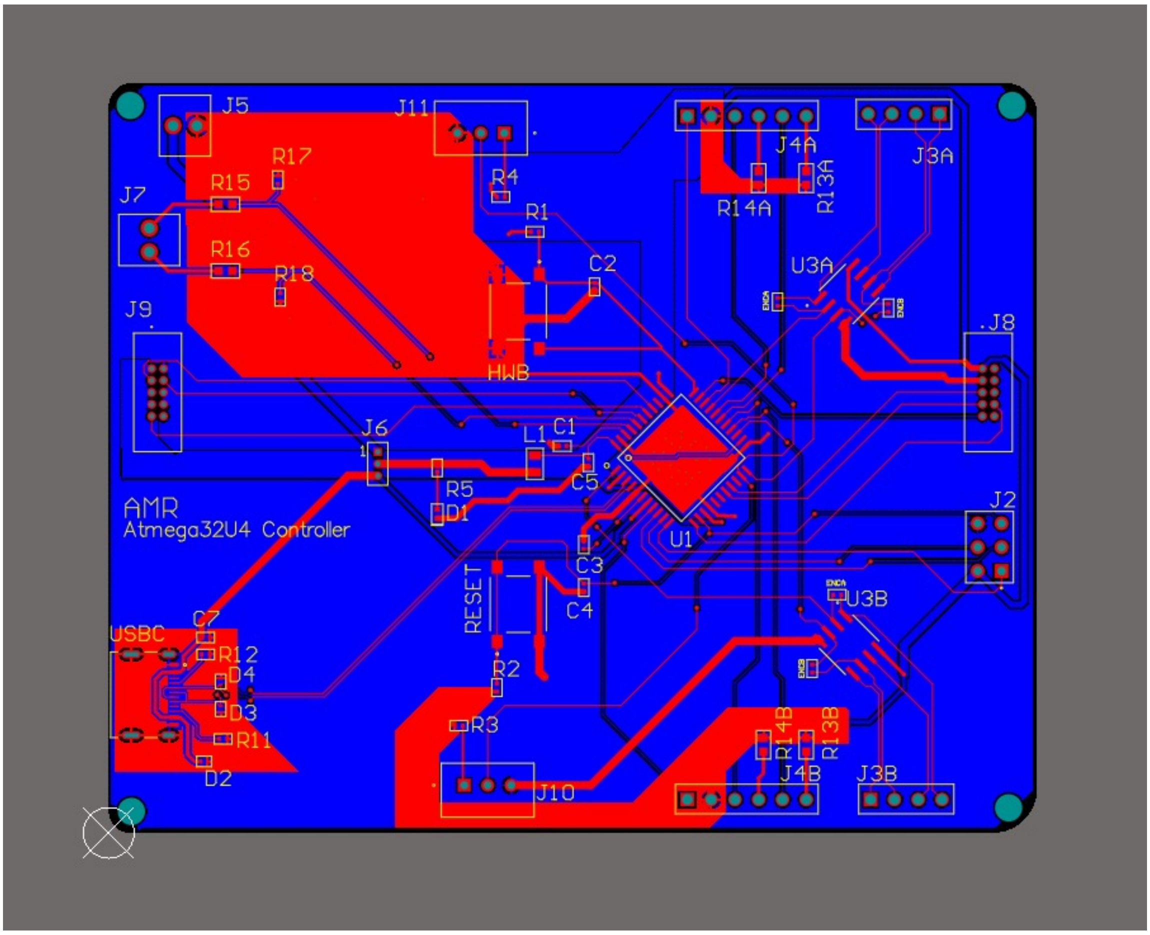

Figure 54: Main PCB Design

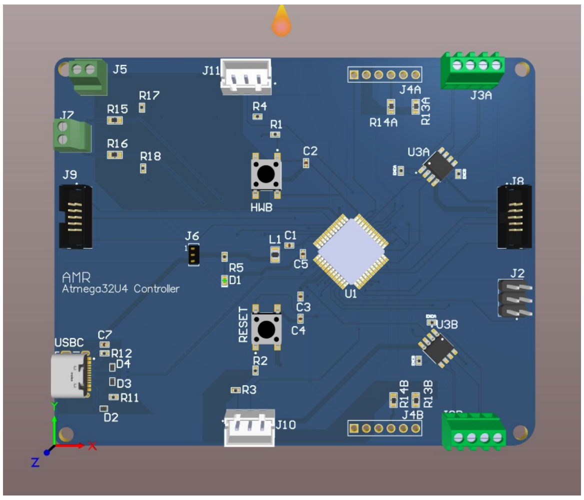

Figure 55: 3D Model Top View

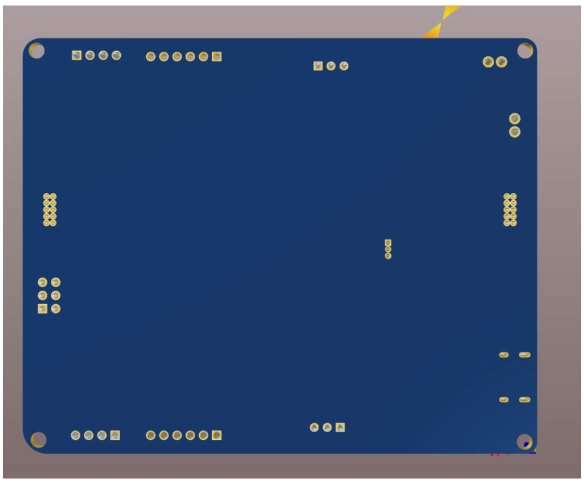

Figure 56: 3D Model Bottom View

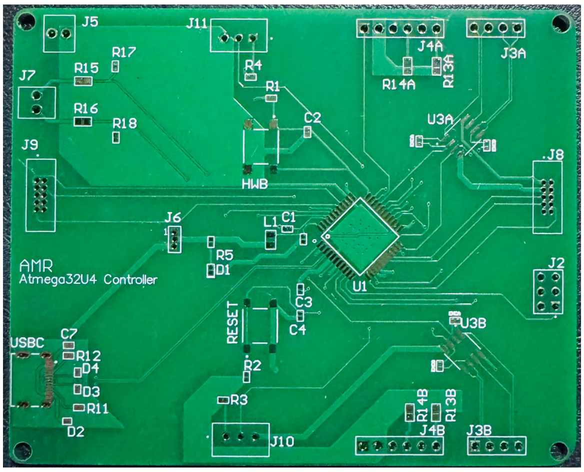

Figure 57: Bare PCB

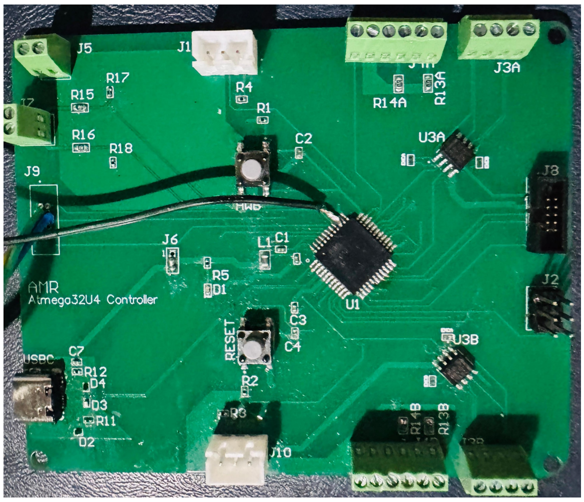

Figure 58: Soldered PCB

12.2 Power PCB

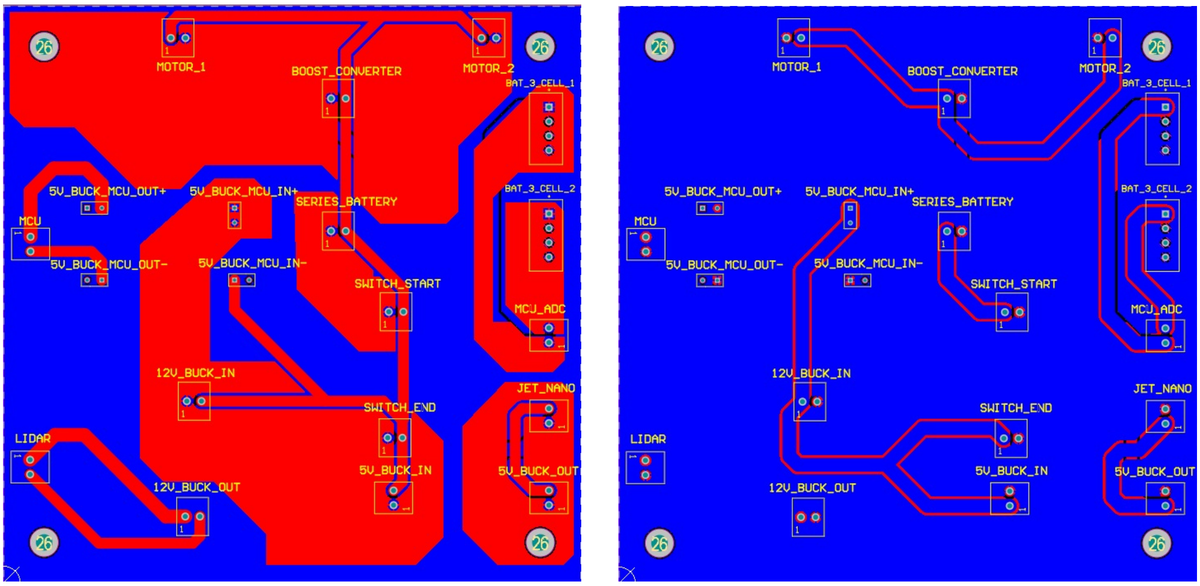

Figure 59: PCB Design

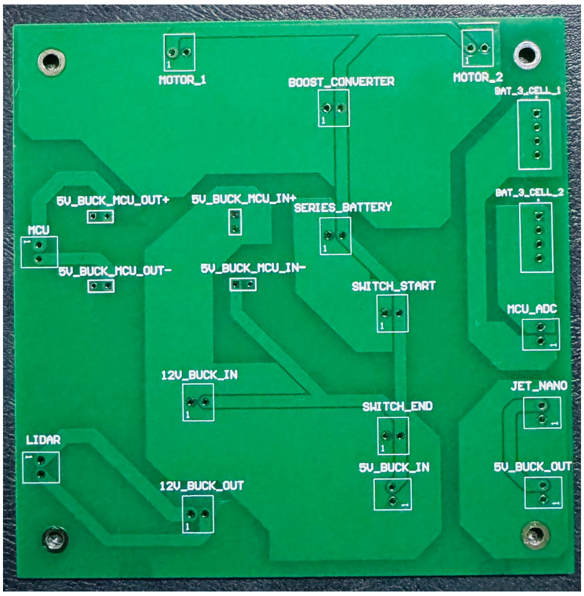

Figure 60: Bare PCB

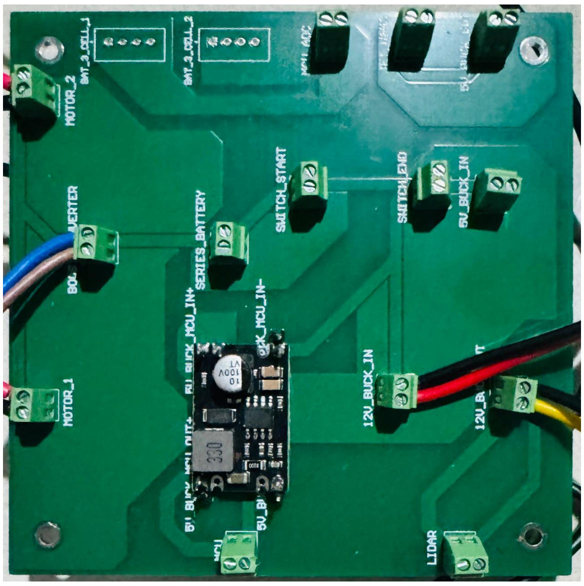

Figure 61: Soldered PCB

12.3 Buffer PCB

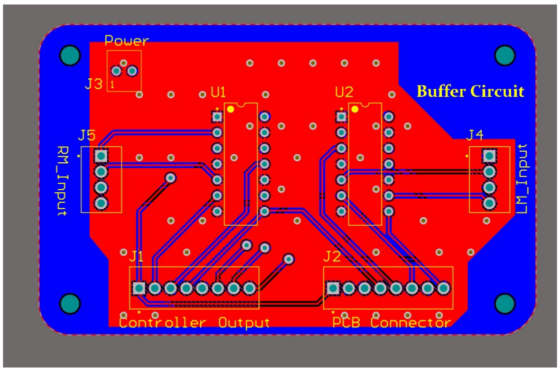

Figure 62: PCB Design

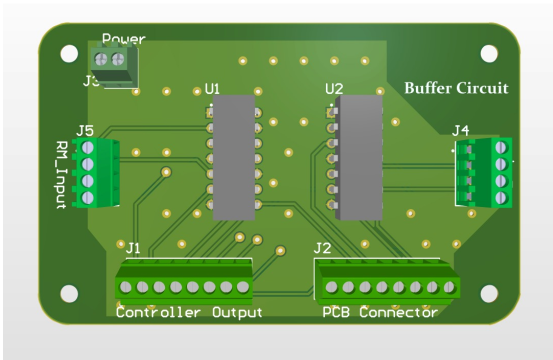

Figure 63: 3D Model

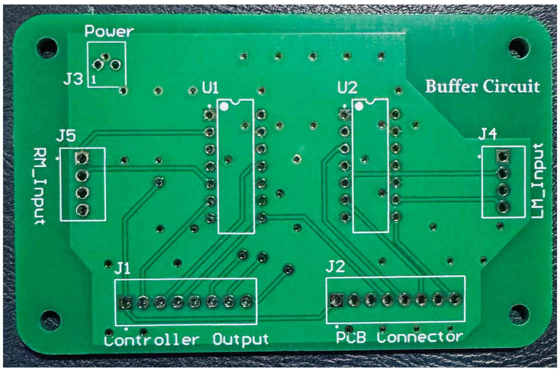

Figure 64: Bare PCB

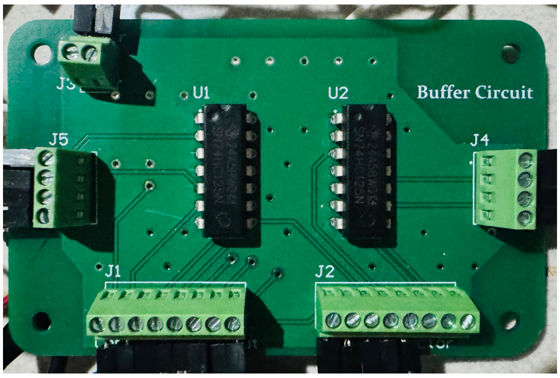

Figure 65: Soldered PCB

12.4 IMU Module PCB

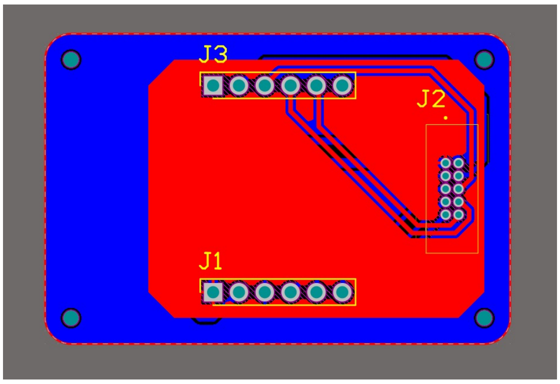

Figure 66: PCB Design

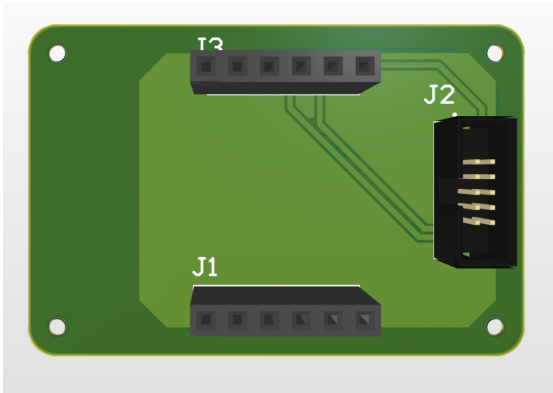

Figure 67: 3D Model

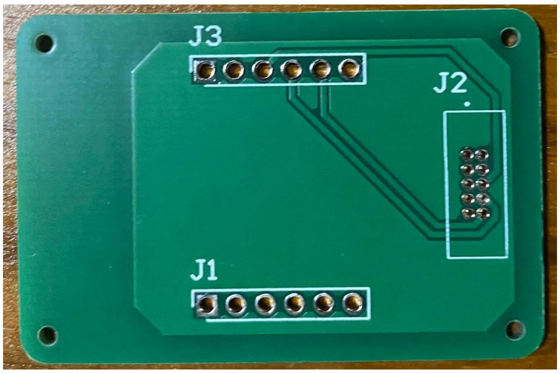

Figure 68: Bare PCB

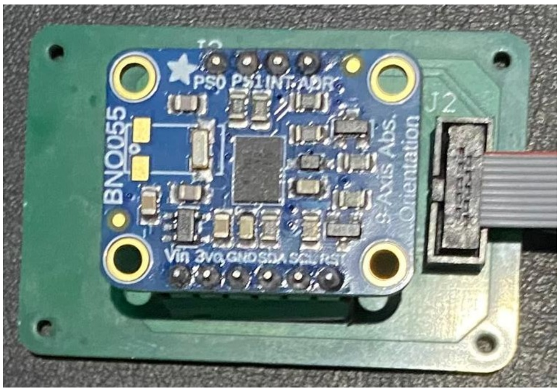

Figure 69: Soldered PCB

13 Safety Compliance

All operational zones around the robot are continuously monitored for hazards by integrated cliff sensors along the chassis front, which immediately halt motion if an unexpected drop is detected. In addition, large, easy-access emergency-stop buttons are mounted on both the sides, providing operators with an instant manual override to cut power to all drive and control systems. These redundant safety features ensure rapid cessation of movement in critical situations and compliance with ISO 13482 requirements for industrial mobile robots.

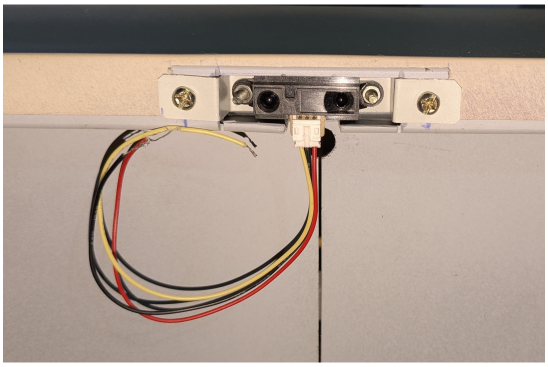

Figure 70: Cliff sensor placement

Figure 71: Emergency Stop Buttons

14 Final Product

14.1 Mechanical Assembly and Enclosure

We began by constructing the skeleton of the AMR from aluminum bars, forming a rigid frame to support all subsequent components. The motor and gearbox mounting points were integrated into this frame with additional metal supports.

Next, zinc–aluminium coated metal sheets were attached to form the enclosure walls. Pillar filler was applied to seams and joints to ensure smooth surfaces prior to painting.

Figure 72: Skeleton frame constructed from aluminum bars.

14.2 Functional Component Placement

The two NEMA-24 stepper motors and planetary gearboxes were assembled and mounted via precision brackets, ensuring wheel alignment. A rigid coupler joins each motor shaft to its driving wheel hub.

Height-adjustable caster wheels at each corner maintain a level platform and allow fine-tuning of ground clearance.

Underneath the frame two cliff sensors were mounted on a dedicated cross-bar, providing reliable obstacle detection.

14.3 Integration of Electrical and Mechanical Systems

A SolidWorks-designed enclosure houses the power PCB and NVIDIA Jetson Nano. Adjacent to this, the battery compartment was fabricated and secured within the chassis. All wiring harnesses are routed through protective channels.

Figure 73: Structure after applying pillar

Figure 74: Structure after painting

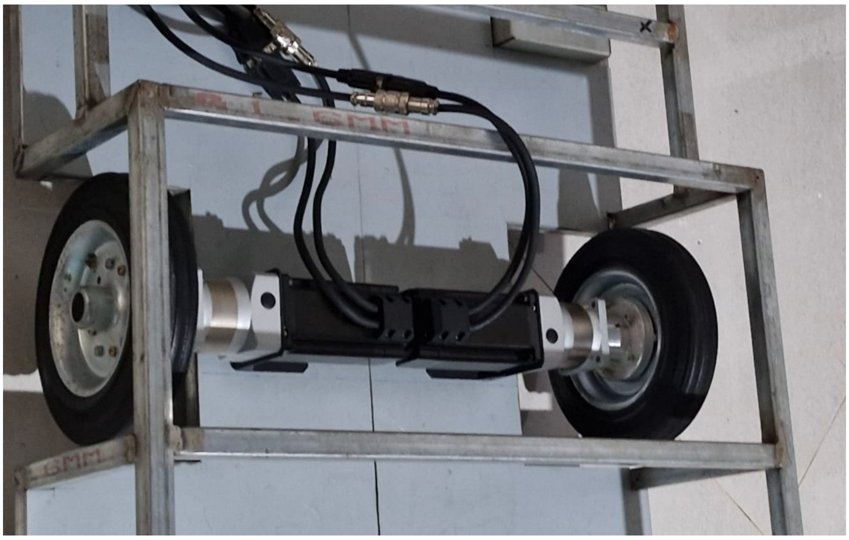

Figure 75: Motors, gearboxes and wheel placement.

Emergency stop buttons were integrated into the side panels via precision cutouts. A cutout for the touchscreen display ensures operator access.

LIDAR and Wi-Fi modules are mounted on the top deck, each with bespoke brackets matching their footprint.

14.4 Maintenance and Serviceability Features

All key components—motors, gearbox, electronics, and sensors—are accessible through removable panels. Quick-release fasteners are used at five main access points, minimizing downtime for inspections and repairs.

Figure 76: Driving wheel with shaft coupler.

Figure 77: Adjustable-height caster wheel

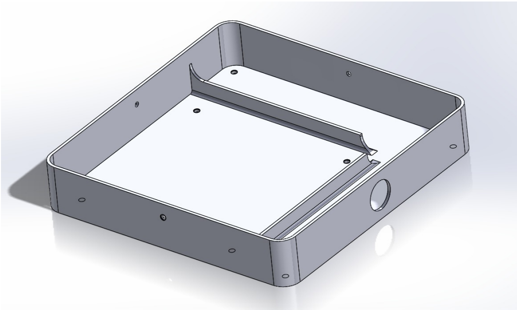

Figure 78: Power PCB Enclosure Bottom

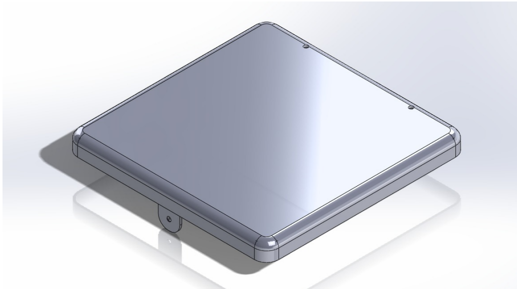

Figure 79: Power PCB Enclosure Lid

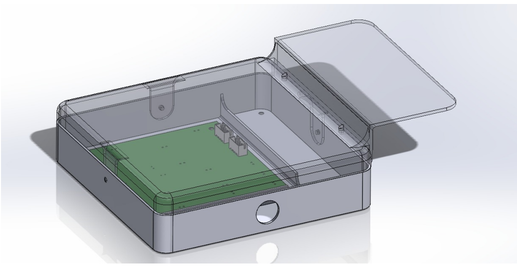

Figure 80: Power PCB Enclosure Assembly

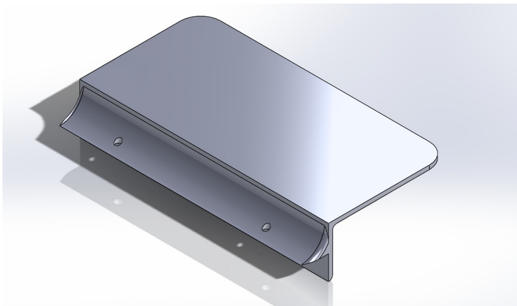

Figure 81: Battery Compartment

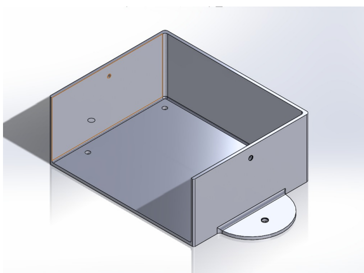

Figure 82: Jetson Nano Enclosure Bottom

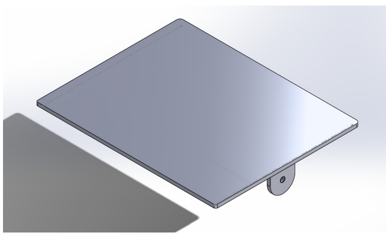

Figure 83: Jetson Nano Enclosure Top

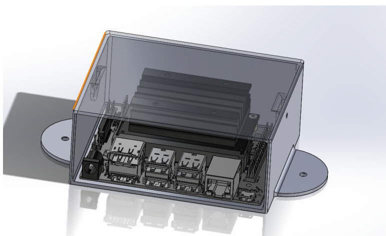

Figure 84: Jetson Nano Enclosure Assembly

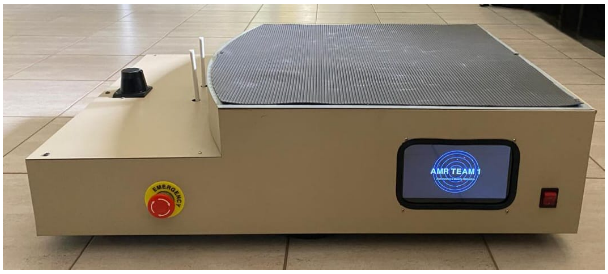

Figure 85: Side Panels

Figure 86: LIDAR and Wi-Fi module assembly

Figure 87: Completed AMR: fully assembled and ready for deployment.

15 Conclusion

The development of a cost-effective Autonomous Mobile Robot (AMR) tailored for structured indoor environments has been approached through a comprehensive design and evaluation process. By analyzing existing market solutions such as Omron, MiR, and Geek+, key features and industry standards were identified and used to inform our design decisions. A reference model was selected to align with the project's goals of functionality, scalability, and affordability.

Component selection was driven by performance requirements and practical constraints, ensuring that each subsystem—from the microcontroller and single-board computer to the LiDAR sensor, motor drive system, and communication modules—contributes effectively to the overall operation of the robot. Emphasis was placed on selecting components that are not only compatible but also readily available and cost-efficient.

The design process incorporated stakeholder feedback, user observations, and a detailed need analysis to ensure that the final concept meets real-world demands. Conceptual designs and finalized block diagrams laid the groundwork for physical development, while careful consideration of power management and mechanical integration ensures operational reliability.

In conclusion, this report outlines a solid foundation for implementing a fully functional AMR. The structured design approach, component integration strategy, and modularity of the system allow for future enhancements and customizations, positioning the robot as a viable solution for material transport and navigation tasks in controlled indoor environments.