Project informations

Block: Robot HW
Person responsible for this block:
eng. Bazan Michal

Table of contents

Change sheet

Date	Description
02/21/2024	Basic info, glossary, requiremets, requirement analysis and design.
03/04/2024	Peripherial needs summary.
03/05/2024	Schematic description regarding REV 0.1, updated glossary.
03/05/2024	Edit figures (REV 0.1 → 0.2).
03/06/2024	Edit figures, add section regarding debouncing encoders (REV 0.2 → 0.3), updated glossary.
03/08/2024	Edif figures, add section regarding level shifting (REV 0.3 → 0.4), remove debouncing section. Add pullups to encoders, (REV 0.4 → REV 0.5), add new component to reference section.
03/11/2024	Edit figures due to small change in power section (REV 1.0 → 1.1).

Glossary

MCU – Master Control Unit

IMU – Inertial Measurement Unit

Debouncing – removing unwanted input noise.

Analysis of the technical state of art, review of the knowledge analysis

Creating a riding robot with sensors involves integrating various technologies and components to achieve stable locomotion and effective sensing capabilities. Here's an analysis of the technical state of the art and a review of knowledge related to this endeavor:

a) **Hardware Components**:

- **Actuators**: Utilizing advanced actuators like brushless DC motors or servo motors can provide precise control over movement.
- **Sensors**: Incorporating a variety of sensors such as gyroscopes, accelerometers, encoders, and proximity sensors enables the robot to gather data about its surroundings and maintain balance.
- **Microcontrollers**: Advanced microcontrollers like Arduino or Raspberry Pi offer the computational power needed for sensor data processing and motor control.
- **Power Supply**: Efficient power management systems, such as lithium-ion batteries or fuel cells, are crucial for prolonged operation.

b) **Locomotion Mechanisms**:

- **Wheeled**: Wheeled locomotion is common due to its simplicity and stability. Differential drive or omnidirectional wheels can provide maneuverability.
- **Legged**: Legged locomotion offers advantages in traversing uneven terrain but requires more complex control algorithms and mechanisms.
- **Hybrid**: Some designs combine wheels with legs or tracks to balance stability and versatility.

c) **Control Systems**:

- **PID Control**: Proportional-Integral-Derivative control loops are commonly used for maintaining balance and controlling movement based on sensor feedback.
- **Machine Learning**: Advanced control strategies involving machine learning techniques like reinforcement learning or neural networks can optimize control in dynamic environments.

d) **Sensor Integration and Fusion**:

- **Sensor Fusion**: Combining data from multiple sensors enhances the robot's perception accuracy and reliability.
- **Environment Mapping**: Techniques like Simultaneous Localization and Mapping (SLAM) enable the robot to create maps of its surroundings for navigation.
- **Obstacle Detection**: Sensors like LiDAR, ultrasonic sensors, or cameras aid in detecting obstacles and planning collision-free paths.

e) **Safety and Redundancy**:

- **Fault Tolerance**: Implementing redundancy in critical components and fail-safe mechanisms ensures the robot can handle unforeseen situations.

- **Emergency Stop**: Incorporating emergency stop mechanisms based on sensor inputs or manual intervention prevents accidents and damage to the robot or its surroundings.

f) **Wireless Communication**:

- **Remote Control**: Providing wireless control interfaces allows operators to monitor the robot's status and intervene if necessary.
- **Data Transmission**: Wireless communication protocols facilitate real-time data transmission between the robot and external devices for telemetry and control purposes.

g) **Human-Machine Interaction**:

- **User Interface**: Designing intuitive user interfaces for controlling and monitoring the robot simplifies operation for end-users.
- **Feedback Mechanisms**: Incorporating feedback mechanisms like haptic feedback or visual indicators enhances user experience and situational awareness.

Requirements regarding the project

In this chapter, we will look into the hardware requirements and implementation details for our project. The project aims to incorporate various components including Inertial Measurement Unit (IMU), distance sensors, WiFi interface, DC motors with encoders, DC motor drivers, and a power management system. Each of these components plays a crucial role in the functionality and performance of the system.

Inertial Measurement Unit (IMU)

The IMU serves as a vital sensor in our project, providing information about the device's orientation, acceleration, and angular velocity. The IMU typically consists of accelerometers, gyroscopes, and magnetometers integrated into a single unit. These sensors enable the device to detect changes in motion, orientation, and magnetic fields. The IMU's data will be utilized for tasks such as motion tracking, gesture recognition, and stabilization.

Distance Sensors

Distance sensors are essential for detecting obstacles and measuring distances within the environment. They utilize various techniques such as ultrasonic, infrared, or laser-based technologies to determine the distance between the sensor and nearby objects. This information is crucial for navigation and obstacle avoidance tasks. The integration of distance sensors enhances the safety and autonomy of the device.

WiFi Interface

The inclusion of a WiFi interface enables wireless communication between the device and external systems such as smartphones, computers, or cloud services. It facilitates data exchange, remote control, and firmware updates over a local network or the internet. The WiFi interface allows for seamless integration with other smart devices and enables remote monitoring and management capabilities.

DC Motors with Encoders

DC motors with encoders provide precise control over the motor's rotation and speed. Encoders generate feedback signals that indicate the motor's position and velocity, allowing for closed-loop control and accurate motion control algorithms. These motors are commonly used in robotics applications for tasks such as propulsion, manipulation, and stabilization. The integration of DC motors with encoders enhances the device's mobility and agility.

DC Motor Drivers

DC motor drivers are electronic circuits that control the speed and direction of DC motors. They regulate the voltage and current supplied to the motors based on input commands from the microcontroller or sensor feedback signals. Motor drivers ensure efficient and reliable operation of the motors while protecting them from overcurrent, overvoltage, and thermal issues. Proper selection and configuration of motor drivers are crucial for achieving optimal performance and longevity of the motors.

Power Management System

The power management system is responsible for managing the device's power supply, distribution, and consumption. It includes components such as batteries, voltage regulators, and power monitoring circuits. The power management system ensures efficient utilization of energy resources, prolongs the device's battery life, and prevents unexpected shutdowns or damage due to power fluctuations. It plays a critical role in the overall reliability and endurance of the device.

Type of Verification: D - Design Review, A - Analysis, T - Test, N/A - not applicable

ID	OBJ_TEXT	Veryfication method
HWE_1_010	Hardware should use IMU and distance sensors in front and rear part of the robot.	D
HWE_1_020	Hardware should include WiFi interface for comm purposes.	D
HWE_1_030	Hardware should be equipped with DC motors.	D
HWE_1_040	Hardware should use encoders.	D
HWE_1_050	Hardware should use proper DC motor drivers.	D
HWE_1_060	Hardware should introduce simple power management system.	D T

Requirements regarding components

In developing the hardware for the robot, specific components are required to meet the functional and operational needs outlined in the project specifications. The following requirements detail the necessary components for the hardware implementation:

Type of Verification: D - Design Review, A - Analysis, T - Test, N/A - not applicable

ID	OBJ_TEXT	Veryfication method
HWE_2_010	All communication interfaces should support 3V3 logic.	D
HWE_2_020	MCU should be equipped with WiFi interface.	D
HWE_2_030	Power management system should provide power supply to logic part of the system	D T
HWE_2_040	Power management system should provide power supply to DC motors.	D T
HWE_2_050	IMU sensor should at least introduce the possibiliy of 6DOF measurement.	D
HWE_2_060	Distance sensors should introduce at least range of 2m.	D T
HWE_2_070	Distance sensors and IMU should provide comm interface to MCU.	D

Main component analysis

Component	Req_ID	Price	Parameters
ESP-WROOM-32E [1]	HWE_2_020 HWE_1_020	59.90	5V supply WiFi 802.11BGN HT40 Bluetooth module 38 GPIOs including: - 3 x UART, - 3 x SPI, - 2 x I2C, - ADC and DAC, - PWM Outputs, - SD card interface.
ESP8266 [2]	HWE_2_020 HWE_1_020	29.00	5V supply, WiFi support, 10 GPIOs including: - UART, - I2C, - PWM Outputs.
SJ01 120:1 6V 160RPM + encoder [3]	HWE_1_030 HWE_1_040	37.90	Supply: 4.5V – 7.5V Current: 170mA Engine gear: 120:1 Rotation speed: 160RPM
SJ02 120:1 6V 160RPM + encoder [4]	HWE_1_030 HWE_1_040	39.50	Supply: 3.0V – 7.5V Current: 170mA Engine gear: 120:1 Rotation speed: 160RPM
IMU 10DoF - MPU9255 [5]	HWE_1_010 HWE_2_050 HWE_2_070	185.00	Supply: 3.3V – 5.5V Comm: I2C DoF: 10
LSM6DS3TR-C 6-DoF [6]	HWE_1_010 HWE_2_050 HWE_2_070	61.90	Supply: 3V/5V Comm: I2C/SPI DoF: 6
HC-SR04 [7]	HWE_1_010 HWE_2_060 HWE_2_070	8.90	Supply: 5V Comm: GPIO (requires logic lever converter) Range: 2cm - 200cm
HY-SRF05 [8]	HWE_1_010 HWE_2_060 HWE_2_070	11.90	Supply: 5V Comm: GPIO (requires logic lever converter) Range: 2cm - 400cm
WB291111 [9]	HWE_1_050	19.90	Logic supply: 5V Load supply: 5V – 46V Imax: 2A Channels: 2
18650 Li-ion Samsung INR18650-25R [10]	HWE_1_060	21.90	Supply: 3.7V Imax: 20A Capacity: 2500mAh
18650 Li-Ion INR18650-F1HR	HWE_1_060	22.90	Supply: 3.6V Imax: 20A Capacity: 2600mAh

Port	Ext. Device	Count
I2C	IMU	1
GPIO Int	Encoder	4
GPIO Input	Distance meter	4
GPIO Output	Distance meter	4
	Motor Driver	4
PWM Output	Motor Driver	2

I2C	GPIO INT	GPIO INPUT	GPIO OUTPUT	PWM OUTPUT
1	4	4	8	2

Table 1: Required peripherials summary

Design

Block diagram

This chapter provides a comprehensive block diagram illustrating the architecture and components of the robot. The block diagram serves as a visual aid to understand the interconnection and functionalities of various modules within the robot system. Each block represents a distinct subsystem or component essential for the overall functionality of the robot.

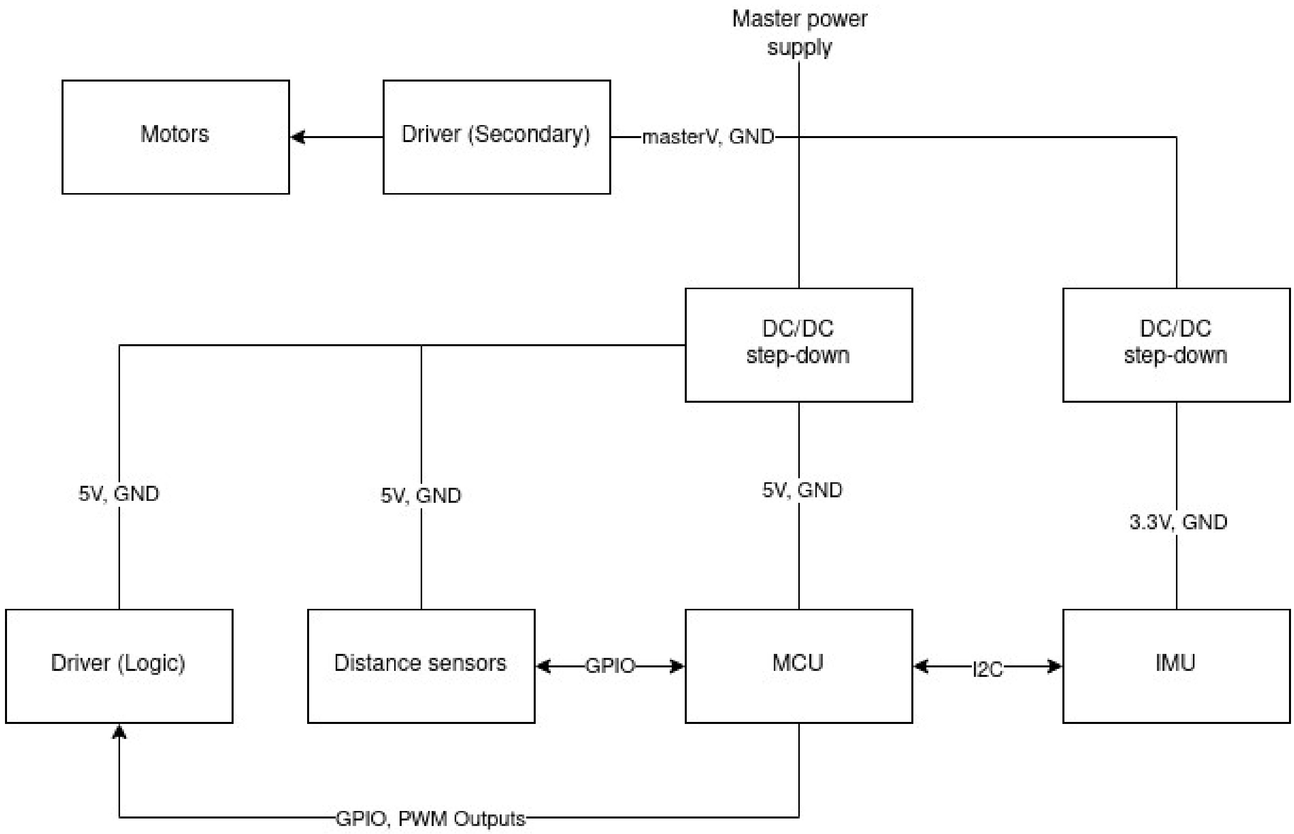

Figure 1: Hardware block diagram

Description table

Block	Description
Master power supply	Two 18650s connected in series supplying HW with 7.4V.
Motors	DC motors making it possible for the robot to move.
Driver (Secondary)	Supply of the DC motors, it is supplied with master power supply.
DC/DC step-down	Conversion of master power supply to required levels.
Distance sensors	Front and rear distance sensors.
MCU	Master control unit – ESP32 module.
Driver (Logic)	Control of the behavior of the motors.
IMU	10DoF sensor.

Electronics design

To be compliant with requirements listed above, hardware design has been divided into six main sections.

MCU

This section contains the MCU and leads for sensors, the motor controller, the communication interface for the IMU, and jumpers to select the MCU's 3.3V or 5V power supply.

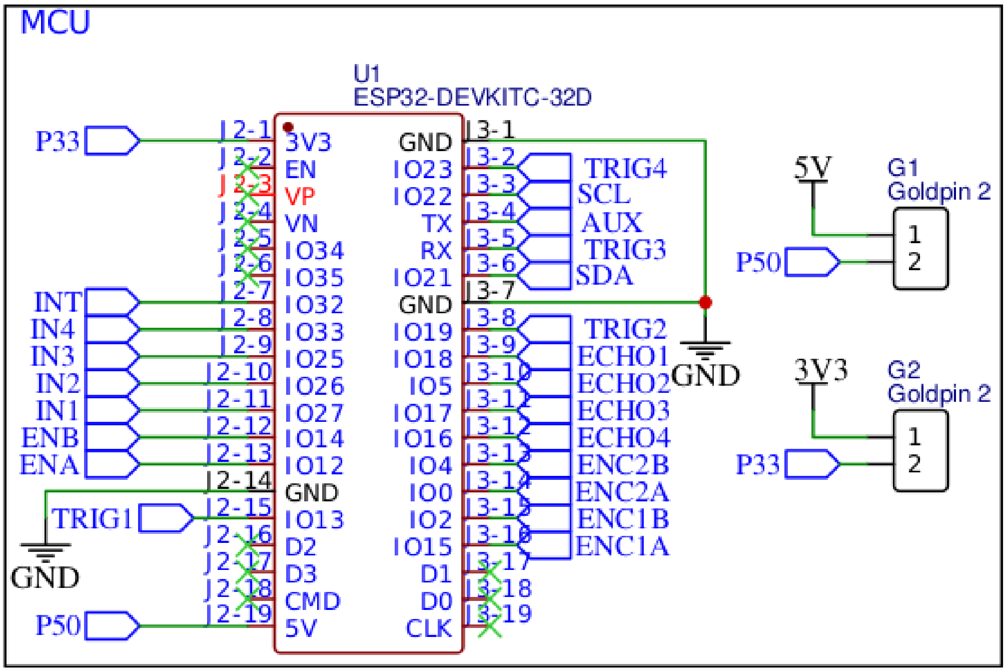

Figure 2: MCU section

Power

The section consists of two linear stabilizers that allow voltage stabilization at 3.3V and 5V levels. Due to the low power loss with the operating conditions of the components, it was decided not to implement step-down converter circuits.

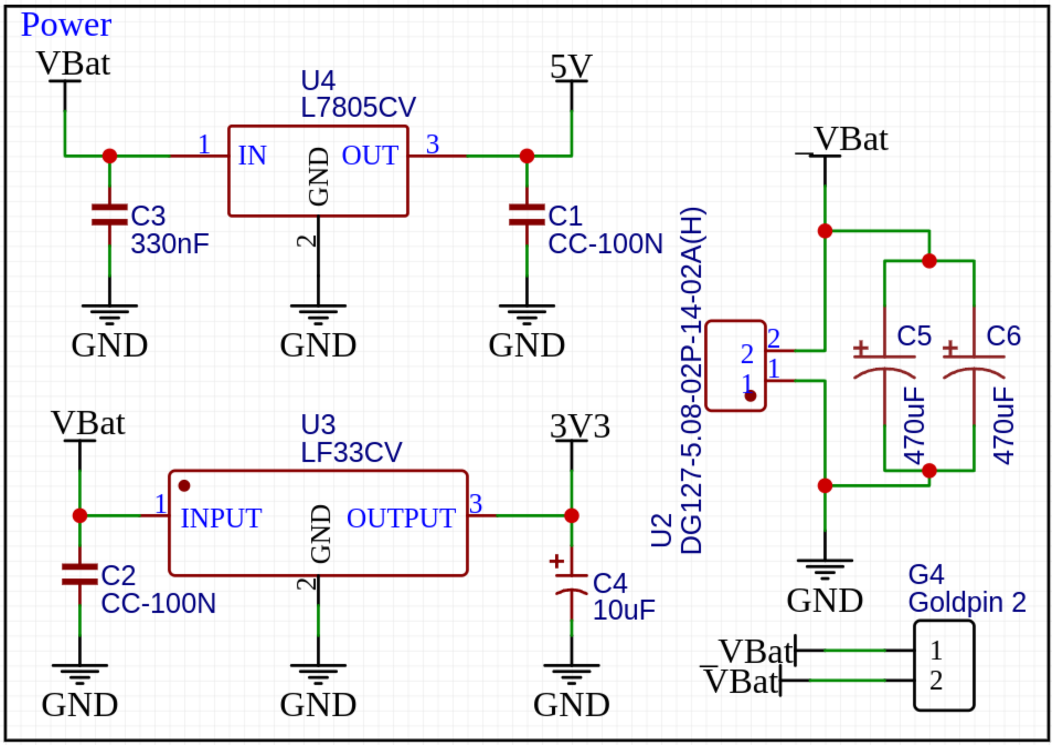

Figure 3: Power section

Distance sensors

This section consists of four goldpin mounting slots for connecting distance sensors.

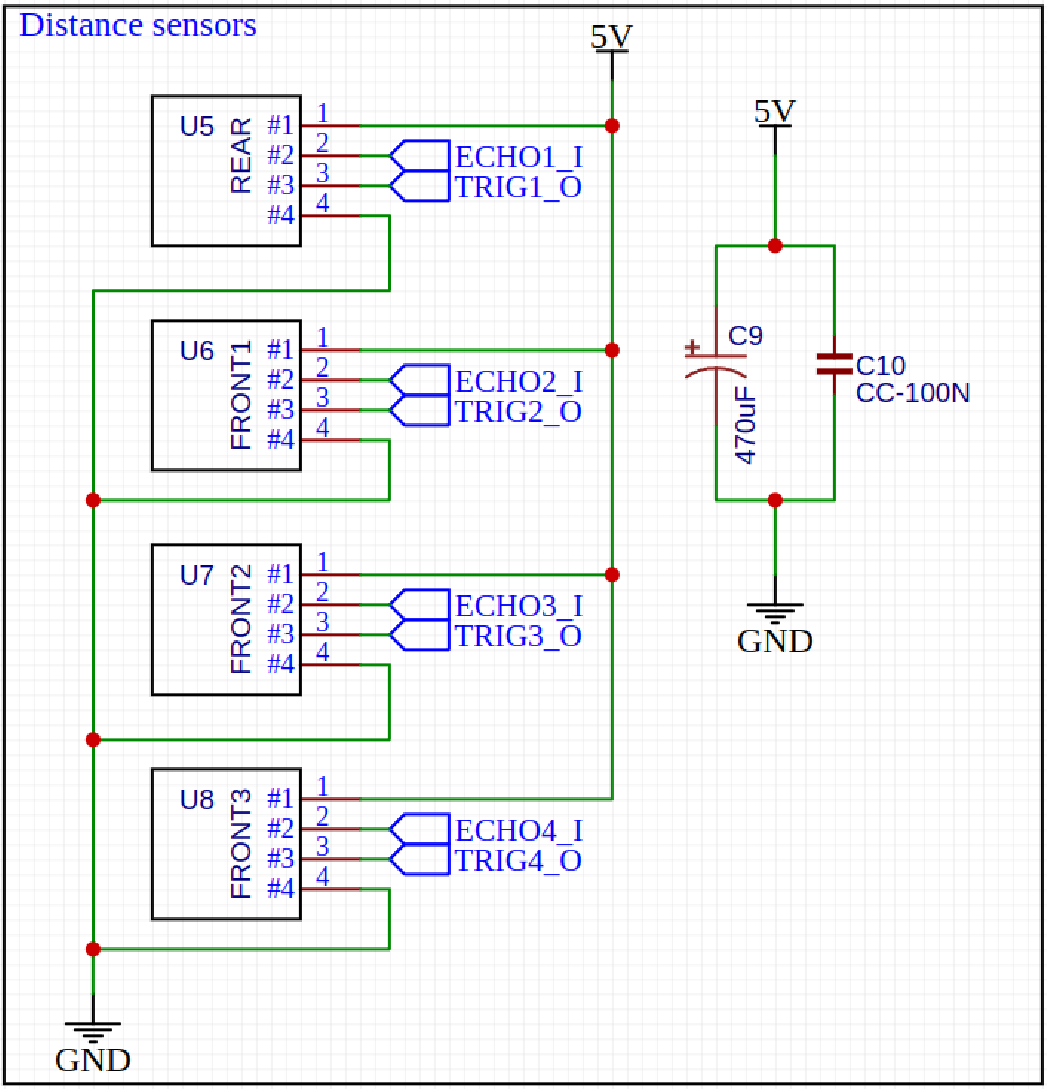

Figure 4: Distance sensors section

Motors

The section consists of goldpin type leads that output control signals to the motor controllers and provide power to the logic.

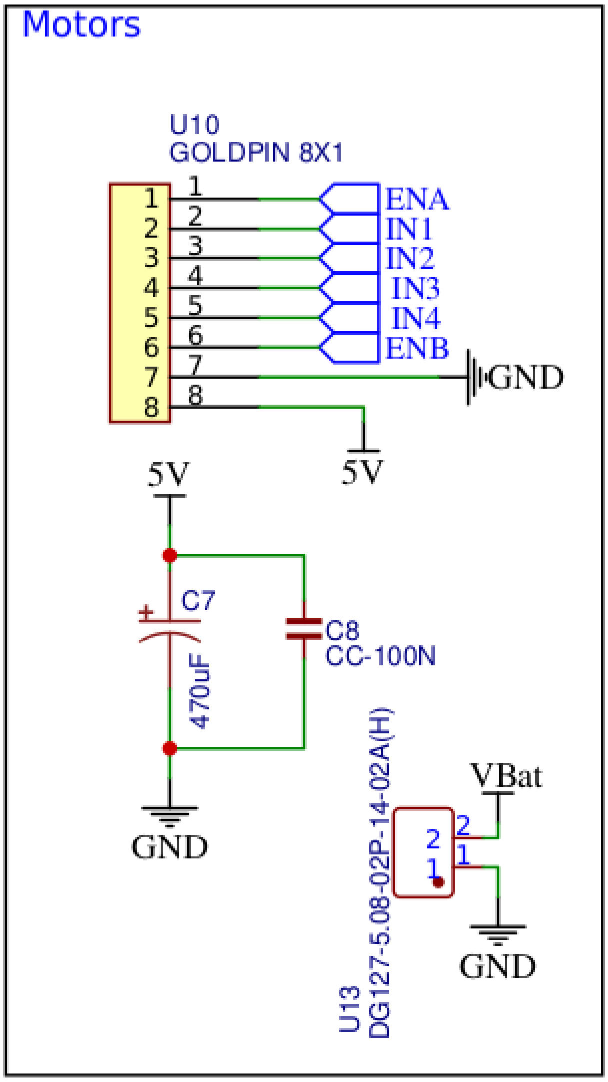

Figure 5: Motors section

MPU9255

The section contains leads for communicating with the MPU9255 IMU and a jumper to "hardware enable" the use of interrupts.

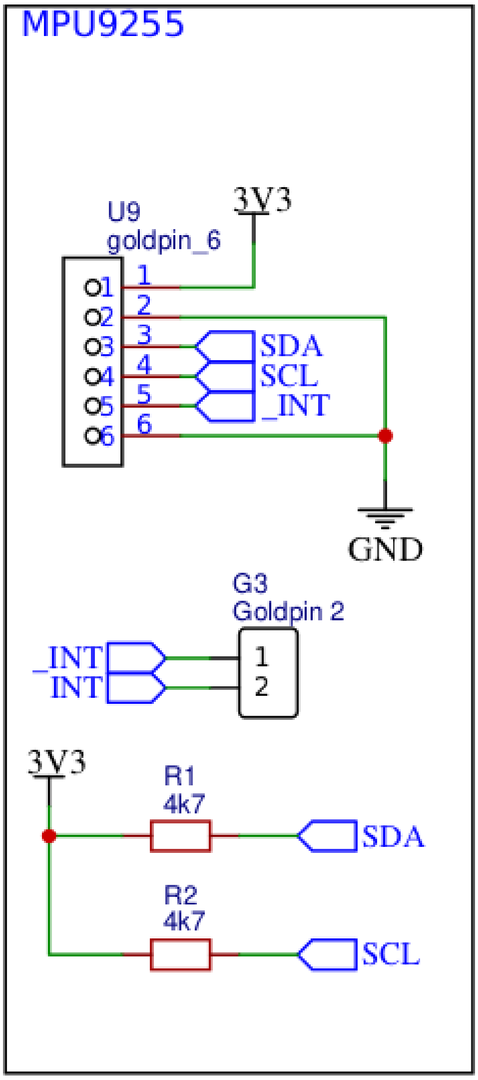

Figure 6: MPU9255 section

Encoders

The section contains leads for connecting encoders to determine odometry.

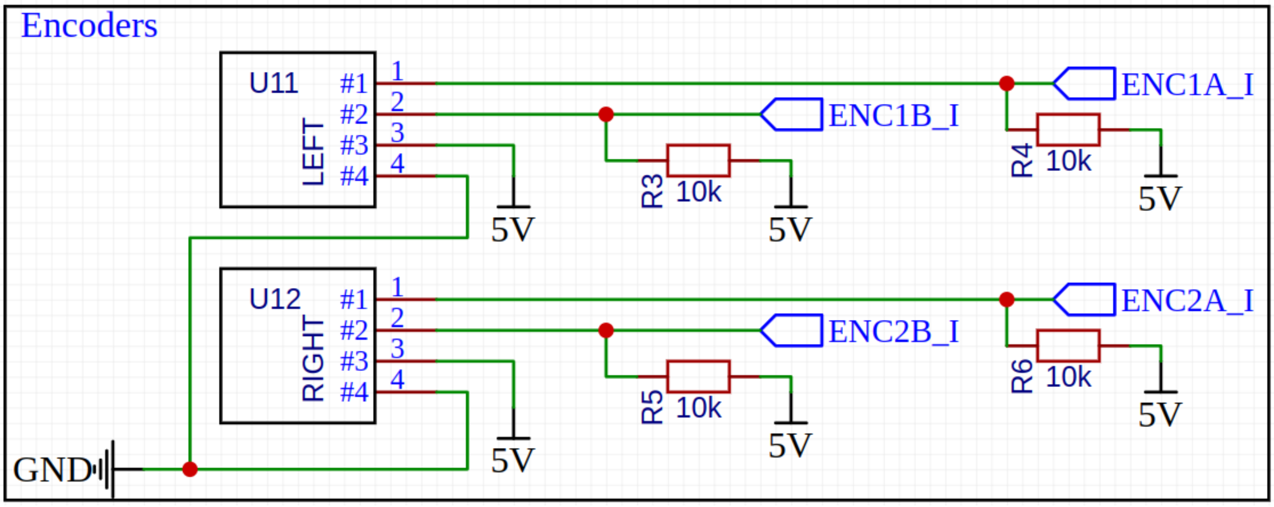

Figure 7: Encoders section

Level shifters

Though esp32 are 5V tolerant, it is better to use logic shifters not to damage MCU.

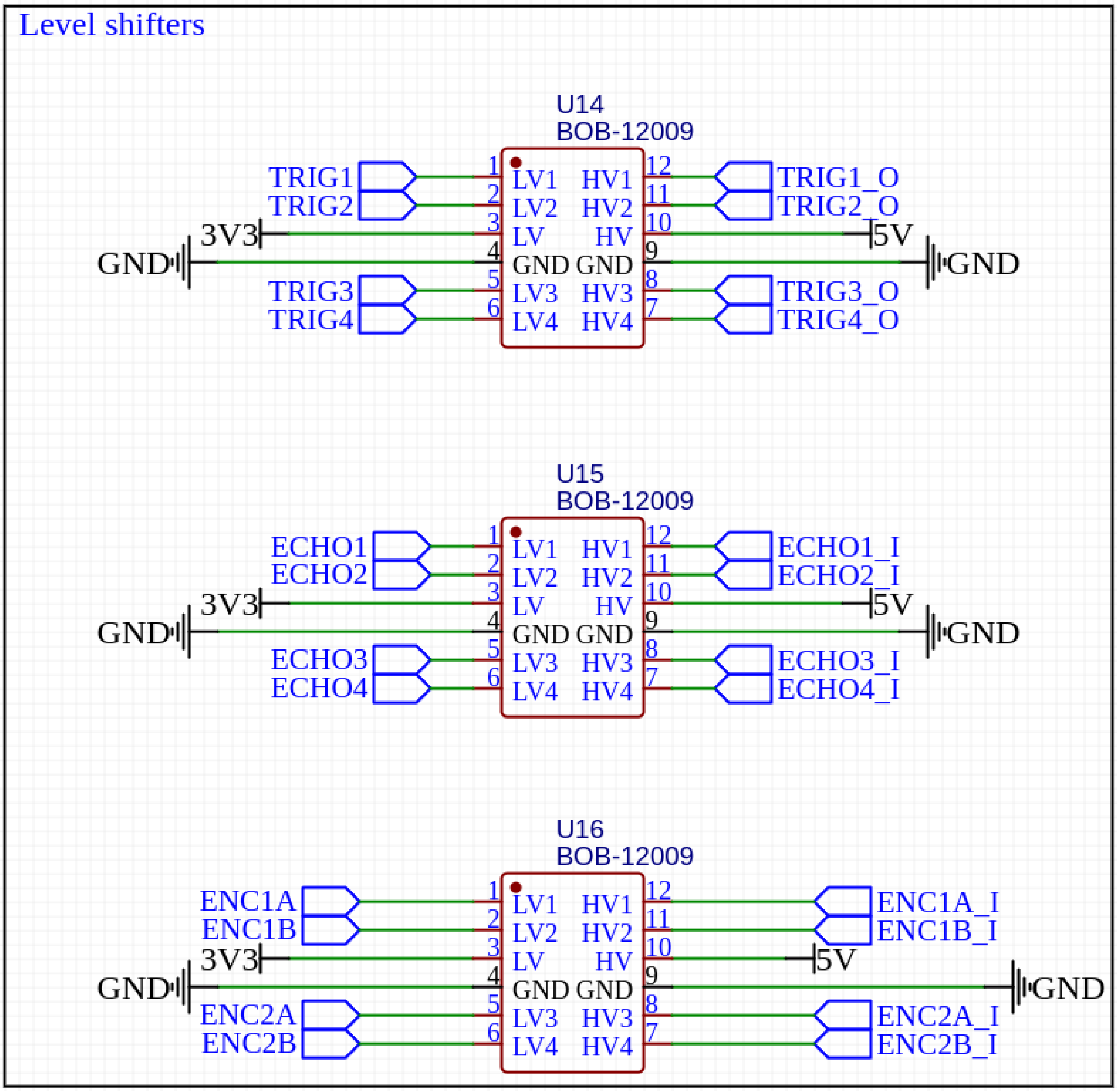

Figure 8: Level shifters

Requirements veryfication

References

Base components

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Schematic

https://github.com/DevxMike/master_degree/blob/master/robot/HW/Schematic_Robot_schematic_2024-03-05.pdf

Additional components

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