Bill of Materials (BOM) Explanation

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Contents

1 Introduction

This document provides an explanation of the Bill of Materials (BOM) used in the project. Each component listed in the BOM is described in detail, including its purpose and other relevant specifications.

2 BOM

Table 1 below outlines the components used in this project along with their purpose and additional information.

Table 1: Main components

Component	Description	Purpose	#	á price (price per robot) SEK	Price in USD
DF45L024048-A	Brushless direct current (BLDC) motor with integrated hall sensors for the wheels	Used to spin the wheels of the robot.	4	830.4 (3273.60)	74.74 (294.6)
Hobbywing FPV XRotor 3110 900KV	Brushless DC motor	High revolutions per minute (RPM) motor used to control the dribbler.	1	175.20 (175.20)	15.77 (15.77)
B-G431B-ESC1	BLDC motor driver	Motor driver with embedded μController current sensing and hall sensing to form a closed-loop control algorithm	5	208.96 (1044.8)	18.8 (94.032)
NUCLEO-H723ZG	μController	Computational power and real-time processing capabilities, supports μROS	1	322.58 (322.58)	29 (29)
Raspberry Pi 4 Model B/8GB	Single-board computer	Processing camera input and performing local path planning	1	979 (979)	88.11 (88.11)
VL53L4CD ToF	Lidar	Obstacle detection (Could not find VL53X ToF)	2	176.32 (176.32)	15.87 (15.87)
VL6180 TOF	Lidar	Obstacle detection	1	39.62 (39.62)	3.57 (3.57)
APDS-9960	RGB Sensor	Ball detection	1	199 (199)	17.91 (17.91)
SENS0374	9-Dof IMU	Acceleration, Gyroscope, Magnetometer	1	191 (191)	17.19 (17.19)
6s 1300mAh -120C - GNB HV XT60	LiPo-battery	Used to power the robot	1	351.20 (351.20)	31.6 (31.6)
iC-PX2604 + PX01S 26-30	Wheel encoders	Will be used for odometry and determining the RPM	4	224.40 (897.60)	20.2 (80.78)
WSEN-ISDS 6 Axis IMU	6-DoF IMU	Will be used for odometry of the robot	10	N/A	N/A
Raspberry Pi Camera-module 3	Camera	Provide images in front of the robot to detect the ball and obstacles	1	369 (369)	33.21 (33.21)

3 Reason for component choice

3.1 DF45L024048-A

During competition a SSL-robot is most of the time accelerating [1]. Having a motor which can provide sufficient torque at any given speed is crucial.

The DF45L024048-A BLDC motors provides a good tradeoff between torque and RPM, with integrated hall sensors. The sensors detect the position of the rotor relative to the stator which gives the ability to control the motors using commutation. The motor controller uses the signals from the hall sensors to determine the exact timing for switching the current in the stator windings. This gives a smooth motor operation while maximizing torque output.

The size of the motor has to be taken into account. Having to large footprint on the motors would cause the kicker (solenoid) to not fit in the chassi. Using a general 5010 sensorless drone motor could be used as demonstrated by [2] but this motor would require a more sophisticated ESC which would take a lot of time to develop and manufacture. The problem with searching for 5010 drone motors is that most websites does not show the full torque graph, they primarly show the torque when the motor is already spinning at 40% throttle and above. Therefore finding a 5010 drone motor with adequate torque at low speeds is deceptively difficult.

Using hall sensors is a common method utilized by several teams and proven to be a winning concept [3][4][5][1].

3.2 Hobbywing FPV XRotor 3110 900KV

The requirements for the dribbler motor is that it can reach high RPM (around 10000 RPM). No feedback is implemented for the dribbler motor, due to the timeframe of the project a control algorithm will not be implemented.

3.3 B-G431B-ESC1

A sensorless controller requires that the BLDC motor produce a measurable back electromotive force (EMF) so the controller can determine the position of the rotor and therefore cannot provide smooth commutation at start up and low speeds. [6]

The chosen electronics speed controller (ESC) has an STSPIN32F0A system in package chip which has an integrated STM32 processor with hall sensor decoding logic and current sensing capabilities. This makes this ESC a good fit with the DF45L024048-A BLDC motor.

The STSPIN32F0A chip is a common choice for controlling BLDC motors in the SSL competitions which has been proven to be reliable and succesful [3][7].

Field-Oriented control (FOC) can be implemented on the B-G431B-ESC1. Guidance and firmware for the B-G431B-ESC1 has been received from Delft Mercurians that will make the process of implementing this streamlined.

A PID system can be implemented on the chip to allow for precise movement and rapid acceleration which is critical to make fast directions changes.

The B-G431B-ESC1 will receive a desired velocity, to use this within a PID system the RPM of each motor is required.

The size and weight of the ESC does also have to be taken in consideration, the B-G431B-ESC1 has a small footprint with a relatively low weight 286g. With all the components integrated on one board will make the assembly process easier and reduce any external components e.g. hall sensing or mosfets. The programming for the integrated STM32 is done using STM32 Motor Control Software Development Kit which is a graphical programming environtment from ST.

3.4 NUCLEO-H723ZG Microcontroller

The NUCLEO-H723ZG is a development board based on the STM32H723ZG chip, it comes with all necessary peripheral communication UART, SPI, I2C and CAN. The STM32H723ZG features an ARM Cortex-M7 core operating at up to 480 MHz, providing good processing power for handling multiple real-time tasks required in our application.

Additionally, the STM32 series is widely adopted in RoboCup competitions, including the **Small Size League (SSL)** [3][8][5]. This widespread use underscores its reliability and effectiveness in competititions. By using STM32H723ZG chip, previous teams implementations that is open sourced can be used for guidance when developing.

To manage the various tasks and ensure smooth operation of our robot, the control architecture will be implemeted using **micro-ROS** in combination with **FreeRTOS** on the NUCLEO-H723ZG.

FreeRTOS is a real-time operating system that provides task scheduling and resource management. Implementing FreeRTOS on the NUCLEO-H723ZG allows us to handle multiple concurrent tasks efficiently, such as sensor data processing, motor control, and communication with other system components.

By using the STM32H723ZG chip future improvements can be made, without having to replace the hardware and potentially the need to re-program/port using another framework.

3.5 Raspberry Pi 4 Model B/8GB

It is important to accurately detect the ball and other robots in a timely manner, therefore a Raspberry Pi camera will be used, and the input image will be processed on the Raspberry Pi 4. The Raspberry pi has been used in the SSL competitions for this purpose [9][10]. A lot of information and open sourced firmware exist.

The Raspberry Pi 4 was also chosen to be able to run the DWA path planning algorithm, due to the timeframe of this project, implementing DWA by ourself would require too much time.

3.6 VL53L4CD ToF Sensor

The **VL53L4CD ToF** (Time-of-Flight) sensor is a laser-based ranging sensor capable of measuring distances with high accuracy. It is used for obstacle detection in the robot, allowing the system to identify obstacles within close proximity. With a range of up to 1300 mm, it is especially suited for detecting obstacles that could interfere with the robot's navigation. The sensor communicates using I2C, which simplifies integration with the existing hardware.

3.7 VL6180 TOF Sensor

The **VL6180 TOF** sensor, also a Time-of-Flight sensor, serves a similar purpose as the VL53L4CD but operates at shorter distances, making it ideal for near-field obstacle detection. It is also chosen for its compact size and I2C communication, which allows it to seamlessly interface with the microcontroller. The shorter range provides additional resolution for objects very close to the robot, further enhancing obstacle detection accuracy.

3.8 APDS-9960 Sensor

The **APDS-9960** sensor is a versatile RGB sensor with integrated IR sensing capabilities. It is primarily used in this project for ball detection, as it can distinguish colors and detect the presence of nearby objects. This feature enables the robot to differentiate the ball from the surroundings based on color and proximity. Communication is handled via I2C, allowing for easy connection to the system's microcontroller.

3.9 SENS0374 Sensor

The **SENS0374**, based on the Bosch BNO055 sensor, is a 9-axis absolute orientation sensor module. It integrates a triaxial accelerometer, gyroscope, and geomagnetic sensor with a 32-bit microcontroller, providing orientation data essential for stable navigation and localization. The module includes an onboard fusion algorithm that combines sensor readings to deliver absolute orientation, minimizing drift over time. The SENS0374 communicates via I2C and SPI, making it flexible for integration with the main controller. This sensor will aid in tracking the robots movement, orientation, and any external forces acting upon it, enhancing its responsiveness in dynamic environments.

3.10 SX1280IMLTRT + SKY66122-11

To obtain a reliable connection to the team server, the SX1280IMLTRT RF transceiver with the SKY66122-11 front-end-module is used.

This implementation has been proven succesful by several teams [3][11].

However, to implement this, a basestation is required and due to the time limitation of this project it is not feasible to design and write firmware for our own network protocol, but these components will be added to the mainboard PCB for future iterations. The communication will instead be done using the wifi on the Raspberry Pi 4.

3.11 iC-PX2604 + PX01S 26-30

This wheel encoder comes as a complete module which will be easy to integrate and in combination with the NUCLEO-H723ZG the resolution of the encoder is increased.

Optical wheel encoders is commonly used by teams competing in the SSL competitions.

3.12 WSEN-ISDS 6 Axis IMU

The IMU chosen is supplied free of charge from Würth electronics. It communicates using I2C or SPI which both are available on the NUCLEO-H723ZG.

3.13 Raspberry Pi Camera-module 3

The Raspberry Pi camera-module 3 is chosen because of its seamless integration with the Raspberry Pi 4.

A custom made solenoid would be preferred, but due to time a generic solenoid will be used for starting car engines. Supplied by MDU.

3.14 PCB

As some of our components require a custom PCB, three PCBs will be designed. A mainboard, kicker-board and encoder board, the main board will host connectors for the battery, motors, sensors, NUCLEO-H723ZG and pin headers for powering the Raspberry Pi. The mainboard will also host the RF transceiver, IMU and voltage regulators.

4 Hardware Architecture

Figure 1 depicting the hardware architecture of the proposed robot.

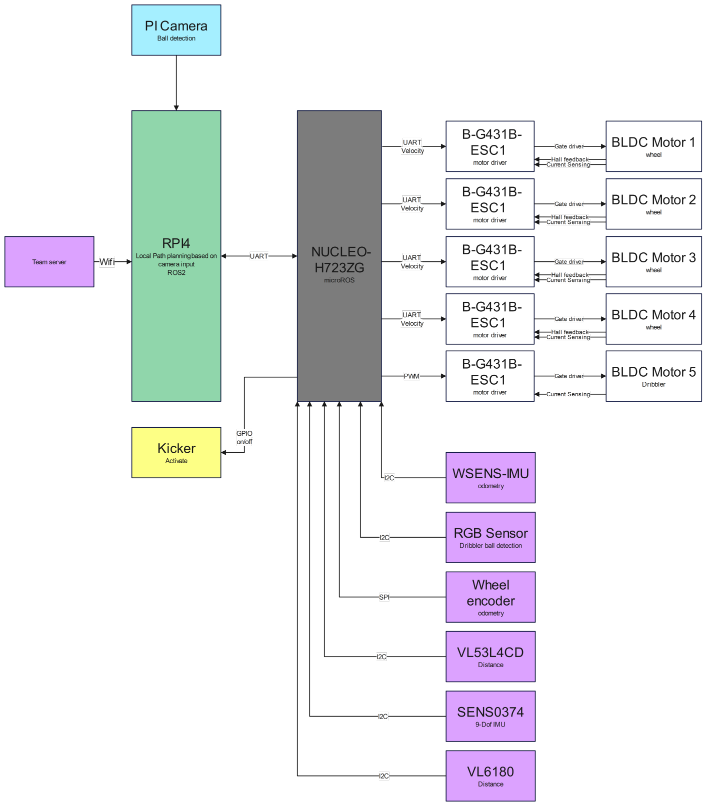

Figure 1: Hardware Architecture

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