

Bill of Materials (BOM) Explanation

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Introduction

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

Component Overview

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

Table 1: Component Descriptions for the Project

Component	Description	Purpose	#	price (price per robot) SEK
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)
Hobbywing FPV XRotor 3110 900KV	Brushless DC motor	High revolutions per minute (RPM) motor used to control the dribbler.	1	175.20 (175.20)
B-G431B-ESC1	BLDC motor driver	Motor driver with embedded μ Controller current sensing and hall sensing to form a closed-loop control algorithm	5	208.96 (1044.8)

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NUCLEO-H723ZG	μ Controller	Computational power and real-time processing capabilities, supports μ ROS	1	322.58 (322.58)
Raspberry Pi 4 Model B/8GB	Single-board computer	Processing camera input and performing local path planning	1	979 (979)
SX1280IMLTRT	Radio frequency (RF) transceiver	Used to transmit data over 2.4Ghz network	1	75.44 (75.44)
SKY66122-11	Integrated front-end-moduel (FEM)	Simplified integration with the RF circuit	1	40.48 (40.48)
6s 1300mAh - 120C - GNB HV XT60	LiPo-battery	Used to power the robot	1	351.20 (351.20)
LT3750	Charging controller for the capacitors of the kicker	Charge controller for the kicker circuit	1	146.93 (146.93)
iC-PX2604 + PX01S 26-30	Wheel encoders	Will be used for odometry of the robot	4	224.40 (897.60)
WSEN-ISDS 6 Axis IMU	6-DoF IMU	Will be used for odometry of the robot	10	N/A
Raspberry Pi Kameramodul 3	Camera	Provide images in front of the robot to detect the ball and obstacles	1	369 (369)
IR Break Beam Sensor - 5mm LEDs	Infrared (IR) sensor	Used to detect if the ball is close to the robot	1	99 (99)
JST 6B-PH-K-S	Connector	Hall sensor connector from the motor	4	3.85 (15.4)
JST B5P-VH	Connector	Motor connector	4	4.06 (16.24)

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Component	Description	Purpose	#	price (price per robot) SEK
Connectors	Passive component	Supplied by Würth	N/A	N/A
Shaft hub with clamping bracket 4mm	Coupler	Couple the wheels with the motor shaft	4	139 (556)
Bearings	Bearings	Make the roller spin (dribbler)	2	18 (36)
Resistors	Passive component	Supplied by Würth or 326	N/A	N/A
Capacitors	Passive component	Supplied by Würth or 326	N/A	N/A
Voltage regulators	DC/DC buck converters	Supplied by Würth	N/A	N/A
Solenoid	Solenoid	Supplied by MDU	1	N/A
PCB	Printed circuit board (PCB)	The students will supply any custom PCB designed	2	N/A
Total price for 1 robot	8398.47			

Reason for component choice

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.

We also have to take the size of the motor into account. Having too large footprint on the motors would cause the kicker (solenoid) to not fit in the chassis. 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.

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

Hobbywing FPV XRotor 3110 900KV

The requirements for the dribbler motor is that it can reach high RPM (around 10000 RPM).

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]

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 with in a PID system the RPM of each motor is required. The RPM will be retrieved by measuring the number of pulses from the hall sensors and calculate the time between them.

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 envirotnment from ST.

NUCLEO-H723ZG Microcontroller

The **NUCLEO-H723ZG** microcontroller was selected due to its robust computational capabilities and versatile feature set, driven by the **STM32H723ZGT6** chip. 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 competitions.

To manage the various tasks and ensure smooth operation of our robot, we will implement a control architecture 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.

This also aligns with the collaboration with Universidad de Antioquia, since they will use FreeRTOS to program the ESP32-S3.

The NUCLEO-H723ZG serves as the central processing unit, coordinating various subsystems through the following workflow:

1. **Sensor Data Acquisition:** The microcontroller collects data from the IMU, wheel encoders, and IR break beam sensors. FreeRTOS manages these tasks to ensure timely and efficient data processing.
2. **Data Processing and Control:** The STM32H723ZG processes the sensor data and executes control algorithms to manage the motors via the **B-G431B-ESC1**.
3. **Communication Handling:** micro-ROS facilitates communication with the Raspberry Pi and team server, allowing for data transmission and reception of control commands.
4. **Actuator Control:** Based on the processed data, the microcontroller sends commands to actuators such as the dribbler.

Raspberry Pi 4 Model B/8GB

It is important to accurately detect the ball and other robots in a timely manner, therefore we have decided to use a camera which image input will be processed by the Raspberry Pi 4. The Raspberry pi has been extensively used in the SSL competitions for this purpose [9] [10]

SX1280IMLTRT + SKY66122-11

To obtain a reliable connection to the team server, we have opted to use the SX1280IMLTRT RF transceiver with the SKY66122-11 front-end-module.

iC-PX2604 + PX01S 26-30

WSEN-ISDS 6 Axis IMU

Raspberry Pi Kameramodul 3

IR Break Beam Sensor - 5mm LEDs

Connectors

Shaft hub with clamping bracket 4mm

Bearings

Resistors

Capacitors

Voltage regulators

Solenoid

PCB

Conclusion

This document serves as a reference for understanding the role of each component in the project. For any further technical details, please refer to the respective datasheets provided by the manufacturers.

References

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