Bill of Materials (BOM) Explanation

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Contents

1 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.

2 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**	**#**	**á 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	Brushelss 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 μController current sensing and hall sensing to form a closed-loop control algorithm	5	208.96 (1044.8)
NUCLEO-H723ZG	μController	Computational power and real-time processing capabilities, supports μROS	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)
TOF400C-VL53L1	Lidar	Chosen by UdeA for obstacle detection	2	176.32 (176.32)
VL6180 TOF	Lidar	Chosen by UdeA for obstacle detection	1	39.62 (39.62)
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)

Table 1: Component Descriptions for the Project

Component	Description	Purpose	#	á price (price per robot) SEK
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 Camera-module 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)
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
LM74500 -QDDFRQ1	Reverse polarity protection	Used to protect against wrong polarity connections	1	16.45 (16.45)
BUK9Y8R5-80EX	N-channel mosfet	Used with the LM74500 -QDDFRQ1	1	17.95 (17.95)
SMBJ58A	TVS+	ESD protection diode, used in reverse polarity circuit	1	4.5 (4.5)
SMBJ26A	TVS-	ESD protection diode, used in reverse polairiy circuit	1	3.53 (3.53)
M3 16mm galvanized steel countersunk screw, 100 pack	Mounting screws	Screws for robot chassi	1	21.6 (21.6)
M3 galvanized steel locking washers, 200 pack	Washers	Chassi assembly	1	69.7 (69.7)

Table 1: Component Descriptions for the Project

Component	Description	Purpose	#	á price (price per robot) SEK
M3 steel locking washers, 200 pack	Locking washers	Chassi assembly	1	83.3 (83.3)
M3 stainless steel nut, 100 pack	Screw nut	Chassi assembly	1	21.85 (21.85)
M3 threaded inserts 3mm, 50 pack	Threades inserts	Chassi assembly	1	95 (95)
Bearings with flange iglidur® M250	Bearings for mini-wheels	Wheel assembly	100	3.34 (334)
X-RING 3.63X2.62/NBR70	Fasten the mini-wheels	Wheel assembly	100	6.2 (620)
Wheel hub 4mm	Fasten wheels to motor	Wheel assembly	4	139 (556)
Total price for 1 robot	**10457.69**			

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.

We also have to take the size of the motor 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 we will not implement a control algorithm for the dribbler.

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].

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 RPM will be retrieved by measuring the number of pulses from the hall sensors and calculate the time between them or by using the optical wheel encoders.

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.

3.3.1 UdeA considerations

B-G431B-ESC1 will work similarly to the one UdeA has chosen, the only difference will be that our ESC can be programmed using the STmicroelectronics X-CUBE-MCSDK gui tool.

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 competitions. By using STM32H723ZG chip we can take advantage of all the previous teams implementations that they have made open sourced to make our life easier when developing.

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.

By using the STM32H723ZG chip we open the potential for future improvements without having to replace the hardware and potentially the need to re-program/port using another framework.

3.4.1 UdeA considerations

The guys from UdeA will be programming on the ESP32-S3 with FreeRTOS as their framework. Their proposed method for motor control is to use a AS5600 sensor for each motor to measure the RPM and using the ESP32-S3 to create a closed-loop control algorithm.

This will be a similar implementation to our intended control-algorithm. We will use an optical wheel encoder to measure the RPM, and will be used as feedback to create a closed-loop PID algorithm.

From our perspective the programming that is required for this is similar to UdeA. And thus we could still collaborate even though the microcontroller is different.

I have also not found any teams that have used the ESP32 as their main processor, and almost every team uses STM32 based controller or a Raspberry Pi compute module.

3.5 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 used in the SSL competitions for this purpose [9][10]. And thus 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.

3.5.1 UdeA considerations

UdeA has chosen two different components, TOF400C-VL53L1 and VL6180 TOF that is going to be used for obstacle detection and ball detection. Since we are going to run computationally intensive tasks on the Raspberry Pi, replacing it would disrupt a lot of our planning between the software and hardware team.

Our proposed idea is that we can add these components for extra input to allow us to collaborate when developing the software for these components.

3.6 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.

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

However, one drawback is that the components require a custom made PCB. This will be solved by creating one mainboard with connectors to our components, battery, motors, sensors and the NUCLEO-H723ZG.

3.6.1 UdeA considerations

I have not yet gotten it confirmed how UdeA has planned to communicate with the server laptop. But from my assumption they will use the WiFi card placed on the ESP32-S3.

Teams have acknowledged the difficulties with enabling a reliable connection to the team server, when using components like the nRF52 and Raspberry Pis. We have not found any teams that have used the ESP32 as their RF communication component.

Therefore we have opted for a different route that has been used by several teams and proven to be reliable[3].

3.7 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. Since we also have a quotation at a reasonable price we have chosen to use this encoder.

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

3.7.1 UdeA considerations

UdeA has chosen to use the AS5600 magnetic encoder. This setup requires that a magnet is glued to the end of the shaft for every motor. This process also require that the magnet aligns properly and does not come loose during movement and vibrations, which we believe is unlikely. We have not gotten more information about how they intended to attach this sensor.

Therefore we would opt for using our optical wheel encoders instead since the integration is done with the wheel assembly and will attach using screws, making the assembly streamlined. Both sensor will be able to provide sensor values that can be used for RPM estimations and odometry.

3.8 WSEN-ISDS 6 Axis IMU

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

3.8.1 UdeA considerations

UdeA has chosen to use two different 9-Dof IMUs, however since we got our IMUs free of charge it is smarter to just use those. They did not mention anything about these sensor during our BOM meeting. The implementation of the sensors will be similar to some degree both our IMU and BNO055 IMU supports I2C as communication protocol.

3.9 Raspberry Pi Camera-module 3

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

3.10 IR Break Beam Sensor - 5mm LEDs

The IR Break Beam sensor will be connected using GPIO pins on the NUCLEO-H723ZG with a pull-up resistor. To detect if the ball is touching the dribbler roller.

3.10.1 UdeA considerations

UdeA has chosen to use GY-9960-3.3 APDS-9960 RGB sensor. They did not specify how this is going to be used or implemented during our meeting about their BOM.

We have decided not to include this sensor in our desired BOM since it is unclear what the purpose is.

3.11 Connectors

Connectors for the main PCB board will be supplied by Würth electronics.

3.12 Shaft hub with clamping bracket 4mm

From our research teams have noticed that if the coupling between the motorshaft and wheels does not have a good fit, the shaft will start to release tiny metal dust which will be collected by the hub of the BLDC motor.

Therefore we have chosen to use this clamp to ensure the coupling is secure.

3.13 Bearings

Bearings used for the roller.

3.14 Resistors

Any Passive components required will be supplied by Würth electroncis or if we can find it in 326.

3.15 Capacitors

Any Passive components required will be supplied by Würth electroncis or if we can find it in 326.

3.16 Voltage regulators

The voltage regulators will be used to ensure our components reveice the correct voltages, 3.3V, 5V, 12V will be integrated on the custom PCB.

The voltage regulators was supplied by Würth electronics.

3.17 Solenoid

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

3.18 PCB

As some of our components require a custom PCB, we will design two PCBs. A mainboard and a kicker-board, the main board will host connectors for the battery, motors, 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.

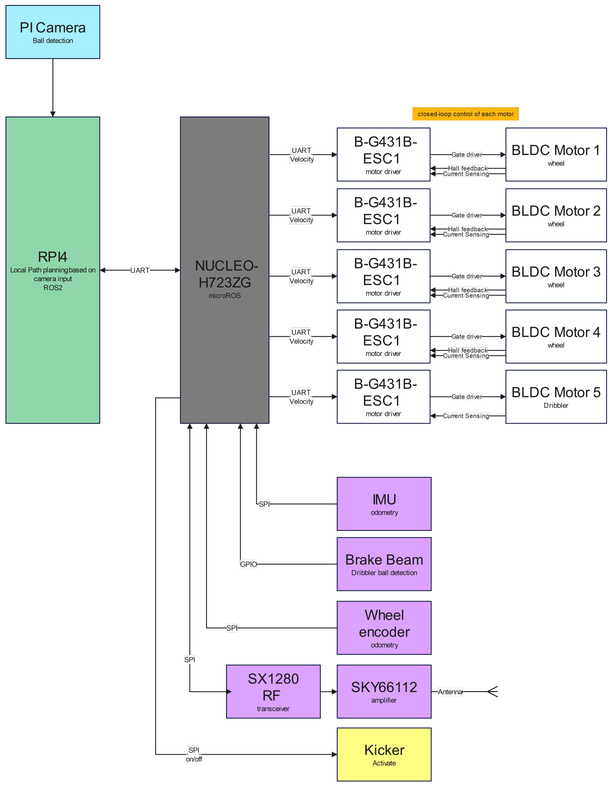

Figure 1: Hardware Architecture

5 Alternative BOM that has equal components to UdeA Collaboration

Table 2: Alternative BOM that has equal components to UdeA

Component	**Replaces**	**Purpose**	**#**	**á price (price per robot) SEK**
MN5208 Navigator Type UAV Multi-Motor KV340	DF45L024048-A	BLDC motor	4	1027.32 (4109.28)
Hobbywing FPV XRotor 3110 900KV	N/A	High revolutions per minute (RPM) motor used to control the dribbler.	1	175.20 (175.20)
B-G431B-ESC1	N/A	Motor driver with embedded μController current sensing and hall sensing to form a closed-loop control algorithm	5	208.96 (1044.8)
ESP32-S3-DevKitC-1-N32R8V	NUCLEO-H723ZG	Chosen by UdeA	1	181.82 (181.82)
TOF400C-VL53L1	N/A	Chosen by UdeA for obstacle detection	2	176.32 (176.32)

Table 2: Alternative BOM that has equal components to UdeA

Component	**Replaces**	**Purpose**	**#**	**á price (price per robot) SEK**
VL6180 TOF	N/A	Chosen by UdeA for obstacle detection	1	39.62 (39.62)
GY-9960-3.3 APDS-9960	N/A	Chosen by UdeA for ball detection	1	44.80 (44.80)
Raspberry Pi 4 Model B/8GB	N/A	Processing camera input and performing local path planning	1	979 (979)
SX1280IMLTRT	N/A	Used to transmit data over 2.4Ghz network	1	75.44 (75.44)
SKY66122-11	N/A	Simplified integration with the RF circuit	1	40.48 (40.48)
6s 1300mAh -120C - GNB HV XT60	N/A	Used to power the robot	1	351.20 (351.20)
LT3750	N/A	Charge controller for the kicker circuit	1	146.93 (146.93)
AS5600-SO_EK_AB	iC-PX2604 + PX01S 26-30	Will be used for odometry of the robot	4	224.40 (897.60)
WSEN-ISDS 6 Axis IMU	N/A	Will be used for odometry of the robot	10	N/A
Raspberry Pi Camera-module 3	N/A	Provide images in front of the robot to detect the ball and obstacles	1	369 (369)
IR Break Beam Sensor - 5mm LEDs	N/A	Used to detect if the ball is close to the robot	1	99 (99)
Connectors	N/A	Supplied by Würth	N/A	N/A
Shaft hub with clamping bracket 4mm	N/A	Couple the wheels with the motor shaft	4	139 (556)
Bearings	N/A	Make the roller spin (dribbler)	2	18 (36)
Resistors	N/A	Supplied by Würth or 326	N/A	N/A
Capacitors	N/A	Supplied by Würth or 326	N/A	N/A
Voltage regulators	N/A	Supplied by Würth	N/A	N/A
Solenoid	N/A	Supplied by MDU	1	N/A
PCB	N/A	The students will supply any custom PCB designed	2	N/A
LM74500 -QDDFRQ1	N/A	Used to protect against wrong polarity connections	1	16.45 (16.45)
BUK9Y8R5-80EX	N/A	Used with the LM74500 -QDDFRQ1	1	17.95 (17.95)
SMBJ58A	N/A	ESD protection diode, used in reverse polarity circuit	1	4.5 (4.5)
SMBJ26A	N/A	ESD protection diode, used in reverse polairiy circuit	1	3.53 (3.53)

Table 2: Alternative BOM that has equal components to UdeA

Component	**Replaces**	**Purpose**	**#**	**á price (price per robot) SEK**
M3 16mm galvanized steel countersunk screw, 100 pack	N/A	Chassi assembly	1	21.6 (21.6)
M3 galvanized steel locking washers, 200 pack	N/A	Chassi assembly	1	69.7 (69.7)
M3 steel locking washers, 200 pack	N/A	Chassi assembly	1	83.3 (83.3)
M3 stainless steel nut, 100 pack	N/A	Chassi assembly	1	21.85 (21.85)
M3 threaded inserts 3mm, 50 pack	N/A	Chassi assembly	1	95 (95)
Bearings with flange iglidur® M250	N/A	Wheel assembly	100	3.34 (334)
X-RING 3.63X2.62/NBR70	N/A	Wheel assembly	100	6.2 (620)
Wheel hub 4mm	N/A	Wheel assembly	4	139 (556)
Total price for 1 robot	**11194.09**			

5.0.1 MN5208

This motor has the same K_v rating as the motors used by UdeA. However since these are FPV drone motors they have a relatively low torque when running at low speeds. I have not been able to find a distributor which gives torque or thrust values for throttle speed lower than 40%.

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