# Design and Development of a Differential Drive Platform for Dragster Competition

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**Abstract.** Robotics competitions have been increasing in the last years since they bring several impacts on students education, such as technical skill development, teamwork, resilience and decision making withing the STEM skills. The article highlights the significance of robotics competitions as platforms for fostering innovation and driving advancements in the field of robotics. This article primarily focuses on the development of a robot in the Dragster category for the 2023 Portuguese Robotics Open. It outlines the strategies devised to tackle the competition's challenges and discusses the obstacles encountered along with the corresponding solutions employed. The article delves into the specific details of the challenges faced and the iterative processes undertaken to enhance the robot's performance and functionalities. By sharing the insights gained from the project, future proposals for iterations of the robot will be presented, aiming to further augment its features and overall performance while sharing knowledge with other teams and community.

**Keywords:** Robot development, Dragster category, Competition challenges

## 1 Introduction

Robotics competitions are major events that bring together teams composed of students, researchers, and robotics enthusiasts. These events consist of various categories that include complex and creative challenges, in which participants must design and construct robots capable of overcoming obstacles and completing specific tasks on predetermined tracks. These categories range from navigating rough terrains to thrilling robot battles, where unique strategies are employed to surpass opponents. Additionally, there are competitions that require the integration of robots into collaborative teams, such as in the case of robot football, among other challenges.

These events provide an excellent opportunity for participants to apply their knowledge of science, technology, engineering, and math (STEM) in a competitive and collaborative environment. They also encourage creativity, teamwork, and problem-solving skills, thus preparing participants to face challenges that may arise in the real world.

The project at hand focuses on developing a robot in the Dragster Major category to participate in the 2023 National Robotics Festival in Tomar, Portugal. This competition has several categories for a wide range of competitors, including Juniors categories for competitors up to the age of 19 and Major categories with no age restrictions covering complex projects.

The purpose of this article is to outline the strategies devised to tackle the competition's challenges and discuss the obstacles encountered along with the corresponding solutions employed. The article will delve into the specific details of the challenges faced and the iterative processes undertaken to enhance the robot's performance and functionalities. By sharing the insights gained from the project, future proposals for iterations of the robot will be presented, aiming to further augment its features and overall performance. Moreover, the article aims to underscore the significance of robotics competitions as platforms for fostering innovation and driving advancements in the field of robotics.

## 2 Category Description

In Dragster category robot is characterized as a racing robot, where it must run on a straight 10 meters long track. The characteristics and dimensions of the track are shown in Figure 1.

The races are contested between two robots and a score is assigned to the participants according to their performance in the race. The robots must follow the red lines, and the robot that reaches the yellow line first gets three points. The second place robot receives one point. If the robot leaves the track or encroaches on the opponent's area, it is awarded zero points. An additional point is awarded to the robot that stops before the blue line and half a point for the robot that stops before the green line. In the real environment, the track has a white background with black lines, the colors have been added to this representation to make the rules easier to understand. The full rules of the competition can be viewed at [8].

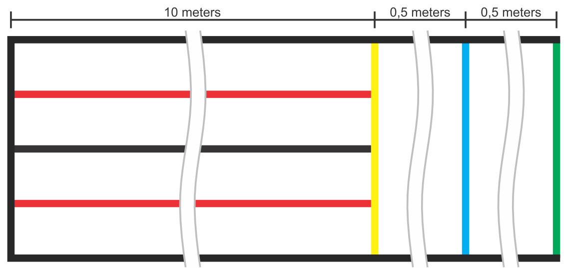



**Fig. 1.** Dragster category track.

## 3 State of Art

Line-following robots are very common in robotics competitions and are present in some version at almost every event. They refer to mobile robots that are able to detect and follow a predefined path, usually demarcated by a black line with a white background or high-contrast colors [6].

In addition to being present in robotics competitions, mobile robots and line following robots are also present in industry. Aimed at improving the interaction between essential parts of the production backbone, task flexibility and robotic mobility are two of the main advantages that mobile manipulators bring to industrial applications [4]. Applications are wide-ranging, such as order picking, material transport, parts and packaging separation, delivery to consumers, etc.

It is essential for a mobile robot to have a positioning system to locate itself in the environment, and this can be done by taking advantage of several physical effects, such as mechanical, acoustic, electromagnetic, magnetic, and optical. According to the application and the environment in which the robot will work, one system is more advantageous than another [9].

## 4 Methodology and Development

The robot design makes reference to a mobile robot and was idealized to be light, fast, and agile. Thus, a differential model was proposed [5], that is, one that uses the difference in rotation between the wheels to move and perform curves.

To make it lighter, it's important to use the minimum of unnecessary parts that could increase the robot's weight and, consequently, decrease its performance. For this, the circuit board was used as body and the motors were attached directly to it.

The entire project was made in Fusion 360[5].

This section will describe the methods and procedures used for the development of the robot shown in Fig. 2.

[5] https://www.autodesk.pt/products/fusion-360/overview

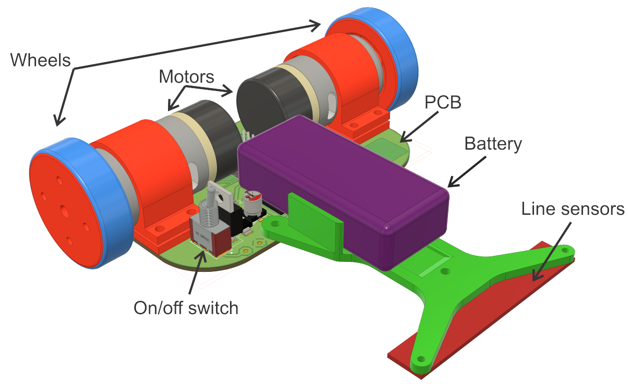



**Fig. 2.** Fusion Project.

### 4.1 The circuit

The first stage of the circuit was the power supply, that was made with a switch used to turn ON the robot, a MOSFET, capacitors to filter electrical interference and a 3.3V voltage regulator IC. The MOSFET had the function of protecting the rest of the circuit from negative voltages and possible accidents, such as the wrong battery connection, by allowing current to flow in only one direction. This solution is better than using a diode, which has a considerable voltage drop for the application. The circuit described can be seen in Fig. 3.

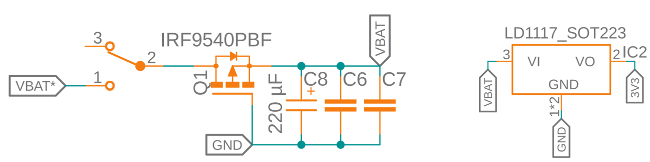



**Fig. 3.** Power supply circuit.

One of the most important parts of a mobile robot is the locomotion, and for this two motors were used. To drive this motors a integrated circuit model TB6612FNG was connected to the GPIOs of the microcontroller, as shown in Fig. 4 and 6. This IC is a dual H bridge driver for DC motors with maximum voltage of 15V, 1.2A average and 3.2A peak per channel [2].

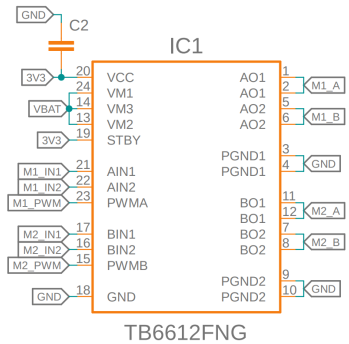



**Fig. 4.** Dual H bridge IC.

A Pololu QTR-8RC reflectance sensor array [7] was used to perform the line sensing, with eight QRE-1113 reflectance sensor [1] and their auxiliary circuit that allowed it to be connected directly to the microcontroller. The model used can be seen in Fig. 5.

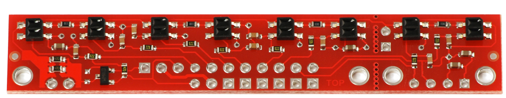


**Fig. 5.** QTR-8RC reflectance sensor array [7].

An ESP32-WROOM-32E module [3] was used as microcontroller due to its native Bluetooth and WiFi wireless connectivity, as well as meeting the necessary hardware requirements related to processing power and peripherals. The use and connection of each pin of the microcontroller can be seen in Fig. 6. A ceramic capacitor was placed near the power supply pin to filter possible high frequency interferences and guarantee the good functioning of the component.

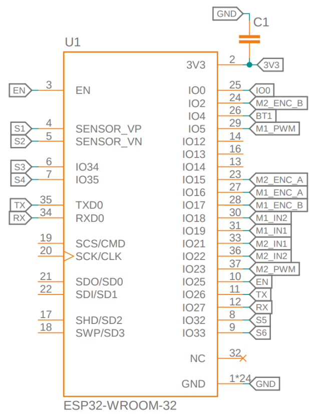



**Fig. 6.** Microcontroller circuit and connections.

The complete circuit of the robot can be seen in Fig 7, which, besides the described parts, shows the connections of the motors and their encoders, the connection of the line sensors, a pushbutton and an interface connector with the microcontroller to perform the upload of code using a programmer circuit.

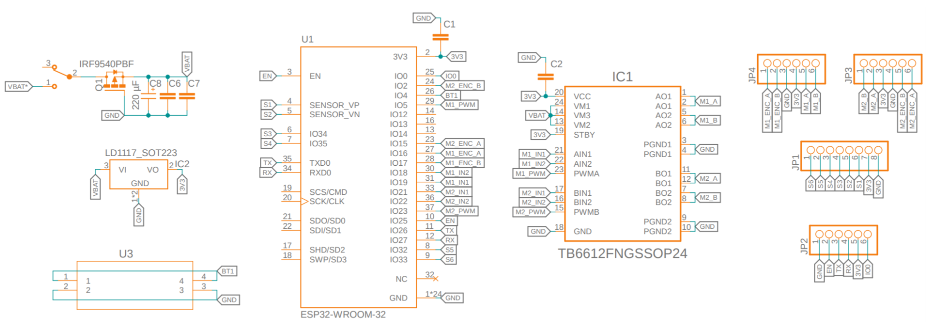



**Fig. 7.** Complete circuit of the robot.

With the circuit schematic completed, the design of the robot PCB was developed in the top layer and considering the geometry as a crucial aspect, since the PCB is used as part of the mechanical assembly. Thus, the holes for fixing the motors, holes for fixing the printed part to support the line sensors and the positioning of components and connectors were idealized to enable a good final assembly of the robot. The final PCB design and the 3D design can be seen in Fig. 8 and Fig. 10. The PCB realized through machining process can be seen in Fig. 9.

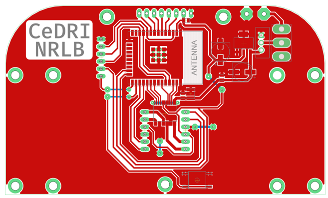



**Fig. 8.** Circuit of the robot.

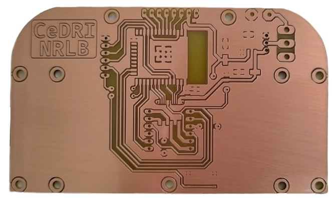



**Fig. 9.** Real PCB.

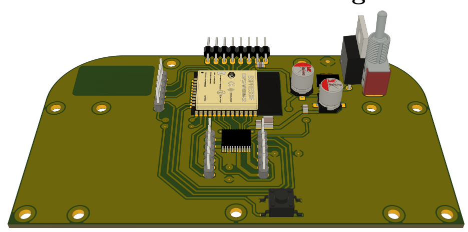


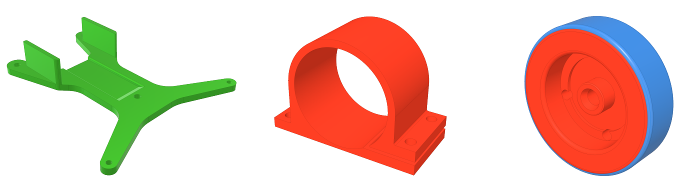
**Fig. 10.** 3D design of the robot circuit.

### 4.2 Printed parts

To support the line sensors, the battery, and the motors it was necessary to design some parts to be manufactured by 3D printing.

For the line sensors the part shown in Fig. 11(a) was designed, which extended the robot to distance the sensors from the wheel axle, so that the robot could identify changes in line direction in time to control the motors and the direction of the robot correctly. In addition, this part was used to support the battery through two stoppers and allowed the passage of the cable that connects the line sensors to the main circuit of the robot.

The part shown in Fig. 11(b) was designed to attach the motors to the back of the robot's main board. The wheels (Fig. 11(c)) were designed to be attached to a bearing, but in the final assembly this was not necessary and was attached to the motor shaft.



(a) (b) (c)

**Fig. 11.** **(a)** Sensor and battery support. **(b)** Motor support. **(c)** Robot wheel.

### 4.3 The battery

To power all circuits and components, a LiPo battery was employed. This choice was made due to its high energy density and, mainly, its lightness characteristics. The model chosen was a Hacker TopFuel Eco-X battery pack, with 900mAh, 11.1V (3S) and a weight of 77g.

### 4.4 Motor Control

Motors without a gearbox were used so that higher speeds could be achieved, with the wheels being connected to the motor shaft. This made the speed control of the motors very easily unstable, because the motor response became very sensitive for the proposed application.

Fig. 12 shows the control diagram used to implement the controller responsible for regulating the speed of the motors. The error value is obtained by comparing the speed reference with the speed measured by the encoders. The error value is used to calculate the action of the PID compensator, which is limited to the maximum values allowed by the system (saturation) and is also modified to implement a dead zone compensation. The motor is driven through an h-bridge circuit with the resulting PWM value.

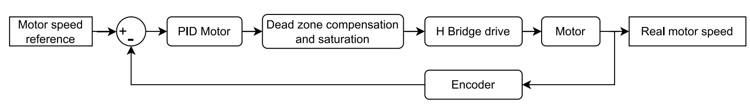



**Fig. 12.** Motor control diagram.

### 4.5 Dead Zone Compensation

The control input corresponds to the desired velocity of the motor, while the DC motor demonstrates a characteristic nonlinearity referred to as a dead zone. This nonlinearity is visually depicted in Fig. 13. Additionally, when utilizing the DC motor without a gear box, a substantial torque is required to initiate movement, thereby exacerbating the dead zone effect. Consequently, in the present scenario, the motor remains unresponsive to reference inputs lower than approximately ± 2.40 V.

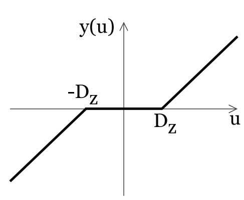



**Fig. 13.** Example of a dead zone nonlinearity.

The strategy used to circumvent this problem was implementing an offset on the speed controller's action to ensure that the motor response remains outside the dead zone. This compensation value was defined by starting from the robot's steady state and increasing the PWM until the robot initiated motion.

### 4.6 Follow Line Control

A centroid algorithm [10] was implemented to calculate the position of the robot relative to the line using the analog values from the reflectance sensors. The algorithm returns zero when the robot is in the center of the line, a positive value when it is to the left of the line, and a negative value when it is to the right of the line. The output value was used as feedback to the control loop.

The control strategy used for the control loop responsible for keeping the robot in the center of the line was typical of a differential line follower. The system error is calculated by subtracting the position of the robot relative to the line by the reference, which was kept at zero. This value is used as input to the PID compensator and its output is used as reference for the speed controllers at differential values according to Eq. 1.

$$\begin{aligned} Speed\ Motor\ A &= Global\ Robot\ Speed + PID\ Output \\ Speed\ Motor\ B &= Global\ Robot\ Speed - PID\ Output \end{aligned} \tag{1}$$

The complete control diagram of the robot can be seen in Fig. 14.

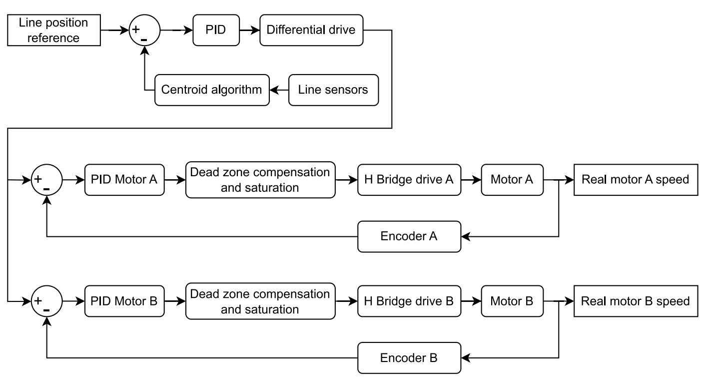


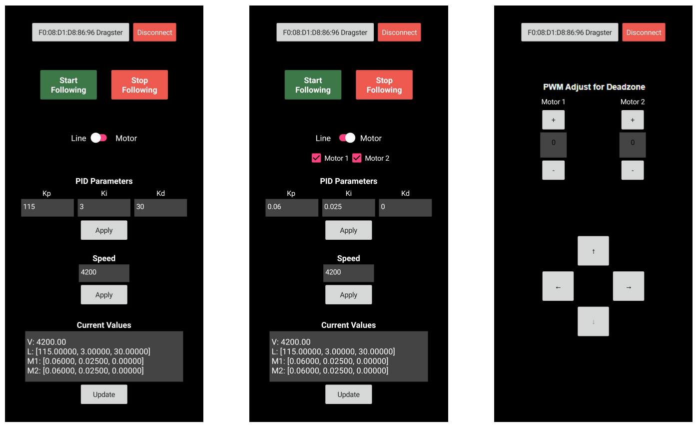

**Fig. 14.** Robot control diagram.

### 4.7 Android App

An Android application was developed using MIT App Inventor[6] as the goal of facilitating the adjustment of the robot's PID and speed values. The screenshots

[6] https://appinventor.mit.edu

(Fig. 15) show the simple and intuitive interface, as well as the main functionalities of the application.




(a) (b) (c)

**Fig. 15.** Android application screenshots: **(a)** Follow Line PID Adjust. **(b)** Motor PID Adjust. **(c)** PWM for Deadzone Adjust.

Using Bluetooth communication, it was possible to adjust the PID values of the follow line and speed control, independently for each motor, as well as to set the average speed of the robot.

This dynamic way to change all these parameters represented a significant time saving, when compared to the time spent to compile and upload code to the microcontroller for each new adjustment.

The application also allowed to start and stop the robot, receive feedback messages, and view the current values. Moreover, it was possible to find out the PWM value whose robot started the movement, to adjust the dead zone, avoiding unwanted movements.

This application was an efficient tool to optimize the robot's performance, with precise control and ease of use.

## 5 Results

All the parts and circuits described have been made and assembled. However, some additional circuits had to be implemented compared to the original design.

The first change was in relation to starting the robot, which according to the rules of the category is done by a light signal positioned at the top of the start of the track. For this, an LDR sensor was positioned on the front of the robot at a height of approximately 20cm. The connection between the LDR sensor and the microcontroller had to be made directly, through wires, since this connection was not foreseen in the original project.

Another change was in relation to the battery and the primary power supply of the robot. As the battery discharged over time, the system response changed, since the maximum supply voltage of the motors decreased as the battery discharged. To solve this problem, a Buck-type DC-DC converter was placed to fix the supply voltage, independent of the battery charge level. This allowed the robot's parameters to be adjusted more precisely, without the influence of the supply voltage. The DC-DC converter was positioned on top of the battery.

The final version of the robot that was demonstrated during the 2023 National Robotics Festival in Tomar, Portugal, in which it achieved first place overall in its category, is shown in Fig. 16. A video of one of the races run by the robot in the competition can be accessed at https://bit.ly/3QbjqlS.

**Fig. 16.** Final version of the assembled robot.

## 6 Conclusion

In general, it can be concluded that the development of the dragster robot met the proposed objectives, since it demonstrated a good performance during the competition and won first place. The table with the final rankings and the robots' performance over the three days of competition can be accessed at https://bit.ly/48Ki9JN. The robot is referred to in the table as the "NRLB" team. It scored 25,20 points to take first place overall and the second best track time, completing the track in 3,27 seconds.

All these following items can be highlighted as positive aspects of the project:

– The electronics worked as expected, and the chosen microcontroller proved to be up to the task.

- The centroid algorithm in combination with the Pololu QTR-8RC reflectance sensor array provided good performance for the line follower control;
- The implementation of dead zone compensation, along with the DC-DC buck converter, made the motor's response more stable and allowed it to reach higher speeds;
- The Android application made the process of adjusting the constants of the PIDs easier and faster;

However, one cannot ignore the challenges that arose along the way. During the competition, some problems were identified that affected the robot's performance in certain situations, such as the impossibility of reversing the motors without burning the H-bridge, impeding the robot to stop within the extra point area, leaving it at a disadvantage compared to the other opponents.

These and other obstacles taught valuable lessons and highlighted the need to further refine the project for a next version. Hence, the paramount enhancement required for the project is the substitution of the existing H-bridge with one featuring a greater current-carrying capacity.

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