Article

Design and Validation of EASYbot: An Open, Scalable and Modular Platform for Educational Robotics

Jonathan Ruiz-de-Garibay * , Pablo Garaizar , Susana Romero-Yesa

Posted Date: 17 March 2026

doi: 10.20944/preprints202603.1267.v1

Keywords: educational robotics; open hardware; engineering education; robotics competitions; Arduino-based platform; embedded systems

Article

Design and Validation of EASYbot: An Open, Scalable and Modular Platform for Educational Robotics

Jonathan Ruiz-de-Garibay [1,*], Pablo Garaizar [1] and Susana Romero-Yesa [2]

[1] Deustek, University of Deusto, Avenida de las Universidades, 24, 48007, Bilbao, Spain
[2] DeusMED, University of Deusto, Avenida de las Universidades, 24, 48007, Bilbao, Spain
* Correspondence: jonathan.garibay@deusto.es

Abstract

Educational robotics (ER) and robotics competitions offer an effective context for developing STEM (Science, Technology, Engineering, and Mathematics) competencies, technical skills and soft skills in engineering degrees. However, current platforms reveal a pedagogical and technical gap: closed commercial systems restrict access to hardware, while open solutions frequently lack a robust and structured architecture for educational settings. Moreover, in both cases, many platforms do not achieve the hardware requirements of the most demanding competitions. To address this issue, the present article presents the design, implementation, and validation of EASYbot, a modular open-hardware robotics platform based on Arduino. The system integrates a microcontroller, a dual USB–battery power supply, high-performance motor power stages, and a plug-and-play interface for input/output and communication peripherals, enabling its use in several competition categories such as mini-sumo or maze robots. The platform is complemented by a state-based programming model and supports libraries that facilitate a learning assessment. The platform provides a scalable ecosystem, enabling students to progress from initial prototyping to optimized hardware control. The validation process encompasses a range of assessments, including technical tests, usability and adoption evaluation through surveys.

Keywords: educational robotics; open hardware; engineering education; robotics competitions; Arduino-based platform; embedded systems

1. Introduction

Educational robotics (ER) has become an established pedagogical tool for developing programming, technical and scientific skills, critical thinking and problem-solving, and social and personal skills at various levels of education [1]. Thanks to its interdisciplinarity, it enables the integration of electronics, programming, control, mechanics, and embedded systems and can be easily combined with active methods such as project-based learning [2,3]. Several studies confirm that incorporating robotics into the classroom not only increases student motivation [4], but also improves their problem-solving skills and promotes the development of computational thinking [5,6]. Recent studies [7,8] demonstrate with quantitative evidence that ER produces significant improvements in the performance of these competencies compared with traditional methods.

In recent decades, the use of robotics has increased significantly in both primary and secondary education [9]. In this early phase, this expansion has been supported by commercial platforms that offer an intuitive introduction to the technology. At the same time, competitive robotics has become increasingly important as an educational tool [10]. In fact, recent publications show that participation in robotics competitions has a direct and measurable impact on improving students' interpersonal skills, project management and self-efficacy [11]. In this context, categories such as line-follower, tracker, mini-sumo or maze robots (see Figure 1) place demands on performance and reliability that promote the application of engineering principles such as iteration, verification, debugging and optimisation.

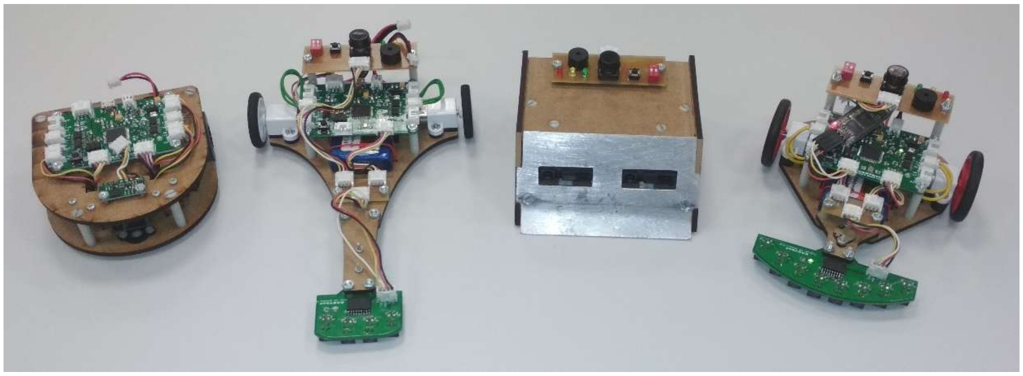


Figure 1. Left to right: maze robot, line-follower robot, mini-sumo robot, and tracker robot.

This transition towards advanced technical applications is reflected in various university initiatives: for example, [12] evaluates a competition robotic project with first-year university students, while [13] details the design and validation of differential traction robots created specifically for teaching automatic control systems. Furthermore, it has been demonstrated that using robots to teach complex concepts, such as trochoidal curves in mathematics [14], improves conceptual understanding compared to traditional teaching methods or the use of passive multimedia resources.

However, the use of pre-configured hardware in ER platforms is not equally effective in certain higher education contexts, particularly where the system needs: (1) flexibility to adapt the robot to different contexts, (2) high-performance for certain competitive environments, (3) open architectures that allow access to and modification of the hardware, (4) programming tools that facilitate the development of advanced control algorithms, and (5) adaptability to different educational levels with a clear pedagogical focus.

To meet this challenge, this article presents a competition ER platform whose design is determined not only by technical requirements but also by educational ones, as recommended in [15]. Specifically, EASYbot is proposed as an open, scalable and modular platform that reduces initial friction while maintaining the technical depth required for higher education in the field of embedded systems. The technical and educational objectives are:

- To ensure unrestricted access to hardware and software, enable performance optimisation, and highlight the mutual influence of electronics and programming.
- To maintain a modular, well-documented, and robust architecture that meets the mechanical, electrical, and educational requirements of robotics competitions.
- Development of a modular and flexible ecosystem that can be adapted to different competition categories without requiring hardware redesign.
- Provision of a scalable solution for different educational levels, allowing the degree of abstraction and complexity of the training to be adapted to the technical knowledge level of the students.

The platform has been developed following a five-phase methodology: (1) research and analysis of robotic platforms used in education, (2) definition of technical and educational requirements, (3) design and implementation of hardware and software, and (4) validation and iterative update of the platform based on technical results and educational experiences, avoiding the purely technical evaluation criticised in [16]. This article does not cover the design or evaluation of robot mechanics, as in most of the projects developed, the students themselves are responsible for developing this part.

The following section provides a brief review of existing robotic platforms as educational tools. Section 3 details the defined educational and technical requirements, and Section 4 describes in depth the platform architecture, the components developed, the integration of peripherals, and the programming model. Finally, the article ends with a technical validation of the platform, an analysis about its adoption by university students, and final conclusions.

2. Robotics Platforms for Educational Use

In recent decades, the catalogue of ER platforms has grown exponentially [17]. However, selecting an appropriate tool for education remains challenging, as it must balance technical depth, cost, and the learning curve [18]. Furthermore, pedagogical success does not depend only on the hardware, but also on the existence of structured educational activity guides to accompany it [19].

Commercial platforms such as LEGO Education (see Figure 2) or VEX Robotics have dominated primary and secondary education thanks to their plug-and-play design and visual programming environments. Although they facilitate deployment in the classroom by reducing technical barriers, their high level of abstraction limits direct access to sensor readings and low-level control. These restrictions prevent the development of optimised control algorithms, which are fundamental to engineering education.

To mitigate the gap between the visual and textual programming, hybrid environments have emerged [20,21]. These solutions allow users to switch between blocks and languages such as Python or C++, thus encouraging computational thinking. However, they often hide peripheral configuration and the temporal behaviour of the system, which are critical elements for consolidating fundamental technical knowledge.

Solutions based on open controllers such as Arduino, Raspberry Pi or BeagleBone represent a step towards greater technical depth [22,23]. By enabling direct configuration of PWM (Pulse Width Modulation) or ADC (Analog to Digital Converter) modules, these platforms facilitate an understanding of embedded architectures. The main advantages are high customisation, access to hardware and software repositories, and the possibility of electronic redesign. However, they generally lack standardized educational architecture. Many open-source robots (Doodlebot [24], underwater robots [25] or FOSSBot [26]) are designed for specific applications, requiring complete redesigns if the context of use changes. For example, Figure 2 shows the Pololu Zumo robot which is designed for mini-sumo category, but it is not possible to reuse in other categories.

Figure 2. LEGO Education WeDo (left) and Pololu Zumo for Arduino (right).

Competitions are highly demanding environments that demand temporal determinism and mechanical robustness. Currently, there is a critical gap, as closed platforms lack the necessary hardware flexibility and advanced frameworks (such as ROS), used in some platforms, introduce excessive architectural complexity for compact systems based on microcontrollers with real-time requirements [27].

The state of the art analysis therefore reveals a clear gap: there is no educational platform specifically designed for competition robotics that simultaneously integrates open hardware, a modular architecture, a plug-and-play peripheral system, and a coherent progressive pedagogical structure. This shortcoming justifies the need for new proposals that combine the advantages of open platforms with an accessible, scalable educational structure oriented towards robotics competitions.

3. Platform Requirements

To develop a platform that bridges the gap identified in the current state of the art between commercial educational kits and open-source systems, it is essential to establish a clear requirements framework. Given the educational focus of this work, the requirements are not limited to hardware and software specifications, but also incorporate criteria related to scalability, modularity, and learning usability, so that the platform can be adapted to different learning levels without sacrificing access and understanding of the system's interior workings. Consequently, the requirements are organised into three blocks: (1) educational requirements, (2) technical requirements, and (3) usability and professional requirements.

3.1. Educational Requirements

The platform must enable comprehensive training in the three key areas of robotics: electronics, programming, and embedded systems. To this end, it must enable students to (1) understand the electronic functioning of sensors, (2) control the motor power stages, and (3) understand power supply systems under real operating conditions. Students must be able to move from (4) block-based visual programming to (5) structured programming in high-level languages, including more advanced aspects such as (6) object-oriented programming and (7) event control. Taken together, this promotes comprehensive learning of the system, in which students understand: (8) the relationship between hardware and software, (9) the modularity of the system, and (10) the reuse of components in different categories of robots.

To achieve this, the system must be scalable, allowing for a gradual transition from high levels of abstraction to direct management of microcontroller resources. This versatility favours active methodologies such as project-based learning (PBL), in which the difficulty of the challenge can be adjusted to the technical maturity of the students.

3.2. Technical Requirements

From a technical perspective, the platform must guarantee reliable and repeatable performance in real environments, across different categories of robots, such as line-follower or mini-sumo robots. This implies the following requirements:

- Kinematics and control: a two-wheel differential drive model is adopted to enable precise movements and agile response, with the ability to implement closed loop control when necessary.
- Integration and robustness: the design must minimise volume and weight by integrating as many components as possible onto the main board to reduce wiring, which is often a major point of failure. Robustness against impacts and vibrations is essential for categories such as mini-sumo robots, where repeated collisions occur.
- Power management: An efficient and monitored power supply system is required to ensure microcontroller stability under motor current peaks, while enabling USB power during programming and debugging phases to reduce battery consumption.

3.3. Usability and Professional Requirements

To ensure good adoption by students without sacrificing technical depth, the platform must present a balanced learning curve. This is achieved through an intuitive architecture based on standardised connectors and modular peripherals, allowing students to understand the robot as an integrated system rather than a simple collection of isolated components. This plug-and-play approach reduces initial frustration caused by physical connection errors (polarity, incorrect wiring, or intermittent contacts), allowing students to focus on system architecture and control logic.

Finally, the EASYbot platform should bring students closer to real-world scenarios of embedded system design, debugging and development, incorporating professional practices such as the use of technical documentation, connection traceability, functional verification and iterative refinement based on failures and measurements.

4. EASYbot Platform

The EASYbot platform is designed as a modular, open and scalable ecosystem for educational and competitive robots. The aim is to support a learning progression from basic assemblies and training programmes to more demanding control strategies, while keeping the relationship between sensing, control, and actuation explicit and visible to students.

4.1. EASYbot Modular Architecture

The modular architecture of the EASYbot platform has been designed to balance operational simplicity with high extensibility. The central core integrates, in a single component, the key elements necessary for data processing, motor control, power management, and peripheral input/output interfaces.

Figure 3 shows the system architecture and includes a microcontroller, a DC-DC voltage regulator, two high-performance H-bridges for motor control, and seven multifunction input/output ports. In addition, it incorporates a battery monitoring system, an ICSP (in-circuit serial programming) connector for bootloader programming and a reset circuit.

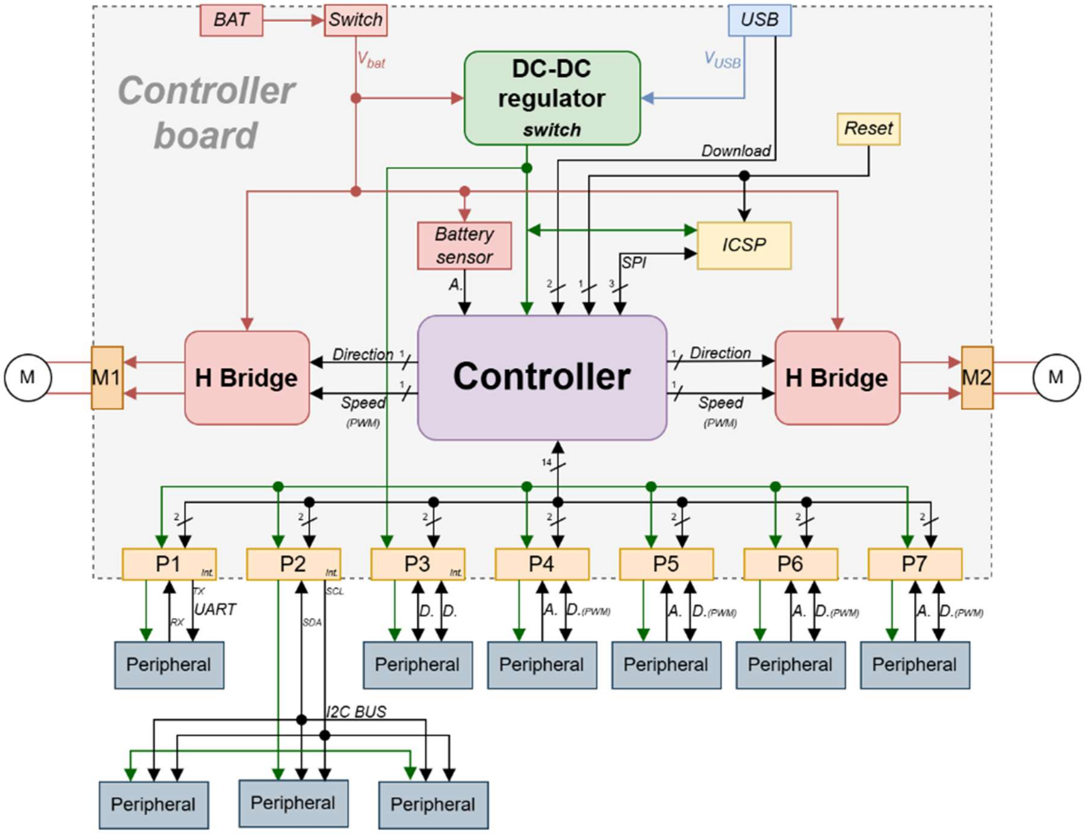


Figure 3. EASYbot hardware architecture and main functional blocks.

All peripheral ports can be used as digital input/output signals; some of them also provide additional functions, such as UART (Universal Asynchronous Receiver-Transmitter) serial communication, an I2C (Inter-Integrated Circuit) bus, analogue inputs or PWM outputs. This multifunctionality allows the robot configuration to be adapted to different practice profiles (training, prototyping or competition) without modifying the motherboard.

doi:10.20944/preprints202603.1267.v1

4.2. Connection System

The reliability of mechanical and electrical connections is one of the key requirements defined for the platform. For this reason, EASYbot uses JST-PH connectors with a 2.0 mm pitch, a choice based on four main technical criteria:

- Mechanical safety: the connector design incorporates a retention mechanism that prevents accidental disconnection during impacts or sudden movements.
- Reverse polarity protection: the geometry of the connector prevents insertion in the wrong orientation, protecting the electronic components from possible damage caused by handling errors.
- Signal distribution: each port provides four pins that allow power signals (VCC and GND) along with analog/digital signals or communication buses (I2C/UART).
- Electrical capabilities: these connectors support up to 100V and 2A of current.

To connect the system to a developer's computer, a micro-USB port is provided that serves as both a programming and serial communication interface, and a power source during debugging and testing. This allows students to power and test sensors, low-power actuators, and control logic without the need for an external battery.

4.3. EASYbot Arduino Board V1.1

The central component of the platform is the EASYbot Arduino Board, a dedicated board that incorporates the technical and educational requirements defined above. It integrates the microcontroller, a power management system, power motor stages, and peripheral connectivity, reducing the number of external modules and associated wirings.

The development of version 1.1 is the result of an iterative improvement process. As summarised in Table 1, the evolution of the hardware has focused on maximising robustness and versatility.

Table 1. Version history of the EASYbot Arduino Board.

Version	Date	Updates
0.4.c	2015/03/03	First operational version.
1.0	2016/08/06	USB connector replaced to improve mechanical retention.
1.1	2025/09/12	Addition of a switch for external-battery power on/off. Update of the capacitors associated with the power motor stages.

4.3.1. Power Supply Subsystem

Efficient power management is essential in the EASYbot platform, given the need to coexist with high motor current demands while ensuring the stability of the control electronics. The system implements a dual power supply architecture that can switch between the USB connection and an external battery (typically a 3.7 V or 7.4 V LiPo battery). This switch is transparent and gives priority to the USB power supply when the system is connected to a computer.

Figure 4 shows the schematic design of this subsystem, which integrates the following key elements: (1) a DC-DC regulator to reduce the input voltage to the required logic levels, (2) support for 3.3 V or 5 V logic on the same hardware by replacing the regulator (essential for scalability, as it allows compatibility with a wide range of sensors and peripherals without external adapters), and (3) a voltage divider that acts as a battery level sensor (this allows software to read the battery status and prevent deep discharges).

To implement the 3.3 V and 5 V logic levels, the design utilises the ADP3338AKCZ-5-R7 and NCP1117ST50T3G low dropout (LDO) regulators, respectively. These components were selected for their design compatibility (they share the SOT-223-3 package), and for a compatible auxiliary circuit, which optimises the board design. Using switch J1, the system can direct the USB input voltage to the logic signal directly, or through the regulator, providing flexible adaptation to the selected operating voltage.

The values of the voltage divider resistors were strategically chosen to maximise the measurement range without compromising resolution: with 3.3 V logic, the system can monitor batteries up to 12.2 V, while in the 5 V version, the range is extended to 18.5 V. Although this measurement method is simple and has limited accuracy, it makes EASYbot independent of the specific battery type used and is suitable as a functional indicator.

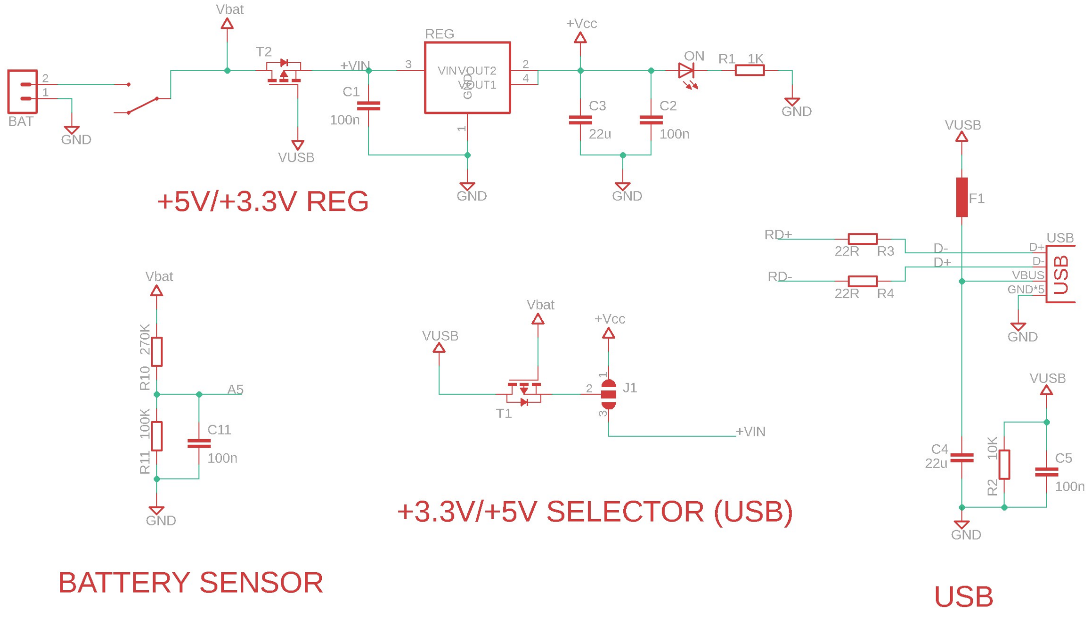


Figure 4. Power-supply subsystem schematic.

4.3.2. Control and Processing Unit

The microcontroller selected for the EASYbot platform is the ATmega32U4, used in the Arduino Micro board. This device offers an adequate balance between performance, low power consumption, and compatibility with the Arduino ecosystem, facilitating its adoption in educational contexts. In addition, the ATmega32U4 incorporates a native USB interface, eliminating the need for external converters and allowing direct communication with a computer for programming and debugging. Figure 5 shows the schematic of this control unit, based on the Arduino Micro documentation.

Arduino provides access to a development environment and a very broad set of libraries, which reduces the barrier to entry for students with no prior experience. At the same time, the use of an AVR microcontroller allows students to delve deeper into aspects of embedded architecture, such as timers, interrupts, and peripheral configuration, when their technical level is high.

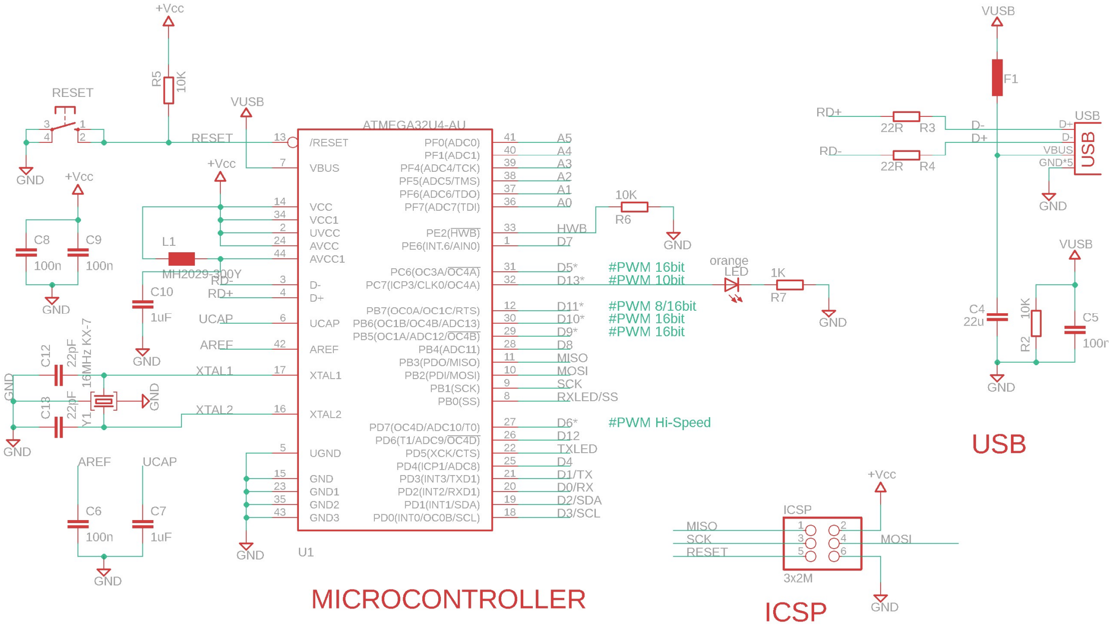


Figure 5. Control and processing unit schematic.

4.3.3. Motor Power Stages

The EASYbot platform's movement system is based on two high-performance H-bridges, designed to support the current demands of competition motors. To ensure efficient commutation and protect the microcontroller logic, MCP1407 gate drivers have been used. These components can supply high peak currents and provide fast MOSFET response, minimising commutation losses and reducing heating in the motor power stage.

Figure 6 illustrates the conceptual design of the H-bridge, in which the control logic has been simplified to two signals per motor (direction and speed). Motor 1 uses pin D4 for direction and pin D5 for speed, while Motor 2 uses pin D12 for direction and pin D6 for speed. The design includes pull-down resistors that force the motor to stop when it is not actively being driven (e.g., during programme loading or after a reset), reducing the risk of unintended starts and improving safety during debugging and testing.

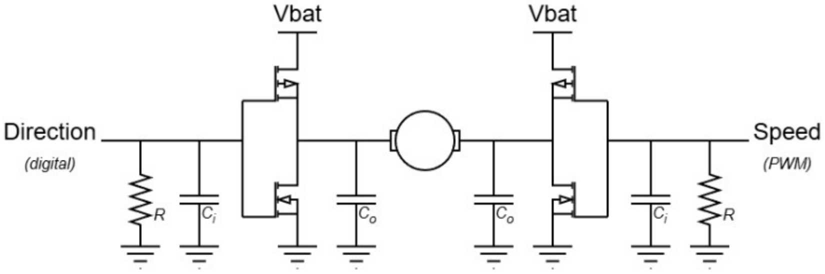
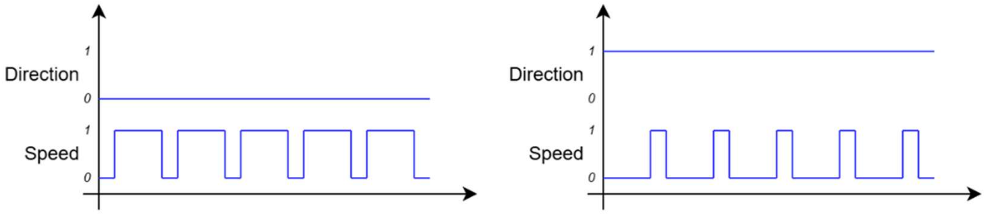


Figure 6. Conceptual design of the H-bridge implemented.

The direction signal is a digital value (‘0’ or ‘1’) that determines the direction of rotation of the motor, while the speed is a PWM signal that regulates the power supplied to the motor. In this scheme, the relationship between the two signals is not linear: when the direction signal is set to high, the PWM signal must operate with an inverted duty cycle; that is, the effective power is modulated by controlling the pulse time at the low logic level. Figure 7 illustrates how 75% of the power is obtained in both forward (a) and reverse (b) motion, avoiding discontinuities when changing direction.



(a) (b)

Figure 7. PWM signals in forward mode (a) and reverse mode (b).

4.3.4. Peripheral Ports

The EASYbot Arduino Board includes seven physical expansion ports, based on the JST-PH standard. These ports provide the primary interface for peripheral connectivity, and follow a predefined pin layout. They are organized under a multifunction architecture, allowing students to configure each port according to the specific needs of the project.

The pin distribution and capabilities of these ports are summarized in Table 2, and can be defined as follows: (1) port P1 is reserved for UART serial communication, (2) port P2 is configured to support an I2C bus, (3) ports P4-P7 allow an analogue sensor to be read on one pin and a PWM output to be generated on the other, (4) ports P1-P3 can be used with external interrupts, and (5) all ports support digital inputs/outputs.

Table 2. Pin assignment of the peripheral ports.

Port	Pin	Main function	Secondary functions
P1	D0	RX	Digital I/O or digital input with interrupt
	D1	TX	Digital I/O or digital input with interrupt
P2	D3	SCL	Digital I/O or digital input with interrupt
	D2	SDA	Digital I/O or digital input with interrupt
P3	D7	Digital input with interrupt	Digital I/O
	D8	Digital I/O	-
P4	A0	Analog input	Digital I/O
	D13	PWM output	Digital I/O
P5	A1	Analog input	Digital I/O
	D11	PWM output	Digital I/O
P6	A2	Analog input	Digital I/O
	D10	PWM output	Digital I/O
P7	A3	Analog input	Digital I/O
	D9	PWM output	Digital I/O

This standardisation of the interface allows students to create prototypes quickly and safely; all ports share the same form factor and a consistent pin map, reducing connection errors (e.g. signal swapping or using an incompatible port). It also promotes a modular view of robotics, in which the incorporation of new functionalities involves the integration of a new peripheral, rather than requiring an electronic redesign. Finally, this homogeneity facilitates the reuse of peripherals in different categories of robots while maintaining the base board.

4.3.5. PCB Layout and Manufacturing Considerations

The printed circuit board (PCB) design of the EASYbot Arduino Board has been optimised to ensure electrical and mechanical robustness under real operating conditions. The placement of components follows a functional block segmentation approach, separating the control logic from the motor power stages to minimise electromagnetic interference (EMI). A critical aspect of the design is the sizing of the copper traces, especially on the lines feeding the H-bridges and the motor outputs. These have been oversized (0,6 mm wide) to support high current peaks without the risk of overheating or excessive voltage drops. In addition, large ground planes have been implemented, which not only provide a stable voltage reference, but also act as passive heat sinks for the motor controllers and voltage regulators.

Finally, the board has been professionally manufactured, with a finish that facilitates soldering and maintenance. Detailed silkscreen printing includes the identification of each pin and expansion port, helping students to identify the board's connections without having to constantly refer to the schematic. Figure 8 shows the assembled EASYbot Arduino Board.

Figure 8. Photograph of the assembled EASYbot Arduino Board.

4.4. Peripherals and Expansion Modules

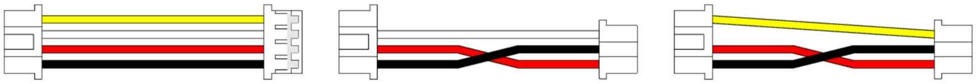
The EASYbot platform has the capacity to integrate a wide range of peripherals in a modular manner, and this approach enables the robot to evolve from a basic configuration to more complex systems. The design of these peripherals follows a principle of interoperability based on the JST-PH connection standard described in Section 4.2, so that each peripheral can be swapped or combined without modifying the rest of the system.

4.4.1. Wiring and Interconnection Systems

Wiring is one of the most critical elements in educational and competition robots, because it is responsible for a large proportion of electrical failures, such us disconnections, intermittent contacts, or breakages related to extraction. For this reason, the EASYbot platform defines an interconnection system based on four-wire cables compatible with the JST-PH connectors on the main board, with the aim of ensuring secure, repeatable connections and a clean and well-organised peripheral layout. Additionally, the choice of colours (black to GND, red to VCC, and white or yellow to signal lines) allows for a consistent map for tracking connections. Three wiring configurations have been defined (with variable lengths depending on the assembly):

- Standard 4-to-4 wiring (see Figure 9a): includes all four cables, with JST-PH connectors at both ends. It is used when power and two signal lines (e.g., communication buses, or peripherals that use both I/O pins) must be carried simultaneously.
- Digital 4-to-3 wiring (see Figure 9b): includes power and a single signal line, intended for digital peripherals. It uses a 4-pin JST-PH connector at the main board end and a 3-pin connector at the peripheral end.
- Analog 4-to-3 wiring (see Figure 9c): includes power and a single signal line, originally intended for analog input peripherals. As the digital wiring, it uses a 4-pin JST-PH connector towards the main board and a 3-pin connector towards the peripheral. Although designed for analog inputs, it can also be used with digital peripherals.

doi:10.20944/preprints202603.1267.v1



(a) (b) (c)

Figure 9. EASYbot wiring configurations: standard 4-to-4 wiring (a), digital 4-to-3 wiring (b), and analog 4-to-3 wiring (c).

When it is necessary to connect two independent peripherals to the same port, an I/O Splitter (see Figure 10) allows the port to be divided into two branches. In this case, a 4-to-3 wiring is used for each peripheral (one digital and one analog), and a standard 4-to-4 wiring connects the splitter to the main board. This splitter is developed for scenarios where the number of peripherals exceeds the number of available ports.

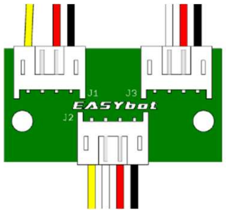


Figure 10. I/O splitter for duplicate peripherals.

The splitter can also be used as an I2C hub, allowing two peripherals to share the same bus using standard 4-to-4 wiring. Using the same scheme, there are hubs for three or more I2C devices, such as the one shown in Figure 11. This makes it easy to expand the peripheral ecosystem when required by the project.

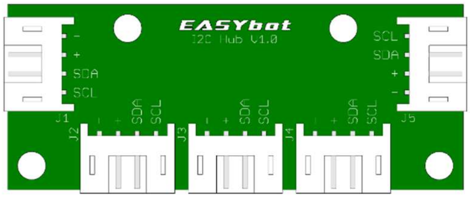


Figure 11. I2C hub for four peripherals (one master and four slaves).

4.4.2. Training Peripherals

To facilitate a progressive learning process, from basic exercises to more complex integrations, the EASYbot platform includes a set of training peripherals designed with the same interconnection system. These components allow the gradual introduction of key concepts such as sensor reading, PWM signal generation, communications or interrupt management. This section describes the peripherals developed, summarises their educational purpose and explains their integration into the platform.

The first training peripheral is a push-button, as it is one of the simplest and most representative digital inputs for introducing digital signal reading. This peripheral is particularly useful in early training sessions to address concepts such as edge detection, software debouncing, or basic timing. The next training peripheral is an LED diode, which is used as an ON-OFF digital output or as a PWM output to regulate brightness. Like the push-button, it integrates a 3-pin JST-PH connector compatible with the digital 4-to-3 wiring, making it easy to use in training activities. The third training peripheral is an angular potentiometer, which must be connected to a port with an analog input using the analog 4-to-3 wiring. This peripheral allows students to read an analog sensor and work on ADC conversion and the scaling of measured quantities.

With these three peripherals and the I/O splitter (Figure 10), various training activities can be carried out using different peripheral configurations. In addition, a fourth peripheral has been developed that combines a push-button and an LED diode within the same hardware module. Figure 12 shows these four peripherals for digital and analog input/output training.

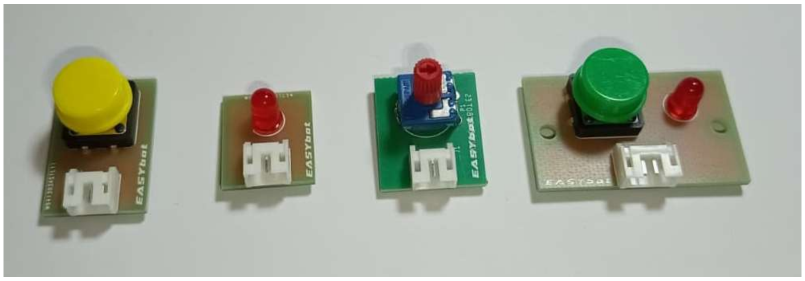


Figure 12. Training peripherals, from left to right: push-button, LED diode, angular potentiometer, and combined push-button and LED diode.

Motor control is fundamental in robotics projects; therefore, the platform integrates the Pololu DC micro-motors. For motor connection, the wiring uses a 2-pin JST-PH connector with no fixed polarity, so that identifying rotation direction and its relationship to the control signals becomes part of the training itself.

Once the training with basic digital and analog I/O peripherals and DC motors is completed, students can work with advanced components, such as the UART serial interface and Bluetooth communication using the HC-05 module. In this case, a dedicated adapter wiring was designed (see Figure 13), because the standard 4-to-4 wiring cannot be used due to the type of connector and the pinout of the HC-05. This solution maintains the platform interconnection model while incorporating a widely used commercial module for basic remote-control practice.

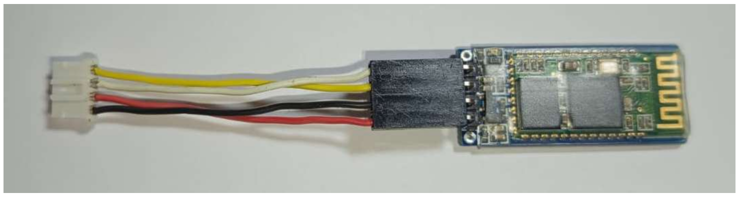


Figure 13. HC-05 Bluetooth transceiver with adapter cable.

To conclude the training, the platform allows to practice with the I2C bus through a peripheral called EASYbot IO Controller. It integrates a double micro-switch, a small push-button and a large push-button, three LEDs of different colours and a buzzer, together with the MCP23008 digital I/O expander. Figure 14 shows this peripheral, which is also designed for use in the competition robots in order to manage and configure them. In this case, it uses a fifth pin on the connector as an interrupt line, allowing the microcontroller to detect peripheral events without continuous polling and introducing students to this programming model. This additional pin must be connected to a port on the main board with interrupt capability.

Figure 14. Photograph of the EASYbot IO Controller module (MCP23008-based I/O expander).

4.4.3. Competition-Robotics Peripherals

The four competition categories implemented with the EASYbot platform are: line-follower, tracker, mini-sumo and maze. In each case, a different combination of peripherals is used, where some modules can be shared between categories (e.g., the EASYbot IO Controller or the HC-05 Bluetooth module), while other peripherals are specific to each category depending on the sensor requirements.

For the line-follower robot, a specific peripheral has been developed that integrates four CNY70 sensors. These sensors distinguish between black and white surfaces and allow the robot to follow the reference line on the circuit. To simplify wiring and improve scalability, this peripheral uses the MCP23008 Digital I/O Expander via the I2C bus. The tracker robot uses a version with eight CNY70 sensors, which are necessary both for line tracking and for detecting lateral markers. Figure 15 shows these two sensor peripherals integrated into the robots.

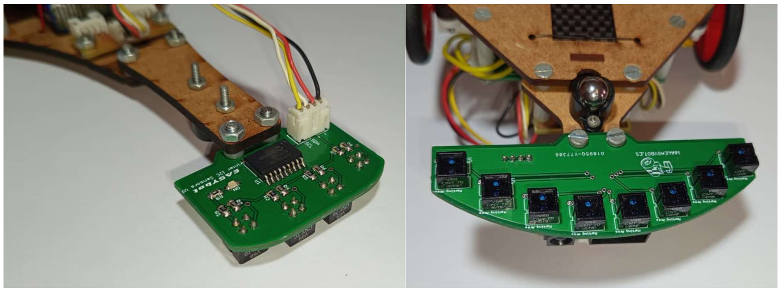


Figure 15. Line-follower sensors (left) and tracker sensors (right).

The mini-sumo robot uses SHARP infrared distance sensors to detect the opponent. In this case, the sensors themselves use 3-pin JST-PH connectors compatible with the analog 4-to-3 wiring. This robot also uses single CNY70 sensors to detect the tatami limit. In this case, a CNY70 sensor board has been developed to facilitate its integration into the robot with a digital 4-to-3 wiring. Figure 16 shows the integration of these peripherals into the robot.

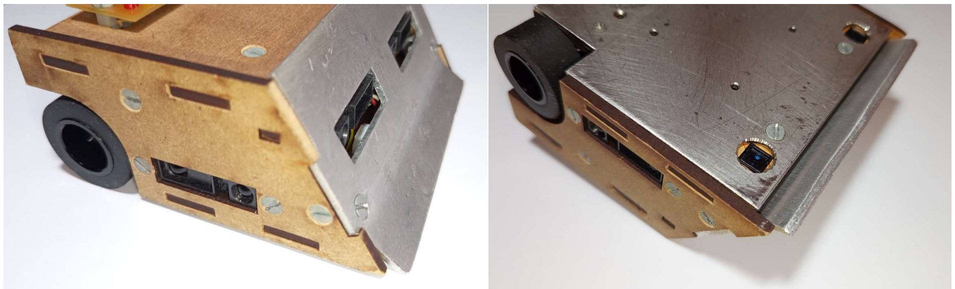


Figure 16. Mini-sumo robot distance sensors (left) and black and white sensor (right).

Finally, the maze category also uses infrared distance sensors: SHARP GP2Y0A51 sensors (range: from 2 to 15 cm). This sensor uses a different 3-pin connector, so it is necessary to adapt the analog 4-to-3 wiring to make it compatible with the EASYbot platform. The use of encoders in the motors is very important in this robot, because motion precision is critical for accurate displacements and controlled turns. To this end, maze robots utilise Pololu optical or magnetic encoders, integrated directly into the DC micro-motors used. Figure 17 shows the optical encoders integrated into the motors of a maze robot.

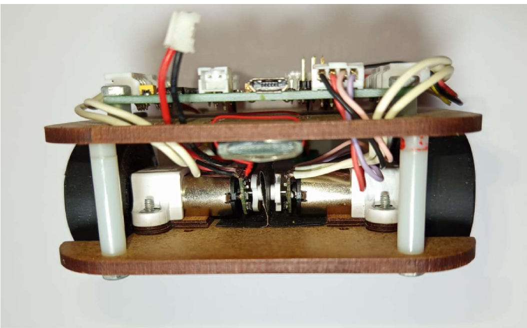


Figure 17. Micro-motors MP 50:1 with an integrated optical encoders.

4.5. Software Design

Software development of the EASYbot platform is conceived as a central element of the overall system. Its main objective is to support a progressive learning process, from introductory exercises to more demanding control developments. To this end, the firmware is based on the Arduino ecosystem (C/C++), organised around a state-based model and supported by auxiliary libraries that reduce initial complexity without preventing more advanced development when a project requires it.

The software is designed according to four principles: (1) modularity, which allows add or replace peripherals without rewriting the robot's overall logic, (2) scalability, so that the same project can evolve from a functional prototype to an optimised version, (3) reusability, minimising software redesign when changing categories, and (4) transparency, so that students can understand what is executing and when it is executing.

These principles are in line with the educational requirements established in Section 3, with special focus on the hardware-software relationship and the gradual introduction of advanced concepts.

4.5.1. Firmware Organization

The firmware structure follows a common pattern in the Arduino ecosystem, and is divided into three blocks:

- Setup: initialises hardware configuration, loads the initial state, and performs basic checks. The aim of this part is to start the robot in a safe state, forcing the outputs to known conditions to prevent unintended motion.
- Loop: repeatedly executes of readings, computing and acting tasks. When timing is required, blocking delays can be used in early stages, and, in more advanced stages, time references based on the system clock can be introduced to improve the robot's responsiveness.
- Events: at a basic level, input peripherals are read through periodic polling, while at advanced levels, interrupts are introduced for the most critical peripherals.

Students can use functions and the object-oriented programming paradigm in their code, and they can also debug the robot's behaviour via the serial port, without modifying the overall structure.

doi:10.20944/preprints202603.1267.v1

4.5.2. State-Based Programming Model

To reduce the complexity of robot behaviours and facilitate functional understanding, the EASYbot platform promotes a programming model based on finite state machines (see Figure 18). In this approach, behaviour is divided into states (e.g., stopped, tracking, attack, turn_right, etc.) and transitions defined by events or conditions (e.g., line detection, distance to opponent, elapsed time, distance travelled, etc.).

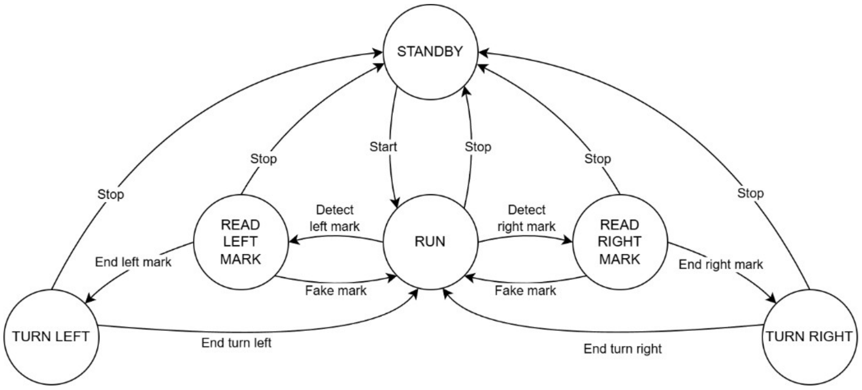


Figure 18. State-transition diagram for a tracker robot.

This model provides three main advantages: (1) it separates logic and control, as each state encapsulates concrete actions, facilitating debugging and maintenance, (2) it encourages reuse of states and transitions between categories, and (3) it supports scalability, since one can start with few states and simple transitions and then introduce more complex strategies without rewriting the entire system.

4.5.3. Available Libraries

The software can use auxiliary libraries that encapsulate access to the most common hardware elements of the platform. Currently, the EASYbot platform includes two dedicated libraries: one for motor control and another for the MCP23008 digital I/O expander.

The *DcMotor* library (https://github.com/jonathanruizdegaribay/DcMotor) allows motor control using the functional model implemented on the EASYbot platform. This library does not hide pin assignments (direction and speed), keeping the hardware-software relationship visible. Its use is recommended after initial training in which students have implemented direct motor control using digital outputs and PWM modulation.

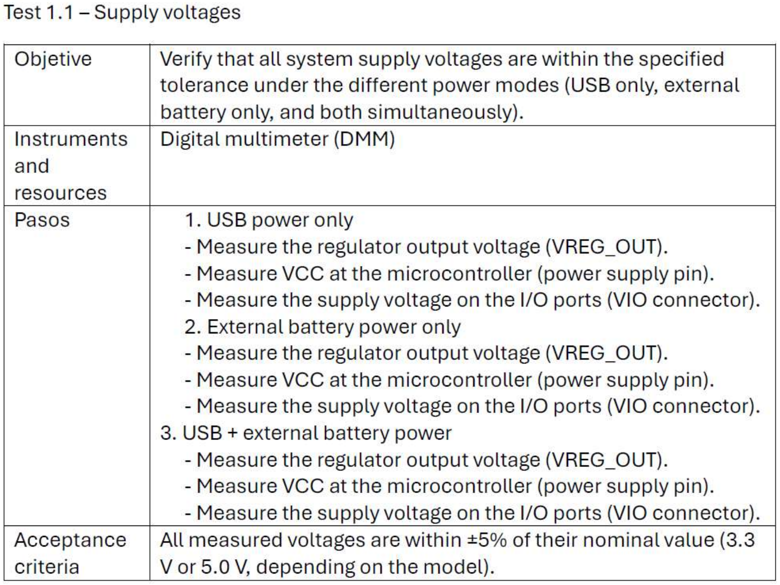
To manage different peripherals based on the MCP23008 digital I/O expander, the *MCP23008* library (https://github.com/jonathanruizdegaribay/MCP23008) simplifies the handling of these peripherals. In advanced courses, this library can be omitted to address I2C communication and its protocol at a lower level.

5. Technical Validation of the Platform

The design and implementation of a robotics platform entail the integration of multiple subsystems (power supply, controller, motor power stages, interconnection, and peripherals), whose behaviour must be evaluated to ensure correct, safe, and reliable operation in both learning and competition contexts.

5.1. Electrical Verification

Since the initial version of the EASYbot platform, a series of tests have been conducted to verify that the various subsystems function within the expected specifications and that the electrical behaviour of the entire system is consistent under real-use conditions (USB and battery supply, load variations, and motor operation). In order to ensure the reproducibility of results and facilitate the traceability between versions, all tests are defined using a uniform structure. This structure includes the objective of the test, the instruments and resources required, the procedural measures, and the acceptance criteria. Figure 19 shows the test sheet utilized to verify the voltage levels on the EASYbot Arduino Board.



Test 1.1 – Supply voltages

Objetive	Verify that all system supply voltages are within the specified tolerance under the different power modes (USB only, external battery only, and both simultaneously).
Instruments and resources	Digital multimeter (DMM)
Pasos	1. USB power only - Measure the regulator output voltage (VREG_OUT). - Measure VCC at the microcontroller (power supply pin). - Measure the supply voltage on the I/O ports (VIO connector). 2. External battery power only - Measure the regulator output voltage (VREG_OUT). - Measure VCC at the microcontroller (power supply pin). - Measure the supply voltage on the I/O ports (VIO connector). 3. USB + external battery power - Measure the regulator output voltage (VREG_OUT). - Measure VCC at the microcontroller (power supply pin). - Measure the supply voltage on the I/O ports (VIO connector).
Acceptance criteria	All measured voltages are within ±5% of their nominal value (3.3 V or 5.0 V, depending on the model).

Figure 19. *Example of test sheet.*

The following sections examine the tests performed on the main EASYbot subsystems. The EASYbot Arduino Board incorporates all of these subsystems, and analogous tests have been defined for the remaining peripherals for technical validation purposes.

5.1.1. Power-Supply Subsystem

Within the power-supply subsystem, a series of tests have been defined to verify voltage stability at the main system nodes, and to confirm consistent electrical behaviour under varying operating scenarios. Specifically, these tests enable the following: (1) validation of switching between USB power and an external battery, (2) verification that voltage levels remain within the expected margins, and (3) assessment of logic-rail stability when current peaks occur due to the power stages. Furthermore, a series of measurements have been obtained at representative nodes to ensure that consumption aligns with projections under operating conditions.

The results of the study were consistent with the expected outcomes. However, a limitation has been identified in the implemented switching system: it is not able to fully isolate the USB supply from the power stages. This observation has been taken into account in the context of the platform's use, and it has been verified that no long-term damage is caused to the USB port, the battery, or the motor power stages. However, students should be made aware of this, especially when performing debugging tests.

A final test related to the power supply concerns validating the accuracy of battery-voltage readings, while also confirming that the ADC input limit is not exceeded (3.3 V or 5 V, depending on the board version).

5.1.2. Motor Power Stages

The motor power stages represent a critical subsystem of the platform, as they are responsible for managing high currents with motor startup and load fluctuations. For this reason, specific tests have been defined to verify three things: (1) correct H-bridge actuation and its response to PWM and direction signals, (2) electrical behaviour under different demand levels (e.g. start-up, sustained load, and direction changes), and (3) robustness under conditions commonly found in competitions.

The results obtained were satisfactory, thereby confirming the stability of the motor power stages and the consistency of the motor-control response. In particular, the correct behaviour of the two-signal-per-motor control model (direction and speed) was verified, as well as the absence of unintended activations during reset and firmware upload.

5.1.3. Input/Output and Communication Interfaces

The input/output and communication interfaces provide the link between the main board and the EASYbot peripheral ecosystem. Consequently, their verification is essential to ensure reproducible behaviour in training and competition scenarios. To validate the system's correct operation, a series of tests have been defined to: (1) confirm availability and correct function assignment in the ports (digital read/write, analog read, and PWM generation), (2) verify correct operation of the intended communication buses (UART, I2C, and SPI), and (3) ensure that the power distributed through the ports remains stable during normal system operation.

The findings indicate that the developed components show tolerance to short-circuits and reverse connections when these situations occur for brief periods. Additionally, it confirms that logic levels at the interfaces are correct in both the 3.3 V and 5 V configurations. Regarding possible interference between data lines, coupling effects were observed in analog inputs during the execution of multiple ADC conversions across different channels. Given the absence of any discernible hardware design faults, the test was repeated on an Arduino Micro board, observing analogous results. The results suggest that the phenomenon may have its origin in the microcontroller's ADC, specifically in its sampling and retention capacity. Students are advised to perform a discard reading if they identify reading errors.

5.2. Functional Tests

To date, platform assembly has been carried out manually. Consequently, a functional-test protocol has been established to verify the correct operation of each unit before its use with students. The objective of this protocol is double: (1) to facilitate the early detection of defects in assembly or soldering, and (2) to ensure the consistent operation of critical subsystems (power supply, programming, reset, motor power stages, and I/O ports), thereby reducing incidents during training sessions.

Functional tests are structured to be executed in an incremental manner, with each successive step in the verification sequence serving to verify the preceding steps. For instance, in the case of the EASYbot Arduino Board, the process starts with microcontroller programming, followed by verification of the I/O ports, the motor power stages, and the battery sensor. In all components, they are not used with students until it has passed all of its functional tests, ensuring a minimum reliability threshold in educational environments. All test programs and acceptance criteria are maintained under version control.

6. Discussion

As reported in Table 1, the initial operational version of the EASYbot Arduino Board was released on March 3, 2015. Preliminary versions of the platform had been utilized prior to the specified date in competition robots developed by the teaching team and in several final-year projects related to robotics, both competition-oriented and general. The objective of this utilization was to validate the design feasibility and consolidate a first stable version of the platform.

During the 2015–2016 academic year, the teaching team of the Industrial Design Engineering degree program initiated an educational project focused on interactive shop windows. The students had limited knowledge in the domain of electronics, and their task was to design and implement a complete embedded system. The EASYbot platform was selected as the hardware base for this project because it allowed students to focus on physical design and interactive programming. This experience served as a test in a scenario that differed from the original competition-oriented objective, thereby confirming the flexibility of the platform to integrate other sensors, actuators and lighting elements, as well as its feasibility in a real installation. Figure 20 shows an example of interactive shop windows at an optician.

Figure 20. Interactive shop window implemented using the EASYbot platform.

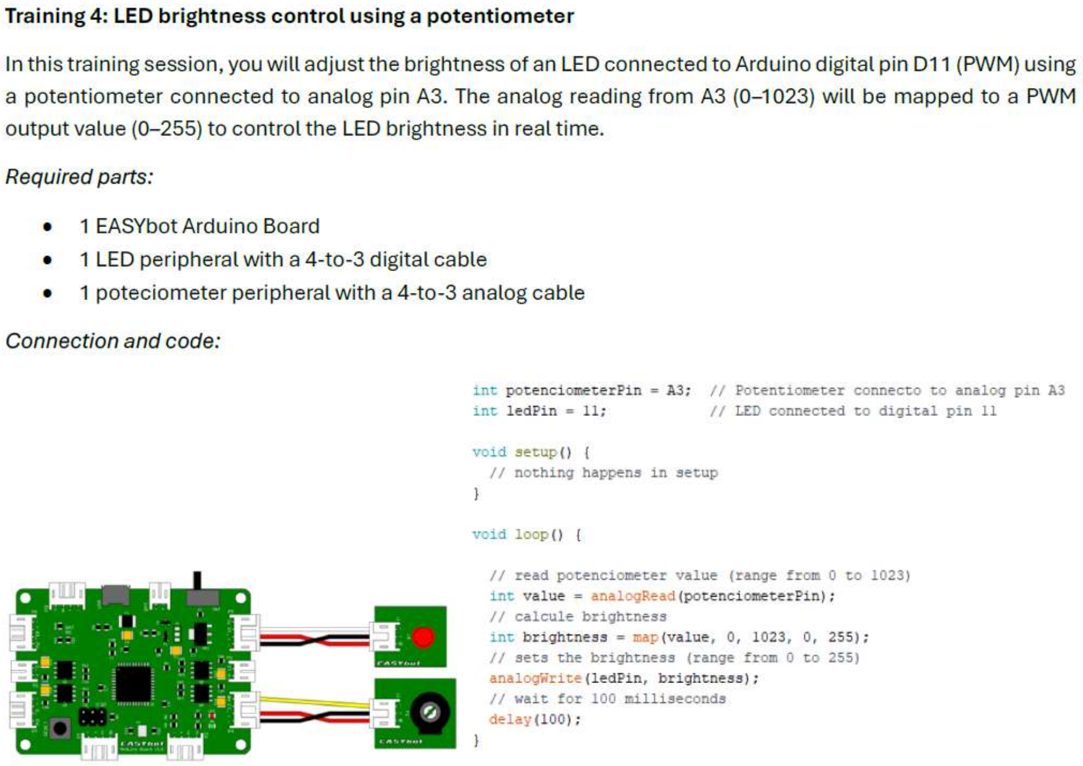
The project was implemented for two years, and in the 2016-2017 academic year, it was replaced by the first edition of the ER Competition Project, in the Industrial Design Engineering degree program. In this inaugural edition, students built a line-follower robot as training project, and subsequently, each student team developed a tracker or a mini-sumo robot.

During the 2018-2019 academic year, the educational robotic competition project was transferred into the Digital Industry degree programme, within the Digital Electronics subject, adding the maze category. This evolution allowed to expand the set of challenges and increased the technical level by introducing requirements for greater precision and control. The project's second iteration kept active until the 2024-2025 academic year; Figure 21 shows the exhibition match in the mini-sumo category.

Figure 21. The final exhibition consists of an "all-versus-all" match in the mini-sumo category.

Furthermore, the platform has been adapted on occasion for use in other, shorter teaching contexts. For instance, during the 2023-2024 academic year, an intensive version was implemented, spanning several weeks and incorporating the line-follower and mini-sumo categories. This iteration was offered within the Industrial Design Engineering degree programme again.

Across all these experiences, the training phase has been particularly relevant. It is developed through experimental laboratory sessions that address different aspects of the platform and the project. Figure 22 shows an example of the worksheet utilized by students to interpret an analog sensor and to operate a PWM peripheral.



Training 4: LED brightness control using a potentiometer

In this training session, you will adjust the brightness of an LED connected to Arduino digital pin D11 (PWM) using a potentiometer connected to analog pin A3. The analog reading from A3 (0–1023) will be mapped to a PWM output value (0–255) to control the LED brightness in real time.

Required parts:

- 1 EASYbot Arduino Board
- 1 LED peripheral with a 4-to-3 digital cable
- 1 poteciometer peripheral with a 4-to-3 analog cable

Connection and code:

```
int potenciometerPin = A3;  // Potentiometer connecto to analog pin A3
int ledPin = 11;            // LED connected to digital pin 11

void setup() {
  // nothing happens in setup
}

void loop() {

  // read potenciometer value (range from 0 to 1023)
  int value = analogRead(potenciometerPin);
  // calcule brightness
  int brightness = map(value, 0, 1023, 0, 255);
  // sets the brightness (range from 0 to 255)
  analogWrite(ledPin, brightness);
  // wait for 100 milliseconds
  delay(100);
}
```

Figure 22. Training worksheet on analog input and PWM output.

6.1. Adoption and Usability

Since the 2018–2019 academic year, usability has been assessed through student surveys, with a quantitative valuation and an open question overall rating of the EASYbot platform. The feedback was generally positive. In the 2023-2025 period, three specific indicators were defined related to the usability: (1) ease of learning, (2) perceived reliability, and (3) documentation quality; and another one about the recommended use of the project in other courses, to evaluate the Technology Acceptance Model (TAM). Table 3 summarises the results obtained from the surveys conducted over the course of the past three editions of the ER project. Two of these surveys were incorporated into the Digital Industry Degree, while the other one was incorporated into the Industrial Design Engineering degree program.

Table 3. Usability survey results (scale 1–5).

Indicator	2023.2024 (Digital Industry)	2023.2024 (Industrial Design)	2024.2025 (Digital Industry)	Mean
Number of students	20	26	26	24
Participation	70%	80.77%	46.15%	60%
Ease of learning	3.90	4.17	3.48	3.85
Perceived reliability	3.50	4.47	3.81	3.93
Documentation quality	3.75	4.42	3.96	4.04
Recommended use	4.73	4.61	4.89	4.74

The results of the usability survey (scale 1–5) are consistent with the TAM model. The perceived ease of use (PEOU) is reflected in ease of learning (mean 3.85). Perceived usefulness (PU) is supported by perceived reliability (3.93) and documentation quality (4.04), indicating that the platform is perceived as reliable and well documented to achieve the project's objectives. The intention to use (BI) is evident in use recommended (average 4.74), showing a high interest to recommend it. Finally, actual use (AU) is confirmed by sustained use of EASYbot in multiple ER project editions and its application in other teaching environments, which reinforces effective adoption beyond declared perception.

In the short project of Industrial Design Engineering, where students receive more guidance and the technical complexity is lower, ratings tend to be higher, in contrast to Digital Industry, where greater autonomy is necessary to understand the platform. This outcome reflects an anticipated pedagogical trade-off between ease of learning and technical depth.

The present study focuses on the design and validation of the EASYbot platform, as well as its technical and adoption validation. A more specific evaluation of educational impact has been previously addressed in works by the same teaching team. [28] shows the implementation of the ER project under a project-based methodology, and learning and motivation outcomes are reported in [29].

6.2. Platform Limitations and Updates

Despite its compact design, several constraints have been identified through real-use testing, primarily associated with mechanical robustness and extreme operating conditions. In version 0.4.c, the USB connector exhibited inadequate mechanical reliability and was prone to damage after extended use. This caused the 2016 update, wherein it was replaced by a connector with enhanced mechanical retention. Furthermore, students' propensity to pull on the cable rather than the connector has resulted in recurrent cable breakages, particularly on the battery connection, which carries an associated risk of short-circuiting. In an effort to mitigate the issue, version 1.1 incorporated an external-battery cutoff switch. This switch was designed to reduce connect/disconnect cycles. Finally, in mini-sumo robots, progressive degradation of the MCP1407 gate drivers has been observed, associated with prolonged motor blocks and high currents. This issue has been addressed in version 1.1, which incorporates new decoupling capacitors in H-bridges to mitigate the voltage peaks generated when the motors are blocked.

The platform architecture enables mitigations that preserve versatility in both educational and competitive settings.

- The architecture is designed to directly support the control of two DC motors. Categories requiring higher traction or multi-motor configurations may necessitate the use of external drivers. These can be integrated in a transparent manner through the I2C bus, or via digital or PWM outputs.
- The base board contains seven physical I/O ports. In cases where projects have higher sensing requirements, adapters can be utilized to connect two peripherals to the same port. Alternatively, I2C-controlled expanders can be employed, thereby facilitating peripheral integration without the need for modifying the main board.
- The battery level sensor, based on a voltage divider has low precision. For competitions that require critical autonomy management, it will be necessary to use an external charge meter that, connected by I2C or to an analogue input, provides more accurate data on consumption and the remaining capacity of the external battery.

6.3. Advantages over Closed and Open-Source Platforms

A comparison of the EASYbot platform with closed commercial kits reveals that it enables greater technical depth by providing access to both the hardware and the programming model. This feature avoids layers of abstraction that limit understanding of the hardware–software relationship. The incorporation of power management, motor power stages, and multifunction ports promotes practices that are in alignment with engineering workflows. In comparison with generic open-source solutions that rely on external modules, the platform offers a common baseline architecture and a

doi:10.20944/preprints202603.1267.v1

standardised interconnection system. This system reduces repetitive integration work and promotes the reuse of peripherals across robot categories.

7. Conclusions and Future Work

The present article presents the design and validation of EASYbot, an open, scalable, and modular platform aimed at ER and use in university-level competitions. The primary contribution of this work is the definition of an architecture that integrates power management, control, and motor power stages, in conjunction with an interconnection standard that facilitates plug-and-play peripheral integration and fosters the reusability of hardware and software across diverse robot categories.

The technical validation process has demonstrated that the platform exhibits stable operation under typical conditions of use and demonstrates reasonable tolerance to connection errors. Furthermore, compatibility of logic levels has been verified in both 3.3 V and 5 V configurations, thereby expanding the range of supported peripherals. Incidents associated with the handling of cabling and connectors have been observed during the ER project development. Furthermore, under extreme conditions, typical of the mini-sumo robot, progressive degradation has been detected in elements of the motor power stages.

The adoption results, validated using the TAM model, confirm a high perceived usefulness and a recommendation intention of 4.74/5 from the students. In contexts that demand greater technical autonomy from students, the perceived ease of learning tends to decrease, confirming that the initial friction is reduced without sacrificing the technical depth.

To date, all platform documentation and project development have been carried out privately, in Spanish, in the Faculty of Engineering at the University of Deusto. The teaching team is currently working on the publication of the EASYbot platform design and implementation, and its corresponding documentation. This initiative is being undertaken under the provisions of a GPL licence and will be available in both Spanish and English. The dissemination of these materials will be facilitated through a new repository on GitHub and via a new web page. The objective is to ensure the replicability of the EASYbot platform by other teaching teams in new academic contexts.

The teaching team is contemplating the following future lines of work: (1) validating the H-bridges update in version 1.1 under intensive use, (2) providing support for other microcontrollers with a more professional character within the EASYbot platform, while maintaining compatibility with the current peripheral ecosystem, (3) analysing other competition categories and kinematic configurations, such as quadcopters, snake robots, humanoids, or even collaborative robots, and (4) exploring the adaptation of the competition ER project to secondary education.

Author Contributions: Conceptualization, J.R-G.; methodology, J.R-G.; design, J.R-G.; validation, J.R-G.; formal writing, J.R-G.; supervision, P.G. and S.R-Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The platform design, schematics, libraries, and documentation will be available in the EASYbot repository at https://github.com/EASYbot-platform/ and via the project portal at www.easybot.es.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Evripidou, S.; Georgiou, K.; Doitsidis, L.; Amanatiadis, A.A.; Zinonos, Z.; Chatzichristofis, S.A. Educational Robotics: Platforms, Competitions and Expected Learning Outcomes. *IEEE Access* **2020**, *8*, 219534–219562. https://doi.org/10.1109/ACCESS.2020.3042555

2. Valls Pou, A.; Canaleta, X.; Fonseca, D. Computational Thinking and Educational Robotics Integrated into Project-Based Learning. *Sensors* **2022**, *22*, 3746. https://doi.org/10.3390/s22103746
3. Coufal, P. Project-Based STEM Learning Using Educational Robotics as the Development of Student Problem-Solving Competence. *Mathematics* **2022**, *10*, 4618. https://doi.org/10.3390/math10234618
4. Lancheros-Cuesta, D.; Fabregat, R. Educational Robotics Intervention in the Motivation of Students. *IEEE Revista Iberoamericana de Tecnologias del Aprendizaje* **2022**, *17*, 131–139. https://doi.org/10.1109/RITA.2022.3166856
5. Rojas, E.M.; Valencia-Arias, A.; Vásquez Coronado, M.H.; Barandiarán Gamarra, J.M.; Agudelo-Ceballos, E.; Benjumea-Arias, M.L.; Vega Mori, L. Educational Robotics for Primary Education: An Analysis of Research Trends. *Eurasia Journal of Mathematics, Science and Technology Education* **2025**, *21*, em2602. https://doi.org/10.29333/ejmste/16050
6. Sapounidis, T.; Tselegkaridis, S.; Stamovlasis, D. Educational Robotics and STEM in Primary Education: A Review and a Meta-Analysis. *Journal of Research on Technology in Education* **2024**, *56*, 462–476. https://doi.org/10.1080/15391523.2022.2160394
7. Ouyang, F.; Xu, W. The Effects of Educational Robotics in STEM Education: A Multilevel Meta-Analysis. *International Journal of STEM Education* **2024**, *11*, 7. https://doi.org/10.1186/s40594-024-00469-4
8. Wang, K.; Sang, G-Y.; Huang, L-Z.; Li, S-H.; Guo. J-W. The Effectiveness of Educational Robots in Improving Learning Outcomes: A Meta-Analysis. *Sustainability* **2023**, *15*, 4637. https://doi.org/10.3390/su15054637
9. Bano, S.; Atif, K.; Mehdi, S.A. Systematic Review: Potential Effectiveness of Educational Robotics for 21st Century Skills Development in Young Learners. *Education and Information Technologies* **2024**, *29*, 11135–11153. https://doi.org/10.1007/s10639-023-12233-2
10. Chew, M.T.; Demidenko, S.; Messom, C.; Sen Gupta, G. Robotics Competitions in Engineering Education. In *Proceedings of the 4th International Conference on Autonomous Robots and Agents (ICARA 2009)*, Wellington, New Zealand, 10–12 February 2009; pp. 624–627. https://doi.org/10.1109/ICARA.2000.4804032.
11. Rocker Yoek, S; Shwartz Asher, D.; Schohet, M.; Dori, Y.J. The Effect of the FIRST Robotics Program on Its Graduates. *Robotics* **2020**, *9*, 84. https://doi.org/10.3390/robotics9040084
12. Abas, P.E. Learning to Engineer: Integrating Robotics-Centred Project-Based Learning in Early Undergraduate Education. *Education Science* **2026**, *16*, 105. https://doi.org/10.3390/educsci16010105
13. Márquez-Sánchez, C.; Sandoval-Gutiérrez, J.; Martínez-Vázquez, D.L. Construction of an Educational Prototype of a Differential Wheeled Mobile Robot. *Hardware* **2026**, *4*, 2. https://doi.org/10.3390/hardware4010002
14. Szilágyi, S.; Körei, A.; Vaičiulytė, I. Teaching and Learning Trochoid Curves: The Importance of LEGO® Drawing Robots and Educational Robotics in Tertiary Mathematics Education. *Education Science* **2025**, *15*, 1472. https://doi.org/10.3390/educsci15111472
15. Alimisis, D. Educational Robotics: Open Questions and New Challenges. *Themes in Science and Technology Education* **2013**, *6*, 63-71.
16. Darmawansah D.; Hwang, GJ.; Chen, MR.A.; Liang JC. Trends and Research Foci of Robotics-Based STEM Education: A Systematic Review from Diverse Angles Based on the Technology-Based Learning Model. *International Journal of STEM Education* **2023**, *10*, 12. https://doi.org/10.1186/s40594-023-00400-3
17. Ribeiro, A.F.; Lopes, G. Learning Robotics: A Review. *Current Robotics Reports* **2020**, *1*, 1–11. https://doi.org/10.1007/s43154-020-00002-9
18. Evripidou, S.; Doitsidis, L.; Tsinarakis, G.; Zinonos, Z.; Chatzichristofis, S. A. Selecting a Robotic Platform for Education. In *IEEE International Conference on Consumer Electronics (ICCE 2022)*; Las Vegas, NV, USA, 2022; pp. 1–6. https://doi.org/10.1109/ICCE53296.2022.9730568
19. Kalaitzidou, M.; Pachidis, T.P. Recent Robots in STEAM Education. *Education Science* **2023**, *13*, 272. https://doi.org/10.3390/educsci13030272
20. Attila, K.; Szilvia, S. From Scratch to Python—Lego Robots as Motivational Tools for Coding. *Multidiszciplináris Tudományok* **2022**, *12*, 247–255. https://doi.org/10.35925/j.multi.2022.3.22

21. Seralidou, E.; Douligeris, C. Investigating the Transition from Block-Based to Text-Based Programming Techniques in Secondary Education in Greece. *European Journal of Engineering and Technology Research* **2022**, 21–27. https://doi.org/10.24018/ejeng.2021.0.CIE.2753
22. Vrochidou, E.; Manios, M.; Papakostas, G.A.; Aitsidis, C.N.; Panagiotopoulos, F. Open-Source Robotics: Investigation on Existing Platforms and Their Application in Education. In *26th International Conference on Software, Telecommunications and Computer Networks (SoftCOM 2018)*, Split, Croatia, 2018; pp. 1–6. https://doi.org/10.23919/SOFTCOM.2018.8555860
23. Weeraratne, A.; Subasinghage, K. Comparison of Open-Source Robotics Platforms for Undergraduate Education. In *International Research Conference on Smart Computing and Systems Engineering (SCSE 2024)*; Colombo, Sri Lanka, 2024; pp. 1–5. https://doi.org/10.1109/SCSE61872.2024.10550891
24. Williams, R.; Safinah, A.; Alcantara, R.;Burghleh, T.; Alghowinem, S.; Breazeal, C. Doodlebot: An Educational Robot for Creativity and AI Literacy. In *ACM/IEEE International Conference on Human-Robot Interaction (HRI '24)*, Boulder, CO, USA, 2024; pp. 772–780. https://doi.org/10.1145/3610977.3634950
25. El-Fakdi, A.; Cufí, X. An Innovative Low Cost Educational Underwater Robotics Platform for Promoting Engineering Interest among Secondary School Students. *Electronics* **2022**, *11*, 373. https://doi.org/10.3390/electronics11030373
26. Chronis, C.; Varlamis, I. FOSSBot: An Open Source and Open Design Educational Robot. *Electronics* **2022**, *11*, 2606. https://doi.org/10.3390/electronics11162606
27. Quigley, M.; Gerkey, B.; Conley, K.; Faust, J.; Foote, T.; Leibs, J; Berger, E.;Wheeler, R; Ng, A. ROS: An Open-Source Robot Operating System. In *ICRA Workshop on Open Source Software*, Kobe, Japan, 2009; pp. 5.
28. Ruiz-de-Garibay, J.; Garaizar, P.; Almeida, A. The Integration of Project-Based Learning in Educational Robotics: Exploring Competition Robots Using the EASYbot Platform. In *International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM 2023)*; Bragança, Portugal, 2023; pp. 514–523. https://doi.org/10.1007/978-981-97-1814-6_50
29. Ruiz-de-Garibay, J; Romero-Yesa, S; Garaizar, P. Proyecto de robótica educativa adaptado al Grado en Ingeniería en Diseño Industrial: Impacto en la motivación y el aprendizaje. En *Educación, creatividad e inteligencia artificial: Nuevos horizontes para el aprendizaje. Actas del VIII Congreso Internacional sobre Aprendizaje, Innovación y Cooperación (CINAIC 2025)*; Madrid, España, 2025; pp. 203–206. https://doi.org/10.26754/uz.978-84-10169-60-9