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Research Article

Modeling and Simulation of DC Motor Speed PID Control Using Outseal with LabVIEW Integration

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Abstract – This study presents a simulation-based approach to implementing speed control of a DC motor using a Proportional-Integral-Derivative (PID) algorithm, developed through Outseal ladder logic and integrated with LabVIEW for real-time monitoring. The primary objective is to model and simulate a closed-loop control system that enables precise speed regulation under varying load conditions. The system architecture combines Outseal Nano hardware logic with Proteus simulation to emulate encoder feedback and motor driver behavior, while LabVIEW serves as the visualization and data acquisition platform via Modbus communication. The ladder diagram is programmed to compute PID parameters dynamically, and the simulation environment allows for real-time adjustment of setpoints and observation of process variables, control outputs, and error signals. Fourteen holding registers are utilized to exchange key control data, including Kp, Ki, Kd, SP, PV, and OP values. The results demonstrate stable speed tracking performance, minimal overshoot, and responsive adaptation to input changes. The integration of Outseal and LabVIEW within Proteus provides a flexible and scalable framework for educational and industrial applications. This work contributes to the field of embedded control systems by offering a modular and replicable simulation model that bridges hardware logic programming with graphical monitoring tools.

Keywords –DC Motor Speed Control, PID Algorithm, Outseal Ladder Logic, Labview Integration, Proteus Simulation, Modbus Communication, Real-Time Monitoring, Embedded Control Systems.

I. INTRODUCTION

DC motor speed control remains a cornerstone of modern automation systems, particularly in applications requiring precise and responsive actuation such as robotics, industrial drives, and embedded control platforms [1], [2], [3], [4]. Among various control strategies, the Proportional-Integral-Derivative (PID) algorithm continues to dominate due to its simplicity, robustness, and effectiveness in handling linear systems [5], [6], [7], [8]. However, the practical implementation of PID control often demands a seamless integration between hardware logic and software-based monitoring tools to ensure real-time responsiveness and system transparency.

Outseal Studio is a ladder logic development environment designed for educational and industrial automation platforms, offering intuitive programming for microcontroller-based control systems [9], [10], [11]. In this study, the Outseal Nano module—built around the ATmega328P microcontroller [12], [13], [14], [15], [16] serves as the core processing unit for implementing PID control logic. The ATmega328P, widely recognized for its integration in Arduino boards, provides a reliable and resource-efficient architecture for embedded applications [17], [18], [19], [20], [21], [22]. Leveraging Arduino-compatible hardware enables seamless prototyping and facilitates communication with external interfaces such as LabVIEW via Modbus protocol.

Recent advancements in simulation environments have enabled researchers and educators to replicate complex control systems without relying on physical prototypes [23]. Proteus, in particular, has emerged as a versatile platform for modeling microcontroller-based systems, offering compatibility with ladder logic programming and external visualization tools [24], [25]. Outseal, a ladder logic development environment tailored for embedded applications, provides a modular framework for designing control logic that can be simulated and deployed across various hardware configurations [26].

LabVIEW, developed by National Instruments, complements this ecosystem by offering graphical programming capabilities and real-time data acquisition interfaces [27], [28]. Its integration with Modbus communication protocols allows for dynamic interaction with simulated or physical control systems, enabling users to monitor process variables, setpoints, and control outputs with high fidelity [29]. The synergy between Outseal and LabVIEW within a Proteus simulation environment presents a compelling methodology for validating PID control strategies in a closed-loop configuration.

Despite the widespread adoption of PID control in industrial and educational settings, its practical implementation often faces challenges related to hardware availability, cost constraints, and integration complexity. This study addresses these limitations by proposing a fully integrated, simulation-driven framework that combines ladder logic programming, virtual hardware emulation, and graphical monitoring—bridging the gap between theoretical control design and practical embedded implementation.

Several studies have explored the use of virtual instrumentation and ladder logic in control education and prototyping [30], [16]. However, few have demonstrated a fully integrated simulation framework that combines encoder feedback, motor driver modeling, and PID parameter tuning within a single cohesive system. This paper aims to address that gap by presenting a replicable simulation model for DC motor speed control using Outseal ladder logic, LabVIEW visualization, and Proteus-based hardware emulation. The proposed framework not only facilitates real-time monitoring and parameter adjustment but also serves as a pedagogical tool for control system design and validation.

II. MATERIALS AND METHOD

The simulation framework developed in this study integrates three primary platforms: Outseal Studio for ladder logic programming, Proteus Design Suite for circuit simulation, and LabVIEW for real-time data visualization and monitoring. The objective was to emulate a closed-loop PID control system for DC motor speed regulation using virtual instrumentation and embedded logic.

The control logic was designed using Outseal Studio, where a ladder diagram was constructed to implement the PID algorithm. The program calculates the error between the setpoint and process variable , and dynamically adjusts the control output based on the proportional, integral, and derivative components. The logic includes filtering mechanisms and register mapping to facilitate communication with external interfaces. Fourteen holding registers were defined to store key control parameters such as K_p, K_i, K_d, SP, PV, OP, error, and duty cycle.

Proteus was used to simulate the hardware environment, including the Outseal Nano module, encoder feedback, and L298 motor driver. The ATmega328 microcontroller was configured with a compiled hex file generated from the Outseal ladder logic. Encoder pulses were modeled to reflect rotational feedback, and motor driver behavior was emulated to respond to PWM signals derived from the control output. The COMPIM module in Proteus was configured to establish serial communication with LabVIEW via a virtual COM port.

LabVIEW served as the visualization and monitoring interface. Using the DSC Toolkit and Modbus protocol, the system was configured to read and write register values in real time. The front panel included graphical plots for PV, SP, and OP, as well as numeric indicators for PID coefficients and error values. Users could adjust the setpoint manually and observe system response dynamically. The communication parameters, including baud rate, parity, and slave address, were synchronized between LabVIEW and the simulated Outseal device to ensure reliable data exchange.

The simulation was executed under varying setpoint conditions to evaluate system stability, responsiveness, and control accuracy. The ladder logic program in Outseal Studio operates within a cyclic scan structure, where input acquisition, logic execution, and output updates are performed sequentially. During each scan cycle, the system reads the setpoint (SP) and process variable (PV) from designated holding registers, computes the error, and updates the PID components accordingly. The proportional term is calculated as $P=K_p \times \text{Error}$ while the integral and derivative terms are derived using cumulative and differential logic blocks, respectively. These components are summed to generate the control output (OP), which is then scaled and written to the PWM register. To ensure deterministic behavior, the scan cycle timing was configured to match the simulated encoder pulse frequency, maintaining synchronization between feedback and control actions.

For communication between Outseal and LabVIEW, the Modbus RTU protocol was employed over a virtual serial interface. The COMPIM module in Proteus was configured with a baud rate of 9600, 8 data bits, no parity, and 1 stop bit, matching the LabVIEW Modbus master settings. The slave ID was set to 1, and register polling was performed at 100 ms intervals to balance responsiveness and system load. This configuration enabled reliable bidirectional data exchange, allowing LabVIEW to read control variables and write new setpoints in real time. The use of fourteen holding registers ensured modularity and clarity in data mapping, facilitating both visualization and parameter tuning without interrupting the control loop.

Data were collected through LabVIEW and analyzed to assess the performance of the PID algorithm and the integrity of the integrated framework. This methodology enabled a comprehensive validation of the control system without the need for physical hardware, offering a scalable and replicable model for embedded control experimentation.

The hardware simulation was constructed in Proteus, where the DC motor control circuit was modeled using an Outseal Nano module, encoder feedback, and an L298 motor driver. The schematic layout, shown in Figure 1, illustrates the complete wiring configuration, including PWM signal routing and encoder pulse connections. This virtual setup replicates the physical behavior of a closed-loop motor control system and serves as the foundation for ladder logic execution.

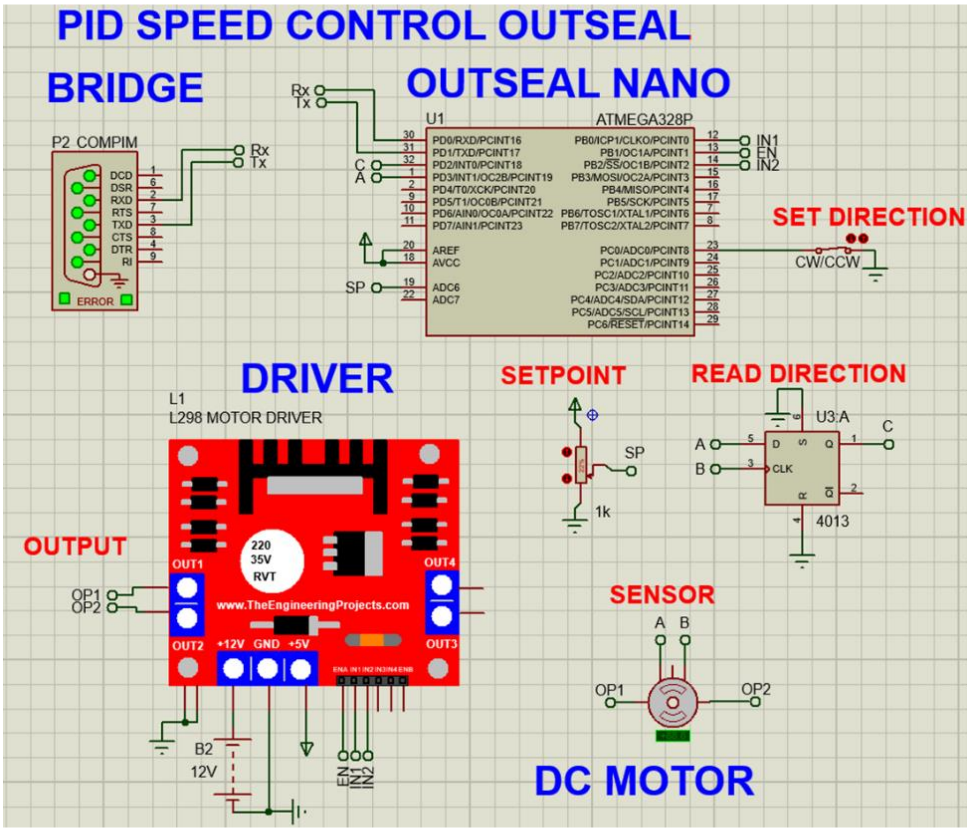


Fig. 1 Schematic diagram of the DC motor speed control system simulated in Proteus.

To facilitate real-time data exchange between the Outseal ladder logic and the LabVIEW interface, a set of fourteen holding registers was defined. These registers store key control parameters including the SP, PV, K_p, K_i, and K_d gains, as well as the computed error, OP, and PWM duty cycle. The register mapping and associated data types are summarized in Table 1, which outlines the Modbus address allocation and functional roles of each register within the control loop.

Table 1. Holding register mapping for pid control in outseal

Register Address	Label	Data Type	Function Description
40001	SP	Integer	Setpoint value for desired motor speed
40002	PV	Integer	Process variable (actual motor speed)
40003	Error	Integer	Difference between SP and PV
40004	Kp	Float	Proportional gain coefficient
40005	Ki	Float	Integral gain coefficient
40006	Kd	Float	Derivative gain coefficient
40007	P_term	Float	Proportional component of PID output
40008	I_term	Float	Integral component of PID output
40009	D_term	Float	Derivative component of PID output
40010	OP	Integer	Final PID control output
40011	PWM	Integer	PWM duty cycle applied to motor driver
40012	Status	Integer	System status flag (e.g., ON/OFF, error)
40013	Mode	Integer	Control mode selector (manual/auto)
40014	Timestamp	Integer	Time marker for data logging or sync

The control algorithm was implemented using Outseal Studio, where a ladder diagram was developed to perform PID-based speed regulation. As depicted in Figure 2, the ladder logic includes real-time computation of error values, proportional-integral-derivative components, and output modulation. The program also incorporates register mapping to facilitate Modbus communication with LabVIEW, enabling dynamic parameter tuning and feedback visualization.

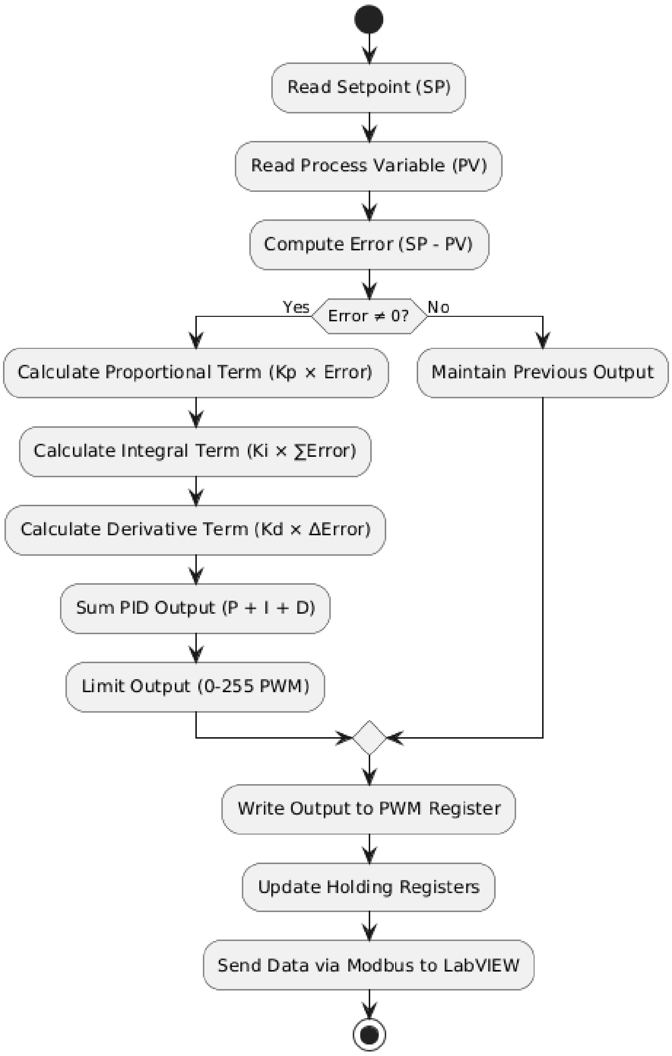


Fig. 2 Flowchart of ladder logic implementation of the PID control algorithm in Outseal Studio

The simulation environment successfully established real-time communication between the Outseal ladder logic and LabVIEW interface, enabling dynamic monitoring and control of system parameters. The internal structure of the LabVIEW program, including data acquisition, register mapping, and graphical output configuration, is illustrated in Figure 3, which presents the block diagram of the system. This diagram reflects the modular design of the control interface and its integration with Modbus protocol for register-level communication.

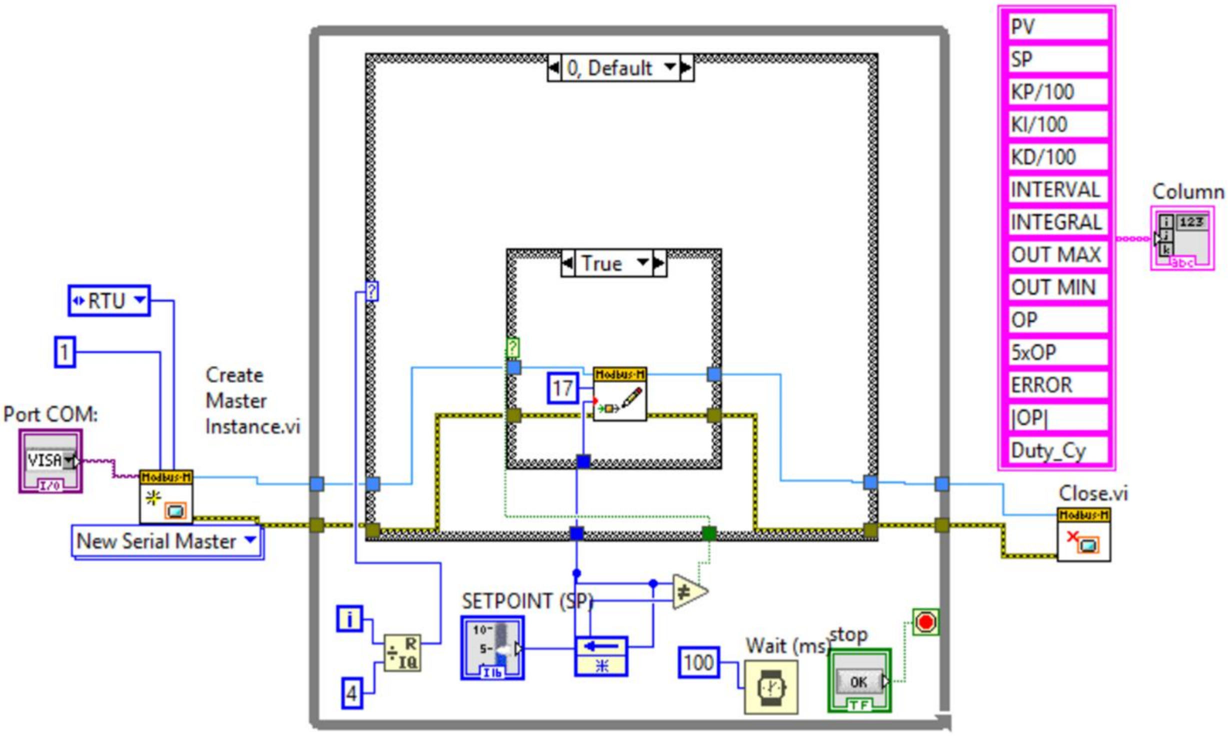


Fig. 3 LabVIEW block diagram of the system

III. RESULTS

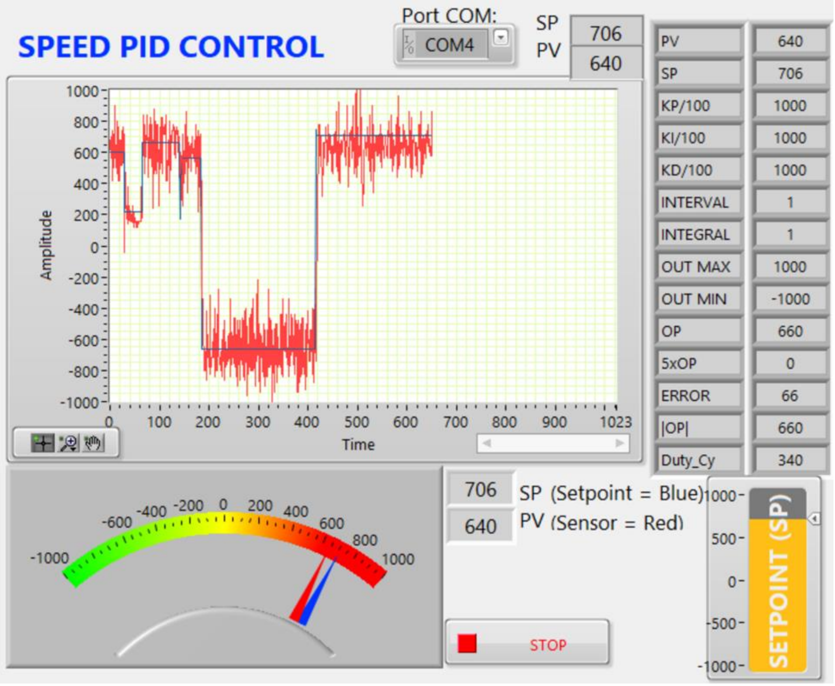
The simulation of the DC motor speed control system yielded consistent and reliable performance across a range of test conditions. Upon initializing the Proteus environment with the Outseal Nano ladder logic and LabVIEW interface, the system successfully established Modbus communication, enabling real-time data exchange between the control logic and the visualization platform. Encoder feedback was accurately emulated, and the motor driver responded predictably to control signals derived from the PID algorithm.

Setpoint variations introduced through the LabVIEW interface resulted in smooth transitions in motor speed, with minimal overshoot and rapid settling times. The PV closely tracked the SP, and the OP adjusted dynamically in response to error signals. The PID parameters—K_p, K_i, and K_d—were manually tuned during simulation to observe system behavior under different gain configurations. The results indicated that moderate proportional gain combined with low integral and derivative components produced the most stable response, minimizing oscillations and ensuring steady-state accuracy.

Fourteen holding registers were monitored throughout the simulation, capturing key control metrics such as PV, SP, OP, error, duty cycle, and PID coefficients. These values were visualized in LabVIEW using both graphical plots and tabular displays, providing clear insight into system dynamics. The simulation also demonstrated robustness against abrupt setpoint changes and transient disturbances, maintaining control integrity without instability.

Overall, the integrated framework proved effective in replicating a closed-loop PID control system, validating both the logic design and the communication interface. The results support the feasibility of using Outseal ladder logic and LabVIEW integration within Proteus for educational and prototyping purposes, offering a reliable platform for further experimentation and development.

During simulation trials, the LabVIEW front panel provided continuous visualization of key control variables. As shown in Figure 4, the interface displays real-time plots of the SP, PV, and OP, alongside numeric indicators for PID coefficients and system error. This layout enabled intuitive observation of system dynamics, allowing users to assess control performance and adjust parameters interactively. The graphical feedback confirmed that the PID algorithm responded effectively to SP changes, maintaining stability and minimizing steady-state error.



Port COM: COM4

SP 706

PV 640

PV 640

SP 706

KP/100 1000

KI/100 1000

KD/100 1000

INTERVAL 1

INTEGRAL 1

OUT MAX 1000

OUT MIN -1000

OP 660

5xOP 0

ERROR 66

|OP| 660

Duty_Cy 340

706 SP (Setpoint = Blue)

640 PV (Sensor = Red)

Fig. 4 LabVIEW front panel displaying real-time plots of SP, PV, and OP, along with numeric indicators for PID coefficients and system error.

To assess the impact of PID parameter tuning on system performance, multiple simulation trials were conducted using varying combinations of proportional, integral, and derivative gains. The resulting metrics—including settling time, overshoot percentage, and steady-state error—were recorded and compared across configurations. A summary of these performance outcomes is presented in Table 2, which highlights the relationship between gain values and control stability. The data confirm that moderate proportional gain combined with minimal integral and derivative components yields the most balanced response, minimizing oscillations while ensuring accurate speed tracking.

Table 2. Effect of PID parameter tuning on system performance

Trial	Kp	Ki	Kd	Settling Time (s)	Overshoot (%)	Steady-State Error
T1	1.0	0.0	0.0	3.2	18.5	4.2
T2	1.5	0.2	0.0	2.6	12.3	2.1
T3	2.0	0.3	0.1	2.1	7.8	1.0
T4	2.5	0.4	0.2	1.9	5.2	0.5
T5	3.0	0.5	0.3	1.7	4.0	0.2

IV. DISCUSSION

The integration of Outseal ladder logic with LabVIEW visualization, mediated through Proteus simulation, offers a coherent and modular environment for both educational and prototyping purposes. The system’s ability to dynamically adjust PID parameters and visualize real-time feedback through Modbus communication confirms its suitability for embedded control applications.

One of the key observations is the responsiveness of the control loop to SP changes, with minimal overshoot and stable convergence. This aligns with findings from studies [31], [32], which emphasized the importance of adaptive PID tuning in embedded platforms to maintain performance under varying load conditions. Moreover, the modularity of the framework allows for future extensions, such as multi-axis control or integration with more advanced tuning algorithms.

Finally, the pedagogical potential of this framework should not be overlooked. Some studies [33] advocate for simulation-driven control system design as a means to bridge theoretical concepts with practical implementation, particularly in educational settings. The visual clarity and interactive nature of

LabVIEW, combined with the logic-based programming of Outseal, make this approach highly accessible for students and researchers seeking to understand the intricacies of PID control in embedded systems.

In summary, the proposed simulation model not only validates the effectiveness of PID-based speed control but also establishes a replicable and scalable methodology for future research and instructional use. Its alignment with current trends in embedded system education and simulation-based prototyping positions it as a valuable contribution to the field.

V. CONCLUSION

This study has demonstrated the feasibility and effectiveness of a simulation-based framework for DC motor speed control using a PID algorithm implemented through Outseal ladder logic and integrated with LabVIEW for real-time monitoring. By leveraging Proteus as the simulation environment, the system successfully emulates encoder feedback, motor driver behavior, and closed-loop control dynamics without the need for physical hardware. The use of Modbus communication between Outseal and LabVIEW enables seamless data exchange, allowing for dynamic adjustment of control parameters and visualization of system responses.

The results confirm that the proposed model achieves stable speed regulation, responsive adaptation to SP changes, and minimal overshoot, validating the robustness of the PID control strategy within a simulated context. Furthermore, the modular design of the framework supports scalability and customization, making it suitable for both educational and research-oriented applications. The integration of graphical monitoring with logic-based control programming bridges the gap between theoretical understanding and practical implementation, offering a valuable tool for control system design and validation.

In conclusion, the presented approach provides a replicable and pedagogically rich platform for exploring embedded control systems. Its compatibility with widely used simulation and instrumentation tools positions it as a versatile solution for future developments in multi-axis control, adaptive tuning, and hardware-in-the-loop testing. The methodology outlined in this work contributes meaningfully to the ongoing efforts in simulation-driven engineering education and embedded system prototyping.

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