

IoT Based RC Car Lap Timer

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Abstract

This project focuses on designing an innovative lap timing system tailored for RC car racing, aimed at enhancing the accuracy and reliability of lap time measurements crucial for determining race rankings. Existing lap timers for RC cars often rely on manual triggering, which impacts accuracy due to the manual start-stop process. To address this, we developed a system based on specific requirements identified through market research, utilizing experimental, observational, and testing methodologies for comprehensive data analysis. Several experiments were conducted using different sensors to optimize performance, employing both qualitative and quantitative analyses. The selected concept demonstrated promising theoretical accuracy. The hardware design incorporated enhancements aligned with the project objectives, while the software architecture ensured seamless integration. Our study results show that the developed lap timer significantly improves the accuracy of lap time measurements for RC car racing. Key focus areas included the sensor's detection range, the sensor's distance, and the RC car's speed at detecting the sensor. Verification was carried out using a device that met minimal acceptance criteria, as it was not possible to achieve the required accuracy in the verification device. Nevertheless, the designed system closely met its intended specifications. The findings are not only relevant to the RC car enthusiast community but also provide insights for the broader field of recreational electronics. This lap timing system offers a valuable enhancement to the RC car racing experience, contributing to the ongoing development of technology within the hobbyist community.

1. Introduction

Remote Control (RC) car racing has evolved from a casual pastime to a competitive and technological hobby embraced by enthusiasts of all ages. The sport's increasing popularity highlights the importance of precision and efficiency in lap timing systems, a critical aspect for enhancing competitiveness and participant engagement [1]. Traditionally, lap times in RC car racing have been manually recorded, often leading to errors and inefficiencies due to human involvement[2]. This shortfall has sparked significant interest in automated solutions that leverage Internet of Things (IoT) technologies.

IoT offers a transformative approach by enabling real-time data collection, transmission, and analysis, making it highly applicable to RC car lap timing systems. By integrating wireless communication, microcontrollers, and sensors, IoT-based systems can provide accurate and consistent lap timing, essential for fair competition and

performance evaluation [3]. Recent advancements in sensors, such as LiDAR, RFID, and infrared, have further expanded the possibilities for innovation in lap timing systems [4].

Several research initiatives have focused on developing sophisticated lap timing systems. For instance, Stepanov (2021) introduced a high-frequency infrared-based timing system for Formula Student cars, achieving remarkable accuracy in competitive racing [5]. Similarly, Telander et al. (2015) demonstrated the reliability of RFID technology in tracking multiple racers simultaneously during large-scale events [6]. These efforts underscore the potential of IoT and sensor technologies in reshaping lap timing systems.

This project aims to design an IoT-based lap timer tailored for RC car racing, addressing the limitations of traditional methods. By integrating RF 433 MHz modules, an ESP32 microcontroller, and a Tiny RTC module, the system offers a cost-effective and scalable solution to ensure accurate lap timing. The study also evaluates the performance of various components to optimize system reliability and user experience. By combining real-time monitoring and robust data handling capabilities, this project not only contributes to the RC racing community but also advances IoT applications in recreational electronics.

2.0 Methodology

The methodology and research approach utilized in this project are fundamental components that guide the collection, analysis, and achievement of objectives. Serving as a roadmap for the research process, this chapter offers transparency and reproducibility by detailing the strategies and techniques employed. It begins with a visual representation of the project's progression and workflow through a project flow chart, followed by a system block diagram illustrating the architecture and interactions of project components. A system flow chart provides further insight into processes and decision points within the system, while a project circuit diagram simulates the project's electrical aspects. This meticulous methodology ensures a clear understanding of the research approach and its rationale, laying the groundwork for successful project implementation and outcomes.

2.1 System Block Diagram and Flow Chart

The IoT-based Lap Timer Tracking System with IR Transmitter and Receiver for Remote Control (RC) Cars is shown as a block diagram in **Fig 1**. The RC car, a vital component of the system, is equipped with a lap timer sensor that detects when it passes a designated lap timer. The sensor is strategically placed on the RC car to reliably detect the timer, identify the car, and send a corresponding signal to the transmitter. This transmitter, which receives the data from the lap timer sensor and converts it into a radio signal, is crucial for the system. This modification allows the data from the RC car to be wirelessly transmitted to the receiver.

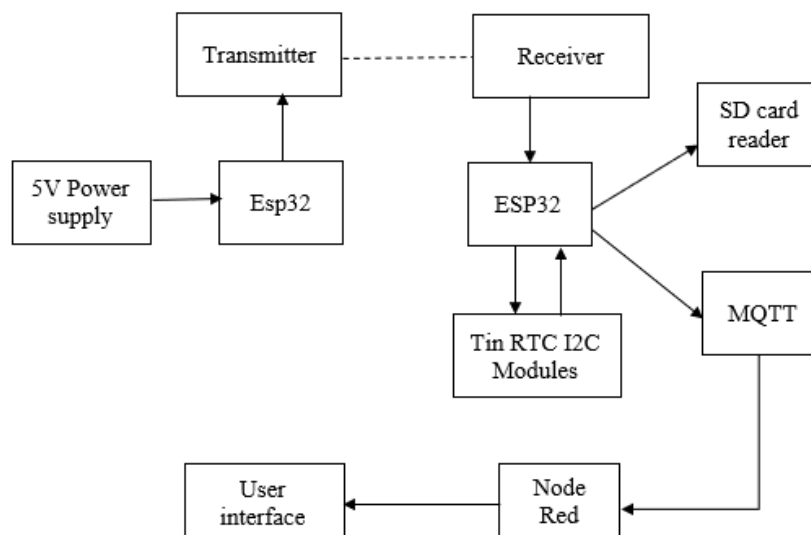


Fig. 1: System Block Diagram

To ensure reliable communication between the RC car and the receiver, the transmitter must be durable, waterproof, and capable of long-distance signal transmission. The receiver, on the other end, is responsible for receiving the radio signal from the transmitter and converting it back into a computer-processable format. Like the transmitter, the receiver needs to be durable and waterproof to withstand external conditions. The lap timer data is then collected and sent to MQTT, allowing the data to be viewed in an application made with Node-RED for the user interface. For backup, lap timing data is also stored on an SD card. An RTC (Real-Time Clock) ensures that the lap timing data is recorded in seconds, minutes, and hours accurately.

Implementing this system can be achieved using various technologies depending on the user's skills and resources, with the ESP32 being a popular choice due to its functionality and flexibility. The system's main goal is to track and record lap times of RC cars during races, helping drivers evaluate their performance and make improvements. By integrating sensors, wireless communication, and computing power, the system provides accurate and timely lap time information, enhancing the overall racing experience.

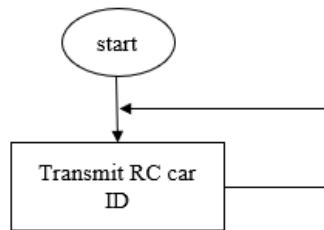


Fig. 2: System flow chart for transmitter

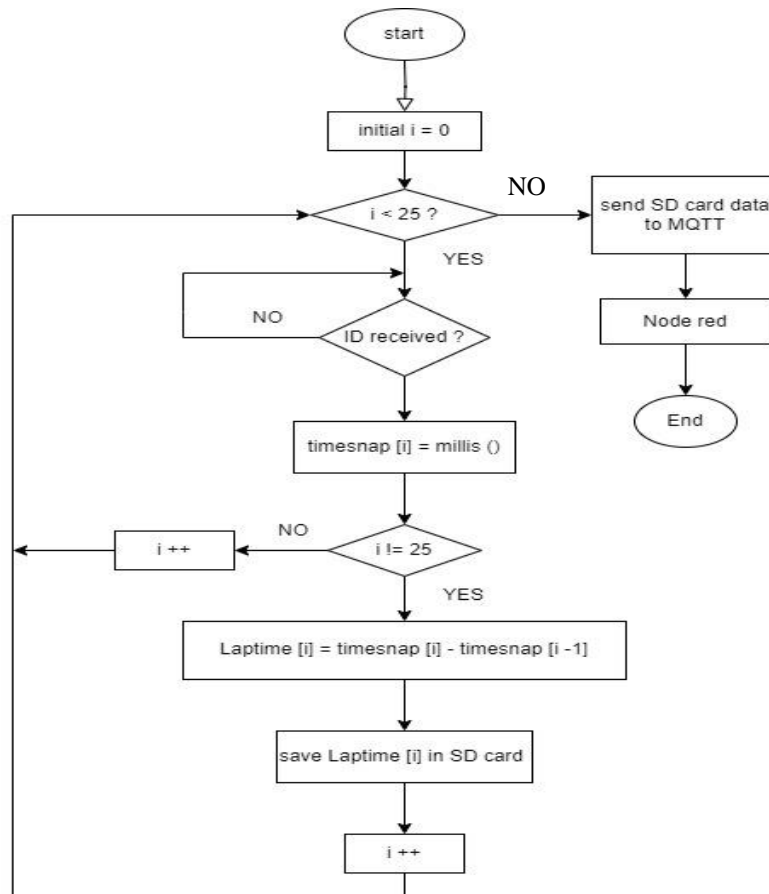


Fig. 3: System flow chart for transmitter

Fig 2 and **Fig 3** show System flowchart for receiver and transmitter. The system program can store 25 lap timing. The program begins by initializing a variable $i = 0$. This counter will keep track of the number of laps completed throughout the race. Next, the program enters a loop that continues as long as the counter "i" remains less than 25. This suggests the program is set to record a maximum of 25 laps. Inside this loop, the program first checks if an ID has been received from the transmitter as shows in figure 3. if no ID is received, the program simply loops back to the beginning, waiting for an ID before proceeding.

Assuming an ID is received, the program then records the current time in milli. This time is stored in an array called "timesnap" for the current lap. Now comes the lap time calculation. The program checks if this is the very first lap. If it's not the first lap, the program calculates the actual lap time by subtracting the previous time stored in "timesnap" at position "i-1" from the current time stored at position "i". This difference represents the time taken to complete the most recent lap. The calculated lap time is then stored in a separate array called "Laptime", again at the position indicated by the counter "i".

Once the lap time is recorded, the program takes this lap time data and saves it onto an SD card for later retrieval. Finally, the program increments the counter "i" by 1 and loops back to the beginning. This loop continues as long as the counter "i" remains less than the maximum lap limit 25. Once the loop condition is no longer met, data store in SD Card will be sent to MQTT data base. From app made from node red the lap timing data can be monitor from MQTT data base.

2.1 Circuit Diagram

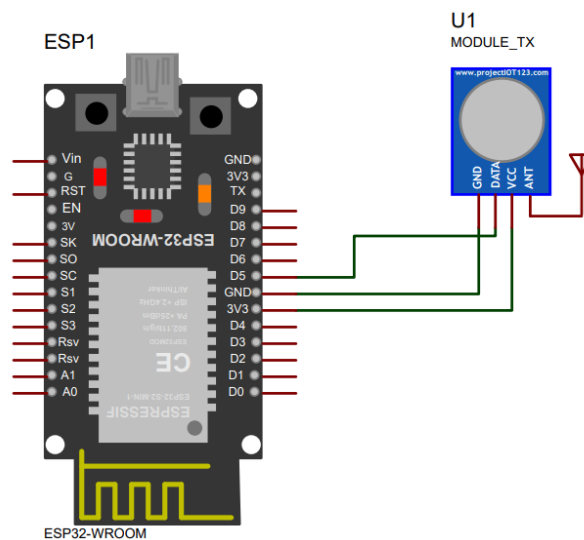


Fig. 4: Circuit Diagram for Transmitter

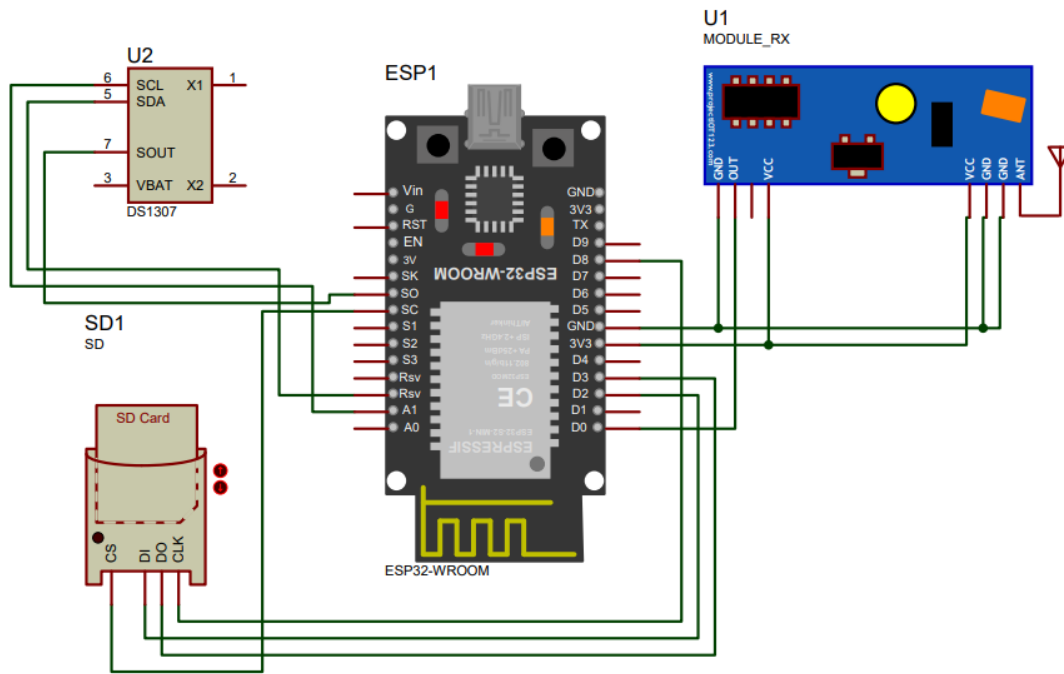


Fig. 5: Circuit Diagram for Transmitter

Fig 4 and **Fig 5** illustrate the transmitter and receiver components of an IoT-based Lap Timer RC car system. Figure 4 focuses on the RF 433 MHz transmitter, which emits radio frequency signals. This transmitter sends signals to the RF 433 MHz receiver at the receiving end, such as the RC car ID. The signal propagates through the air and is captured by the RF 433 MHz receiver, which then decodes and processes the information based on a predetermined modulation and protocol to perform lap timing calculations and trigger appropriate actions.

In the lap timer circuit diagram shown in Figure 3.6, the system includes an ESP32 microcontroller, an RF 433 MHz receiver, a Tiny RTC I2C Module, and a microSD reader. The RF 433 MHz receiver captures signals from the RF 433 MHz transmitter, which might include data such as lap markers or start signals for timing laps. Upon receiving this data, the ESP32 processes it, decodes the information, and uses timestamps or lap markers to calculate lap times accurately. The Tiny RTC I2C Module plays a crucial role in ensuring precise lap timing. It provides a real-time clock function, maintaining accurate timekeeping even when the system is powered off. This allows the ESP32 to timestamp each lap accurately, ensuring the lap times are precise and reliable. The RTC module helps in keeping track of the exact time each lap is completed, which is essential for accurate lap timing and for recording detailed lap histories.

The ESP32 can then save the lap time data, complete with timestamps, to a microSD card or send it to another device or server. Additionally, the ESP32 can provide responses or feedback, such as acknowledging the received data with a signal back to the transmitter or providing status updates through various means. By working together, the ESP32, RF 433 MHz receiver, and RTC module enable accurate lap timing and support various actions based on the received information.

3.0 Result and Discussion

This chapter present the experiment, result and analysis based on hardware and software implemented in this project. The process flow of the Lap Timer for RC Car also included in this chapter. Two experiments have been carried out; first experiment is to find Suitable length of antenna transmitter . Second experiment is to check functionalities of the lap timer on the RC Car Track.

3.1 Experiment with length of antenna transmitter

In this subchapter, an experiment using the ESP32 was conducted to determine the suitable length for the antenna transmitter. This experiment is crucial for determining the appropriate length of the antenna receiver and deciding where to position the RC car at the start of the race. At the beginning of the experiment, a monopole antenna was attached to the RF 433 MHz transmitter using copper wire. The length of the monopole antenna is determined by:

$$L = \frac{\lambda}{4} + \frac{c}{4f}$$

Thus, the maximum length of a quarter-wave antenna for 433 MHz is: 17.3 cm

Where:

1. L = Length of the antenna (meters)
2. c = Speed of light (3×10^8 m/s)
3. f = Frequency (Hz)

To reduce the antenna's range of detection, the antenna length needs to be shortened, which decreases antenna efficiency and, consequently, the detection range. The copper wire will be cut by 0.5 cm each time if the detection range between the transmitter and receiver is not suitable. The maximum detection range must not exceed 120 cm. If the range is equal to or greater than 120 cm, the antenna length is rejected.

Table 1: Result for antenna length, $L = 3$ cm

Distance between transmitter and receiver (cm)	(Delay/ Time taken) to transmitter RC Cat id to receiver (s)									
110	4.26	4.65	16.25	4.78	6.57	3.24	9.54	7.25	3.25	8.45
90	4.44	2.91	3.77	3.55	4.18	15.49	5.99	8.21	8.12	3.22
60	4.81	5.40	0.96	2.15	8.65	6.08	3.59	0.15	8.16	8.27
30	0.06	2.29	0.01	0.11	0.05	0.15	0.14	0.15	0.14	0.15
15	0.11	0.05	0.06	0.05	0.07	0.05	0.20	0.11	0.01	0.11

Table 2: Result for antenna length, L = 0 cm

Distance between transmitter and receiver (cm)	(Delay/ Time taken) to transmitter RC Cat id to receiver (s)									
75	0.23	6.34	8.05	2.27	11.86	0.63	4.75	5.16	1.63	1.13
60	5.38	1.22	4.30	0.46	0.68	0.86	0.49	0.23	0.13	2.58
45	1.26	0.41	0.22	0.73	0.25	3.66	0.86	3.12	0.23	0.09
30	1.09	4.34	0.04	0.01	0.09	0.04	0.04	0.01	0.18	0.64
15	2.76	0.91	0.68	2.22	0.68	0.41	0.22	0.86	0.18	1.68

For an RC car lap timer project, the choice of antenna length is crucial to ensure accurate and reliable lap timing. Based on the results in Tables 1 and Tables 2 and considering the additional testing where the 3 cm antenna allowed the receiver to pick up signals from the transmitter at distances of 3 to 4 meters, this antenna length is not ideal. The excessive range can lead to false lap detections when the transmitter signal is unintentionally received even when the RC car is not crossing the designated lap detection point.

While the 3 cm antenna offers strong and stable communication over a distance of more than 1 meter, this extended range causes inaccuracies for lap timing purposes. In lap timer projects, a shorter detection range is preferable to ensure the signal is received only when the RC car is very close to the receiver. This prevents false positives that could occur due to stray signals.

By contrast, in Table 2, where no antenna is attached (L= 0 cm) the effective detection range is limited to around 75 cm. This shorter range reduces the chance of the receiver detecting the signal when the RC car is far away. However, using no antenna might result in inconsistent performance, especially if there are obstructions or interference. The delays and communication quality are also less reliable compared to using a small antenna. In summary, while a 3 cm antenna provides reliable communication, its extended range of up to 3-4 meters makes it unsuitable for precise lap timing. A shorter antenna or even no antenna is more appropriate, provided the system maintains reliable communication within the intended detection range of approximately less than 1 meter.

3.1 Experiment Functionality of the Lap Timer on the RC Car Track

To verify the performance and reliability of the lap timer system for the RC car track, a series of functionality checks and experiments can be conducted. This ensures that the system accurately detects lap completions while avoiding false positives and maintaining consistent results. The following steps outline the process for checking the lap timer’s functionality, analysing the system's strengths and weaknesses, and optimizing it for practical use.

Table 3: Result RC Car Lap Timer

Car Id	Lap	Lap Time	Date and time
Car : 210119	Lap : 1	Lap Time : 32.99 s	2024/12/19 20:19:24
Car : 210119	Lap : 2	Lap Time : 33.58 s	2024/12/19 20:19:58
Car : 210119	Lap : 3	Lap Time : 28.87 s	2024/12/19 20:20:27
Car : 210119	Lap : 4	Lap Time : 30.72 s	2024/12/19 20:20:57
Car : 210119	Lap : 5	Lap Time : 31.18 s	2024/12/19 20:21:28
Car : 210119	Lap : 6	Lap Time : 34.25 s	2024/12/19 20:22:3
Car : 210119	Lap : 7	Lap Time : 31.68 s	2024/12/19 20:22:34
Car : 210119	Lap : 8	Lap Time : 33.18 s	2024/12/19 20:23:8
Car : 210119	Lap : 9	Lap Time : 32.31 s	2024/12/19 20:23:40
Car : 210119	Lap : 10	Lap Time : 32.26 s	2024/12/19 20:24:12
Car : 210119	Lap : 11	Lap Time : 35.80 s	2024/12/19 20:24:48
Car : 210119	Lap : 12	Lap Time : 32.31 s	2024/12/19 20:25:20
Car : 210119	Lap : 13	Lap Time : 33.40 s	2024/12/19 20:25:54
Car : 210119	Lap : 14	Lap Time : 31.32 s	2024/12/19 20:26:25
Car : 210119	Lap : 15	Lap Time : 31.99 s	2024/12/19 20:26:57
Car : 210119	Lap : 16	Lap Time : 39.32 s	2024/12/19 20:27:36
Car : 210119	Lap : 17	Lap Time : 31.14 s	2024/12/19 20:28:7
Car : 210119	Lap : 18	Lap Time : 30.09 s	2024/12/19 20:28:37
Car : 210119	Lap : 19	Lap Time : 29.46 s	2024/12/19 20:29:7
Car : 210119	Lap : 20	Lap Time : 30.19 s	2024/12/19 20:29:37
Car : 210119	Lap : 21	Lap Time : 28.42 s	2024/12/19 20:30:6
Car : 210119	Lap : 22	Lap Time : 28.69 s	2024/12/19 20:30:34
Car : 210119	Lap : 23	Lap Time : 29.05 s	2024/12/19 20:31:3
Car : 210119	Lap : 24	Lap Time : 32.99 s	2024/12/19 20:31:36
Car : 210119	Lap : 25	Lap Time : 30.41 s	2024/12/19 20:32:7
Car : 210119	Total Time : 795.58 s		

The results presented in Table 3 demonstrate the capability of the RC car lap timer system to record lap times with precision to two decimal places, as well as the corresponding date and time for each lap completion. However, the system shows some inconsistency and low accuracy, with occasional detection occurring up to 2 meters before the car crosses the receiver antenna. Despite this, the system is capable of tracking multiple cars, making it suitable for multi-car racing scenarios.

The recorded lap times for Car 210119 range between 28.42 seconds and 39.32 seconds, highlighting the system's ability to capture varying lap times effectively. The total time for the 25 laps amounts to 795.58 seconds. Each lap entry includes a timestamp, ensuring that the lap times are logged with accurate date and time data, which is useful for post-race analysis and performance tracking. While the system generally functions as intended, these minor inconsistencies indicate areas for improvement in accuracy and detection.

In summary, all components and systems work together to provide lap timing, data logging, and real-time monitoring. The transmitter, receiver, SD card module, MQTT communication, and Node-RED dashboard function seamlessly, effectively capturing and saving lap data for analysis and visualization. Despite the noted limitations, the setup largely meets the requirements for the RC car lap timer project, demonstrating reliable performance throughout the testing process.

4.0 Conclusion

To achieve the objective of developing a transmitter and receiver system for an RC car racing application using the RF 433 MHz module, a comprehensive approach was undertaken to ensure reliable data transmission and reception. The system demonstrated functionality and the ability to handle multiple cars simultaneously, but challenges with detection consistency and accuracy were identified, necessitating future improvements. The transmitter device was developed using an RF 433 MHz transmitter module connected to a microcontroller like the ESP32. This transmitter, securely mounted on the RC car, sent car identity and lap timing data wirelessly. The microcontroller, programmed using the Arduino IDE, encoded the data for transmission without interfering with the car's performance. The receiver device, featuring an RF 433 MHz receiver module connected to an ESP32 microcontroller, was positioned at the finish line. It decoded incoming signals to identify the car and record lap timing information. However, during real-time testing, the receiver detected signals from up to 2 meters away, leading to occasional premature detections before the car reached the intended finish line. To address this, a finish line detection zone of 2 meters was defined to mitigate inaccuracies.

Lap timing data was logged locally via a microSD card module integrated with the receiver, enabling detailed analysis. Real-time monitoring was achieved through serial communication with a computer and a Node-RED dashboard that provided a user-friendly visual interface for race tracking.

While the system reliably captured lap times and supported multi-car racing, the extended detection range introduced inconsistencies in precise lap timing. These findings emphasize the need for optimizing the detection range and improving signal processing to enhance accuracy. In summary, the RF 433 MHz modules and ESP32 microcontrollers effectively enabled data transmission, reception, and logging for RC car racing. The system's multi-car capability makes it a valuable tool for competitive racing applications. Addressing detection inconsistencies and improving precision will ensure a more robust and accurate performance in future iterations.

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