



## Design of 4 servo robot arm with Blynk Control

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### ABSTRACT

The development of robotics technology today is experiencing rapid progress through innovations in various fields, such as the application of artificial intelligence (AI), advanced sensors, and autonomous control systems. Robots are now not only used in the industrial infrastructure sector, but also in the fields of health, transportation, agriculture, and everyday life to help humans complete various tasks. This study discusses the design of a robot arm with four servo motors based on an ESP8266 Wi-Fi microcontroller controlled through the Blynk application. The purpose of this study is to automate the movement of the robot arm in performing a task and to compare its performance with and without the use of a Pulse Width Modulation (PWM) controller PCA9685 module. The system development stages include design analysis, device design and assembly, movement programming, and system testing. The results show that the movement of the robotic arm without PCA9685 has an accuracy rate of 99.323%, while with PCA9685 it reaches 99.77%. The average accuracy percentage increased by 0.447% on the robot arm with the PCA9685 and reduced the complexity of the cables connected to the breadboard by 57.14%.

**Keywords:** Robot Arm, ESP8266, Blynk, PCA9685



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## INTRODUCTION

The term robot was first introduced in England in 1921 by Karel Čapek in a play titled Rossum's Universal Robot. Since then, robots have evolved significantly and have been designed to assist humans in performing a wide range of tasks. The fundamental purpose of robotic technology is to support humans in executing activities that require precision, repetition, or exposure to hazardous environments. Robotic systems can be manually controlled via data transmission through cables or wireless connections. In addition to manual systems, modern robotics also employs automation through pre-programmed movements or artificial intelligence (AI) (Pratheep et al., 2021).

Several studies have been conducted on robotic arm design and control systems. For instance, a Bluetooth-controlled robotic arm has been developed for manipulating organic solar cells (Szolga & Fluera, 2021). Another study focused on robotic arm design for lifting and placing objects using inverse kinematics (Al Tahtawi et al., 2021). Additionally, research has been conducted on the development of robotic arm control using Arduino microcontrollers for mobile device applications (Sutisna & Satria, 2022). These studies demonstrate the increasing integration of robotic systems with microcontrollers and wireless technologies (Mohammed Ali et al., 2022).

However, existing research also highlights several limitations, including instability in robotic arm movement, calibration errors, repetitive manual control, and restricted functionality of certain microcontrollers. In particular, the NodeMCU ESP8266 microcontroller while capable of wireless communication faces challenges in controlling multiple servo motors simultaneously due to pulse width modulation (PWM) instability, high processing load, and a limited number of usable PWM pins (Alifiah et al., 2023). These constraints can reduce the accuracy and responsiveness of robotic arm control systems.

Recent advancements have sought to overcome these technical constraints through the integration of dedicated PWM driver modules such as the PCA9685. Suzilawati et al. (2024) demonstrated that the use of PCA9685 in multi-servo robotic applications enhanced motion precision and reduced signal interference compared to direct microcontroller control. Similarly, Adeagbo et al. (2021) showed that combining ESP8266-based IoT systems with servo driver modules improves communication stability and processing efficiency, making such configurations ideal for small-scale automation systems. These findings underscore the potential of integrating PWM drivers as a crucial enhancement for multi-servo robotic systems operating within IoT environments.

To address these limitations, this study integrates the PCA9685 driver module as an intermediary between the ESP8266 microcontroller and the servo motors. The PCA9685 enables stable PWM signal generation and the control of multiple servos simultaneously, reducing the processing burden on the ESP8266. This research therefore focuses on designing and implementing a four-servo-motor robotic arm controlled via the Blynk application, aiming to automate arm movements and compare performance with and without the PCA9685 module.

This study contributes to existing literature by providing a comparative evaluation of the system's accuracy and wiring efficiency, offering a practical reference for developers seeking to optimize compact robotic systems using IoT-based controllers (Faizura et al., 2022).

## RESEARCH METHOD

This study adopts the Research and Development (R&D) method as a systematic and structured workflow to design and test the robotic arm system (Aradea & Thalib, 2024). The research process begins with analyzing the requirements, designing the system workflow, developing the robotic arm prototype, testing its performance, creating the control application, and evaluating the overall system.

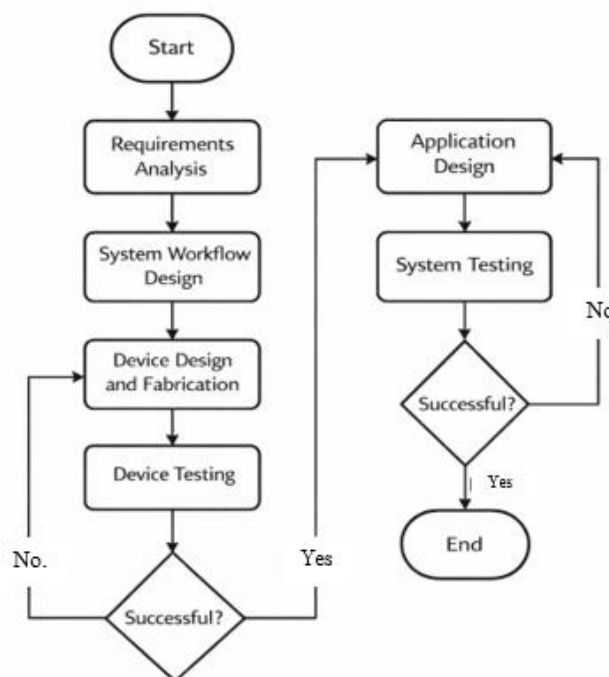


Figure 1. Research Method based on R&D Method

Figure 1 shows the workflow of research based on the R&D method. Workflow begins with analyzing the requirements that will be used for research, designing the flow of the system to be created, designing and making the robotic arm tool, testing the robotic arm's performance, designing the application as a medium to control the robotic arm, and testing the entire system consisting of the robotic arm and application.

The independent variable in this study is the type of control module used (ESP8266 only vs. ESP8266 + PCA9685), while the dependent variables are movement accuracy, servo response precision, and wiring complexity.

## Requirement Analysis

This stage identifies and analyzes both hardware and software components required for the research. The analysis provides an overview of the necessary tools and materials used in building the robotic arm and its control system. The main hardware components include SG90 micro servo motors, the NodeMCU ESP8266 microcontroller, and the PCA9685 motor driver, which serves as an intermediary between the microcontroller and the servo motors to provide stable PWM signals (Wai et

al., 2020). The software components include the Arduino IDE for programming and the Blynk IoT platform as a medium to remotely control the robotic arm.

### System Workflow Design

The workflow design defines the logical sequence of operations within the system, serving as a guide for developing an effective and functional robotic arm prototype. The design process also refers to previous studies on robotic arm motion control, mechanical structure, and microcontroller integration to ensure the developed system follows best engineering practices and supports automation through mobile applications (Afrisal et al., 2022).

### Tool Design and Development

This stage involves both the digital circuit design and the physical assembly of the robotic arm prototype. Once assembled, the prototype proceeds to the testing phase. Circuit design was created digitally before implementation, ensuring proper connection among components such as the power supply, microcontroller, and motor driver.

### Tool Testing

The prototype is tested to assess its performance and ensure that its mechanical and control functions meet design expectations. Testing focuses on measuring movement accuracy, servo response time, and potential signal instability when using ESP8266 alone compared to using PCA9685 (Rahul et al., 2020).

### Application Design

The application is designed using the Blynk platform, serving as a remote interface for controlling the robotic arm. This web-based control application allows users to send commands and monitor arm movement in real time. Blynk was selected because it provides a user-friendly interface and stable connectivity for IoT-based control (Faizura et al., 2022), allowing direct interaction between smartphone devices and the robotic arm hardware.

### System Testing

Integrated testing is conducted to evaluate the performance of the overall system including the robotic arm hardware and control application ensuring optimal functionality, accuracy, and reliability. The test results are analyzed by comparing performance metrics from both configurations to identify efficiency improvements achieved through the integration of the PCA9685 driver (Razaq et al., 2024).

## RESULT AND DISCUSSION

This section presents the results, analysis, and discussion of the robotic arm design controlled via the Blynk application. It includes the system overview, robot arm and application design, and comparative performance between configurations with and without the PCA9685 motor driver.

### System Overview

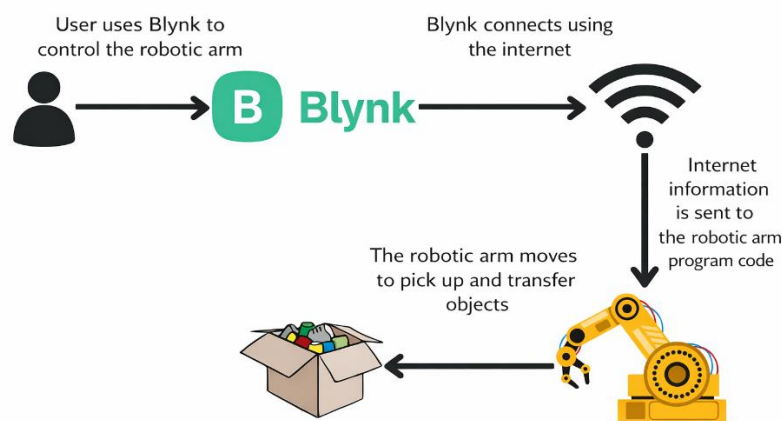


Figure 2. System Overview

Figure 2 shows the general architecture of the designed system. The user controls the robotic arm using the Blynk application via a WiFi network connected to the NodeMCU ESP8266 microcontroller. Commands are transmitted through the cloud to move the servos that perform pick-and-place actions within a reachable distance.

This system structure demonstrates the integration of IoT-based control, which enables flexibility and mobility compared to conventional wired control systems. Similar IoT-based robotic implementations have shown improved usability and remote operation efficiency (Sutisna & Satria, 2022; Szolga & Flueraș, 2021).

### Robot Arm

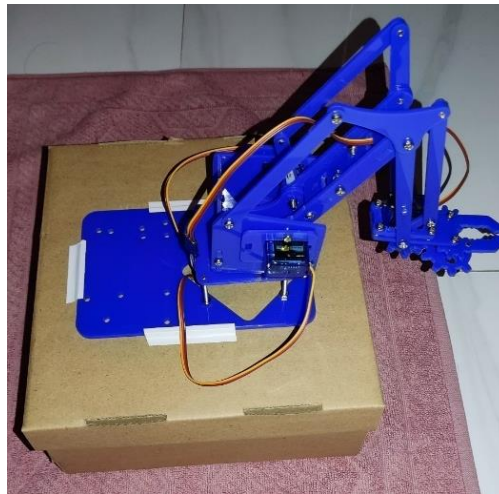


Figure 3. Robot Arm

Figure 3 shows the robotic arm assembled from acrylic material and four servo motors. Each servo performs a distinct movement: base rotation, vertical lift, forward–backward motion, and gripper control.

The mechanical design follows a modular configuration commonly used in lightweight robotic arms for education and automation research (Mohammed Ali et al., 2022). The use of acrylic and SG90 micro servos ensures low cost and low power consumption but introduces limitations in load capacity and movement stability factors further optimized by the control method applied in this study (Aradea & Thalib, 2024).

### Blynk Application

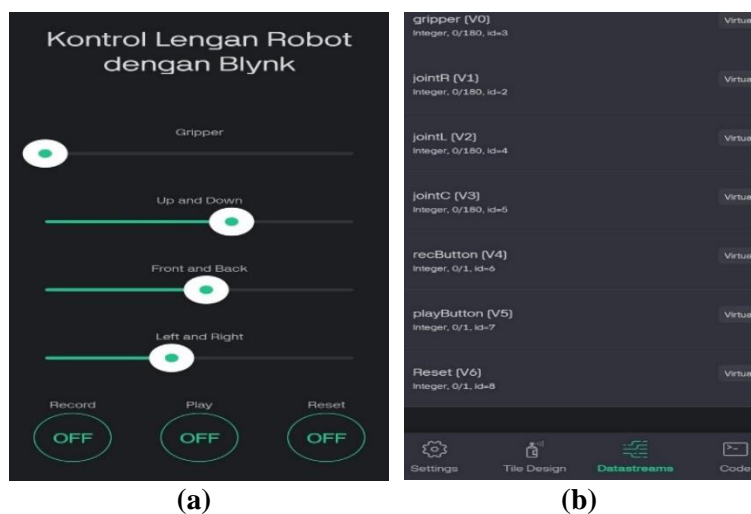


Figure 4. Blynk Application

Figure 4(a) presents the user interface of the Blynk application, which enables the robot arm's movement via four sliders controlling the servos and three buttons (record, play, reset). Figure 4(b) shows the datastream configuration that connects each control element to the microcontroller.

The application simplifies real-time control and motion recording through cloud connectivity, supporting the system's automation feature. Compared to prior studies using Bluetooth-based manual control (Alifiah et al., 2023; Szolga & Flueraș, 2021), the Blynk-based design offers wider control range and improved data synchronization, which contributes to smoother servo movement.

### Research Results of Robot Arm without PCA9685

**Table 1. Research Results of Robot Arm without PCA9685**

Position	Test	Placement (mm)		Displacement (mm)	Information
		Actual	Test		
A – B	1	50	50	0	Success
	2	50	50	0	Success
	3	50	50	0	Success
	4	50	50	0	Success
	5	50	50	0	Success
	6	50	50	0	Success
	7	50	50	0	Success
	8	50	50	0	Success
	9	50	50	0	Success
	10	50	50	0	Success
<b>Average Placement</b>		<b>50 mm</b>			
<b>Average Displacement</b>				<b>0 mm</b>	
<b>Accuracy</b>		<b>100%</b>			
<b>Precision</b>		<b>0 mm</b>			
<b>Error</b>		<b>0%</b>			
B – C	1	100	100	0	Success
	2	100	100	0	Success
	3	100	100	0	Success
	4	100	100	0	Success
	5	100	100	0	Success
	6	100	100	0	Success
	7	100	100	0	Success
	8	100	100	0	Success
	9	100	103	3	Success
	10	100	102	2	Success
<b>Average Placement</b>		<b>100,5 mm</b>			
<b>Average Displacement</b>				<b>0,5 mm</b>	
<b>Accuracy</b>		<b>99,5%</b>			
<b>Precision</b>		<b>3 mm</b>			
<b>Error</b>		<b>0,5%</b>			
C – A	1	150	150	0	Success
	2	150	150	0	Success
	3	150	150	0	Success
	4	150	150	0	Success
	5	150	150	0	Success
	6	150	150	0	Success
	7	150	153	3	Success
	8	150	153	3	Success
	9	150	151	1	Success
	10	150	152	2	Success
<b>Average Placement</b>		<b>150,9 mm</b>			
<b>Average Displacement</b>				<b>0,9 mm</b>	
<b>Accuracy</b>		<b>99,4%</b>			
<b>Precision</b>		<b>3 mm</b>			
<b>Error</b>		<b>0,6%</b>			
A – C – B	1	250	250	0	Success

Position	Test	Placement (mm)		Displacement (mm)	Information
		Actual	Test		
	2	250	250	0	Success
	3	250	250	0	Success
	4	250	250	0	Success
	5	250	250	0	Success
	6	250	256	6	Success
	7	250	257	7	Success
	8	250	256	6	Success
	9	250	258	8	Success
	10	250	257	7	Success
	<b>Average Placement</b>		<b>253,4 mm</b>		
	<b>Average Displacement</b>			<b>3,4 mm</b>	
	<b>Accuracy</b>		<b>98,64%</b>		
	<b>Precision</b>		<b>8 mm</b>		
	<b>Error</b>		<b>1,36%</b>		
B – A – C	1	200	200	0	Success
	2	200	200	0	Success
	3	200	200	0	Success
	4	200	200	0	Success
	5	200	200	0	Success
	6	200	200	0	Success
	7	200	205	5	Success
	8	200	205	5	Success
	9	200	205	5	Success
	10	200	205	5	Success
	<b>Average Placement</b>		<b>202 mm</b>		
	<b>Average Displacement</b>			<b>2 mm</b>	
	<b>Accuracy</b>		<b>99%</b>		
	<b>Precision</b>		<b>5 mm</b>		
	<b>Error</b>		<b>1%</b>		
C – B – A	1	150	150	0	Success
	2	150	150	0	Success
	3	150	150	0	Success
	4	150	150	0	Success
	5	150	150	0	Success
	6	150	150	0	Success
	7	150	152	2	Success
	8	150	153	3	Success
	9	150	152	2	Success
	10	150	152	2	Success
	<b>Average Placement</b>		<b>150,9 mm</b>		
	<b>Average Displacement</b>			<b>0,9 mm</b>	
	<b>Accuracy</b>		<b>99,4%</b>		
	<b>Precision</b>		<b>3 mm</b>		
	<b>Error</b>		<b>0,6%</b>		

Table 1 shows the results of automated pick-and-place tasks performed without the PCA9685 module. The average accuracy obtained from 60 trials was 99.323%, with an error rate of 0.677% and a precision of 3.7 mm.

Although the ESP8266 microcontroller can independently control multiple servos, PWM signal instability may occur due to limited processing capacity, affecting movement precision (Wai et al., 2020).

Research Results of Robot Arm with PCA9685

Table 2. Research Results of Robot Arm with PCA9685

Position	Test	Placement (mm)		Displacement (mm)	Information
		Actual	Test		
A – B	1	50	50	0	Success
	2	50	50	0	Success
	3	50	50	0	Success
	4	50	50	0	Success
	5	50	50	0	Success
	6	50	50	0	Success
	7	50	50	0	Success
	8	50	50	0	Success
	9	50	50	0	Success
	10	50	50	0	Success
<b>Average Placement</b>		<b>5 mm</b>			
<b>Average Displacement</b>				<b>0 mm</b>	
<b>Accuracy</b>		<b>100%</b>			
<b>Precision</b>		<b>0 mm</b>			
<b>Error</b>		<b>0%</b>			
B – C	1	100	100	0	Success
	2	100	100	0	Success
	3	100	100	0	Success
	4	100	100	0	Success
	5	100	100	0	Success
	6	100	100	0	Success
	7	100	100	0	Success
	8	100	100	0	Success
	9	100	100	0	Success
	10	100	100	0	Success
<b>Average Placement</b>		<b>10 mm</b>			
<b>Average Displacement</b>				<b>0 mm</b>	
<b>Accuracy</b>		<b>100%</b>			
<b>Precision</b>		<b>0 mm</b>			
<b>Error</b>		<b>0%</b>			
C – A	1	150	150	0	Success
	2	150	150	0	Success
	3	150	150	0	Success
	4	150	150	0	Success
	5	150	150	0	Success
	6	150	150	0	Success
	7	150	150	0	Success
	8	150	151	1	Success
	9	150	152	2	Success
	10	150	152	2	Success
<b>Average Placement</b>		<b>150,5 mm</b>			
<b>Average Displacement</b>				<b>0,5 mm</b>	
<b>Accuracy</b>		<b>99,67%</b>			
<b>Precision</b>		<b>2 mm</b>			
<b>Error</b>		<b>0,33%</b>			
A – C – B	1	250	250	0	Success
	2	250	250	0	Success
	3	250	250	0	Success
	4	250	250	0	Success
	5	250	250	0	Success

Position	Test	Placement (mm)		Displacement (mm)	Information
		Actual	Test		
	6	250	250	0	Success
	7	250	253	3	Success
	8	250	253	3	Success
	9	250	254	4	Success
	10	250	253	3	Success
	<b>Average Placement</b>		<b>251,3 mm</b>		
	<b>Average Displacement</b>			<b>1,3 mm</b>	
	<b>Accuracy</b>		<b>99,48%</b>		
	<b>Precision</b>		<b>4 mm</b>		
	<b>Error</b>		<b>0,52%</b>		
B – A – C	1	200	200	0	Success
	2	200	200	0	Success
	3	200	200	0	Success
	4	200	200	0	Success
	5	200	200	0	Success
	6	200	200	0	Success
	7	200	200	0	Success
	8	200	201	1	Success
	9	200	202	2	Success
	10	200	202	2	Success
	<b>Average Placement</b>		<b>200,5 mm</b>		
	<b>Average Displacement</b>			<b>0,5 mm</b>	
	<b>Accuracy</b>		<b>99,75%</b>		
	<b>Precision</b>		<b>2 mm</b>		
	<b>Error</b>		<b>0,25%</b>		
C – B – A	1	150	150	0	Success
	2	150	150	0	Success
	3	150	150	0	Success
	4	150	150	0	Success
	5	150	150	0	Success
	6	150	150	0	Success
	7	150	150	0	Success
	8	150	150	0	Success
	9	150	152	2	Success
	10	150	152	2	Success
	<b>Average Placement</b>		<b>150,4 mm</b>		
	<b>Average Displacement</b>			<b>0,4 mm</b>	
	<b>Accuracy</b>		<b>99,73%</b>		
	<b>Precision</b>		<b>2 mm</b>		
	<b>Error</b>		<b>0,27%</b>		

Table 2 presents the test results when using the PCA9685 motor driver. The average accuracy from 60 trials increased to 99.77%, with an error of 0.23% and a precision of 1.7 mm.

This improvement occurs because the PCA9685 provides dedicated PWM channels, reducing the processing burden on the ESP8266 and generating more stable servo signals. The result aligns with previous findings that integrating a servo driver can enhance positioning accuracy and reduce latency in multi-servo systems (Farih et al., 2023).

## Accuracy and Precision Comparison

**Table 3. Accuracy and Precision**

Robot Arm	Accuracy	Precision
without PCA9685	99,323%	3,7 mm
with PCA9685	99,77%	1,7 mm

Table 3 summarizes the comparative results between the two configurations. The robot arm using PCA9685 achieved an accuracy improvement of 0.447% and a precision improvement of 2 mm compared to the configuration without PCA9685.

Overall, the results confirm that offloading PWM signal generation from the main microcontroller leads to more efficient processing and higher precision findings that support previous research on servo control optimization in compact robotic systems (Alifiah et al., 2023; Rahul et al., 2020).

## CONCLUSION

The study concludes that the four-servo robotic arm designed with Blynk control can operate automatically by recording manual movements using the record feature, which are then stored and played automatically through the play feature. Based on 60 experiments conducted on both robotic arm configurations, the use of the PCA9685 driver enhanced the system's accuracy and precision compared to the robotic arm without PCA9685. This improvement occurs because the PCA9685 can generate more stable PWM signals, resulting in higher movement accuracy and smoother control. The ESP8266 microcontroller alone has only one PWM channel, while the PCA9685 provides up to sixteen PWM channels, allowing more efficient signal distribution and improved servo motor performance.

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