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Android Mobile Based Speed Controller Using Brushless DC Motor

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Abstract: This paper details the design and implementation of an Android mobile-based system for controlling the speed of direct current (DC) motors, utilizing modern microcontrollers and wireless fidelity (Wi-Fi) technology. The system is designed and implemented using an Android mobile device, modern microcontrollers, and cloud-based IoT technology. The system incorporates a brushless DC (BLDC) motor, a relay module, an electronic speed controller (ESC), and an ESP-32 microcontroller, which enables remote control of the motor's speed and direction by utilizing the android device and the integration of the ESP-32 microcontroller with the Arduino cloud platform. The results present diverse DC motor control applications in automation and IoT-enabled devices. Advanced motor control techniques have been successfully proven by results from experiments that allow the integration of mobile devices within a 70-meter range for different speed controls.

Index Terms - Android, Brushless DC motor, Internet of Thing and Speed control.

I. INTRODUCTION

The use of mobile platforms to operate a variety of electromechanical systems such as DC motors is rapidly gaining traction as smartphones and tablets become more common. Accessibility and flexibility problems have plagued motor control methods in the past [1]. However, modern application developments have significantly lessened these restrictions [2]. According to [3], mobile-based control systems have various advantages over traditional control techniques, such as smooth interaction with current mobile devices, portability, and user-friendliness. The selection of a brushless DC motor was based on its inherent benefits over brushed motors, including lower heat generation, quieter operation, and increased efficiency [4]. Innovative smartphone and tablet applications offer engineers and enthusiasts the opportunity to create user-friendly interfaces for remotely controlling motors and other devices. This provides a more intuitive approach to the fundamental control of motor operations, as well as advanced features like data logging, real-time monitoring, and feedback control [5]-[6]. The integration of communication modules and sensors into motor systems is essential for enabling remote monitoring and control of motor characteristics. This method is convenient when controlling, managing motors and gives users more freedom. Motor-driven applications, therefore, become more trustworthy and effective. The introduction of mobile technology has completely changed how we communicate with everyday objects and systems [6]. The widespread use of android mobile devices to improve motor control capabilities is investigated in this work. This overcomes the limitations encountered in the previous study and ushers in a new era of improved accessibility and flexibility in motor control by utilizing the power of android platforms to transform mobile devices into reliable controllers for brushless DC motors [7].

A variety of control strategies and processes have been investigated in earlier research in an effort to regulate direction and speed in tasks of a similar nature. Through an analysis of these methodologies, scholars have discerned plausible remedies to mitigate existing constraints. In order to regulate the speed and direction of a DC motor, authors in [8] used bluetooth connectivity on an android application. An android app was used on a smartphone, a bluetooth module, and a motor driver. The C++ programming language was used to program the Arduino. Though, their efforts are limited in terms of regulating speed over large distances. Authors in [9] developed a smart wireless system based on the IoT that allows control over a BLDC motor's direction and speed. They used an infrared (IR) sensor, a raspberry Pi microprocessor, and a Wi-Fi module to leverage IoTs technology. Furthermore, a relay module consisting of an insulated gate bipolar transistor (IGBT) was utilized and the system was controlled using the pulse width modulation (PWM) approach. An Android application and bluetooth technology were used to create a home automation system [10]. Their work utilized a graphical user interface (GUI), bluetooth to transmit the command that was received, and voice prompts to input data into the mobile smartphone through an android application. Their own app was created using MIT App Inventor, but still suffers from a limited operating range. The motor is turned on by sending a single command to the app over bluetooth. A bluetooth-based system was developed for DC motor speed and direction control, using bluetooth technology for communication [11]. The speed control of the DC motor was achieved by means of a PWM signal, which allows speed control from a smartphone. Though their work was secured, affordable, and robust, but there are limitations in the control system aspect, which is vulnerable to privacy and security flaws. According to [12], their study utilized a microcontroller, bluetooth module, and liquid crystal display (LCD) in conjunction with an android mobile application to control the speed and direction of DC motors. They identified several challenges that required further attention, including security weaknesses, bluetooth connectivity issues, and restricted range. An android mobile application-based bluetooth control system for DC motors was developed by [13]. Bluetooth's scalability and resilience in comparison to radio frequency (RF) modules are not fully investigated in their work. Their study did show bluetooth to be a useful substitute for RF modules only. There is need for further research to determine the long-term security of bluetooth technology and dependability in real-world applications. Authors in [14] investigated automating camel racing with IoT-controlled DC motor speed. In their work, the Blink app was used as an interface for regulating motor speed and direction. Also, an ESP-8266 module is coupled to an Arduino microcontroller for IoT support as a means of communication. Their concept was proved effectively, but the study pointed out drawbacks that hindered the study performances, like dependability issues, connectivity problems, and possible security risks related to IoT technology.

II. DESIGN AND METHOD

The major hardware components are ESP-32, brushless DC motor, electronic speed controller (ESC), buck DC to DC converter, and two-channel relay. The hardware components mentioned are briefly discussed below:

ESP-32: ESP-32 is a series of low-cost, low-power on-chip microcontrollers with integrated Wi-Fi and dual-mode bluetooth. Power management modules, low-noise receiver amplifiers, etc. are integrated into the design with built-in filters, as seen in Fig. 1. This work makes use of Wi-Fi, so no external shields or modules are required. The ESP-32 used features an adjustable signal transmitting power, enables antenna diversity, and can achieve up to 150 Mbps of data throughput. The device (ESP-32) also enables multiple simultaneous connections, which is helpful when a device needs to communicate with several other devices or services at once.

Fig.1: ESP-32 controller [15]

***Brushless DC Motor*:** A BLDC uses an electronic controller to switch DC currents to the motor windings. This is an electrically commutated motor, which is a type of synchronous motor that operates with a trapezoidal back electromotive force (EMF) waveform. This produces magnetic fields that effectively rotate in space, and the permanent magnet rotor follows. Due to the elimination of brushes, BLDC motors offer greater efficiency, a higher power density, a larger torque output, a wide speed range, and a high dynamic response due to the low inertia of the rotor. The typical BLDC motor used in this work is shown in Fig. 2.

Fig. 2: Brushless DC motor [15]

Electronic speed controller: An ESC is a purpose-built device designed for controlling the speed of an electric motor using a specialized combination of hardware and firmware. A typical ESC used in the work is shown in Fig. 3.

Fig. 3: Electronic speed controller [15]

Buck DC to DC Converter: A typical bulk DC-DC converter used in this work is shown in Fig. 4, and it is widely used for tasks such as converting higher supply voltages to lower voltages needed by various electronic devices, offering high efficiency levels often exceeding 90%. In this case, it is used to convert the power supply from the battery of 12V to 5V to power the relay module of 5V in order to control the speed direction.

Fig. 4: Buck DC to DC Converter [15]

Two Channel Relay: The use of two-channel relay module with relation to motor control can serve as a bidirectional control which is used to control direction by switching the connections of the motor's terminal. It is also used for control signal that are generated by the microcontroller ESP-32. The microcontroller receives commands, which activate or deactivate the relay to control direction. A two-channel relay used in the work is shown in Fig.5.

Fig. 5: Two-Channel Relay [15]

The block diagram summarizing the system design is shown in Fig. 6. The Wi-Fi reads the information and passes to ESP-32 board, which makes changes in the speed of the motor according to the controller. The direction and the pulse width modulation (PWM) displayed on the smartphone. The simulation and development of the hardware part of the work is shown in the circuit diagram as indicated in Fig. 7. The coding and configuration of EPS-32 is created using Arduino IDE and cloud for the IoT platform. C++ programming language is employed to code the ESP-32 microcontroller with a servo motor. The final connection and the construction of the device are shown in Fig. 8 and Fig. 9 respectively.

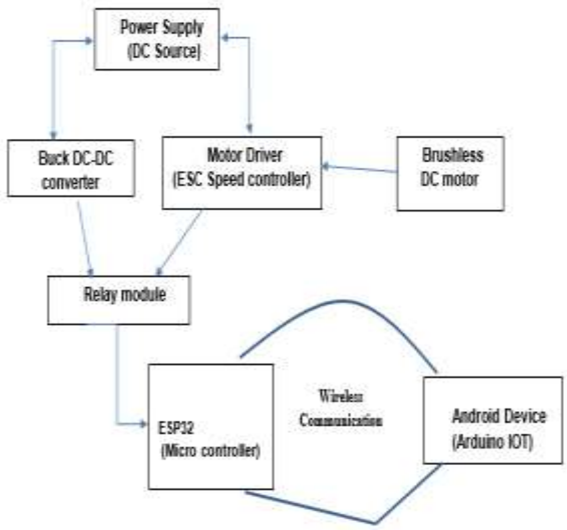

Fig. 6: The block diagram for speed and direction control of a BLDC

Because of the PWM technique's great efficiency and simplicity of use, the speed of the BLDC motor is controlled. Generating square waves with frequencies higher than 1 kHz is the main application of this technique. The duty cycle's mathematical expression used is shown in equation (1.1).

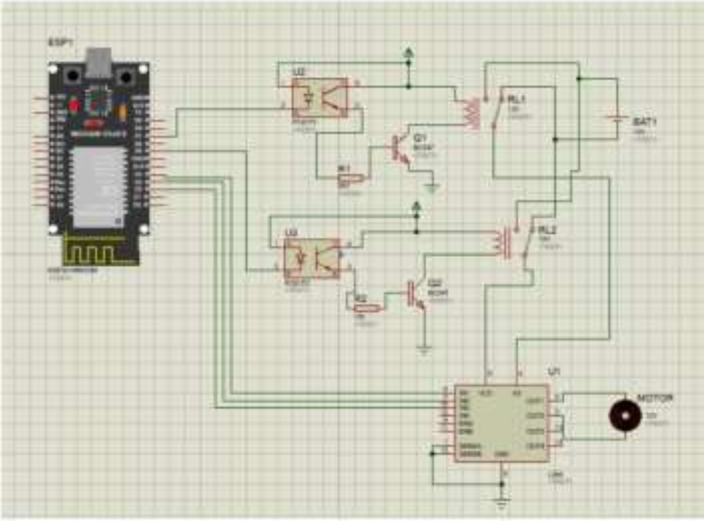

Fig.7: BLDC motor speed controller hardware circuit

$$\% \, duty \, cycle = \left(\frac{t_{on}}{t_{on} + t_{off}}\right) * 100 \qquad (1.1)$$

Where $t_{on} - on \, time$ and $t_{off} - off \, time$

$t_{on} + t_{off} = total \, time.$

The response time of the motor is shown in equation (1.2). This is the difference between the time taken for the motor speed to reach 90% of its final value ($t_{90\%}$) and the time taken for the motor speed to reach 10% of its final value ($t_{10\%}$) after a control signal change.

$$Response \, Time = t_{90\%} - t_{10\%} \qquad (1.2)$$

where $t_{90\%}$ is the time at which the motor speed reaches 90 % of its value after the control signal change.
$t_{10\%}$ is the time at which the motor speed reaches 10% of its final value after the control signal change.

Fig. 8: The connection of the components

Fig.9: BLDC Motor connection

3.0 Results and Discussion

The proposed scheme allows for different speeds and the reversal of rotational direction. The results for various inputs are presented in Table I. Based on input values (0, 1, 2, 3, 4, 5, 6, 7) and duty cycle percentages (0, 45, 50, 65, 85, and 100%), the desired rotational direction (clockwise / anticlockwise) and speed control (0, 1200, 1500 and 1600 rpm) have been achieved. The Wi-Fi range with respect to distance 70 meters (230 feet) was measured as indicated in Table 2. Wi-Fi ranges for controlling the BLDC motor at different speed in revolution per minute (RPM) i.e 1200 RPM (low speed), 1500 RPM (medium speed), and 1800 RPM (high speed) have been obtained.

Table 1. Results obtained during operational command input

Input	Operation Command	Speed (RPM)	Voltage (V)
1	Motor Clockwise	0	0.08
2	Motor Clockwise	45	0.65
3	Motor Clockwise	65	1.45
4	Motor Clockwise	85	1.92
5	Motor Anti-Clockwise	0	0.08
6	Motor Anti-Clockwise	65	1.45
7	Motor Anti-Clockwise	85	1.92
8	Motor Off	0	0

Table 2. Wi-Fi distance covered and the response time

Speed (RPM)	Maximum Wi-Fi Range		Response time (secs.)
	meters	Feet	
1200	Up to 70 m	230	1
1500	Up to 70 m	230	1.02
1800	Up to 70	230	1.02

The android mobile application over IoT successfully controlled the speed of the BLDC motor. The motor speed adjustment was achievable on the application interface. The system provides a smooth speed transitions without any significant delays or interruption. The laboratory experimental testing using oscilloscope was achieved and the waveform indicated torque against time at low, medium and high speed respectively are shown in Fig.10. The response time is calculated and highlighted in the Table 2 for different sample RPM speed. It is measured by initiating speed adjustment commands through the mobile application and recording the time taken for the motor to reach the specific speed.

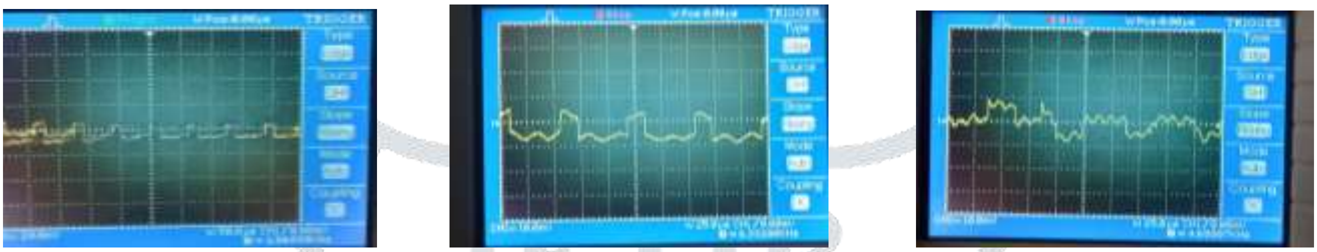

Fig a. Low speed at 1200rpm. Fig b. Medium speed at 1500 rpm Fig c. High speed at 1500 rpm

Fig.10(a-c). Waveform at low, medium and high speed in rpm

IV. CONCLUSION

In this work, the speed and direction control of a BLDC motor has been achieved. By using ESC, ESP-32 and two channel relay module through Wi-Fi by the PWM technique the precise speed regulation and direction control were perfectly achieved. This is crucial for various applications, ranging from robotics to electric vehicles. This process is also used to control various aspects of the BLDC motor using an Android smartphone as a remote control. These functions include speed control, direction control, and more, offering a flexible and convenient way to manage the motor from a distance.

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