Speed and Direction Control of DC Motor using Microcontroller

Sarang Dure[1], Alfiya Sayyad[2], Shraddha Kapse[3], Sagar Zadake[4], Amit Hangarge[5],
Bhagwan Suryavanshi[6], Prof. S.S. Mane[7], Prof. S.N. Gaikwad[8], Prof. V.S. Gangane[9]

[1,2,3,4,5,6] U.G Student, [7,8,9] Assistant professor

Department of Mechanical Engineering

Shri Tuljabhavani College of Engineering, Tuljapur-413601, India

Abstract: **The project is intended to control the speed of a D.C. motor by varying voltage across the terminal. The concept behind the project is, since the speed of D.C. motor is directly proportional to the voltage applied therefore the duty cycle of the pulse is varied (i.e. Pulse with Modulation is used) to control the speed. A microcontroller is used to interface two input buttons for controlling motor speed. The microcontroller programmed in Embedded C language generates PWM i.e. Pulse Width modulation at the output according to program instructions. The ON and OFF time of the pulses or the duty cycle changes the average voltage given to the motor and therefore the speed of the motor changes. The PWM signals are received by a motor driver interfaced to microcontroller for delivering required output in controlling DC motor speed. Working of this project displayed by 16×2 LCD Display.**

Keywords: **Duty cycle; GPIO (General Purpose Input/Output); Digital output; Analog input (if using potentiometer for speed); Interrupts (if used for sensors); Timer module Serial communication (UART, if monitoring speed); Closed-loop control (if sensors used for speed feedback); Open-loop control (if no feedback).**

1. INTRODUCTION

DC motors were the first form of motor widely used for industrial application. Small DC motors are also used in tools, toys and appliances. This motor is a class of rotary electrical machines that converts electrical energy into mechanical energy. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic to change the direction of current flow.

DC motors are classified on the basis of their excitation configuration as follows.

- Separately Excited DC motor
- Self-Excited DC motor
  - Series DC motor
  - Shunt wound DC motor
  - Compound wound DC motor

The basic working principle of DC motor is "Whenever a current carrying conductor is placed in a magnetic field, it experiences a mechanical force". The direction of this force is given by Fleming Left Hand Rule. The project is intended to control the speed of a DC motor by varying voltage across the terminal. The concept behind the project is, since the speed of DC motor is directly proportional to the voltage applied therefore the duty cycle of the pulse is varied (i.e. Pulse Width Modulation is used) to control the speed. A microcontroller is used to interface two input buttons for controlling motor speed. The microcontroller programmed in Embedded C language generates PWM i.e. Pulse Width modulation at the output according to program instructions. The ON and OFF time of the pulses or the duty cycle changes the average voltage given

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2. OBJECTIVES

The increasing demand for automation in industrial and embedded systems has driven interest in efficient motor control technologies. This is due to the growing need for precise motion control in applications such as robotics, electric vehicles, and smart appliances, along with the need to reduce human intervention and improve system reliability. The Speed and Direction Control of a DC Motor using a Microcontroller project has been conceptualized as a cost-effective and practical approach to achieving intelligent motor control through microcontroller-based automation. This section outlines both the primary and secondary objectives of the project, presenting a clear overview of its goals, motivations, and anticipated outcomes.

2.1 Speed Control: Vary the motor speed by adjusting the duty cycle of a PWM (Pulse Width Modulation) signal from the microcontroller. Achieve smooth acceleration and deceleration.

2.2 Direction Control: Use an H-bridge or motor driver IC (e.g., L293D or L298N) to reverse the polarity of the motor terminals. Allow the motor to rotate clockwise or counter-clockwise based on control inputs.

2.3 User Input Interface: Enable user control via switches, keypad, or serial communication like Bluetooth, UART (Universal Asynchronous Receiver/ Transmitter or IR remote).

Optional: Use a potentiometer or sensors for dynamic control.

2.4 Microcontroller Integration: Use a microcontroller (e.g., Arduino, 8051, PIC, or STM32) to read inputs and generate control signals Implement embedded code to manage PWM output and logic for direction.

2.5 Real-Time Monitoring (Optional): Display speed and direction status using LCD or LED indicators.

2.6 Automation and Robotics: DC motor control is essential for automating various tasks in robotics, industrial automation, and other applications where precise movement is required.

2.7 Precision and Accuracy: Microcontroller-based control allows for fine-tuning of speed and direction, enabling accurate and repeatable movements in various applications.

3. WORKING PRINCIPAL

Microcontroller, often paired with an H-bridge driver, controls DC motor speed and direction by generating PWM signals and digital control signals. The PWM signal, with varying duty cycle, adjusts the average voltage applied to the motor, thereby controlling its speed. Digital signals, often from push buttons or other input methods, control the H-bridge to reverse the voltage polarity across the motor, thus changing its direction.

Here's a more detailed explanation:

3.1 Speed Control using PWM:

3.1.1 PWM Generation: Microcontrollers have timers that can be configured to generate Pulse Width Modulation (PWM) signals.

3.1.2 Duty Cycle: The PWM signal's duty cycle (the ratio of on-time to the total period) determines the average voltage delivered to the motor.

3.1.3 Speed Variation: A higher duty cycle means more voltage is applied to the motor on average, resulting in higher speed. Conversely, a lower duty cycle means less voltage and slower speed.

3.1.4 Example: If a 100Hz PWM signal has a 25% duty cycle, the motor will receive voltage for 25% of the time and no voltage for 75% of the time within each cycle.

3.2 Direction Control using an H-bridge:

3.2.1 H-bridge: An H-bridge circuit (often implemented with an L293D or similar IC) is used to reverse the polarity of the voltage applied to the motor.

3.2.2 Switching: The H-bridge uses switches (often transistors) to direct current through the motor in one direction or the other.

3.2.3 Direction Control: By controlling the switching pattern, the microcontroller can make the motor rotate forward or backward.

3.2.4 Example: When switches A and D are on, current flows from positive to negative through the motor, causing it to rotate in one direction. When switches B and C are on, current flows in the opposite direction, causing the motor to rotate in the opposite direction.

3.3 Overall System:

3.3.1 Microcontroller Input: The microcontroller receives input signals from user interfaces (buttons, joysticks, etc.) or sensors.

3.3.2 Control Logic: The microcontroller processes these inputs and generates the appropriate PWM signal for speed control and logic signals for direction control.

3.3.3 Output to Motor: The PWM and direction signals are then sent to the H-bridge driver, which translates them into the voltage and current needed to drive the motor.

4. COMPONENT USED

The Speed and Direction Control of DC Motor using Microcontroller project utilizes a sustainable and efficient approach to control a DC motor through electronic automation. The system is powered by a microcontroller that governs motor speed and rotation direction based on user input. The project has been developed by carefully selecting components that are cost-effective, readily available, and highly compatible for embedded control applications. It integrates mechanical parts, electronic modules, and custom-designed circuits to build a functional and scalable control system. Below is a detailed description of the various components used in this project, categorized by their function.

4.1 DC MOTOR: DC Motor – 12Volts geared motors are generally a simple DC motor with a gearbox attached to it. This can be used in all-terrain robots and variety of robotic applications. These motors have a 3 mm threaded drill hole in the middle of the shaft thus making it simple to connect it to the wheels or any other mechanical assembly. 300 RPM 12V DC geared motors widely used for robotics applications. Very easy to use and available in standard size. Also, you don't have to spend a lot of money to control motors with an Arduino or compatible board. The most popular L298N H-bridge module with onboard voltage regulator motor driver can be used with this motor that has a voltage of between 5 and 35V DC or you can choose the most precise motor diver module from the wide range available in our Motor divers category as per your specific requirements. Nut and threads on the shaft to easily connect and internally threaded shaft for easily connecting it to the wheel. DC Geared motors with robust metal gearbox for heavy-duty applications, available in the wide RPM range and ideally suited for robotics and industrial applications. Very easy to use and available in standard size.

4.2 MICROCONTROLLER: The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital Input/output pins (of which 6 can be used as PWM outputs), 6 analogue inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP (In-Circuit Serial Programming) header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI (Future Technology Devices International Limited) USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter

4.3 Voltage Regulator: The voltage regulator (14) is not actually something you can (or should) interact with on the Arduino. But it is potentially useful to know that it is there and what it's for. The voltage regulator does exactly what it says – it controls the amount of voltage that is let into the Arduino board. Think of it as a kind of gatekeeper; it will turn away an extra voltage that might harm the circuit. Of course, it has its limits, so don't hook up your Arduino to anything greater than 20 volts.

4.4 JUMPER WIRES: A jump wire (also known as jumper, jumper wire, jumper cable, DuPont wire or cable) is an electrical wire, or group of them in a cable, with a connector or pin at each end (or sometimes without them – simply "tinned"), which is normally used to interconnect the components of a breadboard or other prototype or test circuit, internally

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or with other equipment or components, without soldering. Individual jump wires are fitted by inserting their "end connectors" into the slots provided in a breadboard, the header connector of a circuit board, or a piece of test equipment.

4.5 LCD DISPLAY (16X2): The term LCD stands for liquid crystal display. It is one kind of electronic display module used in an extensive range of applications like various circuits & devices like mobile phones, calculators, computers, TV sets, etc. These displays are mainly preferred for multi-segment light-emitting diodes and seven segments. The main benefits of using this module are inexpensive; simply programmable, animations, and there are no limitations for displaying custom characters, special and even animations, etc.

4.6 L298N MOTOR DRIVER: L298 motor shield is a dual full bridge driver designed to drive inductive load i.e. Stepper motor, relays & solenoids. It gives you the control to drive two DC motor with Arduino microcontroller and provide you the royalty to control the direction and speed of the motor.

5V (from Arduino) Logic control voltage

4-8V ~ 35V (from external power source) motor driven voltage

36mA >= Logic supply current Iss

2A >= motor driver current Io

25W Maximum power consumption (T=75C)

PWN, PLL Speed control mode

High 2.3V=<Vin=<5V

Low -0.3V=<Vin=<1.5V

4.7 POWER SUPPLY: An AC adapter, AC/DC adapter, or AC/DC converter is a type of external power supply, often enclosed in a case similar to an AC plug. Other common names include plug pack, plug-in adapter, adapter block, domestic mains adapter, line power adapter, wall wart, power brick, wall charger, and power adapter.

4.7.1 Transformer: Steps down high voltage AC mains to low voltage AC (12-0-12).

5.7.2 Rectifier: Converts AC to DC, but the DC output is varying. Smoothens the DC from varying greatly to a small ripple.

4.7.3 Regulator: Eliminates ripple by setting DC output to a fixed voltage. The basic step in the designing of any system is to design the power supply required for that system. The steps involved in the designing of the power supply are as follows,

1) Determine the total current that the system sinks from the supply.

2) Determine the voltage rating required for the different components.
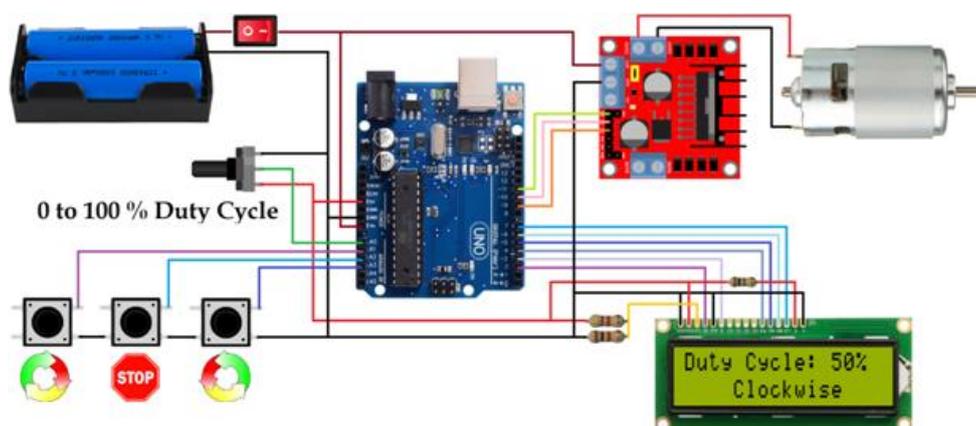
5. CIRCUIT DIAGRAM

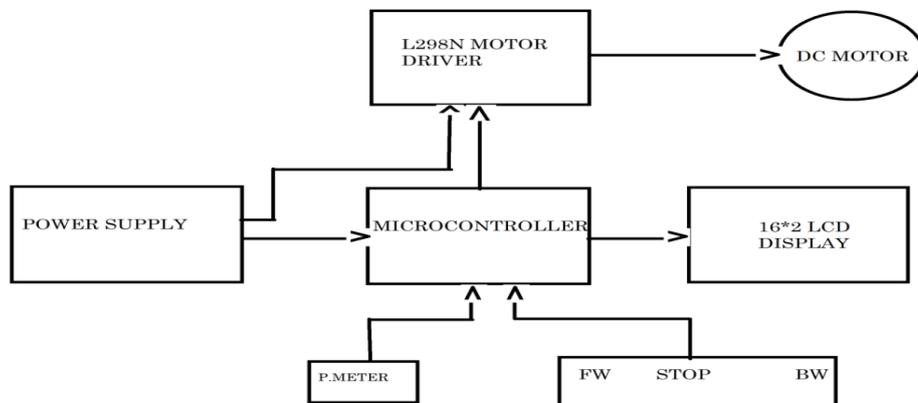**Figure 1: Circuit Diagram**

6. BLOCK DIAGRAM

Figure 2: Block Diagram

7. WORKING

The project involves controlling the speed and rotational direction of a DC motor using a microcontroller, typically an Arduino, 8051, or PIC. The motor cannot be directly driven by the microcontroller because it requires more current than the microcontroller can supply. To overcome this, a motor driver IC such as L293D or L298N is used, which acts as an interface between the low-power control circuit (microcontroller) and the high-power load (DC motor). The microcontroller takes user input through components like a potentiometer (for speed control) and push buttons or switches (for direction control). When the user rotates the potentiometer, it changes the voltage level fed to the analog input pin of the microcontroller. This analog voltage is converted to a digital value using the microcontroller's ADC (Analog-to-Digital Converter).

Using this digital value, the microcontroller generates a PWM (Pulse Width Modulation) signal. PWM is a technique where the motor's power supply is rapidly turned on and off at a fixed frequency, and the proportion of 'on' time (duty cycle) determines the effective voltage and hence the speed of the motor. A higher duty cycle means more power to the motor and faster speed. This PWM signal is sent to the Enable (EN) pin of the motor driver, controlling the speed.

For controlling the direction, two digital output pins of the microcontroller are connected to the motor driver's input pins (IN1 and IN2). The motor driver forms an H-Bridge configuration, allowing current to flow through the motor in either direction. For example, if IN1 is HIGH and IN2 is LOW, the motor rotates in the forward direction. If IN1 is LOW and IN2 is HIGH, the motor rotates in reverse. If both inputs are LOW or HIGH, the motor stops.

The motor driver receives the PWM signal and direction commands from the microcontroller and then powers the DC motor accordingly. As a result, the speed and direction of the motor are precisely controlled by adjusting the duty cycle and the input logic levels. In more advanced setups, feedback systems such as encoders can be added to measure the actual speed and adjust the PWM in real-time for better accuracy (closed-loop control), but in basic models, this remains open-loop.

This type of control system is widely used in robotics, automation systems, electric vehicles, and conveyor belt mechanisms, where precise control over motor behaviour is essential. The implementation demonstrates a fundamental concept in embedded systems and me

8. CALCULATIONS AND DISCUSSION

To control the speed and direction of a DC motor using a microcontroller, we typically use Pulse Width Modulation (PWM) to vary speed and an H-bridge circuit (like L293D or L298N) to control direction. The duty cycle of the PWM signal determines the effective voltage applied to the motor, and thus its speed.

8.1 Duty Cycle and RPM Relationship:

8.1.1 The duty cycle is calculated as:

Duty Cycle (%) = (ON time / Total time) × 100

Higher duty cycle leads to higher average voltage and thus higher motor speed (RPM).

Assuming a 12V, 3000 RPM motor at 100% duty cycle, the table below shows duty cycle vs RPM:

8.2 Microcontroller PWM and Direction Control:

8.2.1 Speed Control (PWM Pin): The PWM pin outputs a square wave signal. The duty cycle is adjusted in software using timers or PWM registers. Direction Control (Digital Pins): Two digital pins connected to the H-bridge control the motor direction.

8.2.2 Logic combinations:

IN1=HIGH, IN2=LOW → Clockwise (CW)

IN1=LOW, IN2=HIGH → Counterclockwise (CCW)

IN1 = LOW, IN2 = LOW or HIGH/HIGH → Brake/Stop

8.3 Discussion and Summary:

8.3.1 Speed Variation Using PWM: PWM effectively changes the motor speed by changing the average voltage. Linear relationship at lower loads, but may become nonlinear due to back EMF and friction.

8.3.2 Direction Control: H-Bridge allows reversing current through the motor to reverse direction.

8.3.3 Efficiency: PWM is energy efficient since the H-bridge transistors operate in ON/OFF mode.

8.3.4 Limitations: At very low duty cycles, motor might not start due to static friction. Load torque affects RPM.

8.3.5 Feedback Control: Using sensors like encoders allows for precise RPM control via PID algorithms.

9. ADVANTAGES & LIMITATIONS

According to the all information of the report we have describe the following advantages and limitations are as follows:

9.1 ADVANTAGE:

9.1.1 Good speed control: DC motors offer highly controllable speed. By changing the armature or field voltage it's possible to achieve wide speed variation and with this level of controllability, DC motors offer the precision required by a wide range of industry applications.

9.1.2 High torque: A DC motor also offers a high starting torque, which makes it perfect for use in applications that are designed to move heavier loads, such as wiper systems and in industrial automation applications, such as conveyor systems or materials handling equipment. The consistent drive power that DC motors deliver means they're ideal for maintaining a constant torque whilst an application is in use, making them an excellent choice for a geared motor solution.

9.1.3 Seamless operation: As DC motors operate with high levels of controllable power across a range of speeds, they offer the benefit of seamless operation. In some industries, it is vital that DC motors can start and stop efficiently to cope with the requirements of the application. If you are looking for a solution that offers rapid acceleration, an option to reverse direction and start/stop efficiency, a DC motor is a good choice.

9.1.4 Free from harmonics: In any electric power system, a harmonic is a voltage or current at a multiple of the fundamental frequency of the system, typically produced by the action of non-linear loads such as rectifiers or saturated magnetic devices. Harmonic frequencies in the power grid can be the cause of power quality problems and harmonics in some AC motors can cause torque pulsations, resulting in a decrease in torque. DC motors are free from issues associated with harmonics.

9.2 LIMITATIONS: Operation and maintenance cost due to presence of commutator and brush gear cannot operate in explosive and hazard conditions due to sparking occur at brush (risk in commutation failure)

9.2.1 Mechanical Wear and Tear: The use of brushed DC motors introduces mechanical components like brushes and commutators, which are prone to wear over time, requiring regular maintenance and limiting long-term reliability.

9.2.2 Not Suitable for Hazardous Environments: Due to sparking at the brushes during commutation, this system is not safe for explosive or flammable environments, where brushless or sealed motor systems are preferred.

9.2.3 Limited Current Capacity: The L298N motor driver used in this project can handle only up to 2A per channel, which limits the power and size of motors that can be controlled. It is not suitable for high-power industrial motors.

9.2.4 No Real-Time Feedback or Protection: The system lacks closed-loop feedback mechanisms (like encoders or sensors for speed, temperature, or current), making it less precise and vulnerable to overheating or overcurrent damage.

9.2.5 Manual Control Only (No Remote Access): Although the design can be upgraded for IoT, the current implementation is restricted to manual input via buttons and potentiometer, lacking remote or automated control capabilities.

9.2.6 Basic User Interface: The 16x2 LCD provides limited information display and no graphical interface, which may be insufficient for more complex monitoring needs in real-world applications

10. APPLICATIONS AND FUTUR SCOPE

Here is a description of the applications and future scope for a speed and direction control system of a D.C. motor using a microcontroller:

10.1 APPLICATIONS:

Microcontrollers are widely used in industrial applications to precisely control the speed and direction of DC motors, enabling automation and efficiency in various processes. These applications span from conveyor systems and robotics to material handling and manufacturing equipment. Microcontrollers offer a cost-effective and flexible solution by generating Pulse Width Modulation (PWM) signals, which are then used to drive motor control circuits like H-bridges, allowing for precise speed and direction control.

10.1.1 DC SERIES MOTOR: The series DC motors are used where high starting torque is required and variations in speed are possible. For example – the series motors are used in the traction system, cranes, air compressors, Vacuum Cleaner, Sewing machine, etc.

10.1.2 DC SHUNT MOTOR: The shunt motors are used where constant speed is required and starting conditions are not severe. The various applications of DC shunt motor are in Lathe Machines, Centrifugal Pumps, Fans, Blowers, Conveyors, Lifts, Weaving Machine, Spinning machines, etc.

10.1.3 DC COMPOUND MOTOR: The compound motors are used where higher starting torque and fairly constant speed is required. The examples of usage of compound motors are in Presses, Shears, Conveyors. The small DC machines whose ratings are in fractional kilowatt are mainly used as control device such in techno generators for speed sensing and in servo motors for positioning and tracking.

10.2 FUTURE SCOPE: The intelligent control of DC series motor and DC separately excited motor with DC-DC converter has been taken up in this work. Further modifications in the fuzzy membership function can also be carried out in the work presented. The intelligent control can be extended for other special electrical motors. The stability analysis of nonlinear ANN controller can be one in future. The controller implementation was done on a NXP 80C51 based microcontroller in the work. The designed control algorithm scan be implemented in other embedded system platforms such as DSP processor VLSI based chips.

11. CONCLUSION

The proposed project technique will make hardware model where the Arduino based Technique is used for control dc motor. Therefore, the speed and the direction of dc Motor can be controlled by use of Arduino. This project demonstrates the successful implementation of a DC motor speed and direction control system using an Arduino Uno microcontroller, Pulse

Width Modulation (PWM), and an L298N motor driver. The objective was to develop a user-friendly and efficient method for controlling motor operations, including speed variation and bidirectional rotation, through simple hardware components and Embedded C programming. The use of PWM proved effective in varying the speed of the DC motor by adjusting the duty cycle, which in turn controls the average voltage supplied to the motor. With the integration of push buttons for directional control (clockwise, anticlockwise, and stop functions), users can easily interact with the system. The inclusion of a potentiometer allowed dynamic speed adjustment, and the real-time display of duty cycle and motor status on a 16x2 LCD added to the usability and monitoring capability of the system. Compared to other approaches found in the literature, this project adopted a more simplified and cost-effective strategy by avoiding complex app development or cloud infrastructure for remote control, focusing instead on a direct and hands-on user interface. However, the system remains scalable and can be upgraded in the future by integrating wireless modules like ESP8266 for IoT functionality.

The choice of Arduino Uno and L298N motor driver contributed to the project's success due to their ease of use, flexibility, and wide community support. Furthermore, the open-source nature of the Arduino ecosystem enabled quick development and testing. In conclusion, the project not only fulfils its primary goal of controlling DC motor speed and direction effectively but also lays the groundwork for future enhancements such as wireless connectivity, sensor-based automation, or industrial-grade protection features. It provides valuable insights into embedded systems, motor control, and practical electronics application

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