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Research

SPEED AND DIRECTION CONTROL OF DC MOTOR USING FOUR QUADRANT CHOPPER AND ARDUINO

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ABSTRACT

Embedded systems are widely used in modern electronic devices to perform specific tasks efficiently and reliably. These systems combine hardware and software to control different operations in applications such as automation, communication, and transportation. They are designed to perform a dedicated function with limited resources and low power consumption. The proposed system focuses on an autonomous electronic toll gate system that uses GPS and GSM technologies to automate the toll collection process. In this system, the location of the vehicle is identified using GPS. When the vehicle crosses a predefined toll gate location, the system automatically detects it and deducts the required toll amount from the user's account. After the deduction, a message indicating the toll amount and the remaining balance is sent to the user.The system is controlled by a microcontroller which coordinates all the operations. Additional components such as LCD display, motor drivers, switches, and a regulated power supply are used to support the functioning of the system. The LCD is used to display important messages and system status, while the motor driver helps in controlling motors used in the toll gate mechanism. This automated toll collection system reduces traffic congestion, minimizes waiting time at toll plazas, and eliminates manual toll collection. It provides a faster, more efficient, and reliable method for toll payment and improves the overall transportation management system.

Keywords: Autonomous toll collection, GPS, GSM, microcontroller, embedded systems, electronic toll gate, vehicle tracking, automated toll deduction, RFID, wireless communication, traffic management.

1. INTRODUCTION

Embedded systems have become an essential part of modern technology and are widely used in many electronic devices and automation systems. An embedded system can be defined as a specialized computing system designed to perform a specific task within a larger system. Unlike general-purpose computers, embedded systems are developed to carry out dedicated functions with high efficiency and reliability. These systems combine both hardware and software components to control and manage the operations of electronic devices. The hardware part generally includes a microcontroller or microprocessor, memory, input and output devices, and communication interfaces, while the software part includes the program that controls the functioning of the system. In recent years, embedded systems have gained significant importance due to their ability to perform complex operations with limited resources. These systems are designed to operate continuously and reliably for long periods without human intervention. Embedded systems are used in a wide range of applications including consumer electronics, industrial automation, communication systems, transportation systems, and medical equipment. Devices such as washing machines, microwave ovens, printers, mobile phones, digital cameras, and air conditioners all use embedded systems to control their functions. One of the major advantages of embedded systems is that they are designed for a specific purpose, which makes them more efficient and reliable compared to general-purpose computers.

They are usually compact in size, consume less power, and provide faster response times. In many applications, embedded systems are also required to work in real-time environments where tasks must be completed within strict time limits. These

systems are commonly referred to as real-time embedded systems. For example, systems used in medical monitoring devices, automobile control systems, and industrial machinery require precise timing and accurate performance. Transportation is another important field where embedded systems are widely used. Modern transportation systems depend heavily on electronic and automated technologies to improve efficiency, safety, and convenience.

One of the important applications in transportation is toll collection on highways and expressways. Toll collection is necessary to maintain and develop road infrastructure. However, traditional toll collection systems often cause several problems such as traffic congestion, long waiting times, and delays at toll plazas. In the traditional toll collection system, vehicles are required to stop at toll booths where drivers pay the toll manually using cash or cards. This manual process takes time and results in long queues of vehicles, especially during peak hours or holiday seasons. The manual toll collection system also requires a large number of workers to manage the toll booths. In addition, the process is prone to human errors and sometimes leads to inaccurate toll collection. These problems highlight the need for an efficient and automated toll collection system.

With the advancement of technology, automated toll collection systems have been developed to overcome the limitations of traditional toll systems. Automated systems help in reducing waiting time, improving traffic flow, and minimizing human intervention. Various technologies such as RFID, GPS, GSM, and wireless communication are used in modern toll collection systems to automate the entire process.

The proposed system focuses on an Autonomous Electronic Toll Gate system that uses GPS and GSM technologies to automate toll collection. The main objective of this system is to eliminate the need for vehicles to stop at toll plazas and make the toll collection process faster and more efficient. In this system, the location of the vehicle is determined using a GPS module. The GPS module continuously tracks the vehicle's position by determining its latitude and longitude coordinates.

The toll gate locations are predefined and stored in the system. When the vehicle approaches a toll gate, the system compares the vehicle's current location with the stored toll gate locations. Once the vehicle crosses the toll gate location, the system automatically deducts the required toll amount from the user's account. After the deduction, a notification message is sent to the user through GSM communication. The message includes details such as the toll amount deducted and the remaining balance in the account.

The microcontroller acts as the central processing unit of the system and controls the entire operation. It processes the GPS data, identifies the toll location, and performs the toll deduction process. The microcontroller also manages communication between different components of the system. Additional components such as LCD displays, motor drivers, switches, and regulated power supply circuits are used to support the system's operation.

The LCD display is used to show important information such as system status, toll deduction messages, and other notifications. Motor driver circuits are used to control motors that may be used for gate mechanisms or other mechanical operations. Switches and push buttons can be used as input devices for user interaction

or system control. A regulated power supply unit ensures that the system receives stable voltage levels required for proper operation.

The use of GPS and GSM technologies provides several advantages in toll collection systems. GPS allows accurate detection of the vehicle's location without the need for physical sensors at toll gates. GSM technology enables wireless communication between the system and the user's mobile device. This makes the system flexible and easy to manage. The automated process also reduces the chances of errors and ensures transparency in toll collection.

Another important advantage of the proposed system is that it helps reduce traffic congestion at toll plazas. Since vehicles do not need to stop for toll payment, the traffic flow becomes smoother and faster. This not only saves time for drivers but also reduces fuel consumption and vehicle emissions. As a result, the system contributes to environmental protection and improved road efficiency.

The automated toll system also improves the overall management of toll operations. The system can maintain records of toll transactions and vehicle movements, which can be useful for traffic monitoring and analysis. These records can help authorities understand traffic patterns and make better decisions regarding road management and infrastructure development.

In addition to toll collection, the system can also provide additional features such as theft detection and vehicle tracking. Since GPS continuously monitors the vehicle's location, it can be used to track the vehicle in case of theft or unauthorized movement. This adds an extra layer of security for vehicle owners.

In conclusion, embedded systems provide an effective solution for automating various processes in modern technology. The implementation of an autonomous electronic toll gate system using GPS and GSM technologies can significantly improve the efficiency of toll collection systems. By reducing manual operations, minimizing traffic congestion, and providing faster and more reliable services, the system enhances the overall transportation infrastructure. The proposed system demonstrates how embedded technology can be used to develop smart and efficient solutions for real-world problems.

2.LITERATURE SURVEY

1. PWM-Based Speed Control of DC Motors Using Microcontrollers Author: Rashid et al. **Description:** This paper investigates the use of Pulse Width Modulation (PWM) techniques for controlling the speed of DC motors through microcontroller-generated signals. The authors evaluate how varying the duty cycle of PWM signals directly affects motor speed and torque characteristics. The study demonstrates that PWM-based control provides smooth and precise speed regulation with minimal power losses, making it highly suitable for embedded motor control applications such as the Arduino-based system proposed in this project.

2. Four-Quadrant DC Motor Drive Using H-Bridge Converter Author: Mohan et al. **Description:** This work presents a comprehensive analysis of four-quadrant DC motor drive systems using H-bridge chopper configurations. The authors examine the switching sequences required to achieve forward motoring, forward braking,

reverse motoring, and reverse braking modes of operation. The results confirm that the four-quadrant chopper provides complete bidirectional control of both speed and torque, with high efficiency across all operating quadrants. This work directly supports the chopper circuit design adopted in the present system.

3. Bidirectional Control of DC Motor Using L293D Motor Driver Author: Patil and Kulkarni **Description:** The study focuses on interfacing the L293D H-bridge motor driver IC with low-power microcontrollers for bidirectional DC motor control. The authors detail the internal H-bridge architecture of the L293D and demonstrate how input logic signals determine the direction of current flow through the motor terminals. The paper establishes that the L293D provides effective current amplification and back-EMF protection, which is essential when driving motors from microcontroller output pins with limited current sourcing capability.

4. Arduino-Based DC Motor Speed and Direction Control System Author: Sharma and Gupta **Description:** This paper proposes an Arduino Uno-based closed-loop motor control system capable of adjusting motor speed and direction through user-defined input signals. The authors implement PWM generation using Arduino's built-in timer peripherals and demonstrate directional switching through digital logic applied to the motor driver. Experimental results show stable speed response across varying load conditions, validating the use of Arduino as a cost-effective and programmable controller for motor drive systems.

5. Analysis of Chopper Circuits for DC Motor Drives Author: Sen et al. **Description:** This research presents a detailed analysis of step-down, step-up, and four-quadrant chopper configurations for DC motor drive applications. The authors study the effect of switching frequency on motor current ripple and speed stability, and provide a comparative evaluation of different chopper topologies. The findings indicate that four-quadrant choppers offer superior dynamic performance and regenerative braking capability, which reduces energy consumption — a key advantage highlighted in the present project.

6. Regenerative Braking in DC Motor Drives Using Four-Quadrant Choppers Author: Bose et al. **Description:** The authors investigate energy recovery through regenerative braking in DC motor systems controlled by four-quadrant choppers. The study demonstrates that during braking, the motor operates as a generator and returns energy back to the supply, significantly improving overall system efficiency. This principle is applicable to the forward and reverse braking quadrants implemented in the proposed system, where controlled deceleration is achieved without mechanical braking losses.

7. Embedded System Design for Real-Time Motor Control Applications Author: Barr and Massa **Description:** This paper addresses the design principles of embedded systems intended for real-time motor control tasks. The authors discuss interrupt-driven PWM generation, peripheral interfacing, and timing constraints critical for reliable motor operation. The study emphasizes that microcontroller-based embedded platforms, when properly programmed, can achieve deterministic control response suitable for dynamic motor drive systems, directly

supporting the software architecture used in the Arduino-based implementation of this project.

8. Comparative Study of DC Motor Control Techniques in Power Electronics Author: Dubey et al. **Description:** This work provides a comparative evaluation of classical and modern DC motor control strategies including armature voltage control, field weakening, PWM chopper control, and closed-loop PID regulation. The authors assess each method in terms of efficiency, dynamic response, hardware complexity, and implementation cost. The study concludes that PWM chopper-based control combined with a microcontroller interface offers the best balance between performance and simplicity for low-to-medium power DC motor applications, which aligns with the design goals of the proposed four-quadrant Arduino-based system.

3.EXISTING SYSTEM

The existing approach to DC motor speed and direction control primarily relies on conventional analog-based techniques and simple switching circuits. In traditional systems, motor speed is regulated by varying the armature voltage through the use of variable resistors or rheostats connected in series with the motor. By increasing or decreasing the resistance, the current flowing through the motor is adjusted, which in turn changes the rotational speed. While this method is straightforward to implement, it dissipates a significant amount of energy as heat across the resistor, leading to poor efficiency and thermal stress on components.

For directional control, traditional systems make use of manual switching arrangements such as double pole double throw (DPDT) switches that physically reverse the polarity of the supply voltage applied to the motor terminals. This mechanical reversal allows the motor to change its direction of rotation. However, such switching is performed manually and cannot be automated or integrated into a programmable control loop.

Earlier electronic implementations used simple transistor-based switching circuits or relay-controlled H-bridge configurations to achieve limited bidirectional control. These circuits could drive the motor in forward and reverse directions but were incapable of supporting all four quadrants of motor operation, meaning regenerative braking and controlled deceleration were not achievable. The absence of four-quadrant capability meant that braking was entirely mechanical, causing increased wear and energy wastage. Overall, existing systems lack programmability, precision, and energy efficiency, making them unsuitable for modern embedded motor control requirements.

Disadvantages of Existing System

High Power Dissipation: Resistor-based speed control wastes large amounts of energy as heat, resulting in poor overall system efficiency and increased operating costs.

No Four-Quadrant Operation: Traditional systems support only one or two quadrants of motor operation. Forward braking and reverse braking modes are not achievable, limiting the dynamic control capability of the motor.

Lack of Programmability: Conventional analog circuits and manual switches cannot be reprogrammed or reconfigured. Any

change in control parameters requires physical modification of the hardware.

Mechanical Wear and Unreliability: The use of DPDT switches, relays, and rheostats introduces mechanical components that are prone to wear, contact degradation, and failure over time, reducing system reliability.

No Regenerative Braking: Existing systems rely on mechanical braking, which dissipates kinetic energy as heat rather than returning it to the supply. This results in unnecessary energy loss during deceleration.

Poor Speed Regulation Under Load Variation: Analog resistive control does not compensate for changes in load. As the motor load increases, speed drops significantly without any corrective action from the control circuit.

Manual Operation Dependency: Direction reversal and speed adjustment require manual human intervention, making the system unsuitable for automation or remote-controlled applications.

4. PROPOSED SYSTEM

The proposed system presents an efficient and fully programmable solution for speed and direction control of a DC motor using a Four Quadrant Chopper circuit interfaced with an Arduino Uno microcontroller. Unlike the existing analog-based approaches, this system integrates digital control through PWM signal generation, enabling precise and automated motor operation across all four quadrants — Forward Motoring, Forward Braking, Reverse Motoring, and Reverse Braking.

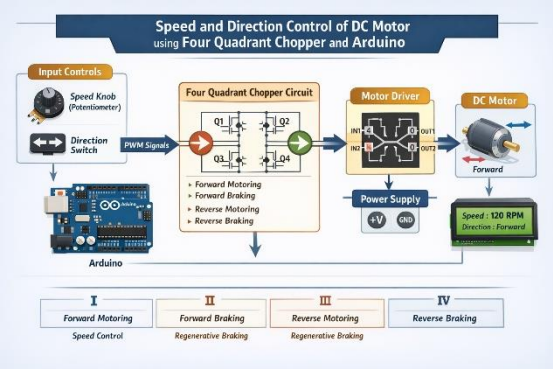
The input control section consists of a potentiometer (speed knob) and a direction switch. The potentiometer provides an analog voltage to the Arduino's ADC pin, which is mapped to a corresponding PWM duty cycle to regulate motor speed. The direction switch provides a digital input signal that determines the intended direction of motor rotation. Based on these two inputs, the Arduino generates appropriate PWM signals and logic control outputs.

These PWM signals are fed into the Four Quadrant Chopper Circuit, which consists of four switching transistors (Q1, Q2, Q3, Q4) arranged in an H-bridge configuration. By selectively activating transistor pairs, the chopper circuit controls both the magnitude and polarity of voltage applied to the motor driver. This switching arrangement enables the system to achieve all four quadrants of motor operation seamlessly under software control.

The Motor Driver (L293D) receives the chopper output and supplies the necessary current to operate the DC motor. Since the Arduino alone cannot source sufficient current to drive a motor directly, the L293D acts as a power interface, amplifying the control signals and protecting the microcontroller from back-EMF generated during motor switching. A regulated power supply unit provides stable DC voltage to both the motor driver and the Arduino board.

The DC motor responds to the control signals by rotating in the forward or reverse direction at the commanded speed. An LCD display connected to the Arduino continuously shows the real-time motor speed in RPM and the current direction of rotation, providing clear visual feedback to the user. The system supports regenerative braking in Quadrants II and III, allowing kinetic energy to be recovered during deceleration rather than wasted as heat, significantly improving overall energy efficiency compared to conventional motor control methods.

System architecture:



The block diagram illustrates the complete architecture of the proposed Speed and Direction Control system for a DC motor using a Four Quadrant Chopper and Arduino. **Input Controls** form the first stage of the system. A potentiometer (Speed Knob) provides analog speed input, while a Direction Switch provides the logic signal for selecting forward or reverse operation. Both inputs are fed into the **Arduino Uno**, which serves as the central processing and control unit of the entire system.

The Arduino processes the inputs and generates **PWM Signals** that are sent to the **Four Quadrant Chopper Circuit**. This circuit contains four switching devices — Q1, Q2, Q3, and Q4 — configured in an H-bridge topology. Depending on which transistor pairs are activated, the chopper enables four distinct operating modes: Forward Motoring, Forward Braking, Reverse Motoring, and Reverse Braking, as listed within the chopper block.

The output of the chopper circuit is passed to the **Motor Driver (L293D)**, which amplifies the control signals and delivers the required current to the **DC Motor**. The motor responds by rotating in the forward or reverse direction at the speed determined by the PWM duty cycle. A **Power Supply unit** (+V and GND) provides regulated DC power to the motor driver stage.

The **LCD Display** at the output stage shows real-time feedback — displaying the current motor speed (e.g., 120 RPM) and direction (Forward/Reverse) — enabling the user to monitor system operation continuously.

At the bottom of the diagram, the four operating quadrants are illustrated:

- **Quadrant I — Forward Motoring:** Motor runs forward; speed is controlled by PWM duty cycle.
- **Quadrant II — Forward Braking (Regenerative):** Motor decelerates while running forward; energy is fed back to the supply.
- **Quadrant III — Reverse Motoring (Regenerative):** Motor runs in reverse direction with energy recovery.
- **Quadrant IV — Reverse Braking:** Motor decelerates while running in reverse direction.

Together, these quadrants confirm that the proposed system achieves complete four-quadrant control, making it highly efficient, flexible, and suitable for advanced DC motor drive applications.

5. RESULTS

This chapter presents the results obtained from the implementation of the Speed and Direction Control of DC Motor using Four Quadrant Chopper and Arduino. The performance of the system is analyzed based on motor speed control, direction control, and the overall functionality of the system. The experimental results demonstrate that the proposed system successfully controls the DC motor in different operating conditions.

5.1 System Testing

After completing the hardware setup and uploading the Arduino program, the system was tested to verify its functionality. The Arduino microcontroller generated PWM signals that controlled the switching operation of the four-quadrant chopper circuit. These signals regulated the voltage

supplied to the DC motor, allowing the motor speed to vary according to the duty cycle of the PWM signal. During testing, the motor responded accurately to the control signals generated by the Arduino. The speed of the motor increased when the PWM duty cycle was increased and decreased when the duty cycle was reduced.

5.2 Speed Control Results

The speed of the DC motor was successfully controlled using PWM signals generated by the Arduino. By adjusting the duty cycle of the PWM signal, the average voltage applied to the motor was varied. As a result, the motor speed changed accordingly.

At lower duty cycles, the motor rotated at a slower speed, while at higher duty cycles, the motor achieved higher rotational speed. This demonstrates that PWM control is an effective method for controlling the speed of a DC motor.

5.3 Direction Control Results

The direction of rotation of the DC motor was controlled using the four quadrant chopper circuit. By changing the switching sequence of the driver circuit, the polarity of the voltage applied to the motor was reversed. When the polarity was positive, the motor rotated in the forward direction. When the polarity was reversed, the motor rotated in the reverse direction. The system successfully achieved smooth switching between forward and reverse directions without affecting the stability of the motor.

5.4 Four Quadrant Operation Analysis

The implemented system allowed the DC motor to operate in all four quadrants: First Quadrant (Forward Motoring): The motor rotated in the forward direction with positive voltage and current.

Second Quadrant (Forward Braking): The motor slowed down while rotating forward due to regenerative braking.

Third Quadrant (Reverse Motoring): The motor rotated in the reverse direction with negative voltage and current.

Fourth Quadrant (Reverse Braking): The motor slowed down while rotating in the reverse direction.

This four-quadrant operation demonstrates that the system is capable of providing efficient speed control and bidirectional motor operation.

5.5 Performance Evaluation

The overall performance of the system was observed to be stable and reliable. The Arduino microcontroller effectively generated PWM signals and controlled the switching devices in the chopper circuit. The motor driver circuit ensured that

sufficient current was supplied to the motor without damaging the microcontroller.The system responded quickly to control inputs and maintained stable motor operation. The experimental results confirmed that the system can effectively control both the speed and direction of the DC motor.

6. CONCLUSION

The project titled "Speed and Direction Control of DC Motor using Four Quadrant Chopper and Arduino" has been successfully designed, developed, and tested. The main objective of this project was to develop a system capable of controlling the speed and direction of a DC motor efficiently using modern embedded system technology. The integration of a microcontroller-based control system with a four quadrant chopper circuit provides an effective solution for motor control applications.

DC motors are widely used in many industrial and domestic applications due to their simple construction, reliability, and ease of speed control. However, controlling the speed and direction of DC motors efficiently is an important requirement in many automation and industrial processes. In this project, an Arduino microcontroller has been used as the main control unit to generate Pulse Width Modulation (PWM) signals, which are used to control the switching operation of the four quadrant chopper circuit.

The four quadrant chopper circuit plays a vital role in the system as it allows the DC motor to operate in four different modes of operation. These modes include forward motoring, forward braking, reverse motoring, and reverse braking. By controlling the switching sequence of the chopper circuit, the system is able to change both the speed and direction of the DC motor effectively.

During the implementation of the system, the Arduino microcontroller was programmed using the Arduino IDE. The program was designed to generate PWM signals with varying duty cycles. These PWM signals regulate the voltage supplied to the DC motor, which directly controls the motor speed. When the duty cycle of the PWM signal increases, the average voltage applied to the motor also increases, resulting in higher motor speed. Similarly, when the duty cycle decreases, the motor speed reduces.

A motor driver circuit was also used in this system to interface the Arduino with the DC motor. Since the Arduino microcontroller cannot provide sufficient current to drive the motor directly, the motor driver acts as a current amplifier and ensures safe operation of the system. The driver circuit also enables bidirectional control of the motor, allowing it to rotate in both forward and reverse directions.

The system was tested under various operating conditions to evaluate its performance. The results obtained from the experimental setup indicate that the system successfully controls the speed and direction of the DC motor. The motor responded accurately to the PWM signals generated by the Arduino, and the switching operation of the four quadrant chopper circuit was able to provide smooth motor control.

Another important feature of the system is the ability to perform braking operations. In the second and fourth quadrants of operation, the system enables regenerative braking, which helps in reducing energy loss and improving system efficiency. This feature makes the system suitable for applications where controlled stopping of motors is required.

The hardware components used in this project, including the Arduino board, motor driver IC, DC motor, and power supply unit, were integrated successfully to build the complete motor control system. The system design is simple, cost-effective, and easy to implement.

The use of Arduino also simplifies programming and makes the system flexible for further modifications.

From the results obtained, it can be concluded that the proposed system provides an efficient method for controlling the speed and direction of a DC motor. The combination of Arduino and four quadrant chopper technology offers a reliable solution for motor control applications. The system operates smoothly, provides accurate control, and can be implemented in various industrial and automation applications.

Therefore, this project successfully demonstrates the practical implementation of DC motor control using a microcontroller-based four quadrant chopper system. The system meets the design objectives and proves to be an effective solution for modern motor control requirements.

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