International Journal of Engineering & Technology
CENTRE OF PROFESSIONAL RESEARCH PUBLICATIONS
ISSN 2049-3444
International Journal of Engineering and Technology Volume 6 No.5, May, 2016

Speed Control of a Dc Motor Using a Chopper Drive

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ABSTRACT

The DC motor is an attractive piece of equipment in many industrial applications requiring variable speed and load characteristics due to its ease of controllability. The "Chopper drive" based speed controlling method is superior in comparison to "Thyristor Controlled Bridge Rectifier" method as far as DC motor speed controlling is concerned. Microcontroller based controlling is adopted to retain simplicity & ease of implementation. This paper is written with the objective of illustrating how the speed of a DC motor can be controlled using a chopper drive. It further explains the methodology used in obtaining the required signal generation to drive the chopper. An Open-loop Control System adopted brings the motor to the speed set by the user irrespective of the load. This drive also provide functions like Start, Stop, Forward braking, reverse braking, increased and decreased speed of motor.

Keyword: *Chopper, DC Motor, Microcontroller 8051, MOSFET.*

1. INTRODUCTION

Standard motors are classified as either constant speed or adjustable speed motors. Adjustable speed motors may be operated over a wide speed range by controlling armature voltage and/or field excitation. The speed below the base speed can be controlled by armature voltage control method and field control method is used for speeds above the base speed.
For the last forty years, the development of various solid state switching devices in the thyristor families along with variety of different digital chips in control/firing circuits has made an impact in the area of DC drive [1]. These power electronic (solid state) controllers are of two types:

1. Thyristor bridge rectifier (Converters) supply from ac supply.

2. Chopper Drives fed from DC supply.

The Chopper Driver method has the following advantages over Thyristor Bridge Rectifiers method.

1. Quick Response

2. Flexibility in control

3. High energy efficiency

4. Light weight & compact control unit.

5. Less ripples in the armature current.

6. Ability to control down to very low speeds.

7. Less amount of machine losses due to less ripple in armature current

8. Small discontinuous conduction region in the Speed-Torque plane.

9. Small discontinuous conduction region improves the speed regulation and transient response of the drive.

2. AIM AND OBJECTIVE

The aim of this paper is to design and implement chopper based DC motor drive. The paper is carried out by the following objectives:

1. Simulation of all four quadrant operation of chopper using MATLAB Simulink.

2. Hardware implementation of chopper drive with protection of Commutation problem.

3. Hardware implementation of micro-controller card. (With IC P89V51RD2)

4. Complete hardware to control speed of brushed DC motor working in all four quadrant.

5. Motor can be work with 1% duty cycle to 99% duty cycle accurately and smoothly by PWM technique

3. COMPLETE BLOCK DIAGRAM

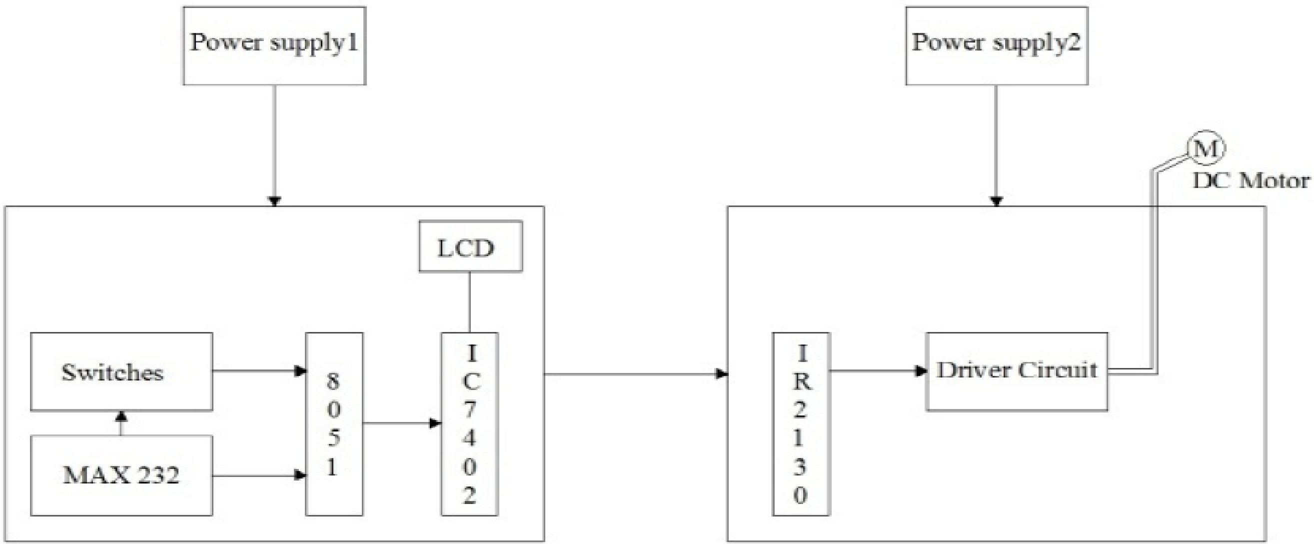


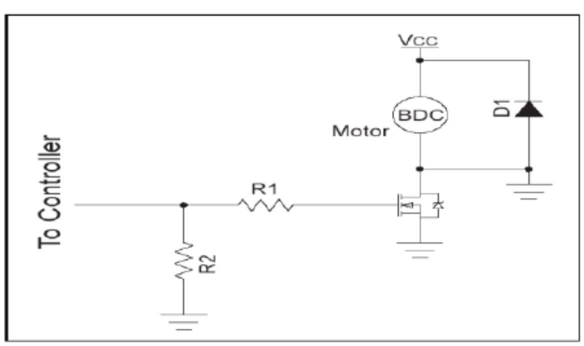
Figure 1: Schematic diagram of hardware set up

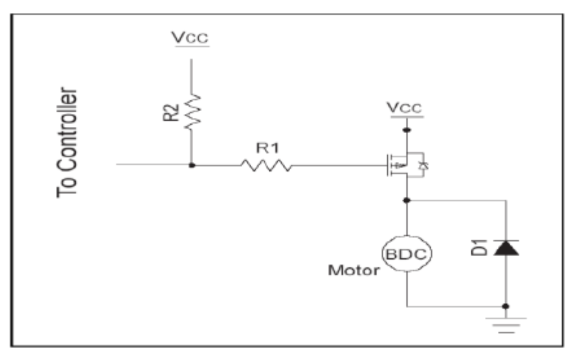
One is microcontroller card which include switches for Start, Stop, Forward braking, reverse braking, Increasing the speed and decreasing the speed. Also it includes MAX 232 IC to transfer controller data from Controller P89V51RD2 to the PC. IC 7402 contain four NOR gate by which we can make two OR gate for PWM comparison for upper MOSFETs used in driver card. For driver circuit, four MOSFETs are used with two legs. Each leg has one upper and one lower MOSFET. LCD is of type 16×2 to display speed of the motor and also duty cycle. Special IC IR2130 provides certain protections for driver circuit [1].

4. SPECIFICATION OF DRIVE

Rating of MOSFET STP80NF55 is 55 V, 80 A. With this drive, it is possible to control the DC motor up to rating of 4.4 KW. For higher rating than 4.4 KW, MOSFET with higher ratings can be employed with heat sink deployed to each MOSFET individually. Transformer ratings are 230 V (prim)/12 V (sec). Two power supplies are provided for providing isolation between driver card and micro-controller card.

A. Driver Card Design Circuit





B.

Figure 2: high side driver circuit

Figure 3: low side driver circuit

Figure 2 and figure 3, shows the position of resistors and how controller is connected when individual MOSFET is ON. As in figure 1, the IC IR2130 gives special functions for this drive. These are:

1. When MOSFET of same leg is in ON mode, it stops to give supply voltage to MOSFETs and Fault LED will glow.

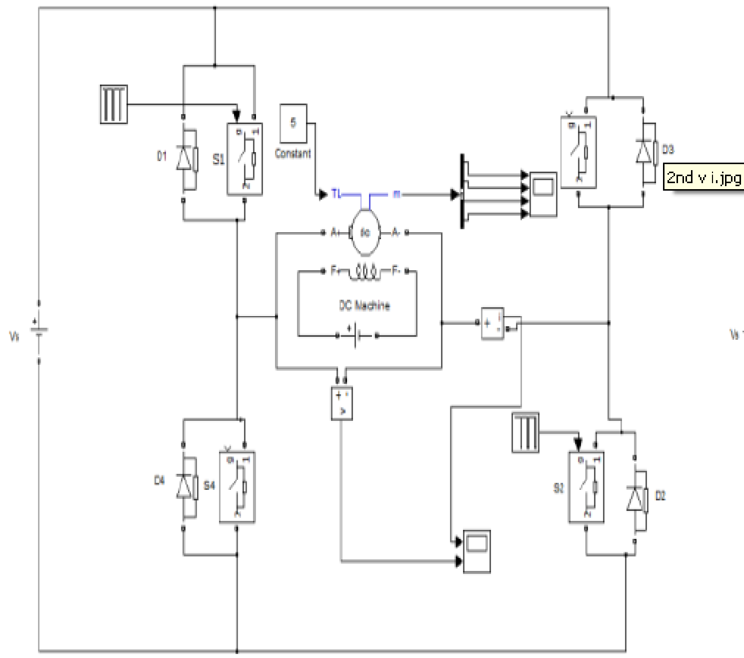
2. If boot strap capacitor is not charged to 10 V or in operation goes below 10 V, it stops working and Fault LED will glow.

3. It provides 20ms delay between each operation to avoid commutation.

4. As in inner construction, it consists NpN- and PnP-transistors, upper MOSFET can be turning off easily even without ground terminal connected with it.

5. SIMULATION CIRCUITS AND WAVEFORMS FOR DIFFERENT QUADRANTS

A. Simulation for First and Second Quadrant



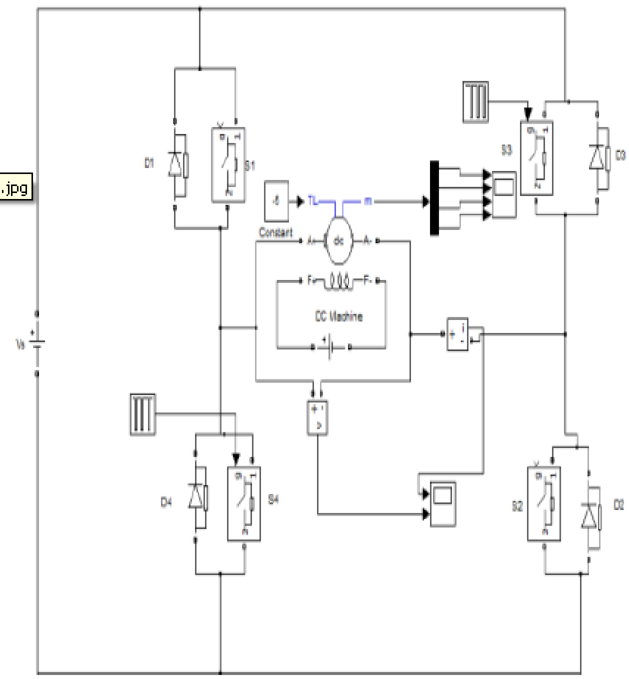
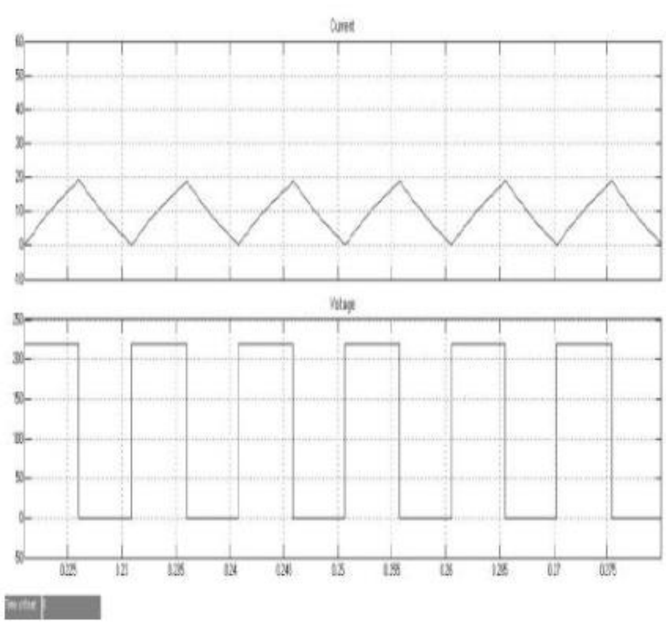


Figure 4: Simulation for First and Second quadrants, Figure 5: Simulation for Third and Four quadrants

B. Simulation Results for all Four Quadrants



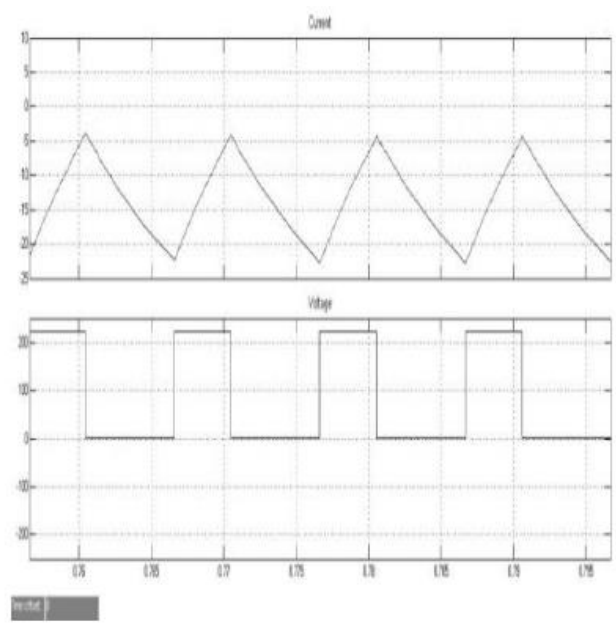
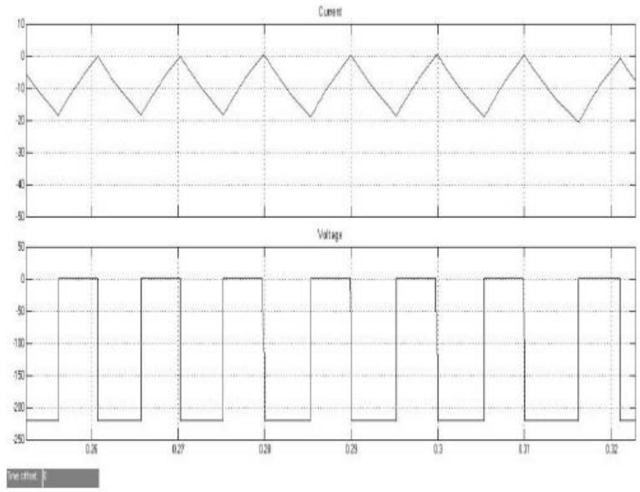


Figure 6: Current and Voltage waveform for First Quadrant Figure 7: Current and Voltage waveform for Second Quadrant



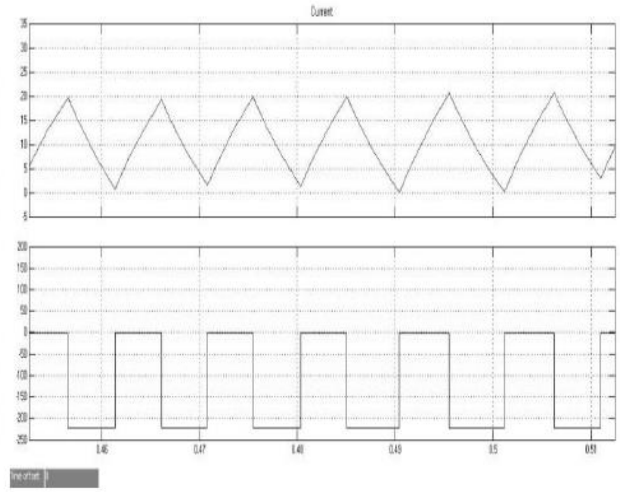


Figure 8: Current and Voltage waveform for Third Quadrant, Figure 9: Current and Voltage waveform for fourth Quadrant

From figure 6, current and voltage both waveforms are laid in positive value as in theoretical fundamentals of Chopper.

From figure 7, current is negative and voltage is positive which is also same as in theoretical. From figure 8, current and voltage both are negative which represent third quadrant operation and figure 9, Current is positive and voltage is negative which represents fourth quadrant operation. All four results for simulation are as identical as theoretical.

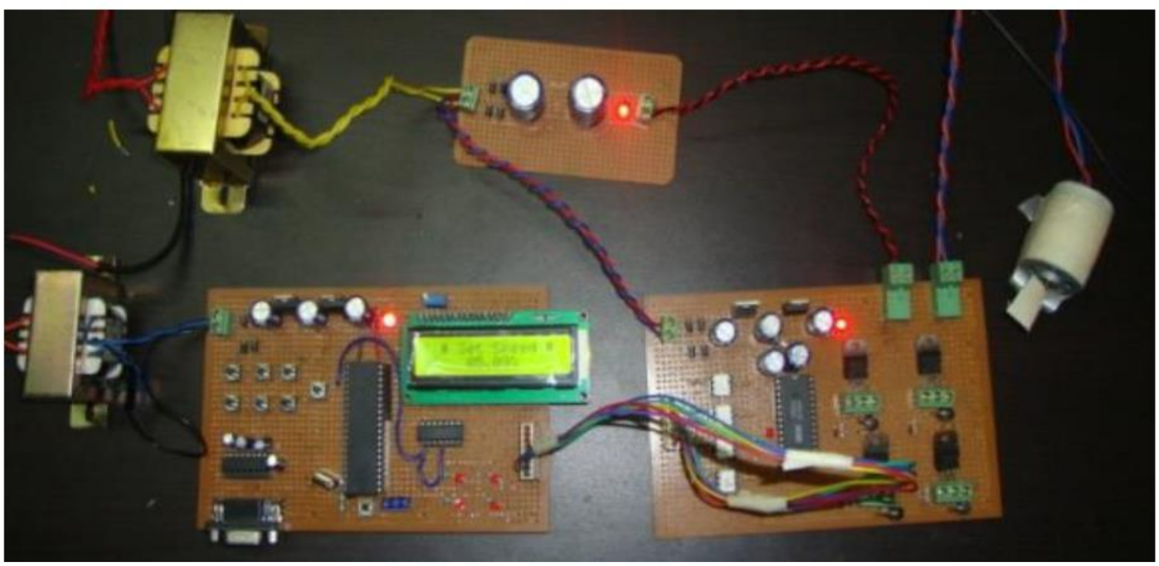


Figure 10: Hardware Set-up

6. Hardware Implementation And Voltage Waveforms For Different Duty Cycles

Figure 10 is for micro-controller P89V81RD2 (8051) design with switches to perform operation like Start, Stop etc. as discuss earlier. Initially speed is set to be 50% duty cycle, means half of the full speed operated at starting. According to the Switches operation, speed can be increased or decreased as required at a particular time. Four LEDs are put in this card to know the status of each MOSFET at a particular point in time. That is to say, the MOSFET that is running and the one not running at a given point in time. Driver card designed with IC IR2130 and opto-coupler MCT2E for isolation between driver card and micro-controller card. MOSFETs STP80NF55 are

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used as switch [2]. Four MOSFETs are used here as shown in figure 10. It is overall hardware of this paper. For simplicity, only this small rating motor is used. This drive is capable of driving DC motor up to 4.4KW rating with extra heat sink providing to each MOSFET. When a higher capacity of motor (above 4.4KW) is to be operated, transformer rating will be changed and also MOSFETs require higher ratings. So by changing rating of motor, only supply is changed and higher range MOSFETs are selected [3, 4, 5].

Voltage Waveforms for Duty Cycles

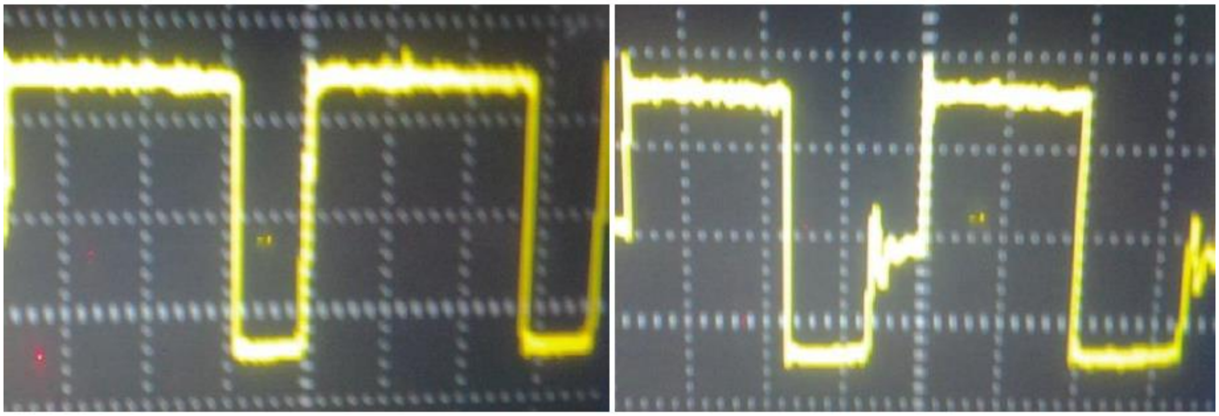

Figure 11: 80% duty cycle

Figure 12: 50% duty cycle

By taking different voltage waveforms for different duty cycles, speed also varies according to the duty cycle. In figure 11 and figure 12, we observe some distortion present in voltage waveform across the motor, it is due to the back emf present in the motor. Here from the above waveforms, we can conclude that back emf of motor is directly proportional to the speed of the motor [6].

7. APPLICATION

When motor is working in normal condition with positive current and voltage, it operates in first quadrant. To stop the motor instantly from running condition, it shifted to fourth quadrant [7, 8]. When motor running with negative current and voltage, e.g. train runs on steeply region, third quadrant mode is achieved. While during this condition to stop the motor instantly, second quadrant is obtained when voltage is positive and current is negative. Hoist application and traction are widely used this application [9, 10, 11].

8. CONCLUSION

The speed of DC motor has been successfully controlled by using chopper as a converter. In simulation, all four quadrant operation of the chopper is done in MATLAB Simulink. In hardware design of drive, using microcontroller 8051 and pulse width modulation scheme, desired speed of the DC motor is achieved easily. All operation of motor like Start, Stop, Forward braking, Reverse Braking, Increasing the speed and also Decreasing the speed is also achieved. The motor can be run as low as 2% to as high as 98% of the duty cycle. Program interface is user friendly enabling flexible and simple operation. Since we control the average armature voltage, speed could be control only below the rated speed.

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