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Four Quadrant Speed Control of DC Motor with Microcontroller ATmega 328 (Arduino Uno)

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***Abstract*: DC motors are widely used in many applications. The main disadvantage of DC motor is; it rotates for some time when supply is disconnected. This is not required in many applications. So four Quadrant operation of DC motor is used. We are using Arduino Uno board for this operation. In four quadrant operation instant breaking of motor is possible, so we are using four quadrant DC motor control for the project.**

***Keywords*: Arduino, DC Motor, DC Supply, TLP250 IGBT Driver IC, Speed Control, PWM.**

1. Introduction

We are using 220V nine Ampere DC motor for four quadrant operation. Speed control of motor is carried out using PWM technique. Arduino board with ATMEGA 328 microcontroller is used to perform the operation of four quadrant operation. Four switches are provided as input to the Arduino Uno board for four quadrant operation. By pressing desired operation DC motor operation will be demonstrated. IGBTs are used in H bridge to operate DC motor. It requires gate driver circuit so we are using TLP 250 gate driver IC's for each IGBT. Pulses from Arduino is given to input of gate driver IC and output of gate driver is given to gate of IGBT. Gate of IGBT is triggered by Arduino. For each quadrant separate switch is provided so it is easy to operate the DC motor as per required quadrant. Pulses from Arduino is of 5V Dc, given to pin 3 of TLP 250 IC. The power supply for this is constructed by using 230V to 12V transformer. Four diodes are used to form a bridge rectifier and a filter capacitor to filter the output. IC 7805 is used to provide 5V regulated supply. TLP 250 require 12V supply for secondary side, which is derived from 7812 regulator IC. This 12V pulses are given to gate of IGBT.

2. Block diagram

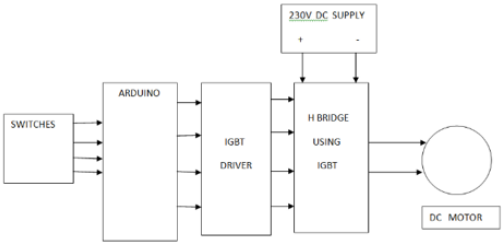

Fig. 1. Block diagram

A. Block diagram description

We are using 220V, 9Amp, 1500 RPM, DC motor for the operation. From the block diagram, there are using four switches for four quadrant operation of motor. This switches are connected to Arduino Uno as input.

Then the output of Arduino Uno is connected to IGBT Gate driver ICs. The output of Gate driver ICs is connected to H-bridge using IGBT, and then DC motor is connected across to H-bridge.

B. Arduino

For the instant speed control of DC motor Arduino Uno ATmega 328 is used because Arduino microcontroller is AVR and has inbuilt 8 bit PWM output which is used to vary DC motor speed very easily. The programming in Arduino is done in C language to operate motor in various modes of four quadrants. Another reason of using Arduino ATmega 328 for speed control is that it will reduce the number of component and circuit is less complicated. Otherwise there are so many components in between ATmega 328 and bridge motor driver. But by using Arduino Uno board only ATmega 328 microcontroller is needed and easy to operate.

Fig. 2. Arduino Uno

C. H-bridge

H-bridge is used to run DC motor in forward or reverse direction. It is also used to break or stop the motor where motor terminals are short i.e. motor terminal will automatically disconnect from the circuit. H-bridge are switching control part which contain four switching devices which are IGBT. The motor is connected across the centre and its look exactly like H structure by activating two particular switches at the same time we can change the direction of the current flow, thus by

changing the direction of rotation of motor. There four switching elements (s1, s2, s3, s4) are usually IGBT. If s3 and s4 are turned ON mode, the left lead of the armature will be connected to the power supply, while the right lead is connected to ground. Current starts flowing through the armature. Then they energize the motor in (let's say) the forward direction and the motor shaft starts spinning. If s1 and s2 are turned ON mode, the reverse will happen, the motor gets energized in the reverse direction, and the shaft will start running backwards or reverse direction. For controlling the speed and direction of motor the controlled voltage is applied to the armature through switching element.

Table 1
Switching table

S1	S2	S3	S4	Result
1	0	0	1	Forward Motoring
1	0	1	0	Forward Breaking
0	1	1	0	Reverse Motoring
0	0	1	1	Reverse Breaking

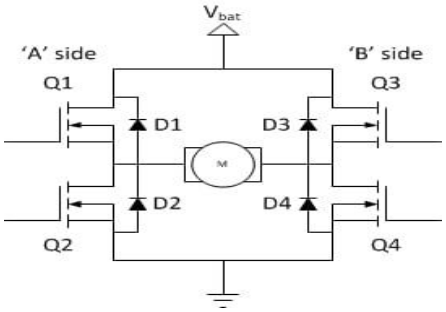

Fig. 3. H-bridge

D. IGBT Driver

The TOSHIBA TLP250 consists of a GaAlAs are light emitting diode for blink and an integrated photodetector. This unit is 8−lead DIP package. TLP250 is suitable for gate driving circuit of IGBT.

Input threshold current: If=5mA(max.)
Supply current (Icc): 11mA(max.)
Supply voltage (Vcc): 10−35V
Output current (Io): ±1.5A (max.)
Switching time (tpLH/tpHL): 1.5μs(max.)
Isolation voltage: 2500Vrms(min.)
UL recognized: UL1577, file No. E67349

Option (D4) type VDE approved: DIN VDE0884/06.92, certificate No.76823 Maximum operating insulation voltage: 630VPK is High permissible over voltage: 4000V.

E. DC motor control

A DC motor may operate in two or more modes (or quadrant) in variable speed of applications. The most common advantage of using DC motor is that the ease of its control. The speed of the DC motor is controlled by applying a variable DC input for instant and rated speed control. For the above rated speeds control, the DC motor is controlled by applying variable current through its field or copper winding. For reversing or changing the direction of rotation, either changing polarity of the supply voltage (which is applied to armature terminals) or the direction of field current has to be changed. By using DC motors, it is possible to obtain smooth and less generating sound, speed control over a wide range in clockwise as well as anti-clockwise direction.

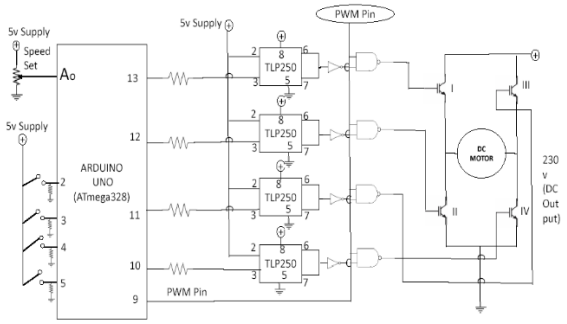

Fig. 4. Circuit diagram

3. Four quadrant operation of DC motor

Four Quadrant Operation or mode of any DC Motor means that machine operate in four quadrants. They are Forward Breaking mode, Forward Motoring mode, Reverse Breaking or stop mode and Reverse Motoring mode. A motor operates in two modes – Motoring and Breaking. A motor drive capable of operating in both directions of rotation or running and producing both motoring and stop modes is called a Four Quadrant Variable Speed Drive.

In Motoring mode, the machine works as the DC motor and converts the electrical energy (DC) into mechanical energy, supporting their mode of motion. In breaking or stop mode, the machine works as generator and converts mechanical energy into electrical energy (DC) and as a result, it opposes the motion. The motor can work in both, forward and Reverse direction, i.e., in Motoring and Breaking operation of mode.

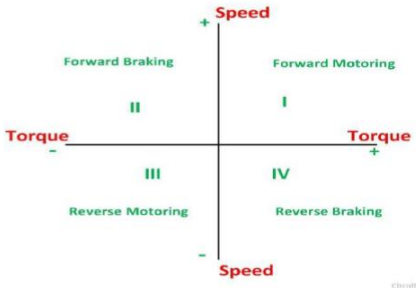

Fig. 5. Four quadrant operation of dc motor

In 1st quadrant power developed is positive (+) and the machine is working as a motor supplying mechanical energy the 1st quadrant operation is known as forward motoring. 2nd quadrant operation is called as breaking. In 2nd quadrant the direction of rotation is positive (+), and the torque is negative (-), and thus the machine operates as the generator developing a

negative (-) torque, which oppose the motion.

The kinetic energy (K.E) of moving rotating parts is available as electrical energy which may be supplied return to the mains. In dynamic breaking dissipated and energy dissipated in the resistance. The 3rd quadrant operation is known as reverse motoring. The motor works, in the reverse direction mode both speed and torque have negative values while the power is positive (+). In the 4th quadrant, the torque is positive (+), and speed is negative (-). This quadrant corresponds to stop in reverse motoring mode. The four quadrant operation mode and its relationship between to speed, torque and power output are as below in the table.

Table 2
Four quadrant operation

Function	Quadrant	Speed	Torque	Power Output
Forward Motoring	I	+	+	+
Forward Breaking	Ii	+	_	_
Reverse Motoring	Iii	_	_	+
Reverse Breaking	Iv	_	+	_

4. Software implementation

By using ARDIUNO software coding will be written in embedded C language. It will be simulated and uploaded to the ARDIUNO by this ARDUINO software.

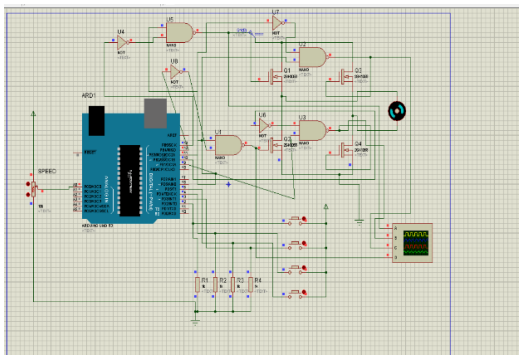

Fig. 6. System tested in software

5. Experimental setup

In this experiment used IGBT and TLP250 are used. TLP250 generate the PWM signal and it provide to the IGBT for their ON and OFF operation and because of this reason operation of the motor performed.

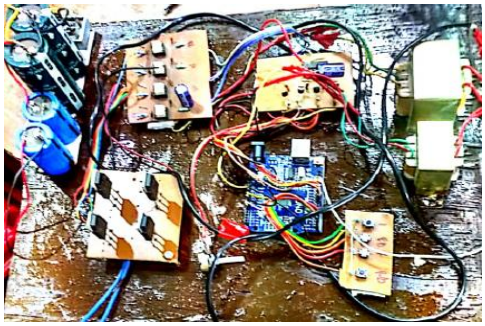

Fig. 7. Complete prototype hardware model

6. Experimental results

A. *Simulation Result Using Proteus Software*

The simulated waveform of Arduino Uno board based DC motor speed control for the four quadrant modes of operation i.e. forward motoring and brake, reverse motoring and brake.

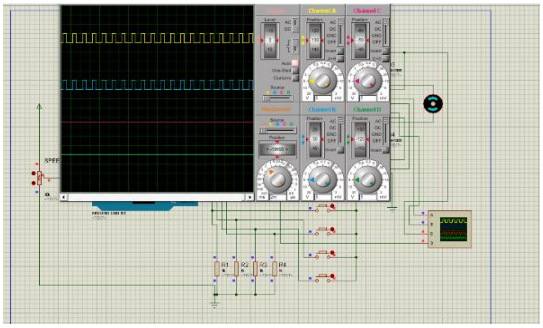

Fig. 8. Waveform of forward motoring of dc motor

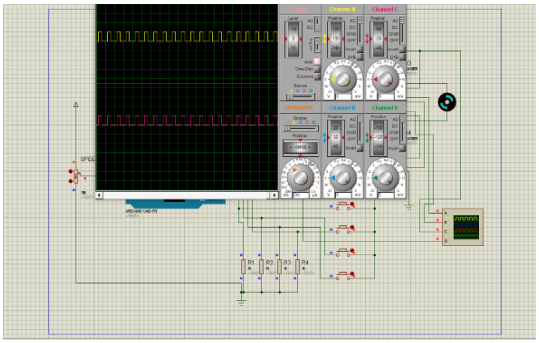

Fig. 9. Waveform of forward breaking of dc motor

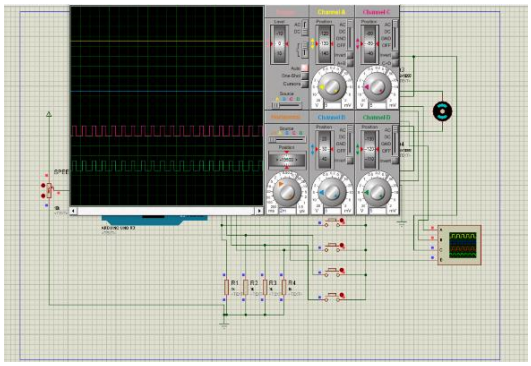

Fig. 10. Waveform of reverse motoring of dc motor

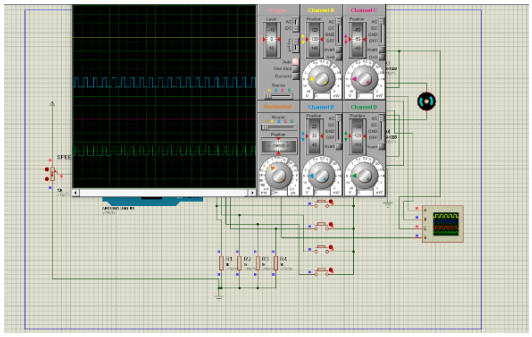

Fig. 11. Waveform of reverse breaking of dc motor

B. Hardware implementation

The hardware model has been designed and implemented for speed control of DC motor using AT mega 328 and the waveform of input pulse given to DC motor from pins to ARDUINO has been observed. The waveform for Four Quadrant modes of operation are achieved for different duty cycles achieved.

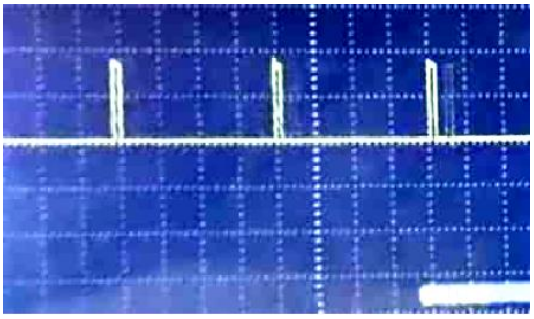

Fig. 12. Forward motoring movement of dc motor

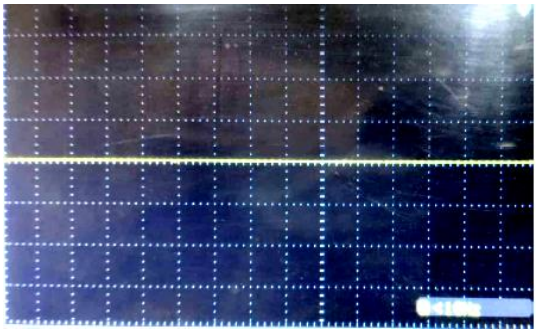

Fig. 13. Forward breaking movement of dc motor

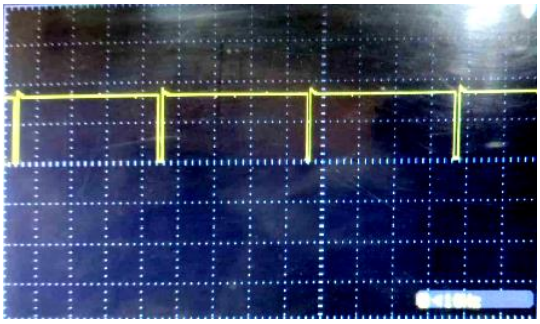

Fig. 14. Reverse motoring movement of dc motor

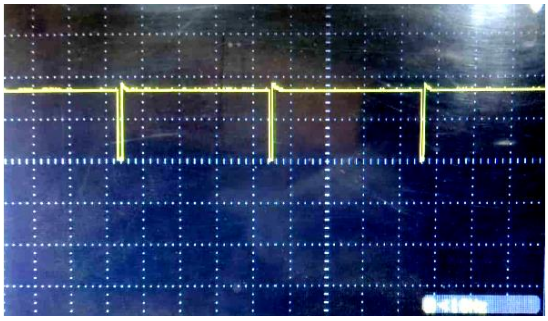

Fig. 15. Reverse breaking movement of dc motor

7. Conclusion

The study of four quadrant speed controlling modes operation of DC motor by using Arduino Uno is done. It is high feasible in economic point of view and have advantages of running motor of higher rating of motors. By using Arduino, it overall reduces the component and devices hence, it will require less space and less complicated. The system is discover to be more efficient and easy the consequences with the design hardware. The motor is able to perform in all four quadrant operating modes.

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