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SPEED AND DIRECTION CONTROL OF DC ELECTRIC MOTOR USING H-BRIDGE DRIVER

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ABSTRACT

The speed of a DC motor depends on the amount of current entering the armature coil and the direction of rotation depends on the direction of current flow. The essence of this research is to implement the most economic and reliable way of varying the speed and changing the direction of rotation of DC motor by electronic means rather than the usual contactor design and use of external resistor for the speed control which is not only bulky in design but also less effective. The methodology employed was the consideration of the fact that the amount of current flowing into the armature of the DC motor determines the speed of the motor and the H- bridge driver could be modeled with transistors for switching and for change of direction of current flow which automatically brings about the change in the rotation of the motor. A multifunctional NE556 timer which can be used to achieve to achieve a lot of electrical designs was used to generate the pulses. These various factors were considered in the design for the control of speed and direction of a DC motor. In this work, A 14 pin 556 DUAL Timer was used to generate the square wave (pulse). Under proper biasing, for simulation purpose, in the Proteus software, this IC is contained in two different pin configurations which are combined to get all the desired pins. Using a variable resistor to vary the duty cycle of the pulse width modulated signal, an H- Bridge driver and a two-pole switch were used to change the direction of the current flow through the armature of the DC motor. Various speeds at different duty cycles were recorded. The system was simulated using proteus software environment and various table generated were plotted using Microsoft Excel. The relationships between the duty cycle / voltage were proportional and that of duty cycle/ speed was also proportional from a certain point above 40% of the rated voltage.

KEYWORDS: H-Bridge Driver, Pulse Generation, Pulse Width Modulation, Timer Circuit, Duty Cycle

1. INTRODUCTION

An Electric motor is a machine that converts electrical energy to Mechanical energy. A large number of motors are used for general purpose in our surrounding from house hold equipment to machine tools in industrial facilities. It is now evident that electric motors are very necessary and indispensable source of powering many industries. DC motor is one of the traditional electric machines; it appeared in the late 19th century compared to the other electric machine such as induction motor (Abdelhak and Bashir, 2015)

The unique nature of DC motor makes it very easy for its speed and direction of rotation to be controlled. DC motor has the internal advantage such as simple control, large electromagnetic torque, ability to adjust the speed range (Hughes, et al 2013). DC motors are very relevant in our Industries for different drives and operation. Because of this, ways of changing the speed and rotation must be employed to meet up with the present realities of life and new trends in operations in our industries. The most popular way of controlling the DC motor is still using PID controllers, however in many working modes of the motor, the nonlinearity of the motor is high which reduces the quality of control system (Thang, 2017). The amount of current entering the armature winding determines the voltage that would be developed, and direction of rotation unlike the case of AC squirrel cage motors whose direction of rotation can be changed by alternating any of the terminals of the three phase supply and the speed which is constant but can only be varied by external connections.

To reverse a DC motor, you need to reverse the direction of current in the motor (James and Glena, 2006). The voltage is determined by the width of the pulse generated by a timer circuit. By pulse width modulation, the duty cycle is determined and consequently the voltage (Vdc). The speed of a DC motor is proportional to the supply voltage. If the voltage drops too far, the motor doesn't get enough power to run, but within a certain voltage, usually from 40% of the rated voltage, the motor will run at varying speeds. The most effective way to control the speed of the motor is with pulse width modulation (PWM) which means that the motor is pulsed ON and OFF at various rates simulating a varying voltage (James and Glena 2006).

There are several solutions for controlling the nonlinear object such as the input-output linearization method, the sliding mode control technique, the back stepping control technique etc. The drawback of the above methods is the existence of the chattering control phenomenon or the difficulty problem in the choice of appropriate Lynapuov function (Thang, 2017). However, we propose a suitable and simple way of control. The problem of heavy and bulky designs when contactors are involved in controlling the change in direction is solved by simple electronic circuit that can bring about the change in current flow by mere use of H- bridge driver which alternates the current direction and the speed control is achieved by the fact that the amount of current into the armature coil determines the Voltage developed which consequently varies the speed. This phenomenon reveals that the amount of current flowing results to proportional speed.

The H-bridge driver is used to achieve the change in direction of rotation of the DC motor.

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2. Materials and Method

2.1 H-Bridge Driver

An H bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. These circuits are often used in robotics and other applications to allow DC motors to run forwards or backwards. [2]. Figure (1) is the structure for the H Bridge driver.

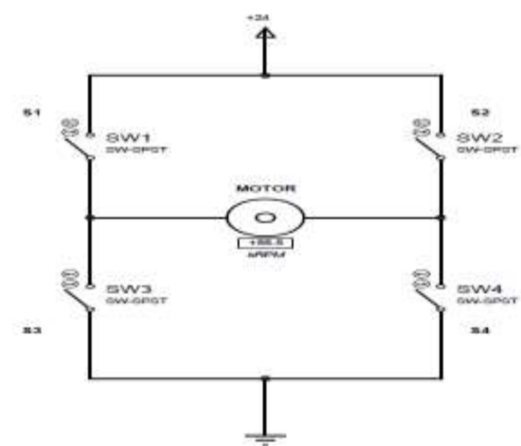

FIGURE:1 MANUAL H-BRIDGE

For the motor to operate in forward and reverse directions there must be a reverse in current. A proper selection of the switches brings about the forward and reverse rotation. The table below illustrates the possible switching positions.

Table 1: Possible Switching Positions

S1	S2	S3	S4	Result	S1	S2	S3	S4	Result
1	0	0	1	Rotate Right	1	0	1	0	breaks
0	1	1	0	,, Left	1	1	0	0	Shot cct
0	0	0	0	Still	0	0	1	1	Short cct
1	0	0	0	,,	0	1	1	1	,,
0	1	0	0	,,	1	0	1	1	,,
0	0	1	0	,,	1	1	0	1	,,
0	0	0	1	,,	1	1	1	0	,,
0	1	0	1	breaks	1	1	1	1	,,

2.2.1 Forward and Reverse Rotation of Motor

To achieve a rotation of the motor in the two directions, the switches have to be closed as indicated, but there are positions to give short circuit which must be avoided, this is achieved through interlocking. The switches are replaced by NPN and PNP transistors which are biased by positive and negative voltage respectively. The configuration below shows the replacement of the switches with transistors.

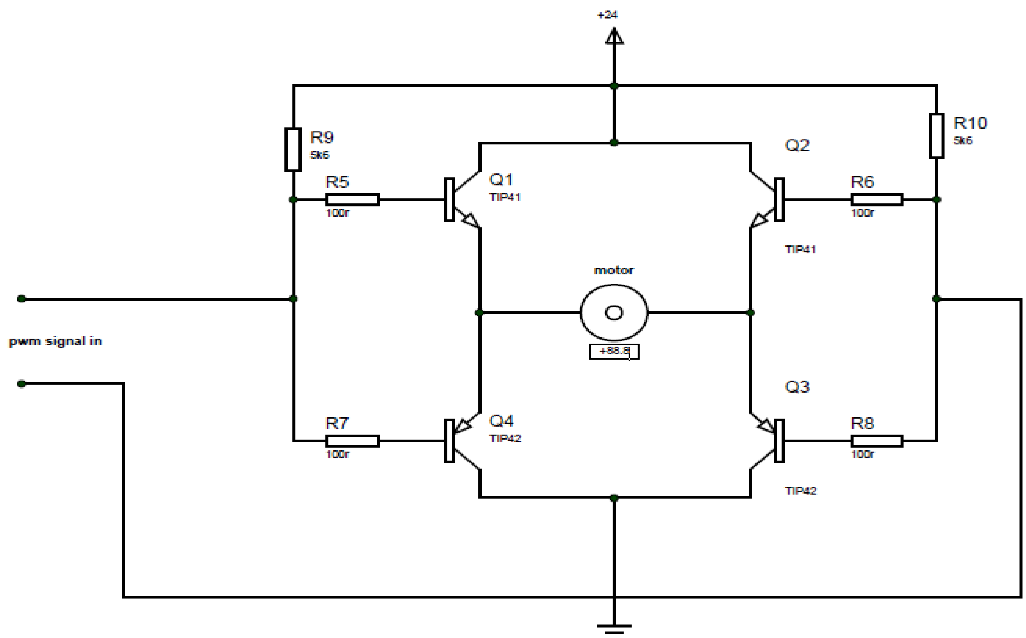

FIGURE:2 H-BRIDGE MOTOR DRIVER

2.2.2 Design of the Circuit (H- Bridge driver using PNP and NPN transistors)

Input Resistance-

I_L =Max motor current

$I_b = I_{L/\beta}$, Where β is the transistor gain, gotten from the data book and I_b is the input current (I_i) to flow through the Load

$I_b^1 = 10 \times I_b$ (to make sure the transistor works in saturation region) [4]

$$V_{DC} = \{\frac{Ton}{Ton+Toff}] \times Vs$$

$$R_{IN} = \frac{Vin - Vbe}{Ib1}$$

From data book, V_{be} =0.7 [5]

From data book, V_{be}= 0.7 (Matt Richardson DC motor Control using H- Bridge http//itp.nyv,edu)

2.3 NE 556 Timer

2.3.1 Generation of the Control Signal

NE 556 Timer is a fourteen pin IC which can be used to generate pulses and many other functions. The IC is connected in an astable mode. Pulses being generated can be increased or decreased in its ON or OFF state depending on the design purpose.

2.3.2 Modulation

Modulation is the process of varying one or more properties of periodic waveform known as carrier signal with a modulating signal that typically contains information to be transmitted (Wikipedia)

2.3.3 Pulse width modulation

Pulse width modulation this is the method of reducing the average power delivered by an electrical signal by effectively chopping it up into discrete parts (Wikipedia)

Varying the width (duty) of pulse with means ON time (Ton) of pulse, the average output Vdc or Vav is given by the equation below.

Vdc= [Ton/Ton+Toff] ×Vs

Where,

Vdc =the DC voltage

Ton=the time "ON" of the pulse

Toff is the time off

Vs is the supply Voltage

The duty cycle of operation of a machine or other devices is the intermittent operation rather than continuous operation of that machine or device.

Duty cycle = [speed reduction/ rated speed] *100%

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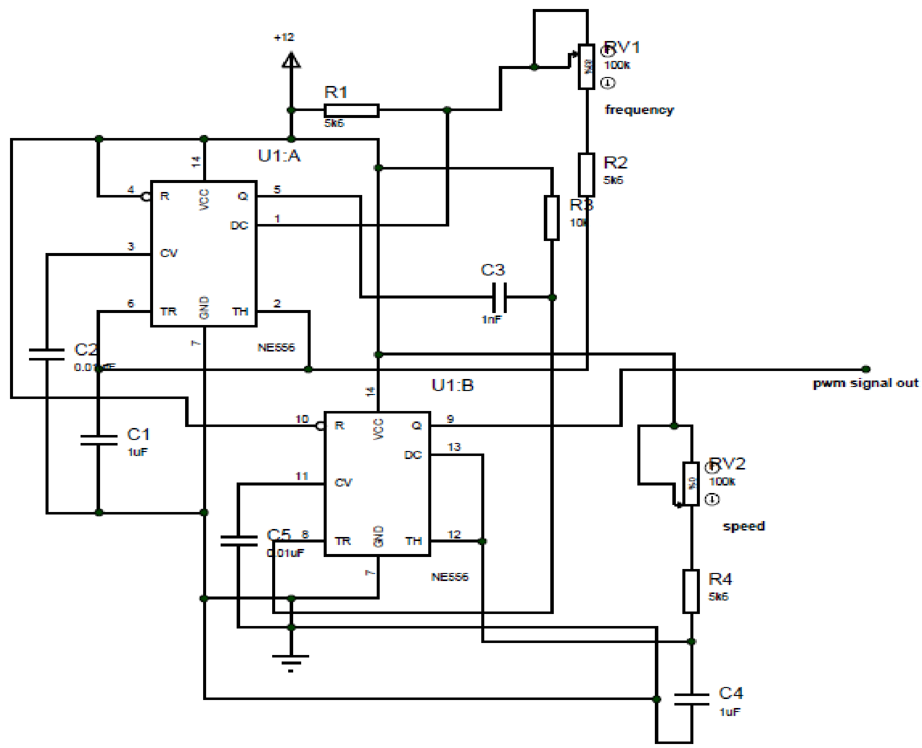

FIGURE:3 PWM GENERATOR

The NE 556 Timer IC is for the pulse generation. The variation of the pulse (which is known as duty cycle) that is fed to the input of the H bridge driver brings about the changes in speed. The process of changing this width is called Pulse Width modulation (PWM). This determines the quantity of voltage across and the current flowing. This in turn determines the speed of the motor. A variable resistor provided varies the duty cycle. The speed is highest at the highest duty cycle and zero speed were recorded from a point where the percentage of Voltage supplied to the armature was less than 40% of the rated motor Voltage.

2.4 Push Pull Switch

Two transistors of PNP and NPN are inter-connected to the input of the H- bridge driver. This circuitry ensures that these switches described as short circuiting if closed as seen in table 1 do not come ON. Even in case of eventuality, the transistors do not come ON. The push Pull switch is as shown in figure 4

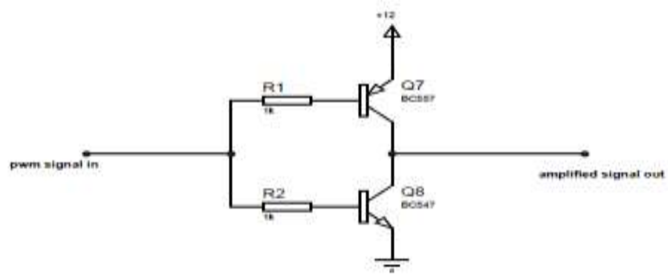

FIGURE:4 PUSH PULL INTER-LOCKING

2.5 Forward and Reverse Rotation Switch

The switch as shown in figure 5, redirects the flow of the current through the H-Bridge driver. The two-position switch allows current to flow to either direction thereby changing the direction of the rotation of the motor.

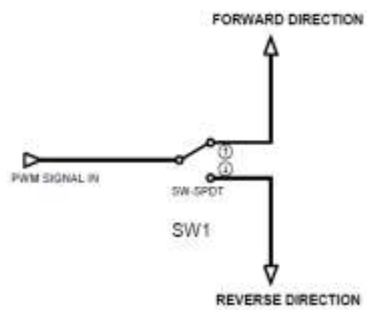

FIGURE: 5 FORWARD & REVERSE SWITCH

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3. SIMULATIONS

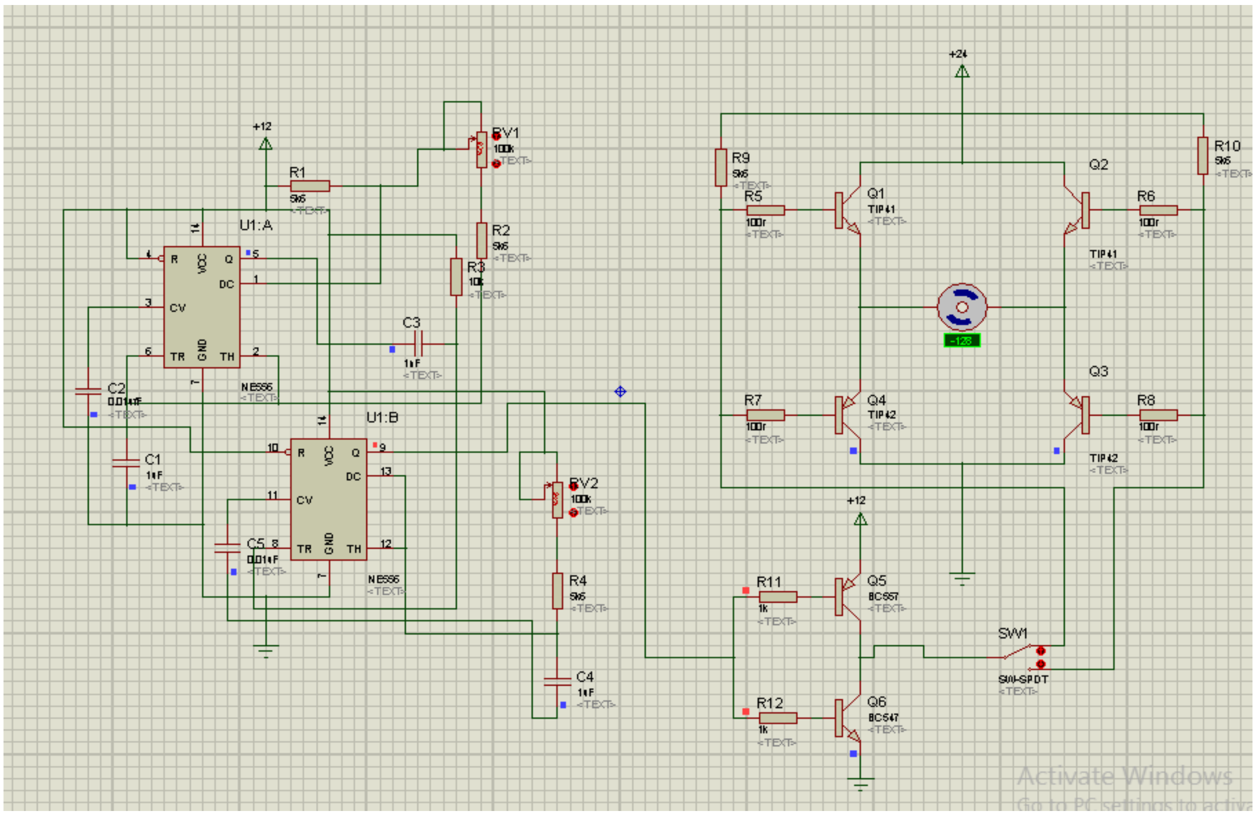

Figure 6: The complete circuit diagram

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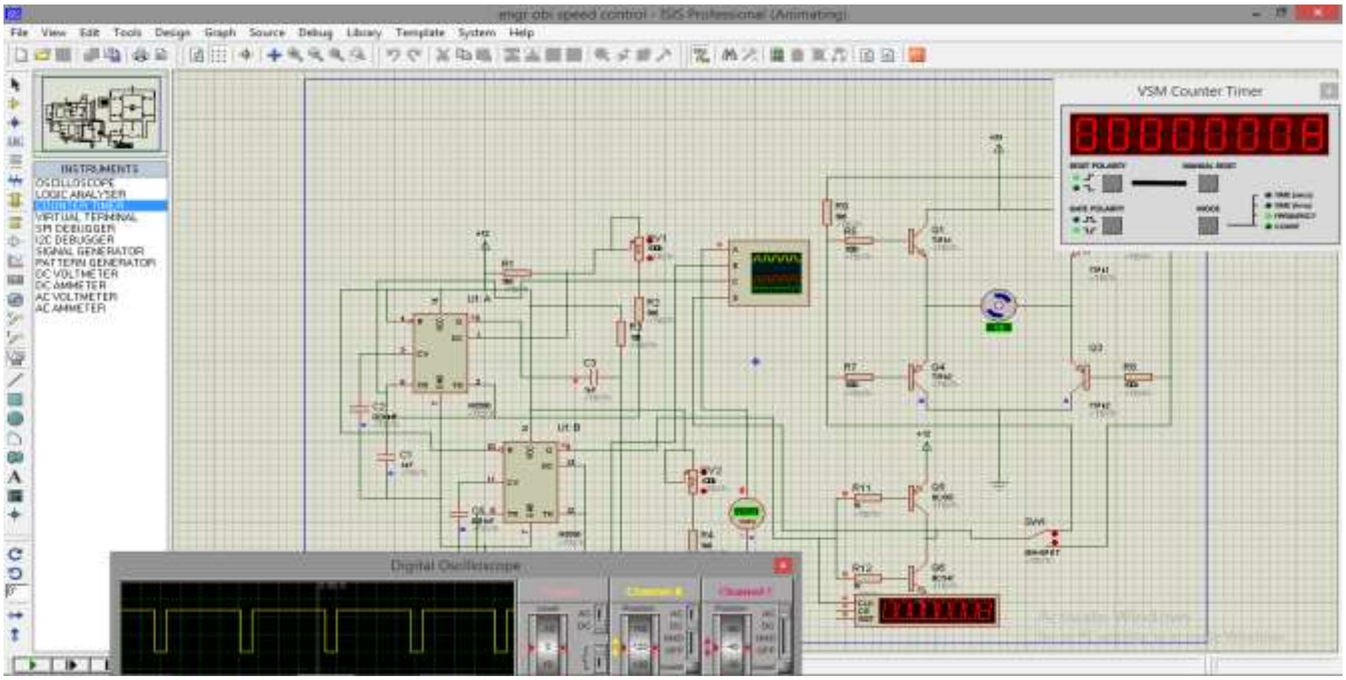

Figure 7: The simulated work

4. RESULTS/DISCUSSIONS

4.1 Results

Table 2: data recorded from instruments

Duty cycle %	Voltage V	Speed RPM
80	12	2000
70	10.5	1759
60	9	1500
40	5	1000
30	4.5	0
20	3	0
10	1.5	0
0	0	0

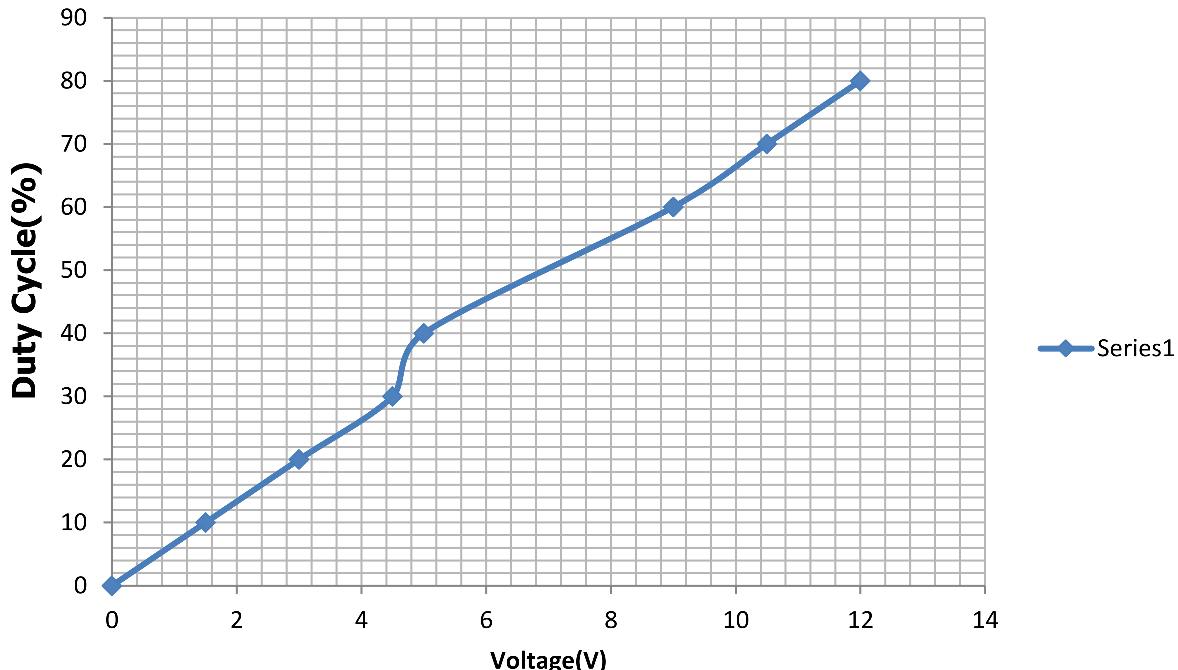

figure8: Graph of ducty cycle aganist voltage

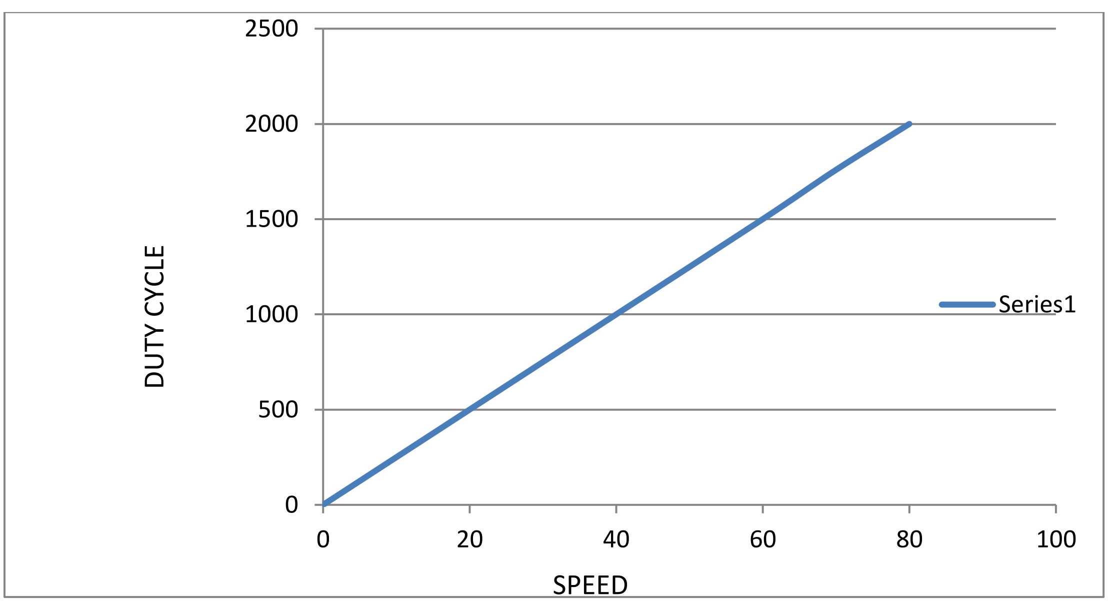

Figure 9: Graph of duty cycle against speed

4.2 Discussions

The entire sub units are connected together as shown in figure 6. To vary the supplied voltage, a variable resistor was used and measuring instruments like the Voltmeter, oscilloscope and speedometer were all used in the design for simulation purposes to get the reading at various points of the pulse width modulation. Duty circle of the PWM was varied from maximum of 80% and the corresponding values of voltages and speed were recorded. At the highest duty circle, a maximum speed of 2000RPM and maximum voltage 12V were recorded from the speedometer of the motor and the voltmeter connected across the output. The tables below show the data gotten.

5. CONCLUSION

The speed of the DC Motor depends on voltage applied to the armature and the duty cycle of the PWM (which can be varied for simulation purposes). Also, the direction of the rotation depends on the direction of the current flowing through the armature coil.

This was achieved using the H- Bridge driver, as the change in current direction was achieved by the use of a two-pole switch.

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