A Flexible Closed Loop PMDC Motor Speed Control System for Precise Positioning

Shakil Seeraji *shakil.ae@mist.edu.bd*
Department of Aeronautical Engineering
Military Institute of Science and Technology
Mirpur Cantonment, Dhaka-1216, Bangladesh

Enaiyat Ghani Ovy *enaiyat_ovy@yahoo.com*
Department of Mechanical and Chemical Engineering
Islamic University of Technology
Board Bazar, Gazipur-1704, BANGLADESH

Tasnim Alam *rim_mist@yahoo.com*
Department of Electrical electronic and communication Engineering
Military Institute of Science and Technology
Mirpur Cantonment, Dhaka-1216, Bangladesh

Ahsan Zamee *zamee_mist@yahoo.com*
Department of Electrical electronic and communication Engineering
Military Institute of Science and Technology
Mirpur Cantonment, Dhaka-1216, Bangladesh

Abdur Rahman Al Emon *emon1535@gmail.com*
Department of Electrical electronic and communication Engineering
Military Institute of Science and Technology
Mirpur Cantonment, Dhaka-1216, Bangladesh

Abstract

The speed control of DC motor is very significant especially in applications where precision is of great importance. Due to its ease of controllability the DC motor is used in many industrial applications requiring variable speed and load characteristics. So the precise speed control of a DC motor is very crucial in industry. In this case microcontrollers play a vital role for the flexible control of DC motors. This current research work investigates the implementation of an ATmega8L microcontroller for the speed control of DC motor fed by a DC chopper. The chopper is driven by a high frequency PWM signal. Controlling the PWM duty cycle is equivalent to controlling the motor terminal voltage, which in turn adjusts directly the motor speed. H-bridge circuit is implemented for the bi-directional control of the motor. A prototype of permanent magnet DC motor speed control system using the microcontroller is developed and tested.

Keywords: ATmega8L Microcontroller, DC Chopper, PWM, Tachogenerator, PMDC Motor, H-Bridge.

1. INTRODUCTION

DC motor transforms electrical energy into mechanical energy. They are used to drive devices such as fans, cars, door locks, seat adjust, mirror adjust, anti-lock braking system window lifts, robot arms, hoists etc. So the speed control of a DC motor is essential in this present industrial world. Many significant researches have been found regarding control techniques of the DC motors.

From earlier research work, some techniques to control the DC motors are notable to be mentioned. Refai [1] designed a PID controller which was based on MC68B00 microprocessor to

control the speed of a DC motor. E^2PROM was used for program storage rather than RAM or ROM to improve the flexibility and avoid memory corruption or power interrupt. Abdelhay and Haque [2] applied a minimum-variance self-tuner to control the speed of a DC motor. By implementing this method satisfactory motor response was found and set point and load disturbances were sustained which was further compared with a PID controller. Microcontroller has been introduced later to regulate the speed of the DC motor. Ume et al. [3] used Motorola MC68HC11 microcontroller to control the speed of a permanent magnet DC motor.
From recent literature survey, the use of microcontroller for the control of DC motor has been found in many research works. Now-a-days, microcontrollers are used in the industrial world to control many types of equipments ranging from consumer to specialized devices. Chattopadhyay et al. [4] designed a microcontroller based position control system where the actuator was operated by the signal obtained from the PC (through key board). In this work, the position of the motor was controlled by the microcontroller based PI controller with interactive display control facilities. Adaptive fuzzy and neural speed controllers have been designed and implemented very recently to control the speed of a DC motor [5-8]. In this present work, the design and implementation of an ATmega8L microcontroller based controller to control a permanent magnet DC motor with speed feedback through a techogenerator is discussed elaborately. The actuator is regulated by a microcontroller based adjustable closed loop controller that controls the speed of a DC motor by using PWM and DC chopper. The system is interfaced to a LCD display so that the state of the system can be monitored by an operator. An H-bridge is implemented in the circuit for controlling the rotation of the motor in clockwise as well as anti-clockwise direction simultaneously. AVR studio4 software is used for programming and PonyProg is used for downloading the program to the microcontroller through parallel port.

2. SYSTEM DESCRIPTION REPEATABILITY

The block diagram of microcontroller based closed loop speed control of DC motor is shown in the figure 1. The motor to be controlled is fed by a DC source through a chopper. The techogenerator senses the speed, which gives voltage as output. And this voltage is fed to the microcontroller to drive the speed of the motor.

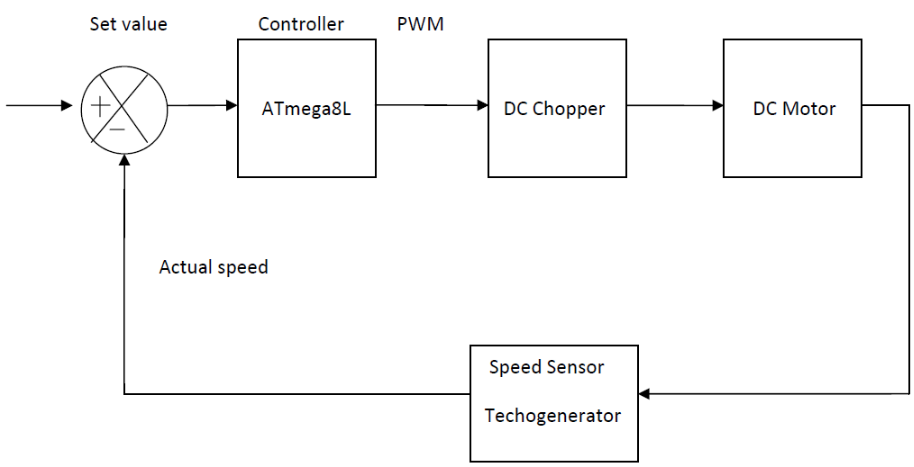

FIGURE 1: Block diagram of microcontroller based closed loop speed control of DC motor.

The output voltage of techogenerator is provided to the microcontroller and microcontroller determines the output voltage of the chopper fed to the DC motor for desired speed.

3. Circuit Hardware and Software Operation

Circuit hardware and software portions are discussed in the following sections.

3.1 Circuit Schematic Diagram

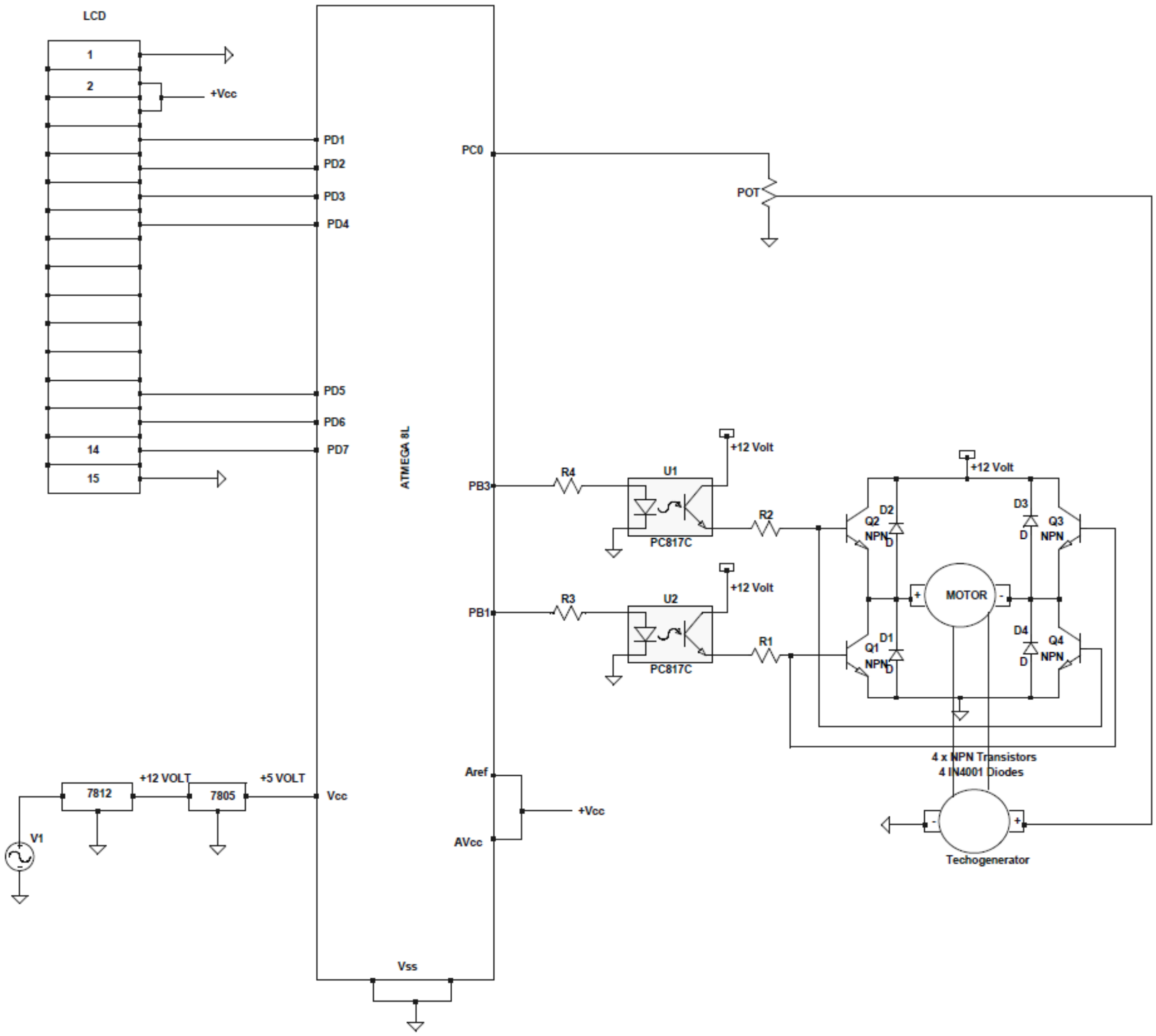

FIGURE 2: Circuit for the speed control of DC motor.

The operation of the control circuit is described below by its different portion.

3.1.1 Pulse Width Modulator Module (PWMM)

PWMM is a very efficient way of providing intermediate amounts of electrical power between fully on and fully off. A simple power switch with a typical power source provides full power only, when switched on. PWM is a comparatively-recent technique, made practical by modern electronic power switches. In this research work, timer/counter2 (8-bit) was used to generate PWM for varying the speed of DC motor (12V). Phase correct mode was used here. It has 2 different modes of operation. Non-inverted mode was selected for this work.

3.1.2 Chopper Circuit

A DC chopper is a dc-to-dc voltage converter. It is a static switching electrical appliance that in one electrical conversion, changes an input fixed dc voltage to an adjustable dc output voltage without inductive or capacitive intermediate energy storage. The name chopper is connected with the fact that the output voltage is a 'chopped up' quasi-rectangular version of the input dc voltage. For this research work, a Buck converter (step down chopper) was implemented.

A pulse with fixed frequency is generated by the microcontroller, which is fed to the base of transistor (D400). Transistor acts here as a switch. The output voltage of the motor is dependent on the amount of the on time of the transistor. The more time transistor remains on more the voltage will produce. A Freewheeling diode (1n4001) is used for back e.m.f. protection given to other portion of the circuit. Output voltage of the motor terminal can be shown by the equation given below.

$$V_{out} = V_{in} \times D$$

Where $D = \frac{T_{on}}{T_{on} + T_{off}}$

And $V_{in} = 12V$

Using the equation and by measuring the voltage by multimeter the following values are obtained.

D (Duty cycle)	Voltage using equation(V)	Voltage measured by multimeter(V)
.1	1.2	3
.3	3.6	5.3
.5	6	7.8
.7	8.4	10
.9	10.8	11.6
1	12	11.6

TABLE 1: Motor terminal voltages at various duty cycles.

3.1.3 Sensor Design

For speed sensing purpose, another motor is used. This motor is used here as a tachogenerator. As it is known that for a DC motor voltage is directly proportional to the speed. The tachogenerator is coupled with the motor. And a potentiometer is connected to the terminal of the tachogenerator. Tachogenerator gives voltage drop across the potentiometer according to the speed of the motor. If the motor runs at a low speed it gives a lower value. And when it runs at its maximum speed it gives a larger amount of voltage. As it is known that speed can be regulated by regulating the pulse width, so varying the duty cycle the speed can be regulated. Output voltages at different duty cycles have been found by varying the duty cycle controller register OCR (output compare register).

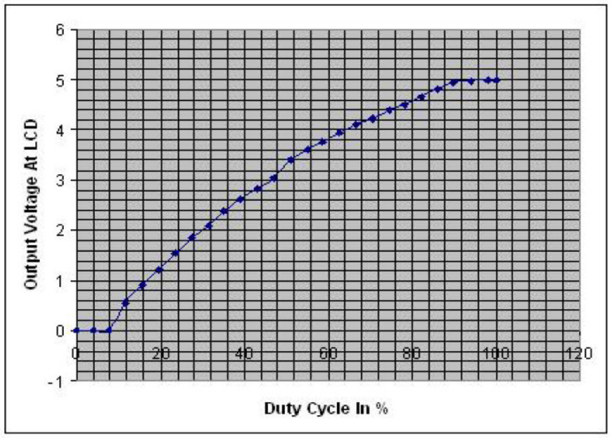

FIGURE 3: Duty cycle vs Output voltage.

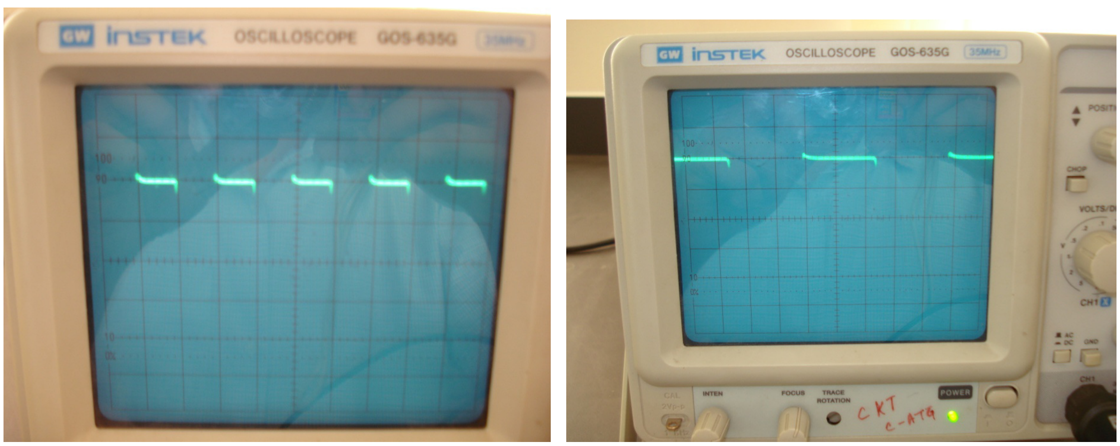

FIGURE 4: Pulses at 20% and 50% duty cycle.

Now the voltage drop across the potentiometer is fed to ADC of the microcontroller. According to the ADC value, microcontroller will take decision whether pulse width needs increment or decrement.

3.1.4 Circuit Logic Development

As this present work is based on the speed controlling of a DC motor, so in this work the desired goal is to achieve a system with constant speed at any load condition. That means the motor will run at fixed speed at any load condition. As it is known that the speed of a DC motor can be varied by PWM technique so according to the value of duty cycle the motor speed can be varied. Now a question arises how it can be measured the variation of speed of the motor? To do this another DC motor is used, which is coupled with the main motor. When the motor will run, it will also make the second motor starts rotating. And the motor will act as a speed to voltage transducer or tachogenerator. That means it will give an output voltage according to speed. By measuring the output voltage drop of the tachogenerator the speed can be measured easily. It is mentioned earlier in the paper that the desire is to maintain constant speed at any load condition so initially PWM variation registers are set at a fixed value. As a result a fixed output voltage at the tachogenerator end will be found. Speed of the motor does not remain same all the time because of the various external forces like air or defect in the motor coupler. Though it does not vary by huge value so the output voltage at the microcontroller is set not by a single value rather it is set by giving a range. For bi-directional controlling of the motor, an H-bridge circuit is used. In the H-bridge circuit four NPN transistors are used as switch to change or choose the direction of current flows to the motor. Opto-coupler is used between the motor and microcontroller for isolation.

Now if a load is applied on the motor, the speed of the motor will suddenly decrease. And with the decrement of the speed output voltage will also decrease. This output voltage is fed to the ADC input of the microcontroller by using a potentiometer. The output voltage of the tachogenerator is scaled to 5V as the microcontroller ADC inputs are 5V supported. As earlier a range of voltages are set for the fixed duty cycle, so when the new value of voltage will be sensed by the microcontroller it will also sense the decrement of the speed by comparing two values. Now the controller unit will tend to improve the speed of the system, so that the output voltage remains same of the tachogenerator. To improve the system speed microcontroller now will start increasing the value of PWM controller register i.e. output compare register (OCR) until the input voltage of the ADC reaches the desired level of voltage. Now after reaching the desired level of voltage, OCR will stop further increment. Now two more condition arises here, that what would happen if the sudden load drops down to very low amount and what would happen if the load is very huge that motor cannot run at its desired speed? When the load will drop down to a low value, the speed of the motor will be very high. As a result output voltage will be also very high. So again controller unit will sense output voltage and will compare with the desired level of voltage. The PWM controller register i.e. OCR will do the reverse operation. Now the value OCR will decrease until the output voltage reaches its desired level. And for the second condition if the load amount is so high that motor cannot run at its desired speed, then OCR will start increasing until reaches its maximum value. For 8 bit timer/counter the maximum value of OCR is 255. Even if after reaching the maximum value, there remains no improvement of the speed, i.e. output voltage does not matches the desired level then microcontroller will send a message “OVERLOAD” using the LCD (16×2 line), so that the user can understand the condition and hence reduce the load of the motor.

3.1.5 PCB (Printed Circuit Board) Design

A printed circuit board, or PCB, is used to mechanically support and electrically connect electronic components using conductive pathways, tracks, or traces, etched from copper sheets laminated onto a non-conductive substrate. ORCAD family release 9.2(layout plus) was used for control circuit design. Designed PCB figure is given below.

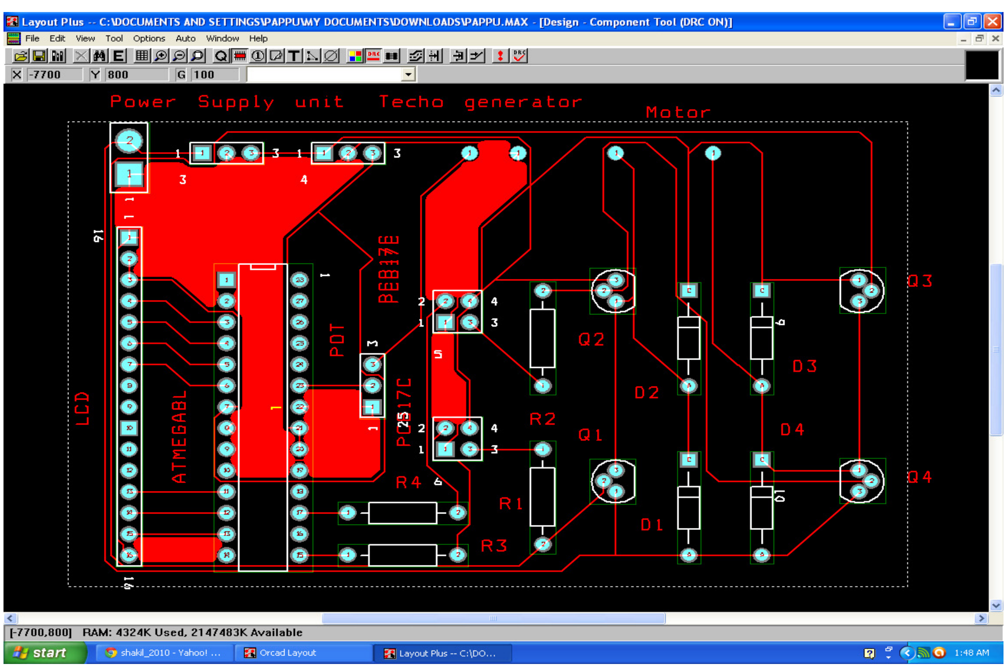

FIGURE 5: PCB layout of the control circuit.

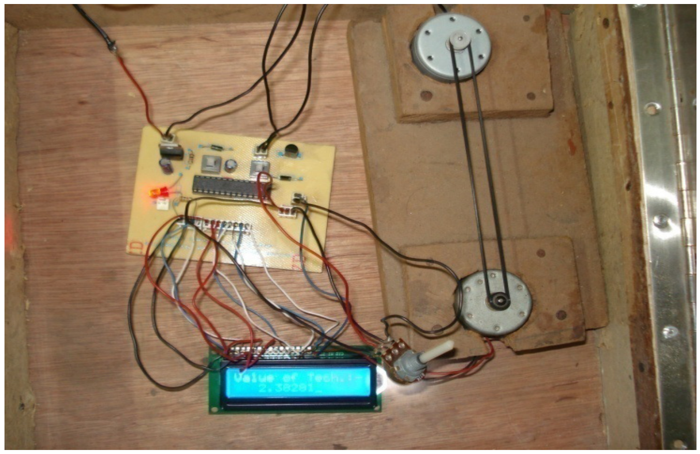

FIGURE 6: The physical setup of the research work.

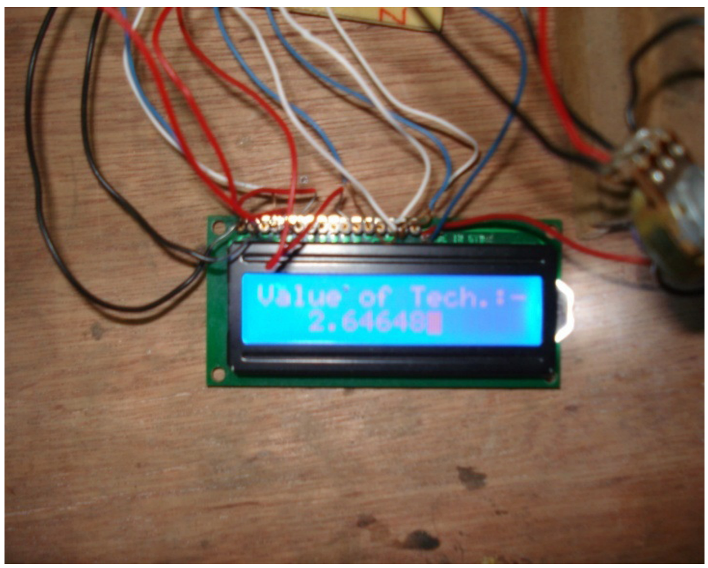

FIGURE 7: Showing value of output voltage of techogenerator.

Figure 8: Showing “OVERLOAD” message.

4. OPERATIONAL FLOW CHART

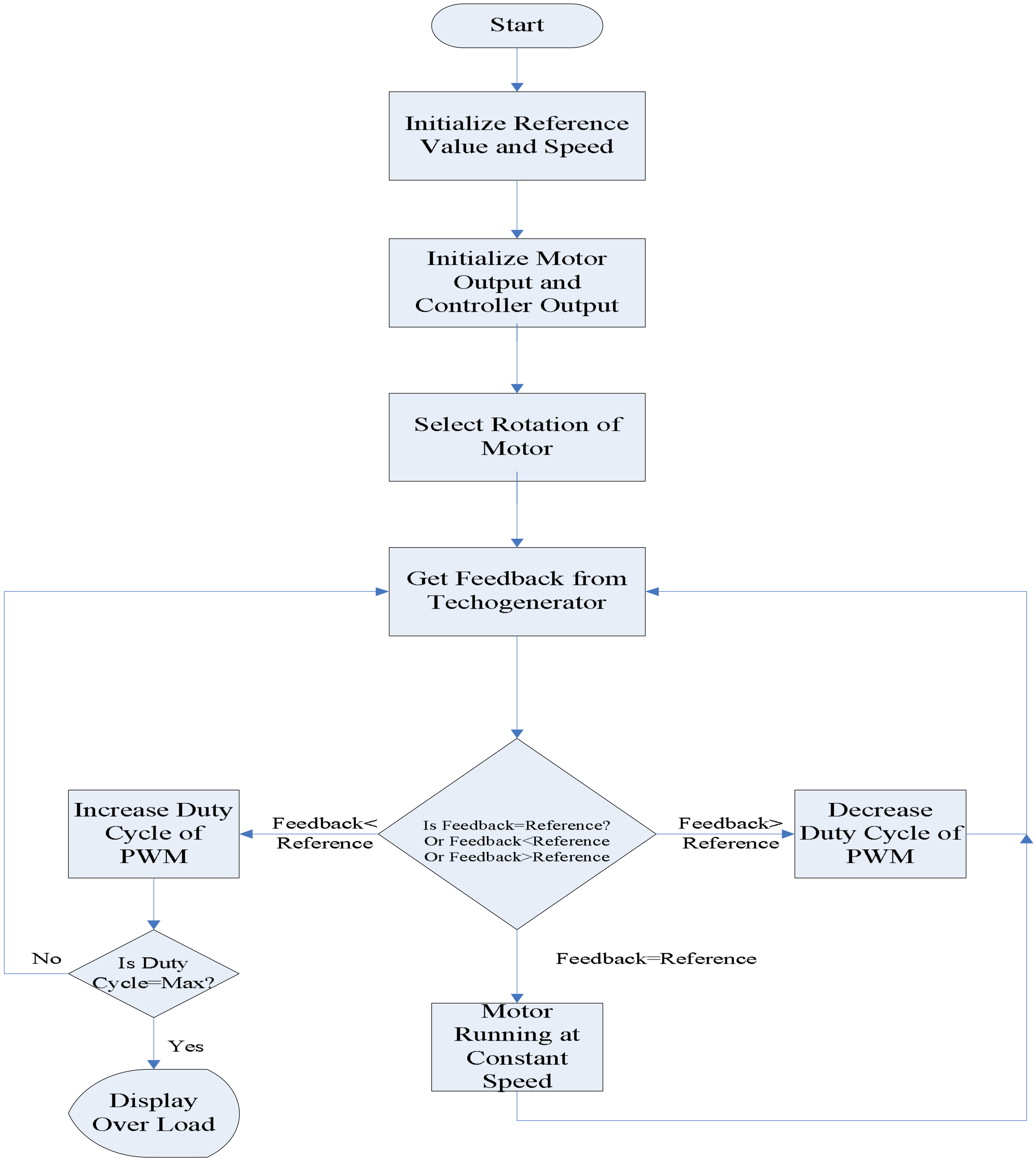

FIGURE 9: Operational flow chart for DC motor speed controller.

5. CONCLUSION

An embedded system is designed and implemented in this work. Controlling a permanent magnet DC motor with speed feedback through a techogenerator is successfully implemented using an ATmega8L microcontroller. Microcontroller provides very less requirement of hardware. The system is made user friendly so that anybody can operate the system without any trouble. LCD display is used to show the condition of the system. After knowing the condition the amount of load can be changed if necessary. Finally it can be concluded here that the system reliability is higher where the PMDC motor can be regulated easily as well as the maintenance of the motor can be also improved.

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