PWM speed control of dc permanent magnet motor using a PIC18F4550 microcontroller

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Abstract. The purpose of this design is to study the advantages of controlling the DC motor speed by adjusting the permanent magnet of DC motors. This had been done by applying the PWM method with relay using PIC18F4550 microcontroller. The output signal from each controllers were compared with the control system and describe the output value and data related to the system. The result shows that the PWM method was able to maintain the motor speed better than the continuous voltage method.

1. Introduction
DC motors have many advantages in technical and economic aspect. Therefore DC motor is widely used in the industrial world. A DC motor that has small power and small starting current be operated by connecting and starting it directly to a voltage source through a power switch. However, for this type of motor with a larger capacity, this cannot be done because the current generated when starting will be large. The amount of the starting current is affected by the large load connected to the motor. Large staring currents that occur for a long time or are always repeated will cause damage to the motor and electric power system where the motor is installed.

This paper presents a method for controlling the amount of current drawn by a DC motor when staring by using controls utilizing a microcontroller. The next part of this paper is a brief description of DC permanent magnet motors, PIC microcontrollers used, experimental methods and results obtained. The final section contains conclusions and discussions.

2. Contractions and Principles of Operations
A DC motor is a machine that functions to convert DC electric power into motion or mechanical energy. DC motors require a supply of DC voltage in the field coil to be converted into mechanical energy. The field coil on a dc motor is called a stator (the part that does not rotate), and the armature coil is called the rotor (rotating part).

2.1. DC motor Permanent magnet
The working principle of the direct current motor is to reverse the voltage signal that has positive and negative value using a commutator, thus the current reversing with the coil of the anchor that rotates in the magnetic field. The simplest form of the motor has a coil in which current can rotate freely between the permanent magnetic poles.

Various types of DC motors that operate on electromagnetic principles currently was used widely. Of these, permanent magnet DC motors have extraordinary characteristics to be used as actuators in automatic equipment. Figure 1 shows the basic structure of permanent magnet DC motors. It is consists of two permanent magnets and an iron house, forming the stator part. The rotor is the rotating part of the motor. The stator is the stationary part of the motor that creates a magnetic flux and then creates torque.
The armature of the DC permanent magnet motor is shown in Figure 2. It is part of the current carrying motor, which interacts with field flux to create torque. The brush is part of the circuit where the electric current flows to the motor from the power supply — brushes made of graphite or metal. DC motors have one or more pairs of brushes. One brush is connected to the positive terminal from the power supply, and the other to negative. The commutator is the part that comes into contact with the brush, which is distributed in armature rolls using brushes and commutators.

2.2. PIC18F4550 Microcontroller

To realize the starting control system and DC motor operation in this study, a PIC18F4550 microcontroller chip is used. This microcontroller is chosen in addition to having a high operating speed and is equipped with basic digital signal processing (DSP) functions, also because this IC is equipped with PWM signal-producing peripherals that are specifically intended to control the motor. With this peripheral, six simultaneous PWM signals can be generated which correspond to what is needed for the three-phase gating inverter used to rotate the motor. This gating signal is equipped with dead-time settings and various another security mechanism.

2.3. PWM (Pulse Width Modulation)

One method that is often used for DC motor control using a microcontroller is Pulse Width Modulation (PWM) method. The speed of the electric motor depends on the modulator voltage. The greater the voltage, the faster the rotation of an electric motor. PWM is a good technique for controlling analog circuits of the motor drive with digital outputs from a microcontroller.
From Figure 4, if the source voltage (Vs) reaches 12 V, then the duty cycle of 20% above PWM output is 2.4 V. Likewise, the 50% duty cycle output of PWM is 6 V, and on duty 80% cycle PWM output is 9.6 V. This means that using a microcontroller output of 5 V, an analog circuit that requires a voltage source of more than 5 V can be controlled using the PWM principle.

The use of this PWM can be used to control motor rotation through changes in PWM duty cycle or PWM pulse width. When the duty cycle is 0%, the motor will stop completely because there is no voltage difference. When the duty cycle is 50%, the motor will rotate at half the speed of the maximum speed because the voltage is half the full voltage. When PWM is in 100% condition, the motor rotates with maximum speed because of the continuous output of PWM.

2.4. DC Motor
The driver is a circuit composed of transistors used to drive a DC motor. The motor can indeed rotate only with DC power, but it cannot be regulated without using a driver, so a driver circuit is needed to regulate the work of the motor. In this DC motor driver can emit currents up to 3-4 A, with the function of Pulse-Width Modulation.

3. Research Methods
A system designed is to make DC motor controller hardware that is controlled by PWM and relay by using the PIC18F4550 microcontroller as a processor for automatic controllers. This hardware selection is taken to retrieve the output signals from each controller to compare the characteristics of the control system has been proven cost-effective, efficient and reliable. To illustrate the output value and data related to the system, block diagram scheme is used as in Figure 5 below:

In Figure 5 the voltage circuit 12 volts, the current enters into the driver circuit which acts to drive 2 DC motors, that are attached to one motor as a generator (load output), which is connected to the microcontroller circuit as the controller will rotate the permanent magnet DC motor, to produce motor rotation stability and generate signals PWM, with the help of the ATMega 8535 AVR microcontroller to trigger the signal conditioning to make it easier to generate a signal to display to the monitor screen,
as a load replacement plus a dummy load circuit to set the resulting simulation load, and to display the Rpm program data on the monitor, the program is obtained from reading the optocoupler sensor installed on the motor that is controlled by the AVR ATmega 8535 microcontroller and has been programmed every 0.5 seconds. The data sent every 0.5 seconds by the microcontroller is the number of rotations / 0.5 seconds to get a percentage of the Rpm graph.

4. Results And Discussion
After the tool design process has been completed, testing of tools and data collection in the form of motor rotation speed measurement (Rpm) is carried out. To get the results of the controller data from the motor by displaying the data displayed the data that has been programmed and recorded the results on the PC monitor screen. To get the data from the control, several methods are carried out.

4.1 Method When Motor Without Load
The x-axis (time) shows the sequence of data transmission from AVR ATMEGA8535. Data is sent every 0.5 seconds. The Y axis (Speed) is a manifestation of the rpm calculation of the number of pulses calculated every 0.5 seconds by AVR ATMEGA8535. The amount of obstacle in the motor shaft is 1 obstacle or 1 pulse/rotation, so that if it counts 1 pulse/round / 0.5 seconds, then it is equivalent to 120 revolutions/minute.

![Figure 6. Loadless motor graphics.](image)

In Figure 6, the results of the motor speed when the DC motor without load motor speed is around 1400 Rpm.

4.2. Method When Full Load Motor
For full load motor, Load is activated when sending data 15th (or at 7th second), and Load is deactivated when sending data 40th (or at 20th second). Figure 7 shows the results of motor speed at full load (100%) there is a decrease in the motor speed of about 600 Rpm.

![Figure 7. Full load motor graph 100%.](image)
4.3. Speed 1000 Rpm
The continuous voltage method for time $t = 0$ to $t = 50$, the speed is around 1000 Rpm. When given a full load, the speed drops to around 200 Rpm.

![Graph of continuous voltage](image)

**Figure 8.** Graph of continuous voltage.

Method PWM method for time $t = 0$ to $t = 50$, speed is around 1000 Rpm fluctuating. When given a full load, the speed drops to around 300 to 350 Rpm.

![Graph of PWM Duty Cycle method](image)

**Figure 9.** Graph of PWM Duty Cycle method = 96.1%.

4.4. Speed 800 Rpm
Continuous voltage method for time $t = 0$ to $t = 50$, speed is around 800 Rpm. When given a full load, the speed drops to around <200 Rpm.

![Continuous voltage method graph](image)

**Figure 10.** Continuous voltage method graph
In the PWM method for time $t = 0$ to $t = 50$, the speed is around 800 rpm fluctuating. When given a full load, the speed drops to around 250 to 300 Rpm.

![Graph of PWM Duty Cycle method](image1)

**Figure 11.** Graph of PWM Duty Cycle method = 94.68%.

4.5. *Speed 600 Rpm*

The continuous voltage method for time $t = 0$ to $t = 50$, the speed is around 600 rpm. When given a full load, the speed drops to around 100 to 150 Rpm.

![Continuous voltage method graph](image2)

**Figure 12.** Continuous voltage method graph.

PWM method for time $t = 0$ to $t = 50$, speed is around 600 Rpm fluctuating. When given a full load, the speed drops to around 200 Rpm.

![Graph of PWM method Duty Cycle](image3)

**Figure 13.** Graph of PWM method Duty Cycle = 93.7%.
4.6. Correlation Data Duty cycle, PWM with Motor Speed

This method takes data from the PWM frequency with PWM Frequency = 1.5 KHz, PIC18F4550 = 20MHz frequency oscillator feeds on motor duty cycle results

| PWM (Program) | Speed (Rpm) | Duty Cycle (%) |
|---------------|-------------|----------------|
| 207           | 1440        | 1              |
| 204           | 1320        | 0.99           |
| 200           | 1200        | 0.97           |
| 199           | 1080        | 0.96           |
| 197           | 960         | 0.95           |
| 196           | 840         | 0.95           |
| 195           | 720         | 0.94           |
| 195           | 600         | 0.94           |
| 193           | 480         | 0.93           |
| 187           | 360         | 0.90           |
| 172           | 240         | 0.83           |
| 166           | 120         | 0.80           |

Table 1. PWM Duty Cycle Correlation Data with Motor Speed.

![Graph of PWM Duty Cycle correlation with Motor Speed.](image)

Figure 14. Graph of PWM Duty Cycle correlation with Motor Speed.

With this method, it can be seen in figure graph 14 even though the motor speed increases the PWM that has been program remains stable with a duty cycle = 1

Table 2. Equivalent Data Amount of pulse per 0.5 seconds with Rpm.

| Rotation Per 0.5 second | Rpm  | Rotation Per 0.5 second | Rpm  |
|------------------------|------|------------------------|------|
| 1                      | 120  | 14                     | 1680 |
| 2                      | 240  | 15                     | 1800 |
| 3                      | 360  | 16                     | 1920 |
| 4                      | 480  | 17                     | 2040 |
| 5                      | 600  | 18                     | 2160 |
| 6                      | 720  | 19                     | 2280 |
| 7                      | 840  | 20                     | 2400 |
| 8                      | 960  | 21                     | 2520 |
| 9                      | 1080 | 22                     | 2640 |
### Table 2. Equivalent Data Amount of pulse per 0.5 seconds with Rpm (cont).

| Rotation Per 0.5 second | Rpm | Rotation Per 0.5 second | Rpm |
|------------------------|-----|------------------------|-----|
| 10                     | 1200| 23                     | 2760|
| 11                     | 1320| 24                     | 2880|
| 12                     | 1440| 25                     | 3000|
| 13                     | 1560|                        |     |

**Figure 15.** Equivalent Graph Amount of Pulse per 0.5 seconds with Rpm.

With this method it can be seen in the figure graph 15 the number pulses (rotation 0.5 seconds), the motor rises and the Rpm will increase.

#### 5. Conclusion

Based on the results of the research conducted and paying attention to the workings of the tool, it can be concluded that the PWM method can maintain motor speed better than the continuous voltage method. The motor speed at full load is relatively better than the continuous voltage method. The motor current at the start of the data can not be recorded because the time is very short. The current sensor used cannot measure the transient time domain.

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