DEVELOPMENT OF SHAKER

(CONTROLLER)

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UNIVERSITI MALAYSIA PAHANG

DEVELOPMENT OS SHAKER
(CONTROLLER)

MOHD HAFIEZAL BIN NORDIN

Report submitted in fulfillment of the requirements for
the award of degree of Bachelor of Mechatronics Engineering

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BORANG PENGESAHAN STATUS TESIS[♦]

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Dedicated to my Parents

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ABSTRACT

The automatic control has played a role in the advance of engineering and science. Nowadays, the control of direct current (DC) motor is a common practice in industry thus the implementation of DC motor of controller speed is important. The main purpose of motor speed controller is to keep the rotation of the motor at the preset speed and to drive a system at the demanded speed. When used in speed application, speed feedback control the DC motor’s speed or confirms that the motor is rotating at the desired speed. The speed of a DC motor usually is directly proportional to the supply voltage. For instance, if we reduce the supply voltage from 12 Volts to 6 Volts the motor will run at half or lower the speed. The advantages used DC motor is provide excellent speed control for acceleration and deceleration with effective and simple torque control. The fact that the power supply of a DC motor connects directly to the field of the motor allows for precise voltage control, which is necessary with speed and torque control applications. The common methods are used to control speed DC motor is Proportional Integral Derivative (PID) and PC based to control it. In this project, the method use as controller is using Arduino Uno as microcontroller for the electric current control to drive a motor. The expectation of this project is to get the precise the demanded speed and to drive a motor at that speed.

ABSTRAK

Kawalan automatik telah memainkan peranan dalam kemajuan kejuruteraan dan sains. Kini, kawalan arus terus (DC) motor adalah biasa amalan dalam industri itu pelaksanaan DC motor pengawal kelajuan adalah penting. Tujuan utama pengawal kelajuan motor adalah untuk memastikan putaran motor pada kelajuan yang ditetapkan dan untuk memandu sistem pada kelajuan yang diminta. Apabila digunakan dalam permohonan kelajuan, maklum balas kelajuan mengawal kelajuan motor DC atau mengesahkan bahawa motor yang berputar pada kelajuan yang dikehendaki. Kelajuan motor DC biasanya adalah berkadar terus dengan voltan bekalan. Sebagai contoh, jika kita mengurangkan voltan bekalan dari 12 volt ke 6 volt motor akan berjalan pada separuh atau lebih rendah kelajuan. Kelebihan digunakan DC motor menyediakan kawalan kelajuan yang cemerlang untuk pecutan dan nyahpecutan dengan kawalan tork berkesan dan mudah. Hakikat bahawa bekalan kuasa motor DC menghubungkan terus kepada bidang motor membolehkan kawalan voltan yang tepat, yang perlu dengan aplikasi kawalan kelajuan dan tork. Kaedah yang biasa digunakan untuk mengawal kelajuan motor DC adalah derivatif Penting Berkadar (PID) dan Komputer berasaskan untuk mengawalnya. Dalam projek ini, kaedah yang digunakan sebagai pengawal menggunakan Arduino Uno sebagai pengawal micro untuk mengawal arus elektrik untuk memandu motor. Jangkaan projek ini adalah untuk mendapatkan tepat kelajuan yang diminta dan untuk memandu motor pada kelajuan itu.

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LIST OF SYMBOLS

KE - A constant based on motor construction

φ - Magnetic flux

If- Field current

Ia - Armature current

Rf- Field resistor

Lf- Field inductor

Ra - Armature resistor

La - Armature inductor

Kv - Motor constant

Kt- Torque constant

Td - Developed torque

TL - Load torque

B - Viscous friction constant

J - Inertia of the motor

w - Motorspeed

ton - Time ON of switches

toff- Time OFF of switch

T - Period

s - Standard deviation

rpm - Rotation per minute

CHAPTER 1

INTRODUCTION

1.1 Project Background

In many industries, a device that used in order to convert electrical energy into mechanical energy is called as the direct current (DC) motor. All result is from the availability of speed controllers which is wide range, easily and many ways. Speed control is very important in most applications, which is for an example, if we have DC motor in radio controller car, if we just apply a constant power to the motor, it is impossible to maintain the desired speed. It will go slower over rocky road, slower uphill, faster downhill and so on. It is important to make a controller to control the speed of DC motor in desired speed. In modern industry, DC motor plays a significant role.

Speed control of dc motor could be achieved using mechanical or electrical techniques. In the past, speed controls of dc drives are mostly mechanical. Requiring large size hardware to implement. Advances in the area of power electronics have brought a total revolution in the speed control of dc drives. This development has launched these drives back to a position of formidable relevance, which were hitherto predicted to give way to ac drives. These drives have now dominated the area of variable speed because of their low cost, reliability and simple control.

To take a signal representing the demanded speed, and to drive a motor at that speed is The purpose of a motor speed controller. There are numerous applications where control of speed is required, as in rolling mills, cranes, hoists, elevators, machine tools, transit system and locomotive drives. These applications may demand high-speed control accuracy and good dynamic responses.

DC motor is widely used in metallurgy, machinery manufacturing and light industry because of its good performance in starting and breaking and its easily controlled speed regulation. In recent years, with the development of the power electronic technology, the thyristor rectifier is commonly used for the power supply of the DC motor, which replaces the AC motor—DC generator power supply system. But DC motor speed control system is a complex multivariable nonlinear control system, because the various parameters influence each other, it's anti—interference ability is weak and it's not suitable for high control performance occasion.

Therefore, in order to enhance DC motor speed control system of anti—jamming and robustness, and improve the response speed and stable precision of the speed regulation system, this paper discuss the PWM DC motor speed control system based on the fuzzy control and neural network control.

In conclusion, in devices ranging from toys, house appliance and robotics to industrial application, the simplicity of control speed made DC motors to be common.

1.2 Objective of the Project

Basically, these projects are having three main objectives. The objectives are a guideline and goal in order to complete this project. This project is conducted to achieve the following objectives:

I. To develop controller using microcontroller as programming.
II. To design the hardware of the controller to control DC motor frequency.
III. To develop precisely control the DC motor.

1.3 Scope of the Project

There are two scopes in this project which is hardware development and software development. For the first scope which is hardware development there are three main section. First are to design a circuit that can integrate with MicroController, nest is to design a circuit for control speed of DC motor, and lastly for to design a circuit for the motor driver.

While For the second scope which is the software development, there are two main sections and that section are. Firstly try to simulate the control system using Multisim software, next develop a software or coding and integrate with Arduino uno.

1.4 Problem Statement

The efficiency and reliability are the most issue discusses in speed controller. In order to save cost, the efficiency element is important. The efficiency of speed controller is depending on method control system. The speed controller usually controls in analog system and an analog signal has a continuously varying value, with infinite resolution in both time and magnitude. For example, a 10 V is an analog and its output voltage is not precisely 10 V, changes over time, and can take any real-numbered value.

Similarly, the amount current drawn from a battery is not limited to a finite set of possible value. Analog signals are distinguishable from digital signals because the latter away take values only from a finite set of predetermined possibilities. DC motor widely used in speed control systems which needs high control requirement such as rolling mill, double-hulled tanker and high precision digital tools. So, it is crucial to control the motor speed in order to achieve good production.

One of the most common methods to drive a DC motor is by using PWM signals respect to the motor input voltage. Manual controller is also not practical in the technology era because it can waste time and cost. Operation cost regarding controller is got attention from industrial field. In order to reduce cost and time, we suggest making a controller based on computer because it is portable. The user can monitor their system at certain place without need to going to the plant (machine) especially in industrial implementation. From that, the man power can be reduced and reserve with computer which is more precise and reliable. The other product regarding this project where control motor via computer may be commercialized but their cost is very expensive. The hardware of this product may be complicated and maintenance cost is higher. The low cost electronic devices can be designed to make a speed controller system. So this thesis will select PWM to control the speed of DC Motor using witdh modulation

1.5 Thesis Outline

Chapter one, it discusses about introduction and overview about this project includes background, objectives and scope of projects.

Chapter two is explanations about literature review as study material and references. The topics that I have studied are about the other method of speed control to compare and analysis their advantages and disadvantages. From the literature review, knowledge can be gained thus implement in this project.

On chapter three, the methodology that I have done are discusses. This is explanations about the method used to complete hardware and software.

Chapter four are discusses of the result and analysis of this project. In this chapter also will explain how PWM is produce and how its control the speed of the DC motor.

Chapter five are describes conclusion and future recommendation to make this project greatly.

This thesis included with references and appendices. Also refer the further information about this project in references which is states the source and their authors. Datasheet of the components, photo and other information also placed on the appendices part.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Although a far greater percentage of electric motors in service are a.c. motors, the d.c. motor is of considerable industrial importance. Its speed can be changed over a wide range by a variety of simple methods is the principal advantage of a d.c. motor. With a.c motors, such a fine speed control is generally not possible. In fact, fine speed control is one of the reasons for the strong competitive position of d.c. motors in the modem industrial applications. In this chapter, we shall discuss the various methods of-speed control of d.c. motors.

2.2 DC Motor

DC motor has been widely used in many application because it can maximize torque in order to generate movement. DC motor is mechanically commutated electric powered from direct an example of DC motor is shown in Figure 2.1. DC motor consist of motor and stator part, it also involve commutating process that switched the current in rotor. The introduction of DC motors to run machinery eliminated the need for local steam or internal combustion engines, and line shaft drive systems. DC motors can operate directly from rechargeable batteries, providing the motive power for the first electric vehicles.

Figure 2.1: DC Motor

Source: www.cytron.com.my

Electric motors play a main role in our daily life. The movement of any device is produced by electric motor. Hair dryer, VCR, disk drive in a computer etc, move due to electric motor. Electric motors can be divided into two basic groups, Direct Current (DC) motors, and Alternating Current (AC) motors. Although there are many designs of electric motors, the fundamental is the same. The technology behind electric motors is the ability to convert electrical energy to mechanical energy.

A *DC motor* is a mechanically commutated electric motor powered from direct current (DC). The stator is stationary in space by definition and therefore its current. The current in the rotor is switched by the commutator to also be stationary in space. This is how the relative angle between the stator and rotor magnetic flux is maintained near 90 degrees, which generates the maximum torque.

The printed circuit board (PCB) motor, using permanent magnet, has a configuration radically different from that of the conventional DC motor. The entire armature winding and the commutator are printed in PCB disk (rotor). This type of motor has several advantages such as high torque that allows it provides rapid acceleration and deceleration. The motor can accelerate from 0 to 4000 rpm in 10 milliseconds. The motor has no cogging torque because the rotor is nonmagnetic.

These motors are particularly suitable for applications requiring high performance characteristics. There are other types of DC motor that have their own advantages and disadvantages. The variety of DC motor types give a variety of control method and also the variety of application that can be performed. In conclusion, DC motors have many types and differ with each other in characteristics of the motor and also the use the motor in appliances. There are several types of DC motors that are available. Their advantages, disadvantages and other basic information are list below in the table below.

Table 2.1: Advantages and Disadvantages of various type DC Motor

TYPE	ADVANTAGES	DISADVANTAGE
Stepper Motor	Very precise speed and position control. High torque at low speed.	Expensive and hard to find. Required a switching control circuit.
DC Permanent Magnet Motor	Small. Compact Easy to find Very inexpensive	Generally small. Cannot vary magnetic field strength.
DC Motor W/field coil	Wide range of speed and torque. More powerful than permanent magnet motors.	Require more current than permanent magnet motors, since field coil, must be energized. Generally heavier than permanent magnet motors. More difficult to obtain.

2.3 Controller

Controller is a chip, an expansion card or a stand-alone device that interfaces with a peripheral devices. This may be a link between two part of a computer for example a memory controller or a controller on an external device that mange the operation of the device. Most microcontrollers at this time had two variants. One had an erasable EPROM program memory, with a transparent quartz window in the lid of the package to allow it to be erased by exposure to ultraviolet light. The other was a PROM variant which was only programmable once; sometimes this was signified with the designation OTP, standing for "one-time programmable".

The PROM was actually exactly the same type of memory as the EPROM, but because there was no way to expose it to ultraviolet light, it could not be erased. The erasable versions required ceramic packages with quartz windows, making them significantly more expensive than the OTP versions, which could be made in lower-cost opaque plastic packages. For the erasable variants, quartz was required, instead of less expensive glass, for its transparency to ultraviolet glass is largely opaque to UV but the main cost differentiator was the ceramic package itself.

The use of micro controller for speed control and protection of dc motor is presented in this paper. The peculiarity of this method is its adaptability to different ratings of motors. By using mechanical or electrical techniques, speed control of dc motor could be achieved. The speed controls of dc drives are mostly mechanical in the past and requiring large *size* hardware to implement. Advances in the area of power electronics have brought a total revolution in the speed control of dc drives.

This development has launched these drives back to a position of formidable relevance, which were hitherto predicted to give way to ac drives. These drives have now dominated the area of variable speed because of their low cost, reliability and simple control. DC drives are widely used in applications requiring adjustable speed; good speed regulation and frequent starting, braking and reversing. Some important applications are: rolling mills, paper mills mine winders, hoists, machine tools, traction, printing presses, textile mills, excavators and cranes. Fractional horsepower dc drives are widely employed -as servo means for positioning and tracking. [1]

By controlling armature or field excitation, adjustable speed drives may be operated over a wide range. Speeds below rated by armature voltage control and above rated using field excitation variation, development of various solid sates switching devices in the form of diodes, transistor and thyristor along with various analog digital chips used in firing controlling circuits, have made dc Drives more accessible for control in innumerable areas of applications. [2]

Every electric motor has to have some sort of controller. The motor controller will have differing features and complexity depending on the task that the motor will be performing. The simplest case is a switch to connect a motor to a power source, such as in small appliances or power tools. The switch may be manually operated or may be a relay or contactor connected to some form of sensor to automatically start and stop the motor. The switch may have several positions to select different connections of the motor. This may allow reduced-voltage starting of the motor, reversing control or selection of multiple speeds.

Overload and over current protection may be omitted in very small motor controllers, which rely on the supplying circuit to have over current protection. Small motors may have built-in overload devices to automatically open the circuit on overload. Larger motors have a protective overload relay or temperature sensing relay included in the controller and fuses or circuit breakers for over current protection. An automatic motor controller may also include limit switches or other devices to protect the driven machinery. A motor controller is a device or group of devices that serves to govern in some predetermined manner the performance of an electric motor.[3]

More complex motor controllers may be used to accurately control the speed and torque of the connected motor (or motors) and may be part of closed loop control systems for precise positioning of a driven machine. For example, a numerically controlled lathe will accurately position the cutting tool according to a preprogrammed profile and compensate for varying load conditions and perturbing forces to maintain tool position. A motor controller might include a manual or automatic means for starting and stopping the motor, selecting forward or reverse rotation, selecting and regulating the speed, regulating or limiting the torque, and protecting against overloads and faults. [4]

2.4 Pulse Width Modulation

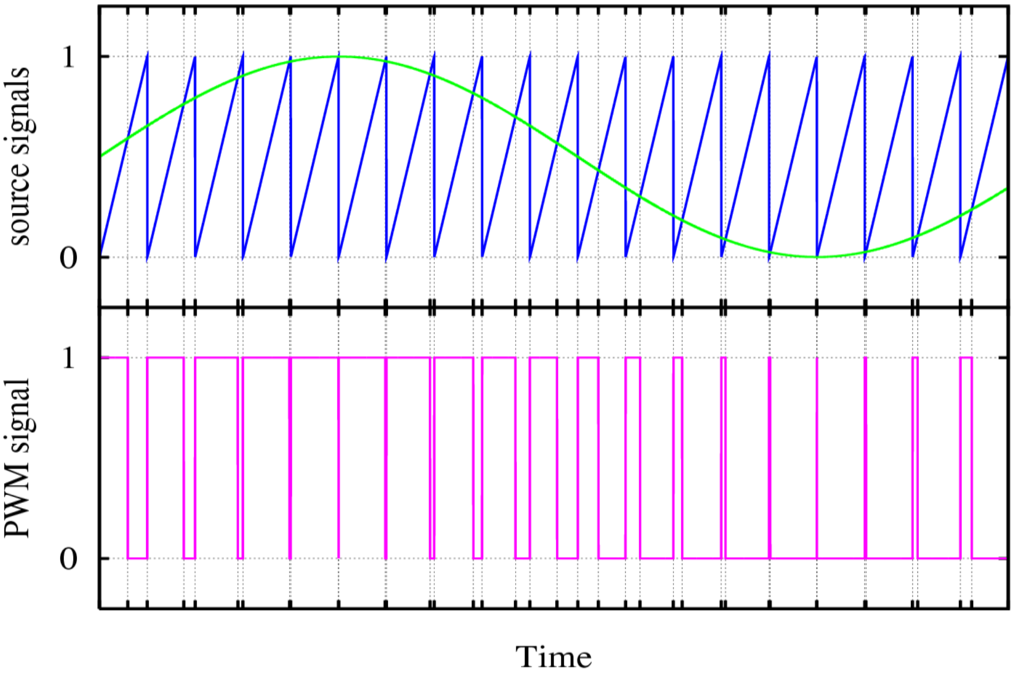

Figure 2.2: Pulse Width Modulation Signal

Source: www.wikipedia.org

Pulse-width modulation (PWM), or pulse-duration modulation (PDM), is a modulation technique that conforms the width of the pulse, formally the pulse duration, based on modulator signal information. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors.The use of stand-alone micro controller for the speed control of DC motor is past gaining ground. Nicolai and Castagnct have shown in their paper how a micro controller can be used for speed control. The operation of the system can be summarized as: the drive form a rectified voltage, it consists of chopper driven by a PWM signal generated from a micro controller unit (MCU). The motor voltage control is achieved by measuring the rectified mains voltage with the analog to-digital converter present on the micro controller and adjusting the PWM signal duty cycle accordingly. [5]

The term *duty cycle* describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on. The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. In the past, when only partial power was needed (such as for a sewing machine motor), a rheostat (located in the sewing machine's foot pedal) connected in series with the motor adjusted the amount of current flowing through the motor, but also wasted power as heat in the resistor element. It was an inefficient scheme, but tolerable because the total power was low. This was one of several methods of controlling power.

There were others—some still in use—such as variable autotransformers, including the trademarked 'Autrastat' for theatrical lighting; and the Variac, for general AC power adjustment. These were quite efficient, but also relatively costly. PWM can be used to control the amount of power delivered to a load without incurring the losses that would result from linear power delivery by resistive means.

Potential drawbacks to this technique are the pulsations defined by the duty cycle, switching frequency and properties of the load. With a sufficiently high switching frequency and, when necessary, using additional passive electronic filters, the pulse train can be smoothed and average analog waveform recovered.High frequency PWM power control systems are easily realisable with semiconductor switches. As explained above, almost no power is dissipated by the switch in either on or off state. However, during the transitions between on and off states, both voltage and current are nonzero and thus power is dissipated in the switches. By quickly changing the state between fully on and fully off (typically less than 100 nanoseconds), the power dissipation in the switches can be quite low compared to the power being delivered to the load.

For about a century, some variable-speed electric motors have had decent efficiency, but they were somewhat more complex than constant-speed motors, and sometimes required bulky external electrical apparatus, such as a bank of variable power resistors or rotating converter such as Ward Leonard drive. However, in addition to motor drives for fans, pumps and robotic servos, there was a great need for compact and low cost means for applying adjustable power for many devices, such as electric stoves and lamp dimmers. One early application of PWM was in the Sinclair X10, a 10 W audio amplifier available in kit form in the 1960s. At around the same time PWM started to be used in AC motor control. [6]

2.5 Speed Control DC Motor Using Microcontroller

Now a days, automatic control systems are used widely to minimize the human errors and increase the production rate with good quality. So most of the machines used in production stream uses induction motors with variable speeds. Using analog methods we can vary the speed, but they are not accurate because of the tolerance of the devices, and also the circuit is complex.

There is a lot of method in controlling DC motor speed, for example Multiple Voltage Control and Ward-Leonard System. In Multiple voltage control method, , the shunt field of the motor is connected permanently to a fixed exciting voltage, but the armature is supplied with different voltages by connecting it across one of the several different voltages by means of suitable switchgear. The armature speed will be approximately proportional to these different voltages. The intermediate speeds can be obtained by adjusting the shunt field regulator.

On the other hands, Ward-Leonard System is used where an unusually wide and very sensitive speed control is required as for colliery winders, electric excavators, elevators and the main drives in steel mills and blooming and paper mills. M1 is the main motor whose speed control is required. The field of this motor is permanently connected across the dc supply lines. By applying a variable voltage across its armature, any desired speed can be obtained. This variable voltage is supplied by a motor-generator set which consists of either a dc or an ac motor M2directly coupled to generator G. The motor M2 runs at an approximately constant speed. The output voltage of G is directly fed to the main motorM1. The voltage of the generator can be varied from zero up to its maximum value by means of its field regulator. By reversing the direction of the field current of G by means of the reversing switch RS, generated voltage can be reversed and hence the direction of rotation of M1. It should be remembered that motor generator set always runs in the same direction

Figure 2.3: Arduino Uno

Source: www.arduino.cc

In order to meet higher performance and reliability requirements, the electric drive systems used in industrial applications are increasingly. The DC motor is an attractive place of equipment in many industrial applications requiring variable speed and load characteristics due to its ease of controllability. Microcontrollers provide a suitable means of meeting these needs. Certainly, part of the recent activity on microcontrollers can be ascribed to their newness and challenge. In this project use microcontroller as controller for the speed controller use PIC.

Another system that uses a microprocessor is reported in the work is reported in journal a brief description the system is as follow: The microprocessor computes the actual speed of the motor by sensing the terminal voltage and the current, it then compares the actual speed of the motor with the reference speed and generates a suitable control signal which is fed into triggering unit.

A simple form of speed control is achieved through a variable potentiometer for a manually controlled system; the operator mentally compares the actual speed to a desired speed and sets the potentiometer accordingly. A simple form of speed control is achieved through a variable potentiometer for a manually controlled system; the operator mentally compares the actual speed to a desired speed and sets the potentiometer accordingly. Updated on the CRT screen each second to a desired speed, he/she corrects the current speed by rotating the potentiometer clockwise to increase or counterclockwise to reduce the speed, by comparing the speed in revolution per seconds (rps). [7]

2.6 Analog to Digital Converter

An analog-to-digital converter (abbreviated ADC, A/D or A to D) is a device that converts a continuous physical quantity (usually voltage) to a digital number that represents the quantity's amplitude. The conversion involves quantization of the input, so it necessarily introduces a small amount of error. The inverse operation is performed by a digital-to-analog converter (DAC). Instead of doing a single conversion, an ADC often performs the conversions ("samples" the input) periodically. The result is a sequence of digital values that have converted a continuous-time and continuous-amplitude analog signal to a discrete-time and discrete-amplitude digital signal.

An ADC is defined by its bandwidth (the range of frequencies it can measure) and its signal to noise ratio (how accurately it can measure a signal relative to the noise it introduces). The actual bandwidth of an ADC is characterized primarily by its sampling rate, and to a lesser extent by how it handles errors such as aliasing. The dynamic range of an ADC is influenced by many factors, including the resolution (the number of output levels it can quantize a signal to), linearity and accuracy (how well the quantization levels match the true analog signal) and jitter (small timing errors that introduce additional noise). The dynamic range of an ADC is often summarized in terms of its effective number of bits (ENOB), the number of bits of each measure it returns that are on average not noise. An ideal ADC has an ENOB equal to its resolution. ADCs are chosen to match the bandwidth and required signal to noise ratio of the signal to be quantized. If an ADC operates at a sampling rate greater than twice the bandwidth of the signal, then reconstructions possible given an ideal ADC and neglecting quantization error. The presence of quantization error limits the dynamic range of even an ideal ADC, however, if the dynamic range of the ADC exceeds that of the input signal, its effects may be neglected resulting in an essentially perfect digital representation of the input signal.

Recently, a fully digital approach to generate a test stimulus by PWM used for high resolution ADCs has been reported with a focus on static test [8]. The advantage of this technique is that a 1-bit data pulse train can convey the wanted test signal without harmonic distortions that is particularly attractive for on-chip test. This is in contrast to the true analog techniques or DA conversion based techniques implemented on a chip, where the spectral purity of the generated signals can be difficult to guarantee.

The other technique, i.e. uniform-PWM is relatively simpler to implement digitally but suffers from harmonic distortion components of the modulating signal. Different algorithmic approaches have been reported to reduce the harmonic content and improve SNR, including enhanced sampling process [9]

2.7 Model of Separately exited DC motor

Figure 2.4 shows a model of separately excited DC motor [10]. When a separately excited motor is excited by a field current of I_f and an armature current of I_a flows in the circuit, the motor develops a back EMF and a torque to balance the load torque at a particular speed. The I_f is independent of the I_a. Each winding are

supplied separately. Any change in the armature current has no effect on the field current. The I_f is normally much less than the I_a. The relationship of the field and armature are shown in Equation 2.1.

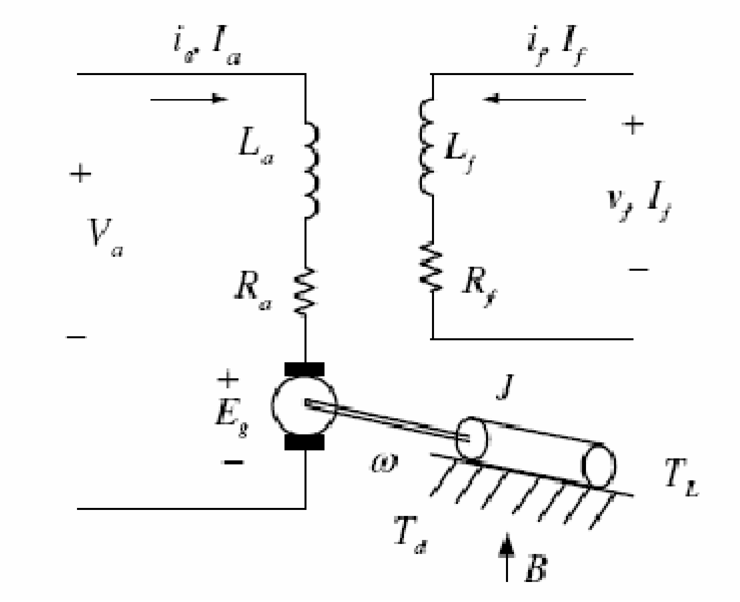

Figure 2.4 Model of separately excited DC motor

Source: www.wikipedia.org

Instantaneous field current:

$$vf = Rfif + Lf\ \frac{dif}{dt} \tag{2.1}$$

where R_f and L_f are the field resistor and inductor respectively.

Instantaneous armature current:

$$Va = RaIa + La\ \frac{dia}{dt} + e_g \tag{2.2}$$

where R_a and L_a are the armature resistor and inductor respectively.

The motor back EMF which is also known as speed voltage is expressed as

$$e_g = K_v\ wi_f \tag{2.3}$$

where K_v is the motor constant (in V/A-rad/s) and *w* is the motor speed (rad/s).

The torque developed by the motor is

$$Td = K_t \varnothing i_f \tag{2.4}$$

where (K_t=K_v) is the torque constant (in V/A-rad/s).

Sometimes it is written as:

$$Td = K_t \varnothing i_f \tag{2.5}$$

For normal operation, the developed torque must be equal to the load torque plus the friction and inertia, i.e.:

$$Td = J\frac{dw}{dt} + Bw + T_L \tag{2.6}$$

where B = viscous friction constant (N.m/rad/s)

T_L = load torque (N.m)

J = inertia of the motor (kg.m^2)

Under steady-state operations, a time derivative is zero. Assuming the motor is not saturated.

For field circuit,

$$V_f = I_f \; R_f \tag{2.7}$$

The back EMF is given by:

$$E_g = K_v \, w \, I_f \tag{2.8}$$

The armature circuit,

$$V_a = I_a \, R_a + E_g = I_a \, R_a + K_v \, wI_f \tag{2.9}$$

The motor speed can be easily derived:

$$w = \frac{V_a - I_a \, R_a}{K_v \, I_f} \tag{2.10}$$

If R_a is a small value (which is usual), or when the motor is lightly loaded, i.e. I_a is small,

$$w = \frac{V_a}{K_v \, I_f} \tag{2.11}$$

That is if the field current is kept constant, the speed motor speed depends on the supply voltage. These observation leads to the *application of variable DC voltage to control the speed* and torque of DC motor.

2.8 Speed Measurement of DC Motor

To start with this project, we need a device that will measure the speed of the motor shaft. There are several methods which can use to measure the speed of motor. Here, we will only discuss about speed measurement by using tachometer and optical encoder.

2.8.1 Speed Measurement by Using Tachometer

Tachometer is an instrument that measure speed motor based on concept of back EMF induced in motor when it is running. The EMF is voltages appear on the commutator segments caused by rotated in the magnetic field by some external force.

The magnitude of the EMF is given by [10],

$$EMF = K_E \emptyset N \tag{2.12}$$

where K_E = a constant based on motor construction

φ = magnetic flux

N = speed of motor (in rpm)

The actual relationship between motor speed and EMF follows and is derived from Equation 2.12,

$$N = \frac{EMF}{K_E \emptyset} \tag{2.13}$$

Thus, the motor speed is directly proportional to the EMF voltage ad inversely proportional to the field flux. For permanent magnet DC motor, when the EMF measured is increases, the speed of the motor is also increases with the gain. So, the speed of motor can be measured by measuring the back EMF using tachometer.

2.9 Microcontroller

Microcontrollers must contain at least two primary components – random access memory (RAM), and an instruction set. RAM is a type of internal logic unit that stores information temporarily. RAM contents disappear when the power is turned off. While RAM is used to hold any kind of data, some RAM is specialized, referred to as registers. The instruction set is a list of all commands and their corresponding functions. During operation, the microcontroller will step through a program (the firmware). Each valid instruction set and the matching internal hardware that differentiate one microcontroller from another [11].

Most microcontrollers also contain read-only memory (ROM), programmable read-only memory (PROM), or erasable programmable read-only memory (EPROM). Al1 of these memories are permanent: they retain what is programmed into them even during loss of power. They are used to store the firmware that tells the microcontroller how to operate. They are also used to store permanent lookup tables. Often these memories do not reside in the microcontroller; instead, they are contained in external ICs, and the instructions are fetched as the microcontroller runs. This enables quick and low-cost updates to the firmware by replacing the ROM.

Where would a microcontroller be without some way of communicating with the outside world? This job is left to input/output (I/O) port pins. The number of I/O pins per controllers varies greatly, plus each I/O pin can be programmed as an input or output (or even switch during the running of a program). The load (current draw) that each pin can drive is usually low. If the output is expected to be a heavy load, then it is essential to use a driver chip or transistor buffer.

Most microcontrollers contain circuitry to generate the system clock. This square wave is the heartbeat of the microcontroller and all operations are synchronized to it. Obviously, it controls the speed at which the microcontroller functions. All that needed to complete the clock circuit would be the crystal or RC components. We can, therefore precisely select the operating speed critical to many applications.

To summarize, a microcontroller contains (in one chip) two or more of the following elements in order of importance [12]:

i. Instruction set

ii. RAM

iii. ROM,PROM or EPROM

iv. I/O ports

v. Clock generator

vi. Reset function

vii. Watchdog timer

viii. Serial port

ix. Interrupts

x. Timers

xi. Analog-to-digital converters

xii. Digital-to-analog converters

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will cover the details explanation of methodology that is being used to make this project complete and working well. A good explanation will give more information about how the methodology can accomplish a perfect result. Methodology is very important because it can influence the result. DC motor speed controller project is consist hardware and software development.

3.2 Research Methodology

Conclude research to make the project much easier to understand then easily to integrate from hardware development into software development. Research methodology also shows the basic or maybe full concepts of the how the system is works. Figure 3.1 show design concepts of research methodology.

i. Literature Review to understand the concepts and functional of the project.
ii. Understand the whole system of hardware and software in sequences.

iii. Design the circuit and build the program.
iv. Testing the system functional.
v. Combining of both software and hardware system.

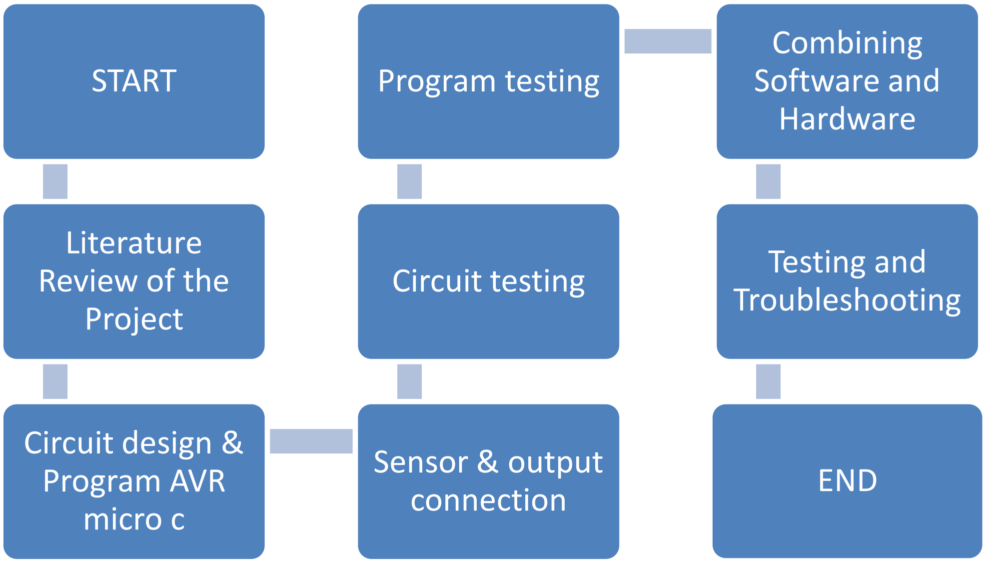

Figure 3.1: Design Step of work methodology

3.3 Hardware Implementation

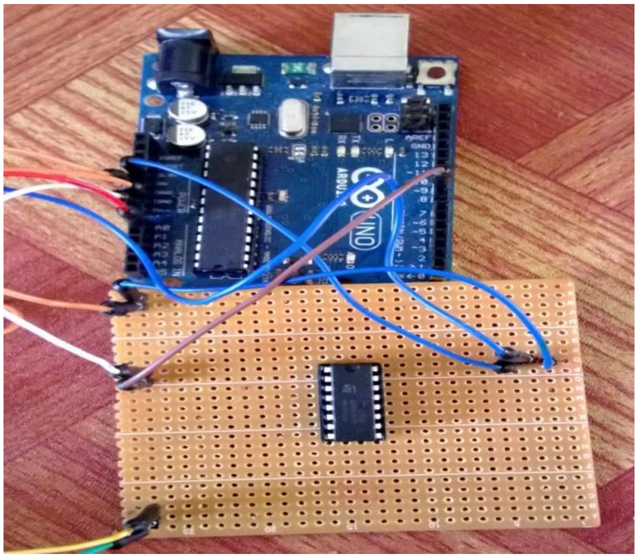

Figure 3.2: Motor Driver L293D connect with Arduino Uno

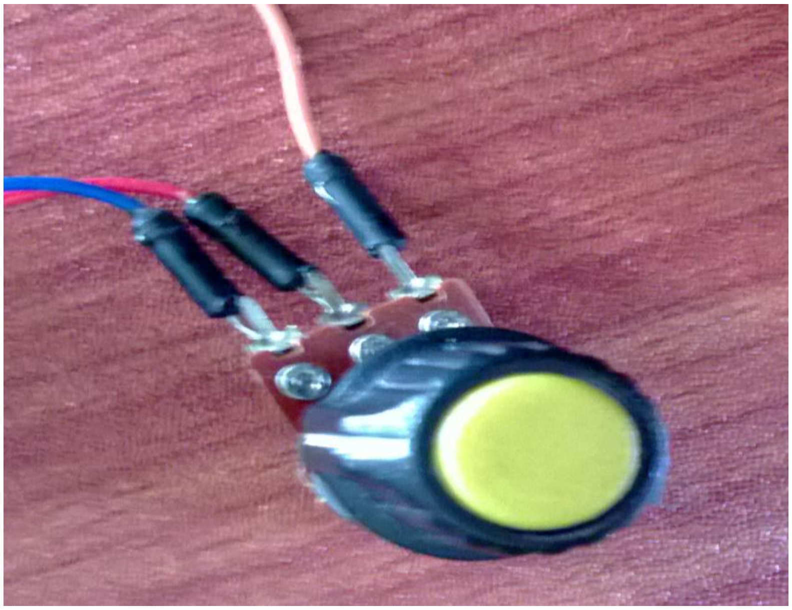

Figure 3.3: POT10k, command connect A0, blue 5V, orange ground

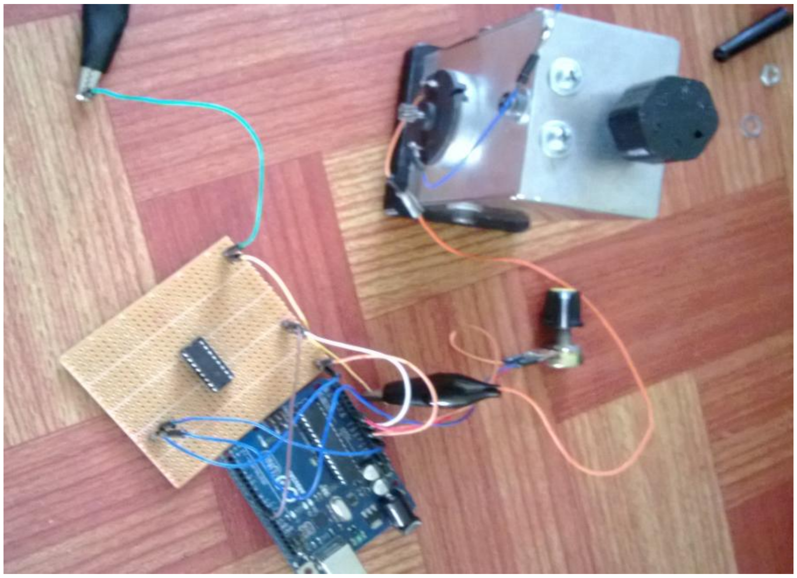

Figure 3.4: Connection of real circuit connect with shaker machine

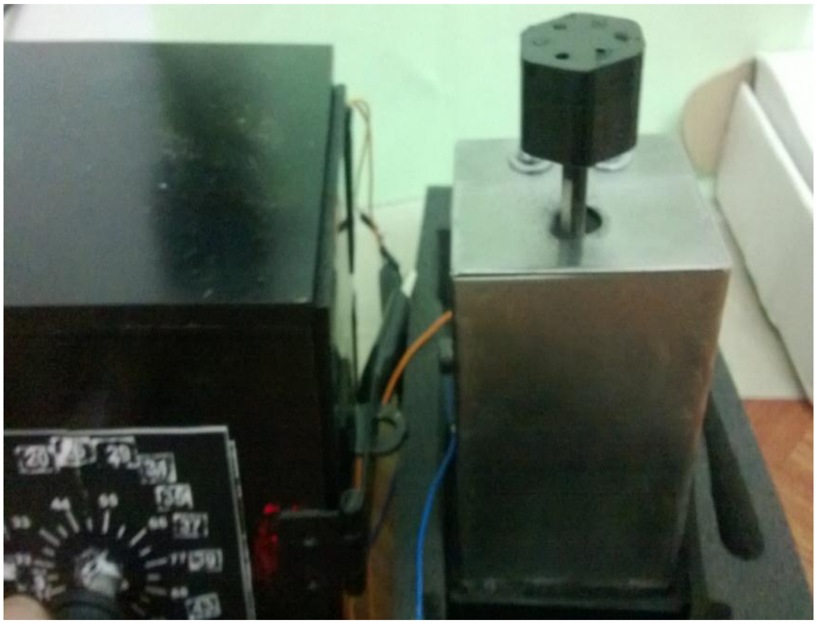

Figure 3.5: Combination with Shaker Machine

3.3.1 Wire/ cable configuration

Blue wire 5V

Brown wire PWM pin no 9

White wire 12V

Orange wire ground

Red wire PWM A0 connect with command pin potentiometer

Yellow wire DC Motor positive

Green wire DC Motor negative

3.3.2 Connection L293D and Arduino

Connect one pin from your pot to 5V, the center pin to analog pin 0, and the remaining pin to ground. Next, connect a pin no 2 L293D to digital pin 9. After declaring two pin assignments (analog 0 for your potentiometer and digital 9 PWM signal) and two variables, sensorValue and outputValue, the only thing that you do will in the setup function is to begin serial communication. Next, in the main loop of the code, sensorValue is assigned to store the raw analog value coming in from the potentiometer. Because the Arduino has an analogRead resolution of 0-1023, and an analogWrite resolution of only 0-255, this raw data from the potentiometer needs to be scaled before using it to on and of the DC motor. In order to scale this value, use a function called map.

```
outputValue = map(sensorValue, 0, 1023, 0, 255);
```

outputValue is assigned to equal the scaled value from the potentiometer. Map() accepts five arguments: The value to be mapped, the low range and high range of the raw data, and the low and high values for that data to be scaled too. In this case, the sensor data is mapped down from its original range of 0 to 1023 to 0 to 255.

The newly mapped sensor data is then output to the analogOutPin on or of the DC motor as the potentiometer is turned. Finally, both the raw and scaled sensor values are sent to the Arduino serial window in a steady stream of data.

The hardware consists of potentiometer acts as a sensor, motor driver L293, 12V dc motor, an Arduino Uno microcontroller which have built 328ATMega Microcontroller. The selection of components is the most important thing need to be considered in hardware module. Functionality and the characteristic of each component is important in design new product. Material selection is a step in the process of designing any physical object. In the context of product design, the main goal of material selection is to minimize cost while meeting product performance goals.

3.4 Software Development

For the software development part, most likely involves in simulation, such as Matlab, Multisim, Pspice, Proteus, C-programming, or any other tools to perform this operation. The type of software development will discuss in this topic.

```
// Analog input, analog output, serial output

 Reads an analog input pin, maps the result to a range from 0 to 255
 and uses the result to set the pulsewidth modulation (PWM) of an output pin.


Also prints the results to the serial monitor.

 The circuit:
 * potentiometer connected to analog pin 0.
   Center pin of the potentiometer goes to the analog pin.
   side pins of the potentiometer go to +5V and ground
 * pin no#2 L293 connected to digital pin PWM no# 9
```

3.5 Block Diagram

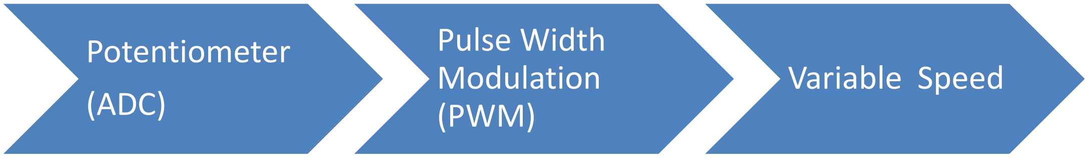

Figure 3.6: Block Diagram

For the circuit input, potentiometer act as a sensor which is come in analog output that is provide analog signal to the circuit or any device that used potentiometer. Then, the signal need to convert from analog to digital signal using Analog to Digital Converter (ADC). After that the, digital signal that will be sampling or mapping which is resulting certain range to be manipulate. Next, at this stage, Pulse Width Modulation (PWM) received digital signal from the potentiometer which is allow potentiometer to control Duty cycle. Duty cycle is the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on. See figure 3.2 for general concept for this type of controller.

3.5.1 Analog to digital Converter

An ADC is defined by its bandwidth (the range of frequencies it can measure) and its signal to noise ratio (how accurately it can measure a signal relative to the noise it introduces). The actual bandwidth of an ADC is characterized primarily by its sampling rate, and to a lesser extent by how it handles errors such as aliasing. The dynamic range of an ADC is influenced by many factors, including the resolution (the number of output levels it can quantize a signal to), linearity and accuracy (how well the quantization levels match the true analog signal) and jitter (small timing errors that introduce additional noise).

Analog-to-digital conversion (ADC) is necessary because, while embedded systems deal with digital values, their surroundings typically involve many analog signals such as, temperature, speed, pressure, the output of a microphone, etc. They all need to be converted into digital data before being processed by the microcontroller. Today, we will see how to read an external analog signal using a AVR microcontroller, and display the conversion output (a digital number) on a serial monitor. The input analog signals will be a varying voltage between 0-5V derived using a potentiometer. Vary the potentiometer and you will see the 10-bit conversion result also vary proportionally from 0- 1023.

3.5.2 Pulse Width Modulation Technique

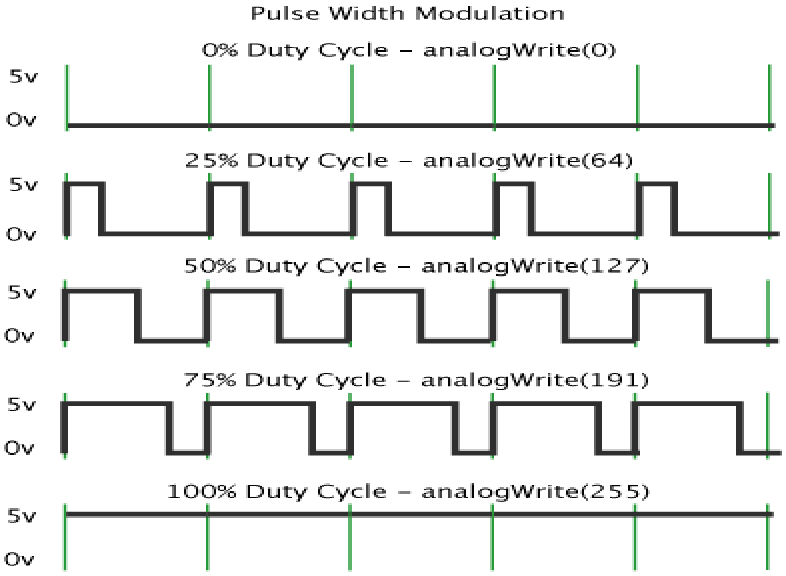

Figure 3.7: Variable Duty Cycle from PWM

Source: www.wikipedia.org/digitalsignalprocessing

Pulse Width Modulation, or PWM, is a technique for getting analog results with digital means. Digital control is used to create a square wave, a signal switched between on and off. This on-off pattern can simulate voltages in between full on (5 Volts) and off (0 Volts) by changing the portion of the time the signal spends on versus the time that the signal spends off. The duration of "on time" is called the pulse width. To get varying analog values, the pulse width has to be change or modulate. If this repeat in on-off pattern fast enough with an DC motor, the result is as if the signal is a steady voltage between 0 and 5v controlling the speed of the DC motor. In the Figure 3.7 above, the green lines represent a regular time period. This duration or period is the inverse of the PWM frequency. In other words, with Arduino's PWM frequency at about 500Hz, the green lines would measure 2 milliseconds each. A call to analogWrite() is on a scale of 0 - 255, such that analogWrite(255) requests a 100% duty cycle (always on), and analogWrite(127) is a 50% duty cycle (on half the time) for example.

3.6 Motor Driver

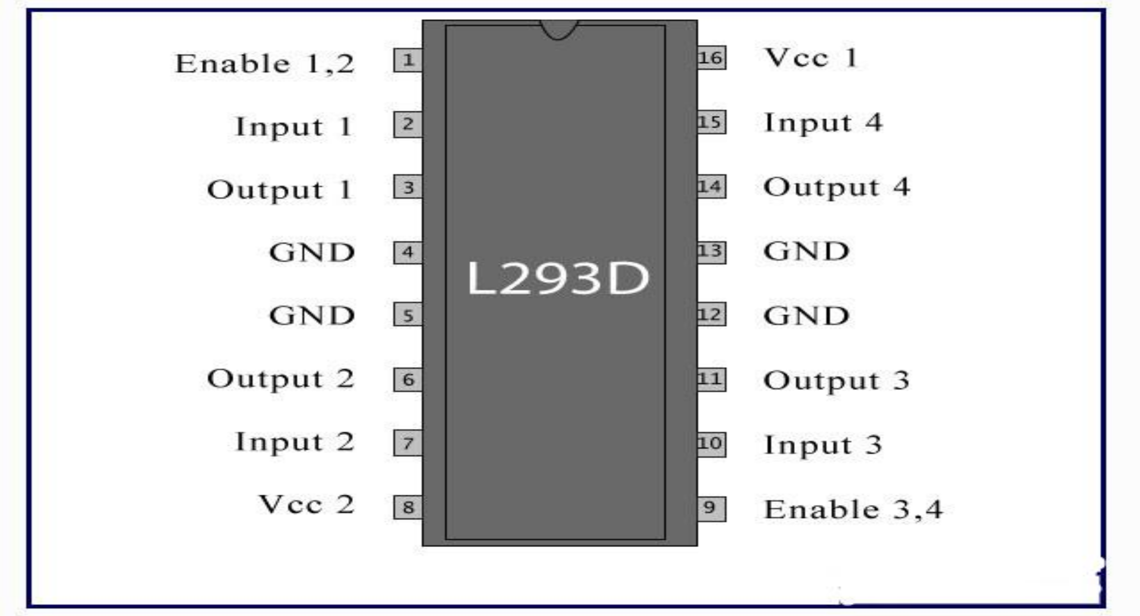

Figure 3.8: Pin L293D Motor Driver

Source: www.alldatasheet.com

Arduino cannot supply the necessary current to drive a motor directly although the DC motor can operate at 5V or less. The microcontroller only can supply a minimum current to any practical DC motor but it is not enough to operate by microcontroller. Depending on the size and rating of the motor, a suitable driver must be selected to take control signals from the microcontroller and deliver the necessary voltage and current to the motor.

The drive motor used in this project is L293D which a standard motor driver and available in many current and voltage rating. This motor driver maximum current is 1A and has four channels. The pin assignment and block diagram of L293D are shown in Figure 3.8. There are two supply voltages: $V_{cc\,1}$ and V_c. $V_{cc\,1}$ is the logic supply voltage, which can be from 4.5 to 36V. V_c is the analog supply voltage and can be as high as 36V.

For this case pin no 1 connect to 12v,pin no 2 connect to pin 9 digtal PWM, pin no 3 connect to Dc Motor Positive, pin no 4,5,12 & 13 connect to ground, pin no 6 connect to DC Motor Negetive, pin no 8 &16 connect to 5V.

3.7 Relationship between speed and frequency

$$1\text{hertz} = 1\text{revolution/second} \quad (3.1)$$

$$1\text{hertz} = 60\text{revolution/minute} \quad (3.2)$$

$$1\text{hertz} = 376.99112\text{radian/minute} \quad (3.3)$$

$$1\ \text{hertz} = 1\ 1/\text{second} \quad (3.4)$$

Figure 3.9: Formula for Frequency to RPM

Frequency is the measurement of the number of occurrences of a repeated event per unit of time. It is also defined as the rate of change of phase of a sinusoidal waveform. In SI units, the result is measured in hertz (Hz), named after the German physicist Heinrich Hertz. 1 Hz means that an event repeats once per second, 2 Hz is twice per second, and so on. This unit was originally called a cycle per second (cps), which is still sometimes used. Other units that are used to measure frequency include revolutions per minute (rpm). Heart rate and musical tempo are measured in beats per minute (BPM). Often, angular frequency is used instead of frequency, measured in radians per second (rad/s).

3.8 Conclusion

From this chapter, it can be conclude that the selection of DC motor characteristic are necessary to be done, so that the specification of the motor to be choose for the shaker machine is compatible with the purpose of the controller will be control. The type of method to control DC motor also need to determined and selected the controller, for this project PWM techniques is selected method to change the speed of DC Motor. By the way, method to done also must be conducted before experiments been done, this because, it important to know the result and do the analysis.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter discusses the results, finding and the analysis of the project. The result of this chapter is related to the chapter 3, all the method that used in this chapter was stated in chapter 3. Result of this chapter was included the theoretical analysis which based on the assumption and calculation. Then, the analysis based on the journal also been done in this chapter by using software. The result of analysis then validated with the result in the journal. The outcome of this research will be discussed in detail by the next topic.

4.2 Result and Finding

Table 4.1: Relationship between Duty Cycle vs Frequency

Duty cycle (%)	**Frequencies (HZ)**
100	**45.8**
95	**44**
90	**43**
85	**42**
80	**40**
75	**39**
70	**37**
65	**35**
60	**31**

55	**29**
50	**26**
45	**20**
40	**15**
35	**12**
30	**10**
25	**9**
20	**7**
15	**6**

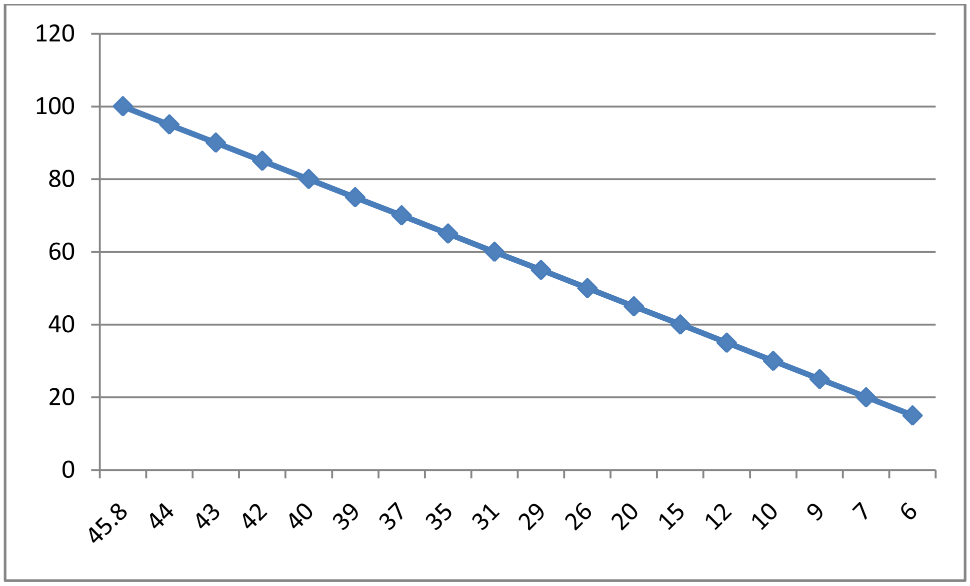

Figure 4.1: Graph relationship between duty Cycle and Frequency

From the result show see table 4.1, at 15% and above, duty cycle the frequency start to rise up. Or in other words at 15% and above the DC motor will start operate, lower than 15% DC motor not function. The lower frequencies that the DC motor can operate are 6Hz which come out from 15% Duty Cycle. While for 50% Duty Cycle the frequencies of DC motor are 26HZ. The higher frequencies that the DC motor can operate are 45.8Hz which is can get from the 100% duty cycle. 45.8Hz comes from the speed of DC motor which is 2748PRM. To change RPM to frequencies just divide by 60.

$$frequency = RPM/60 \;\; \ldots . \qquad (4.1)$$

So the relationship might be come up is the higher duty cycle the bigger frequency produce.

4.2.1 Triangle wave

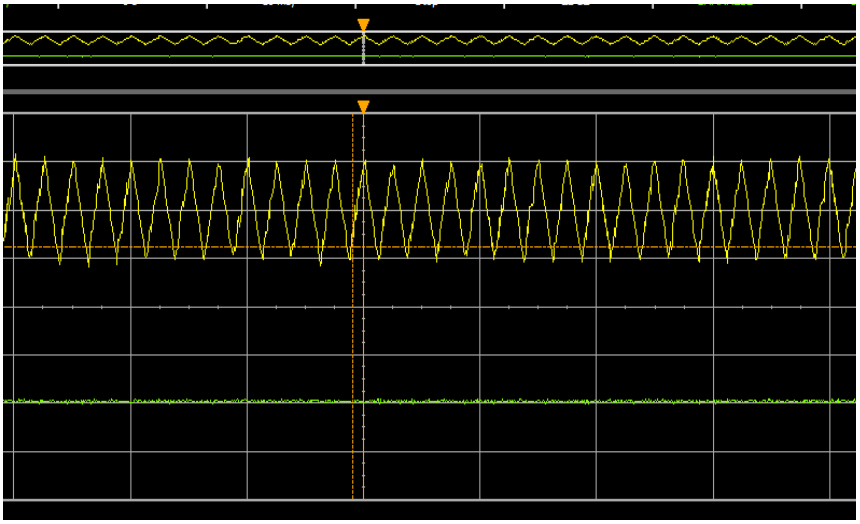

Figure 4.2: Triangle wave

A triangle wave is a non-sinusoidal waveform named for its triangular shape. It is a periodic, piecewise linear, continuous real function. Like a square wave, the triangle wave contains only odd harmonics. However, the higher harmonics roll off much faster than in a square wave (proportional to the inverse square of the harmonic number as opposed to just the inverse). See fig 4.2.

4.2.2 Pulse Width Modulation (Comparator)

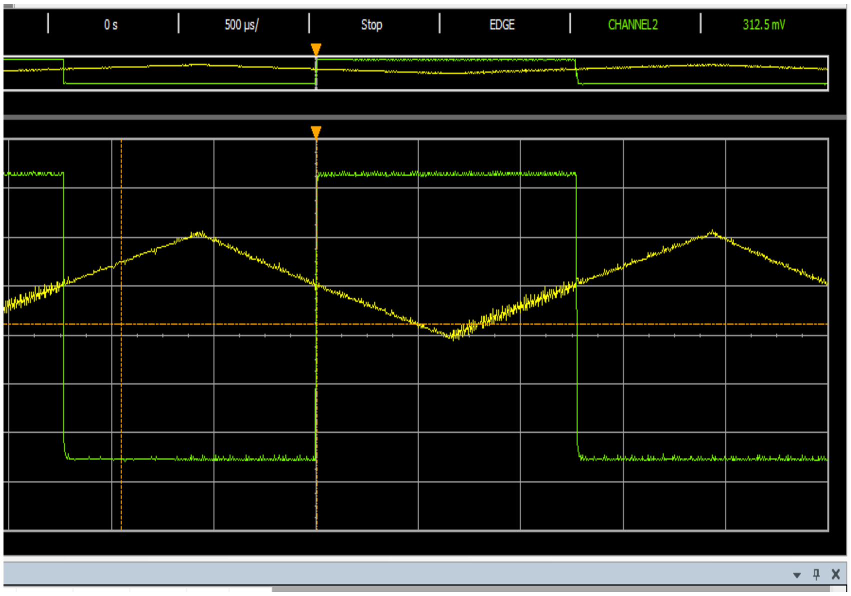

Figure 4.3: PWM signal

The comparator output is high when *v* is higher than the *v*– input voltage of the last op-amp. The value of *v*– is set by potentiometer. Note that the potentiometer creates a voltage divider. Adjusting potentiometer changes the voltage at the *v*– input. In Fig. 4.3, the voltage is shown as 1 V. The higher the value of *v*–, the shorter the time *v*3 stays high.

4.2.3 PWM (Duty Cycle: 52%)

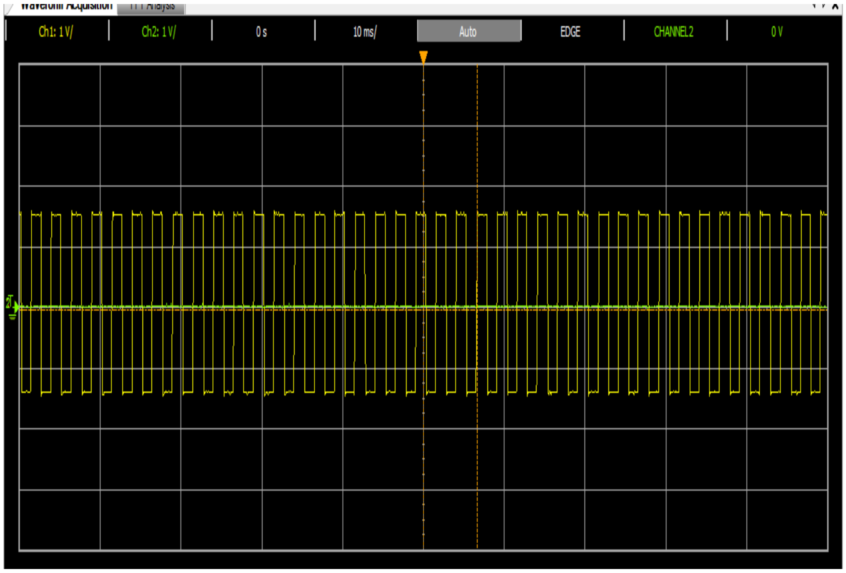

Figure 4.4: PWM (Duty Cycle:52%)

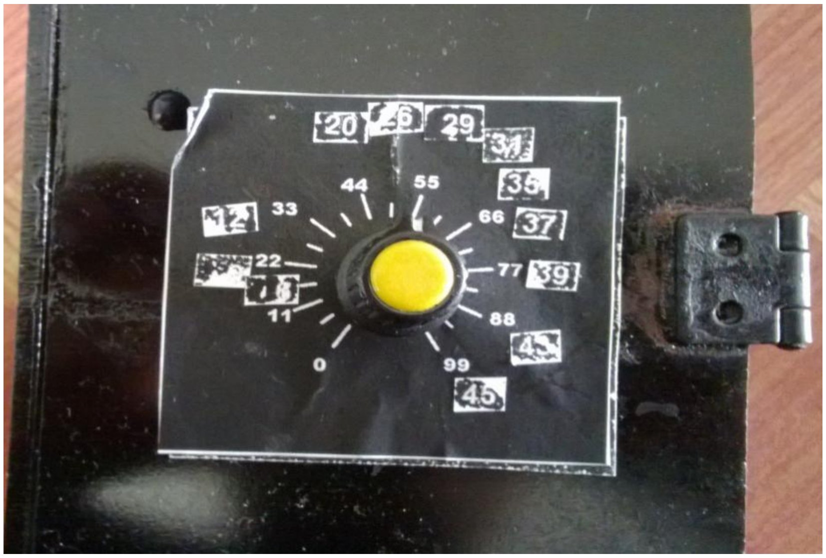

Figure 4.5: POT adjust to 52% Duty Cycle

DC motor will speed at 1620PRM from the equation (1) the frequency get is 27Hz at 52% Duty cycle. Ton is 52% while Toff is 48%.

4.2.4 PWM (Duty Cycle:99%)

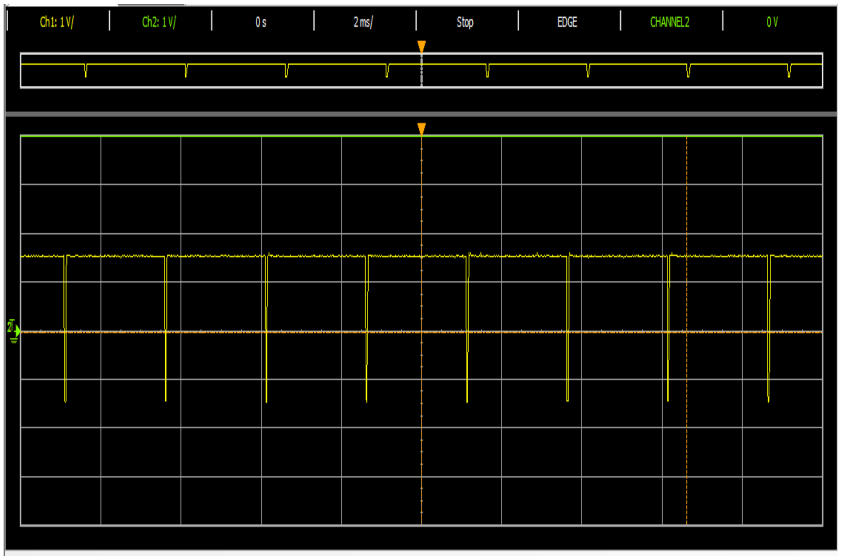

Figure 4.6: PWM (Duty Cycle:99%)

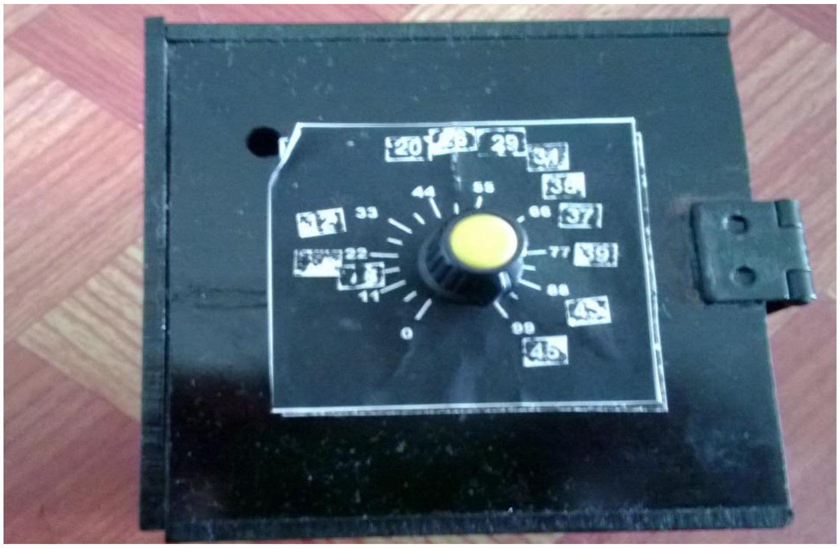

Figure 4.7: POT adjust to 99% Duty Cycle

The DC motor operates ideally closely to idea mode which is 100% Duty Cycle. DC motor will speed at 2700PRM from the equation (1) the frequency get is 45Hz at 99% Duty cycle. Ton is 99% while Toff is 1%

4.2.5 PWM (Duty Cycle:1%)

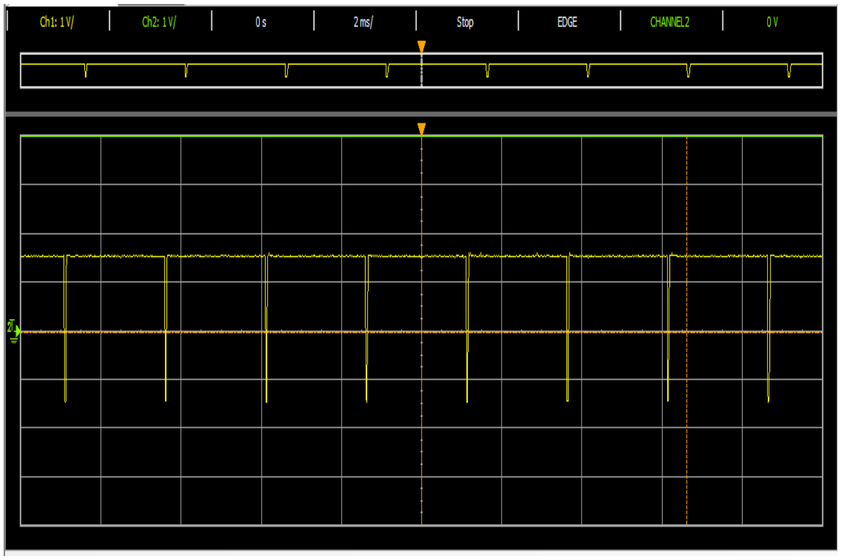

Figure 4.8: PWM (Duty Cycle 1%)

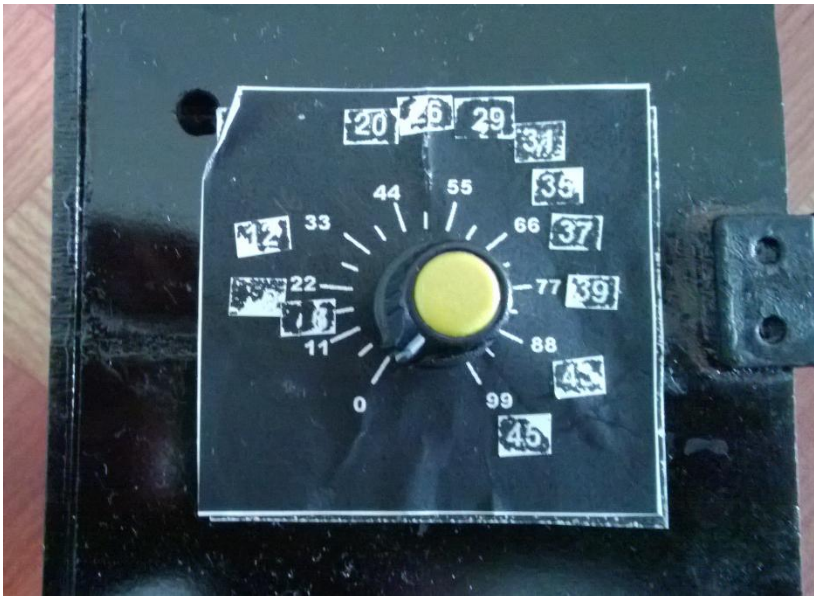

Figure 4.9: POT adjust to 1% Duty Cycle approximately to 0% Duty cycle

The DC motor operates inideally closely to idea mode which is 0% Duty Cycle. DC motor will speed at 0PRM from the equation (1) the frequency get is 0Hz at 1% Duty cycle. Ton is 1% while Toff is 99%.

4.2.6 PWM (Duty Cycle 15%)

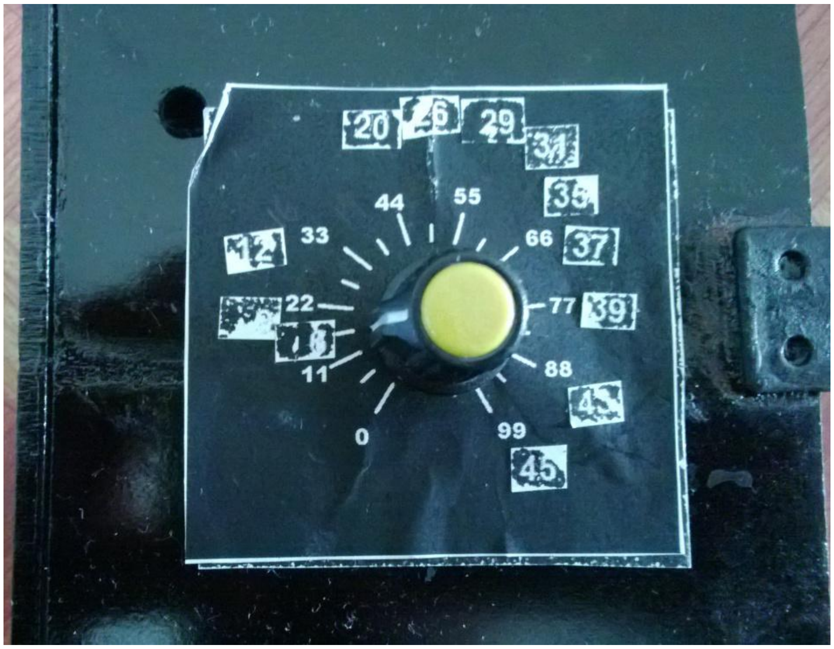

Figure 4.10: POT adjust to 15% Duty Cycle

At this section, the DC Motor start operate and raise up the frequency until it not less than 15% Duty cycle. Where at this point, the speed of Dc Motor is 900RPM or in other word produce 6Hz of frequency.

4.3 Conclusion

The result that was obtained from the experiment shows that the PWM change the Duty Cycle of certain period of time. Analog signal from the potentiometer will adjust the width certain period of time. For example if Ton is 98%, Toff is 2% so the motor will run at the high speed. Otherwise if Ton is 2% and Toff is 98% the speed of motor will run low. Constant speed, and have fast start up process which make the time for shaker machine to move from rest is short. The theoretical analysis result yield of PWM signal. All the result are validated based on the journal that used as references.

CHAPTER 5

CONCLUSION AND RECOMENDATION

5.1 Introduction

This chapter provides finding on this project. Future development and recommendation are noted as a topic in this chapter for enhancement of knowledge in continuing this analysis and research about the DC motor speed controller. Research that have been done also have a weakness or either mistakes. This because analysis just based on the software and assumption which not related with hardware.

5.2 Conclusion

The PWM switching frequency has to be much faster than what would affect the load, which is to say the device that uses the power. Typically switchings have to be done several times a minute in an electric stove, 120 Hz in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

The term *duty cycle* describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on.

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle. So as conclusion the higher the number of duty cycles the bigger frequency.

5.3 Recommendation

There is some improvement that can be done on this machine. For current project, the controller can control DC Motor successfully run in the desire frequency need, interface with computer are recommended for future development of this controller. Visual basic and parallel port might be the simplest term that can be integrate with the controller. It is strongly recommended that things were highlight before is added to the machine and also make this machine do a specific several task.

REFERENCES

[1] Gopal K. Dubey, “Fundamentals of Electric Drives”, .Narosa Publishing House New Delhi, 1989.

[2] Kumara MKSC, Dayananda PRD, Gunatillaka MDPR, Jayawickrama SS, “PC based speed controlling of a dc motor”, A final year report University of Moratuwa Illiniaus USA, 2001102.

[3] National Fire Protection Association (2008). *NFPA 70 National Electrical Code*. 1 Batterymarch Park, Quincy, MA 02169: NFPA. p. 24. Retrieved January 2008.

[4] Siskind, Charles S. (1963). *Electrical Control Systems in Industry*. New York: McGraw-Hill, Inc. ISBN 0-07-057746-3.

[5] J Nicolai T Castagnet , “A Flexible Micro controller Based Chopper Driving a Permanent Magnet DC Motor”, The European Power Electronics Application. 1993.

[6] Schönung, A.; Stemmler, H. (August 1964). "Geregelter Drehstrom-Umkehrantrieb mit gesteuertem Umrichter nach dem Unterschwingungsverfahren". *BBC Mitteilungen* (Brown Boveri et Cie) **51** (8/9): 555–577.

[7] Y. *S.* Ettomi, S. B. M. Noor, S. M.'Bashi and M. I<. Hassan Department of Electrical and Electronic Engineering Faculty of Engineering, Universiti Putra Malaysia, 2003.

[8] D. De Venuto, L. Reyneri, “Fully digital strategy for fast calibration and test of ADCs,” *Microelectronics Journal*, vol. 38, issue 1, pp. 140–147, January 2007.

[9] P. H. Mellor, S. P. Leigh, and B. M. G. Cheetham, “Improved sampling process for a digital, pulse-width modulated Class D power amplifier,” in *Proc. Inst. Elect. Eng. Colloquium Digital Audio Signal Processing*, 1991, pp. 3/1–3/5.

[10] Muhammad H. Rashid. *Power Electronics Circuits, Devices and Applications*. 3rd edition. United States of America: Prentice Hall. 2004.

[11]. Iovine John. *PIC Microcontroller Project Book.* 2nd Edition. Singapore: Mc Graw-Hill. 121-123; 2000.

[12]. Lawrence A. Duarte. *The Microcontroller Beginner's Handbook.* 2nd Edition. United States of America: Prompt Publication. 3-5; 1998.

APPENDICES A

GANTT CHART / PROJECT SCHEDULE FOR FYP 1

FINAL YEAR PROJECT TITLE: DEVELOPMENT OF SHAKER (CONTROLLER)

WEEK TASK	SEPTEMBER			OCTOBER				NOVEMBER				DECEMBER		
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Final Year Project Title Announcement & Briefing	🟩													
Project Title Research	🟩													
Project Objective & Project Scope Setting and With Supervisor		🟩	🟩											
Submission of Project Flow Chart & Gantt Chart for Supervisor Verification			🟩	🟩										
Project Introduction (Chapter 1) Writing & Submission				🟩										
Academic Research For Literature Review				🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩			
Literature Review (Chapter 2) Writing & Submission				🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧			
Project Analysis Identification				🟩	🟩									
Project Methodology (Chapter 3) Writing & Submission						🟩	🟩	🟩	🟩	🟩	🟩			
Complete Log Book Submission												🟩	🟩	
Final Year Project Mock Presentation														🟩
Final Year Project 1 Presentation & Progress Report Submission														

GANTT CHART / PROJECT SCHEDULE FOR FYP 2

FINAL YEAR PROJECT TITLE: DEVELOPMENT OF SHAKER (CONTROLLER)

WEEK TASK	FEBUARY		MARCH				APRIL				MAY			
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Finalize project Analysis Method	🟩													
Project Analysis Confirmation	🟩													
Analysis about the Motor		🟩	🟩	🟩										
Calculation based on assumption			🟩	🟩	🟩									
Analysis data collection						🟩	🟩	🟩	🟩					
Calculation Based on software analysis						🟩	🟩	🟩	🟩	🟩				
Data Validation							🟩	🟩	🟩	🟩	🟩			
Full Thesis Writing												🟩	🟩	
Complete Log Book Submission														🟩
Final Year Project Mock Presentation														🟩

APPENDICES B

Coding

```
const int analogInPin = A0;  // Analog input pin that the potentiometer is attached to

const int analogOutPin = 9; // Analog output pin that the LED is attached to



int sensorValue = 0;        // value read from the pot

int outputValue = 0;        // value output to the PWM (analog out)



void setup()

{

  // initialize serial communications at 9600 bps:

  Serial.begin(9600);

}

void loop()

{

  // read the analog in value:

  sensorValue = analogRead(analogInPin);

  // map it to the range of the analog out:

  outputValue = map(sensorValue, 0, 1023, 0, 255);

  // change the analog out value:

  analogWrite(analogOutPin, outputValue);
```

```
  // print the results to the serial monitor:

  Serial.print("sensor = " );

  Serial.print(sensorValue);

  Serial.print("\t output = ");

  Serial.println(outputValue);



  // wait 2 milliseconds before the next loop

  // for the analog-to-digital converter to settle

  // after the last reading:

  delay(2);

}
```

APPENDICES C

L293D Motor Driver

APPENDICEC D

SPG-30 12V DC Motor