

Palestine Polytechnic University



College of Engineering & Technology
Electrical & Computer Engineering Department

Graduation Project

Dual Converter with Power Transistor and Speed Control for DC Motor

Project Team

Amjad Adnan Amer
Mahmoud Dweikat

Project Supervisor
Dr. Abed AL-Kareem Daud.

Hebron-Palestine

June 2004

Palestine Polytechnic University



College of Engineering & Technology
Electrical & Computer Engineering Department

Graduation Project

Dual Converter with Power Transistor and Speed Control for DC Motor

Project Team

Amjad Adnan Amer
Mahmoud Dweikat

Project Supervisor
Dr. Abed AL-Kareem Daud.

Hebron-Palestine

June 2004

Palestine Polytechnic University
Hebron-Palestine
College of Engineering & Technology
Electrical & Computer Engineering Department

Dual Converter with Power Transistor and Speed Control for DC Motor

Project Team

Amjad Adnan Amer Mahmoud Dweikat

According to the orientations of the supervisor on the project and the examined committee is by the agreement of a staffers all, sending in this project to the Electrical and computer engineering department are in the college of the engineering and the technology by the requirements of the department for the step of the bachelor's degree.

Project supervisor signature

.....

Committee signature

.....

.....

.....

Department head signature

.....

Dedication

We dedicate this Project:

To our parents

To our brothers

To our friends

To our nation

Acknowledgement

To all the one whom teach me and he helped me, to whom arrive me for this science step, to the supervisor of the project Dr. Abdel-Karim Daud, to all are faculty that teach me in the computer and electricity department, to my companions and my sweethearts and my relatives, we dedicate this project it may be support other research in the future.

Abstract

Some cases need operating the machine in the four quadrant for high power application, and speed control of dc motor so the dual converter is used, Also we will put in this project the ability of changing the flow of energy and the rotating direction of the machine, so the cost will be less than the usual dual that are of the same features, and we used MATLAB language to write the program to control of this converter.

The speed of a driven load often needs to run at a speed that varies according to the operation it is performing. The speed in some cases such as Cutting tools may need to constant dynamically to suit the conditions, and in other cases may only change with a change in process. Electric motors and coupling combinations used for a constant the speed. Closed loop controllers employ a feedback loop to keep the motor at constant speed.

Index

<u>Title</u>	<u>Page</u>
Dedication	III
Acknowledgement	IV
Abstract	V
Index	VI
List of Tables	IX
List of Figures	X
1. Introduction	
1.1 Introduction	2
1.2 Importance of the Project	2
1.3 Good Features	3
1.4 Project Objectives	3
1.5 General Block Diagram	4
1.6 Organization	5
2. Basic Concepts	
2.1 DC Machine	7
2.1.1 Motoring Mode	7
2.1.2 Regenerative Mode	10
2.2 Harmonics	11
2.3 Speed Sensing	13
2.4 Feedback	14
2.5 Controllers	15
2.5.1 Type of Controller	15
2.5.2 Characteristics of Controller	19
3. Design Concepts	

3.1Introduction	21
3.2 Close Loop Control of DC Drive	21
3.3 Motor Characteristics	22
3.4 How System Works	25
3.5 Operation Four Quadrants for DC Motor	26
3.5.1 First Quadrant (Forward Motoring)	26
3.5.2 Second Quadrant (Forward Regenerative)	27
3.5.3 Third Quadrant (Reverse Motoring)	28
3.5.4 Fourth Quadrant (Reverse Generating)	29
3.5.5 Operation Four in Quadrant	31
 4.Hardware System Design	
4.1 Power Circuit	33
4.1.1 Power Supply Source	33
4.1.2 Converter with Power Transistors	37
4.1.2.1 Operation the Transistors	38
4.1.2.2 Power Transistor (MOSFETs)	39
4.2 Control Circuit	43
4.2.1 PI-Controller	43
4.3 Interfacing Circuit	46
4.3.1 Interface Circuit	46
4.3.2 Optocoupler	47
4.3.3 Parallel Port	50
4.3.3.1 Introduction to Parallel Port	50
4.3.3.2 Parallel Port Hardware Properties	50
4.3.3.3 Port Address	53
4.3.3.4 How to Connect Circuits to Parallel Port	54
4.3.4 Analog to digital converter (ADC).	55
4.4 Choosing The Motor	57
 5. Software System Design	
5.1 Flow Chart to Control of Converter	62
5.2 What Is MATLAB	63

5.3 How System works	68
6. Protection	
6.1 What is Electrical Protection	71
6.2 Requirements of the Electrical protection System	71
6.3 Protection Against Over Current	72
6.4 Overload	72
6.5 Short Circuit	72
6.6 Fuse and Circuit Breaker	73
6.7 Cooling and Heat Sink	75
7.Conclusions and Recommendation	77
Reference	78
Appendix	79

List of Tables

<u>Table</u>	<u>Page</u>
Table (2.1): Characteristics of controller	19
Table (4.1): Devices requirment Parameter and calculations	□□
Table (4.2): Operation in Four Quadrant	39
Table (4.3): Typical MOSFET Ratings	40
Table (4.4): Status The Pins and Operation the devices .	□□
Table (4.5): Comparison Between Different Signal Coupling Devices.	48
Table (4.6): Pin Assignments of the D-Type 25 pin Parallel Port Connector.	52
Table (4.7): Port Addresses.	54
Table (4.8): Parallel Port Pins Number with Data Lines Index.	55
Table (4.9): Nameplate of DC Motor	57
Table (4.10): Practical Parameters of the Motor	□□
Table (6.1): Motor Power, nominal current, overload current and fuse current	□□

List of Figures

<u>Figure</u>	<u>Page</u>
Figure (1.1): General Block Diagram	4
Figure (2.1): Equivalent circuit of dc motor	8
Figure (2.2): Equivalent circuit of dc generator	11
Figure (2.3): General circuit of the controllers	15
Figure (2.4): P-Controller circuit	16
Figure (2.5): Relation between V_{in} and V_{out} in P-Controller	16
Figure (2.6): I-Controller circuit	17
Figure (2.7) Relation between V_{in} and V_{out} in I-Controller	17
Figure (2.8): D-Controller circuit	18
Figure (2.9): Relation between V_{in} and V_{out} in D-Controller	18
Figure (3.1): Relation between Torque and Speed in DC Motor	□□
Figure (3.2): Relation between Torque and Speed in DC Motor	□□
Figure (3.3): Relation between Torque, Power and Speed in DC Motor.	□□
Figure (3.4): Block diagram of closed-loop converter-fed dc motor	26
Figure (3.5): Forward Motoring	27
Figure (3.6): Reverse Generator	28
Figure (3.7): Reversing Motor	29
Figure (3.8): Forward Generator	30
Figure (3.9): Operation In Four Quadrant	31
Figure (4.1): Circuit of Power Supply to Feed Power Transistor	33
Figure (4.2): Circuit of Power Supply to Feed interfacing circuit (op_D0 & op_D3) and (op_D1 & op_D2) .	□□
Figure (4.3): Circuit of Power Supply to Feed ADC	□□
Figure (4.4): The Wave Form for Input and Output Voltage	35
Figure (4.5): Converter with Power Transistors	37
Figure (4.6): Simple model of an N-channel enhancement type MOSFET	41
Figure (4.7): Typical Current Curves for Various Gate-Source Voltage Levels	41
Figure (4.8): The Circuit of PI Controller	43
Figure (4.9): Block Diagram PI- Controller	44
Figure (4.10): The Wave of Controllers	45

Figure (4.11): Interfacing Circuit	46
Figure (4.12): The Optocoupler (Opto-Isolators)	49
Figure (4.13): Parallel Port Pins	51
Figure (4.14): Analog to Digital Converter	□ □
Figure (4.15): Speed Characteristics	□ □
Figure (4.16): armature voltage control by varying the duty cycle K.	60
Figure (6.1): Heat Sink Figure	75



Appendix

CHAPTER ONE

INTRODUCTION

1.1 Introduction.

1.2 Importance Of The Project .

1.3 Good Features.

1.4 Project Objectives.

1.5 General Block Diagram.

1.6 Organization.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

How a separately excited dc motor can be operated in either direction in either of the two modes, the two modes being the motoring mode and the regenerating mode. It can be seen that the motor can operate in any of the four quadrants. The every quadrant operation is state different by the other quadrant, the first & third quadrant operate in motoring mode, the second & fourth quadrant operate in generative mode.

The speed of motor constant at any load by obtains the speed control with tachogenerator, the converter contains four power transistors can be control by pulses generated from computer, in each quadrant must be operate two transistor.

1.2 Importance Of The Project

- Saving electrical energy by regenerative the energy to the network when the machine operation in generating mode.
- Ability operation the machine in different modes which get flexibility to the system .
- To keep the motor at constant speed with changeable load ,cause flexible and high efficiency in industrial field.

1.3 Good Features

There are three main good features in this project :

- The cost will be less than the usual dual that are of the same features.
- Reblace the thyristors by transistor to get easy control .
- Also, using the personal computer to control of converter by generating the pulses.

1.4 Project Objectives

- Operation the machine in four quadrants.
- Closed loop speed control of separately dc machine.
- Speed control with tachogenerator .
- On the other hand, the project will study how it can be interface the converter with personal computer, and the electronic circuits for this aim, also the software to generate the pulses.

1.5 General Block Diagram

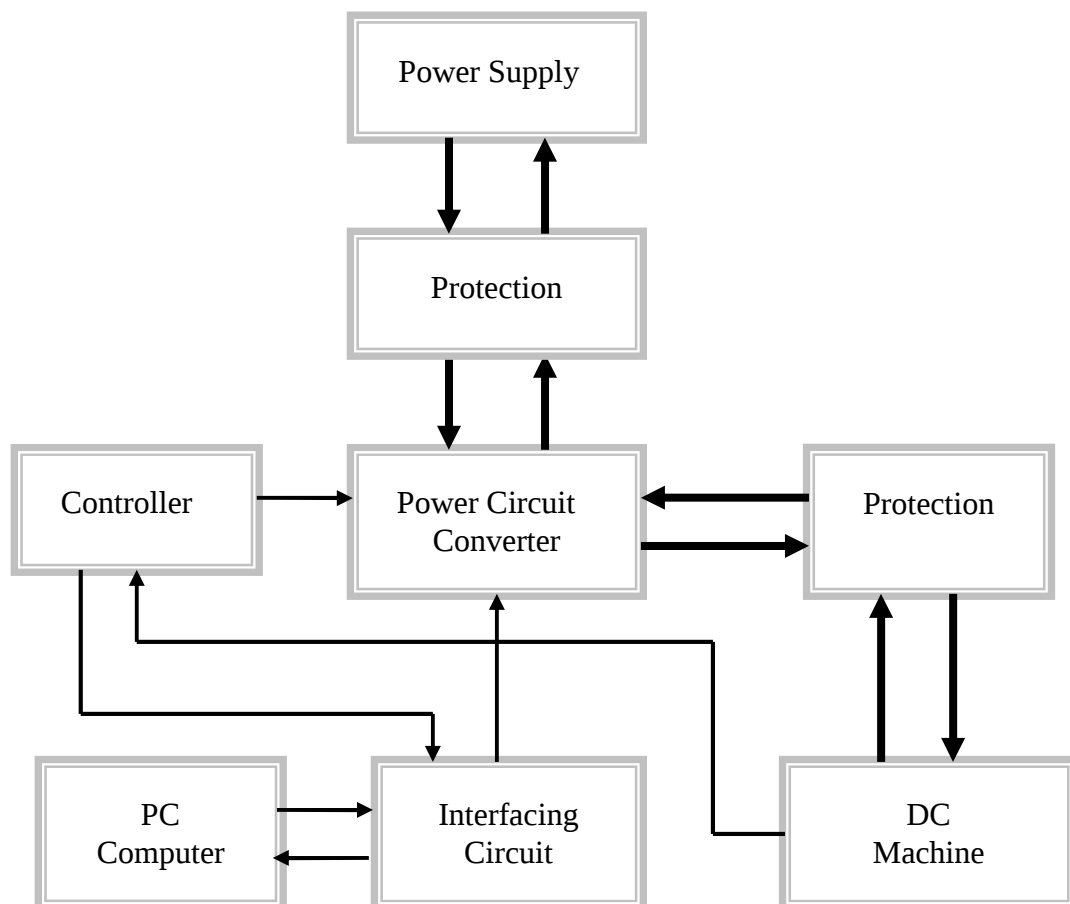


Figure (1.1): General Block Diagram.

1.6 Organization

This project contains seven chapters:

Chapter1 Covers general idea about project, project objectives, and its importance.

Chapter2 Covers theoretical subjects related to the main idea of the project and information about special components.

Chapter3 Covers closed loop system, transfer function of the system, and how system works.

Chapter4 Covers hardware system design (Power and Control Circuit), and design interfacing circuit.

Chapter5 Covers software system design, general algorithms, and flow charts.

Chapter6 Covers electrical protection of the project.

Chapter7 Covers conclusions and recommendations of the project.

CHAPTER TWO

BASIC CONCEPTS

2.1 DC Machine.

2.1.1 Motoring Mode.

2.1.2 Regenerative Mode.

2.2 Harmonics.

2.3 Speed Sensing.

2.3.1 Feedback

2.4 Controllers.

2.4.1 Type of Controllers.

2.4.2 Characteristics Of Controllers.

CHAPTER TWO

BASIC CONCEPTS

2.1 DC Machine

In many application , a DC machine may be operation in one or more modes: motoring, regenerative, and four quadrant .

2.1.1 Motoring Mode

Direct current motors are widely used where high torque for low speed operation or variable speed operation are desired. The number of engineers who design DC motors is small, but most engineers will use DC motors at some point in their careers.

A simple circuit model for a separately excited DC motor is shown in figure (2.1) . The field voltage V_f produces the field current I_f in the field winding. The terminal voltage V_a produces the armature current I_a in the armature winding. Both the armature and the field consist of coils of copper wire, possessing both resistance and inductance. In steady state, we are only concerned with DC flows so we can ignore the inductance. That is why we usually draw inductor symbols, but labels them as resistors.

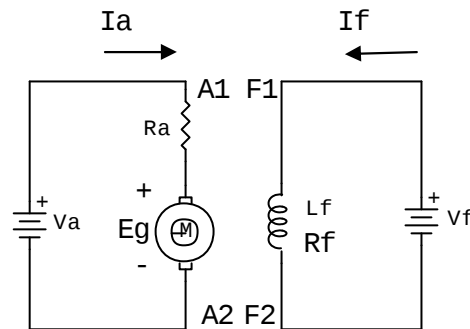


Figure (2.1): Equivalent circuit of dc motor.

The field current I_f produces a flux Φ which cuts the armature winding. The armature current I_a interacts with the flux to produce a torque, which causes the armature to rotate with a mechanical angular velocity ω_m . The movement of the armature winding through the flux produces a speed induced voltage E_g , which opposes the flow of current according to Lenz's Law.

The basic equations of the motor are :

$$V_a = E_g + R_a I_a \dots\dots\dots (2.1)$$

$$T_d = C_f I_a \dots\dots\dots (2.2)$$

$$E_g = C_f \omega \dots\dots\dots (2.3)$$

C_f has the same numerical value in both (2) and (3) if T_d is in Newton meters, f is in Webers, I_a is in Amperes, E_g is in Volts, and ω_m is in radians per second. At the air gap between stator and rotor, the mechanical power is equal to the electrical power.

$$Tdw = E_g Ia \dots\dots\dots (2.4)$$

The total power going into the DC motor is

$$Pin = VaIa + VfIf \dots\dots\dots (2.5)$$

Since this is a DC motor we do not have any phase angles or power factors to think about. The motor losses are

$$Ploss = Ia^2 Ra + VfIf + Prot. \dots\dots\dots (2.6)$$

Where P_{rot} refers to the rotational losses. The gap power is

$$E_g Ia = Pin - Ia^2 Ra - VfIf \dots\dots\dots (2.7)$$

The output power is

$$Pout = Pin - Ploss = E_g Ia - Prot. \dots\dots\dots (2.8)$$

The output torque is less than the developed torque by the amount needed to overcome the rotational losses. It can be determined from the output power and the speed.

$$Pout = Toutw \dots\dots\dots (2.9)$$

where P_{out} is in watts, T_{out} is in Nm, and w_m is in rad/sec.

The efficiency is given by

$$h = \frac{Pout}{Pin} \times 100\% \dots\dots\dots (2.10)$$

The speed characteristic equation is obtained by combining (1) and (3), and solving for w .

$$w = \frac{V_a - I_a R_a}{C f} \dots\dots\dots (2.11)$$

This equation shows that the speed decreases as the armature current increases due to an increased load requirement. The speed regulation, analogous to the voltage regulation seen in the Block on transformers, is defined as

$$SR = \frac{w_{NL} - w_{FL}}{w_{FL}} \dots\dots\dots (2.12)$$

Where NL and FL refer to no load and full load, respectively. Typical values of speed regulation for large DC shunt and separately excited motors are in the range of 5 to 12%, making the DC shunt and separately excited motors basically constant-speed machines.

2.1.2 Regenerative Mode

When the machine operation in the generative mode we must be the induced voltage greater than the terminal voltage and the current is flow into the network .the generated voltage E_g depends on the shaft speed w and the magnetic flux per pole f .

The basic equations of the generator are:

The induced voltage is

$$E_g = V_a + R_a I_a \dots\dots\dots (2.13)$$

The output electrical power is

$$P_{out} = V_a I_a \dots\dots\dots (2.14)$$

The input mechanical power is

$$P_{in} = T \omega \dots\dots\dots (2.15)$$

A simple circuit model for a separately excited DC generator is shown in figure (2.2)

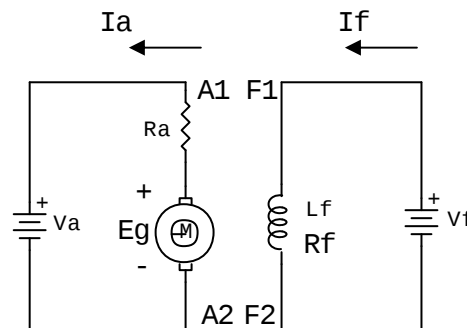


Figure (2.2): Equivalent circuit of dc generator.

2.2 Harmonics

Harmonics is frequencies contained in a composite waveform that are integer multiples of the repetition frequency (fundamental).¹One of the biggest problems in power quality aspects is the harmonic contents in electrical systems. Generally, harmonics may be divided into two types: 1) voltage harmonics, and 2) current harmonics. Current harmonics is usually generated by harmonics contained in voltage supply and depends on the type of load such as resistive , capacitive, and inductive load. Both harmonics can be generated by either the source or the load side.

¹ Malvino, electronic principles, 5th edition.

Understanding the causes, similarities, and differences between current and voltage distortion will help you pinpoint most power quality problems. An electrical system supplies power to loads by delivering current at the fundamental frequency. Only fundamental frequency current can provide real power. Current delivered at harmonic frequencies doesn't deliver any real power to the load. When current of a single frequency is present in a system, you can use the measured values in Ohm's Law and power calculations. However, when currents of more than one frequency are present, direct addition of the current values leads to a summed value that doesn't correctly represent the total effect of the multiple currents. Instead, you need to add the currents in a manner known as the “root mean square” summation.

The same is true for harmonic voltages. To obtain the effective voltage for a system in which voltages of several frequencies are present, you must add the voltages in an rms fashion.

Effects of current distortion. Since operation of nonlinear loads causes the distorted current, which is path dependent, the effect of current distortion on loads within a facility is minimal. Therefore, harmonic currents can't flow into equipment other than the nonlinear loads that caused them. However, the effect of current distortion on distribution systems can be serious, primarily because of the increased current flowing in the system.

Whenever the current in the power system is no longer sinusoidal, we say it is distorted, or that there is harmonic distortion. Harmonic distortion is problematic in that most of the power system's operation is based on, and dependent on, the assumption of sine waves.

Harmonic currents also increase I^2Z heat losses in transformers and wiring. Since transformer impedance is frequency dependent, increasing with harmonic number, the impedance at the 5th harmonic is five times that of the fundamental frequency.

So each ampere of 5th harmonic current causes five times as much heating as an ampere of fundamental current.

Effects of voltage distortion. Besides overheating, the other major effect of current distortion on an electrical system is the creation of voltage distortion. This distortion will have minimal effect on a distribution system, but unlike current distortion, it isn't path dependent. So harmonic voltages generated in one part of a facility will appear on common buses within that facility.

The effect on loads within the facility could be detrimental in certain cases. For example, extreme voltage distortion can cause multiple zero crossings for the voltage wave. For equipment where proper sequencing of operations depends on a zero crossing for timing, voltage distortion can cause disoperation. Voltage distortion appears to have little effect on operation of nonlinear loads connected either phase-to-phase or phase-to-neutral.

2.3 Speed Sensing

Sensing of speed is required for implementation of closed loop speed control system. Speed is usually sensed using tachometer coupled to the motor shaft. A tachometer is an ac or dc generator with a high order of linearity between its speed and output voltage. A dc tachometer is built with a permanent magnetic field and some time with silver brushes to reduce contact drop between the brush and commutator. Typical voltage output are 1V per 1000 rpm .the tachometers output voltage consists of a ripple whose frequency depends on its speed. At low speed, adequate filtering can only be done by a filter with large enough time constant to affect the dynamic of drive. Special large diameter tachometer with large numbers of commutator segment

is sometimes built to overcome this problem. Tachometer is available to measure speed with an accuracy of $\pm 0.1\%$.

2.3.1 Feedback

In a system where a transformation occurs, there are inputs and outputs. The inputs are the result of the environment's influence on the system, and the outputs are the influence of the system on the environment. Input and output are separated by duration of time, as in before and after, or past and present.

In every feedback loop, as the name suggests, information about the result of a transformation or an action is sent back to the input of the system in the form of input data. If these new data facilitate and accelerate the transformation in the same direction as the preceding results, they are positive feedback their effects are cumulative. If the new data produce a result in the opposite direction to previous results, they are negative feedback their effects stabilize the system.

Positive feedback leads to divergent behavior: indefinite expansion or explosion (a running away toward infinity) or total blocking of activities (a running away toward zero). Each plus involves another plus; there is a snowball effect.

In either case, a positive feedback loop left to it self can lead only to the destruction of the system, through explosion or through the blocking of all its functions. The wild behavior of positive loops - a veritable death wish - must be controlled by negative loops. This control is essential for a system to maintain itself in the course of time.

2.4 Controllers

This section will show you the characteristics of the each of proportional (P), the integral (I), and the derivative (D) controls, and how to use them to obtain a desired response and transfer function for each. The figure (2.3) illustrated the general circuit of the controllers.

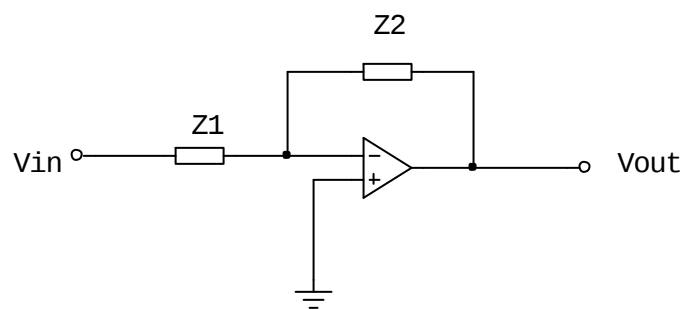


Figure (2.3): General circuit of the controllers.

The transfer function is:

$$G(s) = \frac{V_{out}}{V_{in}} = \frac{-Z2}{Z1} \dots\dots\dots (2.16)$$

2.4.1 Type of Controllers

1. P-Controller (Proportional Controller)

$$Z1 = R1 \text{ And } Z2 = R2$$

The transfer function is:

$$G_p(s) = K_p \dots\dots\dots (2.17)$$

$$V_{out} = K_p V_{in}(t) \dots\dots\dots (2.18)$$

Where:

$$K_p = \frac{R_2}{R_1}$$

The figure (2.4) illustrated the circuit of the P- controller.

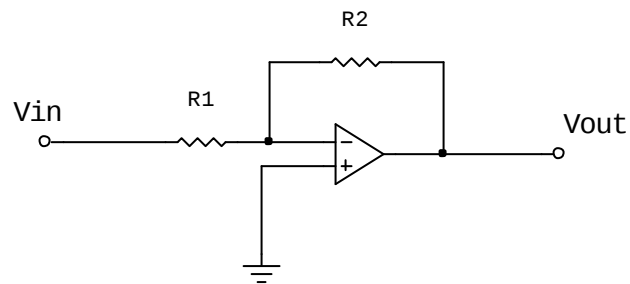


Figure (2.4): P-Controller circuit.

The graph view relation between Vin and Vout .

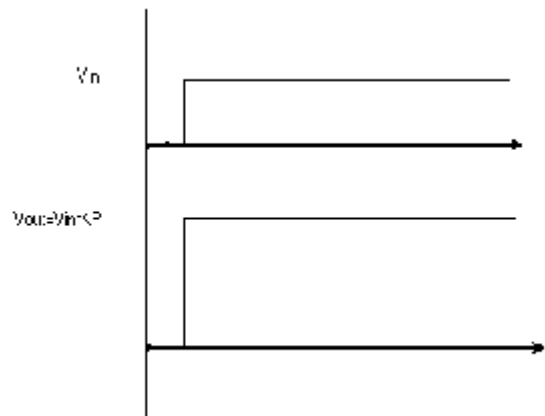


Figure (2.5): Relation between Vin and Vout in P-Controller

2. I-Controller (Integrated Controller)

$$Z1 = R1 \text{ And } Z2 = \frac{1}{\omega C2}$$

The transfer function is:

$$G_I(s) = \frac{Vout(s)}{Vin(s)} = \frac{KI}{s} = \omega R1 C2 \dots\dots\dots (2.19)$$

$$Vout = KI \int_0^t Vin(t)dt + Vin(t = 0) \dots\dots\dots (2.20)$$

$$Vout = KI \int_0^t Vin(t)dt$$

$$Vout = KI \cdot Vin \cdot t \dots\dots\dots (2.21)$$

The figure (2.6) illustrated the circuit of the I- controller.

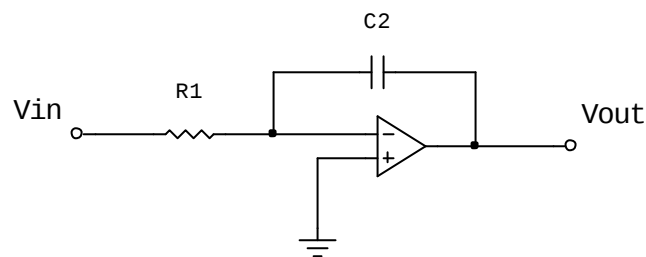


Figure (2.6): I-Controller circuit.

The graph view relation between Vin and Vout

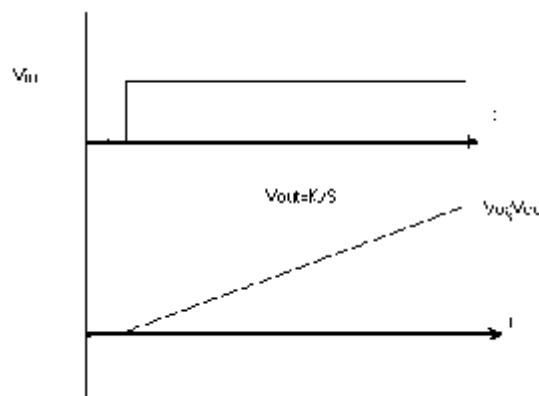


Figure (2.7) Relation between Vin and Vout in I-controller

3. D-Controller (Derivative Controller)

$$Z1 = \frac{1}{sC1} \quad \text{And} \quad Z2 = R2$$

The transfer function is:

$$G_D(s) = \frac{Vout(s)}{Vin(s)} = KD \cdot s \dots\dots\dots (2.22)$$

$$Vout(t) = KD \frac{dVin}{dt} \dots\dots\dots (2.23)$$

$$KD = TD = R2 \cdot C1 \dots\dots\dots (2.24)$$

The figure (2.8) illustrated the circuit of the D- controller.

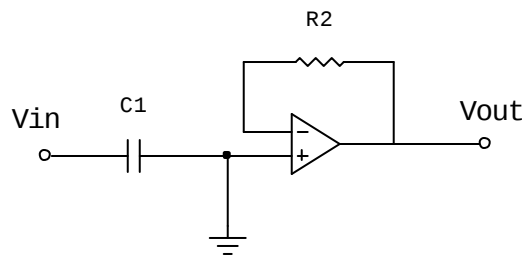


Figure (2.8):D-Controller circuit.

The graph view relation between Vin and Vout

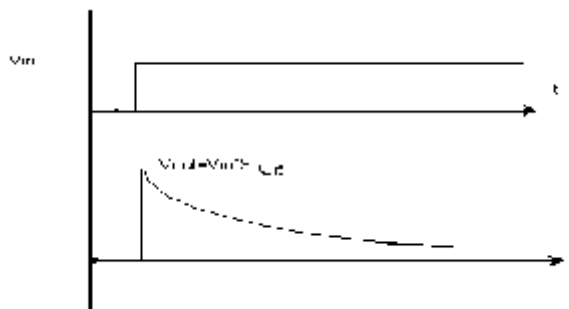


Figure (2.9) Relation between Vin and Vout in D-Controller.

2.4.2 Characteristics Of Controllers

A proportional controller (K_p) will have the effect of reducing the rise time and will reduce but never eliminate the steady-state error. An integral control (K_I) will have the effect of eliminating the steady-state error, but it may make the transient response worse. A derivative control (K_D) will have the effect of increasing the stability of the system, reducing the overshoot, and improving the transient response. Effects of each of controllers K_p , K_D , and K_I on a closed-loop system are summarized in the table shown below.

Table (2.1): Characteristics of controller

C.L. RESPONSE	RISE TIME	OVERSHOOT	SETTLING TIME	S-S ERROR
K_p	Decrease	Increase	Small Change	Decrease
K_I	Decrease	Increase	Increase	Eliminate
K_D	Small Change	Decrease	Decrease	Small Change

.

Note that these correlations may not be exactly accurate, because K_p , K_I , and K_D are dependent on each other. In fact, changing one of these variables can change the effect of the other two. For this reason, the table should only be used as a reference when you are determining the values for K_I , K_p and K_D .

CHAPTER THREE

DESIGN CONCEPTS

3.1 Introduction.

3.2 Closed-Loop Control of DC Drive.

3.3 Motor Characteristics

3.4 How System Works.

3.5 Operation Four Quadrant for Sep .DC Motor.

3.5.1 First Quadrant "Forward Motoring".

3.5.2 Second Quadrant "Forward Generating".

3.5.3 Third Quadrant "Reverse Motoring".

3.5.4 Fourth Quadrant "Reverse Generating".

3.5.5 Operation Four in Quadrant.

CHAPTER THREE

DESIGN CONCEPTS

3.1 Introduction

A Closed-loop system uses a measurement of the out put signal and a comparison with the desired output to generate an error signal that is applied to the actuator.

An Open-loop (direct) system operates without feedback and directly generates the output in response to an input signal.

3.2 Closed-Loop Control of DC Drive

The speed of dc motors changes with the load torque. To maintain a constant speed, the armature (and or field) voltage should be varied continuously by varying the delay angle of ac-dc converter or duty cycle of dc chopper and can be compensated the speed by increase the armature current .In practical drives systems it is required to operate the drive at constant torque or constant speed or constant power; in addition, controlled acceleration and deceleration are required. Most industrial drives operate as closed-Loop feedback systems. A closed-Loop control system has the advantages of improved accuracy, fast dynamic response, and reduced effects of load disturbance.

3.3 Motor Characteristics

Most motors turn at nearly constant speed. However, much of the time the devices they drive may operate at less than maximum design speed.

Torque / Speed Curves

In order to effectively design with D.C. motors, it is necessary to understand their characteristic curves. For every motor, there is a specific Torque/Speed curve and Power curve.

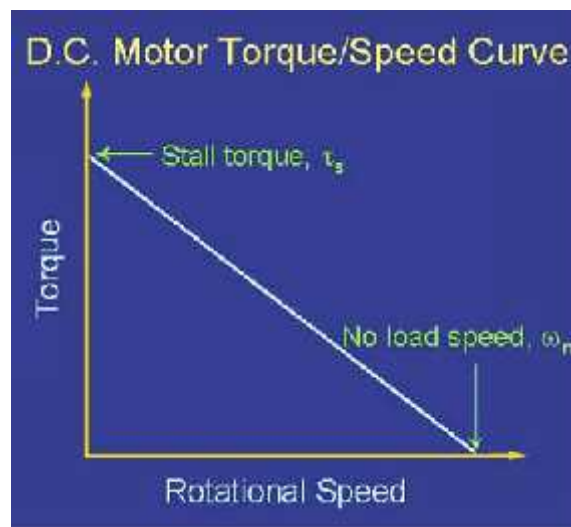


Figure (3.1): Relation between Torque and Speed in DC Motor.

The graph above shows a torque/speed curve of a typical D.C. motor. Note that torque is inversely proportional to the speed of the output shaft. In other words, there is a tradeoff between how much torque a motor delivers, and how fast the output shaft spins.

Motor characteristics are frequently given as two points on this graph:

- The stall torque t_s represents the point on the graph at which the torque is a maximum, but the shaft is not rotating.
- The no load speed w_n is the maximum output speed of the motor (when no torque is applied to the output shaft).

The curve is then approximated by connecting these two points with a line, whose equation can be written in terms of torque or angular velocity as equations (3.1) and (3.2):

$$t_{motor} = t_s - \frac{w t_s}{w_n} \dots\dots\dots (3.1)$$

$$w_{motor} = \frac{(t_s - t) w_n}{t_s} \dots\dots\dots (3.2)$$

recall that earlier we defined power as the product of torque and angular velocity. This corresponds to the area of a rectangle under the torque/speed curve with one cornered the origin and another corner at a point on the curve (see figures (3.2)). Due to the linear inverse relationship between torque and speed, the maximum power occurs at the point where $w = \frac{1}{2}w_n$ and $t = \frac{1}{2}t_s$.

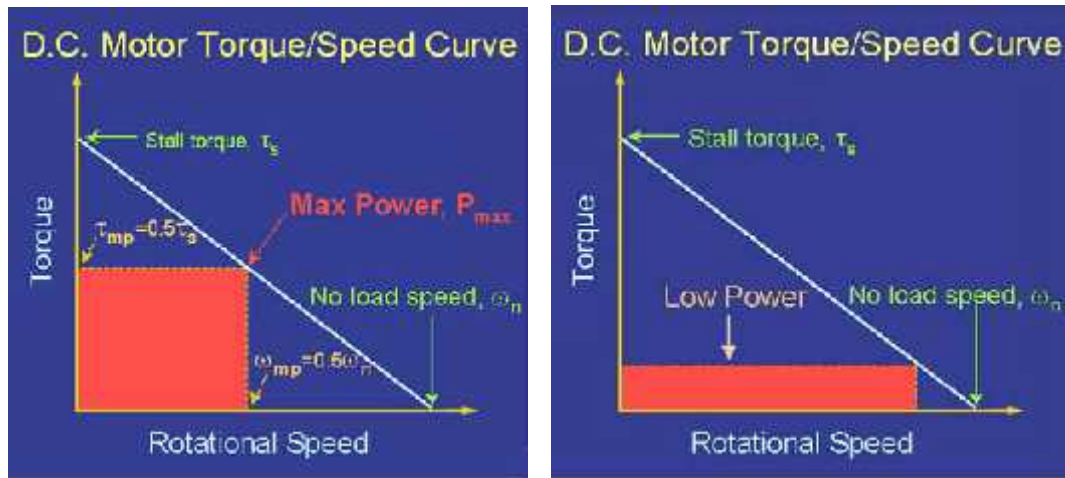


Figure (3.2): Relation between Torque and Speed in DC Motor.

Power / Torque and Power / Speed curves

By substituting equations (3.1). And (3.2). (Torque and speed) into equation (3.3). We see that the power curves for a D.C. motor with respect to both speed and torque are quadratics, as shown in equations. (3.4) and (3.5).

$$P_{rot} = t\omega \dots\dots\dots (3.3)$$

$$P_{motor}(\omega) = -\left(\frac{t_s}{\omega_n}\right)\omega^2 + t_s\omega \dots\dots\dots (3.4)$$

$$P_{motor}(t) = -\left(\frac{\omega_n}{t_s}\right)t^2 + \omega_n t \dots\dots\dots (3.5)$$

From these equations, we again find that maximum output power occurs at $t = \frac{1}{2}t_s$ and $\omega = \frac{1}{2}\omega_n$ respectively.



Figure (3.3): Relation between Torque, Power and Speed in DC Motor.

3.4 How System Works

The motor is required to operate at a desired speed, but it has to meet the load torque, which depends on the armature current. While the motor is operation at particular speed, if a load is applied suddenly, the speed will fall and the motor will take time to come up to the desired speed. A speed feedback response to any disturbance in speed command, load torque, and supply voltage.

Any positive speed error caused by an increased in either speed command or load torque demand will produced a high current I_a . The motor will accelerate to correct the speed error, which makes the motor torque equal to the load torque, resulting in a speed error closed to zero. For any large positive speed error, the current limiter saturates. The speed error is then corrected at the maximum permissible armature current $I_{a(max)}$ until the speed error becomes small and the current limiter comes out

of saturation. Normally, the speed error is corrected with I_a less than the permissible value $I_{a(max)}$.

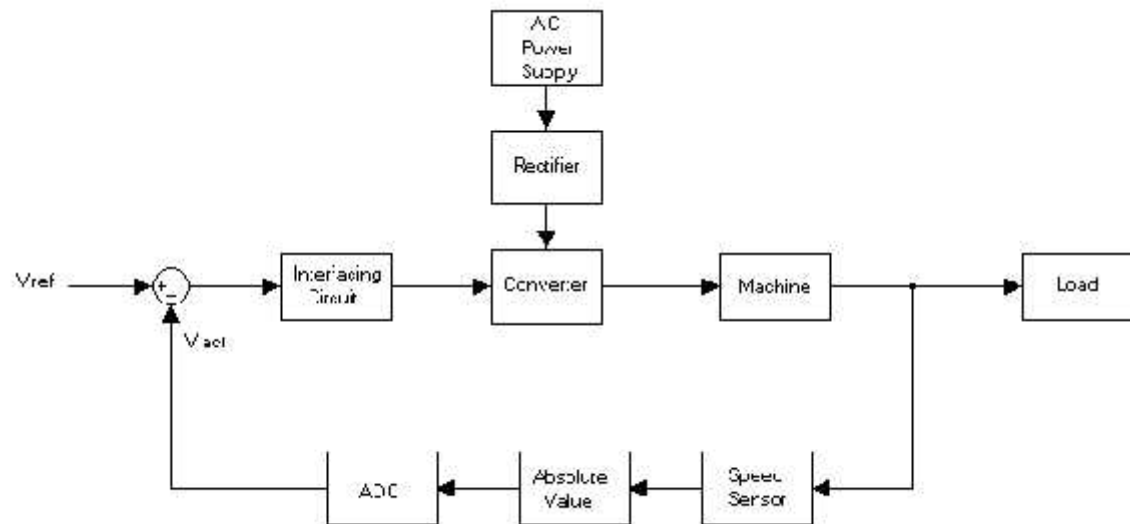


Figure (3.4) Block diagram of closed-loop converter.

3.5 Operation Four Quadrant for DC Motor.

3.5.1 First Quadrant “Forward Motoring”.

Since the field current is constant then C_f is constant, also V_a & R_a are constants and there is no additional resistance then the speed will varied as a function of current and the equation is called. Natural electromechanical characteristics, Then I_a & $V_a(+)$, and other parameter no change.

$$\omega = \frac{V_a}{C_f} - \frac{R_a}{C_f} I_a \dots\dots\dots (3.6)$$

Note that there is no additional resistance and the speed is a function of torque so it is called natural mechanical characteristics

$$\omega = \frac{V_a}{C_f} - \frac{R_a}{(C_f)^2} T \dots\dots\dots (3.7)$$

The figure (3.5) illustrated the circuit of forward motoring.

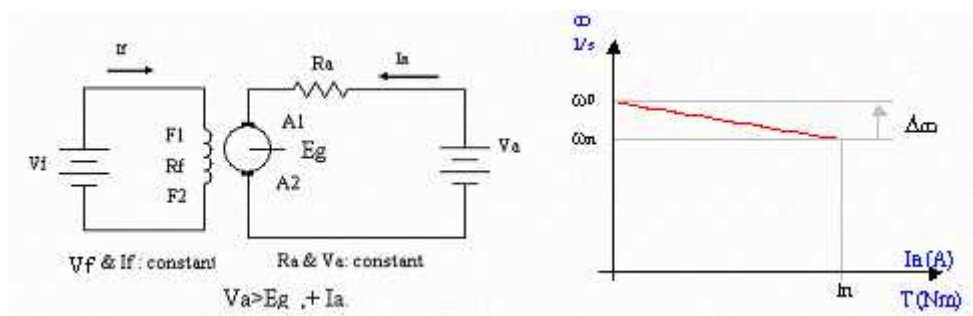


Figure (3.5): Forward Motoring.

3.5.2 Second Quadrant “Forward Generating”

Since the field current is constant then C_f is constant, also V_a & R_a are constants and there is no additional resistance then the speed will varied as a function of current and the equation is called. Natural electromechanical characteristics, then I_a (-), and other parameter no change

$$\omega = \frac{V_a}{C_f} + \frac{R_a}{C_f} I_a \dots\dots\dots (3.8)$$

Note that there is no additional resistance and the speed is a function of torque so it is called natural mechanical characteristics.

$$w = \frac{V_a}{C_f} + \frac{R_a}{(C_f)^2} T \dots\dots\dots (3.9)$$

The figure (3.6) illustrated the circuit of reverse generator.

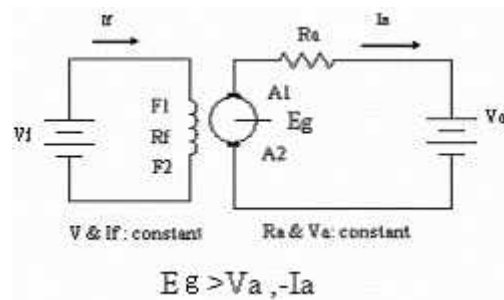


Figure (3.6): Reverse Generator.

3.5.3 Third Quadrants “Reverse Motoring”

Since the field current is constant then C_f is constant, also V_a & R_a are constants and there is no additional resistance then the speed will varied as a function of current and the equation is called. Natural electromechanical characteristics, Then V_a & $I_a (-)$, opposite of the direction speed and other parameter no change

$$w = \frac{-V_a}{C_f} + \frac{R_a}{C_f} I_a \dots\dots\dots (3.10)$$

Note that there is no additional resistance and the speed is a function of torque so it is called natural mechanical characteristics.

$$w = \frac{-V_a}{C_f} + \frac{R_a}{(C_f)^2} T \dots\dots\dots (3.11)$$

The figure (3.7) illustrated the circuit of reverse motoring

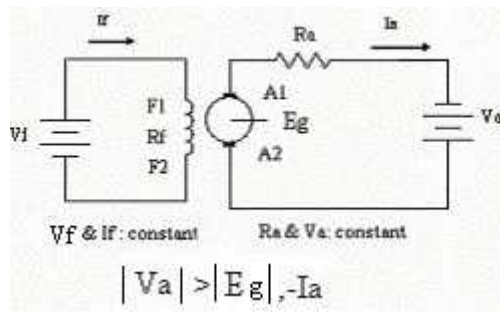


Figure (3.7): Reversing Motor.

3.5.4 Fourth Quadrants “Reverse Generating”

Since the field current is constant then C_f is constant, also V_a & R_a are constants and there is no additional resistance then the speed will varied as a function of current and the equation is called. Natural electromechanical characteristics. Then V_a (-), and other parameter no change

$$w = \frac{-V_a}{C_f} - \frac{R_a}{C_f} I_a \dots\dots\dots (3.12)$$

Note that there is no additional resistance and the speed is a function of torque so it is called natural mechanical characteristics

$$w = \frac{-V_a}{C_f} - \frac{R_a}{(C_f)^2} T \dots\dots\dots (3.13)$$

The figure (3.8) illustrated the circuit of forward generator.

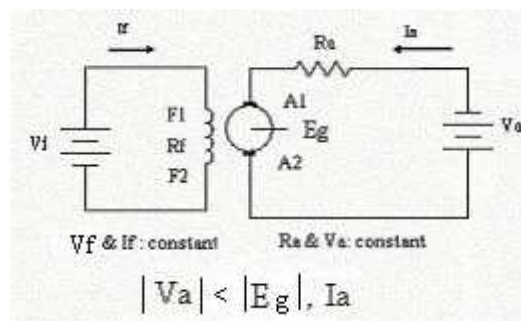


Figure (3.8): Forward Generator.

3.5.5 Operation in Four Quadrants.

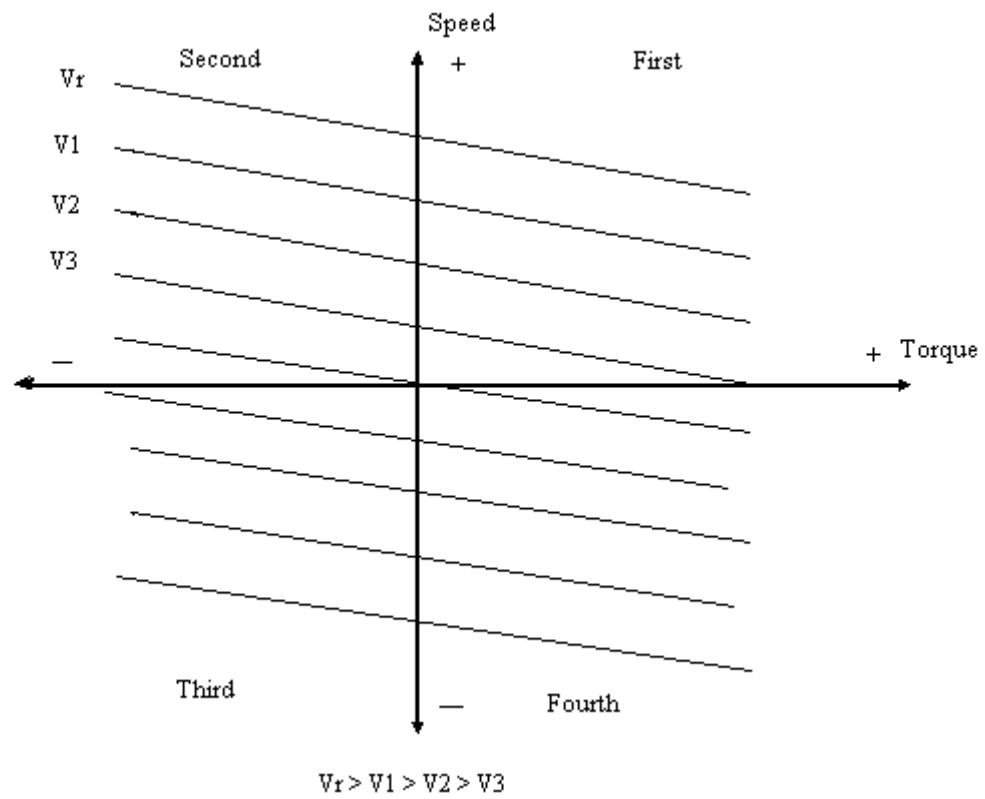


Figure (3.9): Operation in Four Quadrants.

CHAPTER FOUR

HARDWARE SYSTEM DESIGN

4.1 Power Circuit.

4.1.1 Power supply source.

4.1.2 Converter with Power Transistors.

4.1.2.1 Operation the Transistors.

4.1.2.2 Power Transistor (MOSFETs).

4.2 Control Circuit.

4.2.1 PI- Controller.

4.3 Interfacing Circuit.

4.3.1 Interface circuit.

4.3.2 Optocoupler.

4.3.3 Parallel Port.

4.3.3.1 Introduction to Parallel Port.

4.3.3.2 Parallel Port Hardware Properties.

4.3.3.3 Port Addresses.

4.3.3.4 How to Connect Circuits to Parallel Port.

4.3.4 Analog to digital converter (ADC).

4.4 Choosing the Motor.

CHAPTER FOUR

HARDWARE SYSTEM DESIGN

4.1 Power Circuit

4.1.1 Power supply source

Convert of single-phase AC voltage to DC voltage using full wave rectifier.

● **We need two power supply source**

1- To feed power transistor circuit to operate the circuit; take the VDC1 from the output rectifier to the input power transistor VDC1 .at range the voltage 12V, 4A.

The figure (4.1) illustrated the circuit of power supply with regulated voltage to feed power transistor.

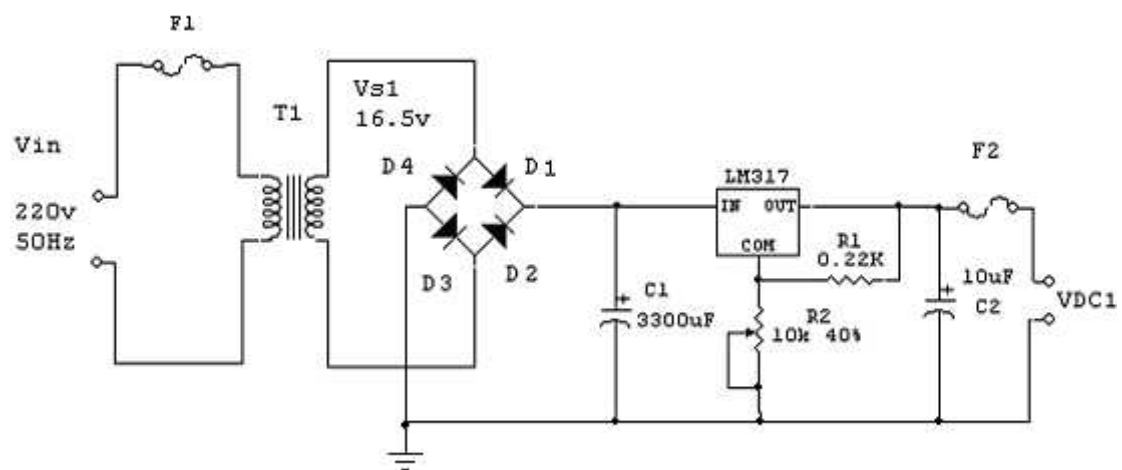


Figure (4.1): Circuit of Power Supply to Feed Power Transistor.

2- To feed control circuit to operate control circuit; take the VDC2 from the output rectifier to feed the interfacing circuit & other contains of control circuit .at range the following:

A - To feed (op-D0 & op-D3) and (op_D1 & op_D2) , at value voltage 5v, 0.5A.

The figure (4.2) illustrated the circuit of power supply with regulated voltage to feed interfacing circuit (op_D0 & op_D3) and (op_D1 & op_D2).

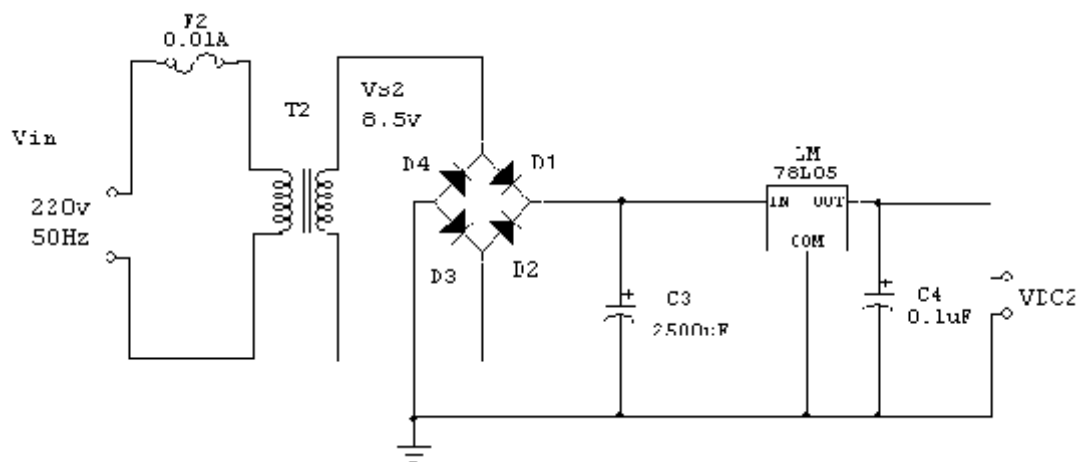


Figure (4.2): Circuit of Power Supply to Feed interfacing circuit (op_D0 & op_D3) and (op_D1 & op_D2) .

B- To feed Analog to digital Converter (ADC), at value voltage 5v, 1A.

The figure (4.3) illustrated the circuit of power supply with regulated voltage to feed ADC.

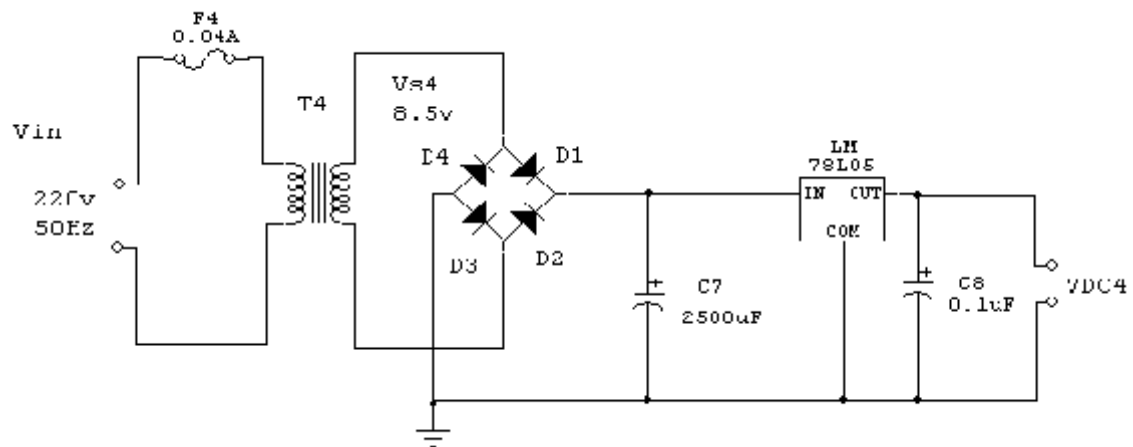


Figure (4.3): Circuit of Power Supply to Feed ADC .

Operation the circuits

When D1-D3 ON

Operation D1 and D3 in half wave positive cycle and at same time D2 and D4 off.

When D2-D4 ON

Operations D1 and D3 in half wave negative cycle and at same time D1 and D3, and

Put the capacitor (C) by obtain pure wave DC.

The figure (4.4) illustrated the waveform for input and output voltage.

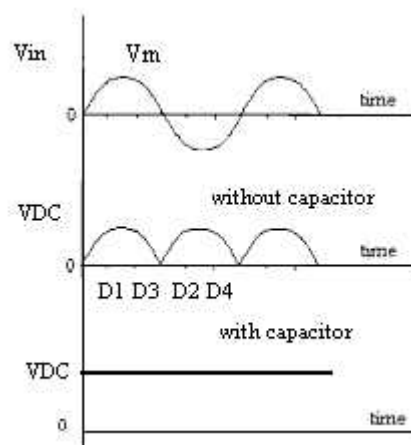


Figure (4.4): The Wave Form for Input and Output Voltage.

• The parameters define

The output voltage of the bridge rectifier is

$$V_{DC} = 2 \frac{V_m}{\pi} \dots\dots\dots (4.1)$$

Where

$$V_m = \sqrt{2}V_{in}$$

Where V_s is the rms voltage

The output frequency.

$$f_{out} = 2 f_{in} \dots\dots\dots (4.2)$$

The ripple voltage.

$$V_{rip} = \frac{I_{DC}}{f \cdot C} \dots\dots\dots (4.3)$$

•Calculation the parameters

The output current of the bridge rectifier is given at following.

$I_{DC1}=4A$, $I_{DC2} = 0.5A$, $I_{DC4} = 1A$, is given by obtain the design, the voltage before regulated must more the voltage need at value or more 3V.

Table (4.1): Devices requirment Parameter and calculations.

	V_s/v	a	V_{DC}/v	f_{out}/Hz	$C/\eta F$
Parameter VDC1	16.5	13	12	100	$C1 = 3500$
Parameter VDC2 Parameter VDC3	8.5	26	5	100	$C3 = 2500$
Parameter VDC4	8.5	25	5	100	$C7 = 2500$

Where:

a: ration of transformer .

V_{in} : The voltage power supply main.

V_s : output voltage from secondary transformer.

VDC: output voltage after regulated from rectifier to send the feed circuit as shown the bellow VDC1, VDC2, VDC3, VDC4.

4.1.2 Converter with Power Transistors

In this converter, we use the DC chopper (Class E) techniques to control of voltage armature.

The figure (4.5) illustrated the converter with power transistors.

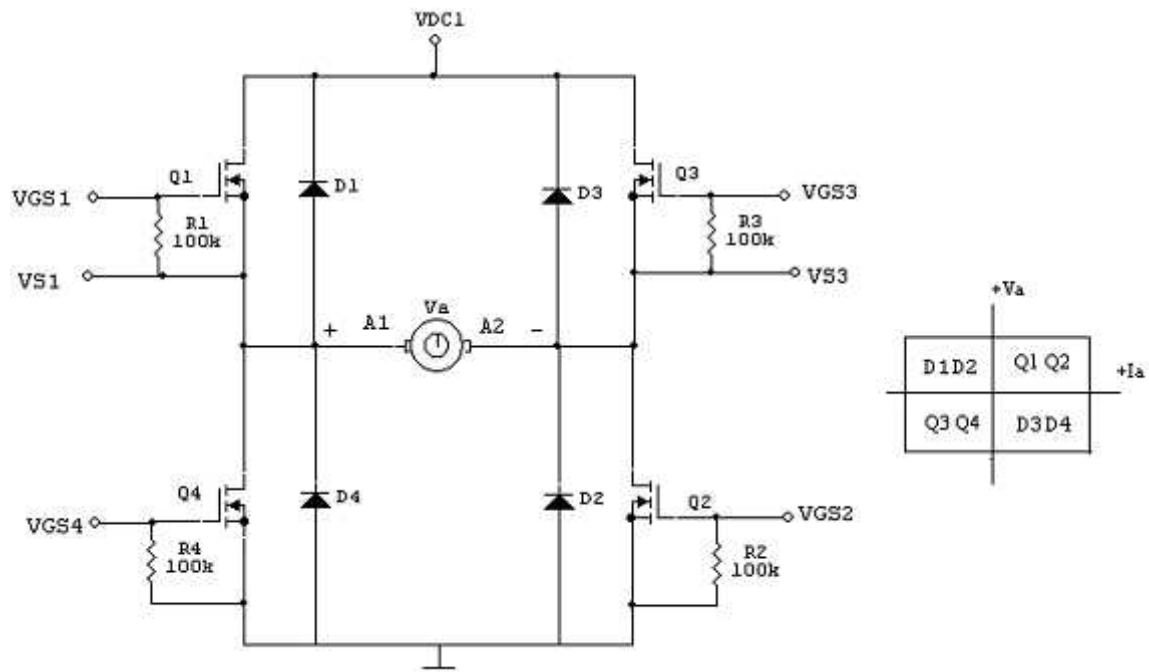


Figure (4.5): Converter with Power Transistors.

4.1.2.1 Operation the Transistors

Forward Motoring. Transistor Q1 and Q2 operates. Transistor Q3 and Q4 are off. When Q1 and Q2 is turn on together, the supply voltage appears across the motor terminals & the armature current rises. When Q1 is turned off and Q2 is still turned on, the armature current decays through Q2 and D4. Alternative, both Q1 and Q2 can be turned off, while the armature current is forced to decay through D3 and D4.

Forward generating. Transistors Q1, Q2 and Q3 are turned off. When transistor Q4 is turned on, the armature current, which raises, flows through Q4 and D2. When Q4 is turned off, the motor, acting as a generator, returns energy to the supply through D1 and D2.

Reverse motoring. Transistor Q3 and Q4 operate. Transistor Q1 and Q2 are off. When Q3 and Q4 are turn on together, the armature current rises and flows in the reverse direction. When Q3 is turned off and Q4 is turned on, the armature current falls through Q4 and D2. Alternatively, both Q3 and Q4 can be turned off, while forcing the armature current to decay through D1 and D2.

Reverse generating. Transistor Q1, Q3 and Q4 are off. When Q2 is turn on, the armature current rises through Q2 and D4. When Q2 is turning off, the armature current falls and the motor return energy to the supply through D3 and D4. And the table (4.2) shows the operation in four quadrants¹.

¹ Rashid, power electronic and application, 5th edition.

Table (4.2): Operation in Four Quadrant.

Operation state	F. Motor	R. Motor	R. Generator	F. Generator
Operation VGS	VGS1 VGS2	VGS3 VGS4	-----	-----
Operation Q	Q1 Q2	Q3 Q4	D1D2	D3D4
State Power	From source	From source	To source	To source
State Ia	+	-	+	-
State Va	+	-	-	+
ω direction				
Quadrant operation	First quadrant	Third quadrant	Fourth quadrant	Second quadrant

4.1.2.2 Power Transistor (MOSFETs)

MOSFETs (Metal Oxide Semiconductor Field Effect Transistors) have been used in power electronics applications their appreciable current carrying and off-state voltage blocking capability with low on-state voltage drop. They have managed to replace BJTs in many applications due to their simpler gate drive requirements and higher positive temperature coefficient which allows devices to be paralleled for higher current capabilities.

Table (4.3): Typical MOSFET Ratings.

I_D	V_{DSS}	R_{DS} typical (max)	V_{GS} (for I_D)	V_T
1A	900V	7 (9)	10V (0.5A)	1.5 - 3.5V
2A	500V	3 (4)	10V (1A)	2 - 4V
9A	200V	0.25 (0.4)	10V (5A)	2 - 4V
13A	500V	0.3 (0.4)	10V (7A)	2 - 4V
45	60V	0.024 (0.03)	10V (25A)	2 - 4V

A simplified diagram of an N-channel enhancement MOSFET is shown in figure (4.6). Drain and source connections are made to higher conduction high doped regions. The metal gate is electrically isolated from the P-type substrate by a layer of non-conducting silicon oxide (SiO_2). When a positive voltage is applied to the gate with respect to the source an electric field will be created pointing away from the base and across the P-region directly under the base. The electric field will cause positive charges in the P-region to move away from the base inducing or enhancing an N-region in its place. Conduction can then take place between the N+(drain) N(enhanced region) N+(source). Increasing or decreasing the gate voltage will cause the induced N channel to grow or decrease in size thus controlling conduction.

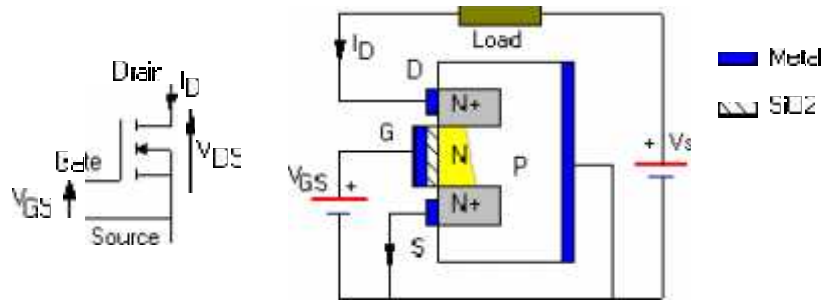


Figure (4.6): Simple model of an N-channel enhancement type MOSFET

The diagram in figure (4.7) shows typical current curves for various gate-source voltage levels.¹

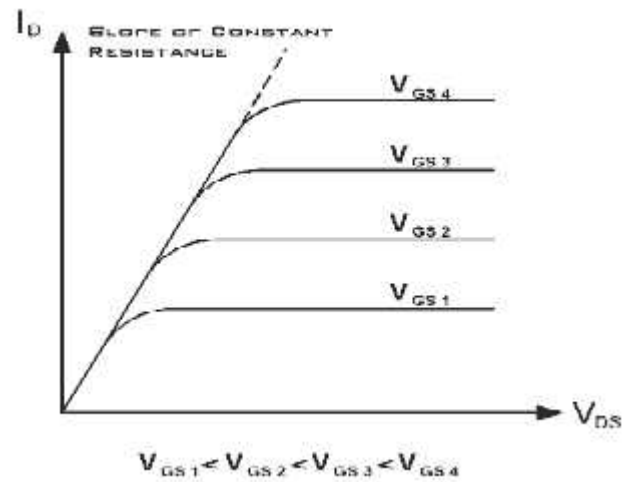


Figure (4.7): Typical Current Curves for Various Gate-Source Voltage Levels.

¹ www.Powerdesingner.com

Important MOSFET Parameters1. Maximum Drain-Source Voltage, V_{DS}

V_{DS} is the maximum instantaneous operating voltage.

2. Continuous Drain Current, I_D

I_D is the maximum current the MOSFET can carry sometimes specified at a particular junction temperature.

3. Maximum Pulsed Drain Current, I_{DM}

I_{DM} is greater than I_D and specified for a particular pulse width and duty cycle.

4. Maximum Gate-Source Voltage, V_{GS}

V_{GS} is the maximum voltage that can be applied between gate and source without damaging the gate insulation.

5. Gate Threshold Voltage, V_T , $\{V_{TH}, V_{GS(th)}\}$

V_T is the minimum gate voltage at which the transistor will turn ON.

4.2 Control Circuit

4.2.1 PI- Controller

The figure (4.8) illustrated the Circuit of PI Controller.

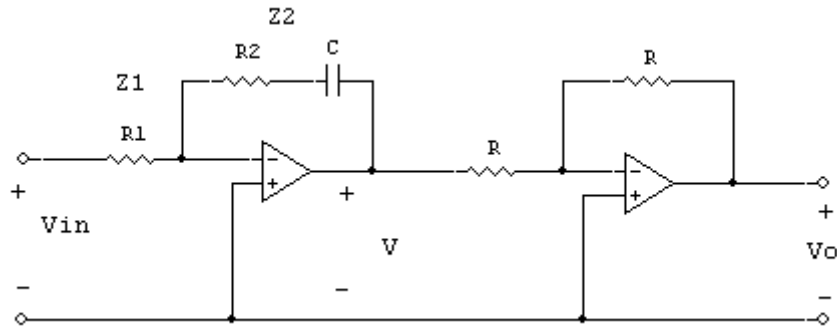


Figure (4.8): The Circuit of PI Controller.

$$Z1 = R1 \text{ And } Z2 = R2 + \frac{1}{CS}$$

$$V(s) = -\frac{Z2}{Z1} Vin = -\frac{1}{R1} \left(R2 + \frac{1}{CS} \right) = -\frac{R2}{R1} \frac{(S + 1/R2C)}{S}$$

$$= \frac{R2}{R1} \frac{(S + 1/R2C)}{S} = Kp \frac{(S + KI/Kp)}{S} \dots\dots\dots (4.4)$$

Where:

$$Kp = \frac{R2}{R1}$$

$$KI = \frac{Kp}{R2C} = \frac{1}{R1C}$$

The figure (4.9) illustrated the Block diagram PI- controller

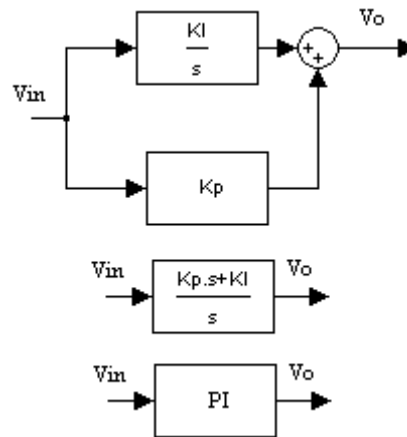


Figure (4.9): Block Diagram PI- Controller.

$$Go(s) = Kp + \frac{KI}{S} \dots\dots\dots (4.5)$$

$$Go(s) = \frac{R2}{R1} \frac{(S + 1/R2C)}{S} = Kp \frac{(S + KI/Kp)}{S} \dots\dots\dots (4.6)$$

The figure (4.10) illustrated the wave of controllers

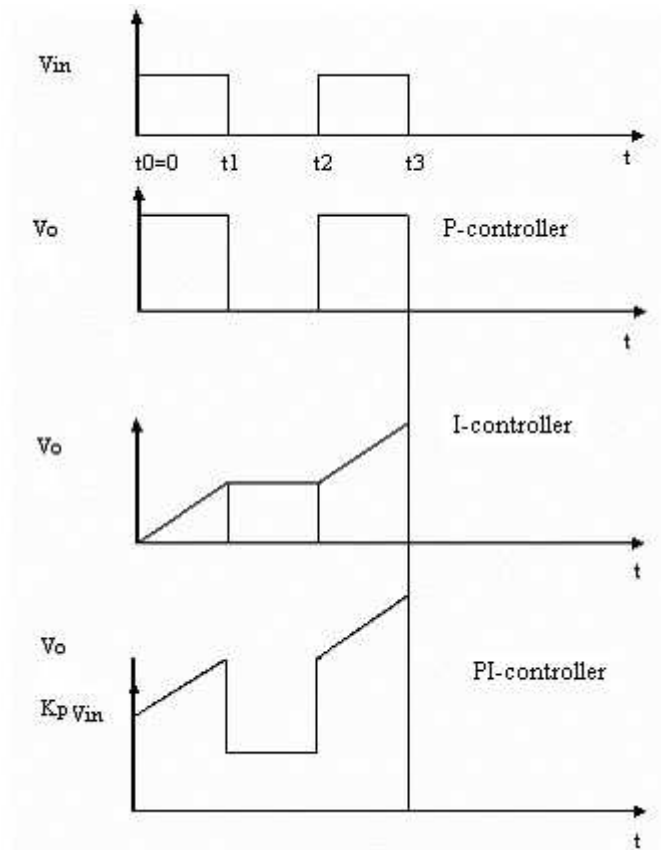


Figure (4.10): The Wave of Controllers.

4.3 Interfacing Circuit

4.3.1 Interface circuit

The figure (4.11) illustrated the interfacing circuit

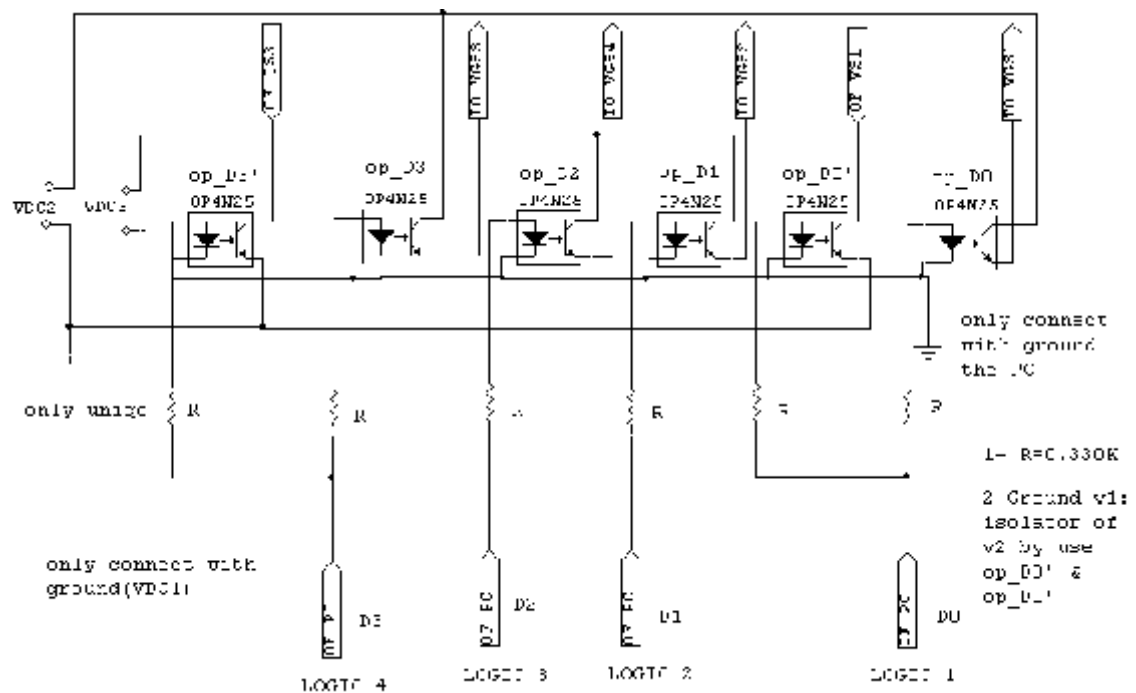


Figure (4.11): Interfacing Circuit.

How the operation

Table (4.4): Status The Pins and Operation the devices .

State the machine	F.Motor		R.Motor		F.generator		R.generator	
PC number port	Pin2	Pin3	Pin4	Pin5	-----	-----	-----	-----
Operation transistor	Q1	Q2	Q3	Q4	D1	D2	D3	D4
State logic	1	1	0	0	The diode used to Protection the transistors			
State logic	0	0	1	1				
State logic	0	0	0	0	D1	D2	Not flow current	
State logic	0	0	0	0	Not flow current		D3	D4

For example:

Run the system forward motor (F.Motor)?

As software can be the sender to interfacing signals to operation Q1 & Q2 of the table (4.4)

```
Putvalue(par.line(1:8),[1 1 0 0 0 0 0 0]);
```

4.3.2 Optocoupler

Optocouplers are also called optoisolators, photon-coupled isolators, photocouplers, photo-coupled pairs and optically coupled pairs. All of the characteristics the optocouplers are electrical; they have no external optical properties. Although optocouplers are not optoelectronic devices, they are in fact one of the simplest electro-optical systems. The table (4.5) below shows a comparison between different signal coupling devices,

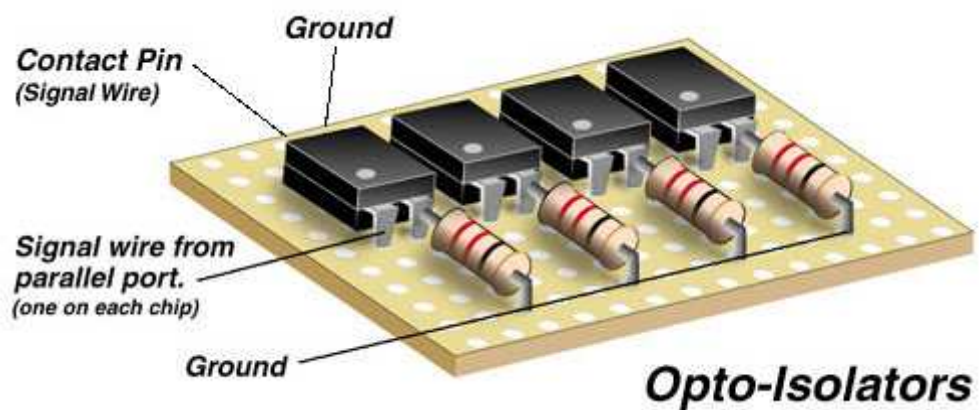
Table (4.5) Comparison between Different Signal Coupling Devices.

Device	Advantages	Disadvantages
Optocoupler	Economical. Solid-state reliability. Medium to high-speed signal transmission. DC & low frequency transmission. High voltage isolation. High isolation impedance. Small size DIP Package. No contact bounce. Low power operation.	Finite ON Resistance. Finite OFF Resistance. Limited ON state current. Limited OFF state voltage. Low transmission efficiency.
Relay	High power capability. Low ON resistance. DC transmission. High voltage isolation.	High cost. High power consumption. Unreliable. Very slow operation. Physically large.

An optocoupler is usually divided into two parts: the input part and the output part. The input consists of an infrared light emitting diode (ILED). The output is usually a phototransistor for DC output, or phototriac for AC output. The link between the two parts is achieved by the infrared light emitted by the diode and received by the phototransistor or phototriac.

When forward current (I_F) is passed through the diode, it emits infrared radiation. The radiant energy is transmitted through an optical coupling medium and falls on the surface of the phototransistor or the phototriac. This causes the phototransistor or the phototriac to conduct the electrical current which passes to the load.

The input voltage and current are very small compared to the output voltage and current. This makes optocouplers very useful in interfacing circuits where a small electrical signal drives a large signal. It also provides protection for the control circuit from overloading and unexpected changes in the load circuit.



The figure (4.12) illustrated the optocoupler (opto-Isolators)

4.3.3 Parallel Port

4.3.3.1 Introduction to Parallel Port

The Parallel Port is the most commonly used port for interfacing home made projects. This port will allow the input of up to 9 bits or the output of 12 bits at any one given time, thus requiring minimal external circuitry to implement many simpler tasks. The port is composed of 4 control lines, 5 status lines and 8 data lines. It's found commonly on the back of your PC as a D-Type 25 Pins female connector. There may also be a D-Type 25 pins male connector. This will be a serial RS-232 port and thus, is a totally incompatible port.¹

4.3.3.2 Parallel Port Hardware Properties

Below is a table of the "Pin Outs" of the D-Type 25 Pins connector and the Centronics 34 Pins connector. The D-Type 25 pins connector is the most common connector found on the Parallel Port of the computer, while the Centronics Connector is commonly found on printers.

- 8 output pins accessed via the DATA Port, pins(2-9).
- 5 input pins (one inverted) accessed via the STATUS Port, pins(1,14,16,17).
- 4 output pins (three inverted) accessed via the CONTROL Port, pins(10,11,12,13,15).
- The remaining 8 pins are grounded, pins(18-25).

¹www.beyondlogic.org/index.html#PARALL.

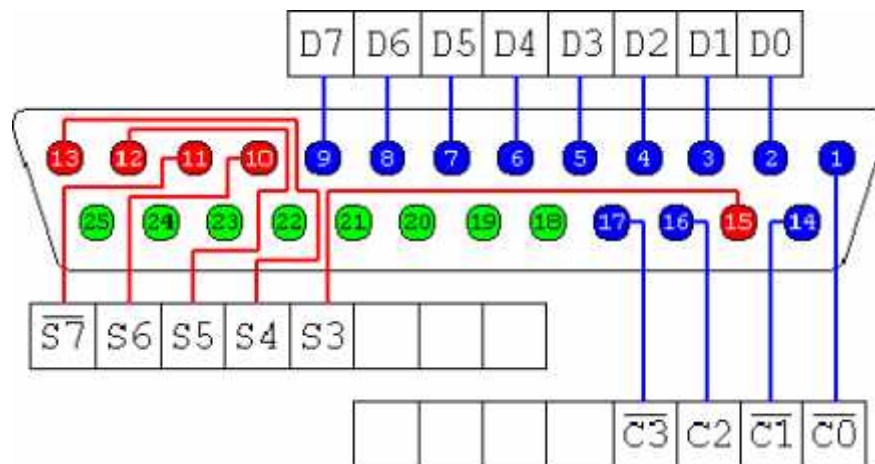


Figure (4.13): Parallel Port Pins.

Table (4.6): Pin Assignments of the D-Type 25 pin Parallel Port Connector.

Pin No (D-Type 25)	Pin No (Centronics)	SPP Signal	Direction In/out	Register	Hardware Inverted
1	1	nStrobe	In/Out	Control	Yes
2	2	Data 0	Out	Data	
3	3	Data 1	Out	Data	
4	4	Data 2	Out	Data	
5	5	Data 3	Out	Data	
6	6	Data 4	Out	Data	
7	7	Data 5	Out	Data	
8	8	Data 6	Out	Data	
9	9	Data 7	Out	Data	
10	10	nAck	In	Status	
11	11	Busy	In	Status	Yes
12	12	Paper-Out / Paper-End	In	Status	
13	13	Select	In	Status	
14	14	nAuto-Linefeed	In/Out	Control	Yes
15	32	nError / nFault	In	Status	
16	31	nInitialize	In/Out	Control	
17	36	nSelect-Printer / nSelect-In	In/Out	Control	Yes
18 - 25	19-30	Ground	Gnd		

The above table uses "n" in front of the signal name to denote that the signal is active low. e.g. nError. If the printer has occurred an error then this line is low. This line normally is high, should the printer be functioning correctly. The "Hardware Inverted" means the signal is inverted by the Parallel card's hardware. Such an example is the Busy line. If +5v (Logic 1) was applied to this pin and the status register read, it would return back a 0 in Bit 7 of the Status Register.

The output of the Parallel Port is normally TTL logic levels. The voltage levels are the easy part. The current you can sink and source varies from port to port. Most Parallel Ports implemented in ASIC, can sink and source around 12mA. However these are just some of the figures taken from Data sheets, Sink/Source 6mA, Source 12mA/Sink 20mA, Sink 16mA/Source 4mA, and Sink/Source 12mA. As you can see they vary quite a bit. The best bet is to use a buffer, so the least current is drawn from the Parallel Port.

4.3.3.3 Port Addresses

The Parallel Port has three commonly used base addresses. These are listed in table 7, below. The 3BCh base address was originally introduced used for Parallel Ports on early Video Cards. This address then disappeared for a while, when Parallel Ports were later removed from Video Cards. They has now reappeared as an option for Parallel Ports integrated onto motherboards, upon which there configuration can be changed using BIOS¹.

LPT1 is normally assigned base address 378h, while LPT2 is assigned 278h. However this may not always is the case as explained later. 378h & 278h have

¹ William stalling, Computer organization and architecture, 4th edition.

always been commonly used for Parallel Ports. The lower case h denotes that it is in hexadecimal. These addresses may change from machine to machine.

Table (4.7): Port Addresses.

Address	Notes:
3BCh - 3BFh	Used for Parallel Ports which were incorporated on to Video Cards - Doesn't support ECP addresses
378h - 37Fh	Usual Address For LPT 1
278h - 27Fh	Usual Address For LPT 2

4.3.3.4 How to Connect Circuits to Parallel Port

PC parallel port is 25-pin D-shaped female connector in the back of the computer. It is normally used for connecting computer to printer, but many other types of hardware for that port are available today.

Not all 25 are needed always. Usually you can easily do with only 8 output pins (data lines) and signal ground. Those pins are presented in the table 8. Those output pins are adequate for many purposes.

Table (4.8): Parallel Port Pins Number with Data Lines Index.

Pin	function
2	D ₀
3	D ₁
4	D ₂
5	D ₃
6	D ₄
7	D ₅
8	D ₆
9	D ₇

Pins 18,19,20,21,22,23,24 and 25 are all ground pins.

Those data pins are TTL level output pins. This means that they put out ideally 0V when they are in low logic level (0) and +5V when they are in high logic level (1). In real world the voltages can be something different from ideal when the circuit is loaded. The output current capacity of the parallel port is limited to only few mA.

4.3.4 Analog to digital converter (ADC).

The Analog to Digital converter is commonly used for monitoring sensors attached to the computer. There could be many different designs for it, but we will use a simple design for this demonstration. The A/D converter uses a circuit called a successive approximation register (SAR). It is basically an up counters with just a little bit of extra logic added to start and stop the counting. The bits from it goes to a Digital to Analog Converter (DAC). Its output is compared to the Analog value that is to be converted. If they are the same, the SAR stops and latches the current count into a register. It also signals to the outside world that its finished converting the analog value. The computer can then read the register's contents

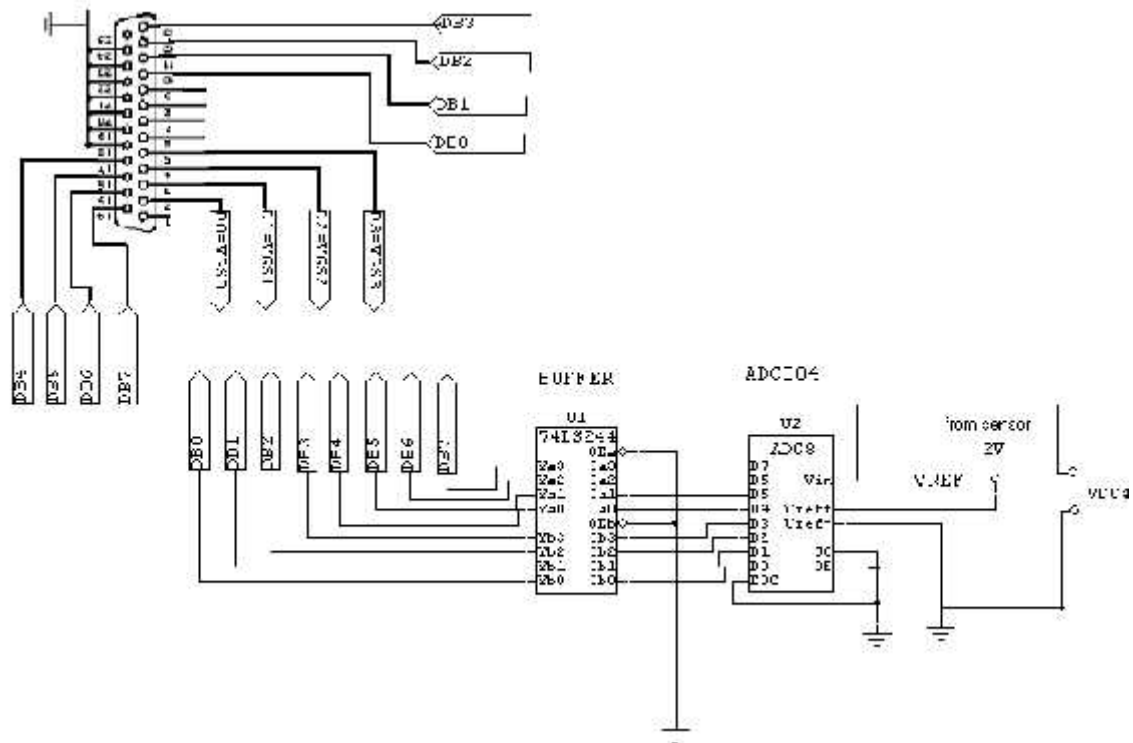


Figure (4.14): Analog to Digital Converter.

4.4 Choosing the Motor

The choosing of motor illustrated in the nameplate in table (4.9) to be as a models represent the operation of speed control in four quadrants.

Table (4.9): Nameplate of DC Motor.

HITACHI DC MOTOR		
TYP D06D401E		
--- MOTOR	NR.C91.1	
30 V	2A	
42W	S1	Cosφ -
2750 rpm	- Hz	
INS.CL.	B	



Define the Parameter

- 1- HITACHI DC MOTOR: name of the company produce.
- 2- TYP D06D4011E: meaning the permit-magnetic DC motor.
- 3- ___ MOTOR: meaning the DC MOTOR.
- 4- Nr. C91.1: number of the motor by the company produced.
- 5- 30 V: rated armature voltage.
- 6- 2 A: rated armature current.
- 7- 42W: rated the power output.
- 8- S1: continues operation
- 9- COS φ __: no any value its DC motor.

10- 2750rpm: rated revolution per minute.

11- __ Hz: no any value its DC motor.

12- INS.CL. B: isolation degree of the dry temperature ($B=130^{\circ}$)

13- $R_a = 2.5\Omega$: is measurement.

Table (4.10): Practical Parameters of the Motor.

Va/v	n/rpm	T/(N.m)	Ia/A
5	190	0.05	0.1
10	690	0.35	0.5
15	1190	0.1	1
20	11705	0.12	1.3
25	2220	0.14	1.5
30	2720	0.16	1.7

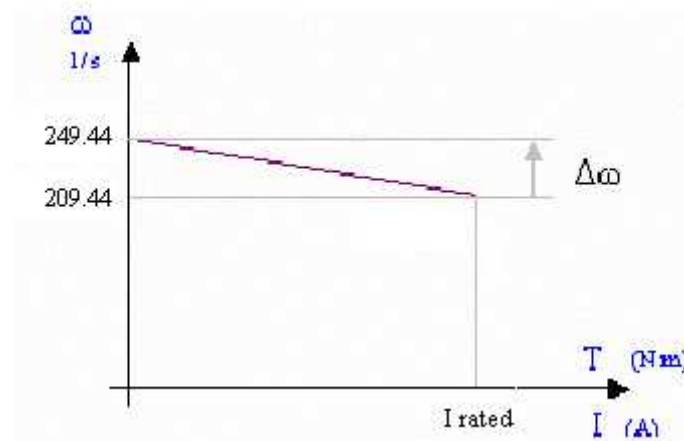


Figure (4.15): Speed Characteristics

Main Equation of DC Chopper

$$V_a = KVDC_1 \dots\dots\dots (4.7)$$

Where:

K: is the duty cycle.

VDC₁: Input dc voltage of DC chopper.

V_a: Output Average voltage.

$$0 \leq K \leq 1 \quad \text{then} \quad 0 \leq V_a \leq V_s$$

The power supplied to the motor is:

$$P_{in} = V_a I_a = KVDC_1 I_a \dots\dots\dots (4.8)$$

$$K = \frac{t_{on}}{T} \dots\dots\dots (4.9)$$

K : From the PC computer using the software program.

$$T = t_{on} + t_{off} \dots\dots\dots (4.10)$$

Where:

$$T = \frac{1}{f}$$

Note:

The speed control of DC Motor by armature voltage control by varying the duty cycle K.

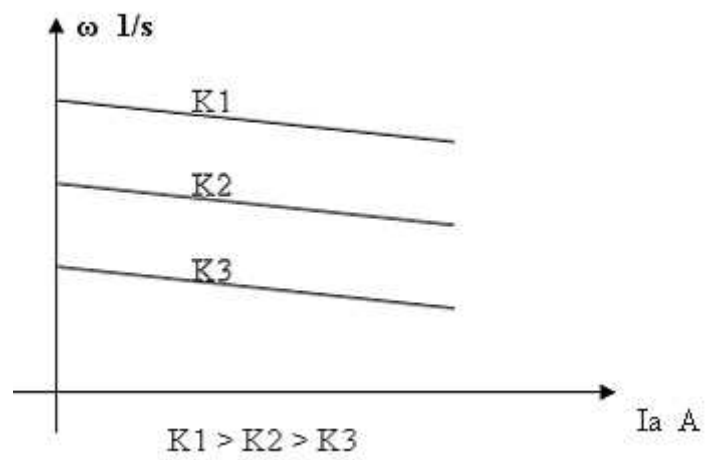
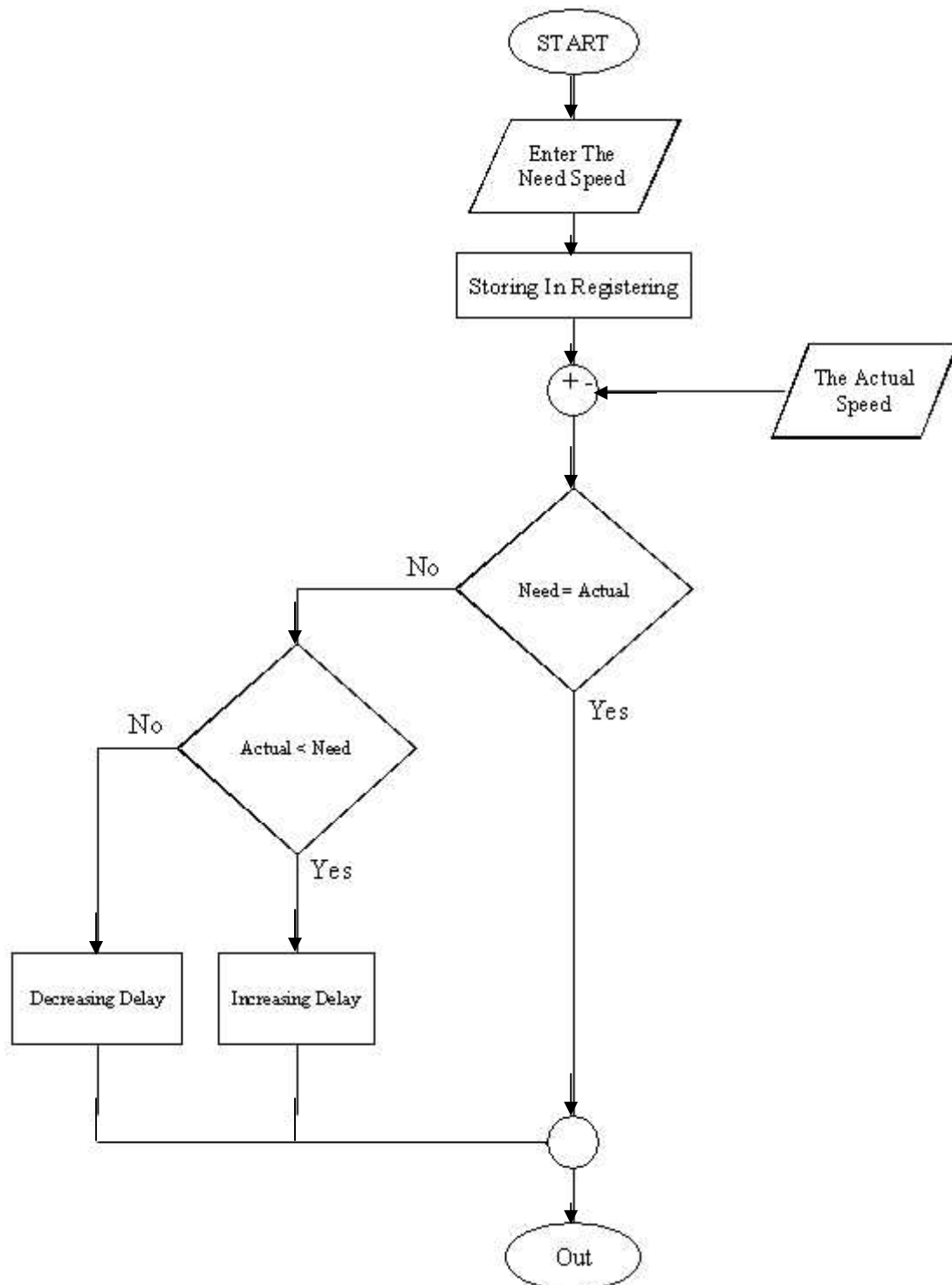


Figure (4.16): Armature Voltage Control by varying the Duty Cycle K .

CHAPTER FIVE

SOFTWARE SYSTEM DESIGN

5.1 Flow Chart to Control of Converter.



CHAPTER FIVE

SOFTWARE SYSTEM DESIGN

5.1 Flow Chart to Control of Converter.

5.2 What Is MATLAB

5.3 How System works

CHAPTER FIVE

SOFTWARE SYSTEM DESIGN

5.1 Flow Chart to Control of Converter.

5.2 What Is MATLAB

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include :

- Math and computation.
- Algorithm development.
- Data acquisition.
- Modeling, simulation, and prototyping.
- Data analysis, exploration, and visualization.
- Scientific and engineering graphics.
- Application development, including graphical user interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar no interactive language such as C or Fortran.

The name **MATLAB** stands for matrix laboratory. **MATLAB** was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects. Today, **MATLAB** engines incorporate the LAPACK and BLAS libraries, embedding the state of the art in software for matrix computation.

The MATLAB System

The **MATLAB** system consists of five main parts:

- **Development Environment.**

This is the set of tools and facilities that help you use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files, and the search path.

- **The MATLAB Mathematical Function Library.**

This is a vast collection of computational algorithms ranging from elementary functions like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix eigenvalues, Bessel functions, and fast Fourier transforms.

- **The MATLAB Language.**

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create complete large and complex application programs.

- **Graphics.**

MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow you to fully

customize the appearance of graphics as well as to build complete graphical user interfaces on your **MATLAB** applications.

- **The MATLAB Application Program Interface (API).**

This is a library that allows you to write C and Fortran programs that interact with **MATLAB**. It includes facilities for calling routines from **MATLAB** (dynamic linking), calling **MATLAB** as a computational engine, and for reading and writing MAT-files.

Writing and Reading Digital I/O Line Values

After you add lines to a digital I/O (DIO) object, you can:

- Write values to lines.
- Read values from lines.

Writing Digital Values

You write values to digital lines with the **putvalue** function. **putvalue** requires the DIO object and the values to be written as input arguments. You can specify the values to be written as a decimal value or as a binary vector (**binvec**). A binary vector is a logical array that is constructed with the least significant bit (LSB) in the first column and the most significant bit (MSB) in the last column. For example, the decimal value 23 is written in **binvec** notation as $[1 \ 1 \ 1 \ 0 \ 1] = 2^0 + 2^1 + 2^2 + 2^4$. You might find that **binvecs** are easier to work with than decimal values because there is a clear association between a given line and the value (1 or 0) that is written to it. You can convert decimal values to **binvec** values with the **dec2binvec** function.

For example, suppose you create the digital I/O object `dio` and add eight output lines to it from port 0.

```
dio = digitalio('nidaq',1);  
addline(dio,0:7,'out');
```

Rules for Writing Digital Values

Writing values to digital I/O lines follows these rules:

1. If the DIO object contains lines from a port-configurable device, then the data acquisition engine writes to all lines associated with the port even if they are not contained by the device object.
2. When writing decimal values:
 - If the value is too large to be represented by the lines contained by the device object, then an error is returned.
 - You can write to a maximum of 32 lines. To write to more than 32 lines, you must use a `binvec` value.
3. When writing binary values,
 - You can write to any number of lines.
 - There must be an element in the binary vector for each line you write to.
4. You can always read from a line configured for output.
5. An error is returned if you write a negative value, or if you write to a line configured for input.

Reading Digital Values

You can read values from one or more lines with the **getvalue** function. **getvalue** requires the DIO object as an input argument. You can optionally specify an output argument, which represents the returned values as a binary vector.

For example, suppose you create the digital I/O object **dio** and add eight input lines to it from port 0.

```
dio = digitalio('nidaq',1);
```

```
addline(dio,0:7,'in');
```

Rules for Reading Digital Values

1. Reading values from digital I/O lines follows these rules:

If the DIO object contains lines from a port-configurable device, then all lines are read even if they are not contained by the device object. However, only values from the lines contained by the object are returned.

2. You can always read from a line configured for output.

3. For National Instruments hardware, lines configured for input return a value of 1 by default.

4. **getvalue** always returns a binary vector (**binvec**). To convert the **binvec** to a decimal value, use the **binvec2dec** function.

5.3 How System works

- 1- We need the speed 690rpm.
- 2- Must constant the speed under any increase the load.
- 3- Operation the motor quadrant1& quadrant 2

From the table (4.10) the speed 690rpm equivalent the $V_a = 10v$.then

$V_a = KVDC1$, then

$10 = K(12)$,then

$K=0.83$.then the software

$ton = 10\text{ ms}$. $T = 12\text{ ms}$, $toff = 2\text{ ms}$.

For the operation motor (F.Motor). of table ().

Putvalue(par.line(1:8),[1 1 0 0 0 0 0 0]) ;

Pause(ton); %ton=0.01second.

Putvalue(par.line(1:8),[0 0 0 0 0 0 0 0]) ;

Pause(toff); %toff=0.002second

Operation the feedback when loading motor using software following:

```

ADC1=getvalue(dio1.line(10:13));
ADC2=getvalue(dio2.line(14:17));
x1=bin2vecdec(ADC1,8);
x2=bin2ecdec(ADC2,8);
X=ADC1+ADC2;

if(ADC==vref)
end
else
    if(ADC<vref)
        ton=(0.0015)+ton;
    end
    else
        if(ADC>vref)
            ton=ton-(0.0015);
        end
        Putvalue(par.line(1:8),[1 1 0 0 0 0 0 0]) ;
Pause(ton); %ton=0.01second.
Putvalue(par.line(1:8),[0 0 0 0 0 0 0 0]) ;
Pause(toff); %toff=0.002second
end.
For the motor of active to generator (quadrant2).
Putvalue(par.line(1:8),[0 0 0 0 0 0 0 0]) ;
Pause(ton); %ton=0.01second.
Putvalue(par.line(1:8),[0 0 0 0 0 0 0 0]) ;
Pause(toff); %toff=0.002second

```


CHAPTER SIX

PROTECTION

6.1 What is electrical protection?

6.2 Requirements of the electrical protection system.

6.3 Protection against over current.

6.4 Overload.

6.5 Short circuit.

6.6 Fuse and circuit breaker.

6.7 Cooling and Heat Sink

CHAPTER SIX

PROTECTION

6.1 What is electrical protection?

Electrical protection it is the protect the electrical system from dangerous that happened from fault in the electrical system. From that the electrical protection not prevent occur the electrical fault but it is prevent the dangerous which is damage the system.

So the (electrical protection is the science solve the electrical fault and the effect of it with small speed to make continuity in the system.

6.2 Requirements of the electrical protection system

1. Reliability: it must operate in unnatural condition.
2. Speed: the time of the operate must less than or equal three cycles.
3. Selectivity: it must keep the continuity of the power with less number times of cutting the current.
4. Simplicity and economy.

6.3 Protection against over current

An over current is the current greater than the rated current of the circuit. It may occur in tow way:

1. As an overload current
2. As short-circuit of fault current.

These condition need to be protecting against in order to avoid damage to circuit conductors and equipment. In practice, fuses and circuit breakers will fulfils both is this needs.

6.4 Overload

Overloads are over current occurring in healthy circuit they may be caused, for example, and faulty appliances or by surges due to motors starting.

The current that we limit the overload is equal or less of the max. Full load current.

6.5 Short circuit

Short circuits current that will flow when a dead short occurs between live conductors (phase to neutral for single phase; phase to phase for three phases). Prospective short circuit current is the same, but the term is usually used to signify the value of the short circuit at fuse or circuit breaker position.

6.6 Fuse and circuit breaker

- **Fuse**

As we all know, fuse is the weak link in a circuit which will break when too much current flows, thus protecting the circuit conductors from damage.

There are many different types and sizes of fuse, all designed to perform a certain function.

Selection of the Fuses

The selection of the circuit breaker depends on three conditions.

1. Construction and dimension wire of fuse.
2. The operation current and voltage.
3. Porcelain housing of the fuse.

- **Circuit breaker**

The on /off of the circuit is considered the basic operation in any electrical system, this operation occurs by means of circuit breaker.

But the very important use of the circuit breaker is in order to open the circuit if any unnatural condition occurs.

Selection of the circuit breaker

The selection of the circuit breaker depends on three conditions.

1. The operation voltage.
2. The full load current.
3. Maximum Fault current.

Table (6.1): Motor Power, nominal current, overload current and fuse current.

Motor Power (KW)	Nominal Current (A)	Overload Current (A)	Fuse Current (A)
0.00	0.00	0.0 – 0.0	1
0.00	0.00	0.0 – 0.0	1
0.00	0.00	0.0 – 0.0	0
0.00	0.00	0.00 – 0.00	0
0.00	0.00	0.0 – 0.0	0
0.00	0.00	0 – 0.0	0
0.00	0.0	0 – 0.0	0
0.00	0.0	0.0 – 0.0	0
0.0	0.0	0 – 0.0	0
0.0	0.0	0 – 0	0
0.0	0.0	0.0 – 0.00	00
0.0	0.0	0.0 – 0.0	00
0.0	0.0	0 – 00	00
0.0	00.0	0 – 00	00
0.0	00.0	00 – 00	00
00	00	00 – 00	00
00	00	00 – 00	00

6.7 Cooling and Heat Sink

Due to on-state and switching losses, heat is generated within the power device. This heat must be transferred from the device to a cooling medium to maintain the operating junction temperature within the specified range. Although this heat transfer can be accomplished by conduction, convection, or radiation, natural or forced-air, convection cooling is commonly used in industrial applications.

The contact area between the device and heat sink is extremely important to minimize the thermal resistance between the case and sink. The surfaces should be flat, smooth, and free of dirt, corrosion, and surface oxides. Silicone greases are normally applied to improve the heat transfer capability and to minimize the formation of oxides and corrosion.

The figure (6.1) illustrated the heat sink.



Figure (6.1): Heat Sink

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATION

2.1 Conclusions

2.2 Recommendation

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATION

2.1 Conclusions

The Dual Converter allows operation the machine in four quadrant and speed control, discussed in Chapter 3, and 4. In addition, if any increasing in the duty cycle due to increase the armature voltage.

Using a computer programs, as MATLAB program in this project, more easily to solve the block diagram, plot the curves and control to converter by generate pulses using the parallel port.

2.2 Recommendation

Table (6.1): Motor Power, nominal current, overload current and fuse current.

Motor Power (KW)	Nominal Current (A)	Overload Current (A)	Fuse Current (A)
0.00	0.00	0.0 – 0.0	1
0.00	0.00	0.0 – 0.0	1
0.00	0.00	0.0 – 0.0	0
0.00	0.00	0.00 – 0.00	0
0.00	0.00	0.0 – 0.0	0
0.00	0.00	0 – 0.0	0
0.00	0.0	0 – 0.0	0
0.00	0.0	0.0 – 0.0	0
0.0	0.0	0 – 0.0	0
0.0	0.0	0 – 0	0
0.0	0.0	0.0 – 0.00	00
0.0	0.0	0.0 – 0.0	00
0.0	0.0	0 – 00	00
0.0	00.0	0 – 00	00
0.0	00.0	00 – 00	00
00	00	00 – 00	00
00	00	00 – 00	00

References:

1. www.powerdesigner.com.
2. www.beyondlogic.org/index.html#PARALL.
3. Malvino, electronic principles, 5th edition.
4. William stalling, computer organization and architecture, 4th edition.
5. Rashid, power electronics and applications, 5th edition.