Sudan University of Science and Technology

College of Graduate Studies

Optimizing of DC Motor Speed Using PID Controller and Grey Prediction Algorithm

سرعة موتور التيار الثابت المثالية باستخدام المتحكم التناسبي و التكاملي و التفاضلي و خوارزمية التوقع الرمادي

A Research Submitted in Partial fulfillment for the Requirements of M.Sc. in Electrical Engineering (Control Engineering)

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الاية

بسم الله الرحمن الرحيم

ي مُدْخَلَ ((79)) صِدْقٍ وَأَخْرِجْنِي مُخْرَجَ صِدْقٍ وَاجْعَلْ لِي مِنْ
لَدُنْكَ سُلْطَانًا نَصِيرا ((80))

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In the Name of Allah, the Most Merciful, the Most Compassionate all praise is to Allah, the Lord of the worlds; and prayers and peace be upon Mohamed His servant and messenger. First and foremost, I must acknowledge my limitless thanks to Allah, the Ever Magnificent; the Ever Thankful, for hishelps and bless. I am totally sure that this Work would have never become truth, without His guidance.

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DEDICATION

To
My Family
And
My Friends
With Love…

Abstract

This research is focus on the adjusting of a DC motor speed, predicts and expects the next values of errors that happen and appear from the difference between the actual speed and the desire speed.As known DC motor speed is hard to stabilize and adjusting in precise way, here we dealing with and use many techniques (PWM, PID controller and grey prediction) in order to reach and achieve suitable resultsfor speed and error.

The main goal of this research is to introduce the grey prediction algorithm by using it to tune the PID controller parameters, the output of the PID controller represent the controlled output (actual motor speed) which will feeding back to subtract from desired value to calculate the error . PWM technique used to control analog circuits using digital outputs, this technique used to control and change the voltage across the motor's terminals.

ATMEGA16 is chosen as the brain board controller to react towards the data received and to monitor the measurements of the output speed through the LCD, the results the expected to get is small values of errors at the majority of the cases study (different set points), and get numbers of errors that expect to be correspond to many and different set points.

المستخلص

هذاالبحث يركز علي ضبط سرعة محرك التيار المستمر ، التنبؤ وتوقع مجموعه من قيم الاخطاء والتي تحث وتظهر كنتيجه للفرق بين اقيمه الحقيقه للسرعه المقرؤه بواسطه الحساس والقيمه المرغوب فيها ،كما هو معلوم فان سرعة محرك التيار المستمر من الصعب تثبيتها وضبطها بطريقة دقيقة لذلك هنا سيتم التعامل مع مجموعة من التقنيات كتقنية نبضة تعديل العرض ،المتحكم التناسبي التفاضلي التكاملي وخوارزمية التوقع الرمادي من اجل الوصول والحصول علي نتائج مقبوله للسرعة ولقيمة الخطأ محرك التيار المستمر من الاليات واسعة الاستخدام والتي قد تستخدم بشكل منفرد او قد تكون عضو فعال في منظومة هندسية اكبر ،ونظرا لاهميته كانت الحوجة دوما للتحكم ولضبط سرعة واتجاه دورانه.

هدا البحث يتناول التحكم وضبط سرعة المحرك الحالية واستخدامها للتنبؤ بمجموعة من قيم الخرج ،يتم ذلك عن طريق بناء المتحكم التناسبي التفاضلي التكاملي واستخدام خوارزمية التنبؤ.

تقوم خوارزمية التنبؤ بالتنبؤ بالقيم المستقبلية لسرعة الموتور تبعا لمخرجات السرعة الحالية وبالتالي يمكن لخوارزمية المتحكم التناسبي التفاضلي التكاملي تلافي الخطأ في سرعة دوران الموتور قبل حدوثه.

تم استخدام المتحكم الدقيق وبرمجته بالخوارزميات المذكوره.النتائج المتحصل عليها تعتبر جيده وتساعد علي ضبط سرعة الموتور.

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$\mathbf{V_f}$	Field voltage
$\mathbf{V_a}$	Armature voltage
$\mathbf{R_f}$	Field resistor
$\mathbf{R_a}$	Armature resistance
$\mathbf{L_f}$	Field inductance
$\mathbf{L_a}$	Armature inductance
$\mathbf{T_m}$	Torque generates by motor
$\mathbf{I_f}$	Field current
$\mathbf{I_a}$	Armature current
$\mathbf{V_R}$	Resistor's voltage
$\mathbf{V_L}$	Inductor's voltage
$\boldsymbol{\omega}\mathbf{(s)}$	Angular velocity
$\mathbf{V_b/E_b}$	Back emf
$\boldsymbol{\Phi}$	The flux
$\mathbf{I_{sh}}$	Shunt field current

$\mathbf{R_{sh}}$	Shunt field winding resistance
$\mathbf{R_c}$	Controller resistance
N	Motor speed
ωr(k)	Reference speed
ia(k-1)	Armature current
ωp*(k)	Estimated speed
Vt(k-1)	Terminal voltage
$\mathbf{Y_{sp}}$	represent the set point value
Y	represents the feedback (measured) value
$\mathbf{k_i}$	Integral gain
$\mathbf{k_d}$	Derivative gain
$\mathbf{k_p}$	Proportional gain
$\mathbf{K_u}$	ultimate gain
$\mathbf{T_U}$	ultimate period
ʎ	tuning parameter
L	time delay
x	the collection composed of sequence X_i
X0	reference sequence

$\mathbf{\Gamma}$	grey relational map
$\mathbf{Y}^{\wedge\,(0)}$	the prediction value of the systems behavior is denoted
$\mathbf{T_i}$	Integral time
$\mathbf{T_d}$	Derivative time

LIST OF ABBREVIATION

AGO	Accumulated generating operation
ADC	Analoge digital converter
BASCOM	BASicCOMpiler
CHR	Chien , hornes and reswick method
CD	Compact disc
CISC	Complex instruction set computing
DC	Derivative controller
T_d	Derivative time
DAC	Digital analoge converter
DSP	Digital signal processor
DVD	digital versatile disc or digital video disc
AC	Direct Alternative current
DC	Direct current
EMF	Electro Magnetic Force
GPIO	General purpose input/output pins
GPU	Graphics Processing Unit
GM	Grey model

GRS	Grey relational space
ISP	in-system programmable
IC	Integral controller
ITAE	Integral of time-weighted absolute error
T_i	Integral time
LED	light emitted diode
LCD	Liquid crystal display
MO	Modulus optimum
MIMO	Multiple inputs multiple outputs
ANN	Neural network
Opamp	Operational amplifier
PM	Permanent magnet
PIT	Programmable Interval Timer
PID	Proportional integral derivative controller
PWM	Pulse width modulation
RISC	Reduced instruction set computing
SPI	Serial Peripheral Interface
SISO	Single input single output

SRAM	*Static random-access memory*
SO	Symmetrical optimum
G_C	Transfer function of the controller
G_P	Transfer function of the process
ʎ	Tuning parameter
UART	Universal asynchronous receiver transmitter
USART	Universal SynchronousAsynchronous Receiver Transmitter

CHAPTER ONE

(INTRODUCTION)

1.1 Introduction

The control system is an interconnection of components forming a system configuration that will provide a desired system response, the basis for analysis of a system is the foundation provided by linear system theory, which assumes a cause–effect relationship for the components of a system. Therefore a component or process to be controlled can be represented by a block; the input–output relationship represents the cause-and-effect relationship of the process, which in turn represents a processing of the input signal to provide an out-Put signal variable, often with power amplification. An open-loop control system utilizes a controller or control actuator to obtain the desired response, an open-loop system is a system without feedback. In contrast to an open-loop control system, a closed-loop control system utilizes an additional measure of the actual output to compare the actual output with the desired output response. The measure of the output is called the feedback signal.

A simple closed-loop feedback control system is a control system that tends to maintain a prescribed relationship of one system variable to another by comparing functions of these variables and using the difference as a means of control. A feedback control system often uses a function of a prescribed relationship between the output and reference input to control the process. Often the difference between the output of the process under control and the reference input is amplified and used to control the process so that the difference is continually reduced. The feedback concept has been the foundation for control system analysis and design Due to the increasing complexity of the system under control and the interest in achieving optimum performance, the importance of control system engineering has grown in the past decade. Furthermore, as the systems become more complex, the interrelationship of many controlled variables must be considered in the control scheme. [8]

Direct current (DC) motors have variable characteristics and are used extensively in variable-speed drives. DC motor can provide a high starting torque and it is also possible to obtain speed control over wide range, it plays a significant role in modern industrial. These are several types of applications where the load on the DC motor varies over a speed range. These applications may demand high-speed control accuracy and good dynamic responses.

In home appliances, washers, dryers and compressors are good examples. In automotive, fuel pump control, electronic steering control, engine control and electric vehicle control are good examples of these. In aerospace, there are a number of applications, like centrifuges, pumps, robotic arm controls, gyroscope controls and so on.

The needs of a speed motor controller came from the importance to make a controller to control the speed of DC motor in desired value.

1.2 Problem Statement

DC motor speed is hard to be stabilized in precise speed. Using Proportional Integral Derivative (PID) controller will minimize the error between the actual speed and set point speed. Another problem rose from tuning PID controller which will need precise tuning values.

1.3 Proposed Solution

Design a microcontroller control system Using Grey prediction algorithm which represents an auto tuning PID procedure that adjusts the parameters of PID controller.

1.4 Objectives

- The main objective of this research is to control the speed of DC motor ,predict and expect next values of errors by using PID controller and grey prediction algorithm
- Design electronic circuit. Using ATmega microcontroller connecting to DC motor, driver motor, sensor and Liquid Crystal Display (LCD).
- Implementation of PID and grey prediction algorithm in software
- Performance evaluation of the proposed system

1.5 Significant Of Research

The scope of work will cover the area of controlling DC motor speed by adjusting the PID controller parameters, the error and error rate between system output and system input represent the input of PID controller, The output from the PID controller represent the actual(controlled) value of speed ,so the usage of the grey prediction algorithm method in order to tuning PID controller itself , will give a proper value of the PID parameters ,which indirectly leads to a proper value of speed ,this can greatly improve system performances by forecasting the output of the system depending on a small amount of data After combining adaptive PID controller with grey prediction controller Grey-prediction model.

1.6 Methodology

The system is developing in several phases. Firstly the physical connection of the electronics circuit components, develop the connection of the microcontroller ATmega16 and its interface with the DC motor through the driver circuit L293D, in addition to the interfacing by ATmega16 and a sensor which handle the task of reading the feedback measured motor speed.

Secondly implementation the software ;the program wrote by bascom code and identify the dc motor parameters ,the ATmega16 ports connection ,the input /output of the drive circuit L293D which connect to the ATmega16 and DC motor respectively , the LCD pins.

then implement the PID function in order to tune DC motor speed ,also implement of the grey prediction method in order to auto tuning PID parameters which help in forecasting the next outputs of the system.

1.7 Research Layout:

This thesis includes five chapters as follow: Chapter two introduces literature review highlighting the PID and grey prediction method and DC motor implementation. Chapter three as well as showed system design of the proposed system and explains the system structure and program. Chapter four

Results and discussion. Chapter five consists of conclusion and recommendation.

CHAPTER TWO

(LITERATURE REVIEW)

LITERATURE REVIEW

2.1 Control Engineering Principles

Control system engineers are concerned with controlling a part of an environment known as a plant or system in order to produce desired Products for society [1]. A prior knowledge of the plant to be controlled is often critical in designing effective control systems.

The application of different engineering principles like that of electrical, mechanical, and/or chemical in order to achieve the desired output make control engineering a multi-faceted engineering domain.

Control systems can be categorized as open-loop control or closed-loop feedback control systems depending on the system architecture and control method applied. Feedback control systems can be further differentiated as single-input-output (SISO) or multiple-input-multiple-output (MIMO), often called multivariable control systems

2.1.1 Open-loop control systems

An open-loop control system is designed to meet the desired goals by using a reference signal that drives the actuators that directly control the process output. Output feedback is not present in this type of system. Figure 2.1. below shows the general structure of an open-loop control system.

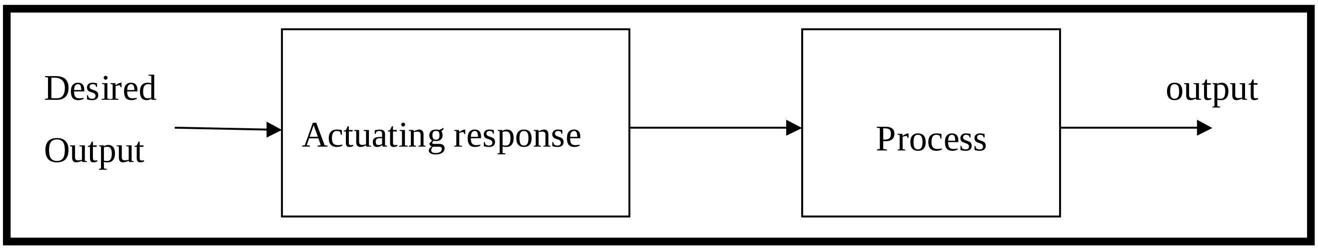


Figure 2.1: Open loop control system

A few examples of open-loop control systems are bread toasters, ovens, washing machines and water sprinkler systems [1].

2.1.2 Closed-loop control systems

In closed-loop control systems the difference between the actual output and the desired output is fed back to the controller to meet desired system output. Often this difference, known as the error signal is amplified and fed into the controller. Figure 2.2. Shows the general structure of a closed-loop feedback control system. A few examples of feedback control systems are elevators, thermostats, and the cruise control in automobiles [2].

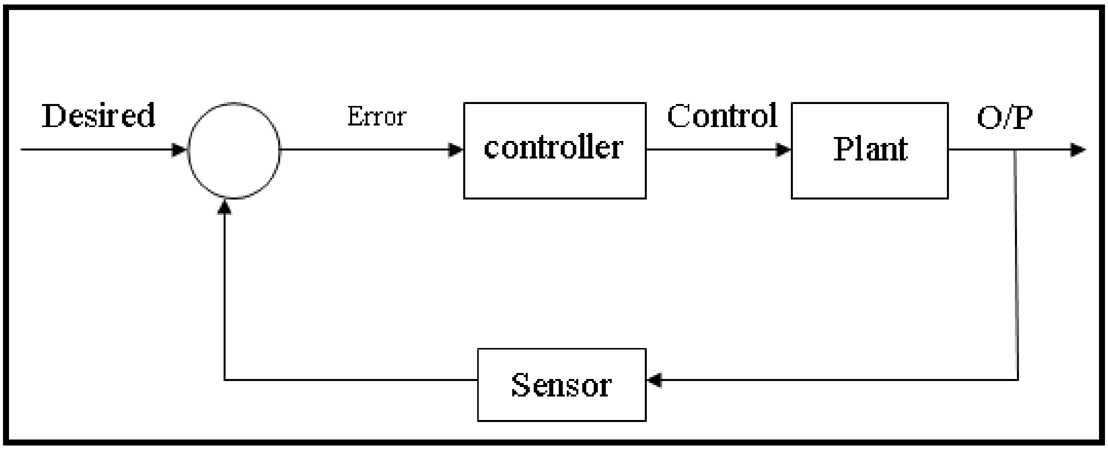


Figure 2.2: Closed loop control system

2.1.3 Multivariable control systems

The increase in complexities of control systems involved and the interrelationship among process variables sometimes requires a multivariable feedback control system.

A general structure of multivariable control system as shown in Figure 2.3.

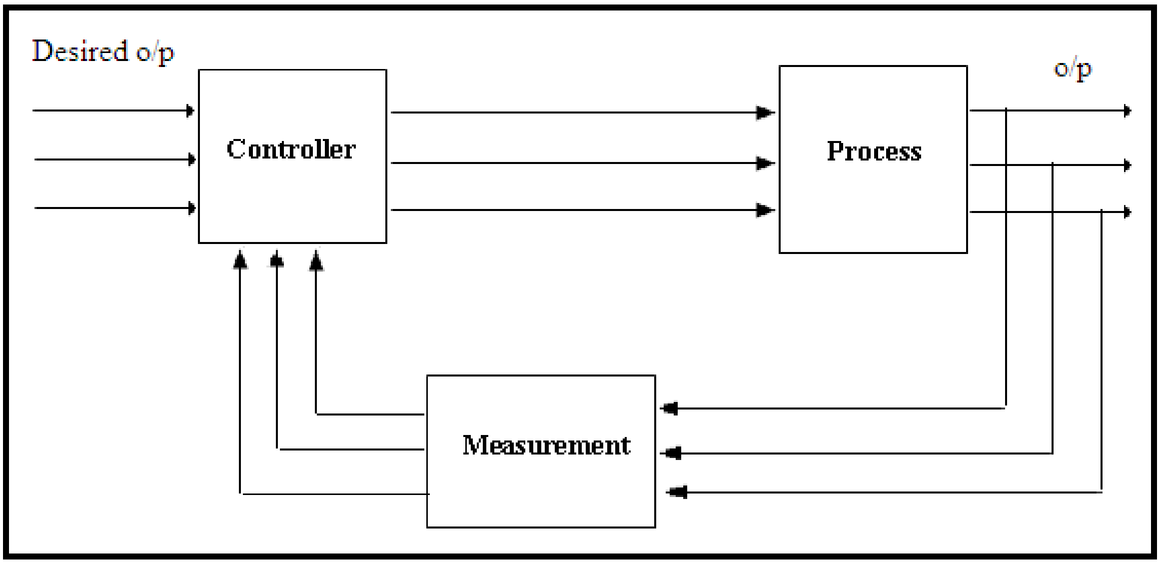


Figure 2.3: Multivariable control system

At normal closed loop control system there are basic components as shown in figure above, brief definitions of those components will mentioned below

2.2 Sensors and Measurements

Basics instrument devices which use at industrial engineering [3]. Such as:

2.2.1 Transducers

Is a device that converts energy from one form to another, Therefore, an actuator is a specific type of a transducer; It has many types such as:

- Thermal Actuators
- Electric Actuators
- Mechanical Actuators

Examples of common transducers including the following:

- A microphone converts sound into electrical impulses and a loudspeaker converts electrical impulses into sound (i.e., sound energy to electrical energy and vice versa).
- A solar cell converts light into electricity and a thermocouple converts thermal energy into electrical energy
- An incandescent light bulb produces light by passing a current through a filament. Thus, a light bulb is a transducer for converting electrical energy into optical energy.
- An electric motor is a transducer for conversion of electricity into mechanical energy or motion.

2.2.2 Sensors

A sensor is a device that receives and responds to a signal. This signal must be produced by some type of energy, such as heat, light, motion, or chemical reaction. Once a sensor detects one or more of these signals (an input), it converts it into an analog or digital representation of the input signal. Based on this explanation of a sensor, you should see that sensors are used in all aspects of life to detect and/or measure many different conditions. It converts a physical parameter to an electric output, Following are different

Types of sensors which are classified by the type of energy they detect.

A. **Thermal sensors**

- Thermometer: measures absolute temperature (discussed in the previous section)
- Thermocouple gauge: measures temperature by its affect on two dissimilar metals
- Calorimeter: measures the heat of chemical reactions or physical changes and heat capacity.

B. Mechanical sensors

- Pressure sensor: measures pressure
- Barometer: measures atmospheric pressure
- Altimeter: measures the altitude of an object above a fixed level
- Liquid flow sensor: measures liquid flow rate
- Gas flow sensor: measures velocity, direction, and/or flow rate of a gas
- Accelerometer: measures acceleration

C. Electrical sensors

- Ohmmeter: measures resistance
- Voltmeter: measures voltage
- Galvanometer: measures current
- Watt-hour meter: measures the amount of electrical energy supplied to and used by residence or business

D. Chemical sensors

Chemical sensors detect the presence of certain chemicals or classes of chemical sand quantify the amount and/or type of chemical detected.

- Oxygen sensor: measures the percentage of oxygen in a gas or liquid being analyzed
- Carbon dioxide detector: detects the presence of CO_2

E. Other types of sensors

❖ Optical

- Light sensors (photo detectors): detects light and electromagnetic energy
- Photocells (photo resistor): a variable resistor affected by intensity changes in ambient light.
- Infra-red sensor: detects infra-red radiation

❖ Acoustic

- Seismometers: measures seismic waves
- Acoustic wave sensors: measures the wave velocity in the air or an environment to detect the chemical species present

❖ Motion: detects motion

❖ Speedometer: measures speed

❖ Geiger counter: detects atomic radiation

❖ Biological: monitors human cells

2.2.3 Actuators

An actuator is a device that actuates or moves something. An actuator uses energy to provide motion. Therefore, an actuator is a specific type of a transducer, it converts an electric signal to a physical output. An electric output from the sensor is normally desirable because of the advantages it gives in further signal processing. There are many methods used to convert physiological events to electric signals. Dimensional changes may be measured by variations in resistance, inductance, capacitance, and piezoelectric effect. Thermostats and thermocouples are employed to measure body temperatures. Electromagnetic-radiation sensors include thermal and photon detectors [3].

2.3 Direct Current Machine

DC machines are the electro mechanical energy converters which work from a DC source and generate mechanical power or convert mechanical power into a DC power [4].

2.3.1 Construction of DC machines

DC machine can be either motors or generator [4]. A DC machine consists mainly of two part the stationary part called stator and the rotating part called rotor. The stator consists of main poles used to produce magnetic flux, commutating poles or interpoles in between the main poles to avoid sparking at the commutator but in the case of small machines sometimes the interpoles are avoided and finally the frame or yoke which forms the supporting structure of the machine. The rotor consist of an armature a cylindrical metallic body or core with slots in it to place armature windings or bars , a commutator and brush gears .The magnetic flux path in a motor or generator is called the magnetic structure of generator or motor. The major parts can be identified as:

- Frame

Frame is the stationary part of a machine on which the main poles and commutator poles are bolted and it forms the supporting structure by connecting the frame to the bed plate. The ring shaped body portion of the frame which makes the magnetic path for the magnetic fluxes from the main poles and interpoles is called Yoke.

- Yoke

In early days Yoke was made up of cast iron but now it is replaced by cast steel. This is because cast iron is saturated by a flux density of 0.8 Wb/sq.m where as saturation with cast iron steel is about 1.5 Wb/sq.m. So for the same magnetic flux density the cross section area needed for cast steel is less than cast iron hence the weight of the machine too. If we use cast iron there may be chances of blow holes in it while casting. So now rolled steels are developed and these have consistent magnetic and mechanical properties.

- End shields or bearings

If the armature diameter does not exceed 35 to 45 cm then in addition to poles end shields or frame head with bearing are attached to the frame. If the armature diameter is greater than 1m pedestral

- Type bearings

Are mounted on the machine bed plate outside the frame. These bearings could be ball or roller type but generally plain pedestral bearings are employed. If the diameter of the armature is large a Brush holder yoke is generally fixed to the frame.

- Main poles

Solid poles of fabricated steel with separate/integral pole shoes are fastened to the frame by means of bolts. Pole shoes are generally laminated. Sometimes pole body and pole shoe are formed from the same laminations. The pole shoes are shaped so as to have. A slightly increased air gap at the tips. Inter-poles are small additional poles located in between the main poles. These can be solid, or laminated just as the main poles. These are also fastened to the yoke by bolts. Sometimes the yoke may be slotted to receive these poles. The inter poles could be of tapered section or of uniform cross section. These are also called as commutating poles or com poles. The width of the tip of the com pole can be about a rotor slot pitch

- Armature

The armature is where the moving conductors are located. The armature is constructed by stacking laminated sheets of silicon steel. Thickness of this lamination is kept low to reduce eddy current losses. As the laminations carry alternating flux the choice of suitable material, insulation coating on the laminations, stacking it etc are to be done more carefully. The core is divided into packets to facilitate ventilation. The winding cannot be placed on the surface of the rotor due to the mechanical forces coming on the same. Open parallel sided equally spaced slots are normally punched in the rotor laminations. These slots house the armature winding. Large sized machines employ a spider on which the laminations are stacked in segments. End plates are suitably shaped so as to serve as ’Winding supporters’. Armature construction process must ensure provision of sufficient axial and radial ducts to facilitate easy removal of heat from the armature winding.

The figure 2.4. Below shows the main components of DC motor

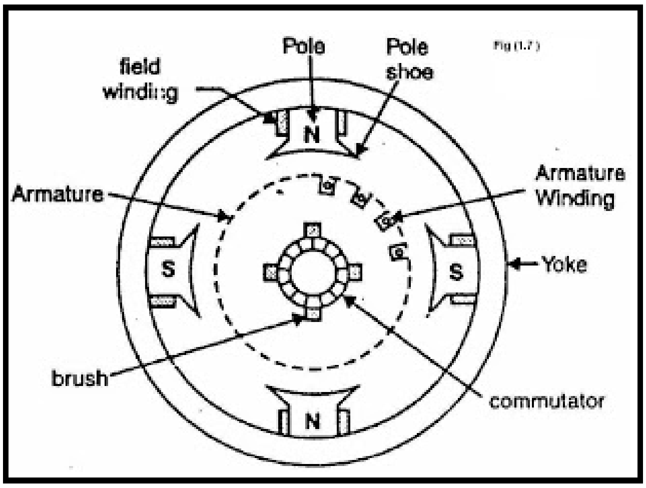


Figure 2.4: the components of DC machine

- Commutating poles
- Compensating winding
- Other mechanical parts

2.4 Motors

An electric motor is an electromechanical device that converts electrical energy to Mechanical energy. This mechanical energy is used for, for example, rotating a pump impeller, fan or blower, driving a compressor, lifting materials etc. Electric motors are used at home (mixer, drill, and fan) and in industry. Electric motors are sometimes called the “work horses” of industry because it is estimated that motors use about 70% of the total electrical load in industry [5].

2.4.1 The basic components of general motor

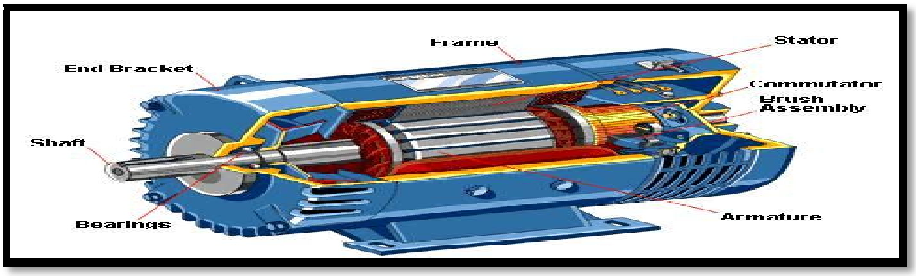


Figure 2.5: motor main components

2.4.2 Classification of the main types of electric motors

The main types are mentioned as shown in figure 2.6. [5].

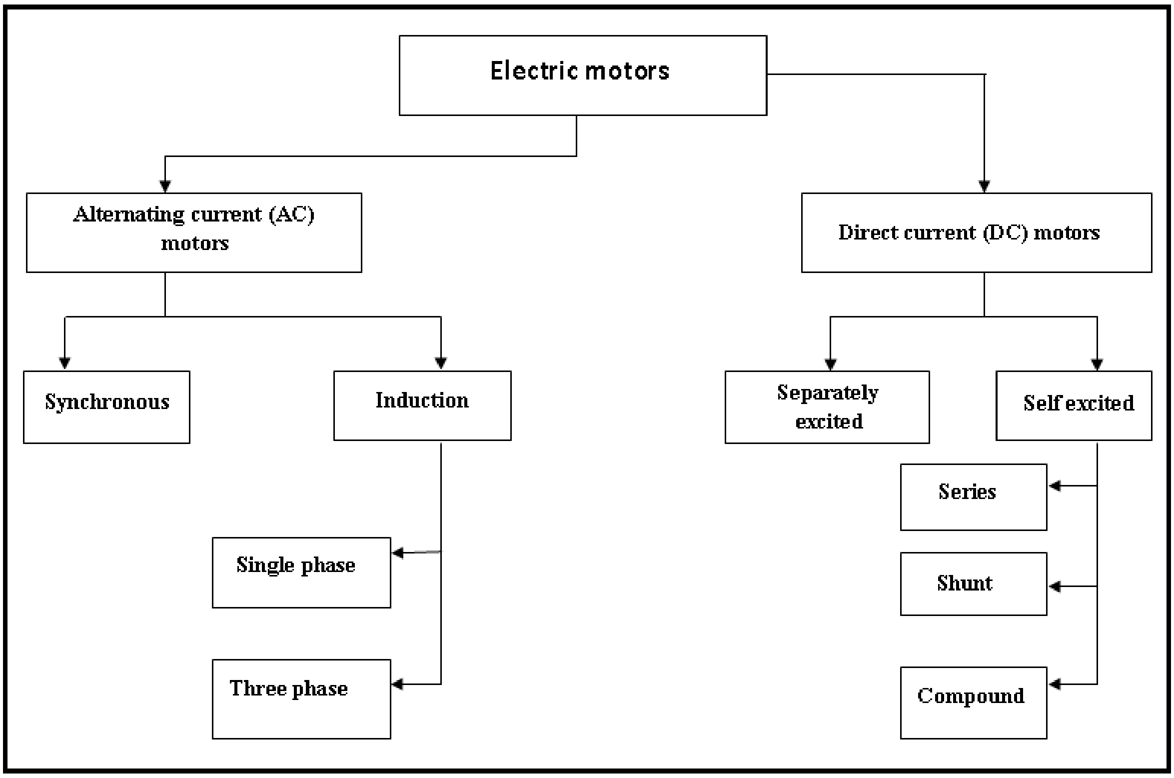


Figure 2.6: The main types of electric motors

And other kinds of motors are:

- Stepper motors
- Brushless DC motors

- Hysteresis motors
- Reluctance motors
- Universal motor

2.4.3 Self exited DC motor

In case of self excited dc motor, the field winding is connected either in series or in parallel or partly in series, partly in parallel to the armature winding, and on this basis it’s further classified as:

- **Series wound DC motor**
- **Shunt wound DC motor**
- **Compound wound DC motor**

❖ Self exited-series DC motor

In case of a series wound self excited dc motor or simply **series wound dc motor**, the entire armature electric current flows through the field winding as its connected in series to the armature winding.

❖ Self exited-shunt DC motor

In case of a **shunt wound dc motor** or more specifically shunt wound self excited dc motor; the field windings are exposed to the entire terminal voltage as they are connected in parallel to the armature winding. As shown in figure 2.7. Below

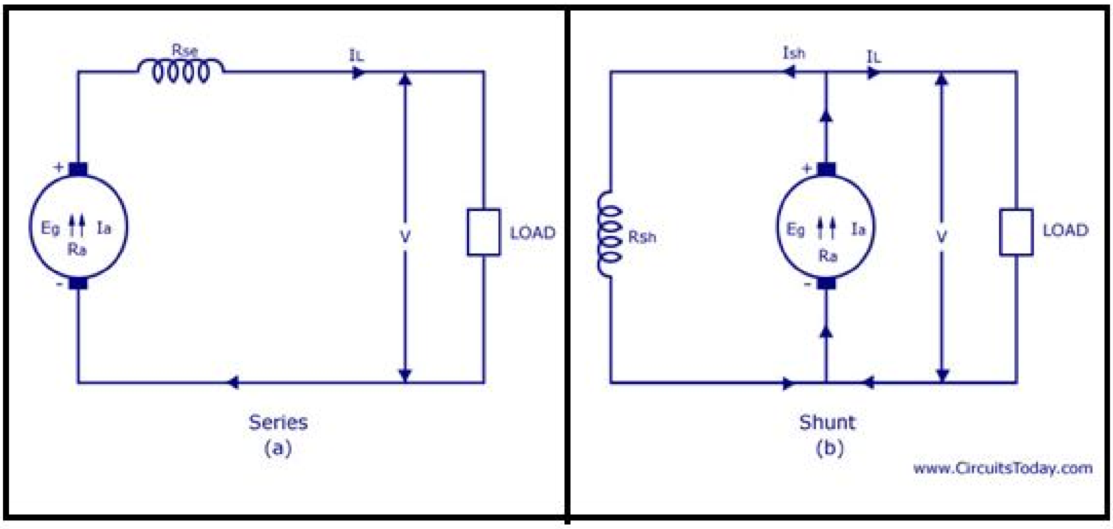


Figure 2.7: (a) self exited (b) self exited shunt DC motor

❖ Self exited-compound DC motor

The compound excitation characteristic in a dc motor can be obtained by combining the operational characteristic of both the shunt and series excited dc motor. The compound wound self excited dc motor or simply **compound wound dc motor** essentially contains the field winding connected both in series and in parallel to the armature winding. As shown in figure 2.8. Below

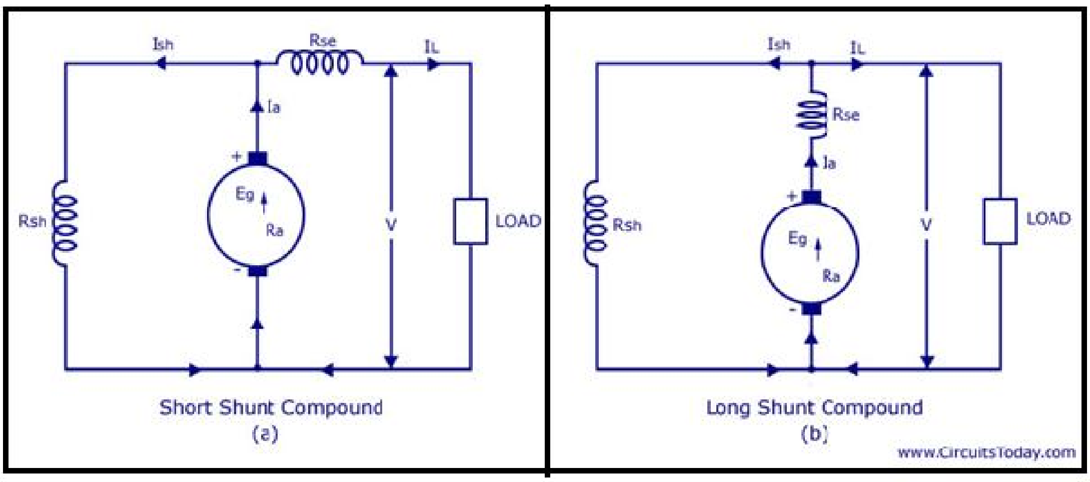


Figure 2.8: self exited compound DC motor

2.4.4 Separately excited DC motor

As the name suggests, in case of a separately excited DC motor the supply is given separately to the field and armature windings. As figure 2.9. Shows .The main distinguishing fact in these types of dc motor is that, the armature electric current does not flow through the field windings, as the field winding is energized from a separate external source of dc electric current

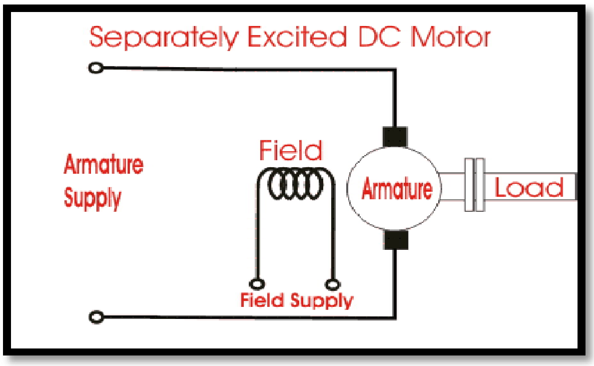


Figure 2.9: Separately exited DC motor

2.5 Alternated Current (AC) Motors

AC electric motor operates by applying alternating current (AC) power to the electric motor. An AC electric motor consists of several parts but the main parts are the stator and rotor. The AC electric motor's stator has coils that are supplied with the alternating current and produces a rotating magnetic field. The AC electric motor's rotor rotates inside the electric motor's coils and is attached to an output shaft that produces torque by the rotating magnetic field. There are two different types of AC electric motors and each of them uses a different type of rotor. The first type of AC motor is called an induction motor (also known as an asynchronous motor). The second type is called synchronous motor.

2.5.1 Induction AC motor

Like most motors, an AC induction motor has a fixed outer portion, called the stator and a rotor that spins inside with a carefully engineered air gap between the two. Virtually all electrical motors use magnetic field rotation to spin their rotors. A three-phase AC induction motor is the only type where the rotating magnetic field is created naturally in the stator because of the nature of the supply. DC motors depend either on mechanical or electronic [6]. Commutation to create rotating magnetic fields. A single-phase AC induction motor depends on extra electrical components to produce this rotating magnetic field. Two sets of electromagnets are formed inside any motor. In an AC induction motor, one set of electromagnets is formed in the stator because of the AC supply connected to the stator windings. The alternating nature of the supply voltage induces an Electromagnetic Force (EMF) in the rotor (just like the voltage is induced in the transformer secondary) as per Lenz’s law, thus generating another set of electromagnets; hence the name – induction motor. Interaction between the magnetic field of these electromagnets generates twisting force, or torque. As a result, the motor rotates in the direction of the resultant torque [6].

2.5.2 Types of AC induction motors

Generally, induction motors are categorized based on the number of stator windings. They are

- Single-phase induction motor
- Three-phase induction motor

2.5.3 Synchronous AC motors

Synchronous motor as shown in figure 2.10. Is naturally a constant-speed motor. They operate in synchronism with line frequency and are commonly used where precise constant speed is required. The synchronous motor is an electric motor that is driven by AC power consisting of two basic components: a stator and rotor. Typically, a capacitor connected to one of the motor's coil, is necessary for rotation in the appropriate direction. The outside stationary stator contains copper wound coils that are supplied with an AC current to produce a rotating magnetic field. The magnetized rotor is attached to the output shaft and creates torque due to the stator's rotating field. The motor's synchronous speed is determined by the number of pair poles and is a ratio of the input (line) frequency. Similar to our stepper motor, our synchronous motor can provide motion solutions for both rotational and linear applications. The Permanent Magnet (PM) synchronous motor is highly efficient and can be stalled when voltage is applied without damage to the motor winding. These motors are characterized by their synchronous speed, power consumption, and pole pairs, starting and running torque.

- Synchronous speed is defined when the rotor under load reaches a constant speed and is determined by the number of motor pole pairs and input frequency.
- Power consumption expressed in Watts is the amount of energy the motor requires under no load conditions.
- The rotor pole pairs are the number of north and south segments the rotor contains.
- Starting torque is the load the motor is capable of moving from a standstill.
- Running torque is the amount of torque that the motor is capable of producing without falling out of synchronism.

2.5.4 Methods of starting synchronous motor

Basically there are three methods that are used to start a synchronous motor:

- To reduce the speed of the rotating magnetic field of the stator to a low enough value that the rotor can easily accelerate and lock in with it during one half-cycle of the rotating magnetic field's rotation. This is done by reducing the frequency of the applied electric power. This method is usually followed in the case of inverter-fed synchronous motor operating under variable speed drive applications.

- To use an external prime mover to accelerate the rotor of synchronous motor near to its synchronous speed and then supply the rotor as well as stator. Of course care should be taken to ensure that the direction of rotation of the rotor as well as that of the rotating magnetic field of the stator is the same. This method is usually followed in the laboratory- the synchronous machine is started as a generator and is then connected to the supply mains by following the synchronization or paralleling procedure. Then the power supply to the prime mover is disconnected so that the synchronous machine will continue to operate as a motor.
- To use damper windings or amortisseur windings if these are provided in the machine. The damper windings or amortisseur windings are provided in most of the large synchronous motors in order to nullify the oscillations of the rotor whenever the synchronous machine is subjected to a periodically varying load

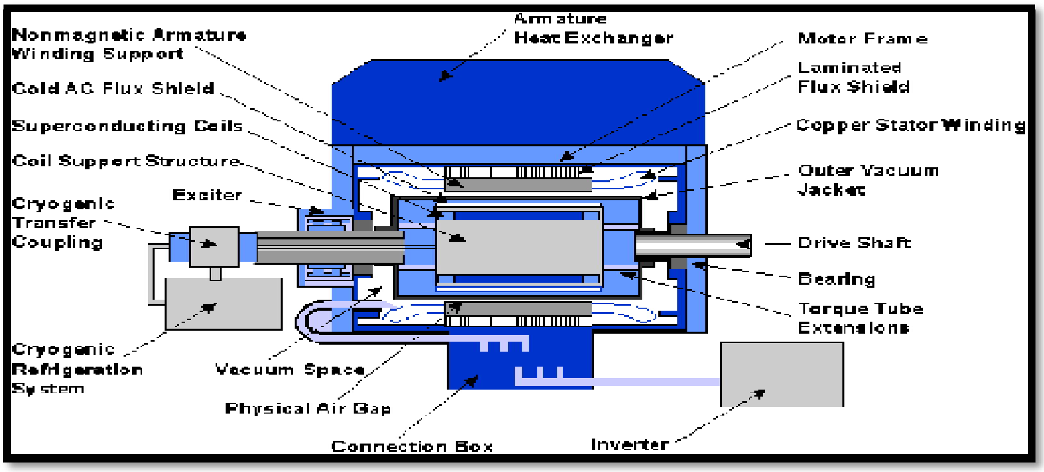


Figure 2.10: synchronous motor

2.6 Stepper Motors

Step motor as shown in figure 2.11. Is a brushless DC electric motor that divides a full rotation into a number of equal steps [7]. The motor's position can then be commanded to move and hold at one of these steps without any feedback sensor (an open-loop controller), as long as the motor is carefully sized to the application. Switched reluctance motors are very large stepping motors with a reduced pole count, and generally are closed-loop commutated.

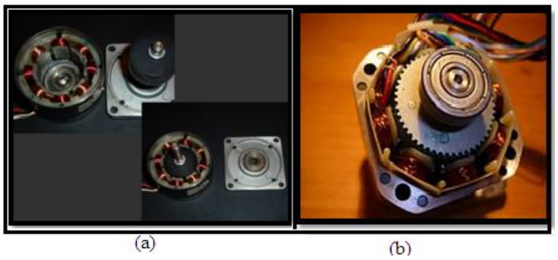


Figure 2.11: (a) bipolar hybrid stepper motor

(b) Stepper motor

2.6.1 Fundamentals of operation

DC brushed motors rotate continuously when voltage is applied to their terminals. The stepper motor is known by its important property to convert a train of input pulses (typically square wave pulses) into a precisely defined increment in the shaft position. Each pulse moves the shaft through a fixed angle. Stepper motors effectively have multiple "toothed" electromagnets arranged around a central gear-shaped piece of iron. The electromagnets are energized by an external control circuit, such as a microcontroller. To make the motor shaft turn, first, one electromagnet is given power, which magnetically attracts the gear's teeth. When the gear's teeth are aligned to the first electromagnet, they are slightly offset from the next electromagnet. So when the next electromagnet is turned on and the first is turned off, the gear rotates slightly to align with the next one, and from there the process is repeated. Each of those rotations is called a "step", with an integer number of steps making a full rotation. In that way, the motor can be turned by a precise angle Types. There are four main types of stepper motors:

1. Permanent magnet stepper (can be subdivided into 'tin-can' and 'hybrid', tin-can being a cheaper product, and hybrid with higher quality bearings, smaller step angle, higher power density)
2. Hybrid synchronous stepper
3. Variable reluctance stepper
4. Lavet type stepping motor

The construction of the stepper motors appear in figure 2.12. Which shown below

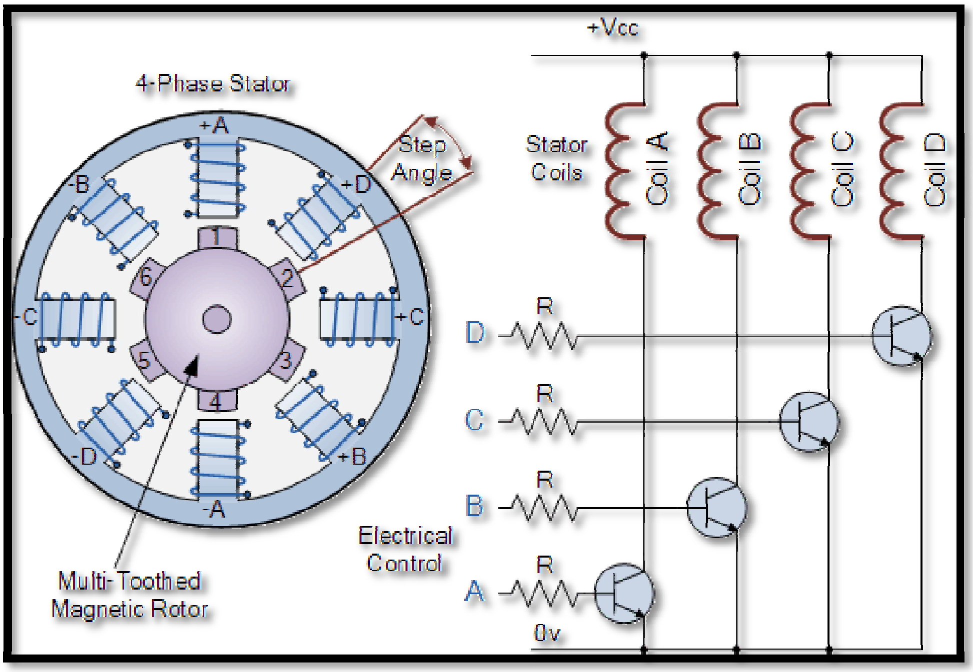


Figure 2.12: stepper motor constructions

The inputs of a stepper motor are signal pulses and the shaft of stepper motor moves between discrete positions proportional to pulses. If the load of the motor is not too great, open-loop control is usually used to control the motor. Stepper motors are used in disk drive head positioning, plotters, and numerous other applications.

2.7 Servo Motors

This is nothing but a simple electrical motor controlled with the help of servomechanism. If the motor as controlled device, associated with servomechanism is DC motor, then it is commonly known **DC Servo Motor**.

If the controlled motor is operated by AC, it is called AC servo motor as shown in figure 2.13. Below

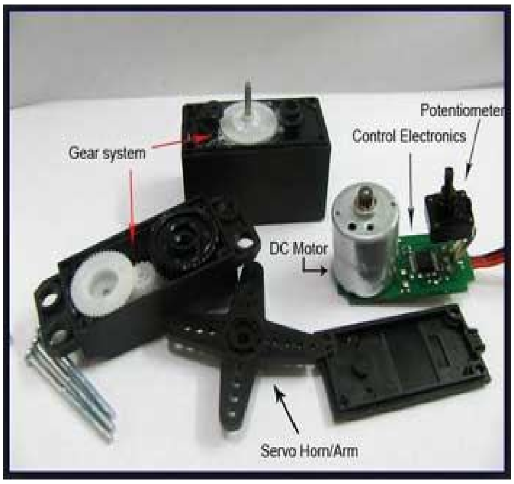


Figure 2.13: servo motor

2.7.1 Servomechanism

A servo system mainly consists of three basic components - a controlled device, an output sensor, a feedback system. This is an automatic closed loop control system. Here instead of controlling a device by applying variable input signal, the device is controlled by a feedback signal generated by comparing output signal and reference input signal. When reference input signal or command signal is applied to the system, it is compared with output reference signal of the system produced by output sensor, and a third signal produced by feedback system. This third signal acts as input signal of controlled device. This input signal to the device presents as long as there is a logical difference between reference input signal and output signal of the system. After the device achieves its desired output, there will be no longer logical difference between reference input signal and reference output signal of the system. Then, third signal produced by comparing theses above said signals will not remain enough to operate the device further and to produce further output of the system until the next reference input signal or command signal is applied to the system. Hence the primary task of a servomechanism is to maintain the output of a system at the desired value in the presence of disturbances.

2.7.2 Servo motor theory

There are some special types of application of electrical motor where rotation of the motor is required for just a certain angle not continuously for long period of time. For these applications some special types of motor are required with some special arrangement which makes the motor to rotate a certain angle for a given electrical input (signal). For this purpose **servo motor** comes into picture. The servo motor has some control circuits and a potentiometer (a variable resistor, aka pot) that is connected to the output shaft. The potentiometer allows the control circuitry to monitor the current angle of the servo motor. If the shaft is at the correct angle, then the motor shuts off. If the circuit finds that the angle is not correct, it will turn the motor the correct direction until the angle is correct. The output shaft of the servo is capable of travelling somewhere around 180 degrees. Usually, it’s somewhere in the 210 degree range, but it varies by manufacturer. A normal servo is used to control an angular motion of between 0 and 180 degrees. A normal servo is mechanically not capable of turning any farther due to a mechanical stop built on to the main output gear. The amount of power applied to the motor is proportional to the distance it needs to travel. So, if the shaft needs to turn a large distance, the motor will run at full speed. If it needs to turn only a small amount, the motor will run at a slower speed. This is called proportional control. How do you communicate the angle at which the servo should turn? The control wire is used to communicate the angle. The angle is determined by the duration of a pulse that is applied to the control wire. This is called Pulse Coded Modulation. The servo expects to see a pulse every 20 milliseconds (.02 seconds). The length of the pulse will determine how far the motor turns. A 1.5 millisecond pulse, for example, will make the motor turn to the 90 degree position (often called the neutral position). If the pulse is shorter than 1.5 ms, then the motor will turn the shaft to closer to 0 degrees. If the pulse is longer than 1.5ms, the shaft turns closer to 180 degrees. This is normally a simple DC motor which is controlled for specific angular rotation with help of additional servomechanism (a typical closed loop feedback control system). Now day's servo system has huge industrial applications. Servo motor applications are also commonly seen in remote controlled toy cars for controlling direction of motion and it is also very commonly used as the motor which moves the tray of a

Compact Disc (CD) or Digital Versatile Disc or Digital Video Disc (DVD) player. Beside these there are other hundreds of servo motor applications we see in our daily life. The main reason behind using a servo is that it provides angular precision, i.e. it will only rotate as much we want and then stop and wait for next signal to take further action. This is unlike a normal electrical motor which starts rotating as and when power is applied to it and the rotation continues until we switch off the power. We cannot control the rotational progress of electrical motor but we can only control the speed of rotation and can turn it ON and OFF. The input of a servo motor is a voltage value and the output shaft of the servo motor is commanded to a particular angular position according to the input voltage. Servo motors are used in radio control airplanes to control the position of wing flaps and similar devices.

2.8 DC Motors

A machine that converts dc power into mechanical energy is known as dc motor. Its operation is based on the principle that when a current carrying conductor is placed in a magnetic field, the conductor experiences mechanical force, the simplest DC rotating machine consists of a single loop of wire rotating about a fixed axis. The magnetic field is supplied by the North and South poles of the magnet Rotor is the rotating part; Stator is the stationary part.

The direction of the force is given by Fleming's left hand rule When the armature of a dc. Motor rotates under the influence of the driving torque, the armature Conductors move through the magnetic field and hence an e.m.f is induced in them.

The induced e.m.f acts in opposite direction to the applied voltage V (Lenz's law) and is known as back or counter e.m.f ,The presence of back e.m.f. makes the DC motor a self-regulating machine i.e., it makes the motor to draw as much armature current as is just sufficient to develop the torque required by the load. Back e.m.f. in a DC motor regulates the flow of armature current i.e., it automatically changes the armature current to meet the load requirement.

2.8.1 DC motor types

- Shunt Wound: In shunt wound motor the field winding is connected in parallel with armature
- Series Wound: In series wound motor the field winding is connected in series with the armature
- Compound wound: Compound wound motor has two field windings; one connected in parallel with the armature and the other in series with it.

- Compound Wound Motor: When the shunt winding is so connected that it shunts the series combination of armature and series field it is called long-shunt connection.

2.8.2 Parts of a DC motor

A simple motor has six parts

- Armature/ Rotor
- Commutator
- Brushes
- Axle
- Permanent Magnet
- DC Power supply
- Commutation in DC motor

In order to produce unidirectional force (or torque) on the armature conductors of a motor, the conductors under any pole must carry the current in the same direction at all times .The function of commutator and brush gear in a dc motor is to cause the reversal of current in a conductor as it moves from one side of a brush to the other.

2.8.3 DC motor transfer function

The figure 2.14. Represents a DC motor attached to an inertial load [8].

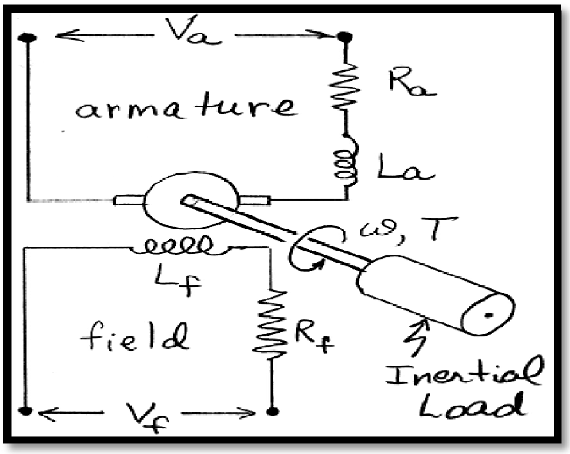


Figure 2.14: DC motor attached to internal load

- The voltages applied to the field and armature sides of the motor are represented by V_f and V_a
- The resistances and inductances of the field and armature sides of the motor are represented by R_f , L_f, R_a, and L_a .
- The torque generated by the motor is proportional to I_f and I_a the currents in the field and armature sides of the motor.

$$T_m = k i_f i_a \tag{2.1}$$

Where T_m is the torque generated by motor

I_f is the current in the field side

I_a is the current in the armature side

- Field-Current Controlled

In a field-current controlled motor, the armature current i_a is held constant, and the field current is controlled through the field voltage. In this case, the motor torque increases linearly with the field current. We write

$$T_m = k_{mf} i_f \tag{2.2}$$

Where T_m is the torque generated by motor

I_f is the current in the field side

By taking Laplace transforms of both sides of this equation gives the transfer function from the input current to the resulting torque.

$$K_{mf} = \frac{T_m(s)}{I_f(s)} \tag{2.3}$$

For the field side of the motor the voltage/current relationship is:

$$v_F = v_R + v_L$$

$$V_f = R_f i_f + L_f \left(\frac{di_f}{dt}\right) \tag{2.4}$$

The transfer function from the input voltage to the resulting current is found by taking Laplace transforms of both sides of this equation.

$$\frac{I_f(S)}{V_f(S)} = \frac{1/I_f}{S+(R_f+L_f)} \tag{2.5}$$

The transfer function from the input voltage to the resulting motor torque is found by combining equations (2.3) and (2.5)

$$\frac{T_m(s)}{V_f(s)} = \frac{T_m(s)}{I_f(s)} \frac{I_f(s)}{V_f(s)} = \frac{K_{mf}/L_f}{S+(R_f/L_f)} \tag{2.6}$$

So, a step input in field voltage results in an exponential rise in the motor torque.

An equation that describes the rotational motion of the inertial load is found by summing moments

$$\sum M = T_m - C\omega = J\omega \quad \text{(Counterclockwise positive)} \qquad (2.7)$$

$$J\omega + C\omega = T_m$$

Thus, the transfer function from the input motor torque to rotational speed changes is

$$\frac{\omega(s)}{T_m(s)} = \frac{1/J}{s+(c/J)} \qquad (2.8)$$

Combining equations (2.6) and (2.8) gives the transfer function from the input field voltage to the resulting speed change

$$\frac{\omega(s)}{V_f(s)} = \frac{\omega(s)}{T_m(s)}\frac{T_m(s)}{V_f(s)} = \frac{K_{mf}/L_f J}{(S+(c/J))(S+R_f/L_f)} \qquad (2.9)$$

Finally, since $\omega = \frac{d\theta}{dt}$, the transfer function from input field voltage to the resulting rotational position change is

$$\frac{\theta(s)}{V_f(s)} = \frac{\theta(s)}{\omega(s)}\frac{\omega(s)}{V_f(s)} = \frac{K_{mf}/L_f J}{S(S+(c/J))(S+R_f/L_f)} \qquad (2.10)$$

- Armature-current controlled

In a armature-current controlled motor, the field current f_i is held constant, and the armature current is controlled through the armature voltage $\boldsymbol{V_a}$. In this case, the motor torque increases linearly with the armature current .We write

$$T_m = k_{ma} i_a \qquad (2.11)$$

The transfer function from the input armature current to the resulting motor torque is:

$$\frac{T_m(s)}{I_a(s)} = K_{ma} \qquad (2.12)$$

The voltage/current relationship for the armature side of the motor is

$$V_a = V_R + V_L + V_b \qquad (2.13)$$

Where

V_b represents the "back emf" induced by the rotation of the armature windings in a magnetic field.

The back emf, V_b is proportional to the speed ω , i.e.

$$V_b(s) = k_b \omega(s)$$

Taking Laplace transforms of Equation (2.13) gives

$$V_a(s) - V_b(s) = (R_a + L_a S) I_a(s)$$

$$V_a(s) - K_b \omega(s) = (R_a + L_a S) I_a(s) \qquad (2.14)$$

As before at equation (2.12), the transfer function from the input motor torque to rotational speed changes is:

$$\frac{\omega(s)}{T_m(s)} = \frac{1/J}{S + (c/J)} \qquad (2.15)$$

Equations (2.12), (2.13) and (2.14) together can be represented by the closed loop block diagram shown below in figure 2.15

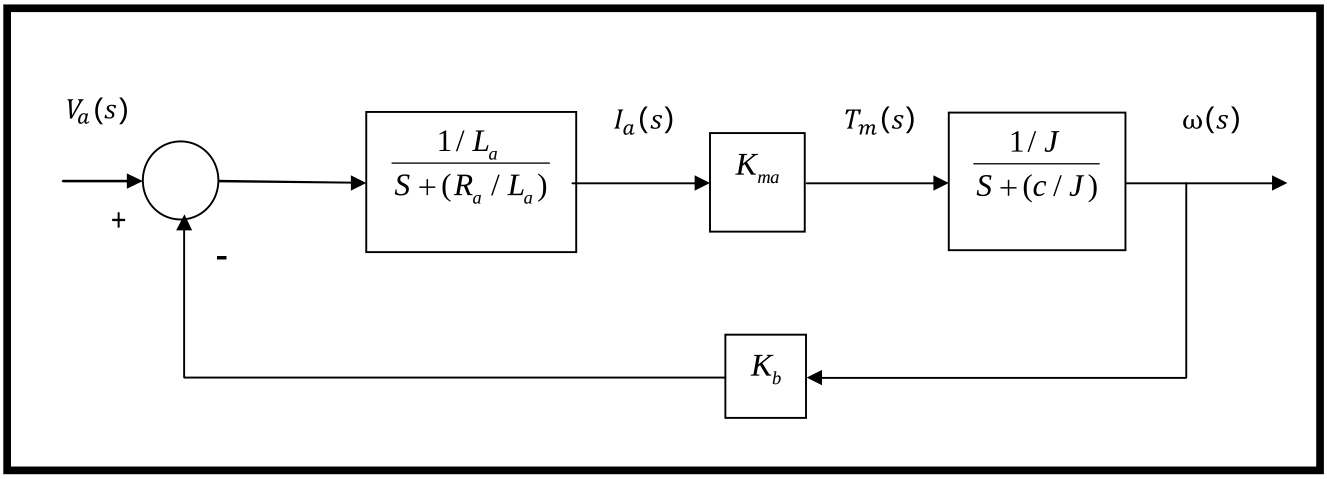


Figure 2.15: function block diagram of dc motor

Block diagram reduction gives the transfer function from the input armature voltage to the resulting speed change

$$\frac{\omega(s)}{V_a(s)} = \frac{K_{ma} / L_a J}{(S + (R_a / L_a)(S + c / J)(K_b K_{ma} + R_f / L_a J)} \quad (2.16)$$

The input of a DC motor is current/voltage and its output is torque (speed).

2.9 Speed Control of D.C. Motor

There are three main methods of controlling the Speed of a dc. Motor, namely:

(i) By varying the flux per pole (Φ), this is known as flux control method.

(ii) By varying the resistance in the armature circuit. This is known as Armature control method.

(iii) By varying the applied voltage V. This is known as voltage control method

2.9.1 Speed control of D.C. shunt motors

The speed of a shunt motor can be changed by:

Voltage control method.

(i) flux control method :

The first method (i.e. Flux control method) is frequently used because it is simple and inexpensive. It is based on the fact that by varying the flux Φ, the motor speed can be changed and hence the name flux control method. In this method, a variable Resistance (known as shunt field rheostat) is placed in series with shunt field winding as shown in Figure 2.16. Below

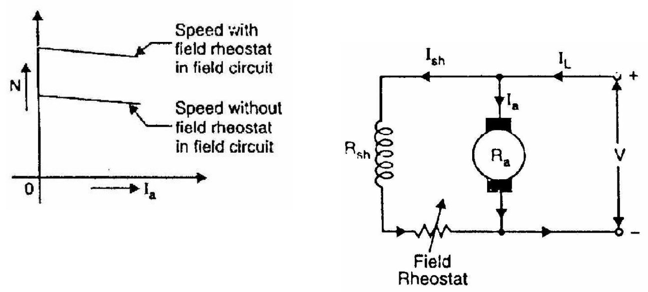


Figure 2.16: speed control-flux method

The shunt field rheostat reduces the shunt field current I_{sh} and hence the flux Φ Therefore, we can only raise the speed of the motor above the normal speed (See Figure 2.15. Generally, this method permits to increase the speed in the ratio 3:1. Wider speed ranges tend to produce instability and poor commutation.

Advantages:

(i) This is an easy and convenient method.

(ii) It is an inexpensive method since very little power is wasted in the shunt Field rheostat due to relatively small value of I_{sh}.

(iii) The speed control exercised by this method is independent of load on the Machine.

Disadvantages:

(i) Only speeds higher than the normal speed can be obtained since the total Field circuit resistance cannot be reduced below R_{sh} —the shunt field Winding resistance.

(ii) There is a limit to the maximum speed obtainable by this method. It is Because if the flux is too much weakened, commutation becomes poorer.

Note: The field of a shunt motor in operation should never be opened because its speed will increase to an extremely high value.

(ii) Armature control method:

This method is based on the fact that by varying the voltage available across the armature, the back e.g. and hence the speed of the motor can be changed. This is done by inserting a variable resistance R_C (known as controller resistance) in series with the armature as shown in Figure 2.17. Below:

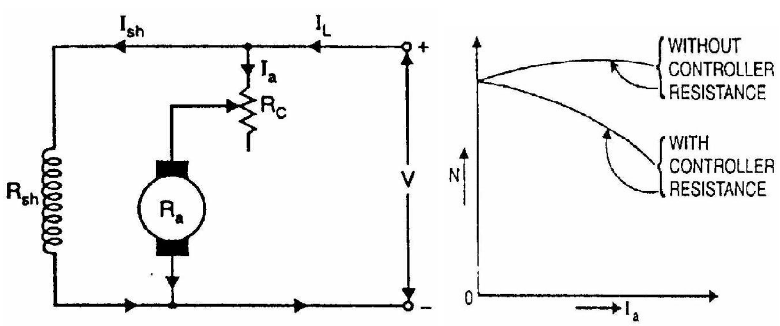


Figure 2.17: speed control armature control method

$$N \propto (V - I_a(R_a + R_c)) \qquad (2.17)$$

Where R_c = controller resistance

Due to voltage drop in the controller resistance, the back e.m.f. (E_b) is

Decreased. Since $N \propto E_b$, the speed of the motor is reduced. The highest speed

Obtainable is that corresponding to R_c = 0. Normal speed. Hence, this method

Can only provide speeds below the normal speed.

Disadvantages:

(i) A large amount of power is wasted in the controller resistance since it

Carries full armature current Ia.

(ii) The speed varies widely with load since the speed depends upon the Voltage drop in the controller resistance and hence on the armature current Demanded by the load.

(iii) The output and efficiency of the motor are reduced.

(iv) This method results in poor speed regulation.

Due to above disadvantages, this method is seldom used to control the speed of Shunt motors.

Note: The armature control method is a very common method for the speed Control of dc series motors. The disadvantage of poor speed regulation is not Important in a series motor which is used only where varying speed service is Required.

(iii)Voltage control method.

In this method, the voltage source supplying the field current is different from That which supplies the armature. This method avoids the disadvantages of poor Speed regulation and low efficiency as in armature control method. However, it is quite expensive. Therefore, this method of speed control is employed for large Size motors where efficiency is of great importance.

- Multiple voltage control: In this method, the shunt field of the motor is Connected permanently across a-fixed voltage source. The armature can be Connected across several different voltages through suitable switchgear.

In this way, voltage applied across the armature can be changed. The speed Will be approximately proportional to the voltage applied across the Armature. Intermediate speeds can be obtained by means of a shunt field Regulator.

- Ward-Leonard system: In this method, the adjustable voltage for the Armature is obtained from an adjustable-voltage generator while the field

Circuit is supplied from a separate source. This is illustrated in Figure 2.18.
The armature of the shunt motor M (whose speed is to be controlled) is
Connected directly to a d.c. generator G driven by a constant-speed a.c.
Motor A . The field of the shunt motor is supplied from a constant-voltage
Exciter E. The field of the generator G is also supplied from the exciter E.
The voltage of the generator G can be varied by means of its field regulator. By reversing the field current of generator G by controller FC, the voltage applied to the motor may be reversed. Sometimes, a field regulator is included in the field circuit of shunt motor M for additional speed adjustment. With this method, the motor may be operated at a speed up to its maximum speed.

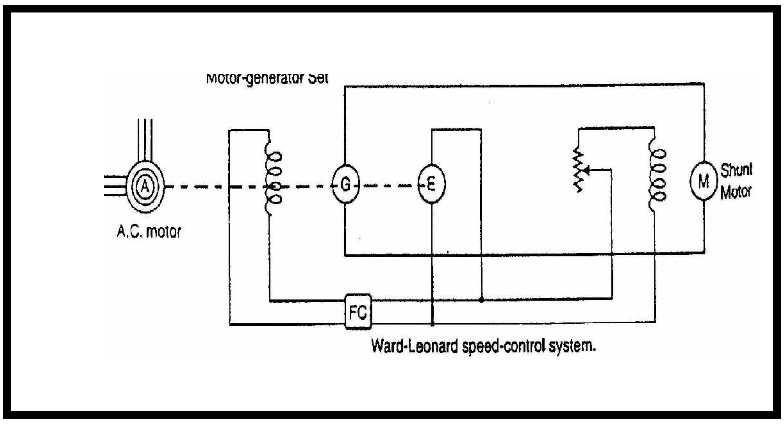


Figure 2.18: ward-leonard speed control system

Advantages
(a) The speed of the motor can be adjusted through a wide range without
Resistance losses which results in high efficiency.
(b) The motor can be brought to a standstill quickly, simply by rapidly
Reducing the voltage of generator G. When the generator voltage is reduced
Below the back e.m.f. of the motor, this back e.m.f. sends current through
The generator armature, establishing dynamic braking. While this takes place, the generator G operates as a motor driving motor A which returns power to the line.

(c) This method is used for the speed control of large motors when a d.c. Supply is not available.

The disadvantage of the method is that a special motor-generator set is required For each motor and the losses in this set are high if the motor is operating under Light loads for long periods.

2.9.2 Speed control of DC series motors

The speed control of DC series motors can be obtained by

1- Flux control method:

In this method, the flux produced by the series motor is varied and hence the Speed. The variation of flux can be achieved in the following ways:

(i) Field diverters: In this method variable resistance (called field diverter) is connected in parallel with series field winding, Its effect is to shunt some portion of the line current from the series field winding, thus weakening the field and increasing the speed .The lowest speed

Obtainable is that corresponding to zero current in the diverter (i.e., diverter is open). Obviously, the lowest speed obtainable is the normal speed of the motor. Consequently, this method can only provide speeds above the normal speed. The series field diverter method is often employed in traction work

As shown in figure2.19.

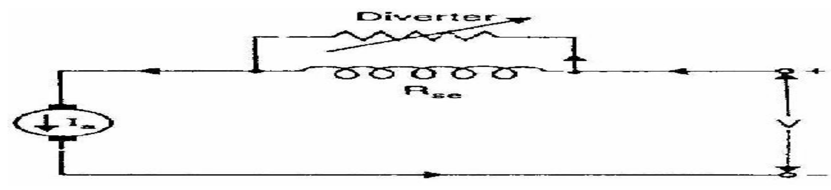


Figure 2.19 speed control of DC series motor-flux method

(ii) Armature diverter: In order to obtain speeds below the normal speed, a Variable resistance (called armature diverter) is connected in parallel with the Armature. The diverter shunts some of the line Current, thus reducing the armature current. Now for a given load, if I_a is decreased, the flux φ must increase. Since the motor Speed is decreased. By adjusting the armature diverter, any speed lower than the normal speed can be obtained $N \propto \frac{1}{\varphi}$,

(iii) Tapped field control: In this method, the flux is reduced (and hence speeds is increased) by decreasing the number of turns of the series field winding. The switch S can short circuit any part of the field, winding, thus decreasing the flux and raising the speed. With full turns of, the field winding, the motor runs at normal speed and as the field turns are Cut out, speeds higher than normal speed are achieved.

as shown in Figure 2.20.

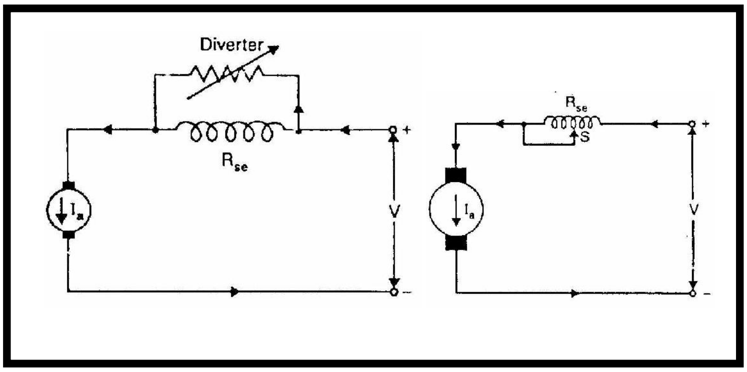


Figure 2.20: tapped field control method

(iv) Paralleling field coils: This method is usually employed in the case of fan Motors. By regrouping the field coils as shown in Figure 2.21. Several fixed Speeds can be obtained

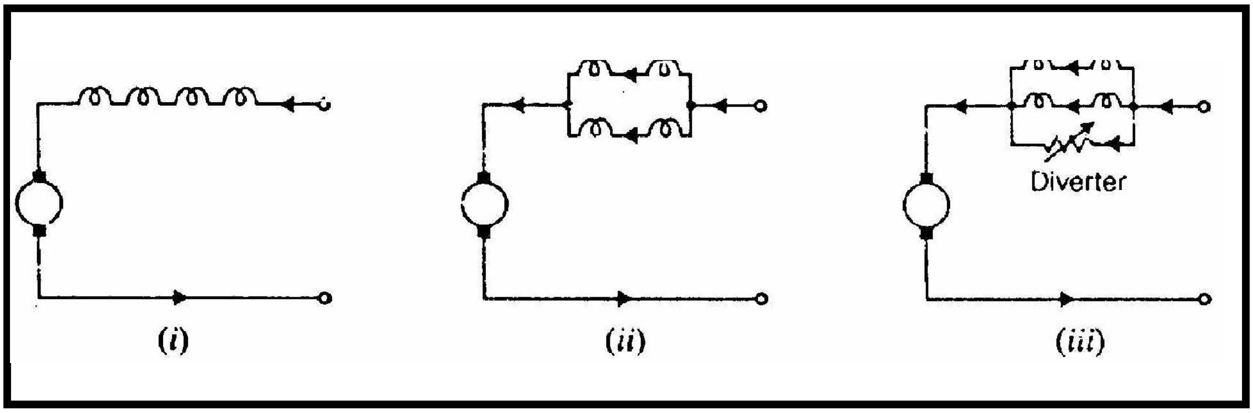


Figure 2.21: parallel field coil

2- Armature-resistance control method:

It is the mostly used method, in this method; a variable resistance is directly connected in series with the supply. this reduces the voltage available across the armature and hence the speed falls. By changing the value of variable

Resistance, any speed below the normal speed can be obtained. This is the most common method employed to control the speed of DC series motors. Although this method has poor speed regulation, this has no significance for series motors because they are used in varying speed applications. The loss of power in the series resistance for many applications of series motors is not too serious since in these applications, the control is utilized for a large portion of the time for reducing the speed under Light-load conditions and is only used intermittently when the motor is carrying Full-load

2.9.3 Series-parallel control

Another method used for the speed control of DC series motors is the series parallel method. In this system which is widely used in traction system, two (or More) similar DC series motors are mechanically coupled to the same load as that shown in figure 2.22.

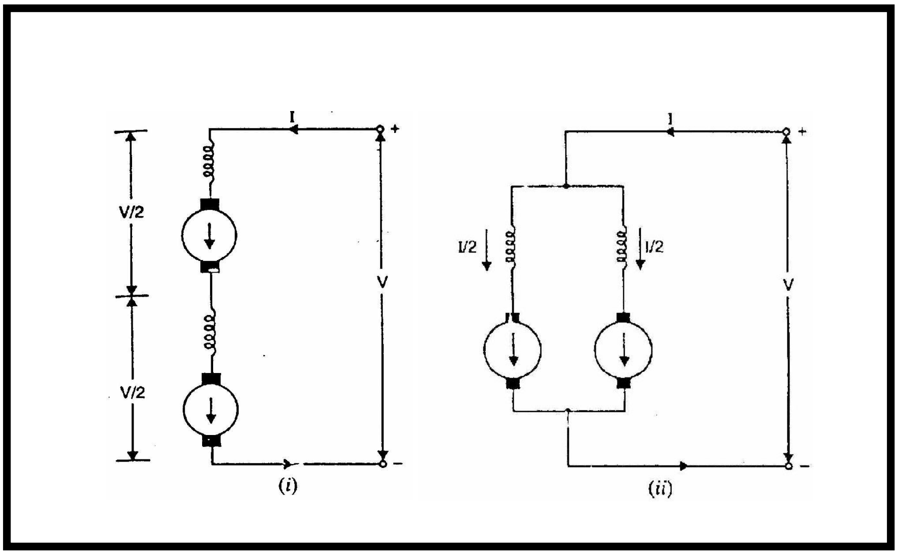


Figure 2.22: series parallel control method

When the motors are connected in series, each motor armature will receive one-half the normal voltage. Therefore, the speed will be low. When the motors are connected in parallel, each motor armature receives the normal voltage and the speed is high, thus we can obtain two speeds. Note that for the same load on the pair of motors, the system would run approximately four times the speed when the machines are in parallel as when they are in series.

2.9.4Series-parallel and resistance control

In electric traction, series-parallel method is usually combined with resistance Method of control. In the simplest case, two DC series motors are coupled Mechanically and drive the same vehicle.

(i) At standstill, the motors are connected is series via a starting rheostat. The Motors are started up in series with each other and starting resistance is cut out step by step to increase the speed. When all the resistance is cut out (See Fig. 2.22), the voltage applied to each motor is about one-half of the line voltage. The speed is then about one-half of what it would be if the full line voltage were applied to each motor

(ii) To increase the speed further, the two motors are connected in parallel and At the same time the starting resistance is connected in series with the combination.

As shown in Figure 2.23. The starting resistance is again cut out step by step until full speed is attained. Then field control is introduced.

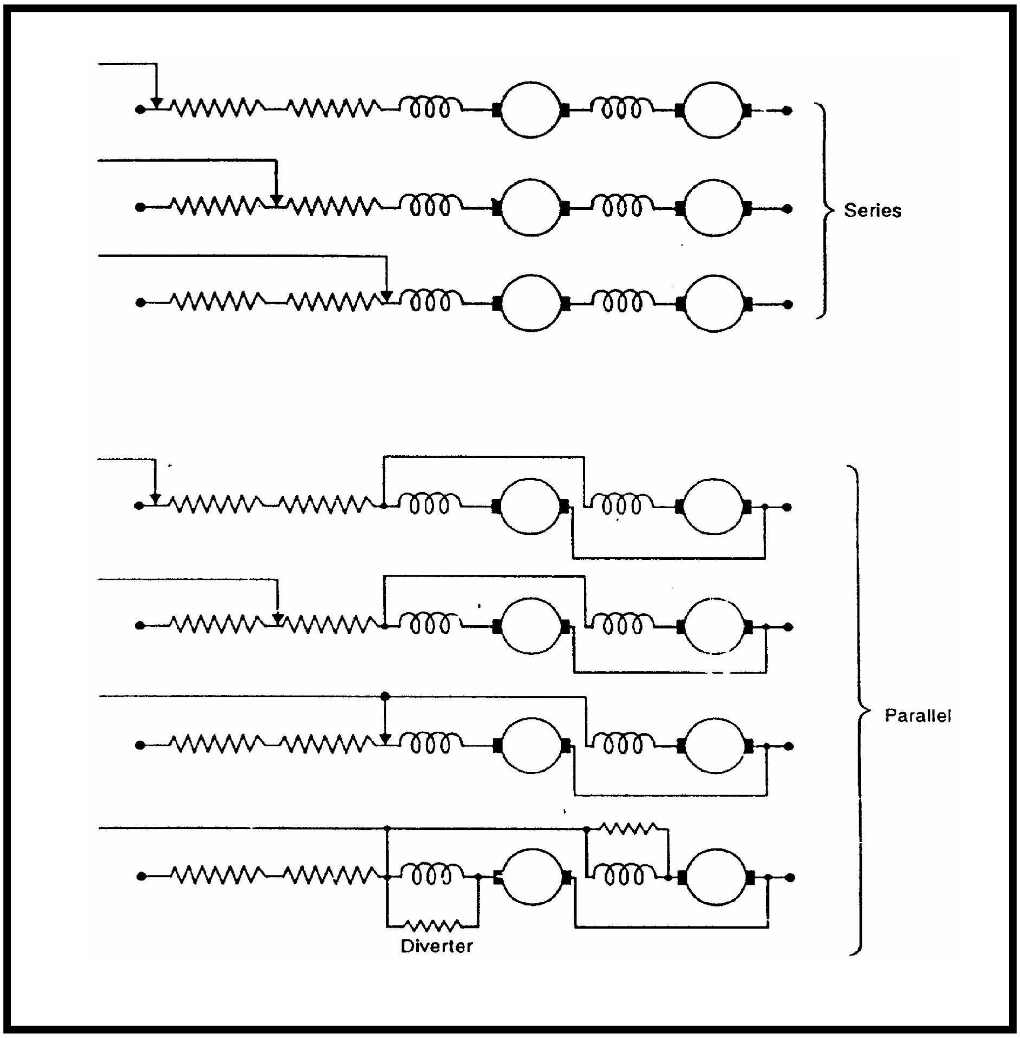


Figure 2.23: series parallel and resistance control method

2.10 previous works and algorithms that performed to control and adjusting DC motor speed

Many methods and algorithms were developed in order to adjusting and control DC motor speed, some of those methods will mention below:

- Speed Control of DC Motor using neural network configuration

The DC motor has been successfully controlled using an ANN. Two A NNs are trained to emulate functions:

Estimating the speed of DC motor and controlling the DC motor, Therefore

ANN can replace speed sensors in the control system mode is using ANN; there is no need to calculate the parameters of the motor when designing the system control. It has shown an appreciable advantage of control system using ANNs above the conventional one, when parameter of the DC motor is variable during the operation of the motors. The s at is fie d ability of the system control with ANNs is much better than the conventional controller. ANN application can be used in adaptive controls for machines with complicated loads

The ANN1 and ANN2 structure consists of an input layer, output layer and one hidden layer. The input and hidden layers are tansig-sigmoid activation functions, while the output layer is a linear function. Three inputs of ANN are reference speed ωr(k), terminal voltage Vt(k-1) and armature current ia (k-1). An d output o f A NN1 is an estimated speed ωp*(k). The ANN2 has four inputs: reference e speed ωr(k), terminal voltage Vt(k-1), armature current ia(k-1) and an estimated speed ωp*(k) from ANN-1. The output of ANN is the control signal for converter Alpha.

- By using thyristor
- By using triac
- By using fuzzy technique

All of those method running for adjusting the speed ,while here we running for adjusting the speed and forecasting the next output by combining many techniques on the way to achieve the goal of the research

2.11 pulse Width Modulation – PWM

The common technique to control the motor speed efficiently is to use a pulse signal known as the pulse width modulation or PWM for short.

Pulse Duration Modulation or Pulse Width Modulation is a powerful technique used to control analog circuits using digital outputs. PWM basically is an ON and OFF pulse signal with a constant period or frequency. The proportion of pulse ON time to the pulse period is called a 'duty cycle' and it expressed in percentage. For example if the proportion of pulse ON time is 50% to the total pulse period than we say that PWM duty cycle is 50% as shown in figure 2.24. The PWM duty cycle percentage is corresponding to the average power produced by the pulse signal; the lower percentage produces less power than the higher percentage. Nowadays PWM has a wide variety of applications such as to create analog voltage level, waveform generation, motor speed control, power control and conversion, measurements and communication etc. Therefore by changing the PWM duty cycle we could change the average voltage across the DC motor terminals, this mean we could vary the DC motor speed just by changing the PWM duty cycle.

PWM uses a rectangular pulse wave as shown in the figure below whose pulse width is modulated, which results in the variation in the average voltage of the waveform.

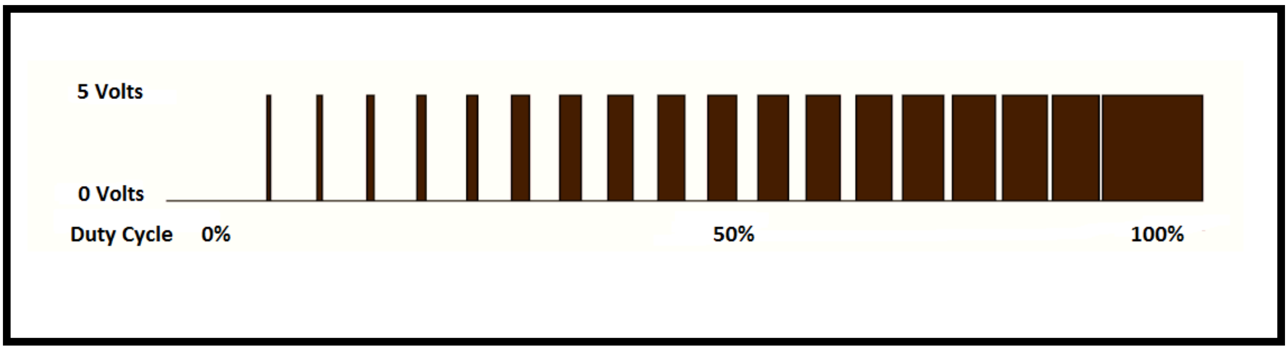


Figure 2.24: pulse width duty cycle

The use of pulse width modulation to control a small motor has the advantage in that the power loss in the switching transistor is small because the transistor is either fully “ON” or fully “OFF”. As a result the switching transistor has a much reduced power dissipation giving it a linear type of control which results in better speed stability. Also the amplitude of the motor voltage remains constant so the motor is always at full strength. The result is that the motor can be rotated much more slowly without it stalling.

2.12 The Microcontroller

A microcontroller (sometimes abbreviated µC, uC or MCU) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications. Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded system By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems. Some microcontrollers may use four-bit words and operate at clock-rate frequencies as low as 4 kHz, for low power consumption (single-digit millwatts or microwatts). They will generally have the ability to retain functionality while waiting for an event such as a button press or other interrupt; power consumption while sleeping (CPU clock and most peripherals off) may be just nanowatts, making many of them well suited for long lasting battery applications. Other microcontrollers may serve performance-critical roles, where they may need to act more like a digital signal processor (DSP), with higher clock speeds and power consumption. Microcontrollers usually contain from several to dozens of general purpose input/output pins (GPIO). GPIO pins are software configurable to either an input or an output state. When GPIO pins are configured to an input state, they are often used to read sensors or external signals. When they configured to the output state GPIO pins can drive external devices such as LEDs or motors. Many embedded systems need to read sensors that produce analog signals. This is the purpose of the analog-to-digital converter (ADC). Since processors are built to interpret and process digital data, i.e. 1s and 0s, they are not able to do anything with the analog signals that may be sent to it by a device. So the analog to digital converter is used to convert the incoming data into a form that the processor can recognize. A less common feature on some microcontrollers is a digital-to-analog converter (DAC) that allows the processor to output analog signals or voltage levels. In addition to the converters, many embedded microprocessors include a variety of timers as well. One of the most common types of timers is the Programmable Interval Timer (PIT). A PIT may either count down from some value to zero, or up to the capacity of the count register, overflowing to zero. Once it reaches zero, it sends an interrupt to the processor indicating that it has finished counting. This is useful for devices such as thermostats, which periodically test the temperature around them to see if they need to turn the air conditioner on, the heater on, etc. A dedicated Pulse Width Modulation (PWM) block makes it possible for the CPU to control power converters, resistive loads, motors, etc., without using lots of CPU resources in tight timer loops.

Universal Asynchronous Receiver/Transmitter (UART) block makes it possible to receive and transmit data over a serial line with very little load on the CPU. Dedicated on-chip hardware also often includes capabilities to communicate with other devices (chips) in digital formats such as I²C and Serial Peripheral Interface (SPI).

2.12.1 Differences between microprocessor and microcontroller

Microprocessor (abbreviated as μP) is a computer electronic component made from miniaturized transistors and other circuit elements on a single semiconductor integrated circuit (IC) (microchip or just chip).The central processing unit (CPU) is the most well known microprocessor, but many other components in a computer have them, such as the Graphics Processing Unit (GPU) on a video card. In the world of personal computers, the terms microprocessor and CPU are used interchangeably. At the heart of all personal computers and most workstations sits a microprocessor. Microprocessors also control the logic of almost all digital devices, from clock radios to fuel-injection systems for automobiles.

Microcontroller is a computer-on-a-chip optimized to control electronic devices. It is designed specifically for specific tasks such as controlling a specific system, microcontroller is basically a specialized form of microprocessor that is designed to be self - sufficient and cost - effective. Also, is a part of an embedded system, which is essentially the whole circuit board.

An embedded is a computer system designed to perform one or a few dedicated functions often with real-time computing constraints. It is embedded as part of a complete device often including hardware and mechanical parts. Examples of microcontrollers are Microchip's PIC, the 8051, Intel’s 80196, and Motorola's 68HCxx series. Microcontrollers which are frequently found in automobiles, office machines, toys, and appliances are devices which integrate a number of components of a microprocessor system onto a single microchip:

•The CPU core (microprocessor)

•Memory (both ROM and RAM)

•Some parallel digital I/O

The difference between the two is that a microcontroller incorporates features of microprocessor (CPU, ALU, Registers) along with the presence of added features like presence of RAM, ROM, I/O ports, counter, etc.

Here a microcontroller controls the operation of a machine using fixed programs stored in ROM that doesn't change with lifetime. From another view point, the main difference between a typical microprocessor and a Micro controller leaving there architectural specifications is the application area of both the devices. Typical microprocessors like the Intel Core family or Pentium family processors or similar processors are in computers as a general purpose programmable device

2.12.2 The ATmega16 microcontroller

- Overview

Is a low-power CMOS 8-bit microcontroller based on the AVR enhanced The ATmega16 RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega16 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed

The AVR core combines a rich instruction set with 32 general purpose working registers.

All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

The ATmega16 provides the following features: 16K bytes of In-System Programmable Flash Program memory with Read-While-Write capabilities, 512 bytes EEPROM, 1Kbyte SRAM, 32 general purpose I/O lines, 32 general purpose working registers, a JTAG interface for Boundary-scan, On-chip Debugging support and programming, three flexible Timer/Counters with compare modes, Internal and External Interrupts, a serial programmable USART, a byte oriented Two-wire Serial Interface, an 8-channel, 10-bit ADC with optional differential input stage with programmable gain (TQFP package only), a programmable Watchdog Timer with Internal Oscillator, an SPI serial port, and six software selectable power saving modes. The Idle mode stops the CPU while allowing the USART, Two-wire interface, A/D Converter, SRAM, Timer/Counters, SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next External Interrupt or Hardware Reset. In Power-save mode, the Asynchronous Timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping .The ADC Noise Reduction mode stops the CPU and all I/O modules except Asynchronous Timer and ADC, to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator Oscillator is running while the rest of the device is sleeping.

This allows very fast start-up combined with low-power consumption. In Extended Standby mode, both the main Oscillator and the Asynchronous Timer continue to run. The device is manufactured using Atmel's high density nonvolatile memory technology. The On-chip ISP Flash allows the program memory to be reprogrammed in-system Through an SPI serial interface, by a conventional nonvolatile memory programmer, or by an On-chip Boot program running on the AVR core. The boot program can use any interface to download the application program in the Application Flash memory. Software in the Boot Flash section will continue to run while the Application Flash section is updated, providing true Read-While-Write operation. By combining an 8-bit RISC CPU

With In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega16 is a powerful microcontroller that provides a highly-flexible and cost-effective solution to many embedded control applications .The ATmega16 AVR is supported with a full suite of program and system development tools including: C compilers, macro assemblers, program debugger/simulators, In-Circuit Emulators, and evaluation kits.

2.13 Proportional-Integral-Derivative (PID) Controller

The PID controller enjoys the honor of being the most commonly used dynamic Control technique. Over 85% of all dynamic (low-level) controllers are of the PID, PID control logic is used in the process control industry because its ability to compensate most practical industrial processes this led to their wide acceptance in industrial applications it has traditionally been chosen by control system engineers due to their flexibility and reliability.

2.13.1 Introduction of PID controller implementations

Classical implementations of the PID controller Contain several active elements to realize the transfer function. For instance, parallel structure using operational Amplifiers (Op Amp).

As shown in figure 2.25.It requires five amplifiers: Differential input amplifier, Proportional amplifier, Integral amplifier, Derivative amplifier and adder. All of those amplifiers constructed with resistors, capacitors.

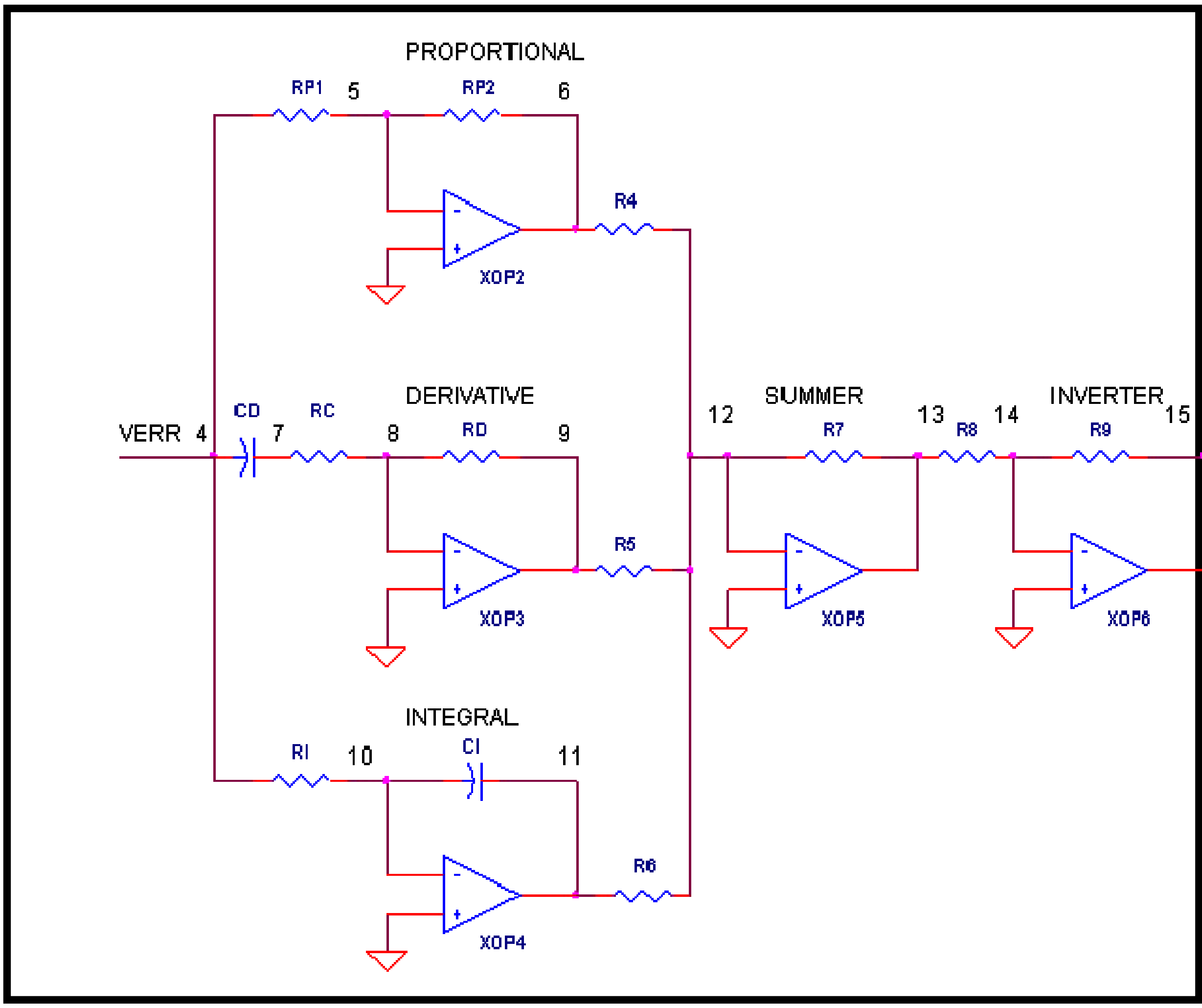


Figure 2.25: PID controller op amps

2.13.2 The PID controller's theory and block diagram

A PID controller calculates an error value as the difference between a measured process variable and a desired set point as shown in figure 2.26.The controller attempts to minimize the error by adjusting the process through use of a manipulated variable [7].

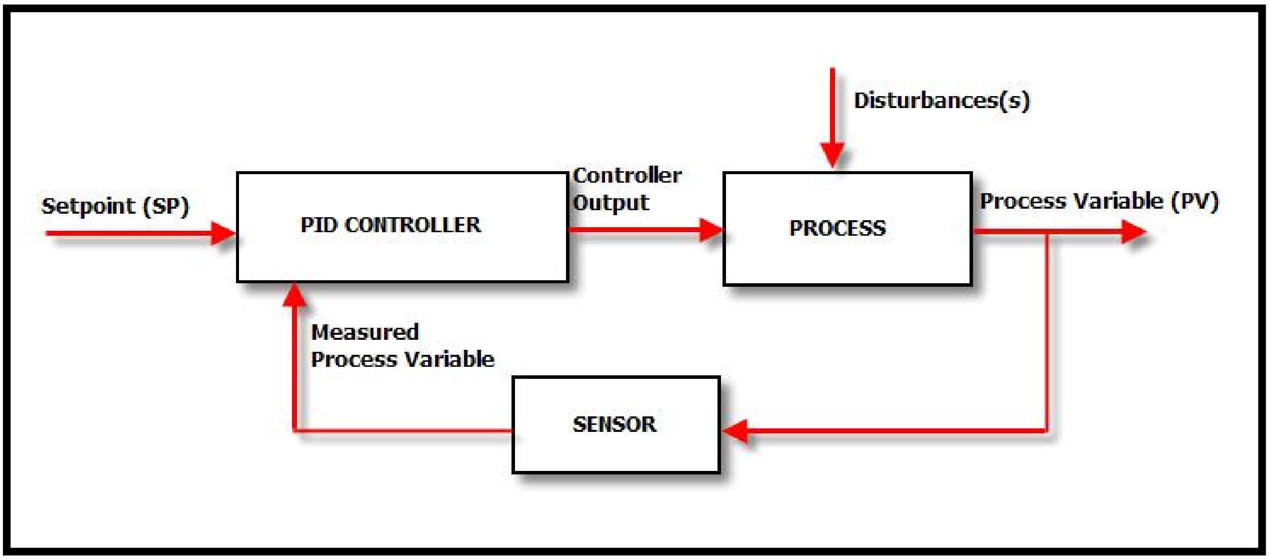


Figure 2.26: the block diagram of the controller and plant (process)

- The process variables

A process variable, process value or process parameter is the current status of a process under control. An example of this would be the temperature of a furnace, a speed of a motor….etc, the current temperature is called the process variable, while the desired temperature is known as the set-point .Measurement of process variables are important in controlling a process. The process variable is a dynamic feature of the process which may change rapidly. Accurate measurement of process variables is important for the maintenance of accuracy in a process. There are four commonly measured variables which affect chemical and physical process.

- The set point

  Is the desired process output that an automatic control system will aim to reach [7].The figures 2.27 and 2.28.Show different representations of PID block diagram

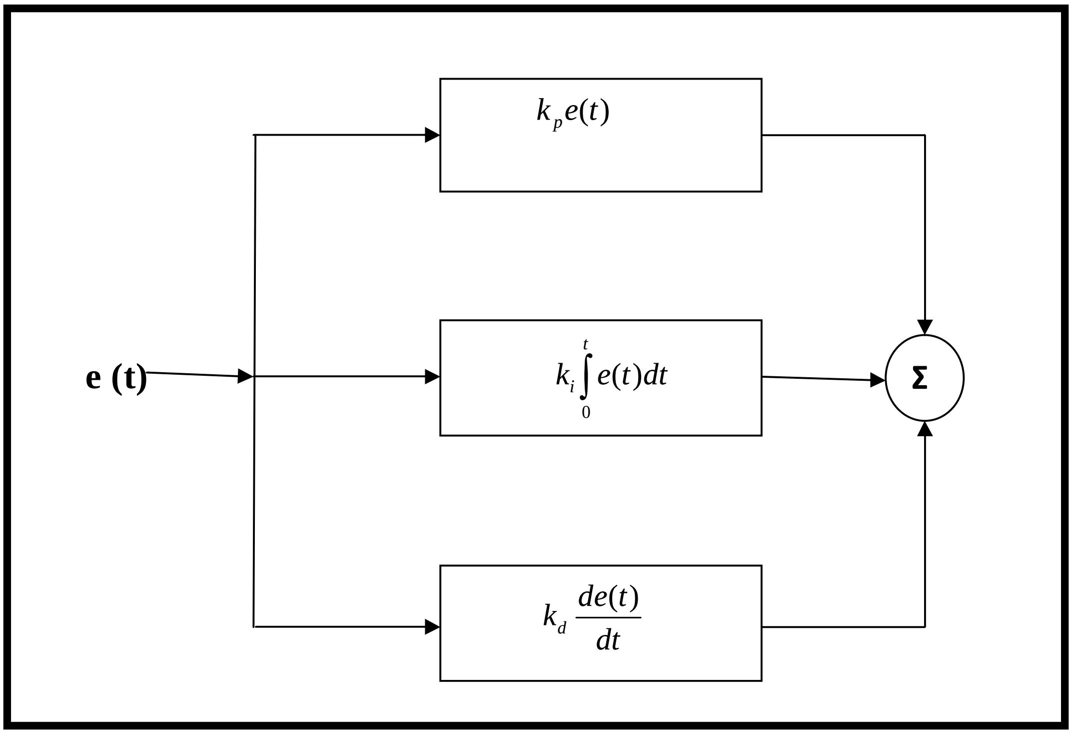


Figure 2.27: PID controller block diagram

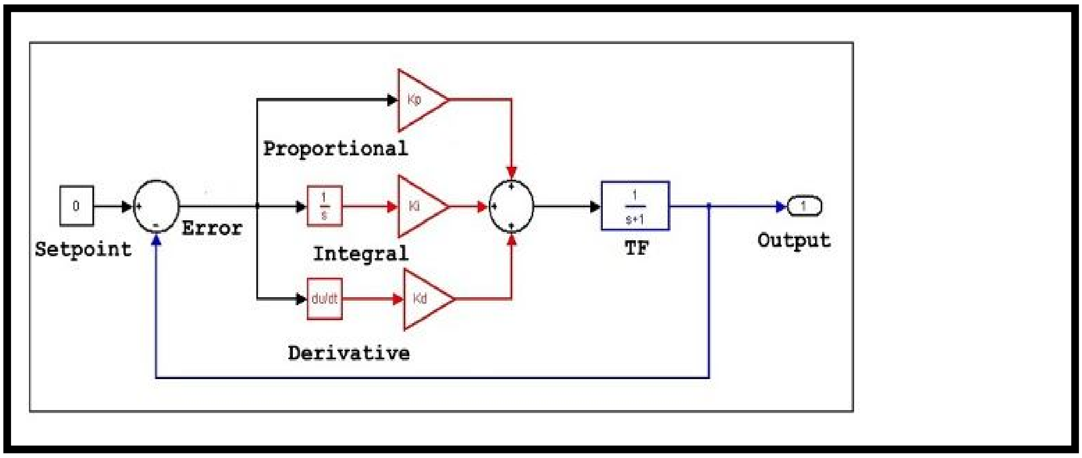


Figure 2.28: PID controller block diagram

2.13.3PID controller transfer function

$$p_{out} = G(s) = k_p + \frac{k_I}{s} + k_D s \qquad (2.18)$$

$$p_{out} = \frac{k_p s + k_I + k_D s^2}{s} \qquad (2.19)$$

The previous equations represent the Laplace transformation form of the PID transfer function, where the next one represents the continuous time transfer function [9].

$$P_{OUT} = K_P e(t) + K_d \frac{de(t)}{dt} + K_I \int_0^{\infty} e(t) \qquad (2.20)$$

The PID algorithm can be described as:

$$\text{POut} = \text{P} + \text{I} + \text{D} = \text{P}_{\text{Gain}} * \text{Err} + \text{I}_{\text{Gain}} * \int \text{Err} + \text{D}_{\text{Gain}} * (\text{Err} - \text{D}_{\text{Err}}) \qquad (2.21)$$

$$u(t) = k(e(t) + \frac{1}{T_i} \int_0^t e(t)dt + T_d \frac{de(t)}{dt}) \qquad (2.22)$$

Where u is the control variable and e is the control error

$$e(t) = Y_{SP}(t) - Y(t) \qquad (2.23)$$

Where: Y_{SP} represent the set point value

Y represents the feedback (measured) value

The control variable is thus the sum of the three terms: the p-term which is the proportional to the error, the I-term which is the proportional to the integral of the error and the D-term which is the proportional of the derivative of the error

The controller parameters are proportional gain K, integral time T_i and derivative time T_d [9].

- Role of a Proportional Controller

The role of a proportional depends on the present error, I on the accumulation of past error and D on prediction of future error. The weighted sum of these three actions is used to adjust Proportional control is a simple and widely used method of control for many kinds of systems. In a proportional controller, steady state error tends to depend inversely upon the proportional gain (ie: if the gain is made larger the error goes down). The proportional Response can be adjusted by multiplying the error by a constant k_p, called the proportional gain. The proportional term is given by:

$$P_{term}=k_p * e(t) \tag{2.24}$$

A high proportional gain results in a large change in the output for a given change in the error. If the proportional gain is very high, the system can become unstable. In contrast, a small gain results in a small output response to a large input error. If the proportional gain is very low, the control action may be too small when responding to system disturbances. Consequently, a proportional controller (k_p) will have the effect of reducing the rise time and will reduce, but never eliminate, the steady-state error.

- Role of an Integral Controller (IC)

An Integral controller (IC) is proportional to both the magnitude of the error and the duration of the error. The integral in a PID controller is the sum of the instantaneous error over time and gives the accumulated offset that should have been corrected previously. Consequently, an integral gain (k_i) will have the effect of eliminating the steady-state error, but it may make the transient response worse.

The integral term is given by:

$$I_{term} = k_I \int_0^t e(t)dt \qquad (2.25)$$

- Role of derivative controller (DC)

  The derivative of the process error is calculated by determining the slope of the error over time and multiplying this rate of change by the derivative gain k_D. The derivative term slows the rate of change of the controller output. A derivative gain (k_D) will have the effect of increasing the stability of the system, reducing the overshoot, and improving the transient response. The derivative term is given by:

$$D_{term} = k_D * \frac{de(t)}{dt} \qquad (2.26)$$

2.13.4The effects of the three main parameters of PID:

Effects of each of controllers k_p, k_D, and k_i on a closed-loop system are summarized in the table shown below [9].

Table 2.1: the effect ions of the PID parameters

Parameter	Rise time	Overshoot	Settling time	Steady state error	Parameter
K_P	Decrease	Increase	Small change	Decrease	K_P
K_I	Decrease	Increase	Increase	Decrease	K_I
K_D	Minor decrease	Minor decrease	Minor decrease	No effect	K_D

2.13.5 When PID control be used

The requirements on control system may included many factors

Such as response to command signal, [9] insensitivity to measurement noise

And process variation and rejection of load disturbance.

The design of the control system also involves aspects of process dynamics, actuators, saturation, and disturbance characteristics; it may seem surprising that a controller as simple as the PID can work so well.

The general empirical is that most industrial process can be control reasonable well with PID control provided that the demands on the performance of the control are not too high.

2.13.6 The efficiency of PID controller

PID control is sufficient when the dominant dynamics are of second order for such process there are no benefits gained by using more complex controller, [9] vice versa on higher order process where complex controller is needed

2.13.7 Tuning methods for PID controller

In testing of thousands of control loops in hundreds of plants, it has been found that more than 30% of installed controllers are operating in manual mode and 65% of loops operating in automatic mode produce less variance in manual than in automatic (i.e. .the automatic controllers are poorly tuned) On other surveys show that the determination of PI and PID controller tuning parameters is a vexing problem in many applications. The most direct way to set up controller parameters is the use of tuning rules

2.13.7.1 Organization of the Tuning Rules

The tuning rules are classified further; the main subdivisions made are as follows:

(i) Tuning rules based on a measured step response (also called process Reaction curve methods)

(ii) Tuning rules based on minimizing an appropriate performance criterion, either for optimum regulator or optimum servo action,

(iii) Tuning rules that give a specified closed loop response (direct Synresearch tuning rules). Such rules may be defined by specifying the desired poles of the closed loop response, for instance, though more generally, the desired closed loop transfer function may be specified .The definition may be expanded to cover techniques that allow the achievement of a specified gain margin and/or phase margin,

(iv) Robust tuning rules, with an explicit robust stability and robust performance criterion built in to the design process,

(v) Tuning rules based on recording appropriate parameters at the ultimate frequency (also called ultimate cycling methods),

(vi) Other tuning rules, such as tuning rules that depend on the proportional gain required to achieve a quarter decay ratios or to achieve magnitude and frequency information at a particular phase lag.

Some tuning rules could be considered to belong to more than one subdivision.

Next a summarized of common methods for tuning [9].

Table2.2: the common methods for tuning PID

Method	Advantages	Disadvantages
Manual	On line method No math expression	Requires experienced personnel
Ziegler-Nichols	Online method Proven method	some trial and error, process upset and very aggressive tuning
Cohen-Coon	Good process models	Offline method Some math Good only for first order processes
Software tools	Online or offline method, consistent tuning, Support Non-Steady State tuning	Some cost and training involved
Algorithmic	Online or offline method, Consistent tuning, Support Non-Steady State tuning ,Very precise	Very slow

- Manual tuning of PID controller

If the system must remain on line ,one tuning method is to first set k_i and k_D values to zero .increase the k_p until the output of the loop oscillate ,then the k_p should be set to approximately half of the value for a "quarter decay" type response .then increase k_i until any offset is is corrected in sufficient time for the process. However, too much k_i will cause instability .finally, increase k_D, if required, until the loop is acceptably quick to reach its reference after a load disturbance. However too much k_D will cause excessive response and overshoot. A fast PID loop tuning usually over shoots slightly to reach the set point more quickly; however, some systems cannot accept overshoot, in which case an over-damped closed loop system is required, which all require a k_p setting significantly less than half that of the k_p setting that was causing oscillation

- Ziegler – Nichols methods

Two classical methods for determining the parameters of PID controllers were presented by Ziegler and Nichols in 1942; these methods are still widely used either in their original form or in some modification. They often form the basis for tuning procedure s use by controller manufactures and process industry. The methods are based on determination of some features of process dynamics. The controller parameters are often express in terms of the features by simple formulas [10].

- The step response method

The first design method presented by Ziegler and Nichols are based on the registration of the open loop step response of the system, which is characterized by two parameters.

The parameters are determined from the unit step response of the process as shown in figure 2.29.below

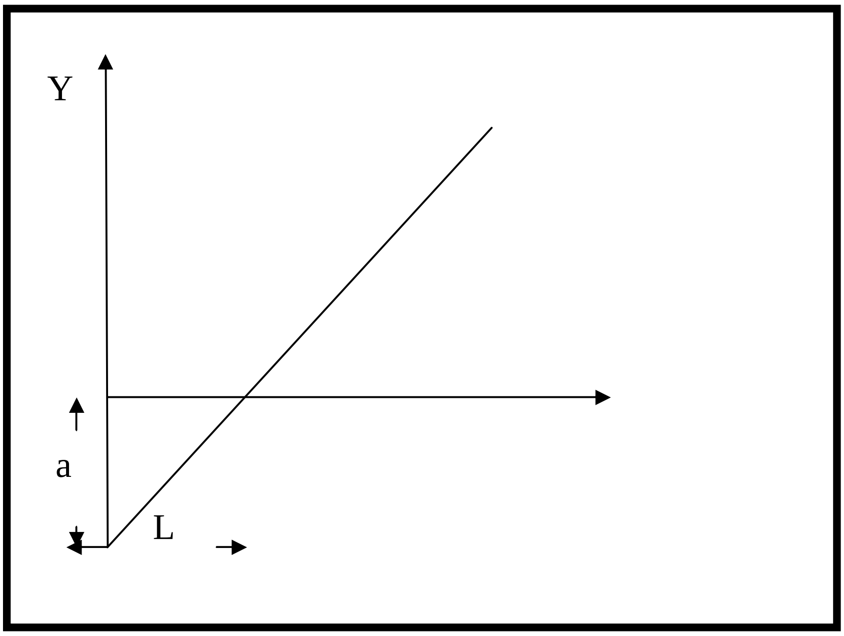


Figure 2.29: characterization of step response in Ziegler Nichols method

The point where the slope of the step response has its maximum is first determined, and the tangent at this point is drawn, the intersection between the tangent and the coordinate axis give the parameter a and L

Ziegler and Nichols have given the PID parameters directly as function of a and L ,These are given in table below, and estimate of the period T_P of the close loop system is also given in the table:

Table 2.3: PID parameters obtained from the Ziegler and Nichols step response method

controller	K	T_i	T_d	T_P
P	1/a	---	---	4L
PI	0.9/a	3L	---	5.7L
PID	1.2/a	2L	L/2	3.4L

- The frequency response method

This method is also based on a simple characterization of the process dynamics

The design is based on knowledge of the point in nquist curve of the process transfer function G(S),where the nquist curve intersect the negative real axis, for historical reasons this point is characterize by the parameters K_U and T_U which are called the ultimate gain and .these parameters can be determined in the following way. Connect a controller to the process, set the parameter so that the control action is proportional $T_i = \infty$ and T_d=0 , increase the gain slowly until the process start to oscillate . The gain when this occur is k_u and the period of oscillation is T_u . The parameters can also be determined approximately by relay feedback.

Ziegler Nichols has given simple formulas for the parameters of the controller in terms of ultimate gain and ultimate period.

- Relations between the Ziegler tuning methods

Insights in to the relations between Ziegler Nichols tuning methods can be obtained by calculate the controller parameters for different systems. Consider a process with the transfer function

$$G(S) = \frac{b}{s} e^{-sL} \tag{2.27}$$

Which is the model originally used by Ziegler and Nichols to derive their tuning rules for the step response method, for this process we have a=b*L the ultimate frequency is $W_U = \frac{\pi}{2L}$, which gives the ultimate period $T_U = 4L$, and the ultimate gain :

$$K_U = \frac{\pi}{2bL} \tag{2.28}$$

The step response method gives the following parameters for the PID controller

$$K = \frac{1.2}{bL} \qquad T_i = 2L \qquad T_d = \frac{L}{2}$$

The parameters given by the frequency response method are

$$T_d = \frac{0.94}{bL} \qquad T_i = 2L \qquad T_d = \frac{L}{2}$$

In this particular case both method gives the same value of integral and derivative time but the step response method give again that is about 25% higher than the frequency response method. The results of this example are quite typical. The step response method often gives higher value of gain.

- The chien ,hornes and reswick method

There has been many suggestion of modification of the Ziegler methods , Chien, Hornes and Reswick (CHR) change the step response method to give better damped closed loop systems. They proposed to use quickest response without overshoot or quickest response with 20% overshoot as design criteria. They also made the important observation that tuning for set point response or load disturbance response is different.

To tuning the controller according to the CHR method the parameters a and L of the process model are first determined in the same way as for the Ziegler Nichols step response method [10]. The controller parameters for the load disturbance response method are then given

Table 2.4: controller parameters obtained from CHR load disturbance response

PARAMETERS	0%			20%		
	k	T_i	T_d	k	T_i	T_d
P	0.3/a	--	--	0.7/a	--	--
PI	0.6/a	4L	--	0.7/a	2.3L	--
PID	0.95/a	2.4L	0.42L	1.2/a	2L	0.42L

The tuning rule based on the 20% design criteria are quite similar to the Ziegler Nichols step response method , however when 0% design criteria is used the gain and the derivative time are smaller and the integral time is larger, this mean that the proportional action ,the integral action as well as the derivative action are smaller.

In set point response method, the controller parameters are not only based on (a) and (L), but also on the time constant T.

- Analytically tuning methods [10].

There are several analytical tuning methods where the controller transfer function is obtained from the specifications by a direct calculation. Let the G_P and G_C be the transfer functions of the process and the controller .the closed loop transfer function obtained with the error feedback is then:

$$G_0 = \frac{G_P G_C}{1 + G_P G_C} \qquad (2.29)$$

Solving this equation for G_C we get

$$G_C = \frac{1}{G_P} \cdot \frac{G_0}{1-G_0} \qquad (2.30)$$

If the closed loop transfer function G_0 is specified and G_P is known, it is thus easy to compute G_c , the key problem is to find reasonable way to determined G_0 based on engineering specifications of the system ,it followed from the equation (2.29)above That all process poles and zeros are cancelled by the controller. This means that the method cannot be applied when the process has poorly damped poles and zeros. The method is also giving a poorly load disturbance response when slow process poles are cancelled.

- λ tuning [10].

The method called λ tuning was developed for process with long dead time L consider a process with transfer function

$$G_P = \frac{K_P}{1+ST^{e-sL}} \qquad (2.31)$$

Assumed that the desired closed loop transfer function is specified as

$$G_0 = \frac{e^{-sL}}{1+S\lambda T} \qquad (2.32)$$

Where λ is the tuning parameter, the time constants of the open and closed loop systems are the same when λ=1.the closed loop respond faster than the open loop system if λ<1.it slower when λ > 1.

- The haalman method

Another approach is to determined the ideal loop transfer function G_ℓ that give the desired performance and to choose the controller transfer function as

$$G_C = \frac{G_\ell}{G_P} \qquad (2.33)$$

Where G_P is the process transfer function, such an approach can give PI and PID controllers provided that G_ℓ and G_P are sufficiently simple, there are many ways to obtain suitable G_ℓ.

For system with a time delay L, haalman has suggested choosing

$$G_\ell(s) = \frac{2}{3Ls} e^{-sL} \tag{2.34}$$

The value 2/3 was found by minimizing the mean square error for the step change in the set point .this choice give a sensitivity M_S =1.9,which is reasonable value. Notice that it is only the dead time of the process that influences the loop transfer function. All other process poles and zeros are canceled which may lead to difficulties [10].

Applying haalman's method to a process with the transfer function

$$G_p(s) = \frac{1}{1+sT} e^{-sL} \tag{2.35}$$

Gives the controller:

$$G_C(s) = \frac{2(1+sT)}{3LS} = \frac{2T}{3T}(1+\frac{1}{ST}) \tag{2.36}$$

Which was a PI controller, A PID controller is obtained if the method is applied to a process with the transfer function:

$$G_P(s) = \frac{1}{(1+sT_1)(1+sT_2)} e^{-sL} \tag{2.37}$$

The parameters of the controller are:

$$k = \frac{2(T_1+T_2)}{3L}, T_i = T_1 + T_2, T_d = \frac{T_1 T_2}{(T_1+T_2)} \tag{2.38}$$

For more complex process it is necessary to approximate the process to obtain a transfer function for the desired form

- Optimization method

Optimization is powerful tool for design controllers, the method is conceptually simple, a controller structure with a few parameters specified. Specification is express as inequalities of functions of the parameters. The specification that is most important is chosen as the function to optimize .the method is well suited for PID controllers where the controller structure and the parameterization are given. There are several pitfalls when using optimization .care must experienced when formulating criteria and constraints; otherwise a criterion will indeed be optimal, but the controller may still be unsuitable because of a neglected constraints. Another difficulty is that the loss function may have many local minima, the third is that the computations required may easily be excessive, numerical problems may also arise .nevertheless optimization is good tool that has successfully been used to design PID controllers [10]. Some of these optimization methods are

- Modulus and symmetrical optimum

Modulus optimum (MO) and symmetrical optimum (SO) are two methods for selecting and tuning controllers that are similar in spirit to method. The acronyms BO and SO are derived from germen words. These methods are based on the idea of finding a controller that makes the frequency response from the set point to plant output as closed to one as possible for low frequencies. If G(s) the transfer function from the set point to the output, the controller is determined in such a way that: G(0)=1

$$\frac{d^n\,|G(iw)|}{dw^n}=0 \text{ at } w=0 \text{ for as many n as possible[10] .}$$

As we discussed the method by haalman is designed for systems having dead time while (MO) and (SO) methods apply to systems without dead time, small dead time can be dealt by with approximation.

An interesting feature of both (BO) and (SO) is that approximation is used to obtain simple low order transfer function. There are possibilities to combine the approaches.

- Tuning PID Controllers using the ITAE Criterion

The minimization of the integral of time-weighted absolute error (ITAE) is usually referred to in literature as a good tuning criterion to obtain controller PID parameters. However this criterion is not often used because its computer implementation is not a very easy task. The search of controller parameters can be obtained for particular types of load and/or set point changes and as this criterion is based on error calculation it can be applied easily for different processes modeled by different process models [11].

The section below describes briefly the steps to implement the ITAE

Criterion in Simulink and MATLAB, Section 4 is devoted to the cases studies: tuning PID controller's parameters for processes translated by first taken the steps taken to design PID controllers using the ITAE performance index are:

1. Develop the process model including the controller algorithms in Simulink.

2. Create a MATLAB m-file with an objective function that calculates the ITAE index.

3. Use a function of MATLAB Optimization Toolbox to minimize the ITAE index.

Step 1 is realized opening a new Simulink window and drag-and-drop all necessary blocks to simulate the process in Simulink. Some global variable must be defined (in this case, the controller parameters).

In step 2, a MATLAB m-file is defined to calculate the ITAE index (the objective function).

The ITAE performance index is mathematically given by:

$$ITAE = \int_0^t t\,|\,e(t)\,|\,dt \qquad (2.39)$$

Where t is the time and

e(t) is the difference between set point and controlled variable.

In step 3, a function of MATLAB Optimization Toolbox is called to calculate the minimum of the objective function defined in step 2.On each evaluation of the objective function, the model developed in simulink is executed and the ITAE performance index is calculated using the multiple application Simpson's 1/3 rule .

2.14 Grey Prediction Algorithm:

A system is called white if the all information of the system is known, on the other hand, a system is called black if we don't know anything about, and thus a grey system is the one which is partially known [12].

"Grey" means poor, incomplete, uncertain, etc. The goal of Grey System and Its applications is to bridge the gap existing between social science and natural Science[13]. Gery theory was proposed by j.L deng in 1982.on the other hand, Grey prediction power comes from its ability to predict the future value with only a few data, and its ability to deal with uncertain, indeterminate data and incomplete data to analyze and establish the systematic relations and a prediction model. Unlike conventional stochastic forecasting theory, Grey prediction simply requires as few as four lagged inputs to construct a Grey differential equation. The Grey prediction has been widely used in studies of social sciences, agriculture, procreation, power consumption and management [13]. As well as other fields.

In Grey theory, two techniques are adopted to establish the model for applications.

The resultant new series is used to establish a difference equation whose coefficients are found via the least-squares method. And the accumulated generating series prediction model value is then obtained.

The estimated prediction value in the time-domain is calculated by means of an inverse accumulated generating operation. Only a few original sequence elements are needed, and one does not have to assume the distribution of the sequence. The generated value is then used to establish a set of Grey difference equation and Grey pseudo differential equation [13].

The application field of the grey system involved agriculture, ecology, economy, meterology, medicine, history, industy, earthquake, geology, military affairs, biological protection etc

2.14.1Grey relational space

The grey relational space (GRS) is one that describes the posture relationships between one main factor and all the other factors in a given system [13]. A GRS is a binary set denoted by (X, Γ), where **X** is the collection composed of sequence X_i to be compared and reference sequence X0, **Γ** is a map set called grey relational map set , $\gamma \in \Gamma$ is an appointed relational map in GRS . Assume that:

$$\gamma\ (X_0(K),X_i(K)) \qquad (2.40)$$

is an image at point k from the series to real number with map γ , and $\gamma(X_0,X_i)$ is an image at all points with k=1,2,3,…..n where

$X_0=(X_0(1)\ldots X_0(n))$

$$X_i= (X_i\ (1)\ldots X_i\ (n)) \qquad (2.41)$$

Let $\gamma(X_{0,\ Xi})$ satisfy that

$$\gamma\left(X_0, X_i\right) = \frac{1}{n}\sum_{k-1}^{n}\gamma(X_0(K), X_i(k)) \qquad (2.42)$$

Then said $\gamma(X_0(k), X_i\ (k))$ is said to be grey relational coefficient at the point k and $\gamma(X_0,X_i)$ to be a grey relational grade ,if Γ satisfied some characteristic as Norm

Interval, Duality Symmetric, Wholeness, Approachability

2.14.2 Grey generating space

In the viewpoint of grey system theory the concepts and the generating techniques are important ideas, let x, y and ψ be the series and $x \in X$, $y \in Y$, $\psi \in \phi$ are collections of dimension n

If $\quad x = \sum_{k=1}^{n} y(k)\Psi_k$

$$y(k) \in y \in Y,\ \psi_K \in \phi\ ,\ x \in X \qquad (2.43)$$

Then ϕ is a basis space, Ψ_k a basis of ϕ and the coordinate Y, Hence (X_i Φ/$Y_)$ is a generating space, suppose that:

$x^{(0)}=(x^{(0)}(1)\ldots..x^{(0)}(n))$

$x^{(1)}=(x^{(1)}(1)\ldots..x^{(1)}(n))$

$$x^{(1)}(k) = \sum_{m=1}^{k} x^{(0)}(m) \quad [17] \qquad (2.44)$$

Grey prediction based on grey model (GM), it has three basic operations: accumulated generating operation (AGO), inverse accumulated generating operation (IAGO) and grey modeling .The GM (1, 1) model is the most commonly used model. The first 1 in GM (1, 1) means that there is only one variable and the next 1 means the first order grey differential equation is used to construct the model as mentioned above Fundamental concepts of grey system theory [13]

2.14.3 Grey system based prediction

Grey models predict the future values of a time series based only on a set of the most recent data depending on the window size of the predictor. It is assumed that all data values to be used in grey models are positive, and the sampling frequency of the time series is fixed. From the simplest point of view.

2.14.4 Generations of grey sequences

The main task of grey system theory is to extract realistic governing laws of the system using available data. This process is known as the generation of the grey sequence (Liu & Lin, 1998).It is argued that even though the available data of the system, which are generally white numbers, is too complex or chaotic; they always contain some governing laws. If the randomness of the data obtained from a grey system is somehow smoothed, it is easier to derive any special characteristics of that system.

For instance, the following sequence that represents the price of a product might be given:

$X^{(0)} = (820, 840, 835, 850, 890)$

It is obvious that the sequence does not have a clear regularity. If accumulating generation suggested in grey system theory is applied to this sequence $^{(1)}$ is obtained which has a clear growing tendency

$X^{(1)} = (820, 1660, 2495, 3345, 4235)$

2.14.5 Grey modeling

In grey system theory a dynamic model with a group of differential equations is developed, which is called grey differential model (GM), to do inferred

1. Stochastic process whose amplitude vary with time is referred to as grey process
2. The grey modeling is based on the generating series rather than on the raw one
3. The grey derivative, parallel shooting and grey differential equation are defined and process in order to build a GM [13].
4. To build a grey model only a few of data are needed to distinguish it

$$X^{(0)}(k)+az^{(1)}(k) = b \qquad (2.45)$$

K=1,2,…….n

Is a grey differential model, called GM(1,1), as it includes only one variable $x^{(0)}$, where

$Z^{(1)}(k)=0.5x^{(1)}(k)+0.5x^{(1)}(k-1)$ (2.46)

K=1, 2, .n

a,b are the coefficients in grey system theory terms, a is said to be developing coefficient and b the grey input , $x^{(0)}(k)$ is a gery derivative which maximize the information density for a given series to be modeled.

A cording to the least square method, we have

$$\hat{a}=\begin{bmatrix} a \\ b \end{bmatrix}=(B^T B)^{-1} B^T \Upsilon_N \quad (2.47)$$

There $$B=\begin{pmatrix} -z^{(1)}(2) & 1 \\ ...... & ...... \\ -z^{(1)}(n) & 1 \end{pmatrix} \qquad \Upsilon_N=\begin{pmatrix} x_1^{(0)}(2) \\ x_1^{(0)}(n) \end{pmatrix} \quad (2.48)$$

Here B is called data matrix.

By regarding the following equation

$$\frac{dx^{(1)}}{dt}+a\otimes(x^{(0)})=b \quad (2.49)$$

As a shadow for

$x^{(0)}(k)+az^{(1)}(k)=b$ we have

$$\chi^{(1)}=\otimes(x^{(1)})=\{x^{(1)} \mid \forall x^{(1)} \in \chi^{(1)}\}$$

$$\begin{Bmatrix} \otimes(x^{(1)}) \mid \otimes(x^{(1)}) \to x^{(1)}(t+\Delta t)/\Delta t \\ .... \to x^{(1)}(t-\Delta t)/\Delta t \end{Bmatrix} \quad (2.50)$$

Where $\otimes^{x(1)}$ is said to be a background grey number

$$\frac{dx^{(1)}}{dt} , \otimes(x^{(1)}) \quad (2.51)$$

Is the weightening value of grey number $\otimes(x^{(1)})$, A grey differential equation having N variables is called GM(1,N) ,whose expression can be written as

$$x_1^{(0)}(k) + az_1^{(1)}(k) = \sum_{i=2}^{N} b_i x_i^{(1)}(k) \tag{2.52}$$

K=1, 2…n

Where b_i is said to be an i^{th} influence coefficient, which means that x_i exercises influence on x_i (the behavior variable), then we have

$$\hat{a} = [a, b_2, ..., b_N]^T$$

$$\hat{a} = (B^T B)^{-1} B^T Y_N \tag{2.53}$$

$$B = \begin{pmatrix} -Z_1^{(I)}(2) & x_2^{(i)}(2) & x^{(i)}{}_N(2) \\ ...... & ...... & ...... \\ -Z_1^{(1)}(n) & x^{(1)}{}_2(n) & x^{(1)}{}_N(n) \end{pmatrix} \qquad \Upsilon_N = \begin{pmatrix} x_1^{(0)}(2) \\ x_1^{(0)}(n) \end{pmatrix} \tag{2.54}$$

Model GM (1, 1) play an important role in grey forecasting, grey programming and grey control.

Model GM (1, N) has laid an important foundation for regional economic programming and grey multivariable control [13].

- GM (n, m) model

In grey systems theory, GM (n, m) denotes a grey model, where n is the order of the difference equation and m is the number of variables. Although various types of grey models can be mentioned, most of the previous researchers have focused their attention on GM (1, 1) models in their predictions because of its computational efficiency. It should be noted that in real time applications, the computational burden is the most important parameter after the performance

- GM (1, 1) model

GM (1, 1) type of grey model is the most widely used in the literature, pronounced as ‘‘Grey Model First Order One Variable”. This model is a time series forecasting model. The differential equations of the GM (1,1) model have time-varying coefficients. In other words, the model is renewed as the new data become available to the prediction model. The GM (1,1) model can only be used in positive data sequences (Deng, 1989). In this paper, since all the primitive data points are positive, grey models can be used to forecast the future values of the primitive data points.

In order to smooth the randomness, the primitive data obtained from the system to form the GM(1,1) is subjected to an operator, named Accumulating Generation Operator (AGO) (Deng, 1989).The differential equation GM(1,1)) is solved to obtain then-n step ahead predicted value of the system. Finally, using the predicted value, the Inverse Accumulating Generation Operator (IAGO) is applied to find the predicted values of original data

- GM (1, N): This represents first-order derivative, but containing N input variables, for multi-variable analysis.
- GM (O, N): This represents zero-order derivative, containing N input variables, for prediction purposes

2.14.6 Grey forecasting

The subjects of grey forecasting include:

- Series forecasting
- Calamities forecasting
- Topological forecasting
- Systematic forecasting

All of these are based on GM(1,1),we call them grey forecasting , whose objective is to unify the field and to bridge the gap between grey process theory and practice Our intension is to make forecasting useful for decision and policy makers who need future prediction[13].

- Grey series forecasting: Grey series prediction is a common technique available for forecasting –which is referred for essential prediction-and direct use of

GM (1,1) will enable us to know where and how the events to forecast would appear.

Let $x^{(0)}$ can be a raw series

AGO $x^{(0)} = x^{(1)}, x^{\square(0)}(\zeta)$ the prediction value at point ζ, then the series prediction process can be written as

IAGO.GM.AGO: $x^{(0)} \rightarrow x^{\square(0)}(\zeta)$

$$x^{(0)} = (x^{(0)}(1),....,x^{(0)}(n)), \zeta > n \qquad (2.55)$$

Where IGAO and GAO are maps which transfer $x^{-(1)}$ to $x^{-(0)}$ and $x^{(0)}$ to $x^{(1)}$ respectively, and GM implies the grey modeling for GM (1, 1) by $x^{(0)}$,for a series prediction.

2.14.7 Grey prediction control

The control principle of conventional control theory ,weather classical or modern , is to control the system behavior according to the state sample which had already occurred .it is then referred to as an afterward manner are as follow :

1-impossible to avert accidents in avedance

2-impossible to control timely

3-weakly adaptable The essential idea of the grey prediction control is to control the system behavior in advance with the control strategy obtained from the prediction controller , based on GM(1,1) ,the figure 2.29.below illustrate the outline for a grey prediction control system. It maintains a desired state within reasonably accurate tolerances even though the output y is varied.

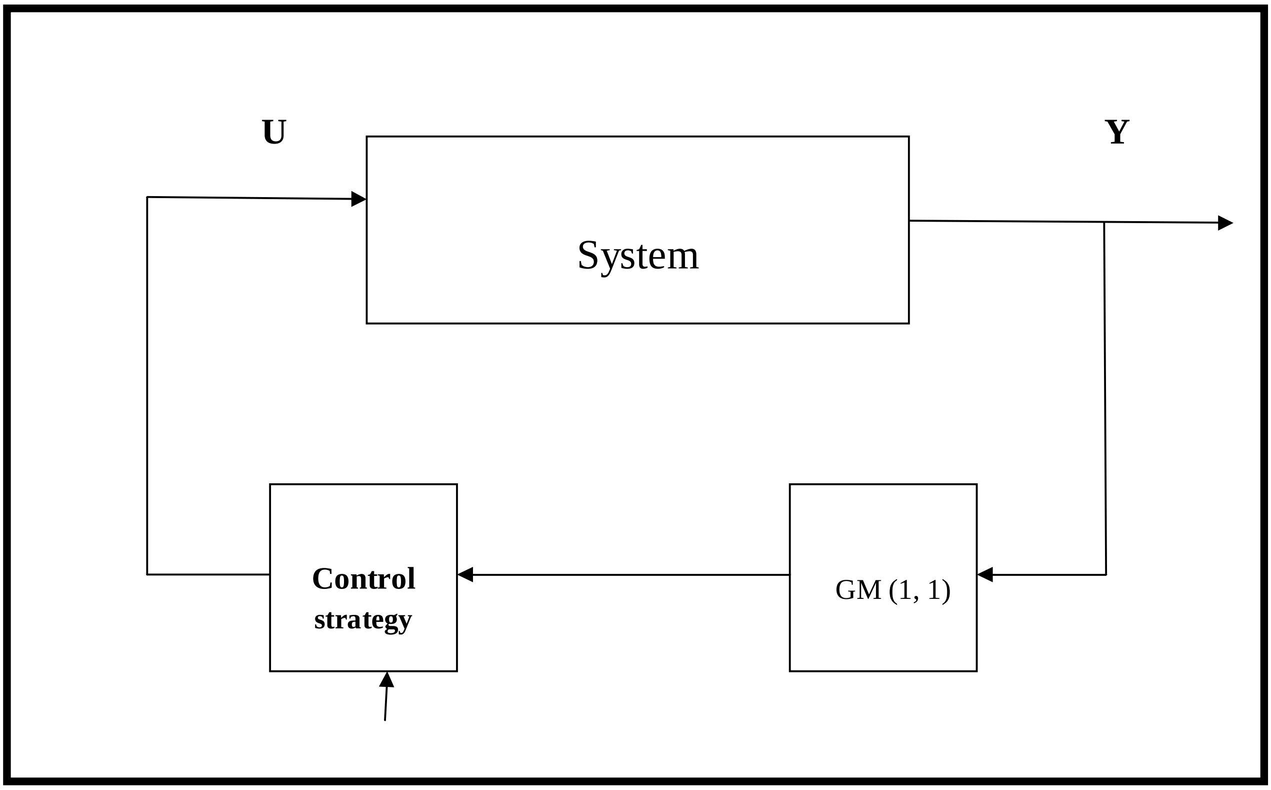


Figure 2.30: grey prediction control system

The output of loop 1(control object) is denoted as y, the prediction value of the systems behavior is denoted as $Y^{\wedge\ (0)}$, which is obtained from the controller 2, the assign quantity is denoted as y^* and U is a control strategy coming from loop 3.The control principles is as follows: a transducer feeds the sample data to prediction controller 2, which function as a computer. The prediction value $Y^{\wedge(0)}$ as a calculated result of the controller 2 is delivered to loop 3, which constitute a controller strategy as compared with Y^* . The control strategy u stems from loop 3, and then stored therein. Should the behavior $Y^{(0)}$ occur in the future, the store strategy u will deal with it and lead the system behavior to a desired state

CHAPTER THREE

(SYSTEM DESIGN)

CHAPTER 3

SYSTEM DESIGN

3.1 Overview

DC motor speed represents a parameter that very difficult to stabilize .The error and error rate between system output(measured value) and system input(desired value) represented the inputs of PID controller which directly used to control the speed of a DC motor by reading the value of the pwm. The PID controller to satisfy control requirements for system should be tuned very well. The idea is to use the gray prediction algorithm method for auto tuning the PID parameters, a grey PID control method (GP PID) show that it can greatly improve system performances by forecasting the output of the system depending on a small amount of data after combining adaptive PID controller with grey prediction controller Gray-prediction model as shown in figure 3.1.Below

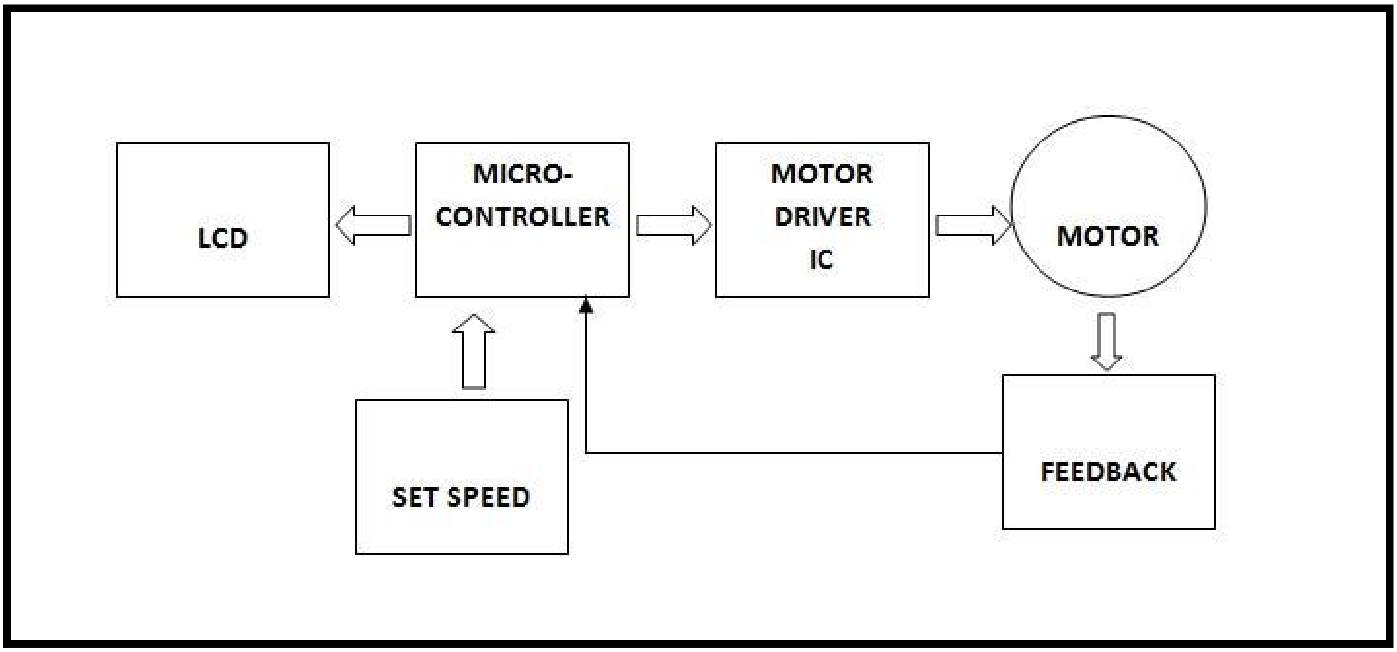


Figure 3.1: block diagram of system tools

3.2.1 The basic design and requirements

The simulated circuit is built with ATmega16 microcontroller, DC motor, L293D drive circuit, sensor and LCD

The AT mega 16 microcontroller ports are programmed by specify it’s pins to achieve specific function, The LCD [LM016L] is connected to the port C. The DC motor connected to the O/P of the drive circuit L293D while it’s I/P connected to the port D. The sensor is connected to the ADC pins which they are specific on PORT A. The next figure shows the stages the followed to design the system of DC motor speed.

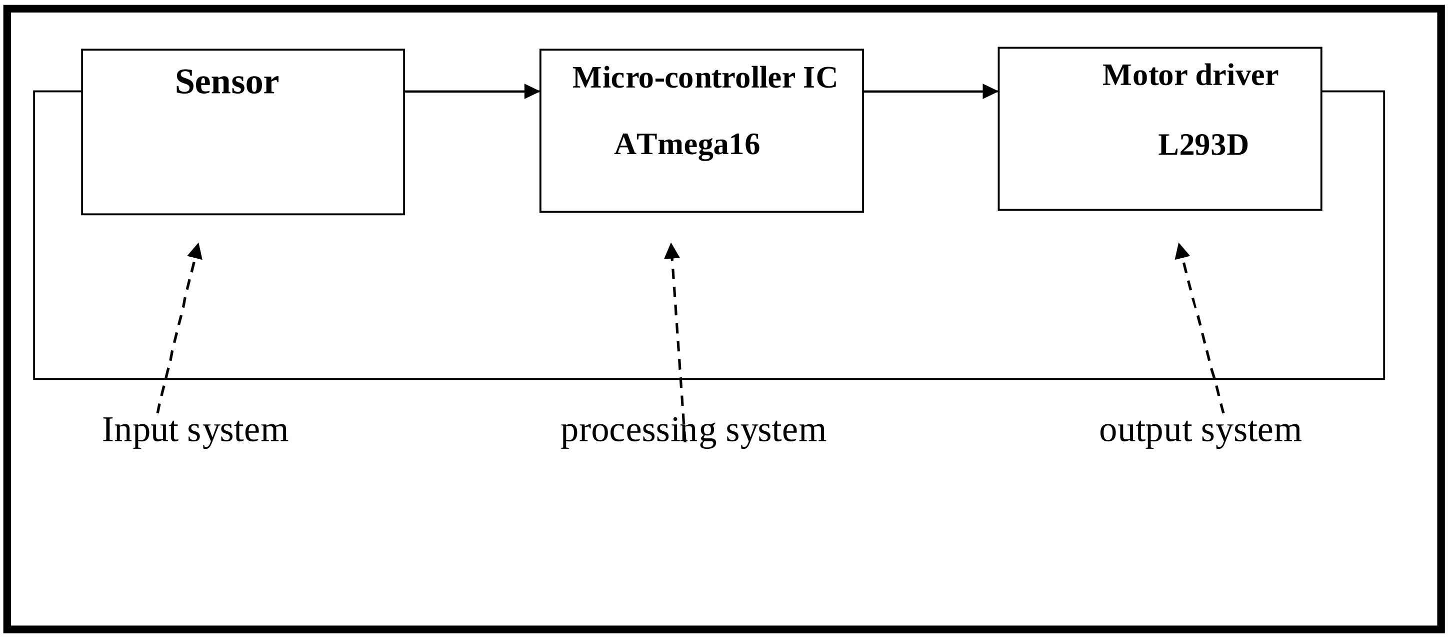


Figure 3.2: stages of the system of speed control

3.2.2 Introduction to ATmelStdio6

Atmel studio 6 or AS6 in short, is the latest integrated development environment (IDE) by Atmel for their 16 bits and 32 bits microcontroller lines.

Since Atmel's AVR microcontrollers were introduced to the market only a few years ago, they are not so well known as the 8051 controllers.

Therefore, this interesting microcontroller family should be described in more detail. Atmel's AVR microcontrollers use a new RISC (reduced instructions set) architecture which has been developed to take advantage of the semiconductor integration and software capabilities of the 1990's. The resulting microcontrollers offer the highest MIPS/mW capability available in the 8-bit microcontrollers market today, the architecture of the AVR microcontrollers was designed together with C-language experts to ensure that the hardware and software work hand-in-hand to develop a highly efficient, high-performance code.

To optimize the code size, performance and power consumption,

AVR microcontrollers have big register files and fast one-cycle instructions.

The family of AVR microcontrollers includes differently equipped controllers - from a simple 8-pin microcontroller up to a high-end microcontroller with a large internal memory. The Harvard architecture addresses memories up to 8 MB directly. The register file is "dual mapped" and can be addressed as part of the on-chip SRAM, whereby fast context switches are possible.

All AVR microcontrollers are based on Atmel's low-power nonvolatile

CMOS technology. The on-chip in-system programmable (ISP), downloadable flash memory permits devices on the user's circuit board to be reprogrammed via SPI or with the help of a conventional

Programming device.

By combining the efficient architecture with the downloadable flash

Memory on the same chip, the AVR microcontrollers represent an

Efficient approach to applications in the "Embedded Controller" market.

Studio 6 comes integrated with latest version of avr-gcc compiler. So the completed development environment can be installed with a single easy to use installer **.**The IDE consist of a high end editor with flawless auto complete. The editor is powered by proven Microsoft visual studio .the editor makes it easy to type and edit C source file with its auto features , the user don't have to refer to the reference manual often as the editor itself shows the parameter requirements of the a function, return type and help.

The code that written to program the DC motor speed by using gery prediction walk through:

1-the main program begins by initializing the subsystems parameters and constants:

- initializing the parameters of the DC motor transfer function (L_a , K_m , K_p , j , C and M)
- initializing the parameters of the PID controller [P, I and D] and also the variables which use to built the PID function
- Initializing the set point

2- Configure the PWM (pulse width modulation)

- Configure the LCD(liquid crystal display) by using port C pins
- Configure the ADC pin

3- Built the function of the grey algorithm to make sure that it will perform it task by adjusting and auto tuning the PID controller parameters in order to predict the next output of the system

- Built the function that will activate the PID controller to make sure that it will Perform its task by reading the value of PWM to calculate the error rate in accurate way in order to adjusting the speed of the motor

4- The program enters in to infinite loop, this infinite loop keeps the DC motor move by its suitable speed as long as it has powered

3.2.3 The processing system

Processing system acts as the brain of the simulated circuit design, which generates desired output for corresponding inputs. For that we use microcontrollers In present days there are several companies that manufacture microcontrollers, for example Atmel, Microchip, Intel, Motorola etc .we will be using ATmega16L microcontroller. It is an Atmel product it is also called AVR. It's used ATmega16L because these design requires not very simple microcontroller, we can't use any microcontroller for that. It is an ISP (in system programmable) device. It means programming (burning) of Atmega IC can be done without removing it from the system. More details are show at the appendex B.

Programming (burning) of microcontroller means transferring the code from computer to microcontroller. It has on chip PWM (pulse width modulation) circuit

3.3.1 Hardware details

The figure 3.3. Shown the ports and main pins of microcontroller chip

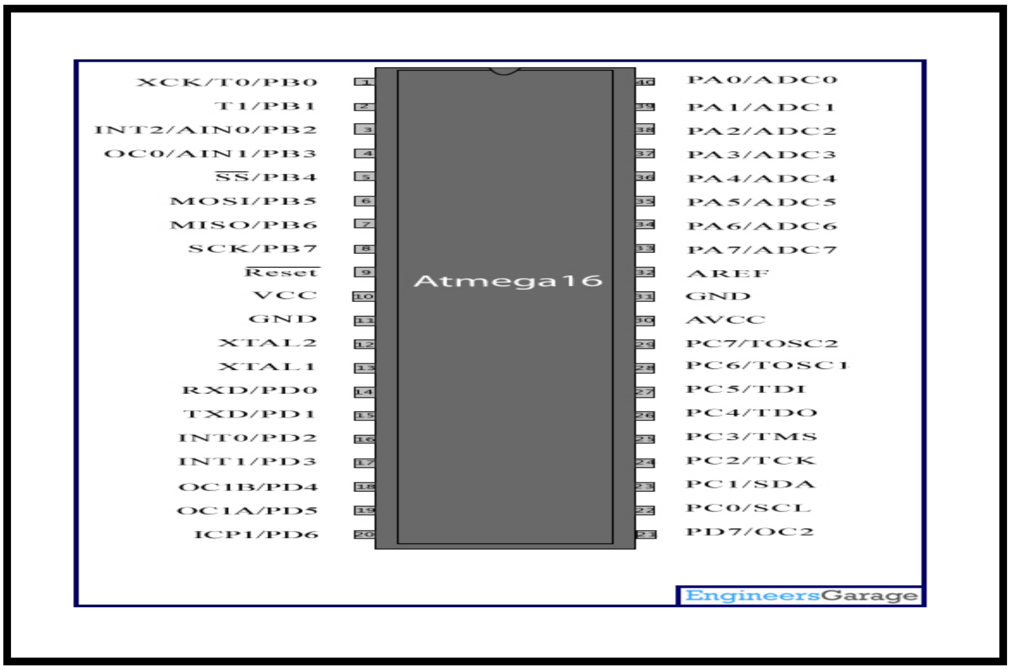


Figure 3.3: integrated circuit of ATmega16

3.3.2The pins description of microcontroller AT mega 16

- VCC: this pin should be connected to power supply
- GND: these pins should be connected to ground
- RESET: Reset Input, A low level on this pin for longer than the minimum pulse length will generate a reset, even if the clock is not running.
- XTAL1: Input to the inverting Oscillator amplifier and input to the internal clock operating circuit.
- XTAL2: Output from the inverting Oscillator amplifier.
- AVCC: is the supply voltage pin for Port A and the A/D Converter. It should be externally connected to VCC, even if the ADC is not used. If the ADC is used, it should be con-nected to VCC through a low-pass filter.
- AREF: is the analog reference pin for the A/D Converter
- Port A (PA7-PA0): Port A serves as the analog inputs to the A/D Converter. Port A also serves as an 8-bit bi-directional I/O port, if the A/D Converter is not used.

Port pins can provide internal pull-up resistors (selected for each bit). The Port A output buffers have symmetrical drive characteristics with both high sink and source capability. When pins PA0 to PA7 are used as inputs and are externally pulled low, they will source current if the internal pull-up resistors are activated. The Port A pins are tri-stated when a reset condition becomes active, even if the clock is not running.

- Port B (PB7-PB0): Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port B also serves the functions of various special features of the ATmega16.

- Port C (PC7-PC0): Port C totally like the previous ports are mentioned, Port C also serves the functions of the JTAG interface ;If the JTAG interface is enabled, the pull-up resistors on pins PC5(TDI), PC3(TMS) and PC2(TCK) will be activated even if a reset occurs.

Also it serves other special features of theATmega16.

- Port D (PC7-PD0)

It is like the rest ports of ATmega16; serves all the general functions and also serves the functions of various special features of the ATmega16

- AVCC

A VCC is the supply voltage pin for Port A and the A/D Converter. It should be externally connected to VCC, even if the ADC is not used. If the ADC is used, it should be connected to VCC through a low-pass filter.

- AREF

AREF is the analog reference pin for the A/D Converter.

3.3.3 Program details

i. programming and simulation

Program for the AVR series of microcontrollers can be written in assembly (AVR ASM) ,C and BASIC ,AVR studio , WinAVR etc. are some free development software's for programming the AVR microcontrollers. We are using win AVR for programming and AVR studio for simulating (simulation means debugging the code on software, one can virtually give the input and check the output for the code).in winAVR programmers notepad we write our code after compilation it generates'. Hex' file that is a hardware level code.

ii.Tachometer

A tachometer is used to calculate the angular speed of a rotating shaft in revolutions per minutes (rpm). Tachometers are used in all factory and manufacturing operations where timing and precision are imperative to consistent and quality production. Automobile tachometers measure the car engine's rpm.

Instead of the tachometer a chip of LM35 temperature sensor is used to get a set of values considered as set points; the value that get from LM35 represent an actual speed value.

The types of tachometers commonly found are mentioned below:

- Analog tachometers - Comprise a needle and dial-type of interface. They do not have provision for storage of readings and cannot compute details such as average and deviation. Here, speed is converted to voltage via use of an external frequency to voltage converter as shown in figure 3.4.This voltage is then displayed by an analog voltmeter [14].

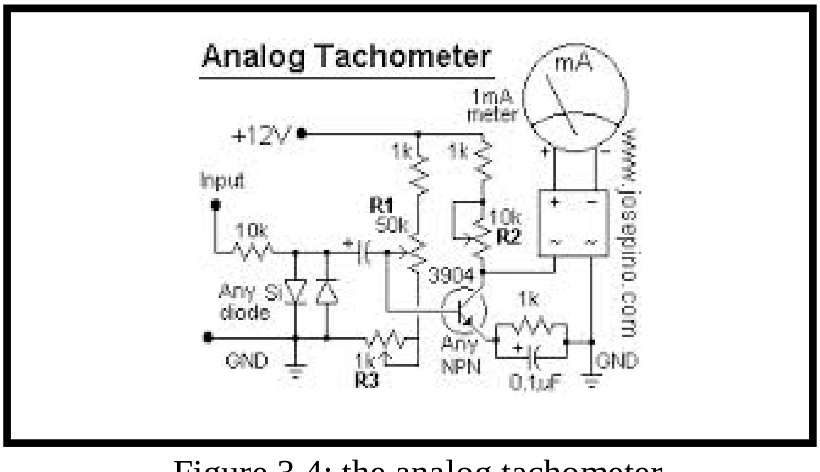


Figure 3.4: the analog tachometer

- Digital tachometers – Comprise LCD or LED readout and a memory for storage as shown in figure 3.5.These can perform statistical operations, and are very suitable for precision measurement and monitoring of any kind of time based quantities. Digital tachometers are more common these days and they provide numerical readings instead of using dials and needles [14]

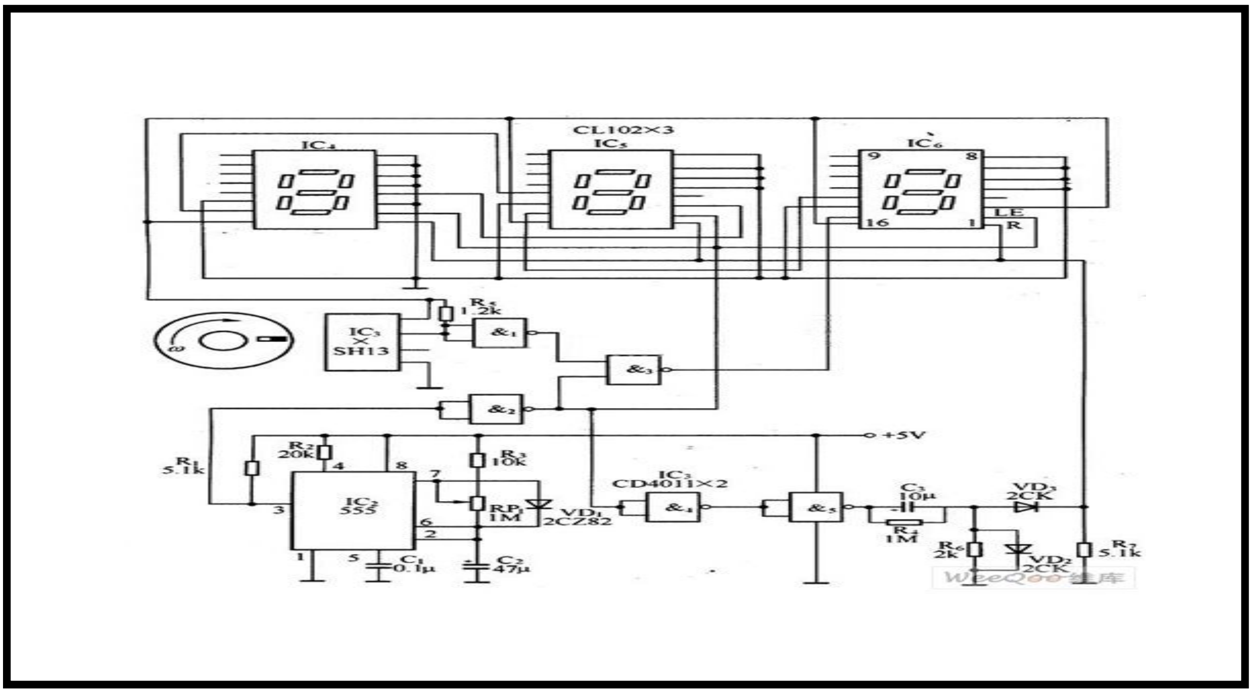


Figure 3.5: digital tachometer

- Contact and non-contact tachometers – The contact type is in contact with the rotating shaft. The non-contact type is ideal for applications that are mobile, and uses a laser or optical disk. In the contact type, an optical encoder or magnetic sensor is used. Both these types are data acquisition methods [14].
- Time and frequency measuring tachometers – Both these are based on measurement methods. The time measurement device calculates speed by measuring the time interval between the incoming pulses; whereas, the frequency measurement device calculates speed by measuring the frequency of the incoming pulses. Time measuring tachometers are ideal for low speed

measurements and frequency measuring tachometers are ideal for high speed measurements [14].

- The working principle of an electronic tachometer is quite simple. The ignition system triggers a voltage pulse at the output of the tachometer electromechanical part whenever the spark plugs fires. The electromechanical part responds to the average voltage of the series of pulses. It shows that the average voltage of the pulse train is proportional to engine speed. The signal from the perception head is transmitted by standard twin screened cable to the indicator.
- The tachometers are temperature compensated to be able to handle operations over an ambient temperature range of – 20 to +70°C (-4 to +158°F).
- The tachometer in a vehicle enables the driver to select suitable throttle and gear settings for the driving conditions as prolonged use at high speeds can cause insufficient lubrication which will affect the engine. It enables the driver to prevent exceeding speed capability of sub-parts such as spring retracted valves of the engine, and overheating, thereby causing unnecessary wear or permanent damage and even failure of engines

Some applications of tachometer:

The following are the key application areas of tachometers:

- Automobiles, airplanes, trucks, tractors, trains and light rail vehicles
- Laser instruments
- Medical applications
- Analog audio recording, a tachometer is a device that measures the speed of audiotape as it passes across the head
- Numerous types of machinery and prime movers
    - To estimate traffic speed and volume [14].

iii. Motor driver L293D:

From microcontroller we cannot connect a motor directly because microcontroller cannot give sufficient current to drive the DC motors. Motor driver is a current enhancing device; it can also be act as switching device. Thus motor driver take the input signals from microcontroller and generate corresponding output for motor.
L293D is a typical Motor driver or Motor Driver IC which allows DC motor to drive on either direction. L293D is a 16-pin IC which can control a set of two DC motors simultaneously in any direction. It means that you can control two DC motors with a single L293D IC. Dual H-bridge Motor Driver integrated circuit (*IC*).The l293d can drive small and quiet big motors as well, check the Voltage Specification at the end of this page for more info. It works on the concept of H-bridge. H-bridge is a circuit which allows the voltage to be flown in either direction. As you know voltage need to change its direction for being able to rotate the motor in clockwise or anticlockwise direction, hence H-bridge IC are ideal for driving a DC motor. In a single l293d chip there two h-Bridge circuit inside the IC which can rotate two dc motor independently. Due its size it is very much used in robotic application for controlling DC motors. Given below is the pin diagram of a L293D motor controller. There are two Enable pins on l293d. Pin 1 and pin 9, for being able to drive the motor, the pin 1 and 9 need to be high. For driving the motor with left H-bridge you need to enable pin 1 to high. And for right H-Bridge you need to make the pin 9 to high. If anyone of the either pin1 or pin9 goes low then the motor in the corresponding section will suspend working. It’s like a switch.

The IC chip of motor driver shown below at figure 3.6. And the pins details at figure 3.7.

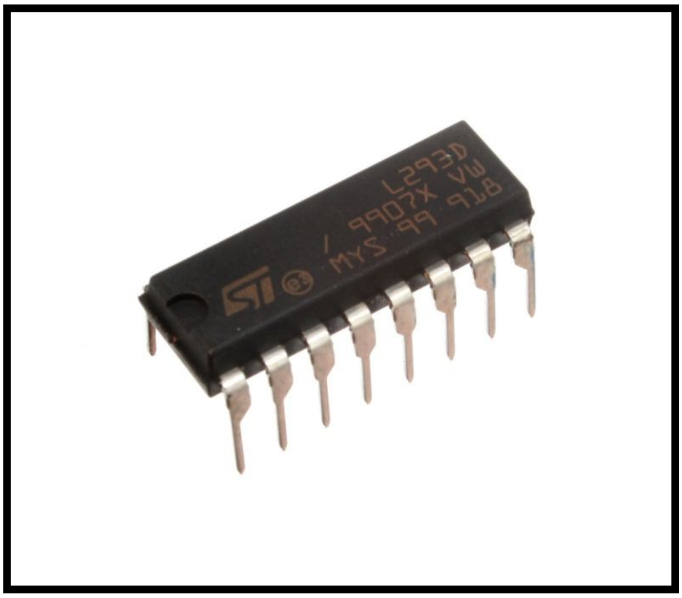


Figure 3.6: the IC chip of DC motor driver

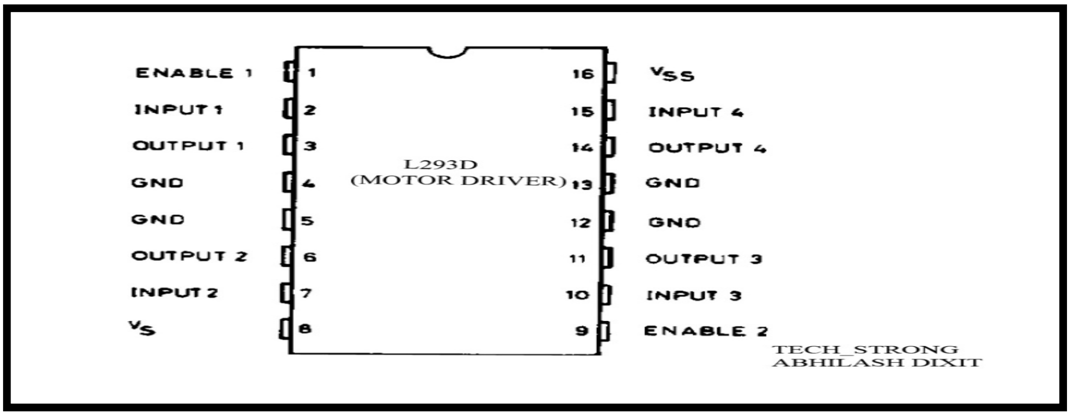


Figure 3.7: pin details of L293D

This motor driver IC that can drive two motor simultaneously.

- Operation of H-Bridge

  The H-bridge arrangement is generally used to reverse the polarity of the motor, but can also be used to 'break' the motor ,where the motor comes to sudden stop, as the motor terminals are shorted ,or to let the motor 'free rum' to a stop ,as the motor is effectively disconnected from the circuit , H bridge shown below in figure 3.8.

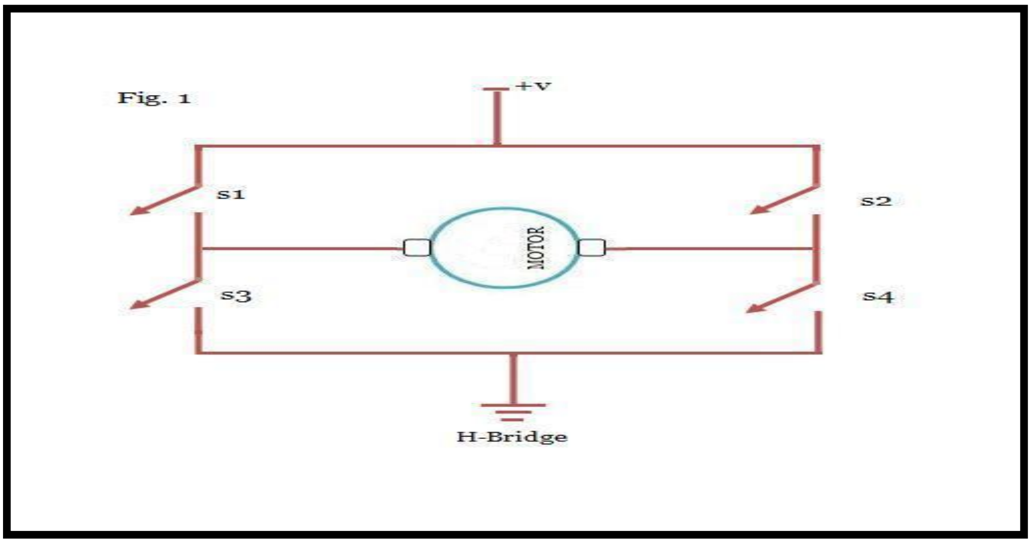


Figure 3.8: the states structure of an H bridge

The next table will show the status of the output according to the input status

Table 3.1: the status of the two outputs

Input A	Input B	Motor State
High	Low	Turns clockwise
Low	High	Turns anti-clockwise
High	High	Braking occurs
Low	Low	Braking occurs

The below figure 3.9. Show the h bridge's simulated circuit

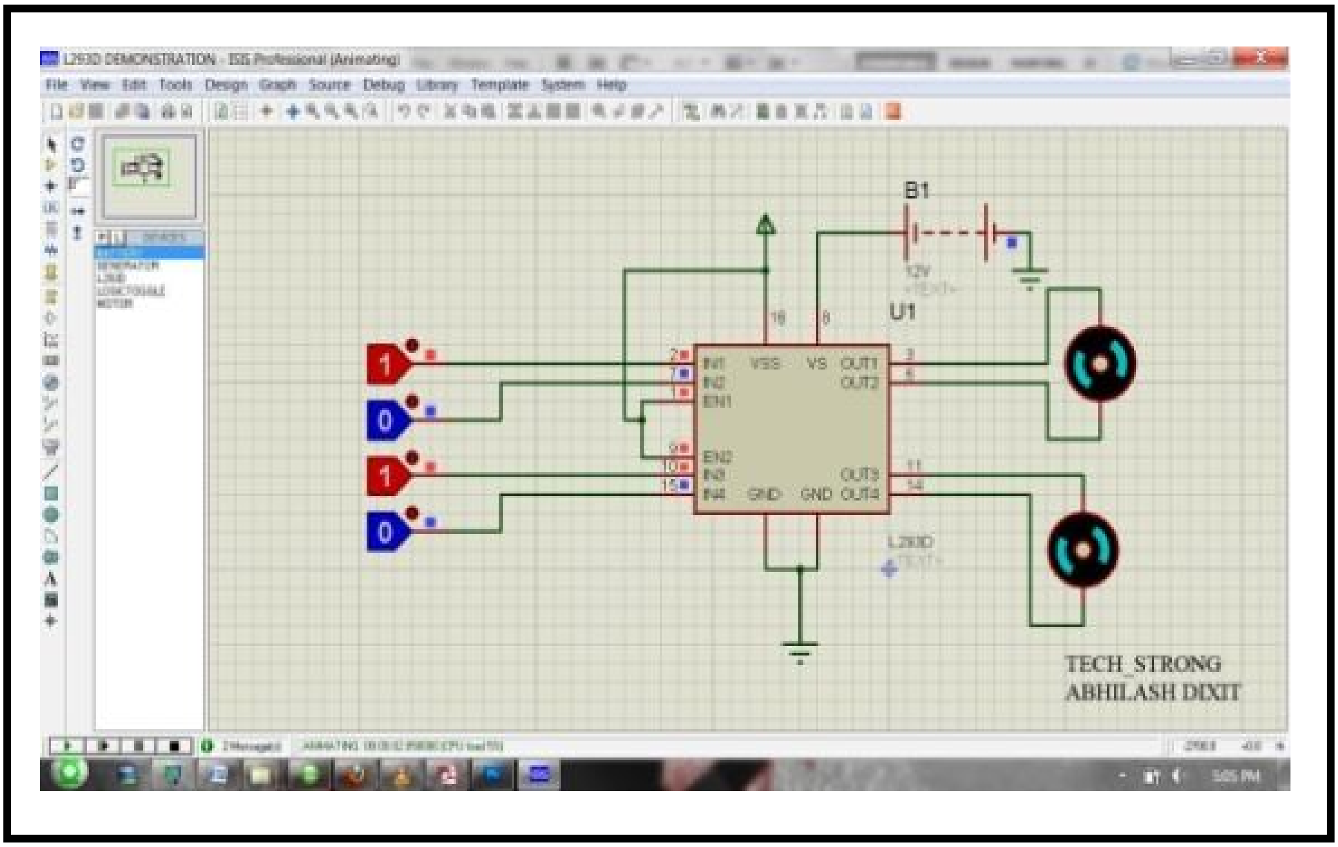


Figure 3.9: Simulated circuit of H-bridge

I v .liquid crystal display (lcd)-LM016L :

The most common application of liquid crystal technology is in liquid crystal displays (LCDs). From the ubiquitous wrist watch and pocket calculator to an advanced VGA computer screen, this type of display has evolved into an important and versatile interface.

A liquid crystal display consists of an array of tiny segments (called pixels) that can be manipulated to present information. This basic idea is common to all displays, ranging from simple calculators to a full color LCD television

As will be shown in the following sections, an LCD consists primarily of two glass plates with some liquid crystal material between them. There is no bulky picture tube. This makes LCDs practical for applications where sizes (as well as weight) are important.

In general, LCDs use much less power than their cathode-ray tube (CRT) counterparts. Many LCDs are reflective, meaning that they use only ambient light to illuminate the display. Even displays that do require an external light source (i.e. computer displays) consume much less power than CRT devices. Liquid crystal displays do have drawbacks, and these are the subject of intense research. Problems with viewing angle, contrast ratio, and response time still need to be solved before the LCD replaces the cathode-ray tube. However with the rate of technological innovation, this day may not be too far into the future.

We will restrict this discussion to traditional nematic LCDs since the major technological advances have been developed for this group of devices. Other LC applications, such as that employing polymer stabilization of LC structure, are discussed in the appropriate section covering those materials. The main LCD pins shown below in figure 3.10. And 3.11.

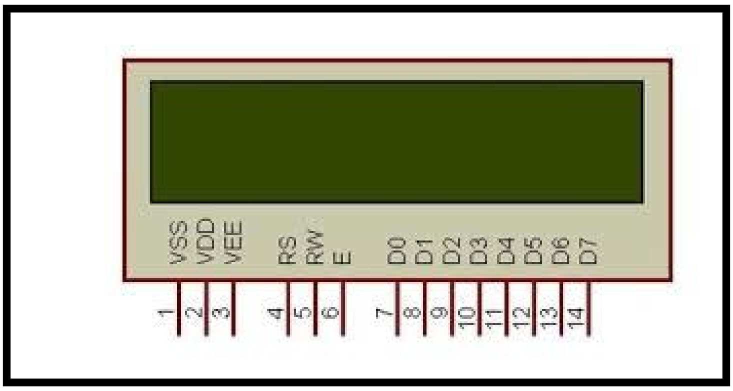
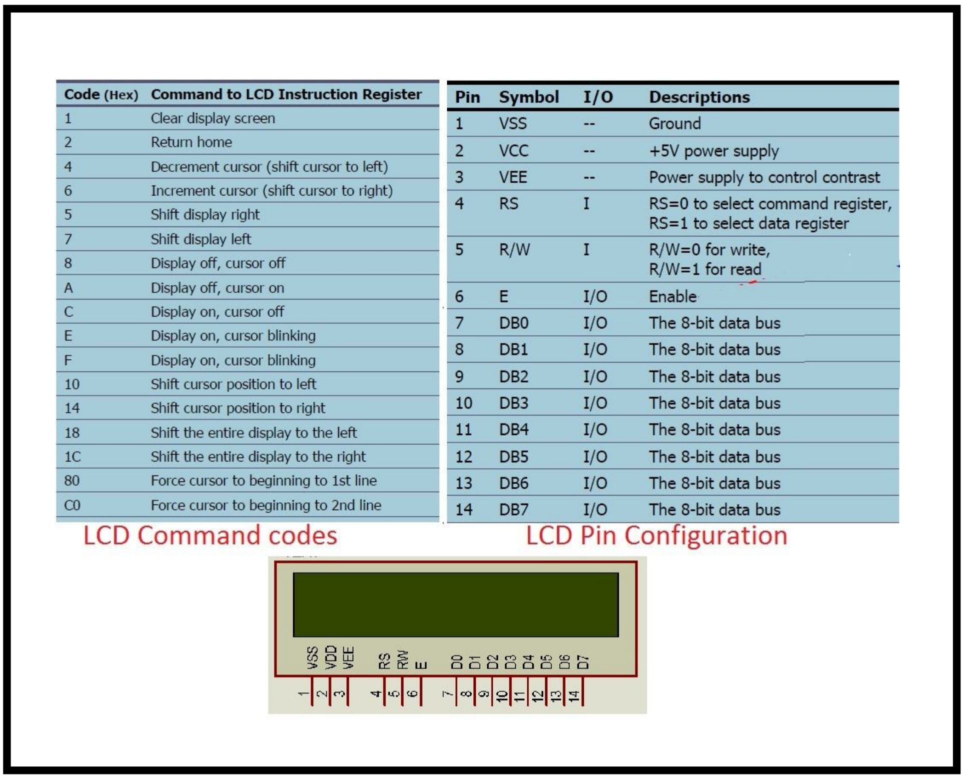


Figure 3.10: the LCD LM016L chip



Code (Hex)	Command to LCD Instruction Register
1	Clear display screen
2	Return home
4	Decrement cursor (shift cursor to left)
6	Increment cursor (shift cursor to right)
5	Shift display right
7	Shift display left
8	Display off, cursor off
A	Display off, cursor on
C	Display on, cursor off
E	Display on, cursor blinking
F	Display on, cursor blinking
10	Shift cursor position to left
14	Shift cursor position to right
18	Shift the entire display to the left
1C	Shift the entire display to the right
80	Force cursor to beginning to 1st line
C0	Force cursor to beginning to 2nd line

LCD Command codes

Pin	Symbol	I/O	Descriptions
1	VSS	--	Ground
2	VCC	--	+5V power supply
3	VEE	--	Power supply to control contrast
4	RS	I	RS=0 to select command register, RS=1 to select data register
5	R/W	I	R/W=0 for write, R/W=1 for read
6	E	I/O	Enable
7	DB0	I/O	The 8-bit data bus
8	DB1	I/O	The 8-bit data bus
9	DB2	I/O	The 8-bit data bus
10	DB3	I/O	The 8-bit data bus
11	DB4	I/O	The 8-bit data bus
12	DB5	I/O	The 8-bit data bus
13	DB6	I/O	The 8-bit data bus
14	DB7	I/O	The 8-bit data bus

LCD Pin Configuration

Figure 3.11: LCD pins description

3.4 Simulated Circuit Connection

The figure 3.12.Show the simulation circuit

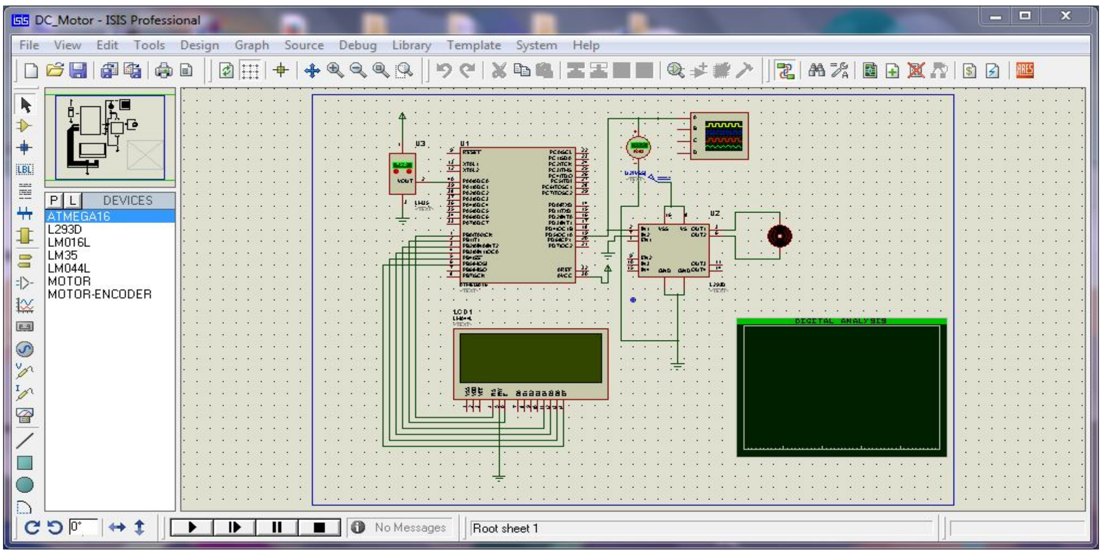


Figure 3.12: simulation circuit

CHAPTER FOUR

(RESULT AND DISCUSSION)

CHAPTER 4
RESULT AND DISCUSSION

4.1 Results and Discussion

The proposed algorithm for control the current speed of DC motor and use it to predict a set of output values was tested in simulation circuit and experimented, by follow a definite set of equations related to the PID controller and GREY prediction algorithm in order to programmed it and use it on the Bascom code to get the objective that we looking for.

The set point of the speed is Q

The value that read from the sensor directly is T

The error is equal to: E =Q-T

But this value that directly get from the sensor will processed by using the PID controller and grey prediction algorithm equations in order to decrease the error value.

By using the grey sequence $X^{(0)}$ = (T0, T1, T2, T3)

Where T0 TO T3 represents the values that get from the sensor and those values have been used as grey sequence.

Then the GREY equations are:

X0=T0*0.1

X1=X0+T1*0.2

X2=X1+T2*0.4

X3=X2+T3*0.8 (4.1)

$$K = \frac{\sum X}{\sum \mu} = \frac{X0 + X1 + X2 + X3}{\mu 1 + \mu 2 + \mu 3 + \mu 4} \quad (4.2)$$

$$\mu(x) = [0.1\ 0.2\ 0.4\ 0.8] \quad (4.3)$$

Where μ(x) represent the membership function

By using GREY algorithm there is an ability to predict more values of output. The value of k that calculated from previous equation (4.2) will subtract from the set point in order to obtain the error.

Numbers of cases will appear bellow all are working in order to calculate the value of k depending on grey sequence (many set points) and then observe the errors value ,where Error =Q-K

- Table 4.1: Set point =80

The summation of membership function =1.5

The T values get from sensor	X* μ(x)	Error
T0=85	T0*0.1=8.5	-2.666
T1=79	T1*0.2=15.8	-8.666
T2=88	T2*0.4=35.2	0.3334
T3=90	T3*0.8=72	2.3334
Total	131.5	

$$K = \frac{\sum X}{\sum \mu} = \frac{X0 + X1 + X2 + X3}{\mu 1 + \mu 2 + \mu 3 + \mu 4} = \frac{131.5}{1.5} = 87.6666$$

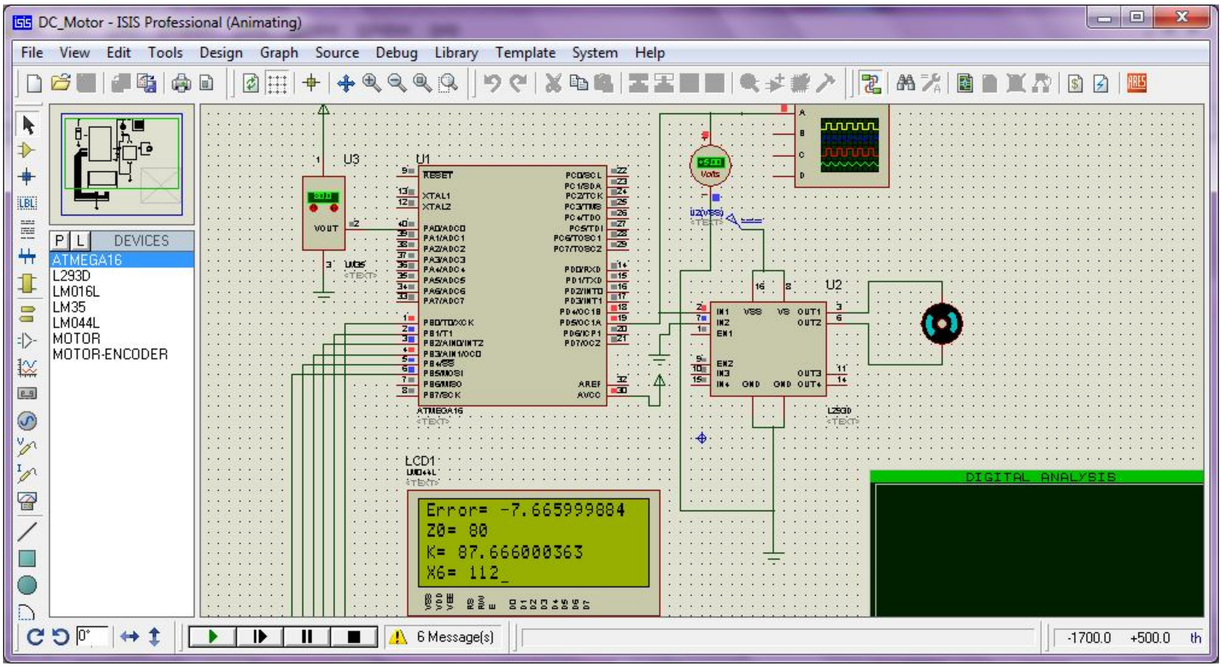


Figure 4.1: sample result-1

Depending on the previous values we notice that the predictive measured value (actual value) is equal 87.666 and this value calculated according to many values assume as set points (grey sequence) and according to all of that the error values are around 0.3 and ±2.7 which represent acceptable values

- Table 4.2: Set point =70

The summation of membership function =1.5

The T value get from sensor	X* μ(x)	The X's parameters	Error
T0=75	T0*0.1=7.5	X0=T0=7.5	-2.666
T1=69	T1*0.2=13.8	X1=T0+T1=21.3	-11.666
T2=78	T2*0.4=31.2	X2=T0+T1+T2=52.5	0.3334
T3=80	T3*0.8=64	X3=T0+T1+T2+T3=116.5	2.3334
Total		116.5	

$$K = \frac{\sum X}{\sum \mu} = \frac{X0 + X1 + X2 + X3}{\mu 1 + \mu 2 + \mu 3 + \mu 4} = \frac{116.5}{1.5} = 77.6666$$

Error=Q-K=70-77.6666=-7.6666

Also on this case we notice that the errors values at the most cases are suitable and not far from the accepted values

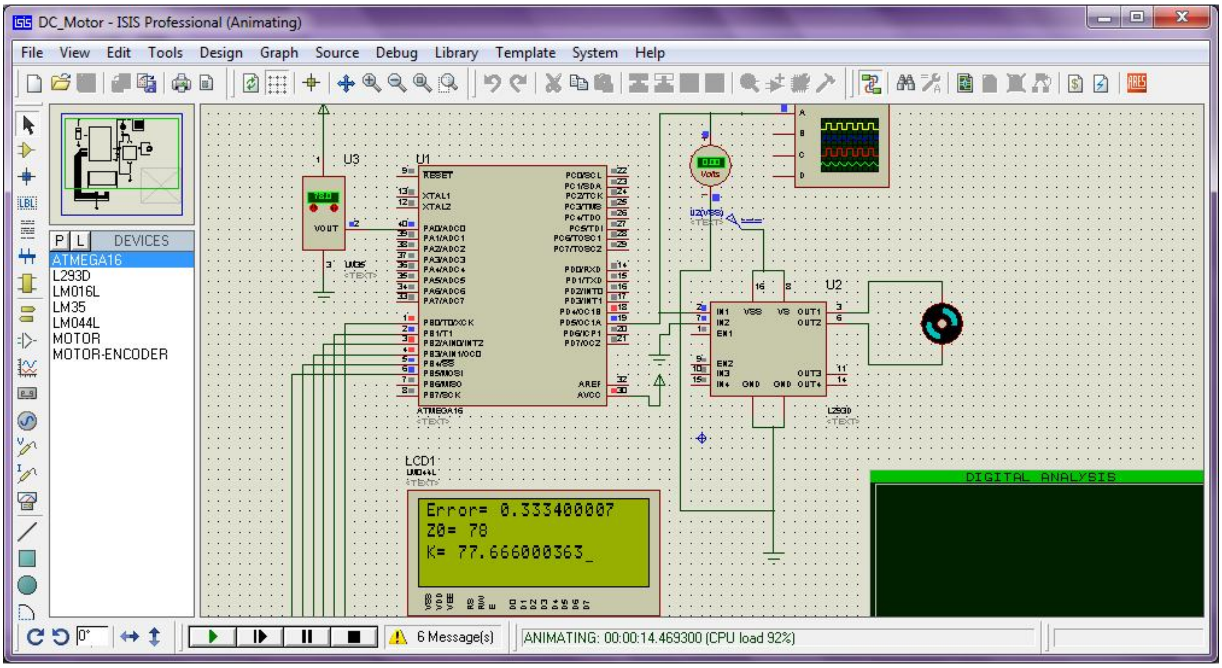


Figure 4.2: sample result-2

- Table 4.3: Set point =75

The T values get from sensor	X* µ(x)	The X's parameters	Error
T0=70	T0*0.1=7	X0=T0=7	-1.2
T1=77	T1*0.2=15.4	X1=T0+T1=22.4	5.8
T2=75	T2*0.4=30	X2=T0+T1+T2=52.4	3.8
T3=68	T3*0.8=54.4	X3=T0+T1+T2+T3=106.8	-3.2
Total		106.8	

$$K = \frac{\sum X}{\sum \mu} = \frac{X0 + X1 + X2 + X3}{\mu 1 + \mu 2 + \mu 3 + \mu 4} = \frac{106.8}{1.5} = 71.2$$

Error =Q –K = 75-71.2 =3.8

Like the previous cases this case reflected acceptable values to error

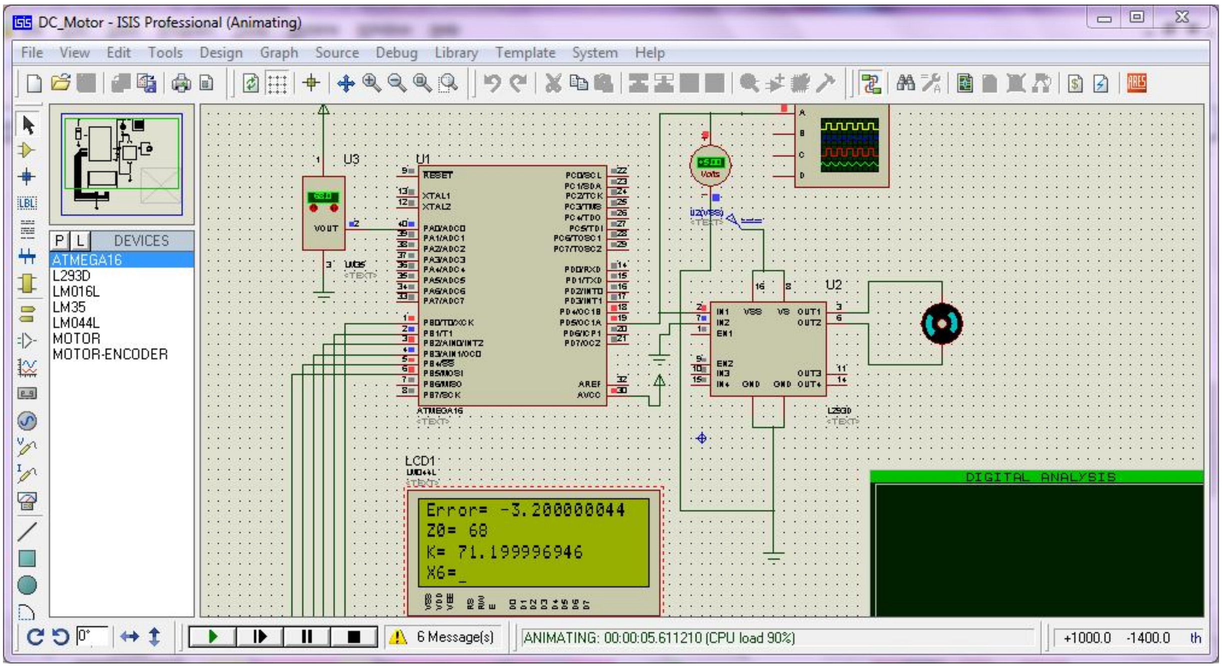


Figure 4.3: sample result-3

- Table 4.4: Set point =90

$$K = \frac{\sum X}{\sum \mu} = \frac{X0 + X1 + X2 + X3}{\mu 1 + \mu 2 + \mu 3 + \mu 4} = \frac{134}{1.5} = 89.3333$$

The T values get from sensor	X* µ(x)	The X's parameters	Error
T0=90	T0*0.1=9	X0=T0=9	0.667
T1=85	T1*0.2=17	X1=T0+T1=26	-4.33
T2=80	T2*0.4=32	X2=T0+T1+T2=58	-9.33
T3=95	T3*0.8=76	X3=T0+T1+T2+T3=134	5.667
Total		134	

According to the assumed setting values and the calculated measured value “k” the values of error are acceptable too

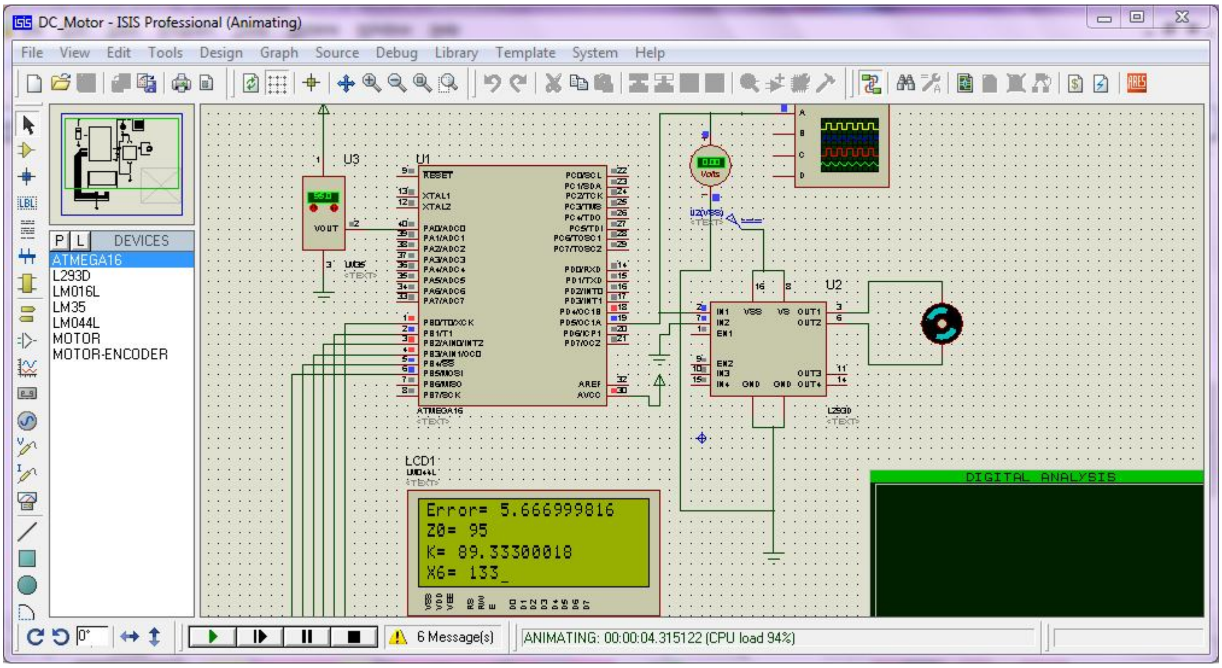


Figure 4.4:sample result-4

CHAPTER FIVE

(CONCLUSION AND RECOMMENDATION)

CHAPTER FIVE

5.1 CONCLUSION

The concept of the PID controller and grey prediction algorithm are implemented on ATmega16 microcontroller. Microcontroller programmed to read the values that get from the sensor, calculate the error depending on the value that obtained by Appling PID concepts and grey prediction algorithm, and also use to make the motor run on suitable speed according to a set of many predicted speeds and errors. The processed value (k) that get from the grey equations calculated depending on many values represent the assumed set point and the value of k will subtract from those set point individually to get many values of predicted errors.

Those values of errors will help to make a good overview of the suitable set point values are required and the expected output values

By studding many cases of different set point sequence at any case, applying the membership values and grey equation on any sequence's value to extract the value of (k) ,as mentioned before ,which used as new measured value (actual value after applying grey algorithm) instead of the old measured value (actual value without applying grey algorithm)

The operator can make good decision about the current operation mode and what is expected in the near future (the expected errors and outputs).

5.2 RECOMMENDATION

Because of many factors like cost, perfect components we aren’t able to use, for better performance follow this simple recommendations:

1. Increase numbers of sensors for more accuracy sensing
2. Use intelligent tuning methods
3. Increase or extends sequence the grey algorithim

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Appendix A

(SOURCE CODE)

```
$regfile "m16def.dat"

$crystal = 8000000

Config Timer1 = Pwm , Pwm = 10 , Compare A Pwm = Clear Down , Compare B Pwm = Clear Down ,
Prescale = 8

'Config Adc = Single , Prescaler = Auto , Reference = Avcc

Enable Interrupts

Config Adc = Single , Prescaler = Auto , Reference = Avcc

Start Adc

Config Lcdpin = Pin , Db4 = Portb.2 , Db5 = Portb.3 , Db6 = Portb.4 , Db7 = Portb.5 , E = Portb.1 , Rs =
Portb.0

Dim X0 As Integer , Y0 As Integer , Z0 As Single , T0 As Integer

Dim X1 As Integer , Y1 As Integer , Z1 As Single , T1 As Integer

Dim X2 As Integer , Y2 As Integer , Z2 As Single , T2 As Integer

Dim X3 As Integer , Y3 As Integer , Z3 As Single , T3 As Integer

Dim L1 As Integer

Dim L2 As Integer

Dim L3 As Integer

Dim L4 As Integer

Dim H1 As Integer

Dim H2 As Integer

Dim H3 As Integer

Dim K As Integer

Dim Q As Word , Error As Integer

Dim Cv As Single                                'PID output

Dim Last_t As Single

Dim Pwm1 As Word
```

```
Dim Sum_error As Single
Dim D_t As Single                    'derivated delta pv                    'difference between
sp and pv
Dim Pterm As Single                   'proprotional calculated part
Dim Iterm As Single                  ' integrated calculated part
Dim Dterm As Single
Dim Pwm_act As Single
Const Kp = 10
Const Ki = 0.2
Const Kd = 0.5
Q = 500

Do
Y0 = Getadc(0)
Z0 = Y0 * 5
T0 = Z0 * 100
T0 = T0 * 10
X0 = T0
Y0 = Getadc(0)
Z1 = Y0 * 5
T1 = Z1 * 100
T1 = T1 * 10
X1 = T0 + T1
Y0 = Getadc(0)
Z2 = Y0 * 5
T2 = Z2 * 100
```

```
T2 = T2 * 10

X2 = X1 + T2

Y0 = Getadc(0)

Z3 = Y0 * 5

T3 = Z3 * 100

T3 = T3 * 10

X3 = X2 + T3

L1 = 1 * X0

L2 = 2 * X1

L3 = 3 * X2

L4 = 4 * X3

H1 = L1 + L2

H2 = H1 + L3

H3 = H2 + L4

K = H3 \ X3

Error = Q - K

'Loop

Locate 1 , 1

Lcd "E= " ; Error

Locate 2 , 1

Lcd "Cv= " ; Cv ,

Locate 3 , 1

Lcd "pwm= " ; Pwm1

Locate 4 , 1

Lcd "k= " ; K
```

```
'Error = Sp - Pv
        Sum_error = Sum_error + Error

        Iterm = Ki * Error                  'integrated cv part
        D_t = Last_t - K
        Last_t = K
        Dterm = Kd * D_t                    'derivated cv part
        Pterm = Kp * Error
        Cv = Pterm + Iterm                  'summing of three calculated terms
        Cv = Cv + Dterm
       'Pwm1 = Cv
        Pwm_act = K * 1024
        Pwm_act = Pwm_act / 1000
        Pwm1 = Pwm_act + Cv
   Compare1a = Pwm1

   If Error = 0 Then Gosub 111
   Waitms 100
   Cls
Loop
111:
Do
Compare1a = Pwm1
Loop
```

Appendix B

L293D
QUADRUPLE HALF-H DRIVER

SLRS008A – SEPTEMBER 1986 – REVISED MAY 1990

POST OFFICE BOX 655303 DALLAS, TEXAS 75265

- **600-mA Output Current Capability Per Driver**
- **Pulsed Current 1.2-A Per Driver**
- **Output Clamp Diodes for Inductive Transient Suppression**
- **Wide Supply Voltage Range 4.5 V to 36 V**
- **Separate Input-Logic Supply**
- **Thermal Shutdown**
- **Internal ESD Protection**
- **High-Noise-Immunity Inputs**
- **Functional Replacement for SGS L293D**

description

The L293D is a quadruple high-current half-H driver designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V. It is designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications.

All inputs are TTL-compatible. Each output is a complete totem-pole drive circuit with a Darlington transistor sink and a pseudo-Darlington source. Drivers are enabled in pairs with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN. When an enable input is high, the associated drivers are enabled, and their outputs are active and in phase with their inputs. External high-speed output clamp diodes should be used for inductive transient suppression. When the enable input is low, those drivers are disabled, and their outputs are off and in a high-impedance state. With the proper data inputs, each pair of drivers form a full-H (or bridge) reversible drive suitable for solenoid or motor applications.

A VCC1 terminal, separate from VCC2, is provided for the logic inputs to minimize device power dissipation.

The L293D is designed for operation from 0°C to 70°C.