CHAPTER TWO

THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 Introduction

Automatic system are common place in people daily life ,they can be found in almost any electronic devices and appliances we use daily, starting from air conditioning systems, automatic doors, and automotive cruise control systems to more advanced technologies such as robotic arms, production lines and thousands of industrial and scientific applications. **DC servo motors** are one of the main components of automatic systems, any automatic system should have an actuator module that makes the system to actually perform its function. The most common actuator used to perform this task is the **DC servo motor**. Historically **DC servo motor** also played a vital role in the development of the computer’s disk drive system, which makes them one of the most important components in people life that we cannot live without it. Due to their importance, the design of controllers for these systems has been an interesting area for researchers from all over the world. However, even with all of their useful applications and usage, servo motor systems still suffer from several non-linear behaviors and parameters affecting their performance, which may lead for the motor to require more complex controlling schemes, or having higher energy consumption and faulty function in some cases.

2.2 Control Systems

Control systems are an integral part of modern society. Numerous applications are all around us like the rockets fire, the space shuttle lifts off, the earth orbit, in splashing cooling water, a metallic part is automatically machined and a self-guided vehicle delivering material to workstations in an aerospace assembly plant glides along the floor seeking its destination [1].

Automatic control has played a vital role in the advance of engineering and science. In addition to its extreme importance in space-vehicle systems, missile guidance systems, robotic systems, and the like, automatic control has become an important and integral part of modern manufacturing and industrial processes. For example, automatic control is essential in the numerical control of machine tools in the manufacturing industries, in the design of autopilot systems in the aerospace industries, and in the design of cars and trucks in the automobile industries. It is also essential in such industrial operations as controlling pressure, temperature, humidity, viscosity, and flow in the process industries [2].

Humans are not the only creators of automatically controlled systems; these systems also exist in nature. Within our own bodies are numerous control systems, such as the pancreas, which regulates our blood sugar. In time of "fight or flight," our adrenaline increases along with our heart rate, causing more oxygen to be delivered to our cells. Our eyes follow a moving object to keep it in view; our hands grasp the object and Place it precisely at a predetermined location [1].

2.2.1 Historical review

The first significant work in automatic control was James Watt's centrifugal governor for the speed control of a steam engine in the eighteenth century. Other significant works in the early stages of development of control theory were due to Minorsky, Hazen and Nyquist among many others. In 1922, Minorsky worked on automatic controllers for steering ships and showed how stability could be determined from the differential equations describing the system. In 1932, Nyquist developed a relatively simple procedure for determining the stability of closed-loop systems on the basis of open-loop response to steady-state sinusoidal inputs. In 1934, Hazen, who introduced the term servomechanisms for position control systems, discussed the design of relay servomechanisms capable of closely following a changing input. Since the late 1950s, the emphasis in control design problems has been shifted from the design of one of many systems that work to the design of one optimal system in some meaningful sense. As modern plants with many inputs and outputs become more and more complex, the description of a modern control system requires a large number of equations.

Classical control theory, which deals only with single input single output systems, becomes powerless for multiple input multiple output systems. Since about 1960, because the availability of digital computers made possible time-domain analysis of complex systems, modern control theory, based on time-domain analysis and synthesis using state variables, has been developed to cope with the increased complexity of modern plants and the stringent requirements on accuracy, weight, cost in military, space and industrial applications.

2.2.2 Open and closed loop control systems

Feedback control systems are often referred to as closed-loop control systems. In practice, the terms feedback control and closed-loop control are used interchange-ably. In a closed-loop control system the actuating error signal, which is the difference between the input signal and the feedback signal (which may be the output signal itself or a function of the output signal and its derivatives and/or integrals), is fed to the controller so as to reduce the error and bring the output of the system to a desired value. The term closed-loop control always implies the use of feedback control action in order to reduce system error.

Those systems in which the output has no effect on the control action are called open-loop control systems. In other words, in an open loop control system the output is neither measured nor feedback for comparison with the input. One practical example is a washing machine. Soaking, washing, and rinsing in the washer operate on a time basis. The machine does not measure the output signal, that is, the cleanliness of the clothes. In any open-loop control system the output is not compared with the reference input. Thus, to each reference input there corresponds a fixed operating condition; as a result, the accuracy of the system depends on calibration. In the presence of disturbances, an open-loop control system will not perform the desired task. Open-loop control can be used, in practice, only if the relationship between the input and output is known and if there are neither internal nor external disturbances. Clearly, such systems are not feedback control systems. Note that any control system that operates on a time basis is open loop. For instance, traffic control by means of signals operated on a time basis is another example of open-loop control.

An advantage of the closed loop control system is the fact that the use of feedback makes the system response relatively insensitive to external disturbances and internal variations in system parameters. It is thus possible to use relatively inaccurate and inexpensive components to obtain the accurate control of a given plant, whereas doing so is impossible in the open-loop case.

From the point of view of stability, the open-loop control system is easier to build because system stability is not a major problem. On the other hand, stability is a major problem in the closed-loop control system, which may tend to overcorrect errors and thereby can cause oscillations of constant or changing amplitude. It should be emphasized that for systems in which the inputs are known ahead of time and in which there are no disturbances it is advisable to use open-loop control. Closed loop control systems have advantages only when unpredictable disturbances and/or unpredictable variations in system components are present. Note that the output power rating partially determines the cost, weight, and size of a control system. The number of components used in a closed-loop control system is more than that for a corresponding open-loop control system. Thus, the closed-loop control system is generally higher in cost and power. To decrease the required power of a system, open-loop control may be used where applicable. A proper combination of open-loop and closed-loop controls is usually less expensive and will give satisfactory overall system performance [2].

2.2.3 Advantages of control systems

Control systems giving the ability to move large equipment with precision that would otherwise be impossible. For example pointing huge antennas toward the farthest reaches of the universe to pick up faint radio signals; controlling these antennas by hand would be impossible. Because of control systems, elevators carry us quickly to our destination, automatically stopping at the right floor. Humans alone could not provide the power required for the load and the speed; motors provide the power, and control systems regulate the position and speed.

Control systems build for primary reasons; Power amplification, remote control, convenience of input form and compensation for disturbances [1].

2.3 Nonlinear Systems

A system is nonlinear if the principle of superposition does not apply. Thus, for a nonlinear system the response to two inputs cannot be calculated by treating one input at a time and adding the results. Although many physical relationships are often represented by linear equations, in most cases actual relationships are not quite linear. In fact, a careful study of physical systems reveals that even so-called "linear systems" are really linear only in limited operating ranges. In practice, many electromechanical systems, hydraulic systems, pneumatic systems, and so on, involve nonlinear relationships among the variables. For example, the output of a component may saturate for large input signals. There may be a dead space that affects small signals. (The dead space of a component is a small range of input variations to which the component is insensitive). Square-law nonlinearity may occur in some components. For instance, dampers used in physical systems may be linear for low-velocity operations but may become nonlinear at high velocities, and the damping force may become proportional to the square of the operating velocity.

In control engineering a normal operation of the system may be around an equilibrium point, and the signals may be considered small signals around the equilibrium. (It should be pointed out that there are many exceptions to such a case). However, if the system operates around an equilibrium point and if the signals involved are small signals, then it is possible to approximate the non- linear system by a linear system. Such a linear system is equivalent to the nonlinear sys-tem considered within a limited operating range. Such a linearized model (linear, time-invariant model) is very important in control engineering.

The linearization procedure to be presented in the following is based on the expansion of nonlinear function into a Taylor series about the operating point and the retention of only the linear term. Because of neglecting higher-order terms of Taylor series expansion, these neglected terms must be small enough; that is, the variables deviate only slightly from the operating condition [2].

2.4 Servo Motors

Also called control motors and have high torque capabilities. Unlike large industrial motors, servomotors are not used for continuous energy conversion but only for precise speed and precise position control at high torques. Of course, their basic principle of operation is the same as that of other electromagnetic motors. However, their construction, design and mode of operation are different. Their power ratings vary from a fraction of a Watt up to a few 100 Watts. Due to their low inertia; servomotors have high speed of response. That is why servomotors are smaller in diameter but longer in length. Servomotors generally operate at very low speeds or sometimes zero speed.Servomotors find wide applications in radar, tracking and guidance systems, process controllers, computers and machine tools. Both DC and AC (2-phase and 3-phases) servomotors are used at present.

2.4.1 DC servomotors

These motors are either separately excited DC motors or permanent magnet DC motors. The schematic diagram of a separately-excited DC motor along with its armature and field MMFs shown in Figure (2.1)

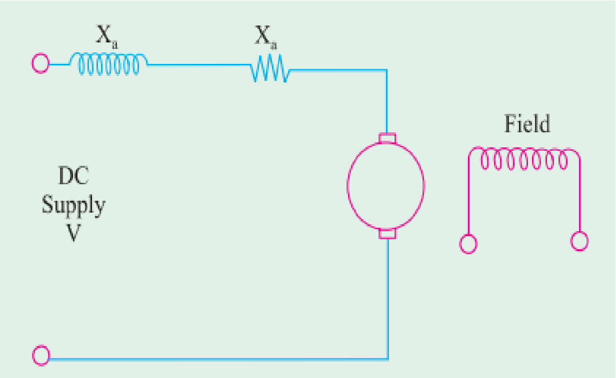


Figure (2.1): The schematic diagram of a separately-excited DC motor

The speed of DC servomotors is normally controlled by varying the armature voltage. Their armature is deliberately designed to have large resistance so that torque speed characteristics are linear and have a large negative slope , The torque/speed characteristics shown in Figure (2.2).

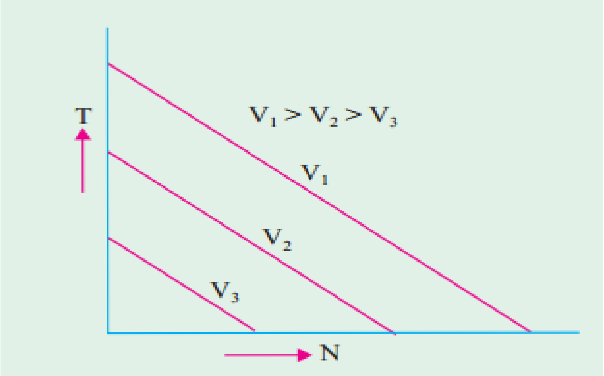


Figure (2.2): Torque/speed characteristics

The negative slope serves the purpose of providing the viscous damping for the servo drive system as shown in Figure (2.3) the armature MMF and excitation field MMF are in quadrature.

This fact provides a fast torque response because torque and flux become decoupled accordingly; a step change in the armature voltage or current produces a quick change in the position or speed of the rotor [3] .

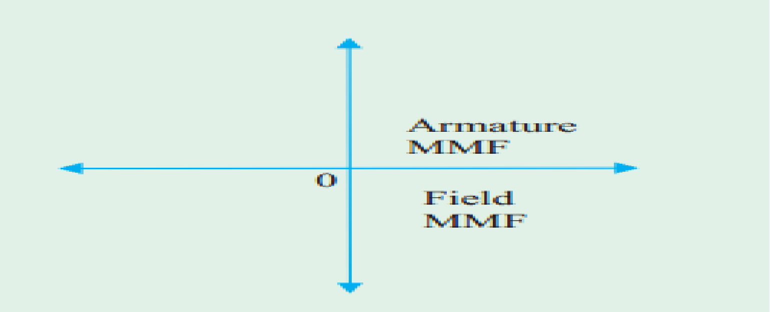


Figure (2.3): The armature MMF and excitation field MMF

2.4.2 Construction of DC servomotor

To fully understand how the servo works, it need to take a look under the hood. inside there is a pretty simple set-up: a small DC motor, potentiometer, and a control circuit. The motor is attached by gears to the control wheel. as the motor rotates, the potentiometer's resistance changes, so he control circuit can precisely regulate how much movement there is and in which direction .when the shaft of the motor is at the desired position , power supplied to the motor is stopped. if not ,the motor is turned in the appropriate direction .the desired position is sent via electrical pulses through the wire signal as shown in figure (2.4) the motor's speed is proportional to the difference between its actual position and desired position .

So if the motor is near the desired position ,it will return slowly ,otherwise it will turn fast , this is called proportional control .this means that the motor will only run as hard as necessary to accomplish the task at hand [4].

Figure (2.4): The Construction of DC servomotor

2.4.3 Servomotor control

Servos are controlled by sending an electrical pulse of variable width , or pulse width modulation (PWM), though the control wire. There is a minimum pulse, a maximum pulse and a repletion rate. A servomotor can usually only turn 90 degrees in either direction for a total of 180 degree movement. The motor’s neutral position is defined as the position where the servo has the same amount of potential rotation in the both the clock wise or counter –clockwise direction .the PWM sent to the motor determines position of the shaft, and based on the duration of the pulse sent via the control wire ;the rotor will turn the desired position .servo motor expects to see pulse every 20 milliseconds (ms)and he length of the pulse will determine how far the motor turns .for example ,a 1.5 ms pulse will make the motor turn to the 90-degree position .shorter than 1.5 ms moves it to 0 degrees ,and any longer than 1.5 ms will turn the servo to 180 degrees ,as shown in figure (2.5).

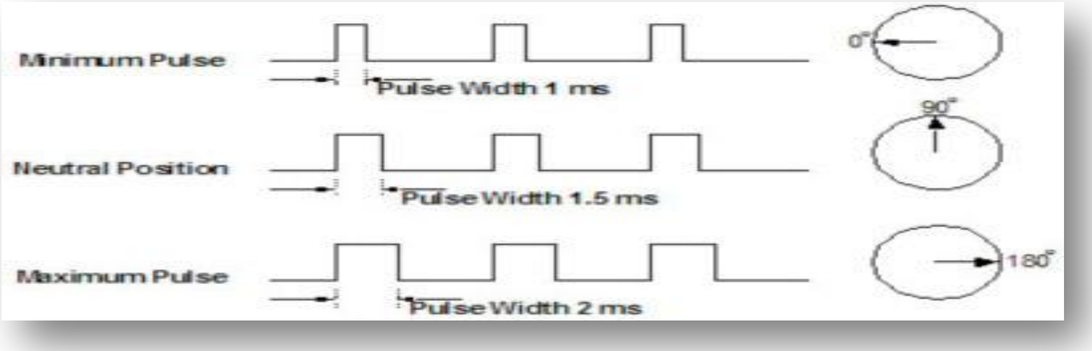


Figure (2.5): Variable Pulse width control servo position

When these servos are commanded to move,they will move to the position and hold that position .if an external force pushes against the servo while the servo is holding a position , the servo will resist from moving out of that position.The maximum amount of force the servo can exert is called the torque rating of the servo. Servos will not hold their position forever though; the position pulse must be repeated to instruct the servo to stay in position [5].

2.5 Proportional Integral Derivative Controller

A proportional integral derivative (PID) controller is a control loop feedback mechanism (controller) widely used in industrial control systems. A PID controller calculates an error value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process through use of a manipulated variable.

The PID controller algorithm involves three separate constant parameters as shown is Figure (2.6) and is accordingly sometimes called three-term control: the proportional, the integral and derivative values, denoted P, I, and D. Simply put, these values can be interpreted in terms of time: P depends on the present error, I on the accumulation of past errors, and D is a prediction of future errors, based on current rate of change. The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve, a damper, or the power supplied to a heating element , Table (2.1) show the effect of increasing a parameter independently.

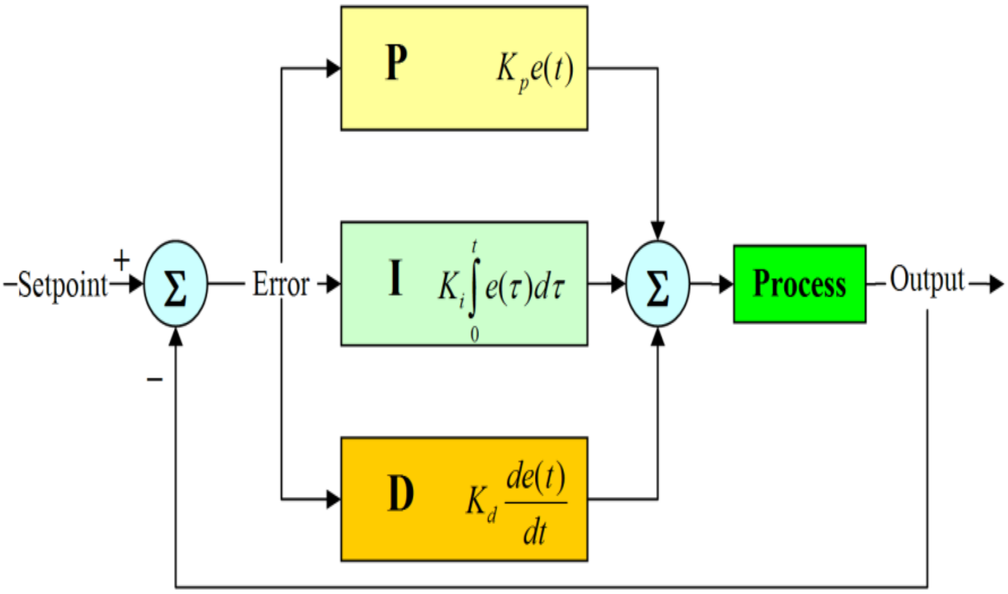


Figure (2.6): Proportional Integral Derivative (PID)

Table (2.1): Effects of increasing a parameter independently

Parameter	**Rise time**	**Overshoot**	**Settling time**	**Steady-state**
K_P	Decrease	Increase	Small change	Decrease
K_I	Decrease	Increase	Increase	Eliminate
K_D	No change	Decrease	Decrease	Small effect

2.5.1 Proportional controller

The Proportional term produces an output value that is proportional to the current error value. The proportional response can be adjusted by multiplying the error by a constant K_p , called the proportional gain constant.

The proportional term is given by:

$$P=K_p\,(e\,(t)) \tag{2.1}$$

A high proportional gain results in a large change in the output for a given change in the error. If the proportional gain is too high, the system can become unstable. In contrast, a small gain results in a small output response to a large input error, and a less responsive or less sensitive controller. If the proportional gain is too low, the control action may be too small when responding to system disturbances. Tuning theory and industrial practice indicate that the proportional term should contribute the bulk of the output change.

2.5.2 Proportional integral controller

The main function of the integral action is to make sure that the process output agrees with the set point in steady state. With Proportional control, there is normally a control error in steady state. With integral action, small positive error will always lead to an increasing signal , and a negative error will give a decreasing control signal no matter how small the error is.

$$PI= K_p\,(e\,(t)) +K_i\int\big(e(t)\big)dt \tag{2.2}$$

2.5.3 Proportional derivative controller

The purpose of the derivative action is to improve the close-loop stability. Because of the process dynamics, it will take some time before a change in the control variable is noticeable in the progress output. Thus, the control system will be late in correction for an error. The action of a controller with proportional and derivative may be interpreted as if the control is made proportional to the predicted process output, where the prediction is made by extrapolating the error by the tangent to the error curve.

$$PD = K_p\,(e\,(t)) + K_d\,(\frac{d(e(t))}{dt}) \qquad (2.3)$$

2.5.4 Proportional integral derivative controller

The Proportional Integral Derivative (PID) controller has three terms. The proportional term (P) corresponds to proportional control. The integral term (I) give a control action that is proportional to the time integral of the zero. The derivative term (D) is proportional to the time derivative of the control error. This term allows prediction of the future error. There are many variations of the PID algorithm that will substantially improve its performance and operability. Those variations are discussed in the next section [6].

$$PID\,(t) = K_p\,(e\,(t)) + K_i\int\big(e(t)\big)dt + K_d\,(\frac{d(e(t))}{dt}) \qquad (2.4)$$

By taking Laplace transform PID controller transfer function become:

$$C(s) = Kp + \frac{Ki}{s} + Kd * s \qquad (2.5)$$

2.5.5 Tuning of proportional integral derivative controller

The process of selecting the controller parameters to meet given performance specifications is known as controller tuning.

There are several methods for tuning a PID loop. The most effective methods generally involve the development of some form of process model, and then choosing P, I, and D based on the dynamic model parameters.

In particular, when the mathematical model of the plant is unknown and therefore analytical design methods cannot be used, PID controls prove to be most useful. In the field of process control systems , it is well known that the basic and modified PID control schemes have proved their usefulness in providing satisfactory control, although in many given situations they may not provide optimal control.

If a mathematical model of the plant can be derived, then it is possible to apply various design techniques for determining parameters of the controller that will meet the transient and steady-state specifications of the closed-loop system. However, if the plant is so complicated that its mathematical model cannot be easily obtained, then an analytical or computational approach to the design of a PID controller is not possible.Then we must resort to experimental approaches to the tuning of PID controllers[2]. There are many methods of PID tuning such as:

- Manual tuning.
- Ziegler-nichols.
- Tyreus luyben.
- Cohen-coon.
- Software tools.

2.6 Fuzzy logic

One of the most popular new technologies is ‘’ intelligent control ‘’ which is defined as a combination of control theory, operations research, and artificial intelligence (AI).judging by the billions of dollars’ worth of sales and thousands of patents issued worldwide, led by Japan since the a noun cement of the first fuzzy chips in 1987, fuzzy logics still perhaps the most popular area in AI.

To understand fuzzy logic it is important to discuss fuzzy sets .in 1965 ,Zadeh wrote a seminal paper in which he introduced fuzzy sets ,that is ,sets with un sharp boundaries .these sets are generally in better agreement with the human mind and reasoning that works with shades of gray ,rather than with just black or white .fuzzy sets are typically able to represent linguistic terms ,for examples ,warm ,hot, high ,low ,close ,far ,etc. Nearly 190 years later (in 1974) ,Japan ,united states ,Europe ,Asia ,and many other part of the world ,fuzzy control is widely accepted and applied .

Conventional set theory distinguishes between those elements that are members of a set and those are not, there being very, clear or crisp boundaries. In a fuzzy set we name all the elements of the universe and supplement to them a number between 0and 1.This number demonstrates to what degree this generic element belongs to the defined fuzzy set. Actually, according to this definition we just add to every element a number which constitutes the membership degree of this element. Actually, a fuzzy set is given by its membership function. The value of this function determines if the element belongs to the fuzzy set and in what degree [7].

2.6.1 Linguistic variables

To specify rules for the rule-base, the expert will use a "linguistic description"; hence, linguistic expressions are needed for the inputs and outputs and the characteristics of the inputs and outputs. "Linguistic variables" is used (constant symbolic descriptions of what are in general time-varying quantities)to describe fuzzy system inputs and outputs. For our fuzzy system, linguistic variables denoted by ~ui are use to describe the inputs ui .Similarly, linguistic variables denoted by~yi are used to describe outputs yi .For instance, an input to the fuzzy system may be described as ~u1 ="position error "or ~u2 ="velocity error", and an output from the fuzzy system may be ~y1 ="voltage in" [8].

2.6.2 Membership Functions:

The simplest membership functions are formed using straight lines. Of these, the simplest is the triangular membership function, and it has the function name trimf. It is nothing more thana collection of three points forminga triangle. The trapezoidal membership function, trapmf, has aflat top and really is just a truncated triangle curve as showninfigure (2.7).

These straight line membership functions have the advantage of simplicity.

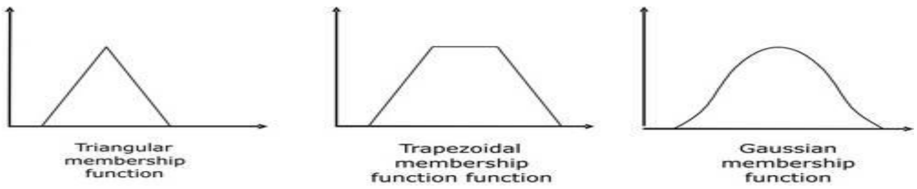


Figure (2.7): Membership function

2.6.3 Fuzzy Sets Operations

There are three types of fuzzy set operation:

- **Union**

The membership function of the Union of two fuzzy sets A and B with membership functions μA and μB respectively is defined as the maximum of the two individual membership functions .This is called the maximum criterion.The Union operation in Fuzzy set theory as shown is Figure (2.8)

$\mu AB=\max (\mu A, \mu B)$

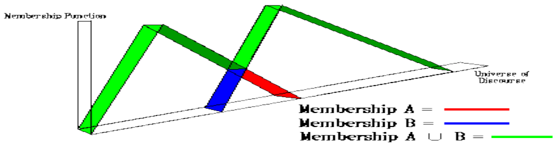


Figure (2.8):The Union operation in Fuzzy set theory

The union operation in Fuzzy set theory is the equivalent of the OR operation in Boolean algebra.

- **Intersection**

The membership function of the intersection of two fuzzy sets A and B with membership functions µ A and µ B respectively is defined as the minimum of the two individual membership functions. This is called the minimum criterion. The Intersection operation in Fuzzy set theoryas shown is Figure (2.9)

$$\mu\hat{A}B=\min(\mu A, \mu B)$$

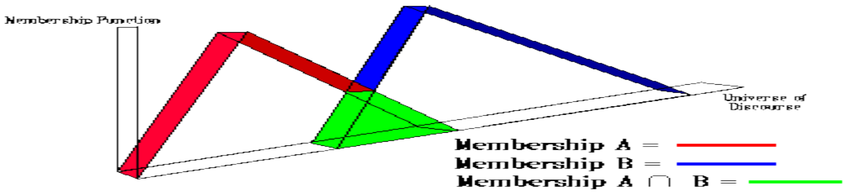


Figure (2.9): The Intersection operation in Fuzzy set theory

The intersection operation in Fuzzy set theory is the equivalent of the AND operation in Boolean algebra.

- **Complement**

The membership function of the complement of a fuzzy set with membership function µ A is defined as the negation of thespecified membership function.The complement operation in Fuzzy set theory as shown is Figure (2.10)

This is called the negation criterion.

$\mu\bar{A}=1-\mu A$

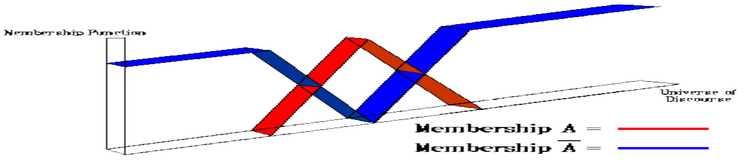


Figure (2.10):The complement operation in Fuzzy set theory

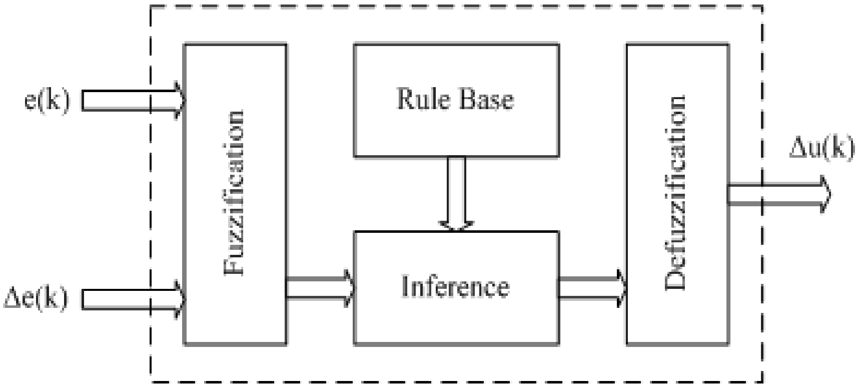
The complement operation in Fuzzy set theory is the equivalent of the NOT operation in Boolean algebra.

2.6.4 The Basics of Fuzzy logic

A fuzzy control is a controller that is intended to manage some vaguely known or vaguely described process.The controller can be used with the process in two modes:

i. Feedback mode when the fuzzy controller acts as a control device.
ii. Feed forward mode where the controller can be used as a prediction device.

Illustrates the basic components of fuzzy logic controller, as shown is Figure (2.11)



Figure(2.11): Fuzzy Logic Control System

The plant output are denoted by Δu(k), the input are denoted by e(k), and the reference input to the fuzzy controller is denoted by Δe(k).

The fuzzy controller has for main components:

- **Fuzzification**

The first block of the fuzzy controller is fuzzification, which converts each piece of input data to degrees of membership by a look up in one or several membership functions .The fuzzification block thus matches the input data with the conditions of the rules to determine how well the condition of each rule matches that particular input instance.There is a degree of membership for each linguistic term that applies to that input variable.

- **Inference mechanism**

Inference mechanism or engine is the processing program in a fuzzy control System. It derives a conclusion from the facts and rules contained in the knowledge base using various human expert techniques.

- **Rule-base**

A group of rules may use several variables both in the condition and the conclusion of the rules. They are based on a set of rules that a human expert would follow in diagnosing a problem.Rule-base also where the knowledge is stored.

- **Defuzzification**

Defuzzification is a process that maps a fuzzy set to a crisp set and has attracted far less attention than other processes involved in fuzzy systems and technologies.Four most common defuzzification methodsare:

- Maximum membership method.
- Center of gravity method.
- Weight average method.
- Mean –maximum membership method.

2.7 Satellite dish system

A position control system converts a position input command to a position output response. Position control systems find widespread applications in antennas robot arms, and computer disk drives.

The current design lacks any sort of compensator controller that would provide stability control. Norman S. Nise investigates the design of a control system for an antenna .The basic idea is that someone, from a control tower, can adjust a simple potentiometer by hand and ultimately move a large antenna. The antenna control system physical layout is shown in figure (2.12).

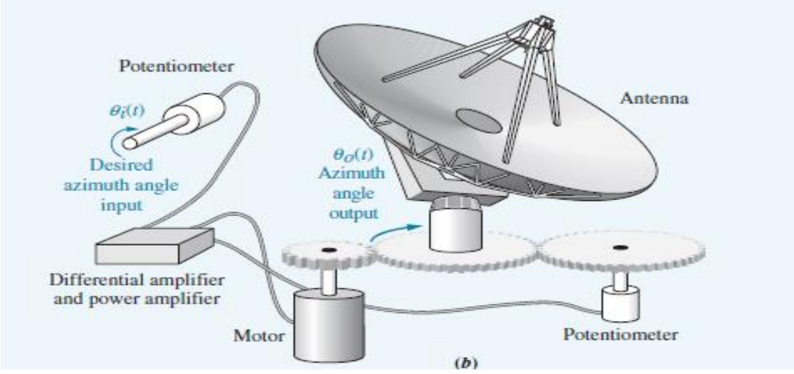


Figure (2.12): Layout of the Antenna Azimuth control system

A satellite dish is a dish-shaped type of parabolic antenna designed to receive electromagnetic signals from satellites , which transmit data transmissions or broadcasts, such as satellite television.

The basic satellite dish consists of the following materials: A parabolic reflector made of fiberglass or metal, usually aluminum, with a protruding steel feed horn and amplifier in its middle. A steel actuator that enables the dish to receive signals from more than one satellite.

When the signal reaches the viewer's house, it is captured by the satellite dish. A satellite dish is just a special kind of antenna designed to focus on a specific broadcast source. The standard dish consists of a parabolic (bowl-shaped) surface and a central feed horn. Figure (2.13) shows the axes of movement of a typical Elevation over Azimuth Tracking frequency [9].

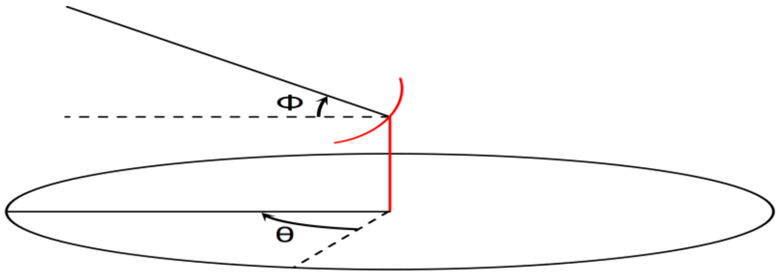


Figure (2.13): Axes of movement of a typical Elevation over Azimuth tracking frequency

2.8 Sensors

A sensor is a device that converts a physical phenomenon into an electrical signal. As such, sensors represent part of the interface between the physical world and the world of electrical devices, such as computers. The other part of this interface is represented by actuators, which convert electrical signals into physical phenomena.

In recent years, enormous capability for information processing has been developed within the electronics industry. In addition, the availability of inexpensive microprocessors is having a tremendous impact on the design of embedded computing products ranging from automobiles to microwave ovens to toys. In recent years, versions of these products that use microprocessors for control of functionality are becoming widely available. In automobiles, such capability is necessary to achieve compliance with pollution restrictions. In other cases, such capability simply offers an inexpensive performance advantage.

Microprocessors need electrical input voltages in order to receive instructions and information. So, along with the availability of inexpensive microprocessors has grown an opportunity for the use of sensors in a wide variety of products. In addition, since the output of the sensor is an electrical signal, sensors tend to be characterized in the same way as electronic devices. The data sheets for many sensors are formatted just like electronic product data sheets. However, there are many formats in existence, and there is nothing close to an international standard for sensor specifications.

The probe is mounted to monitor the position of the target. Changes in the output of the sensor indicate changes in position of the target. When using linear sensors, the output change of the sensor is multiplied by the sensitivity of the sensor to produce a dimensional value. Some sensing systems are available with integral displays that convert the sensor output and display the dimensional value [10].

2.9 Microcontrollers

It is a highly integrated chip that contains all the components comprising a controller. Typically this includes a CPU, RAM, ROM and I/O ports. Unlike a general-purpose computer, which also includes all of these components, a microcontroller is designed for a very specific task to control a particular system. As a result, the parts can be simplified and reduced, which cuts down on production cost.

2.9.1 History of microcontroller

The first computer system on a chip optimized for control applications was the Intel 8048 microcontroller with both RAM and ROM on the same chip. Most microcontrollers at that time had two variants; one had an erasable EEPROM program memory, which was significantly more expensive than the PROM variant which was only programmable once.

The introduction of EEPROM memory allowed microcontrollers (beginning with the Microchip PIC16x84) to be electrically erased quickly without an expensive package as required for EPROM. The same year, Atmel introduced the first microcontroller using Flash memory. Other companies rapidly followed suit, with both memory types. Nowadays microcontrollers are low cost and readily available for hobbyists, with large online communities around certain processors.

Microcontrollers have traditionally been programmed using the assembly language of the target device. Although the assembly language is fast.The microcontrollers manufactured by different firms have different assembly languages, so the user must learn a new language with every new microcontroller he or she uses.

Microcontrollers can also be programmed using a high-level language, such as BASIC, PASCAL, or C. High-level languages are much easier to learn than assembly languages and also facilitate the development of large and complex programs [11].

2.9.2 Microcontroller application

Microcontroller applications found in many life filed, for example in Cell phone, watch, recorder, calculators, mouse, keyboard, modem, fax card, sound card, battery charger, door lock, alarm clock, thermostat, air conditioner, TV Remotes, industrial equipment like Temperature and pressure controllers, counters and timers.

2.9.3 Arduino microcontroller

Arduino is a small microcontroller board with a USB plug to connect to your computer and a number of connection sockets that can be wired up to external electronics, such as motors, relays, light sensors, laser diodes, loudspeakers, microphones, etc. Arduino can either be powered through the USB connection from the computer or from a 9V battery. Arduino can be controlled from the computer or programmed by the computer and then disconnected and allowed to work independently Arduino microcontroller board is shown in figure (2.14) [12].

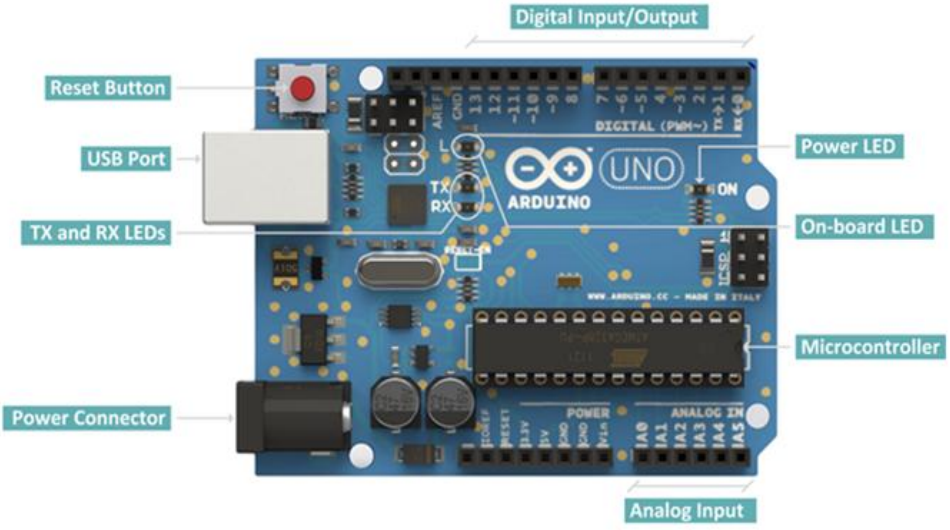


Figure (2.14): Arduino microcontroller board

2.9.4 The Arduino board

It is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating inter-active objects or environments in simple terms, the Arduino is a tiny computer system that can be programmed with your instructions to interact with various forms of input and output. The current Arduino board model, the Uno, is quite small in size compared to the average human hand, as shown in Figure (2.15).

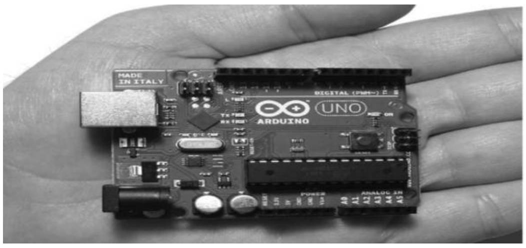


Figure (2.15): An Arduino Uno is quite small.

Although it might not look like much to the new observer, the Arduino system allows creating devices that can interact with the world. By using an almost unlimited range of input and output devices, sensors, indicators, displays, motors, and more, the exact interactions required to create a functional device can be programmed. For example, artists have created installations with patterns of blinking lights that respond to the movements of passers-by, high school students have built autonomous robots that can detect an open flame and extinguish it, and geographers have designed systems that monitor temperature and humidity and transmit this data back to their offices via text message. In fact, there are infinite numbers of examples with a quick search on the Internet.

By taking a quick tour of the Uno Starting at the left side of the board there are two connectors, as shown in Figure (2.16)

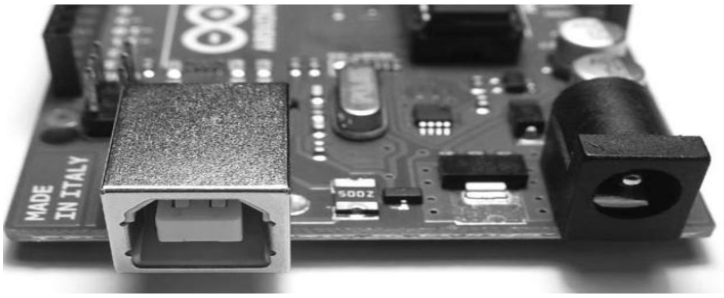


Figure (2.16): The USB and power connectors

On the far left is the Universal Serial Bus (USB) connector. This connects the board to your computer for three reasons; to supply power to the board, to upload the instructions to the Arduino, and to send data to and receive it from a computer. On the right is the power connector, this connector can power the Arduino with a standard mains power adapter.

At the lower middle is the heart of the board: the microcontroller, as Shown in Figure (2.17).

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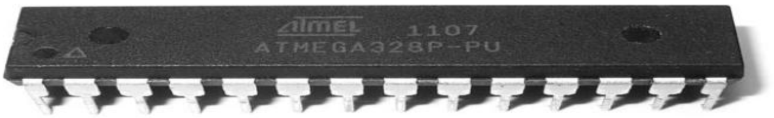

Figure (2.17): The microcontroller

The microcontrollers represent the “brains” of the Arduino. It is a tiny computer that contains a processor to execute instructions, includes various types of memory to hold data and instructions from our sketches, and provides various avenues of sending and receiving data. Just below the microcontroller are two rows of small sockets, as shown in Figure (2.18).

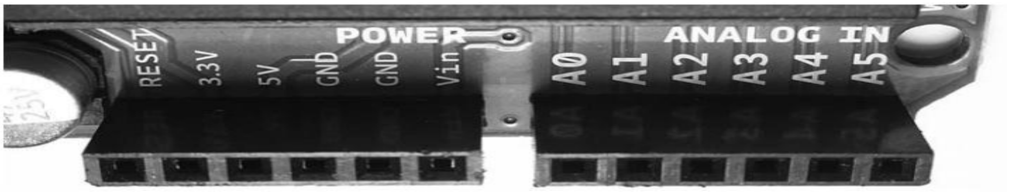

Figure (2.18): The power and analog sockets

The first row offers power connections and the ability to use an external RESET button. The second row offers six analog inputs that are used to measure electrical signals that vary in voltage. Furthermore, pins A4 and A5 can also be used for sending data to and receiving it from other devices. Along the top of the board are two more rows of sockets, as shown in Figure (2.19).

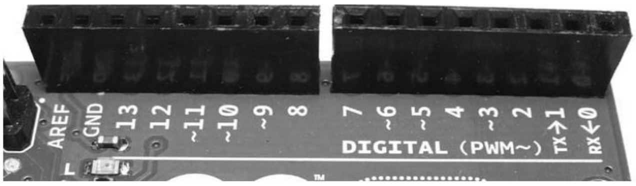

Figure (2.19): The digital input/output pins

Sockets (or pins) numbered 0 to 13 are digital input/output (I/O) pins. They can either detect whether or not an electrical signal is present or generate a signal on command. Pins 0 and 1 are also known as the serial port, which is used to send and receive data to other devices, such as a computer via the USB connector circuitry. The pins labeled with a tilde (~) can also generate a varying electrical signal, which can be useful for such things as creating lighting effects or controlling electric motors.

Next are some very useful devices called light-emitting diodes (LEDs); these very tiny devices light up when a current passes through them. The Arduino board has four LEDs: one on the far right labeled ON, which indicates when the board has power, and three in another group, as shown in Figure (2.20).

The LEDs labeled TX and RX light up when data is being transmitted or received between the Arduino and attached devices via the serial port and USB. The L-LED connected to the digital I/O pin number 13. The little black square part to the left of the LEDs is a tiny microcontroller that controls the USB interface that allows Arduino to send data to and receive it from a computer [13].

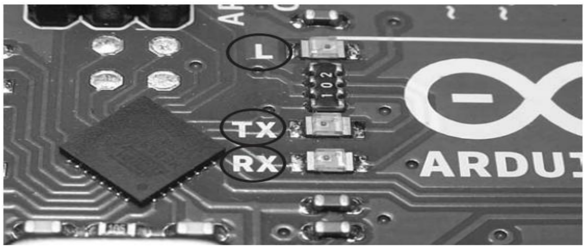

Figure (2.20): The onboard LEDs

And, finally, the RESET button is shown in Figure (2.21).

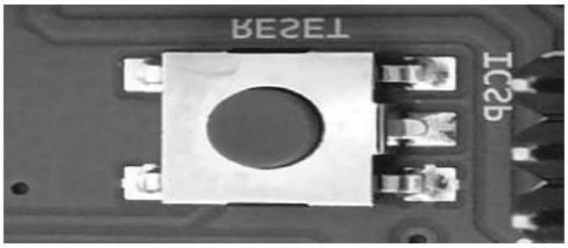

Figure (2.21): The RESET button