CHAPTER ONE

INTRODUCTION

1.1 Background

The word robot was first used by a Czechoslovakian dramatist, Karel Capek, "Rossum's Universal Robots”. The Merriam - Webster Dictionary defines robot as:

- A machine that looks and acts like a human being.
- An automatic apparatus.
- Something guided by automatic controls.

Robotic arm: is A serial-link manipulator comprises a set of bodies, called links, in a chain and connected by joints. Each joint has one degree of freedom, either translational (a sliding or prismatic joint) or rotational (a revolute joint). Motion of the joint changes the relative angle or position of its neighboring links.

1.2 Research Problem

Accidents can be occurred in chemical industries and laboratories ,due to the explosions of chemical reactions. Therefore, safety should have to be secured of these industries and laboratories.

dismantling bombs is very dangerous and cause death. So dismantling should have to be done by using extra tools to avoid risks.

1.3 Research Objectives

The main objectives for this project are

- Study and build hand simulator model to simulate the human hand by using Arduino Mega 328 (UNO).

- Integrate the hardware and software in order to simulate the functions of a human hand.

1.4 Research Methodology

Arduino type Mega328 is used as the primary controller. Besides, it is consist of various inputs and outputs circuits together with a hand simulator model. The Arduino Mega is used to coordinate the functions of various hardware circuitries. And various kinds of sensors were used as input. Servo motors types tower pro MG996 and servo motors tower pro MG995 were used as output.

1.5 Research outlines

This research consist of an abstract and five chapters, the first chapter gives a general introduction about the project and a simple literature review about the robotic arm since their beginnings until nowadays and demonstrates the method and the main purposes of the project. And then chapter two defines the project components, types and their working principles. Then the third chapter illustrates the control system in generally then covers hand simulator control system. After that the fourth chapter gives a brief definition for the components which used in this project then discuss the project circuits and their analysis. Rather to the control system block diagram and its parts function and flow chart. Finally the fifth chapter contains the conclusion and the recommendations.

CHAPTER TWO

Hand Simulator

2.1 Introduction

Existing Robotic Hands Recent improvements in robotics have been used to design new anthropomorphic robotic hands that are very similar to human hands; however, these are very expensive. One major separation between different designs is their drive system. A tendon-drive system uses pulleys to act like the tendons in the human hand, relocating the actuators to the forearm, where there is more space. This space can be used for more actuators or larger actuators, so the hand can be designed with more degrees of freedom or with more power. Some of the limitations of tendon driven hands are that each actuator can only pull, not push, forcing the hand to use either twice as many actuators as other drive methods, or elastics and springs to return the fingers to the straight position. The pulley systems also limit the force that can be applied in the hand because of friction in the system. Other drive systems, which use linkage and gears, have become more popular recently because recent advancements have miniaturized both the actuators and the sensors that are placed in the hands. This combined with under actuation to reduce the total number of actuators necessary has enabled the design of increasingly complex and self-contained robotic hands such as the Sandia Hand. The Sandia Hand is a modular robotic hand in which each of the fingers is entirely self contained, and removable. Their magnetic attachment allows them to fall off if they hit an object with too much force. The hand was designed to allow for adaptation to many situations without redesigning the entire hand. The modular design helped Sandia Labs accomplish this goal because the palm can be changed to a different shape, or even to hold more fingers, without redesigning the finger attachments at all. This design was made possible by the miniature electric motors that can fit inside the fingers, and it has sufficiently precise control to replace a battery in a flashlight. Sandia eventually wants to control the hand autonomously, but currently it is controlled using a glove that is covered with sensors. The top of the line tendon-driven robotic hand is the Shadow Hand. This design uses air powered muscles, developed by the Shadow Robot Company, to pull on the tendons that run through their hand. In their design, two tendons control each joint, or 40 muscles control 20 degrees of freedom. This hand was designed to be integrated into other robotic systems, but can also be controlled with a sensor glove in the same way as the Sandia Hand.

Each actuator in this hand is connected to a rotating drum, with pulleys attached to opposite sides of the drum. As the drum rotates, one pulley is tightened while the other is loosened, allowing a single actuator to control both tendons that are necessary to control the joint. Also, each finger in this hand is under actuated, so a single actuator controls each finger. The fingers comprise four specially manufactured parts, and each of the four fingers is constructed the same way. This reduces the cost because it minimizes the use of special manufacturing.

Other hand designs use one more actuator than the number of degrees of freedom. In this case, all bending is controlled independently for each degree of freedom, while the entire finger is straightened by a single actuator. This uses one extra actuator for each finger or one extra actuator for the entire hand if all fingers are straightened at the same time.

Another variation in hand designs is the choice between copying the structure or the functionality of a human hand. All of the above designs focus on the function of the hand, changing the internal workings to fit their needs. Neurotic’s Labs is attempting to design a robotic hand that simulates a human hand both in dexterity and structure. By imitating the human skeletal structure, they hope to both advance prosthetic and robotic hands, and gain information about biomechanics and the nervous system in hands. The lab wants the hand to simulate a human hand well enough to copy any hand movements, and take input from human neural signals. During their research, they found that the human brain uses groups of muscle movements to simplify the task (neurotics Labs). This information shows that a hand can be designed without all of the complex structures of a human hand, while still accomplishing all of the possible grasps. For example, leaving out one of the five degrees of freedom in the thumb does not restrict the hand in any way.

2.2 Robotic hand control system design

As this project depends on the 3D printing principle it was designed from scratch by making a simple constructor of plastic model. The design implements five degrees of freedom each one for one finger on the human hand itself, beside that there are three degrees of freedom for each finger which are related for the knuckles of those finger.

The mechanism of moving the finger is related to a single servo motor, on the top of this servo motor there is a specific pulley attached to its chain and used to obtain the designated linear movement of the finger from the circular movement of the servo itself. Two fibers are attached to this pulley each one against the other. The ends of these fibers are attached to the far end of the finger, one fiber is attached on the top side of finger and its responsible for pulling the finger up to the hand, the other fiber is attached on the back side of the finger which is responsible of pulling the finger back to its normal position.

Therefore, when the servo pulley turn on one direction it pulls the fiber that is responsible from pulling the finger up to the hand bed. To return the finger to its normal position the pulley must turn on the opposite direction so to pull the other fiber and let the first fiber down so that would pull the finger back to its normal position. That mechanism was repeated to all of the other fingers.

The fiber is a special flexible plastic fiber used to translate and transfer the movement of the servo motor to the finger, by connecting it to the motor pulley the circular movement of it will be translated into a linear one, and that is used to move the finger up and down. It was chosen among many other types of fibers because of its tension force limit and that is approximately about 25Kg/cm.

Special type of pulleys was designed by using a 3D printer, the advantage of it is to control the movement direction of the fibers for each motor, and that would make the tension force on it so concentrated. It is a normal pulley with a radius of about 23mm. a path along of its circumference was made for the fiber to be set on it.

The design of the 3D printer was constructed in pieces, which are fabricated together using many different materials, for example, the pieces of any finger were attached using pieces of small cylindrical iron and then stacked by hot glue. The glue was used among other materials to join the most parts of the hand.

2.2 Hand Simulator Control System Applications:

There are many applications for hand simulator, but the main applications of it which obtained are bomb dismantling, reduce the risk of chemical hazards and nuclear risk, and Use it in dangerous industry fields, use it to find missing persons who’s lost in natural disasters.

Automatic picking of small objects (bottles, bags, tumblers etc) moving on a conveyor and placing at other desired location in industries manufacturing various types of cosmetics, food products, medicines etc.

Automatic metal cutting machines in particular desire profiles, which are located in high temperature zones. iv. Advanced robotic toys, operated with state-of-art hand operated control systems.

Robots controlled cranes, lifting forks etc operated from a distance with fingers/hands controlled remote system. Other possible applications include adapting the hand for any situations in which tasks must be completed in inaccessible areas, for example, sterile lab experiments, projects in outer space, or work in extreme heat or cold could be aided by this hand.

the clumsy robot placed the bomb squad in great danger when it forced the explosives expert to manually disarm a grenade that had been crushed by a robot. Because of the typical design of grippers, the robot had to be positioned carefully to allow for a steady grasp. In this case, the grasp was not steady, leading to the robot dropping the device. The gripper design also made it difficult to retrieve the explosive after it had fallen. More complex grippers which have the ability to adapt their grasp to different objects can increase the stability of the grasp as well as make grasping objects faster and more reliable. In the situation in San Francisco, the bomb disposal robot was used in combination with a human bomb expert. In most cases where a bomb is disarmed without being detonated, a person must perform the task of actually disarming the device. In some cases, this can be done after the threat has been identified by a robot, so the expert can plan how to disarm the device before getting close to the bomb. In other cases, such as where there are trip wires, zipped bags or other obstacles that prevent the robot from accessing the device, the bomb expert must approach the device without knowing what dangers await, then assess the situation and disarm the explosive. In either case, the bomb expert must actually touch the bomb; any mistakes, bad decisions, or bad timing could potentially kill the bomb expert. Currently, some specialized bomb disposal robots can eliminate this danger by disarming specific types of bombs. For instance, the SAPBER robot has a device that can remove the end cap from pipe bombs and allow bomb experts to examine the inner materials. This device, however, is very specialized to handle pipe bombs, and would be useless if the explosive was not a pipe bomb, or was made differently than traditional pipe bombs. The challenge remains to make an effective bomb disposal robot that can disarm bombs with the same capability and adaptability as a human bomb expert.

The wiry bomb Disposal Robot uses a control application, at the user end to control the robot by measuring the change of resistance of the linear slide potentiometer which combined (sew with needle) with gloves and convert it to voltage (vary according to change of potentiometer’s resistance), which input to the arduino type Mega 328 .The Arduino Mega was programmed to read the voltage from analog inputs. Because the voltage was read between the resistor and the bend sensor(we use linear slide potentiometer), the reading would change as the bend sensor was bent, changing the resistance from the sensor. Using the max and min values for each sensor reading, the readings were converted to percentages. The servo settings for maximum and minimum bend for the corresponding joint were also measured and converted to percentages. Then, a program was written to set the servo percentage to the same percentage as the bend sensor, making the hand bend its joint to the same position as the bend sensor is bent to. The bomb technician controls the robot using this application. We have designed it as an assistant robot to the bomb disposal squad but there are a number of other applications of this robot. It can be used by police (In hostage situations), Military (For reconnaissance missions), Fire(To provide video feedback of the site for analysis), Nuclear(For handling hazardous or radioactive materials).

All employers and self-employed people have duties under health and safety law to assess risks in the workplace. The risk assessment forms the basis of the Safety Statement that is required for all workplaces. The Safety, Health and Welfare at Work (Chemical Agents) Regulations, 2001 specifically obliges employers and self-employed persons to assess the risks arising from the use or presence of chemical agents in the workplace. This leaflet is intended to help employers in assessing the risks that relate to chemical agents in the workplace and in determining adequate precautions or control measures to safeguard health and safety.

A risk assessment is simply a careful examination of whatever, in your work or workplace, could cause harm to people, so that you can determine what precautions or controls are necessary to prevent harm. The intention is to prevent accidents or work related ill-health in the workplace. The Control Measures, that are determined to be necessary to adequately safeguard against accidents or ill-health must be specified in writing. This is the outcome of the risk assessment and it is your duty to ensure that it is fully implemented. In specifying the control measures, the risk assessment provides the practical and detailed roadmap to help you manage health and safety in your workplace. Hazardous chemical agents include:

- Substances brought into the workplace and handled, stored and used for processing (e.g. raw materials, solvents, cleaning agents, glues, resins, paints).
- Substances generated by a process or work activity (e.g. fumes from welding/soldering, dust from machining of wood, solvent vapors from painting, dust from quarrying).
- Substances or mixtures produced by the work process including by-products, residues or waste.

  Chemical agents can be considered hazardous not only because of what they contain, i.e. as a constituent or chemical ingredient, but because of the form or way in which they are used at the workplace e.g. hot water used as steam can cause very severe burns and control measures need to be specified to prevent harm.

Thousands of people are exposed to hazardous chemical agents at work. If the exposure is not prevented or properly controlled, it can cause serious illness, sometimes even death. The effects of hazardous chemicals may be immediate or long-term and range from mild eye irritation to chronic lung disease. Skin burns or irritation caused by contact with a corrosive liquid. Being overcome or losing consciousness following inhalation of toxic fumes. Suffering acute symptoms is headache or nausea within hours of inhalation. Poisoning by absorption is through the skin of a toxic substance. Asthma, Dermatitis, Cancer occurring years after exposure to a carcinogenic substance, Genetic damage to offspring occurring years after exposure to a mutagenic substance.

Assess the risks from hazardous chemical agents at your workplace.

Decide what control measures are needed. These control measures must be identified and specified in writing as a record of the risk assessment.

Ensure that the control measures are fully implemented.

You need to find out what is established good custom and practice in your industry for managing these risks and check that you meet this standard.

Advice on good work practices and standards used by, or recommended for your industry may be available from trade associations or from other employers in the same business, from plant/equipment suppliers, from industry specialists and from published authoritative guidance.

If your workplace process is unique and authoritative guidance on good health and safety practice is not available, you will need to formulate a regime of Control Measures that will reliably prevent any adverse health effects. The regime may draw on the following hierarchy of measures, in order of preference:

Elimination: change the process or activity so that the hazardous substance is not used or is not generated.

Substitution: replace it with a safer alternative.

Isolation: separate the hazardous substances from workers.

Engineering controls: use physical measures to minimize workplace contamination, e.g. extraction at source by LEV (local exhaust ventilation);

Administrative controls: use of safe work practices and procedures to minimize contamination, e.g. good hygiene procedures.

Personal Protective Equipment (PPE): provide facemasks, gloves, protective clothing, etc., but only as a last resort or “belt and braces” measure.

The Control Measures themselves must also be checked and maintained at regular intervals. For example, local exhaust ventilation equipment should be examined at suitable intervals against its specification to ensure its continued effectiveness. Sometimes it is necessary to monitor worker exposure at regular intervals to ensure exposure limits are not exceeded. Health surveillance may also be required in certain circumstances. All these measures must be fully specified in writing.

Plans and procedures to deal with accidents and emergencies are considered to be Control Measures. These and other operating procedures may be referenced, rather than included, in the record of the risk assessment.

Recording the risk assessment:

The key outcome of the risk assessment is the specification of adequate control measures. The law requires that the control measures are identified in writing (paper or electronic format). All control measures that are important in safeguarding against adverse health effects should be specified, but you can organize them into whatever order suits your business.

The control measures must be described in sufficient detail so that they are fully specified. For example, “Wear Suitable Respiratory Protection” is not satisfactory. The full type specification of the respiratory protection should be provided in this instance. Similarly, “Use Local Exhaust Ventilation” is insufficient if proper control involves careful specification of the extraction required and necessitates regular testing.

In many cases, you and your employees have the best knowledge and understanding of your work processes and are best placed to carry out the risk assessment. If specification of the control measures is not straightforward, or if complex risks have to be assessed, you may need to engage competent specialist expertise to assist in the task.

CHAPTER THREE

Control System

3.1 Introduction:

Automatic control has played a vital role in the advance of engineering and science. In addition to its extreme importance 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.

Since advances in the theory and practice of automatic control provide the means for attaining optimal performance of dynamic systems, improving productivity, relieving the drudgery of many routine repetitive manual operations, and more, most engineers and scientists must now have a good understanding of this field.

3.2 Closed-Loop Control versus Open-Loop Control

A system that maintains a prescribed relationship between the output and the reference input by comparing them and using the difference as a means of control is called a feedback control system. An example would be a room temperature control system. By measuring the actual room temperature and comparing it with the reference temperature (desired temperature), the thermostat turns the heating or cooling equipment on or off in such a way as to ensure that the room temperature remains at a comfortable level regardless of outside conditions.

Feedback control systems are not limited to engineering but can be found in various non engineering fields as well. The human body, for instance, is a highly advanced feedback control system. Both body temperature and blood pressure are kept constant by means of physiological feedback. In fact, feedback performs a vital function: It makes the human body relatively insensitive to external disturbances, thus enabling it to function properly in a changing environment.

Feedback control systems are often referred to as closed-loop control systems. In practice, the terms feedback control and closed-loop control are used interchangeably. 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 fed back 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. There are many applications use the concept of open loop and closed loop control like microcontrollers.

3.3 Microcontroller

Microprocessor is a CPU (Central Processing Unit) that is compacted into a single chip semiconductor device. It is a general-purpose device, suitable to perform many kinds of applications. When the microprocessor is combined with input or output and memory devices, it is called microcomputer.

The choice of these devices that are combined depends on the specific application. For example, most personal computers contain a keyboard and monitor as standard input and output devices.

The major difference of a microcontroller compared to a microprocessor and microcomputer is that microcontroller consists of central processing unit (CPU), memory devices ROM (Read Only Memory) and RAM (Random Access Memory), input and output ports and timer embedded into a single chip . They also have many on-chip facilities such as serial port, counters, analog to digital converter and interrupt control so that they can be interfaced with hardware and control functions of many kinds of application. It is ideal for many applications in which cost and space are critical.

Microcontroller has a wide range of applications in many control-oriented activities. For example, they are used as engine controllers in automobiles and as exposure and focus controllers in cameras as well as they are used in a elevator control system.

aerent between the microprocessor and microcontroller shown in figure 3.2.

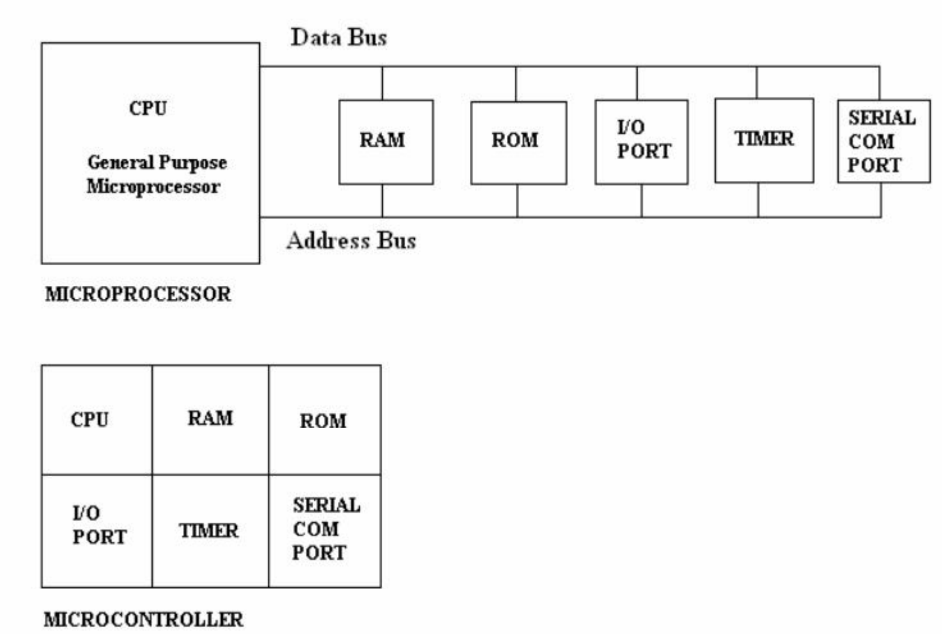


Figure 3.1: The difference between microprocessor and microcontroller

- **The Harvard architecture**

The Harvard architecture is a computer architecture with physically separate storage and signal pathways for instruction and data. The term originated from the Harvard mark I relay-based computer, which stored instruction on punched tape (24 bite wide) and data in electro-mechanical counters.These early machines had data storage entirely contained within the central processing unit and provided no access to the instruction storage as data. Programs needed to be loaded by an operator, the processor could not initialize itself.

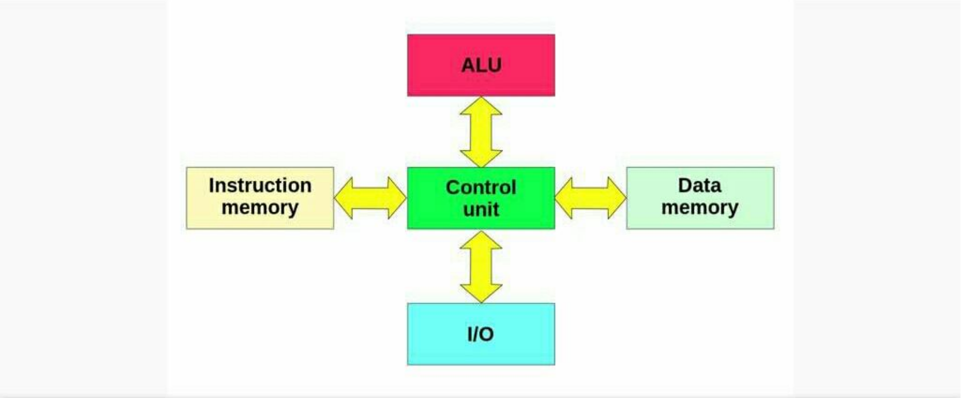


Figure 3.2: The Harvard architecture

- **The Von Neuman architecture**

The Von Neuman architecture is a design model for stored-program digital computer that uses central processing unit (cpu) and asingle separate storage structure (memory) to hold both instruction and data.

Memory

Control unit

Arithmetic logic unit

Input / out put interface

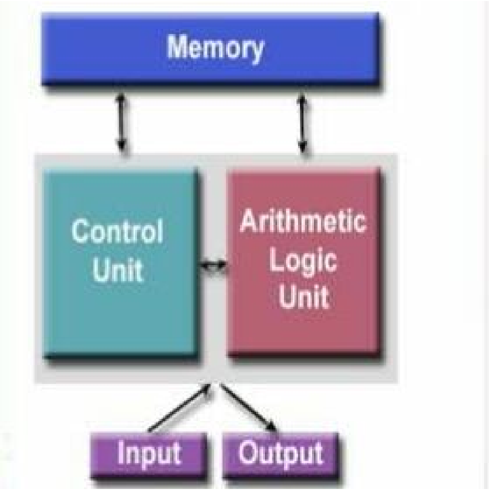


Figure 3.3: The Von Neuman architecture

3.4 Arduino:

Arduino is open-source computer hardware and software Company (that it means philosophy fosters a community that shares its knowledge generously. This is great for beginners as help is often available geographically nearby and always online, at many different skill levels, and on a bewildering array of topics. Example projects are presented not just as pictures of the finished project, but include instructions for making your own or as a starting point for incorporation into your derivative or related projects) project and user community that designs and manufactures microcontroller-based kits for building digital devices and interactive objects that can sense and control the physical world.

The project is based on a family of microcontroller board designs manufactured primarily by Smart Projects in Italy, and also by several other vendors, using various 8-bit Atmel AVR microcontrollers or 32-bit Atmel ARM processors. These systems provide sets of digital and analog I/O pins that can be interfaced to various expansion boards ("shields") and other circuits. The boards feature serial communications interfaces, including USB on some models, for loading programs from personal computers. The Arduino software, known as the Integrated Development Environment (IDE), is free.

For programming the microcontrollers, the Arduino platform provides an IDE (Integrated Development Environment) based on the Processing project, which includes support for C, C++ and Java programming languages.

The first Arduino was introduced in 2005, aiming to provide an inexpensive and easy way for novices and professionals to create devices that interact with their environment using sensors and actuators. Common examples of such devices intended for beginner hobbyists include simple robots, thermostats, and motion detectors.

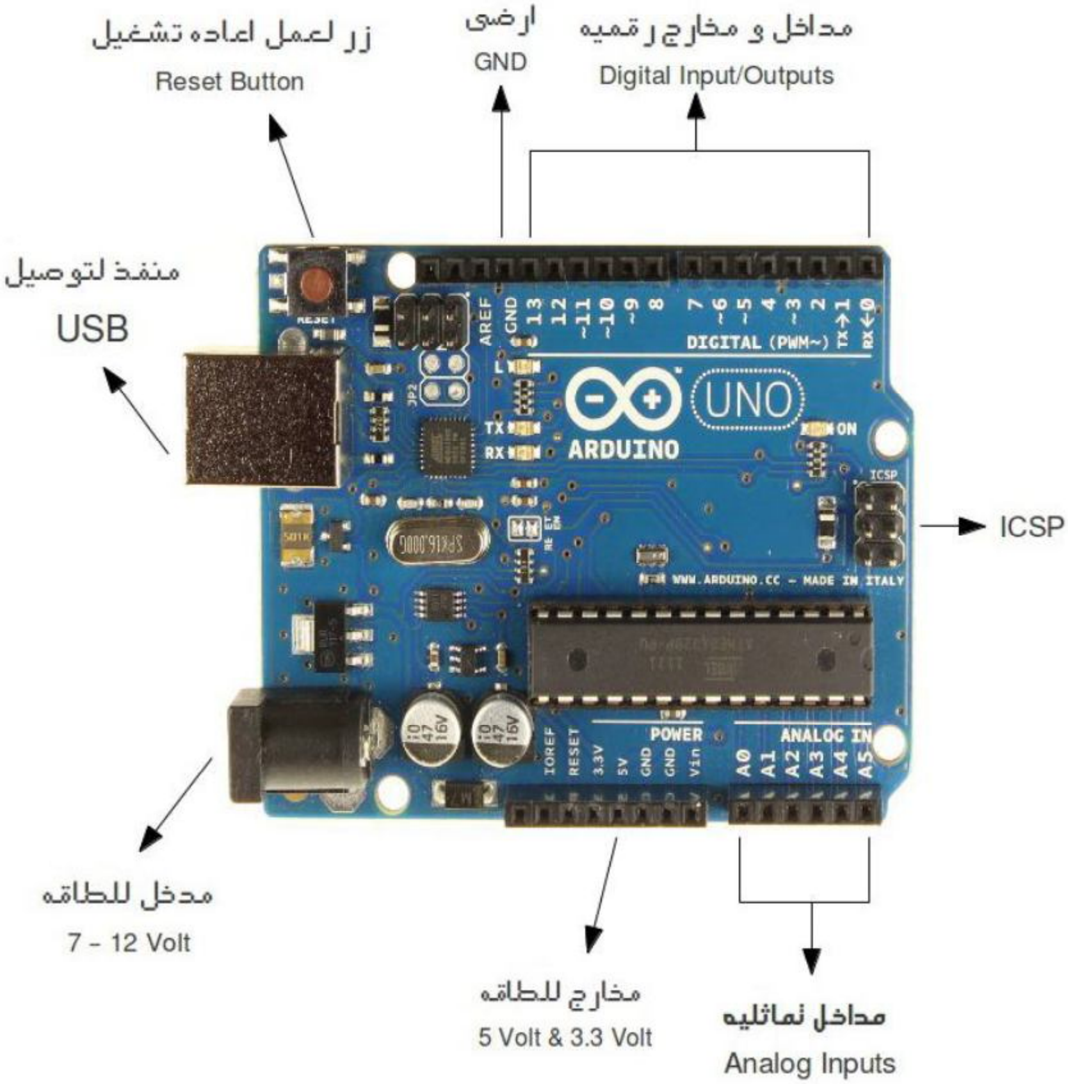


Figure 3.4: Arduino Mega 328 (UNO)

CHAPTER FOUR
APPLICATION

4.1 Introduction:

Several anthropomorphic robotic hand projects have used data gloves as the basis for their control system because the gloves allow the robotic hand to mimic the movements of a human. This is very useful for applications in which a robotic hand performs an action in an environment that is hostile to humans. This includes outer space, certain research settings, and bomb disposal settings. One of the most advanced, commercially available data gloves, the Cyber Glove, has been used to test patterns in human hand movement that can be used to program robotic hands to perform tasks autonomously. The main feature of these data gloves are bend sensors. These sensors change resistance when they are flexed, giving an output that can be interpreted by a computer. In order for a computer to read the sensor, a resistor must be placed between the input voltage and the sensor, and then the sensor must be connected to ground. By reading the voltage between the resistor and the sensor, a computer can calculate the bend of the sensor. Each resistor is responsible for a percentage of the voltage drop, from the input voltage to zero, but the percentages change as the sensor bends, so by knowing the total voltage drop and the voltage drop after the first resistor, the computer can calculate the percentage of voltage dropped across the second sensor. Once this percentage is tested for both straight and bent, the computer can calculate the angle at which a joint is bent. This supplies the data required for a computer to set a servo to the same angle as the joint and command a robotic hand to position its hand in the same way as a the glove.

4.2 System Components:

The main components were used to build the hand model are:

1. Gloves.
2. Arduino Mega 328 (UNO).
3. Slide Linear Potentiometer.
4. Servo Motor type Tower Pro MG996&MG995.

These components will be defined briefly, and then its connection with each other will be cleared.

4.2.1Gloves

A data glove was constructed using a knit glove and five flex sensors (five linear slide potentiometers to act as a flex sensor were used). Elastic fabric was sewn in loops around the first and second joints of the five fingers. A larger loop of the elastic fabric was sewn around the palm above the thumb, and another piece was sewn into that loop to loop below the thumb. On the top of each of these loops, pieces of plastic (cut from Avery plastic dividers) were sewn onto the loops. For each place where the end of the sensor had to pass through that part of the finger, a second piece of plastic was attached above the sewn in one with double sided tape to create a slider. The end of the sensors with the plug was connected to the attachment point of the sensor closer to the palm, and the other end was passed through a slider which held the sensor close to the glove but allowed the sensor to slide past the joint. To sense the hinge joint of the thumb, a sensor was attached across the top of the two sensors for the knuckle joints, and the other end was connected to sense the rotation of the index finger, two plug ends of sensors were attached to a piece of the Avery plastic. One of the sensor ends was sewn to the side of the index finger closer to the thumb and the other was sewn to the outside side of the thumb.

The glove is shown in figure 4.1 below.

Figure 4.1 : Glove construction

4.2.2 Arduino Mega 328 (UNO):

The Arduino/Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM(Pulse Width Modulation) outputs), 6 analog inputs, 2 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB (Universal Serial Bus) cable or power it with a AC-to-DC adapter or battery to get started. The Mega328 board is compatible with most shields designed for Arduino/Genuino Uno and the former boards Duemilanove or Diecimila.

Arduino is composed of two major parts: the Arduino board,which is the piece of hardware you work on when you build yourobjects; and the Arduino Integrated Development Environment,or IDE, the piece of software you run on your computer. You use the IDE to create a sketch (a little computer program) that you upload to the Arduino board. The sketch tells the board what to do.Not too long ago, working on hardware meant building circuitsfrom scratch, using hundreds of different components with strange names like resistor, capacitor, inductor, transistor, and so on. Every circuit was wired to do one specific application, and making changes required you to cut wires, solder connections, and more. With the appearance of digital technologies and microprocessors, these functions, which were once implemented with wires, were replaced by software. Software is easier to modify than hardware. With a few key presses, you can radically change the logic of a device and try two or three versions in the same amount of time that it would take you to solder a couple of resistors.

The Arduino board is a small microcontroller board, which is a small circuit (the board) that contains a whole computer on a small chip (themicrocontroller).This computer is at least a thousand times less powerful than the MacBook I’m using to write this, but it’s a lot cheaper and very useful for building interesting devices.

Massimo Look at the Arduino Uno board: you’ll see a rectangular black piece of plastic with 28 “legs” (or possibly a tiny square piece of plastic if you have the SMD edition)—that chip is the ATmega328, the heart of your board.We (the Arduino team) have placed on this board all the components that are required for this microcontroller to work properly and to communicate with your computer. There are many versions of this board; the one we’ll use throughout this book is the Arduino Uno, which is the simplest one to use and the best one for learning on. Almost everything we’ll talk about applies to all Arduinos, including the most recent ones as well as the earlier ones.

Figure 3-1 shows the Arduino Uno. In Figure 3-1, you see that the Arduino has a row of strips at the top and the bottom with lots of labels. These strips are the connectors, which are used to attach to sensors and actuators. (An actuator is the opposite of a sensor: a sensor senses something in the physical world and converts it to a signal a computer can understand, while an actuator converts a signal from a computer into an act in the physical world. You'll learn much more about sensors and actuators in this book.) At first, all those connectors might be a little confusing. Here is an explanation of the input and output pins you'll learn to use in this book. Don't worry if you're still confused after reading this— there are many new concepts in this book that might take you a while to get used to. We'll repeat these explanations a number of 16 Getting Started with Arduino In fact, there are a variety of Arduino boards, but the most common one by far is the Arduino Uno, which is described here. In Chapter 6 you'll learn about one of the other Arduino boards. different ways, and they'll especially start making sense to you once you start building circuits and experiencing the results.14 Digital I/O pins (pins 0–13) These pins can be either inputs or outputs. Inputs are used to read information from sensors, while outputs are used to control actuators. You will specify the direction (in or out) in the sketch you create in the IDE. Digital inputs can only read one of two values, and digital outputs can only output one of two values (HIGH and LOW). 6 Analogue In pins (pins 0–5) The analogue input pins are used for reading voltage measurements from analogue sensors. In contrast to digital inputs, which can distinguish between only two different levels (HIGH and LOW), analogue inputs can measure 1,024 different levels of voltage. 6 Analogue Out pins (pins 3, 5, 6, 9, 10, and 11) These are actually six of the digital pins that can perform a third function: they can provide analogue output. As with thedigital I/O pins, you specify what the pin should do in yoursketch.The board can be powered from your computer's USB port, most USB chargers, or an AC adapter (9 volts recommended, 2.1 mm barrel tip, center positive). Whenever power is provided at the power socket, Arduino will use that, and if there is no power at the power socket, Arduino will use power from the USB socket. It's safe to have power at both the power socket and the USB socket.

Controlling Servos with a Potentiometer or Sensor connected to the servos. It is almost the same code with the addition of code to read the voltage on a potentiometer. This value is scaled so that the position of the pot (from 0 to 1023) is mapped to a value between 0 and 180 degrees. The only difference in the wiring is the addition of the potentiometer; please see figure below for hardware connection

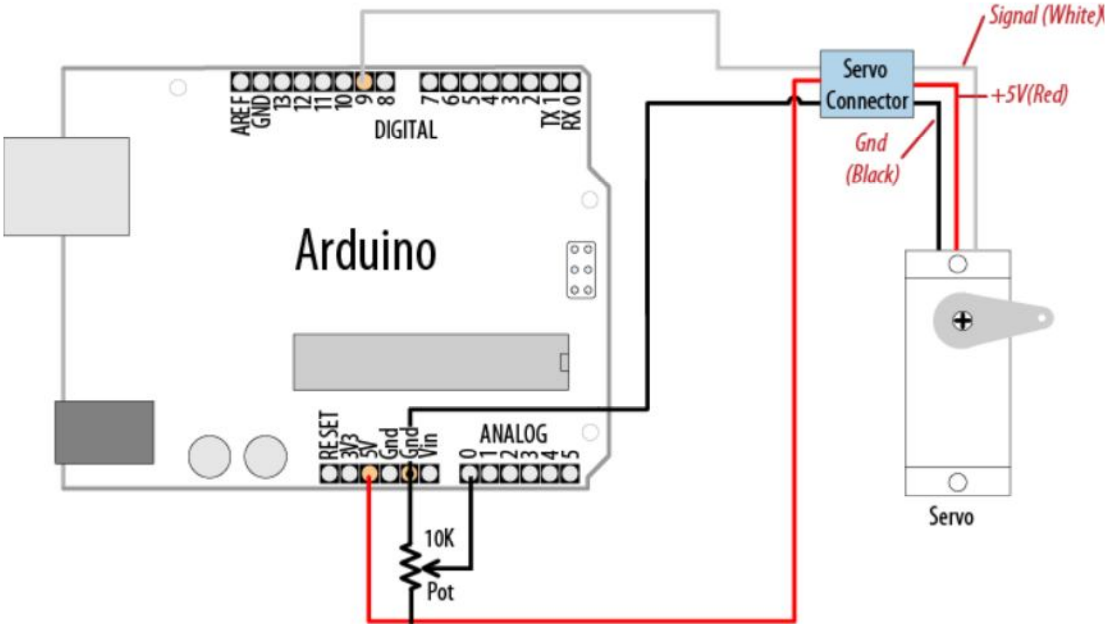


Figure 4.2: Controlling Servos with a Potentiometer or Sensor

Table 4.1: Arduino Mega 328 technical specifications

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	29 KB
Flash Memory for Boot loader	0.5 KB
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz
Length	68.52 mm
Width	53.3 mm
Weight	30

4.2.3 Slide Linear Potentiometer

It relays on the principle of changing the resistance depending on the position of the slider. The slider is the outside part of it; internally there is a metal piece that is attached to a carbon path along the length of the potentiometer, when changing the position of the slider it would change the value of the resistance. (The overall value of the potentiometer used here is 10K Ohm)

To work properly with the Arduino UNO it must be connected to the analog terminal of it because it is rapidly changing its value depending on the slider position. Generally Arduino figures the change in potentiometer resistance value as a change in voltage and that is between 0 and 5 volts, the Arduino would scale it in between 0 and 1023. For example, a resistance of about 5K Ohm would appear to Arduino as 2.5 volts, which is 512.

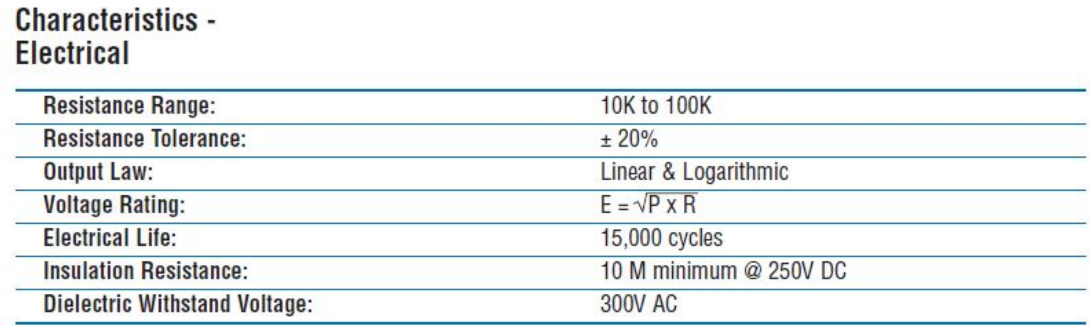
Slide linear potentiometer comes with two-sided resistance for more reliability (each side against the other). So when one side of it is malfunctioned the other side is available to work with, each side of them has three terminals one for the input which is (+5Volts) another for the ground and the last one is output which carries the signal to Arduino analog terminals.

4.2.4 Signal flow Potentiometer

It begins with the side linear potentiometer; Arduino reads the value of it as a voltage of between (0-5) volts and scale it between (0-1023) then as the written code says there is another scaling for the motors. Therefore, Arduino again will scale the value of the resistance to a value of angels in between (0-180) degree, which is suitable for the servo motor. Finally, Arduino would send that angel value to the servo motor to use it for changing its position.

Figure 4.3: Slide linear potentiometer

Table 4.2 Slide linear potentiometer electrical characteristics



Characteristics - Electrical

Resistance Range:	10K to 100K
Resistance Tolerance:	± 20%
Output Law:	Linear & Logarithmic
Voltage Rating:	$E = \sqrt{P \times R}$
Electrical Life:	15,000 cycles
Insulation Resistance:	10 M minimum @ 250V DC
Dielectric Withstand Voltage:	300V AC

4.2.5 Servo motor

Servo motor is a type of motors whose output shaft can be moved to a specific angular position by sending it a coded signal. The servo motor will maintain the position of the shaft as long as you keep applying the coded signal. When you change the coded signal, the angular position of the shaft will change. A common type of servo provides position control. Servos are commonly electrical or partially electronic in nature, using an electric motor as the primary means of creating mechanical force. Other types of servos use hydraulics, pneumatics, or magnetic principles. Positioning servomechanisms were first used in military fire-control and marine navigation equipment. Today servomechanisms are used in automatic machine tools, satellite-tracking antennas, remote control airplanes, automatic navigation systems on boats and planes, and antiaircraft-gun control systems. Other examples are fly-by-wire systems in aircraft which use servos to actuate the aircraft's control surfaces, and radio-controlled models which use RC servos for the same purpose. Many autofocus cameras also use a servomechanism to accurately move the lens, and thus adjust the focus. A servo can be defined also as a mechanical motorized device that can be instructed to move the output shaft attached to a servo wheel or arm to a specified position. Inside the servo box is a DC motor mechanically linked to a position feedback potentiometer, gearbox, electronic feedback control loop circuitry and motor drive electronic circuit. A servomotor is a rotary actuator that allows for precise control of angular position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. Servomotors are not a specific class of motor although the term servomotor is often used to refer to a motor suitable for use in a closed-loop control system. Servomotors are used in applications such as robotics, CNC machinery or automated manufacturing.

Servo Motor Standard servo motors have three wires, which are for power (4 – 6 V), ground and control. The size and shape of the servo motors are dependent on the application. RC servo motor are the common type of servo motors used in robotics and hobby applications due to their affordability, reliability, and simplicity of control by microprocessors.

-RC servo motors are low power servos that can be powered from small batteries and other DC supplies in the range of 100 mA to 2 A.

-There are also high power servo motor types which are powered from AC supplies and used in industrial applications.

There are two types of servo motors - AC and DC. AC servo can handle higher current surges and tend to be used in industrial machinery. DC servos are not designed for high current surges and are usually better suited for smaller applications. Generally speaking, DC motors are less expensive than their AC counterparts. These are also servo motors that have been built specifically for continuous rotation, making it an easy way to get your robot moving. They feature two ball bearings on the output shaft for reduced friction and easy access to the rest-point adjustment potentiometer.

Servo Motor Configuration Servo motors are geared DC motors with the closed-loop circuitry incorporated within them. The basic configuration of a servo motor composed of a DC motor, gearbox, potentiometer and control circuit. DC motor is used to move a gearbox with a large reduction ratio. The final shaft imposes a force on the external load and simultaneously acts on the axis of the feedback potentiometer. So, the potentiometer senses the position of the axis and sends a corresponding voltage to an operational amplifier. This voltage compared to the input voltage, that determines the desired position of the shaft, producing a voltage in the output of the comparator. This voltage powers the motor such that the shaft moves in the necessary direction to align with the angle that corresponds to the voltage applied to the input.

Continuous rotation servos are servos which do not have a limited travel angle, instead they can rotate continuously. They can be thought of as a motor and gearbox with servo input controls. In such servos the input pulse results in a rotational speed, and the typical 1.5 ms center value is the stop position. A smaller value should turn the servo clockwise and a higher one counterclockwise.

Figure 4.4 showing the continuous rotation servo motor type SM-S4315R.

Figure 4.4: Continuous rotation servo motor SM-S4315R

A servo is a mechanical motorized device that can be instructed to move the output shaft attached to a servo wheel or arm to a specified position. Inside the servo box is a DC motor mechanically linked to a position feedback potentiometer, gearbox, electronic feedback control loop circuitry and motor drive electronic circuit.

A typical R/C servo looks like a plastic rectangular box with a rotary shaft coming up and out the top of the box and three electrical wires out of the servo side to a plastic 3 pin connector. Attached to the output shaft out the top of the box is a servo wheel or Arm. These wheels or arms are usually a plastic part with holes in it for attaching push / pull rods, ball joints or other mechanical linkage devices to the servo. The three electrical connection wires out of the side are V- (Ground), V+ (Plus voltage) and S Control (Signal). The control S (Signal) wire receives Pulse Width Modulation (PWM) signals sent from an external controller and is converted by the servo on board circuitry to operate the servo.

R/C Servos are controlled by sending pulse width signals (PWM) from an external electronic device that generates the PWM signal values, such as a servo controller, servo driver module or R/C transmitter and receiver. Pulse Width Modulation or PWM signals sent to the servo are translated into position values by electronics inside the servo. When the servo is instructed to move (Received a PWM signal) the on board electronics convert the PWM signal to a electrical resistance value and the DC motor is powered on. As the motor moves and rotates the linked potentiometer also rotates. Electrical resistance value from the moving potentiometer are sent back to the servo electronics until the potentiometer value matches the position value sent by the on-board servo electronics that was converted from the PWM signal. Once the potentiometer value and servo electronic signals match, the motor stops and waits for the next PWM signal input signal for conversion. The most common details available on a servo are its speed and torque rating. Nearly all servo packages are listed with brand name, model name/ number, speed, and torque output at 4.8 volts and 6.0 volts. Some information about metal, plastic gears or ball bearings may also be listed.

Servo Speed is defined as the amount of time (in seconds) that a servo arm attached to the servo output shaft will move from 0 to 60 degrees.

The lower the time (Seconds) the faster the servo can move an attached wheel or arm. Servo speed is measured by the amount of time (in seconds) it takes a one inch servo arm to sweep left or right through a 60 degree are at either 4.4 or 6.0 volts. A servo rated at 0.22 seconds/60 degrees takes 0.22 seconds to sweep through a 60 degree arc. Some of the fastest servos available move in the 0.06 to 0.09 second range. In some servos, faster speeds may lower torque available.

Servo Torque is defined as ounce-inch (oz-in) the total push / pull power a servo can apply on a 1" servo arm when moving. Typical values of torques of servo motors are in the range of 0,5 to 10 kg/cm. Servos have a certain amount of torque (strength) that is generally proportional to their size. Servos come in all kinds of sizes, strengths and weight. Torque is the measurement of force given over a distance. For most servos in the USA, torque is measured in oz-in (force in ounces times inches, or ounce-inch). Servo Torque is measured by the amount of weight (in ounces) that a servo can hold at 1-inch out on the servo output arm in the horizontal plane, again at either 5.0 or 6.0 volts to see when the servo stalls as it tries to lift the weight horizontally. The reported result is a measurement like this: Servo XYZ = 100 oz/in. @ 6.0 V. That means that Servo XYZ is capable of holding 100 ounces using a 1 inch output arm without excessive deflection at 6.0 input volts. Before understanding the working principle of servo motor we should understand first the basic of servomechanism.

A servo system mainly consists of three basic components - a controlled device, a output sensor, a feedback system. This is an automatic closed loop control system. Here instead of controlling a device by applying the 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 a feedback system. This third signal acts as an 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 the output signal of the system. After the device achieves its desired output, there will be no longer the logical difference between reference input signal and reference output signal of the system. Then, the third signal produced by comparing theses above said signals will not remain enough to operate the device further and to produce a 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.

A servo motor is basically a DC motor (in some special cases it is AC motor) along with some other special purpose components that make a DC motor a servo. In a servo unit, you will find a small DC motor, a potentiometer, gear arrangement and an intelligent circuitry. The intelligent circuitry along with the potentiometer makes the servo to rotate according to our wishes. As we know, a small DC motor will rotate with high speed but the torque generated by its rotation will not be enough to move even a light load. This is where the gear system inside a servomechanism comes into the picture. The gear mechanism will take high input speed of the motor (fast) and at the output, we will get an output speed which is slower than original input speed but more practical and widely applicable. Say at initial position of servo motor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. This output port of the potentiometer is connected with one of the input terminals of the error detector amplifier. Now an electrical signal is given to another input terminal of the error detector amplifier. Now difference between these two signals, one comes from potentiometer and another comes from external source, will be amplified in the error detector amplifier and feeds the Direct Current (DC) motor. This amplified error signal acts as the input power of the DC motor and the motor starts rotating in desired direction. As the motor shaft progresses the potentiometer knob also rotates as it is coupled with motor shaft with help of gear arrangement. As the position of the potentiometer knob changes there will be an electrical signal produced at the potentiometer port. As the angular position of the potentiometer knob progresses the output or feedback signal increases. After desired angular position of motor shaft the potentiometer knob is reaches at such position the electrical signal generated in the potentiometer becomes same as of external electrical signal given to amplifier. At this condition, there will be no output signal from the amplifier to the motor input as there is no difference between external applied signal and the signal generated at potentiometer. As the input signal to the motor is nil at that position, the motor stops rotating. This is how a simple conceptual servo motor works.

Servo motors have been around for a long time and are utilized in many applications. They are small in size but pack a big punch and are very energy-efficient. These features allow them to be used to operate remote-controlled or radio-controlled toy cars, robots and airplanes. Servo motors are also used in industrial applications, robotics, in-line manufacturing, pharmaceutics and food services. The servo circuitry is built right inside the motor unit and has a position able shaft, which usually is fitted with a gear (as shown below). The motor is controlled with an electric signal which determines the amount of movement of the shaft.

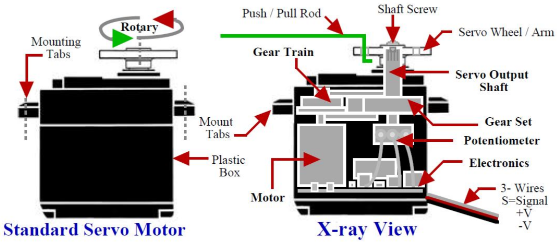


Figure 4.5 Standard servo motor constructions

To fully understand how the servo works, you need to take a look to figure 4.5 which obtain the standard servo motor construction. 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. The motor rotates, the potentiometer's resistance changes, so the 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 signal wire. 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 turn slowly, otherwise it will turn fast. This is called proportional control. This means the motor will only run as hard as necessary to accomplish the task at hand.

Servos are controlled by sending an electrical pulse of variable width, or pulse width modulation (PWM), through the control wire. There is a minimum pulse, a maximum pulse, and a repetition rate. A servo motor 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 clockwise 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 to the desired position. The servo motor expects to see a pulse every 20 milliseconds (ms) and the length of the pulse will determine how far the motor turns. For example, a 1.5ms pulse will make the motor turn to the 90-degree position. Shorter than 1.5ms moves it to 0 degrees, and any longer than 1.5ms will turn the servo to 180 degrees. 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.

The servo motors have their own characteristics like other types of motors, which are voltage, current, operating speed, torque, control pulse, resolution and pulse and weight.

The power supply voltage and current values are specified for each type of servo motors and depend on the application. The common RC servo motors powered from supplies in the range of 4 – 6 V and 100 mA - 2 A .

Operating speed of a servo motor is defined as the time required for the shaft to reach a specified position. Common servos have operating speeds in the range of 0,05 to 0,2 s/60 degree.

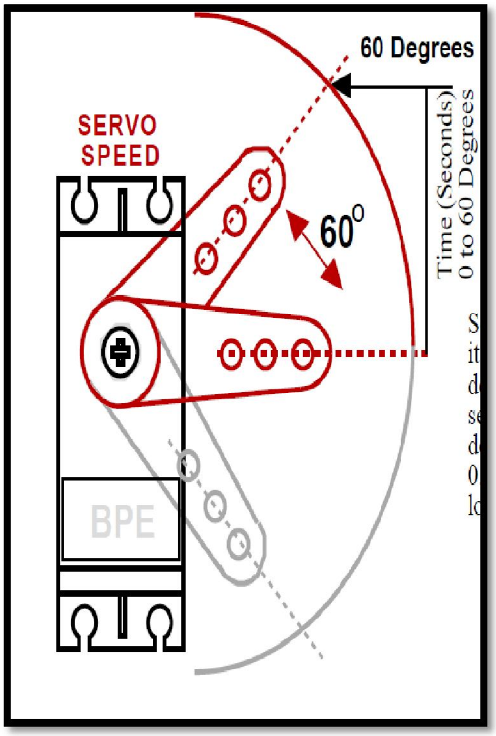


Figure 4.6 :Servo speed representation

Control pulse is referred to the type of pulse used to position the shaft. Two main types of control pulses used in RC applications: center position in 1-2 ms and 1,25-1,75 millisecond.

It defines the precision with which the shaft is positioned when it receives an external command signal. Typical servo motors have resolutions in the range from 1 degree to 10 degree. A typical R/C servo looks like a plastic rectangular box with a rotary shaft coming up and out the top of the box and three electrical wires out of the servo side to a plastic 3 pin connector. Attached to the output shaft out the top of the box is a servo wheel or Arm. These wheels or arms are usually a plastic part with holes in it for attaching push / pull rods, ball joints or other mechanical linkage devices to the servo. The three electrical connection wires out of the side are V- (Ground), V+ (Plus voltage) and S Control (Signal). The control S (Signal) wire receives Pulse Width Modulation (PWM) signals sent from an external controller and is converted by the servo on board circuitry to operate the servo. R/C Servos are controlled by sending pulse width signals (PWM) from an external electronic device that generates the PWM signal values, such as a servo controller, servo driver module or R/C transmitter and receiver. Pulse Width Modulation or PWM signals sent to the servo are translated into position values by electronics inside the servo. When the servo is instructed to move (Received a PWM signal) the on board electronics convert the PWM signal to a electrical resistance value and the DC motor is powered on. As the motor moves and rotates the linked potentiometer also rotates. Electrical resistance value from the moving potentiometer are sent back to the servo electronics until the potentiometer value matches the position value sent by the on-board servo electronics that was converted from the PWM signal. Once the potentiometer value and servo electronic signals match, the motor stops and waits for the next PWM signal input signal for conversion. A pulse width signal (PWM) of approximately 1.5 mille Second (1500 micro Second) is the "neutral" position for the servo. The servo, neutral is defined to be the point where the servomotor has exactly the same amount of potential rotation in the counter clockwise direction as it does in the clockwise direction. When the pulse width signal (PWM) sent to a servo is less than 1.5 m S. the servo moves some number of degrees counterclockwise from the neutral point. When the pulse is greater than 1.5mS the servo moves some number of degrees clockwise from the neutral point. Generally the minimum pulse will be about 1.0 mS and the maximum pulse will be 2.0 ms with neutral (Stop) movement at 1.5 mS R/C servos run on 5 volts DC but they often work with voltages V-, V+ between 4 and 6 volts DC power, near 1 Amp of current. (Torque load on the servo arm determines amps and can be from 200 mA to 1 Amp depending on moving or holding force the servo needs for position) The most common details available on a servo are its speed and torque rating. Nearly all servo packages are listed with brand name, model name/ number, speed, and torque output at 4.8 volts and 6.0 volts. Some information about metal, plastic gears or ball bearings may also be listed.

Servo Power is defined as the amount of DC Voltage needed to operate a Servo without damage. Servo operate from 4.5 to 6.0 volts DC. At the higher voltage servos tend to be faster and sometimes stronger, but can heat up faster when stalled or in a hold position with stress forces against the servo output shaft. Some servo controllers require a separate power source from the control source to deliver the higher 6.0 Volt dc. The current drain (Amps required) depends on the torque being put out by the servo motor and can be in excess of one amp if the servo is stalled under load. It is best to calculate 1 Amp per servo when figuring power supply needs for most servos.

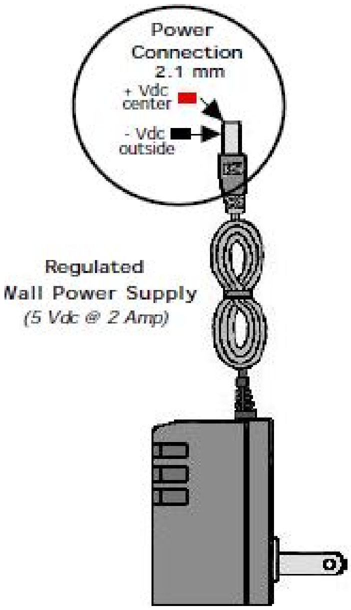


Figure 4.7 Servo power connecti

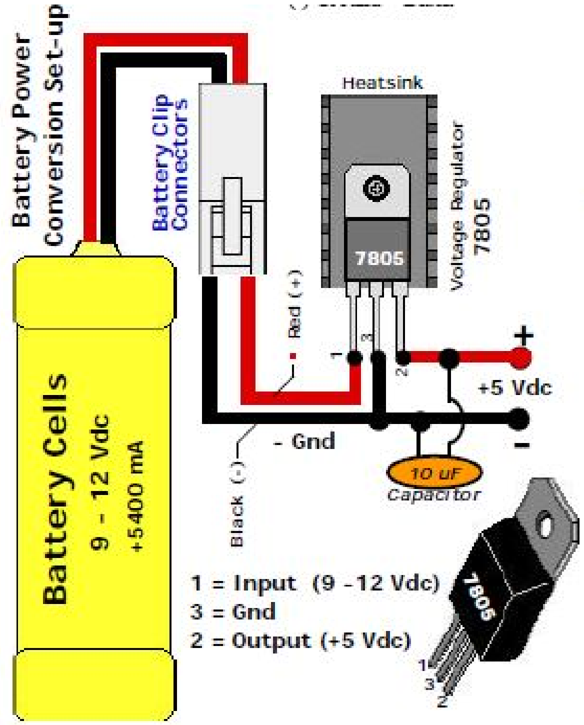
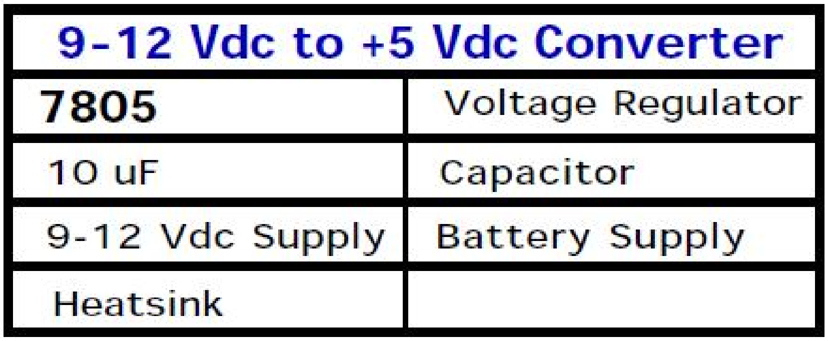


Figure 4.8 Servo power connections

Table 4.3 Servo power details



9-12 Vdc to +5 Vdc Converter	
7805	Voltage Regulator
10 uF	Capacitor
9-12 Vdc Supply	Battery Supply
Heatsink	

Which as shown as figure 4.9.

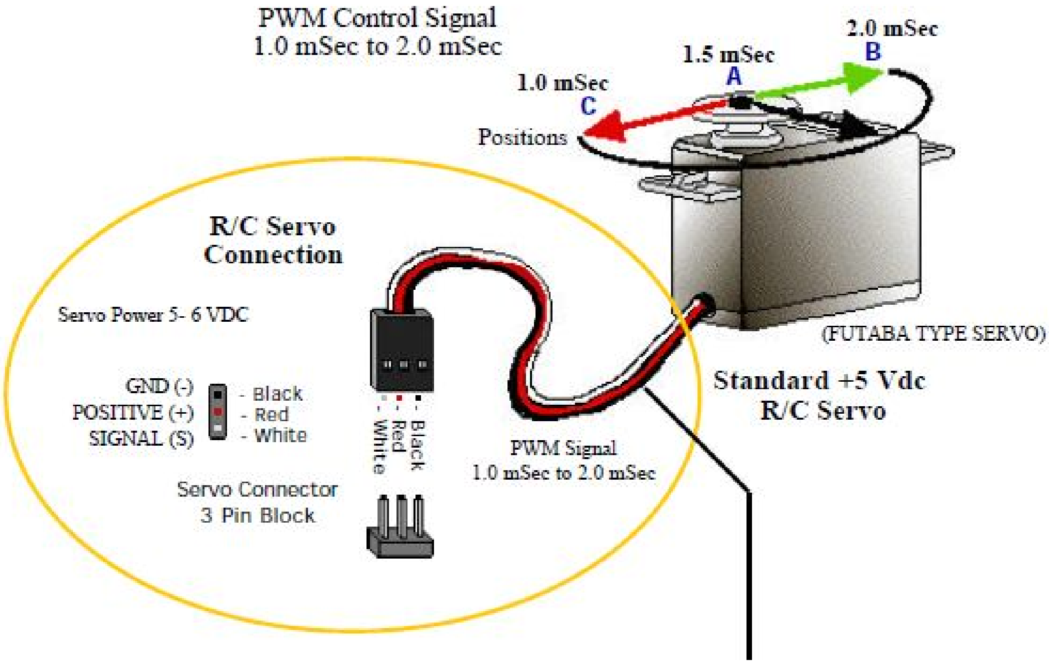


Figure 4.9 R/C servo connection

4.3 System Operation:

The system is a simulator for the human hand, so the principle is almost the same of the human hand movements. The robotic hand will move according to the movement of the person who wearied the glove. According to the move on any specific finger on the glove .the same finger on the robotic hand will move to the same position, that will be represented by transferring signals from the slide potentiometer on the glove to the arduino which convert the received signals to ranges from 0 to 179 degree , then sends it to the pin which the servos are attached at. The movement of the fingers of the robotic arm happens when the servo pulls a wire connected to the end of the glove's finger.

4.4 Code explanation

Arduino C code starts as many of other programing languages does with defining the necessary libraries that is needed in this program. Libraries are special packages of code that are used for definition to specific components with the microcontroller. Libraries are always defined in the form of #include library.h. The library used in this project is the servo library, which manipulates the servo instruction to the complier. Its form is #include Servo.h.

After that, it defines the variables used in this project and there are variables of the slide linear potentiometer, which are:

```
int potpin1 = 1; int val1;
int potpin2 = 2; int val2;
int potpin3 = 3; int val3;
int potpin4 = 4; int val4;
int potpin5 = 5; int val5;
```

It also defines the names associated with the servo motors:

```
Servo myservo1;
Servo myservo2;
Servo myservo3;
Servo myservo4;
Servo myservo5;
```

Under the title (void setup()) it defines where the servo motors are attached:

```
myservo1.attach(3);
 myservo2.attach(5);
 myservo3.attach(6);
 myservo4.attach(10);
 myservo5.attach(11);
```

Under the title void loop() here is the real code. The programmer must put here the code that the microcontroller must execute it repeatedly. Arduino starts the code by scanning all the terminals that are defined as inputs to it. After reading the value of the resistors for the first time, it goes to the next step, which is scaling the value of the potentiometer into a value in the range of (0-1023). Then it makes the other scaling process to angels of about (0-180) degree, then send it to the servo motor for getting right position of it. This process goes on and on unless the power goes off. Arduino scans the input terminals as fast as the oscillator of the microcontroller works.

Arduino code

```
#include   “wire.h”

# include  <servo .h>

Servo myservo1;

Servo myservo2;

Servo myservo3;

Servo myservo4;

Servo myservo5;

Int  potpin1 =  1;  int  va11;

Int  potpin2 =  2;  int  va12;
```

```
Int potpin3  =  3;  int  va13;

Int potpin4  =  4;  int  va14;

Int potpin5  =  5;  int  va15;

Void  setup (  )   {

Myservo 1. Attach ( 3 ) ;

Myservo 2. Attach ( 5 ) ;

Myservo 3. Attach ( 6 ) ;

Myservo 4. Attach ( 10 ) ;

Myservo 5. Attach ( 11 ) ;

//serial .begin (9600);

}

Void loop (  ) {

Delay (500);

Va11 =analog Read (potpin1) ;

//serial . println (va11) ;

Va11 =map ( va11,  1023,  658,  179,   0 );

Myservo1 .write ( va11) ;

Va12 =analog Read (potpin2) ;

//serial . println (va12) ;

Va12 =map ( va12,  1023,  900,  0,  179 );

Myservo2 .write ( va12) ;
Va13 =analog Read (potpin3) ;
```

```
//serial . println (va13) ;

Va13 =map ( va13,  1023, 900, 0,  179 );

Myservo3 .write ( va13) ;
   Va14 =analog Read (potpin4) ;

//serial . println (va14) ;

Va14 =map ( va14, 0,  900,  0,  179 );

Myservo4 .write ( va14) ;
Va15 =analog Read (potpin5) ;

//serial . println (va15) ;

Va15 =map ( va15,  1023, 900,  0,  179 );

Myservo5 .write ( va15) ;
}
```

CHAPTER FIVE

CONCLUSION AND RECOMONDATIONS

5.1 Conclusion:

After constructing a robotic hand according to the proposed design, it was concluded that the basic design of the hand was effective, but limitations in the materials used limited the efficiencies of the system and reduced the dexterity. Some aspects of the design were very effective, for example the repetition in the parts used made the construction of the hand much simpler than if there were many custom parts.

5.2 Recommendations:

We recommend to:

- Further the project can be enhanced by interfacing it with a wireless camera so that the person controlling it can view operation of the arm remotely.
- We can also replace the wired connection between the arduino and the hand with a wireless connection to make the hand operate remotely.

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Appendix:A

Appendix:B

Appendix:C

Appendix:D