# CHAPTER ONE

# INTRODUCTION

## 1.1 Background

The word robot was first used by a Czechoslovakian dramatist, Karel Capek, in his 1921 play "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, 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]

The use of robots has led to increased productivity and improved product quality. Rather than take jobs it has helped to keep manufacturing industries viable in high-labour cost countries. Today many products we buy have been assembled or handled by a robot.

These first generation robots are now a subclass of robotics known as manufacturing robots. Other subclasses include service robots which supply services such as cleaning, personal assistance or medical rehabilitation; field robots which work outdoors , and humanoid robots , that have the physical form of a human being. A manufacturing robot is typically an arm-type manipulator on a fixed base that performs repetitive tasks within a local work cell. Parts are presented to the robot in an orderly fashion which maximizes the advantage of the robot’s high speed and precision. High-speed robots are hazardous and safety is achieved by excluding people from robotic work places. Field and service robots present important challenges. The first challenge is that the robot must operate and move in a complex, cluttered and changing environment.

A delivery robot in a hospital must operate despite crowds of people and a time-varying configuration of parked carts and trolleys. A Mars rover must navigate rocks and small craters despite not having an accurate local map in advance of its travel. Robotic cars, such as demonstrated in the DARPA Grand Challenges (Buehler et al. 2007), must follow roads, obey traffic signals and the rules of the road.

The second challenge for these types of robots is that they must operate safely in the presence of people. The hospital delivery robot operates amongst people, the robotic car contains people and a robotic surgical device operates inside people.

There are many definitions and not all of them are particularly helpful. A definition that will serve us well in this book is a goal oriented machine that can sense, plan and act. A robot senses its environment and uses that information, together with a goal, to plan some action. The action might be to move the tool of an arm-robot to grasp an object or it might be to drive a mobile robot to some place.

Sensing is critical to robots. Proprioceptive sensors measure the state of the robot itself: the angle of the joints on a robot arm, the number of wheel revolutions on a mobile robot or the current drawn by an electric motor. Exteroceptive sensors measure the state of the world with respect to the robot. The sensor might be a simple contact switch on a vacuum cleaner robot to detect collision. It might be a GPS receiver that measures distances to an orbiting satellite constellation, or a compass that measures the direction of the Earth’s magnetic field relative to the robot’s heading. It might also be an active sensor. [2]

## 1.2 Problem Statement

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 Objectives

The main objectives for this project are to:

- Study and build hand simulator model to simulate the human hand by using Arduino type Mega 2560.
- Integrate the hardware and software in order to simulate the functions of a human hand.

## 1.4 Methodology

Arduino type Mega 2560 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 Project Outlines

This project consists of five chapters, chapter one 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 chapter three illustrates the control system in generally then covers hand simulator control system. After that the chapter four 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 chapter five 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 (Birglen, 2008). 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. The total cost of this hand is expected to be $10,000, 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 (Range, 2012). 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. The Shadow Hand is extremely precise, adaptable, and versatile; however it costs $250,000 ("Shadow Dexterous Muscle Hand," . Another design for a tendon-driven hand uses a single actuator to control both the contracting and straightening tendon on each joint. This was designed with cost in mind, and it uses under actuation along with duplicated design aspects to make the hand more affordable. 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 (US. Patent No. 202,843, 2007). 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 (US. Patent No.8 , 052,185, 2011). 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,  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 (Smagt, 2009).

## 2.2 Hand Simulator Control System Applications

There are many applications for this project, but the main applications of it which obtained are:

- Bomb dismantling.
- Reduce the risk of chemical hazards and nuclear risk.
- Use it in dangerous industry fields.
- Use it to find missing person 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.  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.

### 2.2.1 Bomb dismantling

There are some expressions must be defined which are:

#### 2.2.1.1 IED (Improvised Explosive Device)

A device placed or fabricated in an improvised manner incorporating destructive, lethal, noxious, pyrotechnic or incendiary chemicals and designed to destroy, incapacitate, harass or distract. It may incorporate military stores but is normally devised from non-military components .referred to as an IED.

#### 2.2.1.2 Bomb

Is a device of any size or shape which can look obvious or be camouflaged, may vary in its sophistication ,and may not necessary explode (i.e. incendiaries, toxins /noxious substances, sharps, animals/reptiles).referred to as an IED.

#### 2.2.1.3 Bombing

An incident involving the detonation of one or more IEDs.(this definition includes illegally used military explosive ordnance).

#### 2.2.1.4 Bomb threat

Threats, written or verbal, delivered by electronic, oral or other medium, threatening to place or use an improvised explosive, chemical, biological or radiological device at a time, date, place or against any specific person.it is not necessary for any other action to be taken by the offender.

### 2.2.1.5 Hoax device

An item that is placed, designed or manufactured in a manner intended to cause another person to believe the item is an IED. This application is aiming to provide safety to the bomb disposal squad by providing an extra line of defense. Provide a remote monitoring and controlling application for analysis of a suspicious packet (or bomb)

-Allow the user to manipulate the packet using the robotic arm.
-To provide visual feedback from the site of the packet.
-To provide a very user-friendly control application.

-Theoretical background of this application: One of the greatest threats for both police and military forces to handle is explosive devices. For instance, in Afghanistan, there were regularly over 150 casualties a month resulting from improvised explosives in 2009 and 2010 (Cordesman, 2010). Even when a device is found, disarming it is potentially dangerous and unpredictable. Robots are used in many cases to aid bomb squads, but they have many limitations. Current bomb disposal robots have grippers which allow the robot to open doors and access the explosive device; however, in most cases a human must put themselves in danger by disarming the device manually. To further reduce the risks associated with bomb disposal, robots must be developed that can actually disarm explosive devices. The project has been designed keeping in view the current law and order situation in Karachi and throughout the world. Everyday hundreds of trained personnel are either injured or lose their lives while defusing bombs. This can be reviewed by the countless number of news items appearing daily in newspapers around the world. These include the Daily DAWN of 19th JAN 2004 . Another news item points to a similar story in India . Although the idea of our project is original, a number of projects with similar functionalities can be found. For Example the British Police have a bomb disposal robot, the Israeli Army have it and it is also being used by bomb disposal squads and a number of states of

USA.

The main idea of this robot is to provide the bomb disposal squad with safety and security from the risks that they face every day. The bomb disposal squad of Karachi has metal detectors and other equipment for bomb detection and disposal, but they have to risk their lives by approaching the bomb or the suspicious packet without any safety and precautions. Our robot provides an extra layer of protection to the bomb disposal squad by allowing them to check and analyze a suspicious packet before actually approaching it for disposal

## 2.2.1.6 Current bomb disposal practices

Recent developments in robotics have yielded renewed interest in bomb disposal techniques and robots. There are two main goals in improving bomb disposal practices: to disarm the device with as little human contact as possible and to save the evidence contained in the bomb. In the past, the first problem has been solved by making robots that can detonate the bomb. This, however, works against the second goal because it destroys the evidence contained within the bomb that can provide law enforcement with the opportunity to find the maker of the bomb. To do this, the bomb must be disarmed without being detonated, a task which is currently almost entirely manual. There is a potential for vast improvement in the ability to accomplish these goals of bomb disposal by using new technology to improve bomb disposal robots and allowing humans to keep a safe distance from the explosives in more situations. Intentionally detonating the device in a safe area is a strategy that is used often because it ensures that the bomb will not detonate in a dangerous area. If the bomb is in an area with nothing around it, an explosion is the fastest and easiest way to dismantle it. In other situations, the bomb can be moved to a location where the device can be detonated safely. This, however, leads to the challenge of moving the device. Timers or trip switches that are attached to the area around a bomb can make moving it difficult or impossible. If moving the device involves moving it closer to people, a remotely detonated device could decimate the bomb squad. Even when a device is safely detonated, the explosion destroys most of the evidence that could help law enforcement. This makes detonating bombs a perpetual method for eliminating bomb threats because the bomb makers are rarely caught. Additionally, every bomb that is found and detonated helps bomb makers learn how to make a bomb that hits its target instead of being dismantled (Lecher, 2012). In dangerous situations, robots can replace humans by detonating a bomb or moving the device to a safer location where it can be detonated. This keeps people away from the bomb, but the bomb is still detonated. In addition to all of the problems of saving evidence this strategy also introduces different difficulties. The robot must be controlled remotely, making it difficult for the controller to see everything that is happening. Also, the robots have grippers which do not provide an effective grasp of the explosive. This is very apparent in a 2011 news story about the bomb squad in San Francisco. After finding a garage full of live, World War 2-era explosives, the bomb squad used a bomb disposal robot to carry the explosives to bomb experts, who disarmed the devices. While carrying one of the grenades, the robot dropped the explosive then drove over it. The news personnel were horrified, but the driver of the robot was completely oblivious to the incident. Luckily, the grenade did not detonate; however, it took the robot four more minutes to retrieve the bomb and hand it to an explosives expert who was able to disarm the device (“Clumsy! Bomb disposal robot”, 2011). The gripper was unable to hold the bomb while carrying it out of a garage, and once it dropped the bomb, the robot took four minutes to pick it up again, showing deficiencies in the grasper. Even then, the robot did not have the capability to disarm the grenade; instead, it had to hand the explosive to a person to disarm it. This situation could have been very dangerous if instead of a grenade, the explosive had been a device with a timer. As it was, 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. (Massa, 2002) 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 (Lecher, 2012). 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.

### 2.2.1.7 Attempted bombing

An incident involving the use of one or more improvised explosive devices (IEDs) which have failed to function because of an assembly or design defect, component failure or a successful render-safe procedure.

### 2.2.1.8 Suspect item

An item considered to be suspicious by response personnel (police, military or civilian) and requiring further investigation or specialist inspection. The item ‘suspect ’applies only to those items that are eventually declared safe and innocuous.

### 2.2.1.9 System statement of scope

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 2560 .The Arduino Mega was programmed to read the voltage from analog inputs. Because the voltage was read between the resistor and the bend sensor( linear slide potentiometer was used ), 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. The robot was designed 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.

## 2.2.2 Risk assessment of chemical hazards

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.

### 2.2.2.1 risk assessment

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 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 the 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. Some examples of the effects of hazardous chemicals include:

- Skin burns or irritation caused by contact with a corrosive liquid.
- Being overcome or losing consciousness following inhalation of toxic fumes.
- Suffering acute symptoms such as headache or nausea within hours of inhalation.
- Poisoning by absorption 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.

## 2.2.2.2 Assess the risks:

When a chemical hazards risk assessment is carrying out, a number of key questions need to be asked:

- Think about raw materials, substances generated or emitted by the process and final products.

- Consider all persons who may be affected: plant operators, maintenance workers, cleaners, contractors, visitors.

- Information on health hazards can be found on packaging labels. Information may also be obtained from Safety Data Sheets or other information provided by the supplier, from trade magazines, from plant/equipment suppliers or from specialists working in your industry. Useful information is also often available on the Internet.
- Is fire or explosion a risk?

- When is it possible for spills or splashes to occur?

- Under what circumstances might substances be breathed in, swallowed or absorbed through the skin.

- Are exposures likely to be significant? This depends on the duration and frequency of exposure as well as the concentration of the substance involved.
- What malfunction or accident could result in a serious exposure?
- The threat of fire or explosion needs to be guarded against. If good practice for dealing with these risks is well established, you only need to identify the

relevant measures in writing and check that they are in place.

### 2.2.2.3 specifying the Control Measures

•Need to find out what is established good custom and practice in the industry for managing these risks and check that meet this standard.
• Advice on good work practices and standards used by, or recommended for 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 the workplace process is unique and authoritative guidance on good health and safety practice is not available, it 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 (e.g. by measuring concentrations in air) 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, it may need to engage competent specialist expertise to assist in the task.

### 2.2.2.4 Implementing the outcome of the risk assessment

It is duty to ensure that the outcome of the risk assessment is fully implemented. If the assessment has concluded that the existing control measures need to be supplemented, the additional measures should be implemented as soon as is reasonably practicable, taking into consideration the level of risk involved. If the implementation of the additional measures is a complex task, a program or plan for implementation needs to be drawn up. In specifying all the necessary measures to safeguard workers from the effects of hazardous substances, the risk assessment will be a useful tool for you in managing safety in the workplace. It should be brought to the attention of employees and appropriate instruction and training should be provided. Control measures cannot be effective if workers do not know how to use them properly. The risk assessment should be a “living document” that is reviewed if situations change or if there is reason to think that it is no longer valid.

-Examples:
An excerpt from the Record of a Risk Assessment for a “Corrosive Liquids Store” at a medium-sized company Risk: Burns due to contact of corrosive liquid with skin or eyes Control Measures:

- Safety Data Sheet (SDS) to be available in Warehouse Office and consulted as appropriate.

- Only trained, authorized persons allowed in storage area; notices posted at entrance.
- Corrosives to be stored in designated, hazard labeled area (location specified); natural ventilation provided via building design; floor bonding designed to accommodate vessels up to one cubic meter capacity.
- Acidic and alkaline corrosives to be kept in separate zones as per local notices.
- Spill control materials to be kept in designated siding at store entrance; minimum quantities (specified) to be maintained; store man to monitor and re-order as required.

- Store man to inspect corrosives storage area daily for signs of damaged, bulging or leaking containers and for poor housekeeping.

- Store man to inspect incoming containers to ensure they are compatible, properly labeled and not damaged or corroded (in line with training provided).

- Minor spills to be handled by store man as per Emergency Procedure.
- Damaged or leaking containers to be handled as per Operating Procedure.
- In event of spill of greater than 10 liters, supervisor to be alerted; Emergency Procedure to be followed.

- All 200 liter drums to be moved with drum trolley provided; edge or side rolling of drums not permitted (company policy).

- Dispensing to be carried out only at designated area as per Operating Procedure.
- Personal Protective Equipment for store man /operatives:

- Safety footwear, protective clothing, acid-resistant gloves and goggles, all standard plant issue (further detail in Purchasing Specification); use is mandatory while in warehouse area.

- Powered full-face respirator with combined filter type A2B2E1-P3 available in designated container in storeroom for use with Emergency Procedures. respirator to be used/stored/maintained as per

Operating Procedure.

- Emergency eye-wash station and safety shower to be checked daily by store man; record to be maintained in store log.

- Hygiene measures: eating and drinking not permitted.

An excerpt from the Record of a Risk Assessment for “Dispensing Flammable Solvents” at a Printing Plant. Risk: Fire and health effects due to skin/eye contact with solvents, inhalation of vapor.

Control Measures: Dispensing to be carried out only by trained operative in accordance with Operating Procedure and using the following safety measures:

- Dispense only at designated location (well ventilated location, spill tray fitted for spill collection, free of fixed ignition sources, earthling and bonding facilities provided, warning notices posted).

- All ignition sources to be excluded, use of mobile phone or other portable electrical equipment prohibited.

- When dispensing from 210 liter drum, use hand-pump provided, fitted with electrically-conducting flexible hose.

- Only dispense into special safety containers provided for flammable liquids, suitably labeled and fitted with self-closing spring-loaded cap and flame arrestor; dispensing into open-topped cans/buckets not permitted.
- Metal containers to be earthed and bonded before commencing.
- Dispense from only one container at a time.

- Open containers must not be left unattended.

- Ensure both containers are securely closed when dispensing is complete.
- Liquid spills to be cleaned up immediately as per Spill Procedure SP01. spills must not be allowed to accumulate in spill tray.

- Mandatory Personal Protective Equipment (PPE) for operative as follows:

-Anti-static safety footwear;

- Protective chemical-resistant clothing (type/code specified).

- Solvent-resistant gloves (type/code specified).

- Goggles (type/code specified).

- Respiratory Protective Equipment (RPE) for use with Spill Procedure.
- Half-face respirator fitted with A1 filter. See separate RPE instructions.

It must put in mind that the key to safety is the specification and implementation of adequate control measures.

# 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.[1]

## 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, Programmable Logic Controller (PLC) , etc.[1]

## 3.3 Programmable Logic Controller

Programmable logic controllers, also called programmable controllers or PLCs, are solid-state members of the computer family, using integrated circuits instead of electromechanical devices to implement control functions. They are capable of storing instructions, such as sequencing, timing, counting, arithmetic, data manipulation, and communication, to control industrial machines and processes. Figure 3.1 illustrates a conceptual diagram of a PLC application.

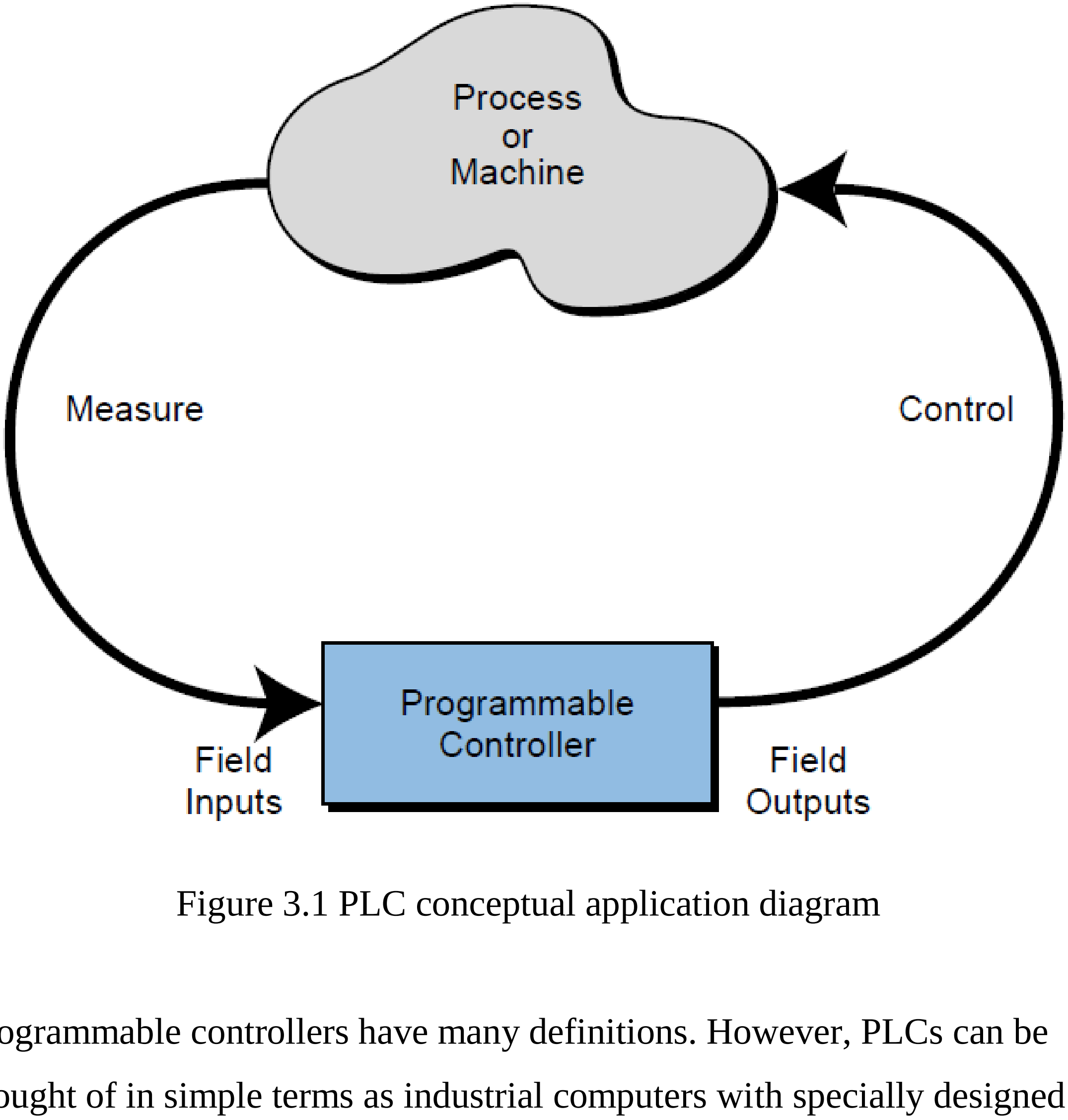


Figure 3.1 PLC conceptual application diagram

Programmable controllers have many definitions. However, PLCs can be thought of in simple terms as industrial computers with specially designed architecture in both their central units (the PLC itself) and their interfacing circuitry to field devices (input/output connections to the real world).

programmable logic controllers are mature industrial controllers with their design roots based on the principles of simplicity and practical application.

## 3.4 Microprocessor, Microcomputer and Microcontroller

Microprocessor is a Central Processing Unit (CPU) 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 Read Only Memory (ROM) and Random Access Memory (RAM), 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. The different between the microprocessor and microcontroller shown in figure 3.2.

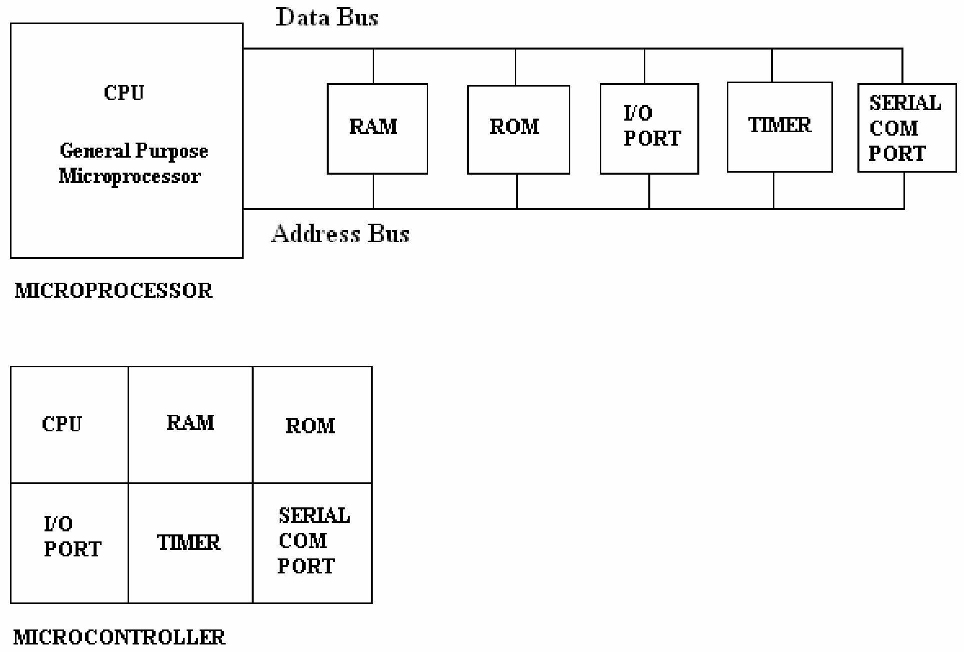


Figure 3.2: The difference between microprocessor and microcontroller

## 3.5 Arduino

Arduino is an open-source computer hardware and software Company (that it mean 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.

Arduino boards are available commercially in preassembled form, or as do-it-yourself kits. The hardware design specifications are openly available, allowing the Arduino boards to be manufactured by anyone. Ad fruit Industries estimated in mid-2011 that over 300,000 official Arduinos had been commercially produced, and in 2013 that 700,000 official boards were in users' hands.

# 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 (Dario, 2007). 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 (B. Miller, personal communication, 11/30/12). [4]

## 4.2 System Components

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

i. Gloves.
ii. Arduino type Mega 2560.
iii. Slide Linear Potentiometer.
iv. Accelerometer, Gyroscope (MPU 6050) sensor.
v. Servo Motor type Tower Pro MG996&MG995.

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

### 4.2.1 Gloves

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.[3]

The glove

is shown in Figure 4.1.

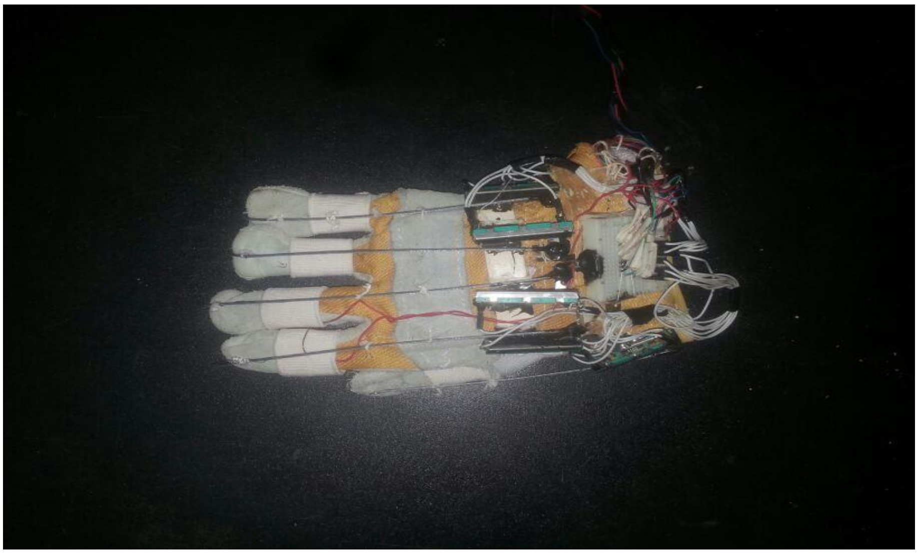


Figure 4.1: Glove construction

### 4.2.2 Arduino Mega 2560

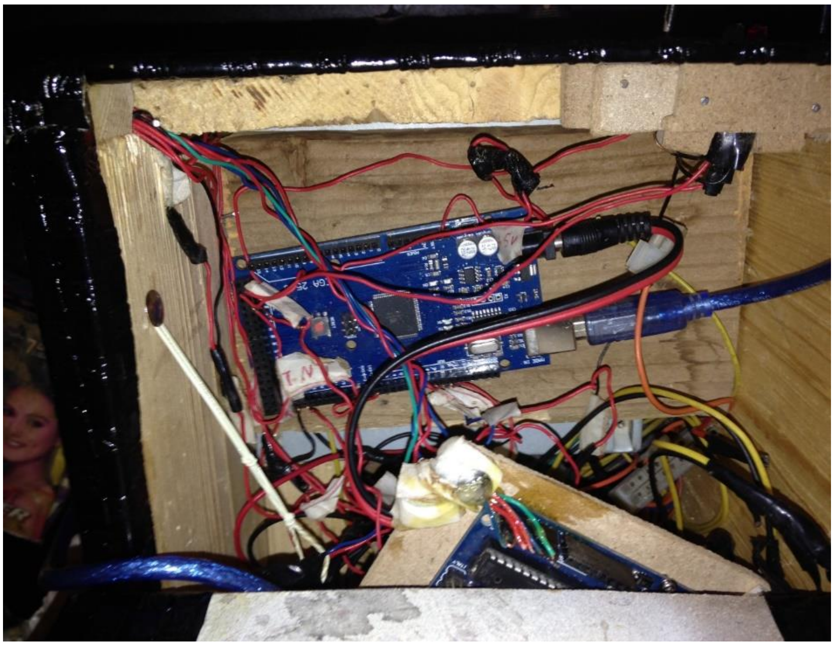


Figure 4.2 Arduino mega 2560 connection

The Arduino/Genuino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM(Pulse Width Modulation) outputs), 16 analog inputs, 4 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 Mega 2560 board is compatible with most shields designed for Arduino/Genuino Uno and the former boards Duemilanove or Diecimila.

Table 4.1: Arduino mega 2560 technical specifications

| | |
|---|---|
| Microcontroller | ATmega2560 |
| Operating Voltage | 5V |
| Input Voltage (recommended) | 7-12V |
| Input Voltage (limit) | 6-20V |
| Digital I/O Pins | 54 |
| PWM Digital I/O Pins | 14 |
| Analog Input Pins | 16 |
| DC Current per I/O Pin | 40 Ma |
| DC Current for 3.3V Pin | 50 Ma |
| Flash Memory | 256 KB |
| Flash Memory for Boot loader | 8 KB |
| SRAM | 8 KB |
| EEPROM | 4 KB |
| Clock Speed | 16 MHz |
| Length | 101.52 mm |
| Width | 53.3 mm |
| Weight | 37 Gram |

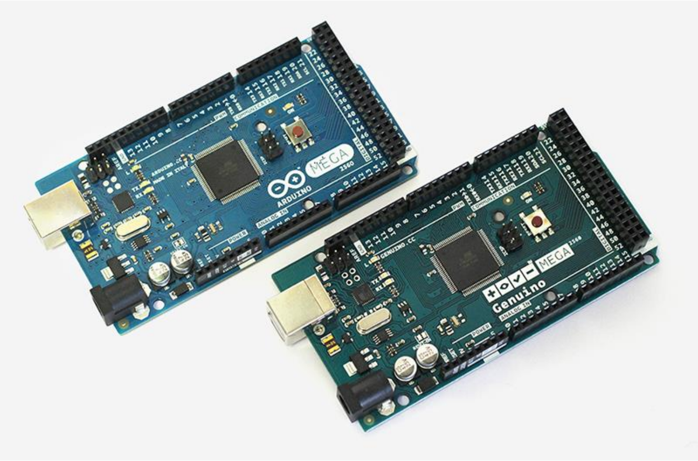


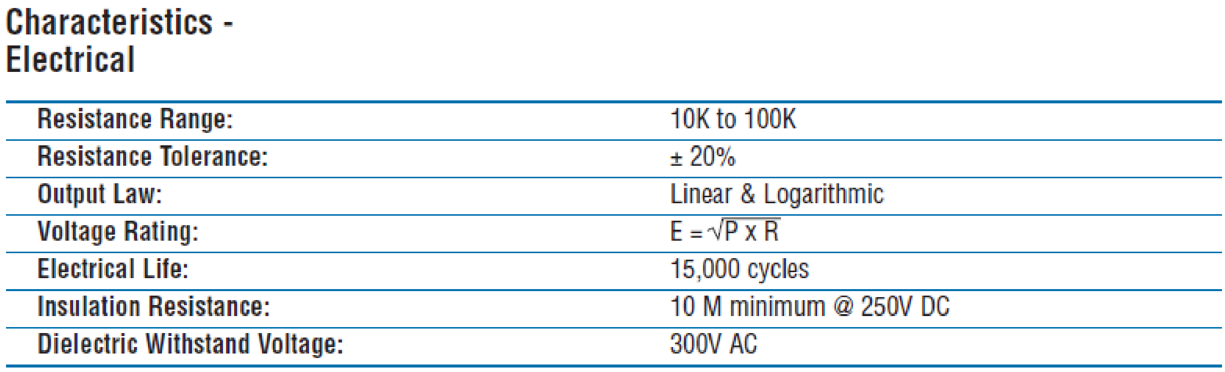
Figure 4.3: Arduino mega 2560

### 4.2.3 Slide Linear Potentiometer

The slide potentiometer is a linear variable resistor with a total resistance of 10 kilo ohm. When you move the lever from one side to the other, its output voltage will range from 0 V to the VCC you apply. It has four pins, 3 of which are connected to VCC, ground( GND) and the ADC IN on the slide, while the remaining pin is connected to a red indicator LED. The indicator LED could be used to visually display the change on the potentiometer.

Figure 4.4: Slide linear potentiometer

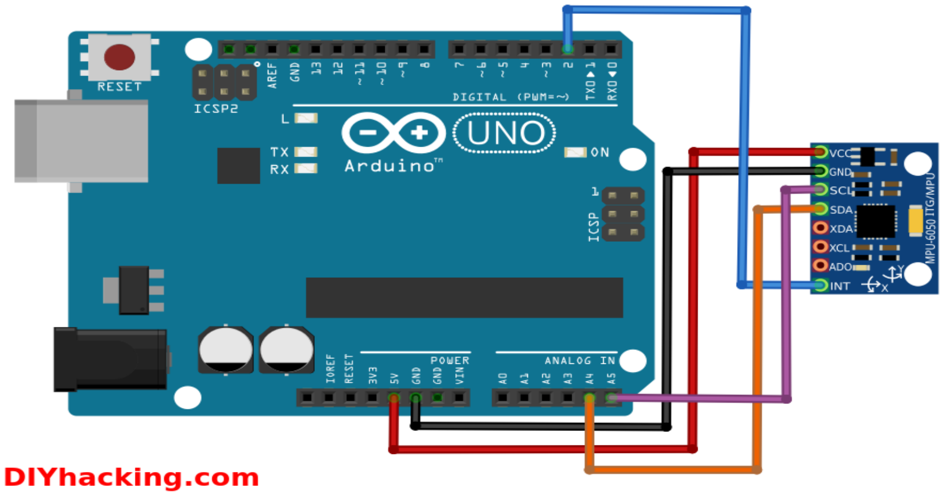
Table 4.2: Slide linear potentiometer electrical characteristics



**Characteristics - Electrical**

| | |
|---|---|
| Resistance Range: | 10K to 100K |
| Resistance Tolerance: | ± 20% |
| Output Law: | Linear & Logarithmic |
| Voltage Rating: | E = √P x R |
| Electrical Life: | 15,000 cycles |
| Insulation Resistance: | 10 M minimum @ 250V DC |
| Dielectric Withstand Voltage: | 300V AC |

### 4.2.4 Accelerometer, Gyroscope (MPU 6050) Sensor



DIYhacking.com

Figure 4.5: Connection of IMU sensor with arduino

Internal Measurement Unit (IMU) sensors are one of the most inevitable type of sensors used today in all kinds of electronic gadgets. They are seen in smart phones, wearable, game controllers, etc. IMU sensors help us in getting the attitude of an object, attached to the sensor in three dimensional space. These values usually in angles, thus help us to determine its attitude. Thus, they are used in smart phones to detect its orientation. And also in wearable gadgets like the Nike fuel band or fit bit, which use IMU sensors to track movement.

IMU sensors, thus have prolific number of applications. It is even considered to be an inexorable component in quad rotors.

## IMU (Internal Measurement Unit ) sensor operation

IMU sensors usually consists of two or more parts. Listing them by priority, they are : accelerometer, gyroscope, magnetometer and altimeter. The MPU 6050 is a 6 DOF (Degrees of Freedom) or a six axis IMU sensor, which means that it gives six values as output. Three values from the accelerometer and three from the gyroscope. The MPU 6050 is a sensor based on MEMS (Micro Electro Mechanical Systems) technology. Both the accelerometer and the gyroscope is embedded inside a single chip. This chip uses I2C (Inter Integrated Circuit) protocol for communication.MPU sensor is shown in figure 4.5 below.

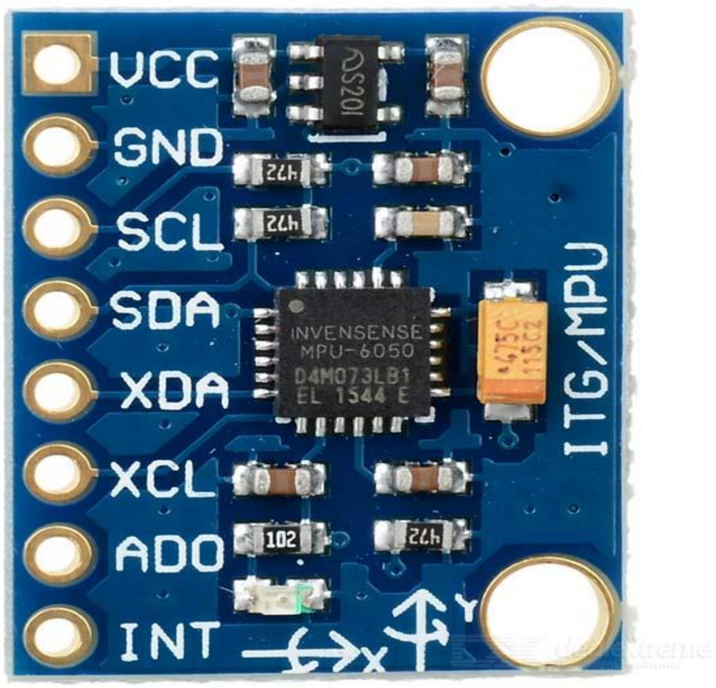
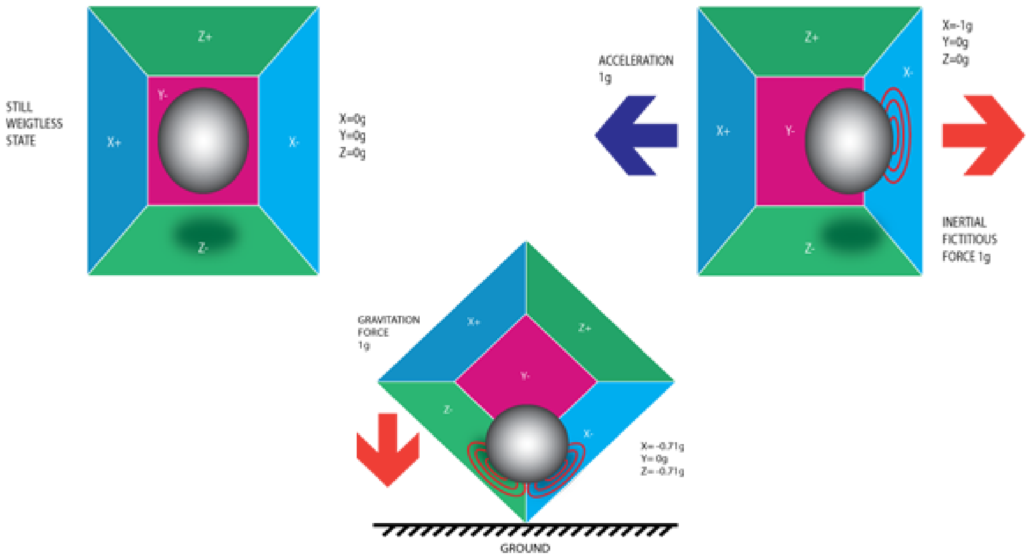


Figure 4.6: MPU sensor

## Accelerometer Operation



:

Figure 4.7 : Accelerometer operation

An accelerometer works on the principle of piezo electric effect. Here, imagine a cuboidal box, having a small ball inside it, like in the picture above. The walls of this box are made with piezo electric crystals. Whenever you tilt the box, the ball is forced to move in the direction of the inclination, due to gravity. The wall with which the ball collides, creates tiny piezo electric currents. There are totally, three pairs of opposite walls in a cuboids. Each pair corresponds to an axis in 3D space: X, Y and Z axes. Depending on the current produced from the piezo electric walls, we can determine the direction of inclination and its magnitude. Figure 4.6 showing the operation of accelerometer.

## Gyroscope Operation:

Gyroscopes work on the principle of Coriolis acceleration. Imagine that there is a fork like structure that is in constant back and forth motion. It is held in

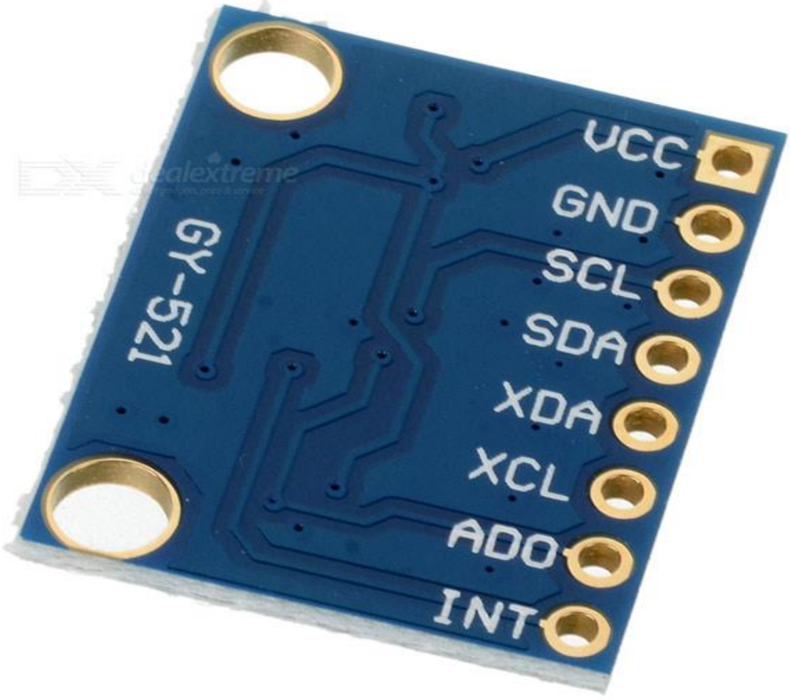


Figure 4.8: GY-521 sensor

place using piezo electric crystals. Whenever, you try to tilt this arrangement, the crystals experience a force in the direction of inclination. This is caused as a result of the inertia of the moving fork. The crystals thus produce a current in consensus with the piezo electric effect, and this current is amplified. The values are then refined by the host microcontroller.

### 4.2.5 Servo motor

Servo motor is a type of motors whose output shaft can be moved to a specific

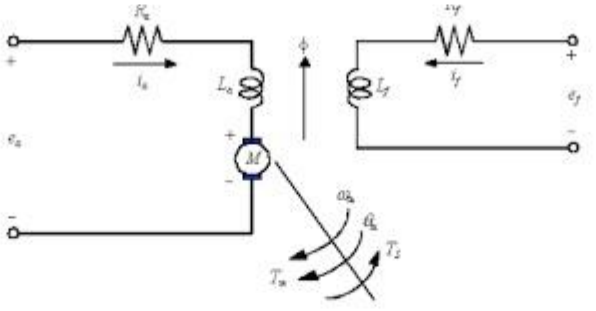


Figure 4.9: Servo motor electrical circuit

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.

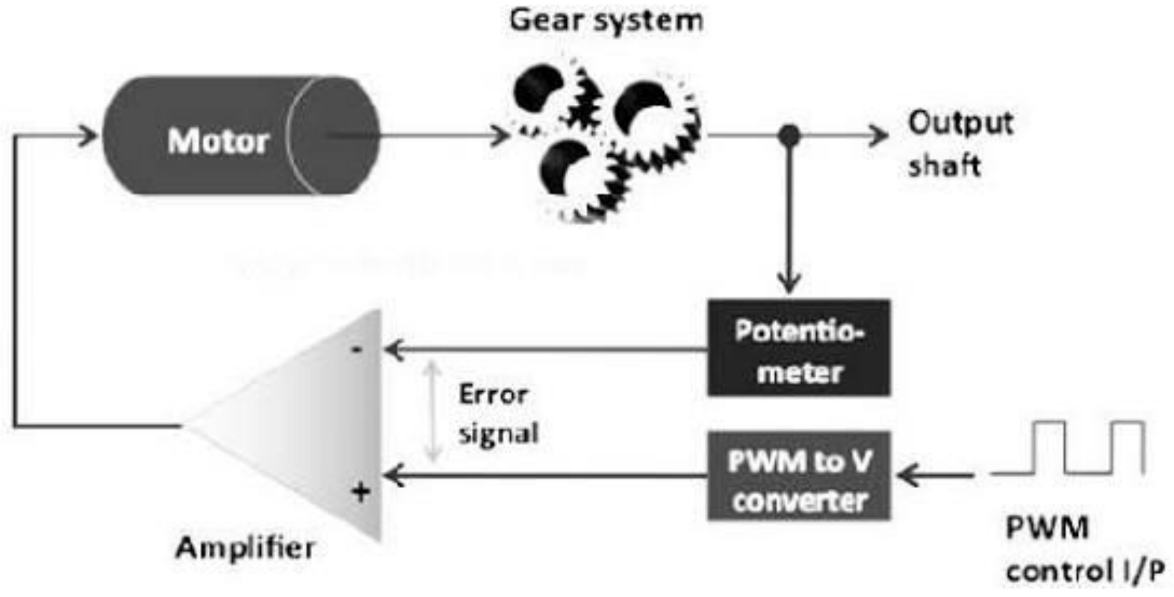


Figure 4.10: Servo motor block diagram

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.

### 4.2.5.1 Types of servo motors

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.

#### 4.2.5.2 Types of servo motors according to it's current

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.

#### 4.2.5.3 Configuration and operating principle of servo motor:

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.

#### 4.2.5.4 Continuous rotation servo motor

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 4.8 showing the continuous rotation servo motor type SM-S4315R.

Figure 4.11: 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

#### 4.2.5.5 Servo speed

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.

Note: 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.

#### 4.2.5.6 Servo torque

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. To convert oz-in to kilogram-centimeters (kg-cm) just divide by 13.9

### 4.2.5.7 Servo motor working principle

Before understanding the working principle of servo motor we should understand first the basic of servomechanism.

### 4.2.5.8 Servo mechanism

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.

#### 4.2.5.9 Working principle of servo motor

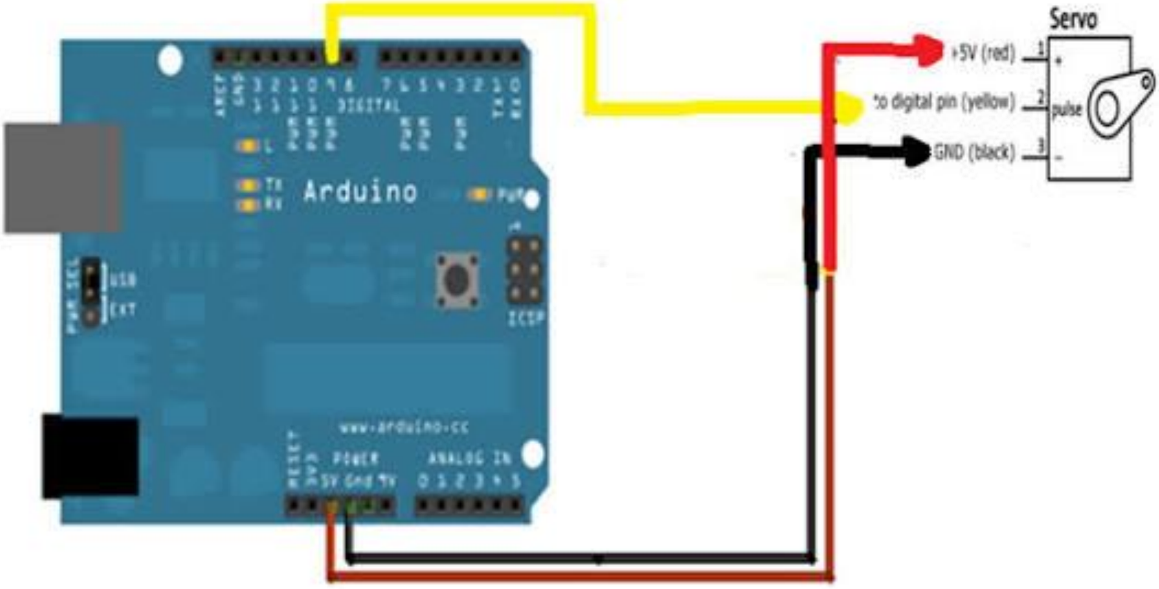


Figure 4.12: Servo connection with the arduino

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

### 4.2.5.10 Servo motor operation

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

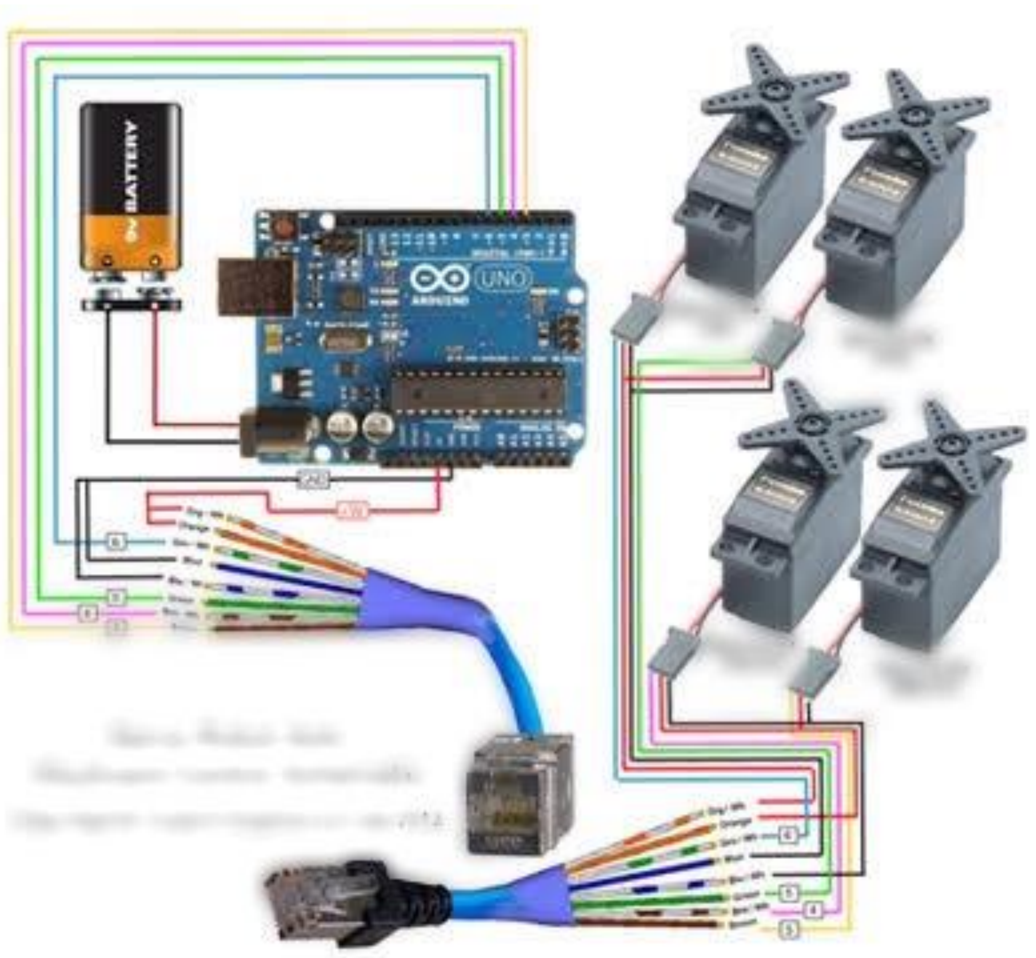


Figure 4.13: Servo connection with the arduino and power supply

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.

### 4.2.5.11 Servo construction

To fully understand how the servo works, you need to take a look to figure 4.9 which obtain the standard servo motor construction. Inside there is

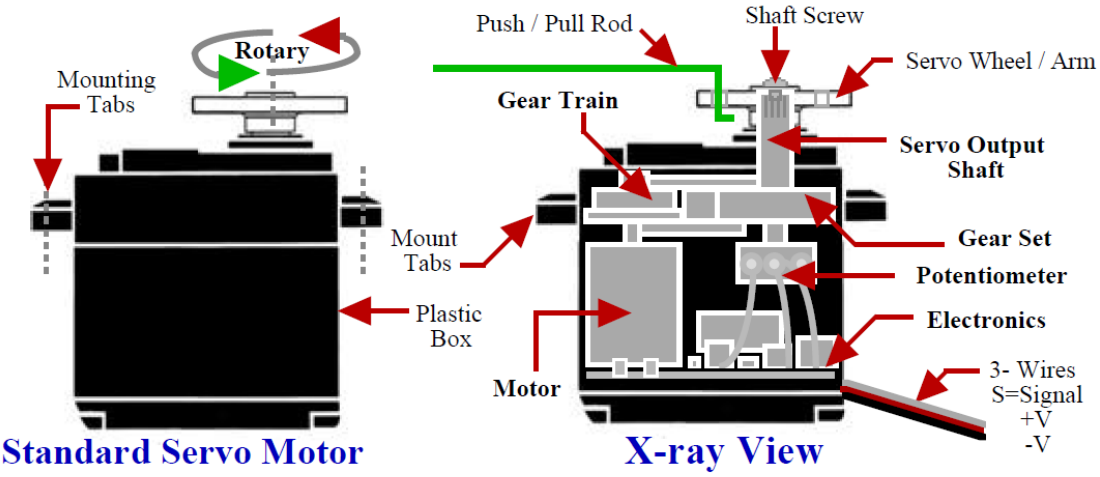


Figure 4.14 Standard servo motor construction

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 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.

### 4.2.5.12 Servo control

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.

### 4.2.5.13 Servo motors usages

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.

### 4.2.5.13 Power supply voltage and current

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 .

### 4.2.5.14 Operating speed

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.

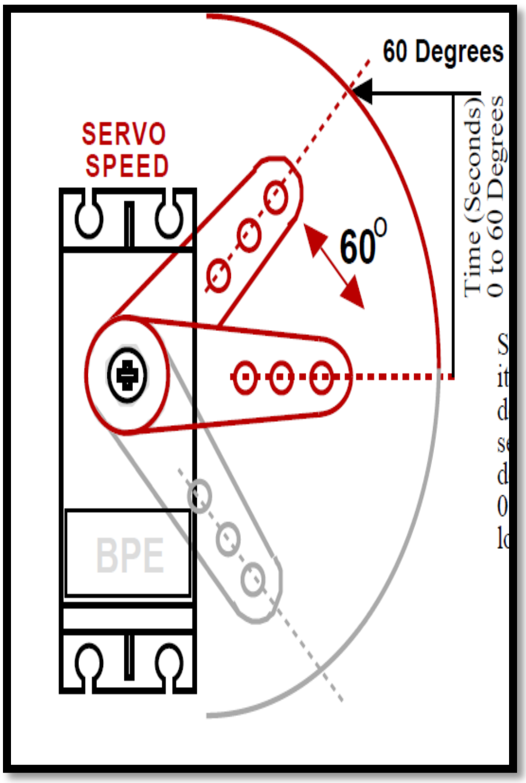


Figure 4.15:Servo speed representation

### 4.2.5.15 Control pulse

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.

### 4.2.5.16 Resolution

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.

### 4.2.5.17 Servo power (4.5- 6.0 VDC)

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 Amper servo when figuring power supply needs for most servos.

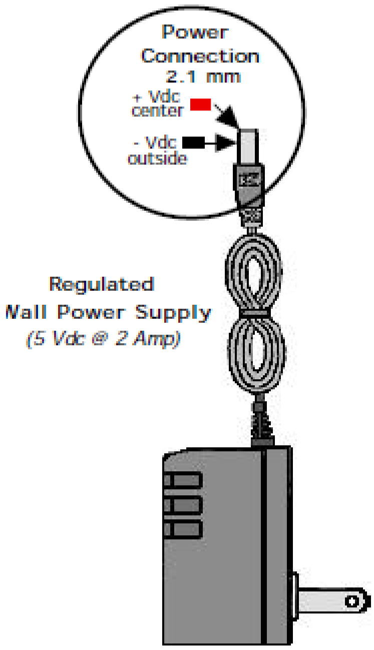


Figure 4.16 Servo power connection

Figure 4.11 showing the servo power connection.

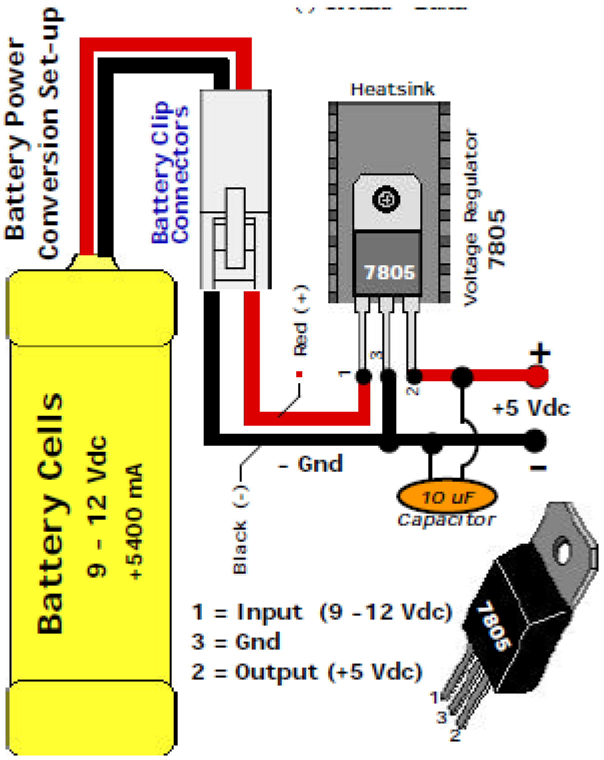
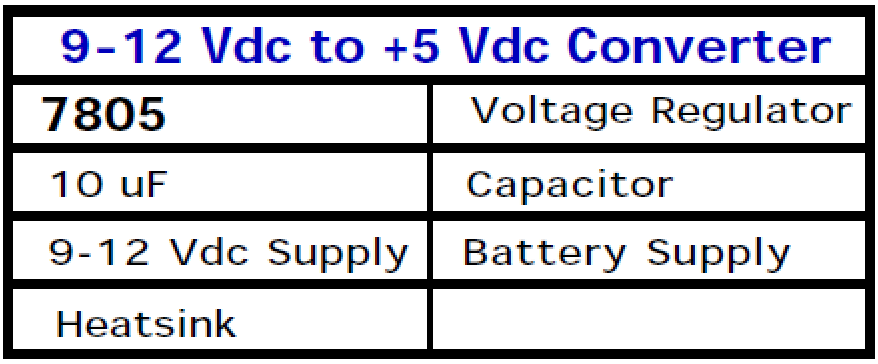


Figure 4.17 Servo power connections

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 | |

## 4.2.5.18 Servo wire information

Which is shown in figure 4.18.

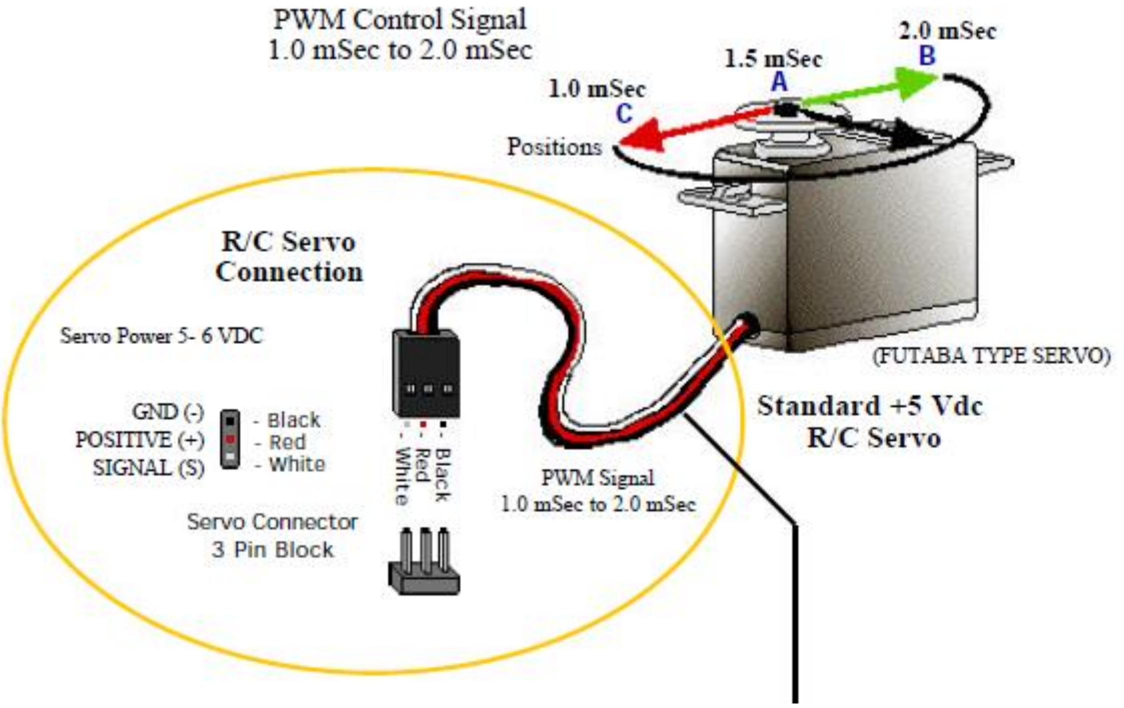


Figure 4.18 R/C servo connection

## 4.3 Design Of The Robotic Arm

To proceed in the direction of design aspects, first mechanical structure has to be designed. Depending on the design requirements electronic parts are configured

with that of mechanical design.

### Mechanical design

Mechanical design involves the selection of suitable motor for our application, deciding on the material to be used for the construction of the arm, i.e. the shaft material and deciding on the location where the motor has to be placed.

- **Selection of motor**

The main criteria to be considered while selection of motor is Torque and the speed of the motor, many different motors are available in the market like servomotors, stepper motor, dc motors with and without gears. These different motors are used according to their applications and requirements. for e.g. If high torque is required and precise speed we need to use servo motors, if we want to only position and if high torques not required then stepper motors are used. The motor can be selected once we know the torque and speed required for our application.

## Torque calculations

The main criteria to be considered for the selection of motor are torque. Torque is the tendency of force to rotate an object about an axis. Mathematically, torque is defined as the cross product of the lever-arm distance and force, which tends to produce rotation. i.e.

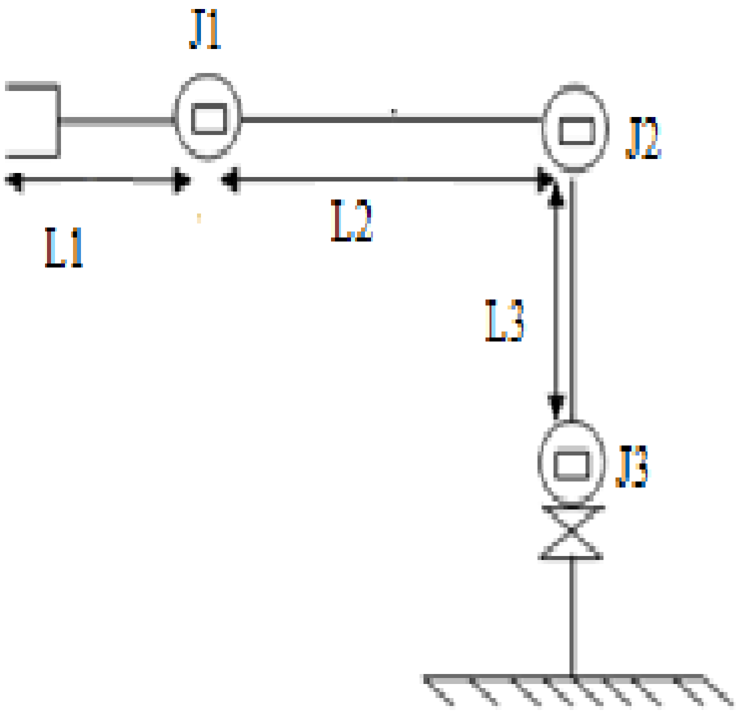


Figure 4.19: Robotic arm design

T= F * L (4.1)

Where, F≡ force acting on the motor

L≡ length of the shaft

Force, F is given by,

F= m * g (4.2)

Where

m≡ mass to be lifted by the motor.

g≡ gravitational constant = 9.8 m/s.

Calculation of the torque starts from the gripper and moves downward till the base joint of the arm. Hence base Joint carries the maximum payload i.e. it should carry the weight of the upper 2 motors also. The robotic arm is of three joints. One motor each at the 3 joints. The torque and speed calculation differs at each joint depending on the payload.

For example, Consider the figure shown above.

Torque for the first joint is calculated as,

$T1 = F1 * L1$

$F1 = m1 * g$

Consider:

Weight to be lifted = 150g

Weight of the gripper = 100g

Total weight on joint1 = m1= 250g

Length of the gripper = L1= 4 inch = 0.1016m

$F1 = 0.25*9.8$

$F1 = 2.45$ N

$T1 = F1*L1$

$= 2.45*0.1016$

$T1 = 0.24892$ Nm

Similarly, the torque for the other joints is also calculated but for the succeeding joints, the weight of the above motor and the length get added.

Torque for 2nd joint = $T2 = F2 (L1+L2)$

Torque for 3rd joint = $T3 = F3 (L1+L2+L3)$

The calculation of the torque can be tabulated as at table below.

Table 4.4: Torque calculations

| Motor locations | Length (inch) | Total mass (gram) | Force Newton | Torque Nm |
|---|---|---|---|---|
| Gripper | L1= 4 | 250 | 2.45 | 0.248 |
| Elbow | L2= 9 | 550 | 5.39 | 1.779 |
| Base | L3= 4 | 850 | 8.33 | 3.596 |

## 4.4 system main block diagram

The main configuration of the system is represented in figure 4.14.

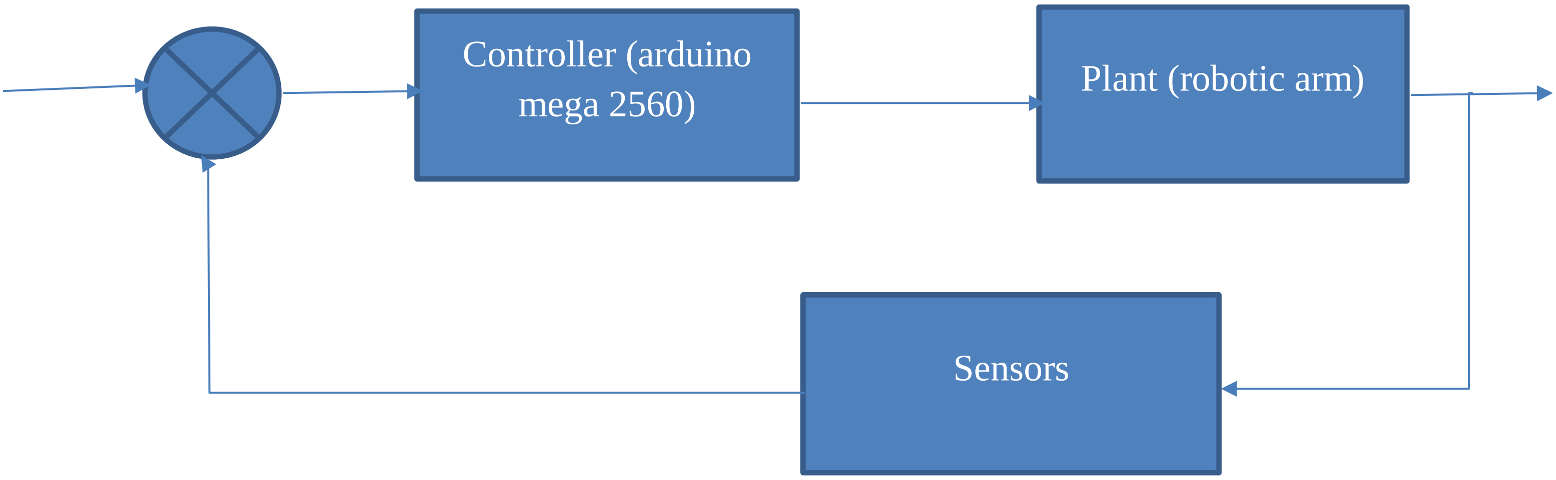


Figure 4.20 Block diagram of the hand simulator control system

## 4.5 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. All the hand operations are obtaining in nine case. The first case hand is at normal case, hence nothing is happening. At case one just the pinkie is moving and clanged with the palm. At case two the the finger next to pinkie is clanged with the palm .at the third case the middle finger moved and clanged to with the palm. At the fourth case the index finger moved and clanged with the palm. Summarizing all of the cases is that the hand move exactly like the human hand (who's wiring the glove) .All the cases are implemented at figures below

Figure 4.21: hand at normal case

Figure 4.22: hand at case one

Figure 4.23: hand at case two

Figure 4.24: hand at case three

Figure 4.25: hand at case four

Figure 4.26: hand at case five

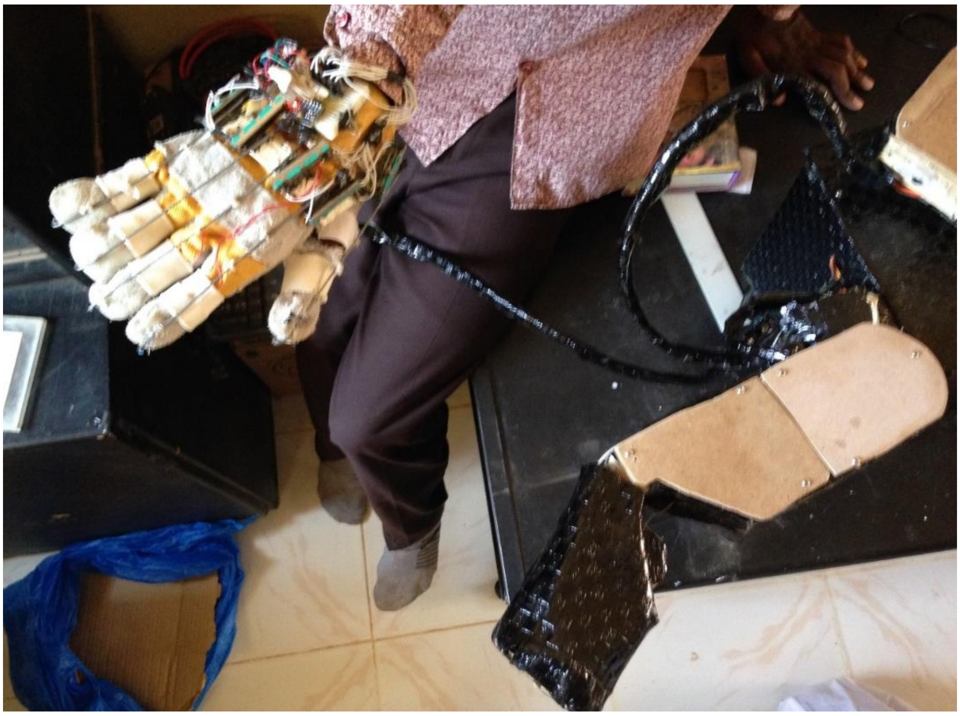


Figure 4.27: Hand at case six

Figure 4.28: Hand at case seven

Figure 4.9: Hand at case eight

Figure 4.30: Hand at case nine

# 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

- 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.
- This design is for a robotic hand that is much less expensive than existing hands, so it is possible to use it in many applications in which other robotic hands are impractical because of their price. Before the hand can be used in many of these situations, however, the project must be extended to include a wrist, and materials must be improved to reduce friction and increase consistency and dexterity. For some situations, the hand could also be made in a different size or with alternative materials to function efficiently in extreme environments. Also, future experiments could focus on the material on the palm and inside of the fingers to give the hand a more compliant, steady grasp of objects. Finally, the design can be resized and adapted for prosthesis with more under actuation to reduce number of servos, and a different type of control system so an amputee could control it. We can also

replace the wired connection between the arduino and the hand with a wireless connection to make the hand operate remotely.

- For intelligence robot arm ,solar cell could be used .
- For more flexibility , this hand can be attached to a non wirily controlled robotic car.
- After the final design it was cleared that there is a problem at the vertical movement of the arm (because of the heavy weight of the hand). So it must be recommended to use servo motor with high torque.

# REFERENCES

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[2] C. Edwards and E. Smith ,’’Design of Simulink-based 2-DOF Robot Arm Control Workstation ,’’31 October 2006.

[3] Saurabh A. Khajone , Dr. S. W. Mohod, V.M. Harne,’’ Implementation of a Wireless Gesture Controlled Robotic Arm ‘’,ISSN 2320-9798,Vol3,Issue 1,In January 2015.

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# Appendix:

## System Code

```
#include "Wire.h"
#include "I2Cdev.h"
#include "MPU6050.h"
#include <Servo.h>
const int ledg=52;
const int ledr=53;
const int switchong=50;// switch to start getting signals from sensors
const int fgrsw=48
Servo myservo1;
Servo myservo2;
Servo myservo3;
Servo myservo4;
Servo myservo5;
Servo myservo6;//for rotating the hand
Servo myservo7;// for the elbow movement
Servo myservo8;// for lifting over all arm
Servo myservo9;//for rotating the all arm
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;
int val6;
int val7; int val8; int val9; int val10;
int val11; int val12;
// gy521 acceleromwter code
MPU6050 accelgyro;
int16_t ax, ay, az;
int16_t gx, gy, gz;

//Variables de l'accéléromètre - pour calculer l'angle
double accXangle
double accYangle;
double accZangle;
//Variables du gyro - pour calculer l'angle
double gyroXangle = 180;
double gyroYangle = 180;
double gyroZangle = 180;
uint32_t timer;
void setup() {
```

```
pinMode(ledg,OUTPUT);
pinMode(ledr,OUTPUT);
pinMode(switchong,INPUT);
pinMode(fgrsw,INPUT);
myservo1.attach(3);
myservo2.attach(4);
myservo3.attach(5);
myservo4.attach(6);
myservo5.attach(7);
myservo6.attach(8);
myservo7.attach(9);
myservo8.attach(10);
myservo9.attach(11);
// gy521 acceleromwter code
Wire.begin();
// Initialisation communication serial
//fonctionne en 8MHz ou en 16MHz
Serial.begin(38400);
// Indication
Serial.println("Initialisation communication I2C...");
accelgyro.initialize();
```

```
// Test de connexion au MPU6050
// Serial.println("Test de connexion au MPU6050...");
// Serial.println(accelgyro.testConnection() :
timer = micros();
}
void loop() {
val6=digitalRead(switchong);//  //to enter storing position or begin to excute the program
if(val6==LOW){   // intializating the over all program
digitalWrite(ledg,HIGH);
digitalWrite(ledr,LOW);
val1 = analogRead(potpin1);
val2 = analogRead(potpin2);
val3 = analogRead(potpin3);
val4 = analogRead(potpin4);
val5 = analogRead(potpin5);
val1 = map(val1, 30, 200, 0, 179);
val2 = map(val2, 900, 90, 0, 179);
val3 = map(val3, 0, 140, 0, 179);
val4 = map(val4, 20, 430, 0, 179);
val5 = map(val5, 0, 870, 0, 179);
myservo1.write(val1);
```

```
myservo2.write(val2);

myservo3.write(val3);

myservo4.write(val4);

myservo5.write(val5);

// gy521 accelerometer code

accelgyro.getMotion6(&ax, &ay, &az, &gx, &gy, &gz);

// Calcular os angulos com base nos sensores do acelerometro

accXangle = (atan2(ax,az) + PI) * RAD_TO_DEG;

accYangle = (atan2(ay,az) + PI) * RAD_TO_DEG;

accZangle = (atan2(ax,ay) + PI) * RAD_TO_DEG;

double gyroXrate = ((double)gx / 131.0);

double gyroYrate = -((double)gy / 131.0);

double gyroZrate = -((double)gz / 131.0);

gyroXangle += gyroXrate*((double)(micros()-timer)/1000000);

gyroYangle += gyroYrate*((double)(micros()-timer)/1000000);

gyroZangle += gyroZrate*((double)(micros()-timer)/1000000);

// gyroZangle=gyroZangle-0.013900;

gyroZangle=gyroZangle-0.377600;

timer = micros();

delay(1);

//  //Tabela Separada para os valores accel/gyro x/y/z values
```

```
//  Serial.print("a/g:\t");
//  Serial.print(ax); Serial.print("\t");
//  Serial.print(ay); Serial.print("\t");
//  Serial.print(az); Serial.print("\t");
//  Serial.print(gx); Serial.print("\t");
//  Serial.print(gy); Serial.print("\t");
//  Serial.println(gz);
//Angulo Giroscopio x/y/z
// determining when the elbow must move
// for the lifting the arm
val11=map(accXangle,80,180,0,179);
myservo8.write(val11);
// for rotating the hand
val12=map(accYangle,180,360,0,179);
myservo6.write(val12);
Serial.print(accXangle); Serial.print("\t");
Serial.print(accYangle); Serial.print("\t");
Serial.print(gyroZangle); Serial.print("\t");
Serial.print("\n");
val7=digitalRead(fgrsw);//49 where the switch between the fingers is attatched
//Serial.print(val7);Serial.print("\n");Serial.print("\t");
```

```
// Serial.print("\n");

//Serial.println("\t");

if(val7==LOW)

{

val8=map(gyroZangle,180,260,0,179);

myservo7.write(val8);// the elbow servo

}

else

{

val9=map(gyroZangle,180,230,179,0);

myservo9.write(val9); //the arm rotating servo

val10=map(gyroZangle,75,180,0,179);

myservo7.write(val10);

// Serial.print(val9);

//Serial.print("\t");

//Serial.print(val10);

}

delay(200);

}

else  {

myservo1.write(0);
```

```
myservo2.write(0);

myservo3.write(0);

myservo4.write(0);

myservo5.write(0);

myservo6.write(0);

myservo7.write(179);

myservo8.write(0);

myservo9.write(180);

digitalWrite(ledr,HIGH);

digitalWrite(ledg,LOW);}}
```