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Theme

Controlled robotic hand by sensors with a synchronicity system

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Dedication

To my incredible mother, your endless love, unwavering support, and boundless patience have been the foundation of my journey. You have been my inspiration, and my greatest cheerleader. Your wisdom and guidance have shaped me into the person I am today, and for that, I am eternally grateful.

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This thesis is dedicated to my family, my Uncle Bouamra and his little family, my cousin Ikram, and My friends who supported me throughout my academic career. I extend my sincere thanks also to my colleague who showed dedication to the success of the work.

Manar SEM

Dedication

بسم الله الرحمان الرحيم و الصلاة و السلام على رسول الله، أما بعد فنحمد الله و نشكره على توفيقه و عونه على إنجاز هذا العمل و انهائه في آجاله المحددة.

أتقدم بالشكر لكل من عائلتي الكريمة و إخوتي على مساندتهم لي طيلة مدة دراسة هذا المشروع و بالأخص أمي و أبي.

أوجه الشكر الجزيل أيضاً للأستاذة المشرفة عميروش نسرين على توجيهاتها لنا طيلة مرحلة الإنجاز.

اشكر جزيل الشكر لزميلتي التي أبدت اجتهادها من أجل إنجاح العمل ، لا انسى أن اخص بالذكر لكل الاصدقاء المتعاونين معي بتوفير الادوات و الحاجيات لإتمام الفكرة بنجاح و بدءا بصديقي مهدي حرز الله و سيد علي غومراسي و لكل من ساهم من بعيد أو قريب .

و ما التوفيق إلا من عند الله و الحمد لله رب العالمين.

ملخص:

يقوم هذا المشروع بإنشاء يد روبوتية يتم تشغيلها بواسطة قفاز يتم ارتداؤه على يد الإنسان، مما يسمح ليد الروبوت بتقليد حركات اليد البشرية في الوقت الفعلي. يعد متحكم **ARDUINO NANO** ومقارنات **LM358** ومشغل المحرك وأجهزة استشعار الجهد كلها مكونات أساسية. ينقسم مشروعنا إلى قسمين، جزء واحد يعمل تحت تحكم الاردوينو مما يؤدي إلى حركة جزء من الإصبع. أما الجزء الثاني فسنتحكم فيه ونحركه للأعلى والأسفل باستخدام دائرة المقارنة ومقياس الجهد.

كلمات المفاتيح: يد روبوتية، قفاز، يد الإنسان، **ARDUINO NANO**, مقارنات **LM358**, أجهزة استشعار الجهد

Résumé :

Ce projet crée une main robotique actionnée par un gant porté sur une main humaine, permettant à la main du robot d'imiter les mouvements de la main humaine en temps réel. Un microcontrôleur Arduino Nano, des comparateurs LM358, un pilote de moteur à pont en H L293D et des capteurs potentiométriques sont tous des composants essentiels. Notre projet est divisé en deux parties, une partie fonctionne sous contrôle Arduino, ce qui entraîne le mouvement d'une partie du doigt. Quant à la deuxième partie, nous allons la contrôler et la faire monter et descendre à l'aide du circuit comparateur et du potentiomètre.

Mots clés : main robotique , main humaine, gant, Arduino Nano, capteurs potentiométriques , comparateurs LM358

Abstract :

This project creates a robotic hand operated by a glove worn on a human hand, allowing the robot's hand to mimic human hand movements in real-time. An Arduino Nano microcontroller, LM358 comparators, L293D H-bridge motor driver, and potentiometer sensors are all essential components. Our project is divided into two parts, One part works under Arduino control, which leads to the movement of part of the finger. As for the second part, we will control it and move it up and down using the comparator circuit and the potentiometer.

Keywords: robotic hand, human hand, glove, Arduino Nano, potentiometer sensors, LM358 comparators

List of Acronyms and Abbreviations

AGV	Automated guided vehicle
ADC	analog-to-digital converter
AREF	Analog Reference
DLR	Deutsche Zentrum für Luft- und Raumfahrt
DC	Direct current
EEPROM	Electrically Erasable Programmable Read-Only Memory
FBS	feedback sensor
HIT	Harbin Institute of Technology
IC	Integrated Circuit
I2C	Inter-Integrated Circuit
IDE	Integrated Development Environment
KH	Kinetic Humanoid
PWM	Pulse Width Modulation
RX	Receive
SPI	Serial Peripheral Interface
SCCA	Self-Contained Compliant Anthropomorphic
SDA	Serial Data Line
SCL	Serial Clock Line
TX	Transmit
VCC	Voltage at the Common Collector
VFBS	voltage of the feedback sensor
VHS	voltage of hand sensor

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General Introduction

Embedded systems are everywhere, powering various devices from simple household appliances to complex industrial machinery. They combine hardware and software designed for specific tasks within larger systems. These systems rely on specialized electronic circuits and software that can operate independently or with minimal human intervention.

Key components of embedded systems include microcontrollers, sensors, and interfacing modules. These elements work together to enable precise control and automation. While electronic circuits serve as the backbone of embedded systems, facilitating the flow and interaction of electrical signals, they also play a crucial role in realizing different functions within these systems. By using components like resistors, integrated circuits, and comparators, these circuits can convert analog signals into digital ones, amplify signals, and perform other essential tasks required for modern electronic devices to function.

One fascinating application of embedded systems and electronic circuits is in the development of robotic hands. Researchers and engineers worldwide are actively exploring ways to create robotic hands that possess similar functionality and dexterity as human hands. This research area encompasses various fields such as prosthetics, teleoperation (remote control), and assistive technologies for individuals with disabilities. By incorporating sensors, actuators, and advanced control algorithms, these robotic hands can execute complex tasks with high precision and responsiveness.

Our project focuses on building a controllable robotic hand that mimics the movements of a human hand in real time. The setup involves a robotic hand and a glove fitted with sensors worn on the human hand. Whenever the wearer performs hand gestures, these movements are instantly replicated by the robotic hand through a synchronization mechanism. To achieve this, we will be using an Arduino Nano microcontroller along with other essential components such as LM358 comparators, L293D H-bridge motor driver, and potentiometer sensors.

By combining the principles of embedded systems engineering with robotics, this project showcases the potential for impactful applications in areas like prosthetics, remote manipulation, and human-machine interaction. It represents a fusion of precise electronics with user-friendly control mechanisms, further enhancing the advancements already made in robotic hand development and ultimately improving the quality of.

Chapter1: General information about robots

1.1 Introduction:

Due to the variety of labor-intensive, repetitive, challenging, and even dangerous tasks [1], researchers and scientists have been interested in creating a new class of machines known as robots since the 1970s [2]. This machine is a mechanical device that can carry out a range of tasks autonomously or by preprogrammed instructions [1]. Robotics has significantly impacted many facets of modern life in recent years [3]. The two initial uses of robots were to meet the needs of the manufacturing sector and the industry in environments that were hostile to humans.

Industrial robotics initially addressed the need for repetitive and automatic object manipulation (manipulation, painting, and surfacing) among manufacturing machines. It is now completed in the manufacturing sector by mobile transport or assistance robots (AGV, assembly assistance), which share many characteristics with service robots [4].

Robotics in hostile environments responds to the need for remote object manipulation (demining, counterterrorism, accident recovery) without requiring human intervention due to the objects' danger (explosive, chemical), the environment's activity (nuclear), or the difficulty of getting there (space). Robots are based on electromechanical and remotely operated systems. Following industrial and intervention robotics, a third orientation has emerged as a result of advancements in micromechanics, microelectronics, and miniaturization, along with the addition of new information processing and communication system capabilities [5]. This has made technological conditions favorable for the development of mobile autonomous or semi-autonomous robots thanks to their ability to learn from and understand artificial and material entities as well as their introduction into highly human-interacted environments to realize professional service applications (agriculture, medicine, cleaning, etc.) and personnel service applications (education, household tasks, etc.) [6].

This chapter will examine the history of robotics, its various forms, and its fields of application.

1.2 Problem Statement:

Today, robots are used in the automotive industry, electronic equipment assembly lines, and other cutting-edge industries. They surpass humans in speed and accuracy. But if the robots' tasks change, they must be reprogrammed. For example, a robotic arm is programmed to remove a steel bar from one table and place it on another table. To perform the same motion on a plastic pipe, the robot hand must be reprogrammed because holding a plastic rod with the same force as a steel rod can cause damage to the plastic. As you can see, even small changes require a lengthy reprogramming process for the robot. One solution to this challenge is teleoperation, which allows a human to control the robot remotely. We need to build and design an anthropomorphic, dexterous, multi-fingered industrial hand that enables precise and accurate grasping. It should have the dexterity and sensitivity of a real human hand. As previously noted, the reprogramming difficulty for robots must be addressed. The industry suffers huge costs as a result of human error, so they must discard a certain number of defective items. The robotic hand will also address this issue because it will be more precise in manipulating objects. Additional situations are hazardous to humans, such as extremely hot temperatures or any hostile setting where a worker could be injured. So, in some cases, our robotic hand will take the place of the human operator. Because it will be managed via teleoperation by a human, it will act as if the worker is handling the goods in that hazardous area.

1.3 Goals of the Project:

The primary goals of this initiative are defined as follows:

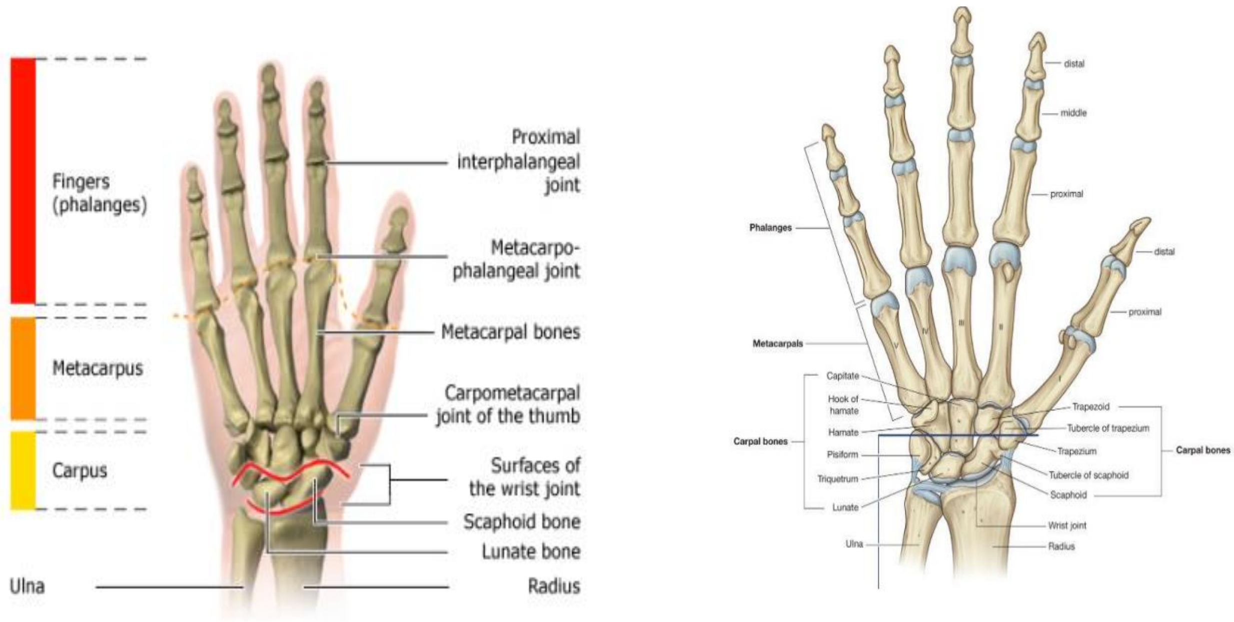
1. Design, fabrication, and installation of the robotic hand.
2. Design the master glove that the human operator will wear to guide the robotic hand movement.
3. Establish a communication connection between the master glove and the slave humanoid robotic hand to relay information about the master hand's motion.

1.4 Human Hand Structure and Movements:

The anatomical explanation is based on Chen's study [7]. Prosthetics often focus on the skeletal system of the hand, but also examine other systems such as integumentary, muscular, lymphatic, neurological, and cardiovascular. The skeletal system consists of bones and tendons. This project focuses on the performance of wrist movements, taking into account both the forearm and wrist skeletal systems. The skeletal region of interest extends

from the elbow to the forearm, including the Ulna and Radius bones, and ends at the wrist, which connects the hand and forearm. This section includes the following bones: Scaphoid, Lunate, Triquetrum, Pisiform, Hamate, Capitate, Trapezoid, and Trapezium. Finally, the hand is made up of five metacarpals (palm bones) and five digits. Each digit is made up of three bones: the proximal, distal, and middle phalanxes, except the thumb, which has only two.
If the anatomical terms are translated into robot kinematics, each bone can be viewed as a link. As is customary, joints exist to connect such linkages. The radiocarpal bone is placed at the wrist, followed by the carpometacarpal bone, which connects the hamate, capitate, trapezoid, and trapezium to the metacarpals. The metacarpal-phalangeal bone connects the metacarpal and proximal phalange bones. Ultimately, the phalangeal bones are separated by the interphalangeal joints (proximal and distal).
This hand anatomy explanation is crucial for creating a 3D hand model. The wrist and finger movements are further detailed in the following paragraph.

Figure 1.1 provides a detailed and pictorial representation of the human hand bones and joints. The joints can move in many ways, including gliding, angular, circular, and unique movements such as inversion, eversion, protraction, and retraction.



(a) Hand bones [8]

(b) Hand joints. [9]

Figure 1.1 : Hand bones and joints

1.5 Definition of Robotics:

The science that studies robots is called robotics. It's a multidisciplinary field with elements of mechanics, computer science, electronics, and more. (10) Furthermore, several specialties are involved in robotics:

•**Mechanics:** robot design, implementation, and modeling.

•**Electronics**: using telecom technologies, robot components are implemented for remote control.

• **IT:** developing software to control the information flow amongst the many robot components.

•**Automatic:** parameter identification, effector and sensor calibration, and control.

•**Signal processing**: the examination of data gathered by the robot's sensors.

• Mathematical models for learning and/or decision-making, trajectory computation, positioning, and planning.

• **Cognitive science:** machine-machine communication, decision-making, and human-machine interactions

1.6 Etymology of the word Robot:

The word "robot" originates from slave languages (Czech) and literally means " slave " or, more accurately, "robota," which denotes forced labor. The precise definition of a robot, in contrast to robotics, is somewhat complicated. intricate combination of electronic and mechanical components, all controlled by artificial intelligence.

1.7 The robot:

This machine can manage objects in its external environment by issuing commands based on the circumstances. These commands are sent through a program that we load into the machine's memory, and the machine is equipped with multiple senses, including detectors and a shield or more to enable movement. As an illustration: If it's on a moving robot with a U-camera attached, it may be trained to avoid impediments in its path so that it can navigate in an unknown room [11].

This picture depicts a synoptic diagram of a robot interacting with its surroundings [12].

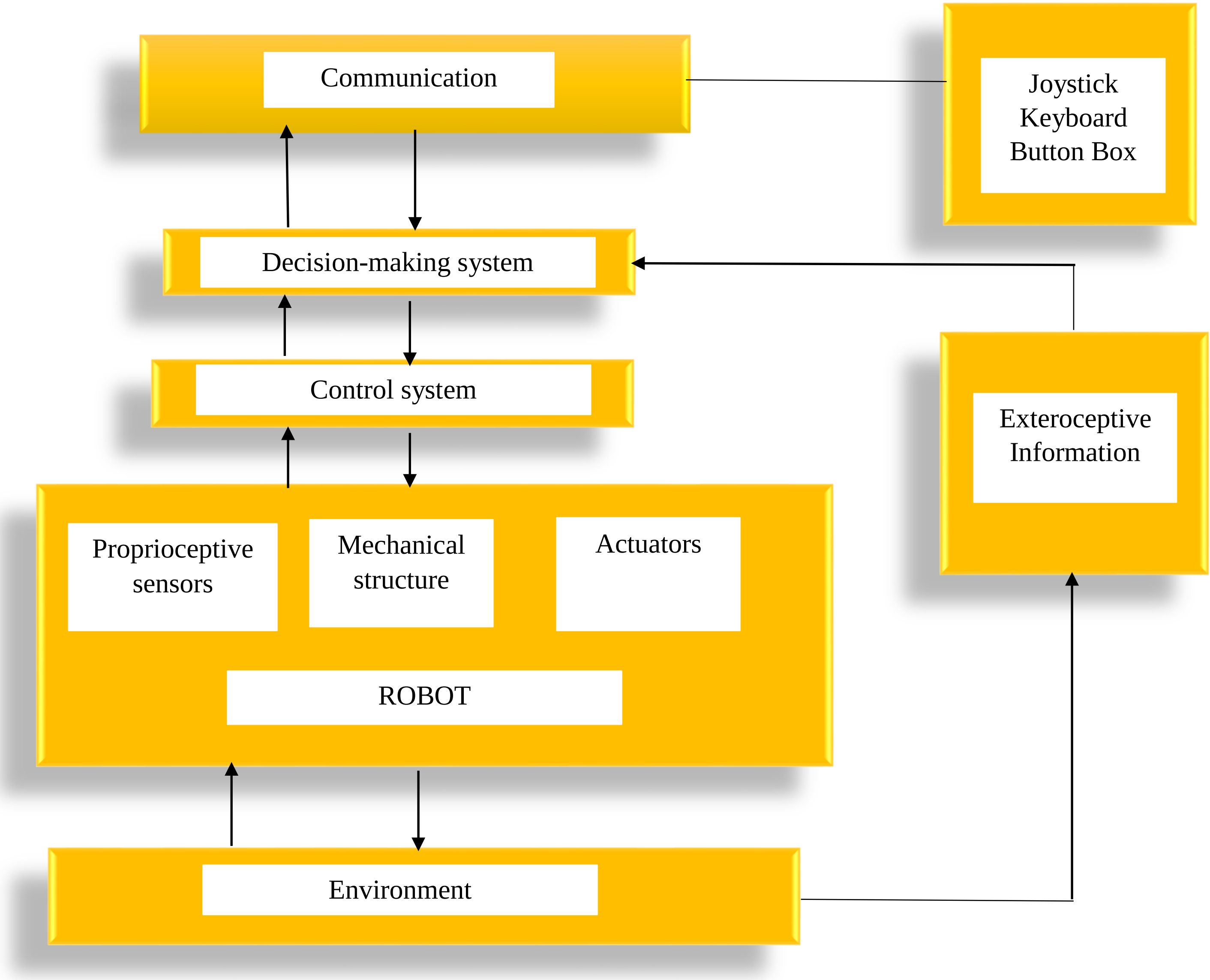


Figure 1.2: Architecture of a Robot

1.8 The history of robot development:

1.8.1 The Clock:

The remains of the scientist Ctesibios were discovered in the year 246 BC, and they exhibit inventiveness and design that correspond to a particular specific era [13].

Figure 1.3: The clock [13]

1.8.2 Automaton of Al Jazari :

Al-Jazari, a scientist, created water clocks that were roughly one meter and thirty-five centimeters in length. These clocks caused a stir in the field of robotics [13].

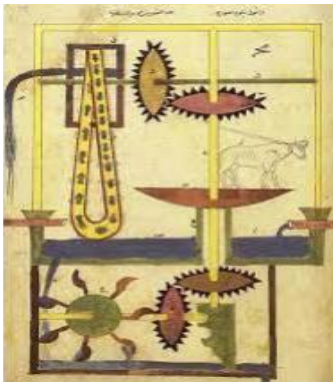


Figure 1.4: Al Jazari automaton [13]

1.8.3 An Automated Duck:

The mechanical duck was created by Jacques de Vaucanson in the eighteenth century (1709), which he regarded as the "golden century" of the transition to automata [13].

Figure 1.5: Mechanical duck [13]

1.8.4 The initial arm to be manipulated remotely:

In 1954, in Argonne, Lorraine, a researcher called Raymond Goertz proposed using electric motors in the joints of teleoperation arms to simplify their design. This technique allows the operator to be several hundred meters distant from the spot [13].

1.9 Robotic types:

Robots can be divided into two primary families:

- Manipulating robots.
- Mobile robots.

1.10 Classification of Robots :

We have three kinds of robots:

● **The manipulators:**

- Trajectories are not random in space.
- Positions are discrete.
- Control is sequential.

●**Telemanipulators:**

Remote handling equipment, including excavators and overhead cranes, was first used in the US around 1945.

- Trajectories can be anywhere in space and are defined instantly by the operator using a control console (joystick).

●**Robots:**

- Robots can follow any trajectory in space,

execute automatically, and respond to external stimuli. [14]

1.11 Application and Design Requirements :

Artificial hands have numerous possible application domains, each with unique requirements. In this area, we examine and categorize the key sectors of application, with the goal of broad categories of application domains.

1.11.1 Assistive Robotics :

Assistive robots must be able to interact and cooperate safely with the environment and humans while performing daily tasks. Whereas robotic hands must be compact, light, and flexible to function under tough conditions and with limited information. Furthermore, their hands must provide high levels of comfort, safety, and robustness. The DLR/HIT (Harbin Institute of Technology) Hand II (103), Fluidic Hand (220) [appendix B] , and SCCA (Self-Contained Compliant Anthropomorphic) Hand (177) [appendix B] are examples of robotic hands created for assisting the sick, old, and disabled. **Figure 1.6 (a)** depicts the DLR/HIT Hand II, which works with the DLR Lightweight Robot arm to assist disabled individuals with daily tasks (221) [appendix B]. [15]

Figure 1.6: DLR/HIT Hand II [12]

1.11.2 Prosthetics :

Prosthetics ought to be lightweight and easy to use, with few input options for amputees. They should also be capable of interacting with humans and the environment and operating under difficult situations.

Hand prostheses are prosthetic devices that replace lost limbs. Many various options are currently available, including the Ottobock Michelangelo Hand (115), the i-Limb Quantum (93), the Open Bionics Hand (23), the Yale Multigrasp Hand (25), and the SoftHand Pro (188) [appendix A]. **Figure 1.7 (b)** depicts a prosthetic hand, namely a BeBionic hand (117) [appendix B] used by an amputee. [15]

Figure 1.7: BeBionic hand [15]

1.11.3 Supervised Manipulation:

The robotic gadget requires remote assistance from a human supervisor to execute manipulation tasks and make high-level decisions. Limited sensory and environmental constraints make its application difficult. Indeed, the human operator frequently advises the trajectory that the robot should take. Hands built for this use must be durable, efficient, and easy to control. This application is typical of an industrial setting. Examples of robotic hands for this field include the iHY (iRobot-Harvard-Yale) Hand (135, 223) and Schaler et al.'s electrostatic gripper (193) [appendix B] . **Figure 1.8 (c)** depicts an operator using a tablet to program and supervise the actions of a robotic manipulator and its end effector. [15]

Figure 1.8: tablet to program and supervise the actions of a robotic manipulator [15]

1.11.4 Teleoperation:

Teleoperation is the direct control of a robotic system from a remote location. Teleoperation differs from supervised manipulation in that the human operator instructs the robot at a lower level. This frequently involves a one-to-one connection between user inputs and robot motions, with a transparent interface. Teleoperation is mostly used to reduce the requirement for human presence in hazardous conditions (e.g., irradiated settings or chemical spill sites) or after natural disasters (e.g. earthquakes). Other potential applications include underwater robotics (for example, retrieving archaeological artifacts from the ocean) (137) [appendix B] . Technologies must be built to operate safely in unexpected and difficult environments, such as grasping fragile or large things. These systems typically have severe criteria for robustness, control simplicity, and adaptivity. The KH (Kinetic Humanoid) Hand (97), the Raphael (Robotic Air Powered Hand with Elastic Ligaments) Hand (104), the Handroid Hand (123), and the SCHUNK S5FH Hand (224) [appendix B] are all examples of robotic hands built for use in this field. **Figure 1.9(d)** is an example of teleoperation by the NASA Robonaut (225) [appendix B] to complete a bimanual job [15].

Figure 1.9: NASA Robonaut [15]

1.11.5 Teleinteraction:

Teleinteraction, which is derived from teleoperation, tries to communicate over distance using audio, video, and interaction with a robotic system. These technologies are primarily intended to collaborate with people, particularly in daily living settings. Hands intended for such applications must meet high standards in terms of human-environment interaction, comfort, and pleasantness. The design criteria prioritize natural motion, safety, robustness, and control simplicity. Examples of robotic hands produced or used in this field of application include the mechanical hand presented by Jau (54) and the hand used by the robot ASIMO (81) [appendix A] . **Figure 1.10 (e)** depicts an example of a teleoperated robot engaging with a person [15].

Figure 1.10: a teleoperated robot engaging with a person [15]

1.11.6 Social robotics:

Social robots are systems that can communicate with humans. This sort of robot is intended to have a human-like (or human-acceptable) look and is typically outfitted with a screen for communication and interaction. Hands built for these robots typically demand a high level of human-robot interaction and pleasantness, as well as stringent safety and design standards.

The Alpha Hand (153) and RBO Hand 2 (226) are two examples of robotic hands built for use in this field **Figure 1.11 (f)** is an example of the REEM humanoid robot (113) [appendix B] assisting a person in a mall [15].

Figure 1.11: REEM humanoid robot [15]

1.11.7 Entertainment:

The goal of entertainment applications is to have a robot for recreation (e.g., toys), domestic use, or animatronics in amusement parks or museums. These robots frequently attempt to mimic a human, animal, or cartoon character, not just in look but also in behavior. Such robots often do not require hands capable of complicated human interactions and operate in controlled environments. Furthermore, their hands are frequently made with strict design formalism and are distinguished by natural movements. Examples of robotic hands for this purpose include the iCub (111) and HRP-4C (114) [appendix B] robots. **Figure 1.12 (g)** provides an example: an NAO robot playing with a youngster [15].

Figure 1.12: NAO robot [15]

1.11.8 Service robotics:

Service robots are designed to assist humans in a variety of jobs and are frequently meant to work in a semi- or fully autonomous mode. They are intended to function in contexts like household settings, necessitating great dependability and positive interactions with humans and the environment. Their design criteria are primarily focused on robustness, adaptability, control simplicity, and natural motion. The Ultralight Hand (227) and the MiyazakiLab Hand (107) [appendix B] are two examples of robotic hands intended for this specific application. **Figure 1.13 (h)** is an example of the DLR Justin robot (228), equipped with the DLR Hand II [appendix B] , holding a broom and cleaning the floor [15].

Figure 1.13: the DLR Justin robot [15]

1.11.9 Autonomous manipulation:

Robots developed for autonomous manipulation are typically intended for usage in controlled environments, however they have recently been deployed in unstructured environments. The former strategy is common in pick-and-place industrial applications. Versatile but strong grippers (with two or three fingers) are typically preferred. Historically, grippers (e.g., 43, 48, 52) [appendix A] used in this context have been intended for minimal human contact, usage in well-structured surroundings, and use in environments where information about the object and the robot's condition is always readily available. Robustness, adaptability, and design formalisms are among the primary needs. Some recent trends are changing this approach to autonomous manipulation, with a focus on new end effectors that can interact with the environment (and, to a lesser extent, with people) to demonstrate intrinsic adaptivity and deal with uncertainties caused by limitations in robot sensorization and perception. In this setting, requirements like robustness and safety remain mandatory. Possible applications include harvesting and garbage picking from boxes holding disorganized objects of various shapes.

Figure 1.14 (i) depicts an example: the RBO Hand, which is utilized here to execute autonomous food handling tasks [15].

Figure 1.14: the RBO Hand [15]

1.11.10 Logistics:

Logistics systems are designed to handle commodities quickly and efficiently in industrial networks. There are two approaches to end effectors in logistics: fixed, ad hoc end effectors designed for specific products and supply chains, and general-purpose systems that can handle multiple goods and are versatile. The former approach is characterized by excellent dependability and resilience but requires a perfect understanding of environmental conditions and rigorous design. The latter approach seeks systems that can interact with the environment and function in unstructured environments while maintaining a high level of resilience and efficiency. Fetch and Freight (164) [appendix B] and different SCHUNK hands (46) [appendix A] are two examples of robotic hands developed for this type of application. **Figure 1.15(j)** is an example of the Velvet Fingers end effector (122) [appendix B] handling a box [15].

Figure 1.15: of the Velvet Fingers end effector [15]

1.12 Conclusion:

In this chapter, we were able to define some basic terms related to robotics.
Essentially, robots designed for general operations, especially with the advancement of multifunctional robotic hands, give us a glimpse into a future full of exciting possibilities. By prioritizing generality,
we can expect robots to become more efficient collaborators, capable of handling a wider range of tasks across industries

Chapter 2: Components, software and tools used

2.1 Introduction:

Today, programmed electronics are progressively replacing traditional electronics. We're also discussing embedded systems or embedded computing. Its purpose is to simplify electronic schematics, minimizing the use of electronic components and so lowering the product's manufacturing costs. This results in more sophisticated and efficient systems using less space.

Electronics have grown rapidly since their inception and continue to do so now. Anyone who wishes to learn electronics may now do so: this work will teach us a combination of electronics and programming. We will discuss embedded electronics, which is a subset of electronics that combines the power of programming with the power of electronics. We will also discuss the electronic components and programming methods used for this project.

2.2 Definition of the Arduino module:

The Arduino module is a printed circuit board made of free material (control platform), with the board's plans available under a free license, as well as some board components such as the microcontroller and complementary components that are not. A programmable microcontroller can evaluate and generate electrical signals in several ways. Arduino is utilized in a variety of applications, including industrial and embedded electronics, modeling, and home automation, as well as in disciplines such as modern art and controlling robots, motors, and lights, interacting with computers, and controlling mobile devices (modeling). Each d9Arduino module includes a +5V voltage regulator and a 16 MHz quartz oscillator (or ceramic resonator in some variants). To program this board, use the Arduino IDE software [16].

2.3 Ranges of the Arduino card

There are currently over 20 variants of the Arduino module; we will highlight a few to help clarify the evaluation of this scientific and academic product:

● The Arduino NG and The Arduino end feature a USB interface for programming and using an ATmega8.

●The Arduino Mini is a smaller version of the Arduino with an ATmega168 microcontroller.

● The Arduino Nano is a compact program card with a USB interface and an ATmega168 microcontroller (or ATmega328 for recent versions).

●The LilyPad Arduino is a simplistic design for wearable applications that uses an ATmega168 microcontroller.

● The Arduino Plus NG features a d9USB interface for programming and using an ATmega168.

● The Arduino Bluetooth uses a Bluetooth interface to program an ATmega168 microcontroller.

● The Arduino Diecimila features a USB port and an ATmega168 microcontroller.

●The Arduino Duemilanove ("2009") uses the ATmega168 microcontroller (or ATmega328 for subsequent versions) and is powered by USB/DC power.

● The Arduino Mega utilizes an ATmega1280 microprocessor for more I/O and memory.

● The Arduino UNO uses an ATmega328 microcontroller.

●The Arduino Mega2560 features an ATmega2560 microcontroller with 256 KBS RAM. It also includes the new ATmega8U2 (ATmega16U2 in the USB revision 3 chipset).

• The Arduino Leonardo with ATmega3 4 chip.

●The Arduino Esplora resembles a visual gaming controller, with a handle and built-in noise, light, temperature, and acceleration sensors [17].

Figure 2.1: The Arduino UNO board [17].

As a microcontroller, we chose an Arduino Nano in our project because of its advantages. The Arduino Nano's modest size makes it ideal for projects that require a small, portable microcontroller. Additionally, the Arduino Nano is substantially less expensive than other Arduino boards, making it an appealing choice for amateurs, students, and professionals. Moreover, the Arduino Nano is simple to use and doesn't require any additional components, making it an excellent choice for novices.

2.4 Arduino Nano:

Arduino Nano is a compact, comprehensive, versatile, and breadboard-friendly Microcontroller board based on the ATmega328p, developed by Arduino. cc in Italy in 2008. It has 30 male I/O headers organized in a DIP30 format [18].

Figure 2.2: Arduino Nano [18]

2.5 Material part:

Typically, any electronic module with a programming interface is built around a programmable circuit or more.

- **The ATmega328 microcontroller:**

An ATMega328 microcontroller is an integrated circuit that combines multiple sophisticated parts on a single chip in a small space during the time of the pioneers of electronics. Today, a huge number of heavy components, such as transistors, resistors, and capacitors, may be welded together to form a little black plastic casing with a certain number of pins that can be programmed in C language. **Figure 2.3** depicts an ATmega 328 microcontroller featured on the Arduino card.

The classic component

The CMS component

Figure2.3: ATMega328 microcontroller [40]

2.5.1 **Arduino Nano Pinout**:

Arduino Nano Pinout consists of 14 digital pins, 8 analog pins, 2 reset pins, and 6 power pins. Each of these digital and analog pins has numerous roles, but their primary function is to be configured as input/output. When Arduino pins are interfaced with sensors, they serve as input pins; however, if you are driving a load, they must be used as output pins [18].

The Arduino Nano Board's pinout is shown in the diagram below [18]:

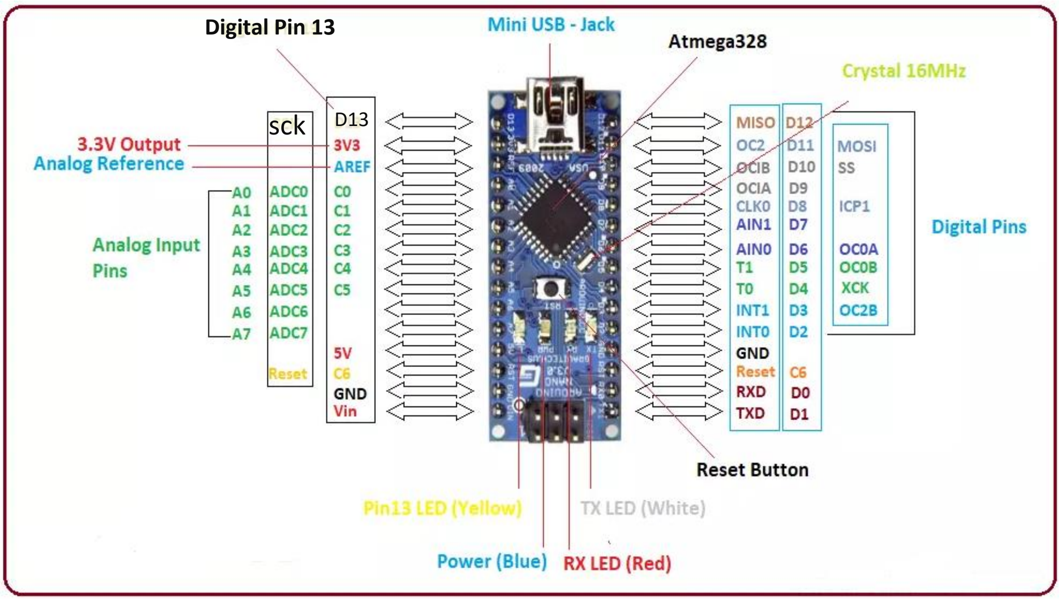


Figure 2.4: Arduino NANO pinout [18]

Each pin on the Nano board has a distinct function. We can see the analog pins that can be used as analog to digital converters, as well as the A4 and A5 pins, which can be utilized for I2C communications. Similarly, there are 14 digital pins, 6 of which are used to generate PWM [18]. Let's take a detailed look at the Arduino Nano Pinout.

2.5.2 **Arduino Nano power pins:**

● **Vin:**

This is the board's input power supply voltage when powered by an external 7 to 12 V source [18].

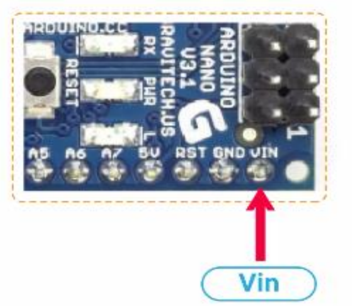


Figure 2.5: Vin pin [18]

● **5V:**

This is the board's regulated power supply voltage, which powers the controller and other components [18].

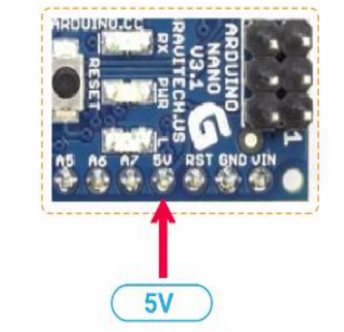


Figure 2.6: 5V pin [18]

● **3V3:**

The voltage regulator on the Nano board generates a minimum voltage [18].

Figure 2.7: 3V3 pin [18]

● **GND Pin:**

These are the board's ground pins. The board has several ground pins that can be interfaced by the need for more than one ground pin [18].

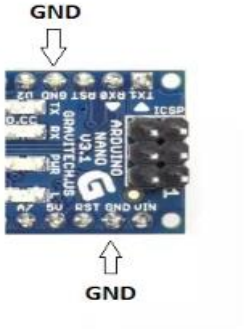


Figure 2.8: GND pins [18]

2.5.3 Arduino Nano function pins:

● **Reset Pin:**

The Arduino Nano features two reset pins on the board; setting any of these pins to LOW will reset the microcontroller [18].

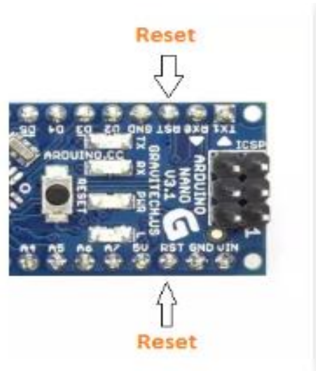


Figure 2.9: Reset pins [18]

● **Pin#13:**

A built-in LED is attached to the Nano board's pin #13. This LED is used to check whether the board is working properly or not [18].

● **AREF:**

This pin serves as a reference voltage for the input voltage [18].

2.5.4 Arduino nano I/O pins:

● **Analogue Pins:**

The circuit contains eight analog pins labeled A0 through A7. These pins are used to measure an analog voltage range from 0 to 5 volts [18].

Figure2.10: Analogue pins [18]

● Digital **Pins:**

The Arduino Nano features 14 digital pins ranging from D0 to D13. These digital pins are utilized to interface third-party digital sensors and modules with the Nano board [18].

● **PWM Pins:**

Arduino Nano contains 6 PWM pins (Pins 3, 5, 6, 9, 10, and 11). (All are digital pins.) These ports create an 8-bit PWM (Pulse Width Modulation) signal [18].

● **External Interrupts**:

Pins 2 and 3 are used to generate external interrupts, which are typically utilized in an emergency to stop the main program and issue crucial instructions. The main program resumes when the interrupt instruction is called and performed [18].

We can summarize Arduino Nano Pinout in this quick overview [18]:

Table2.1: Arduino Nano Pinout [18]

No.	Pin Number	Pin Description
1	D0 - D13	Digital Input / Output Pins.
2	A0 - A7	Analog Input / Output Pins.
3	Pin # 3, 5, 6, 9, 10, 11	Pulse Width Modulation (PWM) Pins.
4	Pin # 0 (RX) , Pin # 1 (TX)	Serial Communication Pins.
5	Pin # 10, 11, 12, 13	SPI Communication Pins.
6	Pin # A4, A5	I2C Communication Pins.
7	Pin # 13	Built-In LED for Testing.
8	D2 & D3	External Interrupt Pins.

2.5.5 Nano pinout for communication protocols:

- **Serial Pins:**

Serial pins are utilized for serial communication where:

- Pin#0 serves as the RX pin for receiving data.
- Pin #1 is Tx, which is used to transmit serial data [18].

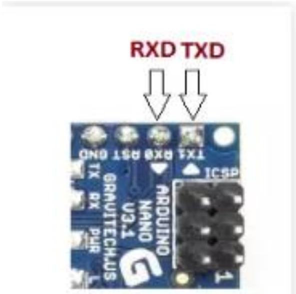


Figure 2.11: Serial Pins [18]

- **SPI Protocol:**

The SPI protocol uses four pins: 10 (SS->Slave Select), 11 (MOSI->Master Out Slave In), 12 (MISO->Master In Slave Out), and 13 (SCK->Serial Clock).
SPI is an interface bus that primarily transports data between microcontrollers and other peripherals such as sensors, registers, and SD cards [18].

- **I2C Protocol:**

I2C communication is implemented utilizing A4 and A5 pins, where A4 represents the serial data line (SDA) that transports data and A5 represents the serial clock line (SCL), which is a clock signal generated by the master device and used for data synchronization between devices on an I2C bus [18].

The following brief table summarizes Arduino's three types of communication protocols [18]:

Table2.2: three types of communications protocols [18]

No.	Communication Protocols	Description
6	Serial Port	1 (Pin#0 is RX, Pin#1 is TX).
7	I2C Port	1 (Pin#A4 is SDA, Pin#A5 is SCL).
8	SPI Port	1 (Pin#10 is SS, Pin#11 is MOSI, Pin#12 is MISO, Pin#13 is SCK).

2.5.6 Arduino Nano specifications:

Each pin on the Nano board has a distinct function. where We can see the analog pins that can be used as analog to digital converters, as well as the A4 and A5 pins, which can be utilized for I2C communications. Similarly, there are 14 digital pins, 6 of which are used to generate PWM. The Arduino Nano has a maximum current rating of 40mA, thus the load attached to its pins should not drain more than that. The Arduino Nano comes equipped with a 16 MHz crystal oscillator. It is used to generate a clock with accurate frequency using a steady voltage.

The flash memory size is either 16KB or 32KB, depending on the Atmega board. For example, the Atmega168 has 16KB of flash memory, and the Atmega328 has 32 KB. Flash memory is used to save code. The bootloader takes up 2KB of total flash memory. The Arduino Nano contains 2KB of SRAM memory. and it features 1KB of EEPROM memory [18].

We will summarize the specifications of the Arduino Nano board in The following table [18]:

Table 2.3: the specifications of the Arduino Nano board [18]

Microcontroller	Atmega328/Atmega168
Operating Voltage	5V
Input Voltage	7 - 12 V
Digital I/O Pins	14
PMW	6 Out of 14 Digital Pins
Max. Current Rating	40mA
USB	Mini
Analog Pins	8
Flash Memory	16KB or 32KB
SRAM	1KB or 2KB
Crystal Oscillator	16 MHz
EEPROM	512byte or 1KB
USART	Yes

2.5.7 Arduino Nano programming :

A microcontroller-based acquisition card, such as ours, must have a programming interface. Arduino's open-source programming environment is available for free download (Mac OS X, Windows, and Linux).

- **Programming Environment:**

The Arduino board programming software functions as a code editor (a language similar to C). Once the program is typed or modified on the keyboard, it is transmitted and saved to the card via the USB connection. The USB wire not only powers the device but also transports data from the Arduino IDE software [20].

- **General program structure (Arduino IDE):**

The Arduino IDE (integrated development environment) is software that allows you to program Arduino or other compatible microcontroller cards.

It mostly brings together into a single tool:

- A text editor that allows you to enter the program's source code.
- A compiler to convert source code into machine language.
- A card manager for microcontroller drivers.
- A library manager. Installation of libraries or programs required for the operation of various modules (screen, sensor, etc.) or functionalities. It also enables you to track the versions.
- A function for uploading programs to microcontrollers.
- A serial port monitor for monitoring program execution status [21].

- **IDE interface:**

The text editor takes up the vast majority of the IDE window. The Arduino IDE interface is composed as follows, from top to bottom:

- Drop-down menus
- Quick access buttons
- File tabs for the project
- Text editor with source code
- Current operation information
- Compilation details

- Status line mentioning the selected microcontroller [21].

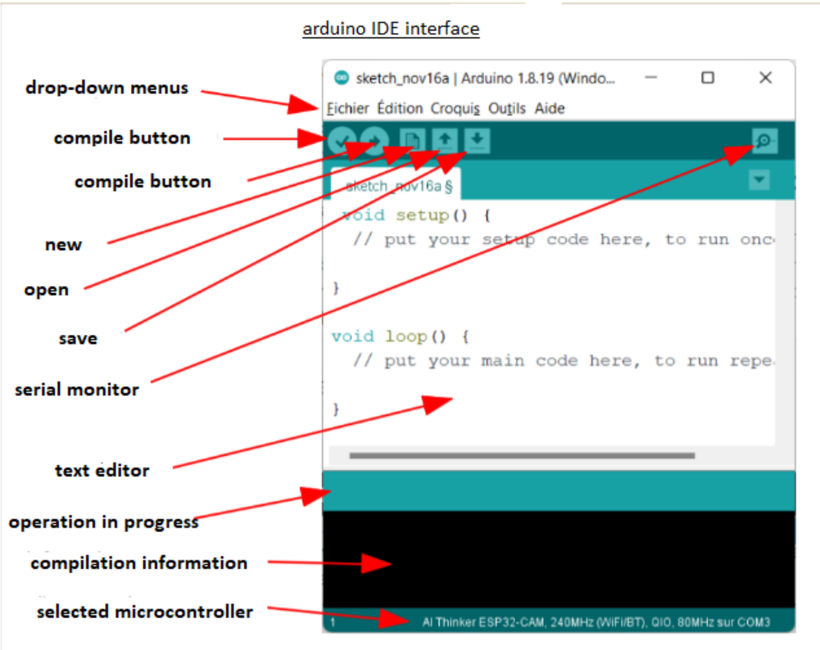


Figure2.12: Arduino IDE interface [22].

- **General principle for programming a microcontroller**:

After launching the IDE:

1. loading the source code in the IDE text editor: this is the program that the microcontroller will execute in a language that the developer can comprehend (C++);
2. Connect the microcontroller to the USB port.
3. Choose the appropriate driver for the attached microcontroller (the IDE must recognize the microcontroller and its communication protocol).
4. compilation of the source program: the generated code is no longer understood by the developer and only by the microcontroller;
5. Upload machine code to the microcontroller via USB (serial port);
6. Disconnect the microcontroller from the computer and install it in the electronic assembly [21].

2.6 servo motor:

2.6.1 What is a servomotor ?

A servo motor is a self-contained sophisticated electromechanical device that efficiently and precisely spins machine or robot components. A servo motor may move slowly while delivering significant torque with high precision and accuracy. This is why it is used in robot design, industrial automation, and control surface positioning in remote control vehicles, among other applications [23].

Figure 2.13: Servo Motor [41]

As previously stated, a servomotor is essentially a direct current motor that is controlled in position by a position sensor (usually a potentiometer) and an electrical circuit within the motor. They are controlled by a control wire and powered by two other wires: the first is connected to the positive power source (+5 or +6 V, depending on the servomotor), and the second is connected to the ground (GND). The control signal is a pulse width modulation (PWM) kind.

By varying the duty cycle of this signal, we communicate to the motor the desired position within a range of feasible positions, typically [0.180°]. The frequency of the pulse width modulated signal is normally around 50 Hz (30 Hz for some models), with pulses lasting 1 to 2 ms [24], as seen in fig2.13. Changing the servo motor gearing allows for broader ranges of motion [25].

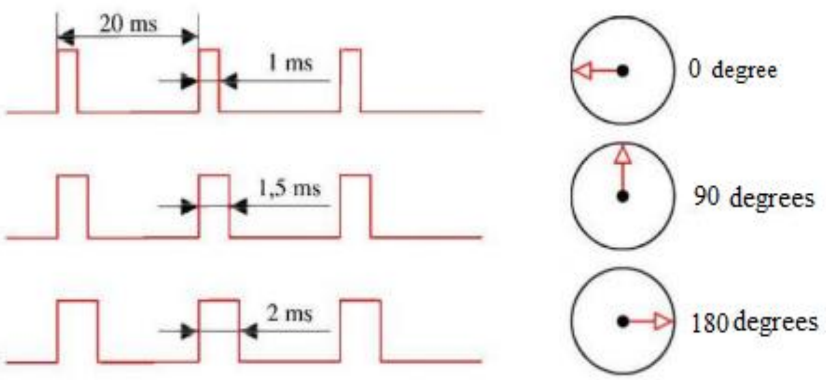


Figure 2.14: Example of a servomotor's position signal [25].

2.6.2 What are servo motors used for?

As previously stated, servo motors are used in robotics, industrial automation, and other applications. A servo motor is used in a variety of devices and systems, including the following:

- ● A radio-controlled model automobile, airplane, or helicopter.
- ● Rotating a shaft connected to the engine's throttle.
- ● Controls the speed of a fuel-powered vehicle or aircraft.
- ● Servos are used in electronic gadgets like DVD and Blu-ray Disc players to extend or retract disc trays.
- ● In autonomous vehicles, servos control the vehicle's speed. The list goes on. In robotics, servo motors are essential components [23].

2.6.3 Types of Servo Motor:

Servo motors come in many sizes and forms. The three major types of servo motors are:

- ●Positional rotation servo motor.
- ●Continuously rotating servo motor
- ●Linear servo motors [23].

- **Positional rotation servo motors:** It is known as a position rotation servo because the motor's shaft rotates and stops at a specific position that it cannot exceed. This sort of servo motor can rotate from 0º to 180º. Some positioning servos may rotate up to 270º, such as the DSS M15S Servo [23].

Figure2.15: 270 º DSS M15S Servo [23]

Positional Rotation Servo motors have a physical rotation-stopping mechanism that prevents the motor from spinning further when the rotating sensor (such as the potentiometer) reaches its limit to avoid damage. Some servo motors use a potentiometer as a feedback sensor. It functions as a voltage-based analog distance and direction sensor, also known as a "Resolver". When a digital rotary sensor is utilized, it is an "encoder" [23].

Figure 2.16: SG90 servo motor (positional rotation servo motor)[23]

- **Continuously rotating servo motor:** This servo motor can rotate more than 360º, as the name implies. Now, in the positional rotation servo motor, we provide a PWM signal with a period of 20mS to regulate the servo motor's movement to a specific place. The table below summarizes the three angular positions in which the positioning rotation servo motor can be moved using ON and OFF times of the PWM signal [23]:

Table 2.4: PWM information for controlling a servo motor [23].

PMW ON time (mS)	PMW OFF time (mS)	Angle (Degrees)
1.0	19.0	0
1.5	18.5	90
2.0	18.0	180

However, with a continuous rotation servo motor, this pulse information does something different: instead of moving the servo shaft to a specific point, the pulses regulate the speed and direction of the motor. The control works as follows: when the servo is turned on for 1.5mS, the shaft moves to the 90º position, which is half of the motor's position. For continuous rotation servo motors, the 1.5mS PWM signal keeps the servo steady. Nevertheless, transmitting a pulse with an ON time of 1.0mS causes the servo to turn clockwise at maximum speed. Sending a pulse with an ON time of 2.0mS will cause the servo to turn anticlockwise at maximum speed. So, to limit speed in either direction, we set the ON timings to 1.0mS for clockwise motion and 2.0mS for anticlockwise motion [23].

Figure 2.17: Continuous rotation Servo Motor [23]

Continuous rotation servo is typically utilized in radar dishes or as a driving motor in mobile robots.

- **Linear Servo Motor:** This type of servo motor uses a unique gear system to convert circular motion to linear motion; it is also known as a linear actuator. As the name says, it is a translational servo motor. It is similar to the positional rotation servo motor in that it has restrictions that it cannot exceed. It can travel back and forth inside these boundaries. This sort of motor is commonly found in jacks, industrial manipulators, robot actuators, and automated door locks [23].

Figure 2.18: Linear servo motor [23]

2.7 Resistors :

A resistor is a two-terminal electrical passive element that offers opposition to current in a circuit. Resistance quantifies the extent to which current flow is impeded, and higher resistance offers more hindrances to current flow. Resistors, such as thermistors, are obtainable in a variety of kinds and values, from fractions of Ohm to tens of millions of Ohms. . A resistor's primary role is to provide opposition to the electron flow. Current is constrained or caused to drop voltage in the circuit to which it is connected. They are passive elements that do not supply energy but rather waste it in the form of warmth where current is passing. According to Ohm's law, the voltage across a resistor is directly proportional to the current passing through it when resistance is acting as the constant of proportionality [26]

Figure 2.19: Resistors [41]

2.7.1 Types of Resistors :

Resistors come in a variety of forms, each tailored to a certain use or environment. There are two main types:

Fixed Resistors:

These resistors have a fixed resistance value. They are the most common type of resistor, with several variations including carbon composition, metal film, and wire-wound resistors.

Variable resistors:

Variable resistors are resistors with adjustable resistance values. This category comprises potentiometers and rheostats, which are frequently used for tuning and calibration in electrical circuits. [27]

2.7.2 Resistors in the circuit:

Resistors can be wired in two ways in a circuit: series and parallel. In a series circuit, the total resistance (RTOT) equals the sum of all individual resistances. In a parallel circuit, the reciprocal of the overall resistance equals the sum of the reciprocals of the individual resistances. These topologies allow for fine-tuning of the overall resistance of a circuit, resulting in more precise control of current flow [27].

2.7.3 Color Coding and Ohmic Values:

Color bands on resistors are commonly used to indicate resistance values. This color coding technique employs a standard palette of colors to represent integers, which, when translated using a color chart, show the resistor's resistance value, tolerance, and, in certain cases, dependability or failure rate. This allows consumers to see the resistance value at a glance without having to measure it. In our project, we used resistors with 10KΩ [27].

The table below displays significant values, decimal multipliers, and tolerance for various resistor color codings.

Color	Numeric Value	Multiplier	Tolerance	Temperature coefficient
BLACK	0	1Ω		250
BROWN	1	10 Ω	±1%	100
RED	2	100 Ω	±2%	50
ORANGE	3	1K Ω		15
YELLOW	4	10 Ω		25
GREEN	5	100 Ω	±0.5%	20
BLUE	6	1M Ω	±0.25%	10
VIOLET	7		±0.1%	5
GREY	8			1
WHITE	9			
GOLD			±5%	
SILVER			±10%	

Figure 2.20: resistors color code calculator [42]

2.7.4 Applications of Resistors:

Resistors are widely used in electronic circuits, providing a range of roles due to their intrinsic qualities. Here are some of their major applications:

●**Current Limiting:** Resistors are widely used to limit the current passing through other circuit components to protect them from harm.

●**Voltage Division:** A series of resistors can be used to split voltage into predictable amounts in a circuit, which is a necessary function in many electronic devices.

●**Heat Generation:** Certain types of resistors, such as heating elements and filament bulbs, take advantage of resistors' heat dissipation properties.

●**Signal Conditioning:** Resistors serve an important role in signal conditioning, such as filtering and attenuation, to maintain signal integrity [27].

2.8 DC Motors:

Electric brushed motors are utilized in a wide range of sectors, including electrical propulsion, cranes, paper presses, and steel rolling mills. They operate by transporting energy from the stator to the armature, with brushes in the stator delivering current to the rotor. Carbon brushes are part of the stator, which carries current to the rotor, resulting in sparks from power drills. But what are carbon brushes, and what do they do? And what is a brushed motor? How do brushed motors work? [28].

2.8.1 What is a carbon brush?

Carbon brushes are sliding contacts used in brushed motors and generators to efficiently carry electrical current. It is composed of one or more carbon atoms and contains shunts and terminals. Brushes are classified into five brush-grade families: carbon graphite, electrographite, metal graphite, silver graphite, and carbon composite. They function on the permanent component of a motor, ensuring that power is transmitted without sparks. They come in a variety of shapes and sizes, and their spring-loaded design ensures seamless power transmission. Manufacturers often sell brushes that are suitable for portable power tools and have dimensions in millimeters or inches [28].

Figure 2.21: DC motors carbon brushes [43]

2.8.2 What is a Brushed DC motor?

Brushed DC motors are a type of DC motor used in motion control. Brushed motors are more common than brushless motors. They are made up of a stator, armature, commutator, and brushes. The stator is a magnet-encased enclosure, the armature is a rotor containing electromagnets, and the commutator is a metal ring linked to the armature shaft. Both types can greatly improve project efficiency [28].

Figure 2.22: Brushed DC motors [44]

2.8.3 What do brushes do in electric motors?

When energy is given to the electromagnet in the armature of a brushed DC motor, it creates a magnetic field that attracts and repels the stator magnets. The armature revolves in a 180-degree circle. To keep the electromagnet spinning, the poles must be reversed. The carbon

brushes are responsible for polarity shifts. They make contact with the armature's two revolving electrodes. The magnetic polarity of the electromagnet reverses as it revolves [28].

2.8.4 Benefits of a Brushed Motor DC :

- In general, building expenses are minimal.
- Rebuilding is a frequent method for extending the life of a product.
- They are simple and inexpensive controllers.
- There is no need for a controller at fixed speeds.
- They are suitable for usage in tough operational situations [28].

2.9 Potentiometer:

A potentiometer is a variable resistor having three terminals, one of which is linked to a slider that moves along a resistor track and is terminated by the other two terminals. This technology allows for the collection of a voltage between the terminal attached to the cursor and one of the two other terminals, which is dependent on the position of the cursor and the voltage to which the resistance is subjected [29].

Figure2.23: different types of potentiometer [45]

We have used a horizontal potentiometer for our project which we can also call Trimpot.

2.9.1 what is a Timpot:

A trumpet, also known as a trimmer potentiometer, is a tiny potentiometer used to tweak, tune, or calibrate circuits. They are usually installed on printed circuit boards and adjusted using a screwdriver. Carbon composition and cermet are often utilized materials. Trimpots are intended for occasional changes and can reach high resolution with multi-turn setting screws. They have a life of 200 cycles [30].

Figure2.24: Timpot Potentiometer [46]

2.9.2 What is the difference between a Trimpot potentiometer and a potentiometer?

The main differences between a potentiometer and a trimpot are size, application, and intended use. Potentiometers are usually larger and meant for user-adjustable controls, while trimpots are smaller and feature precise, fixed adjustments made during manufacturing or troubleshooting.

2.9.3 Principle and Operation of Potentiometers:

A potentiometer operates based on Ohm's Law, which states that the voltage across a resistor is proportionate to the current flowing through it. A potentiometer's resistance can be manually modified, resulting in changes in current and voltage. A potentiometer has three terminals: the wiper (the adjustable contact that glides along the resistance element) and the two ends of the resistance element itself [31].

- The first terminal connects to the voltage source.
- The second terminal, known as the wiper, connects to the output.
- The third terminal connects to the ground, or lower potential end of the voltage source.

2.9.4 Types of Potentiometers :

Potentiometers are classified into several types based on their intended use. Here, we'll talk about three of the most popular types:

- Linear Potentiometers: Also known as linear taper potentiometers, these include a resistance element that equally distributes the resistive value throughout the length of the track.

● Logarithmic Potentiometers: Also known as audio or log taper potentiometers, these resistive values are distributed using a logarithmic curve. They are most commonly utilized in audio applications.

● Digital Potentiometers: These potentiometers can perform the same functions as traditional potentiometers but are operated electronically rather than manually [31].

2.10 H-bridge L293D:

The L293D devices are triple-high current half-height drivers. The L293D is designed to deliver bidirectional drive currents of up to 600 mA at voltages ranging from 4.5 V to 36 V. Both devices are intended to power inductive loads like relays, solenoids, DC and bipolar stepping motors, and other high current/high voltage loads in positive supply applications. Each output contains a complete totem pole drive circuit, including a Darlington transistor sink and a pseudo-Darlington source. Drivers are enabled in pairs: 1, 2EN enables drivers 1 and 2, and 3, 4EN enables drivers 3 and 4. L293D is designed to operate from 0°C to 70°C [32].

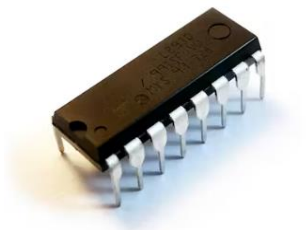


Figure2.25: L293D [47]

2.10.1 The L293D features:

The L293D features are:

● Wide Supply Features include a voltage range of 4.5 V to 36 V and a separate input logic supply.

● Internal ESD protection.

● High Noise- Immunity inputs

● Output Current: 1 A per channel (600 mA for L293D).

● Peak output current: 2 A per channel (1.2 A for L293D).

● Output clamp diodes for inductive transient suppression (L293D) [32].

2.10.2 Total L293D Diagram:

The graphic below depicts the L293D Diagram. The graphic has all the required information and is self-explanatory [32].

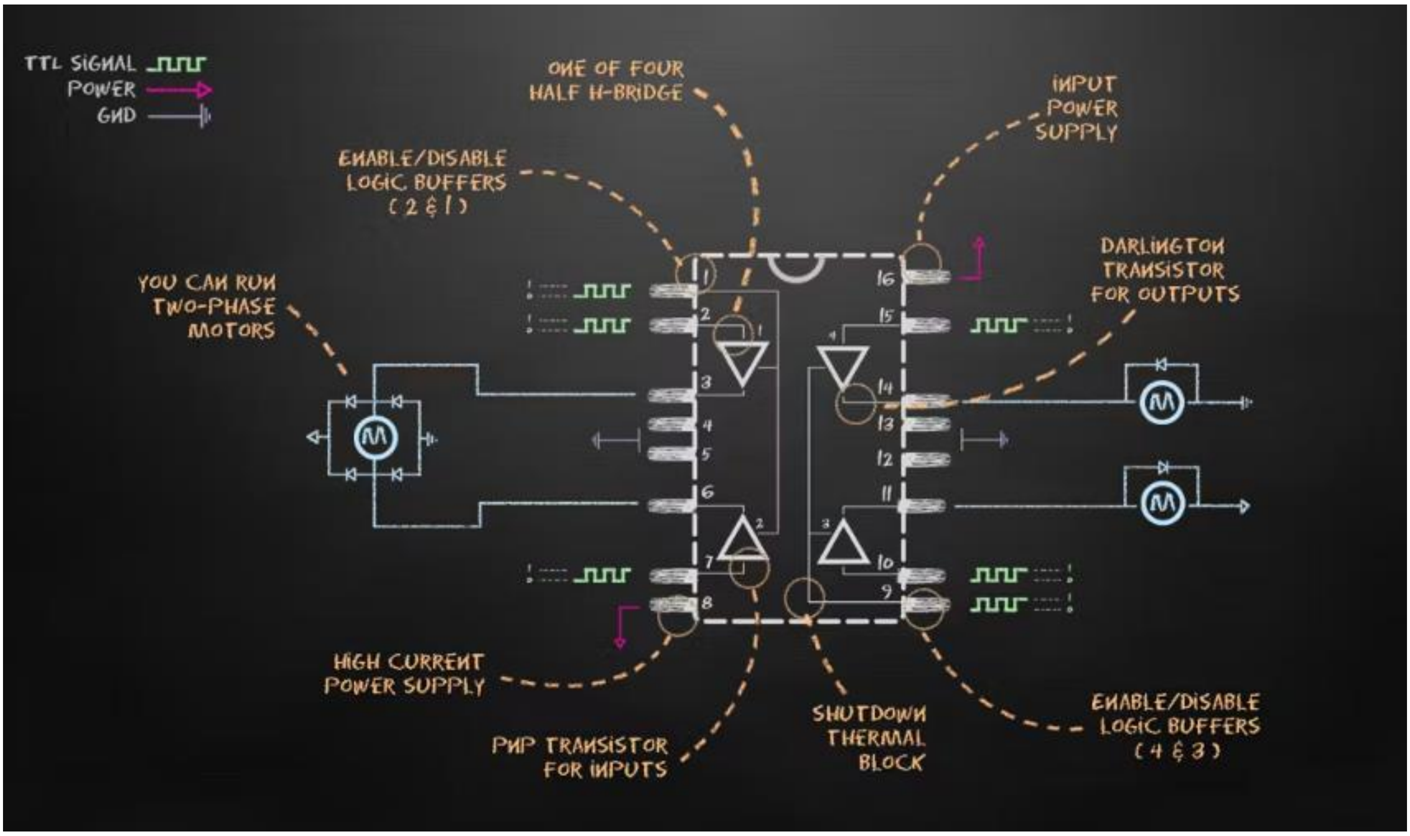


Figure 2.26: L293D Diagram [31]

2.10.3 Darlington transistor :

In electronics, a Darlington transistor (also known as a Darlington pair) is a compound device of a specific design composed of two bipolar transistors coupled so that the current amplified by the first transistor is amplified further by the second. This design provides a significantly larger current gain than each transistor individually. Developed in 1953 by Sidney Darlington [32].

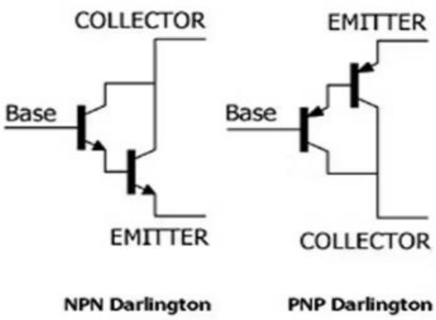


Figure 2.27: Darlington transistor [32]

The Darlington Transistor symbol clearly shows how two transistors are coupled. The photos below demonstrate two types of Darlington transistors. On the left side is NPN Darlington, while on the right side is PNP Darlington. We can see that NPN Darlington consists of two NPN transistors, whereas PNP Darlington comprises two PNP transistors. The first transistor's emitter is connected directly across the base of another transistor, and the two transistors' collectors are connected. This design applies to both NPN and PNP Darlington transistors. In this design, the pair of Darlington transistors provides significantly higher gain and amplification capabilities [32].

2.10.4 L293 & L293D: What's the Difference?

The letter D in the name signifies an internally fitted diode, which implies we don't need to install any additional components. This is the main difference. If you look at the datasheet, you may see some other differences, such as output current. Also, the continuous current in L293 outputs is 1A, while in L293D outputs it is 600 mA. The peak current in L293 outputs is 2 amps, while in L293D outputs it is 1.2 amps [32].

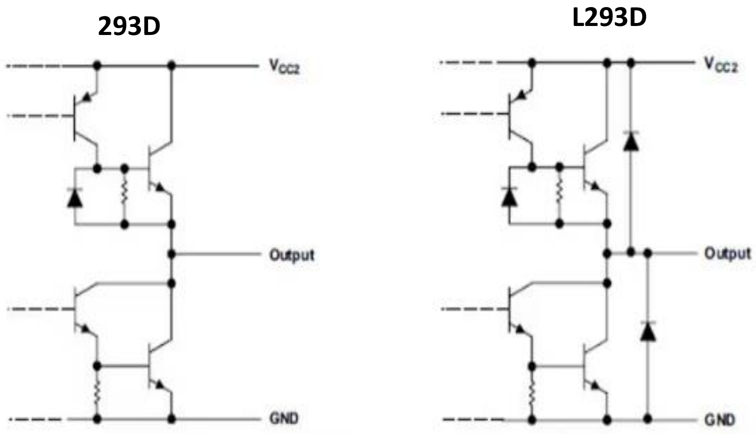


Figure2.28: schematic of outputs for the L293 and L293D [32]

2.11 The LM358 IC:

The LM358 integrated circuit is an excellent two-channel op-amp that is low in power and simple to operate. It was developed and introduced by National Semiconductor. It is made up of two internally frequency-adjusted, high-gain, independent op-amps. This IC is specifically designed to run from a single power supply across a wide voltage range. The LM358 IC is available in a chip-sized form, and its applications include standard op-amp circuits, DC gain blocks, and transducer amplifiers. The LM358 IC is a good, conventional operational amplifier that will meet your demands. It can handle a 3-32V DC supply and a source of up to 20mA per channel. in our project, we utilized it as a comparator. [33]

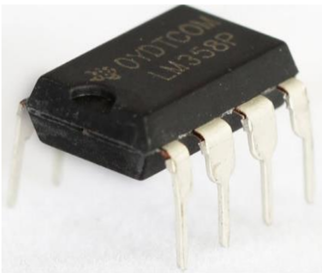


Figure 2.29: LM358 IC [48]

2.11.1 Pin Configuration of LM358 IC:

The pin diagram of LM358 IC consists of eight pins, where:

- Pins 1 and 8 are o/p of the comparator.
- Pins 2 and 6 are inverting i/ps.
- Pins 3 and 5 are non-inverting I/Ps.
- Pin 4 is the GND terminal.
- Pin 8 is VCC+. [33]

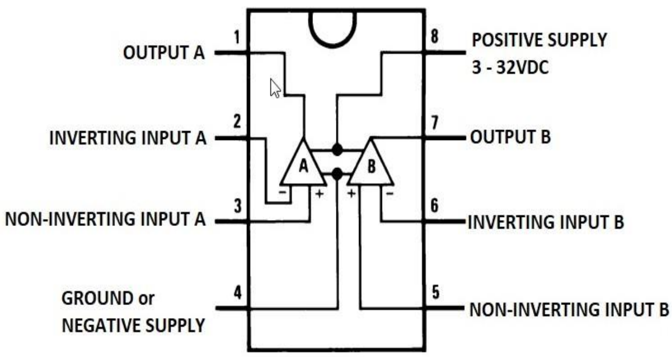


Figure 2.30: LM358 Dual Op Amp Top view[49]

2.11.2 Features of the LM358 IC:

The features of the LM358 integrated circuit are:

- Internally, it has two op-amps and frequency rewarded for unity gains.

-The huge voltage gain is 100 decibels.

- The broad bandwidth is 1 MHz.
- The variety of power supplies includes both single and multiple power supply.
- The range of a single power supply is 3V to 32V.

- The range of dual power supply is from + or -1.5V to + or -16V.
- The supply current drain is low (500 μA).
- 2 mV low i/p offset voltage
- Common mode i/p voltage range includes ground.
- The power supply voltage and differential i/p voltages are comparable.
- The output voltage swing is considerable.[33]

2.12 Conclusion:

This chapter thoroughly described the project's essential components, including the microcontroller, Lm358, and L293d, outlining their functionality and features. This thorough investigation is a significant resource not only for this project but also for future endeavors. Having a comprehensive grasp of these components from the start simplifies the development process and allows for informed decision-making throughout the project lifecycle. This built knowledge base not only ensures the present project's success but also allows for the more efficient and effective deployment of these components in future initiatives.

Chapter 3: Experiments

This chapter outlines the methods and concerns for this project. It begins with a review of the project's flow, followed by the system design approach, techniques, and tools used in this effort. A cost-effective, appropriate, and high-quality material selection is critical to a project's success and perfection. To create properly functioning circuits, it is critical to select the most appropriate components with the exact specifications. The concept applies to both hardware assembly and software development.

3.1 Introduction:

To begin any project, a lot of essential information must be acquired. Researching and doing a literature review yields not just a wealth of information, but also understanding about current technology. The majority of project-related knowledge can be gathered via searching the internet, reading books, and consulting the supervisor in charge. Research is one of the most critical stages in ensuring the project's success.

This research can provide a wealth of information and expertise about which methods will and will not succeed. At this phase, the idea of creating an ideal project emerges. This project requires the selection of an appropriate comparator (op amp) module for the system, as well as additional components. like to obtain the desired outcome, the most appropriate comparator module with the given range and other parameters must be carefully selected.

3.2 Steps to create electrical patterns:

This organization chart allows us to summarize the processes of creating any electronic diagram.

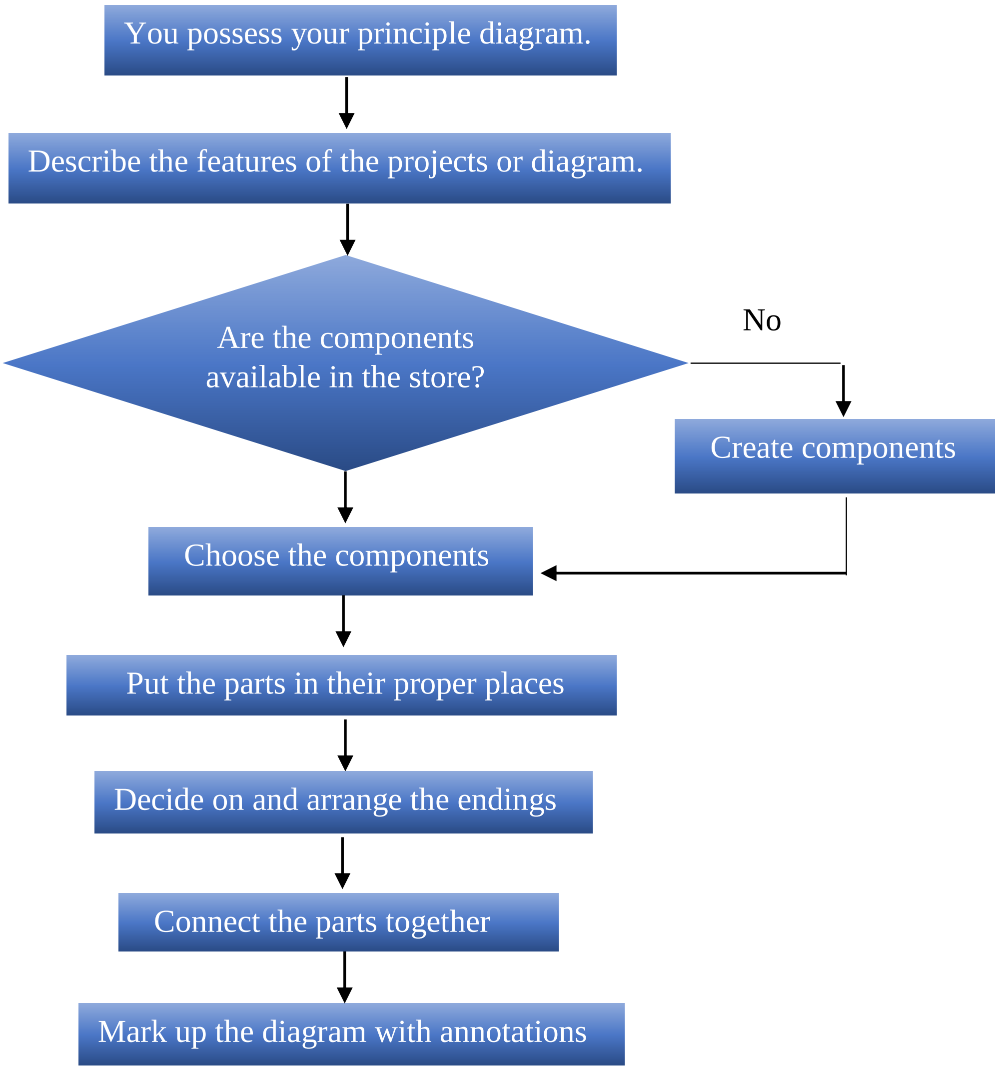


Figure3.1: Diagrams' organizational system showing the stages of seizure [33]

In our project, the robotic hand consists of two parts, part one and part two. part one controls the moving of the finger in a basic way that goes up and down (figure 3.2), whereas other projects did this in their robotic hand. Still, the second part was our challenge of moving the upper part of the finger which we wanted to fold it's self the same as our real upper finger part (figure 3.3), knowing that the other projects in this part, put a thread tied where he pulls it (figure3.4) as we are showing more in those figures:

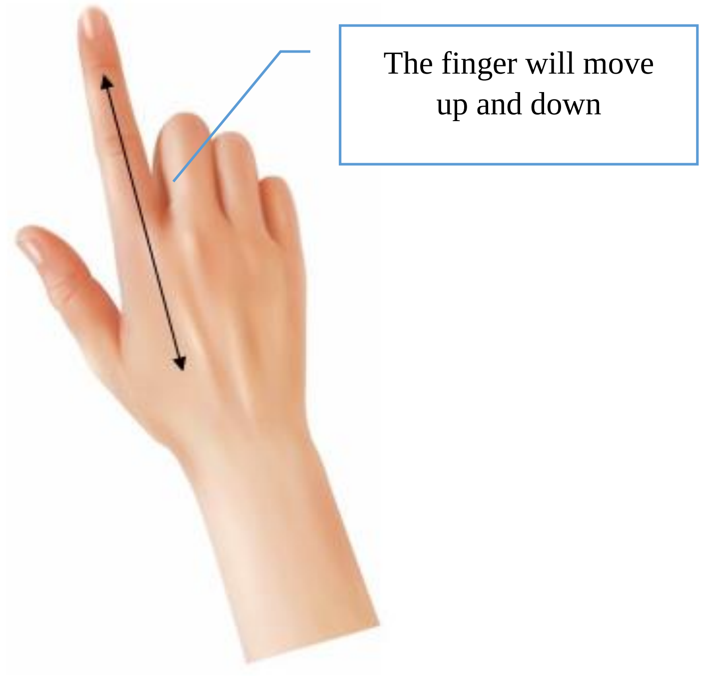


Figure 3.2: An image showing the area of the first part

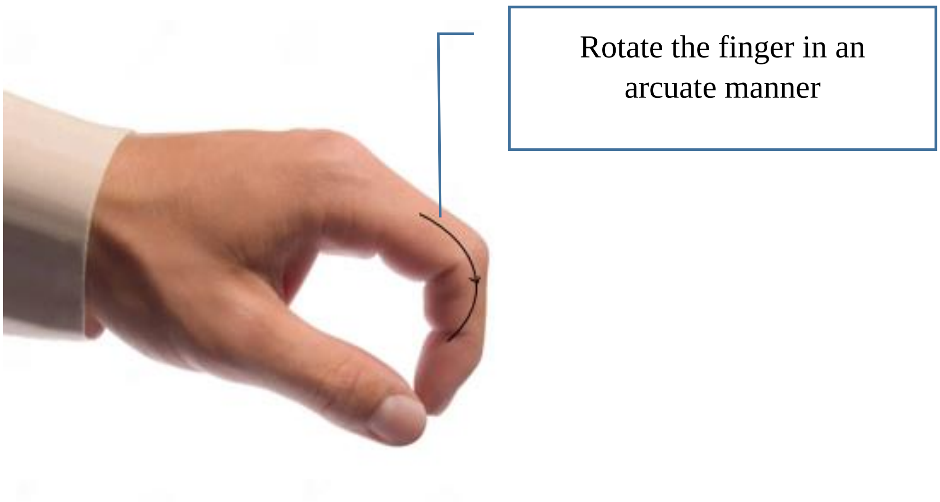


Figure 3.3: An image showing the area of the second part

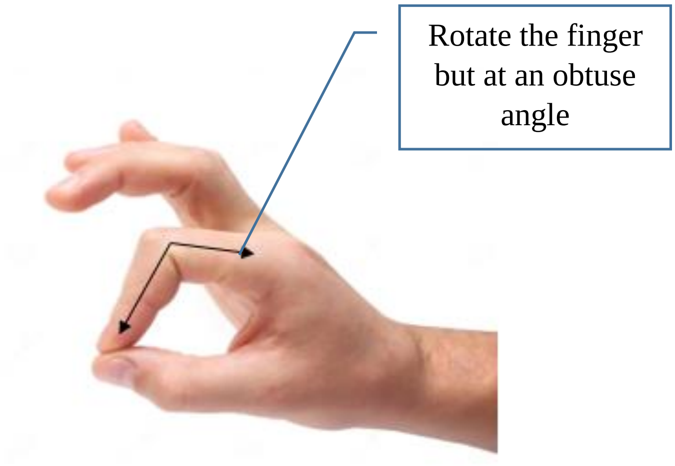


Figure 3.4: An image showing how other projects work

3.3 Arduino- servo motor controlled by potentiometer:

To achieve the first part, we used the circuit with the components below:

To explain more, we are going to describe the process in an organizational chart for just one finger so the process will repeat 3 times:

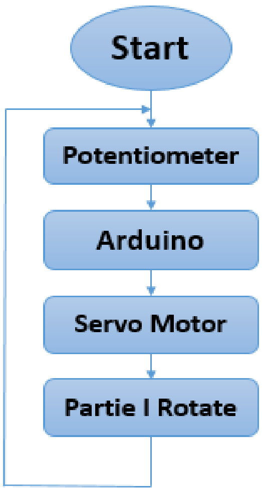


Figure 3.5: an organizational chart explaining the work process of the circuit

The organizational chart above talks about the process of the first part of our robotic finger. The system's core is an Arduino Nano microcontroller whereas The Arduino controls a servo motor based on the position of a potentiometer through a simple process involving analog input and PWM output. The potentiometer, a variable resistor, changes its resistance as its knob is turned, altering the voltage read by the Arduino's analog input pin. The Arduino continuously reads this changing voltage and converts it into a digital value ranging from 0 to 1023. Using the map function, this value is scaled to a range of 0 to 180, corresponding to the angle of the servo motor. Finally, the Arduino sends a PWM signal to the control pin of the servo motor, causing it to move to the desired angle. This setup allows for real-time and precise control of the servo motor by simply adjusting the potentiometer, creating an intuitive and interactive system for various applications.

We simulated the circuit on Tinkercad where the code on the Arduino IDE to clarify more here are the figures below:

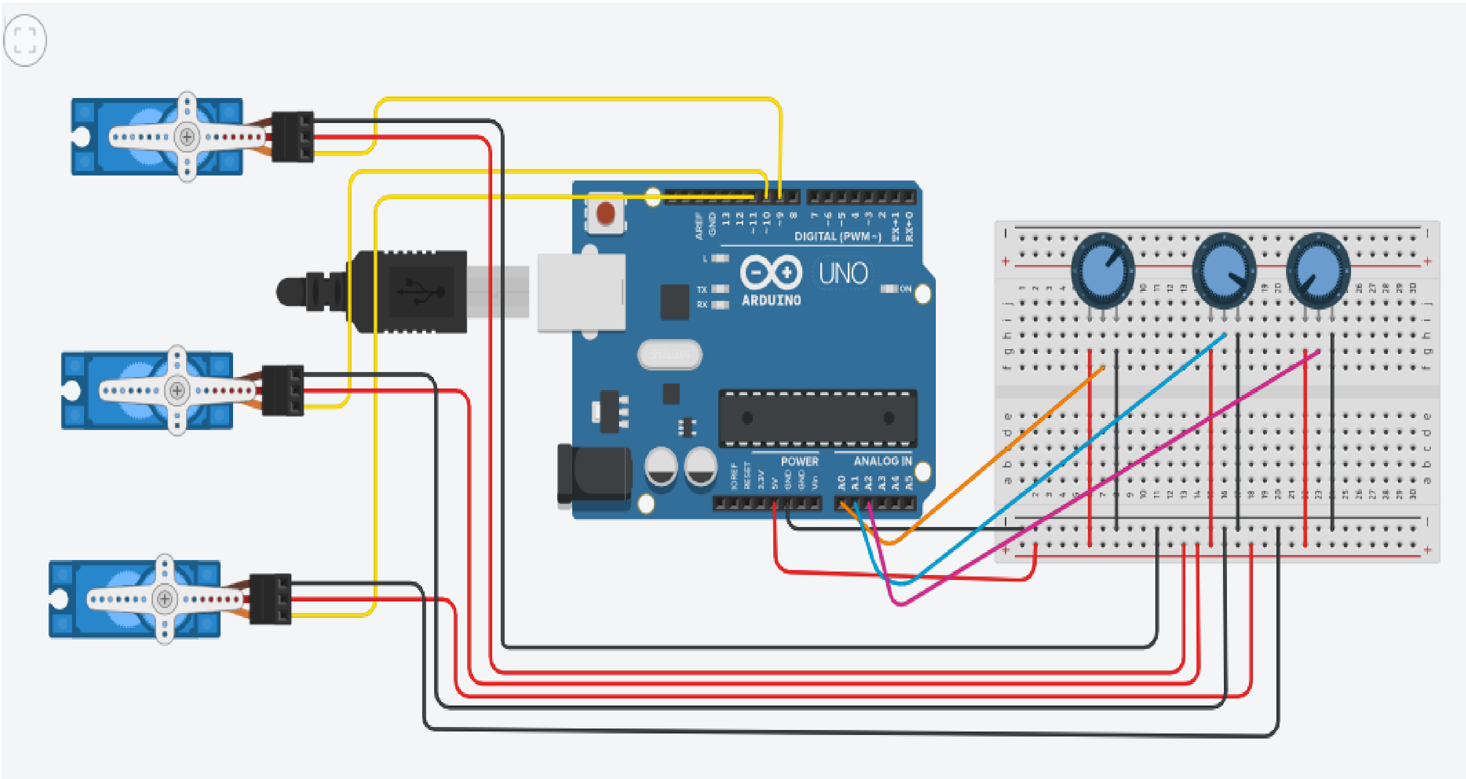


Figure 3.6: TINKERCAD simulation explains the circuit of the process

In the TINKERCAD simulator’s platform, we didn’t find Arduino Nano in its component so we utilized Arduino Uno which gives the same process and results

Now let's move to the second part of our project which is the second part of the fingers, the upper finger part. As we mentioned before this part was a challenge for us, as we had a lot of experiments to try to get the point which is to make an upper part of the finger that rotates approximately at the same degrees as our finger, with high accuracy, without vibration and reducing noise. Whereas other projects, as we said before, often pulled that area with wires for example.

We will mention the experiments that We conducted here in this part to help others, prevent redundancy, and enhance reproducibility to provide a comprehensive view of the research process, including obstacles we faced and lessons that we learned, which is essential for validating and building upon scientific knowledge, including the exchange of failed experiments, which promotes a culture of openness and transparency in science. It supports the spirit of open science, where all research contributes to collective learning and progress regardless of outcome.

3.4 First try with Arduino-ADC and ADC:

3.4.1 What is an Arduino ADC?

An Arduino ADC (analog-to-digital converter) is an integrated circuit that converts analog signals into digital signals for use by microcontrollers and computers. It accomplishes this by measuring the input signal's voltage and converting it into a computer-readable or interpretable value.

The resolution of an Arduino ADC can range from 8 bits to 16 bits, depending on the model utilized. This indicates that the output range will be 0-255 for 8-bit converters and 0-65535 for 16-bit converters. A higher resolution allows for more precise measurements of the analog signal being transformed, here we utilized ADC with an output range of 8-bit. [34]

Features of the Arduino ADC: The Arduino ADC has many features. We will mention some of the features that we took into consideration in our project [34**]**

- **Arduino Analogue Pins :**

The Arduino can read analog signals using its ADC. An ADC is an integrated circuit that converts a continuous physical quantity, such as voltage, current, or pressure, into a digital or binary value. Each Arduino's analog pin can read up to five volts and convert it to a 10-bit value ranging from 0 to 1023. [34].

3.4.2 Resolution :

The resolution of an ADC determines how precise its measurements are. The amount of bits used to represent each sample determines the resolution, which on Arduino boards ranges from 8 to 12 bits. A higher resolution indicates more exact measurements and accuracy. [34]

3.4.3 Benefits of using Arduino ADC:

The primary advantage of utilizing an Arduino ADC is that it simplifies converting analog to digital. The ADC can read an analog voltage from sensors like the potentiometer in our project, which then transforms it into a digital value that can be used for additional processing of the motor control. On the other hand, since we are using the servo motor, ADC has another benefit that can help us, which is The quick sampling rate of the Arduino ADC, it enables precise control over the servo motors that are needed for quick input sampling.

In our study, we conducted numerous trials to obtain suitable results, which we shall discuss in this chapter. Initially, we intended to use the Arduino ADC as depicted in Figure 3.7. We connected the potentiometer sensor to the Arduino's Analog-to-Digital Converter (ADC) and then linked it to the motor. The potentiometer sensor sends its analog signal to the ADC, which converts it into digital values. To accurately detect finger movements, we compared each small finger movement with the voltage changes detected by the sensor and the resulting bit change from the ADC. When the sensor values aligned, the microcontroller sent a command to stop the motor. Unfortunately, the ADC's built-in threshold limitations caused inaccurate readings, affecting the overall accuracy of our system.

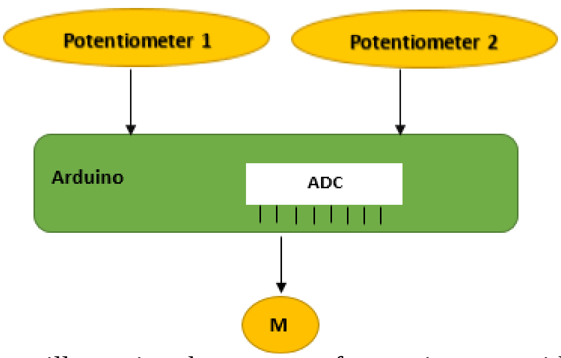


Figure 3.7: A diagram illustrating the process of potentiometer with Arduino-ADC

Therefore, while maintaining the same concept, we decided not to use the Arduino ADC. Instead, we used an external ADC in the form of an 8-bit integrated circuit, where we connected each sensor to the integrated circuit and compared them to microcontrollers as shown in Figure 3.8 below. As a result, the noise decreased but not completely, sampling was still noisy. In another case, we asked ourselves a question: What makes it possible for data to be transferred? We figured out that the Arduino needs to detect any changes in the sensor readings and keep track of these changes constantly by running a loop.

To make this process easier, We choose to use two external ADCs to make the system more stable and precise, one of the ADCs will play the role of the feedback results that come from a potentiometer and drop its values to the ADC to convert it to a binary word. The hand sensor also will give us the analog values from the potentiometer of the hand gloves and drop them into the second ADC, as we planned the microcontroller will compare both of the binary words, and the treatment will be as follows, the values will be changed from the LSB to MSB. If the first word (starting from LSB) is greater than the next word (means first value + one value) that means the finger is going high, if the difference is positive we call the rotation of the finger a positive rotation if the difference is negative than the rotation is in the opposite direction. How the MIC will detect if the value has changed already or not? The division of the bit in the form of the frame allows the microcontroller to check the LSB every time to see if it changed or not, for that we created a frame that can simplify the comparison of the values and detect the direction. The side problem we had was that the quantification was not that perfect because the binary output was balancing between two values that could have the same analog value approximately as a result the final binary output was not as stable as we wanted it, so we set two binary words for one analog value instead one for each analog value. To avoid the miss quantification, and reduce the sensitivity it increases the stability of the dc motor as a result the stability of the finger. Unfortunately, the two values for one analog value were not enough so we added a third value and forth, At some point, we could raise the stability of the system but on the opposite, we lost the sensitivity. The variation was not exactly at any change for every value that comes from the feedback sensor after the ADC.

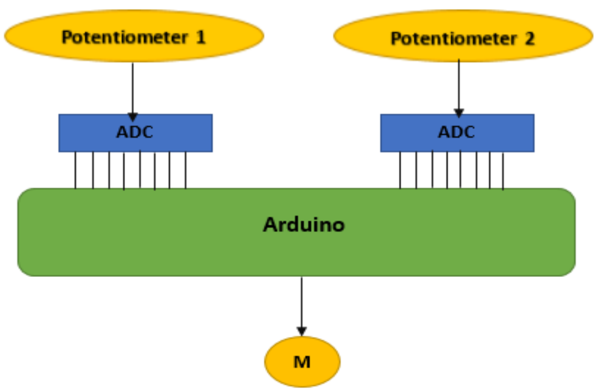
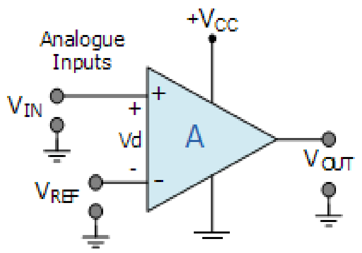


Figure 3.8: A diagram illustrating the process of potentiometer with Arduino and two ADCs

Through our exploration of different strategies for reading the bits, we learned an important lesson about balancing stability and accuracy. While certain adjustments helped improve one aspect, they often came at the expense of the other. To achieve optimal performance, it became clear that further refinements would.

3.5 Second try with making Hysteresis circuits:

3.5.1 Op-amp Comparator Circuit:



If Vin > Vreff than Vout = +VCC

If Vin < Vreff than Vout = 0

Figure 3.9: A diagram explaining Op-amp Comparator Circuit [36]

For the op-amp comparator circuit, let's assume VIN is less than the DC voltage level at VREF (VIN < VREF). Because the non-inverting (positive) input of the comparator is less than the inverting (negative) input, the output will be LOW and at the GROUND, with Vout=0.
If we now increase the input voltage, VIN, so that it exceeds the inverting input's reference voltage, VREF, the output voltage rapidly shifts HIGH towards the positive supply voltage, +Vcc, resulting in positive output saturation. If we drop the input voltage VIN to be slightly less than the reference voltage, the op-amp's output changes back to its negative saturation level, operating as a threshold detector.
Then we can see that the op-amp voltage comparator is a device whose output is dependent on the value of the input voltage, VIN, concerning some DC voltage level, as the output is HIGH when the voltage on the non-inverting input is greater than the voltage on the inverting input, and 0 when the non-inverting input voltage is less than the inverting input voltage. This condition is true whether the input signal is linked to the comparator's inverting or non-inverting input. [35]

3.5.2 Op-amp Comparator with Positive Feedback:

Operational amplifiers can be used as comparators in open-loop mode, however, if the input signal is sluggish or noisy, the op-amp comparator may oscillate. To avoid this, positive feedback is provided surrounding the comparator. This technique includes sending back a portion of the output signal in phase to the non-inverting input using a potential divider made up of two resistors. The amount of feedback is proportional to the ratio. Positive feedback around an op-amp comparator means that once the output is triggered into saturation, there must be a considerable shift in the input signal VIN before the output flips back to the previous saturation point, producing hysteresis. [36]

3.5.3 Comparators with Hysteresis:

- **What's the role of hysteresis?**

When processing slowly fluctuating signals with even minor quantities of noise, comparators typically create several output transitions, or bounces, when the input crosses and re-crosses the threshold region Figure 3.10. Noisy signals can occur in any application, particularly in industrial settings. As the signal reaches the threshold, the open loop gain amplifies the noise, causing the output to briefly bounce back and forth. This is unsatisfactory in most applications, although it can usually be remedied by using hysteresis.[37]

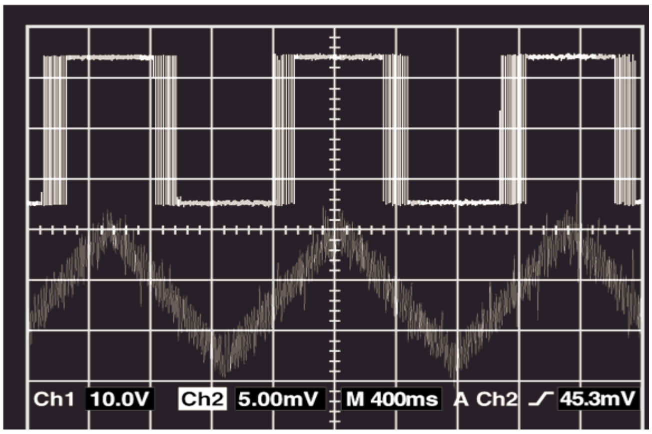


Figure 3.10: Noise causes multiple transitions [37]

- **Inverting Op-amp Comparator with Hysteresis:**

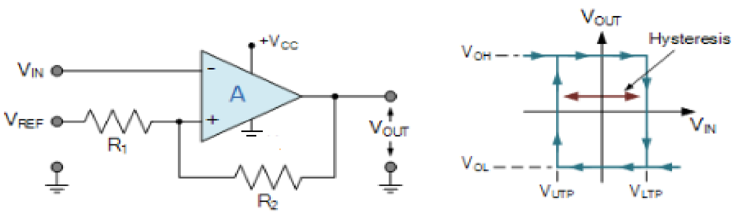


Figure 3.11: Inverting Op-amp Comparator with Hysteresis [38]

The inverting comparator circuit above applies **VIN** to the op-amp's inverting input. Resistors R1 and R2 form a voltage divider network across the comparator, producing positive feedback with a portion of the output voltage showing at the non-inverting input. The resistive ratio of the two resistors employed determines the amount of feedback to the non-inverting input, as follows: [38]

3.5.3 Trying the hysteresis process for one comparator:

Now with obtaining the information about hysteresis that we need above, we are going to talk about one of the experiments which is a circuit utilizing hysteresis where we tried it in at one comparator. Our circuit consists of a comparator of lm358's type which has a positive and negative power inlet and **Vref** attached to the **v-** as for vin input is tied to **v +**, If **Vcc** is equal to 5, **Vref** is equal to 2.5 because Vref is equal to **Vcc**/2, by placing two resists of 10 KΩ, what matters to us is **Vout** where its value changes by changing the value of **Vin** that is variable in our case is that of the hand sensor, and **Vref** is a constant value.

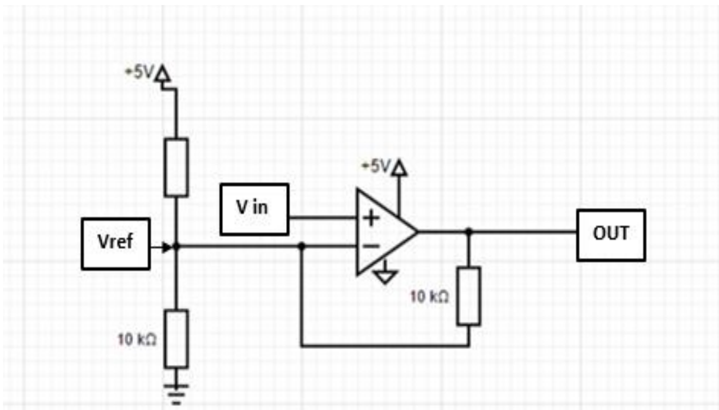


Figure 3.12: A diagram representing the circuit of hysteresis with one comparator

In case **Vref** < **Vin** then: **Vout** = **Vcc**, either if **Vin** < **Vref** then: **Vout** = 0, We will show in the following curve:

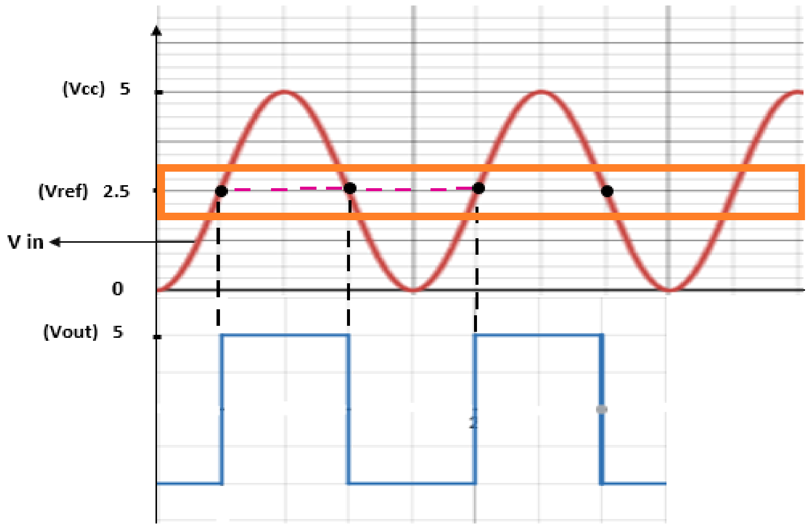


Figure 3.13: Graphic curve explaining hysteresis

We tested this curve for one sensor to manage the signal and observe the change in the output. As we note in the curve, when **VIN** is equal to **Vref** the **Vout** is 0, on the other hand, if **VIN** is bigger than **Vref** then **Vout** is equal to **VCC**, but note that the Vout tension is linked only to **Vref**, which has led to a lack of accuracy, And this is what we don't want because what is meant is that the **Vout** value is linked to a whole field that implies, if the **Vref** is equal to 2.3 or 2.6 or 2.7 all of this gives us one value, **Vout** is equal to 0, This is called hysteresis As shown in the curve in the orange rectangle, and this is one of the most important solutions in which we grow value and it increases accuracy. To complete the hysteresis process, we've added resistance back to **Vref** to compare tensions and from it to stop at the right point. As a result, the hysteresis process gave as good results because in the base this process is developed to solve the situation in one comparator case but when we try it with two comparators, the meaning of the circuit is completely distorted because of two comparators are connected parallel and inverted and two variable resistances which are hand's sensor and feedback sensor, and it becomes in the form of a short circuit since the inputs are connected, and thus the concept of the circuit changes.

3.5.5 Trying to make hysteresis with two comparators:

This is our third attempt at precision for robotic hands, in which we kept the electrical circuit for comparators but continued to experiment and study to achieve our goal of putting a properly functioning circuit while achieving the process of hysteresis and avoiding robotic finger vibration. But before we configured a comparator for each input connected to the two sensors. When one input is greater than the other, the motor rotates in one direction, causing the finger to move in that direction. To enable control of the finger in both directions (up and down), we added a second comparator. The inputs of the two comparators were connected inversely: V+ of the first comparator is connected to V- of the second comparator, and V- of the first comparator is connected to V+ of the second comparator. This setup allows each comparator to control movement in a specific direction. For instance, the output of the first comparator might be 0 while the output of the second comparator is 1. The outputs of both comparators are connected to an H-bridge, which then controls the motor.

Vref is the sensor's tension, which is changeable because the output can be large or small. We suppose that **Vref** = 2.5, and to understand the change better, we divide it into the first and second cases with the circuit shown below**:**

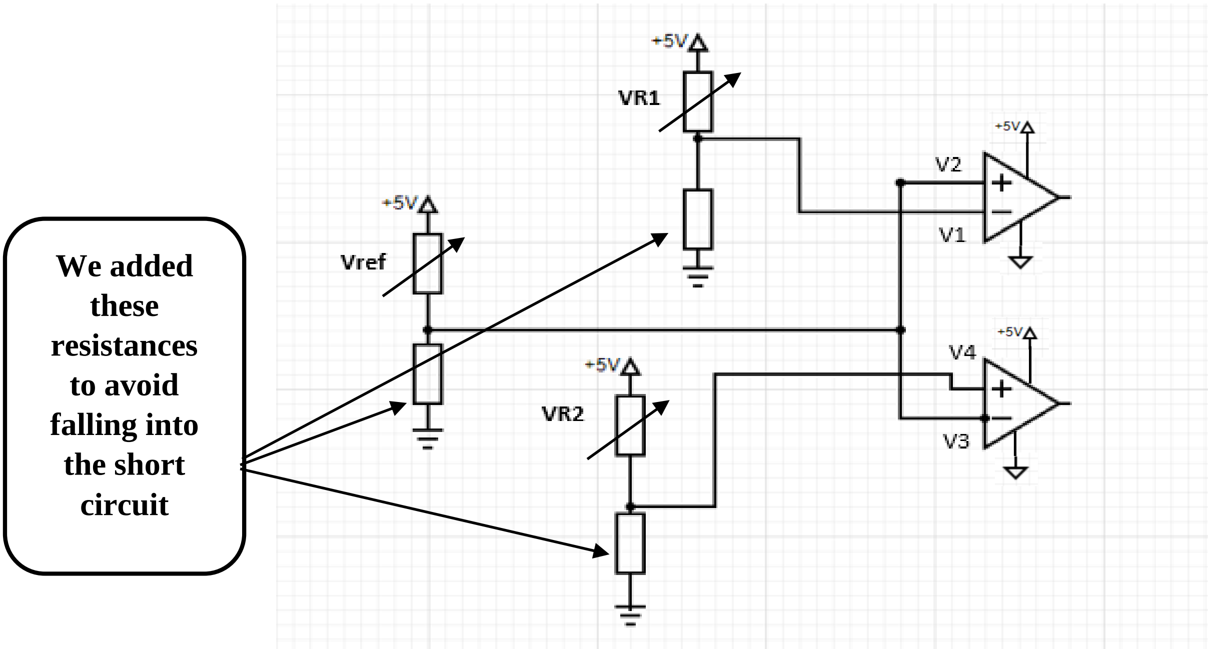


Figure 3.14: A circuit's diagram with two comparators

First case:

As we observe in our electric circuit Vref = 2.5, so v2 = 2.5, v3 = 2.5, v4 = vR2, and v1 = vR1, let us know that the sensors placed on the glove and the robotic hand rotate at the same time but with a short time difference ,For the output of comparison to be equal to 0, we have two cases, or vr2 = 2.5 with v3 = 2.5, the output gives us 0, and on the other hand, we said that for the exit to be equal to 0, it has to be v1 = v2, but we have another case (case 2).

Second case:

which is v1 is big on v2, where v1 is the inverting input and v2 is the non-inverting input, which is a rule of comparison, so we used it.

So we increased the value of VR1 over 2.5 and decreased the value of VR2 below 2.5, causing the tension on the side of the inverting input to exceed the tension on the non-inverting input, yielding the output 0.

To elucidate further, we use hypothetical values as an illustration:

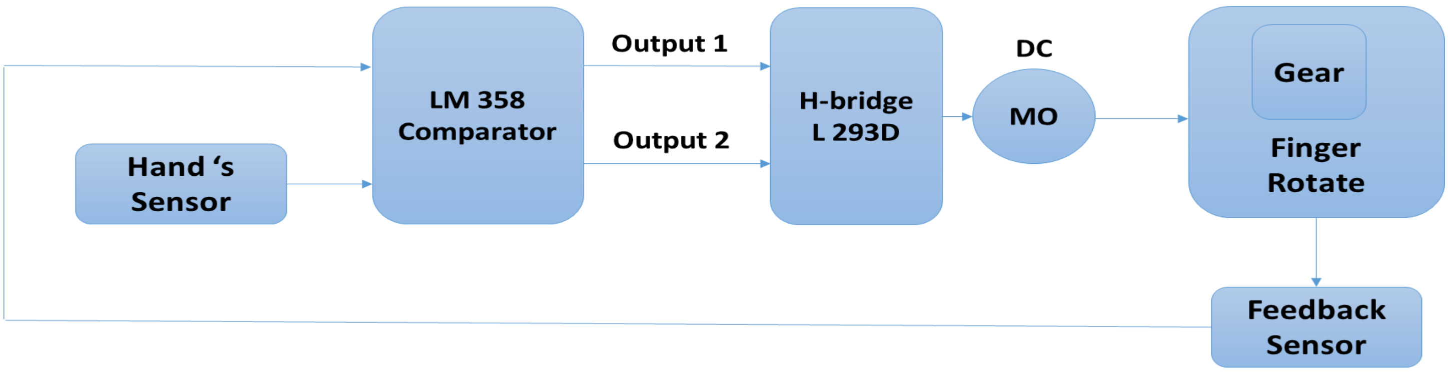
We assigned v4 a value of 2.3, and Vref = v3 = 2.5. So the output tension would be 0 because v3 > v4. Meanwhile, we would do the same thing with VR1 and Vref, but because VR1 is the opposite input tension, we would increase its value, resulting in Vout being 0.

On the other hand, when we want to get 1 in the exit we change Vref to 1, and from it v2 = v3 = 1, with v4 = vR2.

This process is very similar to the process of hysteresis, and that's what we're meant to do just hysteresis by manipulating tensions, therefore, it doesn’t work because of the noise in the input that causes the comparators to switch its outputs repeatedly and rapidly.

3.5.6 The final circuit for the project:

To better illustrate the design and operation of our final circuit, we have created an organizational chart. This chart provides a clear and structured overview of the components we used and the sequential steps involved in the process. Each element of the circuit is depicted, showing how the different parts interact and function together to achieve our project's objectives.



Since we have two potentiometers, we will work with two variable resistors therefore we guessed in this circuit **Figure 3.15.**

We have designed a circuit utilizing two potentiometers, which function as variable resistors. The manually operated potentiometer is connected to the comparator inputs V2 and V3. The feedback potentiometer is directly connected to the feedback variable resistor and routed to input V4, where it becomes its VCC.

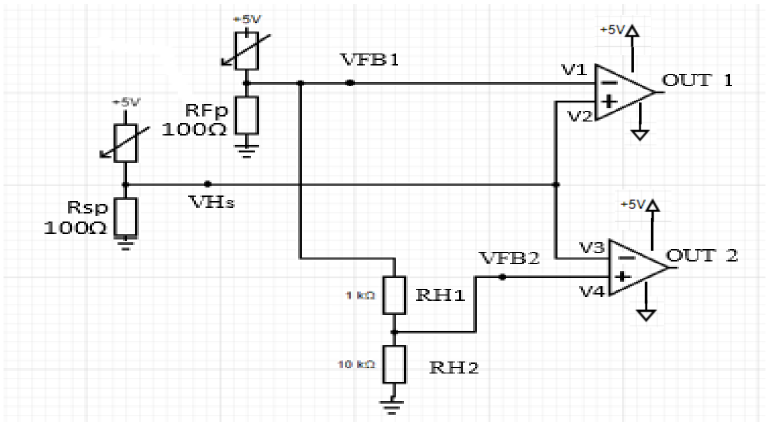


Figure 3.15: A diagram representing the circuit of the final circuit

To create a gap or time delay between signals, we use a voltage divider to reduce the voltage at V4 for example if the heading voltage to v4 is 2.5V it will become 2.0V. Specifically, the voltage is reduced by approximately 0.5V, ensuring a consistent voltage difference due to the voltage divider. To clarify further, we removed approximately 0.5 of the 2.5 tension, resulting in a tension value of 2, and no matter how much we modify the feedback potentiometer, the tension will reach the point, and the input v4 is lowered by 0.5 owing to the tension divider which it will create the Hysteresis process without putting the hysteresis circuit which made good results. We selected an arbitrary resistor value of RH2 = 10kΩ and calculated RH1 to achieve the necessary 0.5V reduction.

3.6 Gear:

A gear is a mechanism made up of two or more toothed wheels that are meshed together. As a result, a gear transmits circular motion from one gear to another by contacting their teeth. It should be remembered that a gear not only transmits a rotational movement but may also raise or decrease the rotational speed depending on the ratio of the number of teeth on the two-gear wheels.

Figure 3.16: Gears in 3D

In our project, we made the gear by copying it at home, using molds made of silicone with a density estimated at 40. We put the gear in the mold and it leaves its shape. Then we put the resin in the mold and the gear is replicated. The reproduced mold and gear are shown in the following images.

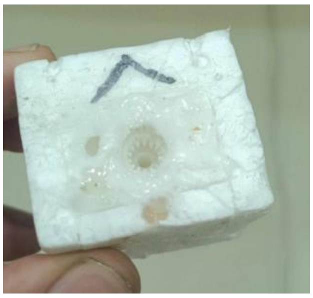


Figure3.17: Gear's Molds

Figure 3.18: Copied Gear

Figure 3.19: Copied Gears

We worked on the mechanical part of the robotic finger so the DC motor could move the finger with the appropriate value of torque and control the speed of the motor. it’s also for controlling the range of the sensor (potentiometer). As a result, we get the voltage values inside the stability zone that is mentioned in chapter 4.

3.7 Conclusion:

In this chapter, we discussed the experiments we conducted to evaluate the performance of the advanced robotic hand system. These tests were designed to assess how accurately, skillfully, and quickly the system can imitate human

Chapter 4: Test and Results

4.1 Introduction:

After looking at all the components and experiments we did in the previous chapters, in this chapter, we will talk about the testing we did to verify hysteresis and the results of our project.

4.2 Arduino- servo motor controlled by potentiometer:

Arduino Code:

```
#include <Servo.h>

// Create servo objects to control the servos
Servo servo1;
Servo servo2;
Servo servo3;

void setup() {
  // Initialize serial communication at 9600 bits per second:
  Serial.begin(9600);

  // Attach the servos to the specified pins
  servo1.attach(9);  // attaches the servo on pin 9 to the servo object
  servo2.attach(10); // attaches the servo on pin 10 to the servo object
  servo3.attach(11); // attaches the servo on pin 11 to the servo object
}

void loop() {
  // Read the values of the potentiometers (values between 0 and 1023)
  int analogValue1 = analogRead(A0);
  int analogValue2 = analogRead(A1);
  int analogValue3 = analogRead(A2);

  // Scale the values to use them with the servos (values between 0 and 180)
  int angle1 = map(analogValue1, 0, 1023, 0, 180);
  int angle2 = map(analogValue2, 0, 1023, 0, 180);
  int angle3 = map(analogValue3, 0, 1023, 0, 180);

```

```
    // Set the servo positions according to the scaled values
    servo1.write(angle1);
    servo2.write(angle2);
    servo3.write(angle3);

    // Print out the values
    Serial.print("Analog1: ");
    Serial.print(analogValue1);
    Serial.print(", Angle1: ");
    Serial.print(angle1);
    Serial.print(" | Analog2: ");
    Serial.print(analogValue2);
    Serial.print(", Angle2: ");
    Serial.print(angle2);
    Serial.print(" | Analog3: ");
    Serial.print(analogValue3);
    Serial.print(", Angle3: ");
    Serial.println(angle3);

    // Small delay to allow for smooth movement
    delay(100);
}
```

Figure 4.1: code of servo motor controlled by potentiometer

4.3 Validation of the hysteresis process:

To ensure the success of this method, we have done some calculations through which we study the value and results of the circuit voltages at each position where the voltage sensor changes, meaning it is close to VCC, in the middle, or when it is close to GND, and also to see if the results of experimenting with the concept of the hysteresis process exist.

First case: The potentiometer value is close to VCC:

certainly, here the value of VFB1 is 5v so we will find the value of VFB2 by calculating this equation:

$$VFB2 = \frac{RH2}{RH1 + RH2} \times VHFB1$$

$$VFB2 = \frac{9{,}94 \times 10^3}{9{,}94 \times 10^3 + 1 \times 10^3} \times 5 \qquad VFB2 = 4.54$$

second case: The potentiometer value is in the middle:

Here we will calculate both VFB1 and VFB2: First, we should calculate the value of the potentiometer resistor in the middle so $\frac{pot}{2} = 4.35 \div 2 = 2.17k\Omega$

$$\frac{pot}{2} + RFP \qquad 2{,}17 + 100 = 102{,}17k\Omega$$

$$VFB1 = \frac{102.17 \times 10^3}{2.17 \times 10^3 + 102.17 \times 10^3} \times 5 \qquad VFB1 = 2.55$$

To get the value of VFB2, we will use the same equation which is :

$$VFB2 = \frac{RH2}{RH1 + RH2} \times VFB1$$

$$VFB2 = \frac{9{,}94 \times 10^3}{9{,}94 \times 10^3 + \ 1 \times 10^3} \times 2.55 \qquad VFB2 = 2.31$$

Third case: The potentiometer value is close to GND:

We will also calculate both VFB1 and VFB2:

$$VFB1 = \frac{RFp}{RFP + Rpotentiometer} \times VCC$$

$$VFB1 = \frac{100}{4.35 \times 10^3 + 100} \times 5 \qquad VFB1 = 112mv$$

For VFB2 : $VFB2 = \frac{RH2}{RH2+RH1} \times VFB1$

$$VFB2 = \frac{9{,}94 \times 10^3}{9{,}94 \times 10^3 + \ 1 \times 10^3} \times 112 \times 10^3 \qquad VFB2 \ = \ 0.101$$

To confirm the process of the hysteresis after this calculation, we convert this equation $VFB2 = \frac{RH2}{RH1+RH2} \times VFB1$ to a function so we can confirm it with a curve, while $f(x) = VRH2$, so it becomes $f(x) = \frac{RH2}{RH2+RH1} x$ which x denotes VFB1 . We see the results of the two curves in the following Figure below.

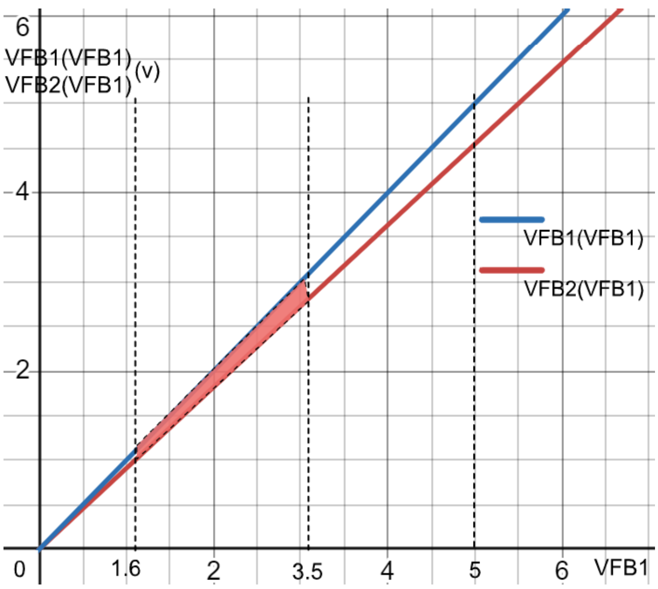


Figure 4.2 : curves representing VFB1 and VFB2

As we can see in the curve, we have two linear functions F(VFB1) and F(VFB2). The space between them is the hysteresis field that we created with the voltage divider. Since the variation will be from 0 to 5 v, we usually take the entire field, still, when we are in the region close to the value 0, it becomes unstable due to the narrowness of the area, so it causes the robotic finger to vibrate. The same goes for the area close to the value 5 v, except that this region is too large, then there is no accuracy and the finger also shakes. Therefore, we chose the central region colored red, which made it more stable and accurate. As for the potentiometer, it also usually changes from 0v to 5v, but since we chose the middle region as we explained previously, we changed the potentiometer so that it does not start from 0 and does not end at the maximum value, by placing it in the middle as well, and this is by twisting it slightly

Above we provided a detailed explanation of the circuit components and their connections. We described setting up the devices and how to handle voltage using a voltage divider to ensure stable operation. It emphasizes the calculation and selection of resistor values to achieve the required voltage reduction and time delay.

We will now describe the dynamic behavior of the system and how it responds to changes in the potentiometer settings in the organizational structure below, where the synchronization system will be explained, and how the process is carried out

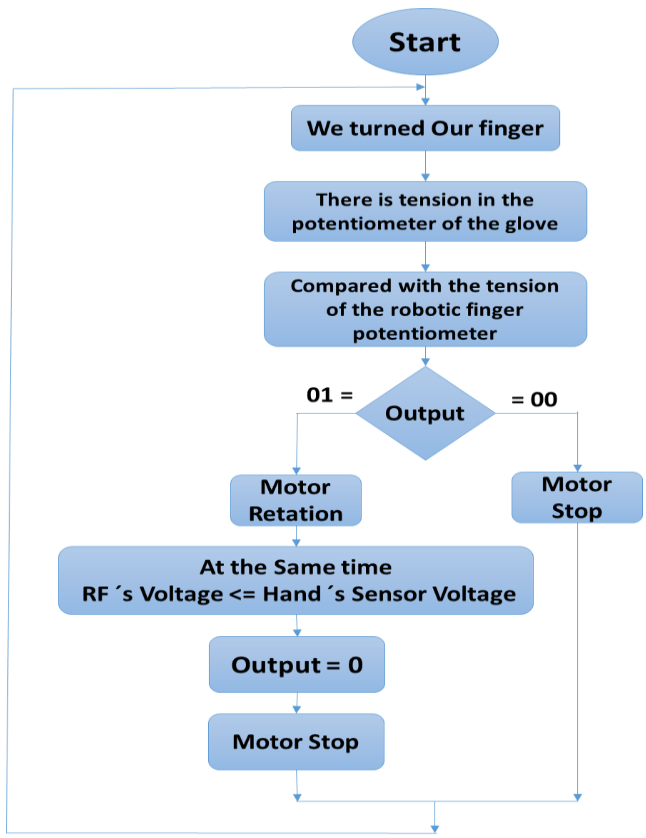


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Figure 4.3: an organizational chart explaining the dynamic behavior of the system

To fully understand the process, we will consider a situation where our robotic finger and the human hand are functioning for one finger. With the same circuit, we named the tensions on which we will base our case where VFBs is the Voltage of the feedback sensor, VHs is the voltage of the Hand sensor, and VFBs' is the voltage that we divided.

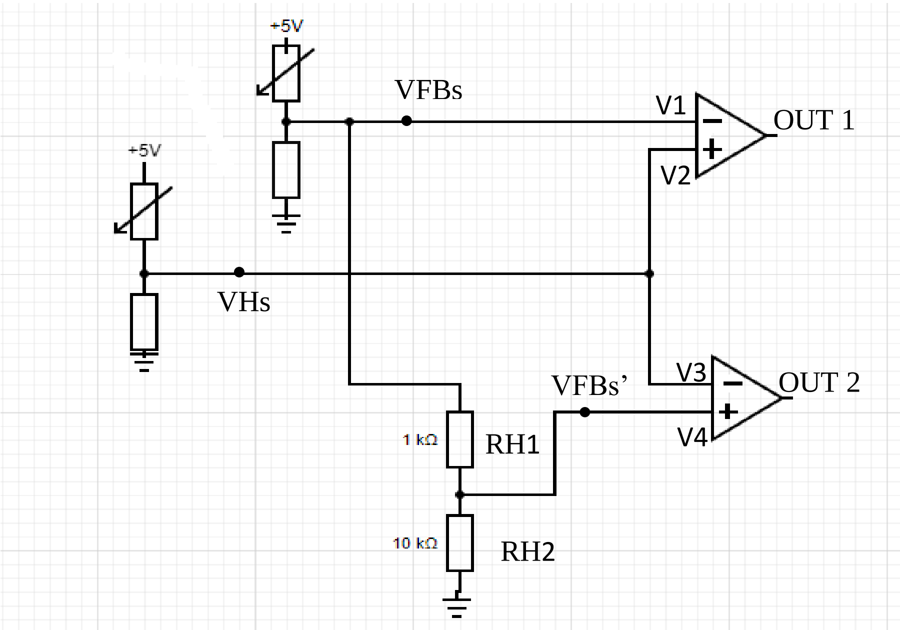

Figure 4.4: the circuit of the experiment

We summarized the process and results in this table

Table 4.1: A hypothetical study of the circuit for a single finger movement

Vcc	VHs	VFBs	VFBs'	V1	V2	V3	V4	OUT1	OUT2	
5v	2	3.1	2.6	3.1	2	2	2,6	0	1	Step 1
5v	Motor rotates									Step 2
5v	2	2.1	1.5	2	2	2	1.5	0	0	Step 3
5v	3.1	1.6	1.1	1.6	3.1	3.1	1.1	0	1	Step 4

Let us explain this table above at each step to understand more:

Step 1: ● The FBS is in its initial state.

● After rotating the hand sensor, it has a new voltage equal to 2.

●The comparison is performed and therefore the output is 01.

Step 2: ● The motor rotates, moving the potentiometer associated with the FBS

●At the same time, the FBS adjusts its voltage to equal the voltage value of the VHS.

Step 3: ● The VFBS now has the same value as the VHS, with an increase of only 0.1 due to the driving force, but it does not affect.

● Here, FBS will stop because both outputs are equal to 0.

We notice that with these values, both fingers were able to go down. To try the two fingers up, we assume step 4

Step 4: ● We set the hand sensor at its value close to the minimum.

● By repeating the FBS process of the same process, the two outputs will be 01, from which the motor will rotate upwards.

4.5 PCB circuit:

PCB is a copper laminated and non-conductive **Printed Circuit Board**, in which all electrical and electronic components are connected in one common board with physical support for all components with a base of board. When PCB is not developed, at that time all components are connected with a wire which increases complexity and decreases the reliability of the circuit, in this way, we cannot make a very large circuit like a motherboard. In PCB, all components are connected without wires, **all components are connected internally**, which will reduce the complexity of the overall circuit design. PCB is used to provide electricity and connectivity between the components, by which it functions the way it was designed. PCBs can be customized for any specifications to user requirements. It can be found in many electronic devices like; TVs, Mobile, Digital cameras, and Computer parts like; Graphic cards, motherboards, etc. It is also used in many fields like; medical devices, industrial machinery, automotive industries, lighting, etc. [39]

To improve the control system's overall performance, reliability, and manufacturability, ensuring that the robotic hand operates accurately and efficiently, we designed a PCB to organize the installation and connection of electronic components. This helps reduce the overall size of the control system, which is critical for wearable devices such as a glove-based control system. We also used a PCB to reduce electrical noise and signal interference, which is important for accurately transmitting the signal from the sensors on the glove to the actuators in the robotic hand. The PCB, on the other hand, allows complex circuits, including microcontrollers, sensors, and actuators, to be integrated compactly and efficiently [appendix C] . This integration is critical for real-time processing and control of robotic hand movements.

to explaine more here are our pcb 3D circuit :

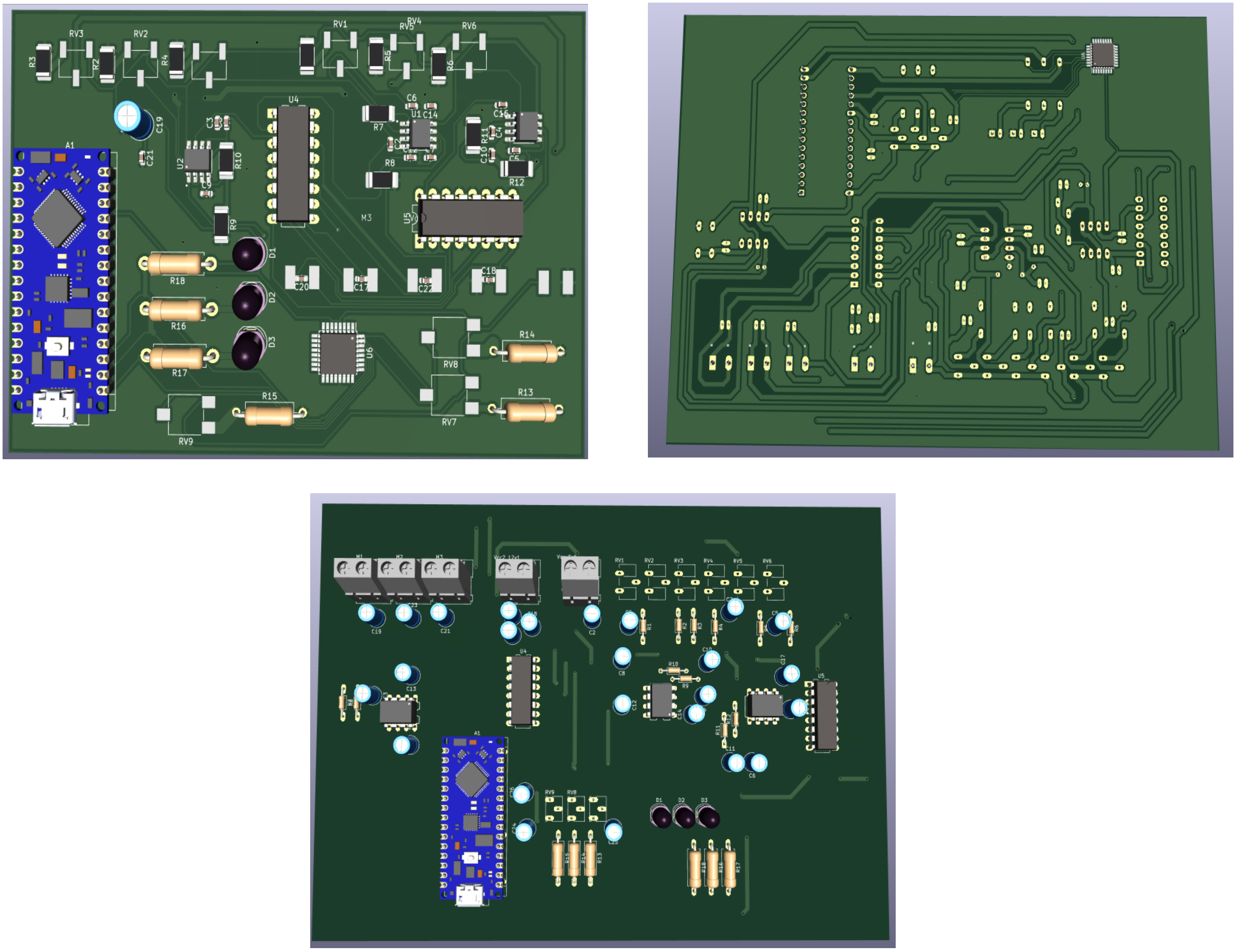

Figure 4.5 : PCB 3D circuits from top and bottom

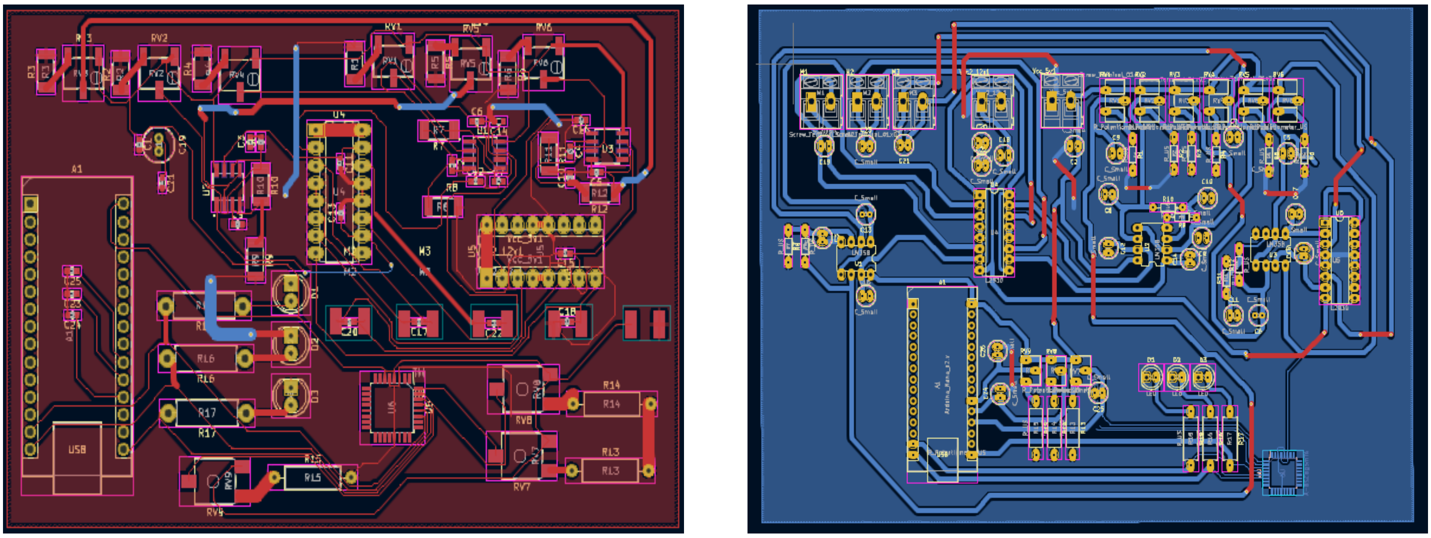

Figure 4.6: PCB Layout design

4.6 3D Design Illustrating the Mechanism of the Robotic Finger:

In this section, we provide the 3D design produced to explain the intricate mechanics of our robotic finger. This design depicts in detail the internal components, such as gears, joints, and actuators, that work together to allow for accurate finger movements. The 3D model illustrates the gear-driven mechanism, demonstrating how each part of the finger is synchronized to simulate the natural motion of a human finger. This thorough design serves as both a blueprint for building the robotic finger and a teaching tool for readers to better grasp the mechanical engineering principles involved. The visual representation emphasizes the design's complexity and creativity, as well as the advanced technology used in our robotic hand systems.

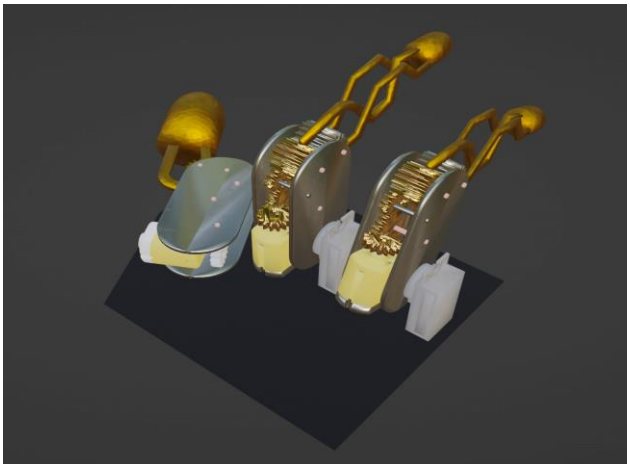

Figure 4.7: 3D design of the robotic hand from the back

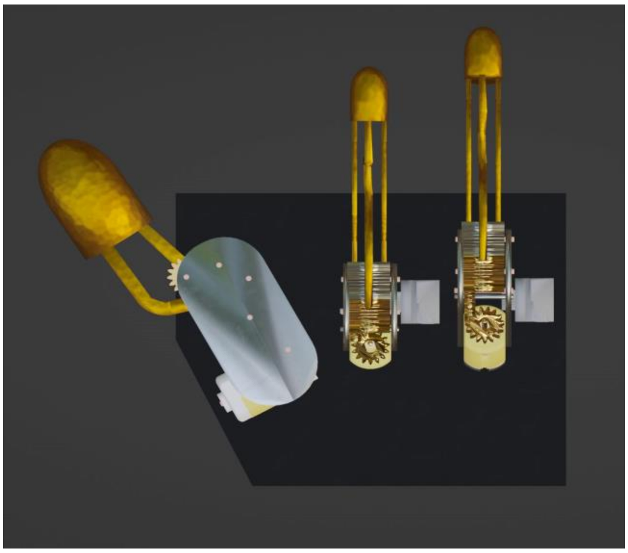

Figure 4.8: 3D design of the robotic hand from above

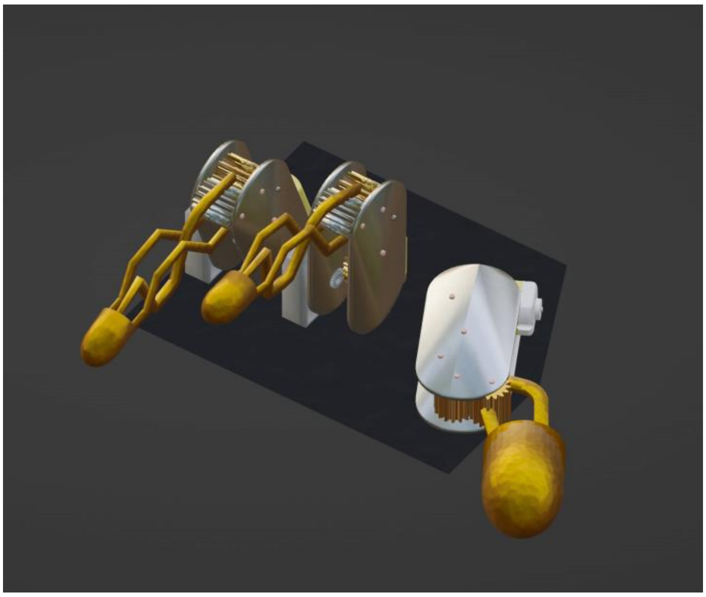

Figure 4.9: 3D design of the robotic hand from the front

4.7 Conclusion:

This chapter has detailed the testing and outcomes of our robotic hand system. The experiments showed that it can accurately and quickly imitate human hand movements. The results also highlighted areas for improvement, such as making the actuators more powerful and flexible in mimicking our hand's actions. These findings provide a strong foundation for future upgrades, making sure our robotic hand can meet the growing need for precise and functional use in real

General conclusion

What if we could design an electrical system or create a robotic hand capable of precisely tracking the movements of a real human hand? Although it is a formidable challenge given the intricate design of the human hand, this advanced robotic hand, operated by a wearable glove, goes beyond mere rehabilitation. While it enables patients to rehabilitate, the underlying technology opens new horizons for human interaction with machines. Imagine deploying robots with these hands for underwater exploration, where safe and precise manipulation of marine life could significantly enhance research. Agriculture could also benefit immensely, as these robotic hands could be used to precisely harvest fruits or vegetables, optimizing productivity and reducing waste. The promise of this technology extends to search and rescue operations, allowing robots to navigate through debris to locate and assist victims in disaster-stricken areas. Moreover, the applications are vast in industrial environments, where these hands can augment the capabilities of robots handling complex assembly tasks or precision manufacturing processes.

This thesis presents the development of an advanced robotic hand capable of mimicking human hand movements through an innovative glove-based control system. The intuitive design allows the wearer's hand movements to be replicated smoothly and accurately, providing significant advances in various fields. Although there are similar projects, not every finger moves in the same way as a human finger. Our goal was to enable the top of the finger to bend in an arcuate manner, akin to a real finger. To achieve this, we conducted numerous experiments, some yielding successful results while others did not meet our expectations. The most significant obstacle was noise, which affected the accuracy of the output and led to failures. To address this problem, we employed the concept of hysteresis, which allowed us to achieve accuracy and eliminate noise by designing a circuit that functions similarly to the hysteresis process, particularly by dividing the tension.

The project is divided into two parts:

1. **Arduino-Controlled Finger Movement**: This section utilizes the Arduino microcontroller to control the motion of individual fingers, enabling precise and responsive manipulation.

2. **Comparison Circuit and Potentiometer Control**: In this part, a comparison circuit and a potentiometer are employed to regulate the upward and downward movement of the robotic hand, ensuring accurate and smooth operation.

This study we made is a complete version of what we all have seen as math results and theoretical applications, this work could be a beginning for the development of the next studies that may come after.

before we dive into the importance of our parts we would like to mention the following; by the previous study we mean to prove the use of a microcontroller in some specific use is not that much need and complexity, it is just enough to provide the needed added value to the community targeted.

it is important to know that the mechanical system is deeply causing a delay that we don't notice and does not affect the performance of our hand, while it can appear for some level when the hand sensor moves faster than what is required. For the mentioned, to combine of the mechanical and electrical combine can hold some errors but it was never the electronic circuit that did the job perfectly, but the addition of the DC motor can raise the error value it depends on the DC voltage whether it is high or low, here where we need to add a complementary block that can find out the speed of the change in the hand sensor and turn it into a system answer in the same speed of the hand sensor change which works exactly for speed feedback with momentum sync and precision.

in this step, which can be done with the help of the microcontroller if needed to look at the complexity of the solution, if we keep the same idea, we can start making another circuit with the appropriate elements and a way of mounting them all together.

we are that far from the step we mentioned but it takes time to achieve, all it takes is to manage elements one by one to reach precision, sync, momentum sync, and stability.

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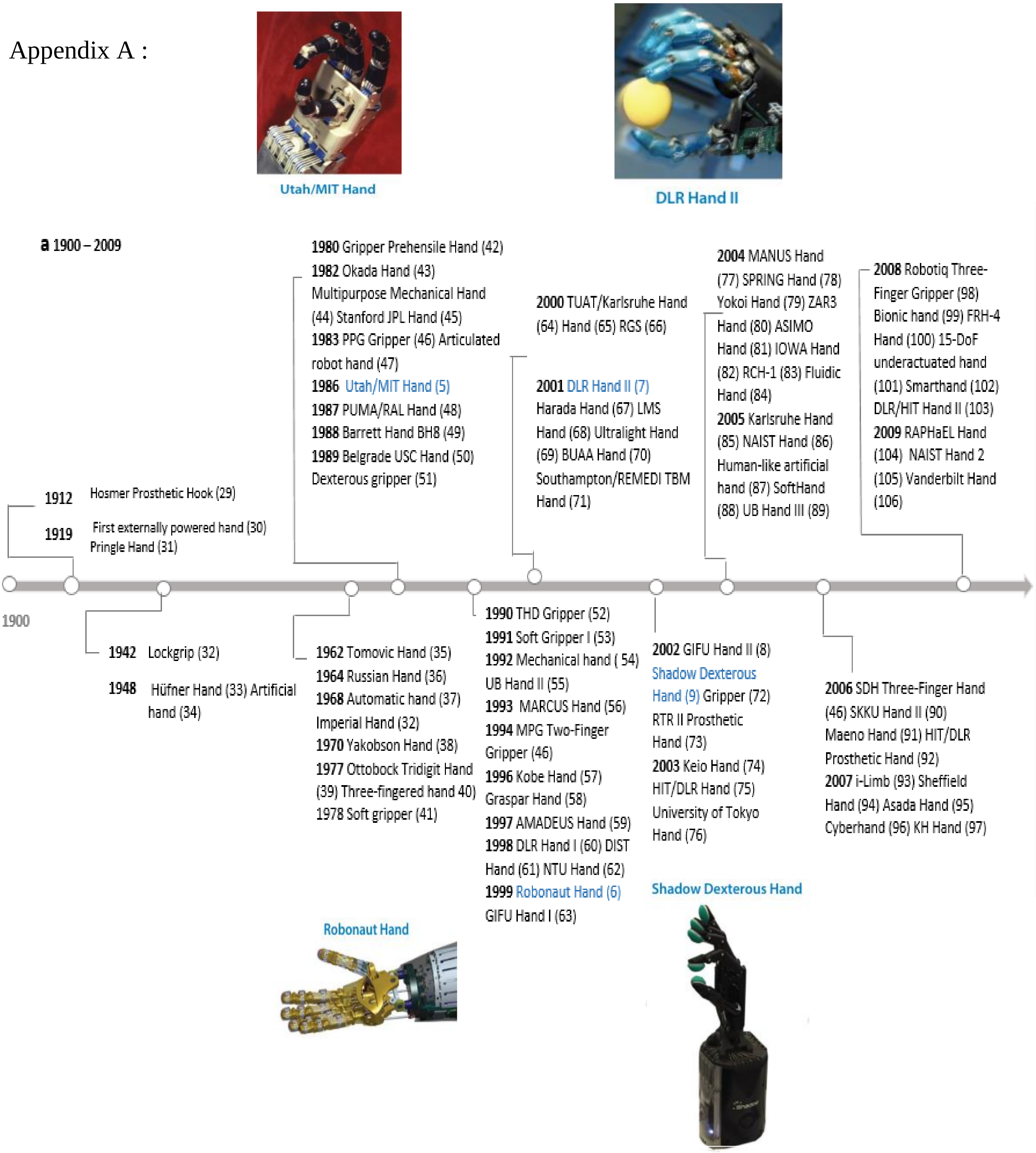
Appendix

Appendix A :

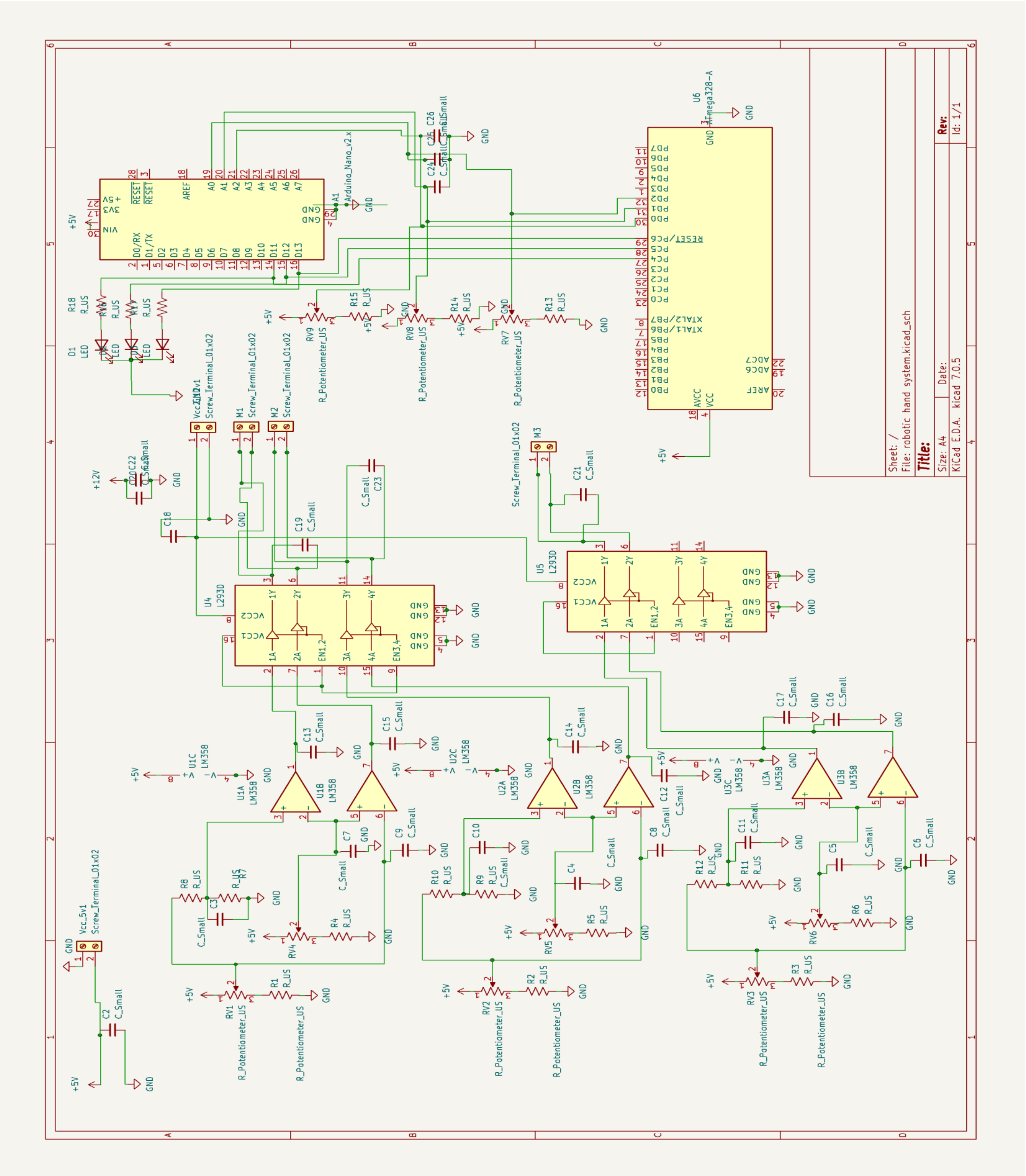


A timeline of all the innovative hands from 1900 -2009. [15]

Appendix B ：

A timeline of all the innovative hands from 2010 -2018. [15]

Appendix C :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