Republic of Iraq
Ministry of Higher Education
& Scientific Research
AL-Nahrain University
Information Engineering College
Systems Engineering Department

Wireless Robotic Human Hand Motion Control using Arduino

Final year project

In partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Systems Engineering

By

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Supervised by

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June 2018 Ramadan 1439

Supervisor Certification

I certify that this project entitled "**Wireless Robotic Human Hand Motion Control using Arduino**" is prepared under my Supervision at AL-Nahrain University / College of Information Engineering / Department of Systems Engineering in partial fulfillment of the requirements for the degree of **Bachelor of Science in Systems Engineering**.

Signature:

Name: Asst. Lec. Zeyad A. Karam

(Supervisor)

Date: 2018/6/10

In view of the available recommendation, I forward this project for debate by the examination committee.

Signature:

Name: Asst. prof. Dr. Osama A. Awad

(Head of Department)

Date: 10/6/2018

Certification of Examination Committee

We chairman and members of the examination committee certify that we read the project entitled "**Wireless Robotic Human Hand Motion Control using Arduino**", and have examined the students "**Elaf Ahmed Saeed**" in its contents and in what is concerned with it, and in our opinion it meets the standards of a project for the degree of **Bachelor**

Signature:

Name: Asst. Prof. Dr. Osama A. Awad

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Date: / / 2018

Abstract

Robotic hand has a great importance in the current life and it interferes in many fields, as the industry,medical and chemical fields that need more power, speed and accuracy that human cannot provide these properties well so in this case is need to robotic hand.

This project involves the design and implementation of robotic hand controlled wirelessly via Bluetooth module for transmit and receive motion signals which emitates human hand fingers motion.

The design consisting of two circuits: the transmission circuit and receiving circuit. The transmitter circuit consists of a glove worn by the person and sensors (flex sensor)supported on it which is sensitive to the fingers of the human hand movement, the microcontroller (Arduino card) will be used for processing of reading signals from sensors and perform the control or actuating signals to servo motors. Two Bluetooth modules (master) is used to send data from the glove that involve the sensors reading to Arduino card and (slave) circuit to receiving control signal from Arduino card and actuate the servo motors. The robotic hand consisting of five fingers is designed and implimentation success fully.Each finger has three degrees of freedom (3DOF's), and controlled via one servo motor to activate the robotic fingers of in the angle of rotation from 0° to 180°. The forward and inverse kinematics for the index figure are derived mathematically for (3 DOF's) robot and its trajectory motion is simulated by using Matlab Simulink.

List of Contents

List of Abbreviation

Abbreviation	Meaning
IFR	International Federation of Robotics
DOF	Degree Of Freedom
IDE	Integrated Development Environment
SPP	Serial Port Protocol
D-H	Denavit –Hartenberg
TX	Transmitter of Arduino
RX	Receiver of Arduino
ADC	Analog to Digital Converter
EN	Enable signal
AT	Attention Command
A0	Analog input port of Arduino

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Chapter 1
Introduction

1.1 Overview

The human hand is one of the most universal tools in nature. It's no wonder that researchers are eager to apply the advantages of the newest evolutionary designs to develop the generation of the robotic hands application. International Federation of Robotics (IFR) defines a service robot as a robot which operates semi- or fully autonomously to perform services useful to the well-being of humans and equipment excluding manufacturing operations, Constructing a robotic hand with the capabilities and dexterity of a human hand requires at least four fingers: three fingers to allow the robotic hand to grip conical parts, and a thumb used as a support structure. Robotic hands classified according to the number offingers,single finger, two finger,multi-finger, and according to structure of fingers used in the robot hand. Robotics can be divided into two areas: industrial and service robotics. These robots are currently used in many fields of applications including office, military tasks, hospital operations, dangerous environment and agriculture. Besides it might be difficult or dangerous for humans to do some specific tasks [1].

There are different designs for robotic hand tools which vary according to its application. Robotic arm forms a key part of robotics design. The tools mounted onto the robotic arm, a variety of different jobs such as soldering, painting and palletizing can be performed. An articulated robotic arm is the most popular type and has a higher DOF (Degree of Freedom), small size and wide operation range, as well as capability to avoid obstacles within a small space.

An articulated robot arm typically consists of rigid rods and rotatable articulations. As shown in figure (1-1) the Robotic hands that use in some applications have many degrees of freedom (DOF) distributed among several kinematic chains ,The complexity of mechanical design is needed to adapt hands to the many kinds of tasks required in unstructured environments, where robotic grasping and manipulation have become crucial. The example about the robotic hand design are the UTAH/MIT hand with 16 actuated joints, 4 per each finger. One of the main issues in designing and controlling robotic hands is that a large number of motors is needed to fully actuate the DOF. This makes both the mechanical and the control system design of robotic hands dramatically more complex[2].

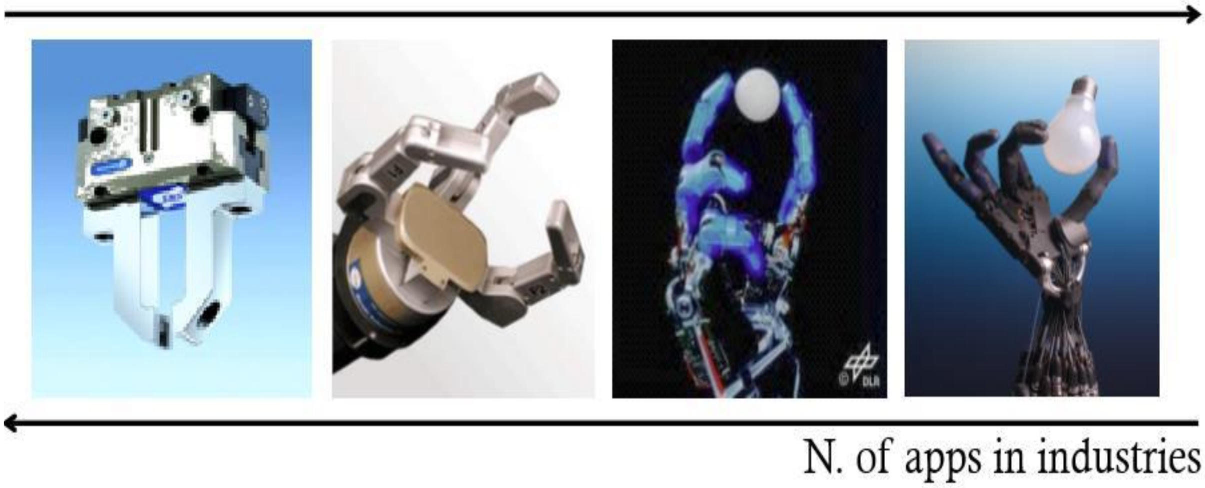


Figure 1-1: The Larger Is the Number of DOF of the robotic hand

1.2 Aims of the Project

The aims of this work can be factorized in following:

- Design Human Hand robot of five fingers each finger has (three degree of freedom and three links).

- Design mechanism for (motion) transfer from servo motors to the robot fingers.

1.3 Robotic Hand Application

- Industrial Application
- Medical Application
- Military Application
- Laboratory Application
- Chemical Application

1.4 Project overview

The project is a movement of robotic hand wirelessly. Consist of two circuits: the transmitter and the receiving circuit. The transmitter circuit is the circuit through which the signals of the human movement are transmitted and the receiving circuit is the one that receives the signal transmitted from the transmitter circuit, processes it and sends it to the Robotic hand to mimic the movement of the hand.

1.5 Project Outlines

The first chapter focus on the overview of robotic human hand, application of the robotic hand, aims of the work, Project overview.

Chapter 2: System Components, Kinematic and Trajectory.

Chapter 3: Design and Implementation.

Chapter 4: Reselts and Discussion .

Chapter 5: Conclusion and Future Work.

Chapter two

System Components, Kinematic and Trajectory

2.1 System Hardware Component

2.1.1 Robotic Hand Design

In this part show the design and connection the robotic hand as shown in figure (2-1) [3].

- **Palm Design**

Design of the palm hand which consists of two parts connected by a joint. This makes the fingers in the hand free movement forward and backward.

- **Finger Design**

The design of the four fingers, which consists each finger of six parts connect with each other by three joints and each finger has three degrees of freedom (DOF).

- **Thumb Design**

The thumb finger, which is also made up of six parts, are connects together by the joints. The thumb finger connects with the hand through a tube so that it is free to move forward and backward.

- **Hand Design**

That robotic hand consists of five fingers and every finger has three degree of freedom (DOF).

- **Servo Brackets**

Here is the design of the base that installs five servo motors in it, which consists of the number of holes which the thread passes through it so as not to intertwine. The five servo motors install on the bracket with its hollow disk that instilled on the motor shift, each finger has two wires connected to the sides of the motor disk, one wire for expand the finger and the other one for constrainthe finger by the disk rotation to another side.

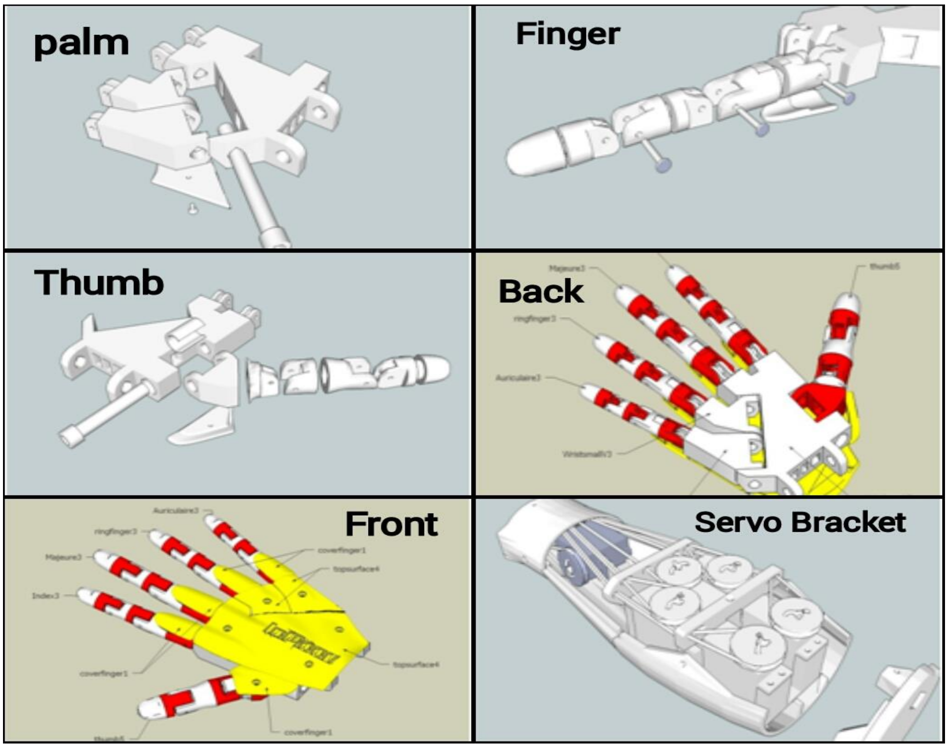


Figure 2-1: Design of hand parts

2.1.2 Arduino UNO R3

Arduino UNO is open source electrronic prototype platform based on flexiable, easy to use hardware and software. The Arduino UNO can sense the environment by receiving input from a variety of sensor and can affect its surroundings by controlling the actuators.

The microcontroller on the board is programmed using the Arduino UNO programming language (based on wiring) and the Arduino development environment (based on processing).Thefigure (2-2) shown the Arduino UNO platform [4].

Figure 2-2: Arduino UNO R3

2.1.3 Servo Motor MG 995

The servo motor unlike dc motors; with servo motors, you can position the motor shaft at a specific position (angle (0-180)) using control signal. This is very useful for controlling any object that you want it to move at certain angle. Servo motors may be classified according to size or torque that it can withstand into mini, standard and giant servos. The figure (2-3) below shows the form of servo motor [5].

Figure 2-3: Servo motor MG 995

2.1.4 Flex Sensor

A simple flex sensor of long 2.7 inch in length will use as motion sensor, the resistance across the sensor increases when the senser bend. Flex sensor are sensors that change in resistance depanding on the amount of the bend on the sensor. As shown in figure (2-4) ,they convert the change in bend to electrical resistance the more the bend, the more the resistance value. Flex sensors are analogue resistors, they work as variable analogue voltage divider. Inside the flex sensors are carbon resistive elements within a thin flexible substrate. The higher the resistance value yielding smaller radius [6].

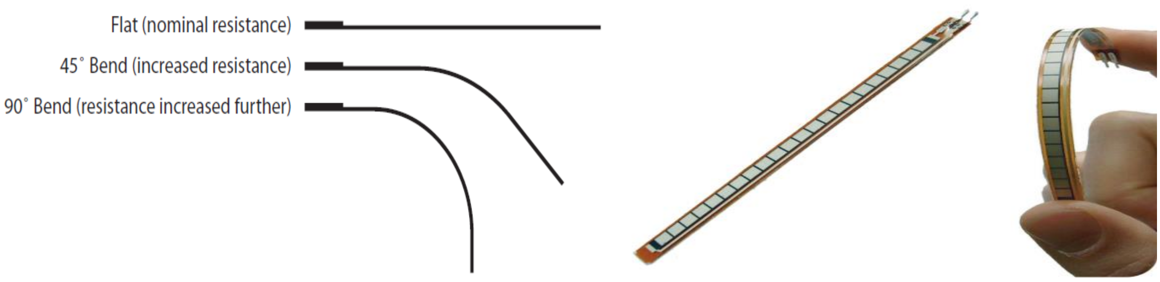


Figure 2-4: Flex sensor

2.1.5Bluetooth HC-05

HC-05 Bluetooth Module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup.Its communication is via serial communication which makes an easy way to interface with controller or PC. HC-05 Bluetooth module provides switching mode between master and slave mode which means it able to use neither receiving nor transmitting data. Figure(2-5) has shown the Bluetooth HC-05 [7].

Figure 2-5: Blutooth Hc-05

2.2 Software Component

- Arduino IDE

Figure 2-6: Arduino Interface

- Matlab

Figure 2-7: Matlab Interface

2.3 Fingers Kinematics

Kinematics can be defined as the study of the motion of robot. The investigation calculates the positions, velocity and acceleration of the robot's links without coming back to the forces bringing on the movement. Their schematic in the x-y plane is shown in Figure (2-8).

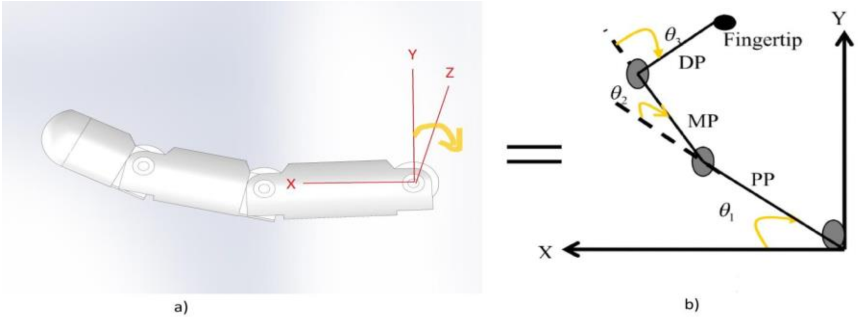


Figure (2-8)

(a) Prototype of prosthetic finger,

(b) Schematic of prosthetic finger lying in the X-Y plane

For the kinematics investigation, there exist two general inquiries to assess the fingertip position. For each joint angle and the geometric link parameters, one can assess the position and orientation of the end effectors of the controller as for the reference frame. This issue is known as forward kinematics. Consequently, therefore for a coveted position and orientation of the end effectors, one can compute the joint angles. This issue is called as inverse kinematics.

Utilizing the D-H (Denavit –hartenberg) representation, that start by tackling the issue of forward kinematics where single link changes are banded to yield a solitary transform that totally depict the position and orientation of fingertip as for the reference casing of the base (the palm).A block diagram shows the relationship between these problems in figure (2-9)[8].

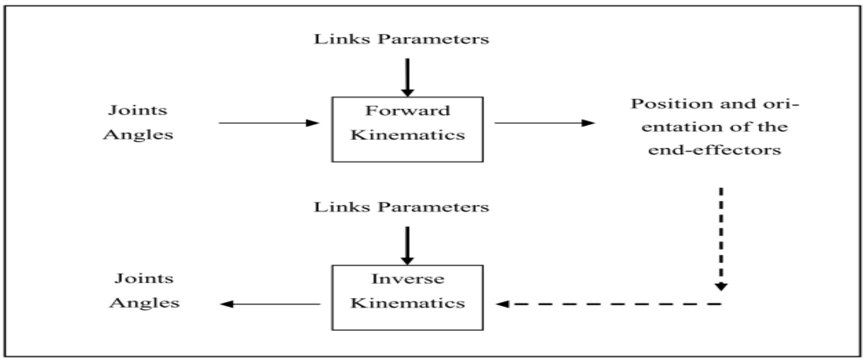


Figure 2-9: Relationship between Forward and Inverse Kinematics

a. Forward Kinematic

The D-H theorem contains four parameters which are: angle, the link/phalanx offset di, the link /phalanx length, and the link/phalanx twist αi. The past four factors are utilized to figure the position and orientation of the fingertip.The forward kinematics the inputs are the joint angle vectors(θ_i) and the link length parameters. The Output is the orientation and the position of the finger[9].

Table 2-1: D-H Parameters of the four fingers

Joint	Twist $\boldsymbol{\alpha_i}$	Length $\boldsymbol{L_i}$	Offset$\boldsymbol{d_i}$	Angle $\boldsymbol{\theta_i}$
1	0	L_1	0	θ_1
2	0	L_2	0	θ_2
3	0	L_3	0	θ_3

The equations of the forward kinematic:

$$\mathrm{p}_{x_{finger}} = L_1 \cos\theta_1 + L_2 \cos(\theta_1+\theta_2) + L_3 \cos(\theta_1+\theta_2+\theta_3) \qquad \textbf{(2.1)}$$

$$\mathrm{p}_{y_{finger}} = L_1 \sin\theta_1 + L_2 \sin(\theta_1+\theta_2) + L_3 \sin(\theta_1+\theta_2+\theta_3) \qquad \textbf{(2.2)}$$

$$\mathrm{p}_{z_{finger}} = 0 \qquad \textbf{(2.3)}$$

$$\varphi = \theta_1 + \theta_2 + \theta_3 \qquad \textbf{(2.4)}$$

b. Inverse Kinematics

For the Inverse kinematics the inputs are the orientation and the position of the fingerand the link length parameters. The Output is the joint angle vectors(θ_i)The Inverse kinematics depends directly on the forward kinematics, to obtain the inverse we will use the equations(2.1),(2.2),(2,4) of the forward kinematics [9].

$$\mathrm{p}'_x = \mathrm{p}_{\boldsymbol{x}} - l_3 \cos\varphi \qquad \textbf{(2.5)}$$

$$\mathrm{p}'_y = \mathrm{p}_{\boldsymbol{y}} - l_3 \sin\varphi \qquad \textbf{(2.6)}$$

(2.7)

$$\theta_1 = \arctan2(p'_y, p'_x) \mp \arccos\left[\frac{l_1^2 + p_x'^2 + p_y'^2 - l_2^2}{2l_1\sqrt{p_x'^2 + p_y'^2}}\right] \quad \textbf{(2.8)}$$

$$\theta_2 = \arctan2(p'_y - l_1 \sin\theta_1, p'_x - l_1 \cos\theta_1) - \theta_1$$

$$\theta_3 = \varphi - \theta_1 - \theta_2 \quad \textbf{(2.9)}$$

2.4 Joint-Space Trajectory Planning

2.4.1 Third-Order Polynomial Trajectory Planning

In this application, the initial location and orientation of the robot is known, and using the inverse kinematic, which find the final joint angles for the desired position and orientation. Now consider one of the joints, which at the beginning of the motion segment at time t_i is at θ_i .That desire to have the joints move to a new value of θ_f at time t_f[10].

These four pieces of information allow us to solve for four unknowns (or a third-order polynomial) in the form of:

θ (t) = c_0+$c_1\,t$ + $c_2\,t^2$ + $c_3\,t^3$ **(2.10)**

At t=0 (t= t_i =zero)

$c_0 = \theta_i$ **(2.11)**

$c_1 = 0$ **(2.12)**

At t=t_f

$$c_2 = \frac{3(\theta_f - \theta_i)}{t_f^2} \quad \textbf{(2.13)}$$

$$c_3 = \frac{-2(\theta_f - \theta_i)}{t_f^3} \quad \textbf{(2.14)}$$

Chapter Three

Design and Implementation

3.1 Software Design and Simulation

3.1.1 Simulink of Kinematic

a. Forward Simulink

In figure (3-1) that shown below the simulink of the forward kinematic by using the equations **(2.1), (2.2) and (2.4)** in chapter two.

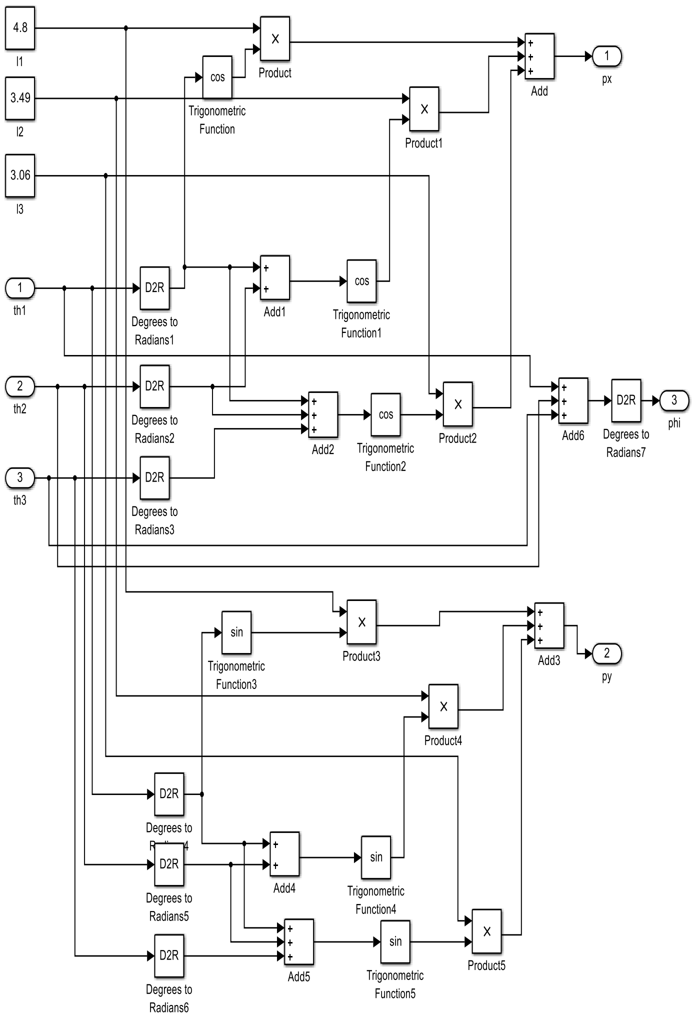


Figure 3-1: Forward Kinematic

b. Inverse Simulink

The simulink of the inverse kinematic for motion of fingre by using the equations of inverse in chapter two**(2.5),(2.6),(2.7) ,(2.8)** and **(2.9)**.In figures(3-2), (3-3) and (3-4) shown the simulink of the equations of θ_1 ,θ_2 and θ_3 with full design of inverse kinematic.

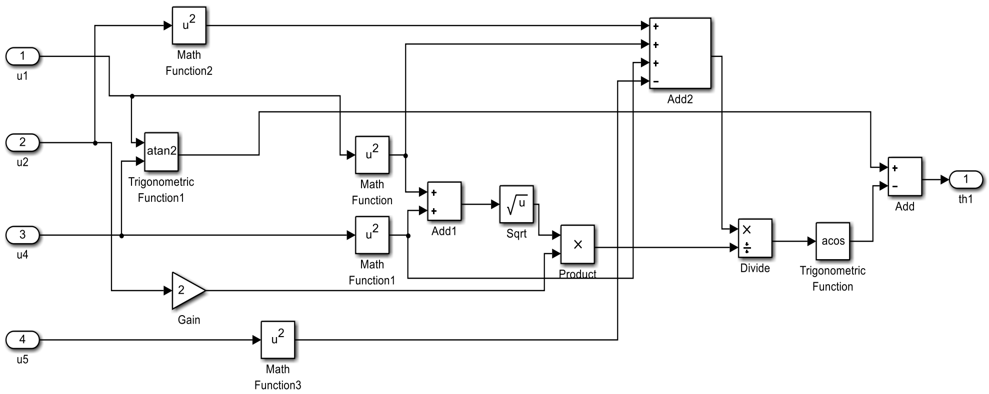


Figure 3-2:Simulink of $\theta 1$

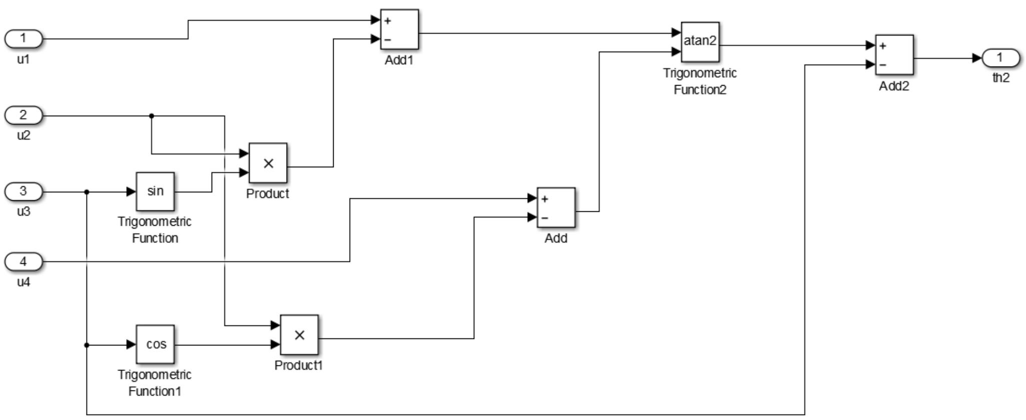


Figure 3-3:Simulink of $\theta 2$

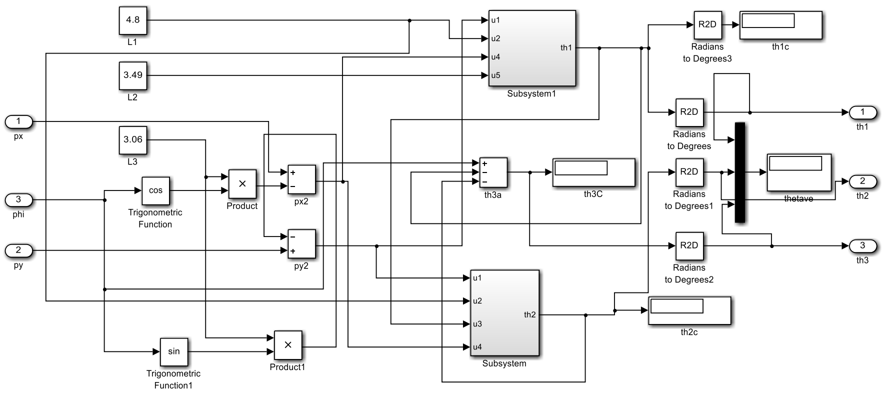


Figure 3-4: Simulink of Inverse Kinematic and the Simulink of $\theta 3$

The figure (3-5) that shown below the full design of the forward and inverse kinematic.

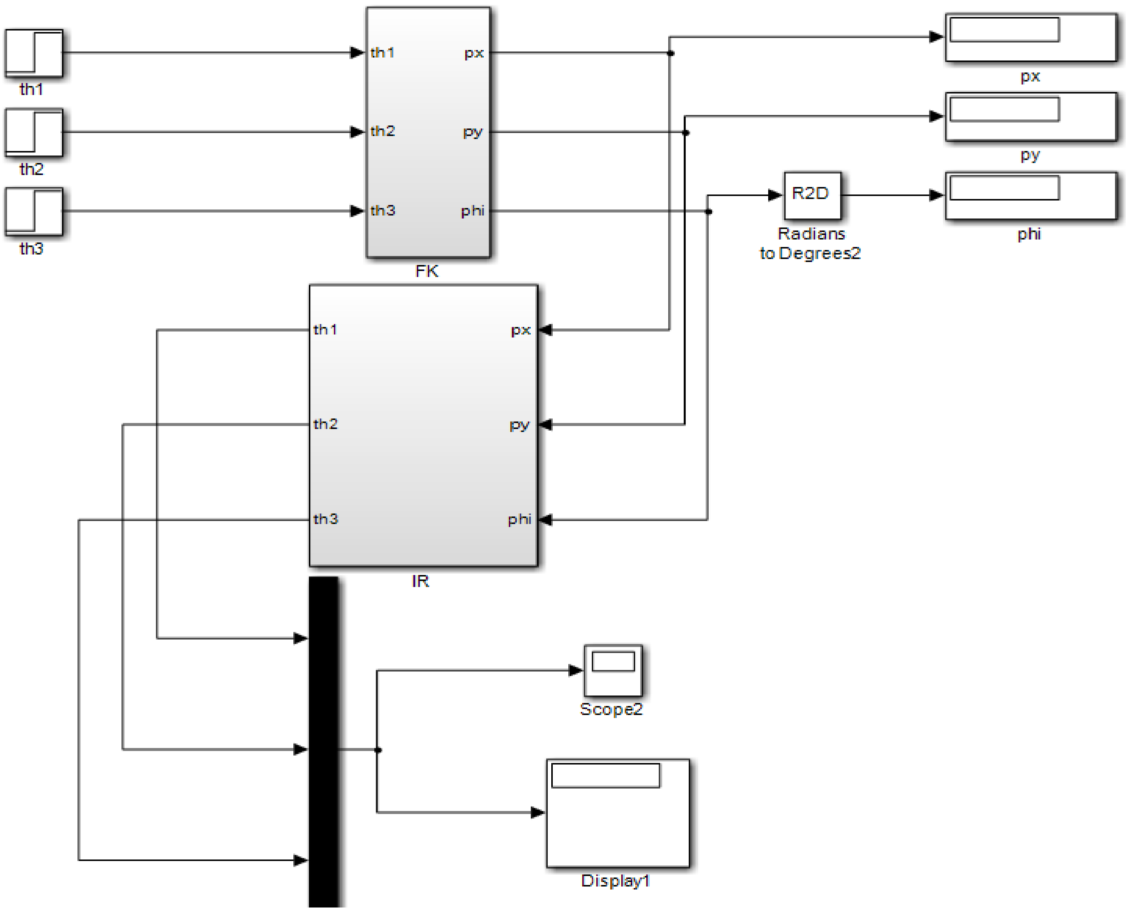
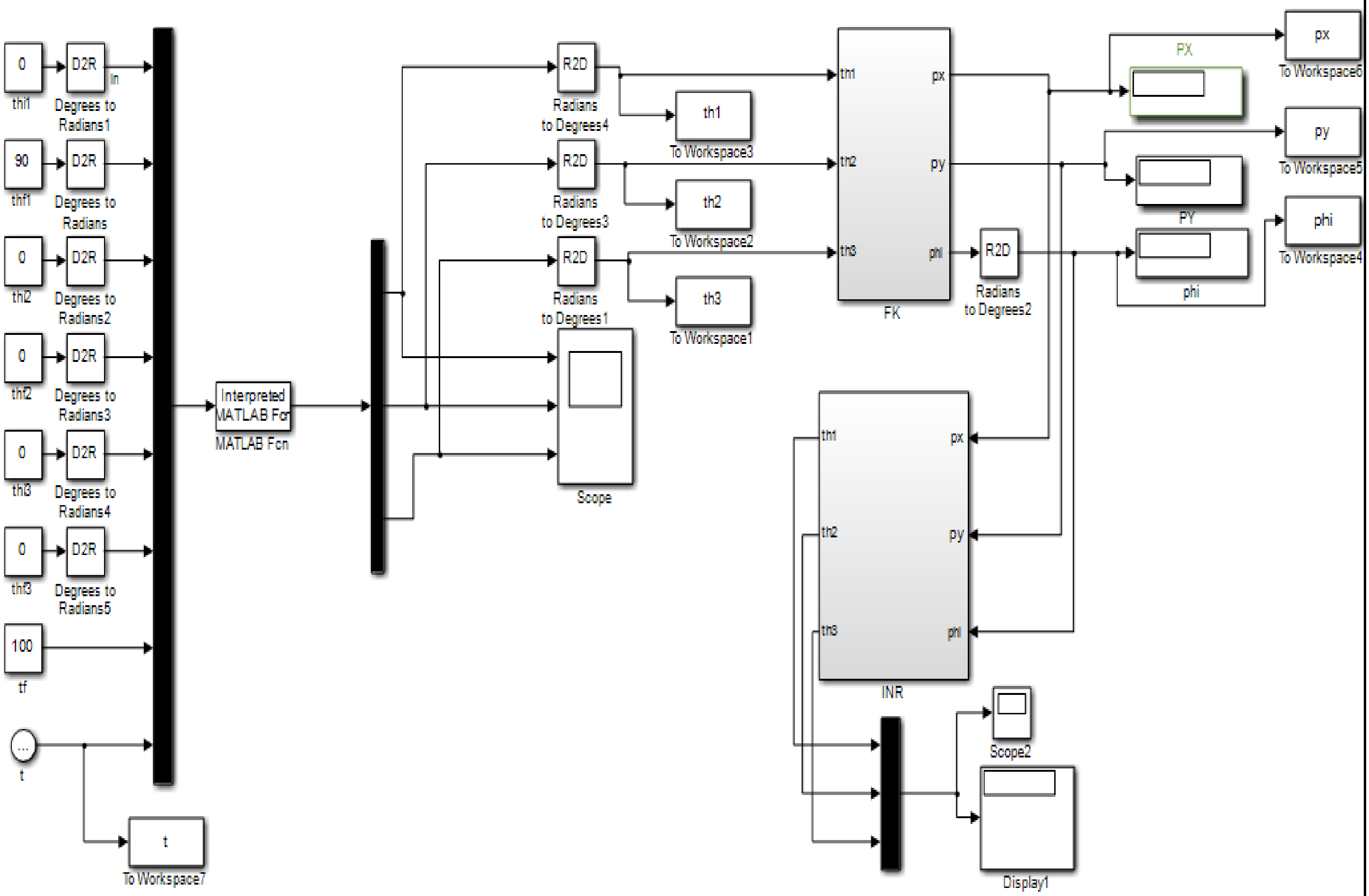


Figure 3-5: Full design of both forward and inverse kinematic

3.1.2 Simulink of Trajectory

The simulink of the trajectory configure by using the inverse and forward kinematic and the input θ_i . θ_f and the equations (2-10),(2-11),(2-13) and (2-14) as shown infigure(3-6).



Figure(3-6): Finger Trajectory

3.1.3 Wire Connection Simulation and Block Diagram Design

a. As shown in the circuits attached in figures (3-8), (3-9) the sensors consists of two pins. One pin is connected to the ground, which takes from the Arduino, while the other pin is connected with the resistor and analog pins of Arduino (A4-A0).

b. The servo motors are made up of three wires: the first one is the ground signal, the middle one is the decoder and the third one is the shutters will connect the digital Arduino pins.

c. Sensors are placed on the glove that measures the movement of the fingers of the hand (the spread and contraction of the fingers). The sensors measure the movement of the fingers by changing the value of their resistance, resistance increases during the contraction and decrease during the extinction.

d. After that, the input signal for Arduino to work for its processing and since the microcontroller does not deal with the signals only analog with digital, the Arduino divides the internal signal from the sensors to the 1024 sample through ADC (Analog to digital Convertor) , and through the map( ) and constrain( ) function converts the signal from (0 - 1023) to (0-180), which represents the angle at which the servo motor rotates.

e. Finally, The motors were make a paste to move the human hand by turning its resistive value into the angle of rotation of the shaft from 0 to 180 degrees. Thus, the robotic hand would move the same movement of the human hand.

i.Block Diagram

In figure (3-7) that shown the block diagram of wire connection between transmitter and receiver circuit.

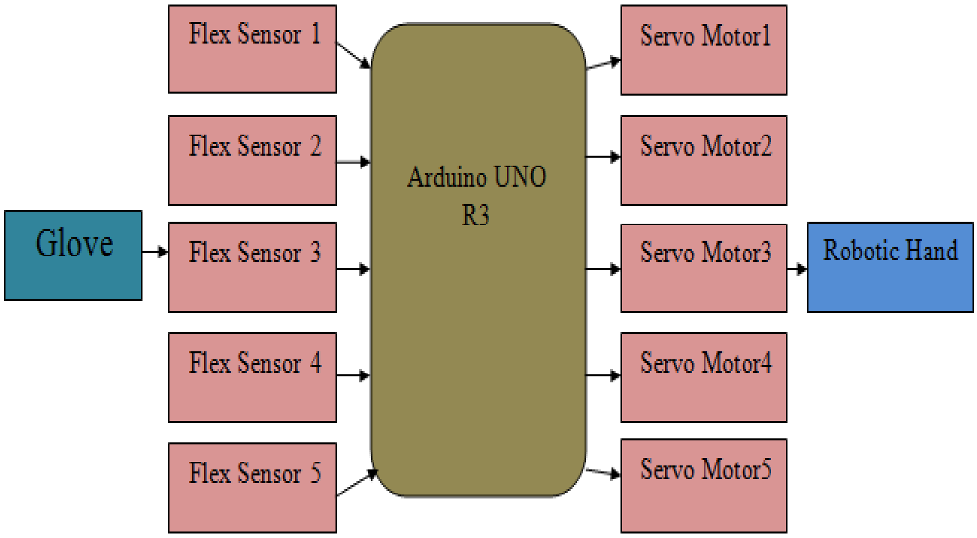


Figure3-7: Block Diagram of the Wire Connection

ii.Fritzing Simulation

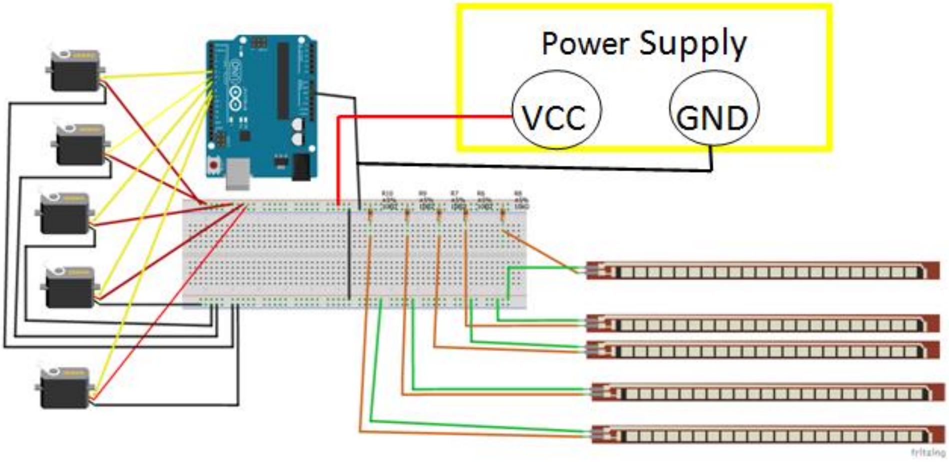


Figure 3-8: SimulationWire connection by fritzing

iii.Protues Simulation

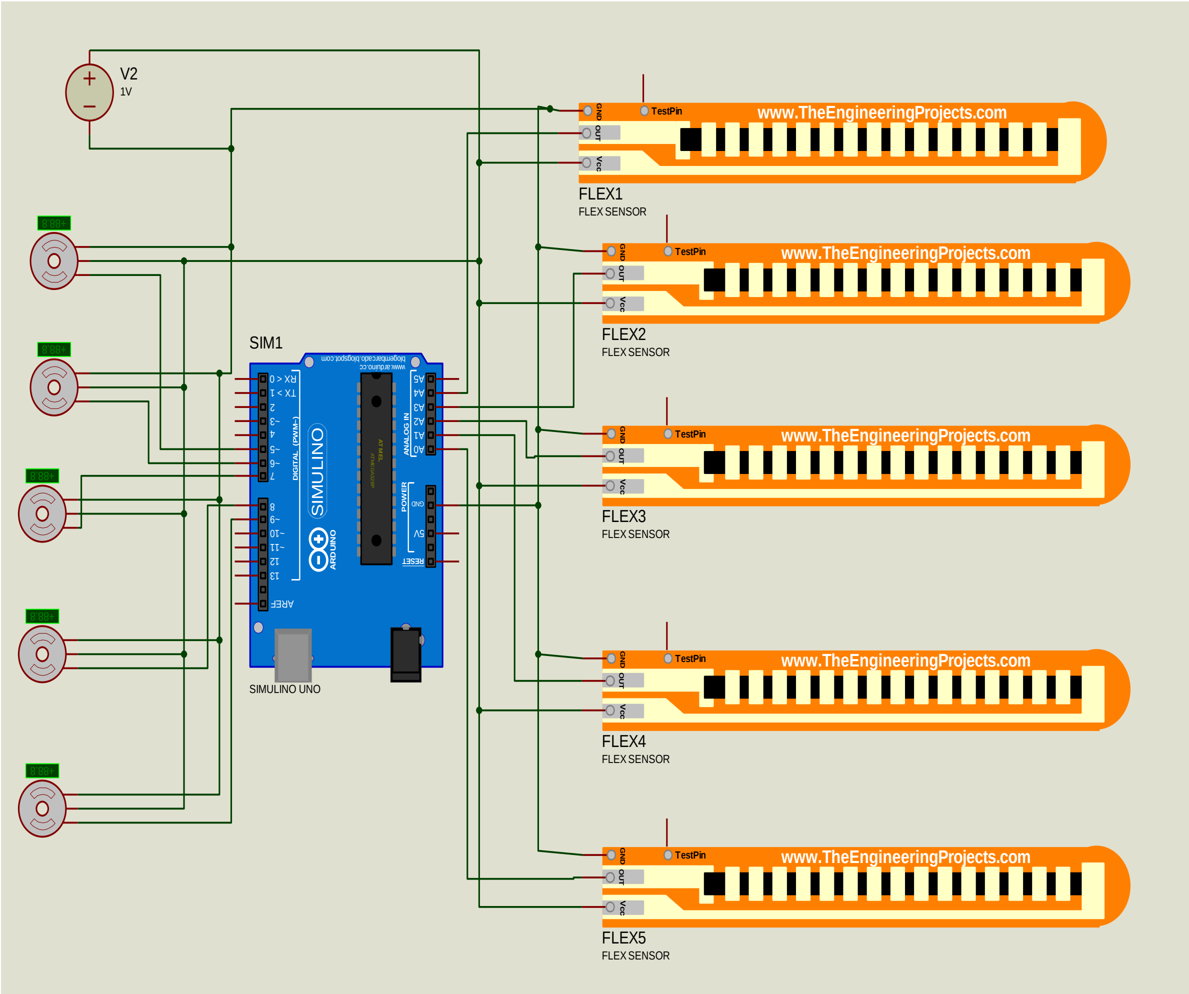


Figure 3-9: SimulationWire connection by Protues

iv. Flowchart of Wire Connection

In the figure (3-10) that shown the flowchart of wire connection between transmitter (sensor circuit) and receiver circuit.

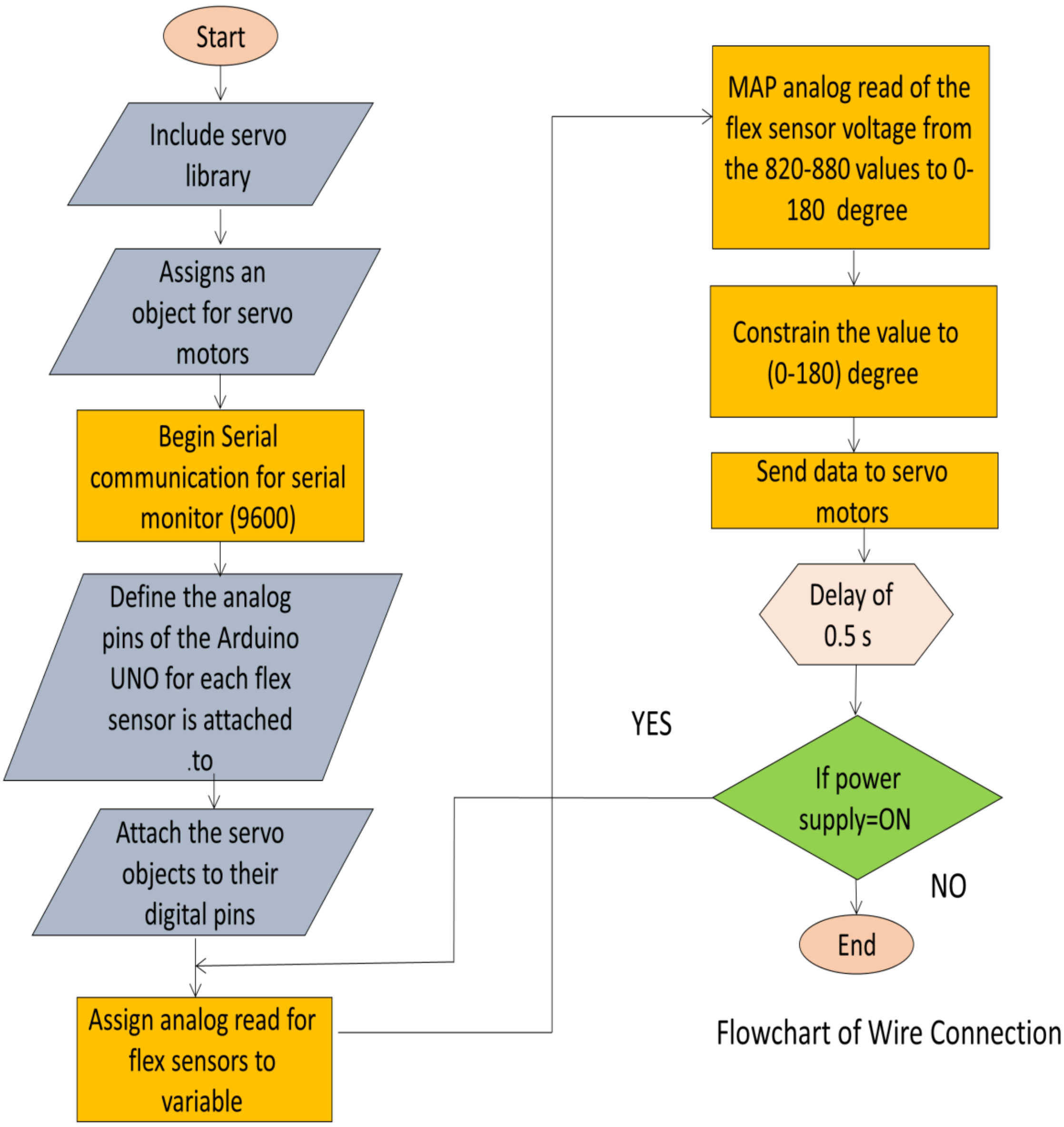


Figure 3-10: Flowchart of wire connection program

3.1.4 Wireless Connection Simulation and Bolck Diagram Design

In wireless connection, that connects additional component: Bluetooth, regulator, and separate voltage source (9v battery).

a. Configuring the HC-05 Bluetooth Module – AT Commands

The Bluetooth is by default work as slave so by using AT commands that converted to master.

i. Slave Configuration

In figure (3-11) below shownthe steps of slave configuration .

1. "AT" which is a test command that got back the message "OK".

2. "AT+UART?" got back the default baud rate which is 9600.

3. "AT+ROLE?" got back a "+ROLE=0" which means that the Bluetooth device is in slave mode.

4. "AT+ADDR?"got back the address of the Bluetooth module like this: 98d3:31:fd5a4d. This Bluetooth connect with driver circuit.

Figure 3-11: AT command/slave module

ii. Master Configuration

In figure (3-12) below shownthe steps of master configuration.

1. The baud rate was checked to make sure it's the same 9600 as the slave device.
2. "AT+ROLE=1" was typed to set the Bluetooth module as a master device.
3. "AT+CMODE=0" was used to set the connect mode to "fixed address"

4. “AT+BIND=” command was set the address of the slave device.

5. This Bluetooth connect with sensor circuit .

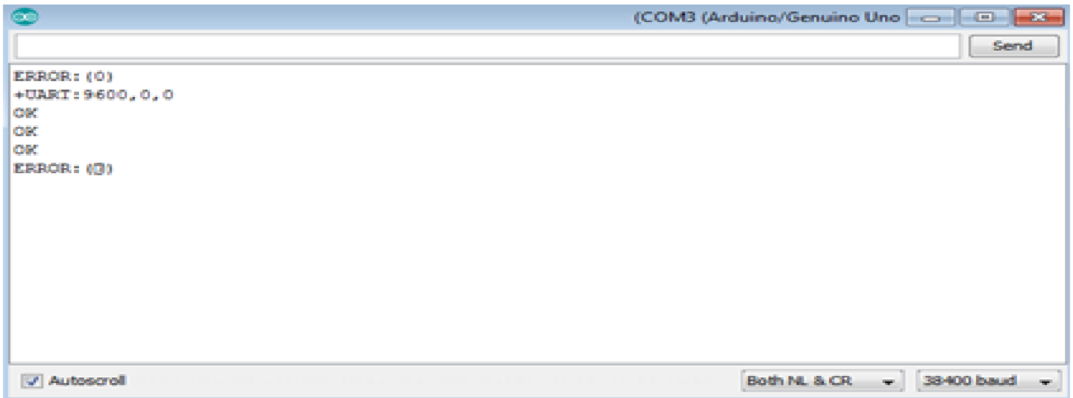


Figure 3-12: AT command/master module

iii. Arduino Uno with Bluetooth ModuleTesting

In the figure (3-13) that shown the Bluetooth connection with Arduino UNO for AT command test.

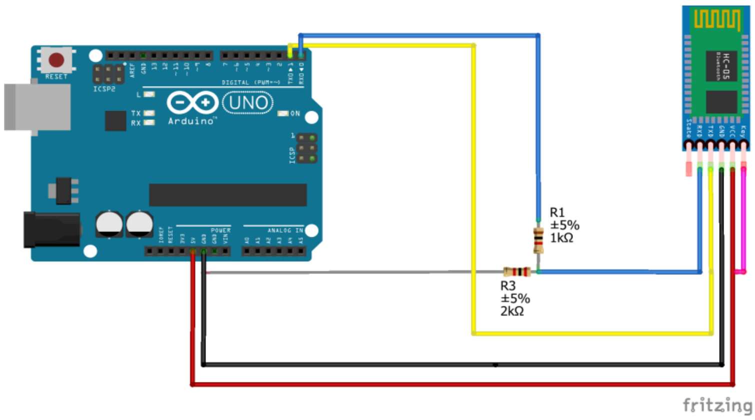


Figure 3-13: Bluetooth connection with Arduino UNO

b. Block Diagram of Wireless Connection

The second test is the wireless connection via tow bluotooth moduls and two Arduino cards to constrict the master (sending end) circuit and (reciving end) the slave circuit. The block diagram shown in the figure (3-14) below is illustrates the wireless connection and send a signal between transmit circuit and received circuit .

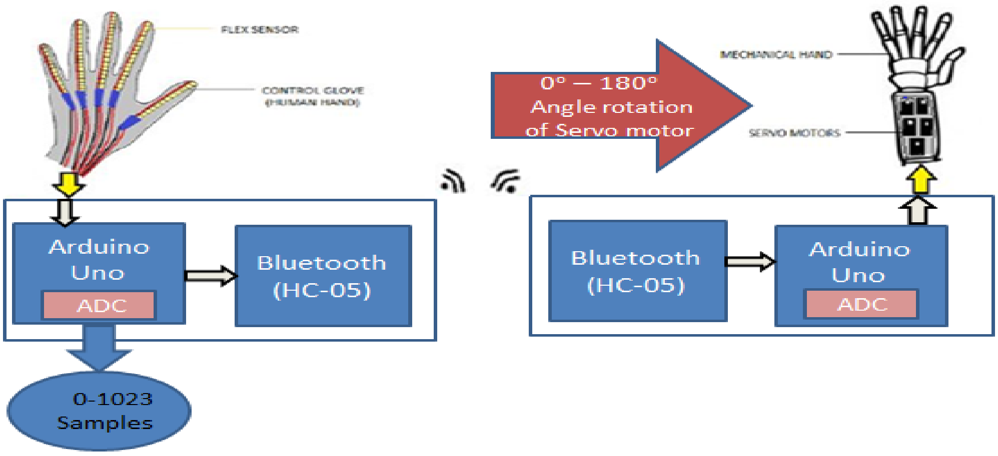


Figure 3-14: Block Diagram of Wireless Connection

The advantage of wireless connection:

- The users can move around freely within the area of the work in wireless connection.
- Not having to lay lots of cables and put those through walls etc.
- The wireless robotic hand could be found useful in environments where it is dangerous for humans.

c. Simulation and Flowchart of Transmitter/Master Circuit

i. Fritzing Simulation

In figure (3-15) that shown the fritzing Design of wireless transmitter /master circuit connection.

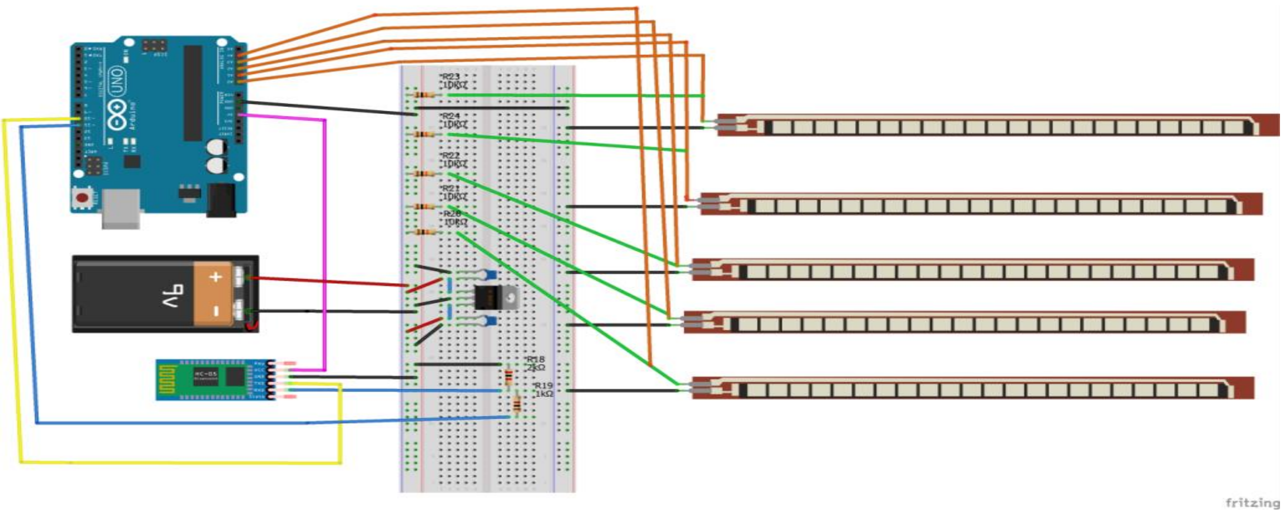


Figure 3-15:Fritzing Simulation of Wireless transmitter/master circuit

ii. Protues Simulation

In figure (3-16) that shown the protues Design of wireless transmitter /master circuit connection.

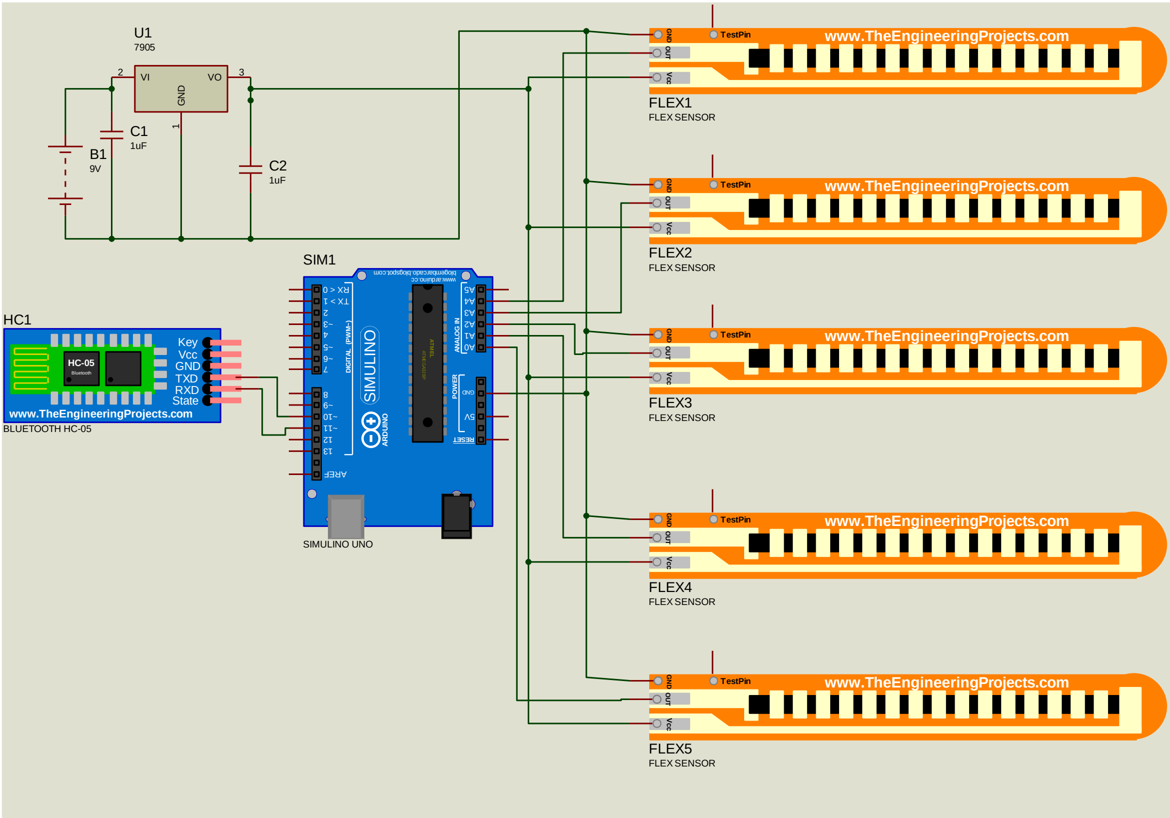


Figure 3-16:Fritzing Simulation Wireless transmitter/master circuit

iii.The Flowchart of Transmitter/Master Wireless Connection

In figure (3-17) that shown the flowchart Design of wireless transmitter /master circuit .

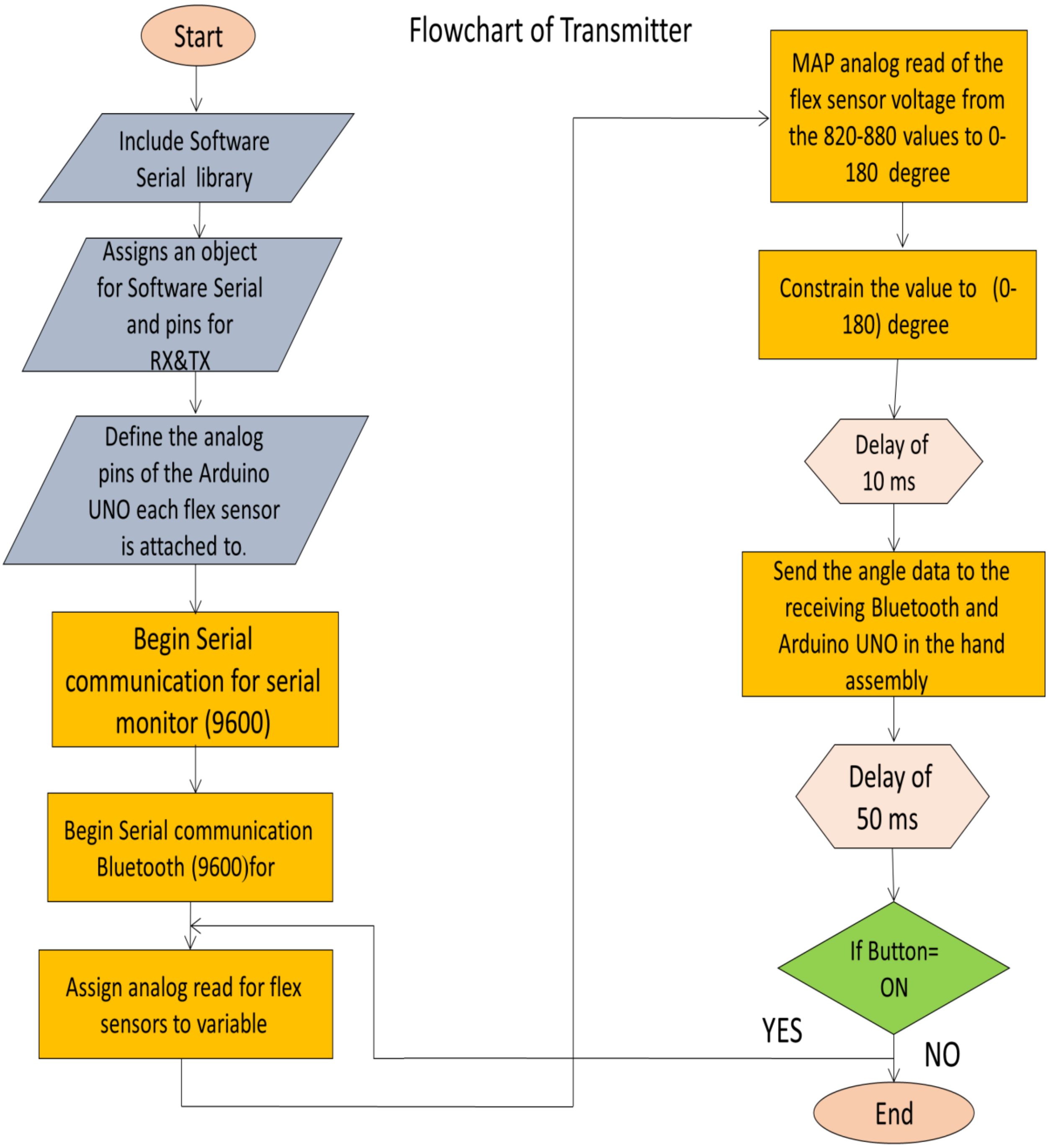


Figure 3-17: Flowchart of Transmitter/Master wireless connection

d. Simulation and Flowchart of Receiver/Slave Circuit

i. Protues Simulation

In figure (3-18) that shown the protues design of wireless receiving/slave Circuit connection.

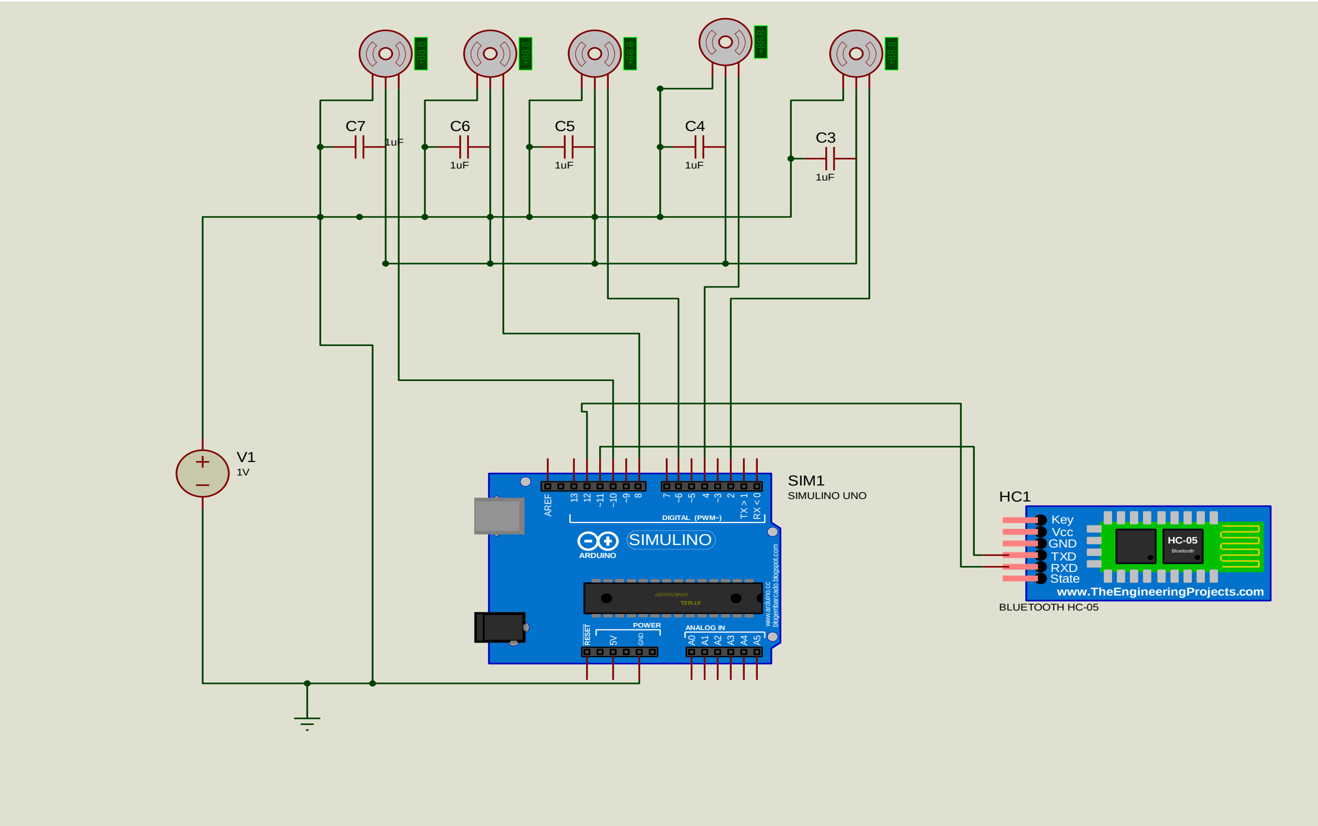


Figure 3-18: Wireless connection receiving/slave circuit

ii. The Flowchart of Program Receiver/Slave Wireless Connection

In figure (3-19) that shown the floechart design of wireless receiving/slave connection.

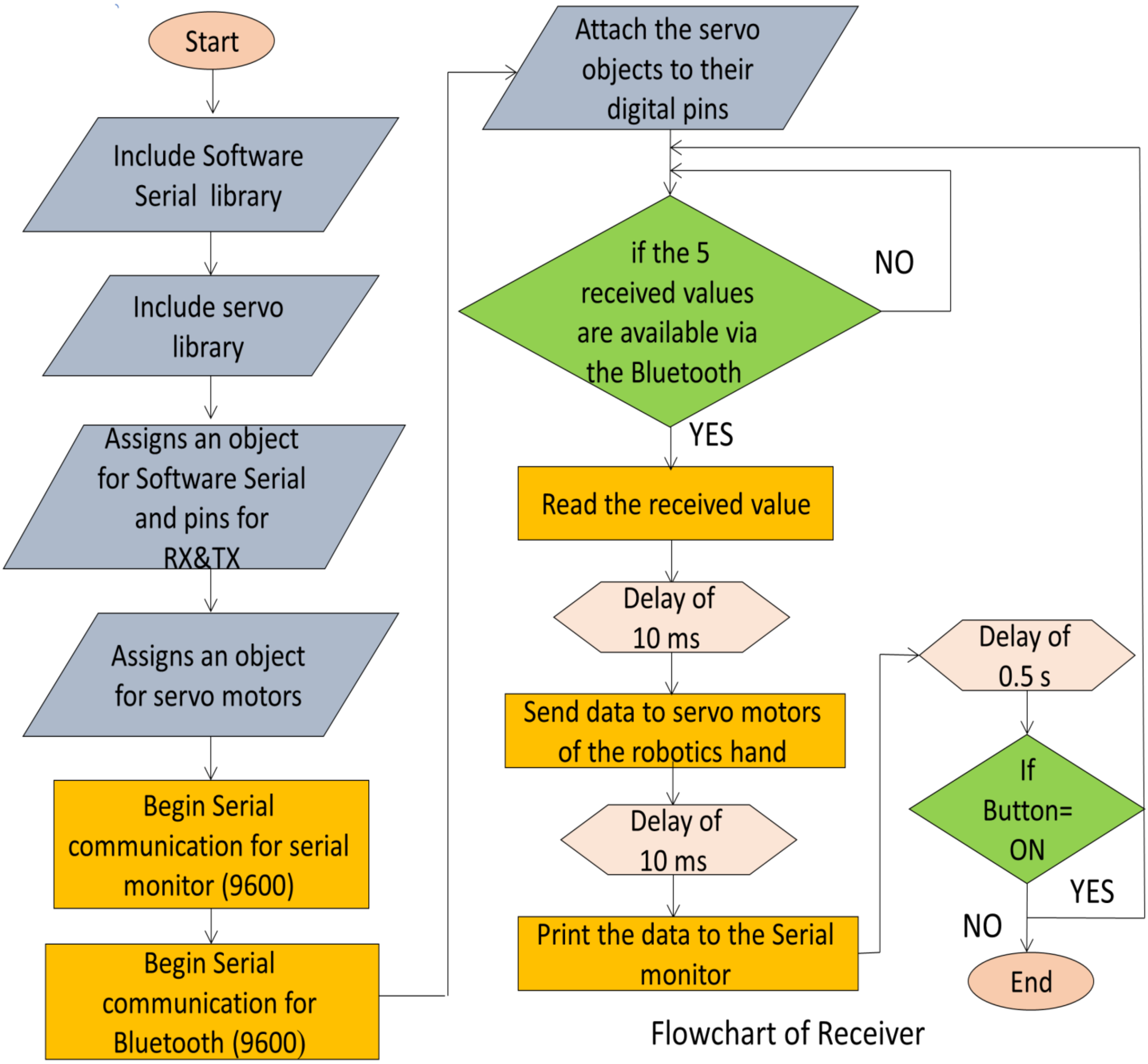


Figure 3-19: The Flowchart of program Receiver/Slave wireless connection

3.2 Hardware Design and Implementation

3.2.1 Wire Interfacing Circuit

This sectionillustrates the interfacing circuit of wire connection which tested in two phases of:

a. Transmitter Interfacing Circuit:

The figure (3-20) that shown the glove that contain the flex sensore and shown the sensor (transmitter) circuit.

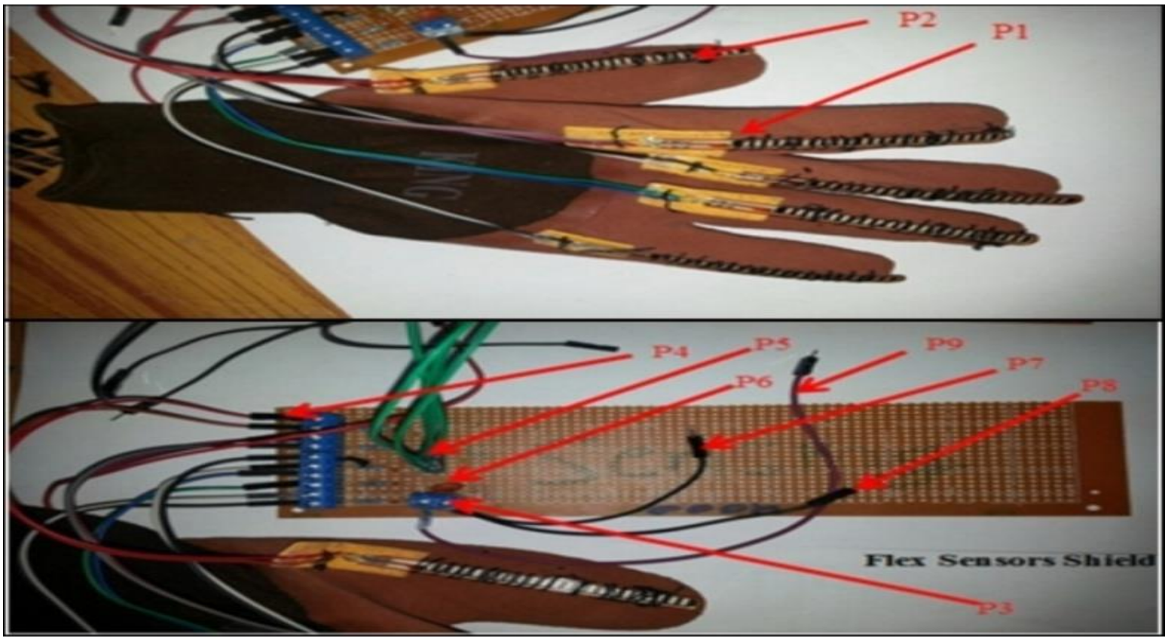


Figure 3-20: The Glove with Flex Sensors and Sensor Circuit

The table (3-1) that sown below the all componnent of the transmitter circuit .

Table 3-1:Parts of the complete wire Transmitter interface system

Part	Name	Duty
P1	Glove	That Wear by human hand
P2	Flex Sensor	Measure the Movement of human figures
P3	Power supply ports	Supplies power to flex sensors
P4	Data wires	Data wires of the flex sensors
P5	Data wires	Wires that connect the servos to the Arduino UNO Pins
P6	Resistor	Used for protection (10Kohm)
P7	Ground Wire	Wire connect to ground of power supply
P8	Ground Wire	Wire connect to ground of Arduino Uno
P9	VCC Wire	Wire connect to VCC of power supply

b. Receive Interfacing Circuit

The figure (3-21) that shown the consists of receive interface circuit.

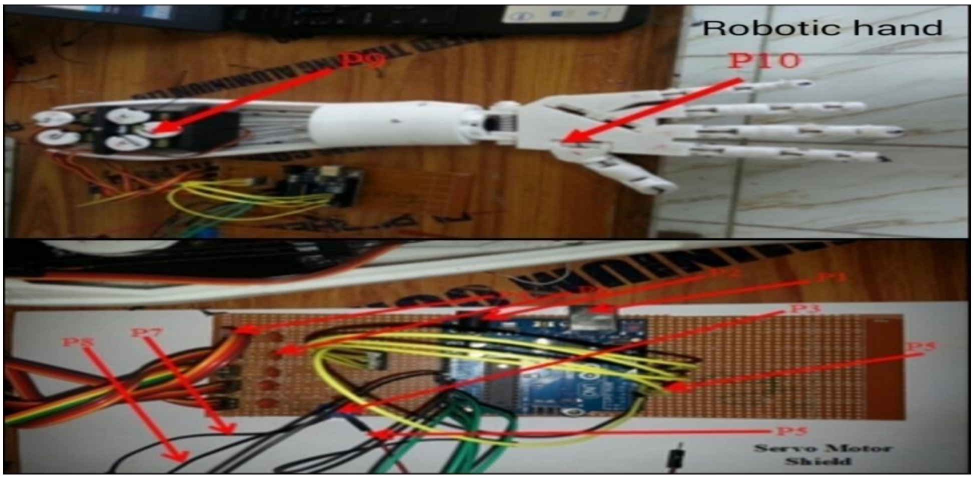


Figure 3-21: Receiver Interface Circuit

Table (3-2) that shown below illustrate all parts of wire interface circuit component.

Table 3-2:Parts of the complete wireReceiver interface system

Part	Name	Duty
P1	Arduino serial port	Connects the Arduino to laptop. Helps to upload codes and communicates between them**.**
P2	Power supply ports	Supplies the Arduino UNO with power from a DC battery
P3	Power supply ports	Supplies power to servo motors
P4	Data wires	Data wires of the Servos
P5	Data wires	Wires that connect the servos to the Arduino UNO Pins
P6	Capacitor	To hold voltage stability
P7	Ground wire	Wire connect to ground of power supply
P8	Ground wire	Wire connect to ground ofArduino Uno
P10	Robotic Hand	That makes copy to the same movement of human hand.

The figure (3-22) shows below the complete wire driving interfacing circuit.

Figure 3-22: The Complete Wire Interfacing Circuit

3.2.2 Wireless interfacing circuit:

This Section was shown the interfacing and control circuit of wireless connection the reading (sensor circuit) and driving (actuators circuit).

a. Transmitter interfacing circuit

The components are the same component of wire connection but it also contains the Bluetooth HC-05 for wireless communication between two circuits, as shown in figure(3-23) .

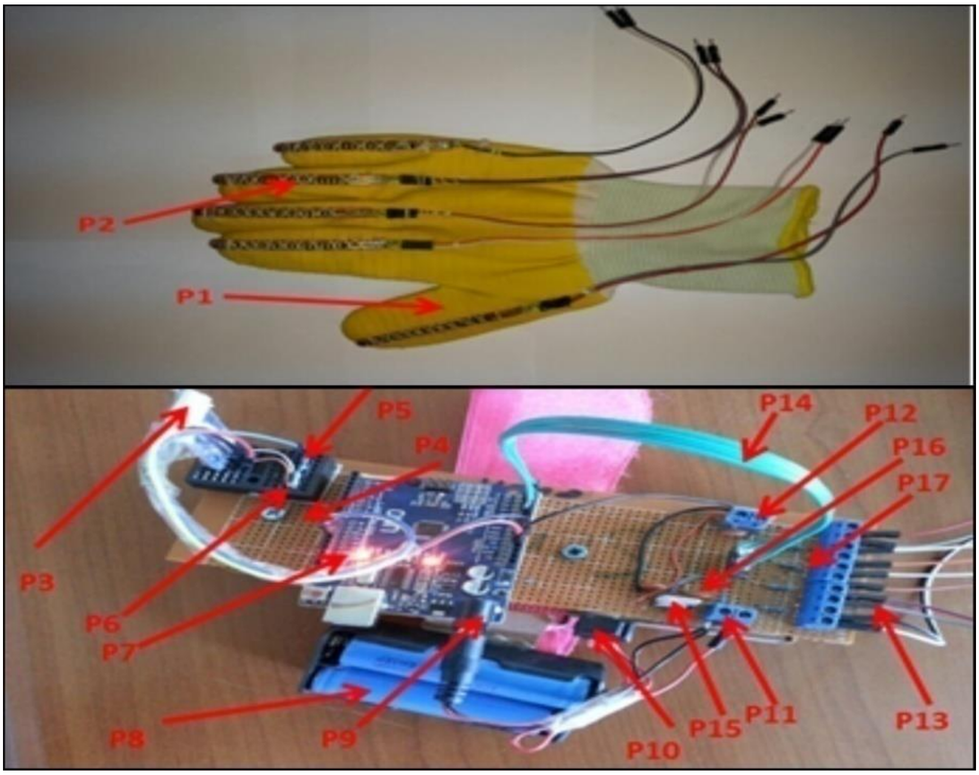


Figure 3-23: Glove with Flex Sensors and Transmit Controller Circuit

The table (3-3) that shown below illustrates the parts of wireless transmitting circuit with Bluetooth module.

Table 3-3:Parts of the complete wireless Transmitter control system

Part	Name	Duty
P1	Glove	That Wear by human hand
P2	Flex Sensor	Measure the Movement of human figures
P4	Resistance	2k resistance that connect to GND and RX of Bluetooth.
P5	Resistance	1k ohm that connect to pin (11) of Arduino and RX of Bluetooth.
P6	Small board	That use for connect the Bluetooth circuit.
P7	Arduino Uno	Is a microcontroller used for processing the signals.
P8	Charger Battery	It use for powered both Arduino UNO and flex sensors.
P9	Power supply ports	Supplies the Arduino UNO with power from a charger battery.
P10	Button	This use for close and open circuit.
P11	Power supply ports	That supplied 9v that enter to regulator.
P12	Power supply ports	That supplied 5v to flex sensors that output from regulator.
P14	Data wires	Wires that connect the flex sensors to the Arduino UNO analog Pins.
P15	Regulator	That is use to convert from 9v that take from battery to 5v that supplied flex sensors.
P16	Capacitor	This use for protect the input and output voltage of regulator from ribbing and noisy.
P17	Resistance	This is 10K ohm that connects to flex sensor.

b. Receive interface circuit

As shown in figure (3-24) In the receive circuit is consisting from robotic hand and receive circuits.

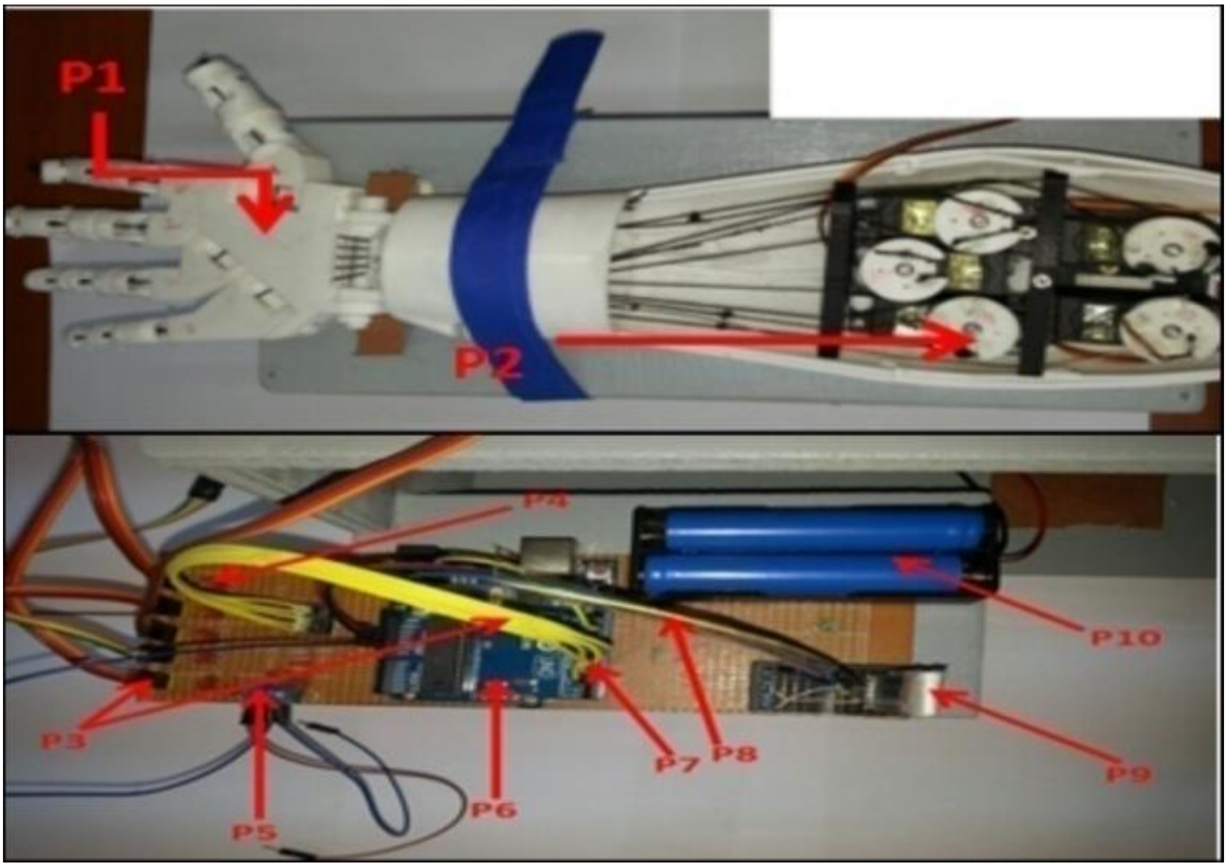


Figure (3-24): Receive interface circuit

The table (3-4) below shows the component of the wireless receiving circuit.

Table 3-4:Parts of the complete wireless Receiver control system

Part	Name	Duty
P1	Robotic hand	This is making copy to the move of the human hand.
P2	Servo motor	Move the figures by angle of rotation (0-180)
P3	Data wires	Wires that connect the servos to the Arduino UNO Pins
P3	Power supply ports	Supplies power to servo motors
P4	Capacitor	To hold voltage stability
P6	Arduino UNO	Is a microcontroller used for processing the received signals.
P7	Data pins	This digital that give the servo motor the signals.
P8	Data Wires	This connects Bluetooth HC-05 with RX and TX of Arduino UNO.
P9	Bluetooth	This is slave Bluetooth that receive the receiver signals.
P10	Battery	DC voltage battery that supplied Arduino.

Chapter Four
Results and Discussion

4.1 Organization of the project

a. **Human hand robot design and motion mechanism**

The hand of the robot was designed by using a three-dimensional printer consisting of five fingers and each finger consisting of three degrees of free movement.

b. **Sensing interfacing circuit design**

Power or flexibility sensors was used to measured the constriction and spread of the fingers via a specially designed circuit to make the sensor signals readable by Arduino card.

c. **Actuation or motion system**

The Servo motor was used to move the fingers of robotic hand by rotate from 0 to 180 degree.

d. **Wire Connection**

Wire connection was used to connected between the transmitter and receiver (Master & slave) circuits.

e. **Wireless Connection**

Wireless connection was used to connected between the transmitter and receiver circuits by using (HC-05) Bluetooth.

4.2 Simulation Results

4.2.1 Kinematic Simulation Results

Table 4-1: Test of Kinematics of Forward and Inverse for the index finger

Theta			Forward Output			Inverse Output		
θ_1	θ_2	θ_3	Px	Py	Phi	θ_1	θ_2	θ_3
0	0	0	11.35	0	0	0	0	0
90	0	0	6.95e-16	11.35	90	90	0	0
0	90	0	4.8	6.55	90	0	90	0
0	0	90	8.29	3.06	90	0	0	90
90	90	90	-3.49	1.74	270	90	90	90
45	45	45	1.23	9.046	135	45	45	45
60	60	60	-2.405	7.176	180	60	60	60

4.2.2 Trajectory Simulation Resultsof Finger Movements

Has shown in table (4-2) the trajectory results after calculation the theta inputs, $\theta_{1,i,f}$, $\theta_{2,i,f}$ and$\theta_{3,i,f}$ .The theta initial $\theta_{1,i}$, $\theta_{2,i}$ and $\theta_{3,i}$ equals zero in all state.

Table 4-2: trajectory Test of finger movement

Theta			Forward Output			Inverse Output		
θ_{f1}	θ_{f2}	θ_{f3}	Px	Py	Phi	θ_1	θ_2	θ_3
90	0	0	$6.95e^{-16}$	11.35	90	80.96	0	50.76
0	90	90	4.8	6.55	90	7.453	58.69	50.9
0	0	90	8.29	3.08	90	1.923	0	5155

Are shown below the plots on two figures the first figure is between positions p_x and p_y. The second figure is between θ and t to produce parabolic plot. The values of theta The results in figures, figure(4-1), figure(4-2),figure(4-3)

1- thi1=0, thf1=90, thi2=0, thf2=0, thi3=0, thf3=0.

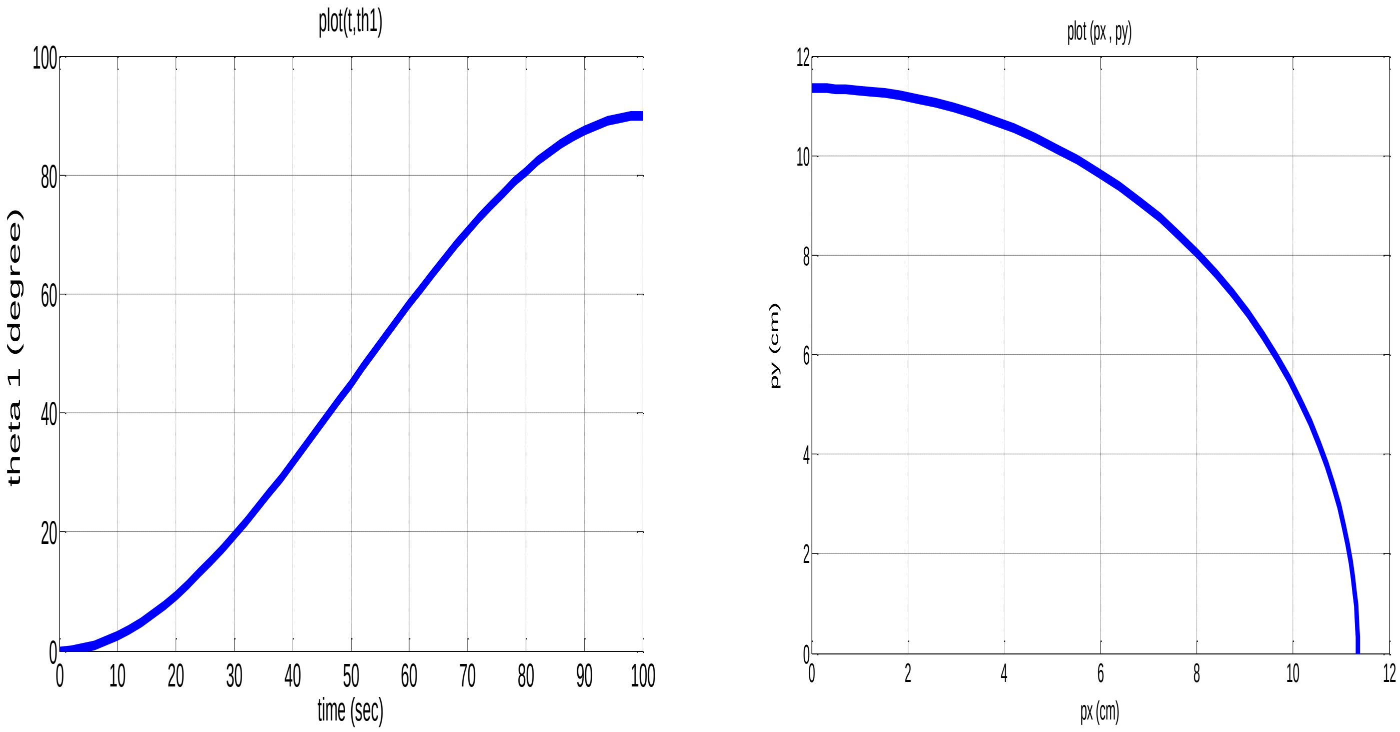


Figure (4-1): Trajectory plot when th1=90

2- thi1=0, thf1=0, thi2=0, thf2=90, thi3=0, thf3=0.

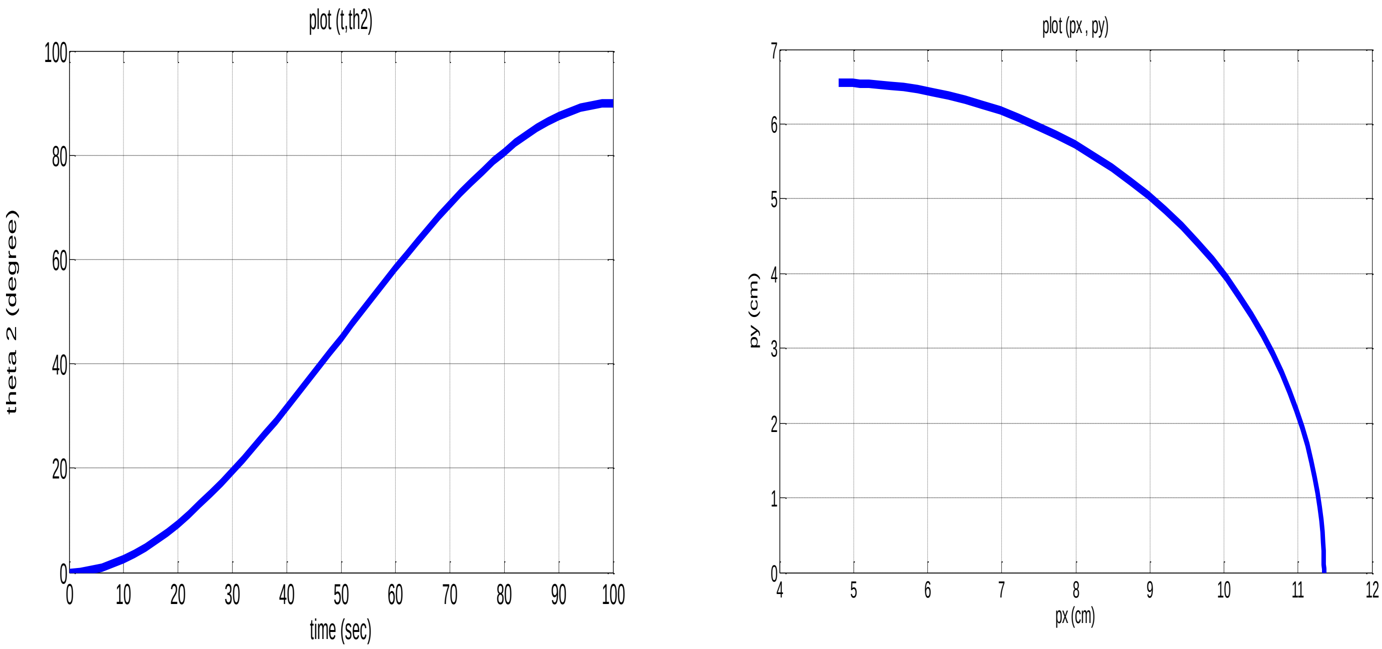


Figure (4-2):Trajectory plot when th2=90

3- thi1=0, thf1=0, thi2=0, thf2=0, thi3=0, thf3=90.

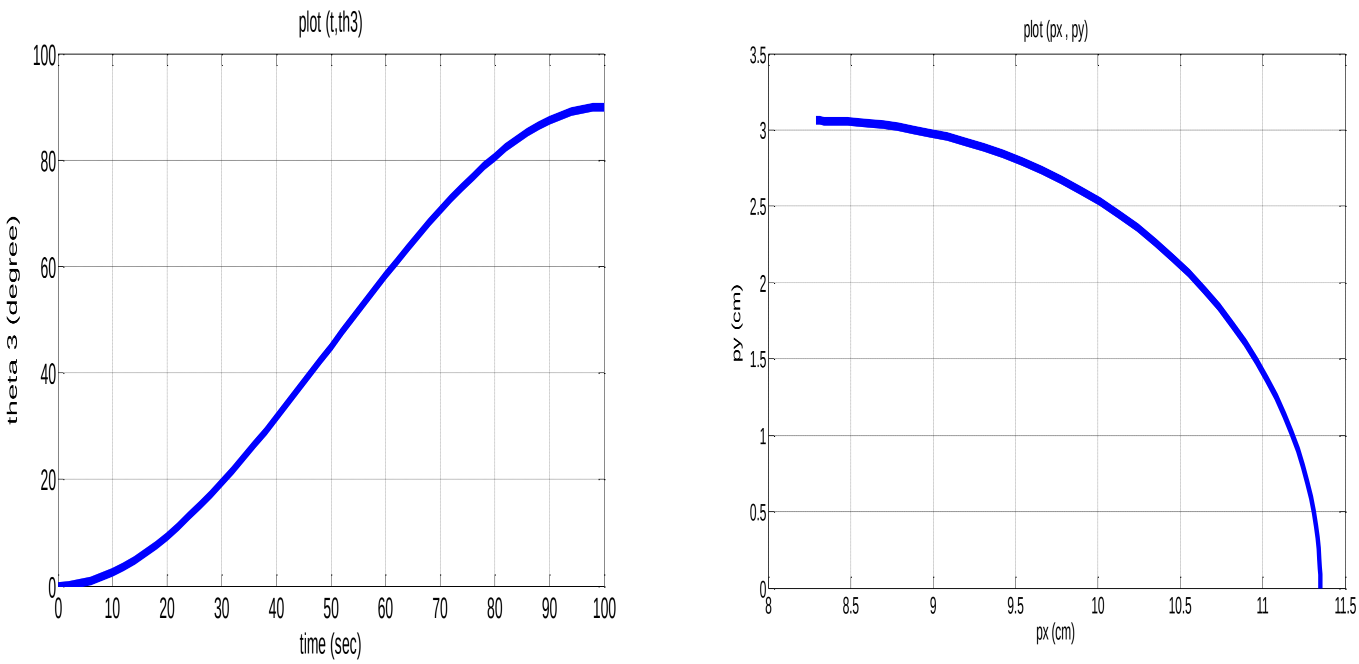


Figure (4-3):Trajectory plot when th3=90

4.3 Physical Results

The physical results will present in two phases of wire and wire connection simultaneously.

a. Wire Connection Results

The movements achieved by wire connection are the open and close of all robotic hand fingers completely, also the test include the opening and closing of each finger individual. The figure (4-4) was shown these result motions.

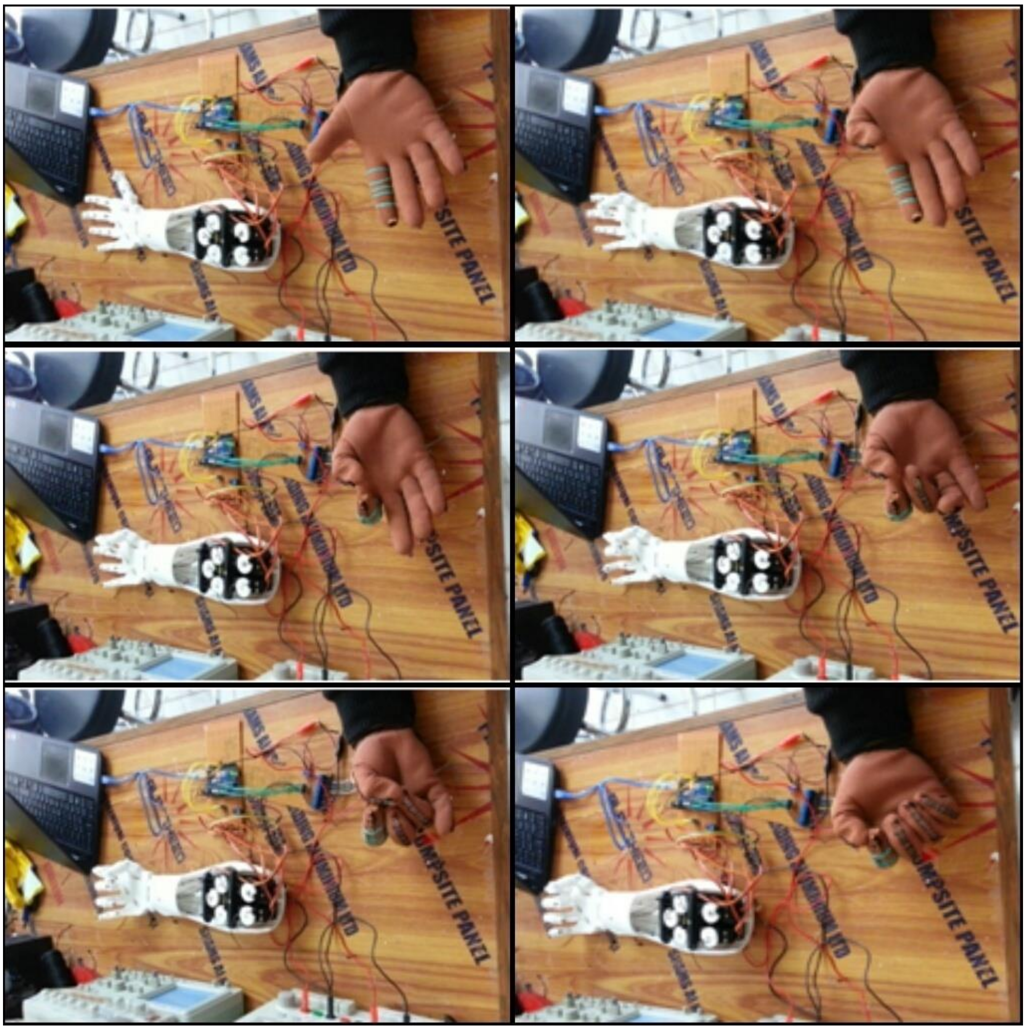


Figure 4-4: All fingers movement of Wire Connection

b. Movements of Wireless Connection

Movements achieved by wireless connection are the open and close of the robotic hand completely one time for all fingers. Figure (4-5)below that shown the wireless movements.

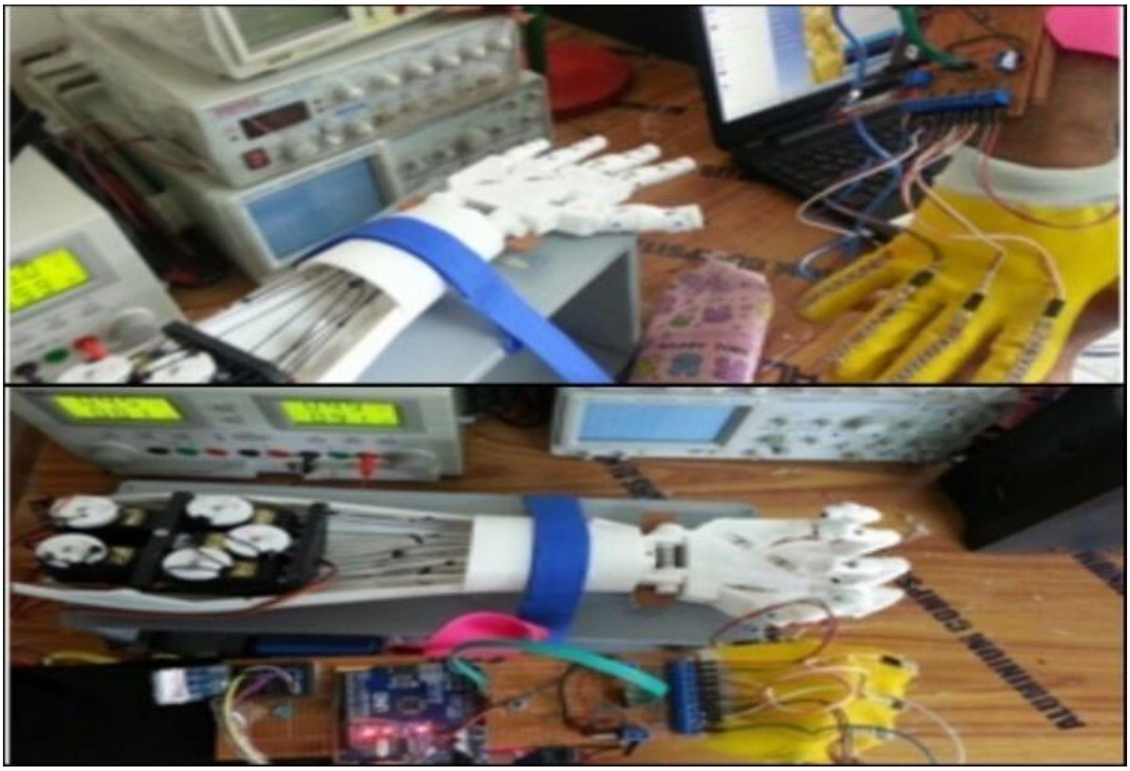


Figure 4-5: Close and open movement of wireless connection

A useful prosthetic (robotic) hand must be able to grasp different shape objects in a significant force and be capable of holding that force for a desired time. So, the artificial hand designed was able to perform a satisfied grasping of some traditional objects in different shapes as shown in Figure (4-6).The figurewas shown the statue of the hand undergoes in order to grasp an object, starting from the open hand till the close consequently with the contraction of the human hand.

Figure 4-6: Grasp of cylindrical object

4.4 Discussion

From the all presented results and test one can concluded that the robotic human hand can be useful in doing tasks from faraway places and with desired movements in order to save the human body from an effect of chemical, radiation and biological processes specially with wireless connection of distance greater than 37 meters as appeared with physical tests.

Chapter Five

Conclusion and Future Work

5.1 Conclusion

1. The artificial hand designed approximates the manipulation abilities of human hand very well.
2. The kinematic analysis of the finger showed that: as the finger length increased, the corresponding workspace envelope also increased which made the middle finger possess the biggest workspace.
3. In spite of the simplicity of the control system, it showed a reliable performance. The sensor used was efficient in a high degree since it was able to record the motion finger and collect it without any noticeable delay.
4. Bluetooth determines the distance in which the person is located and determines that the person must be within the same area as the robotic hand.
5. This project reduces human efforts at places or situations where human interventions are difficult.
6. This project can be used in many applications such as industrial, medical, chemical, military and Laboratory Applications.

5.2 Future Work

The robotic hand needs more calibration with using the best quality of motors. Also adding a controller like PID or fuzzy controller to make the hand motion more stably; that done by adding five flex sensors to be placed on the robotic hand in the same shape as the sensors placed on the glove. This addition for compare between human hand and the robotic hand motions and control the error in motion. This error comes from the wireless connection that affected by the noise around it that making it send small random values to the servo motors. In order to increase the distance of transmission, it replaces the Bluetooth with the Wi-Fi wireless connection (like using NODE MCU module). So that the signal reaches a greater distance.

References

[**1**]Siciliano, Bruno, and OussamaKhatib, eds. **"Springer handbook of robotic".** Springer Science & Business Media, 2008.

[**2**]Yaqub, Muhammad Atif. **"Multi fingered robot hand in industrial robot application using tele-operation."**Diss.UniversitiTun Hussein Onn Malaysia, 2012.

[**3**] Hand Design, http://inmoov.fr/hand-and-forarm ,May,2018.

[**4**]McRoberts, Michael. **"Beginning Arduino."** Après, 2013.

[**5**]Servomotor,**"ServoControl"**http://www.cs.unca.edu/~bruce/Fall09/255L/ServoControl.pdf.

[**6**] Flex Sensor, "**Spectra symbol**," https://www.sparkfun.com/datasheets/Sensors/Flex/flex22.pdf, May, 2018, Datasheet.

[7]Studio, ITead.**"HC-04-Bluetooth to Serial Port Module."** Datasheet, June (2010).

[**8**] B.S.K.K. Ibrahim and A. M. A. Zargoun, "**Modeling and Control of SCARA Manipulator**," Elsevier,Procedia Computer Science, international conference on robot PRIDE, proceeding 42, pp. 106-113, Malaysia, 2014.

[**9**] S. F. HASAN. (Oct., 2016) **BIOMECHATRONIC DESIGN OPTIMIZATION OF ANTHROPOMORPHIC ARTIFICIAL HAND FOR PROSTHETIC** (master's thesis), AL Nahrain University, Dep. of Mechanical Engineering, Iraq.

[10] M. W. Spong, S. Hutchinson, and M. Vidyasagar, **"Robot Modeling and Control"**, John Wiley& Sons Inc, First Edition, 2005.

APPENDIXES

Appendix A

A.1 Arduino Code For Reading Flex Sensor signals(Transmitter Circuit) and Receive Signals by Wire Connection.

```
#include <Servo.h>#
int flex0=A0, flex1=A1, flex2=A2, flex3=A3, flex4=A4;           //Flex sensor pins
Servo serv1, serv2, serv3, serv4, serv5;       // Pins for the control of each Servo.
void setup( ) {
Serial.begin (9600);                              //baund rate of serial monitor
serv1.attach(5) ;
serv2.attach(6) ;
serv3.attach(7) ;
serv4.attach(8) ;
serv5.attach(9) ;
}
void loop ( ) {
// Read the value of flex sensor.
int x0=analogRead(flex0);
 int x1=analogRead(flex1);
int x2=analogRead(flex2);
int x3=analogRead(flex3);
int x4=analogRead(flex4);
int s0=map(x0,820,880,0,180);// Transformation of the values
between 0 and 1023 in the position in degrees of the servo (0-180)
s0=constrain(s0,0,180);// Match values that are outside the range to
their extremes.
Serial.print("s0= ")
Serial.println(s0);                          // Print the values of angles in serial monitor.
int s1=map(x1,820,880,0,180);
s1=constrain(s1,0,180);
Serial.print("s1= ")
Serial.println(s1);                          // Print the values of angles in serial monitor.
int s2=map(x2,820,880,0,180);
s2=constrain(s2,0,180);
Serial.print("s2= ")
```

```
Serial.println(s2);                  // Print the values of angles in serial monitor.
int s3=map(x3,820,880,0,180);
s3=constrain(s3,0,180);
Serial.print("s3= ")
Serial.println(s3);                  // Print the values of angles in serial monitor.
int s4=map(x4,820,880,0,180);
s4=constrain(s4,0,180);
Serial.print("s4= ")
Serial.println (s4);                 // Print the values of angles in serial monitor.
// Indicates to each servo the position in which it has to be placed.
serv1.write(s0);
serv2.write(s1);
serv3.write(s2);
serv4.write(s3);
serv5.write(s4);
delay (500);
}
```

A.2Arduino Code for Reading Flex Sensor signals (Transmitter Circuit)Wireless Connection.

```
#include <SoftwareSerial.h>//Library of software serial of  Bluetooth
SoftwareSerial blue(10,11);            //RX,TX
int flex0=A0,flex1=A1,flex2=A2,flex3=A3,flex4=A4;          //Flex sensor pins
void setup( ) {
Serial.begin(9600);                              //bund rate of serial monitor
blue.begin(9600);                                //bund rate of  Bluetooth
}
Void loop ( ) {
// Read the value of flex sensor.
int x0=analogRead (flex0);
int x1=analogRead (flex1);
int x2=analogRead (flex2);
int x3=analogRead (flex3);
int x4=analogRead (flex4);

int  s0=map(x0,820,880,0,180);                  // Transformation of the values
between 0 and 1023 in the position in degrees of the servo (0-180)
```

```
s0=constrain(s0,0,180);                       // Match values that are outside the range to
                                                          their extremes
blue.write(s0);      //transform the value from to receive circuit
delay(10);                                 //Delay 10ms

int  s1=map(x1,820,880,0,180);
s1=constrain(s1,0,180);
blue.write(s1);
delay(10);                                 //Delay 10ms.

int  s2=map(x2,820,880,0,180);
s2=constrain(s2,0,180);
blue.write(s2);
delay(10);                               //Delay 10ms.

int  s3=map(x3,820,880,0,180);
s3=constrain(s3,0,180);
blue.write(s3);
delay(10);                              //Delay 10ms.
int  s4=map(x4,820,880,0,180);
s4=constrain(s4,0,180);
blue.write(s4);
delay(10);                                 //Delay 10ms.

// Print the values of angles in serial monitor.
Serial.print ("s0= ");
Serial.println (s0);
delay (50);                             //Delay 50ms.
Serial.print ("s1= ");
Serial.println (s1);
delay (50);                            //Delay 50ms.
Serial.print ("s2= ");
Serial.println (s2);
delay (50);                           //Delay  50ms.
Serial.print ("s3= ");
Serial.println (s3);
delay (50);                           //Delay 50ms.
```

```
Serial.print ("s4= ");
Serial.println (s4);
delay (50);                          //Delay 50ms.
}
```

A.3Arduino Code For copy Flex Sensor signals (Receive Circuit) Wireless Connection.

```
#include <SoftwareSerial.h>       //Library of software serial of Bluetooth
#include <Servo.h>                //Library of servo motor.
SoftwareSerial blue (11, 12);                 //RX,TX
Servo serv1, serv2, serv3, serv4, serv5;   // Pins for the control of each
Servo motor.
 int y0, y1, y2, y3, y4;
 void setup ( ) {
Serial.begin(9600);               //bund rate of serial monitor
blue.begin(9600);                 //bund rate of  Bluetooth
//connect digital pins of servo motors (2, 4, 6, 8, 10).
serv1.attach (2);
serv1.attach (4);
serv1.attach (6);
serv1.attach (8);
serv1.attach (10);
}
void loop ( ) {
while (blue.available ( ) >=5)      // Check if data is being received
{
//Read the values that received from transmitter circuit's.
y0=blue.read ( );
delay (10);                          //Delay 10ms.
y1=blue.read ( );
delay (10);                          //Delay 10ms.
y2=blue.read ( );
delay (10);                          //Delay 10ms.
y3=blue.read ( );
delay (10);                          //Delay 10ms.
y4=blue.read ( );  }
```

```
//indicates to each servo the position in which it has to be placed.
serv1.write (y0);
delay (10);                          //Delay 10ms.
serv2.write (y1);
delay (10);                          //Delay 10ms.
serv3.write (y2);
delay(10);                           //Delay 10ms.
serv4.write (y3);
delay (10);                          //Delay 10ms.
serv5.write (y4);
delay (10);                          //Delay 10ms.
// Print the values of angles in serial monitor.
Serial.prinln (y0);
delay (50);                          //Delay 50ms.
Serial.prinln (y1);
delay (50);                          //Delay 50ms.
Serial.prinln (y2);
delay (50);                          //Delay 50ms.
Serial.prinln (y3);
delay (50);                          //Delay 50ms.
Serial.prinln (y4);
delay (50);                          //Delay 50ms.
}
```

Appendix B

B.1 Trajectory Matlab code

```
function out=qudratic1(z)
thi1=z(1);
thf1=z(2);
thi2=z(3);
thf2=z(4);
thi3=z(5);
thf3=z(6);
tf=z(7);
t=z(8);

q1d=thi1+(3*(thf1-thi1)/tf^2)*t^2-(2*(thf1-thi1)/tf^3)*t^3;
q2d=thi2+(3*(thf2-thi2)/tf^2)*t^2-(2*(thf2-thi2)/tf^3)*t^3;
q3d=thi3+(3*(thf3-thi3)/tf^2)*t^2-(2*(thf3-thi3)/tf^3)*t^3;

out(1)=q1d;
out(2)=q2d;
out(3)=q3d;
```

الملخص

تمتلك اليد الروبوتيه أهمية كبيرة في الحياة الحالية وتتداخل في العديد من المجالات ، مثل المجالات الصناعية والطبية والكيميائية التي تحتاج إلى المزيد من القوة والسرعة والدقة التي لا يستطيع الإنسان تقديمها بشكل جيد ، لذا في هذه الحالة يحتاج الى استخدام اليد الآلية.

يتضمن هذا المشروع من تصميم وتحريك اليد الروبوتية ويتم التحكم فيها لاسلكيًا عبر وحدة بلوتوث لإرسال إشارات الحركة واستقبالها والتي تشابه حركة أصابع يد الإنسان.

تصميم المشروع يتكون من دائرتين: دائرة الإرسال ودائرة الاستقبال. تتكون دائرة المرسل من قفاز يرتديه الشخص والمستشعرات (مستشعر الحركه) موضوعه عليه وهو حساس يتحسس حركة أصابع اليد البشرية من خلال التغيير في مقاومته أثناء انقباض او انبساط الأصابع، وسيتم استخدام متحكم (لوحه الأردوينو) لمعالجة إشارات القراءة المستلمه من حساس الاستشعار وارسال إشارات التحكم أو التشغيل الى السيرفو ماطور.أيضا تمس استخدام وحدتي بلوتوث ,البلوتوث المرسل لإرسال البيانات المستلمه من القفازات التي تتضمن الحساسات إلى الأردوينو و بعدها الى البلوتوث. دائرة (الاستلام) التي تحتوي على البلوتوث المستلم لاستقبال إشارة التحكم و ارسالها الى لوحة الأردوينو و تحريك السيرفو ماطور. تم تصميم اليد الروبوتية المكونة من خمسة أصابع بنجاح كامل و كل إصبع له ثلاث درجات من حرية الحركه ، ويتم التحكم فيه عن طريق ماطور سيرفو واحد لكل اصبع لتحريكه بزاوية الدوران من 0 إلى 180 درجة. تم أشتقاق الكينماتيتا الأمامية والعكسية لقمه كل اصبع رياضياً لروبوت يتحرك ثلاث درجات من حرية الحركه وتم تصميم حركة مسار كل أصبع باستخدام محاكاه الماتلاب.

جمهورية العراق

وزارة التعليم العالي والبحث العلمي

جامعة النهرين

كلية هندسة المعلومات

قسم هندسة المنظومات

تحكم حركة اليد الألية لاسلكيا بأستخدام الأردوينو

قدم هذا المشروع كجزء من متطلبات نيل شهادة البكلوريوس في علوم هندسة المنظومات

مقدمة من قبل

ايلاف أحمد سعيد

باشراف

م.م زياد عبد الواحد كرم

يونيو 2018 رمضان 1439