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Design and Implementation of a Laziness Muscle Treatment Device

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Annotation: The project is intended for the measurement of an EMG signal that the device will process and present it. According to the signal, the muscle will be treated using the Bluetooth, (courses, movements in each course, and the speed of movements) will be controlled. sensor will then sense the movement of the arm muscle and measure it's effectiveness , then pass the signal to the Arduino, which will process the signal, converting it from analog to digital, and send it to the smart device to present it. The doctor will adjust the settings (courses, movements, and speed) according to his diagnosis for the case.

1.1. Introduction

Muscle is a fibrous tissue characterized by constriction and expansion and secures the movement of the object. The skeletal muscle is made up of muscle bundles and each bundle consists of muscle fibers called muscle cytoplasm. The sarcoplasm and muscle fibroblast is called sarcolema. The muscular fibula is composed of muscle fibers and the single fiber consists of contiguous muscle segments and muscle parts made up of protein lines, actin and myosin.

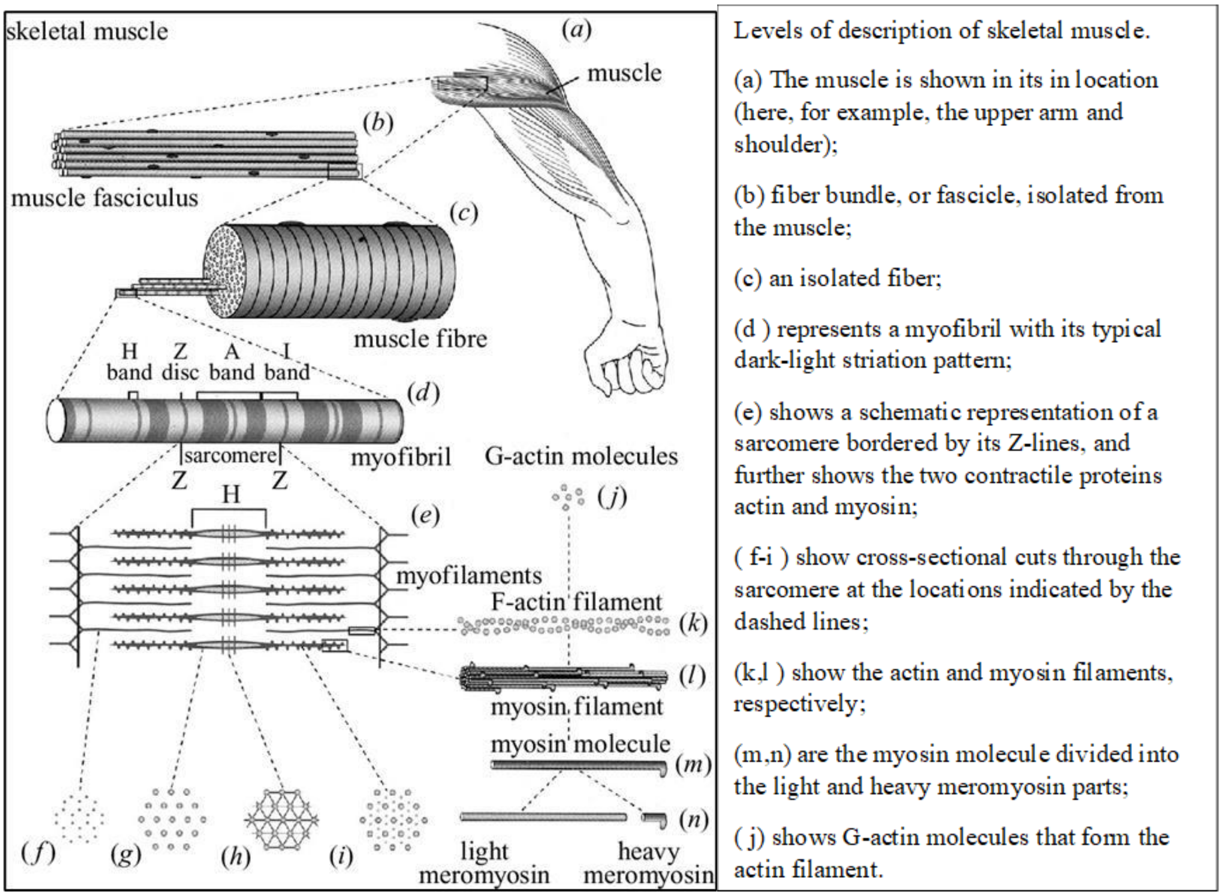


Figure (1-1): Muscle fibers

1.2. Electromyography (EMG):

- Electromyography (EMG) measures muscle response or electrical activity in response to a nerve's stimulation of the muscle. The test is used to help detect neuromuscular abnormalities.
- During the test, three electrodes are placed on the skin (over the muscle). The electrical activity get picked up by the electrodes and then displayed on an oscilloscope (a monitor that displays electrical activity in the form of waves) or other display devices.
- An audio-amplifier is used so the activity can be heard.
- EMG measures the electrical activity of muscle during rest, slight contraction and forceful contraction. Muscle tissue does not normally produce electrical signals during rest. When electrodes are placed on the muscle, a brief period of activity can be seen on the oscilloscope, but after that, no signal will be presented.
- After an electrode gets placed the patient will be asked to contract the muscle.For example by lifting or bending hand The action potential (size and shape of the wave) That the movement creates on the oscilloscope provides information about the ability of the muscle to respond when the nerves are stimulated. As the muscle increase it's contraction more and more muscle fibers are activated, producing action potentials.

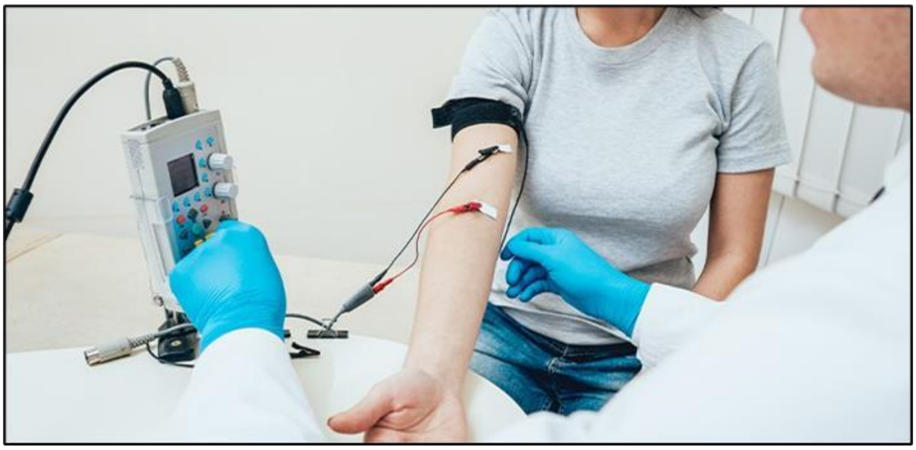


Figure (1-2): EMG test

1.3. Idea of project:

The idea of the project is to use an EMG signals to measure the effectiveness of the arm muscles. The device will perform a physical therapy for the muscle (the diastole and contraction of the arm) . The method is works by connecting servo motor to the arm for the purpose of movement. The artificial arm takes the order from the smart device that display the EMG signal and control the servo motor and based on that will run the session (time, motor speed, number of movements).

1.4. Aims of project:

1. To stimulate the muscle that may suffer from laziness by physical therapy.
2. Reducing physical therapist's effort in treating patients by replacing the his work with this device.

2.1. Theroretical Background

2.1.1. Anatomy of the arm:

There are four main muscles of your arms: biceps, triceps, forearm flexors, and forearm extensors. There are also a handful of other muscles that support these main four.

Anterior arm muscles

The body's anterior muscles tend to be the flexors — they pull your extremities inward, toward your center. So the biceps of the upper arms flex (bend) the elbow, and the forearm flexors on the inside of your forearms flex the wrist and fingers.

Posterior arm muscles

On the back of your arm are the extensor muscles, which perform the opposite function: pulling your extremities out and back. So the triceps extend (straighten) the elbow, and the forearm extensors extend the wrist and fingers.

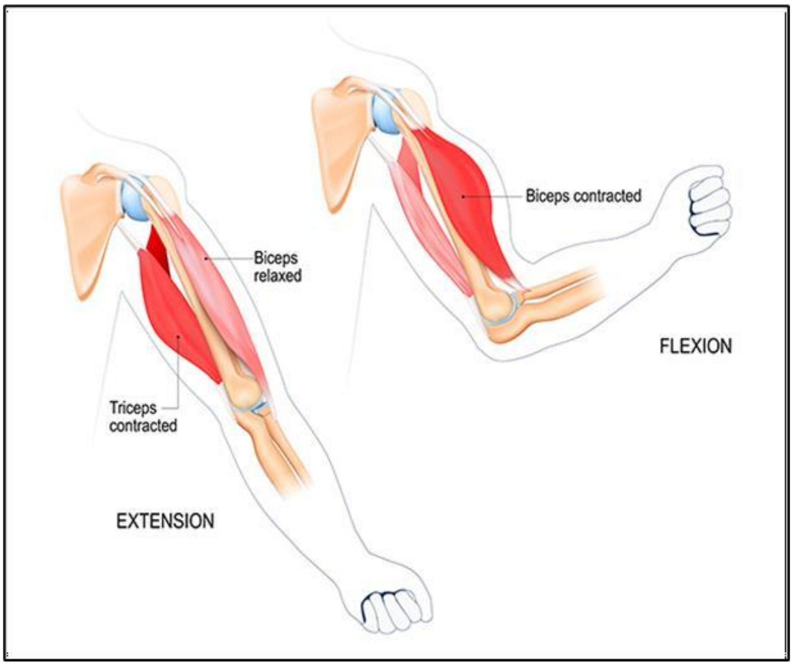


Figure (2-1): Arm muscle.

The Forearm Muscles

Like the upper arm muscles, the forearm muscles can be divided into two parts :

- ✓ The flexors, which lie on the inner side of the forearm and bend the wrist forward.
- ✓ The extensors, which bend lie on the outer side of the forearm and bend it back.

1- Forearm Flexors

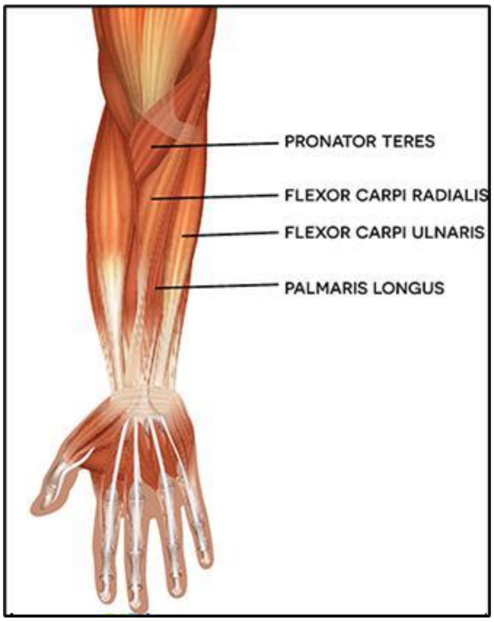


Figure (2-2): Forearm Flexors.

Function:

As a group, the forearm flexors on the insides of your arms flex your wrist forward and turn your hand from a palms-up position to a palms- down position.

Anatomy:

Three layers of muscle make up the forearm flexor group: The superficial group, originating at the funny bone, consists of the flexor carpi ulnaris, the palmaris longus, the flexor carpi radialis, and the pronator teres.

All four of these muscles are long and cable-like and cooperate to flex and pronate the wrist.

Beneath this superficial layer of muscles on the front of your forearm are several other muscles, which work together to articulate your fingers and thumb.

The main one, the flexor digitorum superficialis, tapers into four small tendons which pass through the carpal tunnel — the space beneath the band of tissue along the base of your palm.

Then, another layer runs up your palm and attaches to your fingers to help them flex at the first two joints.

2. Forearm Extensors

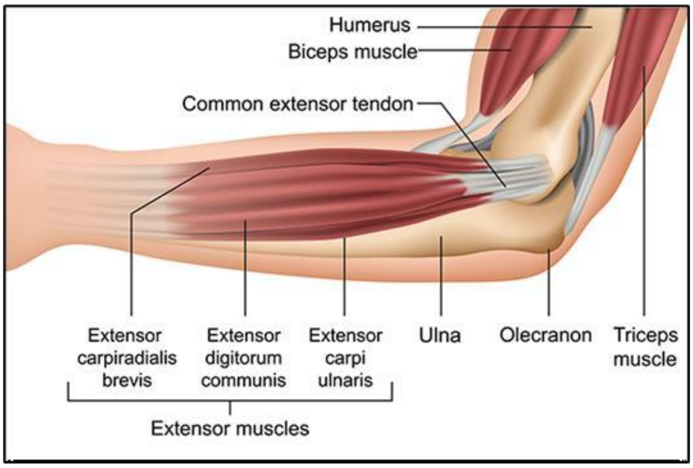


Figure (2-3): Forearm Extensors.

Function:

These muscles extend your wrist, fingers, and thumb, and also aid in supinating the wrist (turning it palm-up).

Anatomy:

Like the muscles on the inside of your forearm, the extensors are long and cable-like, running lengthwise along your forearm and attaching at the fingers.

The largest of these muscles is the brachioradialis: Unlike your other forearm muscles, it originates at the upper arm and attaches on the outside of your wrist, and aids in bending your elbow, thus making it a flexor (like the biceps) rather than an extensor (like the other muscles around it).

Next to the brachioradialis are several similar, smaller muscles that aid in wrist extension and rotation: the extensor carpi radialis longus, the extensor carpi radialis brevis, and the extensor carpi ulnaris.

2.2: Arm Muscles laziness Causes and Treatments:

Muscle laziness happens when your full effort doesn’t produce a normal muscle contraction or movement.

Whether you’re ill or you simply need rest, short-term muscle weakness happens to nearly everyone at some point. A tough workout, for instance, will exhaust your muscles until you’ve given them a chance to recover with rest.

If you develop persistent muscle weakness, or muscle weakness with no apparent cause or normal explanation, it may be a sign of an underlying health condition.

3.2. Arduino Overview

Arduino is an open-source hardware and software company, project, and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices. Its hardware products are licensed under a CC BY-SA license, while software is licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL), permitting the manufacture of Arduino boards and software distribution by anyone. Arduino boards are available commercially from the official website or through authorized distributors. Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards, or breadboards (for prototyping) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs. The microcontrollers can be programmed using the C and C++ programming languages, using a standard API which is also known as the Arduino language, inspired by the Processing language and used with a modified version of the Processing IDE. In addition to using traditional compiler toolchains, the Arduino project provides an integrated development environment (IDE) and a command line tool developed in Go. The Arduino project began in 2005 as a tool for students at the Interaction Design Institute Ivrea [5],

3.3. Arduino UNO and IDE

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc and initially released in 2010 [6]. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts. The word "uno" means "one" in Italian and was chosen to mark the initial release of Arduino Software. The figure (3-1) shows illustration drawing of Arduino UNO with pin configuration.

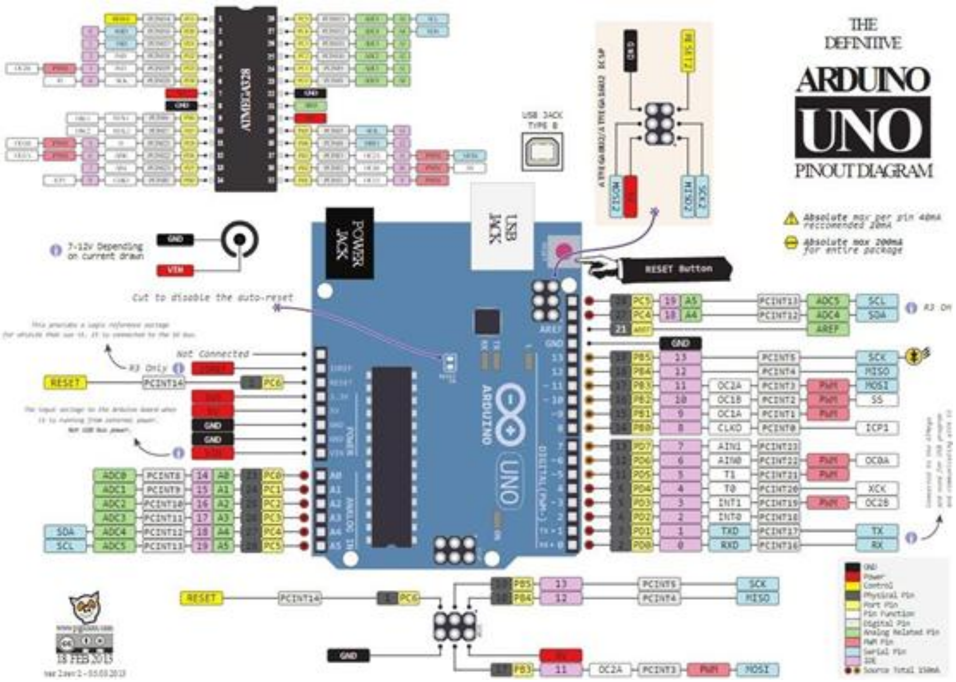


Figure 3-1: Arduino UNO pins configuration

Pin configuration of Arduino UNO

- ✓ Reset Button – This will restart any code that is loaded to the Arduino board
- ✓ AREF – Stands for “Analog Reference” and is used to set an external reference voltage
- ✓ Ground Pin – There are a few ground pins on the Arduino and they all work the same
- ✓ Digital Input/Output – Pins 0-13 can be used for digital input or output
- ✓ PWM – The pins marked with the (~) symbol can simulate analog output
- ✓ USB Connection – Used for powering up your Arduino and uploading sketches
- ✓ TX/RX – Transmit and receive data indication LEDs
- ✓ ATmega Microcontroller – This is the brains and is where the programs are stored
- ✓ Power LED Indicator – This LED lights up anytime the board is plugged in a power source
- ✓ Voltage Regulator – This controls the amount of voltage going into the Arduino board
- ✓ DC Power Barrel Jack – This is used for powering your Arduino with a power supply
- ✓ 3.3V Pin – This pin supplies 3.3 volts of power to your projects
- ✓ 5V Pin – This pin supplies 5 volts of power to your projects
- ✓ Ground Pins – There are a few ground pins on the Arduino and they all work the same
- ✓ Analog Pins – These pins can read the signal from an analog sensor and convert it to digital [7]

3.4. Arduino IDE

Makers, students & professionals have been using the classic Arduino IDE (Integrated Development Environment) ever since Arduino was born.

The Arduino IDE 2.0 is an improvement of the classic IDE, with increased performance, improved user interface and many new features, such as autocompletion, a built-in debugger and syncing sketches with Arduino Cloud.

The Arduino IDE 2.0 features a new sidebar, making the most commonly used tools more accessible. The main feature of Arduino IDE is shown in figure (3-2).

Figure 3-2: Main component of Arduino IDE

- **verify / Upload** - compile and upload your code to your Arduino Board.
- **Select Board & Port** - detected Arduino boards automatically show up here, along with the port number.
- **Sketchbook** - here you will find all of your sketches locally stored on your computer. Additionally, you can sync with the Arduino Cloud, and also obtain your sketches from the online environment.
- **Boards Manager** - browse through Arduino & third party packages that can be installed. For example, using a MKR WiFi 1010 board requires the Arduino SAMD Boards package installed.
- **Library Manager** - browse through thousands of Arduino libraries, made by Arduino & its community.
- **Debugger** - test and debug programs in real time.
- **Search** - search for keywords in your code.
- **Open Serial Monitor** - opens the Serial Monitor tool, as a new tab in the console.

3.5. EMG Muscle Sensor

Measuring muscle activity by detecting its electric potential, referred to as electromyography (EMG), has traditionally been used for medical research.

This sensor will measure the filtered and rectified electrical activity of a muscle; outputting 0-Vs Volts depending the amount of activity in the selected muscle, where Vs stands for the voltage of the power source. It's that easy: stick on a few electrodes, read the voltage out and flex some muscles!

This kit comes with everything you need to start sensing muscle activity with your Arduino or controller of choice. Using muscle sensor kit you can make control using muscle activity [8]. Figure (3-3) shows the EMG muscle sensor.

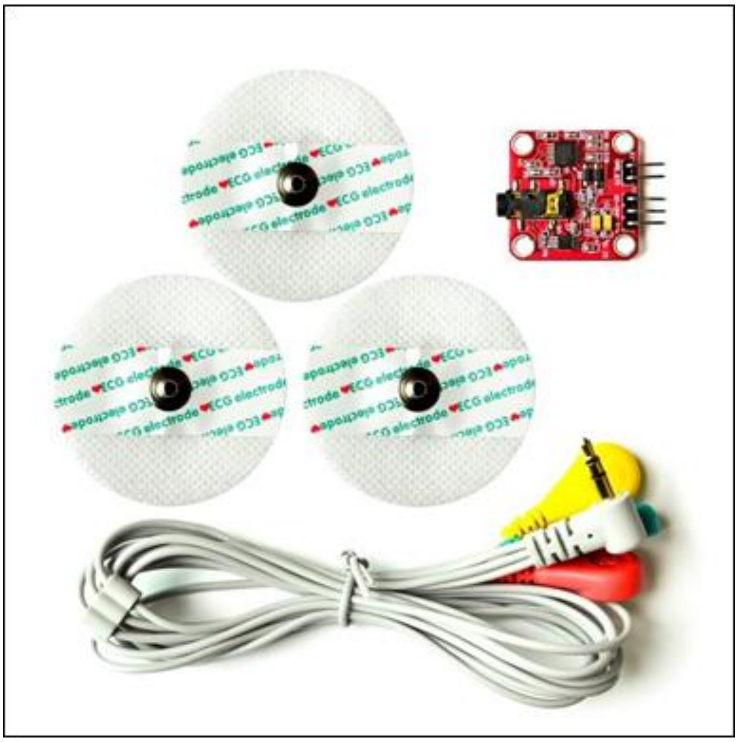


Figure 3-3: EMG sensor

- Features
- ✓ Small Form Factor
- ✓ Specially Designed For Microcontrollers
- ✓ Adjustable Gain
- ✓ Power supply voltage: min. +-3.5V
- Kit Includes
- ✓ Muscle Sensor Board
- ✓ 60 cm Cable Leads
- ✓ 3 Disposable Surface Electrodes

3.6. Servo Motor (DSSERVO)

A digital servo 60 kg is a electric motor, controlled with the help of servo mechanism. A servo motor is a rotary actuator or linear actuator that allows for precise control of angular or linear position.

Figure 3-4: Servo motor DSSERVO

✓ Features

- 100% brand new and high quality , Easy to install, widely used in remote control crawler cars vehicle truck boat aircraft helicopter robot arm ect.
- High Quality 60KG Digital Servo, strong copper & aluminum gears, two ball bearings, CNC aluminium middle shell. For better heat dissipation, also water-resistant.
- High Torque Full Metal Gear Waterproof servo Compatible with Truck , RC Car / Robot/Aircraft/Helicopter/Robot arm / Boat HV and Robotic Servo for 1/5.
- High-precision metal gears with hard anodizing, CNC aluminum middle Shell. High torque steering servo for robot arm, boats, vehicles and remote control toys.
- High Rotation, maximum 180/270 degree rotation.

3.7. Bluetooth HC-05

The HC-05 is a popular module which can add two-way (full- duplex) wireless functionality to your projects. Also can use this module to communicate between two microcontrollers like Arduino or communicate with any device with Bluetooth functionality like a Phone or Laptop [9]. There are many android applications that are already available which makes this process a lot easier. The module communicates with the help of USART at 9600 baud rate hence it is easy to interface with any microcontroller that supports USART. The pinout of Bluetooth is shown in figure (3-5) [10].

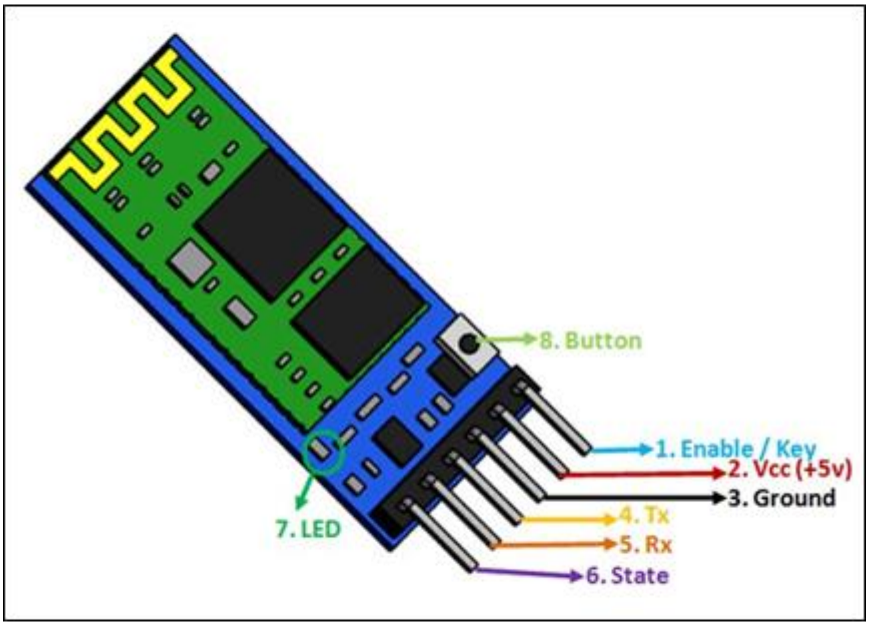


Figure 3-5: Bluetooth HC-05 module

HC-05 Technical Specifications

- ✓ Serial Bluetooth module for Arduino and other microcontrollers
- ✓ Operating Voltage: 4V to 6V (Typically +5V)
- ✓ Operating Current: 30mA
- ✓ Range: <100m
- ✓ Works with Serial communication (USART) and TTL compatible
- ✓ Follows IEEE 802.15.1 standardized protocol
- ✓ Uses Frequency-Hopping Spread spectrum (FHSS)
- ✓ Can operate in Master, Slave or Master/Slave mode
- ✓ Can be easily interfaced with Laptop or Mobile phones with Bluetooth
- ✓ Supported baud rate: 9600,19200,38400,57600,115200,230400,460800.

3.8. Android Application Design using MIT Application Inventor

The smartphone is an information nexus in today's digital age, with access to a nearly infinite supply of content on the web, coupled with rich sensors and personal data. However, people have difficulty harnessing the full power of these ubiquitous devices for themselves and their communities. Most smartphone users consume technology without being able to produce it, even though local problems can often be solved with mobile devices. How then might they learn to leverage smartphone capabilities to solve real-world, everyday problems? MIT App Inventor is designed to democratize this technology and is used as a tool for learning computational thinking in a variety of educational contexts, teaching people to build apps to solve problems in their communities. MIT App Inventor is an online development platform that anyone can leverage to solve real-world problems. It provides a web-based "What you see is what you get" (WYSIWYG) editor for building mobile phone applications targeting the Android and iOS operating systems. It uses a block-based programming language built on Google Blockly.

The MIT App Inventor user interface includes two main editors: the design editor and the blocks editor. The design editor, or designer (see Fig. 2.6), is a drag and drop interface to lay out the elements of the application's user interface (UI). The blocks editor (Fig. 3-6) is an environment in which app inventors can visually lay out the logic of their apps using color-coded blocks that snap together like puzzle pieces to describe the program.

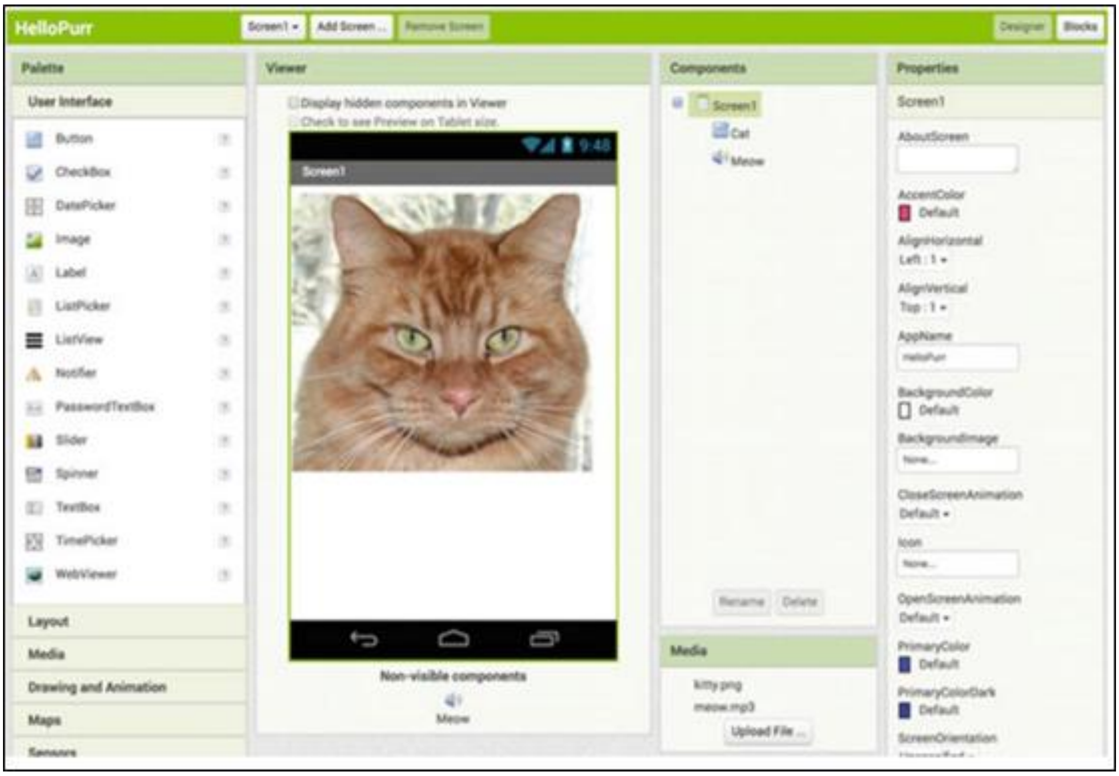


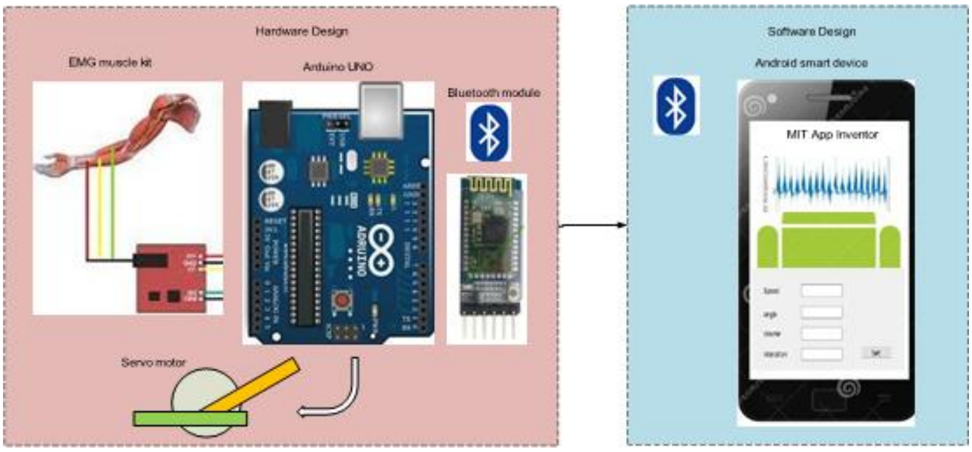
Figure 3-6: MIT application Inventor Editor

App Inventor’s design editor. App inventors drag components out from the palette (far left) to the viewer (center left) to add them to the app.

Inventors can change the properties of the components (far right). An overview of the screen’s components and project media are also displayed (center right)

4.1. Overview

The two main units of proposed project represented in controller and monitor device. The main blocks operation of these units are illustrated in figure (4-1).



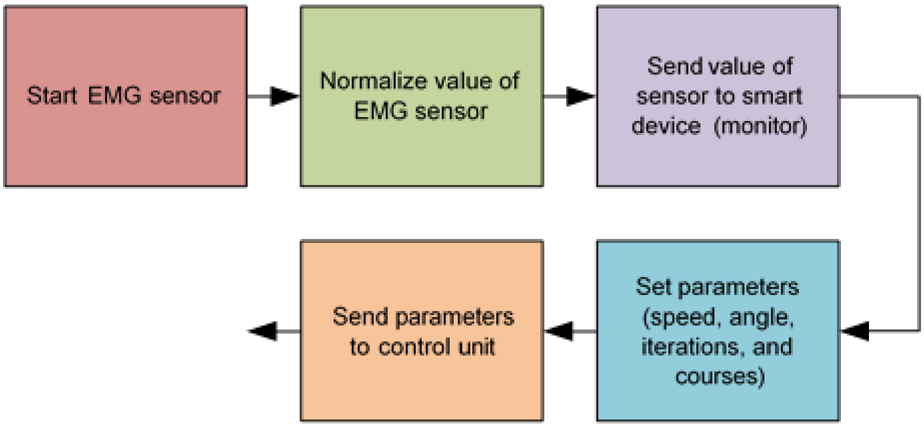


Figure 4-1: Main block diagram of project

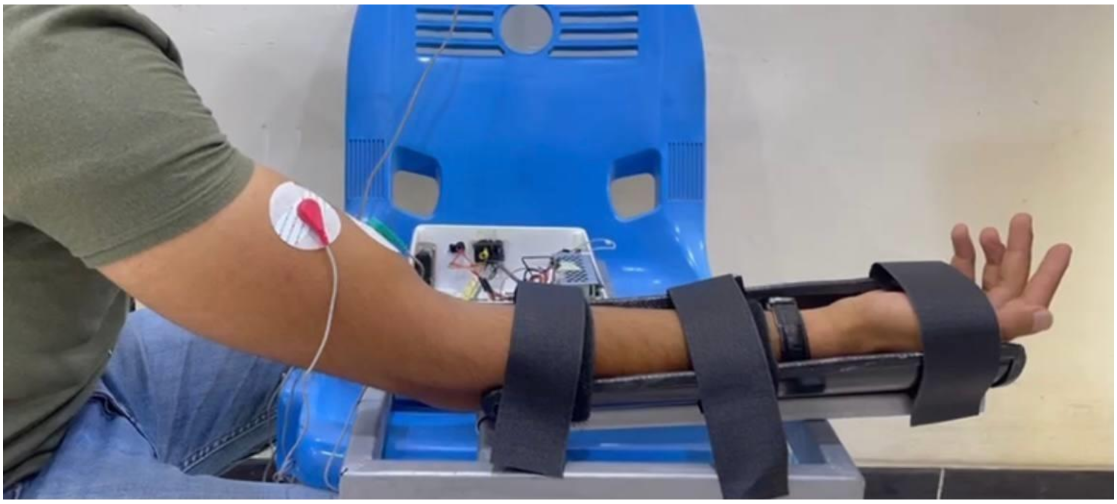


Figure 4-2: Arm in the rest position

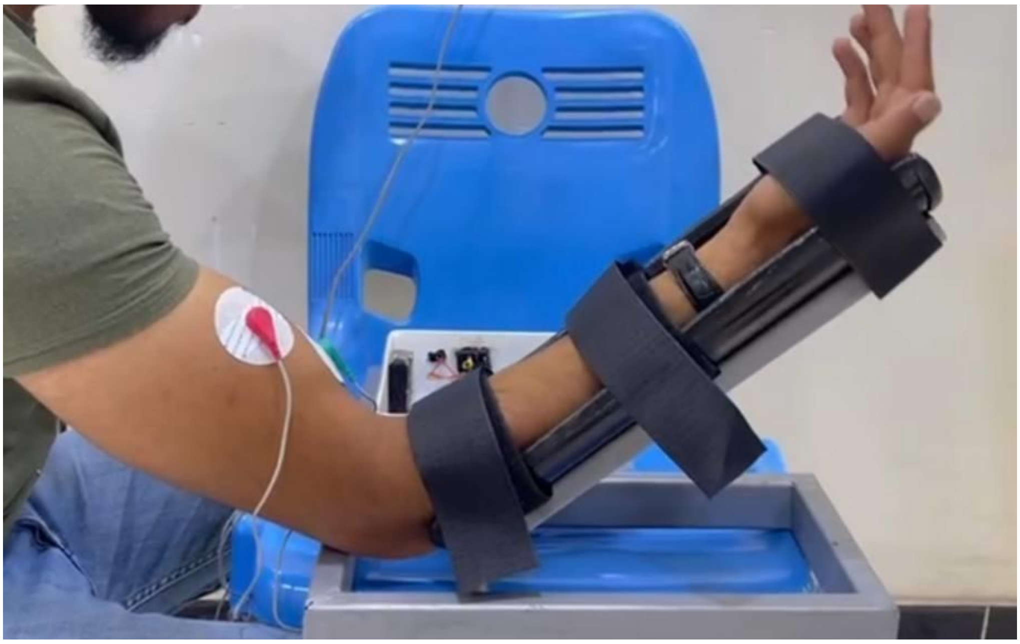


Figure 4-3: The device rises the arm

Each of units will discussed in designing and programming phase in following paragraphs.

4.2. Schematic Diagram of Hardware Description

The hardware of project contains electronics and mechanical parts.

The electronic parts used in this project is list below:

- ✓ Arduino UNO: main controller kit
- ✓ EMG muscle sensor: measure electrical signal generated by muscle.
- ✓ Servo motor: drive the board designed to lift the arm up and down.
- ✓ Bluetooth module: used to transfer the data from Arduino to mobile application and vice versa.

The hardware diagram of components mentioned is illustrated in figure (4-4) and figure (4-5).

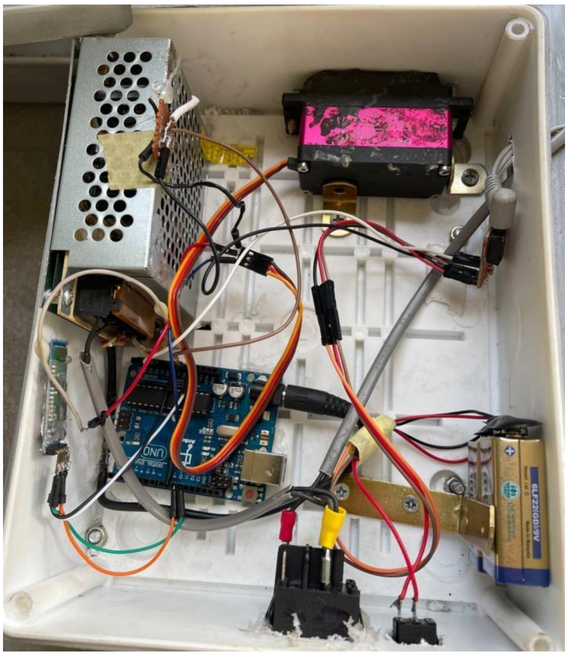


Figure 4-4: circuit components

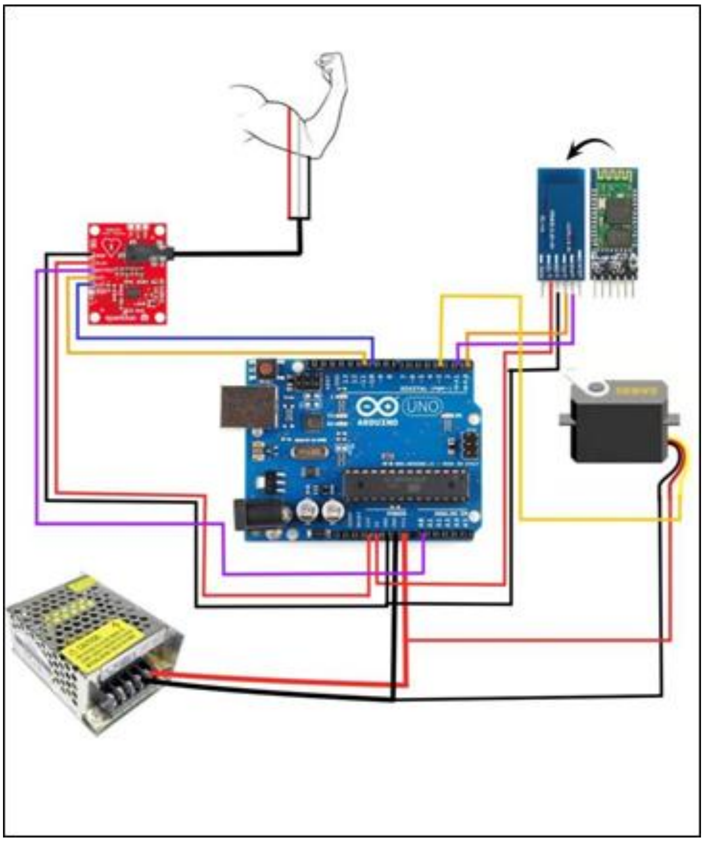


Figure 4-5: Circuit diagram

Each of these component are connected to Arduino UNO and these connections described in following:

- ➢ Bluetooth HC-05: has four pins, VCC connected to Arduino 5v, GND connected to Arduino GND, TX connected to software serial – digital- D4, and RX connected to Arduino D5.
- ➢ Servo Motor: has three pins, VCC connected to 5v of power supply, GND connected to GND of power supply, and signal pin connected to A0 of Arduino.
- ➢ EMG muscle sensor,

The mechanical part is designed to help the arm to be lift up and down.

4.3. Circuit Operation Description

The operations of circuit start by powering Arduino. Below description of circuit operations:

- ➢ First, pairing of both Bluetooth (HC-05 connected with Arduino, and embedded Bluetooth in mobile device) need to configured.
- ➢ If the Bluetooth made connection, a reading of the analogue data of EMG sensor continuously read data by Arduino till the power off.
- ➢ The data of EMG sensor send to mobile device via Bluetooth.
- ➢ Plotter designed in mobile application used to display the data received which determined the EMG signal.
- ➢ In same mobile application there are some parameters for setting the servo motor (speed, angle, iterations, and courses). These parameters need to be concatenated (fused) to send to controller (Arduino) via Bluetooth.
- ➢ If the Bluetooth (HC-05) received any data, then need to split the data in substring.
- ➢ Each of substring (parameters) will be set as parameter of servo.

4.4. Controller Program Description

The program has been written within compiler (Arduino IDE). The procedure of program is described as following:

- ✓ Including softwareSerial library to program. This library used to set two digital pins as serial, in our case, the Bluetooth module (HC-05) has TX and RX pins connected to D4 and D5 of Arduino UNO which these pins configured as software serial.
- ✓ Define variable to be set value of analogue pin (A0) to reading data of EMG sensor.
- ✓ Define variable to set value to control the servo motor on PWM digital pin (D9).
- ✓ Define variables (speed, iteration, course) to configure parameters of servo motor.
- ✓ Set baud rate of software serial (9600) which is suitable rate for our case to transmit/receive data.
- ✓ In sub-routine (LOOP) of program, the procedure keep reading till power off of Arduino.
- ➢ Within loop sub routine, if any data received from mobile via Bluetooth (servo parameter) will do the following:
- ✓ Split the data into (speed, iteration, and course) variables.
- ✓ Speed value will set the delay function, and has three categories (slow, normal, and fast).
- ✓ Iteration value will set the number of movements for each courses.
- ✓ Course value used to set number of courses needed to patient.

- ✓ In same time (within loop sub-routine) data of EMG sensor set to variable and send to mobile device via Bluetooth.

4.5. Mobile Application Design Description

An environment used in this project to design mobile application is called MIT app inventor. The main screen of mobile application of our project is shown in figure (4-6).

Figure 4-6: Mobile Application Design

Each component in mobile application described as following:

- ➢ Image: there two image component used in the application used to display the logo of Al-Farahidi university and other for Medical Instrumentation Technical Engineering department.
- ➢ Button: two buttons are used, first one called "Start" used to transmit the control parameters to controller, and second button used to show up the list of Bluetooth devices found in scope.
- ➢ Picker list: used to select the speed parameter which contains list of three parameters "Slow, Normal, and Fast".
- ➢ TextBox: three textboxes found in design used to enter control parameters which are "Angle", "Iteration", and "Courses".

- Plotter: used to display the EMG signal send by controller.

4.6. Mobile Application Program Description

The procedure of mobile application described as following:

- By clicking on listpicker, list of Bluetooth devices in range displayed, this procedure is shown in figure(4-7).

Figure 4-7: List picker to list the Bluetooth device in scope

- The procedure after picking name of Bluetooth or by MAC address, Bluetooth will connect to the HC-05 module attached to Arduino UNO. The figure (4-8) shows the connection procedure.

Figure 4-8: Return name or MAC address of selected Bluetooth

- To start transmit/receive data via Bluetooth, press on button (SET) used to send set of parameters. These parameters have been fused (concatenated) to be one variable with delimiter ";" among variables, then, send the variable to Arduino's Bluetooth as shown in figure (4- 9).

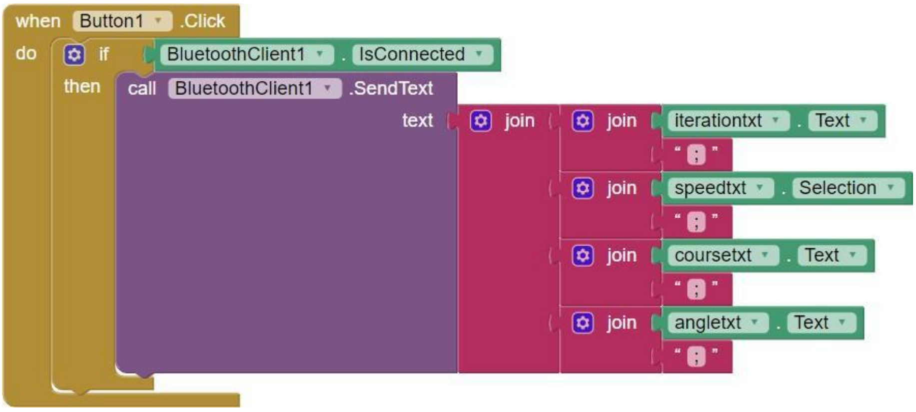


Figure 4-9: Parameters fusion and send data procedure via Bluetooth

- Once Arduino received concatenated string from mobile application, string will be split it into number of variables. In same time, the Arduino send data signal of EMG sensor to mobile device via Bluetooth. When mobile device received any data from Arduino's Bluetooth will the following:
- Check if any data receive

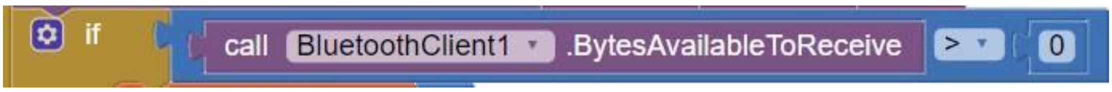


Figure 4-10: Data received by Bluetooth

- Set variable for received data.

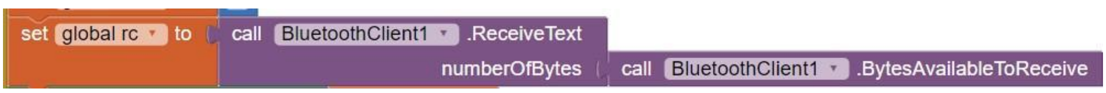


Figure 4-11: Received data into variable procedure

- Split received data by delimiter ";" and put the value into variable VARS.

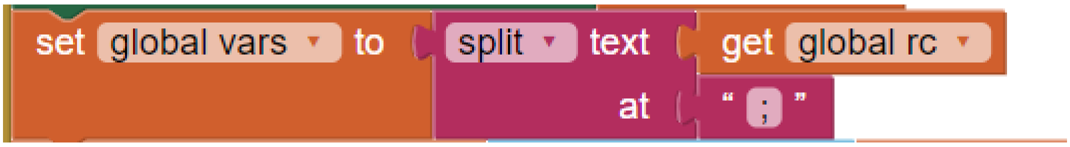


Figure 4-12: Split received data

- Put each variable of split variable into list array, and get the first value which determined the value of EMG sensor.

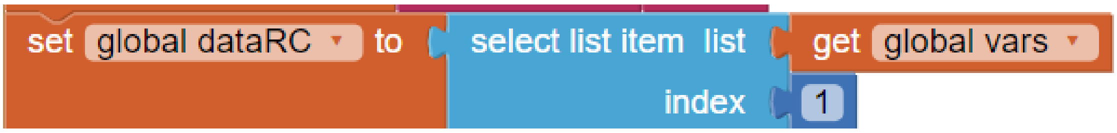


Figure 4-13: Select first data from list array

- Collect data of EMG signal into array in list array XDATA.

Figure 4-14: Put each data into list array

- Draw line by connecting previous data with current one. Also, replace the previous point with current point to draw continuous line on plotter.

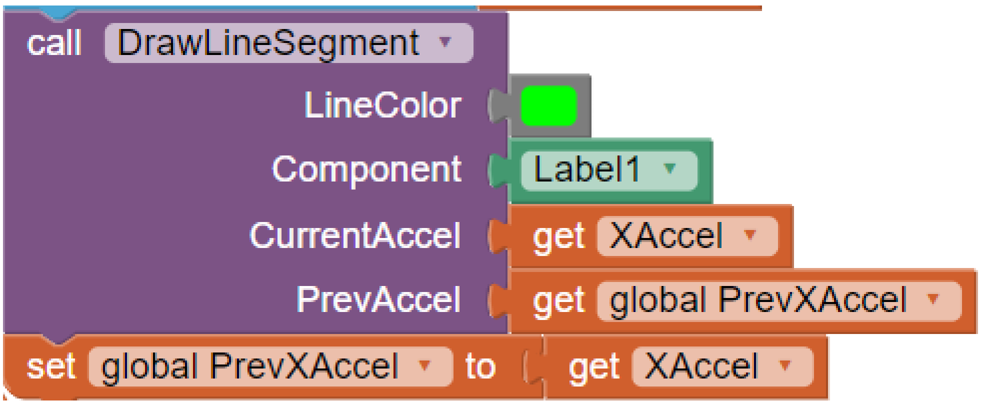


Figure 4-15: Draw line by connecting points

5.1. Conclusions

From the work of design at connect of the project circuit and result; the conclusion is : The torque of the motor used has an effect on the device, so when using a motor with a different torque, it will lead to the development of the model.

5.2. Suggestion for future work

1. Make the project small - sized through :

A. Use of Arduino Nano or Mega.

B. Use MyoWare muscle sensor instead of conventional sensor used .

2. Use a servo motor with high torque to bear the weight of the arm and work more efficiently.

3. Separating the movable arm from the electronic components box of the device, thus not hindering the movement of the arm and making the patient more comfortable

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