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Mimicry Control of the Human Arm to Robot Arm

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Abstract

In this work presented Mimicry control of the human arm to robot arm where robots more often than not we need to control them manually to the run of the non-programmed has previously work. This requires experiment the robot arm of the human arm response , Carried out the work submitted to build a metal structure for the robot arm(articulate type 5DOF) then drive torque equation in each joint and calculate the maximum torque in each joint in the horizontal position of the robot arm and calculate the direct kinematics for the end effect , after add electrical actuator fit with maximum torque on the arm and added position sensors and driver (h-bridge) , electrical component has assembled and connected with micro controller (Arduino Due) witch programming as proportional integral differential (PID) controller . then added the flex sensor position to human arm to measure the angels of joint , this sensor is connected to microcontroller Arduino Uno and programmed to process the zero and span function for sensors and send the data by wireless shield via RS port to the Arduino Due and run the system.

Keywords: PWM ; PID ;Arduino DUE ; DOF ; Servo.

1. Introduction

mimicry robot arm of the human arm an important topic since many applications require the use of the robot manually by giving orders from the human hand such as robots that deal with dangerous materials , in nuclear and military applications . A large number of studies on the control robot arm through the human hand such as vision based system by tracking markers placed at a dorsal side of human hand using cameras to estimate the 3D position of hand to control the robot were proposed [1, 2]. Electromechanical devices (potentiometer and metal parts), are worn by the operator arm to sense the motion of arm [3].

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EMG (electromyography) signals which are measured using non-invasive electrodes are placed at specific locations of human arm and represent the activity of human arm muscles due to motion to drive the robot [4]. Micro-Electro-Mechanical Systems (MEMS) was used to estimate the 3D position and orientation of human hand by integrating inertial sensors such as gyroscope, accelerometer and magnetometer [5]. This paper present controlling to robot arm by using flex sensors fixed on human hand and send the data wireless via RS-port.

2. Mechanical stricture analysis

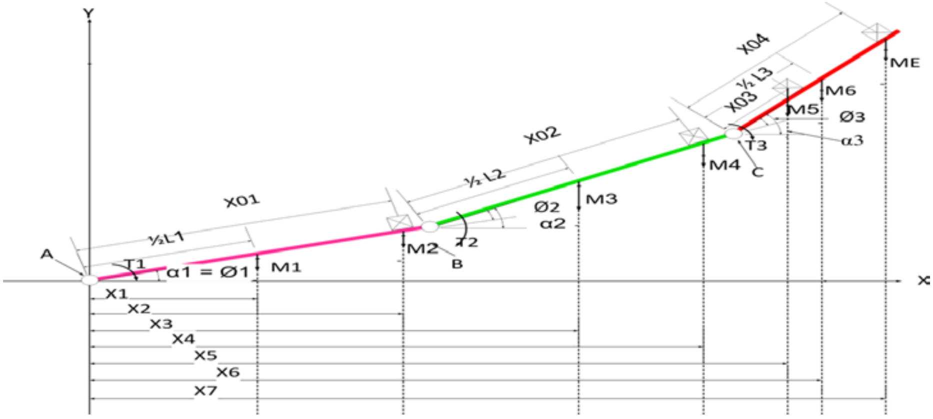


Figure 1: Side view of robot arm

The robot arm which has been built in this research Created three links connected by joints has five degrees of freedom (5 DOF), Every joint is connected with electrical actuator ,that show in figure 1

When :

X_1 …. X_7 : effect distance between the mass and joint A

M_1 …… M_E : mass

T_1 …..T_3 : torque at the joints

The torque in the joint A is given by the equation

$$T_1 = X_1.M_1 + X_2.M_2 + X_3.M_3 + X_4.M_3 + X_5.M_5 + X_6.M_6 + X_7.M_E \quad \text{.....(1)}$$

And the distance of X_1 …. X_7 is given by :

$$X_1 = \frac{1}{2}.L_1.\cos\alpha_1 \quad \text{...(2)}$$

$$X_2 = X_{01}.\cos\alpha_1 \quad \text{... (3)}$$

$$X_3 = L_1.\cos\alpha_1 + {}^1/_2.L_2.\cos\alpha_2 \quad \text{..................... (4)}$$

$$X_4 = L_1.\cos\alpha_1 + X_{02}.\cos\alpha_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

$$X_5 = L_1.\cos\alpha_1 + L_2.\cos\alpha_2 + X_{03}.\cos\alpha_3 \ldots\ldots..(6)$$

$$X_6 = L_1.\cos\alpha_1 + L_2.\cos\alpha_2 + {}^1\!/_2 . L_3.\cos\alpha_3 \ldots(7)$$

$$X_7 = L_1.\cos\alpha_1 + L_2.\cos\alpha_2 + X_{04}.\cos\alpha_3 \ldots\ldots\ldots(8)$$

And $\alpha_1 = \emptyset_1$, $\alpha_2 = \emptyset_1 + \emptyset_2$, $\alpha_3 = \emptyset_1 + \emptyset_2 + \emptyset_3$

In the same way for the T_2 and T_3

$$T_2 = X_8.M_3 + X_9.M_4 + X_{10}.M_5 + X_{11}.M_6 + X_{12}.M_E \ldots\ldots.. (9)$$

$$T_3 = X_{13}.M_5 + X_{14}.M_6 + X_{15}.M_E \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(10)$$

Table 1: The Wight of mass and distance

L_1 = 34 CM	M_1 = 1.49 Kgm	M_2 = 1.78 Kgm
L_2= 42.5 CM	L_2= 42.5 CM	M_3 = 1.62 Kgm
M_4 = 0.62 Kgm	L_3 = 20 CM	M_5= 0.155 Kgm
M_6 = 0.74 Kgm	M_E = 0 Kgm	X_{01}= 28 cm
X_{02} = 38 cm	X_{03} = 16 cm	

From the table 1 we get the maximum torque

$T_1 = 275.6475\ kgm.cm$, T_2=105.9 Kgm.cm , T_3 =9.88 Kgm.cm

So the direct kinematics equations of the end effect is drive and given as :

$$X_3 = [l_1.cos(\emptyset_1) + l_2.cos(\emptyset_1 + \emptyset_2) + l_3.cos(\emptyset_1 + \emptyset_2 + \emptyset_3)].cos(\emptyset_Z) \ldots\ldots\ldots\ldots(11)$$

$$Y_3 = l_1.\sin(\emptyset_1) + l_2.\sin(\emptyset_1 + \emptyset_2) + l_3.\sin(\emptyset_1 + \emptyset_2 + \emptyset_3) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(12)$$

$$Z_3 = [l_1.cos(\emptyset_1) + l_2.cos(\emptyset_1 + \emptyset_2) + l_3.cos(\emptyset_1 + \emptyset_2 + \emptyset_3)].\sin(\emptyset_z) \ldots\ldots\ldots(13)$$

2.1 Electrical section

This part included building a servo motor that consisting of DC motor , gearbox , electronic driver , microcontroller ,and the position sensor the electronic driver is design and build to works efficiently within the wide scope of dc motor limited by voltage and current values , in this work have been using a new innovative way in directional control, the driver consist the three input tow of this input for the direct of motor and the third input for speed control , we sprate the direction from the speed .

2.2 Design and modeling the servo motor

From practical experience was calculated the transfer function and gear ratio of the DC motor that use in this project .

The transfer function is given by : $G(S) = \frac{98.982}{0.019s+1}$ and the gear ratio of gear box $= \frac{1}{54}$

In this research was to use a new control system by segmenting error signal resulting from subtract the feedback signal from the reference signal to the two parts , the first is give a logical rotation order to the electronic driver in one of the directions , the second parts it takes error signal and enters to the proportional integral differential controller and then take the absolute value of the output to convert the pulse width modulating (PWM) pulses and enters the electronic driver as a input to control by the speed of DC motor .

The Figure 2 shown the modeling of practical servo motor.

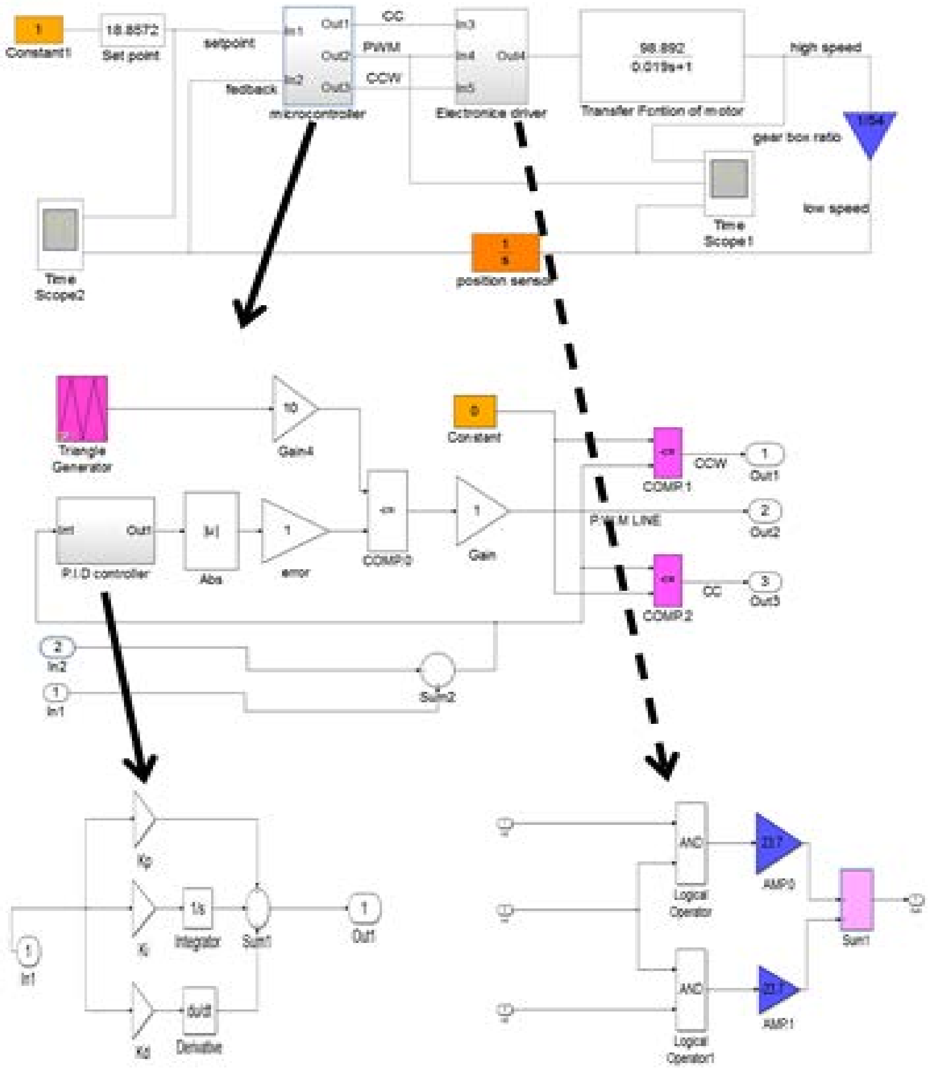


Figure 2: Modeling the practical servo motor by Matlab

The result of run the Simulink is shown in figure 3 , 4 , 5.

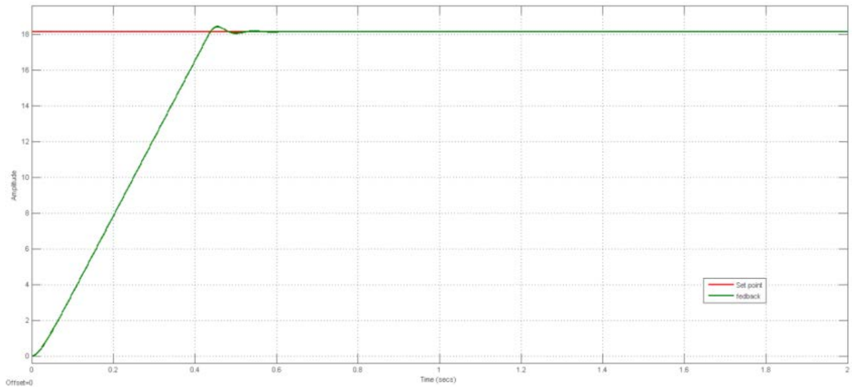


Figure 3: set point with feedback

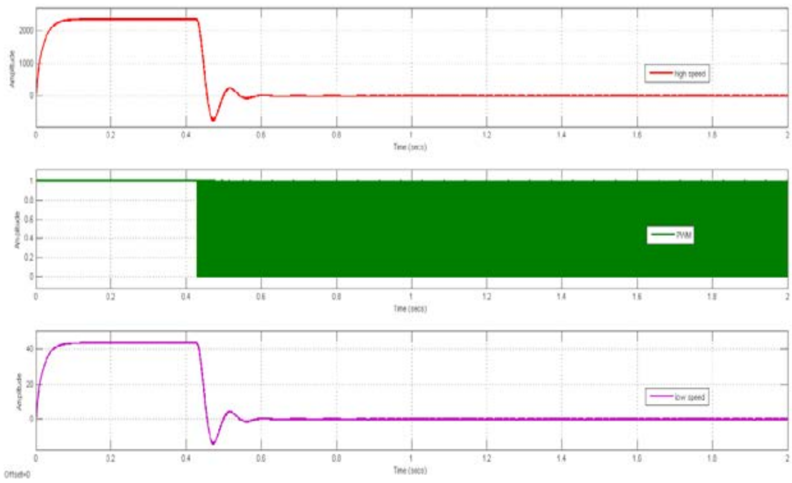


Figure 4: high and low speed with pulse control

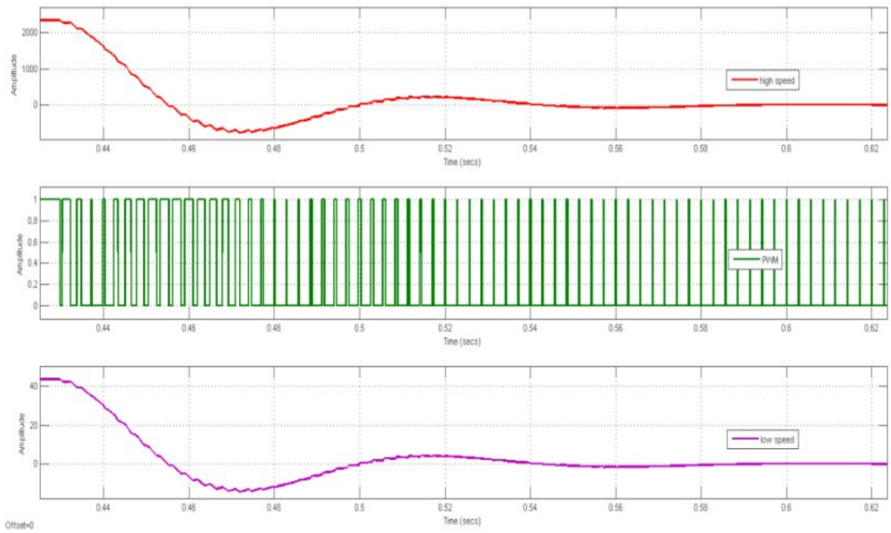


Figure 5: zoom of pulse of control speed

After tuning PID controller , get to the result in figure shown 6 , 7, 8.

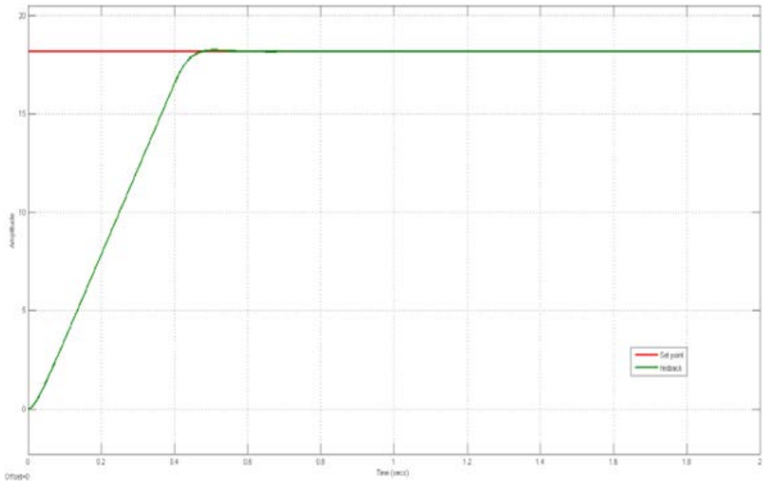


Figure 6: set point with feedback

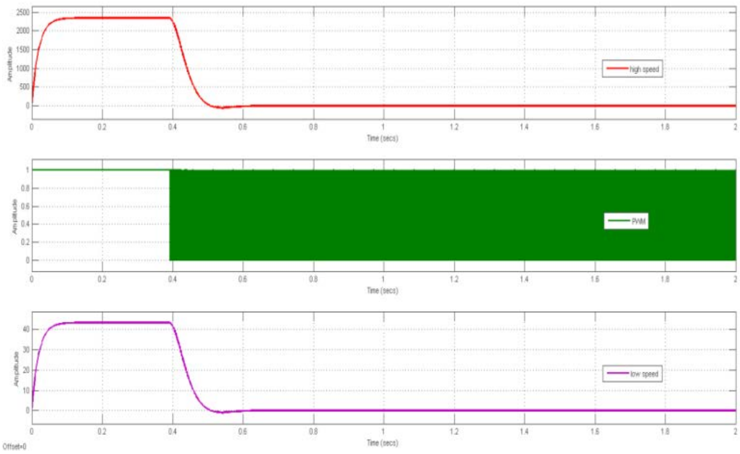


Figure 7: high and low speed with pulse control

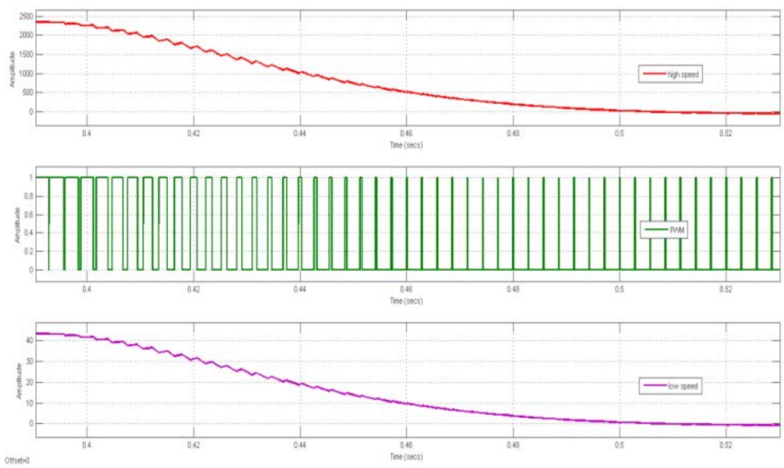


Figure 8: zoom of pulse of control speed

2.3 Final stricture

The final design of the system is shown in figure 9 ,10

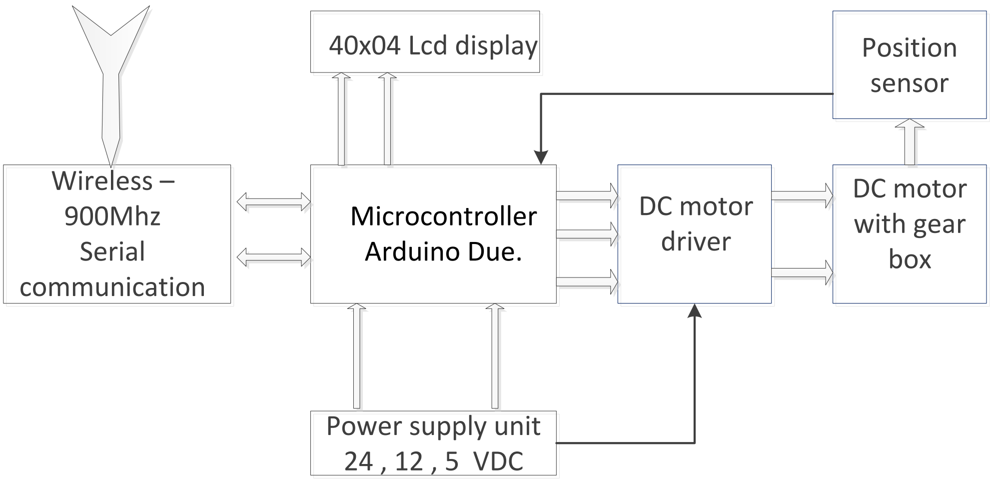


Figure 9: servo system on robot arm joint

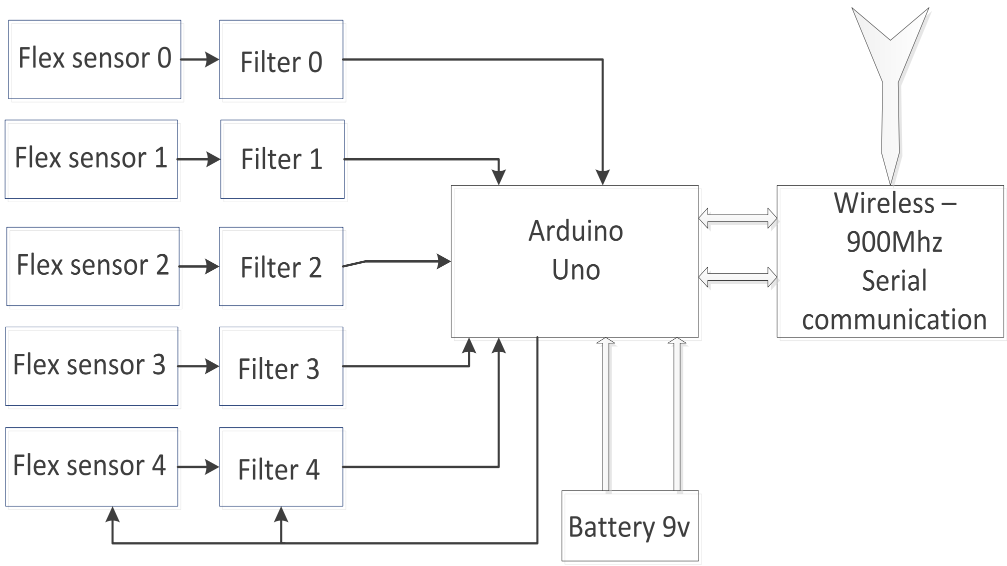
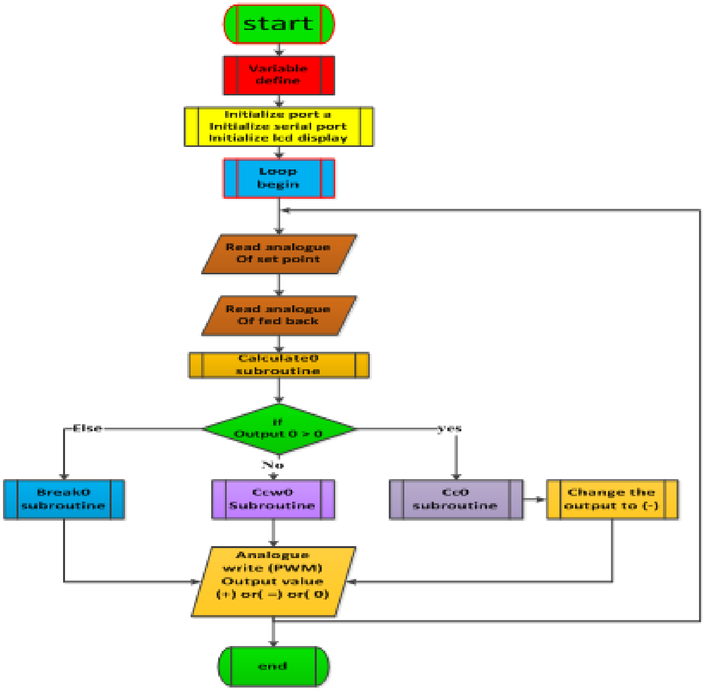


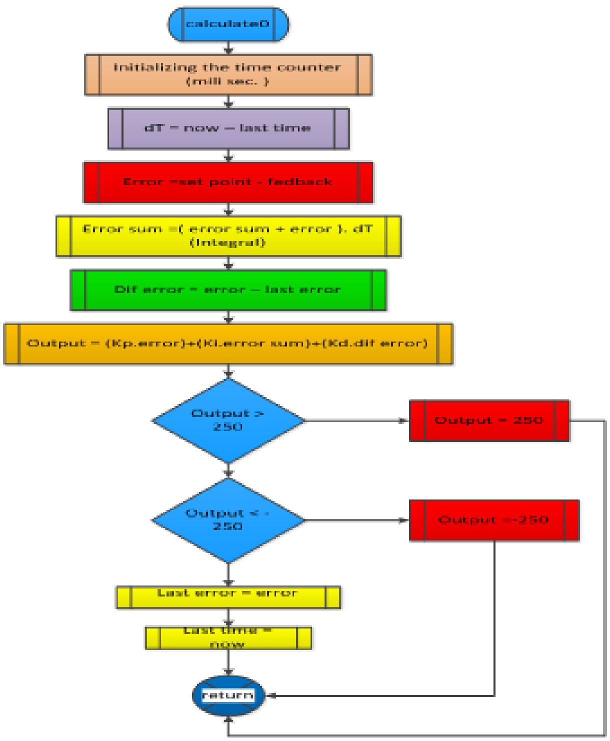
Figure 10: sensors system on the human arm

3. Software

the program algorithm was implemented through Arduino environment on the microcontroller Due. where the use of new algorithm has the ability to deal with any DC motor and use as a servo motor, Since it does not depend on constant time of motor , but her ability to simulation motor through conditional orders (if … then) to get the best as a result of the position , as well as been designed the algorithm controller PID type, was chosen sampling time 1 mili sec. , the flowchart shows the progress of the program, which includes more than Flowchart first main remaining programs routine.



Flow chart 1: algorithm of main program



Flow chart 2: algorithm of routine program

The PID controller algorithm was Experimented from took the reference signal and the feedback signal then enters to the oscilloscope and read the error of sum register the integral part of PID controller from the inside of the microcontroller via RS port and the same for the differential part the figure 11 shown the response of deferential part response .

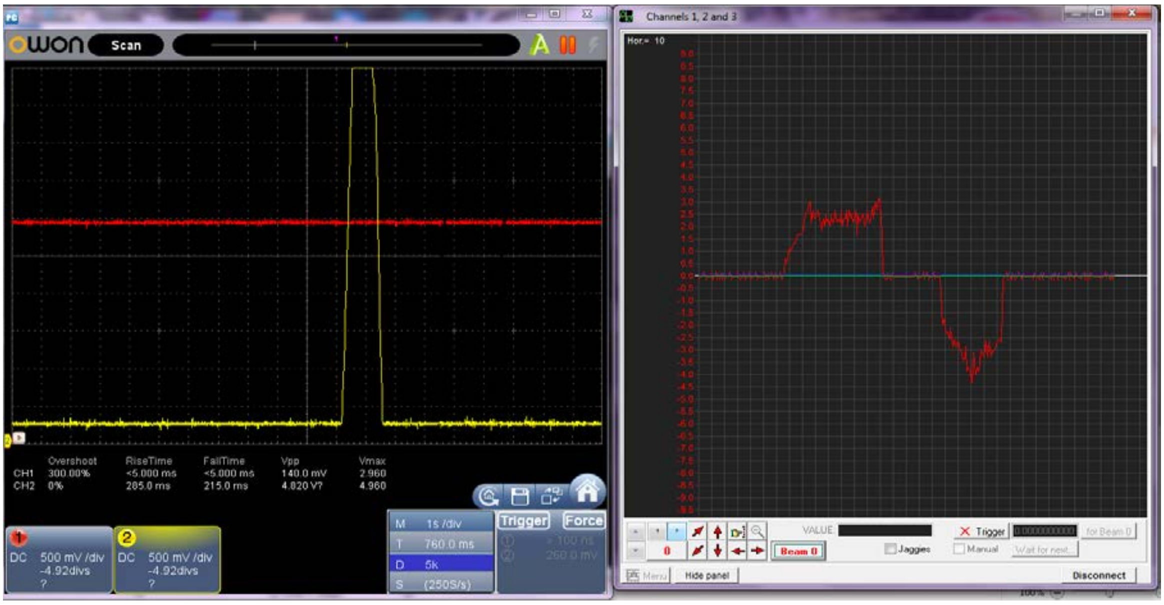


Figure 11: the deferential part of PID controller response

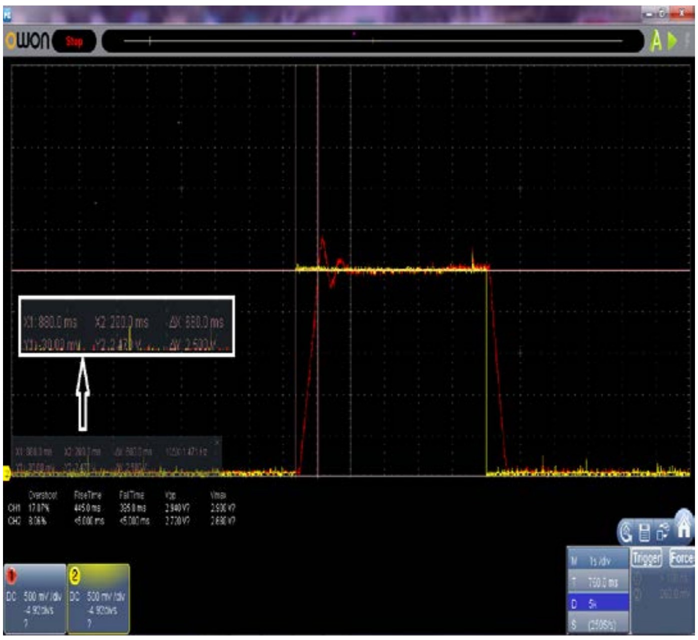


Figure 12: the position response of servo motor with PID

On the basis of these practical results were chosen as sampling time to fit in control system , and run the servo system completed and we get the result shown in figure 12

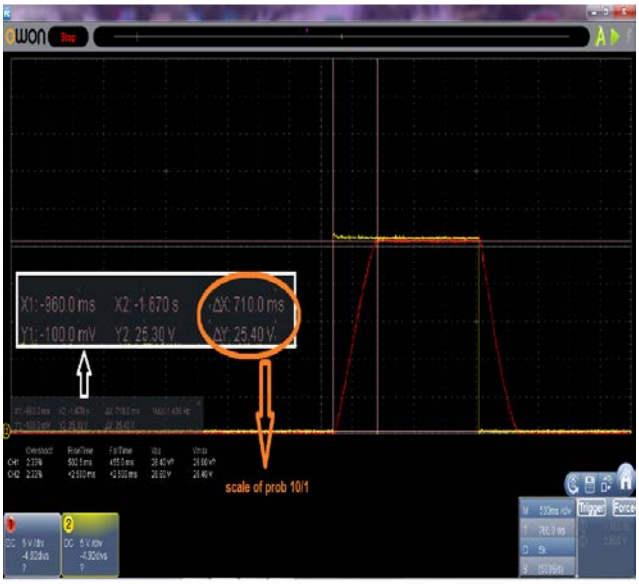


Figure 13: the position response of servo motor after tuning PID

After tuning the PID controller we get the perfect result of response as shown in figure 13

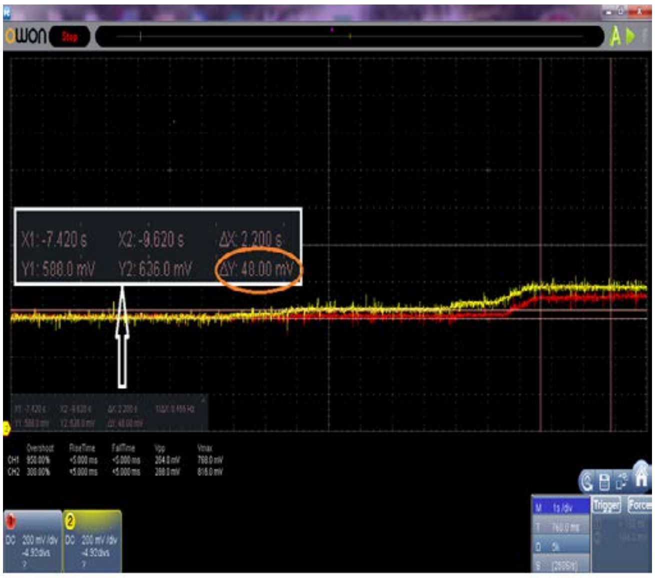
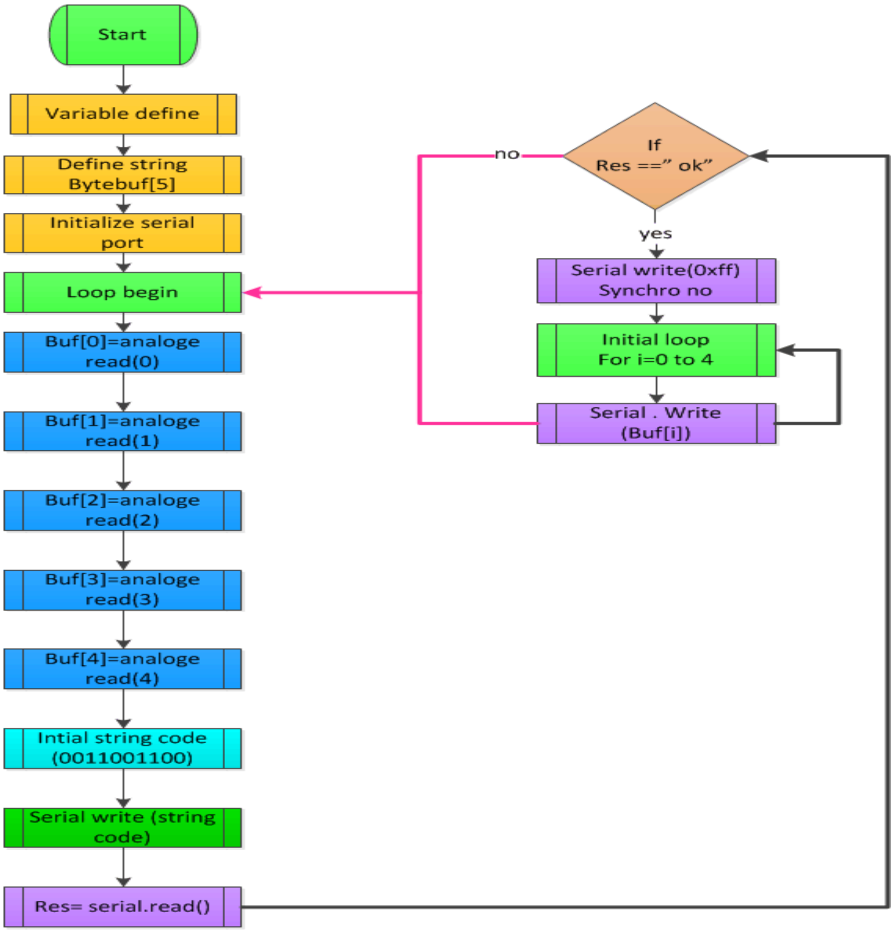


Figure 14: accuracy test of servo motor

In the same test the accuracy of the servo system , the figure 14 shown that

as well was designed algorithm that transfers the signal via the serial port through a wireless card XBee shield , the microcontroller from human side is take the sensors signal that fixed on human arm then send the code to the microcontroller at the robot arm side , when it can to decode this code the robot arm microcontroller send the accept to the human arm microcontroller that send synchronize number to synchronization two microcontroller at last send five angle value to the robot arm microcontroller to control by robot arm servo . the flow chart shown the send code and received accept no. and the figure shown the human arm sensors and robot arm .



Flow chart 3: algorithm of send conde and received the accept

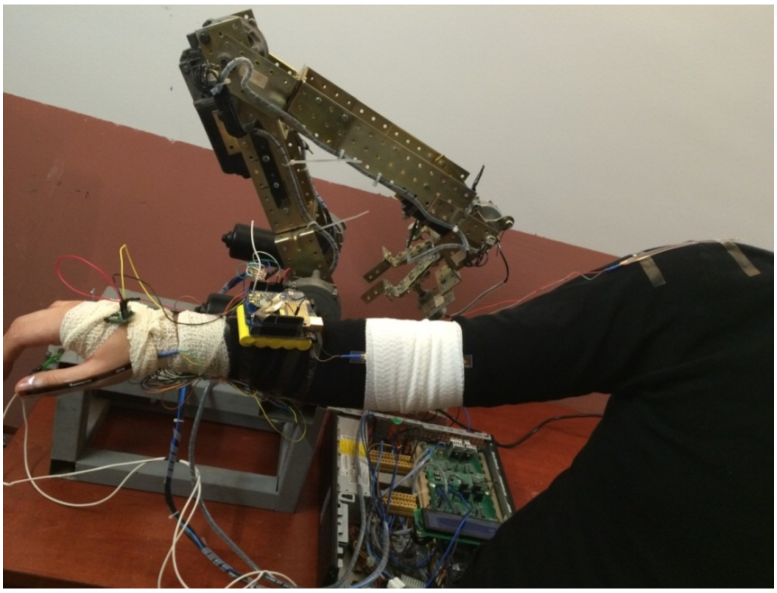


Figure 15: human sensor

4. Conclusion and recommendation

- through mathematical analysis of the structure of the robotic arm show that the installation of the electrical operator in the joint closest to the base link will reduce the dynamic torque on the base operator .
- through practical experiments found that measuring the transfer time of the system is important in the process of building a proportional differential integrative controller algorithm PID controller and is intended transmission speed from zero to rated value and vice versa in the case of break the motor , because the integrative and differential depends on the time, The section Integrative is a process error against time to collect so the combination of the time should be up close to the time of transition for example, travel time is 1 second and the time of error collection 1 millisecond, is going to cause a backlog in the wrong a large amount before reaching the required and the best case method has experience in practice is by dividing the sum of error reasonable limits and not reduce sampling time sampling time of the error rate .
- Through practical experiences in sending a series of bits that have their own width that is observed when they arrive through transport it does not reach all of the same width and explain the reason for that distortions and objections encountered on the way to that necessitated the receiving mode algorithm process that takes a range of pulse width receiving.

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