Arduino Based Robotic Arm with Six Degrees of Freedom

[1]Sapna Singh, [2] Pranjal Bhatia, [3] Pulkit Jain
[1][2][3] Maharaja Surajmal Institute of Technology

***Abstract*- With the increasing automation in industries, the use of robotic arms has been on a rise. Through this project we intend to design and implement a multiutility robotic arm that can perform operations with high degree of accuracy due to its six degrees of freedom. Servomotors having a torque up to 30.4 N-cm are used for the operation of the arm whereas the gripper has the ability to exert torque up to 24.5 N-cm. Arduino is the choice for microcontroller for this project and the programming is done on Arduino IDE. The microcontroller is secured to the board on which the robotic arm is attached.**

Index Terms— Servomotor; Arduino; Degrees of Freedom.

I. INTRODUCTION

A robot is a manmade machine programmed to carry out a set of complex instructions in accordance with a series of codes entered via a computer. A robotic arm is a motorized arm, that can be autonomous or manually controlled. The robotic arm with six degrees of freedom (DOF) is similar to a human arm and hence is able to perform complex tasks with speed and accuracy. Presently, arms with lower degrees of freedom are available but for an effective and efficient replication six Degrees of freedom is necessary. For the construction of the arm, we chose servomotors in contrast to stepper and DC motor due to their ability to rotate accurately within a limited angle and high torque. Servomotors are high performance alternative to stepper and DC motor. Also servomotors come with a control wire so there is no need to construct a driver module for the servo as oppose to stepper and DC motor. Instead of going for an external power source, all the motors have been powered by the microcontroller itself. This helps in reducing the cost and time required to set up an external power source and also decreases the overall weight of the arm. With a maximum output of 500 mA of current from the microcontroller, all the seven motors are able to run smoothly even at full load condition. Each servomotor has three pins: one for ground, one for power and one for PWM. A PCB board is used for shorting the ground pin and power pin of every motor to one another. Out of seven servomotors, two of them are connected to the same PWM pin. This is done in order to make them work in synchronization. The servomotor construction consists of 4 parts: A small DC motor, Gear box of the motor, Control circuit, Potentiometer. The black wire of the servomotor is connected to the ground of the Arduino whereas the red wire is connected to the 5V supply. The white colored wire is the control wire. Servomotors are controlled by connecting this wire to the pwm pin of Arduino. It is done by sending a pulse of variable width, or pulse width modulation. The PWM sent to the motor determines how far the gears of servomotor will move and at what position will the rotation stop. Further, the rotor will turn to the chosen position based on the duration of the pulse sent via the control wire. The length of the pulse ascertains how far the motor turns. Usually, a servomotor can only turn 90 degrees in either direction which accounts for a total movement of 180-degrees. The servomotor has an equal degree of potential rotation in both the directions – clockwise and anti-clockwise.

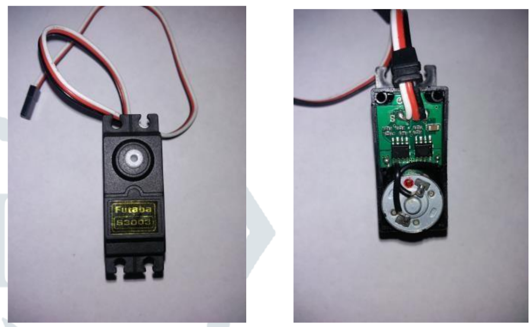

Figure 1(a), 1(b) show the internals of a servomotor.

II. DESIGN OF THE ROBOTIC ARM

The designing of each and every part of the robotic arm was done on AutoCAD 2014. Specific cut outs were made in order to make each part interlock with one another without the use of screws. The choice of material for the frame of robotic arm was a polycarbonate acrylic sheet. This material has rigidity as well as light weight which was ideal for the arm. The base of the arm has been fixed on to a 18 mm wooden board and this board accommodates the entire arm along with the PCB andArduino.Cyanoacrylate has been used to attach the gear mountings on to the frame. A .dxf file was created on AutoCAD and using a CNC laser cutting machine,the entire frame was cut out on the acrylic sheet. During the assembly of the arm, the neutral position of the servomotor (the position where the servo has equal degree of potential rotation in clockwise and anti-clockwise direction) had to be taken into consideration. An improper fixation of the motor can result in a breakdown of the and affect the movement of the arm. The gripper is able to open fully up to 8 cm and exert a force of 24.5 N per cm.

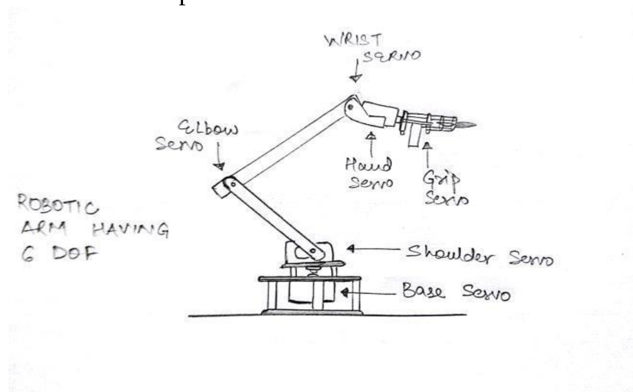

Figure 2 shows the basic layout of the robotic arm.

A. Hardware and Specifications

In our project we have used two types of servomotors: Futaba S30003, SG 90 Tower Pro. The hand and grip servo have the same specifications and are different from the ones used in the base, shoulder, elbow, wrist and hand. Both the servomotors have plastic gears and a rotation range of 180 degrees. The Futaba servomotor weighs about 37g and has a pulse cycle of 30 ms as opposed to SG 90 which weighs about 9g. The total weight lifting capacity of the robotic arm is approximately 3 kg but can be increased by replacing the plastic gear servomotors with the metal gear ones. This is because metal gear servomotors have a high torque rating. Using Arduino 5V and ground pins all the servomotors are being powered. Arduino is able to provide PWM from Pins 3, 5, 6, 9, 10, 11. Hence these are being used for controlling the servomotors. Arduino is able to output current up to 500 mA for each motor thus eliminating the need for an external power source. From the center of the base, the robotic arm can extend roughly up to 40 cm and is able to lift weights and drop them to the desired location. The entire arm can be controlled via the serial monitor window of the Arduino IDE.

B. Servomotors

Servomotors are majorly use in the field of robotics due to their cheap cost, high torque and smooth operation. The motor is attached to the control wheel via the gear box. The gears of a servomotor can be made of either plastic or metal. A metal gear servomotor is able to produce higher torque but is expensive as compared to plastic gear servomotor. As the motor rotates, the potentiometer's resistance changes hence the control circuit is able to control the movement of the servomotor. The desired position is sent via electrical pulses of variable width through the control wire i.e. PWM. As the shaft of the motor reaches the desired position, the power supply is ceased. So, if the motor is near the desired position, it will turn slowly, otherwise it will turn fast. This is called proportional control. Servomotors are able to hold their positions and resist any external force that is applied in order to change their holding position. The maximum amount of force that a servo can exert is known as the torque rating of the servo. Servomotors are small yet efficient and are being used widely in many applications like conveyer belts, automatic door openers, Antenna positioning etc.

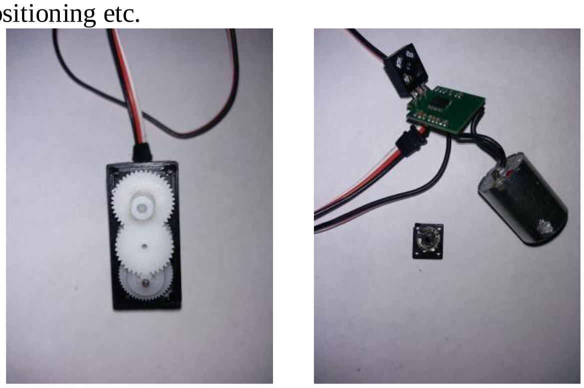

Figure 3(a), 3(b) show the gear box and potentiometer of the servomotor.

The servomotor control circuit comprises of 3 IC's: 9926A, 4953 and AA51880. 9926A acts as a N-channel MOSFET with a wide range of gate drive voltage (2.5 V – 10 V). Whereas 4953 IC acts a P-channel MOSFET with a gate drive voltage range of 4.5 V to 25 V. Both IC's are used for power management application in the servomotor.

AA51880 is a BJT integrated circuit which is used for servomotor control applications. The built-in voltage regulator inside AA51880 provides an extremely stable output voltage. This IC has a small outline package, large driving capability and a built-in voltage regulator. The timing control block of this IC detects the motor position and adjusts the dead band, the output driver block of the IC controls the current direction of the servomotor and the voltage regulator detects the reference voltage. AA51880 also incorporates a linear one-shot and pulse width demodulator for improved positional accuracy. It also has an adjustable dead band range control and a sawtooth and one shot generator.

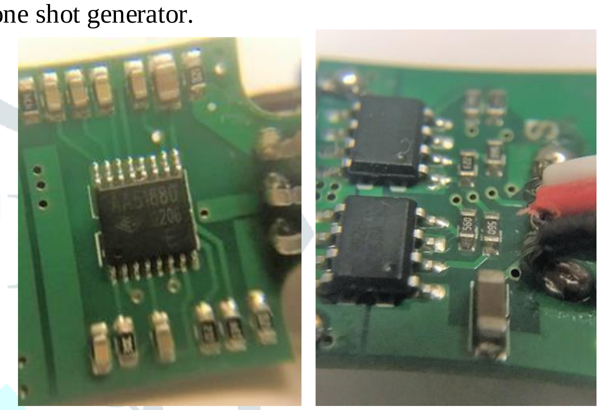

Figure 4(a), 4(b) show the IC AA51880 and IC 9926A respectively.

C. Arduino Microcontroller

Arduino is an open-source platform used for building electronics projects. Arduino comprises of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment). The entire coding of the robotic arm has been done on the IDE. Arduino uno was chosen because of its cheap cost and easy programming. Arduino is a microcontroller based on ATmega328P. It has fourteen digital I/O pins six of which can be used as PWM outputs. The programming on Arduino IDE is similar to C++. The robotic arm is being controlled via the serial monitor.

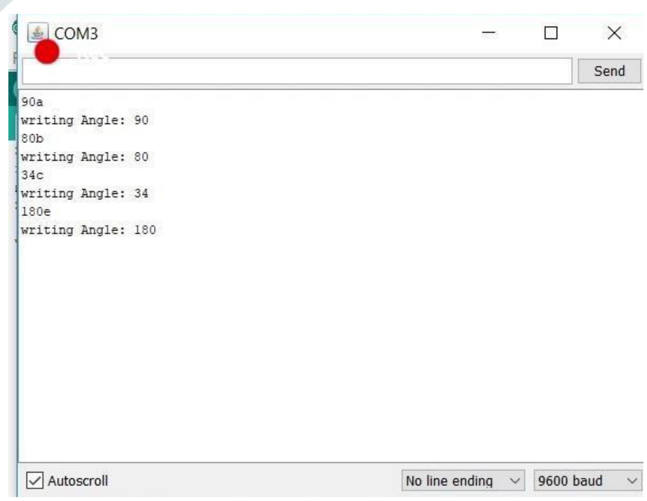

Figure 5 shows the serial monitor of Arduino IDE

The serial monitor acts as a terminal window for controlling the robotic arm, basically a tether between the computer and Arduino. Serial data can be sent and received by using this terminal and incase of an error, debugging can also be done via the serial monitor.

III. WORKING

After uploading the code onto Arduino, serial monitor is opened. Each servo has been assigned to a letter and to control a specific motor, the desired location followed by the servo name has to be mentioned. For example, if the base servo is assigned the letter 'a' then in order to move it to 180 degrees, we have to write '255a/' in the serial monitor. To move a motor to 180 degrees, a data of 255 must be sent from the computer to the microcontroller in order to generate the PWM signals. At 255 the PWM is having 100% duty cycle. For the servo motors PWM width is constant. Initially motor shaft is adjusted to 90 degrees and the servo's can be moved to 0 or 180 degrees. With a total reach of 40 cm, the arm is able to lift stuff even at a distance. The payload capacity for the arm is roughly 3 Kg. Six degrees of freedom make the arm work just like a human arm and gives it the ability to perform complex movements with precision. All the servos are connected in parallel with one another and hence are able to receive a constant voltage of 5V. Despite being powered from Arduino, the motion is quite smooth and the motors are able to hold their positions even at full load. After the arm reaches the desired position, the gripper is closes itself onto the target and grabs it with a force equivalent to 24.5 N-cm.

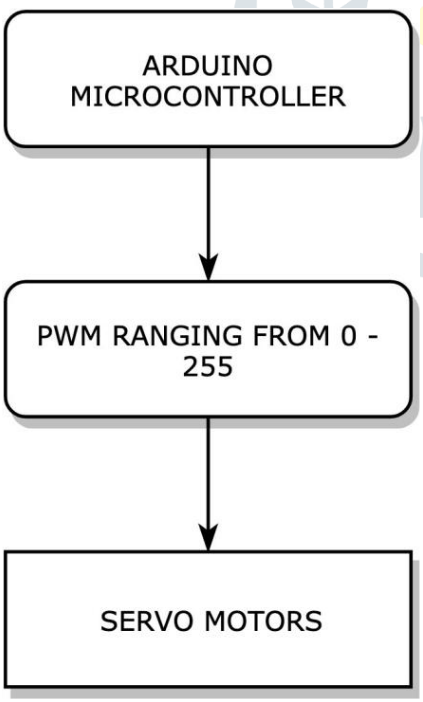

Figure 6 shows the Flow chart for Robotic Arm.

This force is sufficient enough to tightly grip the target and drop it to its desired location. The weight of seven servomotors and the frame of arm itself exert a lot of force and act as a load for the servos. With a maximum current output of 500 mA from arduino, seven motors are able to work in coordination with one another. The controlled motion of servomotors is achieved by changing the resistance of the potentiometer installed in the servos.

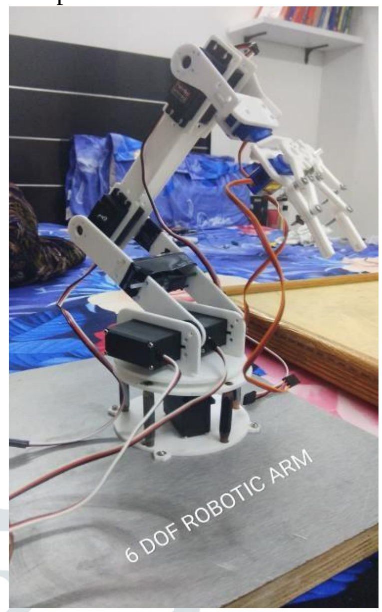

Figure 7 shows the Six DOF robotic arm

The robotic arm is a complex yet an elegant solution for decreasing human interference in the manufacture sector. Using just Arduino and no external power source for the servos, we are able to implement 6 degrees of freedom. This makes robotic arm a cheap and effective alternative.

IV. CONCLUSION

The paper presents the study and control of six DOF robotic arm. Powering servomotors from the Arduino is a non- conventional method, yet it works perfectly for our project. The arm was tested in various environments and was subjected to both fully loaded and unloaded conditions. It was seen during both the operations, no excessive heat was produced by Arduino and the operation of arm was smooth. The total force produced by the gripper servo was found to be sufficient enough for lifting payload of about 3 kgs.

Future work is concentrated on:

(a) Changing plastic gear servos to metal gear servos in order to lift more weight.

(b) Introduce machine learning and apply FIS techniques to make the arm fully autonomous

V. ACKNOWLEDGMENT

The opportunity to work in a team and progress with each other is a refreshingly learning experience, while this could not have been productive without the incessant guidance of our mentor and project supervisor, Ms. Sapna Singh, Lecturer, EEE. It is a pleasure to express our sincere indebtedness and acknowledge the help offered by our mentor on all the stages of the project without which, this project would have not been successfully completed.

We would also thank the entire Electrical and Electronics Department for the relentlessly working towards making this major project submission a fruitful learning activity of our curriculum.

VI. REFERENCES

[1] A.Rama Krishna, G.Sowmya Bala, A.S.C.S. Sastry, B.Bhanu Prakash Sarma and Gokul Sai Alla, "Design And Implementation Of A Robotic Arm Based On Haptic Technology", International Journal of Engineering Research and Applications (IJERA), Vol. 2, Issue 3, May-Jun 2012, pp.3098-3103.

[2] Md. Anisur Rahman, Alimul Haque Khan, Dr. Tofayel Ahmed and Md. Mohsin Sajjad, "Design, Analysis and Implementation of a Robotic Arm- The Animator", American Journal of Engineering Research (AJER), Volume-02, Issue-10, pp-298-307, 2013.

[3] Shri Lakshmi Pravalika and Dr. Alex Noel Joseph Raj, "FPGA Based Robotic Arm With Six Degrees of Freedom", International Journal of Innovations in Engineering and Technology (IJIET), Vol. 2, Issue 1, Feburary 2013.

[4] Karna Patel, "Adaptive Neuro Fuzzy Inference System for Kinematics of 6 DOF Robotic Arm", International Journal of Science & Engineering Research, Volume 7, Issue 1, January-2016.

[5] Tejaswini A. Futane, Shabina Sheikh, Ratnadina Rodge, Aditi K. Sangai and Jayant Sakurikar, "Robotic Arm Controller by using a Tmega16 Microcontroller", International Journal for Innovative Research in Science & Technology (IJIRST), Volume 2, Issue 11, April 2016.

[6] Rahul Gautam, Ankush Gedam, Ashish Zade and Ajay Mahawadiwar, "Review on Development of Industrial Robotic Arm", International Research Journal of Engineering and Technology (IRJET), Volume: 04, Issue: 03, Mar-2017.