ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 10, April 2014

Robotic 2D Plotter

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Abstract*— Robotic 2D Plotter is a plotter that offers the fastest way to efficiently produce very large drawings. The Robotic 2D Plotter which is basically a Selective Compliance Articulated Robot Arm (SCARA) has been implemented in the current work wherein the robot plots the input given from the computer on the drawing board using ATMEGA 8 microcontroller on a open-source physical computing platform Arduino. The Robotic 2D plotter has a two axis control and a special mechanism to raise and lower the pen. Each axis is powered using a single servo motor. Pen control is achieved using a servo. SCARA is an autonomous robotic arm with three Degrees of Freedom (DOF) and two joints which are flexible along the X-Y axis but rigid along the Z axis. This arrangement allows the arm to perform tasks at a faster pace and with increased accuracy.

***Index Terms*-SCARA, Degrees of freedom, axis control, Arduino platform.**

I. INTRODUCTION

Robotics is the branch of technology that deals with the design, construction, operation, and application of robots, as well as computer systems for their control, sensory feedback, and information processing. The design of a given robotic system will often incorporate principles of mechanical engineering, electronic engineering and computer science (particularly artificial intelligence).The term 'robotics' was coined by Isaac Asimov in his science fiction short story called 'Liar' [1]. Robot is an electro mechanical machine which is guided by a electronic circuitry or computer program to perform various tasks. A robotic arm is a robotic manipulator, usually programmable, with functions similar to that of human arm. Robotic 2D Plotter is a plotter that offers the fastest way to efficiently produce very large drawings. Pen plotters will be able to print by moving a pen or other writing device across the surface of a piece of paper. This means that plotters are vector graphics devices, rather than raster graphics. Pen plotters can draw complex line art, including text, but do so slowly because of the mechanical movement of the writing device such as pen. SCARA which refers to Selective Compliance Assembly Robot Arm or Selective Compliance Articulated Robot Arm is used to make a writing robot wherein the robot plots the input given from the computer on the drawing board. The SCARA robot is an X-Y Plotter. The plotters available in the market are Cartesian robots, cylindrical robots and Spherical robot/Polar robots. Cartesian robot are used for pick and place work, application of sealant, assembly operations, handling machine tools and arc welding. It is a robot whose arm has will have three prismatic joints, whose axes are coincident with a Cartesian coordinator [2]. Cylindrical robots are used for assembly operations, handling at machine tools, spot welding, and handling at die casting machines. It is a robot whose axes form a cylindrical coordinate system [2]. Spherical robot/Polar robot are used for handling at machine tools, spot welding, die casting, fettling machines, gas welding and arc welding. It is a robot whose axes form a polar coordinate system [2**].** Jointed-Arm Robot is the arm that connects with a twisting joint .The links within joints are connected with rotary joints. They are also called Articulate Robots.

II. DESIGN METHODOLOGY

The flow chart and block diagram of the robotic 2D plotter are shown in Fig.1 and Fig.2

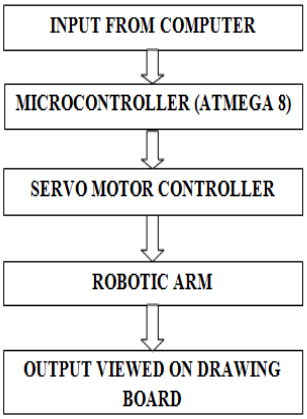

Fig.1. Flow chart of the Robotic 2D Plotter

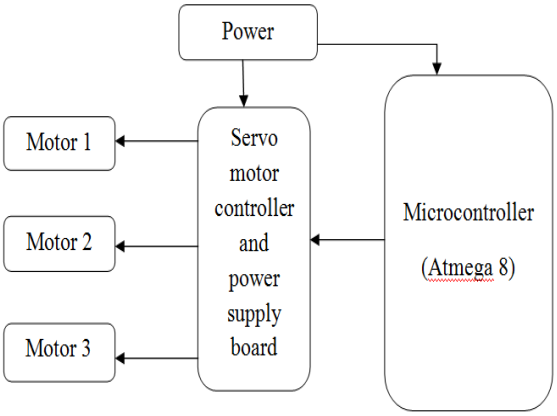

Fig.2. Block diagram 2D plotter

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The components of the 2D plotter include the following:

A. Atmega 8 Microcontroller

The device is manufactured using Atmel's high density non-volatile memory technology. The ATmega8 is supported with a full suite of program and system development tools, including C compilers, macro assemblers, program debugger or simulators, In-Circuit Emulators, and evaluation kits. The features of Atmega8 include 8K BYTES of In-System Programmable Flash Memory and 12 Bytes EEPROM. It has a Watchdog timer, two 8-bit Timer/Counters and one 16-bit Timer/Counter .It consists of three PWM Channels and 23 Programmable I/O Lines. It operates at the clock frequency of 16 MHz with the power supply of 4.5 to 5.5V [3].

B. Servo motor controller board

In order to provide the required amperage to the motor using the low current signal from the microcontroller, motor controller board is used. A motor controller is a device or group of devices that serves to govern in some predetermined manner the performance of a servo motor. A motor controller might include a manual or automatic means for starting and stopping the motor, selecting forward or reverse rotation, selecting and regulating the speed, regulating or limiting the torque, and protecting against overloads and faults.

C. Servo Motors

A servo motor is an electromechanical device that converts electrical energy into mechanical energy. Servo motors can be powered by current sources. Microcontrollers command these motors through the motor controller circuit to take the necessary action. A servo motor mainly consists of a DC motor, gear system, a position sensor which is mostly a potentiometer, and control electronics. The DC motor is connected with a gear mechanism which provides feedback to a position sensor which is mostly a potentiometer.

D. Power supply

The function of regulated power supply is to supply a stable voltage to a circuit or device that must be operated within certain power supply limits. This is used to supply the power to the microcontroller and the driver circuits.

E. Working procedure

The input is given to the microcontroller board using software. The microcontroller used is Atmega8. The code is loaded to the microcontroller using arduino software. The code thus loaded controls the servo motors based on pulse width modulation (PWM). The motion of the SCARA robot arm is controlled by these servo motors and accordingly arm will be moved and the corresponding output is viewed on the drawing board.

III. DESIGN OF 2D PLOTTER

To proceed in the direction of design aspects, first mechanical structure has to be designed. Depending on the design requirements electronic parts are configured with that of mechanical design.

A. Mechanical design

It involves the selection of suitable motor for our application, deciding on the material to be used for the construction of the arm, i.e. the shaft material and deciding on the location where the motor has to be placed. A servomotor is a rotary actuator that allows for precise control of angular position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. To obtain high torque and precise speed servo motors are used.

B. Torque and speed calculation

Torque is the tendency of force to rotate an object about an axis. Mathematically, torque is defined as the cross product of the lever-arm distance and force, which tends to produce rotation.

$$T = F * L \text{ Nm} \quad [2]$$

Where, F= force acting on the motor,
L= length of the shaft Force,
F is given by,

$$F = m * g \text{ N}$$

Where, m=mass to be lifted by the motor
g= gravitational constant= 9.8 m/s
Consider the Fig.3. Torque for the first joint is calculated as,

$$T1 = F1 * L1$$
$$F1 = m1 * g$$

Similarly, the torque for the other joints is also calculated but for the succeeding joints, the weight of the above motor and the length get added [3].

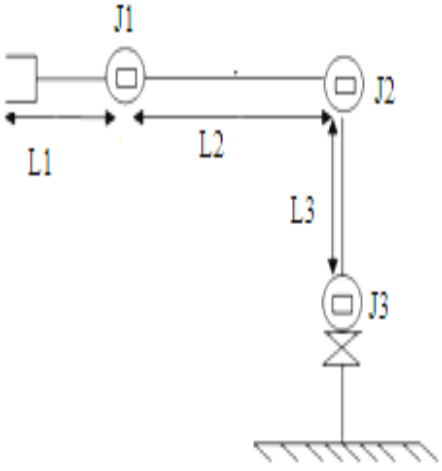

Fig.3. Robotic arm designs

Torque for 2nd joint: T2 = F2 (L1+L2)
Torque for 3rd joint: T3 = F3 (L1+L2+L3)

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C. Speed calculation

For each joint considered, the angular speed and linear speed are calculated as given below:

Angular speed,

$$w = \theta/t = [\theta*\pi/180] / [pps*1.5*10^{-3}] \text{ rad}$$

$$W = W* 9.45 \text{ rpm}$$

Linear speed,

$$V = W * r \text{ m/s}$$

Where, r is shaft length [6].

D. Axis movement

The movement of each arm in the 2D plotter depends on the angle given to the servo motor. The axis movement of the arms is calculated as following:

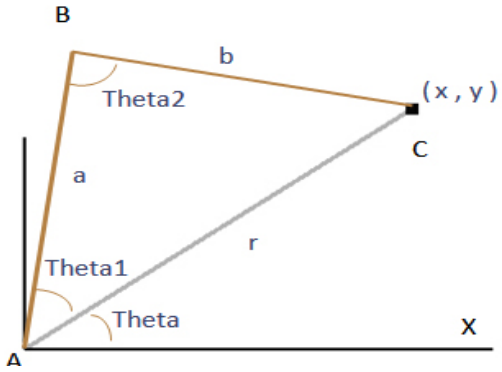

Fig.4. Arm axis movement

Where,
a=length of base arm
b=length of fore arm
From Trigonometry,

$$\text{Tan(theta)} = y/x$$

$$r=\text{sqrt}\ (x2 +y2)$$

$$b2 = a2+r2-2ar \cos(\text{theta1})$$

$$r2 = a2+b2-2ab \cos(\text{theta2})$$ [8]

E. PWM Signals

The position of servo motors can be controlled more precisely than those of standard DC motors and they usually have 3 wires (power, ground and control). PWM signals are used to control the servo motor. A pulse width modulated signal is fed through the control wire. The pulse width is converted into an equivalent voltage. The servo understands the language of pulse position modulation. A pulse of width varying from 1 millisecond to 2 milliseconds in a repeated time frame is sent to the servo for around 50 times in a second. The width of the pulse determines the angular position. A neutral pulse value dependent on servo keeps the servo shaft in the Centre position. Increasing that pulse value will make the servo turn clockwise and the shorter pulse will turn the shaft anti-clockwise [8]. For example, a pulse of 1 millisecond moves the servo towards 0°, while a 2 milliseconds wide pulse would take it to 180°. The pulse width for in between angular positions can be interpolated accordingly. Thus a pulse of width 1.5 milliseconds will shift the servo to 90°.

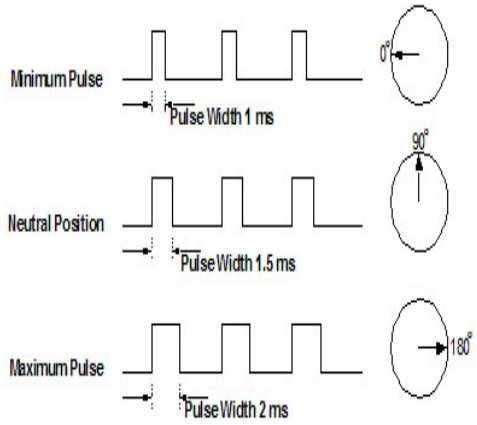

Fig.5. PWM signals

F. Software Specification

Arduino is an open-source physical computing platform based on a single microcontroller board and a development environment for writing the software for the board. It is Inexpensive, Cross-platform, Open-source extensible hardware and software. It provides serial communication, which is available on digital pins 0 (RX) and 1 (TX). The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer.

IV. APPLICATIONS

1. Android/IOIO/Open CV based interactive plotter: Acquired picture can be quickly converted into paths (via edge detection) and plot them using high level Java code running on an Android or PC.
2. PCB creation: Electronic Circuit layout can be plotted on to a copper-clad board which can be etched normally.
3. PCB hole drilling: By replacing the pen with a drill/Dremel tool, the user can precisely drill holes in circuit boards. This technique will greatly simplify printed circuit board production.
4. Plotting of graphs, charts and documents.

V. CONCLUSION

The 2D plotter finds its application in the many fields. It is a useful device in the field of graphics. Letters and images can be drawn by taking the inputs from the PC. Further, additional improvements can be done by incorporating the graphical user interface for making the arm more user friendly and developing a web interface so that arm could be controlled in remote place by the Web browser.

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