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DEVELOPMENT OF SCARA MANIPULATOR WITH TWO DEGREES OF FREEDOM USING DC MOTOR

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ABSTRACT

This paper details the construction of a Robotic Arm or manipulator with SCARA configuration and having DC Motors at its joints. There are two revolute joints present in the manipulator arm which helps the manipulator to be in RRP configuration. The DC Motors are given a pulse for a definite duration according to which they rotate by a certain angle.

Keywords: DC motor, SCARA manipulator, ATMEGA16, L293D Motor driver IC.

1. INTRODUCTION

The details regarding the working of a manipulator arm with a microcontroller and motors are tuned in this study. These manipulators are of many types based upon the applications and the workspace. Thus, while designing a manipulator it is very important to keep in mind the workspace of the application [1]. Robots can be autonomous, semi-autonomous or remotely controlled. Robots are used in an increasingly wide variety of tasks such as for household appliances, like vacuuming floors, mowing lawns, cleaning drains, building cars, in warfare, and in tasks that are too expensive or too dangerous to be performed by investigating humans such as exploring outer space or at the bottom of the sea. The implementation process, software consists of the commands that control a robot's actions and provide information regarding the required tasks. When a program is written by means of software, the robot is able to implement commands and achieve the particular errand. A manipulator is merely an arm that consists of an elbow and a wrist. Robotic manipulators are composed of links connected by joints. Joints are typically are of revolute (rotating) or linear (displacing type). A revolute joint is like a hinge and allows relative rotation between two links. A linear joint allows a linear relative motion between two links. The robots have to interact with their environment, which is an important objective in their development. This interaction is commonly accomplished by means of a sort of arm and gripping device called end effectors [2-5]. The number of joints in a manipulator determines the degrees-of freedom (DOF) of the manipulator. A manipulator should ideally possess at least six independent DOF: three for positioning and three for orientation. The working space of a manipulator is restricted if it has less than 6 DOFs. The complexity of controlling a manipulator increases after 6 DOFs.

The joints of the manipulator consist of DC Motors that rotate when energized with power supply. The pulses given to the DC Motors are strategically timed and delayed so as to give an accurate displacement of the arm to the desired location. The timing of the pulses is programmed into the Microcontroller board whose pins are connected to the DC Motor via a Motor driver [3]. The current output by the microcontroller board is not sufficient to drive a DC Motor. Therefore, a DC Motor Driver IC (L293D) is interfaced to the microcontroller to support its load current.

2. CONSTRUCTION OF MANIPULATOR

A robot manipulator should be viewed as more than just a series of mechanical linkages. The mechanical arm is just one component of an overall Robotic System as shown in Figure-1. This consists of the arm, external power source, end-of-arm tooling, external and internal sensors, computer interface, and control computer. SCARA stands for Selective Compliant Articulated Robot for Assembly. The so-called SCARA shown in Figure-2 is a popular configuration, which, as its name suggests, is tailored for assembly operations [4]. The SCARA Manipulator consists of two revolute joints and one prismatic joint as shown in Figure-2. The revolute joints are rotating joints which create rotation about their axis. They are fitted with DC Motors of appropriate torque and power supply. The motors used here are of 12V. The two DC Motors are fitted at the two joints, the base and the elbow. These two motors are capable of running in both directions: clockwise and counter-clockwise, when power supply is provided to them. If a continuous power supply is given to them, the motors will rotate continuously. Therefore, a short pulse of power supply is given to the DC Motors for a fixed duration so that they rotate for a fixed duration of time [8]. When a pulse is provided to the DC Motor, it rotates in one direction. Reversing the polarity of the power supply reverses the rotating direction of the motor. By trail-and-error it was found that the DC Motor rotates 180^{O} when a pulse of 5V is applied to it for duration of 1 second. Therefore by reducing the time duration of the pulse, the angle rotated by the DC Motor can be controlled. The application for which this study is designed is to fill a tube with a liquid solution using a manipulator and to deliver the solution to a test tube. The manipulator designed for this purpose is a SCARA Manipulator, with two DC Motors located at its joints. The SCARA Manipulator configuration is shown in Figure-2. The two revolute joints are replaced by DC Motors. The DC Motor is powered through a battery supply of 5V. The

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algorithm according to which the motor runs is programmed into the Microcontroller board.

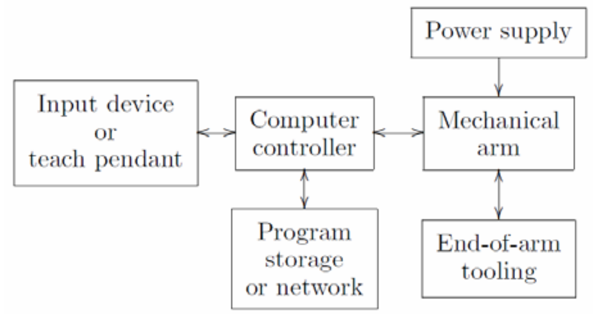

Figure-1. Block diagram of a robotic arm.

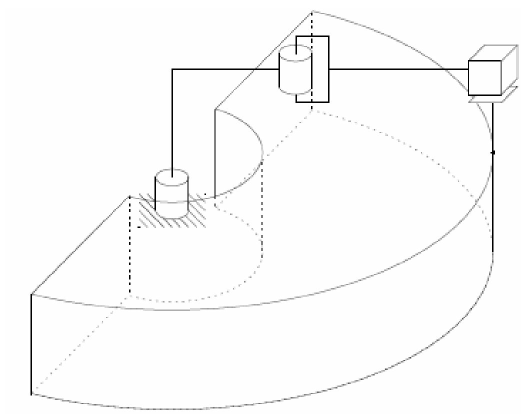

Figure-2. Workspace of a SCARA manipulator.

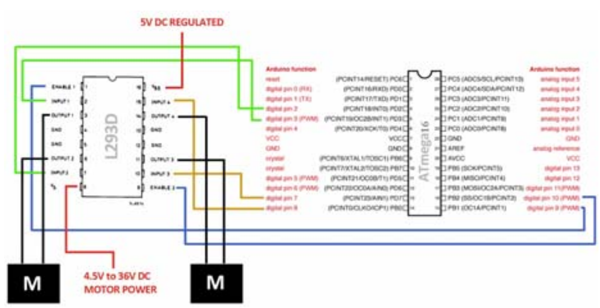

Figure-3. ATMEGA 16 Interface to two DC Motors using L293D IC.

The manipulator is designed using Aluminum rods and G.I. Steel sheets for making the manipulator arm sturdy. The links between the joints are made of light weight Aluminum rods [5]. The bracket assembly, which is used to mount the motor, is made up of G.I. Steel sheets. Two G.I. sheets are taken and curved around the motor to make a bracket and screwed tightly to the Aluminum rods which constitute the links. Lengthy wires are soldered to the motor and brought down the arm's length to the microcontroller board [5]. The base of the manipulator consists of a DC Motor and a tripod stand mounted on a cardboard. This gives the base a sturdy construction so that it can carry the weight of the motor and the whole arm. The bread board and the Microcontroller board are fixed to the base along with the power supply. Due to the high rating current requirement for the motor to run, a motor driver is necessary. A Motor driver IC for the DC Motor is L293D. It is a dedicated quadruple Half H Bridge motor driver IC available in 16 pin package. L293D has a current capacity of 600 mA/channel and has supply voltage range from 4.5 to 36V DC. A maximum of two motors can be supported per IC.

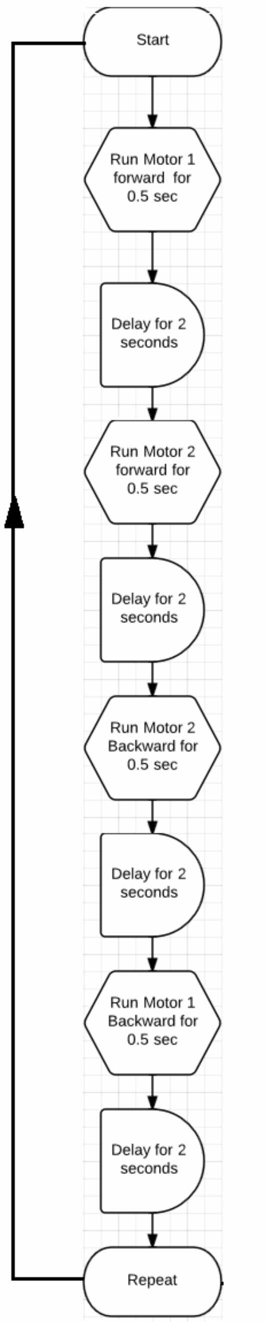

Figure-4. Flow chart for the programming of ATMEGA 16.

3. CIRCUIT CONNECTIONS

The DC Motors are interfaced with the ATMega 16 Microcontroller board using a L293D IC. This IC is a DC Motor driver IC used to deliver the required rating of current to the motors to run. There are advantages in using a DC Motor driver because the current rating of the microcontroller board is small and the Driver IC also supports the two rotating directions of the motor. Thus a motor can rotate in both directions using this driver IC. The programming tool used to program the ATMEGA 16 microcontroller board is AVR Studio (version 5) and ISP programmer is used to burn the program in the flash bits of the ATMEGA 16 microcontroller. The Flash Magic tool is required to burn the *.hex file in the flash ROM memory of the microcontroller [2]. The L293D is a dedicated quadruple Half H Bridge motor driver IC available in 16 pin package. L293D has a current capacity of 600mA/channel and has supply voltage range from 4.5 to 36V DC. It is a circuit which allows motor rotation in both directions. From four terminals of H Bridge can be controlled a DC motor [6]. The circuit connection of an ATMEGA 16 to a DC Motor using a motor driver is shown in the Figure-3. Pins 3 and 6 and 11 and 14 are the output pins that are connected to the two DC Motors. The programming port pins are connected to the L293D pins. The motor 1 will run if "logic 1" is input to the Pin 2 and "logic 0" to pin 7. It will run in reverse direction if the polarity of the power supply is reversed, i.e. "logic 1" to pin 7 and "logic 0" to pin 2. Similarly, the motor 2 output pins are 11 and 14. It will run clockwise if "logic 1" is input to the Pin 10 and "logic 0" to pin 15. It will run in reverse direction if the polarity of the power supply is reversed, i.e. "logic 1" to pin 15 and "logic 0" to pin 10. This concept will be utilized to program the Microcontroller board and configure the pins accordingly.

Table-1. Truth table for L293D.

PIN 2	**PIN 7**	**Description**
0	0	Motor stops
0	1	Motor runs anti-clockwise
1	0	Motor runs clockwise
1	1	Motor stops

4. EXPERIMENTAL SETUP

The programming of the ATMEGA 16 is done using Embedded C coding. The C coding is done using a tool known as AVR studio. This software allows the programmers to program a microcontroller using an ISP (In-System Programming) Programmer cable [7]. The ATMEGA 16 uses an in built timer inside the chip. The programming of the timer is done using this tool. The .hex file is generated by this tool. The flash bits are burned inside the microcontroller using the ISP chip and the flash magic tool. The L293D DC motor driver can support a maximum of two DC motors. The driver is able to run the motor both forward and backward based on the Boolean value given to the IC pins by the Microcontroller. The truth table is given below in Table-2. The 'Pin 0' of the microcontroller is then connected to the 'Pin 2' of the IC and 'Pin 1' to the 'Pin 7' of the IC for Motor 1. Similarly, 'Pin 2' of the microcontroller is connected to the 'Pin 10' of the IC and 'Pin 3' of the microcontroller is connected to the 'Pin 15' of the IC. Figure-4 gives the flowchart for the programming of the microcontroller.

The algorithm for the program to be burned in Flash of Microcontroller is given below:

a) Start
b) Set 'Pin 0' high and 'Pin 1' low to run the Motor 1 in forward direction for 0.5 seconds.
c) Delay for 2 seconds.
d) Set 'Pin 2' high and 'Pin 3' low to run the Motor 2 in forward direction for 0.5 seconds.
e) Delay for 2 seconds.
f) Set 'Pin 3' high and 'Pin 2' low to run the Motor 2 in backward direction for 0.5 seconds.
g) Delay for 2 seconds
h) Set 'Pin 1' high and 'Pin 0' low to run the Motor 1 in backward direction for 0.5 seconds.
i) Delay for 2 seconds.
j) Repeat

Table-2. Pulse duration and angle.

Pulse level	**Duration of the pulse** (sec)	**Rotation angle** (degrees)
5V	0.25	45
5V	0.5	90
5V	0.75	135
5V	1	180

5. RESULT AND DISCUSSIONS

A SCARA manipulator was designed with the help of the ATMEGA 16 Development board and the L293D DC Motor Driver. The repeatability of the manipulator arm was acceptable and the programming of the Development board was simple. The rotation angle of the DC Motor was based on the duration of the pulse given to the DC Motor. The readings are tabulated in Table-2. These robots have a wide range of industrial and medical applications such as pick and place robots, surgical robots etc. They can be employed in places where precision and accuracy are required. Robots can also be employed where human hand cannot penetrate. The screen shot shows the designed robot and its functionality. It is clearly shown that the robotic arm is designed very efficiently and that the designed robotic arm is capable of lifting the objects of medium weight.

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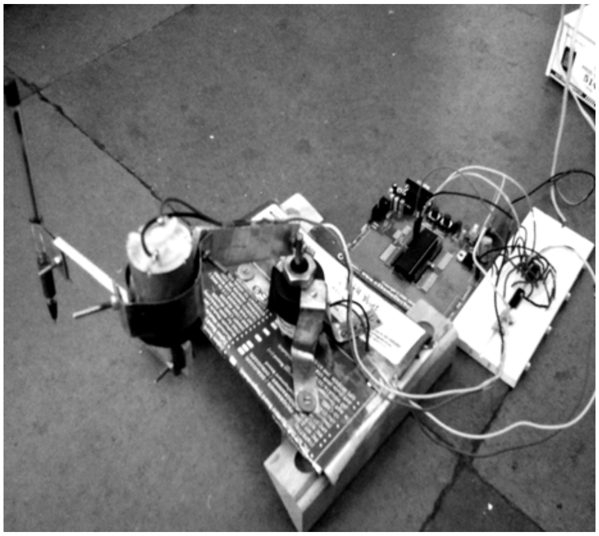

Figure-5. Experimental setup.

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