

Design and implementation of a Pick and place robot for flexible manufacturing system (FMS)

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ABSTRACT :A robot is a machine designed to execute one or more tasks repeatedly, with speed and precision. Robots are being used in variety of industrial applications for various activities like pick and place, painting, assembling of sub systems, and in hazardous places for material handling etc. This paper presents the design and implementation of a pick and place robot using a pic micro controller. The robot was controlled with the pic 18F4680 micro controller which allow easy interface to the control electronics. Joints were moved using stepper motors. The operation of the microcontroller based pick and place robot is achieved through control software written in assembly language.

Keywords: Robot, pick and place robot, microcontroller, stepper motor, assembly language, flexible manufacturing system (FMS), Pic18F4680, automation.

Introduction

A robot is a machine designed to execute one or more tasks repeatedly, with speed and precision (1).Robots can be classified as follow: industrial robots, autonomous mobile robots, robots in space, domestic robots, underwater robots, entertainment robots, robots for warfare/military, robots in research, agricultural robots, intelligent robots, etc.

Robot and automation are employed in order to replace human to perform those tasks that are routine, dangerous, dull, and in a hazardous area. In a world of advanced technology today, automation greatly increases production capability, improve product quality and low production cost. Automation is defined as the process of using specialized mechanical and electronic equipment and devices, such as robots and computers and programmed commands to control production [6, 7].

The aim of this project is to design and implement a pick and place robot for flexible manufacturing system (F M S).

Manufacturing system (F M S).

A pick and place robot, otherwise known as a pick and drop robot [1], is a type of industrial robot equipped with grasping fingers that enable it to transfer materials from one place to another on an assembly line within a manufacturing facility [2,6]. Technically it is called a revolute or jointed arm robot other names such as articulated, anthropomorphic or manipulator arm robot [6].Together with Cartesian-coordinate and selective compliance Arm for Robotic Assembly (SCARA) robots, they form the most common forms of robots readily employed in the industry for manufacturing purposes [6,7].

There are many advantages accruable from the use of a robot as a replacement for from the use of a robot as a replacement for human operator in the industry and these include increase in productivity, profitability and product quality, assurance of just-in-time delivery and to reduce labour cost and shortage, operational hazards and production lead-time, etc [1,4,5,6].

Flexible Manufacturing system (FMS) is an automated manufacturing system in which several machine tools are linked together by a material handling system and a centrally controlling computer. FMS manufactures more than one type of product at the same time, that is each machine in the system processes different product type at any moment, as opposed to an automated production line where only one product is processed at a time [6 and 7].the use of robots in such a system greatly enhances the potentials.

2.1 Operation of pick and place robot

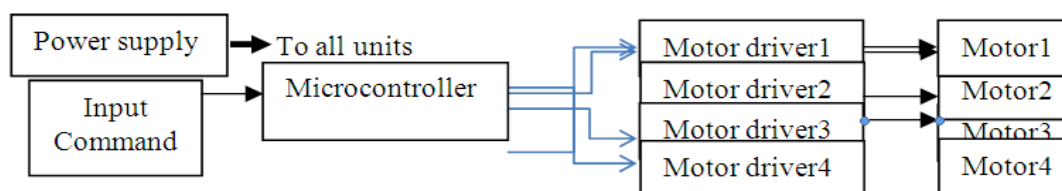


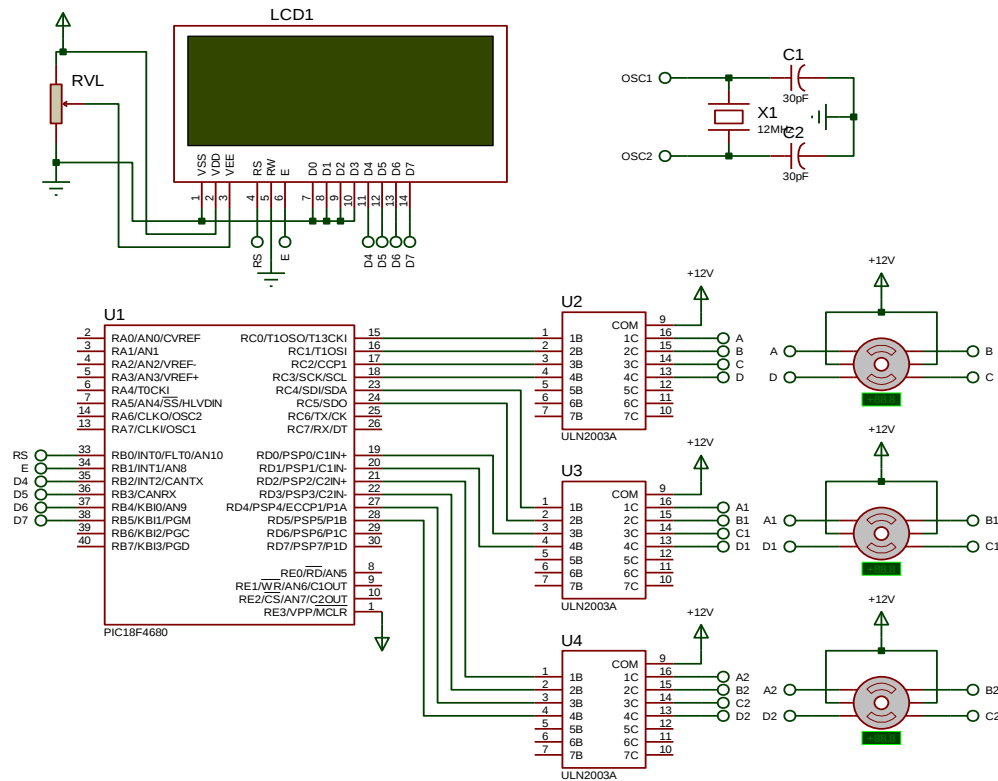
Figure1: block diagram of the pick and place robot

The block diagram of the pick and place robot is shown in fig1. It consists of a pic18F4680 microcontroller, three stepper motors with their respective motor drivers, actuator and power supply. The robotic arm is made up of four joints that are there is four degree of freedom for the robot.in each joint a stepper motor in conjunction with the gears is utilized to bring about the desired movement. The stepper motor at joint 1(base) moves the whole arm sideways from the picking area to the dropping area.motor2 in joint2 (shoulder)controls the rise and fall of both the upper and lower arm in picking and dropping objects. The gripper arm likewise is controlled by a motor, but in conjunction with pneumatic actuation provided by a piston and cylinder and toggle mechanism which enables the tong like fingers to grasp and release objects. Due to the up and down movement of the joint2, the third joint (which allows similar movement) does not need a motor anymore, it is therefore set and fixed in an angle for positioning the arm to pick and drop only.

Depending on the angle needed, stepper motor is always given a signal by the microcontroller to move the desired distance and stop.at other times it is asked to reverse the movement to the initial position. The motor moves clockwise to grasp object and anticlockwise to release the object. All these processes require a precise timing of each function of the stepper motors. At initialization, the robot checks which position the shoulder joint is, and moves it to position zero. The motor at the base has a movement of 180 degrees clockwise and 180 degree anticlockwise to return to position zero. Those at joint2 and 3 require about 45 degrees rise and fall as appropriate.

3. Materials and method

The circuit diagram of the microcontroller based pick and place robot is shown in FIG2:



FIGURE

There are components of the pick and place robot namely: mechanical hardware, electronic hardware and software design.

3.1 Mechanical hardware design

The mechanical hardware components consist of the following [6]:

- The BASE to which the body is attached, and mounted on the floor.
- The BODY which is attached to the base ad arm assembly.
- The ARM which is attached to the body and which carries the wrist that is assembled unto it.
- The WRIST assembled unto the arm and which is in turn assembled with hand.

- e. The HAND, technically called the end effector, attached to and controlled by the wrist and carries either a gripper or a tool for its overall manipulative function.
- f. JOINTS connecting all these various components to facilitate their relative rotational or sliding motions and so provide them with the required degree of freedom. In order to do this, the joint must be powered, however not all joints need actual power; some are passive. E.g. elbow joint. Joints are moved using stepper motor.
- g. MECHANICAL OR RIGID LINKS at each of these joints, two at a joint—the input and the output—the various connecting components being also classified as link; the base is the first link and end effector is the last link

3.2 Electronic Hardware Design

The electronic hardware design consists of the following:

1. Pic18F4680 microcontroller:- Pic18F4680 microcontroller from microchip is a single micro controller which is very easy to be assembled, programmed, and also the price is cheap and it is available. One unit of pic18F4680 microcontroller can be programmed and erased so many times. It includes features for entire analog as well as digital form of operations.
2. Stepper motor driver :- The microcontroller output is not sufficient to drive the motor. Drivers are required for motor rotation. The driver circuit is used for controlling the stepper motor.
3. Bipolar stepper motor:- A bipolar stepper motor is an electromechanical device which converts electrical pulses into discrete mechanical movements. Bipolar stepper motors are known for their excellent size/torque ratio, and provide more torque for their sizes. They are designed with separate coils that need to be driven in either direction for proper stepping to occur.

3.3 Software design

The flow chart of the pick and place robot is depicted in fig3. The operation of the microcontroller-based pick and place robot is achieved through control software written in assembly language.

4. Simulations and Results

The circuit of the pick and place robot was simulated using Proteus VSM. Proteus VSM software is software for running simulations on programmes written in assembly language. The hardware of the pick and place robot was successfully designed and tested. The results of the mechanical testing of the pick and place robot obtained for ten (10) cycles were tabulated as shown in table 1.

Number (Cycles)	Time: Joint1 (Sec)		Time: Joint2 (Sec)		Time: Joint3 (Sec)	
	CW	ACW	CW	ACW	CW	ACW
1	3	2	3	3	2	3
2	3	3	2	3	2	2
3	3	2	2	3	2	2
4	2	3	2	2	3	2
5	2	3	3	3	3	2
6	3	3	3	3	2	2
7	2	3	3	3	2	2
8	3	2	2	3	2	2
9	2	3	2	2	2	2
10	2	2	3	3	2	2

Table 1: results of mechanical testing of the pick and place robot

Pulse (wire)	Coil 1 (AB)	Coil 2 (CD)	Coil 3 (EF)	Coil 4 (GH)	Number In Binary	Decimal Equivalent
1	ON (1)	OFF(0)	OFF(0)	OFF(0)	1000	8
2	OFF(0)	ON(1)	OFF(0)	OFF(0)	0100	4
3	OFF(0)	OFF(0)	ON(1)	OFF(0)	0010	2
4	OFF(0)	OFF(0)	OFF(0)	ON(1)	0001	1

The switching mode is depicted in Table 3.41

SIMULATIONS, PERFORMANCE TESTING AND EVALUATION

4.1 Project Assembly and Organization

The controller was packaged along with the device driver circuit ready for connection to the overall project assembly. Connection was done by the use of cable connectors and plugs. This was after the delivery and assembly of the specified

mechanical and electromechanical components like the end-effector, fasteners, gears and motors. The frame, or arm links, and base were completely fabricated to shape.

Assembly goes thus:

- Motors to frames, base, links or arms at the joints as appropriate, using screws, bolts and nuts, and other fasteners.
- Gears to joints using fasteners, pins and couplings, ensuring contacts with the gears.
- Cover plates to frames, base, links and arms using fasteners.
- Coupling of base, shoulder, waist and elbow at appropriate angles.
- Coupling of end-effector to elbow at the appropriate angle.
- Connection to microcontroller and device driver circuit.

Spray painting of the assembled piece was done to enhance beauty and aesthetics of the entire product. A picture of the overall project assembly is provided in Figure 1.0, Appendix 1.

Figure 4 gives the flow charts of the program executed by the microcontroller. As indicated in the flow charts the microcontroller polls the input switches and after taking the appropriate decision it goes back to monitoring the switches in a continuous loop.

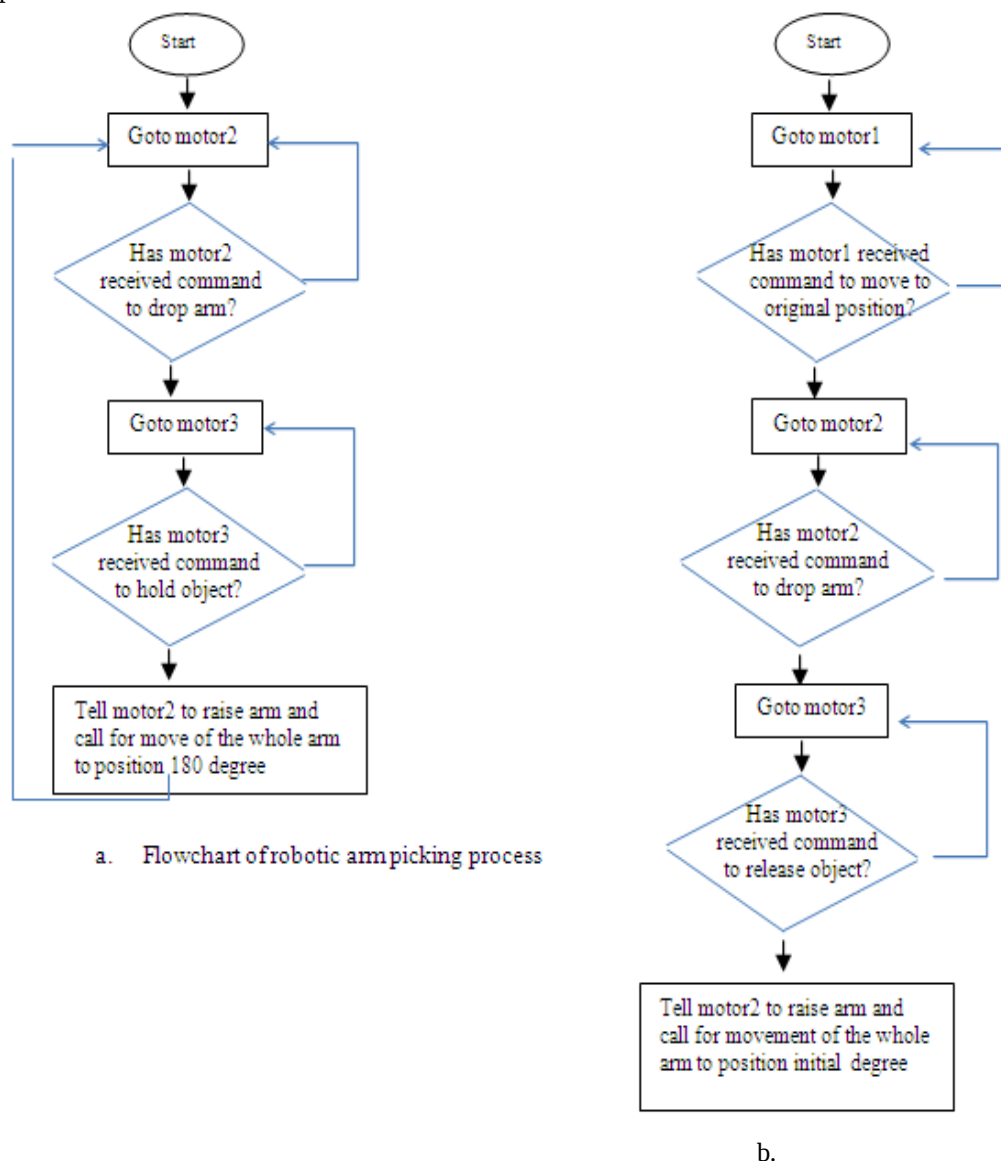


Figure 4: Flow chart of the LED clock

3. Results and Discussions

The program for the microcontroller was written in assembly language and was then compiled into an executable file using the MPLAB8.91 IDE. A software simulation was carried out with the simulator built into the MPLAB IDE to ensure that the program variables and registers changed as desired. The executable file was next imported into the Proteus Design Suite IDE where the hardware circuit shown in figure 2 and 3 was designed and simulated. The program development in MPLAB IDE is shown in figure 5. Figures 6 and 7 show the simulation results for the case when the time is 12:03 and 7:07, respectively. Upon successful completion of the software simulation, the system's hardware was constructed on a vero board and programming of the microcontroller was carried out using PICkit 2 programmer. The process is shown in figure 7 and the hardware construction displaying connections and various times are shown in figure 8, 9 and 10.

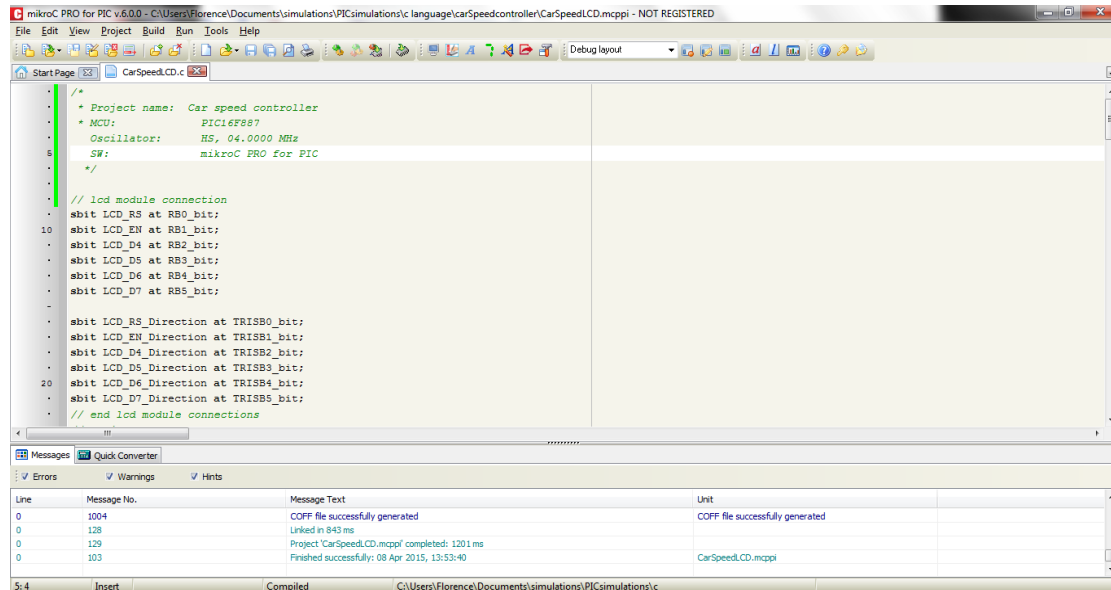


Figure 5. Program Development using mikroC IDE

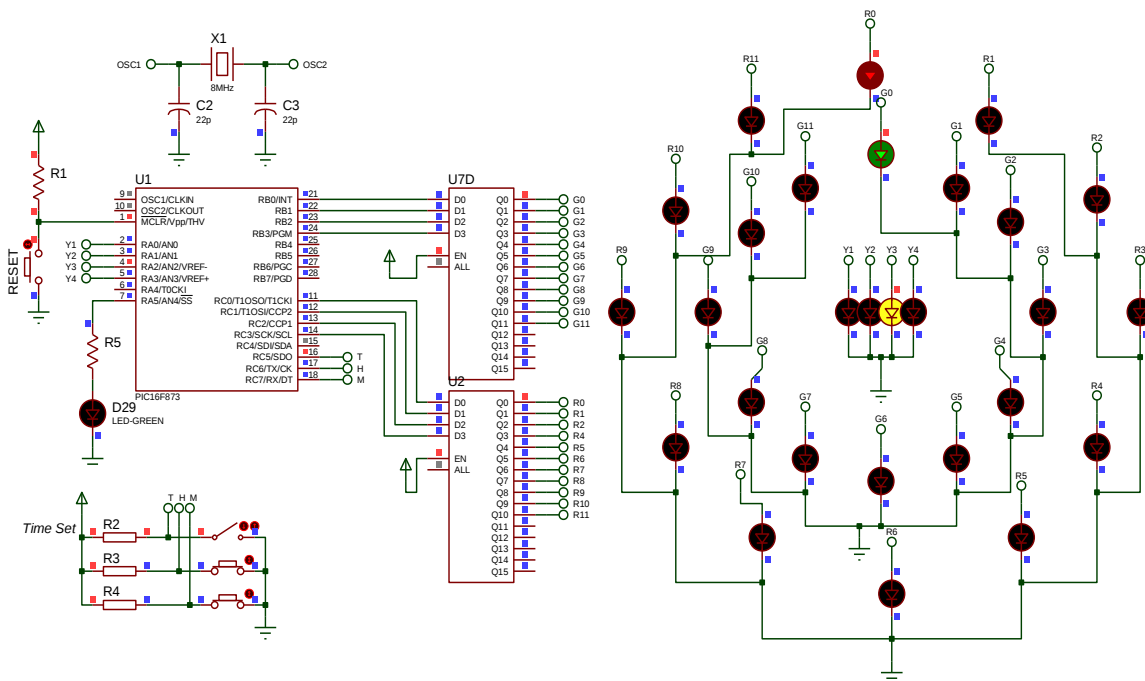


Figure : 12:03

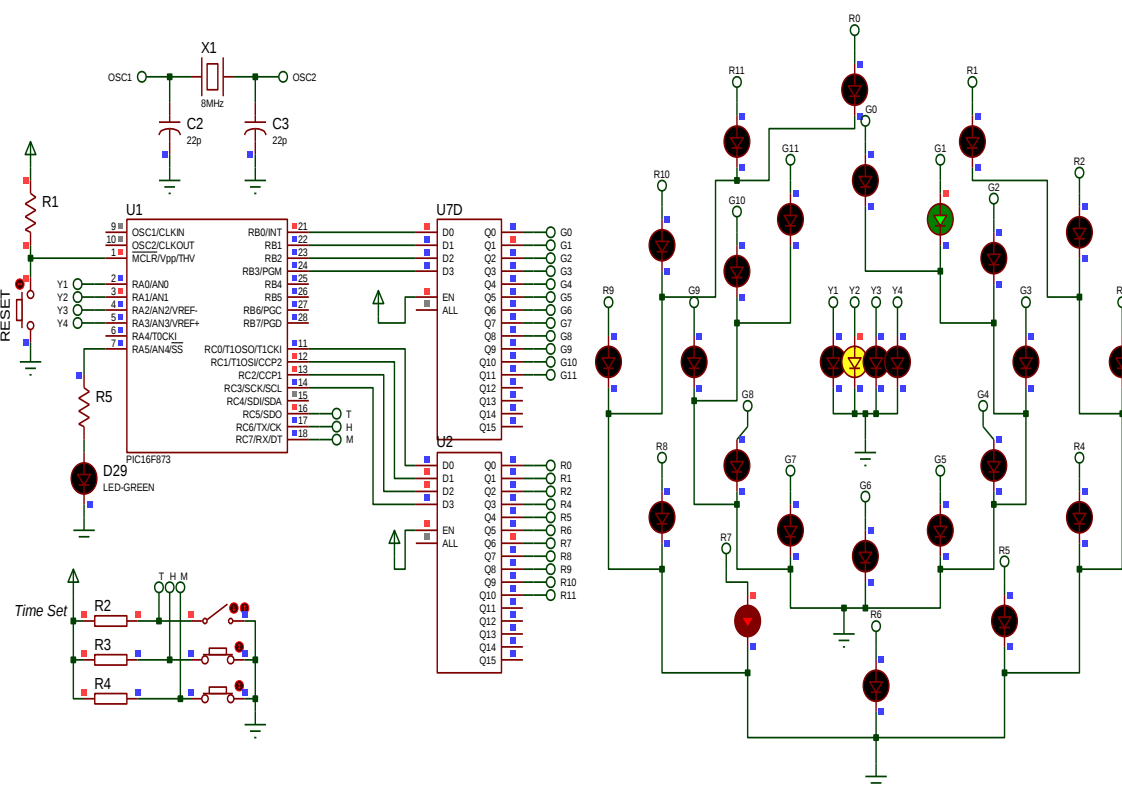


Figure :7:07

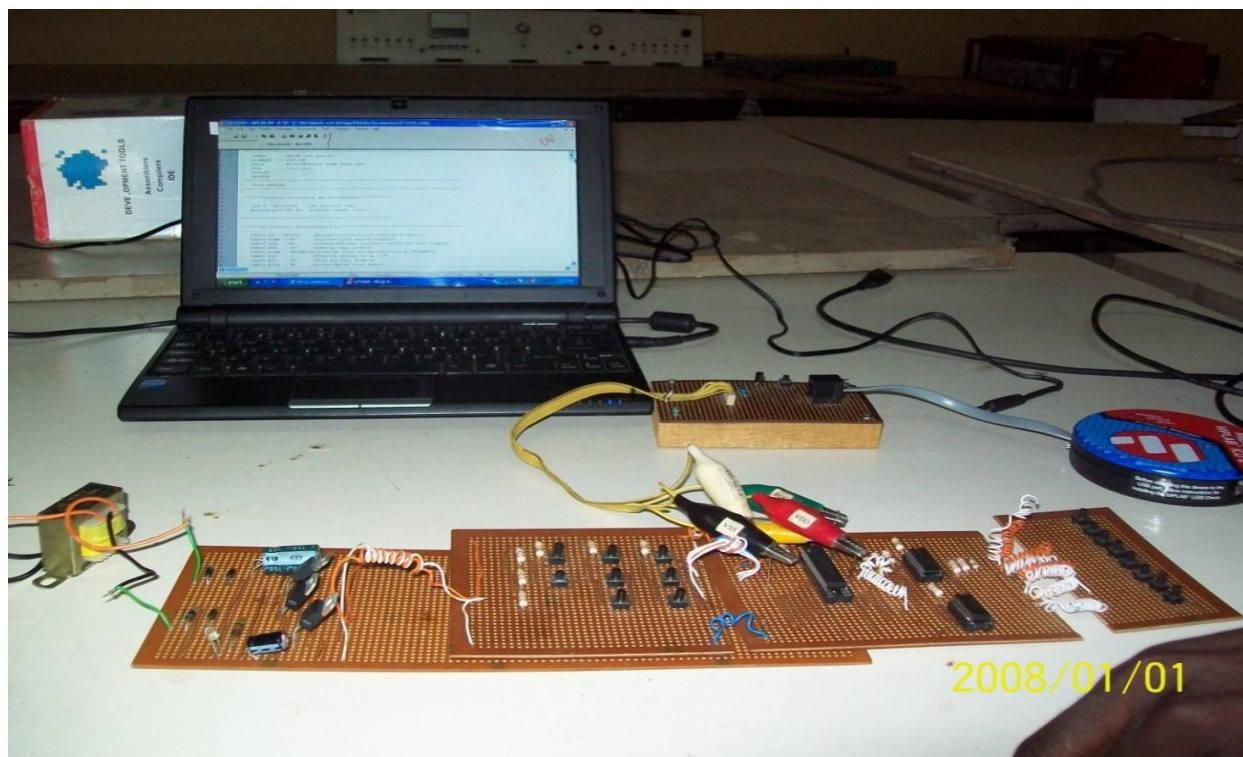
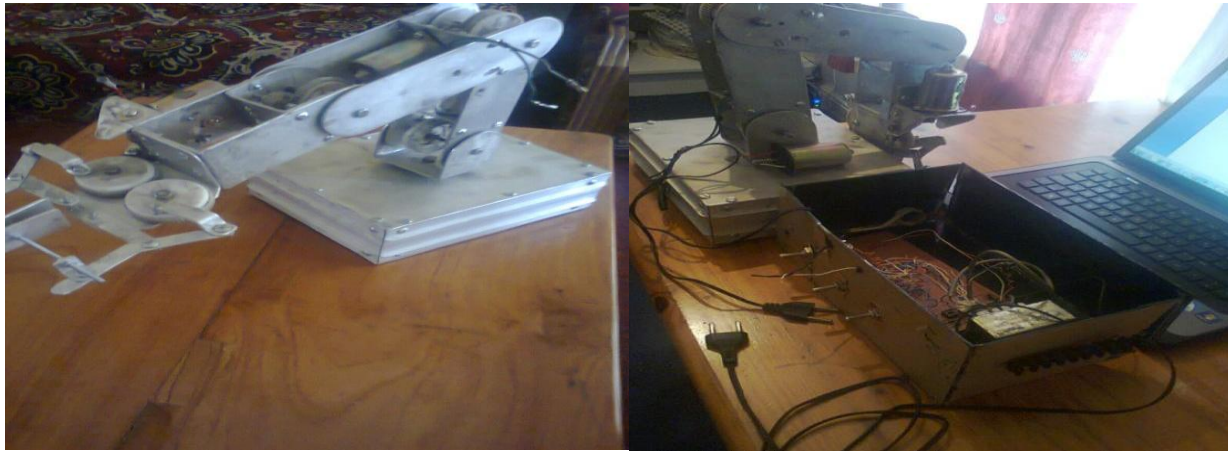


FIGURE:



FIGURE

4.2 Simulation, Performance Testing and Results

1. Simulation and Results

The steps to running the interactive-mode simulation were performed as below and the accompanying results obtained:

- i. The MPLAB IDE and PROTUES VSM programs were installed into the PC separately. The driver circuit bearing the robotic arm control was also drawn while the programme was written.
- ii. The written programme and the driver circuit were imported (built) into the MPLAB IDE program file location using the access command: C:\Pic\pick_and_place_robot.asm. The programme automatically ran and produced the 'Hex' files immediately. Seven of such files were seen including the interactive mode titled "Olotu Simulation Diagram".
- iii. The PROTUES program file was opened by double clicking and then clicking 'File'. This displayed an empty PROTUES platform waiting for further action.
- iv. The 'File' at the top left file menu was clicked and from the pull-down menu, 'Open Design' was chosen to display file folder locations. The locations seen were 'Recent Places', 'Desktop', 'Libraries', 'Computer', and 'Network'.
- v. The location, 'desktop' was clicked and different design folders were displayed including the 'Olotu Simulation Diagram'. It was clicked and the circuit opened.
- vi. 'Play' at the bottom strip menu of the platform was clicked to run the design and all three motors in the circuit diagram were seen making one cycle (CW and ACW) rotations in turn.
- vii. To check further, the switch solenoids in the circuit diagram were closed and opened in turn at each joint and the motors responded appropriately. Only motor 1 turned several cycles to the simulation while the rest turned one cycle each as required.
- viii. Debugging was done to alter the angle of rotation of motor 1 so as to correspond to one cycle of rotation when simulated. This was done by clicking "Debug" at the top left menu to open the program file registers from the pull down menu, and the necessary corrections done.
- ix. Results still showed similar but improved performance for the motors. The result of the circuit simulated waveform using PROTUES VSM is shown in Appendix 6.

2. Performance Testing and Results

Before connecting to the controller, the equipment was tested mechanically by being connected with wires from the motor of each joint to power supply and it performed wonderfully well! Each arm turned the required angle very fast and stopped courtesy of the mechanical stoppers provided at the joints. To reverse the movements, the wire terminals were reversed and the results too were **highly satisfactory**. Each joint performed the cycle of CW and ACW rotation on the average of 2seconds. In order to have enough results, the cycles of rotation were repeated several times and the results obtained for 10 cycles were tabulated as seen in

Table 4.31 below.

Number (Cycle)	Time: Joint 1(sec)		Time: Joint 2(sec)		Time: Joint 3(sec)	
CW	ACW	CW	ACW	CW	ACW	
1	3	2	3	2	3	
2	3	3	2	3	2	
3	3	2	2	3	2	
4	2	3	2	2	3	
5	2	3	3	3	3	
6	3	3	3	3	2	
7	2	3	3	3	2	
8	3	2	2	3	2	
9	2	3	2	2	2	
10	2	2	3	3	2	

To be sure that the design works actually, limitations notwithstanding, the controller was tested with the joints separately, in a 1-off situation, and they worked well without burning the ICs this time around. A few results were collected in this case, owing to limitation of time, and presented in Table 4.32 below:

Number (Cycle)	Time: Joint 1(sec)	Time: Joint 2 (sec)	Time: Joint 3(sec)
1	22	8	7
2	21	7	7
3	23	9	8
4	21	7	7
5	22	8	7

in the main, while these investigations are yet to be carried out, it may be trite to surmise here that the equipment performed presumably well in the presence of some teething problems (impediments) that did not allow for proper analysis to be carried out. However if these obstacles are removed, the robot can perform up to expectation.

4.3 Evaluation of the Reach/Work Envelope, Repeatability, Manipulability, and Accuracy

Aside the physical testing and evaluation, some mathematical analysis can also be performed to determine the viability/reliability of the robot. Some of these are undertaken in the proceeding subsections as follows:

1. Arm Reach/Work Envelope

From Equations 2.7 and 2.8 in Section 2.9.2, the arm-reach with respect to X and Y axis was given as:

Where:

a = length of the hand = 150mm (from specifications/measurements)

b = length of the arm = 150mm (=do=)

c = length of the end-effector = 170mm (=do=)

d = radius of the locus of Joint 2 with respect to the chosen x-axis = 70mm

(assuming the locus to be defined by the joint's x-distance from the base which holds it)

e = height of the same hand joint with respect to the chosen y-axis = 235mm

(assuming this height also to be defined by the Joint's y-distance from the base floor)

and A, B and C are the angles of orientation of the hand, arm, and end-effector respectively = 45 each.

Therefore:

Thus the workspace of this robot is an envelope/volume of 331.59mm x 497.49mm which is seen as adequate because the workspace of a similar Motoman robot within the *Robotworx* series lies between 700mm for 5kg payload and 2852mm for 129kg [1] while that of a standard STrobotics robot is 750mm 2kg payload [visit www.strobotics.com].

2. Repeatability and Manipulability

The repeatability of a robot was also given by Eqn. 2.6 in Section 2.9.1 and this is:

Now from our results of Table of 4.31, the standard deviation of mechanical error can be determined. Let x_i be equal to the individual readings, the mean reading = 2.45mm and N the total number of readings = 60; the std. dev. is given as:

This seen as satisfactory because according to Dr. Ghali [13] the repeatability of a universal robot lies between 1.25 and 2.00 m, and that of a standard 750mm 2kg payload robot by *STrobotics* 0.2mm.

3. Accuracy and Precision

From Section 2.9.1, also, the accuracy of work placement was given by

Where CR the 'Critical Resolution' and SR the 'Spatial Resolution' are given as:

Now for this application, the joint range = 4 and n the number of addressable joints = 3;

Therefore, These are seen as adequate because according to Groover [4], the acceptable precision of manipulative robots lies between 0.002 to 0.005 and 0.020 to 0.040 in real-time applications.

4.5 Evaluation of Project Viability/Reliability

From the preceding discussions, it may be seen that the project is viable and may be reliable if the bottle necks militating against the realization of optimal results are removed. The relevant indices that influenced this conclusion are summarized as follows:

- A good performance with programming and simulation tests using MPLAB and PROTUES.
- A mechanical performance of 2 seconds per cycle and 1kg payload like most other robots.
- The arm-reach or workspace envelope of 331.59mm x 497.49mm which is similar to those of most other robots.
- repeatability of 1.5mm which is also similar to most other robots'.
- The accuracy of (for one joint) and (for multiple joints) which are adequate, as well as the presumed 9000 pounds real-time investment and 1 year recoup period which are seemed as adequate.

4. Conclusions

The revolute pick-and-place robot has been designed and developed following the logical engineering methods and steps envisaged. From the findings of the literature review, the platform was set for the type of parts it was to be made up. These included mechanical components like arm links, base, end-effector and control components like electrical stepper motors, microcontroller, device driver circuit and enabling programming and simulation software. A detailed design analysis and specification for each of these composing units was undertaken in order to select the best for the application.

The components were used to build the robot according to design specifications. The emerging device was tested in both programme simulations and physical tests and evaluation and useful results were recorded. These were a work transfer time of 2secs per cycle and 1kg payload. Simulations and Mechanical testing gave fascinating results of compliance with design specifications and the expectations. However tests with the microcontroller could not give appreciable results due to some impediments including time constraints. Also the much desired integration with the overall FMS in a box project could not be carried out due to time limitations and the teething problems.

On the whole, however, the project is a worthy venture and should be explored to the latter. Given enough time, it could be made to work according to expectations and fulfil both the educational and industrial objectives as stated. Some recommendations for improving the project performance, namely in the areas of design review, incorporation of sensors, and integration with the FMS project are hereby itemised for optimal utilization of the objectives.

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