Design of a FPGA Controller for a Robotic Arm

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In this study, a three-joint robotic arm capable of capturing objects and a Field Programmable Gate Array (FPGA)-based open loop controller for the arm is designed.

The space coordinates are entered by means of a Liquid Crystal Display (LCD) and a keyboard

The rotation angles are determined by inverse kinematic transformation equations

A Very high speed Hardware Description Language (VHDL) programming language is used to develop the mentioned controller inside the FPGA.

The designed controller has been developed in a Xilinx-Spartan-3E FPGA board environment

There are some studies in the literature using FPGA boards in their robotic arm controller.

- An FPGA based five-axis robotic arm using DC motors is realized in reference [8].
- Cartesian-specific control of a three-axis robot manipulator using servo motors is implemented on an FPGA board [10].
- A single FPGA chip is used to embed a fully digital motion controller for a five-axis articulated robotic arm [7].

Introduction

- In this study an open loop position controller is designed for the three-joint robotic arm prototype.
- Controller generates the joint angles required for the actuators to move the robotic arm to the desired space coordinates.
- Generated joint angles by the controller are commanded to the actuators at the joints
- FPGAs are programmed using VHDL language unlike the traditional processors, and the VHDL codes are then converted to digital logic circuits [5] to perform the desired operations.

ARCHITECTURE OF PROPOSED SYSTEM

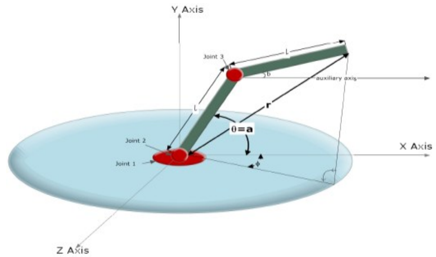

Figure1 Three-Dimensional Model of Three-Axis Robotic Arm

Three dimensional model of the system is shown Fig. 1. The system consists of three parts.

- Mechanical structure
- Software
- Driver circuits

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The Block Diagram of the Program of the System Written in VHDL

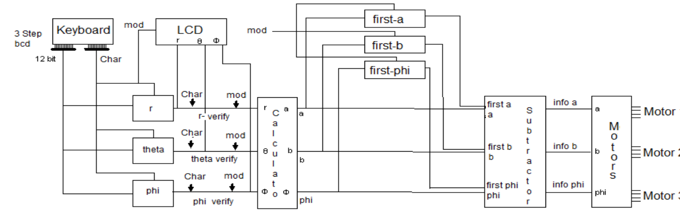

Figure 2 Block Diagram of System

Block Diagram Components;

- PS/2 Keybord input
- LCD interface
- Computation block
- Motor interface

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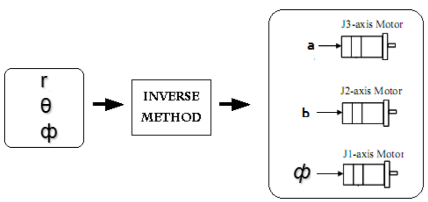

r, is the radius of the tip of the robotic arm from the center,
θ is the angle between the x axis and the tip of the robotic arm,
ϕ is the angle of rotation of the base with respect to x axis.

The a, b, ϕ parameters are in fact the rotation angles of individual motors in related joints.

$$a = \theta + \arcsin(r/2l)$$
$$b = \theta - \arcsin(r/2l)$$
$$\phi_{in} = \phi_{out}$$

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Figure 3: Prototype Robotic Arm

The parameter ‘l’ is lengths of both arms.

Four motors are used

Different driving techniques are used for different type of motors. Control is achieved from a keyboard and an LCD monitor.

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EXPERIMENTAL RESULTS

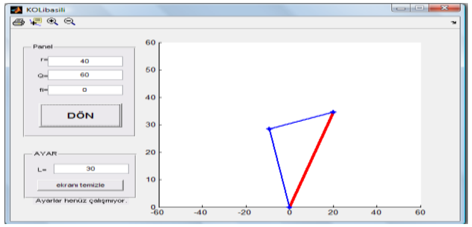


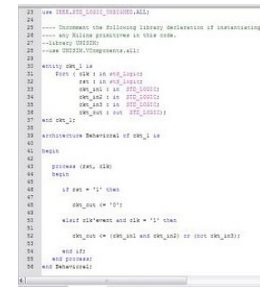
Figure 4: Simulation of Inverse Kinematic Equations

Inverse kinematic equations derived for mechanical modeling are verified by means of MATLAB

On the left hand side of the GUI screen, there are small windows where r, θ, ф and *l* data can be entered.

ARCHITECTURE OF PROPOSED SYSTEM

VHDL codes are written for the control of the motors on each joint of the robotic arm generating the digital control signals that determine the angles of motion for each motor for the desired position of the tip of the robotic arm.



An Example Simulation of the VHDL Code

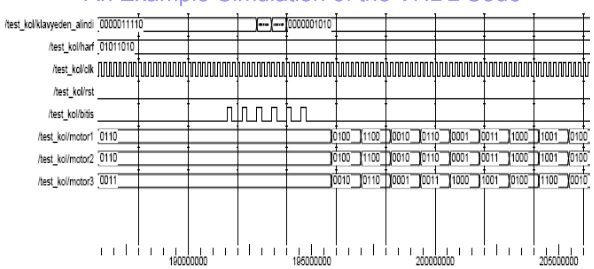


Figure 5 An Example Simulation of the VHDL Code

To cut short the simulation time, the keyboard and LCD interface modules are bypassed during the simulations.

In these simulations the last three row digital signals belongs to the step motor driving circuit logic.

CONCLUSIONS

- In this project, a robotic arm is designed that can reach every point within a semi-circle of radius 70 cm.
- The FPGA controller is programmed in VHDL language.
- Global coordinates of the target point is determined with the help of the keyboard and LCD.
- When the tip of the robotic arm reaches the target point, mechanical hand can capture or drop an object.
- FPGA would provide flexibility due to its re-programmability and parallel and fast data processing due to its internal programmable structure with its many I/O pins available.

Thank You For Your Attention…

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