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Stepper Motor Control Using Xilinx Spartan 3 FPGA

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ABSTRACT

In comparison with microcontrollers, FPGA uses very low power. The objective of the project is to drive a stepper motor by using a Spartan 3 FPGA kit. It also aims in using lesser power in driving the application for which the stepper motor is to be used. A Verilog HDL is written to drive the stepper motor according to the requirement of the application where the stepper motor could be used

KEY WORDS: Xilinx Spartan, FPGA, HDL.

1. INTRODUCTION

An Electrical device that causes movement is a motor. Among the various types Stepper motor accomplishes the rotary motion in Steps which are normally in equal space.

Magnetic field is formed as a result of interaction which is formed by coils present in the motor. The needed angle of rotation of motor's shaft is achieved by on and off mechanism of the inner coils (Weise, 1995; Damm, 1990, Nandha Kumar Thulasiraman, 2010).

Bidirectional operation of the motor is possible. Once the current is delivered to the inner coils the torque is present at the shaft at its rest position. This phenomenon is termed as holding torque. Due to its positioning accuracy this motor find its application in hard drives. Various other usage includes antenna rotators and in robotics.

FPGA is flexible than controllers. The main objective lies in operating the stepper motor using Xilinx Spartan-3 FPGA and to enhance this driving system by interfacing it with a Bluetooth module (Karthik, 2013; Jasmin, 2015).

FPGA is used as a logic sequence generator to produce digital pulses which are then converted to electrical pulses. These electrical pulses are given as an input to the stepper motor. The rotor shaft of a stepper motor rotates by a single step on application of the pulse input (Philomina, 2014; Karthik, 2014; Saravanan, 2014).

Existing System: Control System is digitized due to the emerging development in branches like power electronics, microprocessors and microcontrollers. The essential feature of robotics is to attain the accurate position system which in turn is accomplished by stepper motor. The role of stepper motor is pivotal in robotics. The usual method of controlling the stepper motor relies on issuing the command by using computer or by the usage of processors (Vijayaragavan, 2014; Gopalakrishnan, 2014; Saravanan, 2014).

Also the steper motor can be brought to control by means of programming logic control. The controlling logic is achieved with the help of timers. Digitization is another way to build a control circuit which is expected to gain speed and accuracy. Remodifying the circuit is quite difficult in this type of design (Karthik, 2013; Kanniga, 2011, 2014).

Proposed System: Field programmable gate array (FPGA) is mainly employed for improved speed of operation and also to achieve verification quickly. Flexibility and configurability are the prominent features on Systems that adapts FPGA concepts. The data which is downloaded will be of string type and it is taken as a configurable data by the chip. This data defines the accurate cell design in terms of its functional attribute and sketches the topology of the system.

Usually there are two methods to deploy the design in the FPGA system.one method is by means of schematic capture and the other method is by means of programming by the hardware description languages. This project is based on the programming method to achieve the implementation of rotator stepper motor.

Explanation of The Driver in Stepper Motor: The driver proposed uses logical sequence generated by the Xilinx Spartan-3 FPGA. . The block diagram that explains the working of the stepper motor driving system is given in Fig.1.

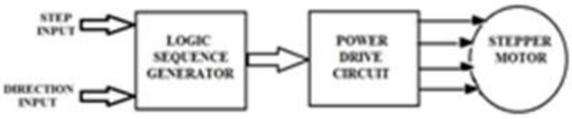

Figure.1. Stepper Motor Driver using FPGA

The step input and direction inputs are applied to the logical sequence generator. The Generated logical pulses are applied to the Power drive circuit. The current pulses from the power drive circuit are applied to the stepper motor. The stepper motor rotates by a single step on application of the pulse

Power Drive Circuit and Stepper Motor

- Power drive circuits are semiconductor switching circuits.
- Current is raised at greater speeds to turn on the step in the phase windings.
- Input is applied as an energized form to the stator windings.
- Angular rotation is obtained as an output.

Logic Sequence Generator

- The logical sequence is framed by means of coding.
- Rotation is obtained by the correct sequencing of discrete pulses to achieve increment in steps.
- The Verilog coding is loaded into Spartan 3 FPGA.
- Spartan 3 FPGA is flexible
- Power drive circuits are semiconductor switching circuits.

Theory of Operation: Rotary behavior of the stepper motor depends on the incoming input pulses. The order in which the input pulses are applied has a direct impact on the movement of motor shaft. The needed angle of rotation of motor's shaft is achieved by on and off mechanism of the inner coils.

In order to operate the stepper motor, is achieved easily by on and off mechanism of the inner coils.

Driver transistors are responsible for excitation of the windings. Rotating the motor at its rated step size, mainly in high speed condition due to natural resonant frequencies of the motor, results in less smooth movement or in some cases leads to halt movement.

Micro stepping is a procedure used to smooth the motor's movement between full steps, solve resonant problems in high speed uses, and increase the step resolution of the motor. Micro stepping also develops the efficiency of the system, since the current in the windings of the motor is handled in a controlled routine rather than being turned on and off sharply.

Two main advantages of this outline have been well reported in the literature such as reduction of resonance behavior and smooth drive with very low ripple torque. A micro stepping procedure known as high torque micro stepping consecutively alternates the current in the two windings of a stepper motor.

Hardware Configuration: The overall driver circuit shown in Figure 8 is realized using a Xilinx Spartan3 (XC3S400 Core) FPGA development board operating at 50 [Mhz] system clock. The switching frequency was set at 40 [Khz]. Furthermore this is the frequency of overall algorithms which are implemented. Besides, measured currents are sampled at this frequency using the AD578 12-bit ADC outside of the development board. Due to the structure of H-bridge circuit, the FPGA software is designed to generate 1 [us] of the dead time for upper and lower switching device pairs to avoid short circuit in switching process.

Our two-phase stepper motor is rated at 2A and 1.8º step angle. Xilinx-ISE software is used as an FPGA development and debugging tool. We had designed and fabricated a linear motion system that attached to the stepper motor. The structure of the linear motion system in CAD environment. This motion system will travel 4mm in forward/backward direction in each stepper motor clockwise/counterclockwise full revolution.

The proposed methodology contains stepper motor and an attached load to its rotor which is a linear motion system (4 [mm] travel per motor full revolution). The implementation is made on FPGA chip (XC3S400-PQ208) and sampling is also done for feedback signals. The sampling frequency of the driver current controller is 40 [KHz], also the PWM switching frequency is 40 [KHz], the supply voltage is 24 [V], each phase inductance is 4.3 [mH], and the phase resistance is 5 [**Ω**]. The input clock frequency of the FPGA board is 50 [MHz].

Functional block diagram:

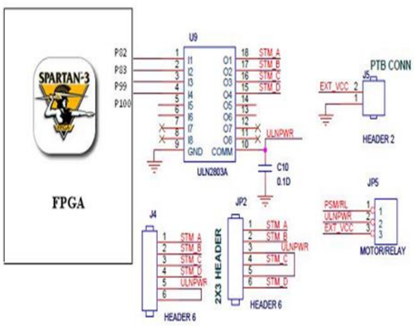

Figure.2. ULN2803A interfaced with spartan-3 FPGA to drive a stepper motor

Algorithm for Generating Logical Sequence

Step 1: Start the Program

Step 2: Initialize clock, start and direction inputs.

Step 3: If the start input is 1 continue to execute the program, else exit.

Step 4: At positive edge of clock initialize the loop m<=m+1.
Step 5: If direction input is high select the step inputs for clockwise rotation using case statement
Step 6: The value of m is modified when positive transition of clock signal is attained
Step 7: The value of m changes at each rising edge of the clock signal.
Step 8: Different step inputs are applied based on the four different combinations of m.
Step 9: Stop the program.

2. SIMULATION RESULTS

Clockwise Rotation

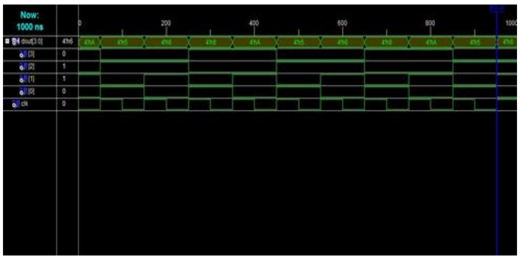

Figure.3. Clockwise Rotation

Counter Clockwise Rotation

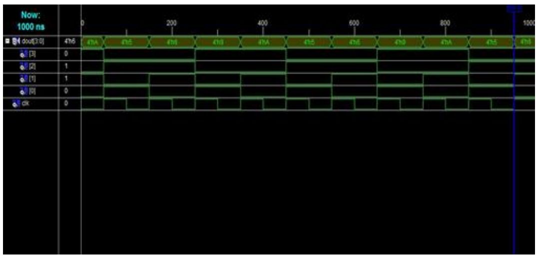

Figure.4. Counter Clockwise Rotation

3. CONCLUSION

Thus the project is used for reducing the power required for driving a stepper motor and to explore the possible usage of FPGA in electrical applications. Since FPGA is highly flexible it can be used in environments where frequent replacement of driver needs is necessary.

Future Enhancements: The system is enhanced by multiplexing principle which is accomplished by serial chain of various devices. Scalability is achieved by this. Two types of techniques namely wired and wireless can be used. This method functions by wired methodology but it is also compatible with wireless techniques.

The current module can interface the robot, bulb and the motor and can control the modules by switch on and off and control the direction of movement of the robot.

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