A Zigbee based wireless reconfigurable Stepper motor controller using FPGA

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***Abstract*--This paper proposes a wireless stepper motor controller designed using Very High Speed Integrated Circuit Hardware Description Language (VHDL) and is implemented on DE0 Altera Field Programmable Gate Array (FPGA). The proposed controller uses the Pulse-Width Modulation (PWM) technique to rotate the motor through the desired angle, speed and direction. Using the proposed controller it is possible to rotate the stepper motor precisely. In addition, the motor has been operated with a speed ranging from 5.625º per second to 20º per second in either clockwise or anticlockwise direction. Features such as manual rotation, to rotate the motor in directional mode, to pause the rotation, to execute the rotation with varying speed at desired region, return-to-zero, and zero position detection have been incorporated in the design. This proposed controller has been designed to operate wirelessly using Zigbee transreceiver module. More over the complete controller can be redesigned and realized in hardware rapidly. Thus, it is easily possible to customize the controller for any industrial applications. In addition, the architecture can be expanded to control more than one motor at one time by addressing technique.**

***Keywords*—Field Programmable Gate Arrays (FPGA), Stepper Motor, Motion Control, Wireless reconfigurable Motor Controller, Zigbee transreceiver module.**

I. INTRODUCTION

Stepper motor is a brushless, open-looped electromechanical device, which can rotate, in a small resolution of angle [1]. It is highly effective in motion control application for high precision and high performance of torque control. Instead, it is low cost, simple and offers better torque performance over wider speed ranges [1]. Stepper motor are used in wide range of precise motion and measurement applications such as nuclear power plant, aeronautics, robotic, automotive, medical, manufacturing industry etc. An ideal example is the pick and place machines used in Surface Mount Technology (SMT) line [1]. Besides, stepper motor is also applied remotely in hazardous and extreme environment such as volcanic region, atomic or chemical plant, narrow spaces such as in a collapsed building or underground, mountain region and robotic application such as flying robot. In such applications a wireless controller with precise controlling features are highly desirable, this project presents one such controllers that is designed using Very High Speed Hardware Description Language (VHDL) and is implemented on Field Programmable Gate Array (FPGA).The system architecture of the controller is shown in Figure1. A friendly Graphical User Interface (GUI) is designed which serves as the control interface to the stepper motor controller.

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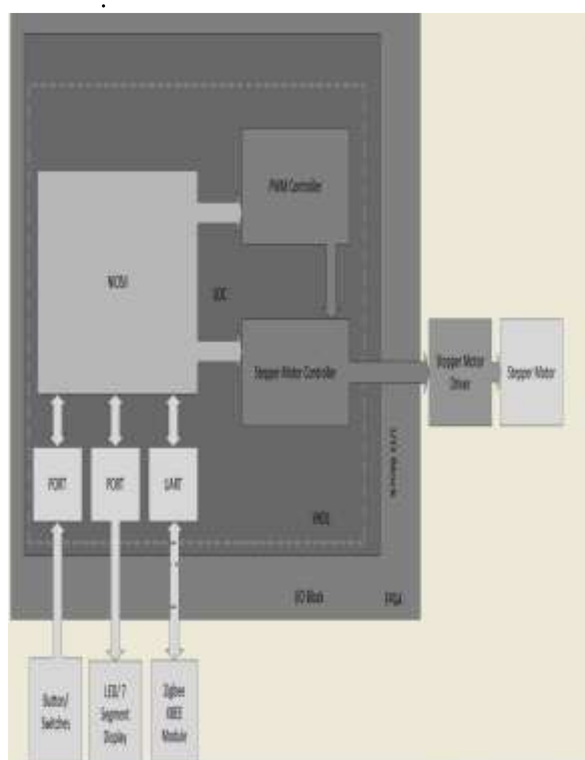

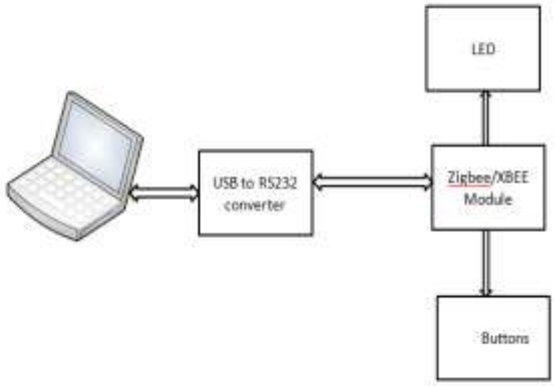

Remote Interface

Figure 1. *System Architecture*

The principle of this proposed system is to control angular displacement at the particular resolution, angular speed ranged from 5.625º per second to 20º per second in either clockwise or anticlockwise direction of the stepper motor using Pulse-Width Modulation (PWM) technique. Features such as rapid response of 10 ms, manual rotation, to rotate the motor in directional mode, to pause the rotation, to execute the rotation with varying speed at desired region (multiple operations), return-to-zero, zero position detection and remote controlling feature are cooperated into this design.

The rest of the paper is organized as follows. In the session 2, previous work is discussed. The session 3, describes the stepper model adopted for this work. In session 4, the VHDL design of the stepper motor controller is discussed. Session 5 discusses the result of the proposed system. Session 6 concludes the paper.

II. PREVIOUS WORK

[1], [2] & [3] provides basic information about stepper motor and its applications. Stepper motor controllers implemented using integrated circuit presented in [4] & [5] uses PIC microcontrollers, 80C196MC and AT89C51 introduced by Intel and Atmel as the design unit. These models use three phase waveform generator to generate PWM signal. However they are customized for certain application only. An open-loop stepper motor driver based on FPGA implementation is presented at [6]. The paper proposes to adjust the duty cycle of the current and voltage inputted into each phase of the motor with an Analogue to Digital Converter (ADC) and sampling regularly for precise positioning purpose. This design involves a numbers of discrete components which are H-bridge circuit, amplifier, anti-aliasing filter and ADC. A two phase stepper motor driver based on FPGA implementation is presented at [7]. The paper proposes to adjust current in each winding of the stepper motor with built-in sine/cosine look-up table in FPGA to improve accuracy in terms of speed and angle of the motion control. Feedback mechanism is integrated and hence it offers accurate positioning. A Novel stepper motor controller based on FPGA hardware implementation is presented at [8]. The paper proposes to use velocity profile generator to calculate the index pulses through a time lagging sequence generation algorithm. LogiBricks has introduced a stepper motor controller implemented in FPGA [9]. It uses DSP module to control angular speed and angular displacement of the motor precisely.

While in this paper, a cost effective wireless reconfigurable controller that uses PWM technique to generate desired signals to control the driver of the motor can be proposed. The PWM technique can be easily achieved with simple algorithm by manipulating system clock that generates signals necessary to precisely control the speed of the motor and to precisely position the motor. The input parameters for the controller are transmitted from a remote system (computer) wirelessly with a data rate of 250kbs Using ZIGBEE Transreceiver module. In addition, the real time status of the motor are transmitted wirelessly to the remote system for monitoring purpose. It has been practically realized that the remote system successfully operates even for a distance that is 70meters apart from the controller. The features such as manual rotation, to rotate the motor in directional and oscillation mode, to pause the rotation, to execute the rotation with varying speed at desired region (multiple operations), return-to-zero, zero position detection and remote controlling feature are cooperated into this design. The whole system is relatively simple, easy to design and low cost. Any changes to the system can be incorporated to the design and realized in hardware rapidly. Thus, the system can be easily customized to many industrial applications without much hassle.

III. STEPPER MOTOR MODEL

The unit model used in this paper is BYJ48-12 manufactured by Dongguan Yuhong Micromotor Co., Ltd. and it consists of two parts, which are motor unit and driver unit. The driver unit is connected between the proposed controller and the motor unit using the available input/output signal connector. It is incorporated with features such as overheat protection, excitation timing indication, manual rotation, current adjustment and step angle setting. There are several advantages like Small measurement, Long Lifespan, High torque, Low noise, Stable speed, High efficiency, Low vibration, Lead out by wire or terminal are both available in this unit model. Besides the controlling algorithm of this driver unit is relatively simple such that it depends on the input electrical pulse only as shown in figure2 [15]. The angular displacement of the motor is depending on the numbers of pulses inputted from PLS input whereas its direction of the motor's movement is depending on DIR input. The number of input electrical pulses is directly proportional to the angular displacement whereas the pulse's width determines the angular speed of the stepper motor. As shown in figure2 when the DIR input is held at logic '1' ('0'), the motor rotate in clockwise direction (anti clockwise direction). In addition, the angular displacement of the motor is depending on the number of pulses observed at the PLS input. The number of pulses is proportional to the angular displacement of the motor. Thus by controlling the pulse width and number of the pulses it is possible to achieve the desired angle of rotation. The next chapter explains the controller design.

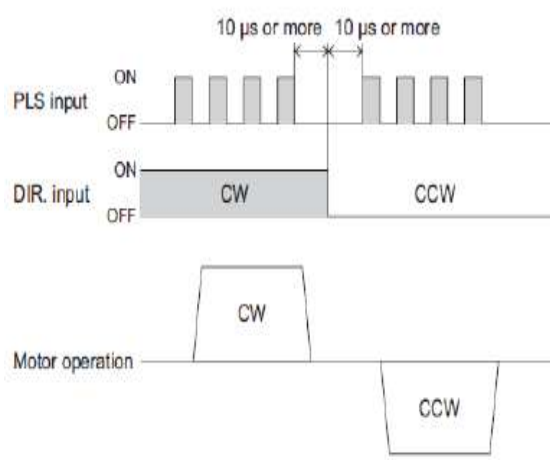

Figure 2. *Controller waveform*

IV. VHDL DESIGN OF THE SYSTEM

The stepper motor controller consists of signal translator, O/P logic, PWM controller, Motor driver. Configurable parameters such as angular displacement, angular speed, direction etc are initially setup in the workstation via the GUI. This information will be transmitted to NIOS-II processor wirelessly at the frequency of 2.5GHZ using Zigbee transreceiver module. Then these parameters are passing to the stepper motor controller and PWM controller. Output of signal translator and PWM controller gives to output logic. Then the output of output logic is given to stepper motor through motor driver. The Stepper motor controller and PWM controller designed using VHDL and implemented on DE0 ALTERA FPGA chip. To control more than one stepper motor we can replicate the stepper motor controller and PWM controller in the same FPGA chip.

Using the Nios II hardware reference designs included in an Altera development kit, you can prototype an application running on a board before building a custom hardware platform. If the prototype system adequately meets design requirements using an Altera-provided reference design, you can copy the reference design and use it without modification in the final hardware platform [5]. Otherwise, you can customize the Nios II processor system until it meets cost or performance requirements. Altera FPGAs provide flexibility to add features and enhance performance of the Nios II processor system [5]. Programming of NIOS-II processor using c language to Communicate with Zigbee model, to Control pulse width in PWM controller and to Control stepping sequence of stepping motor. NIOS-II processor program in such a way that it will accept the data used for controlling stepper motor like speed, direction, step angle from Zig-bee receiver then transmit this data to PWM controller and stepper motor controller. Then data transmitted to stepper motor driver to control stepper motor. In addition, the architecture can be expanded to control more than one motor at one time by addressing technique.

Duration of the pulse width according to the desired speed of the motor entered in GUI based on the formula

$$\text{Speed pulse limit} = \frac{\text{step angle x system clock freq.}}{\text{Speed in degrees per second}}$$

For an example, the duration of the pulse width to rotate the motor at a speed to 5 º per second is determined as following

$$\text{Duration of pulse width} = \frac{10 \text{ x}50 \text{ x}10\text{^}6}{5} = 2\mu s$$

Thus by generating required pulse width in VHDL it is possible to rotate the motor with different speeds.

The number of pulses determines the angular Displacement and it is calculated using the following formula

$$\text{Number of pulses} = \frac{\text{Desired angular displacement}}{\text{Step angle}}$$

Thus the desired angular displacement entered by the user, the number of pulses is determined.

V. GRAPHICAL USER INTERFACE

Figure 3. *GUI*

A GUI is designed using Visual Basic language specifically for this stepper motor controller as shown in Figure 3.As from the figure3, the panel on the left is used to initialize the setting of the data rate and Zigbee module setting for the wireless transmission. The middle panel shows button to control stepper motor. The right panel shows status of connectivity. Through this panel input parameters like step angle, half/full stepping mode, deviations per seconds, polarity of motor are sent to NIOS-II processor using Zigbee transreceiver module. Multiple operations can be inputted via this panel. The LEDs at the bottom are used to indicate connectivity and status of the stepper motor

VI. RESULTS

Simulation Results

The VHDL design for the stepper motor controller and PWM controller is simulated on the DE0 ALTERA FPGA using Quartus-II. For simulation purpose, the step angle is adjusted to 5.625°. The stimulation shows that the precise calibration in angular speed and angular displacement is achieved. To rotate for angular displacement for 20°, the controller generates only four pulses.

Experimental Results

The VHDL design of the controller is implemented on the DE0 ALTERA FPGA. The test results show that the desired angle of rotation with desired speed of rotation is successfully achieved with a latent time of 10ms. The step angle is verified by accumulating the number of pulses that amount to 5.625° of rotation. The other silent features such as manual rotation, to rotate the motor in directional, to pause the rotation, to execute the rotation with varying speed at desired region, return-to-zero, zero position detection are also successfully working. On testing, the controller is able to communicate wirelessly with the GUI system for a distance of 70m.

VII. CONCLUSION

Thus, this paper describes a stepper motor controller designed using VHDL and implemented in FPGA. The system is capable of controlling the stepper motor in terms of various speeds between 5.625° and 20°. In addition, features such as manual rotation, to rotate the motor in directional mode, to pause the rotation, to execute the rotation with varying speed at desired region, return-to-zero, and zero position detection have been incorporated in the design.

This proposed controller successfully operates wirelessly with a distance of 70 meters between the controller and the GUI system. More over any change to the controller can be incorporated to the design and realized in hardware rapidly. Thus, it is easily possible to customize the controller for any industrial applications. Comparing to other technology, the proposed controller is relatively simple, low cost and can be reprogrammable. In addition, the architecture has been expanded to control more than one motor at one time by addressing technique.

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