Abstract
Stepper motor is used in broad application for speed and position control. In this paper the speed profile of stepper motor is analyzed based on Field Programmable Gate Implementation (FPGA). As a speed moving motor it must have rising and falling process which includes missing steps by steps. FPGA gives the different control method for controlling the speed of stepper motor to avoid missing steps. The system based on FPGA has good interfacing thus we can interface more than one stepper motors for further application.

Keywords: Stepper Motor, Speed profile, FPGA,

1. INTRODUCTION
Stepper motor is a digital electromechanical motor which works on the digital input pulses. The advancement in the stepper motor controller is in great demand that is equipped with rich functionality physical size which is more suitable to embed into different system [1]. Due to this advancement such as Simple Programmable Logic Device (SPLD), Complex Programmable Logic Device (CPLD), Field Programmable Gate Array (FPGA), and System On Programmable Chip (SOPC) with wide-spread demand for researcher to develop stepper motor control.

The important criteria of stepper motor is precise positioning, besides precise positioning, stepper motor can also be designed with time constraints, in application which require the controlled object to be positioned at a particular location at a particular instance of time. Stepper motors are widely used in various applications. They can be found in printers, disk drives, X-Y plotters, wedges and jaws in medical accelerators and automobile industry and many others which are required to move controlled objects to accurate positions within nominated time [2]. The most important criteria for stepper motor are the speed and position control depending upon the certain application. Since the frequency of the digital input pulses control the speed of stepper motor, the motor can be rotated at a rated speed matching the requirement of the user. The important features of stepper motor includes it is digital electromechanical motor and hence can be easily interfaced with the electronic circuits which added the advantage of noise tolerance and accuracy to measure. Figure 1 shows the basic block diagram for stepper motor control. It consists of the controller, driver and stepper motor. The controller consist of two most important control i.e. position and speed. They can be categorized base on the velocity profiles, S-curve, linear, and parabolic profiles. For high precision positioning situation, the velocity profile provided by the controller is needed to move controlled object thus to reduce the effect of moment of inertia.

2. SPEED CONTROL ANALYSIS
The speed for a reactive motor is given by the formula [3]

\[ v = \frac{\theta \times f}{360} \]

Where \( f \): pulse frequency, \( \theta \): step angle.

The pulse frequency changes due to fluctuations in the environmental conditions. Thus a fixed number of step-by-step operations are done in every week so that the step error will not accumulate and change the pulse frequency. In actual position of stepper motor control, we must inevitably face the issue of speed. To avoid the lost step phenomenon the general requirement for the highest operating frequency should be less than (or equal) stepper motor in response to the frequency \( f \). This is the operating frequency in which stepper motor can start, stop or reverse rather than out of step
phenomenon. The speed profile can be categorized as S-curve, parabolic and linear. For high precision positioning situation, the velocity profile to move the object by the controller to its accurate position, when speed and time are into consideration, the profile of line and/or S-curve are adopted; to alleviate the effect of moment of inertia, the parabolic and/or linear are most commonly used [4].

![Figure 2 Velocity modes: parabolic, trapezoidal, and S-curve from left to right respectively](image)

The velocity profile of stepper motor has three broad categories: parabolic, trapezoidal, and S-curve as shown in Figure 2. Stepper motors have decreased torque outputs at increased speed and hence it is very important to understand how the controller and the associated electronics can handle the acceleration and deceleration. Position and machining application often deal with changes in velocity and direction. Since stepper motors can stall under dynamic shock, it is important to have a smooth velocity profile [5]. Parabolic Mode has a linearly varying acceleration and velocity which has parabolic shape. Varying acceleration linearly helps in speeding up the motor faster and also avoids dynamic shock to the motor. Trapezoidal Mode is widely used in application which uses slow increase of speed with constant acceleration. The acceleration is constant and the speed varies linearly with time. While decelerating the speed linearly decreases and the motor come to a halt. S-curve Mode has the speed gradually increasing and since the torque is a decreasing function of speed it helps the motor to slowly achieve that torque required. This type of mechanism helps in having smooth transition from start to speed up and vice versa which in turns improve the service life of the electrical and the mechanical systems. Operating performance of S-curve mechanism is also high. A new velocity approach to make use of the velocity profile is discuss in the paper

$$f_{m+1} = \beta \left( \frac{f_m - f_{min}}{2} \right) + f_{min}$$

Where $$f_{m}$$ is the frequency corresponding timing $$t_m$$

$$f_{max}$$ Is the frequency corresponding timing $$f_{max}$$

$$f_{min}$$ Corresponds to minimum frequency rate

$$\beta$$ is the control parameter defined for different velocity profile

1<$$\beta$$<2, parabolic

$$\beta$$ =1, Trapezoidal

0$$\beta$$<1, S-curve

There is a linear relation between $$f_{m+1}$$ and $$\beta$$

3. FPGA BASED CONTROL SYSTEM

A Field Programmable Gate array is a digital integrated circuit that can be programmed to do any type of digital function. There are two main advantages of an FPGA over a microprocessor chip for controller:

An FPGA has the ability to operate faster than a microprocessor chip.

The new FPGAs that are on the market will support hardware that is upwards of one million gates.

FPGAs are programmed using support software and a download cable connected to a computer. Once they are programmed, they can be disconnected from the computer and will retain their functionality until the power is removed from the chip [6]. Figure 4 shows the digital logic technology.

![Figure 4: Digital logic Technology.](image)
The stepper motor and the driver selected for the designing is by PARKER AUTOMATION is LV 341 and driver used is E-DC driver [7]. There are many advantage of using stepper motor it provide accurate positioning, it has excellent response to start, stop and reverse and it has wide speed range. The absolute encoder gives the feedback about current position of load and to ensure the proper functioning of the system to analyze the different speed profile of stepper motor.

4. RESULT AND DISCUSSION
To analyze the performance of this system, the algorithm was implemented on SPARTAN 3AN. The device can provide the clock rate up to 50MHz. the stepper motor used in the system is by PARKER AUTOMATION and the setting of step is kept at 1000 step/rev. The implementation of proposed velocity profile generator is built on a FPGA based system. The encoder and the position sensor output help to move the stepper motor. By taking feedback from the encoder and position sensor we develop double feedback system for this medical instrument for secure operation of this device. $f_{occ}$ is kept as 100 KHz for controlling the speed profile. $f_{occ}$ is varied from 100 KHz to 2MHz and hence the $\theta$ value varies from 0 to 2. Thus it can operate in the three different speed profile the control parameter $\theta$ varies from 0 to 0.7368 that is it lies in S-Curve region frequency varying from 100 KHz to 800 KHz; for trapezoidal $\theta =1$ and $\theta$ lies between 1.157 to 2 for the frequency range of 1.2MHz to 2MHz. 

The Figure 6 shows the RTL schematic and Figure 7, 8, 9 shows simulation results of the VHDL code for S-curve, trapezoidal, parabolic. The VHDL code was written and simulated in XILINX ISE 14.6.

![Figure 6: RTL schematic](image)

![Figure 7: Result for the S-curve based on FPGA](image)

![Figure 8: Result for the trapezoidal based on FPGA](image)
5. CONCLUSION
The result verified to generate various speed profiles based on FPGA implementation. Calculation and simulation were conducted to generate the various speed profile of stepper motor. Due to the system architecture, one FPGA can drive more than one motor without increasing the processing time. The algorithm implemented on FPGA allows a substantial decrease of the equivalent processing time develop by different velocity controller.

References
[1] Benjamin C kuo, Theory and application of step motor, west publishing ,1974