VHDL Implementation of PID Controller on FPGA- A Review

Pradeep Singh Shekhawat[1], Mr. Rakesh Kumar[2]
[2] Assistant Professor
[1, 2] Sobhasaria Group of Institutions, Sikar Rajasthan

Abstract- *PID stands for proportional, integral derivative. It is commonly employed in process control industries for controlling various process variables such as pressure, temperature, level, flow etc It is a feedback controller to generate an output that causes some corrective effort to be applied to a process to derive a measureable process variable towards a desired value known as the set point. The techniques to be adopted for determining the proportional, integral and derivative constants of the controller depends upon the dynamic response of the plant .*

The various elements used in PID controller are set point, Plant, sensor, error signal. Plant is the physical heating and cooling part of the system. Set point is the process variable which is to be controlled .Error signal is the difference between the response of the plant and the desired response (set point). Sensor senses the variable within the plant. Controller can be tuned using various methods. One of the methods is using Zigler Nichols method.

IN FPGA based temperature control. Initially, the digital design (block diagram) will be drafted showing the basic functioning of the hardware in terms of the blocks. This will then be coded in a hardware description language (VHDL). The functioning of the coded design is to be simulated on a simulation software (e.g. ISim). After proper simulation, the design is to be synthesized and then translated to a structural architecture in terms of the components on the target FPGA device (Spartan 3s200ft256) and the perform the post-translate simulation in order to ensure the proper functioning of the design after translation. After the successful simulation of the post-translate model the design is mapped to the existing slices of the FPGA and the post-map model simulated. The post-map model doesn't include the routing delays. After the successful completion of the post-map simulation, the design is then routed and a post-route simulation model with the appropriate routing delays is generated to be simulated on the HDL simulator. After this a programming file is generated to program the FPGA device. The objective is to run the programmed FPGA at a frequency as high as possible. The working of the device is to be demonstrated by making an appropriate testing hardware.

I. INTRODUCTION

PID stands for proportional, integral derivative. It is commonly employed in process control industries for controlling various process variables such as pressure, temperature, level, flow etc. It is a feedback controller to generate an output that causes some corrective effort to be applied to a process to derive a measureable process variable towards a desired value known as the set point. The techniques to be adopted for determining the proportional, integral and derivative constants of the controller depend upon the dynamic response of the plant.

The various elements used in PID controller are set point, Plant, sensor, error signal. Plant is the physical heating and cooling part of the system. Set point is the process variable which is to be controlled .Error signal is the difference between the response of the plant and the desired response (set point). Sensor senses the variable within the plant. Controller can be tuned using various methods. One of the methods is using Zigler Nichols method. It is first assumed that controller has only proportional gain term; we then proceed to determine the critical gain for the closed loop system to just get continuous oscillations. The corresponding period of oscillation is determined, knowing these two values; the PID controller can be tuned. Comparator compares the set temperature value and output response value and generate an error .Depending upon this error controller will adjust the vale of proportional gain, derivative gain and integral gain to generate an output signal using an mathematical equation which is applied to the plant.

PID controllers are process controllers with the following characteristics:

- Continuous process control
- Analog input (also known as "measurement" or "Process Variable" or "PV")
- Analog output (referred to simply as "output")
- Setpoint (SP)
- Proportional (P), Integral (I), and / or Derivative (D) constants

II. OBJECTIVE AND FEATURES OF PID CONTROLLER

The objective of the thesis work is to design PID controller for temperature control using FPGA.

IN FPGA based temperature control. Initially, the digital design (block diagram) will be drafted showing the basic functioning of the hardware in terms of the blocks. This will then be coded in a hardware description language (VHDL). The functioning of the coded design is to be simulated on a simulation software (e.g. ISim). After proper simulation, the design is to be synthesized and then translated to a structural architecture in terms of the components on the target FPGA device (Spartan 3s200ft256) and the perform the post-translate simulation in order to ensure the proper functioning of the design after translation. After the successful simulation of the post-translate model the design is mapped to the existing slices of the FPGA and the post-map model simulated. The post-map model doesn't include the routing delays. After the successful completion of the post-map simulation, the design is then routed and a post-route simulation model with the appropriate routing delays is generated to be simulated on the HDL simulator. After this a programming file is generated to program the FPGA device. The objective is to run the programmed FPGA at a frequency as high as possible. The working of the device is to be demonstrated by making an appropriate testing hardware.

Features:

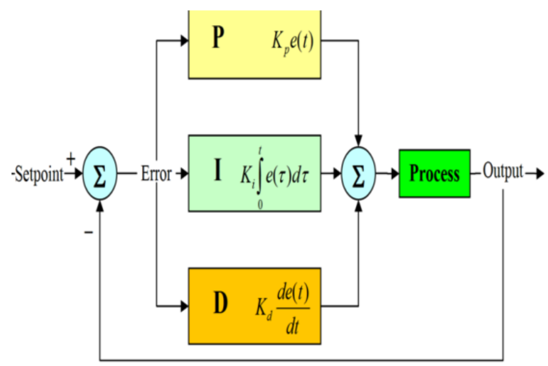
The features of the PID controller which is to be implemented are finalized as specified below:

- PID will control the temperature from ambient to 100 ^{0}C
- We can control the temperature with an accuracy of less than± 1^{0}C
- Cycle time is between 1 second to 66 minutes
- The operation is on the 50 MHZ clock rate

III. PID CONTROLLER

History & Architectures:

- The proportional integral derivative (PID) controllers have been the most commonly used controllers in process industries for over 50 years even though significant development has been made in advanced control theory. According to survey conducted by Japan electric measuring instrument manufacturer association in 1989. 90% of the control loops in industries are of the PID type. These useful functions are sufficient for large number of process applications and the transparency of features lead to the wide acceptance of the users. A strength of the PID controller is that it also deals with the important practical issues such as actuator saturation and integrator windup.PID controllers performs well for a wide class of processes and they give robust performance for a wide range of operating conditions and they are easy to implement using analog and digital hardware. Moreover due to process uncertainties a more sophisticated control scheme is not necessarily more efficient than a well tuned PID controller
- A large industrial process may have hundreds of PID controllers. Proper tuning of the controllers is crucial for achieving the desired response characteristics. They have to be tuned individually to match the process dynamics in order to provide good and robust control performance. The tuning procedure if done manually is very time consuming; the resultant system performance mainly depends upon the experience and process knowledge of the engineers. It is recognized that in practice many industrial control loops are poorly tuned. However with the advent of the auto tuning of PID controller concept, this problem has been solved to the considerable extent.
- .Automatic tuning technique thus draws more and more attention of the researchers and practicing engineers. By automatic tuning we mean a method which enables the controller to be tuned automatically on demand from a operator or external signal. Typically, the user will either push a button or send a command to the controller. Industrial experience has clearly indicated that this is highly desirable and useful feature.



Action of PID controller. [12]

- The main elements used in PID controller are set point, plant, sensor, error signal.

- **Plant**:- The physical heating and cooling parts of the system. Depending upon the output error of the PID controller, heater will be on or off.

- **Sensor**:-The device that measures the variables within the plant. Sensor will sense the temperature of the heater.
- **Set Point**:-Set point is the fixed value of temperature that we want to control. Depending upon the analog value of temperature ADC will control this temperature into digital format.
- **Error Signal**:-This is the difference between the response of the plant and the desired response (set point).This error signal generated will be applied to the PID calculation block.Depending upon the value of the error PID calculation block will take decision.
- **Disturbances**:-These are the unwanted inputs to the plant ,which can be common.The disturbance would be an open entry door allowing aguest of cold air to blow in, guickly droping the temperature and causing the heat to come on.
- **Controller** :-This is the most significant element of the control system.The controller is responsible for several tasks.It measures the signal of the plant sensor, processes the signal and then drives an error based on the signal measurement and the set point.Once the sensor data has been collected and processed, the result must be used to find PID values, which then must be sent out to the Plant for error correction.

<u>Tuning of PID controller</u>:

- Tuning" a control loop is the adjustment of its control parameters (gain/proportional band, integral gain/reset, derivative gain/rate) to the optimum values for the desired control response. The optimum behavior on a process change or setpoint change varies depending on the application. Some processes must not allow an overshoot of the process variable from the setpoint. Other processes must minimize the energy expended in reaching a new setpoint. Generally stability of response is required and the process must not oscillate for any combination of process conditions and setpoints. Tuning of loops is made more complicated by the response time of the process; it may take minutes or hours for a setpoint change to produce a stable effect. Some processes have a degree of non-linearity and so parameters that work well at full-load conditions don't work when the process is starting up from no-load. This section describes some traditional manual methods for loop tuning.

IV. XILINX ISE DESIGN SUITE

History

- In this modern era, **Xilinx ISE** (**I**ntegrated **S**yndissertation **E**nvironment) is a very imperative software tool created by **Xilinx** which provides various functions such as for blend and scrutiny of HDL designs, helps in permitting the designer to synthesize their designs, perform timing analysis, examine RTL diagrams, simulate a design's reaction to diverse stimuli and also establish the objective method with the programmer. **Xilinx** is a technology developed by an American company, mainly a purveyor of programmable logic devices. This technology is also known for originating the field programmable gate array (FPGA) and be the first semiconductor company with a fables built-up model.
- In 1984, Silicon Valley is one of the company which is headquartered in San Jose, California to establish this technology, with additional offices in Longmont, Colorado; Dublin, Ireland; Singapore; Hyderabad, India; Beijing, China; Shanghai, China; Brisbane, Australia and Tokyo, Japan. The one of the foremost FPGA product
- families includes Virtex (high-performance), Kintex (mid-range) and Artix (low-cost), and the retired Spartan (low-cost) series and it also includes chief computer software such as Xilinx ISE and Vivado Design Suite[30][33].

V. CONCLUSION

A VHDL model is developed for controlling the temperature of the bulb. Although Temperature controller system has been developed in this work, but more features can be added to increase its utility. There are several modifications, both to the hardware and software which may improve the system performance. The present-day structure of PID controllers is quite different from the original analog PID controllers. Now the implementation of the PID is based on digital design, these digital PIDs include many algorithms such as anti-wind-up, auto-tuning, adaptive, and fuzzy fine tuning to improve their performances, but the basic actions remain the same.

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