

Design and Synthesis of PLC on FPGA

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ABSTRACT

Programmable logic controller (PLCs) has become an indispensable control unit in the Industrial control field. But the performance of traditional PLC will be restricted by the length of ladder diagram and the operation speed of the microprocessor. It is difficult to adapt to the requirements of high-speed control in modern industry. Therefore, figuring out a way to realize high-speed control becomes more and more important. Field programmable gate array (FPGA) has characteristics of supporting high-speed parallel execution and hardware configuration. Realizing the function of PLC by it can greatly improve the execution speed of control logic and this is an important way to solve the current problems of PLC. The performance of programmable logic controllers is often constrained by the microprocessor and the real-time firmware of the controller. Field programmable gate arrays (FPGAs) are an attractive potential implementation medium for high-speed control because of their fast and parallel execution and programmable nature. Ladder Diagrams are a standard graphical programming method for industrial controllers, but compilers from Ladder Diagrams to FPGA hardware do not yet exist.

So this Project is the conversation of Ladder to VHDL programming in order to meet the FPGA advantages. The project is to implement Batch Processing Application on FPGA based PLC and to have a comparative study on results when implemented on it. The Batch Processing Application the contents are mixed in the user defined proportion taking into consideration of various parameters like the weight of the content used, time each hopper of the content will open in order to pour into the mixer hopper. Then at what temperature and pressure the content is mixed is to be maintained. The FPGA based PLC plays important role in opening and closing of the solenoid valve of each hopper, if the timing delay occurs then mixer is not mixed in the proper proportion. In order to do so the application is implemented on PLC and FPGA based PLC controlled, and the comparison is done related to it. PLC, based on FPGA, can greatly improve the speed of logic control.

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I. INTRODUCTION

Programmable logic controllers (PLCs) are a main stay for industrial process control and automation applications. They are low-cost, reliable, easy to use, and have been proven with years of successful operation. Their discrete analog and digital I/O features and ability to close control loops in the hundreds-of-hertz range meet many application needs. Unfortunately, not all applications easily fit into these constraints. Many new approaches to machine building have necessitated higher-performance controllers with innovative architectures. FPGA combines the real-time computing power of a computer with the reliability and flexibility of a field-programmable gate array (FPGA). The FPGA portion of the RIO architecture enables three core benefits over traditional control systems: high-performance parallel processing, custom hardware flexibility, and hardware logic reliability. Programmable logic controllers (PLCs) are a main stay for industrial process control and automation applications. They are low-cost, reliable, easy to use, and have been proven with years of successful operation. Their discrete analog and digital I/O features and ability to close control loops in the hundreds-of-hertz range meet many application needs. Unfortunately, not all applications easily fit into these constraints. Many new approaches to machine building have necessitated higher-performance controllers with innovative architectures. NI Compact RIO is a PAC that combines the real-time computing power of a computer with the reliability and flexibility of a field-programmable gate array (FPGA). The FPGA portion of the RIO architecture enables three core benefits over traditional control systems: high-performance parallel processing, custom hardware flexibility, and hardware logic reliability.

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II. LITERATURE SURVEY

Field Programmable Gate Array (FPGA) is quite popular Today for its parallel execution mechanism and Reconfigurable hardware structure [1]. Programmable Logic Controller (PLC) is a user friendly, microprocessor based specialized computer that carries out control functions of many types and that of different levels of complexities [2]. Its purpose is to monitor crucial process parameters and adjust process operations accordingly. The PLC will operate any

system that has output devices that go on/off (known as discrete or digital outputs) or vary proportionately (known

as analog outputs). The first PLC system evolved from conventional computers in the late 1960s and early 1970s.

Though the late 1970s, improvements were made in the PLC programs to make them somewhat more user friendly. PLCs are also referred to as Programmable Controllers or

Sequential Processors (i.e. devices that handle step by step

execution of operations) that are widely used in commercial and industrial applications.

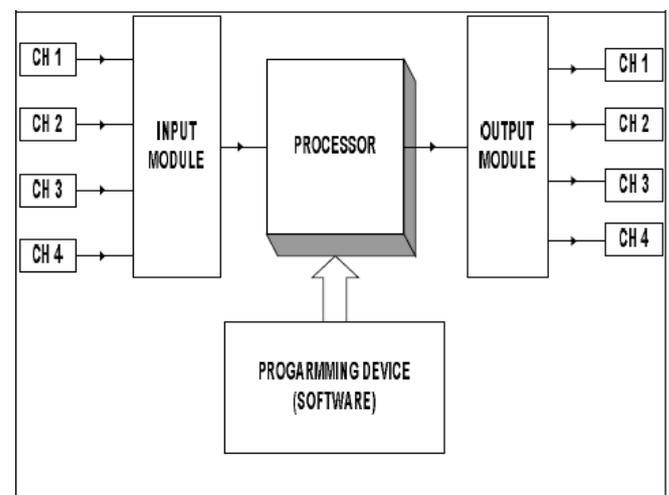


Fig. 1. Block diagram of a typical PLC[4].

B. FPGA TECHNOLOGY

Running advanced algorithms, such as field-oriented control (FOC) for brushless DC motors, can reduce power consumption and increase the life of components. These control algorithm advances are making machines more efficient, but often the algorithms need too much computational power to run on a PLC. For example, an FOC controller must continuously compute the vector control algorithm at a rate of 10 to 100 kHz. In parallel with the control algorithm, additional intellectual property (IP) blocks such as the high-speed PWM outputs need to execute without affecting the timing of the control algorithm. With their inherent parallel execution, FPGAs are able to perform control algorithms with loop rates up to hundreds of kilohertz, with room left over to handle multiple axis control algorithms, data communication for a human machine interface (HMI), or interaction with a host microprocessor. Moreover, with the reconfigurable nature of FPGAs, you can adjust the control algorithm whenever necessary.

A PLC designed using FPGA technology results in better solution providing following advantages:

(a) Short product development cycle

Due to the use of standard HDLs and runs directly in silicon, engineers can try out various types of implementation and hence, product development time is reduced significantly.

(b) Flexibility

Design engineers (PLC manufactures) can easily upgrade the Micro PLC designs. For example some feature or instructions could be added in the existing designs, simply by changing HDL and configuring the same FPGA chip for the modified designed of Micro PLC.

(c) Accuracy

This design provides parallel concurrent execution of blocks in hardware, hence provides better performance and accuracy as compared to conventional PLC.

(d) Very High Speed Performance

These designs is based on FPGA that performs all tasks in parallel, hence execution of the proposed system design is

very fast compare to conventional PLC as the later performs all the operations sequentially.

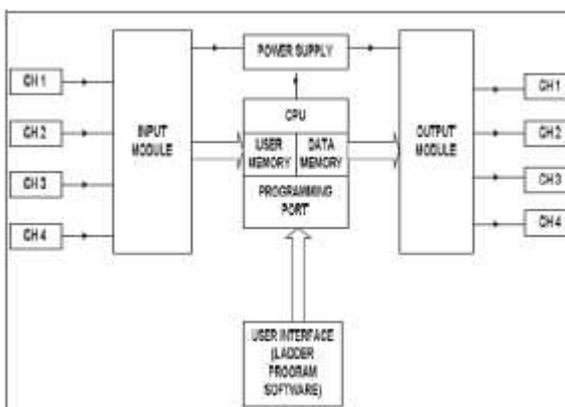
(e) Cost Effective and Compactness

Due to advantages mentioned above, designers can meet

the market requirements by satisfying customer needs with improvement in the performance or functionality of the PLC product. These features result in high performance, low cost and compact designs as compared to the other available solutions.

III. PROBLEM METHOD

Method



A **programmable logic controller, PLC** or **programmable controller** is a digital computer used for automation of typically industrial electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or light fixtures. PLCs are used in many industries and machines.

Early PLCs were designed to replace relay logic systems. These PLCs were programmed in "ladder logic", which strongly resembles a schematic diagram of relay logic. This program notation was chosen to reduce training demands for the existing technicians. Other early PLCs used a form of instruction list programming, based on a stack-based logic solver.

Modern PLCs can be programmed in a variety of ways, from the relay-derived ladder logic to programming languages such as specially adapted dialects of BASIC and C. Another method is State Logic, a very high-level programming language designed to program PLCs based on state transition diagrams.

The main difference from other computers is that PLCs are armored for severe conditions (such as dust, moisture, heat, cold) and have the facility for extensive input/output (I/O) arrangements. These connect the PLC to sensors and actuators. PLCs read limit switches, analog process variables (such as temperature and pressure), and the positions of complex positioning systems. Some use machine vision. On the actuator side, PLCs operate electric motors, pneumatic or hydraulic cylinders, magnetic relays, solenoids, or analog outputs. The input/output arrangements may be built into a simple PLC, or the PLC may have external I/O modules attached to a computer network that plugs into the PLC.

A PLC program is generally executed repeatedly as long as the controlled system is running. The status of physical input points is copied to an area of memory accessible to the processor, sometimes called the "I/O Image Table". The program is then run from its first instruction rung down to the last rung. It takes some time for the processor of the PLC to evaluate all the rungs and update the I/O image table with the status of outputs.

Field Programmable Gate Arrays (FPGAs), offers an alternative solution for complex processing. They offer optimum performance, reduced power consumption, parallel processing, and the flexibility associated to hardware. This fact has led some PLC manufacturers to design a new class of PLC based on FPGAs instead of on sequential processors. The LD network is widely used method for describing control algorithms. This method has been inherited from relay control systems. Contacts and coils represent logic dependencies between signals and function blocks. The LD network processing speed can be increased by parallel execution of the logic operation in programmable hardware. Transforming logic dependencies into combinatorial logic allows increasing performance several orders of magnitude.

The majority of PLC manufacturers use the ladder logic diagram programming language to program their programmable logic controllers (PLCs). Some manufacturers prefer using *logic gate circuits* or *Boolean expressions* to program their PLCs.

For example.

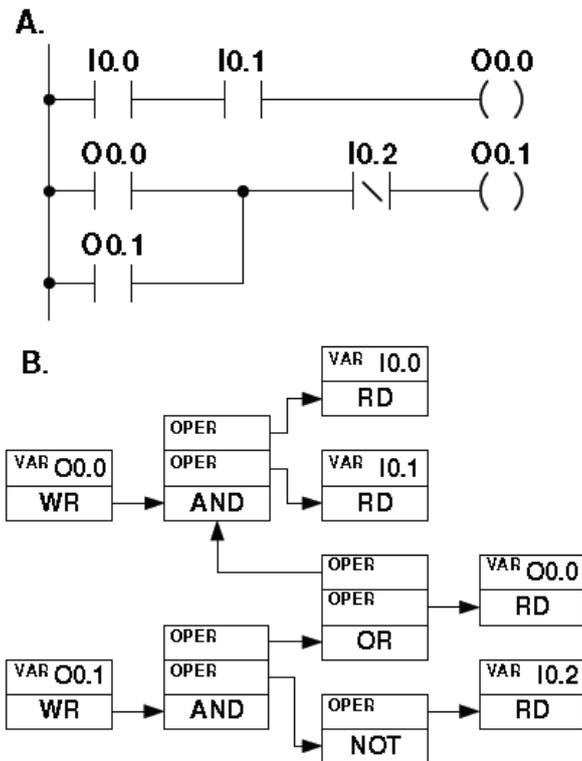
The function of an XOR gate is simulated in the electric circuit displayed in Figure(). Notice that the lamp will be on if one switch is open while the other switch is closed.

Figure () displays a ladder logic diagram that performs the function of an XOR gate. When I:0/0 is on, I:0/1 must be off and vice versa in order to turn on output O:0/0. When either Pushbutton #1 or Pushbutton #2 is pressed, the output is ON. When both pushbuttons are pressed, output is OFF.

Creating logic gate circuits from ladder diagrams

The first step in this process is to find the Boolean expression that represents the ladder logic diagram. You can then draw the logic gate circuit using the Boolean expression.

Step two is writing the equivalent VHDL code.



For e.g.

Entity contact_n0 is

port (

i : in std_logic ;

a : in std_logic;

o : out std_logic) ;

end contact_no ;

architecture arch of contact_no is

begin

o <= a and i ;

end arch ;

The Basic implementation is to give PLC and FPGA inputs at different frequency and check the corresponding outputs.

IV. EXPERIMENTAL STUDY

Batch Mixing Application

The actual software is to be written in Ladder Programming Language. The mixer is designed to take in two liquids from the input pumps, stir and heat them to a mixture before collecting the mixture at the output pumps. All operation instructions come from the programmable logic controller to either switch ON/OFF any component of the mixer subsystem depending on its state or the state of another component. The mixer operates by taking in two different liquids from the input pumps one after the other and then performing a heating and stirring operation on this liquid within the vessel. The mixture collected from the output pump and the whole process begins again. The program starts with the opening of PUMP1 to pour the first liquid into the vessel. A Timer is also set and with this Timer we can vary the quantity of the first liquid which we want to put into the vessel. This is made possible with a flow meter because the product of flow rate and time gives an exact amount of the liquid we wish to pour in first from PUMP1. When the Timer completes the timing operation, it will Deactivate PUMP1 and also open PUMP2 to pour in the second liquid until the containing vessel is FULL. The high level sensor usually indicates that the tank is FULL and at the same time stops PUMP2. It also starts the action of both the MIXER and the HEATER. The MIXER and HEATER must operate together at the same time in an AND operation i.e. starting one also starts the other and stopping one also stops the other. A temperature sensor is used to stop the HEATER and the MIXER. This sensor is active HIGH and usually starts PUMP3 in order to let out the mixture from the containing vessel. An empty containing vessel is usually indicated by the low-level sensor which also starts PUMP1 in order to repeat the mixing process all over again. The system is also designed to empty all the liquid within the containing vessel whenever the STOP button is pushed. This is done with the help of a counter which toggles between states and counts pulses in order to keep PUMP3 open until the low-level sensor is activated. Also pushing the START button will RESET the entire system to begin operation from the beginning. The system is also programmed to indicate when it is IDLE which occurs when it is emptying the vessel after the STOP button has been pushed. Result and discussion

Simulation Results

For simulation only one output, four inputs and 17 select lines are used. The results shown in Fig. 9 are the results of main architecture of system inside FPGA.

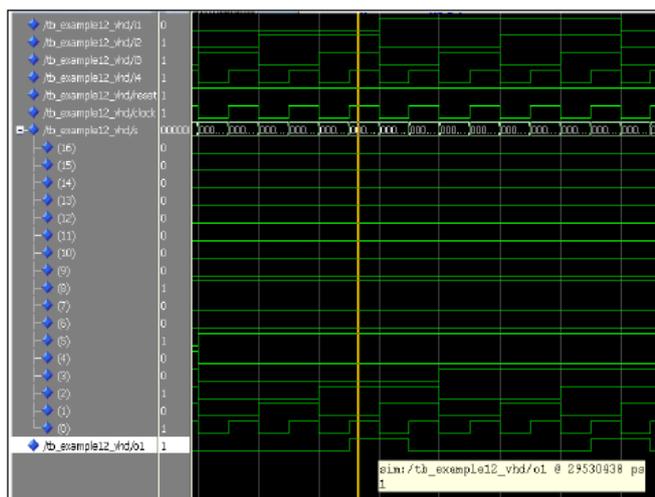


Fig. 9. Results of simulation of architecture inside FPGA.

V. CONCLUSION

This paper describes only the concept of a new implementation approach to FPGA based PLC. This design is limited to only four digital inputs and outputs. To overcome the performance limitation of microprocessor based PLC; the suggested approach provides a better result. The idea described here is best suitable for small-scale applications where the need is a limited number of instructions at a reasonable cost, which also offers the best performance, high speed and compact design approach.

For implementation of the suggested solution, some studies on implementation of control programs into logic description in the form of Hardware Description Language (HDL) have been carried out. Hence, it becomes necessary for the user of the proposed design to have knowledge of design tools to translate, integrate and implement the logic circuit in FPGA.

In the future scope we can create a basic software which will directly create the Ladder programs to VHDL programs, and be able to download on FPGA directly.

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