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Design and Implementation of 8 bit Microprocessor using VHDL

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Abstract - *In this paper, we are designing and implementing the 8 bit Microprocessor using VHDL synthesis tool Xilinx 14.2 on FPGA board. Microprocessor is basically an electronic device which consists of ALU and Control circuitry which is required to work as computer's CPU. The Control unit is the main part of this design, which controls all modules which performs different operations like Arithmetic and Logical operations. Each and every module is designed separately and after that control unit combines these entire module using control signals. Our system was implemented on the Xilinx Spartan 3 XC3S400PQ208 using ISE foundation 14.2 and VHDL. Total 329 slices, 415 slice flip-flops, 320 four inputs LUTs, 38 numbers of Bounded IOBs are used.*

Keywords *– Control Unit, Very High Speed Integrated Circuit Hardware Description Language (VHDL), PROGRAM COUNTER (PC), Arithmetic and Logical Unit (ALU), Control Unit, Instruction Register (IR).*

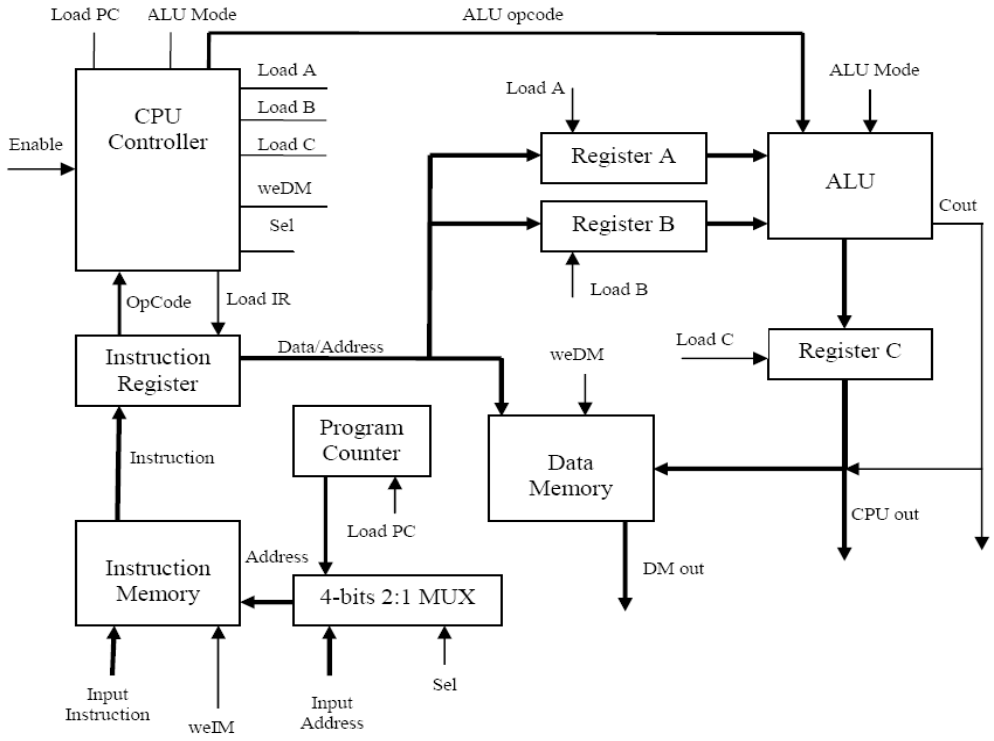
Introduction:

A Microprocessor is a multiusage programmable clock-driven register based device that reads binary instructions from storage device called Instruction Memory, accepts binary data as input and processes data according to that instruction and provides output results. This project works on the VHDL [VHSIC Hardware Description Language]. The advantage of this language when used for system design is that it allows the user to synthesize the code before the actual hardware implementation of system design. We can design eight bit microprocessor with the help of VLSI technology. This technology provides the reduction in the chip size, good power consumption factor, and the high speed of operations.

In this paper we are designing a Microprocessor which consists of ALU, Control unit, Address bus, Data bus, Instruction Register and Instruction Memory. Basically the Microcontroller consists of RAM, ROM, I/O PORTS, TIMER'S and Counters internally, but in Microprocessor all these component are separately interfaced with the processor. The microprocessor is divided into two different parts one is control unit and second one is memory unit. The memory unit is use to store Instruction and Data. The Instruction Memory is used for storing set of instruction hence the size may vary accordingly. The control unit is used for controlling all the control signals which are generated to operate the internal blocks of Microprocessor. Control unit also known as the central processing unit for the microprocessor as it is connected to each block in the processor. All the instructions are executed via instruction register pointed by program counter.

CPU Design: There are various modules in the microprocessor those are:

1. ALU (Arithmetic and Logical Unit)
2. CPU (Central Processing Unit)
3. PC (Program Counter)
4. IR (Instruction Register)
5. DM (Data Memory)
6. Registers (A,B and C)
7. Multiplexer

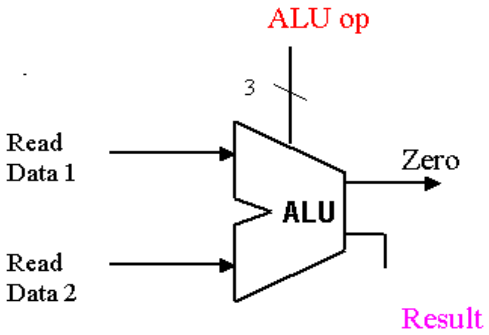


Technical specification:

To design a processor it is very important to take the specification for the processor. This is the first step for design methodology flow. The specifications will influence the architecture of a processor. From the specifications, all the design parameters are considered according to the specifications defined as per the architecture. To design this processor the technical specifications are considered as follows:

- Data bus (8 bit)
- Address bus (4 bit)
- Instruction memory (16 locations)
- Instruction Register (12 bit) IR

ALU design:

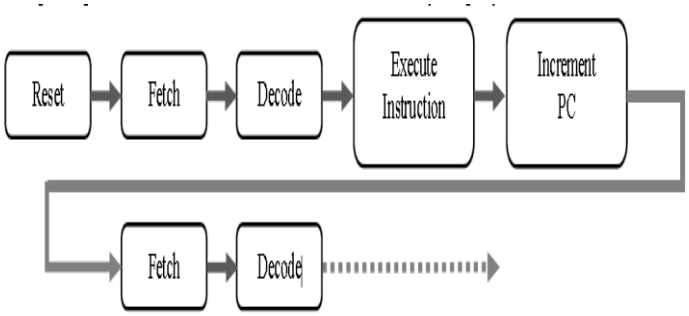


ALU is the most essential entity in the processor because it is concerned with arithmetic, logical and decision making operations to manipulate the given input data. It is considered to be most important unit of processor. The operands provided to the ALU are through the internal registers which are register A and Register B and the result of both the operands is stored in Register C.

Program Counter:

The main function of a program counter is to point the very first address of an instruction which is to be executed after the first start or reset of microprocessor unit and point the next address of memory after execution of first instruction. In our case the program counter is of 4 bit long.

Instruction Register:



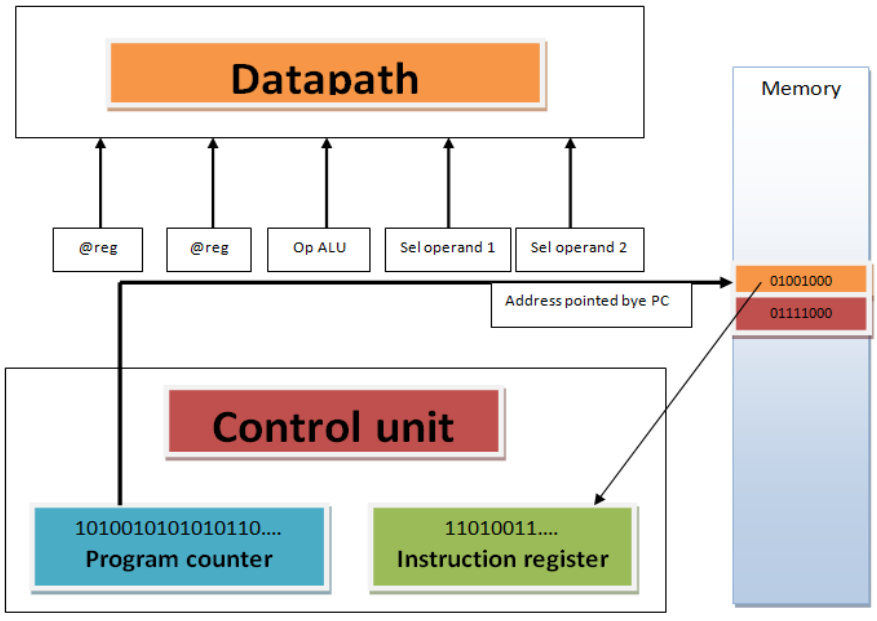
D0	D1	D2	D3	D/O4	D/O5	D/O6	D/O7	O8	O9	O10	O11

D - Data part of given instruction after decoding
O – Opcode of given instruction after decoding
We have twelve bit instruction register out of this twelve bit first eight bits are operand or data bits from D0 – D7 and the last eight bits are decoded as opcode which gives the knowledge about which operation will be execute on the given data. Hence the middle four bits are common in data as well as the opcode part.

Register unit:

There are three general purpose registers in eight bit processor. Registers are the small amount of storage units available for the CPU usage. Registers are CPU storage at run time. The numbers of registers available and size of those registers are important parameter related to the speed of operation and power dissipation. By giving control commands data can be read from registers or it can be write to the registers. The results of arithmetic and logical units are stored in the registers and can be use later.

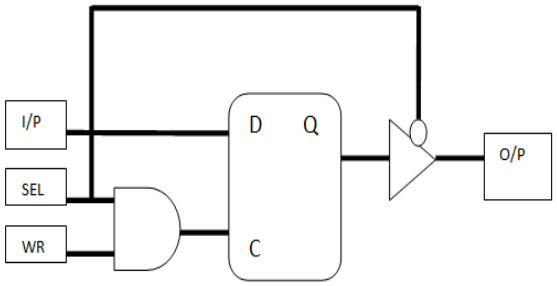
CPU controller:



The control block supplies the necessary signal to make the data flow properly through the CPU and perform the expected functions.
In the program the architecture contains a state machine that causes all appropriate signal values to update based on the current state and input signals and produce a next state for the state machine.
The control block provides all control signals to regulate data traffic for the CPU. The control block is a state machine that contains a number of states for each instruction.

The Controller is the one responsible for synchronizing the work done by all the other components.
It has two inputs, Enable and Opcode. The Opcode is input from the Instruction register.
Initially the Enable is 0 when you are storing instructions into the Instruction Memory. Once you are done, you set the Enable Signal to 1 and the CPU should execute all the instructions stored.

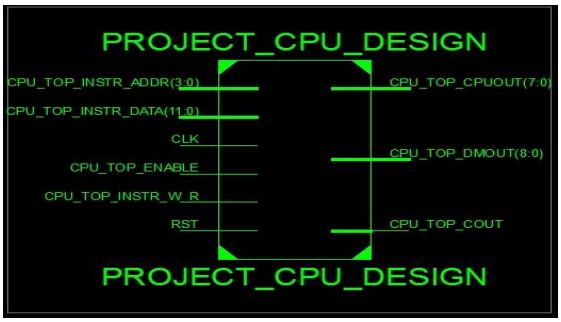
Data Memory:



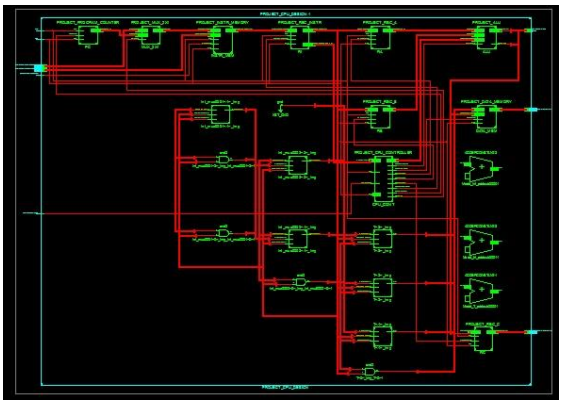
The data memory is a basic SRAM cell structure. Data memory consists of D-flip-flops, tri state buffers and NAND gate. Basically the data memory is used to store the data at a place where user wants to store on particular location in data memory and can be recall later.

Synthesis:

- **Schematic of CPU Design**

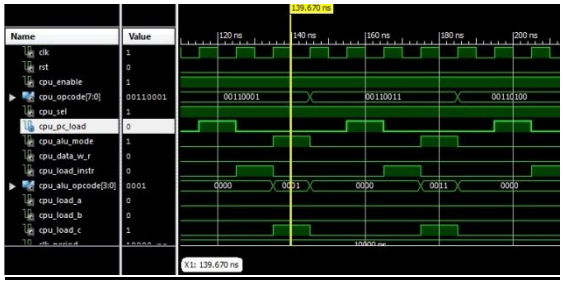


- **RTL Schematic**

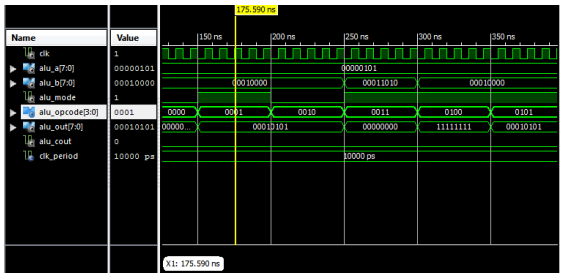


Simulation Results:

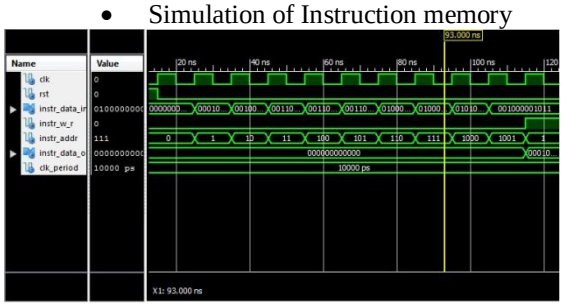
- Simulation of control unit



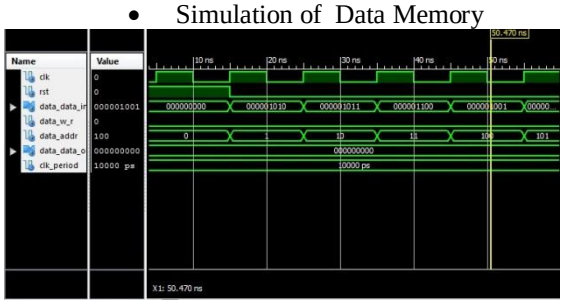
- Simulation of ALU



- Simulation of Instruction memory



- Simulation of Data Memory



- Simulation of Program Counter

Conclusion:

- We are designing and implementing a small and easy to understand Microprocessor using VHDL on FPGA kit.
- By designing the Microprocessor using VHDL we can easily understand the internal operations and monitor the internal signals generated by Control unit.
- After working on FPGA kit we found that it is very flexible to make changes for future modifications.
- The availability of low cost, low power and small weight, computing capability makes it useful in different applications.
- Presently we are designing 8 bit Microprocessor and in future we can expand it for 16 bit, 32 bit and so on as per requirement.
- In our work we have done the VHDL coding of the first three modules and simulated it successfully. We also have tried to implement it in FPGA Kit.

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