**EE 4490 Project # 2**

**By:**

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**Purpose:**

The purpose of this project is to gain familiarity with Verilog and basic computer architecture using the ARMv4 processor as an example.

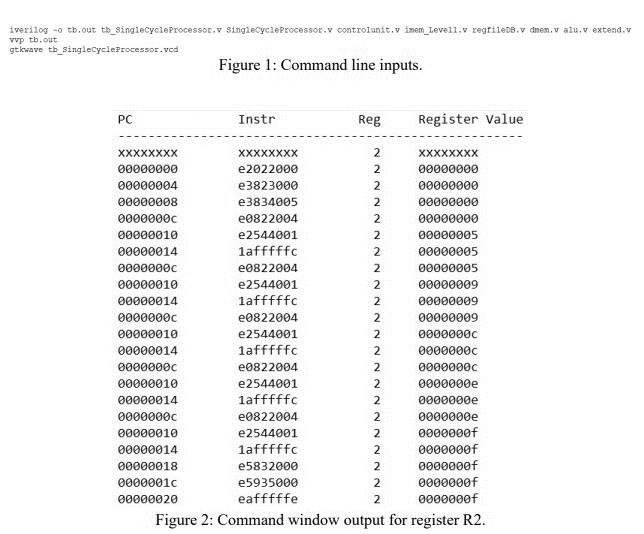
**Given:**

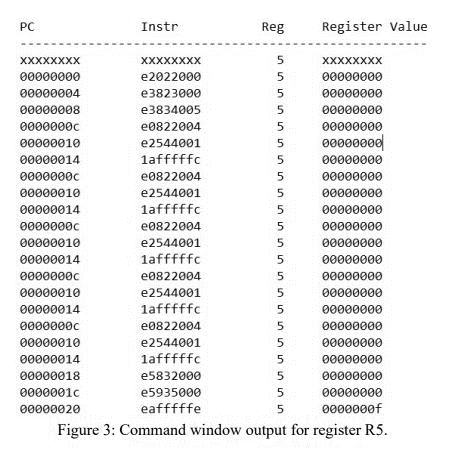
Given is a Verilog ARM implementation of a subset of the full Instruction Set Architecture (ISA).

**Procedure:**

The task is to simulate, design, and test in hardware (on a Digilent Basys 3 FPGA prototyping board) an implementation of a single cycle ARM processor in a series of six steps.

Step 1, The given ARM ISA is verified by simulation using iVerilog, Fig. 1, to output results to the command window, Figs. 2 and 3. GTKWave is then used to display timing diagrams of the processor simulation, Figs. 4 and 5. Registers R2, R3, R4, R5, and R15 were simulated, but only registers R2 and R5 are shown in the figures.





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Step 2, The ARM program, smallProg.s, and machine language in imem.v are examined and deciphered to determine what the program does and what the final contents are in registers R2, R3, R4, R5, and R15, when the program reaches its infinite loop.

Step 3, A new Xilinx Vivado project for the Basys 3 is created, synthesized, implemented, and a bitstream is generated. The program is then downloaded to the board and tested.

Step 4, The top-level module is modified to display the current instruction value. First, a switch input, S10, is added to alternate between displaying the current register value (off) or current instruction value (on). Next, an if-then structure is used to exchange the continual assignments for an always block in which the instruction, Instr, is now an option for inputs A, B, C, and D to Mux4Machine. The ability to display the upper or lower nibble of a register value is retained. Every instruction value is compared with each value from previous simulations.

Step 5, The CMPcd instruction is added to the ARM ISA within the processor. Only changes are made to the control unit, controlunit.v. First, a NoWrite variable is created. Next, another state is created in the always block assigning ALUContol and FlagW for the CMP instruction. NoWrite is added on the left of each blocking assignment and a corresponding bit is added on the right, with only CMP receiving a 1. Finally, the continually assigned RegWrite is ANDed with ~NoWrite, and the instruction is complete. Now the new functionality is tested.

Step 6, The EORcdS instruction is added to the ARM ISA within the processor. First, a new state is added to the ALU, alu.v, accomplishing the XOR operation and assigning the proper flags, which may or may not be used. This requires increasing ALUControl to 3 bits in all modules. Next, two states are created in the always block assigning ALUContol, FlagW, and NoWrite for both the set and don’t set flags cases. With the instructions complete, the instruction memory is altered to test the new functionality by replacing the LDR instruction with an EOREQ instruction

**Conclusion:**

The purpose of this project was to gain familiarity with an ARM processor with a limited ISA and improve upon the given design with added functionality and additional instructions. First, functionality was added to allow for display of the current instruction value. Then, two instructions were added to the given ARM ISA, CMPcd and EORcdS. Three other steps were also completed that simulated, deciphered, and implemented the given processor. All of these tasks were completed, proven functional, and documented

**Schematic:**

Below is the RTL schematic of the top level design.

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