CA Final Project - Report

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1 Design

Our design is drawn in figure 1, which is mostly identical to the design in the textbook, but a few modules, signals and wires are added to support more instructions.

1.1 The Control Module

The control module reads the `opcode`, and output 9 signals:

- `Regwrite`: 1-bit signal.`1` if writing to register is required, `0` otherwise.
- `ALUSrc`: 2-bit signal, one for each ALU input. The input will be from the register if the signal is `0`. The first input will be from PC, and the other input will be from the `ImmGen` if the corresponding signals are `1`.
- `ALUOp`: 2-bit signal. Indicates the instruction type to help ALU control further decides the operation of ALU. The signals are defined as follows:
  - `00`: always add.
  - `01`: always subtract.
  - `10`: R-type intruction. Operation depends on funct7.
  - `11`: R-type intruction. Operation depends on funct7.
- `RegSrc`: 2-bit signal. Together with `ALURegSrc`, they determine the source written back to the register. The meanings of each signals are:

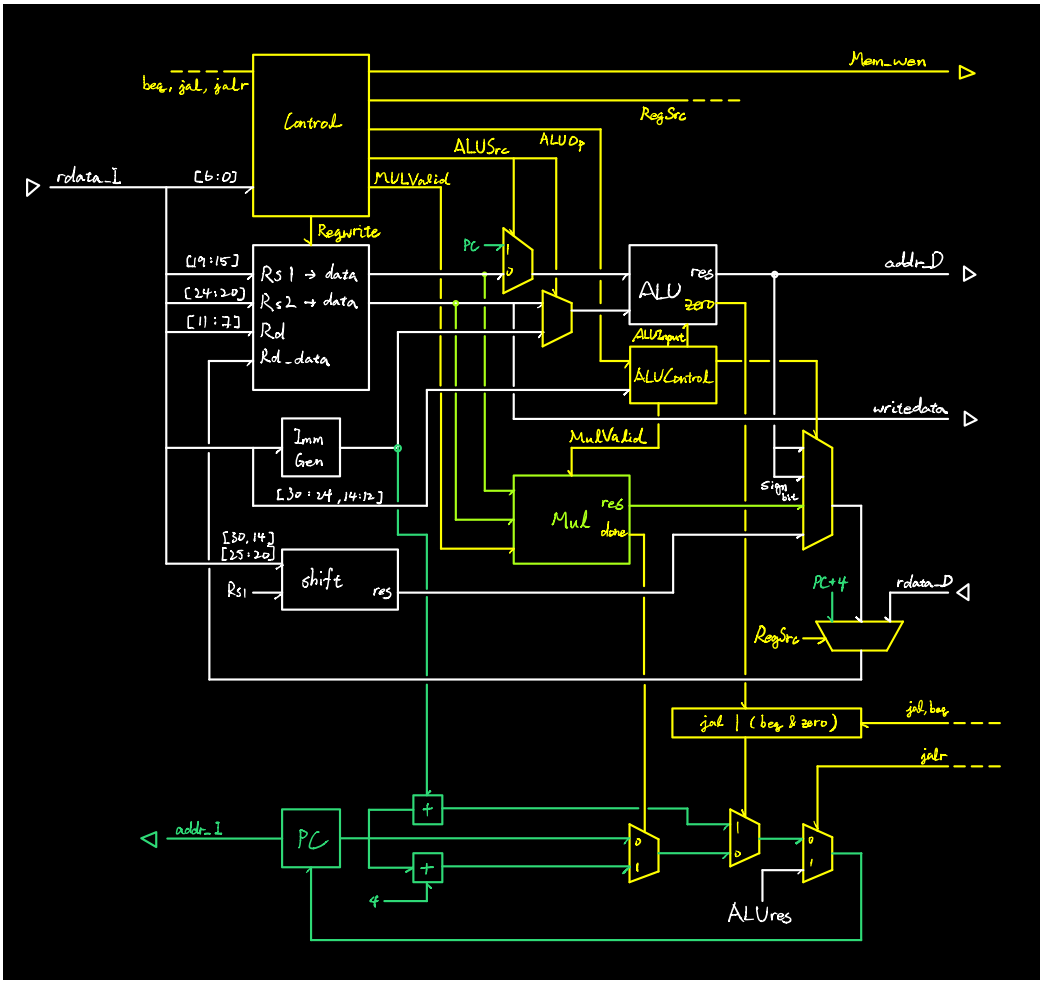

Figure 1: CPU design

  - `00`: ALU
  - `01`: PC + 4
  - `10`: Memory

- `Mem_wen`: 1-bit signal, `1` for writing the memory, `0` otherwise.
- `beq`: 1-bit signal, signaling the branch instruction.
- `jal`: 1-bit signal, signaling the `jal` instruction.

- `jalr`: 1-bit signal, signaling the `jalr` instruction.

The signals for each instructions are listed in table 1.

Intruction	opcode	men_wen_D	RegSrc	ALUop	ALUSrc	Regwrite
lw	0000011	0	011	00	01	1
addi	0010011	X	X	11	01	1
slli	0010011	X	X	11	01	1
slti	0010011	X	X	11	01	1
srai	0010011	X	X	11	01	1
auipc	0010111	X	000	00	11	1
sw	0100011	1	X	00	01	0
add	0110011	X	X	10	00	1
sub	0110011	X	X	10	00	1
mul	0110011	X	X	10	00	1
beq	1100011	X	X	01	00	0
jalr	1100111	0	X	00	01	1
jal	1101111	X	X	X	X	1
DEFAULT		0	000	00	00	0

Table 1: Control signals of each instructions.

1.2 The ALU Control

The ALU control decides the operation of the ALU, and also plays a part in determining the source written back to the register. This module takes `ALUOP`, `funct3` and `funct7` and several output sources as inputs (explained below in the `ALURegSrc` part), then output `ALUInput` to the ALU to control the operation of the ALU, `ALURegSrc` to the multiplexer determining the source written back, and `MulValid` to trigger the multiplication.

- `ALUInput`: 3-bit signal. Determines the operation of the ALU.
  - `010`: add
  - `110`: subtract

  Note that we use 3 bits instead of one, even though there are really two options. The advantage is that it can easily be modified to support more operatios such as `and`, `or`, etc.

- `ALURegSrc`: 32-bit signal. Note that in our code, we have absorbed the multiplexer in figure 1 that takes four inputs (two from ALU results, one from multiplier and one from the shift register) into the ALU control module to avoid redundant code and wires. `ALURegSrc` is the output of the multiplexer in figure 1 and will be set to appropriate write back source according to the instruction type (hinted by `ALUOp`, `funct3` and `funct7`). For example, for R-type and I-type instructions, the output will be the result from the ALU, while for shift instructions the output will be from the shift register.

- `MulValid`: 1-bit signal. `1` if the intruction is `mul`, 0 otherwise. The details about multiplication will be described in section 1.3.

1.3 Multiplication

The mulitiplication module is from HW3. The output signal `done` is `1` unless `MulValid` is `1` and the multiplication state is not in `S_DONE`. `done` controls the PC. When `done` is `0`, the PC is frozen (the next state of PC is the same as the present state). Otherwise it is PC + 4 as usual. This means when instruction is `mul`, the ALU control unit set `mulValid` to 1, and the multiplication process is triggered. During the process the `done` signal is `0` until the result is ready. Before that the PC is frozen, which means all the modules are also frozen except the multiplication module. When the result is ready, the state is in `S_DONE` and `done` is set back to 1, and PC goes on to the next instruction.

2 Required Screenshots

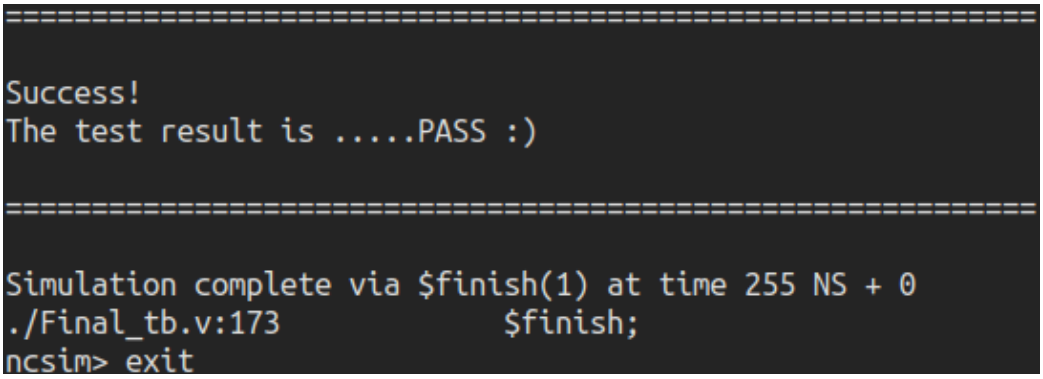

Figure 2: Simulation time of *leaf example*.

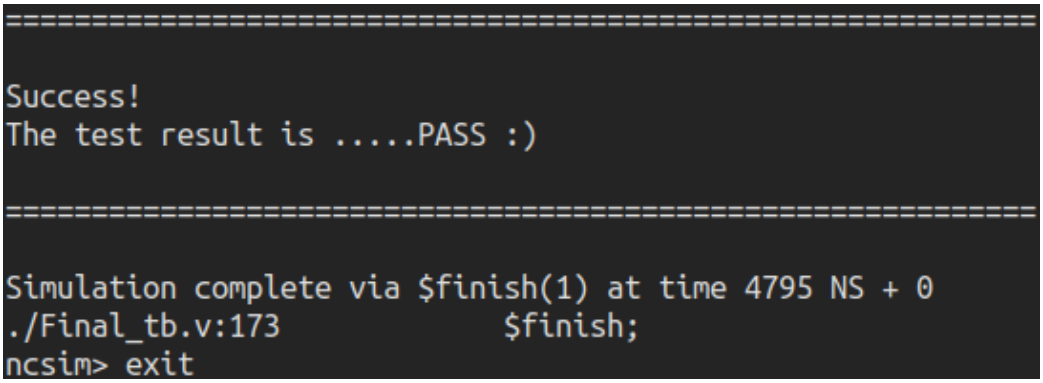

Figure 3: Simulation time of *fact*.

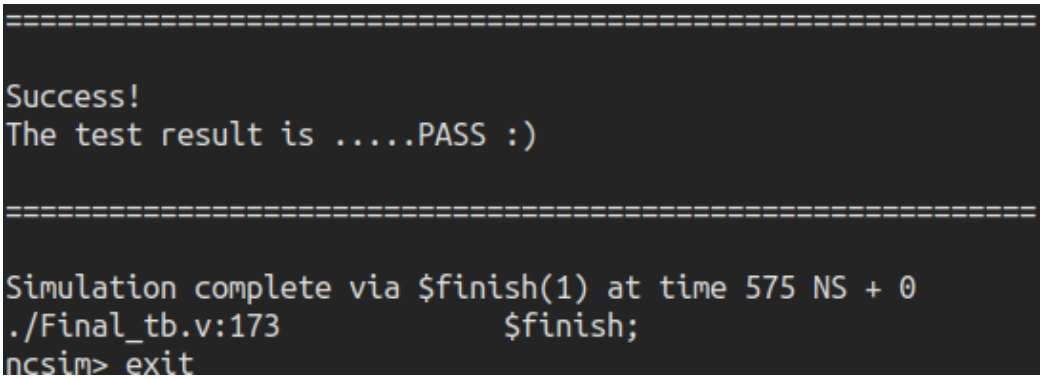

Figure 4: Simulation time of *HW1*.

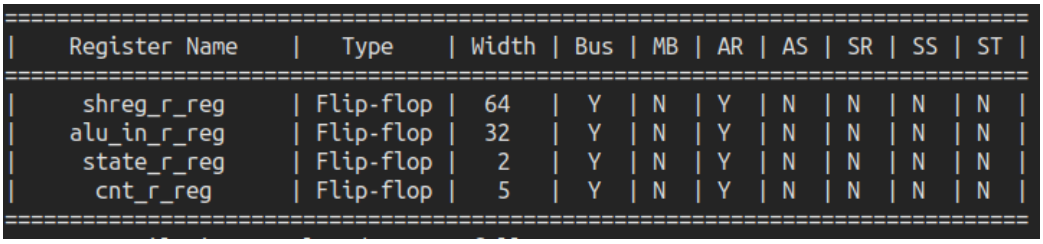

Figure 5: Coding style check.

3 Work Distribution

- Hao-Chien Wang: Control, ALU, ALUControl, debug, report.
- Guo-Wei Ho: Design, instruction generation, ImmGen, multiplier (HW3), multiplexers, all other little stuff, debug.