

Homework 5
RTL, Datapath and Control Unit(FSM and Micro-programming)
Total points: 45 points + 20 points(extra credit)

This assignment is due Tuesday, February 3rd by 5:00 PM for Sections 1 and 2.

Learning Objectives

In the process of completing this homework assignment, students will develop their abilities to

- Write RTL for assembly language instructions.
- Modify the datapath to implement an instruction,
- Modify the control unit to implement an instruction.
- Design the control unit using microprogramming.

General Instructions

- For the micro-programming problems, you do not have to re-produce the micro-program in Figure 5.46. Assume that that part of the micro-program already exists and write down only the new micro-instructions that are required. Also, if you create any new values for the fields, then clearly specify what each new value denotes.
- Submit your answers on a separate sheet of paper.

Problems

1. [20 points] Figure 5.46 in Hennessy and Patterson, shows the microprogram for the control unit of the MIPS architecture that can handle `lw`, `sw`, `beq`, `j` and R-type instructions. Add microcode to this program to implement the following MIPS instructions:
 - a. `addi`
 - b. `jal`
 - c. `mfc0`
 - d. `mtc0`

Hint: A line of microcode or an instruction in a microprogram is equivalent to a state in a state diagram.

2. [5 points] The effect of the instruction `swap rs, rt` is to move the contents of register `rs` to `rt` and move the contents of register `rt` to `rs`. For example, if
 - register `$1` contains `0x0000 0030` and
 - register `$2` contains `0x0000 0400`then the instruction `swap $1, $2` puts `0x0000 0030` in register `$2` and `0x0000 0400` in register `$1`.

The instruction format for the `swap` instruction is shown below:

Opcode	rs	rt	0x0000				
31	26	25	21	20	16	15	0

The RTL for the `swap` instruction

1. $IR = \text{Memory}[PC]$
 $PC = PC + 4$
2. $A = \text{Reg}[IR[25:21]]$
 $B = \text{Reg}[IR[20:16]]$
 $ALUOut = PC + (\text{sign-extend}(IR[15:0]) \ll 2)$
3. $\text{Reg}[IR[20:16]] = A$
 $B = B$
4. $\text{Reg}[IR[25:21]] = B$

For the given RTL description, obtain the microinstructions for the `swap` instruction that can be added to the micro-program of Figure 5.46 of Hennessy and Patterson.

3. [20 points] Problem 5.19 of Hennessy and Patterson (page 429) describes a `wai` instruction.
 - a. Write the RTL description for the `wai` instruction.
 - b. Modify the datapath of Figure 5.33 (H&P) to implement the `wai` instruction. Remember to indicate any changes and additions to the control signals.
 - c. Modify the state diagram of Figure 5.42 (H&P) to implement the `wai` instruction.
 - d. Modify the micro-program of Figure 5.46 (H&P) to implement the `wai` instruction.
4. [Extra credit: 20 points] Problem 5.20 of Hennessy and Patterson (page 429) describes a `jm` instruction.
 - a. Write the RTL description for the `jm` instruction.
 - b. Modify the datapath of Figure 5.33 (H&P) to implement the `jm` instruction. Remember to indicate any changes and additions to the control signals.
 - c. Modify the state diagram of Figure 5.42 (H&P) to implement the `jm` instruction.
 - d. Modify the micro-program of Figure 5.46 (H&P) to implement the `jm` instruction.