

## **CSEE W3827**

# Fundamentals of Computer Systems Homework Assignment 4

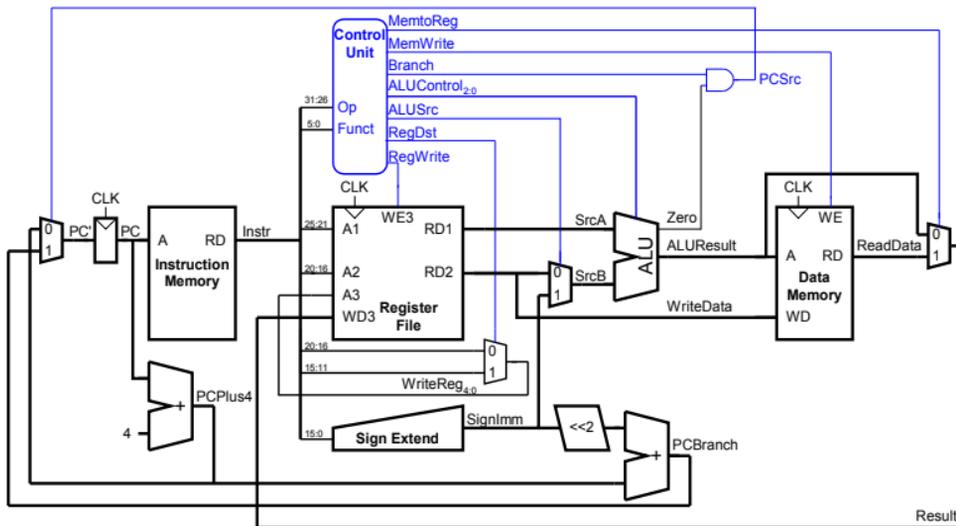
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Due December 4, 2012 at 10:10 AM

Write your name **and UNI** on your solutions

Show your work for each problem; we are more interested in how you get the answer than whether you get the right answer.

1. (25 pts.) Extend the single-cycle MIPS processor to support `slti` (i-format, opcode=001011).



Inst.	OP	RegWrite	RegDst	ALUSrc	Branch	MemWrite	MemToReg	ALUOp
R-type	000000	1	1	0	0	0	0	1-
lw	100011	1	0	1	0	0	1	00
sw	101011	0	-	1	0	1	-	00
beq	000100	0	-	0	1	0	-	01

2. (15 pts.) A processor that does not support the `slti` instruction, can emulate the behavior as follows:

```
subi $d, $s, imm  
srl  $d, $d, 31
```

Imagine two single-cycle processors,  $P_{base}$  which does not support `slti`, and  $P_{slti}$  which does. Consider also two versions of an application:  $A_{slti}$  which is dynamically 10% `slti` instructions, and  $A_{base}$  which is the same application with all of the `slti`'s replaced by the pair of instructions above. Assuming both processors run at the same clock frequency, rank the following combinations of software and hardware, from fastest to slowest, explaining your reasoning.

- $A_{base}$  on  $P_{base}$
- $A_{base}$  on  $P_{slti}$
- $A_{slti}$  on  $P_{slti}$

3. (25 pts.) Consider the tree sum code below.

```
tree_sum:
    bnez $a0, tree_sum_recurse # non-pseudo: bne $a0, $zero, tree_sum_recurse
    li    $v0, 0
    jr    $ra
tree_sum_recurse:
    addi  $sp, $sp, -12
    sw    $ra, 0($sp)
    sw    $s0, 4($sp)
    sw    $s1, 8($sp)
    move  $s0, $a0                # non-pseudo: addi $s0, $a0, 0
    lw    $s1, 0($s0)
    lw    $a0, 4($s0)
    jal   tree_sum
    add   $s1, $s1, $v0
    lw    $a0, 8($s0)
    jal   tree_sum
    add   $v0, $s1, $v0
    lw    $ra, 0($sp)
    lw    $s0, 4($sp)
    lw    $s1, 8($sp)
    addi  $sp, $sp, 12
    jr    $ra
```

- (a) What is the total number of dynamic instructions, when `tree_sum` is called on an N-node tree?
- (b) What is the dynamic ratio of control transfer, memory (i.e, loads and stores), and arithmetic instructions (including `li` and `move`) on an N-node tree?
- (c) Assuming a very large tree (millions of nodes) what is the rough overall instruction mix?
- (d) Consider a single cycle CPU running at 500MHz and a multicycle CPU (5 cycles for memory ops, 3 for control transfers, 4 for arithmetic) running at 2GHz, which will compute tree sums faster?

4. (35 pts.) Fill in the values found on the indicated wires for the first 10 cycles when the tree\_sum code above is executed on the following tree:

```
tiny:      .word 1, tiny1, tiny2
tiny1:     .word 2, 0, 0
tiny2:     .word 3, 0, 0
```

*Assume that the processor supports addi and jal; If any values are undefined given the information provided, simply mark as "undefined".*

