16.482 / 16.561: Computer Architecture and Design
Fall 2013

Homework #4
Due **Wednesday, 10/16/13**

Notes:
- While typed submissions are preferred, handwritten submissions are acceptable.
- Any handwritten solutions that are scanned and submitted electronically <u>must</u> be clearly legible and combined into a single file—<u>simply sending a picture of each scanned page is not an acceptable form of submission</u>.
- For this assignment, **all homework must be submitted no later than 5:00 PM on Friday, 10/18**, as I plan to post the solution that day to allow you enough time to study it prior to the exam on 10/21.

1. (40 points) A 5-stage pipeline contains four staging registers, one between each pair of stages in the datapath; these registers are used to hold information about each instruction as it proceeds through the pipeline. Describe the contents of each register.
   a. <u>Hints:</u> Look at each stage of the pipeline, and think about (a) what information is needed for that stage, and (b) when is it generated? It's probably easiest to think of the last register first and work your way backwards through the pipeline.

2. (60 points) Consider the following code sequence:

```
loop:      add  $t0, $t1, $t2
           lw   $t3, 10($t0)
           lw   $t4, 14($t0)
           sub  $t5, $t4, $t3
           sw   $t5, 18($t0)
           addi $t2, $t2, 4
           slti $t6, $t2, 200
           bne  $t6, $zero, loop
```

   Assume each datapath stage requires the following amount of time to complete:
   - Instruction fetch (IF): 30 ns
   - Instruction decode (ID): 20 ns
   - Execute / address calculation (EX): 25 ns
   - Memory access (MEM): 30 ns
   - Register write back (WB): 20 ns

a. (15 points) How long will one loop iteration take in a single-cycle datapath? (<u>Hint:</u> First determine how long the longest instruction will take to determine the cycle time.)

Problem 2 is continued on the next page.

2 (continued)

b. (15 points) If we assume ideal pipelining (i.e., no hazards and therefore no stalls), how long will one loop iteration take in a pipelined datapath? What is the speedup over the single-cycle datapath (in other words, what's the ratio between their execution times)?

c. (15 points) If we now assume a more realistic pipelined datapath **without** forwarding, how long will one loop iteration take? Show a revised code sequence that includes all necessary no-ops to support your answer.

d. (15 points) Which of the data hazards in this code can be completely resolved using forwarding? For each hazard, list the register number and the two instructions involved.