

# KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

## COMPUTER ENGINEERING DEPARTMENT

### COE 308, Term 982

#### Homework #5

**Due Date: Monday April 19**

The instruction processing of a certain computer has been broken into 5 distinct stages of one cycle each for the purpose of instruction pipelining:

**Stage 1: Instruction Fetch.** At this stage, the whole instruction is read from memory.

**Stage 2: Instruction Decode.** At this stage, the instruction is decoded. Also, the target address of an unconditional branch is calculated.

**Stage 3: Operand Fetch.** At this stage, all source operands are fetched either from memory or registers. The source operands of ALU instructions are stored temporarily in registers A and B.

**Stage 4: Instruction Execution.** At this stage, the instruction is executed and the result of any ALU operation is stored temporarily in register C. Also, at this stage, the decision (taken or not taken) on conditional branches is made and the target address is calculated.

**Stage 5: Operand Store.** At this stage, the destination operand is written to registers or memory.

Assume during the execution of a program, there will no resource conflicts (structural hazards and there is no cache miss; i.e. all stages that uses memory will take one cycle.

The code segment that is to be run on this machine is:

```
                MOVE      R1, -1           ; R1 ← -1
                MOVE      R2, 3           ; R2 ← 3
Repeat:         ADD       R2, R2, R1      ; R2 ← R1 + R2
                JNZ       Repeat         ; branch to Repeat if Zero flag = 0
                ADD       R6, R5, R4
                ADD       R7, R6, R4
```

(a) Calculate the number of cycles needed to execute the above code without the use of the pipeline assuming that each instruction will take exactly 5 cycles to execute.

(b) Calculate the number of cycles needed to execute the code when using the described pipeline. Assume that there is no forwarding hardware and that when the branch instructions are decoded, the pipeline will stall until the target address is calculated and the branch decision is made. Show all work.

Also calculate the improvement due to the use of the pipeline.

(c) Repeat b) assuming that there is maximum forwarding.

(d) Repeat c) assuming that the branch is always predicted to be taken (statically). The branch prediction is done at the second stage.