

EE4218 Computer Architecture  
Sem A 2019-20  
In Class Exercise

(a) Write a program to compute

$$X = A * ((B + C) - D)$$

Do not alter the value of any of the operand locations. The instructions available for use are as follows:

|        |                                           |
|--------|-------------------------------------------|
| PUSH M | $*/TOS \leftarrow M$                      |
| POP M  | $*/M \leftarrow (TOS)$                    |
| ADD    | $*/TOS \leftarrow (TOS+1) + (TOS)$        |
| ADDI K | $*/TOS \leftarrow (TOS) + K$              |
| COMP   | $*/TOS \leftarrow \text{complement}(TOS)$ |
| MUL    | $*/TOS \leftarrow (TOS+1) * (TOS)$        |

N.B. TOS – top of stack, M – memory location, K – integer between 1 to 8.

- (b) For each of the 6 instructions, show the addressing modes of source operand and destination operand, and the number of memory references.
- (c) A microprocessor has a pipeline with 5 stages:
- fetch instruction (FI),
  - decode instruction (DI),
  - fetch **ONE** source operand from memory (FO),
  - execute instruction (EI), and
  - write **ONE** destination operand to memory (WO).

Instructions are issued at a rate of one per clock cycle. Assume that each pipeline stage takes one clock cycle. FI, FO and WO cannot occur simultaneously. Draw the timing diagram showing the pipeline operation in running the program in part (a).

# Solution

(a)

$$X = A * ((B + C) - D)$$

|      |        |        |                                           |
|------|--------|--------|-------------------------------------------|
| I1:  | PUSH B | PUSH M | $*/TOS \leftarrow M$                      |
| I2:  | PUSH C | POP M  | $*/M \leftarrow (TOS)$                    |
| I3:  | ADD    | ADD    | $*/TOS \leftarrow (TOS+1) + (TOS)$        |
| I4:  | PUSH D | ADDI K | $*/TOS \leftarrow (TOS) + K$              |
| I5:  | COMP   | COMP   | $*/TOS \leftarrow \text{complement}(TOS)$ |
| I6:  | ADDI 1 | MUL    | $*/TOS \leftarrow (TOS+1) * (TOS)$        |
| I7:  | ADD    |        |                                           |
| I8:  | PUSH A |        |                                           |
| I9:  | MUL    |        |                                           |
| I10: | POP X  |        |                                           |

(b)

| <u>instruction</u> | <u>source operand</u> | <u>destination operand</u> | <u>number of memory references</u> |
|--------------------|-----------------------|----------------------------|------------------------------------|
| PUSH M             | direct                | stack                      | 2                                  |
| POP M              | stack                 | direct                     | 3                                  |
| ADD                | stack, stack          | stack                      | 4                                  |
| ADDI K             | stack, immediate      | stack                      | 3                                  |
| COMP               | stack                 | stack                      | 3                                  |
| MUL                | stack, stack          | stack                      | 4                                  |

(c)

Time →

|     | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| I1  | FI | DI | FO | EI | WO |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| I2  |    | FI | DI | FO | EI | WO |    |    |    |    |    |    |    |    |    |    |    |    |    |
| I3  |    |    |    |    |    |    | FI | DI | FO | FO | EI | WO |    |    |    |    |    |    |    |
| I4  |    |    |    |    |    |    |    | FI | DI |    | FO | EI | WO |    |    |    |    |    |    |
| I5  |    |    |    |    |    |    |    |    |    |    |    |    |    | FI | DI | FO | EI | WO |    |
| I6  |    |    |    |    |    |    |    |    |    |    |    |    |    |    | FI | DI | FO | EI | WO |
|     |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|     | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 |    |    |    |    |    |
| I7  | FI | DI | FO | FO | EI | WO |    |    |    |    |    |    |    |    |    |    |    |    |    |
| I8  |    | FI | DI |    | FO | EI | WO |    |    |    |    |    |    |    |    |    |    |    |    |
| I9  |    |    |    |    |    |    |    | FI | DI | FO | FO | EI | WO |    |    |    |    |    |    |
| I10 |    |    |    |    |    |    |    |    | FI | DI |    | FO | EI | WO |    |    |    |    |    |