**Module: R4: Computer Architecture**

**Section:** Pipelining & Hazards **Task:** Pipelining & Hazards

**Task**

**Pipelining & Hazards**

* **Question 1:**

1. **Average CPI:**

***For Version A:***

**CPIavg = (%ageA x CPIA) + (%ageB x CPIB) + (%ageC x CPIC) + (%ageD x CPID)**

**CPIavg = (2 x 0.4) + (3 X 0.25) + (3 x 0.25) + (7 x 0.1) = 3**

***For Version B:***

**CPIavg = (%ageA x CPIA) + (%ageB x CPIB) + (%ageC x CPIC) + (%ageD x CPID) + (%ageE x CPIE) + (%ageF x CPIF) + (%ageG x CPIG)**

**CPIavg = (2 x 0.15) + (2 X 0.15) + (4 x 0.1) + (6 x 0.1) + (1 x 0.1) + (2 x 0.2) + (2 x 0.2) = 2.5**

1. **MIPS:**

***For Version A:***

**MIPS =**

**MIPS =**  **= 200 MIPS**

***For Version B:***

**MIPS =**

**MIPS =**  **= 280 MIPS**

1. **Design Choice:**

Processor B with 700 MHz and 280 MIPS is better than processor A with 600 MHz and 200 MIPS.

Here’s why:

* **Clock Speed:** Processor B has a higher clock speed (700 MHz) compared to Processor A (600 MHz). This means that process B can execute more cycles per second, which generally leads to better performance.
* **MIPS:** Processor B also has a higher MIPS (Million Instructions Per Second) value (280 MIPS) compared to Processor A (200 MIPS). This means that the Processor B can theoretically execute more instructions per second, which can lead to better performance.
* **Question 2:**

1. **Non-Pipelined Machine:**

It takes a total of 48 cycles as shown by the table below:

| **Non-pipelined Machine** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Cycles** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** | **29** | **30** | **31** | **32** | **33** | **34** | **35** | **36** | **37** | **38** | **39** | **40** | **41** | **42** | **43** | **44** | **45** | **46** | **47** | **48** |
| **0** | **MUL R3 , R1 , R2** | **F** | **D** | **E1** | **E2** | **E3** | **E4** | **E5** | **E6** | **W** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **1** | **ADD R5 , R4 , R3** |  |  |  |  |  |  |  |  |  | **F** | **D** | **E1** | **E2** | **E3** | **E4** | **W** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **2** | **ADD R6 , R4 , R1** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | **F** | **D** | **E1** | **E2** | **E3** | **E4** | **W** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **3** | **MUL R7 , R8 , R9** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | **F** | **D** | **E1** | **E2** | **E3** | **E4** | **E5** | **E6** | **W** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **4** | **ADD R4 , R3 , R7** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | **F** | **D** | **E1** | **E2** | **E3** | **E4** | **W** |  |  |  |  |  |  |  |  |  |
| **5** | **MUL R10 , R5 , R6** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | **F** | **D** | **E1** | **E2** | **E3** | **E4** | **E5** | **E6** | **W** |

1. **A pipelined machine with five adders and five multipliers without data forwarding:**

It takes a total of 28 cycles as shown by the table below:

| A pipelined machine with five adders and five multipliers without data forwarding | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Cycles** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** |
| 0 | **MUL R3 , R1 , R2** | **F** | **D** | **E1** | **E2** | **E3** | **E4** | **E5** | **E6** | **W** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | **ADD R5 , R4 , R3** |  | **F** | **D** | **-** | **-** | **-** | **-** | **-** | **-** | **D** | **E1** | **E2** | **E3** | **E4** | **W** |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 2 | **ADD R6 , R4 , R1** |  |  | **F** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **D** | **E1** | **E2** | **E3** | **E4** | **W** |  |  |  |  |  |  |  |  |  |  |  |  |
| 3 | **MUL R7 , R8 , R9** |  |  |  |  |  |  |  |  |  |  | **F** | **D** | **E1** | **E2** | **E3** | **E4** | **E5** | **E6** | **W** |  |  |  |  |  |  |  |  |  |
| 4 | **ADD R4 , R3 , R7** |  |  |  |  |  |  |  |  |  |  |  | **F** | **D** | **-** | **-** | **-** | **-** | **-** | **-** | **D** | **E1** | **E2** | **E3** | **E4** | **W** |  |  |  |
| 5 | **MUL R10 , R5 , R6** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | **F** | **D** | **E1** | **E2** | **E3** | **E4** | **E5** | **E6** | **W** |

1. **A pipelined machine with five adders and five multipliers with data forwarding:**

It takes a total of 26 cycles as shown by the table below:

| A pipelined machine with five adders and five multipliers with data forwarding | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Cycles** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** |
| 0 | MUL R3 , R1 , R2 | F | D | E1 | E2 | E3 | E4 | E5 | E6 | W |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | ADD R5 , R4 , R3 |  | F | D | - | - | - | - | - | E1 | E2 | E3 | E4 | W |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 2 | ADD R6 , R4 , R1 |  |  | F | - | - | - | - | - | - | D | E1 | E2 | E3 | E4 | W |  |  |  |  |  |  |  |  |  |  |  |
| 3 | MUL R7 , R8 , R9 |  |  |  |  |  |  |  |  |  | F | D | E1 | E2 | E3 | E4 | E5 | E6 | W |  |  |  |  |  |  |  |  |
| 4 | ADD R4 , R3 , R7 |  |  |  |  |  |  |  |  |  |  | F | D | - | - | - | - | - | E1 | E2 | E3 | E4 | W |  |  |  |  |
| 5 | MUL R10 , R5 , R6 |  |  |  |  |  |  |  |  |  |  |  | F | - | - | - | - | - | - | D | E1 | E2 | E3 | E4 | E5 | E6 | W |

1. **A pipelined machine with one adder and one multipliers without data forwarding:**

It takes a total of 32 cycles as shown by the table below:

| A pipelined machine with one adder and one multiplier without data forwarding | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Cycles** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** | **29** | **30** | **31** | **32** |
| 0 | **MUL R3 , R1 , R2** | **F** | **D** | **E1** | **E2** | **E3** | **E4** | **E5** | **E6** | **W** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | **ADD R5 , R4 , R3** |  | **F** | **D** | **-** | **-** | **-** | **-** | **-** | **-** | **D** | **E1** | **E2** | **E3** | **E4** | **W** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 2 | **ADD R6 , R4 , R1** |  |  | **F** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **D** | **-** | **-** | **-** | **E1** | **E2** | **E3** | **E4** | **W** |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 3 | **MUL R7 , R8 , R9** |  |  |  |  |  |  |  |  |  |  | **F** | **-** | **-** | **-** | **-** | **D** | **E1** | **E2** | **E3** | **E4** | **E5** | **E6** | **W** |  |  |  |  |  |  |  |  |  |
| 4 | **ADD R4 , R3 , R7** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | **F** | **D** | **-** | **-** | **-** | **-** | **-** | **-** | **D** | **E1** | **E2** | **E3** | **E4** | **W** |  |  |  |
| 5 | **MUL R10 , R5 , R6** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | **F** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **D** | **E1** | **E2** | **E3** | **E4** | **E5** | **E6** | **W** |

1. **A pipelined machine with one adder and one multipliers with data forwarding:**

It takes a total of 29 cycles as shown by the table below:

| A pipelined machine with one adder and one multiplier with data forwarding | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Cycles** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** | **29** |
| 0 | **MUL R3 , R1 , R2** | **F** | **D** | **E1** | **E2** | **E3** | **E4** | **E5** | **E6** | **W** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | **ADD R5 , R4 , R3** |  | **F** | **D** | **-** | **-** | **-** | **-** | **-** | **E1** | **E2** | **E3** | **E4** | **W** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 2 | **ADD R6 , R4 , R1** |  |  | **F** | **-** | **-** | **-** | **-** | **-** | **-** | **D** | **-** | **-** | **E1** | **E2** | **E3** | **E4** | **W** |  |  |  |  |  |  |  |  |  |  |  |  |
| 3 | **MUL R7 , R8 , R9** |  |  |  |  |  |  |  |  |  | **F** | **-** | **-** | **-** | **D** | **E1** | **E2** | **E3** | **E4** | **E5** | **E6** | **W** |  |  |  |  |  |  |  |  |
| 4 | **ADD R4 , R3 , R7** |  |  |  |  |  |  |  |  |  |  |  |  |  | **F** | **D** | **-** | **-** | **-** | **-** | **-** | **E1** | **E2** | **E3** | **E4** | **W** |  |  |  |  |
| 5 | **MUL R10 , R5 , R6** |  |  |  |  |  |  |  |  |  |  |  |  |  |  | **F** | **-** | **-** | **-** | **-** | **-** | **-** | **D** | **E1** | **E2** | **E3** | **E4** | **E5** | **E6** | **W** |