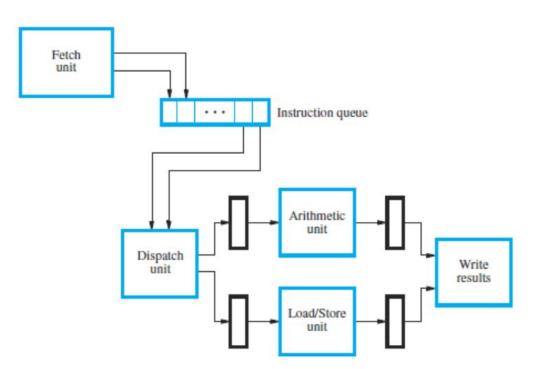
# Exercici 1.12

Considereu un programa que consisteix en 4 accessos a memòria i 4 instruccions aritmètiques. Assumiu que no hi ha caprisc de dependència de dades entre les instruccions. Dues versions d'aquest programa s'executaran en un processador superescalar com el de la Figura 4.



|     | 1   | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|-----|-----|---|---|---|---|---|---|---|---|----|----|
| MEM | IF  |   |   |   |   |   |   |   |   |    |    |
| MEM | IIF |   |   |   |   |   |   |   |   |    |    |
| MEM |     |   |   |   |   |   |   |   |   |    |    |
| MEM |     |   |   |   |   |   |   |   |   |    |    |
| ALU |     |   |   |   |   |   |   |   |   |    |    |
| ALU |     |   |   |   |   |   |   |   |   |    |    |
| ALU |     |   |   |   |   |   |   |   |   |    |    |
| ALU |     |   |   |   |   |   |   |   |   |    |    |

|     | 1  | 2   | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|-----|----|-----|---|---|---|---|---|---|---|----|----|
| MEM | IF | IQ  |   |   |   |   |   |   |   |    |    |
| MEM | IF | IQ  |   |   |   |   |   |   |   |    |    |
| MEM |    | IF  |   |   |   |   |   |   |   |    |    |
| MEM |    | IIF |   |   |   |   |   |   |   |    |    |
| ALU |    |     |   |   |   |   |   |   |   |    |    |
| ALU |    |     |   |   |   |   |   |   |   |    |    |
| ALU |    |     |   |   |   |   |   |   |   |    |    |
| ALU |    |     |   |   |   |   |   |   |   |    |    |

|     | 1   | 2   | 3   | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|-----|-----|-----|-----|---|---|---|---|---|---|----|----|
| MEM | IF  | IQ  | DU  |   |   |   |   |   |   |    |    |
| MEM | IIF | IQ  | БО  |   |   |   |   |   |   |    |    |
| MEM |     | IF  | IQ  |   |   |   |   |   |   |    |    |
| MEM |     | IF. | IQ  |   |   |   |   |   |   |    |    |
| ALU |     |     | IF  |   |   |   |   |   |   |    |    |
| ALU |     |     | IIF |   |   |   |   |   |   |    |    |
| ALU |     |     |     |   |   |   |   |   |   |    |    |
| ALU |     |     |     |   |   |   |   |   |   |    |    |

|     | 1  | 2   | 3   | 4    | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|-----|----|-----|-----|------|---|---|---|---|---|----|----|
| MEM | IF | IQ  | DU  | MEM  |   |   |   |   |   |    |    |
| MEM | IF | IQ  | БО  | -    |   |   |   |   |   |    |    |
| MEM |    | IF  | IQ  | DU   |   |   |   |   |   |    |    |
| MEM |    | IIF | IQ  |      |   |   |   |   |   |    |    |
| ALU |    |     | IF  | IQ   |   |   |   |   |   |    |    |
| ALU |    |     | IIF | IQ   |   |   |   |   |   |    |    |
| ALU |    |     |     | IF   |   |   |   |   |   |    |    |
| ALU |    |     |     | I IF |   |   |   |   |   |    |    |

|     | 1   | 2  | 3  | 4    | 5   | 6 | 7 | 8 | 9 | 10 | 11 |
|-----|-----|----|----|------|-----|---|---|---|---|----|----|
| MEM | IF  | IQ | DU | MEM  | WB  |   |   |   |   |    |    |
| MEM | IIF | IQ | БО | -    | MEM |   |   |   |   |    |    |
| MEM |     | IF | IQ | DU   | -   |   |   |   |   |    |    |
| MEM |     | II | IQ |      | DU  |   |   |   |   |    |    |
| ALU |     |    | IF | IQ   | -   |   |   |   |   |    |    |
| ALU |     |    | IF | IQ   | -   |   |   |   |   |    |    |
| ALU |     |    |    | IF   | IQ  |   |   |   |   |    |    |
| ALU |     |    |    | I IF | IQ  |   |   |   |   |    |    |

|     | 1   | 2   | 3   | 4    | 5   | 6   | 7 | 8 | 9 | 10 | 11 |
|-----|-----|-----|-----|------|-----|-----|---|---|---|----|----|
| MEM | IF  | IQ  | DU  | MEM  | WB  |     |   |   |   |    |    |
| MEM | IIF | IQ  | БО  | -    | MEM | WB  |   |   |   |    |    |
| MEM |     | IF  | IQ  | DU   | -   | MEM |   |   |   |    |    |
| MEM |     | IIF | IQ  |      | DU  | -   |   |   |   |    |    |
| ALU |     |     | IF  | 10   | -   | DU  |   |   |   |    |    |
| ALU |     |     | IIF | IQ   | -   | -   |   |   |   |    |    |
| ALU |     |     |     | IF   | 10  | -   |   |   |   |    |    |
| ALU |     |     |     | I IF | IQ  | -   |   |   |   |    |    |

|     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8 | 9 | 10 | 11 |
|-----|-----|-----|-----|-----|-----|-----|-----|---|---|----|----|
| MEM | IF  | IQ  | DU  | MEM | WB  |     |     |   |   |    |    |
| MEM | IIF | IQ  | БО  | -   | MEM | WB  |     |   |   |    |    |
| MEM |     | IF  | 10  | DU  | -   | MEM | WB  |   |   |    |    |
| MEM |     | IIF | IQ  |     | DU  | -   | MEM |   |   |    |    |
| ALU |     |     | IF  | 10  | -   | DU  | ALU |   |   |    |    |
| ALU |     |     | IIF | IQ  | -   | -   | DU  |   |   |    |    |
| ALU |     |     |     | IF  | 10  | -   | DU  |   |   |    |    |
| ALU |     |     |     | IF. | IQ  | -   | -   |   |   |    |    |

|     | 1   | 2  | 3   | 4   | 5   | 6   | 7   | 8   | 9 | 10 | 11 |
|-----|-----|----|-----|-----|-----|-----|-----|-----|---|----|----|
| MEM | IF  | IQ | DII | MEM | WB  |     |     |     |   |    |    |
| MEM | IIF | IQ | DU  | -   | MEM | WB  |     |     |   |    |    |
| MEM |     | ır | 10  | DU  | -   | MEM | WB  |     |   |    |    |
| MEM |     | IF | IQ  |     | DU  | -   | MEM | WD  |   |    |    |
| ALU |     |    | ır  | 10  | -   | DU  | ALU | WB  |   |    |    |
| ALU |     |    | IF  | IQ  | -   | -   | DU  | ALU |   |    |    |
| ALU |     |    |     | ır  | 10  | -   | DU  | -   |   |    |    |
| ALU |     |    |     | IF  | IQ  | -   | -   | DU  |   |    |    |

|     | 1  | 2  | 3   | 4   | 5   | 6   | 7   | 8    | 9   | 10 | 11 |
|-----|----|----|-----|-----|-----|-----|-----|------|-----|----|----|
| MEM | IF | IQ | DU  | MEM | WB  |     |     |      |     |    |    |
| MEM | IF | IQ | БО  | -   | MEM | WB  |     |      |     |    |    |
| MEM |    | IF | 10  | DU  | -   | MEM | WB  |      |     |    |    |
| MEM |    | IF | IQ  |     | DU  | -   | MEM | \A/D |     |    |    |
| ALU |    |    | IF  | 10  | -   | DU  | ALU | WB   |     |    |    |
| ALU |    |    | IF. | IQ  | -   | -   | DU  | ALU  | WB  |    |    |
| ALU |    |    |     | ır  | 10  | -   | DU  | -    | ALU |    |    |
| ALU |    |    |     | IF  | IQ  | -   | -   | DU   | -   |    |    |

|     | 1   | 2   | 3  | 4   | 5   | 6   | 7   | 8    | 9   | 10  | 11 |
|-----|-----|-----|----|-----|-----|-----|-----|------|-----|-----|----|
| MEM | IF  | IQ  | DU | MEM | WB  |     |     |      |     |     |    |
| MEM | IIF | IQ  | D0 | -   | MEM | WB  |     |      |     |     |    |
| MEM |     | IF  | 10 | DU  | -   | MEM | WB  |      |     |     |    |
| MEM |     | IIT | IQ |     | DU  | -   | MEM | \A/D |     |     |    |
| ALU |     |     | IF | 10  | -   | DU  | ALU | WB   |     |     |    |
| ALU |     |     | IF | IQ  | -   | -   | DU  | ALU  | WB  |     |    |
| ALU |     |     |    | ı_  | 10  | -   | DU  | -    | ALU | WB  |    |
| ALU |     |     |    | IF  | IQ  | -   | -   | DU   | -   | ALU |    |

|     | 1   | 2  | 3  | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11 |
|-----|-----|----|----|-----|-----|-----|-----|-----|-----|-----|----|
| MEM | IF  | IQ | DU | MEM | WB  |     |     |     |     |     |    |
| MEM | IIF | IQ | D0 | -   | MEM | WB  |     |     |     |     |    |
| MEM |     | IF | 10 | DU  | -   | MEM | WB  |     |     |     |    |
| MEM |     | IF | IQ |     | DU  | -   | MEM | WD  |     |     |    |
| ALU |     |    | IF | 10  | -   | DU  | ALU | WB  |     |     |    |
| ALU |     |    | IF | IQ  | -   | -   | DU  | ALU | WB  |     |    |
| ALU |     |    |    | ır  | 10  | -   | DU  | -   | ALU | WB  |    |
| ALU |     |    |    | IF  | IQ  | -   | -   | DU  | -   | ALU | WB |

|     | 1  | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----|----|---|---|---|---|---|---|---|
| MEM | IF |   |   |   |   |   |   |   |
| ALU | 15 |   |   |   |   |   |   |   |
| MEM |    |   |   |   |   |   |   |   |
| ALU |    |   |   |   |   |   |   |   |
| MEM |    |   |   |   |   |   |   |   |
| ALU |    |   |   |   |   |   |   |   |
| MEM |    |   |   |   |   |   |   |   |
| ALU |    |   |   |   |   |   |   |   |

|     | 1   | 2   | 3 | 4 | 5 | 6 | 7 | 8 |
|-----|-----|-----|---|---|---|---|---|---|
| MEM | IF  | IQ  |   |   |   |   |   |   |
| ALU | IIF | IQ  |   |   |   |   |   |   |
| MEM |     | IF  |   |   |   |   |   |   |
| ALU |     | IF. |   |   |   |   |   |   |
| MEM |     |     |   |   |   |   |   |   |
| ALU |     |     |   |   |   |   |   |   |
| MEM |     |     |   |   |   |   |   |   |
| ALU |     |     |   |   |   |   |   |   |

|     | 1  | 2   | 3   | 4 | 5 | 6 | 7 | 8 |
|-----|----|-----|-----|---|---|---|---|---|
| MEM | IF | IQ  | DU  |   |   |   |   |   |
| ALU | IF | IQ  | D0  |   |   |   |   |   |
| MEM |    | IF  | 10  |   |   |   |   |   |
| ALU |    | IF. | IQ  |   |   |   |   |   |
| MEM |    |     | IF  |   |   |   |   |   |
| ALU |    |     | IF. |   |   |   |   |   |
| MEM |    |     |     |   |   |   |   |   |
| ALU |    |     |     |   |   |   |   |   |

|     | 1   | 2   | 3    | 4   | 5 | 6 | 7 | 8 |
|-----|-----|-----|------|-----|---|---|---|---|
| MEM | IF  | IQ  | DU   | MEM |   |   |   |   |
| ALU | IIF | IQ  | ЪО   | ALU |   |   |   |   |
| MEM |     | IF  | IQ   | DU  |   |   |   |   |
| ALU |     | IF. |      |     |   |   |   |   |
| MEM |     |     | ı.e. | IQ  |   |   |   |   |
| ALU |     |     | IF   |     |   |   |   |   |
| MEM |     |     |      | IF  |   |   |   |   |
| ALU |     |     |      | IF  |   |   |   |   |

|     | 1  | 2     | 3  | 4   | 5   | 6 | 7 | 8 |
|-----|----|-------|----|-----|-----|---|---|---|
| MEM | IF | IQ    | DU | MEM | WB  |   |   |   |
| ALU | IF | IQ    | БО | ALU | VVD |   |   |   |
| MEM |    | IF IQ | DU | MEM |     |   |   |   |
| ALU |    |       |    | ALU |     |   |   |   |
| MEM |    |       | ı. | IQ  | DU  |   |   |   |
| ALU |    |       | IF |     |     |   |   |   |
| MEM |    |       |    |     | 10  |   |   |   |
| ALU |    |       |    | IF  | IQ  |   |   |   |

|     | 1  | 2  | 3  | 4    | 5   | 6   | 7 | 8 |
|-----|----|----|----|------|-----|-----|---|---|
| MEM | IF | IQ | DU | MEM  | WB  |     |   |   |
| ALU | IF | IQ | БО | ALU  | VVD |     |   |   |
| MEM |    | IF | IQ | DU   | MEM | WB  |   |   |
| ALU |    | IF |    |      | ALU | VVD |   |   |
| MEM |    |    | IF | IQ D | DII | MEM |   |   |
| ALU |    |    |    |      | DU  | ALU |   |   |
| MEM |    |    |    | IF   | 10  | DU  |   |   |
| ALU |    |    |    | IF   | IQ  | טט  |   |   |

|     | 1  | 2     | 3    | 4   | 5   | 6   | 7    | 8 |
|-----|----|-------|------|-----|-----|-----|------|---|
| MEM | IF | IQ    | DU   | MEM | WB  |     |      |   |
| ALU | IF | IQ    | БО   | ALU | VVD |     |      |   |
| MEM |    | 15 10 | 10   | DU  | MEM | WB  |      |   |
| ALU |    | IF    | IQ   |     | ALU | VVD |      |   |
| MEM |    |       | ı.e. | 10  | DU  | MEM | - WB |   |
| ALU |    |       | IF   | IQ  |     | ALU |      |   |
| MEM |    |       |      | IE  | 10  | DU  | MEM  |   |
| ALU |    |       |      | IF  | IQ  |     | ALU  |   |

|     | 1   | 2   | 3     | 4    | 5    | 6     | 7    | 8   |
|-----|-----|-----|-------|------|------|-------|------|-----|
| MEM | IF  | IQ  | DU    | MEM  | \A/D |       |      |     |
| ALU | IIF | IQ. | 00    | ALU  | WB   |       |      |     |
| MEM |     | IF  | 10    | Q DU | MEM  | WB    |      |     |
| ALU |     | IF  | IQ    |      | ALU  |       |      |     |
| MEM |     |     | IF IC | 10   | DU   | MEM   | - WB |     |
| ALU |     |     |       | IQ   |      | ALU   |      |     |
| MEM |     |     |       | IF   | 10   | IQ DU | MEM  | WB  |
| ALU |     |     |       | IF.  | IQ   |       | ALU  | VVB |