Chapter Six
Pipelining

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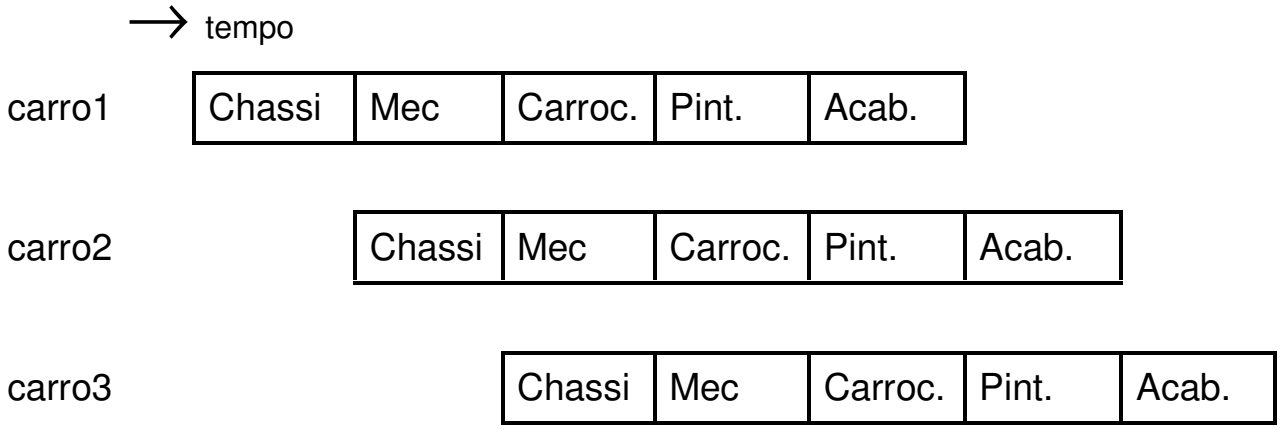
Pipelining: analogia com linha de produção



- **Tempo de fabricação de um carro: C+M+C+P+A**
- **Taxa de produção (carros/h): medido na saída**
  - **throughput: depende do número de estágios e do balanceamento**

- **Objetivo do pipeline:**
  - **distribuir e balancear o tempo em cada estágio**
  - **otimizar o uso de HW dos estágios (taxa de ocupação)**
  - **resumo: aumentar a velocidade e diminuir o hardware**

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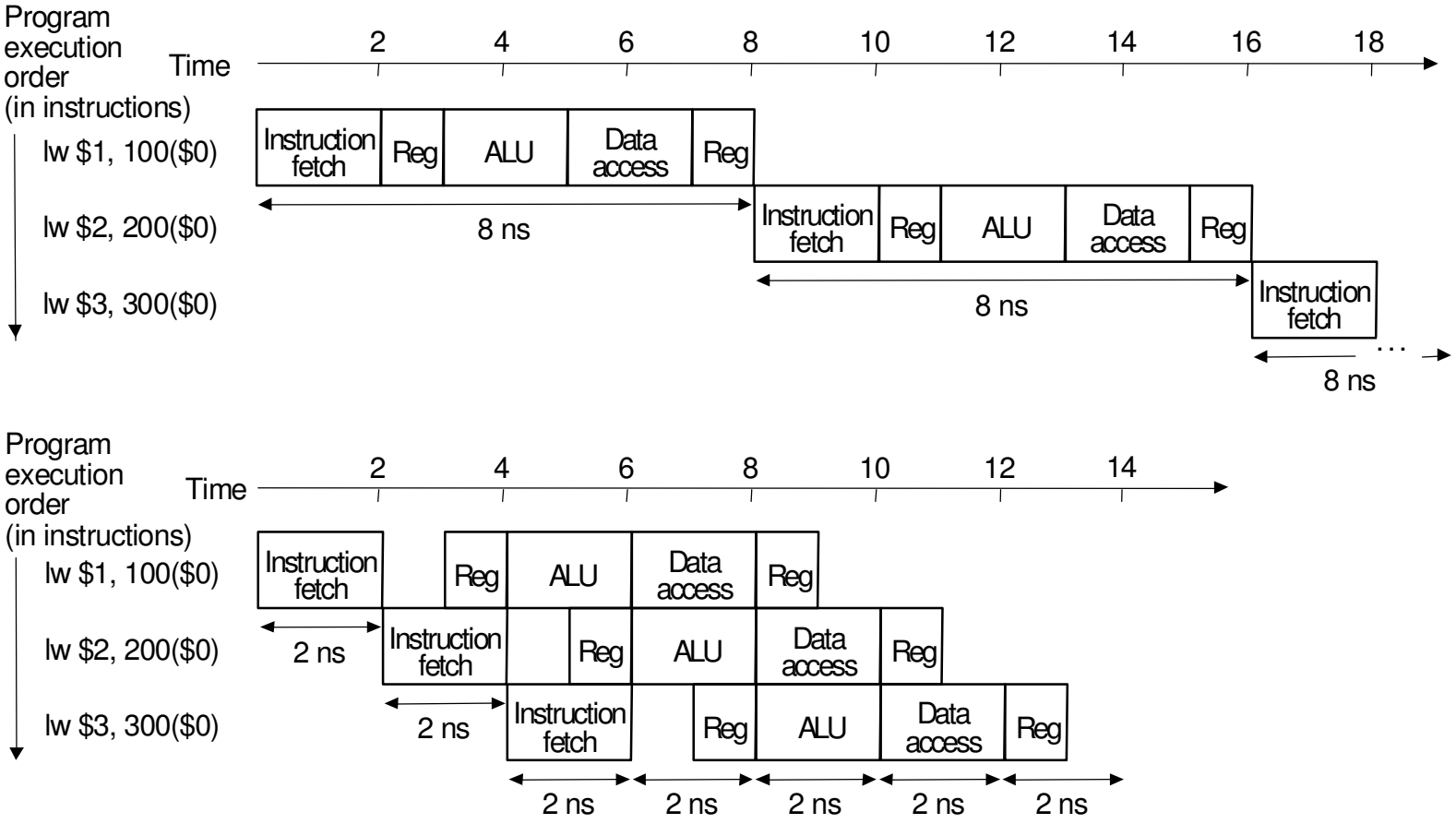
- **Improve perfomance by increasing instruction throughput**



- **tempo de execução de uma instrução: 8 ns e 9 ns (com ou sem pipe)**
- **throughput: 1 instr / 8ns (sem pipeline) ou 1 instr / 2 ns (com)**
- **# de estágios = 5; ganho de 4:1; para obter 5:1 ??**

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Pipelining

- What makes it easy
  - all instructions are the same length
  - just a few instruction formats
  - memory operands appear only in loads and stores
- What makes it hard?
  - structural hazards: suppose we had only one memory
  - control hazards: need to worry about branch instructions
  - data hazards: an instruction depends on a previous instruction
- We'll build a simple pipeline and look at these issues
- We'll talk about modern processors and what really makes it hard:
  - exception handling
  - trying to improve performance with out-of-order execution, etc.

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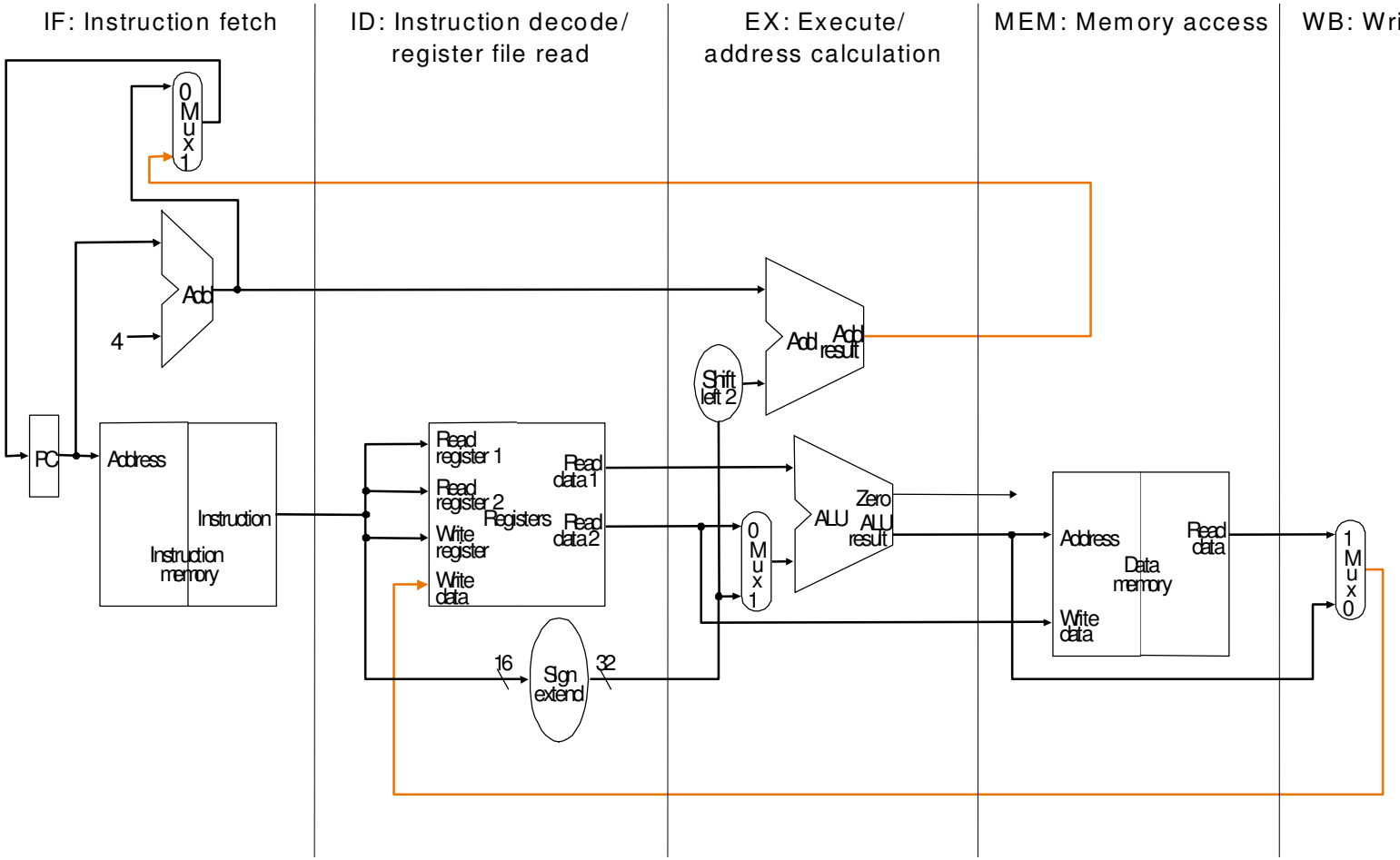
Basic Idea



- ***What do we need to add to actually split the datapath into stages?***

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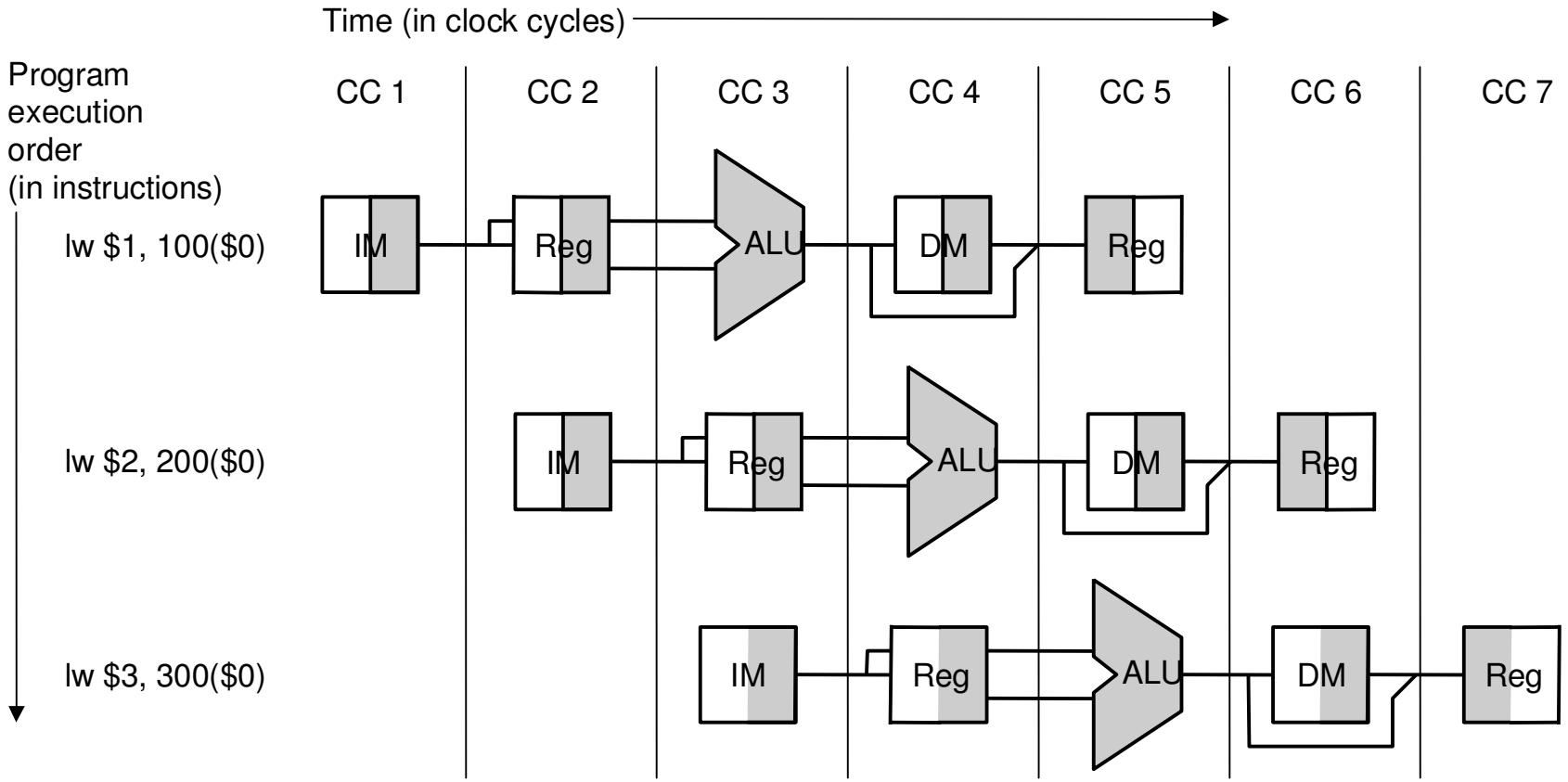
Uma representação para o pipeline



- **Hachurado representa "atividade"**
- **Representação alternativa: imaginando que cada instrução tenha a sua própria via de dados**
- **Outra representação: foto no tempo**

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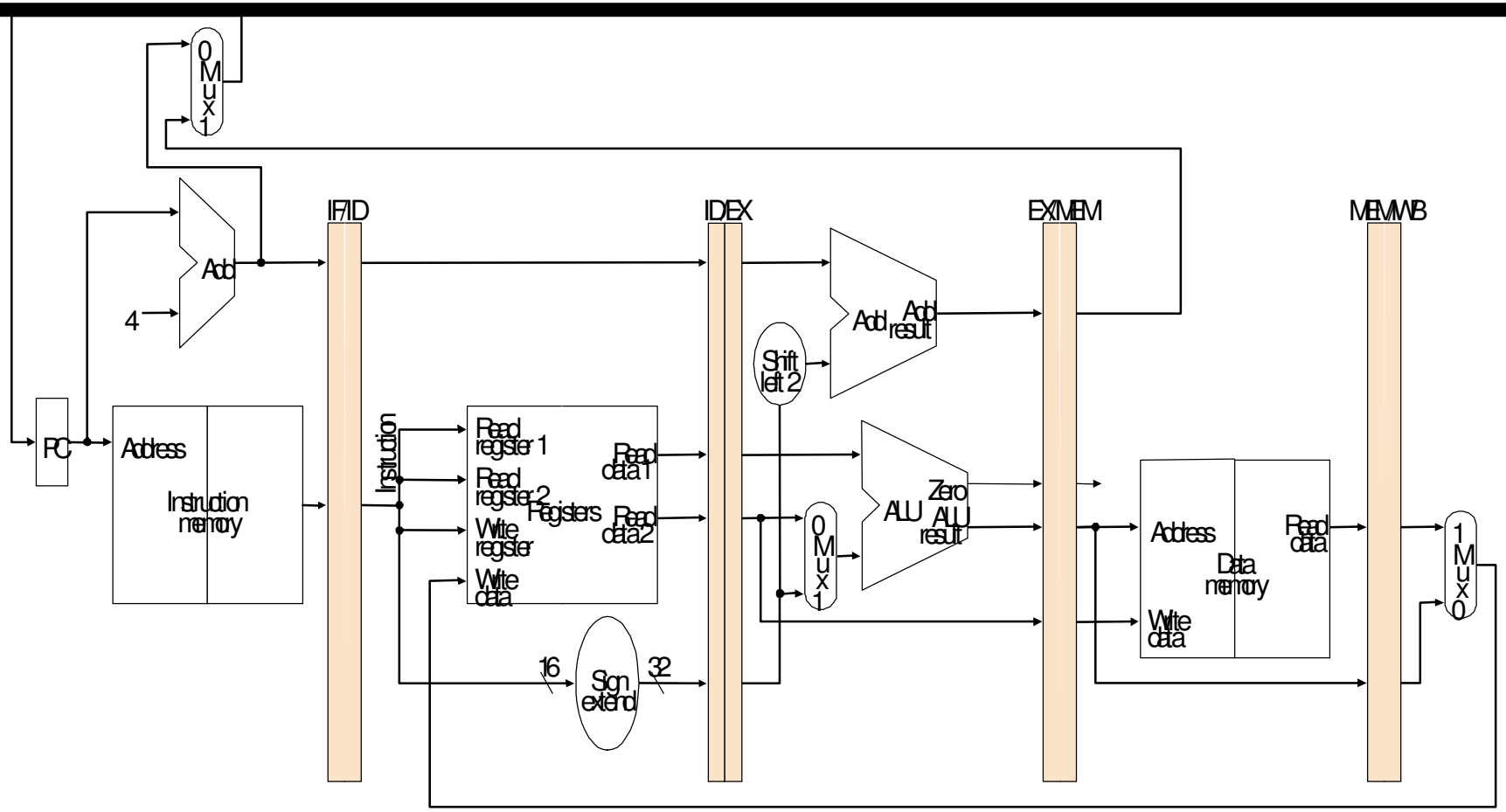
Pipelined Datapath



- **O que é produzido em cada estágio é armazenado em um registrador de pipeline para uso pelo próximo estágio**
- **Problemas com o endereço do registrador de escrita?? Caminhando para esquerda?**

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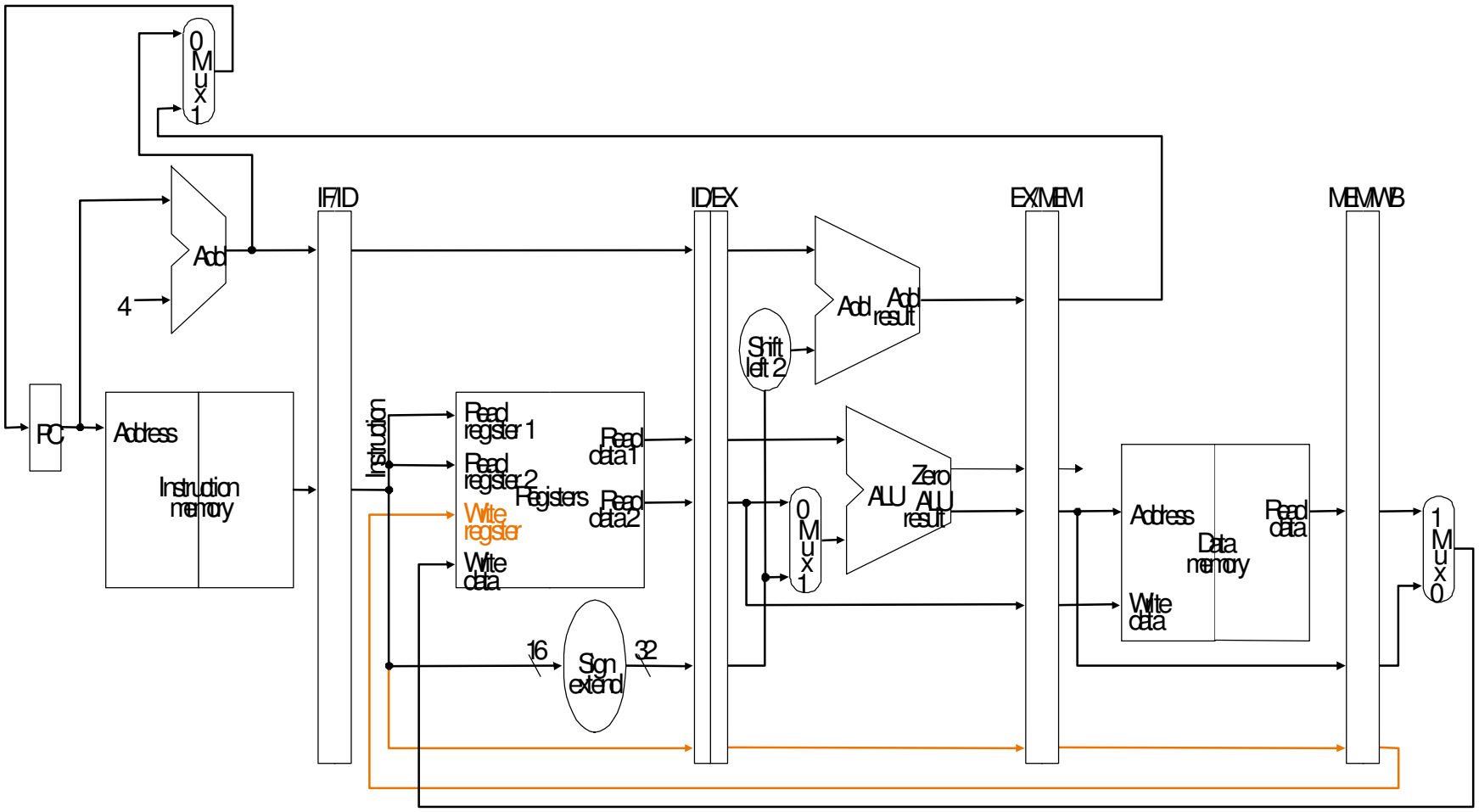
Corrected Datapath



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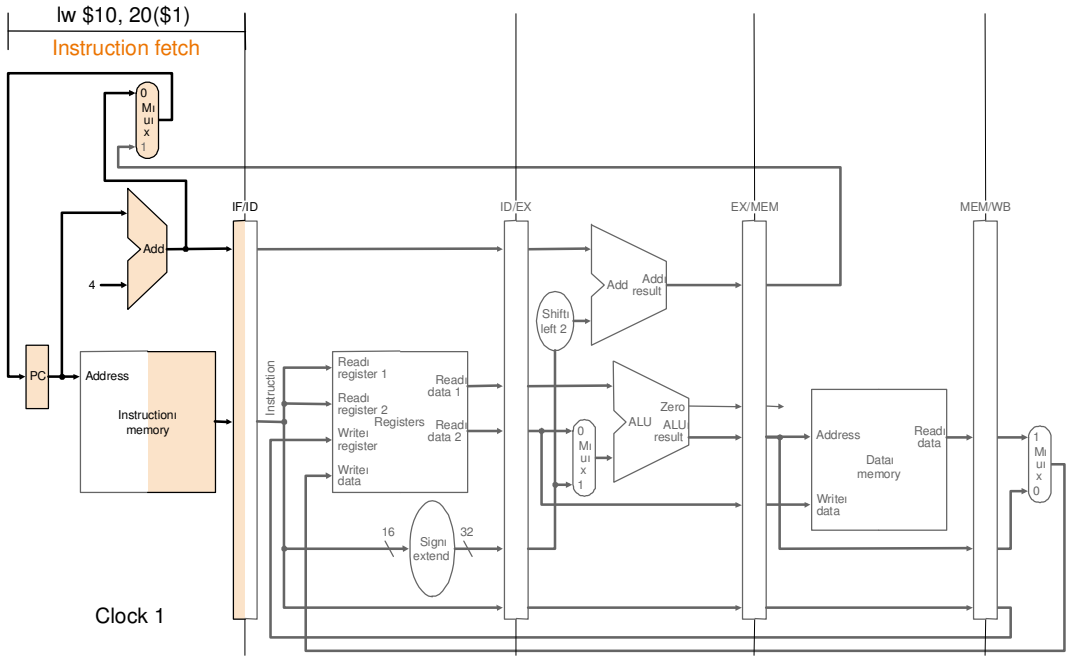
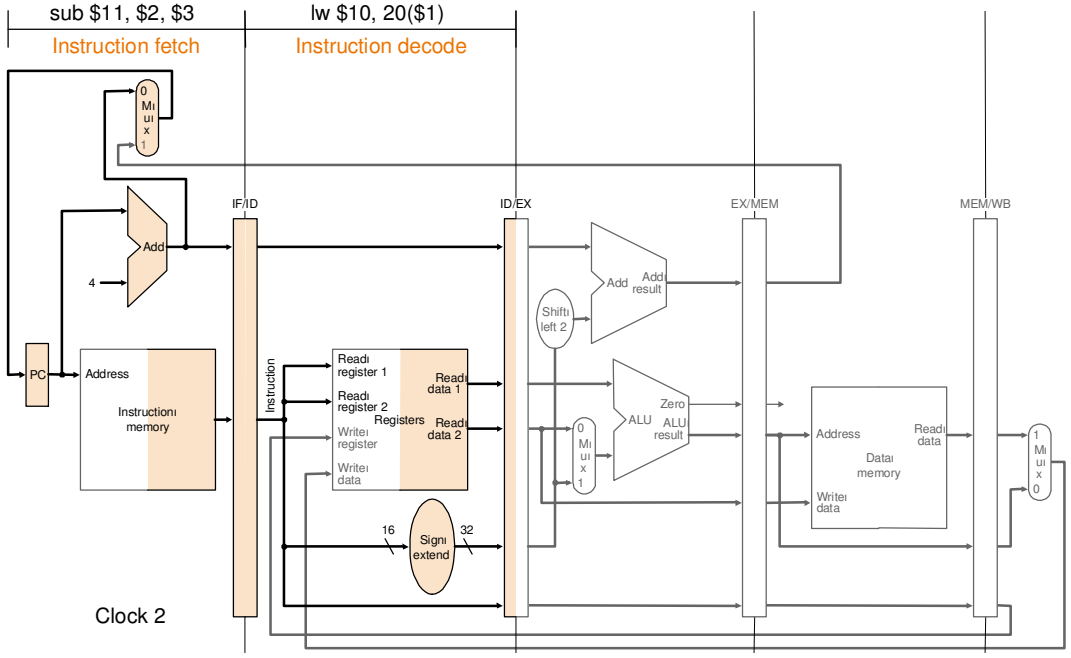
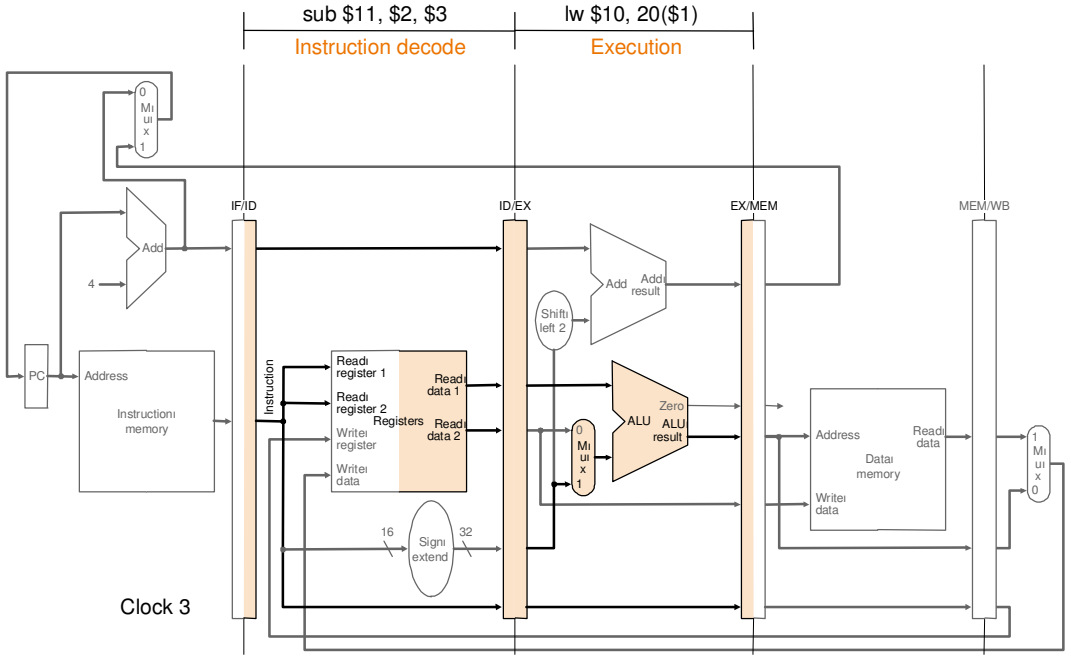
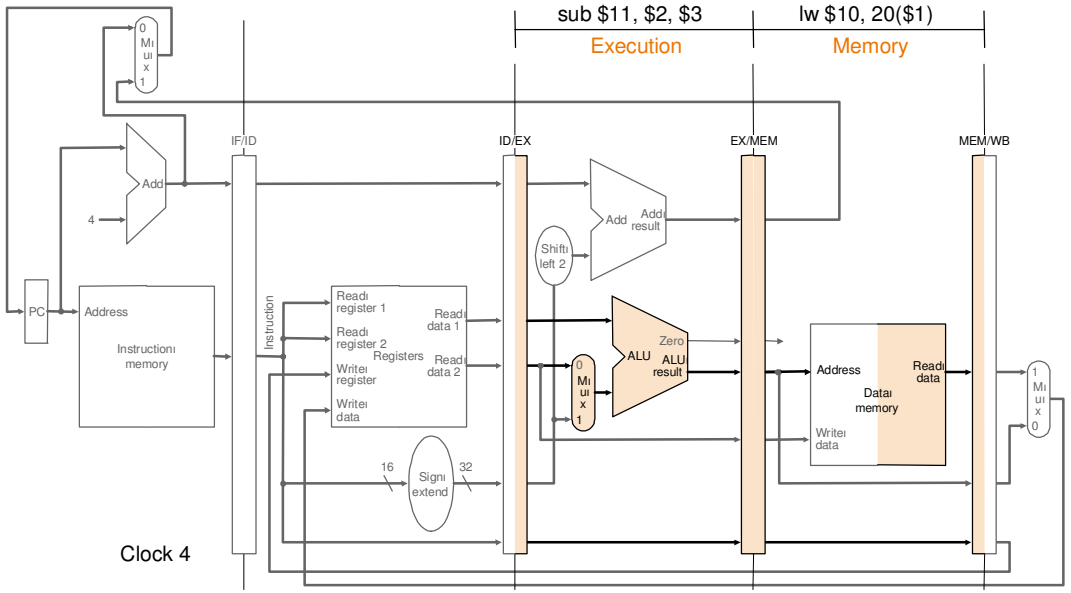
Exemplo com sub e lw (1)



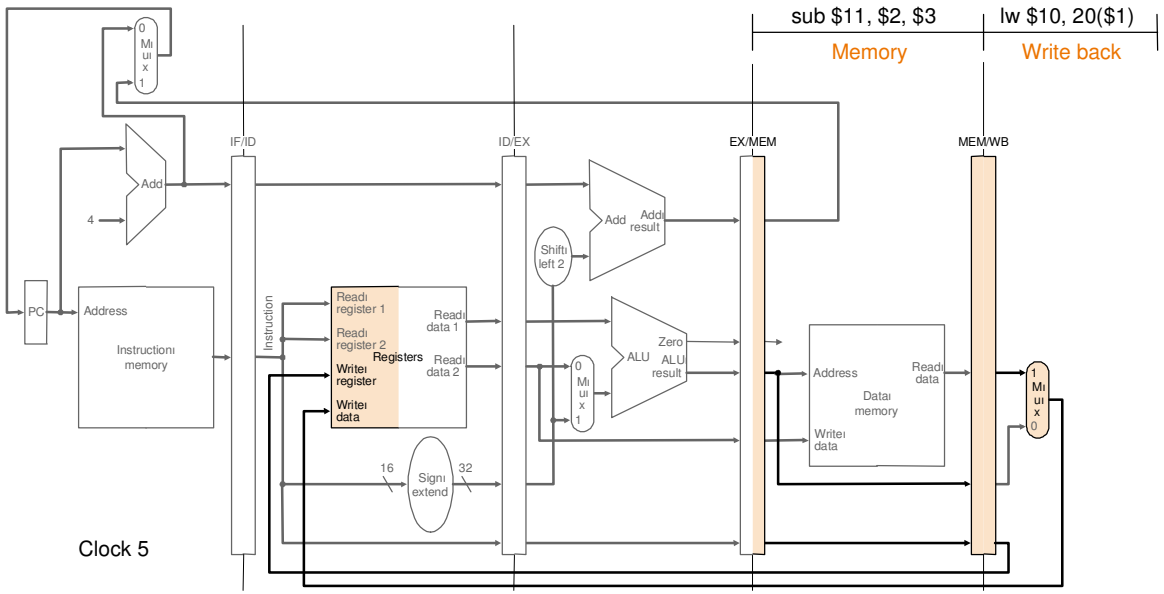


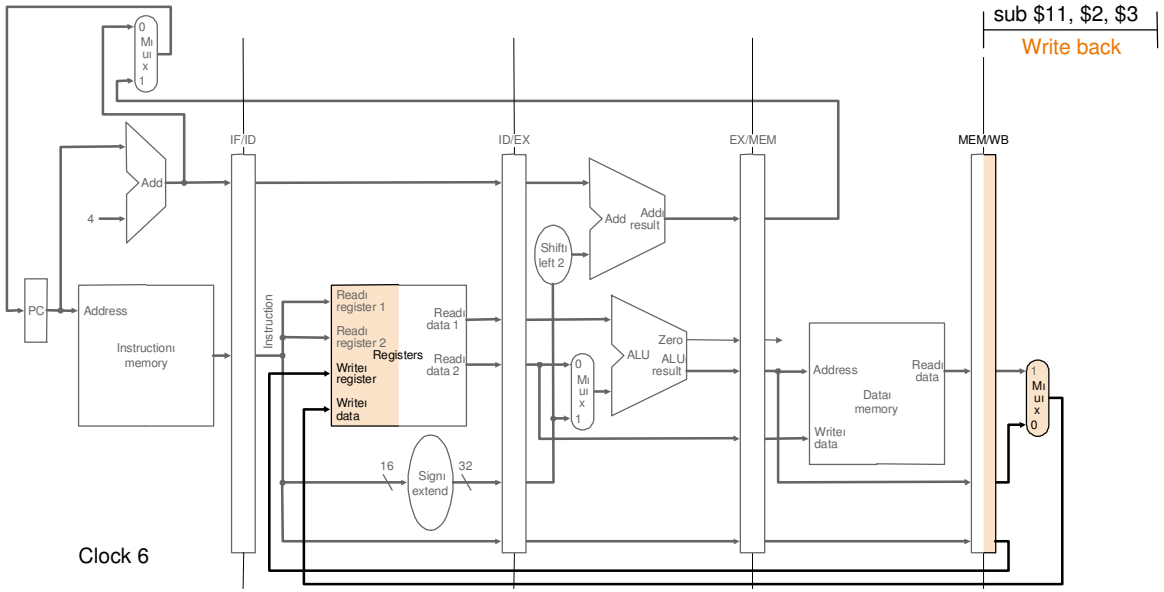
Exemplo com sub e lw (2)



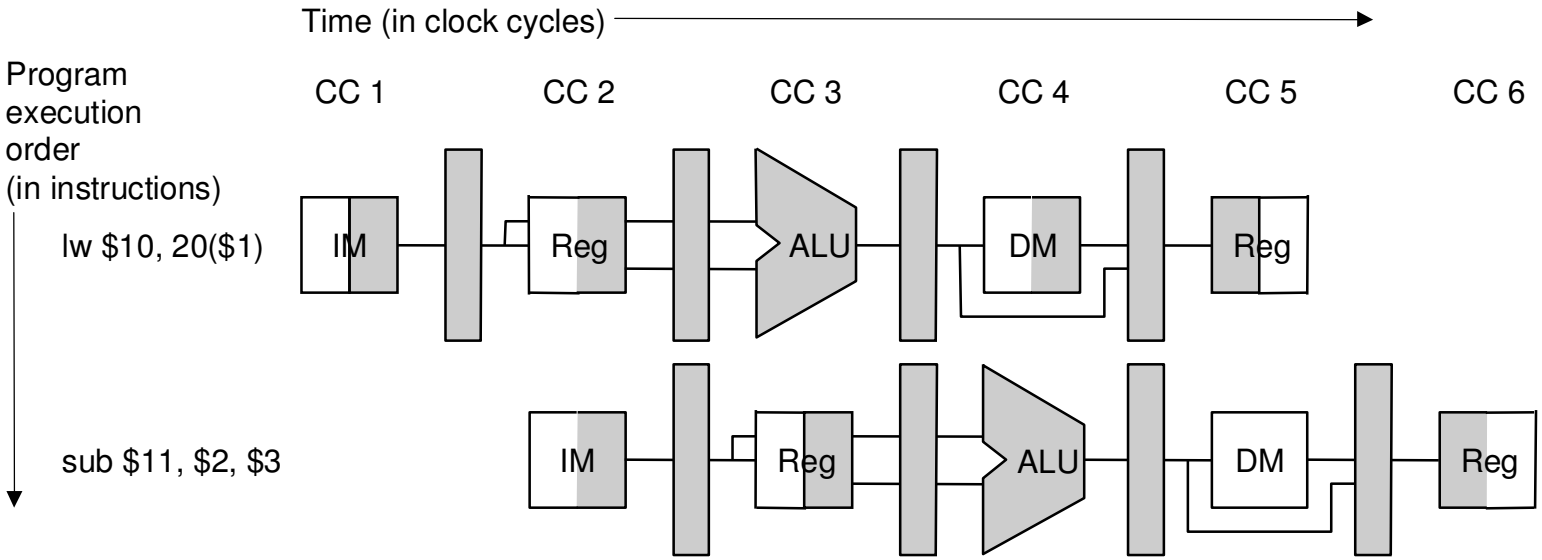


Exemplo com sub e lw (3)





Graphically Representing Pipelines



- **Can help with answering questions like:**
  - **how many cycles does it take to execute this code?**
  - **what is the ALU doing during cycle 4?**
  - **use this representation to help understand datapaths**

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