Chapter 6 Pipelining

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Contents

Computer Organization & Architecture

6-1 Basic Concept

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Contents of this lecture

- Making the Execution of Programs Faster
- What is Pipelining?
- Car Assembly Line Example
- Pipelining a Processor
- Pipeline Terminology
- Pipeline Organization

Making the Execution of Programs Faster

- Two Ways
  - Use faster circuit technology to build the processor and the main memory.
  - Arrange the hardware so that more than one operation can be performed at the same time.
    - In the this way, the number of operations performed per second is increased even though the elapsed time needed to perform any one operation is not changed.

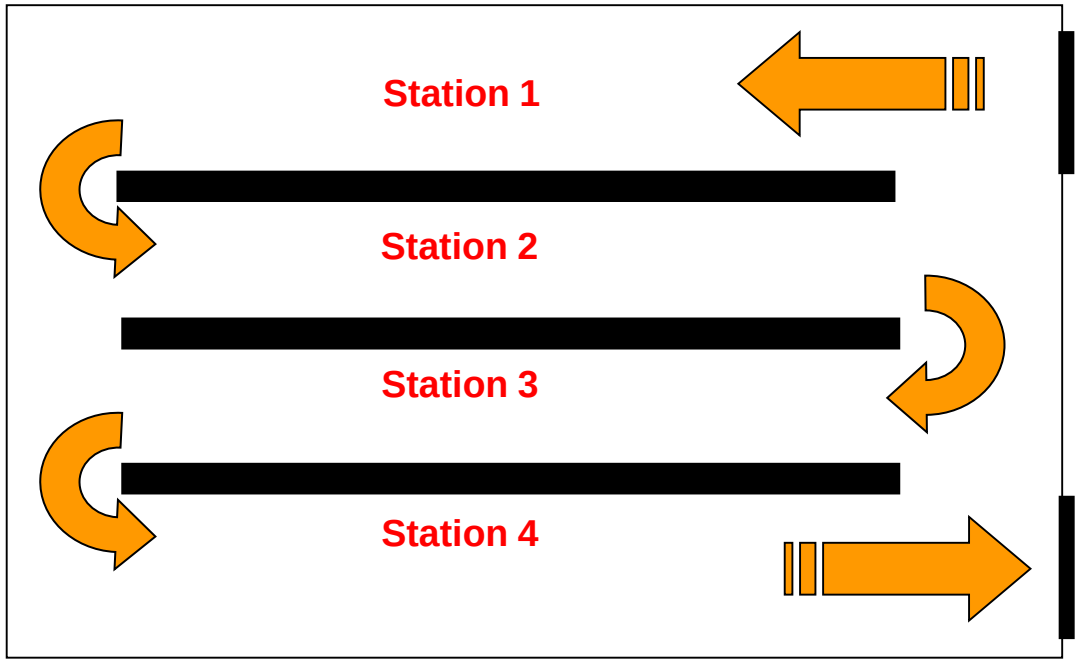
What is Pipelining?

- What is Pipelining?
  - Pipelining is a key implementation technique used to build fast processors. It allows the execution of multiple instructions to overlap in time.
- Key Idea
  - Overlap execution of multiple instructions
- Essence
  - Start executing one instruction before completing the previous one.

Car Assembly Line Example (1)

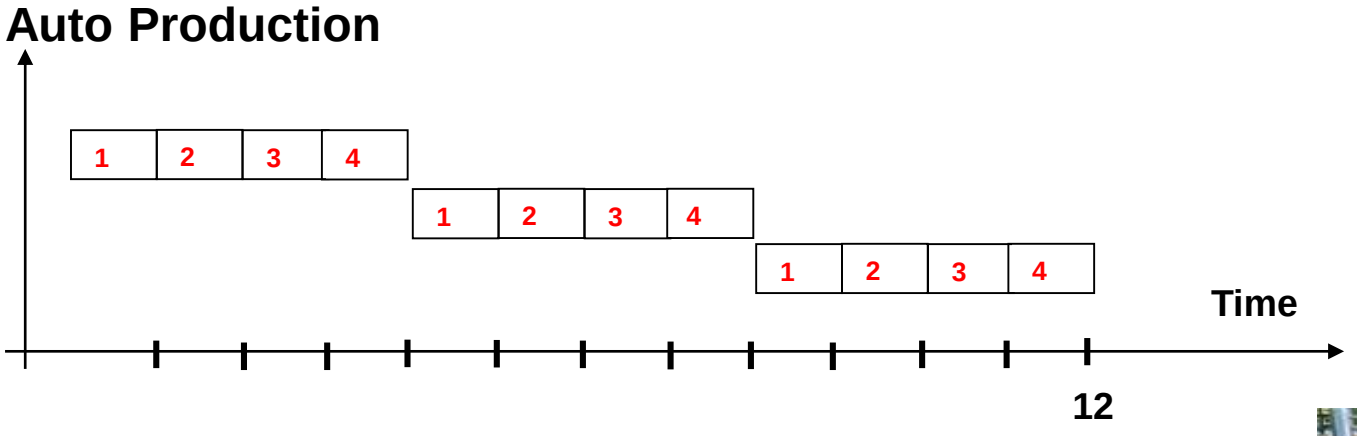
- A pipeline within a processor is similar to a car assembly line.
- Assume that there are 4 stations in a car assembly line:
  - 1. Prepare the automobile chassis
  - 2. Add the body
  - 3. Install the engine
  - 4. Install the other

  For simplicity, assume that each task takes one hour.

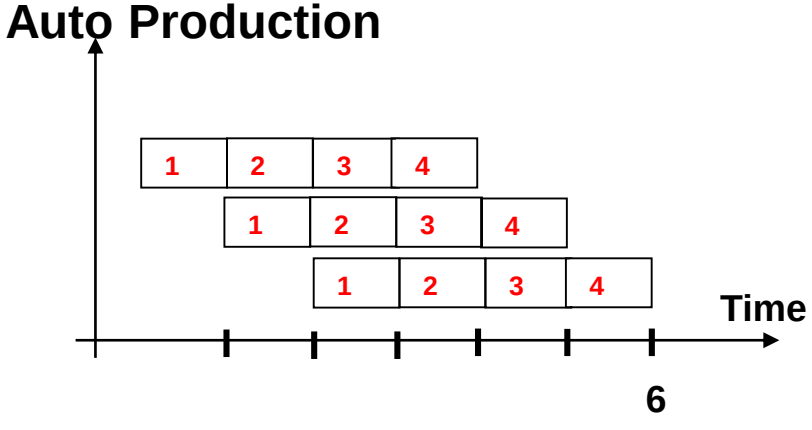


Car Assembly Line Example (2)

- Sequential Auto Production



- Pipelining Auto Production

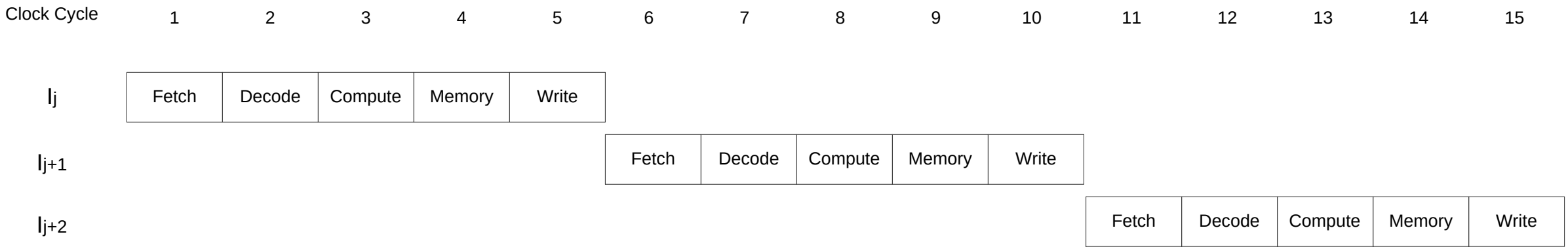


Pipelining a Processor (1)

- Recall the 5 steps in instruction execution (Figure 5.4)
  - 1.Instruction Fetch
  - 2.Instruction Decode and Register Read
  - 3.Execution operation or calculate address
  - 4.Memory access
  - 5.Write result into register

Pipelining a Processor (2)

- Unpipelined Execution



Pipelining a Processor (3)

- Pipelined Execution-The Ideal Case
  - Each instruction takes 1 clock cycle for each stage
  - The processor can accept 1 new instruction per clock
  - Instructions are processed in stages as they pass down
  - Multiple instructions in some phase of execution concurrently

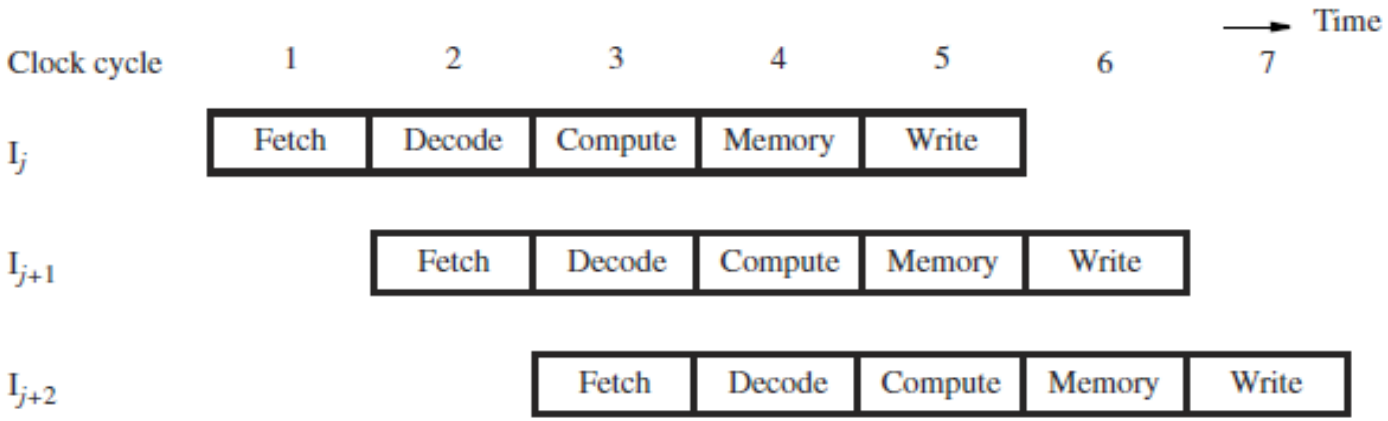


Figure 6.1 Pipelined execution—the ideal case.

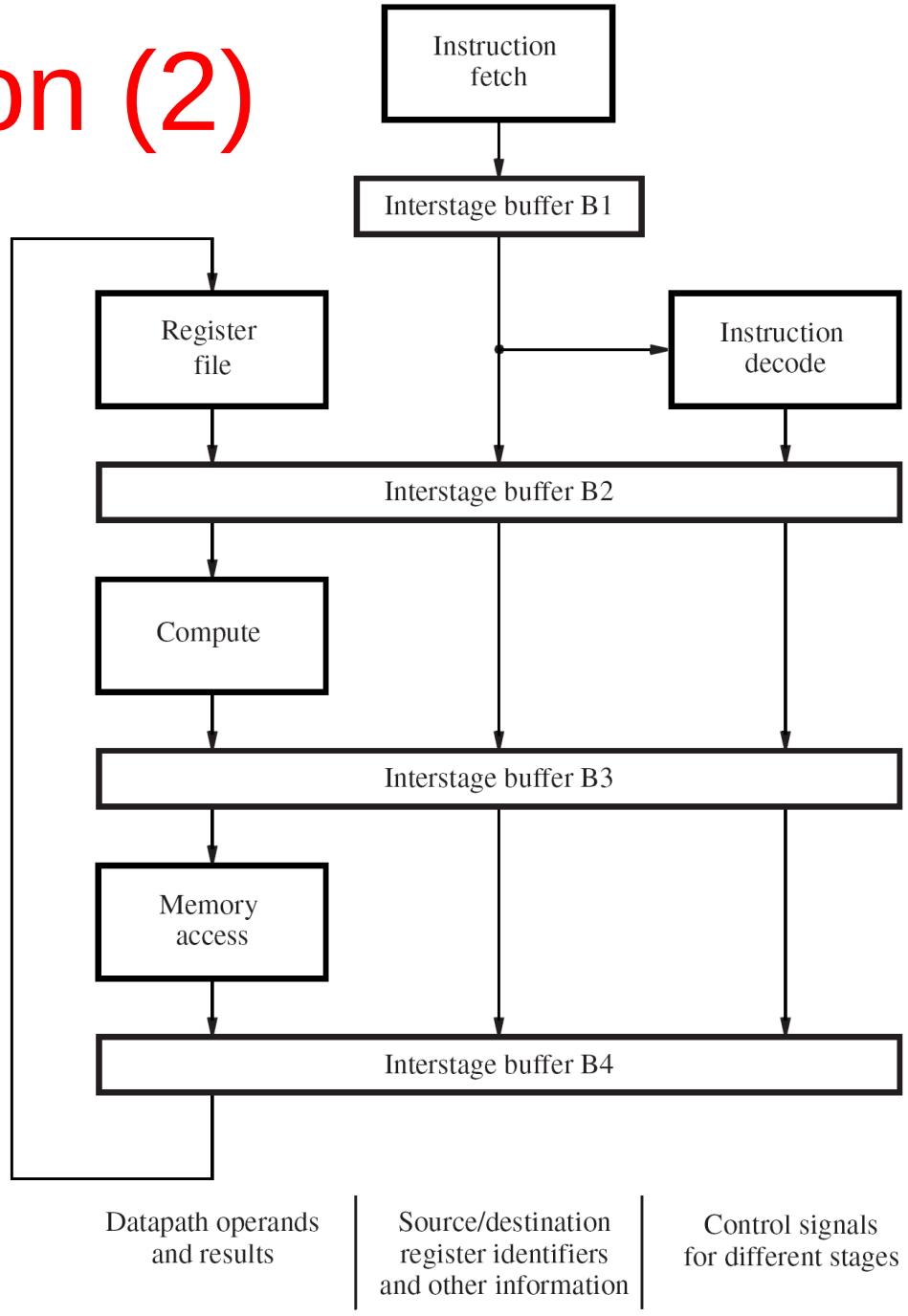
Pipelining Terminology

- Pipe Stage / Pipe Segment
  - A step in the pipeline to complete the instruction
- Pipeline Depth
  - Number of stages in a pipeline.
- Latency
  - How long does it take to execute a single instruction in a pipeline.
- Throughput
  - The number of instructions completed per second.

Pipelining Organization (1)

- Use program counter (PC) to fetch instructions
- A new instruction enters pipeline every cycle
- Carry along instruction-specific information as instructions flow through the different stages
- Use *interstage buffers* to hold this information
  - These buffers incorporate RA, RB, RM, RY, RZ, IR, and PC-Temp registers from Chapter 5
  - The buffers also hold control signal settings

Pipelining Organization (2)



Summary

- Pipelining doesn't improve the latency of instructions (each instruction still requires the same amount of time to complete).
- It reduces the average execution time per instruction.
- It does improve the overall throughput.

Quiz

1. What is the first stage in a typical five-stage CPU pipeline?

   A. Fetch B. Decode C. Compute D. Write

2. When multiple-instructions are overlapped during execution of program, then function performed is called ____.

   A. Multitasking B. Multiprogramming

   C. Hardwired control D. Pipelining

3. *Ture or False?* Pipelining increases processor performance by decreasing the execution time of an instruction.