PIPELINING: INTRODUCTION

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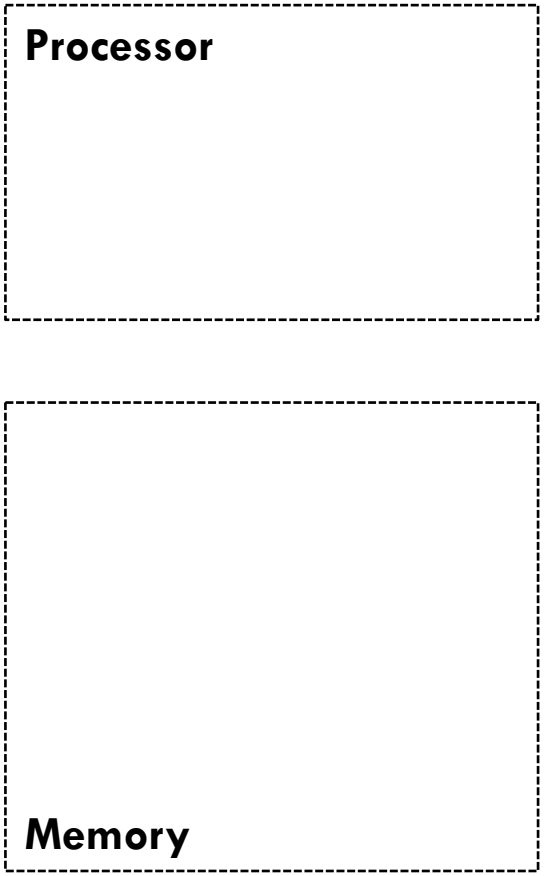
Overview

- Announcement
  - TA hours
    - Thursdays 11:00-1:00 (Payman)
    - Tuesdays 9:30-11:30 (Krunal Jain)
- This lecture
  - Processing instructions
  - Single-cycle architecture
  - Reusing resources
  - Pipelined architecture

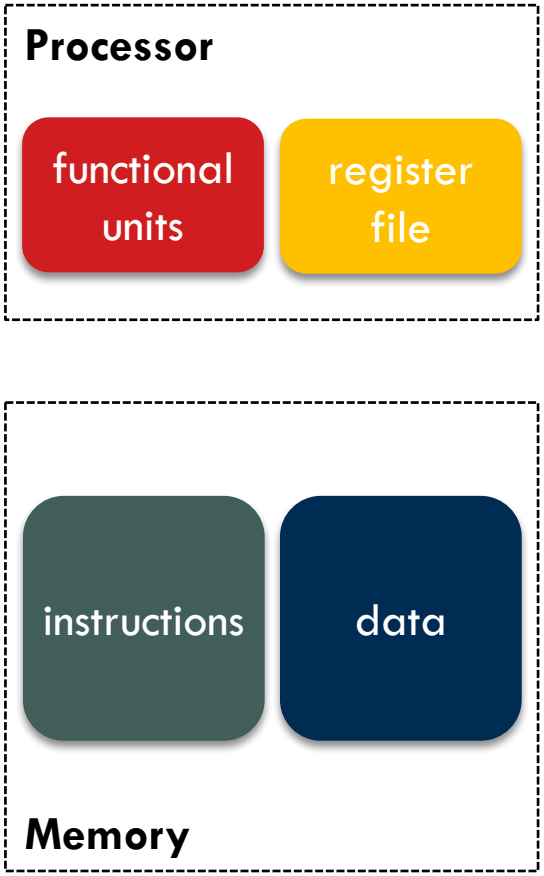
Processing Instructions

- Every RISC instruction may require multiple processing steps



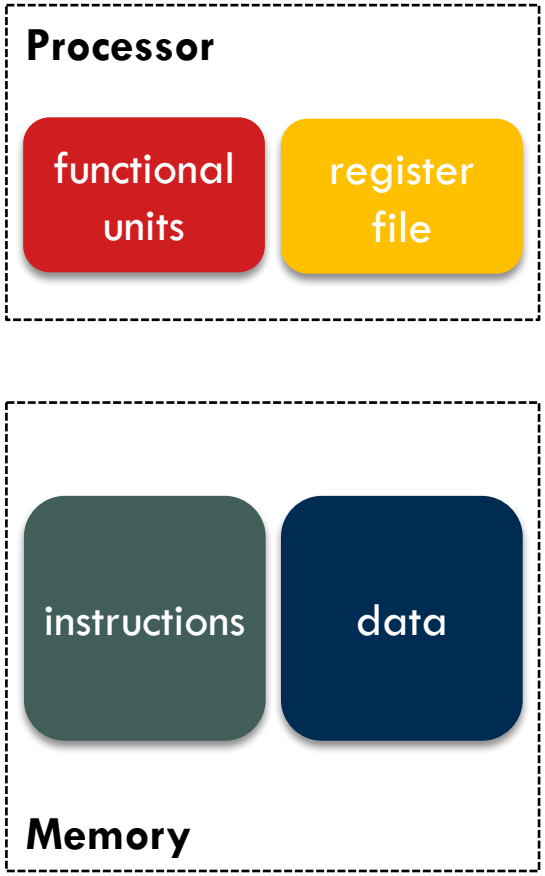
Processing Instructions

- Every RISC instruction may require multiple processing steps



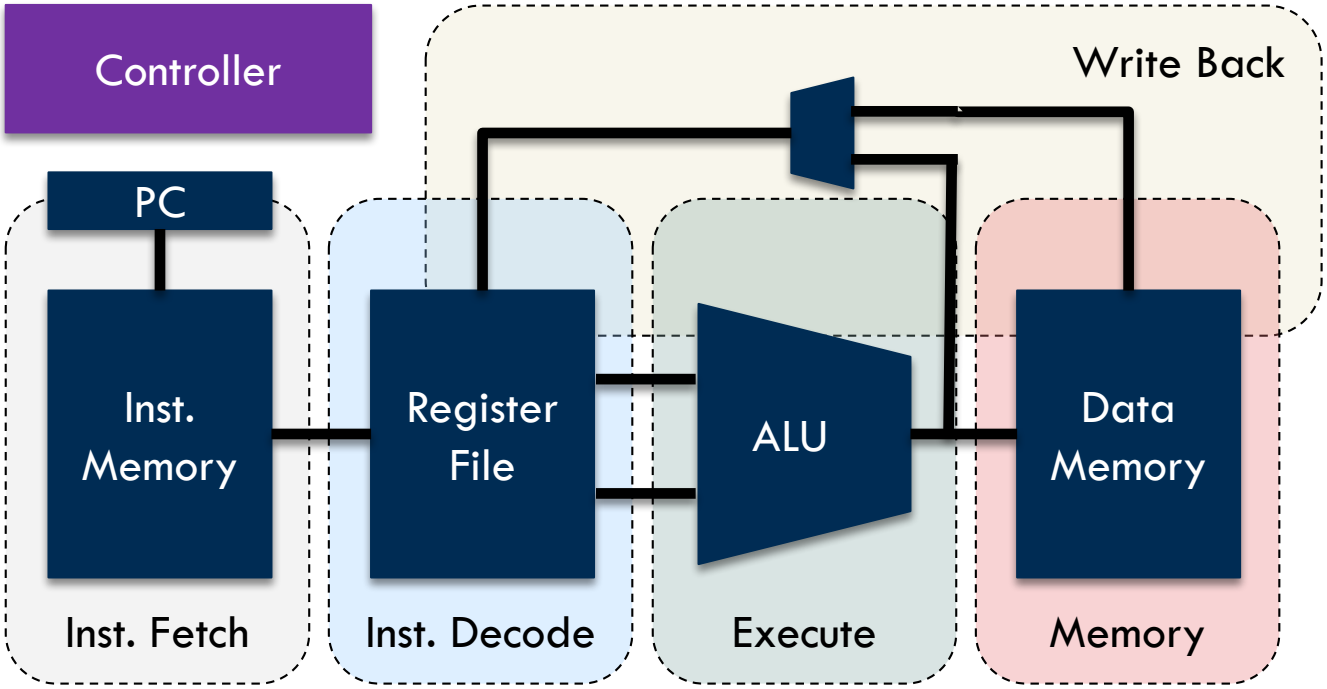
Processing Instructions

- Every RISC instruction may require multiple processing steps
  - Instruction Fetch (IF)
  - Instruction Decode (ID)
  - Register Read (RR)
    - All instructions?
  - Execute Instructions (EXE)
  - Memory Access (MEM)
    - All instructions?
  - Register Write Back (WB)



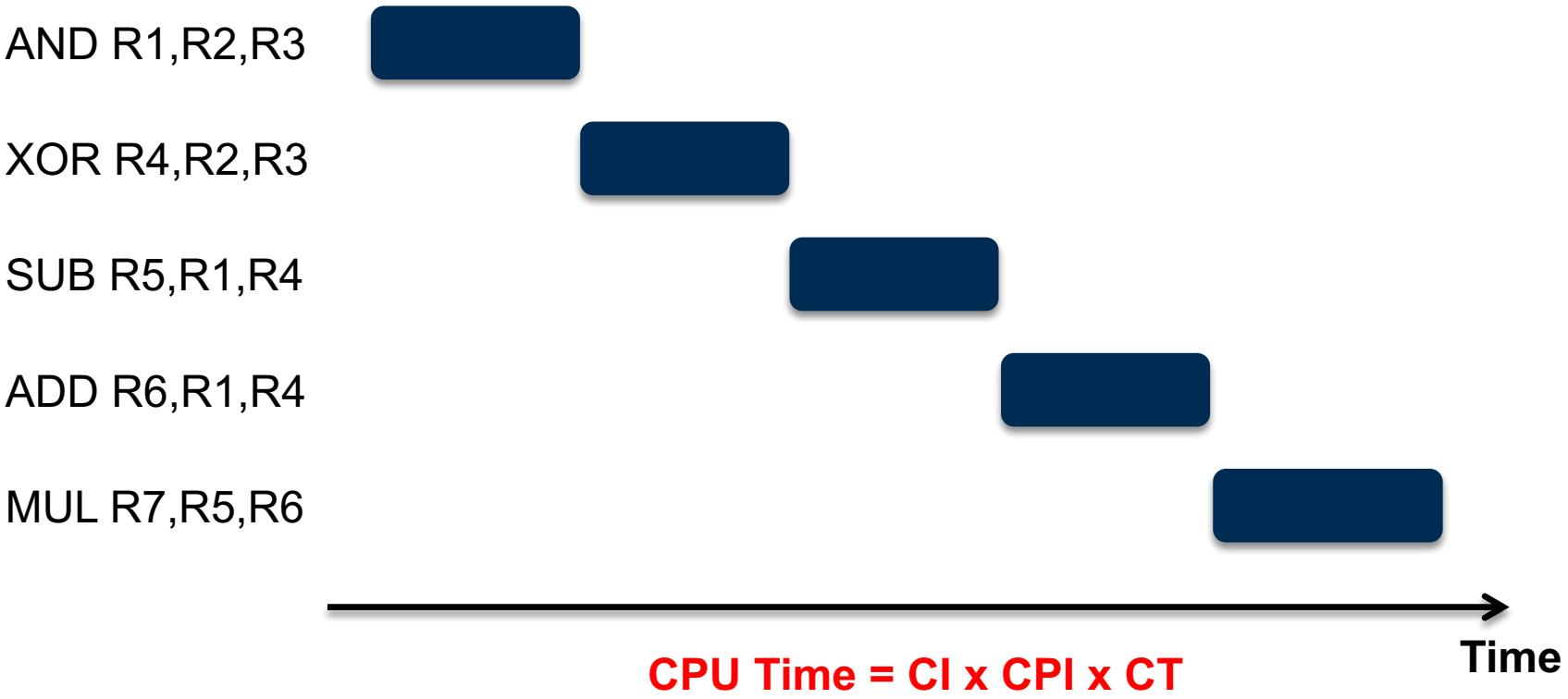
Single-cycle RISC Architecture

- Example: simple MIPS architecture
  - Critical path includes all of the processing steps



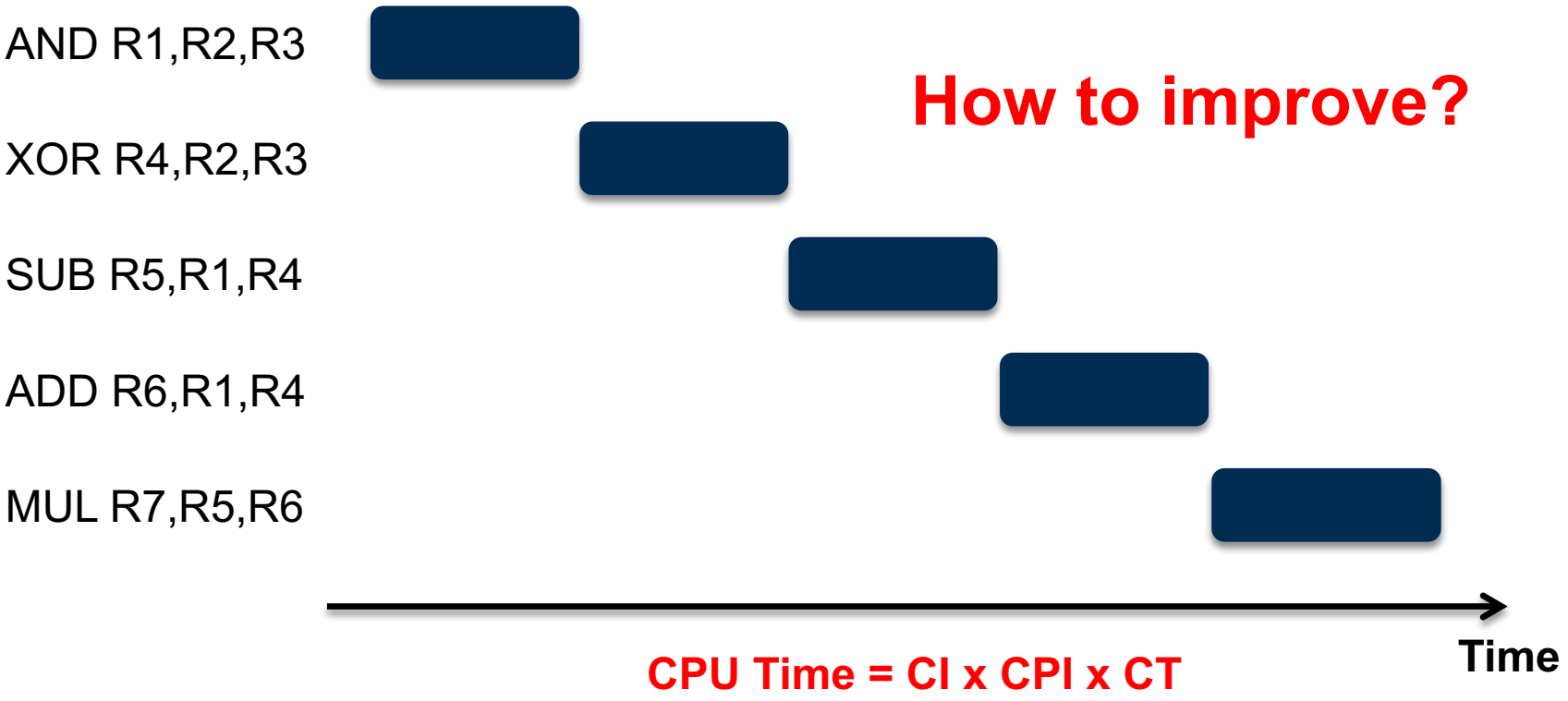
Single-cycle RISC Architecture

- Example program
  - CT=6ns; CPU Time = ?



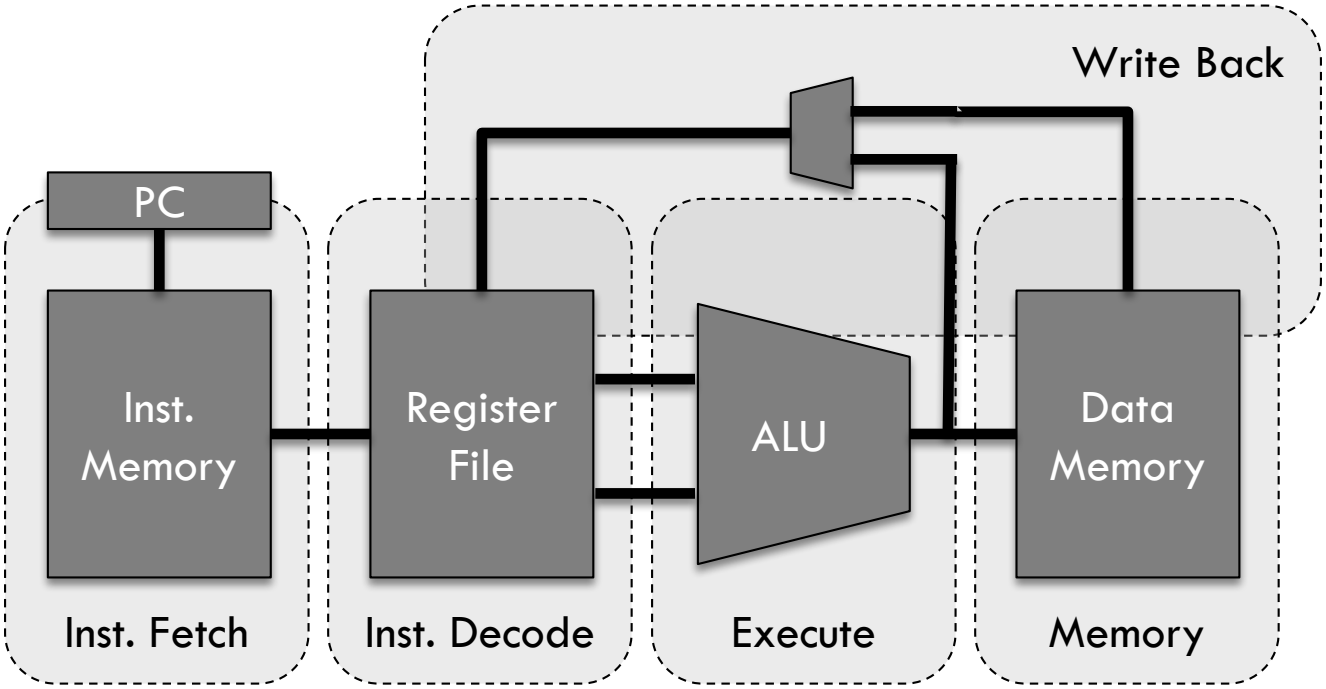
Single-cycle RISC Architecture

- Example program
  - CT=6ns; CPU Time = 5 x 1 x 6ns = 30ns



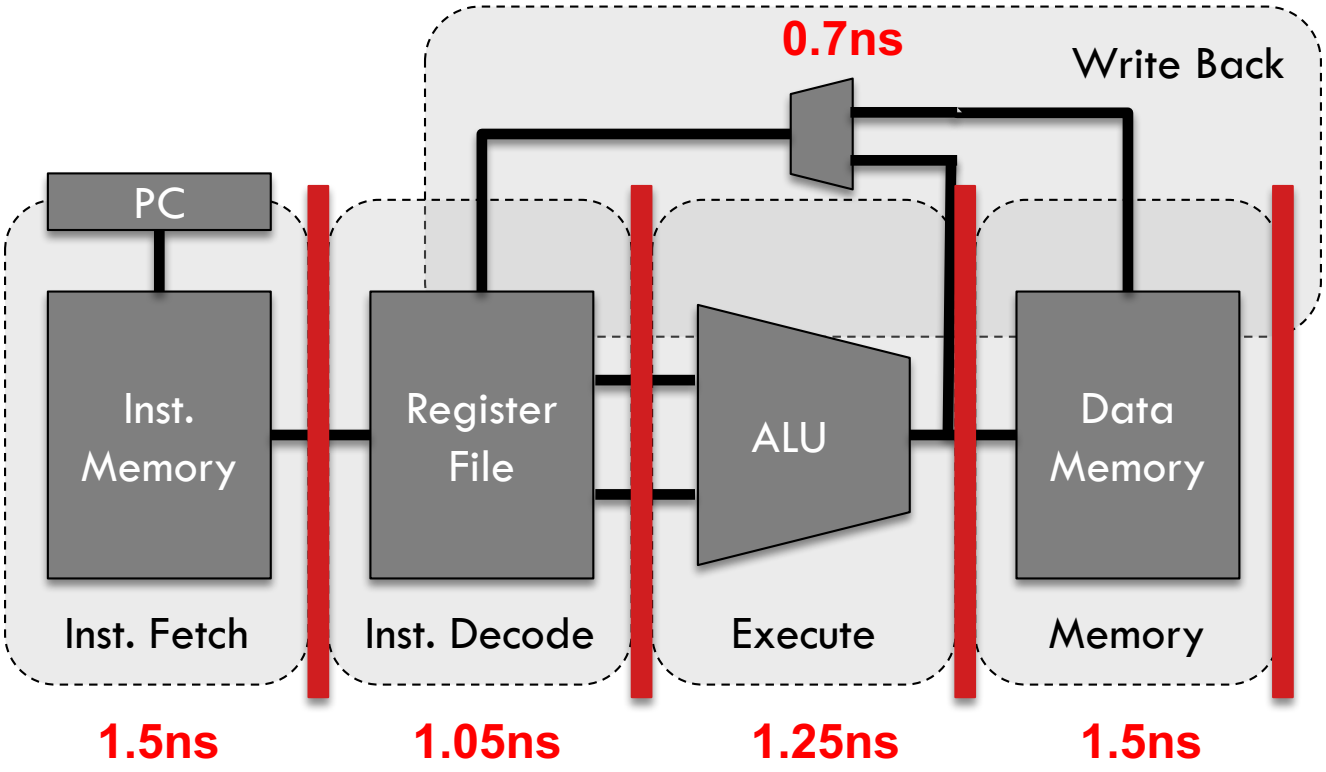
Reusing Idle Resources

- Each processing step finishes in a fraction of a cycle
  - Idle resources can be reused for processing next instructions



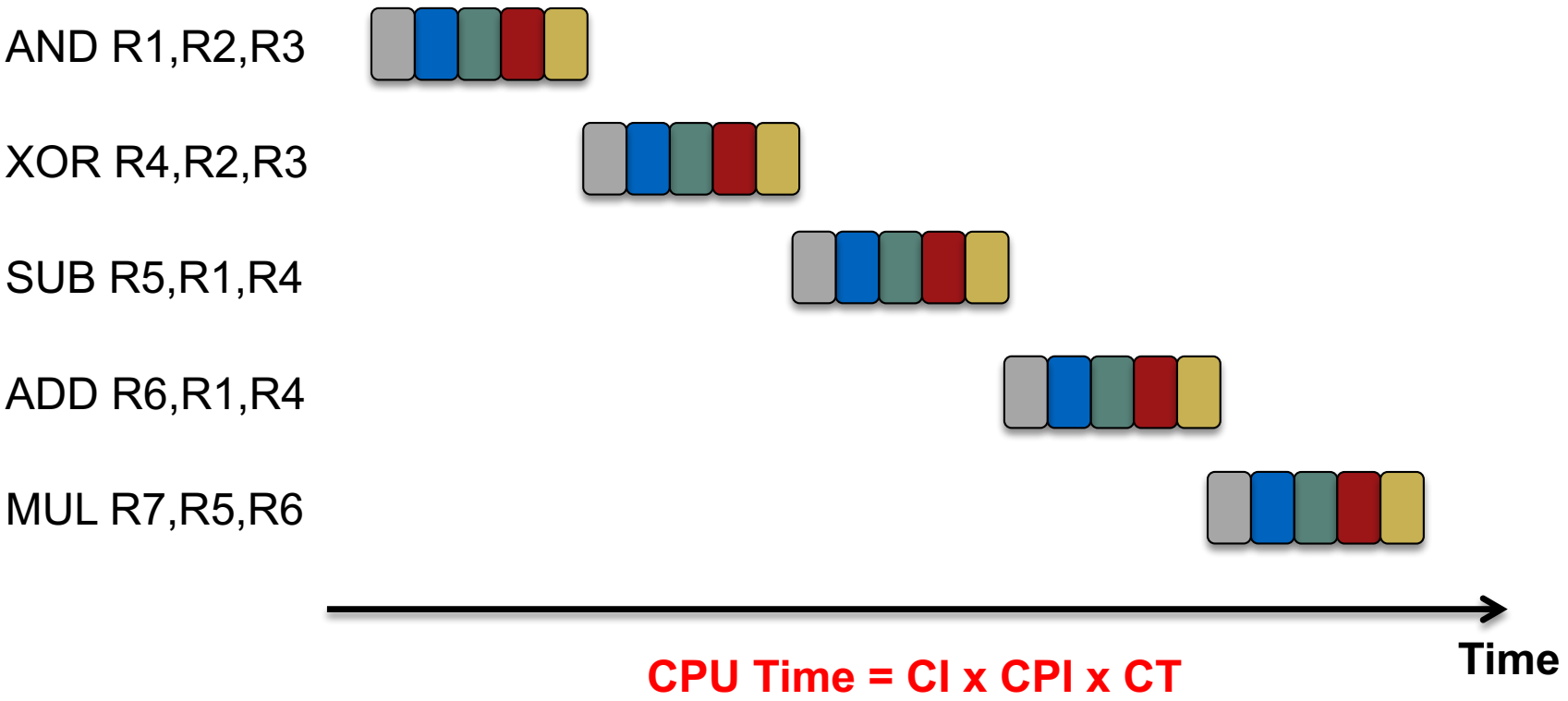
Pipelined Architecture

- Five stage pipeline
  - Critical path determines the cycle time



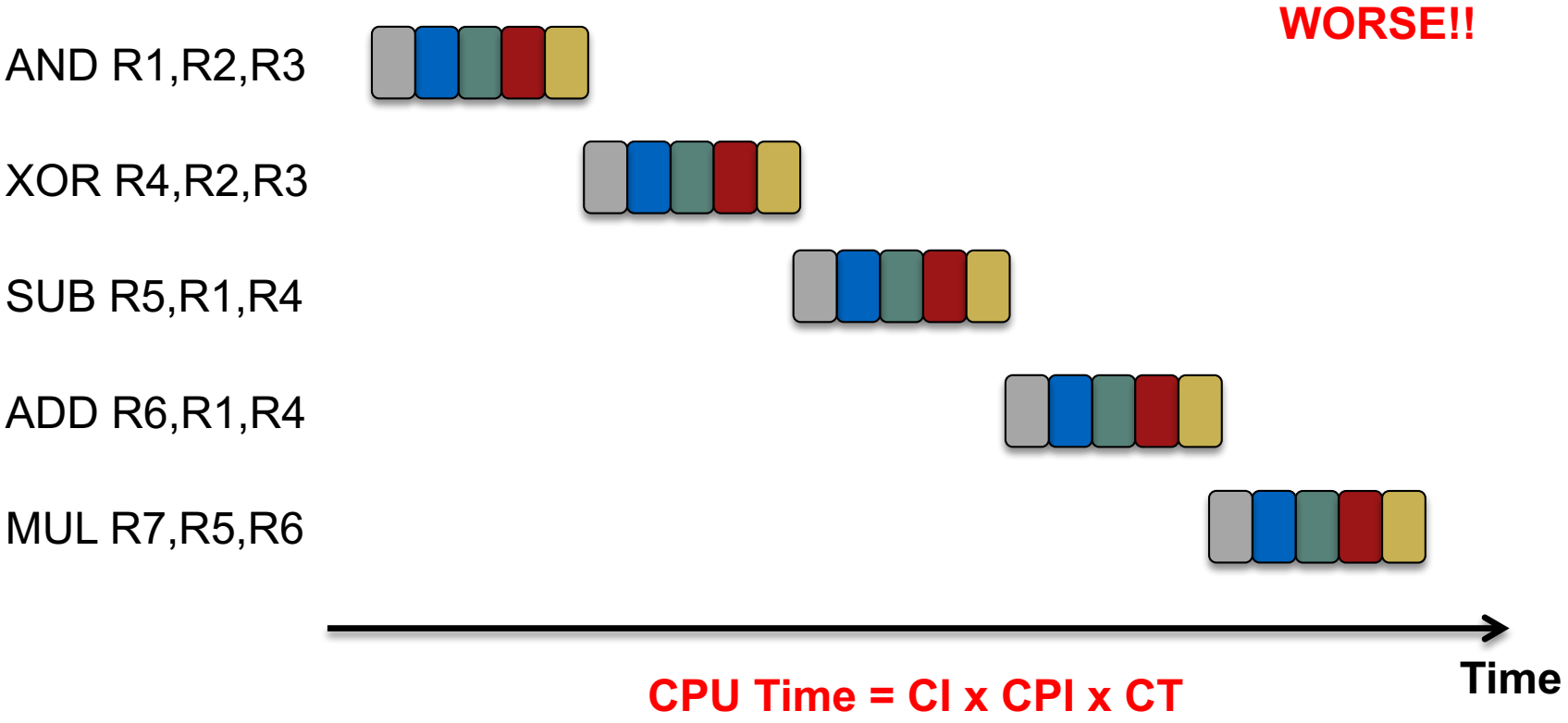
Pipelined Architecture

- Example program
  - CT=1.5ns; CPU Time = ?



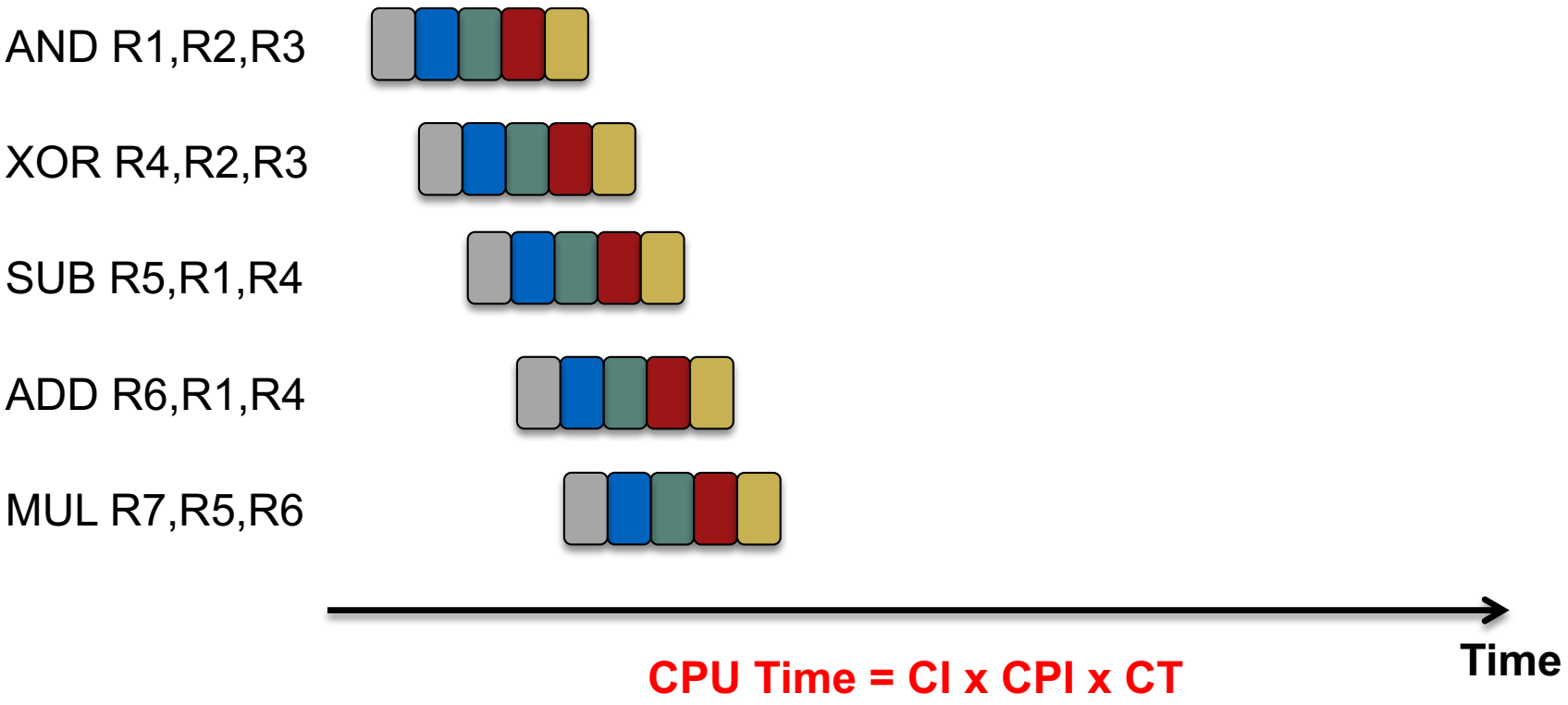
Pipelined Architecture

- Example program
  - CT=1.5ns; CPU Time = 5 x 5 x 1.5ns = 37.5ns > 30ns



Pipelined Architecture

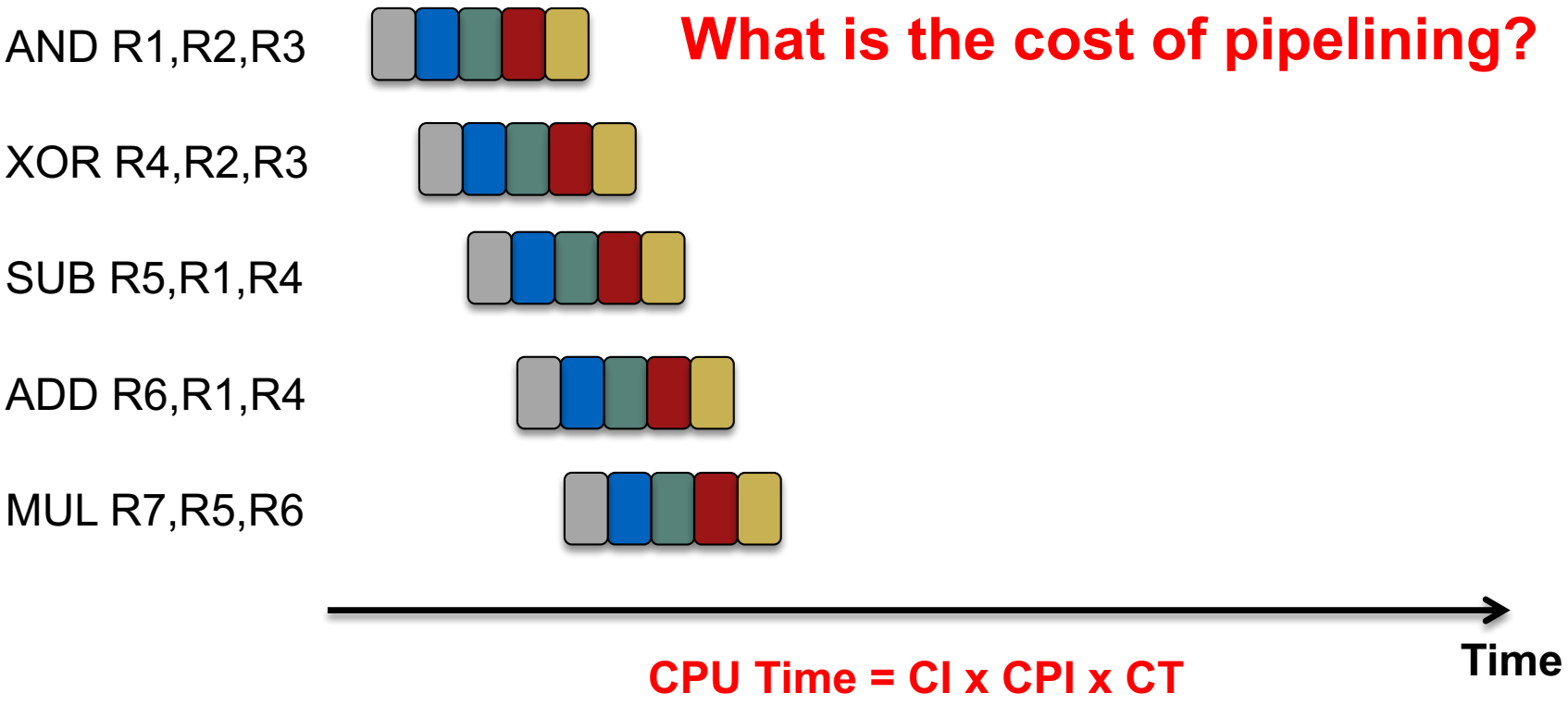
- Example program
  - CT=1.5ns; CPU Time = ?



CPU Time = CI x CPI x CT

Pipelined Architecture

- Example program
  - CT=1.5ns; CPU Time = 5 x 1 x 1.5ns = 7.5ns

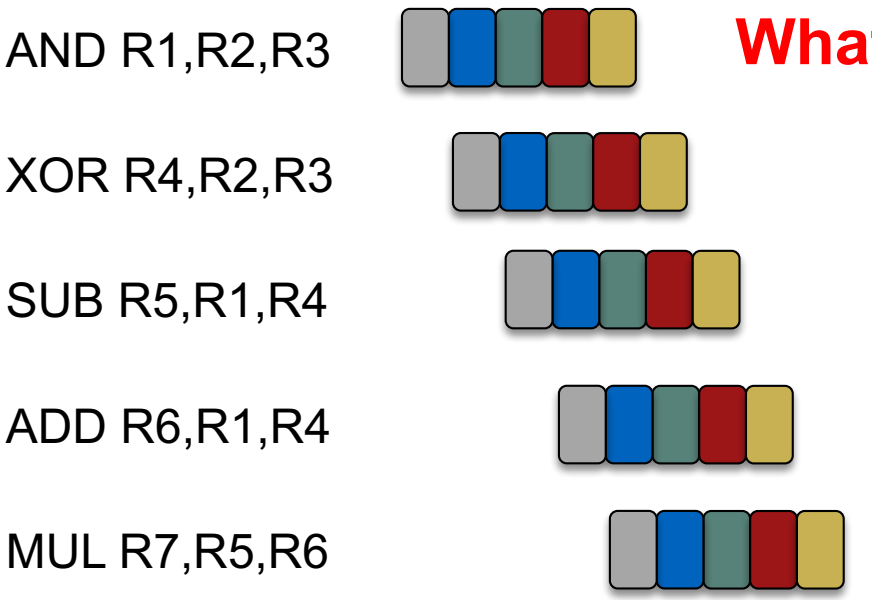


What is the cost of pipelining?

CPU Time = CI x CPI x CT

Pipelined Architecture

- Example program
  - CT=1.5ns; CPU Time = 5 x 1 x 1.5ns = 7.5ns



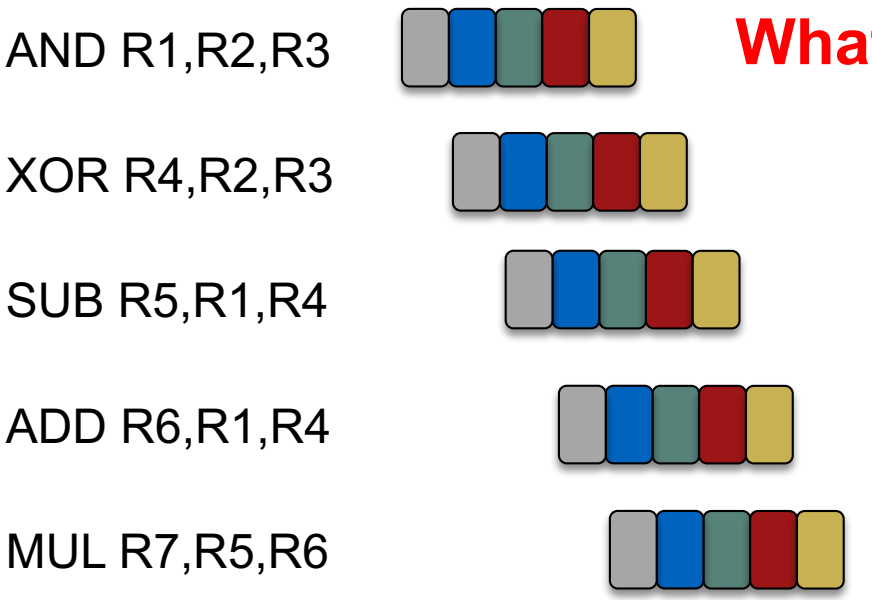
What is the cost of pipelining?

CT: original cycle time
P: no. pipeline stages
t: additional HW delay
New Time = CI x CPI x (t + CT/P)
Speedup = CT / (t + CT/P)

CPU Time = CI x CPI x CT

Pipelined Architecture

- Example program
  - CT=1.5ns; CPU Time = 5 x 1 x 1.5ns = 7.5ns



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CT: original cycle time
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New Time = CI x CPI x (t + CT/P)
Speedup = CT / (t + CT/P)

What about CPI?

CPU Time = CI x CPI x CT