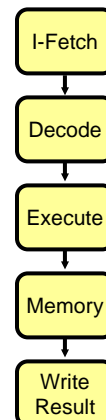


Lecture 11: Pipelining

- Organizational
 - Return exam & discuss it
 - Partial homework #3 solutions handout
- Last Time
 - Datapath control
 - Multicycle machine
- Today
 - Pipelining
(Including analogies using live "laundry basket" demos)

Instruction Execution

- 5 basic steps
 - fetch instruction (F)
 - decode instruction/read registers (R)
 - execute (X)
 - access memory (M)
 - store result (W)

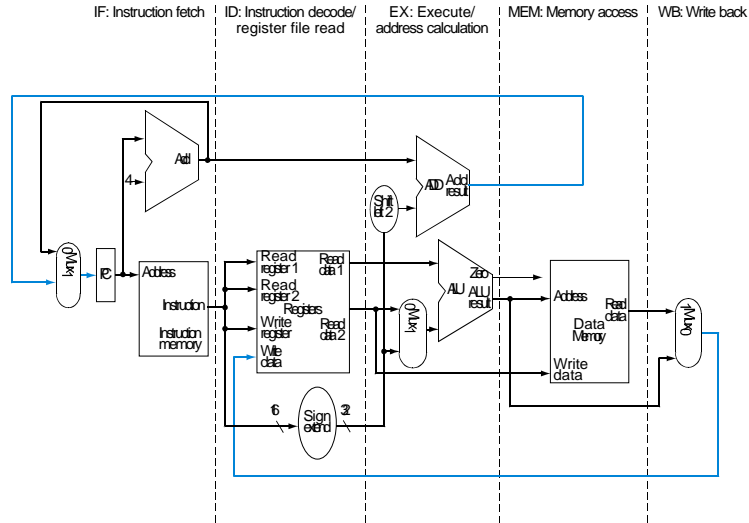


Pipelining

Laundry Pipeline

- 5 steps
 - Wash
 - Dry
 - Iron
 - Fold
 - Put away
- When first load finishes wash...
 - Immediately start the next load
- Eventually...
 - Five loads of laundry in progress at once

MIPS HW can be broken into 5 stages

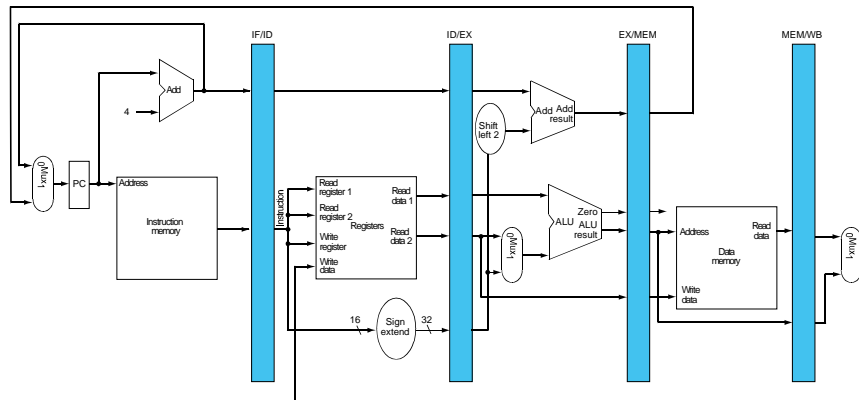


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Lecture 11

5

Separate into 5 stages with latches



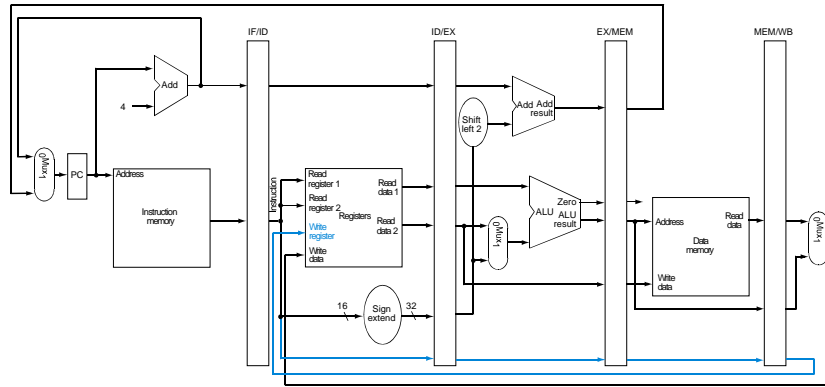
But... does the correct register get written?

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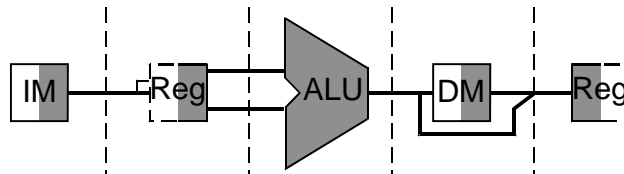
6

Fix to write the correct register

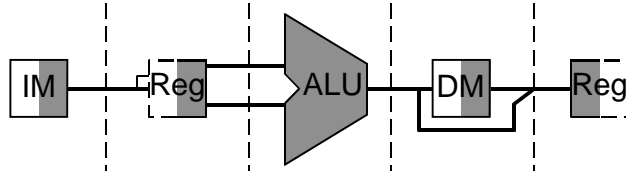


It's like attaching a note to the laundry basket used for a particular load

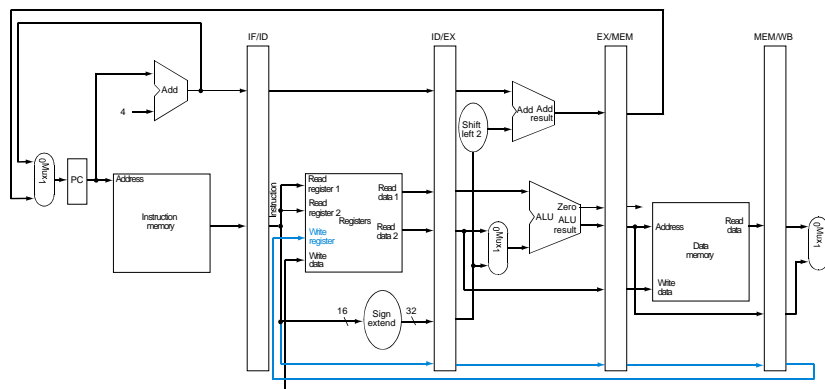
A simplified pipeline diagram



An example of instructions in pipeline

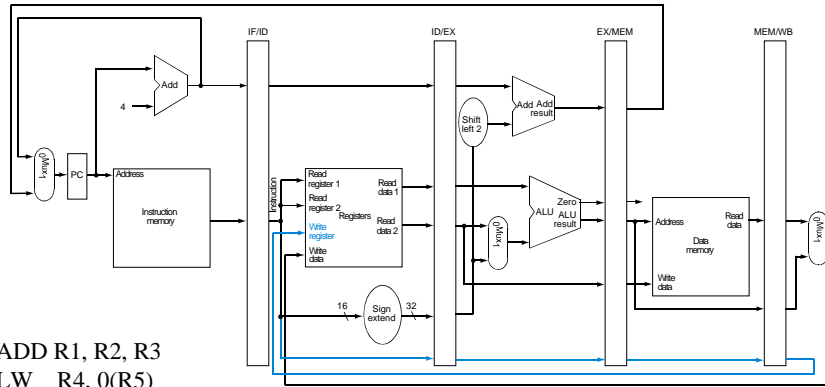


One instruction as it moves through pipeline



ADD R1, R2, R3

Several instructions in progress



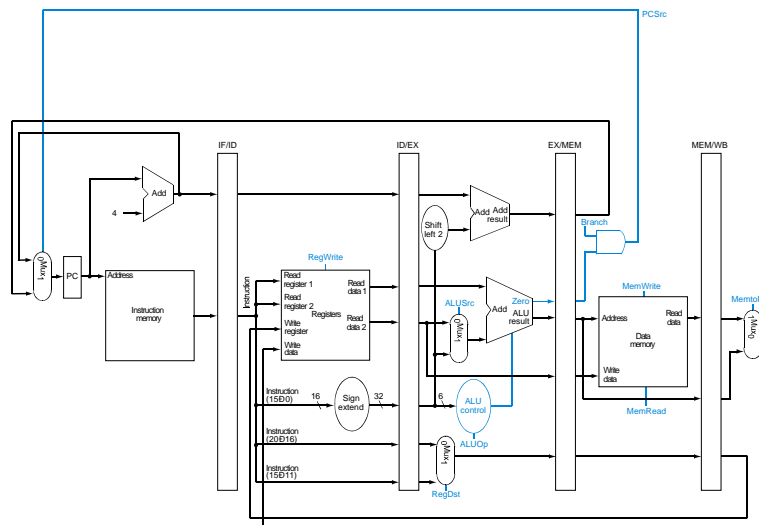
ADD R1, R2, R3
 LW R4, 0(R5)
 OR R6, R7, R8
 AND R9, R10, R11
 SW R12, 0(R13)

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Lecture 11

11

How do we control the pipeline?

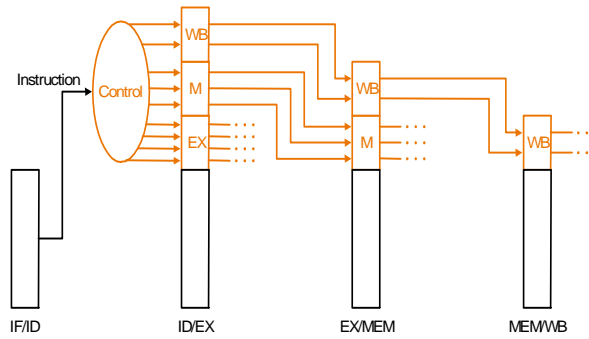


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12

Pass control signals down the pipeline



Laundry Analogy...

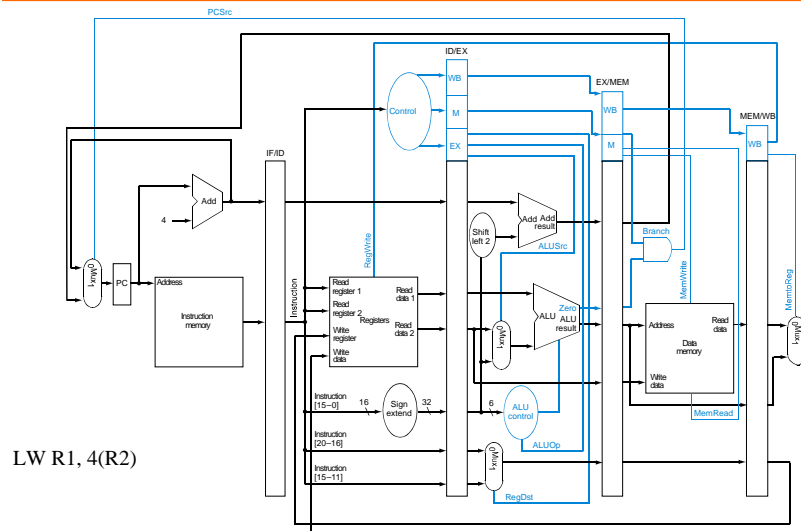
- Attach instructions to basket:
- "wash with cold water"
 - "tumble dry low"
 - "iron on high"
 - "hang in hall closet"

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Lecture 11

13

Datapath with control



LW R1, 4(R2)

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Lecture 11

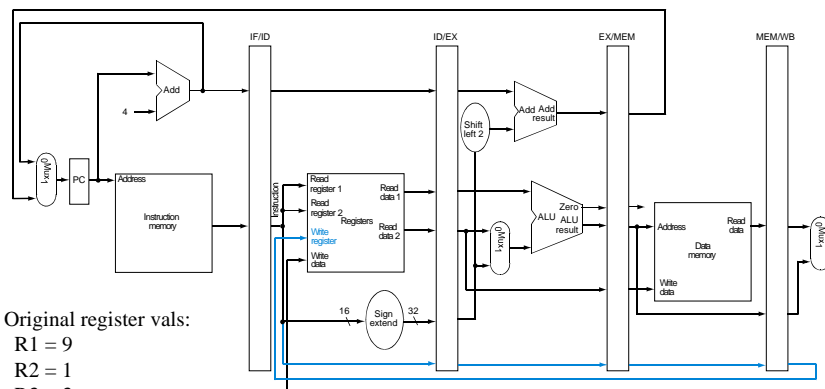
14

A fly in the soup...

- What happens when two instructions depend on one another?

```
ADD R1, R2, R3  
OR  R4, R1, R5
```

- Let's see...



Original register vals:

R1 = 9
R2 = 1
R3 = 3

```
ADD R1, R2, R3  
OR  R4, R1, R5
```


More on this next time

- Data Hazards
 - What you just saw
- Control Hazards
 - Branch instructions

Summary

- Pipelining MIPS architecture
 - Five stages
 - How they're controlled
- Introduction to data hazards

- Next Lecture
 - Pipeline hazards

- Reading assignment - P&H 6.4-6.6, 6.8