CS305
Computer Architecture

Structural Hazards, Pipelined Datapath

Bhaskaran Raman
Room 406, KR Building
Department of CSE, IIT Bombay

http://www.cse.iitb.ac.in/~br

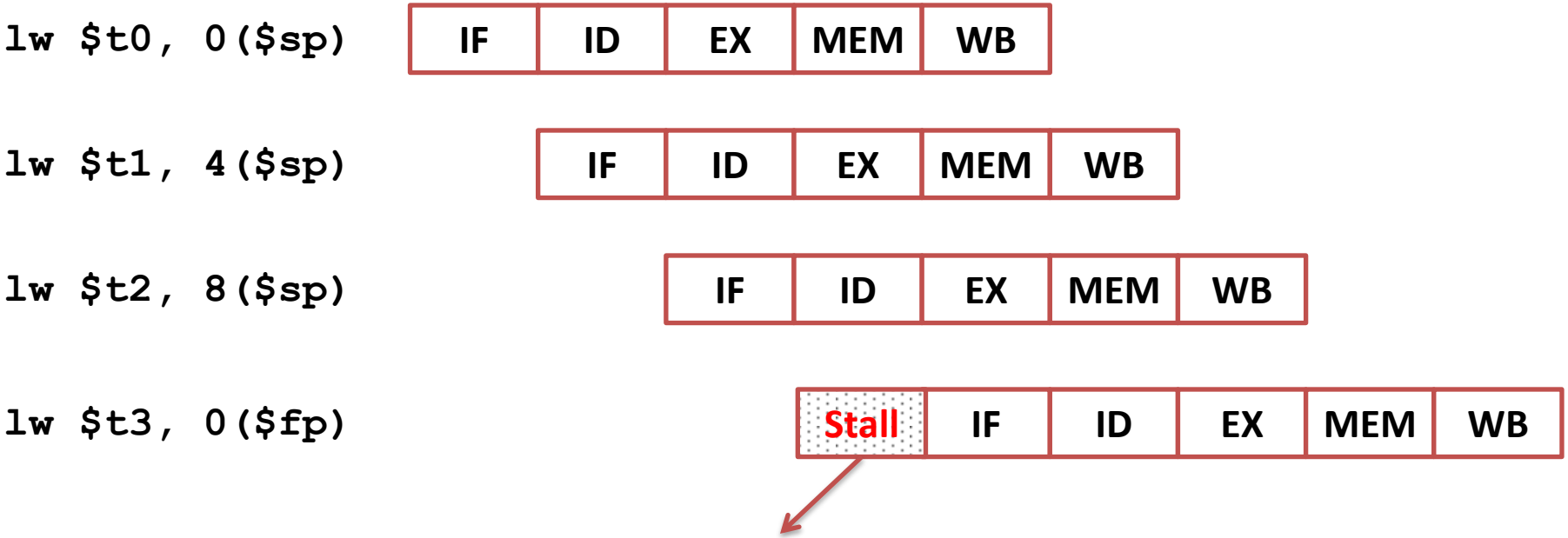
Issues with Pipelining: Hazards

- Hazard: condition or situation which does not allow the pipeline to operate “normally”
- Three kinds:
  - Structural hazards
  - Data hazards
  - Control hazards

Structural Hazard: Hardware Limitation

- Ideally, no hardware limitation
  - Separate spanners for “fit wheels” and “fit accessories”
  - IM and DM must be separate
  - Separate adders for PC+4, branch target computation
- If hardware limitation: structural hazard
  - E.g. same memory for IM and DM
  - Can still use pipelining, as much as possible

Structural Hazard ➔ Stall Pipeline



Bubble in pipeline = 1 Stall = 1 cycle wasted

Performance Evaluation in Pipelined Implementation

- CPI in ideal pipeline = 1
  - CPI is cycles per instruction completion
- CPI in pipeline with stalls = 1 + F_{stall}

Example:

Multi-cycle implementation has 9ns cycle time

Pipelined implementation has 10ns cycle time (due to extra datapath overheads)

Instruction mix:

Reg-reg 65%, beq 15%, lw 15%, sw 5%

What is the ideal speed-up?

What is the speed-up with structural hazard in memory?

4 3 5 4

CPI = 4

CPI = 1 (ideal)

$\frac{4 \times 9ns}{1 \times 10ns} = 3.6$

$\frac{4 \times 9}{1.2 \times 10} = 3$

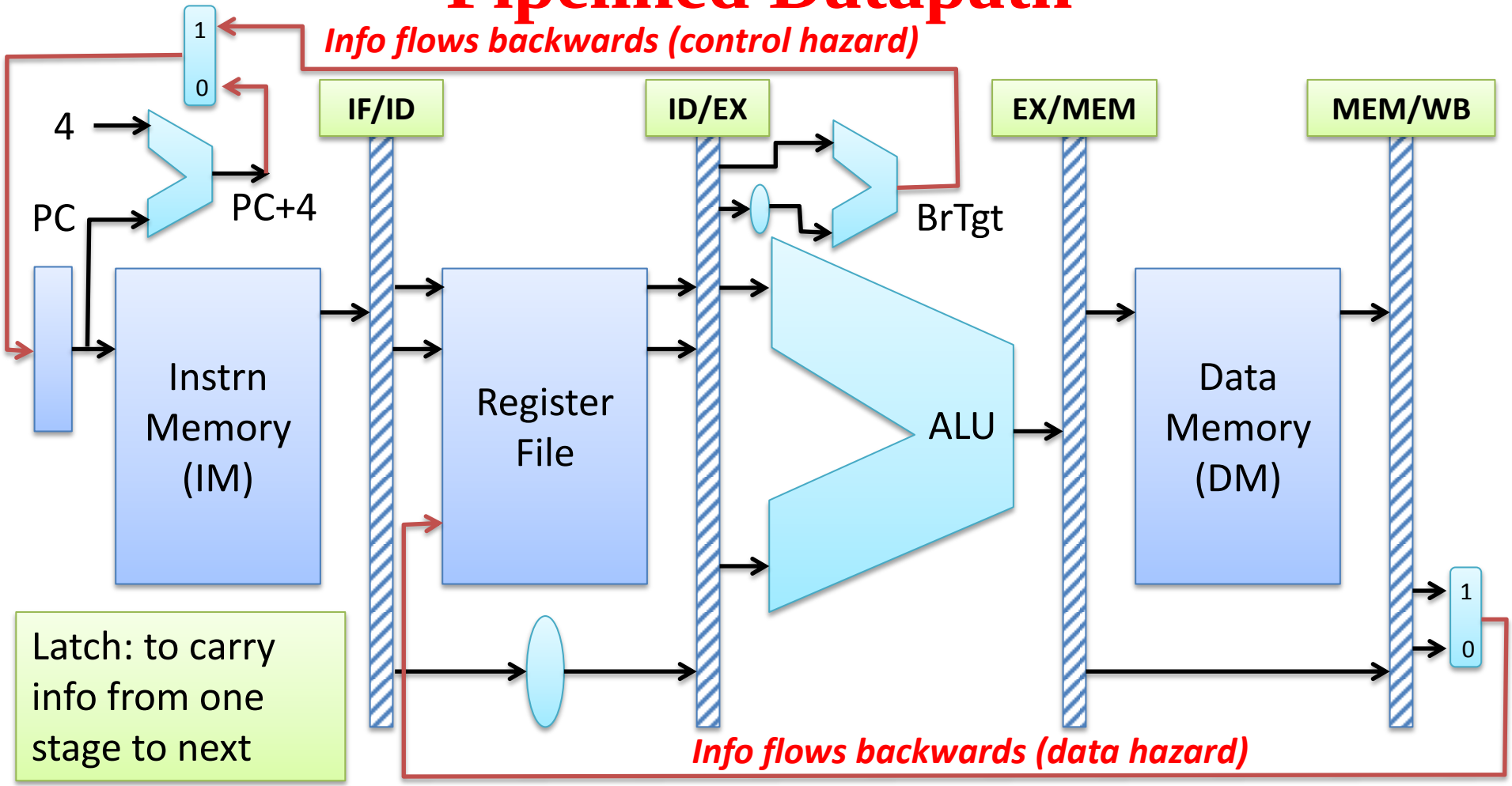
Handling Structural Hazard in the Register File

- Too expensive to stall
- A large fraction of instructions write registers
- Solution:
  - Write RegFile on rising edge (first half)
  - Read RegFile on falling edge (second half)
  - Why this order? Has to do with handling of data hazards

Pipelined Datapath, Control

- Modifications from multi-cycle
  - Simple modifications to datapath
  - Control becomes much more complex
- Same pattern as: single-cycle → multi-cycle

Pipelined Datapath



Summary

- Pipeline hazards:
  - Structural hazard
  - Data hazard
  - Control hazard
- Dealing with hazards: pipeline stall, affects ideal CPI
- Pipelined datapath: minor modifications
- Pipelined control: much more complex!