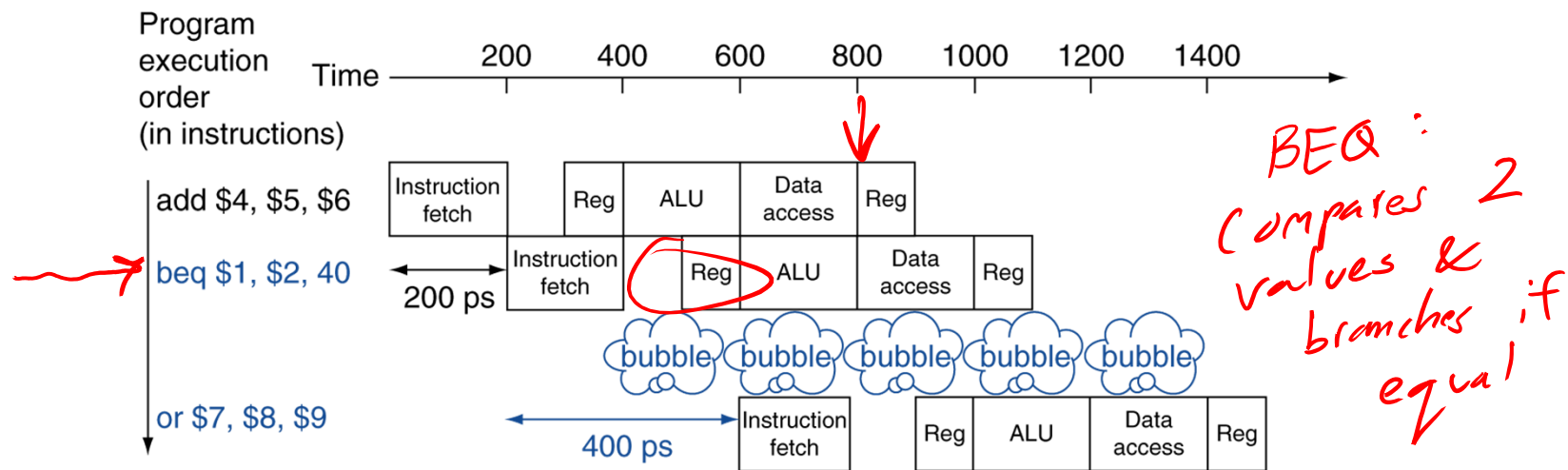


Stall on Branch

- Wait until branch outcome determined before fetching next instruction

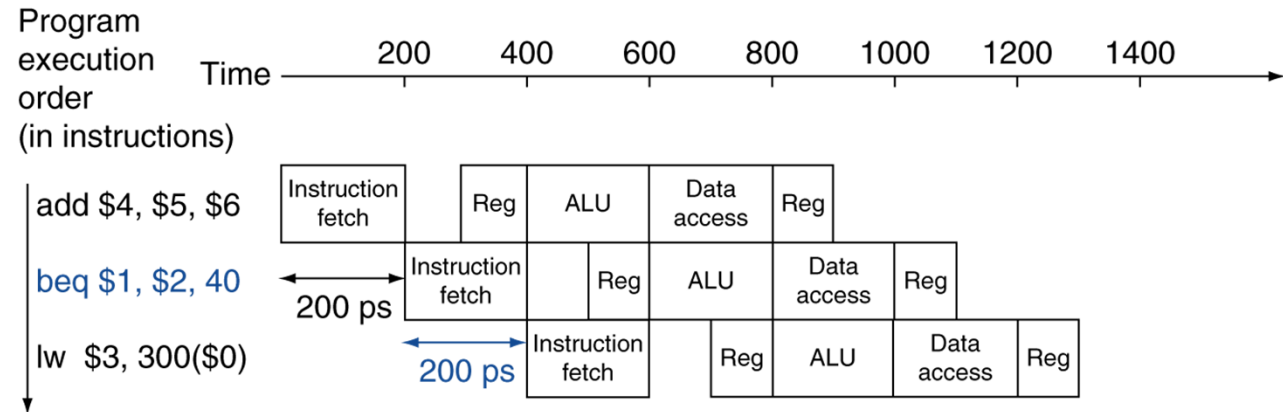


Branch Prediction

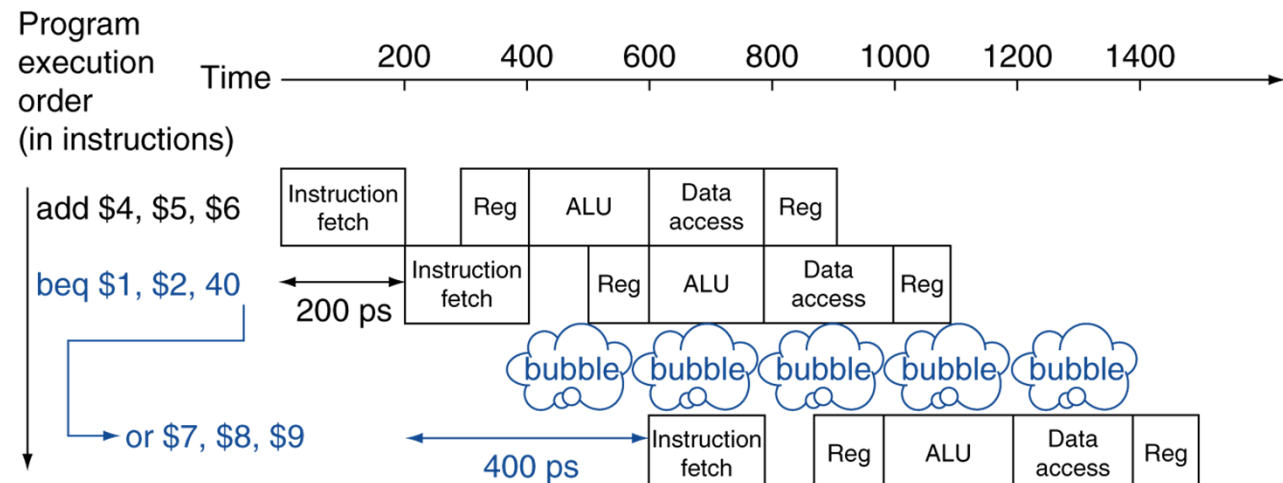
- Longer pipelines can't readily determine branch outcome early
 - Stall penalty becomes unacceptable
- Predict outcome of branch
 - Only stall if prediction is wrong
- In MIPS pipeline
 - Can predict branches not taken
 - Fetch instruction after branch, with no delay

MIPS with Predict Not Taken

Prediction
correct



Prediction
incorrect



More-Realistic Branch Prediction

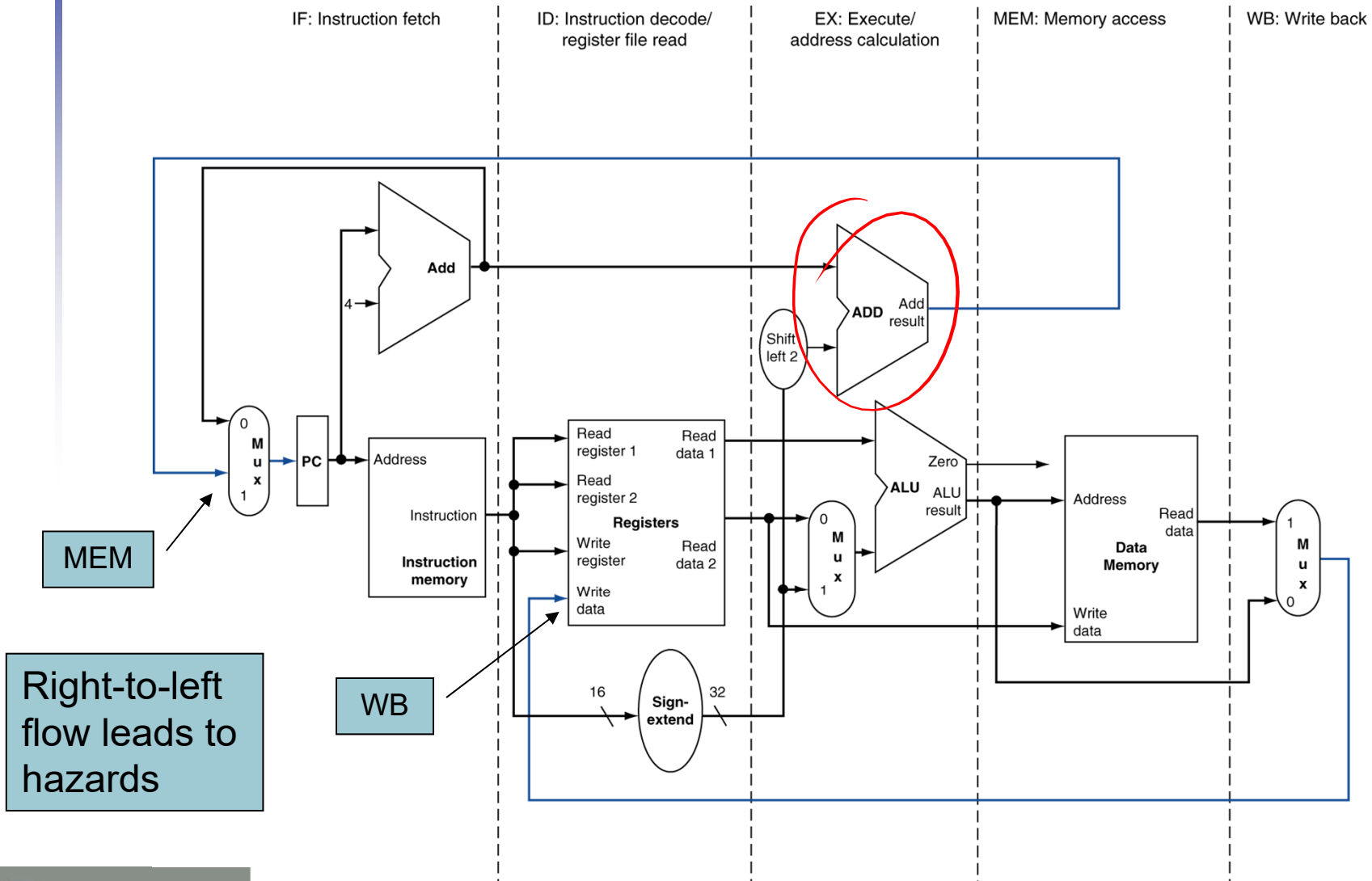
- Static branch prediction
 - Based on typical branch behavior
 - Example: loop and if-statement branches
 - Predict backward branches taken
 - Predict forward branches not taken
- Dynamic branch prediction
 - Hardware measures actual branch behavior
 - e.g., record recent history of each branch
 - Assume future behavior will continue the trend
 - When wrong, stall while re-fetching, and update history

Pipeline Summary

The BIG Picture

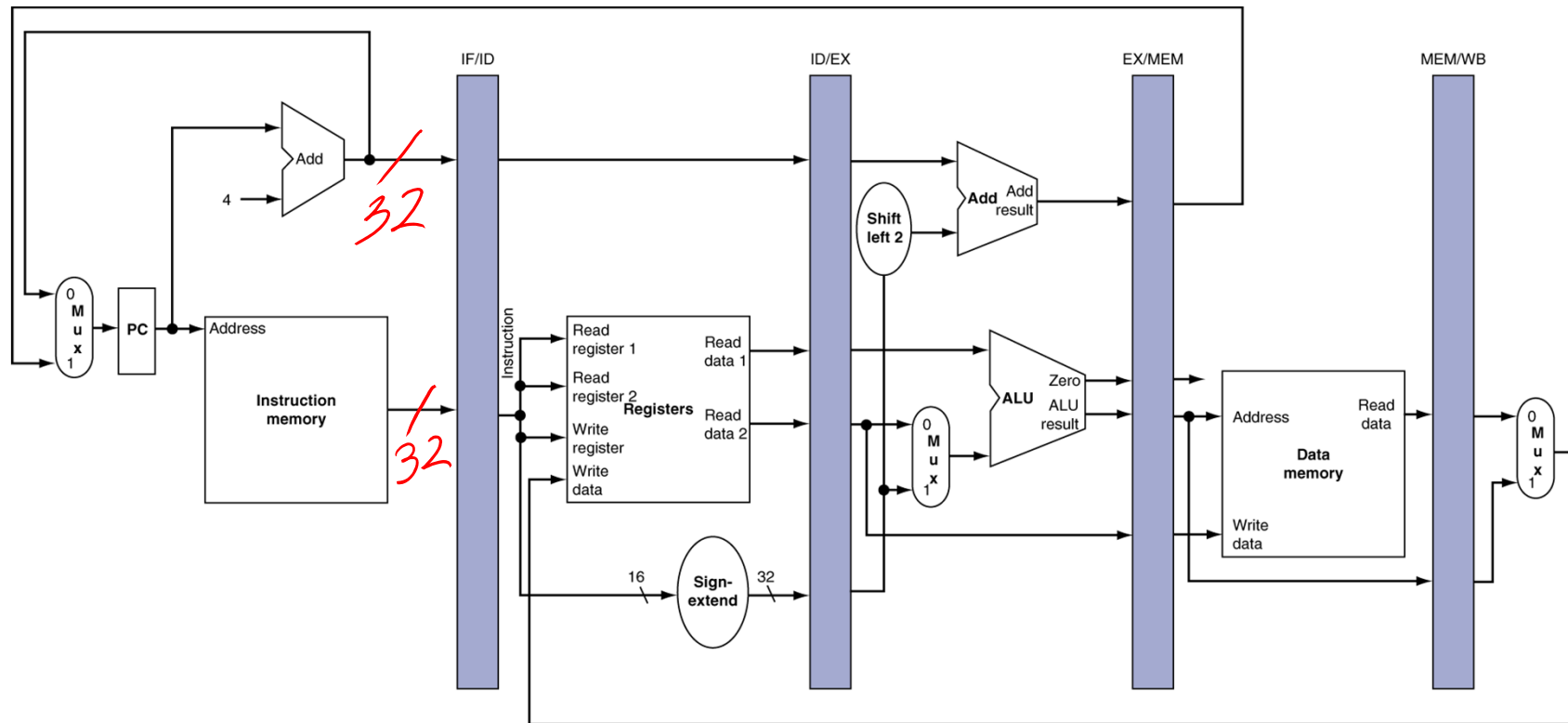
- Pipelining improves performance by increasing instruction throughput
 - Executes multiple instructions in parallel
 - Each instruction has the same latency
- Subject to hazards
 - Structure, data, control
- Instruction set design affects complexity of pipeline implementation

MIPS Pipelined Datapath



Pipeline registers

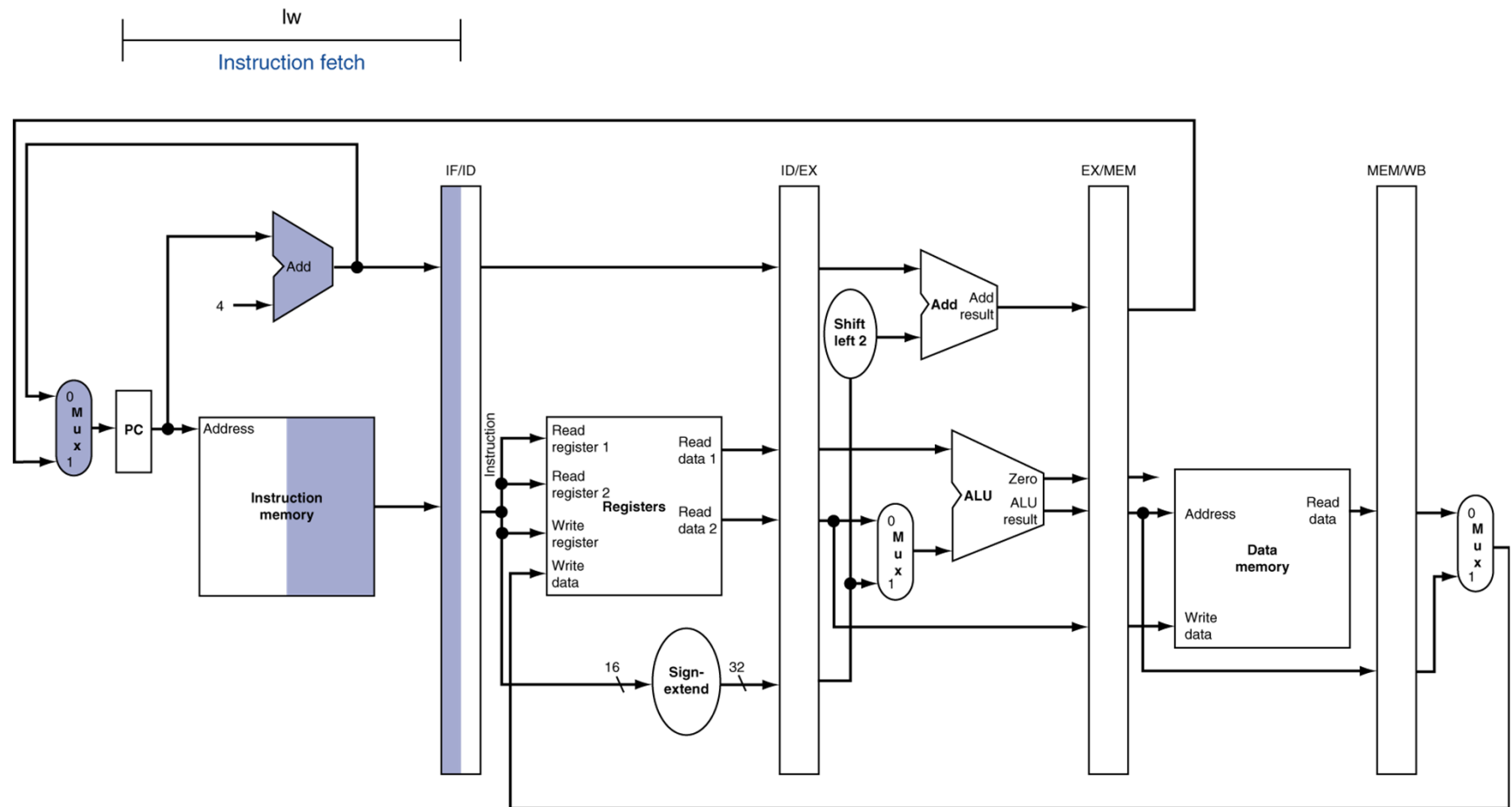
- Need registers between stages
 - To hold information produced in previous cycle



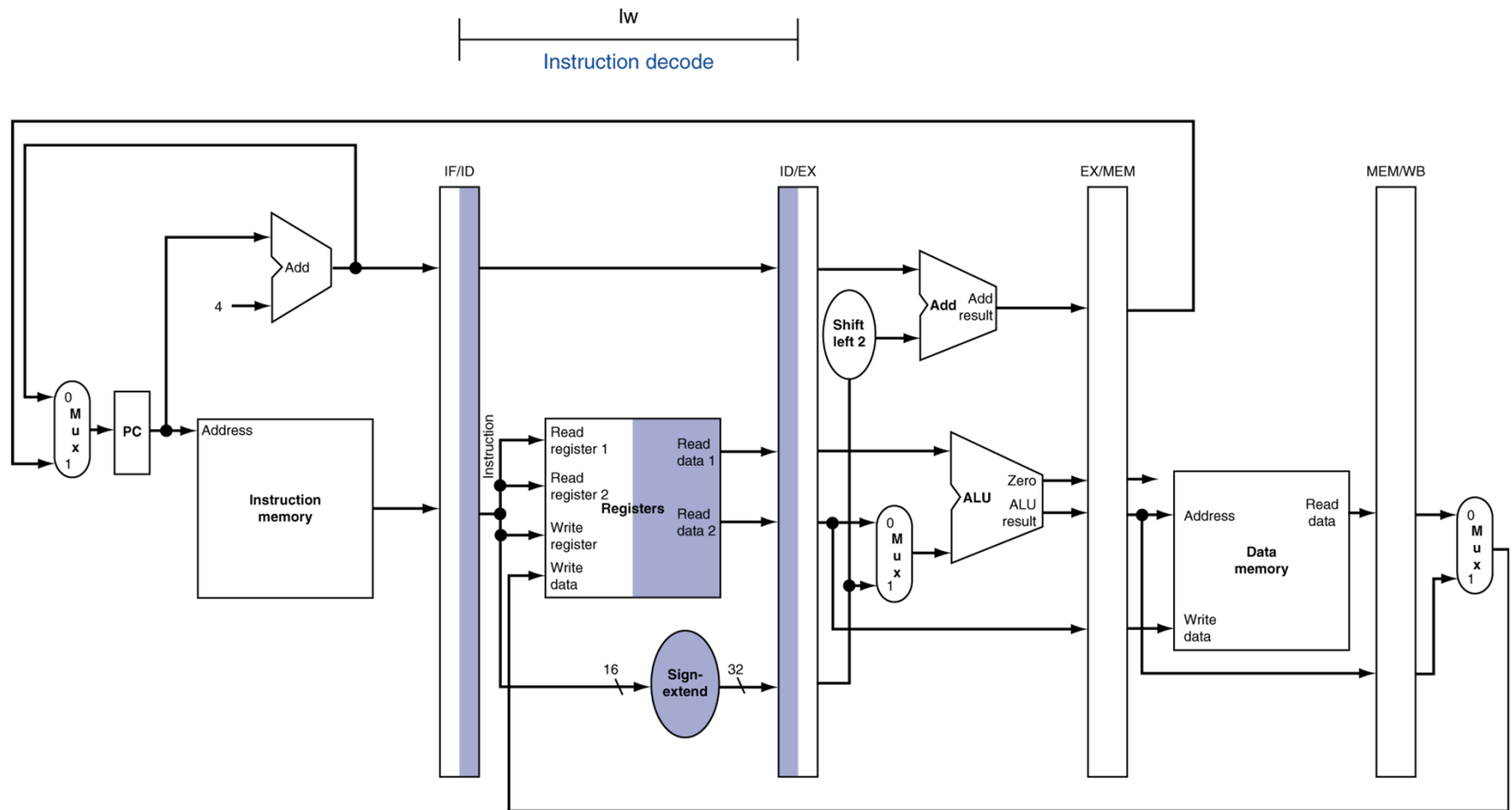
Pipeline Operation

- Cycle-by-cycle flow of instructions through the pipelined datapath
 - “Single-clock-cycle” pipeline diagram
 - Shows pipeline usage in a single cycle
 - Highlight resources used
 - c.f. “multi-clock-cycle” diagram
 - Graph of operation over time
- We’ll look at “single-clock-cycle” diagrams for load & store

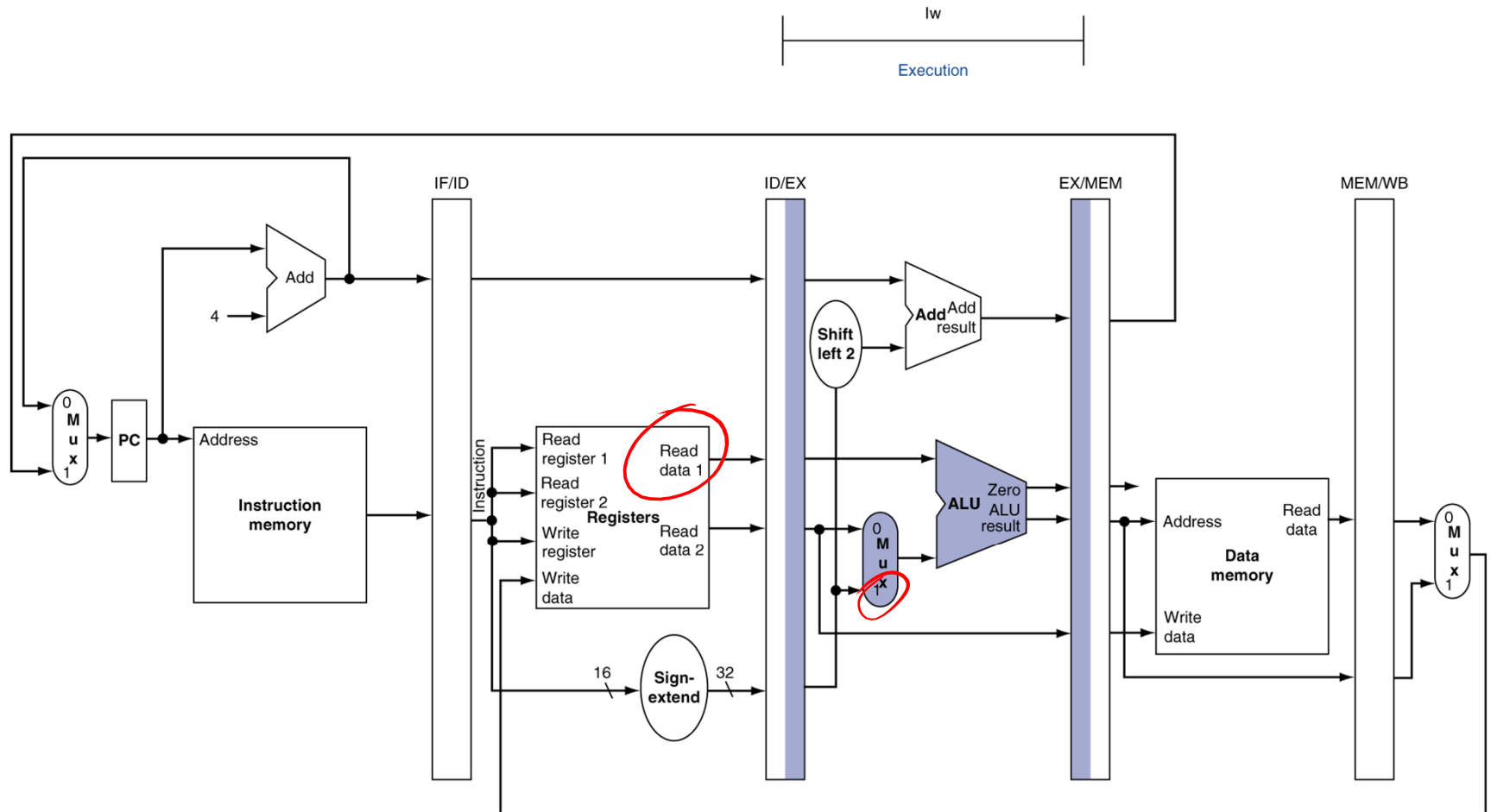
IF for Load, Store, ...



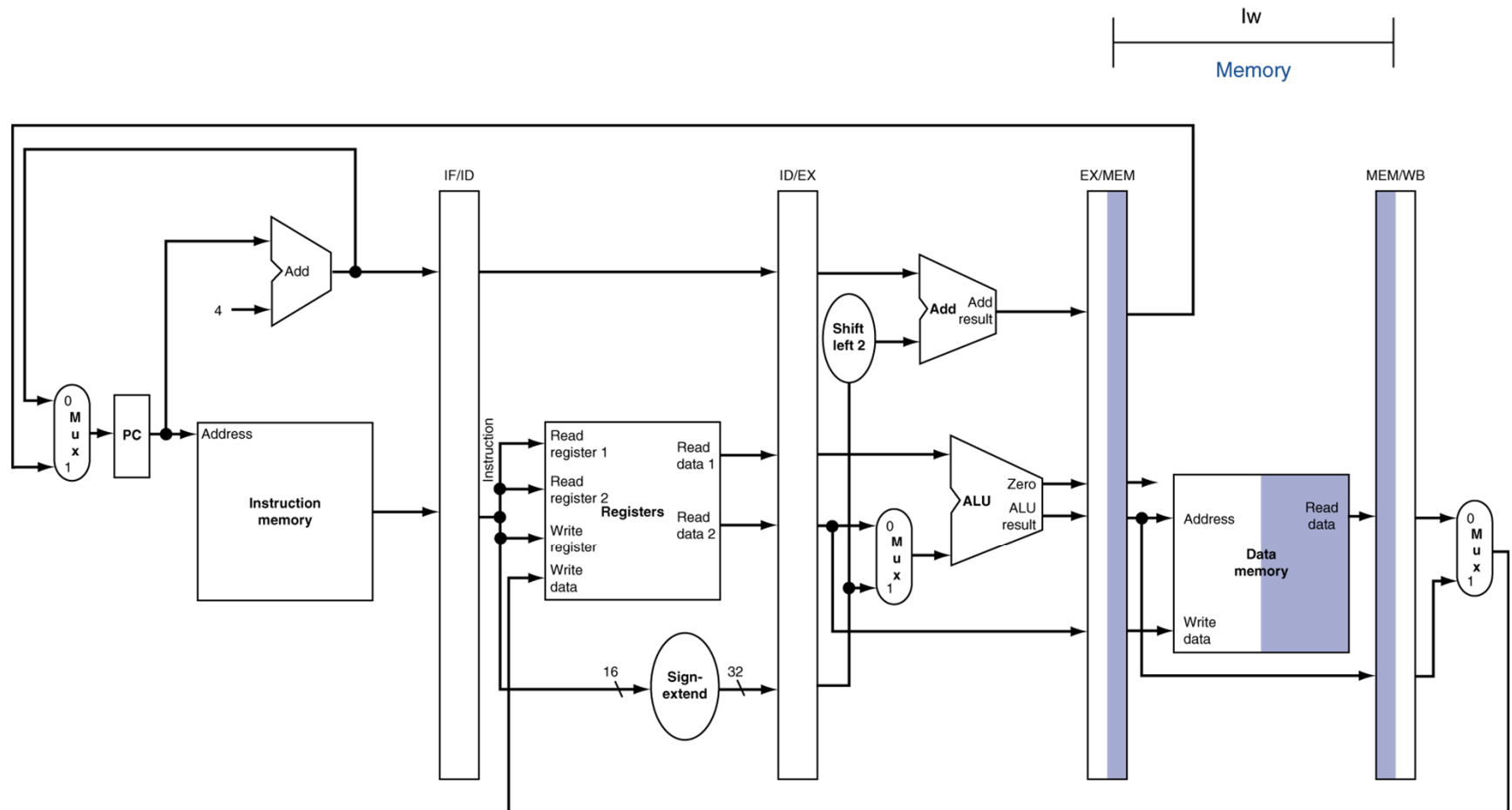
ID for Load, Store, ...



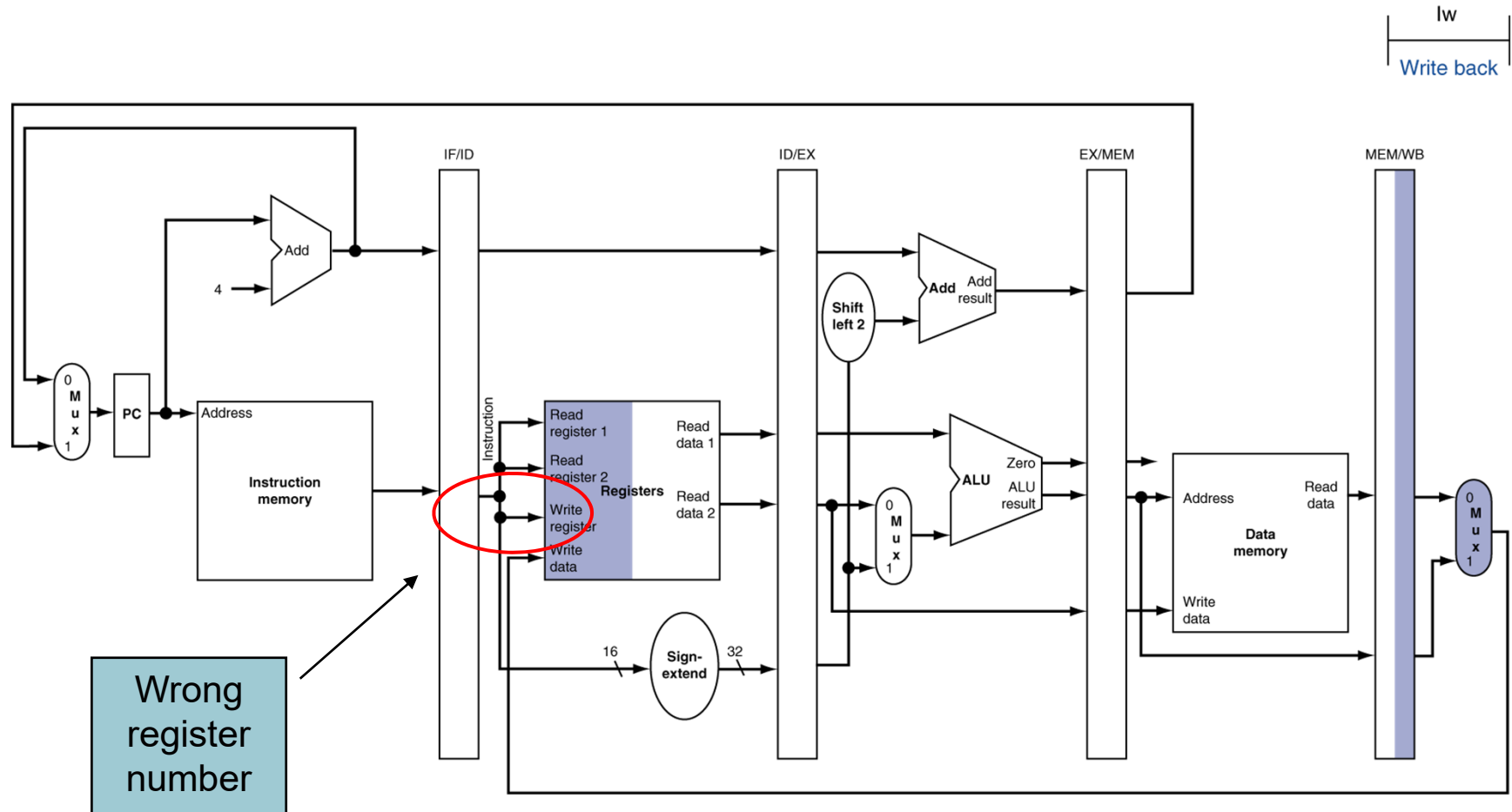
EX for Load



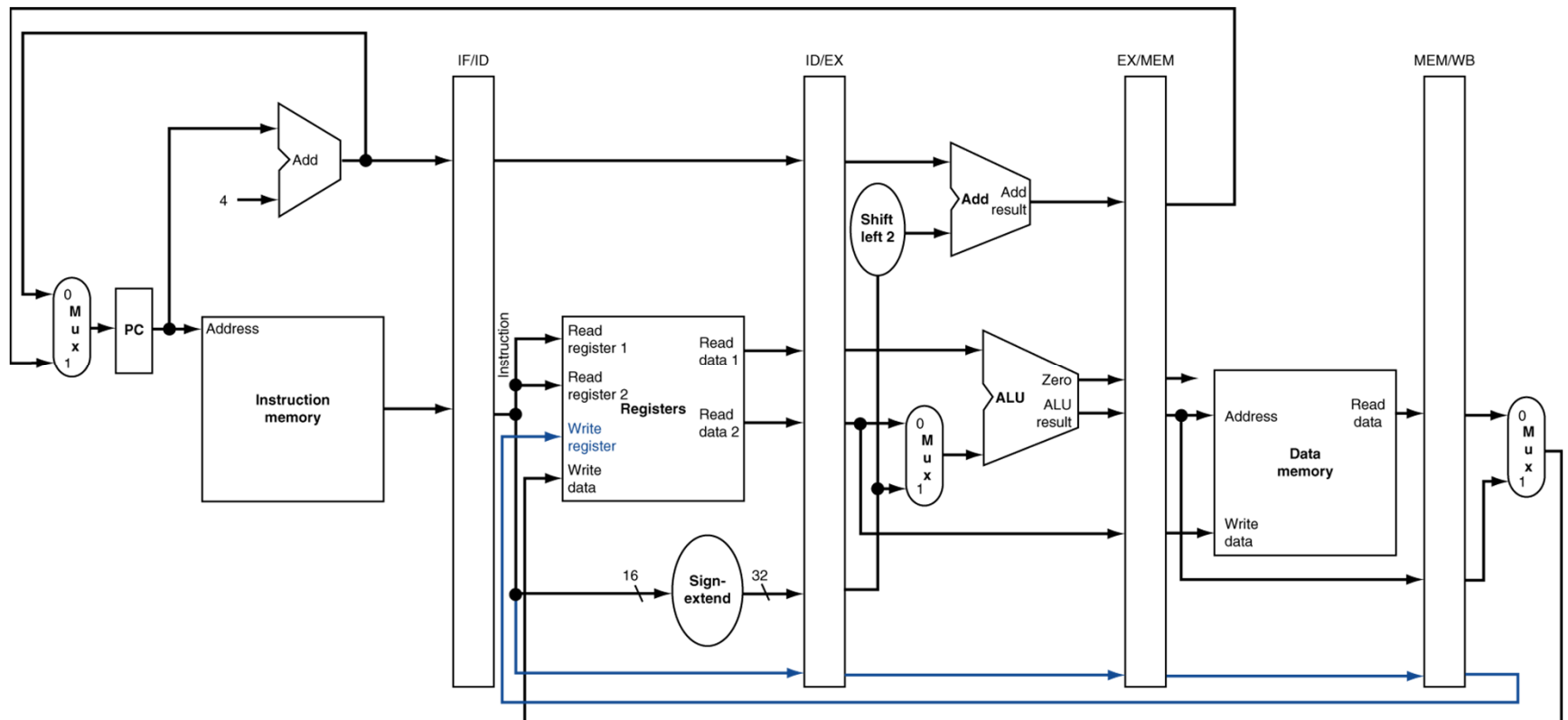
MEM for Load



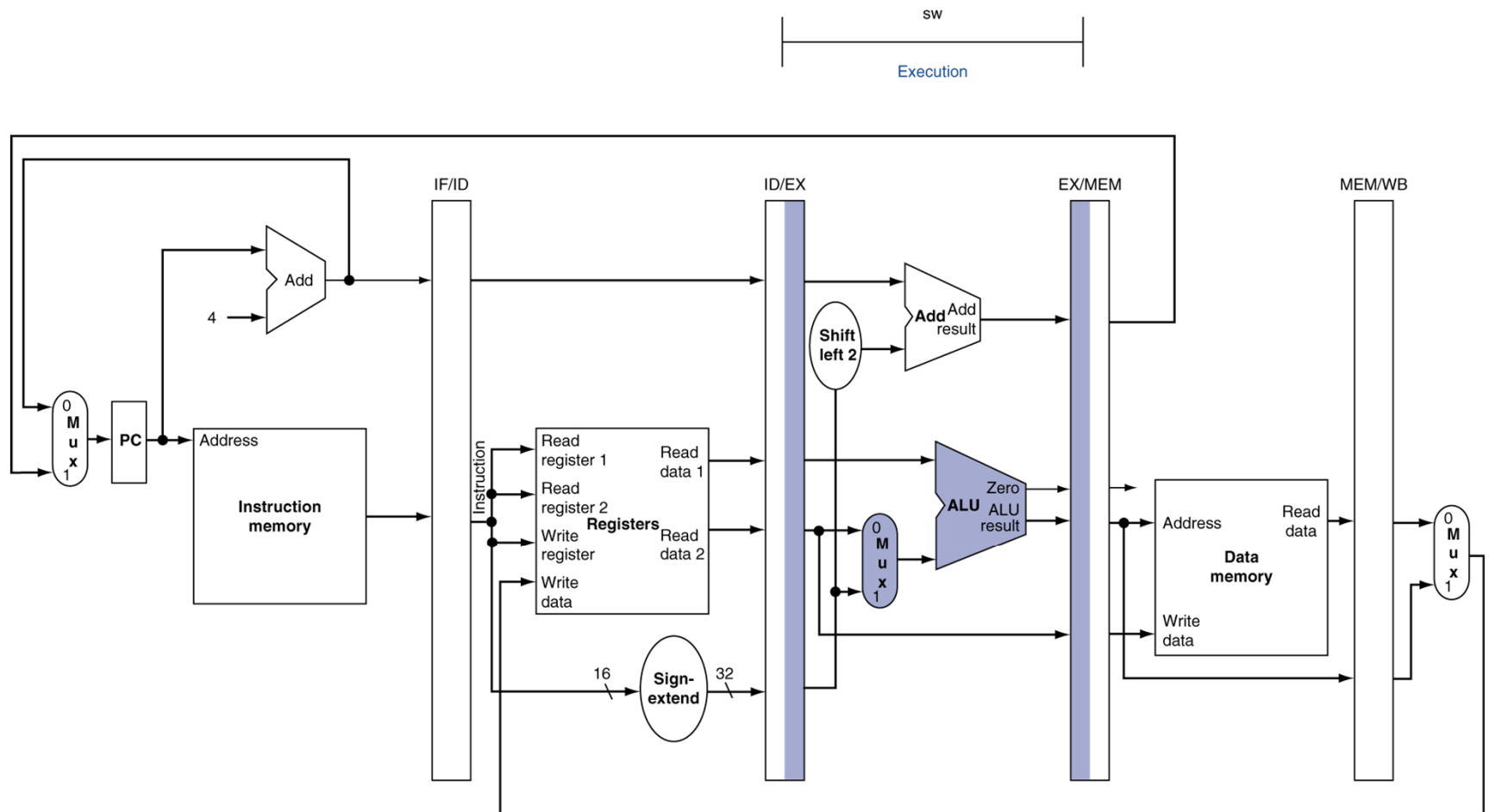
WB for Load



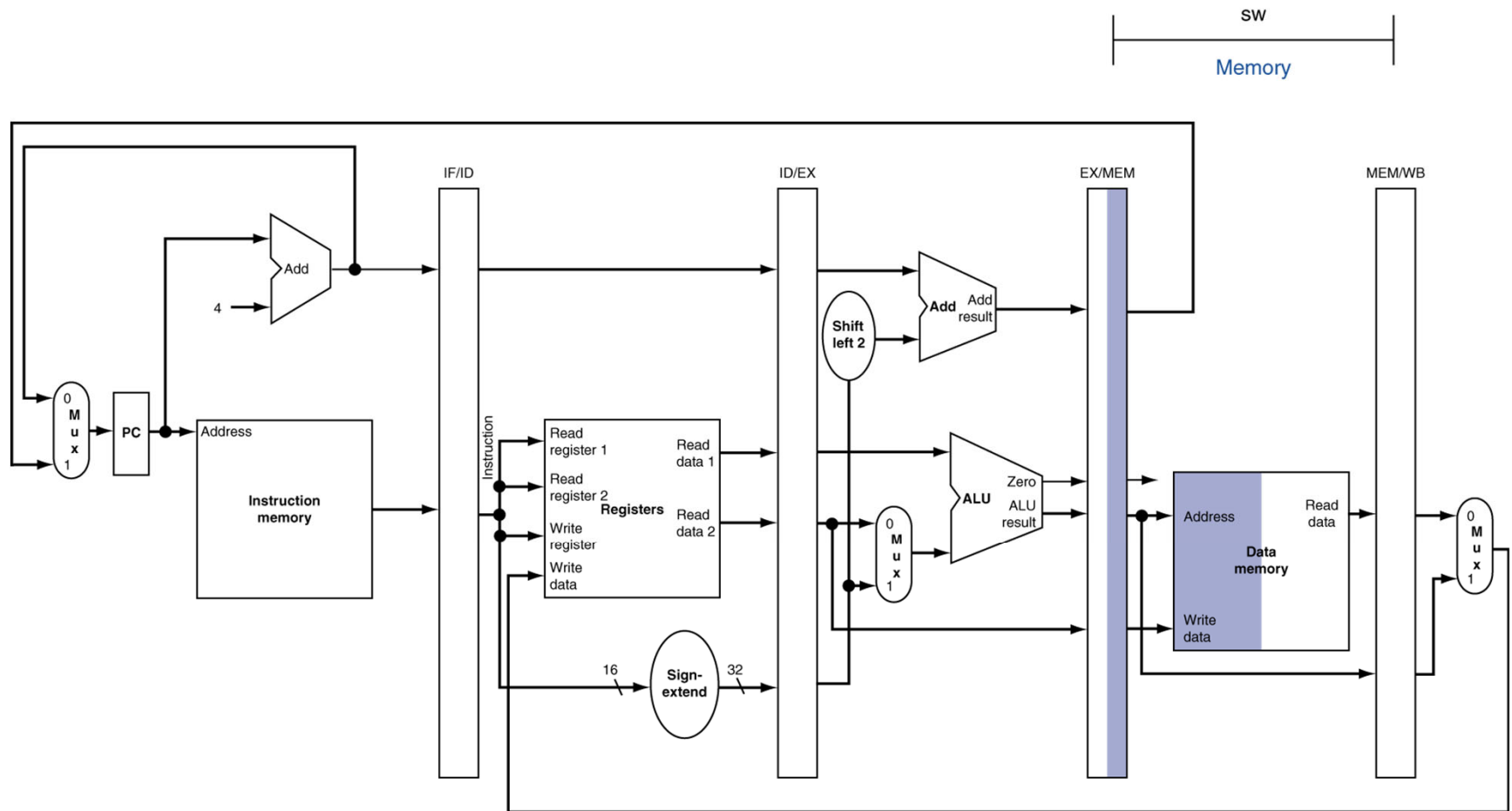
Corrected Datapath for Load



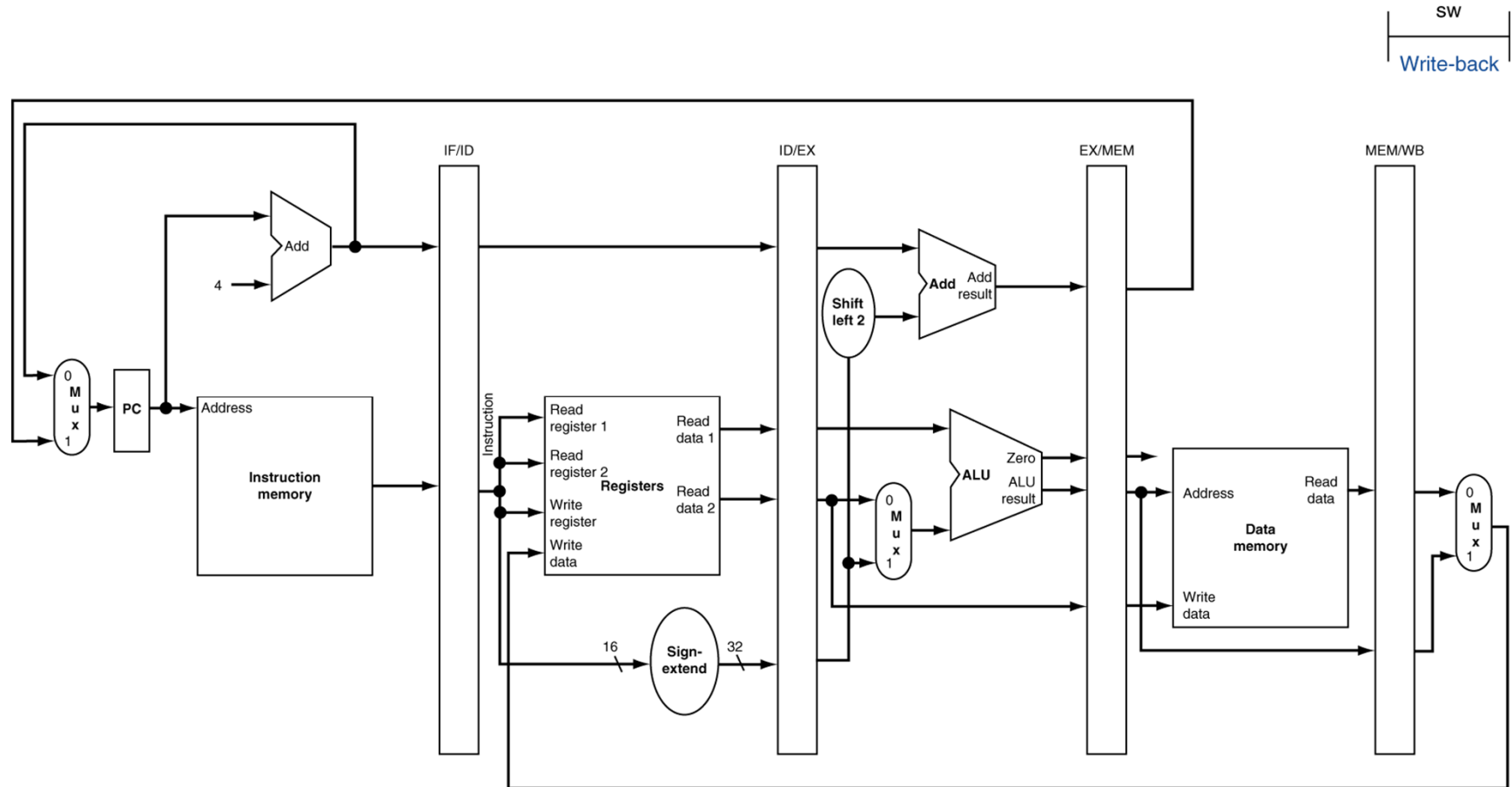
EX for Store



MEM for Store

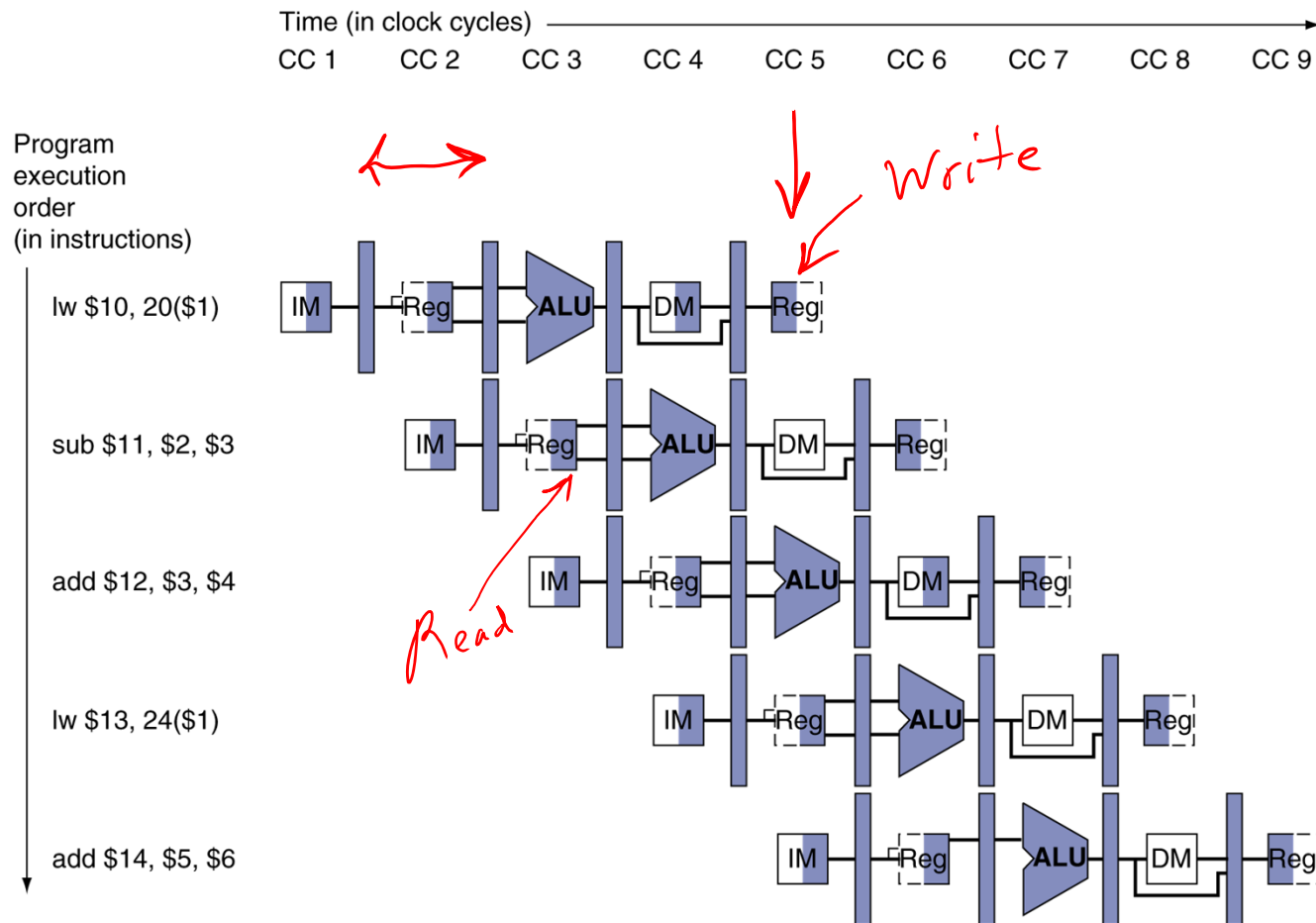


WB for Store



Multi-Cycle Pipeline Diagram

- Form showing resource usage



Multi-Cycle Pipeline Diagram

■ Traditional form

