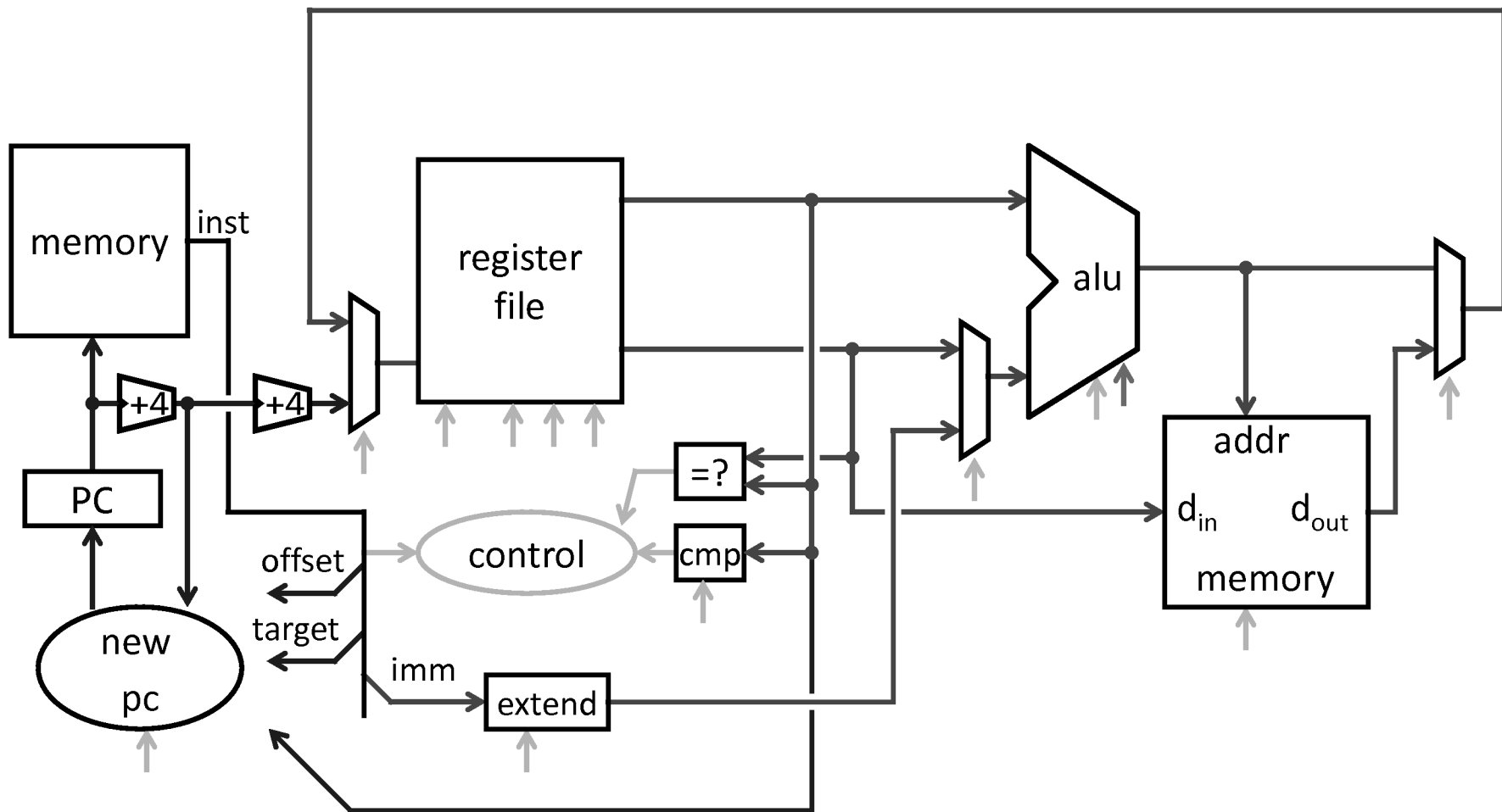
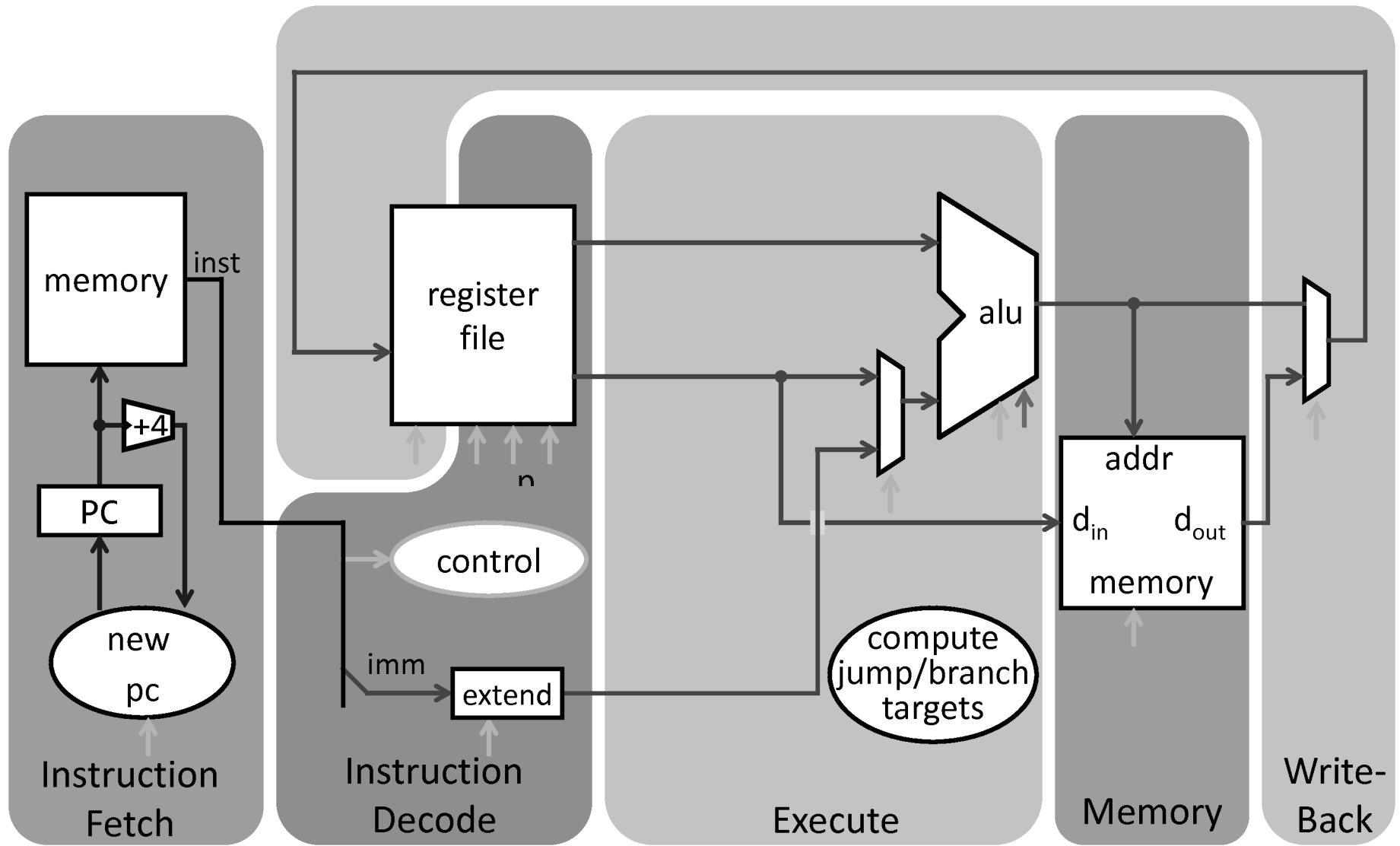


RISC Pipeline

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See: P&H Chapter 4.6





Five stage “RISC” load-store architecture

1. Instruction fetch (IF)

- get instruction from memory, increment PC

2. Instruction Decode (ID)

- translate opcode into control signals and read registers

3. Execute (EX)

- perform ALU operation, compute jump/branch targets

4. Memory (MEM)

- access memory if needed

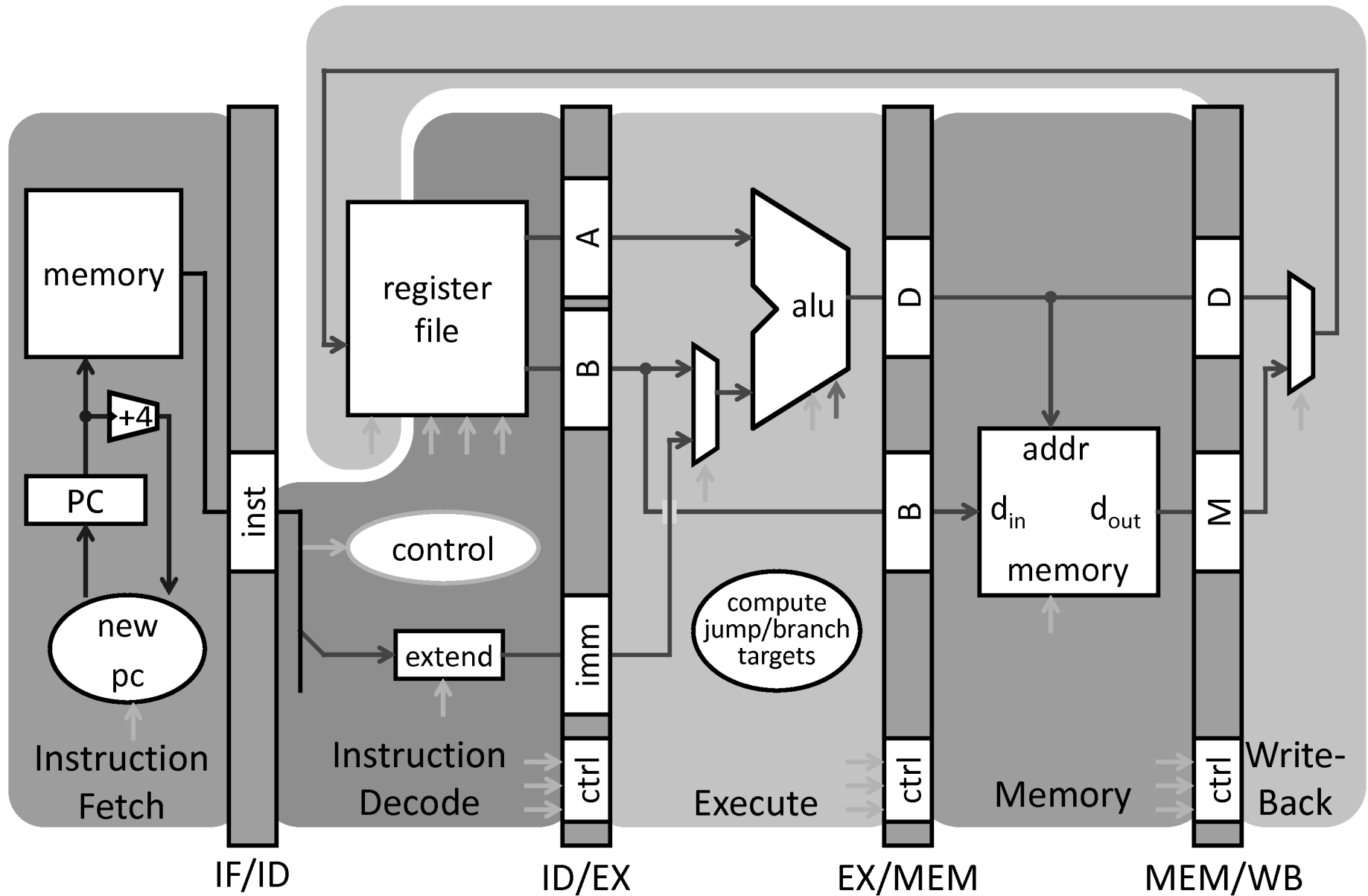
5. Writeback (WB)

- update register file

Break instructions across multiple clock cycles
(five, in this case)

Design a separate stage for the execution
performed during each clock cycle

Add pipeline registers to isolate signals between
different stages



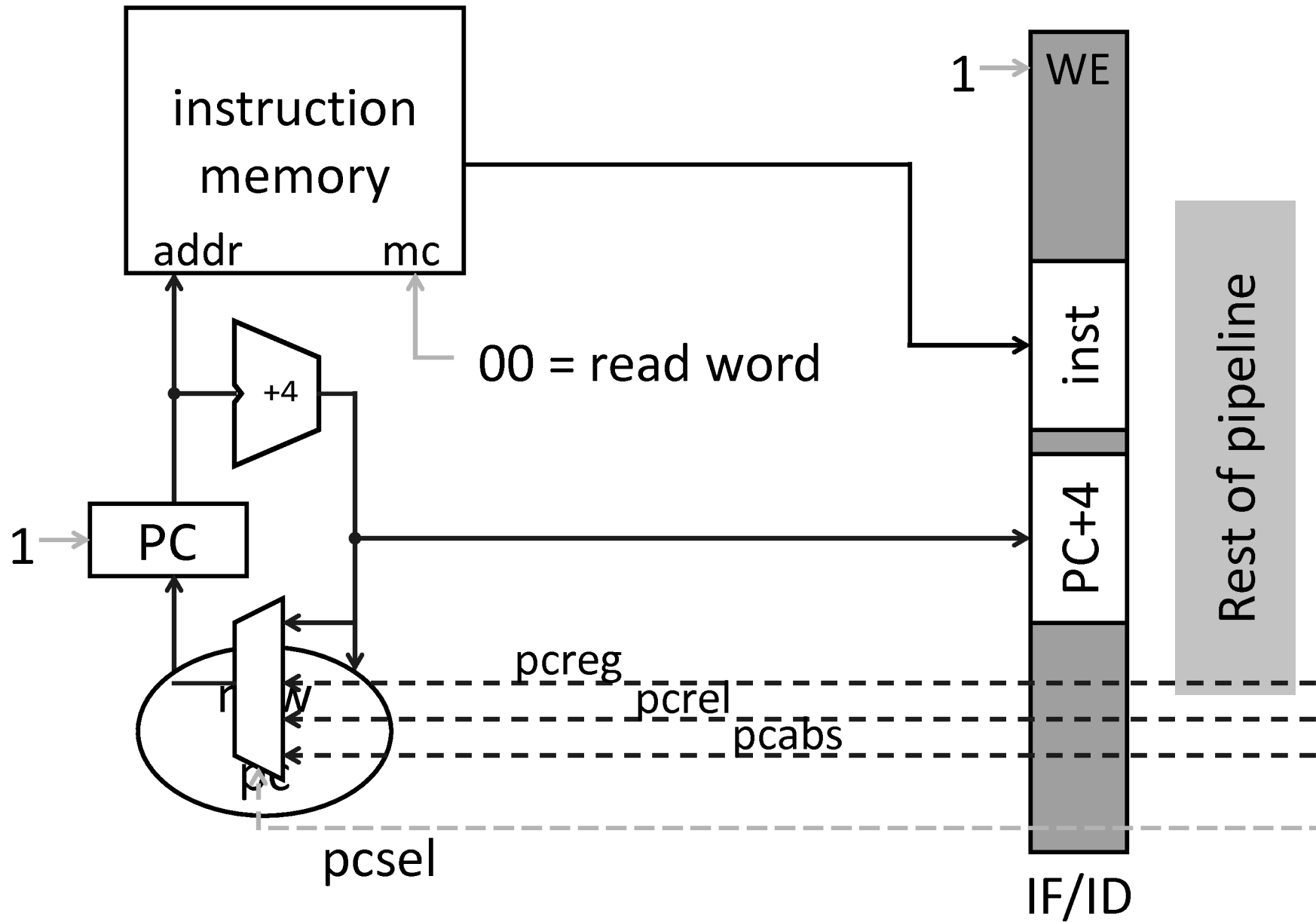
Stage 1: Instruction Fetch

Fetch a new instruction **every** cycle

- Current PC is index to instruction memory
- Increment the PC at end of cycle (assume no branches for now)

Write values of interest to **pipeline register (IF/ID)**

- Instruction bits (for later decoding)
- PC+4 (for later computing branch targets)



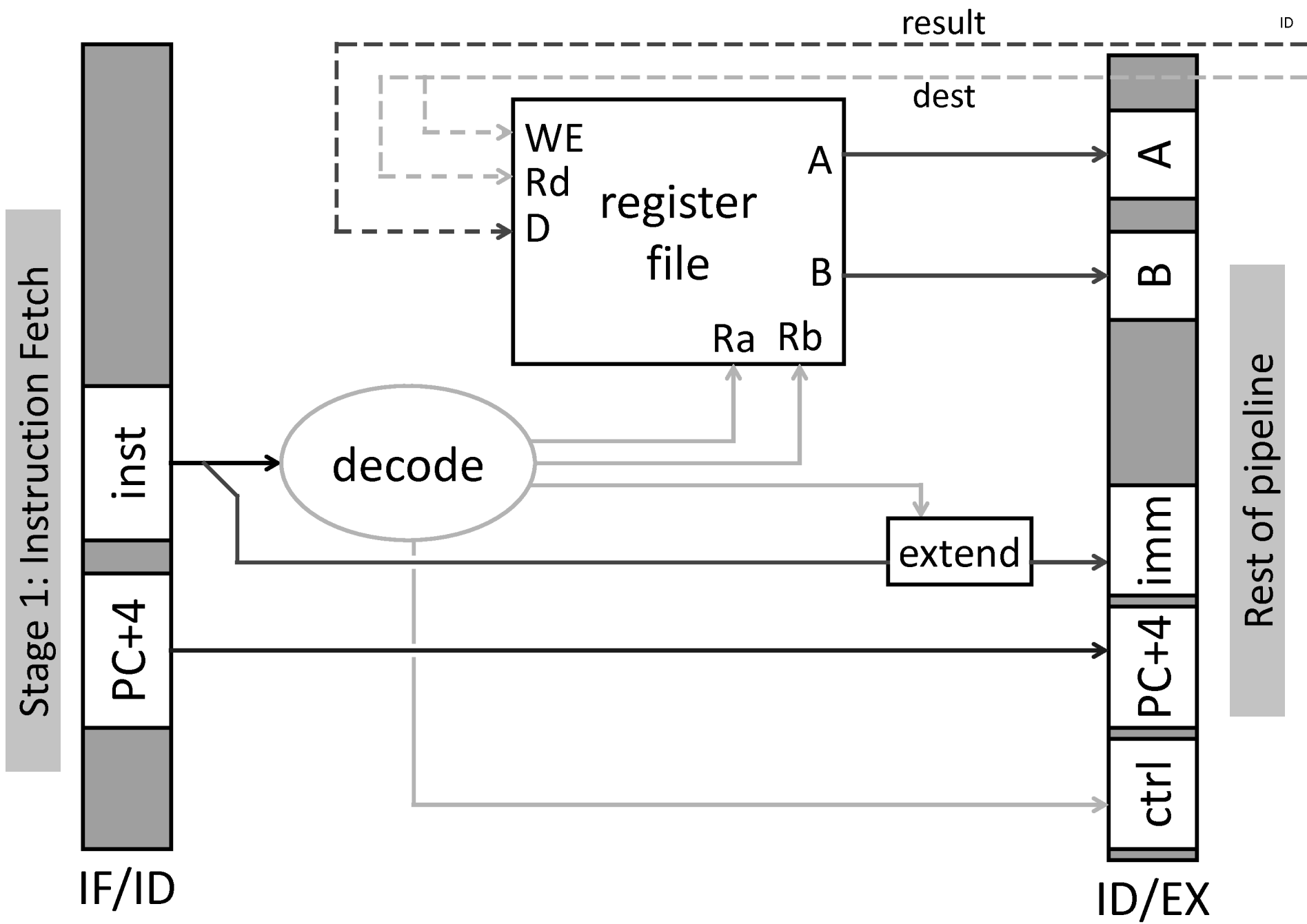
Stage 2: Instruction Decode

On every cycle:

- Read IF/ID pipeline register to get instruction bits
- Decode instruction, generate control signals
- Read from register file

Write values of interest to pipeline register (ID/EX)

- Control information, Rd index, immediates, offsets, ...
- Contents of Ra, Rb
- PC+4 (for computing branch targets later)



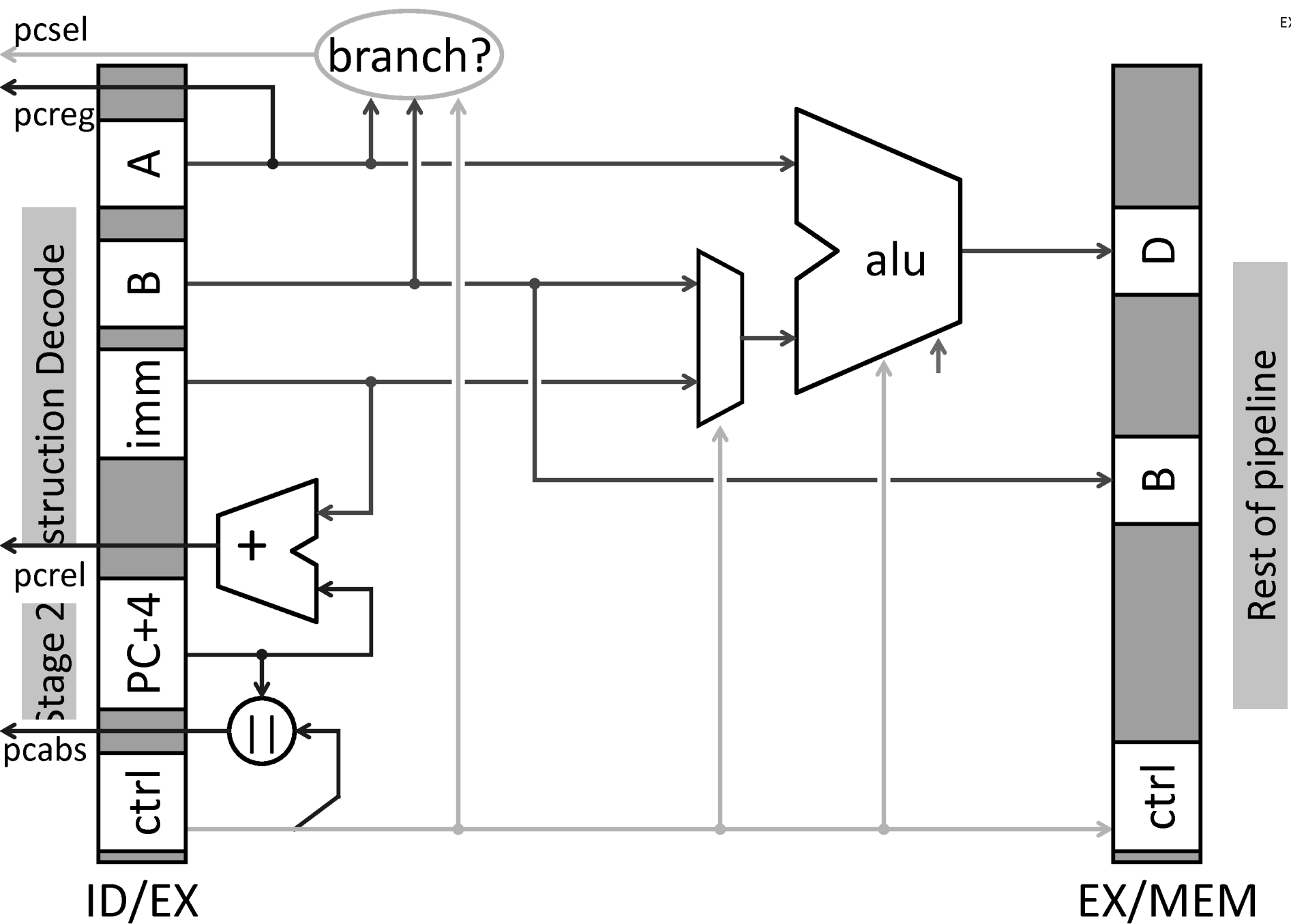
Stage 3: Execute

On **every** cycle:

- Read ID/EX pipeline register to get values and control bits
- Perform ALU operation
- Compute targets (PC+4+offset, etc.) *in case* this is a branch
- Decide if jump/branch should be taken

Write values of interest to **pipeline register (EX/MEM)**

- Control information, Rd index, ...
- Result of ALU operation
- Value *in case* this is a memory store instruction



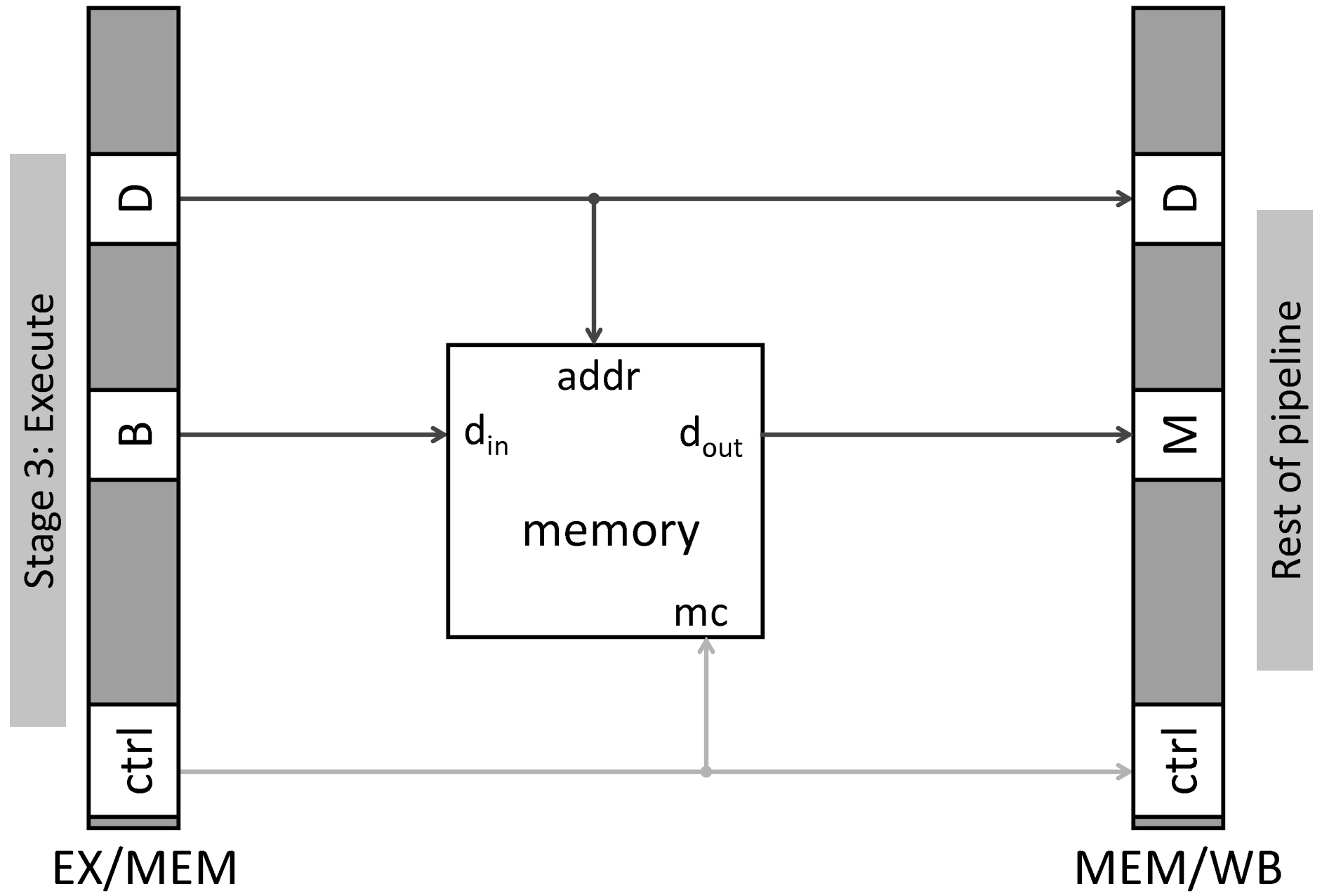
Stage 4: Memory

On every cycle:

- Read EX/MEM pipeline register to get values and control bits
- Perform memory load/store if needed
 - address is ALU result

Write values of interest to pipeline register (MEM/WB)

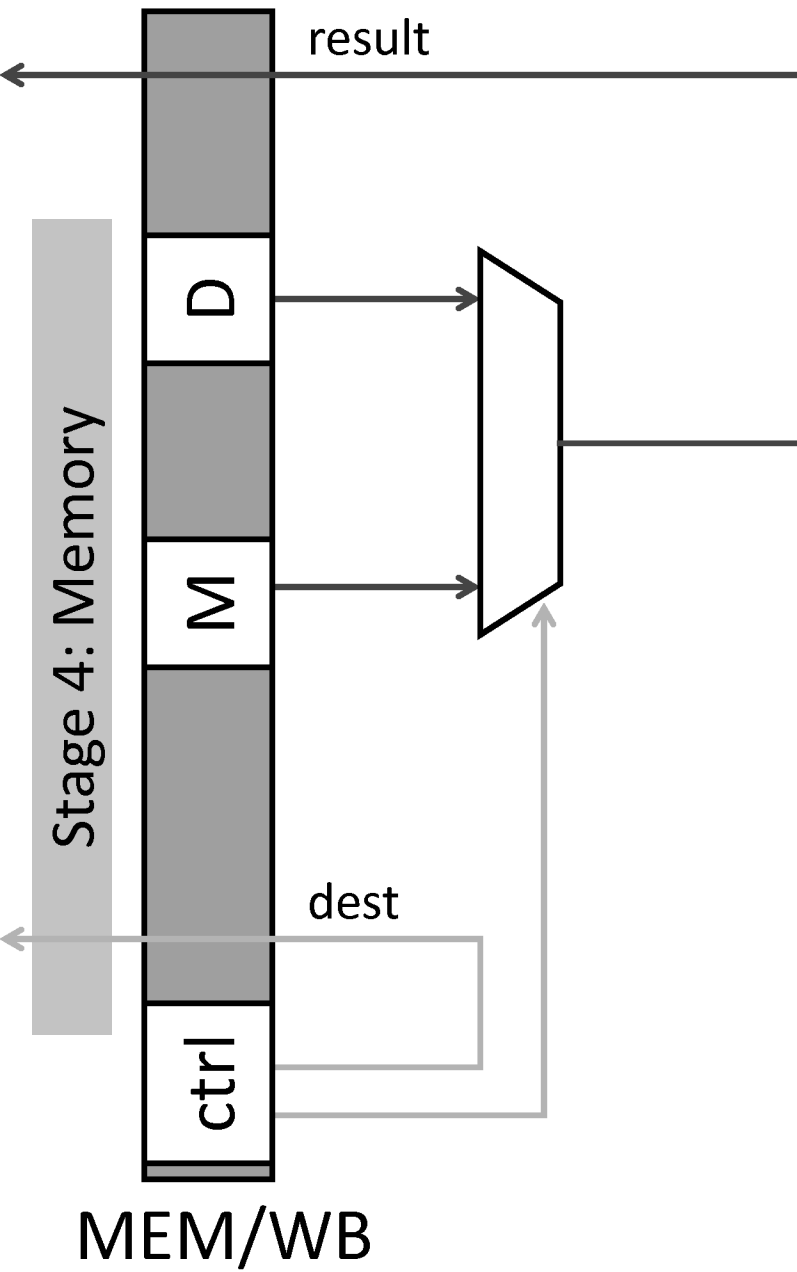
- Control information, Rd index, ...
- Result of memory operation
- Pass result of ALU operation

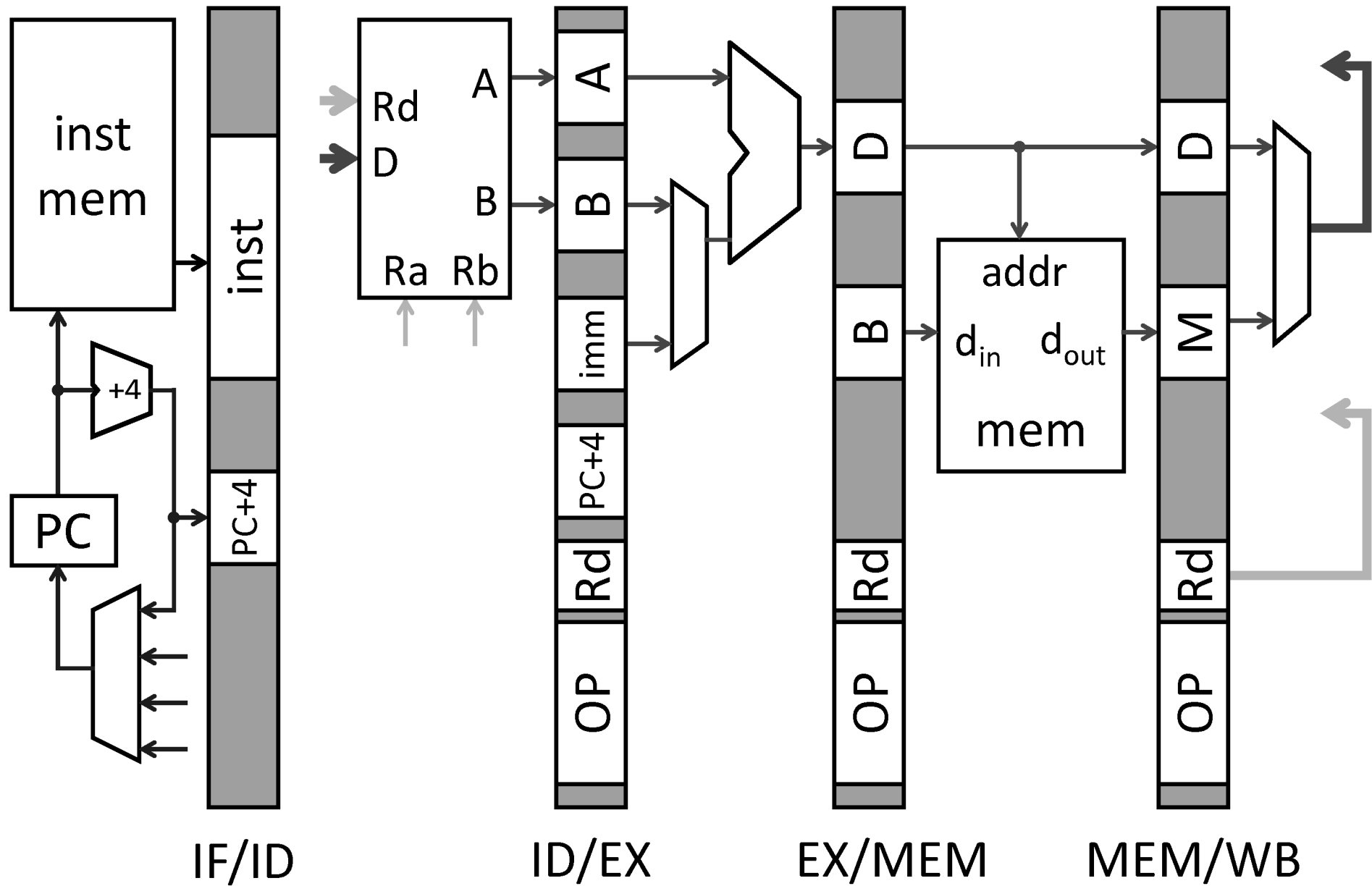


Stage 5: Write-back

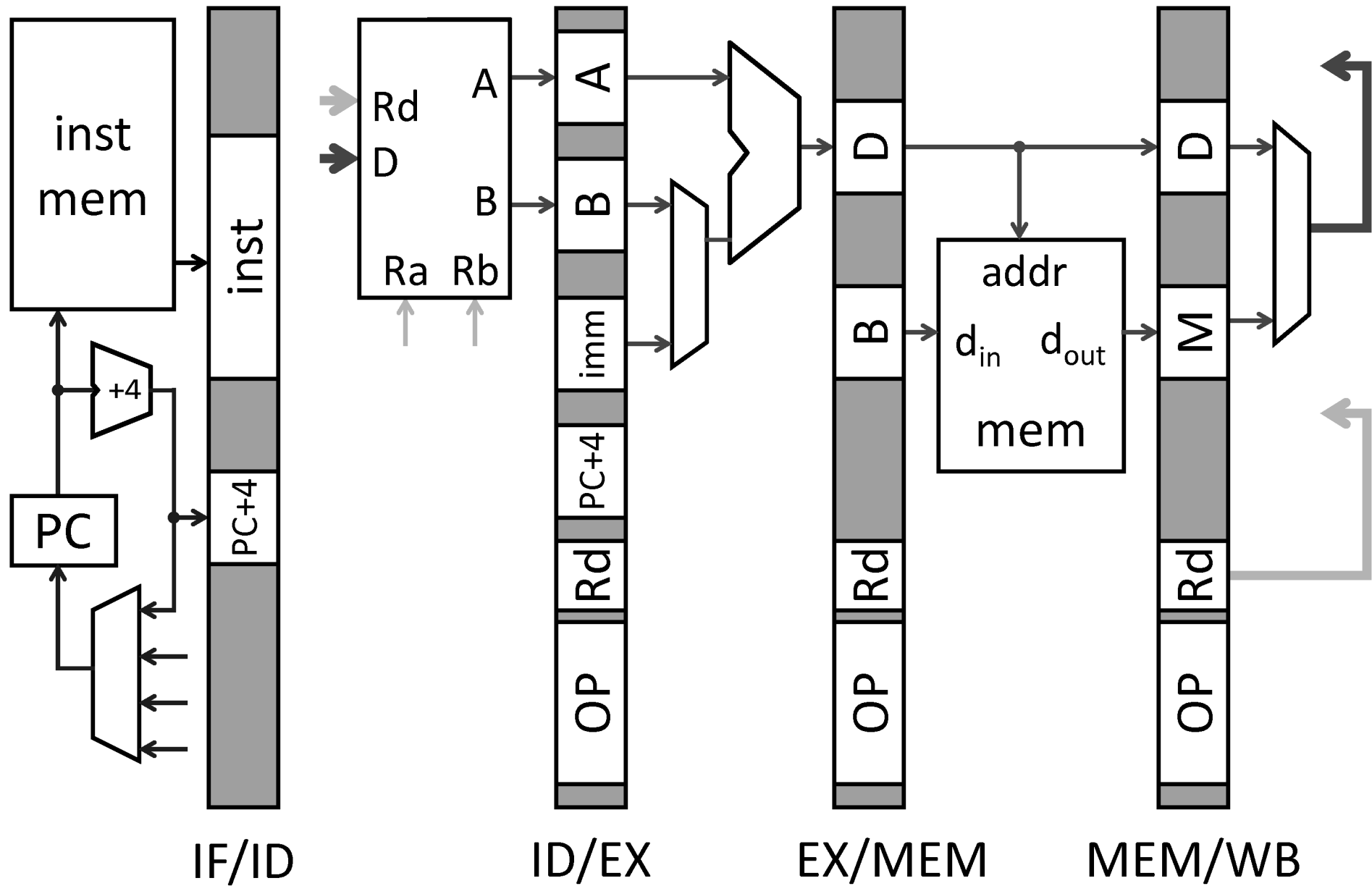
On every cycle:

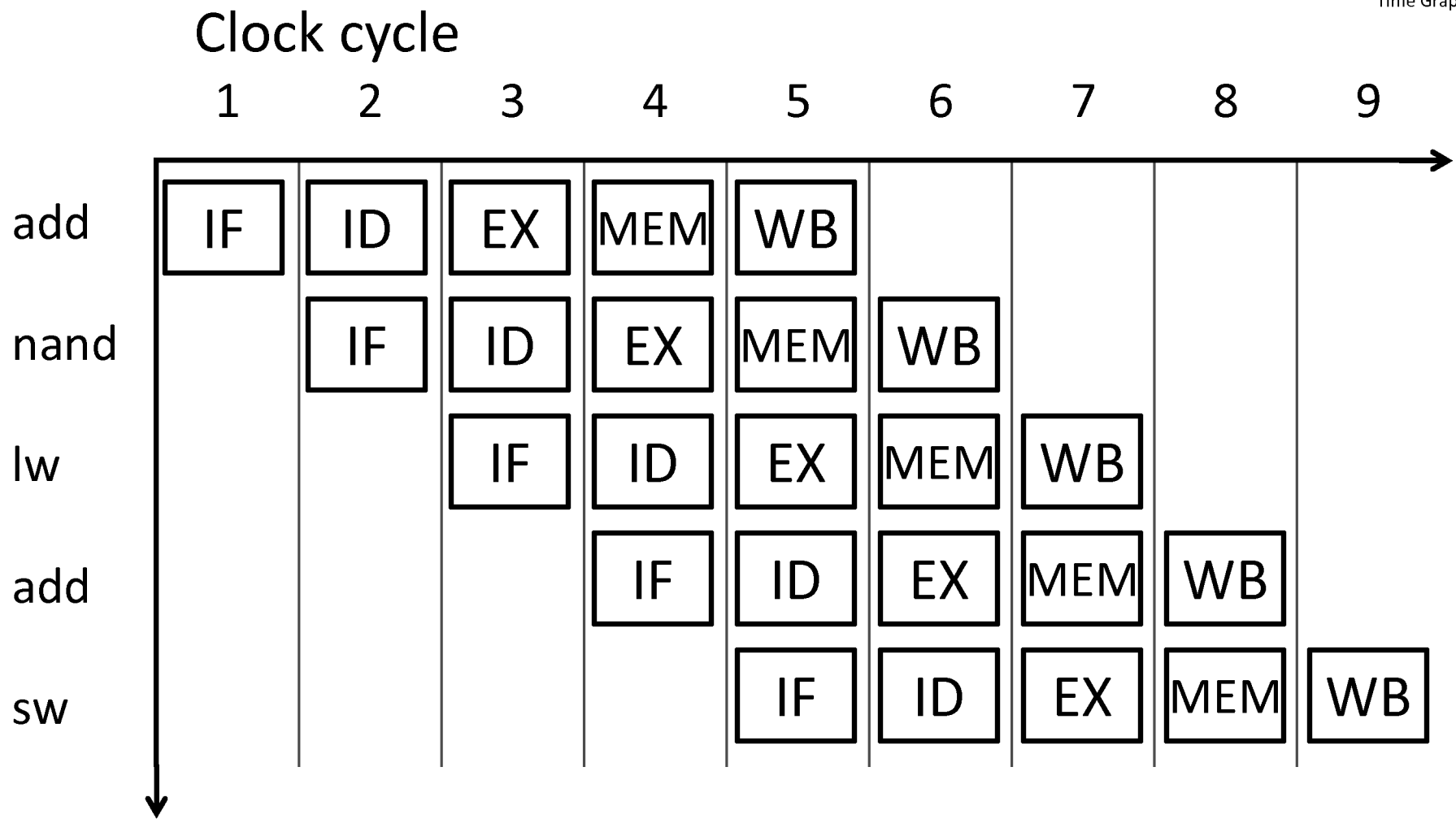
- Read MEM/WB pipeline register to get values and control bits
- Select value and write to register file





```
add    r3, r1, r2;  
nand   r6, r4, r5;  
lw     r4, 20(r2);  
add    r5, r2, r5;  
sw     r7, 12(r3);
```





Latency:

Throughput:

Concurrency:

CPI =

Powerful technique for masking latencies

- Logically, instructions execute one at a time
- Physically, instructions execute in parallel
 - Instruction level parallelism

Abstraction promotes decoupling

- Interface (ISA) vs. implementation (Pipeline)