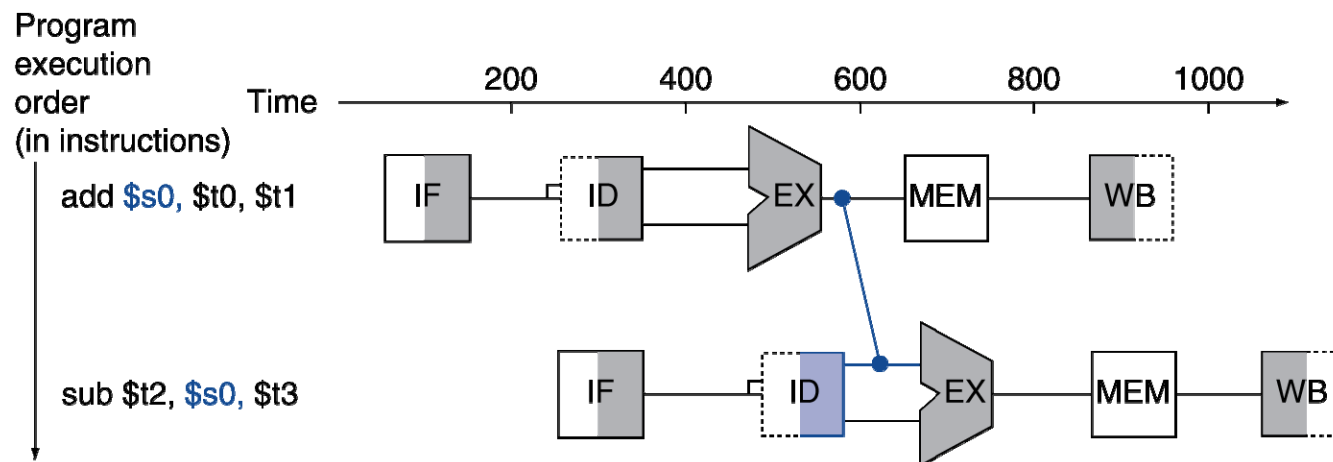# Chapter 4

The Processor

Forwarding (aka Bypassing)

- ## Use result when it is computed
  - ### Don't wait for it to be stored in a register
  - ### Requires extra connections in the datapath

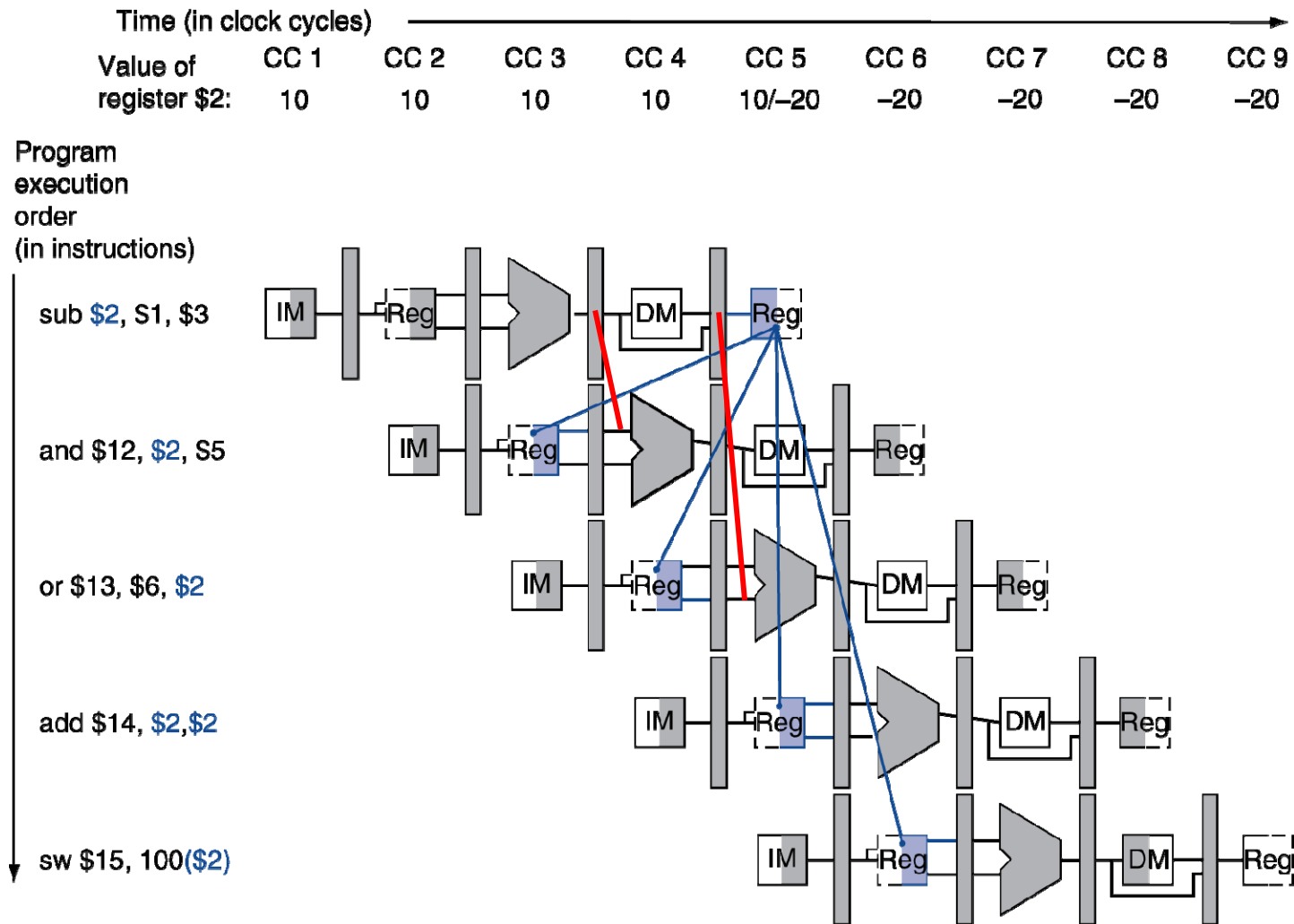# Data Hazards in ALU Instructions

- Consider this sequence:

  ```
  sub  $2,  $1, $3
  and  $12, $2, $5
  or   $13, $6, $2
  add  $14, $2, $2
  sw   $15, 100($2)
  ```

- We can resolve hazards with forwarding
  - How do we detect when to forward?

Dependencies & Forwarding

Detecting the Need to Forward

- Pass register numbers along pipeline
  - e.g., ID/EX.RegisterRs = register number for Rs sitting in ID/EX pipeline register
- ALU operand register numbers in EX stage are given by
  - ID/EX.RegisterRs, ID/EX.RegisterRt
- Data hazards when
  - 1a. EX/MEM.RegisterRd = ID/EX.RegisterRs
  - 1b. EX/MEM.RegisterRd = ID/EX.RegisterRt
  - 2a. MEM/WB.RegisterRd = ID/EX.RegisterRs
  - 2b. MEM/WB.RegisterRd = ID/EX.RegisterRt

Fwd from EX/MEM pipeline reg
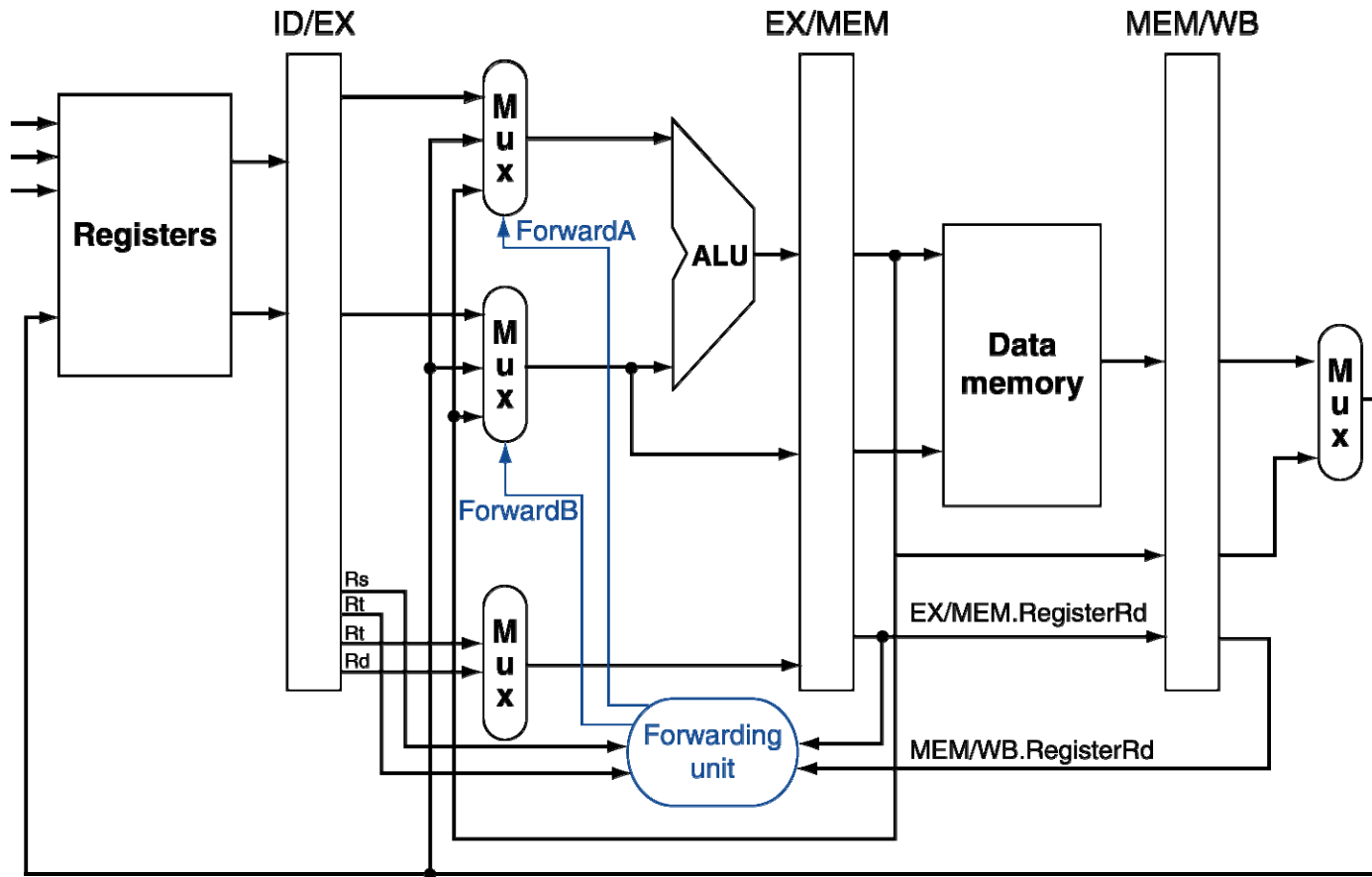
Fwd from MEM/WB pipeline reg

Detecting the Need to Forward

- But only if forwarding instruction will write to a register!
  - EX/MEM.RegWrite, MEM/WB.RegWrite
- And only if Rd for that instruction is not $zero
  - EX/MEM.RegisterRd ≠ 0, MEM/WB.RegisterRd ≠ 0

Forwarding Paths

b. With forwarding

Forwarding Conditions

- EX hazard
  - if (EX/MEM.RegWrite and (EX/MEM.RegisterRd ≠ 0)
    and (EX/MEM.RegisterRd = ID/EX.RegisterRs))
    ForwardA = 10
  - if (EX/MEM.RegWrite and (EX/MEM.RegisterRd ≠ 0)
    and (EX/MEM.RegisterRd = ID/EX.RegisterRt))
    ForwardB = 10

- MEM hazard
  - if (MEM/WB.RegWrite and (MEM/WB.RegisterRd ≠ 0)
    and (MEM/WB.RegisterRd = ID/EX.RegisterRs))
    ForwardA = 01
  - if (MEM/WB.RegWrite and (MEM/WB.RegisterRd ≠ 0)
    and (MEM/WB.RegisterRd = ID/EX.RegisterRt))
    ForwardB = 01

Double Data Hazard

- Consider the sequence:

  add $1, $1, $2
  add $1, $1, $3
  add $1, $1, $4

- Both hazards occur

  - Want to use the most recent

- Revise MEM hazard condition

  - Only fwd if EX hazard condition isn't true

Revised Forwarding Condition

- MEM hazard

    - if (MEM/WB.RegWrite and (MEM/WB.RegisterRd ≠ 0)

        and not (EX/MEM.RegWrite and (EX/MEM.RegisterRd ≠ 0)

            and (EX/MEM.RegisterRd = ID/EX.RegisterRs))

        and (MEM/WB.RegisterRd = ID/EX.RegisterRs))

        ForwardA = 01

    - if (MEM/WB.RegWrite and (MEM/WB.RegisterRd ≠ 0)

        and not (EX/MEM.RegWrite and (EX/MEM.RegisterRd ≠ 0)

            and (EX/MEM.RegisterRd = ID/EX.RegisterRt))

        and (MEM/WB.RegisterRd = ID/EX.RegisterRt))

        ForwardB = 01

Datapath with Forwarding