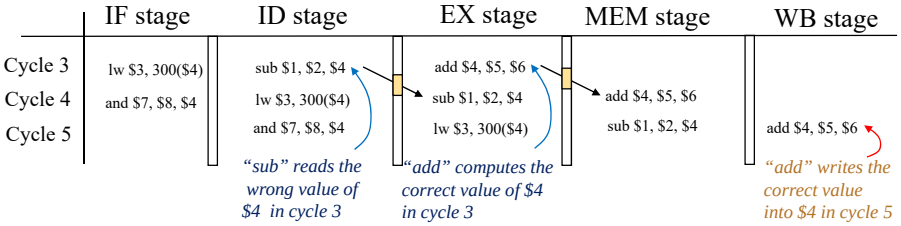
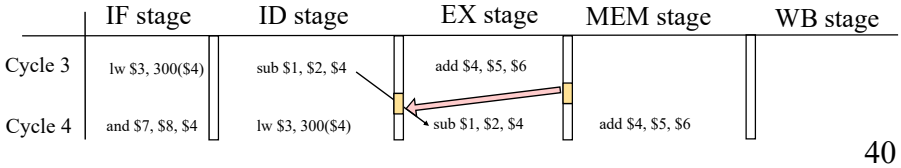
Forwarding: a hardware solution



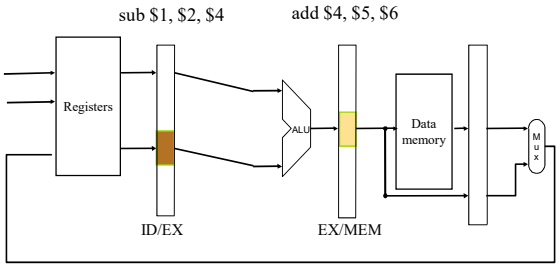
Forwarding: *Allow "add" to pass to the "sub" the data that it will write to $4:*

- At the end of cycle 3, "add" stores the correct value of $4 in the EX/MEM buffer while "sub" stores the wrong value of $4 in the ID/EX buffer
- At the start of cycle 4, forwarding replaces the incorrect data stored in the ID/EX buffer by the correct data stored in the ID/EX buffer.

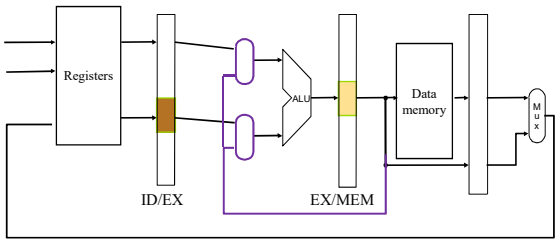


Forwarding from EX/MEM to ID/EX

- The *sub* did read the wrong value from $4 (stored in ID/EX)
- The *add* has the correct value to be written in $4 (stored in EX/MEM)

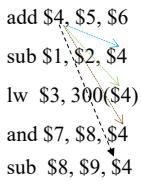


- The *sub* can replace the wrong value read from $4 with the correct one (from EX/MEM) before feeding it to the ALU.
- Why two muxes??



More forwarding paths

Data dependences:



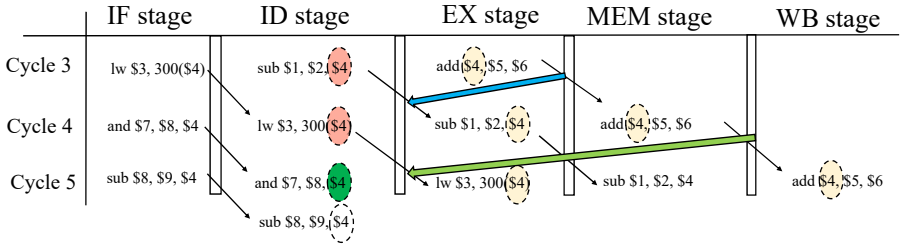
Resolved by EX/MEM → ID/EX forwarding

Resolved by MEM/WB → ID/EX forwarding

Resolved by writing into registers before reading

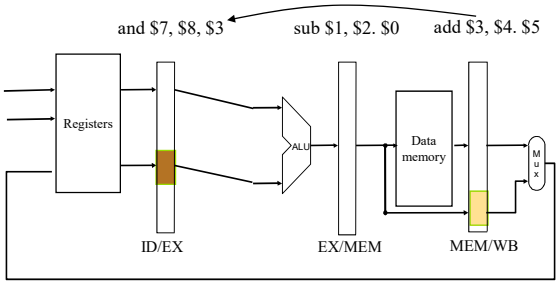
Data dependence does not cause hazards

Solution: Data forwarding

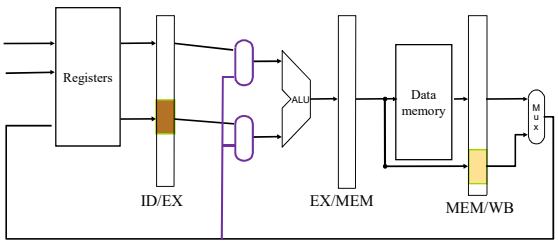


Forwarding from MEM/WB to ID/EX

- The *and* did read the wrong value from $3 (stored in ID/EX)
- The *add* has the correct value to be written in $3 (stored in MEM/WB)



- The *and* can use the correct value that will be written in $3 (from MEM/WB)

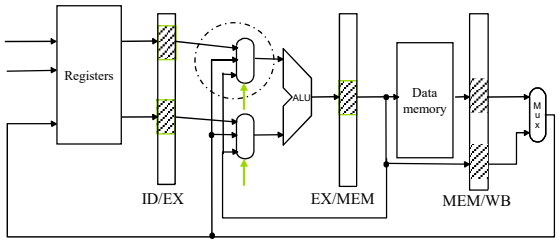


Combining the two forwarding datapaths

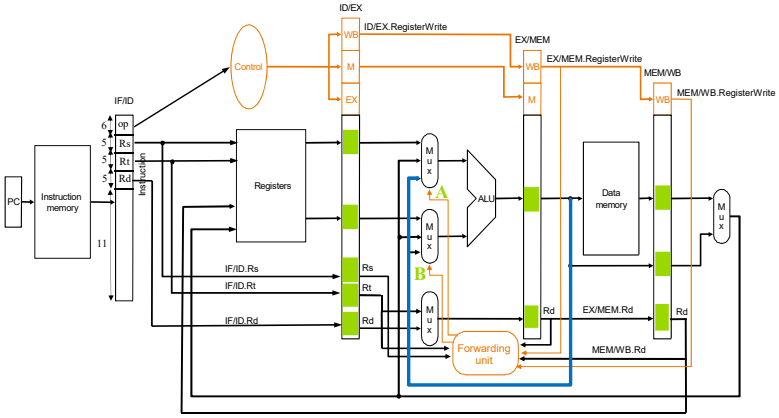
The default is to select the value from ID/EX buffer

Select the value from the MEM/WB buffer if
- the instruction in MEM/WB will write into a register $X
- the instruction in ID/EX did read from register $X

Select the value from the EX/MEM buffer if
- the instruction in EX/MEM will write into a register $X
- the instruction in ID/EX did read from register $X



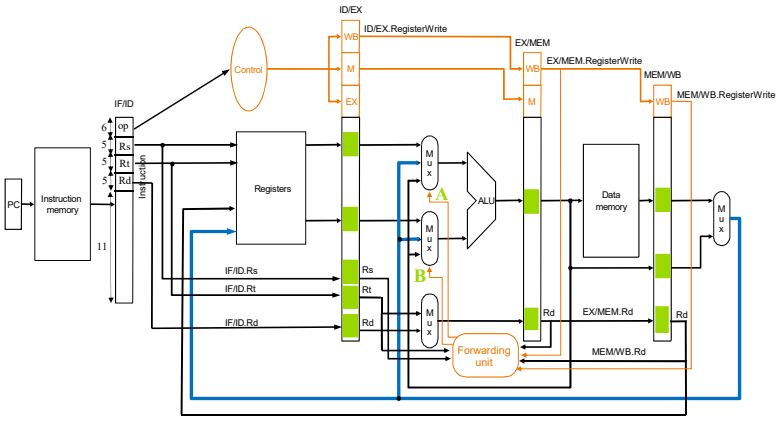
Setting the forwarding datapaths



- Set forward control signal, A, to 10 if
  - EX/MEM.RegisterWrite, and
  - EX/MEM.Rd = ID/EX.Rs, and
  - ID/EX.Rs!= 0

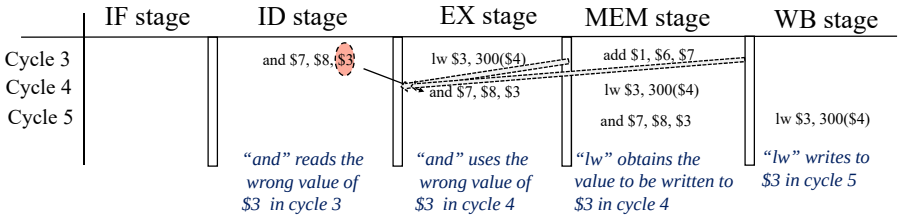
- Set forward control signal, B, to 10 if
  - EX/MEM.RegisterWrite, and
  - EX/MEM. Rd = ID/EX.Rt, and
  - ID/EX.Rt!= 0

Setting the forwarding datapaths



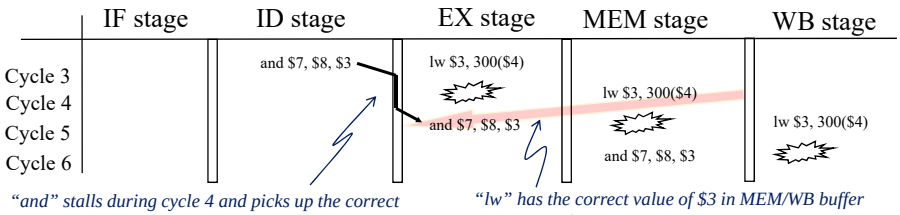
- Set forward control signal, A, to 01 if
  - MEM/WB.RegisterWrite, and
  - MEM/WB.Rd = ID/EX.Rs, and
  - ID/EX.Rs!= 0
- Set forward control signal, B, to 01 if
  - MEM/WB.RegisterWrite, and
  - MEM/WB. Rd = ID/EX.Rt, and
  - ID/EX.Rt!= 0

Forwarding may not be enough



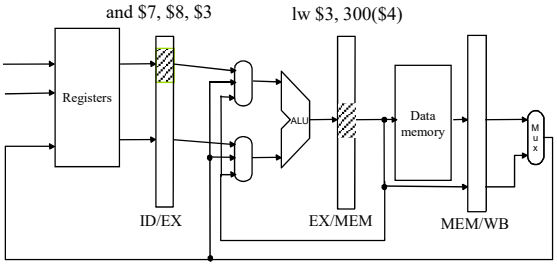
Problem: *can't use forwarding at the beginning of cycle 4 since "lw" produces the data to be written in $3 at the end of cycle 4*

Solution: *need to combine forwarding with stalling the pipe.*

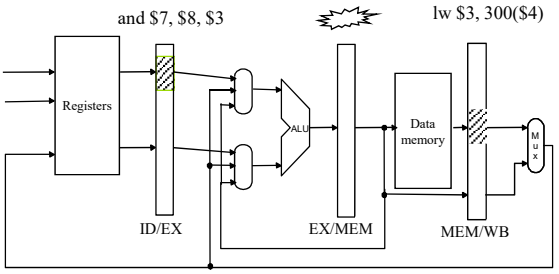


Stalling the pipeline

- The *and* did read the wrong value from $3 (stored in ID/EX)
- The *lw* does not have the value to be written in $3
- We have to make sure that the *lw* and the *and* are separated by at least one instruction



- To separate *and* and *lw* by one instruction, we need to insert a bubble at run time (stall the pipeline).

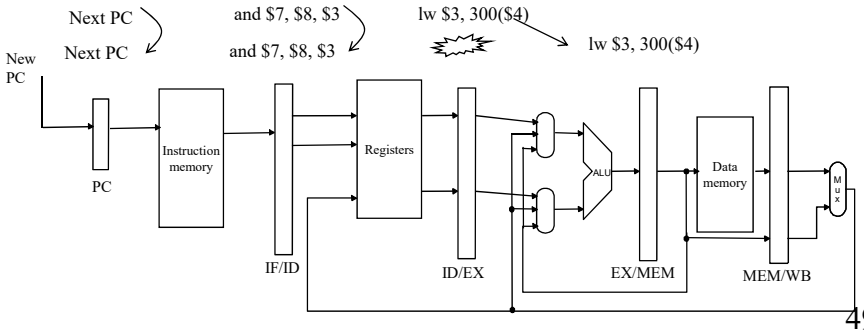


Inserting a bubble (stalling the pipe)

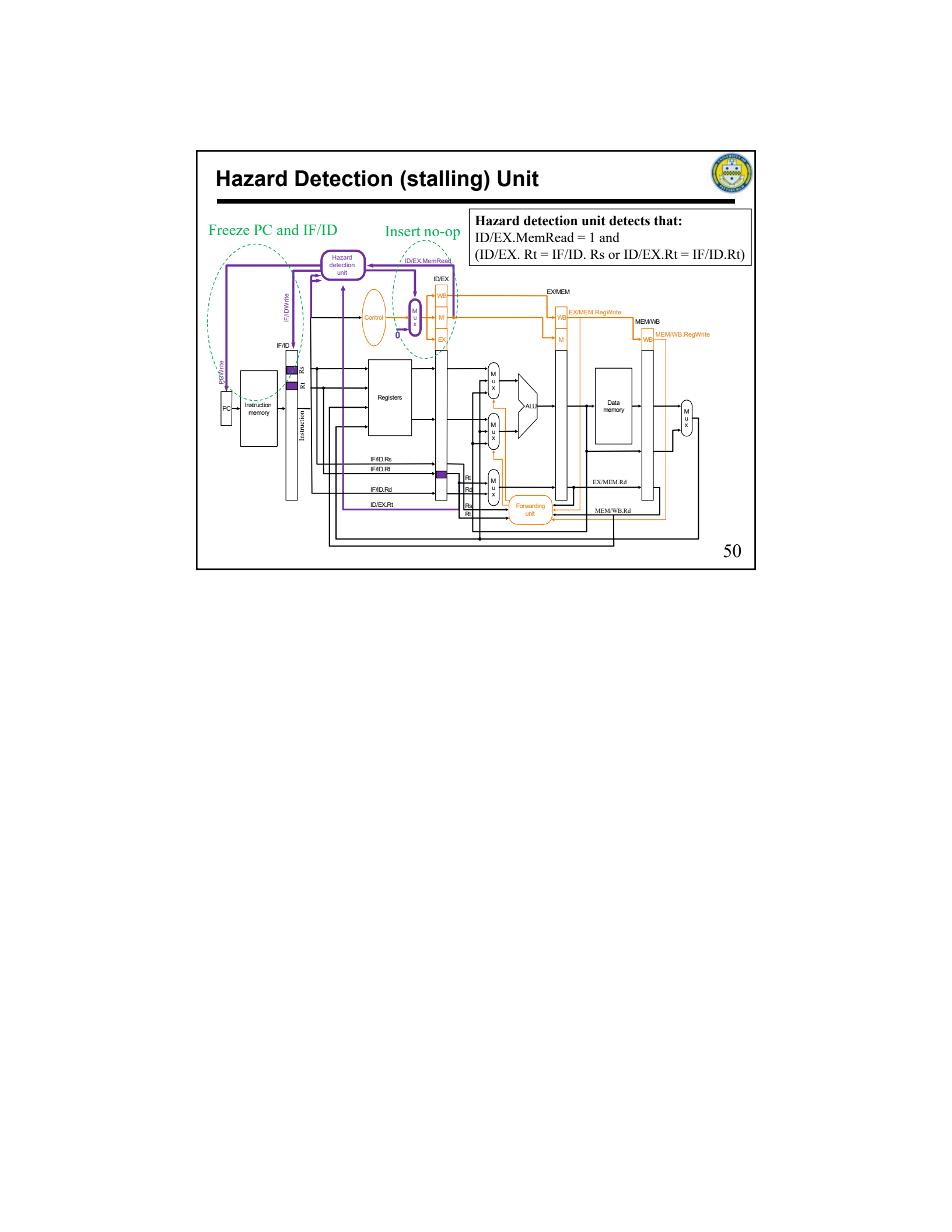
Actually may detect the hazard and stall the pipe when lw is in ID/EX

The hazard occurs if:
- the instruction in ID/EX is a *lw* instruction (will read from memory)
- the instruction in ID/EX will write into a register $X
- the instruction in IF/ID will read from register $X

Stall the pipeline when a hazard is detected:
- freeze the contents of the IF/ID buffer and the PC
- insert a no-op into the ID/EX buffer



Hazard Detection (stalling) Unit



Freeze PC and IF/ID

Insert no-op

Hazard detection unit detects that:
ID/EX.MemRead = 1 and
(ID/EX. Rt = IF/ID. Rs or ID/EX.Rt = IF/ID.Rt)