Hazard County

Pipelining is a good idea, but to make it work, several kinds of hazards have to be avoided, and interrupts must be handled.

Pipelining

- Recall that pipelining initiates an operation on each clock cycle
- The first design goal is to assure that there are no conflicts in the use of the hardware
Data Hazards

40 sub $2,$1,$3

44 and $12,$2,$5

48 or $13,$6,$2

52 add $14,$2,$2

56 lw $15,100($2)

Pipeline Bubbles

40 sub $2,$1,$3

Stall

Stall

Stall

44 and $12,$2,$5
Fowarding for loads

40 lw $15,100($2)

Stall

44 and $12,$2,$15

48 add $14,$2,$2

52 sw $15,100($2)

An inevitable Bubble

Detecting Data Hazards

EX Hazard:

ID/EX.RegWrite and
((ID/EX.RegDst=0 and ID/EX.WriteRegisterRt=IF/ID.ReadRegister1) or
(ID/EX.RegDst=1 and ID/EX.WriteRegisterRd=IF/ID.ReadRegister1) or
(ID/EX.RegDst=0 and ID/EX.WriteRegisterRt=IF/ID.ReadRegister2) or
(ID/EX.RegDst=1 and ID/EX.WriteRegisterRd=IF/ID.ReadRegister2))

MEM Hazard:

EX/MEM.RegWrite and
((EX/MEM.WriteRegister=IF/ID.ReadRegister1) or
(EX/MEM.WriteRegister=IF/ID.ReadRegister2))

WB Hazard:

MEM/WB.RegWrite and
((MEM/WB.WriteRegister=IF/ID.ReadRegister1) or
(MEM/WB.WriteRegister=IF/ID.ReadRegister2))
Forwarding

or $4, $4, $2 and $4, $2, $5
sub $2, $1, $3
before<1>
before<2>

Clock 3
Forwarding

Hazard Detection
Load Hazards

ID/EX.RegWrite and (ID/EX.RegDst = 0) and
((ID/EX.WriteRegisterRt = IF/ID.Read.Register1) or
 (ID/EX.WriteRegisterRt = IF/ID.ReadRegister2))

Consider the sequence to swap stack items

\[
\begin{align*}
    \text{lw} & \quad 10, 0($29) \quad \text{-- Load top item} \\
    \text{lw} & \quad 11, 4($29) \quad \text{-- Load second item} \\
    \text{sw} & \quad 11, 0($29) \quad \text{-- Replace top item} \\
    \text{sw} & \quad 10, 4($29) \quad \text{-- Replace second item}
\end{align*}
\]

Which can be replace by

\[
\begin{align*}
    \text{lw} & \quad 10, 0($29) \quad \text{-- Load top item} \\
    \text{lw} & \quad 11, 4($29) \quad \text{-- Load second item} \\
    \text{sw} & \quad 10, 4($29) \quad \text{-- Replace second item} \\
    \text{sw} & \quad 11, 0($29) \quad \text{-- Replace top item}
\end{align*}
\]