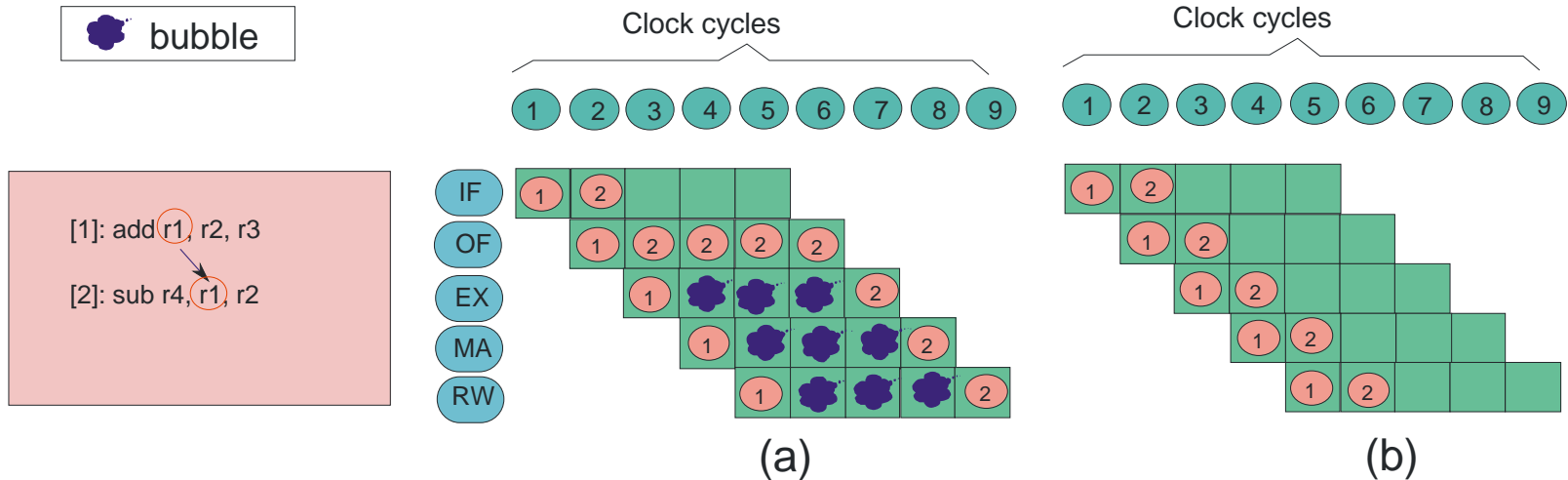


# **Pipelining Hazards and Mitigations (Part 2: Forwarding scheme)**

**Slide courtesy: Smruti  
Ranjan Sarangi**

**Slides adapted by: Dr Sparsh Mittal**

# Relook at the Pipeline Diagram

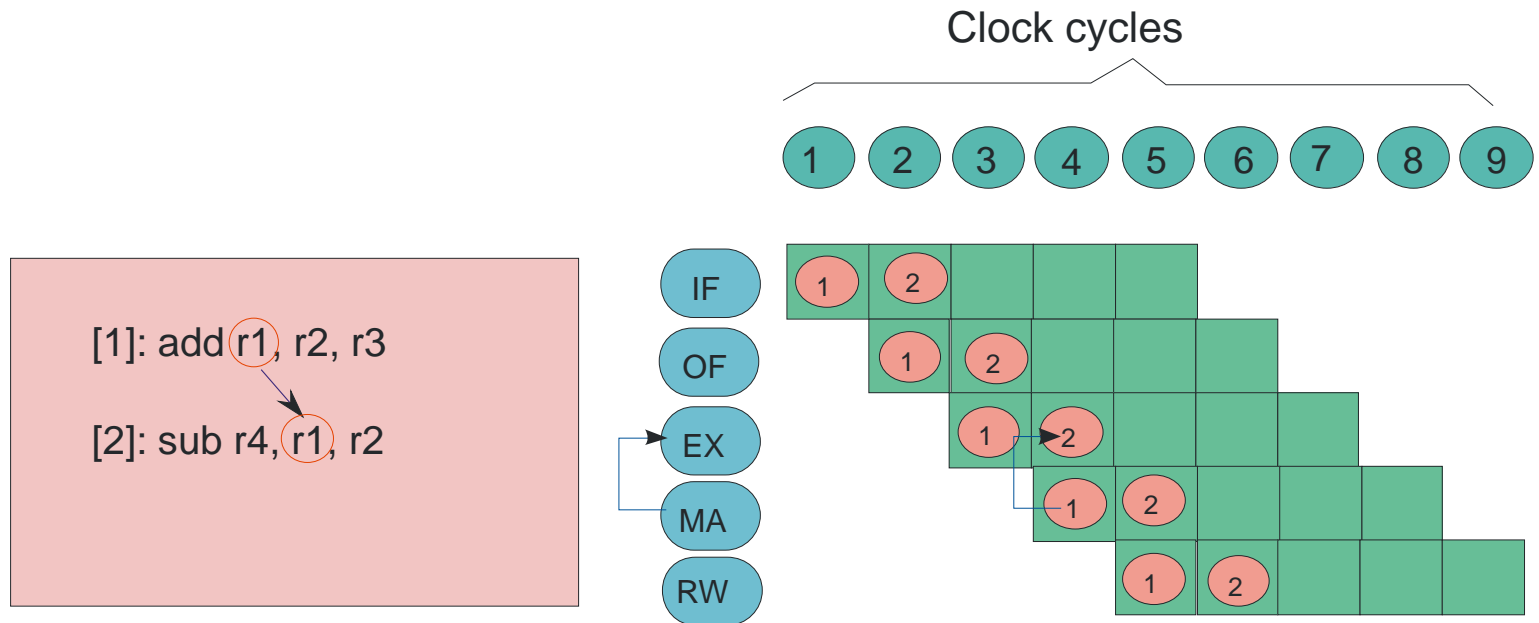


- \* (a) → with bubbles
- \* (b) → no bubbles (may lead to wrong results)

# Crucial Insight (Figure (b))

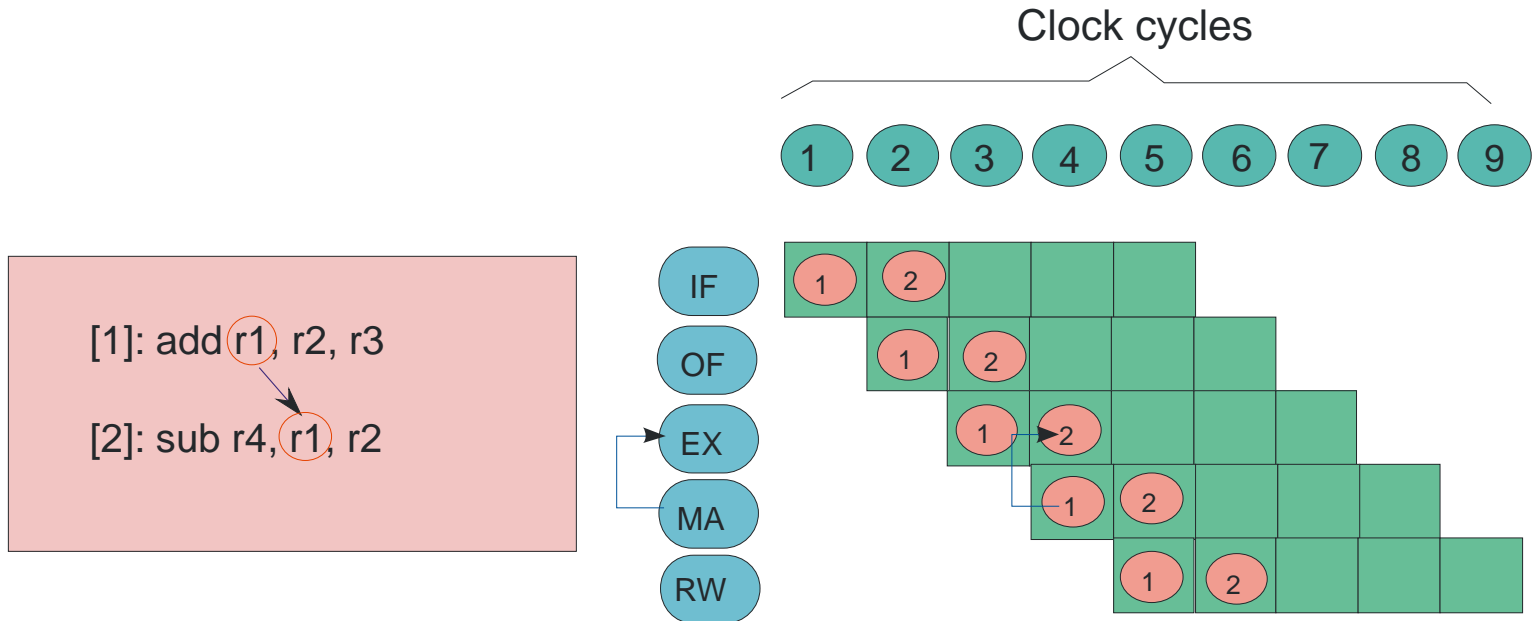
- \* When does instruction 2 need the value of r1 ?
  - \* **ANSWER** : Cycle 3, OF Stage (**wrong!!!**)
  - \* **CORRECT ANSWER** : Cycle 4, EX Stage
- \* When does instruction 1 produce the value of r1 ?
  - \* **ANSWER** : Cycle 5, RW Stage (**wrong!!!**)
  - \* **CORRECT ANSWER** : End of Cycle 3, EX Stage

# Forwarding



- \* If the **correct value** is already there in another stage, we can **forward** it.

# Forwarding from MA to EX



- \* Forwarding in cycle 4 from instruction [1] to [2]

# Different Forwarding Paths

- \* We need to add a multitude of forwarding paths
- \* Rules for creating forwarding paths
  - \* Add a path from a later stage to an earlier stage
  - \* Try to add a forwarding path as late as possible. For, example, we avoid the EX → OF forwarding path, since we have the MA → EX forwarding path
  - \* The IF stage is not a part of any forwarding path.

# Forwarding Path

- \* 3 Stage Paths

- \* RW  $\rightarrow$  OF

- \* 2 Stage Paths

- \* RW  $\rightarrow$  EX

- \* MA  $\rightarrow$  OF (**X Not Required**)

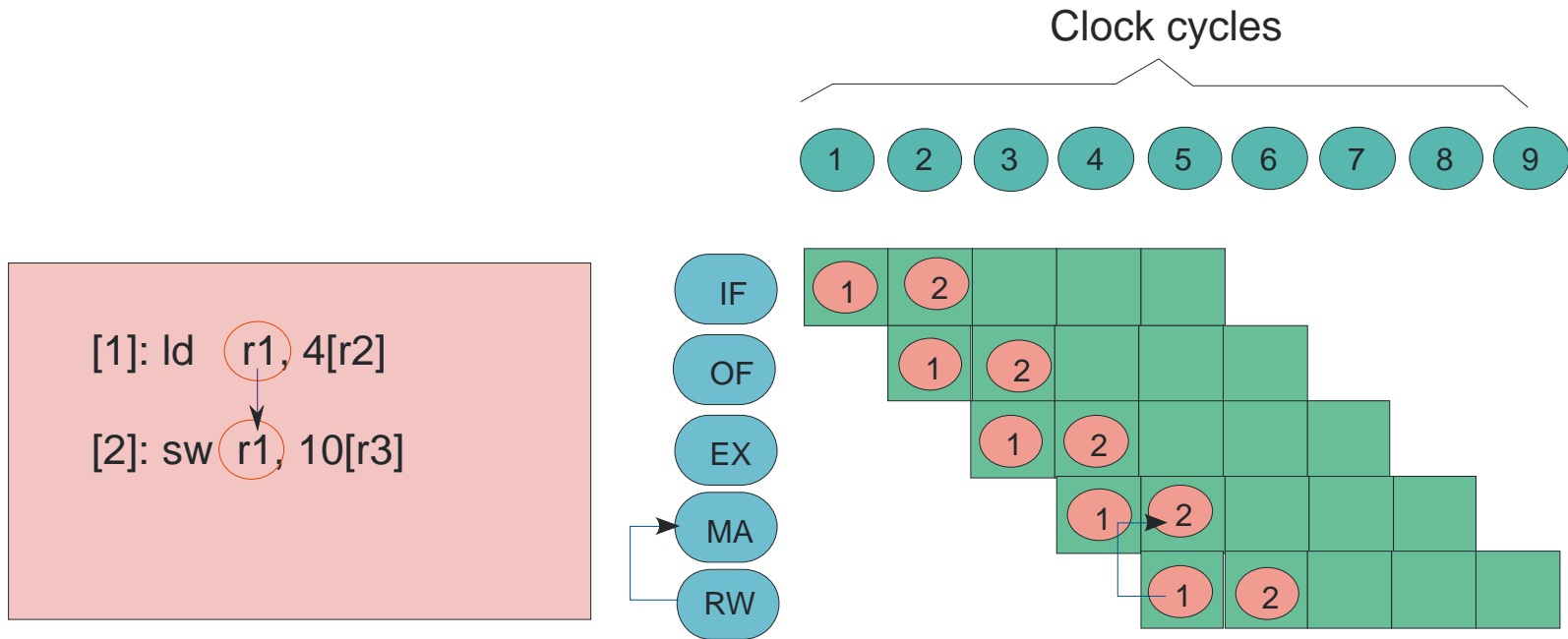
- \* 1 Stage Paths

- \* RW  $\rightarrow$  MA (load to store)

- \* MA  $\rightarrow$  EX (ALU Instructions, load, store)

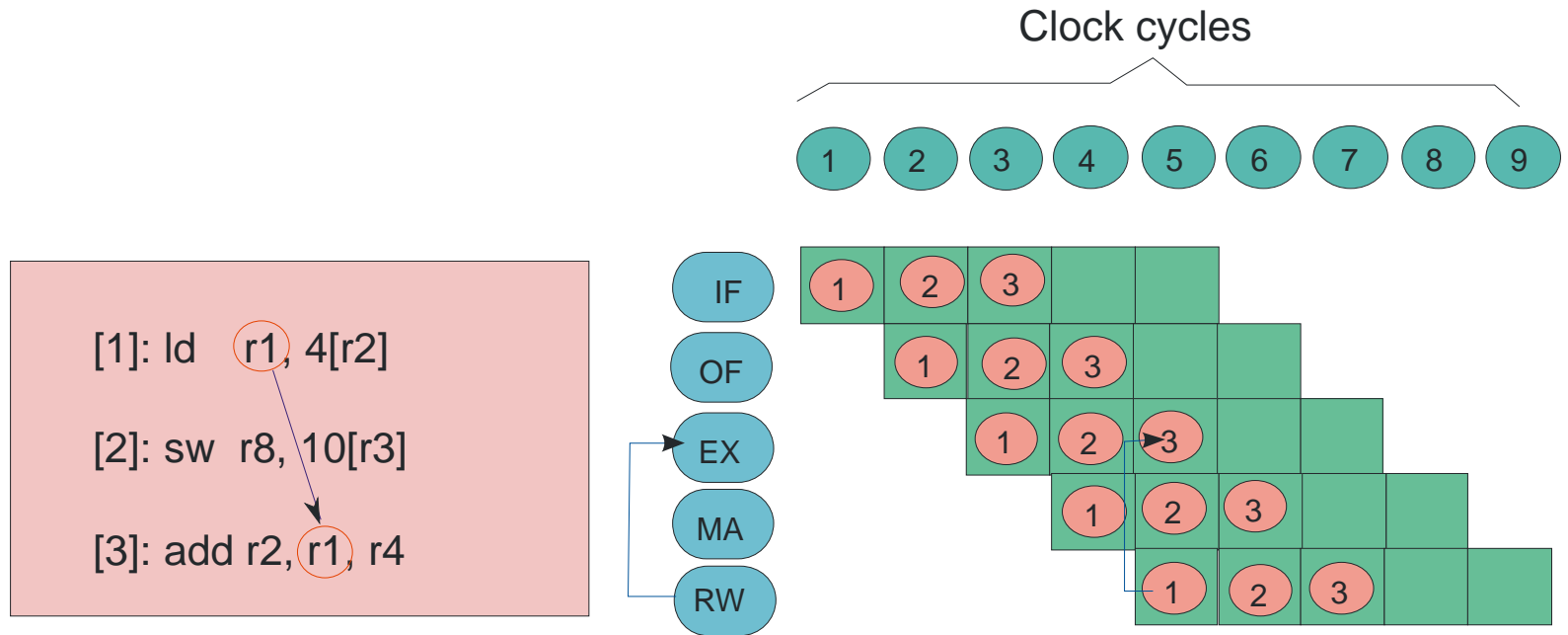
- \* EX  $\rightarrow$  OF (**X Not Required**)

# Forwarding Paths : RW $\rightarrow$ MA

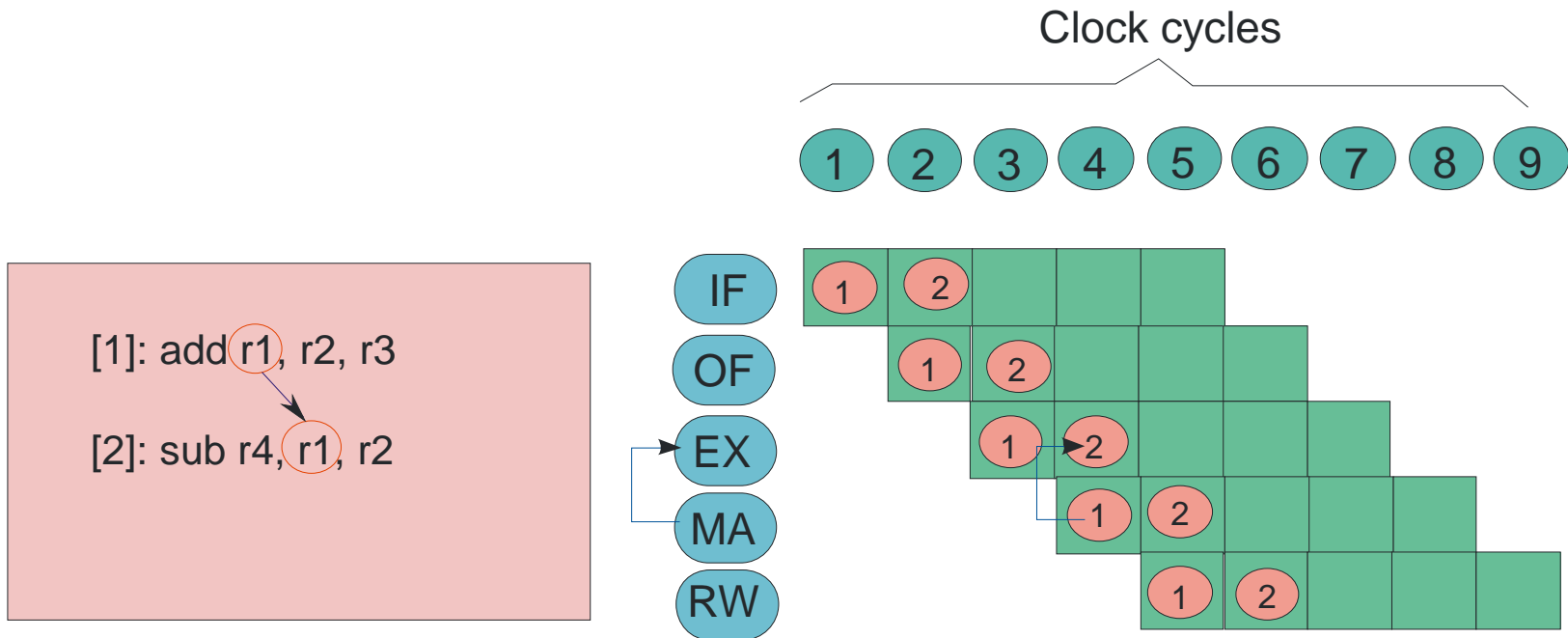




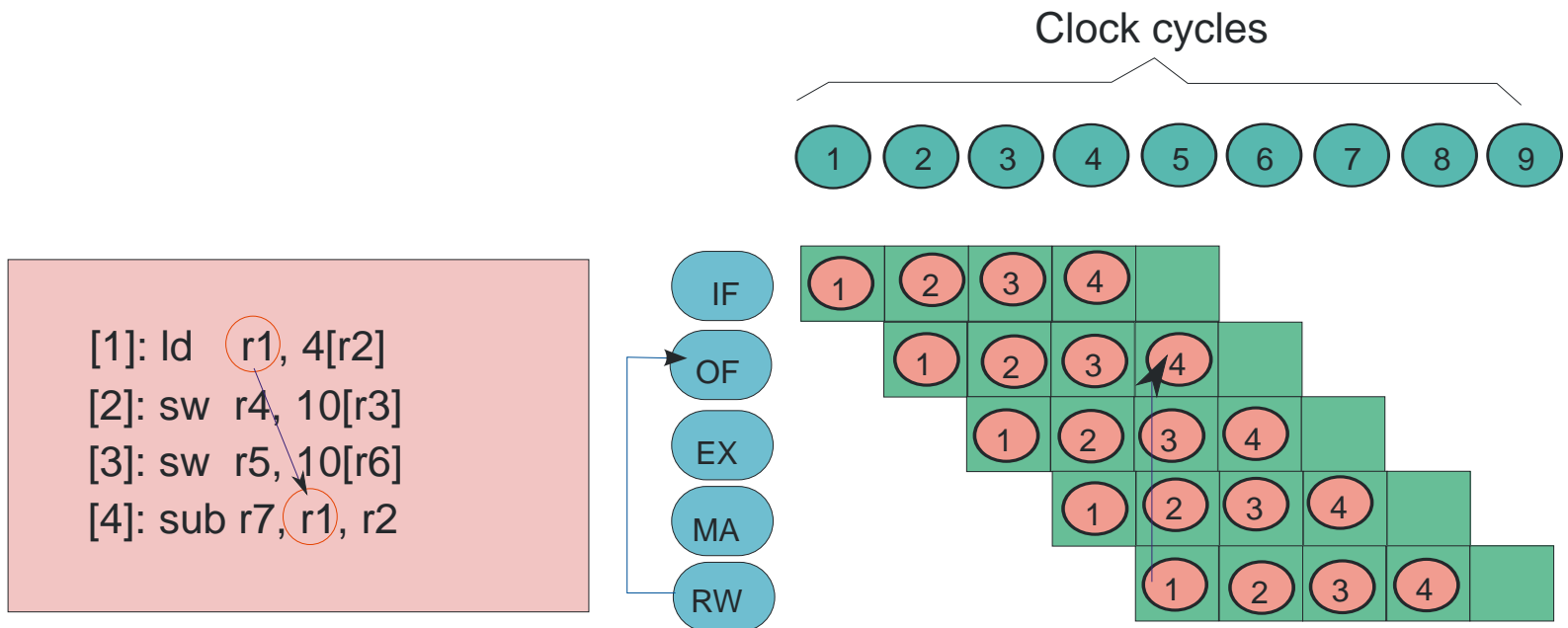
# Forwarding Paths : RW $\rightarrow$ EX



# Forwarding Path : MA $\rightarrow$ EX



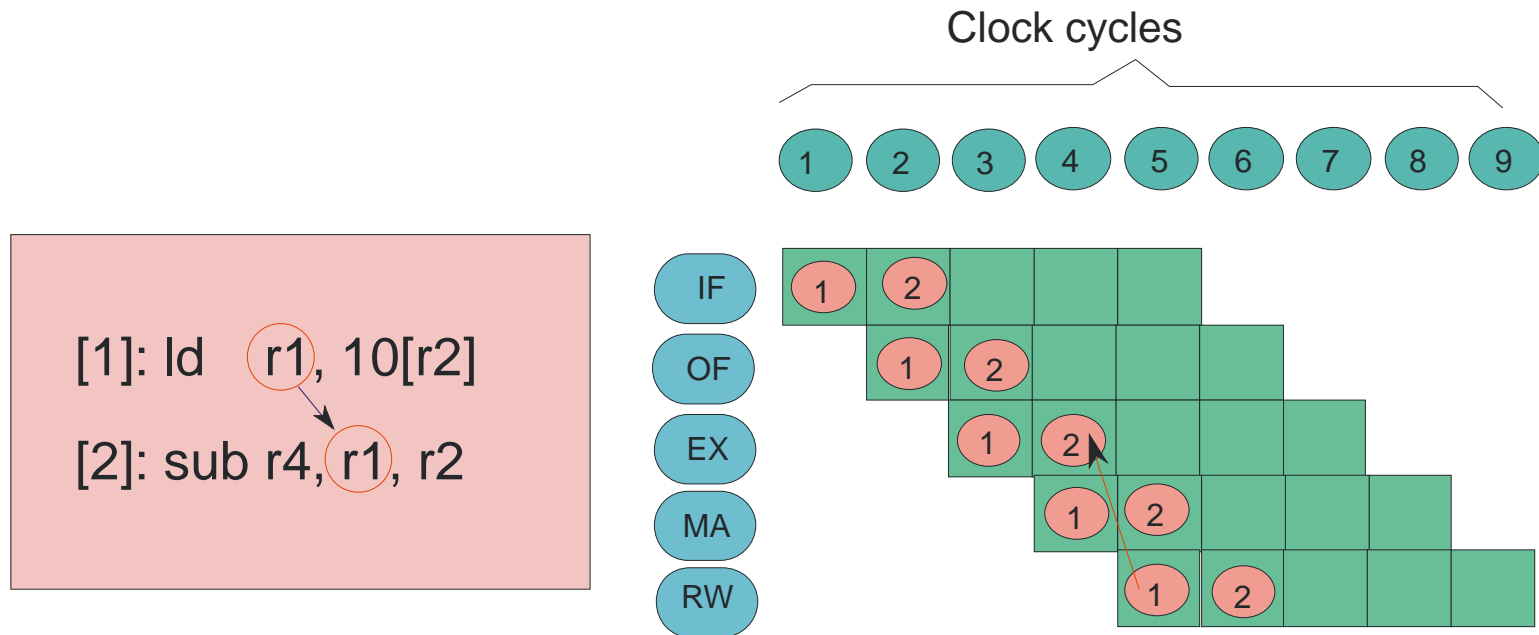
# Forwarding Path : RW $\rightarrow$ OF



# Data Hazards with Forwarding

- \* Forwarding has unfortunately not eliminated all data hazards
- \* We are left with one special case.
- \* Load-use hazard
  - \* The instruction immediately after a load instruction has a RAW dependence with it.

# Load-Use Hazard

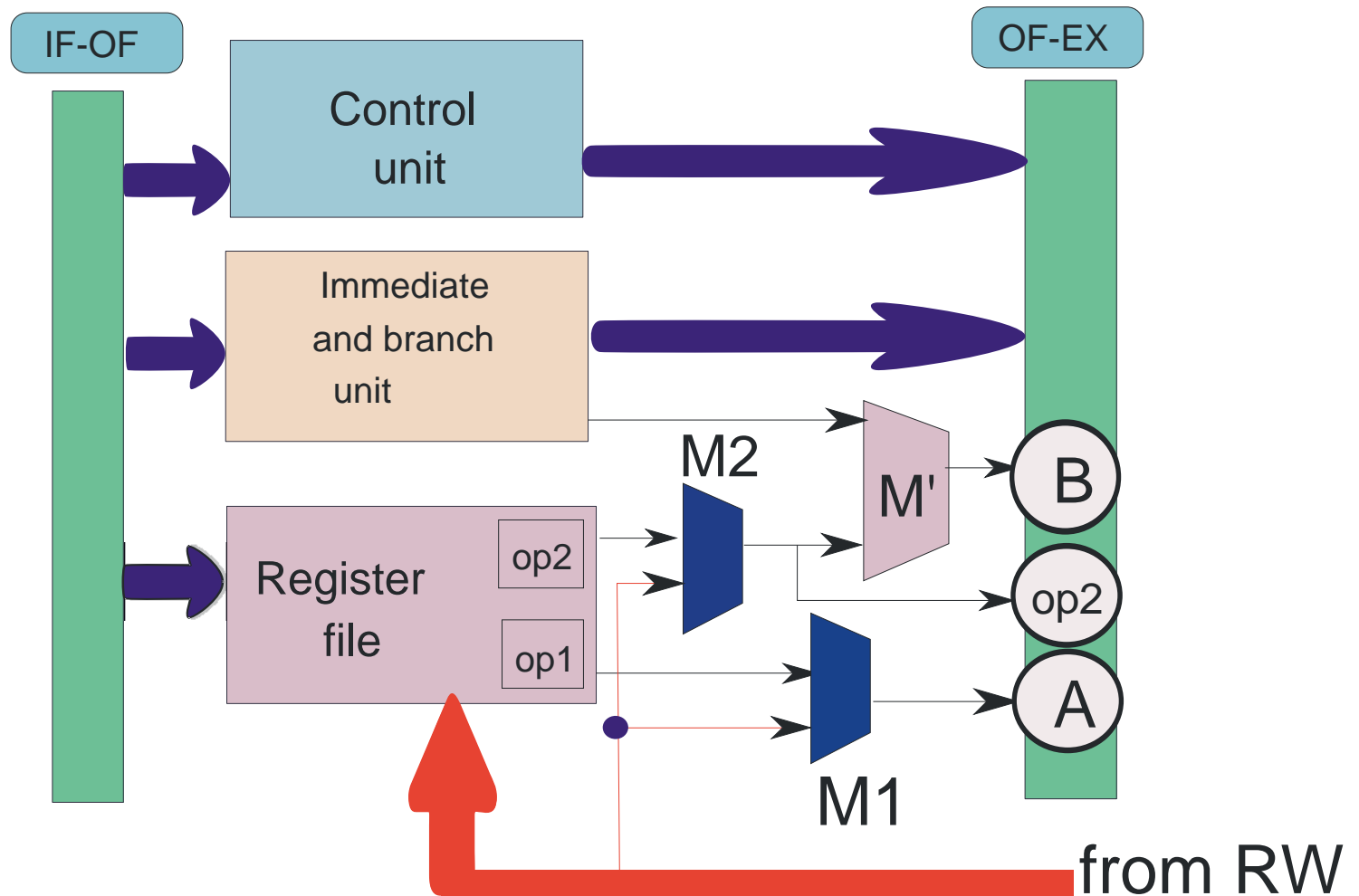


- \* **Cannot forward** (arrow goes backwards in time)
- \* Need to add a bubble (then use RW → EX forwarding)

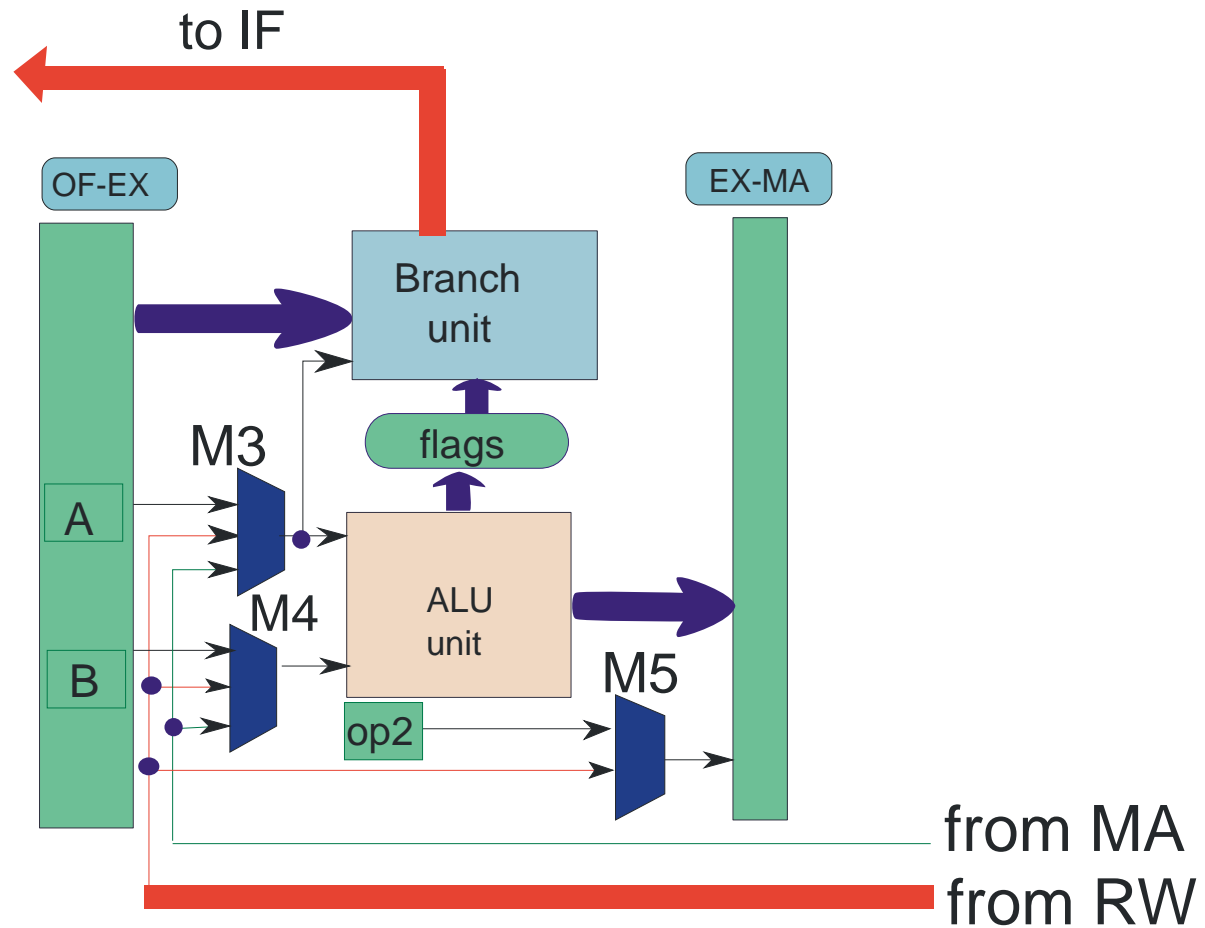
# Implementation of Forwarding

- \* At every stage there is a **choice** of inputs for each **functional unit**
  - \* Use the **default** inputs from the previous stage
  - \* **OR**, use one of the **forwarded** inputs
  - \* Use a **multiplexer** to choose between the inputs
  - \* A dedicated **forwarding unit** generates the signals for the **forwarding multiplexers**

# OF Stage with Forwarding

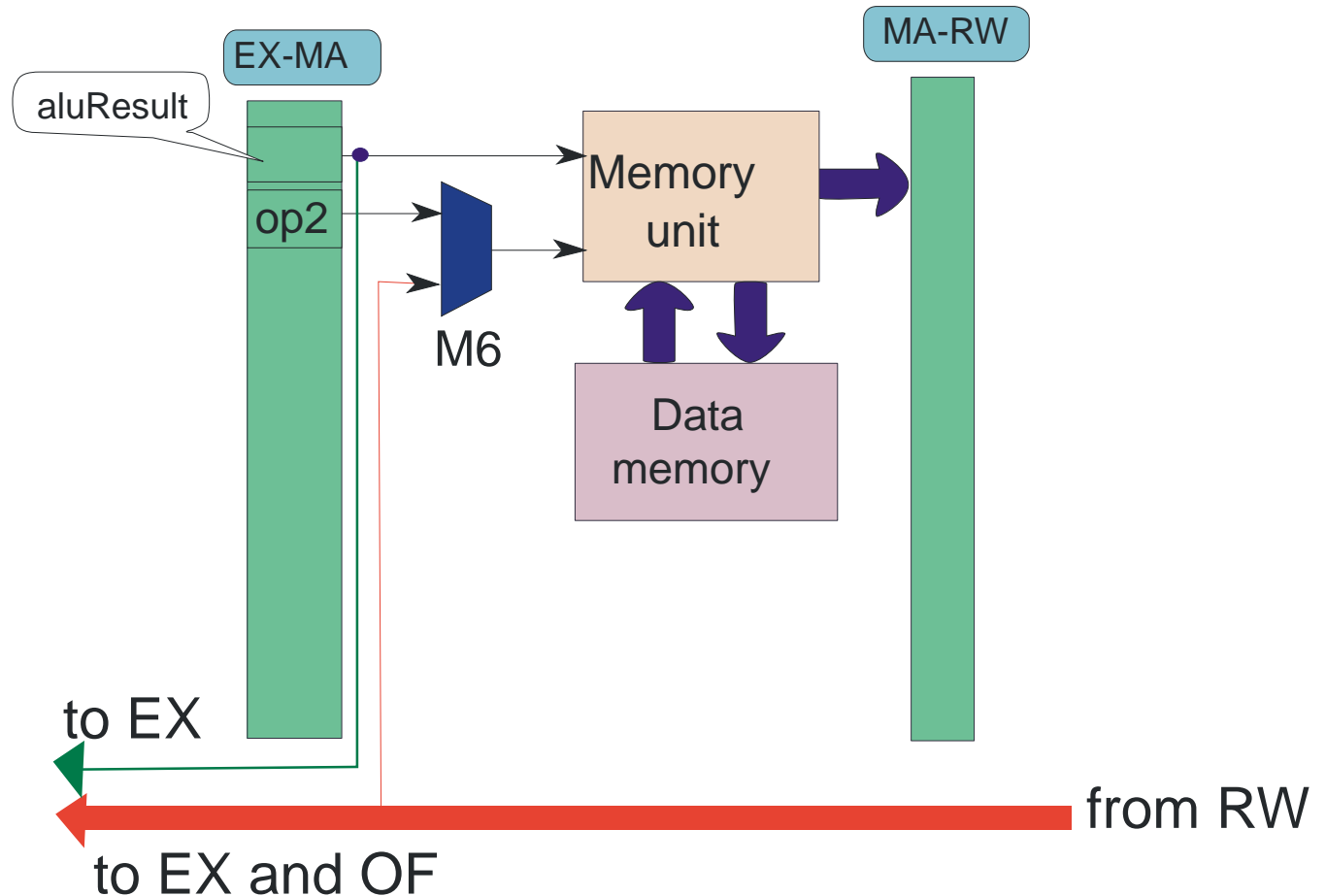


# EX Stage with Forwarding

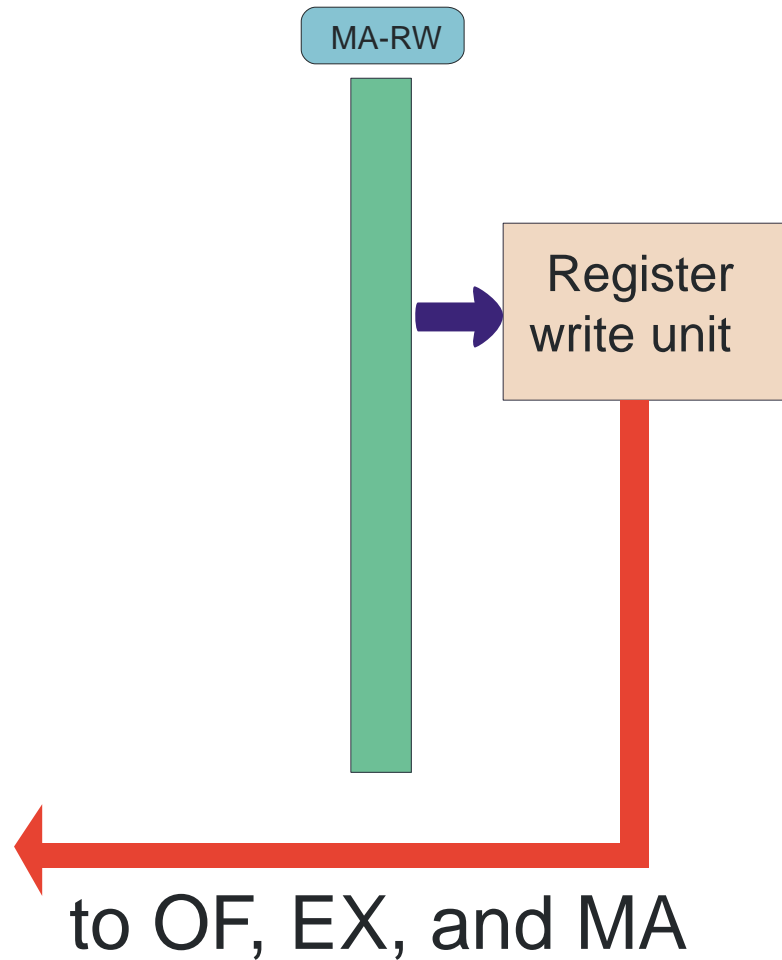




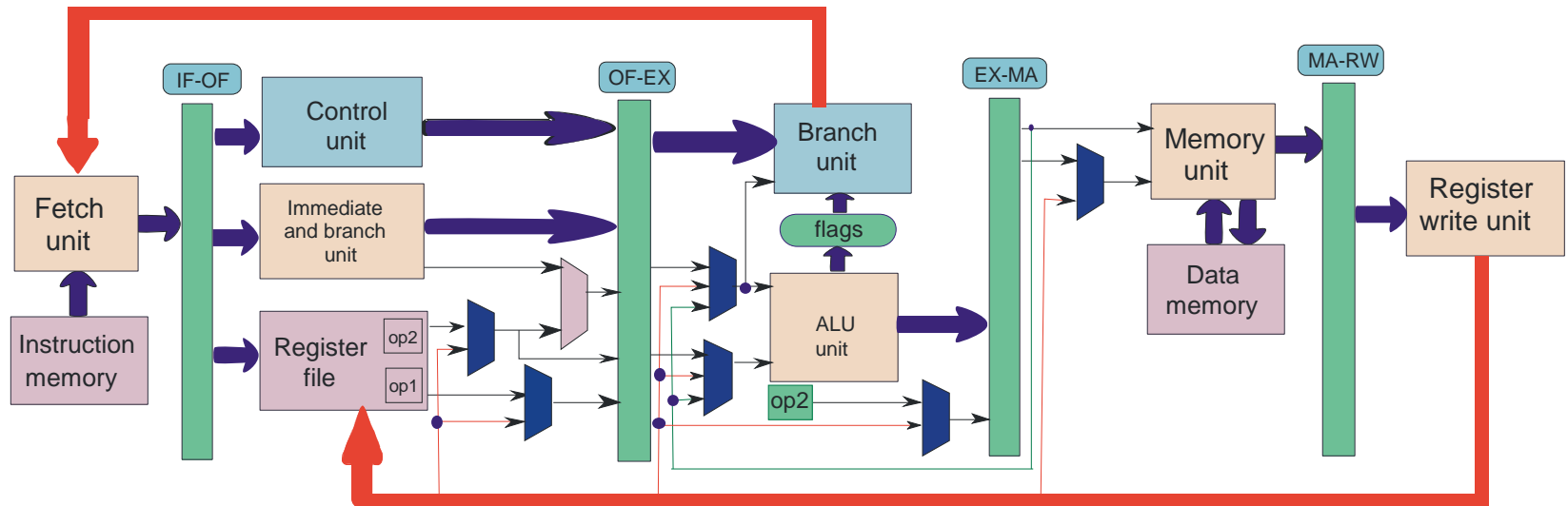
# MA Stage with Forwarding



# RW Stage with Forwarding



# Data Path with Forwarding



# Complete Data Path

