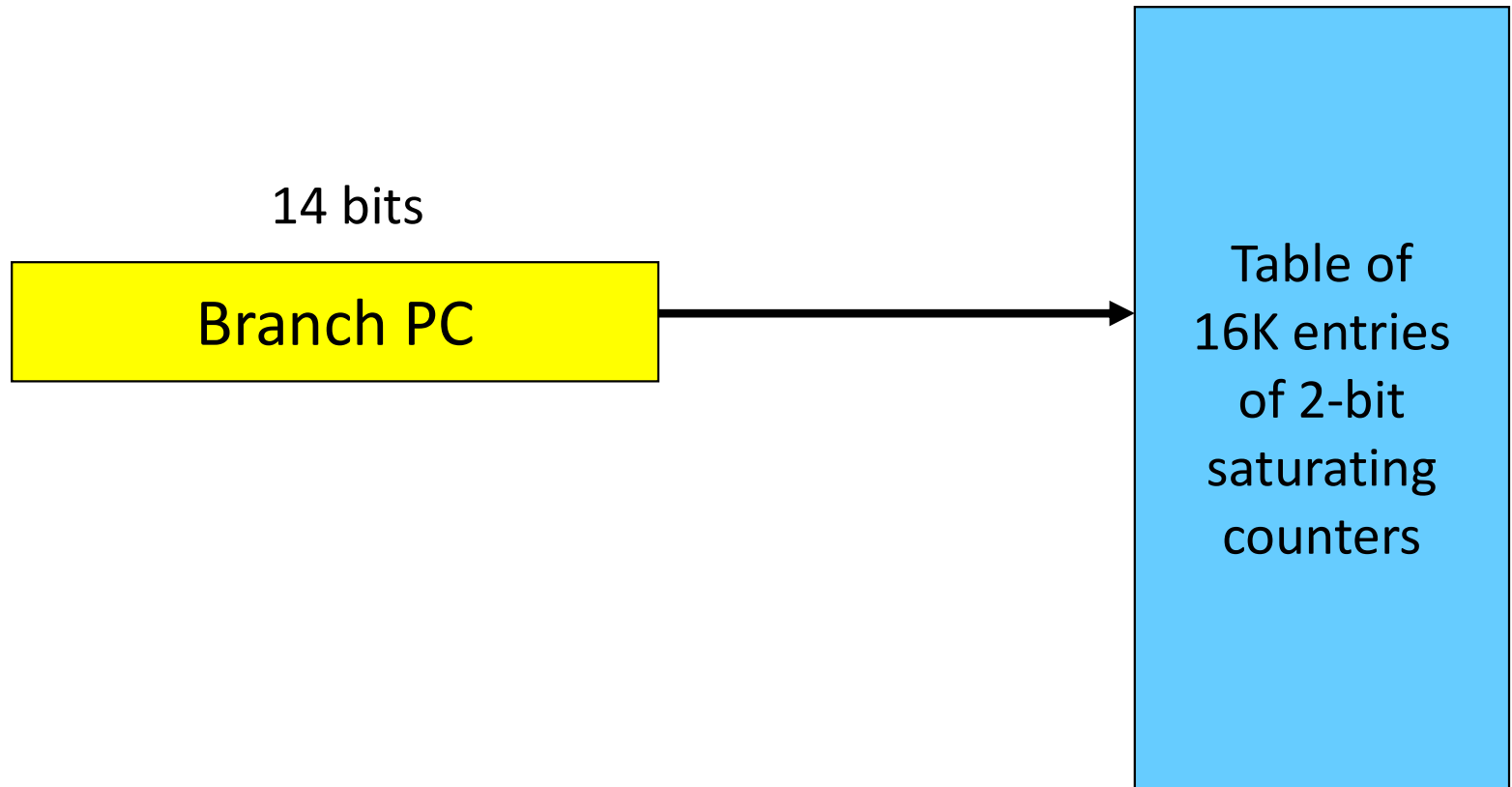# Lecture 20: BPred, OOO

- Today's topics:

  - Branch Predictors
  - Out-of-order execution

- Midterm 2 next Tuesday
  - Same rules as for Midterm 1
  - Notes: bring the sheet from Midterm 1, a new sheet,
                plus the green sheet
  - Basic calculator, no phones/connectivity
  - Content: starts at slide 7 lecture 8 (numerical reps)
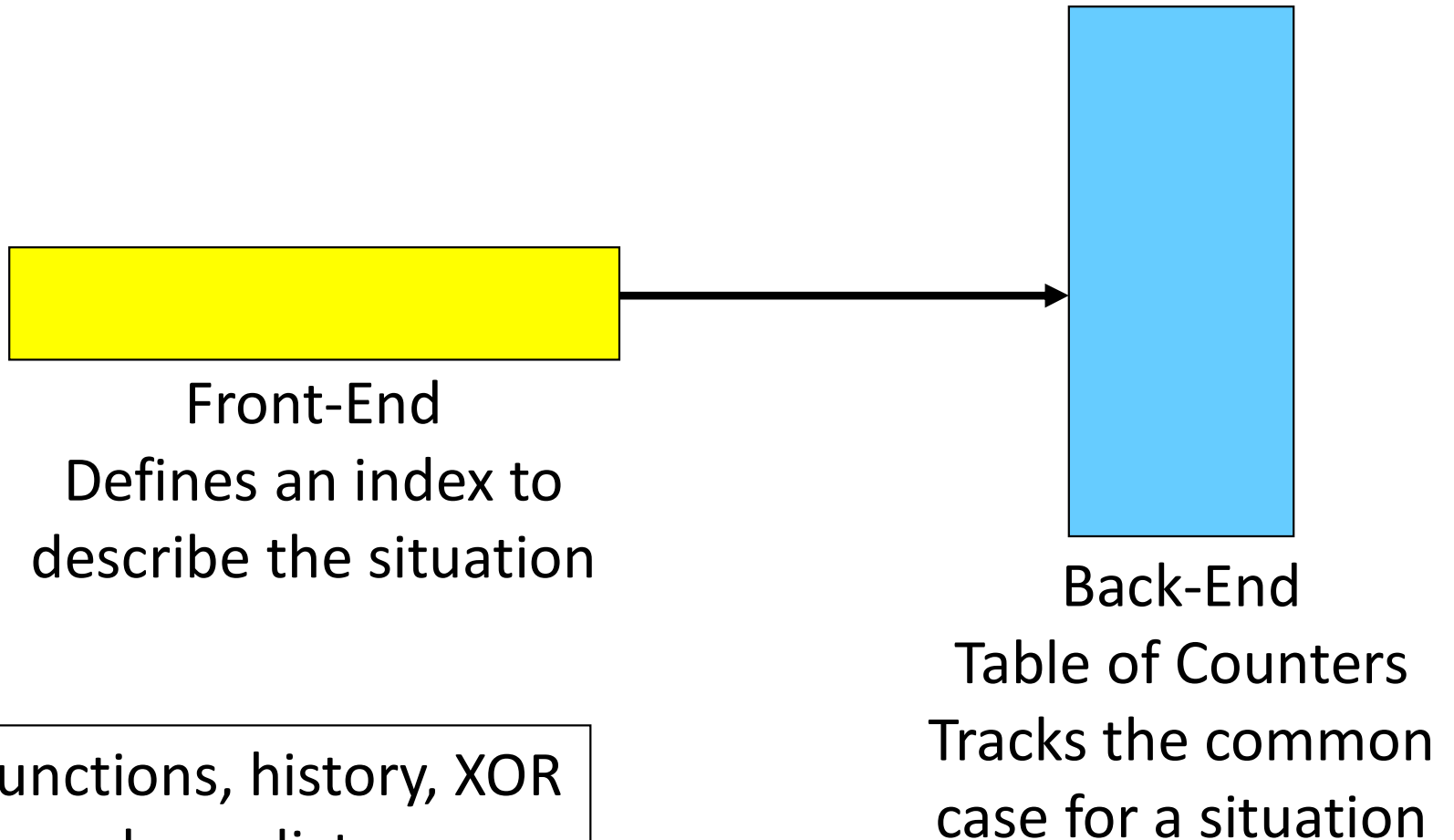   ends at slide 7 lecture 20 (out of order procs)

Bimodal Predictor

14 bits

Branch PC

Table of 16K entries of 2-bit saturating counters

Advanced Predictors

Front-End
Defines an index to
describe the situation

Back-End
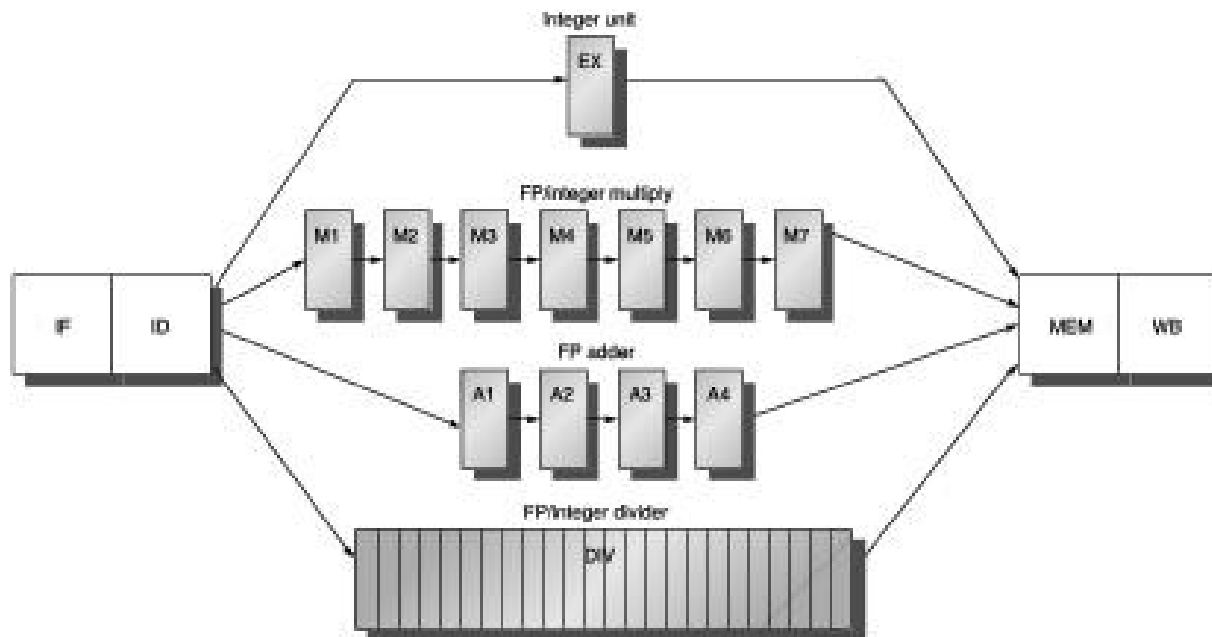Table of Counters
Tracks the common
case for a situation

Indexing functions, history, XOR
Multiple branch predictors
Trade-offs

Advanced Predictors

Indexing functions, history, XOR
Multiple branch predictors
Trade-offs

Multicycle Instructions

Integer unit

EX

FP/integer multiply

M1 M2 M3 M4 M5 M6 M7

IF ID

FP adder

A1 A2 A3 A4

MEM WB

FP/integer divider

DIV

- Multiple parallel pipelines – each pipeline can have a different number of stages

- Instructions can now complete out of order – must make sure that writes to a register happen in the correct order

5

An Out-of-Order Processor Implementation

Reorder Buffer (ROB)

Branch prediction and instr fetch

Instr 1	T1
Instr 2	T2
Instr 3	T3
Instr 4	T4
Instr 5	T5
Instr 6	T6

Register File
R1-R32

R1 ← R1+R2
R2 ← R1+R3
BEQZ R2
R3 ← R1+R2
R1 ← R3+R2

Decode &
Rename

Instr Fetch Queue

T1 ← R1+R2
T2 ← T1+R3
BEQZ T2
T4 ← T1+T2
T5 ← T4+T2

Issue Queue (IQ)

ALU   ALU   ALU

Results written to
ROB and tags
broadcast to IQ

6
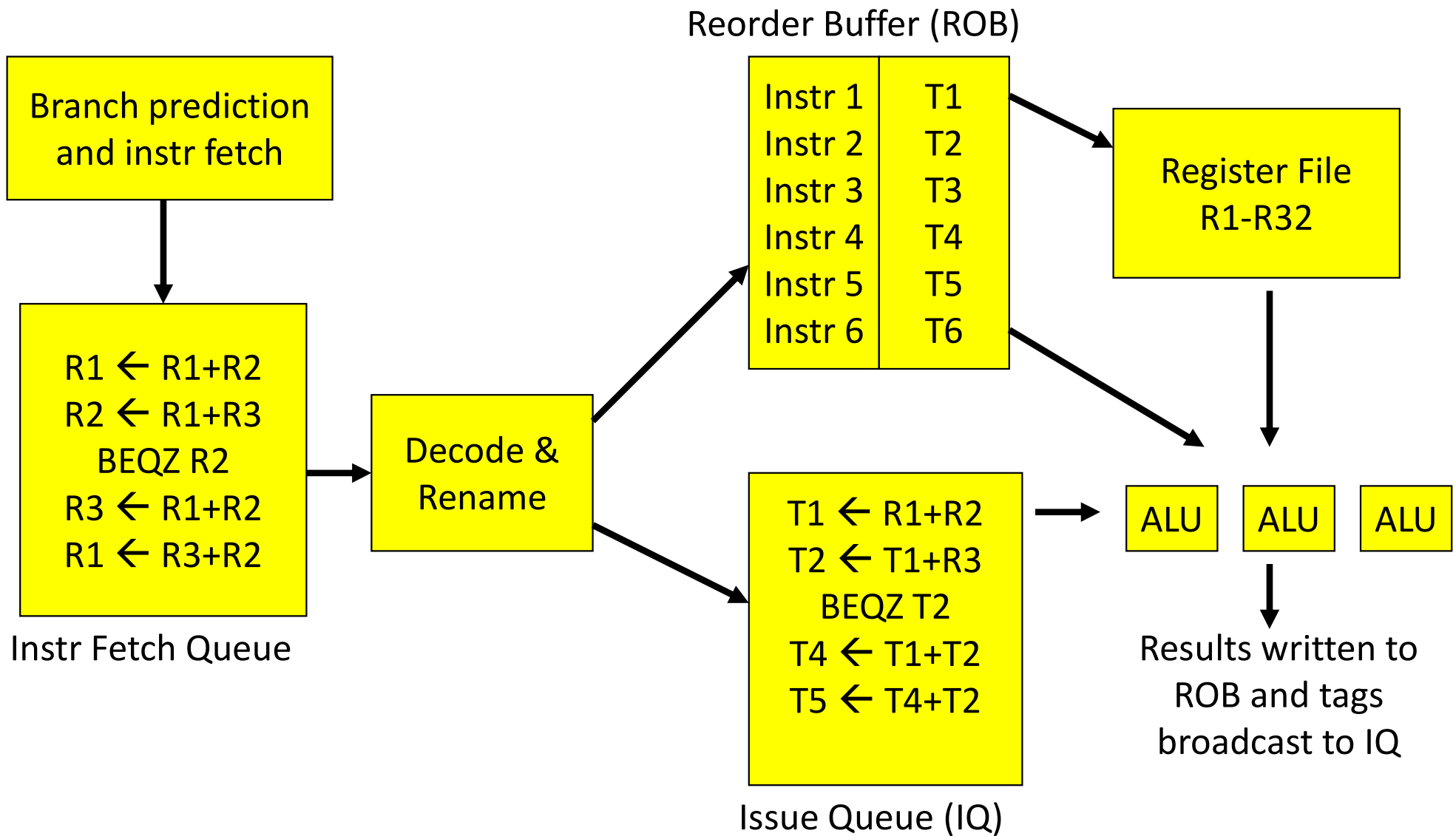
Example Code

Completion times	with in-order	with ooo
ADD R1, R2, R3	5	5
ADD R4, R1, R2	6	6
LW R5, 8(R4)	7	7
ADD R7, R6, R5	9	9
ADD R8, R7, R5	10	10
LW R9, 16(R4)	11	7
ADD R10, R6, R9	13	9
ADD R11, R10, R9	14	10