HW3 Q2.1

Cycle 0

LOOP: subi r1, r1, 1   Fetch
muld f0, f1, f1
addd f0, f2, f2
bne r1, r0, LOOP
addd f1, f2, f3

	Tag	Value	Valid
f0		0	1
f1		1	1
f2		2	1
f3		3	1

	Tag	Value	Valid
r0		0	1
r1		2	1

	Inst	Reg	Value	Valid
A	-	-	-	0
B	-	-	-	0
C	-	-	-	0
D	-	-	-	0
E	-	-	-	0

…
ROB

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP MULT (4 cycles)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

INT ALU (1 cycle)

Cycle 1

LOOP: subi r1, r1, 1   Dispatch
muld f0, f1, f1   Fetch
addd f0, f2, f2
bne r1, r0, LOOP
addd f1, f2, f3

	Tag	Value	Valid
f0		0	1
f1		1	1
f2		2	1
f3		3	1

	Tag	Value	Valid
r0		0	1
r1	A	2	0

	Inst	Reg	Value	Valid
A	subi	r1	-	0
B	-	-	-	0
C	-	-	-	0
D	-	-	-	0
E	-	-	-	0

…
ROB

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP MULT (4 cycles)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	2	1	-	-	0	A
-	-	0	-	-	0	-

INT ALU (1 cycle)

Cycle 2

LOOP: subi r1, r1, 1   Issue (E1)
muld f0, f1, f1   Dispatch
addd f0, f2, f2   Fetch
bne r1, r0, LOOP
addd f1, f2, f3

	Tag	Value	Valid
f0		0	1
f1	B	1	0
f2		2	1
f3		3	1

	Tag	Value	Valid
r0		0	1
r1	A	2	0

	Inst	Reg	Value	Valid
A	subi	r1	-	0
B	muld	f1	-	0
C	-	-	-	0
D	-	-	-	0
E	-	-	-	0

...

ROB

Tag	Value	Valid	Tag	Value	Valid	ROB
-	0	1	-	1	1	B
-	-	0	-	-	0	-

FP MULT (4 cycles)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	2	1	-	-	0	A
-	-	0	-	-	0	-

INT ALU (1 cycle)

Cycle 3

LOOP: subi r1, r1, 1   WB
muld f0, f1, f1   Issue (E1)
addd f0, f2, f2   Dispatch
bne r1, r0, LOOP   Fetch (and predict as Taken)
addd f1, f2, f3

	Tag	Value	Valid
f0		0	1
f1	B	1	0
f2	C	2	0
f3		3	1

	Tag	Value	Valid
r0		0	1
r1	A	2	0

	Inst	Reg	Value	Valid
A	subi	r1	1	1
B	muld	f1	-	0
C	addd	f2	-	0
D	-	-	-	0
E	-	-	-	0

…

ROB

Tag	Value	Valid	Tag	Value	Valid	ROB
-	0	1	-	1	1	B
-	-	0	-	-	0	-

FP MULT (4 cycles)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	0	1	-	2	1	C
-	-	0	-	-	0	-

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

INT ALU (1 cycle)

Cycle 4

LOOP: subi r1, r1, 1 — Commit
muld f0, f1, f1 — Issue (E2)
addd f0, f2, f2 — Issue (E1)
bne r1, r0, LOOP — Dispatch
LOOP: subi r1, r1, 1 — Fetch

	Tag	Value	Valid
f0		0	1
f1	B	1	0
f2	C	2	0
f3		3	1

	Tag	Value	Valid
r0		0	1
r1	-	1	1

	Inst	Reg	Value	Valid	T/NT
A	-	-	-	0	0
B	muld	f1	-	0	0
C	addd	f2	-	0	0
D	bne	-	-	0	T
E	-	-	-	0	

…

ROB

Tag	Value	Valid	Tag	Value	Valid	ROB
-	0	1	-	1	1	B
-	-	0	-	-	0	-

FP MULT (4 cycles)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	0	1	-	2	1	C
-	-	0	-	-	0	-

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	1	1	-	0	1	D
-	-	0	-	-	0	-

INT ALU (1 cycle)

Cycle 5

LOOP: subi r1, r1, 1

muld f0, f1, f1   Issue (E3)

addd f0, f2, f2   WB

bne r1, r0, LOOP   Issue (E1)

LOOP: subi r1, r1, 1   Dispatch

muld f0, f1, f1   Fetch

	Tag	Value	Valid
f0		0	1
f1	B	1	0
f2	C	2	0
f3		3	1

	Tag	Value	Valid
r0		0	1
r1	E	1	0

	Inst	Reg	Value	Valid	T/NT
A	-	-	-	0	0
B	muld	f1	-	0	0
C	addd	f2	2	1	0
D	bne	-	-	0	T
E	subi	r1	-	0	0

…

ROB

Tag	Value	Valid	Tag	Value	Valid	ROB
-	0	1	-	1	1	B
-	-	0	-	-	0	-

FP MULT (4 cycles)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	1	1	-	0	1	D
-	1	1	-	-	0	E

INT ALU (1 cycle)

Cycle 6

~~LOOP: subi r1, r1, 1~~

muld f0, f1, f1	Issue (E4)
addd f0, f2, f2	Waiting
bne r1, r0, LOOP	WB(Taken)
LOOP: subi r1, r1, 1	Issue (E1)
muld f0, f1, f1	Dispatch
addd f0, f2, f2	Fetch

	Tag	Value	Valid
f0		0	1
f1	F	1	0
f2	C	2	0
f3		3	1

Tag	Value	Valid	Tag	Value	Valid	ROB
-	0	1	-	1	1	B
-	0	1	B	-	0	F

FP MULT (4 cycles)

	Tag	Value	Valid
r0		0	1
r1	E	1	0

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP ADD (1 cycle)

	Inst	Reg	Value	Valid	T/NT
A	-	-	-	0	0
B	muld	f1	-	0	0
C	addd	f2	2	1	0
D	bne	-	-	1	T
E	subi	r1	-	0	0
F	muld	f1	-	0	0

…

ROB

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	1	1	-	-	0	E

INT ALU (1 cycle)

Cycle 7

~~LOOP: subi r1, r1, 1~~

muld f0, f1, f1   WB

addd f0, f2, f2   Waiting

bne r1, r0, LOOP   Waiting

LOOP: subi r1, r1, 1   WB

muld f0, f1, f1   Waiting

addd f0, f2, f2   Dispatch

bne r1, r0, LOOP   Fetch (and predict as taken)

	Tag	Value	Valid
f0		0	1
f1	F	1	0
f2	G	2	0
f3		3	1

	Tag	Value	Valid
r0		0	1
r1	E	1	0

	Inst	Reg	Value	Valid	T/NT
A	-	-	-	0	0
B	muld	f1	0	1	0
C	addd	f2	2	1	0
D	bne	-	-	1	T
E	subi	r1	0	1	0
F	muld	f1	-	0	0
G	addd	f2	-	0	0

...

ROB

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	0	1	-	0	1	F

FP MULT (4 cycles)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	0	1	-	2	1	G
-	-	0	-	-	0	-

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

INT ALU (1 cycle)

Cycle 8

~~LOOP: subi r1, r1, 1~~

muld f0, f1, f1   Commit

addd f0, f2, f2   Waiting

bne r1, r0, LOOP   Waiting

LOOP: subi r1, r1, 1   Waiting

muld f0, f1, f1   Issue(E1)

addd f0, f2, f2   Issue(E1)

bne r1, r0, LOOP   Dispatch

LOOP: subi r1, r1, 1   Fetch

	Tag	Value	Valid
f0		0	1
f1	F	0	0
f2	G	2	0
f3		3	1

	Tag	Value	Valid
r0		0	1
r1	E	1	0

	Inst	Reg	Value	Valid	T/NT
A	-	-	-	0	0
B	-	-	-	0	0
C	addd	f2	2	1	0
D	bne	-	-	1	T
E	subi	r1	0	1	0
F	muld	f1	-	0	0
G	addd	f2	-	0	0
H	bne	-	-	0	T

…

ROB

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	0	1	-	0	1	F

FP MULT (4 cycles)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	0	1	-	2	1	G
-	-	0	-	-	0	-

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	0	1	-	0	1	H
-	-	0	-	-	0	-

INT ALU (1 cycle)

Cycle 9

~~LOOP: subi r1, r1, 1~~

~~muld f0, f1, f1~~

addd f0, f2, f2   Commit

bne r1, r0, LOOP   Waiting

LOOP: subi r1, r1, 1   Waiting

muld f0, f1, f1   Issue(E2)

addd f0, f2, f2   WB

bne r1, r0, LOOP   Issue(E1)

LOOP: subi r1, r1, 1   Dispatch

muld f0, f1, f1   Fetch

	Tag	Value	Valid
f0		0	1
f1	F	0	0
f2	G	2	0
f3		3	1

	Tag	Value	Valid
r0		0	1
r1	I	1	0

	Inst	Reg	Value	Valid	T/NT
A	-	-	-	0	0
B	-	-	-	0	0
C	-	-	-	0	0
D	bne	-	-	1	T
E	subi	r1	0	1	0
F	muld	f1	-	0	0
G	addd	f2	2	1	0
H	bne	-	-	0	T
I	subi	r1	-	0	0

…

ROB

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	0	1	-	0	1	F

FP MULT (4 cycles)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	0	1	-	0	1	H
-	0	1	-	-	0	I

INT ALU (1 cycle)

Cycle 10

~~LOOP: subi r1, r1, 1~~

~~muld f0, f1, f1~~

~~addd f0, f2, f2~~

bne r1, r0, LOOP   Commit

LOOP: subi r1, r1, 1   Waiting

muld f0, f1, f1   Issue(E3)

addd f0, f2, f2   Waiting

bne r1, r0, LOOP   WB (not taken!)

LOOP: subi r1, r1, 1   Issue(E1)

muld f0, f1, f1   Dispatch

addd f0, f2, f2   Fetch

	Tag	Value	Valid
f0		0	1
f1	J	0	0
f2	G	2	0
f3		3	1

	Tag	Value	Valid
r0		0	1
r1	I	1	0

	Inst	Reg	Value	Valid	T/NT
A	-	-	-	0	0
B	-	-	-	0	0
C	-	-	-	0	0
D	-	-	-	0	0
E	subi	r1	0	1	0
F	muld	f1	-	0	0
G	addd	f2	2	1	0
H	bne	-	-	1	NT
I	subi	r1	-	0	0
J	muld	f1	-	0	0

...

ROB

Tag	Value	Valid	Tag	Value	Valid	ROB
-	0	1	F	-	0	J
-	0	1	-	0	1	F

FP MULT (4 cycles)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	0	1	-	-	0	I

INT ALU (1 cycle)

Cycle 11 (Frozen for recovery)

~~LOOP: subi r1, r1, 1~~
~~muld f0, f1, f1~~
~~addd f0, f2, f2~~
~~bne r1, r0, LOOP~~
LOOP: subi r1, r1, 1   Waiting
muld f0, f1, f1   Issue(E3)
addd f0, f2, f2   Waiting
bne r1, r0, LOOP   WB (not taken!)
~~LOOP: subi r1, r1, 1~~
~~muld f0, f1, f1~~
~~addd f0, f2, f2~~

	Tag	Value	Valid
f0		0	1
f1	F	0	0
f2	G	2	0
f3		3	1

	Tag	Value	Valid
r0		0	1
r1	E	1	0

	Inst	Reg	Value	Valid	T/NT
A	-	-	-	0	0
B	-	-	-	0	0
C	-	-	-	0	0
D	-	-	-	0	0
E	subi	r1	0	1	0
F	muld	f1	-	0	0
G	addd	f2	2	1	0
H	bne	-	-	1	NT
I	-	-	-	0	0
J	-	-	-	0	0

...

ROB

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	0	1	-	0	1	F

⋮

FP MULT (4 cycles)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

⋮

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

⋮

INT ALU (1 cycle)

Cycle 12

~~LOOP: subi r1, r1, 1~~

~~muld f0, f1, f1~~

~~addd f0, f2, f2~~

~~bne r1, r0, LOOP~~

LOOP: subi r1, r1, 1   Commit

muld f0, f1, f1   Issue(E4)

addd f0, f2, f2   Waiting

bne r1, r0, LOOP   Waiting

addd f1, f2, f3   Fetch

	Tag	Value	Valid
f0		0	1
f1	F	0	0
f2	G	2	0
f3		3	1

	Tag	Value	Valid
r0		0	1
r1		0	1

	Inst	Reg	Value	Valid	T/NT
A	-	-	-	0	0
B	-	-	-	0	0
C	-	-	-	0	0
D	-	-	-	0	0
E	-	-	-	0	0
F	muld	f1	-	0	0
G	addd	f2	2	1	0
H	bne	-	-	1	NT
I	-	-	-	0	0
J	-	-	-	0	0

...

ROB

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	0	1	-	0	1	F

FP MULT (4 cycles)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

INT ALU (1 cycle)

Cycle 13

~~LOOP: subi r1, r1, 1~~
~~muld f0, f1, f1~~
~~addd f0, f2, f2~~
~~bne r1, r0, LOOP~~
~~LOOP: subi r1, r1, 1~~
muld f0, f1, f1   WB
addd f0, f2, f2   Waiting
bne r1, r0, LOOP   Waiting
addd f1, f2, f3   Dispatch

	Tag	Value	Valid
f0		0	1
f1	F	0	0
f2	G	2	0
f3	I	3	0

	Tag	Value	Valid
r0		0	1
r1		0	1

	Inst	Reg	Value	Valid	T/NT
A	-	-	-	0	0
B	-	-	-	0	0
C	-	-	-	0	0
D	-	-	-	0	0
E	-	-	-	0	0
F	muld	f1	0	1	0
G	addd	f2	2	1	0
H	bne	-	-	1	NT
I	addd	f3	-	0	0
J	-	-	-	0	0

...

ROB

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP MULT (4 cycles)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	0	1	-	2	1	I
-	-	0	-	-	0	-

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

INT ALU (1 cycle)

Cycle 14

~~LOOP: subi r1, r1, 1~~
~~muld f0, f1, f1~~
~~addd f0, f2, f2~~
~~bne r1, r0, LOOP~~
~~LOOP: subi r1, r1, 1~~
muld f0, f1, f1   Commit
addd f0, f2, f2   Waiting
bne r1, r0, LOOP   Waiting
addd f1, f2, f3   Issue(E1)

	Tag	Value	Valid
f0		0	1
f1		0	1
f2	G	2	0
f3	I	3	0

	Tag	Value	Valid
r0		0	1
r1		0	1

	Inst	Reg	Value	Valid	T/NT
A	-	-	-	0	0
B	-	-	-	0	0
C	-	-	-	0	0
D	-	-	-	0	0
E	-	-	-	0	0
F	-	-	-	0	0
G	addd	f2	2	1	0
H	bne	-	-	1	NT
I	addd	f3	-	0	0
J	-	-	-	0	0

...

ROB

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP MULT (4 cycles)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	0	1	-	2	1	I
-	-	0	-	-	0	-

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

INT ALU (1 cycle)

Cycle 15

~~LOOP: subi r1, r1, 1~~

~~muld f0, f1, f1~~

~~addd f0, f2, f2~~

~~bne r1, r0, LOOP~~

~~LOOP: subi r1, r1, 1~~

~~muld f0, f1, f1~~

addd f0, f2, f2   Commit

bne r1, r0, LOOP   Waiting

addd f1, f2, f3   WB

	Tag	Value	Valid
f0		0	1
f1		0	1
f2		2	1
f3	I	3	0

	Tag	Value	Valid
r0		0	1
r1		0	1

	Inst	Reg	Value	Valid	T/NT
A	-	-	-	0	0
B	-	-	-	0	0
C	-	-	-	0	0
D	-	-	-	0	0
E	-	-	-	0	0
F	-	-	-	0	0
G	-	-	-	0	0
H	bne	-	-	1	NT
I	addd	f3	2	1	0
J	-	-	-	0	0

…

ROB

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP MULT (4 cycles)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

INT ALU (1 cycle)

Cycle 16

~~LOOP: subi r1, r1, 1~~
~~muld f0, f1, f1~~
~~addd f0, f2, f2~~
~~bne r1, r0, LOOP~~
~~LOOP: subi r1, r1, 1~~
~~muld f0, f1, f1~~
~~addd f0, f2, f2~~
bne r1, r0, LOOP   Commit
addd f1, f2, f3   Waiting

	Tag	Value	Valid
f0		0	1
f1		0	1
f2		2	1
f3	I	3	0

	Tag	Value	Valid
r0		0	1
r1		0	1

	Inst	Reg	Value	Valid	T/NT
A	-	-	-	0	0
B	-	-	-	0	0
C	-	-	-	0	0
D	-	-	-	0	0
E	-	-	-	0	0
F	-	-	-	0	0
G	-	-	-	0	0
H	-	-	-	0	0
I	addd	f3	2	1	0
J	-	-	-	0	0

...

ROB

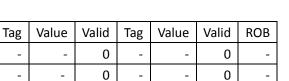| Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP MULT (4 cycles)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

INT ALU (1 cycle)

Cycle 17

~~LOOP: subi r1, r1, 1~~
~~muld f0, f1, f1~~
~~addd f0, f2, f2~~
~~bne r1, r0, LOOP~~
~~LOOP: subi r1, r1, 1~~
~~muld f0, f1, f1~~
~~addd f0, f2, f2~~
~~bne r1, r0, LOOP~~
addd f1, f2, f3   Commit

	Tag	Value	Valid
f0		0	1
f1		0	1
f2		2	1
f3		2	0

	Tag	Value	Valid
r0		0	1
r1		0	1

	Inst	Reg	Value	Valid	T/NT
A	-	-	-	0	0
B	-	-	-	0	0
C	-	-	-	0	0
D	-	-	-	0	0
E	-	-	-	0	0
F	-	-	-	0	0
G	-	-	-	0	0
H	-	-	-	0	0
I	-	-	-	0	0
J	-	-	-	0	0

...

ROB

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP MULT (4 cycles)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
-	-	0	-	-	0	-
-	-	0	-	-	0	-

INT ALU (1 cycle)

HW3 Q2.2

As we see in Q2.1, there are at most 6 instructions in ROB when executing this code, but when there are 6 instructions in Cycle 9, the C item in ROB is in the process of committing. If ROB size is 6, the new dispatch can't take place in the C item in ROB (which is in committing) at the same clock cycle, so the minimum ROB size is 7.