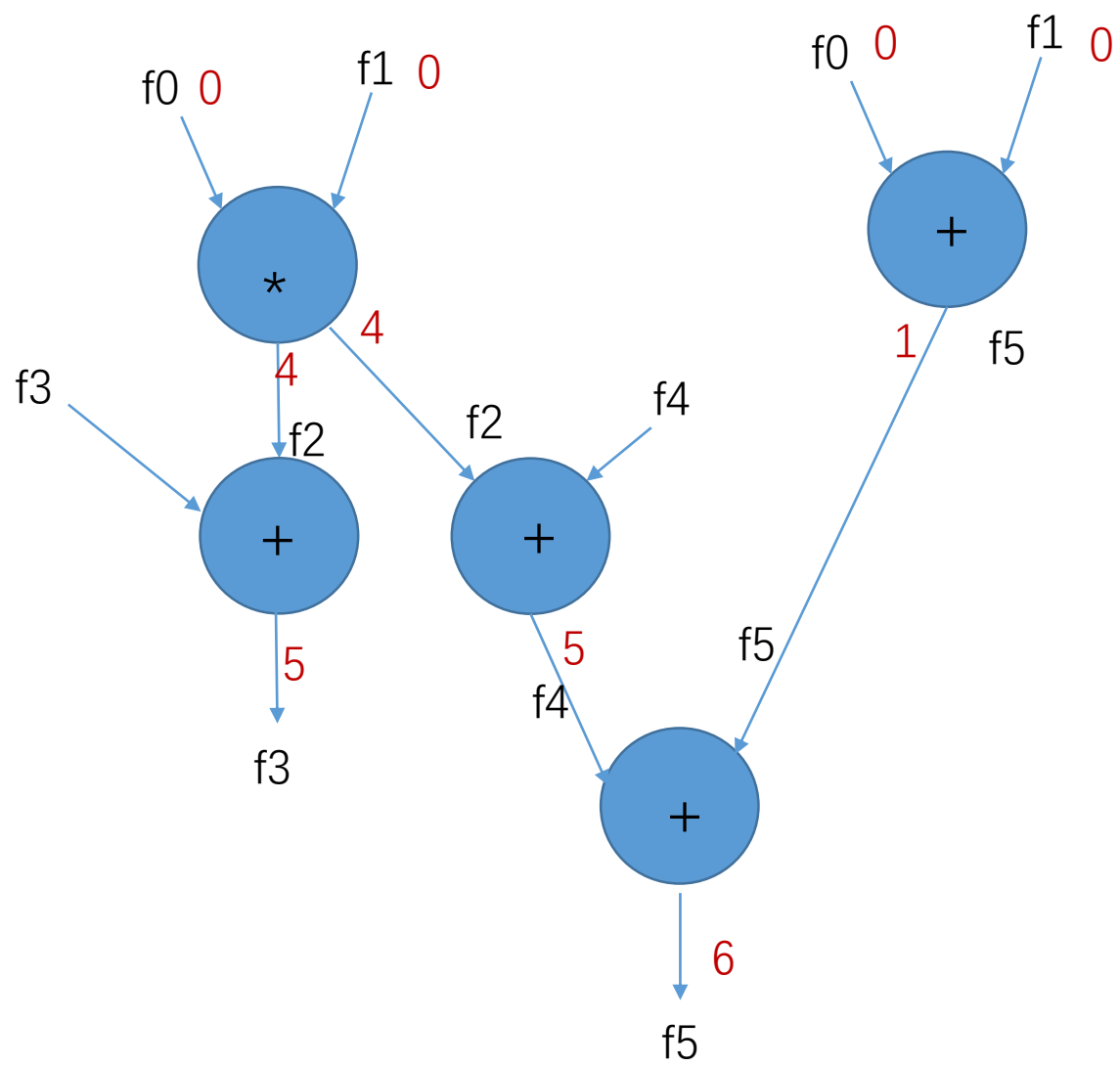


# CS GY Homework 3

Qiming Zhang NetID: qz718

Yuzheng Wang NetID: yw2787

Q1 (a)



- F = fetch, D = dispatch, C = commit, E = execute  
WB = write back, W = waiting,
- W(C) = wait for commit, W(F) = wait for fetch,  
W(E) = wait for execute, W(tag) = wait for a tag

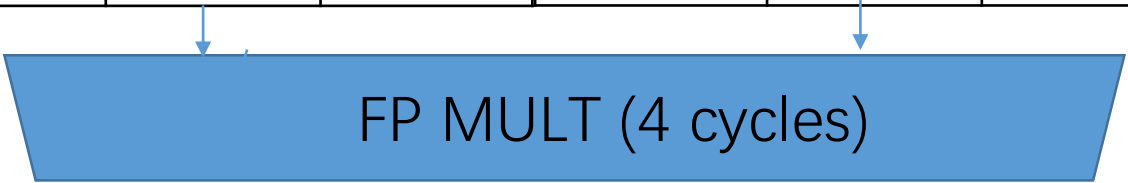
Q1 (b)

# Cycle 0

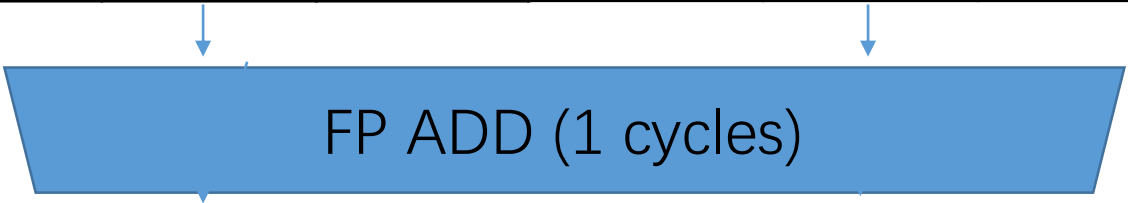
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		2	1
f3		3	1
f4		4	1
f5		5	1

Instruction	Stage
muld f0, f1, f2	
addd f0, f1, f5	
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	

	Tag	Value	Valid	Tag	Value	Valid
x			0			0
y			0			0



	Tag	Value	Valid	Tag	Value	Valid
a			0			0
b			0			0

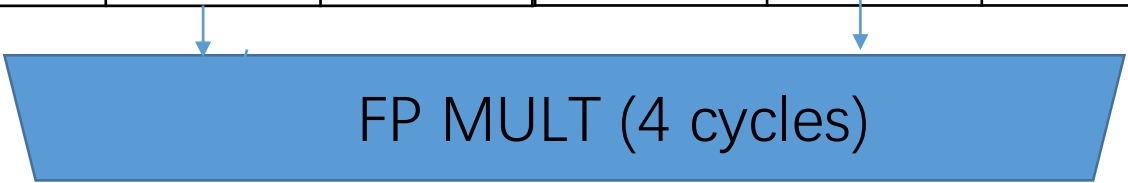


# Cycle 1

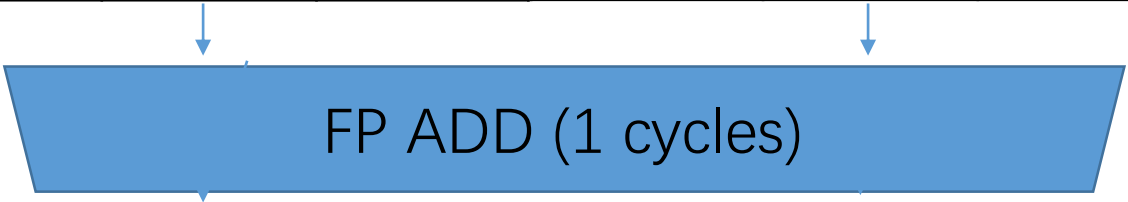
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		2	1
f3		3	1
f4		4	1
f5		5	1

Instruction	Stage
muld f0, f1, f2	F
addd f0, f1, f5	
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	

	Tag	Value	Valid	Tag	Value	Valid
x			0			0
y			0			0



	Tag	Value	Valid	Tag	Value	Valid
a			0			0
b			0			0

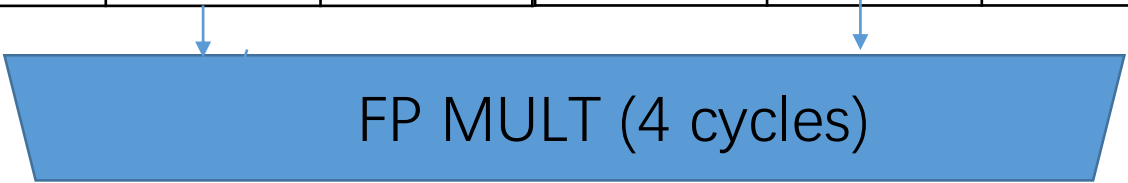


# Cycle 2

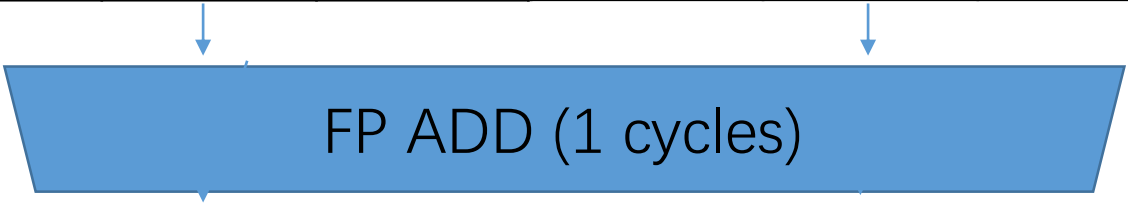
	Tag	Value	Valid
f0		0	1
f1		1	1
f2	x	2	0
f3		3	1
f4		4	1
f5		5	1

Instruction	Stage
muld f0, f1, f2	D
addd f0, f1, f5	F
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	

	Tag	Value	Valid	Tag	Value	Valid
x	~	0	1	~	1	1
y			0			0



	Tag	Value	Valid	Tag	Value	Valid
a			0			0
b			0			0



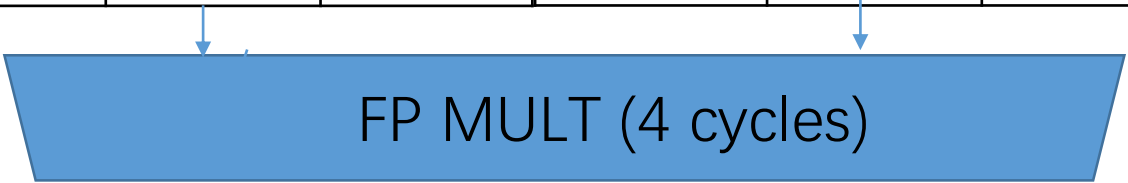


# Cycle 3

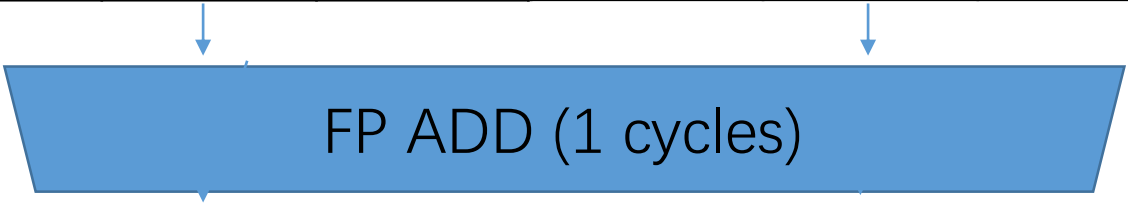
	Tag	Value	Valid
f0		0	1
f1		1	1
f2	x	2	0
f3		3	1
f4		4	1
f5	a	5	0

Instruction	Stage
muld f0, f1, f2	E1
addd f0, f1, f5	D
addd f2, f3, f3	F
addd f2, f4, f4	
addd f4, f5, f5	

	Tag	Value	Valid	Tag	Value	Valid
x	~	0	1	~	1	1
y			0			0



	Tag	Value	Valid	Tag	Value	Valid
a	~	0	1	~	1	1
b			0			0



# Cycle 4

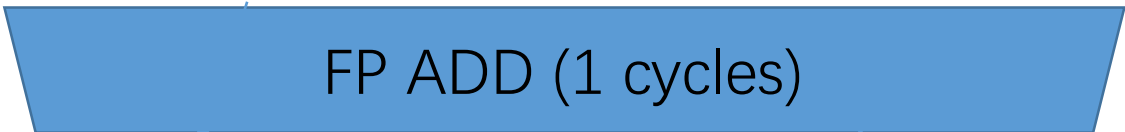
	Tag	Value	Valid
f0		0	1
f1		1	1
f2	x	2	0
f3	b	3	0
f4		4	1
f5	a	5	0

Instruction	Stage
muld f0, f1, f2	E2
addd f0, f1, f5	E1
addd f2, f3, f3	D
addd f2, f4, f4	F
addd f4, f5, f5	

	Tag	Value	Valid	Tag	Value	Valid
x	~	0	1	~	1	1
y			0			0



	Tag	Value	Valid	Tag	Value	Valid
a	~	0	1	~	1	1
b	x	~	0	~	3	1

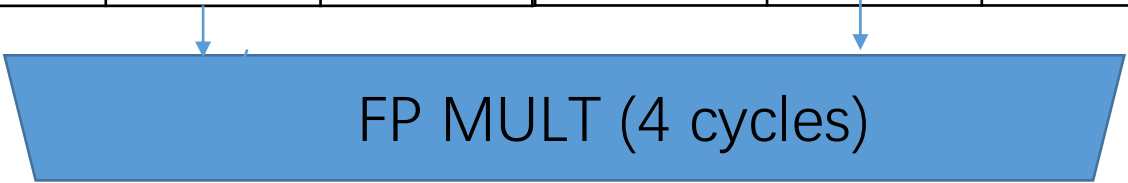


# Cycle 5

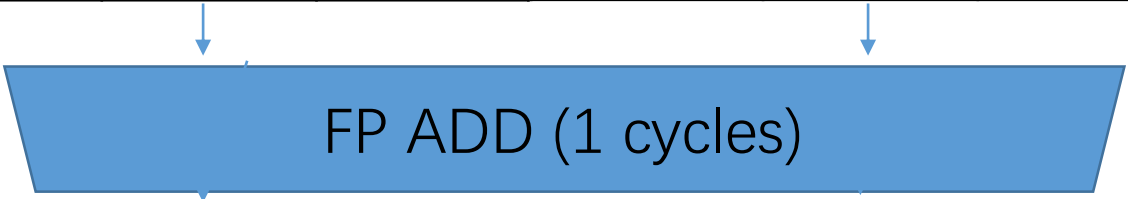
	Tag	Value	Valid
f0		0	1
f1		1	1
f2	x	2	0
f3	b	3	0
f4		4	1
f5		1	1

Instruction	Stage
muld f0, f1, f2	E3
addd f0, f1, f5	WB
addd f2, f3, f3	W(for tag)
addd f2, f4, f4	W(for D)
addd f4, f5, f5	W(F)

	Tag	Value	Valid	Tag	Value	Valid
x	~	0	1	~	1	1
y			0			0



	Tag	Value	Valid	Tag	Value	Valid
a	~	~	0	~	~	0
b	x	~	0	~	3	1

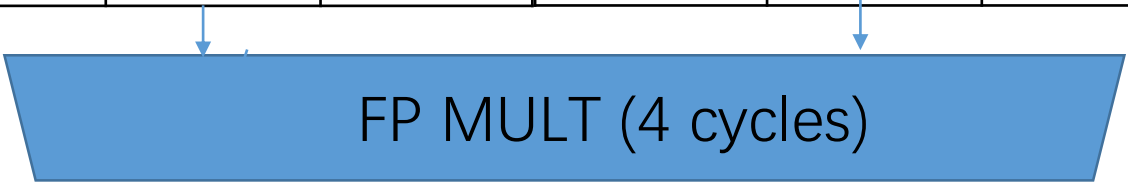


# Cycle 6

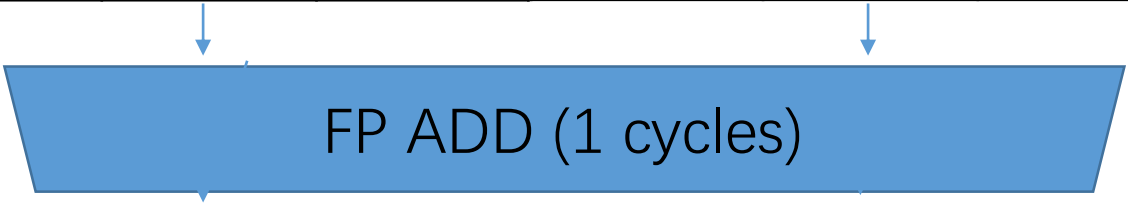
	Tag	Value	Valid
f0		0	1
f1		1	1
f2	x	2	0
f3	b	3	0
f4	a	4	0
f5		1	1

Instruction	Stage
muld f0, f1, f2	E4
addd f0, f1, f5	DONE
addd f2, f3, f3	W
addd f2, f4, f4	D
addd f4, f5, f5	F

	Tag	Value	Valid	Tag	Value	Valid
x	~	0	1	~	1	1
y			0			0



	Tag	Value	Valid	Tag	Value	Valid
a	x	~	0	~	4	1
b	x	~	0	~	3	1

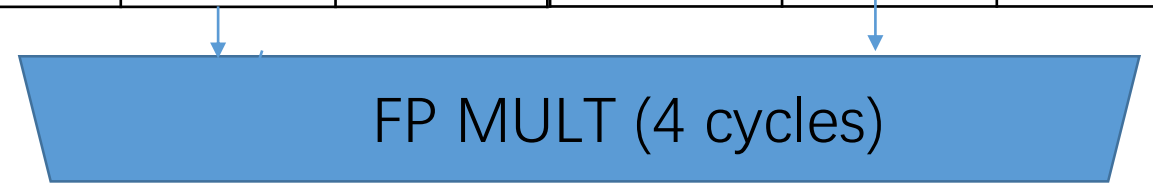


# Cycle 7

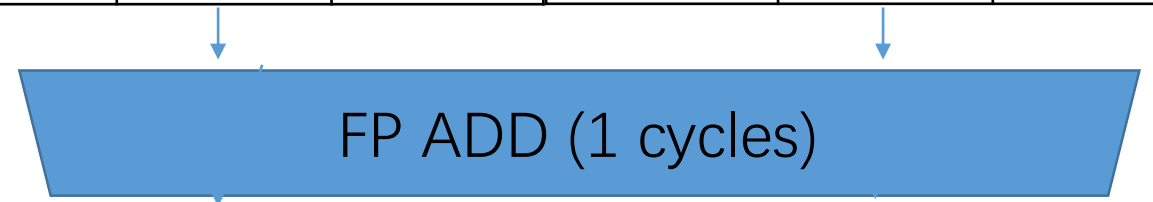
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3	b	3	0
f4	a	4	0
f5		1	1

Instruction	Stage
muld f0, f1, f2	WB
addd f0, f1, f5	DONE
addd f2, f3, f3	W(for tag)
addd f2, f4, f4	W(for tag)
addd f4, f5, f5	W(for D)

	Tag	Value	Valid	Tag	Value	Valid
x	~	~	0	~	~	0
y			0			0



	Tag	Value	Valid	Tag	Value	Valid
a	~	0	1	~	4	1
b	~	0	1	~	3	1

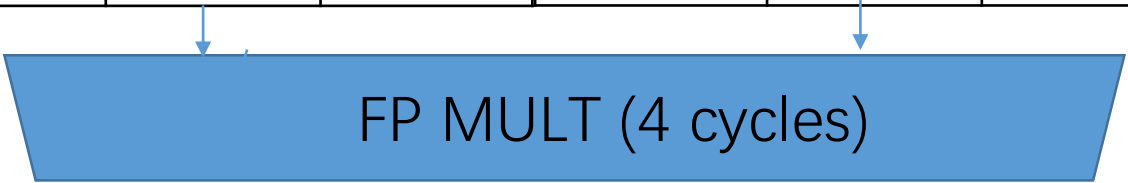


# Cycle 8

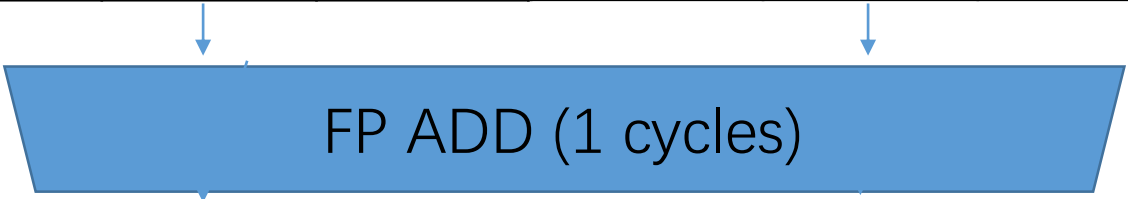
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3	b	3	0
f4	a	4	0
f5		1	1

Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	E1
addd f2, f4, f4	W(for E)
addd f4, f5, f5	W(for D)

	Tag	Value	Valid	Tag	Value	Valid
x	~	~	0	~	~	0
y			0			0



	Tag	Value	Valid	Tag	Value	Valid
a	~	0	1	~	4	1
b	~	0	1	~	3	1

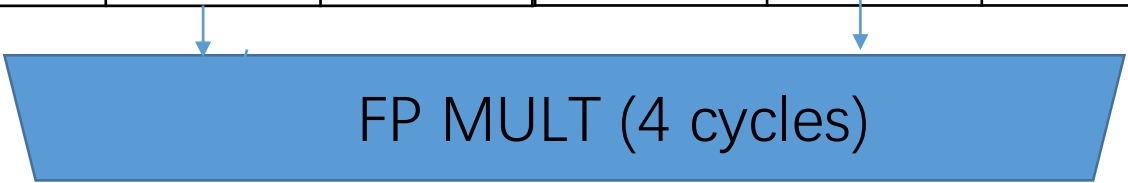


# Cycle 9

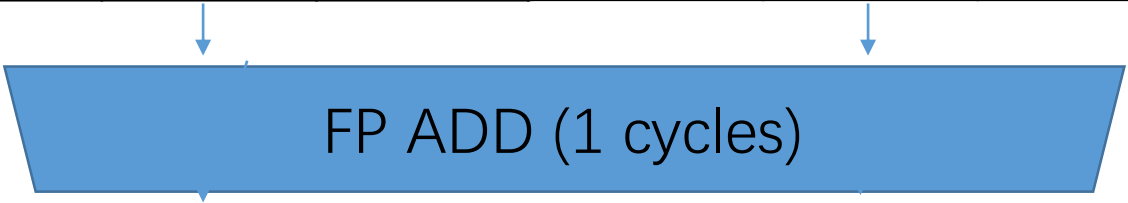
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3		3	1
f4	a	4	0
f5		1	1

Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	WB
addd f2, f4, f4	E1
addd f4, f5, f5	W(for D)

	Tag	Value	Valid	Tag	Value	Valid
x	~	~	0	~	~	0
y			0			0



	Tag	Value	Valid	Tag	Value	Valid
a	~	0	1	~	4	1
b	~	~	0	~	~	0

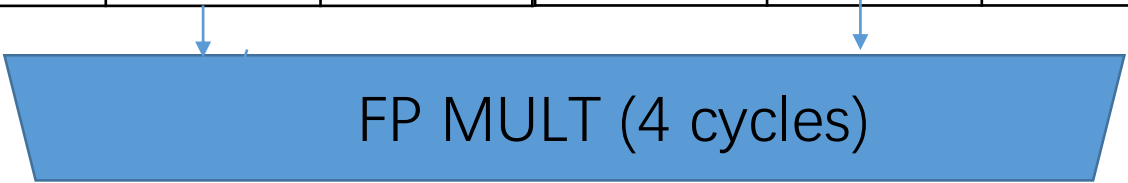


# Cycle 10

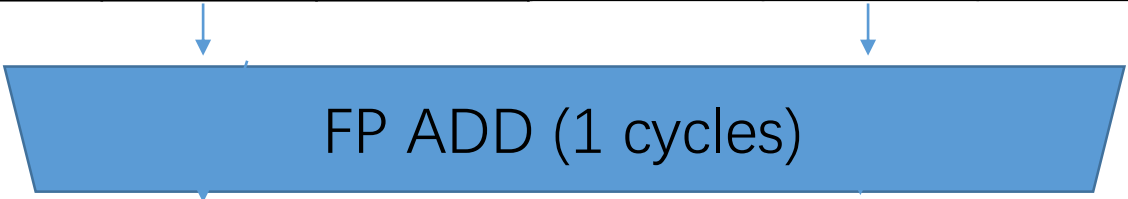
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3		3	1
f4		4	1
f5	b	1	0

Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	WB
addd f4, f5, f5	D

	Tag	Value	Valid	Tag	Value	Valid
x	~	~	0	~	~	0
y			0			0



	Tag	Value	Valid	Tag	Value	Valid
a	~	~	0	~	~	0
b	~	4	1	~	1	1



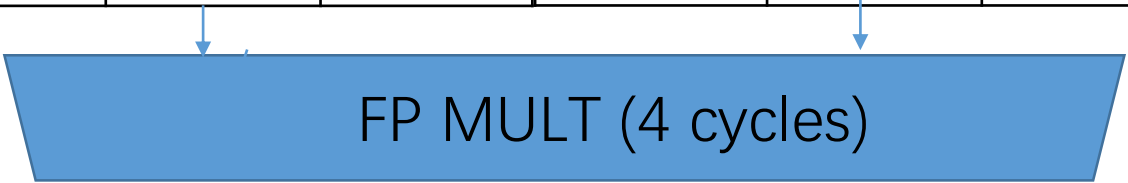


# Cycle 11

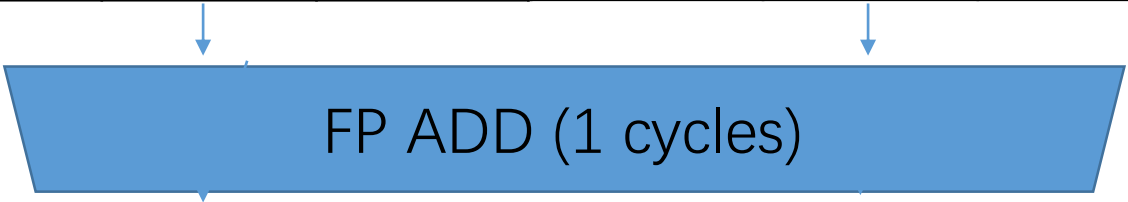
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3		3	1
f4		4	1
f5	b	1	0

Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	DONE
muld f4, f5, f5	E1

	Tag	Value	Valid	Tag	Value	Valid
x	~	~	0	~	~	0
y			0			0



	Tag	Value	Valid	Tag	Value	Valid
a	~	~	0	~	~	0
b	~	4	1	~	1	1

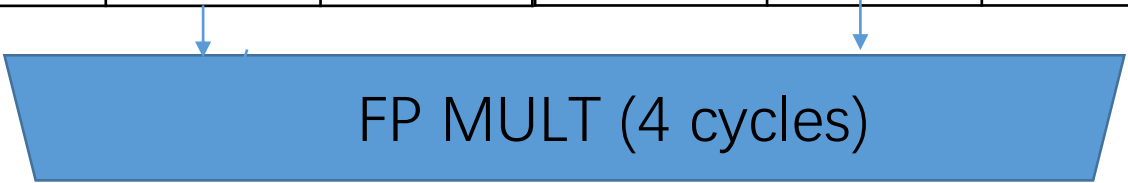


# Cycle 12

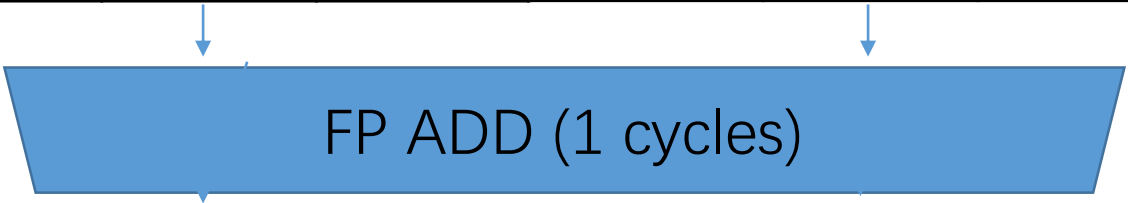
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3		3	1
f4		4	1
f5		5	1

Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	DONE
addd f4, f5, f5	WB

	Tag	Value	Valid	Tag	Value	Valid
x	~	~	0	~	~	0
y			0			0



	Tag	Value	Valid	Tag	Value	Valid
a	~	~	0	~	~	0
b	~	~	0	~	~	0

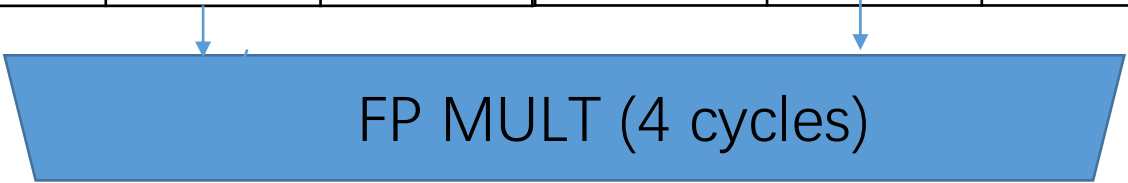


# Cycle 13

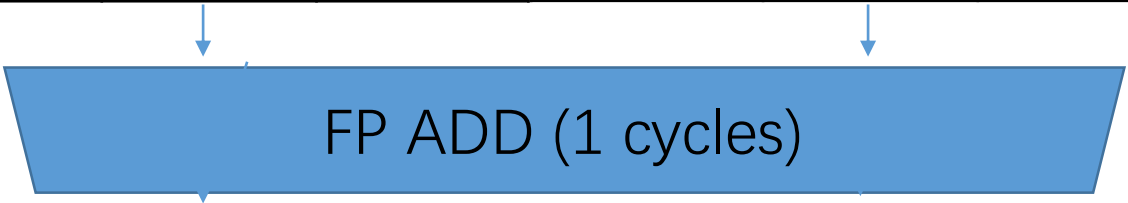
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3		3	1
f4		4	1
f5		5	1

Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	DONE
addd f4, f5, f5	DONE

	Tag	Value	Valid	Tag	Value	Valid
x	~	~	0	~	~	0
y			0			0



	Tag	Value	Valid	Tag	Value	Valid
a	~	~	0	~	~	0
b	~	~	0	~	~	0



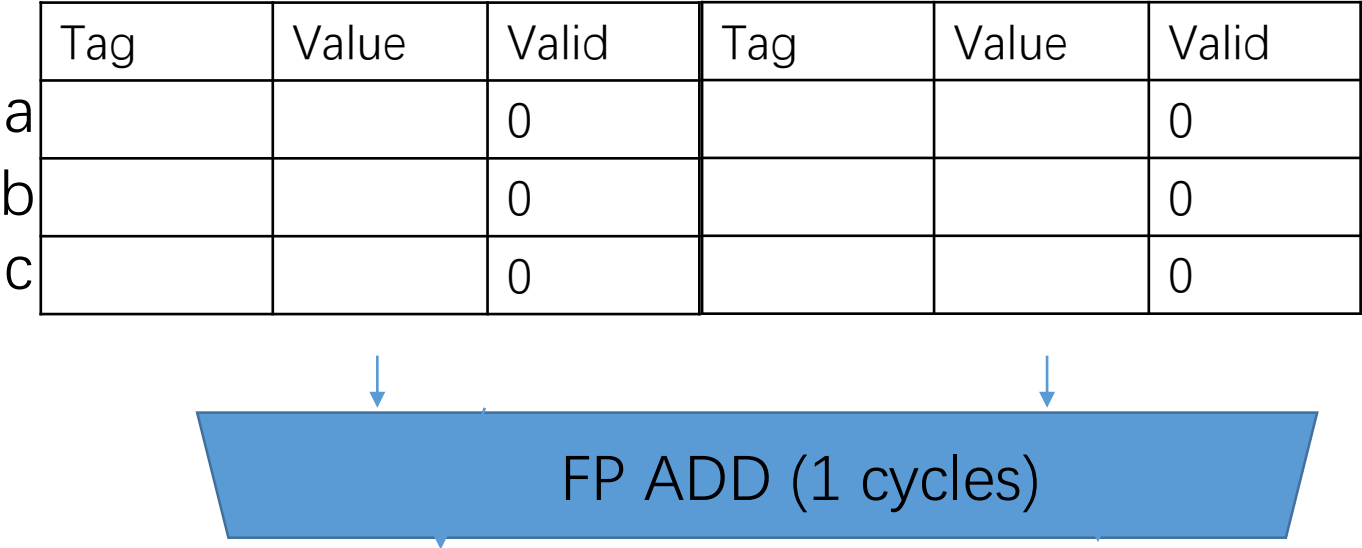
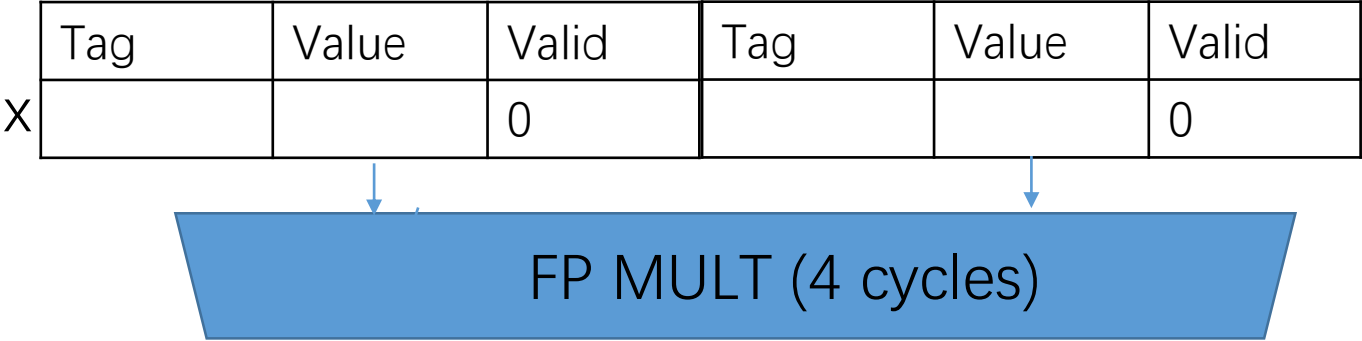
Q1 (c)

Minimum number of FP  
multiply is 1, and FP add  
reservation stations is 3

# Cycle 0

	Tag	Value	Valid
f0		0	1
f1		1	1
f2		2	1
f3		3	1
f4		4	1
f5		5	1

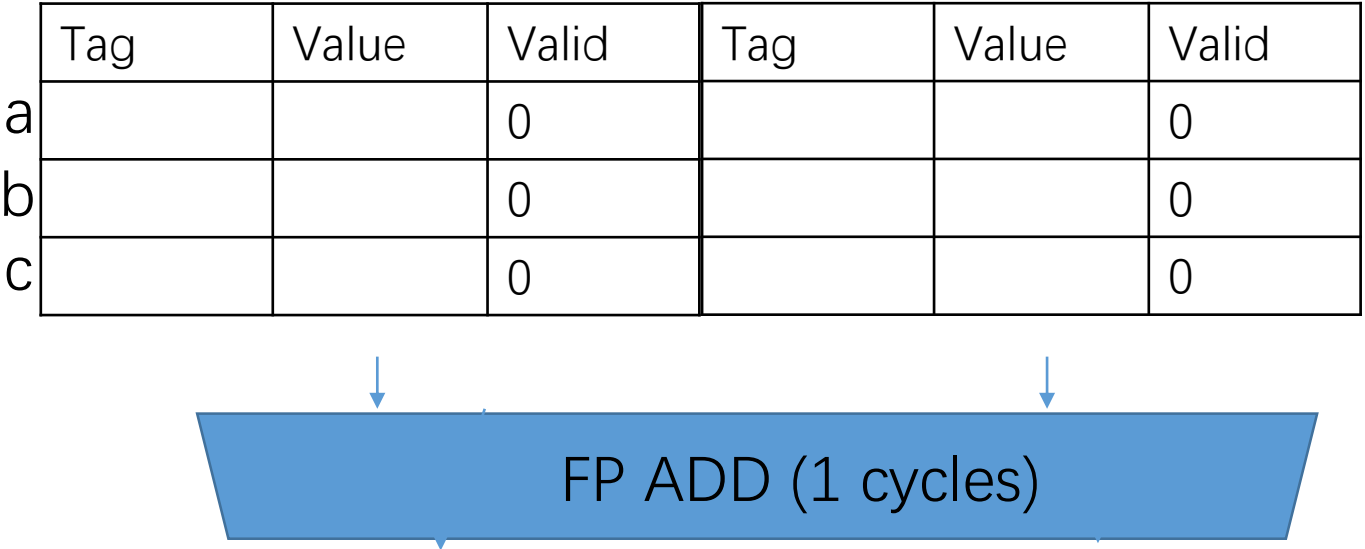
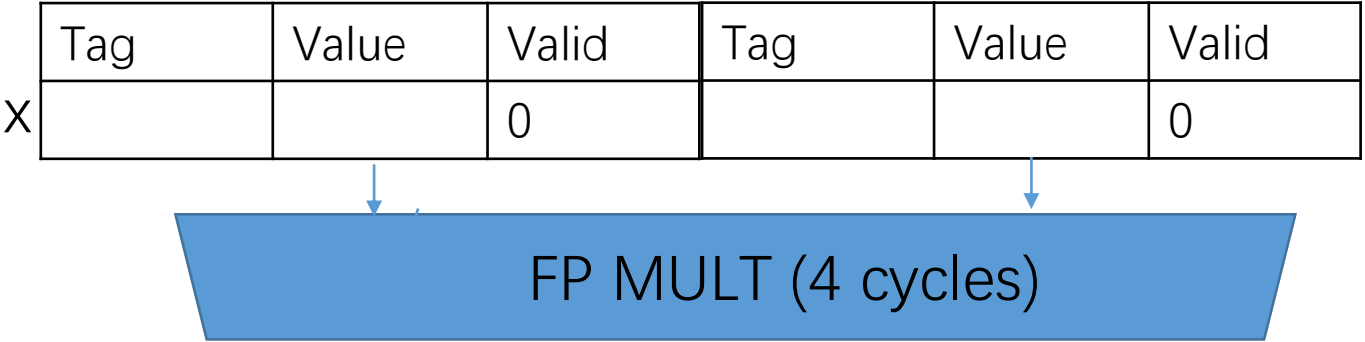
Instruction	Stage
muld f0, f1, f2	
addd f0, f1, f5	
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	



# Cycle 1

	Tag	Value	Valid
f0		0	1
f1		1	1
f2		2	1
f3		3	1
f4		4	1
f5		5	1

Instruction	Stage
muld f0, f1, f2	F
addd f0, f1, f5	
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	



# Cycle 2

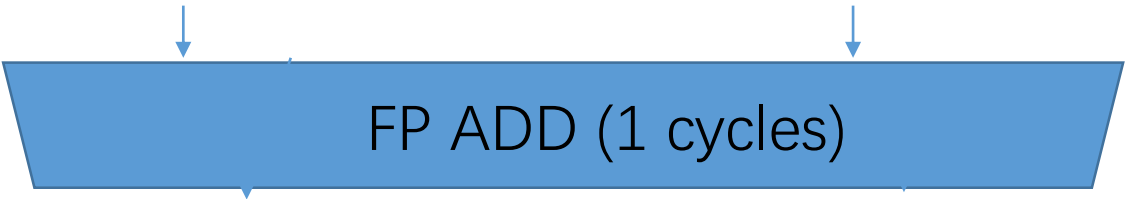
	Tag	Value	Valid
f0		0	1
f1		1	1
f2	x	2	0
f3		3	1
f4		4	1
f5		5	1

Instruction	Stage
muld f0, f1, f2	D
addd f0, f1, f5	F
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	

	Tag	Value	Valid	Tag	Value	Valid
x	~	0	1	~	1	1



	Tag	Value	Valid	Tag	Value	Valid
a			0			0
b			0			0
c			0			0





# Cycle 3

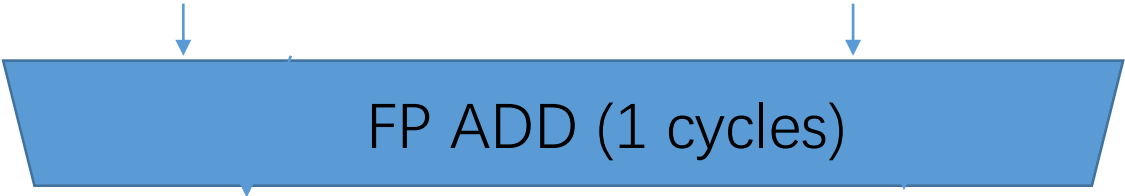
	Tag	Value	Valid
f0		0	1
f1		1	1
f2	x	2	0
f3		3	1
f4		4	1
f5	a	5	0

Instruction	Stage
muld f0, f1, f2	E1
addd f0, f1, f5	D
addd f2, f3, f3	F
addd f2, f4, f4	
addd f4, f5, f5	

	Tag	Value	Valid	Tag	Value	Valid
x	~	0	1	~	1	1



	Tag	Value	Valid	Tag	Value	Valid
a	~	0	1	~	1	1
b			0			0
c			0			0



# Cycle 4

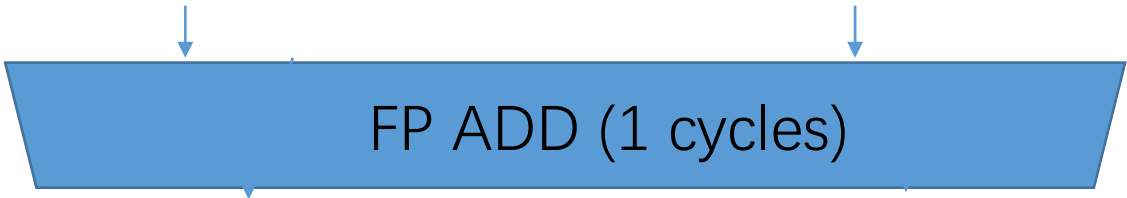
	Tag	Value	Valid
f0		0	1
f1		1	1
f2	x	2	0
f3	b	3	0
f4		4	1
f5	a	5	0

Instruction	Stage
muld f0, f1, f2	E2
addd f0, f1, f5	E1
addd f2, f3, f3	D
addd f2, f4, f4	F
addd f4, f5, f5	

	Tag	Value	Valid	Tag	Value	Valid
x	~	0	1	~	1	1



	Tag	Value	Valid	Tag	Value	Valid
a	~	0	1	~	1	1
b	x	~	0	~	3	1
c			0			0

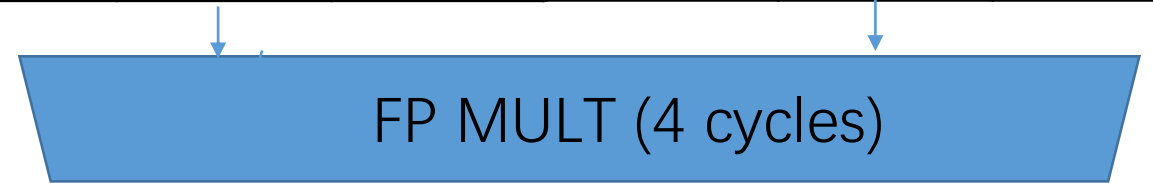


# Cycle 5

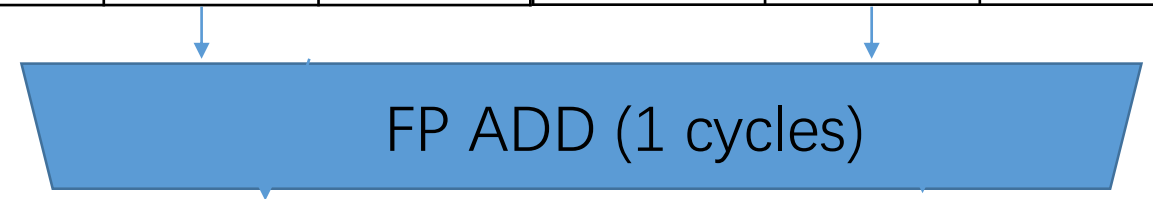
	Tag	Value	Valid
f0		0	1
f1		1	1
f2	x	2	0
f3	b	3	0
f4	c	4	0
f5		1	1

Instruction	Stage
muld f0, f1, f2	E3
addd f0, f1, f5	WB
addd f2, f3, f3	W(for tag)
addd f2, f4, f4	D
addd f4, f5, f5	F

	Tag	Value	Valid	Tag	Value	Valid
x	~	0	1	~	1	1



	Tag	Value	Valid	Tag	Value	Valid
a	~	~	0	~	~	0
b	x	~	0	~	3	1
c	x	~	0	~	4	1

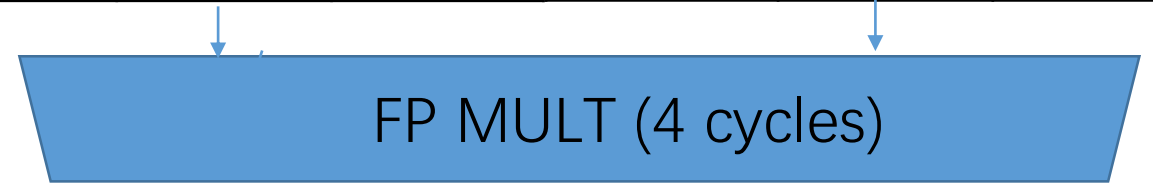


# Cycle 6

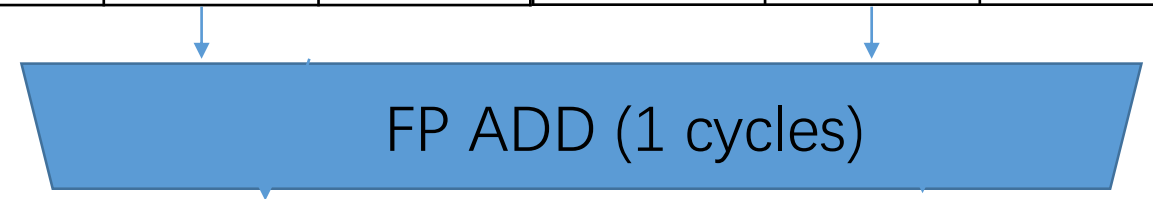
	Tag	Value	Valid
f0		0	1
f1		1	1
f2	x	2	0
f3	b	3	0
f4	c	4	0
f5	a	1	0

Instruction	Stage
muld f0, f1, f2	E4
addd f0, f1, f5	DONE
addd f2, f3, f3	W(for tag)
addd f2, f4, f4	W(for tag)
addd f4, f5, f5	D

	Tag	Value	Valid	Tag	Value	Valid
x	~	0	1	~	1	1



	Tag	Value	Valid	Tag	Value	Valid
a	c	~	0	~	1	1
b	x	~	0	~	3	1
c	x	~	0	~	4	1



# Cycle 7

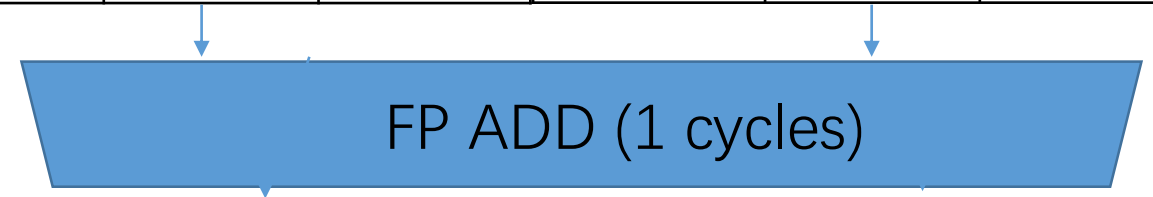
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3	b	3	0
f4	c	4	0
f5	a	1	0

Instruction	Stage
muld f0, f1, f2	WB
addd f0, f1, f5	DONE
addd f2, f3, f3	W(for tag)
addd f2, f4, f4	W(for tag)
addd f4, f5, f5	W(for tag)

	Tag	Value	Valid	Tag	Value	Valid
x	~	~	0	~	~	0



	Tag	Value	Valid	Tag	Value	Valid
a	c	~	0	~	1	1
b	~	0	1	~	3	1
c	~	0	1	~	4	1



# Cycle 8

	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3	b	3	0
f4	c	4	0
f5	a	1	0

Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	E1
addd f2, f4, f4	W(for Exe)
addd f4, f5, f5	W(for tag)

	Tag	Value	Valid	Tag	Value	Valid
X	~	~	0	~	~	0



	Tag	Value	Valid	Tag	Value	Valid
a	c	~	0	~	1	1
b	~	0	1	~	3	1
c	~	0	1	~	4	1



# Cycle 9

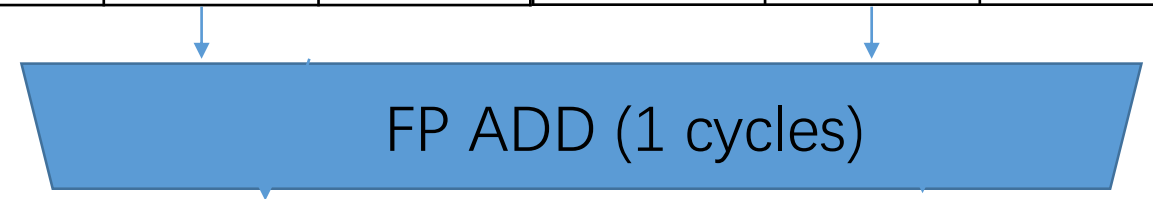
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3		3	1
f4	c	4	0
f5	a	1	0

Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	WB
addd f2, f4, f4	E1
addd f4, f5, f5	W(for tag)

	Tag	Value	Valid	Tag	Value	Valid
x	~	~	0	~	~	0



	Tag	Value	Valid	Tag	Value	Valid
a	c	~	0	~	1	1
b	~	~	0	~	~	0
c	~	0	1	~	4	1



# Cycle 10

	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3		3	1
f4		4	1
f5	a	1	0

Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	WB
addd f4, f5, f5	W(for tag)

	Tag	Value	Valid	Tag	Value	Valid
x	~	~	0	~	~	0



	Tag	Value	Valid	Tag	Value	Valid
a		4	1	~	1	1
b	~	~	0	~	~	0
c	~	~	0	~	~	0





# Cycle 11

	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3		3	1
f4		4	1
f5	a	1	0

Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	DONE
addd f4, f5, f5	E1

	Tag	Value	Valid	Tag	Value	Valid
x	~	~	0	~	~	0



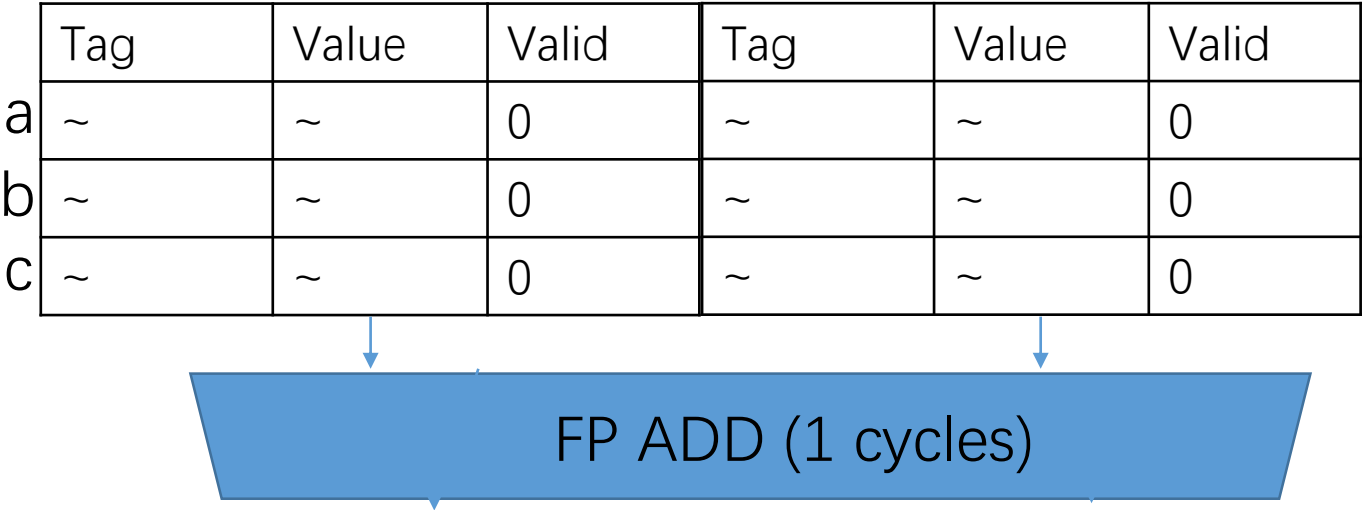
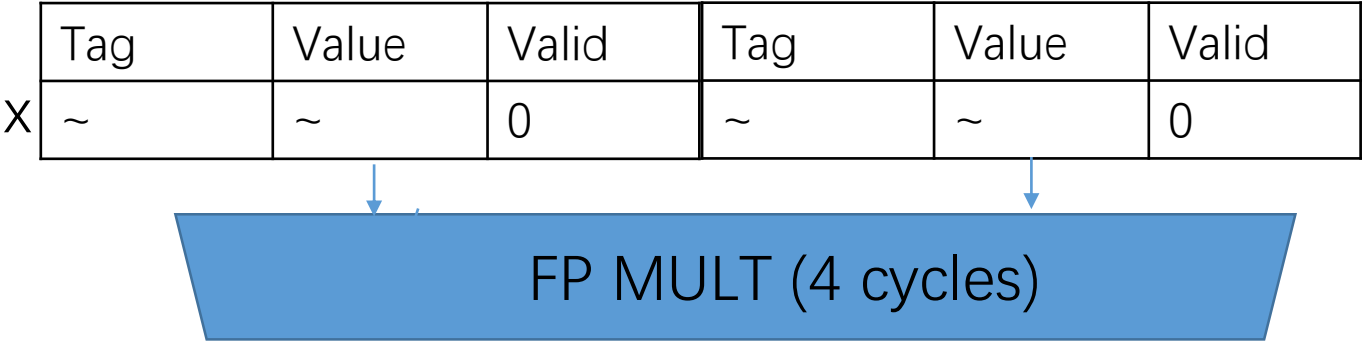
	Tag	Value	Valid	Tag	Value	Valid
a		4	1	~	1	1
b	~	~	0	~	~	0
c	~	~	0	~	~	0



# Cycle 12

	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3		3	1
f4		4	1
f5		5	1

Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	DONE
addd f4, f5, f5	WB



# Cycle 13

	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3		3	1
f4		4	1
f5		5	1

Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	DONE
addd f4, f5, f5	DONE

	Tag	Value	Valid	Tag	Value	Valid
X	~	~	0	~	~	0

## FP MULT (4 cycles)

	Tag	Value	Valid	Tag	Value	Valid
a	~	~	0	~	~	0
b	~	~	0	~	~	0
c	~	~	0	~	~	0

## FP ADD (1 cycles)

Q1 (d)

The smallest value of  $M$  is 2

Cycle 0

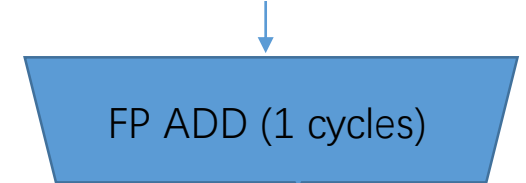
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		2	1
f3		3	1
f4		4	1
f5		5	1

Instruction	Stage
muld f0, f1, f2	
addd f0, f1, f5	
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	

	Tag	Value	Valid	Tag	Value	Valid
X			0			0



	Tag	Value	Valid	Tag	Value	Valid
a			0			0
b			0			0
c			0			0

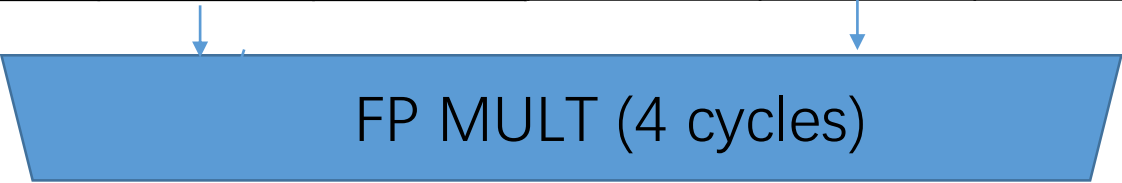


# Cycle 1

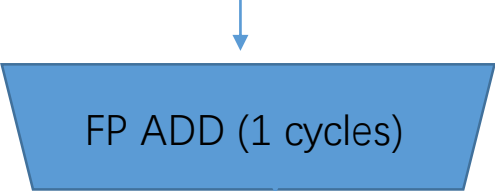
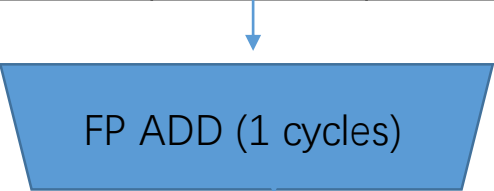
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		2	1
f3		3	1
f4		4	1
f5		5	1

Instruction	Stage
muld f0, f1, f2	F
addd f0, f1, f5	
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	

	Tag	Value	Valid	Tag	Value	Valid
x			0			0



	Tag	Value	Valid	Tag	Value	Valid
a			0			0
b			0			0
c			0			0



# Cycle 2

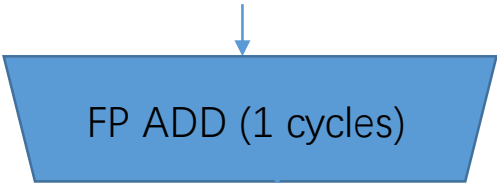
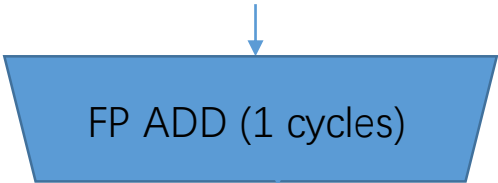
	Tag	Value	Valid
f0		0	1
f1		1	1
f2	x	2	0
f3		3	1
f4		4	1
f5		5	1

Instruction	Stage
muld f0, f1, f2	D
addd f0, f1, f5	F
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	

	Tag	Value	Valid	Tag	Value	Valid
x	~	0	1	~	1	1



	Tag	Value	Valid	Tag	Value	Valid
a			0			0
b			0			0
c			0			0





# Cycle 3

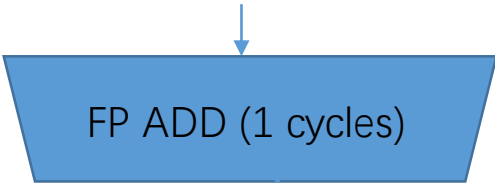
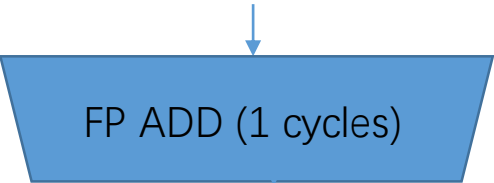
	Tag	Value	Valid
f0		0	1
f1		1	1
f2	x	2	0
f3		3	1
f4		4	1
f5	a	5	0

Instruction	Stage
muld f0, f1, f2	E1
addd f0, f1, f5	D
addd f2, f3, f3	F
addd f2, f4, f4	
addd f4, f5, f5	

	Tag	Value	Valid	Tag	Value	Valid
x	~	0	1	~	1	1



	Tag	Value	Valid	Tag	Value	Valid
a	~	0	1	~	1	1
b			0			0
c			0			0



# Cycle 4

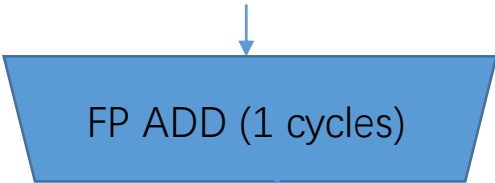
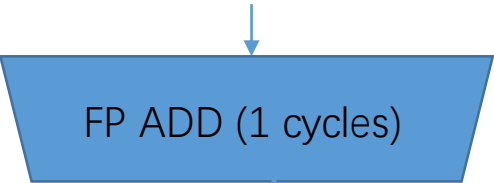
	Tag	Value	Valid
f0		0	1
f1		1	1
f2	x	2	0
f3	b	3	0
f4		4	1
f5	a	5	0

Instruction	Stage
muld f0, f1, f2	E2
addd f0, f1, f5	E1
addd f2, f3, f3	D
addd f2, f4, f4	F
addd f4, f5, f5	

	Tag	Value	Valid	Tag	Value	Valid
x	~	0	1	~	1	1



	Tag	Value	Valid	Tag	Value	Valid
a	~	0	1	~	1	1
b	x	~	0	~	3	1
c			0			0

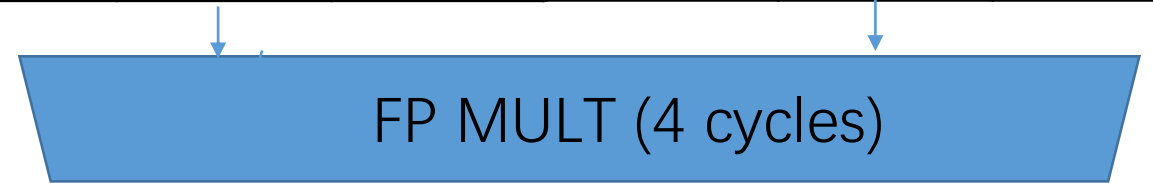


# Cycle 5

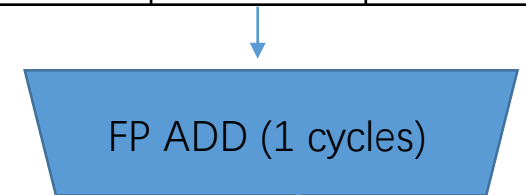
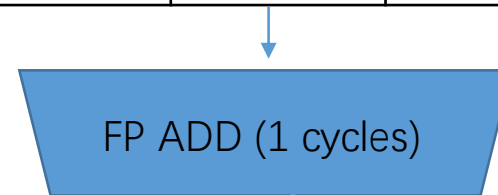
	Tag	Value	Valid
f0		0	1
f1		1	1
f2	x	2	0
f3	b	3	0
f4	c	4	0
f5		1	1

Instruction	Stage
muld f0, f1, f2	E3
addd f0, f1, f5	WB
addd f2, f3, f3	W(for tag)
addd f2, f4, f4	D
addd f4, f5, f5	F

	Tag	Value	Valid	Tag	Value	Valid
x	~	0	1	~	1	1



	Tag	Value	Valid	Tag	Value	Valid
a	~	~	0	~	~	0
b	x	~	0	~	3	1
c	x	~	0	~	4	1



# Cycle 6

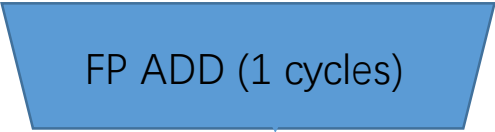
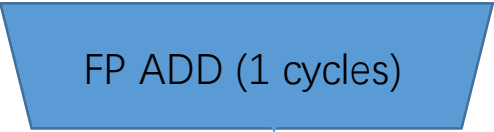
	Tag	Value	Valid
f0		0	1
f1		1	1
f2	x	2	0
f3	b	3	0
f4	c	4	0
f5	a	1	0

Instruction	Stage
muld f0, f1, f2	E4
addd f0, f1, f5	DONE
addd f2, f3, f3	W(for tag)
addd f2, f4, f4	W(for tag)
addd f4, f5, f5	D

	Tag	Value	Valid	Tag	Value	Valid
x	~	0	1	~	1	1



	Tag	Value	Valid	Tag	Value	Valid
a	c	~	0	~	1	1
b	x	~	0	~	3	1
c	x	~	0	~	4	1



# Cycle 7

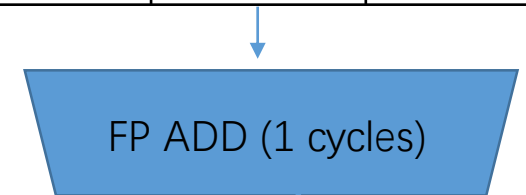
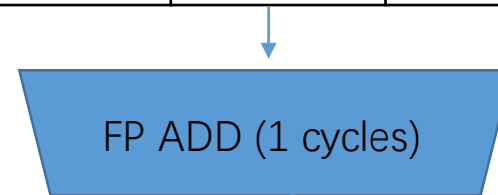
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3	b	3	0
f4	c	4	0
f5	a	1	0

Instruction	Stage
muld f0, f1, f2	WB
addd f0, f1, f5	DONE
addd f2, f3, f3	W(for tag)
addd f2, f4, f4	W(for tag)
addd f4, f5, f5	W(for tag)

	Tag	Value	Valid	Tag	Value	Valid
x	~	~	0	~	~	0



	Tag	Value	Valid	Tag	Value	Valid
a	c	~	0	~	1	1
b	~	0	1	~	3	1
c	~	0	1	~	4	1



# Cycle 8

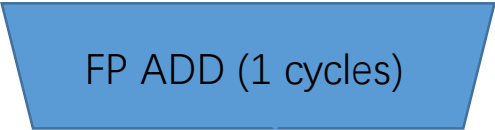
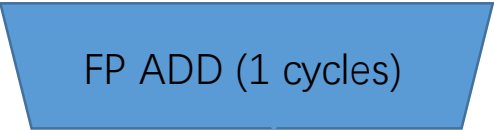
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3	b	3	0
f4	c	4	0
f5	a	1	0

Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	E1
addd f2, f4, f4	E1
addd f4, f5, f5	W(for tag)

	Tag	Value	Valid	Tag	Value	Valid
x	~	~	0	~	~	0



	Tag	Value	Valid	Tag	Value	Valid
a	c	~	0	~	1	1
b	~	0	1	~	3	1
c	~	0	1	~	4	1



# Cycle 9

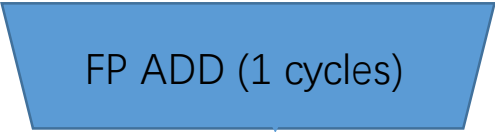
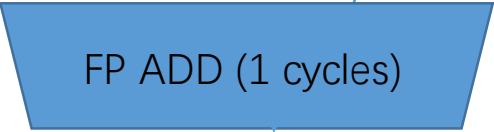
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3		3	1
f4		4	1
f5	a	1	0

Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	WB
addd f2, f4, f4	WB
addd f4, f5, f5	W(for tag)

	Tag	Value	Valid	Tag	Value	Valid
x	~	~	0	~	~	0



	Tag	Value	Valid	Tag	Value	Valid
a	~	4	1	~	1	1
b	~	~	0	~	~	0
c	~	~	0	~	~	0



# Cycle 10

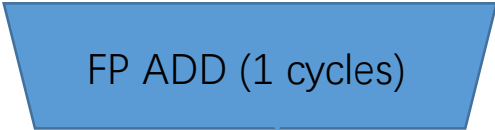
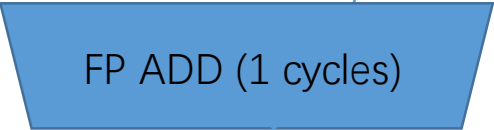
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3		3	1
f4		4	1
f5	a	1	0

Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	DONE
addd f4, f5, f5	E1

	Tag	Value	Valid	Tag	Value	Valid
x	~	~	0	~	~	0



	Tag	Value	Valid	Tag	Value	Valid
a	~	4	1	~	1	1
b	~	~	0	~	~	0
c	~	~	0	~	~	0





# Cycle 11

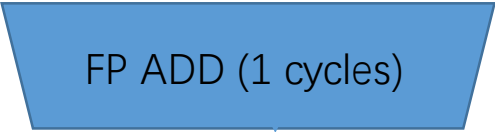
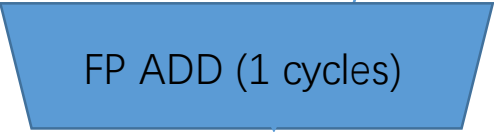
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3		3	1
f4		4	1
f5		5	1

Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	DONE
addd f4, f5, f5	WB

	Tag	Value	Valid	Tag	Value	Valid
x	~	~	0	~	~	0



	Tag	Value	Valid	Tag	Value	Valid
a	~	~	0	~	~	0
b	~	~	0	~	~	0
c	~	~	0	~	~	0



# Cycle 12

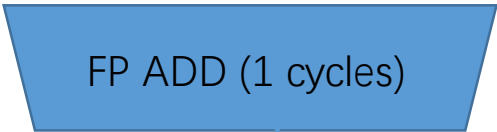
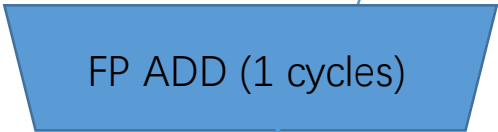
	Tag	Value	Valid
f0		0	1
f1		1	1
f2		0	1
f3		3	1
f4		4	1
f5		5	1

Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	DONE
addd f4, f5, f5	DONE

	Tag	Value	Valid	Tag	Value	Valid
x	~	~	0	~	~	0



	Tag	Value	Valid	Tag	Value	Valid
a	~	~	0	~	~	0
b	~	~	0	~	~	0
c	~	~	0	~	~	0



Q2 (a)

Cycle 0

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

Loop: subi r1, r1, 1  
Muld f0, f1, f1  
Addd f0, f2, f2  
Bne r1, r0, Loop  
Addd f1, f2, f3

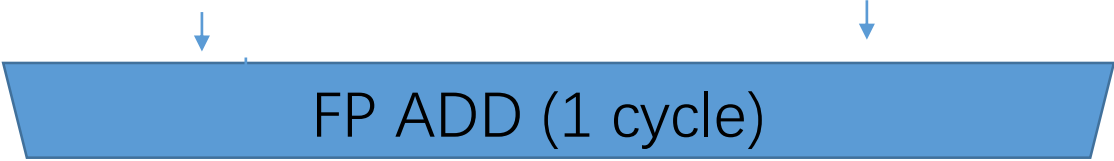
	Tag	Value	Valid
r0		0	1
r1		2	1

	Inst	Reg	value
A			
B			
C			
D			
E			

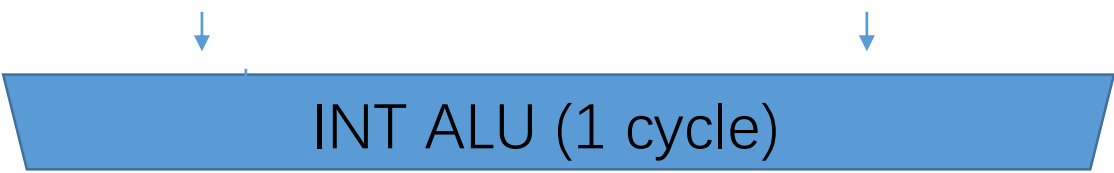
	Tag	Value	Valid	Tag	Value	Valid	ROB
x			0			0	
y			0			0	



	Tag	Value	Valid	Tag	Value	Valid	ROB
a			0			0	
b			0			0	



	Tag	Value	Valid	Tag	Value	Valid	ROB
a			0			0	
b			0			0	



Cycle 1

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

Loop: subi r1, r1, 1 F  
Muld f0, f1, f1  
Addd f0, f2, f2  
Bne r1, r0, Loop  
Addd f1, f2, f3

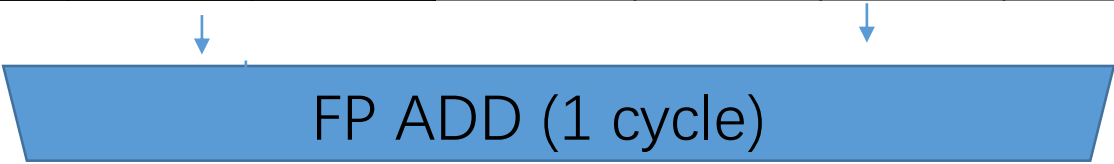
	Tag	Value	Valid
r0		0	1
r1		2	1

	Inst	Reg	value
A			
B			
C			
D			
E			

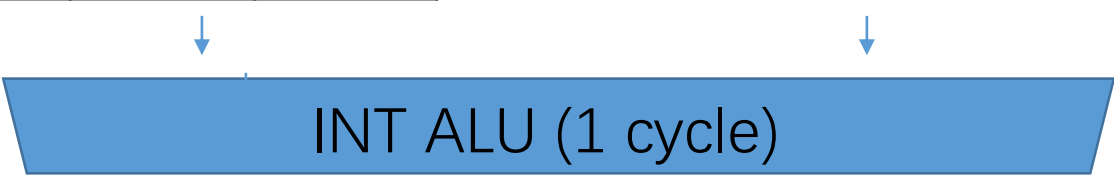
	Tag	Value	Valid	Tag	Value	Valid	ROB
x			0			0	
y			0			0	



	Tag	Value	Valid	Tag	Value	Valid	ROB
a			0			0	
b			0			0	



	Tag	Value	Valid	Tag	Value	Valid	ROB
a			0			0	
b			0			0	



Cycle 2

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

Loop: subi r1, r1, 1 D  
Muld f0, f1, f1 F  
Addd f0, f2, f2  
Bne r1, r0, Loop  
Addd f1, f2, f3

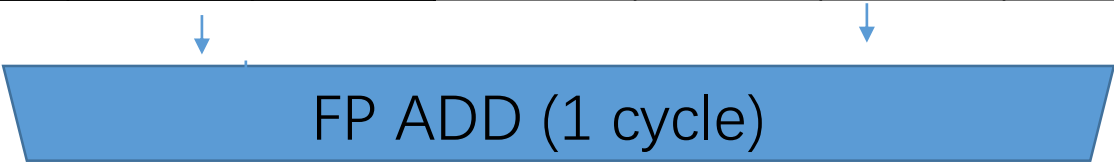
	Tag	Value	Valid
r0		0	1
r1	A	2	0

	Inst	Reg	value
A	SUBI	r1	
B			
C			
D			
E			

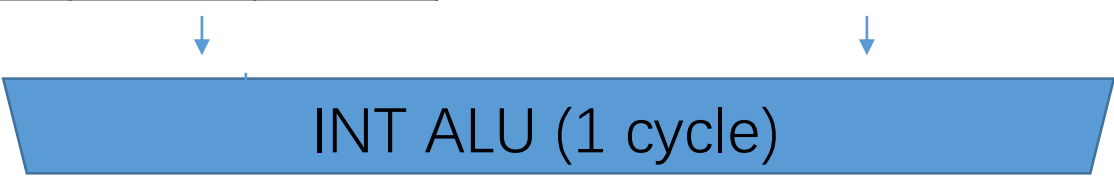
	Tag	Value	Valid	Tag	Value	Valid	ROB
x			0			0	
y			0			0	



	Tag	Value	Valid	Tag	Value	Valid	ROB
a			0			0	
b			0			0	



	Tag	Value	Valid	Tag	Value	Valid	ROB
a	~	2	1	~	1	1	A
b			0			0	



Cycle 3

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

Loop: subi r1, r1, 1 **E1**  
Muld f0, f1, f1 **D**  
Addd f0, f2, f2 **F**  
Bne r1, r0, Loop  
Addd f1, f2, f3

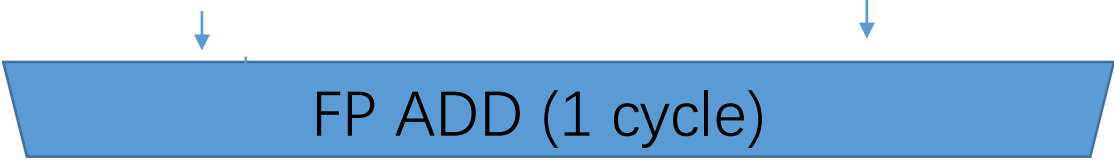
	Tag	Value	Valid
r0		0	1
r1	A	2	0

	Inst	Reg	value
A	SUBI	r1	
B	MULD	f1	
C			
D			
E			

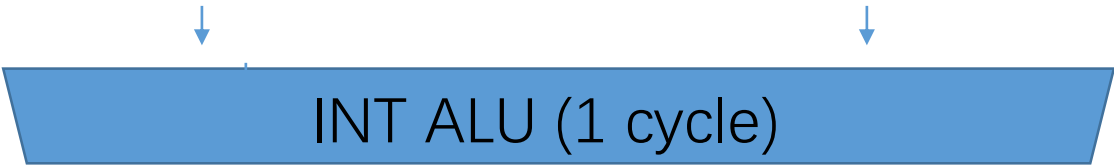
Tag	Value	Valid	Tag	Value	Valid	ROB
~	0	1	~	1	1	B
		0			0	



Tag	Value	Valid	Tag	Value	Valid	ROB
		0			0	
		0			0	



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



Cycle 4

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

Loop: subi r1, r1, 1 WB  
Muld f0, f1, f1 E1  
Addd f0, f2, f2 D  
Bne r1, r0, Loop F  
Addd f1, f2, f3

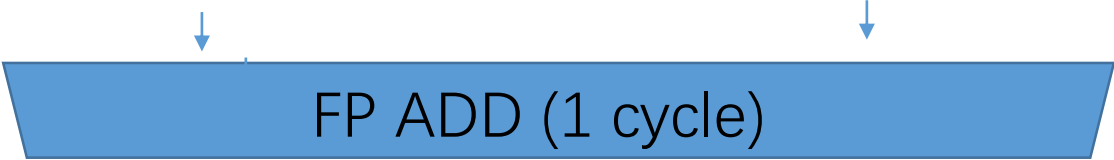
	Tag	Value	Valid
r0		0	1
r1	A	2	0

	Inst	Reg	value
A	SUBI	r1	1
B	MULD	f1	
C	ADDD	f2	
D			
E			

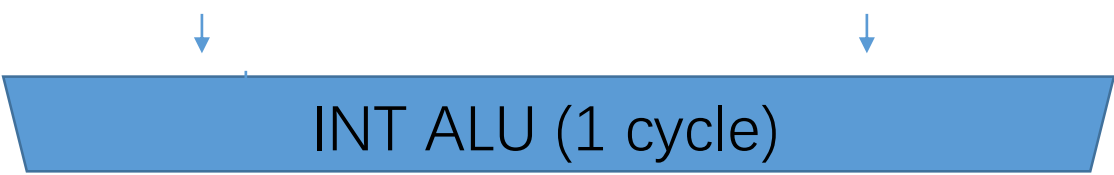
Tag	Value	Valid	Tag	Value	Valid	ROB
~	0	1	~	1	1	B
		0			0	



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



Tag	Value	Valid	Tag	Value	Valid	ROB
~	~	0	~	~	0	
		0			0	





Cycle 5

f0

f1

f2

f3

Tag	Value	Valid
	0	1
B	1	0
C	2	0
	3	1

Loop: subi r1, r1, 1 C, F  
Muld f0, f1, f1 E2  
Addd f0, f2, f2 E1  
Bne r1, r0, Loop D  
Addd f1, f2, f3

r0

r1

Tag	Value	Valid
	0	1
	1	1

A

B

C

D

E

Inst	Reg	value
MULD	f1	
ADDD	f2	
BNE		

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 6

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

Loop: subi r1, r1, 1 **DONE, D**

Muld f0, f1, f1 **E3, F**

Addd f0, f2, f2 **WB**

Bne r1, r0, Loop **E1**

Addd f1, f2, f3

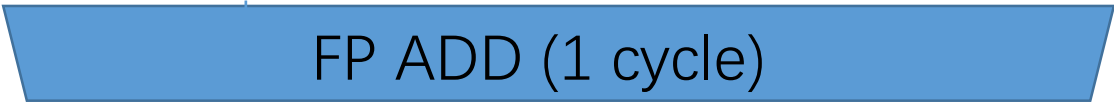
	Tag	Value	Valid
r0		0	1
r1	E	1	0

	Inst	Reg	value
A			
B	MULD	f1	
C	ADDD	f2	2
D	BNE		
E	SUBI	r1	

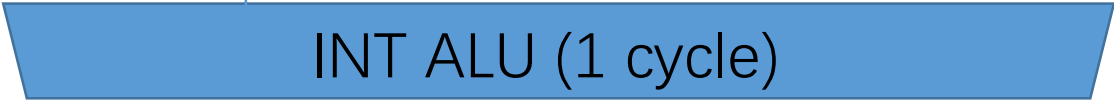
Tag	Value	Valid	Tag	Value	Valid	ROB
~	0	1	~	1	1	B
		0			0	



Tag	Value	Valid	Tag	Value	Valid	ROB
		0			0	
		0			0	



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



Cycle 7

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

Loop: subi r1, r1, 1 **DONE, E1**

Muld f0, f1, f1 **E4, D**

Addd f0, f2, f2 **W(for C), F**

Bne r1, r0, Loop **WB**

Addd f1, f2, f3

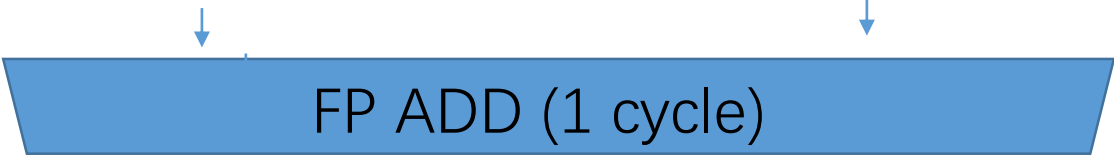
	Tag	Value	Valid
r0		0	1
r1	E	1	0

	Inst	Reg	value
A			
B	MULD	f1	
C	ADDD	f2	2
D	BNE		
E	SUBI	r1	
F	MULD	f1	
G			

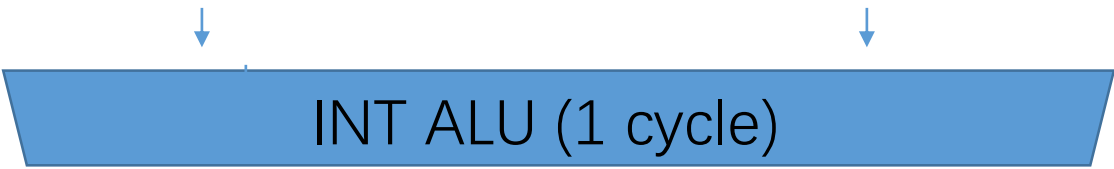
Tag	Value	Valid	Tag	Value	Valid	ROB
~	0	1	~	1	1	B
~	0	1	B	~	0	F



Tag	Value	Valid	Tag	Value	Valid	ROB
		0			0	
		0			0	



Tag	Value	Valid	Tag	Value	Valid	ROB
~	1	1	~	1	1	E



Cycle 8

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

Loop: subi r1, r1, 1 **DONE, WB**

Muld f0, f1, f1 **WB, W(for E)**

Addd f0, f2, f2 **W(for C), D**

Bne r1, r0, Loop **W(for C), F**

Addd f1, f2, f3

	Tag	Value	Valid
r0		0	1
r1	E	1	0

	Inst	Reg	value
A			
B	MULD	f1	0
C	ADDD	f2	2
D	BNE		
E	SUBI	r1	0
F	MULD	f1	
G	ADDD	F2	

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 9

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

Loop: subi r1, r1, 1 **DONE, W(for C), F**  
Muld f0, f1, f1 **C, E1**  
Addd f0, f2, f2 **W(for C), E1**  
Bne r1, r0, Loop **W(for C), D**  
Addd f1, f2, f3

	Tag	Value	Valid
r0		0	1
r1	E	1	0

	Inst	Reg	value
A			
B			
C	ADDD	f2	2
D	BNE		
E	SUBI	r1	0
F	MULD	f1	
G	ADDD	F2	
H	BNE		

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
E	0	1	~	0	1	H
		0			0	

INT ALU (1 cycle)

# Cycle 10

f0  
f1  
f2  
f3

Tag	Value	Valid
	0	1
F	1	0
G	2	0
	3	1

Loop: subi r1, r1, 1 **DONE, W(for C), D**

Muld f0, f1, f1 **DONE, E2, F**

Addd f0, f2, f2 **C, WB**

Bne r1, r0, Loop **W(for C), E1**

Addd f1, f2, f3

Tag	Value	Valid
	0	1
E	1	0

A  
B  
C  
D  
E  
F  
G  
H  
I  
J

Inst	Reg	value
BNE		
SUBI	r1	0
MULD	f1	
ADDD	f2	2
BNE		
SUBI	r1	

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
E	0	1	~	0	1	H
E	0	1	~	0	1	I

INT ALU (1 cycle)

# Cycle 11

f0		0	1
f1	F	1	0
f2	G	2	0
f3		3	1

Loop: subi r1, r1, 1 **DONE, W(for C), E1**

Muld f0, f1, f1 **DONE, E3,**

Add f0, f2, f2 **DONE, W(C), F**

Bne r1, r0, Loop **C, WB**

Add f1, f2, f3

	Tag	Value	Valid
r0		0	1
r1	E	1	0

	Inst	Reg	value
A			
B			
C			
D			
E	SUBI	r1	0
F	MULD	f1	
G	ADDD	f2	2
H	BNE		
I	SUBI	r1	
J	MULD	f1	

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
E	0	1	~	0	1	I

INT ALU (1 cycle)

# Cycle 12

f0  
f1  
f2  
f3

Tag	Value	Valid
	0	1
F	1	0
G	2	0
	3	1

Loop: subi r1, r1, 1 **DONE, W(for C).**  
Muld f0, f1, f1 **DONE, E3,**  
Add f0, f2, f2 **DONE, W(C)**  
 Bne r1, r0, Loop **DONE, WB**  
 Addd f1, f2, f3

Tag	Value	Valid
	0	1
E	1	0

A  
B  
C  
D  
E  
F  
G  
H  
I  
J

Inst	Reg	value
Subi	R1	0
MULD	f1	
ADDD	f2	2
BNE		

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

f0  
f1  
f2  
f3

Tag	Value	Valid
	0	1
F	1	0
G	2	0
	3	1

Loop: subi r1, r1, 1 **DONE, C**  
 Muld f0, f1, f1 **DONE, E4,**  
 Addd f0, f2, f2 **DONE, W(C)**  
 Bne r1, r0, Loop **DONE, W(C)**  
 Addd f1, f2, f3 **F**

Tag	Value	Valid
	0	1
	0	1

A  
B  
C  
D  
E  
F  
G  
H  
I  
J

Inst	Reg	value
MULD	f1	
ADDD	f2	2
BNE		

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 14

f0  
f1  
f2  
f3

Tag	Value	Valid
	0	1
F	1	0
G	2	0
I	3	0

Loop: subi r1, r1, 1 **DONE, DONE,**  
 Muld f0, f1, f1 **DONE, WB,**  
 Addd f0, f2, f2 **DONE, W(C)**  
 Bne r1, r0, Loop **DONE, W(C)**  
 Addd f1, f2, f3 **D**

Tag	Value	Valid
r0	0	1
r1	0	1

A  
B  
C  
D  
E  
F  
G  
H  
I  
J

Inst	Reg	value
MULD	f1	0
ADDD	f2	2
BNE		
ADDD	F3	

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

f0

f1

f2

f3

Tag	Value	Valid
	0	1
	0	1
G	2	0
I	3	0

Loop: subi r1, r1, 1 **DONE, DONE,**

Muld f0, f1, f1 **DONE, C,**

Addd f0, f2, f2 **DONE, W(C)**

Bne r1, r0, Loop **DONE, W(C)**

Addd f1, f2, f3 **E1**

Tag	Value	Valid
r0	0	1
r1	0	1

A

B

C

D

E

F

G

H

I

J

Inst	Reg	value
ADDD	f2	2
BNE		
ADDD	f3	

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 16

f0  
f1  
f2  
f3

Tag	Value	Valid
	0	1
	0	1
	2	1
1	3	0

Loop: subi r1, r1, 1 **DONE, DONE,**  
 Muld f0, f1, f1 **DONE, DONE,**  
 Addd f0, f2, f2 **DONE, C**  
 Bne r1, r0, Loop **DONE, W(C)**  
 Addd f1, f2, f3 **WB**

Tag	Value	Valid
	0	1
	0	1

A  
B  
C  
D  
E  
F  
G  
H  
I  
J

Inst	Reg	value
BNE		
ADDD	f3	2

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

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

Loop: subi r1, r1, 1 **DONE, DONE,**  
Muld f0, f1, f1 **DONE, DONE,**  
Addd f0, f2, f2 **DONE, DONE,**  
Bne r1, r0, Loop **DONE, C**  
Addd f1, f2, f3 **W(C)**

	Tag	Value	Valid
r0		0	1
r1		0	1

	Inst	Reg	value
A			
B			
C			
D			
E			
F			
G			
H			
I	ADDD	f3	2
J			

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

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

Loop: subi r1, r1, 1 **DONE, DONE,**  
Muld f0, f1, f1 **DONE, DONE,**  
Addd f0, f2, f2 **DONE, DONE,**  
Bne r1, r0, Loop **DONE, DONE,**  
Addd f1, f2, f3 **C**

	Tag	Value	Valid
r0		0	1
r1		0	1

	Inst	Reg	value
A			
B			
C			
D			
E			
F			
G			
H			
I			
J			

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 18

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

Loop: subi r1, r1, 1 **DONE, DONE,**  
 Mld f0, f1, f1 **DONE, DONE,**  
 Addd f0, f2, f2 **DONE, DONE,**  
 Bne r1, r0, Loop **DONE, DONE,**  
 Addd f1, f2, f3 **DONE**

	Tag	Value	Valid
r0		0	1
r1		0	1

	Inst	Reg	value
A			
B			
C			
D			
E			
F			
G			
H			
I			
J			

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)

Q2 (b)



- Since we at most store 6 instructions in ROB simultaneously, we need at least 7 ROB entries. The extra one is because if one instruction is committing and another instruction wants to get into ROB when ROB has 6 instructions, the other instruction should wait until the next clock cycle.
- Thus we totally need 7 ROB entries.

Q3

Since we are going to report the results when LARGE is infinite, we don't need to care about the small difference.

- a. B1: 0% (finally always taken 11)  
B2 : 50% (correct at  $4i+2$ ,  $4i+3$ ; wrong at  $4i$  and  $4i+1$  )  
B3 : 100% (always wrong)
  
- a. B1: 0% (finally always taken 11)  
B2: 25% (wrong at  $4i$ , correct at  $4i+1$ ,  $4i+2$ ,  $4i+3$ )  
B3: 50% (wrong at  $4i$ ,  $4i+2$ , correct at  $4i+1$ ,  $4i+3$ )
  
- c. B1: 0% (finally always taken 11)  
B2: 25% (wrong at  $4i$ , correct at  $4i+1$ ,  $4i+2$ ,  $4i+3$ )  
B3: 25% (wrong at  $4i+2$ , correct at  $4i$ ,  $4i+1$ ,  $4i+3$ )