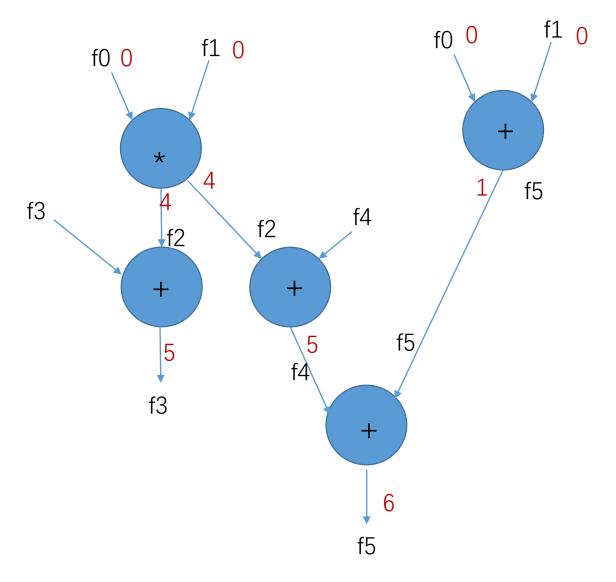
CS GY Homework 3

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Q1 (a)



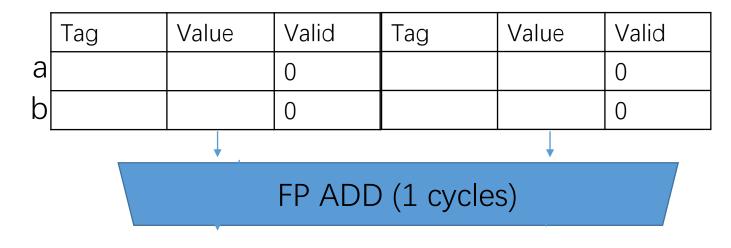
- F = fetch, D = dispatch, C = commit, E = execute WB = write back, W = waiting,
- W(C) = wait for commit, W(F) = wait for fetch,
 W(E) = wait for execute, W(tag) = wait for a tag

Q1 (b)

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

	Tag	Value	Valid	Tag	Value	Valid	
X			0			0	
У			0			0	
		<u> </u>			↓		
		FP MULT (4 cycles)					

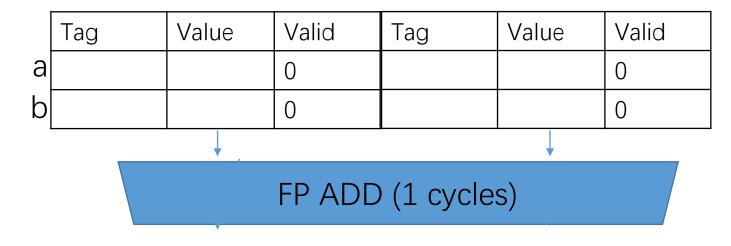
Instruction	Stage
muld f0, f1, f2	
addd f0, f1, f5	
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	



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

	Tag	Value	Valid	Tag	Value	Valid	
X			0			0	
У			0			0	
					•		
		FP MULT (4 cycles)					

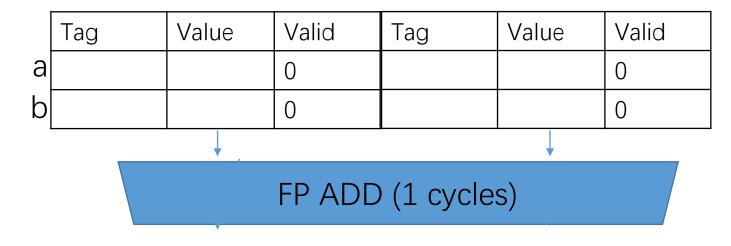
Instruction	Stage
muld f0, f1, f2	F
addd f0, f1, f5	
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	



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

	Tag	Value	Valid	Tag	Value	Valid
X	~	0	1	~	1	1
У			0			0
		<u> </u>			↓	
		FP MULT (4 cycles)				

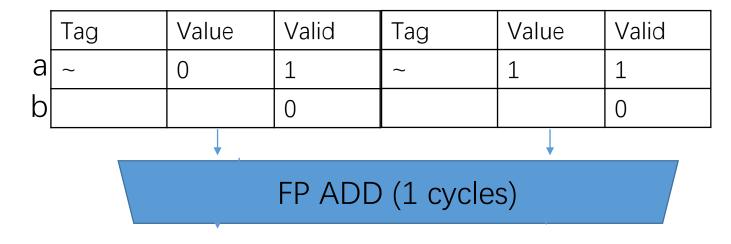
Instruction	Stage
muld f0, f1, f2	D
addd f0, f1, f5	F
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	



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

	Tag	Value	Valid	Tag	Value	Valid
X	~	0	1	?	1	1
У			0			0
		<u> </u>			•	
		FP MULT (4 cycles)				

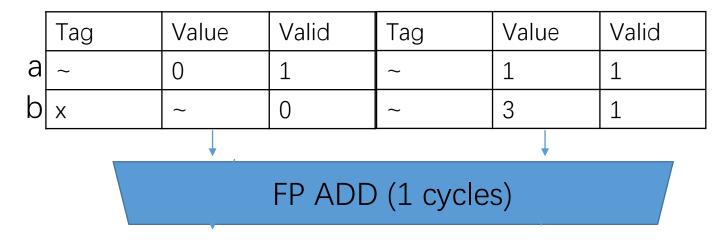
Instruction	Stage
muld f0, f1, f2	E1
addd f0, f1, f5	D
addd f2, f3, f3	F
addd f2, f4, f4	
addd f4, f5, f5	



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

	Tag	Value	Valid	Tag	Value	Valid
X	~	0	1	~	1	1
У			0			0
		· .		-	↓	
	FP MULT (4 cycles)					

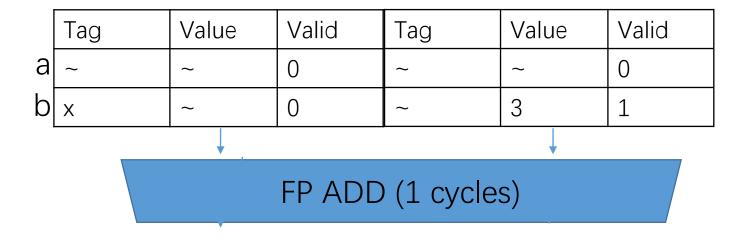
Instruction	Stage
muld f0, f1, f2	E2
addd f0, f1, f5	E1
addd f2, f3, f3	D
addd f2, f4, f4	F
addd f4, f5, f5	



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

	Tag	Value	Valid	Tag	Value	Valid
Χ	~	0	1	~	1	1
У			0			0
		.			V	,
	FP MULT (4 cycles)					

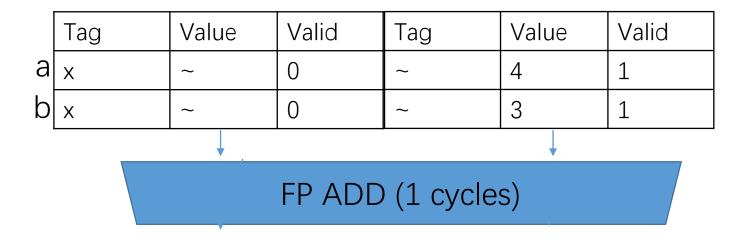
Instruction	Stage	
muld f0, f1, f2	E3	
addd f0, f1, f5	WB	
addd f2, f3, f3	W(for tag)	
addd f2, f4, f4	W(for D)	
addd f4, f5, f5	W(F)	



	Tag	Value	Valid
f0 f1		0	1
f1		1	1
f2	X	2	0
f2 f3 f4 f5	р	3	0
f4	а	4	0
f5		1	1

Tag	Value	Valid	Tag	Value	Valid
~	0	1	~	1	1
		0			0
				V	
FP MULT (4 cycles)					
	Tag ~	Tag Value ~ 0	~ 0 1 0	~ 0 1 ~ 0	~ 0 1 ~ 1

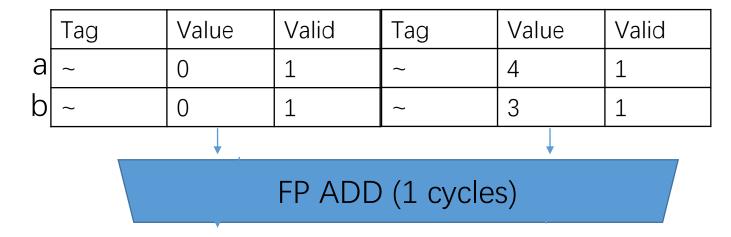
Instruction	Stage
muld f0, f1, f2	E4
addd f0, f1, f5	DONE
addd f2, f3, f3	W
addd f2, f4, f4	D
addd f4, f5, f5	F



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

Tag	Value	Valid	Tag	Value	Valid
~	~	0	~	~	0
		0			0
	<u> </u>			V	
FP MULT (4 cycles)					
	Tag ~	Tag Value ~ ~	~ 0	~ ~ 0 ~	~ ~ 0 ~ ~

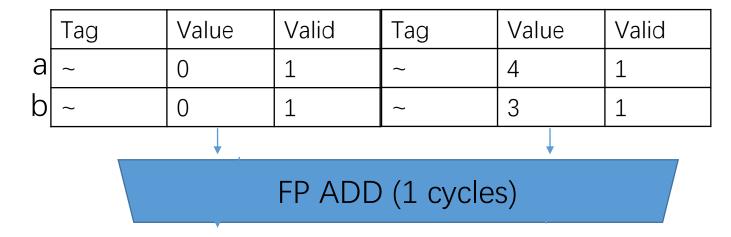
Instruction	Stage	
muld f0, f1, f2	WB	
addd f0, f1, f5	DONE	
addd f2, f3, f3	W(for tag)	
addd f2, f4, f4	W(for tag)	
addd f4, f5, f5	W(for D)	



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

	Tag	Value	Valid	Tag	Value	Valid
X	~	~	0	~	~	0
У			0			0
		<u> </u>		-	+	
			FP MU	ILT (4 cyc	cles)	

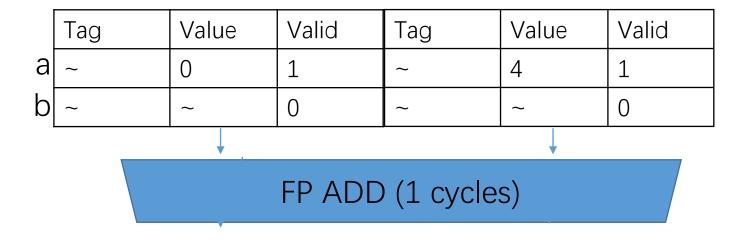
Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	E1
addd f2, f4, f4	W(for E)
addd f4, f5, f5	W(for D)



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

	Tag	Value	Valid	Tag	Value	Valid	
X	~	~	0	?	~	0	
У			0			0	
					↓		
		FP MULT (4 cycles)					

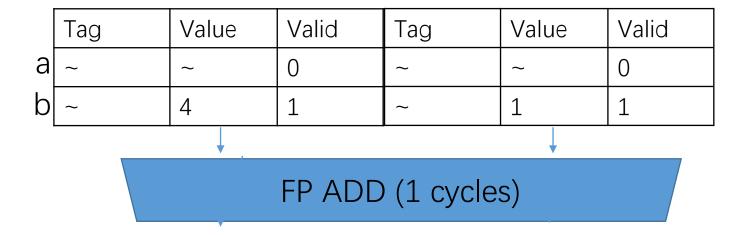
Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	WB
addd f2, f4, f4	E1
addd f4, f5, f5	W(for D)



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

	Tag	Value	Valid	Tag	Value	Valid
X	~	~	0	?	~	0
У			0		,	0
		<u> </u>			\	
	FP MULT (4 cycles)					

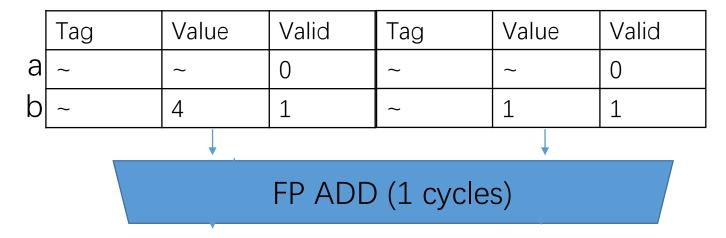
Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	WB
addd f4, f5, f5	D



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

	Tag	Value	Valid	Tag	Value	Valid	
X	~	~	0	?	~	0	
У			0			0	
					↓		
		FP MULT (4 cycles)					

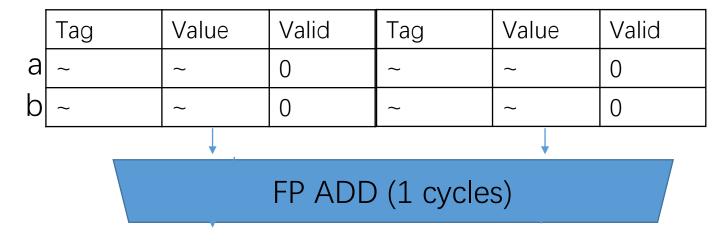
Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	DONE
muld f4, f5, f5	E1



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

	Tag	Value	Valid	Tag	Value	Valid
X	~	~	0	~	?	0
У			0			0
		<u> </u>			↓	
		FP MULT (4 cycles)				

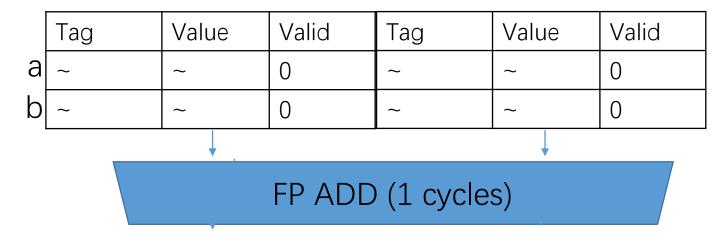
Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	DONE
addd f4, f5, f5	WB



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

	Tag	Value	Valid	Tag	Value	Valid
X	~	~	0	~	?	0
У			0			0
		<u> </u>			↓	
		FP MULT (4 cycles)				

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



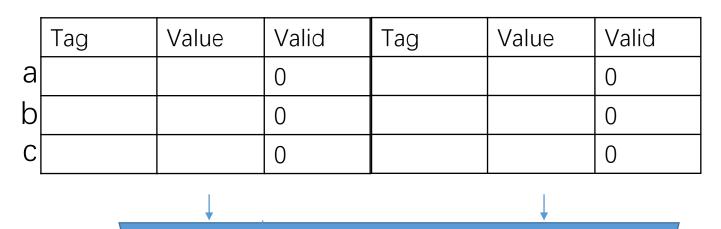
Q1 (c)

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

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

	Tag	Value	Valid	Tag	Value	Valid
X			0			0
		<u> </u>			1	
	FP MULT (4 cycles)					

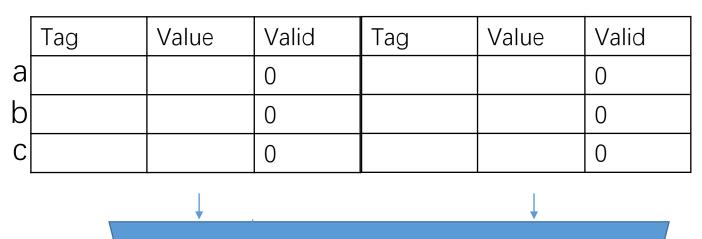
Instruction	Stage
muld f0, f1, f2	
addd f0, f1, f5	
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	



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

	Tag	Value	Valid	Tag	Value	Valid	
X			0			0	
-		<u> </u>			+		
		FP MULT (4 cycles)					

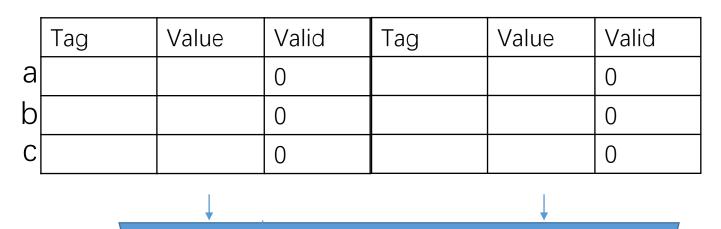
Instruction	Stage
muld f0, f1, f2	F
addd f0, f1, f5	
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	



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

	Tag	Value	Valid	Tag	Value	Valid
X	~	0	1	?	1	1
		<u> </u>			<u> </u>	
	FP MULT (4 cycles)					

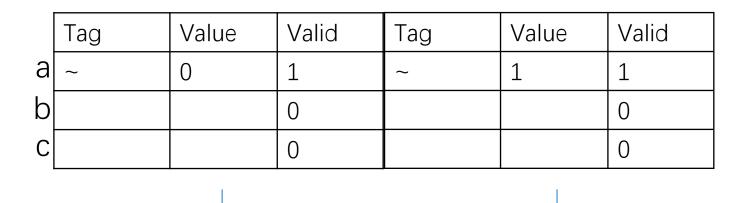
Instruction	Stage
muld f0, f1, f2	D
addd f0, f1, f5	F
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	



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

	Tag	Value	Valid	Tag	Value	Valid
X	~	0	1	?	1	1
		<u> </u>			<u> </u>	
	FP MULT (4 cycles)					

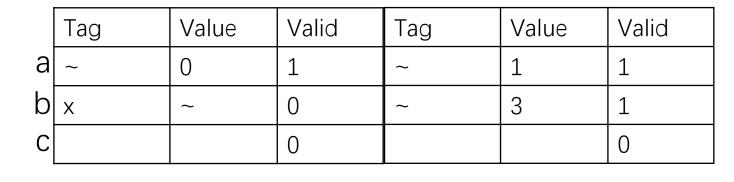
Instruction	Stage
muld f0, f1, f2	E1
addd f0, f1, f5	D
addd f2, f3, f3	F
addd f2, f4, f4	
addd f4, f5, f5	



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

	Tag	Value	Valid	Tag	Value	Valid
X	~	0	1	~	1	1
		<u> </u>			+	
			FP MU	JLT (4 cyc	cles)	

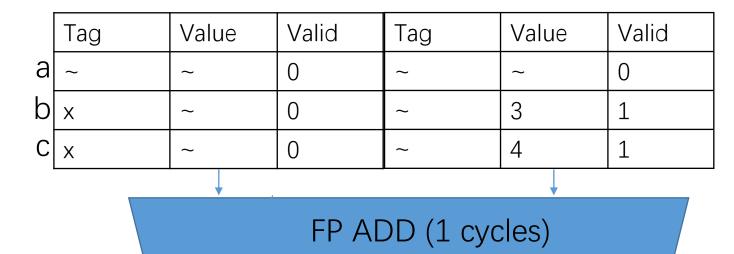
Instruction	Stage
muld f0, f1, f2	E2
addd f0, f1, f5	E1
addd f2, f3, f3	D
addd f2, f4, f4	F
addd f4, f5, f5	



	Tag	Value	Valid
f0 f1		0	1
		1	1
f2 f3 f4 f5	Х	2	0
f3	р	3	0
f4	С	4	0
f5		1	1

	Tag	Value	Valid	Tag	Value	Valid
X	~	0	1	?	1	1
		<u> </u>			<u> </u>	
	FP MULT (4 cycles)					

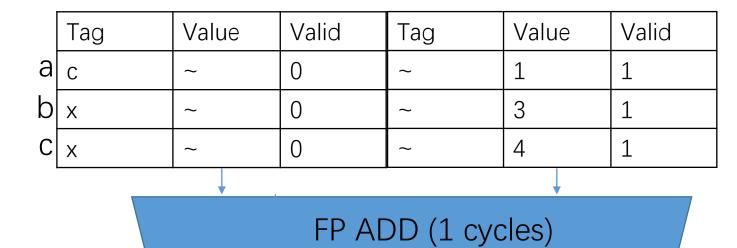
Instruction	Stage
muld f0, f1, f2	E3
addd f0, f1, f5	WB
addd f2, f3, f3	W(for tag)
addd f2, f4, f4	D
addd f4, f5, f5	F



	Tag	Value	Valid
f0 f1		0	1
		1	1
f2 f3 f4 f5	Х	2	0
f3	b	3	0
f4	С	4	0
f5	а	1	0

	Tag	Value	Valid	Tag	Value	Valid	
X	~	0	1	?	1	1	
		<u> </u>			<u> </u>		
		FP MULT (4 cycles)					

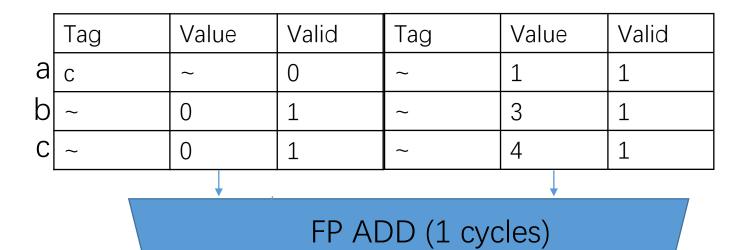
Instruction	Stage
muld f0, f1, f2	E4
addd f0, f1, f5	DONE
addd f2, f3, f3	W(for tag)
addd f2, f4, f4	W(for tag)
addd f4, f5, f5	D



	Tag	Value	Valid
f0 f1		0	1
f1		1	1
f2		0	1
f3 f4 f5	d	3	0
f4	С	4	0
f5	а	1	0

	Tag	Value	Valid	Tag	Value	Valid	
X	~	~	0	?	~	0	
		.			↓		
		FP MULT (4 cycles)					

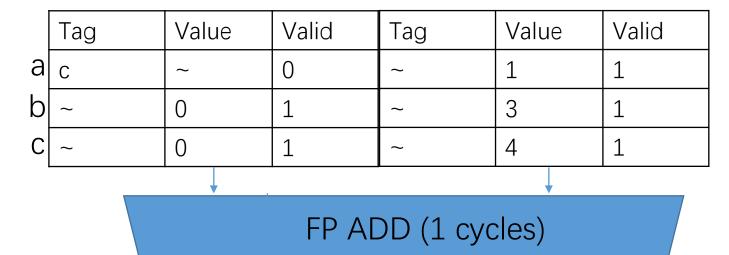
Instruction	Stage	
muld f0, f1, f2	WB	
addd f0, f1, f5	DONE	
addd f2, f3, f3	W(for tag)	
addd f2, f4, f4	W(for tag)	
addd f4, f5, f5	W(for tag)	



	Tag	Value	Valid
fO		0	1
f1		1	1
f2		0	1
f0 f1 f2 f3 f4 f5	р	3	0
f4	С	4	0
f5	а	1	0

	Tag	Value	Valid	Tag	Value	Valid
X	~	~	0	~	~	0
		<u> </u>			I	
			FP MU	JLT (4 cyc	cles)	

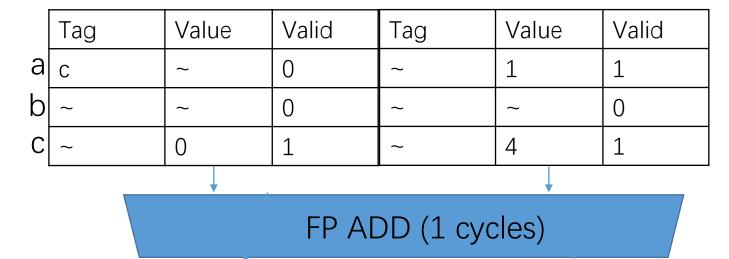
Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	E1
addd f2, f4, f4	W(for Exe)
addd f4, f5, f5	W(for tag)



	Tag	Value	Valid
fO		0	1
f1		1	1
f2		0	1
f0 f1 f2 f3 f4 f5		3	1
f4	С	4	0
f5	а	1	0

	Tag	Value	Valid	Tag	Value	Valid
X	~	~	0	~	~	0
		<u> </u>			I	
			FP MU	JLT (4 cyc	cles)	

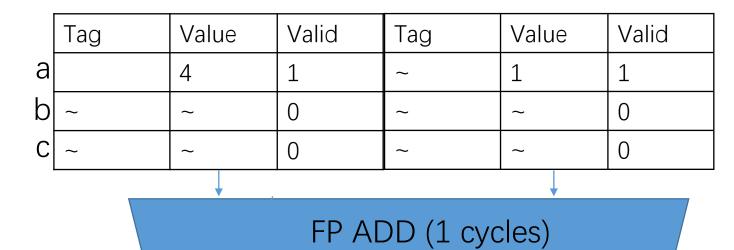
Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	WB
addd f2, f4, f4	E1
addd f4, f5, f5	W(for tag)



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

	Tag	Value	Valid	Tag	Value	Valid	
X	~	~	0	~	~	0	
		<u> </u>			1		
		FP MULT (4 cycles)					

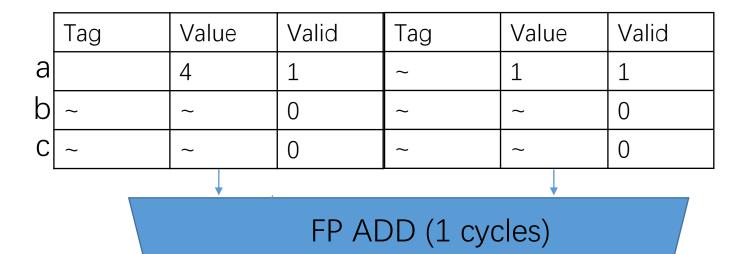
Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	WB
addd f4, f5, f5	W(for tag)



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

	Tag	Value	Valid	Tag	Value	Valid	
X	~	~	0	?	~	0	
		.			↓		
	FP MULT (4 cycles)						

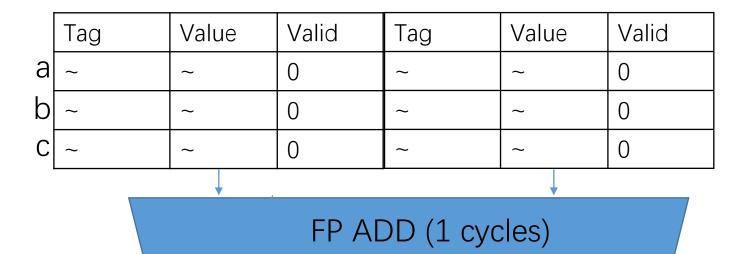
Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	DONE
addd f4, f5, f5	E1



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

	Tag	Value	Valid	Tag	Value	Valid
X	~	~	0	~	~	0
		<u> </u>			I	
			FP MU	JLT (4 cyc	cles)	

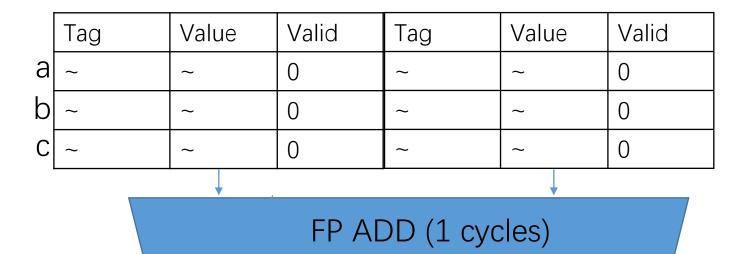
Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	DONE
addd f4, f5, f5	WB



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

	Tag	Value	Valid	Tag	Value	Valid	
X	~	~	0	?	~	0	
		.			↓		
	FP MULT (4 cycles)						

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



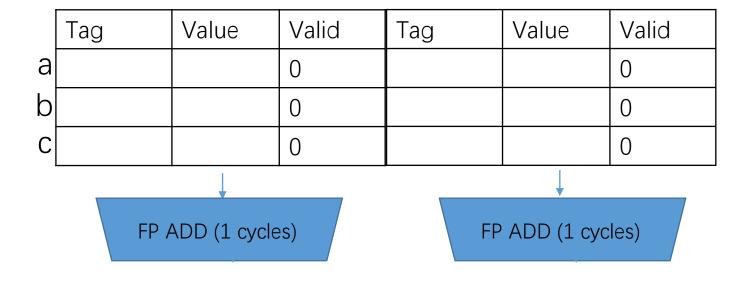
Q1 (d)

The smallest value of M is 2

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

	Tag	Value	Valid	Tag	Value	Valid
X			0		_	0
		<u> </u>			<u> </u>	
			FP MU	ILT (4 cyc	cles)	

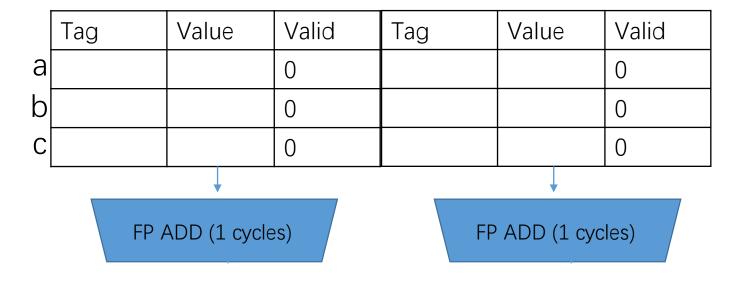
Instruction	Stage
muld f0, f1, f2	
addd f0, f1, f5	
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	



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

	Tag	Value	Valid	Tag	Value	Valid
X			0		_	0
		<u> </u>			<u> </u>	
			FP MU	ILT (4 cyc	cles)	

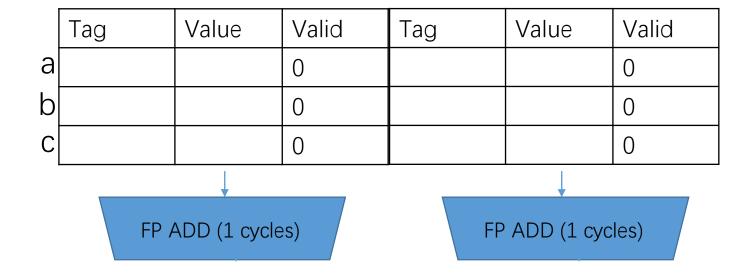
Instruction	Stage
muld f0, f1, f2	F
addd f0, f1, f5	
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	



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

	Tag	Value	Valid	Tag	Value	Valid
Χ	~	0	1	?	1	1
		<u> </u>			<u> </u>	
	FP MULT (4 cycles)					

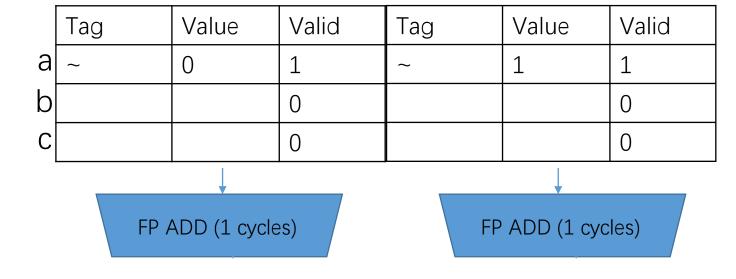
Instruction	Stage
muld f0, f1, f2	D
addd f0, f1, f5	F
addd f2, f3, f3	
addd f2, f4, f4	
addd f4, f5, f5	



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

	Tag	Value	Valid	Tag	Value	Valid
X	~	0	1	~	1	1
		<u> </u>			+	
	FP MULT (4 cycles)					

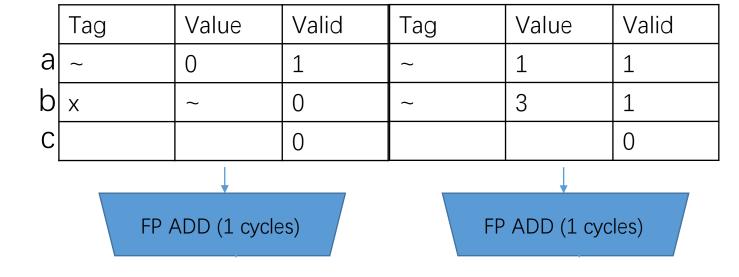
Instruction	Stage
muld f0, f1, f2	E1
addd f0, f1, f5	D
addd f2, f3, f3	F
addd f2, f4, f4	
addd f4, f5, f5	



	Tag	Value	Valid
fO		0	1
f1		1	1
f2	Х	2	0
f0 f1 f2 f3 f4 f5	р	3	0
f4		4	1
f5	а	5	0

	Tag	Value	Valid	Tag	Value	Valid
Χ	~	0	1	?	1	1
		<u> </u>			<u> </u>	
	FP MULT (4 cycles)					

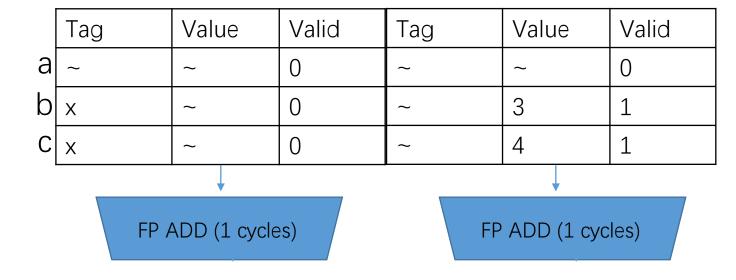
Instruction	Stage
muld f0, f1, f2	E2
addd f0, f1, f5	E1
addd f2, f3, f3	D
addd f2, f4, f4	F
addd f4, f5, f5	



	Tag	Value	Valid
f0 f1		0	1
f1		1	1
f2 f3 f4 f5	X	2	0
f3	р	3	0
f4	С	4	0
f5		1	1

	Tag	Value	Valid	Tag	Value	Valid	
Χ	~	0	1	~	1	1	
		<u> </u>			<u> </u>		
		FP MULT (4 cycles)					

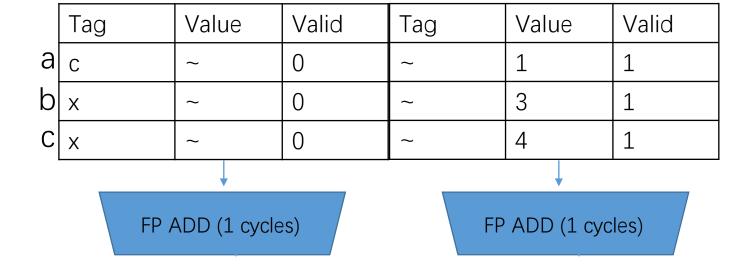
Instruction	Stage
muld f0, f1, f2	E3
addd f0, f1, f5	WB
addd f2, f3, f3	W(for tag)
addd f2, f4, f4	D
addd f4, f5, f5	F



	Tag	Value	Valid
f0 f1		0	1
		1	1
f2 f3 f4 f5	Х	2	0
f3	b	3	0
f4	С	4	0
f5	а	1	0

	Tag	Value	Valid	Tag	Value	Valid	
Χ	~	0	1	~	1	1	
		<u> </u>			<u> </u>		
		FP MULT (4 cycles)					

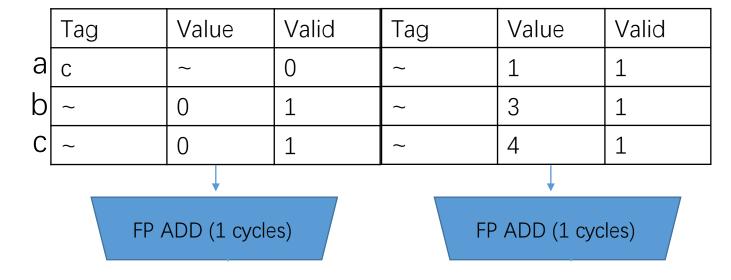
Instruction	Stage
muld f0, f1, f2	E4
addd f0, f1, f5	DONE
addd f2, f3, f3	W(for tag)
addd f2, f4, f4	W(for tag)
addd f4, f5, f5	D



	Tag	Value	Valid
f0 f1		0	1
f1		1	1
f2		0	1
f3 f4 f5	р	3	0
f4	С	4	0
f5	а	1	0

	Tag	Value	Valid	Tag	Value	Valid	
Χ	~	~	0	~	~	0	
•		<u> </u>			<u> </u>		
		FP MULT (4 cycles)					

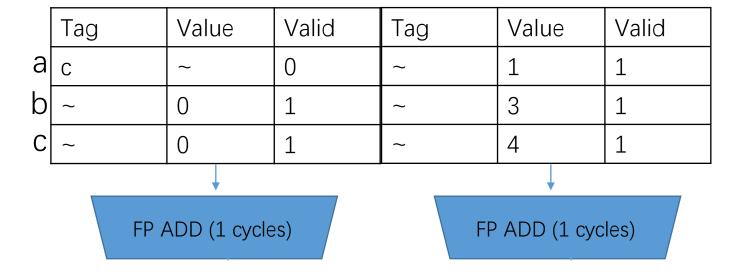
Instruction	Stage
muld f0, f1, f2	WB
addd f0, f1, f5	DONE
addd f2, f3, f3	W(for tag)
addd f2, f4, f4	W(for tag)
addd f4, f5, f5	W(for tag)



	Tag	Value	Valid
f0 f1		0	1
f1		1	1
f2		0	1
f3 f4 f5	р	3	0
f4	С	4	0
f5	а	1	0

	Tag	Value	Valid	Tag	Value	Valid	
X	~	~	0	~	~	0	
		<u> </u>			<u> </u>		
		FP MULT (4 cycles)					

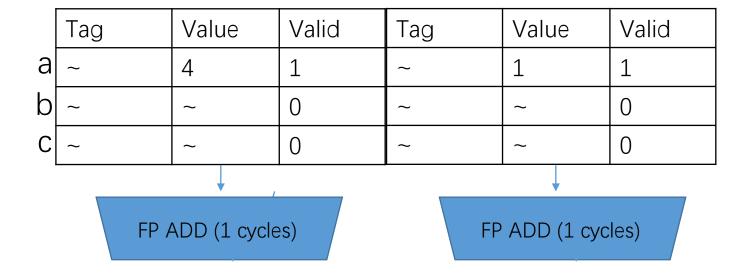
Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	E1
addd f2, f4, f4	E1
addd f4, f5, f5	W(for tag)



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

	Tag	Value	Valid	Tag	Value	Valid	
X	~	~	0	~	~	0	
		<u> </u>			1		
		FP MULT (4 cycles)					

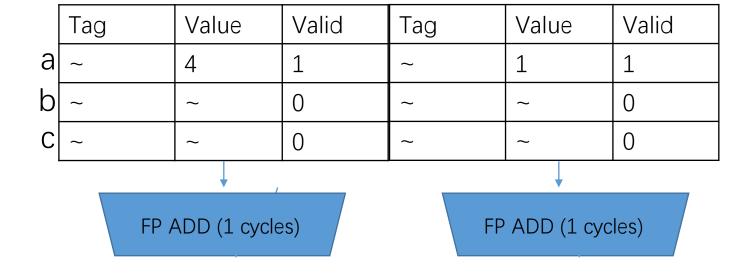
Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	WB
addd f2, f4, f4	WB
addd f4, f5, f5	W(for tag)



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

	Tag	Value	Valid	Tag	Value	Valid	
X	~	~	0	~	~	0	
		<u> </u>			1		
		FP MULT (4 cycles)					

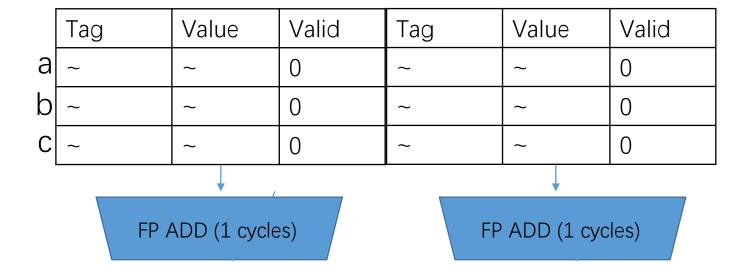
Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	DONE
addd f4, f5, f5	E1



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

	Tag	Value	Valid	Tag	Value	Valid	
X	~	~	0	~	~	0	
		<u> </u>			1		
		FP MULT (4 cycles)					

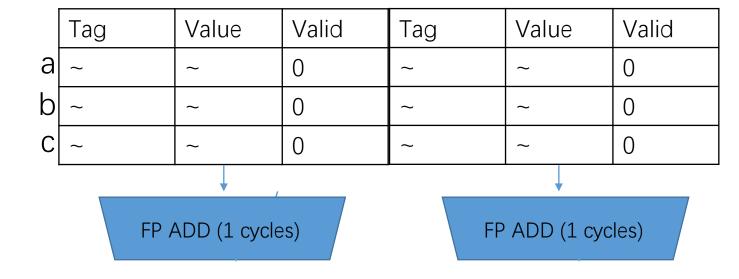
Instruction	Stage
muld f0, f1, f2	DONE
addd f0, f1, f5	DONE
addd f2, f3, f3	DONE
addd f2, f4, f4	DONE
addd f4, f5, f5	WB



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

	Tag	Value	Valid	Tag	Value	Valid			
X	~	~	0	?	?	0			
	FP MULT (4 cycles)								

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



Q2 (a)

 Tag
 Value
 Valid

 f0
 0
 1

 f1
 1
 1

 f2
 2
 1

 f3
 3
 1

	Tag	Value	Valid	Tag	Value	Valid	ROB
Χ			0			0	
У			0			0	

FP MULT (4 cycles)

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

	Tag	Value	Valid	Tag	Value	Valid	ROB
а			0			0	
b			0			0	
•		ı				1	

FP ADD (1 cycle)

	Tag	Value	Valid	Tag	Value	Valid	ROB
а			0			0	
b			0			0	

Cycle	1
CyClC	_

 Tag
 Value
 Valid

 f0
 0
 1

 f1
 1
 1

 f2
 2
 1

 f3
 3
 1

	Tag	Value	Valid	Tag	Value	Valid	ROB
X			0			0	
У			0			0	

FP MULT (4 cycles)

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 rO 0 1 r1 2 1

	Tag	Value	Valid	Tag	Value	Valid	ROB
a			0			0	
b			0			0	
•		I		-	<u>-</u>		

FP ADD (1 cycle)

	Inst	Reg	value
Α			
В			
С			
D			
Е			

	Tag	Value	Valid	Tag	Value	Valid	ROB
a			0			0	
d			0			0	

Cyc	le	2

 Tag
 Value
 Valid

 f0
 0
 1

 f1
 1
 1

 f2
 2
 1

 f3
 3
 1

	Tag	Value	Valid	Tag	Value	Valid	ROB
X			0			0	
У			0			0	

FP MULT (4 cycles)

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 rO 0 1 r1 A 2 0

	Tag	Value	Valid	Tag	Value	Valid	ROB
a			0			0	
b			0			0	
•				-	-	1	-

FP ADD (1 cycle)

	Inst	Reg	value
А	SUBI	r1	
В			
С			
D			
Е			

	Tag	Value	Valid	Tag	Value	Valid	ROB
а	\	2	1	?	1	1	Α
b			0			0	

Tag Value Valid f0 0 f1 0 В f2 f3 3

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

Addd f1, f2, f3

r0

Inst

SUBI

MULD

Tag Valid Value r1 | A 0

value

Reg

r1

В

Ε

Tag	Value	Valid	Tag	Value	Valid	ROB
~	0	1	~	1	1	В
		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	~	1	1	А
		0			0	

 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 r1

Tag Value Valid rO 0 1 r1 A 2 0

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

Tag	Value	Valid	Tag	Value	Valid	ROB
~	0	1	~	1	1	В
		0			0	

FP MULT (4 cycles)

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

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
?	7	0	?	?	0	
		0			0	

 Tag
 Value
 Valid

 f0
 0
 1

 f1
 B
 1
 0

 f2
 C
 2
 0

 f3
 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 r1

Tag Value Valid rO 0 1 1 1

A Reg value
A MULD f1
C ADDD f2
D BNE
E

Tag	Value	Valid	Tag	Value	Valid	ROB
~	0	1	~	1	1	В
		0			0	

FP MULT (4 cycles)

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

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
?	1	1	?	0	1	D
		0			0	

 Tag
 Value
 Valid

 f0
 0
 1

 f1
 B
 1
 0

 f2
 C
 2
 0

 f3
 3
 1

Tag	Value	Valid	Tag	Value	Valid	ROB
}	0	1	}	1	1	В
		0			0	

FP MULT (4 cycles)

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 r1

Tag Value Valid rO 0 1 r1 E 1 0

Tag	Value	Valid	Tag	Value	Valid	ROB
		0			0	
		0			0	

FP ADD (1 cycle)

	Inst	Reg	value
А			
В	MULD	f1	
С	ADDD	f2	2
D	BNE		
Ε	SUBI	r1	

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

	Tag	Value	Valid
fO		0	1
f1	F	1	0
f2 f3	С	2	0
f3		3	1

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

FP MULT (4 cycles)

Loop: subi r1, r1, 1 DONE, E1

Muld f0, f1, f1 E4, D
Addd f0, f2, f2 W(for C), Fr0
Bne r1, r0, Loop WB
Addd f1, f2, f3 r1

Tag Value Valid
FrO 0 1
r1 E 1 0

Tag	Value	Valid	Tag	Value	Valid	ROB
		0	_	_	0	
		0			0	

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
~	1	1	~	1	1	Е

	Inst	Reg	value
Α			
В	MULD	f1	
С	ADDD	f2	2
D	BNE		
Е	SUBI	r1	
F	MULD	f1	
G			

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

TagValueValidTagValueValidROB000~01F

FP MULT (4 cycles)

Loop: subi r1, r1, 1 <mark>DONE, W<u>B</u></mark>

Muld f0, f1, f1 WB, W(for E)
Addd f0, f2, f2 W(for C), Dr0
Bne r1, r0, Loop W(for C), F
Addd f1, f2, f3

TagValueValid01E10

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	

	Inst	Reg	value
Α			
В	MULD	f1	0
С	ADDD	f2	2
D	BNE		
E	SUBI	r1	0
F	MULD	f1	_
G	ADDD	F2	_

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

Tag Value Valid Tag Value Valid ROB F 0 0

FP MULT (4 cycles)

Loop: subi r1, r1, 1 DON	IE, W	<u>(for C), F</u>					
Muld f0, f1, f1 <mark>C, E1</mark>		Tag	V	alue		Valid	1
Addd f0, f2, f2 <mark>W(for C),</mark> Bne r1, r0, Loop <mark>W(for C</mark>			0			1	
Addd f1, f2, f3	r1	E	1			0	
	Inst			Reg	V	alue	

Α

В

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
Е	0	1	~	0	1	Н
		0			0	

f2 ADDD BNE SUBI r1 f1 MULD ADDD F2 BNE

Cycle 10	Cycl	е	1	0
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	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), D

Muld f0, f1, f1 DONE, E2, F Addd f0, f2, f2 C, WB Bne r1, r0, Loop W(for C), E

Addd f1, f2, f3

_, vv	(101 C), D		
F	Tag	Value	Valid
rQ		0	1
r1	E	1	0

	Inst	Reg	value
Α			
В			
С			
D	BNE		
Ε	SUBI	r1	0
F	MULD	f1	
G	ADDD	f2	2
Н	BNE		
1	SUBI	r1	
J			

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	Н
E	0	1	~	0	1	I

Cycle 1	.1
---------	----

	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), E1

Muld f0, f1, f1 DONE, E3, Addd f0, f2, f2 DONE, W(C) Bne r1, r0, Loop C, WB r1 Addd f1, f2, f3

٠, ۱	Tag	Value	Valid
r0		0	1
r1	E	1	0

	Inst	Reg	value
Α			
В			
С			
D			
Ε	SUBI	r1	0
F G	MULD	f1	
G	ADDD	f2	2
Н	BNE		
	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

T												
Cycle 12	Tag	Valu	ie	Valid		Tag	Value	Valid	Tag	Value	Valid	ROB
fC) [0		1				0			0	
f1	- F	1		0		~	0	1	~	0	1	F
f2	2 G	2		0			¥				V	
f3	3	3		1				FP I	MULT (4	4 cycles	s)	
Loop: subi r1, r1, 1 DON	IE, W(f	or C).				Tag	Value	Valid	Tag	Value	Valid	ROB
Muld f0, f1, f1 DONE, E3	3,	Tag	Value	V	alid	l ag	value		rag	value		1.00
Addd f0, f2, f2 <mark>DONE, W</mark> Bne r1, r0, Loop <mark>DONE</mark> ,	/(ር)		0	1		1		0			0	
		_		-				0			0	
Addd f1, f2, f3	r1	E	1	0			+				\	
	Inst		Reg	value				FP A	DD (1 c	cycle)		
А												
В						Tag	Value	Valid	Tag	Value	Valid	ROB
C								0			0	
D					\neg			0			0	
E	Subi		R1	0			+				+	
F	MULE)	f1					INT	ALU (1	cycle)		
G	ADD)	f2	2					,			
Н	BNE											
J												

Cyc	le	13

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

Tag	Value	Valid	Tag	Value	Valid	ROB
		0			0	
~	0	1	7	0	1	F

Tag	Value	Valid	Tag	Value	Valid	ROB
		0			0	
		0			0	

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
(C) 0 1
r1 0 1

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
		0			0	
		0			0	

	Inst	Reg	value
Α			
В			
B C			
D			
Ε			
F G	MULD	f1	
G	ADDD	f2	2
Н	BNE		
1			
J			

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

Tag ROB Valid Tag Value Valid Value 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)

Loop: subi r1, r1, 1 DONE, D<u>ONE,</u>

Muld f0, f1, f1 DONE, WB Addd f0, f2, f2 DONE, W(Bne r1, r0, Loop DONE,

Addd f1, f2, f3 D

В,	Tag	Value	Valid
(G)0	\	0	1
r1	,	0	1

	Inst	Reg	value
Α			
В			
С			
D			
Ε			
F	MULD	f1	0
G	ADDD	f2	2
Н	BNE		
	ADDD	F3	
J			

Cycle 1	5
---------	---

 Tag
 Value
 Valid

 f0
 0
 1

 f1
 0
 1

 f2
 G
 2
 0

 f3
 I
 3
 0

Loop: subi r1, r1, 1 DONE, D<u>ONE,</u>

Muld f0, f1, f1 DONE, C, Addd f0, f2, f2 DONE, W(C) Bne r1, r0, Loop DONE, W(

<u>Addd</u> f1, f2, f3 **E1**

C,	Tag	Value	Valid
W(G)O	`	0	1
r1	,	0	1
,			

	Inst	Reg	value
Α			
В			
B C			
D			
Ε			
F			
G	ADDD	f2	2
Н	BNE		
1	ADDD	f3	
J			

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	1
		0			0	

FP ADD (1 cycle)

Tag	Value	Valid	Tag	Value	Valid	ROB
		0			0	
		0			0	

Cycle 1	L6
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	Tag	Value	Valid
f0		0	1
f1		0	1
f2		2	1
f3	1	3	0

Tag	Value	Valid	Tag	Value	Valid	ROB
		0			0	
		0			0	

Loop: subi r1, r1, 1 DONE, D(ONE,		
Muld f0, f1, f1 DONE, DONE,		Value	Valid
Addd f0, f2, f2 DONE, C r0 Bne r1, r0, Loop DONE, W(C	\	0	1
Addd f1, f2, f3 WB r1	,	0	1

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	

	Inst	Reg	value
Α			
В			
B C			
D			
E			
F			
E F G			
Н	BNE		
1	ADDD	f3	2
J			

Cycle 16		Ta	g	Va	lue	Va	lid	
2, 2.2 20	f0			0		1		
	f1			0		1		
	f2			2		1		
	f3	ı		3		0		
Loop: subi r1, r1, 1 D	ONE	, D0	ONE,					
Muld f0, f1, f1 DONE	, DO	NE,	Tag		Value		Va	lid
Addd f0, f2, f2 DONE Bne r1, r0, Loop DON					0		1	
Addd f1, f2, f3 W(C)	VE, C	r1			0		1	
	Г						- 1	\neg

				_
	Inst	Reg	value	
Α				
В				
B C D				
D				
Е				
E F G				
G H				
	ADDD	f3	2	
J				

Tag	Value	Valid	Tag	Value	Valid	ROB
		0			0	
		0			0	

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	

Сус	le	1	7
_			

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

Tag	Value	Valid	Tag	Value	Valid	ROB
		0			0	
		0			0	

Loop: subi r1, r1, 1 DONE, D(
Muld f0, f1, f1 DONE, DONE,	Tag	Value	Valid
Addd f0, f2, f2 DONE, DONE Bne r1, r0, Loop DONE, DON	IE	0	1
Addd f1, f2, f3 C r1	₹L	0	1

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	_

	Inst	Reg	value
Α			
В			
A B C			
D			
F			
F			
E F G H			
H			
1			
J			

f0												
Tag Value Valid Tag Value Valid	ROB	Valid [Value	Tag	Valid	Value	Tag	id	e Valid	Value	Tag	Cycle 18
f2		0			0				1	0		f0
Tag Value Valid Tag Value Valid FP MULT (4 cycles)		0			0				1	0		f1
Tag Value Valid Tag Value Valid FP ADD (1 cycle)		V						\neg	1	2		f2
Muld f0, f1, f1 DONE, DONE, Addd f0, f2, f2 DONE, DONE, Bne r1, r0, Loop DONE, DONE		5)	4 cycles	MULT (4	FP I					_		f3
Muld f0, f1, f1 DONE, DONE, Addd f0, f2, f2 DONE, DONE, Bne r1, r0, Loop DONE, DONE r1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	ROB	Valid	Value	Tag	Valid	Value	Tag				, DONE,	oop: subi r1, r1, 1 DONE
Addd f1, f2, f3 DONE								Valid	alue V	V	NE, Tag	Muld f0, f1, f1 DONE, DO
Addd f1, f2, f3 DONE		0			0			1	1	0	/ING DONE	Raga TU, TZ, TZ DONE, DC Rne r1 r0 Loop DONE [
A B Tag Value Valid Tag Value Valid F O O O O		+				+		1	1	0		
B Tag Value Valid Tag Value Valid F O 0 0			cycle)	DD (1 c	FP A			lue	Reg valu		Inst	
												А
C 0 0	ROB	Valid	Value	Tag	Valid	Value	Tag					вГ
		0			0							c [
		0			0							D
		+				+						- F
F INT ALU (1 cycle)			cycle)	ALU (1	INT							
G												. –
H												H
												ı
J												j

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)