
COSC4201

Scoreboard

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Based on Slides by

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Overcoming Data Hazards with Dynamic Scheduling

- In the pipeline, if there is data dependency between an instruction already in the pipe and a fetched instruction that can not be hidden by forwarding, the pipeline stalls.
- That is known as static scheduling.
- In *dynamic scheduling* the hardware rearranges the instructions to reduce stalls. It simplifies the compiler and deals with dependences that were not known during the compilation.
- In dynamic scheduling, processor can not remove true data dependence, it tries to avoid stalls.

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Dynamic Scheduling

DIVD F0, F2, F4
ADDD F10, F0, F8
SUBD F12, F8, F14

- ADDD depends on DIVD, can not proceed, SUBD will be stalled also although it doesn't depend on any other instruction.
- The reason is structural and data hazards are checked in the ID stage, once we detected that ADDD depends on DIVD, the pipeline is stalled and no instructions will be fetched
- To proceed with SUBD, we must separate the issue process into 2 parts, checking the structural hazard, and waiting for the absence of data hazards
- We will check for structural hazard when we issue; thus we still use *in-order issue*. However we want the instructions to begin execution as soon as their data operands are ready *out-of-order execution*

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Dynamic Scheduling

- That of course creates out-of-order completion, which creates problems with exception handling, for the time being, we assume imprecise exception.
- We split the ID stage into two parts
 - *Issue* Decode and check structural hazards
 - *Read operands* Wait until no data hazard and read operands
- An instruction fetch stage proceeds the ID stage and may fetch in a single-entry latch, or a queue
- After that the EX stage

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Dynamic Scheduling with scoreboard

- All instructions pass through the *issue* stage in order.
- Scoreboard was first used in CDC 6600
- Have to check for WAW and RAW hazards
- Assume we have one integer unit, two multipliers, one adder, and one divide unit.
- Scoreboard keep information about every instruction from fetch to execute
- The scoreboard controls when an instruction can read operands, start execution and when it can write its result.

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Dynamic Scheduling with scoreboard

- There is no forwarding.
- Notice that there is no specific stage for write back, which means the operands can be written back in the cycle after completion.
- One cycle delay, but the overall performance is better

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Dynamic Scheduling with scoreboard

- Ignoring memory, 4 stages (NO forwarding)
- **Issue** If a FU is free, and no other active instruction has the same destination register (**WAW**), the instruction is issued. Otherwise, the instruction issue stalls, and no other instructions can be fetched (replaces a portion of ID stage in MIPS).
- **Read Operands** the scoreboard monitors the availability of the source operands, if available (no active instruction will write to the source registers, the instruction can read operands and execute (probably out-of-order) (**RAW**))

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Dynamic Scheduling with scoreboard

- **Execution** FU starts execution, after completion it notifies the scoreboard
- **Write Result** Scoreboard checks for WAR hazards, and stalls if necessary

DIV	F0,F2,F4
ADD	F10,F0,F8
SUB	F8,F8,F14
- Scoreboard stalls SUB until ADD reads its operand (note that because DIV will take a long time, ADD stalls).

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Scoreboard

- 1. Instruction status** Indicates which of the 4 steps the instruction is in
- 2. Functional Unit Status** Indicates the state of the FU, there are nine fields
 - Busy** busy or not
 - OP** operation to be performed in the unit
 - F_i** Destination register
 - F_j, F_k** source register number
 - Q_j, Q_k** FU producing source registers F_j, and F_k
 - R_j, R_k** Flags to indicates if F_j, and F_k are ready or not
- 3. Register Result Status** Indicates which FU will write to each register

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Instruction		Instruction status			
		Issue	Read operands	Execution complete	Write result
LD	F6, 34 (R2)	✓	✓	✓	✓
LD	F2, 45 (R3)	✓	✓	✓	
MULTD	F0, F2, F4	✓			
SUBD	F8, F6, F2	✓			
DIVD	F10, F0, F6	✓			
ADDD	F6, F8, F2				

Functional unit status									
Name	Busy	Op	F _i	F _j	F _k	Q _j	Q _k	R _j	R _k
Integer	Yes	Load	F2	R3				No	
Mult1	Yes	Mult	F0	F2	F4	Integer		No	Yes
Mult2	No								
Add	Yes	Sub	F8	F6	F2		Integer	Yes	No
Divide	Yes	Div	F10	F0	F6	Mult1		No	Yes

Register result status									
	F0	F2	F4	F6	F8	F10	F12	...	F30
FU	Mult1	Integer			Sub	Divide			

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Dynamic Scheduling with Scoreboard

- ° Consider the following example
- ° LD F6,34(R2)
- ° LD F2,45(R3)
- ° MULTD F0,F2,F4
- ° SUBD F8,F6,F2
- ° DIVD F10,F0,F6
- ° ADDD F6,F8,F2
- ° Add is 2 cycles, MULT is 10 and divide is 40

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Scoreboard Example Cycle 1

<u>Instruction status</u>				Read	Executic	Write				
Instruction	<i>j</i>	<i>k</i>		Issue	operand complete	Result				
LD F6 34+ R2				1						
LD F2 45+ R3										
MULT F0 F2 F4										
SUBD F8 F6 F2										
DIVD F10 F0 F6										
ADDD F6 F8 F2										
<u>Functional unit status</u>				<i>dest</i>	<i>S1</i>	<i>S2</i>	<i>FU for j</i>	<i>FU for k</i>	<i>Fj?</i>	<i>Fk?</i>
<i>Time</i>	<i>Name</i>	<i>Busy</i>	<i>Op</i>	<i>Fi</i>	<i>Fj</i>	<i>Fk</i>	<i>Qj</i>	<i>Qk</i>	<i>Rj</i>	<i>Rk</i>
	Integer	Yes	Load	F6		R2				Yes
	Mult1	No								
	Mult2	No								
	Add	No								
	Divide	No								
<u>Register result status</u>										
Clock		<i>F0</i>	<i>F2</i>	<i>F4</i>	<i>F6</i>	<i>F8</i>	<i>F10</i>	<i>F12</i>	<i>...</i>	<i>F30</i>
1	<i>FU</i>	Integer								

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Scoreboard Example Cycle 2

<u>Instruction status</u>				<u>Read</u>		<u>Execute</u>		<u>Write</u>	
Instruction	j	k		Issue	operand complete	Result			
LD F6 34+ R2				1	2				
LD F2 45+ R3									
MULT F0 F2 F4									
SUBD F8 F6 F2									
DIVD F10 F0 F6									
ADDD F6 F8 F2									

<u>Functional unit status</u>			dest	S1	S2	FU for j	FU for k	Fj?	Fk?	
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk
	Integer	Yes	Load	F6		R2				Yes
	Mult1	No								
	Mult2	No								
	Add	No								
	Divide	No								

<u>Register result status</u>		F0	F2	F4	F6	F8	F10	F12	...	F30
Clock	2	FU Integer								

- Issue 2nd LD?

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Scoreboard Example Cycle 3

<u>Instruction status</u>				<u>Read</u>		<u>Executing</u>		<u>Write</u>	
Instruction	j	k		Issue	operand complete	Result			
LD F6 34+ R2				1	2	3			
LD F2 45+ R3									
MULT F0 F2 F4									
SUBD F8 F6 F2									
DIVD F10 F0 F6									
ADDD F6 F8 F2									

<u>Functional unit status</u>			dest	S1	S2	FU for j	FU for k	Fj?	Fk?	
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk
	Integer	Yes	Load	F6		R2				Yes
	Mult1	No								
	Mult2	No								
	Add	No								
	Divide	No								

<u>Register result status</u>		F0	F2	F4	F6	F8	F10	F12	...	F30
Clock	3	FU Integer								

- Issue MULT?

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Scoreboard Example Cycle 4

Instruction status				Read Executic Write			
Instruction	j	k		Issue	operand complet	Result	
LD F6 34+ R2				1	2	3	4
LD F2 45+ R3							
MULT F0 F2 F4							
SUBD F8 F6 F2							
DIVD F10 F0 F6							
ADDD F6 F8 F2							

Functional unit status				dest S1 S2 FU for j FU for k Fj? Fk?			
Time	Name	Busy	Op	Fi	Fj	Fk	Rk
	Integer	Yes	Load	F6		R2	Yes
	Mult1	No					
	Mult2	No					
	Add	No					
	Divide	No					

Register result status													
Clock				F0	F2	F4	F6	F8	F10	F12	...	F30	
4		FU		Integer									

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Scoreboard Example Cycle 5

Instruction status				Read Executic Write			
Instruction	j	k		Issue	operand complet	Result	
LD F6 34+ R2				1	2	3	4
LD F2 45+ R3				5			
MULT F0 F2 F4							
SUBD F8 F6 F2							
DIVD F10 F0 F6							
ADDD F6 F8 F2							

Functional unit status				dest S1 S2 FU for j FU for k Fj? Fk?			
Time	Name	Busy	Op	Fi	Fj	Fk	Rk
	Integer	Yes	Load	F2		R3	Yes
	Mult1	No					
	Mult2	No					
	Add	No					
	Divide	No					

Register result status													
Clock				F0	F2	F4	F6	F8	F10	F12	...	F30	
5		FU		Integer									

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Scoreboard Example Cycle 6

Instruction status				Read Executic Write			
Instruction	j	k		Issue	operand complet	Result	
LD F6 34+ R2				1	2	3	4
LD F2 45+ R3				5	6		
MULT F0 F2 F4				6			
SUBD F8 F6 F2							
DIVD F10 F0 F6							
ADDD F6 F8 F2							

Functional unit status				dest	S1	S2	FU for j	FU for k	Fj?	Fk?
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk
	Integer	Yes	Load	F2		R3				Yes
	Mult1	Yes	Mult	F0	F2	F4	Integer		No	Yes
	Mult2	No								
	Add	No								
	Divide	No								

Register result status		F0	F2	F4	F6	F8	F10	F12	...	F30
Clock	6	FU Mult1 Integer								

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Scoreboard Example Cycle 7

Instruction status				Read Executic Write			
Instruction	j	k		Issue	operand complet	Result	
LD F6 34+ R2				1	2	3	4
LD F2 45+ R3				5	6	7	
MULT F0 F2 F4				6			
SUBD F8 F6 F2				7			
DIVD F10 F0 F6							
ADDD F6 F8 F2							

Functional unit status				dest	S1	S2	FU for j	FU for k	Fj?	Fk?
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk
	Integer	Yes	Load	F2		R3				Yes
	Mult1	Yes	Mult	F0	F2	F4	Integer		No	Yes
	Mult2	No								
	Add	Yes	Sub	F8	F6	F2		Integer	Yes	No
	Divide	No								

Register result status		F0	F2	F4	F6	F8	F10	F12	...	F30
Clock	7	FU Mult1 Integer Add								

- Read multiply operands?

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Scoreboard Example Cycle 8a

Instruction status				Read Executic Write			
Instruction	j	k		Issue	operand complet	Result	
LD F6 34+ R2				1	2	3	4
LD F2 45+ R3				5	6	7	
MULT F0 F2 F4				6			
SUBD F8 F6 F2				7			
DIVD F10 F0 F6				8			
ADDD F6 F8 F2							

Functional unit status				dest	S1	S2	FU for j	FU for k	Fj?	Fk?
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk
	Integer	Yes	Load	F2		R3				Yes
	Mult1	Yes	Mult	F0	F2	F4	Integer		No	Yes
	Mult2	No								
	Add	Yes	Sub	F8	F6	F2		Integer	Yes	No
	Divide	Yes	Div	F10	F0	F6	Mult1		No	Yes

Register result status				F0	F2	F4	F6	F8	F10	F12	...	F30
Clock	8	FU		Mult1	Integer			Add	Divide			

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Scoreboard Example Cycle 8b

Instruction status				Read Executic Write			
Instruction	j	k		Issue	operand complet	Result	
LD F6 34+ R2				1	2	3	4
LD F2 45+ R3				5	6	7	8
MULT F0 F2 F4				6			
SUBD F8 F6 F2				7			
DIVD F10 F0 F6				8			
ADDD F6 F8 F2							

Functional unit status				dest	S1	S2	FU for j	FU for k	Fj?	Fk?
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk
	Integer	No								
	Mult1	Yes	Mult	F0	F2	F4			Yes	Yes
	Mult2	No								
	Add	Yes	Sub	F8	F6	F2			Yes	Yes
	Divide	Yes	Div	F10	F0	F6	Mult1		No	Yes

Register result status				F0	F2	F4	F6	F8	F10	F12	...	F30
Clock	8	FU		Mult1				Add	Divide			

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Scoreboard Example Cycle 9

<u>Instruction status</u>			Read		Executic		Write	
Instruction	j	k	Issue	operand	complet	Result		
LD	F6	34+	R2	1	2	3	4	
LD	F2	45+	R3	5	6	7	8	
MULT	F0	F2	F4	6	9			
SUBD	F8	F6	F2	7	9			
DIVD	F10	F0	F6	8				
ADDD	F6	F8	F2					

<u>Functional unit status</u>				dest	S1	S2	FU for j	FU for k	Fj?	Fk?
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk
	Integer	No								
10	Mult1	Yes	Mult	F0	F2	F4			Yes	Yes
	Mult2	No								
2	Add	Yes	Sub	F8	F6	F2			Yes	Yes
	Divide	Yes	Div	F10	F0	F6	Mult1		No	Yes

<u>Register result status</u>		F0	F2	F4	F6	F8	F10	F12	...	F30
Clock										
9	FU	Mult1			Add	Divide				

- Read operands for MULT & SUBD? Issue ADDD?

Scoreboard Example Cycle 11

<u>Instruction status</u>				Read Executic Write			
Instruction	j	k		Issue	operand complet	Result	
LD	F6	34+	R2	1	2	3	4
LD	F2	45+	R3	5	6	7	8
MULT	F0	F2	F4	6	9		
SUBD	F8	F6	F2	7	9	11	
DIVD	F10	F0	F6	8			
ADDD	F6	F8	F2				

<u>Functional unit status</u>				dest	S1	S2	FU for j	FU for k	Fj?	Fk?
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk
	Integer	No								
8	Mult1	Yes	Mult	F0	F2	F4			Yes	Yes
	Mult2	No								
0	Add	Yes	Sub	F8	F6	F2			Yes	Yes
	Divide	Yes	Div	F10	F0	F6	Mult1		No	Yes

<u>Register result status</u>		F0	F2	F4	F6	F8	F10	F12	...	F30
Clock										
11	FU	Mult1			Add	Divide				

Scoreboard Example Cycle 12

Instruction status				Read Executic Write			
Instruction	j	k		Issue	operand complet	Result	
LD F6 34+ R2				1	2	3	4
LD F2 45+ R3				5	6	7	8
MULT F0 F2 F4				6	9		
SUBD F8 F6 F2				7	9	11	12
DIVD F10 F0 F6				8			
ADDD F6 F8 F2							

Functional unit status		dest	S1	S2	FU for j	FU for k	Fj?	Fk?
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk
	Integer	No						
7	Mult1	Yes	Mult	F0	F2	F4		
	Mult2	No						
	Add	No						
	Divide	Yes	Div	F10	F0	F6	Mult1	No

Register result status		F0	F2	F4	F6	F8	F10	F12	...	F30
Clock										
12	FU	Mult1								Divide

- Read operands for DIVD?

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Scoreboard Example Cycle 13

Instruction status				Read Executic Write			
Instruction	j	k		Issue	operand complet	Result	
LD F6 34+ R2				1	2	3	4
LD F2 45+ R3				5	6	7	8
MULT F0 F2 F4				6	9		
SUBD F8 F6 F2				7	9	11	12
DIVD F10 F0 F6				8			
ADDD F6 F8 F2				13			

Functional unit status		dest	S1	S2	FU for j	FU for k	Fj?	Fk?
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk
	Integer	No						
6	Mult1	Yes	Mult	F0	F2	F4		
	Mult2	No						
	Add	Yes	Add	F6	F8	F2		
	Divide	Yes	Div	F10	F0	F6	Mult1	No

Register result status		F0	F2	F4	F6	F8	F10	F12	...	F30
Clock										
13	FU	Mult1				Add	Divide			

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Scoreboard Example Cycle 14

<u>Instruction status</u>			Read	Executic	Write						
Instruction	j	k	Issue	operand	complete	Result					
LD	F6	34+	R2	1	2	3	4				
LD	F2	45+	R3	5	6	7	8				
MULT	F0	F2	F4	6	9						
SUBD	F8	F6	F2	7	9	11	12				
DIVD	F10	F0	F6	8							
ADDD	F6	F8	F2	13	14						

<u>Functional unit status</u>			dest	S1	S2	FU for j	FU for k	Fj?	Fk?	
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk
	Integer	No								
5	Mult1	Yes	Mult	F0	F2	F4			Yes	Yes
	Mult2	No								
2	Add	Yes	Add	F6	F8	F2			Yes	Yes
	Divide	Yes	Div	F10	F0	F6	Mult1		No	Yes

<u>Register result status</u>			F0	F2	F4	F6	F8	F10	F12	...	F30
Clock											
14	FU		Mult1			Add		Divide			

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Scoreboard Example Cycle 15

Instruction status				Read		Executic		Write	
Instruction	j	k		Issue	operand	complete	Result		
LD	F6	34+	R2	1	2	3	4		
LD	F2	45+	R3	5	6	7	8		
MULT	F0	F2	F4	6	9				
SUBD	F8	F6	F2	7	9	11	12		
DIVD	F10	F0	F6	8					
ADDD	F6	F8	F2	13	14				

Functional unit status			dest	S1	S2	FU for j	FU for k	Fj?	Fk?	
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk
	Integer	No								
4	Mult1	Yes	Mult	F0	F2	F4			Yes	Yes
	Mult2	No								
1	Add	Yes	Add	F6	F8	F2			Yes	Yes
	Divide	Yes	Div	F10	F0	F6	Mult1		No	Yes

Register result status			F0	F2	F4	F6	F8	F10	F12	...	F30
Clock											
15	FU		Mult1			Add		Divide			

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Scoreboard Example Cycle 16

Instruction status				Read Executic Write			
Instruction	j	k		Issue	operand complet	Result	
LD F6 34+ R2				1	2	3	4
LD F2 45+ R3				5	6	7	8
MULT F0 F2 F4				6	9		
SUBD F8 F6 F2				7	9	11	12
DIVD F10 F0 F6				8			
ADDD F6 F8 F2				13	14	16	

Functional unit status			dest	S1	S2	FU for j	FU for k	Fj?	Fk?	
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk
	Integer	No								
3	Mult1	Yes	Mult	F0	F2	F4			Yes	Yes
	Mult2	No								
0	Add	Yes	Add	F6	F8	F2			Yes	Yes
	Divide	Yes	Div	F10	F0	F6	Mult1		No	Yes

Register result status			F0	F2	F4	F6	F8	F10	F12	...	F30
Clock											
16	FU		Mult1			Add		Divide			

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Scoreboard Example Cycle 17

Instruction status				Read		Executic		Write	
Instruction	j	k		Issue	operand complet	Result			
LD F6 34+ R2				1	2	3	4		
LD F2 45+ R3				5	6	7	8		
MULT F0 F2 F4				6	9				
SUBD F8 F6 F2				7	9	11	12		
DIVD F10 F0 F6				8					
ADDD F6 F8 F2				13	14	16			

Functional unit status			dest	S1	S2	FU for j	FU for k	Fj?	Fk?	
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk
	Integer	No								
2	Mult1	Yes	Mult	F0	F2	F4			Yes	Yes
	Mult2	No								
	Add	Yes	Add	F6	F8	F2			Yes	Yes
	Divide	Yes	Div	F10	F0	F6	Mult1		No	Yes

Register result status			F0	F2	F4	F6	F8	F10	F12	...	F30
Clock											
17	FU		Mult1			Add		Divide			

- Write result of ADDD (DIV did not read F6)?

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Scoreboard Example Cycle 18

<u>Instruction status</u>			Read		Executic		Write	
Instruction	j	k	Issue	operand	complete	Result		
LD	F6	34+	R2	1	2	3	4	
LD	F2	45+	R3	5	6	7	8	
MULT	F0	F2	F4	6	9			
SUBD	F8	F6	F2	7	9	11	12	
DIVD	F10	F0	F6	8				
ADDD	F6	F8	F2	13	14	16		

<u>Functional unit status</u>			dest		S1	S2	FU for j		FU for k		Fj?	Fk?
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk		
	Integer	No										
1	Mult1	Yes	Mult	F0	F2	F4					Yes	Yes
	Mult2	No										
	Add	Yes	Add	F6	F8	F2					Yes	Yes
	Divide	Yes	Div	F10	F0	F6	Mult1				No	Yes

<u>Register result status</u>												
Clock			F0	F2	F4	F6	F8	F10	F12	...	F30	
18		FU	Mult1			Add		Divide				

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Scoreboard Example Cycle 19

Instruction status				Read		Executic		Write	
Instruction	j	k		Issue	operand	completi	Result		
LD	F6	34+	R2	1	2	3	4		
LD	F2	45+	R3	5	6	7	8		
MULT	F0	F2	F4	6	9	19			
SUBD	F8	F6	F2	7	9	11	12		
DIVD	F10	F0	F6	8					
ADDD	F6	F8	F2	13	14	16			

Functional unit status				dest		S1	S2	FU for j	FU for k	Fj?	Fk?
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk	
	Integer	No									
0	Mult1	Yes	Mult	F0	F2	F4				Yes	Yes
	Mult2	No									
	Add	Yes	Add	F6	F8	F2				Yes	Yes
	Divide	Yes	Div	F10	F0	F6	Mult1			No	Yes

Register result status												
Clock				F0	F2	F4	F6	F8	F10	F12	...	F30
19		FU		Mult1			Add		Divide			

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Scoreboard Example Cycle 20

Instruction status				Read		Executic		Write
Instruction	j	k		Issue	operand complete	Result		
LD	F6	34+	R2	1	2	3	4	
LD	F2	45+	R3	5	6	7	8	
MULT	F0	F2	F4	6	9	19	20	
SUBD	F8	F6	F2	7	9	11	12	
DIVD	F10	F0	F6	8				
ADDD	F6	F8	F2	13	14	16		

Functional unit status		dest		S1	S2	FU for j		FU for k		Fj?	Fk?
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk	
	Integer	No									
	Mult1	No									
	Mult2	No									
	Add	Yes	Add	F6	F8	F2				Yes	Yes
	Divide	Yes	Div	F10	F0	F6				Yes	Yes

Register result status		F0	F2	F4	F6	F8	F10	F12	...	F30
Clock										
20	FU				Add		Divide			

31

Scoreboard Example Cycle 21

Instruction status				Read		Executic		Write
Instruction	j	k		Issue	operand complete	Result		
LD	F6	34+	R2	1	2	3	4	
LD	F2	45+	R3	5	6	7	8	
MULT	F0	F2	F4	6	9	19	20	
SUBD	F8	F6	F2	7	9	11	12	
DIVD	F10	F0	F6	8	21			
ADDD	F6	F8	F2	13	14	16		

Functional unit status		dest		S1	S2	FU for j		FU for k		Fj?	Fk?
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk	
	Integer	No									
	Mult1	No									
	Mult2	No									
	Add	Yes	Add	F6	F8	F2				Yes	Yes
	Divide	Yes	Div	F10	F0	F6				Yes	Yes

Register result status		F0	F2	F4	F6	F8	F10	F12	...	F30
Clock										
21	FU				Add		Divide			

32

Scoreboard Example Cycle 22

Instruction status				Read Executic Write			
Instruction	j	k		Issue	operand complete	Result	
LD	F6	34+	R2	1	2	3	4
LD	F2	45+	R3	5	6	7	8
MULT	F0	F2	F4	6	9	19	20
SUBD	F8	F6	F2	7	9	11	12
DIVD	F10	F0	F6	8	21		
ADDD	F6	F8	F2	13	14	16	22

Functional unit status		dest		S1	S2	FU for j		FU for k		Fj?	Fk?
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk	
	Integer	No									
	Mult1	No									
	Mult2	No									
	Add	No									
40	Divide	Yes	Div	F10	F0	F6				Yes	Yes

Register result status		F0	F2	F4	F6	F8	F10	F12	...	F30
Clock										
22	FU						Divide			

33

Scoreboard Example Cycle 61

Instruction status				Read Executic Write			
Instruction	j	k		Issue	operand complete	Result	
LD	F6	34+	R2	1	2	3	4
LD	F2	45+	R3	5	6	7	8
MULT	F0	F2	F4	6	9	19	20
SUBD	F8	F6	F2	7	9	11	12
DIVD	F10	F0	F6	8	21	61	
ADDD	F6	F8	F2	13	14	16	22

Functional unit status		dest		S1	S2	FU for j		FU for k		Fj?	Fk?
Time	Name	Busy	Op	Fi	Fj	Fk	Qj	Qk	Rj	Rk	
	Integer	No									
	Mult1	No									
	Mult2	No									
	Add	No									
0	Divide	Yes	Div	F10	F0	F6				Yes	Yes

Register result status		F0	F2	F4	F6	F8	F10	F12	...	F30
Clock										
61	FU						Divide			

34

Scoreboard Example Cycle 62

Instruction status				Read Executic Write			
Instruction	j	k		Issue	operand complet	Result	
LD F6 34+ R2				1	2	3	4
LD F2 45+ R3				5	6	7	8
MULT F0 F2 F4				6	9	19	20
SUBD F8 F6 F2				7	9	11	12
DIVD F10 F0 F6				8	21	61	62
ADDD F6 F8 F2				13	14	16	22

Functional unit status									
Time	Name	Busy	Op	dest	S1	S2	FU for j	FU for k	Fj?
	Integer	No		Fi	Fj	Fk	Qj	Qk	Rj
	Mult1	No							Rk
	Mult2	No							
	Add	No							
	0 Divide	No							

Register result status											
Clock	FU	F0	F2	F4	F6	F8	F10	F12	...	F30	
62											