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CSEN 702: Microprocessors Winter 2024

Practice assignment 7

Consider the following code:

MUL R3, R1, R2
ADD R5, R3, R4
ADD R7, R2, R6
ADD R10, R8, R9
MUL R11, R7, R10
ADD R5, R5, R11

Assume multiplication takes 6 cycles and addition takes 4 cycles, to execute. Both units are pipelined.

- a) Consider the regular pipeline with forwarding. Compute the number of cycles needed to execute this code. Show the steps by filling the table.
- b) Re-execute this code using Tomasulo using 3 add reservation stations and 2 multiply reservation stations (Assume tomasulo is used for integer instructions) and compute the number of cycles needed. (Show all the steps and consider R1, R2, R4, R6, R8, R9 are available initially)

Also, if two instructions finish in the same cycle, discuss your opinion on who publishes on CDB first.

Solution

A)

	1	2	3	4	5	6	7	8	9	10	1	1	1	14	15	16	1	1 8	1 9	2	2	22	2	2	2 5	26
MUL											-		•				_	•	9	U	-		3	4	5	
ADD																										
ADD																										
ADD																										
MUL																										
ADD																										

TOTAL=

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	Issue	Execute	Write result
MUL R3, R1, R2			
ADD R5, R3, R4			
ADD R7, R2, R6			
ADD R10, R8, R9			
MUL R11, R7, R10			
ADD R5, R5, R11			

	op	Vj	Vk	Qj	Qk	busy
A1						
A2						
A3						

	op	Vj	Vk	Qj	Qk	busy
M1						
M2						

	Qi	Reg value	NOTES
R1			
R2			
R3			
R4			
R5			
R6			
R7			
R8			
R9			
R10			
R11			

	Issue	Execute	Write result
MUL R3, R1, R2			
ADD R5, R3, R4			
ADD R7, R2, R6			
ADD R10, R8, R9			
MUL R11, R7, R10			
ADD R5, R5, R11			

	op	Vj	Vk	Qj	Qk	busy
A1						
A2						
A3						

	op	Vj	Vk	Qj	Qk	busy
M1						
M2						

	Qi	Reg value	NOTES
R1			
R2			
R3			
R4			
R5			
R6			
R7			
R8			
R9			
R10			
R11			

	Issue	Execute	Write result
MUL R3, R1, R2			
ADD R5, R3, R4			
ADD R7, R2, R6			
ADD R10, R8, R9			
MUL R11, R7, R10			
ADD R5, R5, R11			

	op	Vj	Vk	Qj	Qk	busy
A1						
A2						
A3						

	op	Vj	Vk	Qj	Qk	busy
M1						
M2						

	Qi	Reg value	NOTES
R1			
R2			
R3			
R4			
R5			
R6			
R7			
R8			
R9			
R10			

R11										
	1									
				_						
				C	ycle#_					
	Issue Execute Write result									
MUL	R3, R	1, R2								
ADD	R5, R	3, R4								
	R7, R									
		R8, R9								
		R7, R10								
ADD	R5, R	5, R11								
		op	Vj		Vk	Qj	Qk		busy	
A1										
A2										
A 3										
							<u> </u>			
		1	1				101		Ι,	
M1		op	Ų Vj		Vk	Qj	Qk		busy	
MI										
M2										
	Qi	Reg valu	ıe			NC	TES			
R1										
R2										
R3										
R4										
R5										
R6										

R7

R8

R9

R10		
R11		

	Issue	Execute	Write result
MUL R3, R1, R2			
ADD R5, R3, R4			
ADD R7, R2, R6			
ADD R10, R8, R9			
MUL R11, R7, R10			
ADD R5, R5, R11			

	op	Vj	Vk	Qj	Qk	busy
A1						
A2						
A3						

	op	Vj	Vk	Qj	Qk	busy
M1						
M2						

	Qi	Reg value	NOTES
R1			
R2			
R3			
R4			
R5			
R6			
R7			
R8			

R9			
R10			
R11			

	Issue	Execute	Write result
MUL R3, R1, R2			
ADD R5, R3, R4			
ADD R7, R2, R6			
ADD R10, R8, R9			
MUL R11, R7, R10			
ADD R5, R5, R11			

	op	Vj	Vk	Qj	Qk	busy
A1						
A2						
A3						

	ор	Vj	Vk	Qj	Qk	busy
M1						
M2						

	Qi	Reg value	NOTES
R1			
R2			
R3			
R4			
R5			
R6			
R7			

R8							
R9							
R10							
R11							
				Cycle #	#		
				Issue	Execut	е	Write result
	R3, R						
	R5, R						
	R7, R						
		R8, R9					
		R7, R10 5, R11					
ADD	10, 10	J, KII					
		op	۷j	Vk	Qj	Qk	busy
A1							
A2							
A 3							
			•	•	•		•
		op	۷j	Vk	Qj	Qk	busy
M1							-
M2							
	Qi	Reg val	ıe		NOT	ES	
R1							
R2							
R3							
R4							
R5							

R6

R7									
R8									
R9									
R10									
R11									
				C	ycle#				
				Issue		Execute		Write	result
	R3, R								
ADD	R5, R	3, R4							
	R7, R								
ADD	R10,	R8, R9							
MUL	R11,	R7, R10							
ADD	R5, R	5, R11							
		op	Vj		Vk	Qj	Qk		busy
A1		op .	+-				*	-	
A2									
A 3									
						1	•		
		ор	۷j		Vk	Qj	Qk	:	busy
M1									
M2									
	10:	.				Nome	•		
D1	Qi	Reg val	ue			NOTES			
R1									
R2									
R3									
R4									
R5									
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R6							
R7							
R8							
R9							
R10							
R11							
KII							
				Cycle #	#		
		1 - 50		Issue	Execute		Write result
	R3, R R5, R						
	R7, R						
		R8, R9					
$\overline{}$		R7, R10					
		5, R11					
		op	۷j	Vk	Qj	Qk	busy
A1							
A2							
A3							
			·	•		•	•
		ор	۷j	Vk	Qj	Qk	busy
M1							
M2							
				ļ.	<u>'</u>	Į	<u>'</u>
	Qi	Reg val	ue		NOTI	IS	
R1							
R2							
R3							
R4							

R5									
R6									
R7									
R8									
R9									
R10									
R11									
				C	ycle #				
				Issue		Execute		Write	result
		1, R2							
		3, R4							
		2, R6 R8, R9							
		R7, R10							
		5, R11							
					!				
		op	Vj		Vk	Qj	Qk		busy
A1									
A2									
A 3									
		op	Vj		Vk	Qj	Qk		busy
M1									
M2									
	Qi	Reg valu	1e			NOTE	S		
R1	, 	2.09 .02							
R2									
R3									
	1	1							

R5 R6 R7 R8 R9 R10 R11 Ssue Execute Write result Execute Execute Write result Execute Execute Write result Execute Execute Execute Execute Write result Execute Execute											
R6 R7 R8 R9 R10 R11 Cycle # MUL R3, R1, R2 Issue	R4										
R7 R8 R9 R10 R11 Cycle # MUL R3, R1, R2 ADD R5, R3, R4 ADD R7, R2, R6 ADD R10, R8, R9 MUL R11, R7, R10 ADD R5, R5, R11 OP Vj Vk Qj Qk busy A1 A2 A3 OP Vj Vk Qj Qk busy M1 A2 A3 OP Vj Vk Qj Qk busy M1 A2 A3 OP Vj Vk Qj Qk busy M1 A2 A3 OP Vj Vk Qj Qk busy M1 A2 A3 OP Vj Vk Qj Qk busy M1 M2 OP Vj Vk Qj Qk busy M1 M2 OP Vj Vk Qj Qk busy	R5										
R8	R6										
Cycle #	R7										
Cycle # Cycle # Issue	R8										
Cycle # Issue	R9										
Cycle # Issue	R10										
Issue Execute Write result	R11										
MUL R3, R1, R2 ADD R5, R3, R4 ADD R7, R2, R6 ADD R10, R8, R9 MUL R11, R7, R10 ADD R5, R5, R11					С	ycle #	‡				
ADD R5, R3, R4 ADD R7, R2, R6 ADD R10, R8, R9 MUL R11, R7, R10 ADD R5, R5, R11					Issue			Execut	е	Writ	e result
ADD R7, R2, R6 ADD R10, R8, R9 MUL R11, R7, R10 ADD R5, R5, R11	MUL	R3, R	1, R2								
ADD R10, R8, R9 MUL R11, R7, R10 ADD R5, R5, R11 Op Vj Vk Qj Qk busy A1 A2 A3 Op Vj Vk Qj Qk busy M1 M2 Qi Reg value NOTES R1	ADD	R5, R	3, R4								
MUL R11, R7, R10 ADD R5, R5, R11 Op Vj Vk Qj Qk busy A1 A2 A3 Op Vj Vk Qj Qk busy M1 M2 Qi Reg value NOTES R1	ADD	R7, R	2, R6								
Op Vj Vk Qj Qk busy	ADD	R10,	R8, R9								
Op Vj Vk Qj Qk busy A1 A2 A3 A3 A3 Busy M1 M2 Vj Vk Qj Qk busy M2 NOTES R1 R1 NOTES	MUL	R11,	R7, R10								
A1	ADD	R5, R	5, R11								
A1			•								
A2 A3 Op Vj Vk Qj Qk busy M1 M2 Qi Reg value NOTES			op	٧j		Vk		Qj	Q]	k	busy
A3	A1										
Op Vj Vk Qj Qk busy M1 M2 Qi Reg value R1											
M1 M2 Qi Reg value NOTES R1	A 3										
M1 M2 Qi Reg value NOTES R1											
Qi Reg value NOTES			op	۷j		Vk		Qj	Q]	k	busy
Qi Reg value NOTES	M1										
R1	M 2										
R1											
R2	R1	Qi	Reg val	ue				NO	TES		
	R2										

R3		
R4		
R5		
R6		
R7		
R8		
R9		
R10		
R11		

	Issue	Execute	Write result
MUL R3, R1, R2			
ADD R5, R3, R4			
ADD R7, R2, R6			
ADD R10, R8, R9			
MUL R11, R7, R10			
ADD R5, R5, R11			

	op	Vj	Vk	Qj	Qk	busy
A1						
A2						
A3						

p [Vj	Vk	Qj	Qk	busy
					
<u> </u>	,	, ,	y vj vk		

	Qi	Reg value	NOTES
R1			

R2		
R3		
R4		
R5		
R6		
R7		
R8		
R9		
R10		
R11		

	Issue	Execute	Write result
MUL R3, R1, R2			
ADD R5, R3, R4			
ADD R7, R2, R6			
ADD R10, R8, R9			
MUL R11, R7, R10			
ADD R5, R5, R11			

	op	₹j	Vk	Qj	Qk	busy
A1						
A2						
A3						

	op	Vj	Vk	Qj	Qk	busy
M1						
M2						

Qi	Reg value	NOTES
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R1	
R2	
R3	
R4	
R5	
R6	
R7	
R8	
R9	
R10	
R11	

	Issue	Execute	Write result
MUL R3, R1, R2			
ADD R5, R3, R4			
ADD R7, R2, R6			
ADD R10, R8, R9			
MUL R11, R7, R10			
ADD R5, R5, R11			

	op	Vj	Vk	Qj	Qk	busy
A1						
A2						
A3						

	op	Vj	Vk	Qj	Qk	busy
M1						
M2						
112						

	Qi	Reg value	NOTES
R1			
R2			
R3			
R4			
R5			
R6			
R7			
R8			
R9			
R10			
R11			

	Issue	Execute	Write result
MUL R3, R1, R2			
ADD R5, R3, R4			
ADD R7, R2, R6			
ADD R10, R8, R9			
MUL R11, R7, R10			
ADD R5, R5, R11			

	ор	Vj	Vk	Qj	Qk	busy
A1						
A2						
A3						

	op	Vj	Vk	Qj	Qk	busy
M1						
M2						

	Qi	Reg value	NOTES
R1			
R2			
R3			
R4			
R5			
R6			
R7			
R8			
R9			
R10			
R11			

	Issue	Execute	Write result
MUL R3, R1, R2			
ADD R5, R3, R4			
ADD R7, R2, R6			
ADD R10, R8, R9			
MUL R11, R7, R10			
ADD R5, R5, R11			

	op	Vj	Vk	Qj	Qk	busy
A1						
A2						
A3						

	op	Vj	Vk	Qj	Qk	busy
M1						
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M2								
	Qi	Reg value	e		NOTES			
R1								
R2								
R3								
R4								
R5								
R6								
R7								
R8								
R9								
R10								
R11								
	•		•					
	Cycle #							

	Issue	Execute	Write result
MUL R3, R1, R2			
ADD R5, R3, R4			
ADD R7, R2, R6			
ADD R10, R8, R9			
MUL R11, R7, R10			
ADD R5, R5, R11			

	op	∇j	Vk	Qj	Qk	busy
A1						
A2						
A3						

	op	₹ij	Vk	Qj	Qk	busy

M1			
M2			

	Qi	Reg value	NOTES
R1			
R2			
R3			
R4			
R5			
R6			
R7			
R8			
R9			
R10			
R11			

	Issue	Execute	Write result
MUL R3, R1, R2			
ADD R5, R3, R4			
ADD R7, R2, R6			
ADD R10, R8, R9			
MUL R11, R7, R10			
ADD R5, R5, R11			

	op	Vj	Vk	Qj	Qk	busy
A1						
A2						
A3						

	op	Vj	Vk	Qj	Qk	busy
M1						
M2						

	Qi	Reg value	NOTES
R1			
R2			
R3			
R4			
R5			
R6			
R7			
R8			
R9			
R10			
R11			

	Issue	Execute	Write result
MUL R3, R1, R2			
ADD R5, R3, R4			
ADD R7, R2, R6			
ADD R10, R8, R9			
MUL R11, R7, R10			
ADD R5, R5, R11			

	op	Vj	Vk	Qj	Qk	busy
A1						
A2						
A3						

	op	Vj	Vk	Qj	Qk	busy
M1						
M2						

	Qi	Reg value	NOTES
R1			
R2			
R3			
R4			
R5			
R6			
R7			
R8			
R9			
R10			
R11			

	Issue	Execute	Write result
MUL R3, R1, R2			
ADD R5, R3, R4			
ADD R7, R2, R6			
ADD R10, R8, R9			
MUL R11, R7, R10			
ADD R5, R5, R11			

	op	Vj	Vk	Qj	Qk	busy
A1						
A2						
A3						

	ор	Vj	Vk	Qj	Qk	busy
M1						
M2						

	Qi	Reg value	NOTES
R1			
R2			
R3			
R4			
R5			
R6			
R7			
R8			
R9			
R10			
R11			

	Issue	Execute	Write result
MUL R3, R1, R2			
ADD R5, R3, R4			
ADD R7, R2, R6			
ADD R10, R8, R9			
MUL R11, R7, R10			
ADD R5, R5, R11			

	op	Vj	Vk	Qj	Qk	busy
A1						
A2						

A 3							
		op	Vj	Vk	Qj	Qk	busy
М1							
M2							
	Qi	i Reg value		NOTES			
R1							
R2							
R3							
R4							
R5							
R6							
R7							
R8							
R9							
R10							
R11							