

# Tomasulo - Clk=1

S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

S4: ADDD F0, F12, F14 *I.S.*

Name	Op	Vj	Vk	Qj	Qk	Etime	Issue	Exec	Co.	Write R.
mult1							adddd	1	$1+2=3$	4
mult2							multd	2	$2+4=6$	7
add1	ADD	R(F2)	R(F4)				multd	3	*	12
add2							adddd	4	$4+2=6$	8
F0		F2	F4	F6	F8	F10	F12	F14		
ADD1										

YOU SHOULD TEST, BASED ON WHO WRITES FIRST, HOW TO PROCEED

$$*\max(7+4, 8+2) = 11$$

ADD 2cc, MUL 4cc

# Tomasulo - Clk=1

S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

S4: ADDD F0, F12, F14 *I.S.*

Name	Op	Vj	Vk	Qj	Qk	Etime	Issue	Exec	Co.	Write R.
mult1							adddd	1	$1+2=3$	4
mult2							multd	2	$2+4=6$	8
add1	ADD	R(F2)	R(F4)				multd	3	*	13
add2							adddd	4	$4+2=6$	7
F0		F2	F4	F6	F8	F10	F12	F14		
ADD1										

YOU SHOULD TEST, BASED ON WHO WRITES FIRST, HOW TO PROCEED

$$*\max(8+4, 7+2) = 12$$

ADD 2cc, MUL 4cc

# Exe 1 Tomasulo: the Code

I1: LD F6 32+ R2  
I2: ADDD F2 F6 F4  
I3: MULTD F0 F4 F2  
I4: SUBD F12 F2 F6  
I5: ADDD F0 F12 F2

## CONFLICTS

I1: LD F6 32+ R2

I2: ADDD F2 F6 F4

I3: MULTD F0 F4 F2

I4: SUBD F12 F2 F6

I5: ADDD F0 F12 F2

RAW F6 I1→I2

RAW F6 I1→I4

RAW F2 I2→I4

RAW F2 I2→I3

RAW F2 I2→I5

RAW F12 I4→I5

WAW F0 I3→I5

.

# Exe 1 Tomasulo

- 2 RESERVATION STATIONS (RS1, RS2) + 1 LOAD/STORE unit (LDU1) with latency 2
- 3 RESERVATION STATIONS (RS3, RS4, RS5) + 3 ALU/BR FUs (ALU1, ALU2, ALU3) with latency 3

Instruction	ISSUE	START EXE	WB	Hazards Type	RSi	Unit
I1:LD F6 32+ R2						
I2:ADDD F2 F6 F4						
I3:MULTD F0 F4 F2						
I4:SUBD F12 F2 F6						
I5:ADDD F0 F12 F2						

# Exe 1 Tomasulo

- 2 RESERVATION STATIONS (RS1, RS2) + 1 LOAD/STORE unit (LDU1) with latency 2
- 3 RESERVATION STATIONS (RS3, RS4, RS5) + 3 ALU/BR FUs (ALU1, ALU2, ALU3) with latency 3

Instruction	ISSUE	START EXE	WB	Hazards Type	RSi	Unit
I1:LD F6 32+ R2	1	2	4		RS1	LDU1
I2:ADDD F2 F6 F4	2	5	8	RAW F6 I1-I2	RS3	ALU1
I3:MULTD F0 F4 F2	3	9	12	RAW F2 I2-I3	RS4	ALU2
I4:SUBD F12 F2 F6	4	9	13	RAW F2 I2-I4	RS5	ALU3
I5:ADDD F0 F12 F2	9	14	17	STRUCT RS3 RAW F12 I4-I5	RS3	ALU1

# Exe.3 Tomasulo

- 3 RESERVATION STATIONS (RS1, RS2, RS3) + 3 LOAD/STORE unit (LDU1, LDU2, LDU3) with latency 3
- 3 RESERVATION STATIONS (RS4, RS5, RS6) + 3 FPUs (FPU1, FPU2, FPU3) with latency 3
- 2 RESERVATION STATIONS (RS7, RS8) + 1 Integer ALU ( ALU1) with latency 1

# Exe.3 The conflicts

- I1: LD \$F1, 0(\$R1)
- I2: FADD \$F2, \$F2, \$F3
- I3: ADDI \$R3, \$R3, 8
- I4: LD \$F4, 0(R2)
- I5: FADD \$F5, \$F4, \$F2
- I6: FMULT \$F6, \$F1, \$F4
- I7: ADDI \$R5, \$R5, 1
- I8: LD \$R6, 0(\$R4)
- I9: SD \$F6, 0(\$R5)
- I10: SD \$F5, 0(\$R1)
- I11: ADD \$R1, \$R6, \$R1

## CONFLICTS

I1: LD \$F1, 0(\$R1)  
I2: FADD \$F2, \$F2, \$F3  
I3: ADDI \$R3, \$R3, 8  
I4: LD \$F4, 0(\$R2)  
I5: FADD \$F5, \$F4, \$F2  
I6: FMULT \$F6, \$F1, \$F4  
I7: ADDI \$R5, \$R5, 1  
I8: LD \$R6, 0(\$R4)  
I9: SD \$F6, 0(\$R5)  
I10: SD \$F5, 0(\$R1)  
I11: ADD \$R1, \$R6, \$R1

RAW \$F1 11→16

RAW \$F2 12→15

RAW \$F4 14→15

RAW \$F4 14→16

RAW \$F5 15→10

RAW \$F6 16→19

RAW \$R5 17→19

RAW \$R6 18→11

WAR \$R1 120→111

# Exe.3 Tomasulo

- 3 RESERVATION STATIONS (RS1, RS2, RS3) + 3 LOAD/STORE unit (LDU1, LDU2, LDU3) with latency 3
- 3 RESERVATION STATIONS (RS4, RS5, RS6) + 3 FPUs (FPU1, FPU2, FPU3) with latency 3
- 2 RESERVATION STATIONS (RS7, RS8) + 1 Integer ALU ( ALU1) with latency 1

Instruction	ISSUE	START EXE	WB	Hazards Type	RSi	Unit
I1: LD \$F1, 0(\$R1)						
I2: FADD \$F2, \$F2, \$F3						
I3: ADDI \$R3, \$R3, 8						
I4: LD \$F4, 0(R2)						
I5: FADD \$F5, \$F4, \$F2						
I6: FMULT \$F6, \$F1, \$F4						
I7: ADDI \$R5, \$R5, 1						
I8: LD \$R6, 0(\$R4)						
I9: SD \$F6, 0(\$R5)						
I10: SD \$F5, 0(\$R1)						
I11: ADD \$R1, \$R6, \$R1						

# Exe.3 Tomasulo

- 3 RESERVATION STATIONS (RS1, RS2, RS3) + 3 LOAD/STORE unit (LDU1, LDU2, LDU3) with latency 3
- 3 RESERVATION STATIONS (RS4, RS5, RS6) + 3 FPUs (FPU1, FPU2, FPU3) with latency 3
- 2 RESERVATION STATIONS (RS7, RS8) + 1 Integer ALU ( ALU1) with latency 1

Instruction	ISSUE	START EXE	WB	Hazards Type	RSi	Unit
I1: LD \$F1, 0(\$R1)	1	2	5		RS1	LDU1
I2: FADD \$F2, \$F2, \$F3	2	3	6		RS4	FPU1
I3: ADDI \$R3, \$R3, 8	3	4	7	STRUCT CDB	RS7	AW1
I4: LD \$F4, 0(R2)	4	5	8		RS2	LDU2
I5: FADD \$F5, \$F4, \$F2	5	9	12	○○	RS5	FPU2
I6: FMULT \$F6, \$F1, \$F4	6	9	13	○○ STRUCT CDB	RS6	FPU3
I7: ADDI \$R5, \$R5, 1	7	8	9		RS8	ALU1
I8: LD \$R6, 0(\$R4)	8	9	14		RS1	LDU1
I9: SD \$F6, 0(\$R5)	9	14	17	○○	RS2	LDU2
I10: SD \$F5, 0(\$R1)	10	13	16	○	RS3	LDU3
I11: ADD \$R1, \$R6, \$R1	11	15	18	○	RS7	AW1

# Exe.3 Tomasulo

- 3 RESERVATION STATIONS (RS1, RS2, RS3) + 3 LOAD/STORE unit (LDU1, LDU2, LDU3) with latency 3
- 3 RESERVATION STATIONS (RS4, RS5, RS6) + 3 FPUs (FPU1, FPU2, FPU3) with latency 3
- 2 RESERVATION STATIONS (RS7, RS8) + 1 Integer ALU ( ALU1) with latency 1

Instruction	ISSUE	START EXE	WB	Hazards Type	RSi	Unit
I1: LD \$F1, 0(\$R1)	1	2	5	RAW \$F6 16-19 RAW \$R5 17-19	RS1	LDU1
I2: FADD \$F2, \$F2, \$F3	2	5	6		RS4	FPU1
I3: ADDI \$R3, \$R3, 8	3	4	7	STRUCT CDB	RS7	ALU1
I4: LD \$F4, 0(R2)	4	5	8		RS2	LDU2
I5: FADD \$F5, \$F4, \$F2	5	9	12	RAW \$F2 12-15 RAW \$F4 14-13	RS5	FPU1
I6: FMULT \$F6, \$F1, \$F4	6	9	13	RAW \$F4 14-16 STRUCT CDB	RS6	FPU2
I7: ADDI \$R5, \$R5, 1	7	8	9		RS8	ALU1
I8: LD \$R6, 0(\$R4)	8	9	14	STRUCT CDB	RS1	LDU1
I9: SD \$F6, 0(\$R5)	9	14	17	RAW \$F6 16-19 RAW \$R5 17-19	RS2	LDU2
I10: SD \$F5, 0(\$R1)	10	13	16	RAW \$F5 15-10	RS3	LDU3
I11: ADD \$R1, \$R6, \$R1	11	15	18	RAW \$R6 18-11 STRUCT CDB	RS7	ALU1

# Exe .1 Tomasulo: Code

```
I1:  lw $f1, 0($r0)
I2:  faddi $f1, $f1, C1
I3:  faddi $f2, $f1, C2
I4:  sw $f2, 0($r0)
I5:  lw $f2, 4($r0)
I6:  fadd $f2, $f2, $f2
I7:  sw $f2, 4($r0)
```

## CONFLICTS

I1: lw \$f1, 0(\$r0)  
I2: faddi \$f1, \$f1, C1  
I3: faddi \$f2, \$f1, C2  
I4: sw \$f2, 0(\$r0)  
I5: lw \$f1, 4(\$r0)  
I6: fadd \$f2, \$f2, \$f2  
I7: sw \$f2, 4(\$r0)

RAW \$F1 11-12

RAW \$F1 12-13

RAW \$F2 13-14

RAW \$F2 15-16

RAW \$P2 16-17

WAW \$F1 11-12

WAW \$P2 15-16

WAW \$F2 13-15

WAW \$P2 13-16

WAW \$F2 14-16

WAR \$F2 13-15

# Exe 3.2 Tomasulo

- 2 RESERVATION STATIONS (**RS1, RS2**) + 1 LOAD/STORE unit (**LDU1**) with latency 4
- 2 RESERVATION STATIONS (**RS3, RS4**) + 1 ALU/BR FUs (**ALU1**) with latency 2

Instruction	ISSUE	START EXE	WB	Hazards Type	RSi	Unit
I1:lw \$f1, 0(\$r0)						
I2:faddi \$f1, \$f1, C1						
I3:faddi \$f2, \$f1, C2						
I4:sw \$f2, 0(\$r0)						
I5:lw \$f2, 4(\$r0)						
I6:fadd \$f2, \$f2, \$f2						
I7:sw \$f2, 4(\$r0)						

# Exe 3.2 Tomasulo

$!13 > 6 \Rightarrow \text{NO STORE IN DS}$

- 2 RESERVATION STATIONS (RS1, RS2) + 1 LOAD/STORE unit (LDU1) with latency 4
- 2 RESERVATION STATIONS (RS3, RS4) + 1 ALU/BR FUs (ALU1) with latency 2

Instruction	ISSUE	START EXE	WB	Hazards Type	RSi	Unit
I1:lw \$f1, 0(\$r0)	1	2	6		RS1	LDU1
I2:faddi \$f1, \$f1, C1	2	7	9	RAW \$F1 14-12	RS3	ALU1
I3:faddi \$f2, \$f1, C2	3	10	12	RAW \$F1 12-13	RS4	ALU1
I4:sw \$f2, 0(\$r0)	4	13	17	RAW \$F2 13-14	RS2	LDU1
I5:lw \$f2, 4(\$r0)	7	18	22	STRUCT RS1 STRUCT LDU1	RS1	LDU1
I6:fadd \$f2, \$f2, \$f2	10	23	25	STRUCT RS3 RAW \$F2 15-16	RS3	ALU1
I7:sw \$f2, 4(\$r0)	18	26	30	STRUCT RS2 RAW \$F2 16-17	RS2	LDU1

# Exe.3 Tomasulo

- 3 RESERVATION STATIONS (RS1, RS2, RS3) + 3 LOAD/STORE unit (LDU1, LDU2, LDU3) with latency 3
- 3 RESERVATION STATIONS (RS4, RS5, RS6) + 3 FPUs (FPU1, FPU2, FPU3) with latency 3
- 2 RESERVATION STATIONS (RS7, RS8) + 1 Integer ALU ( ALU1) with latency 1

# Exe.3 The conflicts

- I1: LD \$F1, 0(\$R1)
- I2: FADD \$F2, \$F2, \$F3
- I3: ADDI \$R3, \$R3, 8
- I4: LD \$F4, 0(R2)
- I5: FADD \$F5, \$F4, \$F2
- I6: FMULT \$F6, \$F1, \$F4
- I7: ADDI \$R5, \$R5, 1
- I8: LD \$R6, 0(\$R4)
- I9: SD \$F6, 0(\$R5)
- I10: SD \$F5, 0(\$R6)

## CONFLICTS

I1: LD \$F1, 0(\$R1)  
I2: FADD \$F2, \$F2, \$F3  
I3: ADDI \$R3, \$R3, 8  
I4: LD \$F4, 0(\$R2)  
I5: FADD \$F5, \$F4, \$F2  
I6: FMULT \$F6, \$F1, \$F4  
I7: ADDI \$R5, \$R5, 1  
I8: LD \$R6, 0(\$R4)  
I9: SD \$F6, 0(\$R5)  
I10: SD \$F5, 0(\$R6)

RAW \$F1 11-16

RAW \$F2 12-15

RAW \$F4 14-15

RAW \$F4 14-16

RAW \$F6 16-19

RAW \$R5 17-19

RAW \$R6 18-19

RAW \$F5 15-17

# Exe.3 Tomasulo CC0

- 3 RESERVATION STATIONS (RS1, RS2, RS3) + 3 LOAD/STORE unit (LDU1, LDU2, LDU3) with latency 3
- 3 RESERVATION STATIONS (RS4, RS5, RS6) + 3 FPUs (FPU1, FPU2, FPU3) with latency 3
- 2 RESERVATION STATIONS (RS7, RS8) + 1 Integer ALU ( ALU1) with latency 1

Instruction	ISSUE	START EXE	WB	Hazards Type	RSi	Unit
I1: LD \$F1, 0(\$R1)	1	2	2+3=5		RS1	LDU1
I2: FADD \$F2, \$F2, \$F3	2	3	3+3=6		RS4	FPU1
I3: ADDI \$R3, \$R3, 8	3	4	4+1+1=7	STRUCT CDB	RS7	ALU1
I4: LD \$F4, 0(\$R2)	4	5	8		RS2	LDU2
I5: FADD \$F5, \$F4, \$F2	5	8+1=9	12	RAW SF2 12-15 RAW SF4 14-15	RS5	FPU1
I6: FMULT \$F6, \$F1, \$F4	6	8+1=9	13	RAW F1 11-16 RAW SF4 14-16	RS6	FPU2
I7: ADDI \$R5, \$R5, 1	7	8	9		RS8	ALU1
I8: LD \$R6, 0(\$R4)	8	9	12+1=14	STRUCT CDB	RS1	LDU1
I9: SD \$F6, 0(\$R5)	9	14	17	RAW SF6 16-19	RS2	LDU2
I10: SD \$F5, 0(\$R6)	10	15	18	RAW SF5 15-18 RAW SR6 18-110	RS3	LDU1