

POLITECNICO DI MILANO



High Performance Processors and Systems

Dynamic Scheduling

- Tomasulo Vs Scoreboard -

Marco D. Santambrogio: marco.santambrogio@polimi.it







Outline

- Dynamic Scheduling: just a brief remind
- Scorebord
 - Exercise
- Tomasulo
 - Exercise







Dynamic Scheduling

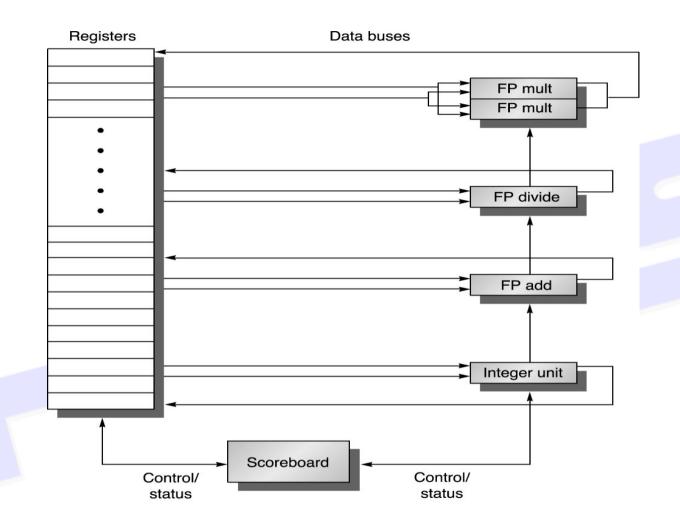
- Scheduling separates dependent instructions
 - Static performed by the compiler
 - Dynamic performed by the hardware
- Advantages of dynamic scheduling
 - Handles dependences unknown at compile time
 - Simplifies the compiler
 - Optimization is done at run time
- Disadvantages
 - Can not eliminate true data dependences







MIPS with Scoreboard



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Exercise

S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2







Scoreboard - Clk=1

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| 1 | | | | | | | | | | | | | | | | |
|-------|------|-----|----|----|-----|-----|-----|-----|-----|----|-----|-------|-------|---------|----------|----------|
| Name | Busy | Op | Fi | Fj | Fk | Qj | Qk | Rj | Rk | Εt | lst | | Issue | Read Op | Exec Co. | Write R. |
| Mult1 | | | | | | | | | | | | addd | 1 | | | |
| mult2 | | | | | | | | | | | | multo | | | | |
| Add1 | YES | ADD | F0 | F2 | F4 | | | YES | YES | | S1 | multo | | | | |
| Add2 | | | | | | | | | | | | addd | | | | |
| | | | | | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | | | | | | |
| ADD1 | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |







Scoreboard - Clk=14

S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| / | | | | | | | | | | | | | | | | |
|------|--------|----|----|----|-----|-----|-----|----|----|----|-----|-------|-------|---------|----------|----------|
| Nam | e Busy | Op | Fi | Fj | Fk | Qj | Qk | Rj | Rk | Εt | Ist | | Issue | Read Op | Exec Co. | Write R. |
| Mult | 1 NO | | | | | | | | | | | addd | 1 | 2 | 4 | 5 |
| mult | 2 NO | | | | | | | | | | | multd | 2 | 3 | 7 | 8 |
| Add1 | NO | | | | | | | | | | | multd | 3 | 9 | 13 | 14 |
| Add2 | NO . | | | | | | | | | | | addd | 6 | 7 | 9 | 10 |
| | | | | | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | | | | | | |
| | | | | | l k | | | | | | | | | | | |







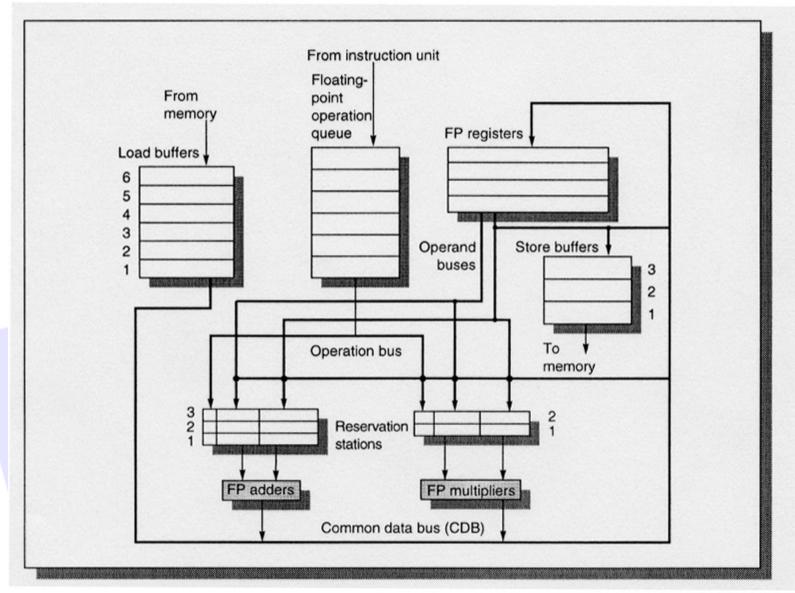
Tomasulo Approach

- Another approach to eliminate stalls
 - Combines scoreboard with
 - Register renaming (to avoid WAR and WAW)
- Designed for the IBM 360/91
 - ▶ High FP performance for the whole 360 family
 - Four double precision FP registers
 - Long memory access and long FP delays
- Can support overlapped execution of multiple iterations of a loop





Tomasulo Approach









Stages

- Issue
 - Empty reservation station or buffer
 - Send operands to the reservation station
 - Use name of reservation station for operands
- Execute
 - Execute operation if operands are available
 - Monitor CDB for availability of operands
- Write result
 - When result is available, write it to the CDB







Exercise

S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Mana | 0- | M | Me | O: | Ok | Edino | | | la auto | Even Co | Marita D |
|-------|-----|-------|-------|----|-----|-------|-----|-------|---------|----------|----------|
| Name | Oβ | Vj | Vk | Qj | Qk | Etime | | | issue | Exec Co. | write R. |
| mult1 | | | | | | | | addd | 1 | | |
| mult2 | | | | | | | | multd | | | |
| add1 | ADD | R(F2) | R(F4) | | | | | multd | | | |
| add2 | | | | | | | | addd | | | |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| ADD1 | | | | | | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Op | Vj | Vk | Qj | Qk | Etime | e | | | Issue | Exec Co. | Write R. |
|-------|-------|-------|-------|----|-----|-------|---|-----|-------|-------|----------|----------|
| mult1 | MULT | R(F6) | R(F8) | | | | | | addd | 1 | | |
| mult2 | | | | | | | | | multd | 2 | | |
| add1 | ADD | R(F2) | R(F4) | | | | 1 | | multd | | | |
| add2 | | | | | | | | | addd | | | |
| | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | | F14 | | | | |
| ADD1 | MULT1 | | | | | | | | | | | |
| | | 1 | | 1 | 1 | 1 | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Op | Vj | Vk | Qj | Qk | Etime | e | | | Issue | Exec Co. | Write R. |
|-------|-------|-------|-------|------|-------|-------|---|-----|-------|-------|----------|----------|
| mult1 | MULT | R(F6) | R(F8) | | | | 3 | | addd | 1 | 3 | |
| mult2 | MULT | | | ADD1 | MULT1 | | | | multd | 2 | | |
| add1 | ADD | R(F2) | R(F4) | | | | 0 | | multd | 3 | | |
| add2 | | | | | | | | | addd | | | |
| | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | | F14 | | | | |
| ADD1 | MULT1 | | | | MULT2 | | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Op | Vj | Vk | Q | Qk | Etime | | | issuc | Exec Co. | Write R. |
|-------|-------|--------|--------|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | MULT | R(F6) | R(F8) | | | 2 | | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | | | MULT1 | | | multd | 2 | | |
| add1 | | | | | | | | multd | 3 | | |
| add2 | ADD | R(F12) | R(F14) | | | | | addd | 4 | | |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| ADD2 | MULT1 | | | | MULT2 | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|-------|--------|--------|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | MULT | R(F6) | R(F8) | | | | 1 | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | | | MULT1 | | | multd | 2 | | |
| add1 | | | | | | | | multd | 3 | | |
| add2 | ADD | R(F12) | R(F14) | | | | 1 | addd | 4 | | |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| ADD2 | MULT1 | | | | MULT2 | | | | | | |
| | | | | | | | - | - | 1 | 1 | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Op | Vj | Vk | Qj | Qk | Etime | , | | | Issue | Exec Co. | Write R. |
|-------|-------|--------|--------|----|-------|-------|---|-----|-------|-------|----------|----------|
| mult1 | MULT | R(F6) | R(F8) | | | | 0 | | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | | | MU | | | | multd | 2 | 6 | |
| add1 | | | | | | | | | multd | 3 | | |
| add2 | ADD | R(F12) | R(F14) | | | | 0 | | addd | 4 | 6 | |
| | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | | F14 | | | | |
| ADD2 | MULT1 | | | | MULT2 | | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| _ | | | _ | | _ | | | | | | |
|------|--------|-------|-------|----|-------|-------|-----|-------|-------|----------|----------|
| Nam | е Ор | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
| mult | 1 MULT | R(F6) | R(F8) | | | 0 | | addd | 1 | 3 | 4 |
| mult | 2 MULT | M(A1) | | | MULT1 | | | multd | 2 | 6 | |
| add | I | | | | | | | multd | 3 | | |
| add | 2 | | | | | | | addd | 4 | | 7 |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| | MULT1 | | | | MULT2 | | | | | | |
| | | - | | - | | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|------|-------|-------|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | | | | | | | | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | M(M1) | | | | | multd | 2 | 6 | 8 |
| add1 | | | | | | | | multd | 3 | | |
| add2 | | | | | | | | addd | 4 | 6 | 7 |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| | | | | | MULT2 | | | | | | |
| | | | | | | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|----|----|----|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | | | | | | | | addd | 1 | 3 | 4 |
| mult2 | | | | | | 3 | | multd | 2 | 6 | 8 |
| add1 | | | | | | | | multd | 3 | | |
| add2 | | | | | | | | addd | 4 | 6 | 7 |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| | | | | | MULT2 | | | | | | |
| | | | | | | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|----|----|----|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | | | | | | | | addd | 1 | 3 | 4 |
| mult2 | | | | | | 2 | | multd | 2 | 6 | 8 |
| add1 | | | | | | | | multd | 3 | | |
| add2 | | | | | | | | addd | 4 | 6 | 7 |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| | | | | | MULT2 | | | | | | |
| | | | | | | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| mult2 1 multd 2 6 add1 multd 3 | Write R. |
|--|----------|
| add1 multd 3 | 4 |
| | 8 |
| add2 addd 4 6 | |
| | 7 |
| | |
| F0 F2 F4 F6 F8 F10 F12 F14 | |
| MULT2 | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|----|----|----|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | | | | | | | | addd | 1 | 3 | 4 |
| mult2 | | | | | | 0 | | multd | 2 | 6 | 8 |
| add1 | | | | | | | | multd | 3 | 12 | |
| add2 | | | | | | | | addd | 4 | 6 | 7 |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| | | | | | MULT2 | | | | | | |
| | | | | | | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|----|----|----|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | | | | | | | | addd | 1 | 3 | 4 |
| mult2 | | | | | | | | multd | 2 | 6 | 8 |
| add1 | | | | | | | | multd | 3 | 12 | 13 |
| add2 | | | | | | | | addd | 4 | 6 | 7 |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| | | | | | MULT2 | | | | | | |
| | | | | | | | | | | | |







Scoreboard Vs Tomasulo

| | Issue | Read Op | Exec Co. | Write R. |
|-------|-------|---------|----------|----------|
| addd | 1 | 2 | 4 | 5 |
| multd | 2 | 3 | 7 | 8 |
| multd | 3 | 9 | 13 | 14 |
| addd | 6 | 7 | 9 | 10 |

| | Issue | Exec Co. | Write R. |
|-------|-------|----------|----------|
| addd | 1 | 3 | 4 |
| multd | 2 | 6 | 8 |
| multd | 3 | 12 | 13 |
| addd | 4 | 6 | 7 |

- Can we do better?
 - ▶ YES!!!... Lets go back to clk6 with Tomasulo...



Time tuner...









S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Op | Vj | Vk | Qj | Qk | Etime | , | | | Issue | Exec Co. | Write R. |
|-------|-------|--------|--------|----|-------|-------|---|-----|-------|-------|----------|----------|
| mult1 | MULT | R(F6) | R(F8) | | | | 0 | | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | | | MU | | | | multd | 2 | 6 | |
| add1 | | | | | | | | | multd | 3 | | |
| add2 | ADD | R(F12) | R(F14) | | | | 0 | | addd | 4 | 6 | |
| | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | | F14 | | | | |
| ADD2 | MULT1 | | | | MULT2 | | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | issue | Exec Co. | Write R. |
|-------|------|--------|--------|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | | | | | , | | | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | M(M1) | | | | | multd | 2 | 6 | 7 |
| add1 | | | | | | | | multd | 3 | | |
| add2 | ADD | R(F12) | R(F14) | | | (|) | addd | 4 | 6 | |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| ADD2 | | | | | MULT2 | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|------|-------|-------|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | | | | | | | | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | M(M1) | | | 3 | | multd | 2 | 6 | 7 |
| add1 | | | | | | | | multd | 3 | | |
| add2 | | | | | | | | addd | 4 | 6 | 8 |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| | | | | | MULT2 | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|------|-------|-------|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | | | | | | | | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | M(M1) | | | 2 | | multd | 2 | 6 | 7 |
| add1 | | | | | | | | multd | 3 | | |
| add2 | | | | | | | | addd | 4 | 6 | 8 |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| | | | | | MULT2 | | | | | | |
| | | | | | | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Maria | A-11 | 3.75 | 3.01- | 0: | O.L. | 45 | | | Tanana a | = | Marida B |
|-------|------|-------|-------|----|-------|-------|-----|-------|----------|----------|----------|
| Name | Ор | Vj | Vk | Qj | Qk | Etime | | | issue | Exec Co. | write R. |
| mult1 | | | | | | | | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | M(M1) | | | 1 | | multd | 2 | 6 | 7 |
| add1 | | | | | | | | multd | 3 | | |
| add2 | | | | | | | | addd | 4 | 6 | 8 |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| | | | | | MULT2 | | | | | | |
| | | | | | | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|------|-------|-------|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | | | | | | | | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | M(M1) | | | 0 | | multd | 2 | 6 | 7 |
| add1 | | | | | | | | multd | 3 | 11 | |
| add2 | | | | | | | | addd | 4 | 6 | 8 |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| | | | | | MULT2 | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|----|----|----|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | | | | | | | | addd | 1 | 3 | 4 |
| mult2 | | | | | | | | multd | 2 | 6 | 7 |
| add1 | | | | | | | | multd | 3 | 11 | 12 |
| add2 | | | | | | | | addd | 4 | 6 | 8 |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| | | | | | MULT2 | | | | | | |













Scoreboard Vs Tomasulo - Clk=1

S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Busy | Ор | Fi | Fj | Fk | Qj | Qk | Rj | Rk | Εt | lst | | Is | sue | Read Op | Exec Co. | Write R. |
|-------|------|-----|----|----|-----|-----|-----|-----|-----|----|-----|-----|-----|-----|---------|----------|----------|
| Mult1 | | | | | | | | | | | | ado | dd | 1 | | | |
| mult2 | | | | | | | | | | | | mu | ltd | | | | |
| Add1 | YES | ADD | F0 | F2 | F4 | | | YES | YES | | S1 | mu | ltd | | | | |
| Add2 | | | | | | | | | | | | ado | dd | | | | |
| | | | | | | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | | | | | | | |
| ADD1 | | | | | | | | | | | | | | | | | |

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|-----|-------|-------|----|-----|-------|-----|-------|-------|----------|----------|
| mult1 | | | | | | | | addd | 1 | | |
| mult2 | | | | | | | | multd | | | |
| add1 | ADD | R(F2) | R(F4) | | | | | multd | | | |
| add2 | | | | | | | | addd | | | |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| ADD1 | | | | | | | | | | | |
| | 1 | 1 | 1 | 1 | 1 | 1 | | | | | |







Scoreboard Vs Tomasulo - Clk=2

S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Busy | Ор | Fi | Fj | Fk | Qj | Qk | Rj | Rk | Et | lst | | Issue | Read Op | Exec Co. | Write R. |
|-------|-------|------|----|----|-----|-----|-----|-----|-----|----|-----|-------|-------|---------|----------|----------|
| Mult1 | YES | MULT | F2 | F6 | F8 | | | YES | YES | | S2 | addd | 1 | 2 | | |
| mult2 | NO | | | | | | | | | | | multd | 2 | | | |
| Add1 | YES | ADD | F0 | F2 | F4 | | | YES | YES | 2 | S1 | multd | | | | |
| Add2 | NO | | | | | | | | | | | addd | | | | |
| | | | | | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | | | | | | |
| ADD1 | MULT1 | | | | | | | | | | | | | | | |

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|-------|-------|-------|----|-----|-------|-----|-------|-------|----------|----------|
| mult1 | MULT | R(F6) | R(F8) | | | | | addd | 1 | | |
| mult2 | | | | | | | | multd | 2 | | |
| add1 | ADD | R(F2) | R(F4) | | | 1 | | multd | | | |
| add2 | | | | | | | | addd | | | |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| ADD1 | MULT1 | | | | | | | | | | |
| | | | | | | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Busy | Op | Fi | Fj | Fk | Qj | Qk | Rj | Rk | Εt | lst | | Issue | Read Op | Exec Co. | Write R. |
|-------|-------|------|-----|----|-------|------|-------|-----|-----|----|-----|-------|-------|---------|----------|----------|
| Mult1 | YES | MULT | F2 | F6 | F8 | | | YES | YES | 4 | S2 | addd | 1 | 2 | | |
| mult2 | YES | MULT | F10 | F0 | F2 | ADD1 | MULT1 | NO | NO | | S3 | multo | 2 | 3 | | |
| Add1 | YES | ADD | F0 | F2 | F4 | | | NO. | NO | _1 | S1 | multo | 3 | | | |
| Add2 | NO | | | | | | | 7 | | | | addd | | | | |
| | | | | | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | | | | | | |
| ADD1 | MULT1 | | | | MULT2 | | | | | | | | | | | |

| Name | Ор | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|-------|-------|-------|------|-------|-------|-----|-------|-------|----------|----------|
| mult1 | MULT | R(F6) | R(F8) | | | 3 | | addd | 1 | 3 | |
| mult2 | MULT | | | ADD1 | MULT1 | | | multd | 2 | | |
| add1 | ADD | R(F2) | R(F4) | | | 0 | | multd | 3 | | |
| add2 | | | | | | | | addd | | | |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| ADD1 | MULT1 | | | | MULT2 | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

S4: ADDD F0, F12, F14

| ne | Busy | Op | Fi | Fj | Fk | Qj | Qk. | Rj | ™ k | Ξt | lst | | | Issue | Read Op | Exec Co. | Write R. |
|-----|-----------------------|--------------------------------------|---|--|---|---|---|--|--|---|--|---|--|--|---|---|--|
| lt1 | YES | MULT | F2 | F6 | F8 | | | NO | NO | 3 | S2 | | addd | 1 | 2 | 4 | |
| lt2 | YES | MULT | F10 | F0 | F2 | ADD1 | MULT1 | NO | NO | | S3 | | multd | 2 | 3 | | |
| d1 | YES | ADD | F0 | F2 | F4 | | | NO | NO | 0 | 51 | | multd | 3 | | | |
| d2 | NO | | | | | | | | | | | | addd | | | | |
| | | | | | | | | | | | | | | | | | |
| | F2 | F4 | F6 | 7 8 | F10 | F12 | F14 | | | | | | | | | | |
| D1 | MULT1 | | | | MULT2 | | | | | | | | | | | | |
| | t1 lt2 l1 l2 | t1 YES lt2 YES l1 YES l2 NO | t1 YES MULT t2 YES MULT t1 YES ADD t2 NO t2 F2 F4 | t1 YES MULT F2 It2 YES MULT F10 I1 YES ADD F0 I2 NO F2 F4 F6 | t1 YES MULT F2 F6 t2 YES MULT F10 F0 t1 YES ADD F0 F2 t2 NO F2 F4 F6 F8 | t1 YES MULT F2 F6 F8 lt2 YES MULT F10 F0 F2 s1 YES ADD F0 F2 F4 s2 NO F2 F4 F6 F8 F10 | t1 YES MULT F2 F6 F8 t2 YES MULT F10 F0 F2 ADD1 t1 YES ADD F0 F2 F4 t2 NO F2 F4 F6 F8 F10 F12 | t1 YES MULT F2 F6 F8 It2 YES MULT F10 F0 F2 ADD1 MULT1 t1 YES ADD F0 F2 F4 t2 NO F12 F14 | t1 YES MULT F2 F6 F8 NO t2 YES MULT F10 F0 F2 ADD1 MULT1 NO t1 YES ADD F0 F2 F4 NO t2 NO F12 F14 | t1 YES MULT F2 F6 F8 NO NO t2 YES MULT F10 F0 F2 ADD1 MULT1 NO NO t1 YES ADD F0 F2 F4 NO NO t2 NO F12 F14 F14 F14 | t1 YES MULT F2 F6 F8 NO NO | t1 YES MULT F2 F6 F8 NO NO NO NO NO NO NO NO NO S3 t1 YES ADD F0 F2 F4 NO NO 0 S1 t2 NO F1 F1 F14 F14 | t1 YES MULT F2 F6 F8 NO NO NO NO NO NO S3 t1 YES ADD F0 F2 F4 NO NO O S1 t2 NO F1 F1 F14 F14 F14 F14 | t1 YES MULT F2 F6 F8 NO NO NO 3 S2 addd t2 YES MULT F10 F0 F2 ADD1 MULT1 NO NO NO S3 multd t2 NO NO NO NO O S1 multd t2 F4 F6 F8 F10 F12 F14 F14 | t1 YES MULT F2 F6 F8 NO NO NO NO 1 S3 multd 2 t1 YES ADD F0 F2 F4 NO NO O S1 multd 3 t2 NO F4 F6 F8 F10 F12 F14 F14 F14 | t1 YES MULT F2 F6 F8 NO NO NO NO NO S2 addd 1 2 t2 YES MULT F10 F0 F2 ADD1 MULT1 NO NO S3 multd 2 3 t1 YES ADD F0 F2 F4 NO NO 0 S1 multd 3 t2 NO F4 F6 F8 F10 F12 F14 F14 F14 | t1 YES MULT F2 F6 F8 NO NO NO NO NO S3 multd 2 3 t1 YES ADD F0 F2 F4 NO NO O S1 multd 3 t2 NO NO NO NO NO S1 multd 3 t2 F4 F6 F8 F10 F12 F14 F14 |

WAW

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | issuc | Exec Co. | Write R. |
|-------|-------|--------|--------|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | MULT | R(F6) | R(F8) | | | 2 | | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | | | MULT1 | | | multd | 2 | | |
| add1 | | | | | | | | multd | 3 | | |
| add2 | ADD | R(F12) | R(F14) | | | | | addd | 4 | | |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| ADD2 | MULT1 | | | | MULT2 | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Busy | Op | Fi | Fj | Fk | Qj / | Qk | Rj | Rk | Εt | lst | | | Issue | Read Op | Exec Co. | Write R | |
|-------|------------------------|---|--|--|--|---|--|--|---|---|---|--|---|---|---|--|--|--|
| Mult1 | YES | MULT | F2 | F6 | F8 | | | NO | NO | 2 | S2 | | addd | 1 | 2 | 4 | | 5 |
| mult2 | YES | MULT | F10 | F0 | F2 | $\overline{\mathbf{Q}}$ | MULT1 | YES | MO | | | | muita | 2 | 3 | | | I |
| Add1 | NO | | | | | | | | | | | | multa | 3 | | | | |
| Add2 | NO | | | | | | | | | | | | addd | | | | | |
| | | | | | | | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | | | | | | | | |
| | MULT1 | | | | MULT2 | | | | | | | | | | | | | |
| | Mult1 mult2 Add1 | Mult1 YES mult2 YES Add1 NO Add2 NO F0 F2 | Mult1 YES MULT mult2 YES MULT Add1 NO Add2 NO F0 F2 F4 | Mult1 YES MULT F2 mult2 YES MULT F10 Add1 NO Add2 NO F0 F2 F4 F6 | Mult1 YES MULT F2 F6 mult2 YES MULT F10 F0 Add1 NO Add2 NO F2 F4 F6 F8 | Mult1 YES MULT F2 F6 F8 mult2 YES MULT F10 F0 F2 Add1 NO NO F10 F2 F4 F6 F8 F10 | Mult1 YES MULT F2 F6 F8 mult2 YES MULT F10 F0 F2 Add1 NO Add2 NO F2 F4 F6 F8 F10 F12 | Mult1 YES MULT F2 F6 F8 mult2 YES MULT F10 F0 F2 MULT1 Add1 NO NO Add2 NO F12 F14 F0 F2 F4 F6 F8 F10 F12 F14 | Mult1 YES MULT F2 F6 F8 MULT YES Mult2 YES MULT F10 F0 F2 MULT YES Add1 NO NO NO P12 F14 F0 F2 F4 F6 F8 F10 F12 F14 | Mult1 YES MULT F2 F6 F8 NO NO mult2 YES MULT F10 F0 F2 MULT YES NO Add1 NO NO NO NO NO NO NO F0 F2 F4 F6 F8 F10 F12 F14 | Mult1 YES MULT F2 F6 F8 NO NO 2 mult2 YES MULT F10 F0 F2 MULT YES NO Add1 NO < | Mult1 YES MULT F2 F6 F8 NO NO 2 S2 mult2 YES MULT F10 F0 F2 MULT YES NO S3 Add1 NO NO S3 NO S3 Add2 NO F12 F14 F14 | Mult1 YES MULT F2 F6 F8 NO NO 2 S2 mult2 YES MULT YES NO S3 Add1 NO NO Add2 NO F12 F14 F0 F2 F4 F6 F8 F10 F12 F14 | Mult1 YES MULT F2 F6 F8 NO 2 S2 addd mult2 YES MULT F10 F0 F2 MULT YES NO S3 multd Add1 NO NO Add2 NO Add2 NO Add2 NO F12 F14 F14 | Mult1 YES MULT F2 F6 F8 NO NO 2 S2 addd 1 mult2 YES MULT F10 F0 F2 MULT YES NO S3 multd 2 Add1 NO NO Add2 NO Add3 Add4 NO Add4 F0 F2 F4 F6 F8 F10 F12 F14 F14 | Mult1 YES MULT F2 F6 F8 NO NO 2 S2 addd 1 2 mult2 YES MULT F10 F0 F2 MULT YES NO S3 multd 2 3 Add1 NO NO Addd Addd Addd Addd Addd Addd Addd F0 F2 F4 F6 F8 F10 F12 F14 F14 F14 | Mult1 YES MULT F2 F6 F8 NO 2 S2 addd 1 2 4 mult2 YES MULT F10 F0 F2 MULT YES NO S3 multd 2 3 Add1 NO NO NO NO S3 multd 3 Add2 NO F2 F4 F6 F8 F10 F12 F14 | Mult1 YES MULT F2 F6 F8 NO NO 2 S2 addd 1 2 4 5 Mult2 YES MULT YES NO S3 multd 2 3 Add1 NO NO S3 multd 3 3 Add2 NO F2 F4 F6 F8 F10 F12 F14 |

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|-------|--------|--------|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | MULT | R(F6) | R(F8) | | | | 1 | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | | | MULT1 | | | multd | 2 | | |
| add1 | | | | | | | | multd | 3 | | |
| add2 | ADD | R(F12) | R(F14) | | | | 1 | addd | 4 | | |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| ADD2 | MULT1 | | | | MULT2 | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Busy | Op | Fi | Fj | Fk | Qj | Qk | Rj | Rk | Εt | lst | | Issue | Read Op | Exec Co. | Write R. |
|-------|-------|------|-----|-----|-------|-----|-------|-----|-----|----|-----|-------|-------|---------|----------|----------|
| Mult1 | YES | MULT | F2 | F6 | F8 | | | NO | NO | 1 | S2 | addd | 1 | 2 | 4 | 5 |
| mult2 | YES | MULT | F10 | F0 | F2 | | MULT1 | YES | NO | | S3 | multd | 2 | 3 | | |
| Add1 | YES | ADD2 | F0 | F12 | F14 | | | YES | YES | | S4 | multd | 3 | | | |
| Add2 | NO | | | | | | | | | | | addd | 6 | | | |
| | | | | | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | | | | | | |
| ADD1 | MULT1 | | | | MULT2 | | | | | | | | | | | |

| | | | | | | | _ | | | | | |
|-------|-------|--------|--------|----|-------|-------|---|-----|-------|-------|----------|----------|
| Name | Op | Vj | Vk | Qj | Qk | Etime | | | | Issue | Exec Co. | Write R. |
| mult1 | MULT | R(F6) | R(F8) | | | | 0 | | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | | | MU | | | | multd | 2 | 6 | |
| add1 | | | | | | | | | multd | 3 | | |
| add2 | ADD | R(F12) | R(F14) | | | | 0 | | addd | 4 | 6 | |
| | | | | | | | 7 | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | I | F14 | | | | |
| ADD2 | MULT1 | | | | MULT2 | | | | | | | |
| | | | | | | | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Busy | Op | Fi | Fj | Fk | Qj | Qk | Rj | Rk | Et | St | | Issue | Read Op | Exec Co. | Write R. |
|-------|-------|------|-----|-----|-------|-----|-------|-----|-----|----|----|-------|-------|---------|----------|----------|
| Mult1 | YES | MULT | F2 | F6 | F8 | | | NO | NO | 0 | 52 | addd | 1 | 2 | 4 | 5 |
| mult2 | YES | MULT | F10 | F0 | F2 | | MULT1 | YES | NO | | S3 | multd | 2 | 3 | 7 | |
| Add1 | YES | ADD2 | F0 | F12 | F14 | | | YES | YES | 2 | S4 | multd | 3 | | | |
| Add2 | NO | | | | | | | | | | | addd | 6 | 7 | | |
| | | | | | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | | | | | | _ |
| ADD1 | MULT1 | | | | MULT2 | | | | | | | | | | | |

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | issue | Exec Co. | Write R. |
|-------|------|--------|--------|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | | | | | | | | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | M(M1) | | | | | multd | 2 | 6 | 7 |
| add1 | | | | | | | | multd | 3 | | |
| add2 | ADD | R(F12) | R(F14) | | | C |) | addd | 4 | 6 | |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| ADD2 | | | | | MULT2 | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| | | | | | | | | | | 1 | | | | | | | |
|-----|------|------|------|-----|-----|-------|-----|------|-----|----------|----------|-----|-------|-------|---------|----------|----------|
| Na | me | Busy | Op | Fi | Fj | Fk | Qj | Qk / | Rj | R | Et | Ist | | Issue | Read Op | Exec Co. | Write R. |
| Mu | ılt1 | NO | | | | | | | | | | | addd | 1 | 2 | 4 | 5 |
| mu | ılt2 | YES | MULT | F10 | F0 | F2 | | | YES | YES | \ | 53 | multd | 2 | 3 | 7 | 8 |
| Ad | d1 | YES | ADD2 | F0 | F12 | F14 | | | NO. | NO | 7 1 | S4 | multd | 3 | | | |
| Ad | d2 | NO | | | | | | | | | 7 | | addd | 6 | 7 | | |
| | | | | | | | | | | | | | | | | | |
| F0 | | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | | | | | | |
| .AD |)D2 | < | | | | MULT2 | | | | | | | | | | | |
| | | | | - | - | | | | | _ | | | | | - | | |

| Name | Op | Vj | Vk | Qj | Qk | Etime | e | | Issue | Exec Co. | Write R. |
|-------|------|-------|-------|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | | | | | | | | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | M(M1) | | | | 3 | multd | 2 | 6 | 7 |
| add1 | | | | | | | | multd | 3 | | |
| add2 | | | | | | | | addd | 4 | 6 | 8 |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | L | | | |
| | | | | | MULT2 | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Busy | Op | Fi | Fj | Fk | Qj | Qk | Rj | Rk | Εt | lst | | lesue | Read Op | Exec Co. | Write R. |
|-------|------|------|-----|-----|-------|-----|-----|------|-----|----|-----|-------|-------|---------|----------|----------|
| Mult1 | NO | | | | | | | | | | | addd | 1 | 2 | 4 | 5 |
| mult2 | YES | MULT | F10 | F0 | F2 | | | YES | YES | 4 | 23 | multd | 2 | 3 | 7 | 8 |
| Add1 | YES | ADD2 | F0 | F12 | F14 | | | NO 1 | NO | 0 | 54 | multd | 3 | 9 | | |
| Add2 | NO | | | | | | | | | | | addd | 6 | 7 | 9 | |
| | | | | | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | | | | | | |
| ADD2 | | | | | MULT2 | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|------|-------|-------|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | | | | | | | | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | M(M1) | | | 2 | 2 | multd | 2 | 6 | 7 |
| add1 | | | | | | | | multd | 3 | | |
| add2 | | | | | | | | addd | 4 | 6 | 8 |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| | | | | | MULT2 | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Busy | Op | Fi | Fj | Fk | Qj | Qk | Rj | Rk | Et | lst | | Issue | Read Op | Exec Co. | Write R. |
|----------|------|------|-----|----|-------|-----|-----|-----|----|----|-----|-------|-------|---------|----------|----------|
| Mult1 | NO | | | | | | | | | | | addd | 1 | 2 | 4 | 5 |
| mult2 | YES | MULT | F10 | F0 | F2 | | | NO. | NO | 3 | S3 | multd | 2 | 3 | 7 | 8 |
| Add1 | NO | | | | | | | | | | | multd | 3 | 9 | | |
| Add2 | NO | | | | | | | | | | | addd | 6 | 7 | 9 | 10 |
| | | | | | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | | | | | | |
| + | | | | | MULT2 | | | | | | | | | | | |

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|------|-------|-------|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | | | | | | | | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | M(M1) | | | 1 | | multd | 2 | 6 | 7 |
| add1 | | | | | | | | multd | 3 | | |
| add2 | | | | | | | | addd | 4 | 6 | 8 |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| | | | | | MULT2 | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

| Name | Busy | Op | Fi | Fj | Fk | Qj | Qk | Rj | Rk | Et | Ist | | | Issue | Read Op | Exec Co. | Write R. |
|-------|------|------|-----|----|-------|-----|-----|----|----|----|-----|---|-------|-------|---------|----------|----------|
| Mult1 | NO | | | | | | | | | | | а | addd | 1 | 2 | 4 | 5 |
| mult2 | YES | MULT | F10 | F0 | F2 | | | NO | NO | 2 | S3 | n | nultd | 2 | 3 | 7 | 8 |
| Add1 | NO | | | | | | | | | | | n | nultd | 3 | 9 | | |
| Add2 | NO | | | | | | | | | | | а | addd | 6 | 7 | 9 | 10 |
| | | | | | | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | | | | | | | |
| 1 | | | | | MULT2 | | | | | | | | | | | | |

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|------|-------|-------|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | | | | | | | | addd | 1 | 3 | 4 |
| mult2 | MULT | M(A1) | M(M1) | | | 0 | | multd | 2 | 6 | 7 |
| add1 | | | | | | | | multd | 3 | 11 | |
| add2 | | | | | | | | addd | 4 | 6 | 8 |
| | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| | | | | | MULT2 | | | | | | |







S1: ADDD F0, F2, F4

S2: MULTD F2, F6, F8 S3: MULTD F10, F0, F2

| Name | Busy | Op | Fi | Fj | Fk | Qj | Qk | Rj | Rk | Et | lst | | Issue | Read Op | Exec Co. | Write R. |
|-------|------|------|-----|----|-------|-----|-----|----|----|----|-----|-----|--------------|---------|----------|----------|
| Mult1 | NO | | | | | | | | | | | add | d 1 | 2 | 4 | 5 |
| mult2 | YES | MULT | F10 | F0 | F2 | | | NO | NO | 1 | S3 | mul | td 2 | 3 | 7 | 8 |
| Add1 | NO | | | | | | | | | | | mul | t d 3 | 9 | | |
| Add2 | NO | | | | | | | | | | | add | d 6 | 7 | 9 | 10 |
| | | | | | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | | | | | | |
| | | | | | MULT2 | | | | | | | | | | | |

| Name | Op | Vj | Vk | Qj | Qk | Etime | | | Issue | Exec Co. | Write R. |
|-------|----|----|----|----|-------|-------|-----|-------|-------|----------|----------|
| mult1 | | | | | | | | addd | 1 | 3 | 4 |
| mult2 | | | | | | | | multd | 2 | 6 | 7 |
| add1 | | | | | | | | multd | 3 | 11 | 12 |
| add2 | | | | | | | | addd | 4 | 6 | 8 |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | |
| | | | | | MULT2 | | | | | | |







S1: ADDD F0, F2, F4

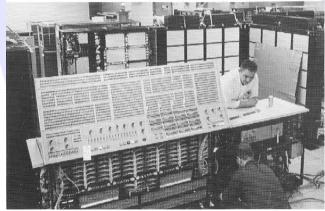
S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

S4: ADDD F0, F12, F14

| Name | Busy | Op | Fi | Fj | Fk | Qj | Qk | Rj | Rk | Εt | lst | | Issue | Read Op | Exec Co. | Write R. |
|-------|------|------|-----|----|-------|-----|-----|----|----|----|-----|-------|-------|---------|----------|----------|
| Mult1 | NO | | | | | | | | | | | addd | 1 | 2 | 4 | 5 |
| mult2 | YES | MULT | F10 | F0 | F2 | | | NO | NO | 0 | S3 | multd | 2 | 3 | 7 | 8 |
| Add1 | NO | | | | | | | | | | | multd | 3 | 9 | 13 | |
| Add2 | NO | | | | | | | | | | | addd | 6 | 7 | 9 | 10 |
| | | | | | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | | | | | | |
| | | | | | MULT2 | | | | | | | | | | | |

Tomasulo's waiting...











S1: ADDD F0, F2, F4

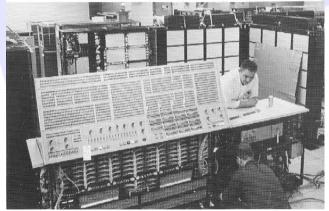
S2: MULTD F2, F6, F8

S3: MULTD F10, F0, F2

S4: ADDD F0, F12, F14

| Name | Busy | Ор | Fi | Fj | Fk | Qj | Qk | Rj | Rk | Et | lst | | Issue | Read Op | Exec Co. | Write R. |
|-------|------|----|----|----|-----|-----|-----|----|----|----|-----|-------|-------|---------|----------|----------|
| Mult1 | NO | | | | | | | | | | | addd | 1 | 2 | 4 | 5 |
| mult2 | NO | | | | | | | | | | | multd | 2 | 3 | 7 | 8 |
| Add1 | NO | | | | | | | | | | | multd | 3 | 9 | 13 | 14 |
| Add2 | NO | | | | | | | | | | | addd | 6 | 7 | У | 10 |
| | | | | | | | | | | | | | | | | |
| F0 | F2 | F4 | F6 | F8 | F10 | F12 | F14 | | | | | | | | | |
| | | | | | - | | | | | | | | | | | |

Tomasulo's now sleeping...











Questions





