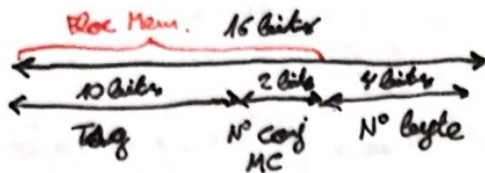


Sessió 6 ex. 2, 10, 11 ← Tema 3

- ② Tamany bloc = 16 bytes  
 Associativitat = 2 (LRU)  
 Num. línies = 8  
 @ de 16 bits  
 Write through + Write no allacat



Conjunt 0	Conjunt 1	Conjunt 2	Conjunt 3
EC8 1	EC5 1	EC6 0	EC7 1
AB4 0	línia 0	AB2 1	línia 0

$$\frac{8 \text{ blocs}}{2 \text{ blocs/conj}} = 4 \text{ conj} \rightarrow 2^2 \rightarrow \text{Nº conj. MC}$$

$$16 \text{ bytes} = 2^4 \rightarrow \text{Nº byte}$$

Tipus	@ de	Bloc de mem.	Conj. MC	Encard/ Fallada	Lectura MP		Escriitura MP	
	hex				si/no	@	si/no	@
1 R byte	8890	889	1	Fallada	Si	8890	No	-
2 W word	EC51	EC5	1	Encert	No	-	Si	EC51
3 W byte	EC62	EC6	2	Encert	No	-	Si	EC62
4 W word	23D3	23D	1	Fallada	No	-	Si	2303
5 W byte	ABA4	ABA	2	Fallada	No	-	Si	AB44
6 R word	ABA5	ABA	2	Fallada	Si	ABA5	No	-
7 R byte	23D6	23D	1	Fallada	Si	23D6	No	-
8 W word	EC57	EC5	1	Encert	No	-	Si	EC57
9 R byte	EC68	EC6	2	Encert	No	-	No	-
10 R word	8899	889	1	Fallada	Si	8899	No	-

1) Conj 1 EC5 0 889 1	2) Conj 1 EC5 1 889 0	3) Conj 2 EC6 1 AB2 0	4) Miss E 5) Miss E	6) Conj 2 EC6 0 ABA 1	7) Conj 1 EC5 0 23D 1
8) Conj 1 EC5 1 23D 0	9) Conj 2 EC6 1 ABA 0	10) Conj 1 EC5 0 889 1			

Conj 0	Conj 1	Conj 2	Conj 3
EC8 1	EC5 0	EC6 1	EC7 1
AB4 0	889 1	ABA 0	línia 0

⑩  $V = 1.2 \text{ V} \parallel f = 2 \cdot 10^9 \text{ Hz} \parallel I_{\text{fugues}} = 3 \text{ A} \parallel C = 5 \cdot 10^{-9} \text{ F}$

a)  $P_{\text{commutació}} = C \cdot V^2 \cdot f = 5 \cdot 10^{-9} \cdot 1.2^2 \cdot 2 \cdot 10^9 = 14.4 \text{ W}$

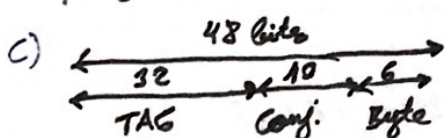
$P_{\text{fuga}} = I \cdot V = 3 \cdot 1.2 = 3.6 \text{ W} ; P_{\text{total}} = 14.4 + 3.6 = 18 \text{ W}$

MC dades 2 associatives de  $128 \text{ KB} \cdot 2^{17}$  capacitat i tamany bloc  $64 \text{ B} \cdot 2^6$

@ de 48 bits.  $I_{\text{fugues}} = 3 \mu\text{A/bit}$ .  $E_{\text{con}} = 5 \cdot 10^{-9} \text{ J per via M. Dades}$ .  $E_{\text{con}} = 25 \cdot 10^{-9} \text{ J per via M. Dades}$

b)  $\text{Blocs MC} = \frac{2^{17} \text{ bytes}}{2^6 \text{ bytes/bloc}} = 2^{11} \text{ blocs} = 2048 \text{ blocs} \parallel \text{Nº conj.} = \frac{2048 \text{ blocs}}{2 \text{ blocs/conj}} = 1024 \text{ conj.}$

$\text{Nº vies} = 2 \text{ (associatives)} \parallel \text{Blocs per via} = 1024 \text{ blocs/via}$



d)  $M_{\text{Dades}} = 1024 \cdot 64 \text{ bytes/bloc} \cdot 8 = 524288 \text{ bits}$

$M_{\text{ditz}} = 1024 \cdot 32 \text{ bits/bloc} = 32768 \text{ bits}$

$\text{Total} = 557056 \text{ bits}$



$$e) P_{fuga} = I \cdot V \cdot N^{\circ} \text{ vies} = 1.671 \text{ A} \cdot 1.2 \text{ V} \cdot 2 \text{ vies} = 4 \text{ W}$$

$$I_{fuga} = 3 \cdot 10^{-6} \text{ A/bit} \cdot 557056 \text{ bits} = 1.671 \text{ A}$$

MC dades 2-associatives (paral. lla, sèrie, predictor de via)

Benchmark amb 4.10<sup>9</sup> inst. dinàmiques i realitza 10<sup>9</sup> accessos i 2.10<sup>9</sup> operacions aritmètiques de punt flotant. 10% fallades a MC

$$g) \text{ MFLOPS} = \frac{2 \cdot 10^9 \text{ flop}}{5 \text{ s}} \cdot 10^{-6} \text{ MFLOPS/flop} = 400 \text{ MFLOPS}$$

$$g) \text{ Cicles totals} = 5 \text{ s} \cdot 2 \cdot 10^9 \text{ Hz} = 10 \cdot 10^9 \text{ cicles} \quad \text{CPI} \quad \frac{10\%}{100}$$

$$\text{CPI paral. lla} = \frac{10 \cdot 10^9 \text{ c}}{4 \cdot 10^9 \text{ inst}} = 2.5 \text{ c/i} \quad \text{Cicles perduts mem} = 0.1 \text{ fallades/acc} \cdot 10^9 \text{ accessos} \cdot 20 \text{ c/fallada} = 2 \cdot 10^9 \text{ cicles}$$

$$\text{Cicles ideal} = 10 \cdot 10^9 \text{ cicles} - 2 \cdot 10^9 \text{ cicles} = 8 \cdot 10^9 \text{ cicles}$$

$$\text{CPI ideal} = 8 \cdot 10^9 \text{ c} / 4 \cdot 10^9 \text{ inst.} = 2 \text{ c/i}$$

$$h) 1 \text{ accés MC} \Rightarrow 2 \text{ vies etiq} \text{ i } 2 \text{ vies dades} \rightarrow E = 2 \cdot 5 \cdot 10^{-9} + 2 \cdot 25 \cdot 10^{-9} = 60 \cdot 10^{-9} \text{ J} = 60 \text{ nJ}$$

$$i) P_{dinàmica} = \frac{E}{t} = 0.2 \cdot 10^9 \cdot 60 \cdot 10^{-9} \text{ J} = 12 \text{ J/s} = 12 \text{ W}$$

$$E = 10^9 \text{ accessos} / 5 \text{ s} = 0.2 \cdot 10^9 \text{ accessos/s}$$

$$j) P_{\text{total}} = P_{\text{CPU}} + P_{\text{fugues}} + P_{\text{commut}} = 18 + 4 + 12 = 34 \text{ W}$$

$$k) E_{\text{total}} = P_{\text{total}} \cdot t = 34 \cdot 5 = 170 \text{ J} \quad \text{Efic.} = 400 \text{ MFLOPS} / 34 \text{ W} = 11.76 \text{ MFLOPS/W}$$

Sèrie: Accés de 2 cicles. Realització 20 cicles. Paral. lla  $\rightarrow$  penalització 1 cicle

$$l) \text{ Cicles} = C_{\text{ideal}} + C_{\text{perduts fallades}} + C_{\text{perduts encerts}} = 10 \cdot 10^9 \text{ c} + 0.9 \text{ encerts/acc} \cdot 10^9 \text{ accessos} \cdot 1 \text{ c/encert} = 10.9 \cdot 10^9 \text{ c} \quad \text{Taxe} = 10.9 \cdot 10^9 \text{ c} / 2 \cdot 10^9 \text{ Hz} = 5.45 \text{ s}$$

$$\text{MFLOPS} = (2 \cdot 10^9 \text{ flop} / 5.45 \text{ s}) \cdot 10^{-6} \text{ MFLOPS/flop} = 367 \text{ MFLOPS}$$

$$m) 1 \text{ accés} \rightarrow 2 \text{ vies etiq} + 1 \text{ via dades} \parallel E = 2 \cdot 5 \cdot 10^{-9} + 25 \cdot 10^{-9} = 35 \cdot 10^{-9} \text{ J} = 35 \text{ nJ}$$

$$n) 10^9 \text{ accessos} / 5.45 \text{ s} = 0.183 \cdot 10^9 \text{ acc/s} \quad \text{J/s} = \text{W}$$

$$P_{\text{dinàmica}} = E/t = 0.183 \cdot 10^9 \text{ acc/s} \cdot 35 \cdot 10^{-9} \text{ J} = 6.42 \text{ J/s} = 6.42 \text{ W}$$

$$o) P_{\text{total}} = P_{\text{CPU}} + P_{\text{fugues}} + P_{\text{commut}} = 18 \text{ W} + 4 \text{ W} + 6.42 \text{ W} = 28.42 \text{ W}$$

$$p) E = P \cdot t = 28.42 \text{ W} \cdot 5.45 \text{ s} = 155 \text{ J} \quad \text{Efic.} = 367 \text{ MFLOPS} / 28.42 \text{ W} = 12.91 \text{ MFLOPS/W}$$

Predictor: Mem. de 8000, 1 bit. Taxa d'encert 80%. Consumeix 1 mJ = 10<sup>-9</sup> J

$$q) \text{ No} \quad n) I_{fuga} = 8192 \text{ bits} \cdot 3 \cdot 10^{-6} \text{ A/bit} = 24.6 \text{ mA} \parallel P_{fuga} = I \cdot V = 24.6 \cdot 10^{-3} \text{ A} \cdot 1.2 \text{ V} = 29.5 \text{ mW}$$

En menar.

$$r) \text{ Cicles} = \text{Cicles ideal} + \text{Cicles perduts fallades cache} + \text{Cicles perduts fallades predictor} = 10 \cdot 10^9 \text{ c} + 0.2 \text{ encerts/acc} \cdot 10^9 \text{ accessos} \cdot 1 \text{ c/encert} = 10.2 \cdot 10^9 \text{ c} \quad \text{Taxe} = 10.2 \cdot 10^9 \text{ c} / 2 \cdot 10^9 \text{ Hz} = 5.1 \text{ s}$$

$$\text{MFLOPS} = (2 \cdot 10^9 \text{ flop} / 5.1 \text{ s}) \cdot 10^{-6} \text{ MFLOPS/flop} = 392 \text{ MFLOPS}$$

t) Encert predictor  $\rightarrow$  predictor + 1 via etiq. + 1 via dades

Fallada predictor  $\rightarrow$  predictor + 2 vies etiq. + 2 vies dades

$$E_{\text{encert}} = 1 \text{ mJ} + 5 \text{ mJ} + 25 \text{ mJ} = 31 \text{ mJ} \quad \text{E}_{\text{fallades}} = 1 \text{ mJ} + 10 \text{ mJ} + 50 \text{ mJ} = 61 \text{ mJ}$$

$$E_{\text{mitjana}} = 0.8 \cdot 31 \text{ mJ} + 0.2 \cdot 61 \text{ mJ} = 37 \text{ mJ}$$



$$u) \frac{10^9 \text{ operacions}}{5.1 \mu} = 0.196 \cdot 10^9 \text{ operacions} \mu // P_{dinàmica} = E/t = 0.196 \cdot 10^9 \text{ operacions} \mu \cdot 37 \cdot 10^{-9} J = 7.25 W$$

$$v) P_{total} = P_{CPU} + E_{fugues} + P_{mem.} + P_{comand.} = 18 + 4 + 0.03 + 7.25 = 29.28 W$$

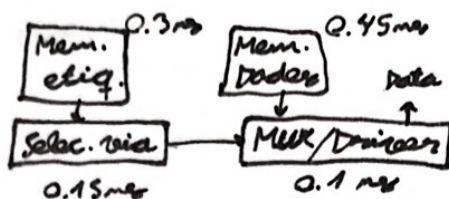
$$w) E = P \cdot t = 29.28 \cdot 5.1 = 149 J // Efic. = \frac{392 \text{ MFLOPS}}{29.28 W} = 13.39 \text{ MFLOPS/W}$$

$$x) \frac{Série}{Paral. bla} = \frac{12.91}{11.76} = 1.098 \Rightarrow (1.098 - 1) \cdot 100 = 9.8\%$$

$$\frac{Prod. via}{Série} = \frac{13.39}{12.91} = 1.037 \Rightarrow (1.037 - 1) \cdot 100 = 3.7\%$$

Processador X1:

a) MC dades amb implementació paral. bla. Taccís cache = 1c

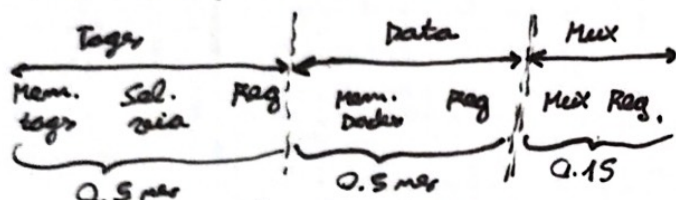


$$t_c = 0.45 + 0.1 = 0.55 \text{ ms}$$

$$t_{accís} = 0.55 \cdot 1c = 0.55 \text{ ms}$$

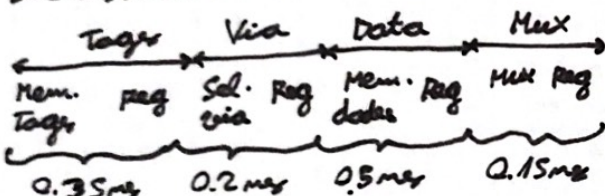
Processador X3:

MC dades segmentada en 3 etapes. Taccís = 3c



$$t_c = 0.5 \text{ ms} // t_{accís} = 0.5 \cdot 3 = 1.5 \text{ ms}$$

Processador X4:



$$t_c = 0.5 \text{ ms} // t_{accís} = 0.5 \cdot 4 = 2 \text{ ms}$$

Percenta  $2 \cdot 10^9$  inst.: 60% inst. aritmètiques, 20% inst. salt, 20% inst. accés mem.

↳ 5 cicles

↳ 4 cicles

↳ 4 cicles

$$d) \text{ Inst. arit.} : 2 \cdot 10^9 \cdot 60\% = 1.2 \cdot 10^9 \text{ inst.} // \text{ Inst. salt} : 2 \cdot 10^9 \cdot 20\% = 0.4 \cdot 10^9 \text{ inst.}$$

$$\text{ Inst. accés mem.} : 2 \cdot 10^9 \cdot 20\% = 0.4 \cdot 10^9 \text{ inst.} // \text{ Taccís cache} \begin{cases} X_1: 1c \\ X_3: 3c \end{cases}$$

$$CPI_{X_1} = 0.6 \cdot 5 + 0.2 \cdot 4 + 0.2(4+1) = 4.8 c/i$$

$$CPI_{X_3} = 0.6 \cdot 5 + 0.2 \cdot 4 + 0.2(4+3) = 5.2 c/i$$

$$e) \text{ Texe}_{X_1} = 2 \cdot 10^9 \cdot 4.8 \cdot 0.55 \cdot 10^{-9} = 5.28 \mu // \text{ Texe}_{X_3} = 2 \cdot 10^9 \cdot 5.2 \cdot 0.5 \cdot 10^{-9} = 5.2 \mu$$

$$\text{speedup} = 5.28 / 5.2 = 1.015 \Rightarrow (1.015 - 1) \cdot 100 = 1.5\%$$

f) P té un 10% de fallades a MC dades. T rendització = 60 cicles

$$CPI = CPI_{ideal} + CPI_{mem} = 4.8 + 0.2 \cdot 0.1 \cdot 60 = 6 c/i // \text{ Texe}_{X_1} = 2 \cdot 10^9 \cdot 5 \cdot 0.55 \cdot 10^{-9} = 6.6 \mu$$

$$CPI = 5.2 + 0.2 \cdot 0.1 \cdot 60 = 6.4 c/i // \text{ Texe}_{X_3} = 2 \cdot 10^9 \cdot 6.4 \cdot 0.5 \cdot 10^{-9} = 6.4 \mu$$

$$\text{speedup} = \frac{6.6}{6.4} = 1.03125 \Rightarrow (1.03125 - 1) \cdot 100 = 3.125\%$$