

### 3.1.1. Direct mapping

Fast MATH →  
Intransitity

Address Word → 32 bits

Data Word → 32 bits - 4B

split Cache → data 16 KiB

instn. 16 KiB

1 block = 16 words =  $2^4$  words =  $2^4 \cdot 2^2 B = 2^6 B$   
(byte addressing)

$$2^9 \text{ bits} = 512 \text{ bits}$$

total memory  $2^{32} B = 2^{10} \cdot 2^2 B = 4 \text{ GiB}$

Cache Size = 16 KiB =  $2^4 \cdot 2^{10} B = 2^{14} B$

=  $2^{14} / 2^6 \text{ blocks} = 2^8 \text{ blocks} = 256 \text{ blocks}$

index = 8 ←

Main Memory :  $4 \text{ GiB} = \frac{2^{30} \cdot 4 \text{ B}}{2^6 \text{ B}} \text{ blocks} = 2^{26} \text{ blocks}$

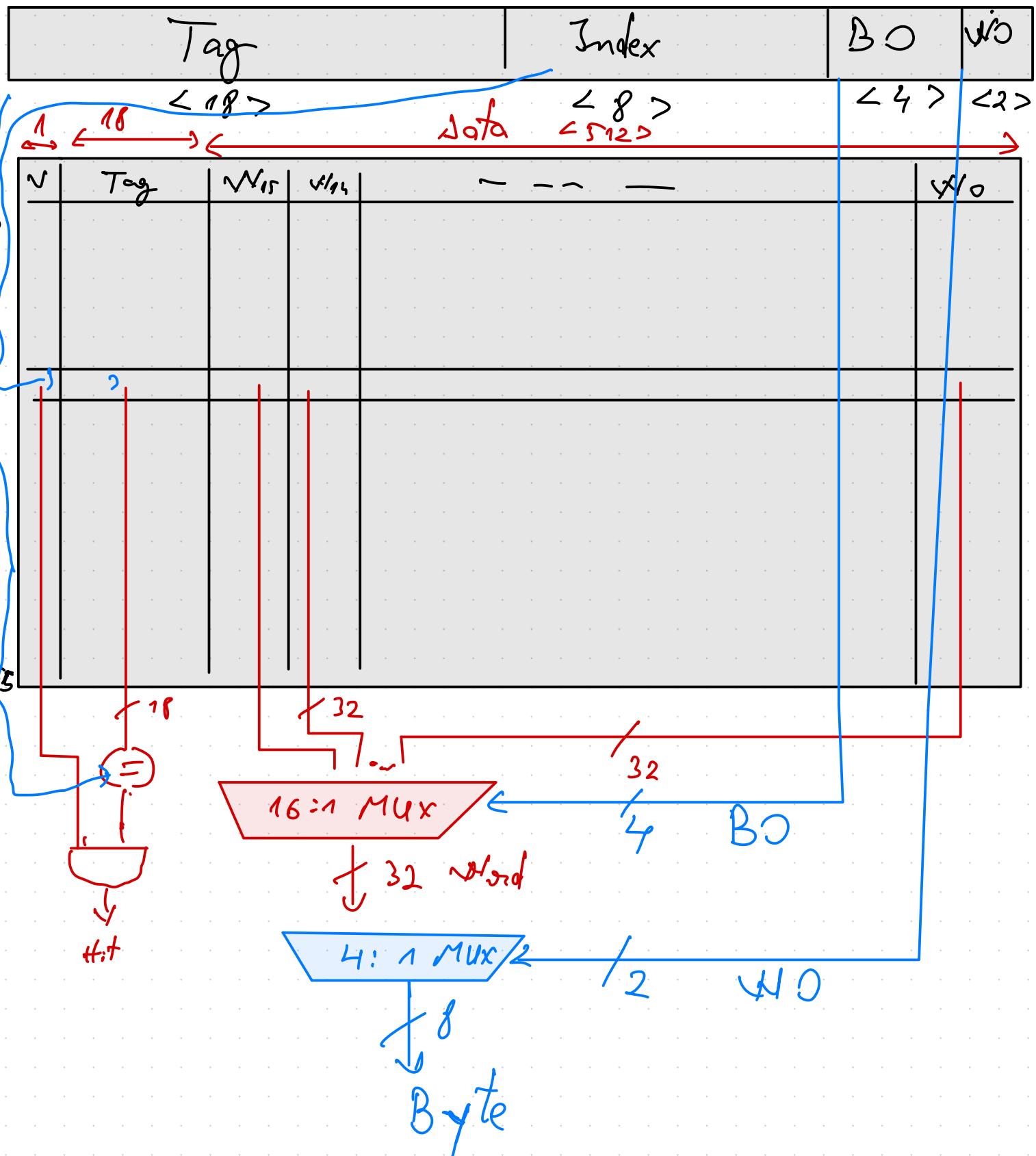
tag size =  $m - m = 26 - 8 = 18$

# Address Field

31

15 14

6 5 4 3 2 1 0

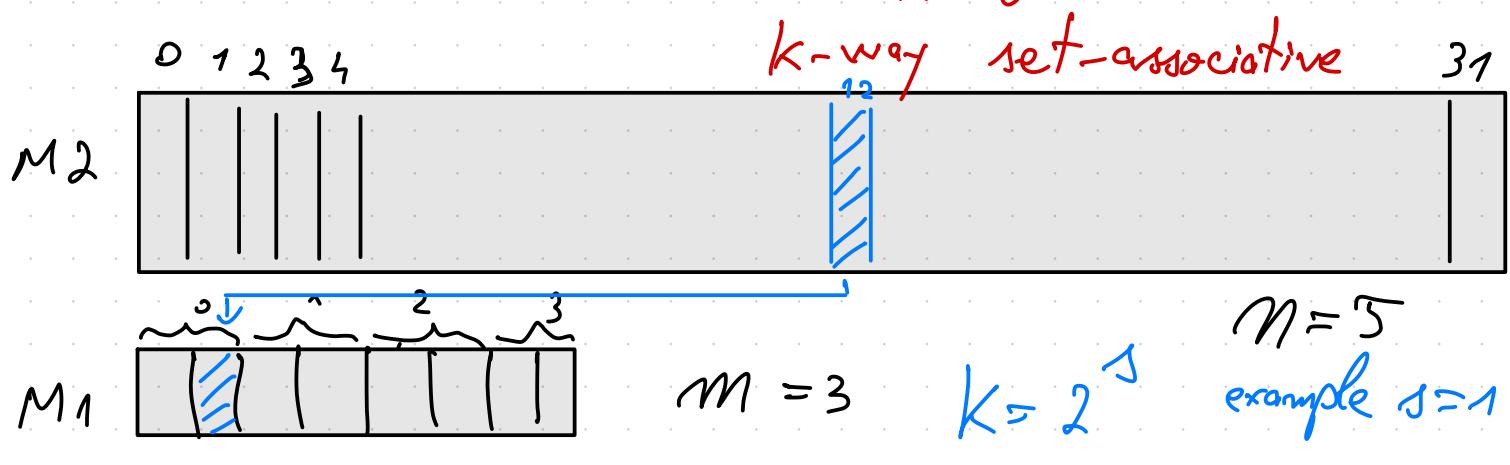


# Cache Performance Benchmarks :

Mem Access  $\leftarrow$  Hit  
Miss

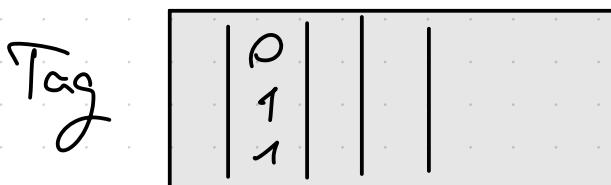
$$\text{Hit Rate} = 1 - \text{Miss Rate}$$

## 3.1.2 Set-associative mapping



$$12 \bmod 2^2 = 0 \leftarrow$$

Block Index       $\underbrace{0\ 11}_{\text{Tag}}, \underbrace{00}_1$



"Câte linii băgăti acolo, profu?"

Mihai "Uncancellable" Udeescu

$$MM = 2^{24} \text{ words}$$

$$1 \text{ word} = 1 \text{ byte}$$

$$1 \text{ block} = 4 \text{ words}$$

$$\text{Size } M_1 = 1 \text{ k; Block}$$

Address

8192

Code

230

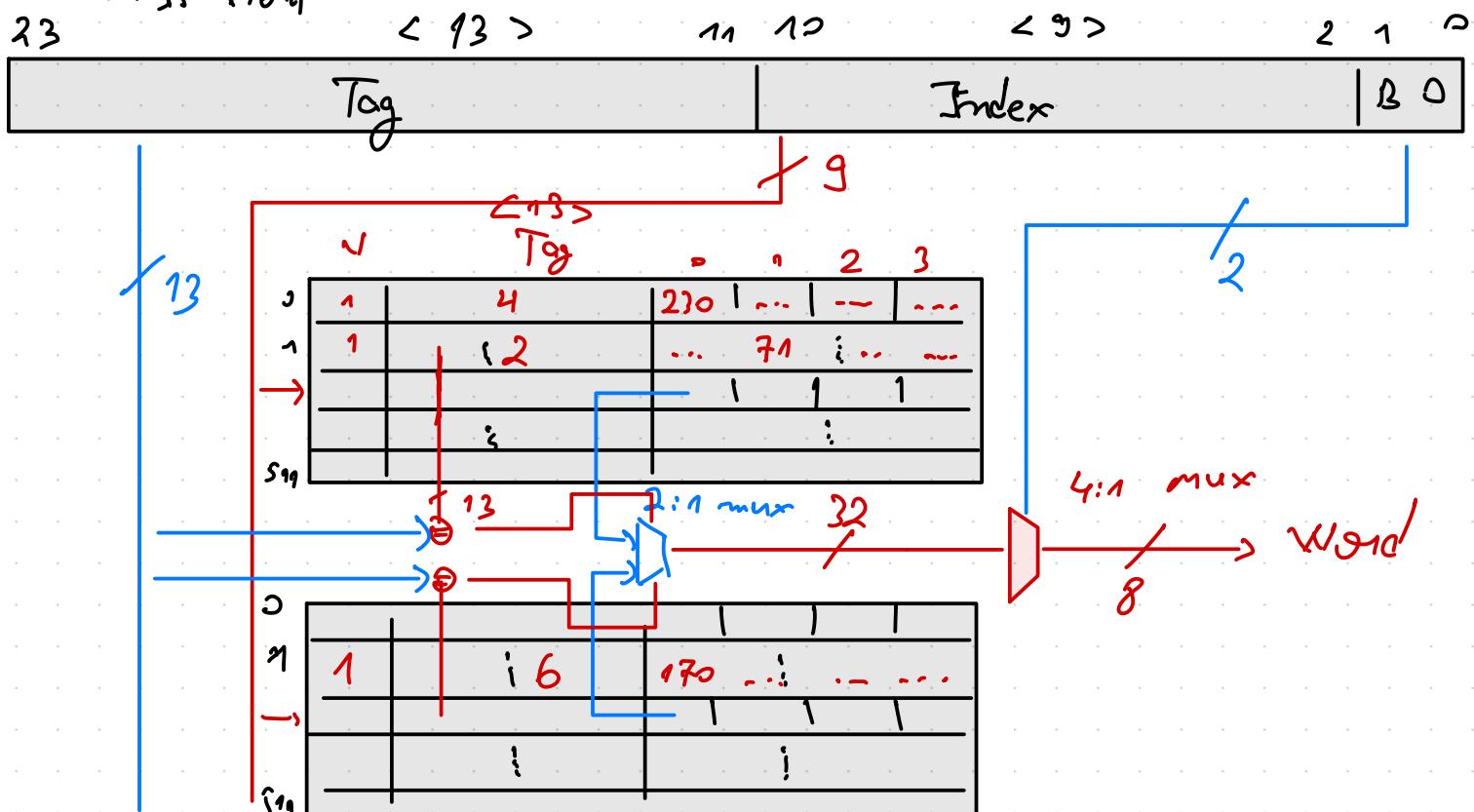
4102

71

12292

170

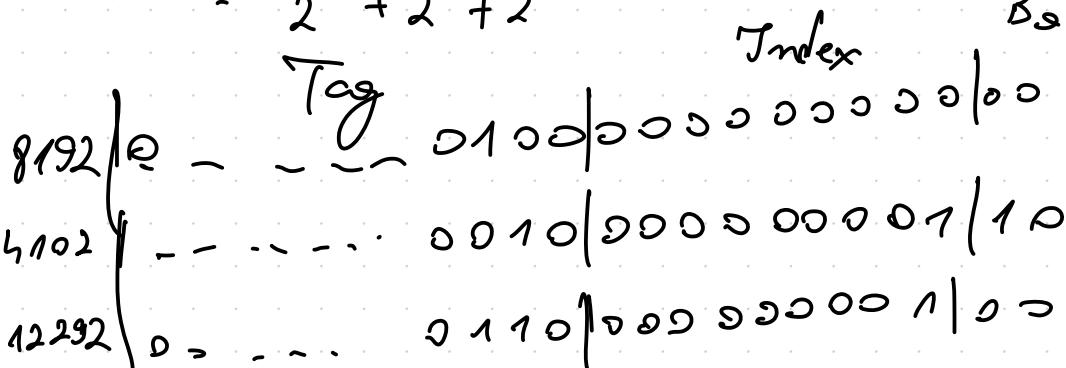
Address Word



$$4102 = 2^{12} + 2^2 + 2^1$$

$$8192 = 2^{13}$$

$$12292 = 2^{13} + 2^{12} + 2^2$$



"No exists fairness pre human acts. Wake up!"

M. Ushesee

VAX 11/780

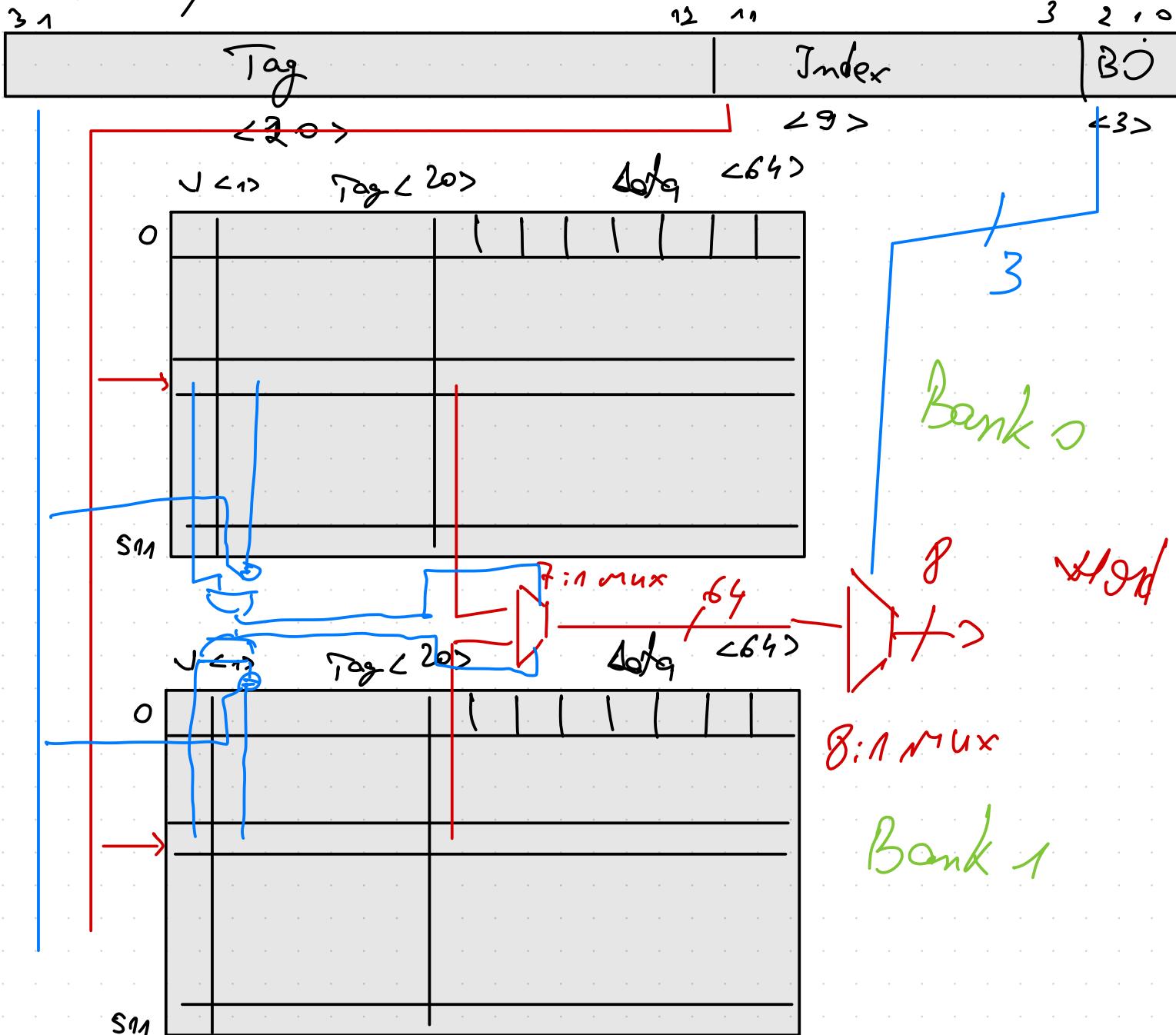
Size (MM) = 4 GiB

1 word = 1 B

1 block, 8 words =  $2^3 B$  = 64 bits → index

Cache data size = 1 kB block:  $\frac{2^{10}}{2} = 2^9$  sets

2-way set associative cache



$$\text{Size MM} = 4 \text{ GiB} = 2^{30} \cdot 2^2 \text{ B} = 2^{32} \text{ B}$$

$$1 \text{ word} = 32 \text{ bits} = 4 \text{ B} \quad (2^2) \rightarrow \text{w/o}$$

$$1 \text{ block} = 32 \text{ words} = 2^5 \cdot 2^3 \text{ B} = 2^8 \text{ B}$$

$$\text{size Cache} = 256 \text{ kB} = 2^{10} \text{ B} \downarrow \text{BO}$$

4-way SA cache       $k=4$      $k=2^3 \rightarrow 1=2$

31	16	15	7 6	2 1 0
----	----	----	-----	-------

Tag	Index	BO	WO
-----	-------	----	----

$$1 \text{ block} = 2^5 \text{ words} = 2^7 \text{ B}$$

$$\text{Cache Size} = \frac{2^{10} \text{ B}}{2^7 \text{ B}} = 2^3 \text{ blocks}$$

$$\frac{2^3 \text{ blocks}}{2^2 \text{ blocks/set}} = 2^1 \text{ sets}$$

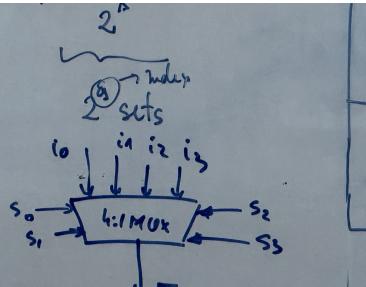
Index  $\leftarrow$  ⑨

2-way SA cache

$$k_2 = 2^1$$

$$A=1$$

$s_3 s_2 s_1 s_0$	$i$
0 0 0 1	i0
0 0 1 0	i1
0 1 0 0	i2
1 0 0 0	i3



Example 4

$$\text{Size (MM)} = 4 \text{GiB} = 2^2 \cdot 2^{30} \text{B} = 2^{32} \text{B}$$

Byte addressable

$$1 \text{ word} = 32 \text{ bits} = \frac{2^5}{2^3} = 2^2 \text{B}$$

$$1 \text{ block} = 32 \text{ words} = 2^5 \text{ words} = 2^{10} \text{ bits}$$

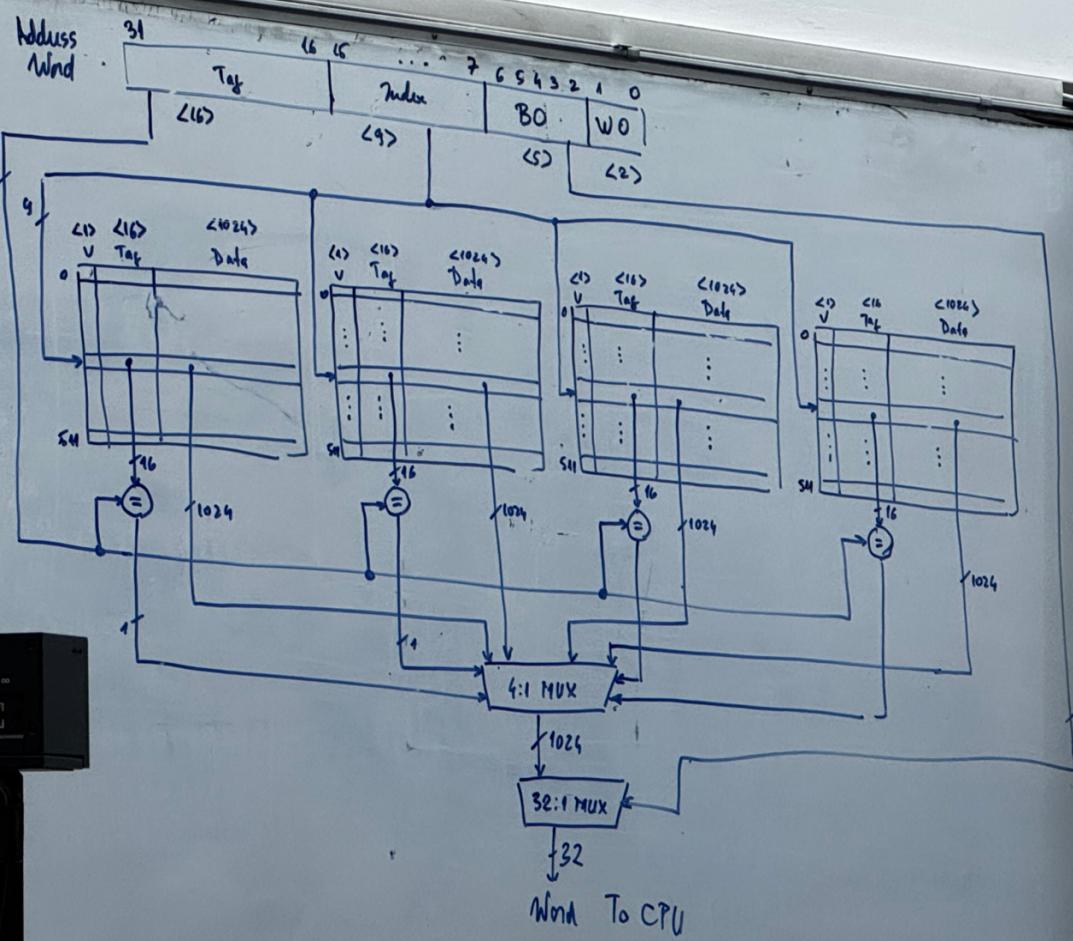
$$\text{Data size (Cache)} = 256 \text{KiB} = 2^8 \cdot 2^{10} \text{B} = 2^{18} \text{B}$$

$k$ -way SA cache  $\Rightarrow k=4$   
 $k=2^A \Rightarrow A=2$

$$1 \text{ block} = 2^5 \text{ words} = 2^5 \cdot 2^2 \text{B} = 2^7 \text{B}$$

$$\text{Cache size} = \frac{2^{18} \text{B}}{2^7 \text{B}} = 2^4 \text{ Blocks}$$

$$\begin{aligned} 2^4 \text{ blocks} &= 2^3 \text{ sets} \\ 2^2 \text{ blocks/set} & \end{aligned}$$



"N-aveti niciun drept!" M. Uderescu

4-way SA cache

8 blocks / bank

4 words / block

MM  $\rightarrow$   $2^{16}$  words

Word addressing

Initial cache empty

$\rightarrow$  Write back

$\rightarrow$  LRU replacement

$\rightarrow$  Cache access time  $\Rightarrow T_{ac} = 2 \text{ ms}$

Miss Penalty  $= T_{mp} = 20 \text{ ms}$

a) address format

b) Hit Ratio + Average Memory Access Time

1 5 3 2 1 0

Tag	Index	BO
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$2^5$   
stop  
30

start

31

32

;

105

;

160

4x

## Example 5

4-way SA

$$8 \text{ blocks/bank} = 2^3$$

$$4 \text{ words/block} = 2^2$$

$$1 \text{ M} \rightarrow 2^{16} \text{ words}$$

Word addresses

Initially empty

Write back

LRU replacement

$$\text{Cache access time} = t_{ac} = 2 \mu\text{s}$$

$$\text{Miss Penalty} = 20 \mu\text{s}$$

a) address format

b) Hit Ratio + AMAT

Average Memory Access Time.

Tag		Index	BD	Block index
5	9	3	2	1
25				0 - 3
26				4 - 7
27				8 - 11
28				12 - 15
29				16 - 19
STOP	30	START		20 - 23
				24 - 27
				28 - 31
				32 - 35
				36 - 39
				40 - 43
				44 - 47
				48 - 51
				52 - 55
				56 - 59
				60 - 63
				64 - 67
				68 - 71
				72 - 75
				76 - 79
				80 - 83
				84 - 87
				88 - 91
				92 - 95
				96 - 99
				100 - 103
				104 - 107
				108 - 111
				112 - 115
				116 - 119
				120 - 123
				:

	V	Tag	Data
0	1	1	32 - 35
1	1	1	36 - 39
2	1	1	40 - 43
3	1	1	44 - 47
4	1	1	48 - 51
5	1	1	52 - 55
6	1	1	56 - 59
7	1	0	28 - 31

0	1	2	64 - 67
1	1	2	68 - 71
2	1	2	72 - 75
3	1	2	76 - 79
4	1	2	80 - 83
5	1	2	84 - 87
6	1	2	88 - 91
7	1	1	92 - 95

0	1	2	3	4	5	6	7
1							
2							
3							
4							
5							
6							
7							

0	1	2	3	4	5	6	7
1							
2							
3							
4							
5							
6							
7							

1M  
1H (1M)  
1H (3H)

