

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 \swarrow $2^6 = 2^4 \text{ words / block} \cdot 2^2 B/\text{word}$

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

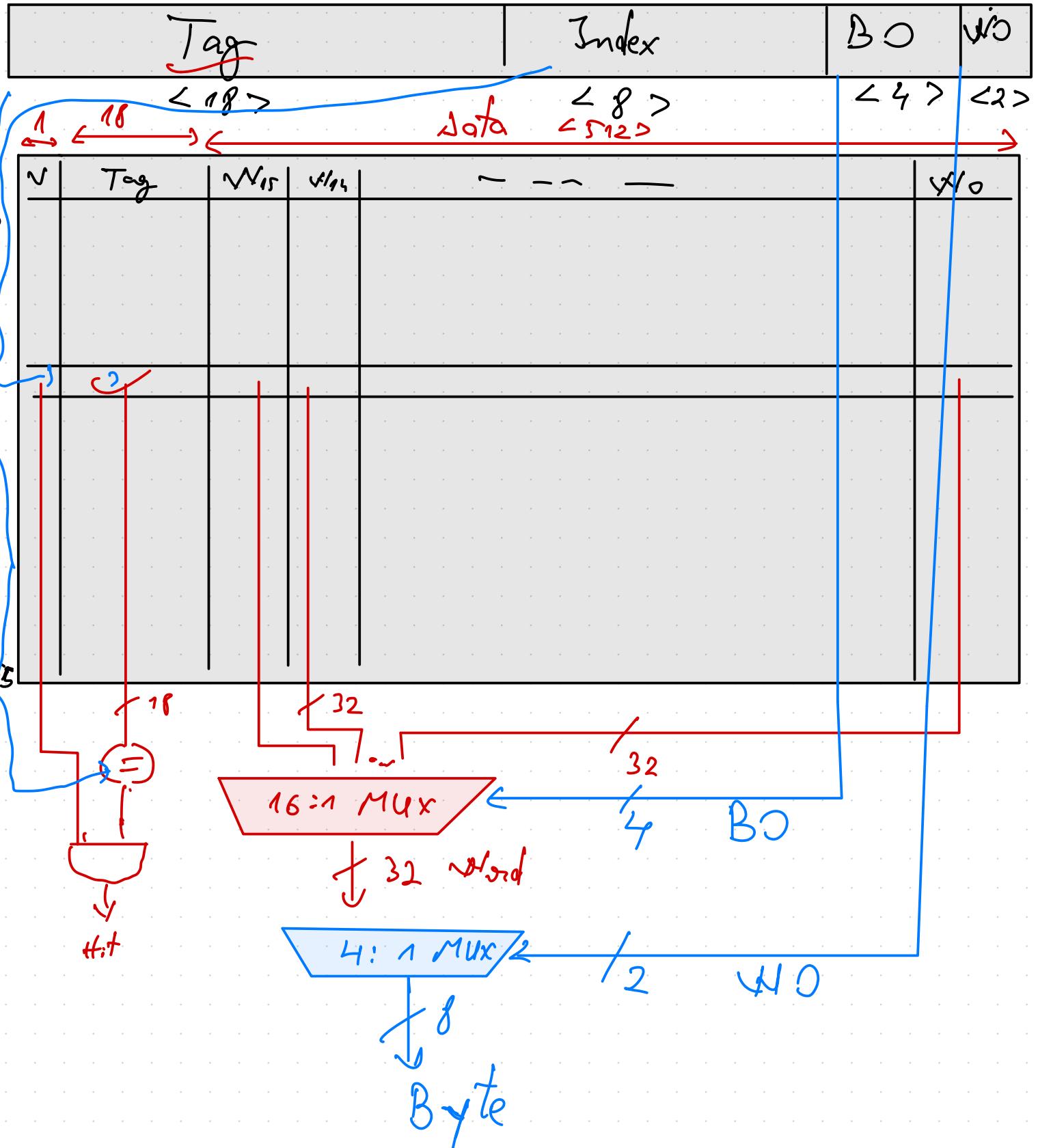
tag size = $N - m = 26 - 8 = 18$

Address Field 32 - N10 - BO - Index = Tag Size

31

15 14

6 5 4 3 2 1 0

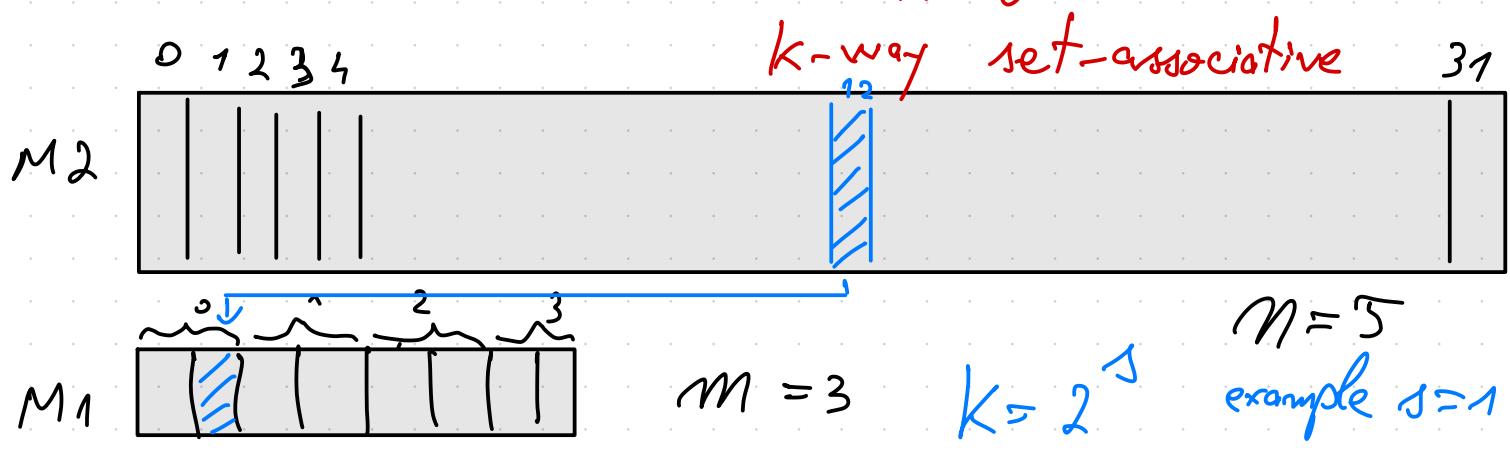


Cache Performance Benchmarks :

Mem Access \leftarrow Hit
Miss

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

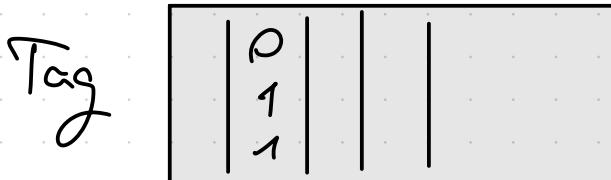
3.1.2 Set-associative mapping



$$i = j \bmod 2^{m-s}$$

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

Block Index $\underbrace{0\ 1\ 1}_{\text{Tag}}, \underbrace{0\ 0}_{1}$



"Câte linii băgăti acolo, profu?"

Mihai "Uncancelable" 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

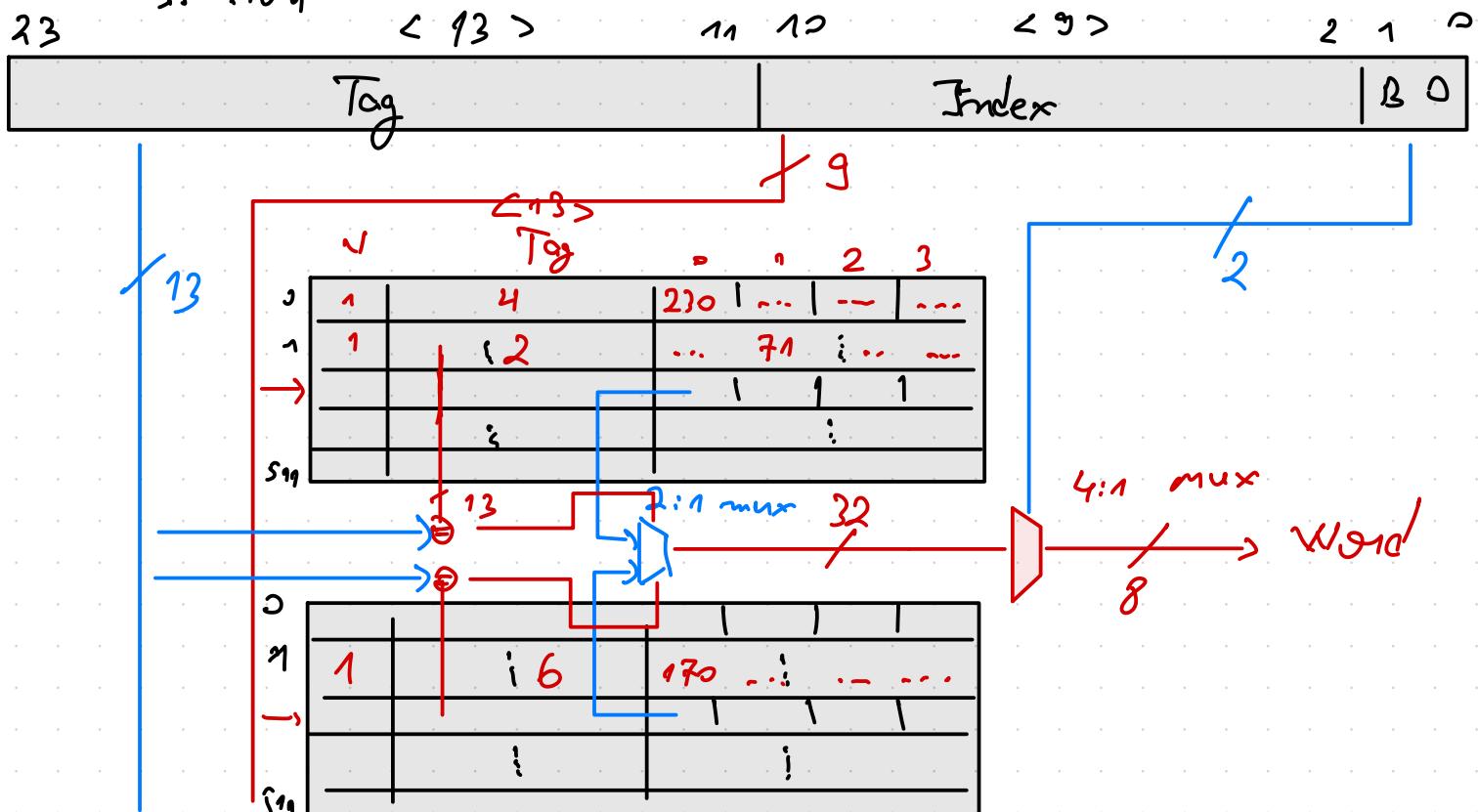
4102

71

12292

170

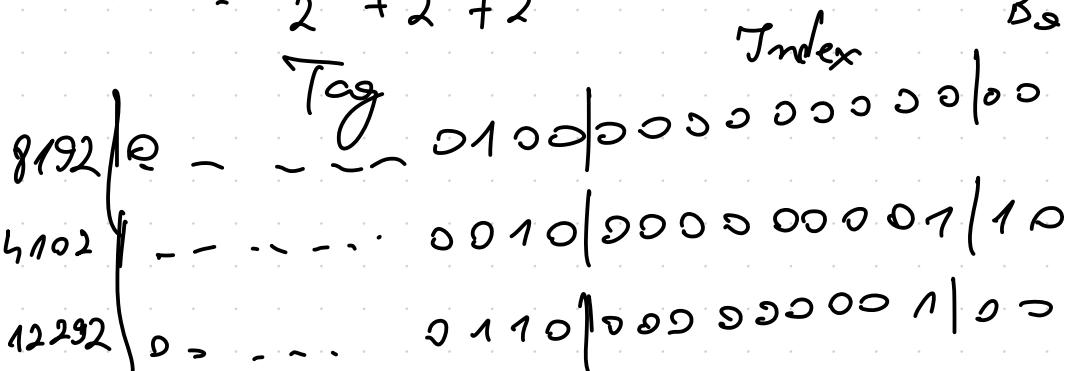
Address Word



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

$$8192 = 2^{13}$$

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



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

M. Ushesee

VAX 11/780

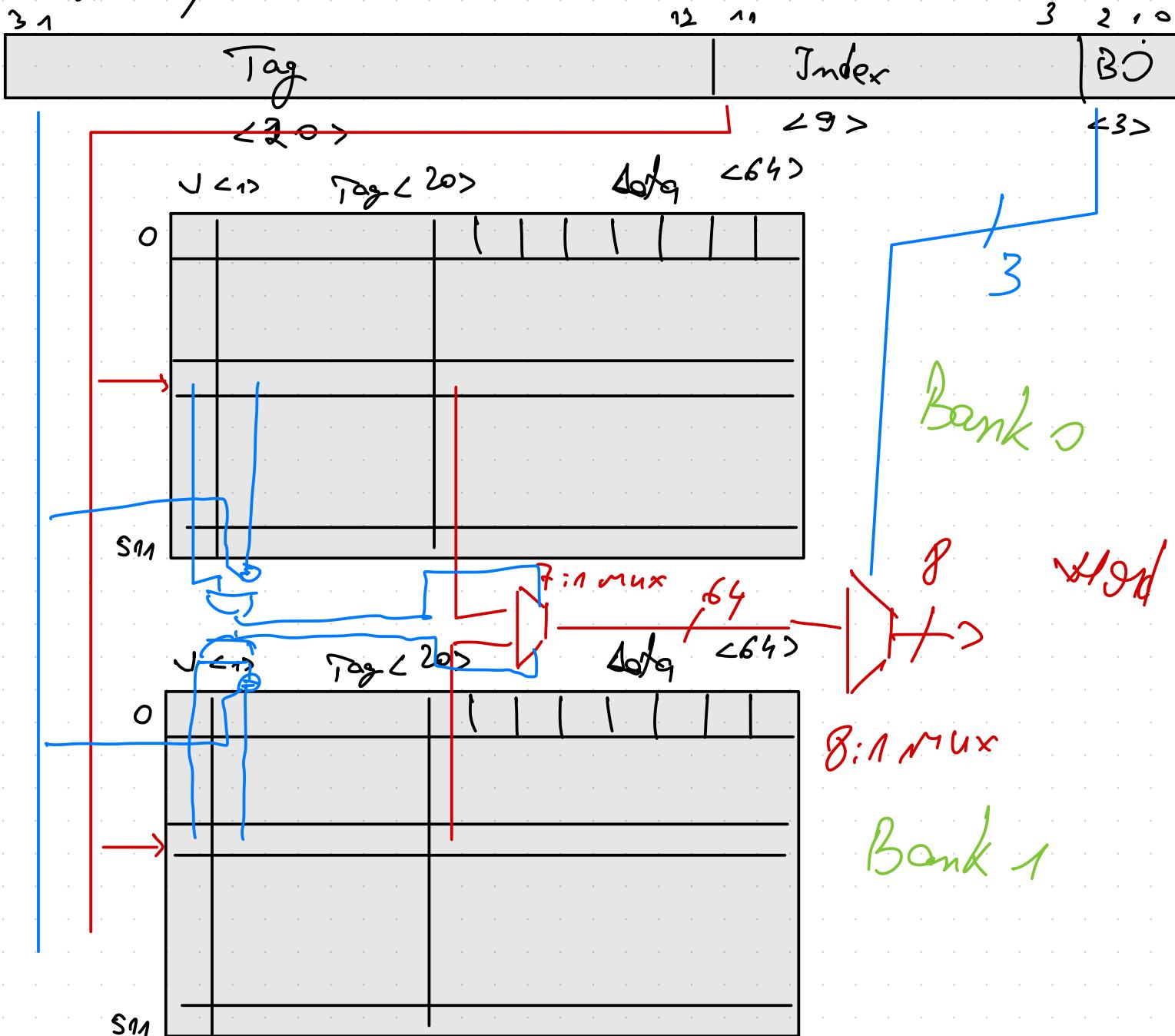
Size (MM) = 4 GiB

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
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Tag	Index	BO	WO
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$$1 \text{ block} = 2^5 \text{ words} = 2^7 \text{ B}$$

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

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

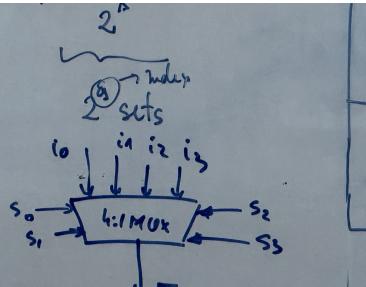
$\leftarrow 9) \text{ Index}$

(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

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

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

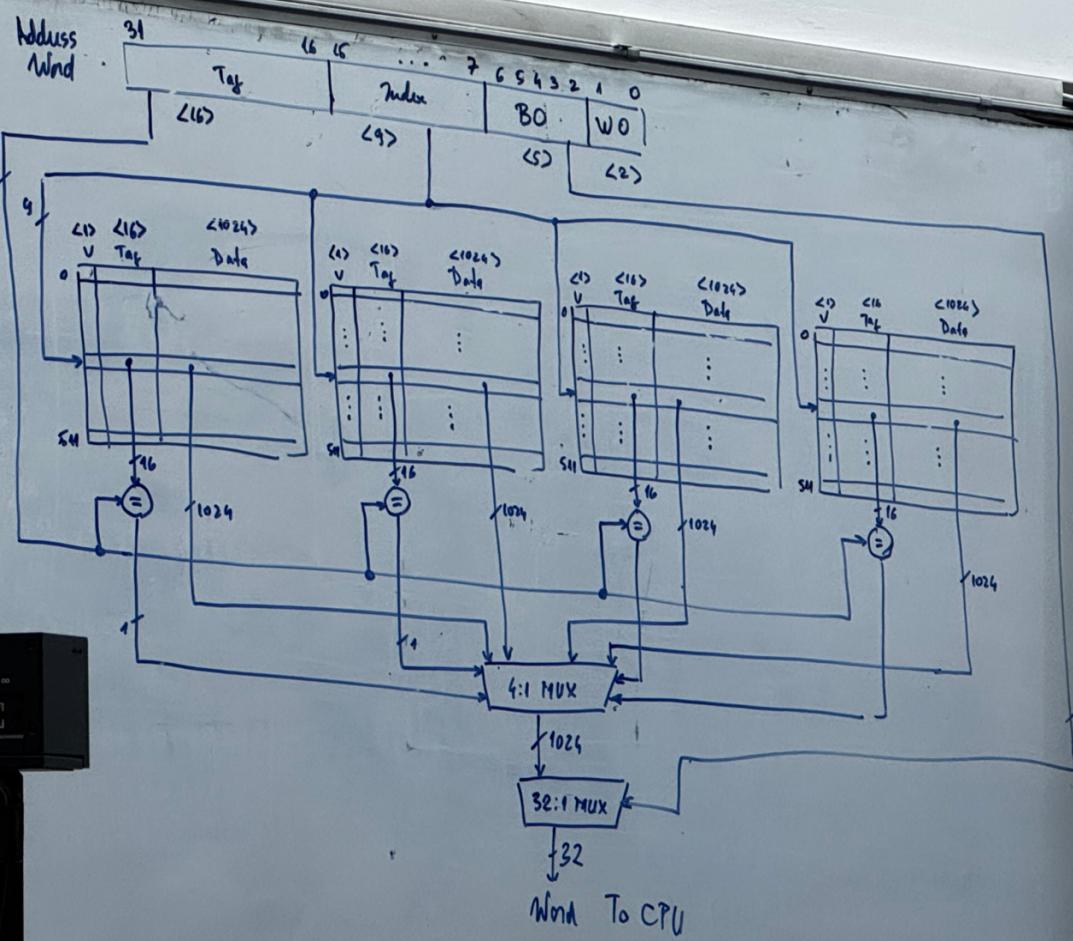
$$\text{Data size (Cache)} = 256 \text{ KiB} = 2^8 \cdot 2^{10} \text{ B} = 2^{18} \text{ B}$$

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

2^3

2^2

2^4 blocks

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

15 3 2 1 0

Tag	Index	BO
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2^5

start

stop

30

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	BO	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	MIA	20 - 23
31				24 - 27
32				28 - 31
:				32 - 35
105				36 - 39
:				40 - 43
160				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			

0			
1			
2			
3			
4			

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

