CS & IT ENGINEERING

COMPUTER ORGANIZATION AND ARCHITECTURE

Cache Organization

Lecture No.- 06

By- Vishvadeep Gothi sir

Recap of Previous Lecture

Topic Cache Mapping

Topic Direct Mapping

Topic Tag & Index

Topics to be Covered

- Topic: Direct Mapping
- Topic: Set Associative Mapping
- Topic: Fully Associative Mapping

[NAT]

mm add.

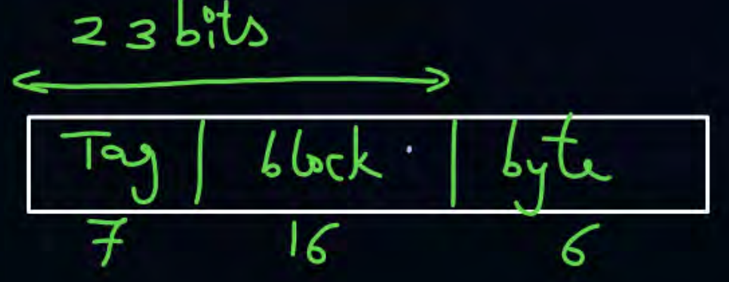
mm block no.	offset

#Q. Blocks in Main memory = 2^{23}

Blocks in Cache memory = 2^{16}

Block Size: 64 Bytes $= 2^6$ B

Direct Mapping



mm size = $2^{23} * 2^6 B = 2^{29} B$

⇓

mm add = 29 bits

No. of bits required for Byte Offset = ? 6 bits

No of bits required for main memory address = ? 29 bits

Index-bits = ? 16

Tag-bits = ? 7

Size of Tag Directory = ? $2^{16} * 7$ bits

[NAT]

1 word = 4 Bytes

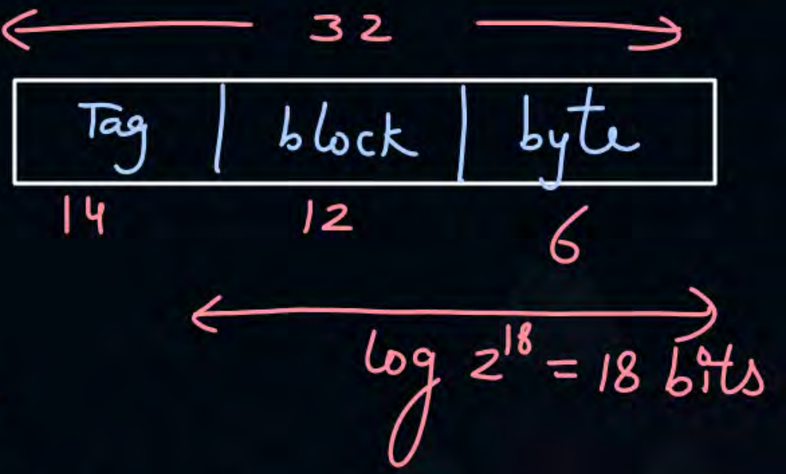
#Q. 32-bit architecture CPU

Main Memory Size = 4GB = 2^{32} B ⇒ add. = 32 bits

Cache Size = 256KB = 2^{18} B

Block Size = 16 Words = 16 * 4 = 64 B

Direct Mapping



No. of bits required for Byte Offset = ? 6

No of bits required for main memory address = ? 32

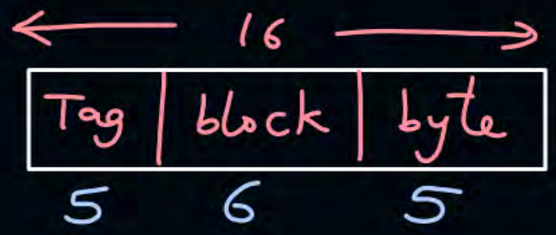
No of bits required for main memory block no. = ? 26 bits

Index-bits = ? 12 bits

Tag-bits = ? 14 bits

Size of Tag Directory = ? 2^{12} * 14 bits

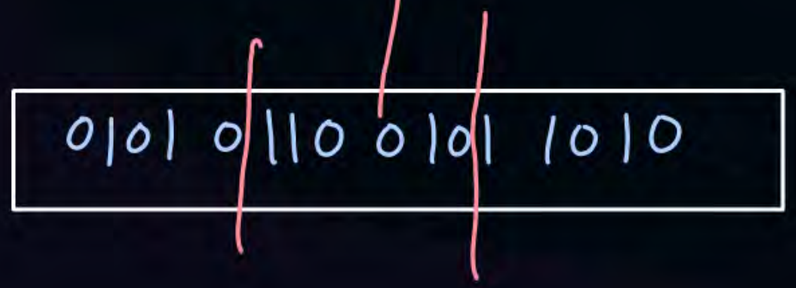
Topic : Calculating CM Block Number from MM Address



MM add. $= (6E4D)_{16}$ =

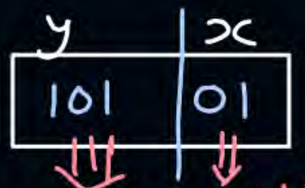
both addresses map to same cm block.

MM add. $= (565A)_{16}$ ⇒



If mm add. given in decimal:-

Binary $\Rightarrow (10101)_2 = (21)_{10}$



3 bits 2 bits

$x = 2^2$

$= 4$

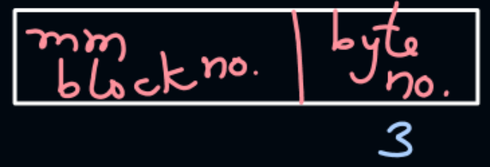
$x = 21 \% 4 = 1$

$y = \lfloor 21 / 4 \rfloor = 5$

$(101)_2 \Rightarrow (5)_{10}$

$(01)_2 = (1)_{10}$

mm add.



block size = 8 bytes = 2^3 ⇒ byte no = 3 bits

byte no. = (mm add.) % block size

mm block no. = $\lfloor$ (mm add.) / block size $\rfloor$

$$\text{cm block no.} = (\text{mm block no.}) \% \text{ no. of blocks in cache}$$

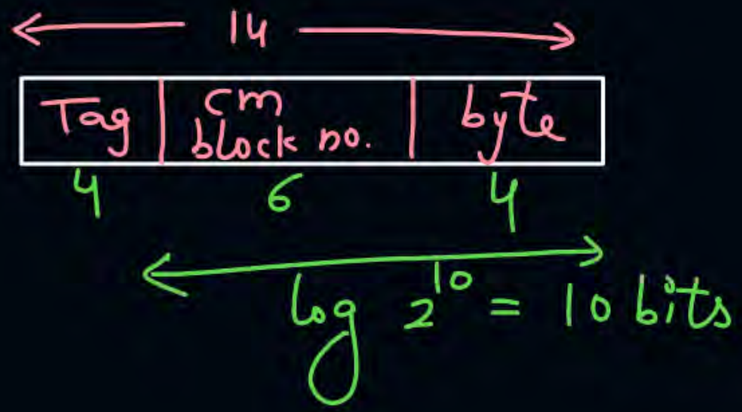
$$\text{Tag} = \left\lfloor (\text{mm block no.}) / \text{no. of blocks in cache} \right\rfloor$$

ex:- block size = 16 bytes

cm size = 1kB

mm add = 14 bits

Direct mapping

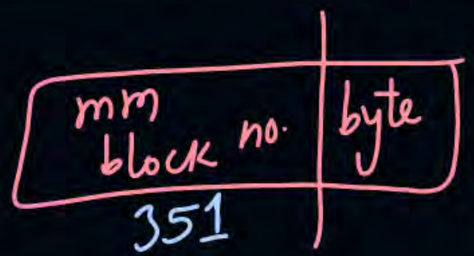


no. of blocks in cache = $2^6 = 64$

add. = $(5623)_{10}$ ⇒

mm block no = $\lfloor \frac{5623}{16} \rfloor = 351$

byte no. = 5623 % 16 = 7

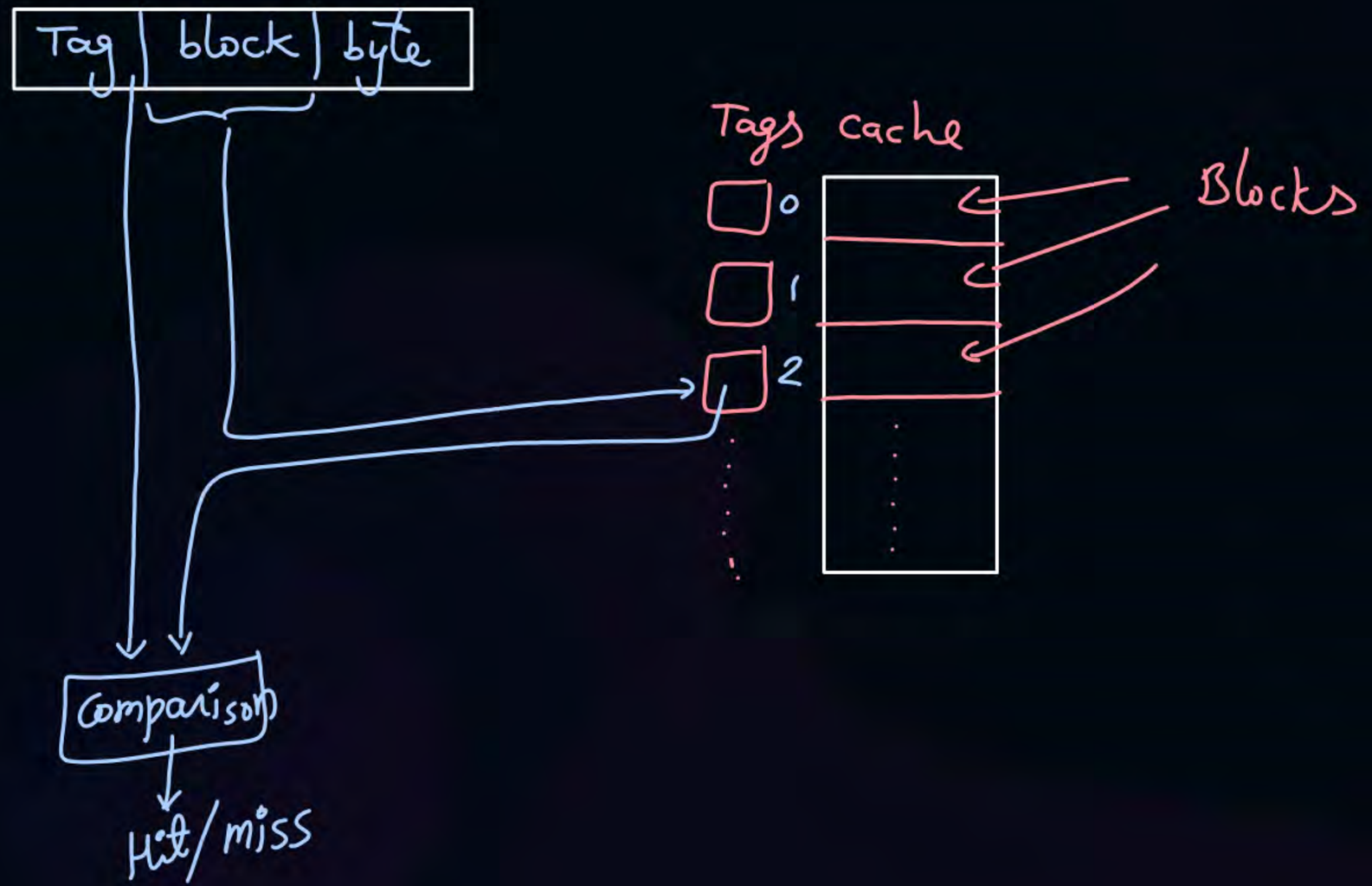


cm block no. = 351 % 64 = 31

Tag = $\lfloor 351 / 64 \rfloor = 5$

Topic : Checking Hit/Miss in Direct Mapped Cache

mm add.

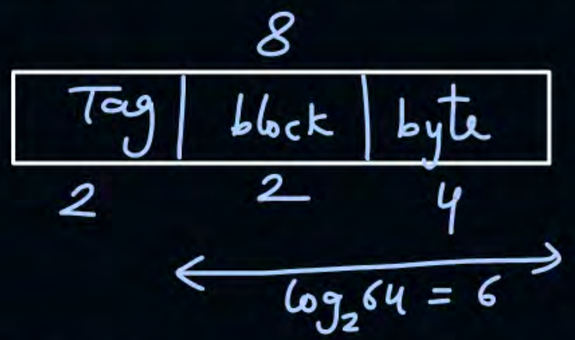


[MCQ]

#Q. Consider a 64 bytes direct mapped cache with a block size of 16 bytes. Main memory size is 256bytes. Currently in the cache, the blocks are having tags as follows:

	Block	Tag	
0	00	10	2
1	01	01	1
2	10	11	3
3	11	01	1

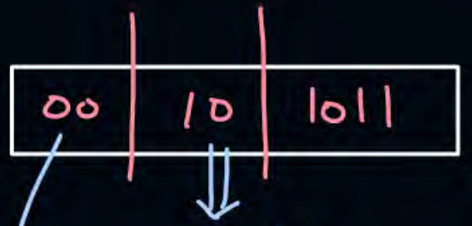
mm add. = 8 bits



Identify the correct statement with respect to the availability of the main memory data into cache?

a) Main memory byte number 243 present in cache
b) Main memory byte number 143 present in cache
c) Main memory byte number 43 present in cache
d) Main memory byte number 119 present in cache

c) $(43)_0 = (00101011)_2$



cm block no = 10

⇓

goto cache at block 10
& check tag there = 11

Tag = 00 } not matching

⇓

miss

(c) mm block no = $\lfloor \frac{43}{16} \rfloor = 2$

cm block no. = 2 % 4 = 2

Tag = $\lfloor 2/4 \rfloor = 0$

check at cm block no. 2 tag 0 is there or not

⇓

not

⇓

miss

a) $(243)_{10}$

mm block no = 15

cm block no = $15 \% 4 = 3$

Tag = $\lfloor 15/4 \rfloor = 3$ } miss

b) $(143)_{10}$

mm block no = $\lfloor 143/16 \rfloor = 8$

cm block no = $8 \% 4 = 0$

Tag = $8/4 = 2$ } hit

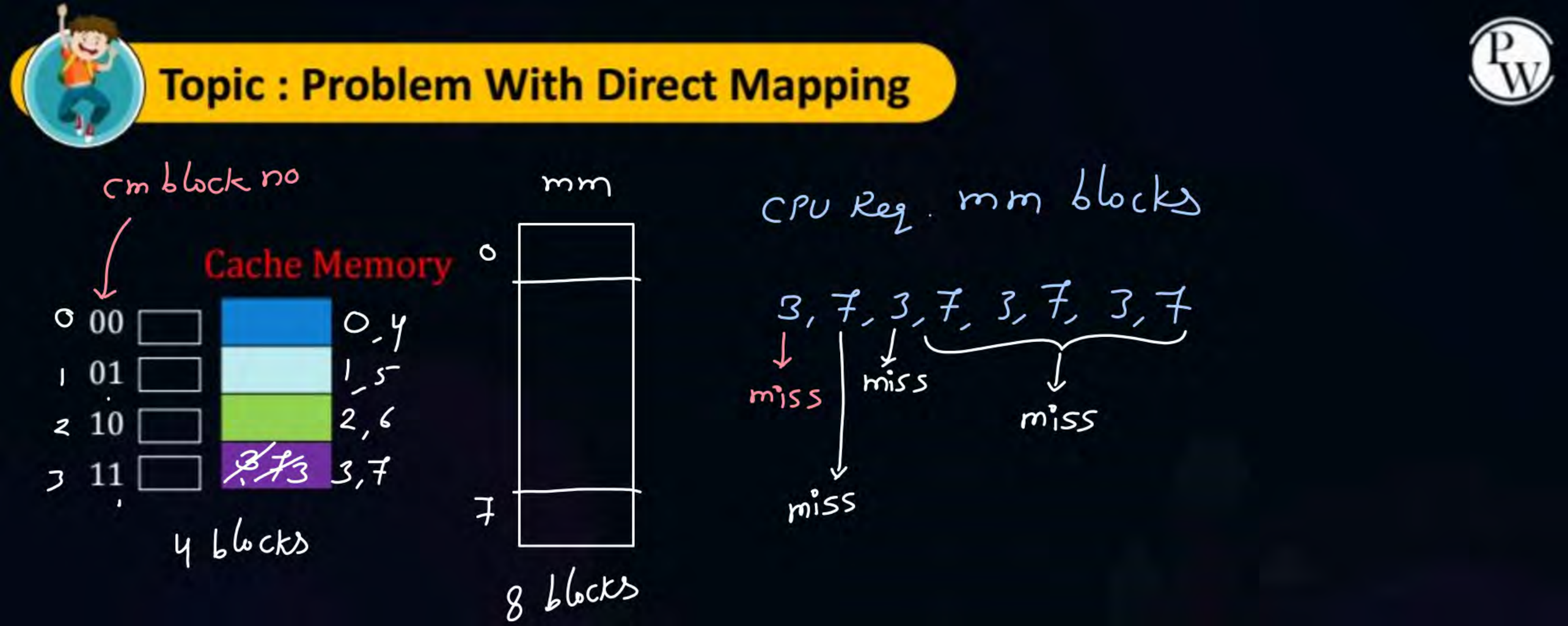
d) $(119)_{10}$

mm block no = $\left\lfloor \frac{119}{16} \right\rfloor = 7$

cm block no = $7 \% 4 = 3$

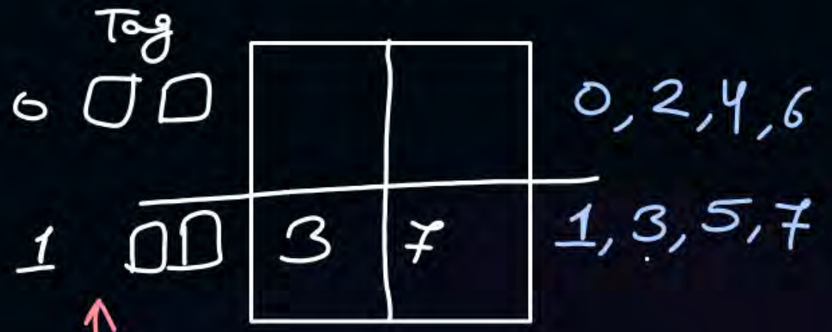
Tag = $7/4 = 1$ } hit

Topic : Problem With Direct Mapping



Topic : Set Associative Mapping

2-way set associative



cm set no. (Index)

8 blocks

CPU Req. mm block no.

3, 7, 3, 7, 3, 7, 3, 7

miss

miss

Hit

Direct mm block no.

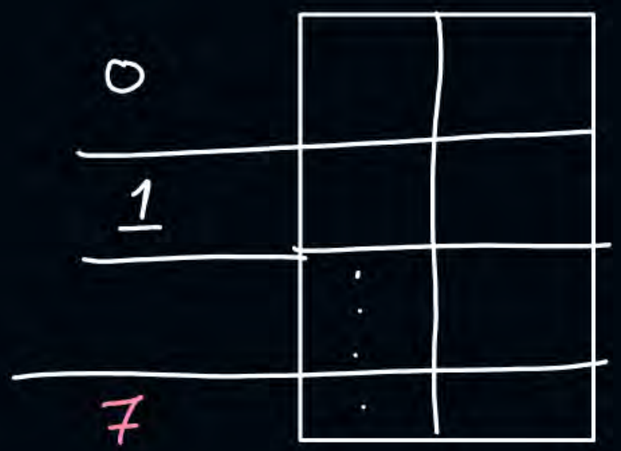
Tag	cm block no.
1	2

2-way mm block no.

Tag	Set no.
2	1

if cache ⇒ 16 blocks

2-way set ass.



$$\text{no. of sets in cm} = \frac{\text{no. of blocks in cm}}{\text{associativity}}$$

$$\text{no. of bits for cm set no.} = \log_2(\text{no. of sets in cache})$$

$$\text{cm block no.} = (\text{mm block no.}) \,\%\, \text{no. of sets in cache}$$

Topic : Set Associative Mapping

mm add.

for each block Tag info^{n} is maintained.

Tag directory Size

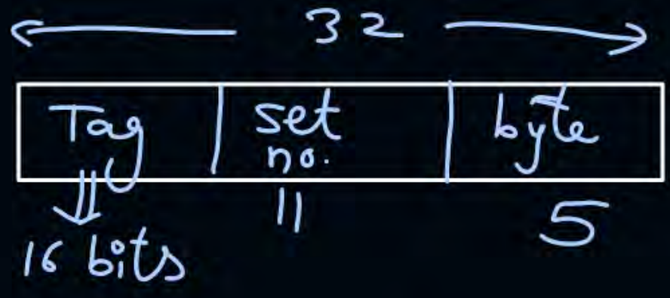
= no. of blocks * (Tag + extra bits)
in Cache

Ques) mm add = 32 bits

Cm size = 128 kbytes

2-way set associative

block size = 32 bytes $= 2^5$ B



no. of blocks in cm $= \frac{128\,kB}{32\,B} = \frac{2^{17}}{2^5} = 2^{12}$

no. of sets in cm $= \frac{2^{12}}{2} = 2^{11} \Rightarrow$ set no = 11 bits

Tag directory size

$= 2^{12} * 16$ bits

[NAT]

#Q. A computer has a 512Kbyte, 4-way set associative, write back data cache with block size of 16 Bytes. The processor sends 34 bit addresses to the cache controller. Each cache tag directory entry contains, in addition to address tag, 2 valid bits, 1 modified bit and 1 replacement bit

1. The number of bits in the tag field of an address is 17 bits
2. The size of the cache tag directory is $= 2^{15} * (17+2+1+1)$ bits $= 2^{15} * 21$ bits

34

Tag	Set	byte
17	13	4

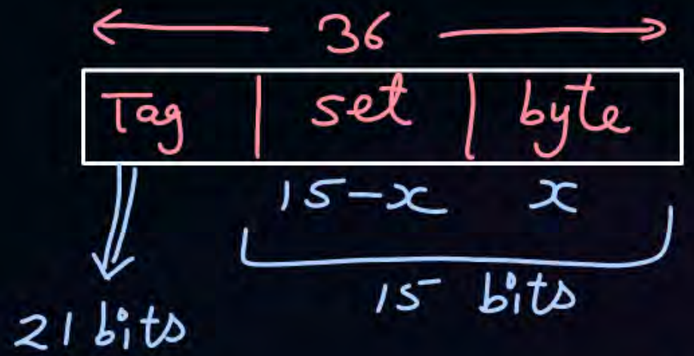
no. of blocks in cm $= \frac{512\,KB}{16\,B} = \frac{2^{19}}{2^4} = 2^{15}$

no. of sets in cm $= \frac{2^{15}}{4} = 2^{13} \Rightarrow$ set no = 13 bits

[NAT]

2^{18}

#Q. The width of the physical address on a machine is 36 bits. The width of the tag field in a 256 KB 8-way set associative cache is 21 bits ?



assume block size = 2^x bytes ⇒ byte no. = x bits

no. of blocks in cache = $\frac{256\,KB}{2^x\,B} = 2^{18-x}$

$\log_2\left(\frac{cm}{size}\right) - \log_2 k$

$\log 2^{18} - \log 8 = 15$ bits

no. of sets in cache = $\frac{2^{18-x}}{8} = \frac{2^{18-x}}{2^3} = 2^{15-x}$

k-way set associativity

set no. = $(15-x)$ bits

2 mins Summary

Topic Direct Mapping

Topic Set Associative Mapping

Topic Fully Associative Mapping

Happy Learning

THANK - YOU