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TP7: Cache Memory

1) (Direct Mapped Cache) A computer using direct mapped cache has 2^{20} words of main memory and a cache of 32 blocks, with each block containing 16 words.
   a) How many blocks of main memory are there?
   b) What is the format of a memory address as seen by the cache, that is, what are the sizes of the tag, block, and word fields?
   c) To which cache block will $0DB63_{16}$ map?
2) Suppose a computer using direct mapped cache has 2^{32} words of main memory and a cache of 1024 blocks, where each cache block contains 32 words.
   a) How many blocks of main memory are there?
   b) What is the format of a memory address as seen by the cache, that is, what are the sizes of the tag, block, and word fields?
   c) To which cache block will $000063FA_{16}$ map?
3) A computer using direct mapped cache has 2^{16} words of main memory and a cache of 64 blocks, where each cache block contains 8 words.
   a) How many blocks of main memory are there?
   b) What is the format of a memory address as seen by the cache (sizes of tag, block, and word fields)?
   c) To which cache block will $3A7C_{16}$ map?
4) (Fully Associative Cache) A computer with 2^{24} words of memory and a cache with 128 blocks, where each cache block contains 64 words.
   a) How many blocks of main memory are there?
   b) What is the format of a memory address as seen by the cache, that is, what are the sizes of the tag, block, and word fields?
   c) To which cache block will $01D872_{16}$ map?
5) Suppose a computer using fully associative cache has 2^{16} words of main memory and a cache of 64 blocks, where each cache block contains 32 words.
   a) How many blocks of main memory are there?
   b) What is the format of a memory address as seen by the cache, that is, what are the sizes of the tag and word fields?
   c) To which cache block will the memory reference $F8C9_{16}$ map?
6) A computer using fully associative cache has 2^{20} words of main memory and a cache of 64 blocks, where each cache block contains 32 words.
   a) How many blocks of main memory are there?
   b) What is the format of a memory address (sizes of tag and word fields)?
   c) To which cache block will $0B7A4_{16}$ map?

Solution

Exercise 1:

a. How many blocks of main memory are there?

+ Number of main block = $\frac{\text{total size}}{\text{blocksize}} = \frac{2^{20}}{16} = \frac{2^{20}}{2^4} = \mathbf{2^{16}\ blocks}$

b. What is the format of a memory address as seen by the cache and compute the size of the tag, block, and word field.

+ Total bits = $\log_2$(main memory in size in words) = $\log_2 2^{20}$ = **20 bits**

+ Word field = $\log_2$(block size in words) = $\log_2 16 = \log_2 2^4$ = **4 bits**

+ Block field = $\log_2$(number of cache blocks) = $\log_2 32 = \log_2 2^5$ = **5 bits**

+ Tag field = Total bits – Block bits – Word bits = 20-5-4 = **11 bits**

Tag=11	Block=5	Word=4

c. To which cache block will $0DB63_{16}$ map?

+ $(0DB63)_{16}$= (0000 1101 1011 0110 0011)$_2$

Tag	Block	Word
00001101101	10110	0011

+ Cache block = $(10110)_2$ = $\mathbf{22_{10}}$

Exercise 2:

a. How many blocks of main memory are there?

+ Number of main block = $\frac{\text{total size}}{\text{blocksize}} = \frac{2^{32}}{32} = \frac{2^{32}}{2^5} = \mathbf{2^{27}\ blocks}$

b. What is the format of a memory address as seen by the cache and compute the size of the tag, block, and word field.

+ Total bits = $\log_2$(main memory in size in words) = $\log_2 2^{32}$ = **32 bits**

+ Word field = $\log_2$(block size in words) = $\log_2 32 = \log_2 2^5$ = **5 bits**

+ Block field = $\log_2$(number of cache blocks) = $\log_2 1024 = \log_2 2^{10}$ = **10 bits**

+ Tag field = Total bits – Block bits – Word bits = 32-10-5= **17 bits**

Tag=17	Block=10	Word=5

c. To which cache block will $000063FA_{16}$map?

+ $(000063FA)_{16}$= (0000 0000 0000 0000 0110 0011 1111 1010)$_2$

Tag	Block	Word
00000000000000000001100011	11111	1010

+ Cache block = $(11111)_2$ = **31_{10}**

Exercise 3:

a. How many blocks of main memory are there?

+ Number of main block = $\frac{\text{total size}}{\text{blocksize}} = \frac{2^{16}}{8} = \frac{2^{16}}{2^3} = \mathbf{2^{13} blocks}$

b. What is the format of a memory address as seen by the cache and compute the size of the tag, block, and word field.

+ Total bits = $\log_2$(main memory in size in words) = $\log_2 2^{16}$ = **16 *bits***

+ Word field = $\log_2$(block size in words) = $\log_2 8 = \log_2 2^3$ = **3 *bits***

+ Block field = $\log_2$(number of cache blocks) = $\log_2 64 = \log_2 2^6$ = **6 *bits***

+ Tag field = Total bits – Block bits – Word bits = 16-6-3= **7 *bits***

Tag=7	Block=6	Word=3

c. To which cache block will $3A7C_{16}$ map?

+ $(3A7C)_{16}$= $(0011\ 1010\ 0111\ 1100)_2$

Tag	Block	Word
0011101	00111	1100

+ Cache block = $(00111)_2$ = **7_{10}**

Exercise 4:

a. How many blocks of main memory are there?

+ Number of main block = $\frac{\text{total size}}{\text{blocksize}} = \frac{2^{24}}{64} = \frac{2^{24}}{2^6} = \mathbf{2^{18} blocks}$

b. What is the format of a memory address as seen by the cache and compute the size of the tag, block, and word field.

+ Total bits = $\log_2$(main memory in size in words) = $\log_2 2^{24}$ = **24 *bits***

+ Word field = $\log_2$(block size in words) = $\log_2 64 = \log_2 2^6$ = **6 *bits***

+ Tag field = Total bits – Word bits = 24-6= **18 *bits***

Tag = 18	Word = 6

c. To which cache block will $01D872_{16}$ map?

+ $(01D872)_{16} = (0000\ 0001\ 1101\ 1000\ 0111\ 0010)_2$

+ Since this computer was fully associative cache, that means cache block can go anywhere (no fixed mapping).

Exercise 5:

a. How many blocks of main memory are there?

+ Number of main block = $\frac{\text{total size}}{\text{blocksize}} = \frac{2^{16}}{32} = \frac{2^{16}}{2^5} = \mathbf{2^{11} blocks}$

b. What is the format of a memory address as seen by the cache and compute the size of the tag, block, and word field.

+ Total bits = $\log_2(\text{main memory in size in words}) = \log_2 2^{16} =$ **16 *bits***

+ Word field = $\log_2(\text{block size in words}) = \log_2 32 = \log_2 2^5 =$ **5 *bits***

+ Tag field = Total bits – Word bits = 16-5= **11 *bits***

Tag = 11	Word = 5

c. To which cache block will $F8C9_{16}$ map?

+ $(F8C9)_{16} = (1111\ 1000\ 1100\ 1001)_2$

+ Since this computer was fully associative cache, that means cache block can go anywhere (no fixed mapping).

Exercise 6:

a. How many blocks of main memory are there?

+ Number of main block = $\frac{\text{total size}}{\text{blocksize}} = \frac{2^{20}}{32} = \frac{2^{20}}{2^5} = \mathbf{2^{15} blocks}$

b. What is the format of a memory address as seen by the cache and compute the size of the tag, block, and word field.

+ Total bits = $\log_2(\text{main memory in size in words}) = \log_2 2^{20} =$ **20 *bits***

+ Word field = $\log_2(\text{block size in words}) = \log_2 32 = \log_2 2^5 =$ **5 *bits***

+ Tag field = Total bits – Word bits = 20-5= **15 *bits***

Tag = 15	Word = 5

c. To which cache block will $0B7A4_{16}$ map?

+ $(0B7A4)_{16} = (0000\ 1011\ 0111\ 1010\ 0010)_2$

+ Since this computer was fully associative cache, that means cache block can go anywhere (no fixed mapping).