CEC 470: Computer Organization and Architecture

Total Points: 50

Homework 5

Due: Thursday Nov 10th at 11:59 pm

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Review Questions

1. (5 points) For a direct-mapped cache, a main memory address is viewed as consisting of three fields. List and define the three fields.
Tag – Portion of the cache address used as a unique identifier for a group of data.

Line Index – Indicates which portion of cache that will hold one block.

Block Offfset – Indicate which word to access within the block.

2. (5 points) For a set-associative cache, a main memory address is viewed as consisting of three fields. List and define the three fields.

Tag – Portion of cache set to indicate tag position in the set.

Set Index – Indicates which set to center to access its blocks.

Block Offset – Indicates which word to access within the block.

Problems

3. (5 points) Consider the following code:

```
for (i = 0; i < 20; i+ +)
for (j = 0; j < 10; j+ +)
a[i] = a[i]* j
```

a. Give one example of the spatial locality in the code.

Accessing array a[], since the consequent array accesses will be accessing memory locations that are next to each other.

b. Give one example of the temporal locality in the code.

For the inner for loop, the array accesses element a[i], as the j is incremented with each iteration since a[i] is accessed multiple times within a short time frame.

4. (5 points) A **set-associative** cache consists of 64 lines, divided into four-line sets. Main memory contains 4K blocks of 128 words each. Calculate word offset bits, set index bits and tag bits for the given set-associative cache.

Main memory = 4KB = 2^2 x 2^{10} x 2^7= 2^{19} (19 address bits total)
# of sets = 64 cache lines (2^6) / 4 lines per set (2^2) = 16 sets = 2^4 (4 set index bits)
Block size = 128 words = 2^7 bytes (7 offset bits)
19-4-7 =8 tag bits

5. (10 points) Consider a machine with a byte addressable main memory of 2^{16} bytes and block size of 8 bytes. Assume that a direct mapped cache consisting of 32 lines is used with this machine.
a. How is a 16-bit memory address divided into tag, line number, and byte number?

Main memory = 2^{16} bytes (16 address bits total)
# of lines = 32 = 2^5 (5 line index bits)
Block size = 8 bytes = 2^3 bytes (3 offset bits)
16 - 5 - 3 = 8 tag bits

b. Into what line would bytes with each of the following addresses be stored?

0001 0001 0001 1011 = line 00011
1100 0011 0011 0100 = line 00110
1101 0000 0001 1101 = line 00011
1010 1010 1010 1010 = line 10101

6. (5 points each = 20 points) Consider a computer with the following characteristics: total of 1Mbyte of main memory; word size of 1 byte; block size of 16 bytes; and cache size of 64 Kbytes.

a. For the main memory addresses of F0010, 01234, and CABBE, give the corresponding tag, cache line address, and word offsets for a direct-mapped cache.

Main memory = 2^0 x 2^{20} = 2^{20} bytes (20 address bits total)
# of lines = 64KB cache (2^{16})/16B block size (2^4) = 2^{12} (12 line index bits)
Block size = 16 bytes = 2^4 (4 offset bits)
20 – 12 - 4 = 4 tag bits

F0010: 1111 0000 0000 0001 0000
Tag- 1111
Line- 0000 0000 0001
Offset- 0000

01234: 0000 0001 0010 0011 0100
Tag- 0000
Line- 0001 0010 0011
Offset- 0100

CABBE: 1100 1010 1011 1011 1110
Tag- 1100
Line- 1010 1011 1011
Offset- 1110

b. Give any two main memory addresses with different tags that map to the same cache slot for a direct-mapped cache.
C0003

a. Offset- 0011
b. Line- 0000 0000 0000
c. Tag- 1100

5000A

d. Offset- 1010
e. Line- 0000 0000 0000
f. Tag- 0101

c. For the main memory addresses of F0010 and CABBE, give the corresponding tag and offset values for a fully associative cache.

F0010: Tag- F001
Offset- 0

CABBE: Tag- CABB
Offset- E

d. For the main memory addresses of F0010 and CABBE, give the corresponding tag, cache set, and offset values for a two-way set-associative cache.
F0010: 1111 0000 0000 0001 0000
Tag- 1111 0
Set- 000 0000 0001
Offset- 0000

CABBE: 1100 1010 1011 1011 1110
Tag- 1100 1
Set- 010 1011 1011
Offset- 1110