# King Fahd University of Petroleum and Minerals
# College of Computer Sciences and Engineering
Department of Computer Engineering

## COE 308 – Computer Architecture (T032)

## Homework # 03 (SOLUTION)

***** Show all your work. No credit will be given if work is not shown! *****

**Problem # 1:** Consider a computer system that has a cache consisting of 128 blocks. The MM contains 256K blocks, each consisting of 32 words. Answer the following assuming (i) fully associative cache, (ii) direct cache, then (iii) set associative with sixteen-block sets:

1. How many bits are needed for the MM address?
2. How many bits are needed for each of the TAG, SET, and WORD fields?

**Solution:**
MM size = $256K \times 32 = 2^{23}$

**(i) Fully Associative:**

1. # MM address bits = $\lceil \log_2 \text{MM size} \rceil = \lceil \log_2 2^{23} \rceil = 23$ bits
2. # WORDs per block = 32 words $\Rightarrow$ # WORD field bits = $\lceil \log_2 32 \rceil$ = 5 bits
   # SETs = 1 $\Rightarrow$ # SET field bits = $\lceil \log_2 1 \rceil$ = 0 bits
   # TAGs = # MM blocks / # SETs = 256K / 1 = 256K = $2^{18}$ $\Rightarrow$ # TAG field bits = $\lceil \log_2 2^{18} \rceil$ = 18 bits

**(ii) Direct:**

1. # MM address bits = $\lceil \log_2 \text{MM size} \rceil = \lceil \log_2 2^{23} \rceil = 23$ bits
2. # WORDs per block = 32 words $\Rightarrow$ # WORD field bits = $\lceil \log_2 32 \rceil$ = 5 bits
   # SETs = 128 $\Rightarrow$ # SET field bits = $\lceil \log_2 128 \rceil$ = 7 bits
   # TAGs = # MM blocks / # SETs = 256K / 128 = 2K = $2^{11}$ $\Rightarrow$ # TAG field bits = $\lceil \log_2 2^{11} \rceil$ = 11 bits

**(i) Set Associative:** Eight-block sets $\Rightarrow$ 8-way set associative

1. # MM address bits = $\lceil \log_2 \text{MM size} \rceil = \lceil \log_2 2^{23} \rceil = 23$ bits
2. # WORDs per block = 32 words $\Rightarrow$ # WORD field bits = $\lceil \log_2 32 \rceil$ = 5 bits
   # SETs = 128 / 16 = 8 $\Rightarrow$ # SET field bits = $\lceil \log_2 8 \rceil$ = 3 bits
   # TAGs = # MM blocks / # SETs = 256K / 8 = 32K = $2^{15}$ $\Rightarrow$ # TAG field bits = $\lceil \log_2 2^{15} \rceil$ = 15 bits

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**Problem # 2:** Solve problem 3.5 from the textbook.

**Solution:**

- Cache consists of 256 blocks of 16 bytes each
- Each cache block will have an associated TAG field
- The processor will generate a total of $2^{32}$ possible addresses
- The number of possible blocks generated by the processor is $2^{32} / 16 = 2^{28}$
- The # bits associated with the TAG, SET, and WORD fields are as follows:
  - # WORDs per block = 16 words $\Rightarrow$ # WORD field bits = $\lceil \log_2 16 \rceil$ = 4 bits
  - # SETs = 256 $\Rightarrow$ # SET field bits = $\lceil \log_2 256 \rceil$ = 8 bits
  - # TAGs = $2^{28} / 256 = 2^{20}$ $\Rightarrow$ # TAG field bits = $\lceil \log_2 2^{20} \rceil$ = 20 bits

| Address | TAG | SET | WORD | Hit/Miss | Comment |
|---|---|---|---|---|---|
| 000 53272105 | 53272 | 10 | 5 | Miss | |
| 000 53502120 | 53502 | 12 | 0 | Miss | |
| 000 53271130 | 53271 | 13 | 0 | Miss | |
| 000 53272106 | 53272 | 10 | 6 | Hit | Same SET & TAG as 1st reference |
| 000 53502124 | 53502 | 12 | 4 | Hit | Same SET & TAG as 2nd reference |
| 000 53261130 | 53261 | 13 | 0 | Miss | Same SET as 3rd reference but different TAG |
| 000 53272104 | 53272 | 10 | 4 | Hit | Same SET & TAG as 1st reference |

**Total # of misses generated = 4**