# Computer Systems - Architecture

## Main Memory Tutorial - Solutions

1 (a) 4G x 32-bit = 4 x $2^{30}$= $2^2$x $2^{30}$ = $2^{32}$
Therefore **32 bits** are required to uniquely address each 32-bit word.

(b) Each word is 32 bits = 4 bytes, so if main memory is byte-addressable we have
4 x 4 Gigabytes i.e. 4 x 4 x $2^{30}$ = $2^2$ x $2^2$x $2^{30}$ = $2^{34}$
Therefore **34 bits** are required to uniquely address each byte.

2 (a) **Big-endian**

| | | | |
|---|---|---|---|
| Word 0 | = | Byte 0 | Byte 1 |
| Hex | FF | 01 | |
| Binary | 1111 1111 0000 0001 | -ve => take 2's complement | |
| 2s Complement | 0000 0000 1111 1111 | is 255 in decimal => negate to get result | |

Therefore Word 0 holds the integer **–255**

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(b) **Little-endian**

| | | | |
|---|---|---|---|
| Word 0 | = | Byte 1 | Byte 0 |
| Hex | 01 | FF | |
| Binary | 0000 0001 1111 1111 | +ve => is 511 in decimal | |

Therefore Word 0 holds the integer **+511**

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3 a) RAM chips per memory module = 32bit/4bit = **8**
b) Memory Modules = Memory rows / Module Rows = 1G/256M = **4**
c) RamChips = MemoryModules x ChipsPerModule = 4x8 = **32** or (1Gx32) / (256Mx4) = **32**
d) 256M module rows = $2^{28}$. Therefore **28** address bits are needed.
e) Memory is word-addressed, 1G words = $2^{30}$ Therefore **30** address bits are needed
f) 14 **div** 256M (Module Length) = Memory Module **0**
g) 14 **mod** 4 (Memory Modules) = Memory Module **2**

4 a) If memory is byte-addressable, 1Gx4 bytes = $2^{30}$x$2^2$=$2^{32}$ Therefore **32** address bits are needed

For (b) & (c) we need *to divide the address by the number of bytes in a memory word* since we have byte addressing, e.g. in this case divide by 4 since there are 4 bytes in a 32-bit memory-word.

b) (14/4) **div** 256M (Module Length) = Memory Module **0**
**c)** (14/4) **mod** 4 (Memory Modules) = Memory Module 3 **(see below)**

5 For some types & sizes of data we would have to re-order the transmitted data. Students should be able to give examples of which types of data need to be re-ordered.

Memory layout for question 4(c)

| Module | Word | | | | Byte | | | |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 |
| | 4 | 4 | 4 | 4 | 16 | 17 | 18 | 19 |
| | 8 | 8 | 8 | 8 | 32 | 33 | 34 | 35 |
| | 12 | 12 | 12 | 12 | 48 | 49 | 50 | 51 |
| | … | … | … | … | … | … | … | … |
| 1 | 1 | 1 | 1 | 1 | 4 | 5 | 6 | 7 |
| | 5 | 5 | 5 | 5 | 20 | 21 | 22 | 23 |
| | 9 | 9 | 9 | 9 | 36 | 37 | 38 | 39 |
| | 13 | 13 | 13 | 13 | 52 | 53 | 54 | 55 |
| | … | … | … | … | … | … | … | … |
| 2 | 2 | 2 | 2 | 2 | 8 | 9 | 10 | 11 |
| | 6 | 6 | 6 | 6 | 24 | 25 | 26 | 27 |
| | 10 | 10 | 10 | 10 | 40 | 41 | 42 | 43 |
| | 14 | 14 | 14 | 14 | 56 | 57 | 58 | 59 |
| | … | … | … | … | … | … | … | … |
| 3 | 3 | 3 | 3 | 3 | 12 | 13 | 14 | 15 |
| | 7 | 7 | 7 | 7 | 28 | 29 | 30 | 31 |
| | 11 | 11 | 11 | 11 | 44 | 48 | 46 | 47 |
| | 15 | 15 | 15 | 15 | 60 | 64 | 62 | 63 |
| | … | … | … | … | … | … | … | … |