Key to Tutorial 3
Basic Operations

Exercise 1

1. Perform the following binary additions:
   - 10101010 + 11001110 = **1 0111 1000**
   - 110111 + 101100 + 110010 = **1001 0101**
   - 1110111 + 1110111 + 1001011 + 101110 = **1 0110 0111**

2. Perform the following octal additions:
   - 467 + 671 = **1360**
   - 2276 + 657 + 125 = **3302**

3. Perform the following hexadecimal additions:
   - B796 + CAFE = **18294**
   - 8979 + 3965 = **C2DE**
   - 324 + 99F + B2A = **17ED**

4. Perform the following binary subtractions:
   - 11101101010 – 110101110 = **101 1011 1100**
   - 10110001 – 10011111 = **1 0010**
   - 1101111 – 111010 = **11 0101**

5. Perform the following binary multiplications:
   - 1101101 × 10101 = **1000 1111 0001**
   - 10010010 × 101001 = **1 0111 0110 0010**

6. Perform the following binary divisions:
   - 1011100 / 101 (5 digits after the point) = **1 0010.01100**
   - 1010101010 / 1101 (4 digits after the point) = **11 0100.0111**

Exercise 2

1. How many different numbers can be made with 1 bit, 2 bits, 3 bits and *n* bits?

   1 bit → 2 numbers
   2 bits → 4 numbers
   3 bits → 8 numbers
   n bits → 2^n numbers

A memory device has 14 address lines (each address line can be either 0 or 1):

2. How many addresses are available? Use power-of-two, decimal and hexadecimal notations.

   Number of available addresses = $\mathbf{2^{14} = 16{,}384_{10} = 4000_{16}}$

3. What is the hexadecimal value of the highest address?

   Let us call the number of available addresses N. The addresses are numbered from 0 to $N - 1$.
   Therefore, the highest address is: $4000_{16} - 1_{16} = \mathbf{3FFF_{16}}$.

A memory device has 16 address lines (each address line can be either 0 or 1):

4. How many addresses are available? Use power-of-two, decimal and hexadecimal notations.

   Number of available addresses = $\mathbf{2^{16} = 65{,}536_{10} = 10000_{16}}$

5. What is the hexadecimal value of the highest address?

   Let us call the number of available addresses N. The addresses are numbered from 0 to $N - 1$.
   Therefore, the highest address is: $10000_{16} - 1_{16} = \mathbf{FFFF_{16}}$.

The memory space of a microprocessor is made up of 4 memory devices (**M1**, **M2**, **M3** and **M4**). **M1** and **M2** both have 14 address lines. **M3** and **M4** both have 16 address lines. **M1** should be located in the lowest part of the memory space, followed by **M2**, **M3** and **M4**. The lowest address of the memory space is 0.

6. Write down the lowest and highest addresses for each device in the memory space. You should draw a table and use hexadecimal notation.

Device	Lowest Address	Highest Address
M1	0000_{16}	$3FFF_{16}$
M2	4000_{16}	$7FFF_{16}$
M3	8000_{16}	$17FFF_{16}$
M4	18000_{16}	$27FFF_{16}$

7. Write down the total number of addresses. Use hexadecimal notation.

   Total number of addresses = $27FFF_{16} + 1_{16} = \mathbf{28000_{16}}$

8. Write down the minimum number of address lines required by the microprocessor.

   $27FFF_{16} = 10\ 0111\ 1111\ 1111\ 1111_2 \rightarrow$ 18 bits are required to encode the highest address.
   Therefore, the microprocessor requires at least 18 address lines.