# Lecture (01)
# Introduction: The world of Microcontrollers – I

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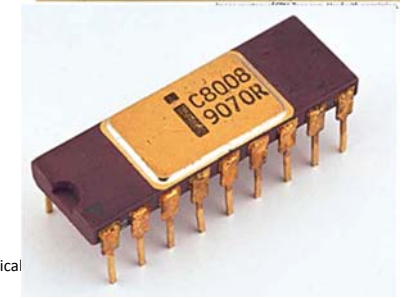
## Agenda

- Preface
- Microcontroller versus microprocessor
- World of numbers
- Logic circuits



## Preface

- In1971 Intel presents their new 4004 microprocessor It was the first 4-bit microprocessor with the speed of 6000 operations per second.
- April 1972 Intel and Texas Instruments presents their first 8-bit microprocessor called the 8008 to the market. It was able to address 16Kb of memory, had 45 instructions and the speed of 300 000 operations per second.




- Intel kept on developing it and in April 1974 it launched 8-bit processor called the 8080. It was able to address 64Kb of memory, had 75 instructions and initial price was $360.

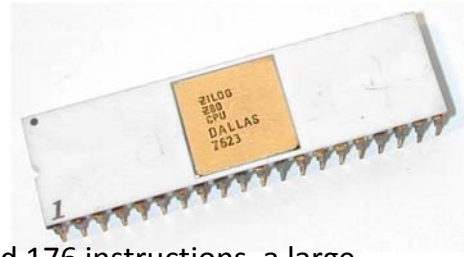

- Motorola launched 8-bit microprocessor called 6800
- Motorola was the first company that also manufactured other peripherals such as 6820 and 6850

- In 1975 MOS Technology announced that it was selling processors 6501 and 6502 (8 bits MP) at $25
- in response to the competitor, both Motorola and Intel cut the prices of their microprocessors to $69.95.


- Due to low price, 6502 became very popular so it was installed into computers such as KIM-1, Apple I, Apple II, Atari, Commodore, Acorn, Oric, Galeb, Orao, Ultra and many others.
- Soon appeared several companies manufacturing the 6502 (Rockwell, Sznertek, GTE, NCR, Ricoh, Commodore took over MOS Technology).



- In 1976 Zilog announced the Z80, a new processor had to be compatible with the 8080, i.e. it had to be able to perform all the programs written for the 8080.



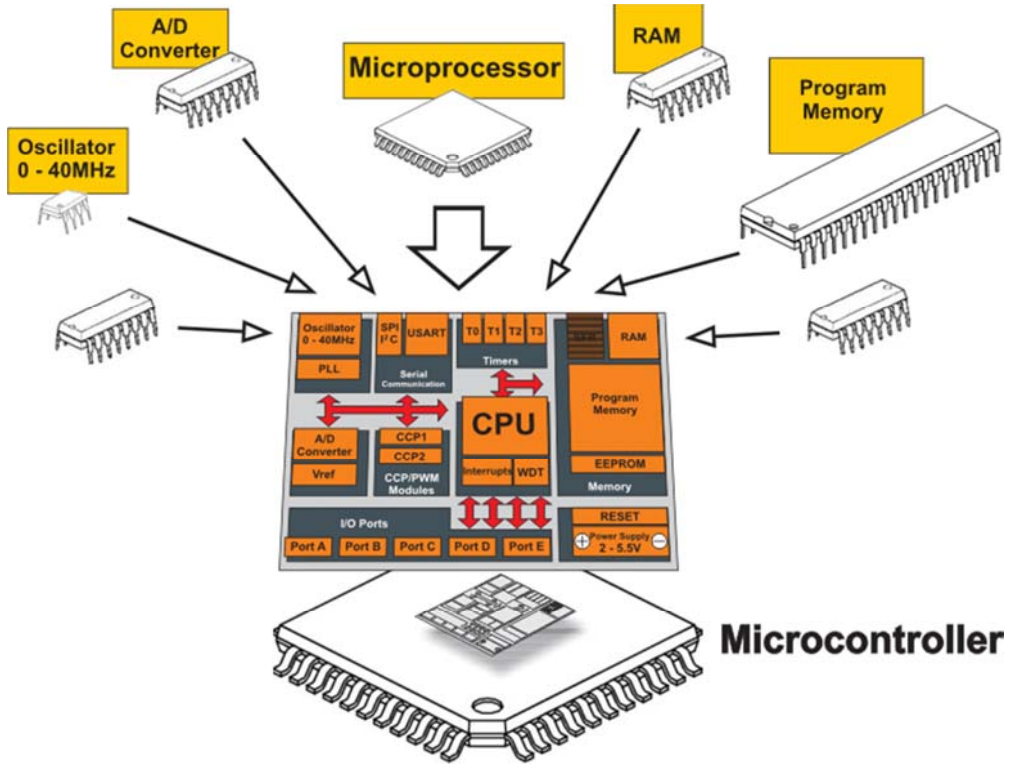

- Z80 address 64Kb of memory, had 176 instructions, a large number of registers, built in option for refreshing dynamic RAM memory, single power supply, greater operating speed etc.
- The Z80 was a great success and everybody replaced the 8080 by the Z80. Certainly the Z80 was commercially the most successful 8-bit microprocessor at that time



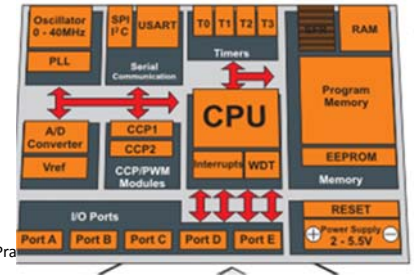
# Microcontroller versus microprocessor

- Microprocessor needs other components such as memory or for data transmission must be added to it.
- Microprocessors are considered to be powerful computer machines,
- Their weak point is that they are not adjusted to communication to peripheral environment.
- To do so microprocessors must use specialized circuits added as external chips.
- Microprocessors are the pure heart of the computers.





- On the other hand, microcontroller is designed to be all of that in one.
- No other specialized external components are needed for its application because all necessary circuits which otherwise belong to peripherals are already built into it.
- It in any case saves the time and space needed to design a device.






# World of numbers

- The whole universe can be described with ten digits only.
- But, does it really have to be like that?
- Do we need exactly ten digits?
- And why we decide to use 10 digits? Why not 100 digits or even 5 digits?
- Why do we use exactly these numbers: 100, 101 and 102 ?
- Why is it always about the number 10?
- In other words, because we use base-10 number system, i.e. decimal number system.



- What dose 764 mean?:
  - four units, six tens and seven hundreds.
  - 4 + 60 + 700.
  - 4*1 + 6*10 + 7*100.
  - 4*10^0 + 6*10^1 + 7*10^2



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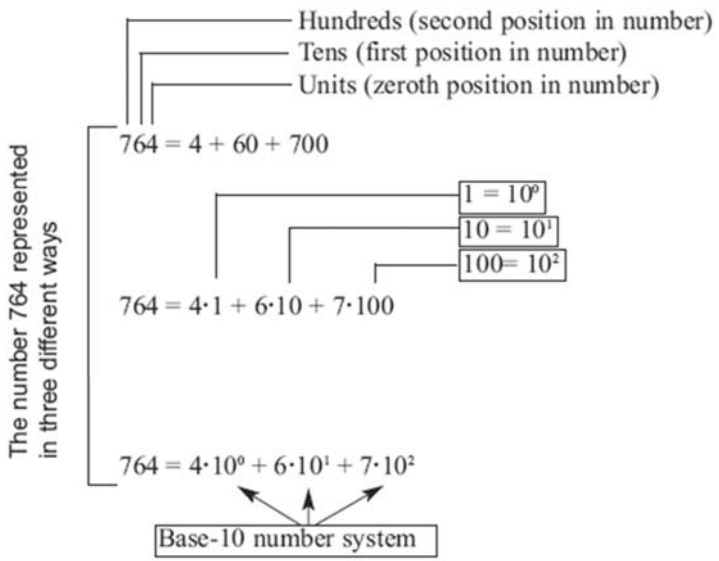
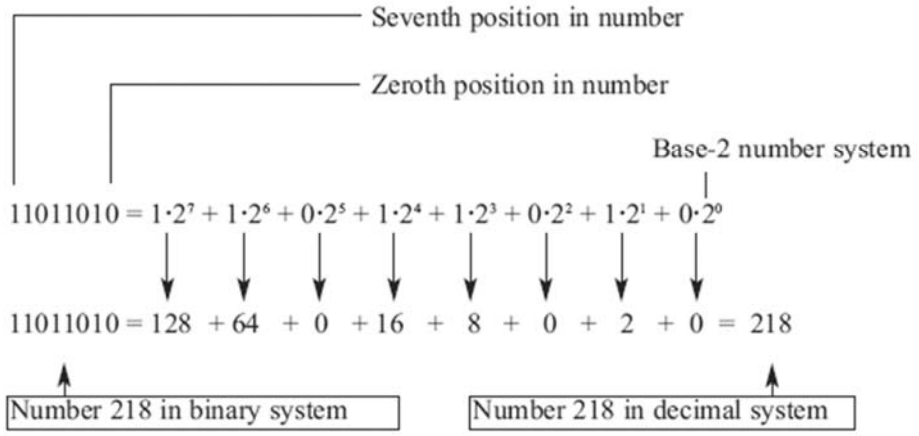


**Binary number system**

- What would happen if only two digits would be used- 0 and 1?
- if we would be restricted when comparing two sizes, i.e. if we could only state that something exists (1) or does not exist (0)?
- follow the same logic like in the previous example, but in inverse order.








- The most complicated electronic circuits cannot with accuracy determine difference between two sizes (two voltage values, for example) if they are too small (lower than several volts).
- The reasons for that are electrical noises “realistic working environment” (unpredictable changes of power supply voltage, temperature changes, tolerance to values of built in components etc.).
- Imagine a computer which would operate upon decimal numbers bers by recognizing 10 digits in the following way: 0=0V, 1=5V, 2=10V, 3=15V, 4=20V... 9=45V !? Did anybody say batteries?



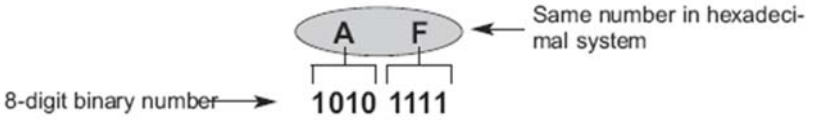
- Far simpler solution is the use of binary logic where 0 indicates that there is no voltage and 1 indicates that there is voltage. Simply, it is easier to write 0 or 1 instead of “there is no voltage” or “there is voltage”.
- It is so called logic zero (0) and logic one (1)
- All numbers are represented by two digits only and in which it is only important to know whether there is voltage or not.
- Of course, we are talking about digital electronics.

**Hexadecimal number system**

- people had many difficulties in handling binary numbers, so a new number system which facilitated work has been established.
- number system using 16 different digits, The first ten digits are the same as digits we are used to (0, 1, 2, 3,... 9) but there are six digits more, the six letters of alphabet A, B, C, D, E and F are used.
- The question why Hex? What is the purpose of this seemingly bizarre combination? ??!!!!



- Just look how perfectly everything fits the story about binary numbers.




- The largest number that can be represented by 4 binary digits is the number 1111. It corresponds to the number 15 in decimal system. That number is in hexadecimal system represented by only one digit F. It is the largest one-digit number in hexadecimal system.



- The largest number written with eight binary digits is at the same time the largest two-digit hexadecimal number.
- Have in mind that the computer uses 8-digit binary numbers. Accidentally?



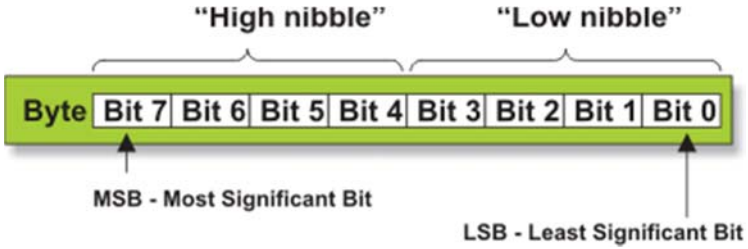
- **Hexadecimal to binary number conversion**

$$E4 = \underbrace{1110}_{E}\underbrace{0100}_{4}$$

| DEC. | BINARY | | | | | | | | HEX. |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 |
| 4 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 4 |
| 5 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 5 |
| 6 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 6 |
| 7 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 7 |
| 8 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 8 |
| 9 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 9 |
| 10 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | A |
| 11 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | B |
| 12 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | C |
| 13 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | D |
| 14 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | E |
| 15 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | F |
| 16 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 10 |
| 17 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 11 |
| ..... | | | | | | | | | |
| ..... | | | | | | | | | |
| ..... | | | | | | | | | |
| 253 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | FD |
| 254 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | FE |
| 255 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | FF |

**Bytes**

- A byte or a program word consists of eight bits placed next to each other, All mathematical operations can be performed upon them
- The largest value has the left-most bit called most significant bit (MSB). The right-most bit has the least value and is therefore called least significant bit (LSB).



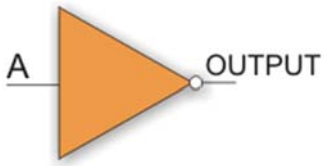



# Logic circuits

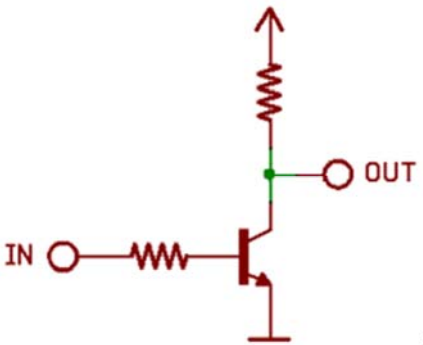
- digital integrated circuit, microcontroller and microprocessor comprise only a few different elements called "logic circuits" or "logic gates"
- the main basic logic gates are AND, OR and NOT logic circuits.
- The principle of their operation is known as Boolean algebra.
- As some program instructions used by the microcontroller perform the same way as logic gates but in form of commands.



- **NOT gate**




| A | Output |
|---|---|
| 0 | 1 |
| 1 | 0 |



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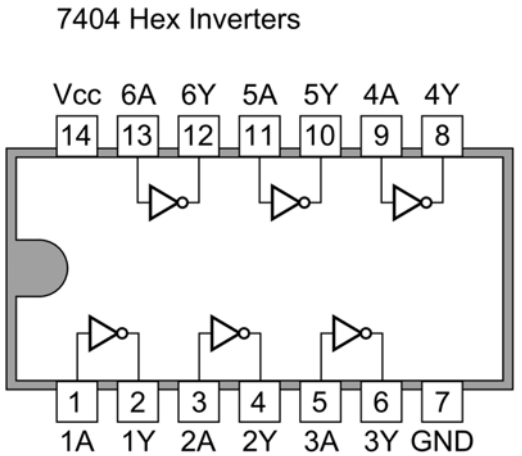
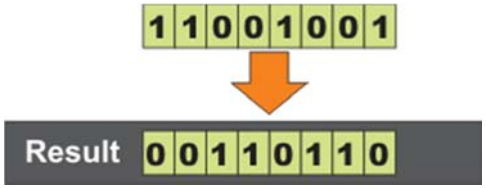
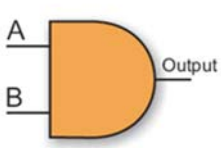


- In a program, logic NO operation is performed on one byte bits.
- The result is a byte with inverted bits. If byte bits are considered to be a number, inverted value is actually a complement of that number, i.e.
- The complement of a number is what is needed to add to it to make it reach the maximal 8 bit value (255).





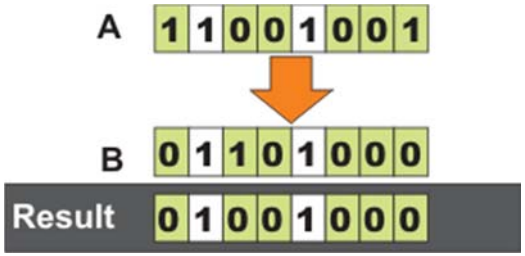

- **AND gate**
- A logic gate “AND” has two or more inputs and one output.
- A logic one (1) will appear on its output only in case both inputs (A AND B) are driven to logic one (1).




| A | B | Output |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

- In case the gate has more than two inputs, the principle of operation is the same: a logic one (1) will appear on its output only in case all inputs are driven to logic one (1).



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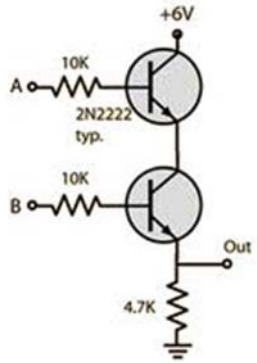
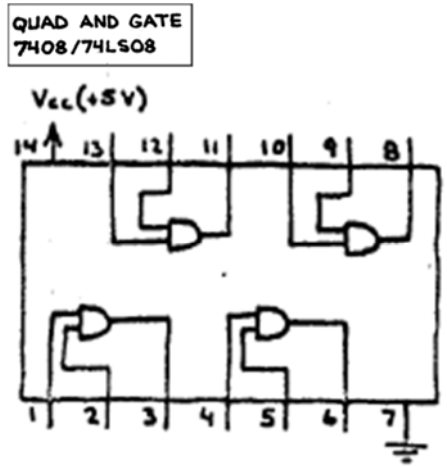
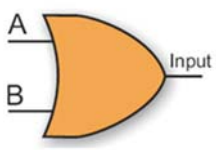


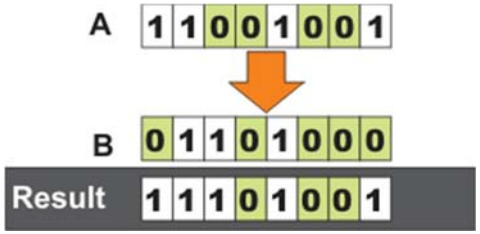



## OR Gate

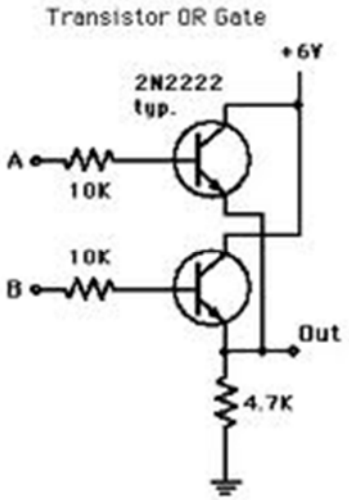
- A logic one (1) will appear on its output in case either one or another output (A OR B) is driven to logic one (1).
- Logic zero (0) will only appears in both inputs are logic zero (0)

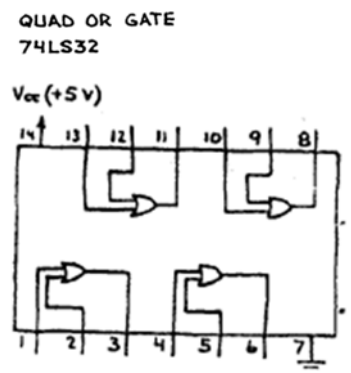



| A | B | Output |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |





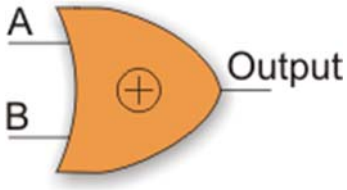



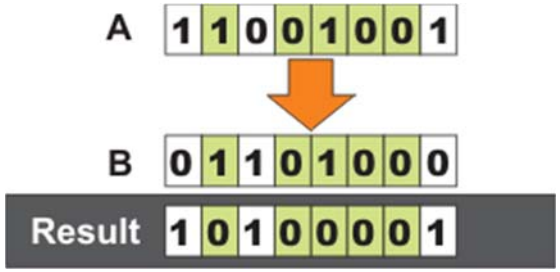





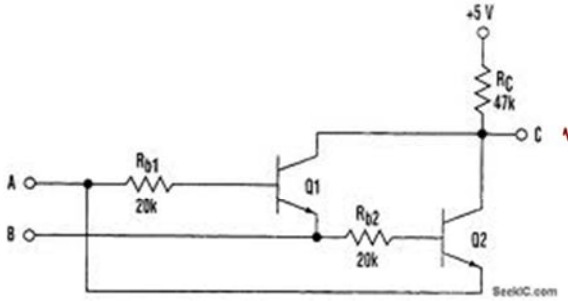

## EXCLUSIVE OR gate

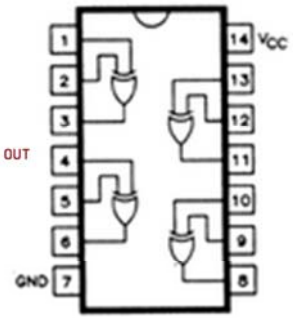
- A logic one (1) appears on its output only in case the inputs have different logic states.



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Thanks,

See you next Week, isA