Digital systems and basics of electronics

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Computer systems, microprocessors and microcontrollers - lecture 11

Calculating machines - historical background

- *abacus* - first abacus (600-500 BC - Egypt or China),
- 650 - Indians discover numeric Zero - the beginning of written calculations,
- 1100 - The first multiplication table,
- 1612 - John Napier (1550-1617) used logarithms and the decimal point (invented in the Netherlands)
- 1617 - tool to help in multiplying - ćubes Napier"
- 1622 - William Oughtred (1574-1660) creates a *logarithmic slider*,
- 1623 - Wilhelm Schickard (1592-1635) constructed four operation calculator,
- 1642 - Blaise Pascal (1623-1662) creates a "Pascalene- 5-digit *machine adding*, recognized for *first calculating machine*.

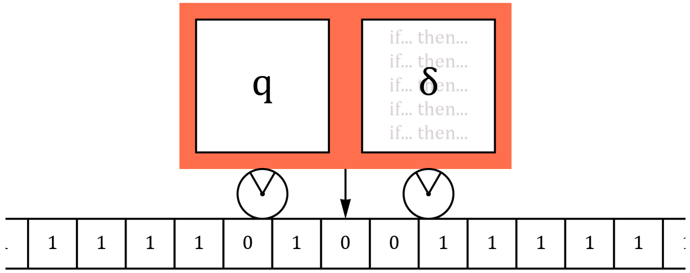
- Gottfriend Wilhelm von Leibniz (1646-1716) built a four operations calculating machine
- 1822 - Charles Babbage (1792-1871) began to construct machine for navigational calculations.
- 1842 - Ada Augusta King (daughter of Lord Byron) first programmer (she used the machine Babbage),
- 1854 - George Bool develops logical calculus,
- 1903 - Nicola Tesla patents electrical logic gates
- 1935-1938 - Konrad Zuse (1910 - 1995) builds **Z1** - *first computer on relays* (binary systemm).

Contemporary computer

- 1937 - **Alan Turing (1912-1954)** develops the theory of a universal machine (performing algorithms),
- 1941 - Zuse creates **Z3** using floating-point arithmetic,
- 1943 - *Colossus* - decrypt computer,
- 1944 - Howard Aiken (1900-1973) and engineers from IBM are building the *Harvard Mark* computer,
- 1945 - John von Neumann publishes the idea of "machine at Princeton",
- 1943-1946 *ENIAC* - the first computer on the lamps (University of Pennsylvania),
- 1948 - *EDSAC* computer based on the idea of John Neumann (Cambridge),
- 1949 - *EDVAC* - universal von Neumann computer,

- 1950 - *ACE* - computer built according to the design of Turing,
- 1951 - *UNIVAC* - the first commercially sold computer,
- 1954 - *IBM 704* - first computer with operating system,
- 1963 - *DEC PDP-5* - first minicomputer,
- 1964 - third-generation computers on integrated circuits,
- 1971 - *Intel 4004* - first microprocessor,
- 1972 - *Cray Research* - The first supercomputers,
- 1974 - *processor Intel 8080*,
- 1975 - personal computer *Altair*,
- 1981 - the beginning of the era of personal computers - the first IBM PC.

The algorithm and the Turing machine



Formalities - $\{Q, \Sigma, \delta, q_0, F\}$, where:

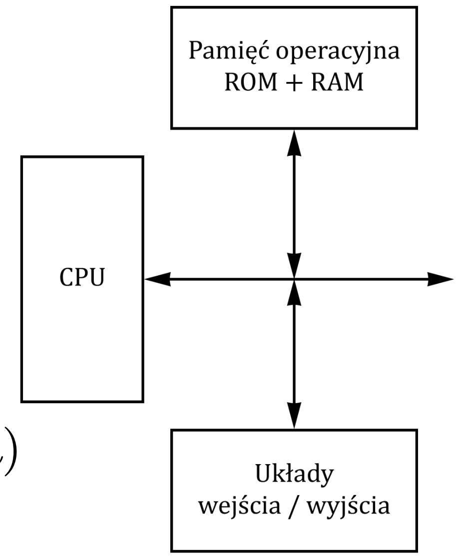
- Q - set of *state machine*,
- Σ - *alphabet* - set of tape symbols
- δ - *transition function*:

$$\delta : Q \times \Sigma \longrightarrow Q \times \Sigma \times \{R, L, N\}$$

  R, L, N corresponds to the direction of movement of the tape reader.

- q_0 - *initial state*,
- F - set of *the final states*.

Von Neumann computer - 1945



Components of the von Neumann computer:

- ALU processor
- computer memory (containing *data* and *program*)
- input - output devices

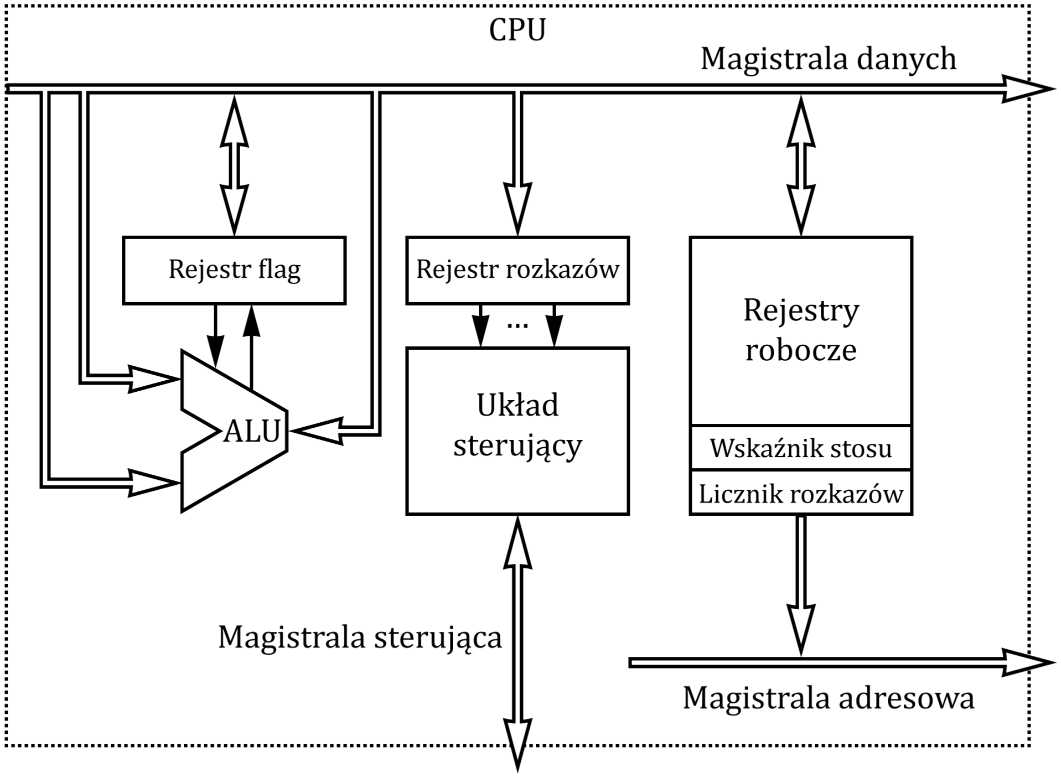
Features von Neumann computer:

- finite list of commands,
- possibility of the program and its storage in a memory (such as data)
- sequential read instructions from memory and executing.

Harvard architecture

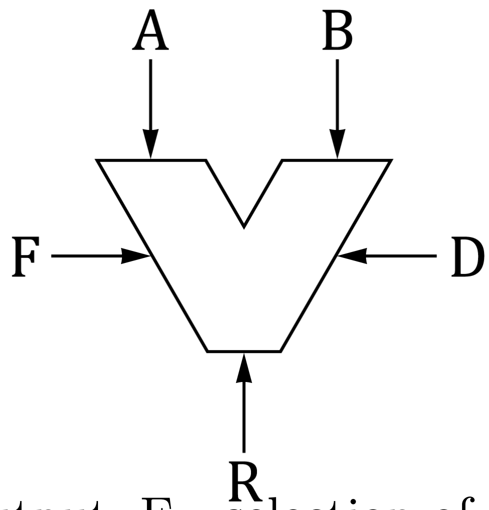
- *Data storage* is separated from the *commands memory* (otherwise than in von Neumann architecture),
- A simpler, compared to the von Neumann architecture, construction is faster performance - used in digital numerical processing,
- *Harvard architecture* is now widely used in the *single-chip microcomputers* (program is in ROM (called Read Only Memory), the data in RAM (Random Access Memory)).

Architecture CPU vs organization



- Processor architecture - Functional

ALU and control unit



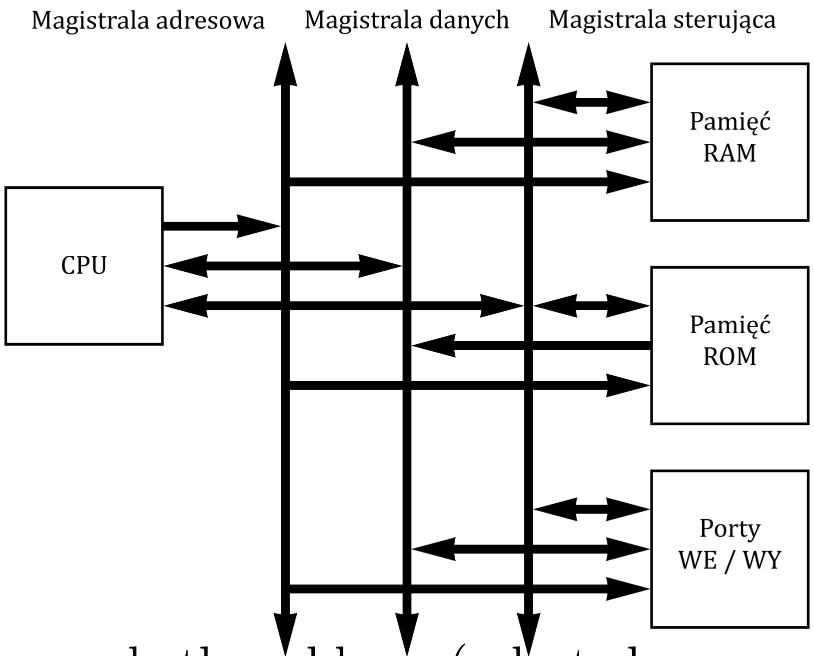
A and B - data, R - output, F - selection of operations D - exit status

- *Arithmetic-Logical Unit* combinational circuit, performed on the data in the arithmetical operations (such as addition, subtraction) and logical (eg, OR, AND),
- *control system* - decodes the commands and controls its execution.

Processor registers

- *Accumulator A, ACC* - register directly cooperating with ALU,
- *Stack Pointer SP* - indicates the end of the stack (the highlighted area of memory),
- *Programm Counter PC* - program memory address of the current instruction to execute,
- *Instruction Register* - contains the command code executed command,
- *Flags Register* - contains a Flags (bit tags) can be set depending on the result operation performed (eg, excess, zero parity bit),
- *General Purpose Registers* - for general purposes.

Buses of μ-C



- *address bus* - sends the address (selected memory cell or I / O device)
- *data bus* - transfers data between the μP a memory or I / O device)
- *system bus* - provides control signals.

Instruction cycle

Format command:

op code	arguments

Instruction cycle:

- *fetch opcode* - get to the register command command code. command codes are stored in memory as data (von Neumann architecture),
- *decode command* - interpretation of the loaded code command (usually a byte) as command from the command list processor,
- *execute a command* - loads more arguments command, depending on the particular command execution over the operation of the control system. Save the result in memory external processor or register.

Features CISC architecture

CISC *Complex Instruction Set Computers* – name of the architecture of microprocessors with the following characteristics:

- The presence of complex, specialized instruction - require from a few to several machine cycles,
- A wide range of addressing modes (complex structure of address decoders),
- Relatively long list of processor instructions.

Disadvantages of CISC architecture:

- too long list of commands - some of them are rarely used,
- too much time is wasted on operations rewriting from memory to registers and vice versa,
- generally low efficiency in numerical calculations.

Features of RISC architecture

RISC *Reduced Instruction Set Computers* - name of the architecture of microprocessors with the following characteristics:

- Reduced number of instructions to a minimum,
- Reduce addressing modes, allowing instruction codes are simpler, more unified, (simplifies the instruction decoder),
- Reducing communications between the memory and the CPU,
- *Pipelining* (called pipelining) - parallel execution of orders.

Currently popular processors developer's perspective are seen as CISC, but their core is a RISC-head. Orders are broken down into CISC microcode (called microops), which are then performed by RISC-executive head block.

Microcontrollers μC

Microcontroller - computer implemented in a single chip, comprising a central processing unit (CPU), RAM, in general, the program memory and extensive input-output systems.

The term microcontroller comes from the main area of application, which is controlled electronic devices.

Construction of microcontroller

A typical microcontroller comprises:

- calculating unit (ALU) - mostly 8-bit,
- data memory (RAM),
- Program Memory,
- Universal input ports - some of these ports may have alternative functions, selectable programmatically
- controllers serial or parallel (UART, SPI, I2C, USB, CAN, etc.)
- Analog-to-digital or digital-to-analog
- Timers
- control system work properly (watchdog)
- internal non-electrical sensors (eg temperature)

microcontroller clocking

The system clock of the microcontroller can be clocked:

- *external signal treated* (solution often used in large systems requiring synchronous collaboration of many individuals),
- *own generator*, requiring the connection of external retaining elements clock frequency (it is mostly quartz resonator and two capacitors)
- *internal arrangement treated*, which does not require connecting additional components

Modern microcontrollers achieve clock frequencies up to several hundred MHz, but in most timing applications may be much slower.

Programming languages μC

- High level languages (eg. VB, C, Java)
- Assembler

Programming methods μC

ROM program memory can be programmed in three ways:

1. *High Voltage Programming* or programming method introduced over 15y.o. ago programmable memory EPROM using signals 12V - requires the programmer.
2. *ISP (In-System Programmable)* which does not require removal from the system memory in which is running.
3. *Bootloader* - after reset μC program is run located in the Bootloader, which through bandwidth (eg serial port) connects to a host computer, retrieves the program code and place it in a dedicated the ROM area.

Review of current microcontrollers

The most popular microcontrollers:

1. The undisputed standard for mass market company imposed *Intel*, which introduced market microcontroller *8051*,
2. Very popular are also microcontrollers *business AVR Atmel* - on the basis Laboratory classes will be conducted,
3. *PIC* business *Microchip Technology*,
4. other.

Microcontrollers AVR ATmega328

A detailed description in the data sheet. To be continued.

Task for laboratory

1. Write a program which after reset, via a serial link will send the message "Hello world",
2. Run the calculator performs basic arithmetic operations on two operands in infix notation. Each event (including numbers and signs) should be confirmed by pressing enter.
3. Run the calculator performs basic arithmetic operations on two operands in infix notation that reads the entire expression and makes its analysis.