Digital systems and basics of electronics

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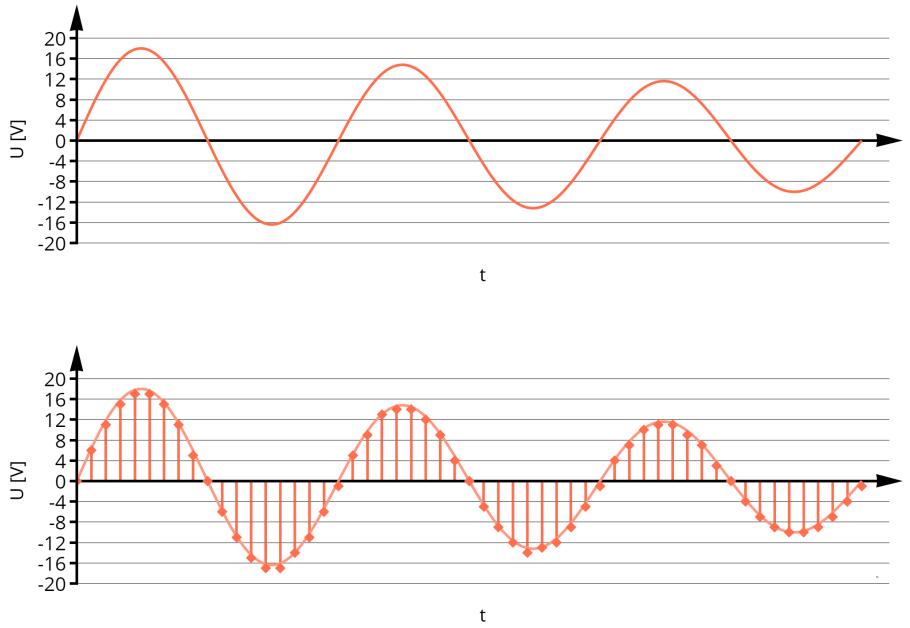
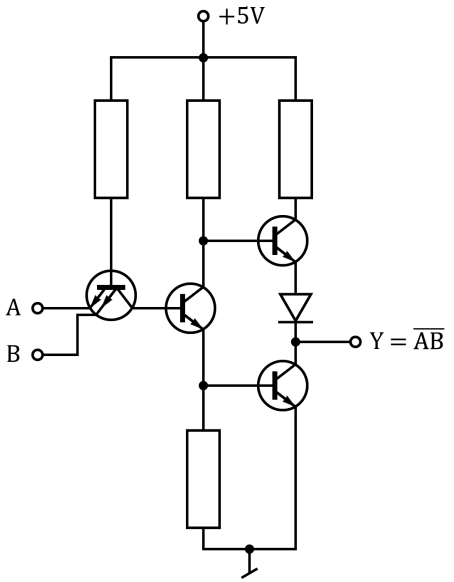
Microcontroller peripherals - lecture 13

Analog and digital signals



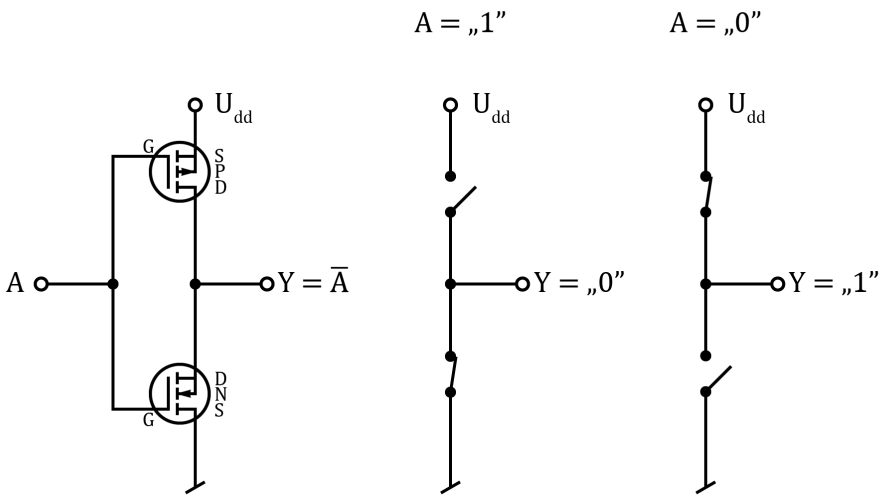
- *Analog signal* - a signal that can take any value from the continuous range,
- *Discrete signal* - a signal created by sampling a continuous signal,
- *Binary representation* - binary sample reading.

Digital signal - TTL



- TTL circuits are made of bipolar transistors and are supplied with 5 V DC.
- When the potential is from $0V$ $div 0.8V$ (in relation to ground) the TTL signal is low - **logic 0**.
- For a potential between $2V \div 5V$ is high - **logic 1**.
- When the voltage value is in the range of $0.8V \div 2V$ - the signal is undefine

Digital signal - CMOS



- CMOS circuits are made of MOS transistors with the opposite type of conductivity and connected in such a way that only one of them conducts in a logical state,
- CMOS systems are relatively simple and cheap to produce, enabling very high packing densities,
- Digital circuits made in CMOS technology can be supplied with $3 \div 18V$,

- They practically do not receive static power, only when the logical state changes,
- Logic levels are similar to supply voltages (common - logic “0”, supply “1”). Sometimes the percentage classification - “0” - applies to voltages in the range of $0 - 30\%$, “1”- $70 - 100\%$.

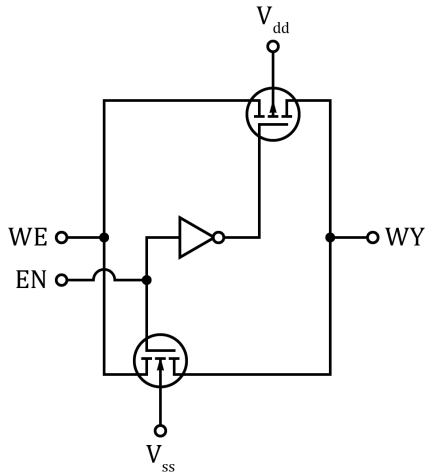
Low Voltage Circuits

- Currently there is a clear tendency to reduce the supply voltage,
- A series of CMOS digital circuits manufactured for $3.3V$ are produced, $2.5V$ or even $1.8V$,

Third logical state and open collector gates

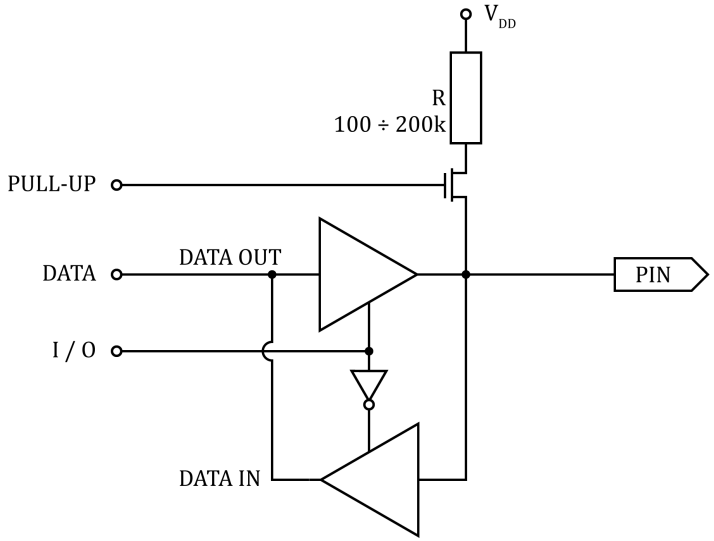
- In addition to logical '0' and logical '1', there is a third logical state - **high impedance**,
- When the system point is not galvanically connected to the digital system, it is in **in a high impedance state**,
- In order for a point of the circuit being in a high impedance state to be treated as logical '0' or '1', it should be connected via a resistor to ground or power supply, respectively. Resistors of this type are called **pull up resistor**,
- Logic gates are being built, whose output may remain in a high impedance state.

Transmission gates



- In addition to standard gates in CMOS technology, *transmission gates* are produced, which can be treated as an analog key,
- This gate consists of two complementary transistors connected in parallel and an inverter that provides gate control in counter-phase.
- Multipliers and demultiplexers are made in this technology, which can also switch analog signals - see documentation 4051.

Input / output port - operating mode selection



- Change of function from output to input:
  - blocking or unblocking the buffer (I / O signal),
  - the ability to activate the pull-up circuit (PULL-UP signal),
- Possible output states:
  - LOW state,
  - HIGH state,

Software configuration of the I / O port

- Set the functions of individual pins:
  - *pinMode(13, OUTPUT);* - setting 13 pin as the output,
  - *pinMode(14, INPUT);* - setting 14 pin as the input,

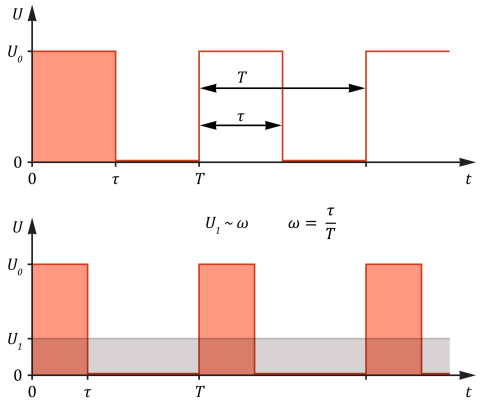
  A pin can only have one role - either input or output
- The current efficiency of a single pin is $40mA$ (both positive and negative),
- If the Pin is configured as an output it cannot be connected directly to ground or power supply,

Control signal standards

- Some control signal standards are mandatory (universal) for different brands of equipment, but some companies may use their own standards.
- The most popular control signal standards:
  - PWM (universal)
  - PCM (universal)
  - PPM (universal)
  - SPI_RX (universal)
  - SBUS (Futaba, Frsky)
  - IBUS (Flysky)
  - MSP (Multiwii)
  - other

PWM - Pulse-Width Modulation)

- *Pulse fulfillment factor* is the ratio of the pulse duration to the period of that pulse $\omega = \frac{\tau}{T}$,



- PWM modulation through the fill factor determines the amplitude (usually) of the signal,
- Converts a digital signal to an analog signal through a low-pass filter (integration)
- Widely used in engine speed control, in microprocessor system

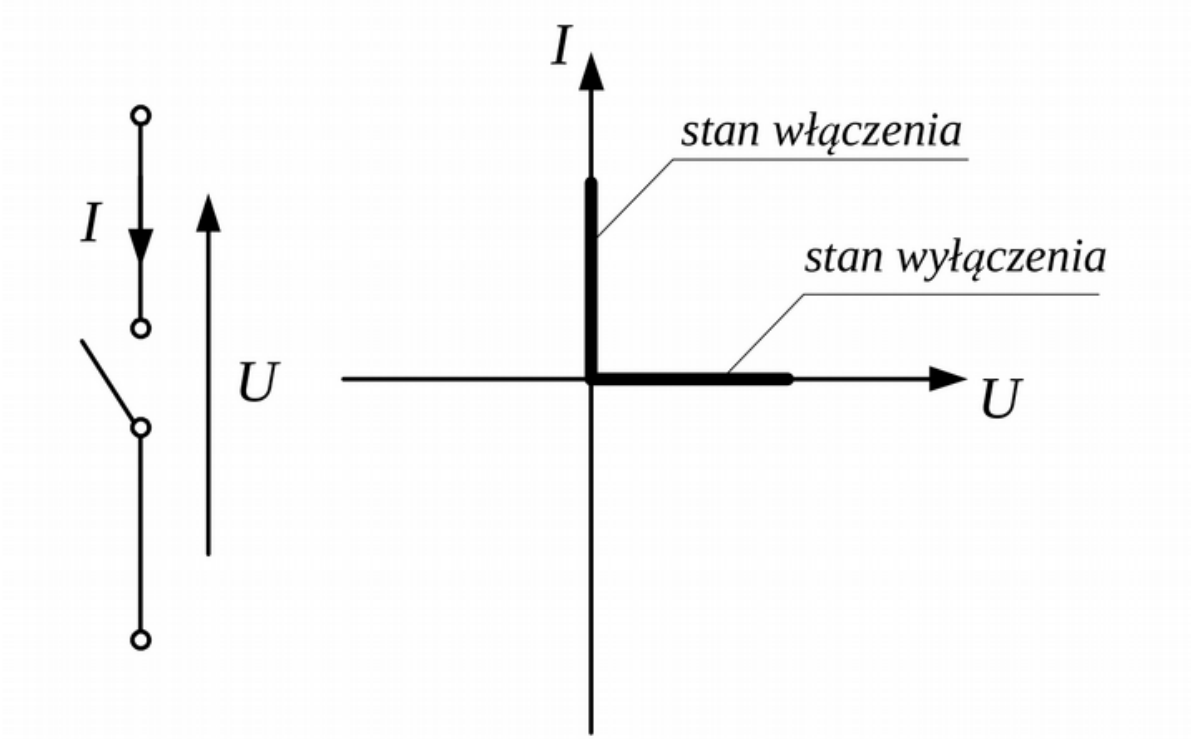
Servos

- *Modeling servo* - is controlled using three wires: ground (black or yellow), power supply (red) and control (brown),
- Servo control is done impulsively. The pulses occur at intervals of $20ms$ (50 Hz) and vary from 1 to $2ms$ in width. The pulse width corresponds to the angle of rotation:
  - Pulse width $1,5ms$ - **neutral position** (90°),
  - Pulse width $1,25ms$ - position (0°),
  - Pulse width $1,75ms$ - position (180°),

PPM - Pulse Position Modulation

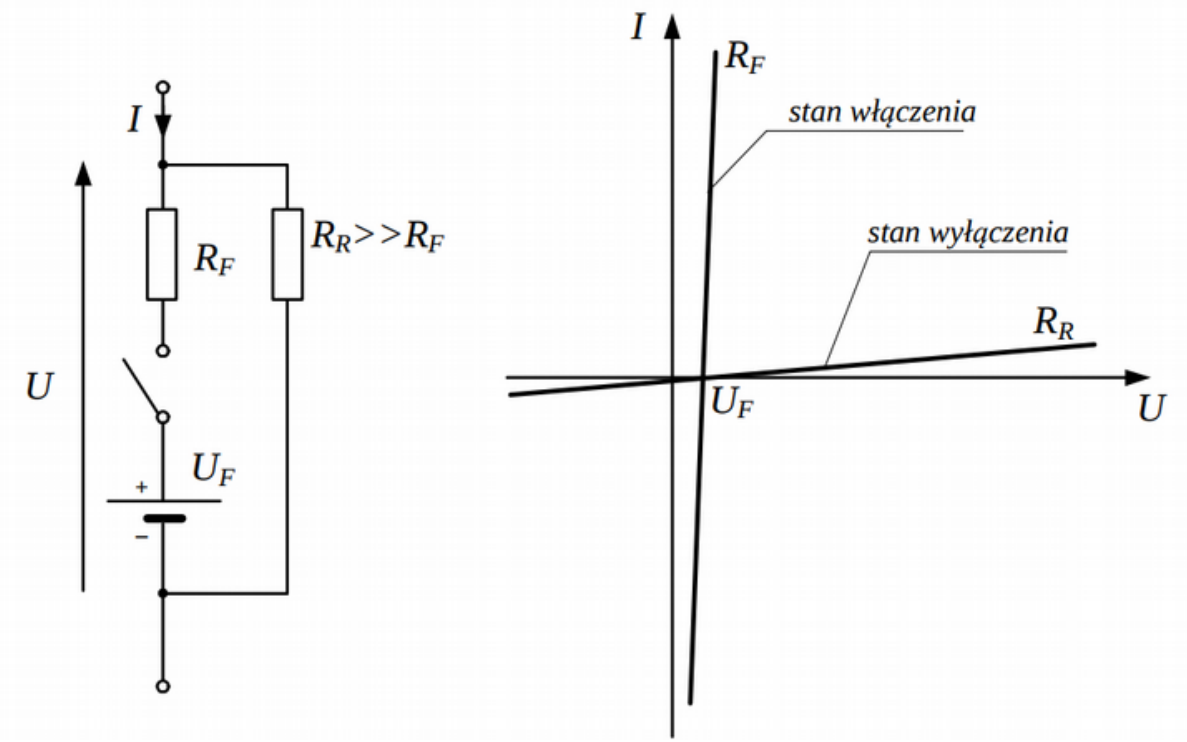
- PPM also known as CPPM or PPMSUM.
- The advantage of PPM is that only one signal wire is needed for several channels (usually 8 channels max.) Instead of many individual wires
- while the PPM signal is analog,

Transistor key - ideal



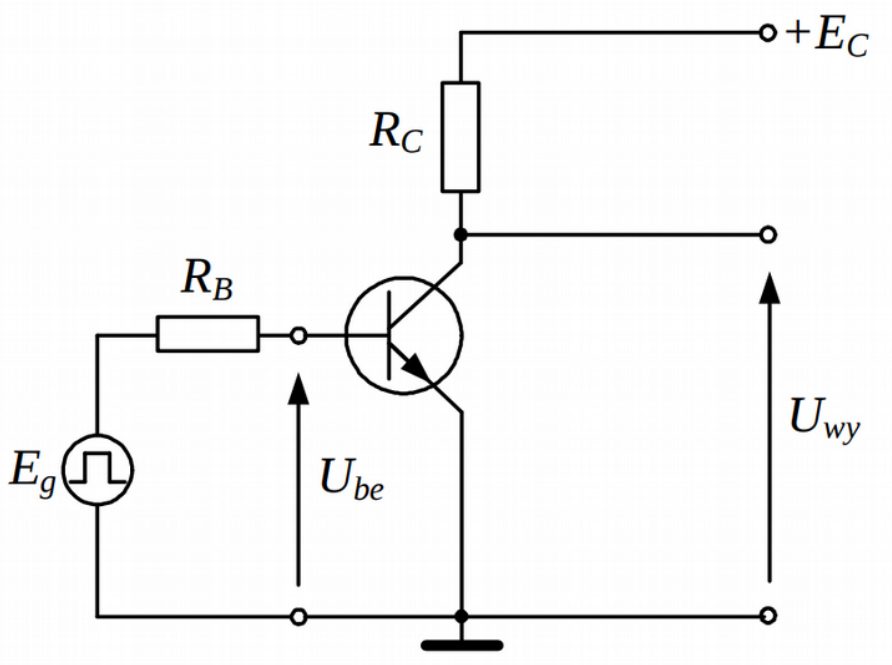
- zero resistance when switched on,
- infinite resistance in the off state.

Transistor key - real



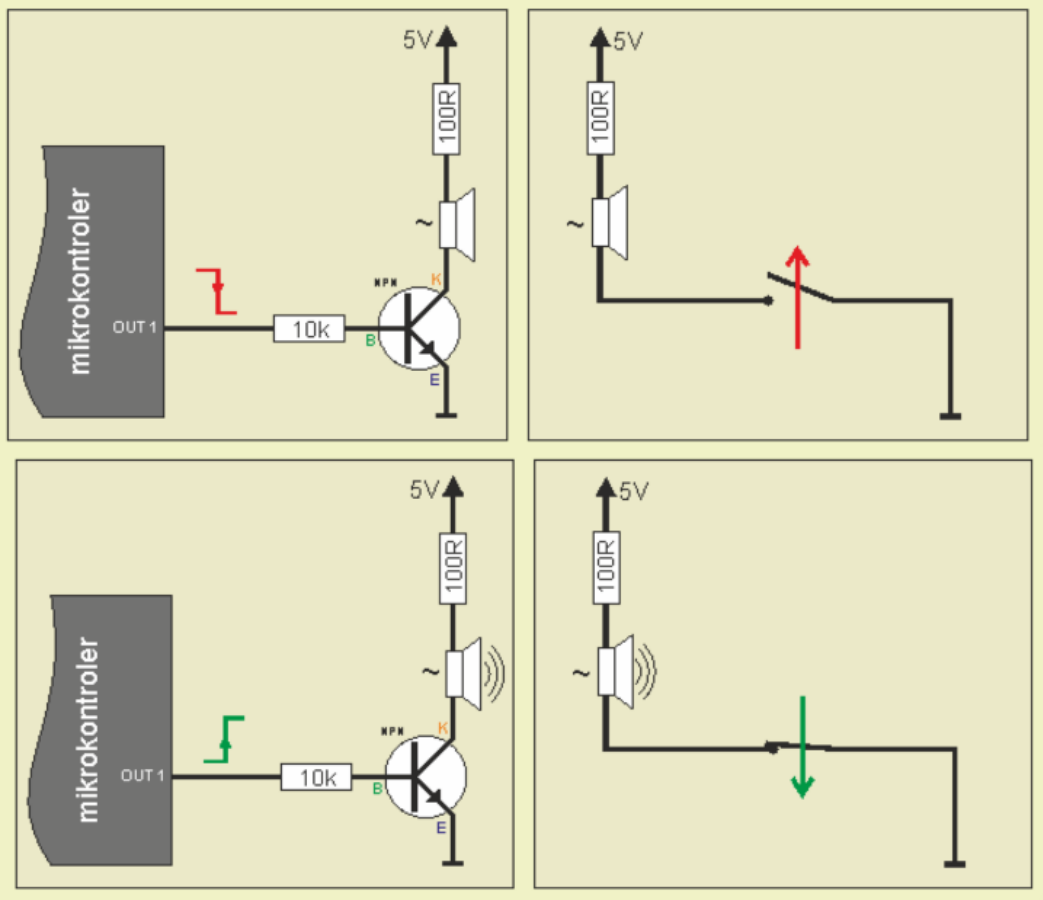
- Non-zero resistance on state R_F
- Finished resistance in the off state R_R

Bipolar transistor as a key

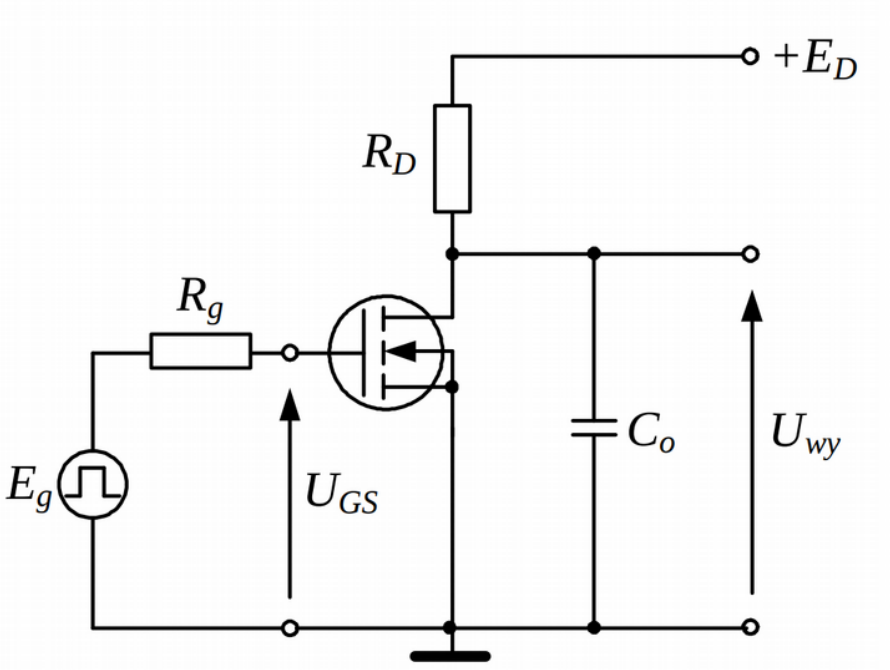


- The transistor is controlled by a strong signal from locked to saturation.

Bipolar transistor as a switch

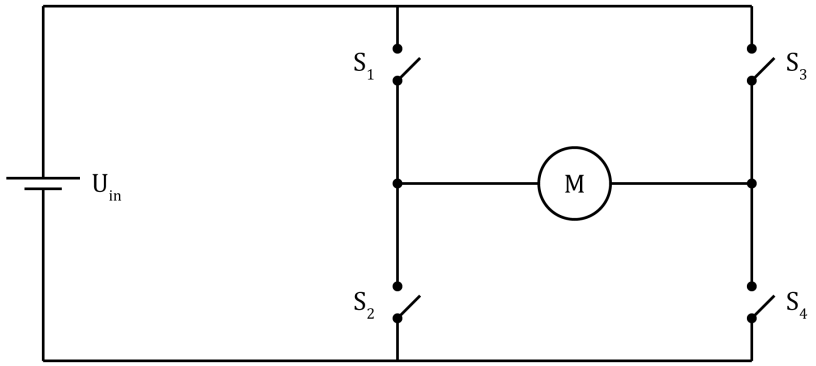


MOSFET transistor as a key



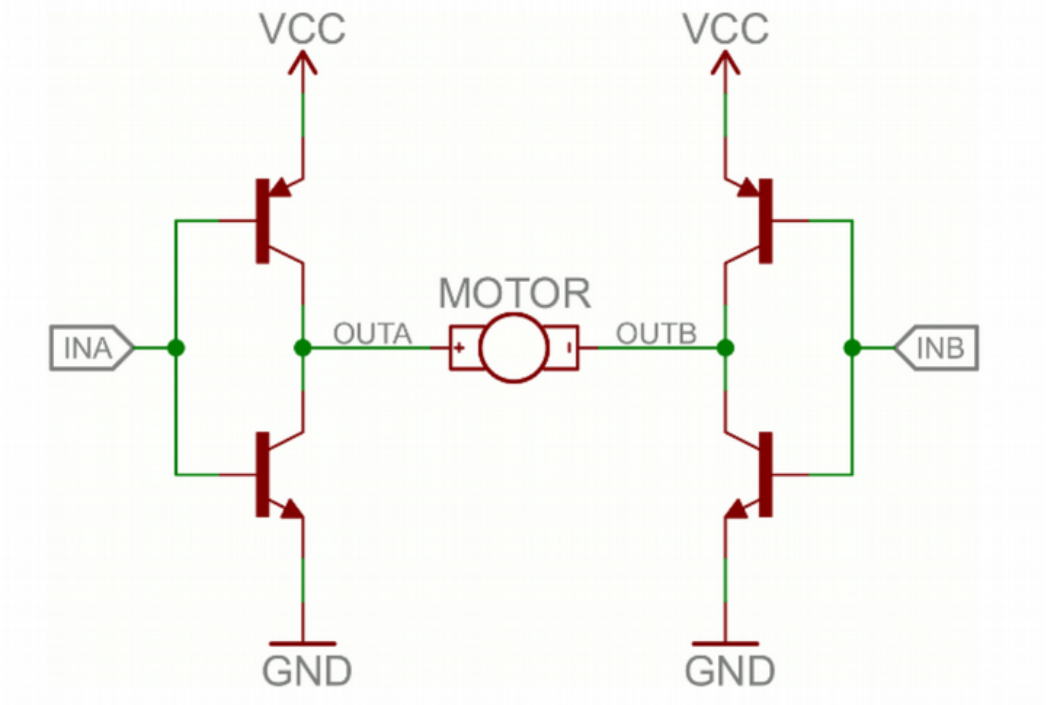
- MOS circuits used in integrated digital circuits as well as in analog circuits.

Motor control DC



- The engine speed is regulated by a fill factor,
- The direction of rotation is achieved by selecting switches:
  - Switches $\{S_1, S_4\}$ - one direction
  - Switches $\{S_2, S_3\}$ - reverse direction

H-bridge with bipolar transistors



Brushless motor control

- These motors are made as miniature three-phase motors,
- The motor controller at the input has a servo signal standard, the output directly controls the motor (three-phase)

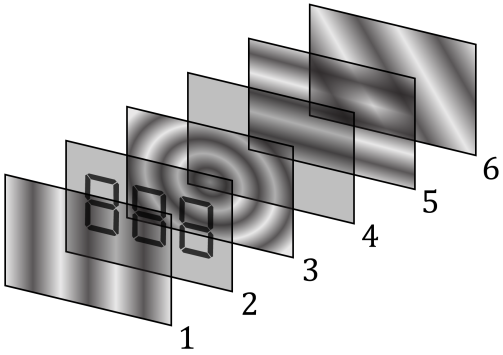
LCD display

Liquid Crystal Display – an image display device whose operating principle is based on a change in polarization of light due to changes in the orientation of liquid crystal particles.

All types of liquid crystal displays consist of four basic ones elements:

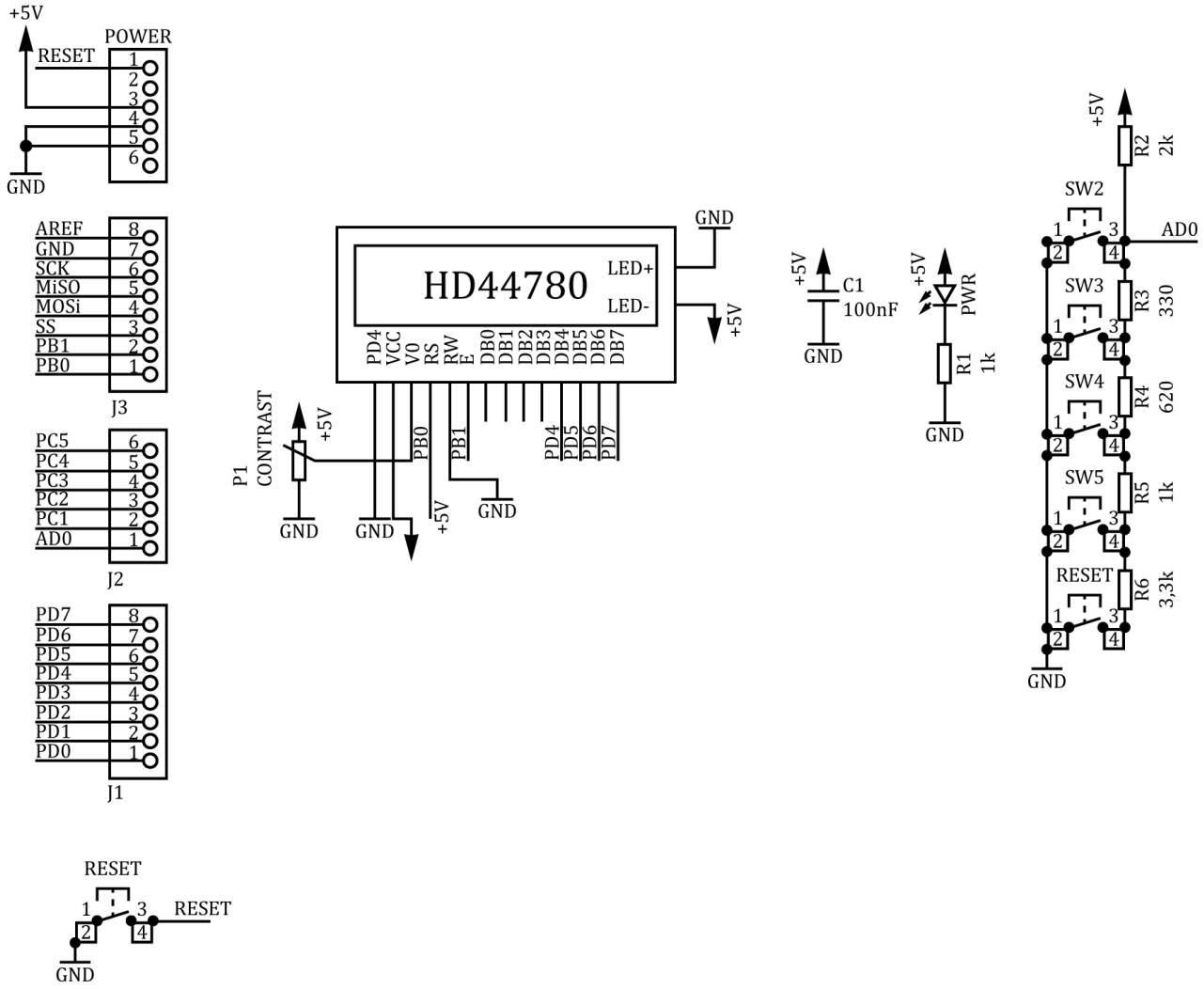
- *cells* in which a small amount of liquid crystal is embedded,
- *electrodes*, which are the source of the electric field acting directly on the liquid crystal of two thin
- *foil*, one of which acts as a polarizer and the other as an analyzer.
- *mirrors* - light sources.

LCD display - working principle



1. *Vertical filter* - for polarization of incoming light,
2. *Glass plate with coated electrodes*. The displayed images will have the shape of applied electrodes.
3. *Liquid crystal layer*,
4. *Glass plate* with horizontal grooves to change the polarization of light,
5. *Horizontal filter* - it is used to dim the reflected light,
6. *reflecting surface* - is used to reflect the light beam.

Arduino LCD display

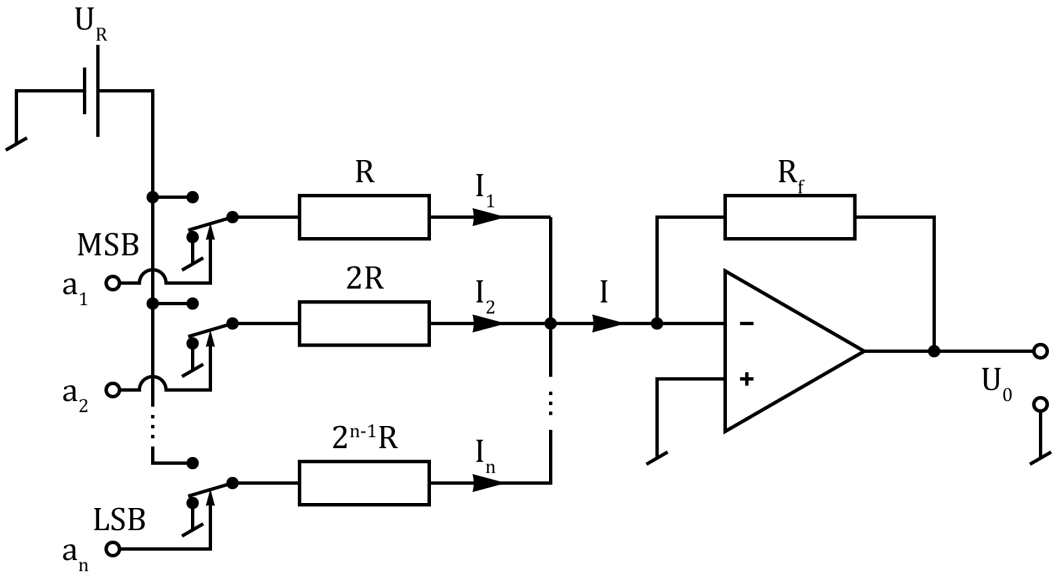


Digital to Analog Converter, DAC

Digital to Analog Converter, DAC - device that converts a digital standard (binary number) signal into an analog signal in the form of a voltage proportional to that number.

- The DAC converter has n inputs and one output.
- DAC converters work based on one of three processing methods:
  - parallel,
  - by weight,
  - counting.

DAC converters with weighted resistors



- If i-th bit are equal to 1, then the current $I_i = \frac{U_R}{R \cdot 2^{i-1}}$ will flow through the corresponding resistor, otherwise $I_i = 0$.
- The operational amplifier works as an adder.
- Current sources are also used instead of resistors.

ADC – Analog to Digital Converter

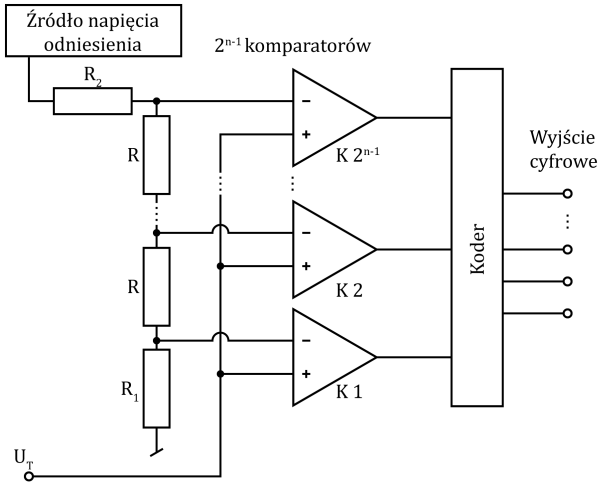
ADC – Analog to Digital Converter) is a circuit used to convert an analog (continuous) signal into a digital representation (digital signal).

The analog signal can be converted into a string of bits:

- *direct comparison method*
- *weight compensation method* (with subsequent sampling).
- *time method with double integration*,
- *frequency method*.

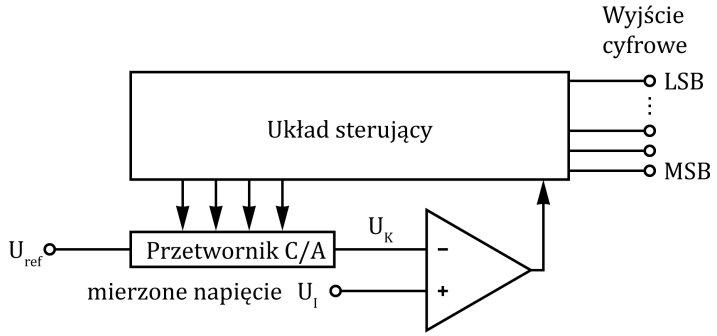
D / A converters are used to build A / D converters

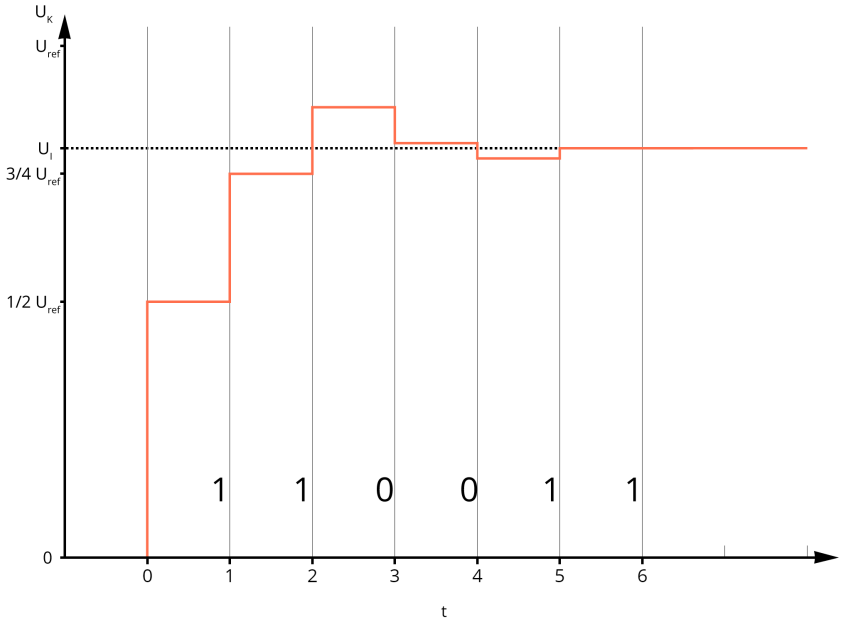
A / D converter based on direct comparison method



- The input voltage is compared by $2^n - 1$ comparators.
- The comparator outputs are digital information in binary code.
- Advantage - high processing speed
- Disadvantage - a very large number of comparators. Monolithic transducers are produced resolutions of 6 to 8 bits and processing times of 10 - 20 ns.

Converter based on the weight compensation method



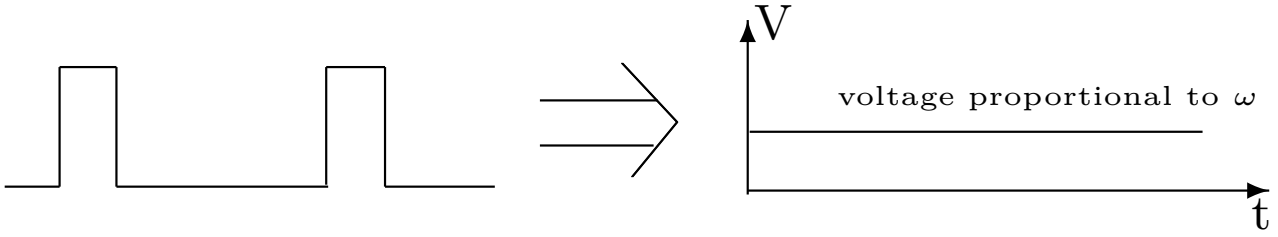


Converter based on the weight compensation method

- The processing consists in another comparison of the processed voltage U_i with the reference voltage U_r produced in the D-A converter,
- First, the input voltage is compared to half the voltage of the full processing range,
- For an n-bit converter, the full processing cycle includes n comparisons,
- Advantage - the ability to build multi-bit converters, the disadvantage - it significantly extends the time sampling.

ADC and DAC converters in μC

- *Analog-to-digital converters* - built into μC. An analog signal (not exceeding the supply voltage) can be supplied to several μC inputs. The analog signal sources are then keyed.
- In μC has no direct analog output. The analog signal is obtained by integrating the PWM signal. Integration can be accomplished through a low-pass filter or it takes place in a controlled object (e.g. motor).



Task for labs

1. Display the scrolling *" hello world "* on the LCD display,
2. Write a program displaying on the upper line of the LCD display the analog voltage value read from pin A0 (in volts) and on the lower line the read logic value of this pin.
3. Write a program that displays data sent over the serial interface on the LCD. Link parameters are set by the teacher. The controller should send back ASCII codes of the read characters separated by a space.