Astable flip-flop with "555" ic.

1 Objectives

The aim of the exercise is to learn the principles of operation and parameters, built an astable flip-flop based on the integrated circuit "555".

2 Components and instrumentation

2.1 *Operating principle of the astable "555" flip-flop.*

The exercise uses the integrated circuit of the "555" type mono/astable flip-flop. It is produced by many manufacturers both in bipolar (e.g. LM555) or unipolar (e.g. MC1555) technology. Its internal structure is shown in Fig.1. The system consists of two comparators K1 and K2, an RS type trigger and output stages. Transistor T is open collector (output 7 – “discharge”) and is used as a discharge key for working capacity C.

The internal resistive divider is used to obtain voltages of approximately 2/3 and 1/3 of the supply voltage. These voltages polarize the inputs of the comparators K1 and K2. The comparator K1 will reset the flip-flop P if the voltage on terminal 6 (threshold) rises above 2/3 of VCC. At the same time, the transistor T is activated. The comparator K2 sets the trigger P to the logic state of one (high voltage) when the voltage at pin 2 (trigger) falls below 1/3VCC - then the transistor T is switched off. Input 4 (reset) is used to reset the flip-flop independently of the state of the other inputs, i.e. shorting this input to ground (low state), forces output 3 of the system to be low. If input 4 is not used, it should be connected to the power supply (8). The input 5 (control) can be used as modulating input or should be connected to the ground by means of a decoupling capacitor of 10nF.
Fig. 1 shows the schematic diagram of the 555 system working in the configuration of the astable flip-flop (multivibrator).
In the case of multivibrator, the pin (2) is connected to the capacitor C (and to the output 6). After turning on the power, the capacitor starts charging through RA + RB resistors (when the diode D4 is mounted, it is R3 and diode) as the low state (near 0V) on pin 2 has triggered the system. In consequence a high state appears at the output (3). When the voltage on capacitor C reaches the value of ⅔Vcc = V (5) - which is monitored by the comparator K1 (lead 6) - the output state (3) changes to low (near to 0V). At the same time, the internal transistor is turned on and capacitor C begins to discharge through transistor (pin 7) and resistor RB. At the same time, the voltage at the input (2) connected to capacitor C dstart to fall down and when it reaches the level of release of the comparator K2 (⅓Vcc) = ½V (5), the whole cycle is repeated. Fig. 3 shows exemplary waveforms generated in the system.

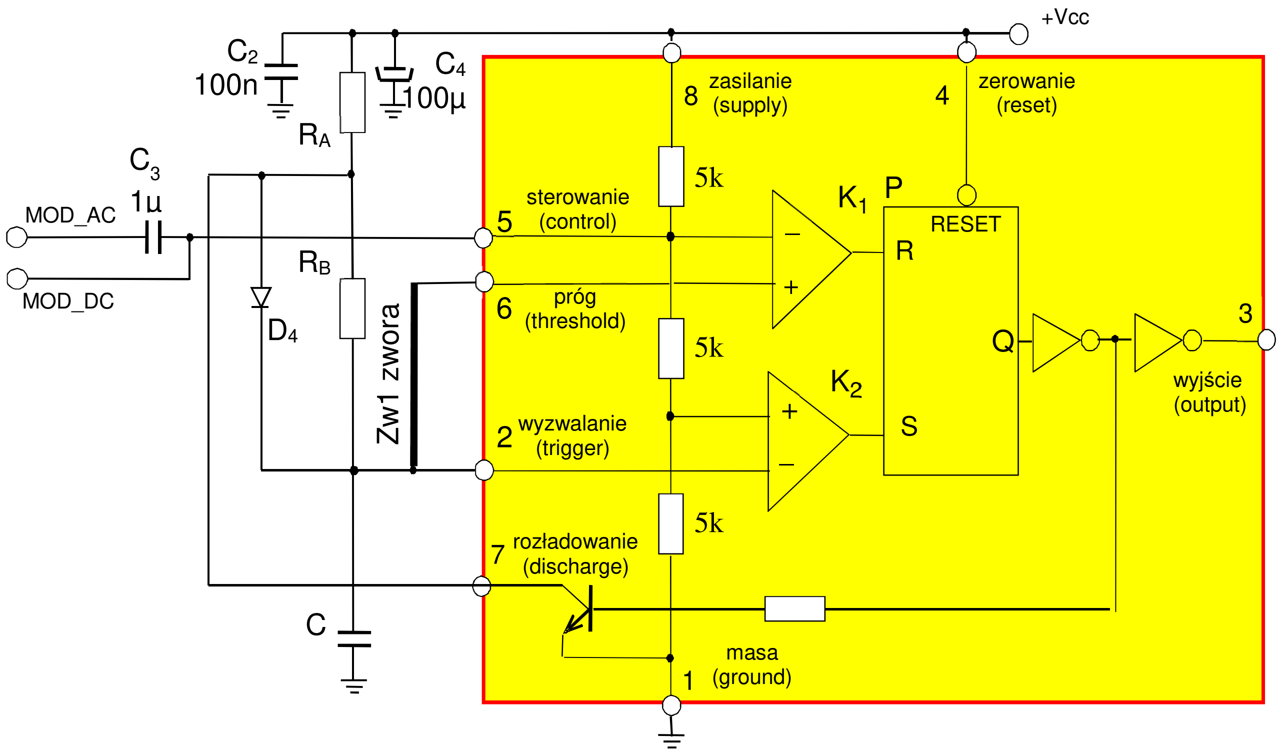

Fig.1. Asatble flip-flop (multivibrator).

The duration time of the high state (when the diode D4, RB is mounted, it is omitted in this pattern):

$$t_1 = (R_A + R_B)C\ln\left(\frac{Vcc - \frac{1}{2}V(5)}{Vcc - V(5)}\right) = (R_A + R_B)C\ln 2 \approx 0.693(R_A + R_B)C \quad (1)$$

The duration ime of low satate:

$$t_2 = R_B C\ln\left(\frac{V(5)}{\frac{1}{2}V(5)}\right) = R_B C\ln\left(\frac{\frac{2}{3}Vcc}{\frac{1}{3}Vcc}\right) \approx 0.693 R_B C \cdot \quad (2)$$

Period of the siglal:

$$T = t_1 + t_2 = 0{,}693(R_A + 2R_B)C \, . \quad (3)$$

Frequency: *(for frequency aove 20 kHz this equasion can be unadequote)*

$$f = \frac{1}{T} = \frac{1{,}44}{(R_A + 2R_B)C} \, . \quad (4)$$

Duty cycle of the generated waveform:

$$D = \frac{t_1}{T} = \frac{R_A}{R_A + 2R_B} \, . \quad (5)$$

Notice: When the diode D4 is mounted in formulas (3) to (5) instead of 2RB only RB will occur. Then it will be possible to achieve a duty cycleo nearly 50% (for RA≈RB).

Driving the input 5, through the capacitor C3 (Fig. 1, and 2) with the voltage modulation signal VMOD_AC from an external generator (input MOD_AC), the effect of frequency modulation can be obtained. The modulating voltage changes the levels of the internal inputs of the comparators over time. As a result, the voltage to which the capacitor C is charged (and discharges) changes. When it is decreased, the charging time decreases. With increasing modulating voltage the charging time of the capacitor increases. In this way, the period of the generated waveform T and in consequence the frequency f of the output signal depends on the instantaneous value of the modulating signal. The MOD_DC input is used to lead the DC voltage to input 5 from external voltage supply (the MOD_AC input must be disconnected), which allows the multivibrator to be tuned to a certain frequency by means of DC voltage (Voltage Controlled Oscillator - VCO).
Fig. 3 shows exemplary waveforms in the system when controlling the Mod_AC input.

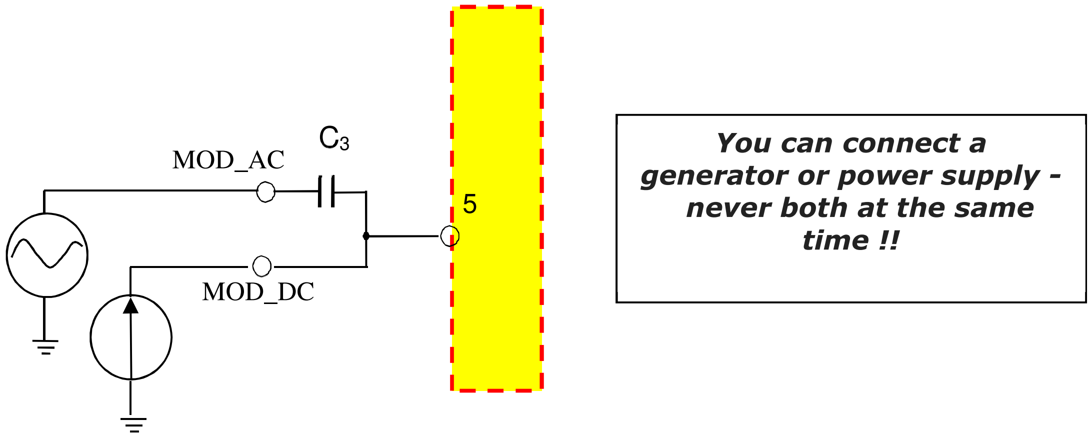

Fig. 2. The way of connecting the modulating signals.

The momentary period of the output signal can be calculated from the formula:

$$\frac{1}{f} = T = t_1 + t_2 = (R_A + R_B)C\ln\left(\frac{Vcc - \frac{1}{2}V(5)}{Vcc - V(5)}\right) + R_B C \ln 2 \,, \tag{6}$$

where V (5) is the voltage on the lead 5 (in case, when D4 is implemented, in the first component RB should be omitedt).

2.2 *Experimental setup*

The complete wiring diagram of the laboratory system is shown in Fig.4, and in Fig.5 there are assembly diagrams of the PCB.

The basic elements of the system that affect the operation of the circuit are RA, RB and capacitor C resistors. Their significance is described in the previous paragraphs.
Diode D4 enables faster charging of the capacitor C (omitting RB), affecting the duty cycle of waveform of the astable generator (in the formula (2) RB can be omitted). It is then possible to obtain the duty cycle of close to. 50%.
The introduction of a modulating signal through the MOD_AC input from an external generator enables the study of modulator systems in dynamic conditions (modulation with a AC signal). Connecting the regulated external power supply to the MOD_DC input allows testing of modulator systems in static conditions (DC voltage modulation).

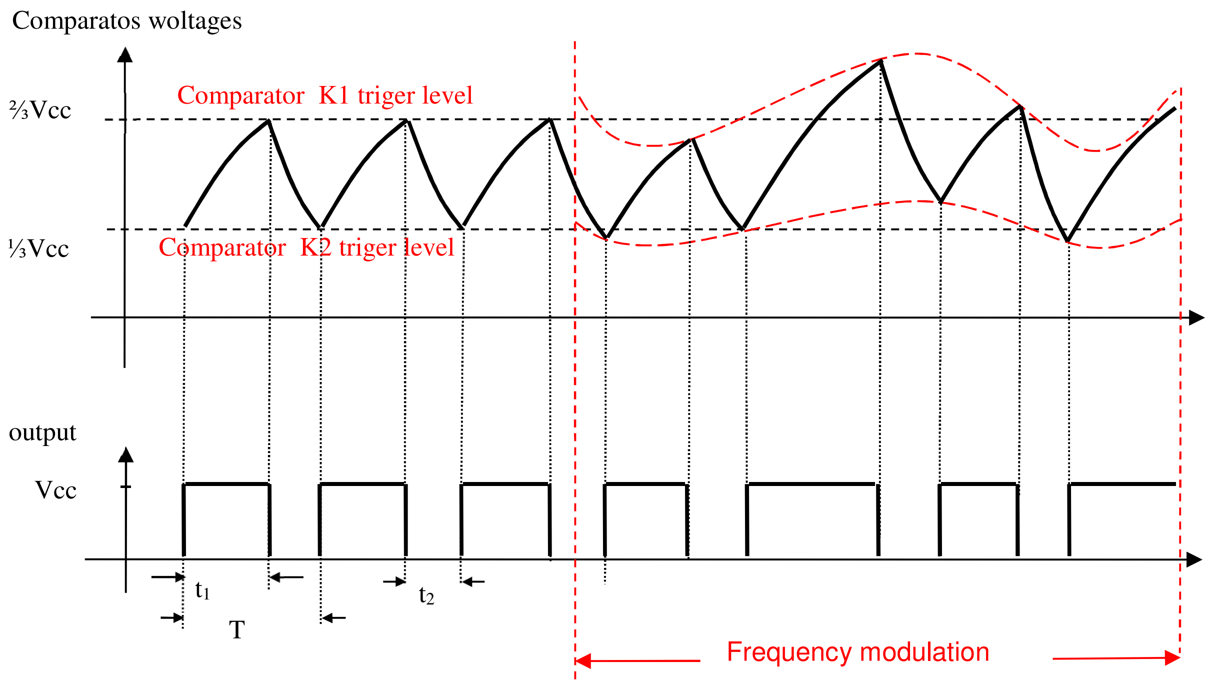

Fig. 3. Waveform in astable flip-flop without and with modulation.

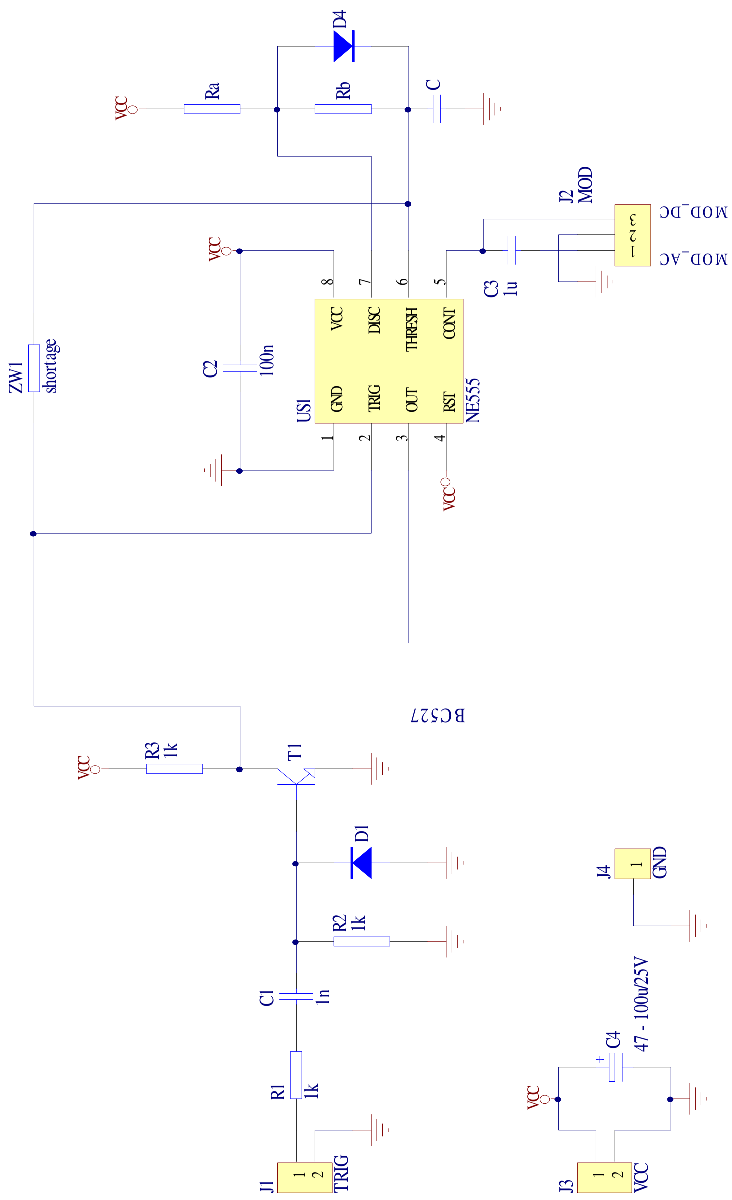

Fig. 4. Schematic diagram of examined circuit.

Notice: ***<u>In the diagram elements of both mono- and a-stable flip-flop are included.</u>***

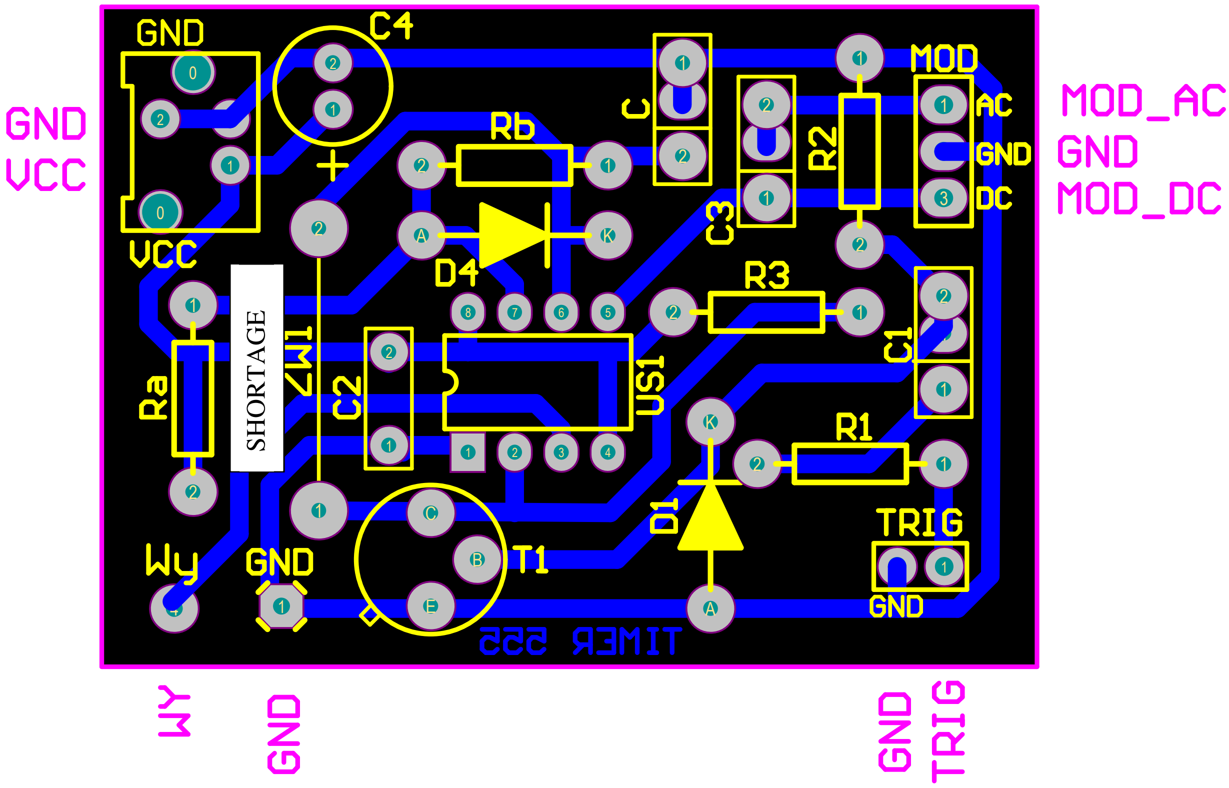

Fig.5.PCB of „555"circuit – top view.
On PCB elements of both mono and astable flip-flop are shown..

3 Classes preparation

NOTICE: The preparation time for classes is estimated at 4 to 6 hours

3.1 *.Readings*

[1] Lab materials and lectures of the course.
[2] U. Tietze, Ch. Schenk, Electronic circuits. Handbook for Designers and Applications, Springer, 2008, pp. 587-609, .
[3] P. Horowitz, W. Hill, The Art of Electronics, Cambridge Univ. Press, London, 2015, pp. 425-471

3.2 *Problems*

1. What does it mean and how it is measured: rise time, fall time, droop, period, pulse duty factor?
2. Name basic configurations of flip-flop circuits – draw schematics diagrams ?
3. Operation principle of „555" IC..
4. Name some applications of monostable and astable versions of „555" ?
5. .Explain the pulse with modulation: parameters, properties, exemplary applications
6. Explain principle of frequency modulation and name some application of it ?

3.3 *Detailed preparation*

Before the exercise, students are given fro tutor the required operating frequency as well as duty cycle of output waveform (system with or without D4 diode) and power supply voltage.

The flip-flop system should be designed, i.e. assume the value of some elements and calculate the remaining values (the best choice is to accept the capacitance value and calculate the resistances). The values of some parameters can be suggested by the tutor Calculated values should be put on the printed diagram from Fig. 4 (non-assembled elements should be crossed out).

The designed system should be simulated in the program for analysis of electronic circuits (e.g. LTspice) and print output waveforms and the voltage waveforms on the capacitor (terminal 6 of the integrated circuit). Simulations should be carried out in such a way that they correspond to the measurements described in point 4.3.

Tables templates and grids for possible charts should be prepared as well..

4 To do

4.1 *Circuit assembling*

Before assembling the system, the values of elements (resistors and capacitors) should be measured, and their values should be entered on the prepared diagram next to the calculated values. The system should be assembled in accordance with the assembly diagram shown in Fig.5
Notice:

- the diagram from Fig.4 and the PCB from Fig.5 contain elements for both the astable and monostable flip-flop systems;
- assemble only the elements shown in the diagram from Fig. 1
- diode D4 is assembled when is really important,
- if the circuits for shaping trigger pulses have been assembled on the PCB as for the monostable flip-flop system, this will not affect the operation of the astable system and should not be disassembled; however, it is necessary to reject the R3 ***resistor.***

4.2 *Putting the circuit into operation*

- Choose the supply voltage from the range of 5-15V (typicaly V_{CC} =5V), turn on the power supply and connect circuit,
- To the output of circuit connect the scope probe of channel 1 and probe of channel 2 to the capacitor C (pin6 of IC)
- If the system is working properly on the scope are seen waveform as in the Fig. 3. If not, turn of supply and check the circuit

5 Measurements and report content.

1 Observe and print screenshots of the oscilloscope of the output waveform and the voltage on the capacitor C (as in Figure 3 - without modulation). Compare the results with those calculated and obtained in the simulation, in particular, read the threshold voltages of the comparators.

2 By changing the VCC supply voltage from 0V to 15V measure the frequency of the output waveform f = f (VCC) using the oscilloscope, and the amplitude of the output pulse VOUTamp = VOUTamp(VCC) (place the results in the table 4.4.1 and prepare the graph). Determine the minimum working voltage of the system. Measured parameters of the waveforms should be compared with those calculated and with simulation results.

3 Connect a function generator to the MOD_AC input of the tested system (use signal shape: triangular or sinusoidal, peak-to-peak voltage about ¼ of the supply voltage, frequency 10 to 20 times lower than the working frequency of the system). If everything works correctly, the waveforms shown in Figure 3 (for modulation) can be observed on the oscilloscope. If the waveforms are not synchronized, the image on the digital oscilloscope can be stopped. The screenshot should be printed.

4 Disconnect the modulation signal from the MOD_AC input. To the MOD_DC input, connect a DC voltage supply with a pre-set voltage of ½ of the supply voltage. Changing the VMOD_DC voltage in the range of 20% to 80% of the supply voltage (Vcc), measure the output frequency f (pin 3) with the oscilloscope. The measurement results collect in Table 4.4.2. and sketch the graph f = f (VMOD_DC). Parameters of the waveform compare with those obtained in simulation.

Table.1 Frequency of output signal and it peak-peak voltage vs. Supply voltage.

lp.	**Vcc [V]**	**Uout(amp)**	**f [kHz]**
1			
2			
3			

Table .2 Frequency of output waveform vs. Modulating DC voltage.

lp.	VMOD_DC [V]	f [kHz]
1		
2		
3		