Monostable flip-flop with "555" ic.

1 Objectives

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

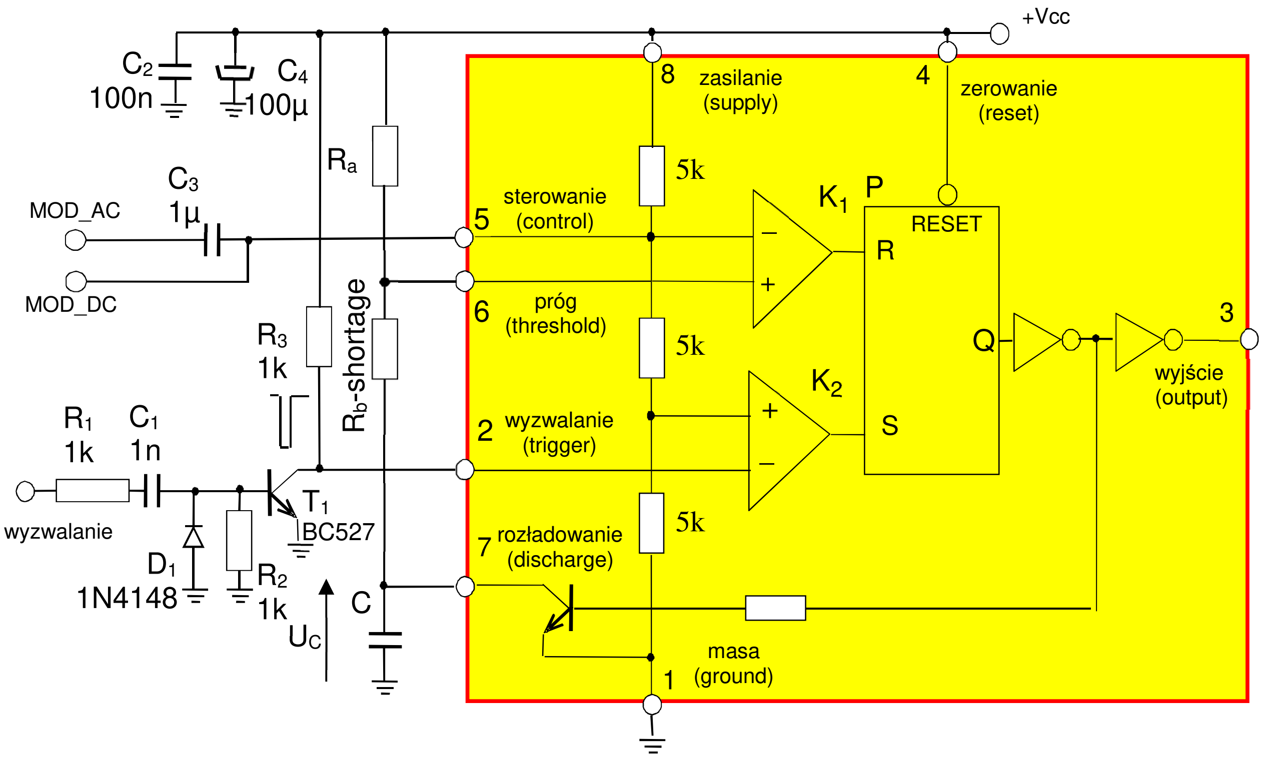
2 Components and instrumentation

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 mono-stable flip-flop (monovibrator).

In stady-state condition the pin 2 (*Trigger*) is in high state – the voltage no less than $⅔Vcc$, on the output (3) the voltage is in low state (c.a. 0V), the capacitor C is discharged (U_C = 0V), as the transistor T is saturated. Driving input 2 with the trigger pulse of the level of less than $⅓Vcc$ and duration of minimum 50ns causes the change of the state of the comparator K2 and sets the flip-flop P to the "1" stat – on the output 3 high voltage appears of the level of ca. VCC. The base of transistor is than not polarized and – the transistor do not discharge the capacitor C. The capacitor start to charges with R_A. When the voltage on capacitor U_C excide the value of $⅔Vcc$, (it is monitored by means of K_1 – pin 6 - *threshold*) High state of comparator will change the flip-flop to „0" (Reset). On the output 3 low voltage appear and capacitor will fast discharged by the transistor (pin 7). Before the voltage across the capacitor C reach the value of less than *1/3Vc*c the voltage on pin 2must be recovered to high state (more than $⅓Vcc$).



Rys.1. Monostabel flip-flop

Driving the input 5 with external voltage DC or AC one can change the threshold of comparator K_1 and achieve the modulation effect.

Duration time of output pulse can be estimate with a formula:

$$T = R_A C \ln\left(\frac{Vcc}{Vcc - V(5)}\right) = R_A C \ln\left(\frac{Vcc}{Vcc - \frac{2}{3}Vcc}\right) \approx 1{,}1 \cdot R_A \cdot C \qquad (1)$$

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 pulse width modulation can be obtained. The modulating voltage changes the levels of the internal input of the comparator over time. As a result, the voltage to which the capacitor C is charged changes. When it is decreased, the charging time decreases. With increasing modulating voltage the charging time of the capacitor increases. In this way, the pulse duration of the generated pulse T 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 monovibrator to be tuned to a certain pulse duration by means of DC voltage.

The momentary pulse width can be estimated with equation:

$$T = R_A C \ln\left(\frac{Vcc}{Vcc - V(5)}\right) \qquad (2)$$

In Fig. 3 an examples of system waveforms are shown in the input control *MOD_AC*.

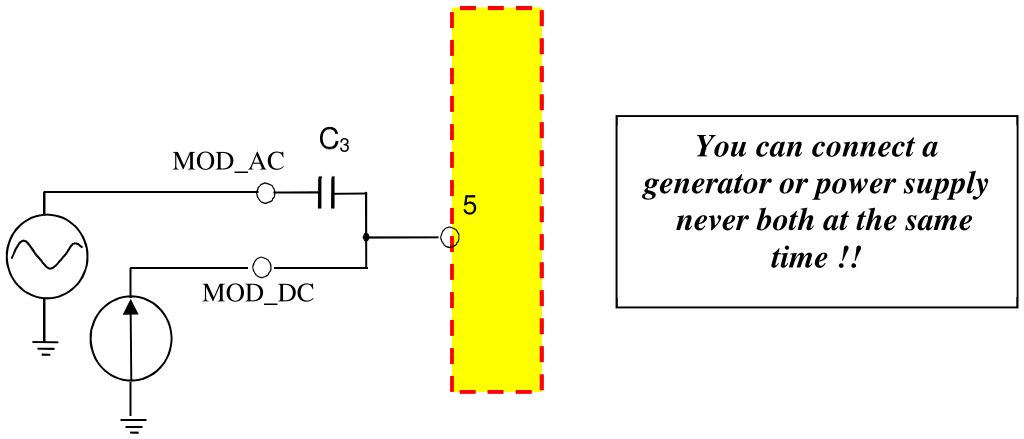


Fig. 2. The way of connecting the modulating signals.

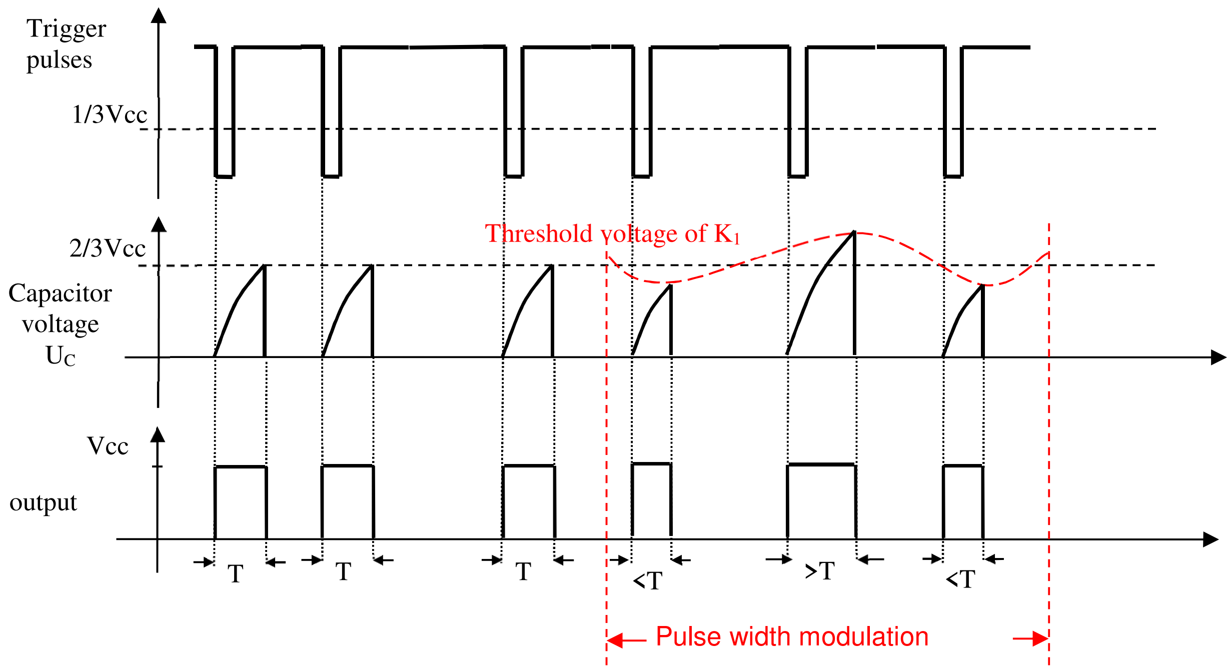


Fig. 3. Waveform in monostable flip-flop without and with modulation.

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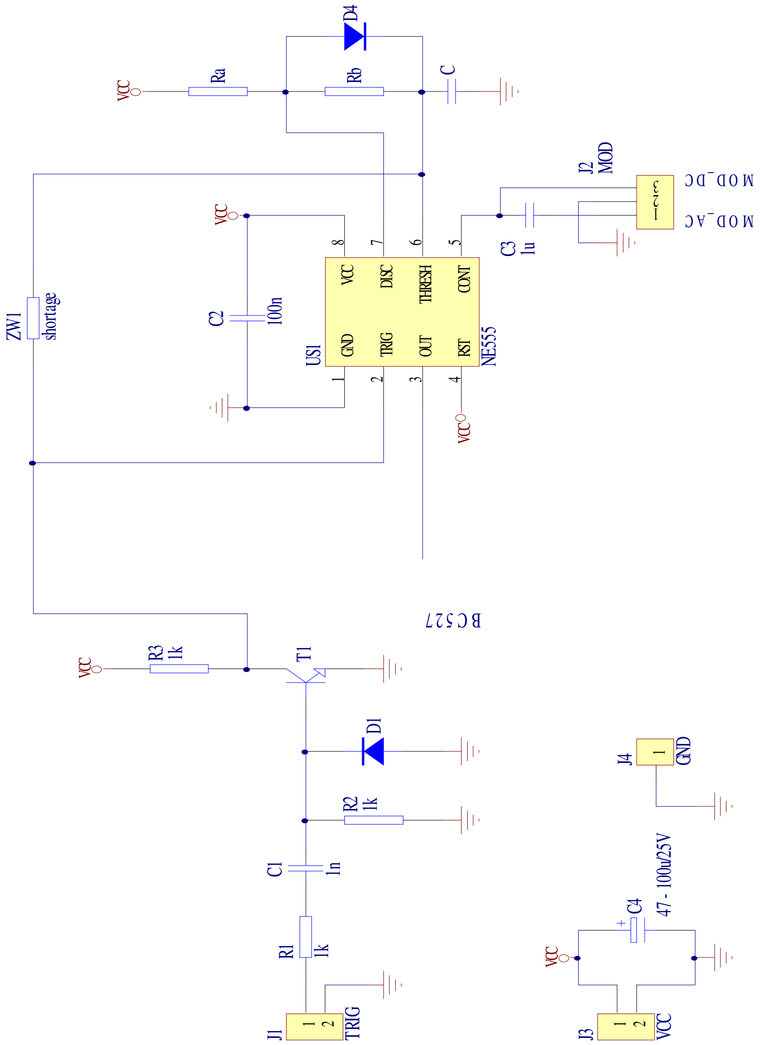

Fig. 4. Full schematic diagram of circuit under test..
Notice: ***In the diagram elements of both mono- and a-stable flip-flop are included***

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.

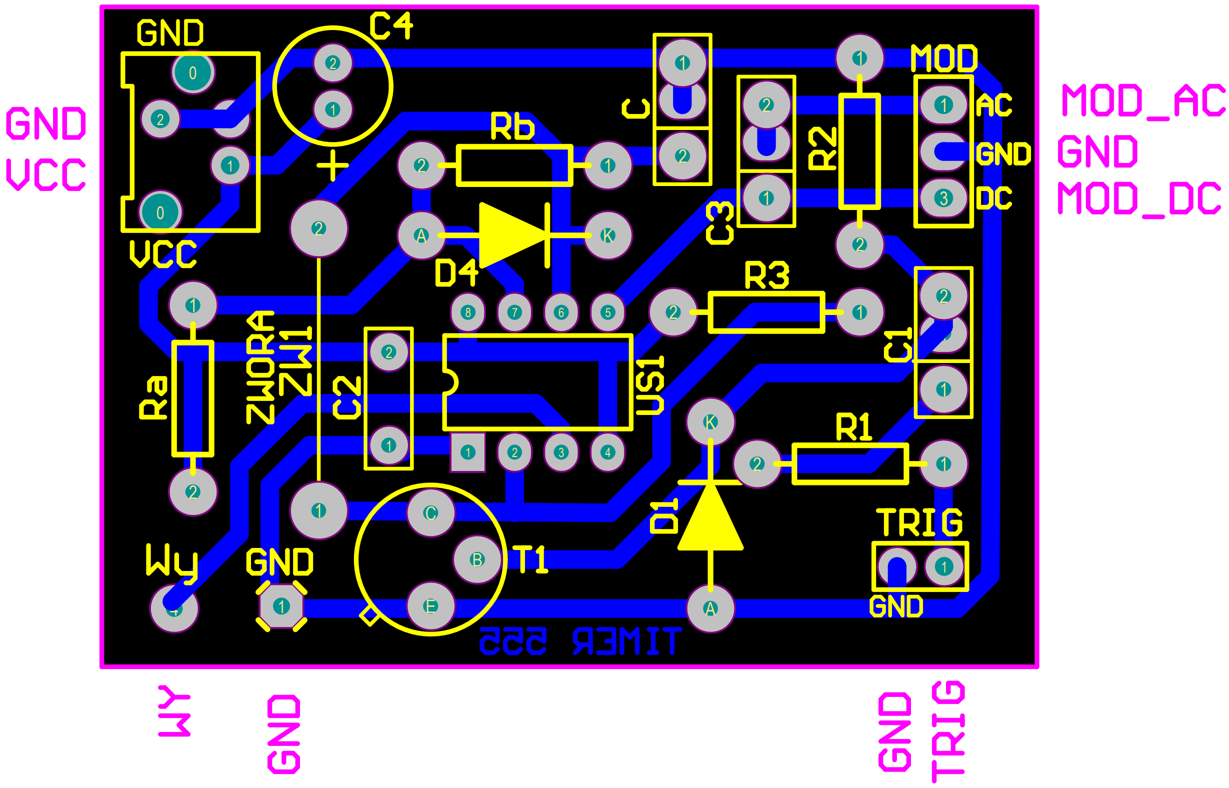

Fig.5.PCB of „555" circuit – top view „555" top view.
On PCB elements of both mon-o and a-stable flip-flop are shown.

3 Classes preparation

Przygotowanie do zajęć może wynosić od 2 do 4 godzin.

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 pulse width modulation and name some application of it ?

3.3 Detailed preparation

3. 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.
4.
5. 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).
6.
7. The designed system should be simulated in the program for analysis of electronic circuits (e.g. LTsice) 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.
8.
9. 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,
- the shortage ZW1 is not assembled in mono-stable flip-flop.

4.2 . Putting the circuit into operation

- Choose the supply voltage from the range of 5-15V (typically VCC =5V), turn on the power supply and connect circuit,

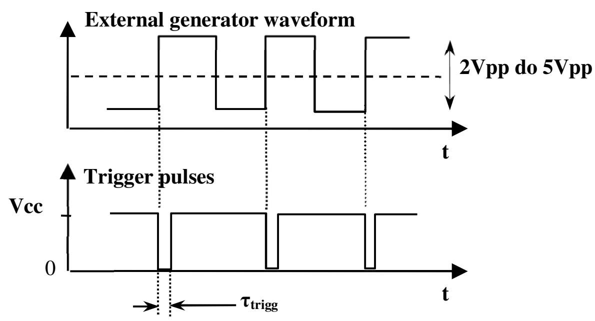

Fig.6. External generator waveform and trigger pulses.

- Trigger pulses on transistor collector should looks like in Fig.6. Duration time of these pulses should be as short as a few μs. If not check the 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 V_{CC} supply voltage from 0V to 15V measure the width of the output pulse T = T (V_{CC}) using the oscilloscope, and the amplitude of the output pulse V_{OUTamp}= V_{OUTamp} (V_{CC}) (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 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 pulse width T (pin 3 - or out) 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.

Tabel .1 Pulse width of the signal and amplitude vs. Supply voltage.

lp.		**Vcc [V]**	**Uout(ampl)**	**T[us]**
1				
2				

Tabel.2 Pulse width vs. modulating DC voltage.

lp.	VMOD_DC [V]	T[us]
1		
2		
3		