Crystal oscillators

1. Objectives

The aim of the exercise is to get acquainted with issues concerning the generation of waveforms (including sinewaves) in the basic structures of crystal generators. In addition, the exercise aims to familiarize with surface mount technique SMT (Surface Mount Technology/ Technics or SMD – Surface mounting Devices).

2. Components and instrumentation.

In the exercise, it is possible to test quartz generators operating in the three simplest and most popular system structures:

- Colpitts-Pierce quartz generator with bipolar transistor,
- quartz generator implemented on TTL gates,
- quartz generator implemented on CMOS inverters

2.1. Colpittsa-Pierce's oscillator with bipolar transistor.

The Colpitts-Pierce quartz generator system working in parallel resonance is shown in Fig. 1.

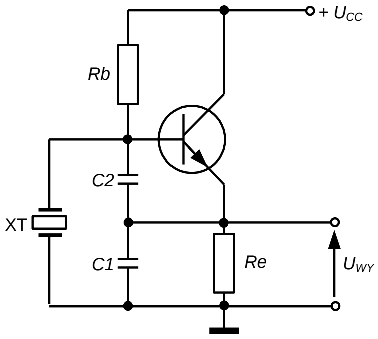

Fig. 1. Colpittsa-Pierce oscillator with BJT.

Using, in the system, quartz resonators with resonance values up to several tens of MHz, the elements C1, Re in the generator system can be selected according to the graph shown in Fig.2.

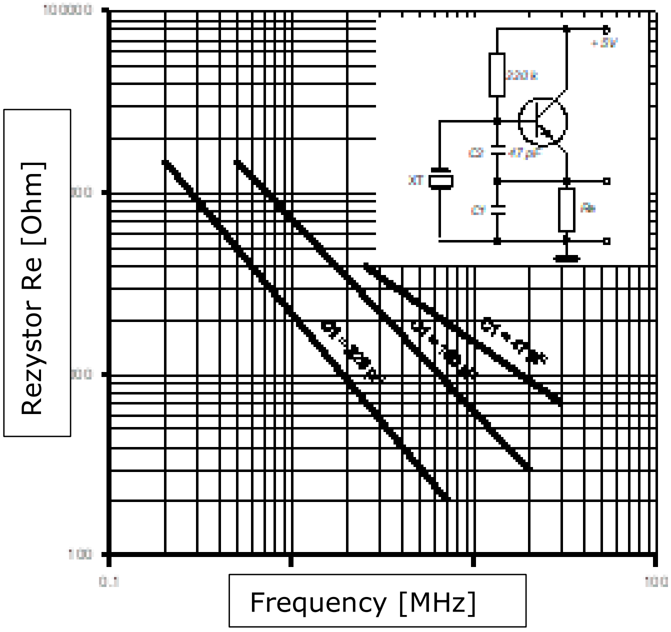

Fig. 2. Selection of C1 and Re elements in the Colpitts-Pierce oscillator

2.2. Quartz oscillator implemented using TTL digital IC

Fig. 3 presents a diagram of a quartz oscillator implemented using NAND gates in TTL technology. The oscillator works in series resonance. In this system, while maintaining the same resistance values, quartz resonators with a frequency from a few to 10 MHz can be used.

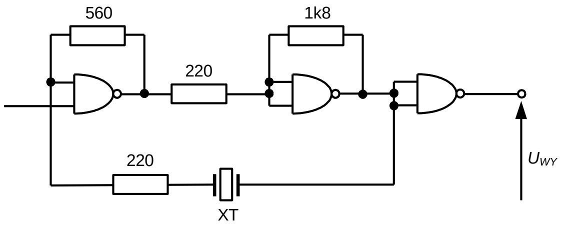

Fig. 3. Cristal oscillator with serial resonance implemented with NAND gates in TTL technology

In the laboratory exercise, it is proposed to implement the system using TTL series 74LS00 (pins of the IC are shown in in Fig.4).

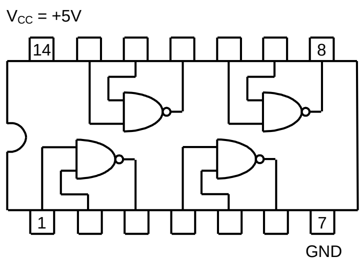

Fig. 4. Pins of IC type 74LS00 in SOT14 outline.

2.3. Quartz oscillator implemented using CMOS digital IC

Fig. 5 presents a diagram of a quartz oscillator implemented using inverters. The oscillator works in parallel resonance. The C1 and C2 values in the system should have approximately equal values. These capacitors increases the stability of the generator, however, too large values can cause problems excitation of oscillation. When using quartz resonators with frequencies from a few to 10 MHz, C1 = C2 capacities 22 - 47 pF should be used.

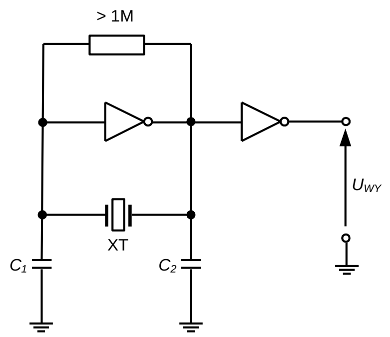

Fig. 5.The crystal oscillator with parallel resonance carried out using CMOS IC.

In the laboratory exercise, it is proposed to implement the system using CMOS series 74069 (pins of the IC are shown in in Fig.6).

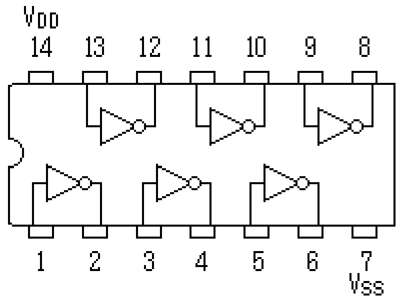

Fig. 6. Pins of IC type 74LS00 in SOT14 outline

In Fig. 7 and 8 the PCB view is shown and the electric scheme of the implemented oscillator circuits..

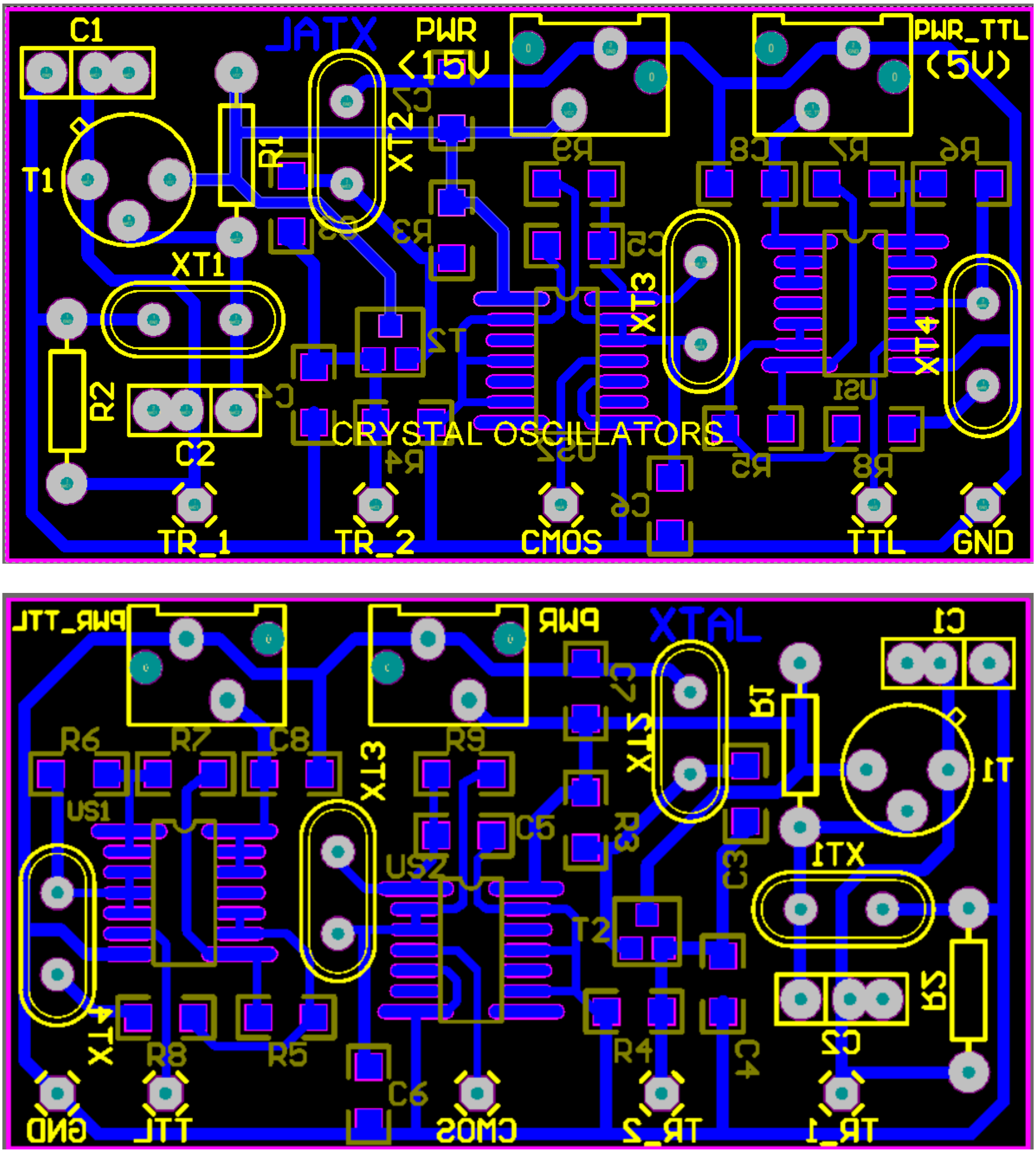

Fig. 7. View of the PCB used in the lab classes.

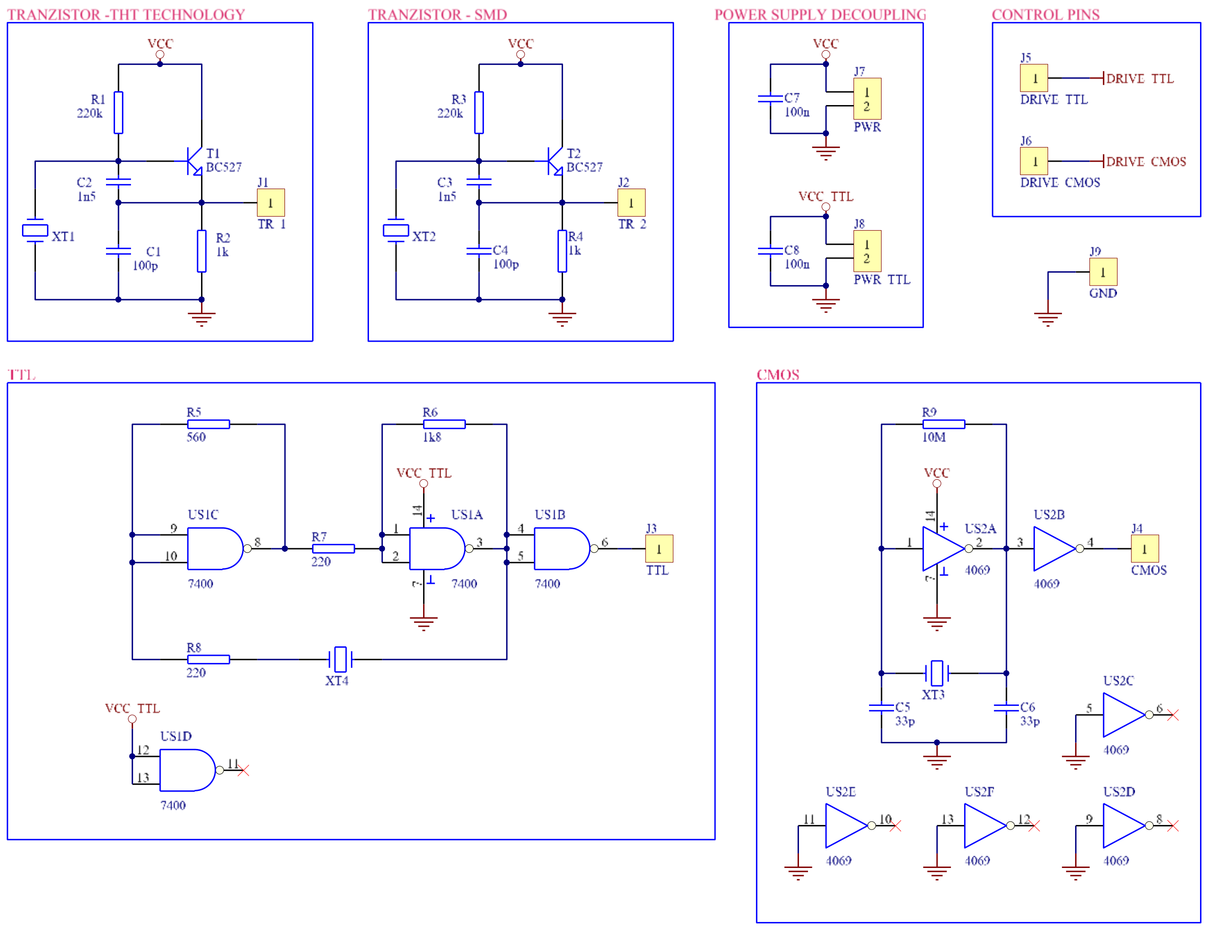

Fig. 8. Schematic diagrams of crystal generators.

3. Preparation.

Estimated preparation time for classes is 2 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, p. 438-572, .

[3] P. Horowitz, W. Hill, The Art of Electronics, Cambridge Univ. Press, London, 2015, p.223-291

3.2. Problems

1) What is the equivalent circuit of a quartz crystal resonator ?
2) What is the series and parallel resonance of a crystal resonator?
3) At what frequencies (parallel or serial) do the generators built in the laboratory, work?
4) Sketch the quartz resonator impedance module as a function of frequency.
5) What are the conditions of amplitude and phase of signal generation?
6) Name the known RC, LC oscillators.

3.3. Detailed preparation

In this exercise, you do not need to calculate anything.

4. Contest of the report

The laboratory exercise, in addition to familiarizing with the typical systems of crystal oscillators, aims to familiarize the students with the SMT technology. Electronic components intended for surface mount technology (SMT) are called SMD (Surface Mounted Devices) elements. These elements, compared to elements used in the through-hole technology (THT), are characterized by small dimensions and a flat casing. This allows you to significantly miniaturize the size of the printed circuit board (PCB). Due to the size of SMD components, surface mounting is usually carried out using soldering machines. However, while maintaining precision, it can also be performed using a traditional manual soldering method.
Before soldering the SMD element, apply a small amount of tin to one of the fields to which this element is to be soldered. Then place the SMD element precisely on the circuit board. While pressing the element to the plate, warm up the place with the previously deposited tin. When the element fits into this place and adheres to the plate, it will be stationary, you should start soldering the remaining ends.

4.1. Colpittsa-Pierce oscillator with BJT

In the crystal oscillator from Fig.1, the values of the elements as in the schematic diagram (fig.8) should be used and crystal resonator of 2-8MHz.
This system is possible to assemble in two assembly techniques: THT or SMT (Fig.7. area TR_1 - THT area TR_2 - SMT).

After assembling the circuit in one of the techniques one should:

1) connect the scope to the oscillator output (probe with a division of 10x),
2) supply the oscillator system with DC voltage Vcc = 5V,
3) at the oscillator output, observe the shape and frequency (with an accuracy of 5-6 significant digits) of the obtained waveform, as well as the amplitude.
4) sketch a graph of the amplitude value of the generated signal vs. the supply voltage (0-15V)

4.2. Quartz oscillator implemented using TTL digital IC

In the crystal oscillator from Fig.3, the values of the elements as in the schematic diagram (Fig.8) should be used and crystal resonator the same as in 4.1.

NOTICE: When using the TTL IC, remember that the voltage supplying this circuit varies from 4.75V to 5.25V. Exceeding the supply voltage above the upper value can damage the circuit !!

After assembling the oscillator (Fig. 7 TTL area) one should:

1) connect the scope to the generator output (probe with a division of 10x),
2) supply the generator system with constant voltage Vcc TTL = 5V,
3) observe the frequency (with an accuracy of 5-6 significant digits) of the obtained waveform, as well as the amplitude.

4.3. Quartz oscillator implemented using CMOS digital IC

In the crystal oscillator from Fig.5, the values of the elements as in the schematic diagram (Fig.8) should be used and crystal resonator the same as in 4.1.

After assembling the oscillator (pole CMOS in Fig.7) one should:

1) connect the scope to the oscillator output (probe with a division of 10x),
2) supply the oscillator system with DC voltage Vcc = 5V,

3) at the oscillator output, observe the shape and frequency (with an accuracy of 5-6 significant digits) of the obtained waveform, as well as the amplitude.
4) sketch a graph of the amplitude value of the generated signal vs. the supply voltage (0-15V)

4.4. Content of the report

The report should contain:

1) Screen shots (photographs) of waveforms for each of the assembled oscillators and precise frequencies of the generated signals (accuracy up to 5-6 significant figures).
2) Result tables and diagrams of measured relationships (from 4.1 and 4.3)
3) Conclusions regarding generated frequencies and shape characteristics of generated waveforms.