FYSP1110/K1 (FYSP110/K1) USE OF AN OSCILLOSCOPE

1 Introduction

In this exercise you will get basic knowledge about how to use an oscilloscope. You'll also measure properties of components, which you are already familiar with from earlier laboratory works in the course FYSP1082, like "Basic instruments for electricity" and "Basic components of electricity".

A cathode-ray oscilloscope is basically a device for measuring electric potential differences. More general it can also show e.g. time dependencies between different measured quantities, provided that they can be transformed to electric signals. Such properties are e.g. dc and alternating (ac) currents, frequency, phase difference, time, sound and other waves.

Before performing the exercises, please, read some of the following literature e.g.:

- Young & Freedman: *University Physics (10th ed.)*, chapter 24-7: The Cathode-Ray Tube, pages 751 – 754
- B+K Precision's guide book to oscilloscopes
- Manual of the oscilloscope used (Hameg HM 303-6)

The following report tells very briefly how to use an oscilloscope. The questions in the text are for learning. If needed, ask help from the demonstrator.

2 The oscilloscope

The names of the parts of the oscilloscope used in this exercise are mostly from Hameg, the analogue oscilloscope used in this work. Main parts of an oscilloscope are

- cathode-ray tube with deflecting plate electrodes
- inlet channels with amplifiers; the input signal is connected to the deflectors, which bends the electron beam to a certain point of the screen (fluorescent material)
- sweep generator and trigger, which are needed in order to get stable images from time dependent signals.

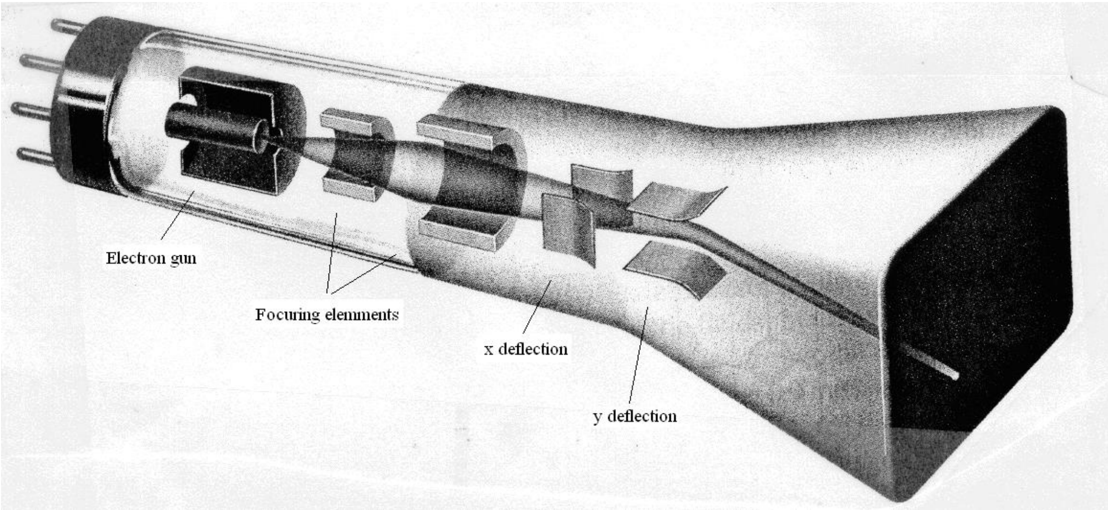

Fig 1. Main components of a cathode-ray tube

One of the most important parts of the analogue oscilloscope is the **electron gun** which with focusing electrodes accelerates a narrow electron beam typically to 5 kV (Calculate the speed of the electrons. Do you need Einstein's theory?). The electron beam travels in between two sets of deflectors (horizontal and vertical) and finally hits the fluorescent screen where it shows up as a bright spot. From now on, this region is being called " the spot". The size and brightness of the spot depends of the FOCUS applied. The place of the beam spot depends directly on the potential (difference) of deflector-plates, which is defined by the input signal – ***read*** Young & Freedman (10^{th} ed.) chapter 27-4!

Oscilloscope has usually two input channels, which allows you to monitor two signals simultaneously. That kind of oscilloscope is a double-beam oscilloscope. You may study signal(s) in an electric circuitry without disturbing it since typically the input resistance or impedance is as large as ~1 MΩ (in some oscilloscopes you can set the input impedance to 50 Ω).

Today the analogue cathode-ray oscilloscope has been mostly replaced by a digital oscilloscope, in which the electron tube is replaced by amplifier and logic circuitry. There are no great differences between these two types of oscilloscopes, only background technique is different.

Measurement conditions and the measured target define the type of an oscilloscope to be chosen. Typical quality criteria are:

- number of channels needed
- band width defines the frequency range needed. Typically few tens of MHz.
- sensitivity defines how weak signals can be monitored.

Setting the potential range

To set the range of measured potentials the amplification of the y-scale in the oscilloscope can be changed from the VOLT/DIV button (or VERTICAL SCALE button). Two-ray oscilloscope has two of them. This allows you to study two signals, which may differ by several orders of amplitude-magnitude, simultaneously. The signals to be amplified are independent of each other. The oscilloscope is calibrated so that the point the beam hits tells directly the amplitude of the signal(s) fed in. The red fine tuning button in VOLT/DIV should always be clicked to Cal position. If so, the position of the VOLT/DIV button (e.g. 20 mV/cm) tells what is the relation between the distance on the screen and the voltage to be measured. The screen is equipped with horizontal and vertical lines which are separated by 1 cm distance from each other.

Setting the sweeping speed

The measured signal is usually connected to the vertical deflectors. The horizontal ones can be used to study time dependency of the signal. Evenly changing voltage is connected into these plates and it can adjust the beam so, that the spot moves on the oscilloscopes screen from left to right. The speed of this point is so called sweeping speed which can be adjusted by user. From TIME/DIV one can select a constant sweep speed for the electron beam in horizontal direction. The TIME/DIV scale (e.g. 10 ms/cm) is also calibrated by the manufacturer. Make sure that the central fine tuning knob is in the calibration position. In some cases, fine tuning button can be used to utilise the entire horizontal screen. **Remember however, that the fine tuning knob in wrong position is the most common source of error in the oscilloscope measurements.**

Settings of the input channel

The input can connected to deflector plates in with options DC, AC and GND. Direct voltages are measurable with setting DC, only, as alternating ones are acceptable in both DC and AC.

In GND (ground) position both vertical deflectors are connected to the ground potential. Therefore there is no electric field between the deflectors and the electron beam shows now the position of zero voltage. The position of the zero potential on the screen can be tuned with VERTICAL POSITION, POSITION or POS switch to a suitable place. This switch is in some cases marked with arrow up down signs. In double-channel oscilloscopes both channels have their own up-down switches. Digital oscilloscopes usually have only one switch, which can handle both channels.

In DC mode the signal must be connected to the upper deflector and the lower one to the core of the coaxial cable and to ground of the oscilloscope. Now the position of electron beam shows ”the absolute” potential of the measured signal compared to the ground potential. In AC-mode the measured signal (the active center-cable) is connected to the upper deflector and the core to lower one, but they are left without grounding. This allows you to measure e.g. small fluctuations on top of a say 100V DC-voltage.

Trigger

The purpose of the oscilloscope trigger is to adjust the graphs shown on the oscilloscope screen so that possibly separate graphs can coincide. In other words, to put them in same position. By using the trigger, one can get a more readable and stable oscilloscope view. Triggering can be performed in various different ways. In the NORMAL mode (NM) the triggering depends on the value of the input potential. Double-beam oscilloscope has two inputs. The TRIG.I/II switch is for deciding to which of the input channels are in use and followed by. If the second input is needed, press the DUAL selector (button). As the input voltage reaches its specific value, triggering happens. This level is called a trigger level and it can be adjusted by using LEVEL switch.

Alternating input voltage can reach the specific trigger level in two ways. It can decrease until it reaches the trigger level, or it can increase until the trigger level is reached. In the first case, the signal is being triggered from its ascending slope. In the latter case, triggering is being done from the descending slope, see figure 2. Selection between slopes can be done via SLOPE switch. The +/- marking on the switch tells, if the slope is rising or decreasing. If the signal voltage is not going to reach the trigger level, there is no trigger in the normal mode and there will be nothing on the screen. There is a led indicator on the oscilloscope that turns on, if trigger level coincides with voltage.

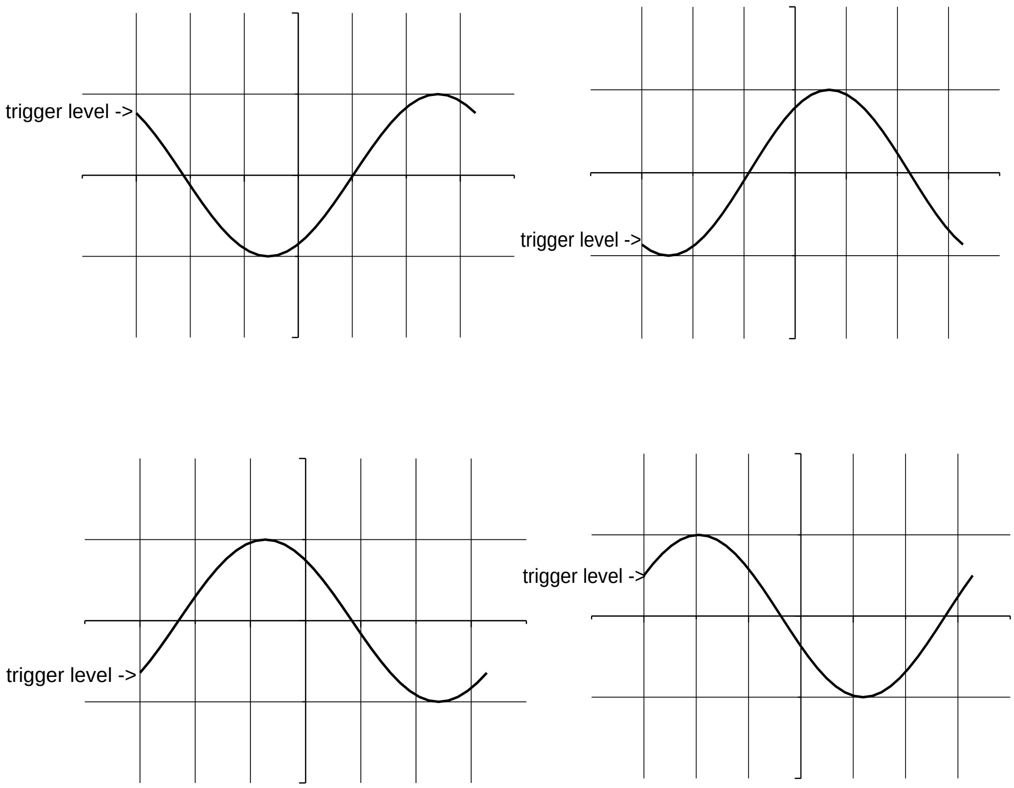

Figure 2. Pictures on the oscilloscope screen, when different LEVEL and SLOPE settings are used. Trigger is set on descending part (top) and ascending part (bottom) of the signal.

In the Auto mode (AT), the oscilloscope first scans the whole range of the signal and will then scale the limits of the trigger level respect to the value of the signal voltage. After this, the trigger happens automatically from the section of the signal you can choose with the LEVEL switch. AT mode is useful to use in situations, where the signals are simple enough and have frequency over or at least 20 Hz.

Graph of the signal will be stable, if the trigger level stays the same between trigger events. With low frequencies (a few Hz or around), there will be a delay in reaching of the trigger level. That leads to the situation, where triggering begins automatically in the AT mode before the trigger level is actually reached.

TRIGGER SOURCE has in addition to the normal inputs 1 and 2 also two other positions: EXT(ernal) and LINE. In EXT position the trigger signal must be connected to the EXT input.

XY-mode

The oscilloscope can be used as a xy plotter, see fig. 3. In that case, sweep generator is turned off. The first signal will deviate the electron beam to horizontal, another to vertical direction. XY functioning is commonly used when measuring the phase difference between two signals.

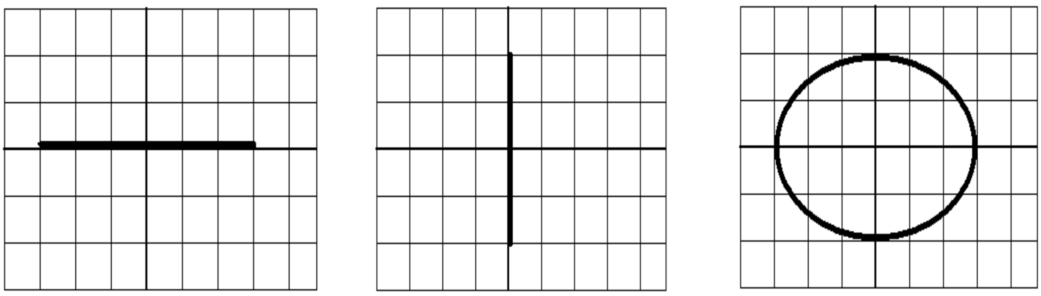

Figure 3. Principles of the XY mode: the signal of the second channel which is mapped on to y-axis is grounded (GD switch is on) and signal from another channel is shown parallel to x- axis. In the second picture, situation is reversed. In third picture, both signals are shown and they are mapped onto the same picture as a function of time.

3 Briefly on electric components and phase-difference

In the AC circuit, the resistor behaves similarly as in the DC circuit. There is no phase difference when the resistor is used in the AC/DC circuit. Only the amplitude is changing. A coil and a capacitor can create phase difference between the current and voltage. In the coil, this difference is around 90 º. In the capacitor, difference is -90 º, in other words, maximum value of the voltage lags that of the current. Total phase difference of the coil and capacitor depends on the reactances of the components.

4 Measurements

The experimental part consists of the following exercises. Print a pre-filled questionnaire found on the student laboratory web pages. Do not forget to use the manual of the oscilloscope.

Tasks:

1. **DC potential.** Measure electromotive force of a flat and a cylindrical battery by using the oscilloscope and a digital voltmeter. Don't forget the error estimate! (see the manuals of the voltmeters). Notice, that DC input has to be used with the oscilloscope.
2. **AC potential.** Use a 5 V AC source (the yellow transformer). Measure U_{max} and U_{eff} with the oscilloscope as well as with the analogue and digital voltmeters. Deduce the period time and frequency of the AC signal (do not forget the error limits!). For the frequency, use whole width of the screen! Answer with reason, whether one should use one or several periods. From what part of the period one should take the readings? Why so? (When determining period time and frequency, try to use the different positions of the SLOPE and LEVEL switches.)
3. **Cumulative potentials.** Connect the AC source and the flat battery used in the previous task as shown in the arrangement of figure 4. Try out different positions of the AC/GRD/DC switches. What happens and why? Sketch a figure in each case.

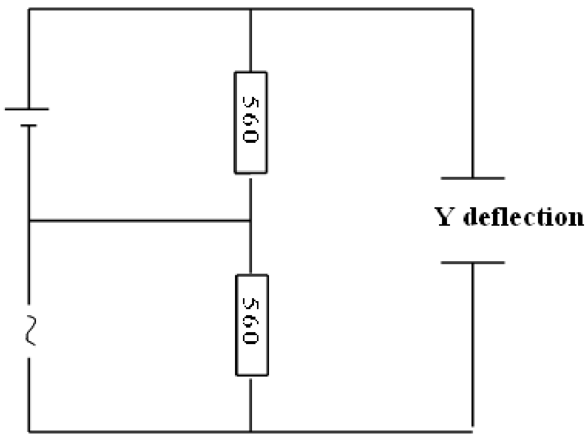

Figure 4. The circuit for testing AC/GRD/DC positions of the oscilloscope

4. **Trigger modes**. Bring the sine wave into the scopes input and use it to test AUTO and NORMAL modes. You can generate the signal by using the signal generator or transformer (yellow plastic casket, which is marked as “muuntosähkö”). Use the NORMAL mode and adjust trigger by using LEVEL switch so, that picture of the sine wave appears on the oscilloscopes screen. Adjust also the voltage range and sweeping frequency of the oscilloscope if needed to. Draw a picture of the signal of your oscilloscope on the answer sheet. What is the trigger level, and is it on the ascending or descending part of the signal? Turn SLOPE switch into the different position and draw a picture. Mark the trigger level on that picture too. After you can see the sine wave on the scopes screen, adjust the trigger level up to the point, that input signal will never reach. What happens and why? Draw a picture of the slope just before it reaches the trigger level.

   Next, change the oscilloscope from the NORMAL mode to the AUTO mode without changing trigger level. Still check out what happens, if you turn the LEVEL switch over its whole range. Try with both positions of the LEVEL switch.

5. **Phase difference in the LRC circuit.** Build the LCR circuit shown in figure 5. Use a table top function generator like GW Instek (or corresponding). Use the following components: C=1µF, R = 220 Ω and L between 170 - 350 mH. Determine the phase difference of the LCR circuit with f = 180 Hz. Phase difference can be estimated by measuring the distance between separate signals when they are in same phase. (You need to measure over all components e.g potential over resistor and other

components. Phase difference can be calculated from equation (1), where Δt is the time difference of the same phases of the two signals. T is period time.

$$\varphi = \frac{\Delta t}{T} 360^\circ \qquad (1)$$

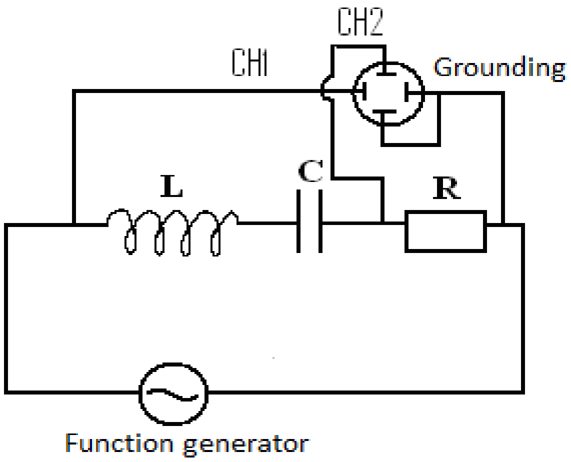

Figure 5. The setup for determining the phase difference in the LCR circuit.

The phase difference of the LRC circuit in XY mode. . Determine the phase difference in a circuit used in task 5 by utilizing the XY mode of the oscilloscope. In the previous task the phase difference was determined by using the dual channel operation mode of the oscilloscope. That mode shows the signals of both channels at the same time as a function of time ((x(t) and y(t)). In the XY mode, first signal is displayed as a function of the other.

In the case of the LRC circuit, the picture which forms on the oscilloscope screen (see fig. 6) is either an oblique ellipse, a circle or a line. It has been explained in the manual of Hameg, how it is possible to determine the phase differences, which are not more than 90 degrees.

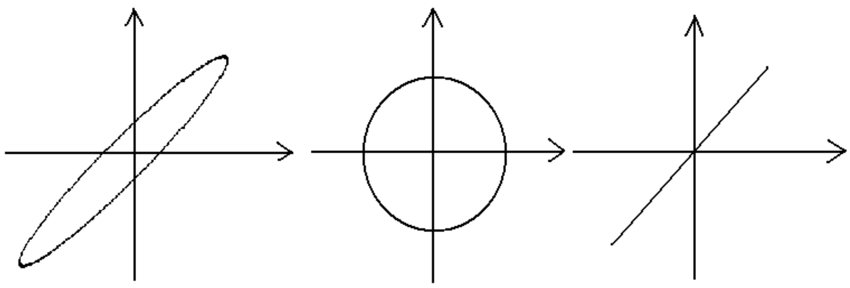

Figure 6. Some xy plots you might see on the scopes screen. In the picture left phase-difference is 45º, in middle 90º and to the right 0º.

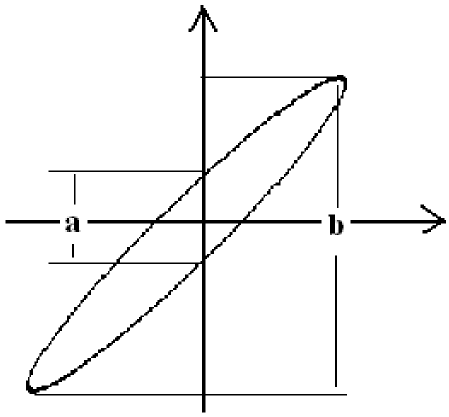

Figure 7. Determination of the phase difference using XY mode

Phase difference can be solved using eq. (2) from the quantities *a* and *b* in Figure 7:

$$\sin\varphi = \frac{a}{b}, \tag{2}$$

or in other words,

$$\varphi = \arcsin\frac{a}{b}.$$

5 Results

Return the notes made during the measurements supplemented with the drawings and answers to the questions. Error estimates are required only for those measurements indicated in the questionnaire.