

## Task IV. Analysis of the signals

**Required knowledge:** Human voice; Electrical phenomena in living systems; Electric properties of tissues

### 1. Measuring the voltage and frequency of electric signals with the oscilloscope

Main task:

To learn how to operate an oscilloscope, and its use for voltage and frequency measurement of periodic electric signals.

Measurement aids and implements:

Two-channel oscilloscope, generator of alternating voltage (further only "generator"), junction cables.

Procedure:

**NOTE: SEE GRAPHIC INSTRUCTION ON WEB (WWW.MUNI.CZ/BOFYZ)!**

- 1) Connect the generator with the oscilloscope, i.e. the generator output with the input of the oscilloscope vertical amplifier (channel A or B) by means of junction cables.
  - 2) Switch on the oscilloscope, adjust optimum brightness and track focusing and test the vertical and horizontal track shifts, switching over and continuous regulation of the deflection factor and the time base. Knobs for continuous control of the deflection factor and the time base (red control elements) must be set in the right position during all measurements!!!
  - 3) Switch on the generator. Adjust knobs for continuous control and switches of voltage setting in arbitrary positions.
  - 4) Adjust the maximum height of the track on the screen, but within the limits of the grating, by means of the deflection factor switch (in the channel with the input signal). Adjust the position in which the number of periods of the displayed signal will be well and quickly assessable (e.g. 5 – 10 periods) by means of the time base switch.
  - 5) Adjust the track position of the displayed signal with the knob for the vertical track shift and record its HEIGHT in divisions of the grating (Y) and the adjusted deflection factor (S) into the table. Adjust the position of the displayed signal with the knob for horizontal shift and record the number of whole periods of the signal (N), the corresponding number of the horizontal grating divisions (X) and the value of the time base in s/division (T) into the table.
- (Time base values on the left-hand side of the time base switch are in ms/division, on the right-hand side are in the  $\mu$ s/division – necessary to convert!)
- 6) Repeat the procedure described in points 3) through 5) four times for other distinctively altered voltages and frequencies of output signal of the generator.
  - 7) a) Calculate peak-to-peak voltage U for each measured signal

$$U = Y \cdot S \quad /V/$$

where Y means the number of vertical divisions of the grating corresponding to the track height of the displayed signals, and S is the deflection factor (V/division) adjusted with the corresponding switch.

- b) Calculate the frequency f for each measured signal

$$f = \frac{N}{X \cdot T} \quad /Hz/$$

where N denotes the number of selected periods of the displayed signal, X is the

number of horizontal divisions of the grating corresponding to the number  $N$  of selected periods, and  $T$  denotes the value of the time base (s/division) adjusted with the corresponding switch.

**In record:**

**Create a table with measured and calculated values for five different signals:**  
**a) values of height of track ( $Y$ ), values of deflection factor ( $S$ ) and calculated voltage values of the measured signals ( $U$ ), and**  
**b) numbers of whole periods of the signal ( $N$ ), corresponding numbers of the horizontal grating divisions ( $X$ ) and the values of the time base in s/division ( $T$ ) and calculated frequency values ( $f$ ) of measured signals.**  
**possible. Plot the waveforms of tuning forks and determine their corresponding frequency. Verify that the found frequencies correspond approximately to the actual frequency of used tuning forks. Discuss possible discrepancies.**

## 2. Frequency dependence of tissue and tissue model impedance.

Main tasks:

To acquaint with the function of passive electric elements in alternating current circuit with variable frequency, its use as a tissue model and low-pass filter.

To verify impedance character of tissues in alternating current network with variable frequency.

Task 1

**Frequency dependence of impedance of human organism tissues**

Measurement aids and implements:

Generator of alternating voltage (further only "generator"), two-channel oscilloscope, interconnecting module with resistor of known resistance, skin surface electrodes, cellulose wadding, ECG gel, ether, junction cables.

**Necessary knowledge: Ohm law, volt-ampere characteristics, impedance of human organism - self-study**

Procedure:

- 1) Attach to the interconnecting module (according to symbols on the module) junction from the generator, from the two-channels A and B of the vertical oscilloscope amplifier (in the earthing clips of module ( $\perp$ ) connect green eventually black earthing plugs of cables from the generator and oscilloscope). Insert the connector to correspondingsocket with cables connecting the skin electrodes. (Compare the wiring with schematic task connection diagram.)
- 2) Fasten the two electrodes on the upper extremity by means of the fastening rubber band, best on the forearm (on the dorsal and the volar sides). The contact areas must be degreased with ether and spread with ECG gel. Attach cables, which lead to the connector inserted in the interconnecting module, to the electrodes by means of banana plugs.
- 3) Put in operation the oscilloscope and the generator. Adjust the deflecting factor  $0.5V/T$  (i.e.  $0.5\text{ V}$  per one division of the measuring grating) for channel A of the oscilloscope vertical amplifier. Select the frequency of **100Hz** on the generator, and (by regulating its output voltage) adjust the height of the displayed track on channel A of the oscilloscope to 2 divisions of the measuring grating. This **peak-to-peak voltage  $U_g = 1V$**  must be constant

during the whole measurement.

4) According to the voltage magnitude of the displayed signal on channel B of the oscilloscope, adjust the suitable deflecting factor for the accurate reading of the track height. Record the frequency of the measured voltage, the height of the track in channel B (number of divisions of the measuring grating) and the adjusted value of the deflecting factor (to determine the voltage  $U_R$ ) into the prepared table.

5) Adjust gradually further frequencies: 100, 250, 500, 750 Hz, 1, 2, 4, and 8 kHz on the generator. Check or adjust the output voltage of the generator on channel A of the oscilloscope (1V) and repeat the procedure included in point 4 after each adjustment of frequency. Adapt the frequency of the time base of the oscilloscope to the voltage frequency from the generator in order to read exactly the height of the tracks on the screen.

6) Calculate the magnitude of the tissue impedance  $Z$  for each frequency of voltage  $U_z$  occurring on it ( $U_z$  is the difference of the output voltage of the generator  $U_g$  and voltage drop  $U_r$  across the known resistor  $R$ ) from current  $I_z$  through the whole circuit (it is calculated from the voltage drop  $U_r$  across resistor  $R$  and from its resistance (available at the place of the task). For calculations use the following equation:

$$Z = \frac{U_z}{I_z} = \frac{U_g - U_r}{\frac{U_r}{R}} \quad /\Omega/$$

The symbols used are explained in the circuitry below.

**In record:**

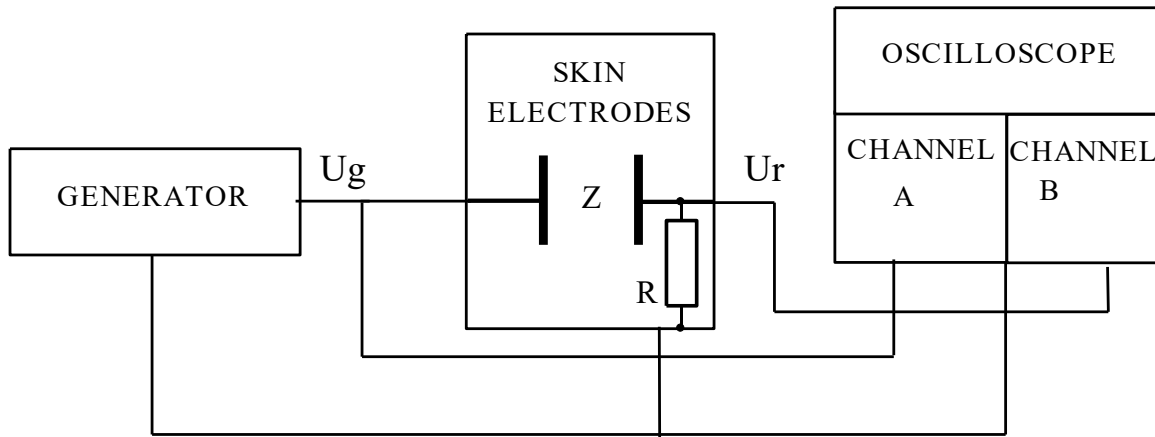
- Create the table with tissue impedance values ( $Z$ ) calculated for each measured frequency.
- Plot the graph of the dependence of measured tissue impedance on frequency.

Example for Table

frequency (Hz)	$U_g$ (V)			$U_r$ (V)			$Z$ ( $\Omega$ )
	defl. fact.	divisions	voltage (V)	defl. fact.	divisions	voltage (V)	
	S	Y	Y*S	S	Y	Y*S	
100	0.5	2	1				
250	0.5	2	1				
500	0.5	2	1				
750	0.5	2	1				
1000	0.5	2	1				
2000	0.5	2	1				
4000	0.5	2	1				
8000	0.5	2	1				

Fill in the real measured and calculated values into empty fields.

Circuit diagram for measuring tissue impedance



### 3. Measuring skin resistance

Main task:

Measuring skin resistance.

Measurement aids and implements:

Multimeter HC506, skin electrodes, rubber bands, junction cables, cellulose wadding, alcohol, saline, contact gel for ECG (ECG gel).

Procedure:

- 1) By means of rubber bands attach two electrodes to the forearm of the subject, and connect them with the multimeter by means of the junction cables.
- 2) Set the switch for measuring of resistance to the position with symbol  $\Omega$ . Read the value of the resistance (see display - values will be in  $\Omega$ ,  $k\Omega$  or  $M\Omega$ !).
- 3) Remove the electrodes and wipe the epidermis with alcohol. After attachment the electrodes to the same position measure the resistance  $R_2$ .
- 4) Apply saline between the epidermis and the electrodes and measure the resistance  $R_3$ .
- 5) Apply ECG gel between the epidermis and the electrodes and measure the resistance  $R_4$ .

**Record:** Create the table of measured resistance values and explain the differences, discuss the effect of used contact media.