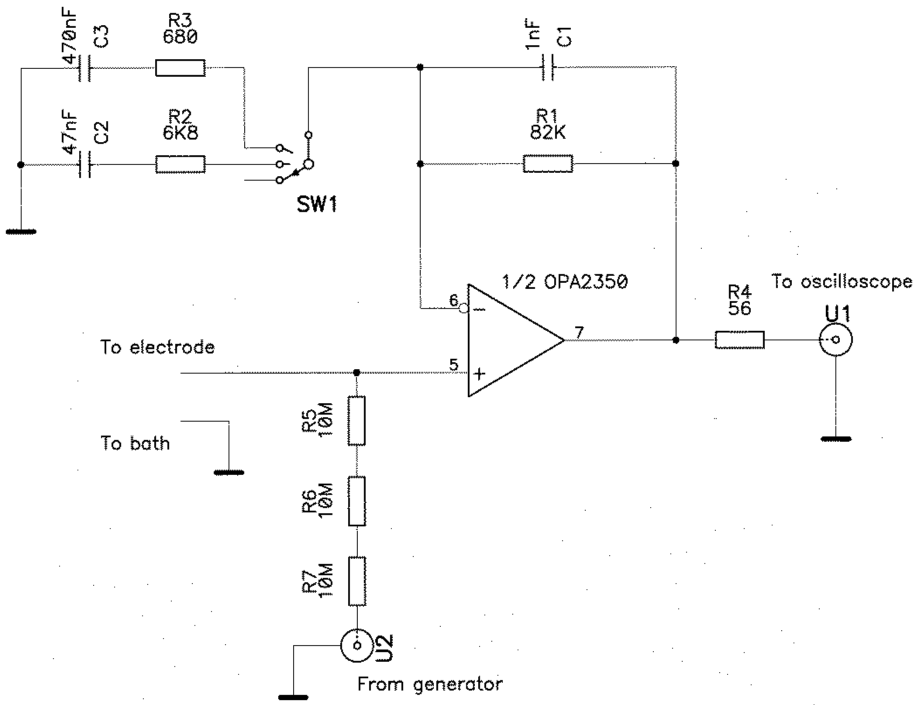
Exercise G

Knowing the impedance of electrophysiological recording electrode is important for estimation of its recording capabilities – number of cells that can be recorded or separated, sensitivity to noise and etc. However, current that one should pass through such electrode for measurement should not be too high: cells in the vicinity of the electrode tip can be destroyed. For the extracellular recording electrode the current should not exceed 30 nA. Most of electrical activity of single cells (spikes) lies in the frequency range 300-3000 Hz. Thus, to estimate suitability of the electrode to record such activity, its impedance is usually measured at 1000 Hz.

To measure the impedance of the electrode build the circuitry depicted below. Use the previously assembled in Exercise C power supply on two batteries. Use the second part of OPA2350 double amplifier that was not used before.

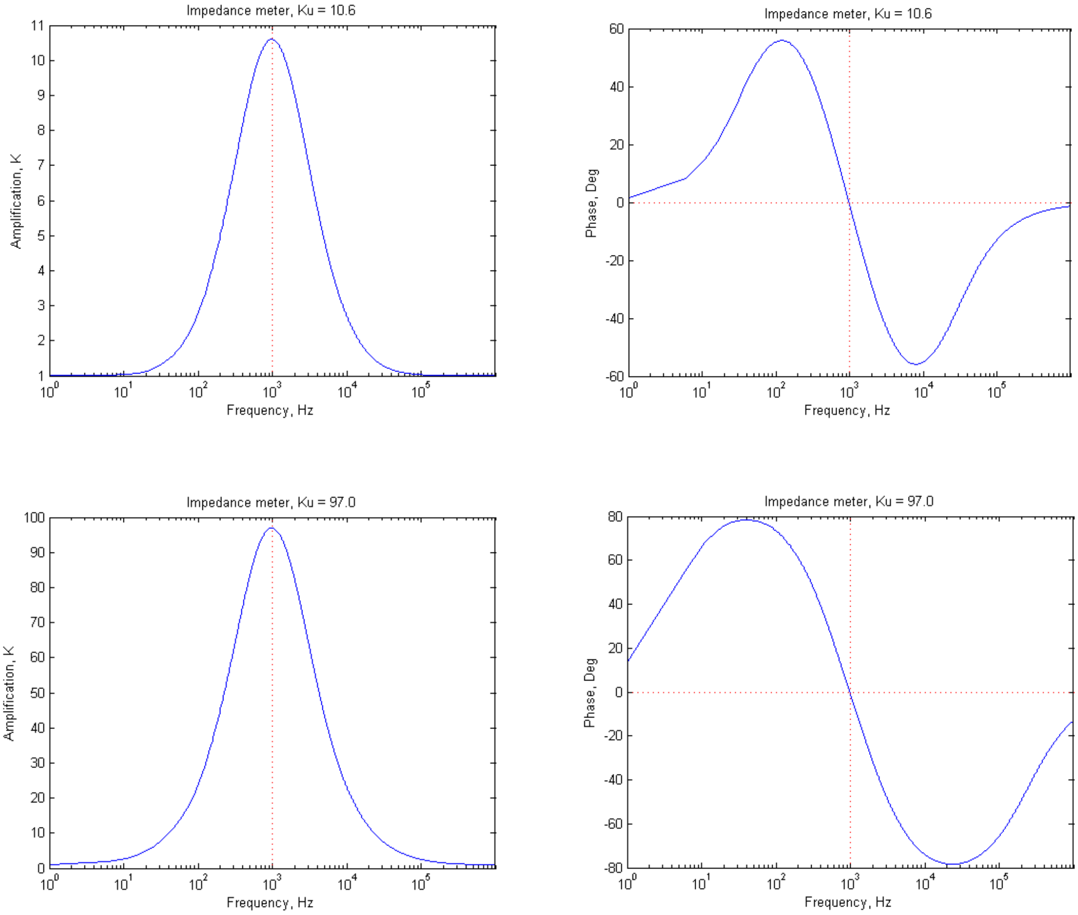


Additional component:
U3 – Switch SS-14M DP2 (Distrelec 200187)

When switch SW1 is in the lowest position (disconnected), the amplifier works as a unit gain follower. When the switch is in the middle position, the components are selected in a way to have the gain about 10 (10.6) at 1kHz, and when in the top-most position - approximately 100 (97.0). Having this switch one can chose the most convenient gain for the measurement (that gives the output amplitude about 1V, but less 1.5V to avoid clipping). The amplification cascade has the frequency band 500 Hz – 2 kHz approximately. It amplifies signals selectively around frequency of interest 1 kHz. The transfer function of the cascade is described by equation:

$$K = 1 + \frac{R1}{R2} * \frac{1}{(1 + i * Omega * C1 * R1) * (1 + \frac{1}{i * Omega * C2 * R2})}$$

Absolute value of this transfer function and its phase are plotted below for two cases Ku = 10.6 (R2 = 6K8, C2 = 47nF) and Ku = 97.0 (R2 = 680, C2 = 470nF). Note that the amplification cascade introduces (almost) zero phase shift at the frequency of interest 1KHz.



The impedance of unknown component (electrode) is measured by the voltage drop on the divider consisting from 30MOhm resistor and this unknown component. Use signal generator to apply sinusoidal voltage of 1V amplitude to this divider. The high-ohmic resistor in the divider is used to limit the testing current by 33 nA to avoid cell damage if one shall use the device to measure impedance of the electrode in the brain tissue. To verify functionality of cascade, measure the impedance of two known components – 1M resistor, 1% accuracy and 150 pF capacitor. Check the capacitance by LCR-meter. This can be done also by multimeter, but specialized LCR meter is more precise. Do your measurements coincide with expected? How can you explain the difference? How can one improve the accuracy? Hint: measure the parasitic impedance of the device input when the component is not connected. Then subtract this parasitic impedance from the measurement results. Don't forget that the impedance can have real (active) and imaginary (capacitive) parts. Which part is dominant in the current case?

Measure the impedance of the tip of 10 um Teflon insulated wire that is typically used in tetrodes for neuronal recording. The expected impedance should be about 1-5 MOhm. For measurement cut a piece of wire about 15 cm. Melt/burn the insulation by the lighter or soldering iron at the distance of several centimeters from one end, but not the tip, as if the tip is de-insulated, the wire is difficult to put in the connector. Take the 1.27 mm mother connector (Distrlec 120009). Remove one pin by pushing it out. Put the wire in the hole in a way to have the de-insulated part in the connector and put the pin back. The wire will be reliably fixed between the pin and the plastic part of the connector. Measure the impedance of the electrode placing its tip in the aluminium dish with the isotonic saline solution (0.9% NaCl). Try to do this as precise as possible. Compare your measurement with the measurement by the commercial electrode impedance tester BAK Electronics IMP-2A (BAK_Electronics_IMP-2A.pdf).

If you have time: Try to figure out which measurement is more accurate. If your impedance meter outperforms the commercial device in accuracy - congratulations!