Exercise B

Let's setup a very simple RC-filter circuit. A simple RC low-pass filter consists of a resistor and a capacitor. While the current that flows through a resistor is given by the voltage applied to it, the current that flows from a capacitor is proportional to the change of the voltage, i.e.

$$I = C\,\frac{dU}{dt}$$

The symbol of a capacitor is shown in Figure 1, the unit of capacitance is Farad. Now we know enough to understand the circuit in Figure 2, a low-pass filter.

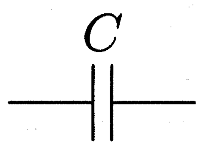

Figure 1: A capacitor.

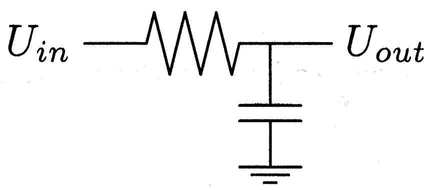

Figure 2: A low-pass filter consists of a resistor, a capacitor and a ground connection.

- Setup a low-pass filter circuit (R = 1K and C = 0.1µF). Connect U_{in} to a function generator and the first channel of an oscilloscope. Connect U_{out} to the second channel of the oscilloscope.
- Suppose that R and C are unknown. Looking at the filter response to 1V step, estimate the frequency of -3dB attenuation of the filter (cutoff frequency). How much does it differ from the theoretical F_{-3dB}?
- Apply a sinusoidal voltage with 1V amplitude to the filter input. Measure the attenuation U_{out}/U_{in} for different input frequencies, in order to describe the filter for all input frequencies.
- Plot your points in a log-log-plot. There are two phases, where the points can be fitted by straight lines that intersect. Take a few more measurements around the point of intersection.
- What is the attenuation at the frequency, where the two lines intersect? Compare this frequency with $F_{-3dB} = \frac{1}{2\pi RC}$, called the cutoff frequency.
- Exchange capacitor and resistor. What happens? Repeat the experiments above and draw the attenuation into the same log-log-plot.

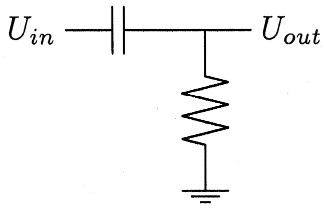

Figure 3: A high-pass filter.

- Write the equations for:
    1. Attenuation ratio U_{out}/U_{in} of the first order filter as a function of input signal frequency.
    2. Phase shift between input and output signals.

  The charts of these dependencies are shown in fig. 1-19 on page 28 and fig. 1-20 on page 30 of Bretschneider & Weille "*Electrophysiological Methods & Instrumentation*". A hint: one can search the stationary solution of the differential equation in the form
  $f(t) = a \cdot \sin(\omega t) + b \cdot \cos(\omega t)$.