II. WSK: Alternating current circuits

Key words: Alternating voltage and -current, electromagnetic coil and inductance, capacitor and capacitance, impedance (alternating current resistance), rms current value and rms voltage value, differential equation for charging- and discharging curve, time constants, cutoff frequencies, bandwidth.

1. Measurement of the charge- and discharge curves of a capacitor.

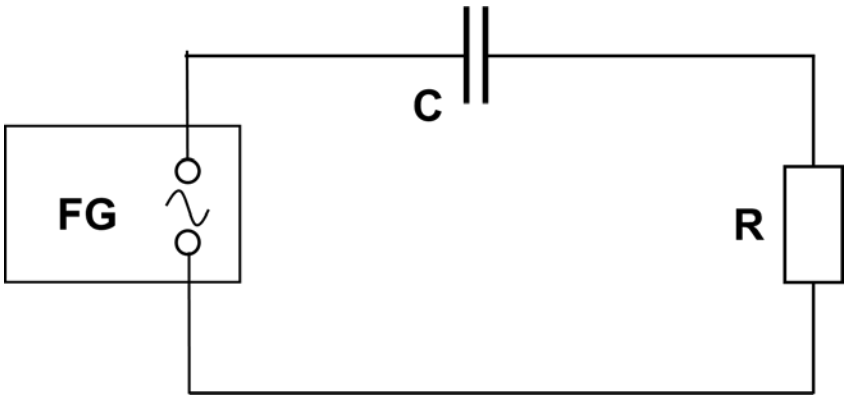

Fig. 6: R-C circuit for recording the charge and discharge curves of a capacitor of capacitance C. The function generator FG serves as voltage source. The resistor R is required for current limitation. The oscilloscope for observing the charge and discharge curve is not shown.

Tasks:
-Assemble a R-C circuit using a 18 kΩ resistor, a 1 μF capacitor and a function generator as driver (see Fig. 6). Connect the oscilloscope to the circuit in a suitable manner (Note the grounding point of the circuit: At the function generator and at the oscilloscope one connection pole each is earthed and the out- and inputs cannot be freely occupied). Set the waveform on the frequency generator to square wave. The frequency of the square wave signal should be suitable for observing the charge and discharge curve. If necessary, optimize the settings on the function generator and on the oscilloscope.
- Determine the capacitance C of an unknown capacitor based on the voltage drop across the capacitor as a function of time. To do this, plot the voltage drop on a logarithmic scale over time.
- Vary the time constant of the circuit at a fixed frequency of the square wave signal. Vary the frequency of the square wave signal at a fixed time constant of the circuit. Describe and discuss your observation qualitatively. Explain the relationship with the AC resistance (impedance) of a capacitor heuristically.

2. Measurement of frequency response of a high-, low- and band-pass filter.

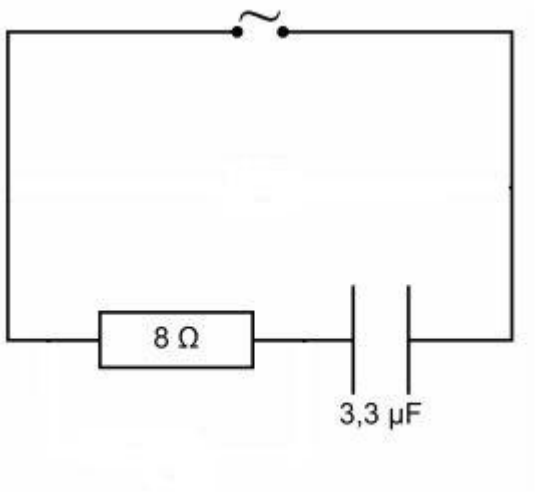

Fig. 7 RC circuit for use as a high pass filter. The measuring instruments and the connections for the output voltage are not shown.

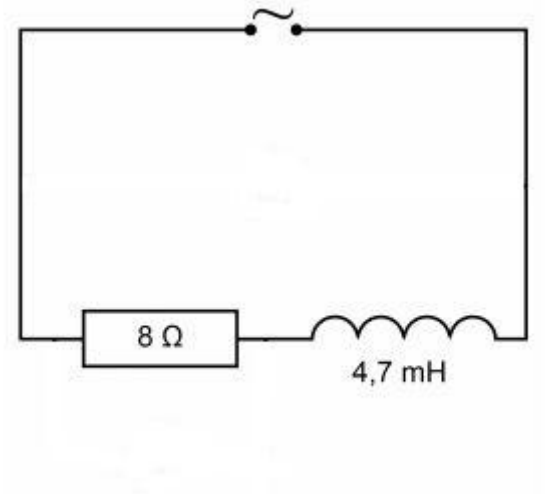

Fig. 8: RL Circuit for use as a low-pass filter. The measuring instruments and connections for the output voltage are not shown.

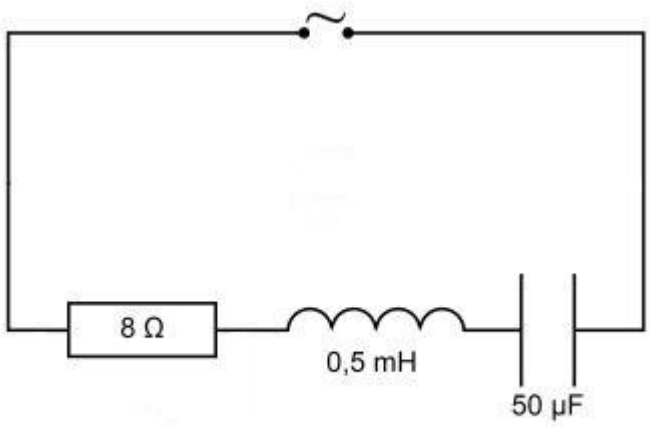

Fig. 9: RLC Circuit for use as a band-pass filter. The measuring instruments and the connections for the output voltage are not shown.

Tasks:
-Assemble the frequency filters corresponding to the circuit diagrams in Fig. 7-9. The 8 Ω resistors represent loads. Connect measurement instruments correctly to record the frequency response (see below) of the filter networks.
-Determine the frequency response for all three filter networks by measuring the generator voltage and the voltage across the load resistors as a function of frequency in the range 50 Hz to 20 kHz (in suitable gradations of measured values). Take note that the generator voltage does not remain constant because of the comparatively high internal resistance of the function generator.
-Determine the cutoff frequencies of the low and high pass filters and the bandwidth of the band filter.
- Determine the slope of the frequency response in the frequency range above (below) the cutoff frequency of the low-pass filter (high-pass filter).
-Compare the obtained values for cut off frequencies, bandwidth and slope with your theoretical expectations.

3. Questions for preparation

The following section summarizes some questions and remarks about the most important terms, definition and concepts related to passive AC circuits. Some questions about measurement instruments and there handling can be found here. Please use suitable literature to read about terms unknown to you.

Resistance, Inductance, Capacity

Which relationships are used to define inductance, resistance and capacitance?

Charging / discharging a Capacitor

The resistor in the circuit of Fig. 6 limits the current. Why is current limitation necessary for charging a capacitor?
Which form do you expect for the charge / discharge curve of a capacitor?
Why do you need an oscilloscope to record the charge- and discharge curve of a capacitor?
Why is it necessary to apply a square wave voltage to the RC circuit for this measurement?
How long does it take to charge the capacitor?
How and why does the duration of this process changes when you increase (decrease) the capacity of the capacitor or increase (decrease) the resistance value of the resistor?

Filter network circuits

RC, RL- and RCL devices (s. Fig. 7-9) represent frequency dependent voltage dividers, i.e. the attenuation of the output voltage depends on the frequency. Therefore these devices can be used as filter networks.

How does the impedance of a capacitor depend on the frequency?
How does the impedance of an electromagnetic coil depend on the frequency?
How does the total impedance of the series connection of a coil and a capacitor depend on the frequency?
Across which component the output voltage must be tapped in order that the circuits shows the intended filter characteristics?
Which output voltage do you expect for the high and low pass filters in the limits of very high and very low frequencies?
How would you construct a high-pass filter using an electromagnetic coil and a resistor?
How would you construct a low-pass filter using a conductor and a resistor?

Frequency response

The relationship between which parameters is depicted by the frequency response?
How is the frequency response adequately plotted?

What is a cutoff frequency of a filter network?
What is the bandwidth of a filter network?
How could you find the cutoff frequencies of the high / low pass filters and bandwidth of the band pass filter theoretically (suppose you known the values of the components)?
How would you determine these quantities experimentally / graphically?

Measurement instruments and function generator

Which parameters of the output signal can you set on a typical function generator?
Under which circumstances does the internal resistance of a function generator influence the current/voltage values measured at a connected load?

Which axis of oscilloscope display relates to the input voltage?
Which parameter relates (typically) to the other axis?
What is the purpose of the trigger function on an oscilloscope?

Literatur:
Feel free to use further sources which are well suited for your needs

1. https://www.allaboutcircuits.com/technical-articles/low-pass-filter-tutorial-basics-passive-RC-filter/
Online tutorial on low pass filters, includes also some general remarks and concepts

2. https://www.physik.fu-berlin.de/studium/lehre/gp/dateien/gp-doku/GP2_English_new.pdf
GP-Script pp. 49-52