Semiconductor Devices and Analog Circuits

Lab 1

BASIC INFORMATION

During the labs, we will make use of the following devices:

oscilloscope,
function generator,
power supply,
multimeter.
Manuals for this equipment is avialable in the lab.
Apart from the mentioned devices, we will use breadboards to connect the circuits under test.

It is obligatory for you to get to know how to use the following

Oscilloscope:

- the use of ”autoset” button
- channel 1 and channel 2 settings, including direct current/alternating current coupling (DC / AC)
- the key for automatic measurement ”measure”, and especially measurement and meaning of the following:
  - peak to peak voltage
  - frequency
  - mean value
  - RMS value
- XY mode
- timebase knob
- amplitude knob
- trigger level knob

Function generator:

- signal shape
- signal output:
  - 50 Ohm
  - TTL
- frequency
- offset
- symmetry/duty cycle
- amplitude

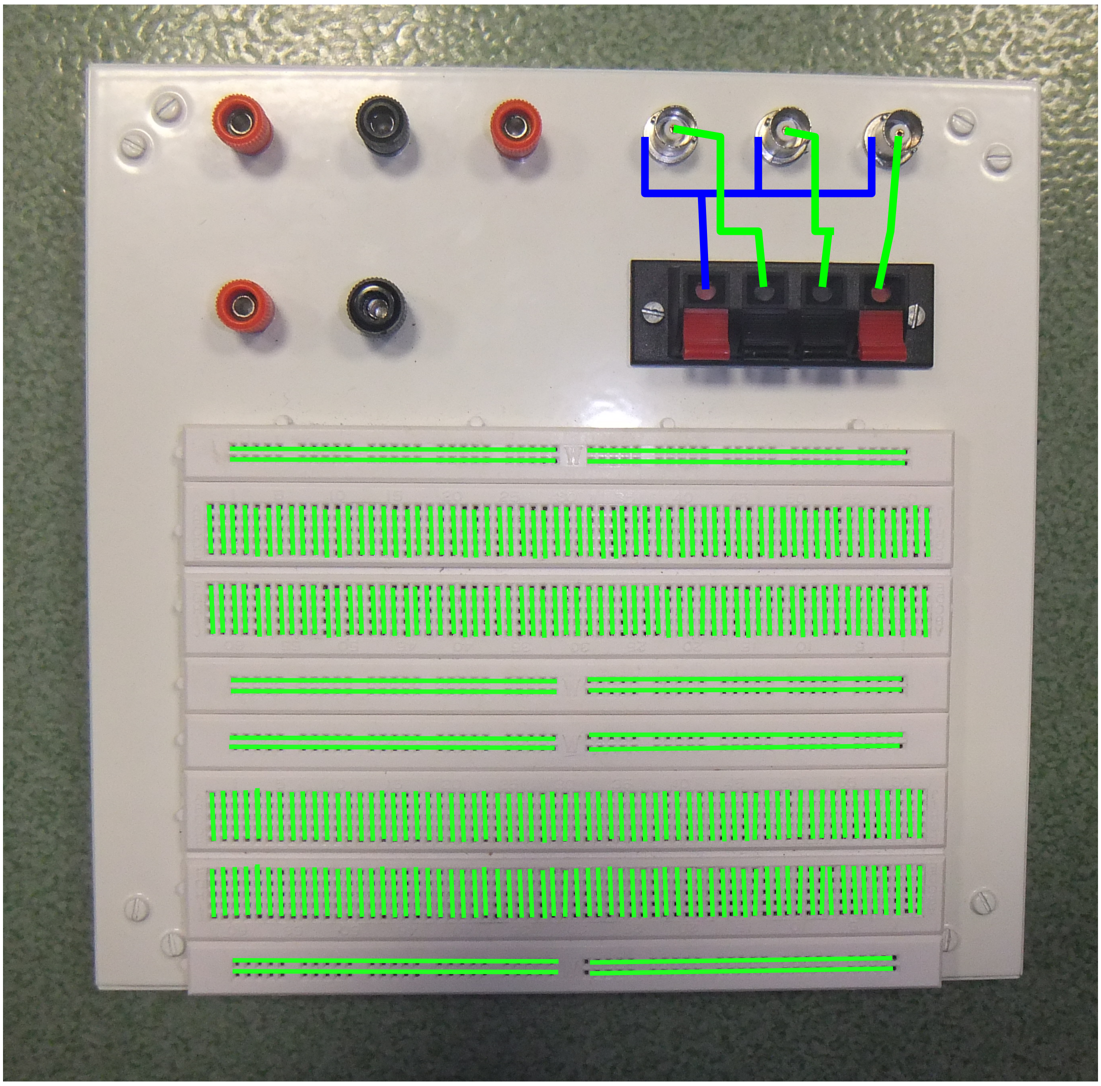
Power supply:

- what voltages and on what outputs are available?
- how to adjust the voltage on the 0-30V output?
- Current limit on 0-30V output – how does it work?

Multimeter:

- voltage measurement (it is necessary to check whether the probes are plugged in the correct terminals)
  - connect in **<u>parallell</u>** to the measured device
- resistance measurement (do not hold the resistor in your hands – lay it on the table and push probes to the leads without touching the resistor with your hands)
- current measurement (it is necessary to check whether the probes are plugged in the correct terminals)
  - connect in **<u>series</u>** with the measured device

Breadboard connection diagram:



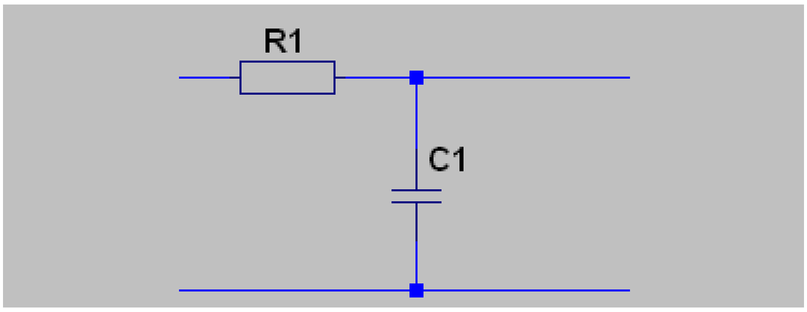
Lowpass RC filter measurement

1. Read from the marking and then measure all the components that you have in the tray.

2. Choose the following two components:
   R from the range 4 – 20 kΩ
   C from the range 22 – 47nF
   calculate time constant and corner frequency basing on the measured values of the components:

   $$\tau = RC$$
   $$f_c = \frac{1}{2\pi\tau}$$

3. Build the following circuit from the components that you selected



   R1 = 4 – 20 kΩ
   C1 = 22 – 47nF

4. With the use of the signal generator (sinusoidal shape) and the oscilloscope, measure the corner frequency of the filter (output voltage amplitude equal to 0.707 of input voltage amplitude).

5. Measure with the oscilloscope the phase offset between input and output signal for the corner frequency. You can use Lissajous method or cursors. Set one cursor to the start of the period of the input signal, second cursor to the start of the period of the output signal and calculate the phase offset $\Delta\phi = \frac{\Delta t}{T} \cdot 360^{o}$ where T is the period of the signal.

6. Measure the rate at which the frequency response is falling for the frequencies above the corner frequency. In order to do that, you need to measure the amplitude of output signal for input frequency equal to $10 f_c$ and $20 f_c$. Calculate the ratio of those values. Present the results in the common for such calculations decibels per octave (dB/oct).

7. Observe the output signal for the square input signal of the frequency:
   f_{in}=0.1 f_c
   $f_{in} = f_c$
   f_{in}= 10 f_c

8. Measure the rise time of the output volatge for the step input. Connect to the input of the filter the square signal of the frequency of approximately 100 Hz. The rise time is defined as the time during which the output voltage rises from 10% to 90% of the final voltage. Perform the measurement with cursors and using the automatic measurements of the oscilloscope. Please verify whether the rise time satisfies the formula:

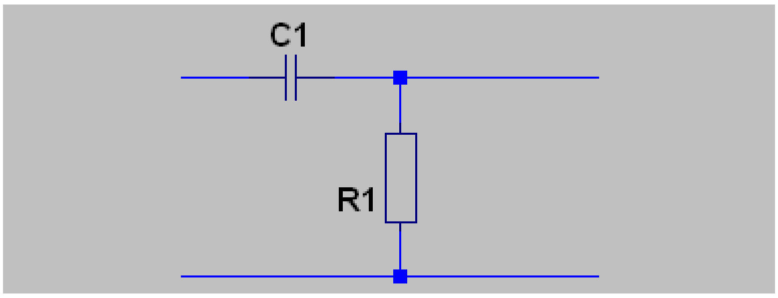
$$t_r = \frac{0,35}{f_c}$$

Highpass RC filter measurement

1. Choose R and C from the following ranges:
   R = 2 – 10 kΩ
   C = 2,2 – 10 nF
   calculate the time constant and corner frequency:

$$\tau = RC$$
$$f_c = \frac{1}{2\pi\tau}$$

2. Build the circuit:



   R1 = 2 – 10 kΩ
   C1 = 2,2 – 10 nF

3. Find the corner frequency of the filter (output amplitude = 0.707 * input amplitude).

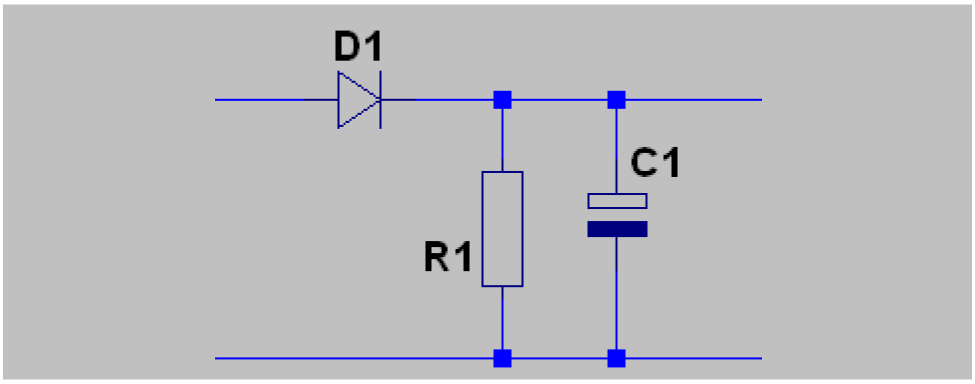
4. Measure phase offset between input and output sinewave of the following frequencies:
   $f \ll f_c$
   $f = f_c$
   $f \gg f_c$

5. Measure the filter response to a DC signal. Make sure that the oscilloscope channel is in DC mode. Vary the input DC voltage and observe how the output signal changes. Do the same observations for sinusoidal and square waves. Set input frequency $f_{in} > 10 f_c$.

6. Test how this circuit performs in the role of differentiator. Set the input frequency to $f_{in} = 0.1 f_c$, and shape to square wave. Observe the output signal. Compare the output signal to the output of an ideal differentiator circuit.

Half wave recitfier

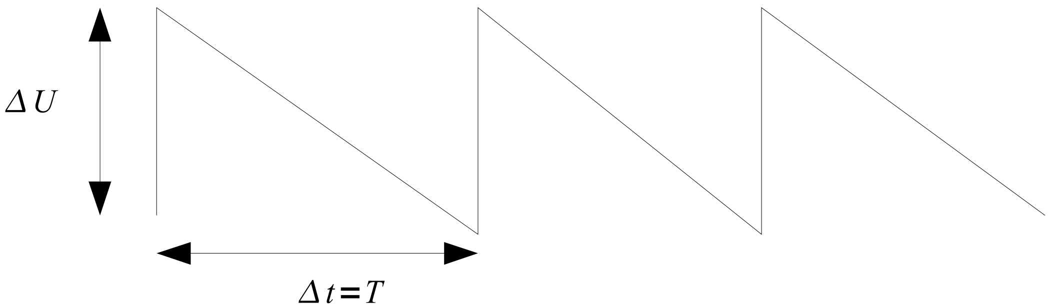
1. Build the following circuit:



R1 = 3 – 5 kΩ
C1 = 22 – 47 µF

2. Connect the generator to the input of the circuit. Set the signal shape to sinusoidal. Use the oscilloscope to find the relation between the ripple voltage ΔU and the input signal frequency in the range 20 Hz – 200Hz.

3. Derive the formula for ripple voltage using the assumption that the capacitor is discharged with a constant current during the whole period of the input signal and only recharged in indefinitely short time once in a period. Compare the formula results with the results that you obtained previously from the measurements.

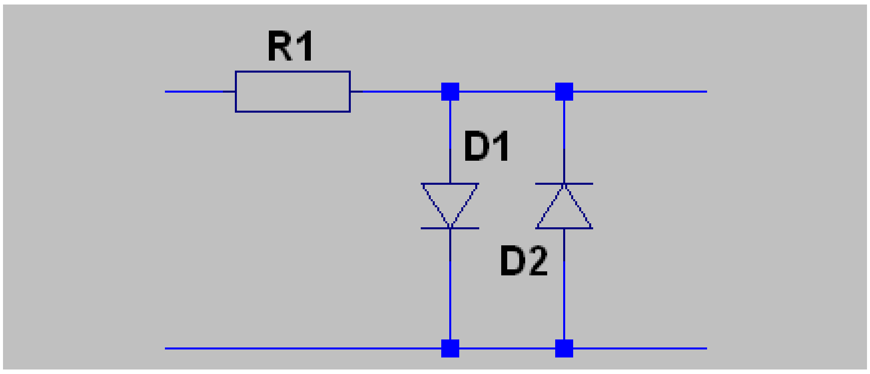


$$I_c = C\frac{\Delta U}{\Delta t}$$

$$I_c = \frac{U_{average}}{R1}$$

Diode limiter circuit

1. Build the following circuit:



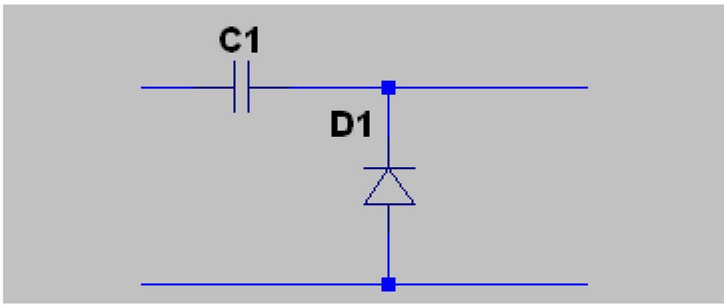
R = 2 – 5 kΩ

2. Connect sinusoidal signal with an amplitude of 10V and frequency of 100 Hz to the input. Observe the shape of the output signal. Use both channels of the oscilloscope with the input signal on one channel and output on the second channel. Align the channels so that the limiting action of the circuit is obvious.

3. Display the characteristics $U_{out} = f(U_{in})$. (use XY mode). Prepare the graph (pay attention to the axis marking), please mark the characteristical points and put the appropriate voltage values.

DC voltage recovery circuit

1. Build the following circuit:

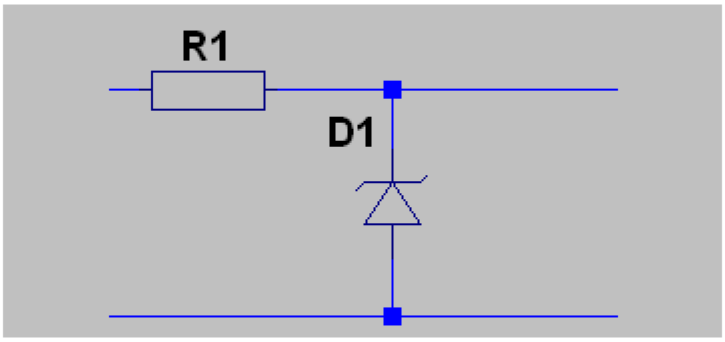


   C1 = 22 – 68 nF

2. Connect a sinusoidal signal with an amplitude of 5V and frequency of 1kHz to the input. Please observe how does the variation of the input DC voltage and input amplitude influence the output voltage. Please make sure that the oscilloscope is in DC mode.

Zener diode voltage stabilizer

1. Build the following circuit:



R1 = 1 kΩ
U_z = 3,6 V

2. <u>All the measurements must be performed using a multimeter.</u>
Please connect the input voltage (5V) from a power supply. Measure both – input and output voltage. Vary the input voltage in the range from 5V to 15V with the step of 1V.
Please calculate the stabilization coefficient $S=\frac{\Delta U_{¿}}{\Delta U_{out}}$ for each pair of measure points.
Please calculate the dynamic resistance of the Zener diode $r_d=\frac{\Delta U_{out}}{\Delta I_z}$ for each pair of measure points.