2023-01-26

Analog Eletronik IE1202 - Home Laboratory 1

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MUTTAKIN KARIM
November 25, 2020
Group - 15

1 Introduction

The following short experimental tasks have been designed to complement the knowledge that you acquired after reading the book, solving theoretical problems, and attending the lectures. One of the main objectives is that you quickly get familiar with electronics experimental work and become comfortable when working in an electronic lab environment.

This lab comprises 2 short tasks. You will design, simulate, build, and measure a non-inverting amplifier, and a summing amplifier. You will have to do some hand-calculations directly on a print-out of this lab manual. Screen-shots of simulations and measurement plots need to be added to a separate document. After finishing the lab, scan the lab manual and attach the document containing the screen shots as appendix. A single PDF file must be uploaded to Canvas.

NOTE1: Circuit schematics and simulation setups for all laborations are available as part of the QUCS material (project directory IE1202_HEMLAB_prj). All QUCS material can be downloaded from `https://github.com/saul-rodriguez/QUCS_ANALOG_ELEKTRONIK`

NOTE 2: To avoid any problems due to over-current and excessive loading, please use resistance values larger than 500 Ω!

NOTE 3: When you dimension the resistors, try to use the closest value that you have available in your kit.

2 Non-Inverting Amplifier

2.1 Circuit Theory

For the circuit in Fig. 1, calculate the value of R2 so that the voltage gain $A_V = V_{OUT}/V_{IN} = 11$.

Your hand calculation:

$$A_V = \frac{-R_1}{R_2} = \frac{V_{out}}{V_{IN}} = \frac{R_1 + R_2}{R_2} = 11 \Rightarrow R_2 = 1k\Omega$$

Answer: R2 = $1k\Omega$

What is approximately the minimum value of R2 that can be used before the output voltage is clipped?

Your hand calculation:

$$5 = \frac{10k + R_2}{R_2} \cdot 100m \Rightarrow R_2 = \frac{10k \cdot 100m}{5 - 100m} = 204\Omega$$

Answer: R2 = 204Ω

2.2 Circuit Simulation

Open QUCS and set up a schematic like in Fig. 1. Replace R2 with the values that you calculated and run transient simulations. Save screen-shots of the simulation plots and add them to an appendix at the end of this lab. Is the simulated and calculated gain the same? Are the clipping points the same? Comment your findings:

Comments: The simulated and calculated values are the same. (1.1)
The clipping points are also similar and lie close to each other.

2.3 Circuit construction and measurements

Since this is the first time you will do these measurement, we will take it step by step. As you get familiar with the equipment, it will become intuitive.

Before starting this step, make sure that the 5V power bank batteries are fully charged. You can use a USB mobile charger for this purpose (when the batteries are fully charged a green led will turn-on). With the exception of the 5V power banks, connect all the other components of the inverting amplifier as shown in Fig. 2. If you are not sure about how to select the resistor values, check the chart in Fig. 3. Set the oscilloscope probes to 1X.

Important! Note how the 5V power bank will be connected in series in order to create +5V, 0V (ground), and -5V. It is very important that you understand this since we will use this configuration during the rest of the course. The power banks have limited thermal and short-circuit protection; therefore, it is highly recommended to connect them carefully in order to avoid that they get damaged. For internal connections, we will always use the color RED for 5V, BLACK for 0V (ground), and BLUE for -5V. Do not use these colors for other purposes!

Connect the USB cable from the PicoScope instrument to your computer and start the PicoScope software. Now, connect the 5V batteries. Configure the signal generator: select a Sine waveform, Start Frequency = 1 kHz, Amplitude = 100 mV, Offset = 0V. Enable the signal generator (do not enable the sweep option). Now, change the number of samples to 100 MS, and the time base to 500 μS/div. Click on Trigger and select Auto. Also, select channel A as source for the trigger. Make sure that the oscilloscope probes are set as 1X. You can do this by clicking on A and B and changing the settings if necessary. Likewise, you can change the resolution from 8 bits to, for instance, 10 bits (very recommendable). Now change the input

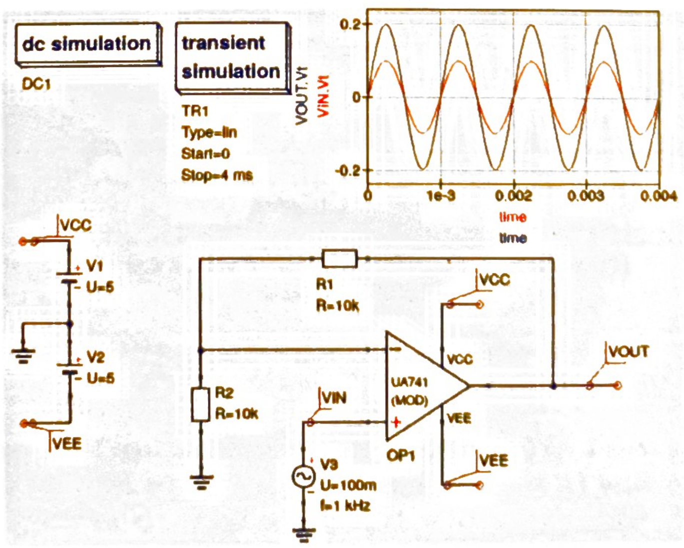


Figure 1: Non-Inverting Amplifier

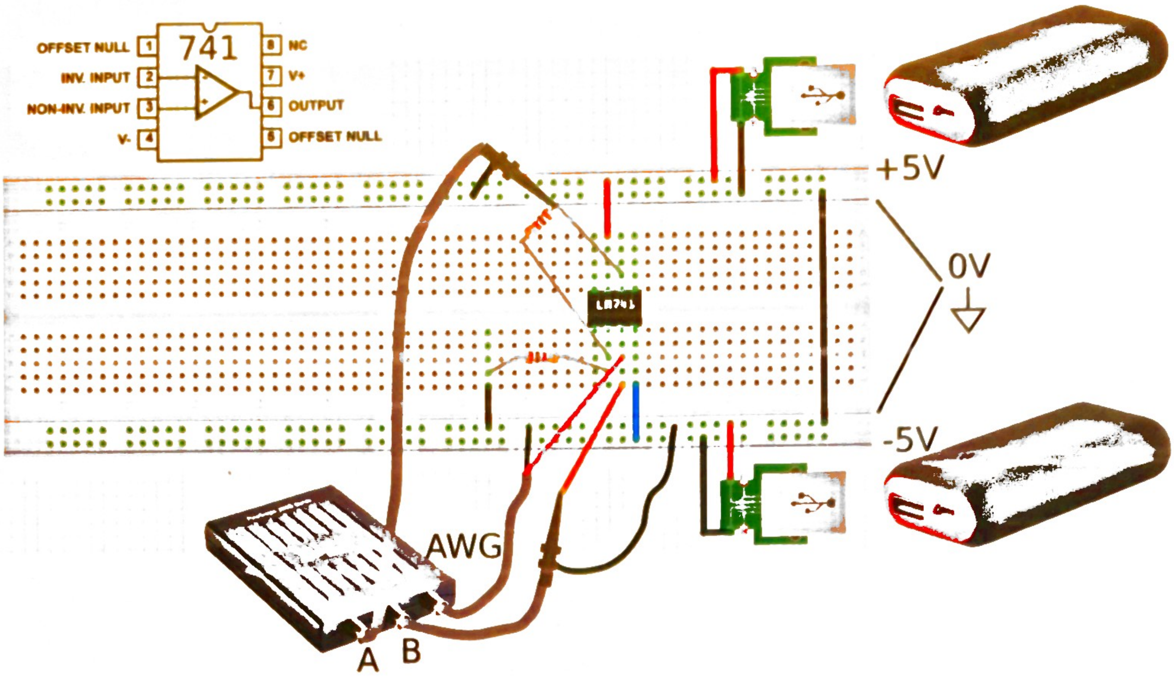
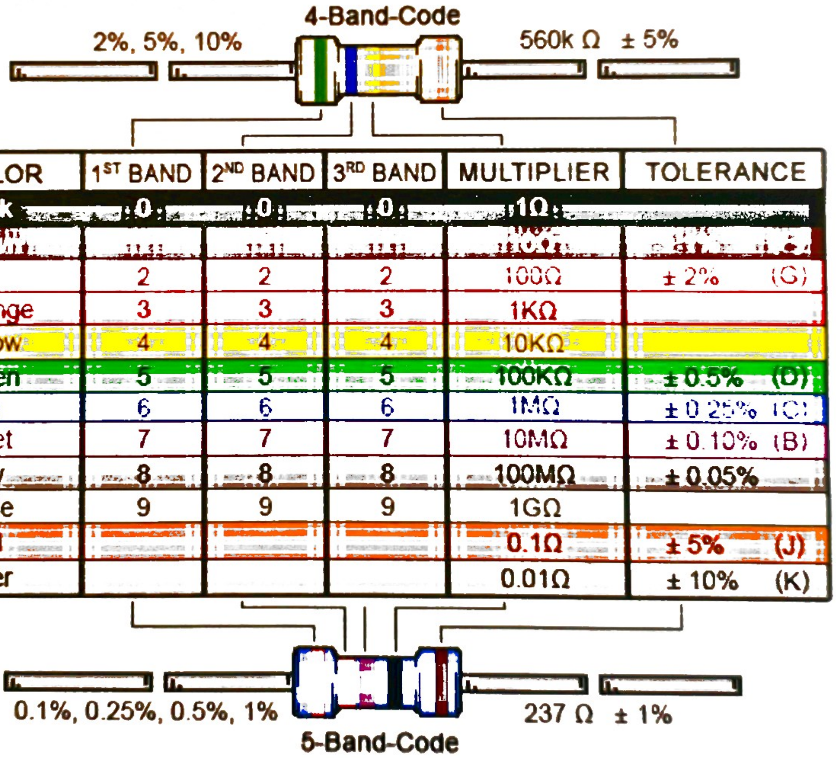


Figure 2: Non-Inverting Amplifier, prototype on breadboard



COLOR	1ST BAND	2ND BAND	3RD BAND	MULTIPLIER	TOLERANCE
Black	0	0	0	1Ω	
Brown	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Red	2	2	2	100Ω	± 2% (G)
Orange	3	3	3	1KΩ	
Yellow	4	4	4	10KΩ	
Green	5	5	5	100KΩ	± 0.5% (D)
Blue	6	6	6	1MΩ	± 0.25% (C)
Violet	7	7	7	10MΩ	± 0.10% (B)
Grey	8	8	8	100MΩ	± 0.05%
White	9	9	9	1GΩ	
Gold				0.1Ω	± 5% (J)
Silver				0.01Ω	± 10% (K)

Figure 3: Resistor color chart

range for channel A to ±2 V and for channel B to ±200 mV. Fig. 4 shows the PicoScope setup and the input voltage (channel B) and output voltage (channel A) waveforms.

Measure the amplitude of the input and output voltage waveforms. Is the simulated and measured gain the same?

Answer: It was very close, with a difference of -1.

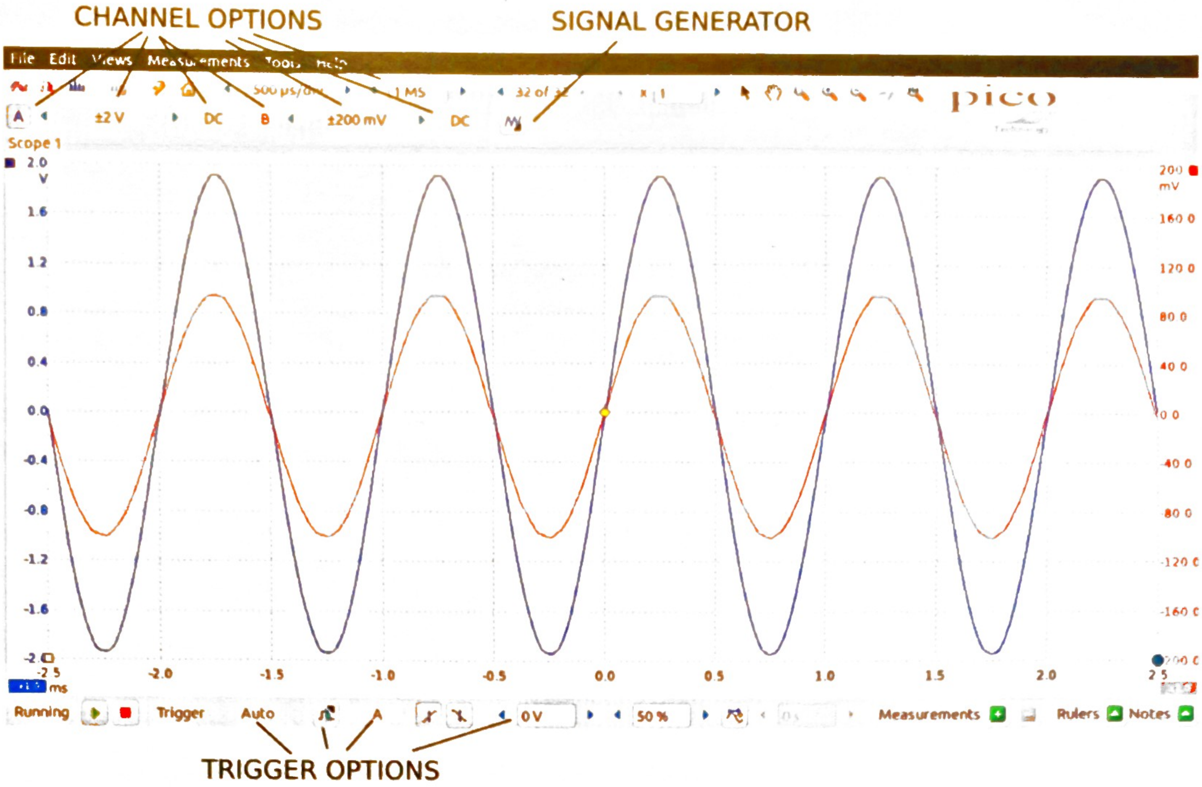


Figure 4: PicoScope setup

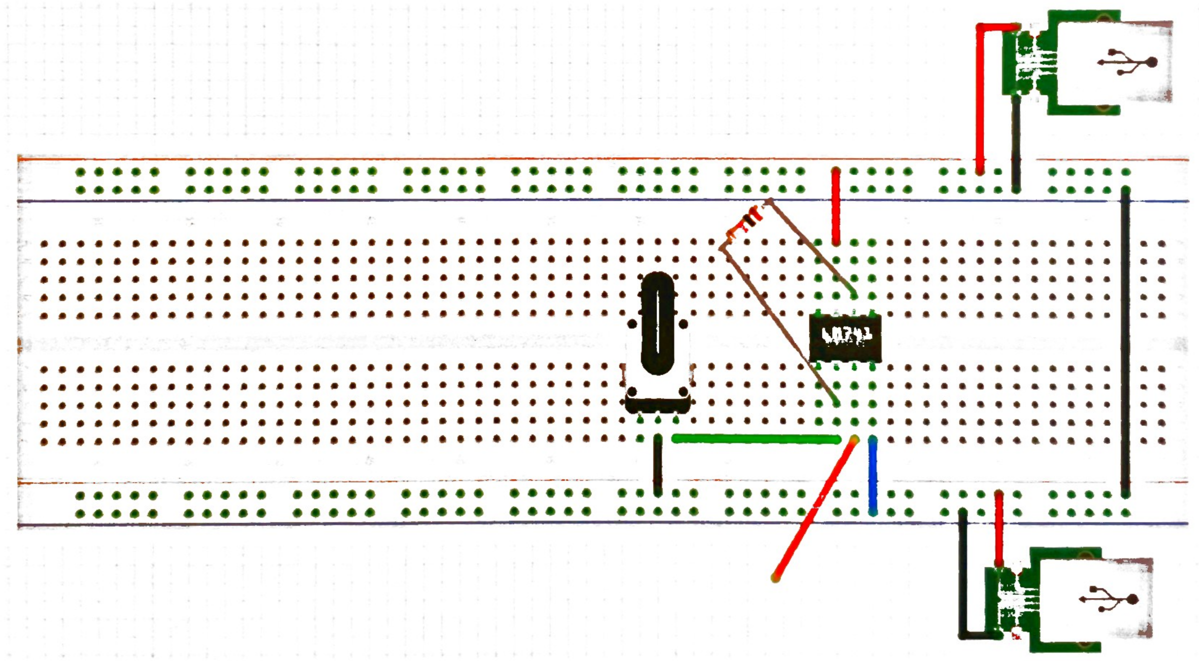


Figure 5: non-inverting amplifier with variable gain

Disconnect the power banks batteries. Replace R2 by a potentiometer as shown in Fig. 5 and connect the power banks batteries again. Now the amplifier has variable gain! Move the potentiometer and experiment with different gains. Increase the gain until the output starts to clip.

At what positive and negative voltage does the output of the amplifier clips?

Answer: Voltage clips at: positiv (+4,313 V) & negativ (-3,706 V)

Reduce the gain so that the amplification remains in the linear region. Change the view to spectrum mode and reduce the frequency span to 10 kHz. Identify the fundamental and harmonics both at the input and output. Take a screenshot of the spectrum.

Is there a visible distortion deterioration between the input and output? Explain.

Answer: There is little deterioration at the hormonic, but it is not so noticeable. One clear spike shows that the frequency is sinusoid

Change the view to the time domain and increase the gain so that the output voltage starts clipping. Change the view to the spectrum mode. Check the levels of the fundamental and harmonics. Take a screenshot of the spectrum.

Question 6: Is there a visible distortion deterioration between the input and output? Explain.

Yes. There is visible distortion. Many large spikes in the harmonics which makes it difficult to tell which type of frequency it is.

3 Summing Amplifier

3.1 Circuit Theory

Fig. 6 shows a summing amplifier. The objective of this circuit is to amplify V3 a factor of 10 and provide a 1.5V DC offset to the amplified so that it can be connected to an analog-to-digital (ADC) converter which accept signals from 0 V-3.3 V. Your task is to find values of R2 and R3 that accomplish these requirements.

Your hand calculation: $U_{UT} = -\left(\frac{R_1}{R_2} V_3 + \frac{R_1}{R_3} V_{2in}\right)$

$$\Rightarrow 1.5 = \frac{-1000}{R_2} + \frac{50u}{R_3}$$

Answer: R2 = 1kΩ

Answer: R3 = 33kΩ

3.2 Circuit Simulation

Open QUCS and set up a schematic like in Fig. 6. Replace R2 and R3 with the values that you calculated and run a transient simulation. Save a screen-shot of the simulation plot and add it to an appendix at the end of this lab. Is the simulated and calculated gain the same?

Comments: Yes, they are consistent with the simulations. offset is found to be 1.5. The amplitude is also found to be 1v.

3.3 Circuit construction and measurements

Mount the circuit of Fig. 6 on the breadboard (you just need to do small modifications to what you did in Section 3). Connect the PicoScope to the circuit: channel A to VOUT, channel B to VIN, and AWG to VIN. Connect the 5V power bank batteries, and start the PicoScope software. Configure the generator and oscilloscope settings in the same way we did in Section 2. Observe the input and output waveforms. Save a screenshot and append it to the end of the lab. Are your measurements consistent with your simulations?

Comments: They are very close as the offset is the same. The amplitude is over 2. The output in measured circuit was 60mv compared to the simulated are of 100mV. Peak was at 2.1 V and trough was at 0.9 v approximately.

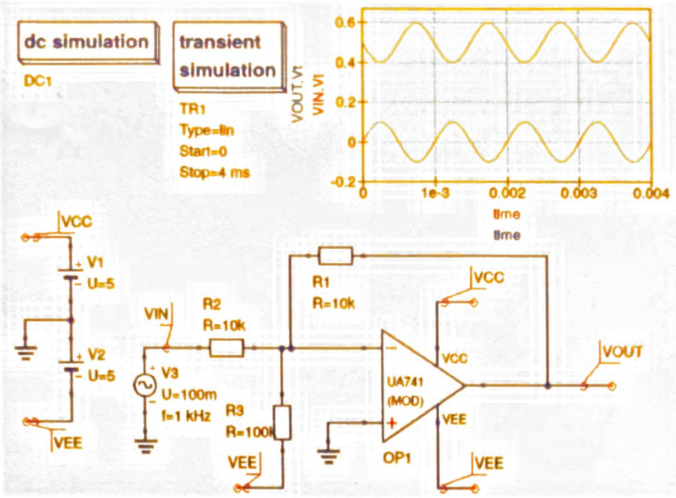


Figure 6: Summing Amplifier

4 Comments on the laboration

Here you can give as much feedback as possible on this lab. How long time did it take you to complete this lab? Did you find this lab useful to reinforce underlying concepts such as inverting/non-inverting amplifier, summing amplifier? Did the practical experimentation on the breadboard clarify concepts from the book and lectures?

It took us 5-6 hours to complete the lab. Yes, it helped to understand inverting/non inverting amplifiers. Yes, the practical experiments helped to understand the concepts.

2023-01-26

Analog Elektronik IE1202 - Home Laboratory 2

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November 25, 2020

Group-15

1 Introduction

The following 2 tasks will give you some hands-on experience on basic active filters. You will design, simulate, connect, and measure 1st and 2nd order low-pass active filters.

Very often, the amount of filtering provided by 1st order filters is insufficient since a single pole/zero only results in a slope of ±20 dB/dec. You may need to cascade several 1st order filters in order to reject undesired frequencies. To alleviate this problem, we will introduce the Butterworth filter which can provide a slopes of ±40 dB/dec with a single opamp.

2 Inverting amplifier 1st order Low-Pass filter

2.1 Circuit Theory

For the circuit in Fig. 1 calculate the value of R_2 and C_1 so that the low-frequency gain = 20 dB, and the cut-off frequency f_c = 1 kHz.

Your hand calculation: $f_1 = \frac{1}{2\pi R_1 C_1}$ $\Rightarrow$ $20\,dB = -\frac{R_1}{R_2}$

$\Rightarrow R_2 = 1k\Omega$

$10^3 = \frac{1}{2\pi 10^4 C_1}$

Answer R2: $1k\Omega$
Answer C1: 16nF

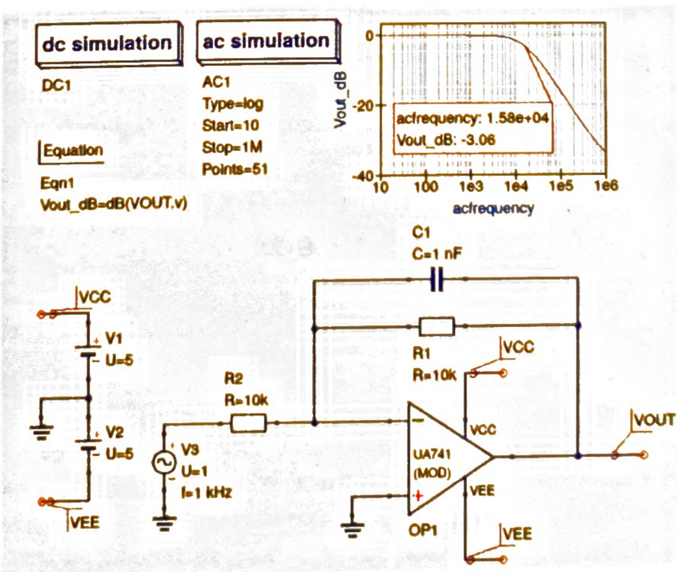


Figure 1: Inverting Amplifier low pass filter

2.2 Circuit Simulation

Open QUCS and set up a schematic like in Fig. 1. Replace R_2 and C_1 with the values that you calculated and run an AC simulation. Save screen-shots of the simulation plots and add them to an appendix at the end of this lab. Is the simulated and calculated transfer function the same?

Comments: Yes, at 1kHz the funtion begins to drop. This the cut off frequency.

2.3 Circuit Construction and Measurements

Mount the circuit of Fig. 1 on the breadboard. Replace R_2 and C_1 with the values that you simulated in the previous subsection. Connect the arbitrary signal generator and channel B probe to the input. Connect channel A probe to the output. Configure the AWG so that it outputs a sine signal of 100 mV amplitude and frequency of 100 Hz. Enable the AWG and check the amplitude of the waveforms. Change the time base to around 10 ms/div and the number of samples to at least 1 MS. The low frequency gain should be approximately what you calculated before.

Now you will test the frequency response of your circuit and compare it to your simulations. Change the PicoScope to spectrum mode. The first thing to do here is to set the spectrum range. Since the cut-off frequency of your filter is 1 kHz, you may want to set the spectrum range to at least 24 kHz. After that, click on Spectrum Options. Here you may want to change the number of spectrum bins (recommended a large number), and the window function (for instance Hamming, etc. You are welcome to try out all the alternatives!). In addition, in the Y Axis group, change the Y scale to Logarithmic and the logarithmic units to dBV. In the X Axis group, change the X scale to Log 10. Now, got to the top menu, and click on Measurements -¿ Add new Measurement. Select the channel B (input voltage) and for measurement "Amplitude at Peak". Repeat the step for channel A (output voltage). Finally, open the AWG options. Here you can increase/decrease the AWG frequency by using the blue arrows at "Start Frequency". An example of the whole setup is shown in Fig. 2.

Now you are ready to perform a manual frequency sweep. For each frequency that you will test, write down the current frequency and the average values (dBV) of channel A and B. Increase the frequency in steps (click the right arrow to increase the frequency by 1 step) until you cover at least 20 kHz. Remember that the the gain at each frequency can be expressed as $\text{Gain}_{\text{dB}} = \text{Channel}_{A,dBV}$ - $\text{Channel}_{B,dBV}$. Save screen-shots at 1 kHz and 10 kHz and append them at the end of the lab. Plot the gain vs. frequency on a paper and compare it to what you simulated before. Is the simulated and measured frequency response the same?

Comments: Yes, both shows a cutoff at 1kHz and a gain of 20dB.

3 2^{nd} Order Low-Pass Butterworth filter

3.1 Circuit Theory

Fig. 3 shows a Sallen-Key low-pass filter. This filter is very popular due to its simplicity. With only very few components it is possible to produce a transfer function with 2 complex poles in the denominator. Furthermore, if it is desired a frequency response with maximal flatness in the pass-band, the poles can be placed at Butterworth positions by using the following equations:

$$\omega_0 = 2\pi f_0 = \frac{0.707}{R_2 C_1} \tag{1}$$

$$R_1 = 2R_2 \tag{2}$$

$$R_2 = R_3 \tag{3}$$

$$C_2 = 2C_1 \tag{4}$$

where f_0 is the cut-off frequency. The design would typically start by fixing either the capacitors and finding the size of the resistors for a particular cut-off frequency.

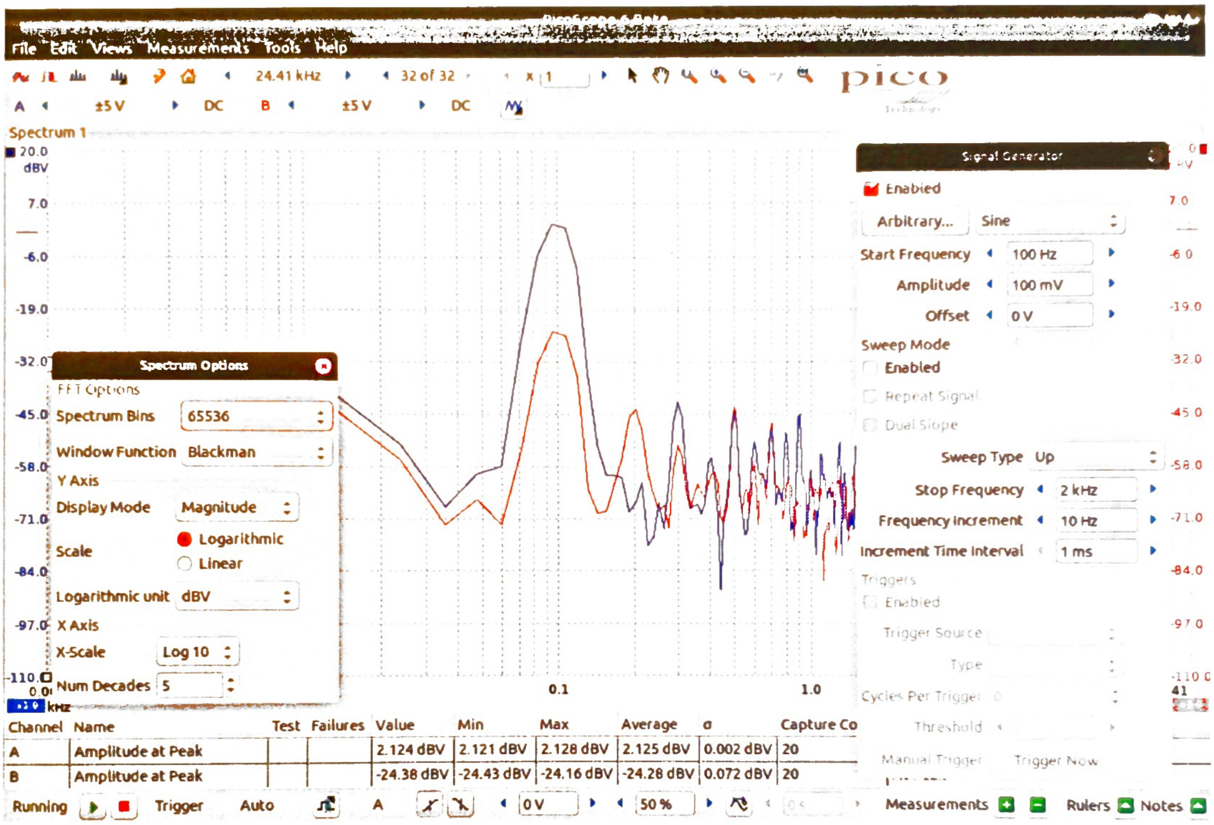


Figure 2: Non-Inverting Amplifier

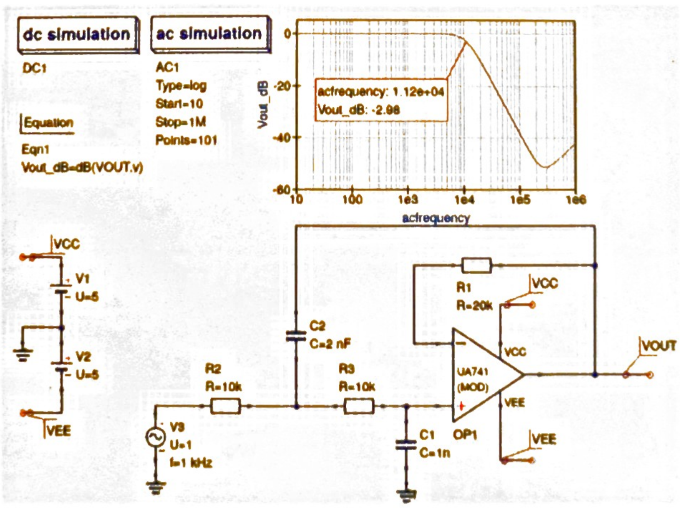


Figure 3: Sallen-Key low-pass filter

Task: dimension the resistors and capacitors in Fig. 3 so that the 2nd order low-pass filter has a cut-off frequency of 1 kHz. Sketch the magnitude of the transfer function (no need to find the mathematical expression, just sketch it).

3.2 Circuit Simulation

Open QUCS and set up a schematic like in Fig. 3. Replace R_1, R_2, C_1, and C_2 with the values that you calculated and run an AC simulation. Save screen-shots of the simulation plots and add them to an appendix at the end of this lab. Is the simulated and sketched transfer function the same?

Comments: The cutoff freqency is the same at 1kHz.

3.3 Circuit Construction and Measurements

Mount the circuit of Fig. 3 on the breadboard. Replace Replace R_1, R_2, C_1, and C_2 with the values that you simulated in the previous subsection. Connect the arbitrary signal generator and channel B probe to the input. Connect channel A probe to the output. Configure the AWG so that it outputs a sine signal of 100 mV amplitude and frequency of 100 Hz. Enable the AWG and check the amplitude of the waveforms. Change the time base to around 20 ms/div and the number of samples to at least 1 MS. Change the PicoScope to spectrum mode and perform a manual frequency sweep as in the previous tasks. Save screen-shots at 100 Hz, 1 kHz, and 10 kHz. Is the measured and simulated gain the same?

Comments: It closely resembles up until 10k wen it starts to flatten out at 30dB. Slowing the function of a low pass filter. The cutoff freqency is estimated to be around 1k which is also seen on the ~~SF~~ circuit.

4 Comments on the laboration

Here you can give as much feedback as possible on this lab. How long time did it take you to complete this lab? Did you find this lab useful to reinforce underlying concepts such as low-pass and high-pass filtering, signal spectrum, etc?

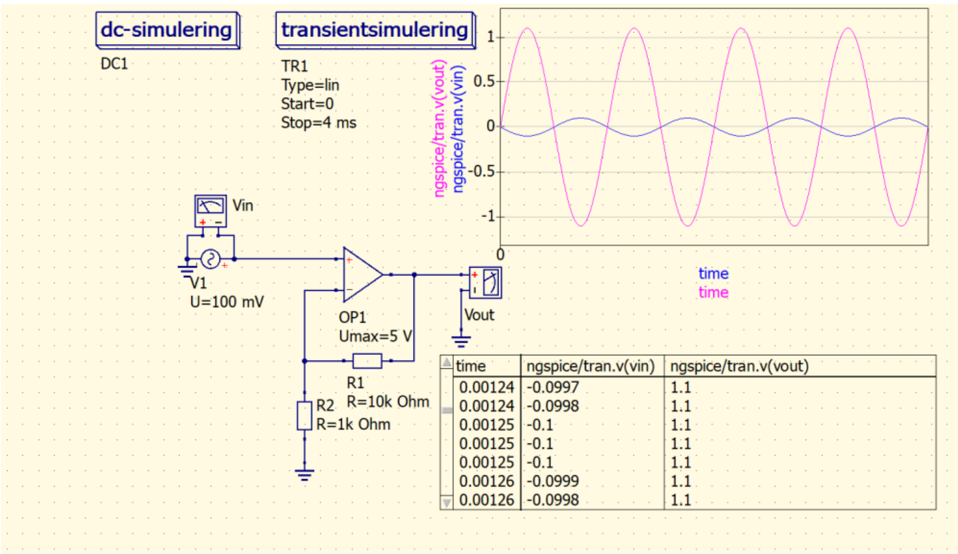
It took us 4 hours to complete the lab. Yes, we understood the concept of a low-pass filter but we have some questions that can be discussed.

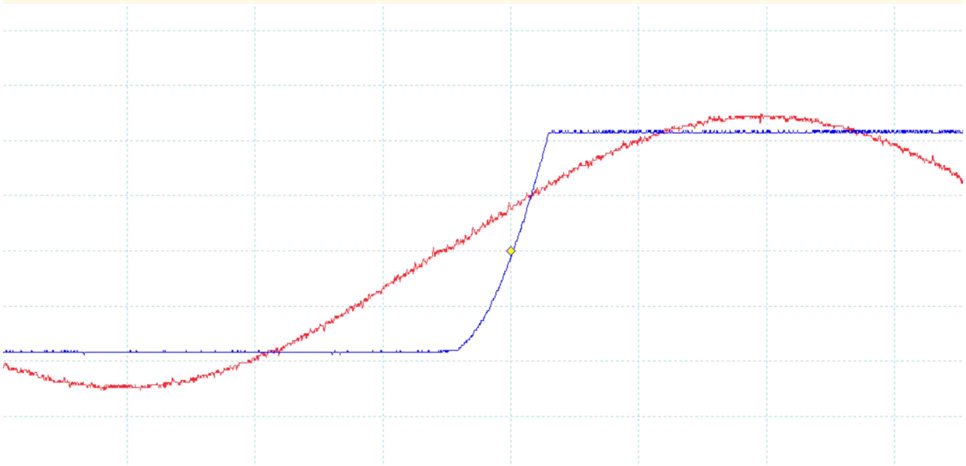
Appendix

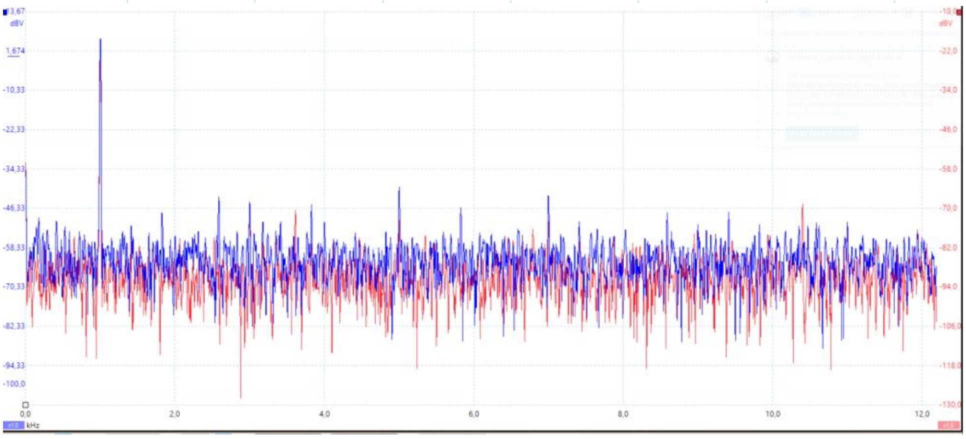
Analog electronic

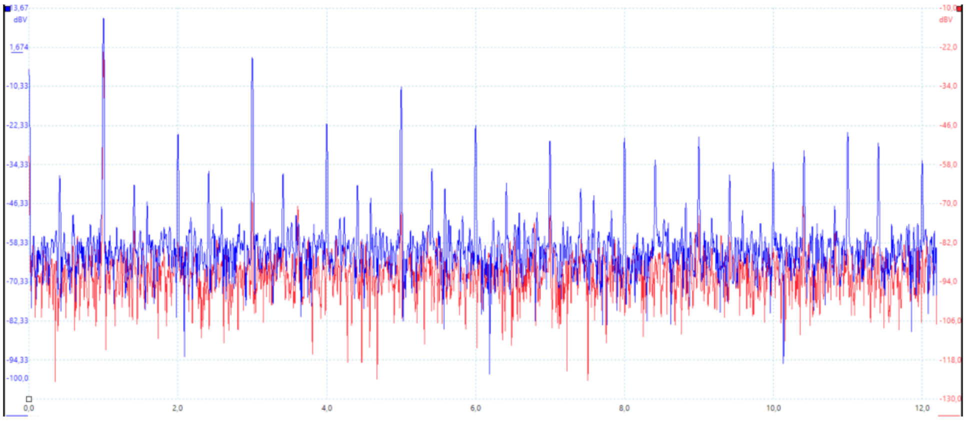
Lab 1

2.2

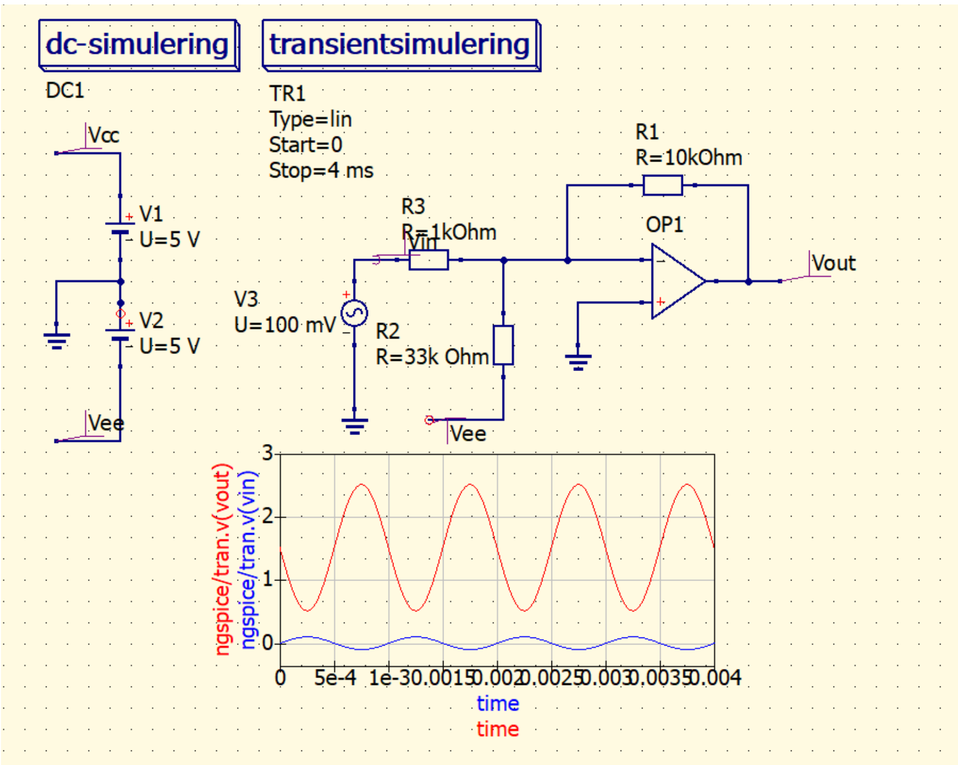








3.2


dc-simulering
transientsimulering
DC1
TR1
Type=lin
Start=0
Stop=4 ms
Vcc
V1
U=5 V
V2
U=5 V
Vee
V3
U=100 mV
R3
R=1kOhm
Vin
R2
R=33k Ohm
R1
R=10kOhm
OP1
Vout
Vee
ngspice/tran.v(vout)
ngspice/tran.v(vin)
time
time

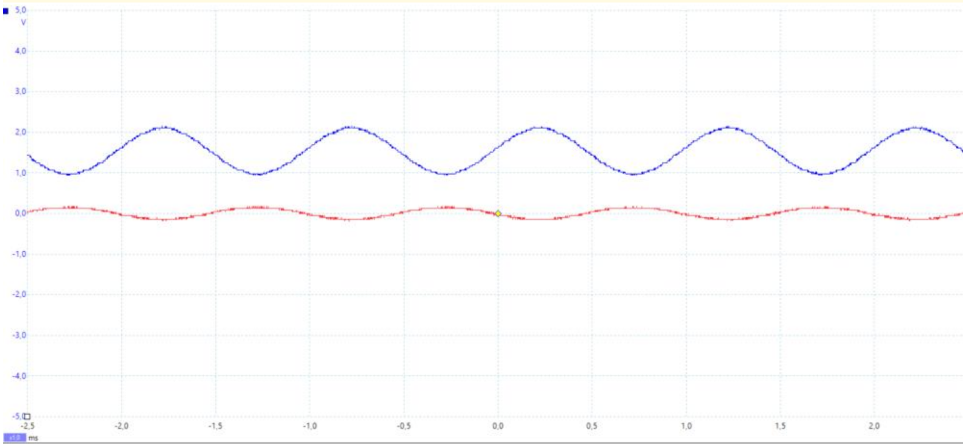


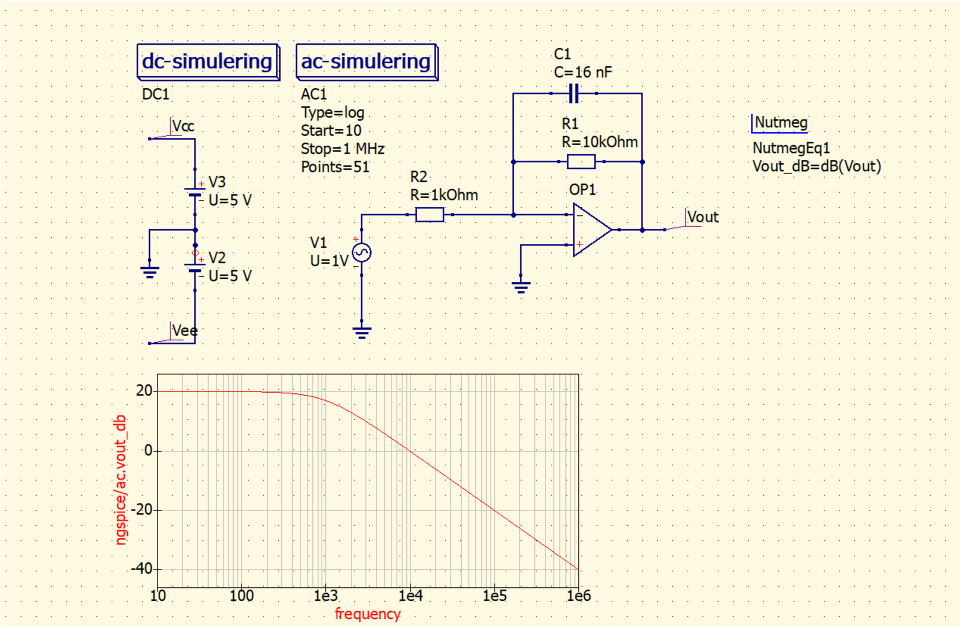
Table 1: With minor distortion

Frequncy (kHz)	A, Output (dBV)	B, Input (dBV)
0	-38	-56
1	5	-24
2		
3	-41	-70
3.6		-71
4	-50	
5	-43	-73
6		
7	-46	-73
8		
9	-44	-73
10		

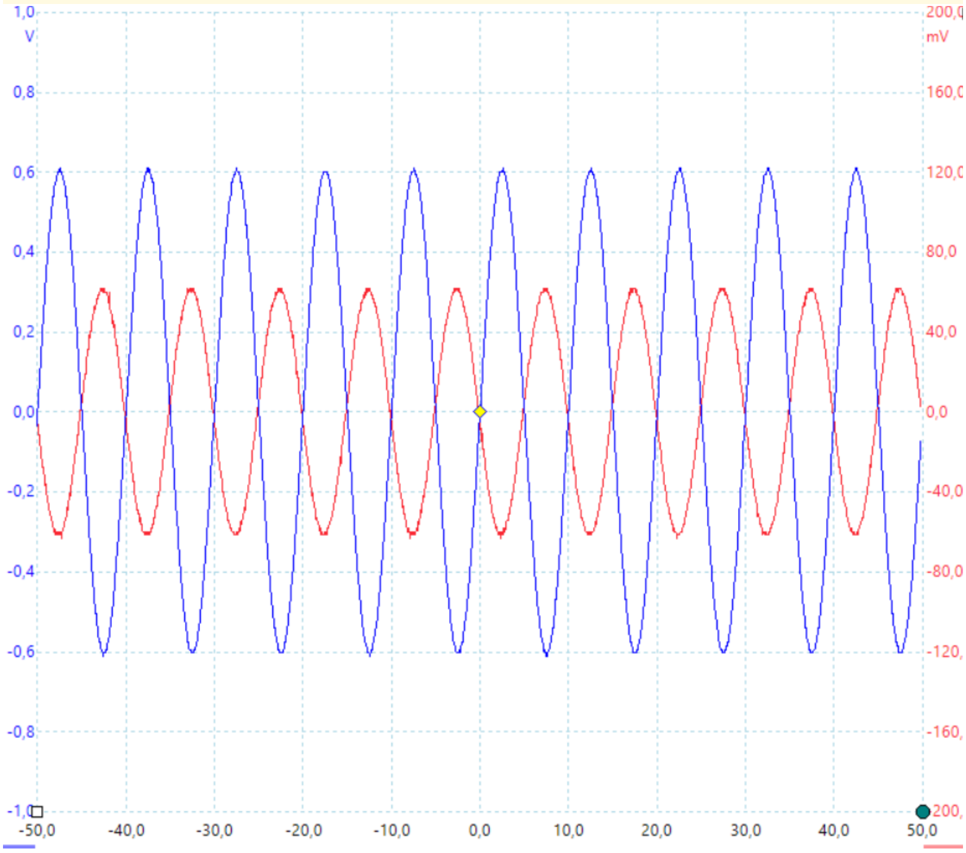
Table 2: With distortion

Frequncy (kHz)	A, Output (dBV)	B, Input (dBV)
0	-5	-55
1	10	-25
2	-22	
3	-2	-70
3.6		-70
4	-21	
5	-13	-72
6	-24	
7	-36	-72
8	-29	
9	-24	-73
10	-37	

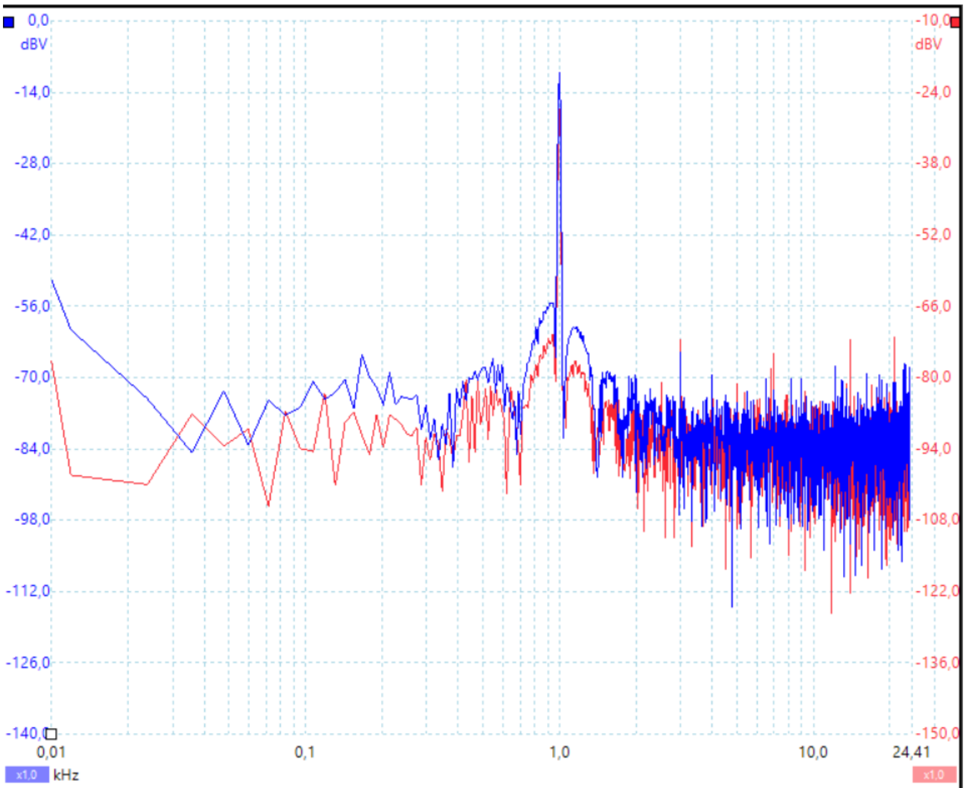
Lab 2



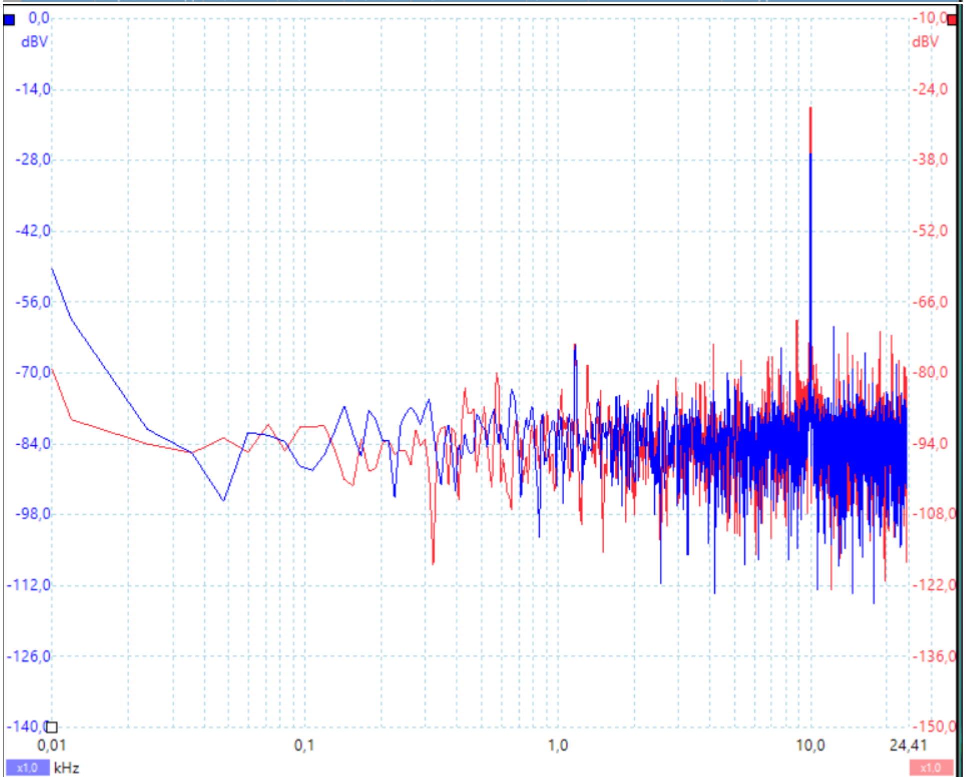
dc-simulering
DC1
ac-simulering
AC1
Type=log
Start=10
Stop=1 MHz
Points=51
C1
C=16 nF
R1
R=10kOhm
R2
R=1kOhm
OP1
Vout
Vcc
V3
U=5 V
V2
U=5 V
Vee
V1
U=1V
Nutmeg
NutmegEq1
Vout_dB=dB(Vout)
ngspice/ac.vout_db
frequency



V
mV



Kanal	Namn	Värde	Min	Max	Genomsnitt	σ	Infångningstal	Omfång
B	Amplitud vid topp	-27,35 dBV	-27,36 dBV	-27,35 dBV	-27,35 dBV	0,003 dBV	20	Vid topp

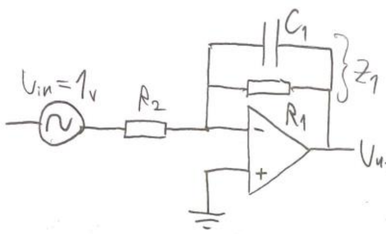


Kanal	Namn	Värde	Min	Max	Genomsnitt	σ	Infångningstal	Omfång
B	Amplitud vid topp	-27,34 dBV	-27,41 dBV	-27,34 dBV	-27,36 dBV	0,019 dBV	20	Vid topp
A	Amplitud vid topp	-26,66 dBV	-26,75 dBV	-26,64 dBV	-26,67 dBV	0,028 dBV	20	Vid topp

Lab 2: 2.3

Frequncy (Hz)	A, Output (dBV)	B, Input (dBV)	Difference (A-B)(dBV)
100	-8.4	-28	19.6
200	-8.0	-28	20
300	-8.0	-28	20
400	-9.4	-29	19.6
500	-8.4	-27	18.6
600	-9.4	-28	18.6
700	-10	-28	18
800	-10	-28	18
900	-12	-29	17
1k	-10	-28	18
2k	-14	-28	14
3k	-18	-28	10
4k	-26	-34	8
5k	-28	-34	6
6k	-26	-31	8
7k	-28	-34	6
8k	-30	-33	3
9k	-30	-33	3
10k	-31	-33	2
20k	-33	-33	0
50k	-40	-31	9
100k	-53	-31	22

2.3 Calculations.



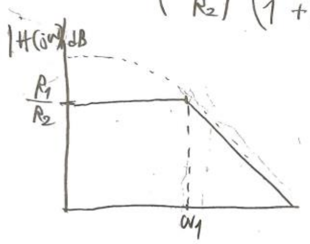
$R_1 = 10k\Omega$

$R_2 = ?$

$C_1 = ?$

$$\frac{U_{ut}}{U_{in}} = \left(-\frac{Z_1}{R_2}\right) = \left(-\frac{\frac{\frac{1}{j\omega C}\cdot R_1}{\frac{1}{j\omega C}+R_1}}{R_2}\right) = (-1)\cdot\frac{R_1\cdot\frac{1}{1+j\omega R_1 C}}{R_2}$$

$$= \left(-\frac{R_1}{R_2}\right)\cdot\left(\frac{1}{1+j\omega R_1 C}\right) \qquad \omega_1 = \frac{1}{R_1 C}$$



$$f_1 = \frac{1}{2\pi R_1 C}$$

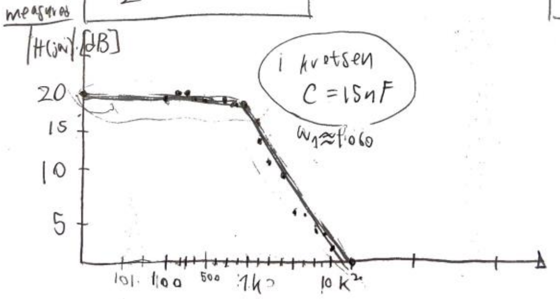
$$10^3 = \frac{1}{2\pi 10^4 C}$$

$$C_1 = \frac{1}{2\pi 10^7} \approx 1{,}6\cdot 10^{-8}$$

$$\boxed{C_1 = 16nF}$$

$$20\,dB \Rightarrow 10 = \frac{10\,000}{1000} = \frac{R_1}{R_2}$$

$$\boxed{R_2 = 1000\Omega}$$



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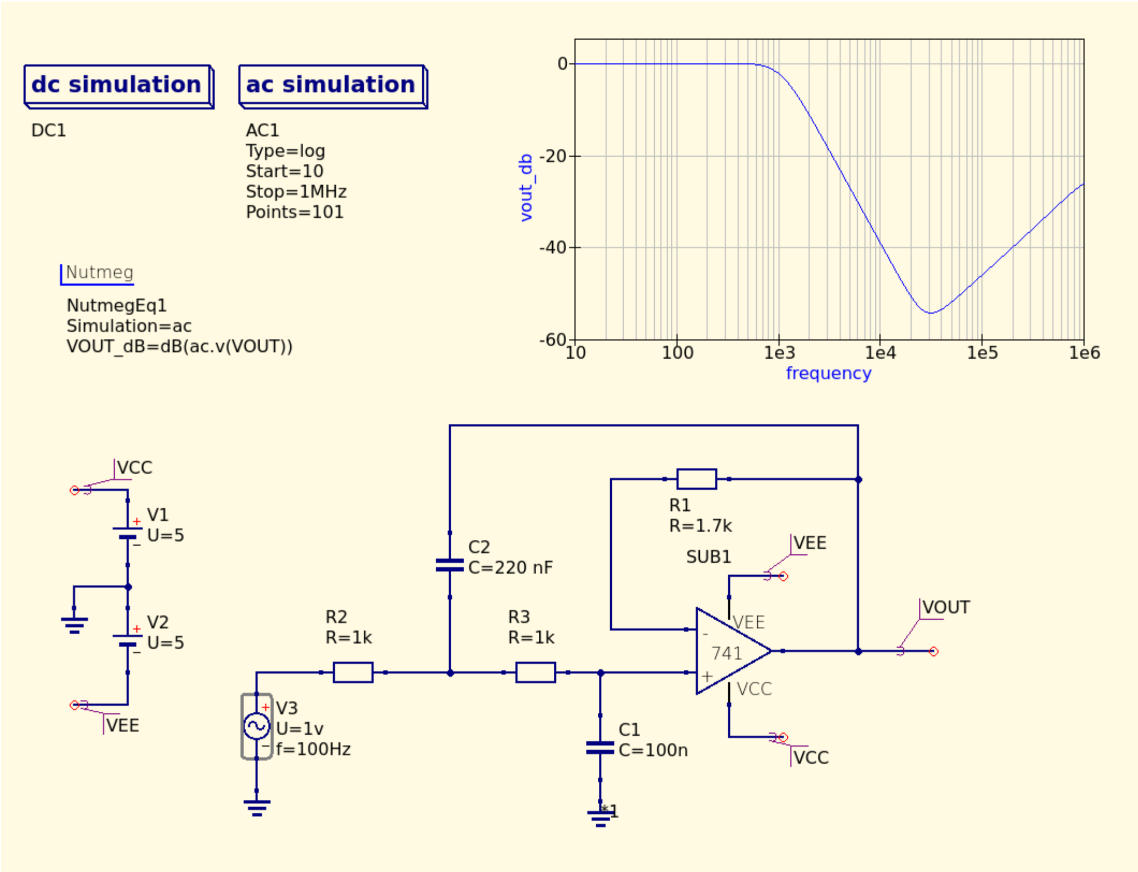
$A = 588$

$B = (-58{,}7)$ $\}\cdot(-10)$

3.2 Circuit simulation



3.2 Calculations

$\omega_0 = 2\pi f_0 = \frac{0.707}{R_2 C_1}$ f_0 = cutoff

$f_0 = 1kHz$

$f_0 = \frac{0.707}{2\pi R_2 C_1} = 10^3$

$R_2 \cdot C_1 = \frac{0.707}{2\pi \cdot 10^3} \approx 113M$, $R_2 = 1k\Omega$

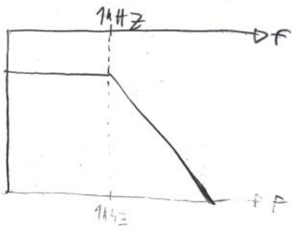
$C_1 = 113nF$

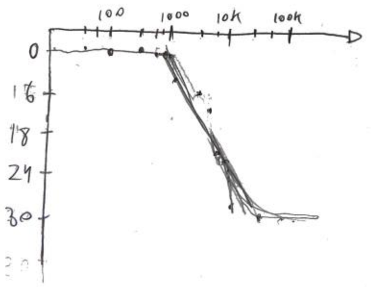
$R_1 = 2k\Omega$ $R_3 = 1k\Omega$

$R_2 = 1k\Omega$

$C_1 \approx 113nF \Rightarrow 100nF$

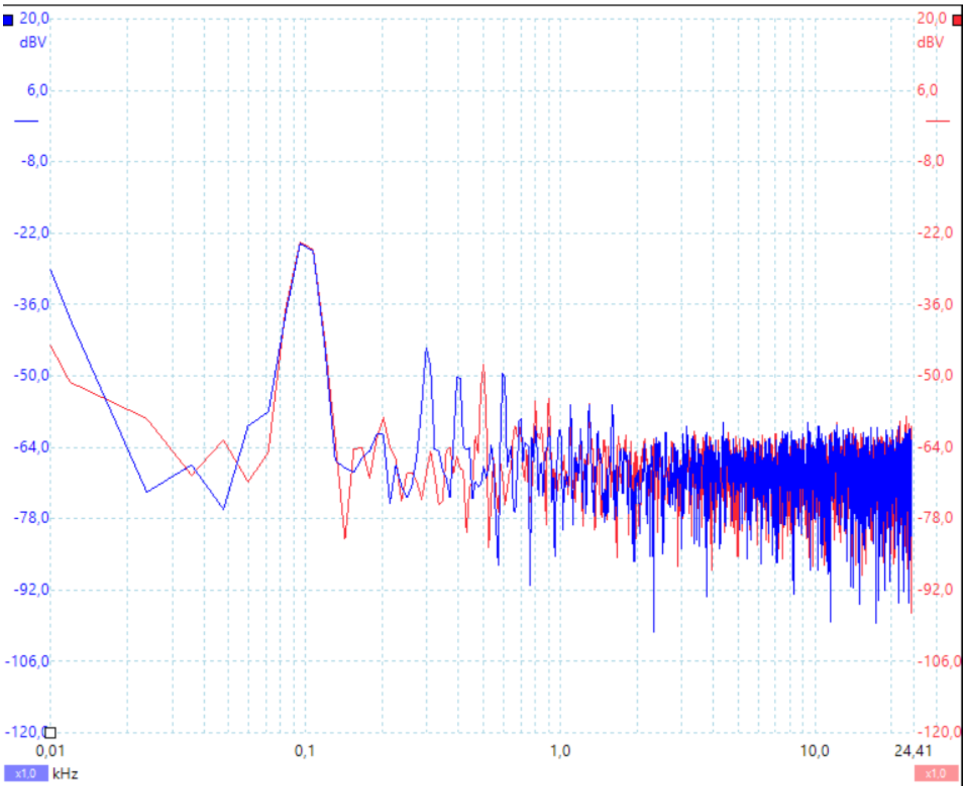
$C_2 \approx 226nF \Rightarrow 220nF$



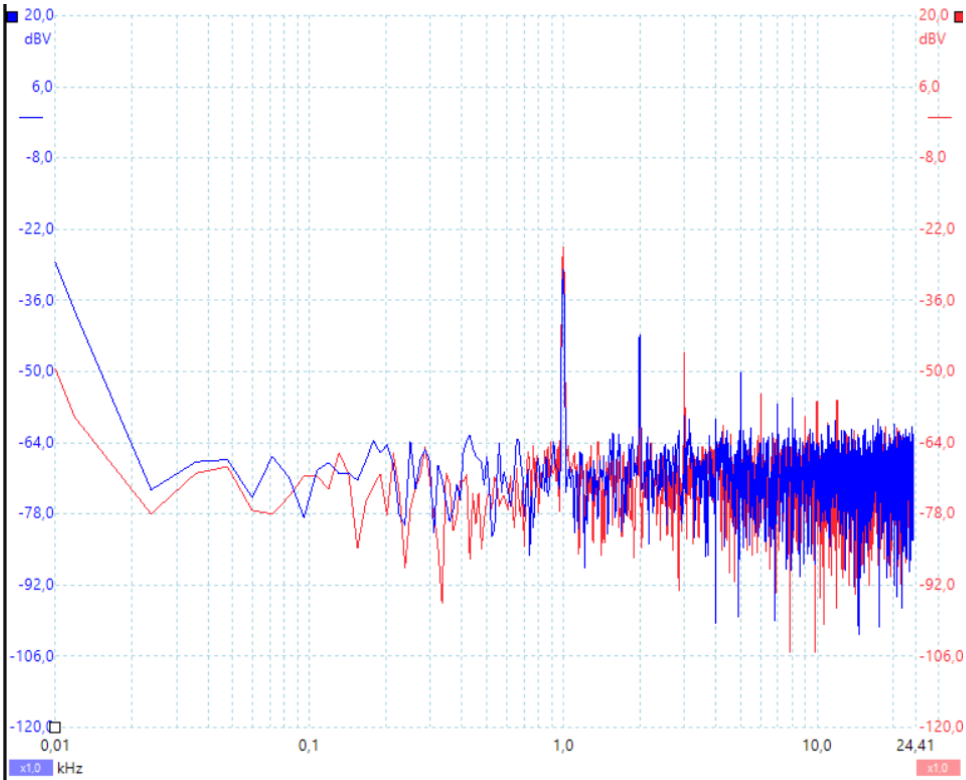


Lab2 : 3.3

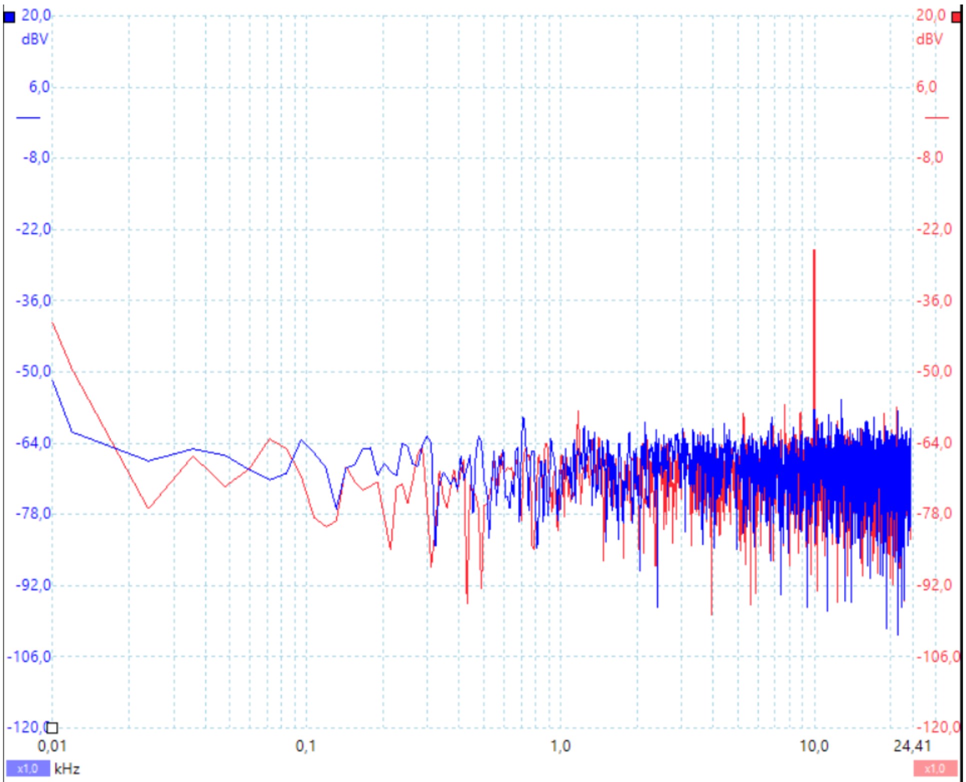
Frequncy (Hz)	A, Output (dBV)	B, Input (dBV)	Difference (A-B)(dBV)
100	-24	-24	0
200	-23	-23	0
300	-23	-23	0
400	-25	-24	1
500	-24	-22	2
600	-26	-25	1
700	-26	-25	1
800	-27	-25	2
900	-30	-27	3
1k	-30	-25	5
2k	-36	-26	10
3k	-41	-27	10
4k	-45	-27	14
5k	-48	-27	21
6k	-50	-27	23
7k	-51	-26	25
8k	-52	-26	26
9k	-53	-26	27
10k	-54	-26	28
20k	-57	-26	31
50k	-57	-27	30
100k	-57	-26	31



Kanal	Namn	Värde	Min	Max	Genomsnitt	σ	Infångningstal	Omfång
A	Amplitud vid topp	-24,05 dBV	-24,06 dBV	-23,9 dBV	-24 dBV	0,064 dBV	9	Vid topp
B	Amplitud vid topp	-23,74 dBV	-23,88 dBV	-23,74 dBV	-23,81 dBV	0,058 dBV	7	Vid topp



Kanal	Namn	Värde	Min	Max	Genomsnitt	σ	Infångningstal	Omfång
A	Amplitud vid topp	-29,82 dBV	-29,88 dBV	-23,82 dBV	-25,79 dBV	2,702 dBV	20	Vid topp
B	Amplitud vid topp	-25,4 dBV	-26,78 dBV	-23,73 dBV	-24,39 dBV	0,891 dBV	20	Vid topp



Kanal	Namn	Värde	Min	Max	Genomsnitt	σ	Infångningstal	Omfång
A	Amplitud vid topp	-55,21 dBV	-57,34 dBV	-29,49 dBV	-45,15 dBV	12,1 dBV	20	Vid topp
B	Amplitud vid topp	-25,94 dBV	-26,63 dBV	-25,33 dBV	-25,83 dBV	0,379 dBV	20	Vid topp