Linear Network Analysis and Synthesis. Lab 1, April 2024

Session 1

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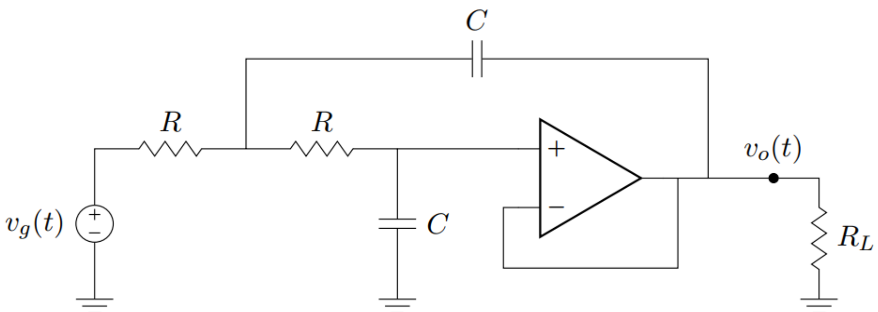
DATE and TIME: Apr 3, 2024 11:00 AM
CLASSROOM: 4.1.E05

Insert the screenshots with each of the setups that you use in your measurements. Always reason the validity of the results obtained, and make the comments you consider pertinent.

NOTE: If the measurements taken in the laboratory do not correspond to the theoretical result obtained in the preparatory work or with previous lab results, you must either find the error in the theoretical approach, or find the error in the measurement, or try to explain the discrepancy.



1. Design of the *Sallen-Key* circuit.
Assume that R = 50 Ω and design the *Sallen-Key* circuit studied in the preparatory work so that at 1000 Hz $|V_O|$ is 3 dB lower than $|V_g|$. [5%]

V_o being 3 dB lower than V_g means:

$$|H(\omega)|^2 = \frac{1}{2}$$

As shown in the pre-lab work

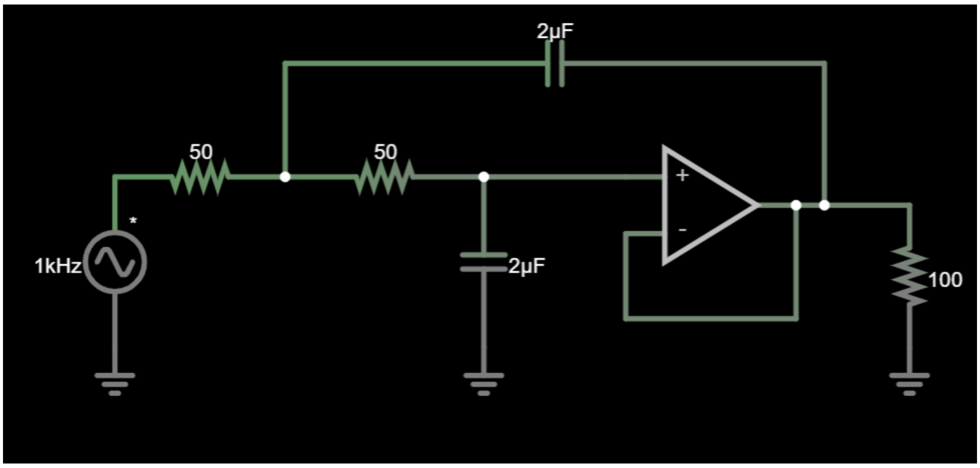
$$|H(\omega)|^2 = \frac{1}{2} \Leftrightarrow \omega = \frac{\sqrt{\sqrt{2}-1}}{RC}$$

From this, we can solve for C

$$C = \frac{\sqrt{\sqrt{2}-1}}{R\omega} = \frac{\sqrt{\sqrt{2}-1}}{R\,2\pi\,f} = \frac{\sqrt{\sqrt{2}-1}}{50\,\Omega\cdot 2\,\pi\cdot 1000\,Hz} = 2.048\mu F$$

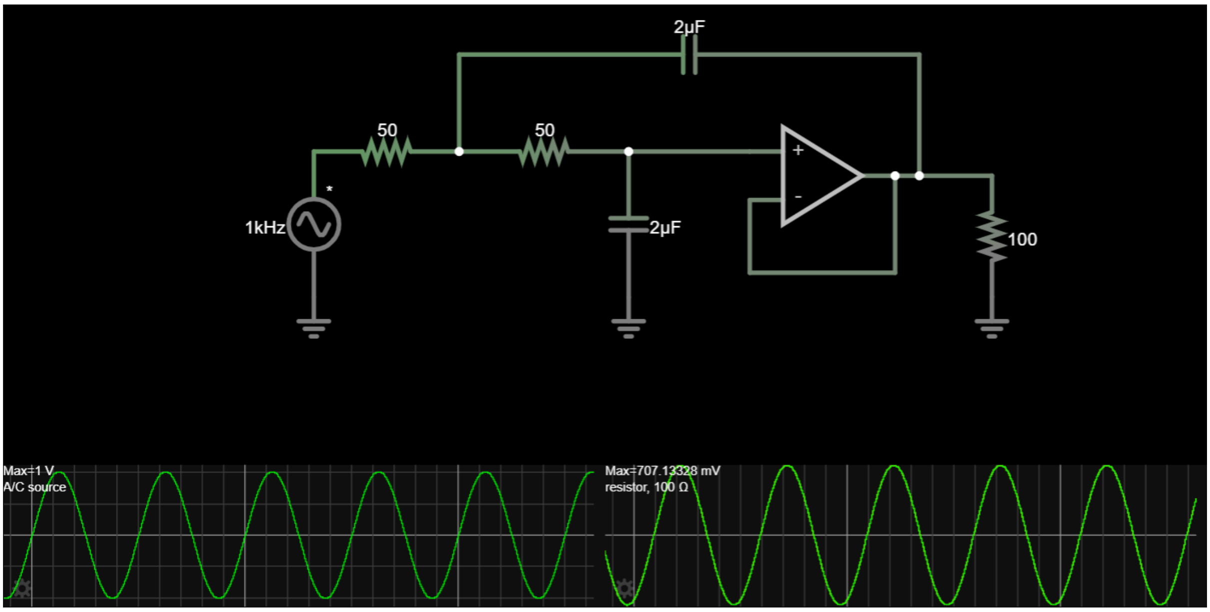
C= $12.87\mu F$

2. Simulation of the designed circuit.
Draw the designed *Sallen-key* circuit in the circuit simulator. Use an ideal operational amplifier. [5%]



https://tinyurl.com/26eh3c2z

3. Design check.
Set up a measurement that allows you to check that the output amplitude a is 3 dB lower than the input amplitude at 1000 Hz. [5%]



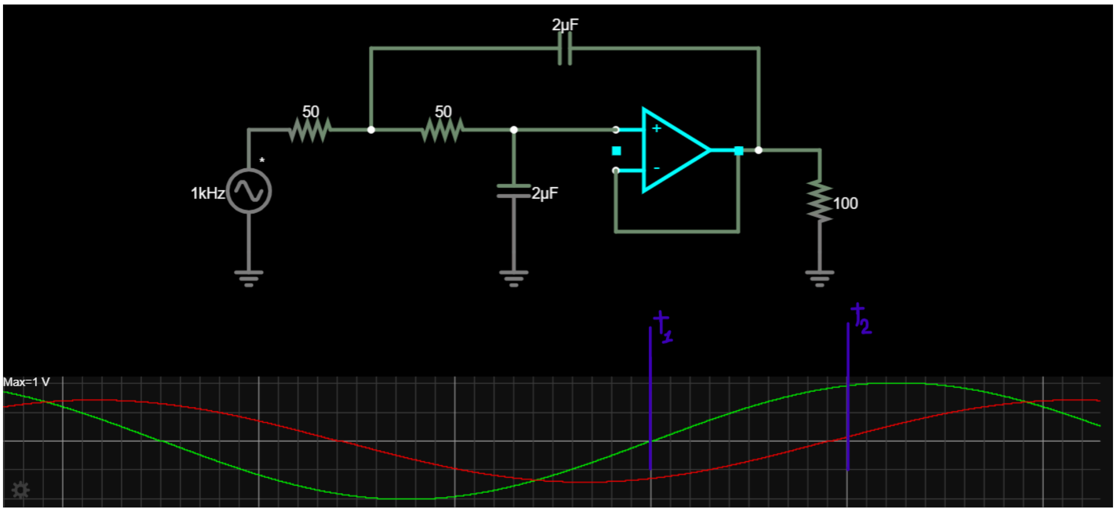
https://tinyurl.com/26eh3c2z

The circuit is set up with the given and calculated values, plus an arbitrary load resistor of 100 Ω. The two *scopes* show a measurement of voltage at the input (*A/C source*) and the output (*resistor, 100 Ω*). The output amplitude is, as expected, 3dB lower than the source:

the square of the transfer function amplitude is $\frac{1}{2}$, so the transfer function without squaring is $\frac{1}{\sqrt{2}}$, and the amplitude of the output is $\frac{1}{\sqrt{2}} \cdot 1$, which is approximately 0.707.

4. Measurement of the phase shift.

Measure the phase shift between the input signal and the output signal at 1000 Hz, and check if the result is the one obtained from preparatory work theoretical work. [5 %]



https://tinyurl.com/288waoac

In order to measure the phase shift, I amplified the plot, overlapped both input and output, and then used the cursor to take a sample of adjacent time instants at which both signals crossed the 0V line on their rising edge, getting the following data:

$$t_1 = 18ms$$

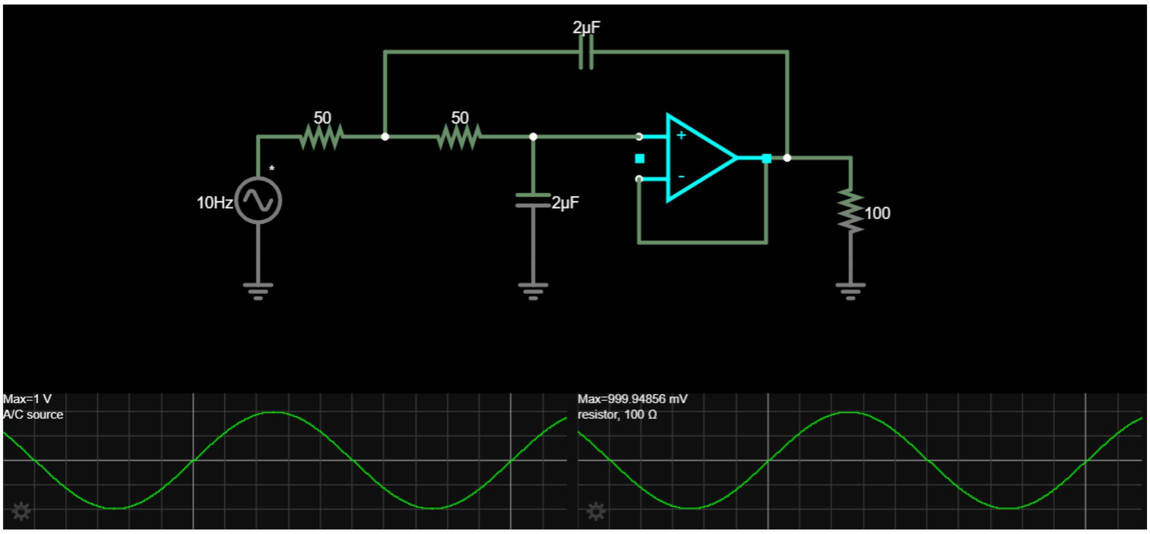
$$t_2 = 18.182ms$$

Given that the period for a 1000 Hz wave is 1ms, and the time shift, we can obtain the phase shift

$$\frac{18.182\,ms - 18\,ms}{1\,ms} \cdot 2\pi = 1.143\,rad$$

5. Measurement at low frequency.

Repeat the previous two items for a frequency much lower than 1000 Hz (try, for example, with 10 Hz). **Don't forget to scale the time axis!** [5 %]

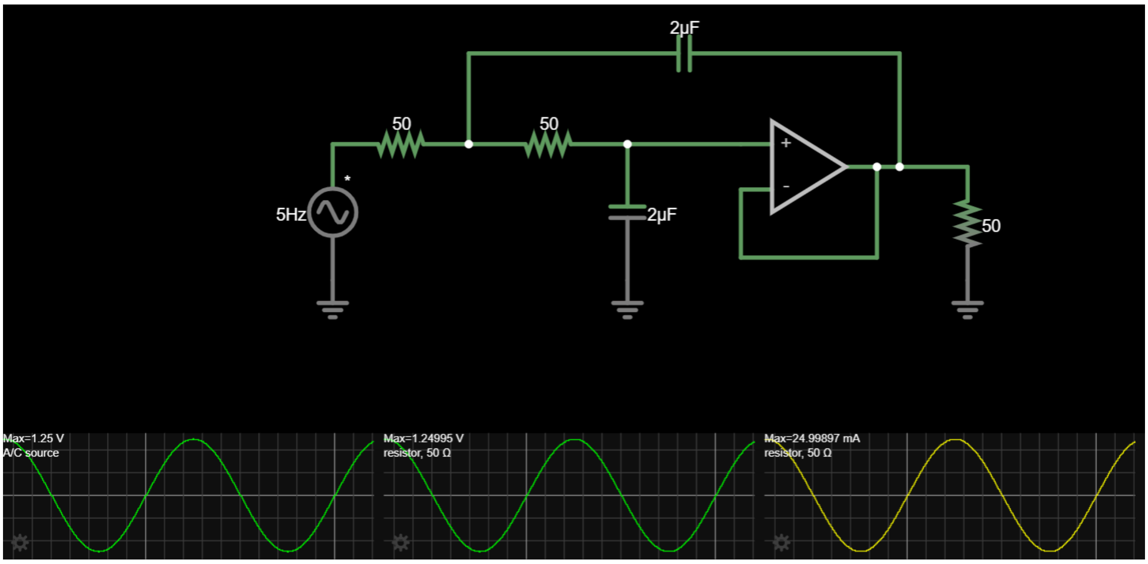


https://tinyurl.com/2226cwuk

As expected from the pre-lab work, at low frequencies the **gain approaches 1**. When the plots are combined, they overlap almost perfectly, and when comparing time instants, both input and output signals are essentially in phase. The **phase shift approaches 0**.

6. Check output current in the operational amplifier

Configure a measurement at 5 Hz with the input voltage amplitude equal to the one calculated in section 6 of the previous theoretical assignment. Check that the output current remains below the required 25 mA value ? [5 %]



https://tinyurl.com/2cz43fnt

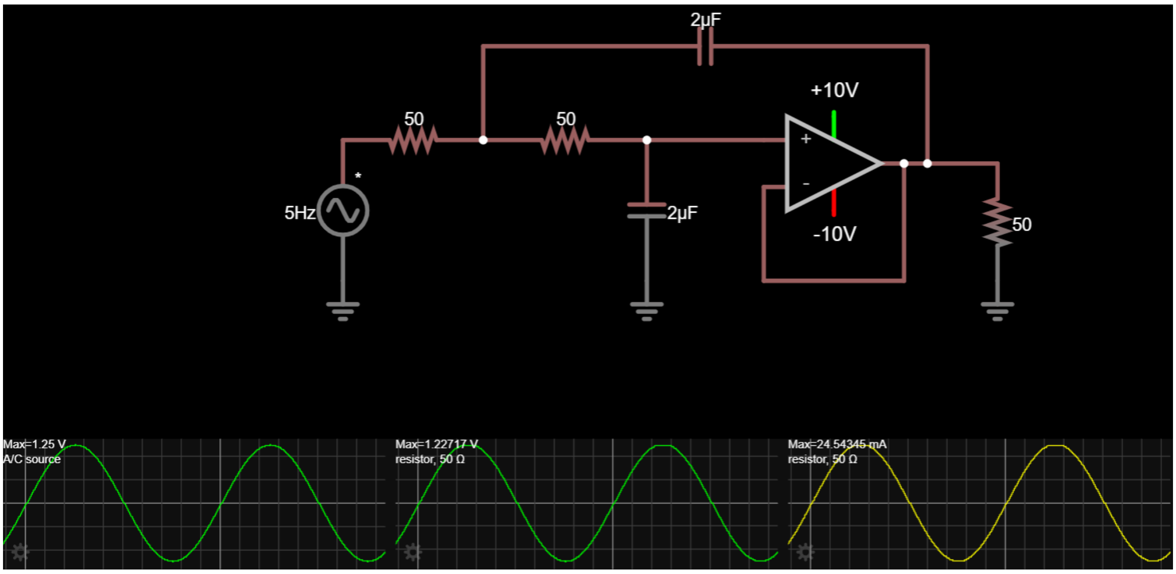
For this section, the load resistor was set to 50 Ω, as specified in the pre-lab guide. An output current scope was added. As predicted for frequencies close to 0, the current stays below the 25 mA limit.

7. Real operational amplifier at 5 Hz.

Replace the ideal operational amplifier with a real operational amplifier with the following characteristics:

- Model: LM741
- Output current limit: 25 mA
- Response speed (slew rate): 600 mV/μs
- Powered by +10 V and −10 V DC voltage sources.

Do the results change anything? [5%]



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THe results are mostly the same, save for a slightly lower output voltage and current from the OpAmp. The gain is 0.98168 as compared to the previous 0.99992, and the phase shift stays virtually 0.