Lab 6. Frequency response of high-order circuits

1. Objective

Learn by simulation properties of more complicated passive circuits containing only R and C elements.

2. Introduction

If you design a low-pass or high-pass filter, the 1st order circuit can only provide the attenuation of 20 dB per decade of frequency. If you need a more selective circuit, a higher order circuit should be considered. In this case, circuit simulation is the best way to determine the required values for circuit elements.

In most cases utilization of inductors in circuits is not appreciated due to difficulty in integrating on chips, cost, size. If the inductive impedance is absolutely necessary, an equivalent OpAmp circuit with a capacitive network will be used instead. In this lab you have to simulate frequency response of 2nd order low-pass filter and Wien-bridge band-pass filter. The latter circuit is popular for implementation of relatively-low frequency generators.

3. Circuit simulation

Part 1. 2nd order low-pass filter

Perform simulation of the magnitude and phase responses for the circuit in Figure 1 in the frequency range of 100 Hz to 1 MHz.

![Figure 1.](image-url)
Plot the results on a Bode diagram, determine the value of cut-off frequency (-3 dB point) and the slope of the magnitude of the transfer function above the cut-off frequency.

**Part 2. Wien-bridge circuit**

Using complex number analysis, obtain the expression for the transfer function of the Wien-bridge circuit shown in Figure 2. It can be described as a voltage divider in terms of $Z_1$ and $Z_2$ impedances. Simplify the expression and obtain the final analytical results for magnitude and phase frequency responses in terms of $R$ and $C$.

![Figure 2.](image)

Determine in terms of $R$ and $C$ the frequency corresponding to the maximum of the transfer function. Determine the maximum value of the transfer function. Simulate the magnitude and phase responses (Bode plot) for this circuit within the frequency range of 100 Hz to 100 kHz. $R$ and $C$ have the same values as in circuit in Figure 1. Determine the frequency bandwidth of the circuit at the level of 0.707 (-3dB) with respect to the maximum.

**4. Report**

The report should include the goal, a short description of the work, the results and conclusions. Attach the printouts.