DIGITAL STORAGE OSCILLOSCOPES

Part II: Oscilloscope probe and filter frequency response

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POLITECNICO DI TORINO

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Team

Team no.

Student	Last name	First name	Signature
1			
2			
3			
4			

1 Assignment

In this lab you will practice with a digital storage oscilloscope (DSO) and its usage to measure the frequency response of filters.

Fill the PDF form and upload it on *Portale della didattica*, one upload for each team, by 29 April 2024.

2 Step response of an *RC* low-pass filter

2.1 Assembling the circuit

1 Assemble the circuit of figure 1 on the breadboard. Figure 2 shows a possible way of assembling the circuit.

2 Turn on the function generator Hantek HDG2032B and the oscilloscope.

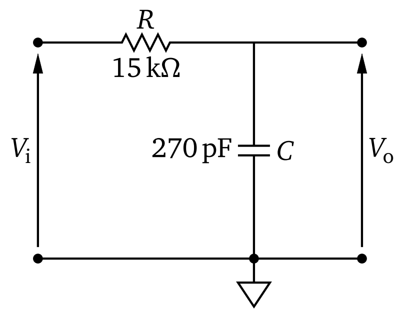

Figure 1: Circuit diagram of the *RC* filter.

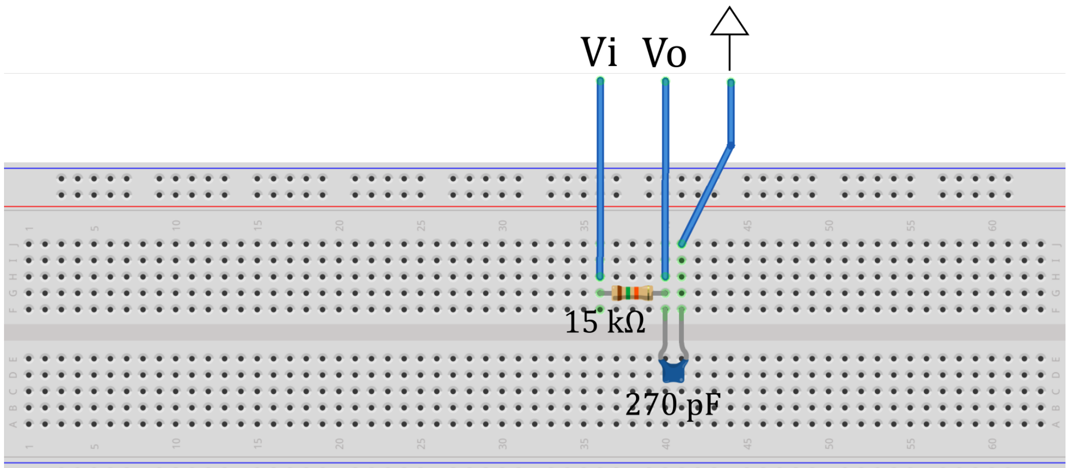

Figure 2: A possible way of assembling the *RC* filter of figure 1.

2.2 Rise-time and cut-off frequency (Coaxial cable)

1 Calculate the nominal cut-off frequency f_{H} for the circuit of figure 1. Calculate the nominal rise-time with the formula $t_{\mathrm{r}} \approx 0.35/f_{\mathrm{H}}$. Report the result in table 1 on the following page.

2 Using a BNC-to-BNC cable, a BNC T adapter and a coaxial cable with crocodile clips, connect the function generator output to the oscilloscope CH1 input and then to the circuit input V_{i}. **Warning:** The black clip is the ground.

3 Using a coaxial cable with crocodile clips, connect the circuit output V_{o} to the oscilloscope CH2 input.

4 Set the input coupling of both inputs to DC.

5 Set the function generator for a 1 kHz square wave. Measure the step-response rise time at the filter output and calculate the cut-off frequency from the formula $f_{\mathrm{H}} \approx 0.35/t_{\mathrm{r}}$. Report the results in table 1.

6 Compare the measured values with that obtained at point 1 above. Do they agree? How do you explain the results obtained? Comment below table 1.

Table 1: Filter's step-response with coaxial cable.

	Theoretical	Measured
Rise time		
Cut-off frequency		

Comments:

2.3 Rise-time and cut-off frequency (Oscilloscope probe)

1 Disconnect the coaxial cable from the circuit output and the CH2 input and replace it with an attenuating oscilloscope probe (1 : 10 attenuation).

2 Compensate the probe (ask for a suitable screwdriver).

3 Measure the step-response rise time and calculate the cut-off frequency from the formula $f_H = 0.35/t_r$. Compare these values with the theoretical ones and those obtained in section 2.2. What can you conclude? Report the results in table 2 and comment below.

Table 2: Filter's step-response with the oscilloscope probe.

	Theoretical	Measured
Rise time		
Cut-off frequency		

Comments:

3 Frequency response of the *RC* low-pass filter

A generic linear time-invariant filter with voltage input and output (figure 3) is characterised by a transfer function

$$H(\mathrm{j}2\pi f) = \frac{V_\mathrm{o}}{V_\mathrm{i}},$$

where V_i is the complex phasor associated with a sinusoidal input voltage at frequency f, and V_o is the phasor associated with the corresponding sinusoidal output voltage.

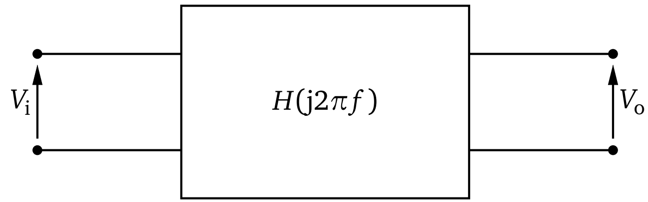

Figure 3:

$H(\mathrm{j}2\pi f)$ is thus a complex number which changes with f. The Bode plots are graphical representations of the quantities $G(f) = 20\log|H(\mathrm{j}2\pi f)|$ and $\varphi(f) = \arg H(\mathrm{j}2\pi f)$ as a function of the frequency (figure 4). $G(f)$ is the magnitude of the transfer function, expressed in decibel (dB), and $\varphi(f)$ is the phase. The frequency axis is logarithmic.

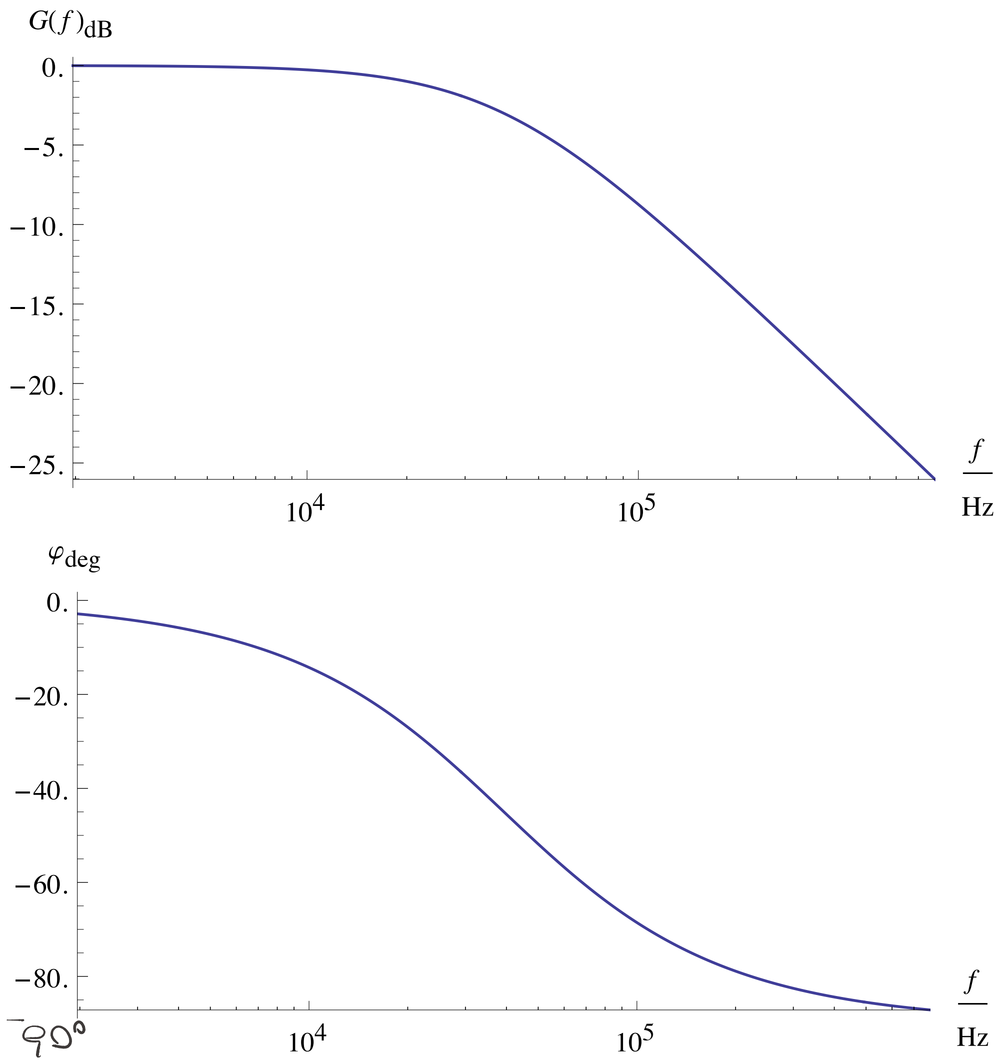

Figure 4: Example Bode plots.

1 Using the attenuating probe to connect the oscilloscope to the filter's output, measure $G(f)$ and $\varphi(f)$ for the filter assembled in §2.1 at the frequencies 1 kHz, 2 kHz, 5 kHz, 10 kHz, 20 kHz, 50 kHz, 100 kHz, 200 kHz and 500 kHz. Report the measurements in table 3.

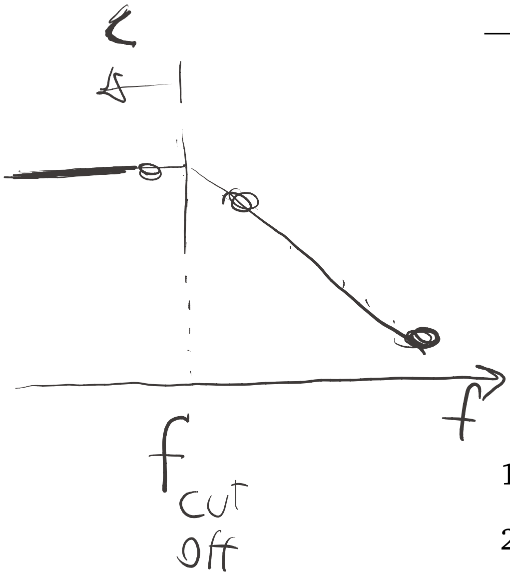

Table 3: Measured transfer function of the *RC* filter.

f /kHz	$G(f)$	$\varphi(f)$	$H(2\pi i f)$
1			1
2			1
5			1
10			1
20			1
50			0,7
100			0,44
200			0,24
500			0,12