Problem set: RC circuits as signal filters—the Bode plot

Worksheet

5. Pilot test the circuit. What do you notice about the input and output signals as you change the wave generation frequency from 0.1 *f* to 10 *f* *(f is the cutoff frequency in cycles/second for this circuit)?*

L 10 kHz L 1 kHz

As the wave generation frequency increases, the more the lines of the input and output signals get closer to one another. When the frequency is at 0.1 f, we can see the amplitudes of the input signal is way higher than the output. However, at 10 f the amplitudes and frequency are the same.

The Bode plot uses a *relative* amplitude of the voltages using the decibel unit (dB_V),

$$dB_V = 20 \cdot log_{10}\left(\frac{V}{V_{ref}}\right) \quad 1\text{V}$$

For our case, the 1V ("Carrier" signal amplitude) is the V_{ref}. Measure V relative to 2.5V.

Determine the dB_V from the measured signal amplitude at the cutoff frequency? *This should be -3 dB. What is the % error?*

$dB_V = 20 \cdot \log_{10}\left(\frac{V}{V_{ref}}\right)$ Error: 3 %

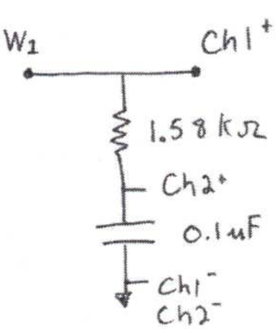
correct? $20 \cdot \log_{10}\left(\frac{1}{2.5}\right) = -3,10$

Compute the phase shift in degrees at the cutoff frequency for your circuit. *This should be 45º. What is the % error?*

$\varphi = \text{atan}(-RC\omega)$ -1,58k 0.1pF

$RC = 10 \cdot 10^{-6} \cdot 1100$ $\varphi = \text{atan}(-0{,}158\omega)$ $\varphi = 45°$ $-RC\omega$

$\varphi = \text{atan}(-0{,}158 \cdot 2\pi)$ $-158 \cdot 10^{-4}\omega$ $\omega = 2$



For the RC circuit, describe what you see happening to the signal amplitude when the input goes from low frequency (~10Hz) to high frequency (100 kHz).

Low frequency: high amplitude
High frequency: low amplitude

Compute the angular phase shift at the *characteristic frequency,* using the equation, $\varphi = (-RC\omega)$

$\varphi = (-RCw)$ $\varphi = \mathrm{atan}(-RCw)$

This phase shift should be the same for all filters at the characteristic frequency.

$-RCw$

$-(1.58)(0.1)(2\pi) \approx 1$

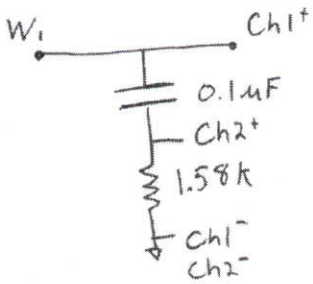
Correct?

What does the Bode plot tell you about the RC filter's response to low($f < \frac{1}{2\pi\tau}$)and high($f > \frac{1}{2\pi\tau}$) frequencies? (Is this the same as what you've observed?)

At low frequencies, the gain is high while at low frequencies the gain is low.

This signal *attenuation/decade* is an important performance metric for filters.

What does the Bode plot tell you about the performance of the CR circuit at low and high frequencies?



When frequency is low, the bode plot shows that the gain is low while at high frequenc the gain is high.

$\text{Gain} = \frac{V_{out}}{V_{in}}$

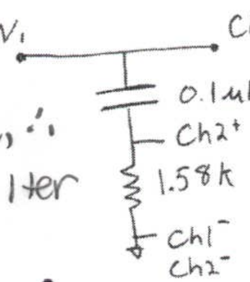
Like the RC filter, this CR filter is a 1st-order roll-off filter.

Let's name these circuits! Match the names below with a good name for each circuit:

Gain?

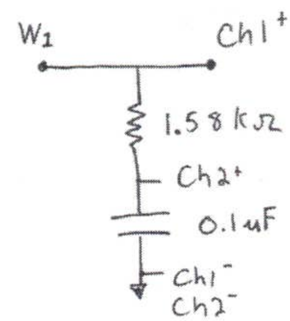
CR Circuit

Gain is high at high freq, ∴ high pass filter



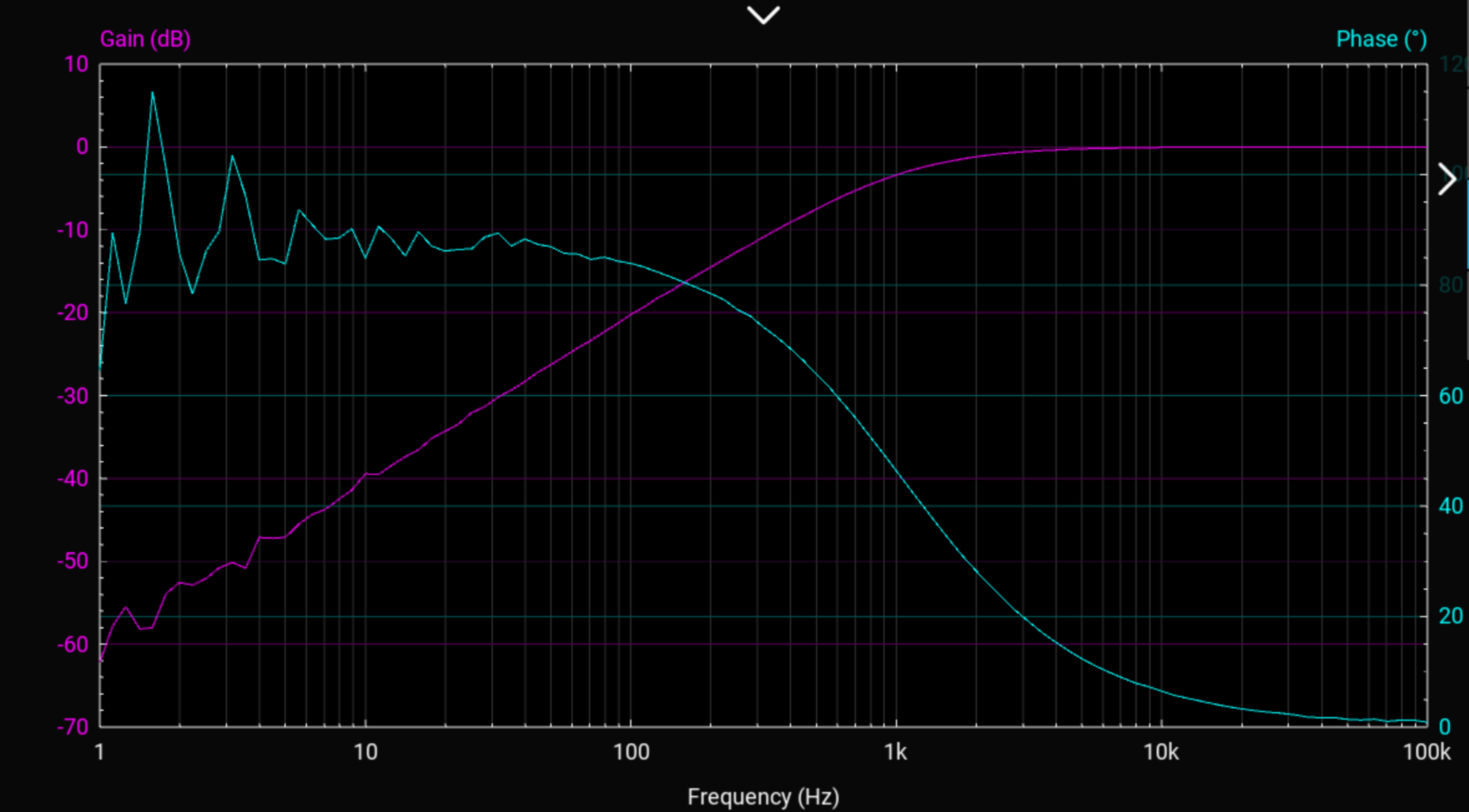
c - capacitor comes first

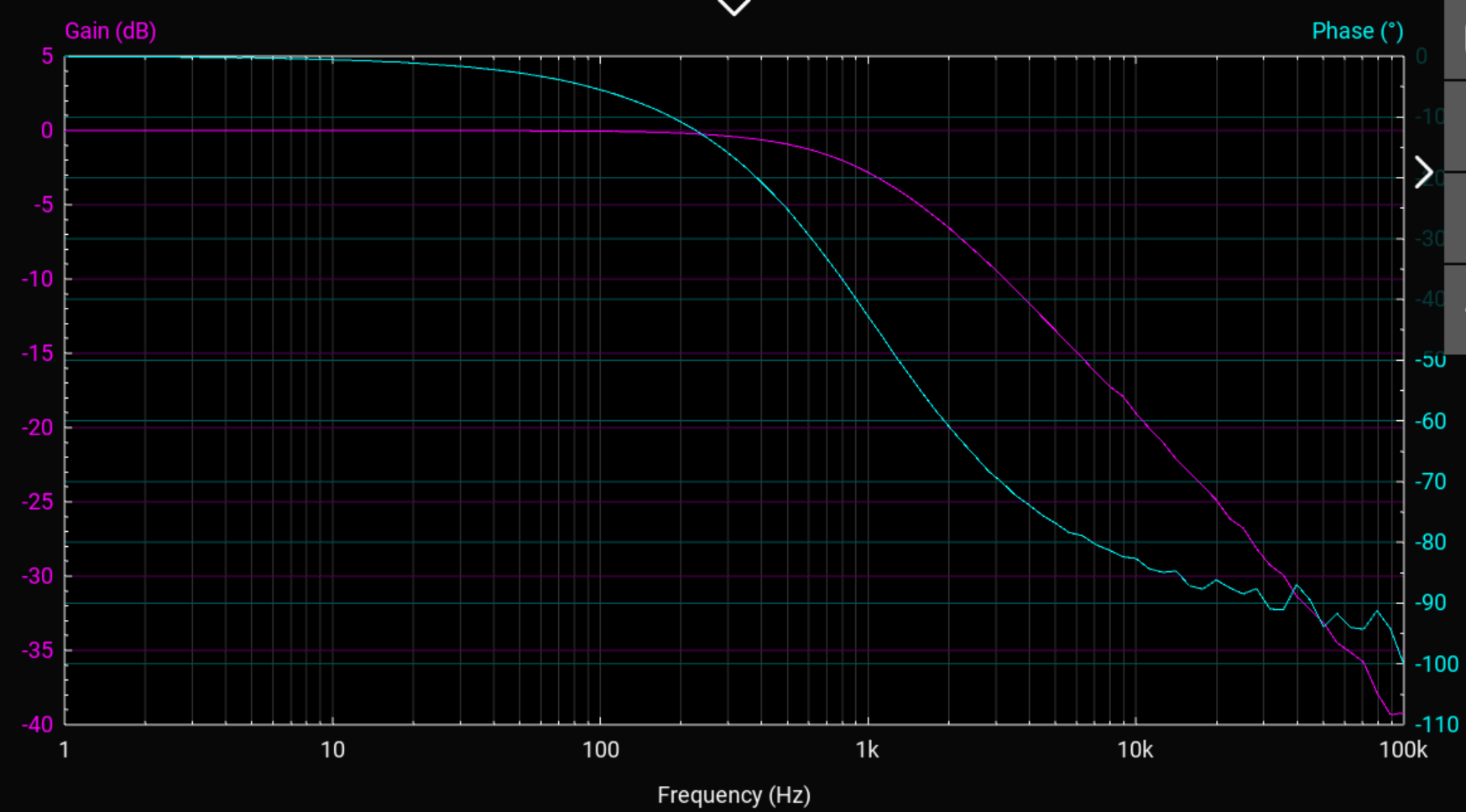
RC Circuit



Gain is low at low freq, ∴ low pass filter

Naming


Gain (dB)
Phase (°)
10
0
-10
-20
-30
-40
-50
-60
-70
80
60
40
20
0
1
10
100
1k
10k
100k
Frequency (Hz)


Gain (dB)
Phase (°)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-50
-60
-70
-80
-90
-100
-110
1
10
100
1k
10k
100k
Frequency (Hz)