PHY405 Lab 2

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Collaborators for all questions: none. Partner (for Lab 1-10): Jacob Villasana.

R-1

Methodology: current is conserved through the circuit. Ohm's law gives $V = IR$, so $I = \dfrac{V_{\text{res}}}{R_{\text{res}}}$ across the whole circuit including the resistor. Then, if V_{term} is the voltage across the power supply alone, by Kirchoff's law, $V_{\text{drop}} = V_{\text{term}} - V_{\text{res}}$. The internal resistance is then $\dfrac{V_{\text{drop}}}{I} = R_{\text{int}}$. Invoking the conservation of current, one has

$$R_{\text{int}} = \frac{V_{\text{term}} - V_{\text{res}}}{I} = \frac{V_{\text{term}} - V_{\text{res}}}{V_{\text{res}}/R_{\text{res}}} = R_{\text{res}} \left(\frac{V_{\text{term}}}{V_{\text{res}}} - 1 \right). \tag{1}$$

Therefore only two measurements are required. A $15\Omega \pm 5\%$ resistor was chosen as the external shunt resistor because not a lot of voltage was going to be used in the circuit. The voltage was set to -0.010 ± 0.01V on the DC power supply. The voltmeter was used to measure V_{term} and V_{res} independently. $V_{\text{term}} = -8.85 \pm 0.05$ mV, $V_{\text{SHUNT}} = -8.83 \pm 0.05$ mV. Hence

$$R_{\text{int}} = (15) \left(\frac{8.85}{8.83} - 1 \right) = 0.03397 \pm ?\, \Omega \simeq 34 \pm ?\, \text{m}\Omega. \tag{2}$$

The error is propagated via $\sqrt{0.05^2 + \left(\dfrac{0.05}{8.83}\right)^2 + \left(\dfrac{0.05}{8.85}\right)^2} * 0.03397 = 0.002\Omega$, so $R_{\text{int}} = 34 \pm 2\, \text{m}\Omega$.

R-2

Methodology: A lowpass circuit was designed according to the schematic in figure ?:

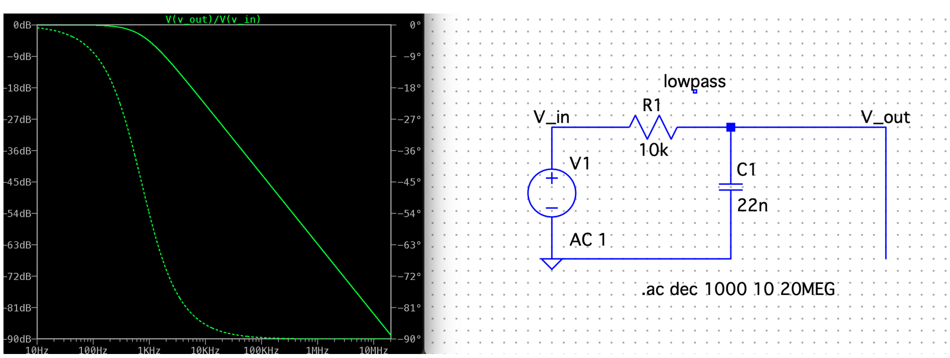

Figure 1: LTSpice schematic of the lowpass filter implemented in the first part of this lab, using a 10k resistor and a 22nF capacitor.

with a 10k resistor and a 22nF capacitor.
Using the voltmeter, on resistance and capacitance measurement settings, respectively, the resistance of the 10k resistor was measured to be $9.940 \pm 0.001\, \text{k}\Omega$, and the capacitor 22.60 ± 0.05 nF.

R-3

Starting at 10Hz, frequencies, wave phase differences, and the input and output voltages were measured using the oscilloscope. They were recorded in the lab notebook with their respective uncertainties. The data was imported into Python and plotted on Frequency vs Phase / Frequency vs Attenuation axes. The voltage attenuation is given by $20\log_{10}\left(\frac{V_{\text{pp2}}}{V_{\text{pp1}}}\right)$.

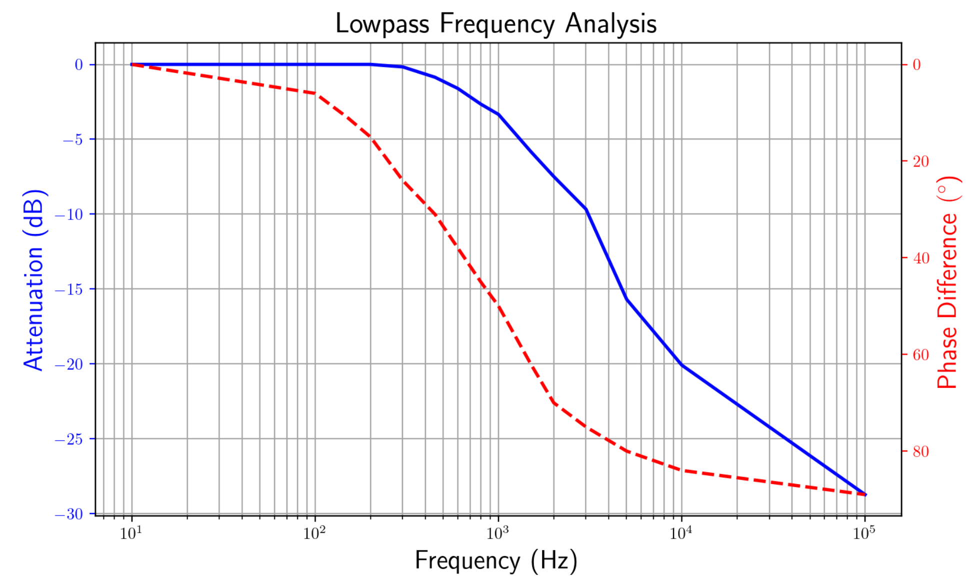

Figure 2: Plot of hand-drawn data from the manual oscilloscope frequency response analysis. The phase is shown in dashed red, while the voltage attenuation is shown in blue, both as a function of frequency.

R-4

This plot of phase and attenuation vs frequency is as expected and is consistent with that of the Bode plot generated by the LTSpice analysis. The only difference would be the phase not dropping to -90 faster, i.e. not around the 10kHz mark. Similarly, the attenuation plot immediately drops to $-\infty$ on the LTSpice plot, but appears even itself back out on the hand-drawn plot.

R-5

Methology: Using `analyze`→`Frequency Response Analysis`→`Setup`→`Run Analysis`,
a Bode plot of the capacitor lowpass filter was generated on the scope. Note that the -3dB cutoff is $\frac{1}{2\pi(10000)(22\times 10^{-9})} \approx 723$Hz, shown to be consistent with the Bode plot.

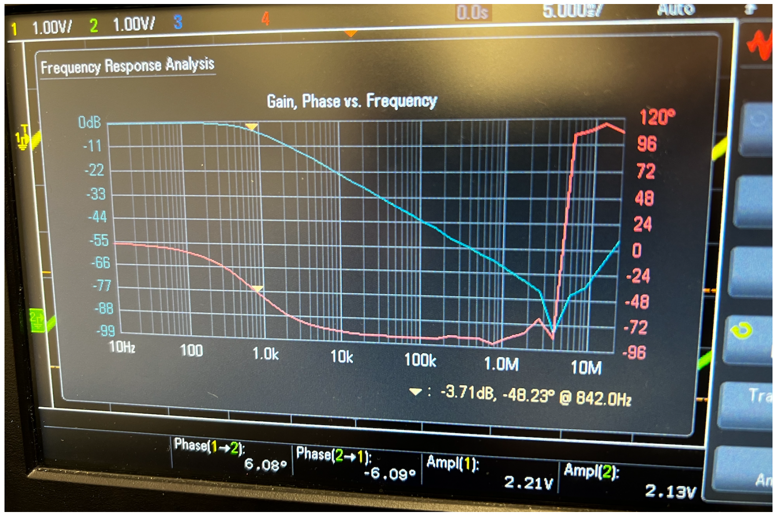

Figure 3: Lowpass Bode plot generated from the frequency analysis on the oscilloscope. As in Figure 2, the voltage is shown in blue, and phase difference shown in red.

R-6

Methodology: In the terminal (mac), `pip install -U pyvisa` was executed. Then, NI-Visa was installed from the NI site. At first, the USB was not appearing on the input, but after restarting the oscilloscope, the usb input was copied over. On the `Utility` menu on the scope, the USB visa address was copied into the python script to verify the matching of the Visa address. After some debugging, the code ran and properly read the scope input. The Bode plot code was ran with the same lowpass filter attached (10Hz - 20MHz, 36pts, High-Z).

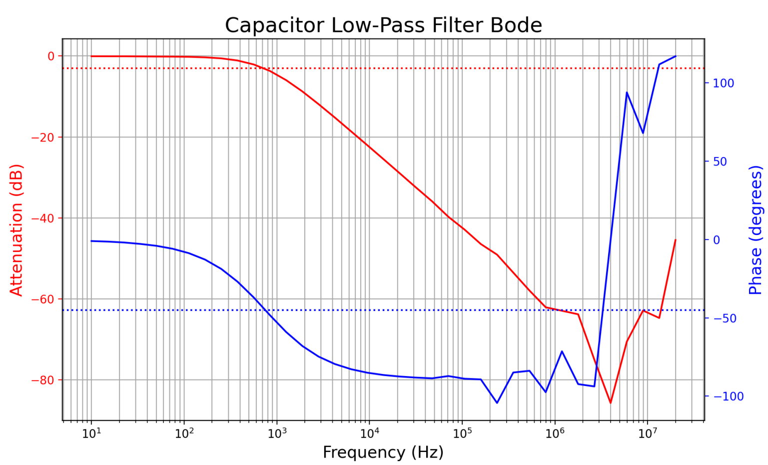

Figure 4: Identical lowpass Bode plot generated via computer control of the oscilloscope - it is identical to that of the Figure 3 plot.

Compared to the Bode plot shown in Figure *, it appears to be identical, with the $\sim$ 723Hz -3dB cutoff shown. Hence there is a direct data export into python from the scope.

R-7

Methodology: A 10mH inductor was chosen because 12mH inductors were not available. The 22nF capacitor from the lowpass in R2 - R6 was replaced with the inductor. Using thee same python code (computer was still hooked up to scope), another Bode plot was produced.

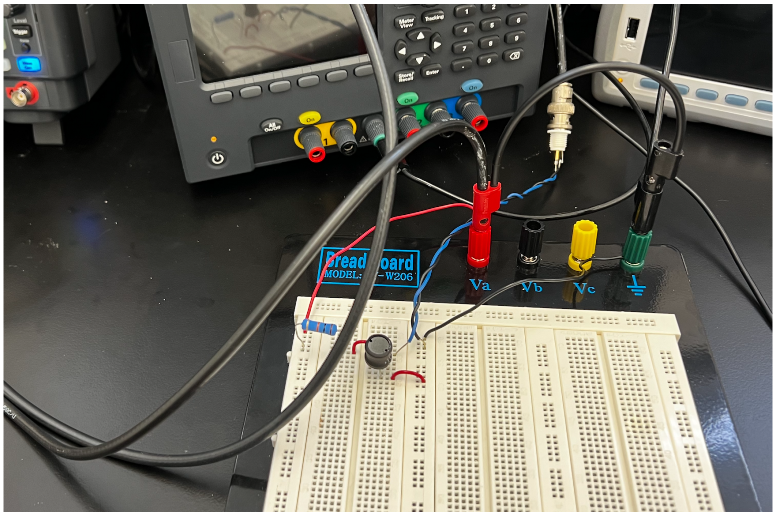

Figure 5: Highpass inductor circuit, with a 10k resistor and 10mH inductor. This circuit is identical to that of the lowpass constructed from R-2 to R-6, except with the capacitor exchanged with the inductor.

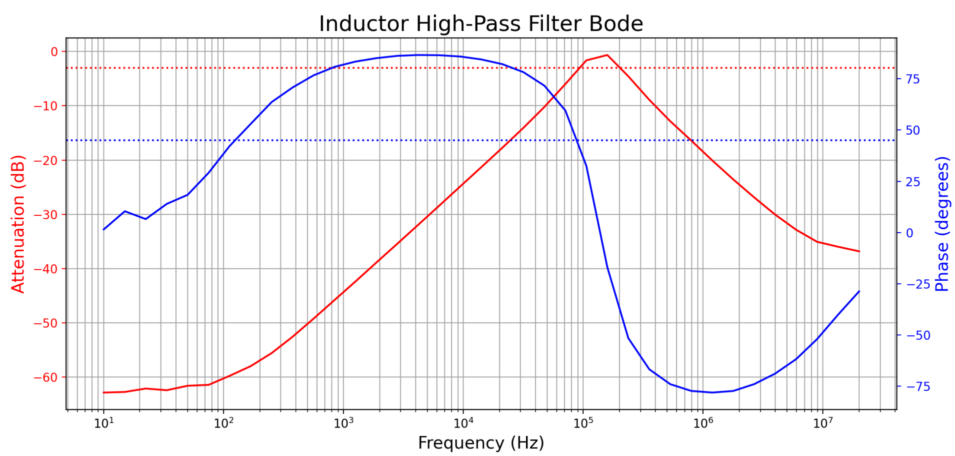

Figure 6: Bode plot frequency analysis of the inductor highpass filter constructed previously, obtained via computer control and python of the oscilloscope.

Though the scope Bode plot contains a lowpass, it appears to act like a bandpass filter around $f_c = \dfrac{R}{2\pi L} = 1.326 \times 10^5$ Hz. Compared to that of the LTSpice schematic, it is not consistent with that of a proper lowpass filter. This is probably due to internal capacitances (breadboard) or perhaps an error in constructing the circuit (yes, we made sure the inductor was facing the right way)...

R-8

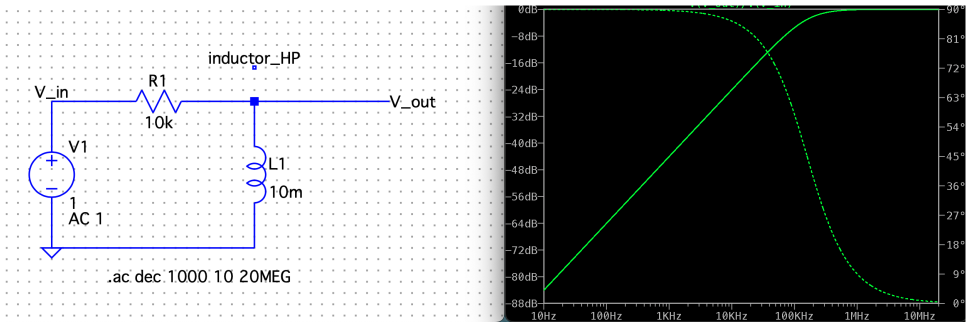

Figure 7: An equivalent circuit construction and frequency response analysis of the inductor highpass filter in LTSpice.

Methodology: The lowpass filter cutoff must be the larger frequency value. We place a highpass and lowpass filter in series (schematic shown below). Keeping the 22nF capacitors for both filters, we are subject to choosing the resistors. Hence $R = \dfrac{1}{2\pi C f_L}$. For $f_L = 5$ kHz and $C =$ 22nF, $R_L = 1.446\text{k}\Omega$ (lowpass). Similarly, the highpass will cutoff at 500Hz: $R_H = \dfrac{1}{2\pi C f_H} = 14.46\text{k}\Omega$ (highpass). Hence a $R_L = 1.5\text{k}\Omega$ was chosen for the lowpass and a $R_H = 15\text{k}\Omega$ resistance for highpass.

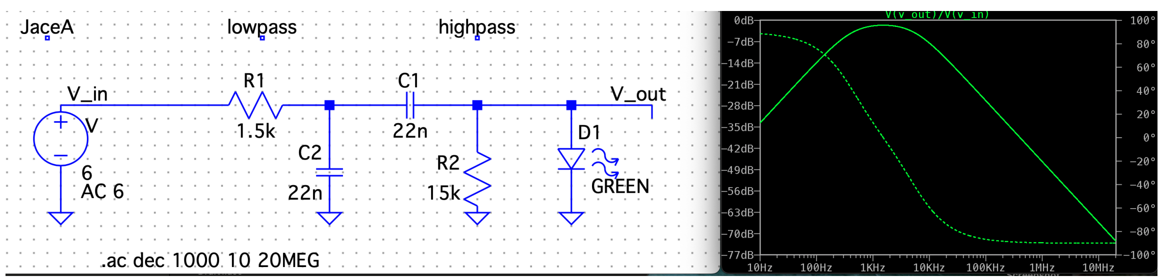

Figure 8: Circuit and Bode plot of the bandpass filter, constructed by placing a lowpass and then a highpass in series, taking the output through a green LED. Frequency response of the circuit taken as V_{out}/V_{in} (right hand side).

The LED circuit was constructed by placing a green diode across the output and forcing it to the ground. Initializing the oscilloscope with 8 Vpp, the LED would faintly turn on between 400 - 5.2k Hz. To make the LED glow more, the voltage was turned up to 12 and the frequency was placed around 4.4 kHz. An instance of the filter is shown below:

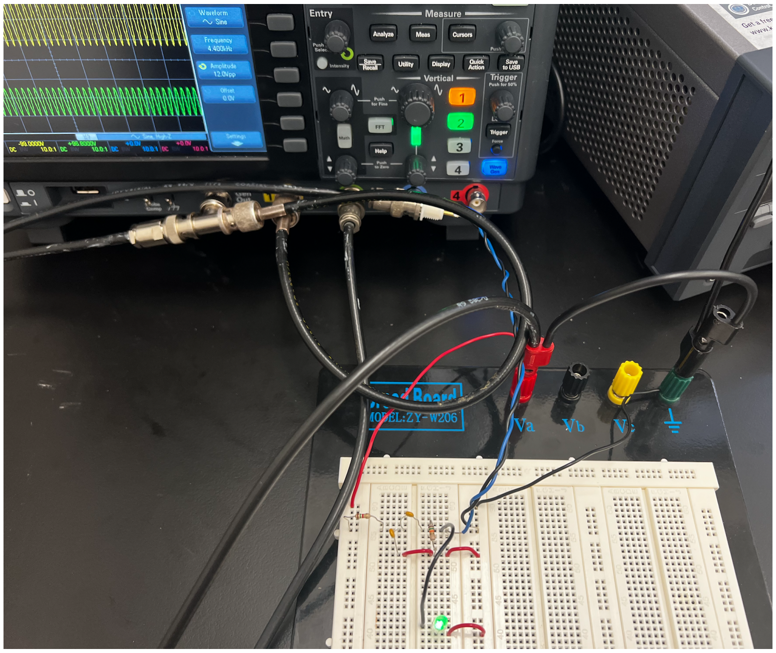

Figure 9: The bandpass circuit constructed in the breadboard from Figure 8. Including a 1.5k, 15k resistors and 22nF capacitors, taking the output through a green LED and grounding all the necessary outputs.

where the LED would turn off for small ($\sim$ 300 Hz) and large ($\sim$ 6 kHz) frequencies (it worked very well).