# PHY405 Lab S

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

## R-1

**Methodology:** A blank schematic was opened, and from the 'circuits' menu, the schematic diodes $\rightarrow$ diode limiter was selected. The diodes were deleted and substituted with LED's. In the 'edit component' option, the color value of the left LED was changed to blue = 1, red = 0. The resistor in the circuit was left at 110Ω. The 'out' analogue output was exchanged with a ground (for no particular reason - I was figuring out how it worked). The AC generator was edited to be a square wave at 100Hz. Voltmeters were selected from the draw $\rightarrow$ outputs and labels $\rightarrow$ add voltmeter/scope probe and drawn overtop the LED's to measure the exchange in voltage. In each voltmeter edit window, 'show value' was selected. The AC source and both voltmeters were selected as 'view in new scope' so that voltage-time plots were generated below. At the gear(s) in each plot (bottom left corner), the maximum voltage display was set to $\pm 5V$ (manual vertical scale), and the horizontal scale was nudged to 2ms/div. This was important in viewing the plot(s) since the frequency of the source was changed. My name was added to the plot using the 'add text' option under the outputs and labels menu dropdown.

**Circuit Link:** https://tinyurl.com/2ya8fnt6

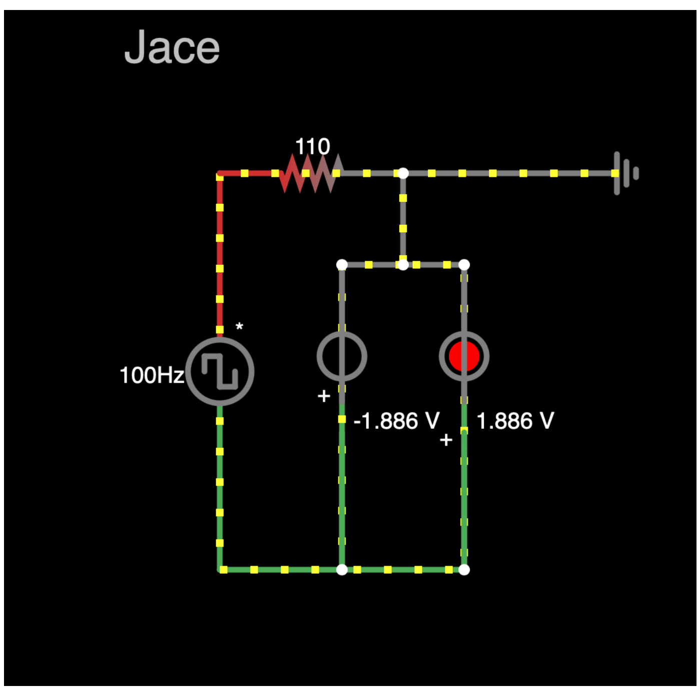


*Figure 1: alternating LED circuit in Falstad using a 100Hz AC square wave, red and blue LED's, and voltmeters.*

### R-2

*Note: I completed R3 before R2, and used the tools from LTSpice to create a Bode plot for this bandpass filter prior to using Falstad, as I was having trouble with the attentuations of the filters extending past their specified frequency cutoffs.*

**Methodology:** Using references given in the lab manual (the high pass and low pass circuit schematics in Falstad: `https://www.falstad.com/circuit/e-filt-hipass.html`), the first attempt was to place the filters in series so that every frequency that passed through the first filter would also pass through the second filter. An LED was added and an analogue output was drawn out. The schematic is shown below.

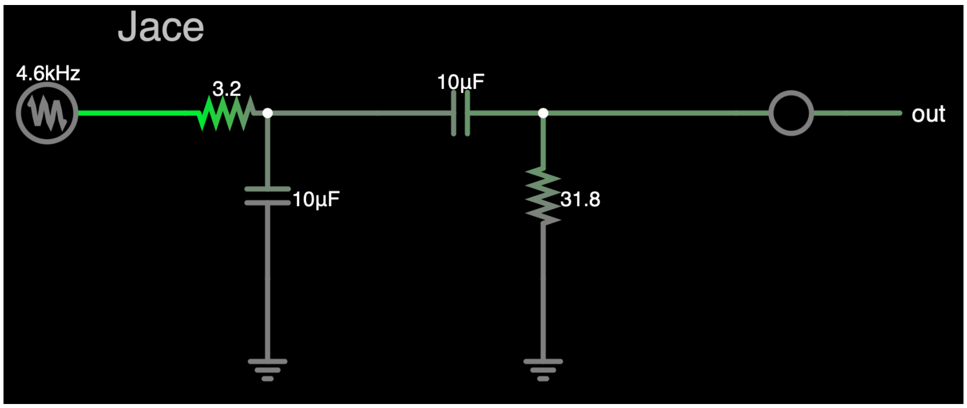


*Figure 2: initial attempt at creating bandpass filter, by placing lowpass and highpass filters in series and returning an analogue output with an LED which did not light up. An AC sweep was used as a source from 20Hz to 6kHz.*

The voltage source was replaced with an AC sweep (found under the draw → inputs and sources menu) and edited to sweep from 20Hz to 6kHz over 100ms. The values of the resistances / capacitances were found using

$$f = \frac{1}{2\pi}\frac{1}{RC} \tag{1}$$

where $f$ is the cutoff frequency. I chose to leave $C$ fixed at $10\mu$F for each capacitor and to vary $R$. For the upper cutoff frequency of 5kHz, the given resistance value was $R_1 \simeq 3.2\Omega$, and this was the lowpass filter. Similarly, for the highpass, a cutoff frequency of 500Hz yielded $R_2 \simeq 31.8\Omega$.
The first problem was that the LED was not lighting up (eventually, I found that this was because the circuit was not closed). The 'out' line was removed and the LED was connected to the front of the circuit and a ground was placed for the LED line, but under these conditions the LED would always light up for any frequency value and thus the filter was not working.
I was having difficulty computing the decimal ratios of $V_{\text{in}}$ and $V_{\text{out}}$, as my LED would only light up under certain conditions (and I wanted to make sure my voltage attenuation was exaclty -3dB so that I could set a condition on the LED lighting up) so I turned to LTSpice to draw the circuit. Since the ground is arbitrary, I connected the circuit in a loop, removed the LED and placed a resistor to mimick a load. In the analysis command line, I specified an AC sweep from 10-10kHz for 1000 pts/decade, and the AC voltage was set to 6V. When creating the Bode plot for the first time, I found that my filters were inconsistent and that the cutoffs were too high, and this was because I had incorrectly placed the wrong resistance values in the wrong places. Once I changed them, I created a new Bode plot for $V_{\text{out}}/V_{\text{in}}$, which was consistent with what I was looking for.

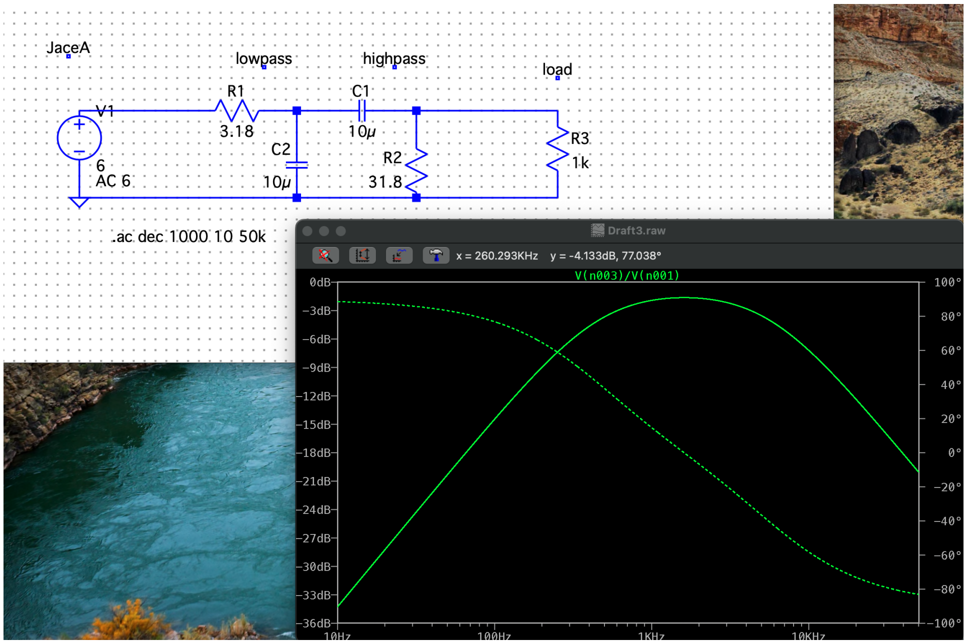


*Figure 3: bandpass filter Bode plot using LTSpice. This was completed to diagnose problems with frequency cutoffs and attenuation prior to implementing the circuit in Falstad. Frequency response is shown in green over a range of 10MHz.*

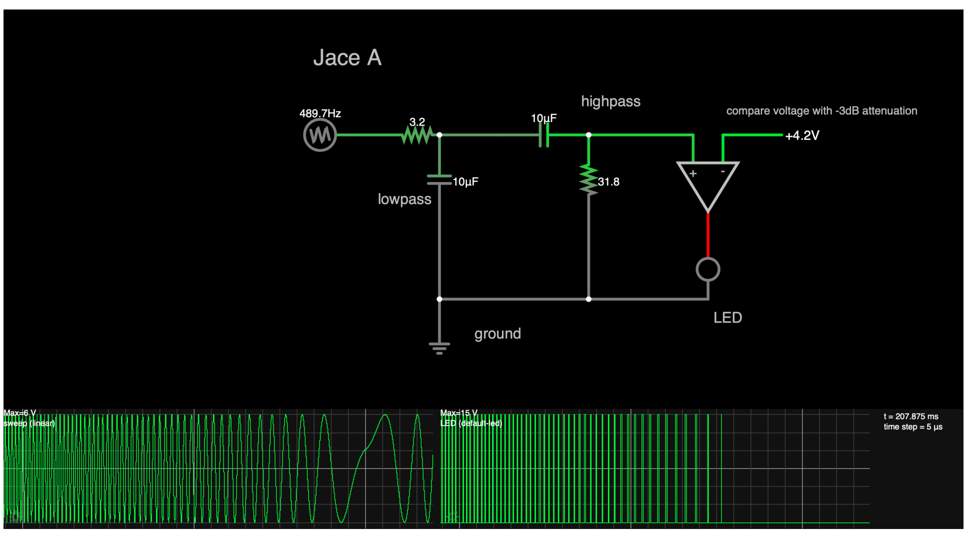


*Figure 4: Bandpass circuit implemented in Falstad, using the circuit created in LTSpice and a comparator to match the output voltage of the circuit with the 3dB attenuation so that the LED turns on within a specific frequency range.*

This exact circuit was copied into Falstad and the load resistor was replaced with the LED. To make the LED turn on within a given frequency, this meant that attenuation must be less that 3dB within those frequncy values (dictated by the bandass), which corresponds to $V_{\text{in}} \cdot \dfrac{1}{\sqrt{2}} \implies \dfrac{6}{\sqrt{2}} \approx 4.18\text{V}$. An Op-Amp (comparator) was added at the end of the circuit, going to LED, going to ground, and the input $+$ voltage was compared with $4.18$V in the $-$ side. Hence, the LED will only light up if

the output from the bandpass is within the $500 - 5k$ Hz range. The final schematic is shown above in Figure 4.
**Circuit Link:** `https://tinyurl.com/26yvqwcg`
*Not sure if I am allowed to use an Op-Amp to specify the reference voltage for when the LED turns on, but I found that if I didn't have the comparator the LED would just always turn on whenever the AC would force current (of any voltage) into the LED.*

### R-3

**Methodology:** Referencing the Falstad lowpass filter (`https://www.falstad.com/afilter/circuitjs.html?cct=$+1+0.000005+5+50+5+50%0A%25+4+12262437.237946307%0AO+800+304+912+304+0%0Ag+800+432+800+464+0%0Ar+640+304+800+304+0+187%0Ac+800+304+800+432+0+0.00001+0%0A170+640+304+608+304+3+20+1000+5+0.1%0Ao+4+32+0+34+5+0.00009765625+0+-1%0Ao+0+32+0+34+5+0.00009765625+1+-1%0A`), the wires were drawn using F3 in a blank schematic in LTSpice. The voltage source was added: the negative end was connected to ground. It was set as an AC source at 6V and 0 phase offset. The resistors were placed in using F2 (select components) and 'res' was selected. The value was changed to 187Ω to match that of the Falstad model. The capacitor was chosen under 'cap' and placed on the orthogonal wire into the ground to create the lowpass. It was selected to edit and 'choose from database', where the component '885012108021 WCAP-CSGP 1206' X5R capacitor was selected (after a bit of searching). An output voltage line was added, with a resistor of arbitrary resistance (I chose 1k) so that the output/input voltage ratio could be measured. Every loose wire was then connected to a ground. Labels for $V_{\text{in}}$ and $V_{\text{out}}$ were added as well as my name using the 'text' draft.

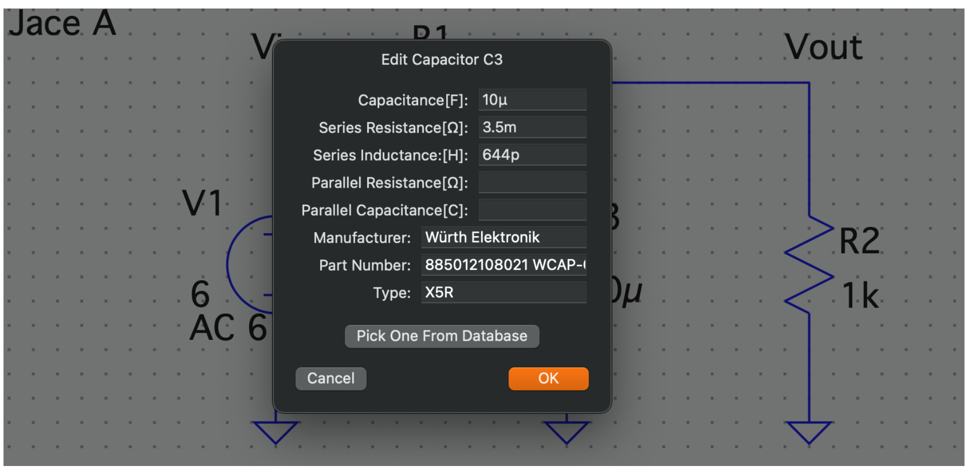


*Figure 5: selecting the appropriate capacitor for the lowpass circuit construction in LTSpice.*

To analyze the circuit, right-clicking and selecting: draft → SPICE directive → help me edit → analysis cmd, where 'AC analysis' was chosen. The nature of sweep was selected to be 'decade' (with 1000pts), a starting frequency of 10Hz and ending at 10MHz to plot a full spectrum of the bandpass. The SPICE command was `.ac dec 1000 10 10MEG` and then the circuit was run. In the plotting window, the voltage ratio $V_{\text{in}}/V_{\text{out}}$ was plotted (that is, V(n002)/V(n001)). The schematic and plot were shown below:

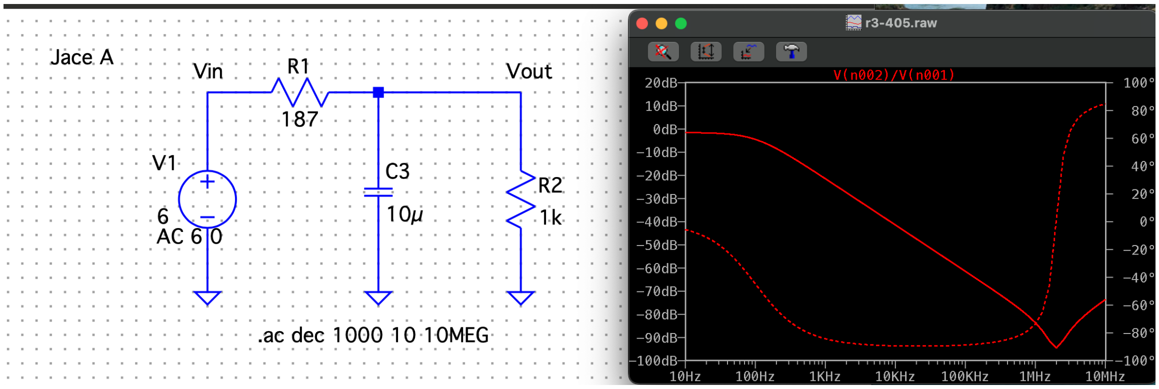


*Figure 6: circuit schematic (left) and frequency response / Bode plot (right) of a lowpass filter created in LTSpice over an AC sweep from 10Hz to 10MHz.*

**Difference between LTSpice / Falstad Bode plots:** What is different about the LTSpice Bode plot with that of Falstad's is that it appears as a large band-stop filter shifted to a large frequency value to mimick a lowpass. In Falstad's plot, the frequency response continues to drop past 1MHz and further into higher frequencies (∼GHz), while in the LTSpice plot it appears to increase past around 10MHz instead of continuing to cutoff the frequencies. However, for low-frequency values, they appear to behave the same with the same 0-3dB attenuation from 0 - 1kHz.