PHY405 Lab S

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R-1: Flashing LEDs Circuit

In this part of the lab, a simple circuit was designed using LEDs and a waveform generator with a square wave to alternately flash red and blue LEDs. A resistor was included to limit the current through the LEDs and prevent damage.

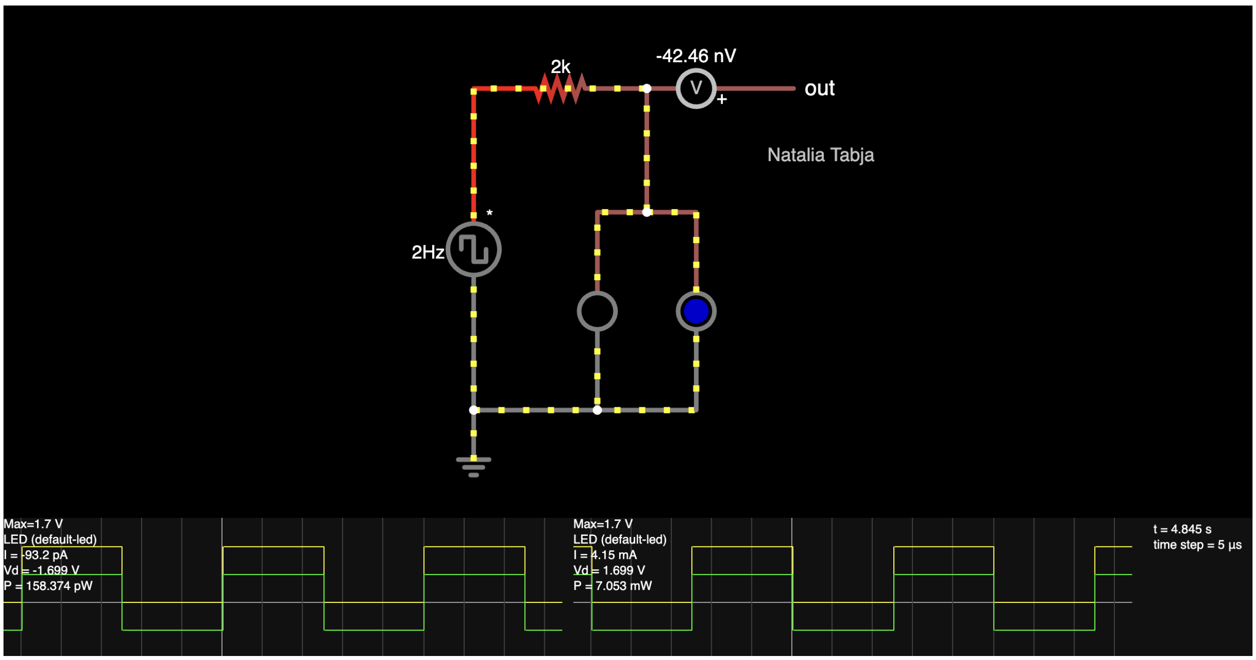

Figure 1: R1 Circuit

Details of the R1 Circuit:

- Waveform Generator: 10 V peak-to-peak square wave, 2 Hz.
- Resistor Value: 2kΩ to ensure the current remains below 10 mA.
- LEDs: Red and Blue LEDs placed in opposite directions to flash alternately.

Observations: The oscilloscope traces show the input square wave and the voltage across the LEDs, and the LEDs flashed in an alternating fashion, with both LEDs never being on simultaneously, as expected.

Falstad Circuit Link: R1 Simulation HyperLink

R-2: Band-Pass Filter Circuit with LED

In this part of the lab, a band-pass filter circuit was designed using resistors and capacitors to allow the LED to light up only when the input frequency is between 500 Hz and 5000 Hz. The circuit combines a high-pass filter and a low-pass filter.

Details of the R2 Circuit:

- Sinusoidal Input: 6 V peak-to-peak.
- High-Pass Filter: Resistor (`R1 = 1 kΩ`) and Capacitor (`C1 = 250 nF`).
- Low-Pass Filter: Resistor (`R2 = 2 kΩ`) and Capacitor (`C2 = 25 nF`).
- LED: Green LED connected at the output.

Theoretical Calculations: To meet the cutoff frequencies, the capacitance values were calculated as:

- C_1 (High-Pass Filter Capacitor):

$$C_1 = \frac{1}{2\pi f_{c1} R_1} \approx 318 \text{ nF}$$

- C_2 (Low-Pass Filter Capacitor):

$$C_2 = \frac{1}{2\pi f_{c2} R_2} \approx 32 \text{ nF}$$

Although the initial resistance and capacitance values were chosen based on the theoretical calculations above, the simulations showed the need for adjustments (e.g., the LED would light up at 6kHz and 400Hz. Thus, the capacitance values were fine-tuned to ensure the LED behaved correctly at the target frequency range. The initial values for C_1 and C_2 were adjusted as follows:

- $C_1 = 250\,\text{nF}$, $C_2 = 25\,\text{nF}$.
- $R_1 = 1\,\text{k}\Omega$, $R_2 = 2\,\text{k}\Omega$ (resistor for fine-tuning the low-pass cutoff).

Observations: The LED lights up when the input frequency is between 500 Hz and 5000 Hz and turns off outside this range. Minor deviations were observed near the cutoff points, but overall the circuit behaves as expected.

Falstad Circuit Link: R2 Simulation Hyperlink

R-3: RC Low-Pass Filter Bode Plot Analysis

In this part of the lab, an RC low-pass filter was designed, simulated, and analyzed using LTSpice. The circuit consisted of a resistor and a capacitor, with the output taken across the capacitor.

Details of the Low Pass RC Filter:

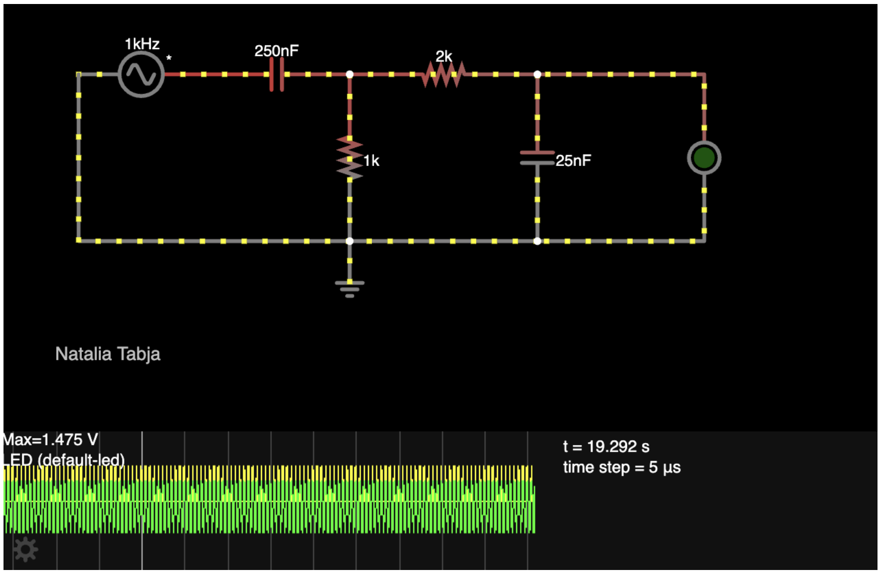

Figure 2: R2 Circuit

- Input: Sinusoidal AC source with a peak-to-peak amplitude of 1 V.
- Resistor: $R = 187\,\Omega$
- Capacitor: $C = 10\,\mu\text{F}$ (Würth Elektronik 885012108021 WCAP-CSGP 1206 X5R ceramic capacitor)
- Cutoff Frequency (f_c): Calculated as: $f_c = \frac{1}{2\pi RC} \approx 85\,\text{Hz}$

Simulation Command: An AC analysis was performed using LTSpice with the following parameters:

```
.ac oct 100 10 10k
```

Observations: The Bode plot generated from the simulation confirmed the expected behavior of the low-pass filter:

- In the passband (frequencies below f_c), the gain remained relatively constant.
- Beyond the cutoff frequency, the output signal becomes progressively weaker as the frequency increases, as expected for a low-pass filter. At higher frequencies, the filter significantly attenuates the signal, allowing only lower-frequency components to pass through effectively.
- The phase shift increased as the frequency approached the cutoff point, reaching $-90°$ at very high frequencies.

Circuit and Bode Plot Screenshot:

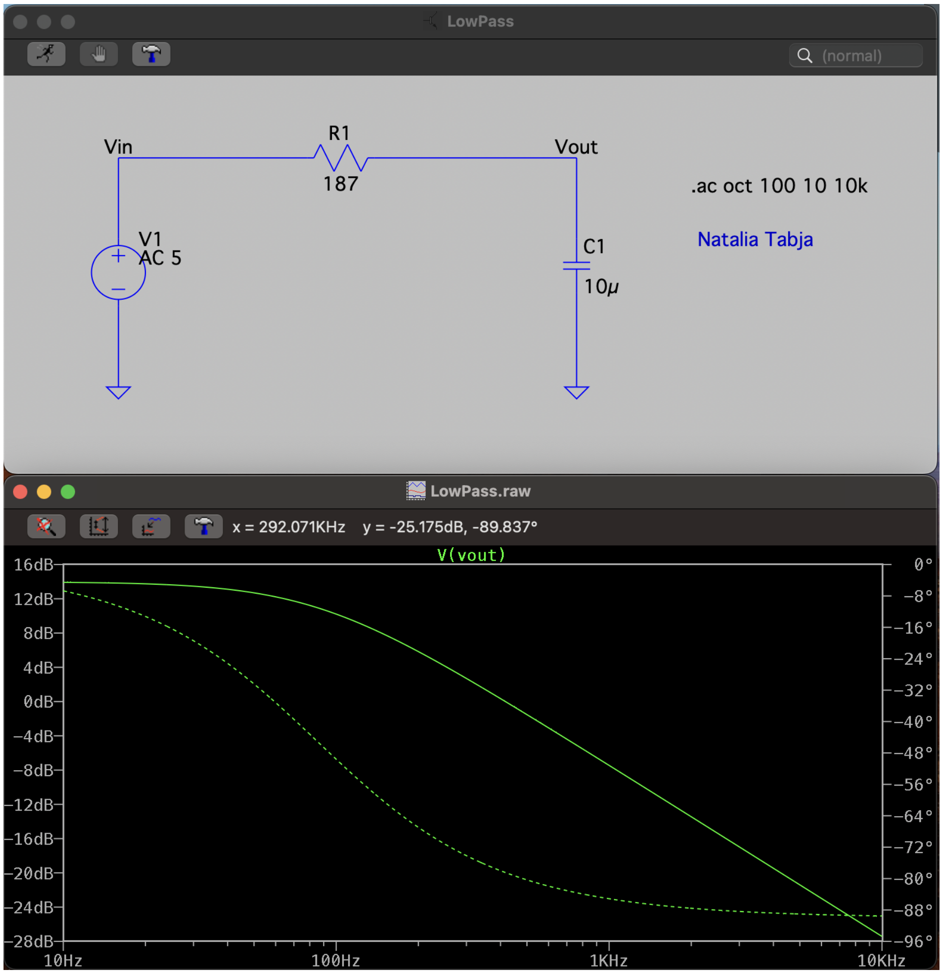

Figure 3: Bode Plot of RC Low-Pass Filter

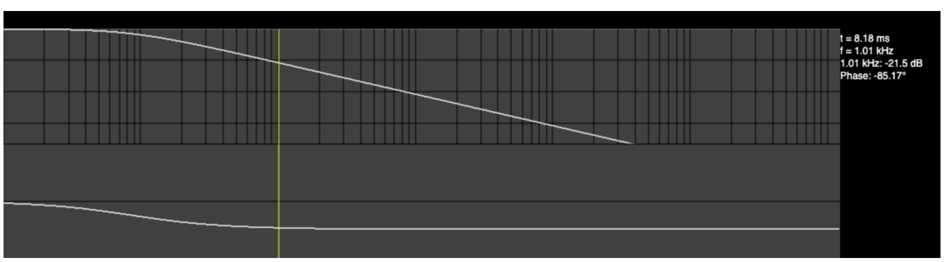

Figure 4: Falstad Low Pass Bode Plot

Comparison with Falstad Simulation: The simulation results obtained using LTSpice and the Falstad Circuit Simulator showed similar Bode plot shapes over the frequency range of 10 Hz to 10 kHz. While the magnitude responses aligned closely, there were differences in the recorded phase shift (e.g., at 1000Hz, the phase shift was -92.6º in LTSpice, whereas in Falstad it was about -85.2º). These discrepancies can be attributed to differences in the numerical algorithms/approximations of each simulator.