SW Implementation

Introduction

In this lab, we investigated the behavior of voltage dividers, RL Circuits and circuits that involve OPAMPs through asked implementations of circuits and made use of the values we obtained from transient and frequency domain analyses to interpret how such circuits with their particular elements function. In order to make this possible, we created a voltage divider circuit made up of 2 resistors and a voltage supply, a similar RL circuit, and multiple circuits made up of OPAMPs and investigated what kind of circuits they are through changing values of certain variables, like values of resistors or inductors, or the amplitude and shape of waves that we send to the circuits and observing the change of input and output voltages.

Analysis

As for the voltage divider circuit, I chose R1 = 7.5 ohms and R2 = 15 ohms, and sent a sinusoidal signal that has 7.5V amplitude and 10 kHz frequency. In a voltage divider circuit, the voltage of our output can be found by the formula:

$$Vo = Vin * \frac{R2}{R1 + R2}$$

Since the ratio, R2/(R1+R2) equals 0.66, the output voltage should be a sinusoidal wave with the same phase and frequency with the input wave, but with the 0.66 times the amplitude. Using transient analysis, observing the voltage division should be useful. I chose the time of the transient analysis in order to observe 3-4 periods of the waves using the formula:

$$\frac{1}{f} = T$$

4T, which is 0.4 ms was the time for the analysis.

For the first RL circuit, the input wave changed to a sinusoidal wave with amplitude 8V, frequency 100 kHz, and I chose R1 as 33 ohms and L1 as 47 µH. Here the 4T equaled around 40 µs, which made the time for transient analysis to observe 4 periods. For an RL circuit, the current change that occurs due to the sinusoidal behavior of the input voltage repeatedly changes the magnetic field within the inductor, and such a change creates a voltage across it. As the frequency increases, the phase difference between output and input voltages also increases. Also, at low frequencies, the reactance of the inductor is given by the formulas:

$$XL = 2\pi f L$$

At low frequencies, the overall impedance of the circuit is mostly determined by the resistance, and as a consequence most of the voltage drops at the resistor, not letting great portions of the input voltage to go across the inductor. As the frequency increases, the impedance it dominated by the inductor, and most of the input voltage goes across the inductor, making the RL circuit a high pass filter. A slight voltage drop and phase change can be observed on the first RL circuit, as the frequency is high enough.

For the second RL circuit, I chose R1 = 30 ohms and chose L1 as 47 µH, also including the 50 ohms resistance that the signal generator brings. Here, the input wave is 8 V sinusoidal wave, but the frequency is observed on a range of 100 Hz to 10 MHz and a small signal AC analysis is made. Here the input voltage is observed after the first resistor, as this 50 ohms resistor is placed inside the signal generator. Making an observation of how the voltage ratio between the output and input voltages changes, one should be able to conclude that the RL circuit is a high-pass filter.

For the first OPAMP circuit, an inverting amplifier circuit is developed, with R1 = 220 Ω, R2 = 660 Ω, R3 = 2KΩ, Vcc = 10V and Vee = -10V. The input sine wave has amplitude 2V and 1KHz frequency. In an inverting OPAMP circuit, the ratio of output and input voltage is found by the formula:

$$\frac{Vo}{Vi} = -\frac{R2}{R1}$$

Here the circuit should amplify the circuit and almost create a symmetrical version to the time axis with 1/3 the magnitude as the ratio between output and input voltages is -1/3.

Later, changing the input wave to a square wave of 1V amplitude and 2 ms period that has 50% duty cycle, which has rise and fall times of 10 nanoseconds should give a similar result, inverting the square wave -1/3 times. After on, I changed R1 to 8kΩ, and replaced the second resistor with a 3 nF capacitor. At one point, it was asked to bring the OPAMP to saturation, and to do that increasing the R2 was necessary, making it 660 kiloohms instead of 660 ohms should be sufficient to bring the OPAMP to saturation, as this ratio is well over the inverting ratio and should surpass the limits of -+10V. Adding a capacitor for a third OPAMP circuit created an integrator circuit that creates lower slopes on the output square wave, changing the shape of it, as the capacitor charges and discharges as the square wave changes value. The formula for an integrator circuit is given by:

$$Vo = -\frac{1}{R1 * C}\int_0^t Vin * dt + c$$

We can observe that due to this integration process, the shape of the input pulse wave should be symmetrical to the time axis, and its rise and fall edges should have lower slopes.

Simulations

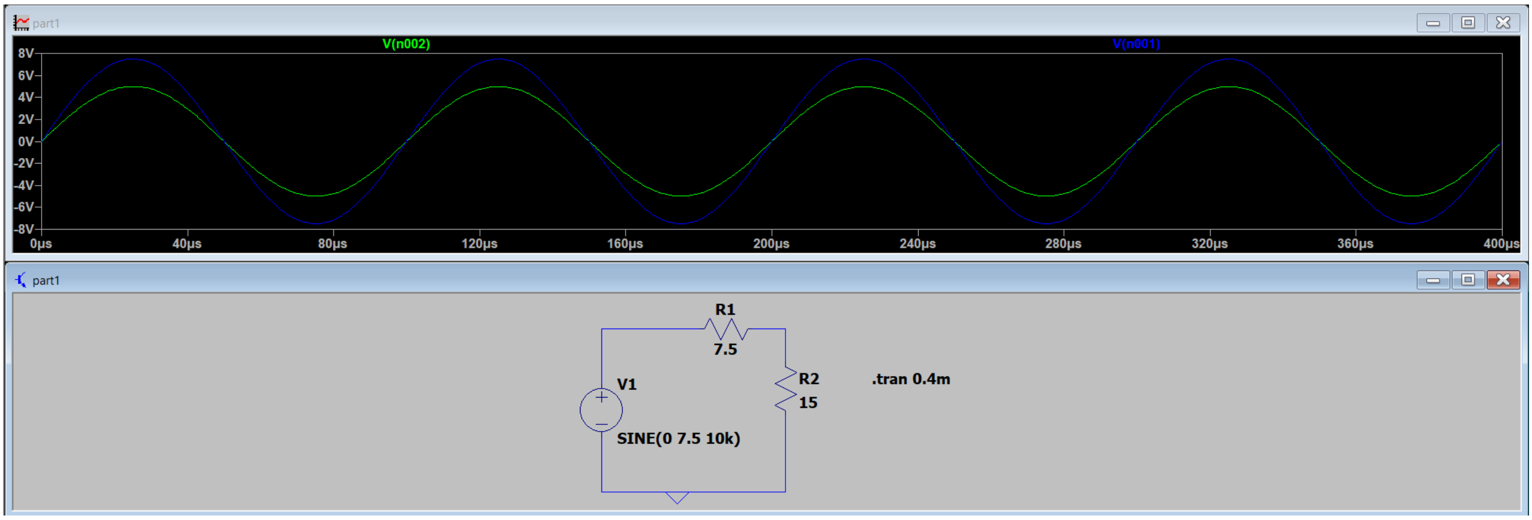


Figure 1: Voltage Divider Circuit

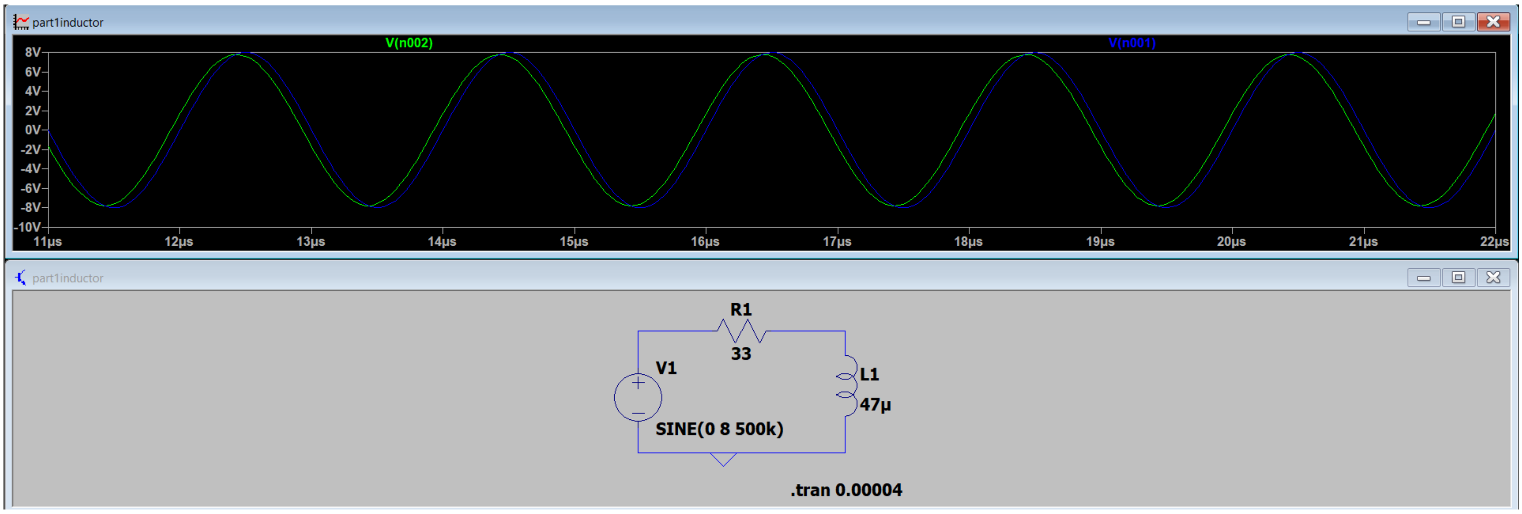


Figure 2: First RL Circuit

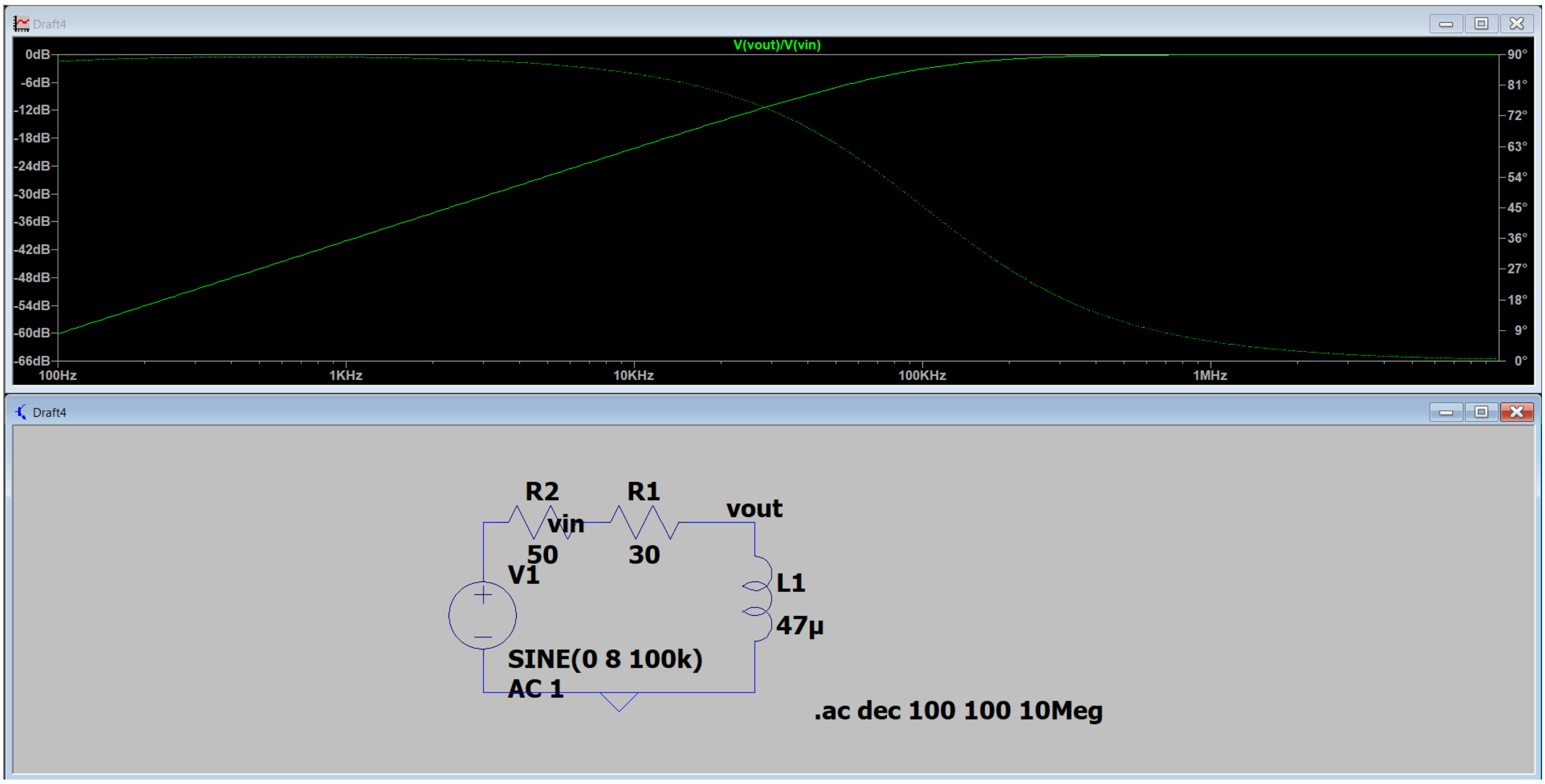


Figure 3: Second RL Circuit

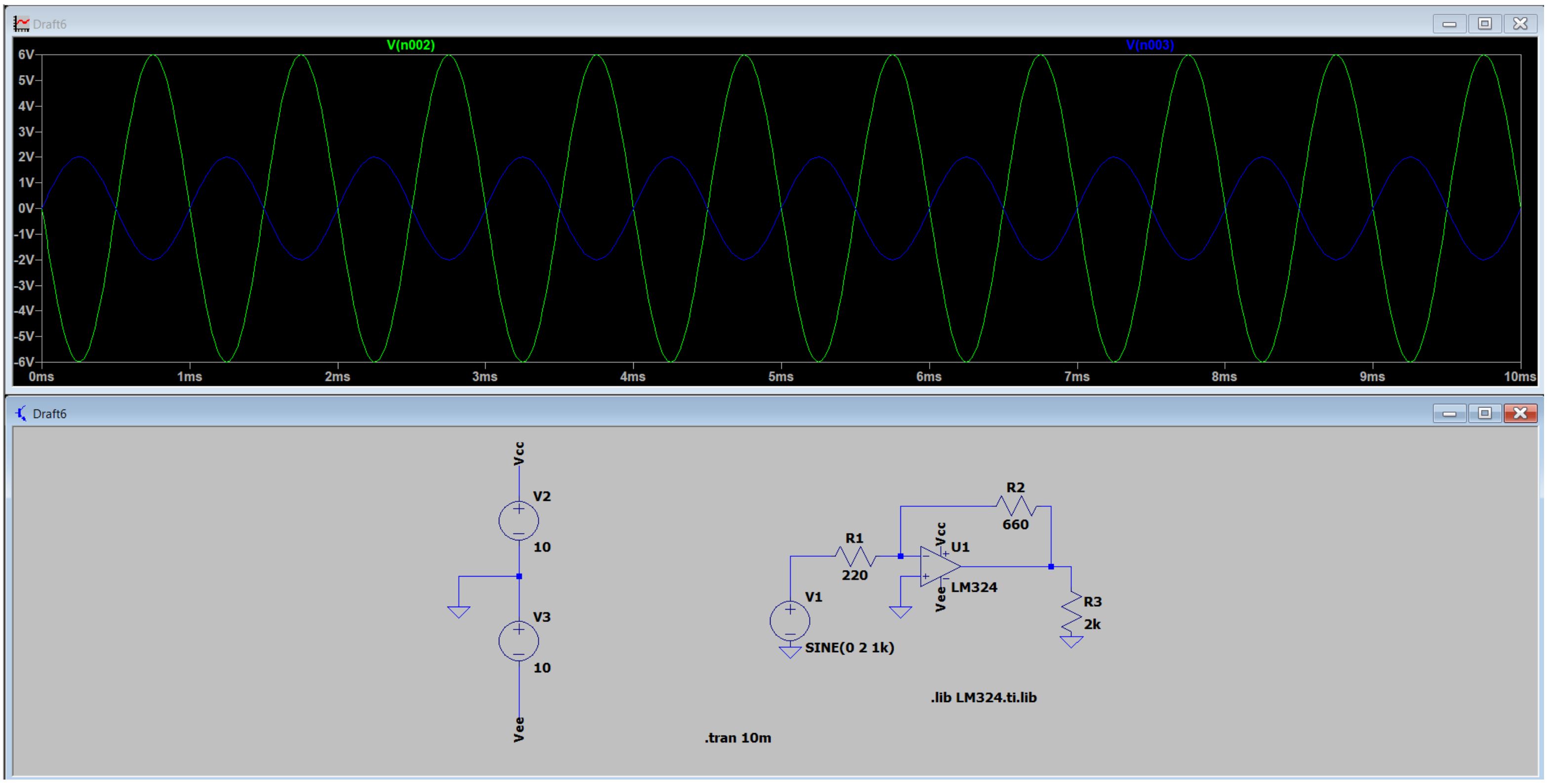


Figure 4: First OPAMP Circuit

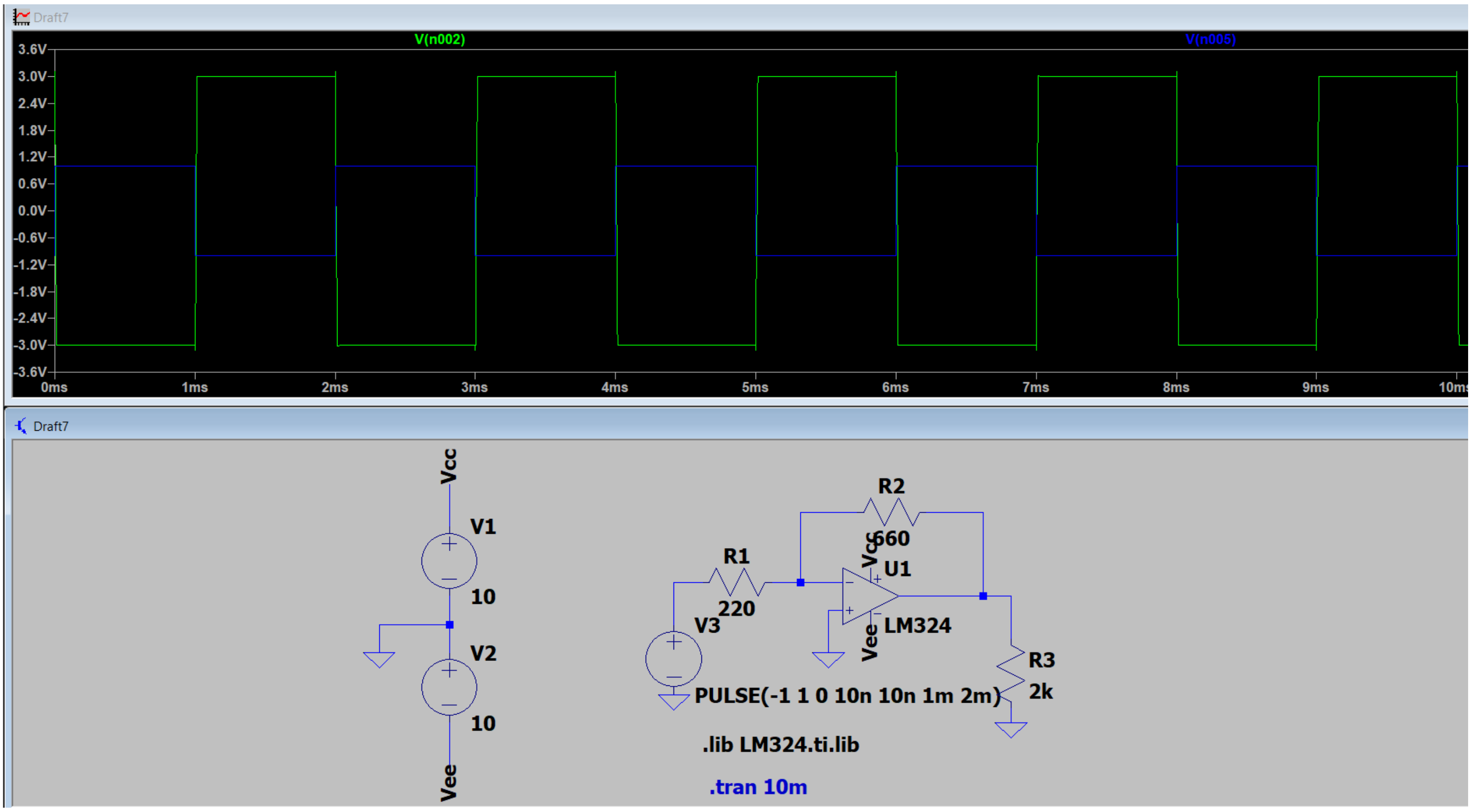


Figure 5: Second OPAMP Circuit

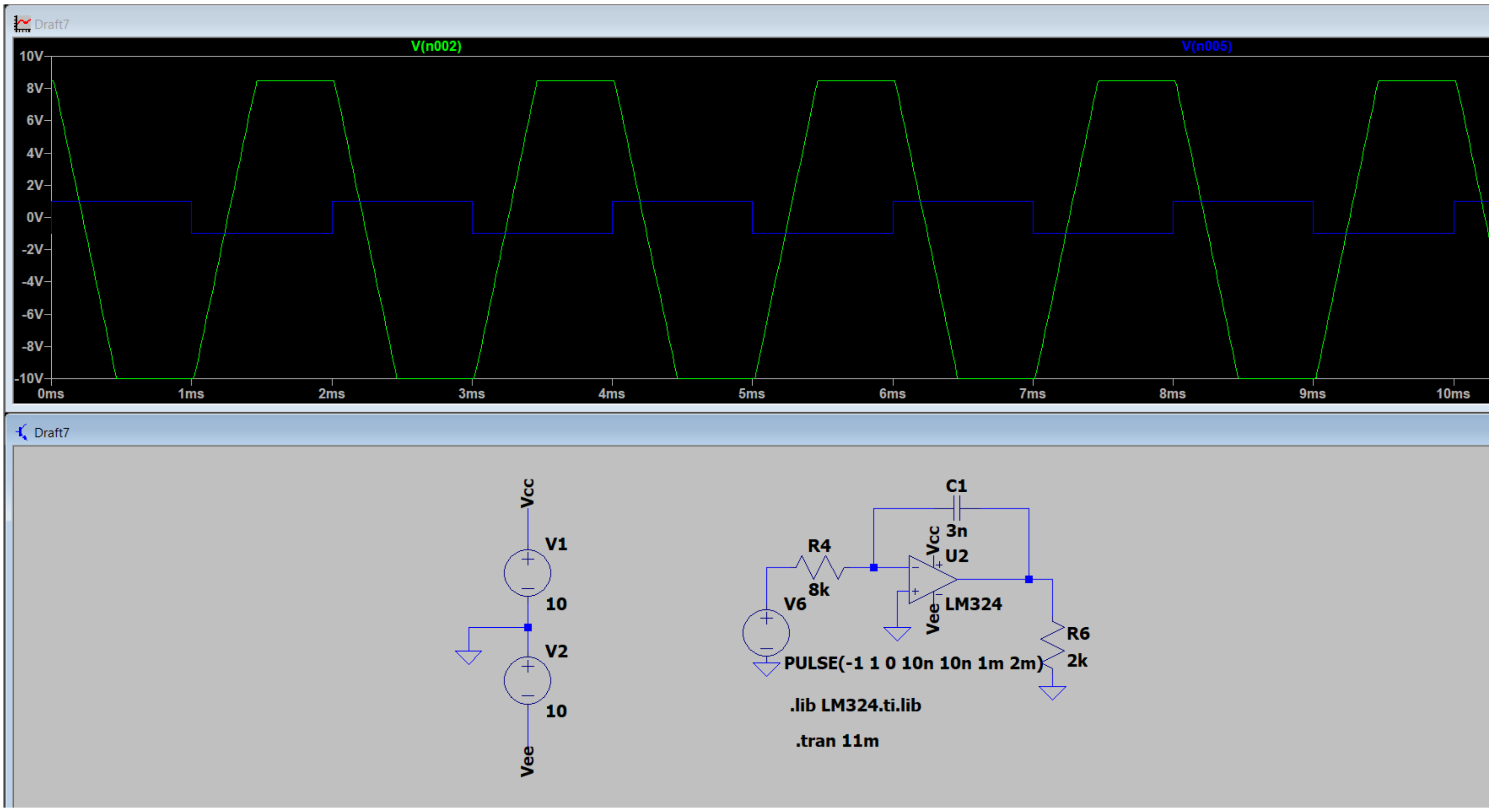


Figure 6: Third OPAMP Circuit

HW Implementation

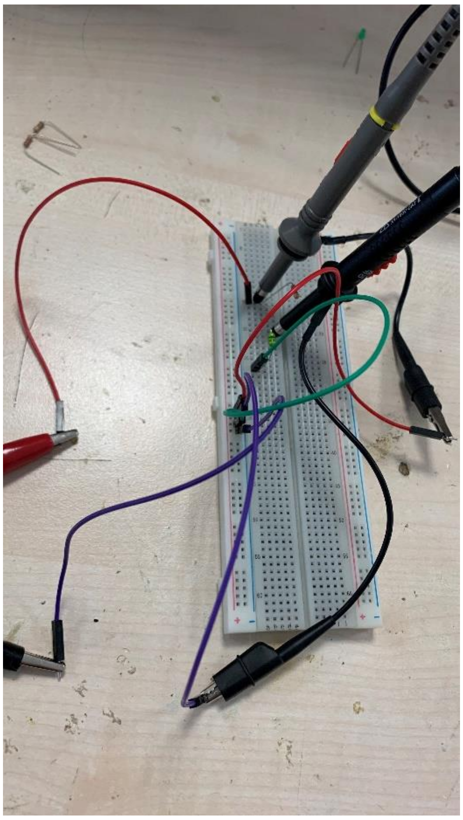


Figure 7: RL Circuit

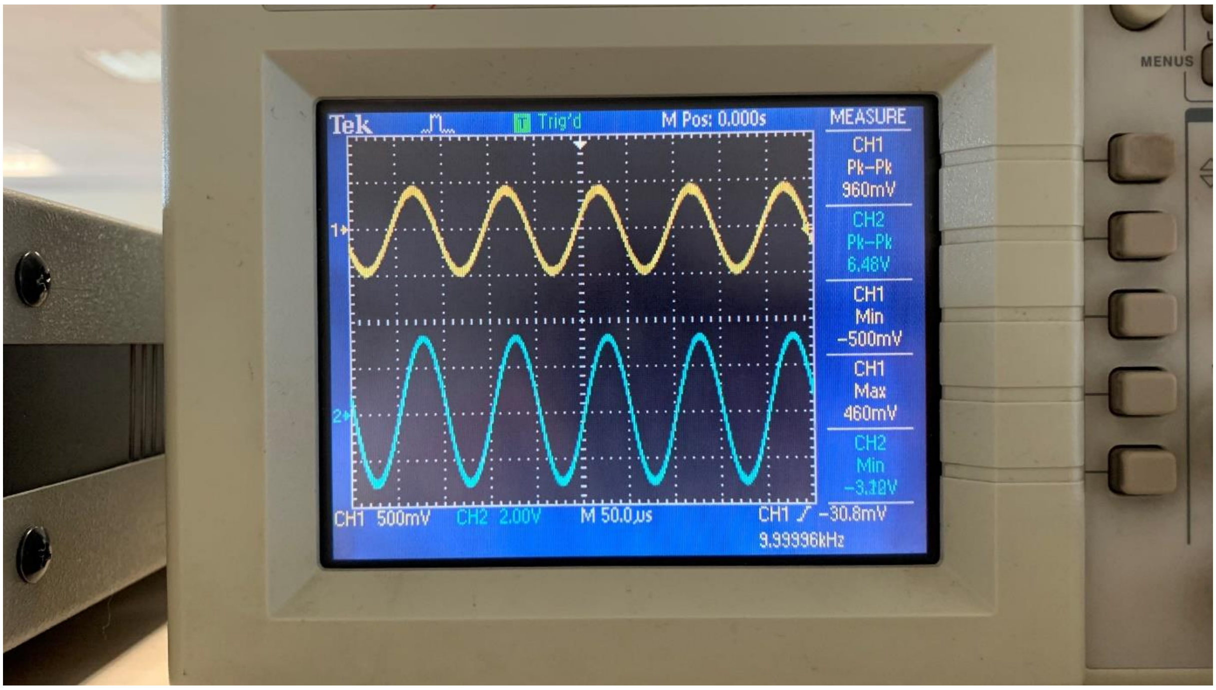


Figure 8: RL Circuit values with frequency 10kHz

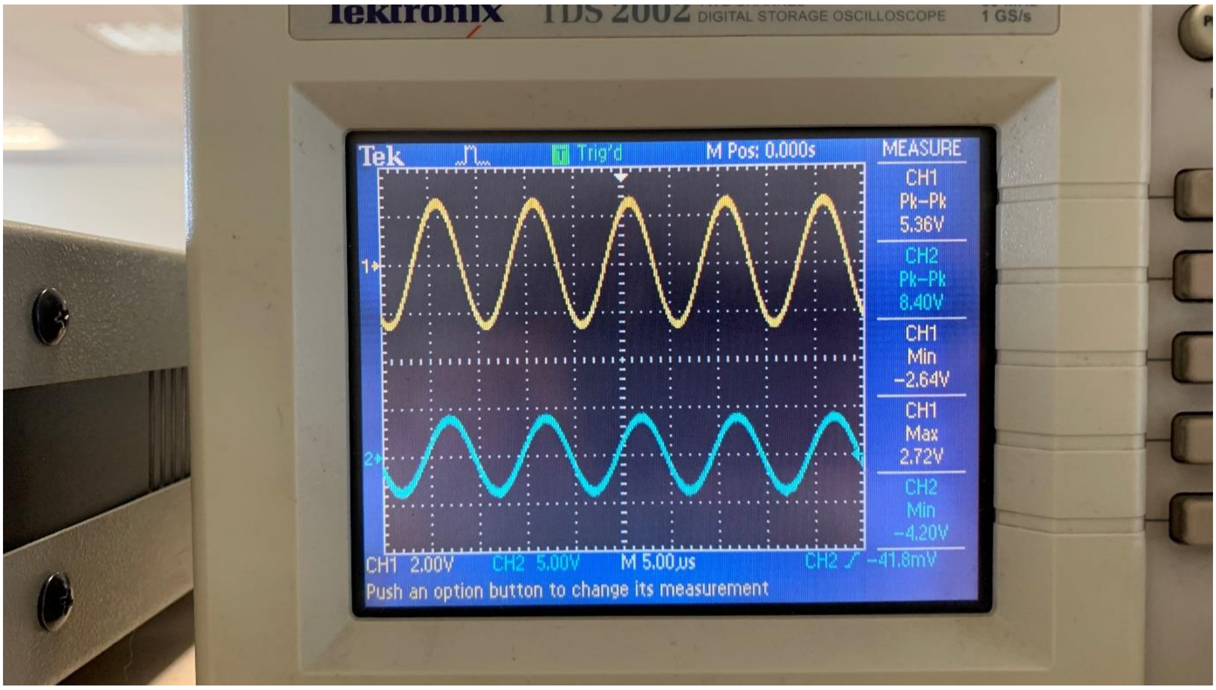


Figure 9: RL Circuit values with frequency 100 kHz

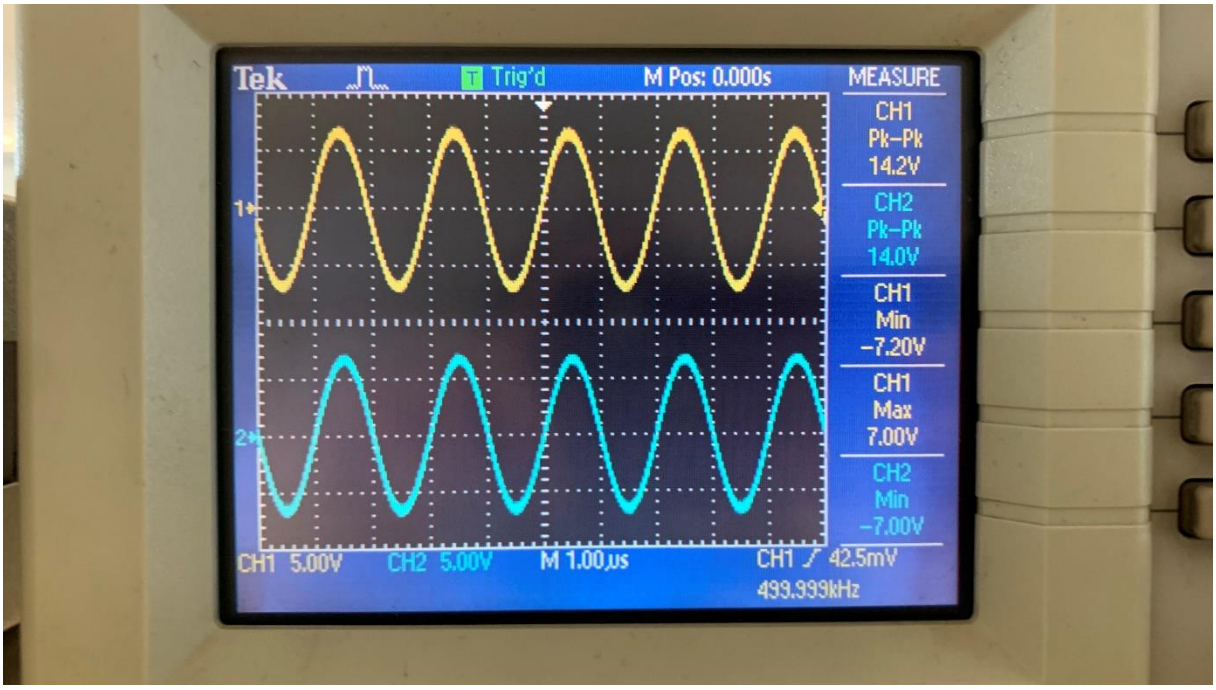
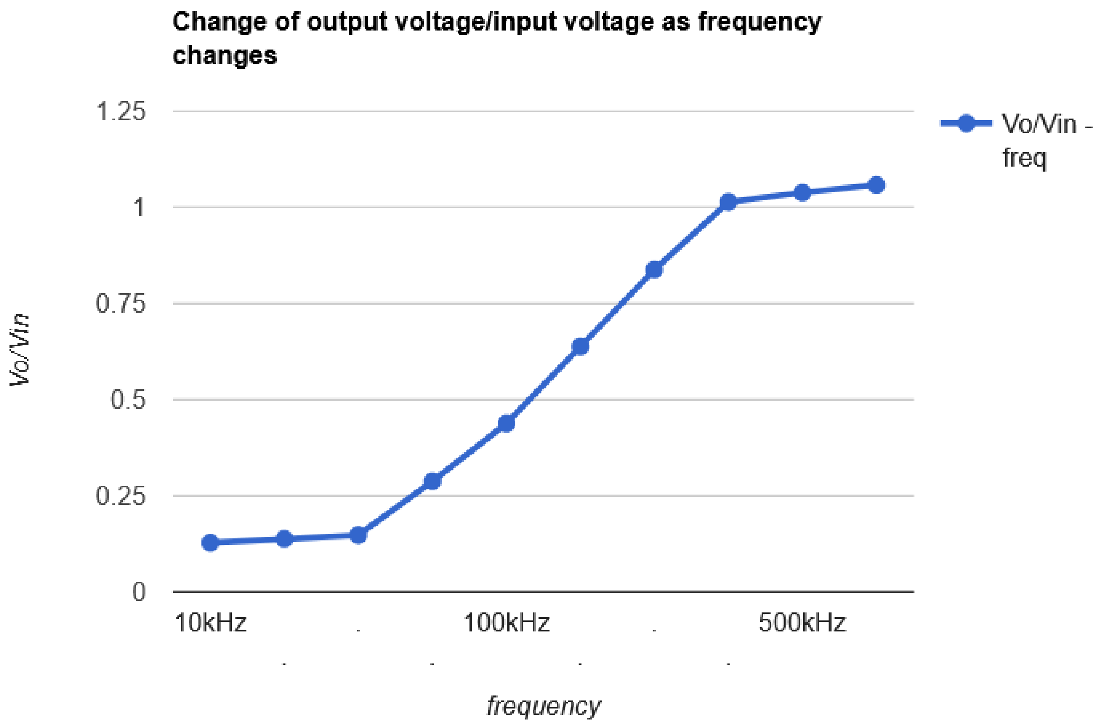


Figure 10: RL Circuit values with frequency 500 kHz

	10 kHz	100 kHz	500 kHz
Vo	0.96 V	5.36 V	14.2 V
Vin	6.48 V	8.40 V	14 V
Vo / Vin	0.148	0.638	1.014

Table 1: Change of input and output voltages as frequency changes



Graph 1: Change of output voltage/input voltage as frequency changes

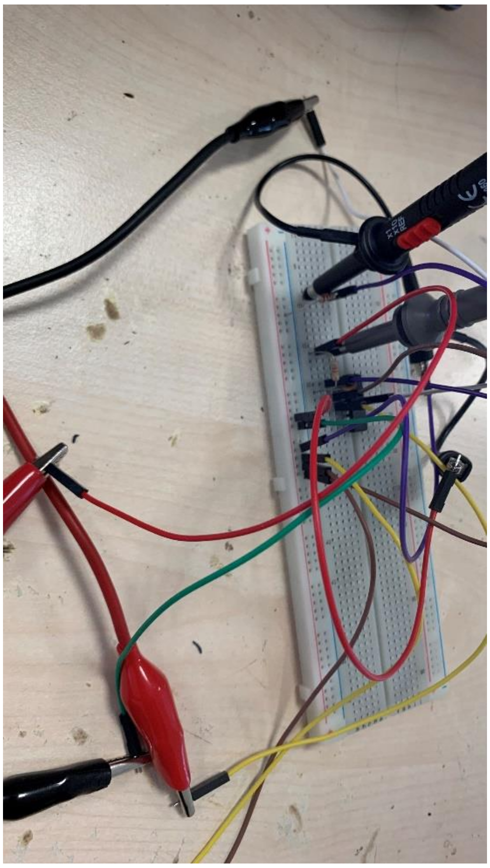


Figure 11: General Design of the OPAMP Circuits

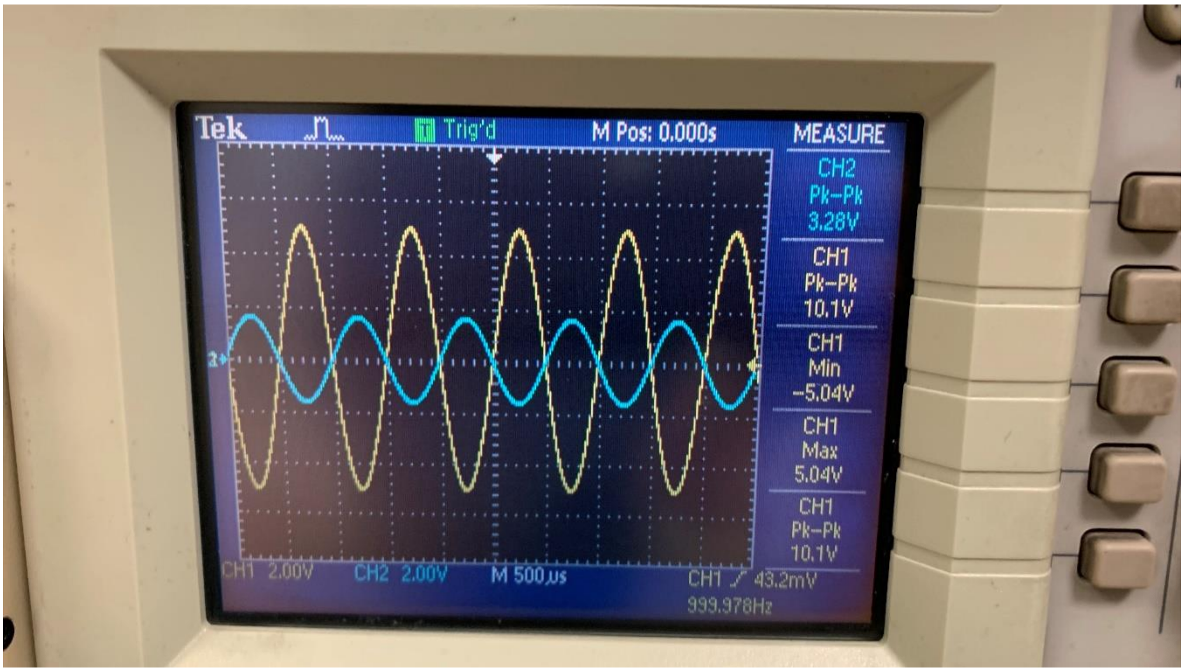


Figure 12: Inverting Amplifier OPAMP Circuit

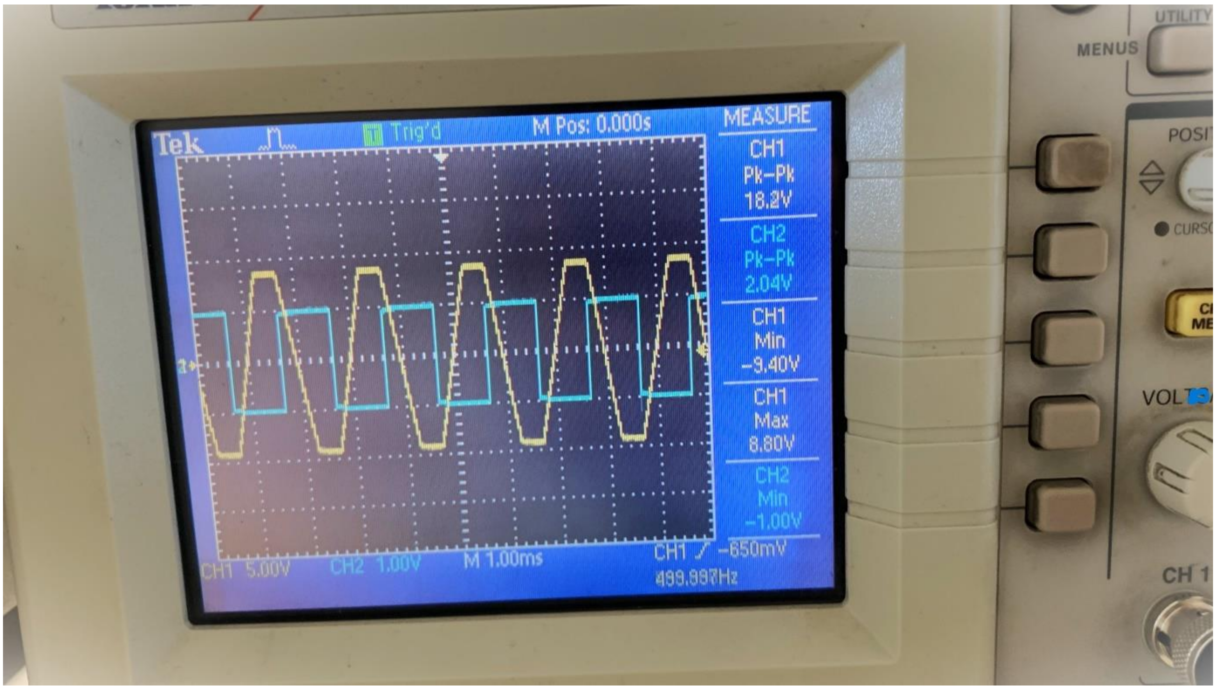


Figure 13: Integrator OPAMP Circuit

Conclusion

The first lab's hardware implementations gave results that carry similar characteristics with the simulated circuits. Each graph of the same circuit looks almost identical at first for its software and hardware implementation, reflecting the similar nature of the hardware implementation's equipment and design. However after further inspection, one may notice the differences between voltage values and phase differences. Examples for such differences may be differences in the inverting ratio of the first OPAMP circuit, or the found voltages of the RL circuits at desired frequencies. Such minor differences such as differences in voltage measurements or phase differences could be due to many reasons, such as component tolerances, internal resistances, improper grounding, internal problems within lab equipment or human measurement errors. Such real-world factors could be dealt with by thorough testing of lab equipment and components, correct implementations in order to for the results to further align with simulation results.