EEE-202 Circuit Theory | Lab 1 Report

Introduction:

In this lab, our objective was to get used to the LTSpice program and its interface as well as analysing circuits both digital and physical. The lab assignment consisted of two segments. These segments one software based and one hardware based each assisted us when demonstrating both the mathematical ideal properties and the real life results of the circuits respectively.

Software:

- Circuit 1:

The first circuit (Circuit 1(A)) consisted of a voltage source, a resistor that I arbitrary chose to be 7.5Ω and a 15Ω that was later changed to a 10μH inductor (Circuit 1(B)).

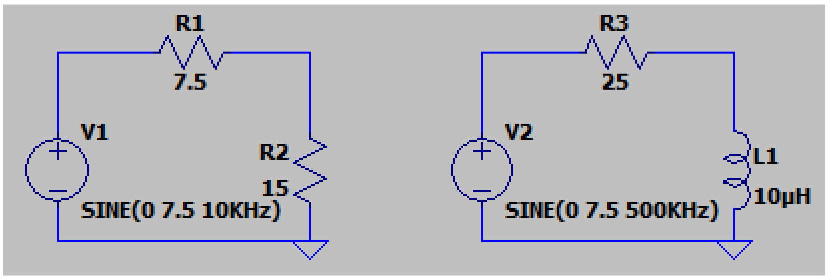

Figure 1.1.1: LTSpice schematic of Circuit 1(A&B)

The first circuit acts as a voltage divider. When measuring the voltage of the node between R1 and R2 the voltage will be given by the equation:

$$\mathrm{V1}\,\frac{\mathrm{R2}}{\mathrm{R1}+\mathrm{R2}} = \mathrm{Vout}$$

The output voltage then can be calculated to be 5V with no phase difference which can be seen in the following plot.

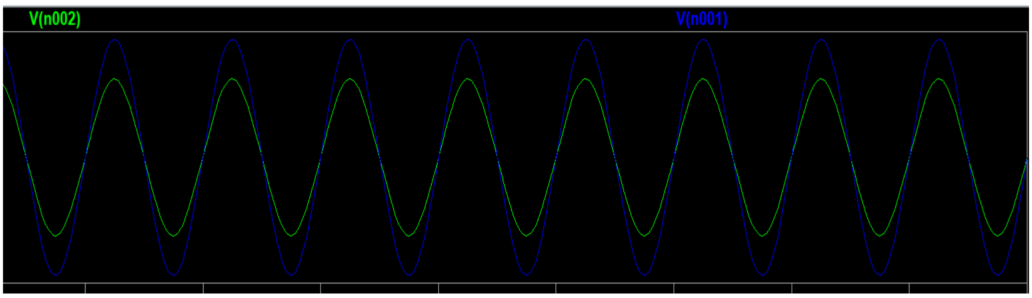

Figure 1.1.2: Plot of voltages of Circuit 1(A)

Unlike the resistor, inductors are frequency dependent circuit elements. Therefore, the properties of the circuit will chage depending on the frequency of the source. The circuit will still act as a circuit divider following the equation:

$$\mathrm{V1}\,\frac{X}{\mathrm{R1}+X}=\mathrm{Vout} \qquad X=j\omega L$$

Since X is complex there will be a phase difference between the output and the input. However, the relation between their peak-to-peak voltages will still follow the given equation. Two plots of the circuit are given below with different frequencies:

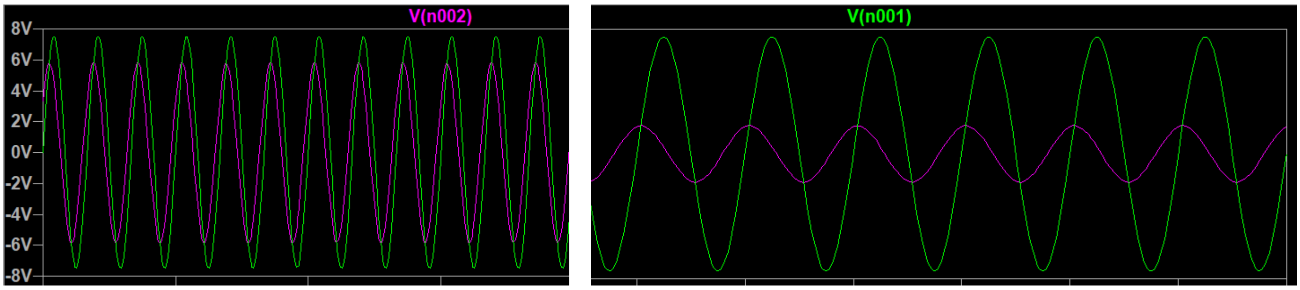

Figure 1.1.3: Plots of the voltages in Circuit 1(B) in 500KHz and 100KHz

We can observe the voltage of L1 is lower when the frequency is lower and this supports the theoretical knowledge provided by the equations above. The frequency dependency of inductor circuits will be provided in more detail in Circuit 2.

- Circuit 2:

In Circuit 2, an additional resistor is introduced to Circuit 1(B) to simulate the signal generator's internal serial resistance that is present in non-ideal real life circuits.

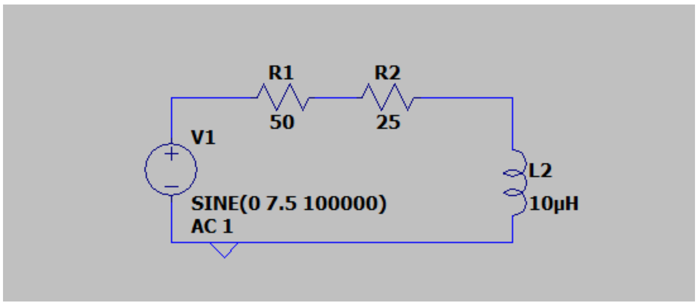

Figure 1.2.1: Schematic of Circuit 2

As previously discussed in Circuit 1(B) this circuit will act as a frequency dependent voltage divider. The equivalent serial resistances of R1 and R2 will be put into the formula as R1. The frequency dependency of the circuit can be plotted as a logarithmic plot in frequency domain. The following graph Figure 1.2.2 shows the transfer function of the circuit.

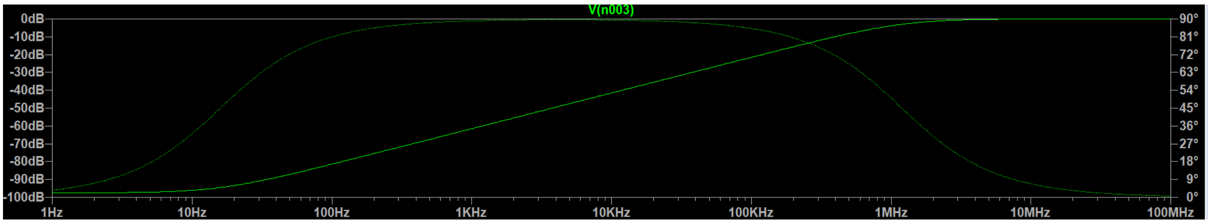

Figure 1.2.2: Transfer function of Circuit 2.

The transfer function shows a high-pass filter since in high frequencies the gain is 0dB meaning input voltage is equal to the output voltage. However, in low frequencies the circuit abates the signal. A comment on this behaviour can be made using our basic knowledge about the inductors. At low frequencies the inductor behaves as a short-circuit making the output voltage zero. However, at high frequencies the inductor acts as a open circuit. Since no current flows through an open circuit, the node voltage of the output is directly the same as the input voltage since there is no voltage drop through the resistor. A final note on this circuit can be made about the corner frequency of the system. The corner frequency can be seen from the plot to be around 1-2MHz and the calculated value is 4/3 MHz.

- Circuit 3:

For the third circuit, we have an inverting amplifier (Circuit 3(A) and a integrating amplifier (Circuit 3(B)) both utilising an operational amplifier (OPAMP).

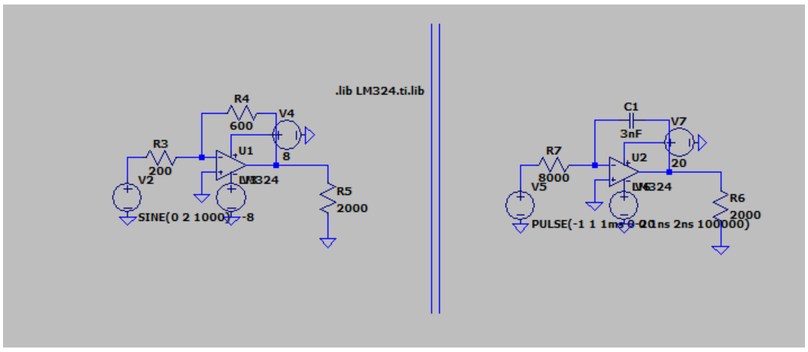

Figure 1.3.1: The schematics of Circuit 3(A&B)

Circuit 3(A) is an inverting amplifier with a gain of 3x. This ratio can be calculated using nodal analysis, the given resistances, and the fact that ideal OPAMP's take no current input from its positive and negative terminals. This calculations are made assuming the OPAMP is not saturated which happens when the output voltage is greater or less than the supply voltages. The supply voltages are arbitrarily chosen in this case to be 8(A) and 20(B) so that the OPAMP is not saturated. Example waveforms for not saturated and saturated signals in Circuit 3(A) is given in the plots below.

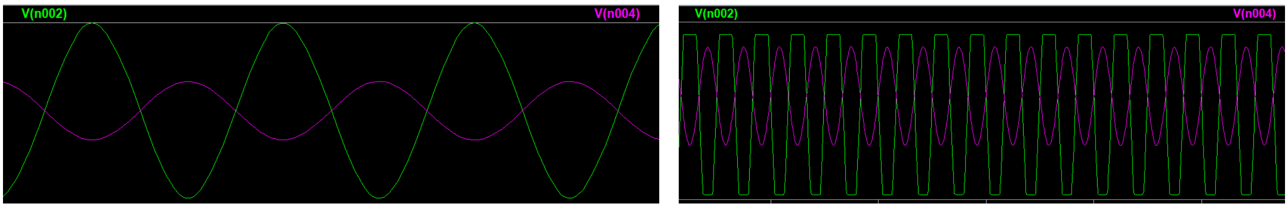

Figure 1.3.2: Plots of not-saturated and saturated waveforms in Circuit 3(A)

Saturated waveforms get “clipped” after they reach the supply voltage as can be observed from the Figure 1.3.2. However, when the wave is not clipped the gain can be observed to be 3x from the figure.

Circuit 3(B) features a capacitor which results in the amplifier acting as an integrating circuit whose output waveform can be seen below.

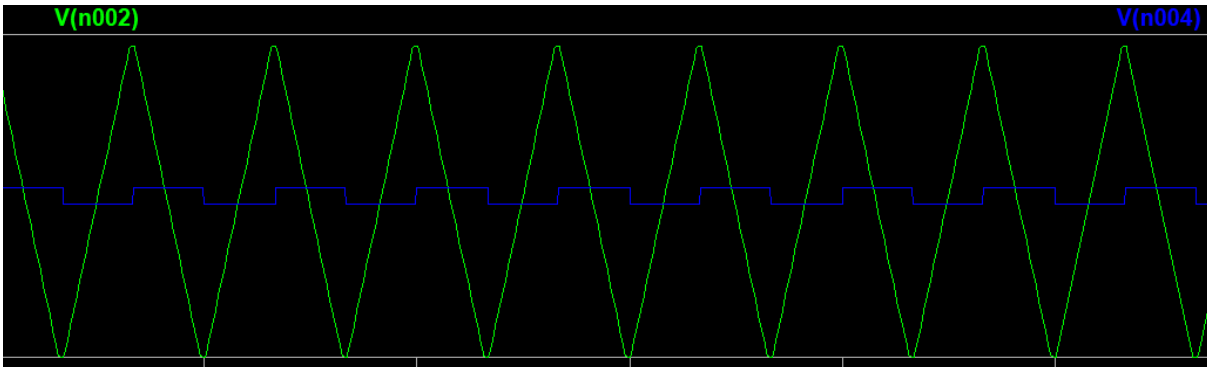

Figure 1.3.3: Output waveform of the integration amplifier in Circuit 3(B)

The integral of a constant (square wave) would provide a line with a non-zero slope which in turn produces this triangular wave since the constant is switching between -1 and 1.

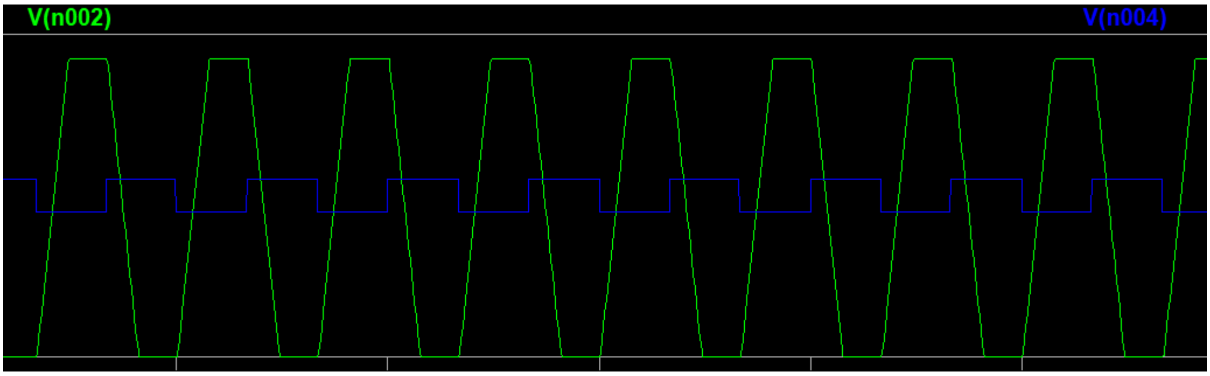

Figure 1.3.4: Clipperd output waveform of Circuit 3(B)

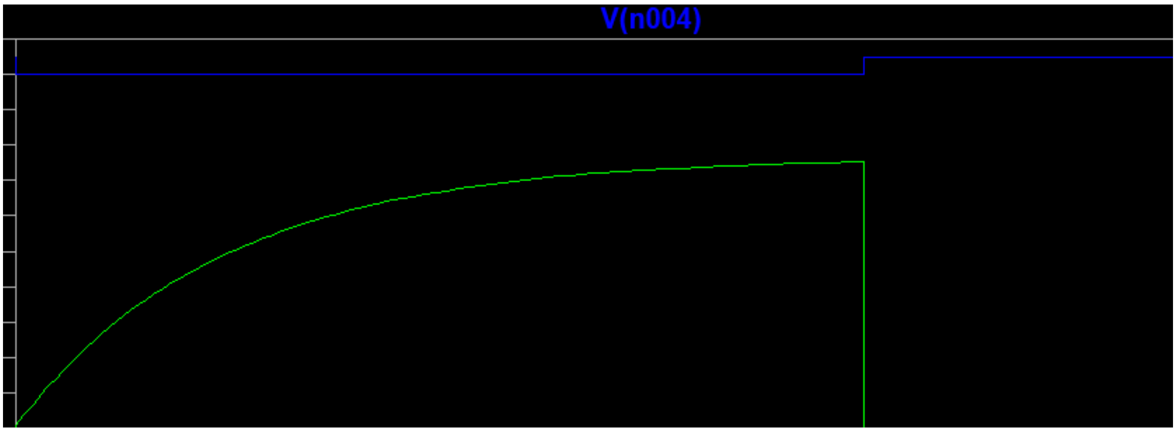

Figure 1.3.5: Output waveform of Circuit 3(B) with square wave between 0, -1

The circuit behaves as a DC - RC circuit when the input square wave is given to oscillate between 0 and -1. The output waveform resembles a charge/discharge that is repeating with each pulse.

Hardware:

- RL Circuit (Circuit 2)

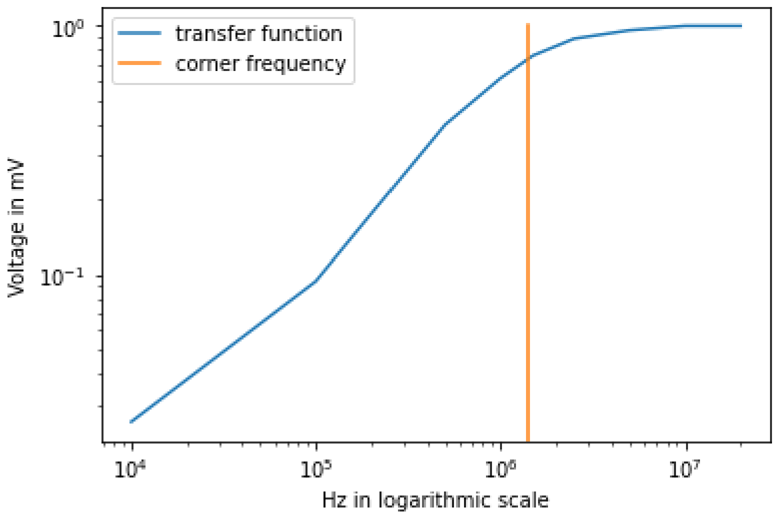

Figure 2.1.1: Experimental transfer function of Circuit 2

The transfer function of Circuit 2 is given. Which has the same approximate corner frequency as the theoretical calculations and the LTspice simulations.

Amplitude	Frequency
1V	10MHz
960mV	5MHz
888mV	2.5MHz
760mV	1.5MHz
616mV	1MHz
400mV	500KHz
94mV	100KHz
25.6mV	10KHz

Table 2.1.1: Voltage amplitudes - Source frequencies of Circuit 2

- OPAMP Circuit (Circuit 3)

Source Peak-to-Peak Voltage	Output Peak-to-Peak Voltage
2V	6V
4V	12V
5V	15V
16/3V	16V
6V	16V(saturated)
7V	16V(saturated)
8V	16V(saturated)
9V	16V(saturated)

Table 2.2.1: Peak-to-Peak voltages of input and output Circuit 3(A)

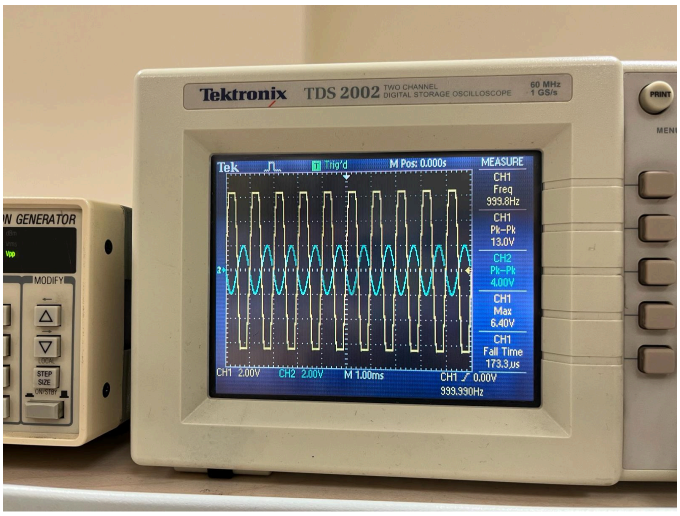

Figure 2.2.1: Output and input waveforms of Circuit 3(A)

Pulse - Peak-to-Peak	Triangular - Peak-to-Peak
0.64V	6.8V
1.2V	13.4V
2V	26V
2.24V	26V
3V	Saturated 30V
3.2V	Saturated 30V
6V	Saturated 30V

Table 2.2.2: Peak-to-Peak voltages of input and output Circuit 3(B)

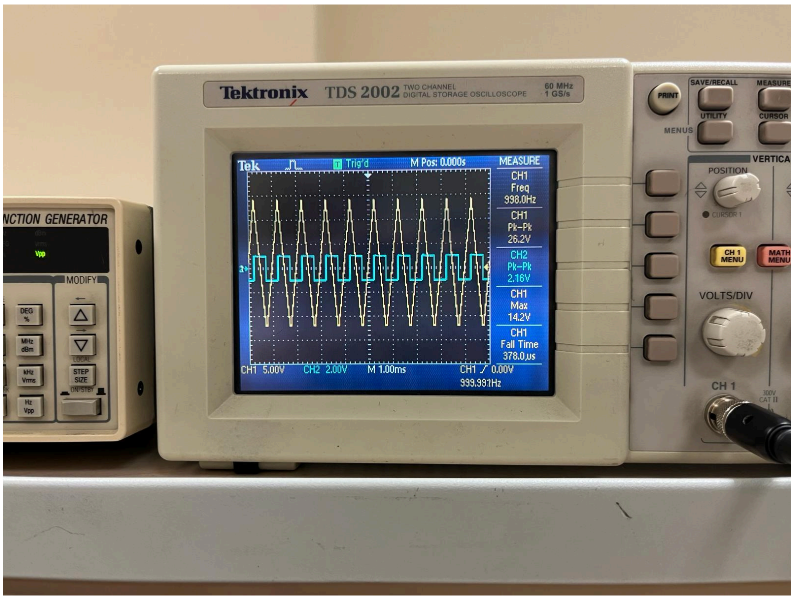

Figure 2.2.2: Output and input waveforms of Circuit 3(B)

It should be noted that the supply voltages of the OPAMP are 15, -15 on the positive and negative terminals respectively.