Fall
2019

ELEC 202 Project

FALL 2019

AHMET HAMDI ÜNAL (60167)

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Introduction:

In this project, we are to design two oscillators. These two oscillators will produce two different sound waves at different frequencies. Since the last number of my Koç University Student ID is 7 the frequency values for me is as follows:

Table 1: Frequency Values of the Dual Tone for (7)

Low Frequency (Hz)	High Frequency (Hz)
852	1209

As stated in the manual, the resulting output is called dual tone. The frequencies given above are chosen to avoid harmonics.

The main outline of the project is as follows:

1- Design two oscillators work around the given frequencies above.
2- Sum the output of these two components (summing amplifier).

It should be noted that +9V is to be supplied to op-amps since it is the value which is stated in the manual.

Theory of Oscillators:

First, design the oscillator with f=852 Hz.

$$RC = \frac{1}{2\pi f} = \frac{1}{2\pi(852)} = 1.868 \times 10^{-4}$$

So, select R and C values accordingly. Let us choose $R = 18.3\ k\Omega$. According to the formula[1] given above $C = \frac{RC}{C} = 10.2\ nF$. For this op-amp to work properly, its gain must be at least 3 according to Barkhausen [2]criterion. We work this out by changing R_f and R_g values. Let us choose $R_g = 2\ k\Omega$, $R_f = 4\ k\Omega$ since

$$\frac{V_o}{V_i} = 1 + \frac{R_f}{R_g} \geq 3$$

Same procedure is to be applied for the second oscillator. Now, f=1209 Hz.

$$RC = \frac{1}{2\pi f} = \frac{1}{2\pi(1209)} = 1.316 \times 10^{-4}$$

Let $R = 18.3\ k\Omega \rightarrow C = \frac{RC}{C} = 10.2\ nF$.

$R_g = 2\ k\Omega$, $R_f = 4\ k\Omega$

In the end, we implement a summing amplifier to sum these two frequencies. Recall the input output relation of the summing amplifier:

$$V_o = -R_{ff}\left(\frac{V_1}{R_{i1}} + \frac{V_2}{R_{i2}}\right)$$

Thus, $R_{ff} = R_{i1} = R_{i2}$ chosen as $1\ k\Omega$. Therefore, $V_o = -(V_1 + V_2)$.

[1] See Section 10.9.2 at *Fundamentals of Electric Circuits*, 5th Ed., by Alexander, C. K.; Sadiku, M. N. O. for derivations.

[2] Op. cit.

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PSpice Designs:

Table 2: PSpice Circuit Layout of 852 Hz Oscillator

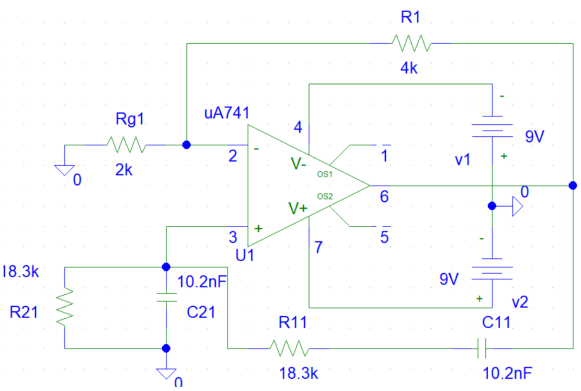

Table 3: Output Voltage for 852 Hz

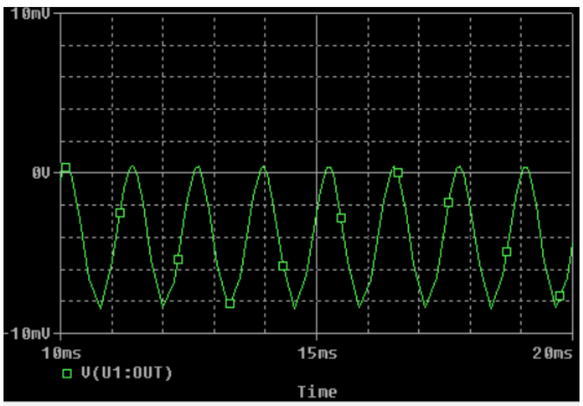

Table 4: FFT of 852 Hz

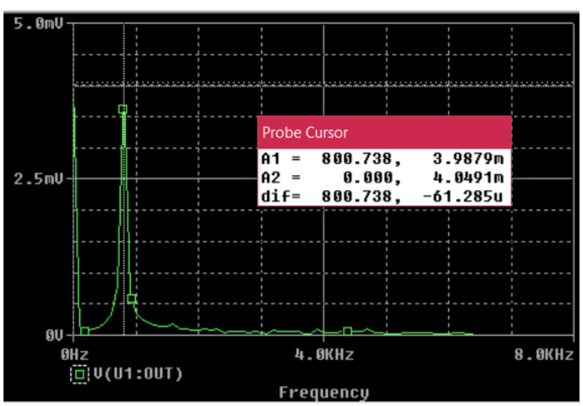

Table 5: PSpice Circuit Layout of 1209 Hz Oscillator

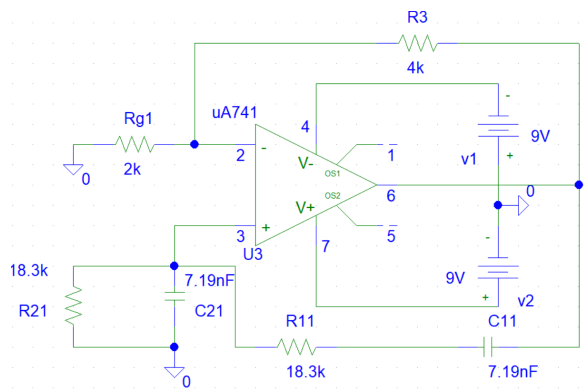

Table 6: Output Voltage for 1209 Hz

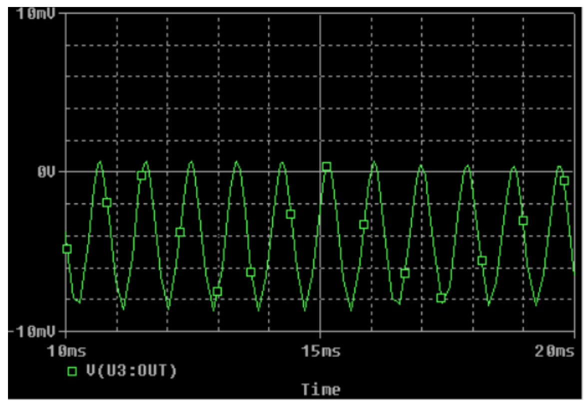

Table 7: FFT of 1209 Hz

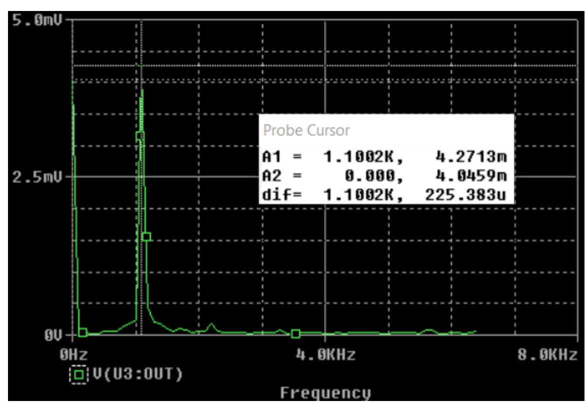

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Table 8: Overall Circuit Layout with Summing Amplifier

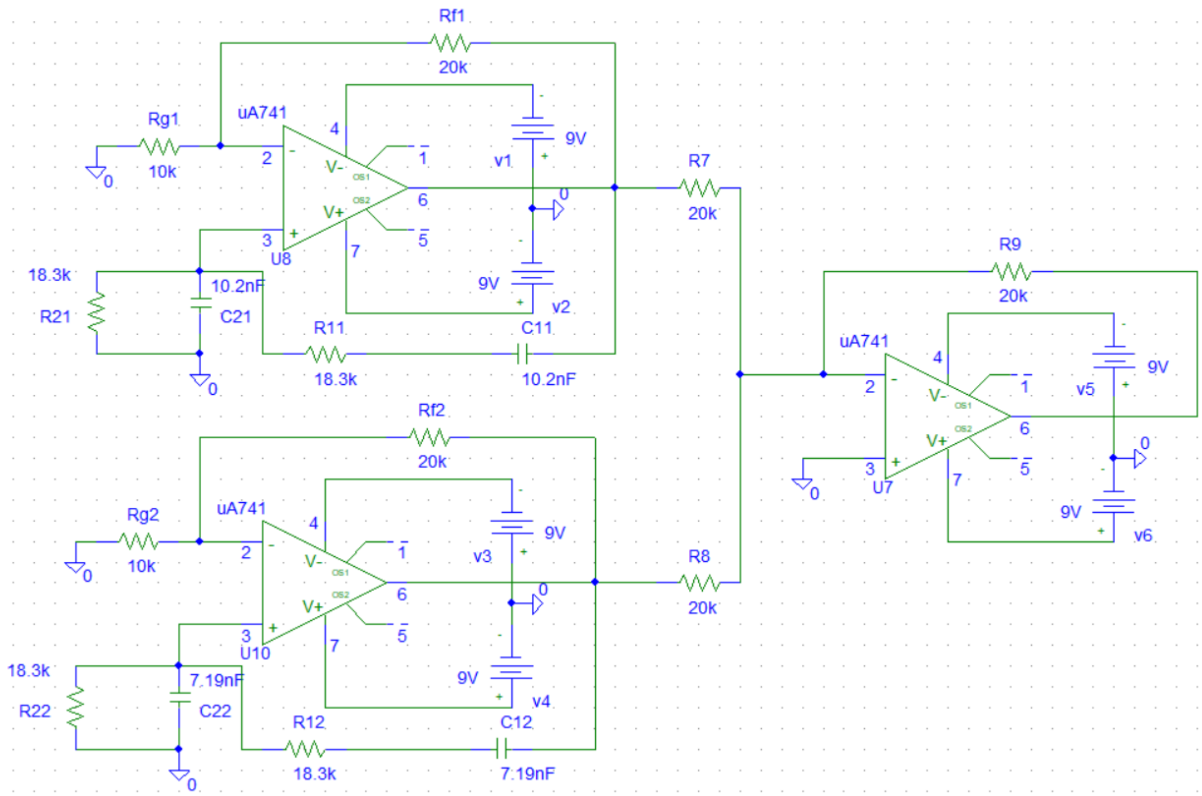

Table 9: Output Voltage of Summing Amplifier

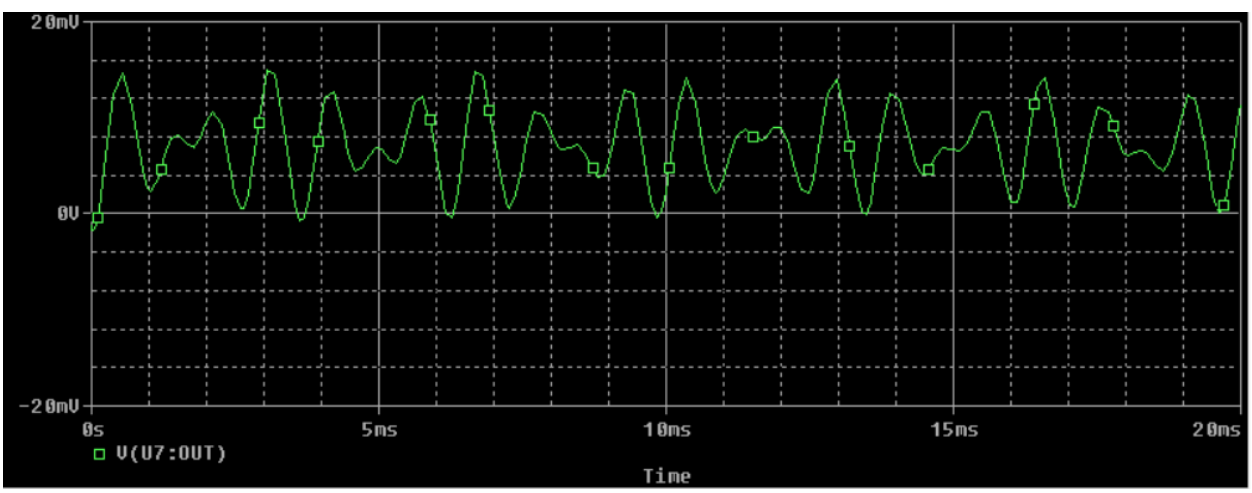

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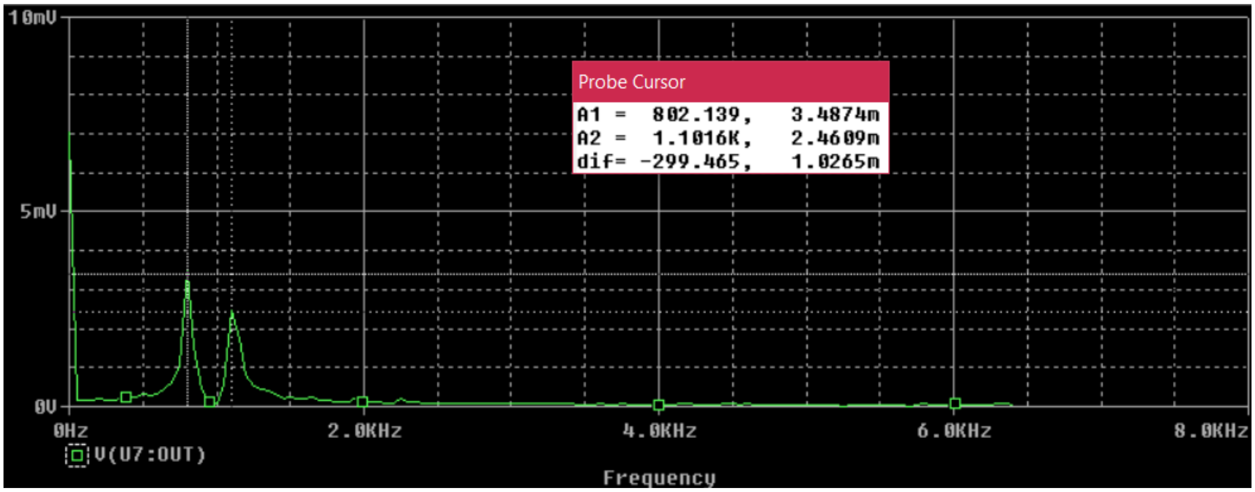
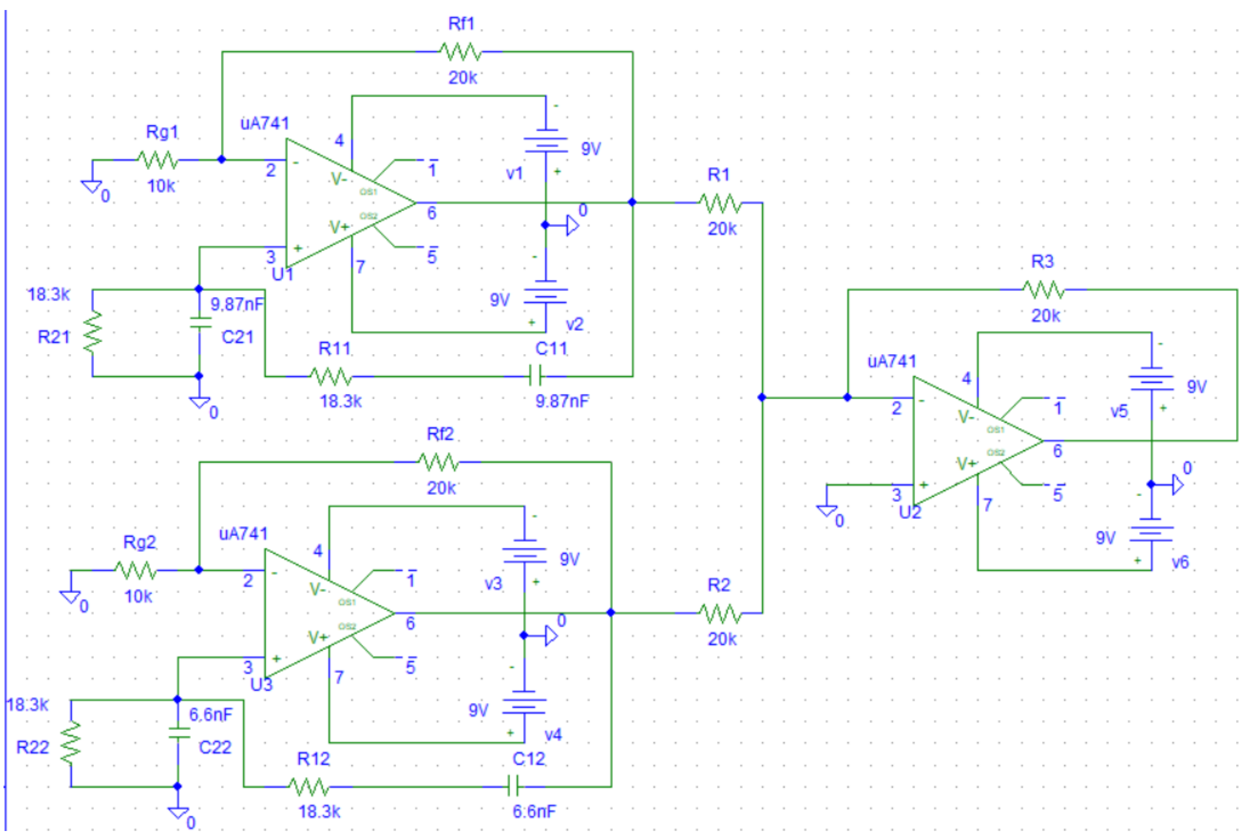
Table 10: FFT of Summing Amplifier Output



As observed, error is above 1.5%. This is because the op amp is not an ideal one, therefore, oscillator frequency values are different than what we expect. To solve this issue, we can slightly change capacitance or resistance values that will match the frequency we want to achieve by trial and error. Second approach is to use another software (LTspice) that has ideal op amp implemented inside and see that error is below 1.5%. Both approaches will be provided in the upcoming sections.

1. Change Capacitance Values to Get the Wanted Frequency Output

Table 11: Overall Circuit with Slightly Changed Capacitance Values



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For 852 Hz oscillator C is changed to 9.87nF and for 1209 Hz oscillator C is changed to 6.6nF. For these new slightly manipulated capacitance values, we get the following outputs from the summing op amp:

Table 12: Voltage Output of the Summing Amplifier for new C Values

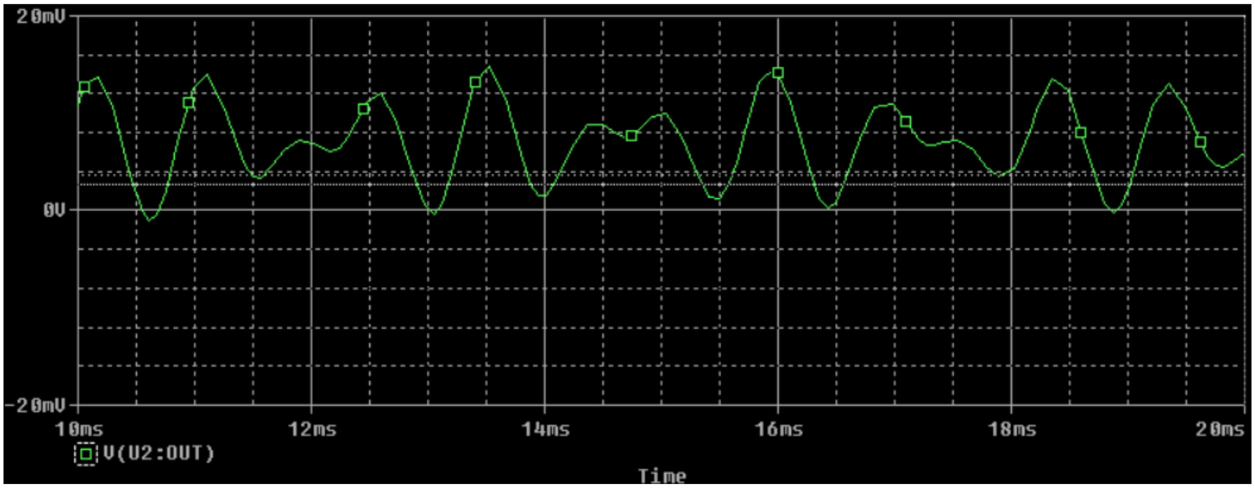
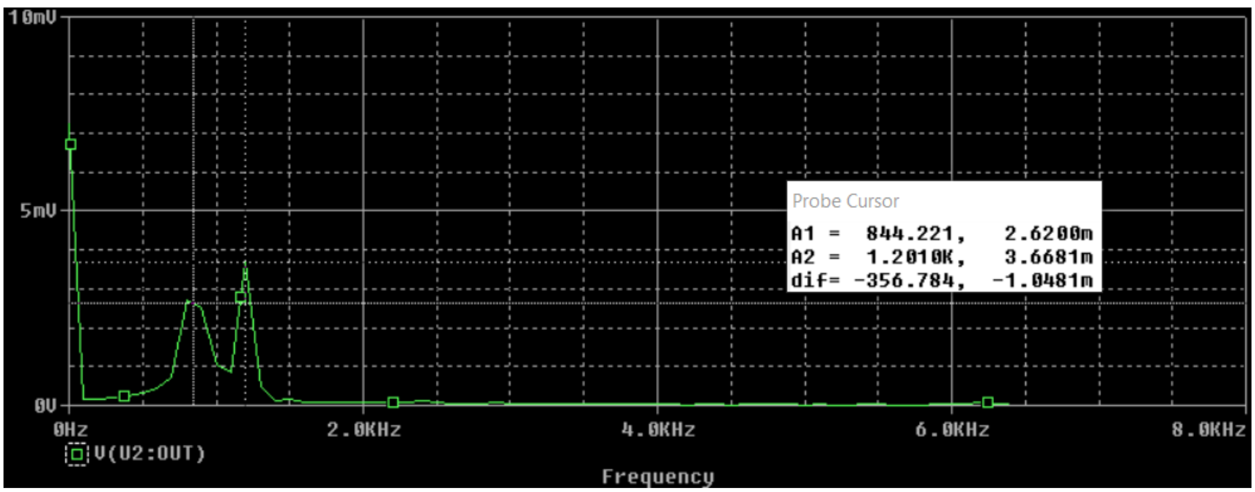


Table 13: FFT of the Summing Amplifier for new C Values



Observe that the second peak is at 1201 Hz; therefore, error is $\frac{|1209-1201|}{1209} \times 100 \rightarrow 0.66\%$. For the first peak, since PSpice does calculations for considerably large intervals, we do not observe the end point of the peak. Therefore, it is deduced that the peak is between the end points of the flat surface observed. I have read this value as 844 Hz. The error is $\frac{|852-844|}{852} \times 100 \rightarrow 0.94\%$. So, by changing the theoretical values slightly, we get the results that we are asked to find. Now, consider the second approach where we use an ideal op amp by using LTspice.

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2. LTspice Circuit Design and Simulation Outputs and FFT:

Table 14: LTspice Dual Tone Circuit

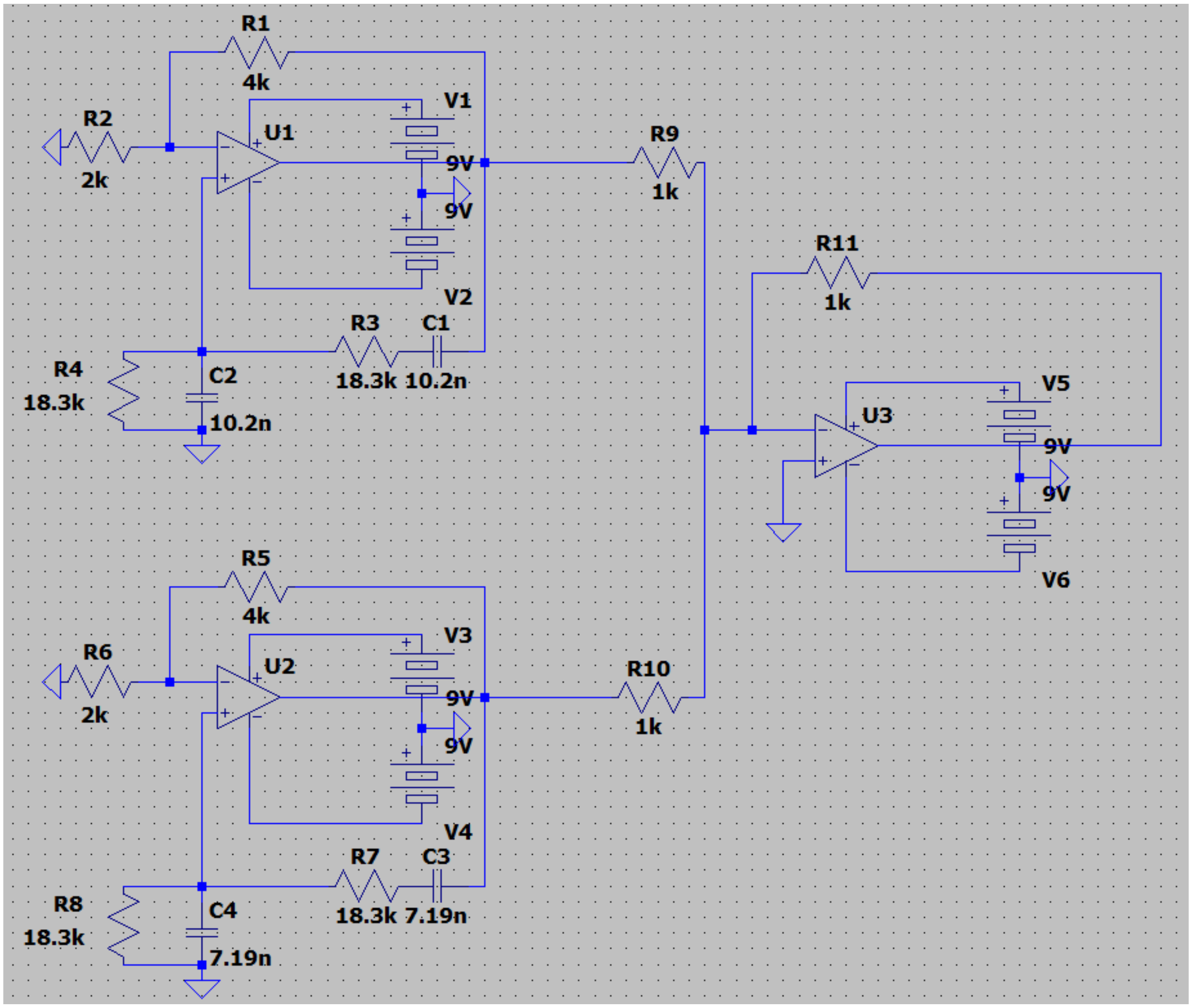

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Table 15: LTSpice 852 Hz OScillator Voltage Output

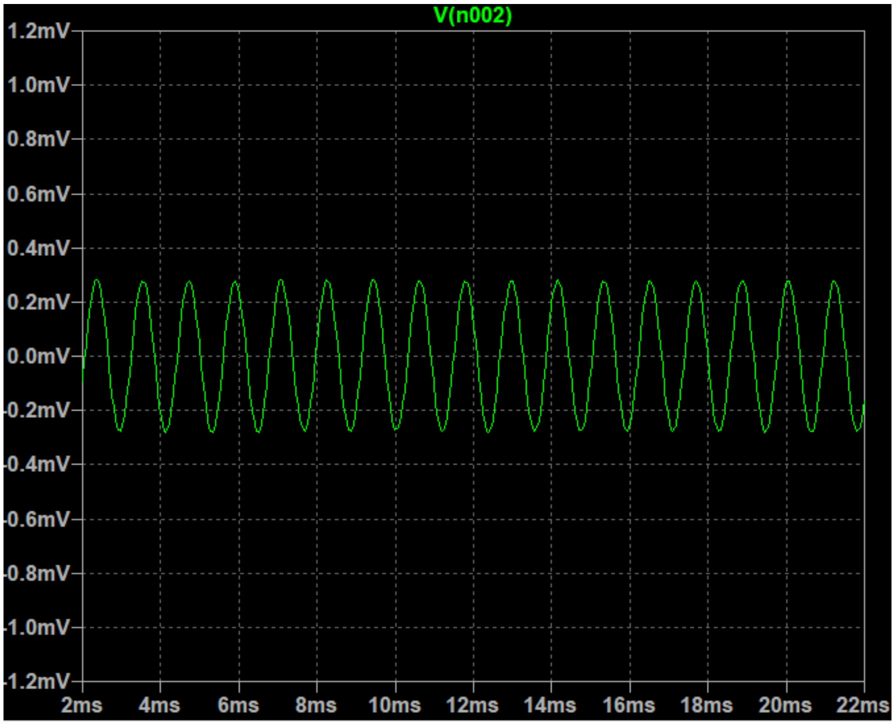


Table 16: LTSpice 1209 Hz OScillator Voltage Output

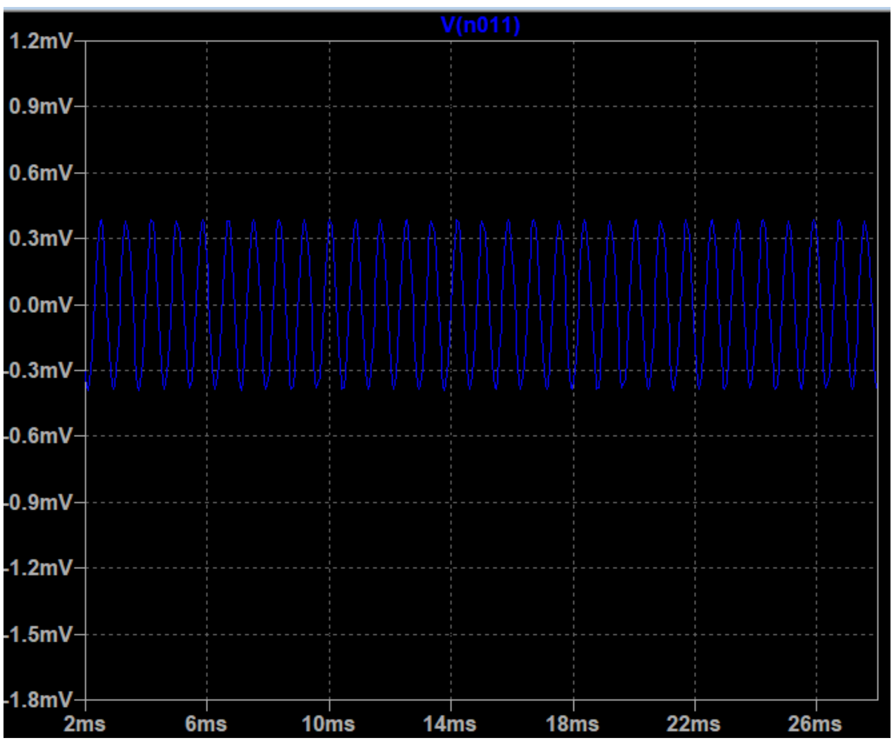


Table 17: LTSpice Summing Amplifier Voltage Output

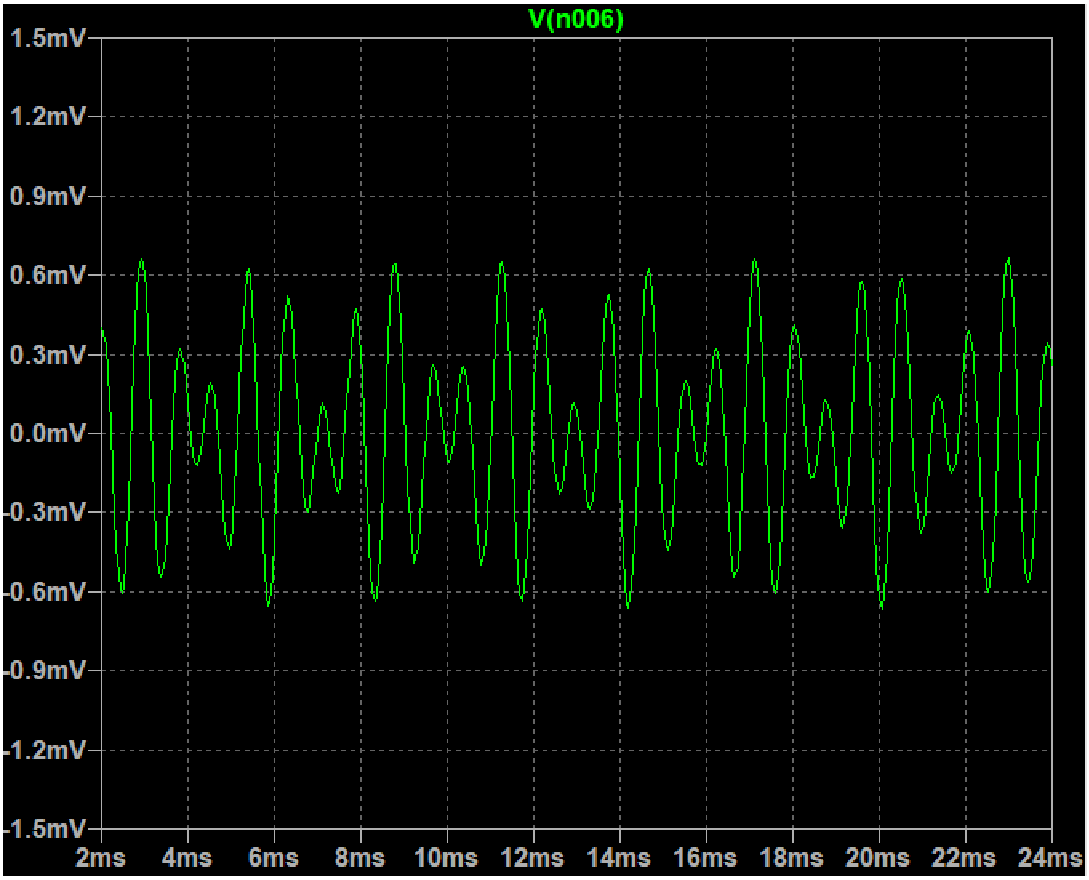


Table 18: LTSpice Summing Amplifier Voltage Output FFT

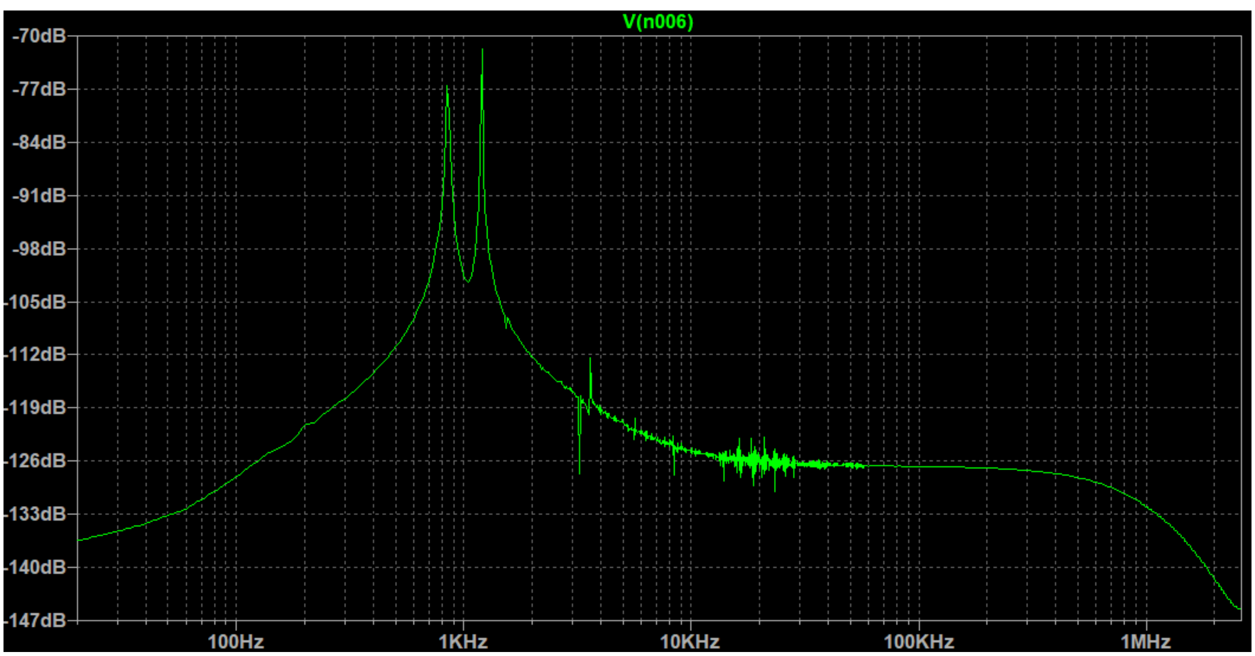
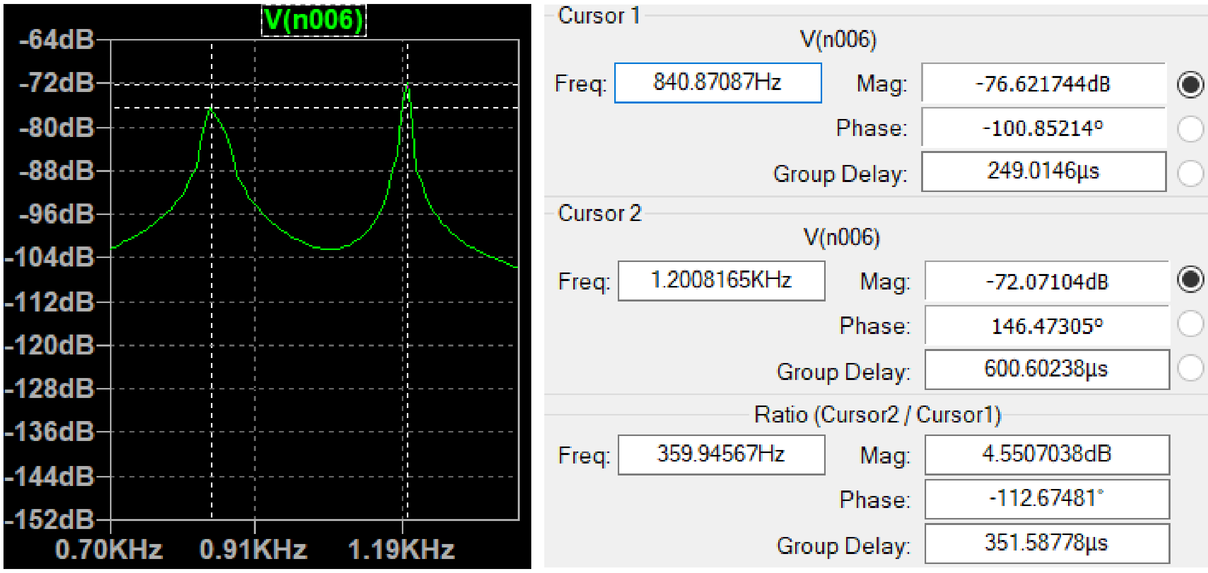


Table 19: LTSpice Summing Amplifier Voltage Output FFT (zoomed in to peaks)



Here, errors are $\frac{|852-840|}{852} \times 100 \rightarrow$ 1.41% and $\frac{|1209-1200.8|}{1209} \times 100 \rightarrow$ 0.68%, so they are very small and in the range ±1.5%. They confirm with the theoretical values. This confirms the assumption that non-idealness of the op amp is the cause of the error for the PSpice circuit design.

Conclusion

It is possible to generate AC circuits by using DC components. Throughout the simulations and designs and having used three different programs (TI TINA, LTspice, PSpice), I have very well understood the importance of how ideal the op amp is. The PSpice results are probably more realistic, whereas LTspice results agrees with theoretical values up to a higher rate. Overall, both results were educational in different ways.