ELEC 353 – Project 3

Section 003

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The Colpitts Oscillator in Figure 1 was designed in LTspice to produce oscillation as shown in Figure 2. After the initial start-up, the oscillation is steady at approximately 70.5 kHz when provided with a DC bias.

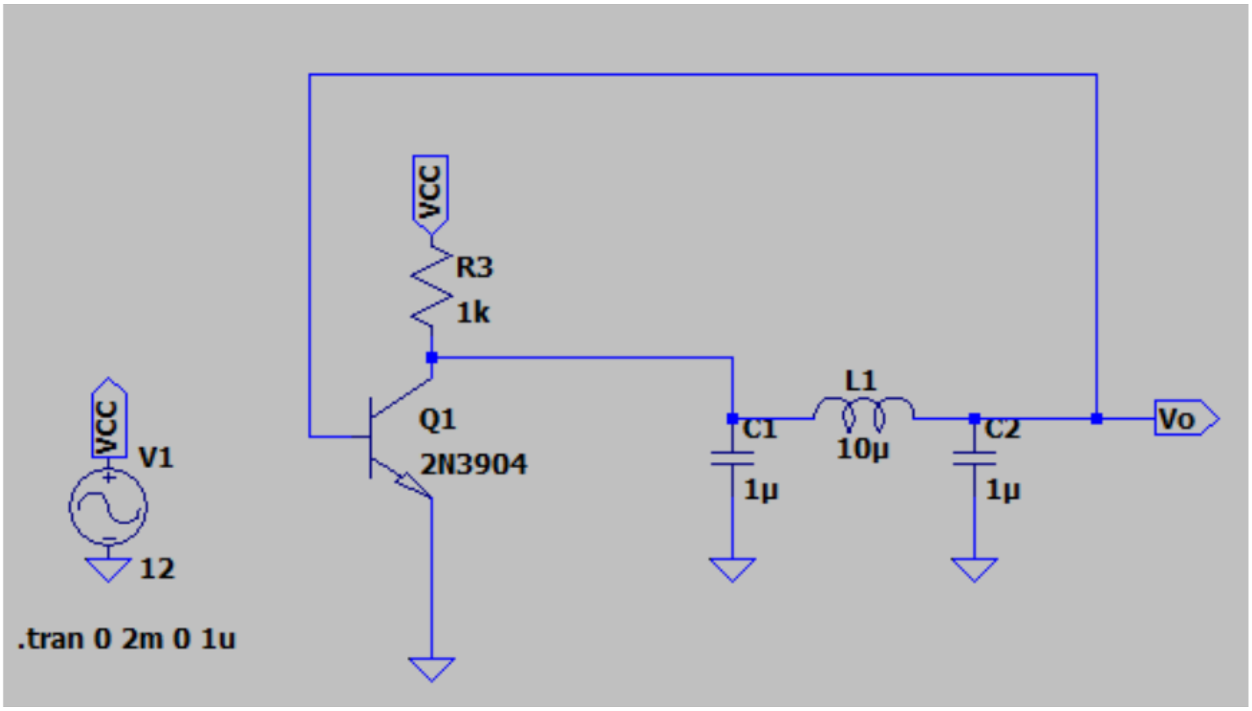

Figure 1: LTspice schematic of Colpitts Oscillator

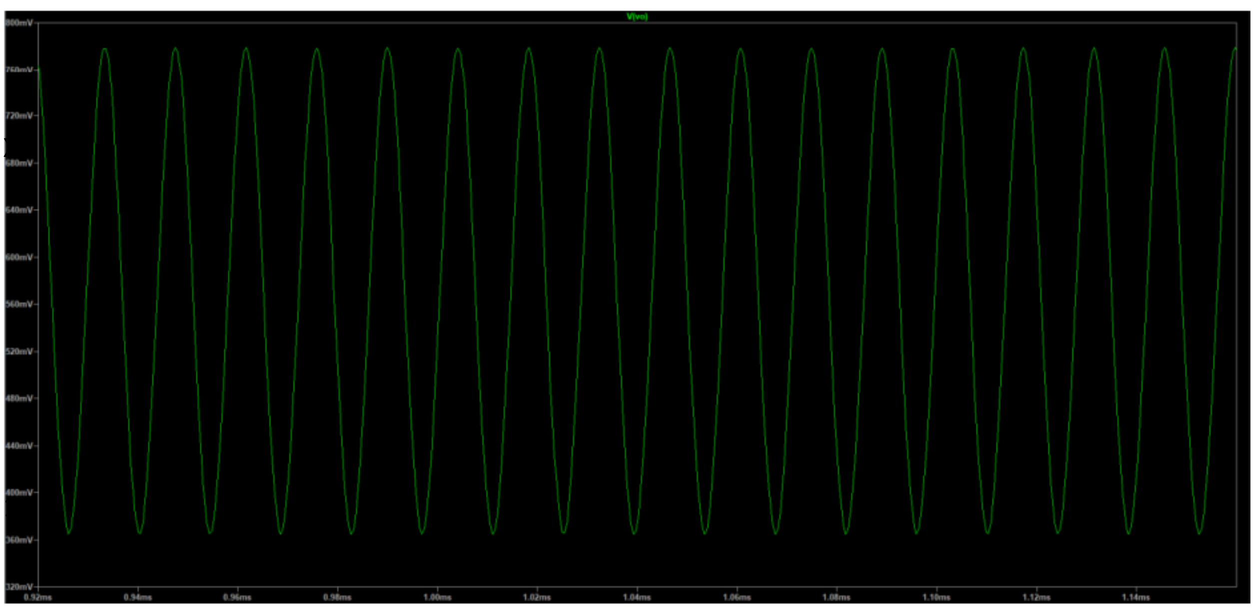

Figure 2: Output voltage oscillation based on DC bias

Applying a Fourier Transform, the frequency domain output was plotted in figure 3. The peaks in frequency indicate that there are gain producing poles at about 70.8 kHz (dominant), 141 kHz, 211.7 kHz, and 282 kHz.

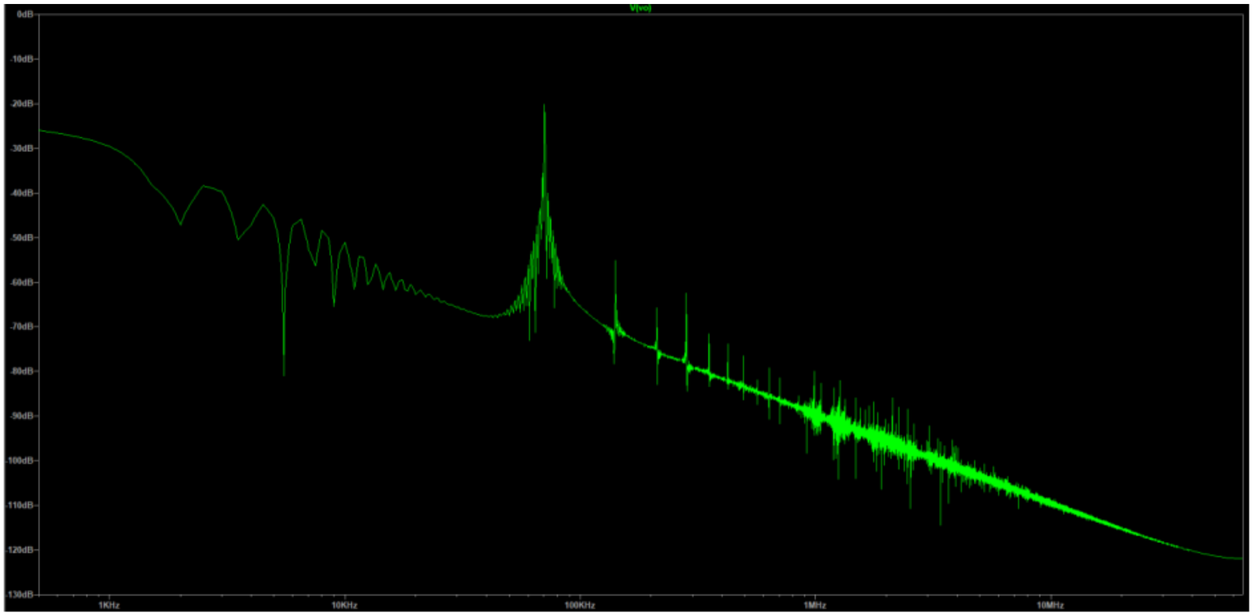

Figure 3: Frequency domain output od Colpitts Oscillator based on Fourier Transform

A bode plot was created by adding a 1V AC sweep to the DC bias. Shown in figure 4, also indicating a dominant pole near 70.8 kHz.

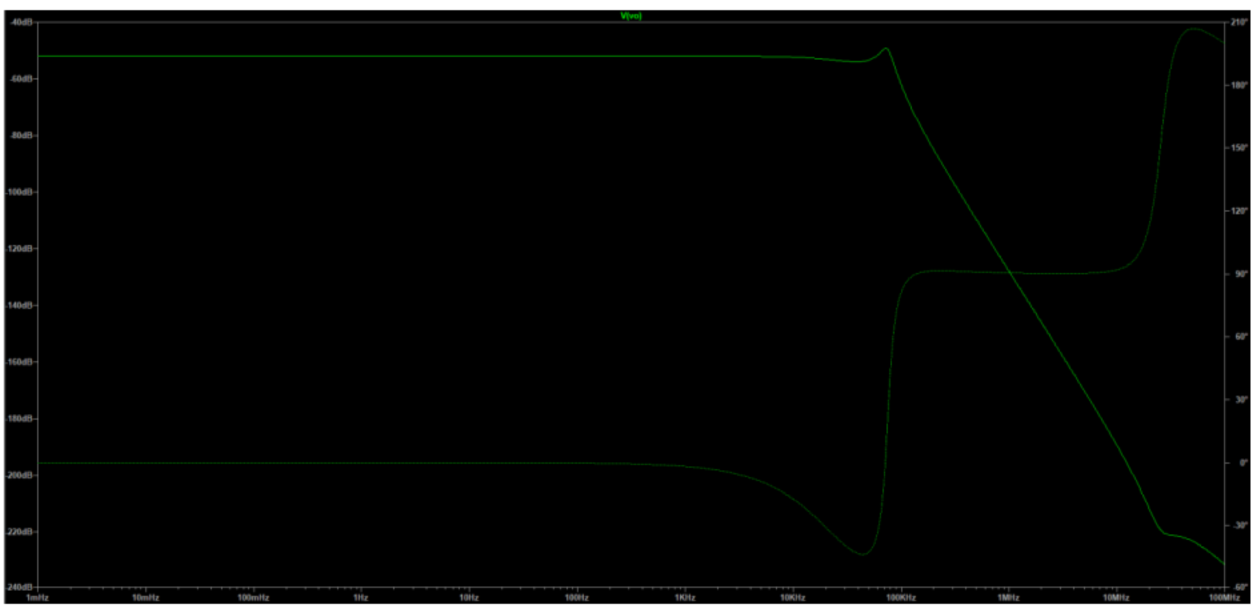

Figure 4: Bode plot of oscillator based on AC sweep

In order to buffer the output, open loop unity gain a 741 Op Amp was incorporated in design (see figure 5).

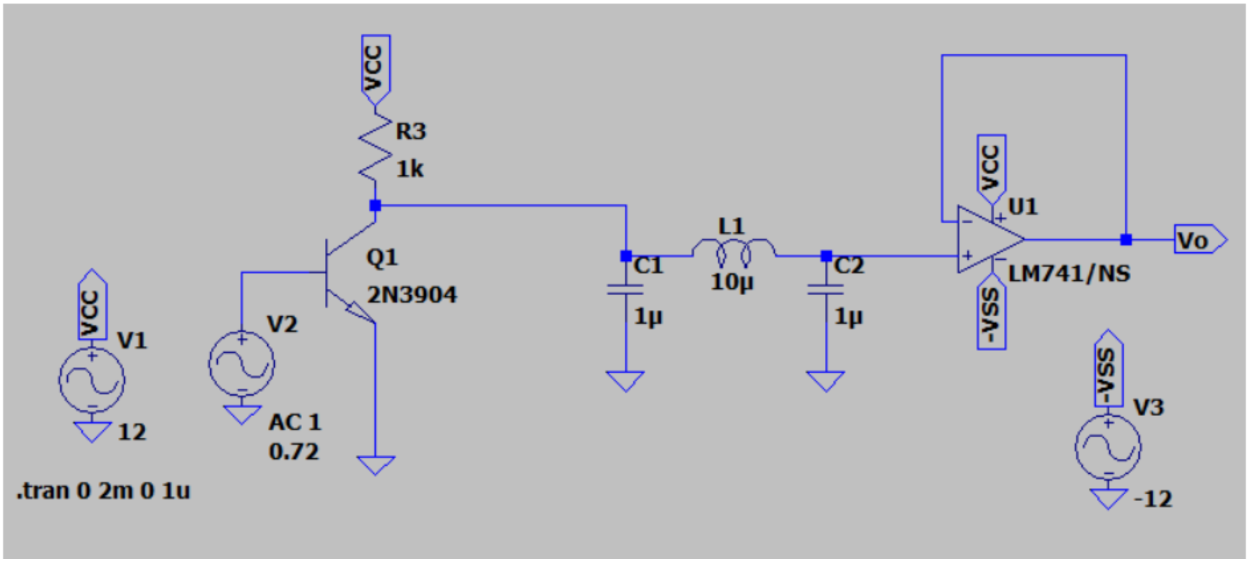

Figure 5: LTspice schematic od oscillator with 741 Op Amp buffer output

Using a sinusoidal DC signal into the gate of the NPN transistor with a DC offset of 0.72 V, an amplitude of 1 V and a frequency of 70 kHz, this generates the transient response at output shown in Figure 6. DC offset was determined based off the starting closed loop transient voltage response. Transient response was found to oscillate around 1.6 kHz.

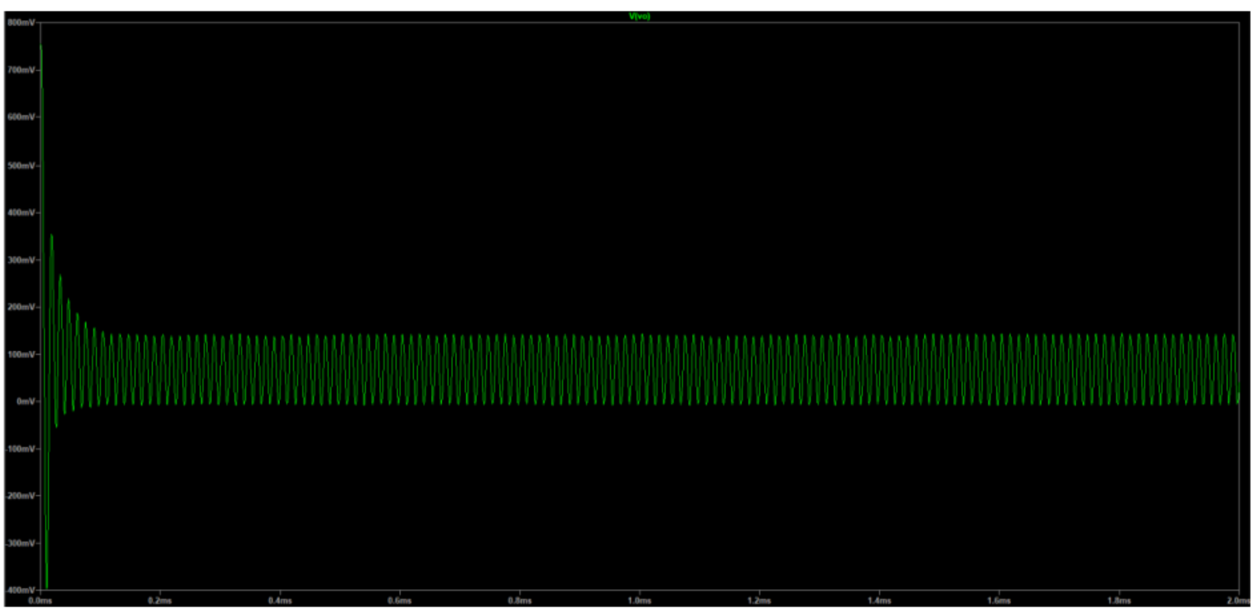

Figure 6: Transient Response of oscillator with 741 Op Amp buffer.

After applying an AC sweep to the circuit, the phase and magnitude of buffered oscillator is shown in figure 7. Bode plot displays a pole (dominant) around 70 kHz.

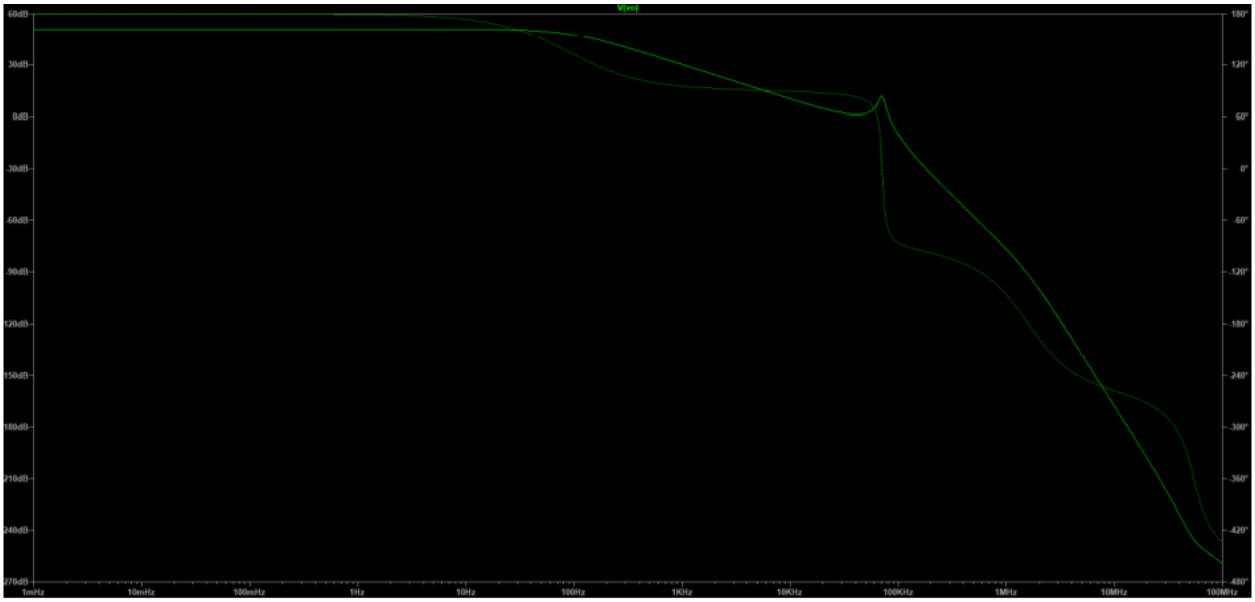

Figure 7: Frequency response of transient response of 741 Op Amp buffered oscillator

Once bode plot is obtained applying a Fourier Transform to the plot displays a dominate pole around 70 kHz and another one around 139.5 kHz. (See figure 8)

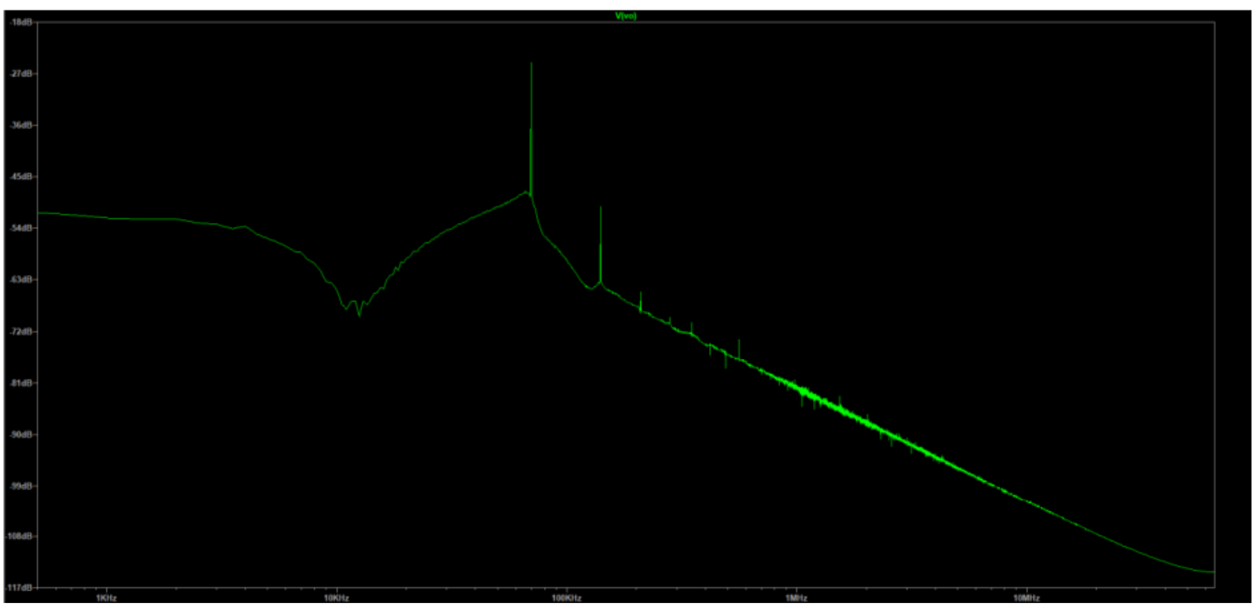

Figure 8: Bode plot of buffered oscillator

Impedance was calculated by measuring the voltage drop caused by the NPN transistor at the gate. This was accomplished by creating resistance with a resistor in series. Using the voltage drop at the input the input resistance was found to be 3.2 kΩ.

ELEC 353 – Lab 5: Oscillators

GROUP 13

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Introduction

The purpose of this lab was to design an oscillator and analyze its behaviour. Prior to the lab experiment, an oscillator was designed and simulated in LTSpice to obtain values and data of the oscillator's 'ideal' behaviour – these results were then compared to the values obtained from the physical design.

The oscillator that was designed in this lab consisted of one 2N39904 NPN transistor, one 1kΩ resistor, two 1µF capacitors in parallel, and one 10µH inductor. A picture of the lab members with the physical oscillator constructed in the lab is shown in Figure 1 below.

Part 1 – Oscillator Construction

In the first part of the lab, the oscillator was constructed. The oscillator design was based off the pre-lab oscillator that was designed in LTspice. The simulated circuit is shown below in Figure 2, and the physical circuit that was constructed is shown in Figure 3.

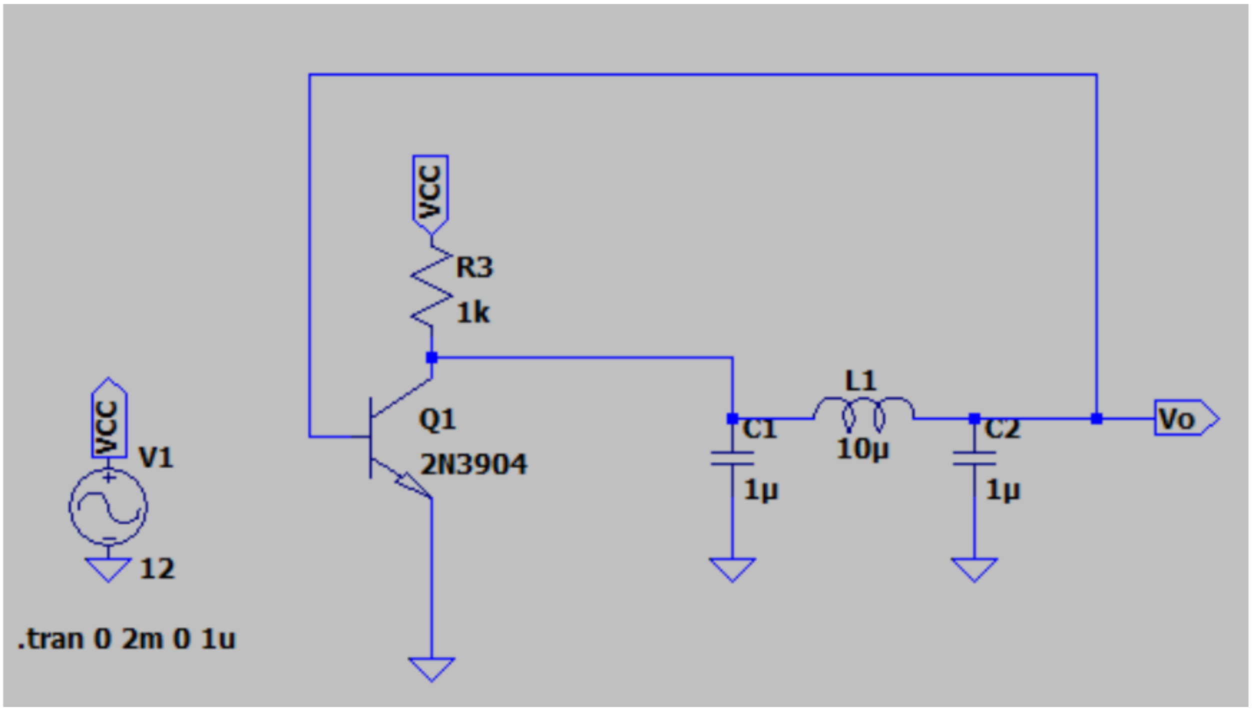

Figure 1: The LTspice oscillator design. The physical oscillator shown in Figure 3 was constructed based on this oscillator. In LTspice, a bias voltage of +12V was used.

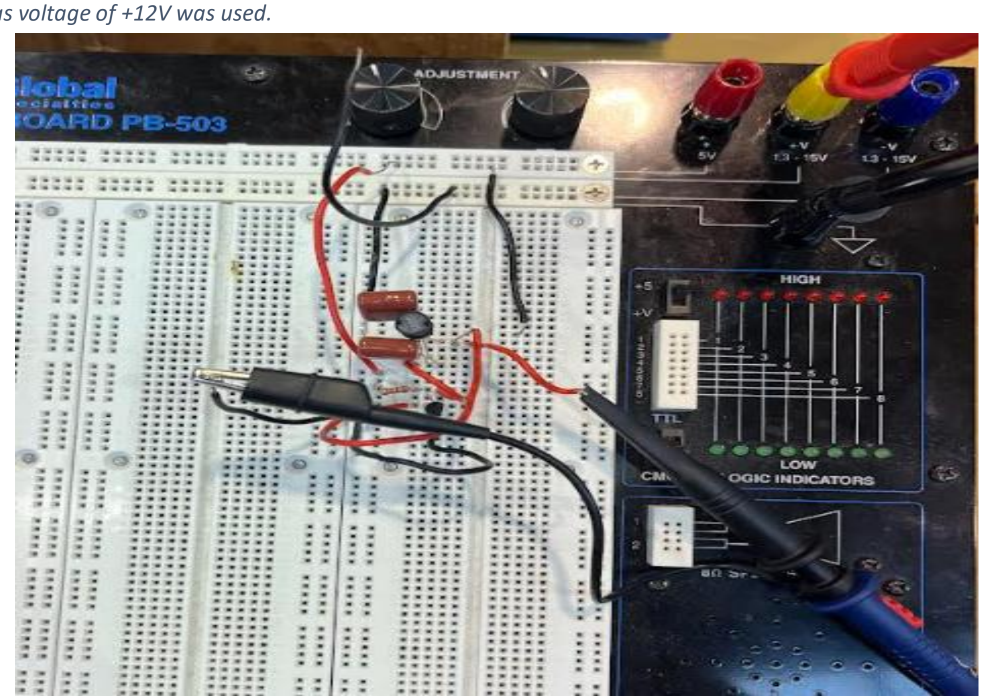

Figure 2: The physical oscillator, consisting of an NPN transistor, one resistor, one inductor, and two parallel capacitors.

Using the oscilloscope, the time domain of the oscillator output was captured. A picture of this is shown in Figure 4 below. This output matches the output that was simulated in LTspice, which is shown in Figure 5. The physical oscillator had a peak-to-peak amplitude of 400mV, which was comparable to the simulated results, which also had a peak-to-peak output of approximately 400mV.

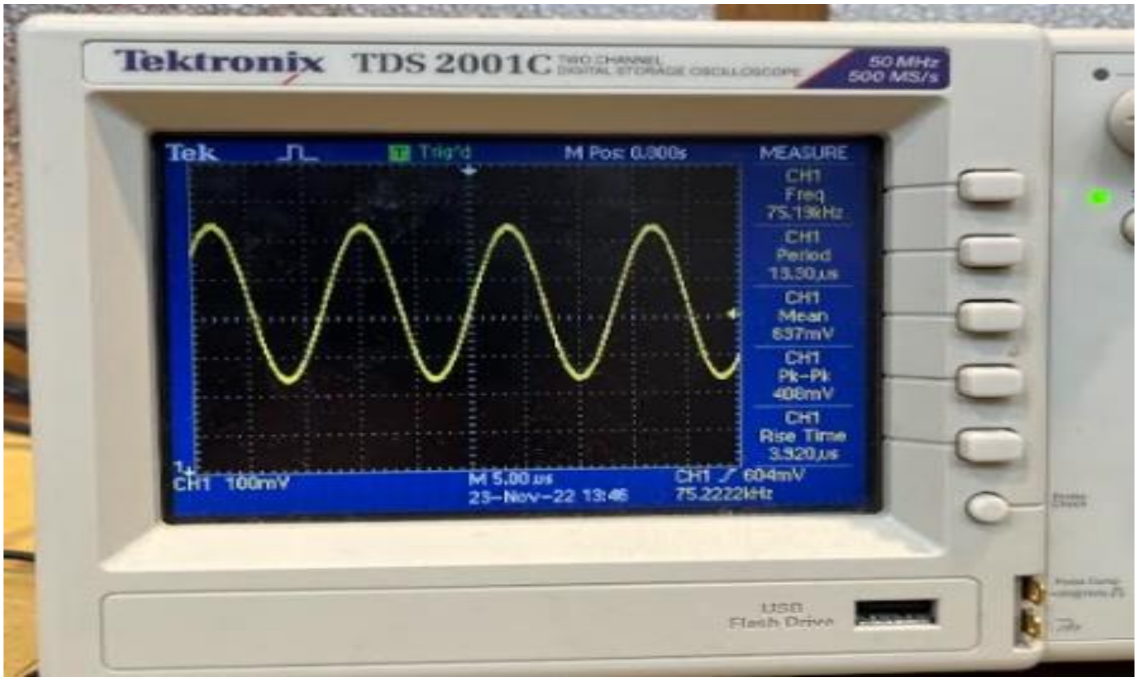

Figure 3: The time domain of the oscillator output, where the pk-pk amplitude is shown to be 400mV, which is comparable to the simulated results shown in Figure 5.

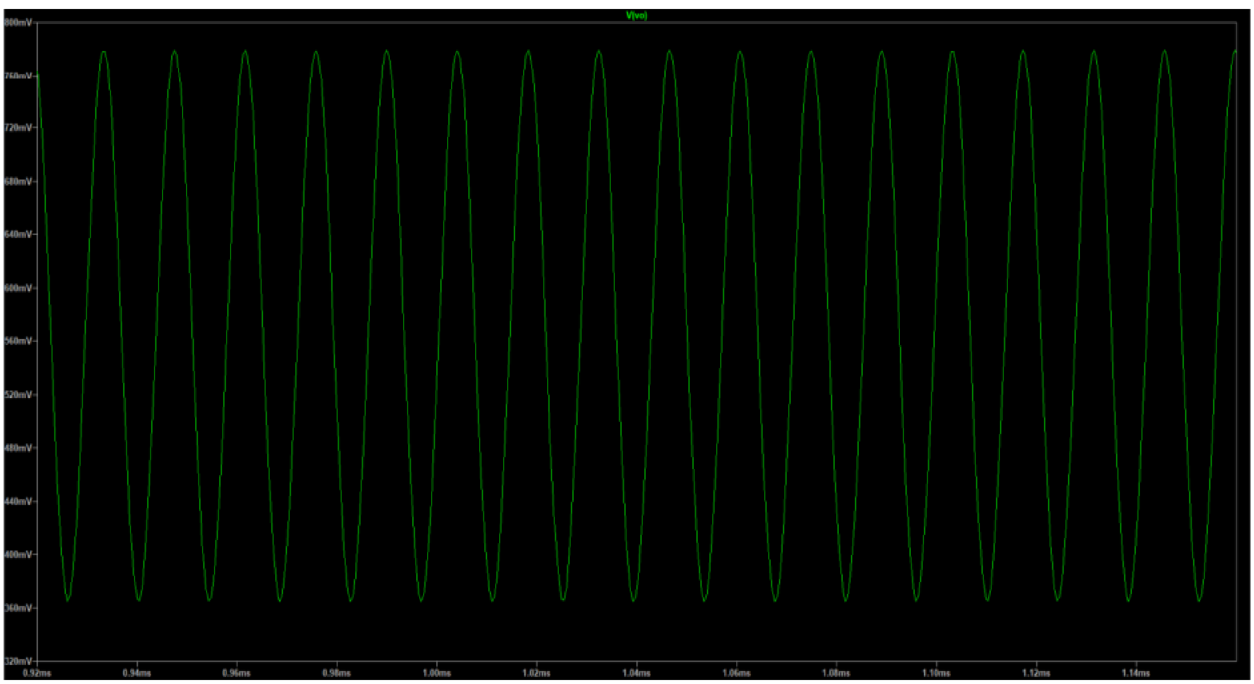

Figure 4: The simulated time domain output of the oscillator. Here, the pk-pk voltage is approximately 400mV.

The bias voltage of the physical circuit was measured using a multimeter; the multimeter read +11.93V, which is within 1% error of the simulated bias voltage of 12V.

Part 2 – Frequency Domain

By setting the oscilloscope to FFT mode, the frequency domain of the oscillator was analyzed. A picture of frequency domain spectrum of the physical circuit is shown in Figure 6. The frequency domain of the simulated oscillator is shown in Figure 7.

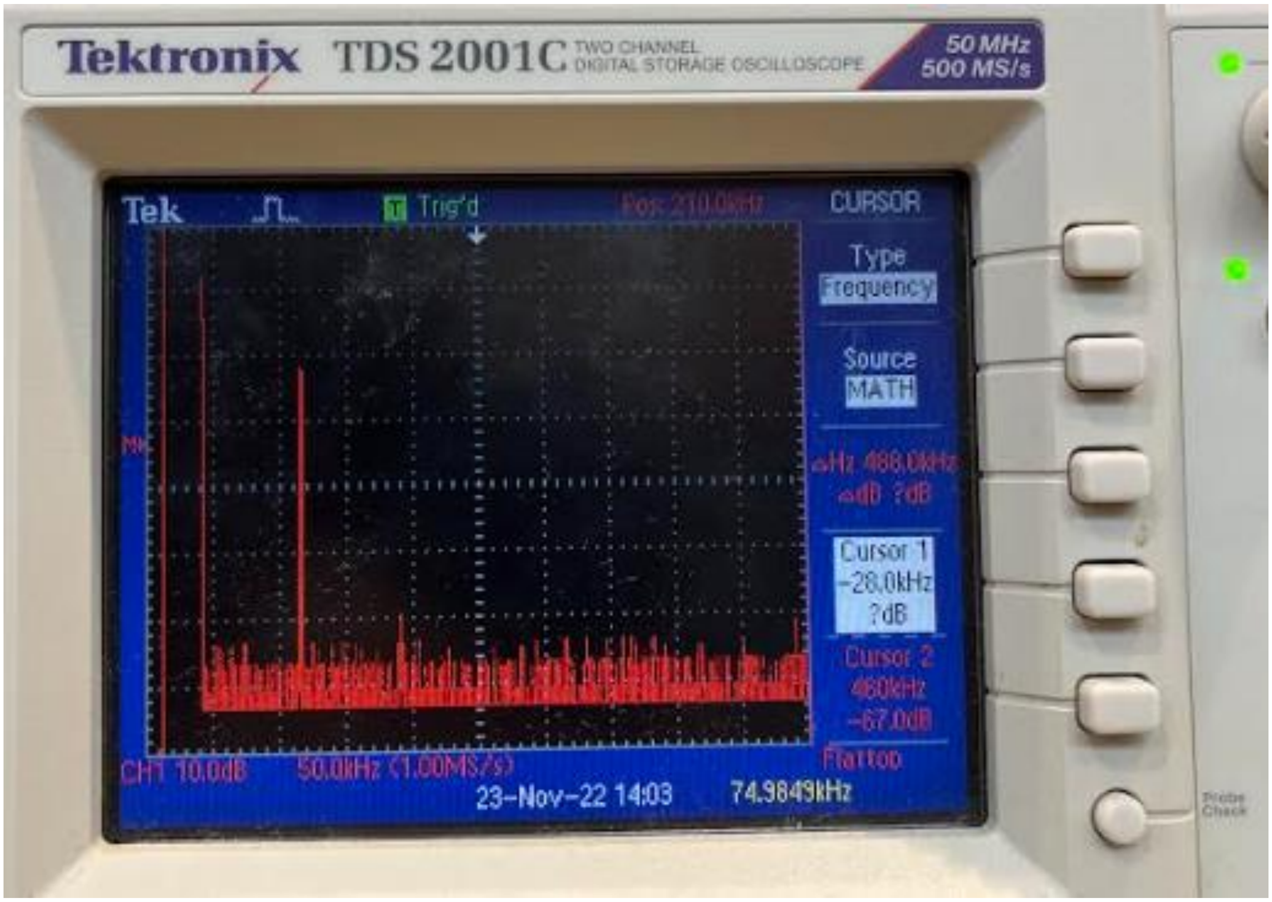

Figure 5: The frequency domain spectrum of the physical oscillator, as measured by the bench top oscilloscope.

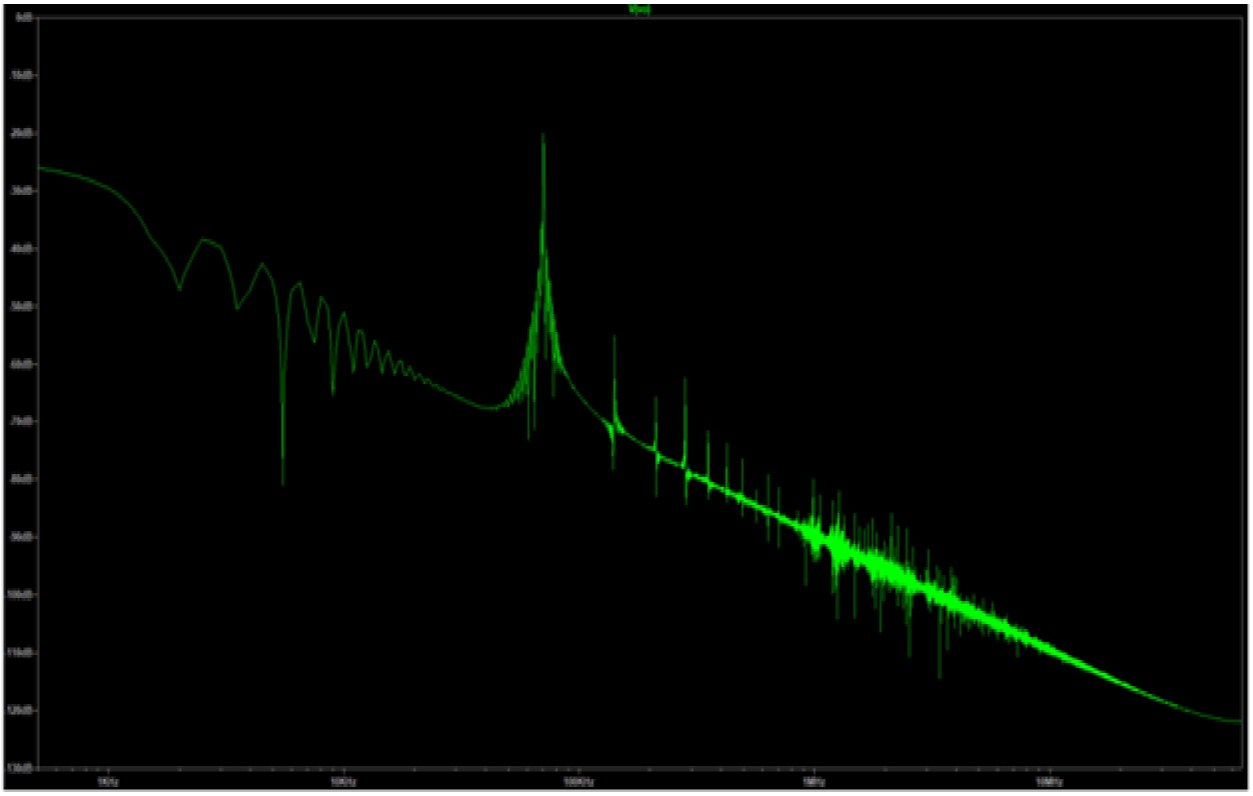

Figure 6: The frequency domain spectrum of the simulated oscillator, as captured by LTspice.

Using the cursors on the bench top oscilloscope, the harmonics of the physical oscillator were measured and compared to the harmonics obtained through the software simulation of the circuit. A comparison of the simulated and measured harmonics are summarized in Table 1. It was found that the harmonics obtained from the physical oscillator were 2-5% greater than the values that were obtained through LTspice.

Table 1: The harmonics of the frequency domain of the simulated circuit (left column) and the physical circuit (right column). The physical oscillator harmonics were obtained by using the cursors on the oscilloscope.

Simulated Harmonics (kHz)	Measured Harmonics (kHz)
70.8	74.0
141	148
211.7	216
282	286

Part 3 – Open-Loop Frequency Domain

The closed loop oscillator was opened, and a function generator was added. A DC offset of approximately 0.78V was added to the function generator. The frequency was adjusted to low values seen in blue in the figure 8 picture (frequency was adjusted through experiment for a cleaner wave). Input waveform was recorded in blue, the output waveform with gain was recorded in yellow.

The gain was calculated to be 1.13. The calculation used a measurement of 104 mV as the input voltage and 118 mV as the output voltage.

From completing project 3 we used the prior information to predict an input resistance of 3.2 kΩ. Through trial and error of connection the variable resistor in series with the input we found an input resistance of 3340 Ω.

- To calculate the phase difference, you use the equation theta = (frequency)*(360 dgerees)*(time difference)
    - You can convert to radians if need-be

The phase difference was calculated using the equation below. The frequency was quantitively observed to be 1/38*10^-6 Hz. The time difference found through the oscilloscope axes was found to be 2 microseconds. Thus, resulting in a phase difference of 1.9*10^(-11).

$$Phase\ difference = \left(\frac{1}{T}\right) * 360° * time\ difference$$

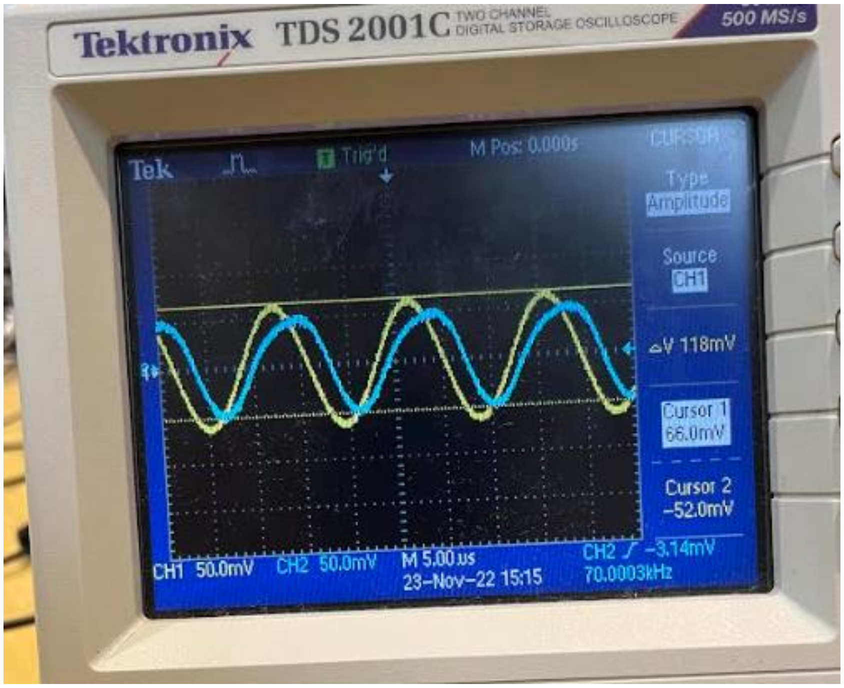

Figure 7: Input and output wave forms after function generator