Project 2: Colpitts & Crystal Oscillator

Ahmad Malik & Nicholas Singh

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ECE-393-A Junior Lab

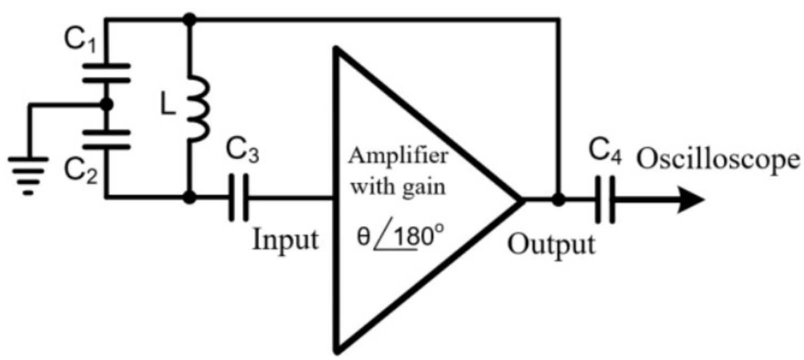
Professor Koo

Project Description

The goal of this project was to incorporate an LC tank Colpitts Oscillator into our transistor amplifier from project 1. To receive full marks, our amplifier should be able to handle precisely 4 MHz, generate a peak-to-peak amplitude greater than 6v, and consume less than 100mw of power. In addition to this, we should replace the inductor of the Colpitts Oscillator with a 4MHz crystal oscillator and observe a 4MHz output.

Design

Below is the basic block diagram describing the functions of a Colpitts Oscillator in conjunction with the transistor amplifier we designed earlier. The LC tank has the same 180° phase shift as the amplifier, so there is positive feedback entering the input of the amplifier. The main driver of the oscillation is the ambient noise of the room which is amplified and locked at an exact frequency designated by the capacitor and inductor value of the LC tank.



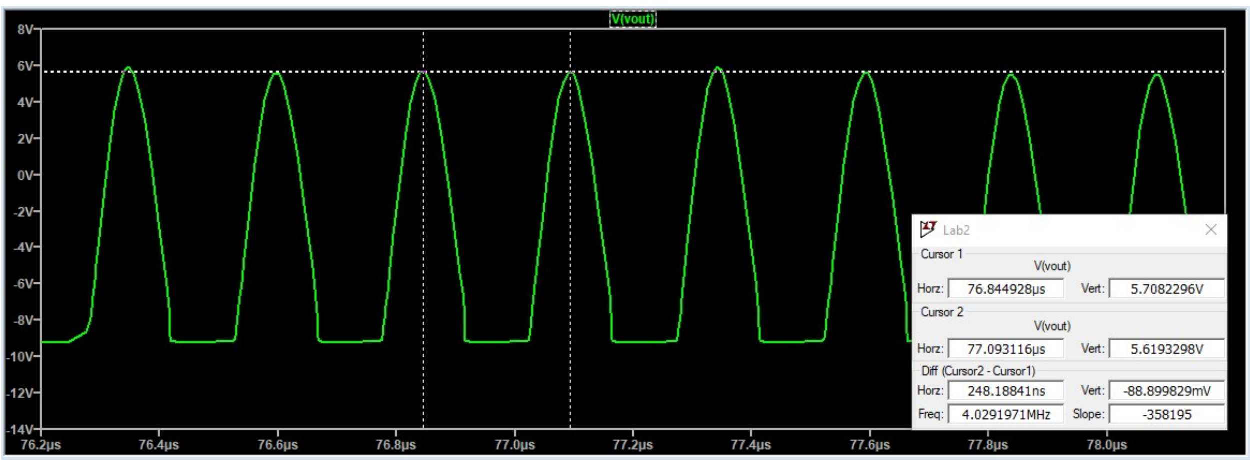
The C1, C2, and L values, are found by applying the formula for the resonant frequency of a Colpitts Oscillator.

$$fr = \frac{1}{2\pi\sqrt{L \cdot C_T}} \quad ; \quad C_T = \frac{C_1 C_2}{C_1 + C_2}$$

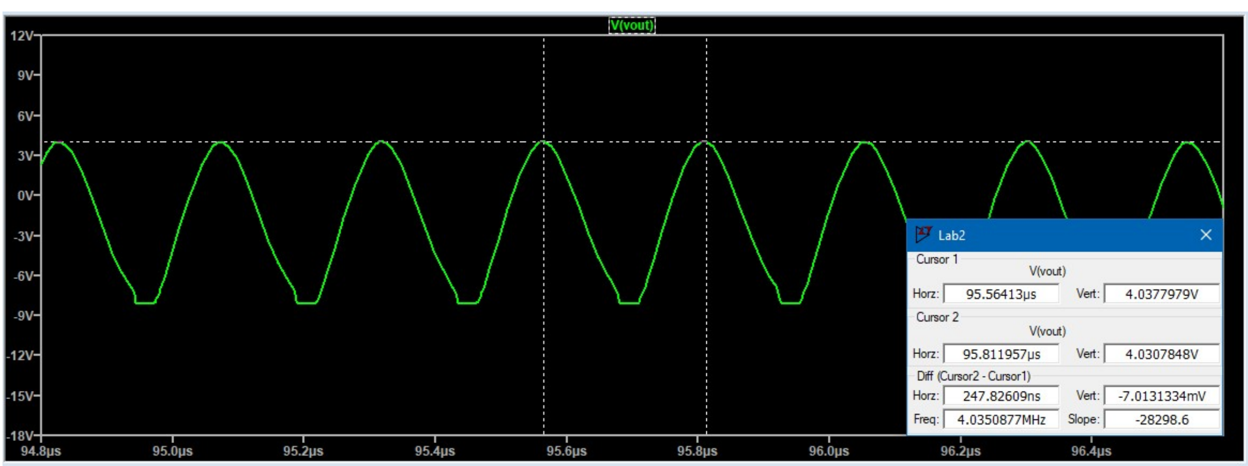
Since we want the oscillator to operate at 4MHz, $f_r = 4Mhz$. Furthermore, we want to choose the inductor with the smallest available value (we chose 10mH) so that we can choose larger values for the capacitors ($C_T = 158pF$). This is important because if the capacitor values are too small, they will be more susceptible to the parasitic capacitance on the breadboard and result in the frequency of the oscillator to vary.

In regards to the capacitor values, the ratio $\frac{C_2}{C_1}$ is referred to as the feedback ratio and it results in an extra amplification of the input voltage signal that is fed into the transistor. This is necessary to consider because if we chose capacitor values such that the feedback ratio is high, then our amplifier might become over saturated resulting in signal distortion. If we chose capacitor values that are too similar, the peak to peak gain of the amplifier might be too low, even resulting in signal degradation from parasitic capacitance. So while holding C_T constant, we picked a feedback ratio of roughly 2, where $C_1 = 220pF$ and $C_2 = 560pF$.

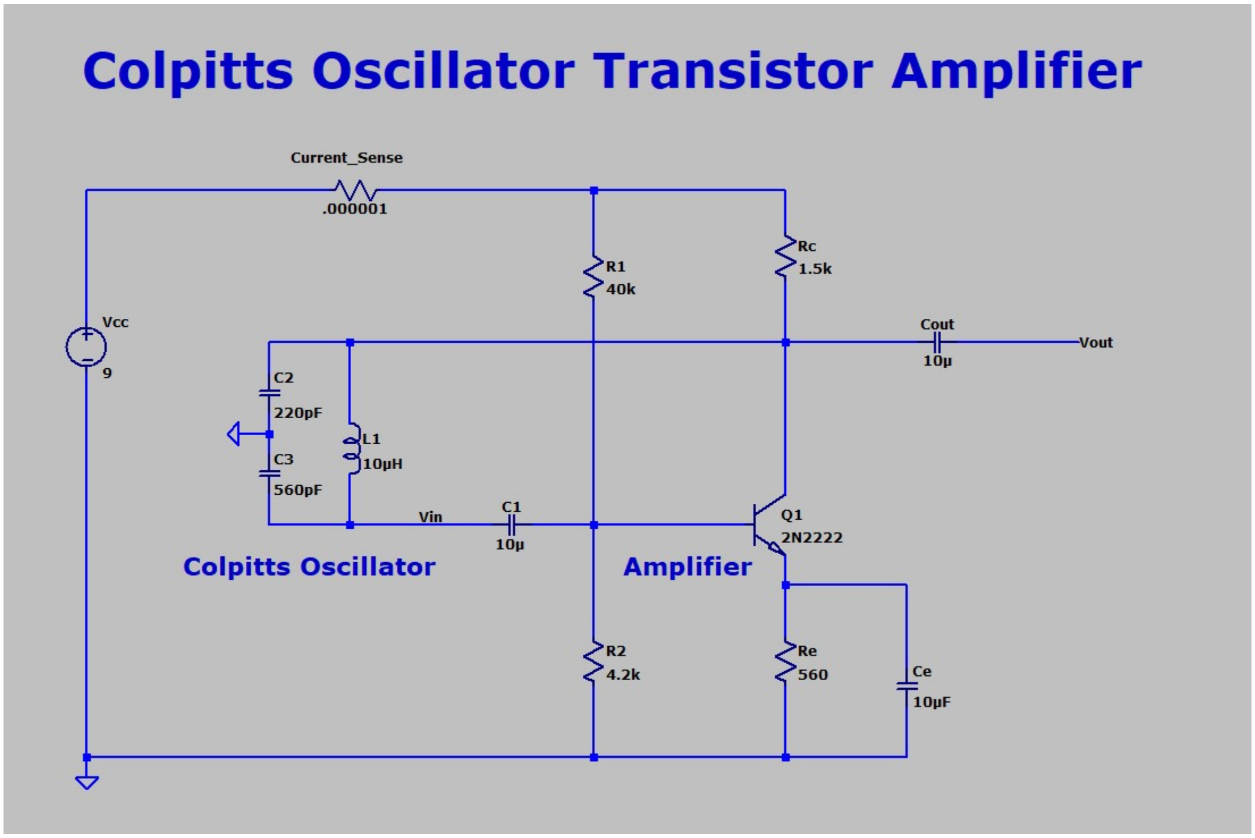
Due to our amplifier from project 1 having quit a large gain, it was highly susceptible to over saturation if the input signal is relatively large, resulting in the output signal having distortion. See below for a trial simulation. Notice the peak-to-peak voltage of the output is almost the same as Vcc and it is over saturated as well.



To fix this issue, we lowered the Vcc of our amplifier to 9v and increased the value of the degenerative resistor on the emitter of the transistor from 150Ω to 560Ω. These two modifications resulted in a lower output gain and resulted in less saturation and a cleaner sine wave. Below is the wave after changing the emitter's resistor; later when we lower the Vcc and the wave has fewer defects but lowers in peak-to-peak voltage.



Final Schematic



Note: The "Current_Sense" resistor is used to get the approximate current draw of the circuit.

Simulation Results

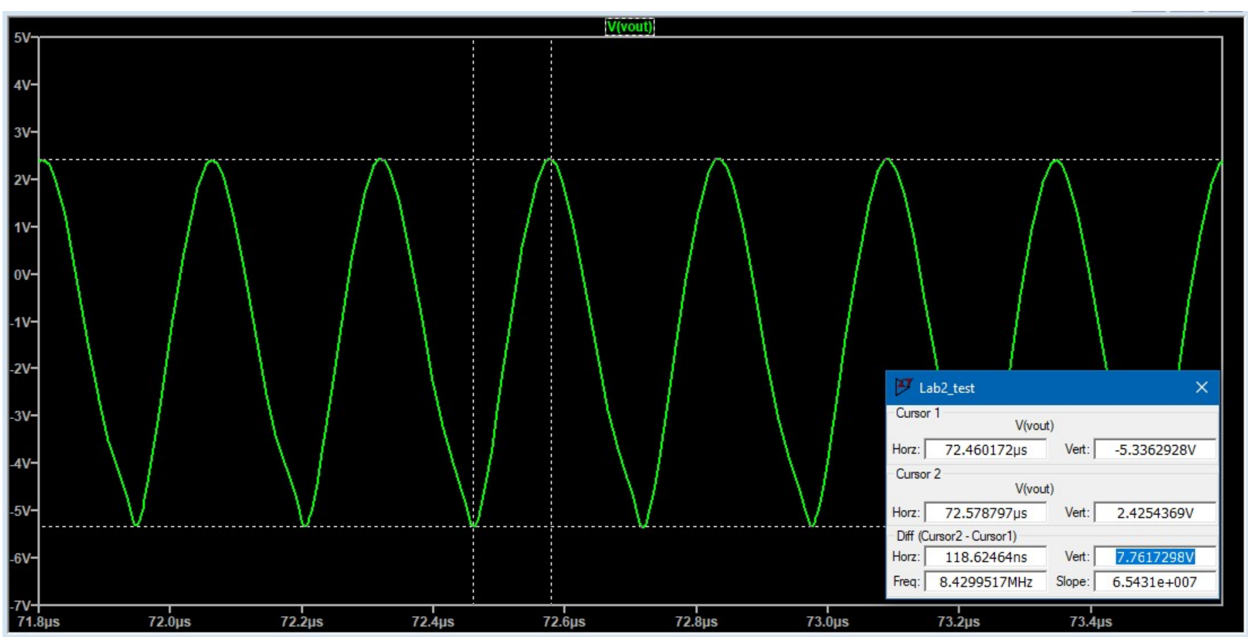


Figure 1: Output waveform is 7.76v peak-to-peak

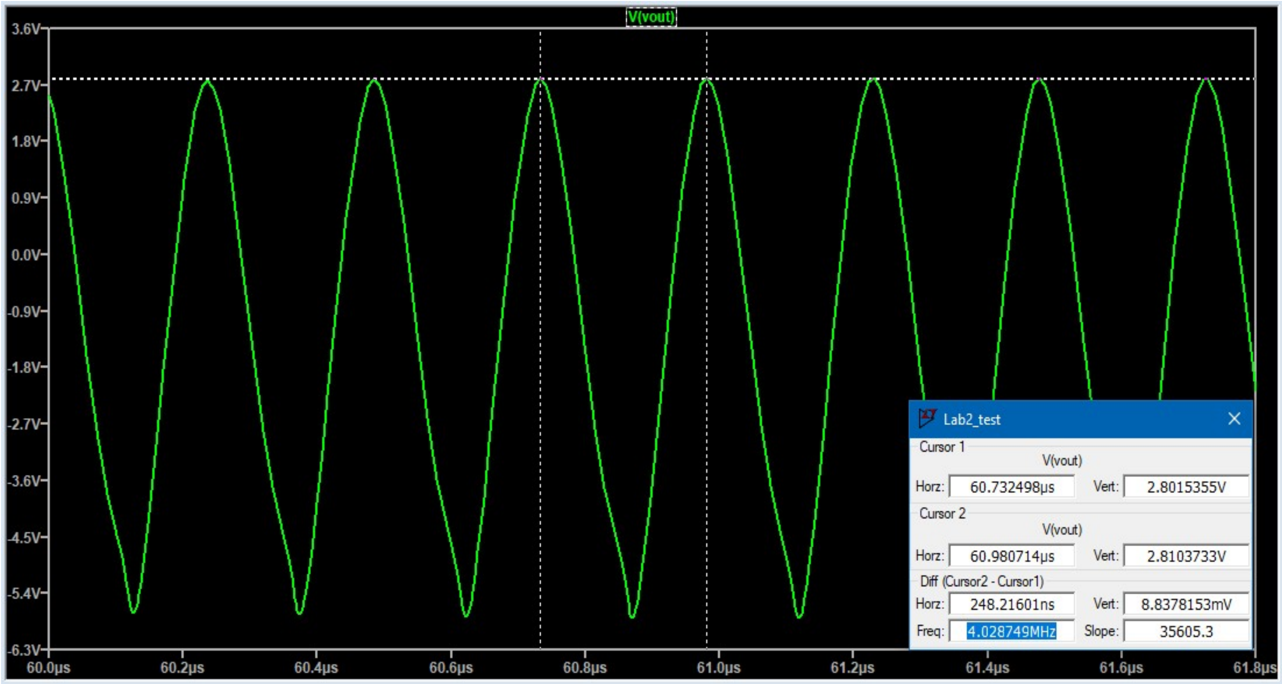


Figure 2: Output waveform is operating at approximately 4MHz

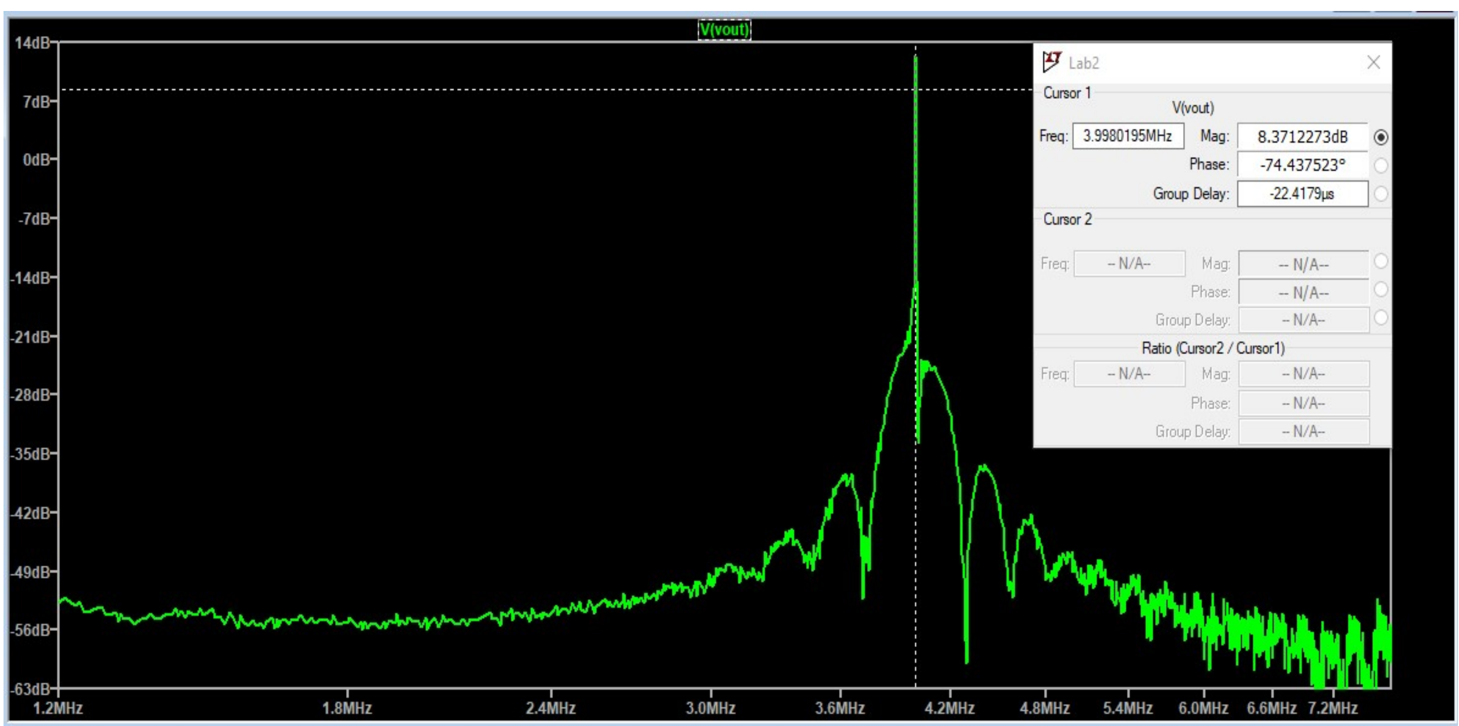


Figure 3: FFT of Waveform shows the gain peaks at around 4MHz

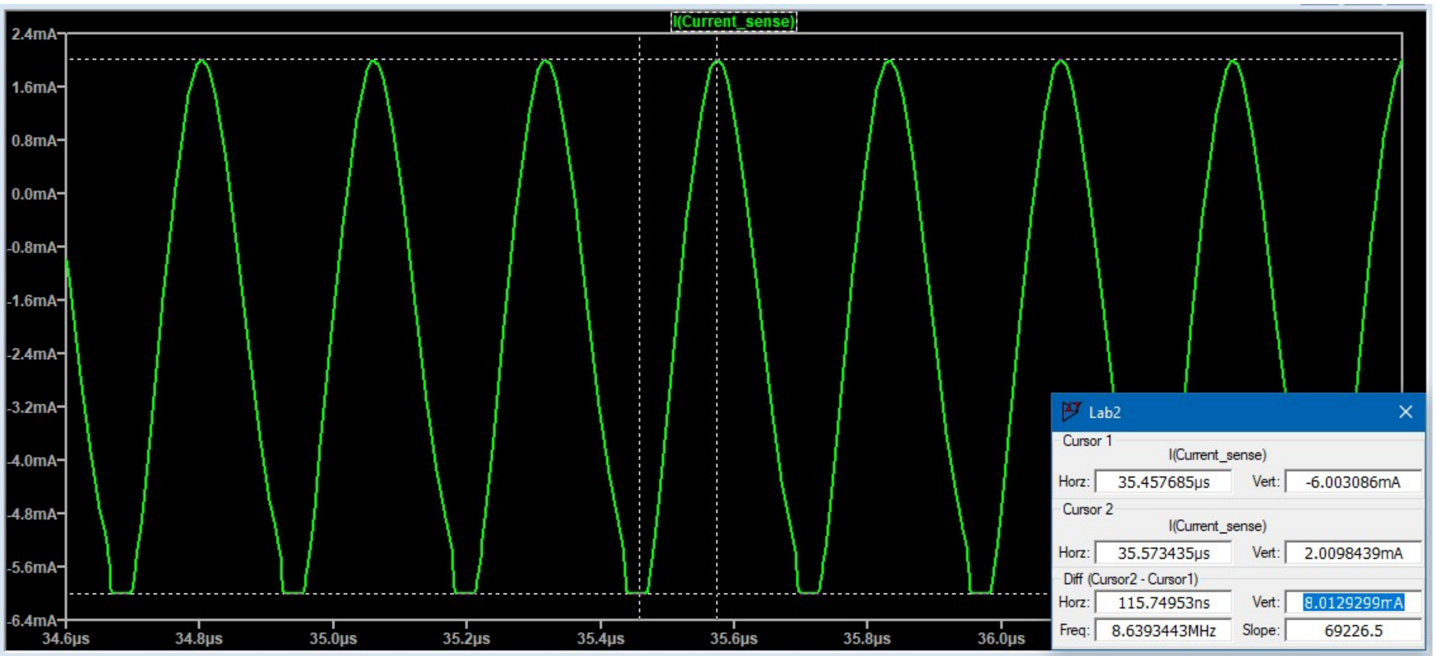


Figure 4: The circuit consumes a peak-to-peak value of 8mA, which is 50.9mW RMS

Lab Results

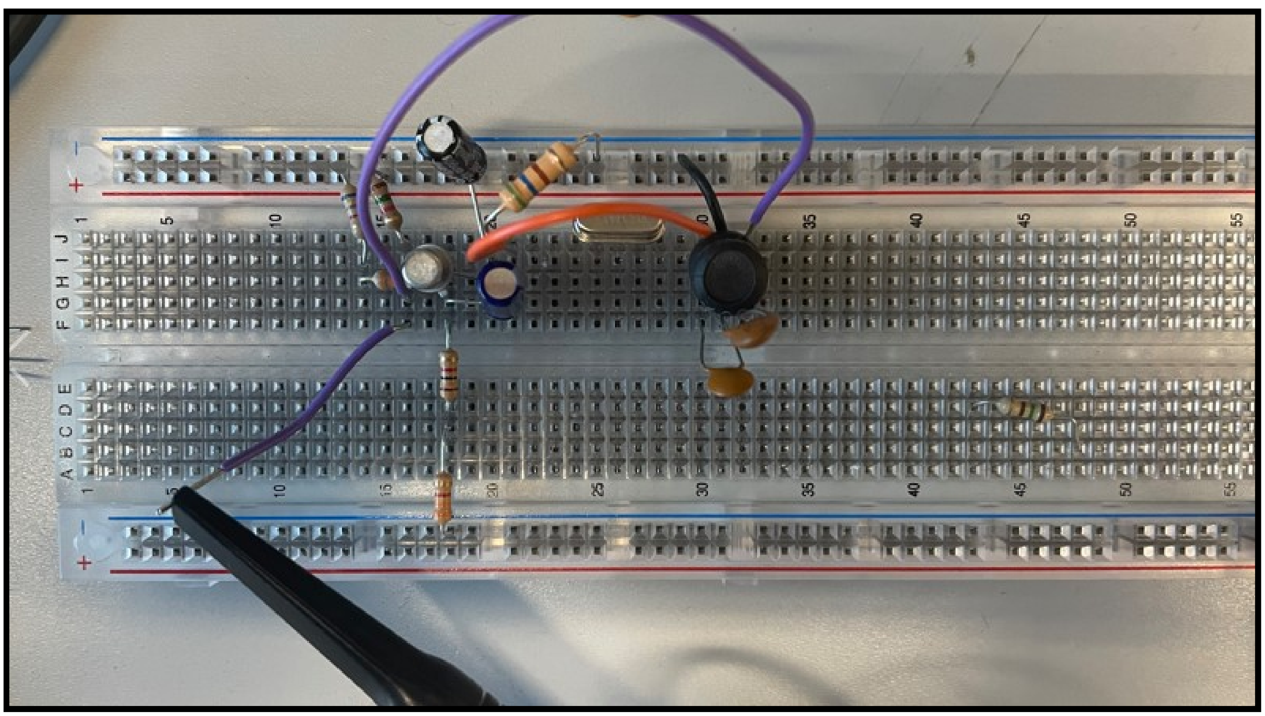


Figure 5: Implemented LC tank for Colpitts Oscillator on Breadboard with amplifier

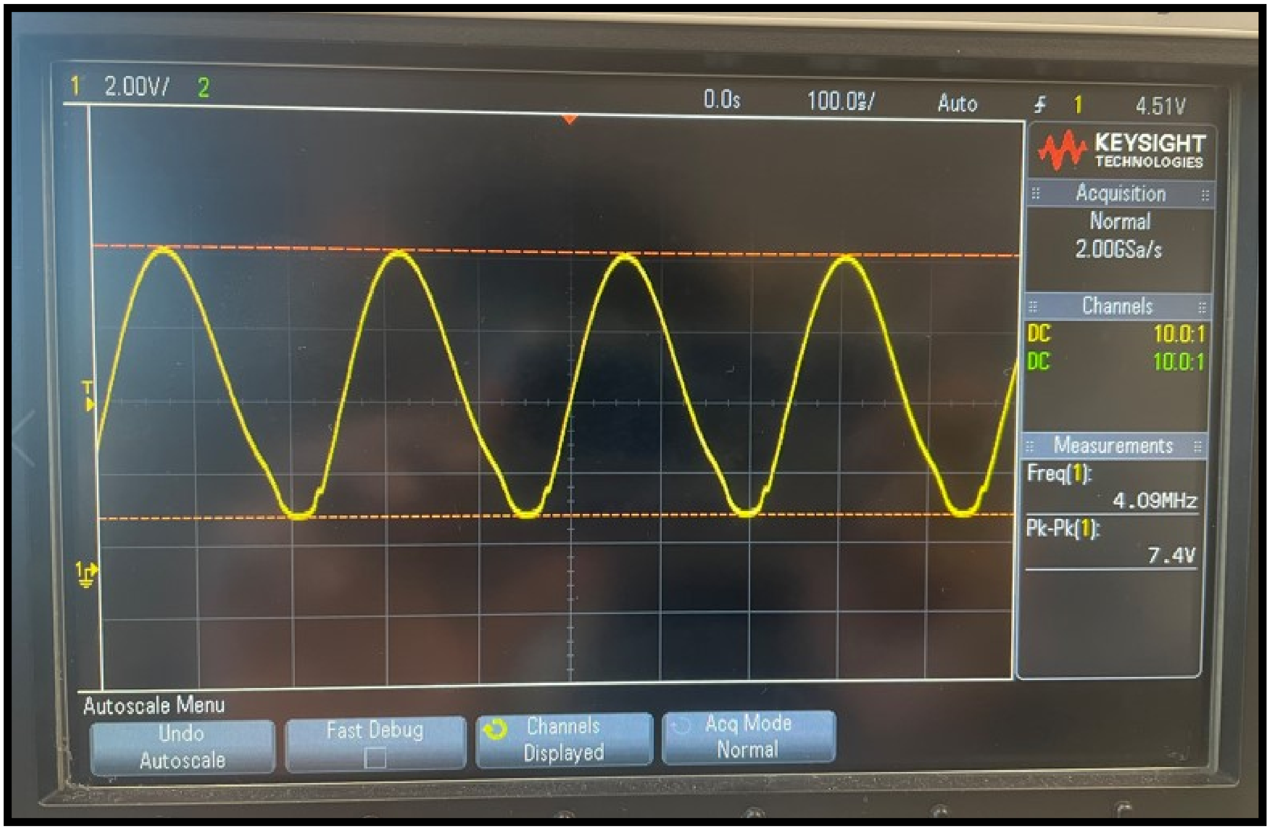


Figure 6: Oscillator has a peak-to-peak voltage of 7.4v and operates around 4.09MHz

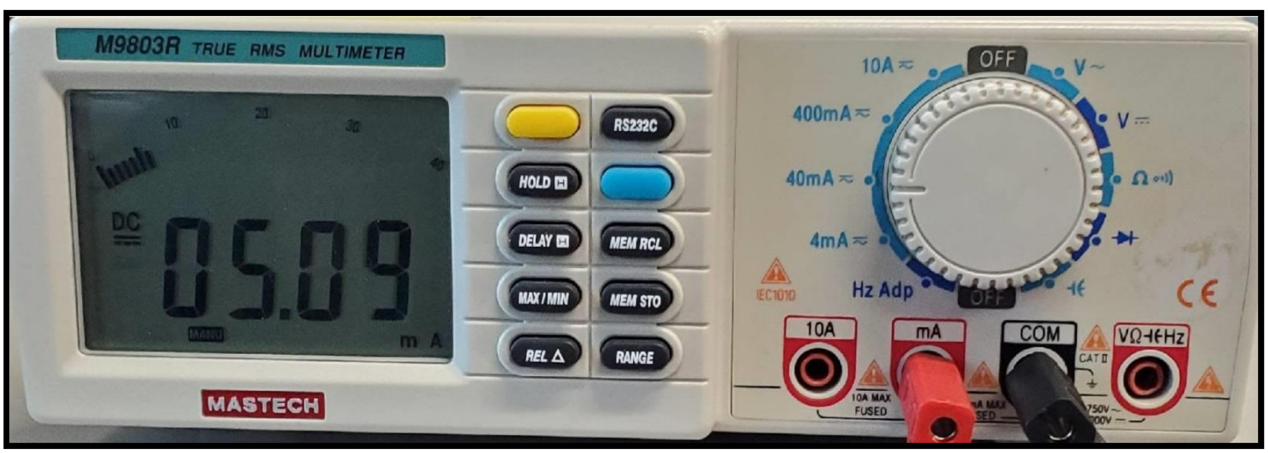


Figure 7: Colpitts Oscillator draws 5.09mA, which is 45.8mW

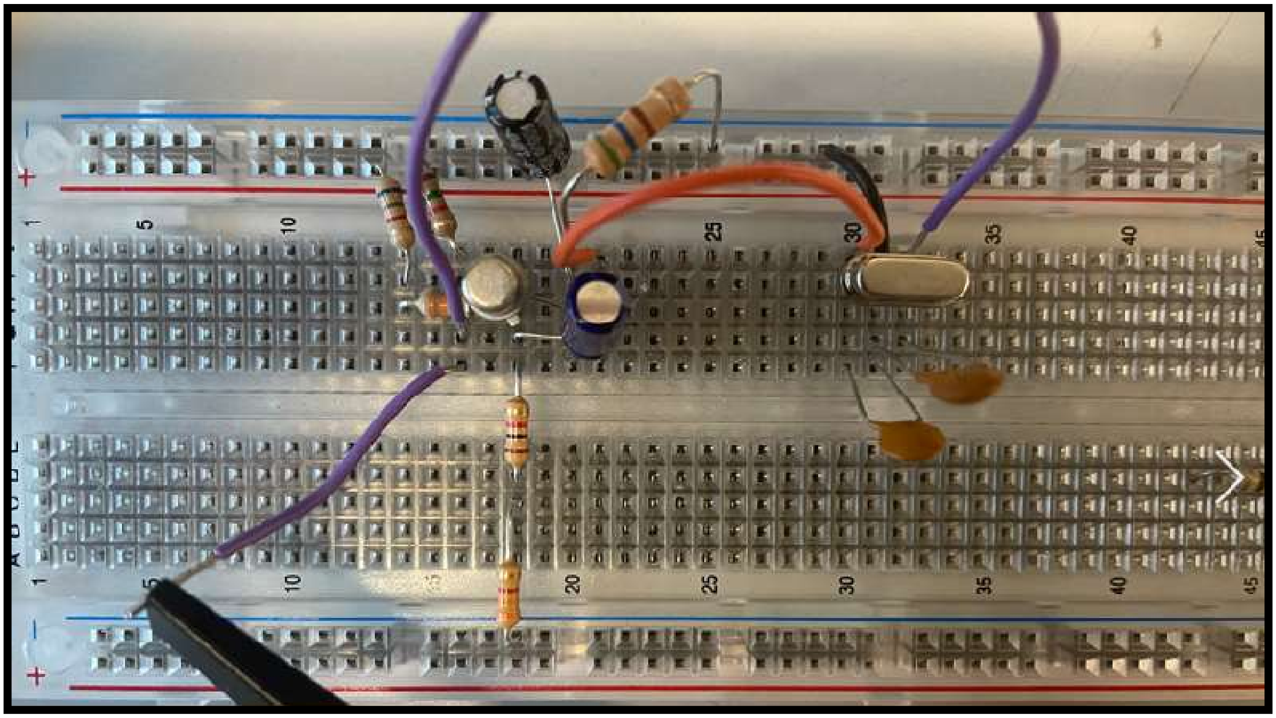


Figure 8: Implementing a 4MHz Crystal Oscillator instead of an Inductor

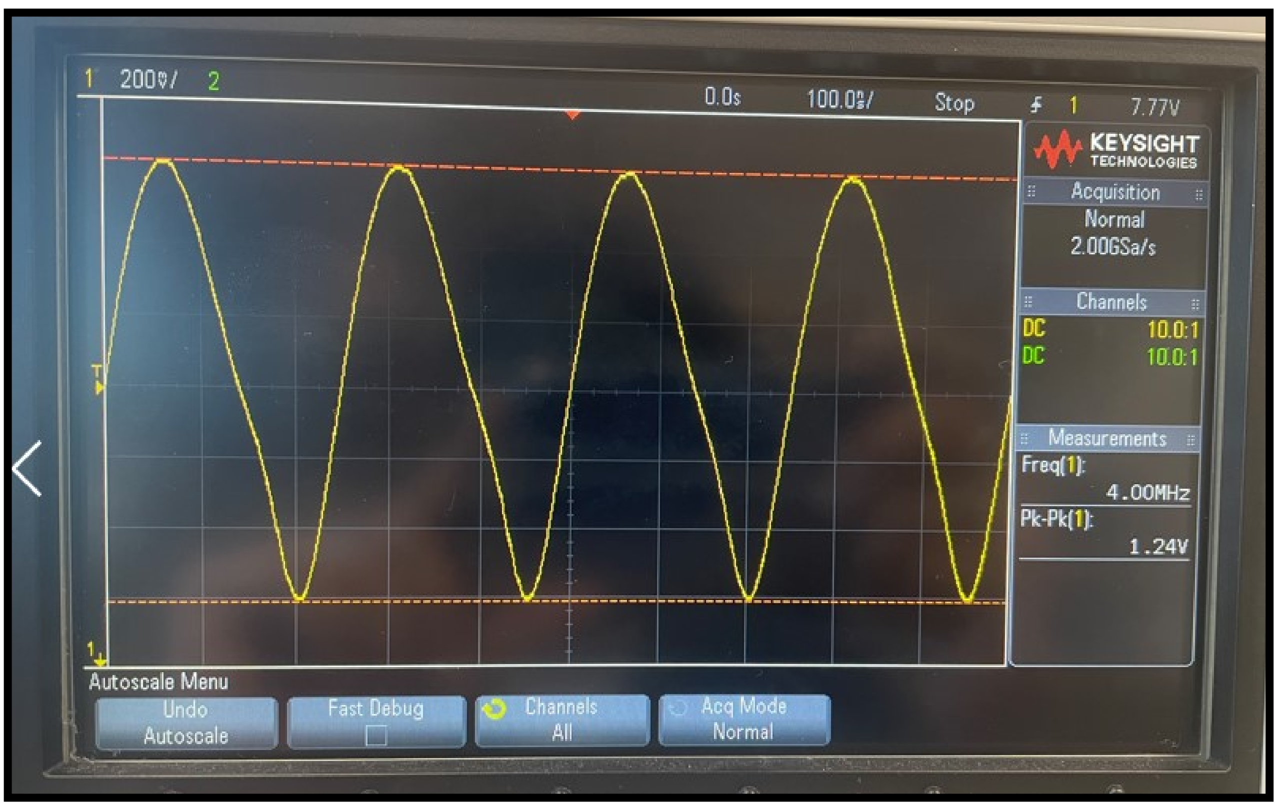


Figure 9: Crystal Oscillator operating at 4.00MHz with 1.24v Peak-to Peak

Table of Results

value	Simulation	Lab Measurements
Peak-to-Peak Voltage	**7.76v**	**7.40v**
Operating Frequency	**4.03MHz**	**4.09MHz**
Power Consumption	**50.9mW**	**45.8mW**