Project: **Switched Capacitor Active Band-Pass Filter**

Abstract

The main objective of this design project is to help students to design and implement solutions for electrical engineering problems by making them familiarize with different types of electronic circuits consisting of several components such as ICs, MOSFETs, resistors and capacitors in order to know how to design, construct and test these circuits using the following two different methods. First of all, we use the Pspice programming to analyze and design several electronic circuits where in this project we use the Pspice programming in order to design and analyze the circuit in figure 1 as shown in pages 5 & 6. Second, we implement our electronic circuit for this project in the Electronics II Lab, and we verify our results as shown in the images taken from the oscilloscope. Ultimately, we apply what we have learned so far from the lectures in implementing and designing our circuit design for this project.

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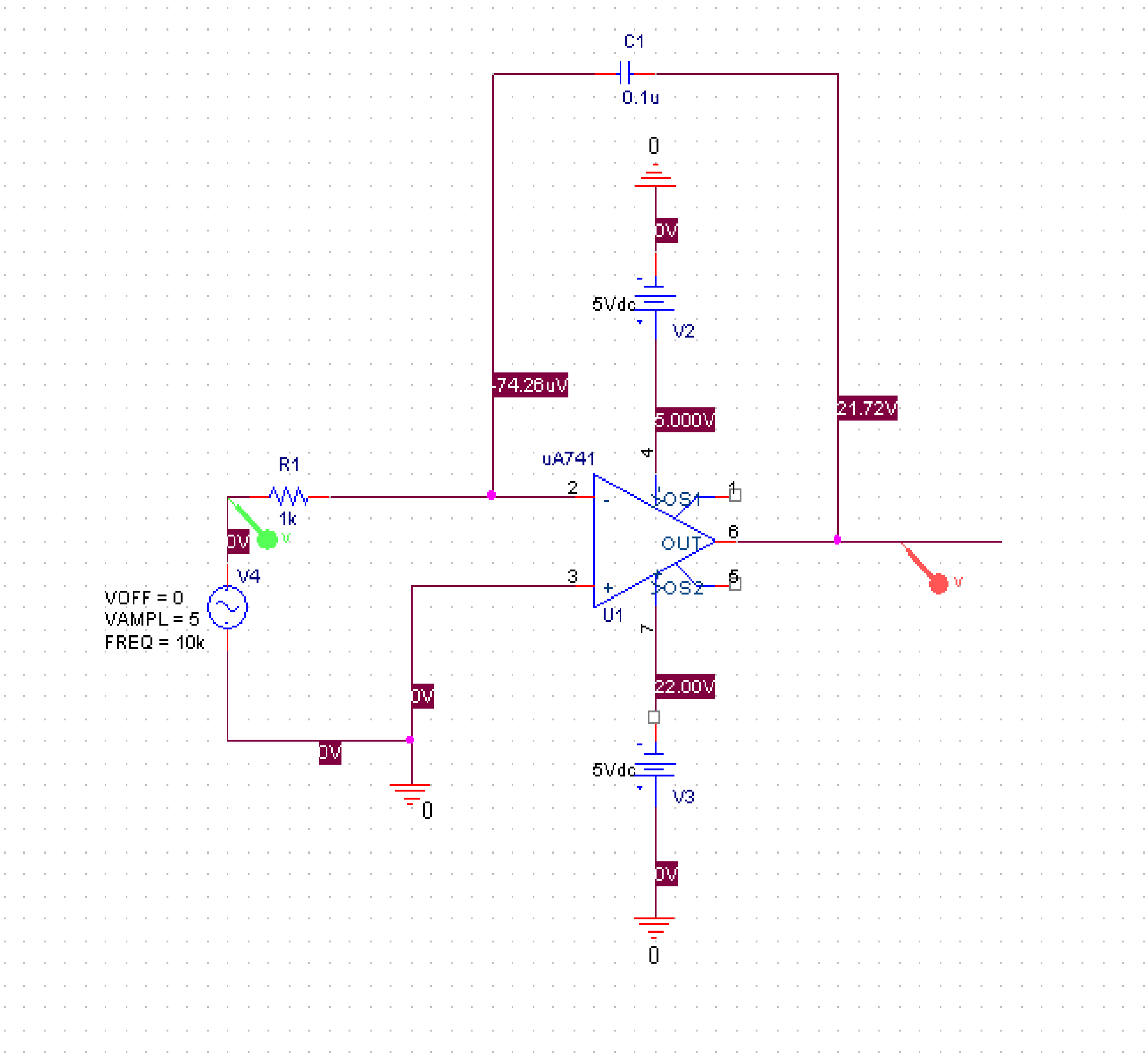
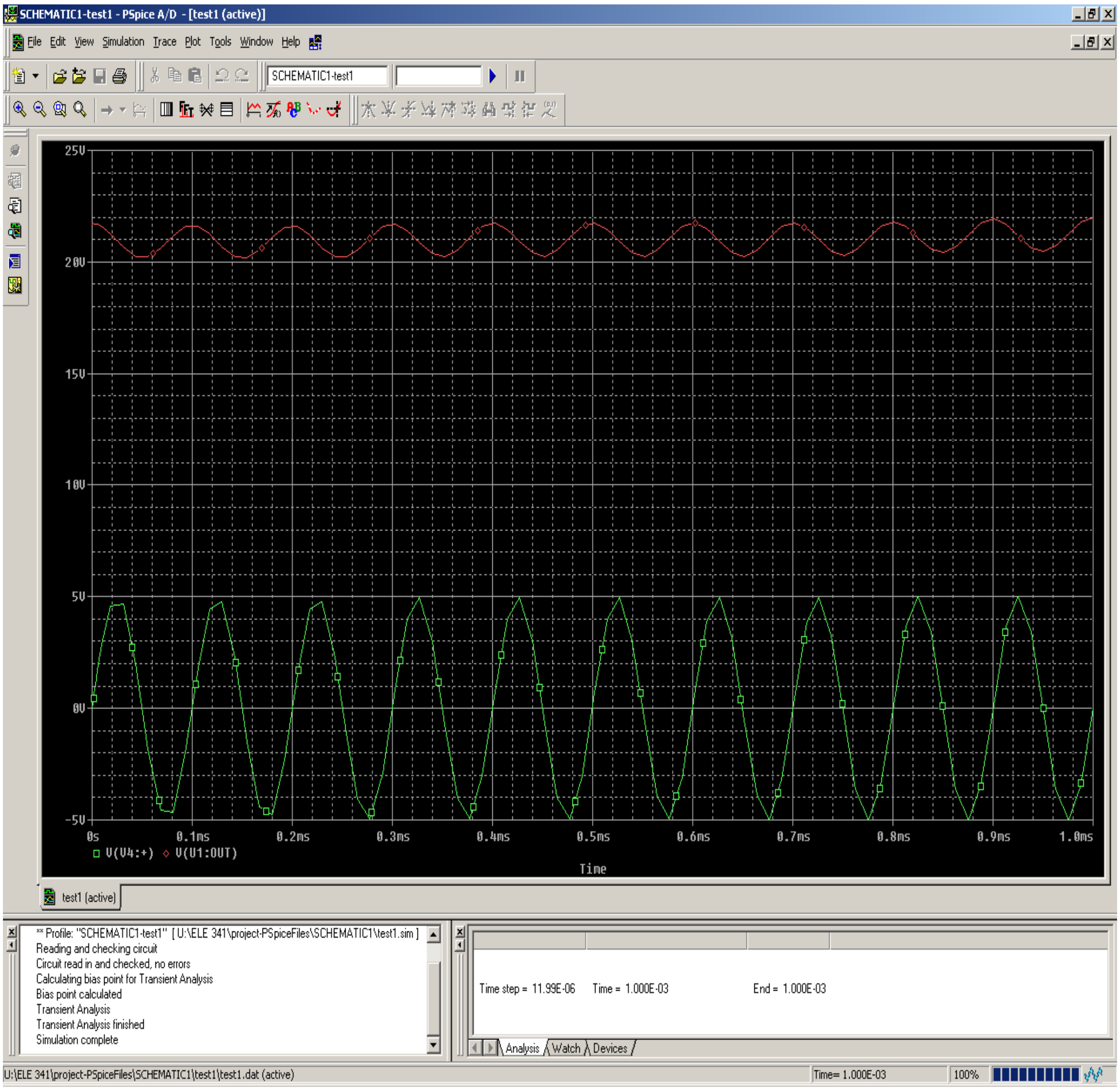
Pspice Simulation:-

We simulate our electronic circuit design for figure 1 using the Pspice software as shown below in this page and the next page as well.



Ultimately, we got the following waveforms from the Pspice simulations as follows:



Part I: Results

First of all, we implement the circuit given below using R1=1kΩ and C2=0.1uF.

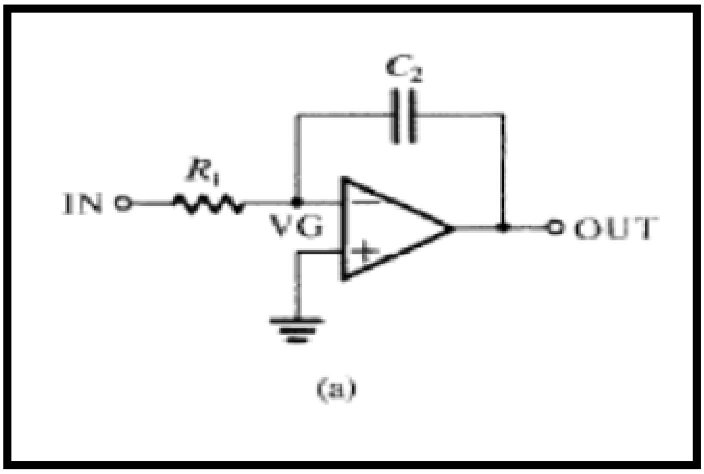


Figure 1: Operational Amplifier Circuit

Then, we measure the cutoff frequency for the above circuit which is equal to 400kHz.

Moreover, we implement the circuit given in the figure 2 below.

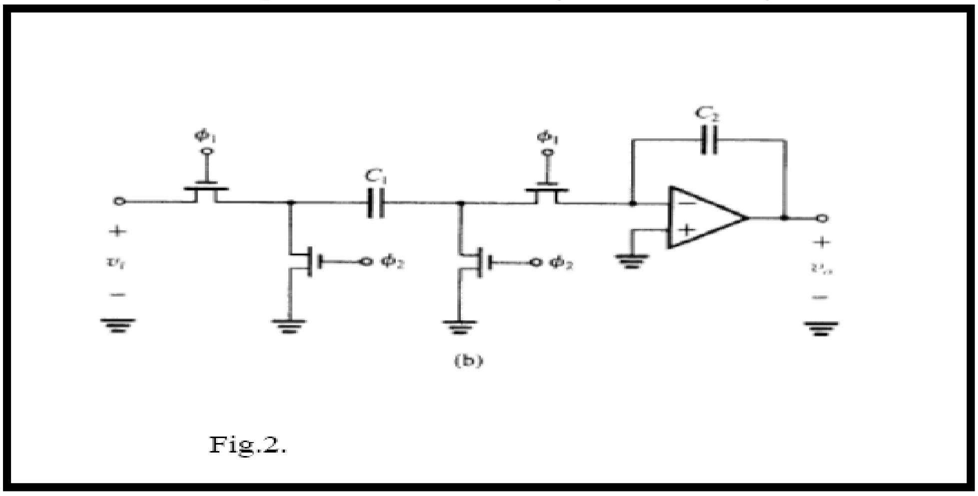


Figure 2: Operational Amplifier Circuit with Switched Capacitor

Then, we measure the cutoff frequency values for two cases:
Case 1: using the clock frequency Φ_1 = 10KHz.
The cutoff frequency for case 1 is 172Hz
Case 2: using the clock frequency to 100 KHz
The cutoff frequency for case 2 is 421Hz

Comment on Results

Replacing the first resistor (R1) by the switch capacitor in the above figure 2 will change the cutoff frequency values where increasing the clock frequency value such as using 100kHz will increase the value of cutoff frequency from 172Hz to 421Hz in the ratio of about two times. Also, changing the clock frequency will change the cutoff frequency values as a result because the clock signals are out of the phase where the clock frequency = 1/Tc such as if the clock frequency equals 10kHz, then the period will equal to 1/10kHz=0.0001 and by increasing the clock frequency to be equal to 100kHz, the period will equal to 1/100kHz=0.00001. Ultimately, increasing the period Tc , the equivalent resistance will increase according to Req=Tc/C1, and as a result the C1 will be decreasing. Therefore, the value of cutoff frequency will be increasing as the capacitor decreasing because the cutoff frequency is inversely proportional to the capacitor as follows:

Cutoff frequency = $f = \frac{1}{2\pi\tau_P}$ where τ_P = Req*C.

Part II: Results

In this part, we design and implement a second order band pass filter as given in Figure.3 below with f0 =10 kHz, Q = 20 and unity center frequency gain. Moreover, we verify the frequency response of circuit given by Figure.3 using component values for our design. Furthermore, we replace resistor Rg by switched capacitor circuit in order to get the same pass band for the filter, and we verify the pass band and Q values by using clock frequency Φ_1 =200kHz.

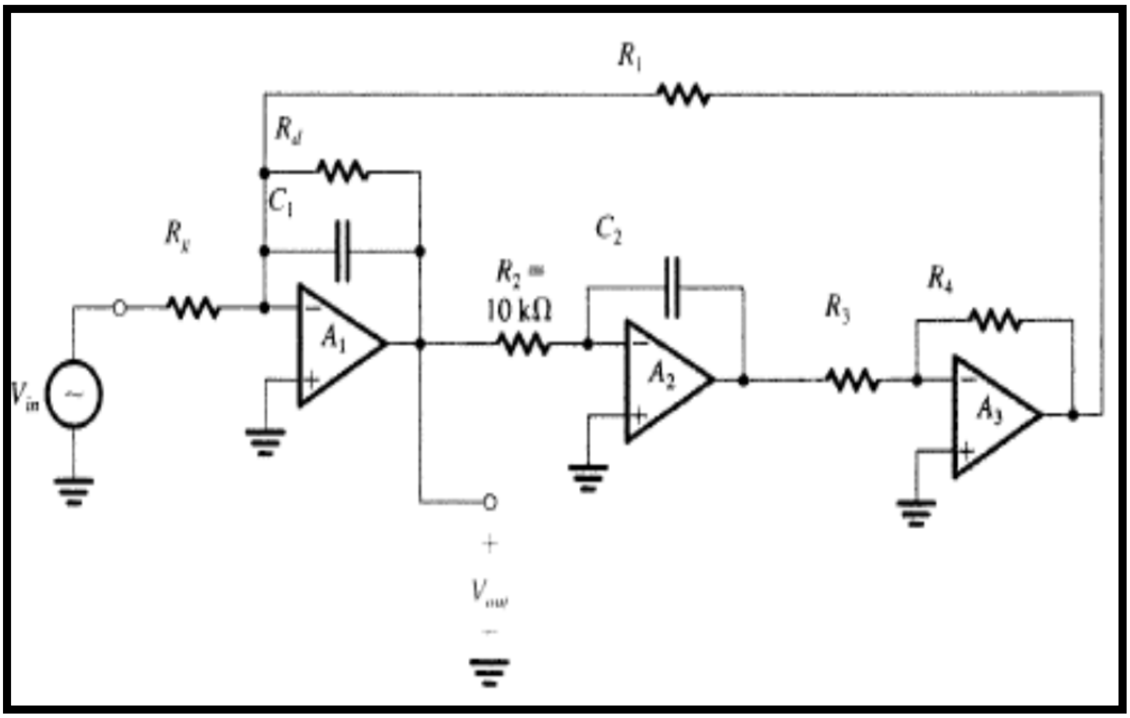


Figure 3: The Second Order Band Pass Filter

Design Calculations

Let C1 = 10 nF = C2.

Q = 20 -> BW = Fo/Q = 10K / 20 = 500

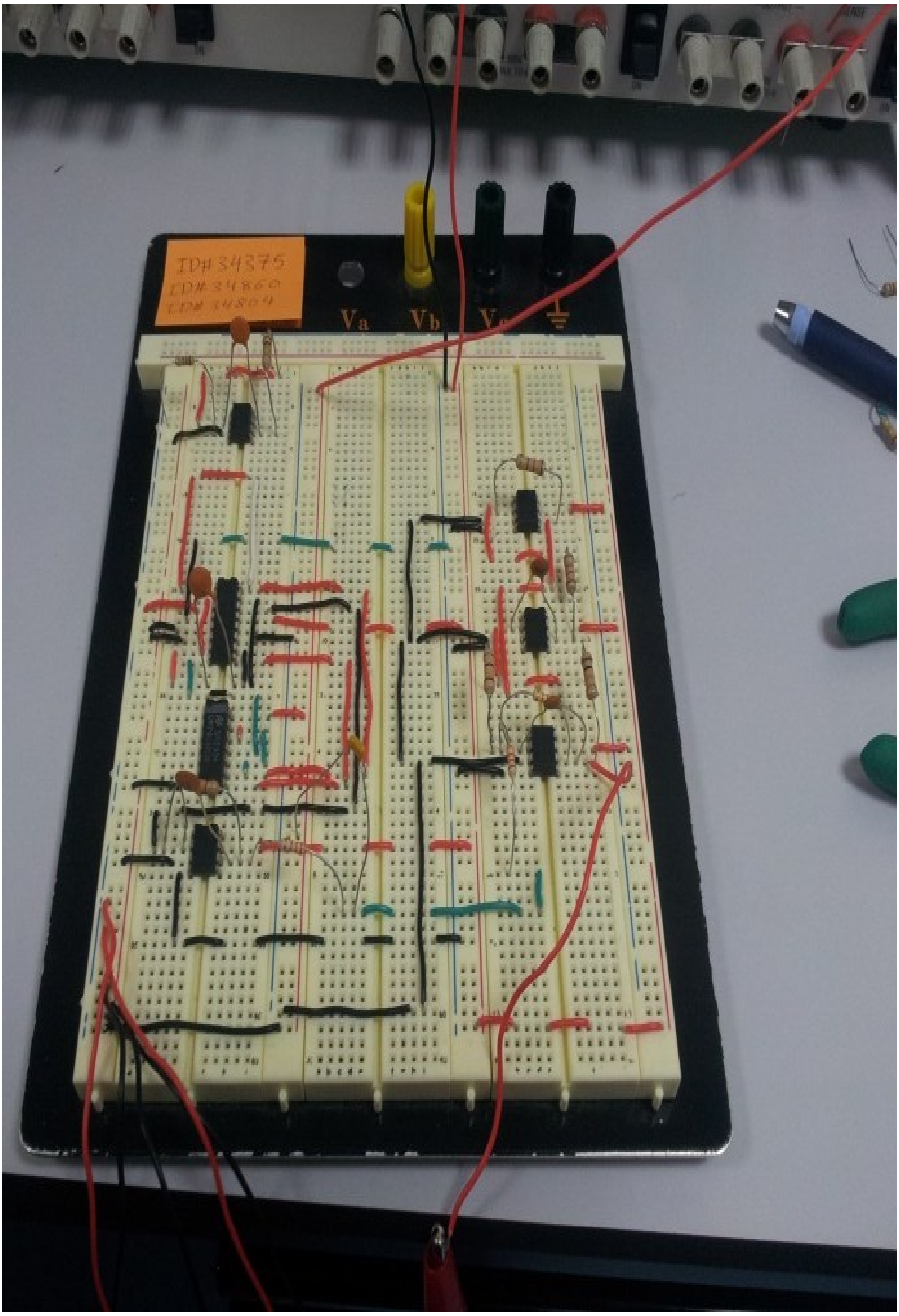
Rg = 1/(2*pi*R*BW) = 31.8 kΩ

Av (max) = Rg/R and Av = 1 (unity gain) -> Rg = R = 31.8 kΩ

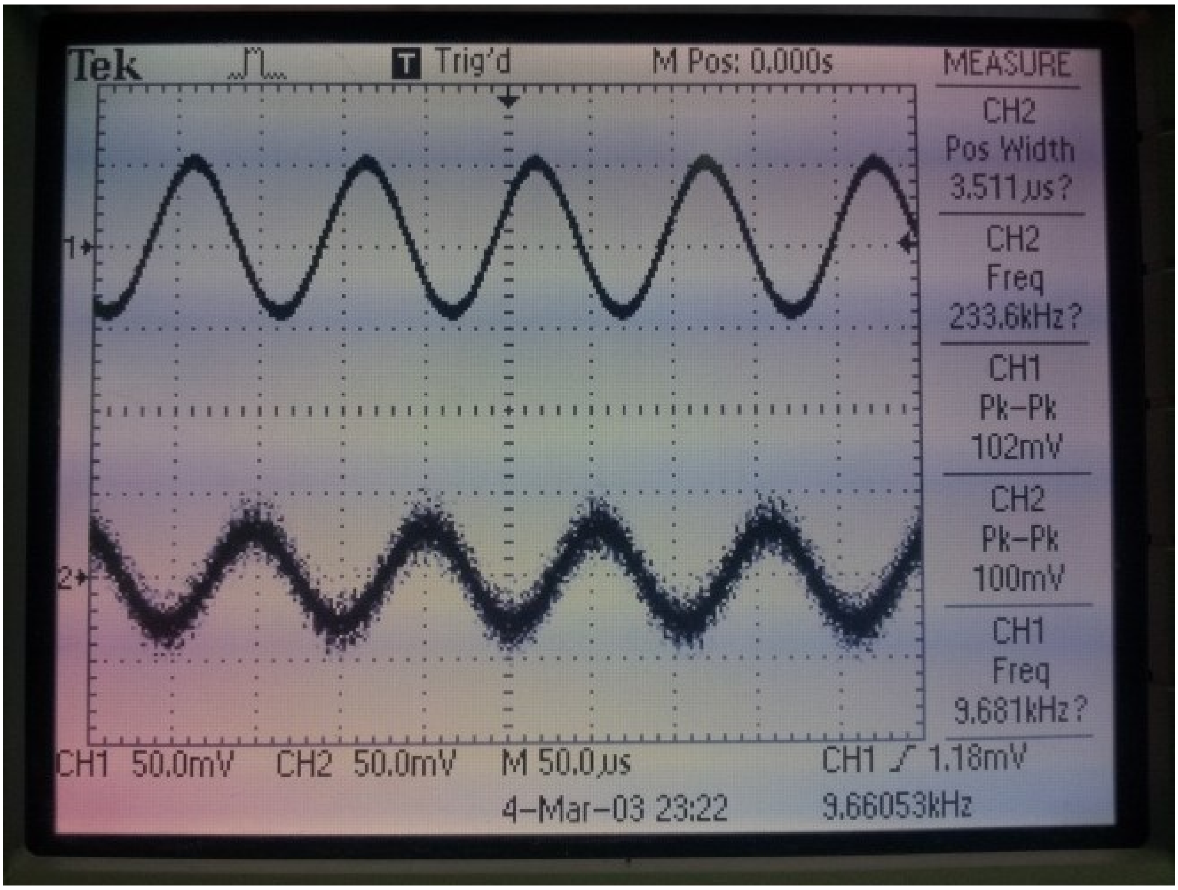
Fo = 1/(2*pi*C*sqrt(R2*R1)), R2 = 10k Ω-> R1 = 253 Ω

Let R3 = R4 = 1.2kΩ

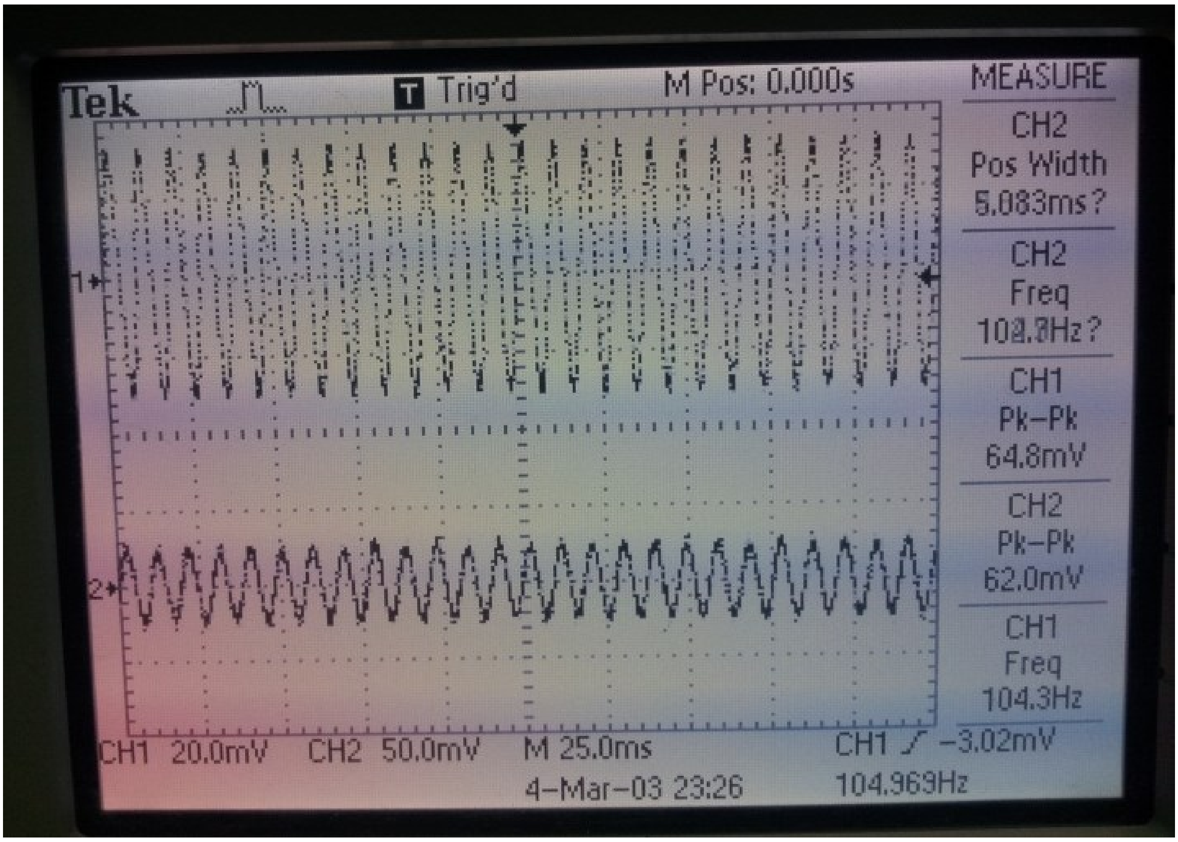
Some images from our circuit implementation in the Electronics II Lab



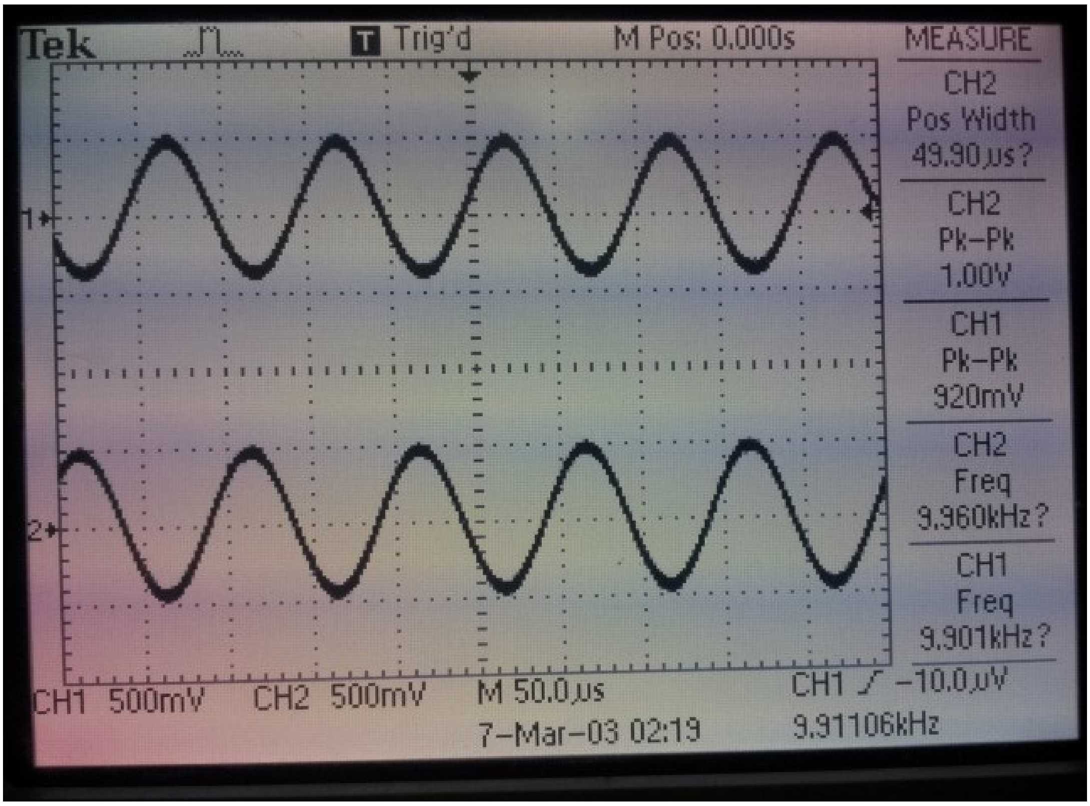
Our Circuit Design


Tek
Trig'd
M Pos: 0.000s
MEASURE
CH2
Pos Width
3.511µs?
CH2
Freq
233.6kHz?
CH1
Pk-Pk
102mV
CH2
Pk-Pk
100mV
CH1
Freq
9.681kHz?
CH1 50.0mV CH2 50.0mV M 50.0µs CH1 ⁄ 1.18mV
4-Mar-03 23:22 9.66053kHz

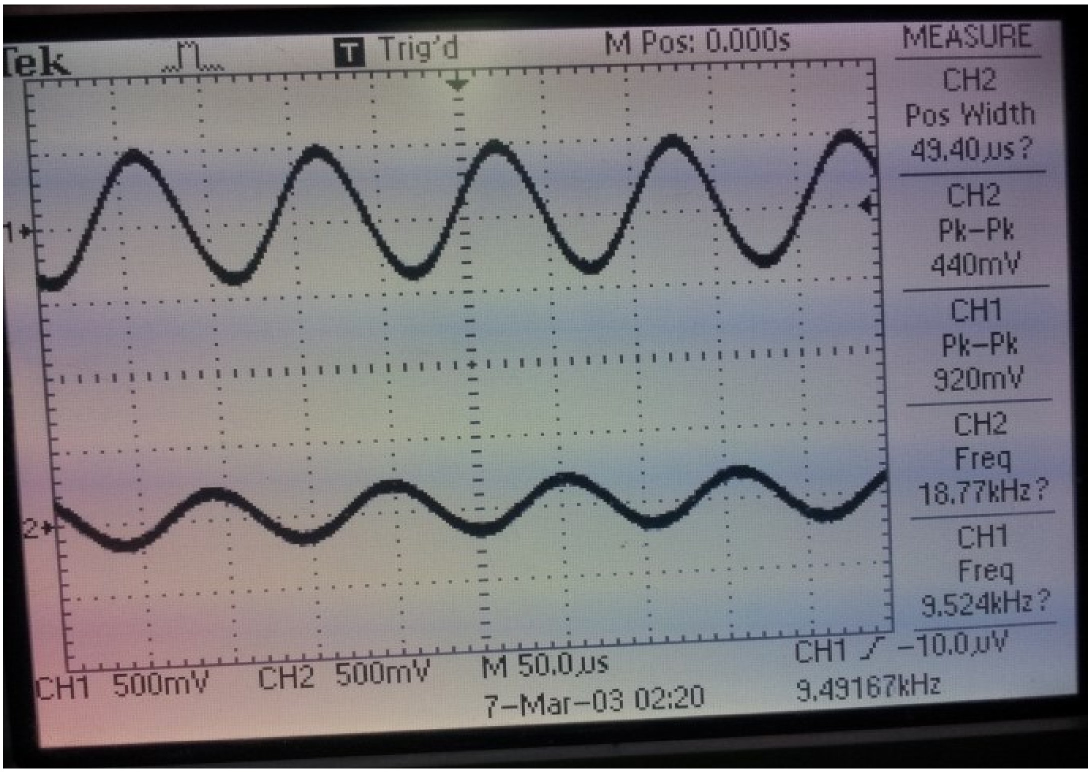
Band Pass


Tek
Trig'd
M Pos: 0.000s
MEASURE
CH2
Pos Width
5.083ms?
CH2
Freq
CH1
Pk-Pk
64.8mV
CH2
Pk-Pk
62.0mV
CH1
Freq
104.3Hz
CH1 20.0mV CH2 50.0mV M 25.0ms CH1 ⁄ -3.02mV
4-Mar-03 23:26 104.969Hz

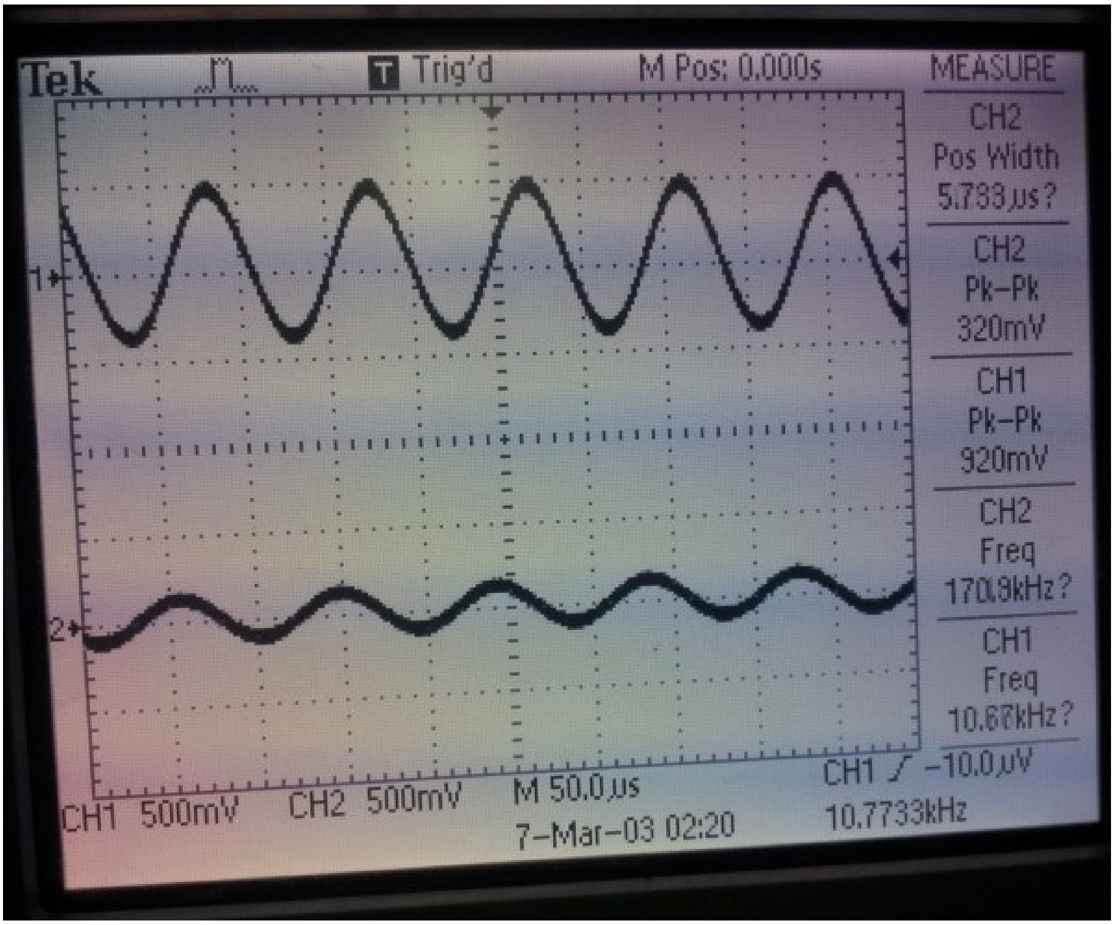
The Output after Switched Capacitor



Pass Band



At lower Frequency (High Pass Filter)



At Higher Frequency (Low Pass Filter)

Our Results for Part II

With the switched capacitor our Fo = 9.9 kHz. BW = 1.3 K -> Q = 7.6
This is because the impedance of the switched capacitor was much lower than the Rg.

Conclusion

Overall, after completing our project in Electronics II (ELE341), we were able to utilize Pspice programming to analyze and design electronic circuits. Moreover, we also were able to design several circuits such as "Switched Capacitor Active Band-pass Filter" circuit where through each part of this project, we implemented one part of the whole project circuit, and we verified our results by Mr. Madathumpadical Narayanan, our Electronics II Lab instructor. Furthermore, in this project, we applied the team skills where we divided the work between ourselves in order to do the required task in less possible time. Ultimately, this project is one of the most important applications in the electronics area where we can applied our gained skills from this project in designing and implementing any electronic circuit in the future.