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Section-02

EEE202 CIRCUIT THEORY LAB5 REPORT

Purpose:

Objective of this experiment is to design a band-pass filter according to the given specifications for a 50Ω load resistance.

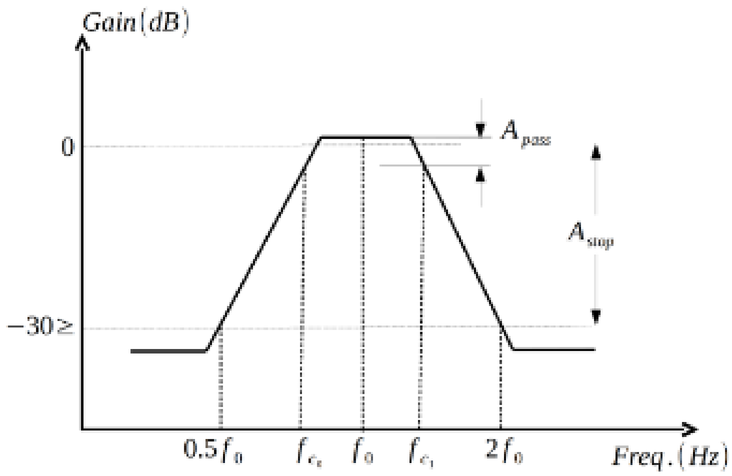


Fig1.1 AC analysis of the desired band pass filter

Central frequency: $3Mhz \leq f_0 \leq 6Mhz$

Passband width: $f_{c_1} - f_{c_0} = 0.05 f_0$

Gain variation in the passband: $A_{pass} \leq 3dB$

Stopband attenuation: $A_{stop} \geq 30dB$

Fig1.2 desired specifications for the band pass filter

Methadology:

The central frequency of the bandpass-filter is selected as 4MHz and the 3-dB bandwith equals to:

$$\Delta f = 0.05 * 4MHz = 200kHz$$

In order to obtain the desired band-pass filter, second order butterworth filter will be used.The order of filter is selected for the most optimal effiency.The design of the band-pass filter consists of two steps.At first a second order low pass filter (LPF) is designed and in the continuing step inductor and capacitor values, that are attached to LPS, are calculated.

First Step:

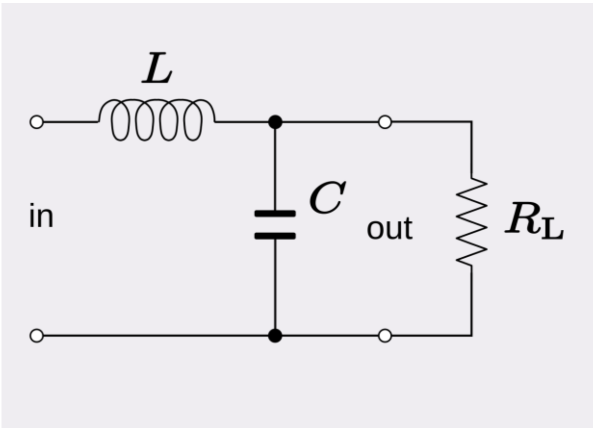


Fig2.1 second order LPF

The capacitance and inductance values of butterworth LPF can be calculated as following.

$$L_1 = \frac{a_1 * R_L}{2\pi * \Delta f}$$

$$C_2 = \frac{a_2}{2\pi * \Delta f * R_L}$$

The 3-Db cutoff frequency of this LPF should be equal to Δf and constants a_1, a_2 can be found by looking at the “Prototype Element Values in Butterworth LPF” table.

TABLE 8.3 Element Values for Maximally Flat Low-Pass Filter Prototypes ($g_0 = 1$, $\omega_c = 1$, $N = 1$ to 10)

N	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}	g_{11}
1	2.0000	1.0000									
2	1.4142	1.4142	1.0000								
3	1.0000	2.0000	1.0000	1.0000							
4	0.7654	1.8478	1.8478	0.7654	1.0000						
5	0.6180	1.6180	2.0000	1.6180	0.6180	1.0000					
6	0.5176	1.4142	1.9318	1.9318	1.4142	0.5176	1.0000				
7	0.4450	1.2470	1.8019	2.0000	1.8019	1.2470	0.4450	1.0000			
8	0.3902	1.1111	1.6629	1.9615	1.9615	1.6629	1.1111	0.3902	1.0000		
9	0.3473	1.0000	1.5321	1.8794	2.0000	1.8794	1.5321	1.0000	0.3473	1.0000	
10	0.3129	0.9080	1.4142	1.7820	1.9754	1.9754	1.7820	1.4142	0.9080	0.3129	1.0000

Fig2.2 Prototype Element Values in Butterworth LPF

a_2, a_1 are selected as 1.4142, Δf=200kHz, $R_L = 50\Omega$.Substituting the values:

$$L_1 = \frac{1.4142 * 50}{2\pi * 200 * 10^3}$$

$$L_1 = 56.27\mu H$$

$$C_2 = \frac{1.4142}{2\pi * 200 * 10^3 * 50}$$

$$C_2 = 22.51nF$$

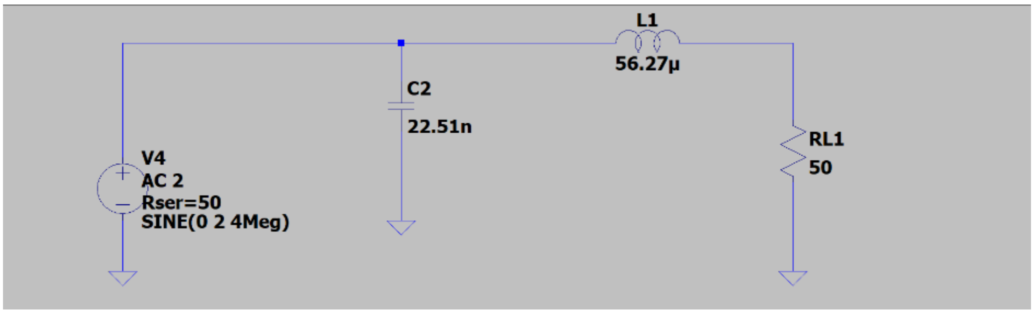


Fig2.3 designed LPF

Second Step:

In this step, second order butterworth filter is obtained by adding parallel connected matching inductor and capacitor.The added inductor and capacitor should be cancelling previous inductor and capacitors at 4MHz in order to obtain 0db gain at center frequency.The inductor (L_2) is connected parallel with C_2 and the capacitor $C_1$is connected series with L_1.

$$L_2 = \frac{1}{(2\pi f_0)^2 * C_2}$$

$$L_2 = \frac{1}{(2\pi * 4 * 10^6)^2 * 22.51 * 10^{-9}}$$

$$L_2 = 70.34nH$$

$$C_1 = \frac{1}{(2\pi f_0)^2 * L_1}$$

$$C_1 = \frac{1}{(2\pi * 4 * 10^6)^2 * 56.27 * 10^{-6}}$$

$$C_1 = 28.13pF$$

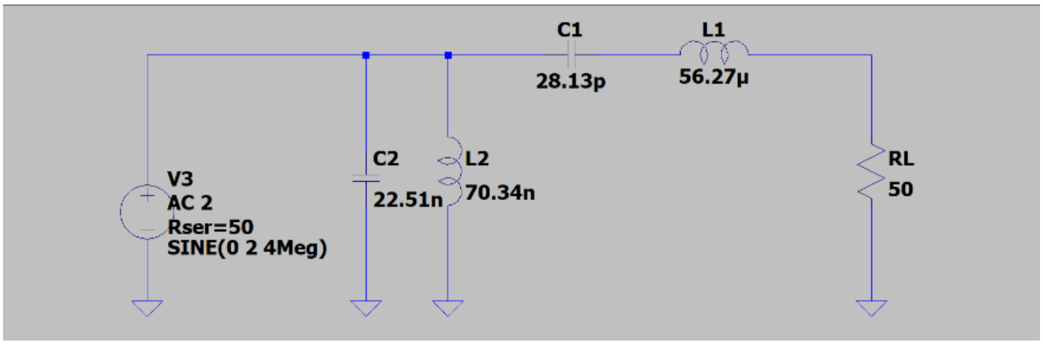


Fig3.1 designed second order butterworth filter

The circuit is completed and ready to be tested in software.

Software Results:

At first, the 3-dB cutoff frequency of designed LPF is tested. $f_c = \Delta f = 200\text{kHz}$

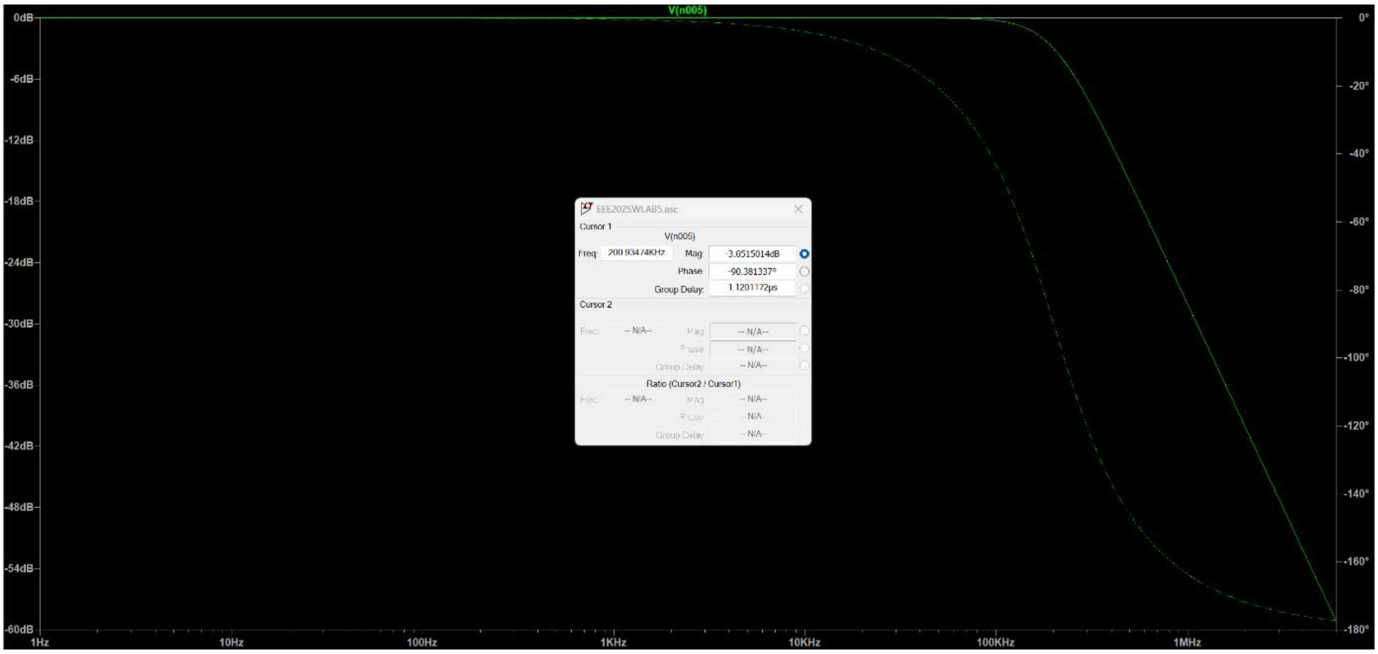


Fig4.1 simulation result of LPF

As it can be seen, at -3.05db the frequency equals to 200.93kHz, the LPF Works porperly.Now simulation result of butterworth filter will be investigated.

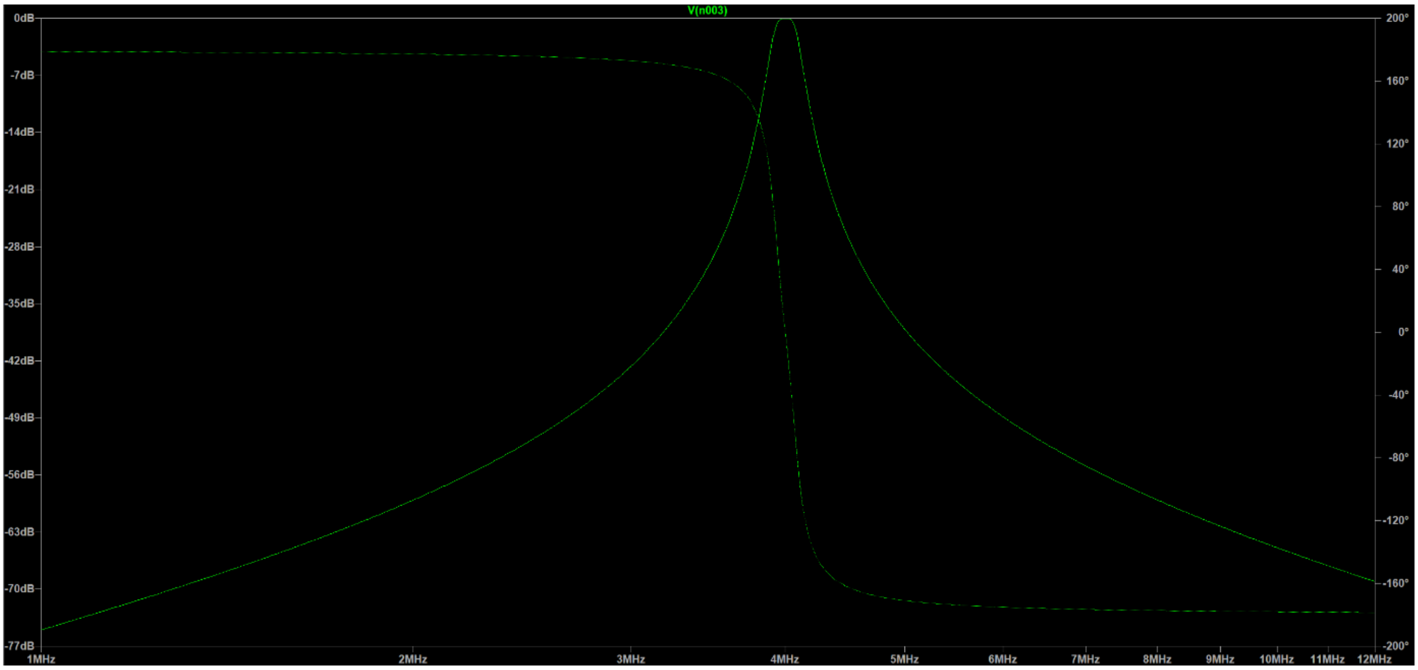


Fig4.2 AC analysis of butterworth filter at output

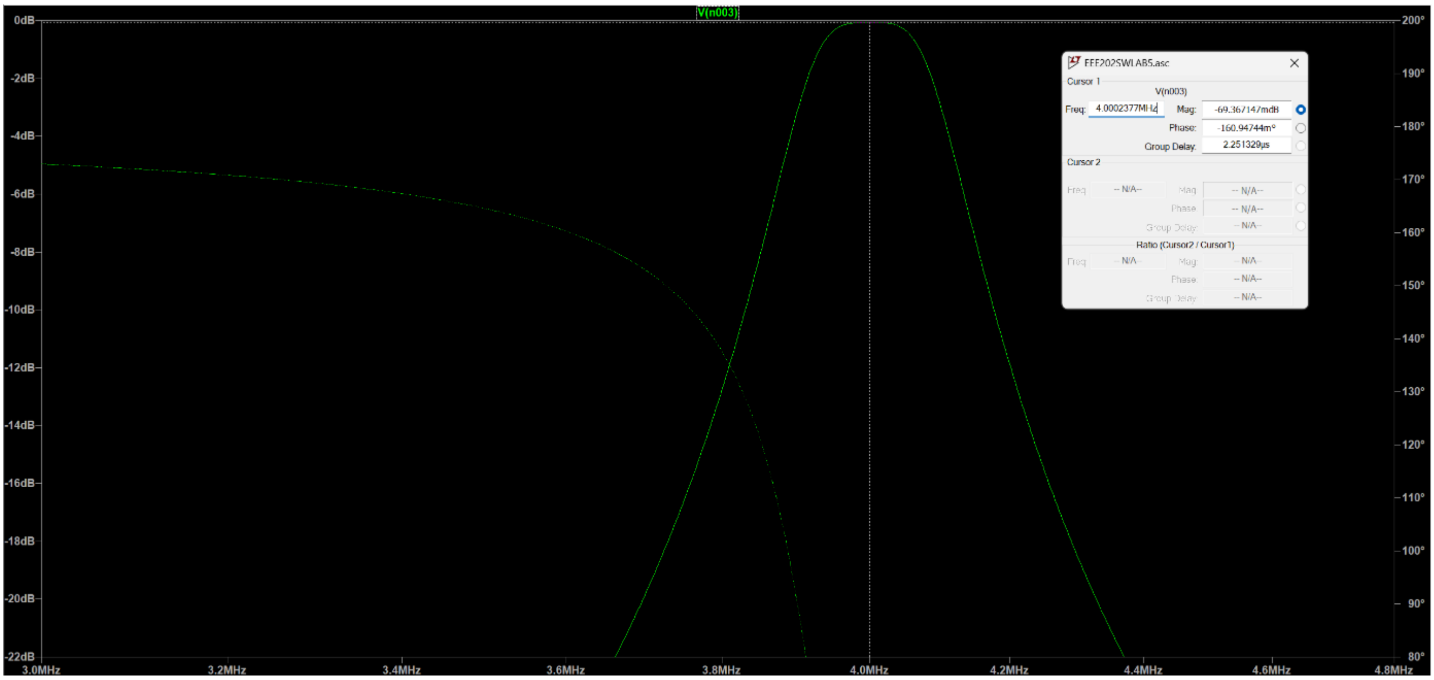


Fig4.3 demonstration of center frequency as 4.0MHz

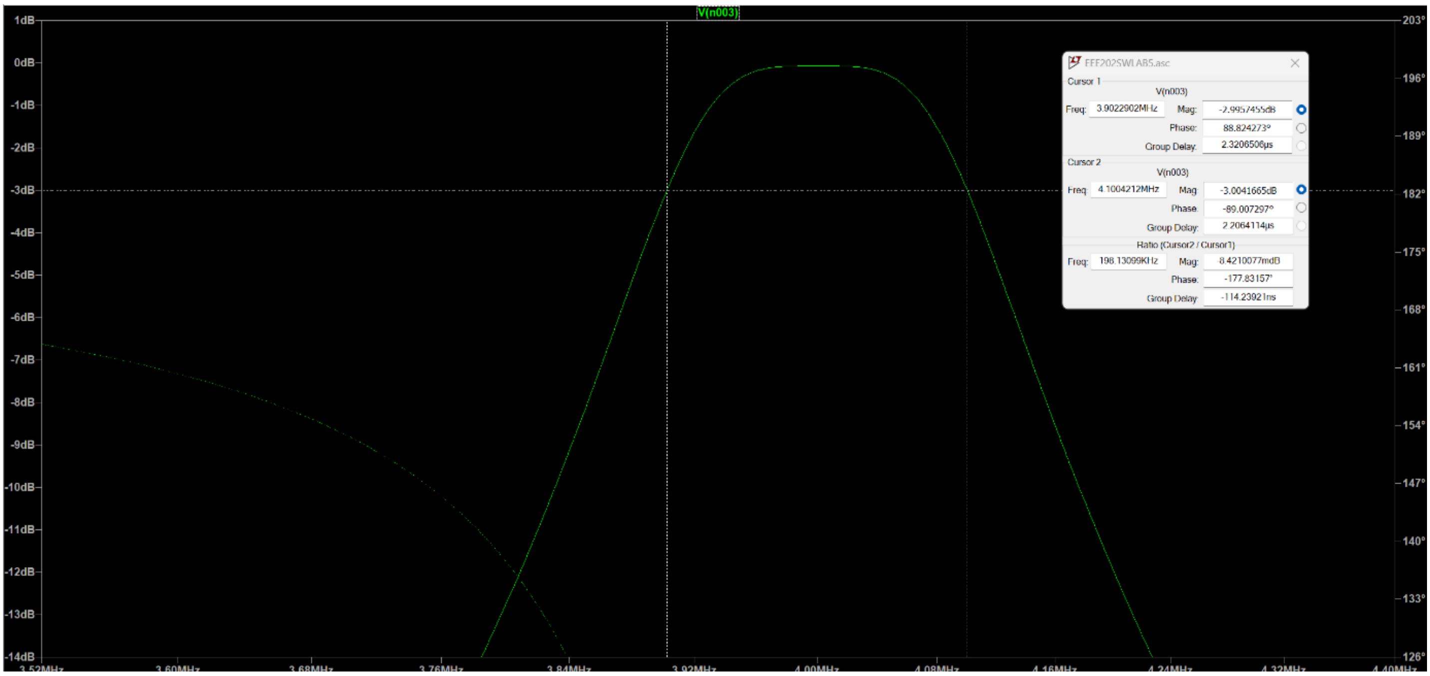


Fig4.4 demonstration of bandwidth

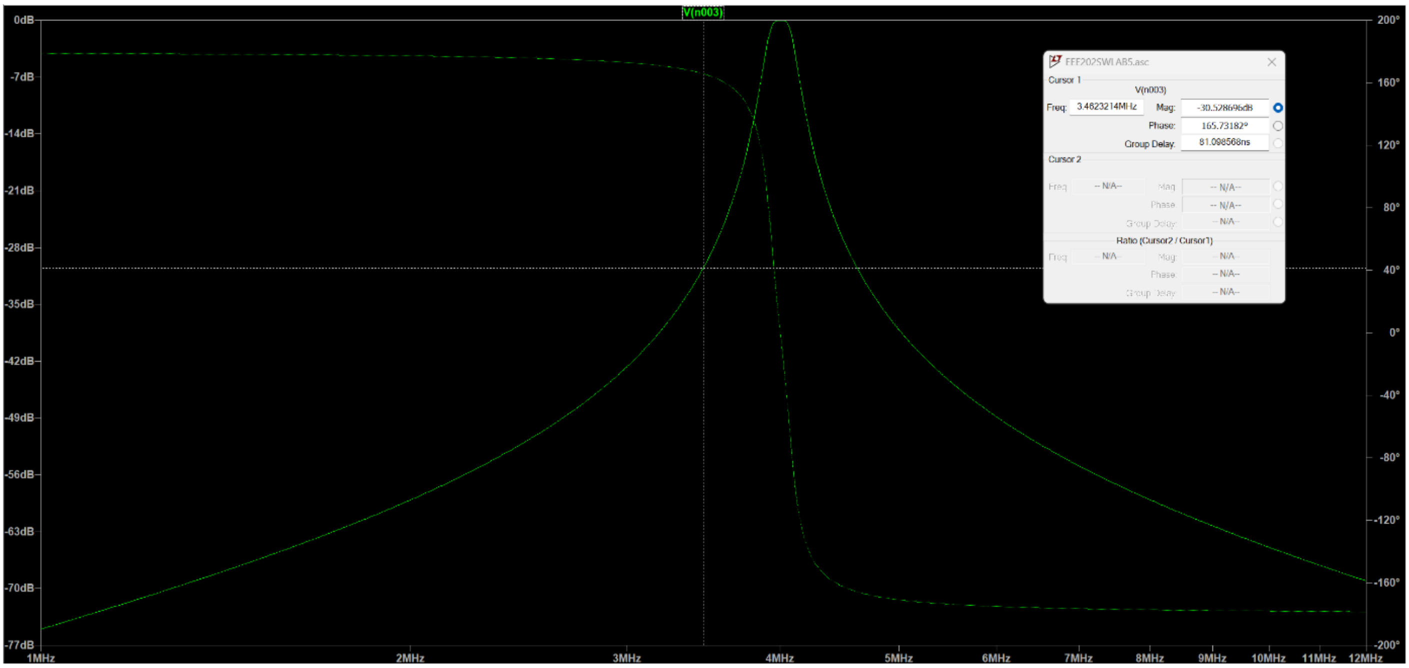


Fig4.5 demonstration of stop band < -30dB

The central frequency is 4.0MHz, bandwidth is 200kHz,stop band is less than -30db,gain variation do not exceed 3db.The designed second order butterworth filter meets every requirement for the desired band pass filter.So, the filter Works properly and ready to be implemented in hardware part.

Hardware Results:

In this part components are implemented on breadbord.Later on a frequency gain graph is drawn by observing 10 points 350kHz apart and f_{c1}, f_{c2}, f_0.

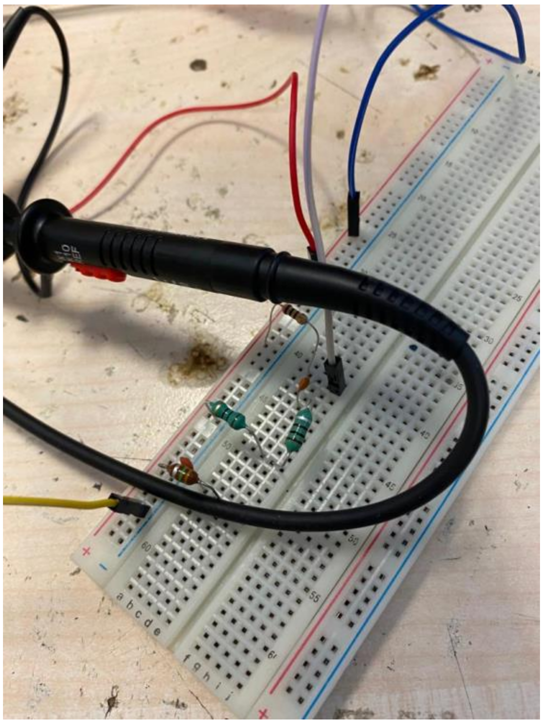


Fig5.1 hardware implementation

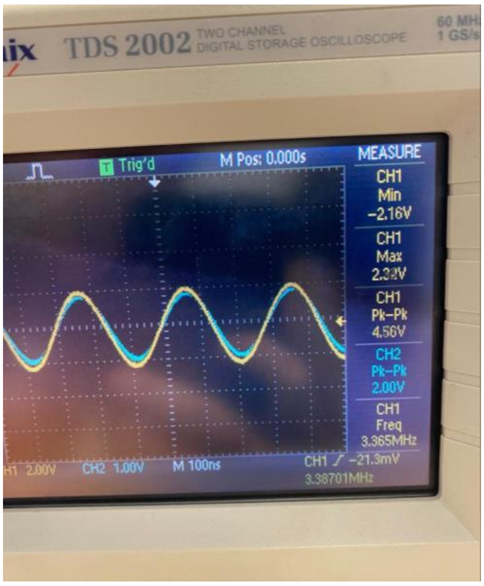


Fig5.2 voltage at central frequency (f_0)

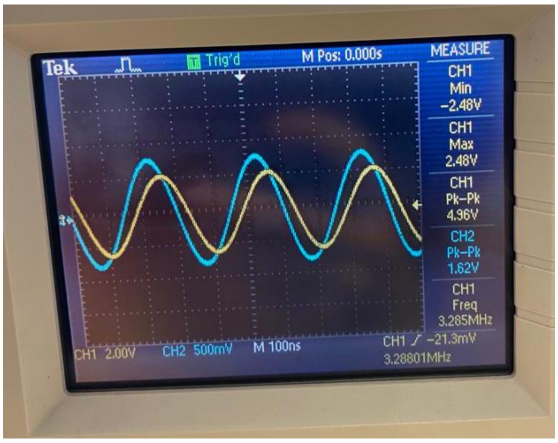


Fig 5.3 first cutoff frequency (f_{c1})

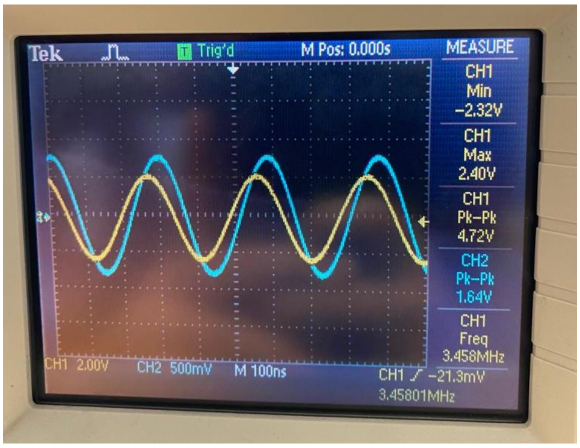


Fig5.4 second cutoff frequency (f_{c2})

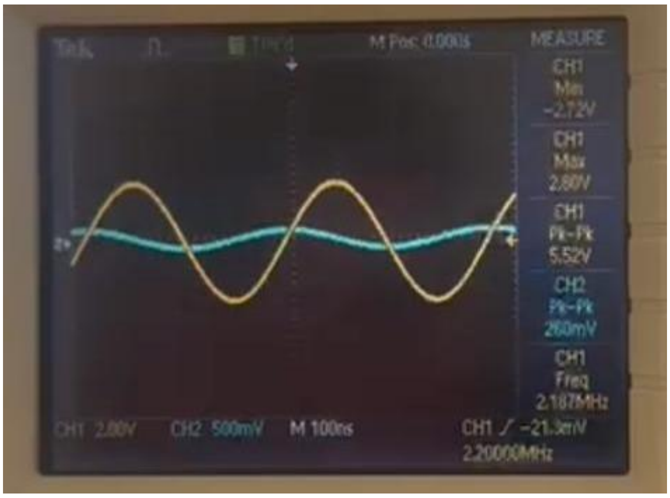


Fig5.5 input-output at 2.20MHz

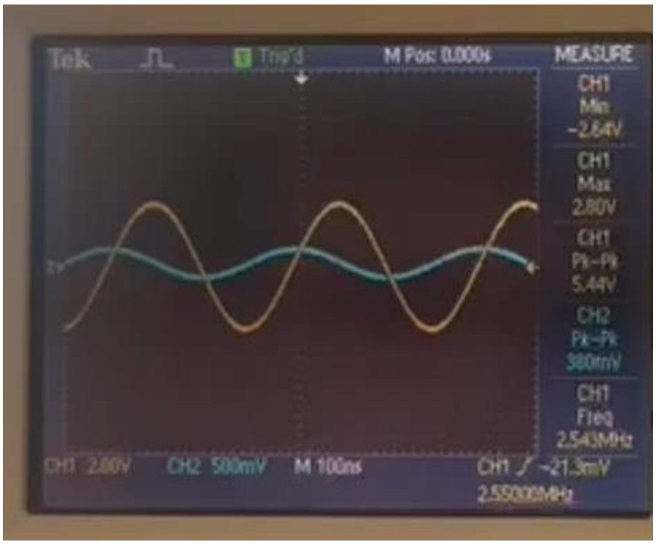


Fig5.6 5 input-output at 2.55MHz

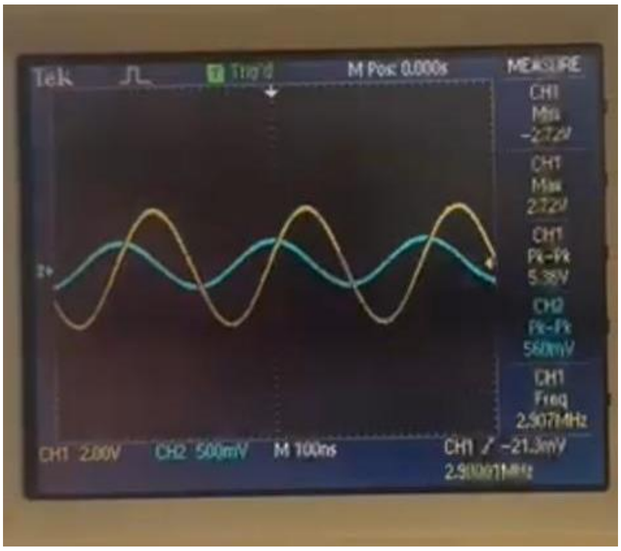


Fig5.7 5 input-output at 2.90MHz

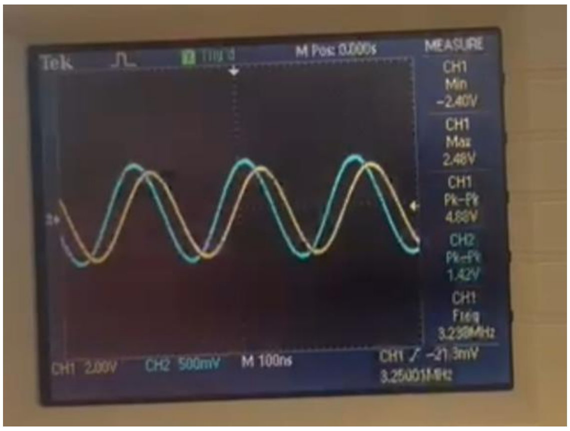


Fig5. 5 input-output at 3.25MHz

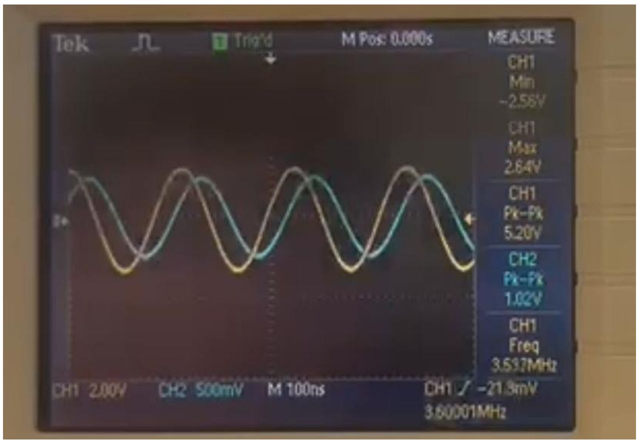


Fig5.9 5 input-output at 3.60MHz

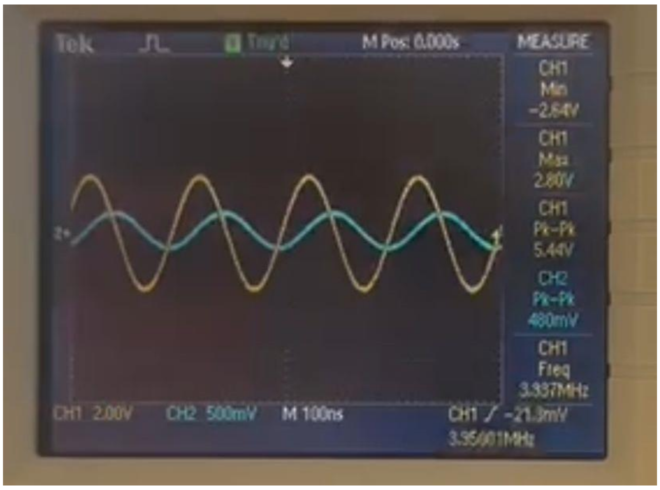


Fig5.10 5 input-output at 3.95MHz

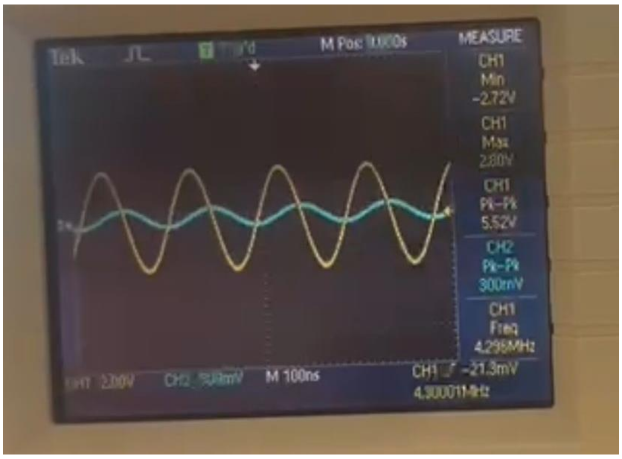


Fig5.11 5 input-output at 4.30MHz

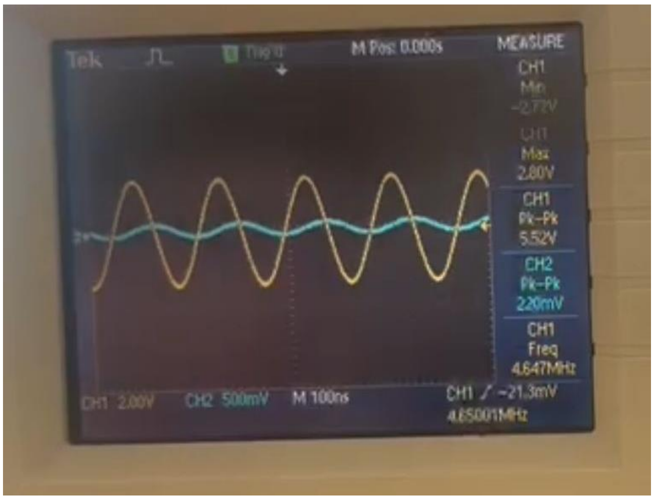


Fig5.12 5 input-output at 4.650MHz

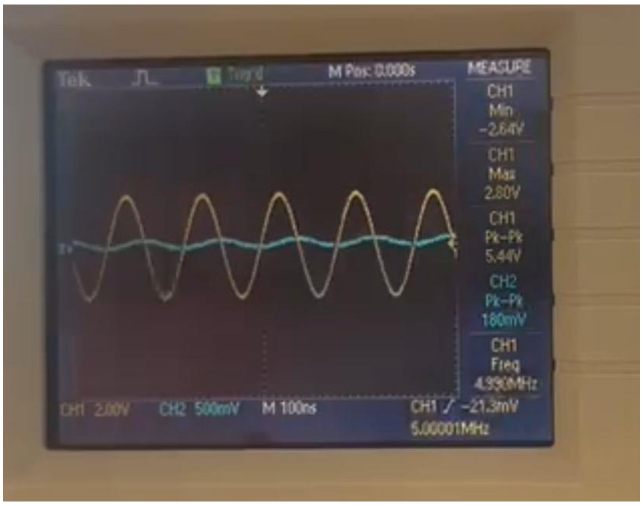


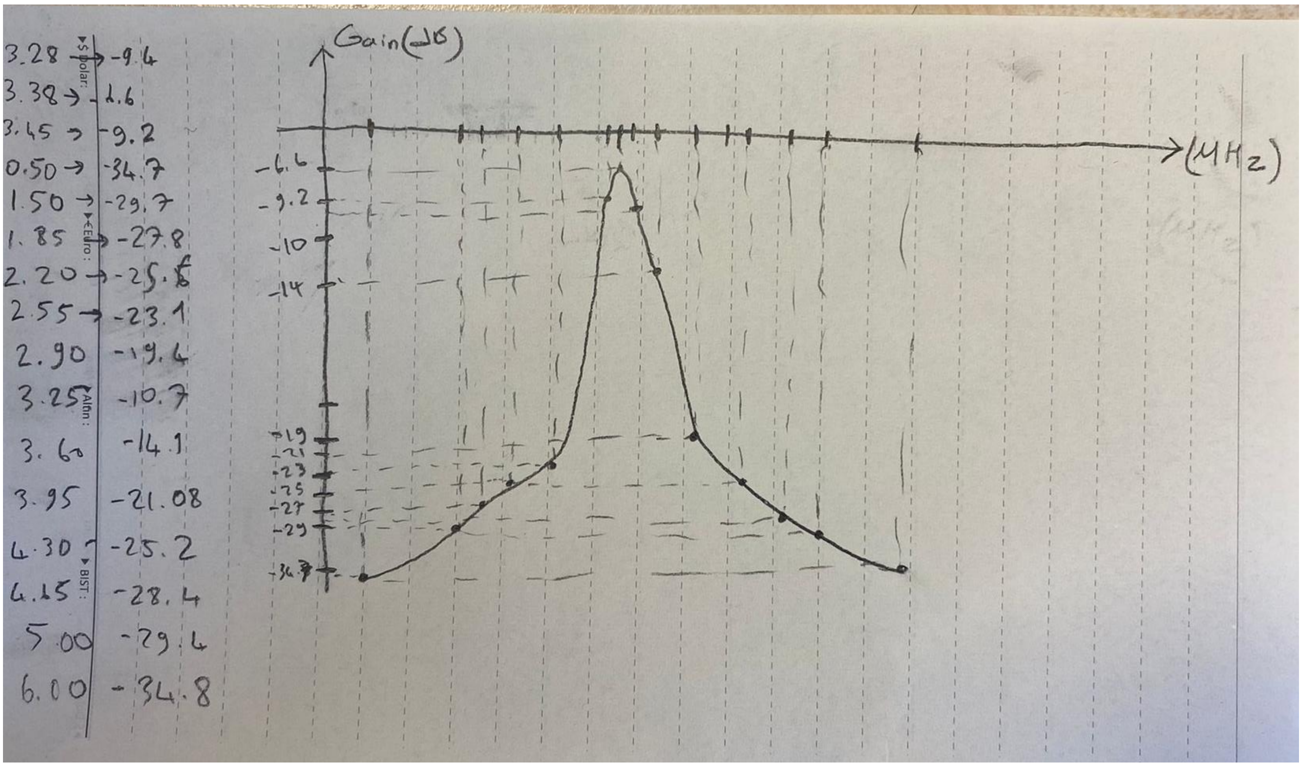
Fig5.13 5 input-output at 5.0MHz

Frequency(MHz)	Gain(dB)
2.20	-25.6
2.55	-23.1
2.90	-19.4
3.25	-10.7
3.28	-9.4
3.36	-6.6
3.45	-9.4
3.60	-14.1
3.95	-21.0
4.30	-25.2
4.65	-28.4
5.00	-29.4

Table1 hardware gain results

	Desired	Hardware	Error(%)
f_0	4MHz	3.38MHz	15.5
Δf	200kHz	170kHz	15

Table2 bandwith and central frequency error



Plot1 frequency-gain graph according to hardware results

All of the results are within the tolarated error range for the hardware lab (%20).The implementation and design can be considered as successful.

Conclusion:

This lab assignement is useful to familiarize students with band-pass fiters and AC analysis.The desired band pass filter is designed by using second order butterworthfilter in order to have the most efficient circuit.At first a second order LPF is designed and later on one inductor and one capacitor is added to resonate the circuit at central frequency in order to obtain highest gain at the central frequency.The software and hardware implemtations can be considered as successful since the results are in the tolarated error range.The slight differences are the consequences of uncertainity of occilloscope and signal generater, obtaining the theoratical inductance value by using two inductors in hardware lab,small internal resistance of jumper and crocodile cables and human errors.