جامعة الأمير مقرن بن عبد العزيز
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Electrical Engineering Department

Project of Electric Circuits II (EE 202)

"Passive Band Pass Filter"

Supervised by

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Content

I. Introduction

Objectives

- Constructing a working Band Pass Filter circuit.
- Applying the knowledge that we have gained in our Electric Circuit 2 course.
- Demonstrating the theory and the experiment.
- Being creative in implementation & explanation.

Theory

- **Band Pass Filter**

A bandpass filter (BPF) is a circuit that enables frequencies within a certain frequency range to pass through while rejecting (attenuating) frequencies outside that range. A bandpass filter is a combination between a low pass filter and a high pass filter.

- **The low pass filter** isolates signals with frequencies greater than the cutoff frequency.
- **The high pass filter** is used to isolate signals with frequencies lower than the cutoff frequency.

By connecting the high pass and low pass filters in a cascade, a new filter is created that allows signals with a specific frequency range or band to pass while attenuating signals with frequencies outside of this band, the **Band Pass Filter.**

There are two cutoff frequencies in the Band Pass Filter. A high pass filter provides the first cutoff frequency. This determines a band's higher frequency limit, also known as the higher cutoff frequency. The low pass filter's cutoff frequency is the second. This determines the band's lower frequency limit, also known as the lower cutoff frequency.

There are many types of bandpass filter circuits, but in our project, we just used a **series RLC bandpass filter**, which is a wide-band BPF.

- **RLC bandpass filter**

This bandpass filter contains only a resistor, inductor, and capacitor as shown in **Figure 1.**

The RLC bandpass filter can be configured in two ways based on the connection of RLC. In the first configuration, the series LC is connected to a series load resistor. In the second configuration, parallel LC that we did not use in our project.

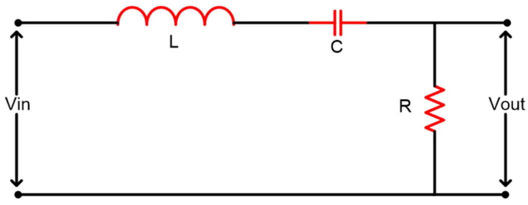

Figure 1: Circuit diagram for RLC Band Pass Filter

- **The equation for cut off frequencies 1 and 2 of the RLC bandpass filter is shown in figure 2**

$$\omega_{c1} = -\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \left(\frac{1}{LC}\right)},$$

$$\omega_{c2} = \frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \left(\frac{1}{LC}\right)}.$$

Figure 2: Series RLC band pass filter equation for Cut frequency 1 and 2

Also, we have some related parameters to the BPF circuit:

- **Band Width (β):** it is the width of the passband.

$$\beta = \omega_{c2} - \omega_{c1} \quad = \frac{R}{L}.$$

- **Center Frequency - Resonant Frequency (wₒ):** the frequency for which a circuit's transfer function is purely real.

$$\omega_o = \sqrt{\omega_{c1} \cdot \omega_{c2}} \quad \omega_o = \sqrt{\frac{1}{LC}}.$$

- **Quality Factor (Q):** it is the ratio of the center frequency to the bandwidth**.**

$$Q = \omega_o/\beta = \sqrt{\frac{L}{CR^2}}.$$

II. Circuit Design

We have assembled this circuit on a board & in a simulation. The measurements were taken in both.

Components

- Function generator (AC source).
- 1uF capacitor.
- 10mH inductor.
- 10kΩ Potentiometer (in practical) – 10kΩ variable resistor (in simulation).
- Tektronix Oscilloscope.
- Bode Plotter (in simulation only).

Execution

To be creative in this project, we used a potentiometer, which is a variable resistor. This will change the shape of the filter. When increasing the value of the resistor we will get a wider bandwidth.

We have created a schedule that represents all values for the parameter that concern us, and you can see it below:

Band Pass Filter Values								
wc1	wc2	R	L	C	fc1	fc2	w0	β
990.1951	1.01E+05	1000	0.01	1.00E-06	157.59	16073.09	1.00E+08	1.00E+05
498.7562	2.00E+05	2000	0.01	1.00E-06	79.38	31910.37	1.00E+08	2.00E+05
332.9638	3.00E+05	3000	0.01	1.00E-06	52.99	47799.48	1.00E+08	3.00E+05
249.8439	4.00E+05	4000	0.01	1.00E-06	39.76	63701.74	1.00E+08	4.00E+05
199.9201	5.00E+05	5000	0.01	1.00E-06	31.82	79609.29	1.00E+08	5.00E+05
166.6204	6.00E+05	6000	0.01	1.00E-06	26.52	95519.48	1.00E+08	6.00E+05
142.828	7.00E+05	7000	0.01	1.00E-06	22.73	111431.19	1.00E+08	7.00E+05
124.9805	8.00E+05	8000	0.01	1.00E-06	19.89	127343.85	1.00E+08	8.00E+05
111.0974	9.00E+05	9000	0.01	1.00E-06	17.68	143257.13	1.00E+08	9.00E+05
99.99	1.00E+06	10000	0.01	1.00E-06	15.91	159170.86	1.00E+08	1.00E+06

Table 1: BPF values

As you can see, whenever we increase the resistance, our bandwidth will be wider. Therefore, we can control our **β** by controlling our **R**.

In the next subsection, you can notice how the bandwidth will change in every bode plot.

❖ Simulation

After we have understood the BPF design and how it works, we have constructed our circuit in the simulation as shown in **Figure 3**. In this circuit, we had three parts, in each part we used a different value of the potentiometer, starting with 1kΩ and ending with 10kΩ.

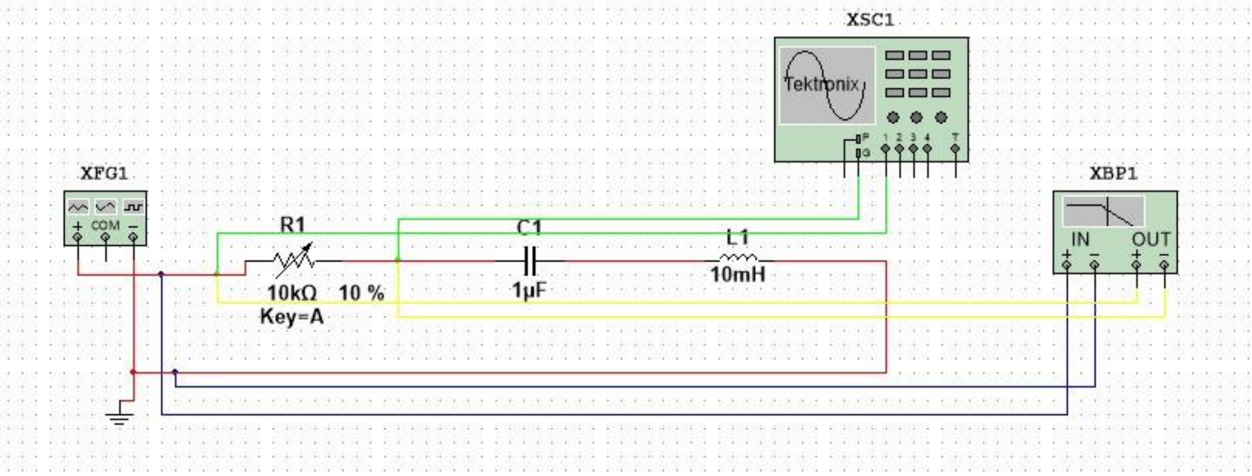

Figure 3: The BPF Circuit

➢ In the first part, in the same circuit, we used 1kΩ for the potentiometer, and we got the output and the bode plot as shown in **Figure 4**.

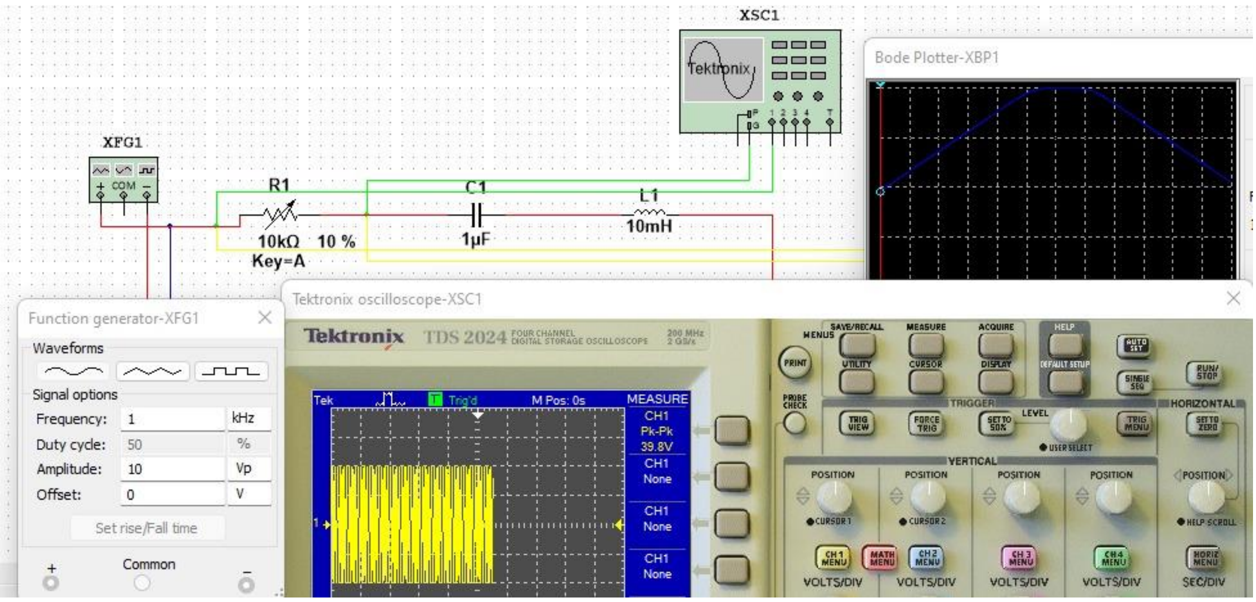

Figure 4: The Output and The Bode Plot at 1kΩ

➢ In the second part, we used 5kΩ for the potentiometer, and we got the output and the bode plot as shown in **Figure 5**.

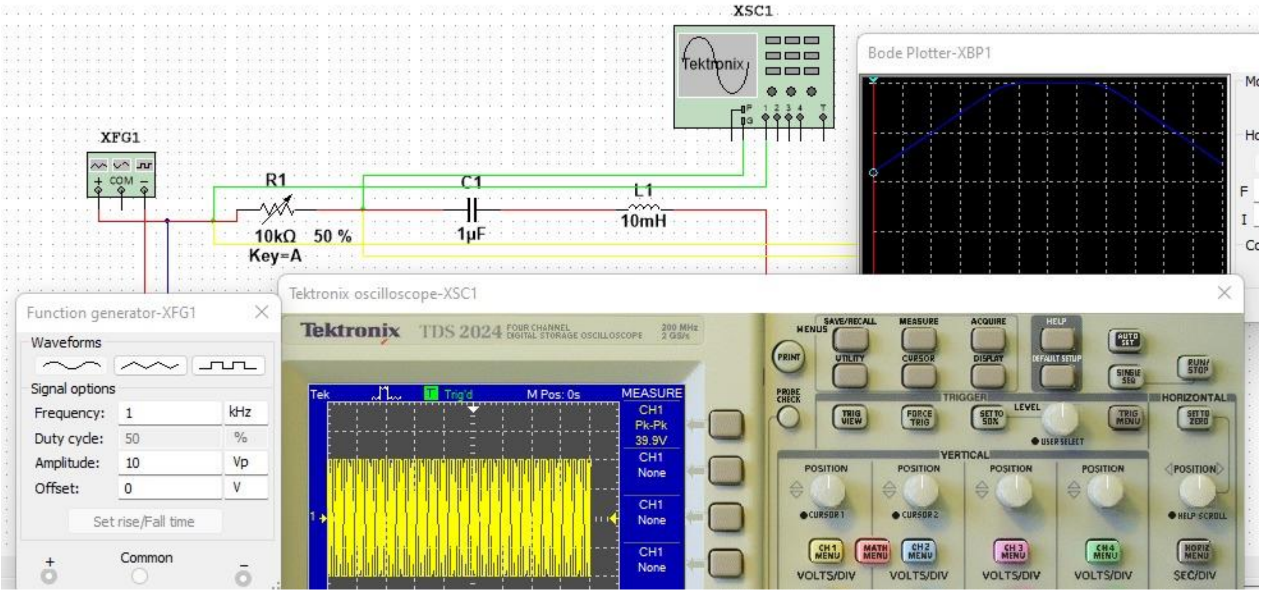

Figure 5: The Output and The Bode Plot at 5kΩ

➢ In the third part, we used 10kΩ for the potentiometer, and we got the output and the bode plot as shown in **Figure 6.**

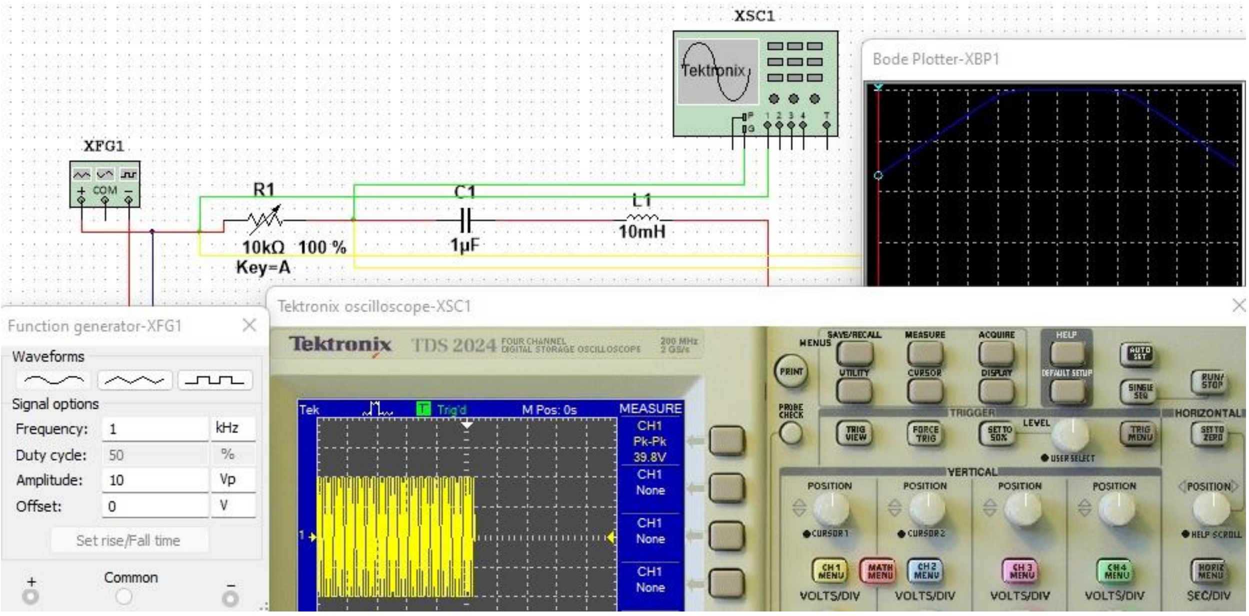

Figure 6: The Output and The Bode Plot at 10kΩ

❖ Practical

After experimenting, we became ready to assemble the circuit on the board practically, as shown in **Figures 7,8, and 9**.

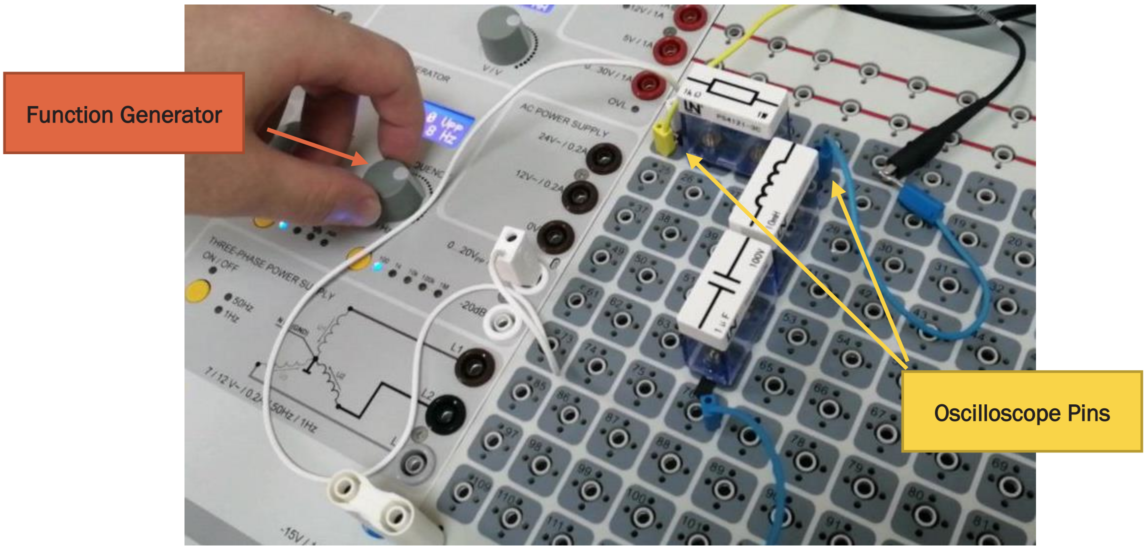

Figure 7: BPF Circuit at 1kΩ

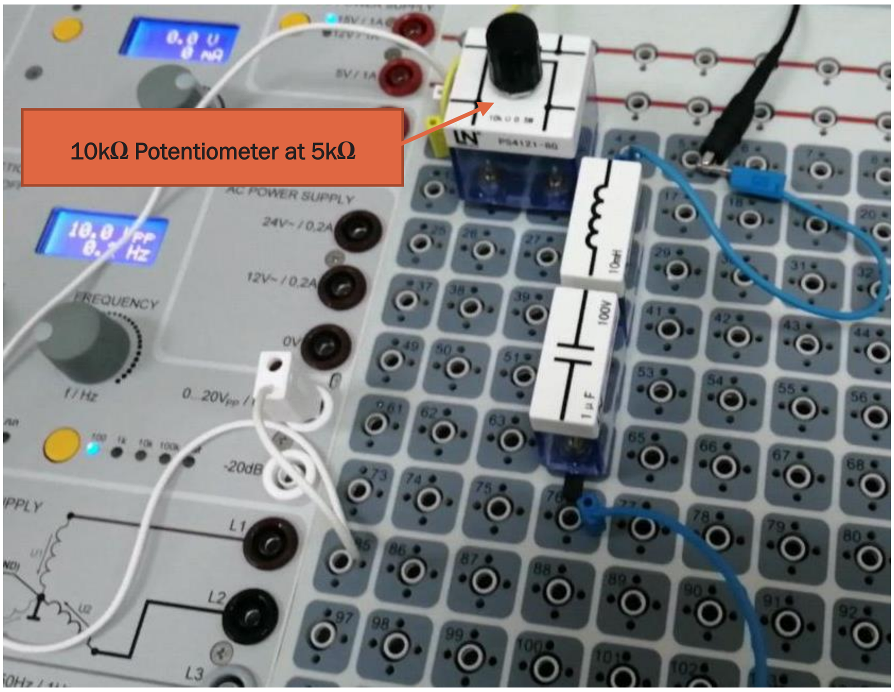

Figure 8: BPF Circuit at 5kΩ

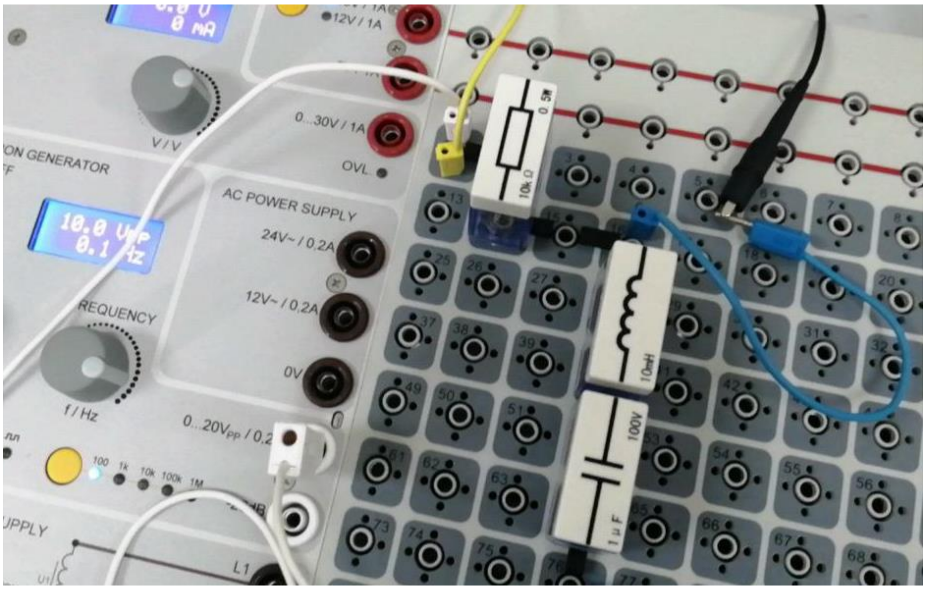

Figure 9: BPF Circuit at 10kΩ

And here is an output example:

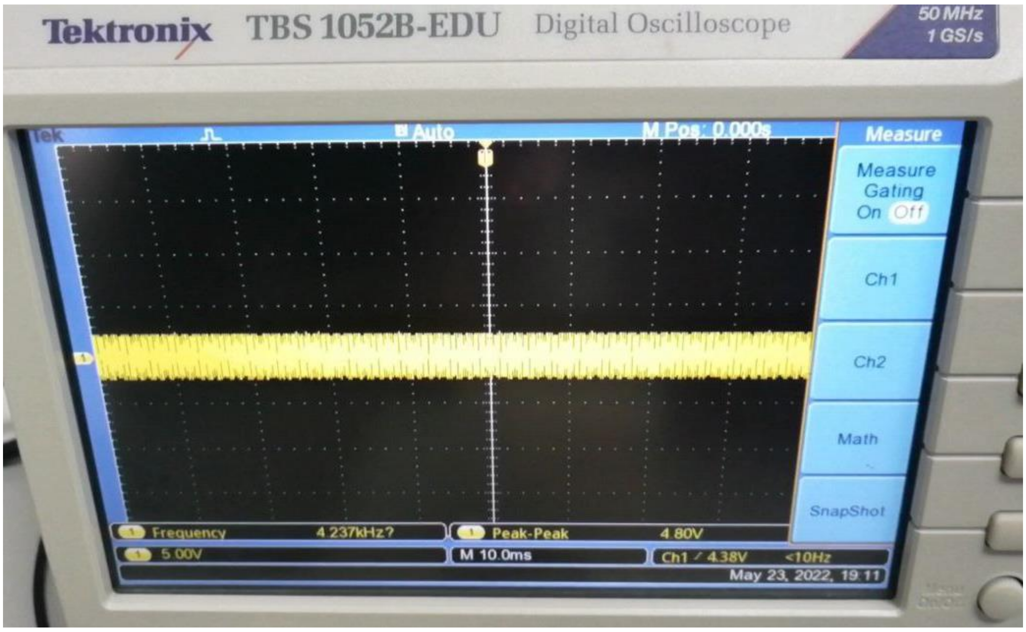

Figure 10: Oscilloscope output

III. Applications

- We can use this filter in military communication applications; to choose signals from a variety of signals.
- This filter is applicable in sonar instruments, medical, and seismology applications.
- BPF uses in the transmitter is to limit the bandwidth of the output signal to the selected band for communication. Therefore, using our circuit, we could change the bandwidth directly by changing the resistance.

IV. Conclusion

In the end, we were able to use the knowledge that we gained in our electric circuit course to construct a functioning circuit. It was clear to us that a bandpass filter is made by cascading together a single low pass filter with a high pass filter. We determined that the width of frequency depends on the values of R and C and because of that we used a potentiometer to control the bandwidth. Finally, we calculated the values of the resistor, inductor, and capacitor from the bandwidth and center frequency, and also a simulation of the RLC bandpass filter has been done.

V. References

Nilsson, James William, and Susan A. Riedel. *Electric circuits*. Pearson, 2020.

Work distribution (for the report & the video)

Mustafa Haider: Practical + written content + photography

Marwan Bitar: Practical + simulation + written content + Theory explanation

Hamza Alashi: Practical + written content + video design