Bilkent University
EE202-002 Lab 3 Report:
Maximum Power Transfer

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Purpose:

The purpose of this lab is to design at least two different passive linear circuits to transfer maximum power to 180Ω load from a voltage source with output impedance 50Ω at a frequency between 5 and 10Mhz.

Methodology:

To transfer maximum power to the load, the source impedance and the conjugate of the load impedance must be equal. When this equality is achieved, the average power in the source is equal to the average power transferred to the load and is calculated as follows:

$$I = \frac{V}{R_S + R_L}$$

$$P_A = I^2 * \frac{R_S + R_L}{2}$$

$$P_A = (\frac{V}{R_S + R_L})^2 * \frac{R_S + R_L}{2}$$

When $R_S = R_L{}^*$

$$P_A = \frac{|V|^2}{8R_S}$$

In this lab, the available average supplied power is 62.5 mW when $R_S = 50\,\Omega$ and the voltage source is 5 V sinusoidal. Circuit can be designed by using various methods such as L-section, π-section, and T-section to achieve maximum power transfer. The π-section and the T-section methods will be used in this lab.

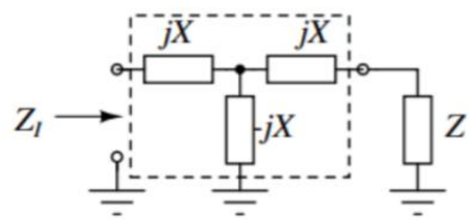

Figure 1: T-section Method

The proper capacitor and inductor values are calculated as follows:

$$X = \pm\sqrt{R_S * R_L} = \pm\sqrt{50 * 180} = \pm 94.8$$

When the frequency is 7.5 MHz and $X = -94.8$:

$$-jX = \frac{-j}{2\pi f C}$$

$$C = \frac{1}{2\pi f X} = \frac{1}{2\pi * 7.5 * 10^6 * 94.8}$$

$$C = 223.8\,pF \cong 220\,pF$$

$$jX = j2\pi f L$$

$$L = \frac{X}{2\pi f} = \frac{94.8}{2\pi * 7.5 * 10^6}$$

$$L = 2.01\,\mu H \cong 2\,\mu H$$

Software Lab

1- The π -Section Method

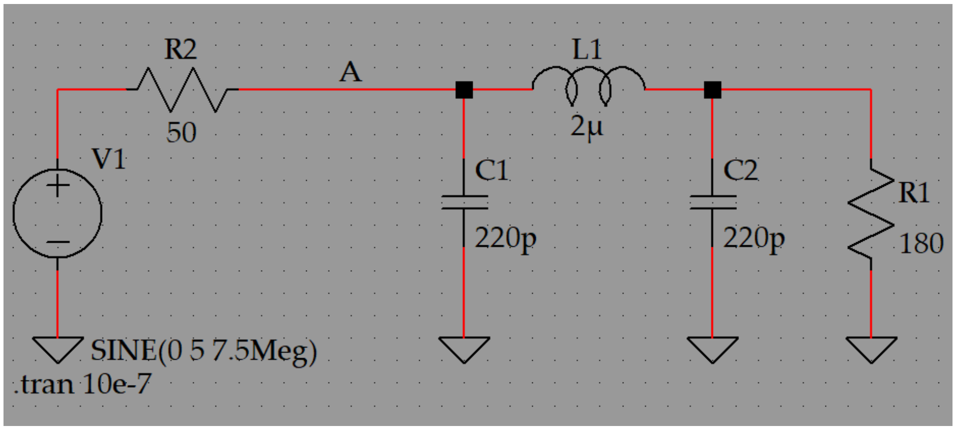

Figure 2: π -section Circuit

1- Results

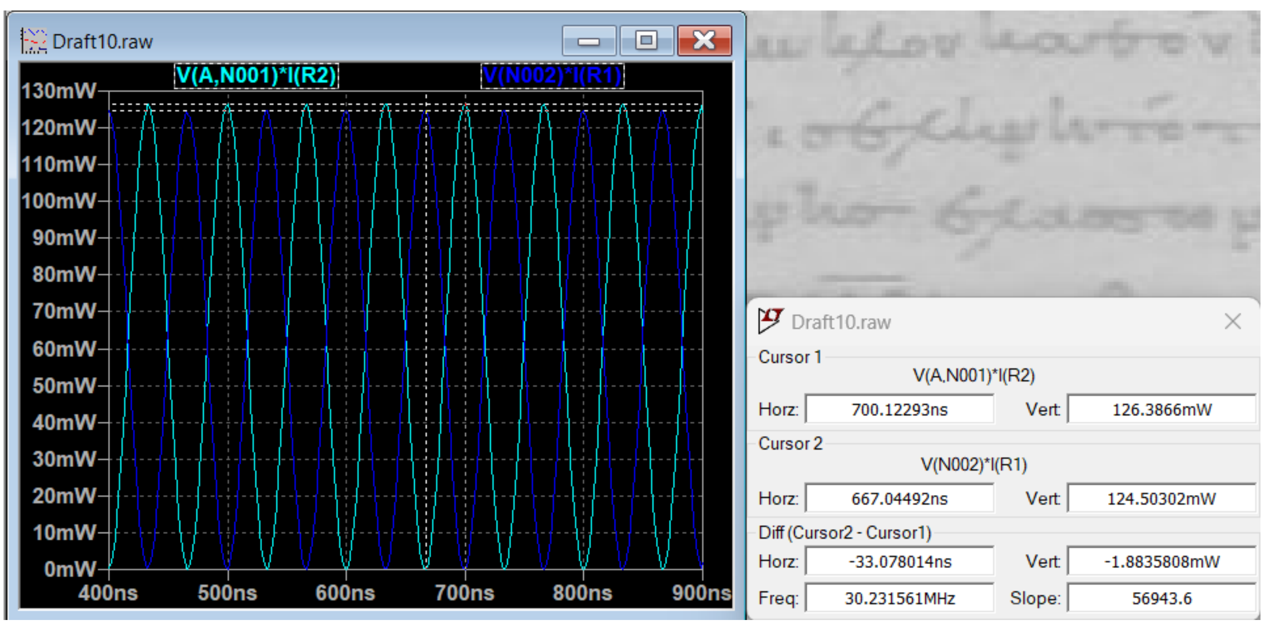

Figure 3: Power Plot of π -section

The maximum available average power is 62.5 mW, the supplied average power at the source is 63.19 mW, and the average power delivered to the load is 62,25 mW. The error is 1.49 %, and the transfer ratio is 98.51 %.

2- The T-Section Method

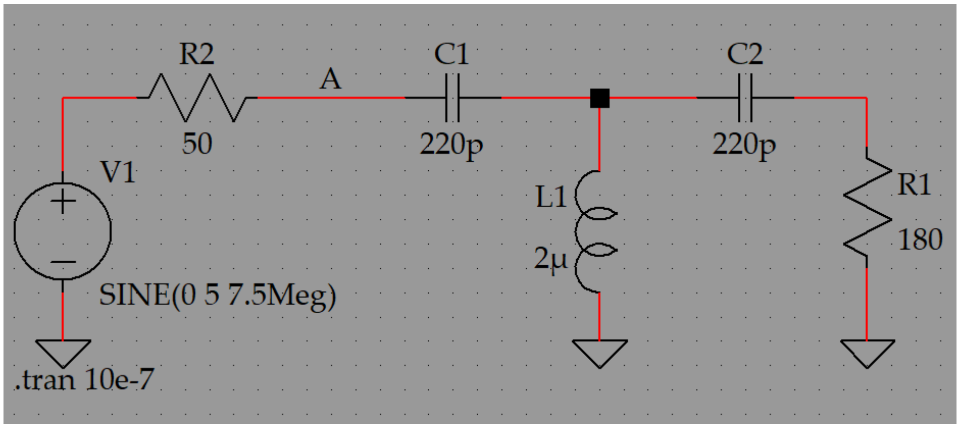

Figure 4: T -section Circuit

2- Results

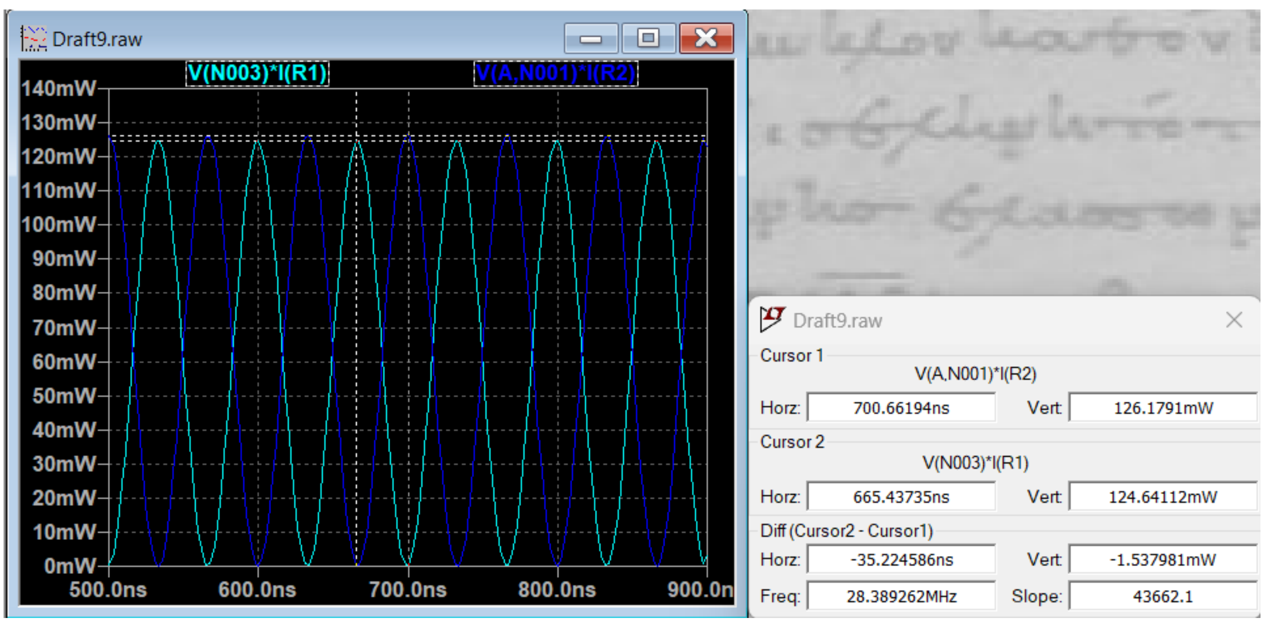

Figure 5: Power Plot of T -section

The maximum available average power is 62.5 mW, the supplied average power at the source is 63.09 mW, and the average power delivered to the load is 62,32 mW. The error is 1.22 %, and the transfer ratio is 98.78 %.

3- Without Matching Circuit

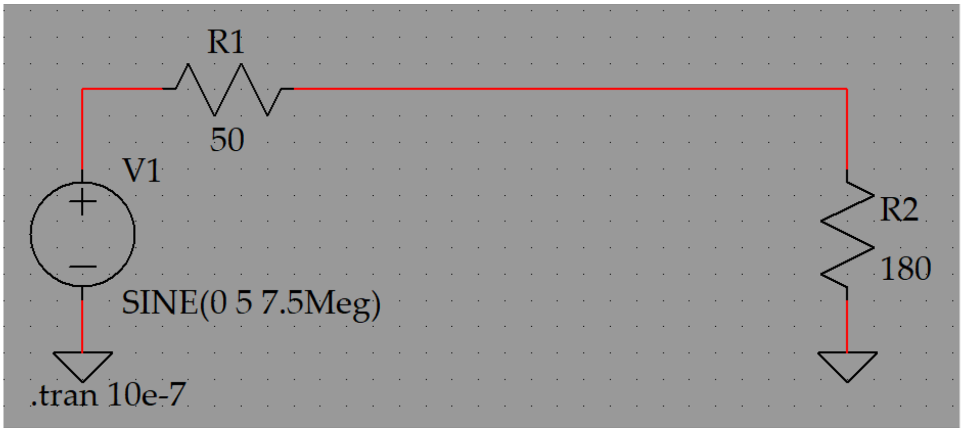

Figure 6: Circuit without matching Part

3- Results

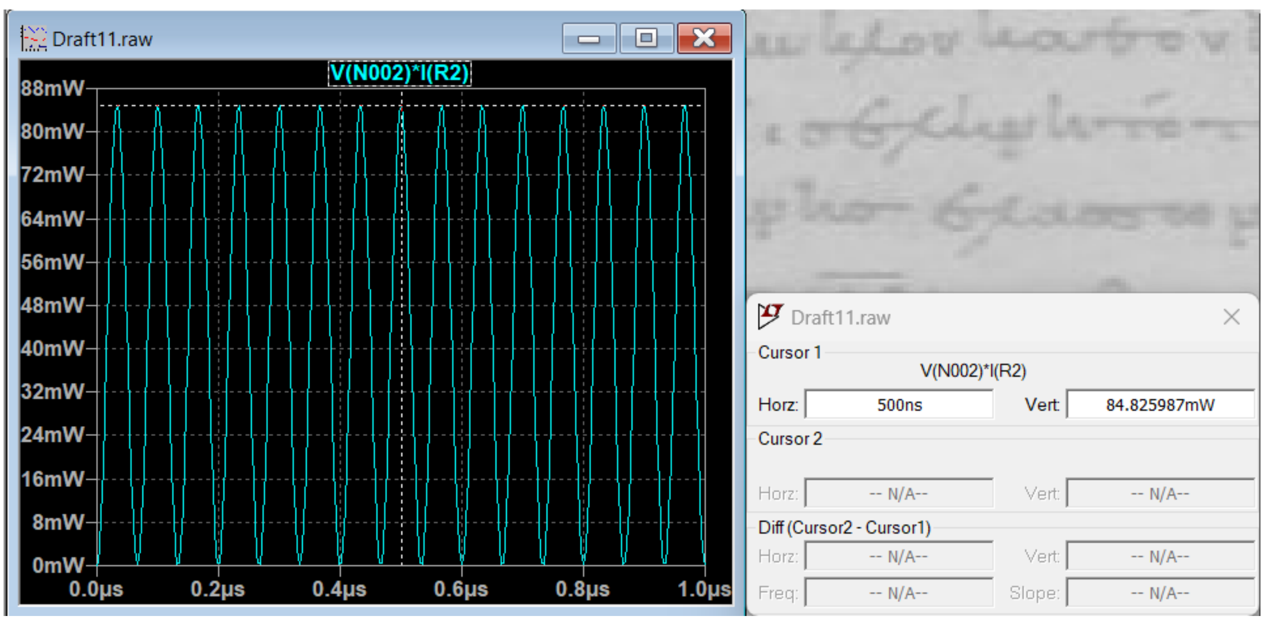

Figure 7: Power Plot of the Circuit without matching Part

The supplied average power at the source is 63.05 mW, and the average power delivered to the load is 42,43 mW. When the circuits with and without matching circuits are compared, it is seen that the power transferred to the load has increased significantly. As can be understood from here, the matching circuits designed can be used for maximum power transfer.

Hardware Lab

A 47 Ω resistor was connected to the signal generator to find the maximum power that could be transferred, and the voltage value on load was measured as 2.48 V from the oscilloscope.

$$P_A = \frac{V^2}{2R_S}$$

When the above formula is used, the maximum power that can be transferred and the supplied power were calculated as 65.43 mW.

1- The π -Section Method

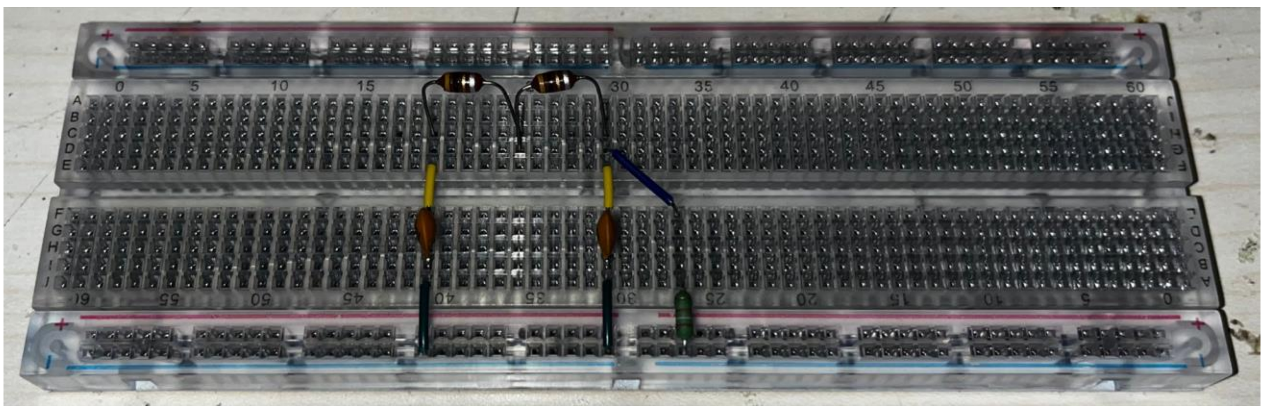

Figure 8: π -section Circuit

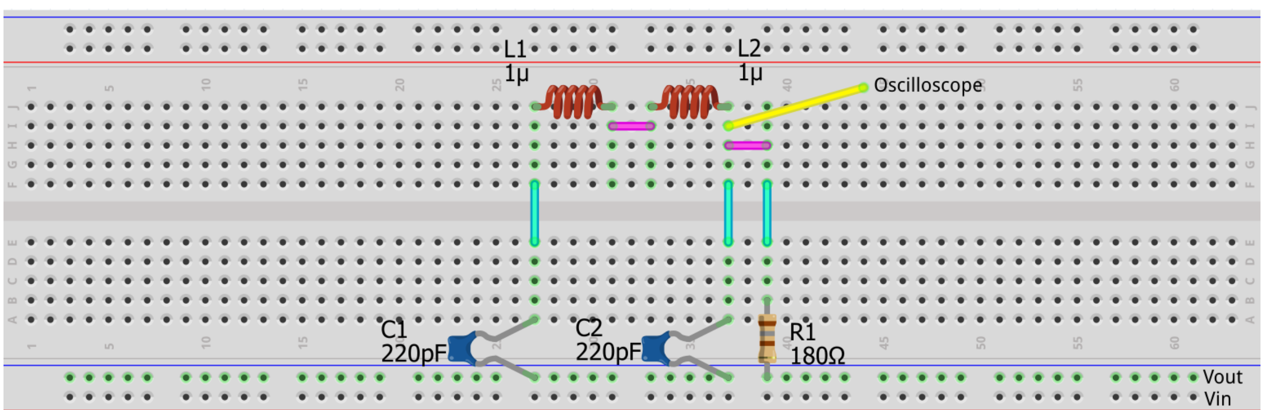

Figure 9: Schematics of the π -section Circuit

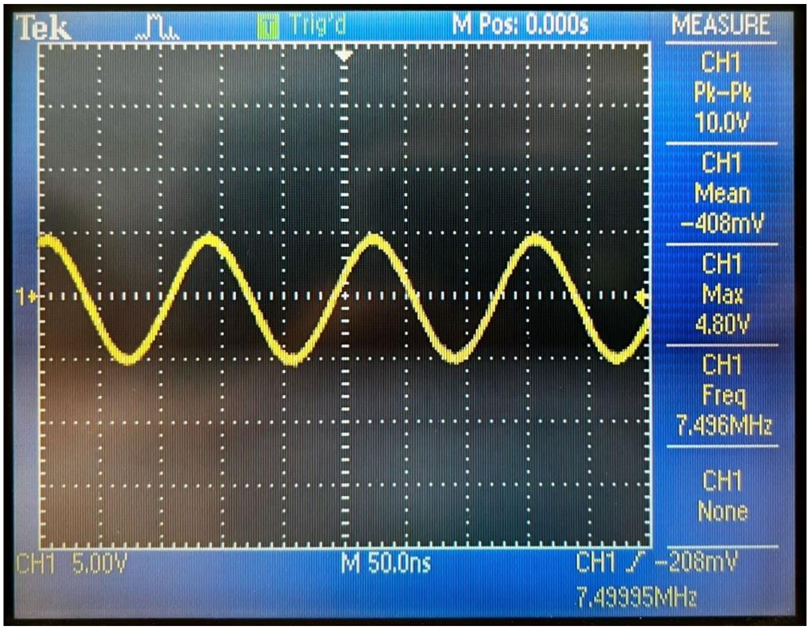

Figure 10: The Voltage Value of the Load Resistor

	Software Result	**Hardware Result**	**Error**
Supplied Power	63.19 mW	65.43 mW	3.54 %
Transferred Power	62,25 mW	61.28 mW	1.56 %
Transfer Ratio	98.51 %	93.67 %	4.91 %
Error	1.49 %	6.33 %	-

Table 1: The π -section Circuit Software and Hardware Results

2- The T-Section Method

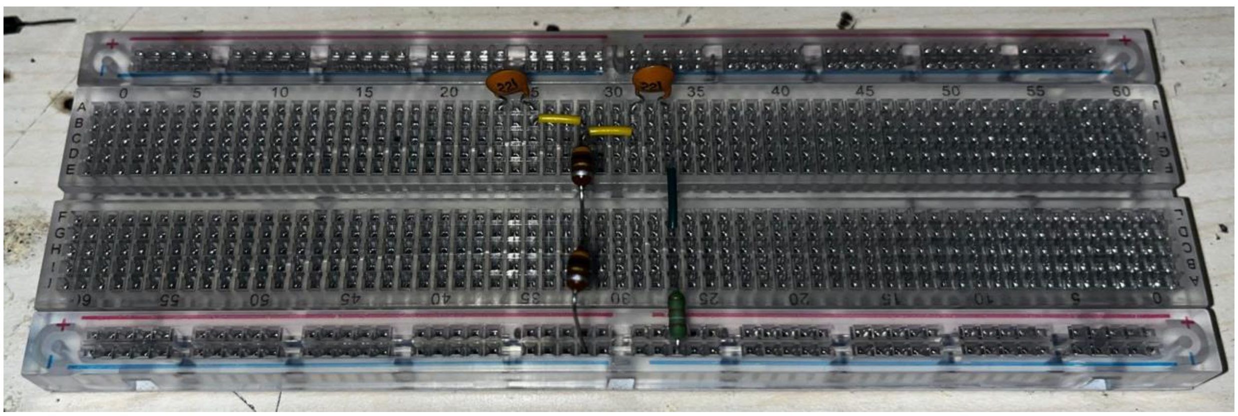

Figure 11: T -section Circuit

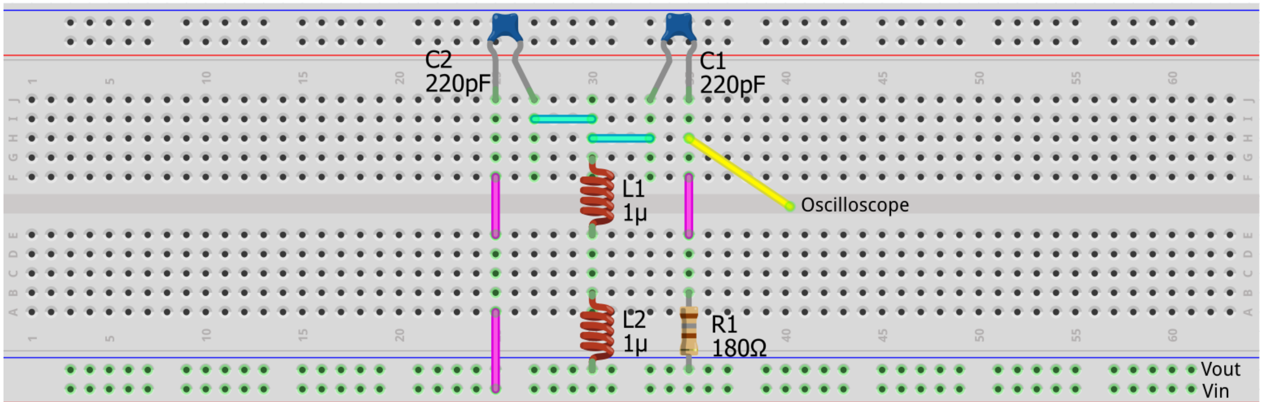

Figure 12: Schematics of the T -section Circuit

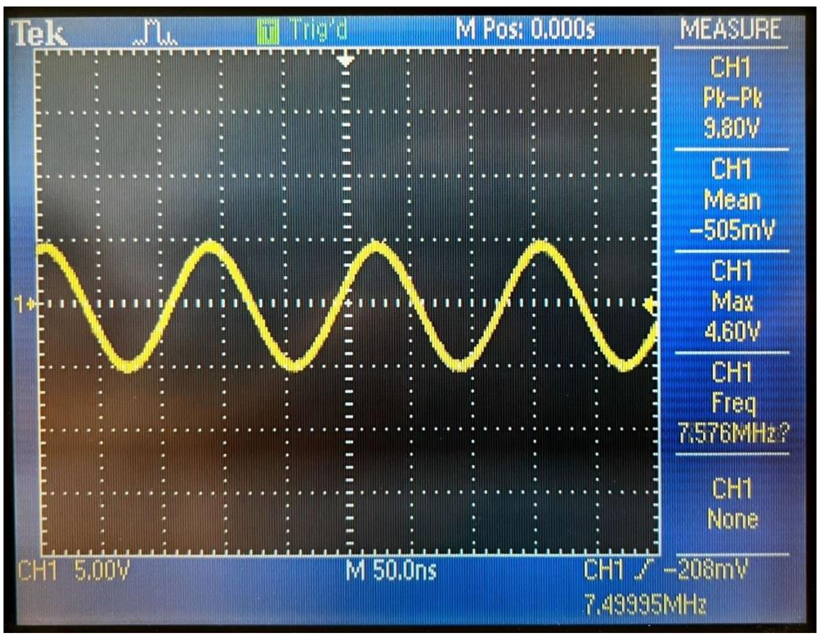

Figure 13: The Voltage Value of the Load Resistor

	Software Result	**Hardware Result**	**Error**
Supplied Power	63.09 mW	65.43 mW	3.62 %
Transferred Power	62,32 mW	57.26 mW	8.79 %
Transfer Ratio	98.78 %	89.24 %	9.63 %
Error	1.22 %	10.76 %	-

Table 2: The T -section Circuit Software and Hardware Results

Conclusion

This lab aimed to design at least two different passive linear circuits to transfer maximum power to 180Ω load from a voltage source with output impedance 50 Ω at a frequency between 5 and 10Mhz. The π-section and the T-section methods were used for this lab. The methods used in the design were verified because the simulated circuits performed the maximum power transfer with a loss of approximately 1.5%. For the implementation of the hardware part, the desired inductor value was obtained by connecting the inductors in the lab environment in series. While the values taken in the measurements made after the implementation of the circuits were similar to the software part, the errors were below 10%. These errors occurred in the circuits due to the imprecise component values and the material quality or sensitivity of the oscilloscope, signal generator, and breadboard. In summary, thanks to this lab, maximum power transfer using impedance matching and the methods that can be used for this has been learned.