EEE- 202 Circuit Theory Lab-3

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Section - 2
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I. SOFTWARE IMPLEMENTATION

1) Introduction

In this lab, 2 impedance equalization circuits are to be designed and asked to be implemented to transfer maximum power to 150Ω load from a voltage source with output impedance 50Ω at a frequency between 10Mhz and 15Mhz.

2) Analysis

maximum power transfer is calculated as follows: Consider a circuit with 2 separate series impedances.

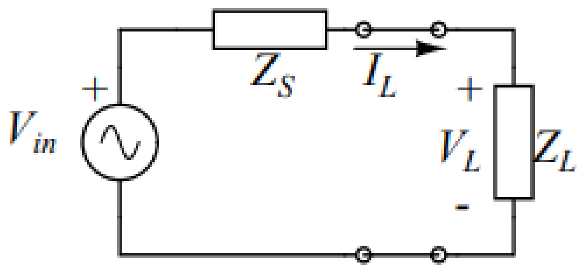

Fig. 1: Circuit with 2 series impedance

current flowing through the circuit:

$$I_L = \frac{V_{in}}{R_S+R_L}$$

Power at load R_L:

$$P_L = \frac{|I_L|^2 * R_S}{2} = \frac{1}{2} * \frac{|V_{in}|^2 * R_L}{(R_S+R_L)^2}$$

To find the maximum value, we take the derivative.

$$\frac{dP_L}{dR_L} = \frac{1}{2} * |V_{in}|^2 * \frac{d}{dR_L} * \frac{R_L}{(R_S+R_L)^2} = \frac{1}{2} * |V_{in}|^2 * \frac{R_S^2 - R_L^2}{(R_S+R_L)^4} = 0$$

It can be seen from here that $R_L = R_S$ to maximize power.

I have chosen Pi and T section circuit to implement.

For capacitors and inductors to have the same impedance (due to $\frac{1}{WC}$ and WL), the values are taken as follows:

Component	Value
Inductors	jX
Capacitors	$-jX$

TABLE I: Value representation of inductors and capasitors

for Pi matching circuit:

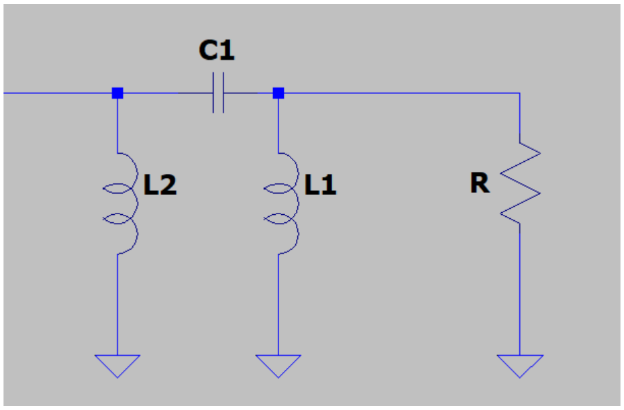

Fig. 2: Pi impedance matching circuit

Total impedance on load:

$$R_{load} = \frac{(\frac{RjX}{R+jX} - jX) * jX}{\frac{RjX}{R+jX} - jX + jX} = \frac{X^2}{R}$$

for T matching circuit:

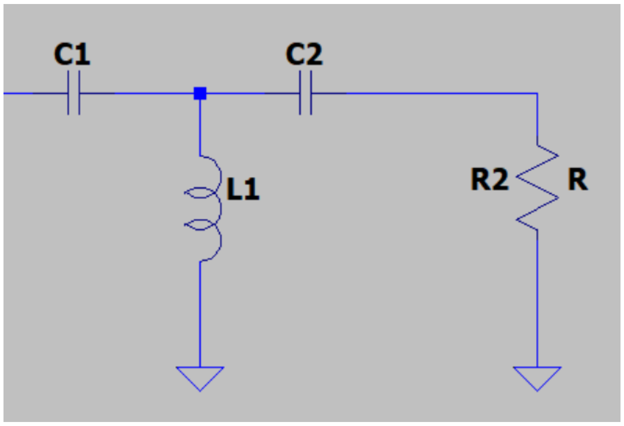

Fig. 3: T impedance matching circuit

Total impedance on load:

$$R_{load} = \frac{RjX}{R+jX} - jX + jX = \frac{X^2}{R}$$

calculating the required values:

Chosen frequency value is $13MHz$
$X = \sqrt{R_S * R_L} = \sqrt{50 * 150} = 86.6$
$w = 2 * \pi * 13M = \pi * 26M$
$L = \frac{X}{W} = 1.06\mu H$
$C = \frac{1}{wX} = 0.14136nF$

variable	Value
X	86.6
w	10K$\pi * 26M$
L	$1.06\mu H$
C	$0.14136nF$

TABLE II: Values of the circuit variables

When we take the given voltage $10V$, the power on the resistor is expected to be as follows:

$$P_L = \frac{(\frac{V_t}{2})^2}{R_S} = \frac{V_t^2}{4R_S} = \frac{10^2}{4{*}50} = 500mW$$

3) *Simulations*

In this area, we will simulate the circuit with the values selected in the previous section and observe whether the expected results are given in the virtual circuit.(In the graphs green shows the power at the output and blue shows the power at the input impedance unless otherwise specified.)

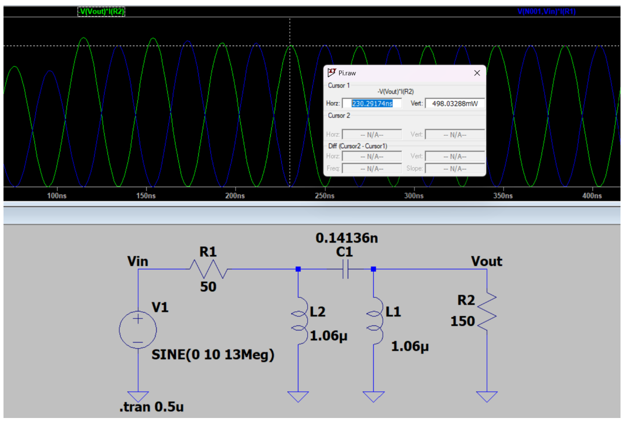

Fig. 4: Pi impedance matching circuit and its power graph on load

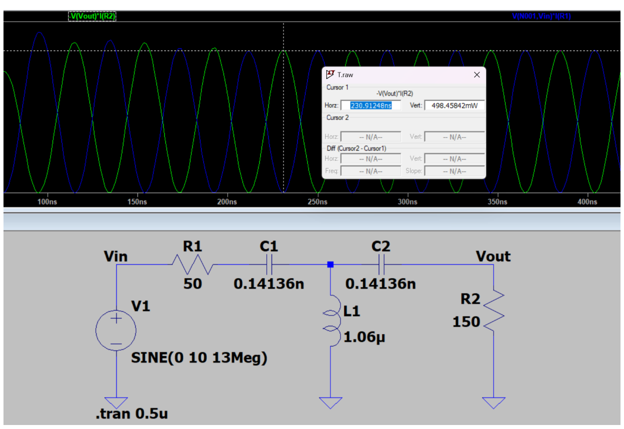

Fig. 5: T impedance matching circuit and its power graph on load

	Power(mW)	error
Pi section load power	$498.032mW$	0.33%
T section load power	$498.45mW$	0.31%

TABLE III: Error rate of power on load

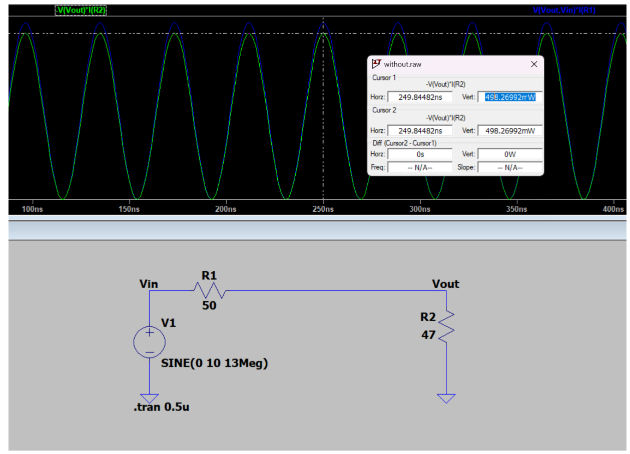

Fig. 6: 47Ω connected to signal generator directly

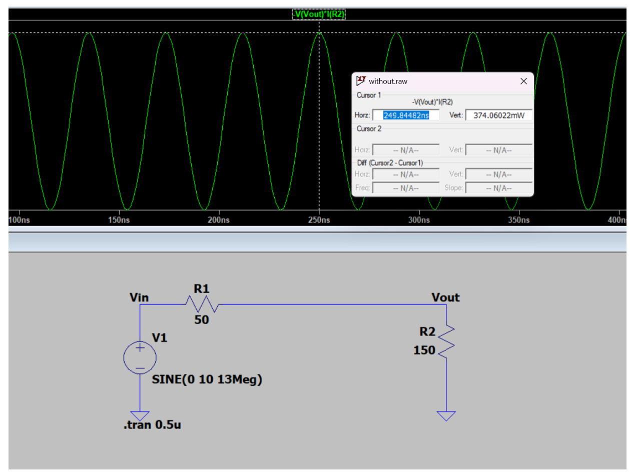

Fig. 7: 150Ω connected to signal generator directly

As can be seen, connecting 150 ohms directly reduces the delivered power.

II. Hardware implementation

In this section, the circuit that I have calculated and simulated before will be implemented in real life.

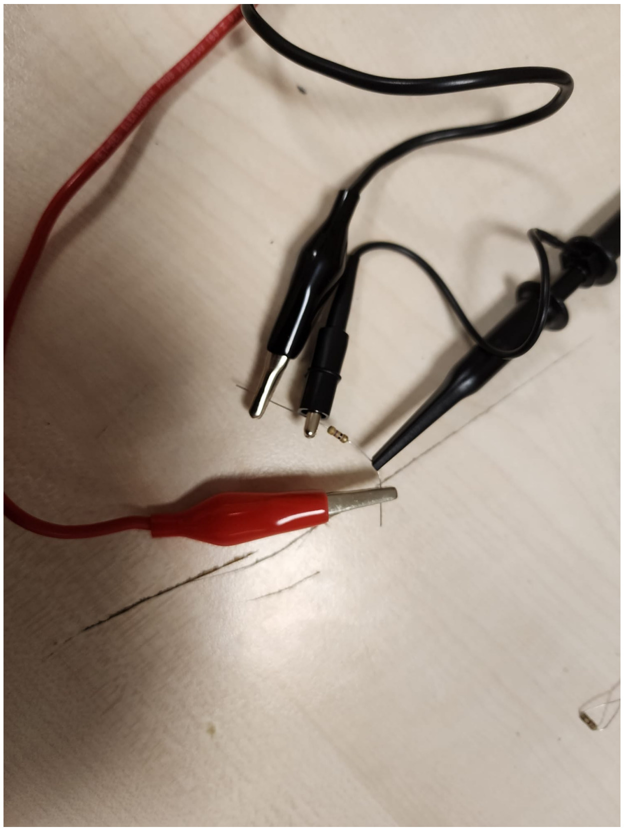

Fig. 8: 47Ω connected to signal generator

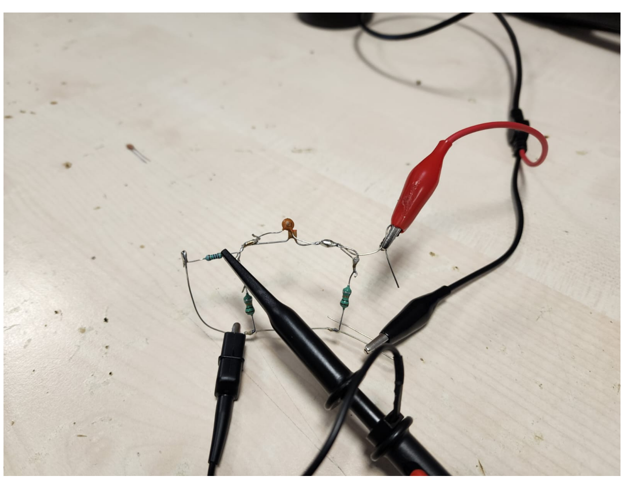

Fig. 9: Pi section circuit

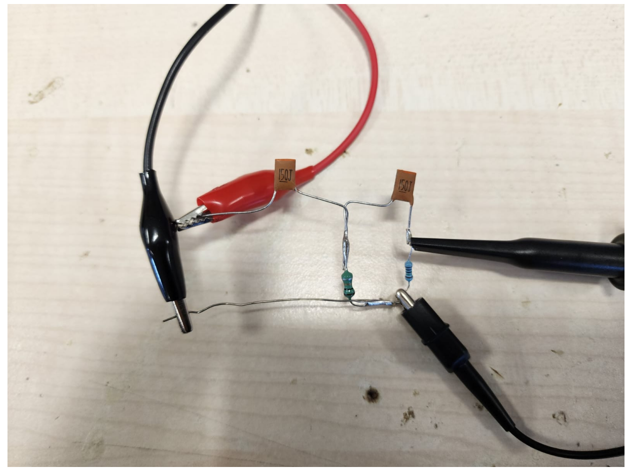

Fig. 10: T section circuit

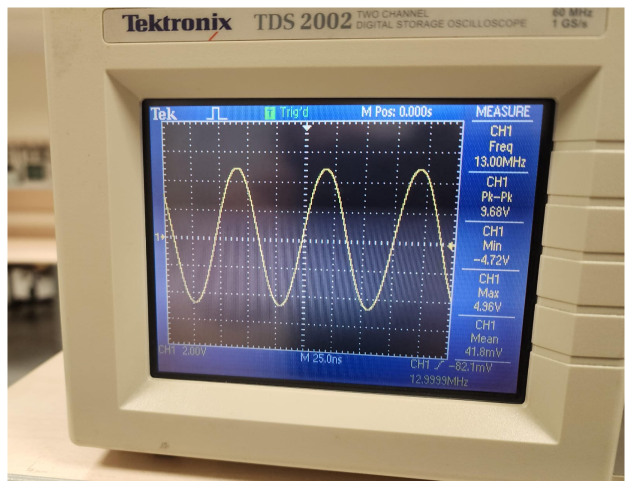

Fig. 11: 47Ω's measurement

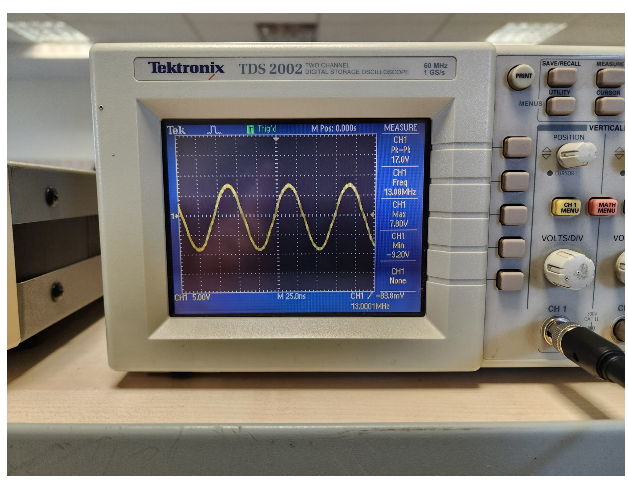

Fig. 12: Measured value of voltage on load in Pi section circuit

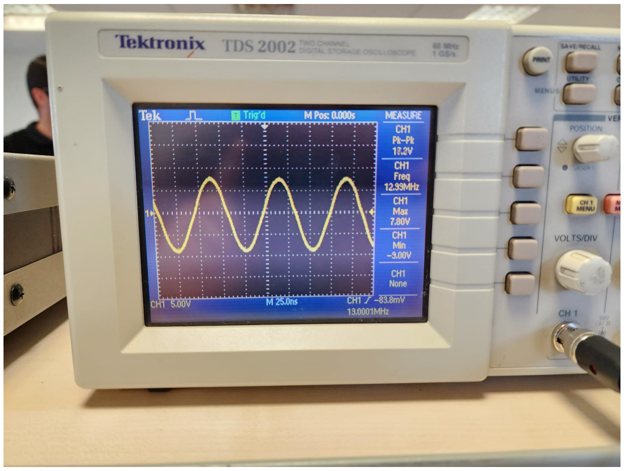

Fig. 13: Measured value of voltage on load in T section circuit

Circuit	Voltage on load	power on load	error rate
47Ω	$4.84V$	$498mW$	0.4%
Pi section	$8.5V$	$481mW$	3.8%
T section	$8.6V$	$493mW$	1.4%

TABLE IV: Error rate of power on load

Conclusion

As a result, 2 matching circuits were installed between 50 ohms and 150 ohms at 13MHz in accordance with the given values. There was a very small and negligible error rate between the simulated values and the real life values. The error rate may be due to various external factors such as cable resistance, non-ideal signal generator and human error. So this experiment is successful.

References

1) Atalar, A., and Köymen, H.(2023) *Analog Electronics*(4th ed.). Meteksan.
2) eepower.com. (2022, july, 07). *What is an Inductor?*. https://eepower.com/technical-articles/what-is-an-inductor/
3) https://en.wikipedia.org/(2023,november,9). https://en.wikipedia.org/wiki/Impedance_matching.