Bilkent University
EE202-002 Lab 2 Report:
Voltage Spike Generator

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Purpose:

This lab aims to design a passive linear circuit to generate high voltage spikes from 10 V peak-to-peak square wave with a source resistance of 50 Ω and frequency less than 5 MHz.

Methodology:

The requirements of the desired voltage spike are as follows:

-The input is a 10 V peak-to-peak square wave and frequency less than 5MHz.
-The input also has 50 Ω source resistance.
-The voltage spikes' peak value, Vp, must be $15\ V \leq Vp \leq 25\ V$.
-Full widths at half maximum (FWHM) must be less than 80ns ($\Delta t < 80ns$).
-Spikes are not required to be square-shaped.
-The fall and rise times of the square wave are 10ns.

The desired output voltage waveform is given below:

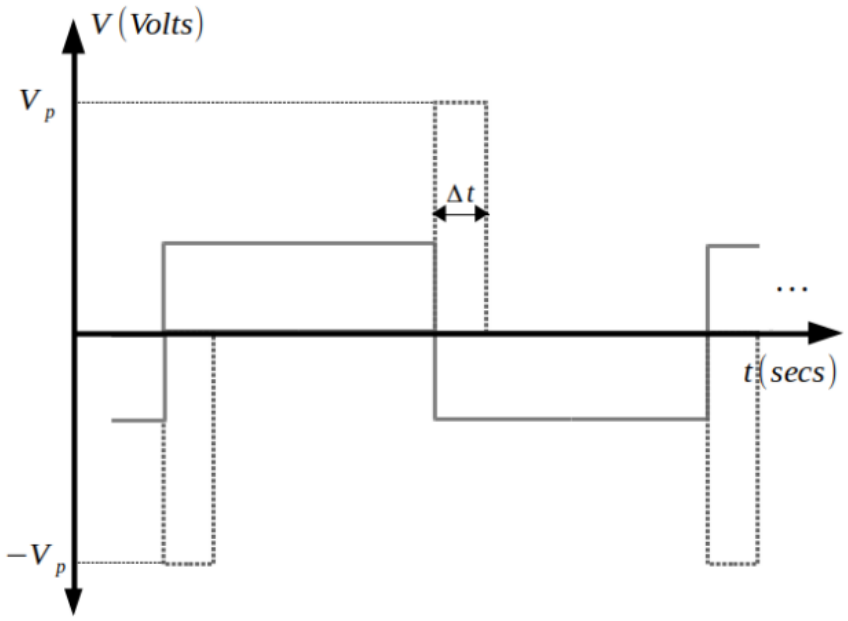

Figure 1: Input is a square pulse (gray line). Dashed lines show the desired output.

A transformer circuit will be designed to provide these conditions due to the inductor kickback feature. Thus, the transformer with suitable primary and secondary winding numbers is expected to create a voltage spike at a desired voltage value between 15 V and 25 V.

This lab aims to design a transformer to create a voltage spike of about 20 V, four times the input.

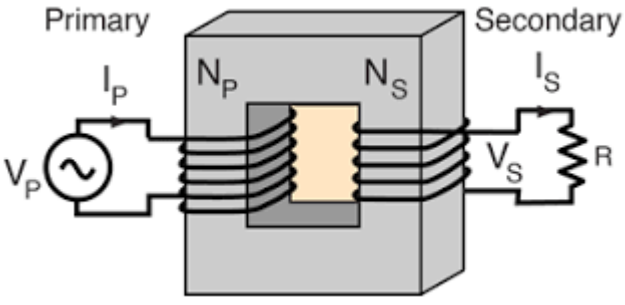

Figure 2: Transformer

By using Faraday's Law (1) and the relation between inductance and winding values (2):

$$\frac{V_S}{V_P} = \frac{I_P}{I_S} = \frac{N_S}{N_P} \quad (1)$$

$$L = A_l * n^2 \quad (2)$$

According to equation (1), the number of the secondary winding must be four times the primary winding number to obtain a transformer whose secondary voltage value is four times the primary voltage value.

Software Lab

The circuit designed to be simulated using LTSpice is as follows:

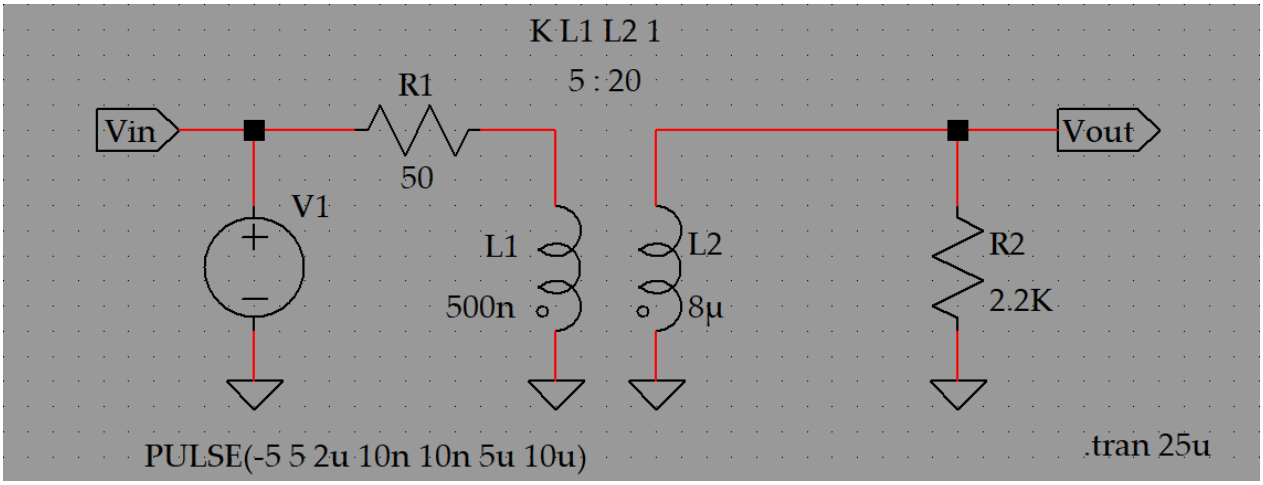

Figure 3: The Transformer Circuit

Since the determined winding ratio was 4, winding numbers were chosen as $N_S = 20$ and $N_P = 5$. The chosen inductor core is T38-8, $A_l = 20\ nH/t^2$. According to equation (2), the inductor values are $L_P =$ 500n and $L_S =$ 8µ. The value selected for the load resistor is 2.2k Ohm.

Results

The simulation results of the transformer circuit simulated in LTSpice are as follows.

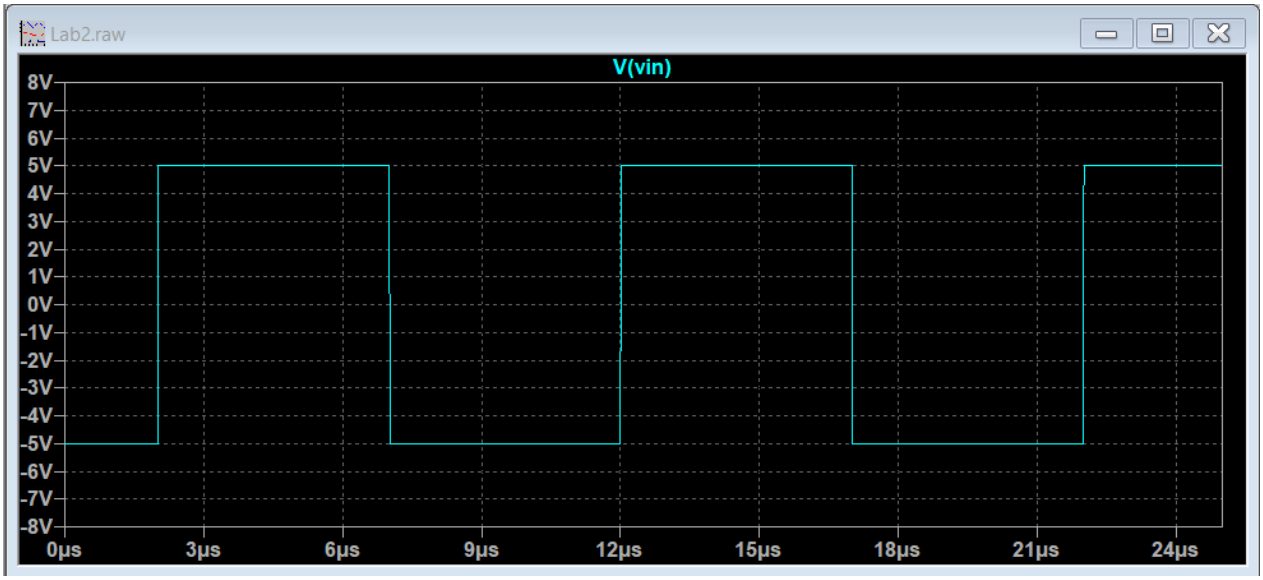

Figure 4: The waveform of Input Voltage

10 V peak-peak square wave input voltage. The fall and rise times of the square wave are 10 ns, and the frequency is 100k Hz.

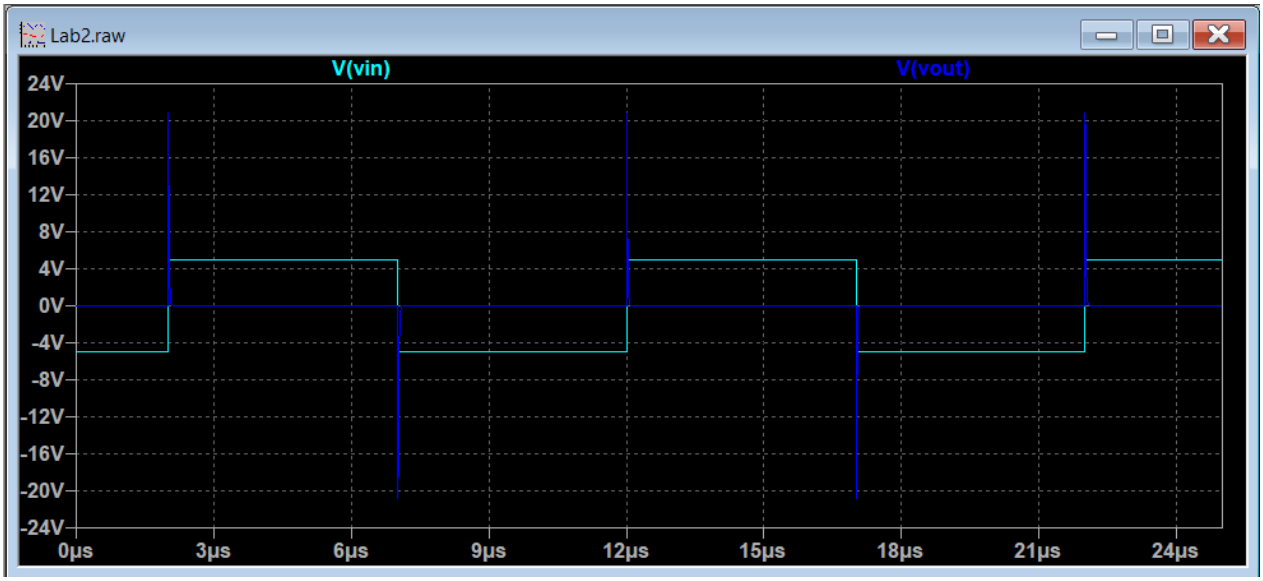

Figure 5: The Waveforms of Input and Output Voltage

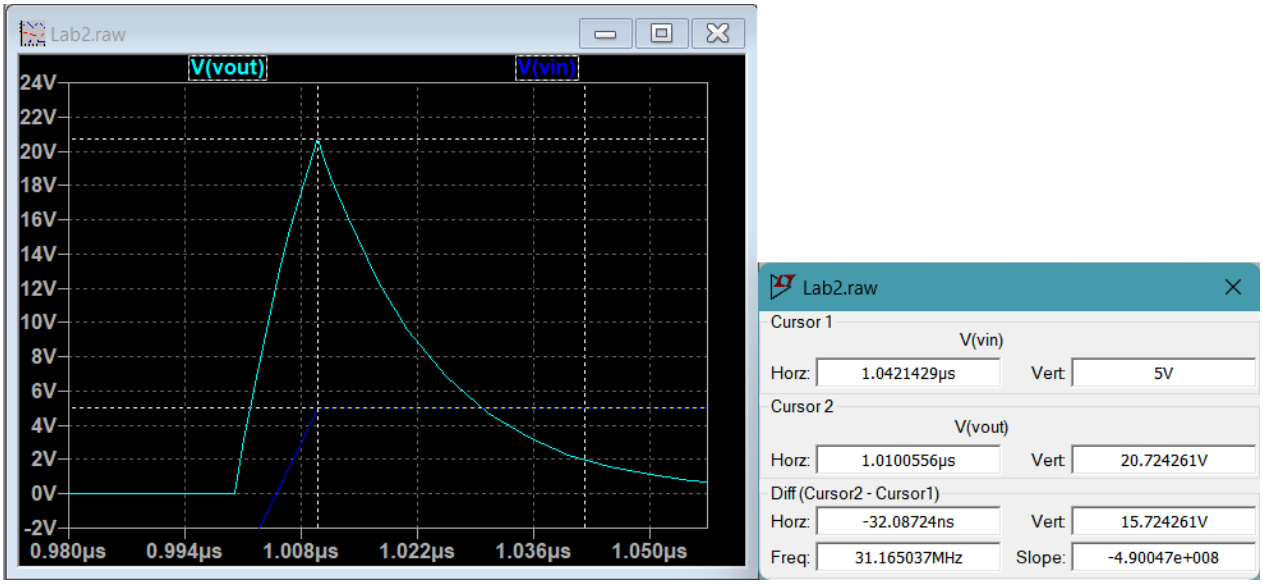

Figure 6: Peak Voltage Values of Vout and Vin

The output voltage's peak value is 20.72 V. Since this is between 15 V and 25 V, this value is suitable for lab requests.

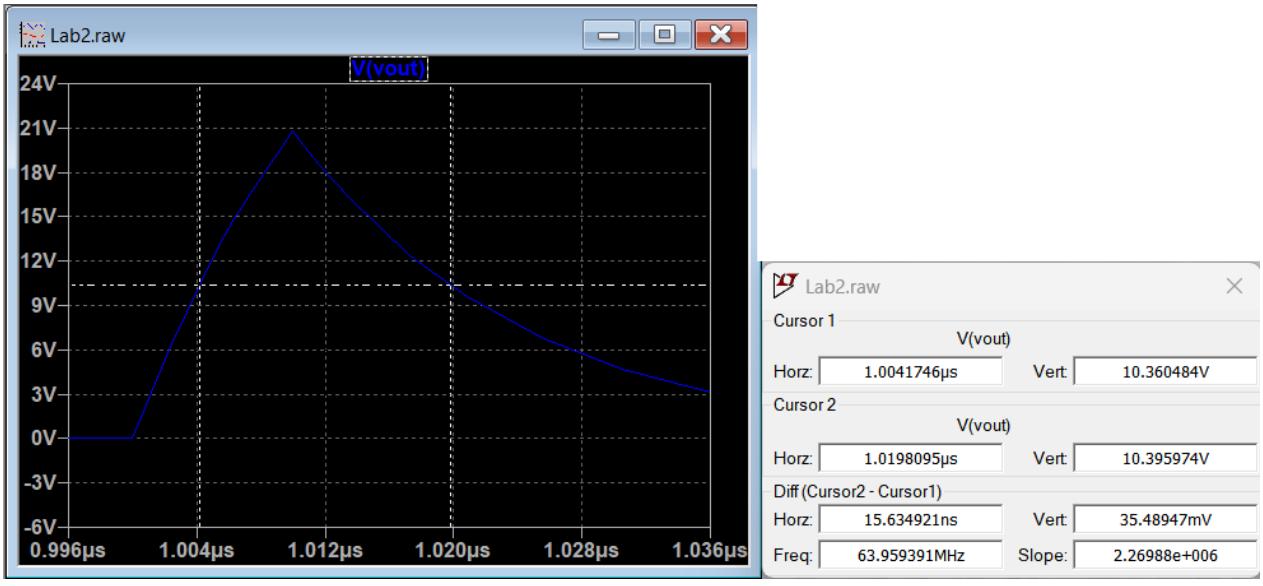

Figure 7: Full widths at half maximum (FWHM) value of Voltage Spike

The FWHM of the spike is 15.63 ns. Since this is less than 80 ns, this value is suitable for lab requests.

Hardware Lab

For the hardware implementation, the chosen inductor core is T38-8 and winding numbers are selected as $N_S = 20$ and $N_P = 5$, the same as the software lab. According to these, the inductor values are $L_P = 500\text{n}$ and $L_S = 8\mu$. However, the load resistor is replaced with 390 Ohm.

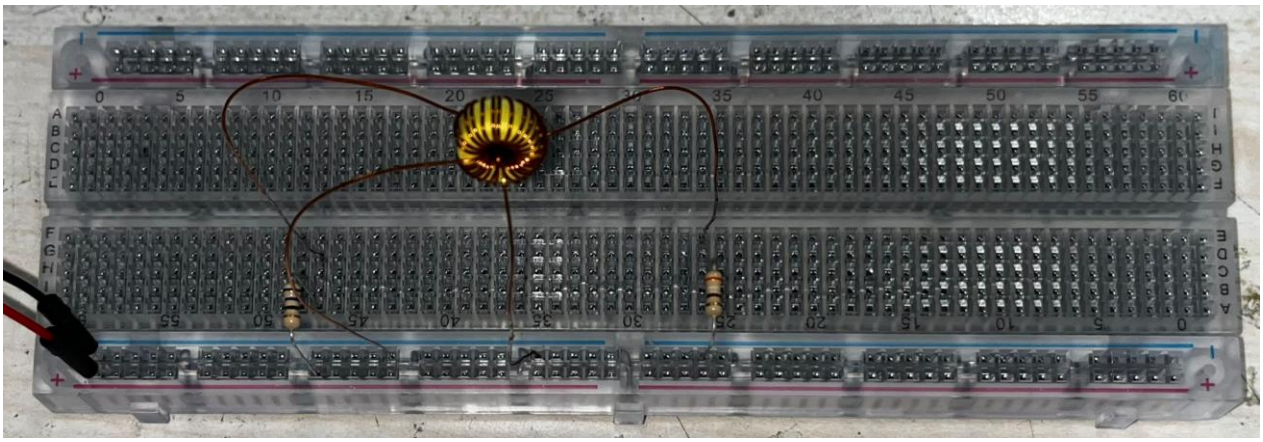

Figure 8: The Voltage Spike Generator

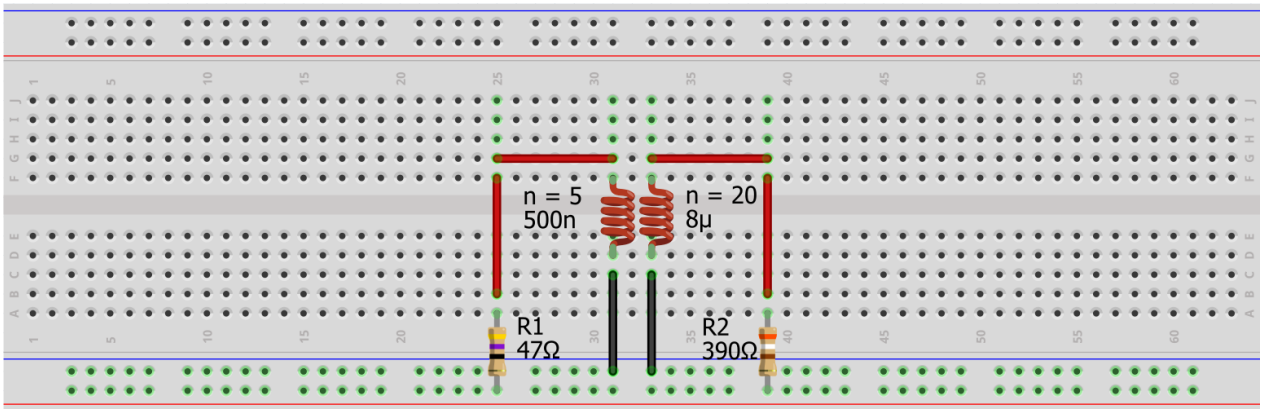

Figure 9: Schematics of Voltage Spike Generator

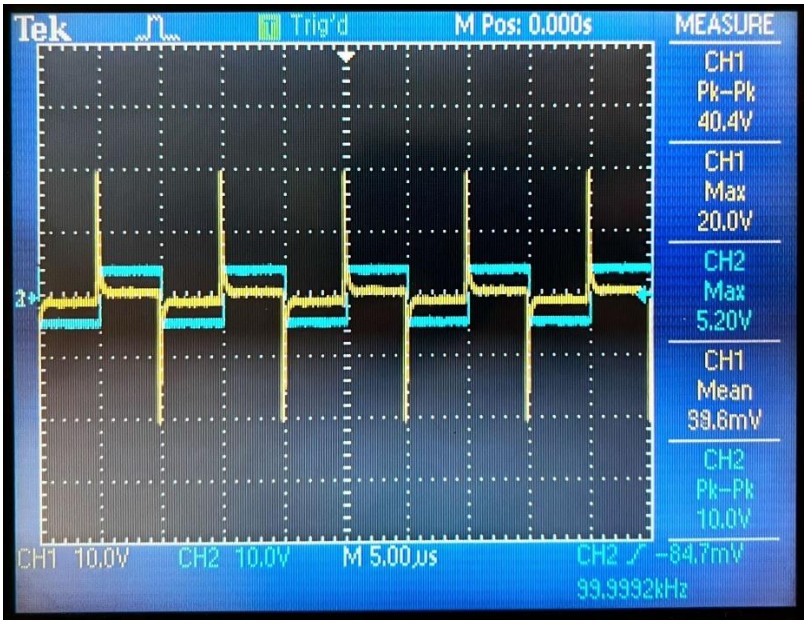

Figure 10: The Waveforms of Input and Output Voltage

Voltage Spike	Software Result	Hardware Result	Error
100 kHz	20.7 V	20.0 V	3.38 %

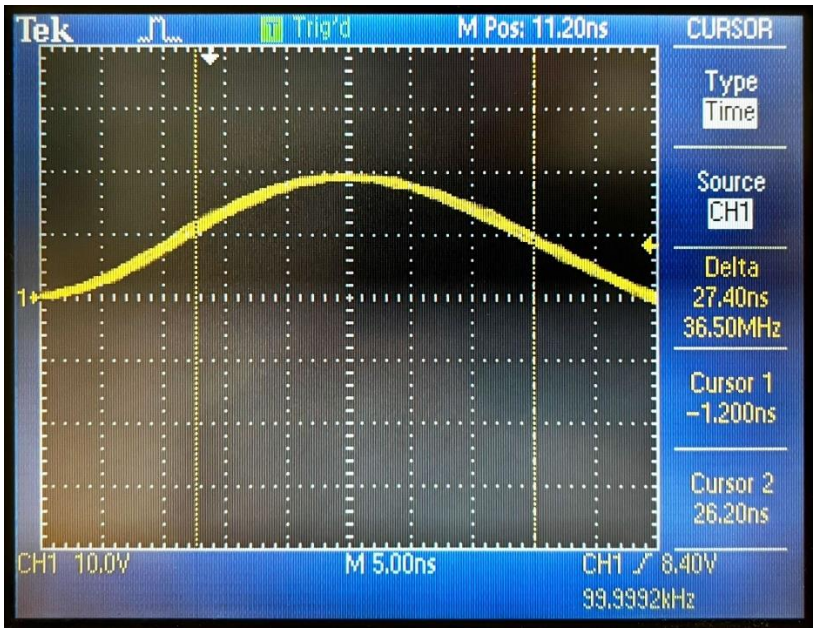

Figure 11: Full Widths at Half Maximum (FWHM) Value of Voltage Spike

FWHM	Software Result	Hardware Result	Error
100 kHz	15.6 ns	27.4 ns	75.6 %

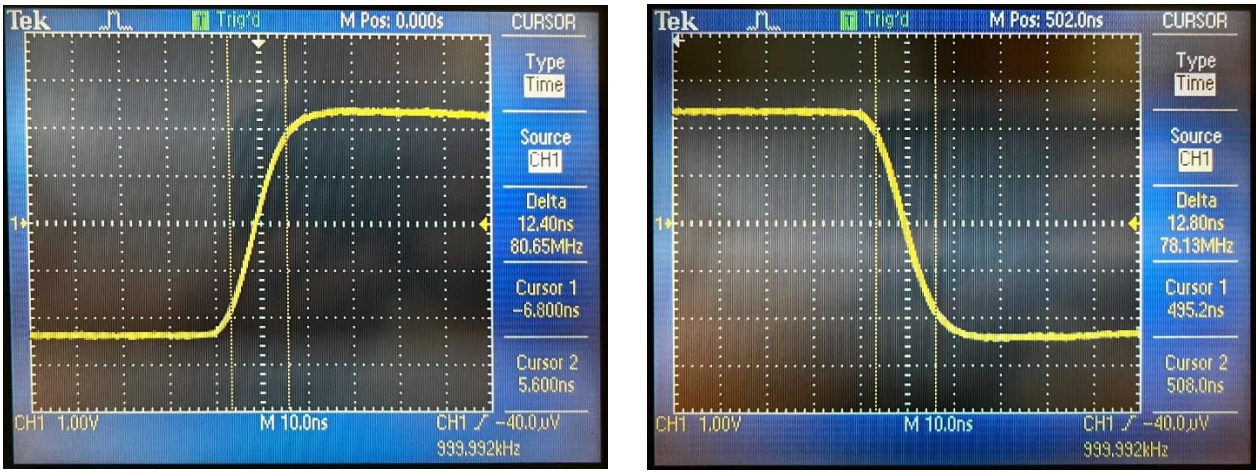

Figure 12: The Rise and Fall Times of the Square Wave

Rise / Fall Times	Software Result	Hardware Result	Error
Rise Time	10.0 ns	12.4 ns	24.0 %
Fall Time	10.0 ns	12.8 ns	28.0 %

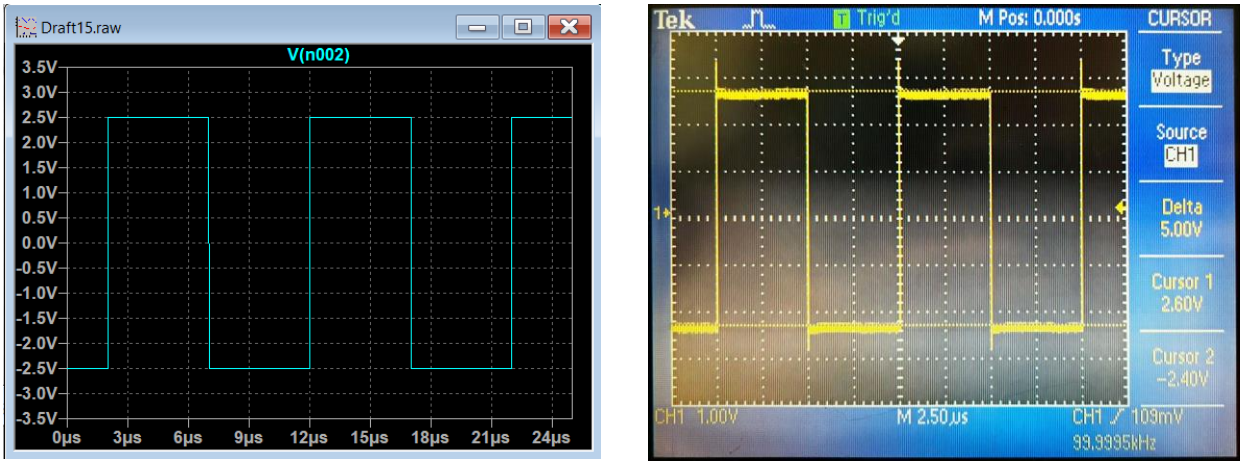

Figure 13: Peak Values of the Square Wave by Connecting a 47Ω Resistor Across the Terminals of the Source

Voltage Divider	Software Result	Hardware Result	Error
Peak Value	2.5 V	2.5 V	0 %

Conclusion

The goal of this lab was to create a passive linear circuit that can produce high voltage spikes from a 10 V peak-to-peak square wave with a source resistance of 50 Ohm and a frequency under 5 MHz. As a result of implementing the designed transformer circuit, a voltage spike of 20 V was obtained. In addition, the full width at half the maximum value of the voltage spike was measured as 27.4 ns. The lab was successfully completed as these values fulfilled the requirements of being between 15 V and 25 V and being less than 80 ns. At first, the output voltage value of the circuit that was implemented with the values in the software part differed from the LTSpice result. This may be because the transformer used in LTSpice is considered ideal, without leakage, and has no inner resistance. This difference was fixed by changing the value of the load resistor. An error of 3.38% occurred in the voltage spike value 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, it was learned how to create a transformer circuit on LTSpice and create a voltage spike using a transformer.