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Course Code: EEE202

Section: 02

Experiment Number: 02

Date: 23.10.2023

Lab 2: Voltage Spike Generating Passive Linear Circuit

Software Implementation

Introduction:

The purpose of this experiment is to design a passive linear circuit to generate high voltage spikes from 10V peak – to –peak square wave with a source resistance of 50 Ω and frequency less than 5 MHz. For this specific experiment, it is wanted that V_p, peak value of the voltage spikes must be between $15V \leq V_p \leq 20V$. Also, *Full Width at Half Maximum (FWHM)* value must be less than 90ns ($\Delta t < 90ns$).

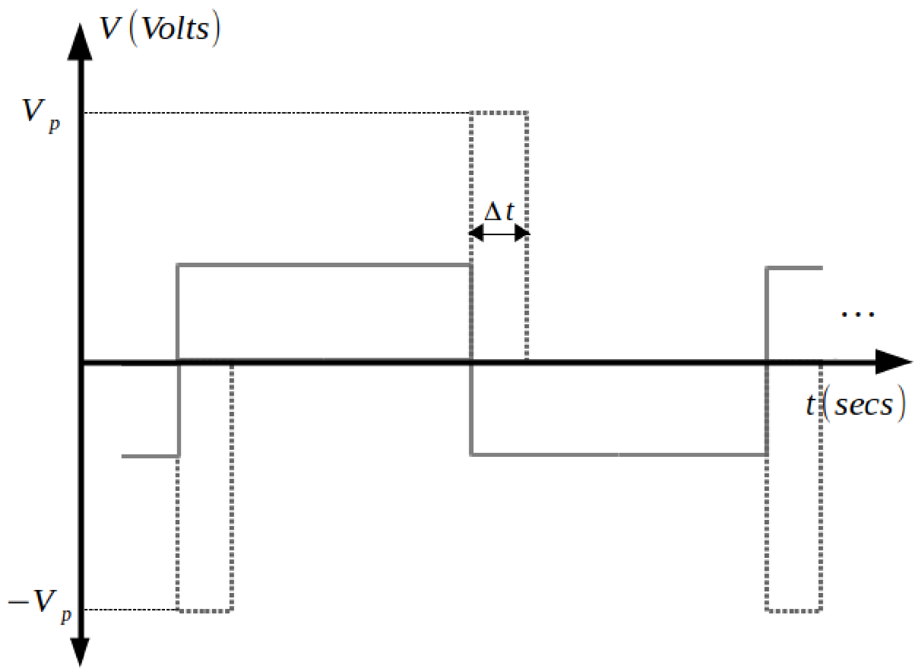

Figure 1: Desired Graph

Methodology:

To satisfy the purpose of the experiment, which is creating voltage spikes, I used a transformer. The logic behind the voltage spikes can be related to inductors. When the current going through the inductor is instantaneously ceased, inductor creates voltage spikes, therefore I used a transformer in this experiment. The input voltage is a square voltage with pulse -5V and 5V. There is 10 nanoseconds between each pulse. Lastly, I choose 1µH and 6µH inductors to design the transformer, and added a 10KΩ resistor in series with the 6µH side of the transformer to limit the voltage spikes.

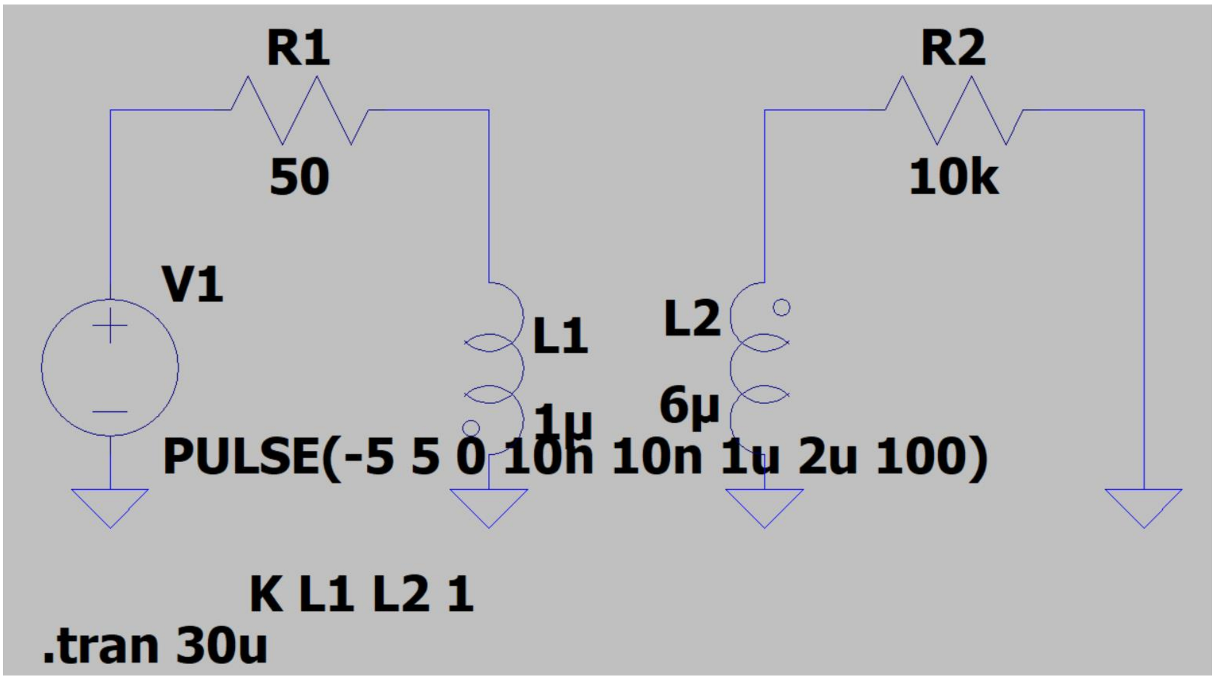

Figure 2: Designed Circuit

Analysis:

The number of turns can be found the (Eqn. 1) which shows the relation between inductor value (L) with number of turns (N) and core of the toroid (A_L).

$$L = N^2 A_L$$

Eqn. 1: Equation for Inductor

I used T38-8/90 toroid in the lab which has the value $A_L = 20nH/N^2$.

Using the Eqn. 1, corresponding number of turn values are found (Eqn. 2 and Eqn. 3).

$$N_1 = \sqrt{\frac{10^{-6}H}{2 \times 10^{-8}H}} \sim 7$$

Eqn. 2: Number of Turns for 1µH Inductor

$$N_2 = \sqrt{\frac{6 \times 10^{-6}H}{2 \times 10^{-8}H}} \sim 17$$

Eqn. 3:Number of Turns for 6µH Inductor

So, for 1µH side of the transformer, N_1 = 7 turns and for the 6µH side of the transformer, N_2 = 17.

Applying Kirchoff's Voltage Rule to the Figure 1, we get the following equation.

$$-V_1 + V_{R1} + V_{L1} = 0$$

Eqn. 4: Kirchoff's Voltage Rule

Using element constraints and after doing some math, we get the following equation for the current of the 1 µH inductor.

$$i(t) = 0.1 - 2(10^7)t + 0.42(1 - e^{\frac{-50t}{10^{-6}}})$$

Eqn. 5: Current equation for 1µH inductor

Using (Eqn. 5), V_{L1} can be found.

When t = 10nanoseconds, V_{L1}(10ns) = 7.86 V

The obtained result of V_{L1} can be observed from the simulation (Figure 4).

Simulations:

The rise time of the input voltage can be observed in the following figure

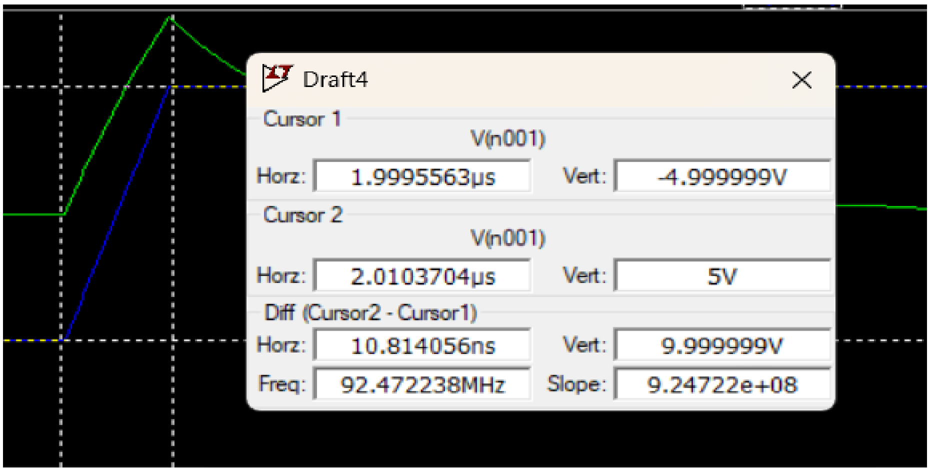

Figure 3:Rise time of V_{in}

The maximum value of V_{L1} is calculated to be 7.86V. From the following figure (Figure 4) it can observed that maximum value for V_{L1} is 7.64V.

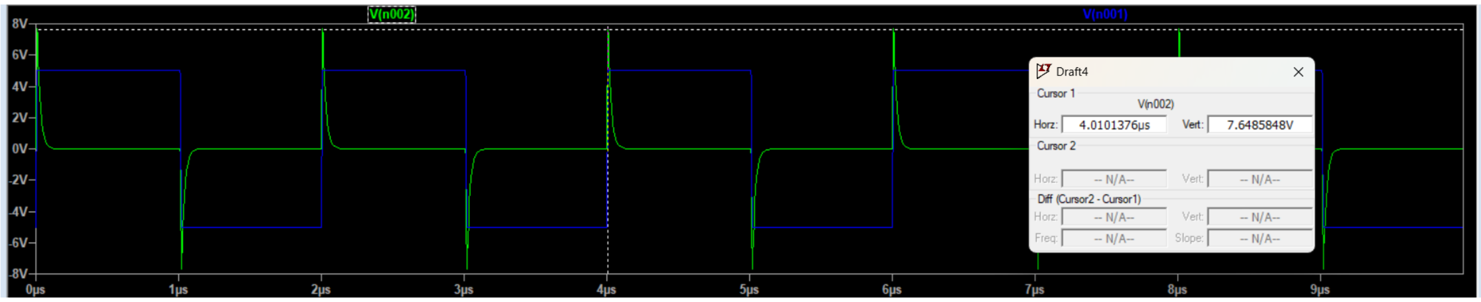

Figure 4:Waveform of V_{L1}

The value of V_{L2} can be seen from the figure below (Figure 5).

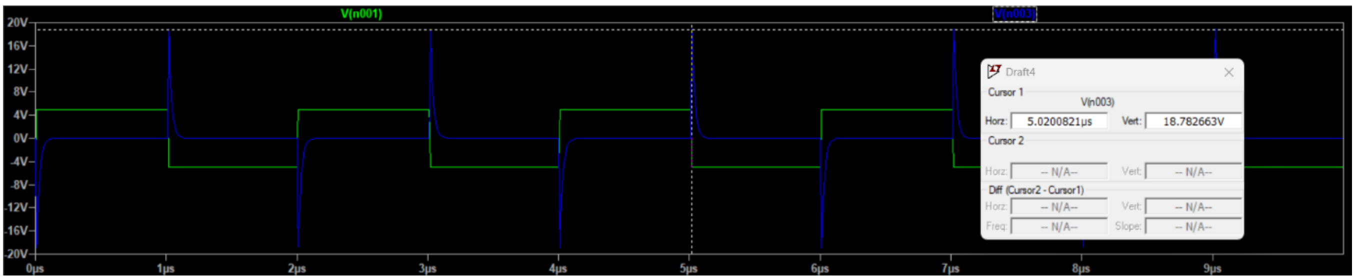

Figure 5: Waveform of V_{L2}

In the figure above, both input and output voltages can observed. The maximum value that output voltage can reach is 18.78V.

In the figure below (Figure 6) "Full Width at Half Maximum (FWHM)" can be seen. $\Delta t = 20.79\ ns$.

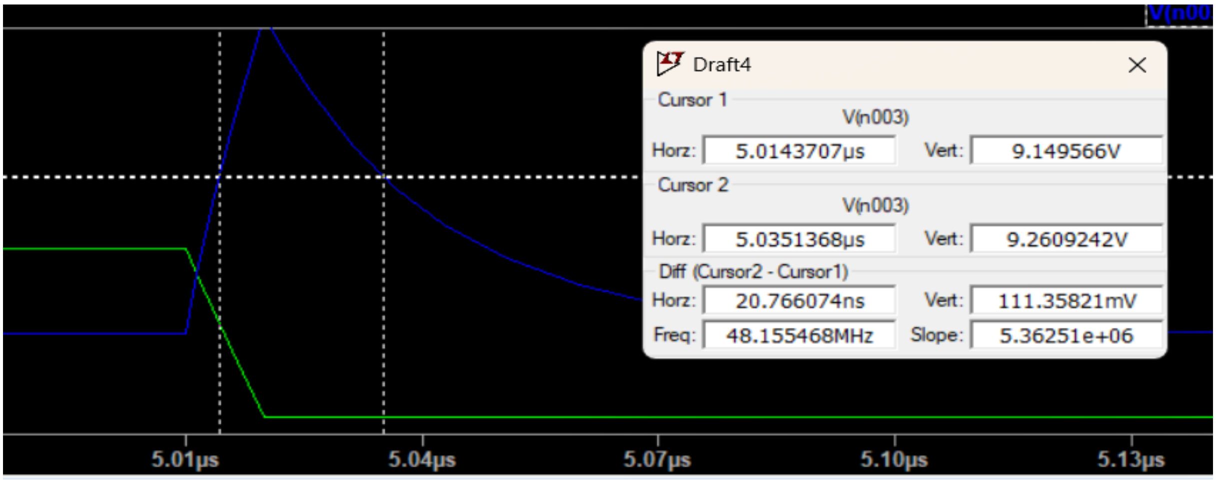

Figure 6: Full Width at Half Maximum Value

Hardware Implementation

In the hardware part of the experiment, in order to create the circuit designed in software part, a transformer is made by hand. The primer inductor of the transformer has 7 turns and inductance value of 1µH, seconder inductor of the transformer has 17 turns and inductance value of 6µH. These values are winded to T38-8/90 toroid. The created transformer is checked in the SR720 LCR meter. The values of the primer and seconder inductance value can be seen in figures (Figure 7 and Figure 8) below.

Figure 7:Inductance value for the primer inductor

Figure 8: Inductance value for the seconder inductor

The designed circuit can be seen below (Figure 9).

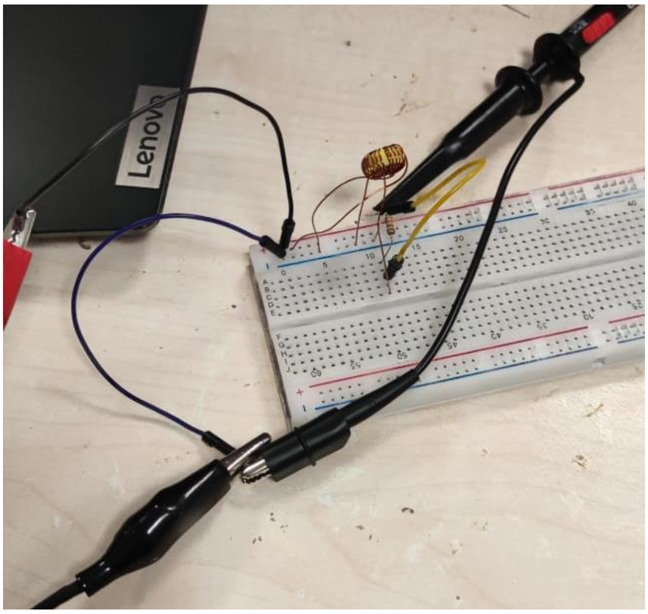

Figure 9: Hardware Implementation of the circuit

To observe the fall and rise times, I connected a 47Ω resistor across the terminals of signal generator and inspected the waveform from the oscilloscope.

Falling time of the input voltage can be observed in the figure below (Figure 10).
$Fall\ time\ (\Delta t) = 19.6\ ns.$

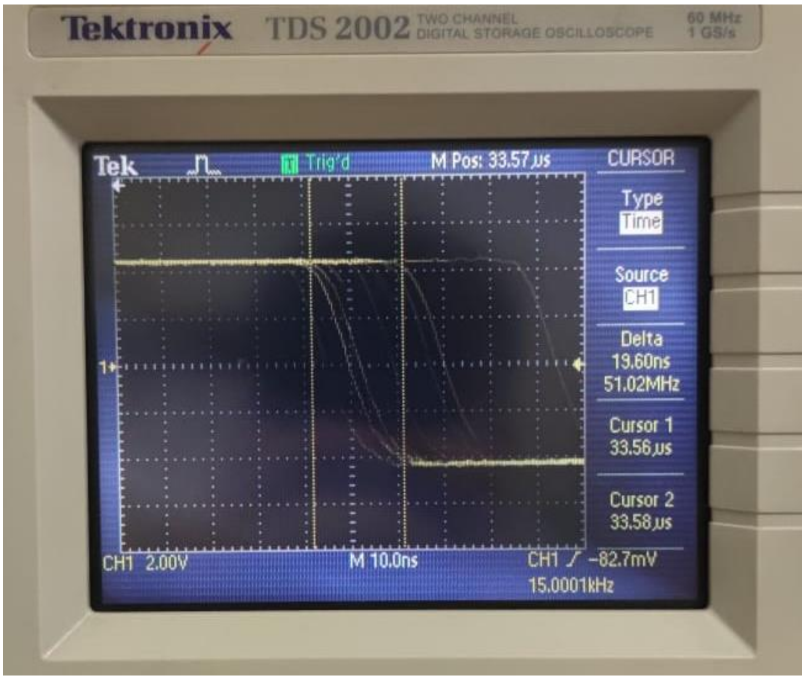

Figure 10:Falling time of square input voltage

Rising time of the input voltage can be observed in the figure below (Figure 11).
$Rise\ Time\ (\Delta t) = 17.8\ ns.$

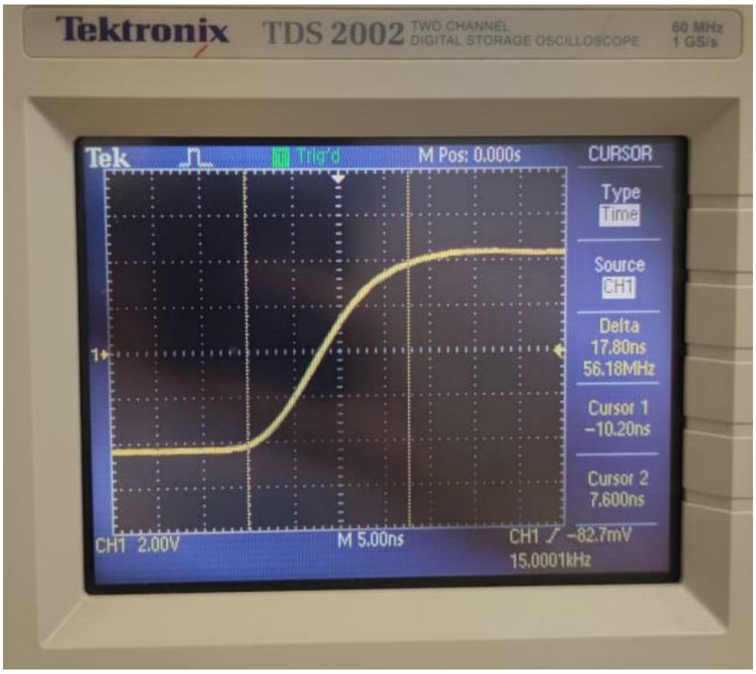

Figure 11: Rising time of square input voltage

The maximum voltage and peak-to-peak voltage values can seen in the figure below (Figure 12).

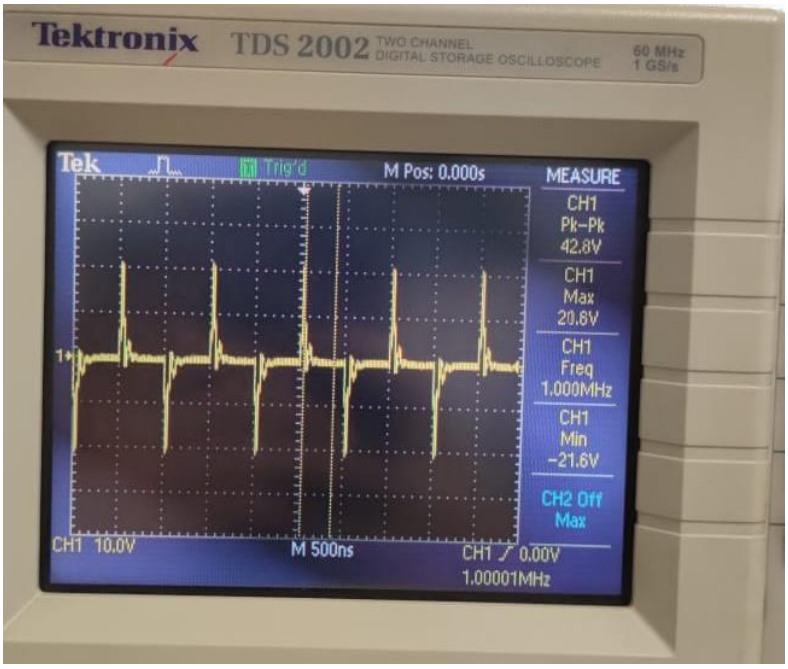

Figure 12: Maximum output voltage and peak-to-peak voltage values

From Figure 12;

V_{max}: 20.8 V

$V_{p\text{-}p}$: 42.8 V

From the figure given below, “Full widht at half maximum” value can be observed (Figure 13). $FWHM\ (\Delta t) = 34.00\ ns$.

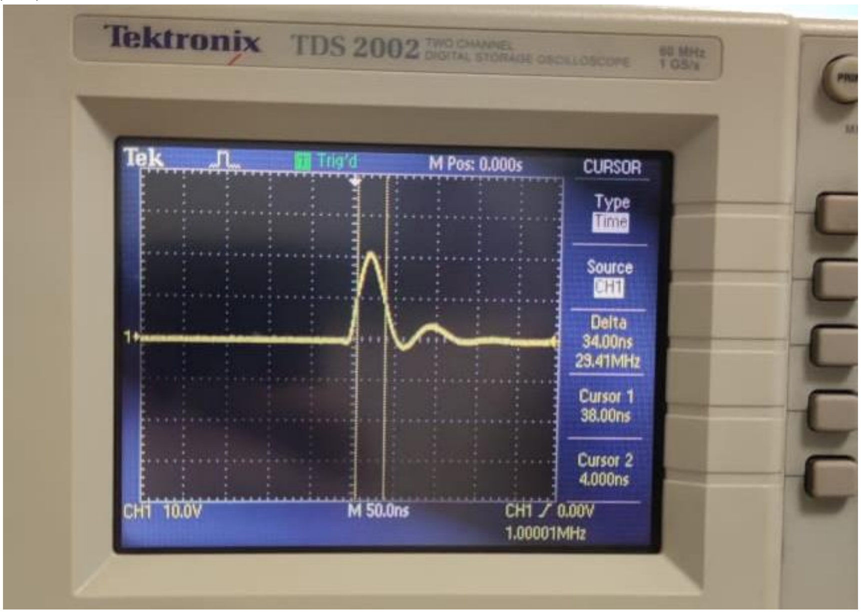

Figure 13: Full Width at Half Maximum

The results obtained both from software and hardware implementations can be inspected and compared in the table (Table 1) given below.

	Software	Hardware
V_{max} of seconder inductor (V)	18.78 V	20.8 V
Full Width at Half Maximum (ns)	34.00 ns	20.79 ns

Table 1: Software and Hardware values

Conclusion:

The main purpose of the experiment is creating a voltage spike generator from 10V peak-to-peak sqaure wave with a source resistance of 50Ω and frequency less than 5 MHz. Another condition that is to be satisfied is V_P, peak value of the voltage spikes must be $15 \leq V_P \leq 20$.

The main reason behind the voltage spikes in the circuit is happening due to the pulse wave, because when the square input voltage suddenly reduced, imnductors create voltage spikes due to the change in the current, $\frac{L_1 di}{dt}$.

Throughout the experiment, some error occured. In the software part, the errors mostly caused by the lack of sensitivity of experimenter while measuring the datas from LTSpice. In the hardware part, may occurred due to the signal generators unstability. Also, because the transformer is handmade, there may be some error occured. However, looking at (Table 1), results for software and hardware parts are slightly different from each other.