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Section: 1

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Bilkent University Electrical and Electronics Engineering

EE202-Circuit Theory

Lab 2:

Voltage Spike Generator

Introduction:

The purpose of this lab is to design a passive linear circuit to generate high voltage spikes from 10V peak-to-peak square wave with a source resistance of 50Ω and frequency less than 5MHz. The peak value of the spikes must be between 15V < V_p< 20V. Full width at half maximum (**FWHM**) must be less than 90ns.

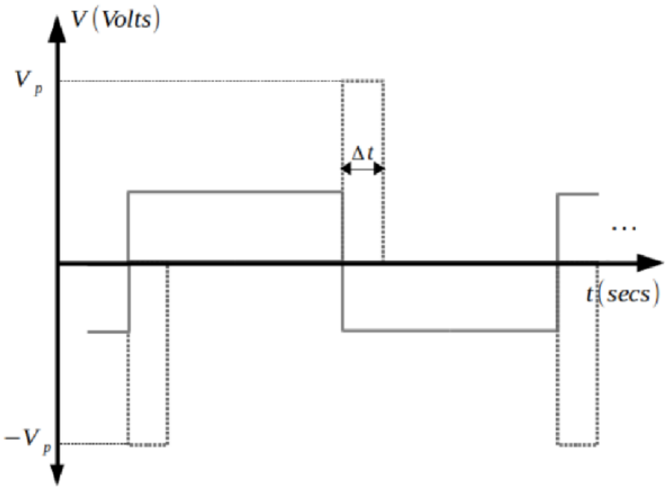

Figure 1 The Lab Task

Methodology:

Transformers offer a more straightforward means of generating voltage spikes when compared to inductors. This ease of use stems from the transformers' capability to modify voltage levels through the adjustment of turns ratios and efficient energy transfer via magnetic coupling. Consequently, transformers provide a controlled and predictable voltage spike generation method, making them a preferred choice in various applications. In contrast, inductors primarily store energy within a magnetic field and are less suited for producing voltage spikes. Therefore, I preferred to use a transformer to easily manipulate output voltage in a desired way.

Part 1: Software Implementation

Analysis:

To choose the turn ratio we need to first consider the voltage ratio from Faraday's Law of Induction (eq. 1). Also, there is a relationship between the inductance and turn number (eq. 2). From these two equations we derive now eq.3. Also, in the lab, we have the toroidal core which has a value of 20 as an inductance per turn.

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

$$L = A_l * n^2 \quad \text{(eq. 2)}$$

(In this equaiton "A_l" is the constant called inductance per turn)

$$\left(\frac{V_P}{V_S}\right)^2 = \left(\frac{L_P}{L_S}\right) \quad \text{(eq. 3)}$$

With the formulas and given input and output voltage ratios of 5/15 and 5/20, I concluded to pick 1/3 ratio (ratio between 1/3 and 1/4) of voltages so that, a 1/3 ratio of turn numbers. Therefore, I need to have the ratio 1/9 for the inductance value. I picked 720 nH for the input section of the transformer and 6.48 µH (see Table 1). I used 720Ω at the output of the transformer as a load resistance. I have set the pulse signal (square wave) with 10n rise and 10n fall time, 50% duty cycle, and 2.5MHz input frequency and I set the leakage constant to 1 assuming 100% ideal transformer we have (Figure 1). However, I will se some errors in the Hardware part. Software result shown in Figure 2 and in Figure 3 we can see the FWHM is 22.1 ns (which is very above 90ns) with the help of the cursors.

$L(nH)$	$A_l(nH/t^2)$	n
720	20	6
6480	20	18

Table 1: L Values I Picked In Relation with the Turn Number

Simulations:

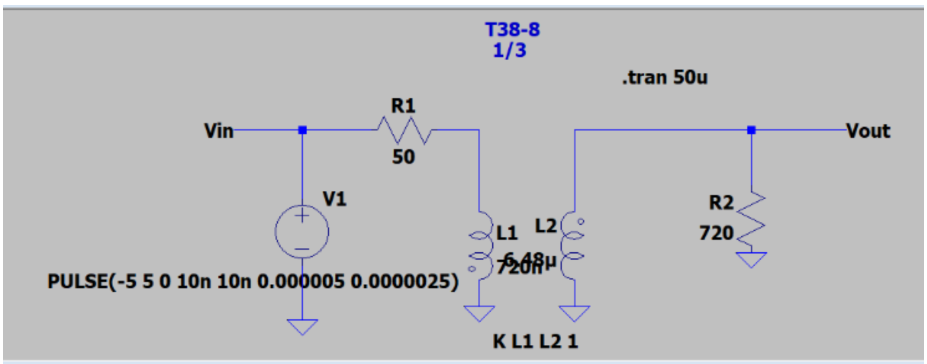

Figure 1: Voltage Spike Generator Circuit

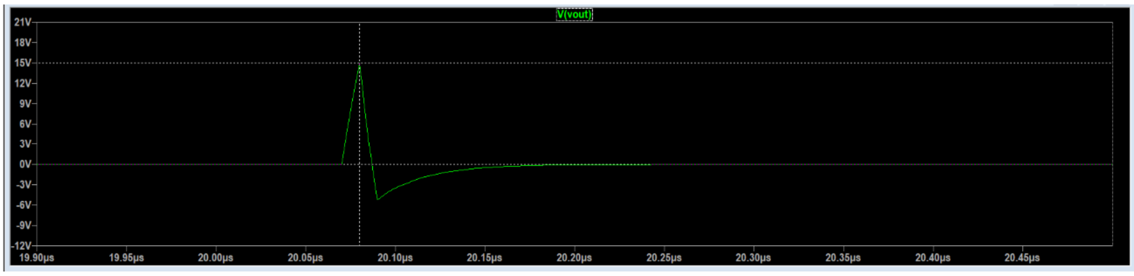

Figure 2.1: Simulation of the Spike with the Peak Value 15V

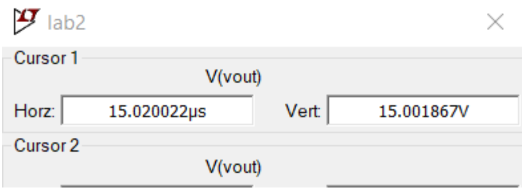

Figure 2.2: Output Voltage of the Spike Checked with the Cursor

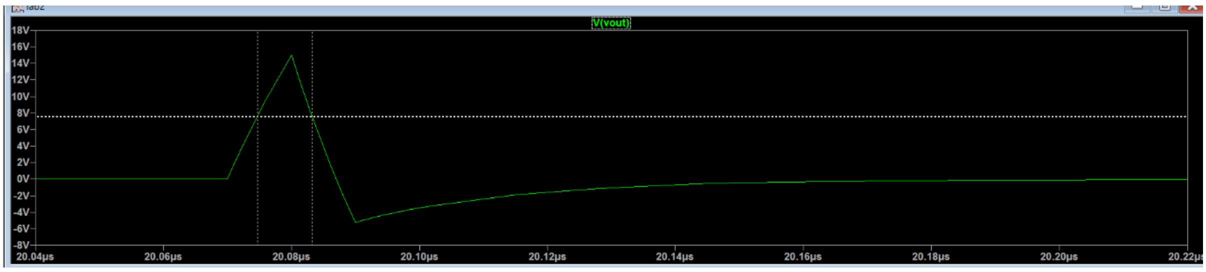

Figure 3.1: Simulation of the Spike Controlling FWHM

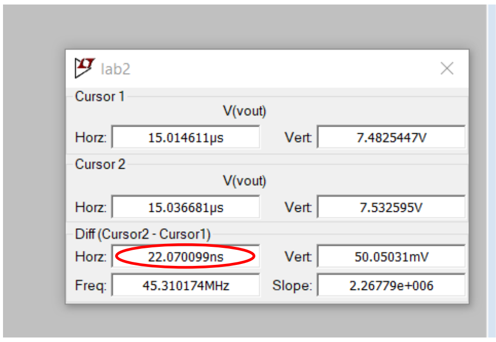

Figure 3.2: FWHM less than 90ns

Part 2: Hardware Implementation

In the hardware part, I got 12V as an output (Figure 5) meaning 20% error occurred which is a little high. I kept the input and output turn numbers the same, however, the reason why I got a very high error I needed to change the load resistance and higher it to 2kΩ. However, I still get some errors. Furthermore, I couldn't pick higher frequencies in order the lower the error because this time spikes got distorted. Also, I observed 24ns FWHM (Figure 6) with 9.09% error which is acceptible. Finally I connected a 47Ω resistor across the terminals of the signal generator. By doing this we halved the internal resistance of the signal generator by connecting in parallel. After that I observed fall and rise times (Figure 7). These values are the time difference between a value 10% less than the maximum value and a value 10% more than the minimum value.

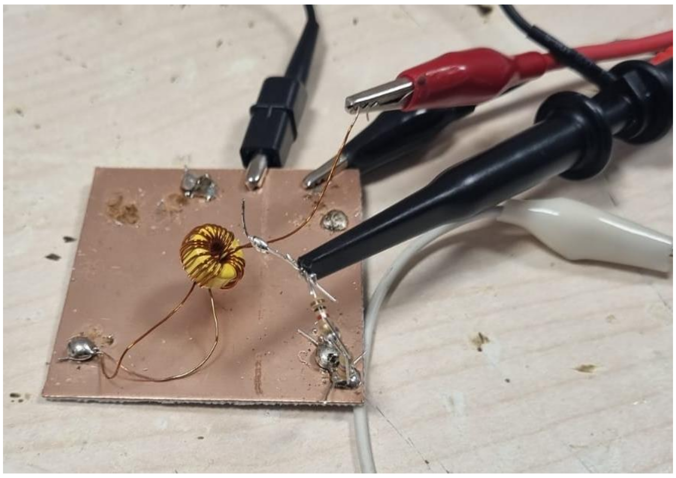

Figure 4: Hardware Implementation of the Circuit

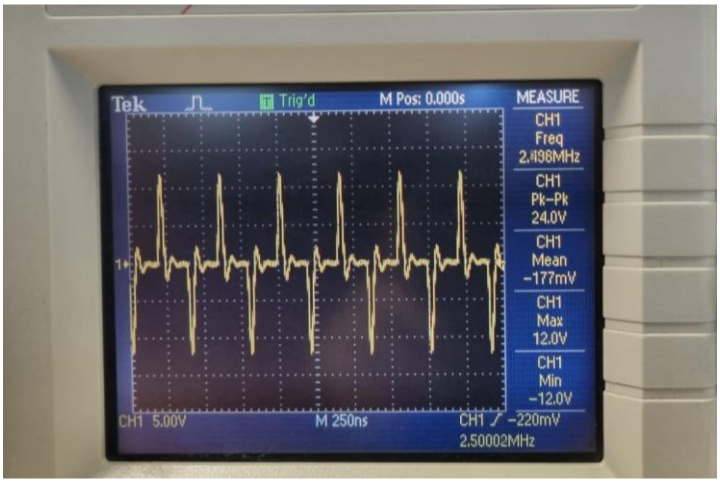

Figure 5: 12V peak Voltage at 2.5MHz as an Output

Figure 6: 24ns FWHM in Hardware part

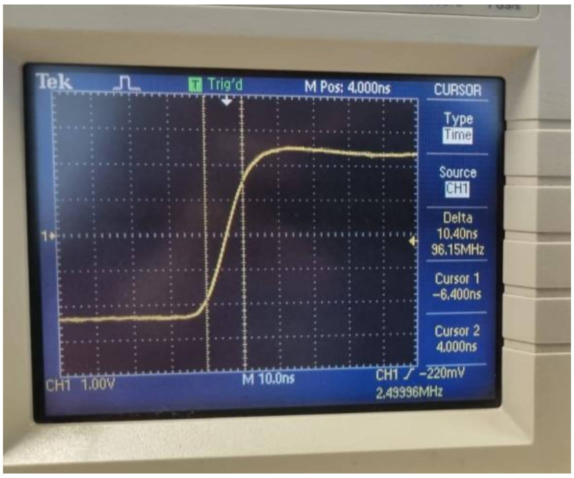

Figure 7.1: Rise Time

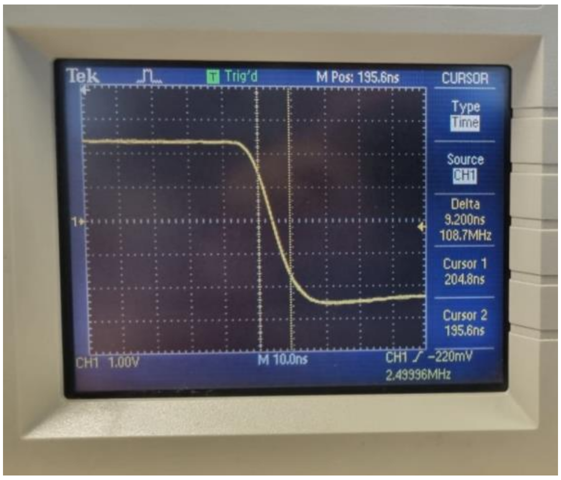

Figure 7.2: Fall Time

Conclusion:

In this experiment, the primary objective was to generate a high-voltage spike within the 15V-20V peak range with a FWHM of less than 90ns, using a 10Vpp square wave as the input signal. During the simulation, we assumed an ideal transformer with a leakage coefficient of 1, implying 100% ideal transformer behavior. However, in the hardware lab, I got a 20% error in finding the output voltage which is 12V even lower than 15V which is not in the range. This can be because in real life there is a leakage and components have internal resistors. Also, external circumstances could have an effect on the flux change which can cause an error and lastly, winding couldn't be done 100% perfectly which again can cause an error. The reason why I got lower voltage in the output. Changing windings was harder and the reason why with the high number of windings a little change of turn number wouldn't give valuable effect to the output voltage I higher my load resistance 720Ω to 2.2kΩ. Also, I observed 24ns FWHM with 9.09% error which is acceptible again. As a result, in this lab, I learned how to generate a voltage spike and how to debug to get required values. Moreover, I learned a lot about transformers, leakage concept, and FWHM.

REFERENCES

Equations 1, 2, 3 from:

Book-Electric-Circuits-9th-ed-J.-Nilsson-S.-Riedel-Prentice-Hall-2011.pdf