Bilkent University

Circuit Theory-EE202

LAB2: Voltage Spike Generator

Sait Sarper Özaslan

22002861

Purpose:

The purpose of this lab is to design a passive linear circuit which creates voltage spikes from 10V peak to peak pulse source with source resistance of 50 ohms and frequency of less than 5MHz.

Methodology:

As for the specifications of the circuit :

- Input is 10Volt peak to peak pulse source with frequency less than 5MHz
- Source resistance of 50Ohms.
- Voltage peak (V_p) should be around $15 \leq V_p \leq 25$Volts
- FWMH needs to be less than 80ns
- The rise and fall times of the square wave are 10ns.

Using these specifications the expected voltage output is as follows:

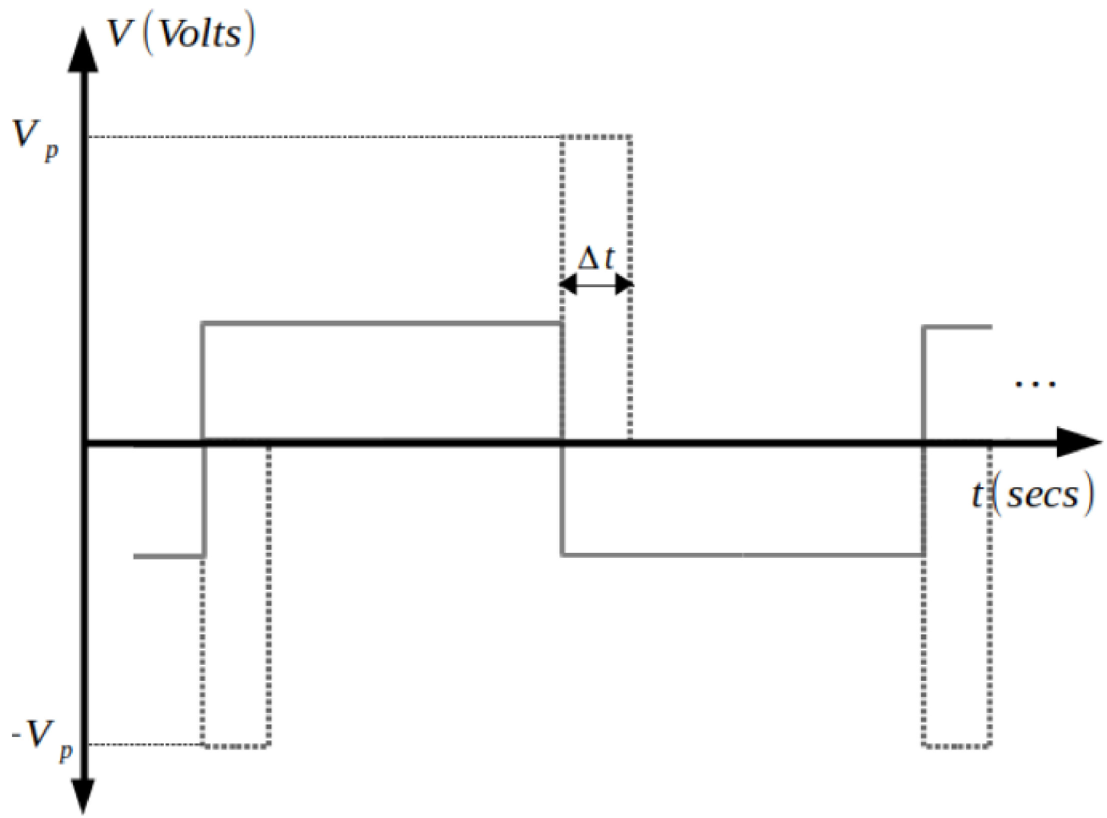

Fig1: Output Voltage in Dashed Lines

To achieve this a transformer will be used to benefit from electromagnetic induction between the inductors. In other words, a transformer will be used to step up AC pulse voltage of 5 Volt peak to between 15-25 volts. In this lab I aimed the output voltage to be around 3.75 times higher than the input voltage.

The voltage relation for a transformer can be expressed from Faraday's Law of Induction. In other words, the created magnetic flux in the primary winding causes, magnetic flux in the second winding as well. This relation can be expressed as:

$$\frac{V_S}{V_P} = \frac{I_P}{I_S} = \frac{N_S}{N_P}$$

In here "S" stands for the secondary winding's voltage, current and number of windings whereas P stands for primary winding's voltage, current and number of windings.

- Using this equation, the secondary winding needs to **3.75 times** higher than the primary winding. I used 4 turns to 15 turns for this lab.
- In such case the expected voltage is to **be 18.75 Volts**

As a transformer consists of two inductors, we need to know inductance as well which can be found through:

$$L=A_L*n^2$$

- From this we can see that the secondary winding, whose number of turns is 3.75 times higher than the primary winding, will have **14.0625 times** higher inductance than the primary winding.

After finding these relations, I moved onto the software lab.

One last part that we need to ensure is that FWMH is less than 80ns to find that we need to calculate the **time constant** from the first winding's inductance.

$$\tau = \frac{L1}{R1}$$

From inductance calculation L1 is 320 nH and R1 is 50 ohms.

$$\tau = 6.4ns$$

This means it should take around 32ns to reach 0 Volts from the peak. This will certainly ensure that FWMH will be lower than 80ns

Software Lab:

Circuit designed is as follows:

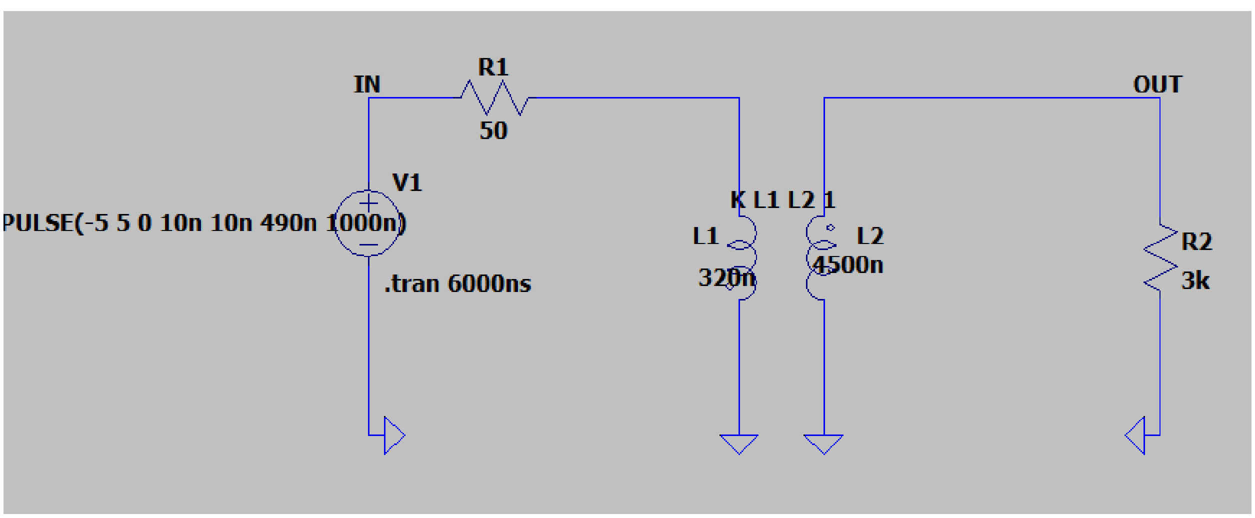

Fig2: Transformer Circuit

- The determined turn ratio is 3.75 which means the inductors' ratio is 14.0625.
- To get a realistic result coupling constant was picked 1.
- Chosen inductor core is T38-8, $\mathbf{A_L = 20nH/t^2}$.

- According to the inductor equation, the primary winding with 4 number of turns will be **L1= 320nH** and secondary will be **L2= 4500nH**.
- The selected resistor value is **3k Ohm.**

For the voltage divider part I also used this circuit:

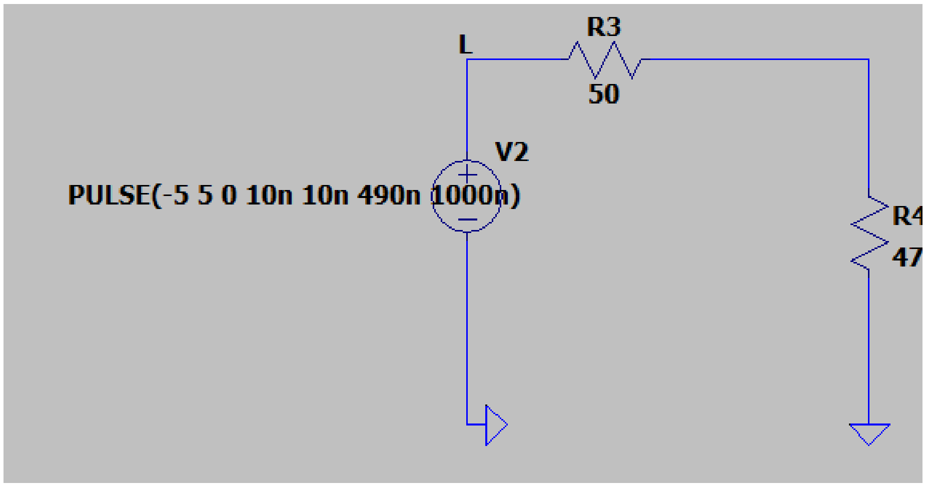

Fig 3: Voltage Divider

Software Results:

Here are the simulation results.

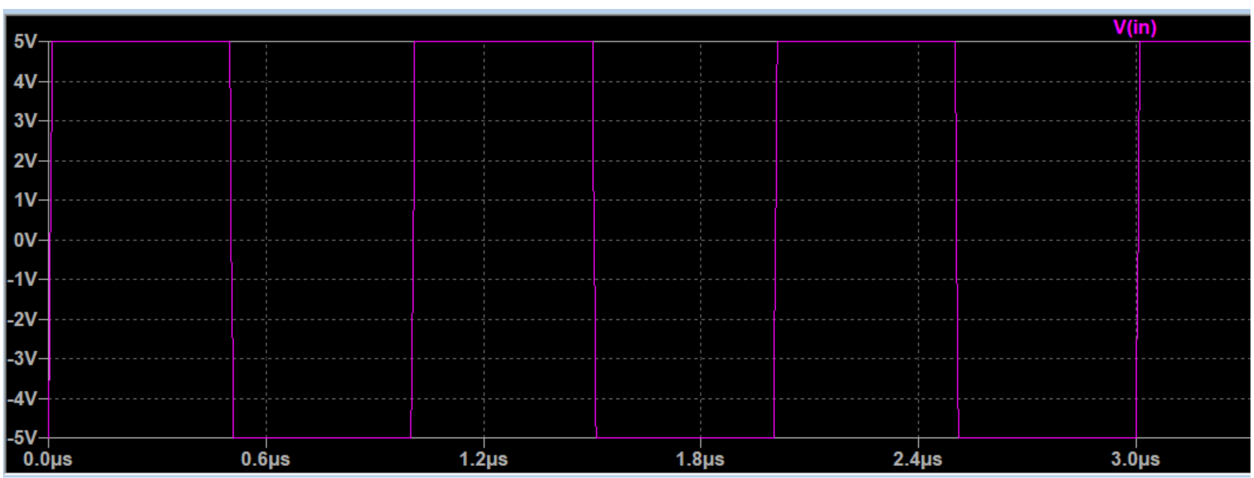

Fig 4: Input Voltage

Here is a 10 Vpp pulse source with 1MHz. Rise times and fall times are 10ns. This can also be seen from figure 2.

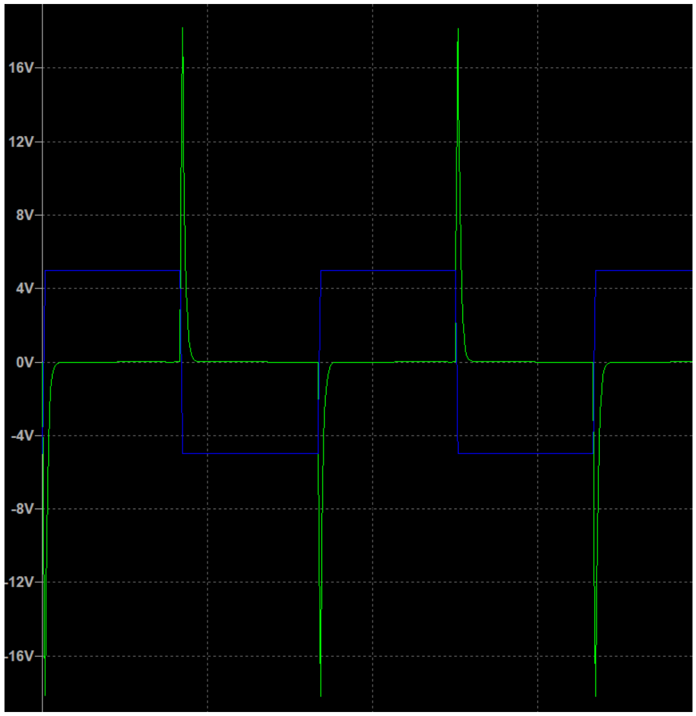

Fig 5: Waveform of Input and Output Voltage

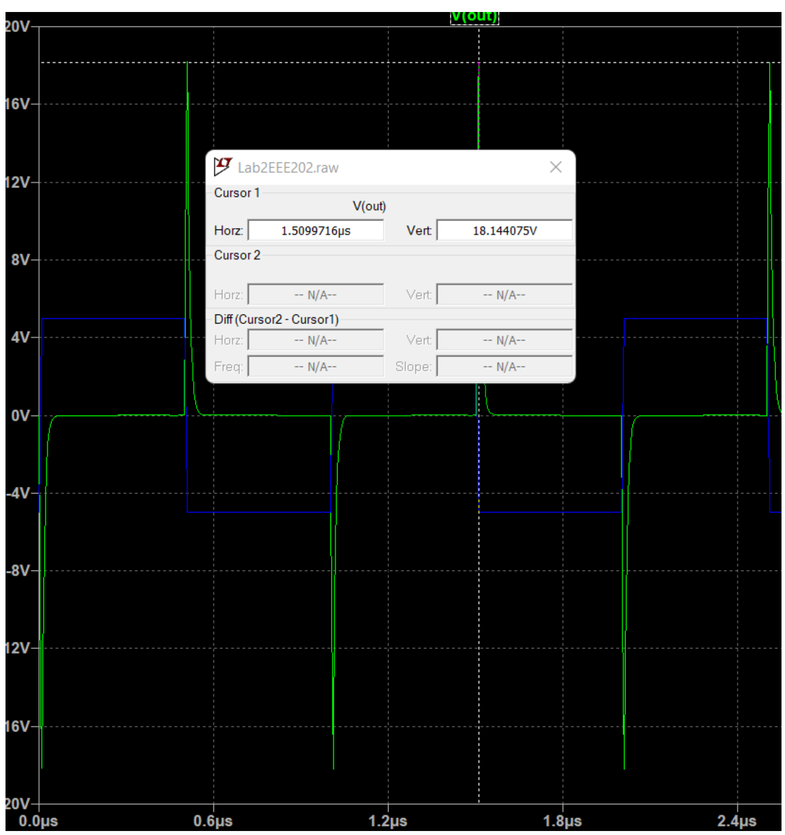

Fig 6: Peak voltage of Output and Input

- Vout is 18.14Volts, expected voltage was 18.75V
- Vin is 5V

Error rate: %3.25

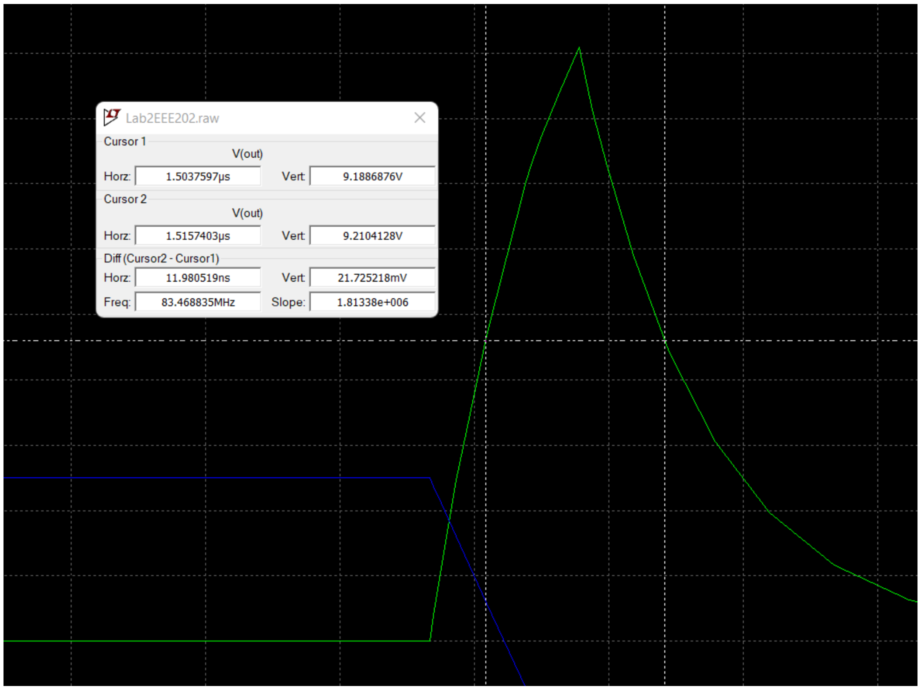

Fig 7: FWMH of 12ns

It can be seen that full width at half maximum is **12ns ,** which is less than 80ns. This is suitable for lab requests.

Finally here are the voltage divider results.

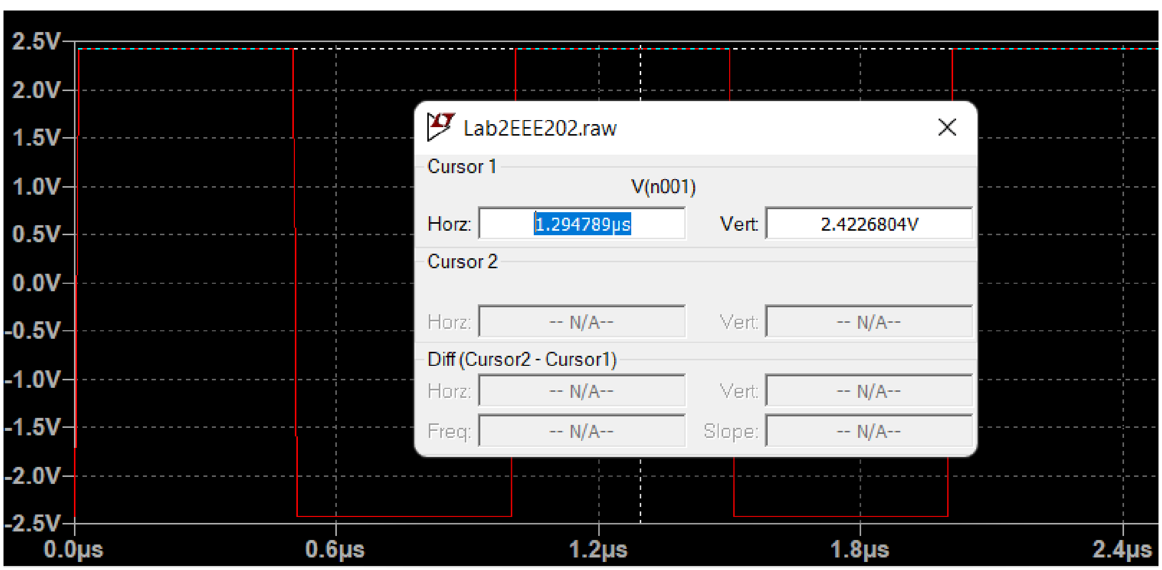

Figure 8: 2.42 volts on 47 ohm

- It can be seen that 47 ohm gave 2.42 volts as output voltage which would be the exact same result we would get from the voltage divider calculation.

Hardware Lab:

For hardware implementation following was done:

- Inductor core T38-8 was used.
- Ns=15 turns
- Np = 4 turns
- Lp = 320nH
- Ls = 4500nH
- Different from the software, load resister **of 8.2k** Ohm was used.
- 1Mhz 10Vpp source.

Here is the circuit in question:

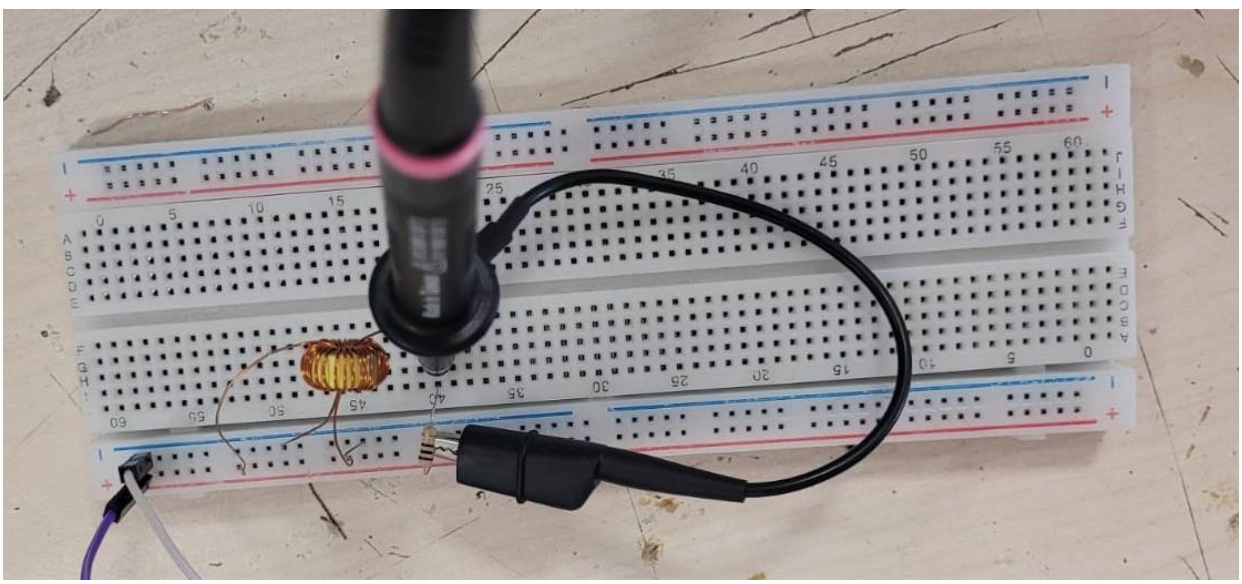

Fig 9: Hardware Implementation

Starting of with the square wave which we added a 47ohm resistor and measured the rise, fall and peak values.

Here are the values:

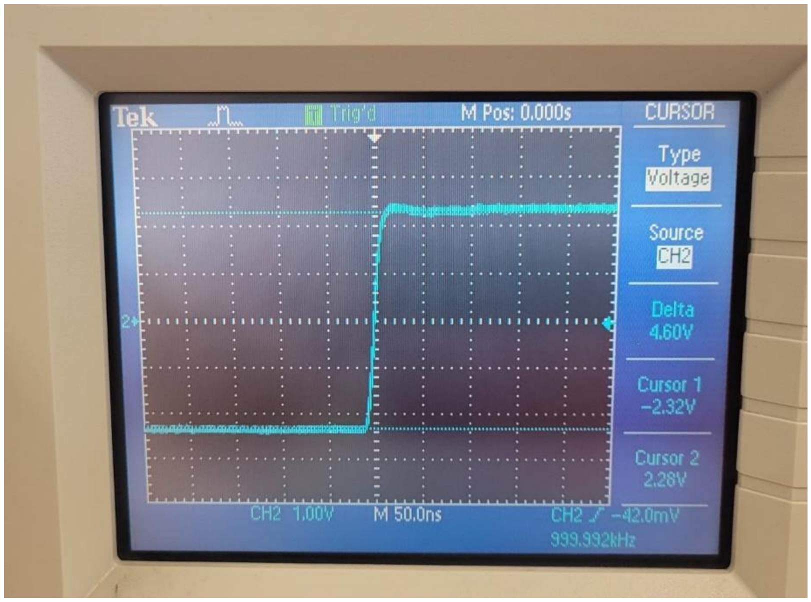

Fig 10: Peak voltage of Input

From voltage divider with 47 and 50 ohm the expected voltage is 2.42 v.

Fig 11 & 12: Fall and Rise time of 13.2ns in Input

1MHz Source	Software	Hardware	Error
Voltage	2.42V	2.3V	4.95%
Rise-time	10ns	13.2ns	32%
Fall-time	10ns	13.2ns	32%

Table 1: Squarewave Voltage, Rise & Fall Time

After this part I moved onto the next part, the voltage spikes. Here are the results,

Fig 13: Voltage spike of 15.2 Volts on 5 Volt square-wave input

Voltage Spike	Software	Hardware	Result
1Mhz	18.14V	15.2V	16.2%

Table 2: Voltage Spike

- There is also the error of 18.9% if we choose to compare it to the expected result of 18.75V.
- Spike Duration is certainly shorter than the input period.

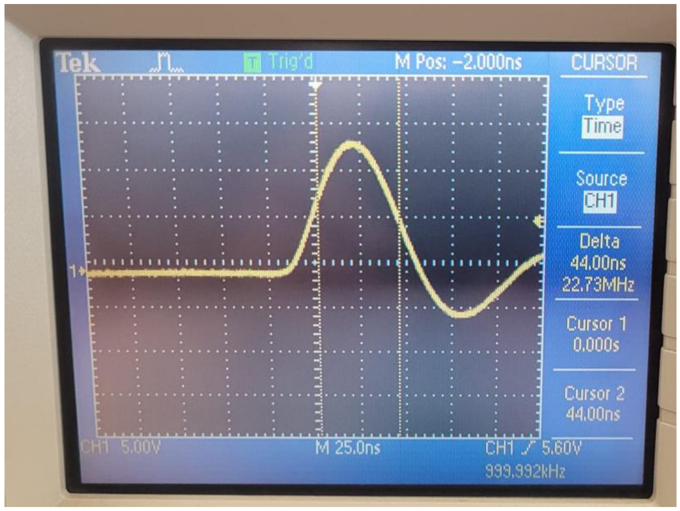

Fig 14: Full widths at half maximum value of Voltage Spike

FWMH	Software	Hardware
1MHz	11.98ns	44ns

Table 3: FWMH values

In this part error was not considered as an important value.

Conclusion:

The goal of this lab was to learn how to create a passive linear circuit capable of transforming 10 Volt peak to peak square wave into voltage spike that is 15-25 Volts. Moreover, frequency of the circuit needed to be less than 5MHz and the FWMH needed to be less than 80ns.

To begin with, the voltage divider part had some errors. The error in max voltage might be due to inner resistance possibly being higher than 50ohms or the voltage supply giving less than it is supposed to. The error in rise and fall time could be explained by the delays in the machine itself, as we are looking at the values in nanoseconds it is unavoidable.

Though I had expected to see 18.75 volts due to coupling constant I have used I found the value of **18.14V** which is probably due to load resistor I have picked. After increasing the load resistor value to 12k for instance the simulation gave of 18.55 volts indicating that my guess was right. However, I have no information about the relation between load resistors and inductance values of the transformer.

This value dropped down to **15.2 Volts** in the hardware. Voltage drop might be caused by the coupling constant being actually lower than 1 meaning that there is leakage in the circuit which means windings I have made are probably not as closeknit to the toroidal core as it should be. However, 16.2% error is negligible within the lab limits and this can be fixed if I use a higher resistor value or increase the second winding's number of turns.

The increase in FWMH can also be explained from the coupling constant and winding. As FWMH mainly caused by the primary winding that means I could have used a different number of turn or made the windings tighter than what it was. On the other hand, this part of the lab it was considered enough for FWMH to be less than 80ns so I preferred not to change the preserve the voltage values I have found.

Finally, there is also the possible errors caused by the oscilloscope, probe and breadboard itself. To fix the breadboard error I actually tried using soldering however this proved difficult every time I had to change components.