EEE 202 - Lab 2 Report - Voltage Spikes

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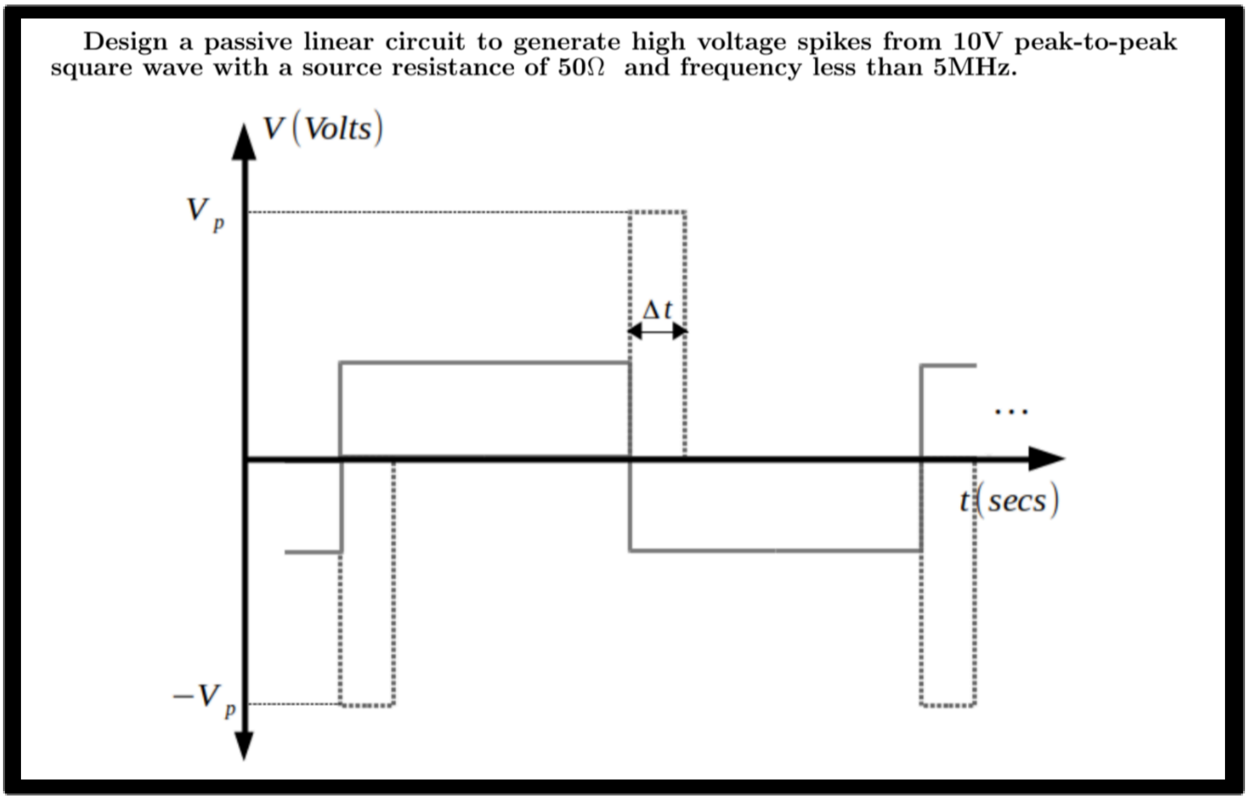


Figure 1.1: Lab Assignment Exampe Graph

- Introduction:

In this lab, we are asked to generate voltage spikes with a amplitude of ~20V to 25V from a square wave using only passive components. There are a different methods one can utilise to generate a voltage spike. Inductive spikes are being utilised in this lab due to its configurability and simplicity.

- Theory:

A simple inductive spike can be generated when the current in an inductor drops almost instantaneously. This can be inferred from the voltage formula of an inductor.

$$V = L\frac{di}{dt}$$

When we assume the current drop is instantaneous and the current through the inductor is non-zero, we can assume dt approaches '0'. The current drops to zero therefore we can assume $di = i_0$ Therefore, the equation becomes:

$$V = L\frac{i}{0} = \infty$$

In an ideal setting where dt is 0 the output voltage would be infinite. However, due to the resistance of inductors and wires etc. the voltage spike is not as high.

- Methodology and Software Implementation

To produce this drop in current, the given square wave generator is enough by itself as seen in Figure 2.1. However, the voltage spikes do not have the desired amplitude

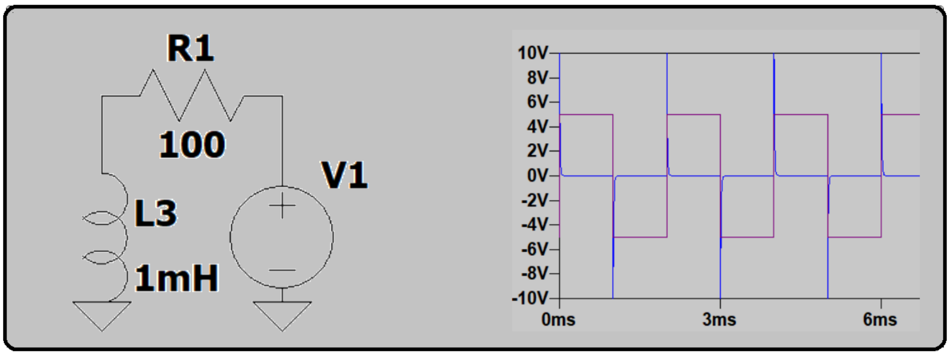


Figure 2.1: Basic inductive spike circuit and output waveform

To control the output amplitude, we can just implement a transformer instead of the inductor. The secondary side can increase the voltage to observe a higher amplitude.

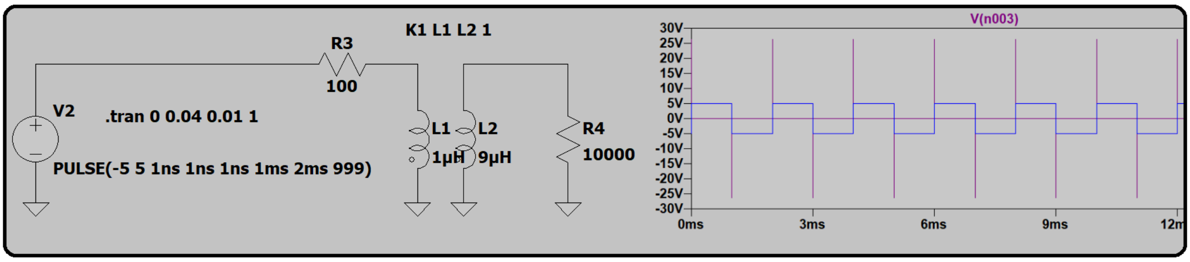
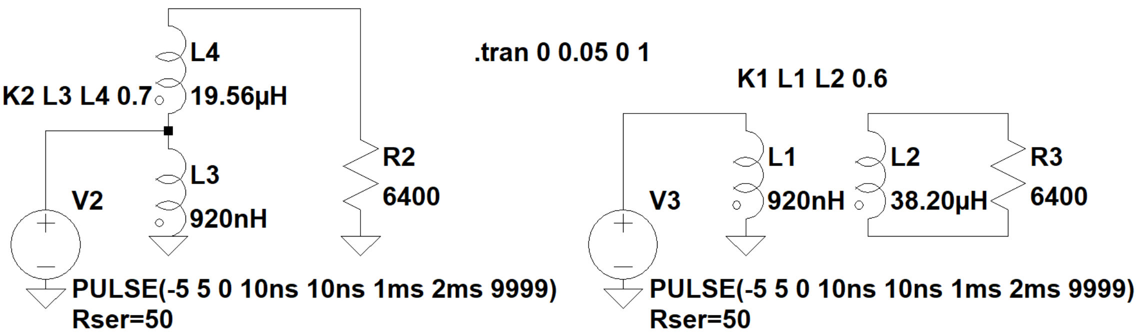


Figure 2.2: Inductive spike circuit with controlled amplitude and output waveform

- Hardware Implementation

To implement this circuit using real life components, we need to adjust the values to match non-ideal components. We can use an auto-transformer to simplify the winding process of the transformer or we can increase the windings of the inductor to compensate for the loss. I designed two circuits using both of these methods. Both circuits' schematics are provided below.



Circuit 1: Auto-Transformer Circuit

The circuit is modified to include an auto-transformer that has a 7:25+7 ratio that generates a spike of ~21V

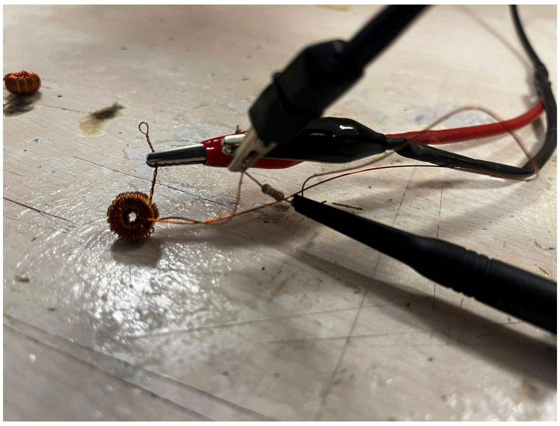


Figure 3.1: Auto-Transformer Circuit Hardware

Since the windings are not overlapping and sufficiently spread out this circuit achieves the same ratio of inductances using less windings. This was a more logical and consistent implementation therefore the continuing measurements are measured on this circuit.

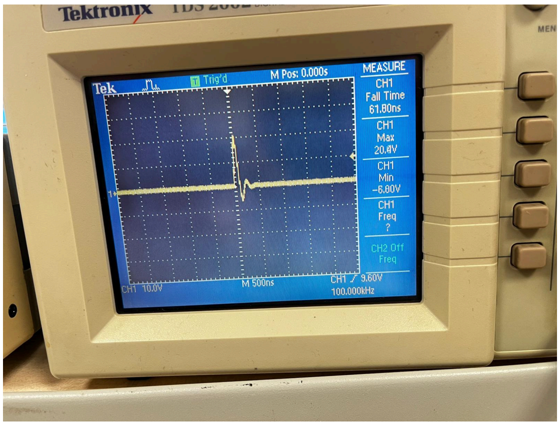


Figure 3.2: Waveform of Auto-Transformer Circuit

Circuit 2: Transformer Circuit

The windings of the secondary are increased to have an approximate ratio of 7:40. The reason for the high amount of windings in the secondary is the core loss. The additional windings are winded on top of the previous windings for the secondary.

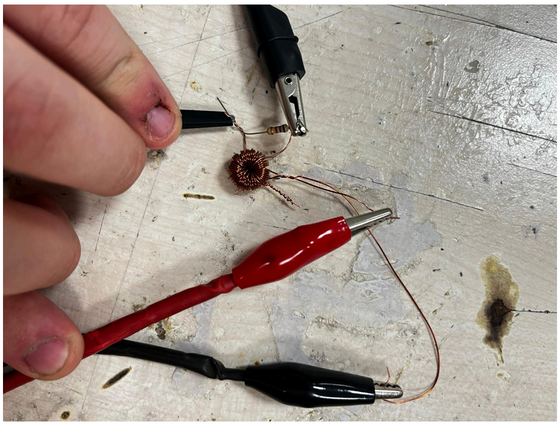


Figure 3.3: Transformer Circuit Hardware

Again with these windings the amplitude of the voltage spikes were around 21V. However, since the amount of windings are more than then expected amount and due to the leakage. This circuit was used.

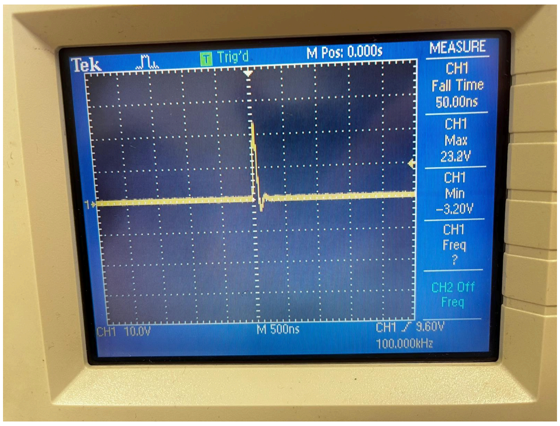


Figure 3.4: Waveform of Transformer Circuit

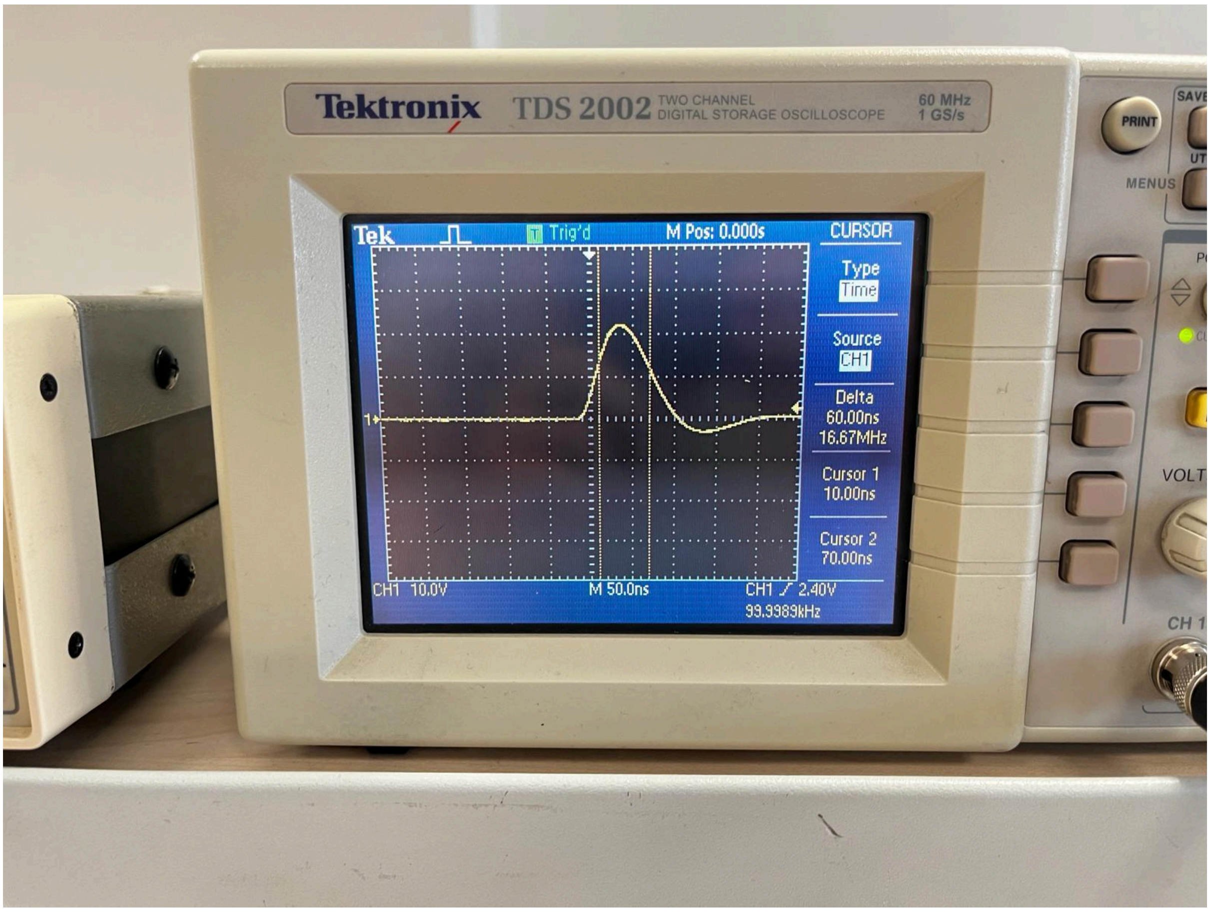


Figure 3.5: Spike Duration of Auto-Transformer Circuit

The voltage spike resembles an underdamped oscillation. However, underdamped oscillations are a result of a second-order circuit therefore we have to have some capacitive elements. This is caused by the capacitance between the windings of the toroid.

It should also be noted that the inductance values are 960nH,21μH respectively

Error Calculation:

The maximum voltage of the spike of the theoretical autotransformer circuit was found to be 21V. The experimental voltage was approximately 22V. The error percentage from these values comes out as:

$$\frac{\Delta V}{V_{thereotical}} = \frac{1}{22} = 4.5\%$$

However, utilising the non-ideal model for inductors, using the correct toroidal core loss, and adjusting the signal generator’s rise and fall times gives us a different theoretical perspective.

Figure 3.6: Rise and Fall times of the signal generator measured on a 47Ω resistor.

The error in this circuit can be traced back to three main reasons. Capacitance between the windings, rise and fall time difference between hardware and software, and the leakage of the toroidal core. The leakage of the toroidal core can be changed in LTspice to compensate for this effect the value of which can be found in the datasheet for the core. Finally, to compensate for the capacitances of the inductors, parallel capacitors are connected to the inductors with the respective measured capacitance values. The realistic model of the circuit after compensating for these factors will look like the circuit given in Figure 3.7.

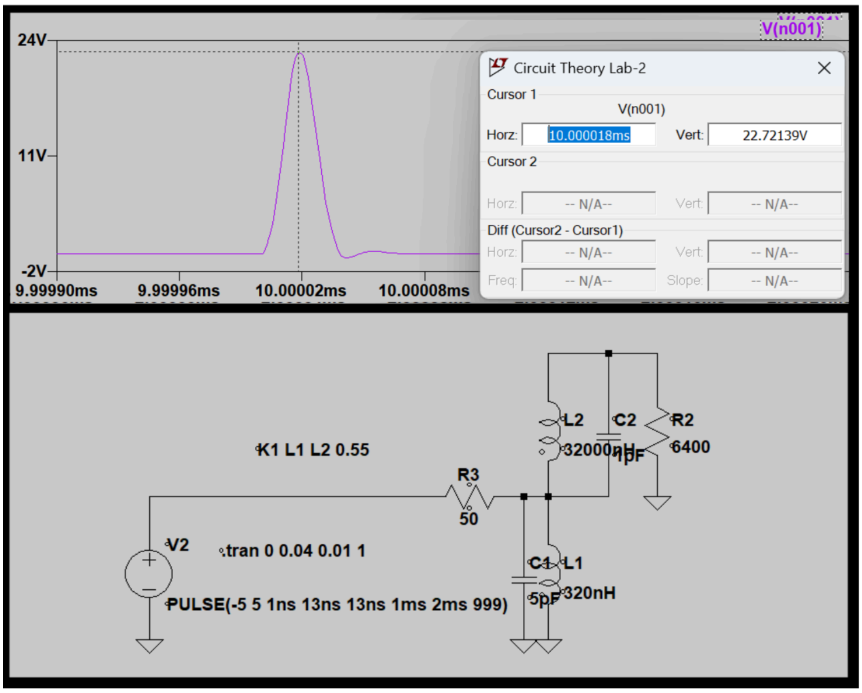


Figure 3.7: Realistic model of the final circuit

After these modifications the error percentage comes out to be 3.08%.

$$V_{theory} = 22.7V \text{ and } V_{hardware} = 22V$$

$$\frac{\Delta V}{22.7V} = \frac{0.7}{22.7} = 3.08\%$$

- ## Conclusion

In this lab, we studied the behavior of inductive spikes and their mathematical calculations. We then manipulated these inductive spikes to get the desired value for the software implementation. For the hardware implementation, we needed to wind copper wires around a toroidal core to get the desired transformers. However, in doing so it became apparent that directly winding the inductors are not a practical method to get the desired ratio. Alternatively, an auto-transformer was used to reduce the number of required loops. We also needed to account for the capacitances of the non-ideal inductors while explaining the waveform.