University of Colorado Boulder
ECEE Department

ECEN 2250 - Introduction to circuits and electronics - Fall 2023

Location: Engineering Center, ECCR 1B40, MWF 2:30PM - 3:20PM

Instructor: Professor Eric Bogatin

Lab #7: RC and RL circuits and transient response

Date of Experiments: 11/08/23

Name: Connor Sorrell

Experiment 1: Simulate the step response of an RC circuit

After building the circuit but before simulating, I put rule #9 to use. I expect the voltage across the resistor to start to exponentially decay from 1 to 0 V, and then drop down to -1V and exponentially rise back to 0V. I expect the voltage across the capacitor to show the RC time constant of the circuit, and show 63% of the final voltage after 1ms. Sure enough, the simulation looks exactly like I expected, and after 1 ms (the time constant), the voltage is 630mv, 63% of the final voltage level.

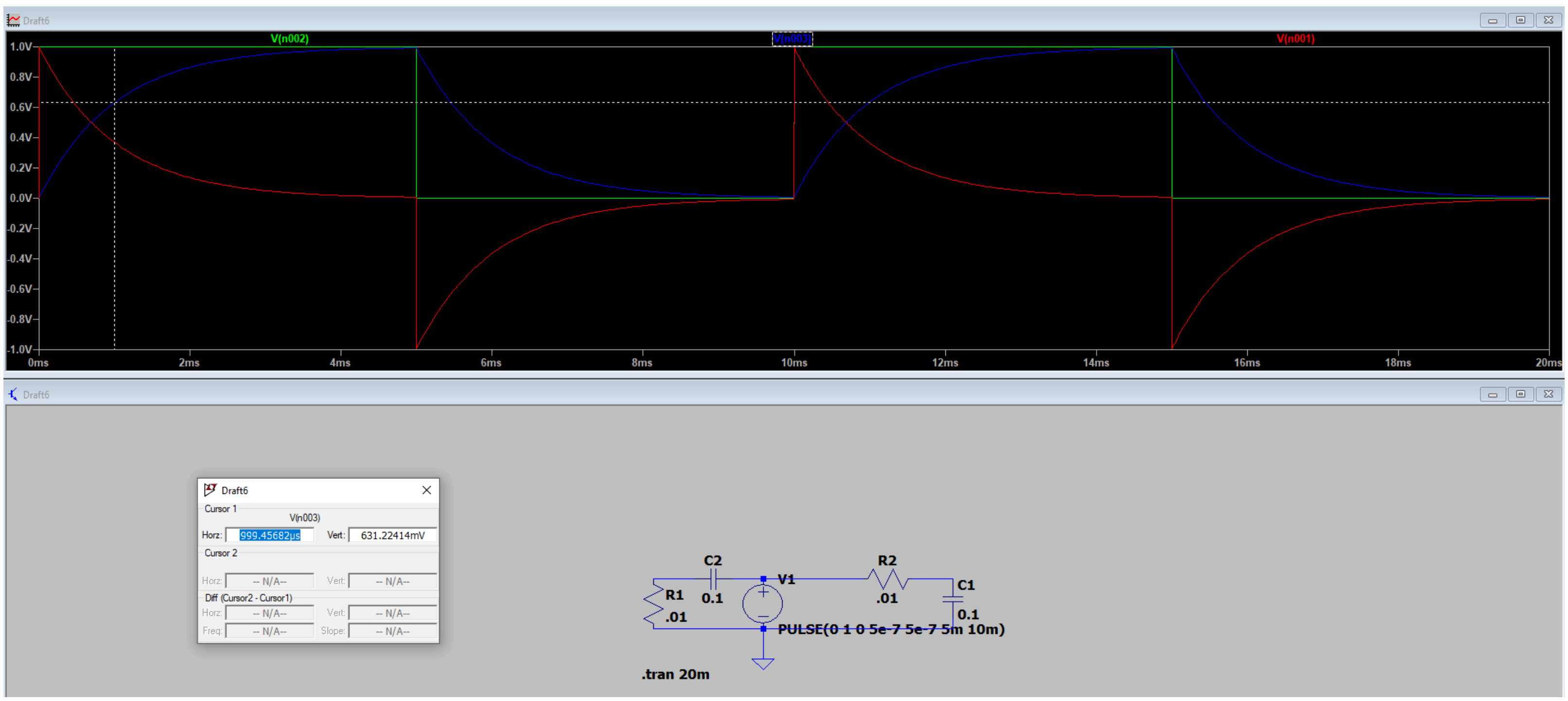

Figure 1.1.0: Screenshot of the circuit and its simulation which shows the 3 waveforms: Voltage through the source (green line), voltage across the capacitor (blue line), and voltage across the resistor (red line). This circuit has an RC time constant of 1ms, with resistor values of 0.01 ohms and capacitor values of 0.1 farads, which are values that work to get the T = RC = 1ms. The total simulation time is 20ms, accounting for two full 2 cycles of the square wave. After 1 time constant, the voltage across the capacitor shows 63% of its final value.

The waveform for the voltage across the source (green wave) shows the pulse wave from 0 to 1 V. It is on for 5 ms, turns off for 5 ms, and repeats twice. This correlates to the on time in the pulse wave (5ms) and the period (10ms).

The waveform for the voltage across the capacitor, also the RC time constant, (blue wave) shows that after 1 time constant, we see 63% of the final voltage. After 3 time constants, we see 95% of our final value, and after 5 time constants, we see over 99% of our final value.

The waveform for the voltage across the resistor (red wave) shows a 1V exponential decay, and then when the voltage across the source drops its 1V, the current flows through it in the opposite direction, so a negative voltage is across the resistor. Essentially, the capacitor is letting the dv/dt run through it when it is large, but it blocks the dc component. This is interesting and very useful to know in the real world because it gives us a hint as to how we might engineer an inverting supply. If we only have a 0 to 5 V supply, if we manipulate the voltage across the resistor, we could make a negative voltage supply from a positive supply.

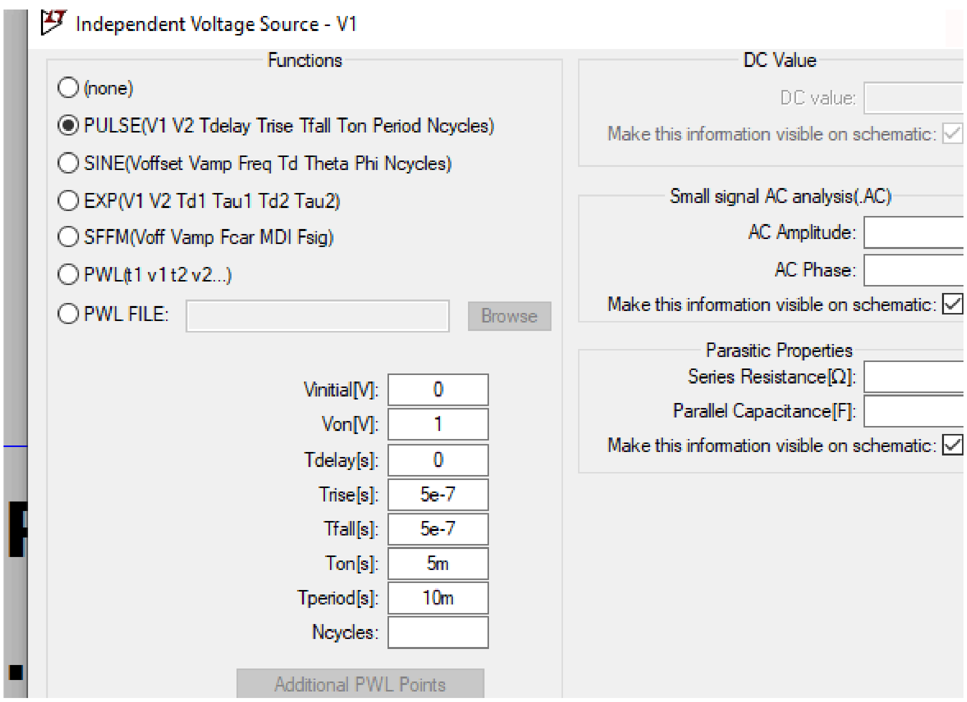

Figure 1.1.1: Shows the values of the pulse wave coming from the voltage source.

Experiment 2: Measure the step response of an RL circuit

After building the circuit but before simulating, I put rule #9 to use. I expect the voltage across the inductor to start to exponentially decay from 1 to 0 V, and then drop down to -1V and exponentially rise back to 0V. I expect the voltage across the resistor to show the RL time constant of the circuit, and show 63% of the final voltage after 1ms. Sure enough, the simulation looks exactly like I expected, and after 1 ms (the time constant), the voltage is 630mv, 63% of the final voltage level.

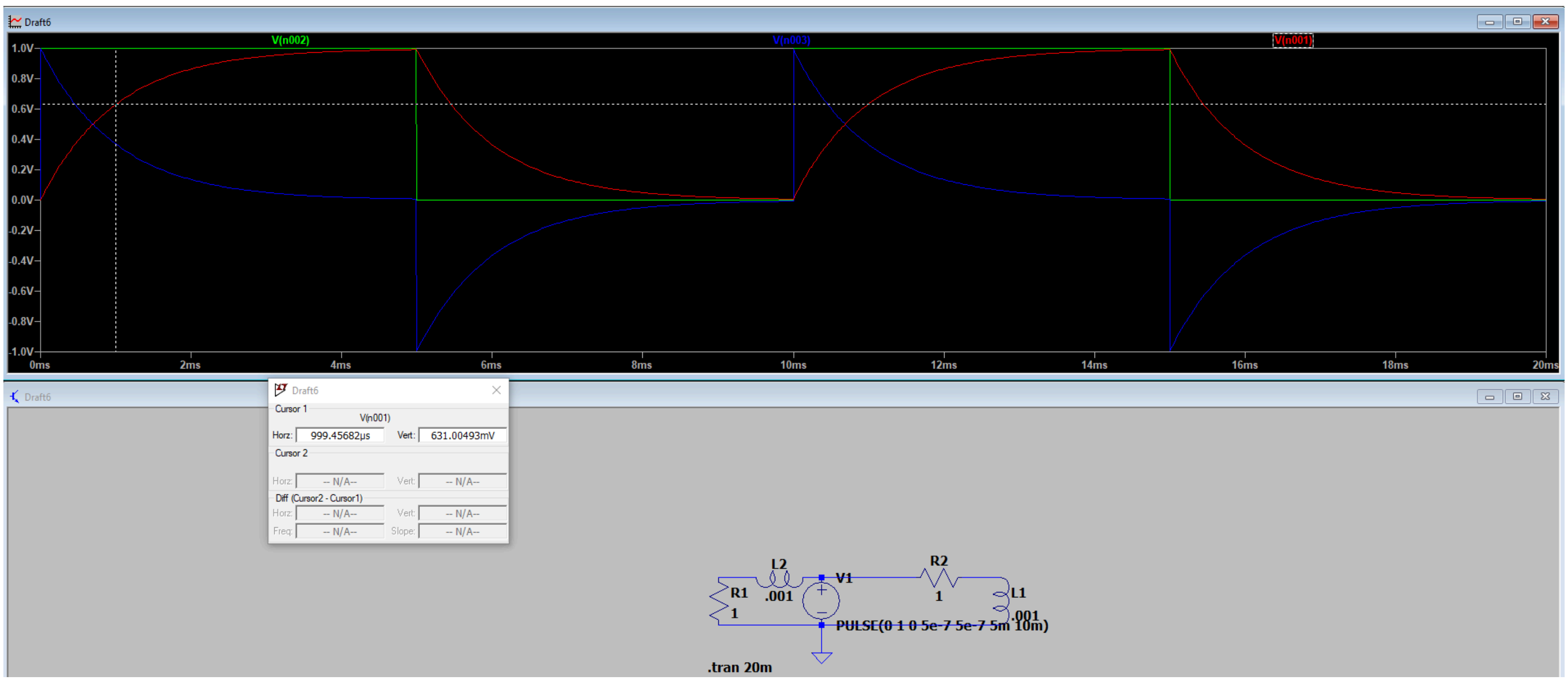

Figure 1.1.0: Screenshot of the circuit and its simulation which shows the 3 waveforms: Voltage through the source (green line), voltage across the inductor (blue line), and voltage across the resistor (red line) which is also the current through the inductor. This circuit has an RL time constant of 1ms, with resistor values of 1 ohms and capacitor values of 0.001 farads, corresponding to the time constant T = L/R = .001/1 = 1ms. The total simulation time is 20ms, accounting for two full 2 cycles of the square wave. After 1 time constant, the voltage across the inductor shows 63% of its final value.

The waveform for the voltage across the source (green wave) shows the pulse wave from 0 to 1 V. It is on for 5 ms, turns off for 5 ms, and repeats twice. This correlates to the on time in the pulse wave (5ms) and the period (10ms).

The waveform for the voltage across the inductor (blue wave):
After a long time, we know the voltage across the inductor has to be zero. Initially, the voltage is zero as well. But, when we suddenly turn on the 1V, all the voltage will go across the inductor, showing a sudden increase of 1V. Then, the wave shows a 1V exponential decay as the current builds up through the inductor. After around 5 time constants, the voltage is pretty much zero, and then the voltage turns off. When the voltage across the source drops its 1V, the current in the inductor has to change direction, causing a negative voltage.

The voltage across the resistor wave: (red)
We see the same current will slowly increase, so we will see a voltage exponentially increasing across the resistor to the full 1V value, and then the voltage decreases slowly because of the current in the inductor.