EE 11L: Circuits Laboratory I

Experiment #3
Experiment 3: Transient Response of the 1st-Order Circuits

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Objectives

To understand and investigate the natural and step response of first order capacitive and inductive circuits. To design a first-order circuit with certain characteristics. To analyze initial conditions within a circuit containing inductors and capacitors

Theory

Capacitors The i-v relation of a capacitor is

$$i = C\frac{dv}{dt}$$

The voltage across a capacitor cannot change unless infinite current is applied
RC Circuits when a capacitor and a resistor is connected in series with a voltage source V we have the following equation for the voltage v_C across the capacitor

$$v_C + RC\frac{dv_C}{dt} = V$$

Therefore the response to a step voltages source $V(t) = Vu(t)$ is

$$v_C(t) = V(1 - e^{\frac{-t}{RC}})$$

and the time constant is $\tau = RC$
Inductors The i-v relation of a capacitor is

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

The current across a inductor cannot change unless infinite voltage is applied.

RL circuits when a capacitor and a resistor is connected in series with a voltage source V we have the following equation for the voltage v_l across the capacitor

$$v_l + \frac{L}{R}\frac{dv_l}{dt} = V$$

Therefore, the response to a step voltage source $V(t) = Vu(t)$ is

$$v_C(t) = V(1 - e^{-\frac{R}{L}t})$$

Lab 1: Experiment Setup

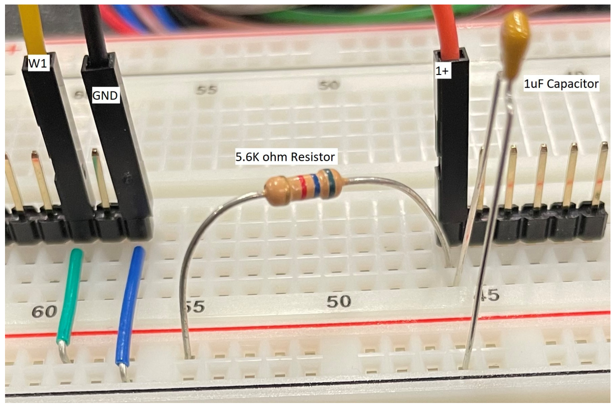

Figure 1: Lab 1 Setup

Lab 1: Measurement

The measured time constant is $531.56\mu s$

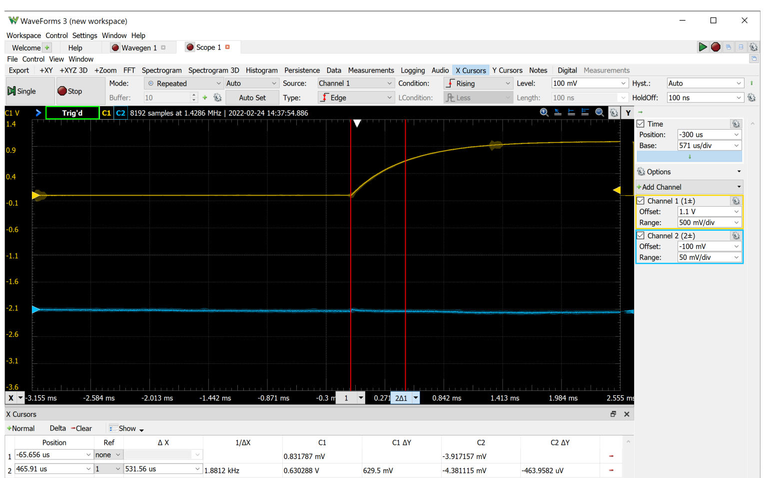

Figure 2: Measurements from the oscilloscope for Lab 1, C1:VC the voltage response of the capacitor

Lab 1: Discussion

The experimental time constant is $531.56\mu s$ and the theoretical time constant is $560\mu s$. The difference between these two values is 8.35%

Since the resistor is in parallel with the capacitor, the resistor's voltage response is $V_r = V(t) - V_c(t)$ where V_r is the voltage across the capacitor and $V_c(t)$ is the voltage across the capacitor. Therefore, as the capacitors voltage increases, the resistor's voltage decreases, and vice versa.

Increasing the sampling rate increases the resolution of the signal. This allows for a more accurate reading for the time constant.

When you increase the frequency of the input, the signal begins to be unable to reach the theoretical steady state voltage.

Lab 2: Experiment Setup

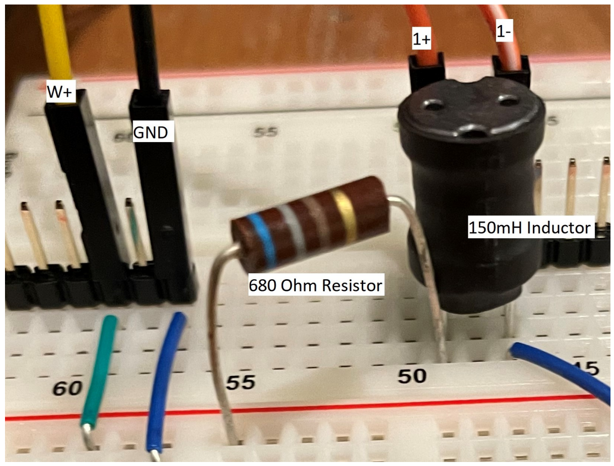

Figure 3: Lab 2 Setup

Lab 2: Measurement

The measured time constant is $178.784\mu s$

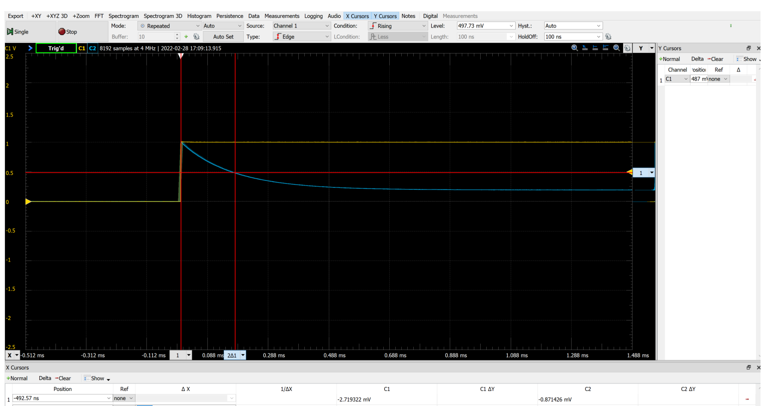

Figure 4: Measurements from the oscilloscope for Lab 1, C1:VL the voltage response of the inductor

Lab 2: Discussion

The measured internal resistance of the inductor is 159.5Ω, therefore the theoretical 178.784μs. and the measured time constant is 178.41μs The difference between these two values is 0.2%

Yes the internal resistance must be considered, since the steady state voltage is 0.19V not 0 volts as it should be theoretically.

In the RL circuit the voltage jumps and slowly falls back down when presented with a unit step input. In a RC circuit, the current slowly increases when presented with a unit step input

Lab 3: Experiment Setup

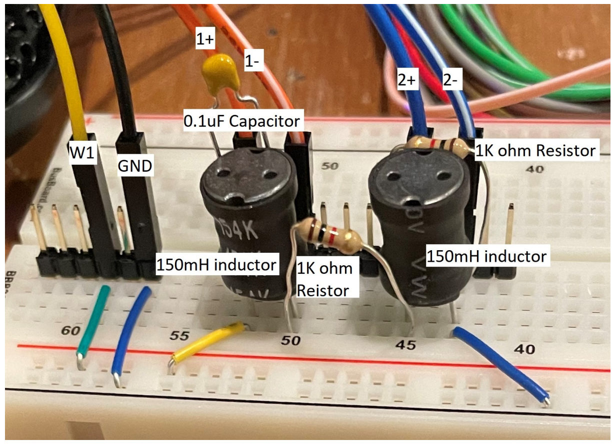

Figure 5: Lab 3 Setup

Lab 3: Measurement

$V_{c1}(t)$

	$t = 0^-$	$t = 0^+$	$t = \infty$
Theoretical	0V	0V	0V
Measured	0.3687V	0.3682V	0.2583V

$V_{R1}(t)$

	$t = 0^-$	$t = 0^+$	$t = \infty$
Theoretical	3V	2.5V	2V
Measured	2.274V	1.769V	1.5138V

$V_{R2}(t)$

	$t = 0^-$	$t = 0^+$	$t = \infty$
Theoretical	0V	-0.5V	0V
Measured	0.325V	-0.201V	0.215V

Lab 3: Discussion

The measured voltages varied significantly from the predicted voltage because of the internal resistance in the inductor and capacitor.

Lab 4: Experiment Setup

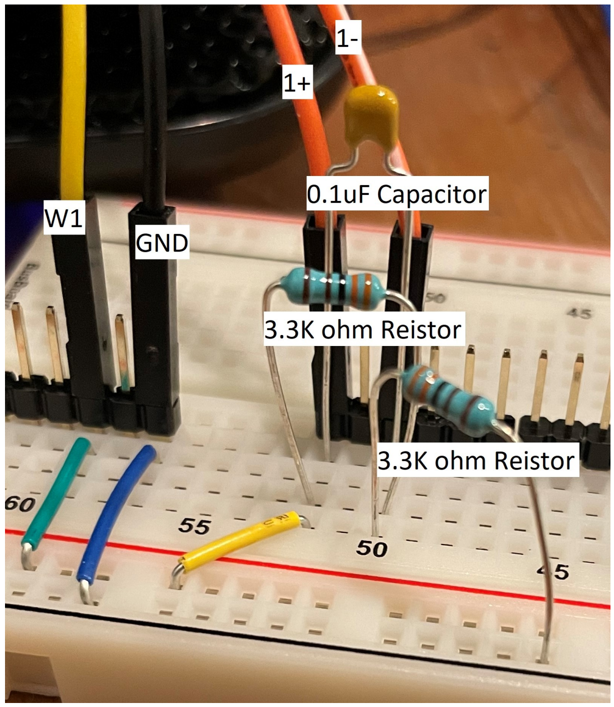

Figure 6: Lab 4 Setup

Lab 4: Measurement

The measured time constant is $159\mu s$

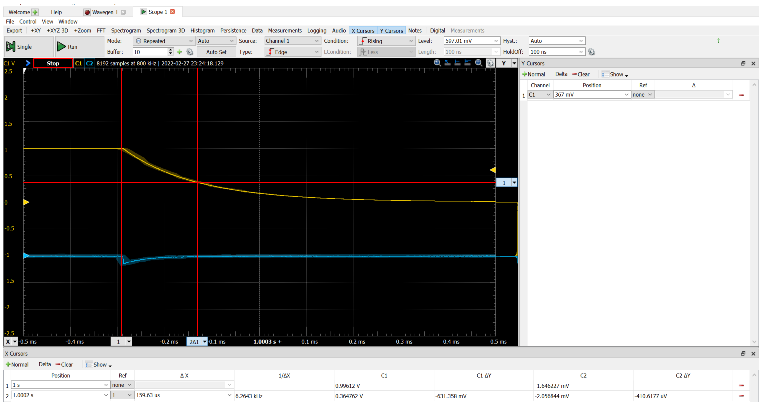

Figure 7: Measurements from the oscilloscope for Lab 4, C1:VC the voltage response of the capacitor

Lab 4: Discussion

the expected voltage response to start at 1V and then fall to 0 and the theoretical time constant is $165\mu s$. The difference between the measured and expected time constant is 3.6%.

Lab 5: Setup

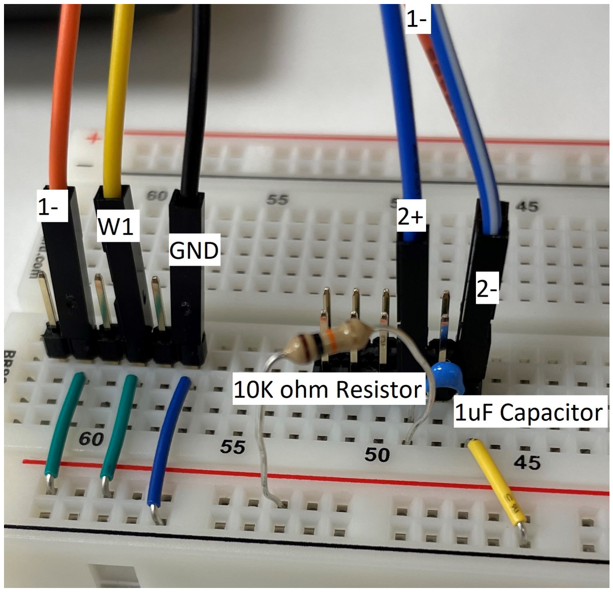

Figure 8: Lab 5 Setup

Lab 5: Measurements

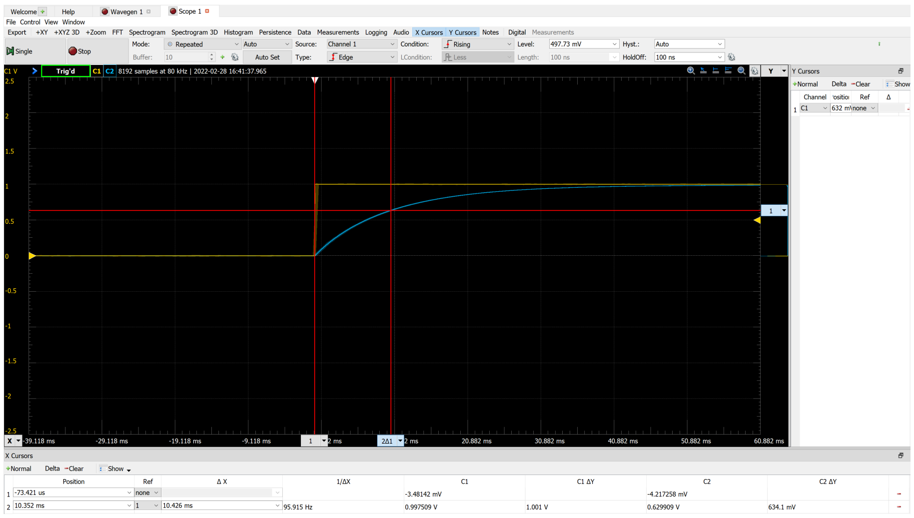

Figure 9: Measurements from the oscilloscope for Lab 4, C1:VC the voltage response of the capacitor

Lab 5: Discussion

I was able to replicate the given voltage response with a $10K\Omega$ resistor and a $1\mu F$ Capacitor. The time constant of the given voltage response was $9.3274mS$, the voltage response of the circuit I constructed was $10.426mS$.

Conclusion

We understood and investigated the natural and step response of first order capacitive and inductive circuits. We designed a first-order circuit with certain characteristics. We analyzed initial conditions within a circuit containing inductors and capacitors.