Faculty of Engineering, Alexandria University
Computer & Communications Program

EEC116
Analysis of Electrical Circuits

Lab 2 Report
EXAMPLE DOCUMENT

Transient Response
in RC & RL Circuits

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Abstract—**This lab report follows an experiment measuring the transient response of RC and RL circuits, where the step response is taken to illustrate how capacitors resist instantaneous change in voltage, and inductors resist instantaneous change in current.**

1. RC Step Response

1.1. The Circuit

The RC circuit in Figure 1 is a schematic of the circuit connected to a function generator with the input voltage set to $10\mathrm{V}_{\mathrm{p.p}}$, 500 Hz, 5V offset, and the output voltage measured across the 100 nF capacitor.

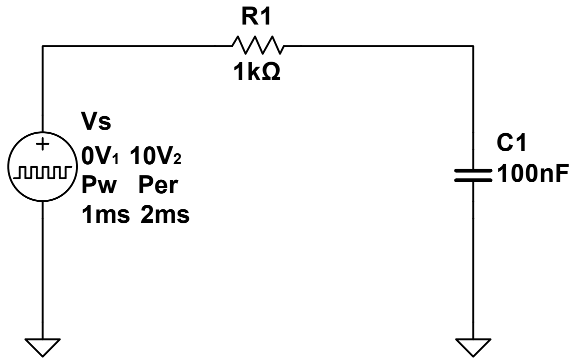

Figure 1: RC circuit given in lab

1.2. Theoretical Step Response

The expression for the time constant τ used to describe the voltage across the capacitor is $\tau = RC$.

Therefore, the theoretical value for τ in this circuit is known to be $1000 \times 100 \times 10^{-9} = 100 \times 10^{-6}$s. The duration of time after which the circuit settles from a transient response to a steady-state response is approximately $\tau_{\text{setting}} = 5\tau = 500 \times 10^{-6}$s.

1.3. Experimental Data

The equation describing the voltage across an uncharged capacitor in a series RC circuit following a voltage step is

$$v_{\mathrm{C}}(t) = V_{\mathrm{S}}\left(1 - e^{-t/\tau}\right)$$

In our circuit, the voltage when the time $t = \tau$ is

$$10\left(1 - \frac{1}{e}\right) = 6.321\mathrm{V}$$

We can look for the duration of time that has passed until this voltage is measured across the capacitor using an oscilloscope. Doing so in the lab, we have obtained the value $t = \tau = 180\mu$s.

By also looking at the beginning of the plateau on the plot from the oscilloscope, we have also obtained the $\tau_{\text{setting}} = 580\mu$s.

1.4. Simulated Data

By assembling the circuit in Figure 2 in NI Multisim, where the V1 is a `STEP_VOLTAGE` component, with an initial voltage of 0V and a final voltage of 10V, and by measuring the voltage across the capacitor in the "Transient" simulation type, we can obtain the plot of V_{out} relative to the ground as shown in Figure 3.

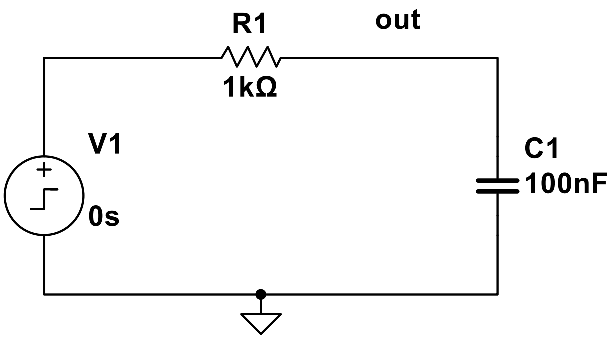

Figure 2: RC circuit used in simulation

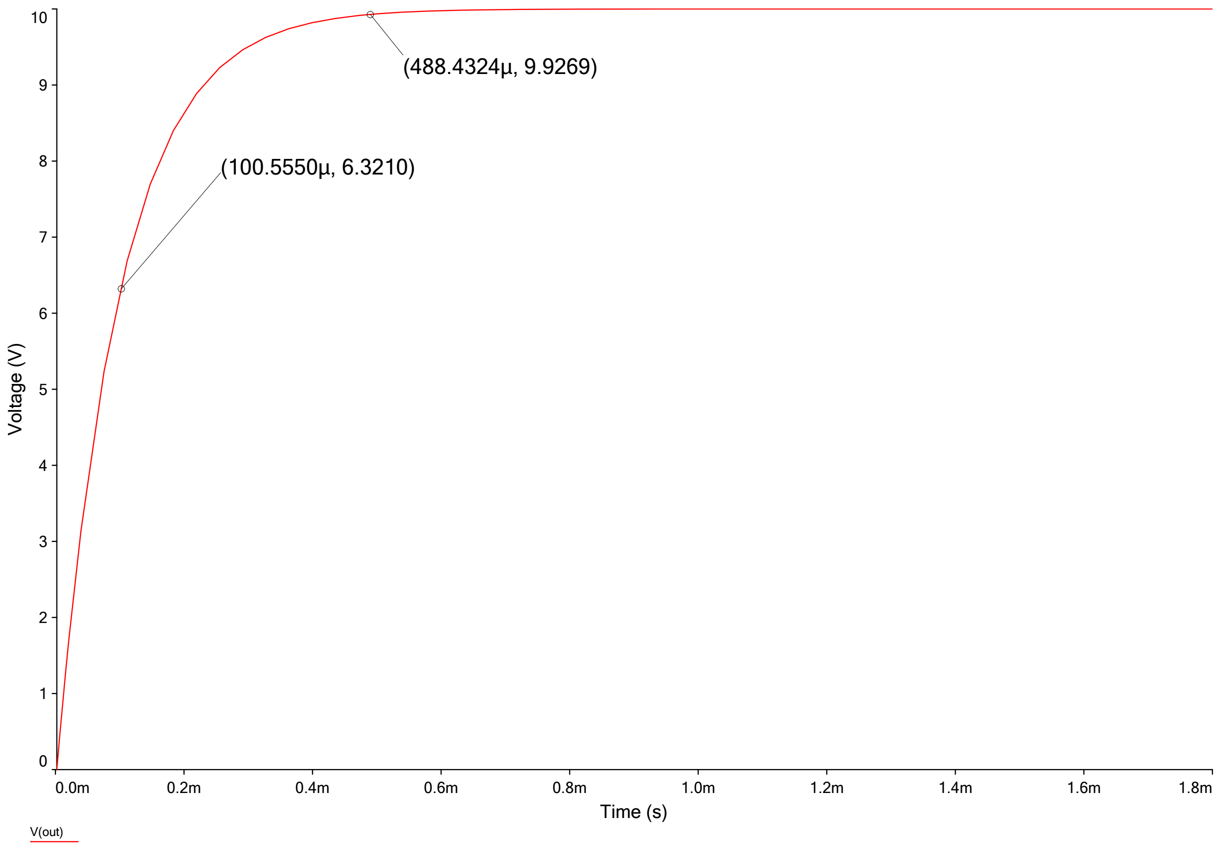

Figure 3: Plot of the transient response from the simulated RC circuit from NI Multisim, showing the simulated $\tau = 100\mu$s and the estimated $\tau_{\text{setting}} = 488\mu$s

1.5. Conclusion

Scenario	$\tau(\mu s)$	$\tau_{\text{setting}}(\mu s)$
Theoretical	100	500
Experimental	180	580
Simulated	100	488

Table 1: τ values compared

2. RL Step Response

2.1. The Circuit

The RL circuit in Figure 4 is a schematic of the circuit connected to a function generator with the input voltage set to $10\text{V}_{\text{p.p}}$, 20 kHz, 5V offset, and the output voltage measured across the $1\text{k}\Omega$ resistor.

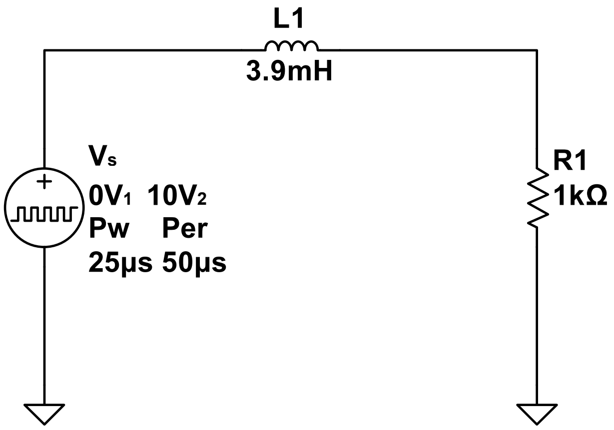

Figure 4: RL circuit given in lab

2.2. Theoretical Step Response

The expression for the time constant τ used to describe the voltage across the capacitor is $\tau = \frac{L}{R}$.

Therefore, the theoretical value for τ in this circuit is known to be $\frac{3.9\times10^{-3}}{1000} = 3.9 \times 10^{-6}\text{s}$. The duration of time after which the circuit settles from a transient response to a steady-state response is approximately $\tau_{\text{setting}} = 5\tau = 19.5 \times 10^{-6}\text{s}$.

2.3. Experimental Data

The equation describing the voltage drop across an inductor in a series RL circuit following a voltage step is

$$v_{\text{L}}(t) = V_{\text{S}}\left(e^{-t/\tau}\right)$$

In our circuit, the voltage when the time $t = \tau$ is

$$\frac{10}{e} = 3.678\text{V}$$

Since measuring the voltage difference across the inductor is difficult in practice, we will instead look at the voltage difference across the resistor. When $v_{\text{L}} = 3.678\text{V}$, $v_{\text{R}} = 6.321\text{V}$.

We can look for the duration of time that has passed until this voltage is measured across the resistor using an oscilloscope. Doing so in the lab, we have obtained the value $t = \tau = 6\mu\text{s}$.

By also looking at the beginning of the plateau on the plot from the oscilloscope, we have also obtained the $\tau_{\text{setting}} = 16\mu\text{s}$.

2.4. Simulated Data

By assembling the circuit in Figure 5 in NI Multisim, where the V1 is a `STEP_VOLTAGE` component, with an initial voltage of 0V and a final voltage of 10V, and by measuring the voltage across the capacitor in the "Transient" simulation type, we can obtain the plot of $V_+ - V_-$ (voltage across resistor) as shown in Figure 6.

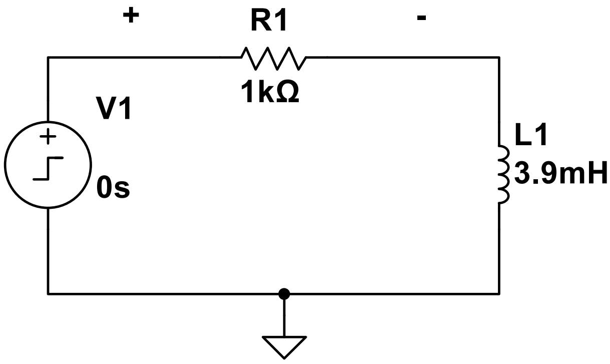

Figure 5: RL circuit used in simulation

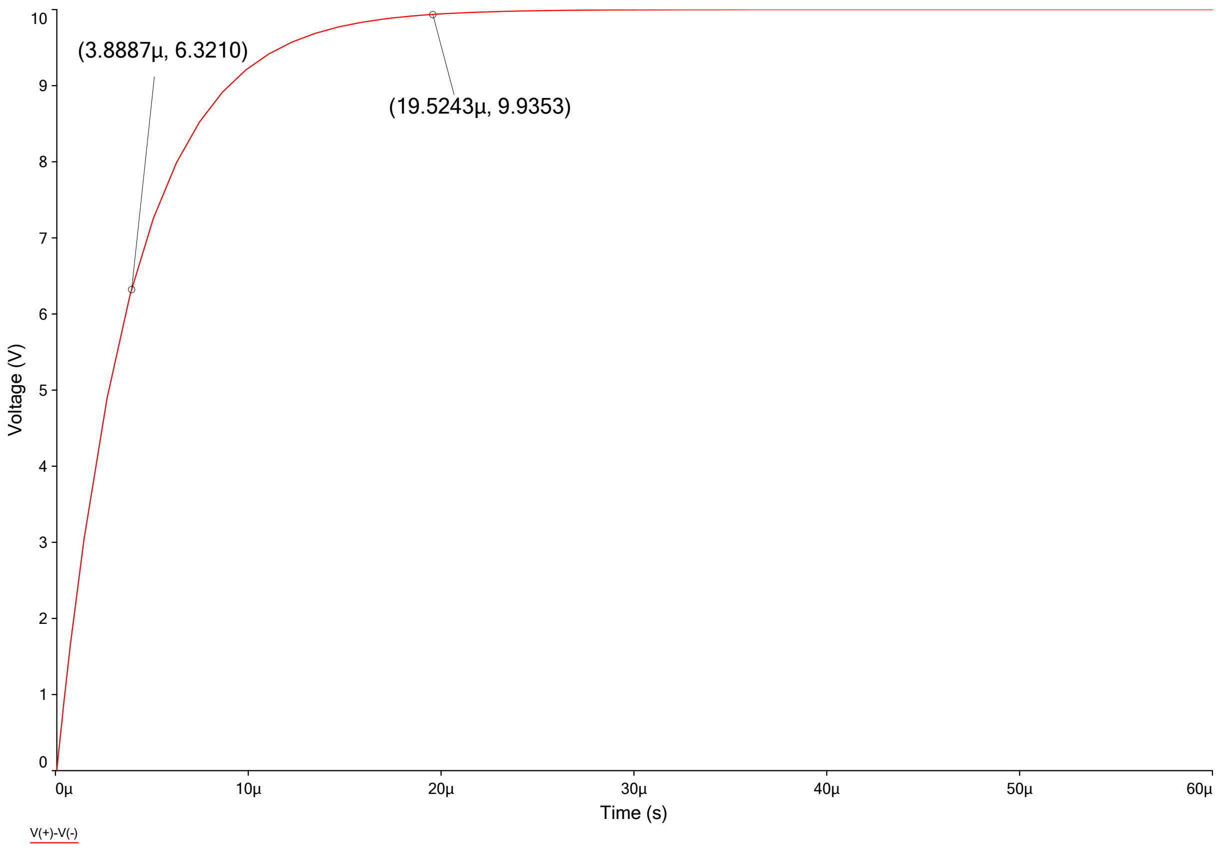

Figure 6: Plot of the transient response from the simulated RL circuit from NI Multisim, showing the simulated $\tau = 3.89\mu s$ and the estimated $\tau_{\text{setting}} = 19.52\mu s$

2.5. Conclusion

Scenario	$\tau (\mu s)$	$\tau_{\text{setting}} (\mu s)$
Theoretical	3.9	19.5
Experimental	6	16
Simulated	3.89	19.52

Table 2: τ values compared