

EXPERIMENT 6: Transient Response of an RL Circuit

Objective:

Study the transience due to inductors using a series RL circuit and understand the time constant concept.

Equipment:

- NI – ELVIS
- Resistor (1 K Ω)
- Inductor (33mH) or (150 mH if you are provided by instructor)

Theory:

This lab is similar to the RC Circuit Lab except that the Capacitor is replaced by an Inductor. In this experiment, we apply a square waveform to the RL circuit to analyse the transient response of the circuit. The *pulse-width* relative to the circuit's *time constant* determines how it is affected by the RL circuit.

Time Constant (τ): It is a measure of time required for certain changes in voltages and currents in RC and RL circuits. Generally, when the elapsed time exceeds *five time constants* (5τ) after switching has occurred, the currents and voltages have reached their final value, which is also called steady-state response.

The time constant of an RL circuit is the equivalent inductance divided by the Thévenin resistance as viewed from the terminals of the equivalent inductor.

$$\tau = L / R \quad (1)$$

A **Pulse** is a voltage or current that changes from one level to the other and back again. If a waveform's high time equals its low time, as in figure, it is called a *square wave*. The length of each cycle of a pulse train is termed its *period* (T). The *pulse width* (t_p) of an ideal square wave is equal to half the time period.

The relation between pulse width and frequency for the square wave is given by:

$$f = \frac{1}{2t_p} \quad (2)$$

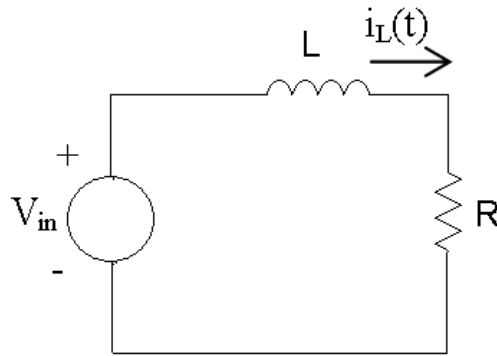


Figure 1: Series RL circuit

In an R-L circuit, voltage across the inductor decreases with time while in the RC circuit the voltage across the capacitor increased with time. Thus, *current* in an RL circuit has the same form as voltage in an RC circuit: they both rise to their final value exponentially according to $1 - e^{-t/\tau}$.

The expression for the current build-up across the Inductor is given by

$$i_L(t) = \frac{V}{R} (1 - e^{-(R/L)t}) \quad t \geq 0 \quad (3)$$

where, V is the applied source voltage to the circuit for $t \geq 0$. The response curve is increasing and is shown in figure 2.

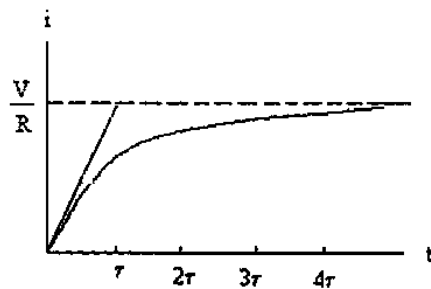


Figure 2: Current build up across Inductor in a Series RL circuit.
(Time axis normalised by τ)

The expression for the current decay across the Inductor is given by:

$$i_L(t) = i_0 e^{-(R/L)t} \quad t \geq 0 \quad (4)$$

where,

i_0 is the initial current stored in the inductor at $t = 0$
 $L/R = \tau$ is time constant.

The response curve is a decaying exponential and is shown in figure 3.

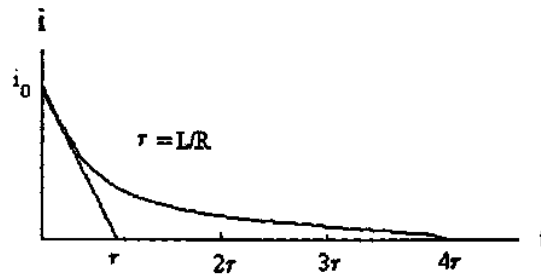


Figure 3: Current decay across Inductor for Series RL circuit.

Since it is not possible to directly analyse the current through Inductor on a Scope, we will measure the output voltage across the Resistor. The resistor waveform should be similar to inductor current as $V_R = I_L R$. From the resistor voltage on the scope, we should be able to measure the time constant τ which should be equal to $\tau = L / R_{total}$.

Here, R_{total} is the total resistance and can be calculated from $R_{total} = R_{inductance} + R$.

$R_{inductance}$ is the measured value of inductor resistance and can be measured by connecting inductance to an ohm-meter prior to running the experiment.

Procedure:

1. Measure the inductor resistance by connecting its terminals to an Ohmmeter. You can use NI-Elvis Ohm-meter by connecting it into Current Hi and Current Low inputs on your board.
2. Set up the circuit shown in **Figure 4** with the component values $R = 1k\Omega$ and $L = 33mH$ (or $150 mH$ if you are provided) and switch on the ELVIS board power supply.

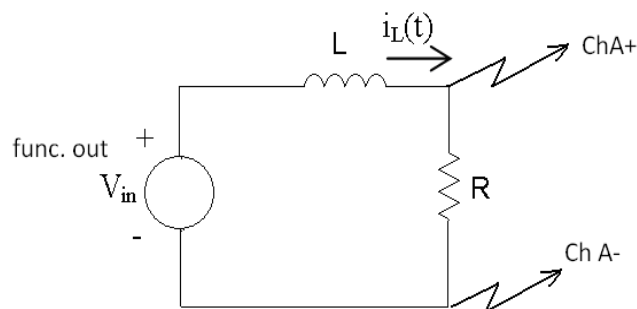


Figure 4: Experiment Set-Up

3. Select the Function Generator from the NI - ELVIS Menu and apply a $4V_{p-p}$ square wave as input voltage to the circuit using the amplitude control on the FGEN. Calculate the applied frequency using equation (2) for $t_p = 5\tau$

- Select the Oscilloscope from the NI - ELVIS Menu. Set the resistor voltage on Channel A, Source on Channel B, Trigger and Time base input boxes as shown in figure 4 below. (Note your output may not be different from the one in the figure- figure just for demonstration purposes.)

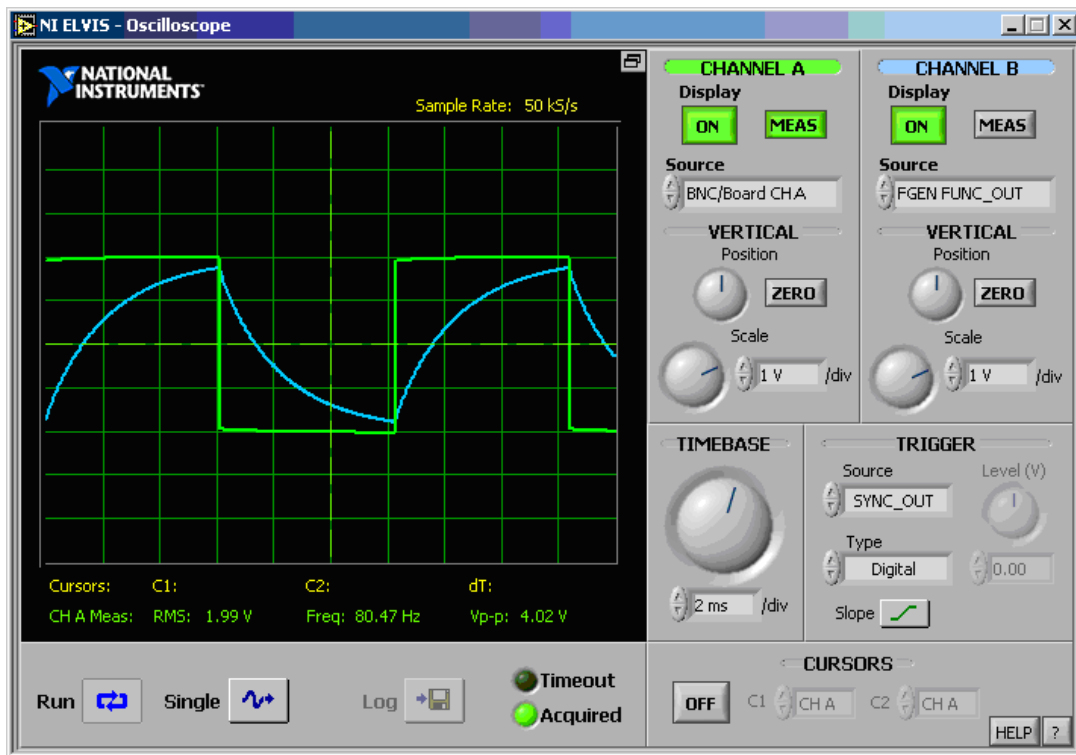


Figure 4: Oscilloscope Configuration.

This configuration allows the oscilloscope to look at the output of the circuit on channel A, output of the function generator on channel B. Make sure you have clicked on the run button of the FGEN panel and on the OSC panel. Any settings on the FGEN panel cause changes on the oscilloscope window.

- The V_R waveform has the same shape as $i_L(t)$ waveform. From V_R waveform measure time constant τ and compare with the one that you calculated from L/R_{total} . (Hint: Find the time that corresponds to $0.63V_R$ value). See theory for more details.
- Observe the response of the circuit and record the results again for $t_p = 25\tau$, and $t_p = 0.5\tau$.

Questions for Lab Report:

- Include plots of V_R for different t_p values given above in Procedure 4.
- A Capacitor stores charge. What do you think does an Inductor store? Answer in brief.