EXPERIMENT 6:
Transient Response of 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 KΩ)
➢ Inductor (33mH)

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.

$$\tau = L \, / \, R \qquad\qquad (1)$$

A ***Pulse*** is a voltage or current that changes from one level to the other and back again. If a waveform's hight 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,

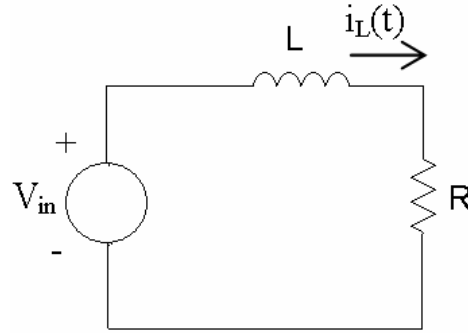$$f \;=\; \frac{1}{2 \, t_p} \qquad\qquad (2)$$

Figure 1: Series RL circuit

In the RL 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

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

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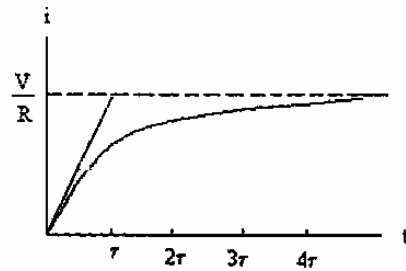

Figure 2: Current build up across Inductor in a Series RL circuit.

(Time axis normalised by τ)

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

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

where, i_0 is the initial current stored in the inductor at t = 0 and
L/R = τ is time constant.

The response curve is a decaying exponential and is shown in figure 3.
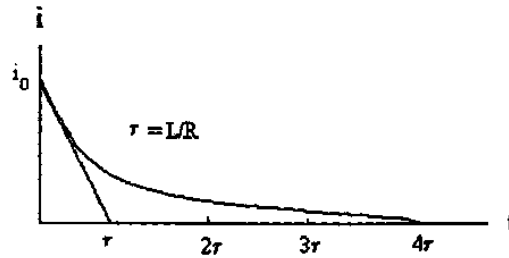
Figure 3: Current decay across Inductor for Series RL circuit.

Since it is not possible to directly analyse the current through Inductor on a Scope, we measure the output voltage across the inductor. It should be noted that the voltage across the inductor decreases with time when the current increases.

Procedure:

1. Set up the circuit shown in **Figure 1** with the component values R = 1kΩ and L = 33mH and switch on the ELVIS board power supply.
2. 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.
3. Select the Oscilloscope from the NI - ELVIS Menu. Set the Source on Channel A, Source on Channel B, Trigger and Time base input boxes as shown in figure 4 below.
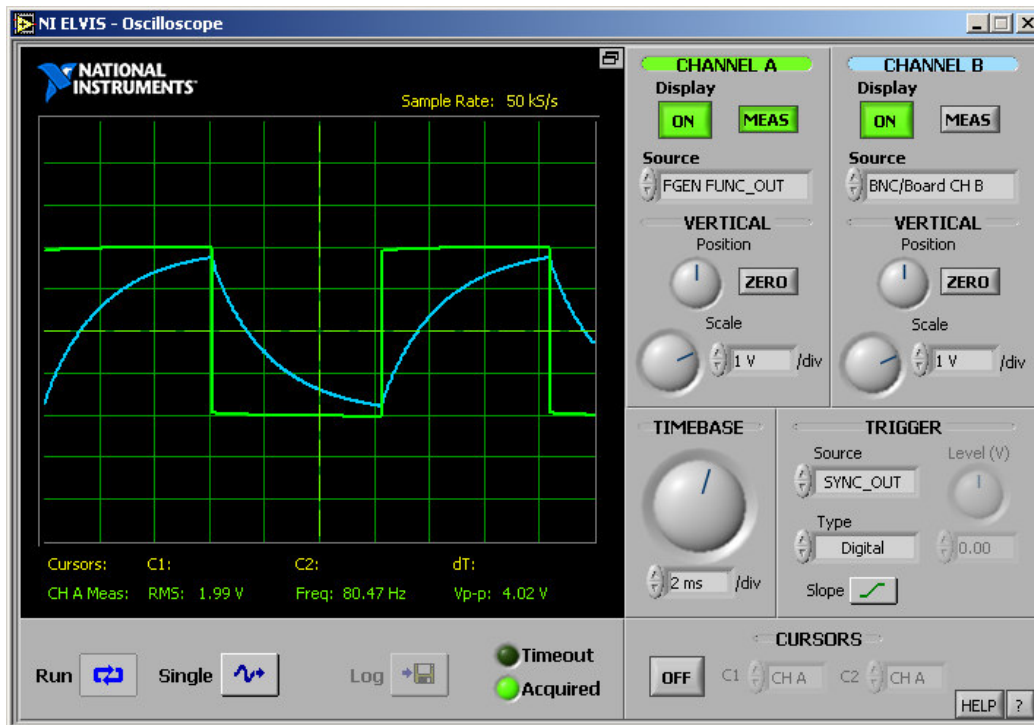

Figure 4: Oscilloscope Configuration.

This configuration allows the oscilloscope to look at the output of the function generator   on channel A, the output of the circuit 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.

4. Observe the response of the circuit record the results when $t_p = 25\tau$, $t_p = 5\tau$ and $t_p = 0.5\tau$.

Questions for Lab Report:

1. Obtain plots of V_R for different t_p values given above in Procedure 4.

2. 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. (Hint: Find the time that corresponds to $0.63V_R$ value)

3. A Capacitor stores charge. What do you think does an Inductor store? Answer in brief.