Lab#5 Pulse Response of Simple RC & RL Circuits

This lab demonstrates the **transient response** of the capacitor and inductor. The voltage of the capacitor gradually **changes up**, as the current of the inductor gradually charges up with the following differential equations:

Capacitor	Inductor
$i_C(t) = c\frac{dv_C}{dt}$	$v_L(t) = L\frac{di_L}{dt}$

The voltage across the capacitor of a simple RC circuit in Fig. (5.1) can be expressed as:

$$v_C(t > 0) = V_{ss} + (V_{0^-} - V_{ss})e^{-\frac{t}{\tau}}, \text{ where } \tau = R_{total}C \text{ and } V_{ss} = V_T$$

Since $V_0 = 0V$,

$$v_C(t > 0) = V_{ss}(1 - e^{-\frac{t}{\tau}}) \qquad (1)$$

The current through the inductor of a simple RL circuit in Fig. (5.2) can be expressed as:

$$i_L(t > 0) = I_{ss} + (I_{0^-} - I_{ss})e^{-\frac{t}{\tau}}, \text{ where } \tau = L/R_{total} \text{ and } I_{ss} = \frac{V_T}{R_{total}}$$

Since $I_0 = 0$ A,

$$i_L(t > 0) = I_{ss}(1 - e^{-\frac{t}{\tau}}) \qquad (2)$$

The characteristics of the capacitor and inductor at transient $t=0^+$ are as follows:

	Capacitor	Inductor
Current	**Max**	Charging
Voltage	Charging	**Max**

The initial values of the voltage and current at $t=0^+$ can be obtained by replacing t=0 in equations (1) and (2), and their differential equations:

Multisim

Please follow the steps below to setup the simulation environment and build your circuits

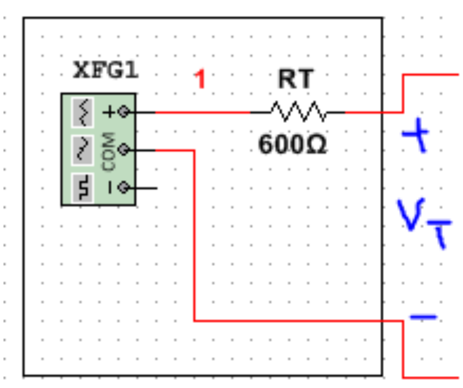
1. Setting up **Interactive simulation** environment
2. Use the following components to build your circuits:
   - Resistor: RESISTOR_RATED
   - Capacitor: CAPACITOR_RATED
   - Inductor: INDUCTOR_RATED
3. You only need to use:
   - Function generator as voltage source
   - Oscilloscope to measure voltage signal

Lab Procedure

Part I. Internal resistance of the function generator

A physical function generator has a Thevenin equivalent internal resistance. In the lab manual, this internal resistance is given as RT=600Ω. Multsim function generator does not have an internal resistance. You will need to add a resistor to learn how to measure the internal resistance.

Step 1: Connect a 600Ω resistor to the function generator to act as RT. Set the function generator as described in the lab manual and use an oscilloscope (Channel A) to measure the open circuit voltage VT.



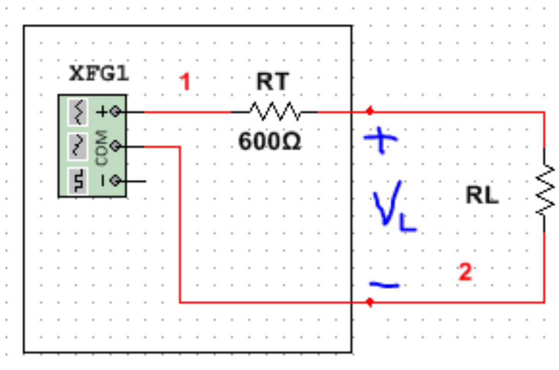
Function generator settings:

- Frequency: 1 kHz
- Amplitude: 2 V_P

Oscilloscope settings:

- Channel A, scale: 1 V/div
- Timebase, scale: 100 us/div

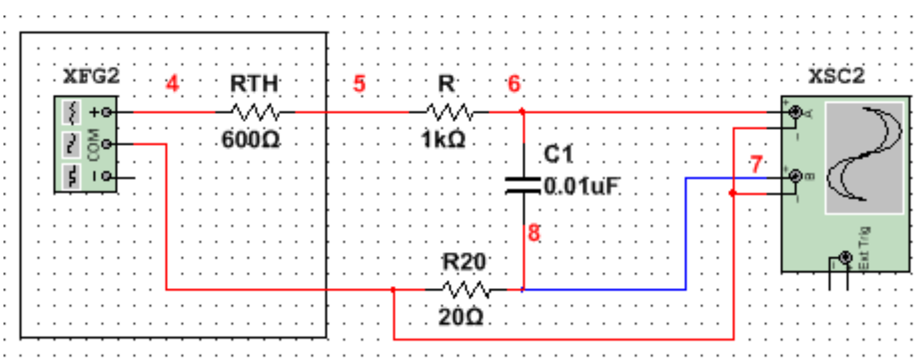
Step 2: Connect a load resistor and measure the voltage. You will find RT, when $VL = \frac{VT}{2}$



Step 3: Change the VT to a different waveform and V_{peak}. You will still get $VL = \frac{VT}{2}$ when RL=RTH.

Part II: The RC-circuit pulse response
NOTE: Switching Steps 4 and 5 from the lab manual

Step 4: Construct the circuit with Channel A measuring the capacitor voltage and Channel B measuring the capacitor current. The capacitor current is the same as the current through 20Ω resistor, $i_C(t) = \frac{v_{R20}}{20}$.



Step 5: Set the function generator to provide a square wave at 1 kHz frequency with 3 V_P AC and 3V DC offset:

- Waveforms: Square wave
- Frequency: 1 kHz
- Amplitude: 3 VP
- Offset: 3V

Use default oscilloscope settings with the following changes:

Timebase	Channel A	Channel B	Trigger
Scale: 100 µs/Div	Scale: 1 V/Div Y pos. (Div): -3	Scale: 50 mV/Div	Use Auto. But, try Single to display 1 duty cycle.

NOTE: Make sure you can see the rising edge of the capacitor voltage.

Step 6: Plot $v_C(t)$ and $i_C(t)$ using Graphs (5.1) and (5.2), respectively. Beam off Channel B to plot $v_C(t)$, by pressing the 0 button. Then, beam off Channel A to plot $i_C(t)$.

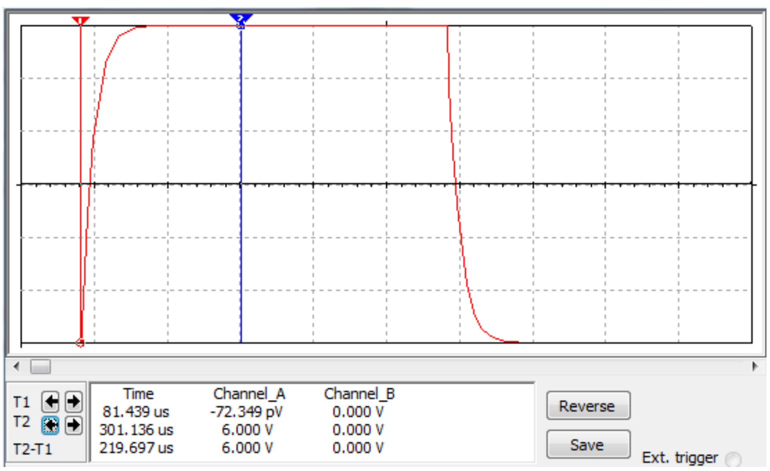
Step 7: Measure τ using the capacitor voltage. Beam off Channel B.

At steady state, when $t = \infty$,

$$v_C(t = 0) = V_{ss}(1 - e^{-\infty}) = V_T(1 - 0) = V_T$$

When $t = \tau$,

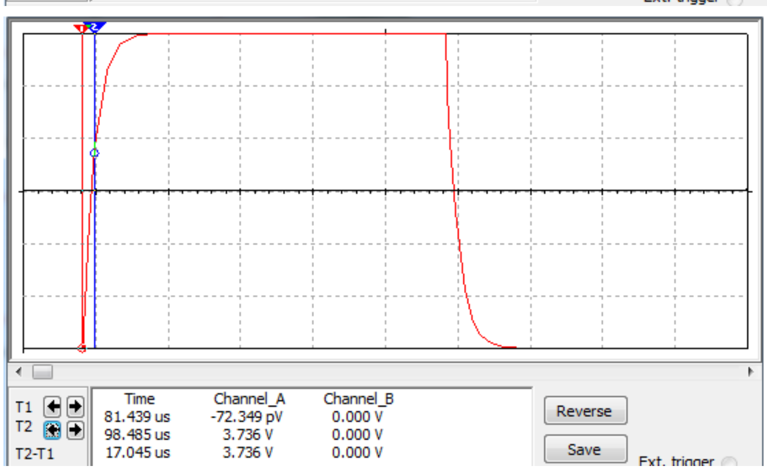
$$v_C(t = \tau) = V_{ss}\left(1 - e^{-\frac{\tau}{\tau}}\right) = V_T(1 - 0.37) = 0.63V_T$$



Place T1 at the beginning of the transient

Use T2 to measure V_T (VT = 6 V)

That means when $t = \tau$,
$v_C(t) = 3.79$ V



Move T2 to channel A voltage as close to 3.79 V as possible.

The time constant for the capacitor voltage to change up to v_C=3.79 V is:

T2-T1 = 17µs

Step 8: Replace the 1 kΩ with R=6.8 kΩ and plot the graphs. If you cannot see the signals on the oscilloscope, make sure you change the Trigger setting back to Auto.

Part II: The RL-Circuit Pulse Response

Step 9: Build the circuit by replacing the capacitor with an L=50 mH inductor and set R back to 1 kΩ.

Change the oscilloscope settings to:

Timebase	Channel A	Channel B	Trigger
Scale: 100 µs/Div	Scale: 2 V/Div Y pos. (Div): -2	Scale: 20 mV/Div Y pos. (Div): -2	Use Auto. But, try Single to display 1 duty cycle.

Plot the $i_L(t)$ and $v_L(t)$ in Graphs (5.3) and (5.4), respectively

Repeat the measurement for time constant τ and max. inductor voltage (v_L) in Table 5.6.

From equation (2), the voltage across the inductor is

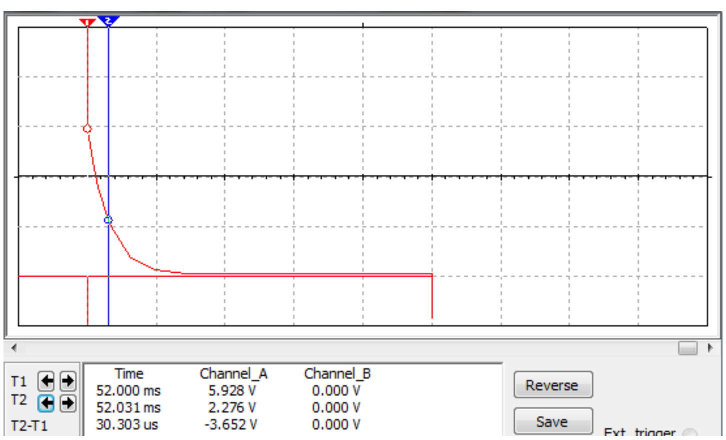
$$v_L(t) = L\frac{di_L}{dt} = I_{ss}\frac{L}{\tau}e^{-\frac{t}{\tau}} = Ke^{-\frac{t}{\tau}}$$

When $t = 0$, voltage across the inductor is maximum,

$$v_L(t = 0) = Ke^{-\frac{0}{\tau}} = K$$

When $t = \tau$,

$$v_L(t = \tau) = Ke^{-\frac{\tau}{\tau}} = 0.37\ K$$



Use T1 to measure K at $t = 0$. K should be close to V_T.

Since K=5.928,

$$v_L(t = \tau) = 2.19\ V$$

Move T2 to as close to 2.19 as possible to get

$$\tau = T2 - T1 = 30\ \mu s$$

Repeat the step using L=150 mH.