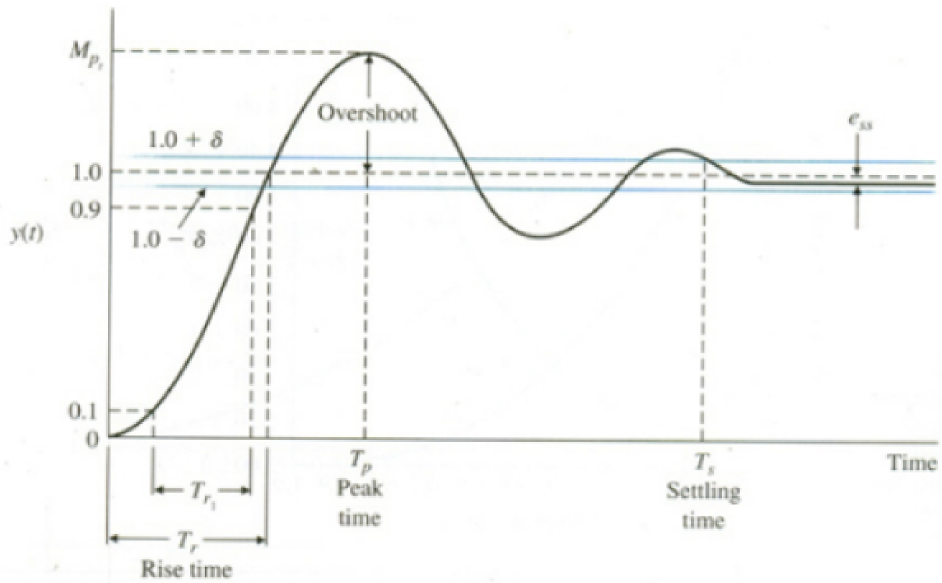
Lab 4

Step Response Of RLC Circuit

Motivation: The complete response of RLC circuits to step inputs involves determination of the transient and steady-state solutions of the circuit. Since the energy storage elements such as inductor or capacitor do not permit instantaneous change in the energy, the transient part of the solution makes a smooth transition from one energy level to another. Thus a gradual change takes place from some initial level till the new steady-state level is reached. Sudden loading of a generator or a beam in a structure, sudden change in the setting of a value or a failure of a hydraulic pump involves response due to the step input. Step function apart from being mathematically simple to analyze, represents a rather severe type of the disturbance appearing in the system. Moreover, an arbitrary function can be approximated in the form of a series of step inputs that facilitates the finding of the response to any arbitrary input.

The dynamic characteristics of simple systems can be described by second order (RLC circuit) differential equations. The complete response is then identified in two parts - complementary function (transient solution) and particular integral (steady-state solution). It is always possible to obtain the complete response of complicated systems such as linear combinations of first and second-order systems. Although attention here is confined to electrical circuits, the same basic model can be used to represent a wide range of mechanical, pneumatic or chemical systems.



Terms:

Rise time (tr) is the time required to reach at final value by a under damped time response signal during its first cycle of oscillation. If the signal is over damped, then rise time is counted as the time required by the response to rise from 10% to 90% of its final value.

$$t_r = \frac{\pi - \phi}{\omega_n \sqrt{1 - \zeta^2}}$$

Peak time (tp) is simply the time required by response to reach its first peak i.e. the peak of first cycle of oscillation, or first overshoot.

$$t_p = \frac{\pi}{\omega_n \sqrt{1 - \zeta^2}}$$

Maximum overshoot (Mp) is straight way difference between the magnitude of the highest peak of time response and magnitude of its steady state. Maximum overshoot is expressed in term of percentage of steady-state value of the response. As the first peak of response is normally maximum in magnitude, maximum overshoot is simply normalized difference between first peak and steady-state value of a response.

$$M_p = e^{-\frac{\zeta\Pi}{\sqrt{1-\zeta^2}}}$$

Equations:

- General expression of the transfer function of 2nd order control system: $\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$

  Here, ζ and ω_n are the damping ratio and natural frequency of the system, respectively.

- Damping ratio, $\zeta = \frac{R}{2}\sqrt{\frac{C}{L}}$
- Natural frequency, $\omega_n = \frac{1}{\sqrt{LC}}$
- Damping frequency, $\omega_d = \omega_n\sqrt{1 - \zeta^2}$
- Time Period, $T = \frac{2\Pi}{\omega_d} = \frac{2\Pi}{\omega_n\sqrt{1-\zeta^2}}$
- Damping frequency, $\omega_d = \omega_n\sqrt{1 - \zeta^2}$
- Undamped: $\zeta=0$
- Underdamped: $\zeta<1$

  Time Constant of response: $T= \frac{1}{\zeta\omega_n}$
- Critically damped: $\zeta=1$

  Time Constant of response: $T= \frac{1}{\omega_n}$
- Overdamped: $\zeta>1$

  Time Constant of response: $T = \frac{1}{\left(\zeta - \sqrt{\zeta^2 - 1}\right)\omega_n}$

Objectives:

1. Observe the step response of the RLC circuit and adjust the parameters so that an underdamped response of the series RLC circuit is obtained. Observe and trace the response.
2. From the traced response, obtain the period of oscillation, time constant and peak overshoot and compare these values with theoretically calculated values.
3. Adjust the parameter values so that a critical response of the series RLC circuit is obtained.
4. Compare the critical resistance with the theoretically calculated value.

(A) Simulation Procedure for step response of RLC circuit

1. Draw circuit as shown in Fig 4.1 on LTspice schematic window. Set C= 0.1uF , R = {R} and L= 1mH with internal series resistance 3.5 ohm.
2. Apply source voltage as pulse with Vinitial=0, Von=5 V, Tdelay=0, Trise=0, Tfall=0, Ton=5m,Tperiod=5m, Ncycles=0.
3. Go to .op command and write **.step param R 10 300 20**. Paste it into the schematic window.
4. Simulate and plot the waveform of voltage across the capacitor.
5. Note the period of oscillation, time constant and peak overshoot.
6. Calculate damping factor, $\xi=(Req/2)\sqrt{(C/L)}$ and calculate critical resistance (ξ=1). Req= R+Rint (internal series resistance of inductor)
7. Observe the waveform for different combinations of R(10,100,200,300 Ω) keeping L = 1mH with 3.5 ohms series resistance and C= 0.1uF.
8. Submit waveforms for both cases i.e. ideal and practical values of components.

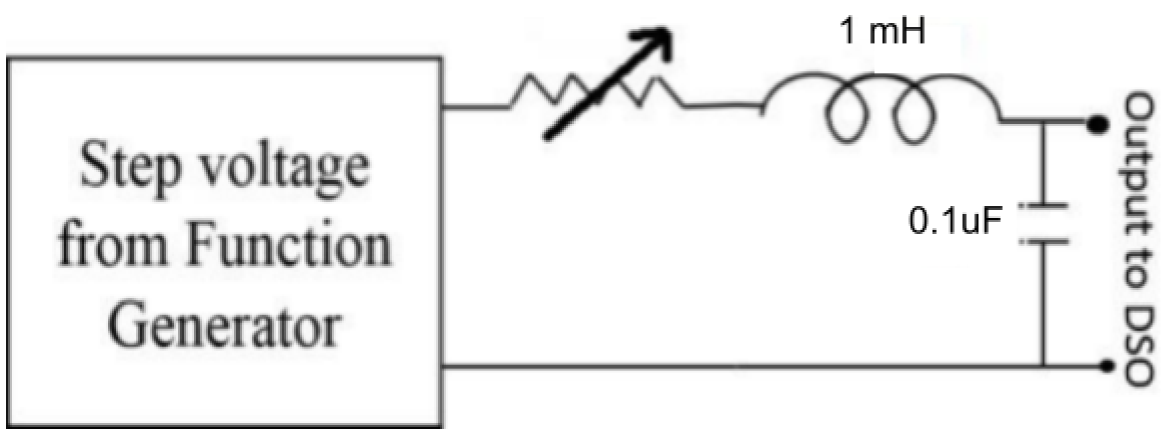


Fig. 4.1

(B) Implementation on Breadboard

1. Connect circuit on breadboard as shown in Fig 4.1.
2. Follow all steps for C= 0.1uF , L= 1mH and R=10,100,200,300 Ω
3. Apply source voltage from DSO and observe the waveform from the output channel.

(C) Observation

C=0.1uF, L=1mH (3.5Ω internal series resistance)

1. **Find Critical Resistance**
2. **Fill up the table for theoretical, LTSpice & Practical**

S.No	R	Period of oscillation	Time constant	Peak overshoot	Damping ratio
1	10Ω				
2	100Ω				
3	200Ω				
4	300Ω				

Deliverables:

When coming to the lab:

- Check the file format & grading rubrics (already posted on the classroom (BE Lab Flow).
- Submit the LTSpice file (.asc) of this experiment to the classroom (individual task).
- Keep the theoretical & LTSpice results of this experiment with you on a rough copy.
- Submit the practical file with completed experiment-3 and index on entering the lab.