Measurement System Behavior

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MECE 3320: Measurements & Instrumentation Lab Exercise

I. Introduction

In this lab exercise, you will determine the response of a number of measuring devices and simple circuits to dynamic inputs in order to better understand dynamic measurements.

II. Procedure

A. Part-1: First Order Systems

1. Response to a Step Input

Build the circuit shown in Figure 1 below. Connect channel 1 of the oscilloscope to the input of the circuit and channel 2 to the output. Use a $5000Hz$, $1V$ peak-to-peak square wave from the function generator as input to the circuit. Measure the 90% rise time of the output signal and calculate the time constant based on the measured rise time.

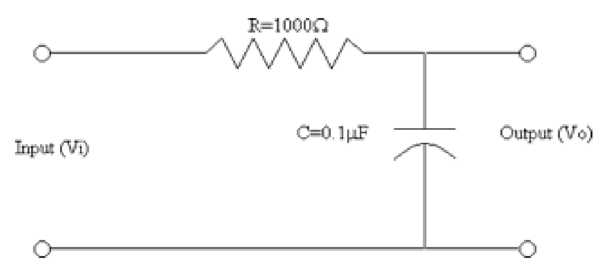

Figure 1. RC Circuit

Calculate the time constant from the following expression:

$$e^{-\frac{t}{\tau}} = \frac{T_\infty - T}{T_\infty - T_0}\tau \quad = \frac{-t_{90}}{ln(1-0.90)} \tag{1}$$

2. Response to a Sine Input

Using the circuit shown in Figure 1 measure the phase shift and magnitude ratio (output amplitude / input amplitude) using a $5000Hz$ $1V$ peak-to-peak sine wave as the input.

The magnitude ratio (output amplitude/input amplitude) and phase shift for a first order system are

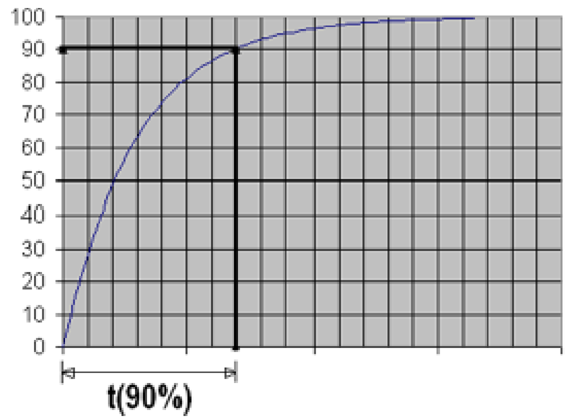

Figure 2. Oscilloscope Trace

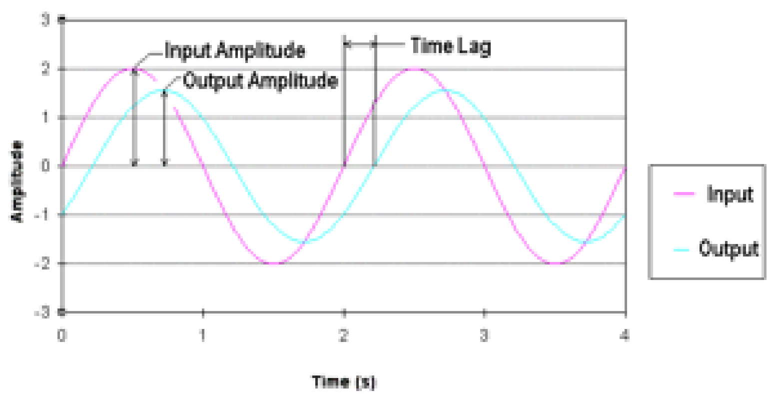

Figure 3. Phase Response of a 1st order system

simply functions of the time constant and the frequency.

$$M(\omega) = \frac{1}{\sqrt{1 + (\omega tau)^2}} \Phi \quad = -tan^{-1}(\omega\tau) = time\ lag \times frequency \times 360^0 \tag{2}$$

B. Part-2: Second Order Systems

1. Response to a Step Input

Build the circuit shown in figure below. Connect channel 1 of the oscilloscope to the input of the circuit and channel 2 to the output. Use a $1\,V$ peak-to-peak $500Hz$ square wave from the function generator for the input to the circuit. Measure the ringing frequency of the output signal and the signal amplitude at the valley after the first peak.

The magnitude ratio, phase shift, and resonance frequency for a second order system are often expressed as functions of the undamped natural frequency and the critical damping ratio. From the step response of an underdamped second order system the ringing frequency and amplitude at a known point in time on the step response can be measured and used to determine the critical damping ratio and undamped natural frequency.

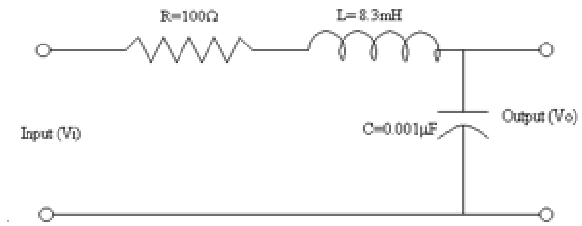

Figure 4. RLC Circuit

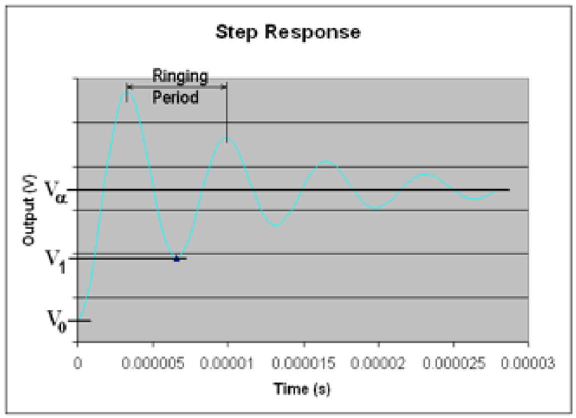

Figure 5. Step Response of a Second Order System

$$\xi = \frac{1}{\sqrt{1 + \left[\frac{2\pi}{ln(V_\alpha - V_1/V_\alpha - V_0)}\right]^2}} \tag{3}$$

$$\omega_d = \omega_n \sqrt{1 - \xi^2} \tag{4}$$

2. Response to a Sine Input

Measure the magnitude ratio using the circuit with a $1\,V$ peak-to-peak sine wave for the input signal at 10kHz. Repeat the measurement of magnitude ratio at frequencies of 25, 50, 75, and 100kHz. The magnitude ratio is given by

$$M(\omega) = \frac{1}{\sqrt{\left\{[1 - (\omega/\omega_n)^2]^2 + [2\xi\omega/\omega_n]^2\right\}}} \tag{5}$$

Plot the magnitude ratio versus frequency.

III. Report

For this lab you will write the Results and Discussion of Results sections of a full report.