

NORTHWESTERN UNIVERSITY TECHNOLOGICAL INSTITUTE

ECE-270

Experiment #3

TIME AND FREQUENCY DOMAINS - CIRCUIT RESPONSES PRELAB

1. Use the values specified in the lab for the resistor, capacitor and/or inductor and calculate f_C or f_R for circuits 2 through 8.
2. Calculate V_{out}/V_{in} as a function of f for circuits 2,4 and 8.

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INTRODUCTION

There are two major methods for analyzing circuit behavior. One way is to suddenly apply a signal to the circuit and observe the various currents and voltages as functions of time. This is called “Time Domain Analysis”, and such responses can be either calculated from the differential equations governing the circuit or measured in the laboratory. These responses always consist of exponential functions or sinusoids or some product of an exponential function and a sinusoid. The two best signals to apply to a circuit for measuring time domain responses are short duration pulses (ideally of infinitesimally short duration and infinite amplitude) and step functions (an abrupt change from one level to another) as shown in Figure 1.

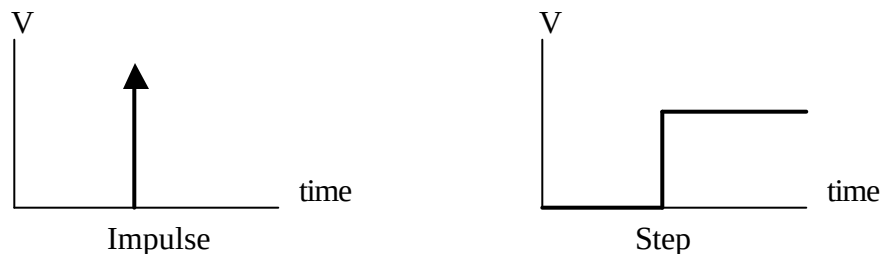


Figure 1

The other method of circuit analysis is called “Frequency Domain Analysis”. This method consists of applying sine waves of different frequencies, but of equal amplitude, to the circuit. These sine waves are applied to the circuit one frequency at a time while the magnitudes and relative phases of the various currents and voltages are recorded. For each input sine wave, the various measured signals will also be sinusoidal with the same frequency as that of the input signal. However, the magnitudes and phase angles may be functions of frequency.

Circuit elements and their corresponding impedances are indicated in Figure 2 ($j^2 = -1$).

Circuit #1 is a simple voltage divider such that:

$$V_{out} = V_{in} \frac{R_2}{R_1 + R_2}$$

where R_2 is the resistor across the output.

PROCEDURE

In this lab, we will do both time domain and frequency domain measurements on eight simple circuits. For the time domain measurements, we will apply a relatively low frequency square wave. This closely approximates applying a series of step functions to the circuit, but allows enough time between each step for the circuit to completely respond. Use a frequency of approximately 500Hz. Draw an accurate sketch of the input signal and the output signal for each circuit. Include all peak voltage values and important time marks (peaks, decay times, etc.). For circuits 1 through 5 relate the time scale to time constants RC or L/R.

For the frequency domain response, calculate the theoretical cutoff (f_c) or resonant frequency (f_R). Apply a sine wave to the input of the circuit and measure the relative phase and magnitude of the output with respect to the input. Repeat this measurement for frequencies of $0.1f_c$, $0.2f_c$, $0.4f_c$, $0.6f_c$, $0.8f_c$, f_c , $1.5f_c$, $2f_c$, $4f_c$, $6f_c$, $10f_c$ (or equivalent points with respect to f_R). Make an accurate plot of the peak-to-peak amplitude of the output divided by the peak-to-peak amplitude of the input as the frequency is varied. Also, make an accurate plot of the relative phase of the output with respect to the input as a function of frequency.

Perform both the time domain and frequency domain measurements on each circuit before moving on to the next. For circuit 1 use 100Ω and 300Ω resistors. For circuits 2 through 8 use $R = 100\Omega$, $C = 0.1\mu F$ and $L = 10mH$. Note that the function generator has a source resistance of 50Ω . Justify your results for each circuit by calculating the theoretically expected response (for V_{out}/V_{in} and for phase difference) . Why is the input a function of frequency for circuits 2 through 8?

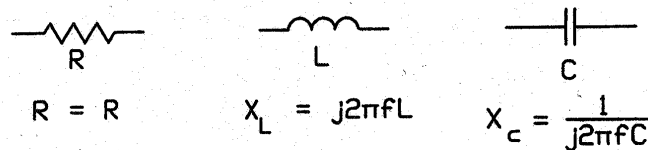
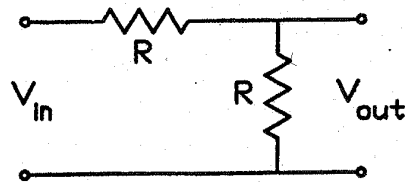


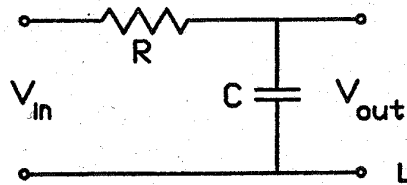
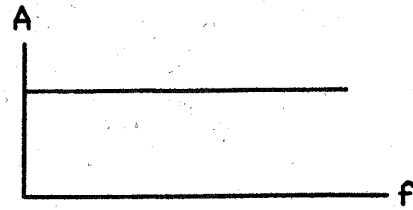
Figure 2

Circuit

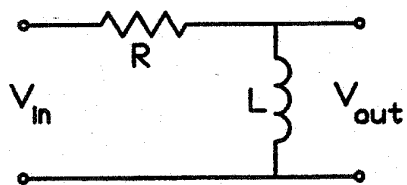
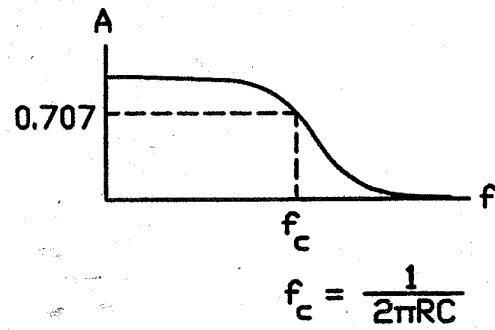


① Voltage Divider

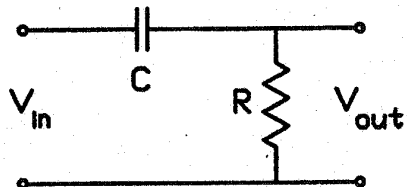
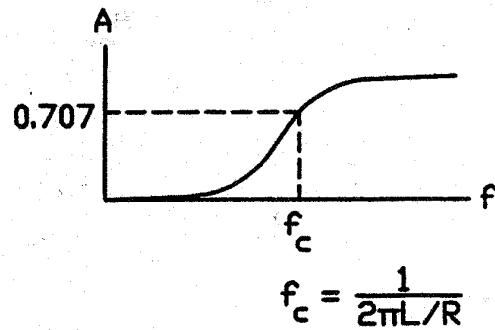
Frequency Response



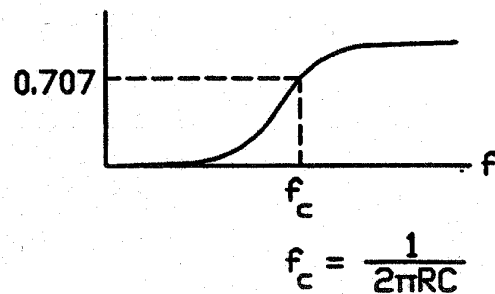
② Low Pass

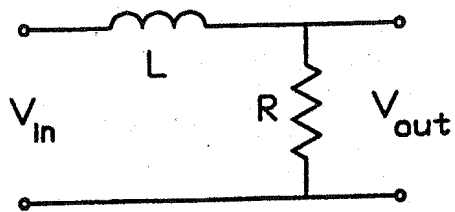


③ High Pass

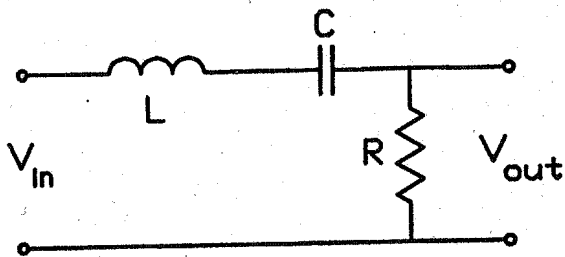
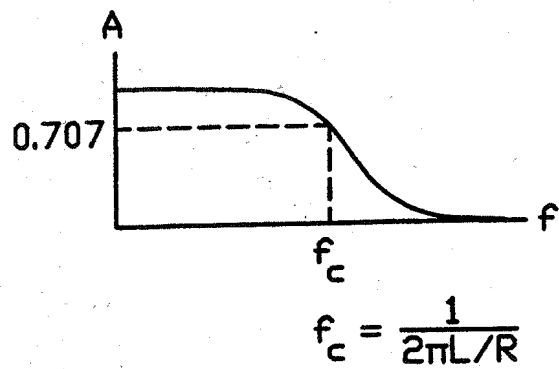


④ High Pass

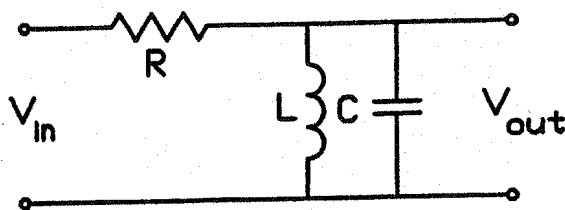
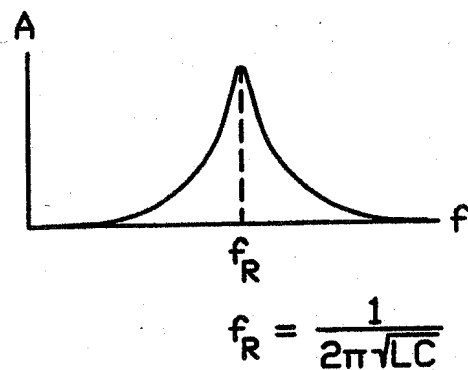




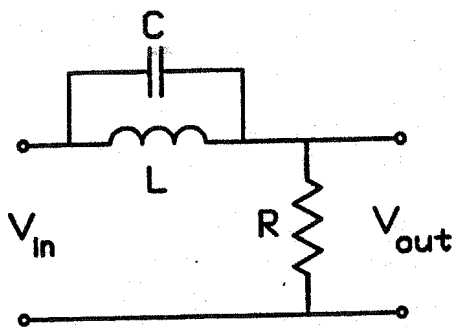
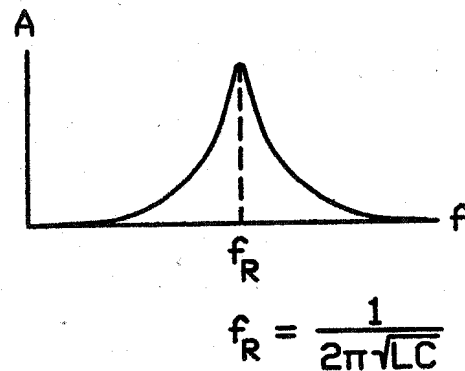
⑤ Low Pass



⑥ Band Pass



⑦ Band Pass



⑧ Band Reject (Notch)

