

# Filling the Gaps Between Courses: A Proposal to Develop a Network Analysis Laboratory Manual

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## ABSTRACT:

Filling the gap between the engineering courses is crucial to understand the theory and practice. The passive filter circuits are the circuits comprising the passive components or the circuits that does not include the DC power supply. The Passive filter circuits will be proposed to be a segue between the course I and course II engineering courses at the institution. Although the proposed lab experiment(s) can be used as a smooth transition between any circuit analysis courses that are offered as sequences in engineering curricula, they are also helpful in making a bridge between the topics of DC and AC Analysis in a single circuit analysis course. This paper proposes that for a course sequence case, the assignment of RL and RC passive filters as the final experiment of the course I would serve as a smooth transition between the course sequences.

To explain the concept of passive filter, oscilloscope, function generator, and network analyzer equipment must be introduced. If the mentioned equipment is presented at the end of course I, course II instructor can demonstrate equipment briefly and students will be prepared enough to use it immediately. The low pass filters (LPF) and high pass filter (HPF) passive filters topics will be explained thoroughly in the next course while students are prepared to understand the topics deeply. In addition to AC hardware measurements, the mathematical calculations (e.g., filter gain, the Cutoff frequency, and the time constant ( $\tau$ )) will be carried out. The simulation for LPF and HPF will be accomplished using Multisim and students will explore the coincidence of the hardware results and the simulation, particularly, the Bode diagram. Essentially, Bode diagram concept, will be introduced in course II, however, authors' intention is to prepare the students for the concept. Furthermore, the instructor will utilize a continuous square waveform to show the charging and discharging diagrams of the capacitors in the RC circuit (i.e., square wave response). Course instructor will illustrate the effect of varying the time constants and its relation to the RC circuit applications (e.g., integrator and differentiator). Finally, students will be asked to apply a sinusoidal waveform as an input to RC and/or RL circuits and compare the change of the output to the input waveforms. By changing the position of the resistor and capacitor, a simple LPF or HPF can be made by exploring the frequency response.

## I. Introduction

Passive filters are made up of passive components such as resistors, capacitors and inductors and have no amplifying elements (transistors, op-amps, etc) so have no signal gain, therefore their output level is always less than the input.

Filters are so named according to the frequency range of signals that they allow to pass through them, while blocking or "attenuating" the rest. The most commonly used filter designs are the:

1. The Low Pass Filter – the low pass filter only allows low frequency signals from 0Hz to its cut-off frequency ( $f_c$ ) point to pass while blocking those any higher.
2. The High Pass Filter – the high pass filter only allows high frequency signals from its cut-off frequency, ( $f_c$ )point and higher to infinity to pass through while blocking those any lower.

Simple First-order passive filters (1st order) can be made by connecting together a single resistor and a single capacitor in series across an input signal, ( $v_{in}$ ) with the output of the filter, ( $v_{out}$ ) taken from the junction of these two components. Depending on which way around we connect the resistor and the capacitor with regards to the output signal determines the type of filter construction resulting in either a Low Pass Filter or a High Pass Filter. As the function of any filter is to allow signals of a given band of frequencies to pass unchanged while attenuating or weakening all others that are not desired, we can define the amplitude response characteristics of an ideal filter by using an ideal frequency response curve of the four basic filter types as shown.

## II. Filter Designs

### A. RC Low Pass Filter (LPF)

Students were required to Construct the circuit of Figure.1. Given the values of resistor (R) and Capacitor (C), students were asked to vary the input frequency from 200 Hz to 100 KHz as shown in Table.1 and measure the  $v_{out}$  while maintaining the  $v_{in}$  at 2 VPP for each value of frequency. Consequently, students will Compute the voltage gain  $A_V$  for each frequency and Compute the dB loss for each frequency indicated in Table.1.

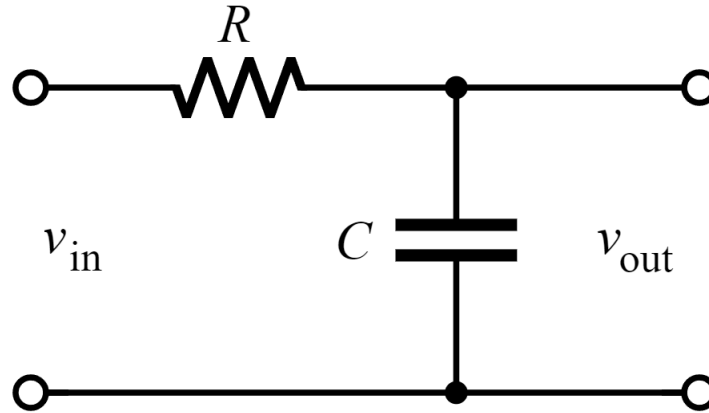


Figure. 1. Low Pass Filter (LPF)

Frequency (Hz)	$v_{in}$ (V)	$v_{out}$ (V)	$A_V = \frac{v_{out}}{v_{in}}$	Loss = $20 \log_{10}(A_V)$ (dB)
200				
500				
5000				
10000				
100000				

Table.1. LPF measurements table

### B. RL High Pass Filter (HPF)

Students were required to Construct the circuit of Figure.2. Given the values of resistor (R) and Inductor (L), students were asked to vary the input frequency from 200 Hz to 100 KHz as shown in Table.1 and measure the  $v_{out}$  while maintaining the  $v_{in}$  at 2 VPP for each value of frequency. Consequently, students will Compute the voltage gain  $A_V$  for each frequency and Compute the dB loss for each frequency indicated in Table.2.

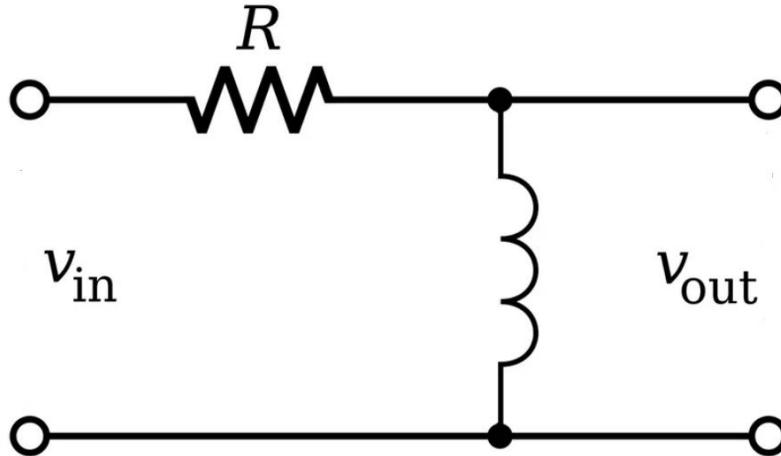


Figure. 2. High Pass Filter (HPF)

Frequency (Hz)	$v_{in}$ (V)	$v_{out}$ (V)	$A_V = \frac{v_{out}}{v_{in}}$	Loss = $20 \log_{10}(A_V)$ (dB)
200				
500				
5000				
10000				
100000				

Table.2. HPF measurements table

### III. Simulation

Students will Simulate the design of figure.3 and figure. 4. Which represent LPF and HPF, respectively. The following steps are given to help students navigate through the Multisim software.

- 1) Place the signal voltage sources family under the sources group as  $v_{in}$ . You can change the frequency by clicking the voltage source and change the value in the frequency.
- 2) Place a Bode Plotter to plot the frequency response both filters [connect Bode Plotter in port to the source voltage and connect Bode Plotter out ports to the output voltage], then run the simulation and display the frequency response.
- 3) Define the cutoff frequency from the frequency response graphs as depicted in fig.5 and fig.6.

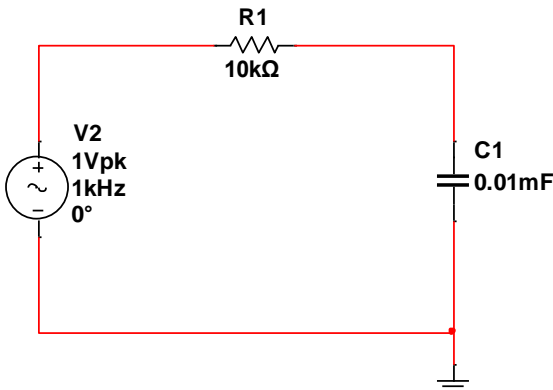


Figure. 3. LPF with AC voltage source

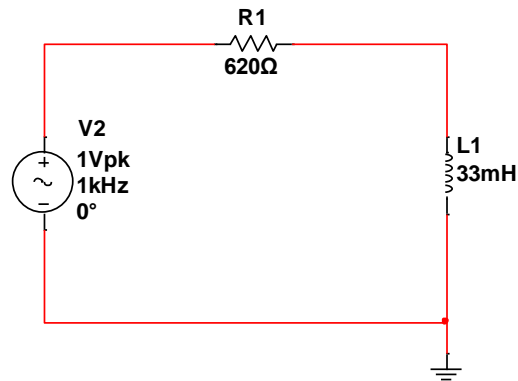


Figure. 4. HPF with AC Voltage source

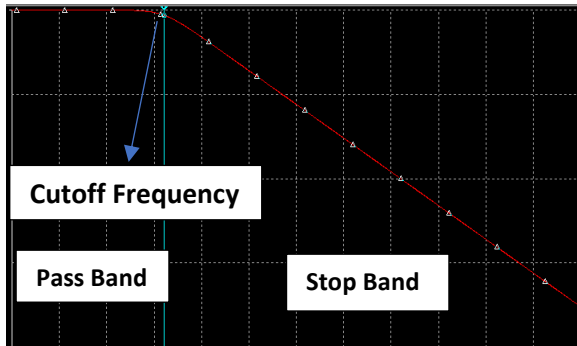


Figure. 5. LPF Bode plot

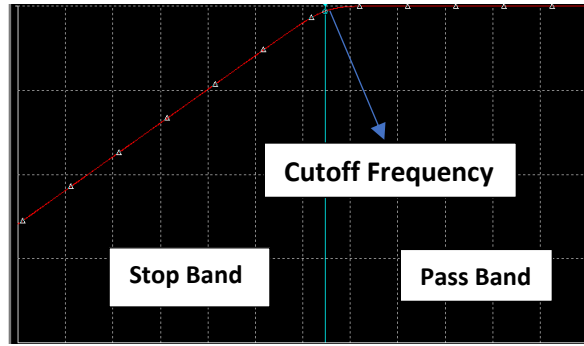


Figure. 6. HPF Bode Plot

#### IV. Required Results

The following questions were questioned to the students to answer and include in the report.

1. Calculate cutoff frequency for RC filter.
2. From the fig. 5 above find the frequency that has loss of -3dB.
3. Compare the frequency from the questions 1 and 2.
4. Calculate cutoff frequency for RL filter
5. From the fig. 6 above find the frequency that has loss of -3dB.
6. Compare the frequency from the questions 4 and 5.

The following are the definitions to the main terms mentioned in the paper.

Formulae and definitions:

1. Peak Voltage ( $v_p$ ): The maximum instantaneous value of a function as measured from the zero-volt level.
2. Peak-to-Peak Voltage ( $v_{pp}$ ): The full voltage between positive and negative peaks of the waveform; that is, the sum of the magnitude of the positive and negative peaks
3. RC low pass filter (LPF) cut-off frequency:  $f_c = \frac{1}{2\pi RC}$
4. RL high pass filter (HPF) cut-off frequency:  $f_c = \frac{R}{2\pi L}$
5. The cut-off frequency of a filter is the frequency at which the magnitude of the output voltage signal drops by a factor of 70%.
6. A -3 dB gain corresponds to an (Output power/Input power) ratio of 0.5, i.e., the output power of the circuit reduces by a factor of half.

#### V. Conclusion

In this extended abstract, the concept of passive filter, oscilloscope, function generator, and network analyzer equipment were introduced in the Network analysis I course. The low pass filters (LPF) and high pass filter (HPF) passive filters topics were explained thoroughly in the next course (Network analysis II) where students will be prepared to understand these topics deeply. In addition to AC hardware measurements, the mathematical calculations (e.g., filter gain, the Cutoff frequency, and the time constant ( $\tau$ )) will be carried out. The simulation for LPF and HPF were accomplished using Multisim and students will explore the coincidence of the hardware results and the simulation, particularly, the Bode diagram.