VANIER COLLEGE - Computer Engineering Technology
247-205 Circuit Analysis & Simulation II

Lab 6 : High-Pass (HP) Filter and Unknown Capacitance

Purpose:

a) To measure the frequency response of an RC high pass filter
b) To familiarize with filter characterization of gain in decibels
c) To determine the capacitance of an unknown component through measurement techniques

To be submitted:

a) **Deadline:** At the end of the lab session NO Extension, submit through LEA before end of class.
b) **No formal report required**.
c) Fill in results of all tables (clearly labelled). If calculation is involved, clearly indicate formula used for the calculation.

Equipment:

Oscilloscope, ac meter, waveform generator, resistors, capacitor.

Theory:

Frequency filters exist in many circuit configurations. The basic circuits that we have seen so far are called “passive” filters since they contain no amplifying devices.

The frequency response of a filter is characterized as a plot of its voltage gain, in decibels, versus frequency. The voltage gain is determined with the following equation:

$$A_v(dB) = 20\log\frac{V_o}{V_i}$$

High pass filters ideally would pass, unchanged, all frequencies from the desired cutoff frequency, while totally reject all lower frequencies. Simple RC filters are not so ideal. They can leave the desired frequencies almost unchanged, but can only progressively attenuate frequencies below the cutoff frequency. The result is a response plot which is relatively flat for high frequencies, then at cutoff frequency, slopes downwards for lower frequencies. The slope rate will be -20 dB per decade, or 20 dB for each factor of ten change in frequency. At cutoff frequency, the circuit response will be -3dB down from its high frequency level.

Pre-lab questions

1. What is the high-pass filter? Explain why the circuit in Figure 1 is a high-pass filter.

A high-pass filter is a circuit who rejects certain frequencies below the calculated cutoff frequency. Figure 1 is a high-pass filter because the output is from the 3.3kΩ resistor. If the output would be from the 22nF capacitor, then the circuit would be a low-pass filter.

2. Calculate the cutoff frequency for this circuit (show calculations).

Refer to question 1 at the end of this paper.

3. For the circuit of Figure 1, calculate magnitudes (in rms) for the quantities required in Table 1. Indicate the formula that you used to calculate.

Frequency	Calculation						
	X_C	Z	Ig	V_C	V_R	Phase	$A_v(dB)$
800Hz	*9kΩ*	*9.3kΩ*	*215μA*	*1.94V*	*710mV*	*-70º*	*-9dB*
2KHz	*3.6kΩ*	*4.8kΩ*	*416μA*	*1.50V*	*1.37V*	*-47º*	*-3dB*

Table 1: Series RC circuit calculation

Lab Work:

Part 1: High pass RC filter

1.

Frequency	V_i	V_o	A_v(dB)
100 Hz	*2V*	*80.10mV*	*-2.79E+01*
300 Hz	*2V*	*236mV*	*-1.86E+01*
600 Hz	*2V*	*459mV*	*-1.28E+01*
800Hz	*2V*	*601mV*	*-1.04E+01*
1 kHz	*2V*	*733mV*	*-8.72E+00*
2 kHz	*2V*	*1.24V*	*-4.15E+00*
3 kHz	*2V*	*1.53V*	*-2.33E+00*
6 kHz	*2V*	*1.89V*	*-4.91E-01*
10 kHz	*2V*	*1.97V*	*-1.31E-01*
30 kHz	*2V*	*2.02V*	*8.64E-02*

Table 1: High Pass RC Measurement

2. Connect the following circuit.

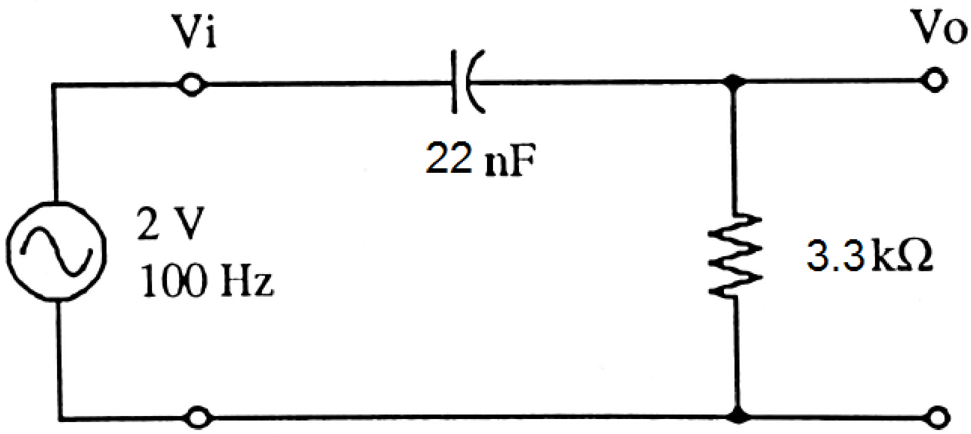


Figure 1 : High Pass RC Filter

3. Measure V_i and V_o, and calculate the voltage gain in decibels. Record in `Table 1`. Repeat this step for the remaining frequencies listed in the table.

Frequency	V_i	V_o	A_v(dB)
100 Hz	*2V*	*80.10mV*	*-2.79E+01*
300 Hz	*2V*	*236mV*	*-1.86E+01*
600 Hz	*2V*	*459mV*	*-1.28E+01*
800Hz	*2V*	*601mV*	*-1.04E+01*
1 kHz	*2V*	*733mV*	*-8.72E+00*
2 kHz	*2V*	*1.24V*	*-4.15E+00*
3 kHz	*2V*	*1.53V*	*-2.33E+00*
6 kHz	*2V*	*1.89V*	*-4.91E-01*
10 kHz	*2V*	*1.97V*	*-1.31E-01*
30 kHz	*2V*	*2.02V*	*8.64E-02*

Table 1: High Pass RC Measurement

4. Use the data in the table to plot the response curve (Vo vs Frequency and Av vs Frequency in logarithmic scale) for the RC high pass circuit.

   Refer to the attached excel spreadsheet for the two graphs.

Part 2: Unknown capacitance

Your Instructor will provide you with one or more unmarked capacitors in order to have you determine their capacitance. Based on your knowledge and hand-on experience in the lab so far, which approach could you use to determine this unknown capacitance?

Explain and comment on your approach. Verify your approach by determine the value of those unmarked capacitors.

Calculations:

$(Measured)V_C = 1.5V$

$(Measured)I_G = 60nA$

$$X_C = \frac{V_C}{I_G}$$

$$X_C = \frac{1.5V}{60nA}$$

$$X_C = 25M\Omega$$

$$C = \frac{1}{2\pi f X_C}$$

$$C = \frac{1}{2\pi(100Hz)(25M\Omega)}$$

$$C = 63.6pF$$

A common capacitor value that can be bought to be used would be a 62pF capacitor.

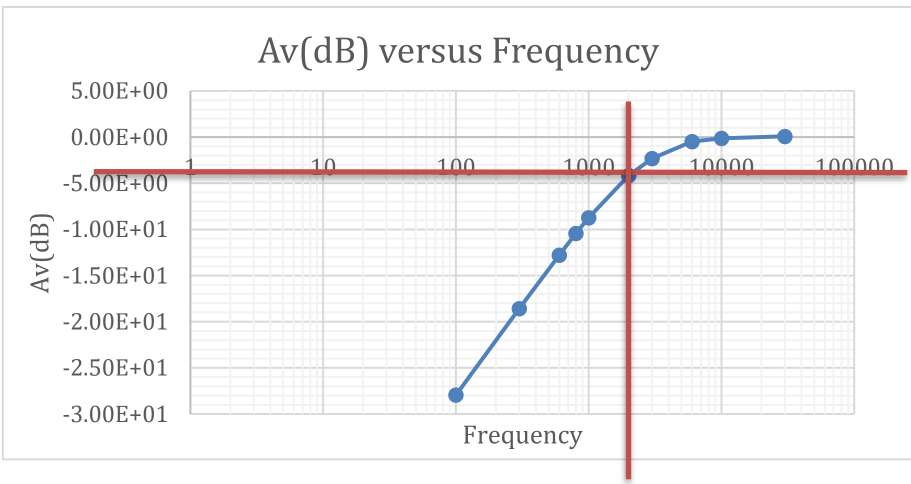
In the end, the mysterious capacitor value was 56pF, which is not far from my calculated value of 63.6pF. To briefly explain, I used the values that I knew that I had already and reformulated the X_C formula to give me the result of the mysterious capacitor. Step 1 was to measure the voltage across the capacitor using the AC voltmeter then measure the current in the circuit using the AC ammeter. Then, applying ohm's law and substituting the values of V_C and I_G, I got a result of 25MΩ as the value of X_C. Finally, manipulating the X_C formula and plugging in the values I know, I received the value of C of 63.6pF.

<u>Questions</u>:

Show all your working steps wherever necessary

Refer to your graph for the RC high pass filter.

1. Draw a horizontal line at -3 dB and read the frequency at which your response curve intersects this line. Compare this frequency with your theoretical cutoff frequency of the filter.



The red line indicates the value of ~-3(dB) with respect to its frequency ~2 kHz.

Calculated cutoff frequency:

$$f_C = \frac{1}{2\pi RC}$$

$$f_C = \frac{1}{2\pi(3.3k\Omega)(22nF)}$$

$$f_C = 2.19\ kHz$$

My calculated cutoff frequency and my reading from the graph above are within the accepted tolerance. My calculated cutoff frequency was 2.19 kHz and I read around 2 kHz from the graph above. This means that any frequency below ~2 kHz would be rejected as this graph represents the circuit of a high-pass filter.

2. Read the voltage gain at frequency of 800 Hz, and compare with the theoretical calculated value.

Calculated:

$$log20 = (\frac{V_O}{V_I})$$

$$log20 = (\frac{710mV}{2V})$$

$$= -9dB$$

Measured:

$$log20 = (\frac{V_O}{V_I})$$

$$log20 = (\frac{601mV}{2V})$$

$$= -10.4dB$$

The two values I compared are within accepted tolerance. My calculated value was -9dB and my measured value was -10.4dB. As you can see, these values are very close to each other.