PHYS222

AC Circuits Lab on

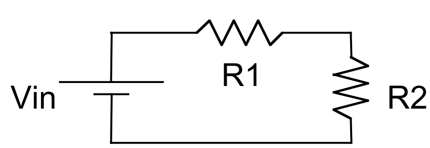
High- and low-pass RC filters

Advanced reading- Serway (Chapter 33- sections 1, 2, 4 ,7 & 9)

Objective: The purpose of this experiment is to use a capacitor and a resistor to build and study the properties of a high-pass filter which blocks low frequencies, and a low-pass filter which blocks high frequencies.

Theory: For a resistor with resistance R in an electrical circuit, the relationship between the applied voltage (V) and the current (I) passing through the resistor is given by Ohm's Law: V=IR. Similarly for a capacitor with capacitance C the relationship is V=IXc. Here X_C is called the **capacitive reactance** and whose magnitude is defined by $X_C=1/\omega C$. ω is the angular frequency ($2\pi f$) of the applied voltage. This is the analog of Ohm's Law for capacitors, and the capacitive reactance is analogous to resistance. So we can use Ohm's law in AC circuits involving capacitors.

We notice that for a DC voltage (ω=0) the capacitive reactance is infinite, so no current passes through the capacitor. At low frequencies the reactance is high and at high frequencies the reactance is low. *So we can think of a capacitor as a resistor with a resistance that depends upon the frequency of the applied voltage.*



First consider the above circuit. Kirchhoff's voltage law says that Vin = I (R1+R2). The voltage across R2 is given by V2 = I R2 so V2 = Vin R2/(R1+R2). Similarly the voltage across V1 is given by V1 = Vin R1/(R1+R2). Hence the resistor with the larger resistance has a larger voltage across it.

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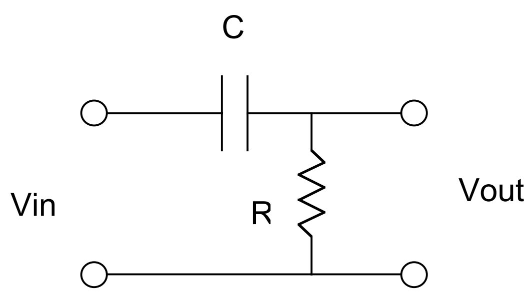
This result will be used below in AC circuits with capacitors and resistors. Remember that the reactance Xc plays the role of resistance for a capacitor.

(Here we are only interested in the magnitude of the capacitive reactance, $X_c=1/\omega C$.)

Circuit 1:



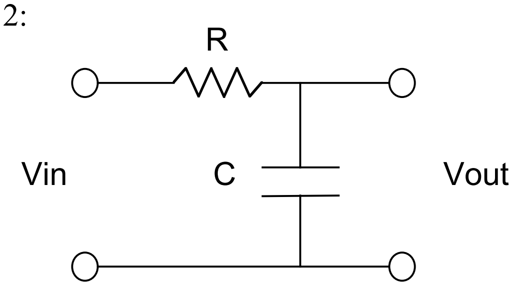
Consider Circuit 1 above.

At low frequencies the capacitor acts like a high resistance, so most of the input voltage will be across it, so Vout, which is measured across the resistor will be much smaller than Vin.

At high frequencies the capacitor acts like a small resistance so most of the input voltage will appear across the resistor and Vout will be almost equal to Vin.

This circuit is called a high pass filter. It passes high frequency input signals but blocks low frequencies. This could be used to keep low frequencies out of a tweeter.

Circuit 2:



Consider Circuit 2.

At low frequencies the capacitor acts like a high resistance, so most of the input voltage will be dropped across it, so Vout will be almost equal to Vin.

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At high frequencies the capacitor acts like a small resistance so most of the input voltage will appear across the resistor and Vout will be much smaller than Vin.

This circuit is called a low pass filter. It passes low frequency input signals but blocks high frequencies. This could be used to keep high frequencies out of a bass speaker.

Questions

1) Show that the gain should be equal to 0.707 at the cutoff frequency.

2) Suppose you have a low pass filter with a cut off frequency of 10 kHz and a high pass filter with a cutoff frequency of 20 kHz and you put these two circuits in series. Sketch a plot of gain vs. frequency.
Hint: first consider the plot of gain vs. frequency for each circuit separately then imagine what would happen if a signal passed through both.

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Procedure for RC filters (high Pass-Low Pass) lab

1) Measure the values of the resistor and capacitor. Construct a circuit like Circuit 1 by connecting the capacitor and the resistor in series. Connect the oscilloscope and the voltmeter to measure the voltage across the resistor.

2) Calculate the cutoff frequency from $f_c = \omega_c/2\pi = 1/2\pi RC$. This should be the frequency at which the output power is equal to one half of the input power, or, equivalently, the output voltage is equal to 0.707 of the input voltage. Record this number.

3) Set the input voltage, the voltage across the signal generator, to 2 volts peak to peak.

4) Measure the output voltage of the circuit over a frequency range of 1 kHz to 10 kHz in 1 kHz increments. *You will need to adjust the input voltage back to 2 volts as you change the frequency*. Plot gain (Vout/Vin) vs. frequency. Print this plot.

5) Find the cutoff frequency from the plot by locating the frequency at which the gain is equal to 0.707.

6) Compare the calculated and measured cutoff frequency.

7) Repeat for Circuit 2.