Laboratory 6
AC Circuits and Filters

Key Concepts:
- Voltage and Phase Relations in AC Circuits
- Low-pass, High-pass and Bandpass filters

Equipment Needed:
- Digital Multimeter
- Oscilloscope
- Protoboard

Components Needed:
- (2) 10 kΩ Resistor
- (1) 2.7 kΩ Resistor
- (2) 0.01 μF Capacitor
- (1) 1 μF Capacitor

Overview:
We have seen how resistors and capacitors may be used to shape waveforms. Here we will explore RC circuits in their use as filters. The laboratory has four parts:
Part A: Measuring AC voltages in RC circuits
Part B: Low Pass filters
Part C: High Pass filters
Part D: Bandpass filters

Procedure

Part A:
Construct the circuit shown below, with R = 2.7 kΩ and C = 1 μF. Set the function generator to produce a 10 Hz sine wave of 5 V peak-to-peak. Using the DMM as a voltmeter, measure $V_{in}$, the voltage across the resistor ($V_R$) and the voltage across the capacitor ($V_C$).

$V_{in} =$ ______________

$V_R =$ ______________

$V_C =$ ______________

Question: Is $V_{in}$ what you expected? Explain.
**Question:** According to Kirchoff’s Voltage Law, $V_{in} = V_R + V_C$. Does this hold true for the DMM data? Why or why not?

Change the driving frequency to 1000 Hz and measure $V_{in}$, $V_R$ and $V_C$ again using the DMM.

$V_{in} =$ ________________ $V_R =$ ________________ $V_C =$ ________________

**Question:** If your data are different for the 120 Hz signal explain what is happening.

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**Part B:**
Construct a low pass filter using the same circuit as above, with $R = 10$ kΩ and $C = 0.01$ µF. Use the oscilloscope to measure $V_{out}$, the peak voltage. Vary the driving sine-wave frequency from 10 Hz to 100,000 Hz in decade intervals (10, 100, 1000, etc). Also measure the phase angle between $V_{in}$ and $V_{out}$ for each frequency. Plot your results on the graphs below.
**Question:** The break-point frequency is given by $f_B = 1/(2\pi RC)$. For this circuit, calculate the theoretical break-point frequency.

$$f_B = \text{___________________}$$

From your graph above, estimate the actual break-point frequency.

$$f_B = \text{___________________}$$

Keeping in mind oscilloscope accuracy (about 5%), resistor tolerance (5%) and capacitor tolerance (about 20%), how does the theoretical value of $f_B$ compare with the actual value?

**Question:** In terms of current flow in the circuit, describe why the phase angle between $V_{in}$ and $V_{out}$ changes as a function of frequency.

**Question:** Why is this circuit called a low pass filter?
**Part C:**
Construct a high pass filter by switching the resistor and capacitor in the previous circuit. As before, vary the driving sine-wave frequency from 10 Hz to 100 kHz in decade intervals and measure the peak voltage of \( V_{\text{out}} \) and phase angle between \( V_{\text{in}} \) and \( V_{\text{out}} \). Graph the results.

**Question:** The break-point frequency is given by \( f_B = 1/(2\pi RC) \). For this circuit, calculate the theoretical break-point frequency.

\[ f_B = \text{___________________} \]

From your graph above, estimate the actual break-point frequency.

\[ f_B = \text{___________________} \]
Keeping in mind oscilloscope accuracy (about 5%), resistor tolerance (5%) and capacitor tolerance (about 20%), how does the theoretical value of \( f_B \) compare with the actual value?

**Question:** In terms of current flow in the circuit, describe why the phase angle between \( V_{in} \) and \( V_{out} \) changes as a function of frequency.

**Question:** Why is this circuit called a low pass filter?

**Part D:**
We have constructed a low pass filter that filters out high frequencies and a high pass filter that filters out low frequencies. Often a filter is required which filters out both high and low frequencies but allows frequencies within a certain range to pass. This is a bandpass filter. It is basically a high pass filter added on to the output of a low pass filter.
Once again vary the driving frequency from 10 Hz to 100 kHz in decades and measure $V_{out}$ and the phase angle. Graph on the two graphs below.

Question: Describe quantitatively how would the $V_{out}$ vs. frequency graph change if $R_2$ were decreased to 1 kΩ? How would the graph change if $C_1$ were increased to 0.1 μF?