Lab 1, First Order RC Low-Pass Filters

Note: You must do the design and simulation (parts A and B) before coming to the Lab. You need to show your completed simulation to a Lab assistant before proceeding to parts C and D.

Purpose: To design, simulate, build, and test a first order low-pass filter and compare its response with theory in both time and frequency domains.

Part A: Design a first-order low-pass RC filter for the voice band (0-4 kHz) that rejects noise in the frequency range of 25 kHz-1.1 MHz coming over the same line. The filter must meet the following specifications:
1) Transfer function in the range of 0-4 kHz should be greater than $-1 \text{ dB}$
2) The transfer function should be minimized at 25 kHz, the low end of the noise (i.e., design your filter so that the transfer function at 25 kHz is as small as possible).
3) Use a 22 nF capacitor (good quality capacitors with this value is available).

What is the corner frequency of the filter you have designed? Calculate the magnitude of its transfer function at 25 kHz.

Part B: Use PSpice to simulate the circuit you have designed. Use a 1 V AC source as $V_i$. Specify a AC sweep from 100 Hz to 100 kHz. Plot the magnitude of transfer function in dB as a function of frequency (log scale for frequency axis). Verify that your design matches the specifications. Also plot phase of transfer function as a function of frequency (log scale for frequency axis). On both plots mark the corner frequency.

Part C: Assemble your circuit in the Lab on the protoboard. Set the function generator to produce a sin wave with a peak-to-peak amplitude of 10 V. Attach the function generator to the input ($V_i$). Attach the scope Channel A to the input and Channel B to the output ($V_o$) of the filter. Set the function generator frequency to 100 Hz. Measure the amplitude
of the Transfer Function $|V_o/V_i|$ by recording peak-to-peak amplitude of both the input and output voltages. Measure the phase of the transfer function by measuring the time difference between the two signals, $\Delta T$, e.g., time difference when the signals cross zero value. The phase difference between the two signal is then $360^\circ \Delta t/T$ where $T$ is the period of the signal. Repeat the measurement of the magnitude and phase of transfer function for frequencies between 100 Hz and 100 kHz (3 points per decade will be sufficient, near 1, 2, and 5). Tabulate your results.

Plot the measured magnitude of transfer function in dB and its phase as functions of frequency (log scale for frequency axis). Compare your data with your theoretical calculations. Explain the differences. You may want to measure the value of resistor and capacitor that you have used in building your circuit. That can help you explain the differences.

**Part D**: Set the function generator to give a square wave at about 300 Hz with a peak-to-peak magnitude of 10 V. Expand the horizontal display of the scope to show the rising edge of the output signal. Print the output signal. Estimate the time constant of the circuit from the output rise time. Write down the step response of the circuit and calculate its time constant. Compare theoretical value with experimental measurement and report any differences.

Use PSpice to simulate the step response of the RC circuit. This is done by using VPULSE function in PSpice. Plot the results (one period of the wave) and compare with your experimental results and theoretical calculations.