Note: You must do the circuit design, circuit analysis and PSpice simulations before coming to the Lab. PSpice simulation of part B can be done after you have completed your Lab work.

Note: For all experiments, OpAmps are powered with ±15 V supplies.

Part A – Inverting Amplifier: Consider the circuit below with $R_1 = 10 \text{ k}\Omega$ and $R_2 = 100 \text{ k}\Omega$. What is the gain of this amplifier circuit?

Lab Exercise:
1) Assemble the circuit on the proto-board. Set the function generator to produce a sinusoidal wave with an amplitude of 1 V (peak-to-peak), zero DC offset, and frequency of 1 kHz. Attach the function generator to the input and attach scopes channels A and B to input and output respectively. Measure the gain of the amplifier circuit.

2) Increase the amplitude of the input. At some point, the output saturates. Measure the upper and lower saturation voltages ($V_{sat}^+$ and $V_{sat}^-$). Compare them to the supply voltages.

3) Set the input to be a square wave with an amplitude of 1 V (peak-to-peak), zero DC offset, and frequency of 5 kHz. Due to slew-rate limit, the output is not exactly a square wave. Expand the time scale on the scope and measure the rise time of the output accurately. Calculate the slew-rate limit of your circuit. Change the frequency to 10 kHz and repeat the experiment. Does slow-rate limit depend on the input frequency?
**Part B – Low-Pass Filter:**

*Design:* Design an active low-pass filter with a gain of -10 and a cut-off (corner) frequency of 1.6 kHz. Use $R_1 = 10 \, \text{k}\Omega$ and find $R_2$ and $C_2$ to meet the design specifications.

*PSpice Simulation:* Use PSpice to simulate this circuit and obtain the frequency response for the frequency range of 100 Hz to 100 kHz. Attach the Bode plot to your lab report. From the Bode plot, find the filter gain and cut-off frequency. Do they match design specifications?

*Lab Exercise:* Build the circuit. Set up the function generator to produce a sinusoidal wave with an amplitude of 0.1 V (peak-to-peak). Scan the frequency range of 100 Hz to 100 kHz and measure the output voltage at each selected frequency. Take sufficient data points to make meaningful plots. (You need at least 3 points per decade and measurements about every 500 Hz between 1 and 3 kHz that brackets the cut-off frequency). Be watchful of the shape of the output signal. If it departs from sinusoidal wave (becoming triangular due to slew rate limit), note the frequency, reduce the amplitude of the input signal and continue your measurements. Report the data in tabular form and plot the Bode plots. Compare the Bode plot and the cut-off frequency with your PSpice simulations and analytical calculations. Write down your observations from this set of experiments and calculations.
Part C – High-Pass Filter:

Design: Design an active high-pass filter with a gain of -1 and a cut-off (corner) frequency of 1.6 kHz. Use \( R_2 = 100 \, \text{k}\Omega \) and find \( R_1 \) and \( C_1 \) to meet the design specifications.

PSpice Simulation: Use PSpice to simulate this circuit and obtain the frequency response for the frequency range of 100 Hz to 100 kHz. Attach the Bode plot to your lab report. From the Bode plot, find the filter gain and cut-off frequency. Do they match design specifications?

Lab Exercise: Build the circuit. Set the function generator to produce a sinusoidal wave with an amplitude of 0.1 V (peak-to-peak). Scan the frequency range of 100 Hz to 100 kHz and measure the output voltage at each selected frequency. Take sufficient data points to make meaningful plots. (You need at least 3 points per decade and measurements about every 500 Hz between 1 and 3 kHz that brackets the cut-off frequency). Be watchful of the shape of the output signal. If it departs form sinusoidal wave (becoming triangular due to slew rate limit), note the frequency, reduce the amplitude of the input signal and continue your measurements. Report the data in tabular form and plot the Bode plot. Compare the Bode plot and the cut-off frequency with your PSpice simulations and analytical calculations. Write down your observations from this set of experiments and calculations.