Equipment and Supplies

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<th>Instrument</th>
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<td>1.6kΩ resistor (via variable resistor box)</td>
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Pre-Laboratory Assignment (STEPS 1-5)

1. Consider the circuit of Figure 1. Using phasor analysis, find the circuit voltage gain \( \frac{v_{\text{out}}}{v_1} \) and phase \( \angle v_{\text{out}} - \angle v_1 \) as a function of the voltage source frequency in Hz.

![Figure 1. Low Pass RC Filter](image)

2. Obtain gain and phase plots (Bode plot) of this circuit using LTspice® (that is, plot the voltage gain and phase shift as a function of the voltage source frequency). In the LTspice® “Edit Simulation Cmd” menu use an AC Analysis and be sure that the voltage source value is AC 1. Use a DECADE frequency sweep from 1 Hz to 1 MHz with 100 points per decade. After running your simulation, right click in the plot plane and select “Add Trace” and plot \( V(\text{out}) \). Also in the plot plane menu select “Manual Limits” and set the “Top,” “Tick,” and “Bottom” values to 0, 20, and -60, respectively, and then select a “Decibel” vertical axis. Add a plot grid using the plot plane menu. Your graph should be identical to Figure 2 (you can change the background color using the “Tools”->“Color Preferences” dialog box). Place a copy of the plot in your lab notebook. The plot must be large enough to enable accurate plotting of experimental data during lab.

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3. The 3dB frequency is the frequency at which the voltage gain is $\frac{1}{\sqrt{2}} \approx 0.707$ times the peak gain. Since the peak gain for this circuit is one (0dB), the 3dB frequency is the frequency at which the gain is 0.707 (-3dB). For this circuit

$$f_{3dB} = \frac{1}{2\pi R_1 C_1} \text{ (Hz)}$$

where the phase shift is -45°. Compute and verify the 3dB frequency using your plots.

4. Verify at least two other gain and phase values on the plot using your equations from pre-laboratory step 1.

5. Repeat pre-laboratory steps 1 to 4 for the circuit of Figure 3. The phase shift at $f_{3dB}$ is 45°.
Procedures

Part One

1. Build the circuit of Figure 1. Use a waveform generator for the voltage source to produce a sinusoid that varies between -1V and 1V. Connect the waveform generator to CH 1 of the oscilloscope. Connect $V(out)$ to CH 2 of the oscilloscope.

Using oscilloscope cursors, accurately measure the voltage gain $\frac{V(out)}{V1}$ and the phase shift between $V(out)$ and $V1$ for at least ten frequencies more or less evenly spread between 1 Hz and 1 MHz. Is there a problem with your high frequency measurements? Tabulate and then plot your gain and phase shift results (as single points) on your SPICE plot for points that you measured accurately. They must be in close agreement!

**BEFORE PROCEEDING TO THE NEXT STEP** ask the lab instructor to verify your results.

2. Change the waveform generator to a square wave. Place a plot of $V1(t)$ and $V(out)(t)$ in your lab notebook.

3. **CRITICAL:** Complete the worksheet on the last page. You must attach this as the LAST PAGE of your lab report. **REPORTS WITHOUT A COMPLETED WORKSHEET** will not be accepted.
Part Two

4. Build the circuit of Figure 3. Use a waveform generator for the voltage source to produce a sinusoid that varies between -1V and 1V. Connect the waveform generator to CH 1 of the oscilloscope. Connect \( V(\text{out}) \) to CH 2 of the oscilloscope.

Using oscilloscope cursors, accurately measure the voltage gain \( \frac{V(\text{out})}{V_1} \) and the phase shift between \( V(\text{out}) \) and \( V_1 \) for at least ten frequencies more or less evenly spread between 1 Hz and 1 MHz. Is there a problem with your high frequency measurements? Tabulate and then plot your gain and phase shift results (as single points) on your SPICE plot for points that you measured accurately. They must be in close agreement!

BEFORE PROCEEDING TO THE NEXT STEP ask the lab instructor to verify your results.

5. Change the waveform generator to a square wave. Place a plot of \( V_1 \) and \( V(\text{out}) \) in your lab notebook.

Analysis

1. Why are the gain and phase plots measured using a sinusoidal source?

2. Explain the shape of the low and high pass filter outputs for laboratory procedures steps 2 and 5 (filter responses to square wave input).

Credits and Copyright
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1. Compute a new 3dB frequency as

\[ f_{3dB} = 1000(2N + 1) \text{(Hz)} \]

where \(N\) is the number of aisles between your bench and the lab door.

2. Keeping \(C1=0.1\text{uF}\), compute the value of \(R1\) needed to realize this new 3dB frequency assuming that the circuit should meet the following specification:
   a. The circuit 3dB frequency must be within 5% of \(f_{3dB}\).

Enter your value here. Be sure to include units.

R1  

3. Replace \(R1\) with this new value using a resistor substitution box.

4. Describe how you can quickly verify that your circuit realizes the specified \(f_{3dB}\) (limited to the space below):