UNIVERSITY OF CALIFORNIA AT BERKELEY
College of Engineering
Department of Electrical Engineering and Computer Sciences

EE105 Lab Experiments

Experiment 7: Frequency Response

1 Objective

You have already seen the performance of several BJT amplifiers. These were designed to operate well at certain small-signal frequencies, and indeed there is a frequency limit imposed by the parasitic capacitances of BJT devices. In this lab, you will observe how an amplifier responds to different input frequencies, making use of the National Instrument Bode Analyzer software. This lab will help familiarize you with the native capacitances in a transistor, and how the frequency response is affected by these capacitances and external loads as well.

2 Materials

Component	Quantity
2N4401 NPN BJT	1
10 kΩ resistor	1
1 kΩ resistor	1
51 Ω resistor	1
1 nF Capacitor	1

Table 1: Components used in this lab

3 Procedure

3.1 Frequency Response of Common Emitter Amplifier

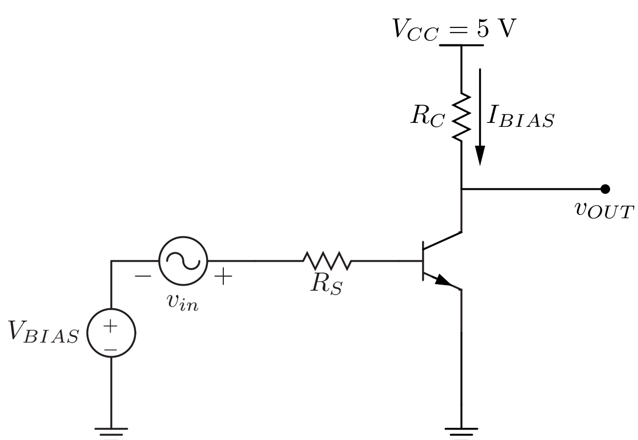

Figure 1: Common emitter amplifier test setup

1. Construct the common emitter amplifier as shown in Figure 1. Use a $R_C = 10\ \text{k}\Omega$ and $R_S = 51\ \Omega$.

2. Use a function generator to generate a 25 mV peak-to-peak, 1 kHz sinusoidal signal with a DC offset of 580 mV. This signal is both V_{BIAS} and v_{in} combined, and will be referred to as v_{IN}. *Note: You may notice some nonlinear effects on the output waveform. This is due to the high input signal amplitude that we are using. We choose this amplitude to avoid noise from the oscilloscope messing up our Bode plot measurements in a later step.*

3. What is I_{BIAS} and the DC voltage at V_{OUT}?

4. Using the oscilloscope, plot input v_{IN} on **Channel 2** and output v_{OUT} on **Channel 1**. Make sure to transfer the waveforms over to the Lab Report.

5. What are the magnitude and phase of v_{out}/v_{in} measured from the oscilloscope?

6. Instead of using the oscilloscope to measure the magnitude and phase of v_{out}/v_{in} at other frequencies manually, let's use NI Bode Analyzer software to automate the process. To avoid errors from the software, make sure you follow the instructions below to set up the software:

   - Make sure that v_{IN} is on Channel 2 and v_{OUT} is on Channel 1.
   - Connect the Trigger Output from the function generator to the External Trigger port of the oscilloscope.
   - Open `NI Bode Analyzer.exe` from the computer desktop.
   - When both the function generator and the oscilloscope are turned on, click "Refresh" under "Resource Name."
   - The function generator is configured to a higher GPIB address than the oscilloscope. Select the GPIB device with a higher GPIB address for the function generator, and select the GPIB device with a lower GPIB address for the oscilloscope.
   - Set the stop frequency to 2 MHz for this measurement. You can leave the starting frequency at its default value.
   - Set the amplitude of the input signal to 25 mV and the DC offset to 290 mV. *Note: We set the DC offset to* 290 mV *because the function generator outputs an offset that is twice as large as the value entered here.*
   - Hit "Run"! The software will start sweeping the input across different frequencies to generate a Bode plot.

7. After the software is done producing the Bode plot, you can drag the cursor on the plot to read out the magnitude and phase at different frequencies. Drag the cursor to around 1 kHz. What are the magnitude and phase obtained with the software? How different is this measurement compared to the one obtained with the oscilloscope?

8. Now drag the cursor to a point where the gain decreases from its DC value by 3 dB. This is the dominant pole of the amplifier. What is the pole frequency? What is the phase at this frequency? Is the phase consistent with the magnitude? (Recall that at the -3 dB point, the phase should be drop from its DC value by 45 degrees.)

9. You can export the plot by right clicking on the plot, and then select "Export Simplified Image." You can also export the data points as a .csv (which can be opened in Microsoft Excel) file by clicking the "Export" button. Print the plot out and turn it in with your Lab Report. You do not have to find the second pole because it occurs at a frequency higher than what is measureable by our equipment.

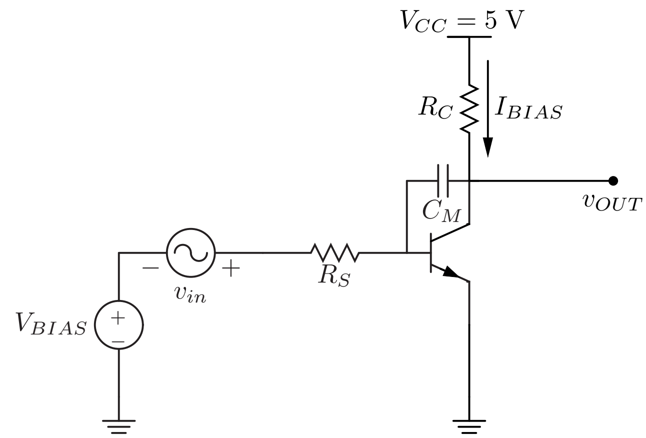

Figure 2: Miller capacitor test setup

3.2 Miller Effect

1. The Miller effect can be best examined by introducing a Miller capacitor across the amplifier. Let's take a look at the impact of the Miller effect by adding a 1 nF capacitor for C_M as shown in Figure 2.
2. Repeat the above procedures on using the NI Bode Analyzer to find the frequency response of this amplifier, but set the stop frequency to 500 kHz. Attach the Bode plot to the Lab Report.
3. How does the dominant pole of this amplifier compare to the dominant pole of the previous amplifier? Is this expected?
4. In this amplifier, we are using a 1 nF capacitor to simulate a large base-collector capacitor (C_μ). If we are to design an amplifier with high bandwidth, is a transistor with a large C_μ desirable?

3.3 Output Capacitance

1. Let's examine the impact of output capacitance on a common emitter amplifier. Take out the Miller capacitor C_M from Section 4.2 and place it at the output as shown in Figure 3.

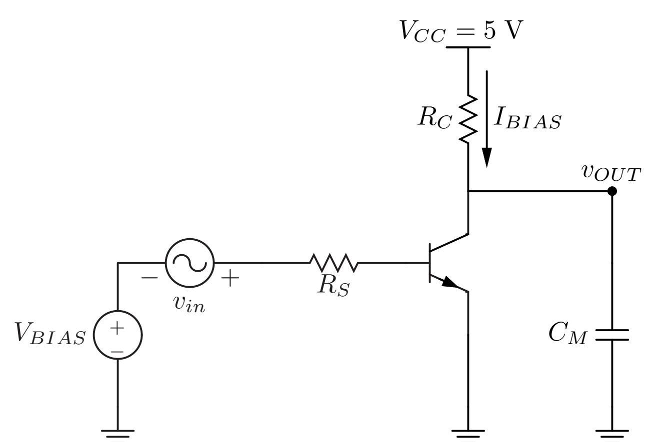

Figure 3: Output capacitance test setup

2. Repeat the above procedures on using the NI Bode Analyzer to find the frequency response of this amplifier, but set the stop frequency to 500 kHz. Attach the Bode plot to the Lab Report.
3. How does the dominant pole of this amplifier compare to the dominant poles of the previous two amplifiers? Is this expected?

3.4 Common Collector Amplifier

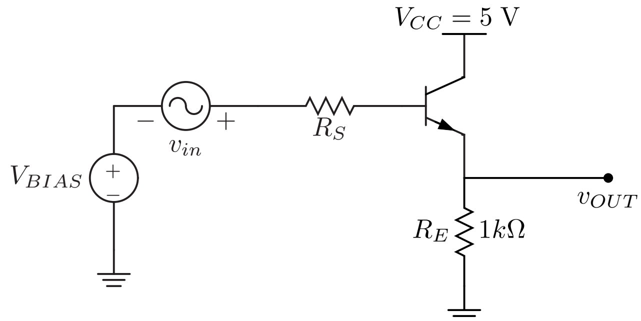

Figure 4: Common collector amplifier test setup

1. The common collector amplifier is a wide bandwidth amplifier. Let's examine the frequency response of this amplifier by building the common collector amplifier as shown in Figure 4. Configure the NI Bode Analyzer with an input signal of amplitude 1 V and DC offset of 1 V (which is 2 V effective DC offset) for v_{in} and V_{BIAS}.

2. Repeat the above procedures on using the NI Bode Analyzer to find the frequency response of this amplifier. Attach the Bode plot to the Lab Report. However, keep in mind that the breadboard has a parasitic capacitance that will start deforming the signal when the signal frequency goes beyond approximately 1 MHz. You can observe this effect at the output of the amplifier using the oscilloscope. Therefore, the experiment in finding the dominant pole of this amplifier is only an approximation. *Note: You may not be able to find the pole with the equipment in the lab. If this is the case, just mention that you cannot find the pole.*

3. How does the bandwidth of this amplifier compare to the bandwidths of the previous amplifiers? *Note: If you could not measure the dominant pole, a qualitative answer is sufficient.*