ECE 351 LAB 6
Low Frequency Response of an Amplifier

Before you do this lab, find what capacitors are available in the stock room. You can use slightly different values if necessary. Purchase the capacitors and then make the calculations for the capacitors that you have purchased. This will avoid the problem of making calculations for parts that are not available.

6.1 Prelab Calculations

The amplifier in Figure 6-1 is designed to have a collector current between 15 mA and 30 mA. For the 2N3904 transistor, $50 \le \beta \le 350$. Make the following calculations. For minimum and maximum calculations, use resistor tolerances, capacitor tolerances (+80%, -20% for electrolytic capacitors), and variations in β. For calculations, you may need to know that $I_{C\,\min}$, $r_{\pi\,\min}$, $\beta_{\min}$, and $g_{m_{\min}}$ occur together and $I_{C\,\max}$, $r_{\pi\,\max}$, $\beta_{\max}$, and $g_{m_{\max}}$ occur together.

1. Find an expression for the pole due to C_S in Figure 6-2.
2. Find the minimum and maximum frequencies of the pole due to C_S in Figure 6-2. Fill in **Table 6-1**.
3. Find an expression for the pole due to C_E in Figure 6-3. Assume that C_S is a short.
4. Find the minimum and maximum frequencies of the pole due to C_E in Figure 6-3. Fill in Table 6-2.
5. Find an expression for the pole due to C_L in Figure 6-5.Assume that C_S is a short.
6. Find the minimum and maximum frequencies of the pole due to C_L in Figure 6-5. Fill in Table 6-3.
7. Find the overall lower 3 dB frequency of the amplifier of Figure 6-6. Note that the pole due to C_S in the circuit of Figure 6-6 is not at the same frequency as the pole due to C_S in the circuit of Figure 6-2. In Figure 6-6 the pole due to C_S is at:

$$\omega_{C_S} = \frac{1}{C_S\left(R_S + R_1 \| R_2 \| r_\pi\right)}$$

Find the maximum value of this new value of ω_{C_S}. To find the maximum value of the overall lower 3 dB frequency, ω_L, use the approximation

$$\omega_L \approx \omega_{C_S} + \omega_{C_E} + \omega_{C_L}$$

If you use the maximum values of ω_{C_S}, ω_{C_E}, and ω_{C_L}, the measured overall 3 dB frequency will always be less than the calculated approximation. Since we are always concerned with the lower 3 dB frequency being less than a specified value, if the approximation is less than the specification then the actual value will be less. Since all we know is that $\omega_L(Actual) \le \omega_L(Calculated)$, it only makes to calculate the maximum value of ω_L. Calculate the maximum value of ω_L and enter the value in Table 6-4.

8. Use PSpice to obtain a Bode plot of V_o / V_s for the amplifier in Figure 6-6.

6.2 Laboratory Procedure

6.2.1 Bias Measurements

Wire the circuit of Figure 6-1 without the capacitors. Measure the collector current and verify that it is between 15 and 30 mA. Measure V_{CE} and verify that the BJT is not saturated. With V_S set to zero measure the polarity of the voltages which will appear across the bias capacitors. Check to see if the voltage polarity across the capacitors is as indicated in Figure 6-1. Due to device tolerances your circuit may have different voltage polarities across the capacitors. If so, wire the capacitors according to your bias measurements.

6.2.2 Frequency Response Due C_S

Wire the circuit shown in Figure 6-2. Wire C_S so that it is consistent with the voltage polarity measured in the bias measurement. This amplifier will have a voltage gain of approximately 5. Fill in the results in **Table 6-1**. Use the measurement technique given below to measure the 3 dB frequency.

Table 6-1: Measured data for the circuit of Figure 6-2.

	(rad/sec)	Hz
ω_{C_S} (max)		
ω_{C_S} (min)		
$\omega_{C_S}(measured)$		

1. Set the function generator to a 1 kHz sine wave. This frequency is approximately mid-band for this amplifier.
2. Set the amplitude of the function generator so that V_o is an undistorted sine wave. Usually 1 $V_{peak\text{-}peak}$ is a good amplitude.
3. Measure the mid-band gain V_o/V_s at 1 kHz.
4. Find the lower 3 dB frequency of this amplifier. The 3 dB frequency occurs when the gain has been reduced to 0.707 of the mid-band gain. Assuming that the amplitude of V_S remains constant, the 3 dB frequency occurs when the amplitude of V_o has been reduced to 0.707 of its mid-band value.

Note that the lower3 dB frequency will be around 10 Hz. **Print the scope screen showing the amplifier input, output, and the frequency at the -3 dB point.**

6.2.3 Frequency Response Due to C_E

Wire the circuit shown in Figure 6-3. C_E is an emitter bypass capacitor and makes the gain V_o/V_s large at midband. Note that C_S has been changed to 1000 μF. This places the pole due to C_S at a much lower frequency than the pole due to C_E, making the pole due to C_E the dominant pole. Since the pole due to C_S is at such a low frequency, C_S can be considered a short at frequencies where C_E will be affecting the gain of the amplifier.

Since the gain of this amplifier is so high you may not be able to make V_S small enough to keep V_o from saturating or clipping. To avoid saturating or clipping use the circuit of Figure 6-4. The gain of this amplifier is still V_o/V_s. Since it is easier to measure larger signals, the gain V_o/V_{sig} should be measured and multiplied by the voltage divider ratio to obtain the gain V_o/V_s:

$$\frac{V_o}{V_S} = \frac{V_o}{V_{Sig}}\left(\frac{100+1}{1}\right)$$

Measure the lower 3 dB frequency and fill in the result in Table 6-2.

Print the scope screen showing the amplifier input, output, and the frequency at the -3 dB point

Table 6-2: Measured data for the circuit of Figure 6-3.		
	(rad/sec)	**Hz**
ω_{C_E} (max)		
ω_{C_E} (min)		
$\omega_{CE}(measured)$		

6.2.4 Frequency Response Due to C_L

Wire the circuit shown in Figure 6-5. As in section 6.2.3, C_S is large to make the pole due to C_L the dominant pole. Measure the lower 3 dB frequency and enter the result in Table 6-3. **Print the scope screen showing the amplifier input, output, and the frequency at the -3 dB point**

Table 6-3: Measured data for the circuit of Figure 6-5.		
	(rad/sec)	**Hz**
ω_{C_L} (max)		
ω_{C_L} (min)		
$\omega_{CL}(measured)$		

6.2.5 Overall Frequency Response

Wire the circuit shown in Figure 6-6.

1. Measure the 3 dB frequency of V_o/V_s and enter the result in Table 6-4.
2. Measure V_o/V_s at several frequencies. Enter the measured data in **Table 6-5** and then use MATLAB to generate a Bode plot of V_o/V_s
3. Compare this Bode plot to the one obtained from PSpice. Since you are interested in the low frequency response of this amplifier, your Bode plot should include the mid-band gain and all poles of interest. In other words, your Bode plot should include frequencies from 1 Hz up to 100 kHz.
4. **Print the scope screen showing the amplifier input, output, and the frequency at the -3 dB point**

Table 6-4: Measured data for the circuit of Figure 9.6.		
	(rad/sec)	**Hz**
$\omega_{3dB}(\max - calculated)$		
$\omega_{3dB}(measured)$		

Table 6-5: Gain and freqyency response for the circuit of Figure 6.6.

Frequency (Hz)	$\omega\left(r/s\right)$	v_s	v_o	Gain $\left(\frac{v_o}{v_s}\right)$	Gain in Decibels $20Log_{10}\left(\frac{v_o}{v_s}\right)$

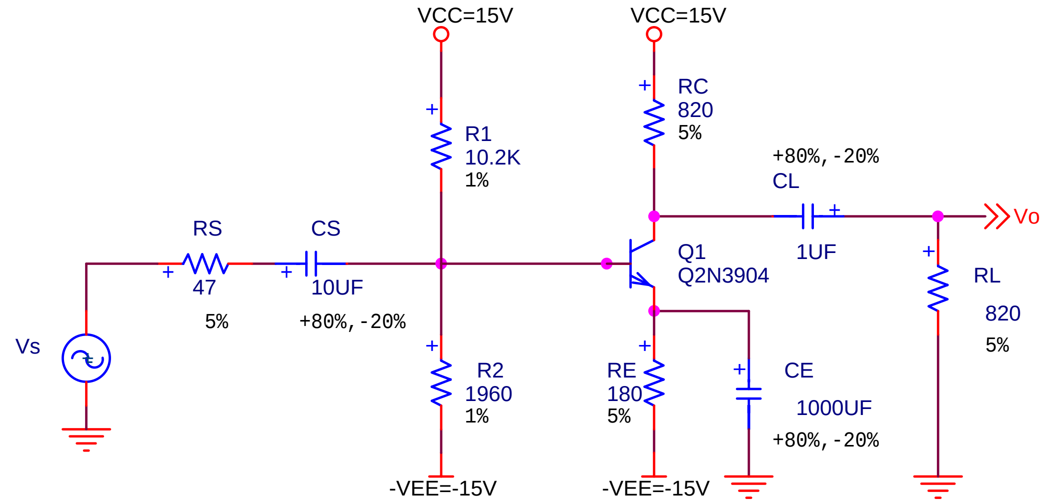

Figure 6-1: Single stage amplifier.

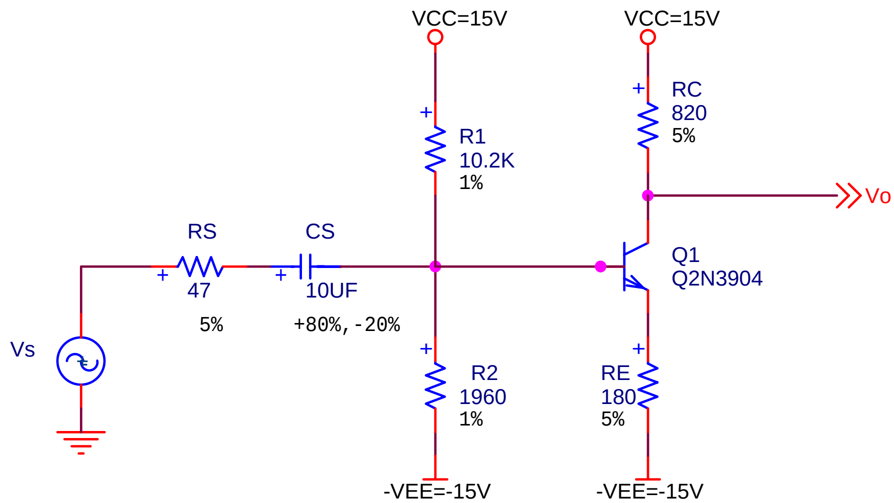

Figure 6-2: Single stage amplifier for finding the pole due to C_S **.**

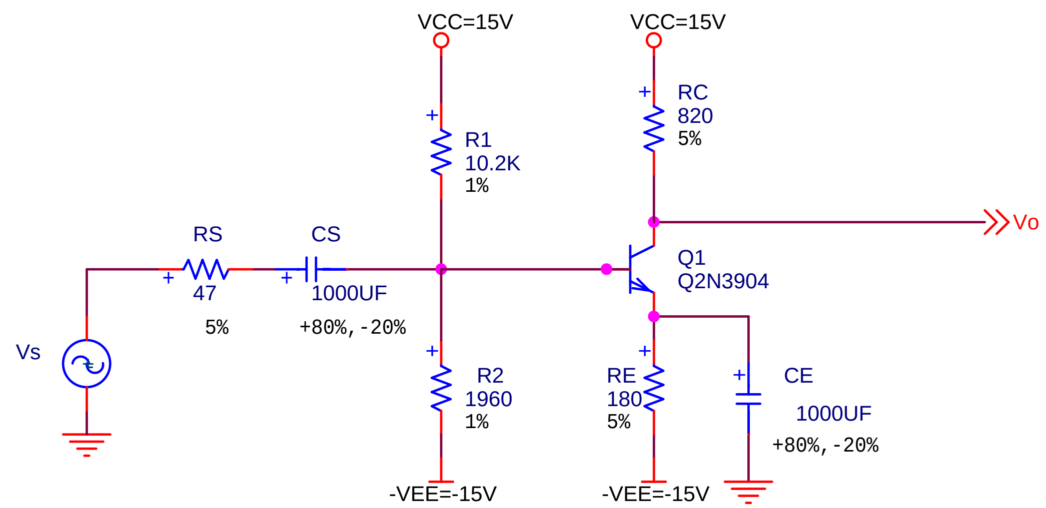

Figure 6-3: High gain amplifier.

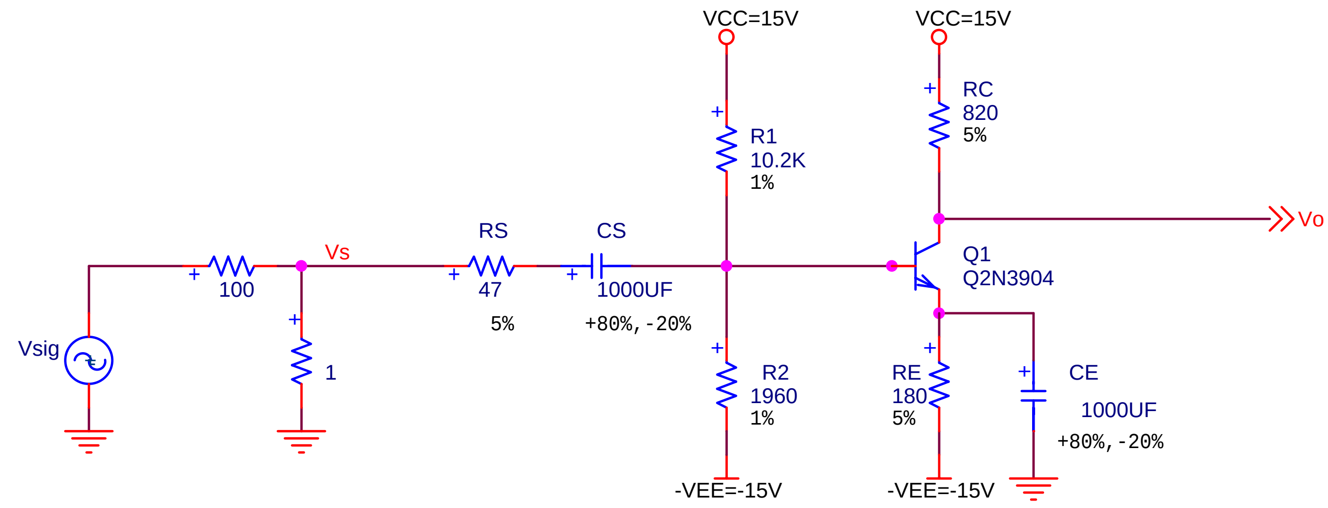

Figure 6-4: Circuit for finding the pole due to C_E.

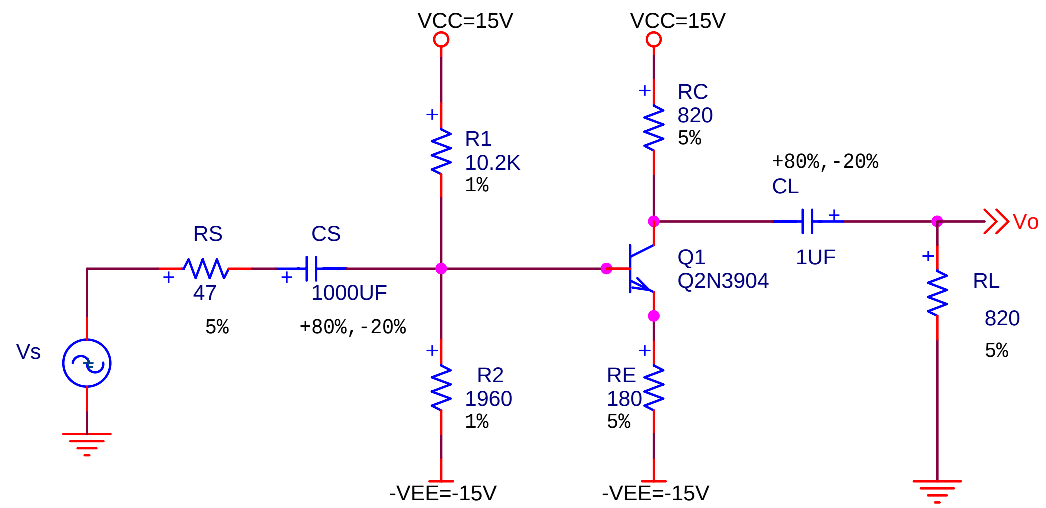

Figure 6-5: Circuit for finding the pole due to C_L.

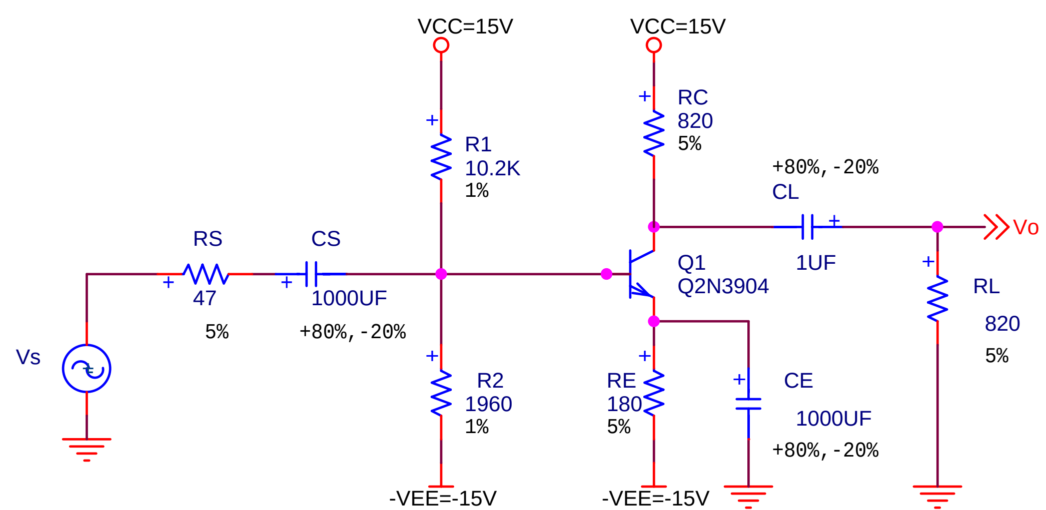

Figure 6-6:Circuit to find the overall lower 3 dB Frequency.