EE315 - Electronics Laboratory

Experiment - 7 Simulation
BJT Amplifier Frequency Response

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Preliminary Work

1=) a=) C-E Loop

$10 - R_C \times I_{CQ} - V_{CEQ} - R_E \times \frac{\beta+1}{\beta} \times I_{CQ} = 0$

$5m(R_C + \frac{301}{300} R_E) = 5$

$R_C + \frac{301}{300} R_E = 1k$

$V_{Th} = \frac{R_2}{R_1+R_2} \times 10 = \frac{10k}{R_1+10k} \times 10$

$R_{Th} = R_1 // R_2 = R_1 // 10k = \frac{10k R_1}{R_1+10k}$

$\boxed{R_C = 700\Omega \quad R_E = 300\Omega}$

B-E Loop

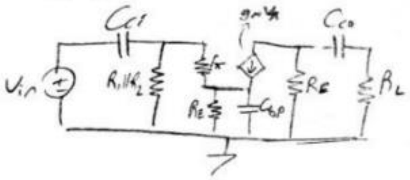
$V_{Th} - R_{Th} \times \frac{I_{CQ}}{\beta} - V_{BE} - R_E \times \frac{\beta+1}{\beta} \times I_{CQ} = 0$

$\frac{10 \times 10k}{R_1+10k} - \frac{10k \times R_1}{R_1+10k} \times \frac{5m}{300} - 0.7 - 300 \times \frac{301}{300} \times 5m = 0$

$\boxed{R_1 = 35.351k\,\Omega \quad R_2 = 10k\,\Omega}$

$5k \leq R_1 // R_2 = 7.8k\Omega \leq 10k$

b=)



$g_m = \frac{I_C}{V_T} = 0.19232\,℧$

$r_\pi = \frac{\beta}{g_m} = 1.560k\,\Omega$

$\frac{1}{g_m} = 5.2\,\Omega$

For C_{ci}

$R_{eq} = R_{Th} // (r_\pi + (1+\beta) R_E) = 7.8k // 91.86k = 7.189k\Omega$

$f = \frac{1}{2\pi \tau} = \frac{1}{2\pi C_{ci} R_{eq}} = 2.214\ Hz$

For C_{co}

$R_{eq} = R_C + R_L = 4.6k$

$f = \frac{1}{2\pi C_{co} R_{eq}} = 3.46\ Hz.$

For C_{bp}

$R_{eq} = (\frac{R_{Th}}{\beta} + \frac{1}{g_m} // R_E) = 31.1\Omega$

$f = \frac{1}{2\pi C_{bp} R_{eq}} = 107.88\ Hz$

2=) Loop C-E

$10V - V_{CEQ} - I_{EQ} \times R_E = 0$

$5m \times R_E = 5$

$R_E \approx 1k\Omega$

$I_{EQ} \approx I_{CQ}$

assume $R_2 = 15k\Omega$

Loop B-E

$\frac{10 \times R_1}{R_1 + R_2} - I_{BQ} \times R_{Th} - V_{BE} - I_{EQ} R_E$

$\frac{10 \times 15k}{R_1 + 15k} - \frac{5m}{200} \times \frac{15k \times R_1}{15k + R_1} = 5.7$

$R_1 = 10.6k\Omega$

$R_{Th} = R_1 // R_2 = 6.21k\Omega$

b=) For C_{ci}

$R_{eq} = R_{Th} // (r_\pi + (\beta+1) R_E) = 6.21k\Omega$

$f_{ci} = \frac{1}{2\pi C_{ci} R_{eq}} = 2.56\ Hz$

$g_m = \frac{I_{CQ}}{V_T} = 0.1923\ \mho$

$r_\pi = \frac{\beta}{g_m} = 1.560k\Omega$

For C_{co}

$R_{eq} = R_L + \frac{R_E \cdot r_\pi}{r_\pi + (1+\beta) R_E} = 3.907k\Omega$

$f_{co} = \frac{1}{2\pi C_{co} R} = 0.767$

Procedure

1.a) Build the circuit given in Figure **1** using the values calculated in the preliminary work. Set the input voltage to **20 mVpeak**. Record the values of v_{in}, v_{out} and calculate $A_V = 20 \log|v_{out}/v_{in}|$, sweeping the input frequency from **50 Hz** to **100 kHz**.

f (Hz)	v_{in} (V)	v_{out} (V)	A_V (dB)
50	39.920665mV	318.51184mV	18.021
100	39.947593mV	663.00638mV	24.389
200	39.917863mV	1.2539865V	29.924
500	39.944837mV	2.376004V	35.476
1000	39.938139mV	3.0868835V	37.749
2000	39.963076mV	3.3724014V	38.518
5000	39.963471mV	3.4992219V	38.838
10000	39.933508mV	3.5188902V	38.887
20000	39.922167mV	3.5210034V	38.892
50000	39.917076mV	3.5362508V	38.929
100000	39.952992mV	3.5347568V	38.926

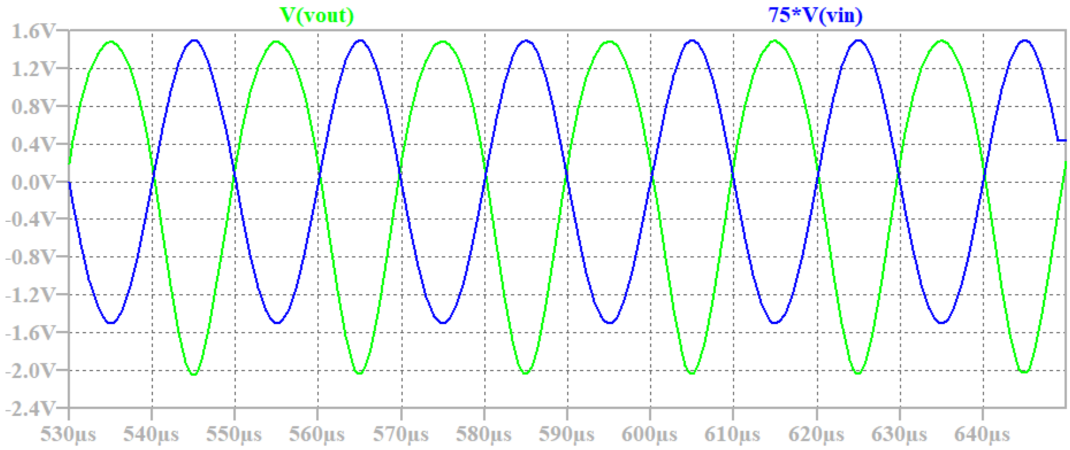
1.b) Increase the input signal level until output voltage clipping occurs. Record the maximum input and output levels of undistorted sine wave signal.

>>Vin(peak) = 47mV

>>Vout(peak to peak) = 7.429992V

1.c) Note the phase shift between output and input. Is your amplifier inverting or noninverting?

>>There is 180degree phase difference so, it is an inverter amplifier. Vin voltage is multiplied by 75 to observe the phase difference more clearly.



1.d) Is the bandwidth of your common emitter amplifier suitable for an audio amplifier? Which one of the three capacitors (**C_{Ci}**, **C_{Co}**, or **C_{bp}**) is the component that limits the bandwidth? What should be done to cover the frequency range required for an audio amplifier?

>>Human being's frequency range of ear is 20Hz to 20kHz. However, our circuit is not giving steady gain before 1kHz. So, it is not perfectly suitable for audio amplifiers.

>>**C_{bp}** has dominant effect on lower frequency. Thus, **C_{bp}** limits the bandwidth.

>>We are supposed do expand our bandwidth. We know **C_{bp}** limits, thus if we increase the capacitance of **C_{bp}** , we can cover the frequency range required for an audio amplifier.

1.e) What will be the voltage gain of your common emitter amplifier, if **R_L = 8Ω** (input resistance of a common speaker)?

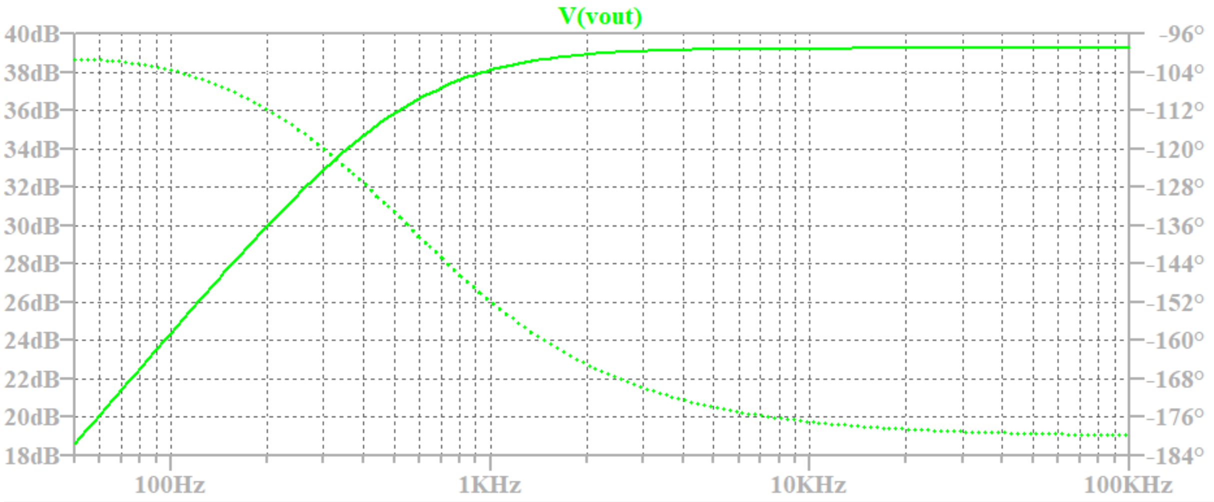
>>Vout = 48.32305mV

Vin = 39.663138mV

In 10k Hz which is inside the midband range.

Thus, the voltage gain is Av = 1.218336

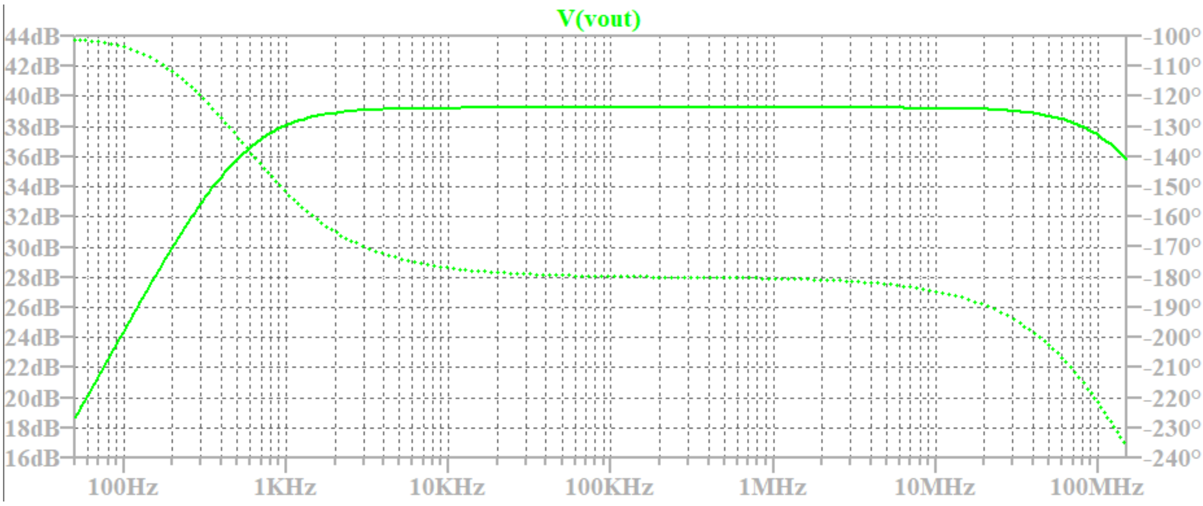
1.f) Right-click on the ***v_{in}*** source, select "**(none)**" as the source function and set **AC amplitude** to **1.0** in the **Small signal AC analysis (.AC)** section. Right-click on the "**.tran.....**" simulation command, select the **AC analysis** tab, select "**Decade**" sweep type with **100** points per decade resolution and set the frequency range from **50 Hz** to **100 kHz**. Run simulation and observe ***v_{out}*** as a function of frequency. Compare the AC analysis results with the **A_V** values found in **1.a**.



>>As we observed in 1.a, after 1kHz the the acceleration of the increment of voltage gain goes to the zero. Thus, we were expecting to became steady after reaching 1kHz.

1.g) Increase stop frequency to **100Meg** in the **.AC** simulation command. Run simulation and record the **-3 dB** high frequency cut-off point.

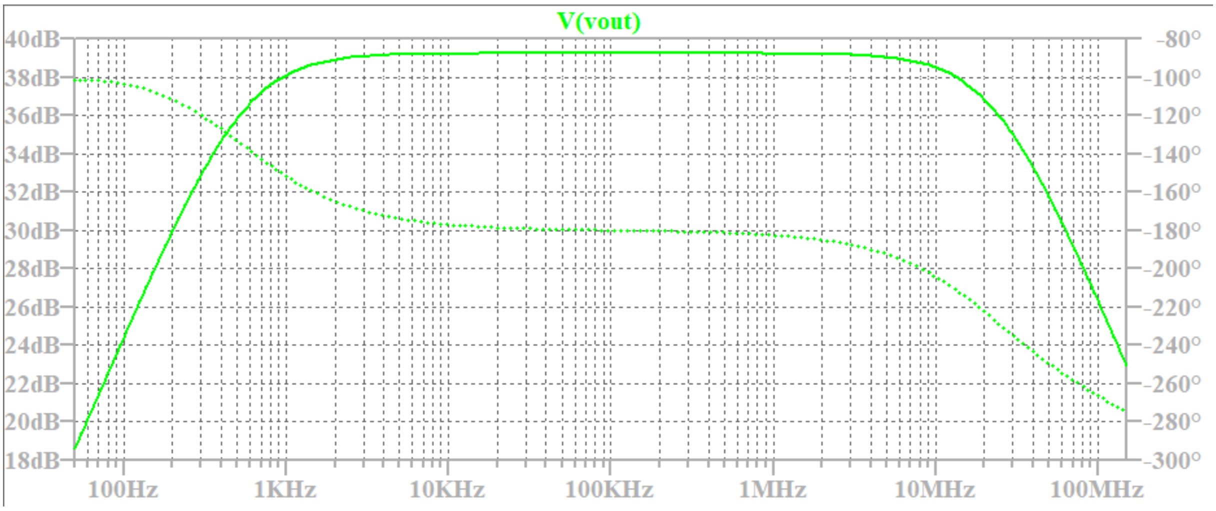
F_{HFC} = 136.82275MHz



1.h) Typically there is a **10 pF** capacitance between two neighboring slots of a breadboard. In order to simulate the transistor behavior on a breadboard, connect a **10 pF** capacitor between base and collector pins of the transistor and connect another **10 pF** capacitor between base and emitter pins. Run simulation and record the **-3 dB** high frequency cut-off point with the added capacitors.

F_{HFC} = 22.985793MHz

Explain the change in the high cut-off frequency.



>>The capacitor between base and collector dominates the cut off frequency at high frequency. Thus, after adding that capacitor, our high cut off frequency decreases. Because, at high frequency, our capacitor becomes short circuit and this results V(out) equal to the V(base). Due to this result, we observe decaying behavior at high frequency.

2.a) Build the circuit given in Figure **2** using the values computed in the preliminary work. Set the input voltage to **100 mVpeak**. Record the values of v_{in}, v_{out} and calculate $A_V = 20 \log|v_{out}/v_{in}|$, sweeping the input frequency from **50 Hz** to **100 kHz**.

f (Hz)	v_{in} (V)	v_{out} (V)	A_V (dB)
50	199.58997mV	197.22889mV	-0.103
100	199.17241mV	197.62081mV	-0.067
200	199.91172mV	197.3036mV	-0.114
500	199.5426mV	197.42387mV	-0.092
1000	199.8533mV	197.77936mV	-0.084
2000	199.61536mV	197.38353mV	-0.097
5000	199.51326mV	197.25116mV	-0.099
10000	199.59232mV	197.57241mV	-0.088
20000	199.19262mV	197.1666mV	-0.088
50000	199.58244mV	198.01168mV	-0.068
100000	199.73321mV	198.02119mV	-0.074

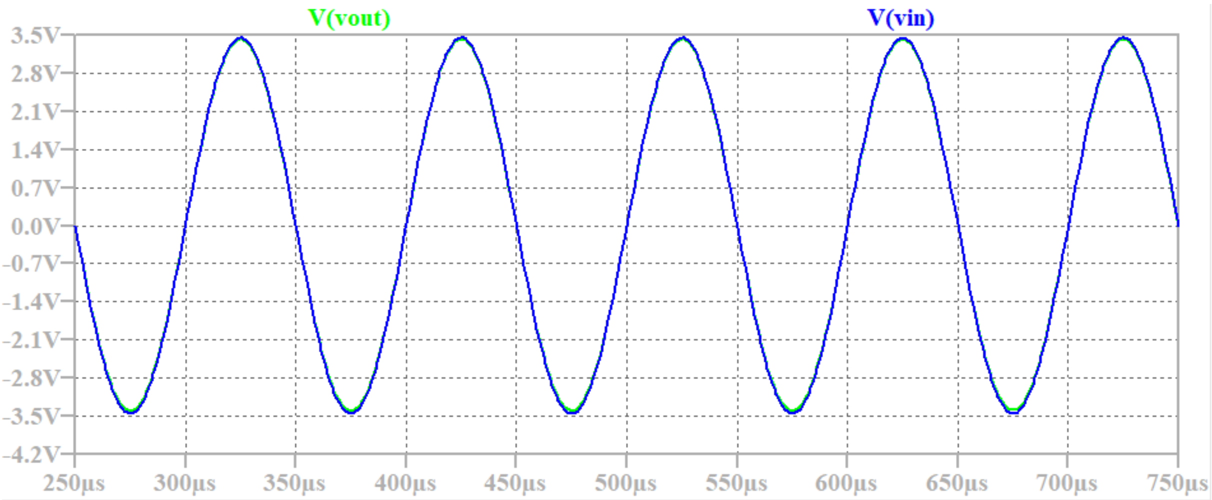
2.b) Set input frequency to **10 KHz** and increase the input signal level until output voltage clipping occurs. Record the maximum input and output levels of undistorted sine wave signal.

>>Vin peak = 3.45

>>Vout peak = 3.5444121V

2.c) Is your amplifier inverting or noninverting?

>>This is a noninverting amplifier. Because Vin and Vout signals are top of each other. This means, they are in the same phase.

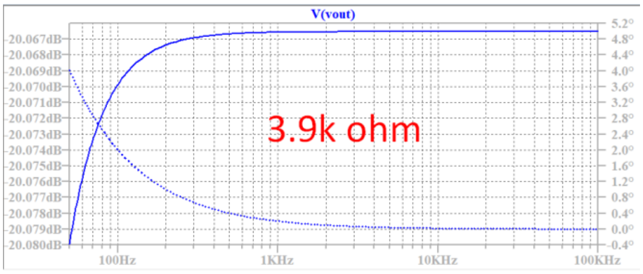


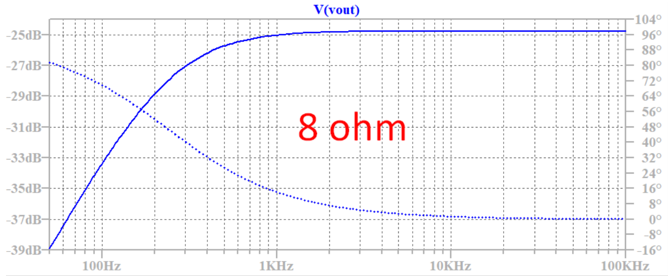
2.d) Is the bandwidth of your common collector amplifier suitable for an audio amplifier?

>>Yes, because the bandwidth of our circuit is greatly including ears frequency range.

2.e) What will be the voltage gain of your common collector amplifier, if $\mathbf{R_L = 8\Omega}$? How will this change affect the bandwidth? What can be done to restore the bandwidth?

>>The voltage gain at 1kHz is Av = Vout/Vin = 93.5489mV/199.1401mV = 0.4697



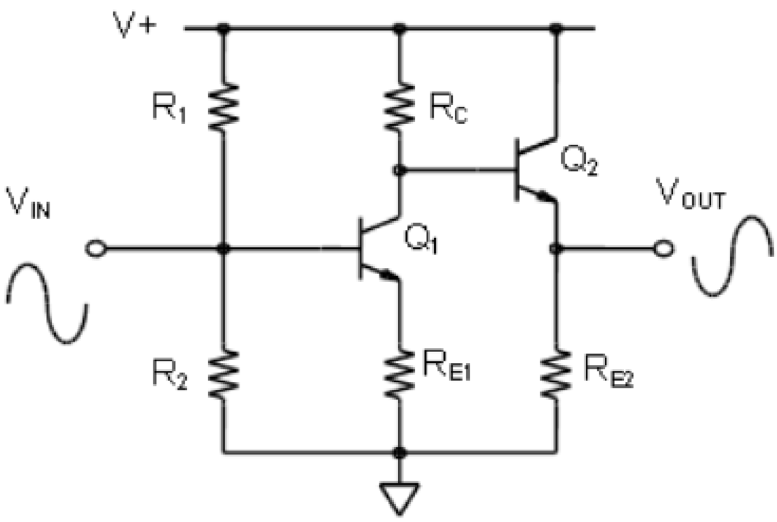


>> As we can see from the graph above, when we have 8ohm R_L, starting frequency of bandwidth increases, this results in decrease on bandwidth.

>>We know that Cco specifies this behavior. Thus, we can increase Cco to restore this result to get similar bandwidth as the first case.

2.f) What is the main purpose of using the emitter follower?

>>The emitter follower circuit has unity voltage gain and high current gain amplifier. Because of this unity gain property, it is useful as a buffer amplifier. It provides isolation between two circuits. It has high input impedance and low output impedance. If we use the common emitter to amplify and the emitter follower as a buffer, we would have steady amplifier. With this kind of common emitter and emitter follower amplifier, we get an output that is almost independent of load resistance and we have input voltage that is almost independent of input source resistance.



Conclusion

>>In this laboratory session, we observed 2 kind of BJT amplifier circuit which are common emitter and common collector amplifiers. They have quiet different features to use an amplifier.

In the first part of this experiment, firstly, we observed change on voltage gain by changing frequency. We saw and increasing and after 1kHz constant voltage gain. Then, we found our input voltage limit and if our circuit is inverting and noninverting by looking phase shift. After that, we observed our circuit as audio amplifier if it is suitable or not and what limits the bandwidth and what to do to compensate. In **1.e**, to observe real world circumstance we set R_L as 8ohm. Lastly, we did AC analysis with AC sweep feature of LTSpice and we did the same thing with inner capacitance of the BJT.

In the second part of this experiment, we started with the similar process and we observed unity voltage gain for any frequency. Then similarly, we found our input voltage limit, found out if we have inverting or noninverting amplifier and if we have suitable circuit for audio amplifier. We analyzed our voltage gain with real 3.9kohm and 8ohm load resistance. Lastly, we examine the purpose of using emitter follower.

In conclusion, we observed the behavior of two different BJT amplifier circuit and we found out that if we cascade both amplifiers, we can obtain an amplifier which is independent of input and output resistance.