EE315 - Electronics Laboratory
Experiment - 4 Simulation
BJT Small Signal Analysis

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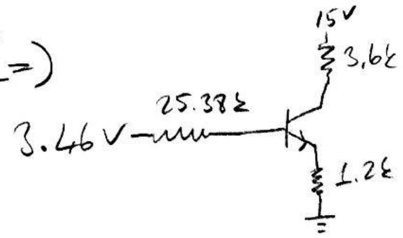
Preliminary Work

1=)



$R_{Th} = 110k \| 33k = 25.38k$

$V_{Th} = 15 \times \frac{33}{33+110} = 3.46V$

B-E Loop

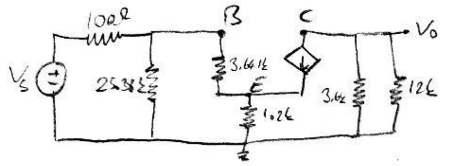
$3.46 = i_B \times 25.38k + 0.7 + 1.2k \times (\beta+1) \times i_B$

$i_B = 7.14 \mu A$

$i_C = 2.142 mA$

$g_m = \frac{I_{CQ}}{V_T} = \frac{2.142mA}{26mV} = 82.385 m℧$

$r_\pi = \frac{\beta}{g_m} = \frac{300}{82.385m} = 3.641 k\Omega$



$R_i = R_{Th} \| (r_\pi + (\beta+1) R_E)$

$A_V = \frac{-\beta \times (R_C \| R_L)}{(r_\pi + (1+\beta) R_E)} \times \frac{R_i}{R_i + R_s} = -2.27$

$R_{out} = R_C = 3.6 k\Omega$

$A_i = \frac{25.38}{330.18} \times 300 \times \frac{3.6}{15.6} = 4.503$

$R_{in} = R_s + R_{Th} \| (r_\pi + (\beta+1) R_E) = 23.78k\Omega$

Limits of the Signal

$i_{B(sat)} = 10.4 \mu A$

$3.46 + V_{s(sat)} = 25.38 \times i_{B(sat)} + 0.7 + (1.2k)(\beta+1)(i_{B(sat)})$

$V_{s(sat)} = 1.26V$

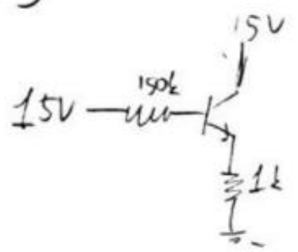
$V_{Th} - R_{Th} i_B - V_{BE} - R_E i_E \le 0$

$V_{s(cut\ off)} = 3.03V$

$1.26V \le V_S \le 3.03V$

Saturation Cut off

2=)



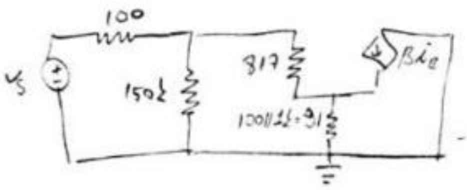
B-E Loop

$15 - 150k \times i_B - 0.7 - 1k(\beta+1) \times i_B = 0$

$i_B = 31.7\,\mu A \qquad i_C = 3.56\,mA$

$g_m = \frac{I_C}{V_T} = \frac{3.54}{26} = 267\,m℧$

$r_\pi = \frac{\beta}{g_m} = \frac{300}{0.367} = 817\,\Omega$



$A_v = \frac{23.6k}{23.7k} \times \frac{31 \times 301}{28.2k} = 0.367$

$A_i = \frac{150}{150+782} \times 301 = 253.36$

$R_{in} = 103.3k + 0.1 = 103.4k$

$R_{out} = \frac{1}{g_m} \| R_C \| R_L \| r_\pi = 2.55\,\Omega$

Limits of the Signal

$i_{B(sat)} = \frac{15V}{1k \times (\beta+1)} = 49.8\,\mu A$

$15V + V_{S(sat)} = 150k \times i_B + 0.7 + 1k \times 301 \times i_B$

$V_{S(sat)} = 8.16V\ (sat)$

Cut off $\quad V_{BE} < 0.7$

$15 - 150k \times i_B = V_E + 0.7$

$15 - V_{CE} = V_E \qquad V_{S(cut\ off)} = 4.8V$

$4.8V \leq V_S \leq 8.16V$

Cut off $\qquad$ Saturation

Results

1. Build the circuit given in Figure **1** and select **BC547B** as the transistor model. Set the ***value*** of the voltage source v_S to obtain **1 kHz** sine wave, with **2 Vp-p** amplitude. Select a **4.7 µF Al electrolytic** capacitor model (right-click on the capacitor figure and click on "Select Capacitor"). Note the polarity of the capacitors on the circuit diagram.

1.a) Measure the voltage gain, A_V.

$V_{Sp\text{-}p}$ =1.998015V $V_{Op\text{-}p}$ =4.5129207V A_V =-2.2587

1.b) Determine the current gain, A_i, by measuring the current through R_S and R_L.

$I_{Sp\text{-}p}$ =84.643559µA $I_{Lp\text{-}p}$ =375.94006µA A_i =-4.4414

1.c) Disconnect R_L and measure the input resistance, R_{in}.

$V_{Sp\text{-}p}$ =1.9981866V $I_{Sp\text{-}p}$ =84.626074µA R_{in} =23.611k

1.d) Measure peak-to-peak output voltage while R_L is disconnected. Connect R_L and change its value to obtain half the output voltage measured without any load that will give the R_{out} of the amplifier.

$V_{Op\text{-}p(NoLoad)}$ =5.8658202V(Half) R_{out} =3.6k

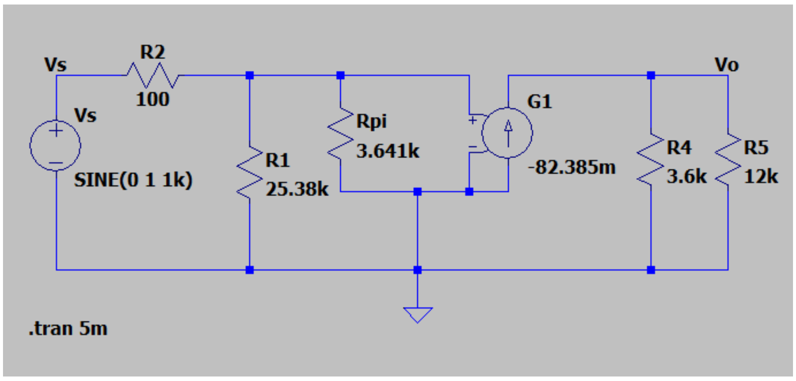
1.e) Find the maximum peak v_S amplitudes before the transistor goes into cut-off or saturation. Compare the results with your calculations in the preliminary work.

$V_{Speak(cut\text{-}off)}$ =2.65V $V_{Speak(sat)}$ = 1.4V

1.f) Connect a **4.7 µF** capacitor in parallel to R_E. Make sure that the polarity of the capacitor matches the DC voltage polarity on R_E. Measure the voltage gain, A_V, again as described in step **1.a**.

$V_{Sp\text{-}p}$ =1.9930987V $V_{Op\text{-}p}$ =10.803381V A_V =5.420394384

1.g) Draw the small signal model of the common-emitter amplifier with the capacitor in parallel to R_E, and calculate the voltage gain, A_V, based on your model.



A_V= -221.14439

2. Build the emitter-follower circuit given in Figure **2**. Verify that the voltage source output is set to **1 Vp-p**, **1 kHz**, and repeat the steps **1.a**, **1.b**, and **1.c** for this circuit

2.a) Measure the voltage gain, **A_V**.

$V_{Sp\text{-}p}$ = 998.18426mV $V_{Op\text{-}p}$ = 869.33985mV A_V = -0.87

2.b) Determine the current gain, **A_i**.

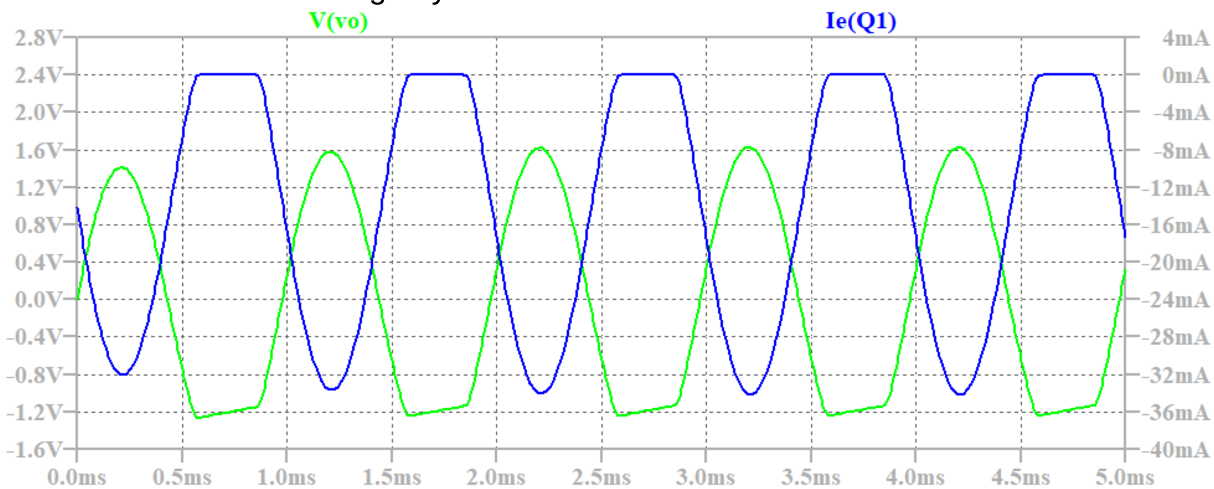
$I_{Sp\text{-}p}$ = 42.151482µA $I_{Lp\text{-}p}$ = 8.6903228mA A_i =-206.1689

2.c) Disconnect **R_L** and measure the input resistance, **R_{in}**.

$V_{Sp\text{-}p}$ = 998.22767mV $I_{Sp\text{-}p}$ = 10.777318µA R_{in} =92.623k

2.d) Increase v_S amplitude to **2.0 Vp-p** and observe v_O waveform. How do you explain the distortion in the v_O waveform?

>>When we have approximately under -0.8V v_S, behavior of cut off region is observed which is the situation that when the V_{BE} value is less than it has to be which is 0.7 volt. As we can see in the graph below which is **4.0 Vp-p** to observe more clearly, when v_S, goes under -0.8V, Ie current is exactly zero. Which means that transistor is not conducting anymore.



2.e) Find a way to restore the v_O waveform while keeping v_S amplitude at **2.0 Vp-p**, and **R_L = 100 Ω**. Explain how you can restore the v_O waveform.

>>We can decrease **R_E** lower than 1kohm, which will restore v_O waveform while keeping v_S amplitude same as before. Because when **R_E** is decreased, the Ic current becomes greater due to the equation of C-E loop which is
$V_{CC} – R_1{*}I_b – V_{BE} – R_E{*}(beta+1){*}I_b = 0$. Thus, lower R_E, compensates lack of Vcc.

Also, If we decrease R1, again we are able to restore the v_O waveform. Because, lower R1 results in greater Ib due to the equation of B-E loop which is
$V_{CC} – R_1{*}I_b – V_{BE} – R_E{*}(beta+1){*}I_b = 0$. Thus, lower R_1, compensates lack of Vcc.

Lastly, we can simply increase Vcc amplitude value.

2.f) Measure the output resistance, **R_{out}** using the method described in step **1.d**. Make sure that the output waveform is not distorted while you measure **R_{out}**.

$V_{Op\text{-}p(NoLoad)}$ =991.67044mV **R_{out} =28**

Conclusion

>>In this experiment, we dived in small signal analysis of BJT amplifiers, especially common-emitter and common collector amplifiers.

In the first experiment, we analyzed the npn type common emitter amplifier. We figured out that how to measure the $\mathbf{A_V}$ $\mathbf{A_i}$ $\mathbf{R_{in}}$ $\mathbf{R_{out}}$ values in simulation. I observed similar results with my preliminary work. Then, we observed when the transistor got into saturation or cut off region on changing v_S amplitude. In **1.f,** we see that when we add **4.7 μF** capacitor in parallel to $\mathbf{R_E}$, we observed greater $\mathbf{A_V}$. Because, that capacitor cancels $\mathbf{R_E}$ in DC analysis which results in greater voltage gain. In the last part, small signal model of the last circuit with LTspice.

In the last experiment, we analyzed the npn type common collector amplifier. Again, we measured the $\mathbf{A_V}$ $\mathbf{A_i}$ $\mathbf{R_{in}}$ $\mathbf{R_{out}}$ values in simulation. In **2.d,** we observed the saturation of the circuit while changing v_S amplitude and find out the reason of the distortion. In **2.f**, we figured out what to do to restore the v_O waveform.