ECE3110J Electronic Circuit Homework 4

Due: **Tuesday June 17th 11:59a.m.**

Note:

1) Please use A4 size paper or page.
2) Please clearly state out your final result for each question.
3) Please attach the screenshot of Pspice simulation result if necessary.

One day the antenna in your phone goes wrong. So you decide to build a new antenna. The information is transferred through a set of sinusoidal waves that varies in time.

However, due to the low energy of electromagnetic wave, you have to build an amplifier to make the input signal larger.

Now your task is as follows:

Consider the following BJT amplifiers, determine their small-signal, open-circuit voltage gain $A_v = \frac{v_o(t)}{v_i(t)}$ **respectively.**

Neglect the Early effect.

Try to follow the steps to solve each question

1) Complete a D.C. Analysis.
2) Calculate the small-signal circuit parameters for each BJT.
3) Carefully replace all BJTs with their small-signal circuit model.
4) Set all D.C. sources to zero.
5) Analyze small-signal circuit.

Question 1. Simple CE Stage
You start with a simple common emitter single stage amplifier as in Figure. 1. To reduce your computation, please assume $V_{BE} = 0.7V$, $V_T = 0.025V(T = 300K)$

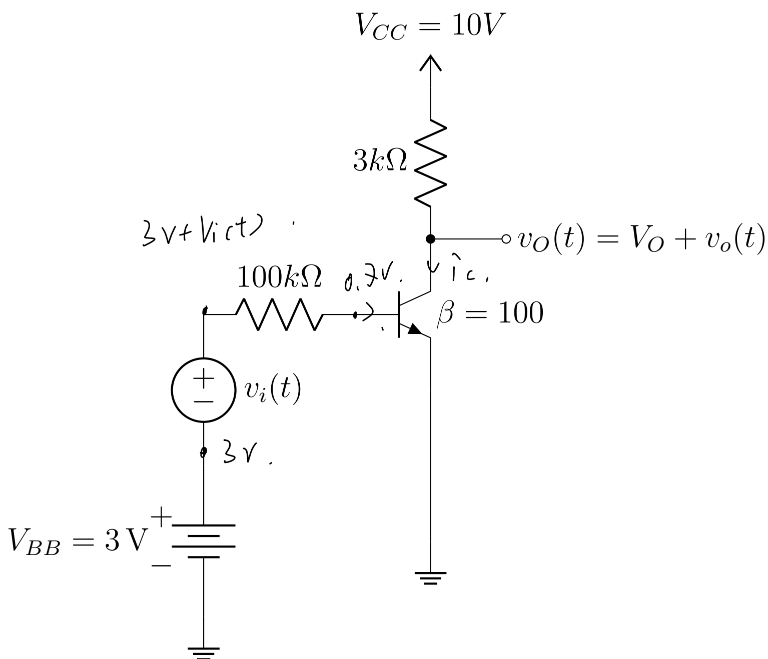


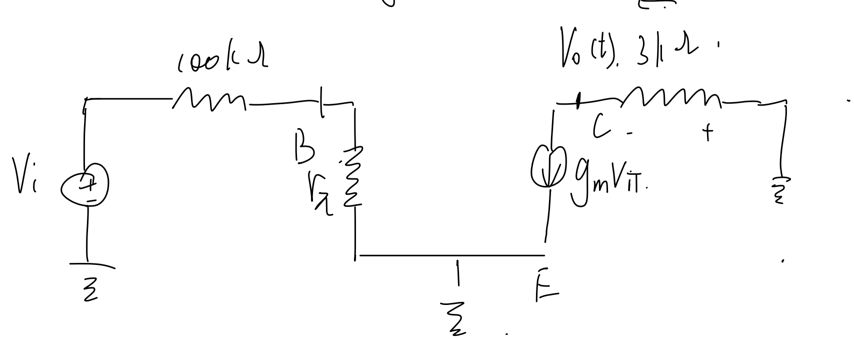
FIGURE 1. Simple CE Stage

$$i_B = \frac{3V-0.7V}{100\times10^3} = 2.3\times10^{-5}A.$$

$$i_C = \beta i_B = 2.3\times10^{-3}A.$$

$$g_m = \frac{i_C}{V_T} = \frac{2.3\times10^{-3}}{2.5\times10^{-2}} = 0.092.$$

$$r_\pi = \frac{\beta}{g_m} = 1087.0\ \Omega.$$



$$V_\pi = V_i\frac{r_\pi}{r_\pi+100k\Omega} = 0.0108V_i$$

$$V_o + g_m V_\pi \cdot 3k\Omega = 0.$$

$$\boxed{A_V = \frac{V_o}{V_i} = -g_m\cdot 0.0108\cdot 3k = -2.98}$$

Question 2. CE Stage with coupling capacitor

You realize that the gain A_v is too small mainly because the $R_{BB} = 100k\Omega$ is too large. However, a large R_{BB} is required to keep $V_C > V_B$.

You find out that placing a resistor at emitter side can largely reduce R_{BB} required by raising up V_E and thus raising V_B. Then, a coupling capacitor C is connected in parallel with source resistor. The capacitance is large enough to work as **DC open and AC short**.

Still, to analyze the circuit in Figure. 2, please assume $V_{BE} = 0.7V$, $V_T = 0.025V (T = 300K)$

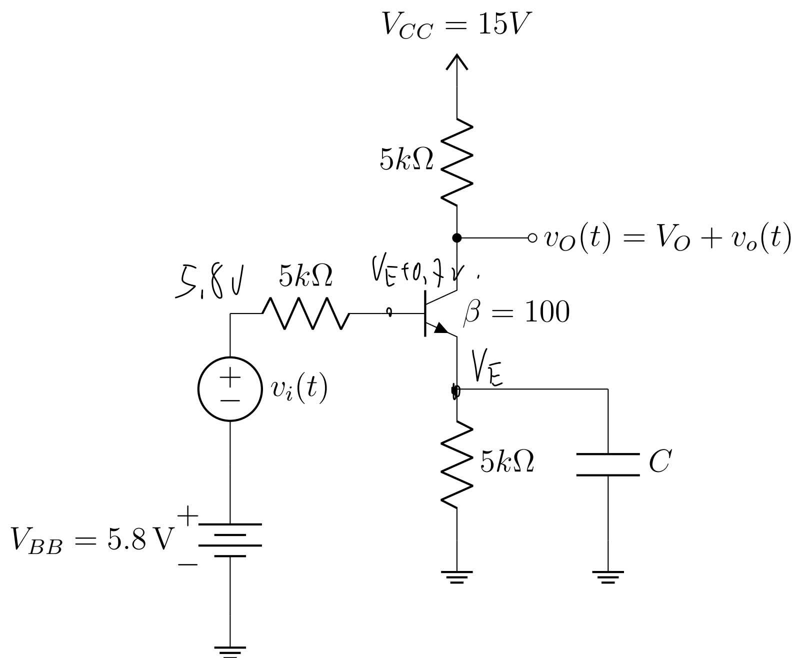


FIGURE 2. CE Stage with coupling capacitor

$$i_B = \frac{5.8 - 0.7 - V_E}{5\times10^3} = 1.02\times10^{-3} - 2\times10^{-2} V_E.$$

$$i_E = 101\, i_B$$

$$i_E \cdot 5k\Omega = V_E.$$

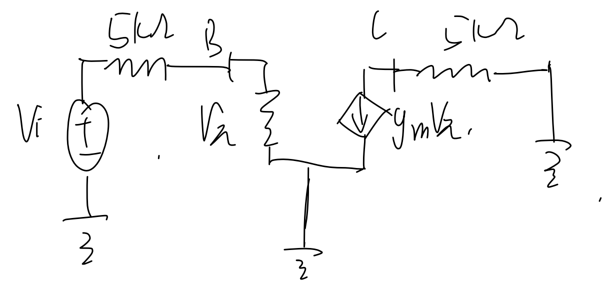
$$5\times101\times10^3 (1.02\times10^{-3} - 2\times10^{-4} V_E) = V_E$$

$$V_E = 5.05V.$$

$V_B = 5.75V$ $\quad i_B = 1\times10^{-5}A$ $\quad i_C = 1\times10^{-3}A$.

$$g_m = \frac{i_C}{V_T} = \frac{1\times10^{-3}}{0.025} = 4\times10^{-2}.$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{4\times10^{-2}} = 2.5\times10^{3}\,\Omega.$$



$$V_\pi = V_i \cdot \frac{r_\pi}{r_\pi + 5k\Omega} = 0.33 V_i.$$

$$V_o + g_m V_\pi \cdot 5\, 10^3 = 0.$$

$$\boxed{A_v = \frac{V_o}{V_i} = -g_m \cdot 0.33 \cdot 5 \cdot 10^3 = -66.67.}$$

Question 3. CB Stage PNP

You want to get a positive A_v however the former amplifier gives negative A_v.

So you try the circuit shown in Figure. 3

Notice that this is a **PNP** BJT. $V_{EB} = 0.7V$,$V_T = 0.025V$.

(Hint: Try a different small signal model if you find one model too complicated for you)

$i_E = \frac{10-0.7}{10\times10^3} = 9.3\times10^{-4}A$.

$i_C = i_E \cdot \frac{100}{101} = 9.2\times10^{-6}A$

$g_m = \frac{i_C}{V_T} = \frac{9.2\times10^{-4}}{0.025} = 3.68\times10^{-2}$

$r_\pi = \frac{\beta}{g_m} = 2717.4\Omega$

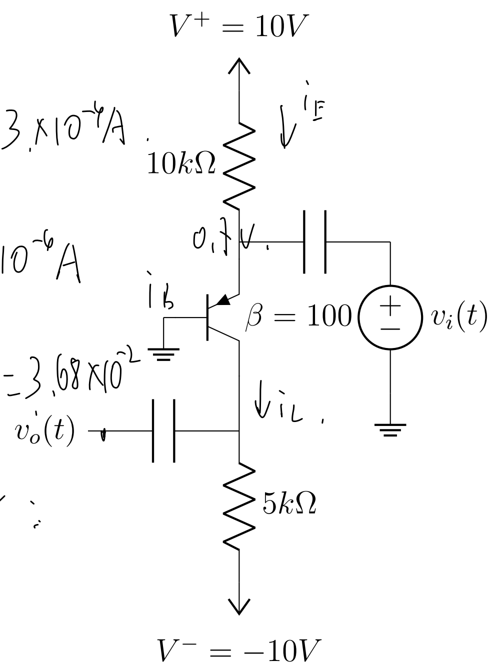
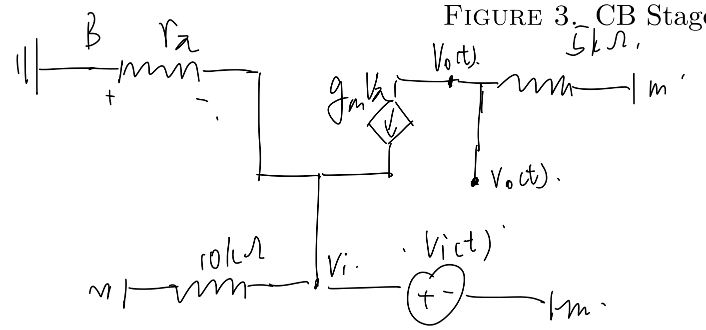


FIGURE 3. CB Stage PNP



$V_\pi = -V_i$.

$V_o - V_i + V_i + g_m V_\pi \cdot 5k\Omega = 0$.

$V_o = 5k\Omega \cdot g_m \cdot V_i$.

$\boxed{A_v = \frac{V_o}{V_i} = 5\times10^3\times3.68\times10^{-2} = 184}$