EE 321 Analog Electronics, Fall 2011
Homework #9 solution

5.130. For the common-emitter amplifier shown in Figure P5.130, let $V_{CC} = 9\,\mathrm{V}$, $R_1 = 27\,\mathrm{k\Omega}$, $R_2 = 15\,\mathrm{k\Omega}$, $R_E = 1.2\,\mathrm{k\Omega}$, and $R_C = 2.2\,\mathrm{k\Omega}$. The transistor has $\beta = 100$, and $V_A = 100\,\mathrm{V}$. Calculate the dc bias current I_E. If the amplifier operates between a source for which $R_{\text{sig}} = 10\,\mathrm{k\Omega}$ and a load of $2\,\mathrm{k\Omega}$, replace the transistor with its bybrid-π model, and find the values of R_{in}, the voltage gain v_o/v_{sig}, and the current gain i_o/i_i.

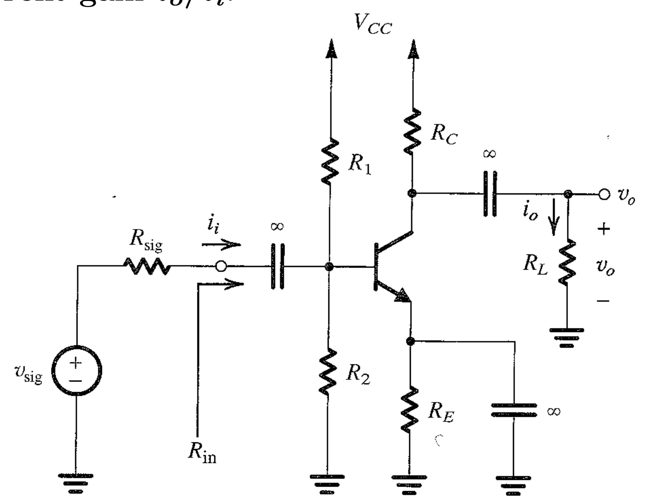


FIGURE P5.130

We have

$$V_B = (i_1 - i_B)\, R_2 \qquad V_B = V_{BE} + (\beta + 1)\, R_E i_B \qquad V_B = V_{CC} - i_1 R_1$$

and we can eliminate i_D and i_B from the first equation.

$$V_B = \left(\frac{V_{CC} - V_B}{R_1} - \frac{V_B - V_{BE}}{(\beta + 1)\, R_E} \right) R_2$$

$$V_B \left[1 + \frac{R_2}{R_1} + \frac{R_2}{(\beta + 1)\, R_E} \right] = V_{CC} \frac{R_2}{R_1} + V_{BE} \frac{R_2}{(\beta + 1)\, R_E}$$

$$V_B = \frac{V_{CC} \frac{R_2}{R_1} + V_{BE} \frac{R_2}{(\beta+1) R_E}}{1 + \frac{R_2}{R_1} + \frac{R_2}{(\beta+1) R_E}} = \frac{9 \times \frac{15}{27} + 0.7 \times \frac{15}{101 \times 1.2}}{1 + \frac{15}{27} + \frac{15}{101 \times 1.2}} = 3.03\,\mathrm{V}$$

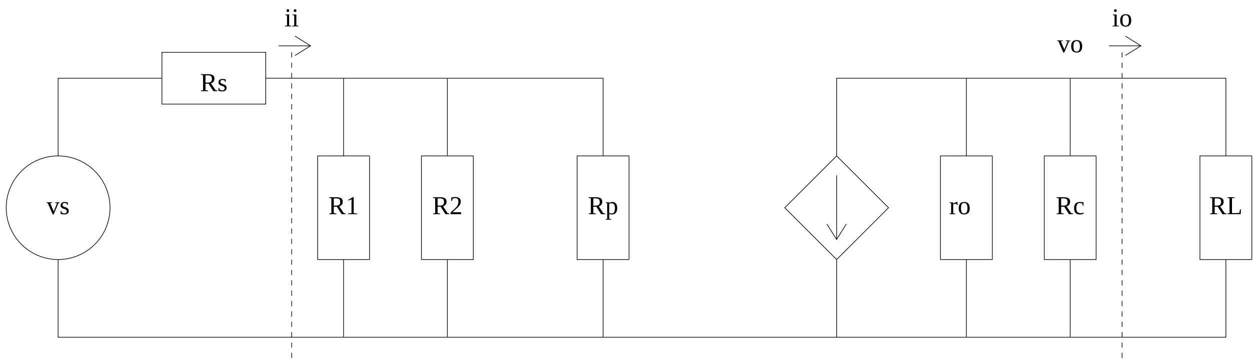
Note that for $(\beta + 1)\, R_E \gg R_2$ and $V_{CC} \gg V_{BE}$ the expression for V_B reduces to the voltage divider expression,

$$V_B = V_{CC} \frac{\frac{R_2}{R_1}}{1 + \frac{R_2}{R_1}} = V_{CC} \frac{R_2}{R_1 + R_2} = 9 \times \frac{15}{15 + 27} = 3.21\,\mathrm{V}$$

I will proceed with the result from the fully correct expression. Next, the emitter current is

$$I_E = \frac{V_E}{R_E} = \frac{V_B - V_{BE}}{R_E} = \frac{3.03 - 0.7}{1.2} = 1.94\,\text{mA}$$

The small-signal model looks like this



The input resistance is

$$R_{\text{in}} = R_1||R_2||r_\pi$$

where

$$r_\pi = \frac{\beta}{g_m} = \frac{\beta V_T}{I_C} = \frac{\beta V_T}{\alpha I_E} = \frac{(\beta+1)\,V_T}{I_E} = \frac{101 \times 25}{1.94} = 1302\,\Omega$$

such that

$$R_{\text{in}} = R_1||R_2||r_\pi = 27||15||1.302 = 1.15\,\text{k}\Omega$$

The voltage gain is

$$G_v = -\frac{R_{\text{in}}}{R_{\text{in}} + R_s} A_v = -\frac{R_{\text{in}}}{R_{\text{in}} + R_s} g_m \left(R_C||r_o||R_L\right) = -\frac{R_{\text{in}}}{R_{\text{in}} + R_s} \frac{\beta I_E}{(\beta+1)\,V_T} \left(R_C||r_o||R_L\right)$$

where

$$r_o = \frac{V_A}{I_C} = \frac{V_A}{\alpha I_E} = \frac{(\beta+1)\,V_A}{\beta I_E} = \frac{101 \times 100}{100 \times 1.94 \times 10^{-3}} = 52.1\,\text{k}\Omega$$

and then

$$\begin{aligned} G_v &= -\frac{R_{\text{in}}}{R_{\text{in}} + R_s} \frac{\beta I_E}{(\beta+1)\,V_T} \left(R_C||r_o||R_L\right) \\ &= -\frac{1.14}{1.14 + 10} \frac{100 \times 1.94}{101 \times 25} (2.2||52.1||2) \\ &= -\,8.07 \end{aligned}$$

5.131. Using the topology of Fig. P5.130, design an amplifier to operate between a 10 kΩ source and a 2 kΩ load with a gain v_o/v_{sig} of −8. The power supply

available is 9 V. Use an emitter current of approximately 2 mA and a current of about one-tenth of that in the voltage divider that feeds tbe base, with the dc voltage at the base about one third of the supply. The transistor available has $\boldsymbol{\beta} = 100$ and $\boldsymbol{V_A} = 100$ V. Use standard 5% resistors (See Appendix G)

This is the same circuit as before, except choose the nearest 5% resistors. In that case choose $R_1 = 27\,\text{k}\Omega$, $R_2 = 15\,\text{k}\Omega$, $R_E = 1.2\,\text{k}\Omega$, $R_C = 2.2\,\text{k}\Omega$. Well, it turns out the problem is identical to P5.130. That was easy.