# ECE 523/421 - Analog Electronics
## University of New Mexico
### Solutions Homework 5

**Problem 7.128**

**The CE amplifier circuit of Fig. P7.128 is biased with a constant-current source I. It is required to design the circuit (i.e., find values for I, RB, and RC) to meet the following specifications:**

**(a) $R_{in}$ ≅10 kΩ.**

**(b) The dc voltage drop across $R_B$ is approximately 0.2 V.**

**(c) The open-circuit voltage gain from base to collector is the maximum possible, consistent with the requirement that the collector voltage never fall by more than approximately 0.4 V below the base voltage with the signal between base and emitter being as high as 5 mV.**

**Assume that $v_{sig}$ is a sinusoidal source, the available supply VCC=5 V, and the transistor has β=100. Use standard 5% resistance values, and specify the value of I to one significant digit. What base-to-collector open-circuit voltage gain does your design provides? If Rsig = RL =20 kΩ, what is the overall voltage gain?**

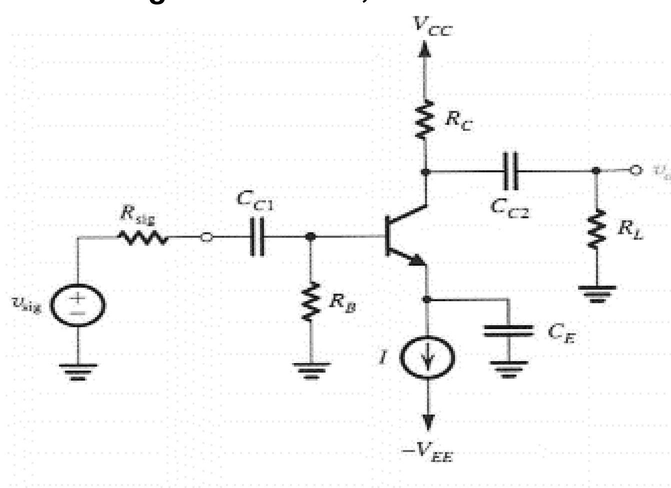



Figure P7.128

For $R_B$ = 0.2 V

$$I_B R_B = 0.2V$$

$$\frac{I}{\beta+1} R_B = 0.2V$$

$$I R_B = 0.2 \; x \; 101$$

$$R_{in} = R_B \, || r_\pi = 10k\Omega$$

$$R_B \, || \frac{V_T}{I_B} = 10$$

$$R_B \,||\, \frac{\frac{0.025}{I}}{\beta + 1} = 10$$

Solving the parallel

$$\frac{0.025 \; x \; 101 R_B}{I R_B + 0.025 \; x \; 101} = 10$$

$$R_B = 90 k\Omega$$

$$I = \frac{0.2 \; x \; 101}{90 k\Omega} = 0.22 \; mA$$

For meeting the third specification

$$V_C - |A_{vo}| \; x \; 0.005 = V_B + 0.005 - 0.4$$

Where

$$V_C = V_{CC} - I_C R_C$$

$$V_C = 5 - 0.22 R_C$$

$$|A_{vo}| = g_m R_C$$

$$|A_{vo}| = 8.7 R_C$$

$$V_B = -\frac{0.22}{101} \; x \; 90 = -0.2V$$

Values into the equation

$$5 - 0.22 R_C - 8.7 R_C \; x \; 0.005 = -0.2 + 0.005 - 0.4$$

$$R_C = 21.2 k\Omega$$

Selecting the 5% resistors and I to one significant digit

$$R_B = 91 k\Omega$$

$$R_C = 22 k\Omega$$

$$I = 0.2 \; mA$$

Calculating the gain

$$g_m = \frac{\alpha I_C}{V_T} \cong \frac{0.2}{0.025} = 8 \, {}^{mA}/_{V}$$

$$A_{vo} = -g_m R_C = -176$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{8} = 12.5 \; k\Omega$$

$$R_{in} = R_B \,||\, r_\pi = 11 k\Omega$$

$$G_v = -\frac{11}{20 + 11} \, x \; 8(22||20) = -29.7$$

**Problem 7.129**

**In the circuit of Fig. P7.129, $v_{sig}$ is a small sine-wave signal with zero average. The transistor β is 100.**

**(a) Find the value of RE to establish a dc emitter current of about 0.5 mA.**
**(b) Find RC to establish a dc collector voltage of about +0.5 V.**
**(c) For RL =10 kΩ, draw the small-signal equivalent circuit of the amplifier and determine its overall voltage gain.**

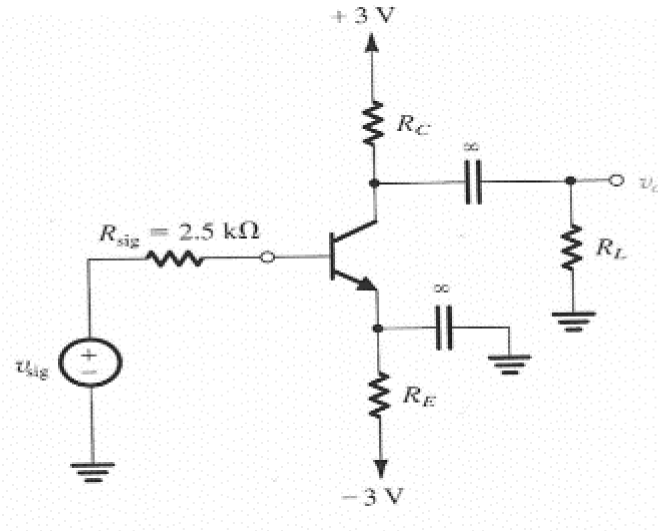



Figure P7.129

For $I_E = 0.5\ mA$, and applying KVL

$$I_B R_{sig} + V_{BE} + I_E R_E = 3$$
$$\frac{0.5}{101} x\ 25 + 0.7 + 0.5 R_E = 3$$
$$R_E = 46 k\Omega$$

$$I_C = \alpha I_E \cong 0.5\ mA$$
$$V_C = 0.5 = 3 - 0.5 R_C$$
$$R_C = 5 k\Omega$$

$$g_m = \frac{I_C}{V_T} = \frac{0.5}{0.025} = 20\ {}^{mA}/_{V}$$
$$r_\pi = \frac{\beta}{g_m} = \frac{100}{20} = 5\ k\Omega$$
$$G_v = \frac{v_o}{v_{sig}} = -\frac{5}{5 + 2.5} x\ 20(5||10)$$
$$G_v = -44.4$$

**Problem 7.130**

**The amplifier of Fig. P7.130 consists of two identical common-emitter amplifiers connected in cascade. Observe that the input resistance of the second stage, Rin2, constitutes the load resistance of the first stage.**

**a) For VCC =15 V, R1 =100 kΩ, R2 =47 kΩ, RE =3.9 kΩ, RC = 6.8 kΩ, and β=100, determine the dc collector current and dc collector voltage of each transistor.**

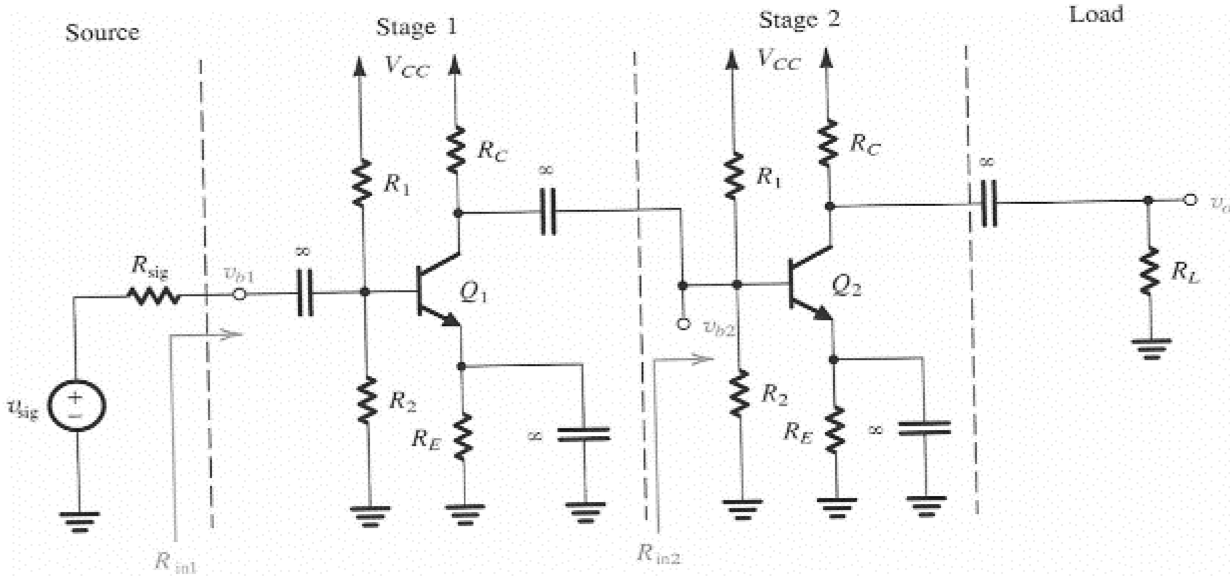
**(b) Draw the small-signal equivalent circuit of the entire amplifier and give the values of all its components.**

**(c) Find Rin1 and vb1/vsig for Rsig =5 kΩ.**

**(d) Find Rin2 and vb2/vb1.**

**(e) For RL =2 kΩ, find vo/vb2.**

**(f) Find the overall voltage gain vo/vsig.**




$$V_{BB} = V_{CC}\frac{R_2}{R_1 + R_2} = 15\frac{47}{100+47} = 4.8V$$

$$R_B = R_1||R_2 = 100||47 = 32k\Omega$$

$$I_E = \frac{V_{BB} - V_{BE}}{R_B + \frac{R_B}{\beta + 1}} = 0.97\ mA$$

$$I_C = \alpha I_E \cong 1\ mA$$

$$V_C = V_{CC} - I_C R_C = 15 - 1x6.8 = 8.2V$$

b)

$$g_m = \frac{I_C}{V_T} = \frac{1}{0.025} = 40\,{}^{mA}/_{V}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{40} = 2.5\ k\Omega$$

c)

$$R_{in1} = R_1||R_2||r_\pi = 2.32k\Omega$$

$$\frac{v_{b1}}{v_{sig}} = \frac{R_{in}}{R_{in} + R_{sig}} = \frac{2.32}{2.32 + 5} = 0.32$$

d)

$$R_{in2} = R_1||R_2||r_\pi = 2.32k\Omega$$

$$\frac{v_{b2}}{v_1} = \frac{v_{b2}}{v_{\pi 1}} = -g_m(R_C||R_2)$$

$$\frac{v_{b2}}{v_1} = -40(6.8||2.32) = -69.2$$

e)

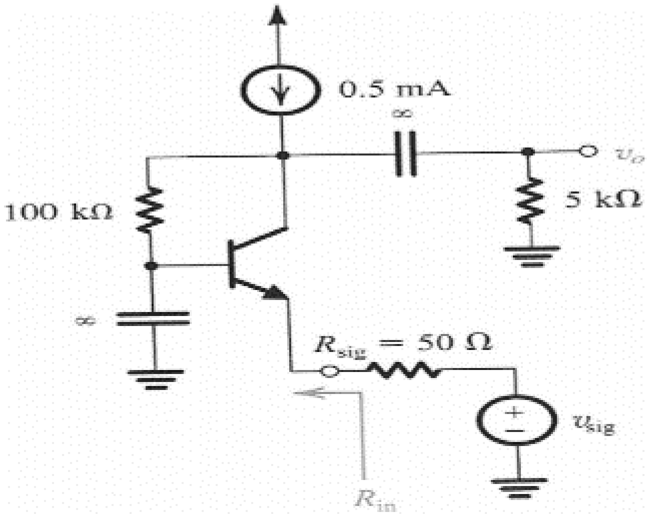
$$\frac{v_o}{v_{b2}} = \frac{v_0}{v_{\pi 2}} = -g_m(R_C||R_L)$$

$$\frac{v_o}{v_{b2}} = -40(6.8||2) = -61.8$$

f)

$$\frac{v_o}{v_{sig}} = \frac{v_o}{v_{b2}} x \frac{v_{b2}}{v_{b1}} x \frac{v_{b1}}{v_{sig}} = 1368.5$$

**Problem 7.133**
**For the circuit in Fig. P7.133, find the input resistance Rin and the voltage gain vo/vsig. Assume that the source provides a small signal vsig and that β=100.**




$$I_C = \alpha I_E \cong 0.5\,mA$$
$$r_e = \frac{V_T}{I_E} = \frac{25\,mV}{0.5\,mA} = 50\Omega$$
$$R_{in} = r_e = 50\Omega$$

$$i_e = \frac{-v_{sig}}{r_e + R_{sig}} = \frac{-v_{sig}}{50+50} = \frac{-v_{sig}}{0.1\,k\Omega}$$
$$v_o = -\alpha i_E (5||100)$$
$$v_o = -\alpha \frac{-v_{sig}}{0.1\,k\Omega}(5||100)$$
$$\frac{v_o}{v_{sig}} = \alpha \frac{(5||100)}{0.1\,k\Omega} = 47.6$$

**Problem 7.135**

**For the emitter follower in Fig. P7.135, the signal source is directly coupled to the transistor base. If the dc component of vsig is zero, find the dc emitter current. Assume β=100. Neglecting ro, find Rin, the voltage gain vo/vsig, the current gain io/ii , and the output resistance Rout.**

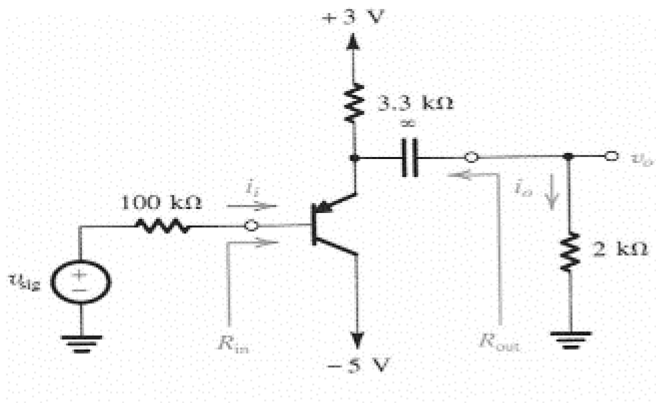



Figure P7.135

$$I_E = \frac{V_{CC} - V_{BE}}{R_E + \frac{R_B}{\beta + 1}} = \frac{3 - 0.7}{3.3 + \frac{100}{100 + 1}}$$

$$I_E = 0.54\, mA$$

$$r_e = \frac{V_T}{I_E} = \frac{25\, mV}{0.54\, mA} = 46.3\Omega$$

$$R_{in} = (\beta + 1)[r_e + (3.3||2) = 130.4k\Omega$$

$$\frac{v_b}{v_{sig}} = \frac{R_{in}}{R_{in} + R_{sig}} = \frac{130.4}{130.4 + 100} = 0.566$$

$$\frac{v_o}{v_b} = \frac{(3.3||2)}{(3.3||2) + r_e} = \frac{1.245}{1.245 + 0.0463} = 0.964$$

$$\frac{v_o}{v_{sig}} = \frac{v_o}{v_b} x \frac{v_b}{v_{sig}} = 0.55$$

$$i_o = \frac{v_o}{2\, k\Omega}$$

$$i_i = \frac{v_b}{130.4\, k\Omega}$$

$$\frac{i_o}{i_i} = \frac{v_o}{v_b} x \frac{130.4}{2} = 62.9$$

$$R_{out} = 3.3||(r_E + \frac{R_B}{\beta + 1})$$
$$R_{out} = 789\Omega$$