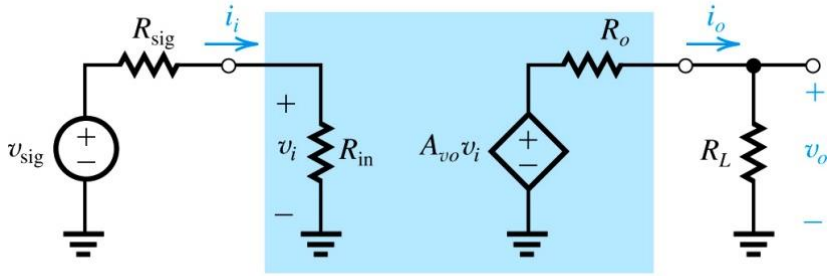
Homework #15

Problems 7.59, 7.60, 7.64, 7.68, 7.71, and 7.75

Problem 7.59

An amplifier with an input resistance of 100 kΩ, an open-circuit voltage gain of 100 V/V and an output resistance of 100 Ω is connected between a 20-kΩ signal source and a 2-kΩ load. Find the overall voltage gain G_v. Also find the current gain, defined as the ratio of the load current to the current drawn from the signal source.



$$G_v \equiv \frac{v_o}{v_{sig}} = \frac{R_{in}}{R_{in}+R_{sig}} A_{vo} \frac{R_L}{R_L+R_o}$$

$$G_v = \frac{100\text{k}\Omega}{100\text{k}\Omega+20\text{k}\Omega} 100\frac{\text{V}}{\text{V}} \frac{2\text{k}\Omega}{2\text{k}\Omega+100\Omega}$$

$$G_v = 79.4\,\frac{V}{V}$$

$$A_i \equiv \frac{i_o}{i_{sig}} = \frac{{v_o}/{R_L}}{{v_{sig}}/{(R_{in}+R_{sig})}} = G_v \frac{R_{in}+R_{sig}}{R_L}$$

$$A_i = 82.645 \frac{100\text{k}\Omega+20\text{k}\Omega}{2\text{k}\Omega} = 4762\frac{\text{A}}{\text{A}}$$

Problem 7.60

Specify the parameters R_{in}, A_{vo} and R_o of an amplifier that is to be connected between a 100-kΩ source and a 2-kΩ load and is required to meet the following specifications:

(a) No more than 5% of the signal strength is lost in the connection to the amplifier input;

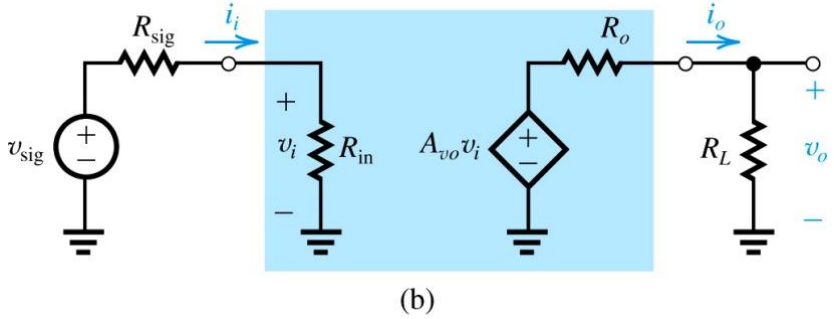
(b) If the load resistance changes from the nominal value of 2 kΩ to a low value of 1 kΩ, the change in output voltage is limited to 5% of nominal value; and

(c) The nominal overall voltage gain is 10 V/V.

Problem 7.60a

Specify the parameters R_{in}, A_{vo} and R_o of an amplifier that is to be connected between a 100-kΩ source and a 2-kΩ load and is required to meet the following specifications:

(a) No more than 5% of the signal strength is lost in the connection to the amplifier input;



$$\frac{R_{in}}{R_{in}+R_{sig}} \geq 0.95$$

$$R_{in} \geq 0.95\left(R_{in}+R_{sig}\right)$$

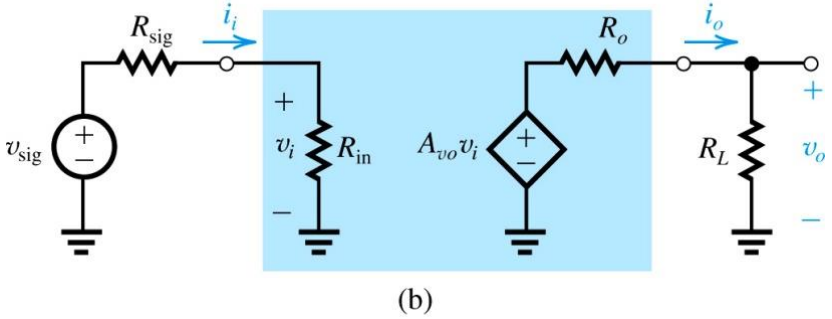
$$R_{in} \geq \frac{0.95}{.05}R_{sig} = 19 \times 100\text{k}\Omega$$

$$R_{in} \geq 1900\text{k}\Omega$$

Problem 7.60b

Specify the parameters R_{in}, A_{vo} and R_o of an amplifier that is to be connected between a 100-kΩ source and a 2-kΩ load and is required to meet the following specifications:

(b) If the load resistance changes from the nominal value of 2 kΩ to a low value of 1 kΩ, the change in output voltage is limited to 5% of nominal value; and



$$v_o = \frac{R_L}{R_L + R_o} A_{vo} v_i$$

$$\frac{v_{o1k}}{v_{o2k}} = \frac{\frac{R_{L1k}}{R_{L1k} + R_o} A_{vo} v_i}{\frac{R_{L2k}}{R_{L2k} + R_o} A_{vo} v_i} \geq 0.95$$

$$\frac{\frac{1\text{k}\Omega}{1\text{k}\Omega + R_o} A_{vo} v_i}{\frac{2\text{k}\Omega}{2\text{k}\Omega + R_o} A_{vo} v_i} \geq 0.95$$

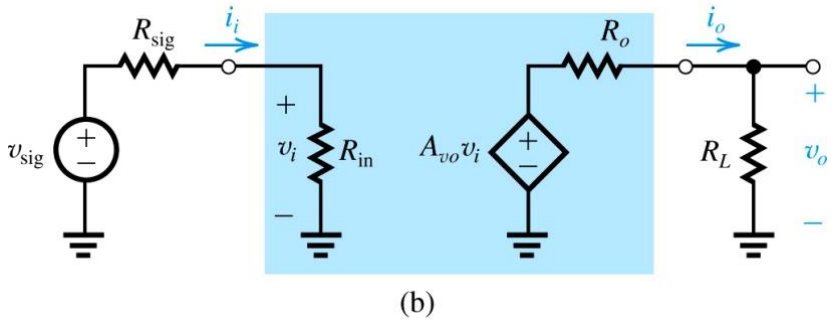
$$\frac{1\text{k}\Omega}{1\text{k}\Omega + R_o} \left(\frac{2\text{k}\Omega + R_o}{2\text{k}\Omega} \right) \geq 0.95$$

$$R_o \leq 111\Omega$$

Problem 7.60c

Specify the parameters R_{in}, A_{vo} and R_o of an amplifier that is to be connected between a 100-kΩ source and a 2-kΩ load and is required to meet the following specifications:

(c) The nominal overall voltage gain is 10 V/V.



$$A_v \equiv \frac{v_o}{v_i} = A_{vo}\frac{R_L}{R_L + R_o} = 10\frac{\text{V}}{\text{V}}$$

$$A_{vo} = A_v\frac{R_L + R_o}{R_L}$$

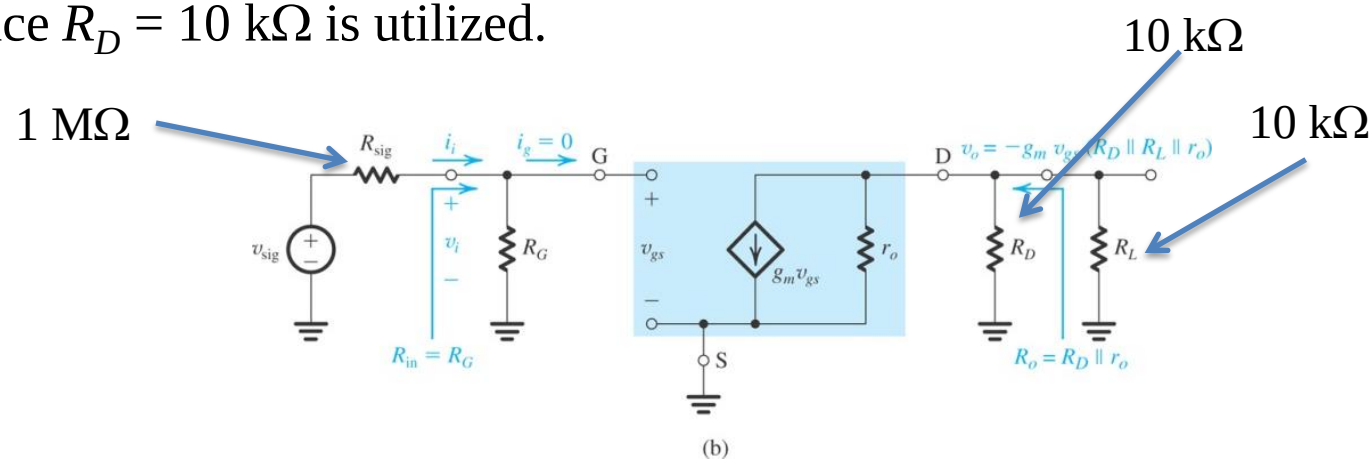
$$A_{vo} = 10\frac{\text{V}}{\text{V}}\frac{2\text{k}\Omega + 111\Omega}{2\text{k}\Omega} = 10.56\frac{\text{V}}{\text{V}}$$

or

$$A_{vo} = 10\frac{\text{V}}{\text{V}}\frac{1\text{k}\Omega + 111\Omega}{1\text{k}\Omega} = 11.11\frac{\text{V}}{\text{V}}$$

Problem 7.64

Calculate the overall voltage gain of a CS amplifier fed with a 1 MΩ source and connected to a 10 kΩ load. The MOSFET has g_m = 2 mA/V and a drain resistance R_D = 10 kΩ is utilized.



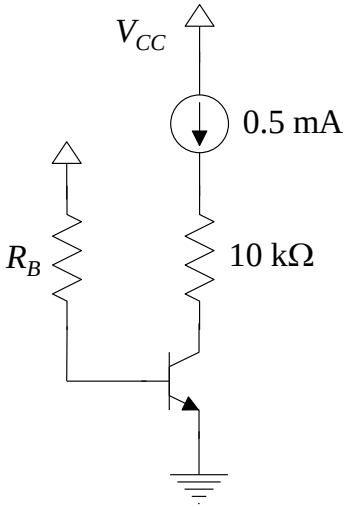
$$G_v = -\frac{R_G}{R_G + R_{sig}} g_m (R_D \parallel R_L)$$

$$(R_D \parallel R_L) = 5000\Omega$$

$$G_v = -g_m (R_D \parallel R_L) = -10.0 \frac{\text{V}}{\text{V}}$$

Problem 7.68

A CE amplifier utilizes a BJT with $\beta = 100$ biased at $I_C = 0.5$ mA; it has a collector resistance $R_C = 10$ kΩ. Assume $R_B >> r_\pi$. Find R_{in}, R_o, and A_{vo}. If the amplifier is fed with a signal source having a resistance of 10 kΩ, and a load resistance $R_L = 10$ kΩ is connected to the output terminal, find the resulting A_v and G_v. If the peak voltage of the sine wave appearing between base and emitter is to be limited to 5 mV, what v_{sig} is allowed, and what output voltage signal appears across the load?



$$I_C = 0.5\text{mA} \qquad r_\pi = \frac{V_T}{I_B} = \beta\frac{V_T}{I_C} = 5\text{k}\Omega \qquad R_{in} = r_\pi \parallel R_B \approx r_\pi = 5\text{k}\Omega$$

$$R_o = R_C = 10.0\text{k}\Omega$$

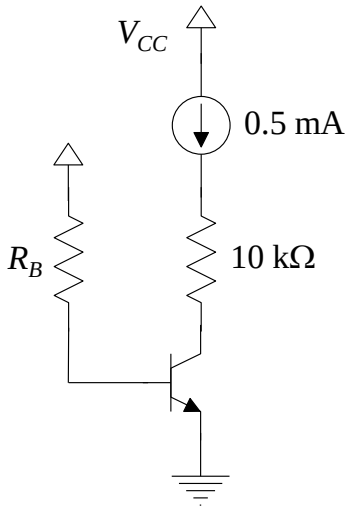
$$g_m = \frac{I_C}{V_T} = 20\ \text{mA/V} \qquad A_{vo} \equiv \frac{v_o}{v_i} = -g_m R_C = -200\text{V/V}$$

$$A_v \equiv \frac{v_o}{v_i} = -g_m(R_C \parallel R_L) = -g_m(R_o \parallel R_L) = -100\text{V/V}$$

$$G_v \equiv \frac{v_o}{v_{sig}} = -\frac{r_\pi}{r_\pi + R_{sig}} g_m(R_C \parallel R_L) = -\frac{r_\pi}{r_\pi + R_{sig}} A_v = -33.33\text{V/V}$$

Problem 7.68

A CE amplifier utilizes a BJT with β = 100 biased at I_C = 0.5 mA; it has a collector resistance R_C = 10 kΩ. Assume $R_B >> r_\pi$. Find R_{in}, R_o, and A_{vo}. If the amplifier is fed with a signal source having a resistance of 10 kΩ, and a load resistance R_L = 10 kΩ is connected to the output terminal, find the resulting A_v and G_v. If the peak voltage of the sine wave appearing between base and emitter is to be limited to 5 mV, what v_{sig} is allowed, and what output voltage signal appears across the load?



$$G_v \equiv \frac{v_o}{v_{sig}} = -33.33\text{V/V}$$

$$v_\pi = 5\text{mV} \Rightarrow v_{sig} = 15\text{mV}$$

$$\hat{v}_o = \hat{v}_{sig} G_v = 15\text{mV} \times G_v = 500\text{mV}$$

Problem 7.71

A MOSFET connected in the CS configuration has a transconductance g_m = 5 mA/V. When a resistance R_S is connected to the source lead, the effective transconductance is reduced to 2 mA/V. What do you estimate the value of R_S to be?

No source resistor

$$G_v = -\frac{R_G}{R_G + R_{sig}} g_m (R_D \parallel R_L \parallel r_o)$$

With source resistor

$$G_v = -\frac{R_G}{R_G + R_{sig}} \frac{R_D \parallel R_L}{1/g_m + R_S}$$

$$g_{meff} = \frac{g_m}{1 + g_m R_S} = 2\frac{\text{mA}}{\text{V}}$$

$$g_{meff} = \frac{5\frac{\text{mA}}{\text{V}}}{1 + 5\frac{\text{mA}}{\text{V}} R_S} = 2\frac{\text{mA}}{\text{V}}$$

$$1 + 5\frac{\text{mA}}{\text{V}} R_S = \frac{5\frac{\text{mA}}{\text{V}}}{2\frac{\text{mA}}{\text{V}}} = 2.5$$

$$R_S = 0.3\text{k}\Omega$$

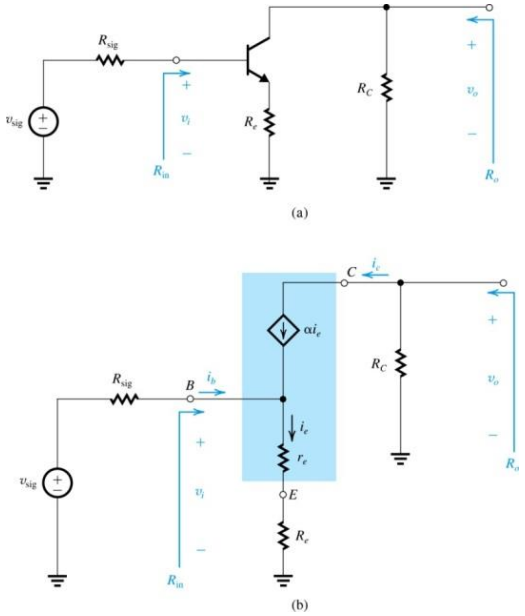
Problem 7.75

Design a CE amplifier with a resistance R_e in the emitter to meet the following specifications:

(i) Input resistance R_{in} = 15 kΩ.

(ii) When fed from a signal source with a peak amplitude of 0.15 V and a source resistance of 30 kΩ, the peak amplitude of v_π is 5 mV.

Specify R_e and the bias current I_C. The BJT has $\beta = 74$. If the total resistance in the collector is 6 kΩ, find the overall voltage gain G_v and the peak amplitude of the output signal v_o.



$$R_{in} = (\beta + 1)(r_e + R_e) = (74 + 1)(r_e + R_e) = 15\text{k}\Omega$$

$$r_e + R_e = 200\Omega$$

$$\frac{v_\pi}{v_{sig}} = \frac{R_{in}}{R_{in} + R_{sig}} \frac{r_e}{r_e + R_e} = \left(\frac{15\text{k}\Omega}{15\text{k}\Omega + 30\text{k}\Omega}\right)\frac{r_e}{200\Omega} = \frac{5\text{mV}}{150\text{mV}}$$

$$\Rightarrow r_e = \frac{5\text{mV}}{150\text{mV}}\left(\frac{45\text{k}\Omega}{15\text{k}\Omega}\right)200\Omega = 20\Omega$$

$$r_e + R_e = 200\Omega \Rightarrow R_e = 180\Omega$$

$$r_e = \frac{V_T}{I_E} \Rightarrow I_E = \frac{25\text{mV}}{20\Omega} = 1.25\text{mA}$$

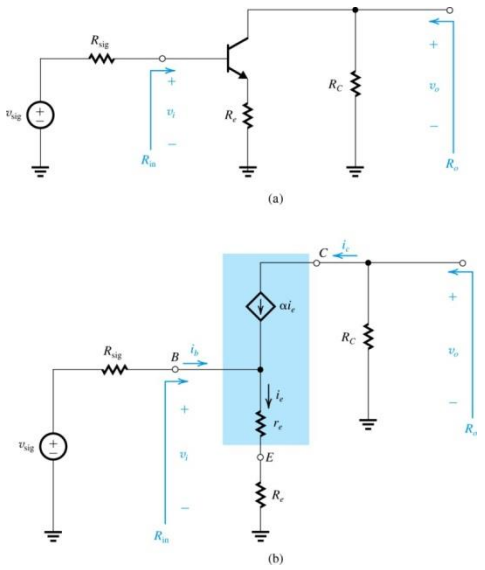
Problem 7.75

Design a CE amplifier with a resistance R_e in the emitter to meet the following specifications:

(i) Input resistance R_{in} = 15 kΩ.

(ii) When fed from a signal source with a peak amplitude of 0.15 V and a source resistance of 30 kΩ, the peak amplitude of v_π is 5 mV.

Specify R_e and the bias current I_C. The BJT has $\beta = 74$. If the total resistance in the collector is 6 kΩ, find the overall voltage gain G_v and the peak amplitude of the output signal v_o.



$$I_E = 1.25\text{mA} \Rightarrow I_C = \frac{\beta}{\beta+1} I_E = \frac{74}{75} 1.25\text{mA} = 1.233\text{mA}$$

$$g_m = \frac{I_C}{V_T} \simeq 50 \frac{\text{mA}}{\text{V}}$$

$$A_v = \frac{-g_m R_o}{1 + g_m R_e} = \frac{-50 \frac{\text{mA}}{\text{V}} 6\text{k}\Omega}{1 + 50 \frac{\text{mA}}{\text{V}} 180\Omega} = -\frac{300\,\text{V/V}}{10} = -30.0\,\text{V/V}$$

$$G_v = \frac{R_{in}}{R_{in} + R_{sig}} A_v = \left(\frac{15\text{k}\Omega}{15\text{k}\Omega + 30\text{k}\Omega} \right) (-30.0\,\text{V/V}) = -10.0\,\text{V/V}$$