Electronics

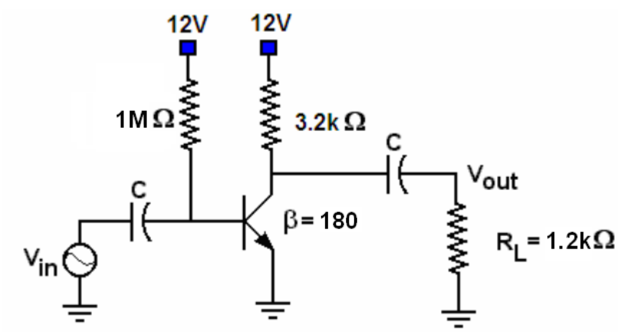
Common emitter amplifier

Problem 1.- In the following Common Emitter Amplifier:

a) Find the Q-point, also called quiescent point. That is, find the DC base current (I_B), the DC collector current (I_C) and the DC voltage collector-emitter (V_{CE}).

b) Is the transistor in the active region?

c) Calculate the voltage gain on the amplifier assuming the capacitors behave like short-circuits at the signal frequency.



Solution: The base circuit gives us:

$$I_B = \frac{12 - 0.7}{1M\Omega} = 11.3\mu A$$, so:

$$I_C = \beta I_B = 180 \times 11.3\mu A = 2.03mA$$

And the collector side gives:

$$V_{CE} = 12 - 3.2k\Omega(2.03mA) = 5.5V$$

The transistor is in the active region.

To calculate the voltage gain, notice that the dynamic resistance is:

$$r_d = \frac{25mV}{I_B} = \frac{25mV}{11.3\mu A} = 2.21k\Omega$$

The signal is coupled through a capacitor directly to this resistance, so:

$i_B = \dfrac{V_{in}}{2.21k\Omega}$, which means that the collector current is: $i_C = \dfrac{180 \times V_{in}}{2.21k\Omega}$

This current goes through the load resistance in parallel with the collector resistance:

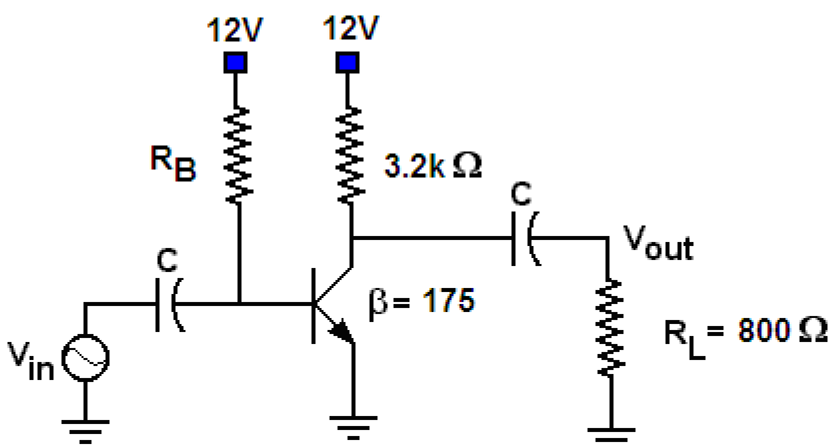
$$R = \frac{1}{1/3.2k\Omega + 1/1.2k\Omega} = 0.872k\Omega \text{, so}$$

$$\frac{V_{out}}{V_{in}} = -0.872k\Omega \frac{180}{2.21k\Omega} = \mathbf{-71}$$

Problem 2.- In the circuit given below,

a) Find the value of base resistance (R_B) that would put the transistor in the middle of the active region.

b) Calculate the voltage gain on the amplifier. Assume the capacitors behave like short-circuits at the signal frequency.



Solution:

a) To find the base resistance (R_B), given that the voltage collector emitter is half the source voltage:

$$V_{CE} = \frac{12V}{2} = 6V$$

The voltage drop across the collector resistor has to be 6V too, so the collector current will be:

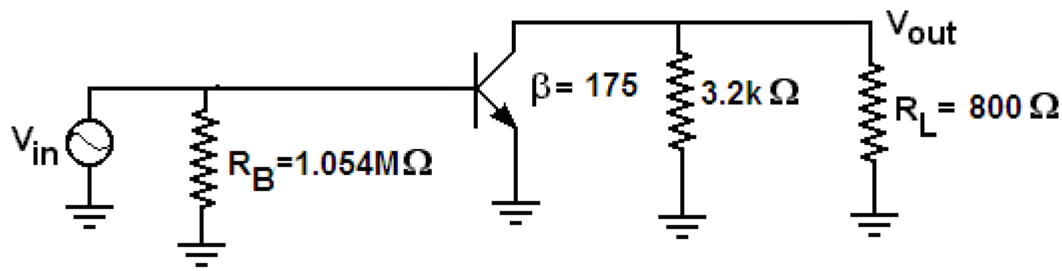
$$I_C = \frac{6V}{3.2k\Omega} = 1.875mA$$

With this information we can find the base current: $I_B = \frac{I_C}{\beta} = \frac{1.875mA}{175} = 10.7\mu A$

To find R_B we write the base loop equation:

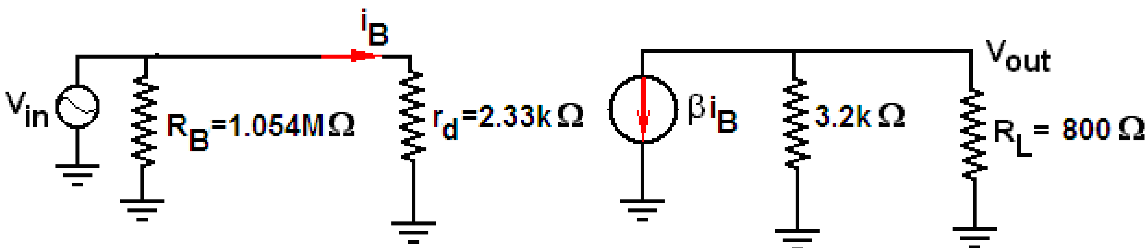
$$12V = R_B I_B + 0.7V \rightarrow R_B = \frac{12V - 0.7V}{10.7\mu A} = \mathbf{1.054M\Omega}$$

b) To calculate the voltage gain of the amplifier, we do an AC analysis: assuming the capacitors behave like short-circuits at the signal frequency, gives us the circuit:



The model for the transistor consists of a dynamic resistance on the base-emitter side and a current source on the collector side.

The value of the dynamic resistance will be: $r_d = \frac{25mV}{I_B} = \frac{25mV}{10.7\mu A} = 2.33k\Omega$ and the current source will have a value of βi_B as shown in the figure:



Since the signal is connected directly to the base resistance, the base current will be:

$$i_B = \frac{V_{in}}{r_d} = \frac{V_{in}}{2.33k\Omega}$$

Multiplying by beta we get the collector current:

$$i_C = \beta i_B = \beta \frac{V_{in}}{2.33k\Omega} = \frac{175 V_{in}}{2.33k\Omega}$$

Notice that the load resistance and the collector resistance are in parallel, giving an equivalent of:

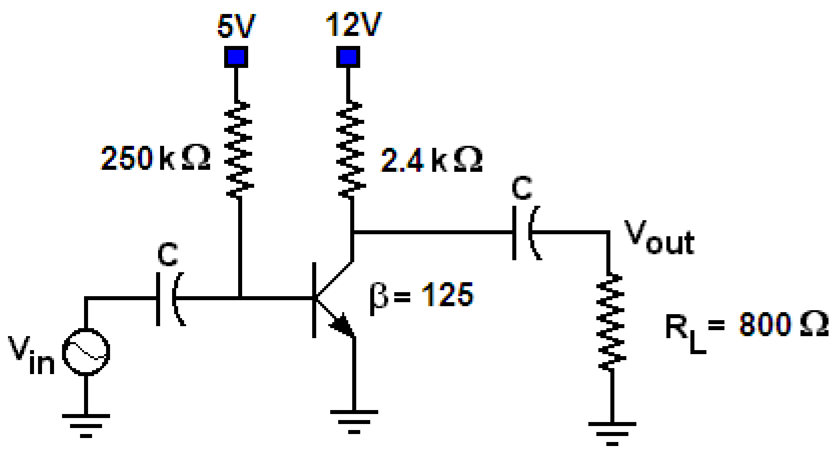
$$R_{eq} = \frac{1}{\frac{1}{3.2k\Omega} + \frac{1}{800\Omega}} = 640\Omega$$

The output voltage will be the collector current times this resistance:

$$V_{out} = -R_{eq} i_C = -640\Omega \frac{175V_{in}}{2.33k\Omega} = -\frac{175(640\Omega)}{2.33k\Omega} V_{in} = -47.9V_{in}$$

So the voltage gain is **-47.9**

Problem 3.- Calculate the voltage gain in the following amplifier. Also check that it is working in the linear region (make sure V_{CE} is something sensible).



Solution: First we calculate the Q point of the transistor, to do this:

The base loop equation is

$$5\text{V} = 250\text{k}\Omega \text{I}_\text{B} + 0.7\text{V} \rightarrow \text{I}_\text{B} = \frac{5\text{V} - 0.7\text{V}}{250\text{k}\Omega} = 17.2\mu\text{A}$$

With this value we can calculate the collector current:

$$\text{I}_\text{C} = \beta \text{I}_\text{B} = 125(17.2\mu\text{A}) = 2.15\text{mA}$$

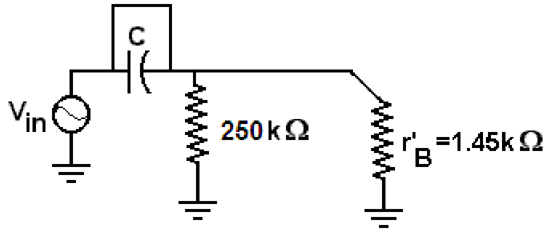
With this value of the collector current, the collector-emitter voltage is

$$\text{V}_\text{CE} = 12\text{V} - 2.4\text{k}\Omega(2.15\text{mA}) = 6.84\text{V}$$

This is perfectly OK. The transistor is in the middle of the linear region.
Now we can look at the small signal circuit. The capacitors are going to behave like short circuits at high frequency and the base emitter junction will be represented by a resistance whose value is:

$$\text{r'}_\text{B} = \frac{25\text{mV}}{\text{I}_\text{B}} = \frac{25\text{mV}}{17.2\mu\text{A}} = 1.45\text{k}\Omega$$

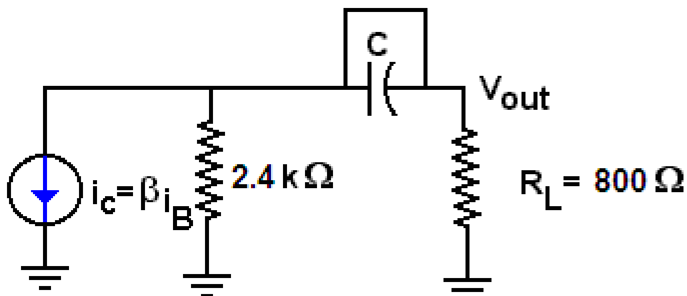
With these points in consideration, the base loop looks like this:



The base current will be:

$$i_B = \frac{V_{in}}{1.45k\Omega}$$

The collector loop will be:



Where the collector current is given by:

$$i_C = \beta i_B = 125\frac{V_{in}}{1.45k\Omega}$$

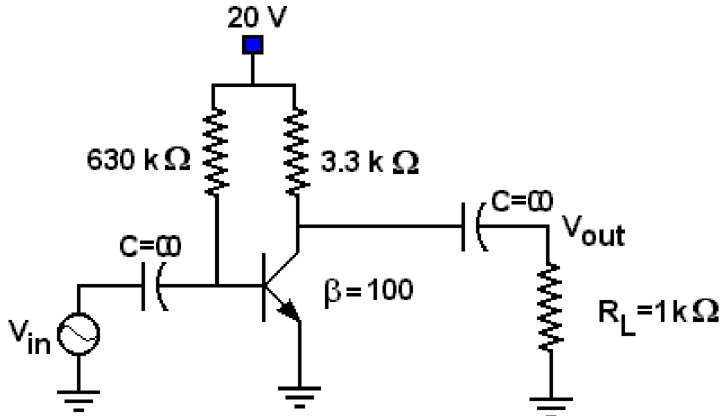
The load resistor and the collector resistor are in parallel, so they give an equivalent of:

$$R_{equivalent} = \frac{1}{\frac{1}{2400\Omega}+\frac{1}{800\Omega}} = 600\Omega$$

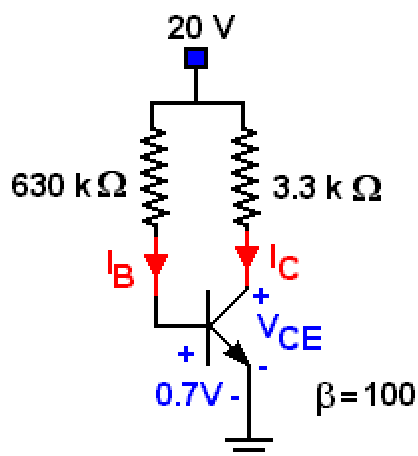
So, the voltage gain will be:

$$Gain = \frac{V_{out}}{V_{in}} = \frac{-i_C R_{equivalent}}{V_{in}} = \frac{-600\Omega\left(125\frac{V_{in}}{1.45k\Omega}\right)}{V_{in}} = \mathbf{-51.7}$$

Problem 4.- Calculate the voltage gain of the following amplifier:



Solution: To solve this problem we first find the Q point. To do this we analyze only the DC signals. In this case, the capacitors behave like open circuits so the circuit looks like this:



We can start analyzing the base loop first. The voltage base emitter is approximately 0.7V, so the base current is:

$$I_B = \frac{V_{BB} - 0.7V}{R_B} = \frac{20V - 0.7V}{630k\Omega} = 30.6\mu A$$

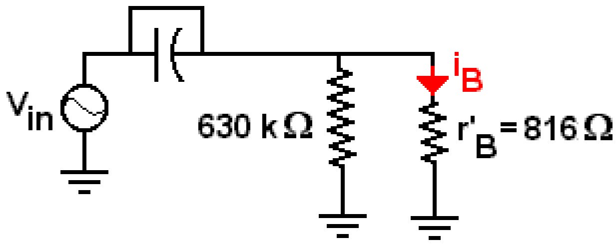
We need this value to get the internal, dynamic resistance of the base-emitter junction, but we should also check that the transistor is in the active region. So let's see the collector loop:

$$I_C = \beta I_B = 100(30.6\mu 0) = 3.06mA$$
$$V_{CE} = V_{CC} - R_C I_C = 20V - 3.06mA(3.3k\Omega) = 10.1\ V$$

This last value tells us that the transistor is operating in the middle of the active region (perfect!). Now we analyze the small signals: This time the capacitors behave like short circuits. From the point of view of the base loop, the transistor looks like a simple resistance with a value of:

$$r'_B = \frac{25\text{mV}}{I_{BQ}} = \frac{25\text{mV}}{30.6\mu\text{A}} = 816\Omega$$

The base loop in small signal looks like this:



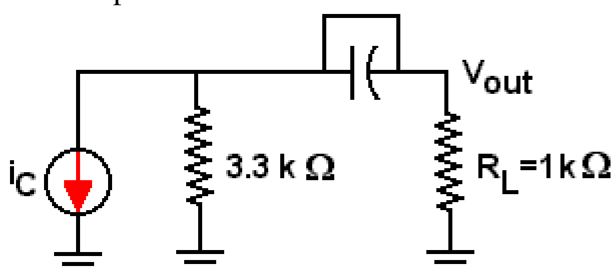
The small signal current (i_B) can be calculated now:

$$i_B = \frac{V_{in}}{r'_B} = \frac{V_{in}}{816\Omega}$$

The collector current is then:

$$i_C = \beta i_B = 100\frac{V_{in}}{816\Omega}$$

Now we analyze the collector loop. Recall that the transistor behaves like a current source:



Notice that the load resistor is in parallel with the collector resistor. They together have an equivalent value of:

$$R_{out} = R_L // R_C = \frac{R_C R_L}{R_C + R_L} = \frac{(3.3\text{k}\Omega)(1\text{k}\Omega)}{3.3\text{k}\Omega + 1\text{k}\Omega} = 767\Omega$$

The output voltage is this resistance times the collector current:

$$V_{out} = -i_C R_{out} = -100\frac{V_{in}}{816\Omega}(767\Omega) = -94V_{in}$$

So the voltage gain is **-94**.