AC Analysis of a Common-Emitter Amplifier

The Common-Emitter Amplifier is used to achieve high voltage gain and employs a bi-junction transistor (BJT). A diagram of the common-emitter amplifier is shown in figure 1.

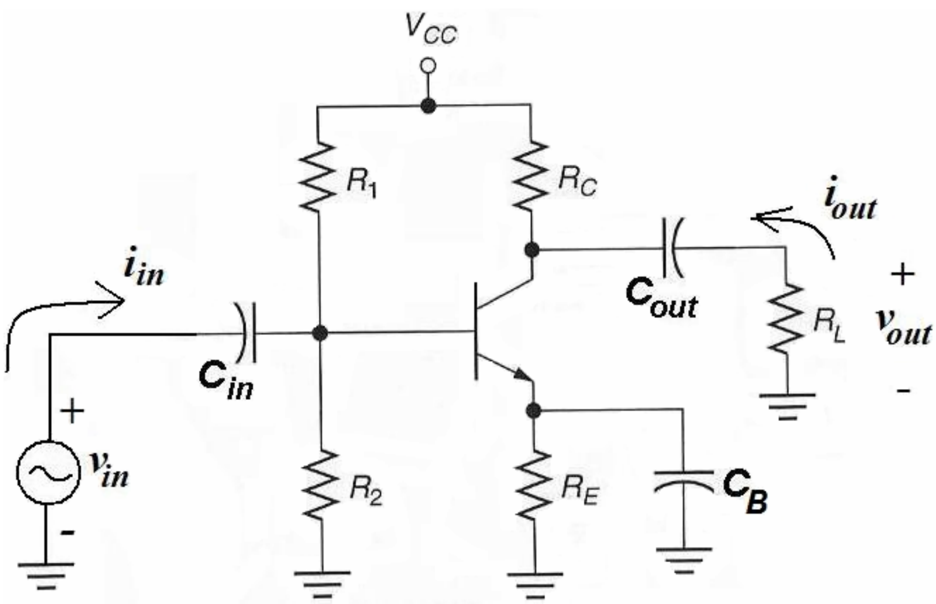

Figure 1. Common emitter (CE) amplifier circuit

Parameter definitions:

- R_1, R_2 = Voltage Divider Resistors
- R_C = Collector Resistor
- R_E = Emitter Resistor
- I_B = DC Base Current
- I_C = DC Collector Current
- I_E = DC Emitter Current
- V_B = DC Base Voltage
- V_C = DC Collector Voltage
- V_E = DC Emitter Voltage
- V_{BE} = DC Base-Emitter Voltage
- V_{CC} = DC Supply Voltage
- h_{FE} = DC Current Gain $= \frac{I_C}{I_B}$

- v_{in} = AC input voltage
- i_{in} = AC input current
- v_{out} = AC output voltage
- i_{out} = AC output current

The AC analysis of the common emitter amplifier involves replacing the transistor with its AC equivalent circuit, shown in figure 2.

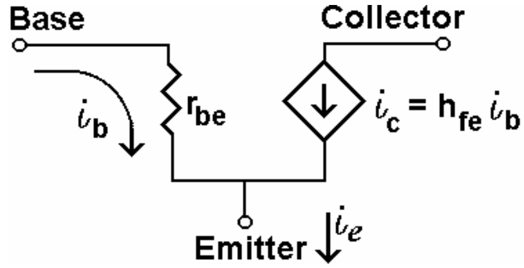

Figure 2. AC equivalent circuit of a bi-junction transistor

The parameters of this equivalent circuit are:

i_b = AC base current

i_c = AC collector current h_{fe} = AC Current Gain $= \frac{i_c}{i_b}$

i_e = AC emitter current r_{be} = Internal AC resistance of the base-emitter junction

The value of the AC current gain (h_{fe}) is typically fairly close to the DC current gain (h_{FE}). The AC resistance of the base-emitter junction (r_{be}) is calculated from:

$$r_{be} = \frac{0.025}{I_E} \quad \text{where } I_E = \text{DC Emitter Current}$$

Since this is a superposition problem, we short out the DC power supply VCC in Figure 1, and connect the AC equivalent circuit in Figure 2. We also short out all capacitors, because they will be selected to assure AC shorts over the frequency range of the input voltage, v_{in}. The result is the AC equivalent circuit of the entire amplifier shown in figure 3.

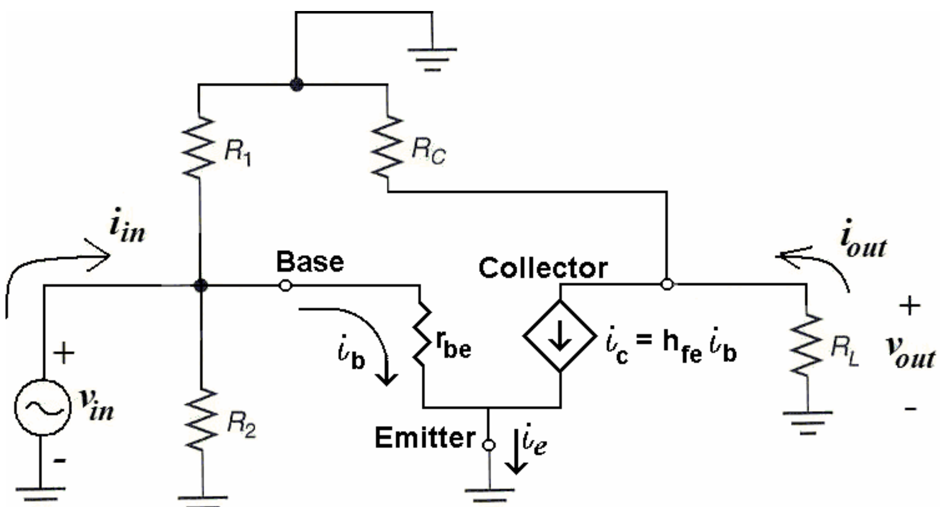

Figure 3. AC equivalent circuit of the common emitter (CE) amplifier

The circuit in Figure 3 can be simplified to that shown in figure 4.

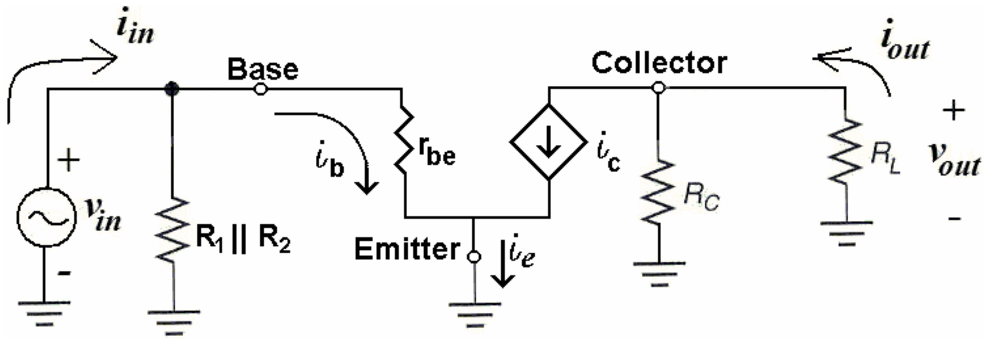

Figure 4. AC equivalent circuit of the common emitter (CE) amplifier

<u>DC Analysis.</u>

Given the amplifier parameters:

- V_{BE} = DC Base-Emitter Voltage
- V_{CC} = DC Supply Voltage
- h_{FE} = DC Current Gain h_{fe} = AC Current Gain
- R_1 = First Voltage Divider Resistor
- R_2 = Second Voltage Divider Resistor
- R_C = Collector Resistor
- I_E = DC Emitter Current

Compute the voltage gain $A_v = \frac{v_{out}}{v_{in}}$

The AC resistance of the base-emitter junction (r_{be}) is calculated from:

$$r_{be} = (h_{fe} + 1)\left(\frac{0.025}{I_E}\right) \tag{1}$$

By Ohm's law, the AC base current is $i_b = \frac{v_{in}}{r_{be}}$ (2)

The AC collector current is $i_c = h_{fe} i_b$ (3)

The AC collector current is pulled through the parallel combination of R_C and R_L. So by Ohm's Law, the output voltage is:

$$v_{out} = i_c (R_C \| R_L) \tag{4}$$

Example 1. Given the amplifier parameters:

V_{BE} = 0.7 V
V_{CC} = 12 V
v_{in} = 10 mV rms
$H_{FE} = H_{fe}$ = 100
R_1 = 10000
R_2 = 5000
R_C = 2000
R_E = 1000
R_L = 5000

Compute the voltage gain $A_v = \frac{v_{out}}{v_{in}}$

Solution:

From Example 1 in the DC analysis handout, we computed the DC emitter current to be:

$$I_E = 3.195\,mA \qquad \text{(P1.1)}$$

The AC resistance of the base-emitter junction (r_{be}) is calculated from:

$$r_{be} = (h_{fe}+1)\left(\frac{0.025}{I_E}\right) = (100+1)\left(\frac{0.025}{0.0003195}\right) = (101)(7.825\,\Omega) = 790.3\,\Omega$$

By Ohm's law, the AC base current is $i_b = \frac{v_{in}}{r_{be}} = \frac{0.01}{790.3} = 0.00001265 = 12.65\,\mu A \quad rms$

The AC collector current is

$$i_c = h_{fe} i_b = (100)(12.65\times10^{-6}) = 1265\times10^{-6} = 1.265\times10^{-3} = 1.265\,mA\ rms$$

The AC output voltage is:

$$\begin{aligned} v_{out} &= i_c(R_C \| R_L) = (1.265\,mA\ rms)(2000\|5000) \\ &= (1.265\,mA\ rms)\left(\frac{(2000)(5000)}{2000+5000}\Omega\right) \\ &= (1.265\,mA\ rms)\left(\frac{10000000}{7000}\Omega\right) \\ &= (1.265\,mA\ rms)(1429\,\Omega) \\ &= (1808\,mV\ rms) = 1.808\,V\ rms \end{aligned}$$

The voltage gain is $A_v = \frac{v_{out}}{v_{in}} = \frac{1808\ mV\ rms}{10\ mV\ rms} = 181$