Lecture (07)
BJT Amplifiers 4

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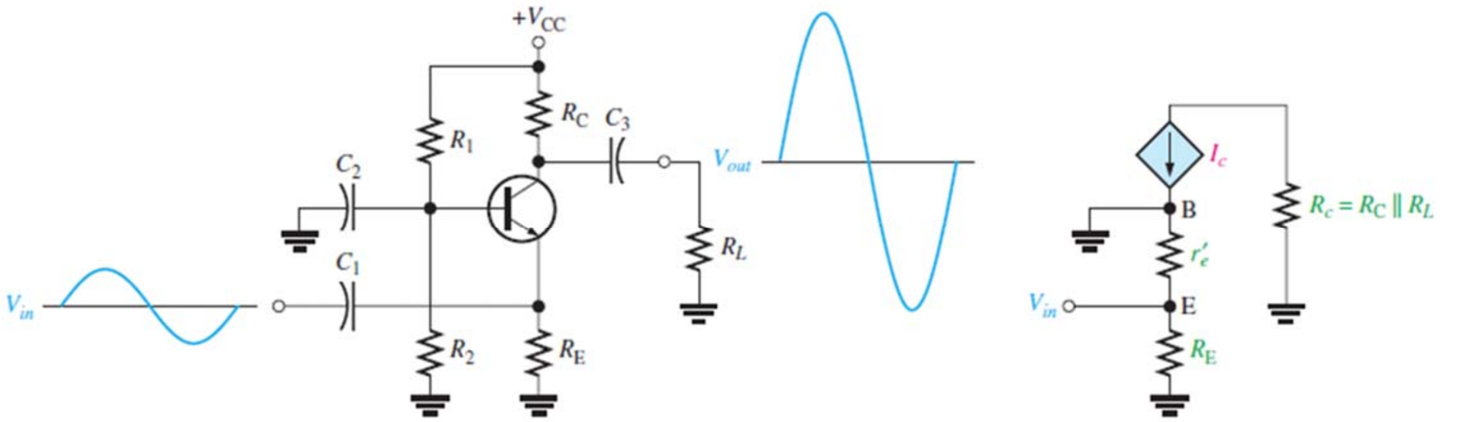
THE COMMON-BASE AMPLIFIER

- The base is the common terminal and is at ac ground because of capacitor *C*2
- The input signal is capacitively coupled to the emitter.
- The output is capacitively coupled from the collector to a load resistor.

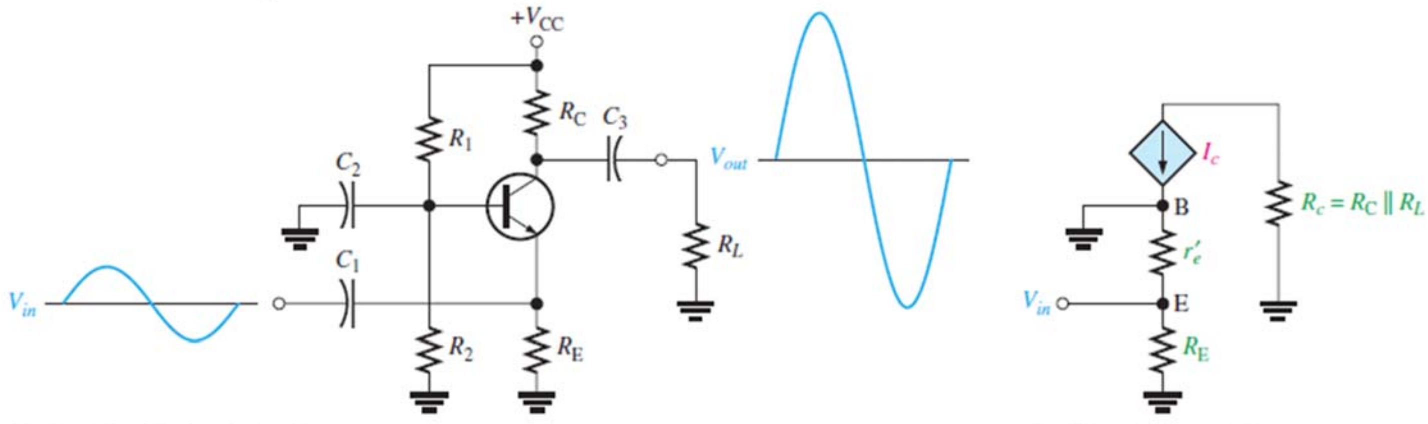


(a) Complete circuit with load

(b) AC equivalent model

Voltage Gain

- *Vin = Ve, Vout = Vc*
- $$A_v = \frac{V_{out}}{V_{in}} = \frac{V_c}{V_e} = \frac{I_c R_c}{I_e(r'_e \parallel R_E)} \cong \frac{I_e R_c}{I_e(r'_e \parallel R_E)}$$
- If $R_E \gg r'_e$, then
- $$A_v \cong \frac{R_c}{r'_e}$$



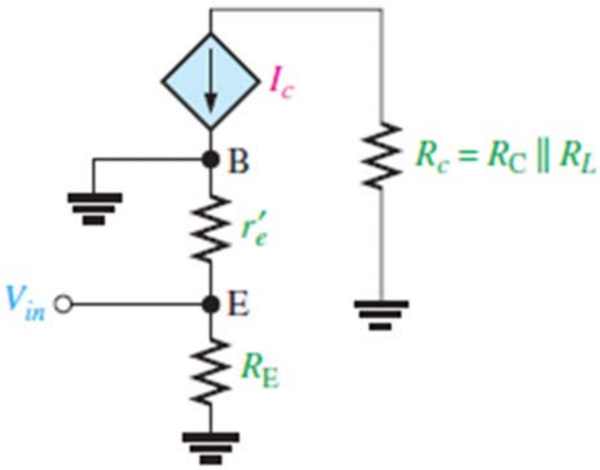
(a) Complete circuit with load (b) AC equivalent model

Input Resistance

- $$R_{in(emitter)} = \frac{V_{in}}{I_{in}} = \frac{V_e}{I_e} = \frac{I_e(r'_e \parallel R_E)}{I_e}$$

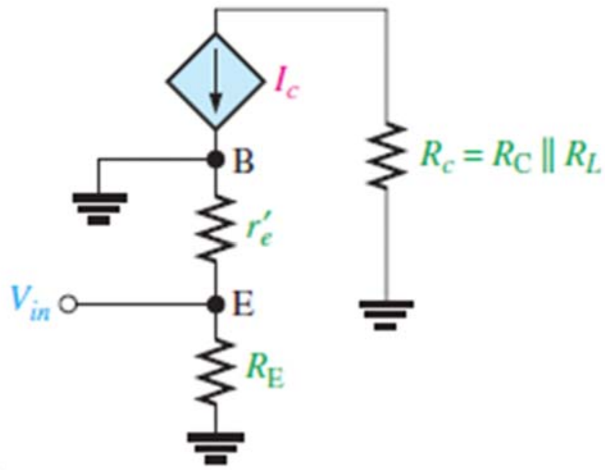
If $R_E \gg r'_e$, then

$$R_{in(emitter)} \cong r'_e$$



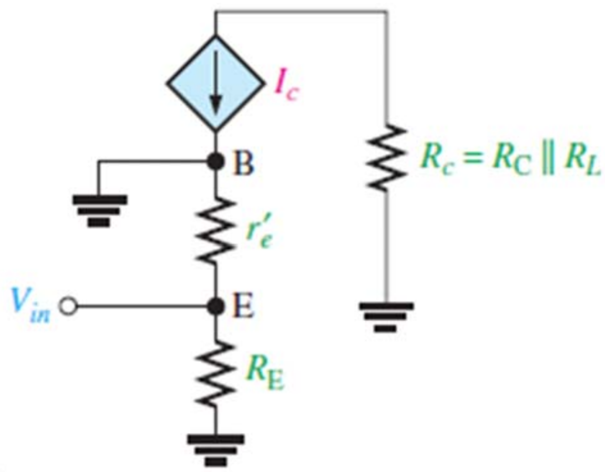
Output Resistance

- r'_c, appears in parallel with R_C
- than R_C, r'_c is typically much larger
- $R_{out} \cong R_C$



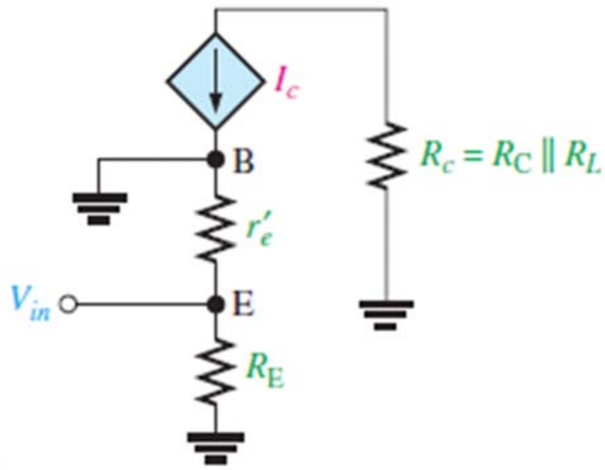
Current Gain

- The current gain is the output current divided by the input current.
- I_c is the ac output cur- rent, and I_e is the ac input current.
- Since $I_c \cong I_e$,



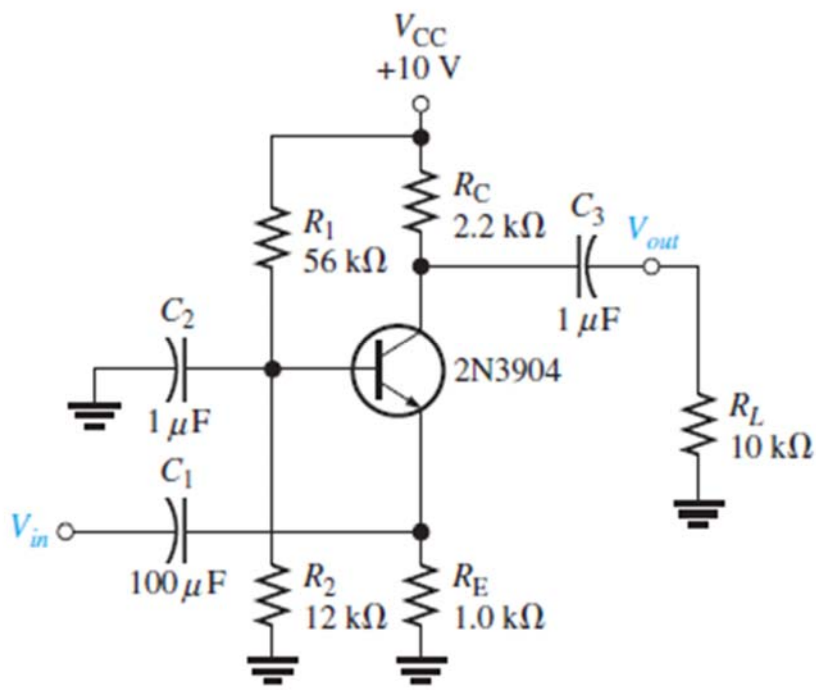
Power Gain

- Since the current gain is approximately 1
- $A_p = A_v A_i,$
- $A_p \cong A_v$



Example 01

Find the input resistance, voltage gain, current gain, and power gain for the amplifier in Figure ˉ ˉˉ $\beta_{DC} = 250$.



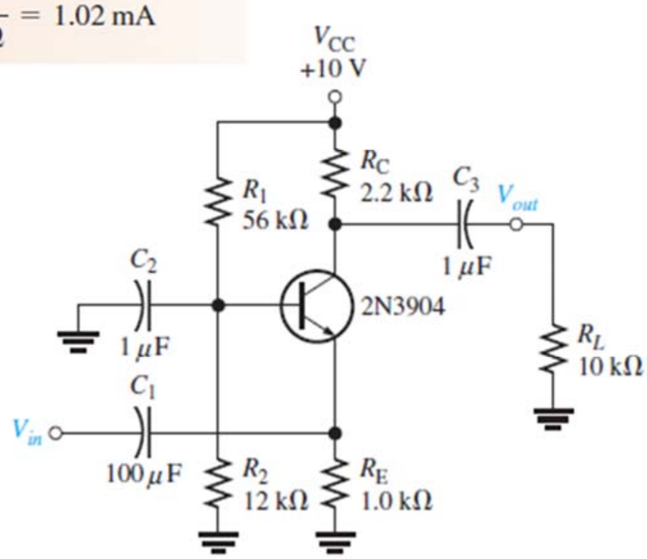
Example 01

First, find I_E so that you can determine r'_e. Then $R_{in} \cong r'_e$.

$$R_{TH} = \frac{R_1 R_2}{R_1 + R_2} = \frac{(56\,\text{k}\Omega)(12\,\text{k}\Omega)}{56\,\text{k}\Omega + 12\,\text{k}\Omega} = 9.88\,\text{k}\Omega$$

$$V_{TH} = \left(\frac{R_2}{R_1 + R_2}\right)V_{CC} = \left(\frac{12\,\text{k}\Omega}{56\,\text{k}\Omega + 12\,\text{k}\Omega}\right)10\,\text{V} = 1.76\,\text{V}$$

$$I_E = \frac{V_{TH} - V_{BE}}{R_E + R_{TH}/\beta_{DC}} = \frac{1.76\,\text{V} - 0.7\,\text{V}}{1.0\,\text{k}\Omega + 39.5\,\Omega} = 1.02\,\text{mA}$$



$$R_{in(emitter)} \cong r'_e$$

$$A_v \cong \frac{R_c}{r'_e} \qquad A_P \cong A_v$$

Therefore,

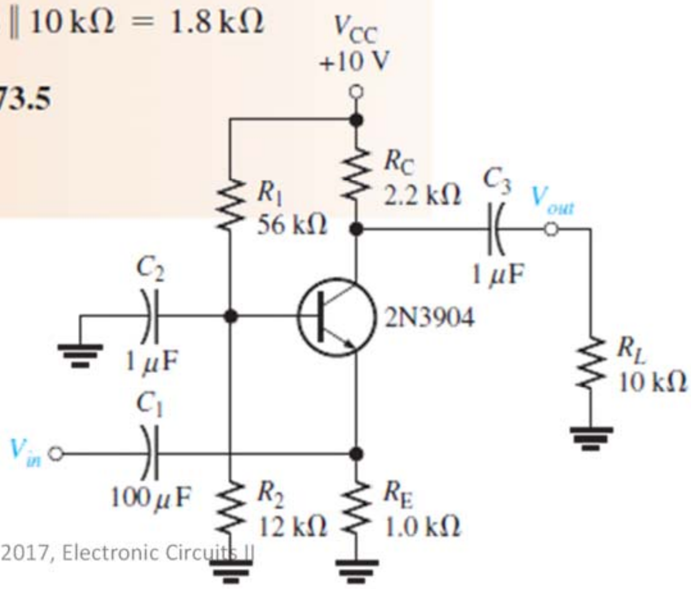
$$R_{in} \cong r'_e = \frac{25\,\text{mV}}{I_E} = \frac{25\,\text{mV}}{1.02\,\text{mA}} = \mathbf{24.5\,\Omega}$$

Calculate the voltage gain as follows:

$$R_c = R_C \| R_L = 2.2\,\text{k}\Omega \| 10\,\text{k}\Omega = 1.8\,\text{k}\Omega$$

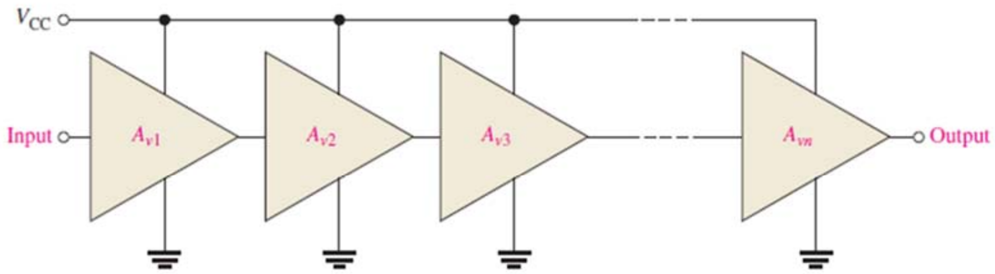
$$A_v = \frac{R_c}{r'_e} = \frac{1.8\,\text{k}\Omega}{24.5\,\Omega} = \mathbf{73.5}$$

Also, $A_i \cong \mathbf{1}$ and $A_p \cong A_v = \mathbf{76.3}$.



Multistage Amplifier

- The overall voltage gain A'v, of cascaded amplifiers,



$$A'_v = A_{v1}A_{v2}A_{v3}\ldots A_{vn}$$

- Amplifier voltage gain is often expressed in **decibels** (dB) as follows:

$$A_{v(dB)} = 20 \log A_v$$

- This is particularly useful in **multistage** systems because the overall voltage gain in dB is the *sum* of the individual voltage gains in dB

$$A'_{v(dB)} = A_{v1(dB)} + A_{v2(dB)} + \cdots + A_{vn(dB)}$$

Example 02

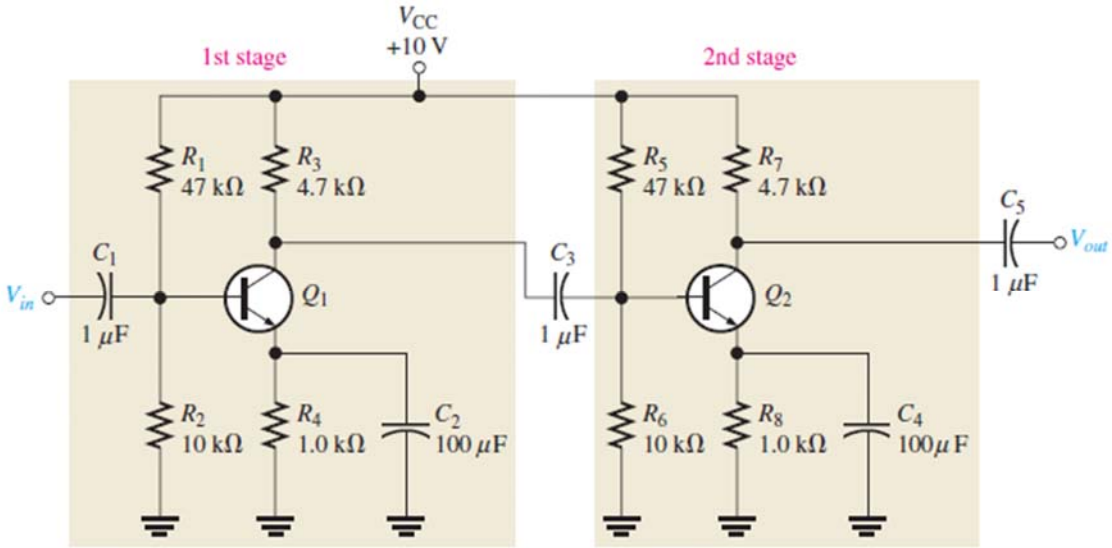
A certain cascaded amplifier arrangement has the following voltage gains: $A_{v1} = 10$, $A_{v2} = 15$, and $A_{v3} = 20$. What is the overall voltage gain? Also express each gain in decibels (dB) and determine the total voltage gain in dB.

$$A'_v = A_{v1}A_{v2}A_{v3} = (10)(15)(20) = \mathbf{3000}$$
$$A_{v1(\text{dB})} = 20 \log 10 = \mathbf{20.0\ dB}$$
$$A_{v2(\text{dB})} = 20 \log 15 = \mathbf{23.5\ dB}$$
$$A_{v3(\text{dB})} = 20 \log 20 = \mathbf{26.0\ dB}$$
$$A'_{v(\text{dB})} = 20.0\text{ dB} + 23.5\text{ dB} + 26.0\text{ dB} = \mathbf{69.5\ dB}$$

- $Av=10^{Av_{db}/20}$ = 10^(69.5/20)=2985.38

Capacitively-Coupled Multistage Amplifier

- we will use the two-stage capacitively coupled amplifier in Figure
- The output of the first stage capacitively coupled to the input of the second stage.

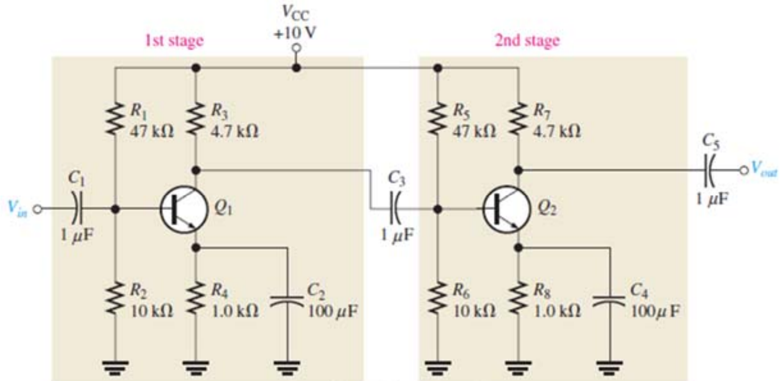


$\beta_{DC} = \beta_{ac} = 150$ for Q_1 and Q_2

- Capacitive coupling prevents the dc bias of one stage from affecting that of the other but allows the ac signal to pass without attenuation XC==0

Loading Effects

- the total input resistance of the second stage presents an ac load to the first stage.
- the effective ac collector resistance of *Q*1 is the total of all these resistances in parallel (*R*3, *R*5, *R*6, and *Rin*(*base*2))



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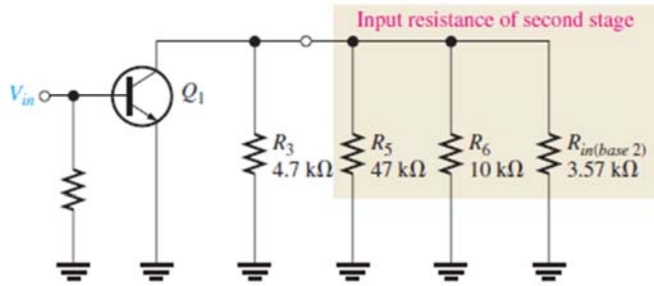


- The ac collector resistance of the first stage is

$$R_{c1} = R_3 \| R_5 \| R_6 \| R_{in(base2)}$$

$$R_{c1} = 4.7\,\text{k}\Omega \,\|\, 47\,\text{k}\Omega \,\|\, 10\,\text{k}\Omega \,\|\, 3.57\,\text{k}\Omega = 1.63\,\text{k}\Omega$$

- You can verify that $I_E = 1.05$ mA, $r'_e = 23.8\Omega$, and $R_{in(base2)} = 3.57\,\text{k}\Omega$.
- Therefore, the base-to-collector voltage gain of the first stage is

$$A_{v1} = \frac{R_{c1}}{r'_e} = \frac{1.63\,\text{k}\Omega}{23.8\,\Omega} = 68.5$$

- *Voltage Gain of the Second Stage*; The second stage has no load resistor, so the ac collector resistance is *R*7, and the gain is

$$A_{v2} = \frac{R_7}{r'_e} = \frac{4.7\,\text{k}\Omega}{23.8\,\Omega} = 197$$

- ***Overall Voltage Gain***

$$A'_v = A_{v1}A_{v2} = (68.5)(197) \cong 13{,}495$$

- If an input signal of 100uv , then output voltage is = (100 mV)(13,495) =1.35 V

$$A'_{v(\text{dB})} = 20\log(13{,}495) = 82.6\text{ dB}$$

DC Voltages in the Capacitively Coupled Multistage Amplifier

- Since both stages are identical, the dc voltages for *Q*1 and *Q*2 are the same.
- $\beta_{DC}R4 >> R2$, $\beta_{DC}R8 >> R6$

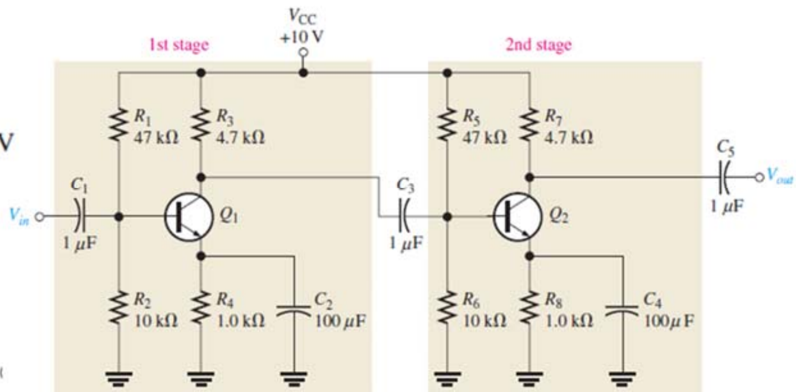
$$V_B \cong \left(\frac{R_2}{R_1 + R_2}\right)V_{CC} = \left(\frac{10\text{ k}\Omega}{57\text{ k}\Omega}\right)10\text{ V} = 1.75\text{ V}$$

$$V_E = V_B - 0.7\text{ V} = 1.05\text{ V}$$

$$I_E = \frac{V_E}{R_4} = \frac{1.05\text{ V}}{1.0\text{ k}\Omega} = 1.05\text{ mA}$$

$$I_C \cong I_E = 1.05\text{ mA}$$

$$V_C = V_{CC} - I_CR_3 = 10\text{ V} - (1.05\text{ mA})(4.7\text{ k}\Omega) = 5.07\text{ V}$$



$\beta_{DC} = \beta_{ac} = 150$ for Q_1 and Q_2

Direct-Coupled Multistage Amplifiers

- no coupling or bypass capacitors in this circuit.
- The dc collector voltage of the first stage provides the base-bias voltage for the second stage.
- Because of the direct coupling, this type of amplifier has a better low-frequency response (Direct-coupled amplifiers can be used to amplify low frequencies all the way down to dc (0 Hz)) than the capacitively coupled.
- The increased reactance of capacitors at lower frequencies produces gain reduction in capacitively coupled amplifiers.