Analog & Digital Electronics

Course No: PH-218

Lec-9: BJT Single Stage CE Amplifier

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Amplifier

An amplifier is a circuit which magnify (amplify) the input signal.

Characteristics of an amplifiers

1. Gain (A) = V_{out} / Vi_n - Large
2. Input Resistance (R_{in}) - Large
3. Output Resistance (R_{out}) - Small
4. Bandwidth (Frequency response) - Large

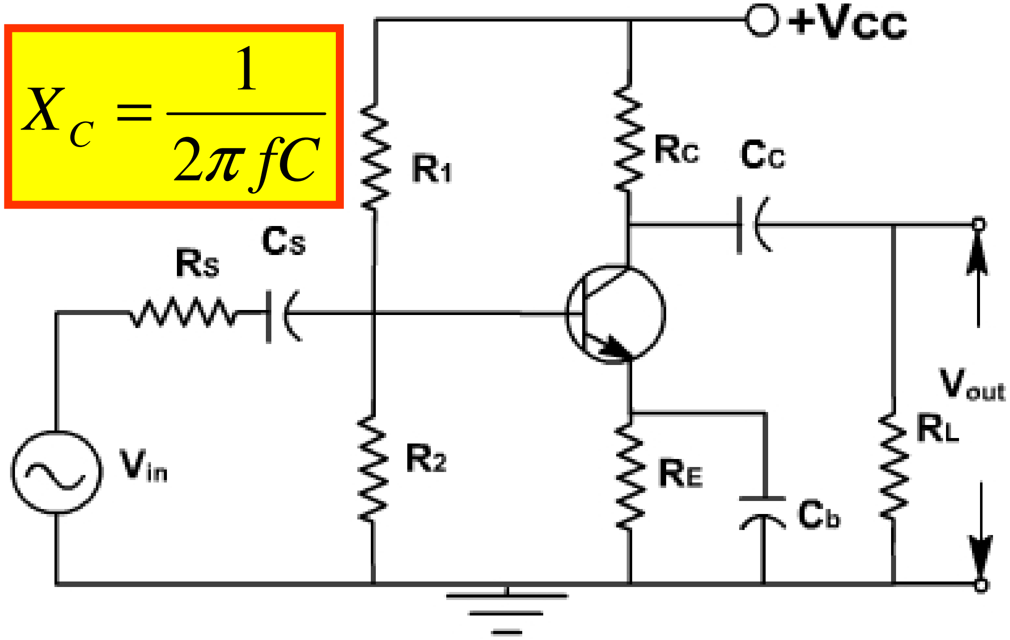
Families of amplifiers

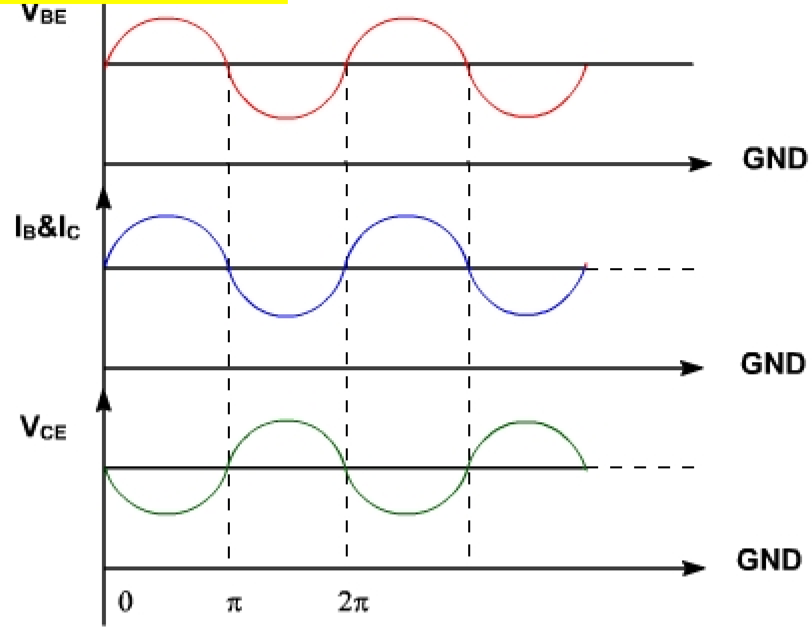
BJT Mode	Input	Output
Common-Emitter	Base	Collector
Common-Base	Emitter	Collector
Common-Collector	Base	Emitter

Common emitter BJT Amplifier

The higher the freq., the lower the capacitor impedance.

$$X_C = \frac{1}{2\pi f C}$$





➢The coupling capacitor (C_S and C_C) is used to pass the ac input signal and block the dc voltage from the preceding circuit.

➢This prevents dc in the circuitry on the left of the coupling capacitor from affecting the bias.

➢ The emitter bypass capacitor (C_b) is used to bypass the R_E and short circuits the ac signal through C_b since voltage gain decreases because of presence of R_E

Common emitter BJT Amplifier

- Transistor is biased with a Q point near the middle of a dc load line.

- When ac source is coupled to the base. This produces fluctuations in the base current and hence in the collector current of the same shape and frequency.

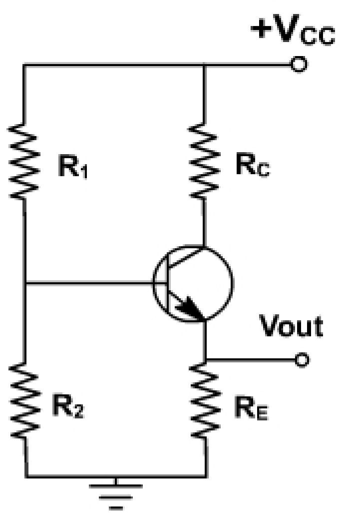
- During positive half cycle, base current increase, causing the collector current to increase. This produces a large voltage drop across the collector resistor; therefore, the voltage output decreases and negative half cycle of output voltage is obtained.

- Conversely, on the negative half cycle of input voltage less collector current flows and the voltage drop across the collector resistor decreases, and hence collector voltage increases we get the positive half cycle of output voltage.

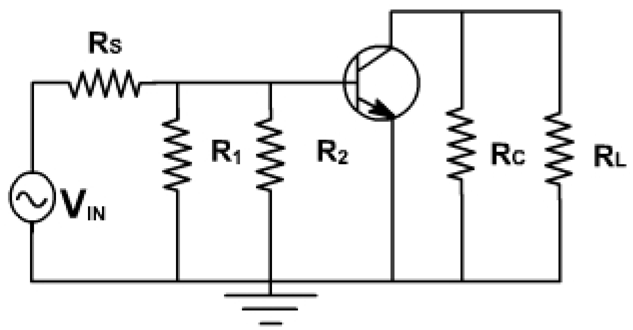
The ac output voltage is inverted with respect to the ac input voltage, meaning it is 180^o out of phase with input.

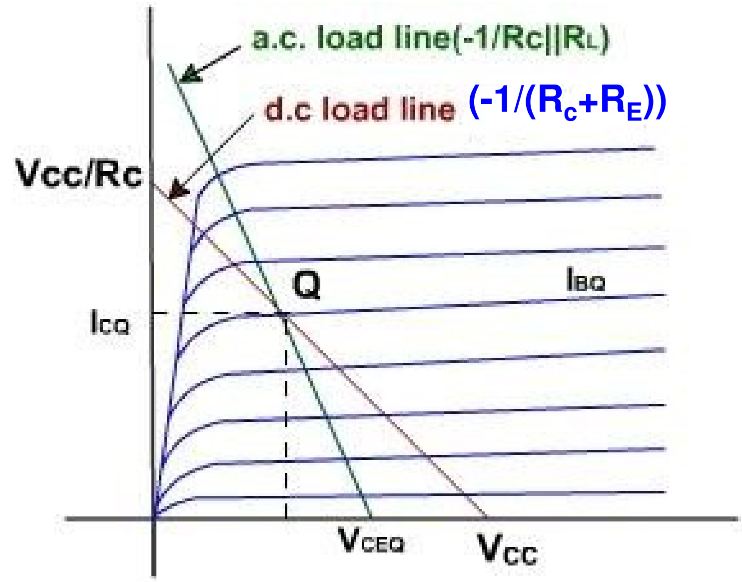
AC Load Line for Common emitter BJT Amplifier

DC Equivalent ckt



AC Equivalent ckt





$$V_{CE} = V_{CC} - I_C(R_C + R_E)$$

and $$I_C = -\frac{V_{CE}}{R_C + R_E} + \frac{V_{CC}}{R_C + R_E}$$

$$V_{CE} = 0, \quad I_C = \frac{V_{CC}}{R_C + R_E}$$

and $$I_C = 0, \quad V_{CE} = V_{CC}$$

When considering the ac equivalent circuit, the output impedance becomes $R_C \parallel R_L$ which is less than $(R_C + R_E)$. In the absence of ac signal, this load line passes through Q point. Therefore ac load line is a line of slope $(-1 / (R_C \parallel R_L))$ passing through Q point. Under this condition, Q-point is not in the middle of load line, therefore Q-point is selected slightly upward, means slightly shifted to saturation side.

Performance Parameters of a CE BJT Amplifier

Input Impedance (Z_{in})

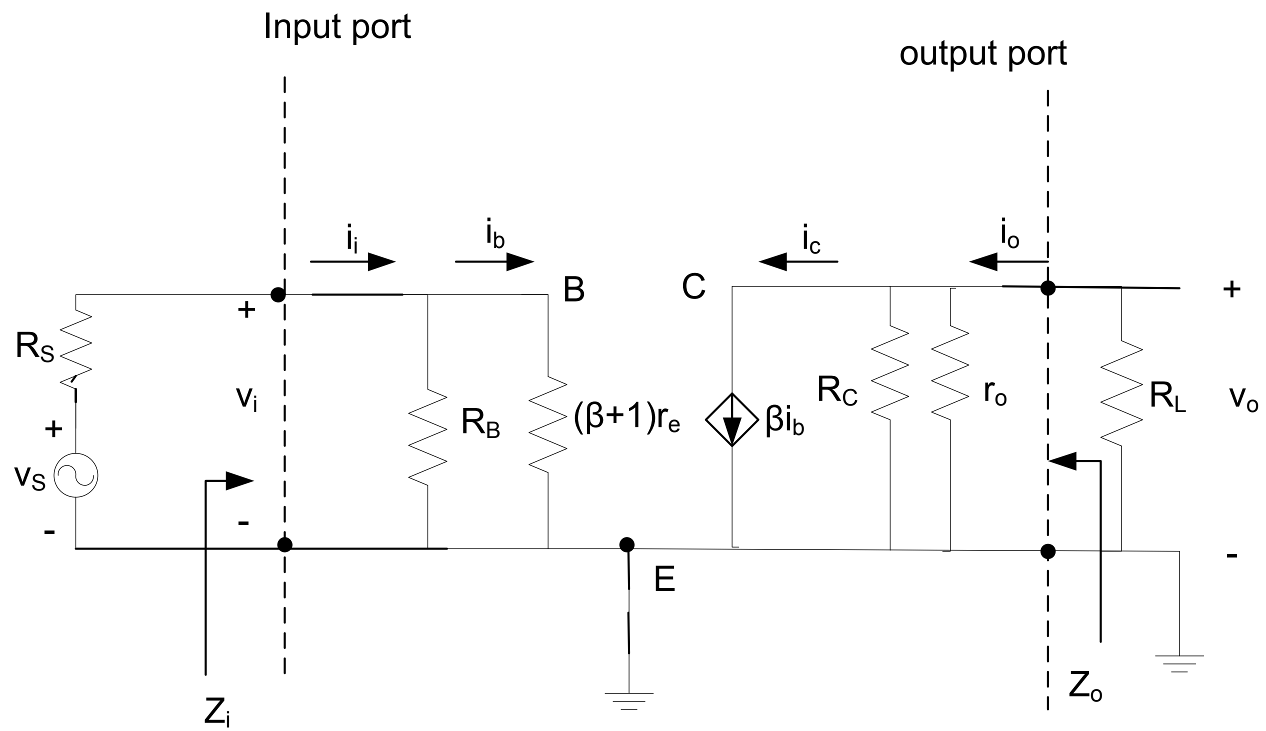
$$Z_i = [R_1 \backslash\backslash R_2 \backslash\backslash (\beta+1) r_e]$$

Output Impedance (Z_{out})

$$Z_{out} = (R_C \,//\, r_o)$$

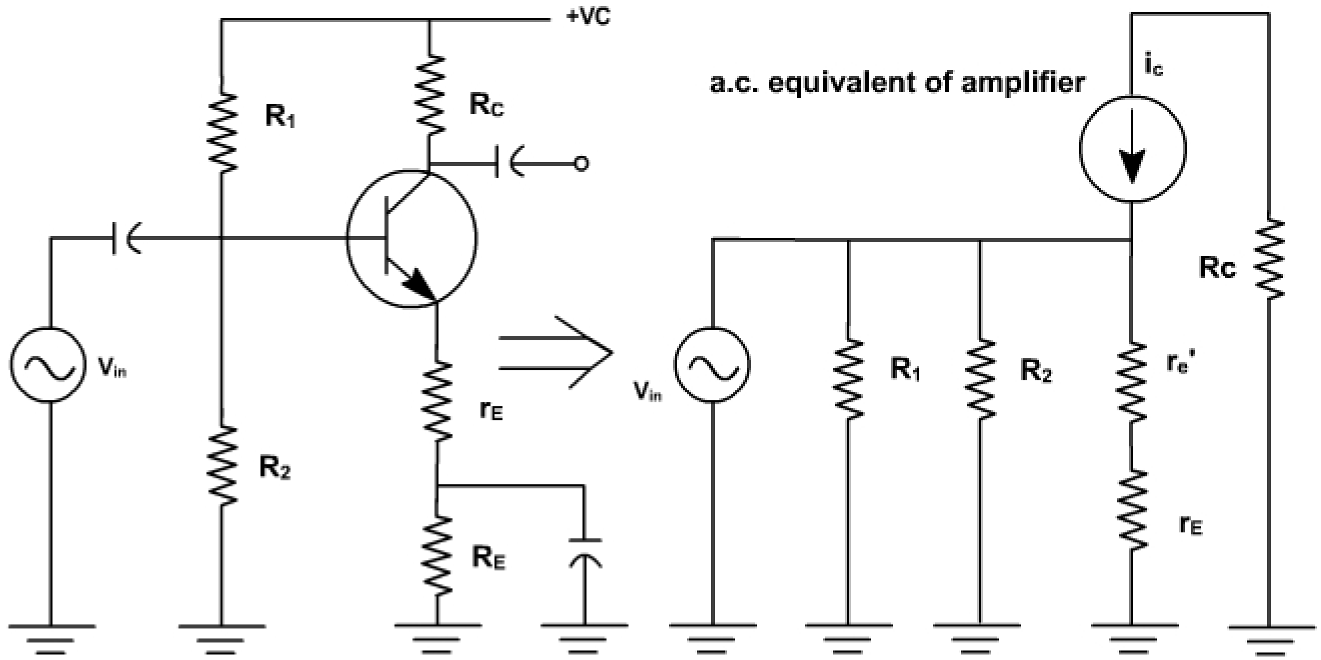
Voltage Gain (A_v)

$$A_v = \frac{-\beta R_C \| r_o \| R_L}{(\beta+1) r_e} \approx \frac{-R_C \| r_o \| R_L}{r_e}$$



Swamped CE BJT Amplifier

Swamped amplifier is an amplifier that uses a partially bypassed emitter resistance to increase ac emitter resistance. Also referred to as a **gain-stabilized amplifier**.



$$A_v = -\frac{R_c}{(r_E + r_e')}$$

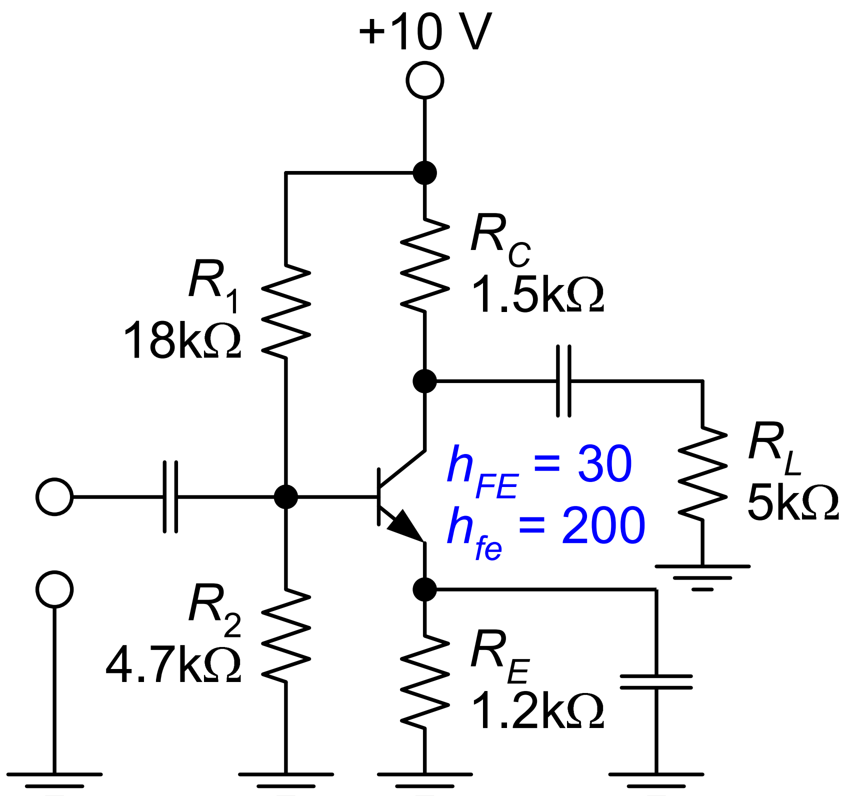
$$r_e' = \frac{V_T}{I_E}$$

r_E provides negative feedback

- Any change in r'_e will change the voltage gain in CE amplifier.

- To make it stable, a resistance r_E is inserted in series with the emitter and therefore emitter is no longer ac grounded.

Calculate the voltage gain of the amplifier.



$$V_{th} = V_{CC}\frac{R_2}{R_1+R_2} = 10\text{V}\frac{4.7\text{k}\Omega}{22.7\text{k}\Omega} = 2.070\text{V}$$

$$R_{th} = R_1 \parallel R_2 = 4.7\text{k}\Omega \parallel 18\text{k}\Omega = 3.727\text{k}\Omega$$

$$I_B = \frac{V_{th}-V_{BE}}{R_{th}+(h_{FE}+1)R_E} = \frac{2.070\text{V}-0.7\text{V}}{3.727\text{k}\Omega + 31\times 1.2\text{k}\Omega} = 33.49\mu\text{A}$$

$$I_C = h_{FE}I_B = 30\times 33.49\mu\text{A} = 1.005\text{mA}$$

$$I_E = \left(h_{FE}+1\right)I_B = 31\times 33.49\mu\text{A} = 1.038\text{mA}$$

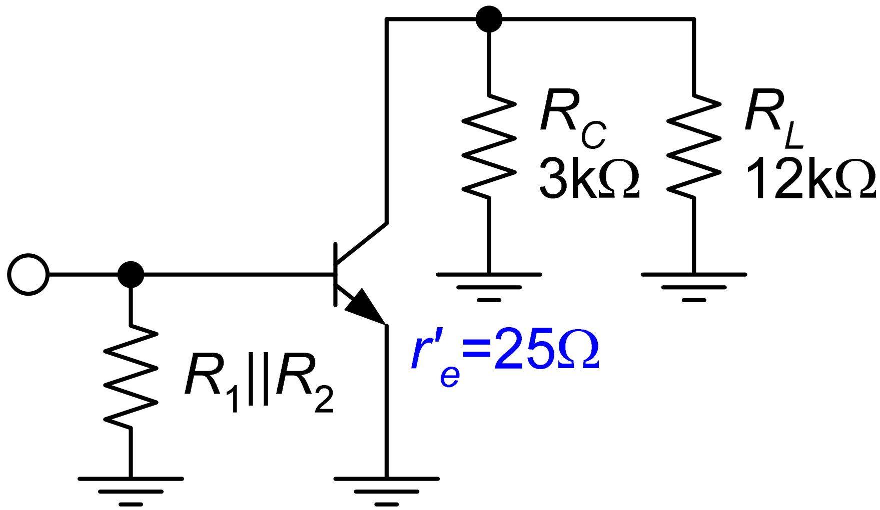
$$r_e' = \frac{25\text{mV}}{I_E} = \frac{25\text{mV}}{1.038\text{mA}} = 24.08\Omega$$

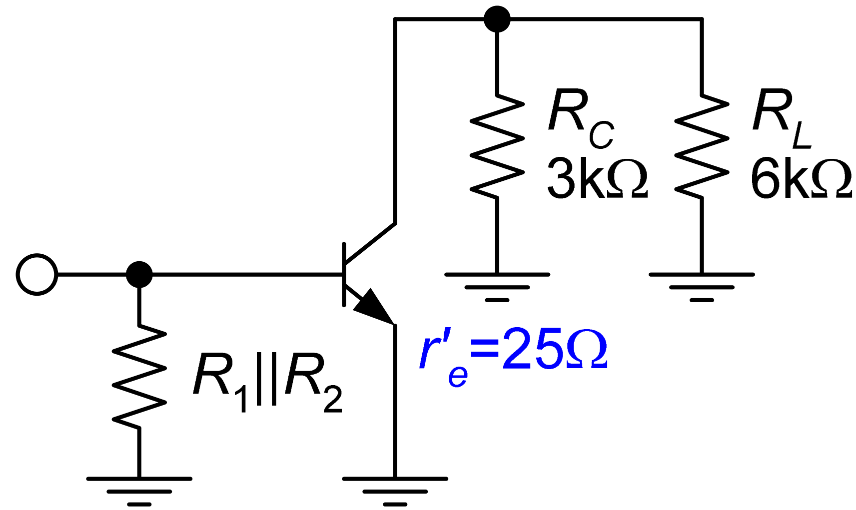
$$r_C = R_C \parallel R_L = 1.5\text{k}\Omega \parallel 5\text{k}\Omega = 1.154\text{k}\Omega$$

$$V_{CE} = V_{CC} - I_C R_C - I_E R_E = 10\text{V} - 1.005\text{mA}\times 1.5\text{k}\Omega - 1.038\text{mA}\times 1.2\text{k}\Omega = 7.247\text{V} \quad (\text{active})$$

$$A_v \cong -\frac{r_C}{r_e'} = -\frac{1.154\text{k}\Omega}{24.08\Omega} = -47.91$$

The Effects of Loading





$$r_C = R_C \parallel R_L = 2.4\text{k}\Omega$$

$$A_v = -\frac{r_C}{r'_e} = -96$$

$$r_C = R_C \parallel R_L = 2\text{k}\Omega$$

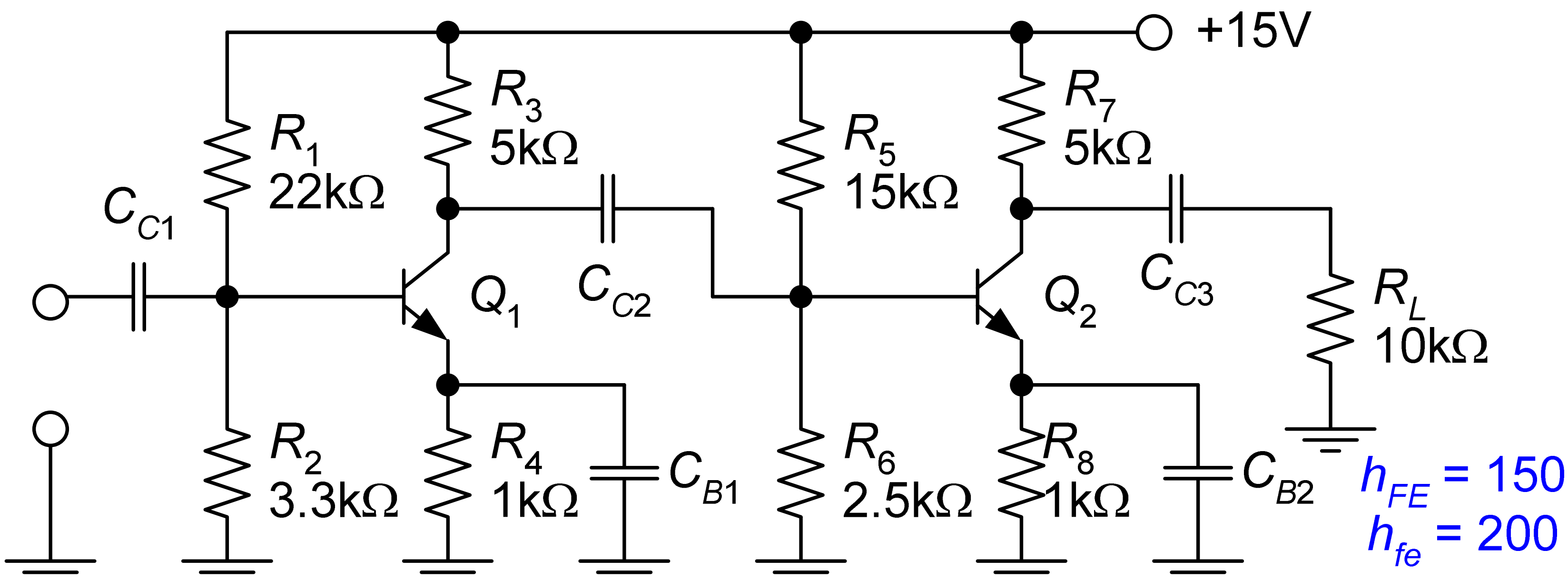
$$A_v = -\frac{r_C}{r'_e} = -80$$

The lower the load resistance is, the lower the voltage gain.

No load $r_C = R_C = 3\text{k}\Omega$

$$A_v = -\frac{r_C}{r'_e} = -\frac{3\text{k}\Omega}{25\Omega} = -120 \text{ (max. gain)}$$

Determine A_v of the 1st stage. Assume that r'_e for the 1st stage is 19.8 Ω and r'_e for the 2nd stage is found to be 17.4 Ω. For the 2nd stage, h_{fe} is 200.



$$Z_{in(base)} = \left(h_{fe} + 1\right) r'_e = 201 \times 17.4 = 3.497\text{k}\Omega$$

$$Z_{in} = R_5 \parallel R_6 \parallel Z_{in(base)} = 1.329\text{k}\Omega$$

$$r_C = R_3 \parallel Z_{in} = 5\text{k}\Omega \parallel 1.33\text{k}\Omega = 1.05\text{k}\Omega$$

$$A_v = -\frac{r_C}{r'_e} = -\frac{1.05\text{k}\Omega}{19.8\Omega} = -53.03$$