EE210: Microelectronics-I

Lecture-25 :Common Collector Amplifier-1

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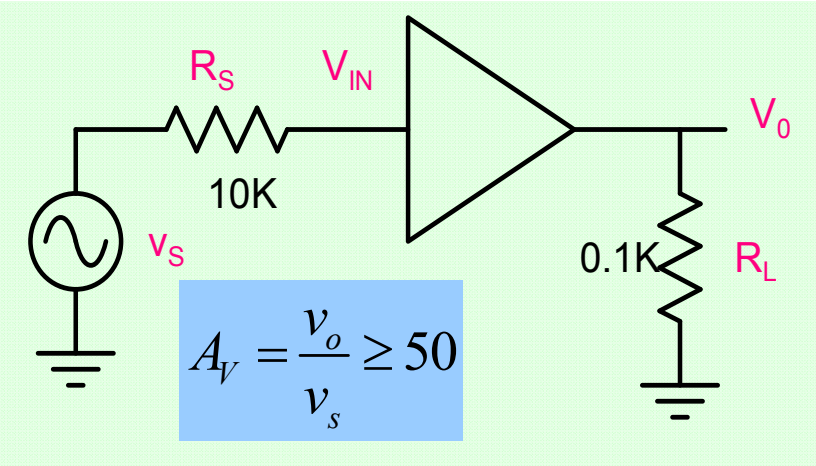
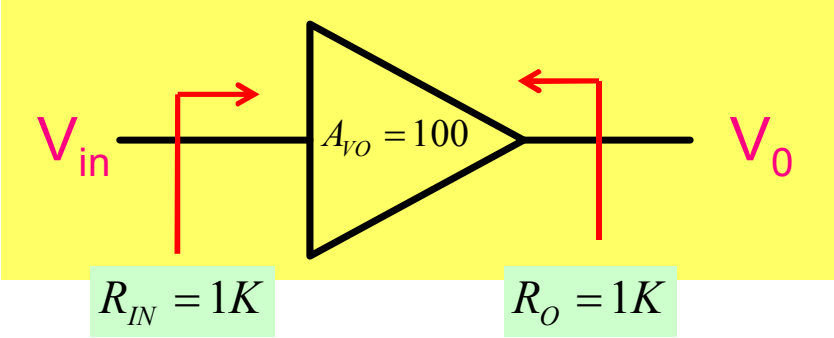
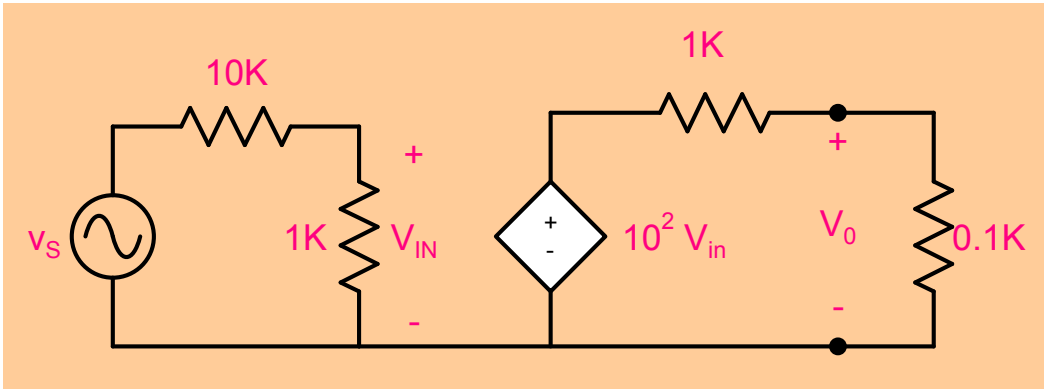
Example



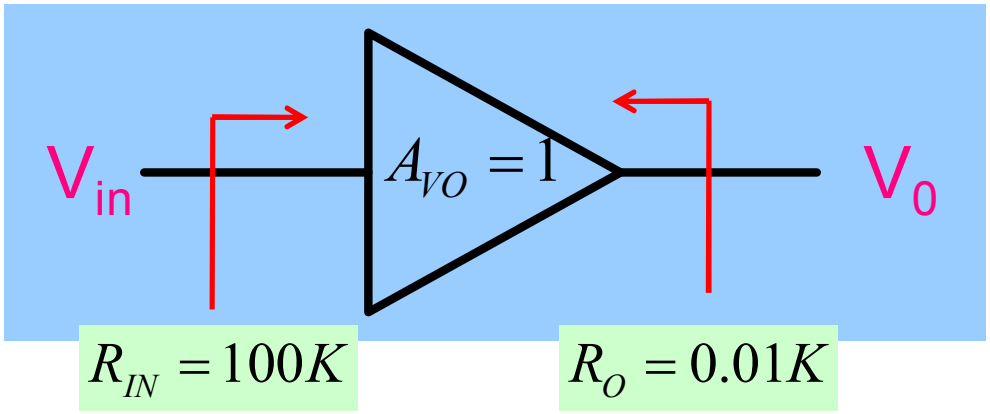




$$A_V = \frac{v_o}{v_s} = \left(\frac{R_{in}}{R_S + R_{in}}\right) \times A_{VO} \times \left(\frac{R_L}{R_O + R_L}\right) = 0.826$$

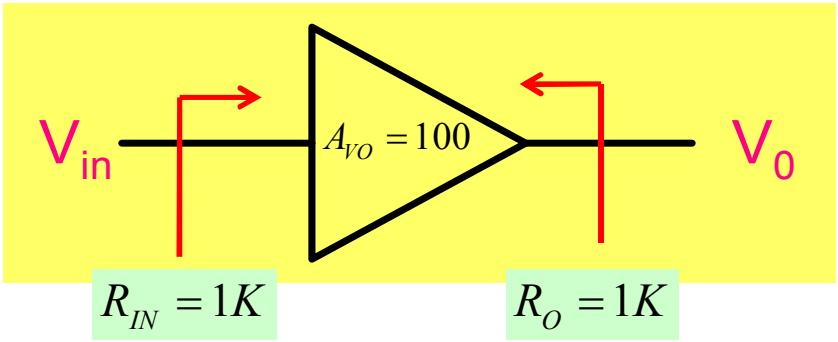
A CE amplifier by itself may not be sufficient for all applications

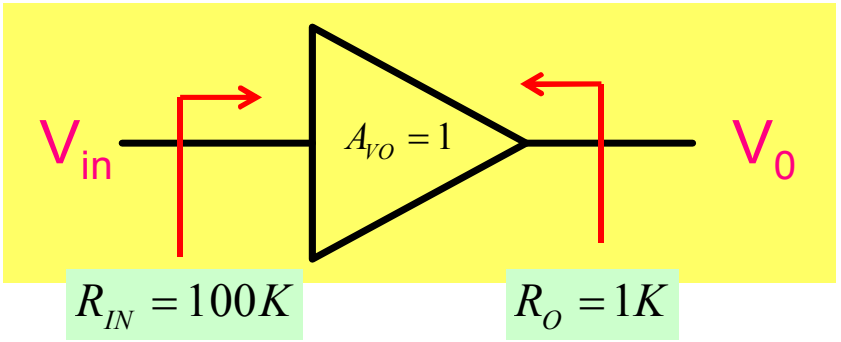
Suppose we have a new amplifier stage with the following characteristics



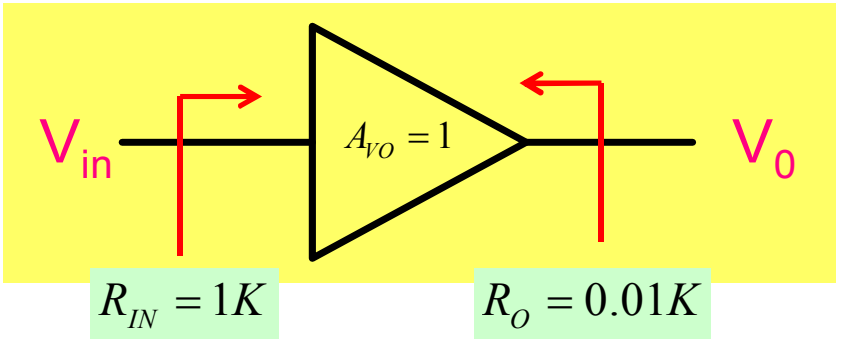
High bandwidth
High swing & linearity

$$\frac{R_{in}}{R_O} = 10^4$$

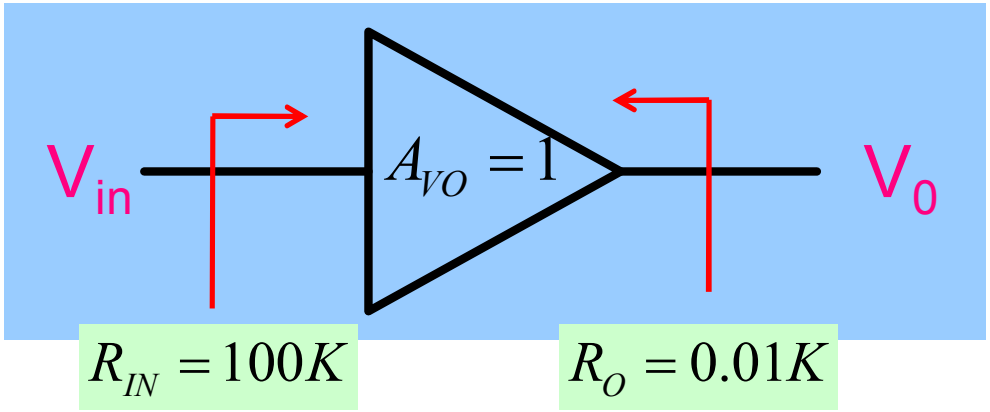


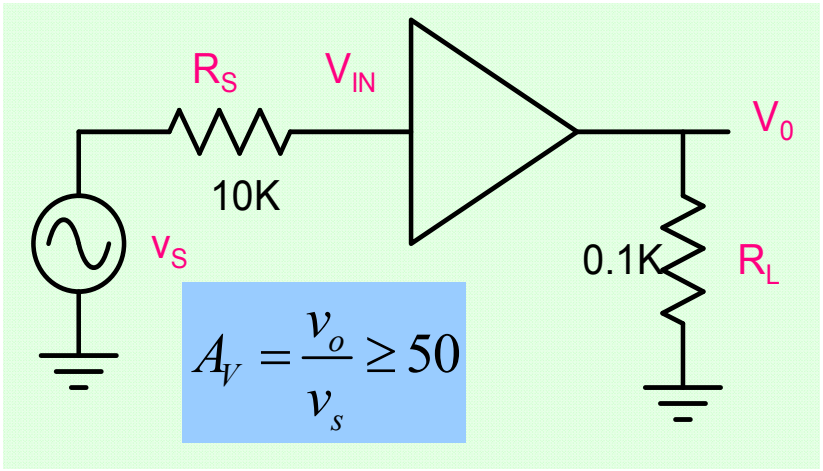


$$\frac{A_{vo} \times R_{in}}{R_O} = \beta = 100$$

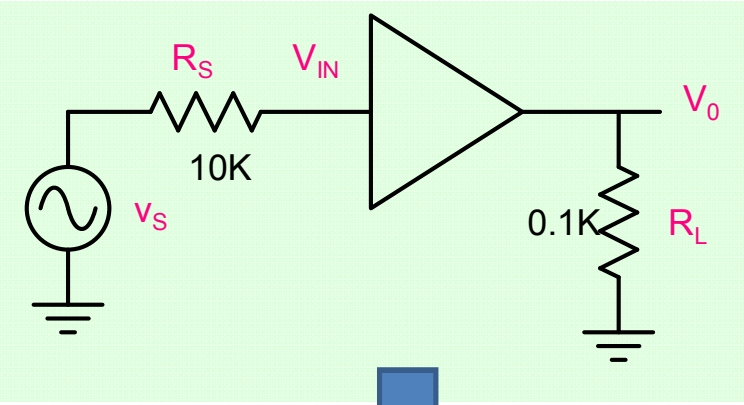


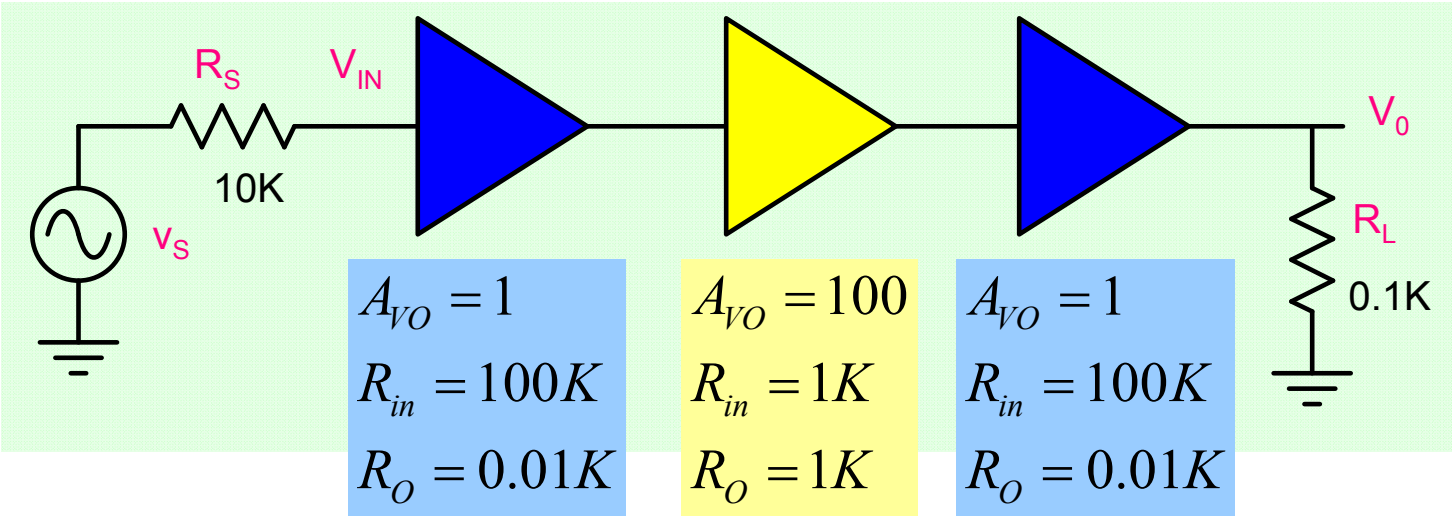
Can we use this amplifier for our application?



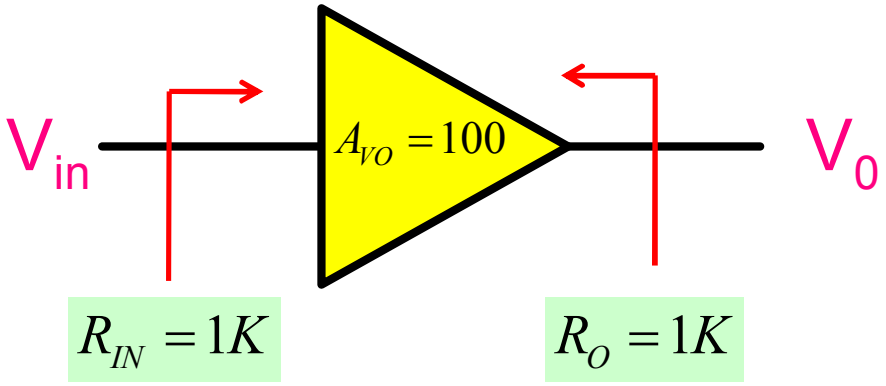


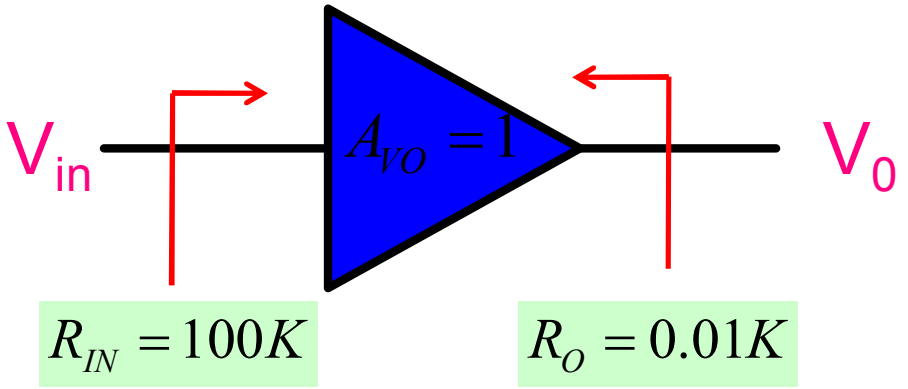
Not directly but in combination with the first amplifier



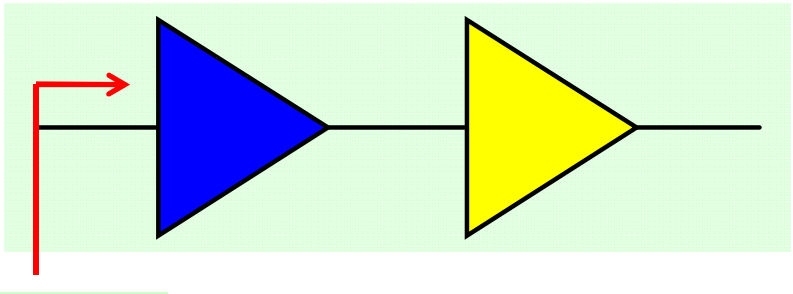


$$A_V = \frac{v_o}{v_s} = A_{VO} \times \frac{R_{in}}{R_S + R_{in}} \times \frac{R_L}{R_O + R_L} = 81$$

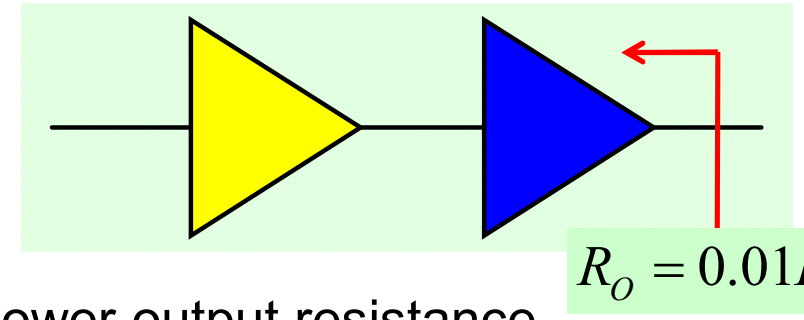




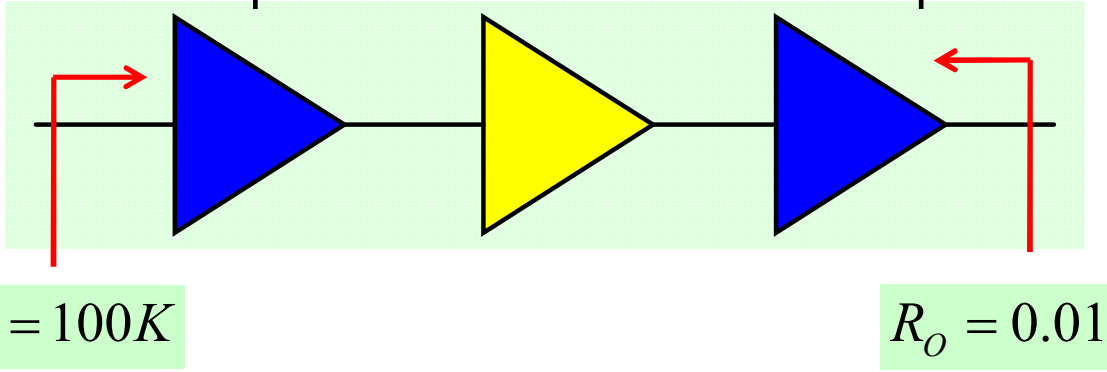
Increased input resistance



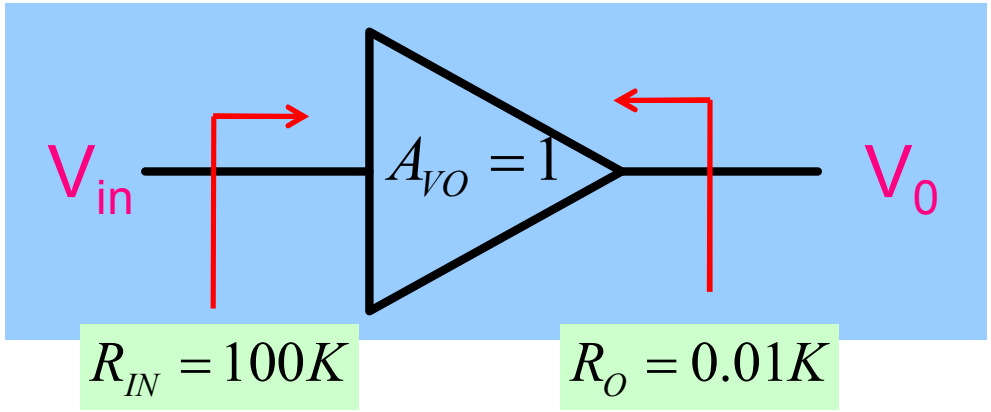
Lower output resistance



Increased input resistance and lower output resistance



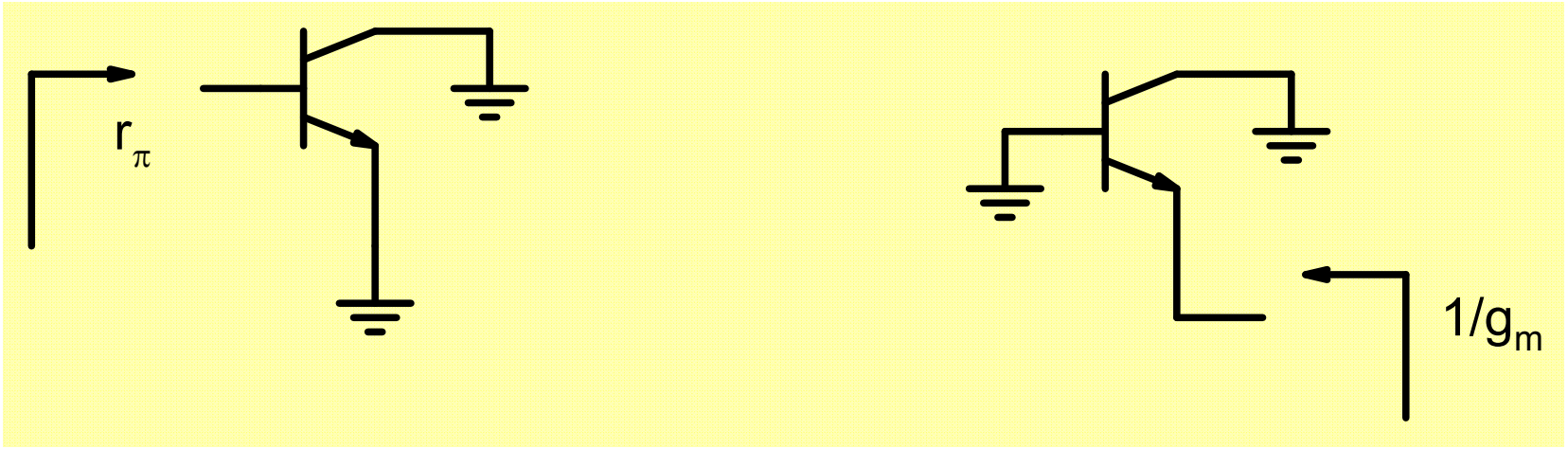
What are we looking for?

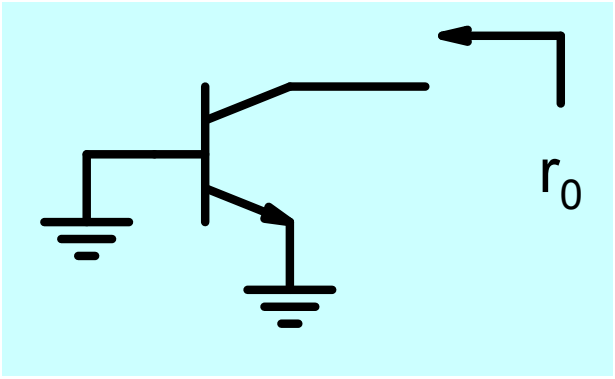


High bandwidth
High swing & linearity

- Low output resistance and high input resistance
- Large voltage swing with good linearity
- High bandwidth

Low output resistance



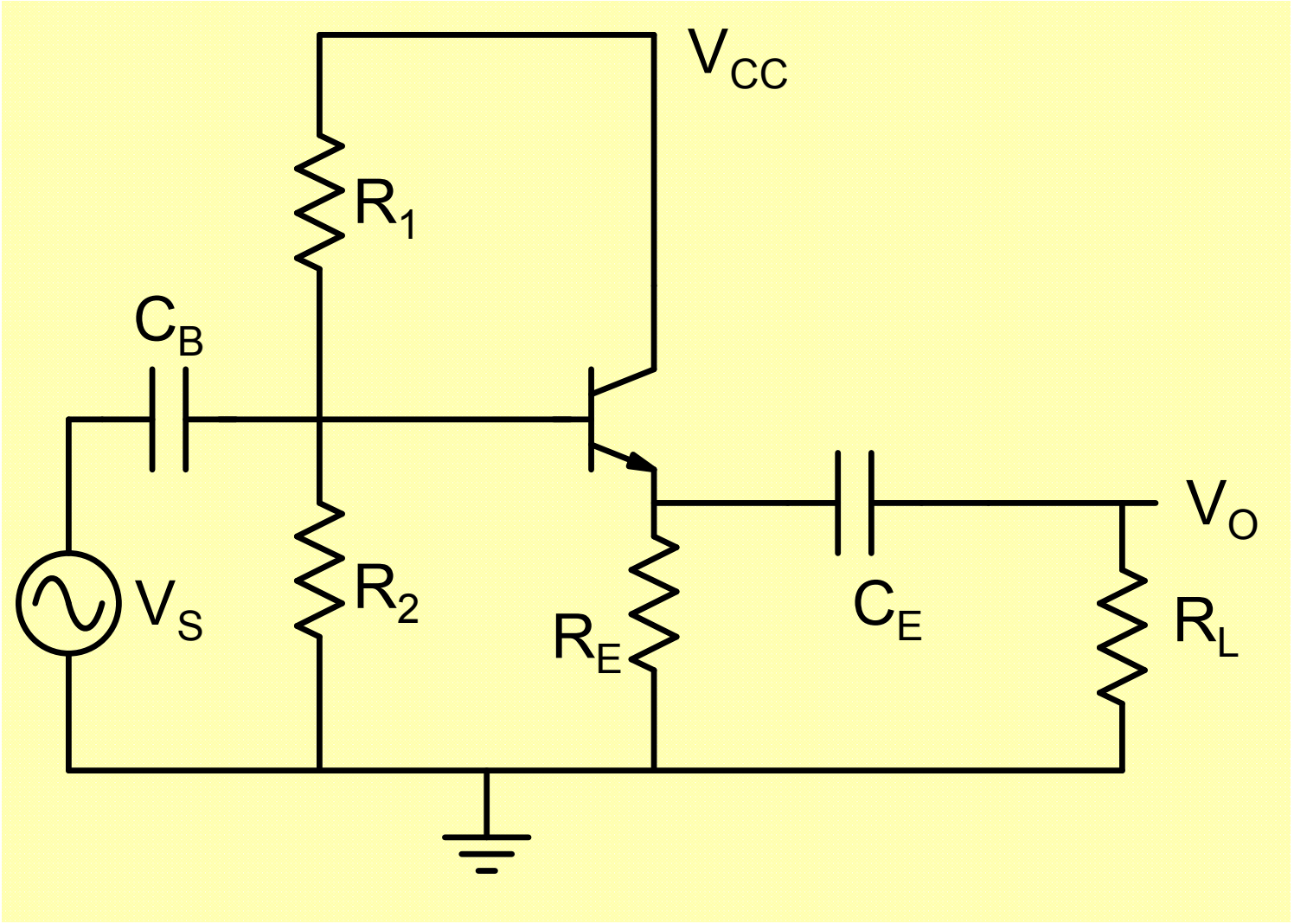


$$I_c = 2.6mA, \beta = 100, V_A = 104V$$

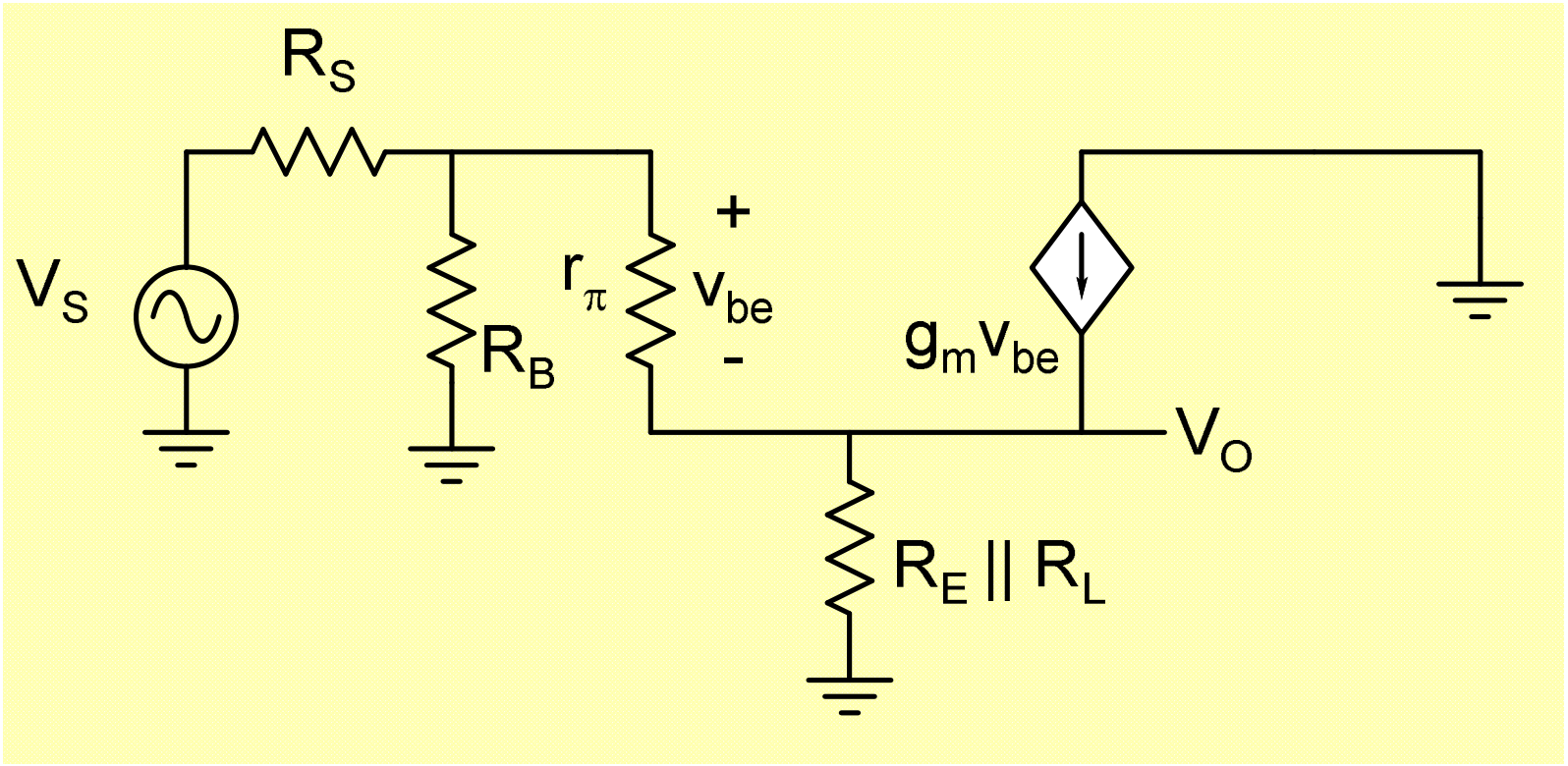
$$1/g_m = 10, r_\pi = 1000, r_o = 4 \times 10^4$$

$$1/g_m << r_\pi << r_o$$

Common Collector Amplifier



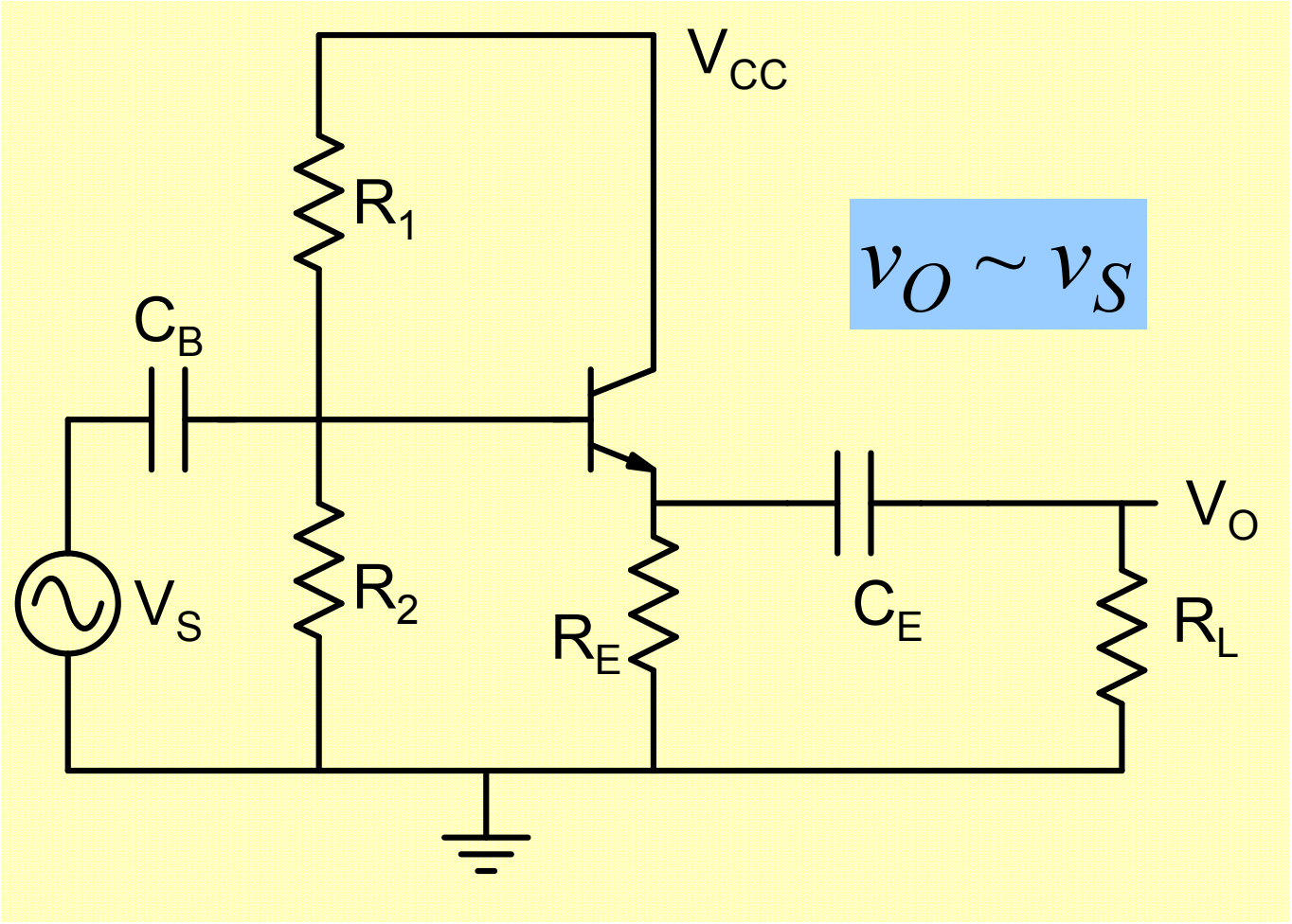
Small Signal Analysis



$$A_V = \left(\frac{1}{1 + R_S / R_B}\right) \times \frac{(\beta + 1) \times R_E \| R_L}{R_S \| R_B + r_\pi + (\beta + 1) \times R_E \| R_L}$$

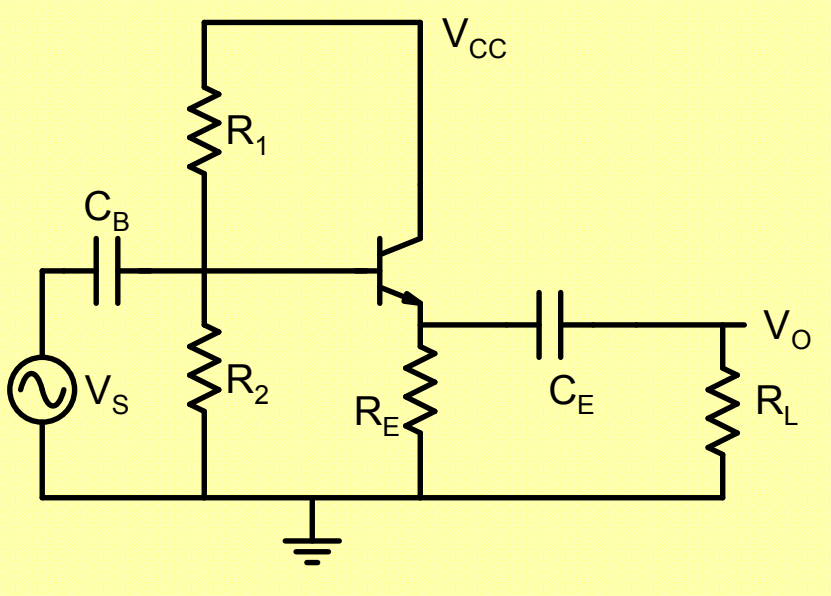
Less than unity but almost ~1

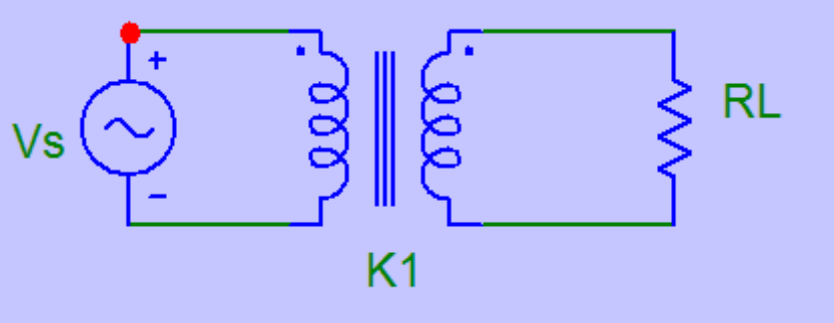
Emitter Follower



Why is emitter follower called an amplifier when its voltage gain is less than unity?

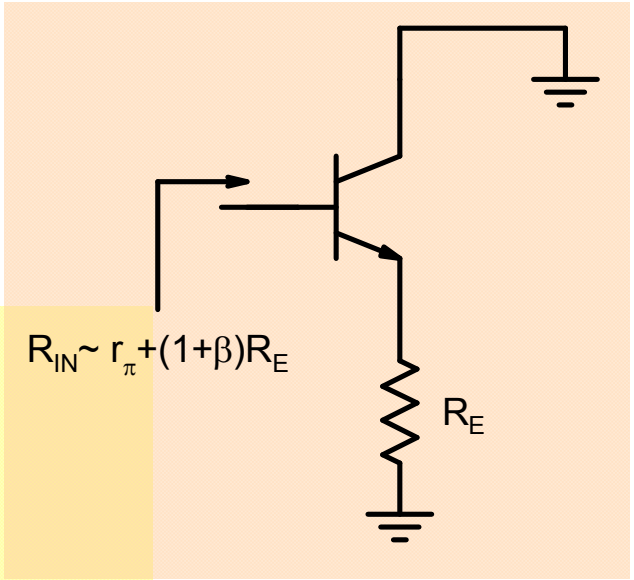
Why don't we call a step-up transformer an amplifier?

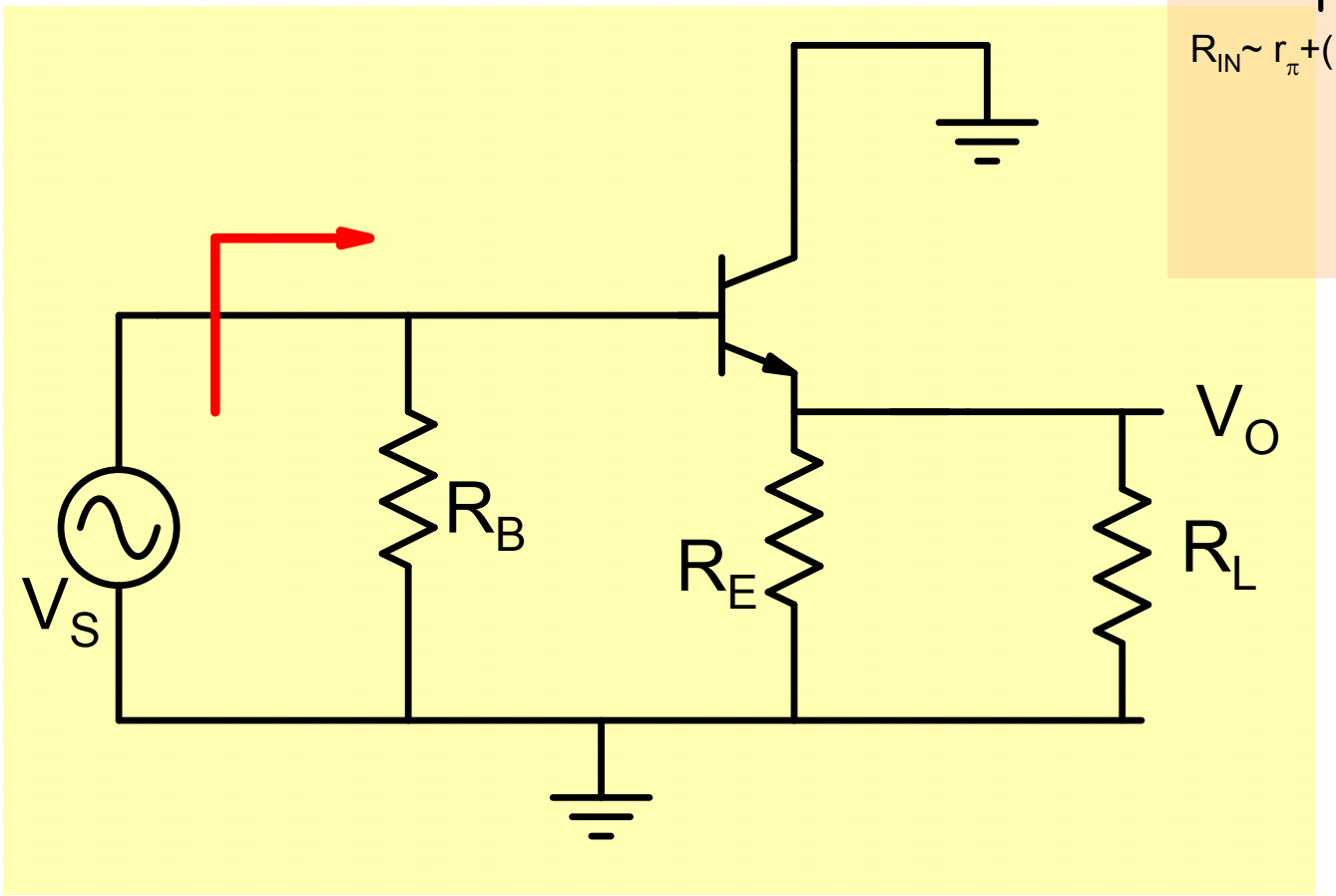




A necessary condition is **Power Gain**

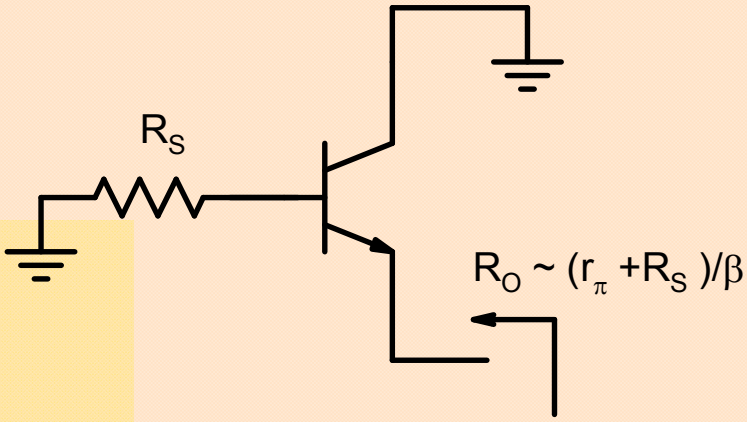
Input Resistance

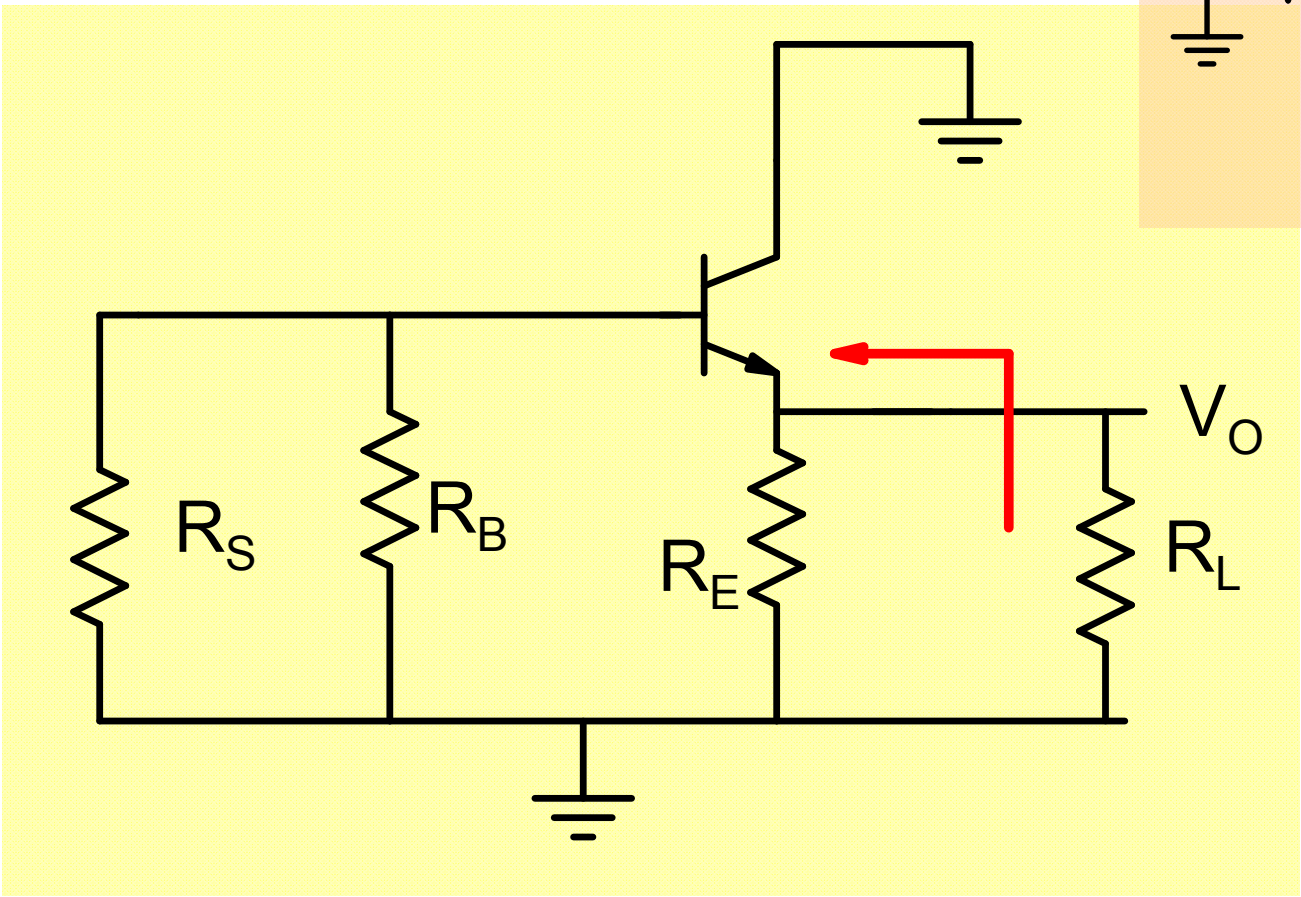




$$R_{in} = (r_\pi + (\beta + 1) \times R_E \| R_L) \| R_B$$

Output Resistance





$$R_O = \frac{(r_\pi + R_B \| R_S)}{\beta + 1} \| R_E$$

Relationship between gain, input & output resistances

$$A_V = \frac{R'_S}{R_s} \times \frac{(\beta+1) \times R'_E}{R'_S + r_\pi + (\beta+1) \times R'_E}$$

$$A_V \sim 1$$

$$R'_S = R_s \| R_B ; R'_E = R_E \| R_L$$

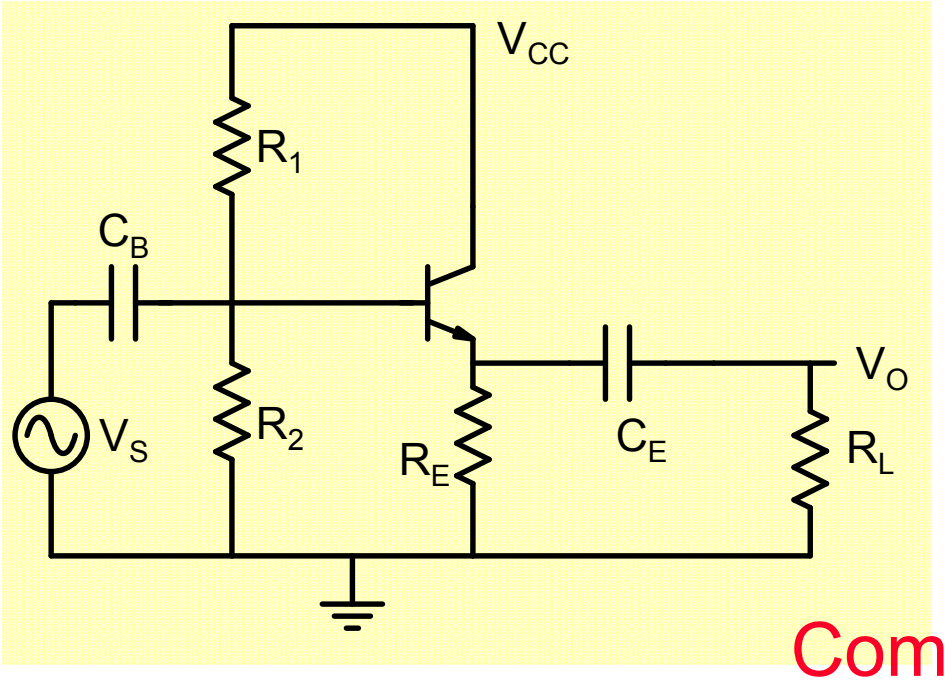
$$R_O = \frac{(r_\pi + R'_S)}{\beta+1} \| R_E$$

$$R_O \cong \frac{(r_\pi + R'_S)}{\beta+1}$$

$$R_{in} = \{r_\pi + (\beta+1) \times R'_E\} \| R_B$$

$$R_{in} \cong (\beta+1) \times R'_E\}$$

$$\frac{R_{in}}{R_O} \cong \beta \times \frac{I_{CQ} R_E}{V_T} \frac{1}{1 + R'_S / r_\pi} \times \frac{1}{1 + R_E / R_L}$$



To obtain high swing

$$I_{CQ}R_E \sim \frac{V_{CC}}{2}$$

$$\frac{R_{in}}{R_O} \cong \beta \times \frac{V_{CC}}{2V_T} \frac{1}{1+R_S'/r_\pi} \times \frac{1}{1+R_E/R_L}$$

Comparison with CE amplifier

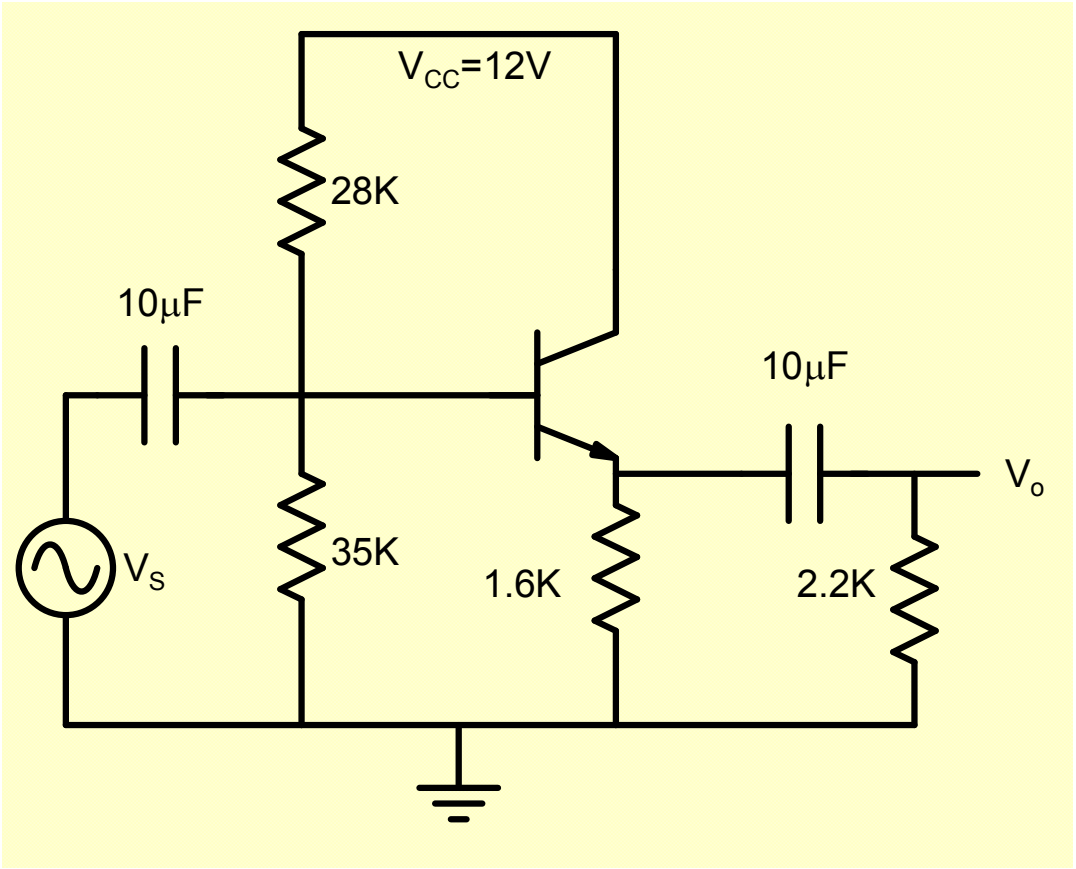
$$\frac{A_V \times R_{in}}{R_O} \cong \beta$$

Even with a gain of unity

$$\frac{R_{in}}{R_O} \cong \beta$$

Clearly, a common collector amplifier can deliver much lower output resistance and higher input resistance as compared to CE amplifier. Further it has higher swing and low distortion !

Example



$$\beta = 100$$

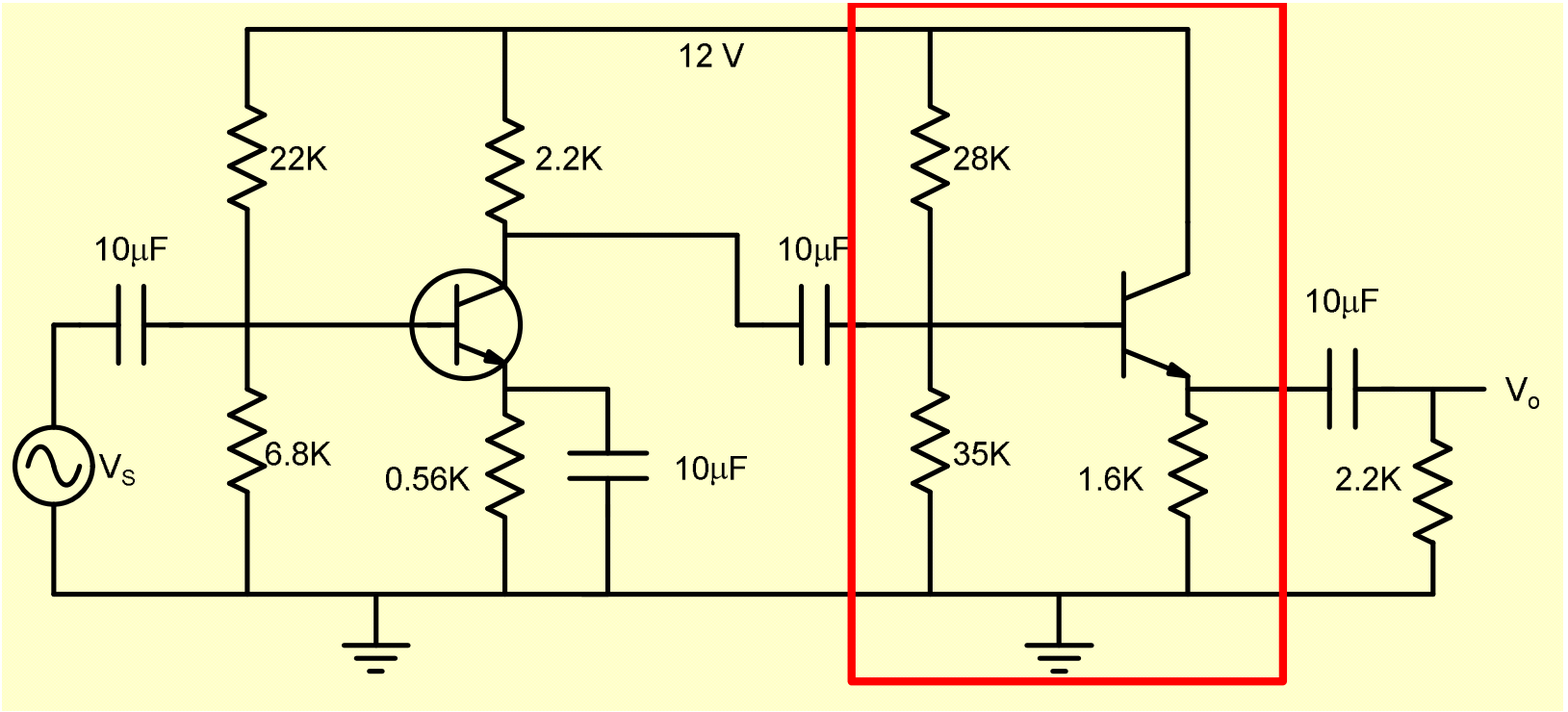
$$I_{CQ} = 3.4mA; V_{CEQ} = 6.5V$$

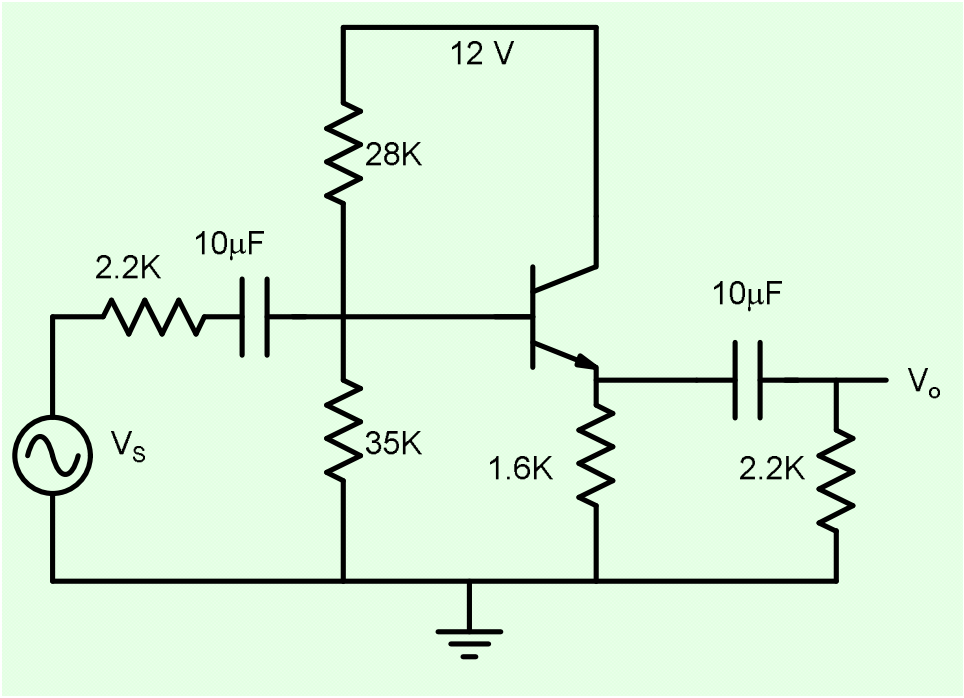
$$A_V = 0.99;$$

$$R_{in} = 13.4K\,(R_B = 16k)$$

$$R_O = 9.5\Omega$$

$$\frac{R_{in}}{R_O} = 1.4 \times 10^3 \cong \beta \times 14$$





$$\beta = 100$$

$$I_{CQ} = 3.4mA; V_{CEQ} = 6.5V$$

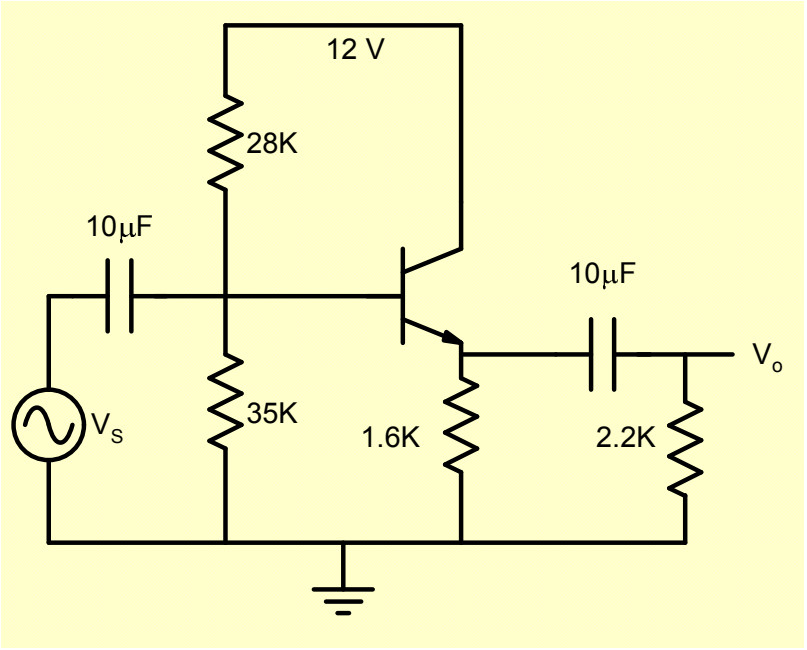
$$A_V = 0.85;$$

$$R_{in} = 13.4K\,(R_B = 16k)$$

$$R_O = 27\Omega$$

$$\frac{A_V R_{in}}{R_O} = 422 \cong \beta \times 4.2$$

Example



$$\beta = 100$$

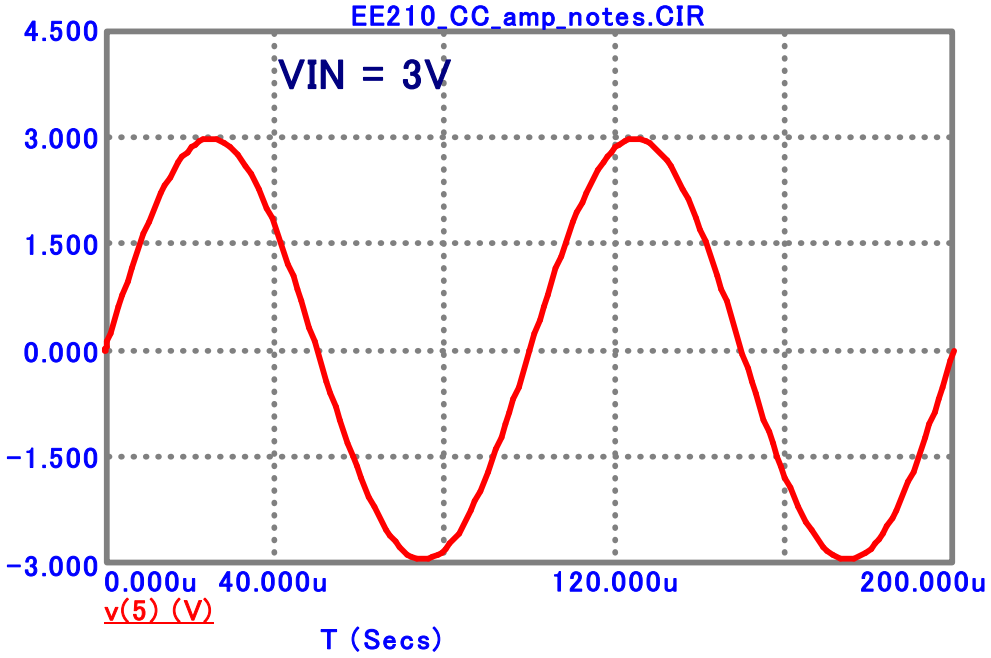
$$I_{CQ} = 3.4mA; V_{CEQ} = 6.5V$$

$$A_V = 0.99;$$

$$R_{in} = 13.4K\,(R_B = 16k)$$

$$R_O = 9.5\Omega$$

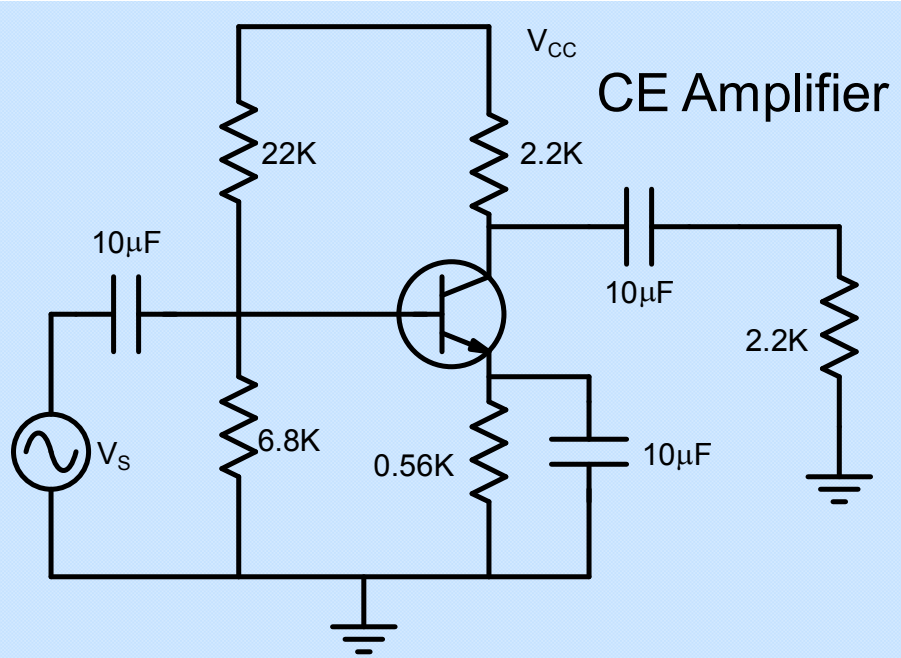
$$\frac{R_{in}}{R_O} \cong \beta \times 14$$

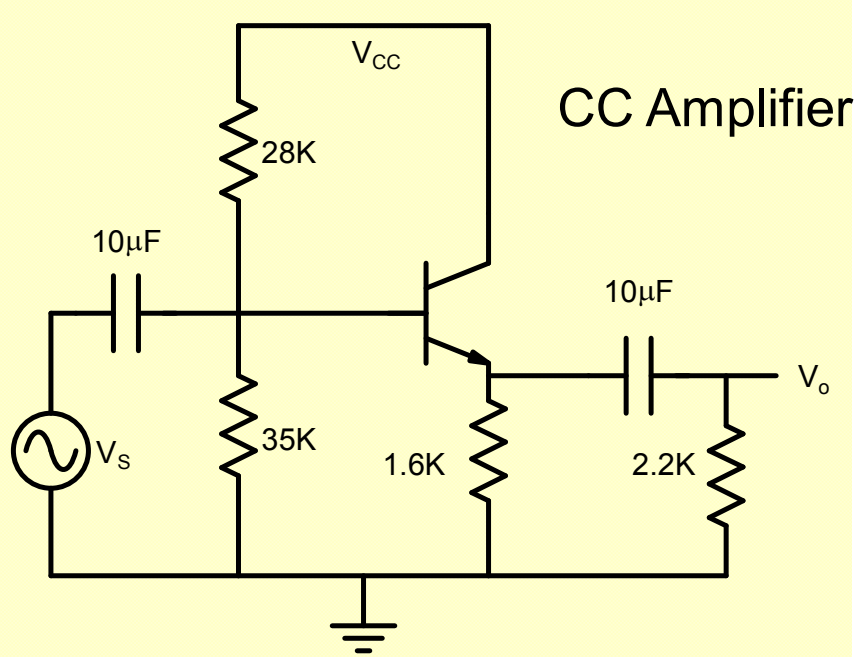


V_{OM} ~6V p-p

THD ~0.5%

Comparison-1





$\beta = 100$

$I_{CQ} = 3.4mA; V_{CEQ} = 2.57V$

$A_V = 110.7; R_{in} = 0.82K\ ; R_O = 2.2K$

$v_{om} = 0.39V\ @\ THD = 1.9\%$

$f_L = 1.67kHz; f_H = 5.8MHz$

$\beta = 100$

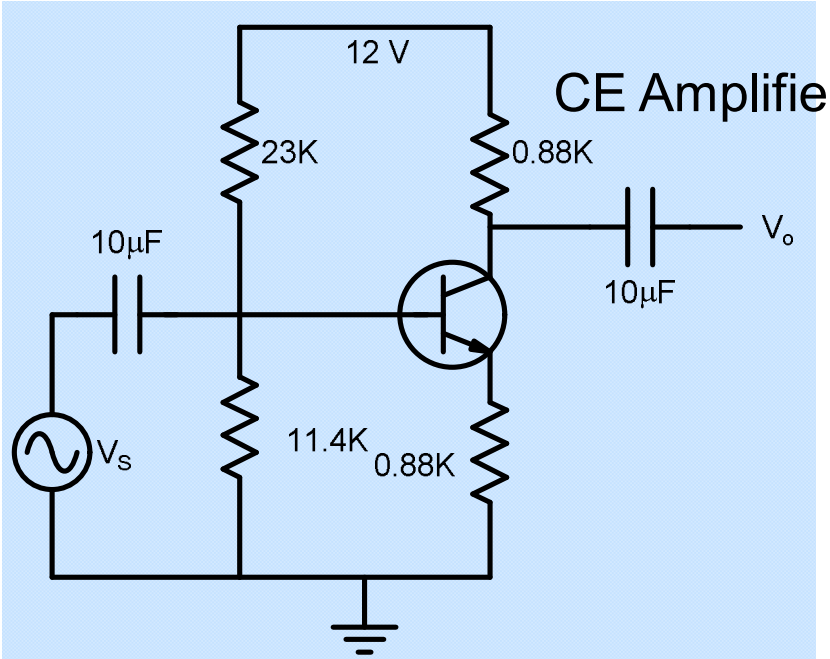
$I_{CQ} = 3.4mA; V_{CEQ} = 6.5V$

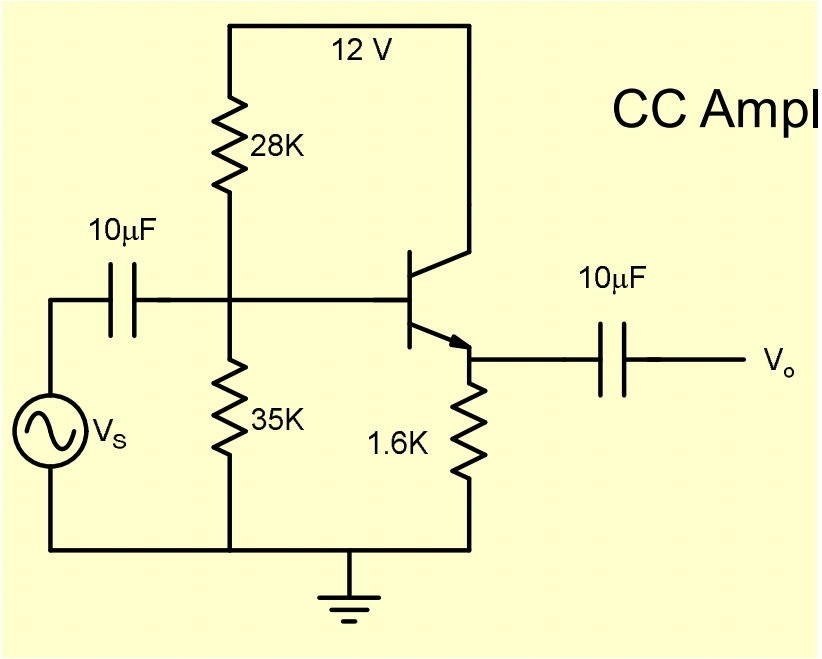
$A_V = 0.99; R_{in} = 13.4K\,(R_B = 16k); R_O = 9.5\Omega$

$v_{om} = 3V\ @\ THD = 0.5\%$

$f_L = 7.6Hz; f_H = 3.1GHz$

Comparison-2





$\beta = 100$

$I_{CQ} = 3.4mA; V_{CEQ} = 6V; R_B/\beta R_E = 0.09$

$A_{Vo} = 0.98; R_{in} = 7K\ ; R_O = 0.88K$

$$\frac{A_{Vo} \times R_{in}}{R_o} = 7.8$$

$v_{om} = 3V\ @\ THD = 0.5\%$

$f_L = 2.3Hz; f_H = 50MHz$

$\beta = 100$

$I_{CQ} = 3.4mA; V_{CEQ} = 6.5V; R_B/\beta R_E = 0.1$

$A_V = 0.99; R_{in} = 14.2K\ ; R_O = 9.5\Omega$

$$\frac{A_{Vo} \times R_{in}}{R_o} = 1.5 \times 10^3$$

X 192

$v_{om} = 3V\ @\ THD = 0.5\%$

$f_L = 1.1Hz; f_H = 3.8GHz$

X 76