EE210: Microelectronics-I

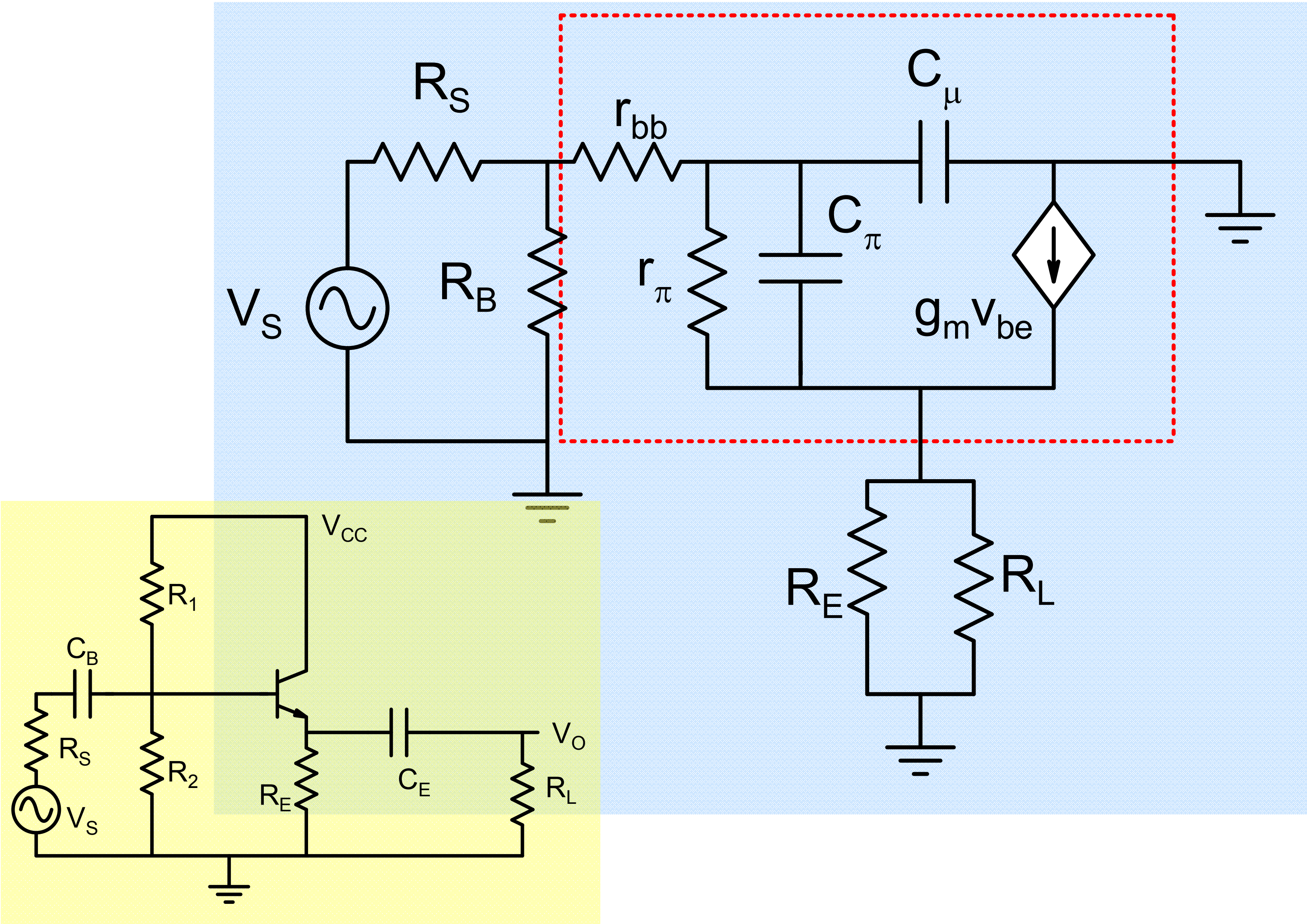
Lecture-27 :Common Collector Amplifier-3

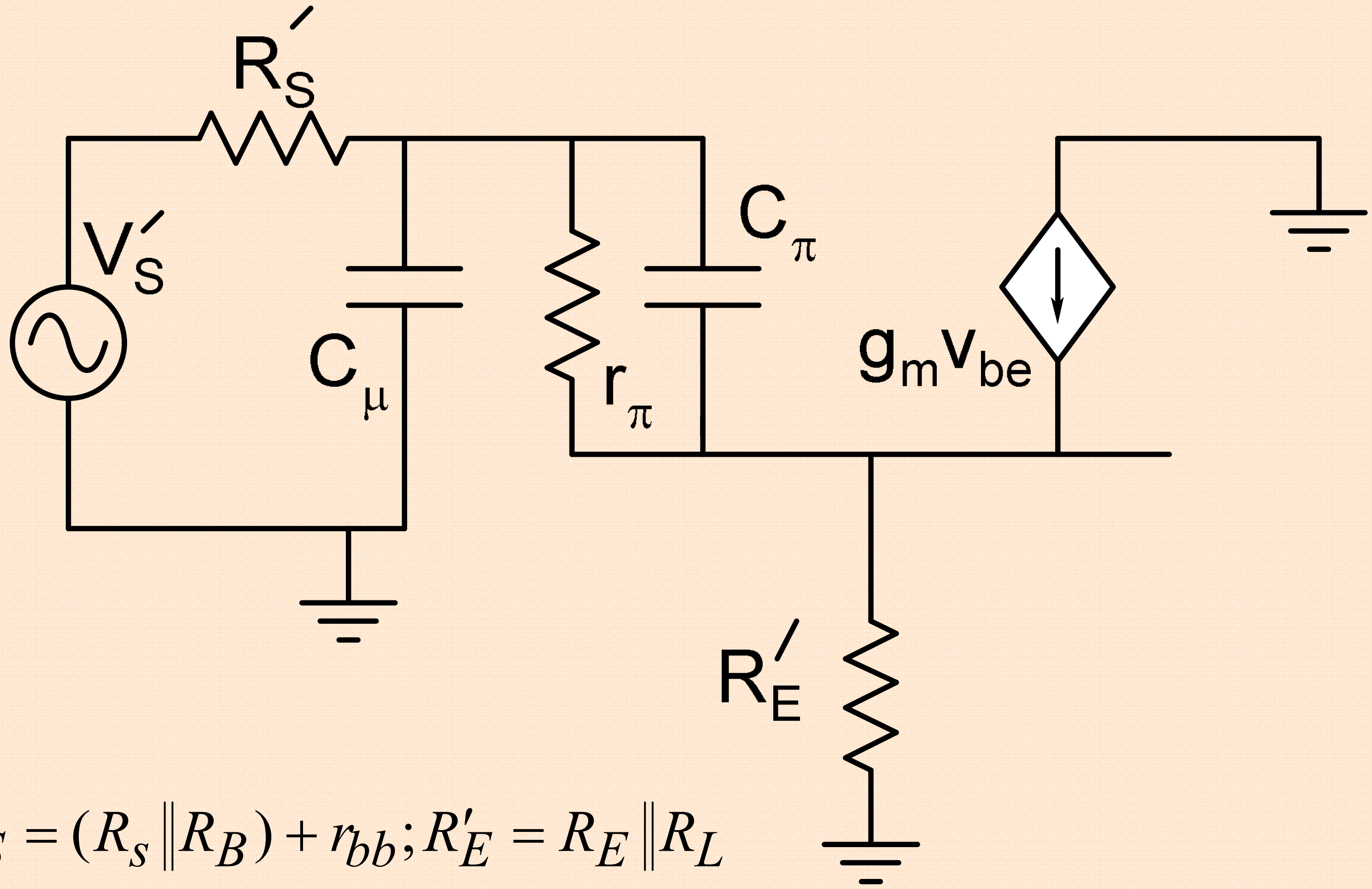
Instructor - Y. S. Chauhan

Slides - B. Mazhari
Dept. of EE, IIT Kanpur

Frequency Response

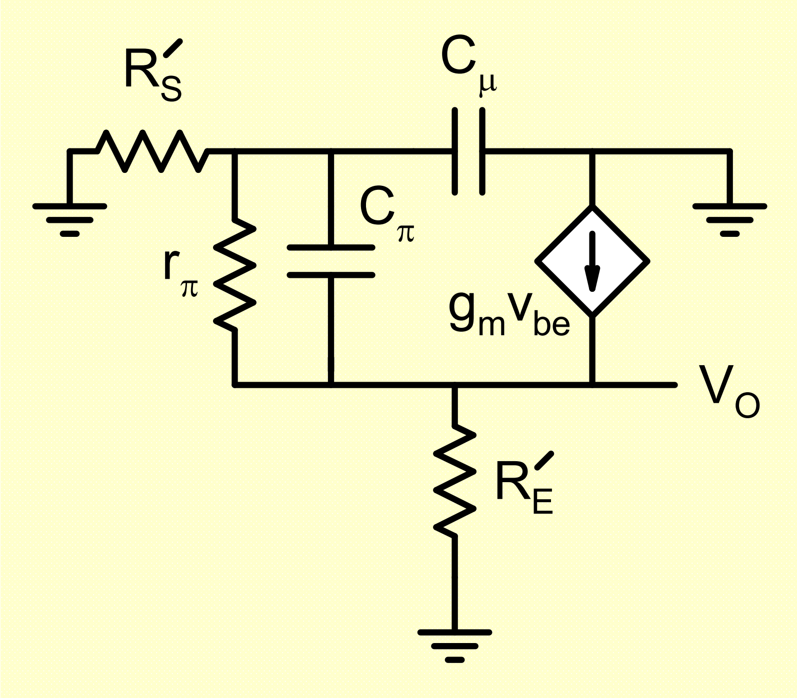
Frequency Response





$$R'_S = (R_s \| R_B) + r_{bb}; R'_E = R_E \| R_L$$

Open Circuit time constant approach



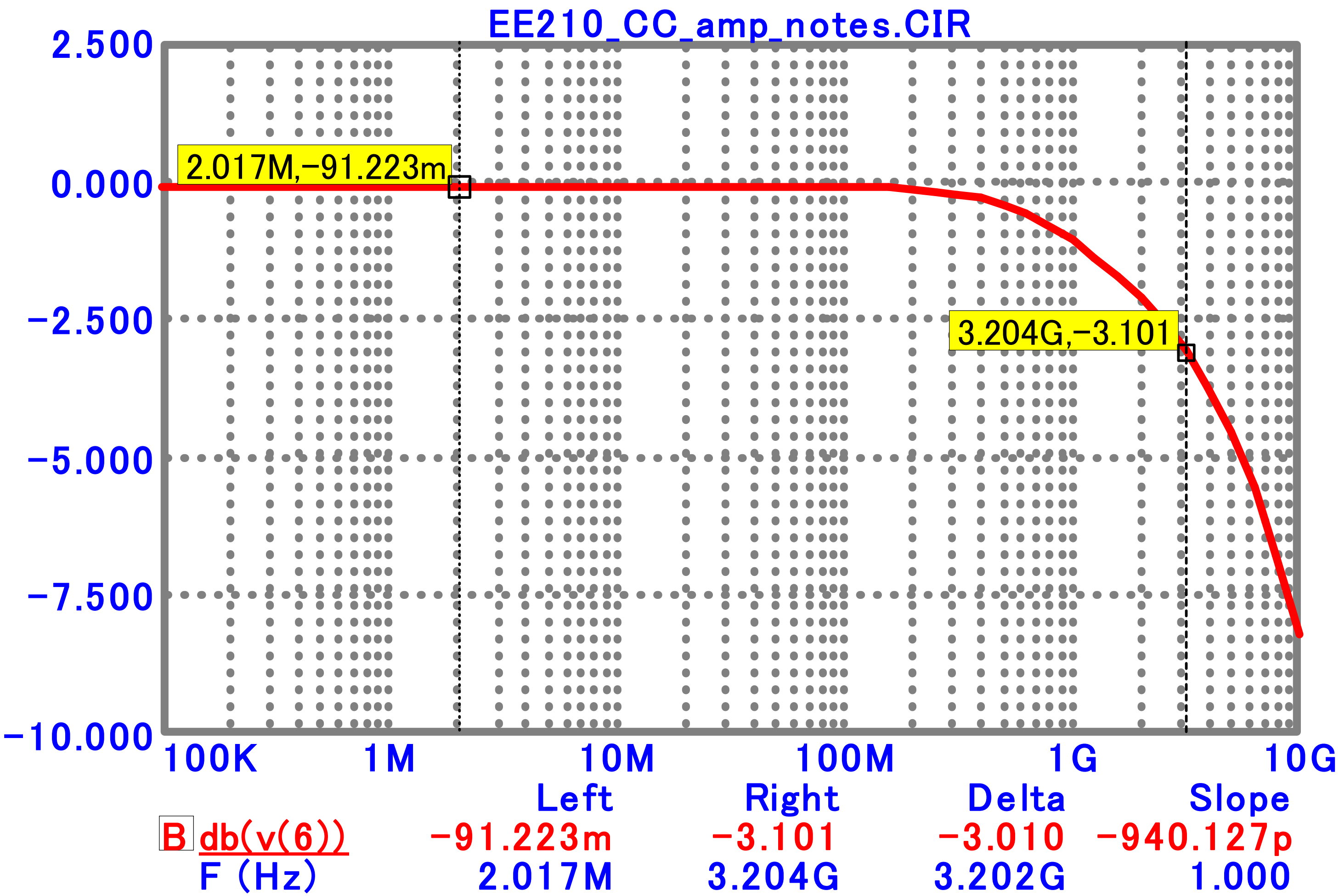
$$R_\pi = \frac{1+\dfrac{R'_E}{R'_S}}{1+\dfrac{\dfrac{g_m R'_E}{R'_S}}{1+\dfrac{R'_S}{r_\pi}}} \times (R'_S \parallel r_\pi)$$

$$\cong \frac{1}{g_m} \; as \; R'_E \to \infty$$

$$R_\mu = R'_s\left(1 - \frac{R'_S}{r_\pi + R'_s + (1+\beta)R'_E}\right)$$

$$\cong R'_s \; as \; R_E \to \infty$$

$$f_H \cong \frac{1}{2\pi \times \left(R'_S C_\mu + \dfrac{C_\pi}{g_m}\right)} ?$$



simulated is ~3GHz while $f_H \cong \dfrac{1}{2\pi \times (r_{bb} C_\mu + \dfrac{C_\pi}{g_m})} = 126MHz$

G-Number

Why is actual 3dB frequency so much higher?

$$f_H \cong \frac{1}{2\pi \times (R'_S C_\mu + \frac{C_\pi}{g_m})}$$

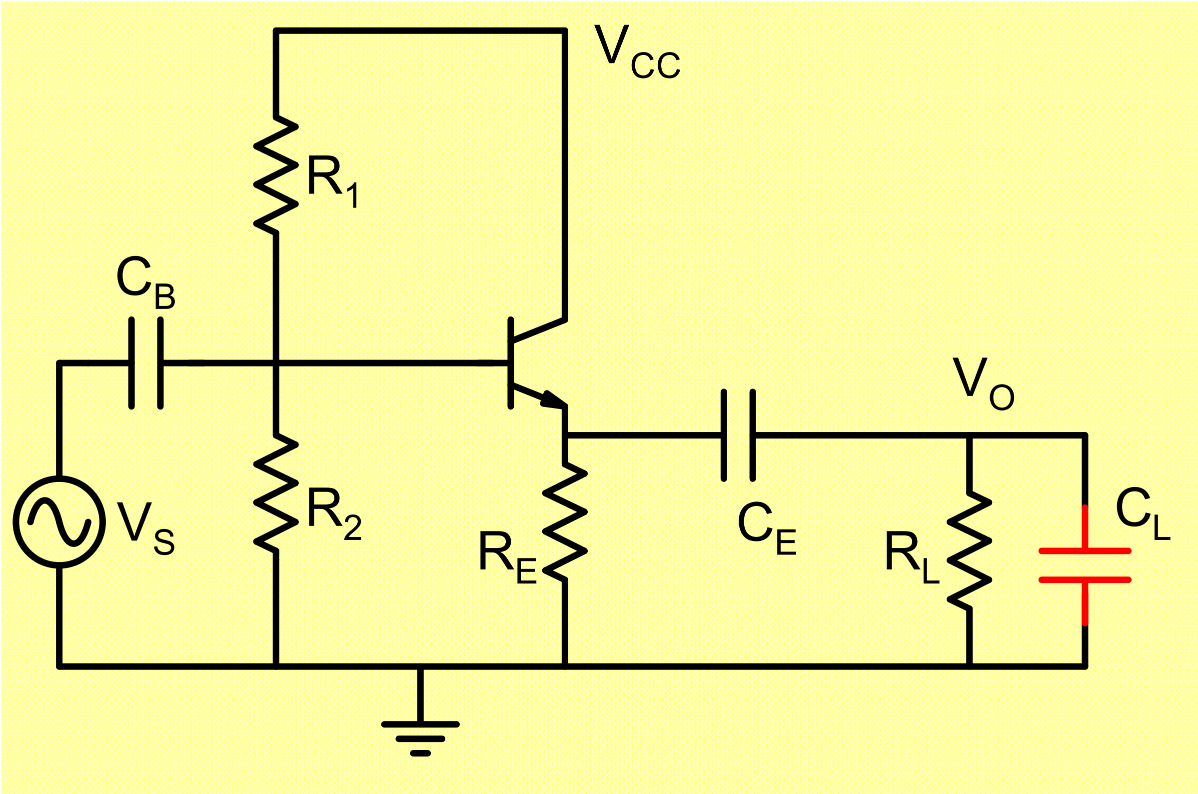
$$H(s) \cong \frac{1 + \frac{C_\pi}{g_m} s}{1 + (R'_S C_\mu + \frac{C_\pi}{g_m}) s + \frac{R'_S}{g_m} C_\pi C_\mu s^2}$$

Besides the pole, there is a zero as well which is very close to the pole resulting in a cancellation effect !

$$f_Z \cong \frac{1}{2\pi \times \frac{C_\pi}{g_m}} = 156 MHz$$

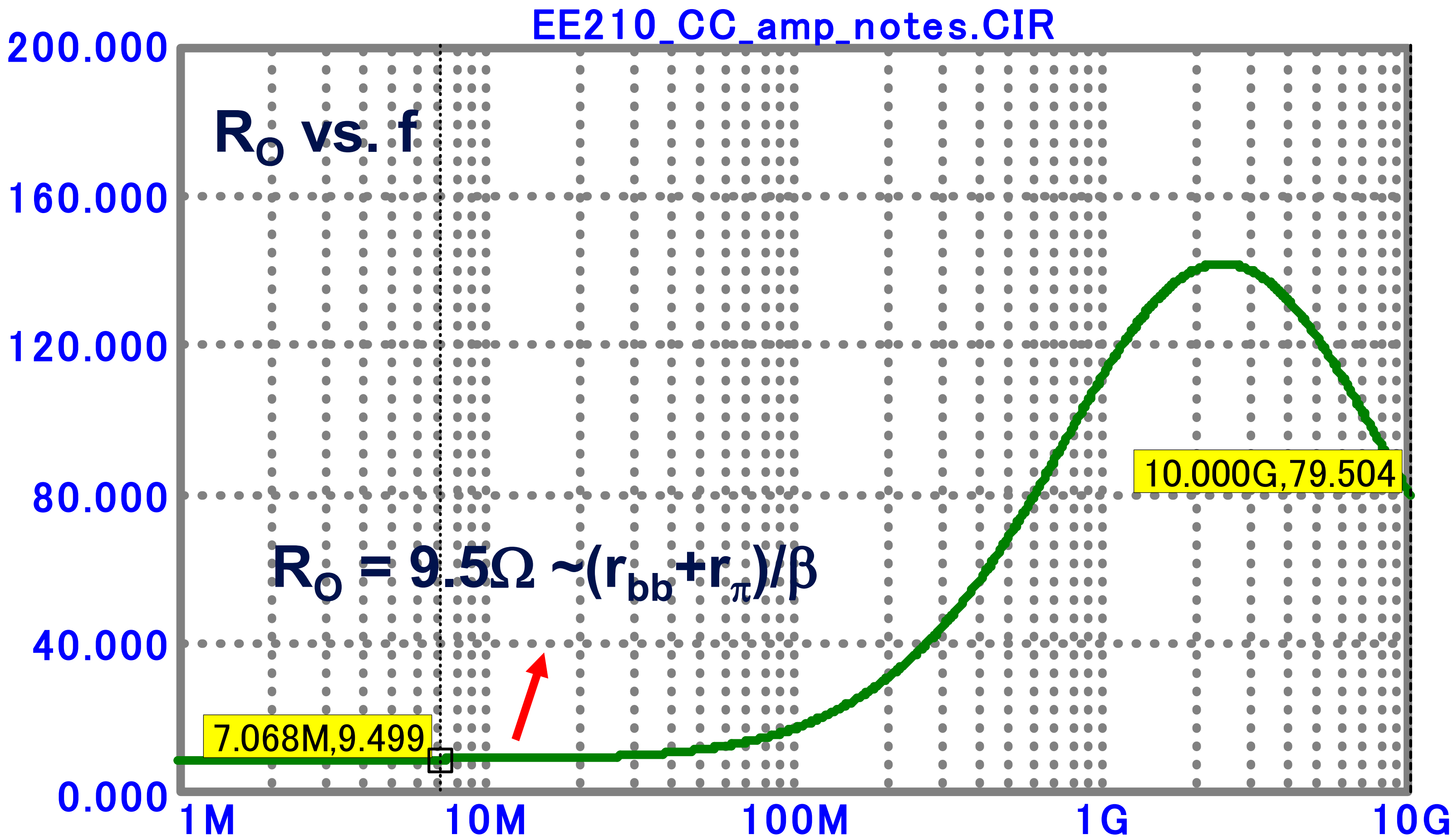
$$f_H \cong \frac{1}{2\pi \times R'_S C_\mu} = 4.5 GHz$$

Often the frequency response is dominated by the load capacitance



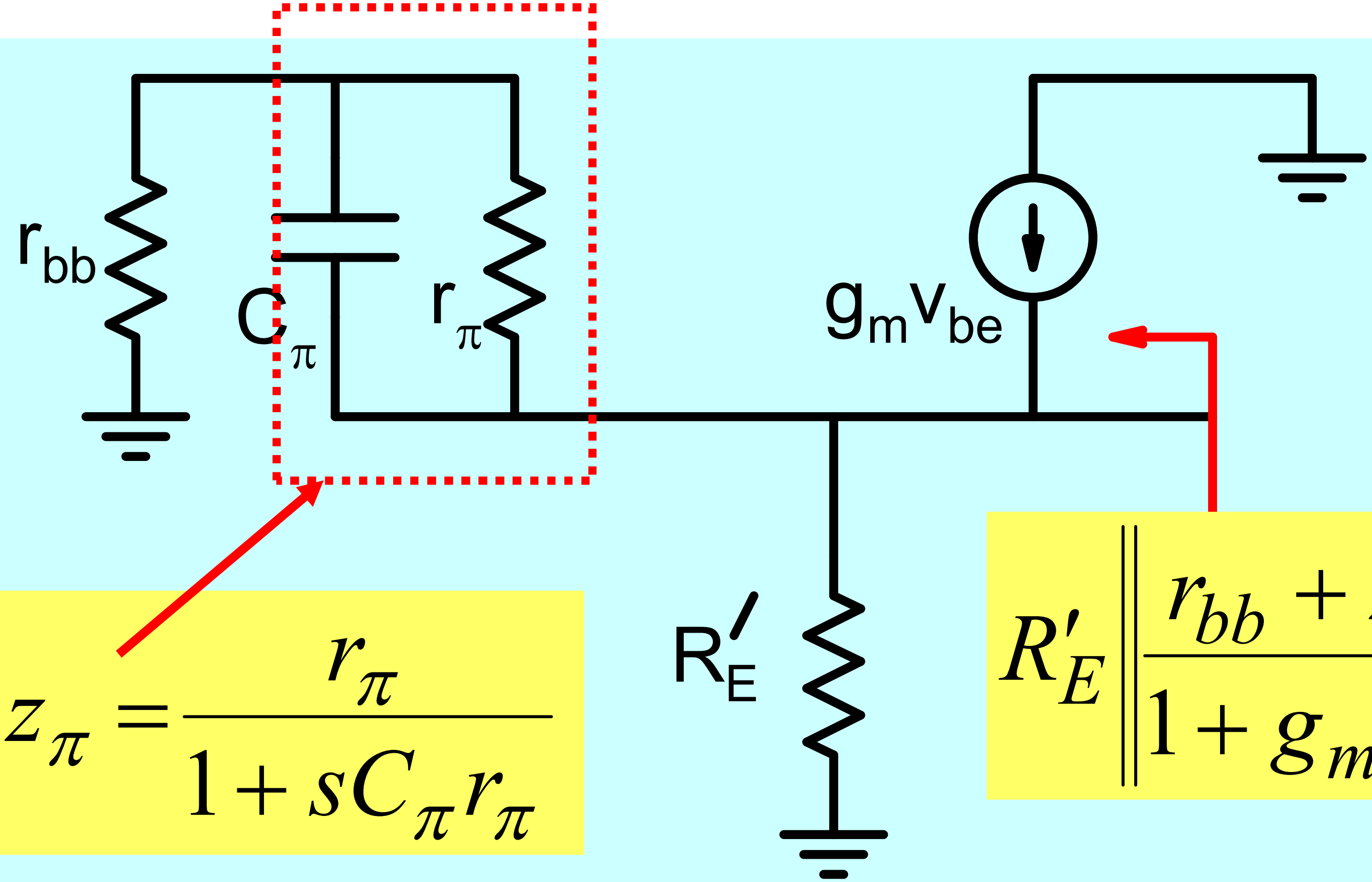
$$f_H \cong \frac{1}{2\pi \times (r_{bb} C_\mu + \dfrac{C_\pi}{g_m} + R_O \| R_L \times C_L)}$$

Output Resistance: Frequency response



	Left	Right	Delta	Slope
B v(5)/I(CE)	9.499	79.504	70.004	7.005n
F (Hz)	7.068M	10.000G	9.993G	1.000

Behavior is inductive at higher frequencies



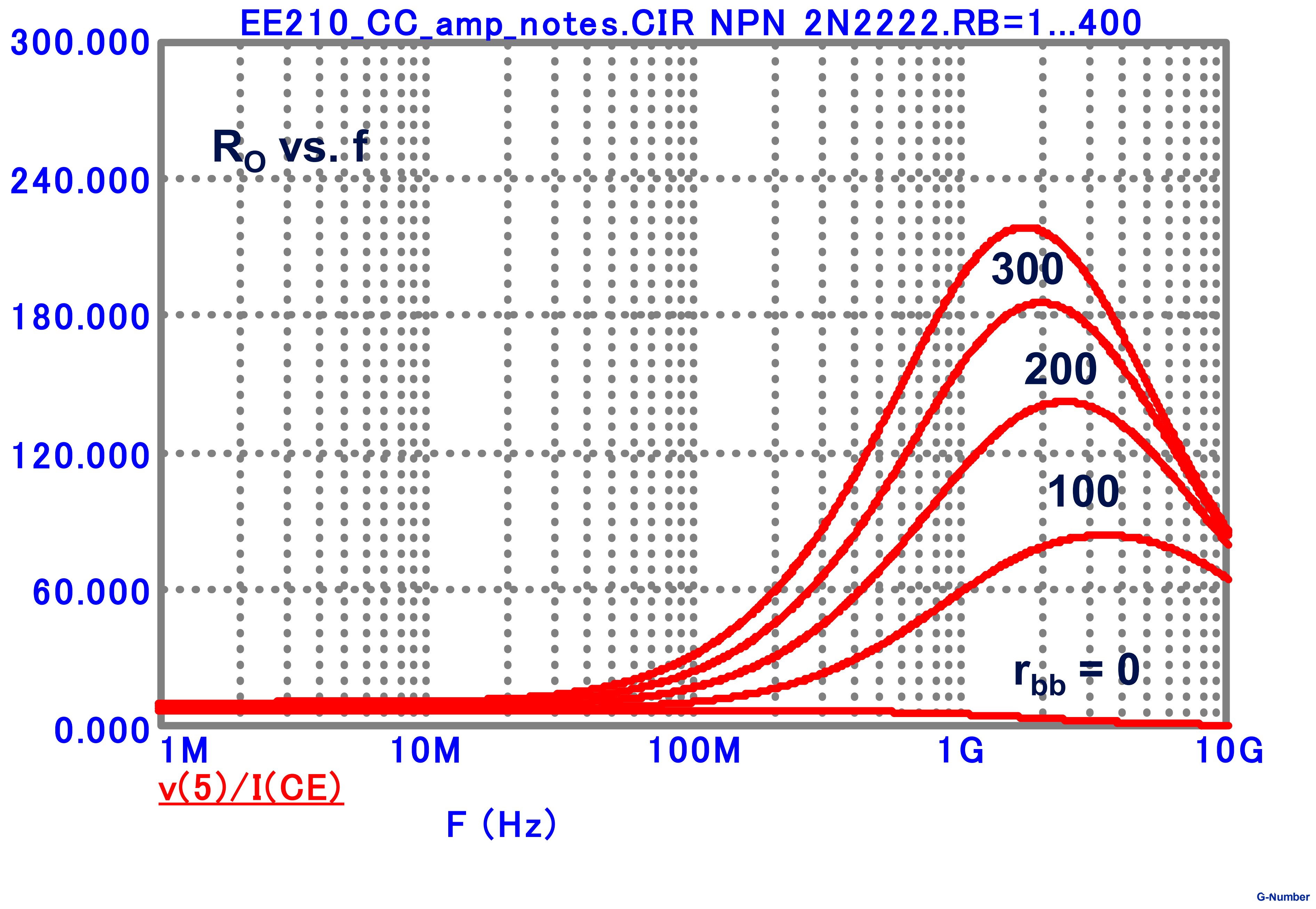
$$z_\pi = \frac{r_\pi}{1 + sC_\pi r_\pi}$$

$$R_E' \,\Big\|\, \frac{r_{bb} + z_\pi}{1 + g_m z_\pi}$$

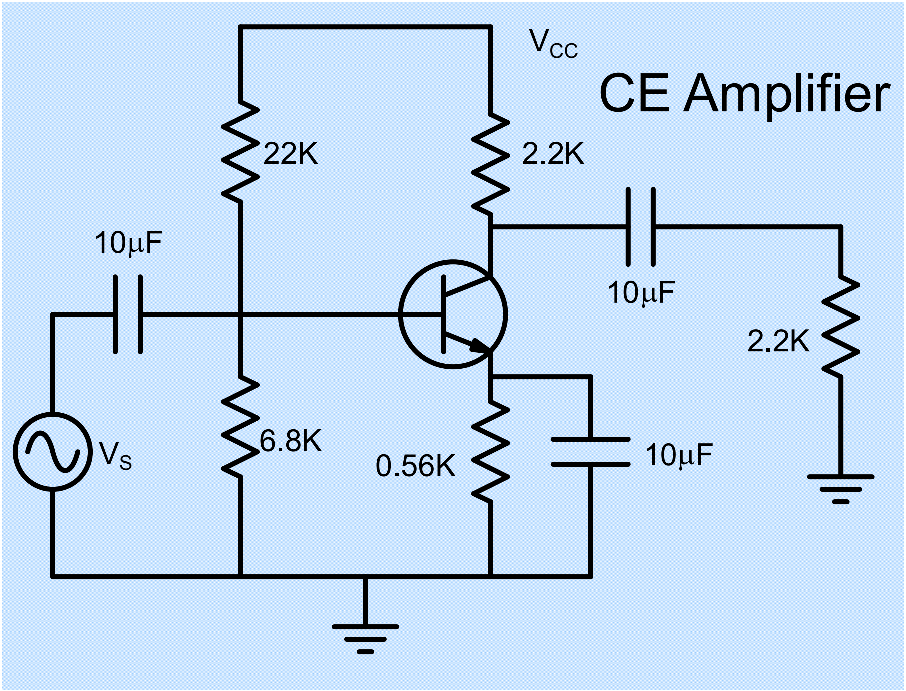
$$z_\pi \cong \frac{1}{sC_\pi}$$

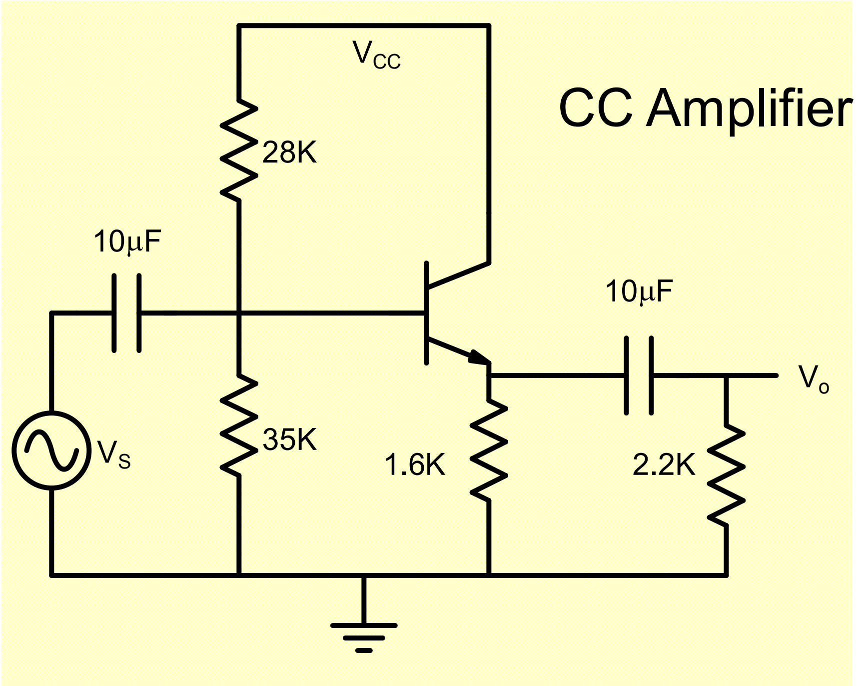
$$R_O \cong \frac{1}{g_m} \times \frac{1 + sr_{bb}C_\pi}{1 + s\dfrac{C_\pi}{g_m}}$$

G-Number


EE210_CC_amp_notes.CIR NPN 2N2222.RB=1...400
R_O vs. f
300
200
100
r_{bb} = 0
300.000
240.000
180.000
120.000
60.000
0.000
1M
10M
100M
1G
10G
v(5)/I(CE)
F (Hz)
G-Number

Summary





$$\beta = 100$$

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

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

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

$$f_L = 1.67kHz; f_H = 5.8MHz$$

$$\beta = 100$$

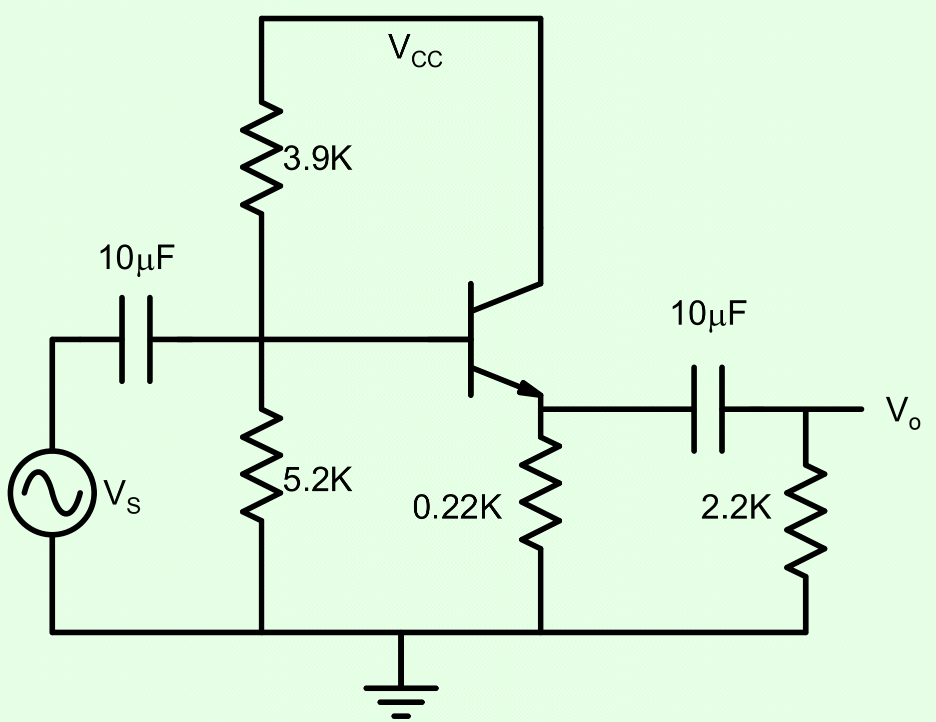
$$I_{CQ} = 3.4mA; V_{CEQ} = 6.5V$$

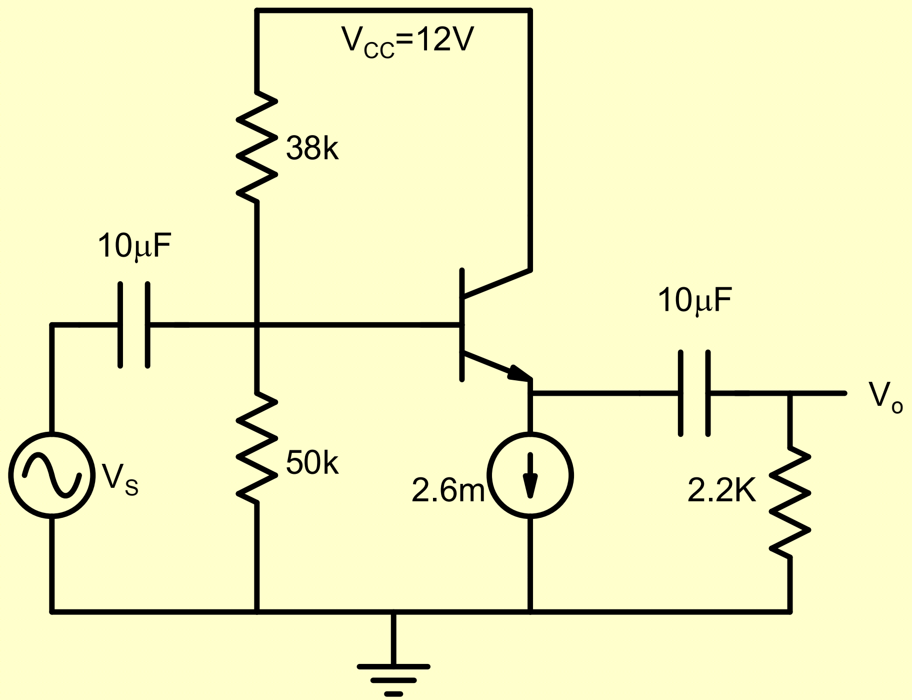
$$A_V = 0.99; R_{in} = 13.4K\,(R_B = 16k); R_O = 9.5\Omega$$

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

$$f_L = 7.6Hz; f_H = 3.1GHz$$

Summary





$$I_{CQ} = 25mA; V_{CEQ} = 6.5V$$

$$A_V = 0.98; R_{in} = 2K; R_O = 3\Omega$$

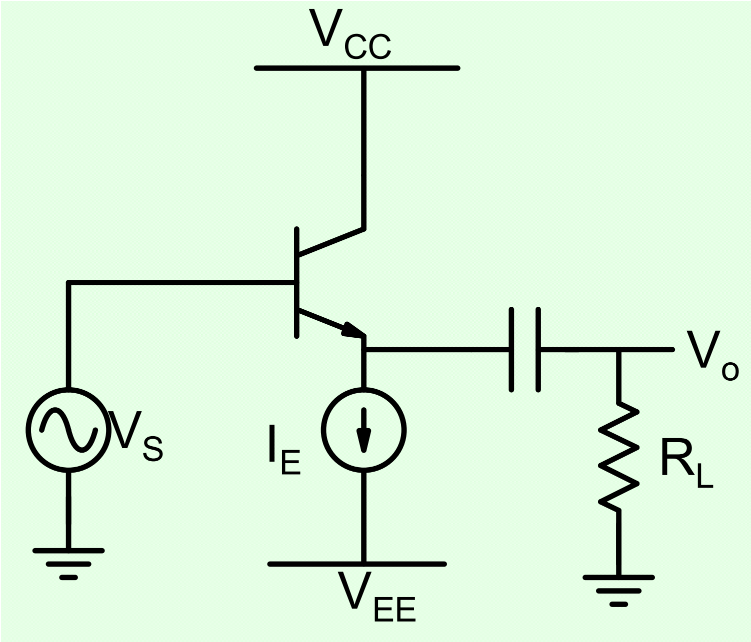
$$V_{om} = 6V$$

$$I_{CQ} = 2.6mA; V_{CEQ} = 6.5V$$

$$A_V = 0.99; R_{in} = 19.7K; R_O = 9.5\Omega$$

$$V_{om} = 6V$$

Power Gain



$$P_{in} = \frac{v_S^2}{2R_{in}}$$

$$P_o = \frac{v_O^2}{2R_L}$$

Noting that $v_O \sim v_S$

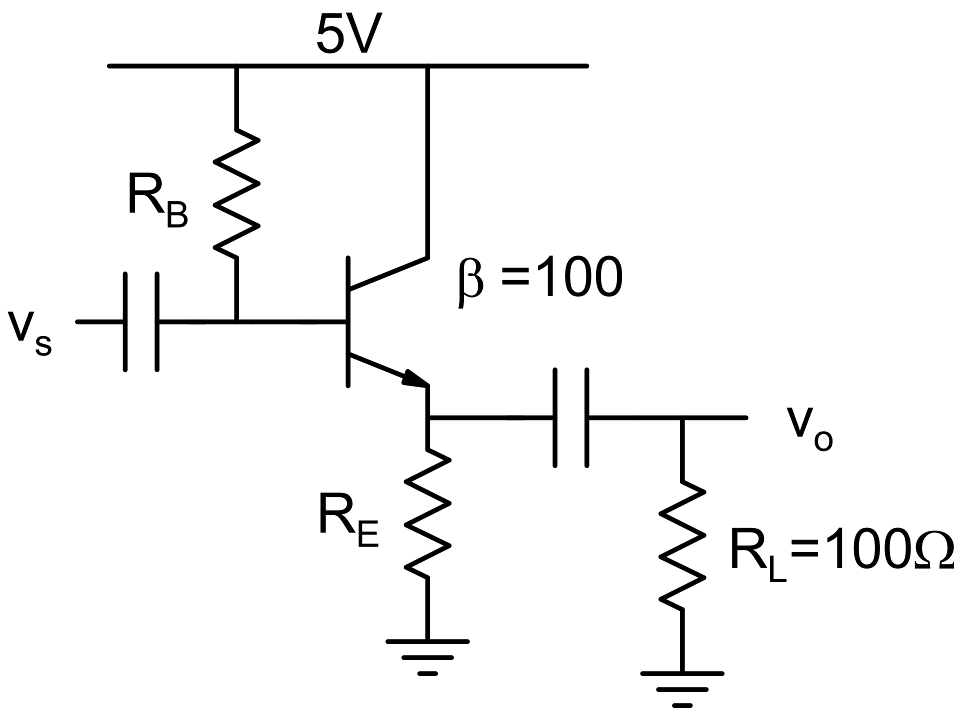
$$\frac{P_o}{P_{in}} \cong \frac{R_{in}}{R_L}$$

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

$$\frac{P_o}{P_{in}} \cong \beta$$

Example-1

Determine the values of resistors R_B and R_E to obtain a maximum output voltage swing of 1V.



$$V_O \le I_{CQ} R_E \| R_L$$

$$I_{CQ} \frac{R_E \times R_L}{R_E + R_L} \ge V_O$$

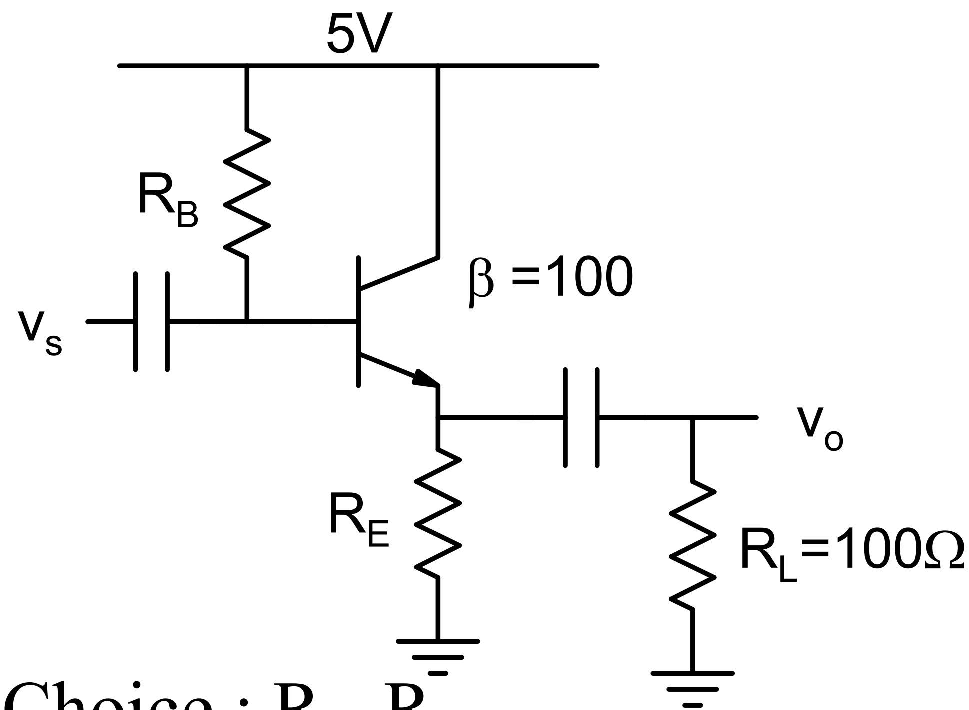
$$V_E \ge V_O \times \left(1 + R_E / R_L\right)$$

$$V_O \le V_{CC} - V_{CEsat} - V_E$$

$$V_E \le V_{CC} - V_{CEsat} - v_o$$

$$V_O \le V_{CC} - V_{BE} - I_{CQ} R_E$$

$$V_E \le V_{CC} - V_{BE} - V_O$$



Choice : R_B, R_E

$$V_E \geq V_O \times \left(1 + R_E / R_L\right)$$

$$V_E \leq V_{CC} - V_{CEsat} - v_o$$

$$V_E \leq V_{CC} - V_{BE} - V_O$$

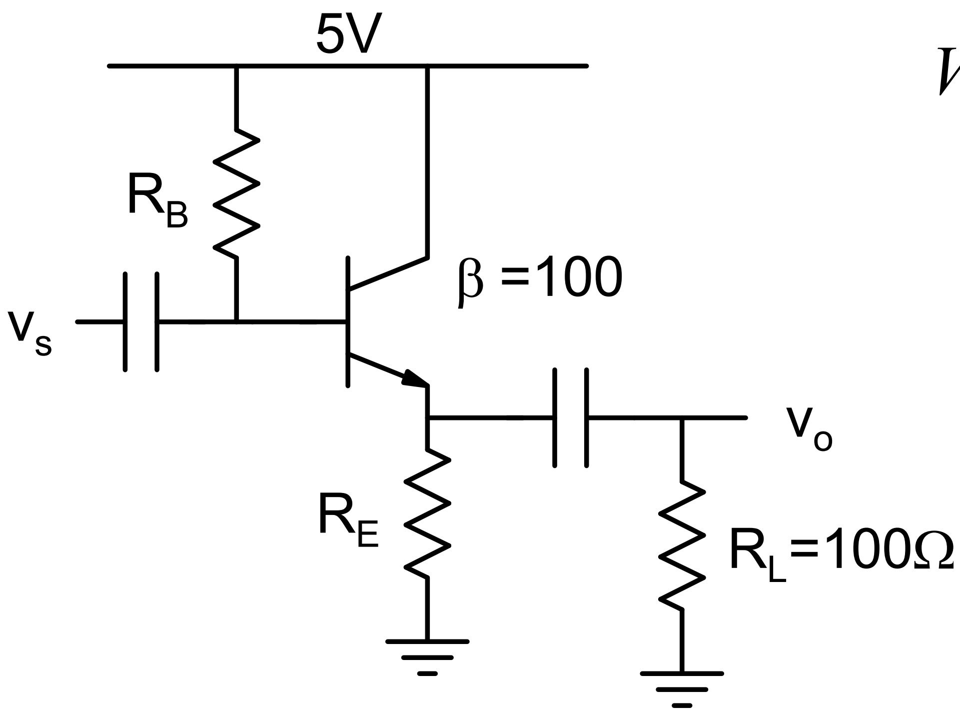
$$I_{CQ} = \frac{V_E}{R_E}$$

Choice : R_E, V_E

G-Number

Example-1

Determine the values of resistors R_B and R_E to obtain a maximum output voltage swing of 1V.



$$V_E \geq V_O \times \left(1 + R_E / R_L\right) = 1 + R_E / R_L$$

$$V_E \leq V_{CC} - V_{BE} - V_O = 3.3V$$

$$I_{CQ} = \frac{V_E}{R_E} \geq \frac{1}{R_E} + \frac{1}{R_L}$$

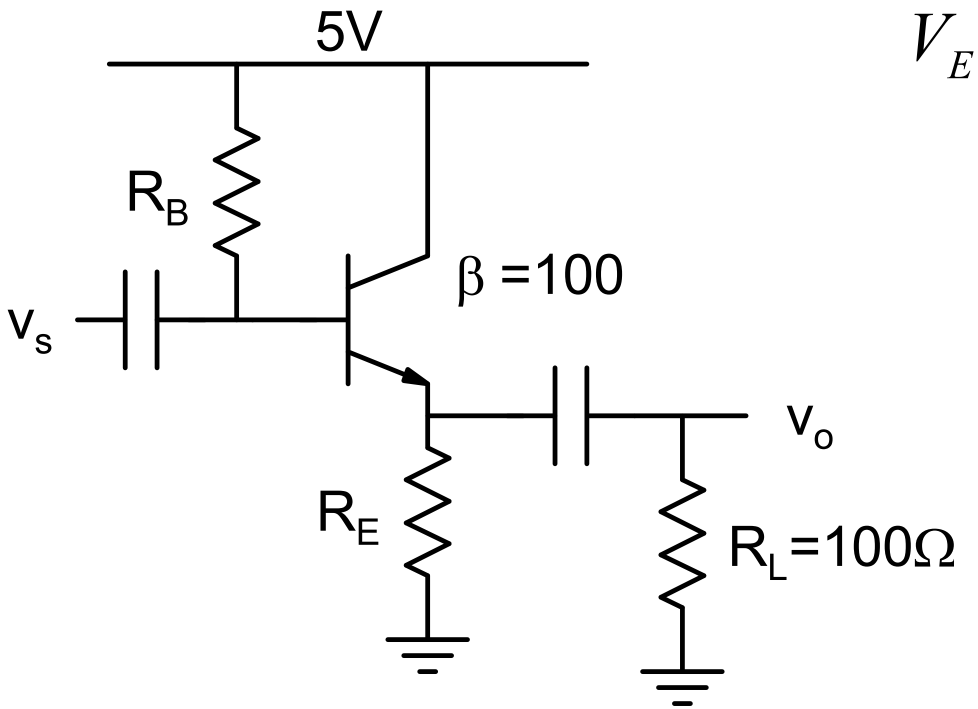
Choose $R_E = 2R_L = 200\Omega$

$V_E = 3.1V$ and $I_{CQ} = 15.5\text{mA}$

$$I_{CQ} = \frac{V_{CC} - 0.7 - V_E}{R_B} \times \beta \Rightarrow R_B = 7.7k\Omega$$

Example-2

Determine the values of resistors R_B and R_E to obtain a maximum output voltage swing of 2V.



$$V_E \geq V_O \times \left(1 + R_E / R_L\right) = 2 + 2R_E / R_L$$

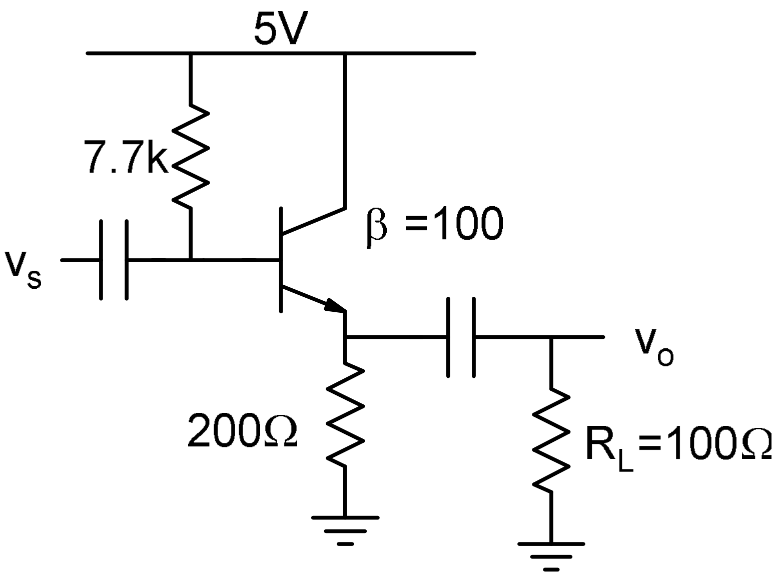
$$V_E \leq V_{CC} - V_{BE} - V_O = 2.3V$$

$$I_{CQ} = \frac{V_E}{R_E} \geq \frac{2}{R_E} + \frac{2}{R_L}$$

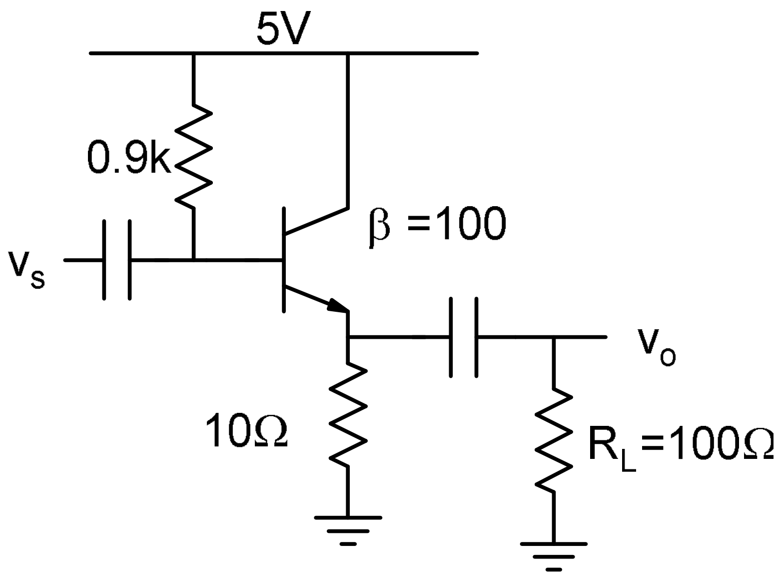
Choose $R_E = 0.1R_L = 10\Omega$

$V_E = 2.25V$ and $I_{CQ} = 225\text{mA}$

$$I_{CQ} = \frac{V_{CC} - 0.7 - V_E}{R_B} \times \beta \Rightarrow R_B = 0.9k\Omega$$



$$I_{CQ} = 15.5\text{mA}; V_O = 1V$$



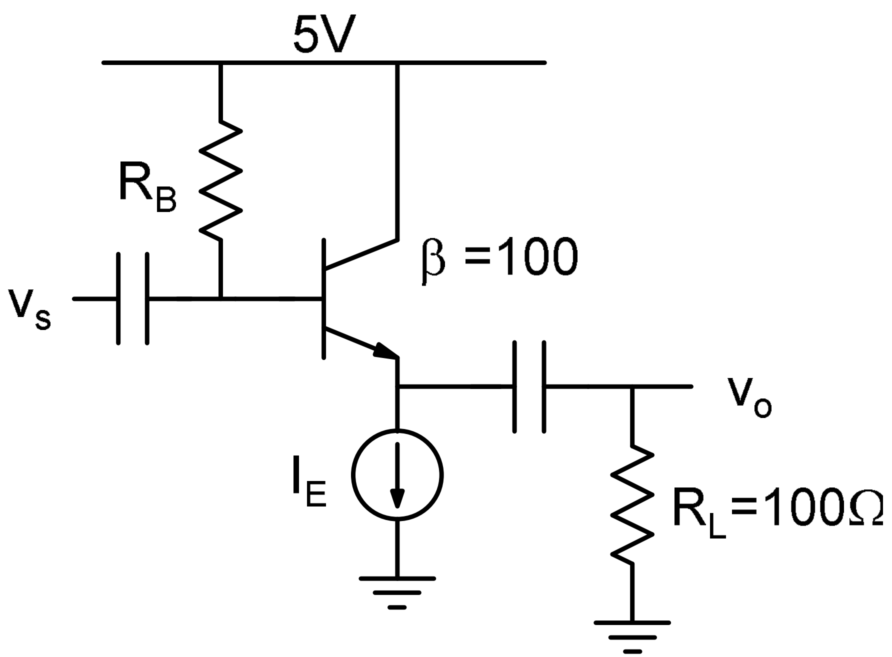
$$I_{CQ} = 225\text{mA}; V_O = 2V$$

$$V_O = 2V \Rightarrow P_L = 20mW$$

$$P_S = V_{CC} \times I_{CQ} = 1.1W \Rightarrow \eta = \frac{P_L}{P_S} = 1.8\%$$

Example-3

Determine the values of resistors R_B and R_E to obtain a maximum output voltage swing of 2V.



$$I_E \geq \frac{V_O}{R_L} = 20mA$$

$$V_E \leq V_{CC} - V_{BE} - V_O = 2.3V$$

$$V_E \geq V_O = 2.0V$$

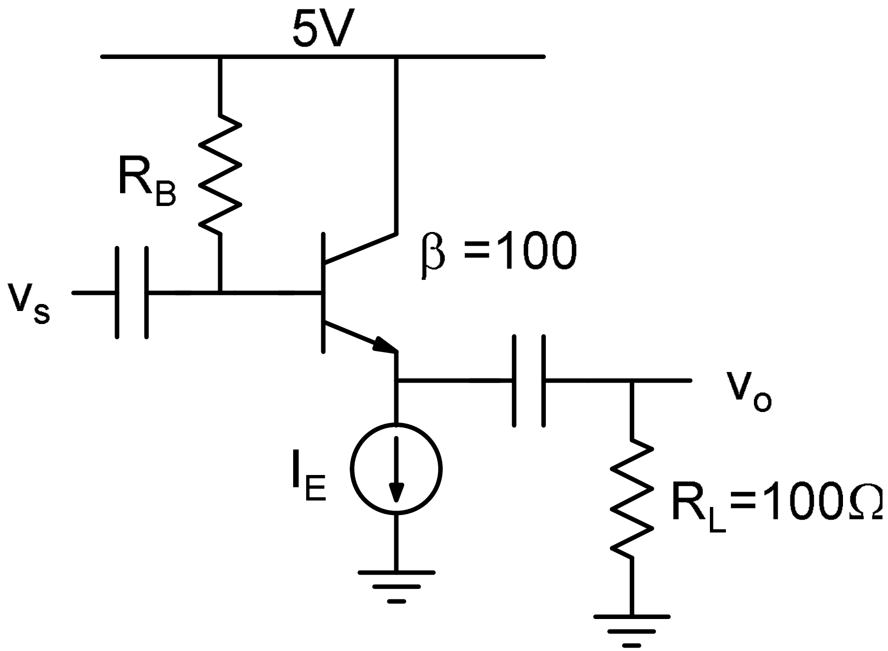
$$\text{Choose } I_E = 22\text{mA}$$

$$V_E = 2.1V$$

$$I_{CQ} = \frac{V_{CC} - 0.7 - V_E}{R_B} \times \beta \Rightarrow R_B = 9.5k\Omega$$

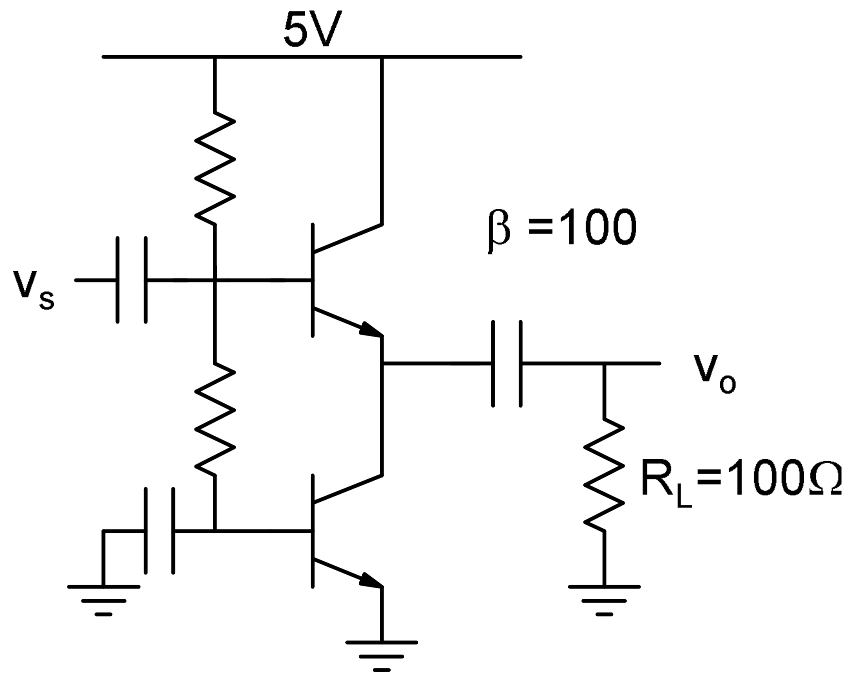
$$V_O = 2V \Rightarrow P_L = 20mW$$

$$P_S = V_{CC} \times I_{EQ} = 110mW \Rightarrow \eta = \frac{P_L}{P_S} = 18\%$$



Choose $I_E = 22mA$

$V_E = 2.1V$



Choose $I_E = 22mA$

$V_E = 2.5V$