EE210: Microelectronics-I

Lecture-23 :Common Base Amplifier-1

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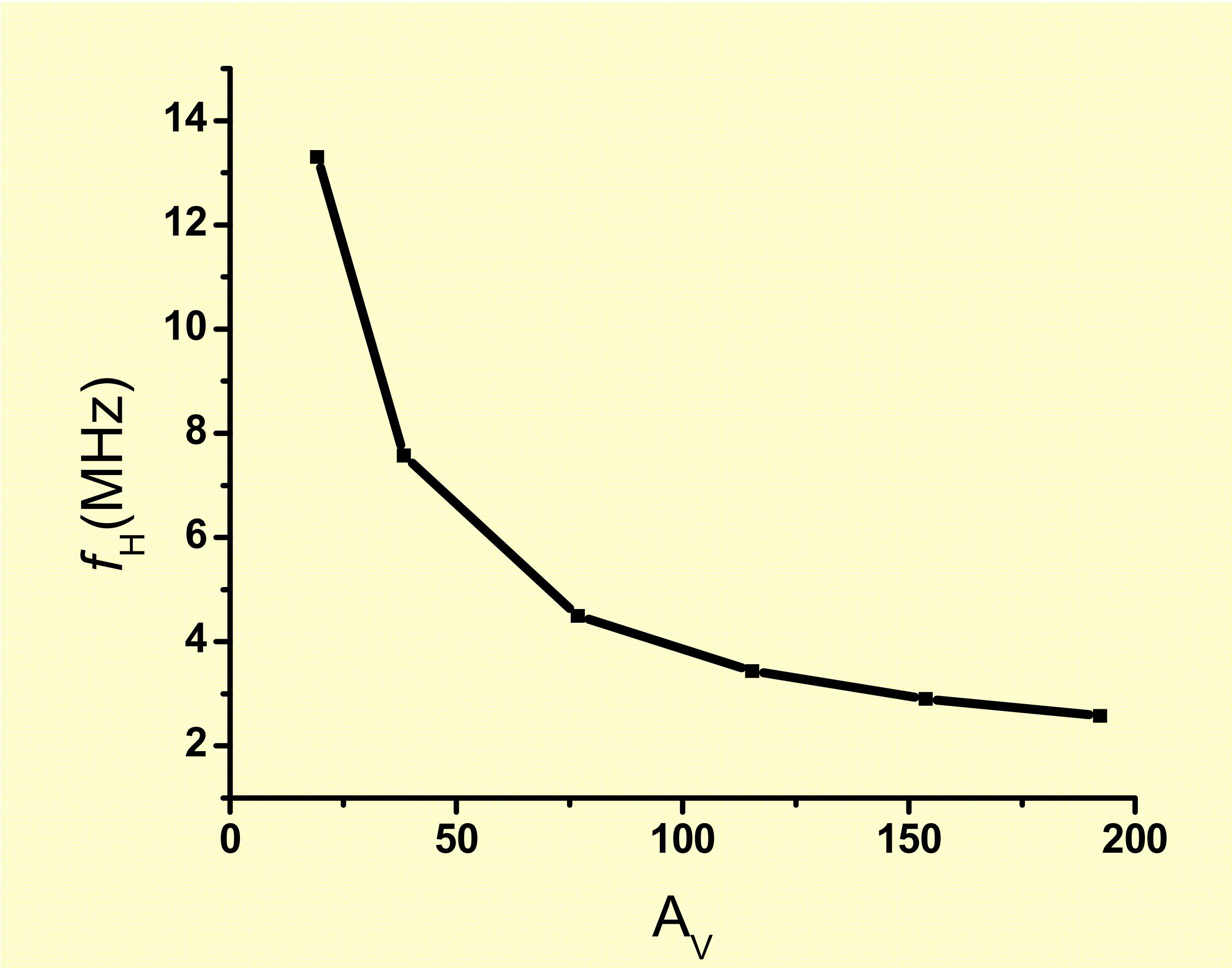
Outline

- ❑ Voltage Gain, Input and Output Resistance, current gain
- ❑ Comparison with CE amplifier
- ❑ Frequency response
- ❑ Cascode amplifier

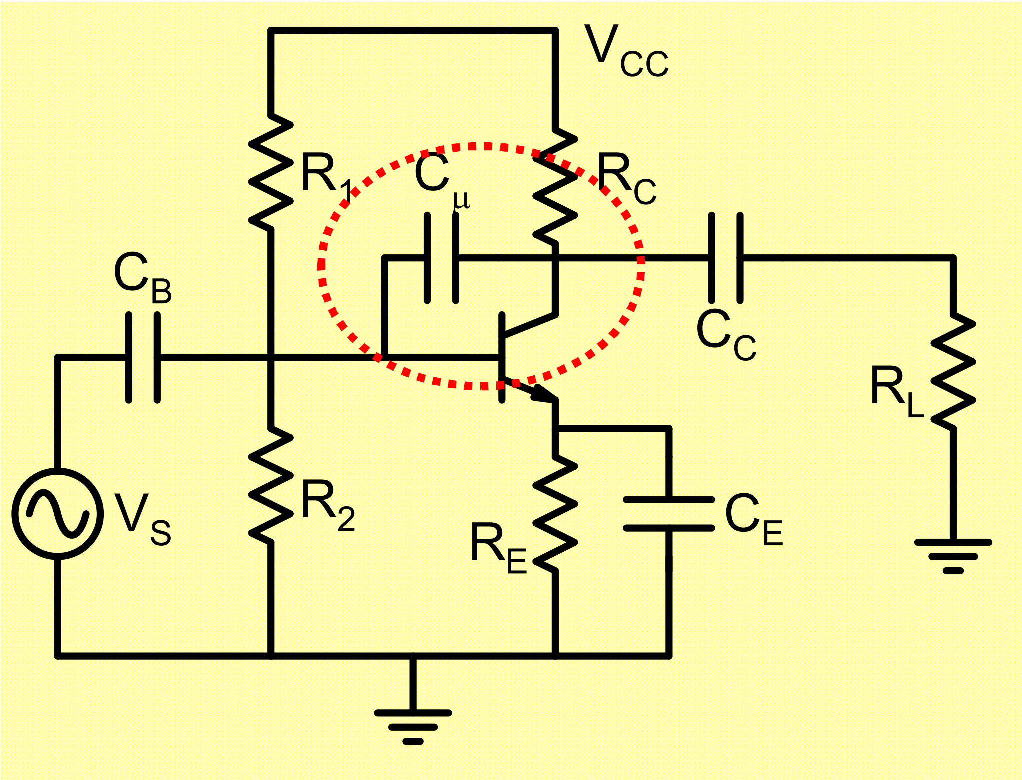
Common Base Amplifier

Why do we need another amplifier when we have a CE amplifier?

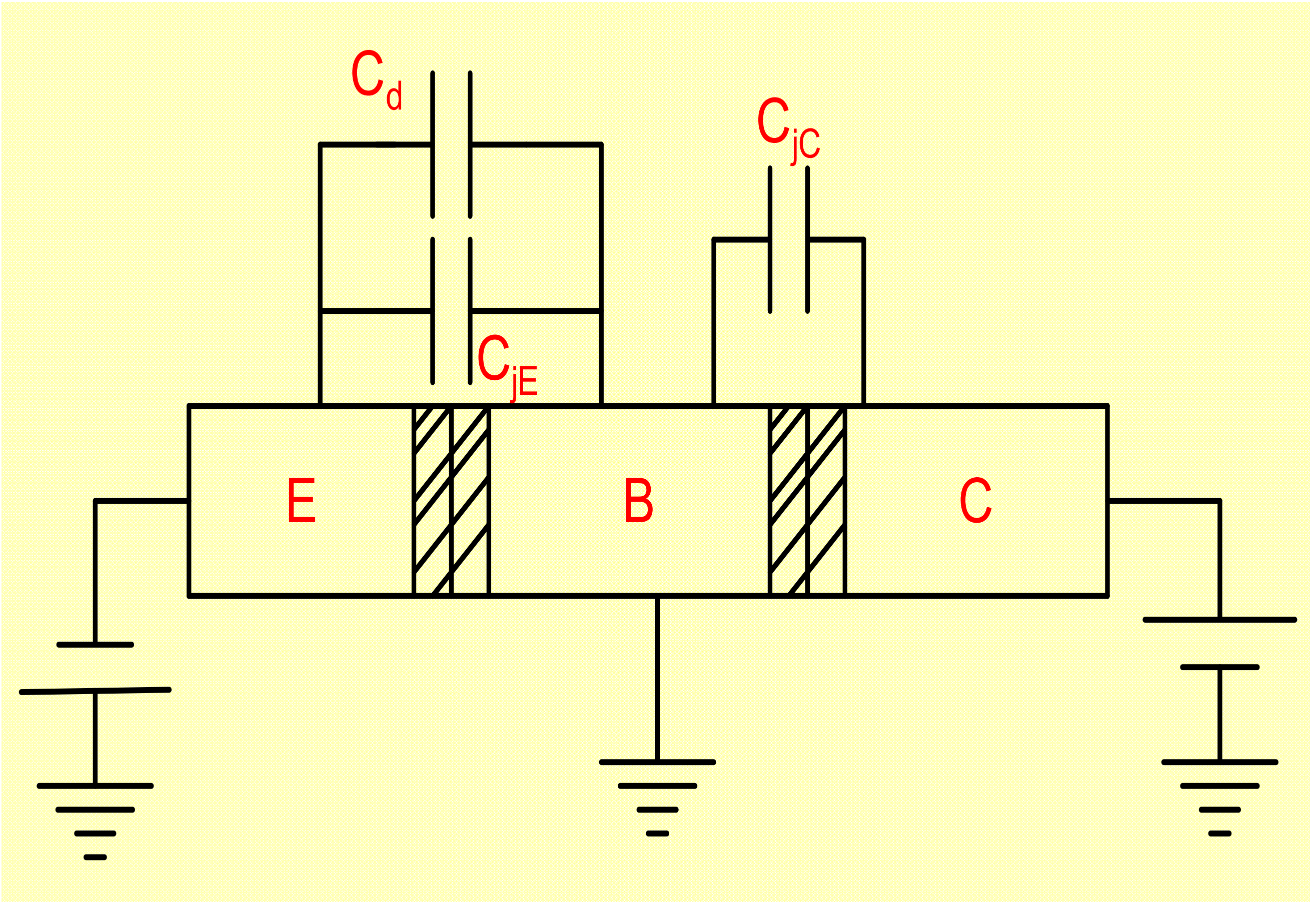


Problem: Miller's capacitance reduces bandwidth at high gain

$$\omega_H \cong \frac{1}{(R'_S \| r_\pi)\{C_\pi + C_\mu(1+g_m R'_C)\} + R'_C C_\mu}$$

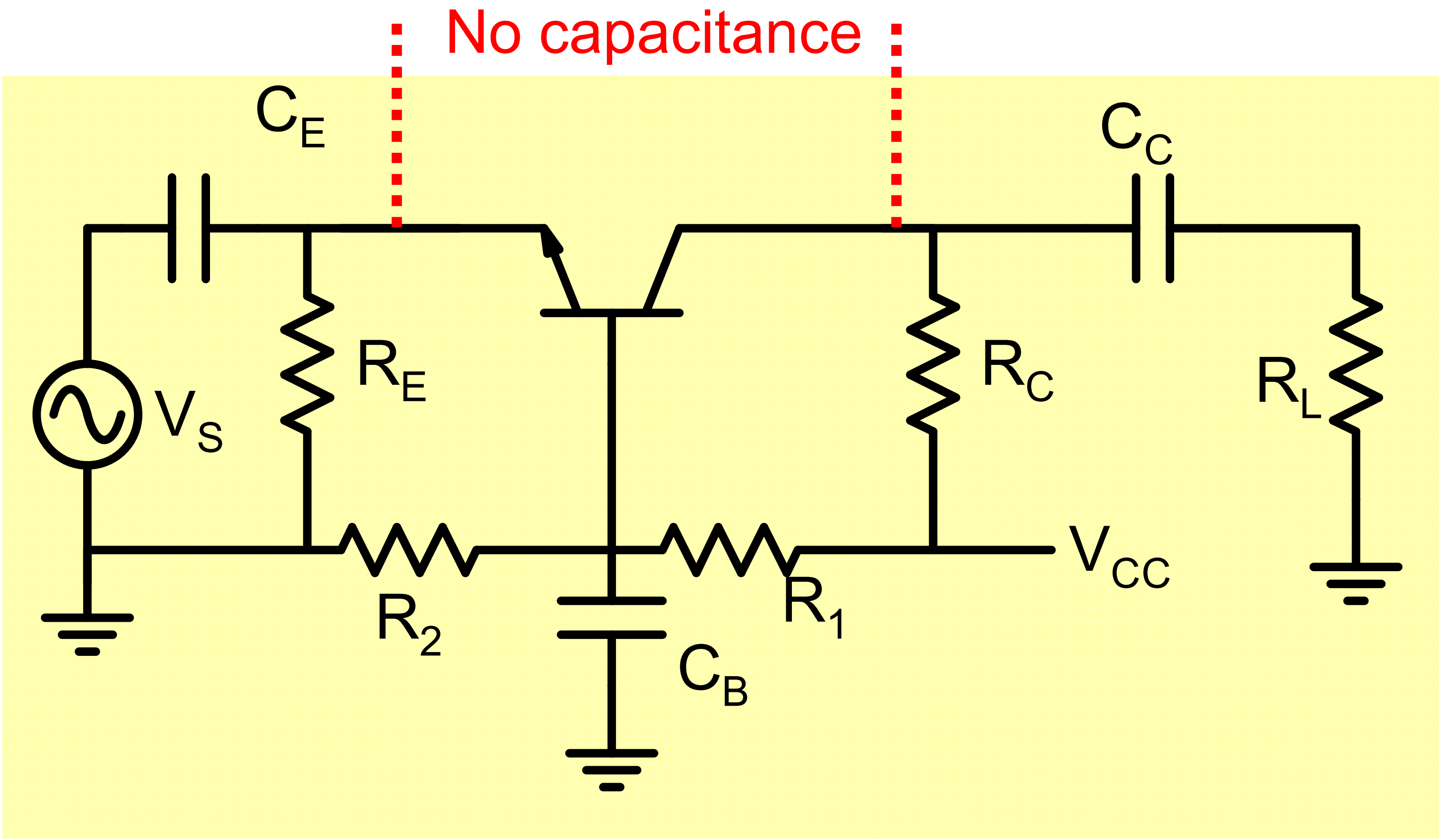


Look for an amplifier circuit in which there is no capacitance between input and output ports

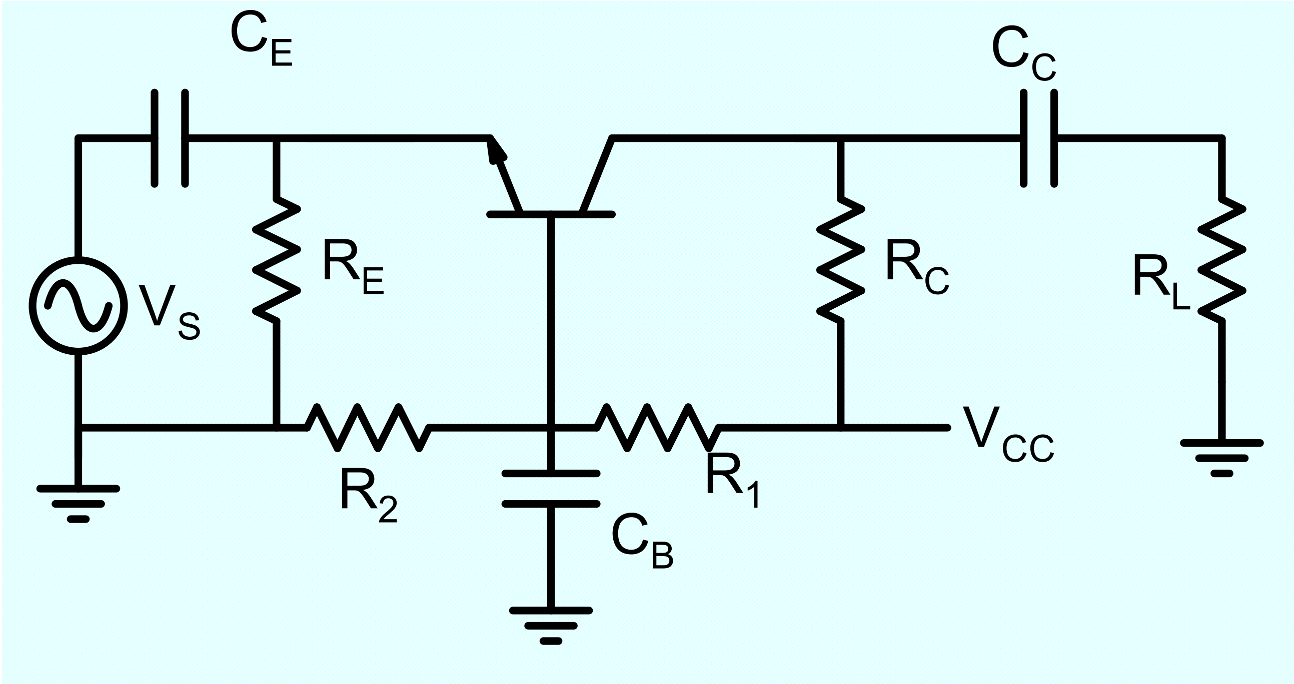


Note that there is no capacitance between emitter and collector

Natural solution is a Common Base (CB) Amplifier



dc Analysis

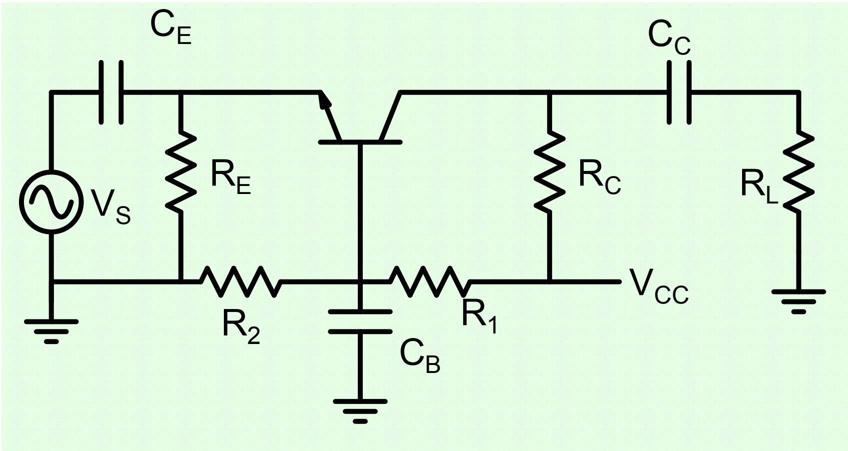


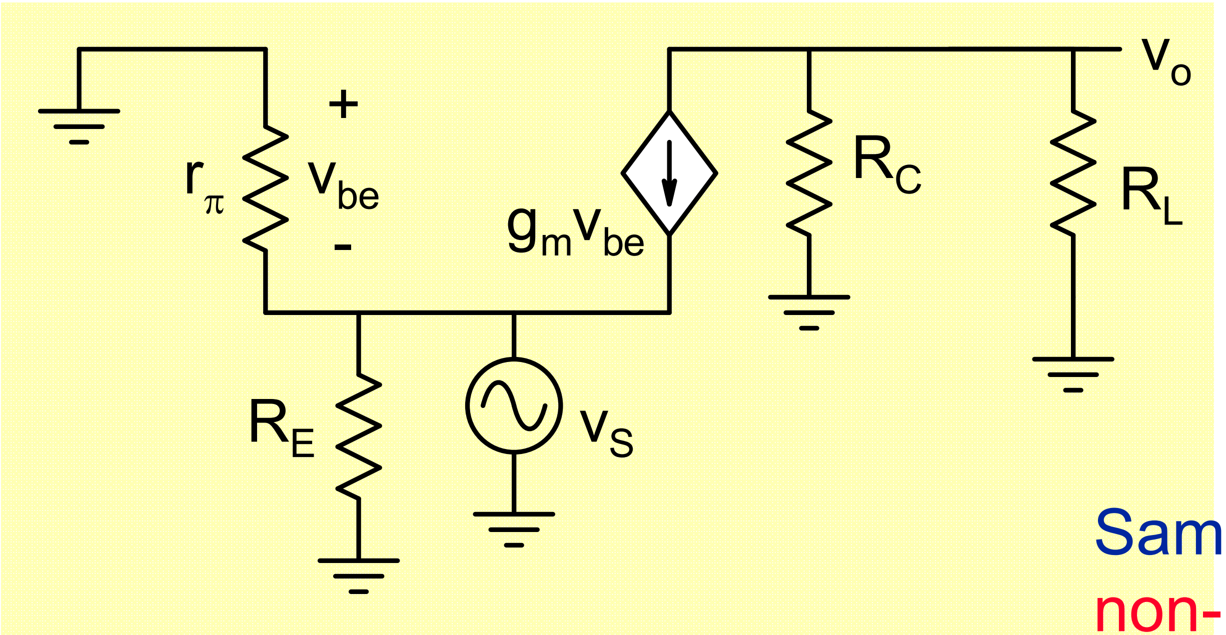
$$I_{CQ} = \frac{V_{CC}\dfrac{R_2}{R_1 + R_2} - V_{BE}(on)}{\dfrac{R_B}{\beta} + R_E}$$

$$V_{CC} = V_{CEQ} + I_{CQ}(R_C + R_E)$$

$$S = \frac{\Delta I_{CQ} / I_{CQ}}{\Delta\beta / \beta} = \frac{1}{1 + \dfrac{\beta R_E}{R_B}}$$

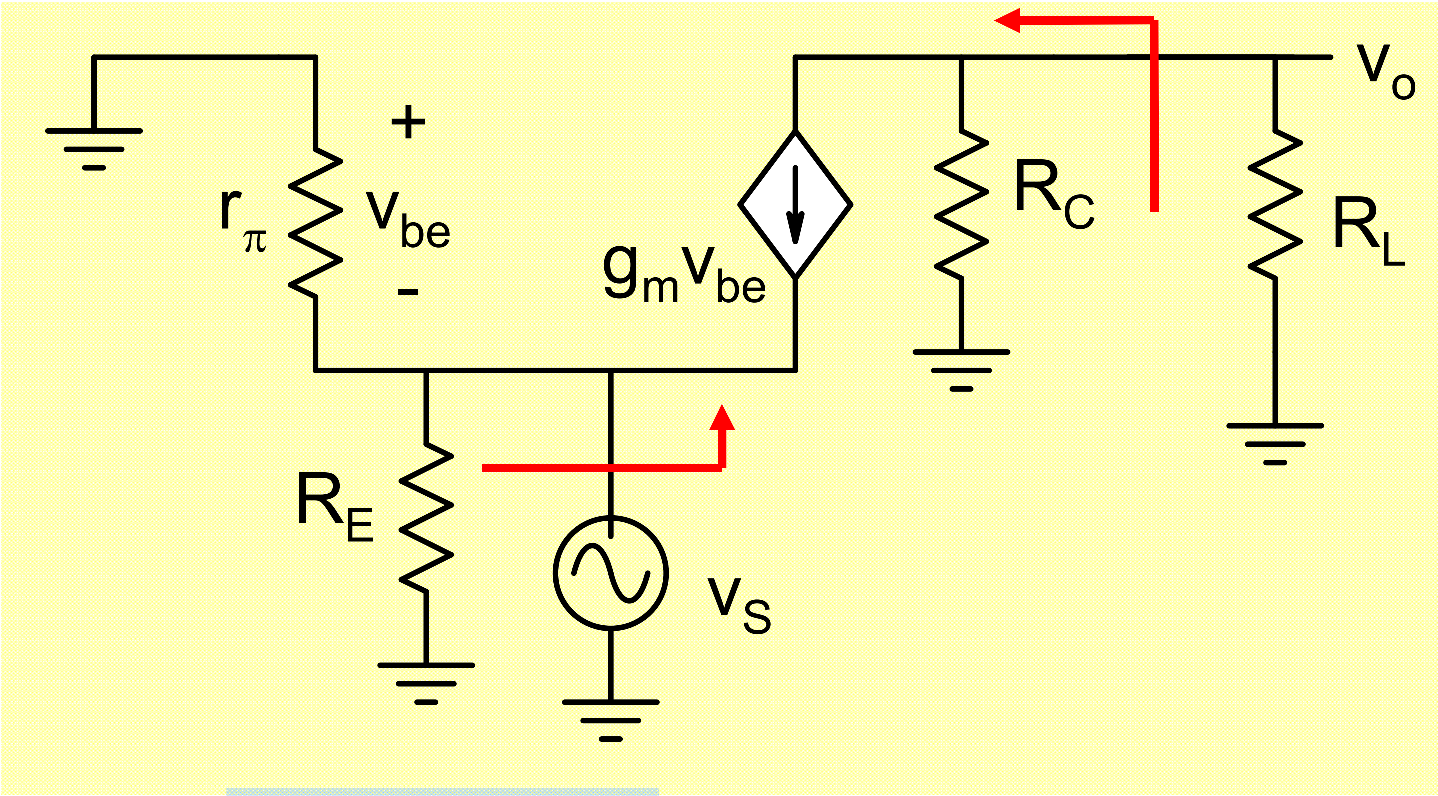
Mid-frequency small signal analysis





$$A_V = +\frac{I_{CQ}}{V_T} \times R_C \| R_L$$

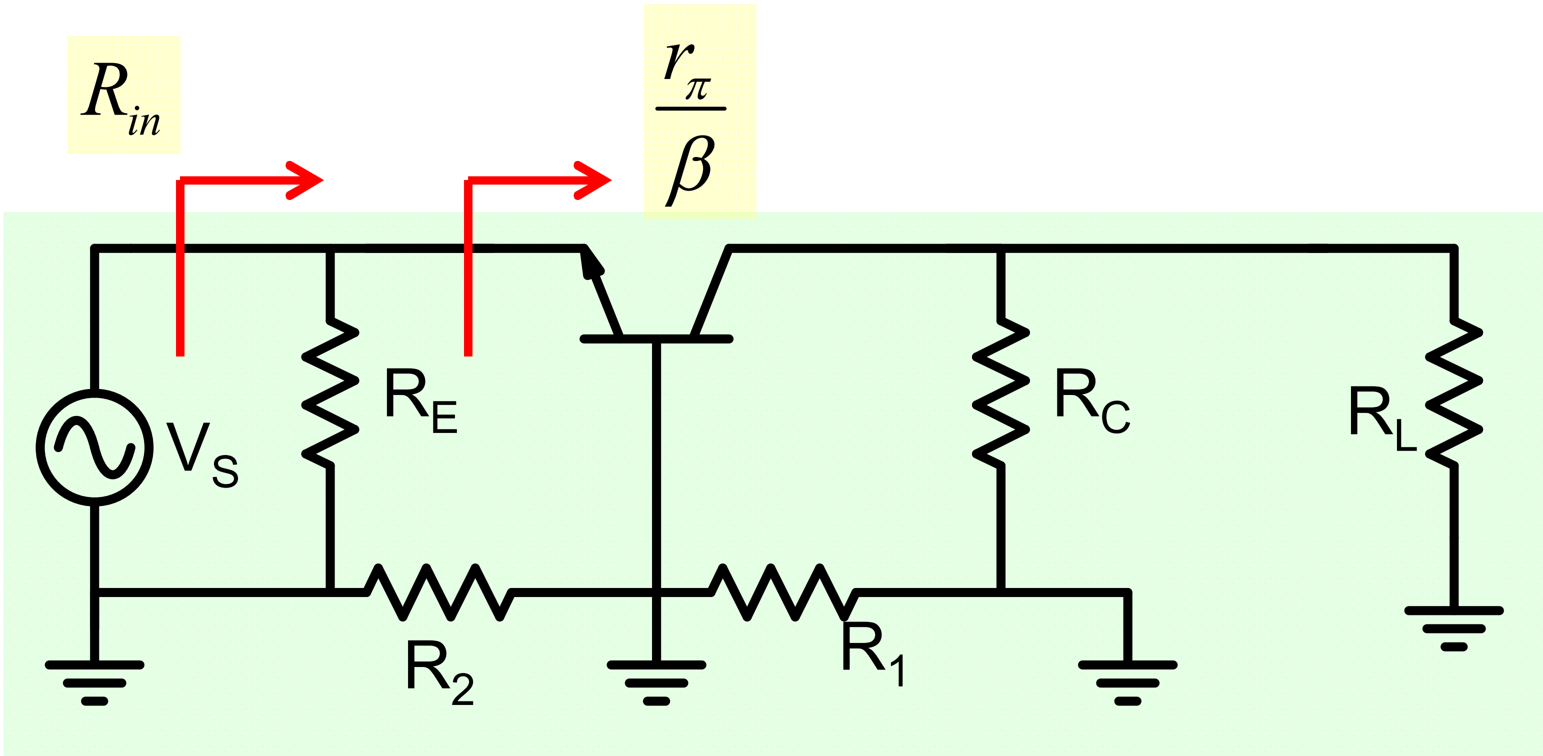
Same as CE amplifier but non-inverting



$$R_{in} \cong \frac{r_\pi}{\beta} \| R_E$$

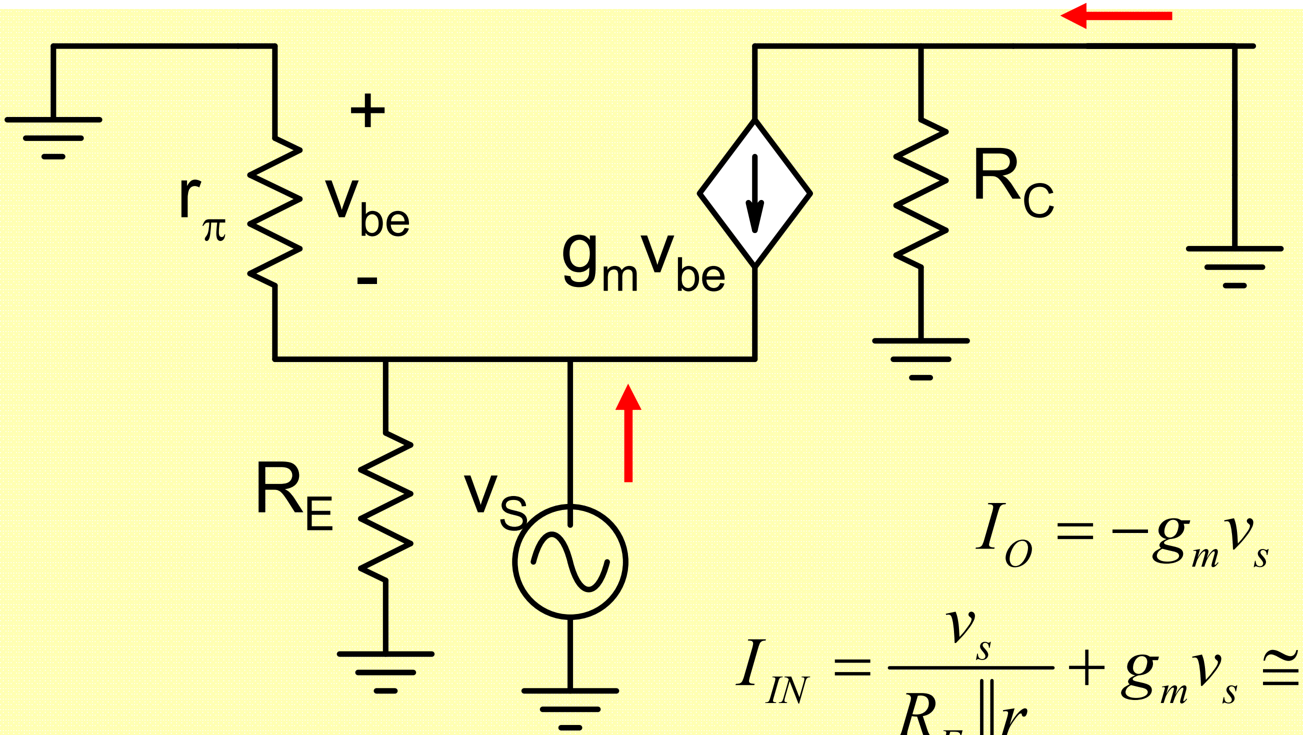
$$R_o = R_C$$

Voltage swing is same as CE amplifier



$$R_{in} \cong \frac{r_\pi}{\beta} \| R_E$$

Short Circuit Current Gain



$$I_O = -g_m v_s$$

$$I_{IN} = \frac{v_s}{R_E \| r_\pi} + g_m v_s \cong v_s(g_m + \frac{1}{r_\pi})$$

$$A_{IS} = \frac{I_O}{I_{IN}} \cong -\frac{\beta}{\beta + 1}$$

$$A_V = \frac{I_{CQ}}{V_T} \times R_C \| R_L$$

$$R_{in} \cong \frac{r_\pi}{\beta} \| R_E$$

$$R_o = R_C$$

$$R_{in} < \frac{r_\pi}{\beta} = \frac{V_T}{I_{CQ}}$$

$$A_V < \frac{I_{CQ}}{V_T} \times R_C$$

$$\frac{A_V \times R_{in}}{R_O} \le 1$$

Tradeoff between voltage gain, input and output resistances

100 .01K

$$\frac{A_V \times R_{in}}{R_O} \leq 1$$

1K

Parameter	Voltage Gain	Input Resistance	Output Resistance
Value	High	Low	Medium

Amplifier	Voltage Gain	Input Resistance	Output Resistance
CE	High	**Medium**	Medium
CB	High	**Low**	Medium

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

$$\frac{A_V \times R_{in}}{R_O} \leq 1$$

A better Comparison with CE amplifier

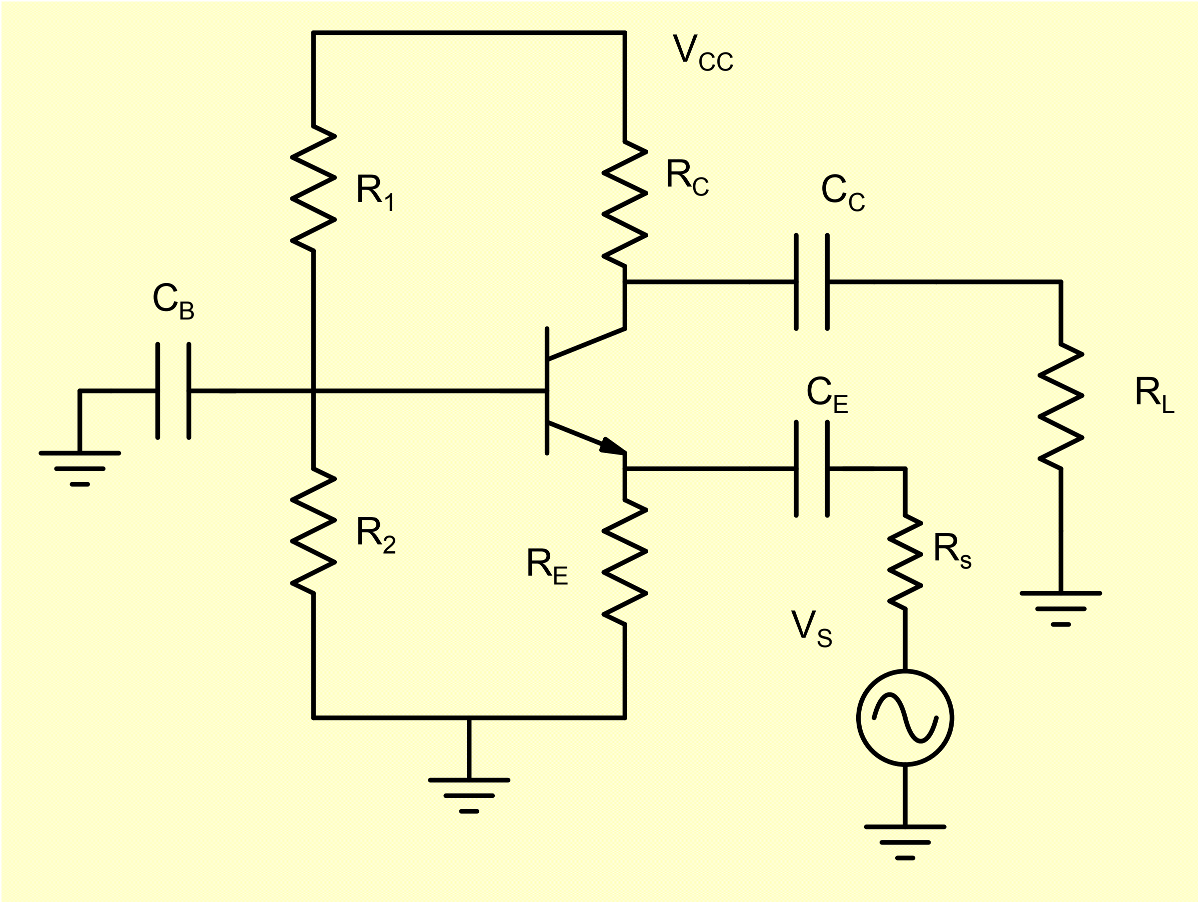
$$\frac{A_V(CB) \times R_{in}(CB)}{R_O(CB)} \sim 1$$

$$\frac{A_V(CE) \times R_{in}(CE)}{R_O(CE)} \sim \beta$$

$$\frac{A_V(CE)}{A_V(CB)} \times \frac{R_{in}(CE)}{R_{in}(CB)} \times \frac{R_O(CB)}{R_O(CE)} \sim \beta$$

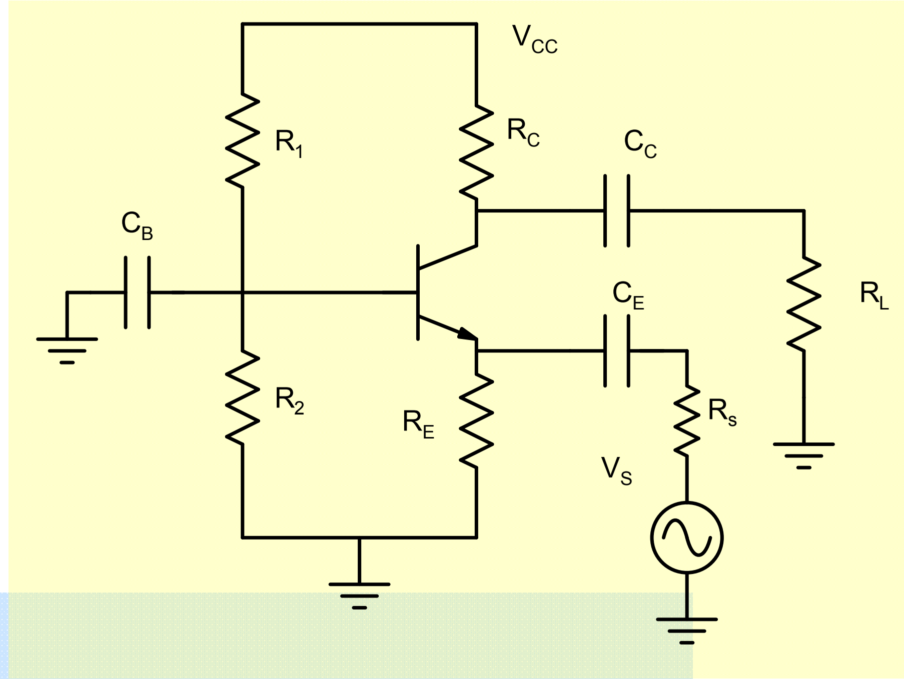
1 1x10^2 1 x10^2 1 x10^2

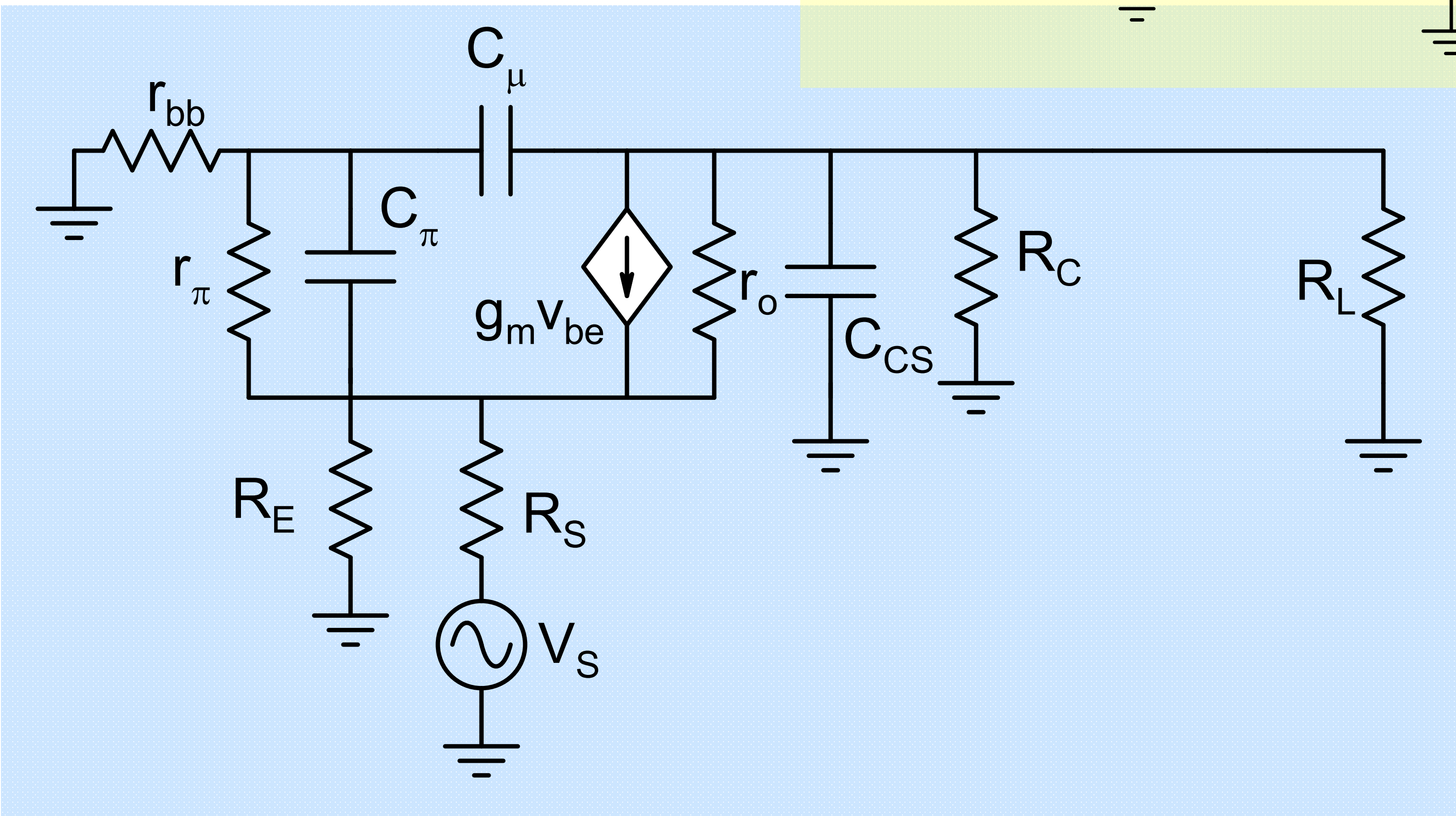
Frequency Response



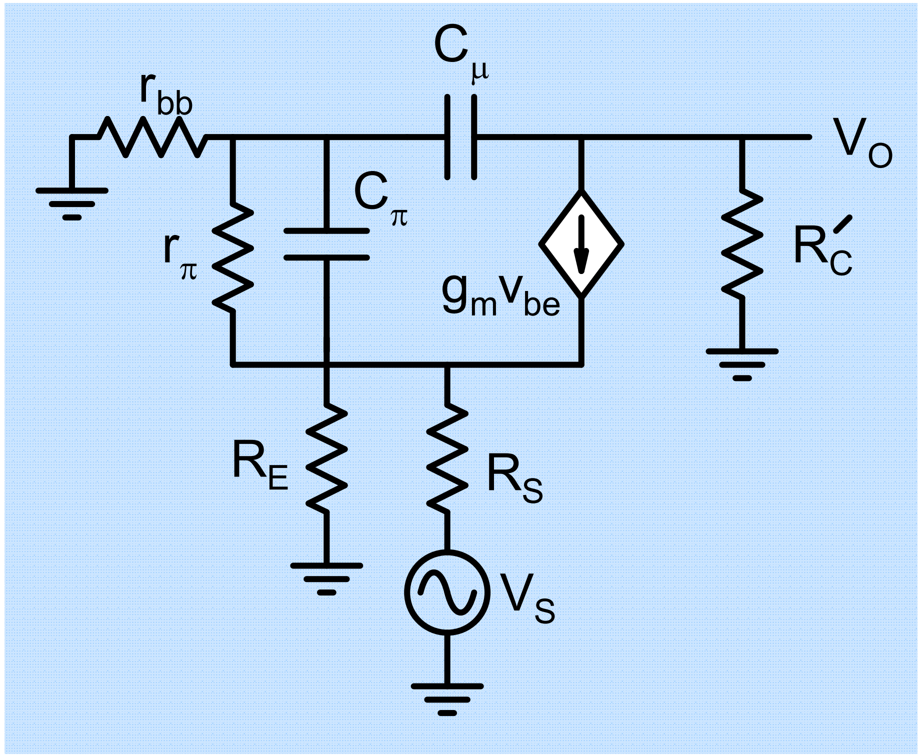
Lower Cutoff frequency is similar to CE amplifier

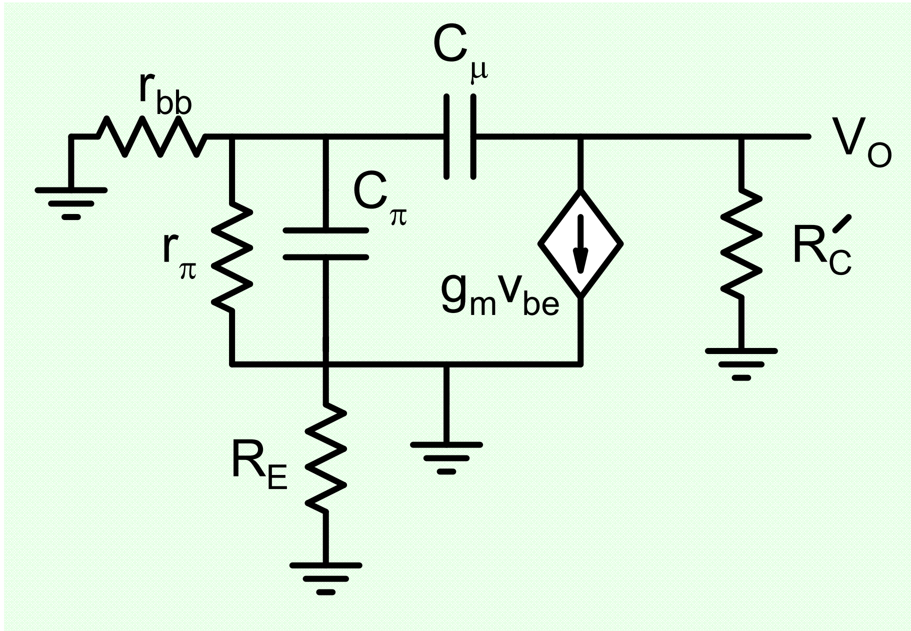
Upper Cutoff Frequency

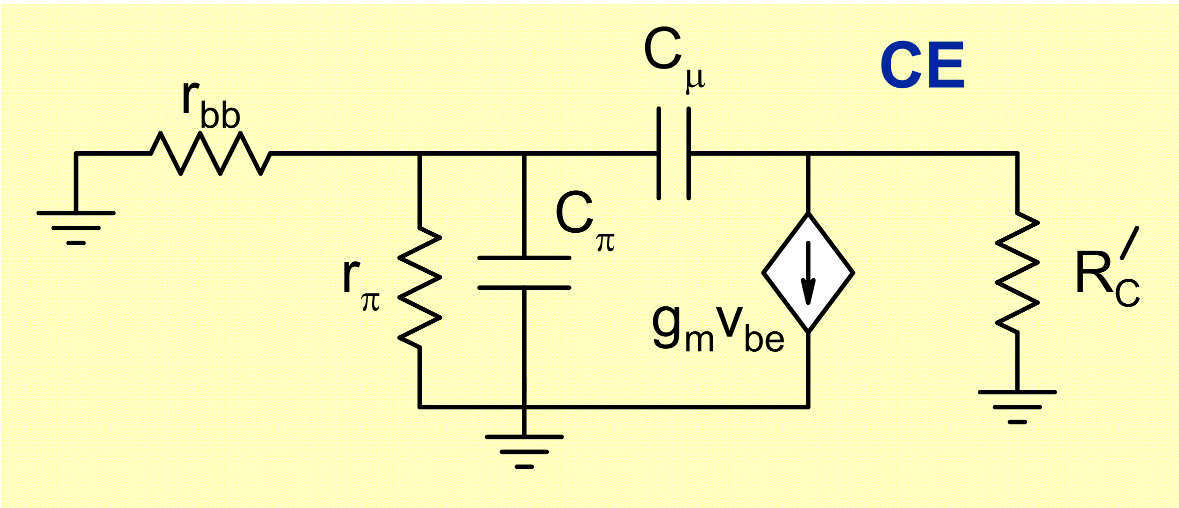




Negligible Rs



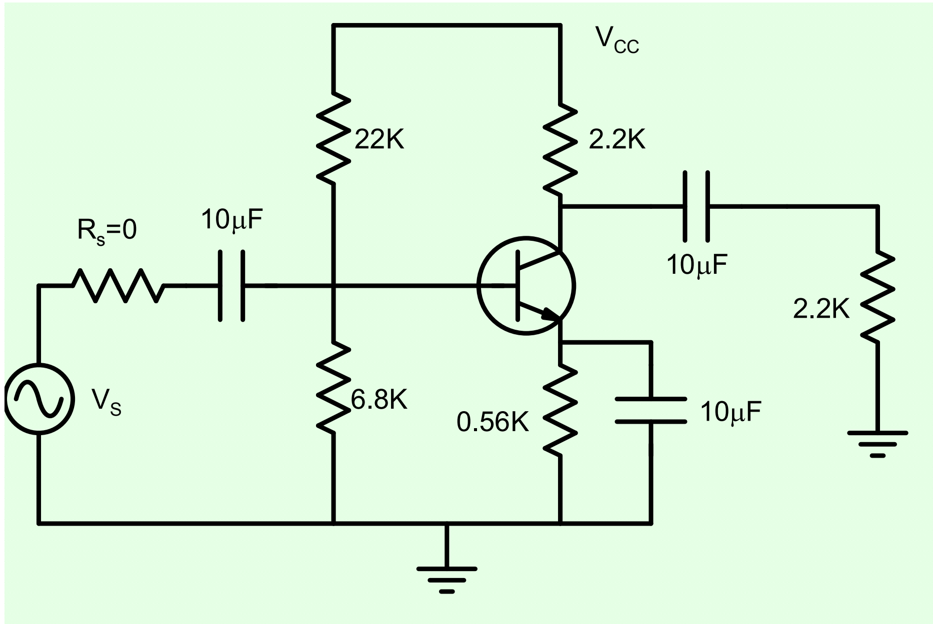


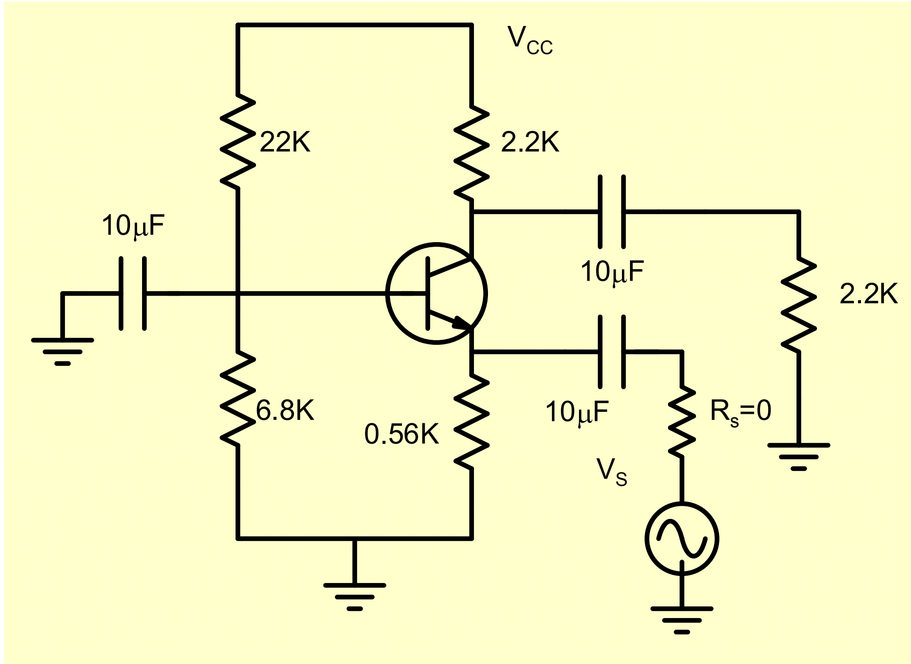


CB has same upper cutoff frequency as CE !

Example

Simulation Results





$$A_V = -110.7$$

$$R_{in} = 0.82k\Omega; R_o = 2.2k\Omega$$

$$\frac{A_v \times R_{in}}{R_O} = 41 \quad < \beta$$

$$f_H = 5.8MHz$$

$$A_V = 110.7$$

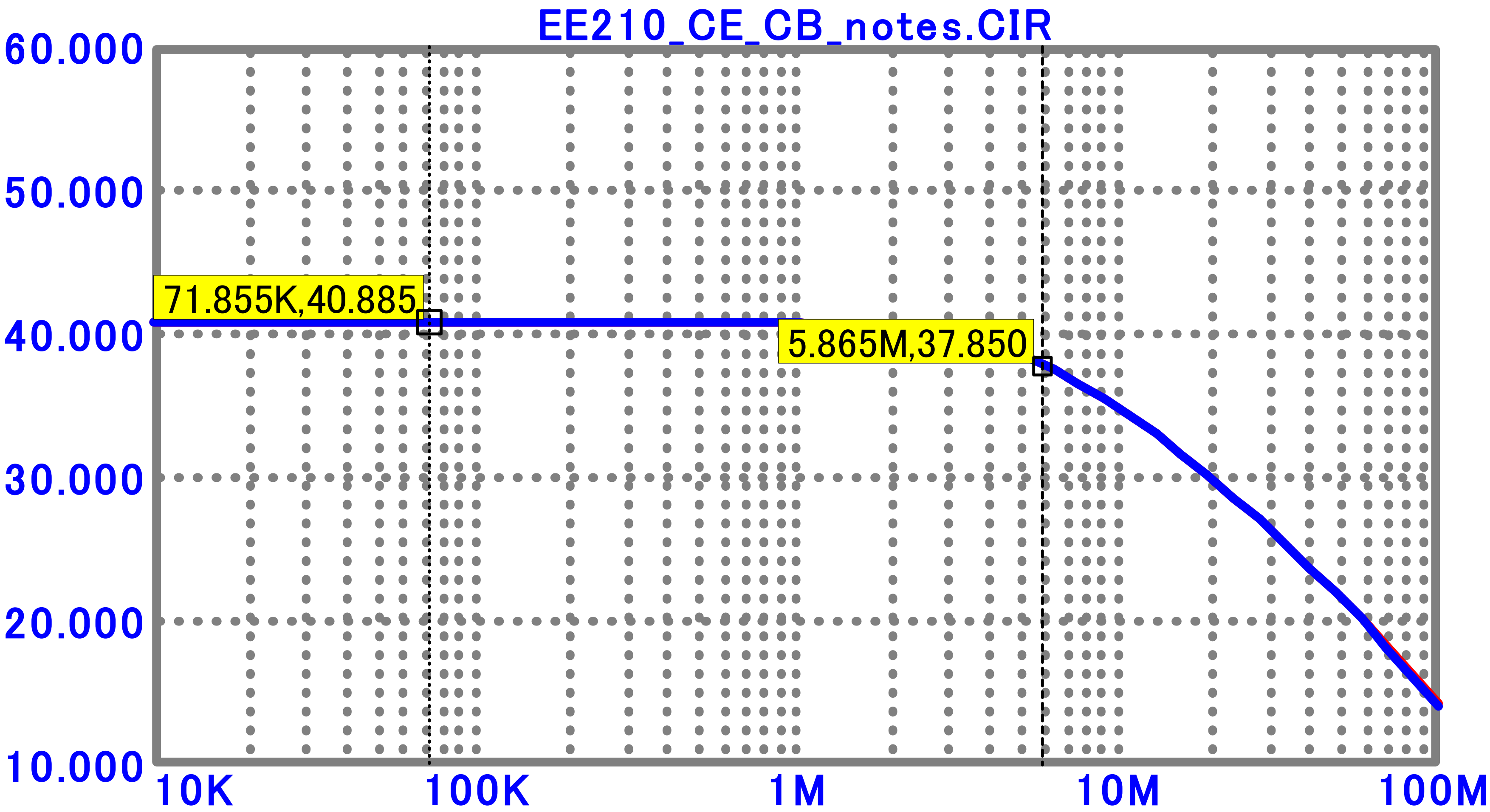
$$R_{in} = 9.66\Omega; R_o = 2.2k\Omega$$

$$\frac{A_v \times R_{in}}{R_O} = 0.48$$

$$f_H = 5.8MHz$$

Simulation results

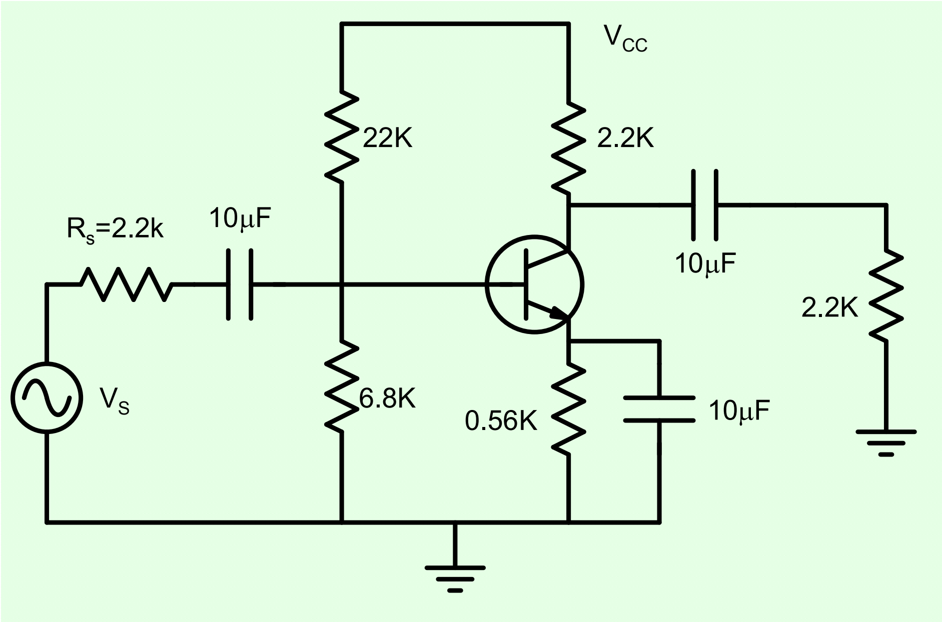
Both amplifiers have same response for RS=0

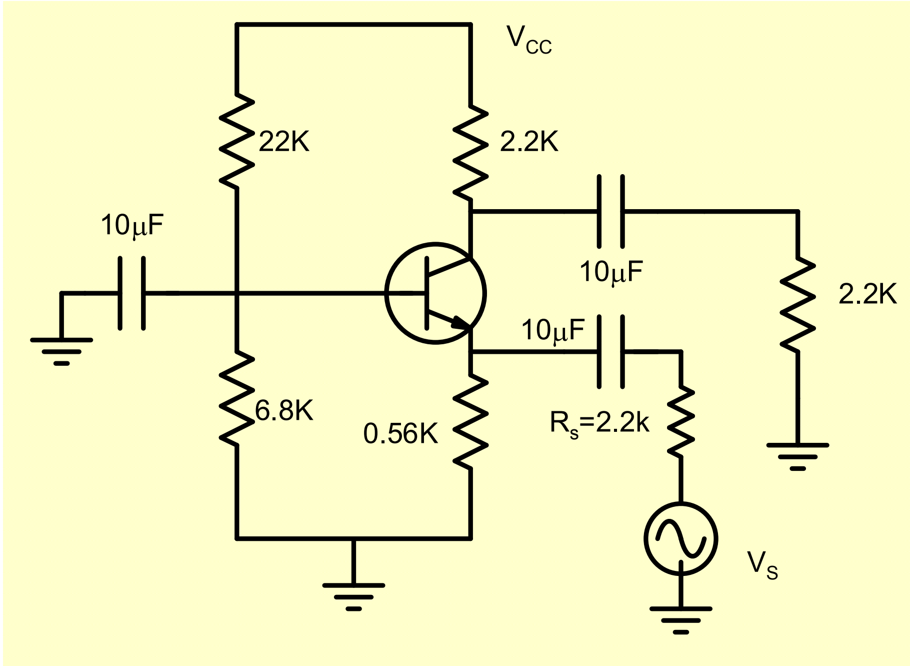


	Left	Right	Delta	Slope
B db(v(7))	40.885	37.850	-3.035	-523.897n
db(v(11))	40.888	37.852	-3.036	-524.012n
F (Hz)	71.855K	5.865M	5.793M	1.000

G-Number

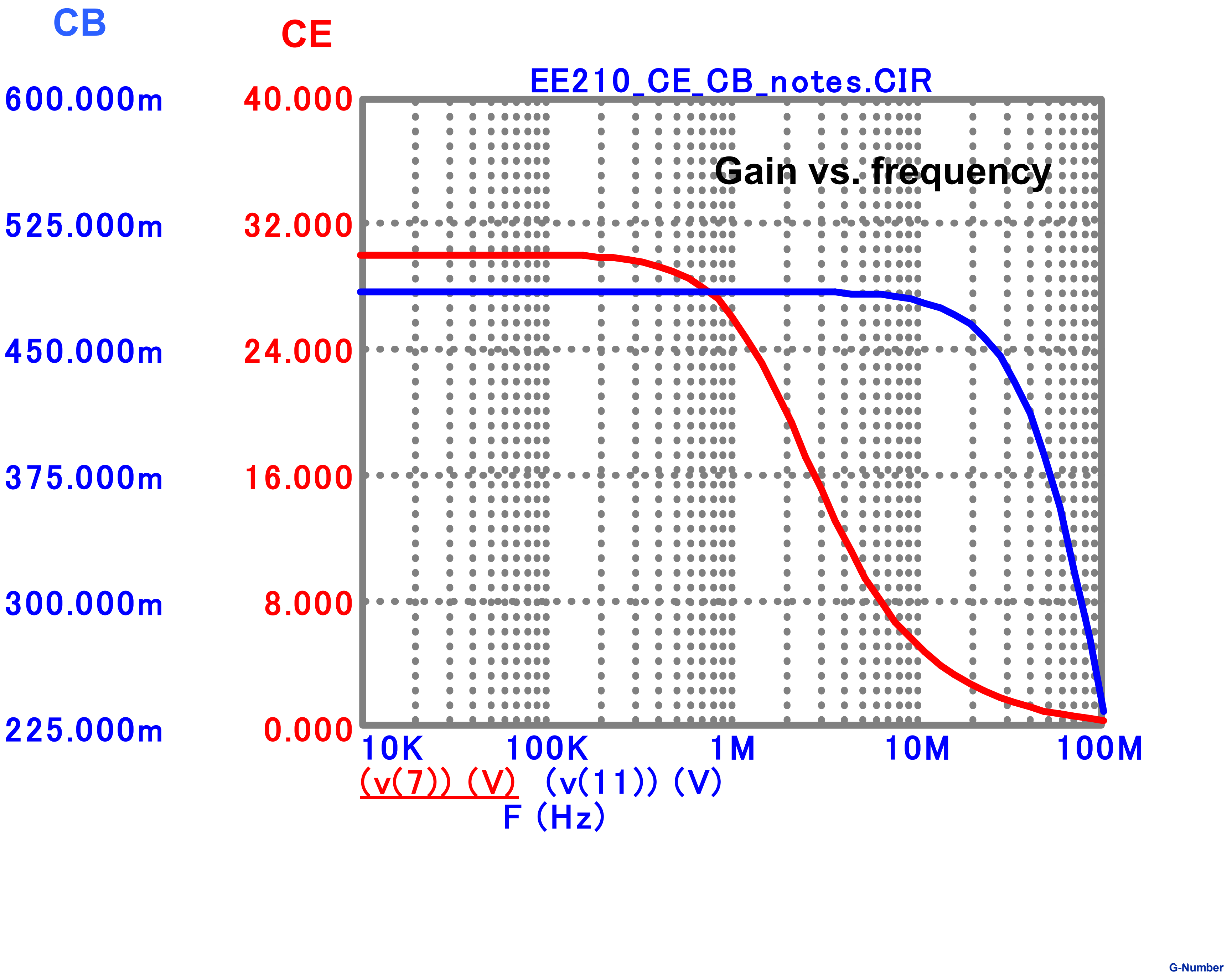
RS = 2.2k



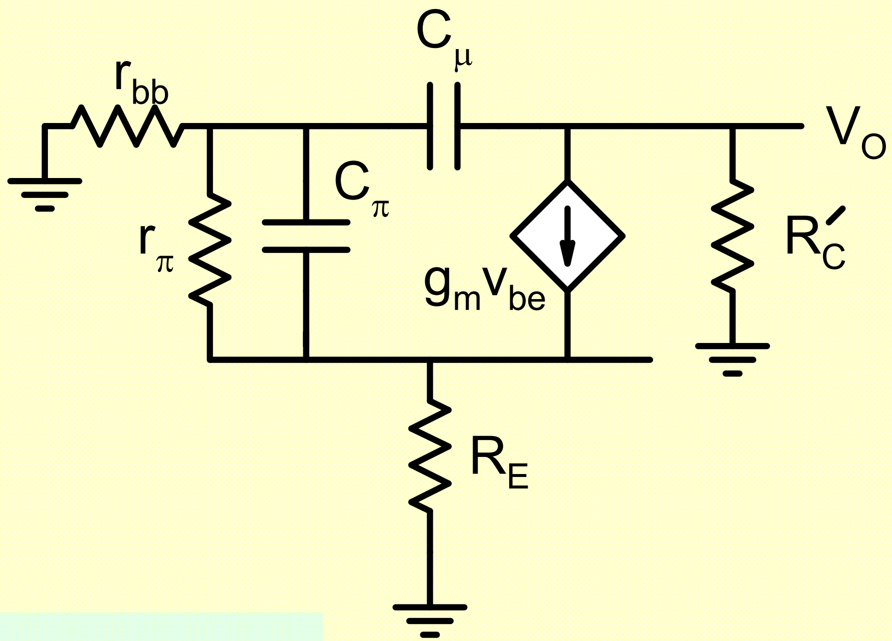


CE: $A_V = -30; f_H = 1.76MHz$

CB: $A_V = 0.48; f_H = 61MHz$


CB
CE
EE210_CE_CB_notes.CIR
Gain vs. frequency
600.000m
525.000m
450.000m
375.000m
300.000m
225.000m
40.000
32.000
24.000
16.000
8.000
0.000
10K
100K
1M
10M
100M
(v(7)) (V)
(v(11)) (V)
F (Hz)
G-Number

Effect of emitter (source) resistance

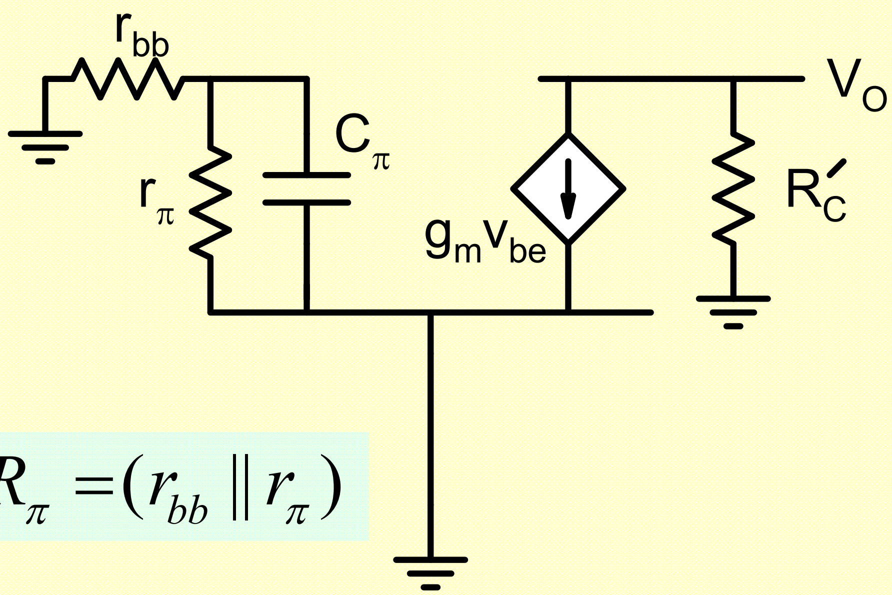


$$R_\pi = \frac{1+\dfrac{R_E}{r_{bb}}}{1+\dfrac{g_m R_E}{1+\dfrac{r_{bb}}{r_\pi}}} \times (r_{bb} \parallel r_\pi)$$

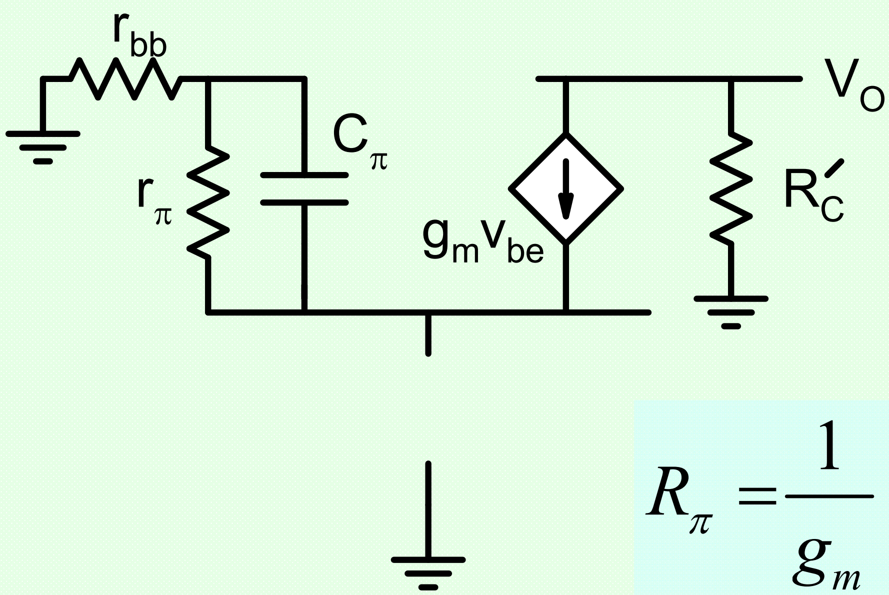
$$\cong \frac{1}{g_m} \; as \; R_E \to \infty$$

$$R_\mu = r_{bb} + R_C + \frac{(\beta R_C - r_{bb}) \times r_{bb}}{r_\pi + r_{bb} + (1+\beta) R_E}$$

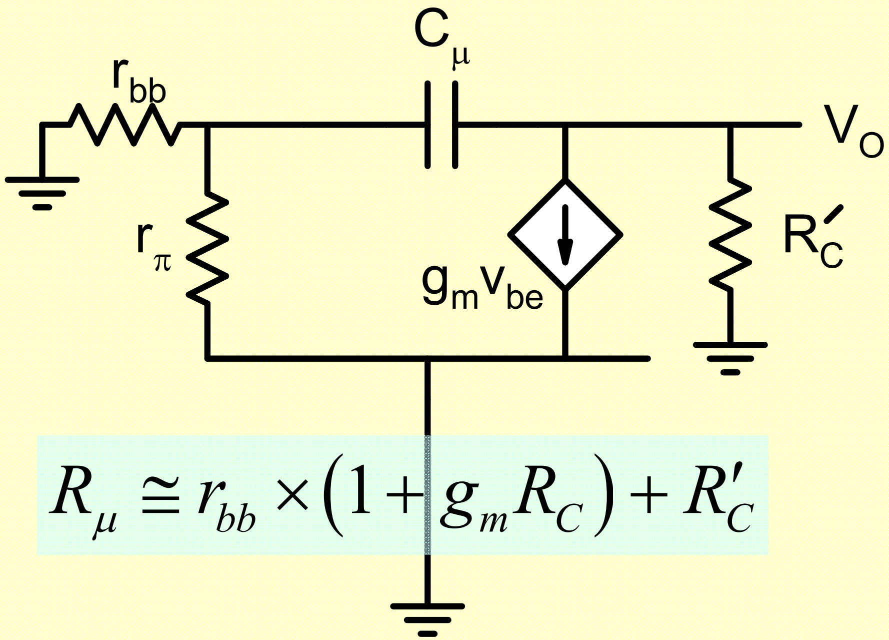
$$\cong r_{bb} + R_C \; as \; R_E \to \infty$$



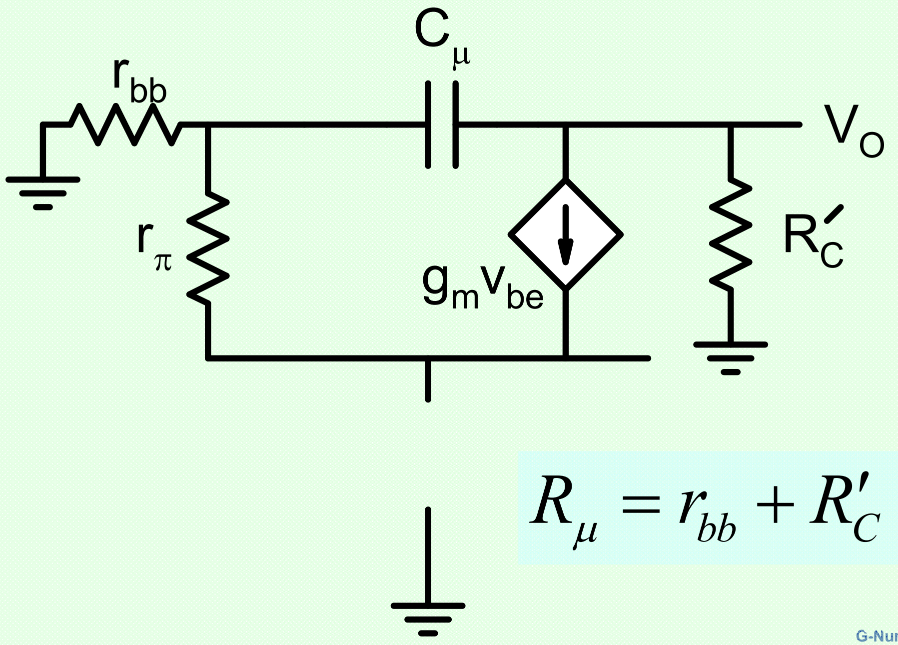
$$R_\pi = (r_{bb} \parallel r_\pi)$$



$$R_\pi = \frac{1}{g_m}$$



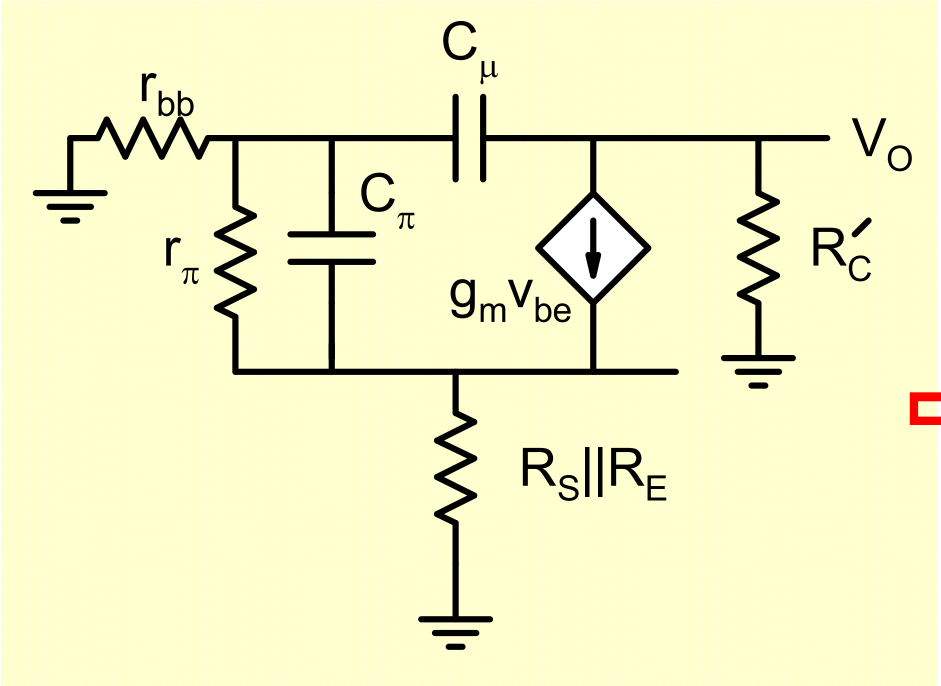
$$R_\mu \cong r_{bb} \times \left(1 + g_m R_C\right) + R'_C$$

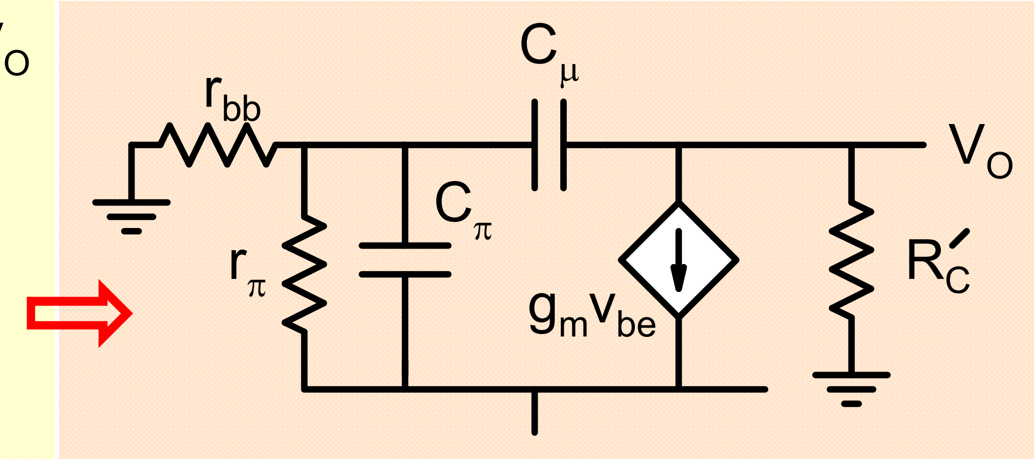


$$R_\mu = r_{bb} + R'_C$$

G-Number

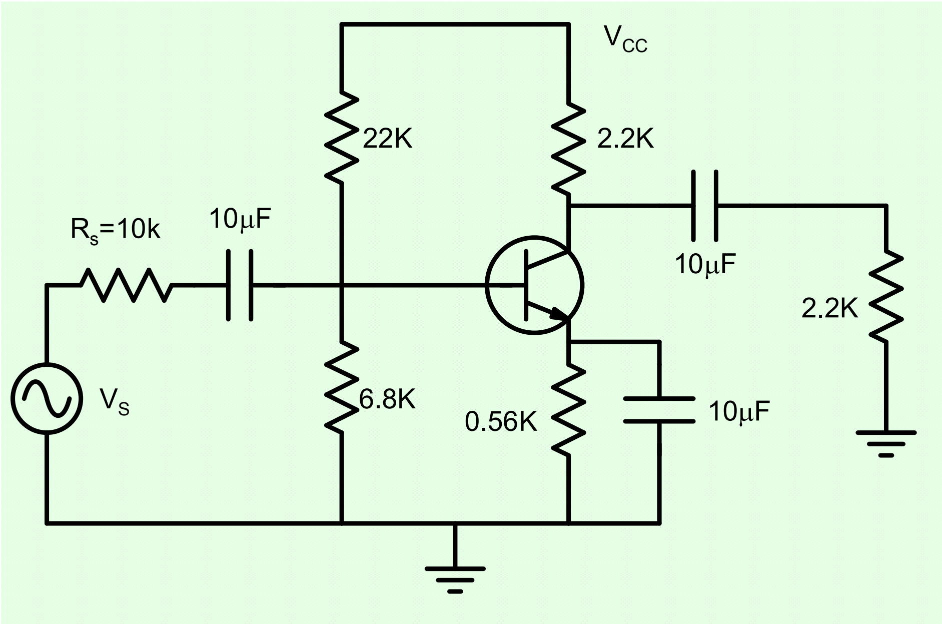
Large source and emitter resistance

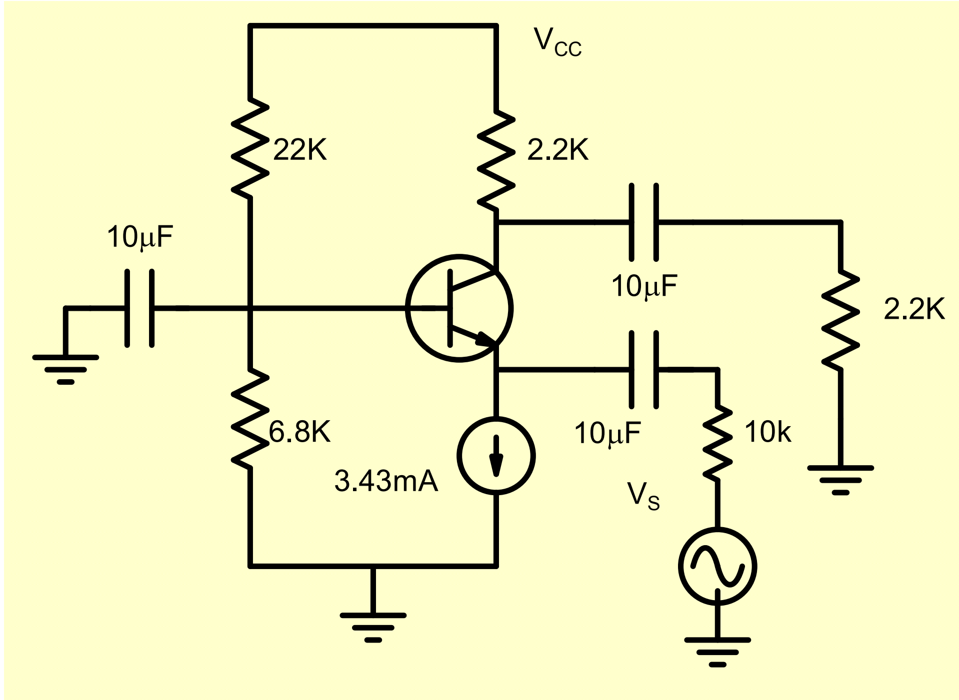


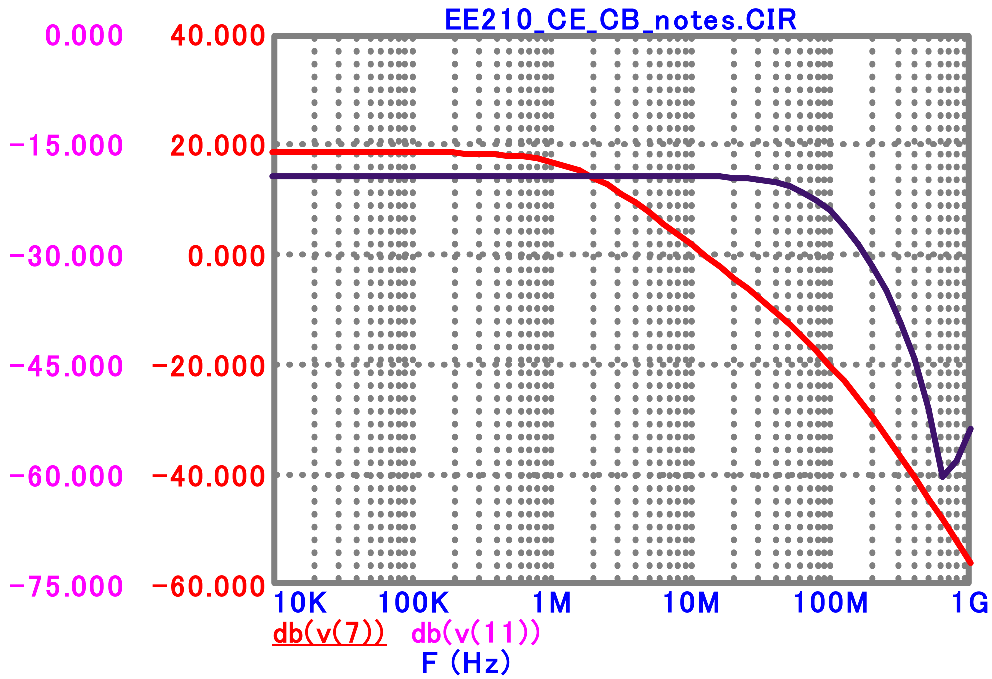


$$\omega_H \cong \frac{1}{(r_{bb} + R_C')C_\mu + \dfrac{C_\pi}{g_m}}$$

No Miller's effect and effect of Cπ is reduced as well

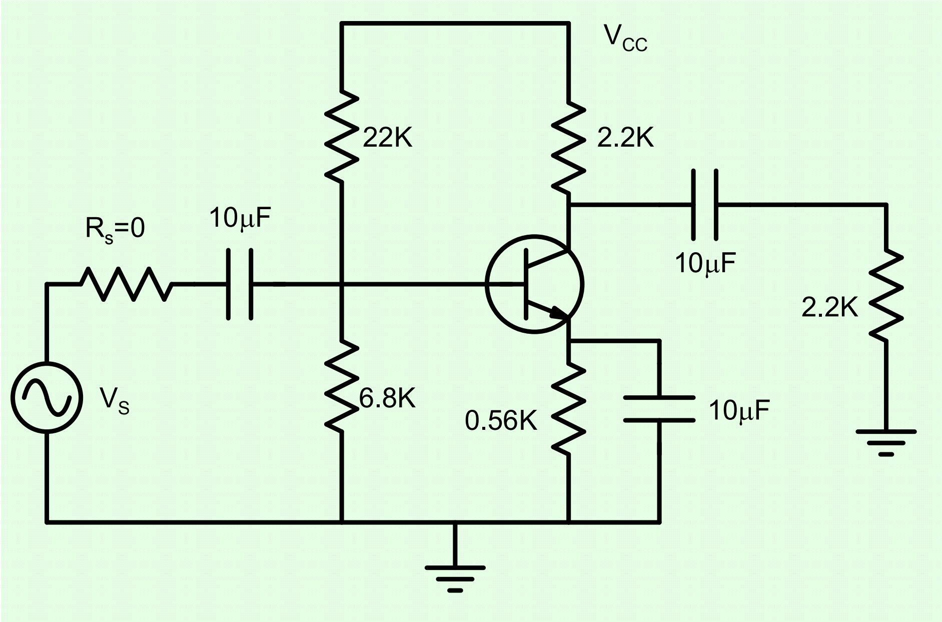






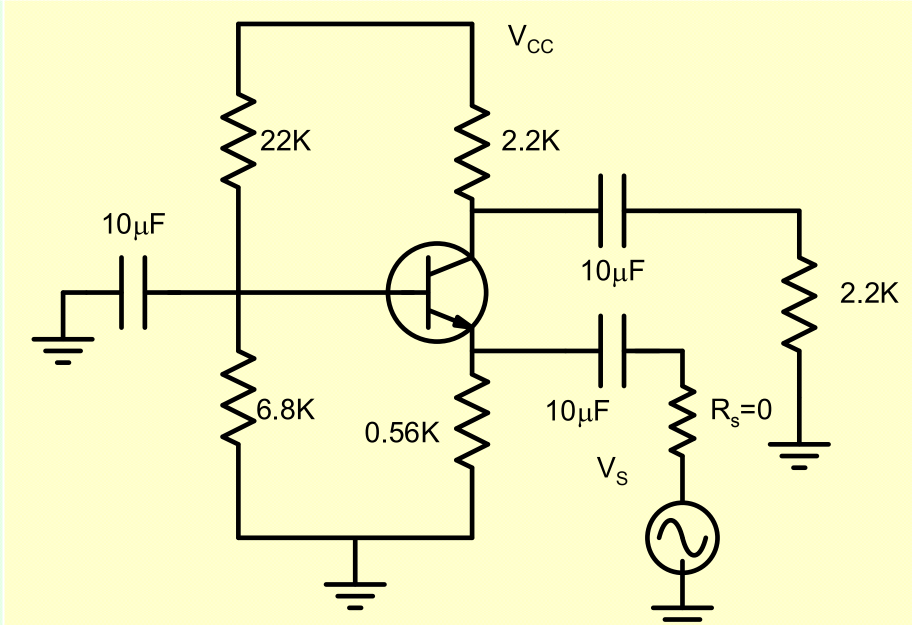
$$\text{CE: } A_V = -8.3;\ f_H = 1.45MHz$$

$$CB: A_V = 0.1;\ f_H = 73.5MHz$$



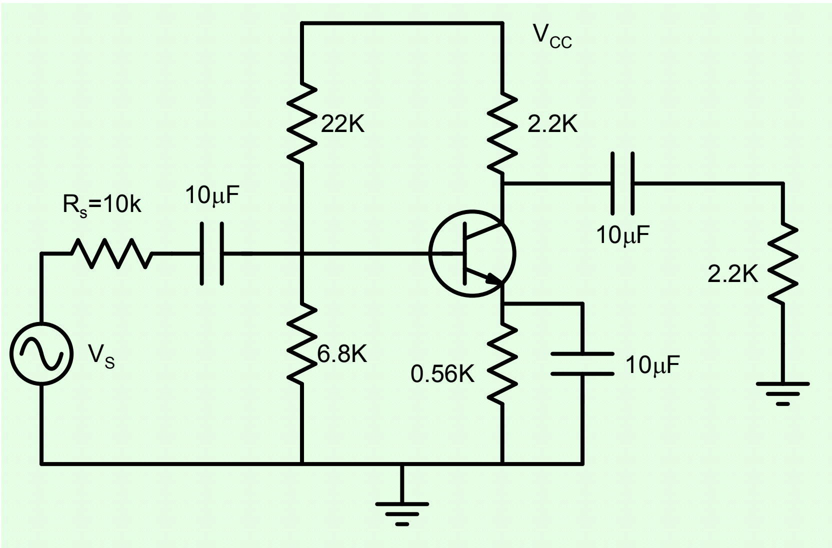
$$A_V = -110.7; R_{in} = 0.82k\Omega; R_o = 2.2k\Omega$$

$$f_H = 5.8MHz$$

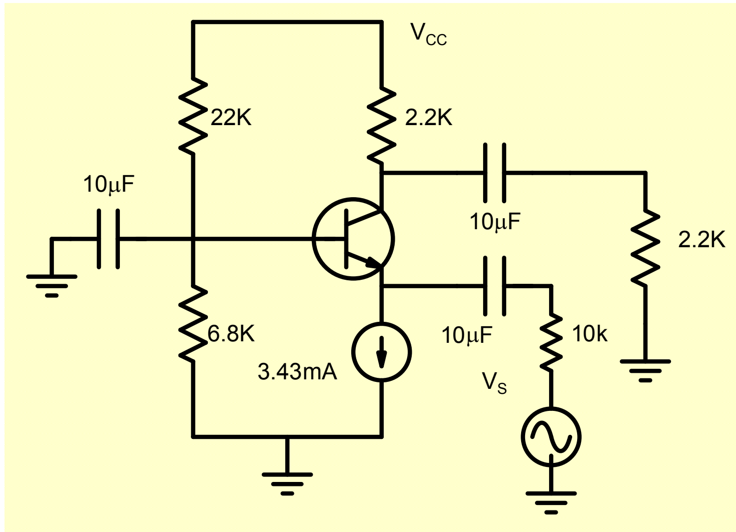


$$A_V = 110.7; R_{in} = 9.66\Omega; R_o = 2.2k\Omega$$

$$f_H = 5.8MHz$$

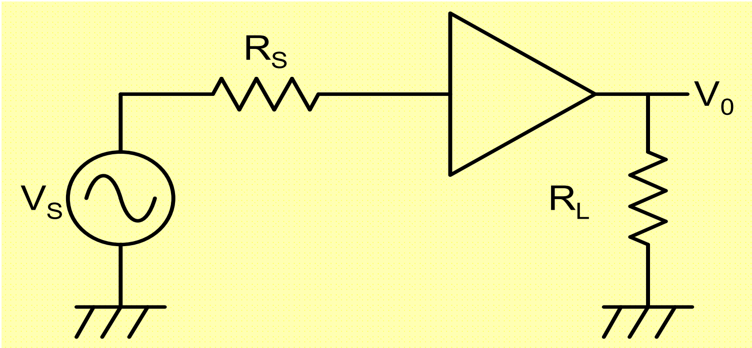


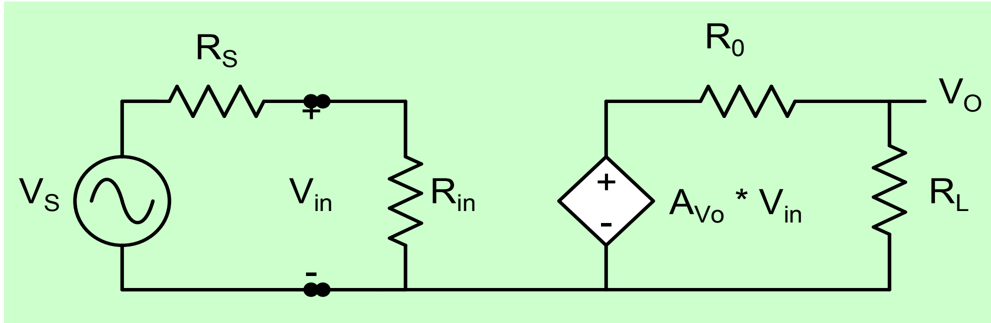
CE: $A_V = -8.3; f_H = 1.45MHz$



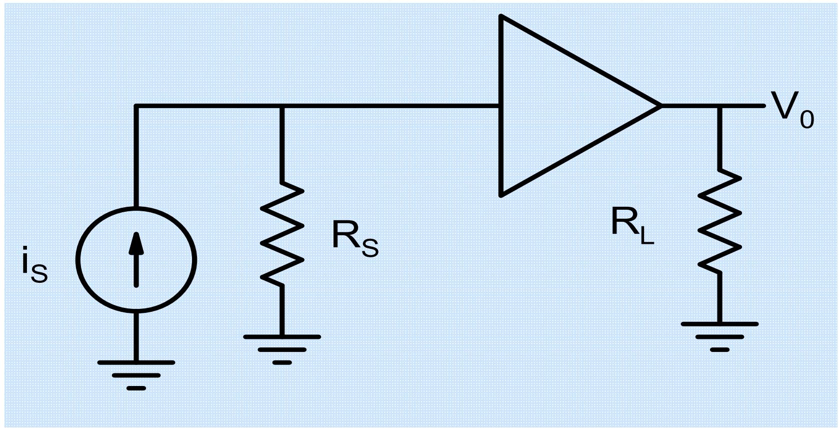
$CB: A_V = 0.1; f_H = 73.5MHz$

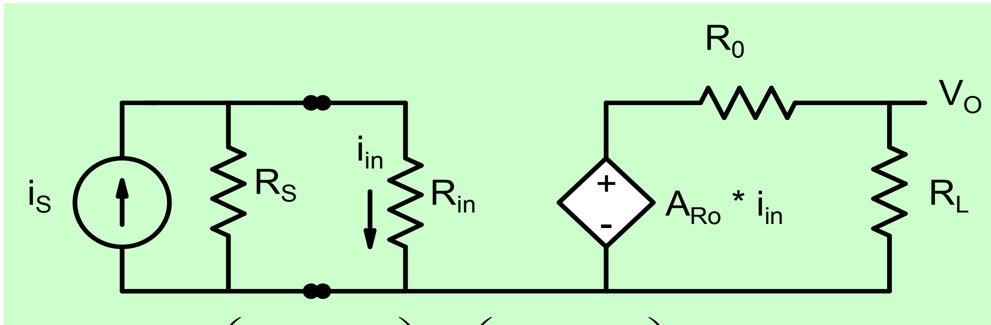
G-Number





$$\frac{v_o}{v_s} = \left(\frac{1}{1+\frac{R_S}{R_{in}}} \right) \times \left(\frac{1}{1+\frac{R_O}{R_L}} \right) \times A_{VO}$$

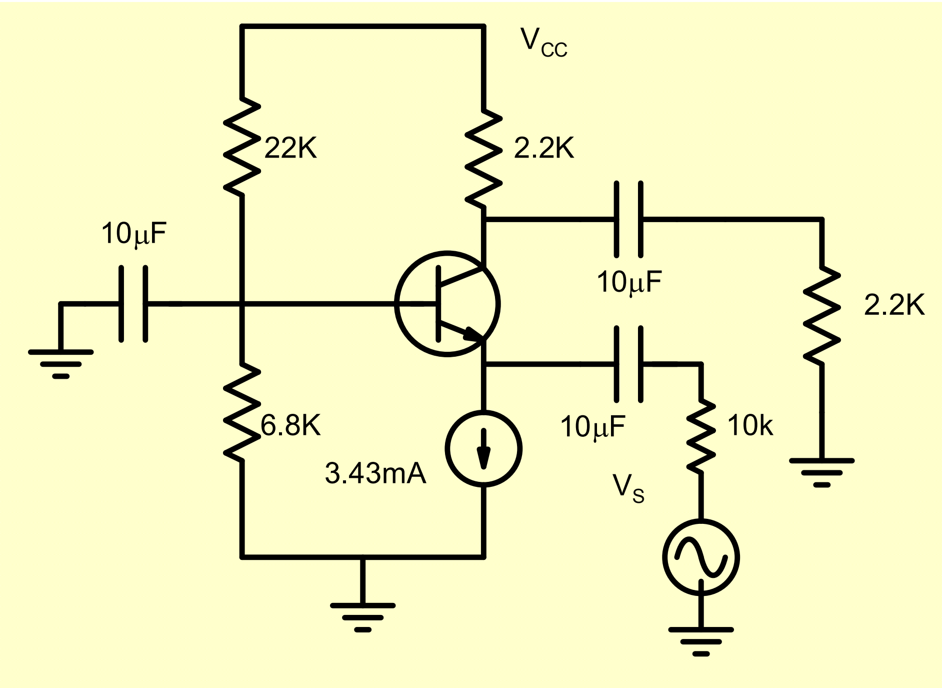


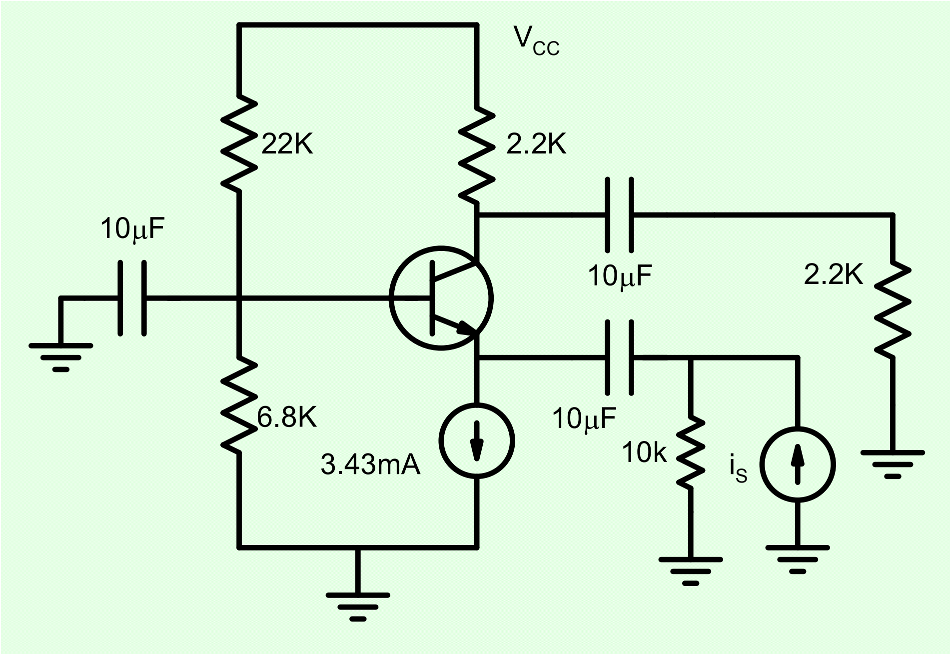


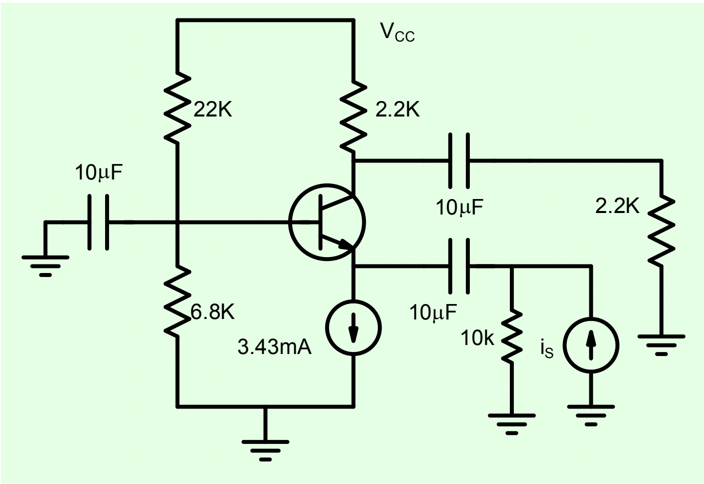
$$\frac{v_o}{i_s} = \left(\frac{1}{1+\frac{R_{in}}{R_S}} \right) \times \left(\frac{1}{1+\frac{R_O}{R_L}} \right) \times A_{RO}$$

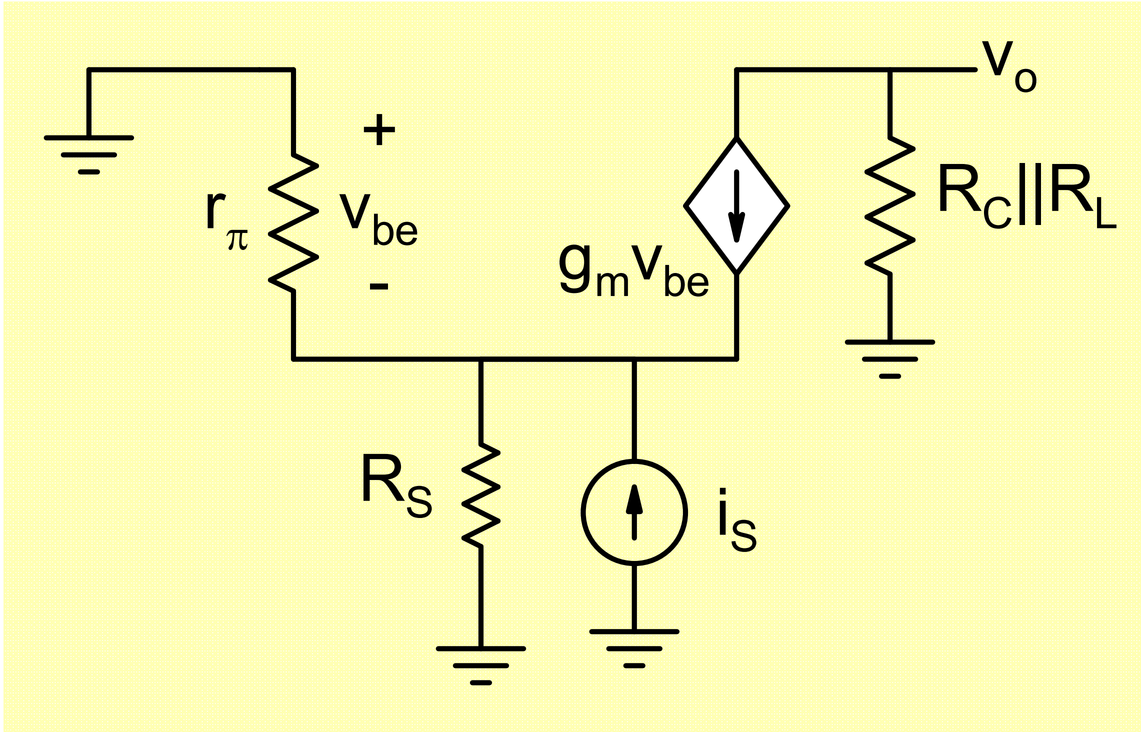
Low input resistance is desirable for current input:trans-resistance amplifier

Low input resistance in CB amplifier makes it well suited for current input









$$v_o \cong i_s \times R_C \| R_L$$

How do we utilize an amplifier with current input and high bandwidth?