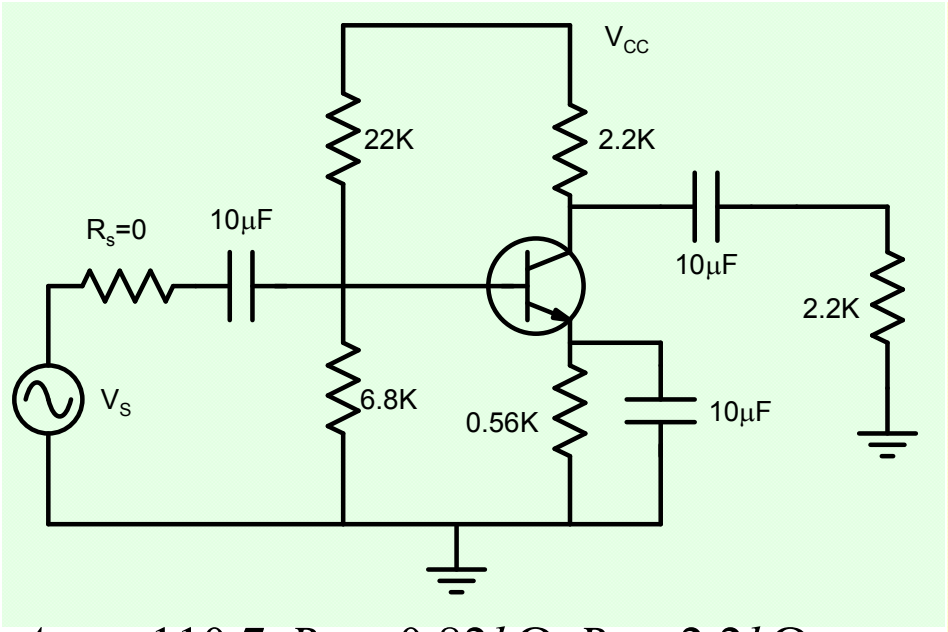
EE210: Microelectronics-I

Lecture-24 :Cascode Amplifier

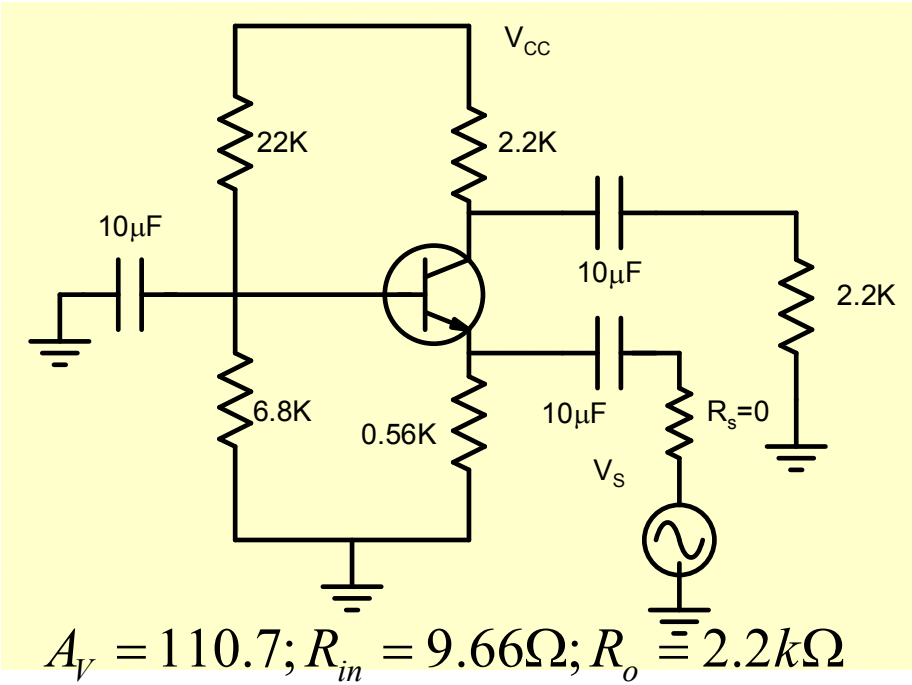
Instructor - Y. S. Chauhan

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



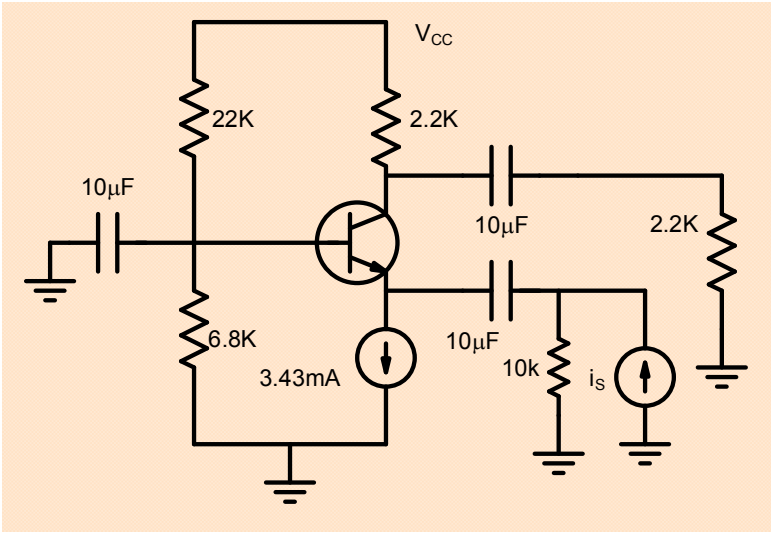
$A_V = -110.7; R_{in} = 0.82k\Omega; R_o = 2.2k\Omega$

$f_H = 5.8MHz$



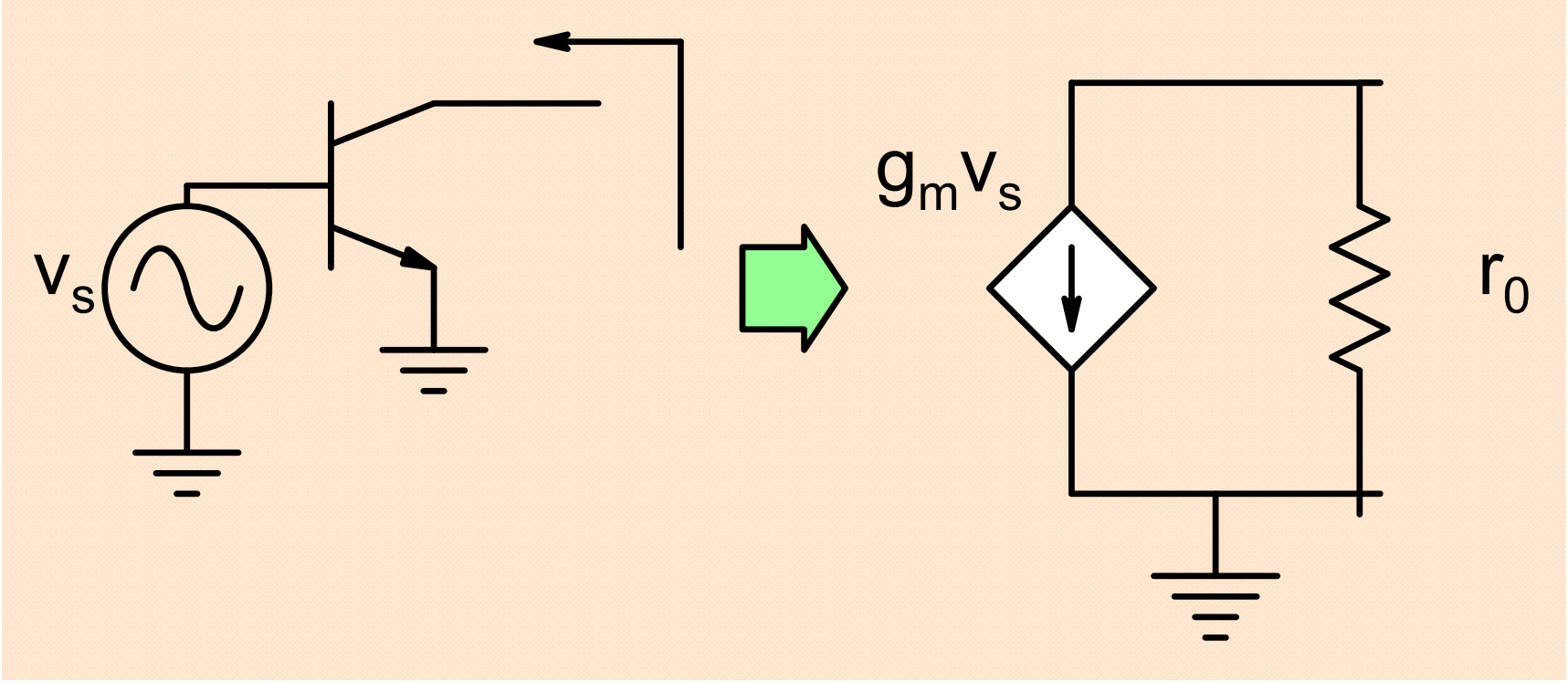
$A_V = 110.7; R_{in} = 9.66\Omega; R_o = 2.2k\Omega$

$f_H = 5.8MHz$



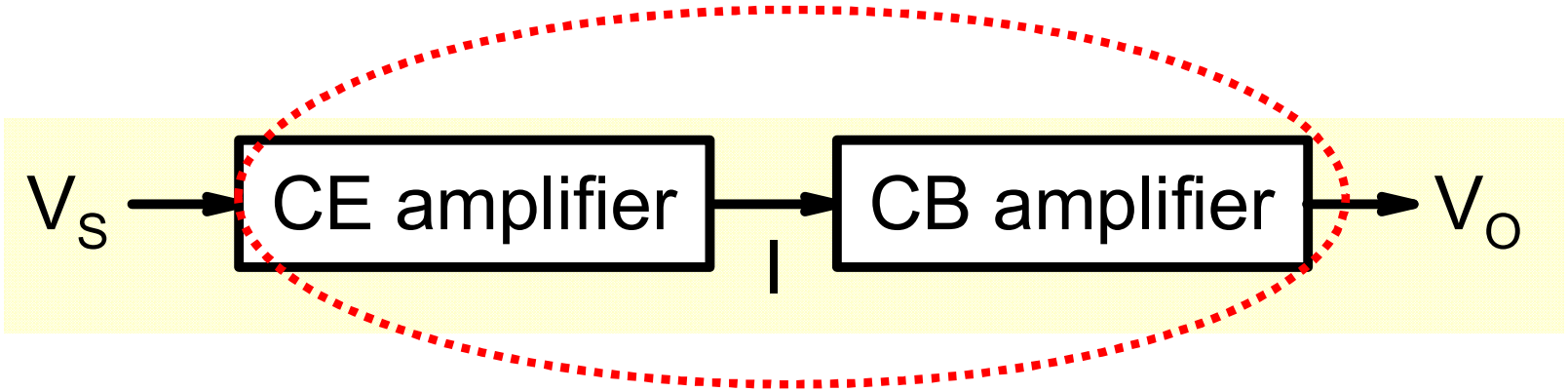
$CB: A_V = 0.1; f_H = 73.5MHz$

CE amplifier

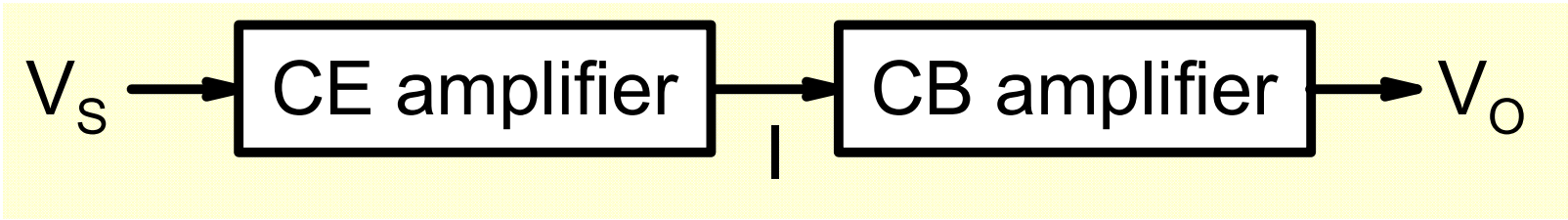


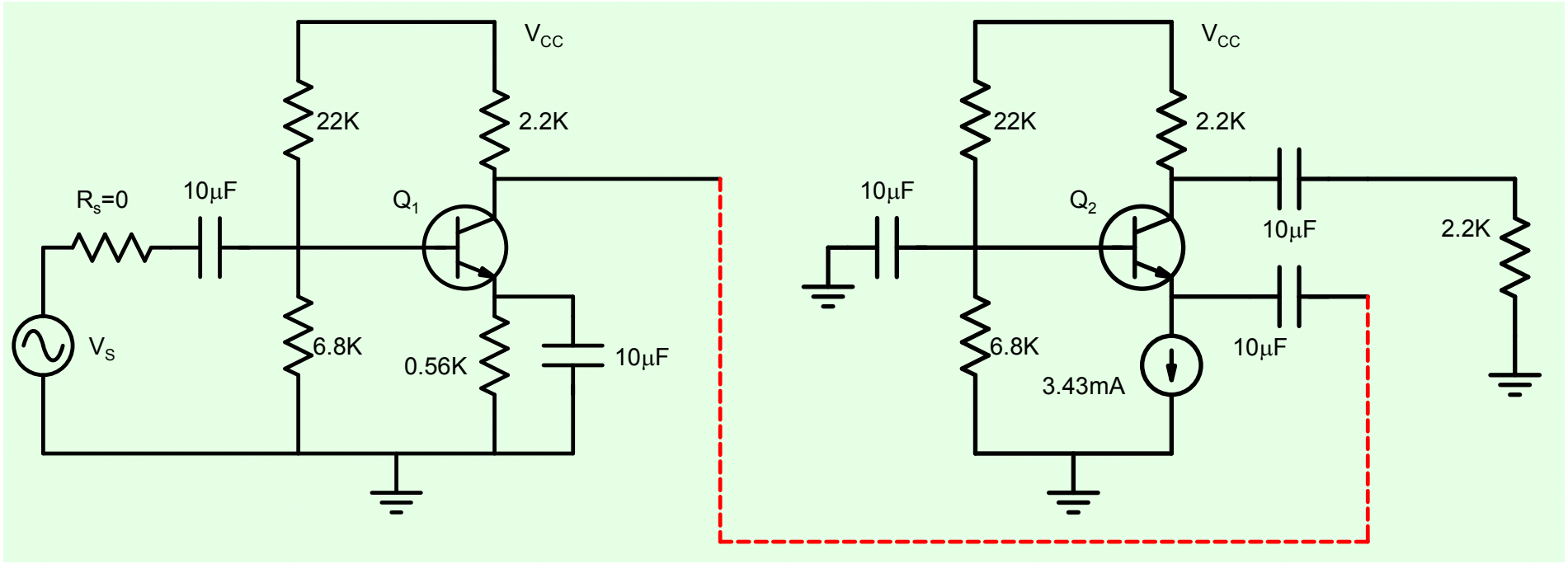
A CE amplifier is a good voltage to current converter !

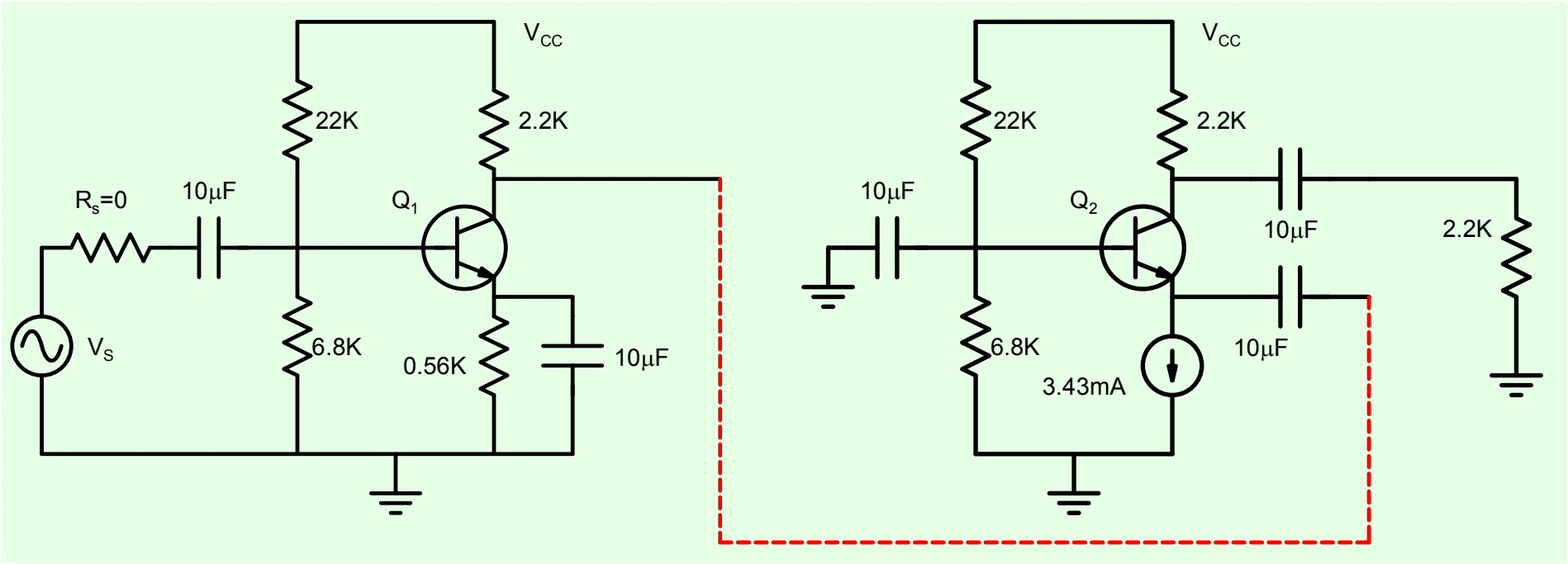
Strategy

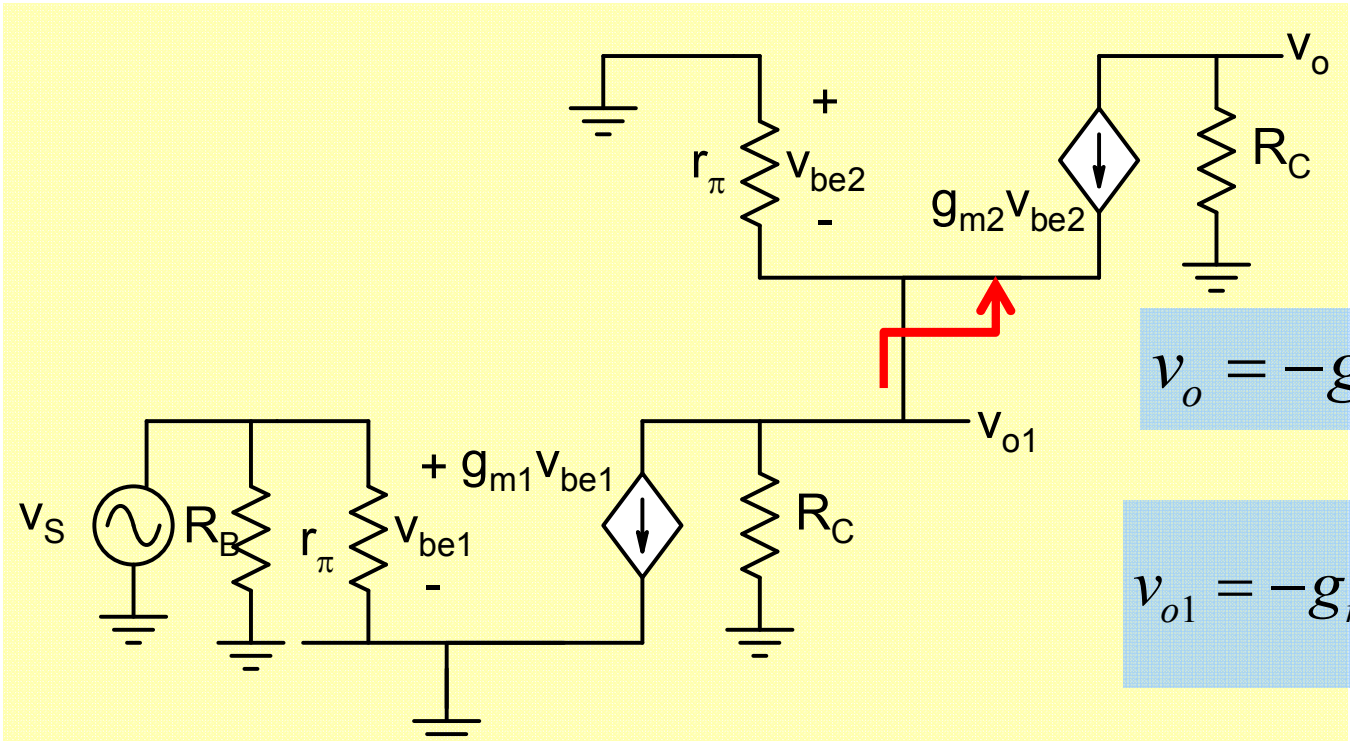


Cascode


V_S
CE amplifier
CB amplifier
V_O


V_{CC}
22K
2.2K
R_s=0
10μF
Q_1
V_S
6.8K
0.56K
10μF
V_{CC}
22K
2.2K
10μF
Q_2
10μF
2.2K
6.8K
10μF
3.43mA

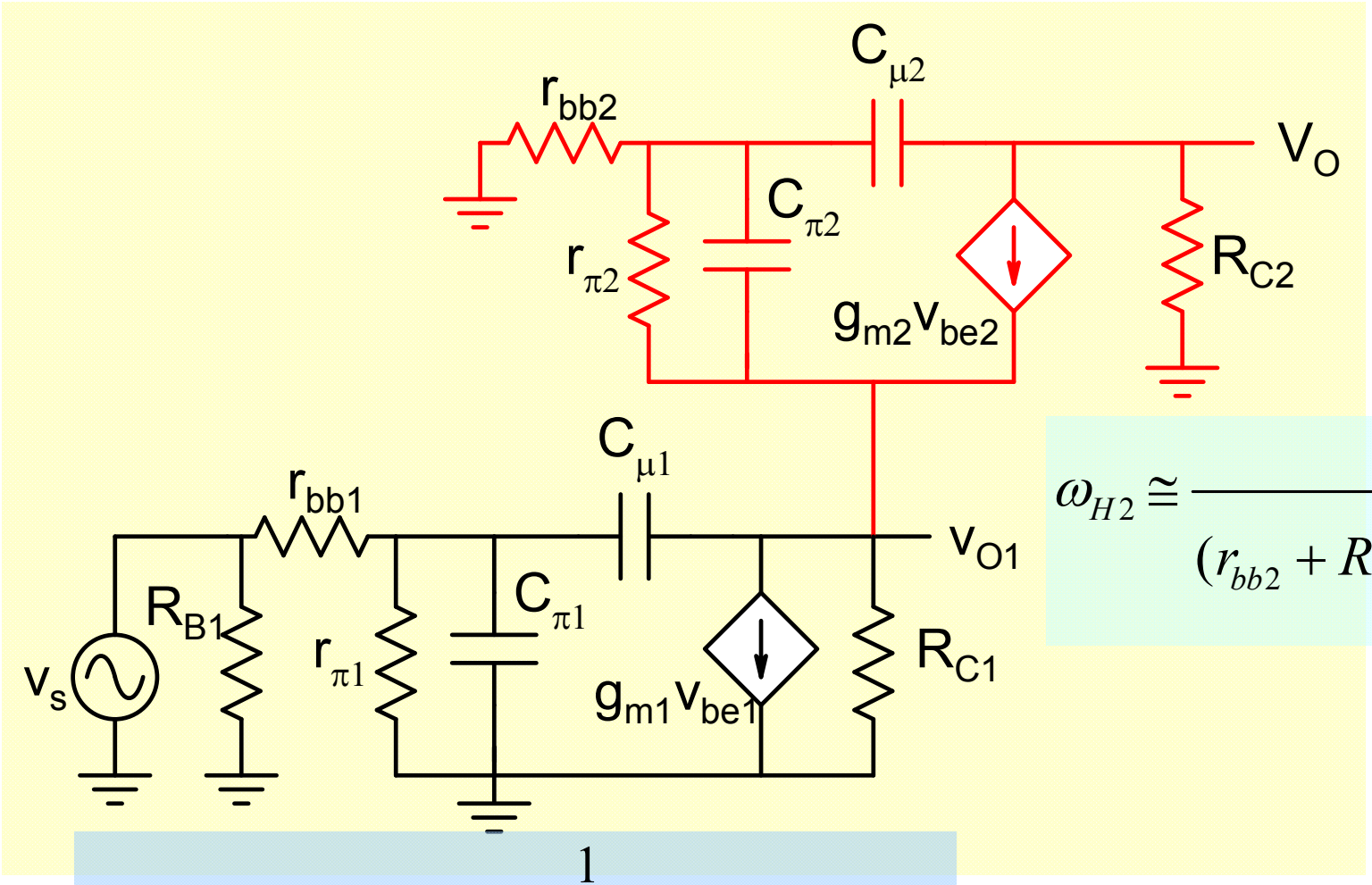




$$v_o = -g_{m1}v_s \times R_C \| R_L$$

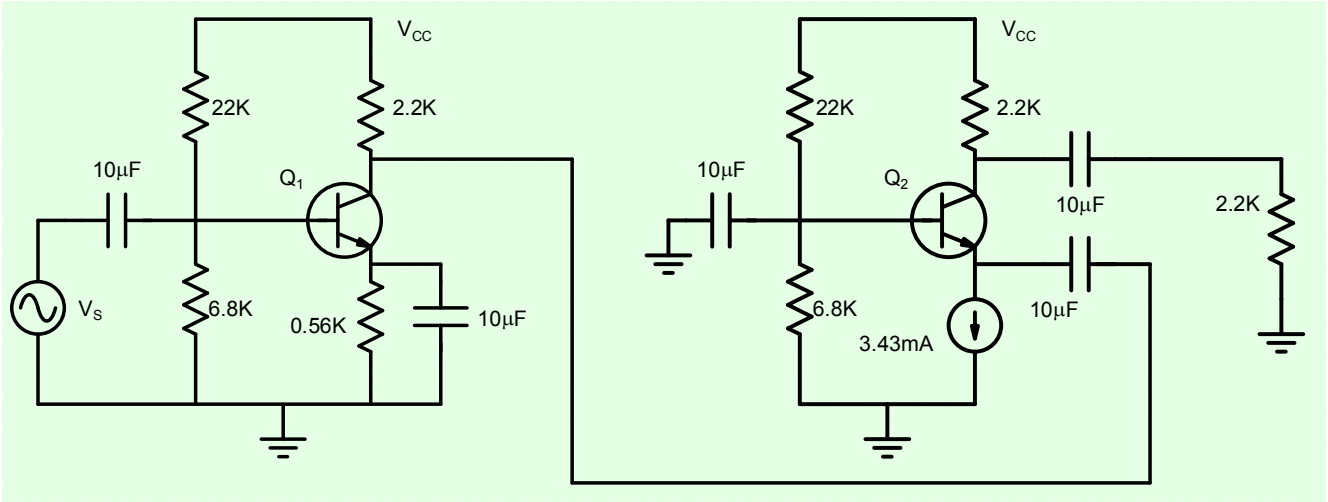
$$v_{o1} = -g_{m1}v_s \times \frac{1}{g_{m2}}$$

$$CE: \omega_H \cong \frac{1}{(R_S' \| r_\pi)\{C_\pi + C_\mu(1+g_m R_C')\} + R_C' C_\mu}$$



$$\omega_{H2} \cong \frac{1}{(r_{bb2} + R_{C2}')C_{\mu 2} + \frac{C_{\pi 2}}{g_{m2}}}$$

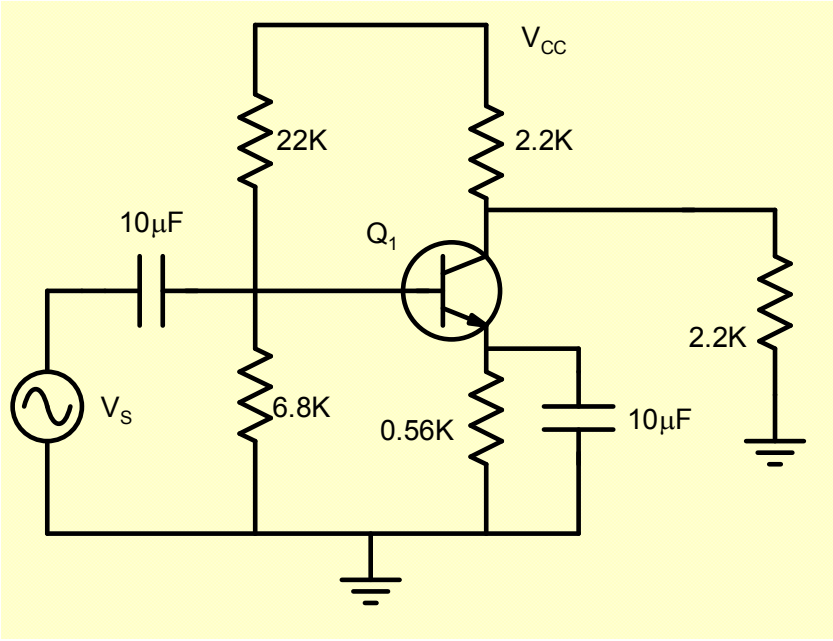
$$\omega_{H1} \cong \frac{1}{(r_{bb1} \| r_{\pi 1})\{C_{\pi 1} + C_{\mu 1}(1 - A_{v1})\} + \frac{C_{\mu 1}}{g_{m2}}}$$



$$A_V = 113$$

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

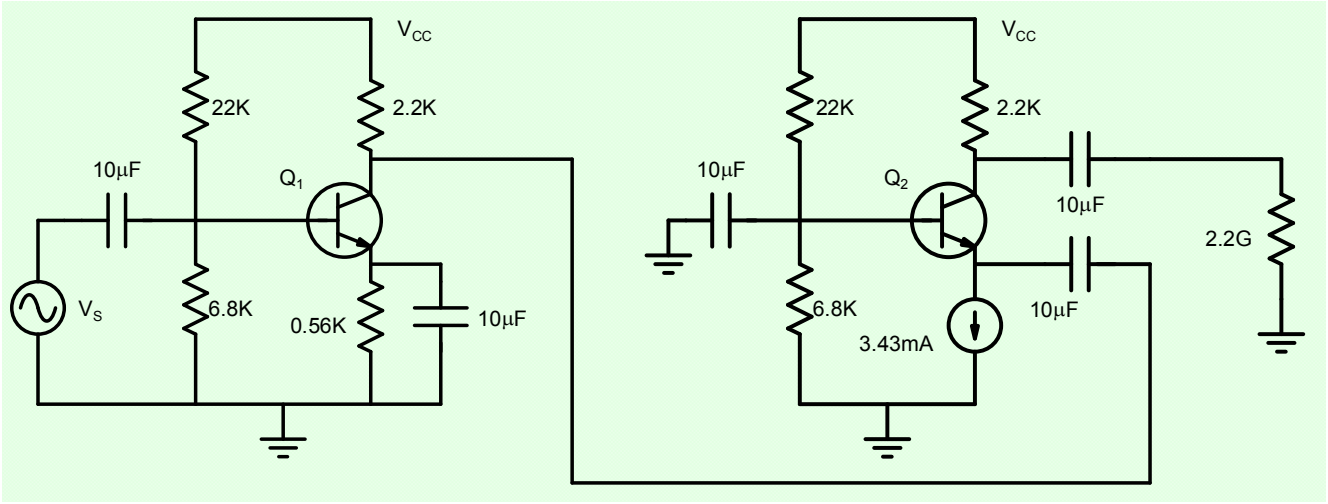
$$f_H = 7.36MHz$$



$$A_V = 110.7$$

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

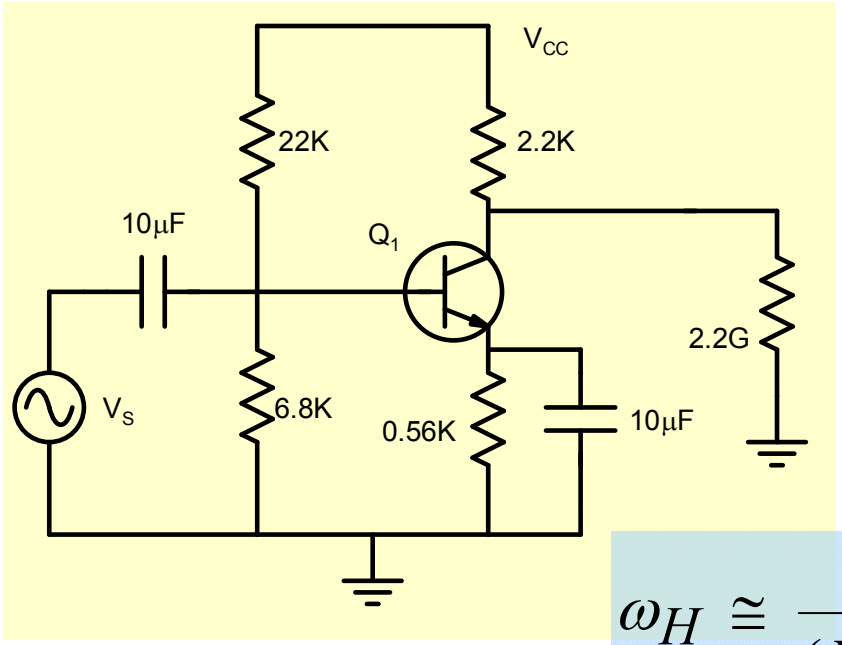
$$f_H = 5.8MHz$$



$$A_V = 226$$

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

$$f_H = 7.28MHz$$



$$A_V = 213.6$$

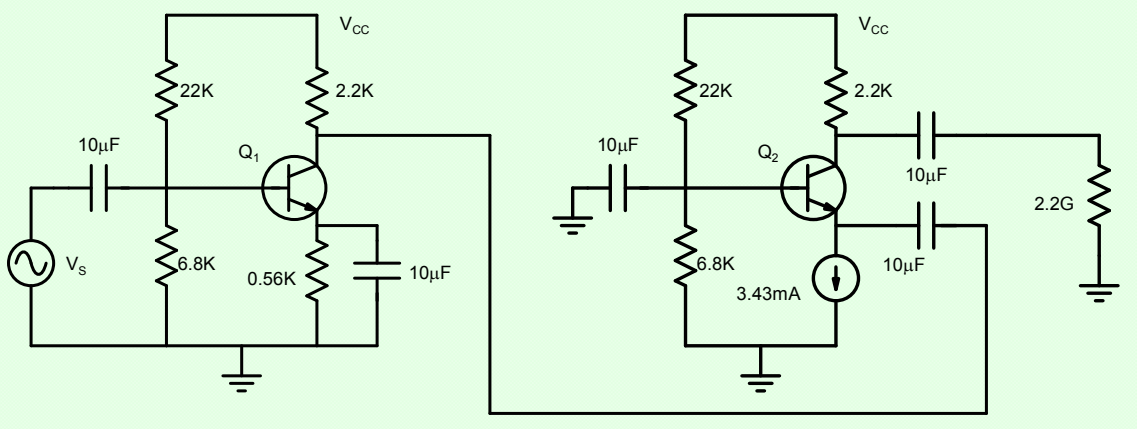
$$R_{in} = 0.82k\Omega; R_o = 2.2k\Omega$$

$$f_H = 4.88MHz$$

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

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

τ_F reduced from 1ns to 0.1ns



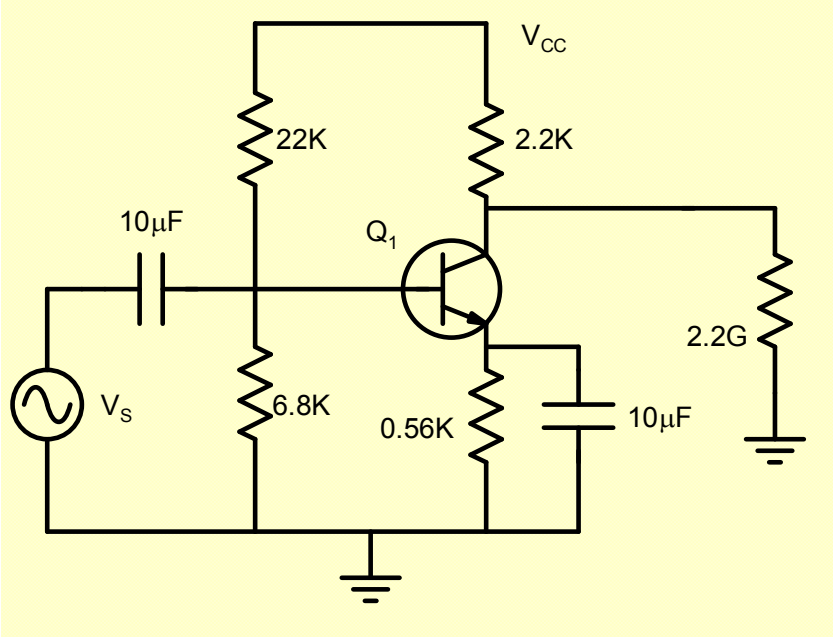
$R_L = \infty$

$I_{CQ} = 2mA; R_C = 2.2k;$

$A_V = 145.4; f_H = 46.44MHz$

$I_{CQ} = 3.4mA; R_C = 2.2k;$

$A_V = 226.1; f_H = 35.3MHz$



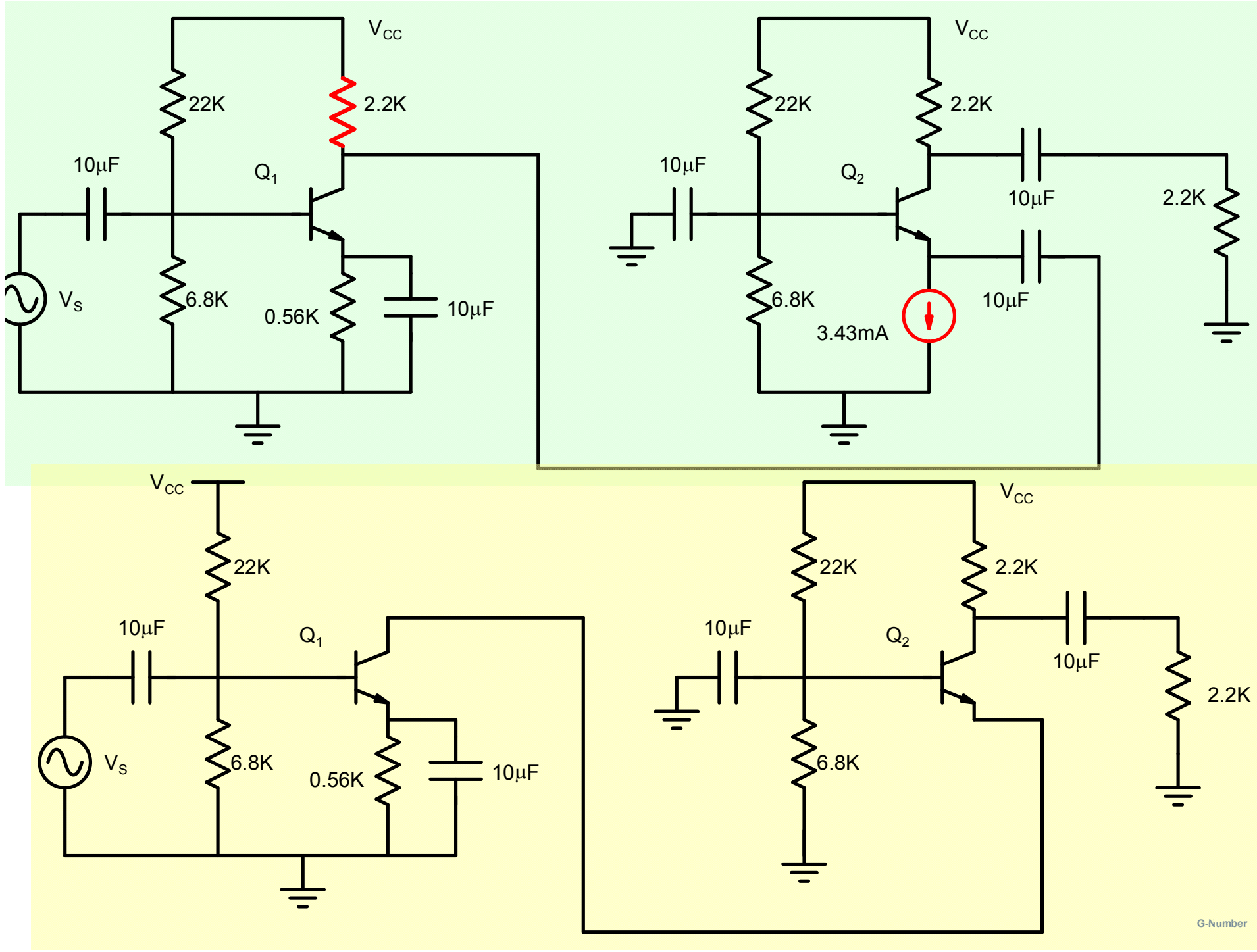
$R_L = \infty$

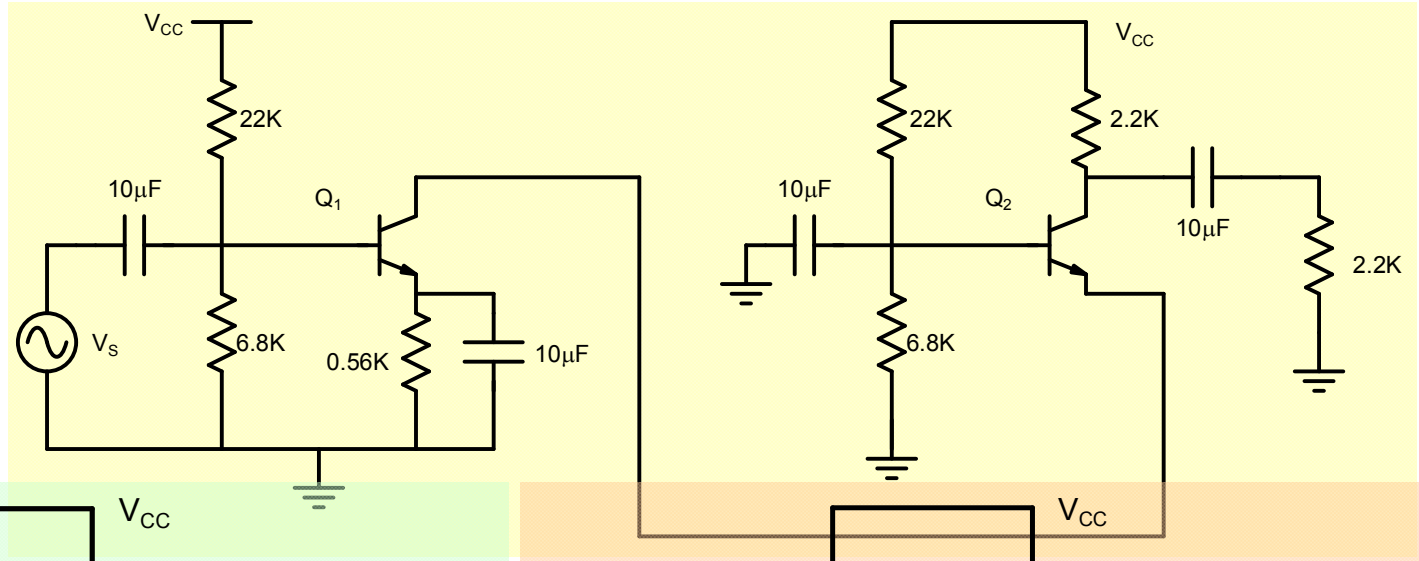
$I_{CQ} = 2mA; R_C = 2.2k;$

$A_V = 141.9; f_H = 17.1MHz$

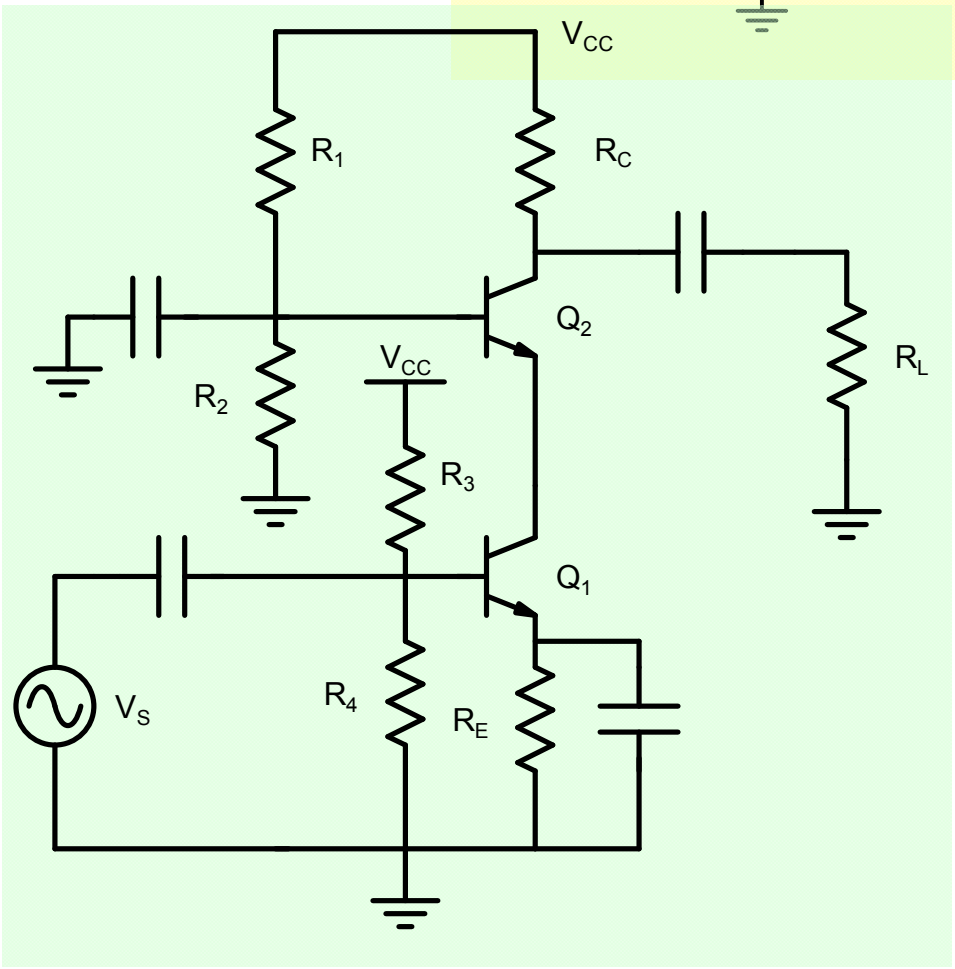
$I_{CQ} = 3.4mA; R_C = 2.2k;$

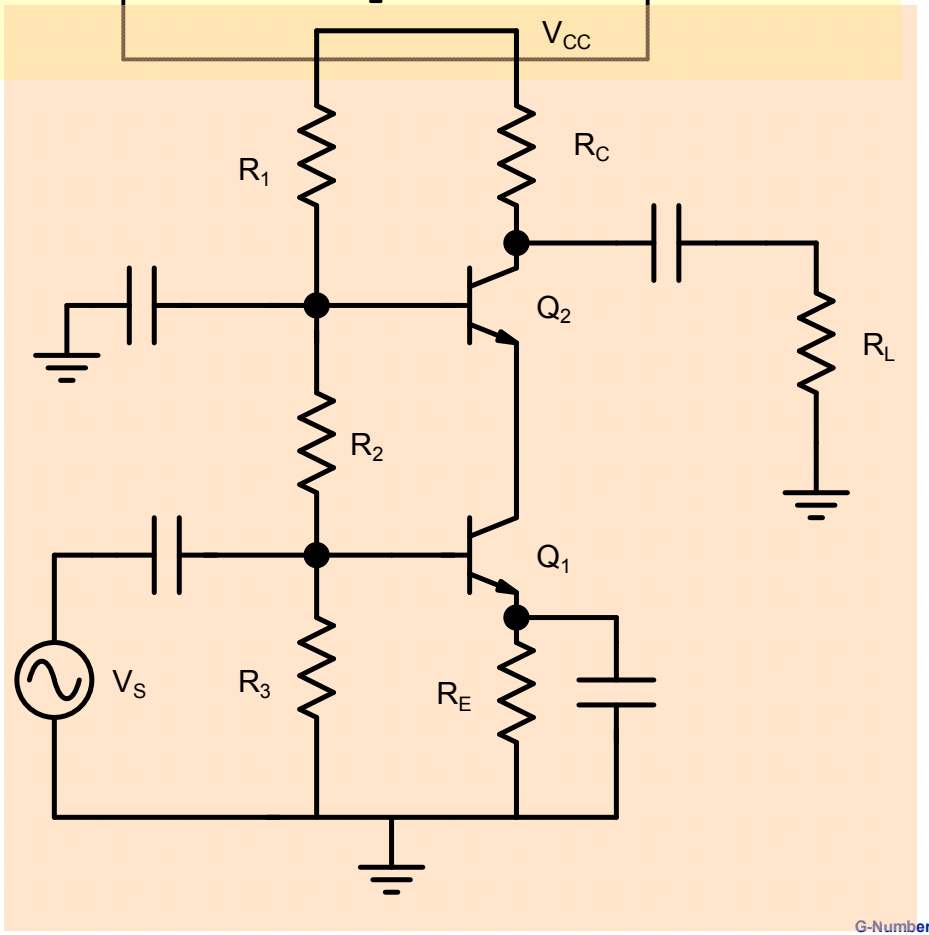
$A_V = 213.6; f_H = 9.4MHz$


V_{CC}
22K
2.2K
10μF
Q_1
V_S
6.8K
0.56K
10μF
V_{CC}
22K
2.2K
10μF
Q_2
10μF
2.2K
6.8K
10μF
3.43mA
V_{CC}
22K
10μF
Q_1
V_S
6.8K
0.56K
10μF
V_{CC}
22K
2.2K
10μF
Q_2
10μF
2.2K
6.8K
G-Number

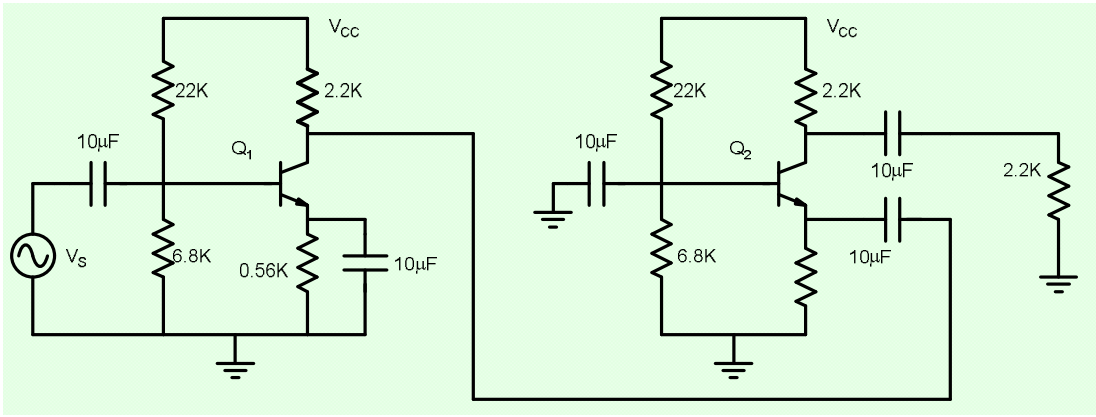

V_{CC}
22K
10μF
Q_1
V_S
6.8K
0.56K
10μF

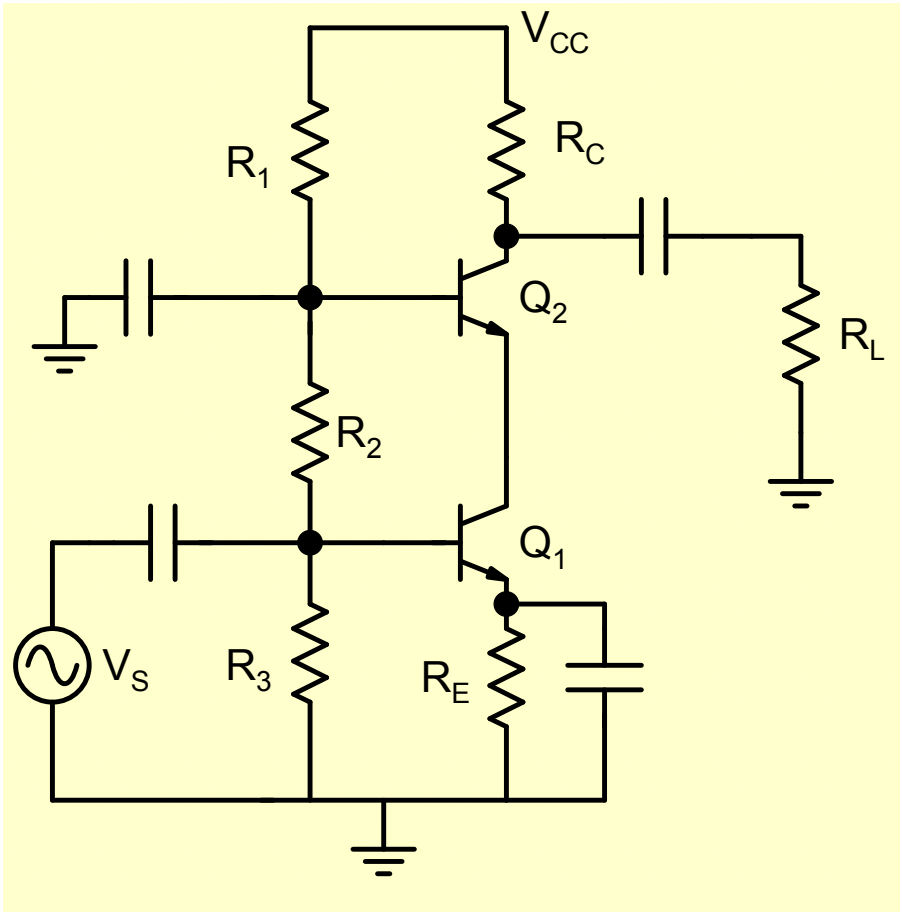
V_{CC}
22K
2.2K
10μF
Q_2
10μF
2.2K
6.8K


V_{CC}
R_1
R_C
Q_2
R_L
R_2
V_{CC}
R_3
Q_1
V_S
R_4
R_E

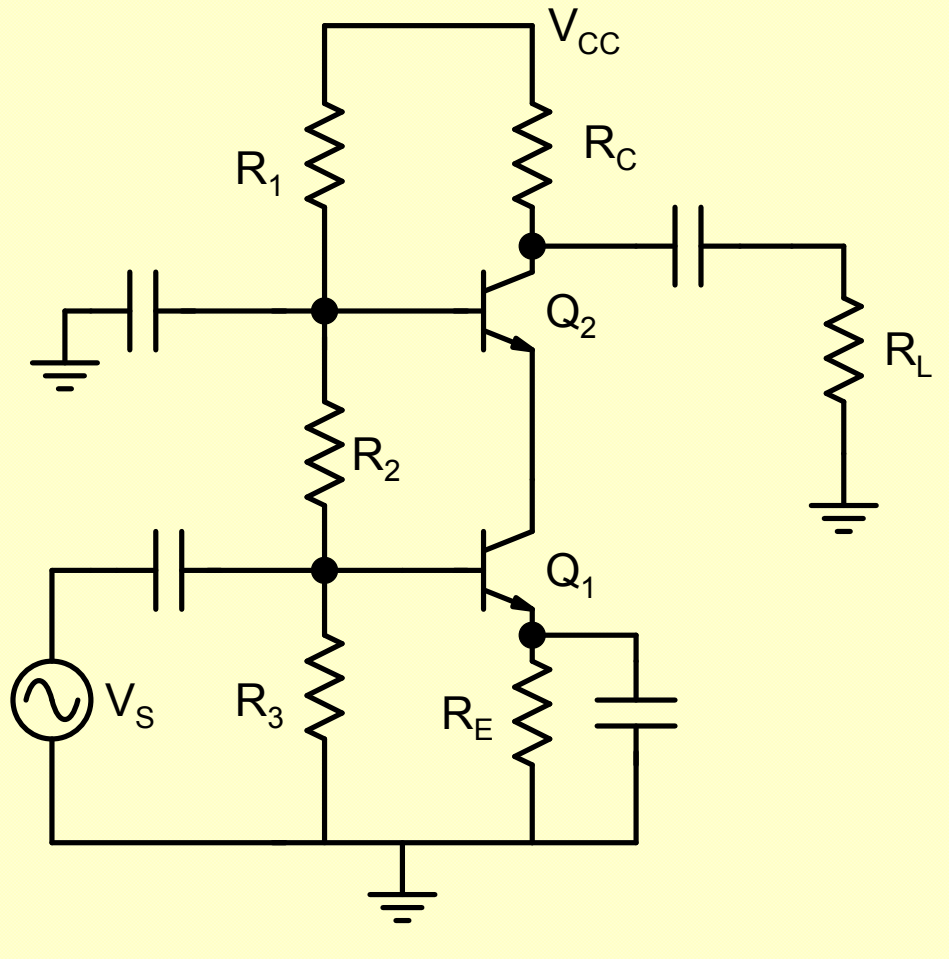

V_{CC}
R_1
R_C
Q_2
R_L
R_2
Q_1
V_S
R_3
R_E

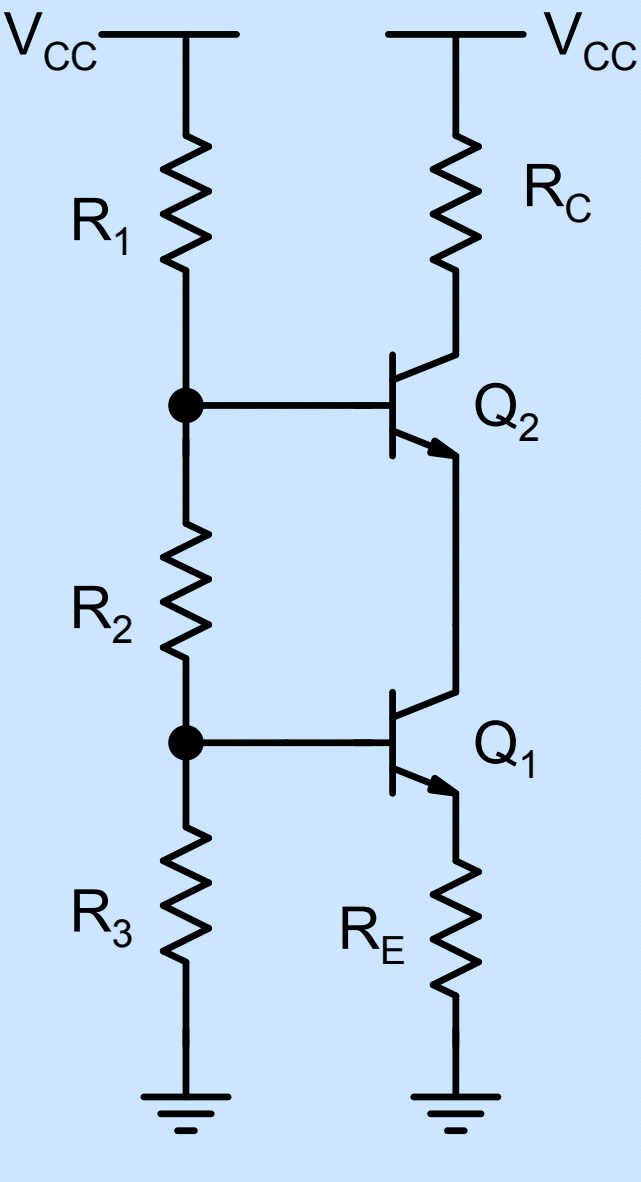
Cascode Amplifier

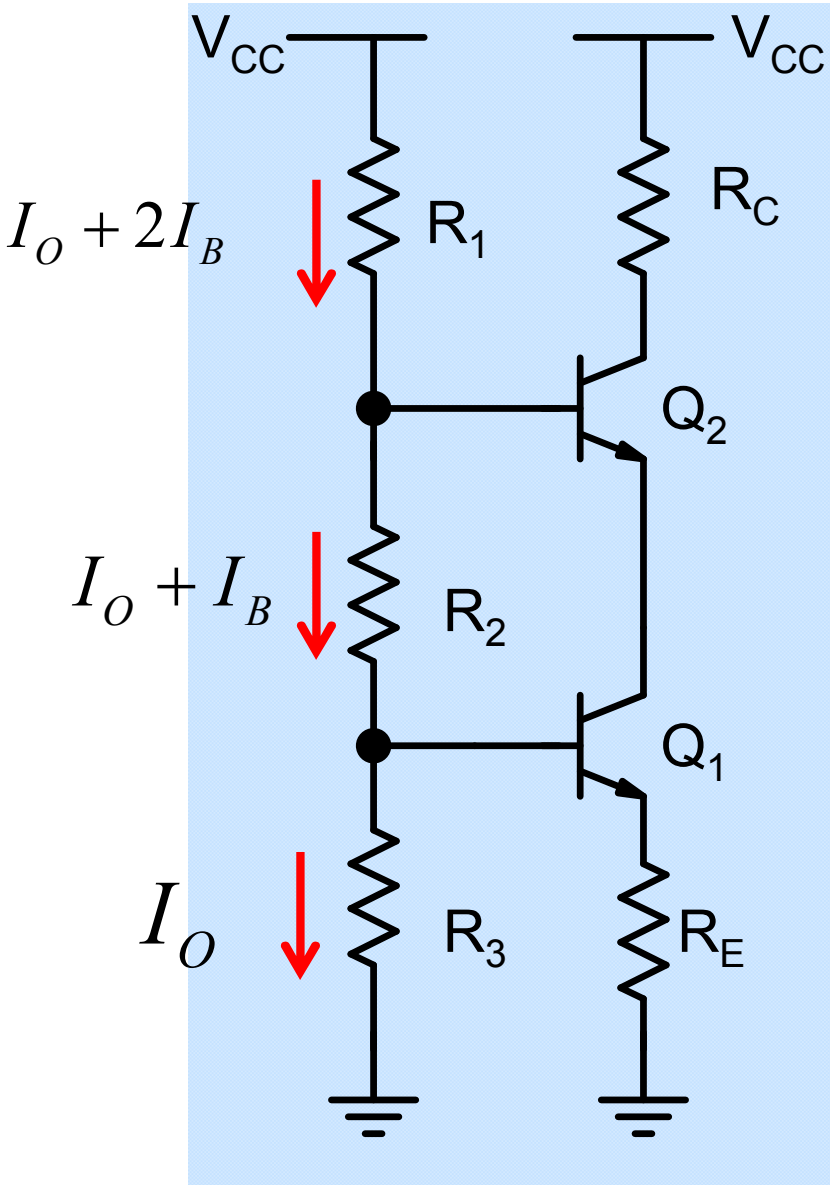




Bias point Analysis

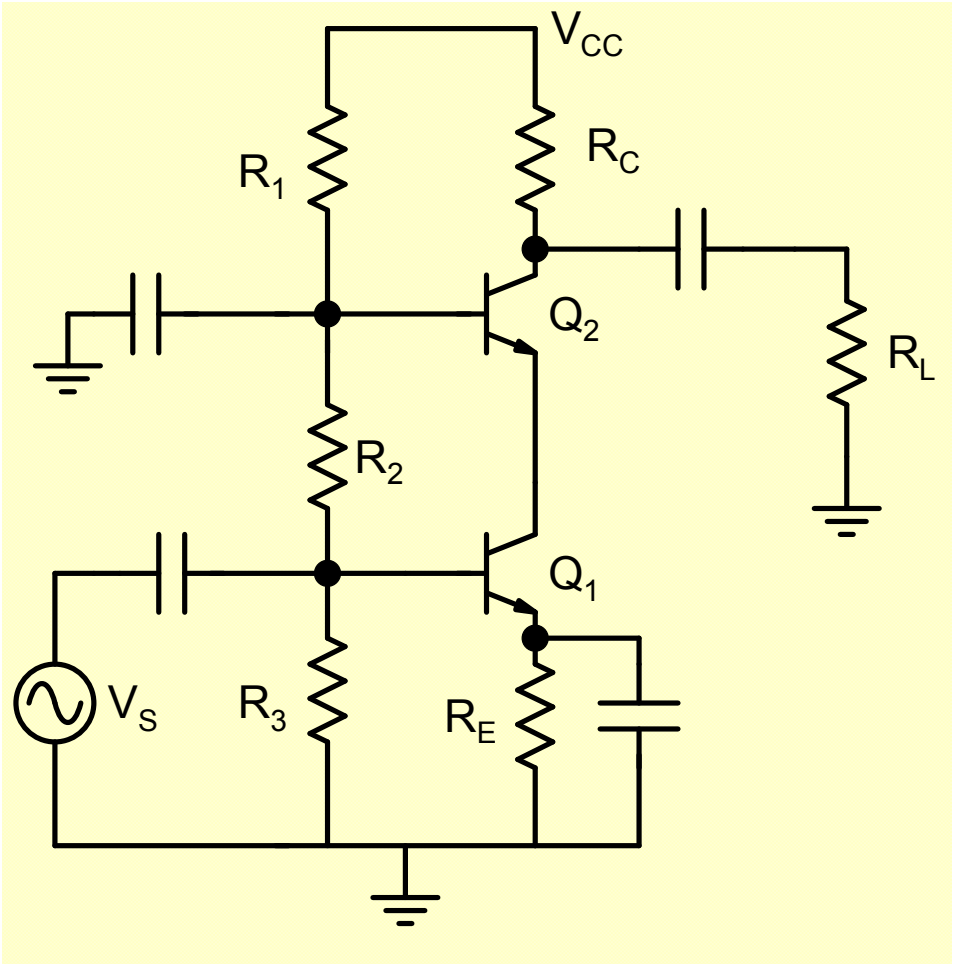


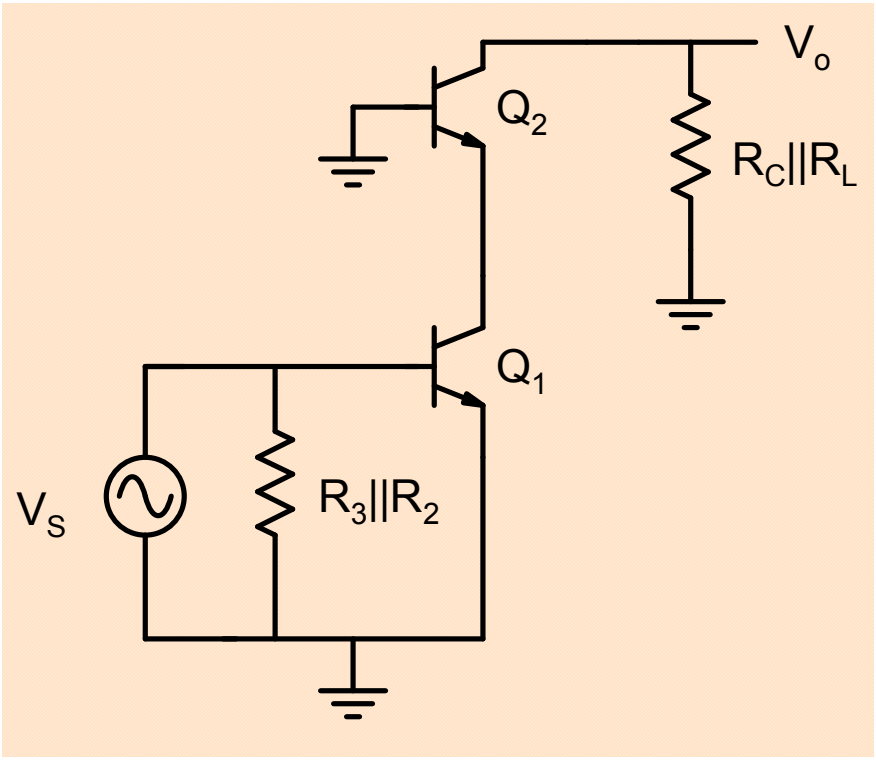


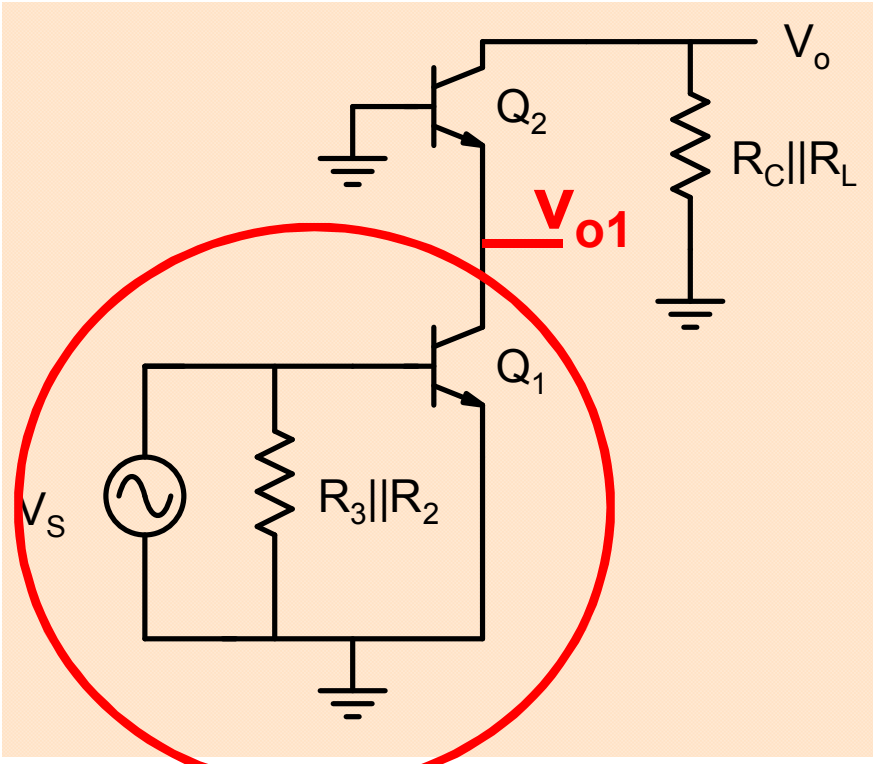


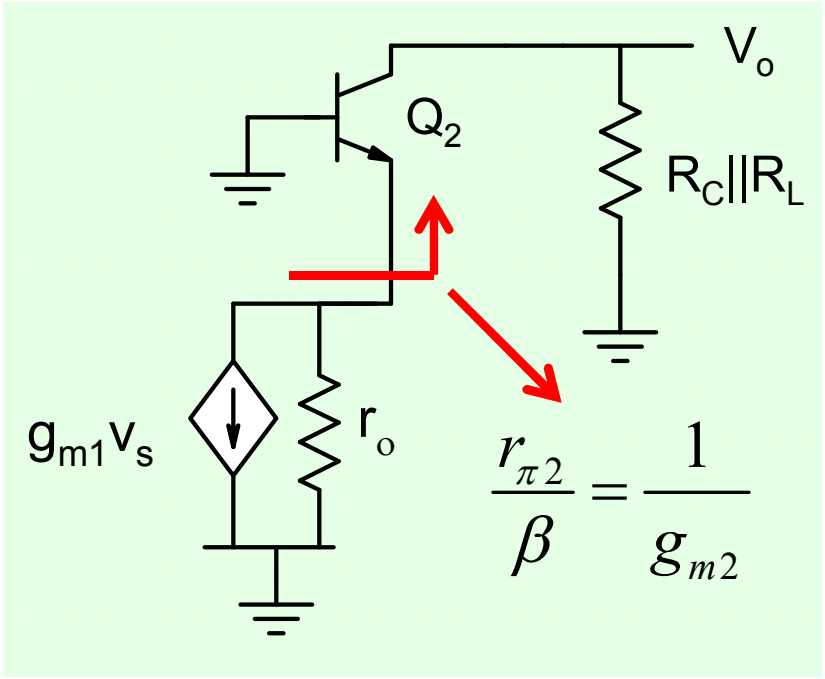
$$V_{CC} = (I_O + 2I_B) \times R_1 + (I_O + I_B) \times R_2 + I_O \times R_3$$

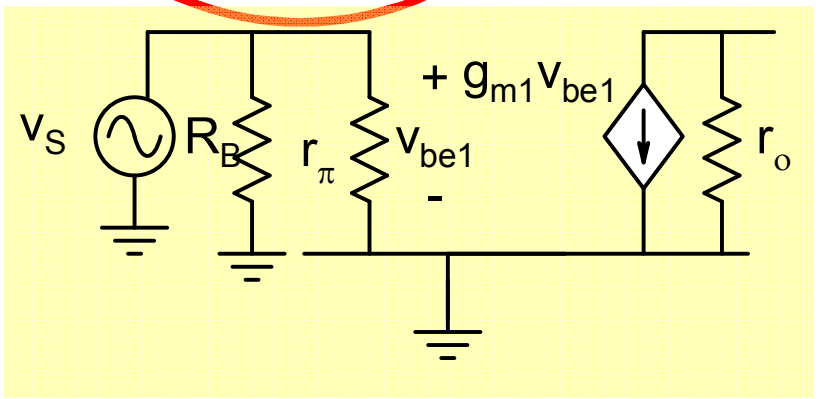
$$I_O \times R_3 = V_{BE} + I_E \times R_E$$


V_{CC}
R_1
R_C
Q_2
R_L
R_2
Q_1
V_S
R_3
R_E


V_o
Q_2
$R_C||R_L$
Q_1
V_S
$R_3||R_2$

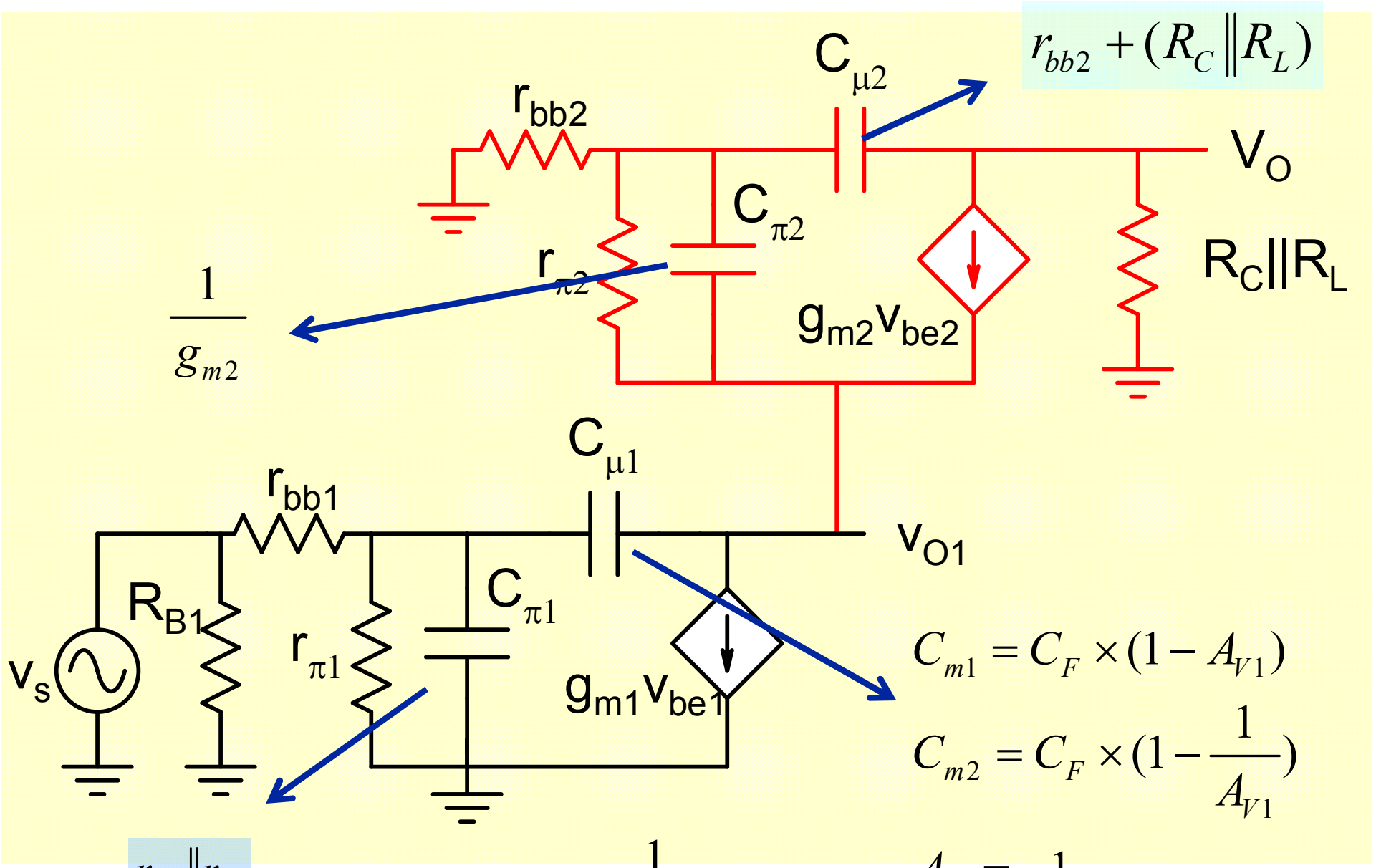




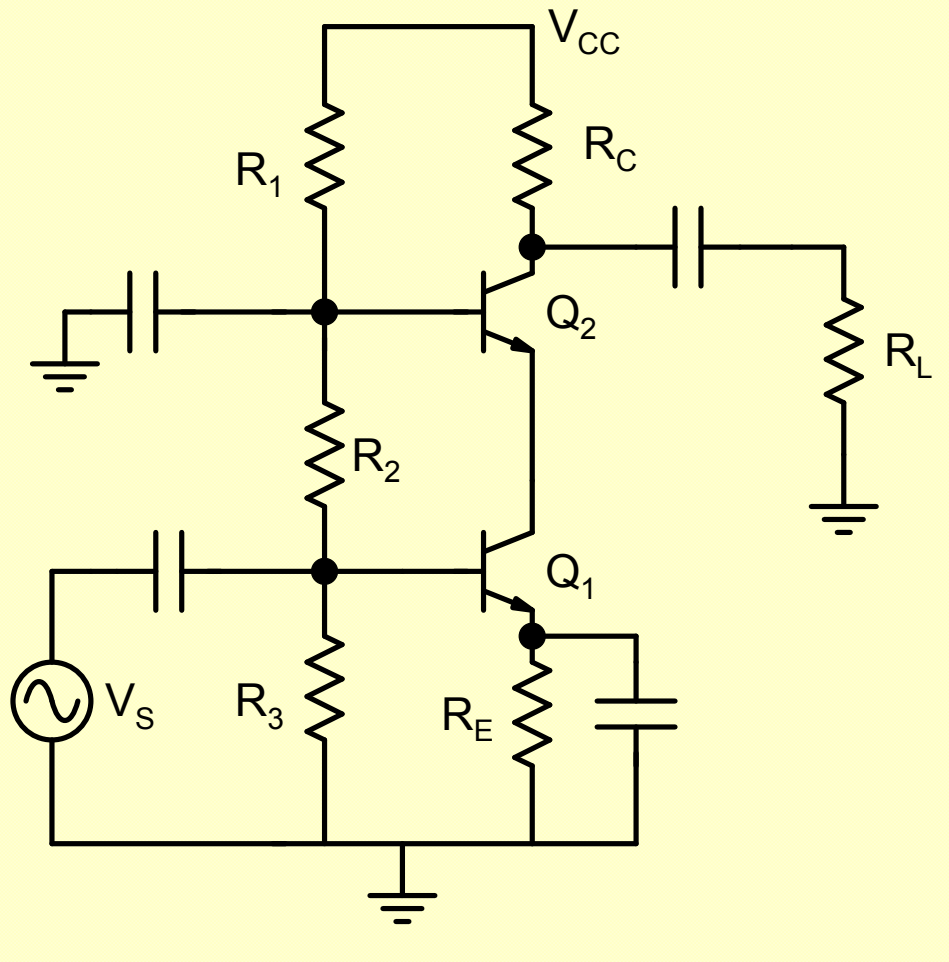


$$\frac{v_o}{v_s} = -g_{m1} \times R_C \left\| R_L \right.$$

$$\frac{v_{o1}}{v_s} = -g_{m1} \times \frac{1}{g_{m2}} = -1$$

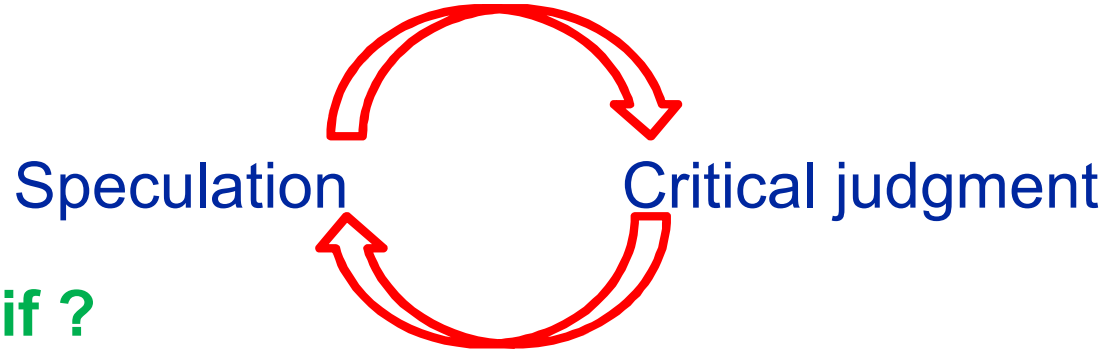

$r_{bb2} + (R_C \| R_L)$
$C_{\mu 2}$
r_{bb2}
V_O
$C_{\pi 2}$
$r_{\pi 2}$
$R_C \| R_L$
$\frac{1}{g_{m2}}$
$g_{m2} v_{be2}$
$C_{\mu 1}$
r_{bb1}
v_{O1}
R_{B1}
$C_{\pi 1}$
v_s
$r_{\pi 1}$
$g_{m1} v_{be1}$
$C_{m1} = C_F \times (1 - A_{V1})$
$C_{m2} = C_F \times (1 - \frac{1}{A_{V1}})$
$r_{bb1} \| r_{\pi 1}$
$f_H = \frac{1}{2\pi \sum \tau}$
$A_{v1} = -1$

Cascode Amplifier



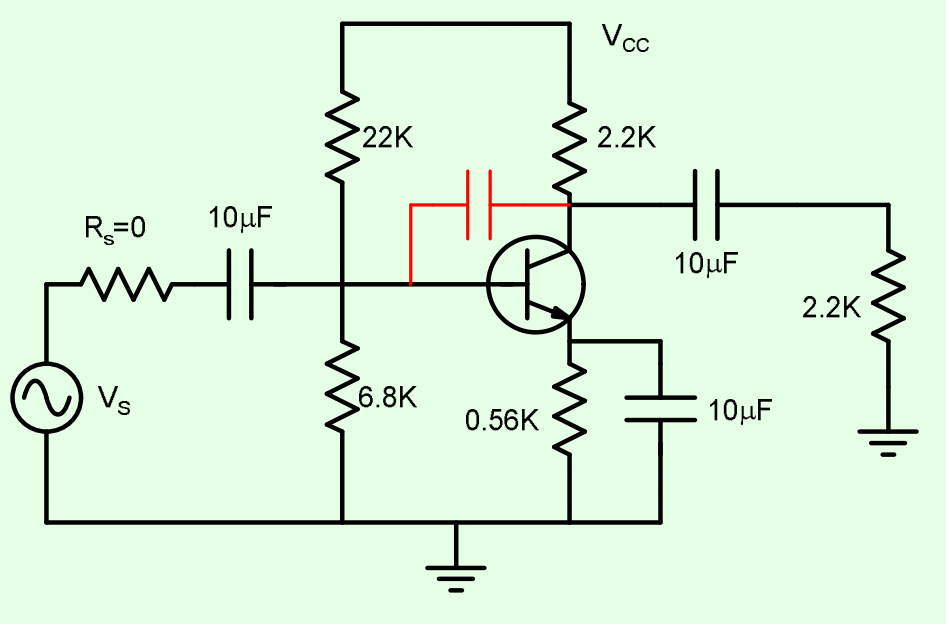
1. Same voltage gain, input and output resistance as a CE amplifier
2. Improved upper cutoff frequency
3. Reduced sensitivity of upper cutoff frequency to increase in voltage gain

Common-Base Amplifier: Lessons in design



What – if ?

- Understand the current solution and its limitations



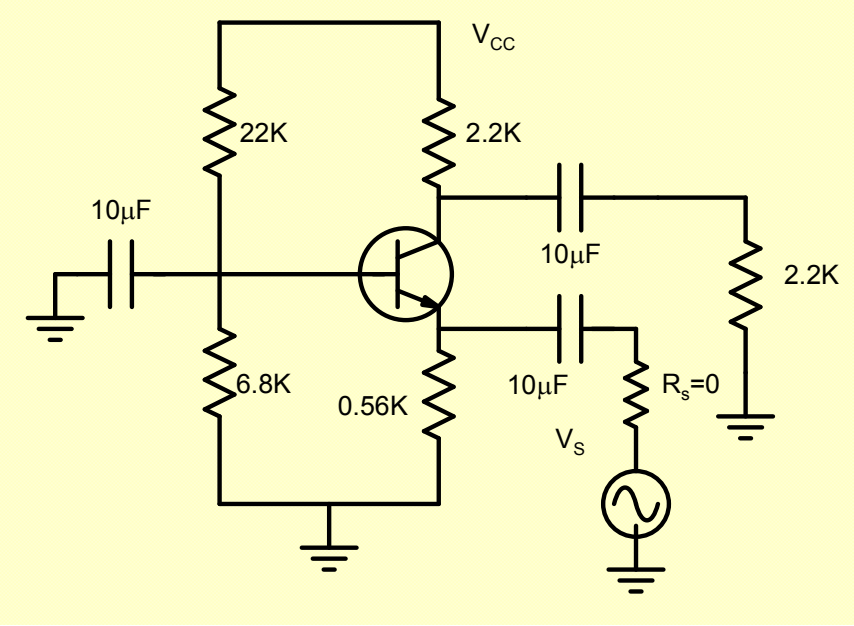
$$A_V = -110.7$$

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

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

$$f_H = 5.8MHz$$

- What – if ?



- Critical analysis

$$A_V = 110.7$$

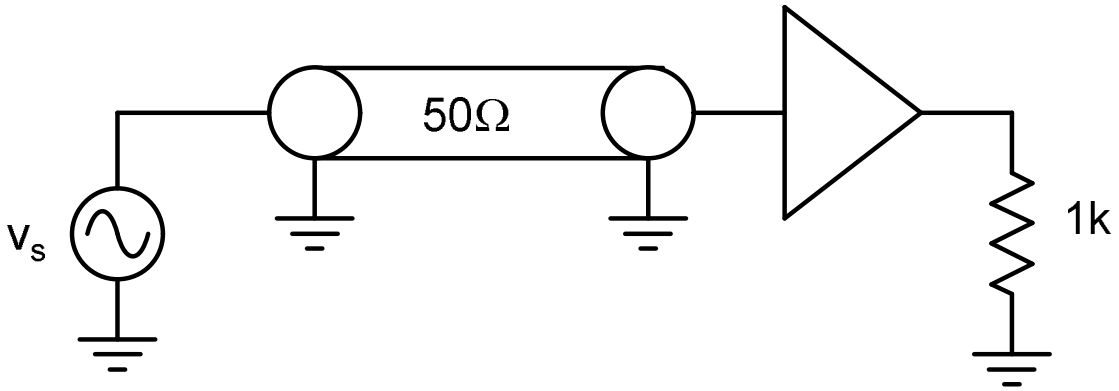
$$R_{in} = 9.66\Omega, R_o = 2.2k\Omega$$

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

$$f_H = 5.8MHz$$

Sometimes, a perceived disadvantage could actually be advantageous

Application of low input resistance

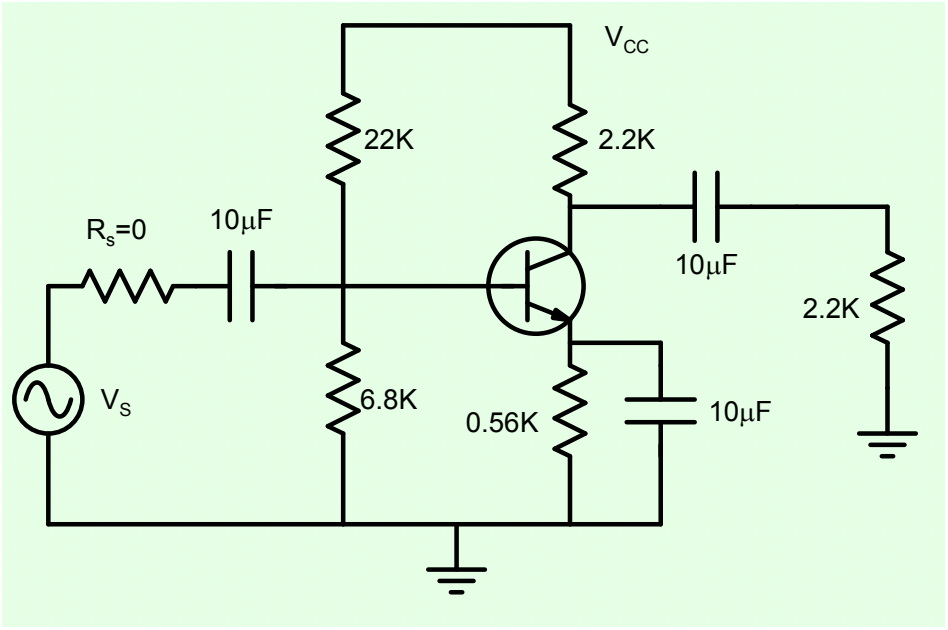


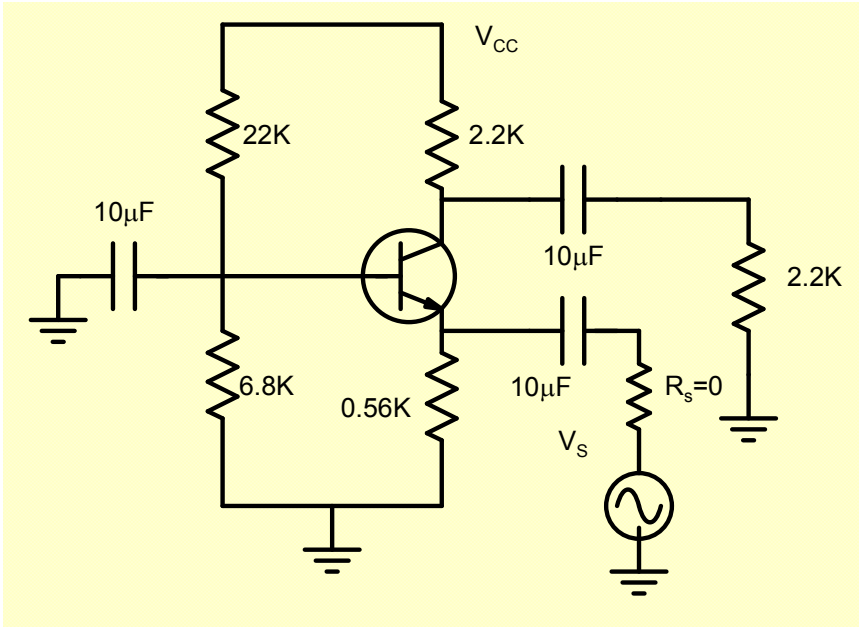
$$\text{CE}: R_{in} \sim r_\pi = \frac{V_T}{I_{CQ}}\beta = 50\Omega$$

I_{CQ}=52mA for β=100

$$\text{CB}: R_{in} \sim \frac{r_\pi}{\beta} = \frac{V_T}{I_{CQ}} = 50\Omega$$

I_{CQ}=0.52 mA for β=100





$$A_V = -110.7$$

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

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

$$f_H = 5.8MHz$$

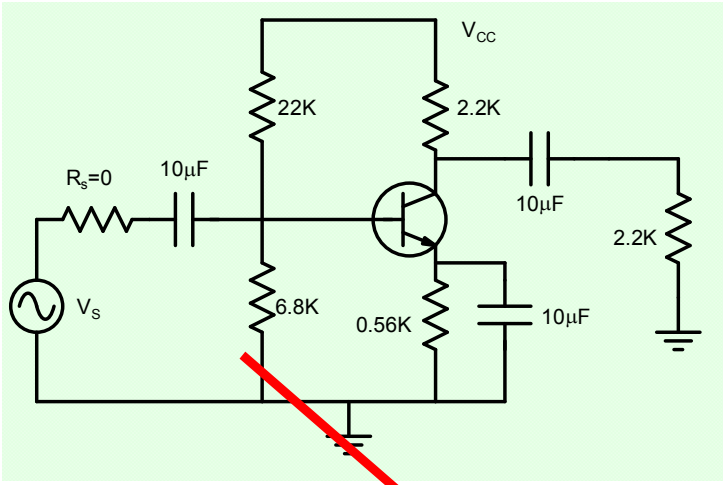
$$A_V = 110.7$$

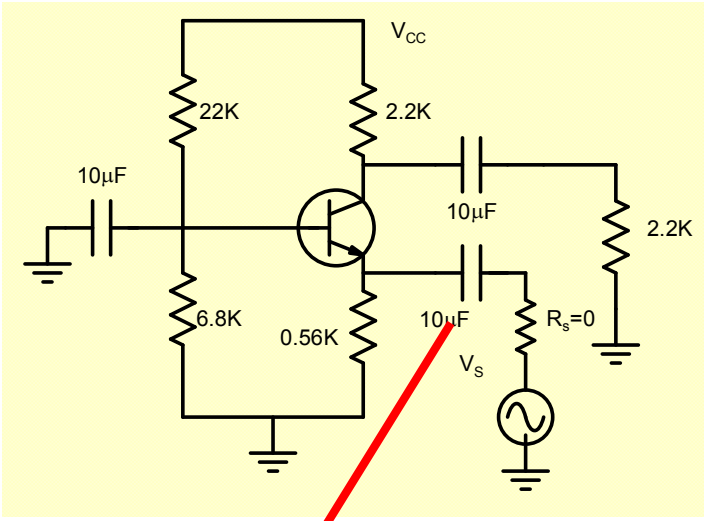
$$R_{in} = 9.66\Omega; R_o = 2.2k\Omega$$

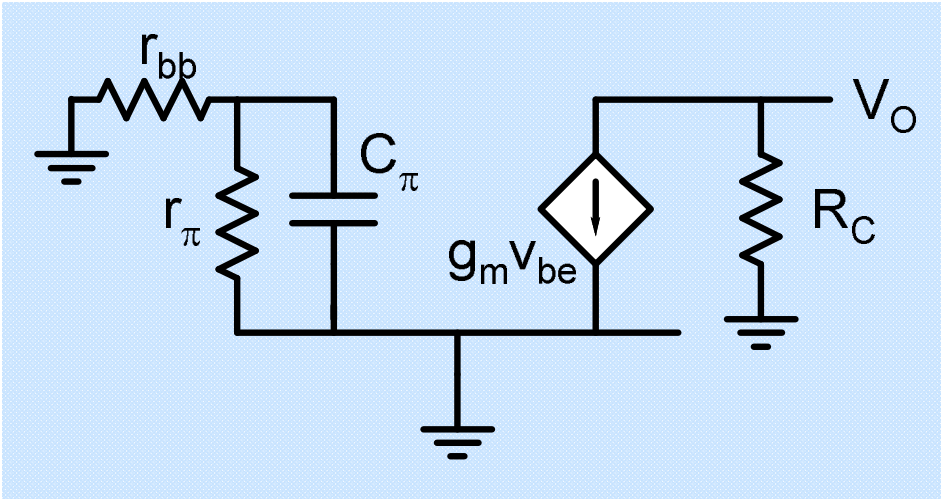
$$\frac{A_v \times R_{in}}{R_O} = 0.48$$

$$f_H = 5.8MHz$$

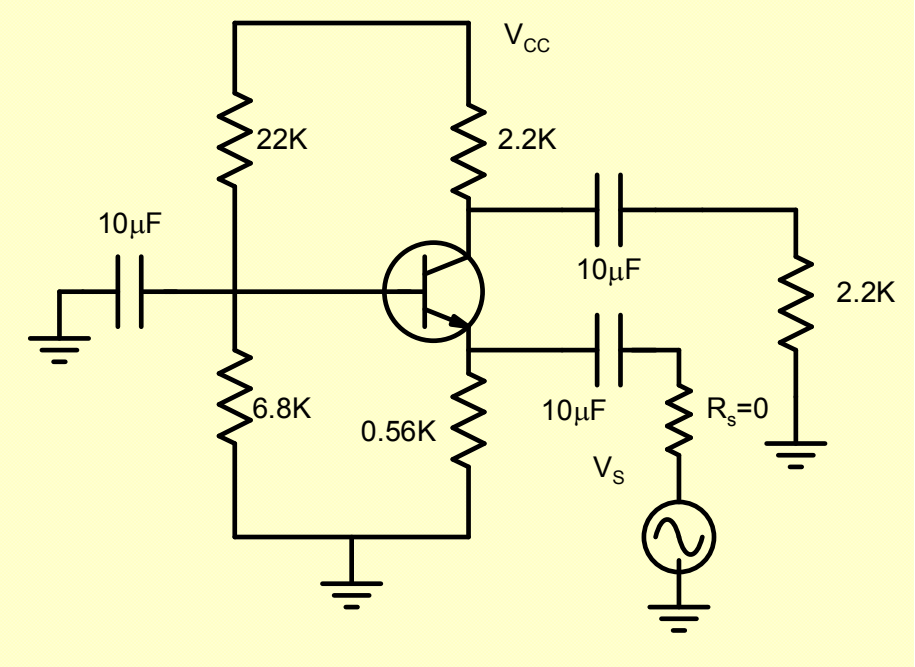
Critical analysis

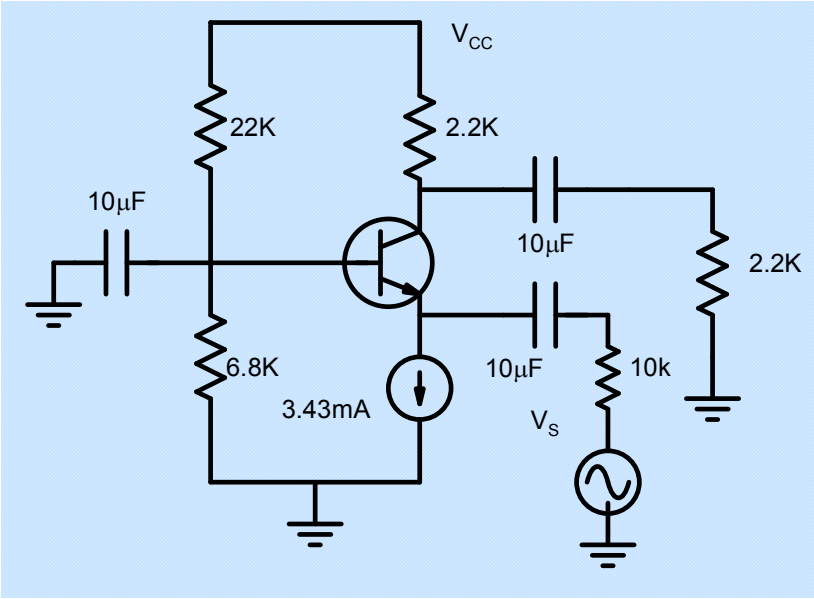






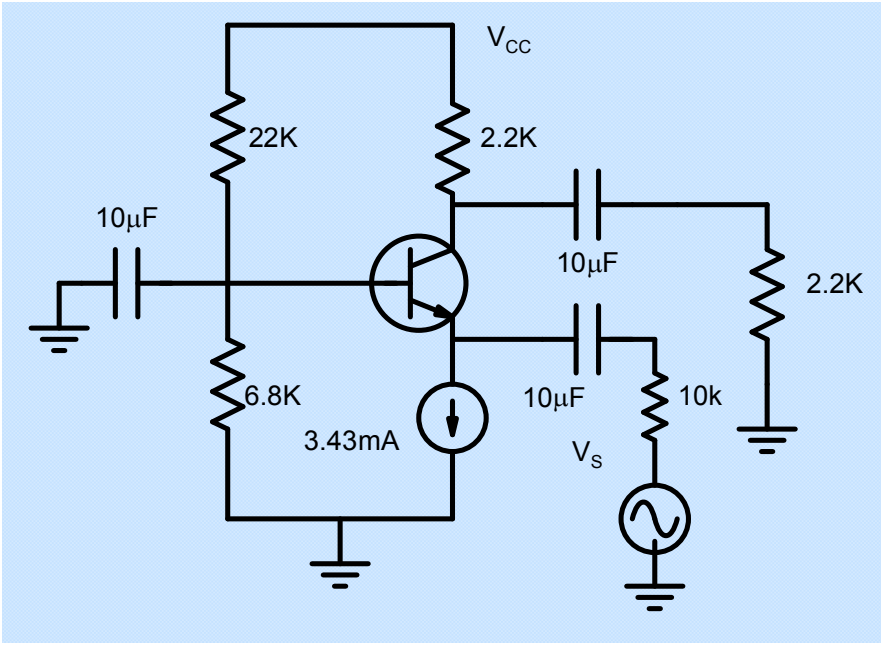
- What – if ?

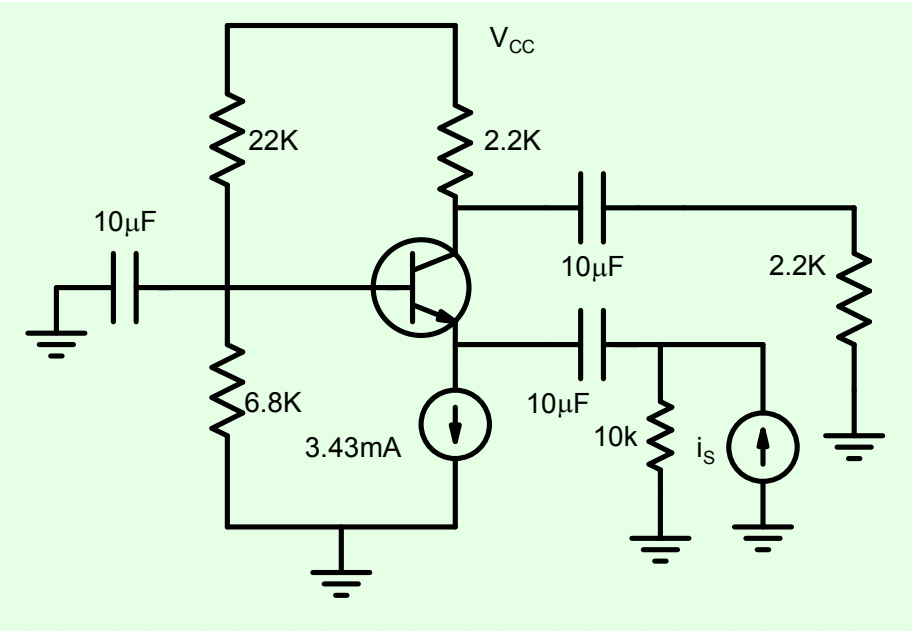




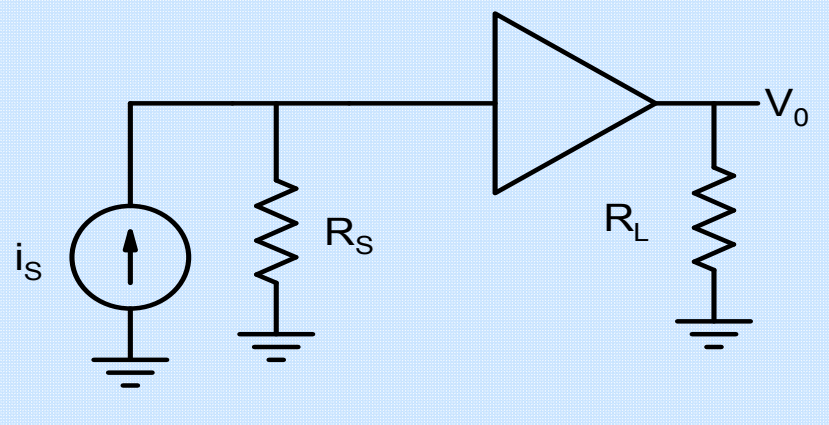
$$A_V = -110.7; f_H = 5.8MHz$$

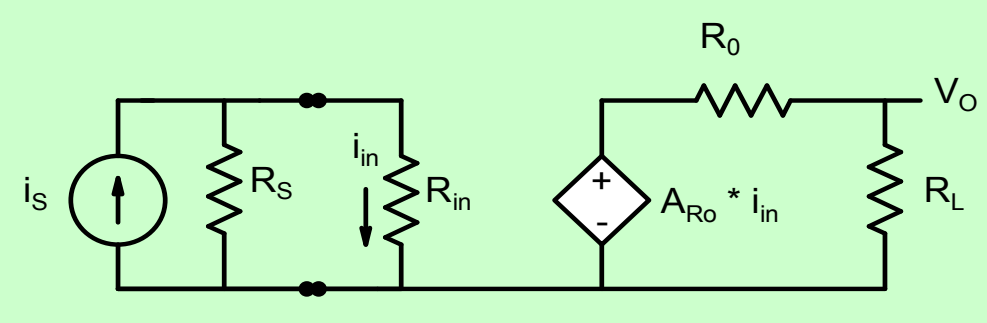
$$CB: A_V = 0.1; f_H = 73.5MHz$$


V_{CC}
22K
2.2K
10μF
10μF
2.2K
6.8K
3.43mA
10μF
10k
V_S


V_{CC}
22K
2.2K
10μF
10μF
2.2K
6.8K
3.43mA
10μF
10k
i_S

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

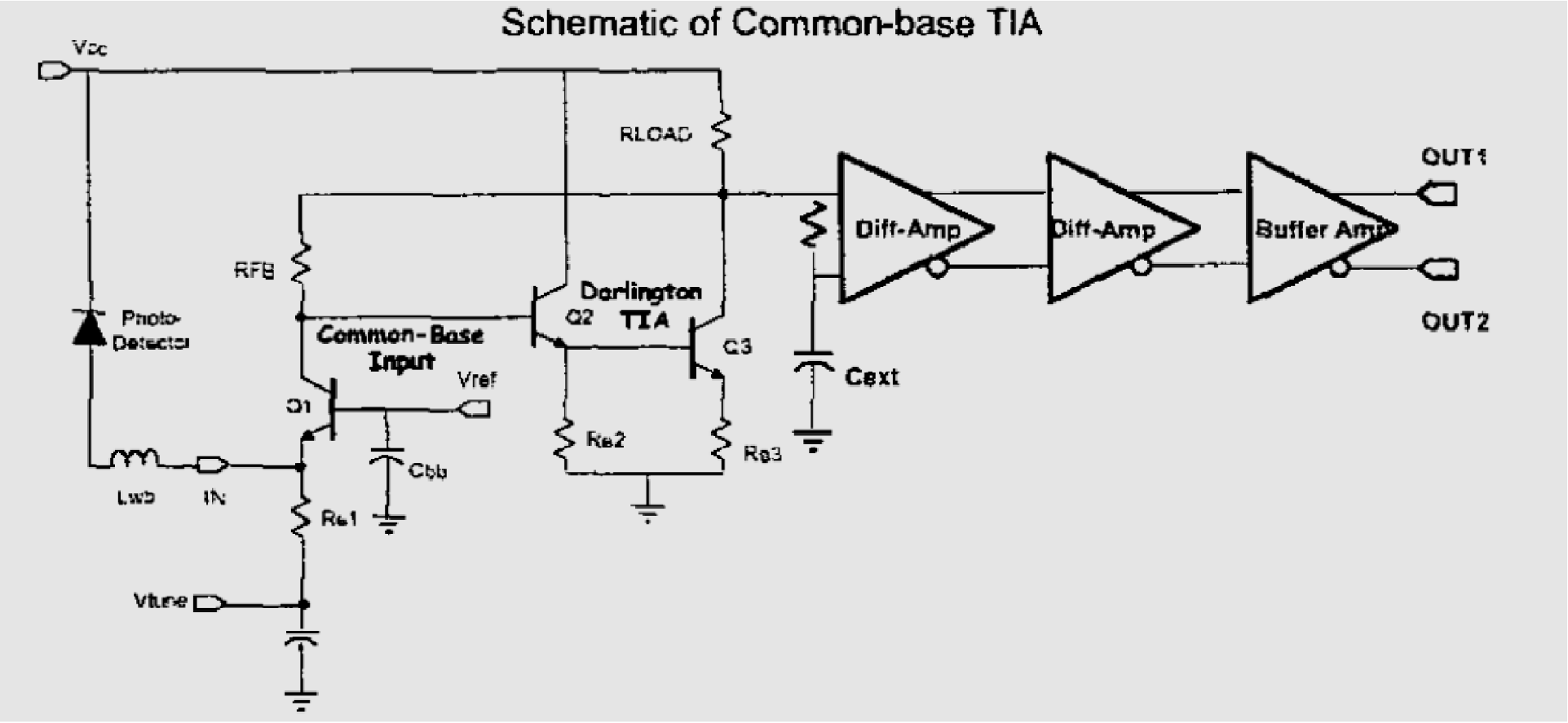


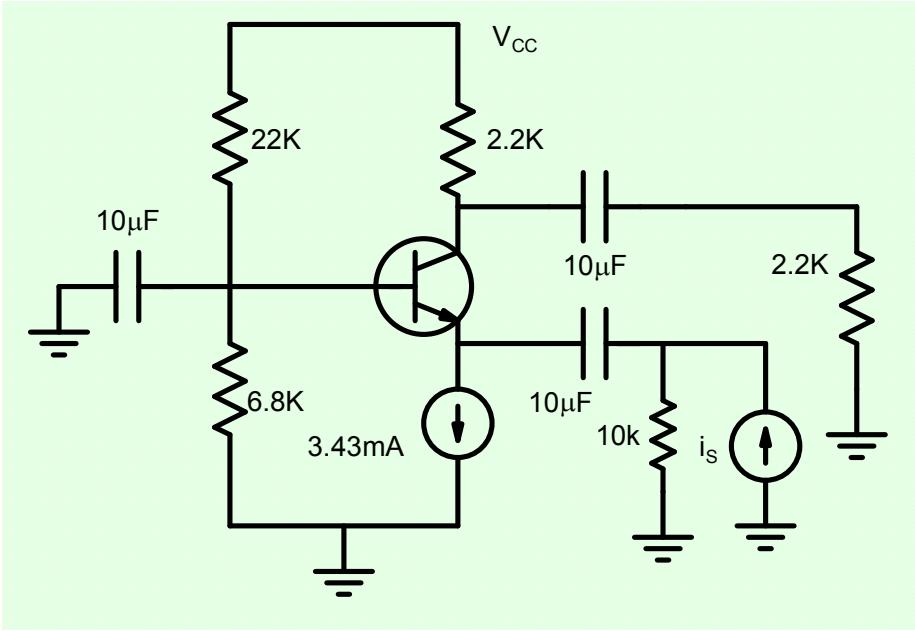


$$\frac{v_o}{i_s} = \left(\frac{1}{1 + \frac{R_{in}}{R_S}} \right) \times \left(\frac{1}{1 + \frac{R_O}{R_L}} \right) \times A_{RO}$$

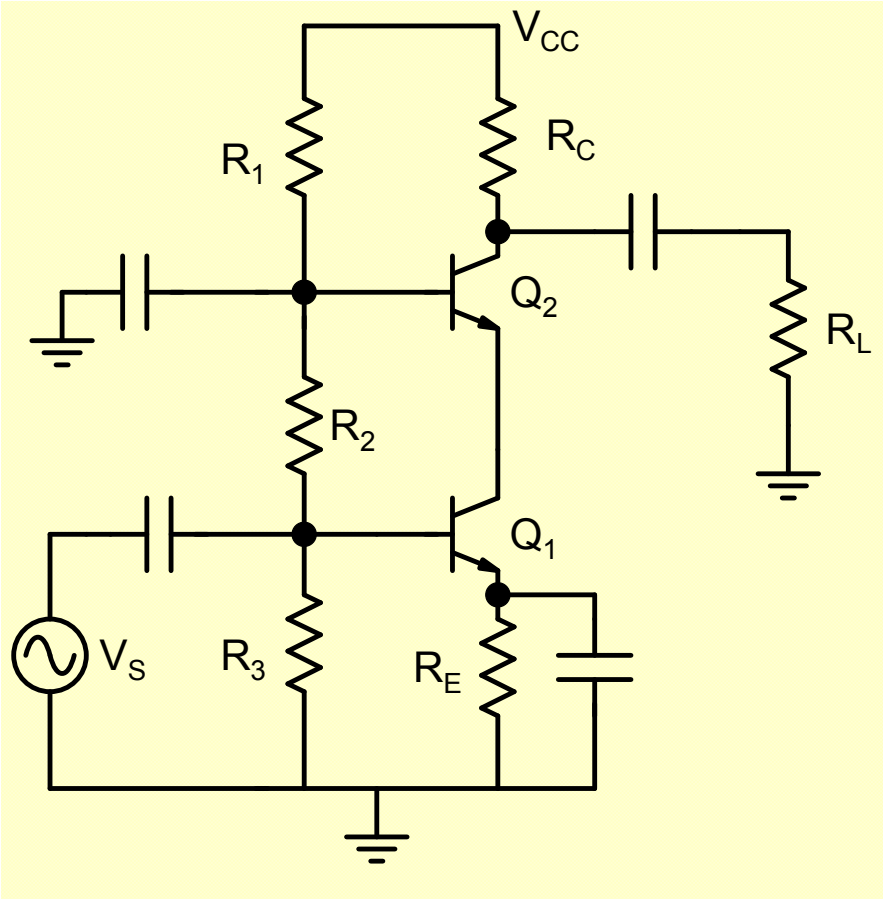
AN InP HBT COMMON-BASE AMPLIFIER WITH TUNABLE TRANSIMPEDANCE FOR 40 GB/S APPLICATIONS

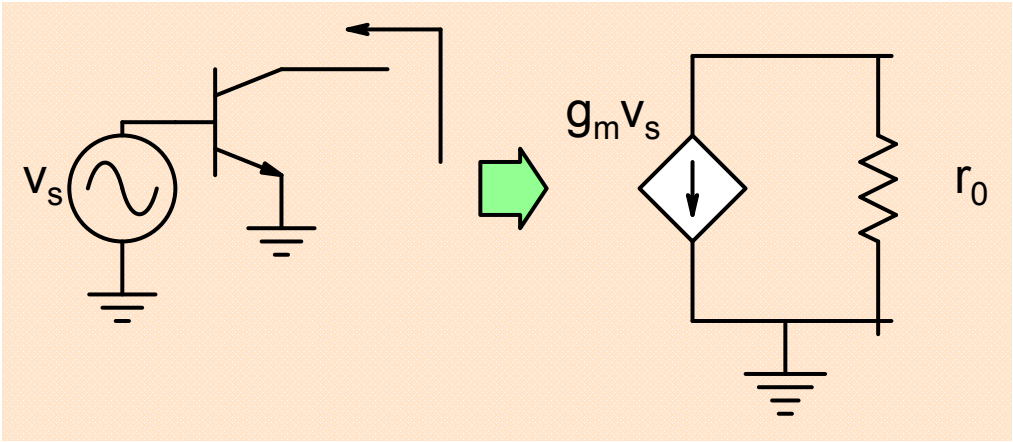
Kevin W. Kobayashi

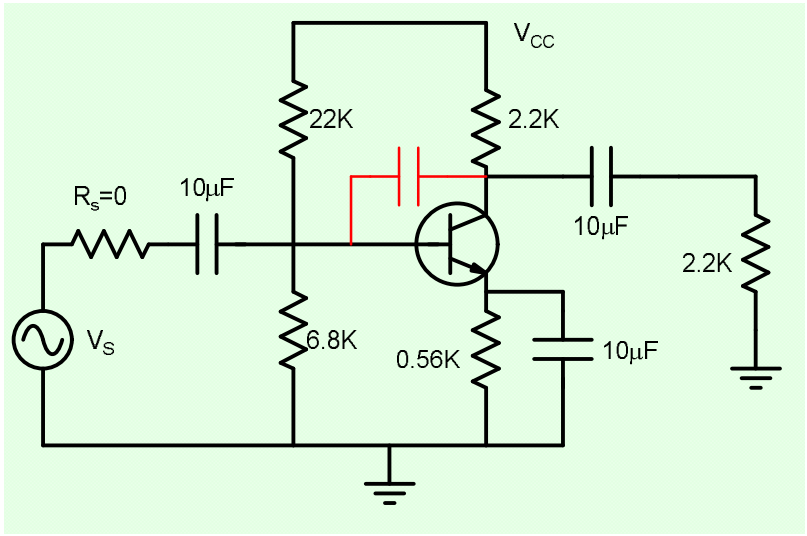


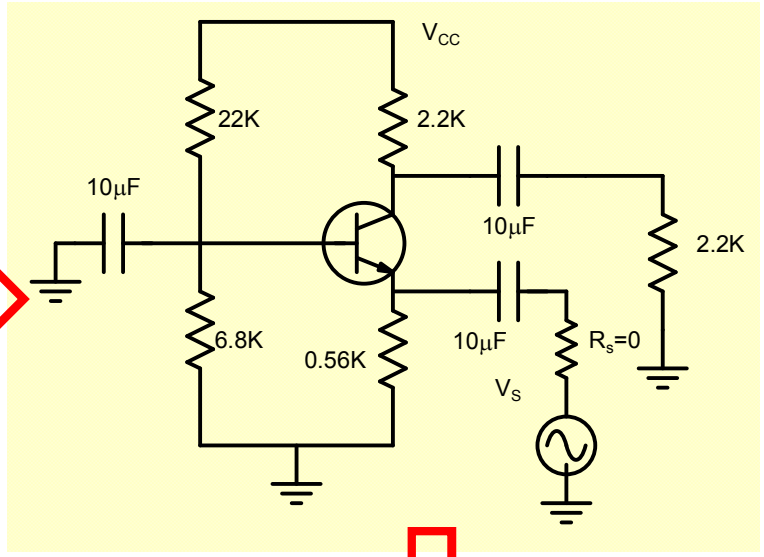

V_{CC}
22K
2.2K
10μF
10μF
2.2K
6.8K
3.43mA
10μF
10k
i_s

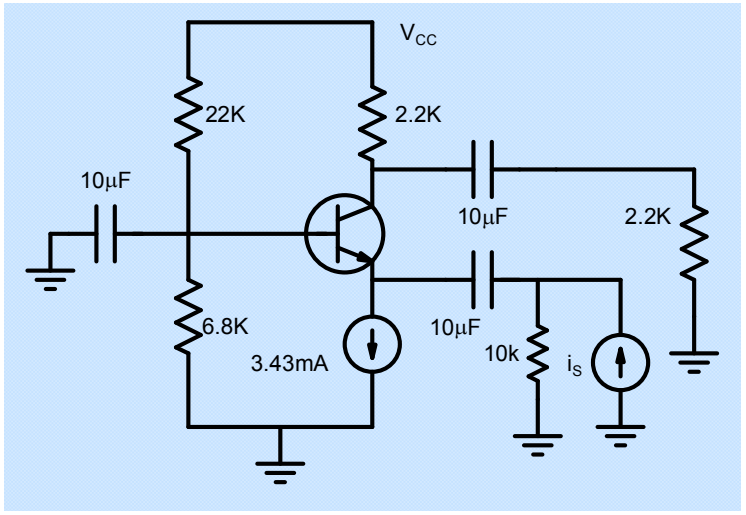
- What – if ?

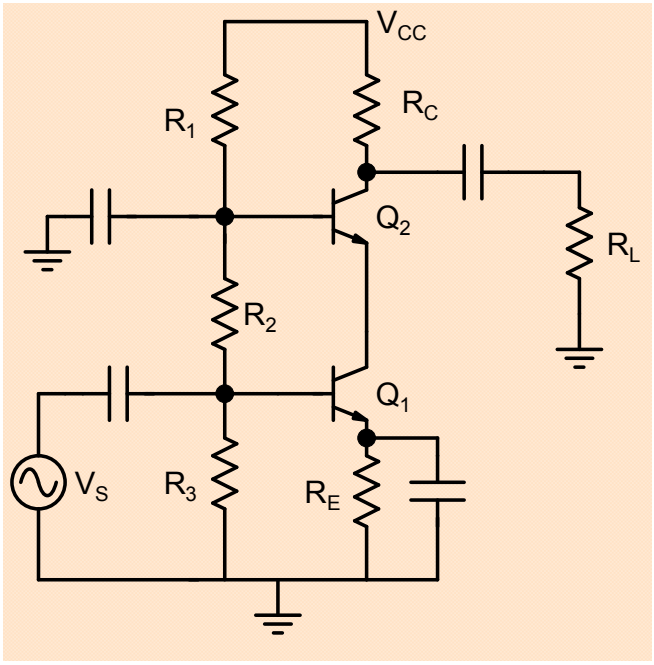

V_{CC}
R_1
R_C
Q_2
R_L
R_2
Q_1
V_S
R_3
R_E


v_s
$g_m v_s$
r_0


V_{CC}
22K
2.2K
R_s=0
10μF
10μF
2.2K
V_S
6.8K
0.56K
10μF


V_{CC}
22K
2.2K
10μF
10μF
2.2K
6.8K
0.56K
10μF
R_s=0
V_S


V_{CC}
22K
2.2K
10μF
10μF
2.2K
6.8K
3.43mA
10μF
10k
i_S


V_{CC}
R_1
R_C
Q_2
R_L
R_2
Q_1
V_S
R_3
R_E