Lecture-2

Common Emitter, RC Coupled and Common Source Amplifier

Short-circuit time-constant method (SCTC)

- To determine the lower-cutoff frequency having *n* coupling and bypass capacitors:

$$\omega_L \cong \sum_{i=1}^{n} \frac{1}{R_{iS} C_i}$$

R_{iS} = resistance at the terminals of the *i*th capacitor C_i with all the other capacitors replaced by short circuits.

Common-emitter Amplifier

Given :

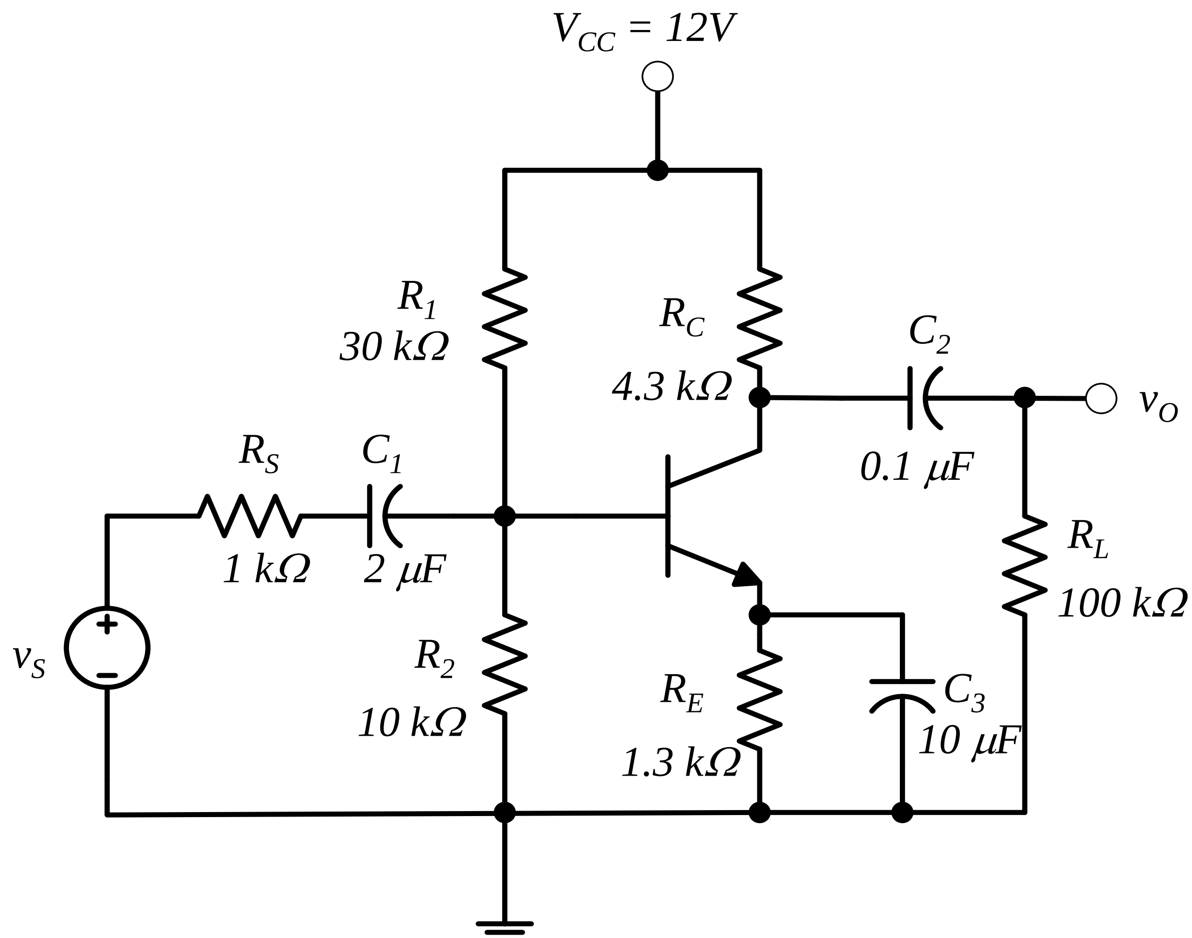
Q-point values : 1.73 mA, 2.32 V

β = 100, V_A = 75 V

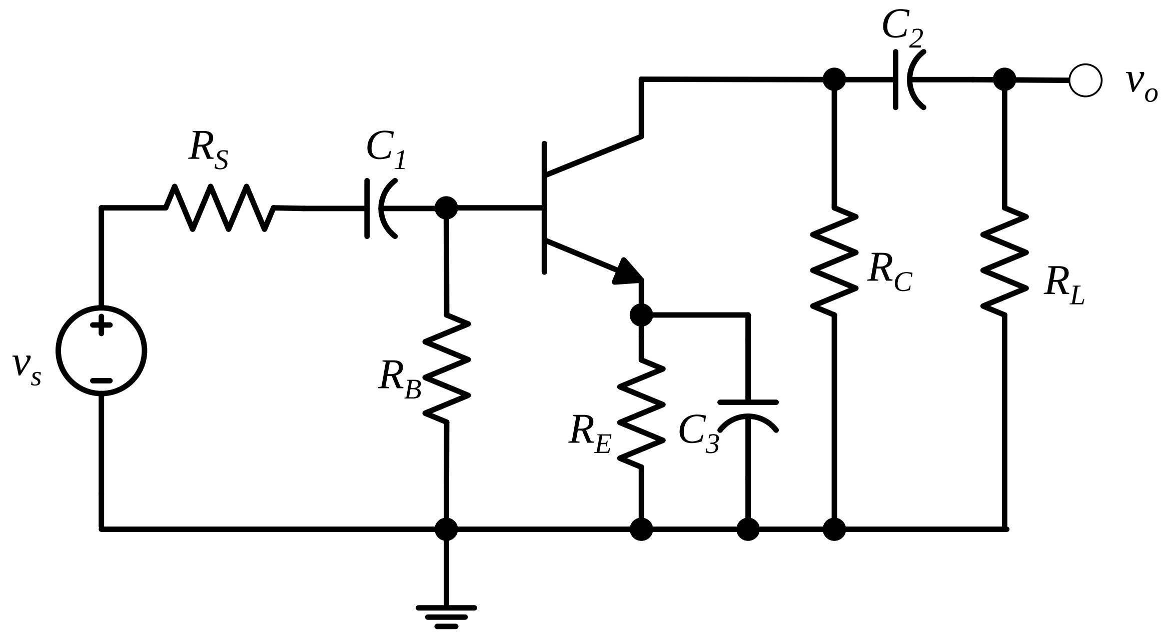
Therefore,

r_π = 1.45 kΩ,

r_o =44.7 kΩ

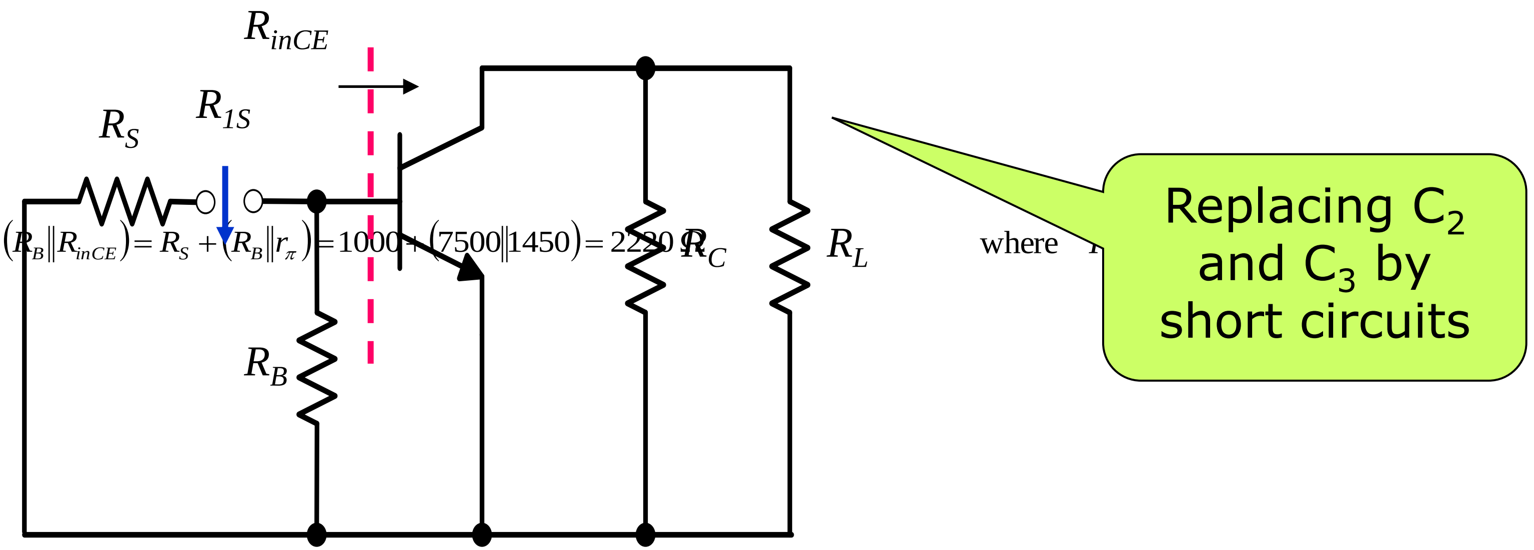


Common-emitter Amplifier
- Low-frequency ac equivalent circuit



In the above circuit, there are 3 capacitors (coupling plus bypass capacitors). Hence we need to find 3 resistances at the terminals of the 3 capacitors in order to find the lower cut-off frequency of the amplifier circuit.

Circuit for finding R_{1S}

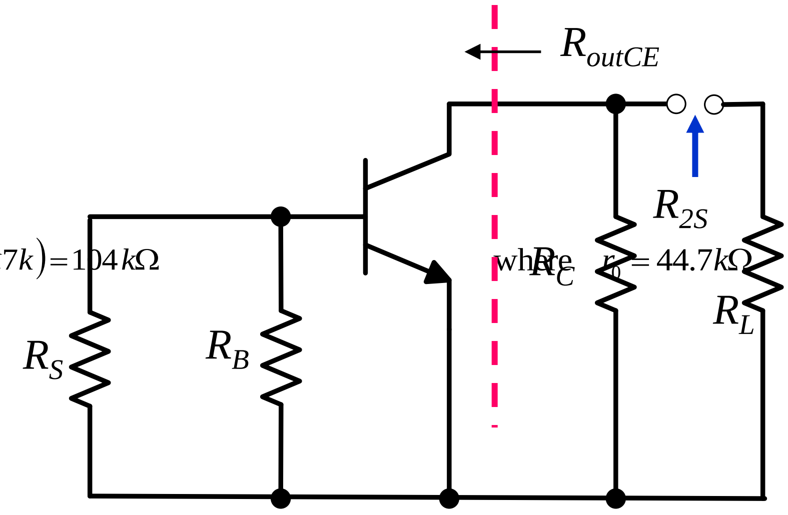


$$R_{1S} = R_S + (R_B \| R_{inCE}) = R_S + (R_B \| r_\pi) = 1000 + (7500 \| 1450) = 2220\ \Omega$$ where

$$\frac{1}{R_{1S}C_1} = \frac{1}{(2.22\,k\Omega)(2.00\,\mu F)} = 225\, rad/s$$

Circuit for finding R_{2S}

Replacing C_1 and C_3 by short circuits



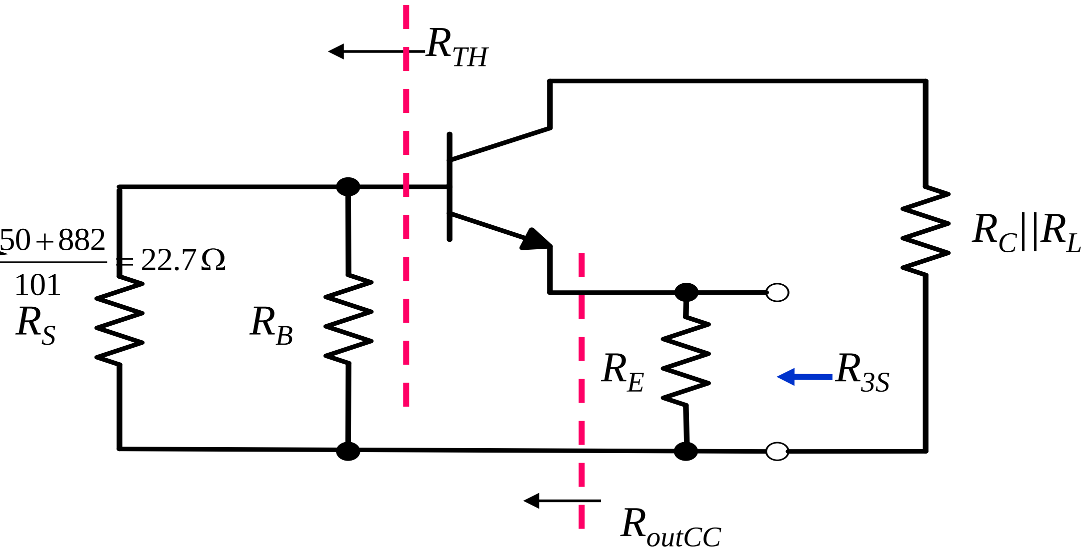
$R_{2S} = R_L + \ldots (4.3k \| 44.7k) = 104\,k\Omega$ where $r_o = 44.7k\Omega$

$$\frac{1}{R_{2S}C_2} = \frac{1}{(104\,k\Omega)(0.100\,\mu F)} = 96.1\,rad/s$$

Circuit for finding R_{3S}

Replacing C_1 and C_2 by short circuits

$[illegible]\|\frac{1450+882}{101}=22.7\,\Omega$



$$\frac{1}{R_{3S}C_3}=\frac{1}{(22.7\Omega)(10\mu F)}=4410\ rad/s$$

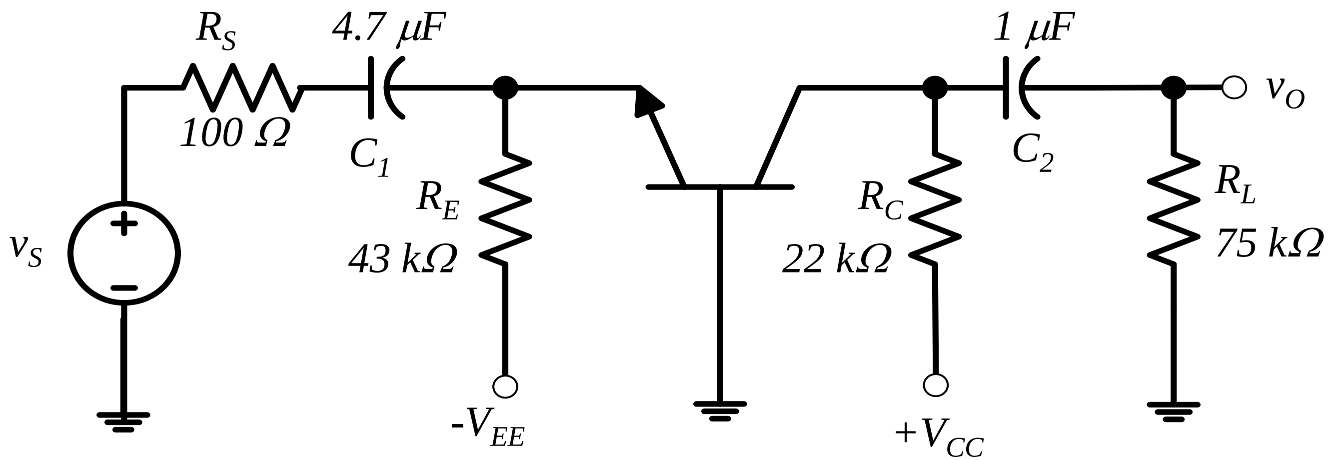
$$R_{TH}=R_S\|R_B=882\,\Omega$$

Estimation of ω_L

$$\omega_L \cong \sum_{i=1}^{3} \frac{1}{R_{iS} C_i} = 225 + 96.1 + 4410 = 4730\, rad/s$$

$$f_L = \frac{\omega_L}{2\pi} = 753\, Hz$$

Common-base Amplifier



Given :

Q-point values : 0.1 mA, 5 V

$\beta = 100$, $V_A = 70$ V

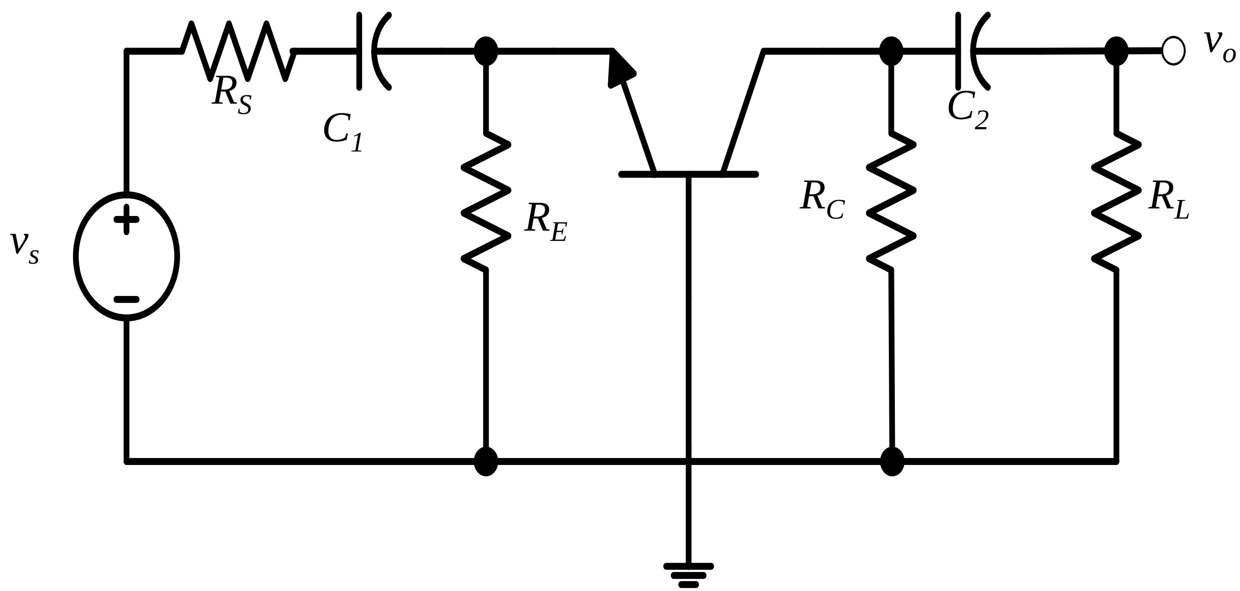
Therefore,

$g_m = 3.85$ mS, $r_o = 700\ k\Omega$

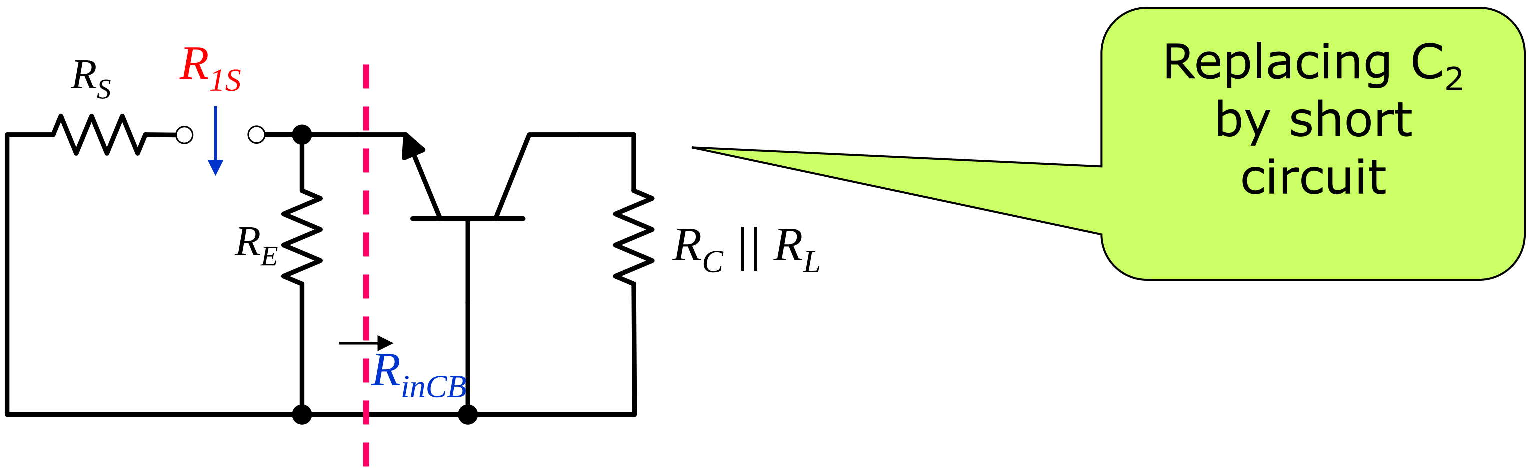
$r_\pi = 26\ \Omega$

Common-base Amplifier

- Low-frequency ac equivalent circuit



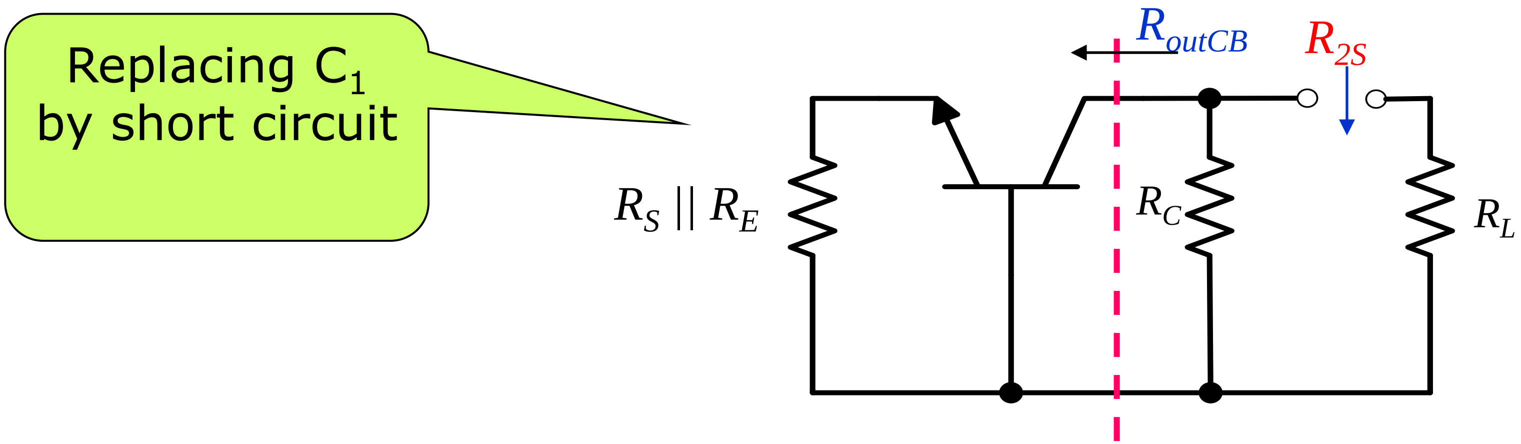
Circuit for finding R_{1S}



$$R_{1S} = R_S + \left(R_E \| R_{inCB}\right) \cong R_S + \left(R_E \left\| \frac{r_\pi}{1+\beta}\right.\right) = 100 + \left(4300 \| 0.26\right) \cong 100\ \Omega$$

$$\frac{1}{R_{1S}C_1} = \frac{1}{\left(100\,\Omega\right)\left(4.7\,\mu F\right)} = 2.13 \times 10^{-3}\ rad/s$$

Circuit for finding R_{2S}



$$R_{2S} = R_L + \left(R_C \| R_{outCB}\right) \cong R_L + R_C = 75k + 22k = 97\,k\Omega$$

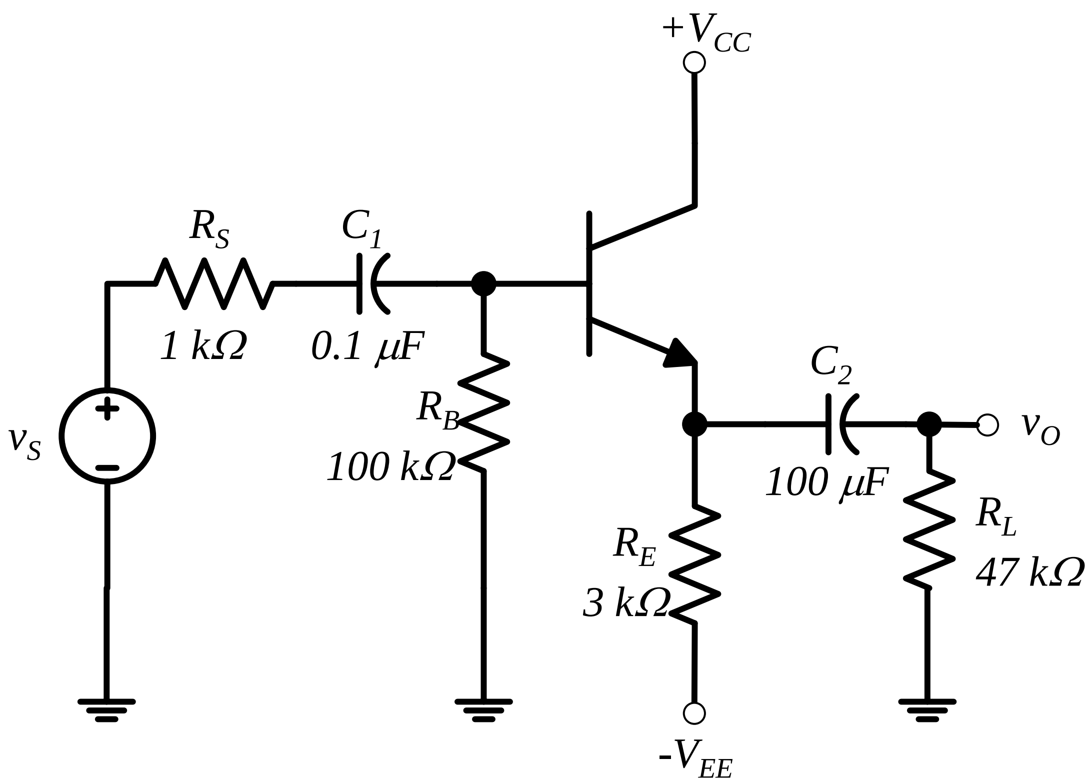
$$\frac{1}{R_{2S}C_2} = \frac{1}{(97\,k\Omega)(1\mu F)} = 10.309\ rad/s$$

Estimation of ω_L

$$\omega_L \cong \sum_{i=1}^{2} \frac{1}{R_{iS} C_i} = 2.13 \times 10^{-3} + 10.309 \cong 10.309\, rad/s$$

$$f_L = \frac{\omega_L}{2\pi} = 1.64\, Hz$$

Common-collector Amplifier



Given :

Q-point values : 1 mA, 5 V

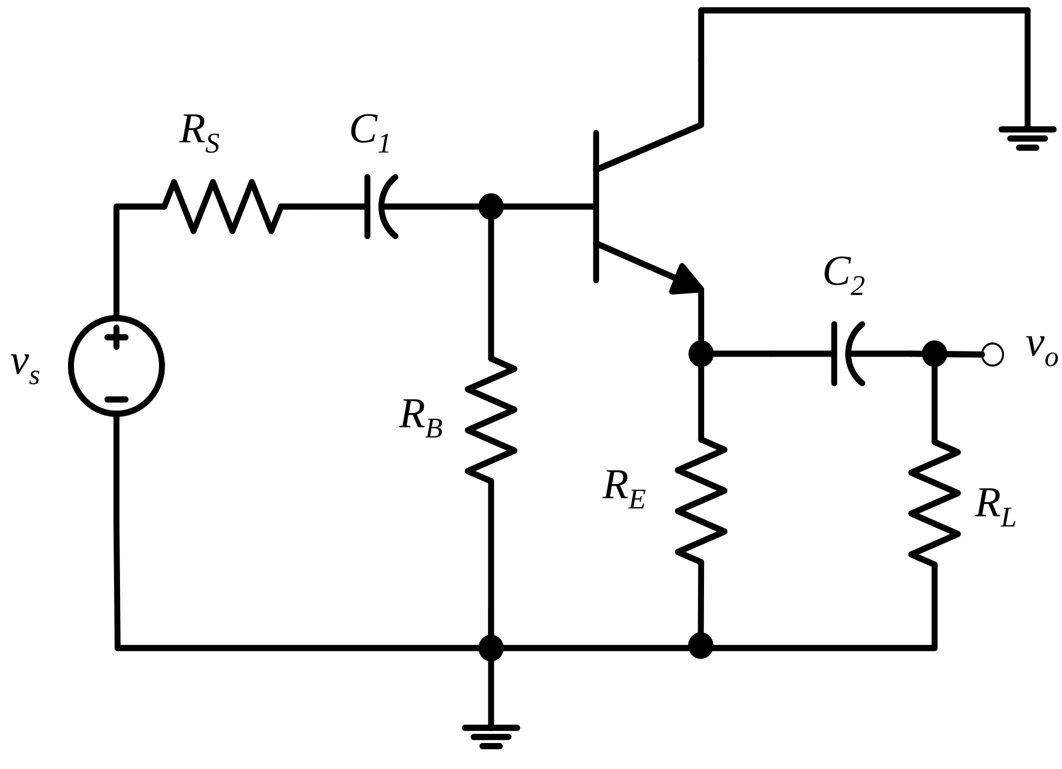
β = 100, V_A = 70 V

Therefore,

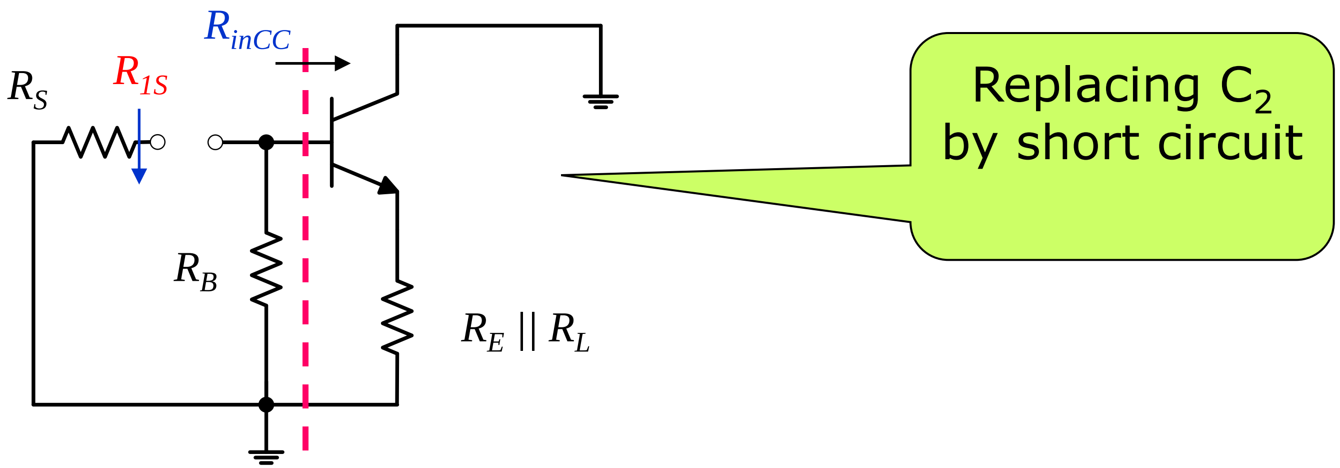
r_π = 2.6 kΩ, r_o =70 kΩ

Common-collector Amplifier

- Low-frequency ac equivalent circuit



Circuit for finding R_{1S}



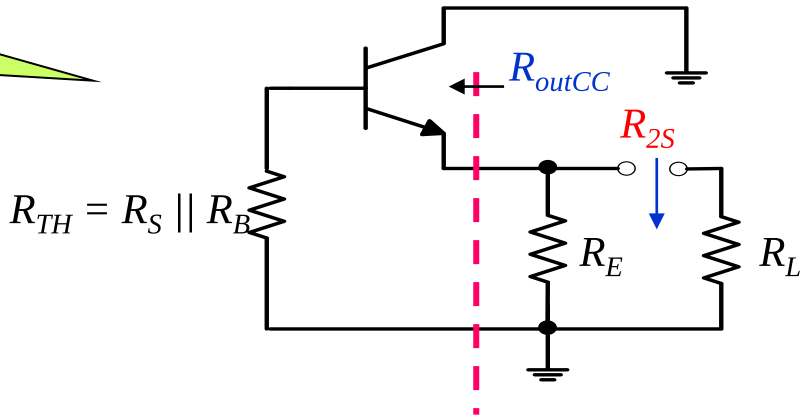
$$R_{1S} = R_S + \left(R_B \| R_{inCC}\right) = R_S + \left(R_B \| \left[r_\pi + (\beta+1)\left(r_o \| \; R_E \| R_L\right)\right]\right)$$

$$= 74.43\,k\Omega$$

$$\frac{1}{R_{1S}C_1} = \frac{1}{(74.43\,k\Omega)(0.1\,\mu F)} = 136.18\,rad/s$$

Circuit for finding R_{2S}

Replacing C_1 by short circuit



$$= 47.038\,k\Omega$$

$$R_{2S} = R_L + \left(R_E \| R_{outCC}\right) = R_L + \left(R_E \left\| \frac{R_{TH} + r_\pi}{\beta + 1} \right\| r_o \right)$$

$$\frac{1}{R_{2S} C_2} = \frac{1}{(47.038\,k\Omega)(100\,\mu F)} = 0.213\, rad/s$$

Estimation of ω_L

$$\omega_L \cong \sum_{i=1}^{2} \frac{1}{R_{iS}C_i} = 136.18 + 0.213 = 136.393\, rad/s$$

$$f_L = \frac{\omega_L}{2\pi} = 21.7\, Hz$$

Example

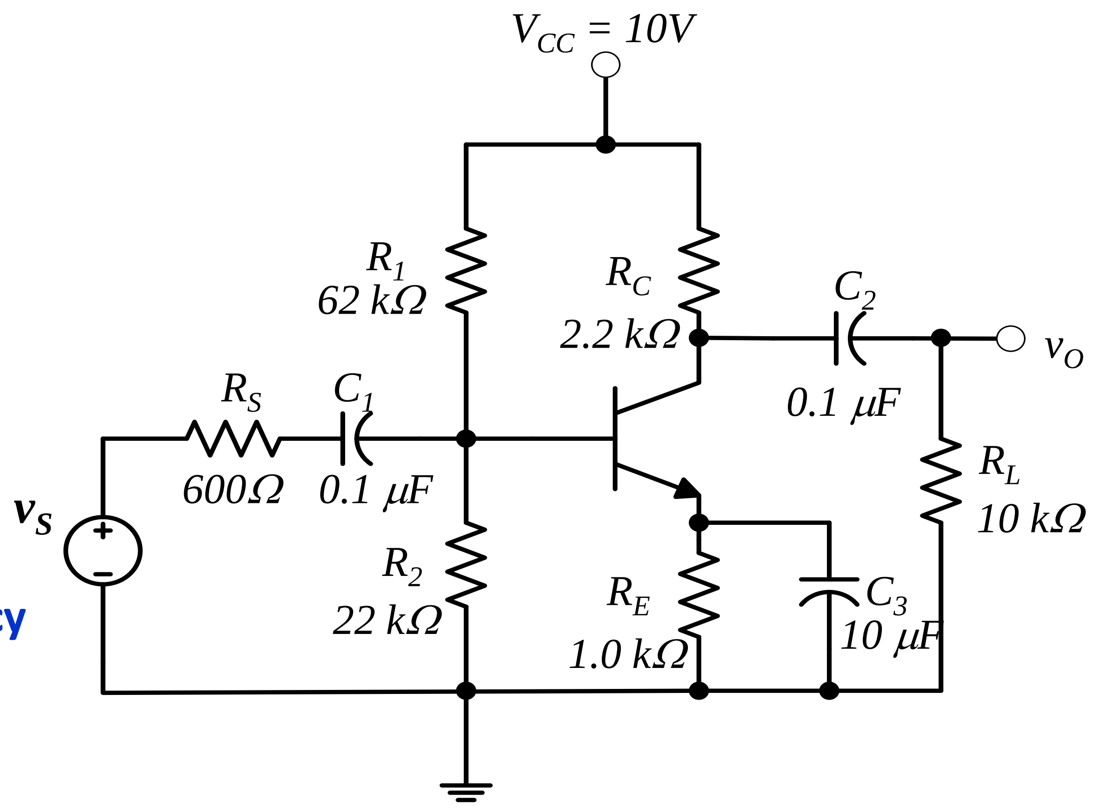
Given :

Q-point values : 1.6 mA, 4.86 V

β = 100, V_A = 70 V

Therefore,

r_π = 1.62 kΩ, r_o = 43.75 kΩ, g_m = 61.54 mS



Determine the total low-frequency response of the amplifier.

Low frequency due to C_1 and C_2 C_3

Low frequency due to C_1

$$R_{1S} = R_S + \left(R_B \| r_\pi\right) = 600 + \left(16.24k \| 1.62k\right) = 2.07\,k\Omega$$

$$R_B = R_1 \| R_2 = 16.24\,k\Omega$$

$$f_{C_1} = \frac{1}{2\pi R_{1S} C_1} = \frac{1}{2\pi\left(2.07\,k\Omega\right)\left(0.1\mu F\right)} = 768.86\,Hz \cong 769\,Hz$$

Low frequency due to C_2

$$R_{2S} = R_L + \left(R_C \| r_o\right) = 10\,k + \left(2.2k \| 43.75k\right) = 12.09\,k\Omega$$

$$f_{C_2} = \frac{1}{2\pi R_{2S} C_2} = \frac{1}{2\pi\left(12.09\,k\Omega\right)\left(0.1\mu F\right)} = 131.64\,Hz \cong 132\,Hz$$

Low frequency due to C_3

Low frequency due to C_3

$$R_{3S} = R_E \left\| \frac{r_\pi + R_{TH}}{\beta + 1} = 1k \right\| \frac{1.62k + 0.58k}{101} = 21.32\,\Omega$$

$$R_{TH} = R_S \| R_B = 0.58\,k\Omega$$

$$f_{C_3} = \frac{1}{2\pi R_{3S} C_3} = \frac{1}{2\pi(21.32\Omega)(10\mu F)} = 746.5\,Hz \cong 747\,Hz$$