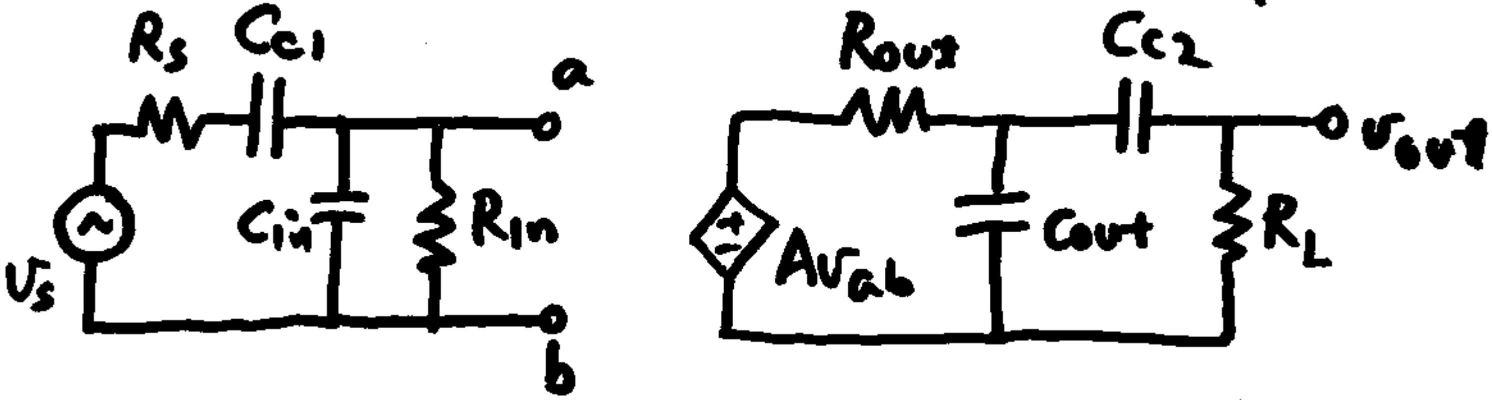
A Model for a Non-ideal Amp.



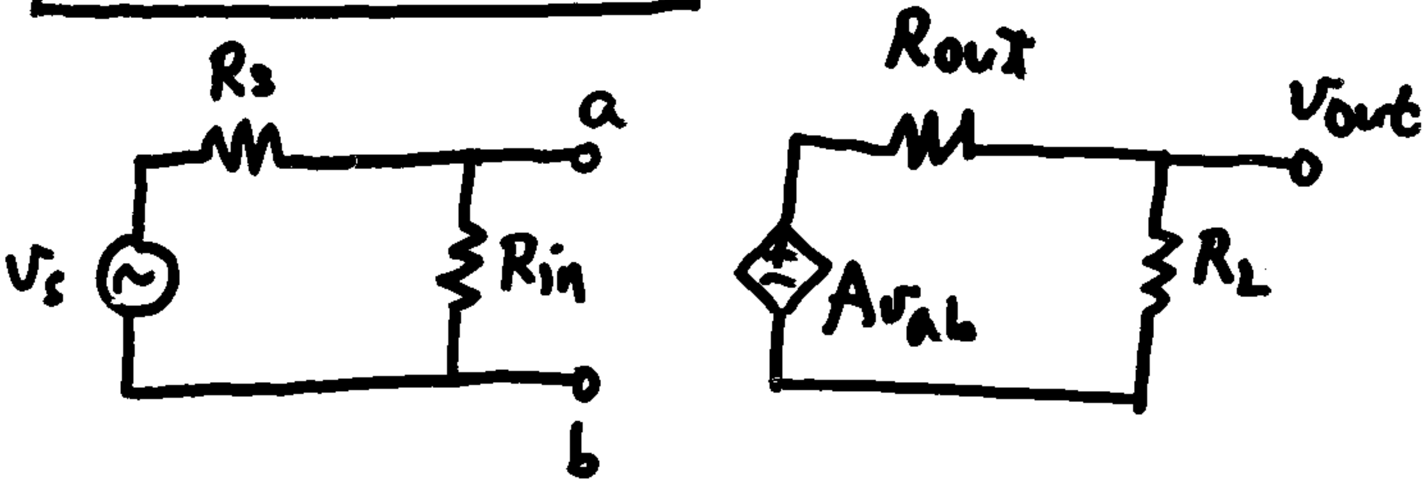
C_{c1} & C_{c2} large, μF

C_{in} & C_{out}, parasitic capacitors
very small, pF

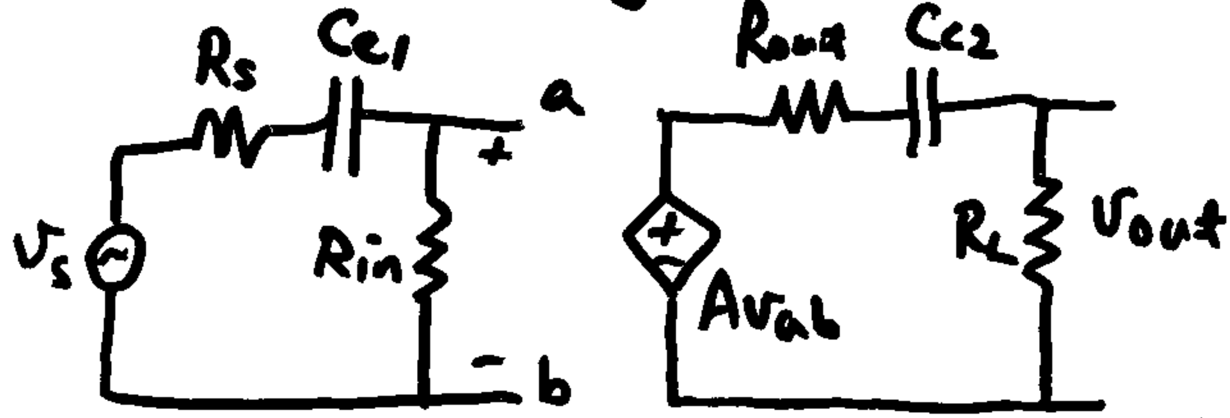
R_{in} : BJT $k\Omega$
MOSFET $M\Omega$

R_{out} : $\Omega \sim k\Omega$

$\boxed{\text{MIDBAND MODEL}}$



LOW FREQUENCY MODEL



$$\omega \downarrow \;\Rightarrow\; \frac{1}{j\omega C} \uparrow$$

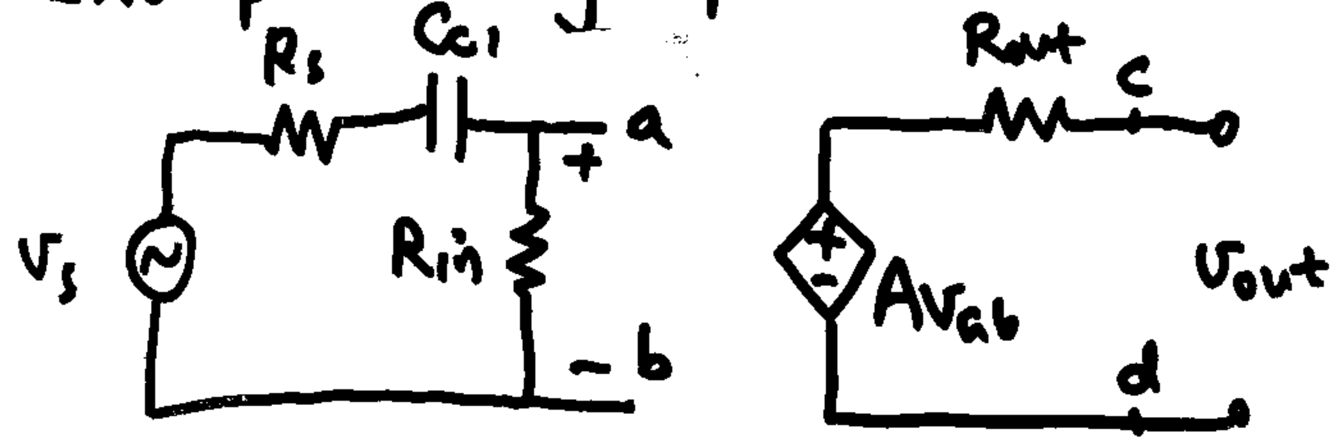
$$\Rightarrow v_{ab} \downarrow$$

$$\Rightarrow v_{out} \downarrow$$

Low-frequency fall of voltage gain

High-pass filter

Example : Single-pole circuit



Single-pole circuit

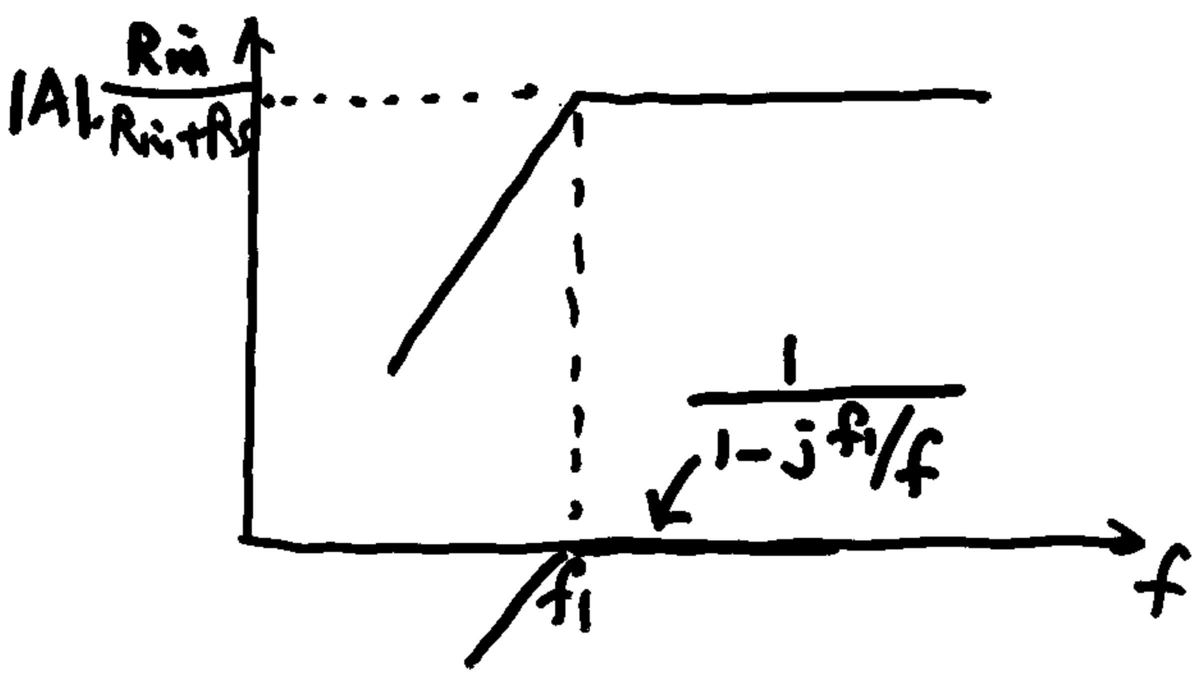
$$A_{v_s} = \frac{v_{out}}{v_s} = \frac{v_{ab}}{v_s} \times A$$

$$\frac{v_{ab}}{v_s} = \frac{R_{in}}{R_{in} + R_s + 1/j\omega C_{C1}}$$

$$A_{v_s} = \frac{R_{in}(j\omega C_{C1})}{1 + j\omega C_{C1}(R_{in}+R_s)} A$$

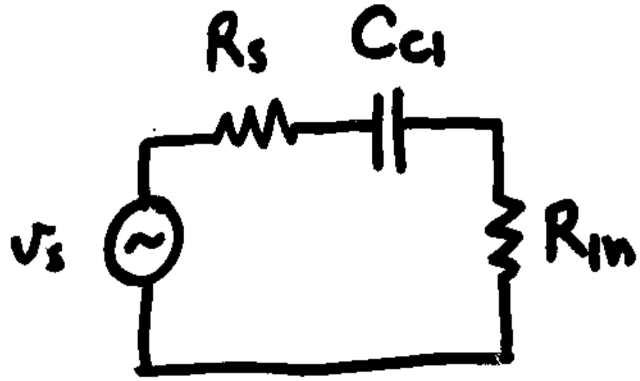
$$= \frac{R_{in}}{R_{in}+R_s} \cdot A \cdot \frac{1}{1 - j/2\pi f C_{C1}(R_{in}+R_s)}$$

$$\text{Let } f_1 = \frac{1}{2\pi C_{C1}(R_{in}+R_s)}$$



$\tau_s = C_{C1}(R_{in} + R_s)$: open-circuit time constant

C_{in} is open



Thevenin equi. impedance seen by C_{C1}

$(R_s + R_{in})$

$$\omega_1 = 2\pi f_1 = \frac{1}{\tau_s} = \frac{1}{C_{C1}(R_{in}+R_s)}$$

Double - pole circuit

$$\tau_{S1} = C_{C1}(R_{in} + R_S)$$

$$\tau'_{S1} = C_{C2}(R_{out} + R_L)$$

$$A_{vs} = \frac{R_{in}}{R_{in} + R_S} A \frac{R_L}{R_L + R_{out}} \times$$

$$\frac{1}{1 - j\frac{\frac{1}{2\pi\tau_{S1}}}{f}} \cdot \frac{1}{1 - j\frac{\frac{1}{2\pi\tau'_{S1}}}{f}}$$

$$f_1 = \frac{1}{2\pi\tau_{S1}} = \frac{1}{2\pi(R_{in}+R_s)C_{C1}}$$

$$f'_1 = \frac{1}{2\pi\tau'_{S1}} = \frac{1}{2\pi(R_L+R_{out})C_{C2}}$$

Where is the lower corner frequency?

Eg $A = 22\,V/V$

$R_{in} = 10k\Omega, \quad R_{out} = 325\Omega$

$R_s = 600\Omega, \quad R_L = 1k\Omega$

$C_{c1} = 10\mu F, \quad C_{c2} = 40\mu F$

(a) Midband gain.

$$A_{MB} = \frac{10}{10+.6}\, 22\, \frac{1}{1+.325} = 15.7\,V/V$$

(b) Lower corner frequency due to C_{c1}

$$f_1 = \frac{1}{2\pi C_{c1}(R_{in}+R_s)} = 1.50\text{ Hz}$$

(c) Lower corner frequency due to C_{c2}

$$f_1' = \frac{1}{2\pi C_{c2}(R_L+R_{out})} = 3.00\text{ Hz}$$

(d) Overall gain as a function of frequency

$$A_{v_s} = 15.7 \times \frac{1}{1-j\frac{1.50}{f}} \times \frac{1}{1-j\frac{3.00}{f}}$$

Overall Lower Corner Frequency

$$\left[1+\left(\frac{f_1}{f_L}\right)^2\right]\left[1+\left(\frac{f_1'}{f_L}\right)^2\right]=2$$

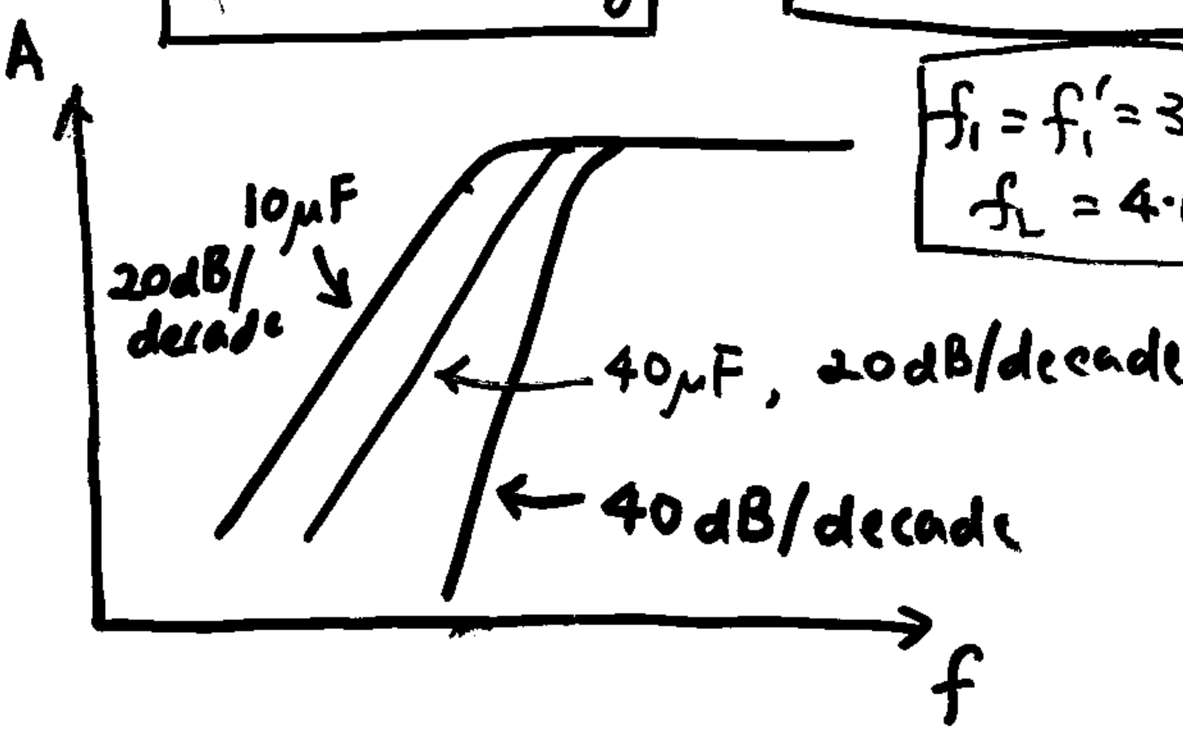
$$f_L^4-(f_1^2+f_1'^2)f_L^2-(f_1^2 f_1'^2)=0$$

Eg.

$$\boxed{\begin{aligned} f_1 &= 1.50\,\text{Hz}\\ f_1' &= 3.00\,\text{Hz}\\ f_L &= 3.58\,\text{Hz}\end{aligned}}$$

$$\boxed{\begin{aligned} f_1 &= 1.50\,\text{Hz}\\ f_1' &= 30.0\,\text{Hz}\\ f_L &= 30.07\,\text{Hz}\end{aligned}}$$

$$\boxed{\begin{aligned} f_1 = f_1' &= 3\,\text{Hz}\\ f_L &= 4.66\,\text{Hz}\end{aligned}}$$



Approximation for f_L

1 For each C_c,

Determine R_{eff} seen by C_c assuming that other C_c's are shorted

Calculate $R_{eff} \cdot C_c = \tau_i$

2. Approximate $\omega_L = \frac{1}{\tau_1} + \frac{1}{\tau_2} + \ldots$

$>$ true lower corner freq

Note:

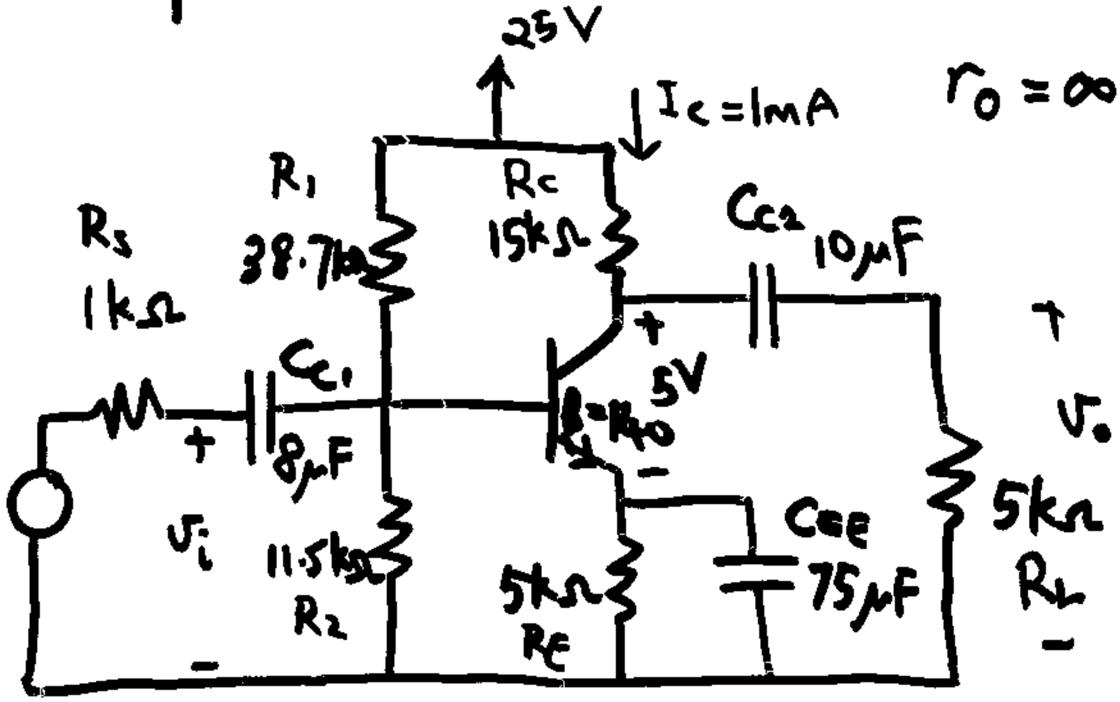
1. Works well when there exists a single dominant τ_i

2. Otherwise, pick the ~~closests~~ dominant τ_i's that are close

solve $\left[1+\left(\frac{f_1}{f_{min}}\right)^2\right] \cdots \left[1+\left(\frac{f_1^{(n)}}{f_{min}}\right)^2\right] = 2$

$f_{min} = \frac{1}{2\pi \tau_{min}}$, use τ_{min} & remaining τ_j's to approx ω_L

CE Example



C_{C1}: $R_{eff,c1} = R_s + R_1 \| R_2 \| r_\pi$

$$\tau_{s,c1} = [R_s + R_1 \| R_2 \| r_\pi] C_{c1}$$

$$= 28.6\,ms$$

$$f_{1,c1} = 5.6\,Hz$$

C_{C2}: $R_{eff,c2} = R_o + R_L$

$$\tau_{s,c2} = 0.2\,s$$

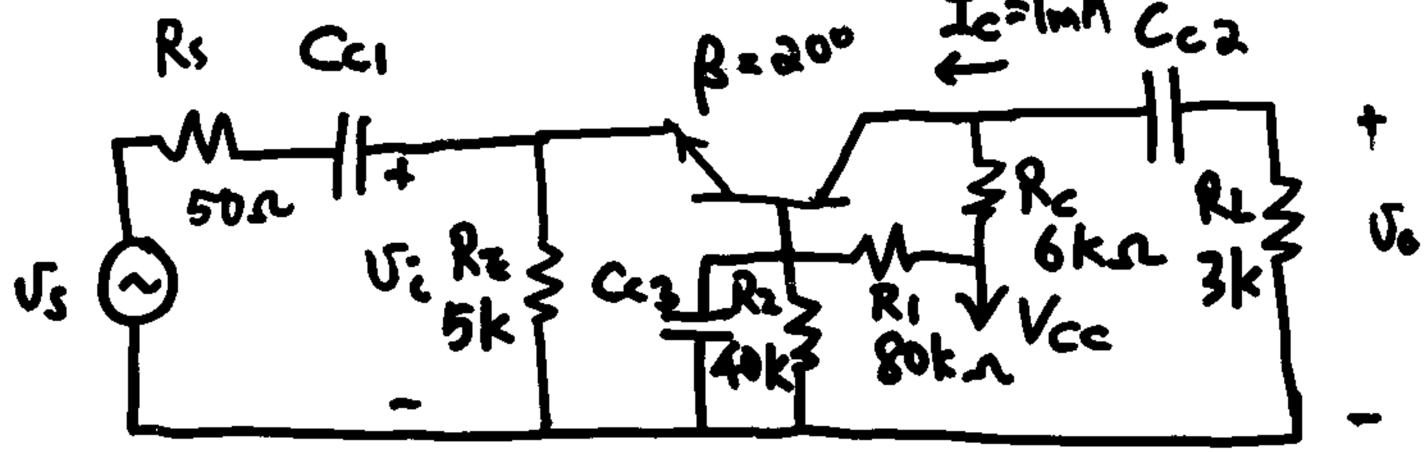
$$f_{1,c2} = 0.8\,Hz$$

C_E : $R_{eff,CE} = R_E \| \dfrac{r_\pi + R_1 \| R_2 \| R_s}{\beta + 1}$

$$\tau_{s,CE} = 2.5\,ms$$

$$f_{1,CE} = 63\,Hz \quad \boxed{63\,Hz < f_L < 69.4\,Hz}$$

CB Amplifier Design



$g_m = 38.5\ mA/V \qquad r_o = \infty$

$r_\pi = 5.2\ k\Omega$

Want $f_L = 10\,Hz$.

$$\tau_{s,c1} = \left[R_s + R_E \,\Big\|\, \frac{r_\pi}{\beta+1}\right] C_{c1}$$

$$\tau_{s,c2} = \left[R_L + R_C\right] C_{c2}$$

$$\tau_{s,c3} = \left[R_1 \| R_2 \| (r_\pi + (\beta+1)(R_s \| R_E))\right] C_{c3}$$

Which will be smallest?

$$\tau_{s,c1} \doteq \left(R_s + \frac{r_\pi}{201}\right) C_{c1} = 76\, C_{c1}$$

$$\tau_{s,c2} = 9000\, C_{c2}$$

$$\tau_{s,c3} \doteq \left(R_1 \| R_2 \| r_\pi + (\beta+1) R_s\right] C_{c3} \doteq 9600\, C_{c3}$$

if $C_{c1} = C_{c2} = C_{c3}$

$\tau_{s,c1}$ is smallest

Pick $2\pi \cdot 10 = \frac{1}{76 C_{c1}}$

$\Rightarrow C_{c1} = 209\,\mu F$

Pick C_{c2}, C_{c3} s.t. $\tau_{s,c2}, \tau_{s,c3} \gg \tau_{s,c1}$

$2\pi \cdot 1 = \frac{1}{9000 C_{c2}}$

$\Rightarrow C_{c2} = 18\,\mu F$

$2\pi \cdot 1 = \frac{1}{9600 C_{c3}}$

$\Rightarrow C_{c3} = 17\,\mu F$