AEO-2014
Final Sl'ns

(1)

a) $K_{vo} = -100$ (@ $R_g = 0$ & $R_y = \infty$)

When $R_g = R_y = 10k\Omega \rightarrow \frac{V_o}{V_i} = K_{vo} \cdot \frac{R_y}{r_o + R_y} = -80 \Rightarrow \boxed{r_o = 2{,}5k\Omega}$

$\frac{V_o}{V_g} = (-80) \cdot \frac{r_i}{R_g + r_i} = -48 \Rightarrow \boxed{r_i = 15k\Omega}$

b) $\omega_{k1} = \frac{1}{C_1 \cdot (R_g + R_i)} = \frac{1}{C_1 \cdot 25k}$, $\omega_{k2} = \frac{1}{C_2 \cdot (r_o + R_y)} = \frac{1}{C_2 \cdot 12{,}5k}$

$\omega_{k1} = \omega_{k2} \Rightarrow \boxed{\frac{C_1}{C_2} = \frac{1}{2}}$ If $f_L = 70Hz \rightarrow \underbrace{f_{k1} = f_{k2}}_{\text{Double pole}} = f_L \cdot \sqrt{\sqrt{2}-1} = 45{,}05Hz$

$f_{k1} = \frac{1}{2\pi C_1\, 25k} = 45{,}05Hz \Rightarrow \boxed{C_1 = 141{,}3nF}$ $\boxed{C_2 = 282{,}6nF}$

c) $\tau = \frac{1}{\omega_L} = 2{,}27ms \longrightarrow$ For the tilt (δ) : $\Delta V = V_m \cdot (1 - e^{-t/\tau})$

$\frac{\Delta V}{V_m} = \delta = 1 - e^{-t/\tau} \leqslant 0{,}02$

$\Rightarrow t_d$: Pulse width, $1 - e^{-t_{dmax}/\tau} = 0{,}02 \rightarrow t_{dmax} = -\tau \cdot \ln(0{,}98)$

$\Rightarrow \boxed{t_d \leqslant 45{,}9\mu s}$

d) When $R_g = 0$, the pole contribution from $C_i \longrightarrow \infty$

At the output side: $C_o' = C_o + (1 - \frac{1}{K}) \cdot C_\tau$ ($K = -100$)

$\omega_k' = \frac{1}{C_o' \cdot \underbrace{(r_o // R_y)}_{2k\Omega}}$, $t_r = \frac{0{,}35}{f_k'} = 10ns \Rightarrow f_k' = 35MHz$

$\rightarrow C_o' = 2{,}27pF$

$\Rightarrow \boxed{C_\tau = 267{,}3fF}$

When $R_g = 10k\Omega$: $\omega_{k1}' = \frac{1}{C_i' \cdot (R_g // r_i)}$, $C_i' = C_i + (1 - K) \cdot C_\tau$ ($K = -100$)

$(R_g // r_i) \rightarrow 6k\Omega$

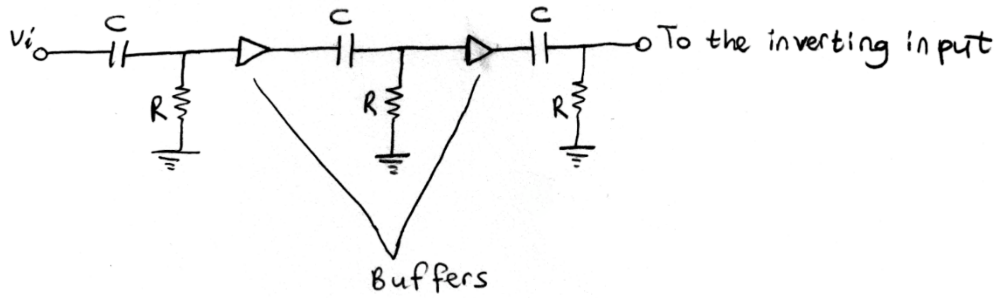
$\omega_{k2}' = 35MHz$

$\rightarrow t_{r_{Tot}} = \sqrt{t_{r_1}^2 + t_{r_2}^2} = \sqrt{t_{r_1}^2 + (10ns)^2} = 726ns \Rightarrow t_{r1} = 725{,}9ns$

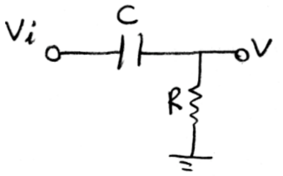
$t_{r_1} = \frac{0{,}35}{f_{k1}'} = 725{,}9ns \Rightarrow f_{k1}' = 482{,}2kHz$

$f_{k1}' = \frac{1}{2\pi C_i' \cdot 6k} = 482{,}2kHz \Rightarrow C_i' = 55pF \rightarrow \boxed{C_i = 28pF}$

② Phase-shift network:



Since K_3 is an inverting opamp, this network should give a 180° of phase-shift. As they are buffered, each RC filter will have a 60° of phase-shift.



$$\frac{V(s)}{V_i(s)} = H(s) = \frac{s}{s+\omega_k} \text{, where } \omega_k = 1/RC$$

$$H(s)\Big|_{s=j\omega} = H(\omega) = \frac{j\omega}{j\omega+\omega_k}$$

$$\rightarrow |H(\omega)| = \sqrt{\frac{\omega^2}{\omega^2+\omega_k^2}}$$

$$\rightarrow \measuredangle H(\omega) = 90° - \tan^{-1}(\omega/\omega_k)$$

At the oscillation frequency (ω_o):

$$\measuredangle H(\omega)\Big|_{\omega=\omega_o} = 90° - \tan^{-1}(\omega_o/\omega_k) = 60° \Rightarrow \omega_o = \frac{\omega_k}{\sqrt{3}}$$

$$\Rightarrow \boxed{f_o = \frac{1}{2\pi\sqrt{3}RC}}$$

$$|H(\omega)|\Big|_{\omega=\omega_o} = \sqrt{\frac{\omega_o^2}{\omega_o^2+\omega_k^2}} = \sqrt{\frac{\omega_o^2}{\omega_o^2+3\omega_o^2}} = \frac{1}{2}$$

Since three stages are cascaded with buffers:

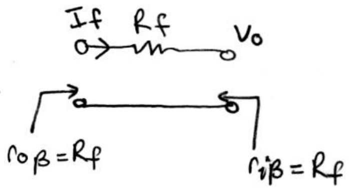
$$|H(\omega)|^3 = \frac{1}{8}$$

Then, $K_3 = -8 \rightarrow \boxed{R_2 = 8R}$

③ $K(s) = \frac{V_o}{V_i} = \frac{2\pi 10^7}{s + 2\pi 10^3} = K_o \cdot \frac{w_K}{s + w_K} \Rightarrow$ $w_K = 2\pi 10^3$ rad/s, $K_o = 10^4$ (V/V)

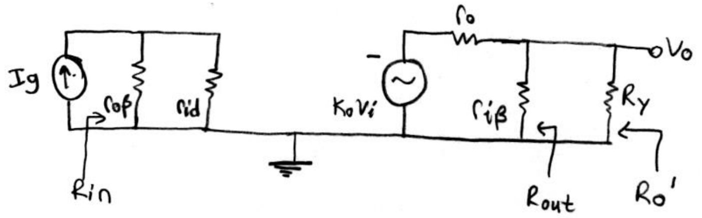
a) $\boxed{K_o = 10^4 \left(\frac{V}{V}\right)}$

b) Negative shunt-shunt f.b. (Gerilimden akım g.b.)



$\beta = \frac{I_f}{V_o} = \frac{-1}{R_f} = -1\mu S$

→ Remove Vg and Rg, put an ideal current source Ig instead:



$Z_m = \frac{V_o}{V_i} \cdot \frac{V_i}{I_g} = -K_o \cdot \overbrace{\frac{R_y // r_{i\beta}}{r_o + R_y // r_{i\beta}}}^{2k\Omega} \cdot \overbrace{(r_{o\beta} // r_{id})}^{90{,}9k\Omega}$

$\Rightarrow Z_m = -606 M\Omega$

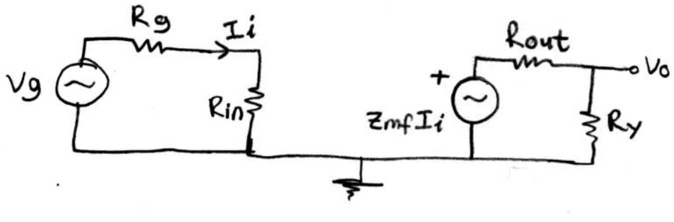
$Z_{mf} = \frac{Z_m}{1 + \beta Z_m} \approx \frac{1}{\beta} = -1M\Omega$

$(1 + \beta Z_m = 607)$

$R_{in} = \frac{r_{o\beta} // r_{id}}{1 + \beta Z_m} = 149{,}8\,\Omega$

$R_o' = \frac{R_y // r_{i\beta} // r_o}{1 + \beta Z_m} = 1{,}1\Omega = R_{out} // R_y \Rightarrow R_{out} \cong 1{,}1\Omega$

d)



$I_i = \frac{V_g}{R_g + R_{in}}$

$V_o = Z_{mf} \cdot I_i \cdot \underbrace{\frac{R_y}{R_{out} + R_y}}_{\approx 1} \approx Z_{mf} I_i$

$\Rightarrow \frac{V_o}{V_g} = \frac{Z_{mf}}{R_g + R_{in}} = -868{,}3 \left(\frac{V}{V}\right)$

c) GBW product does not change w/ f.b.

→ w/o f.b. : BW = 1kHz, G = 10^4 → GBW = 10^7

w/ f.b. : G = −868,3 ⇒ $\boxed{BW = 11{,}5\ kHz}$