HW # 07

Abdullah Mentşoğlu
171024001

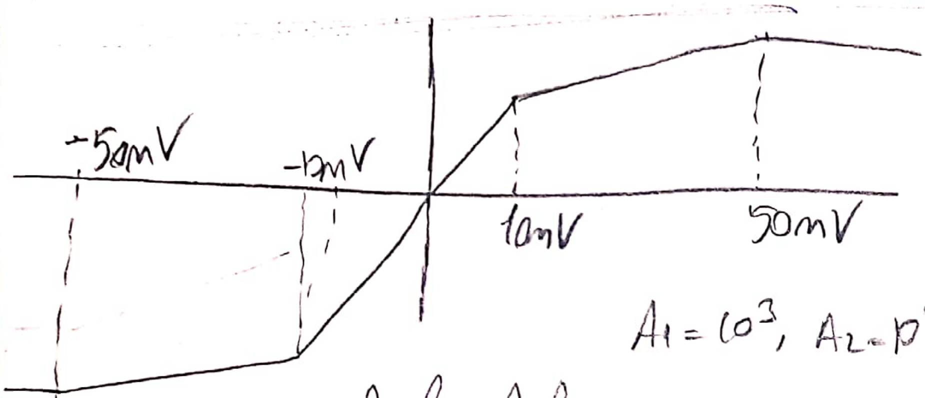
Q1. A particular amplifier has a nonlinear transfer characteristic that can be approximated as follows.

(a) For small input signals $|V_i| \leq 10mV$, $v_o/v_i = 10^3$

(b) For intermidiate input signals, $10mV \leq |V_I| \leq 50mV$ $v_o/v_i = 10^2$

(c) for large input signals, $|V_I| \geq 50mV$, the output satuates.

If the amplifier is connected in a negative-feedback loop, find the feedback factor β that reduces the factor of 10 change in gain to only a 10% change. What is the transfer characteristic of the amplifier with feedback



$$A_{1,f} = \frac{A_1}{1+A_1\beta}$$

$$A_1 = 10^3, \quad A_2 = 10^2 \qquad A_{2,f} = \frac{A_2}{1+\beta A_2}$$

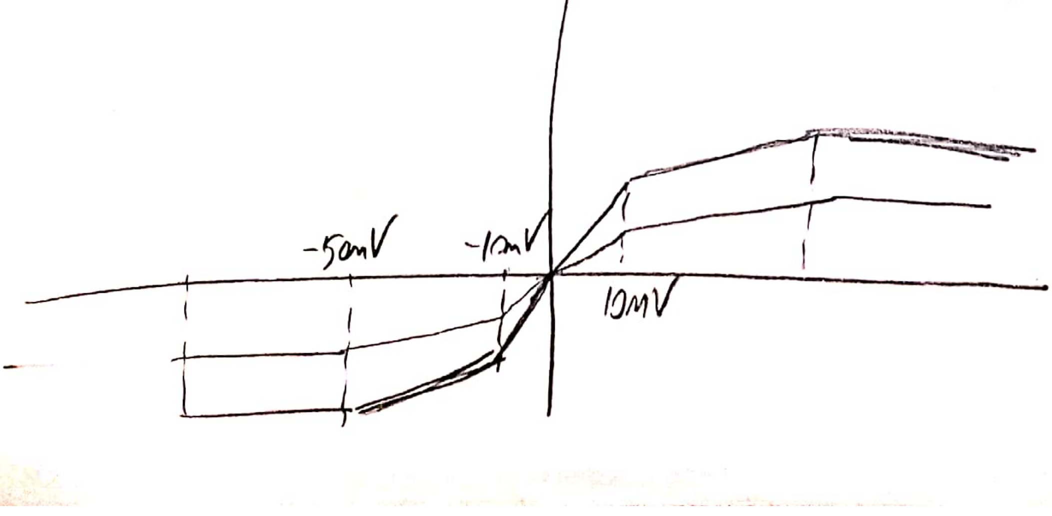
$$A_{1,f} > A_{2}f \qquad A_{1,f} = A_{2,f}(1+10\%)$$

$$\frac{A_1}{1+A_1\beta} = \frac{A_2}{1+\beta A_2} \longrightarrow \frac{\cancel{10^3}\,10}{1+\beta . 10^3} = \frac{\cancel{10^2}}{1+10^2\beta} \cdot (1.1)$$

$$\frac{10+1000\beta}{1+1000\beta} = 1.1 \longrightarrow 10+1000\beta = 1.1+1100\beta$$

$$100\beta = 8.9 \qquad \boxed{\beta = 8.9\times10^{-2}}$$

$$A_{1}f = \frac{10^3}{1+10^3 . 8.9\times10^{-2}} = \frac{1000}{90} = 11.1 \qquad A_{2}f = \frac{10^2}{1+10^2 . 8.9\times10^{-2}} = \frac{100}{9.9} = 10.101$$



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Q2. A feedback amplifier is to have a closed-loop gain of $A_f = 60dB$ and a sensitivity of 10% to the open-loop gain A. Determine the open-loop gain with a unity feedback $\beta = 1$

$A_f = 60dB \qquad 20\log_{10} A_f = 60 \qquad A_f = 1000$

$\log_{10} A_f = 3$

$$S_A^{A_f} = \frac{\partial A_f}{\partial A} \cdot \frac{A}{A_f} = \frac{1}{\beta A + 1} \cdot \underbrace{S_A^{A}}_{100\% = 1} = \frac{1}{1+\beta A} = 10\% = \frac{1}{10} \qquad \beta A = 9$$

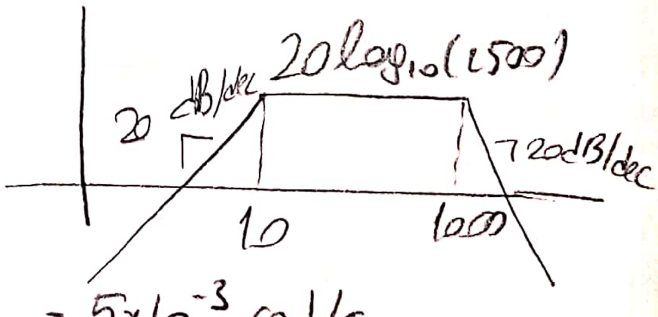
$$A_f = \frac{A}{1+A\beta} = \frac{A}{10} = 1000 \qquad \boxed{A = 10.000}$$

$$\beta . A = 9 \qquad \boxed{\beta = \frac{9}{10{,}000} = 9 \times 10^{-4}}$$

Q3. The feedback factor of an amplifier is $\beta = 0.8$. The open-loop gain A can be expressed in Laplace's domain of s as

$$A(s) = \frac{250s}{(1+0.1s)(1+0.001s)}$$ determine (a) the closed-loop low-frequency gain A_{of} (b) the closed

$$A(s) = \frac{250\,s}{\underbrace{\left(1+\frac{s}{10}\right)}_{\approx \frac{s}{10}}\underbrace{\left(1+\frac{s}{1000}\right)}_{\approx 1}} = A(s) \approx \frac{250s}{\left(\frac{s}{10}\right).(1)} = 2500$$



$1 + G\beta = 1 + 2500 \cdot 0.8 = 2001 = A_{of}$

low freq $\rightarrow \dfrac{10}{1+G\beta} = \dfrac{10}{2001} \cong \dfrac{50}{10000} = 5 \times 10^{-3}$ rad/s

high freq $\rightarrow 1000(1+G\beta) = 1000 . 2001 = 2 \times 10^{6}$ rad/s

$GBW = 2500 . 1000 = 2{,}5 \cdot 10^{6}$ Hz

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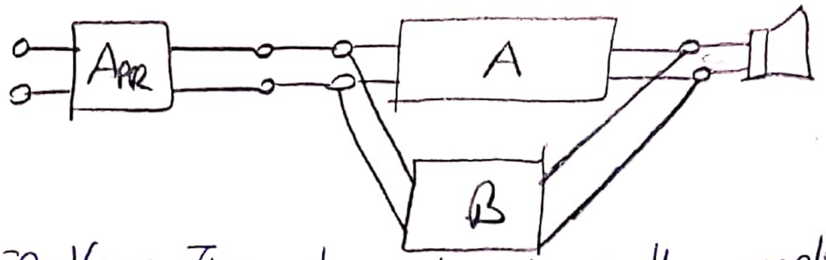
Q4. Figure P9.9a shows a nonfeedback amplifier of voltage gain A that delivers 5W to a 5ohm speaker when the amplifier

$V_{in} = 50mV_{rms}$



Input voltage is 50mVrms. The nonlinear distortion in the amplifier output is 1% of the output signal value.

(a) Find the numerical value of the gain A.

(b) Find the value of β required in fig P.9.9b to reduce the distortion to 0.1% with the same output signal amplitude.

(c) Find the value of gain A_{PR} required in preamp

$$\frac{V_{rms,out}^2}{R_L} = P_{rms,out} \qquad V_{rms,out} = \sqrt{5W \cdot 5\Omega} = 5V_{rms}$$

$$\text{GAIN} \rightarrow A = \frac{V_{rms,out}}{V_{rms,in}} = \frac{5V_{rms}}{50mV_{rms}} = 100$$

$$\underbrace{A}_{\text{first config.}} = \underbrace{A_{PR}}_{\text{gain preamp.}} \cdot \underbrace{\frac{A}{1+A\beta}}_{\text{gain amp. feedback}} \qquad A_{PR} = 1 + A\beta$$

$$\text{Distortion}_2 = \frac{\text{Distortion}_1}{1+A\beta} \Rightarrow 0.1\% = \frac{1\%}{1+A\beta}$$

$$A_{PR} = 1 + A\beta = 10 \qquad \frac{A}{1+A\beta} = 10$$

$$A.\beta = 10 \quad \beta = \frac{9}{A} = \frac{9}{100} = 0.09$$

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Q5. For an amplifier with shunt feedback. $R_{i,f} = 140\,\Omega$, $R_o = 2k\Omega$, $R_{o,f} = 26k\Omega$, $A_f = 20$, $\omega_H = 10^4$ rad/s, $\omega_{L,f} = 10$ rad/s

find β, A, β, $\omega_{H,f}$, and ω_L

Changing a resistor in amplifier A from 10kΩ to 11kΩ changes Af from 20 to 21. Use sensitivity to find the new value of A.

shunt feedback $\Rightarrow \dfrac{R_i}{1+\beta A} = R_{i,f}$ $\quad R_o = 2k\Omega$, $\quad R_{o,f} = 26k\Omega$

$(1+A\beta)R_o = R_{o,f} \quad 26k\Omega = 2k\Omega(1+A\beta) \quad 1+A\beta = 13 \quad A\beta = 12$

$A_f = \dfrac{A}{1+A\beta} = 20 \Rightarrow A = \underbrace{(1+A\beta)}_{13}\underbrace{A_f}_{20}$ $\quad \boxed{A = 260}$

$\beta = \dfrac{12}{A} = \dfrac{12}{260} =$ $\quad \boxed{\beta = 0.0461}$

$\omega_{H,f} = \omega_H(1+A\beta) = (10^4\,\text{rad/s})(13) = 13 \times 10^4$ rad/s

$\omega_{Lf} = \dfrac{\omega_L}{(1+A\beta)} \Rightarrow 10 = \dfrac{\omega_L}{13}$ $\quad \boxed{\omega_L = 130 \text{ rad/s}}$

$\boxed{GBW = A.\omega_H = 260.10^4 \text{ rad/s}}$

$S_P^{A_f} = \dfrac{S_P^A}{1+\beta A}$, $\quad S_P^A = \underbrace{\dfrac{\Delta A_f}{\Delta P} \cdot \dfrac{P}{A_f}}_{} = \dfrac{1}{1+\beta A} \cdot \dfrac{\frac{\Delta A}{A}}{\frac{\Delta P}{P}} = S_P^A \cdot \dfrac{1}{1+\beta A}$

$\dfrac{\Delta A_f}{A_f} = \dfrac{1}{1+\beta A} \cdot \dfrac{\Delta A}{A} = \dfrac{21-20}{20} = \dfrac{1}{13} \cdot \dfrac{\Delta A}{260}$

$\Delta A = \dfrac{260.13}{20} = 169$

$\boxed{A_{son} = A + \Delta A = 260 + 169 = 429}$

$A: \longrightarrow \dfrac{429-260}{260} . 100 = 65\%$

A_f: ~~20~~ $\dfrac{21-20}{20} . 100 = 5\%$

4