GTU
Electronics Engineering

ELEC 331
Electronic Circuits 2

Fall Semester

Instructor: Assist. Prof. Önder Şuvak

HW 7
Questions and Answers

Updated November 17, 2017 - 12:56

Assigned:

Due:

Answers Out:

Late Due:

Contents

Effects of Feedback on Distortion **Sedra 8.20**

D8.20 A particular amplifier has a nonlinear transfer characteristic that can be approximated as follows:

(a) For small input signals, $|v_I| \leq 10$ mV, $v_O / v_I = 10^3$
(b) For intermediate input signals, 10 mV $\leq |v_I| \leq 50$ mV, $v_O / v_I = 10^2$
(c) For large input signals, $|v_I| \geq 50$ mV, the output saturates

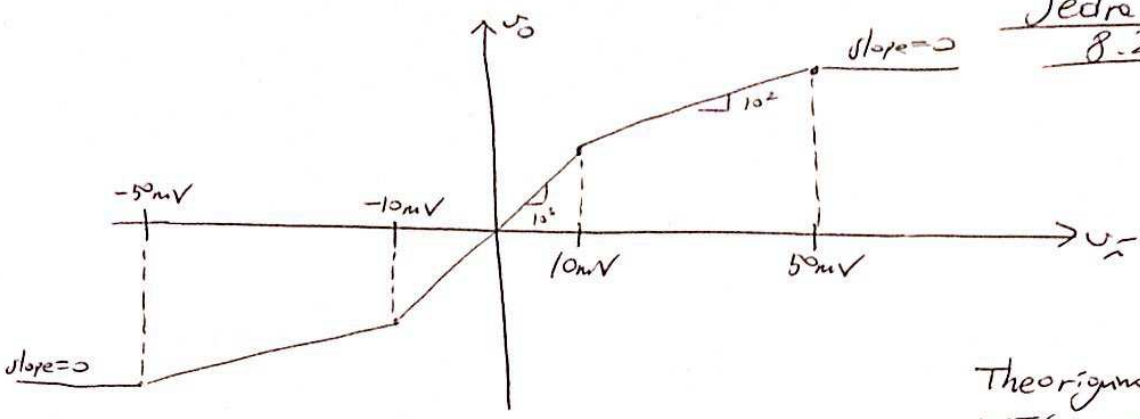
If the amplifier is connected in a negative-feedback loop, find the feedback factor β that reduces the factor-of-10 change in gain (occurring at $|v_I| = 10$ mV) to only a 10% change. What is the transfer characteristic of the amplifier with feedback?

Notes: None.

Additional Tasks: None.

Necessary Knowledge and Skills: Gain calculations for a feedback amplifier.

Sedra 8.20



The original VTC curve is highly nonlinear

Let $A_1 = 10^3$

$A_2 = 10^2$

with feedback

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

$$A_{2,f} = \frac{A_2}{1 + A_2\beta}$$

the same feedback factor β needs to be used.

With feedback, we will still have

$$A_{1,f} > A_{2,f}$$

It is required that we have

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

$$\frac{\cancel{A_1}\,10^3}{1 + \cancel{A_1}_{10^3}\,\beta} = \frac{\cancel{A_2}\,10^2}{1 + \cancel{A_2}_{10^2}\,\beta}(1.1) \Rightarrow \text{Solve for } \beta$$

1

Sedra
8.20
contin-

$$10(1+100\beta) = (1+1000\beta)1.1$$

$$10 + 1000\beta = 1.1 + 1100\beta$$

$$8.9 = 100\beta$$

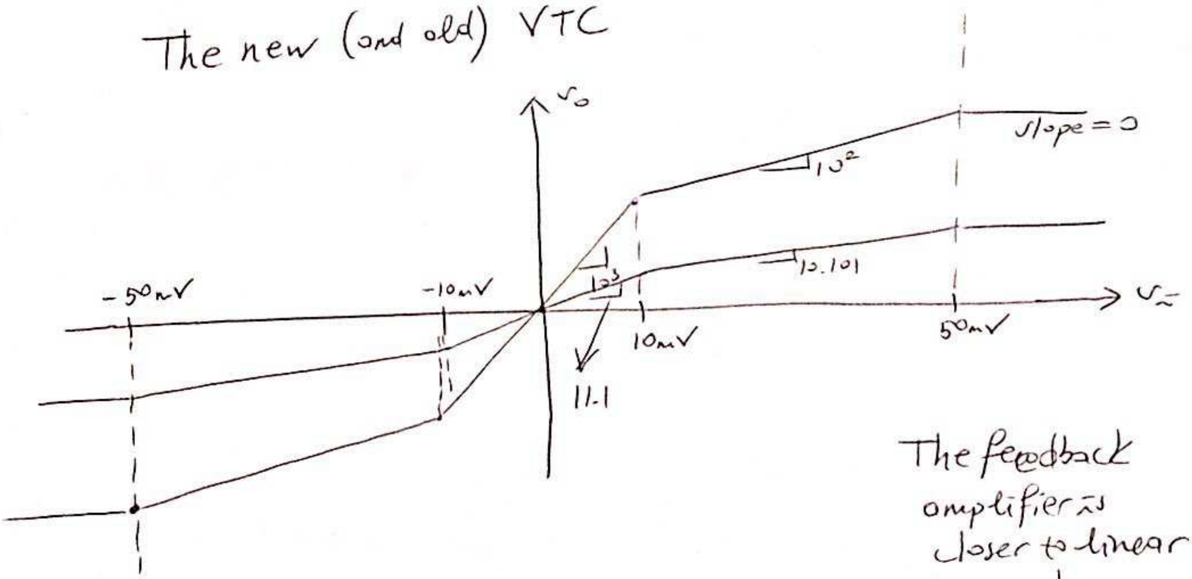
$$\beta = \frac{8.9}{100}$$

then $$A_{1,f} = \frac{10^3}{1+10^3\frac{8.9}{10^2}} = \frac{1000}{90} = 11.1$$

10% difference

$$A_{2,f} = \frac{10^2}{1+10^2\frac{8.9}{10^2}} = \frac{100}{9.9} \simeq 10.101$$

The new (and old) VTC



The feedback amplifier is closer to linear (almost has a uniform gain at all ranges of input)

Note: Such VTC graphs as above need to be interpreted as in:

→ The component of the input ≤ 10mV gets A_1 ($A_{1,f}$) gain

→ The component of the input in excess of 10mV but ≤ 50mV obtains A_2 ($A_{2,f}$) gain

→ The component of the input in excess of 50mV obtains no gain.

(2)

Effects of Feedback on Sensitivities **Rashid 10.5**

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

Notes: None.

Additional Tasks: None.

Necessary Knowledge and Skills: Effects of feedback on sensitivities, improvement factor.

There is something wrong in the statement of the question, neglect the ($\beta=1$) information.

Rashid
10.5

$$A_f = 60\text{dB in dB}$$

$$20\log_{10} A_f = 60$$

$$A_f = 1000$$

$$S_A^{A_f} = \frac{\partial A_f}{\partial A}\,\frac{A}{A_f}$$

$$= \frac{1}{1+\beta A}\,\underbrace{S_A^{A}}_{100\%=1} = \frac{1}{1+A\beta} = 10\% = \frac{1}{10}$$

Then $1 + A\beta = 10 \Rightarrow A\beta = 9$

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

then $A = 10^4$

and $\beta = \frac{9}{A} = \frac{9}{10^4} = 9\times10^{-4}$

Effects of Feedback on Bandwidth **Rashid 10.7**

10.7 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-loop bandwidth BW, and **(c)** the gain–bandwidth product GBW.

Notes: None.

Additional Tasks: None.

Necessary Knowledge and Skills: Bode plots, transfer functions, low and high frequency cut-off, effects of negative feedback on cut-off frequencies.

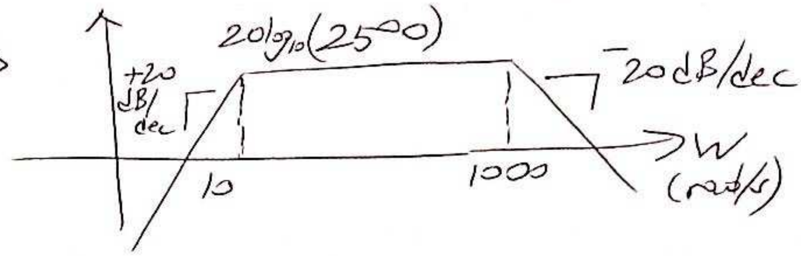
Rashid
10.7

$$A(s) = 2500 \frac{s}{\left(1+\frac{s}{10}\right)\left(1+\frac{s}{1000}\right)}$$

For computing the midband gain $A(s) \simeq 2500 \frac{s}{\left(\frac{s}{10}\right)(1)}$

$$= 25000$$

magnitude Bode plot $\Rightarrow$



$$1 + G\beta = 1 + 2500 \cdot 0.8$$
$$= 2001 = A_{of}$$ (closed-loop low-freq gain)

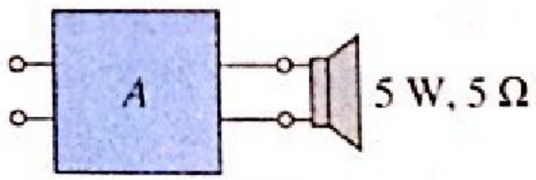
low freq cut-off $\Rightarrow \frac{10}{1+G\beta} = \frac{10}{2001} \simeq \frac{5\cancel{0}}{1000\cancel{0}}$
$= 0.005$ rad/sec

high freq cut-off $\Rightarrow 1000(1+G\beta)$
$= (1000)(2001) \simeq 2$ MHz

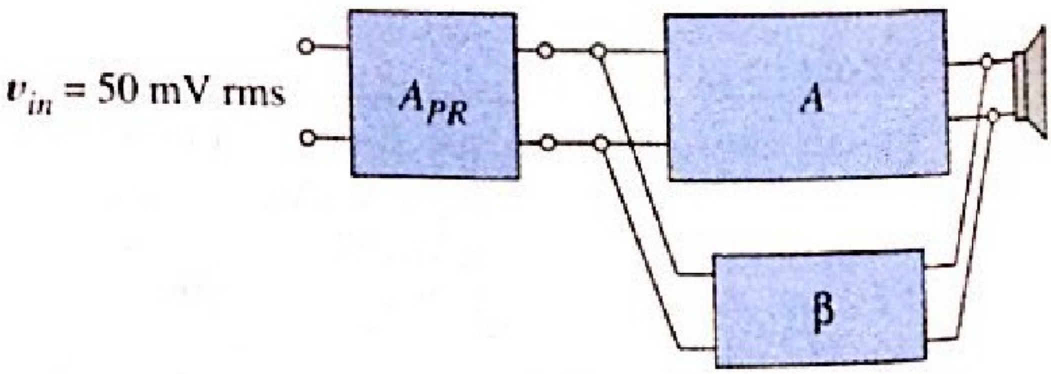
$$GBW = 2500 \cdot 1000 = 2.5\,\text{MHz} \;(\ldots)$$

Effects of Feedback on Distortion **Malik 9.9**

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



(a)



(b)

Figure P9.9

Effects of Feedback on Distortion **Malik 9.9**

input voltage is 50 mV rms. 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. P9.9b to reduce the distortion to 0.1%, with the same output signal amplitude.
(c) Find the value of gain A_{PR} required in the preamp.

Notes: None.

Additional Tasks: None.

Necessary Knowledge and Skills: Effects of feedback on distortion, improvement factor, distortion reduction, preamplification (low distortion).

Molik
9.9

$$\frac{v_{out,RMS}^2}{R_L} = P_{out,rms}$$

$$v_{out,RMS} = \sqrt{5W \cdot 5\Omega}$$
$$= 5V_{rms}$$

$$\text{Gain } A = \frac{v_{out,RMS}}{v_{in,RMS}}$$
$$= \frac{5V_{rms}}{50mV_{rms}} = 100$$

The gain of both configurations should be the same.

$$\underbrace{\underbrace{A_{PR}}_{\text{gain of the preamplifier}} \cdot \underbrace{\frac{A}{1+A\beta}}_{\text{gain of the amplifier with feedback}}}_{\text{gain of the } \cancel{\text{first}} \text{ second configuration}} = \underbrace{A}_{\text{gain of the } \cancel{\text{second}} \text{ first configuration}}$$

Therefore $A_{PR} = 1 + A\beta$

(1)

Mark 9.9 Contin.

A_{PR} is a low gain value, then this pre-amplifier can be designed to have almost no distortion.

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

$$0.1\% = \frac{1\%}{1+A\beta}$$

then $1+A\beta = 10$

$$A\beta = 9$$

$$\beta = \frac{9}{A} = \frac{9}{100} = 0.09$$

$A_{PR} = 1 + A\beta = 10$ } the ampli with this gain does not introduce distortion

$\frac{A}{1+A\beta} = \frac{100}{10} = 10$ } this ampli introduces 0.1 % distortion for an output of 5V, rms.

2

Effects of Feedback **Malik 9.14**

9.14 For an amplifier with shunt feedback, $R_{if} = 110\ \Omega$, $R_o = 2\ \mathrm{k\Omega}$, $R_{of} = 26\ \mathrm{k\Omega}$, $A_f = 20$, $\omega_H = 10^4$ rad/s and $\omega_{L,f} = 10$ rad/s.

(a–e) Find R_i, A, β, $\omega_{H,f}$, and ω_L.

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

Notes: None.

Additional Tasks: None.

Necessary Knowledge and Skills: Effects of feedback on I/O impedances, gain, and cut-off frequencies, sensitivities.

Molik
9.14

shunt feedback $\Rightarrow \dfrac{R_i}{1+\beta A} = R_{if}$

where R_i is the input impedance without feedback

R_{if} is the input imp. with feedback

A is the forward gain

β is the feedback factor

$(1+A\beta)$ is the improvement factor

We are not yet sure if
current-shunt or
voltage-shunt
feedback is employed.

$R_o = 2k\Omega$
$R_{of} = 26k\Omega$ ↓ output impedance increased with current feedback.

Therefore, indeed, current-shunt feedback is employed.
This is a current amplifier with current shunt feedback. A and β are unitless.

1

Malik
9.14
contin.

$$(1+A\beta) R_o = R_{of}$$

$$1+A\beta = 13$$

$$A\beta = 12$$

$$A_f = \frac{A}{1+A\beta} = 20 \Rightarrow A = \underbrace{(1+A\beta)}_{13} \underbrace{A_f}_{20}$$

$$= 260 \text{ (unitless)}$$

$$\beta = \frac{12}{A} = \frac{12}{260} \text{ (unitless)}$$

$$W_{H,f} = W_H(1+A\beta) = (10^4 \text{ rad/s})(13) = 1.3\times10^5 \text{ rad/sec}$$

$$W_L = W_{L,f}(1+A\beta) = (10 \text{ rad/s})(13) = 130 \text{ rad/sec}$$

---

unity gain frequency (or G·BW product) $\approx A_f \cdot W_{H,f}$

$$= A \cdot W_H = \frac{A}{(1+A\beta)}(W_H)(1+A\beta)$$

$$= 260 \cdot 10^4 = 2.6\times10^6 \text{ rad/sec}$$

2

We know from sensitivity calculations

$$S_{\beta}^{A_f} = \frac{S_{\beta}^{A}}{1+\beta A}$$

Malik 9.14 contin.

Then we have

$$S_{\beta}^{A_f} \cong \underbrace{\frac{\frac{\Delta A_f}{A_f}}{\frac{\Delta \beta}{\beta}} = \frac{1}{1+\beta A} \frac{\frac{\Delta A}{A}}{\frac{\Delta \beta}{\beta}}}\cong S_{\beta}^{A}\frac{1}{1+\beta A}$$

$$\frac{\Delta A_f}{A_f} = \frac{1}{1+\beta A}\frac{\Delta A}{A}$$

$$\frac{(21-20)}{20} = \frac{1}{13}\frac{\Delta A}{260}$$

$$\Delta A = 260\,\frac{13}{20} = 169$$

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

Note that $A: 260 \to 429$ (65% change)

while $A_f: 20 \to 21$ (5% change)

 3