GTU

Electronics Engineering

ELEC 331

Electronic Circuits 2

Fall Semester

Instructor: Assist. Prof. Önder Şuvak

HW 8

Questions and Answers

Updated November 17, 2017 - 12:59

Assigned:

Due:

Answers Out:

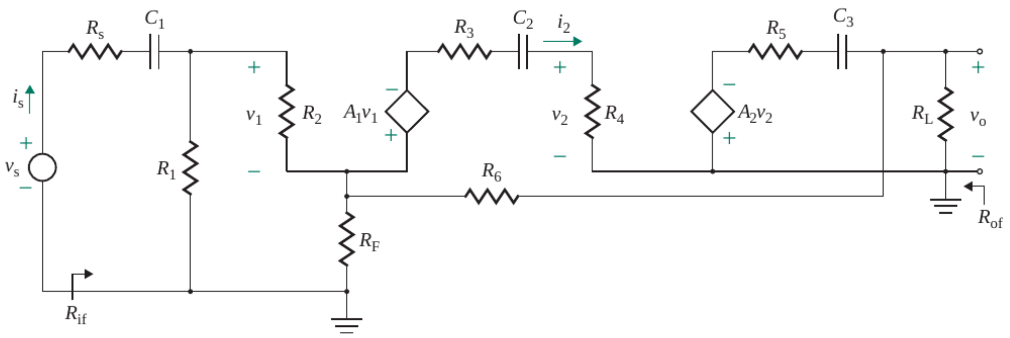
Late Due:

Contents

Voltage Series Feedback on a Voltage Amplifier **Rashid 10.13**

10.13 The feedback amplifier in Fig. P10.13 has $A_1 = 50$, $A_2 = 60$, $R_s = 500\ \Omega$, $R_1 = 15\ \text{k}\Omega$, $R_2 = 1.5\ \text{k}\Omega$, $R_3 = 250\ \Omega$, $R_4 = 1.5\ \text{k}\Omega$, $R_5 = 250\ \Omega$, $R_6 = 2\ \text{k}\Omega$, $R_L = 4.7\ \text{k}\Omega$, $R_F = 500\ \Omega$, $C_1 = C_2 = C_3 = 0.1\ \mu\text{F}$, and $v_s = 100$ mV. Determine **(a)** the input resistance $R_{if} = v_s/i_s$, **(b)** the output resistance R_{of}, and **(c)** the overall voltage gain $A_f = v_o/v_s$. Assume C_1, C_2, and C_3 are shorted at the operating frequency.

FIGURE P10.13



Notes: None.

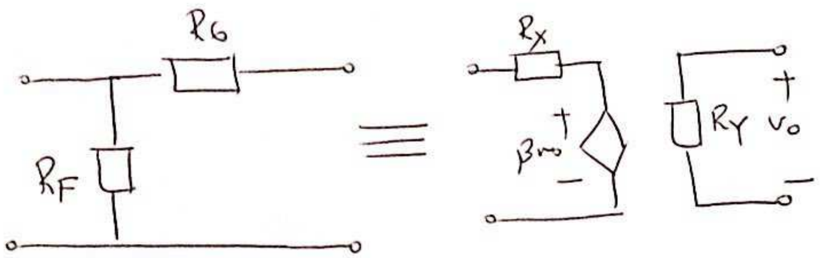
Additional Tasks: Analyze this circuit as a voltage amplifier with voltage series feedback. Numerical values of the required quantities should be computed as the last task.

Necessary Knowledge and Skills: Modeling a given circuit as a voltage amplifier, input/output impedance and gain calculations, feedback network modeling, idealizing the feedback network by carrying its impedance loads into the non-feedback amplifier, remodeling the non-feedback amplifier, analyzing the feedback amplifier (non-feedback amplifier and the feedback network combined) to compute the input/output impedances and gain.

Model the feedback network

Rashid 10.13

(*)



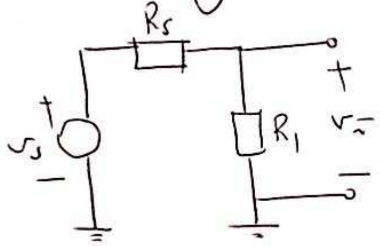
(This is voltage amplifier with voltage-series feedback)

$$R_X = R_F // R_G$$

$$R_Y = R_F + R_G$$

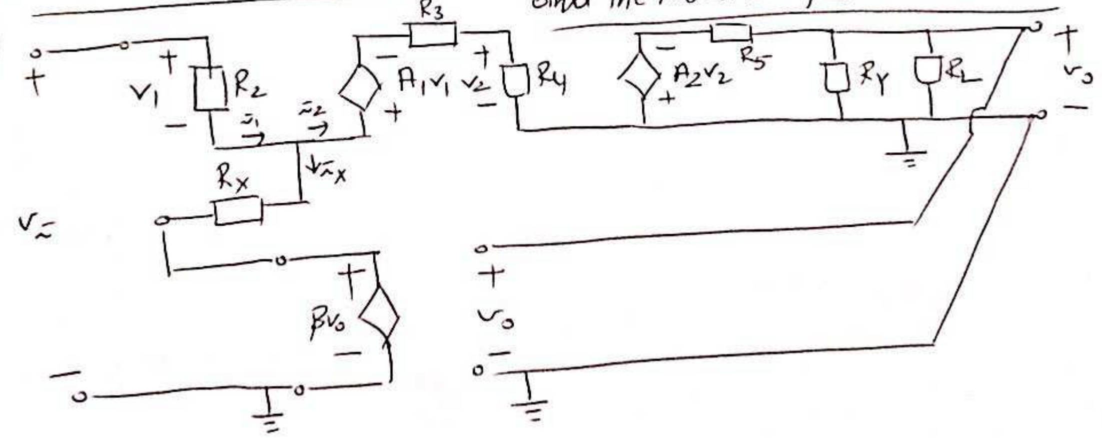
$$\beta = \frac{R_F}{R_F + R_G}$$

(**) Leave the following part until later.



Schematics of the (VA, FL) Feedback-Loaded Voltage Amplifier and the idealized feedback network

(***)



Kill β ($\beta = 0$) and analyze VA, Al

Rashid 10.13 Contin.

Compute $\frac{v_1}{v_i}$, $\frac{v_2}{v_i}$, $\frac{v_i}{i_1}$ (Refer to (***))

(KVL) $+v_i - v_1 - A_1 v_1 - (R_3 + R_4) i_2 = 0$

(KVL) $+v_i - v_1 - i_x R_x = 0$

(KCL) $i_1 = i_2 + i_x$

$v_1 = i_1 R_2$

$v_2 = i_2 R_4$

$$v_i = (1 + A_1) v_1 + (R_3 + R_4) i_2$$

$$\frac{v_1}{R_2} = i_2 + i_x$$

$$\frac{v_i - v_1}{R_x} = i_x$$

$$v_i = (1 + A_1) v_1 + (R_3 + R_4)\left[\frac{v_1}{R_2} - \frac{v_i - v_1}{R_x}\right]$$

$$v_i\left[1 + \frac{R_3 + R_4}{R_x}\right] = v_1\left[1 + A_1 + \frac{R_3 + R_4}{R_2 /\!/ R_x}\right]$$

$$\frac{v_1}{v_i} = \frac{\left[1 + \frac{R_3 + R_4}{R_x}\right]}{\left[(1 + A_1) + \left(\frac{R_3 + R_4}{R_2 /\!/ R_x}\right)\right]}$$

2

Rashid
10.13
Contin.

Note that

$$\frac{v_1}{v_i} = \frac{i_1 R_2}{v_i} = R_2 \left(\frac{v_i}{i_1}\right)^{-1}$$

$$r_{in,VA,FL} = \frac{v_i}{i_1} = R_2 \Big(\underbrace{\frac{v_1}{v_i}}_{\text{see the bottom of pg 2}}\Big)^{-1}$$

$$\frac{v_2}{v_i} = \frac{R_4 i_2}{v_i} = \frac{R_4}{v_i}\left[\frac{v_1}{R_2} - \frac{v_i - v_1}{R_x}\right]$$

$$= \frac{R_4}{v_i}\left[\frac{v_1}{R_2 /\!/ R_x} - \frac{v_i}{R_x}\right]$$

$$= \frac{R_4}{R_2 /\!/ R_x}\underbrace{\frac{v_1}{v_i}}_{\text{see the bottom of pg 2}} - \frac{R_4}{R_x} \underset{\Uparrow}{<} 0$$

check this numerically

Refer to (***)

$$\frac{v_o}{v_2} = (-A_2)\frac{R_Y /\!/ R_L}{R_Y /\!/ R_L + R_5} < 0 \quad \text{if } A_2 > 0$$

then

$$\frac{v_o}{v_i} = \underbrace{\frac{v_2}{v_i}}_{\text{see pg 3}}\ \underbrace{\frac{v_o}{v_2}}_{\text{see above}} = A_{VA,FL}$$

$$r_{out,VA,FL} = R_5 /\!/ R_Y /\!/ R_L$$

3

Rashid
10.B
contin.

Now apply feedback theory to compute:

$$A_f = \frac{A_{vA,fl}}{1+\beta A_{vA,fl}}$$

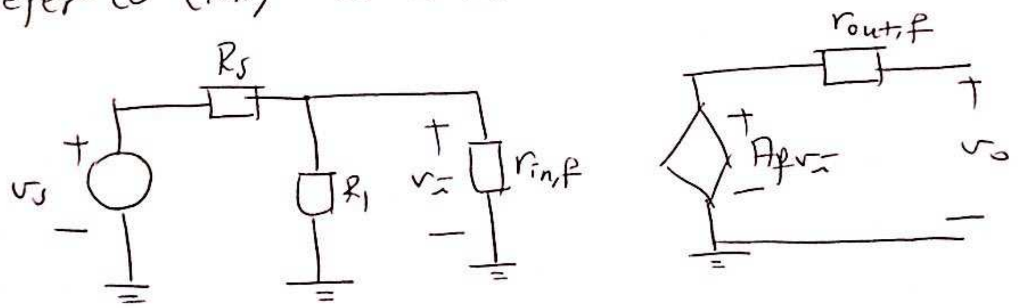
$$r_{in,f} = \left(1+\beta A_{vA,fl}\right) r_{in,vA,fl}$$

$$r_{out,f} = \frac{r_{out,vA,fl}}{1+\beta A_{vA,fl}}$$

Analysis of the feedback amplifier

Now analyze the whole circuit:

Refer to (**) and above



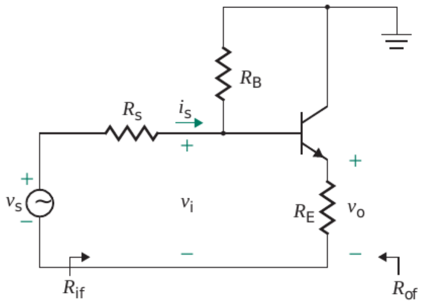
$$\frac{v_o}{v_s} = \frac{r_{in,f} // R_1}{r_{in,f} // R_1 + R_s} A_f$$

4

Voltage-Series Feedback in the Emitter-Follower Stage **Rashid 10.18**

10.18 D The emitter follower in Fig. P10.18 has $R_B = 75\ \text{k}\Omega$, $R_E = 750\ \Omega$, $R_L = 10\ \text{k}\Omega$, and $R_s = 250\ \Omega$. The transistor parameters are $h_{fe} = 150$, $r_\pi = 250\ \Omega$, and $r_o = \infty$. Draw a block diagram of the feedback mechanism. Use the techniques of feedback analysis to calculate **(a)** the input resistance R_{if}, **(b)** the output resistance R_{of}, and **(c)** the closed-loop voltage gain A_f.

FIGURE P10.18



Notes: None.

Additional Tasks: None.

Necessary Knowledge and Skills: Voltage amplifiers and non-idealities modeling, gain and input/output impedance calculations, voltage-series feedback, feedback network analysis, feedback-loaded voltage amplifier analysis, effects of voltage-series feedback.

Outline for the analysis (in terms of the parameters) Rashid 10.18

⇒ draw the small-signal equivalent (the feedback network and the type of feedback should be identified)

~~⇒ Model the nonfeedback (forward) amplifier as a voltage amplifier (VA)~~

⇒ Compute the parameters of the feedback network (note that this a voltage-series or series-shunt type of feedback)

⇒ Load the nonfeedback amplifier with the nonideal input/output impedances of the feedback network, model the new/modified forward amplifier again as voltage amplifier, now feedback-loaded (VA, fl). Note that the feedback network (now idealized) is killed during this procedure.

⇒ Analyze the feedback loaded VA (VA, fl) together with the feedback network to compute the

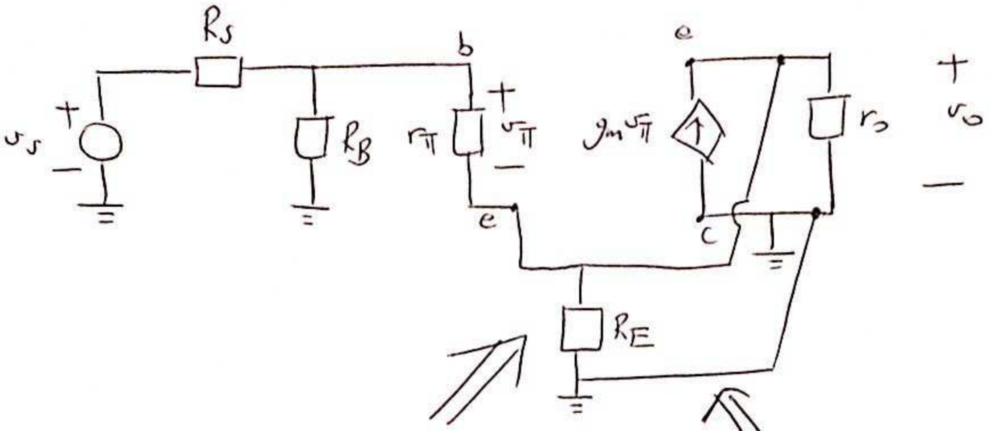
A_f, $r_{in,f}$, $r_{out,f}$

parameters of the feedback amplifier (or called the amplifier with feedback)

1

Rashid 10.18 continued

• Small-signal Equiv. of the cir.

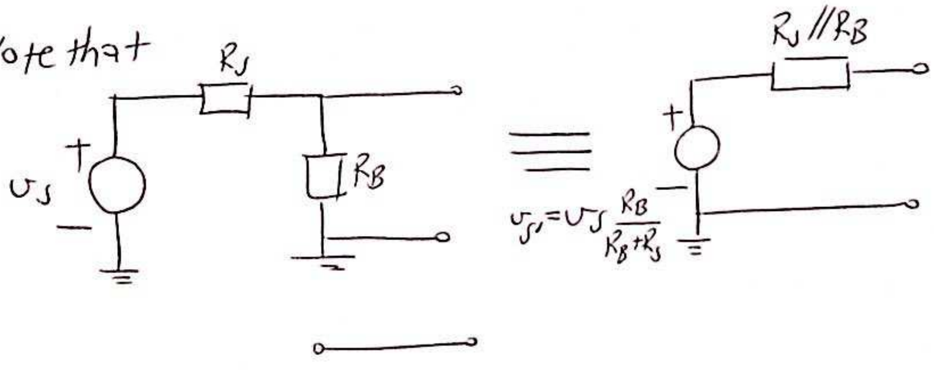


series (type of feedback into the input)

shunt (type of sampling)

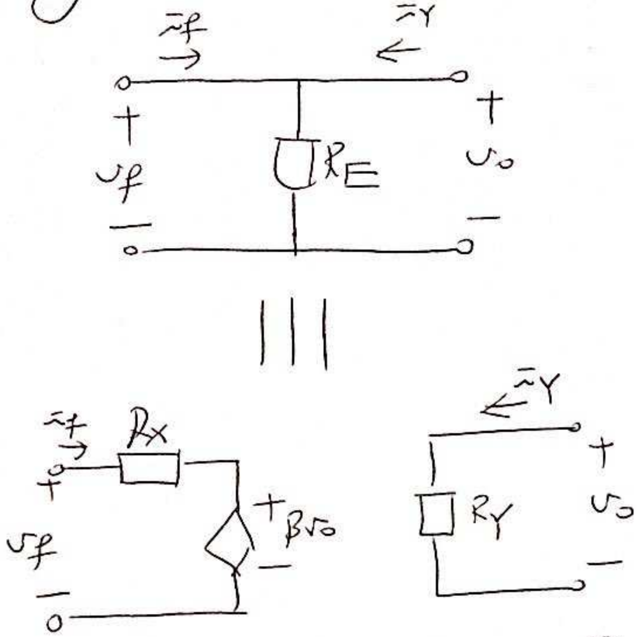
Therefore, this is an example of series-shunt (or voltage series type of feedback).

Note that



Rashid 10.18
Contin-

- Analyze the feedback network



$$\beta = \frac{v_f}{v_o}\bigg|_{i_f=0} = 1$$

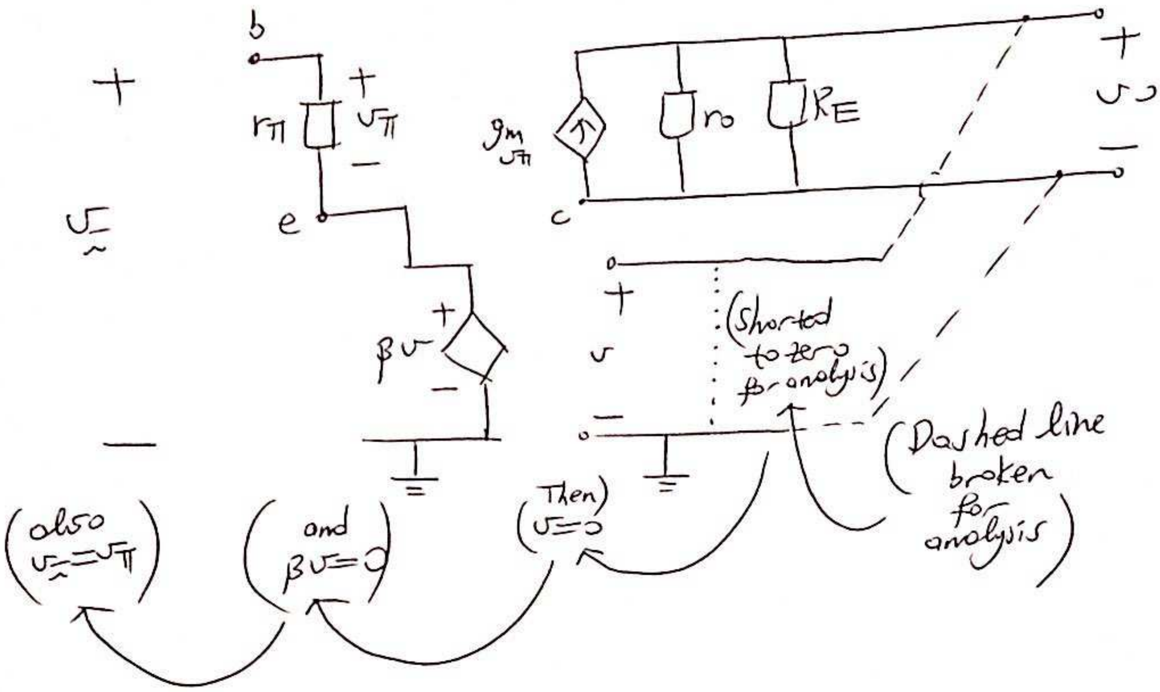
$$R_x = \frac{v_f}{i_f}\bigg|_{v_o=0} = 0$$

$$R_Y = \frac{v_o}{i_Y}\bigg|_{i_f=0} = R_E$$

3

- Analyze the following nonfeedback amplifier as VA. (now feedback-loaded therefore VA, fl)

Rashid 10.18 Contin.



Parameters of the feedback loaded ampli. are

$$A_{VA,fl} = g_m (r_o // R_E)$$

$$r_{in,VA,fl} = r_\pi$$

$$r_{out,VA,fl} = r_o // R_E$$

(4)(B)

Rashid 10.18 contin

- Compute the parameters of the feedback amplifier (or amplifier with feedback)

We use the properties of voltage-series feedback (Note that $\beta = 1$)

$$A_f = \frac{A_{VA,FL}}{1 + A_{VA,FL}\,\beta} = \frac{g_m (r_o // R_E)}{1 + g_m (r_o // R_E)}$$

$$r_{in,f} = r_{in,VA,FL}\left(1 + A_{VA,FL}\,\beta\right) = r_\pi \left(1 + g_m (r_o // R_E)\right)$$

$$r_{out,f} = \frac{r_{out,VA,FL}}{1 + A_{VA,FL}\,\beta} = \frac{r_o // R_E}{1 + g_m (r_o // R_E)}$$

with $r_o \gg R_E$ the above answers are

$$A_f \approx \frac{R_E}{1/g_m + R_E}$$

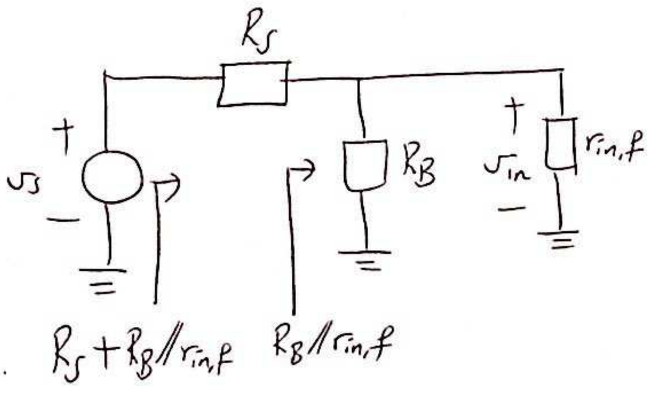
$$r_{in,f} \approx r_\pi \left(1 + g_m R_E\right)$$

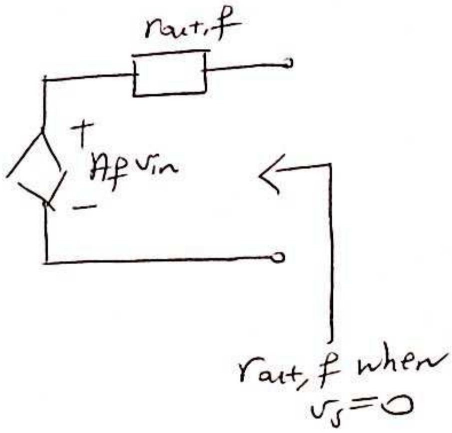
$$r_{out,f} = R_E // \frac{1}{g_m}$$

(5)

Rashid
10.18
contin-

• Now analyze the whole cir.





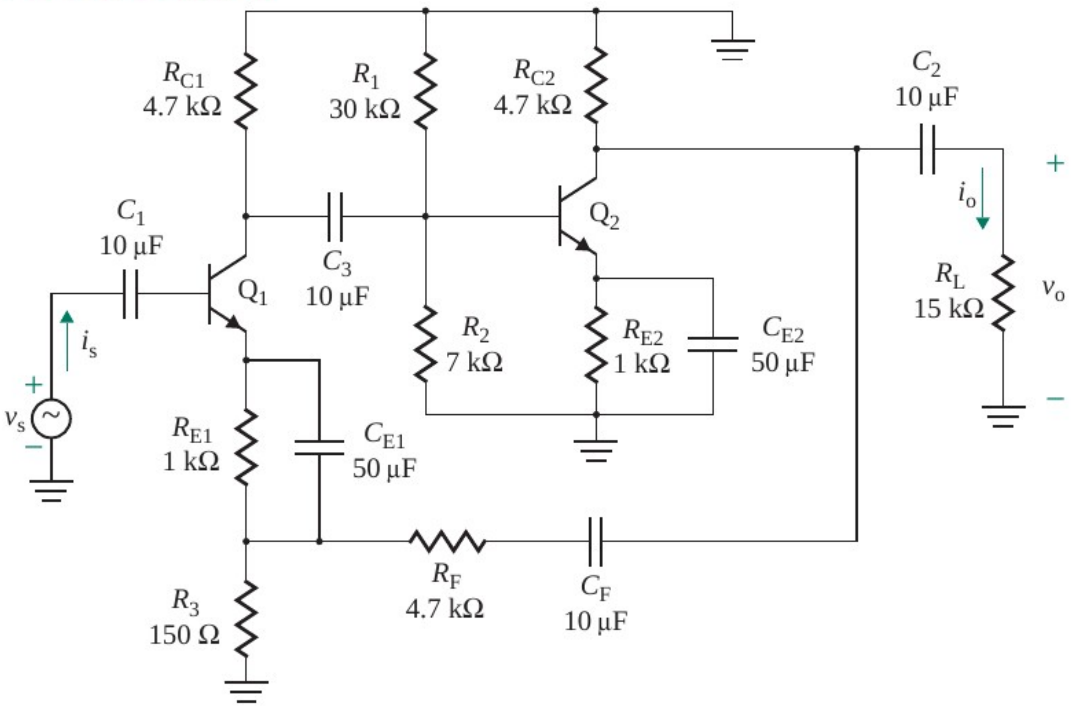
$$A_{realized} = \frac{r_{in,f} // R_B}{r_{in,f} // R_B + R_s} \cdot A_f$$

6

Voltage-Series Feedback on a Voltage Amplifier **Rashid 10.19**

10.19 Use the techniques of feedback analysis to calculate the input resistance R_{if}, the output resistance R_{of}, and the closed-loop voltage gain A_f of the amplifier in Fig. P10.19. The transistor parameters are $h_{fe} = h_{fe1} = h_{fe2} = 10$, $r_{\pi1} = r_{\pi2} = 250\ \Omega$, $r_o = 1.5\ k\Omega$, and $r_\mu = \infty$.

FIGURE P10.19



Notes: None.

Additional Tasks: None.

Necessary Knowledge and Skills: Voltage amplifiers and non-idealities modeling, gain and input/output impedance calculations, voltage-series feedback, feedback network analysis, feedback-loaded voltage amplifier analysis, effects of voltage-series feedback.

Cascaded CE amplifiers: (+) voltage gain

Rashid 10.19

voltage series (or series shunt) feedback on a voltage amplifier

Tasks

⇒ identify the feedback network and model it

⇒ load the forward amplifier (VA, voltage amplifier) with the feedback network nonidealities to obtain the feedback-loaded VA (VA, fl).

⇒ Analyze VA, fl to obtain

$A_{VA,fl}$

$r_{in,VA,fl}$

$r_{out,VA,fl}$

⇒ Analyze the whole feedback amplifier to obtain

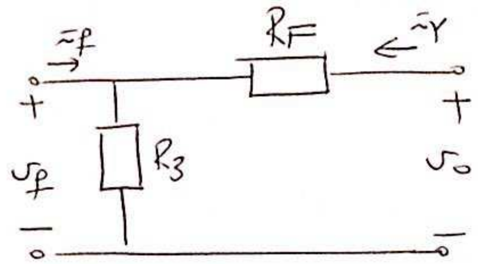
$$A_f = \frac{A_{VA,fl}}{1+\beta A_{VA,fl}}$$

$$r_{in,f} = r_{in,VA,fl}\left(1+\beta A_{VA,fl}\right)$$

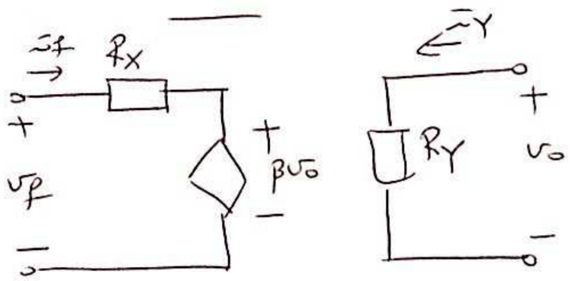
$$r_{out,f} = \frac{r_{out,VA,fl}}{1+\beta A_{VA,fl}}$$

1

Rashid
10.19
contin.



$\equiv$



$R_Y = R_3 + R_F$

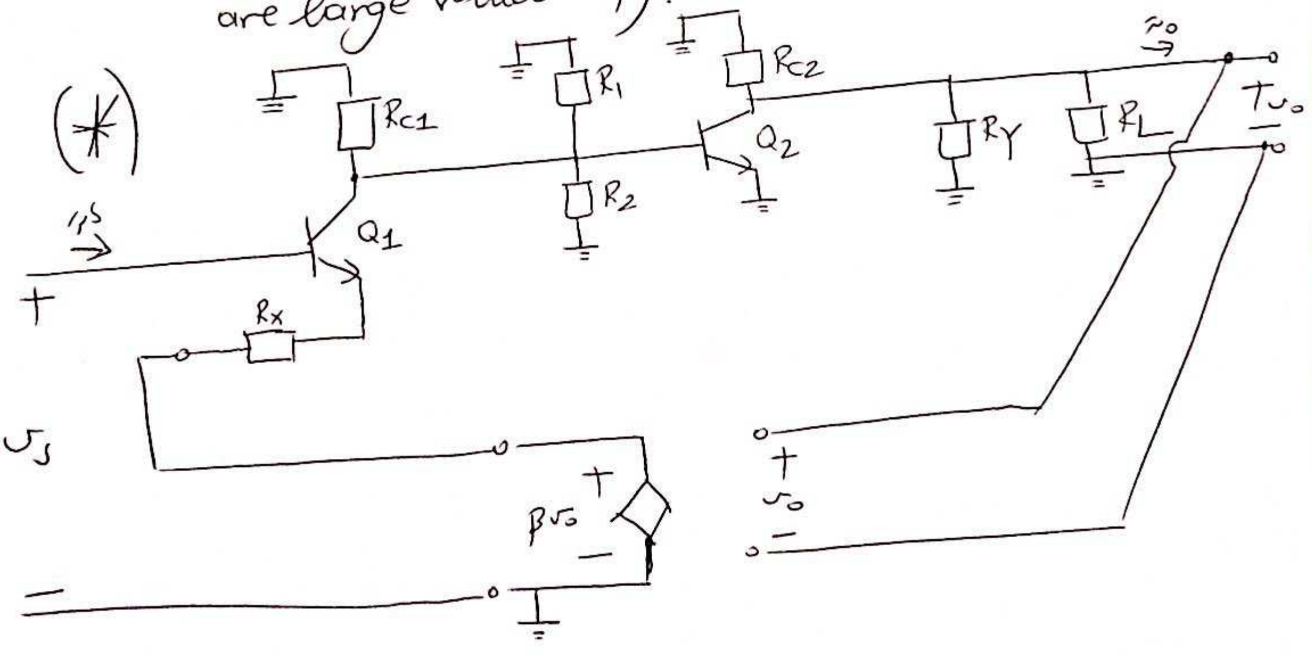
$R_X = R_3 // R_F$

$\beta = \dfrac{R_3}{R_3 + R_F}$

Schematics of $\overline{\text{VA}, \text{FB}}$ and the feedback network

$\Longrightarrow$ Note that C_1, C_2, C_3, C_{E1}, C_F, C_{E2} are all short circuited in midband (these are large valued cap).

(*)



2

Rashid
1019
Contin.

In the schematics of (*):

$\Rightarrow$ set $\beta = 0$

$$\Rightarrow r_{in,vA,fe} = \frac{v_j}{i_s}\bigg|_{i_o=0}$$

(which means $i_o = 0$)

$$\cong r_{\pi 1}(1 + g_{m1} R_X)$$

$$\Rightarrow A_{vA,fe} = \frac{v_o}{v_j}\bigg|_{i_o=0}$$

$$\cong \left[-\frac{g_{m1}}{1+g_{m1}R_X}\right]\left[R_{C1} // R_1 // R_2 // r_{\pi 2} // \left[r_{o1}(1+g_{m1}R_X)\right]\right]$$

$$\cdot \left[-g_{m2}\right]\left[R_{C2} // r_{o2} // R_Y // R_L\right]$$

$\Rightarrow$ Note that when $v_j = 0$

$$R_{in,c1} \cong (r_{\pi 1} // R_X)(1 + g_{m1} r_o)$$

$$R_{out,b2} = R_1 // R_2 // R_{C1} // R_{in,c1}$$

then $r_{out,vA,fe} \cong R_{C2} // R_Y // R_L // \underbrace{R_{in,c2}}_{r_o}$

Since the emitter of Q_2 is connected to gnd in midband, we do not need to account for $R_{in,c1}$ or $R_{out,b2}$ in this computation.

Scanned by CamScanner

(3)

Rashid 10.19 contin-

Analysis of the feedback amplifier (VA, fl + the idealized feedback network)

$\Rightarrow$ First ~~I~~ see the results on pg 3

$$\Rightarrow \beta = \frac{R_3}{R_3 + R_F}$$

$$\Rightarrow A_f = \frac{A_{VA,fl}}{1 + \beta A_{VA,fl}}$$

$$r_{in,f} = r_{in,VA,fl}\left(1 + \beta A_{VA,fl}\right)$$

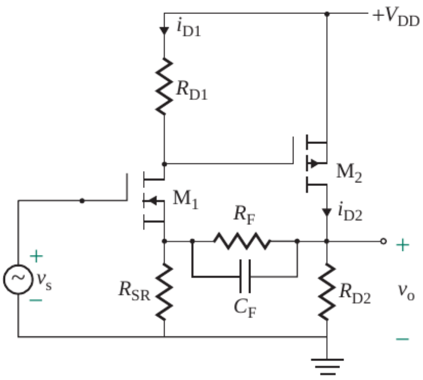
$$r_{out,f} = \frac{r_{out,VA,fl}}{1 + \beta A_{VA,fl}}$$

4

Voltage-Series Feedback on a Voltage Amplifier **Rashid 10.22**

10.22 The MOS amplifier shown in Fig. P10.22 is biased to have the following small-signal MOS parameters: $g_{m1} = 1.2\ \text{mA/V}$, $r_{o1} = 25\ \text{k}\Omega$, $g_{m2} = 1.6\ \text{mA/V}$, and $r_{o1} = 25\ \text{k}\Omega$. If $R_{D1} = 1.5\ \text{k}\Omega$, then $R_{D2} = 1\ \text{k}\Omega$, $R_{SR} = 500\ \Omega$, $R_F = 5\ \text{k}\Omega$, and $C_F = 20$ pF. Determine **(a)** the voltage gain without feedback $A = v_o/v_s$, **(b)** the voltage gain with feedback A_f, and **(c)** the feedback capacitor C_F to limit the high frequency $f_H = 50$ kHz.

FIGURE P10.22



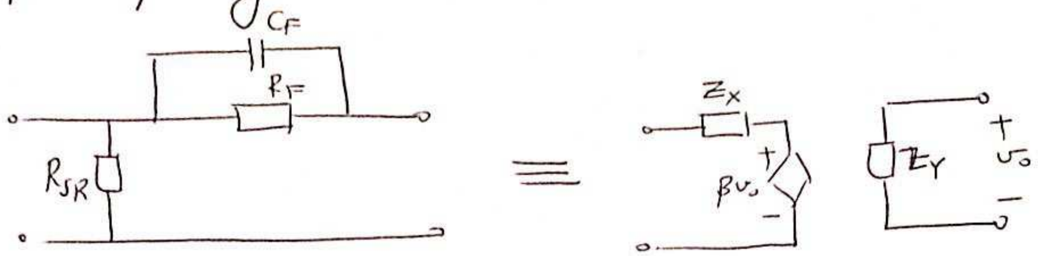
Notes: None.

Additional Tasks: None.

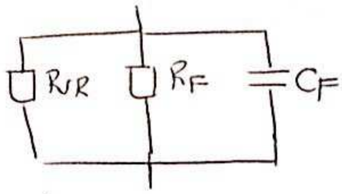
Necessary Knowledge and Skills: Voltage amplifiers and non-idealities modeling, gain and input/output impedance calculations, voltage-series feedback, feedback network analysis, feedback-loaded voltage amplifier analysis, effects of voltage-series feedback, design equation for high-frequency cut-off involving the feedback capacitor, effect of feedback on high-frequency cut-off.

Rashid
10.22

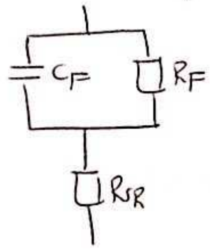
The voltage-series feedback network consists of the following circuit:



$Z_X \equiv$



$Z_Y \equiv$



$$\beta(s) = \frac{R_{SR}}{R_{SR} + \dfrac{R_F \frac{1}{sC_F}}{R_F + \frac{1}{sC_F}}} = \frac{R_{SR}}{R_{SR} + \dfrac{R_F}{1 + sR_F C_F}}$$

$$= \frac{R_{SR}(1 + sR_F C_F)}{R_F + R_{SR} + sR_F C_F R_{SR}}$$

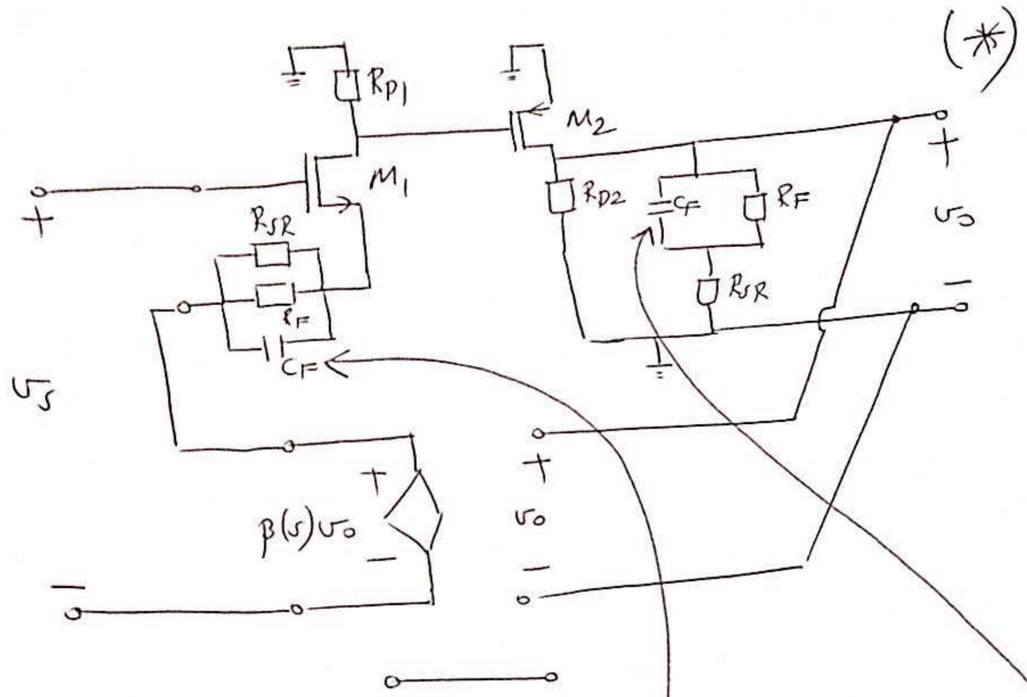
$$= \frac{R_{SR}}{R_F + R_{SR}} \cdot \frac{1 + \dfrac{s}{\underbrace{1/R_F C_F}_{\to \omega_z}}}{1 + \dfrac{s}{\underbrace{\dfrac{1}{C_F R_F \frac{R_{SR}}{R_F + R_{SR}}}}_{\to \omega_p}}}$$

call this β (low freq value of $\beta(s)$)

1

Schematics of the feedback loaded (VA, PC) amplifier and feedback network:

Rashid 10.22 contin



Above in (*) set $\beta(s)=0$.

Apply OCTC first.

$\underline{C_1 = C_F}$

$$R_1 = R_{SR} /\!/ R_F /\!/ \left[\frac{R_{D1}+r_{o1}}{1+g_{m1}r_{o1}}\right]$$

(see the relevant doc. for derivations)

$g_{m1}r_{o1} \gg 1$ (intrinsic gain)

if $r_{o1} \gg R_{D1}$, then this term $\approx \dfrac{1}{g_{m1}}$

if true

$$R_1 \cong \frac{1}{g_{m1}}$$

Note that $\tau_1 = R_1 C_1$

$\underline{C_2 = C_F}$

$$R_2 = R_F /\!/ \left[R_{SR} + r_{o2} /\!/ R_{D2}\right]$$

if $R_{D2} \ll r_{o2}$, then this term $\approx R_{D2}$

if true

$$R_2 \cong R_F /\!/ \left[R_{SR} + R_{D2}\right]$$

$$\tau_2 = R_2 C_2$$

(2)

Rashid
10.22
contin.

OCTC

$$W_H \cong \frac{1}{\tau_1 + \tau_2}$$

Note that τ_1 and τ_2 may not be comparable.

Check: In the computations for OCTC

$$R_1 = \underbrace{R_{SR}}_{0.5K} // \underbrace{R_F}_{5K} // \left[\frac{\overbrace{R_{P1}}^{1.5k\Omega} + \overbrace{r_{o1}}^{25k\Omega}}{1 + \underbrace{g_{m1}}_{1.2mS}\, \underbrace{r_{o1}}_{25k\Omega}} \right]$$

$$R_1 \cong 0.5K // 5K // \underbrace{\frac{1}{1.2mS}}_{0.8K} \approx \frac{(0.5)(0.8)}{1.3} K \approx 0.3K$$

$$R_2 = \underbrace{R_F}_{5K} // \left[\underbrace{R_{SR}}_{0.5K} + \underbrace{r_{o2}}_{+\infty} // \underbrace{R_{D2}}_{1K} \right]$$

$$R_2 \cong 5K // 1.5K \approx \frac{(5)(1.5)}{(6.5)} K \cong 1.15K$$

Therefore, $\tau_1 = R_1 \underbrace{C_1}_{C_F}$ and $\tau_2 = R_2 \underbrace{C_2}_{C_F}$ are comparable

Need to use this formula.

 3

Rashid 10.22 contin.

Now in (*) set both C_F's in the VA,fl to O.C., keep $\beta(s)=0$.

Compute (set $R_X = R_{SR} // R_F$ and $R_Y = R_F + R_{SR}$)

$$A_{VA,fl} = \left[\frac{-g_{m1}}{1+g_{m1}R_X}\right]\left[R_{P1} // \left[(1+g_{m1}R_X)r_{o1}\right]\right] \cdot \left[-g_{m2}\right]\left[R_{D2} // R_Y // r_{o2}\right]$$

$$r_{in,VA,fl} = +\infty$$

$$r_{out,VA,fl} = R_{D2} // R_Y // \underbrace{r_{o2}}_{+\infty}$$

Now analyze the feedback amplifier (VA,fl and the feedback network)

$$r_{in,f} = r_{in,VA,fl}\left(1 + \underbrace{A_{VA,fl}}_{\text{midband value see above (pg 4)}}\ \underbrace{\beta}_{\text{low-freq (midband value) see pg 1}}\right) = +\infty$$

$$r_{out,f} = \frac{r_{out,VA,fl}}{1 + A_{VA,fl}\,\beta}$$

(4)

Now analyze the high-frequency cutoff of the feedback amplifier

Razavi 10.22 contin

(Not easy since $\beta(s)$ depends on the freq)

$$A_{VA,FL}(j\omega) = \frac{A_{VA,FL}}{1 + \frac{j\omega}{\omega_H}}$$

$A_{VA,FL}$ → see pg 4

ω_H → see pg 3

$$\beta(j\omega) = \beta \frac{1 + \frac{j\omega}{\omega_Z}}{1 + \frac{j\omega}{\omega_P}} \Rightarrow \text{see pg 1}$$

$$A_f(j\omega) = \frac{A_{VA,FL}(j\omega)}{1 + \beta(j\omega) A_{VA,FL}(j\omega)}$$

$$= \frac{\dfrac{A_{VA,FL}}{1 + \frac{j\omega}{\omega_H}}}{1 + \dfrac{A_{VA,FL}}{1 + \frac{j\omega}{\omega_H}} \beta \dfrac{1 + \frac{j\omega}{\omega_Z}}{1 + \frac{j\omega}{\omega_P}}}$$

$$= \frac{A_{VA,FL}}{1 + \frac{j\omega}{\omega_H} + \beta A_{VA,FL} \dfrac{1 + \frac{j\omega}{\omega_Z}}{1 + \frac{j\omega}{\omega_P}}}$$

omitting the higher order term

$$\cong \frac{A_{VA,FL}\left(1 + \frac{j\omega}{\omega_P}\right)}{1 + \frac{j\omega}{\omega_H} + \frac{j\omega}{\omega_P} + \beta A_{VA,FL} + \dfrac{\frac{j\omega}{\omega_Z}}{\beta A_{VA,FL}}}$$

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Rashid 10.22 contin.

$$A_f(j\omega) \cong \underbrace{\frac{A_{VA,fe}}{1+\beta A_{VA,fe}}}_{\text{midband value}} \cdot \frac{1+\frac{j\omega}{\omega_p}}{1+\dfrac{j\omega}{\left(\omega_H // \omega_p // \frac{\omega_z}{A_{VA,fe}\beta}\right)\left(1+A_{VA,fe}\beta\right)}}$$

$A_f(j\omega)$ has a zero and a pole approximately.

see pg 1

$$\omega_p = \frac{1}{C_F R_F \frac{R_{SR}}{R_{SR}+R_F}} \qquad \frac{R_{SR}}{R_F} = \frac{1}{10} \text{ (see the question)}$$

$$\omega_p \cong \frac{11}{C_F R_F} = 11 \cdot \omega_z$$

$$A_{VA,fe}\beta > 0$$

approximate numerical value for (see pg 4 and the question)

$$A_{VA,fe} = \left[\frac{-1.2mS}{1+(1.2mS)\underbrace{(0.5K//5K)}_{0.5K}}\right]\underbrace{\left[1.5K//\left[25K\left(1+(1.2mS)(0.5K//5K)\right)\right]\right]}_{\approx 1.5K}$$

$$\cong \left[-1.6mS\right]\underbrace{\left[1K//(5.5K)//+\infty\right]}_{\approx 0.9K}$$

$$A_{VA,fe} \cong \left(\frac{-1.2mS}{1.6}\right)(-1.6mS)(1.5K)(0.9K)$$

$$\cong \underbrace{(1.2)(1.5)}_{1.8}(0.9) = 1.62$$

$$\beta = \frac{1}{11}$$

$A_{VA,fe}\beta \approx 0.15$

6

Rashid 10.22 contin.

Therefore

$$\frac{W_Z}{A_{VA,fe}\beta} = \frac{W_P}{(11)(0.15)} \cong \frac{W_P}{1.6}$$

Numerical value for W_H ⇒ see pg 3

$$W_H \cong \frac{1}{C_F(1.15K+0.3K)} = \frac{1}{C_F(1.45K)}$$

$$W_P = \frac{1}{C_F(5K)\frac{0.5K}{5.5K}}$$ ⇒ see pg 1 and the question

$$= \frac{1}{C_F(0.45K)}$$

$$\frac{W_Z}{A_{VA,fe}} \cong \frac{1}{C_F(0.45K)(1.6)} = \frac{1}{C_F(0.72K)}$$

see pg 6

$$A_f(jw) \cong \frac{1.62}{1.15}\,\frac{1+\frac{jw}{\frac{1}{C_F(0.45K)}}}{1+\frac{jw}{\left[\frac{1}{C_F(1.45K)} // \frac{1}{C_F(0.45K)} // \frac{1}{C_F(0.72K)}\right](1.15)}}$$

Note that the pole is lower than the zero.
The pole is:

$$W_{H,f} \cong \frac{1.15}{C_F(2.62K)} = \frac{1}{C_F(2.28K)} = 2\pi\underbrace{(50KHz)}_{\text{specification}}$$

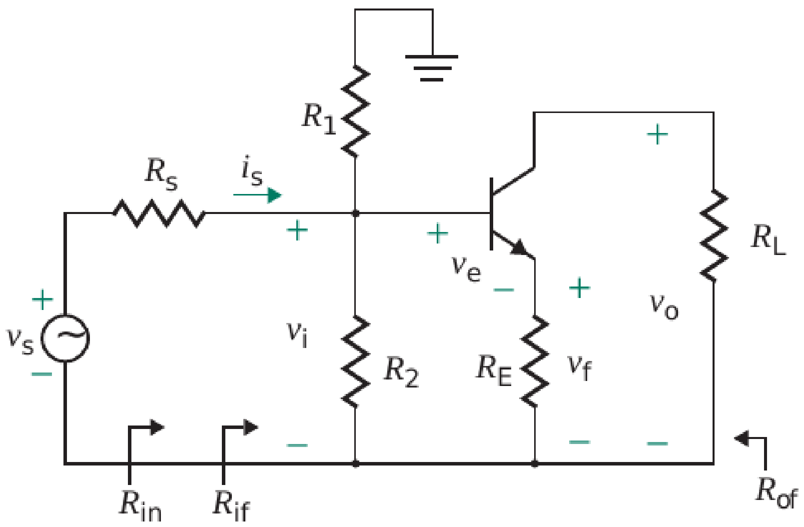
Calculate C_F from this equation
$C_F \cong 1.4nF$

7

Current-Series Feedback on the CE Stage **Rashid 10.26**

10.26 Use the techniques of feedback analysis to determine the input and output resistance of the CE transistor amplifier in Fig. P10.26. The circuit parameters are $R_s = 500\ \Omega$, $R_E = 250\ \Omega$, $R_2 = 15\ \text{k}\Omega$, $R_1 = 5\ \text{k}\Omega$, $R_C = 5\ \text{k}\Omega$, and $R_L = 10\ \text{k}\Omega$. The π-model parameters are $r_o = 25\ \text{k}\Omega$, $h_{fe} = 150$, $r_\pi = 250\ \Omega$, $g_m = 0.3876$ A/V, and $r_\mu = \infty$.

FIGURE P10.26



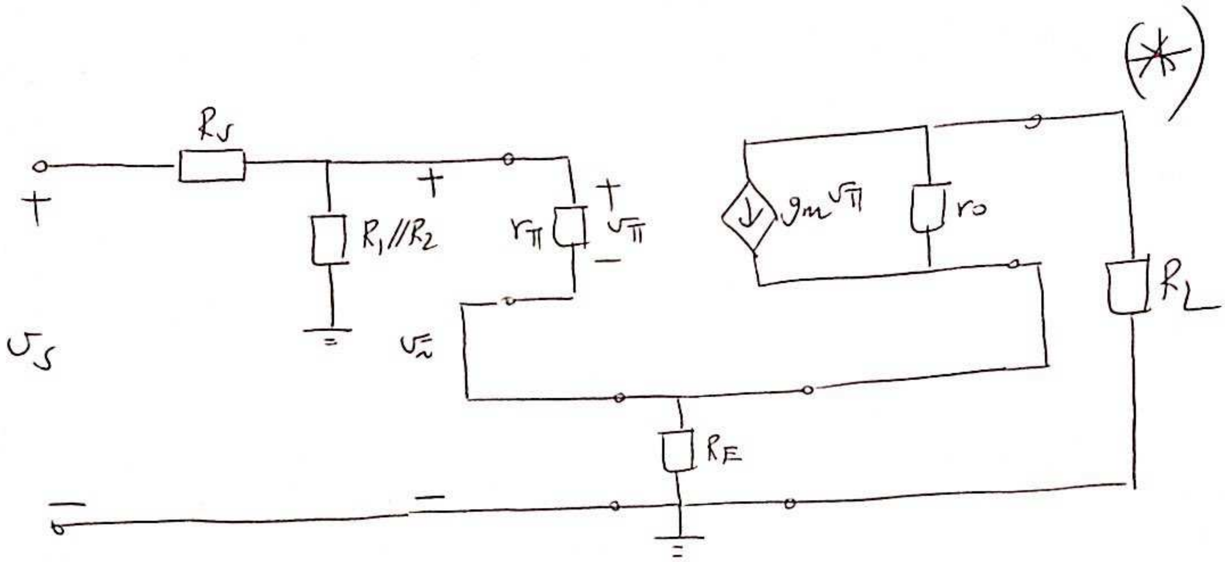
Notes: None.

Additional Tasks: None.

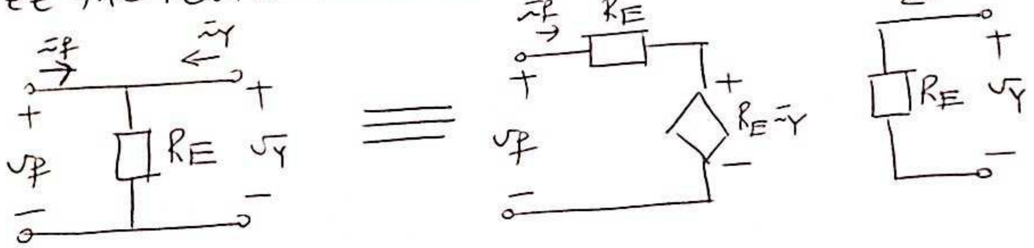
Necessary Knowledge and Skills: Modeling the CE stage as a transconductance amplifier, current-series feedback network modeling in a practical amplifier, gain and i/o impedance computations, feedback-loaded TCA analysis, effect of feedback on gain and i/o impedances.

Rashid
10.26

Schematics of the amplifier (identifying the feedback network)



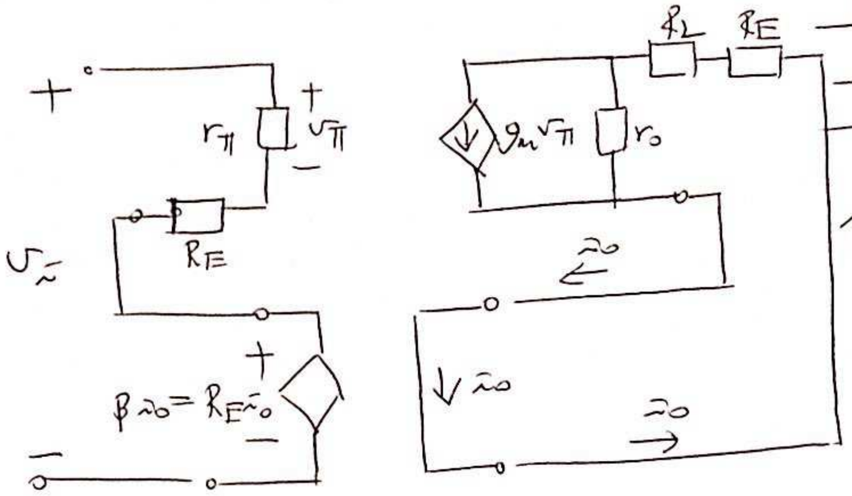
See the related document on how to model



Then the feedback-loaded TCA (TCA, fl) and the idealized feedback network schematics is as follows.

Rashid 10.26 contin.

(**)



$\Rightarrow$ set $\beta = 0$

Analysis of TCA, fl (the forward but feedback-loaded TCA)

$\Rightarrow r_{in,TCA,fl} = r_\pi + R_E$

$$A_{TCA,fl} = \frac{r_\pi}{r_\pi + R_E} g_m \frac{r_o}{r_o + R_L + R_E}$$

$$r_{out,TCA,fl} = r_o + R_L + R_E$$

Analysis of the whole network (TCA, fl and the feedback network)

Recall $\beta = R_E$

$$r_{in,f} = r_{in,TCA,fl}(1 + \beta A_{TCA,fl})$$

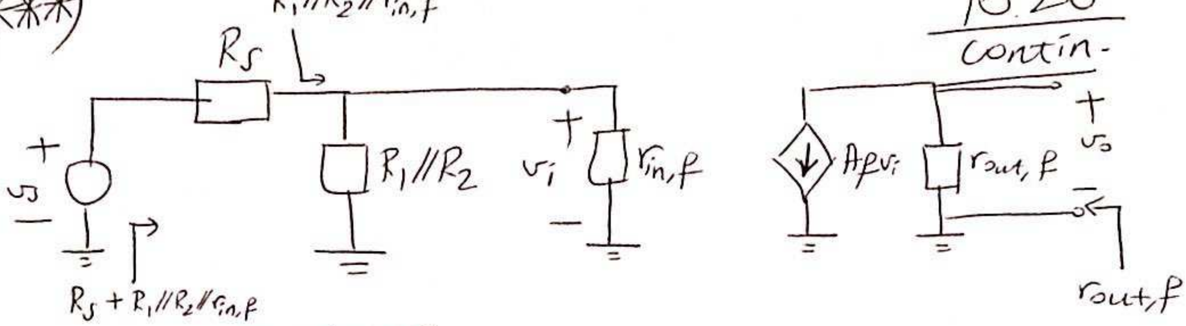
$$r_{out,f} = r_{out,TCA,fl}(1 + \beta A_{TCA,fl})$$

$$A_f = \frac{A_{TCA,fl}}{1 + \beta A_{TCA,fl}}$$

2

Rashid
10.26
contin.

(***)



$$\frac{v_o}{v_s} = \frac{r_{in,f} // R_1 // R_2}{r_{in,f} // R_1 // R_2 + R_S} \left[-A_f \right] r_{out,f}$$

The resistances have been pointed out in (***).
Calculation of the numerical values — exercise.

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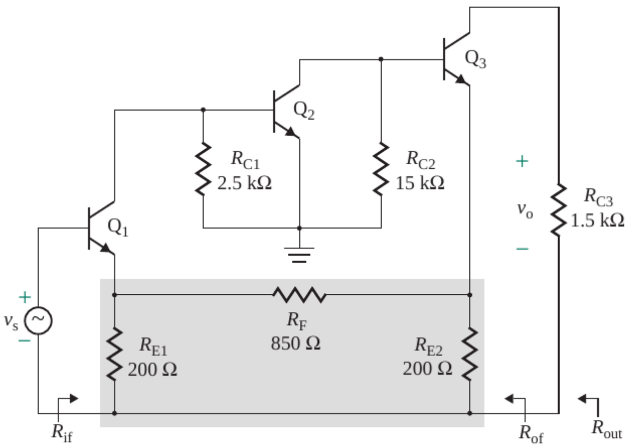
3

Current-Series Feedback on a TCA **Rashid 10.28**

10.28 P The AC equivalent circuit of a feedback amplifier is shown in Fig. P10.28. The circuit values are R_{C1} = 2.5 kΩ, R_{C2} = 5 kΩ, R_{C3} = 1.5 kΩ, R_{E1} = 100 Ω, R_{E2} = 100 Ω, R_F = 750 Ω, and R_s = 0. The transistor parameters are h_{fe} = 100, r_π = 2.5 kΩ, r_o = 25 kΩ, and $r_\mu = \infty$. Use the techniques of feedback analysis to calculate **(a)** the input resistance R_{if}, **(b)** the output resistance R_{of}, and **(c)** the closed-loop voltage gain A_f.

FIGURE P10.28



Notes: None.

Additional Tasks: None.

Necessary Knowledge and Skills: Modeling the CE stage as a transconductance amplifier, current-series feedback network modeling in a practical amplifier, gain and i/o impedance computations, feedback-loaded TCA analysis, effect of feedback on gain and i/o impedances.

There is current − series feedback

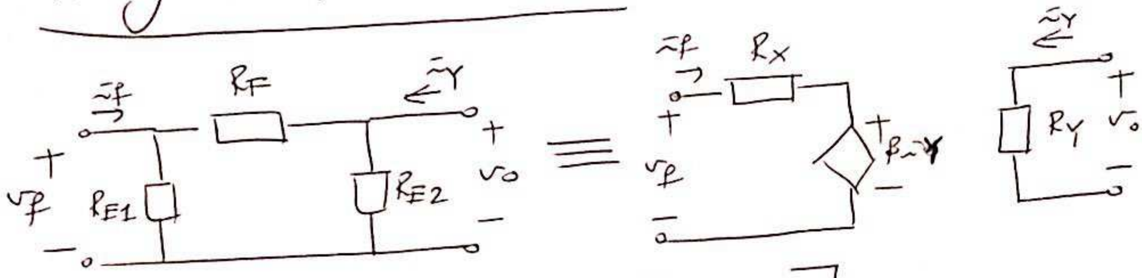
series series

involved in this circuit.

Rashid 10.28

The whole amplifier identifying the feedback network has already been drawn.

Analyze the feedback network (see pg 668 of Rashid)



$$R_X = \left.\frac{v_f}{i_f}\right|_{i_Y=0} = R_{E1} \,//\, [R_F + R_{E2}]$$

$$R_Y = \left.\frac{v_o}{i_Y}\right|_{i_f=0} = R_{E2} \,//\, [R_{E1} + R_F]$$

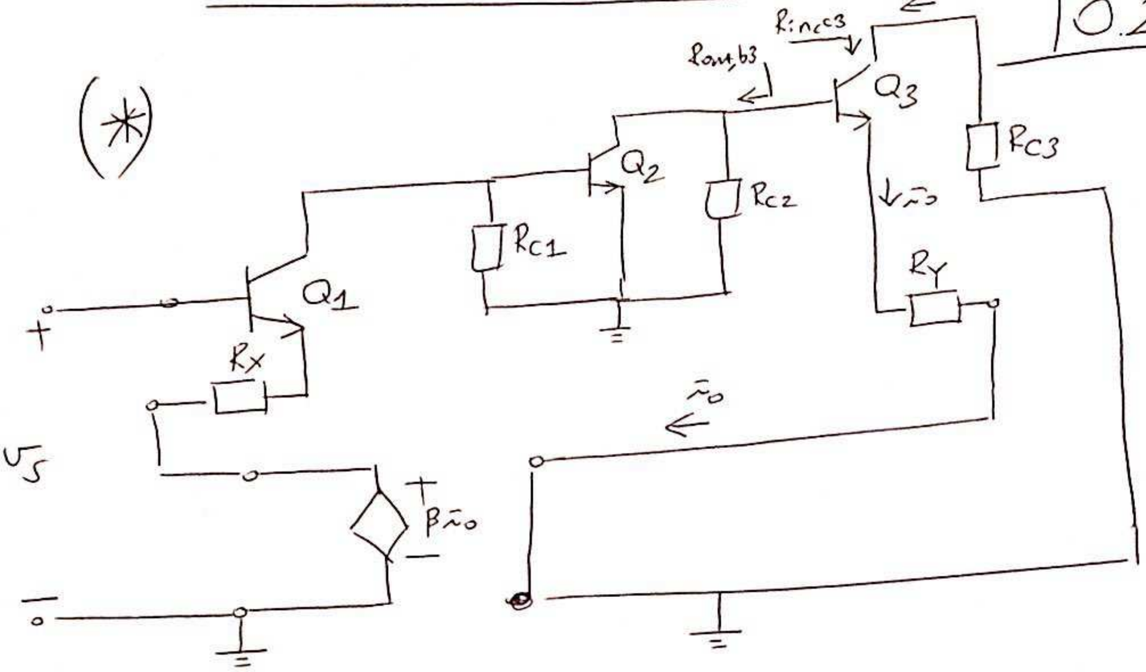
$$\beta = \left.\frac{v_f}{i_Y}\right|_{i_f=0} = \frac{R_{E2}}{R_{E2} + R_{E1} + R_F} \cdot R_{E1}$$

Next ⇒ Draw the schematic of TCA, fl and the current-series feedback network.

TCA, fl and the feedback network

Rashid 10.28

(*)



Above in (*), set $\beta = 0$, Analyze TCA, fl

$$A_{TCA,fl} \cong \left[\frac{-g_{m1}}{1+g_{m1}R_X}\right]\left[\left[(1+g_{m1}R_X)r_{o1}\right] // R_{C1} // r_{\pi 2}\right]$$

$$\cdot \left[-g_{m2}\right] \cdot \left[r_{o2} // R_{C2} // \left[r_{\pi 3}(1+g_{m3}R_Y)\right]\right]$$

$$\cdot \left[\frac{g_{m3}}{1+g_{m3}R_Y}\right]$$

Rashid 10.28 contin.

$$r_{in,TCA,fe} \cong r_{\pi 1}\left(1+g_{m1} R_x\right)$$

$$r_{out,TCA,fe} \cong R_{C3} + R_{in,c3}$$

note that $R_{out,b3} = R_{C2} // r_{o2}$

then $R_{in,c3} = \left(1+g_{m3} r_{o3}\right)\dfrac{R_Y r_{\pi 3}}{R_Y + r_{\pi 3} + R_{out,b3}} + r_o + \dfrac{R_Y R_{out,b3}}{R_Y + r_{\pi 3} + R_{out,b3}}$

(see related document on the derivation)

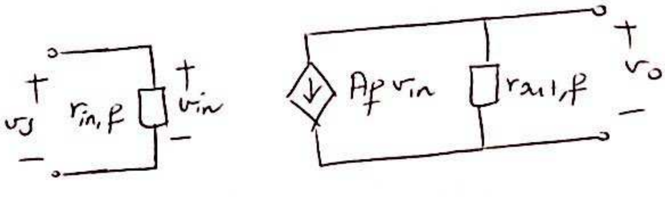
if the trailing two terms can be neglected $\approx \left(1+g_{m3} r_{o3}\right)\left[\dfrac{R_Y r_{\pi 3}}{R_Y + r_{\pi 3} + R_{out,b3}}\right]$

Now analyze the whole amplifier:

$$A_f = \frac{A_{TCA,fe}}{1+\beta A_{TCA,fe}}$$

$$r_{in,f} = r_{in,TCA,fe}\left(1+\beta A_{TCA,fe}\right)$$

$$r_{out,f} = r_{out,TCA,fe}\left(1+\beta A_{TCA,fe}\right)$$



$$\frac{v_o}{v_s} = -A_f\, r_{out,f}$$

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