Elektronik II

Final çalışması: geri besleme ve frekans cevabı

Orijinal not: Final-notu.pdf

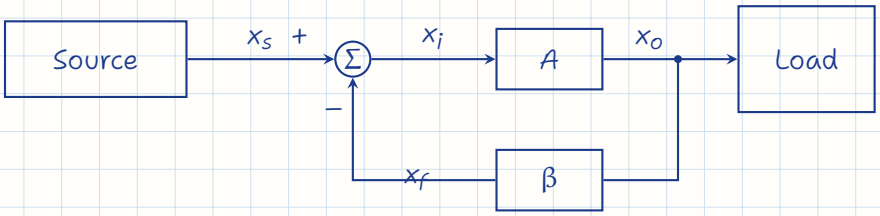
UYARI Bu belge, el yazısı ders notlarından Claude (Anthropic) yardımıyla dijitale aktarılmıştır. Yardımcı kaynak olarak hazırlanmıştır; hata veya eksik içerebilir. Lütfen orijinal notları ve ders kaynaklarını esas alın.

NOTICE *This document was transcribed from handwritten lecture notes with the help of Claude (Anthropic). It is meant as a supplementary resource and may contain errors or omissions. Always check against the original notes and official course material.*

orj. s. 1

Feedback

The general feedback structure

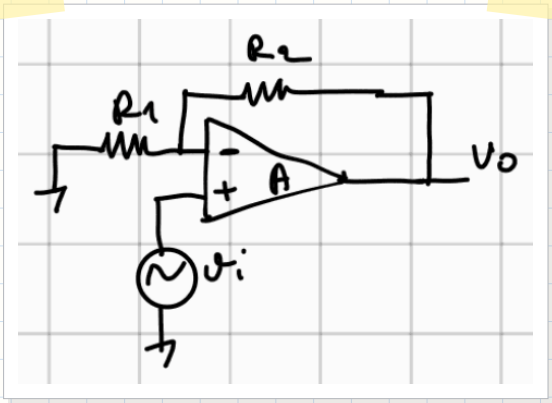


A = open loop gain
β = feedback factor
x_i = Input signal
x_s = signal source
x_o = output signal
x_f = sampled output

$$\left(\frac{x_o}{x_s}\right)_{CL} = ?$$

$$x_o = A\,x_i$$
$$x_f = \beta \cdot x_o$$
$$x_i = x_s - x_f$$
$$x_i = x_s - \beta\,x_o$$
$$x_i = x_s - A\beta\,x_i$$
$$x_s = x_i\,(1 + A\beta)$$

$$\left(\frac{x_o}{x_s}\right) = \frac{A\,x_i}{x_i\,(1 + A\beta)} = \frac{A}{1 + A\beta}$$

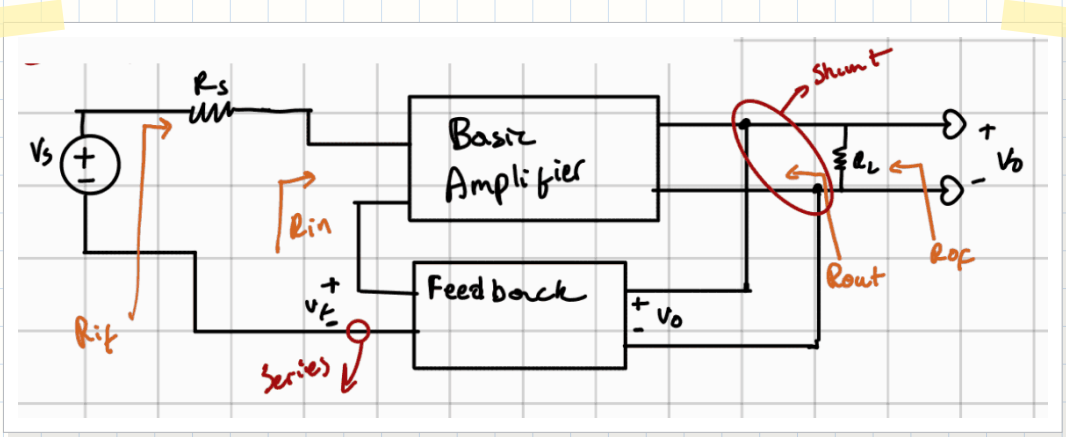


orijinal çizim, s. 1

$$\frac{v_o}{v_i} = \left(1 + \frac{R_2}{R_1}\right) \approx \frac{1}{\beta}$$

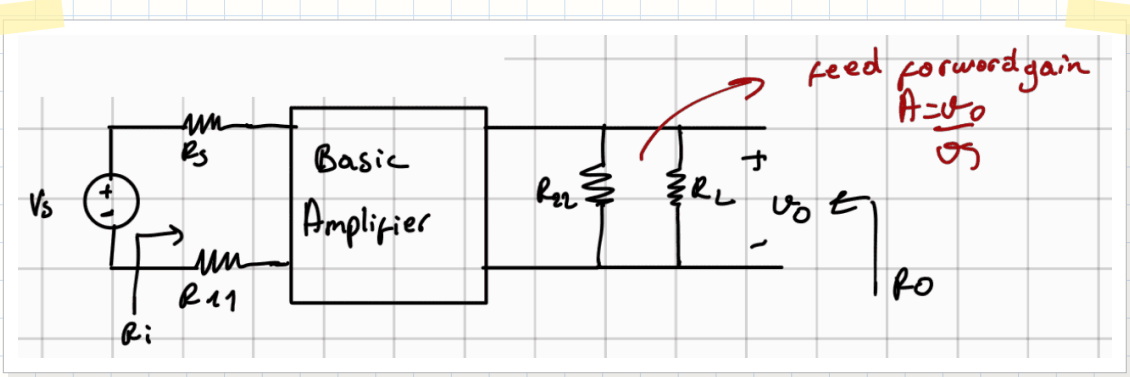
$$\beta = \left(1 + \frac{R_2}{R_1}\right)^{-1}$$

Voltage Amplifiers (Shunt-Series)

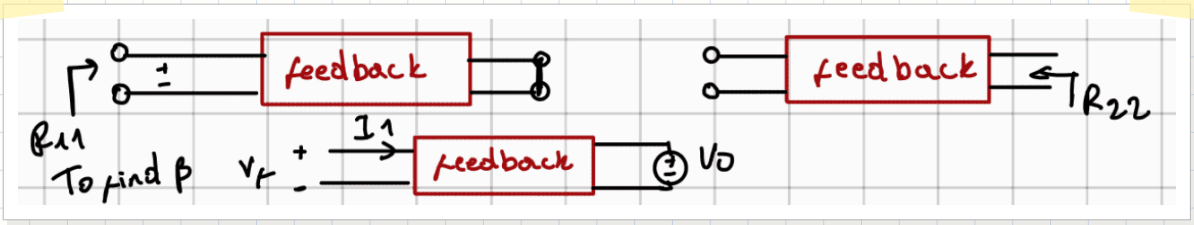


orijinal çizim, s. 1

Two port network equivalent



orijinal çizim, s. 1

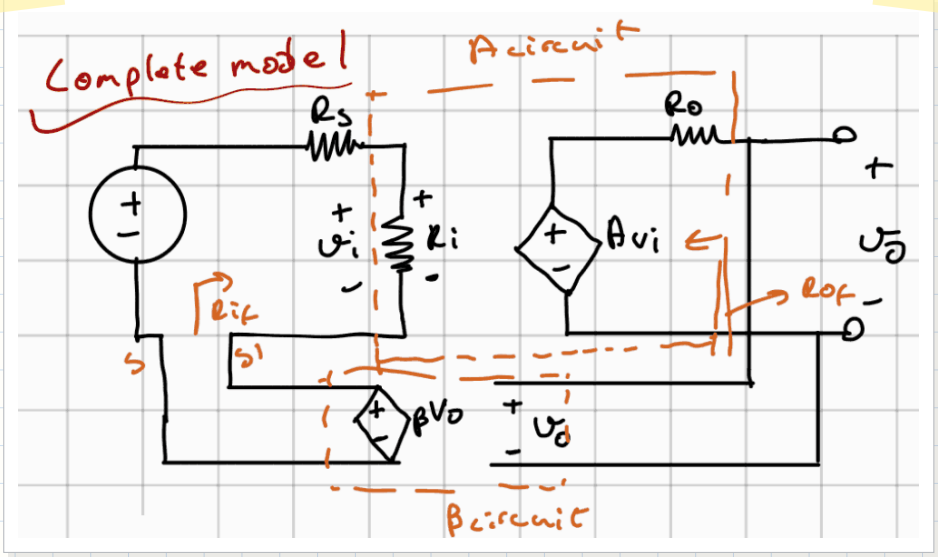


orijinal çizim, s. 1

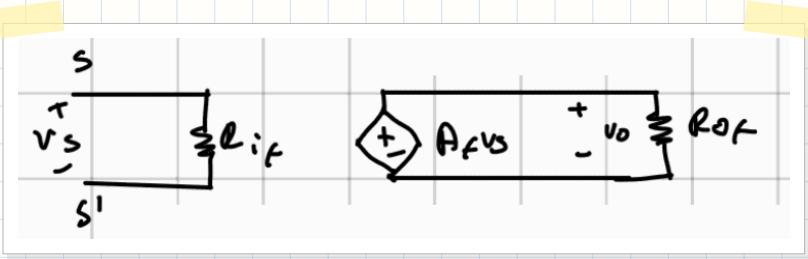
$$\beta = \frac{V_f}{V_o}\bigg|_{I_1}$$

orj. s. 2

Complete model



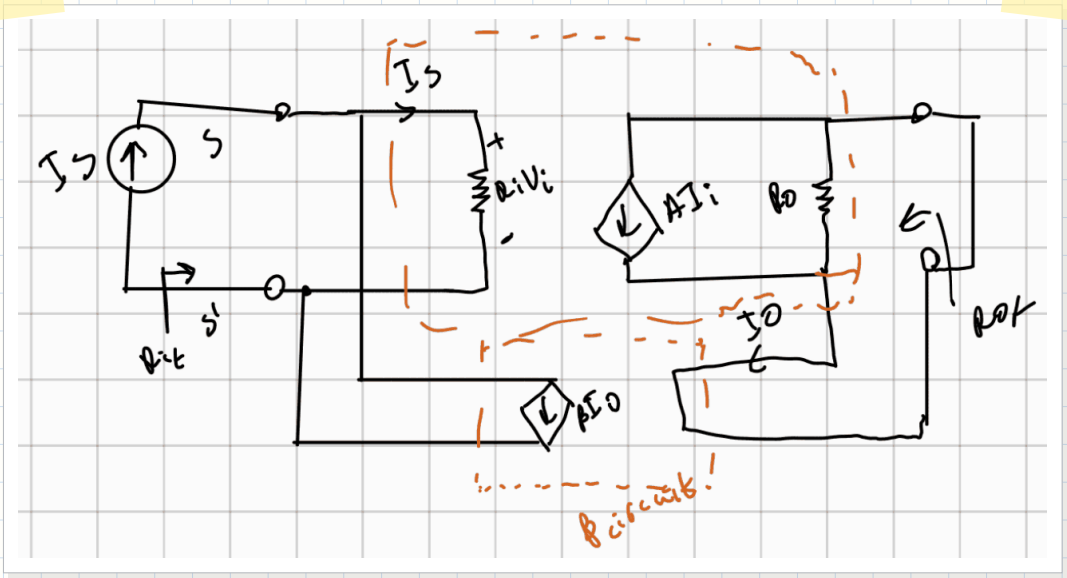
orijinal çizim, s. 2



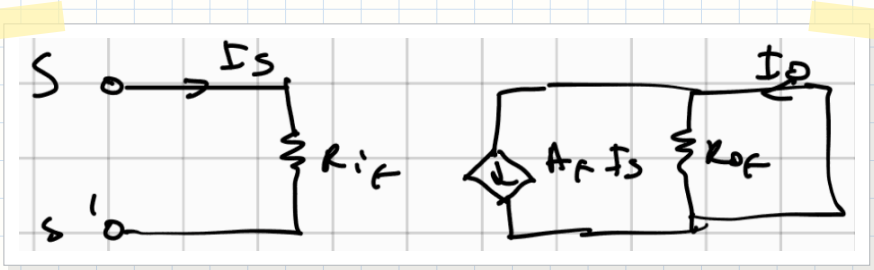
orijinal çizim, s. 2

$$A_f = \frac{A}{1 + A\beta} \qquad R_{if} = (1 + A\beta) R_i \qquad R_{of} = \frac{R_o}{(1 + A\beta)}$$

Current Amplifier feedback



orijinal çizim, s. 2



orijinal çizim, s. 2

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

$$R_{if} = \frac{R_i}{1 + A\beta}$$

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

orj. s. 3

Soru



orijinal çizim, s. 3

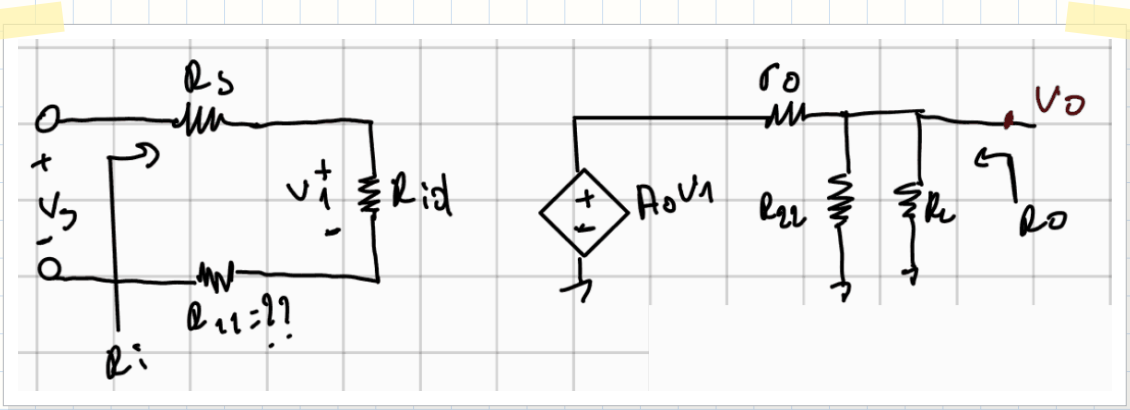
$$R_{11} = R_1 \parallel R_2 \qquad R_{22} = R_1 + R_2$$



orijinal çizim, s. 3

$$\frac{V_f}{V_o} = \frac{R_1}{R_1 + R_2} = \beta$$

$$R_{eq} = R_s + R_{id} + R_{11} =$$



orijinal çizim, s. 3

$$\frac{v_o}{v_1} = \frac{R_{22} \parallel R_L}{r_o + R_{22} \parallel R_L} \cdot A_0$$

$$A = \frac{v_o}{v_s} = \frac{v_o}{v_1} \cdot \frac{v_1}{v_s}$$

$$\frac{v_1}{v_s} = \frac{R_{id}}{R_s + R_{id} + R_{11}} \cdot \frac{v_s}{v_s}$$

(sağdaki v_s/v_s çarpanı çizilerek sadeleştirilmiş)

$$A = \underbrace{\frac{R_{id}}{R_s + R_{id} + R_{11}}}_{R_i} \cdot \frac{R_{22} \parallel R_L}{r_o + R_{22} \parallel R_L} \cdot A_0$$

$$A_f = \frac{A}{1 + A\beta} \qquad \beta = \frac{R_1}{R_1 + R_2}$$

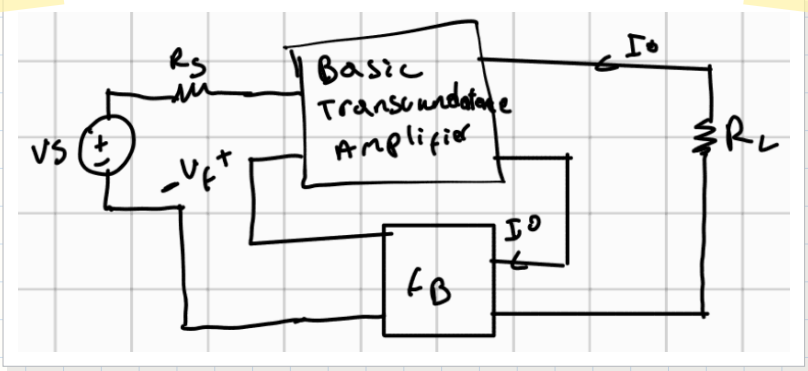
orj. s. 4

$$R_{if} = (1 + A\beta) R_i \qquad R_{of} = \frac{R_o}{(1 + A\beta)}$$

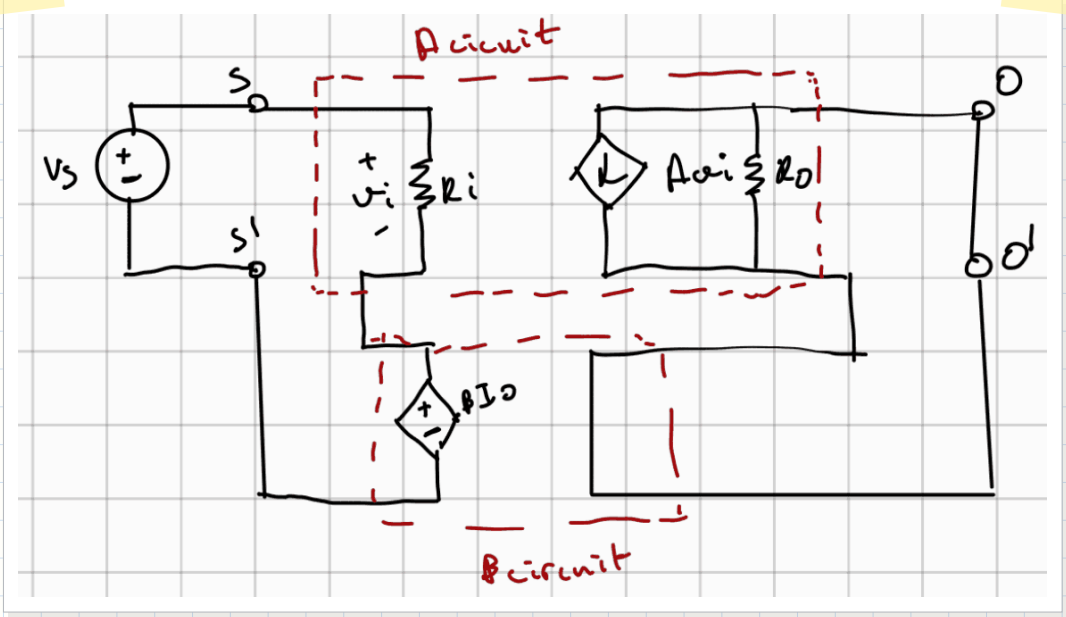
(?O) (I)

Series – Series feedback Topology

-Suitable for transconductance Amplifier

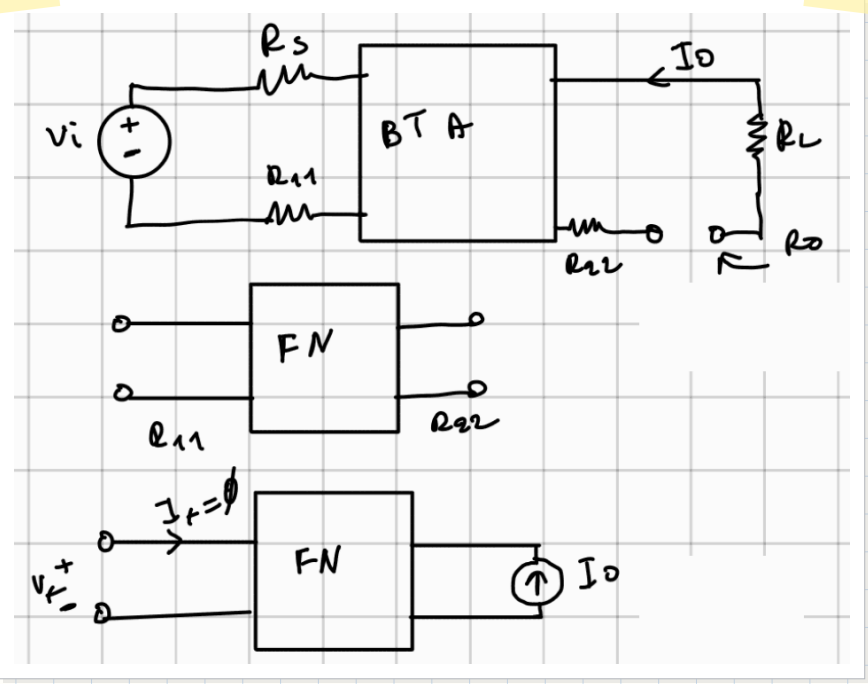


orijinal çizim, s. 4



orijinal çizim, s. 4

Two port equivalent circuit



orijinal çizim, s. 4

$$\frac{I_o}{V_1} = A$$

$$\beta = \frac{V_f}{I_o}$$

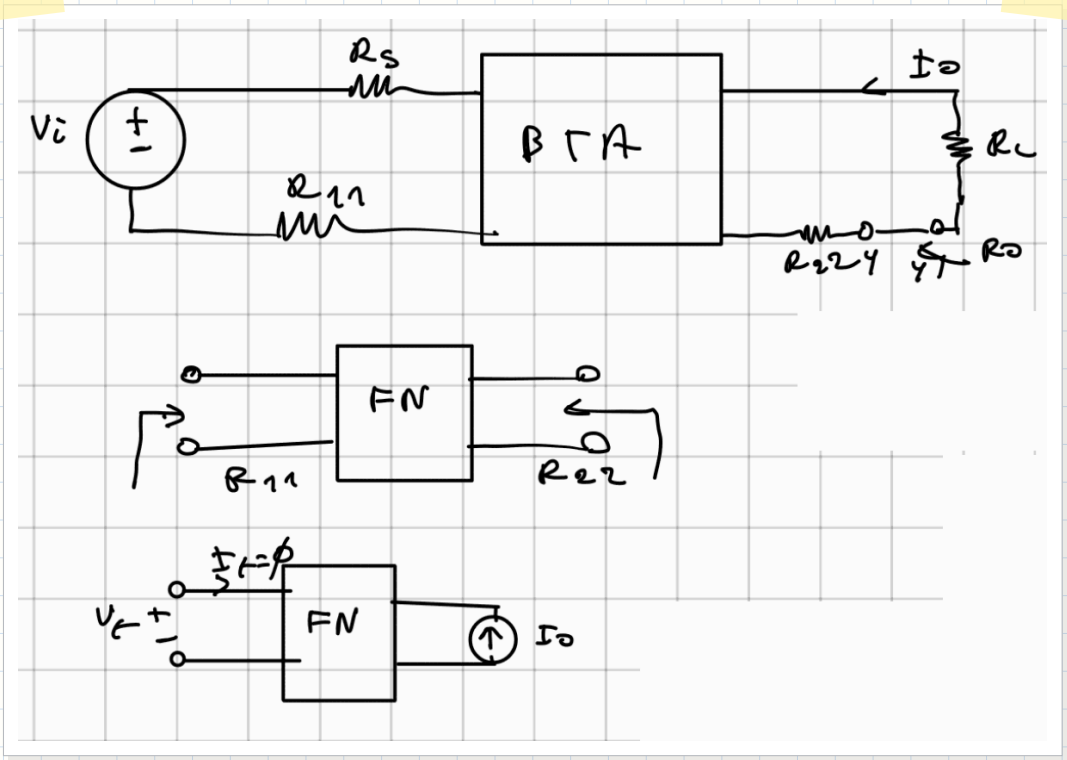
$$R_{if} = R_i (1 + A\beta)$$

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

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

orj. s. 5

Two-port equivalent circuit



orijinal çizim, s. 5

$$\frac{I_o}{V_1} = A$$

$$\beta = \frac{V_f}{I_o}$$

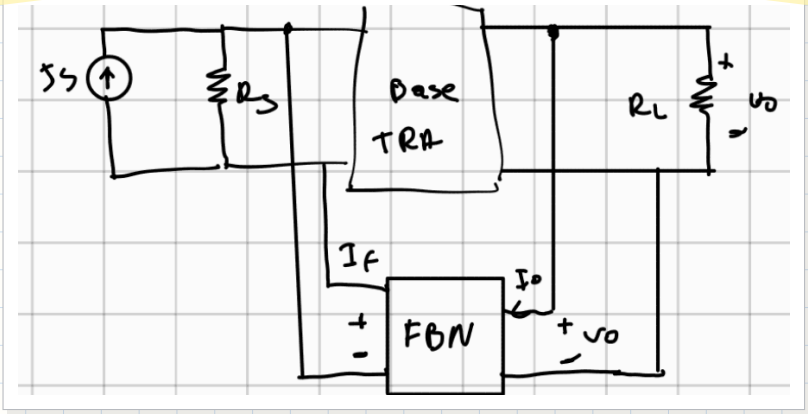
$$R_{if} = R_i (1 + A\beta)$$

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

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

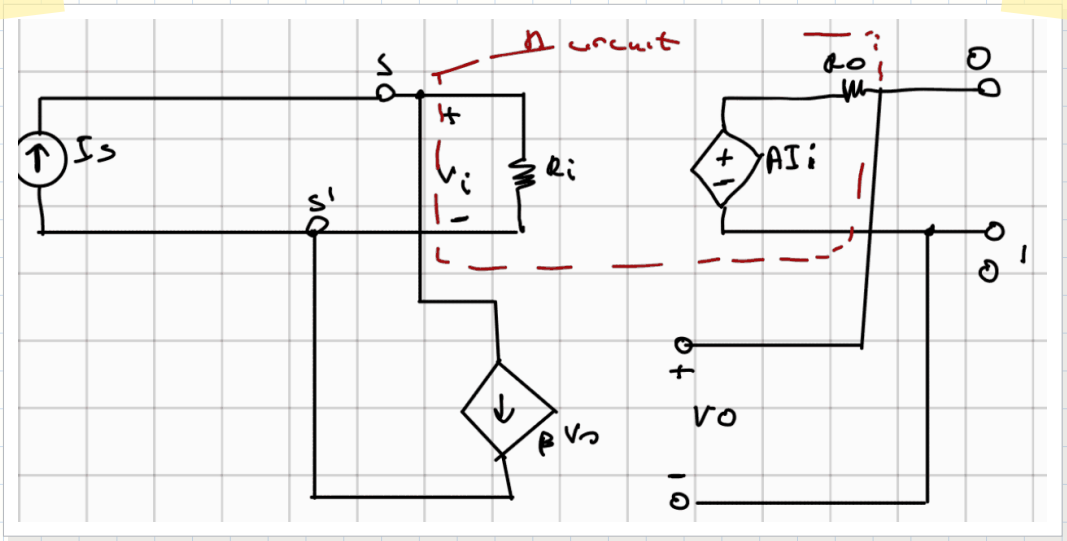
Shunt – Shunt feedback topology

(Trans resistance amplifier)



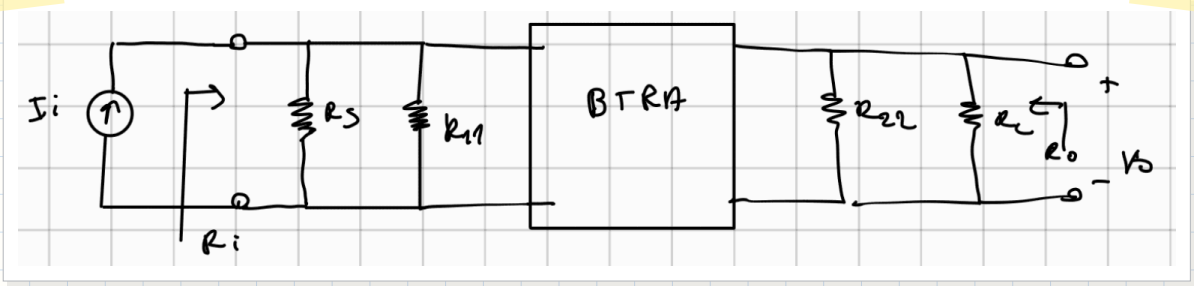
orijinal çizim, s. 5

$$A = \frac{V_o}{I_s}$$

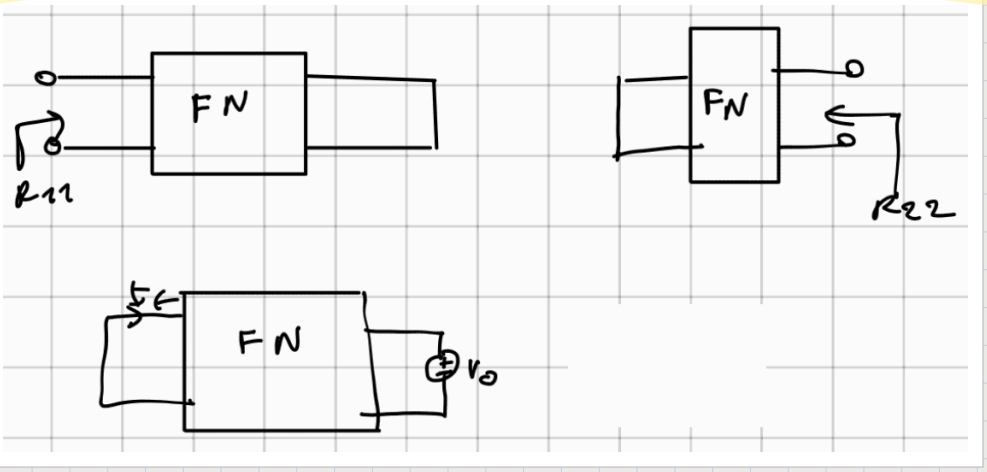


orijinal çizim, s. 5

orj. s. 6



orijinal çizim, s. 6



orijinal çizim, s. 6

$$\beta = \frac{I_f}{V_o}$$

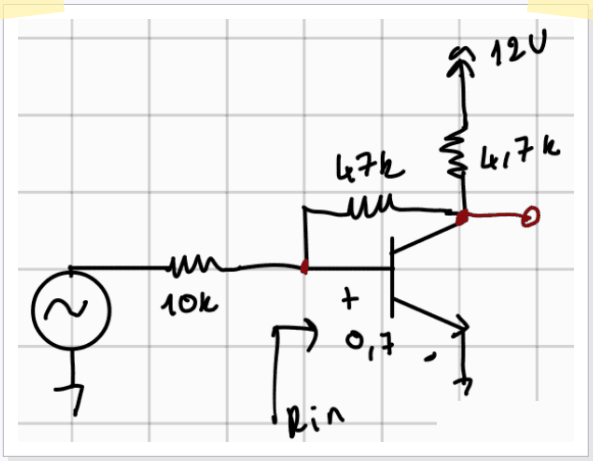
$$R_{if} = \frac{R_i}{1 + A\beta}$$

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

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

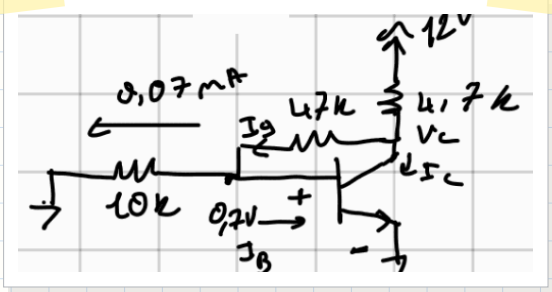
Örnek 2

ignore r_o ‖ $\beta = 100$ $(V_A = \infty)$



orijinal çizim, s. 6

DC



orijinal çizim, s. 6

$$\frac{0,7}{10k} = 0,07\ mA$$

$$\frac{12 - V_C}{4,7} = I_C + \frac{V_C - 0,7}{47k}$$

orj. s. 7

$$I_C = \frac{12 - V_C}{4,7k} - \frac{V_C - 0,7}{47k}$$

$$I_C = \frac{120 - 11\,V_C + 0,7}{47k}$$

$$\frac{V_C - 0,7\ V}{47k} = I_B + 0,07\ mA$$

$$I_B = \frac{V_C - 0,7}{47k} - 0,07\ mA$$

$$\frac{100\,V_C - 70}{47k} - 7\ mA = \frac{120 - 11\,V_C + 0,7}{47k}$$

$$100\,V_C - 70 - 120 + 11\,V_C - 0,7 = ?329$$

$$\frac{111\,V_C}{111} = \frac{?329 + 120 + 70,7}{111}$$

$$V_C = 4,68\ V$$

$I_C = 1,47\ mA$

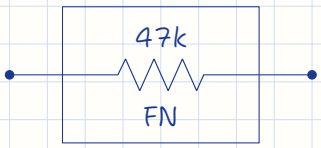
$I_B = 0,0147\ mA$

$$g_m = \frac{I_C}{V_T} = 58\ mS$$

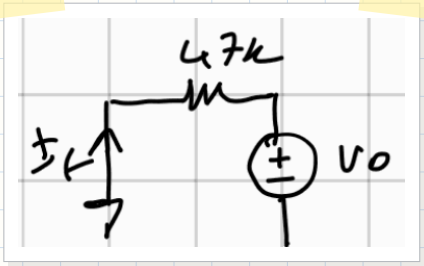
$$r_\pi = \frac{(\beta + 1)}{g_m} = 1,7\ k\Omega$$

a) Feedback type
(Shunt–Shunt)

b) Feedback network



c) $R_{11} = R_{22} = 47\ k\Omega$

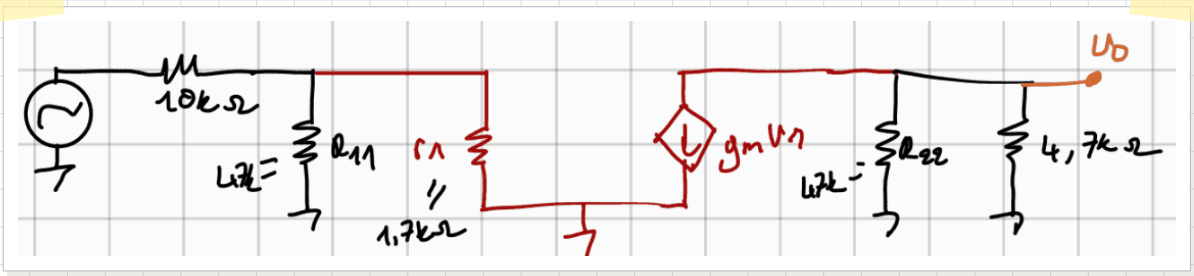


orijinal çizim, s. 7

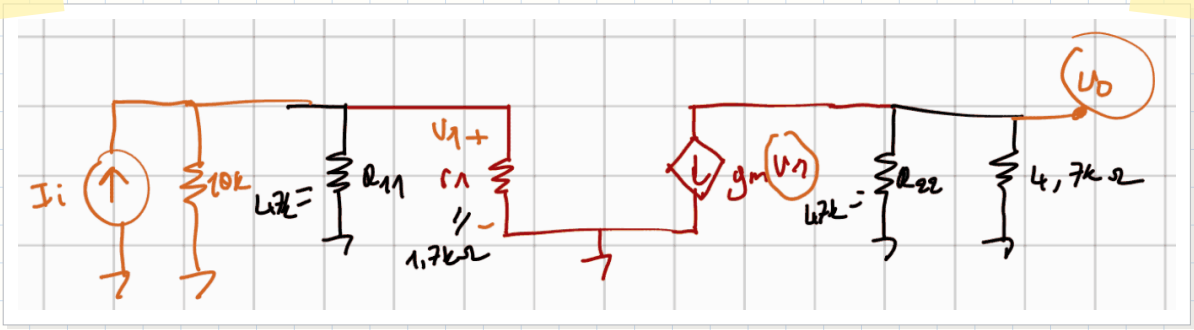
$$\frac{I_f}{V_o} = \frac{-1}{47k\Omega} = \beta$$

orj. s. 8

d)



orijinal çizim, s. 8



orijinal çizim, s. 8

$$A = \frac{V_o}{I_{in}} = \frac{v_o}{v_\pi} \cdot \frac{v_\pi}{I_{in}} \qquad \frac{v_o}{v_\pi} = -(4{,}7k \parallel 47k)\, g_m$$

$$\frac{v_\pi}{I_i} = \frac{I_i\,(10k \parallel 47k \parallel 1{,}7k)}{I_i}$$

$$A = -(4{,}7k \parallel 47k) \cdot 58m \cdot \underbrace{(10k \parallel 47k \parallel 1{,}7k)}_{1{,}4\ k\Omega}$$

$$A = -341{,}04\ k\Omega$$

$$R_i = 1{,}4k \qquad R_o = 4{,}27k$$

$$A_f = \frac{A}{1 + A\beta} = -43{,}06\ k\Omega$$

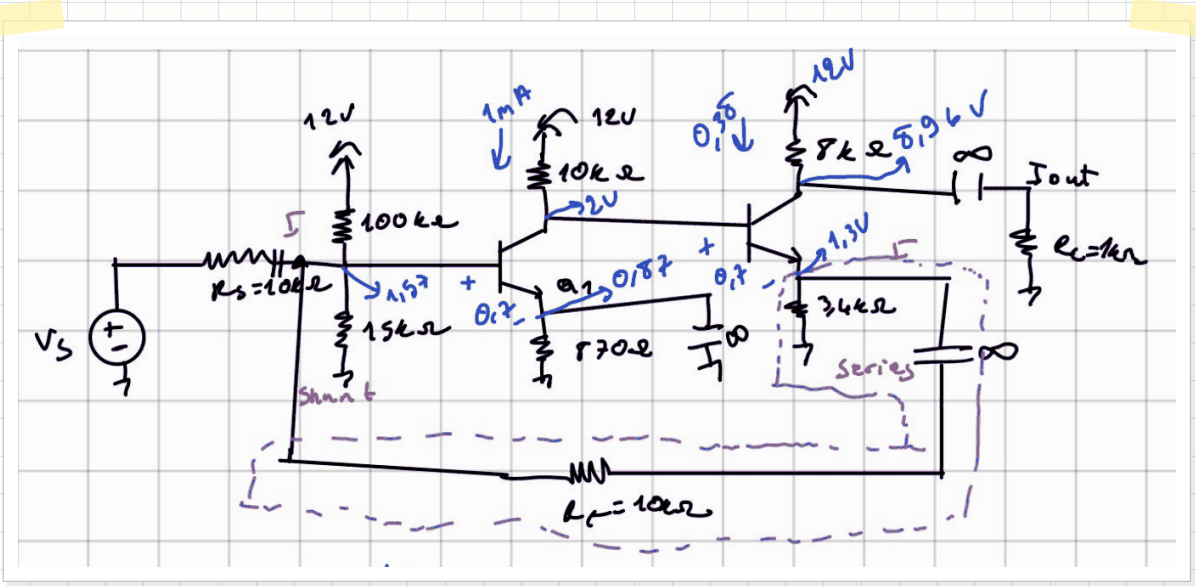
$$R_{if} = \frac{R_i}{1 + A\beta} \qquad R_{of} = \frac{R_o}{1 + A\beta}$$

$$V_s = 10k\, I_i \qquad \frac{V_o}{V_s} = \frac{V_o}{10k \cdot I_i}$$

feedback

$$\frac{V_o}{I} = A_f$$

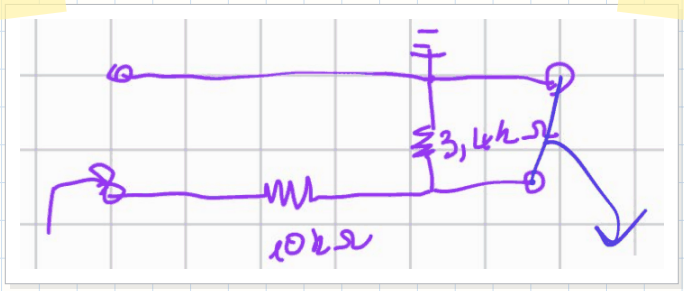
orj. s. 9



orijinal çizim, s. 9

a) Series–Shunt

b)

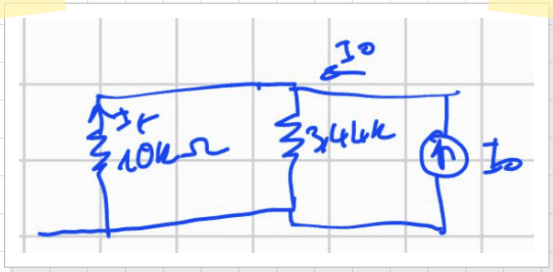


orijinal çizim, s. 9

$$R_{11} = 13{,}4\ k\Omega$$

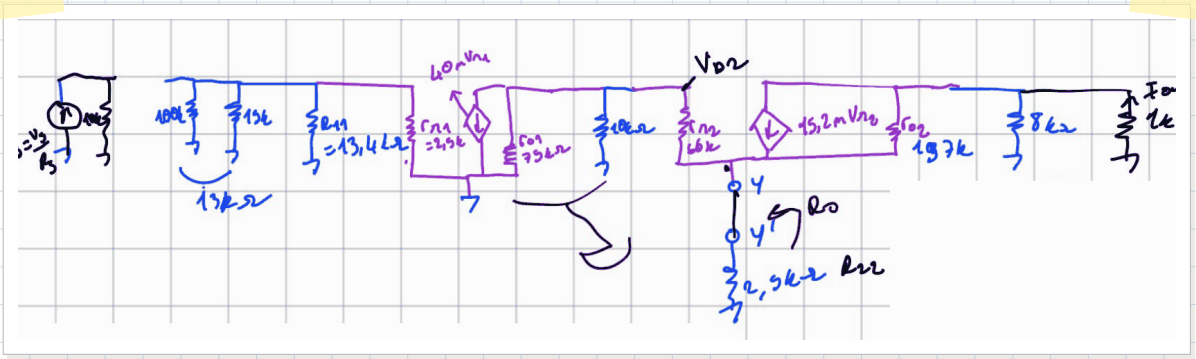
$$R_{22} = 10k \parallel 3{,}4k = 2{,}53k$$

β

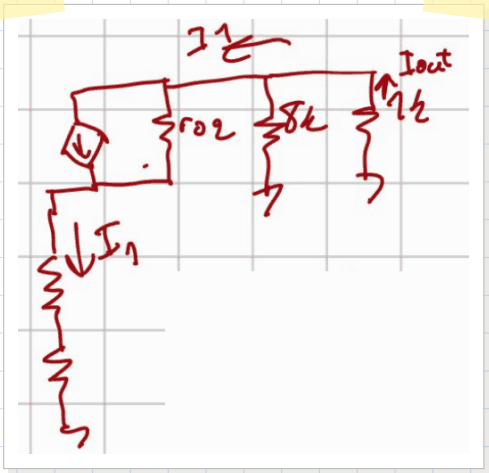


orijinal çizim, s. 9

$$\beta = \frac{I_f}{I_o} = \frac{-3{,}4k}{13{,}4k} \simeq -0{,}25\ [A/A]$$



orijinal çizim, s. 9



orijinal çizim, s. 9

$$I_1 \cdot \frac{8k}{9k}$$

$$A = \frac{I_{out}}{I_s} = \frac{I_{out}}{v_{\pi 2}} \cdot \frac{v_{b2}}{v_{\pi 1}} \cdot \frac{v_{\pi 1}}{I_s}$$

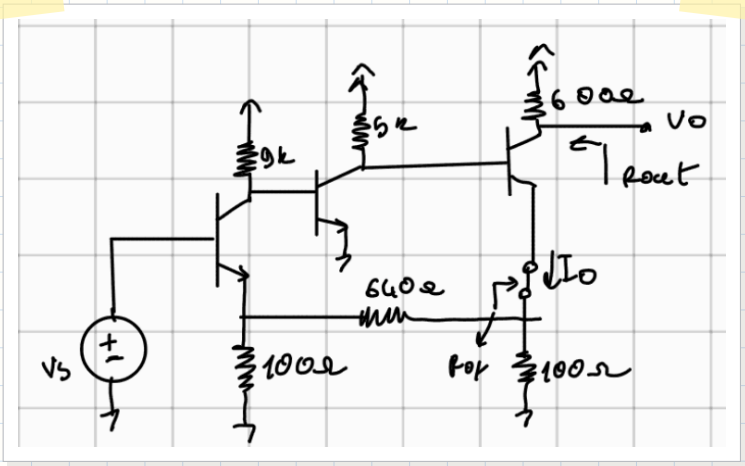
$$v_{\pi 1} = I_s\,(10k \parallel 13{,}4k \parallel 13k \parallel 2{,}5k) = 1{,}55k\,I_s$$

$$v_{b2} = -g_{m1}\,v_{\pi 1}\left(75k \parallel 10k \parallel (6{,}6k + \underbrace{250k}_{(\beta+1)(2{,}5k)})\right) \simeq -\text{?}320\,v_{\pi 1}$$

orj. s. 10

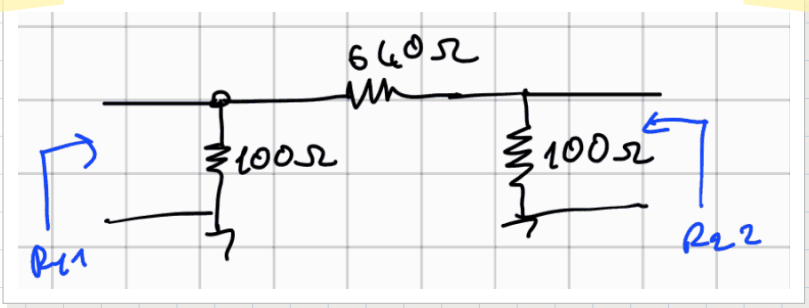
$$I_{out} = \frac{v_{b2}}{\frac{6{,}6k\Omega}{100} + 2{,}5k} \cdot \frac{8k}{9k}$$

$$\frac{I_{out}}{I_s} = -192{,}4\ [A/A]$$



orijinal çizim, s. 10

1) Series-Series Transconductance

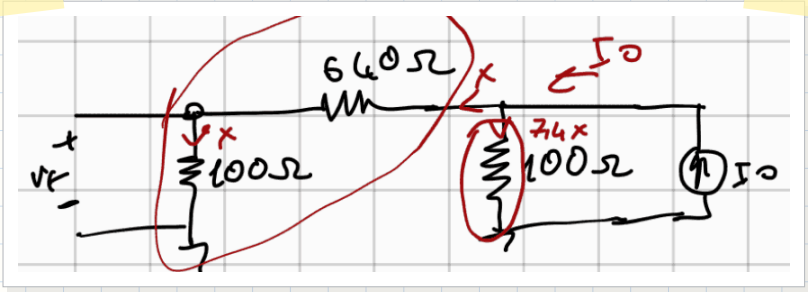


orijinal çizim, s. 10

$$R_{11} = 100 \parallel (640 + 100) = 88\ \Omega$$

$$R_{22} = 100 \parallel (640 + 100) = 88\ \Omega$$

β = ??



orijinal çizim, s. 10

$$\frac{V_f}{I_o} = \frac{100x}{8{,}4x} = 11{,}9\ \Omega$$

$$g_{m1} = \frac{I_C}{V_T} = 24\ mS$$

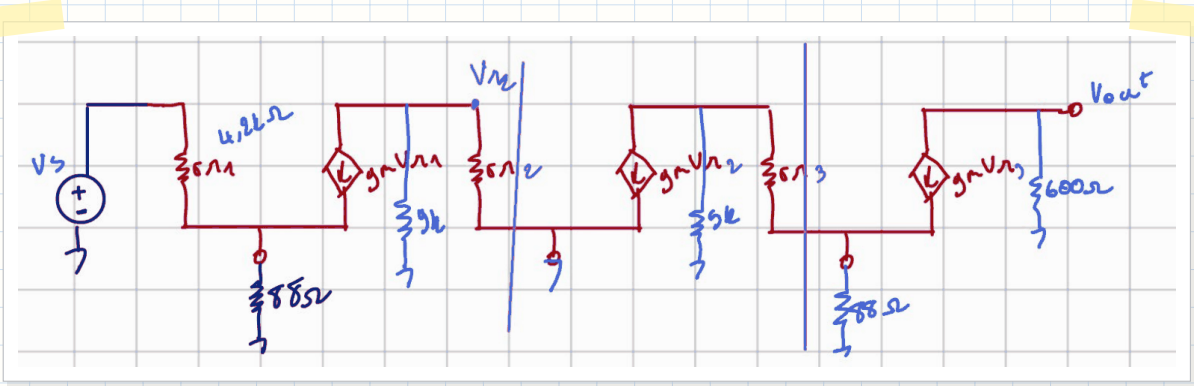
$$g_{m2} = 40\ mS$$

$$g_{m3} = ?160\ mS$$

$$r_{\pi 1} = \frac{(\beta + 1)}{g_m} = 4{,}2\ k\Omega$$

$$r_{\pi 2} = 2{,}5k \qquad r_{\pi 3} = 0{,}625k$$

orj. s. 11



orijinal çizim, s. 11

$$A = \frac{I_o}{V_s} = \frac{I_o}{v_{\pi 3}} \cdot \frac{v_{\pi 3}}{v_{\pi 2}} \cdot \frac{v_{\pi 2}}{v_{\pi 1}} \cdot \frac{v_{\pi 1}}{V_s}$$

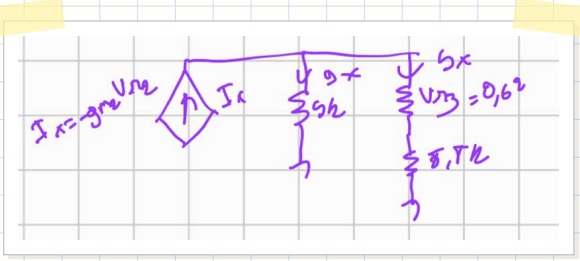
$$V_s = v_{\pi 1} + 88\left(0{,}024\, v_{\pi 1} + \frac{v_{\pi 1}}{4200}\right)$$
$$V_s = 3{,}03\, v_{\pi 1}$$
$$\frac{V_s}{v_{\pi 1}} = 3{,}03$$

$$v_{\pi 2} = \frac{-\,g_{m1}\, v_{\pi 1} \cdot 2{,}5k \cdot 9k}{11{,}5k} \quad (?\ 24m)$$
$$= -47\, v_{\pi 1}$$

$$\frac{A_{?\ id}\, R_2}{R + R_2}$$

$$I_o = g_{m3}\, v_{\pi 3} + \frac{v_{\pi 3}}{0{,}62k}$$

$v_{\pi 3} =$



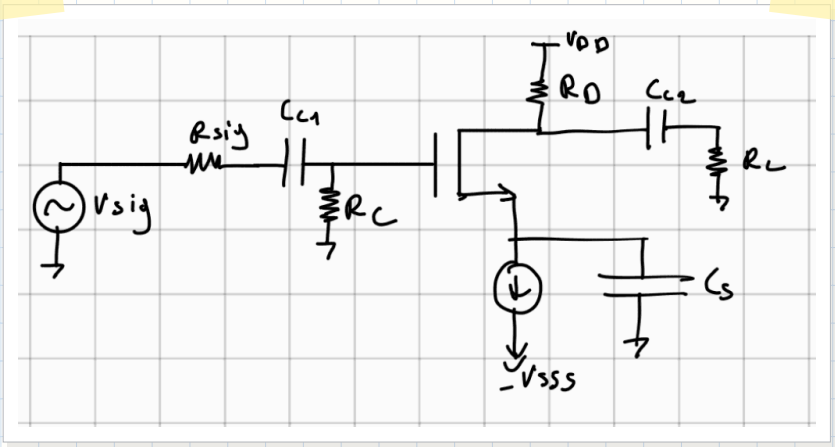
orijinal çizim, s. 11

$$v_{\pi 3} = 3{,}1x = -8{,}86\, v_{\pi 2}$$
$$I_x = 14x$$
$$v_{\pi 3} = \frac{-g_m\, v_{\pi 2}}{14} \cdot 0{,}62k \quad (?\ v_{\pi 2})$$
$$= -8{,}86\, v_{\pi 2}$$

Frequency Response

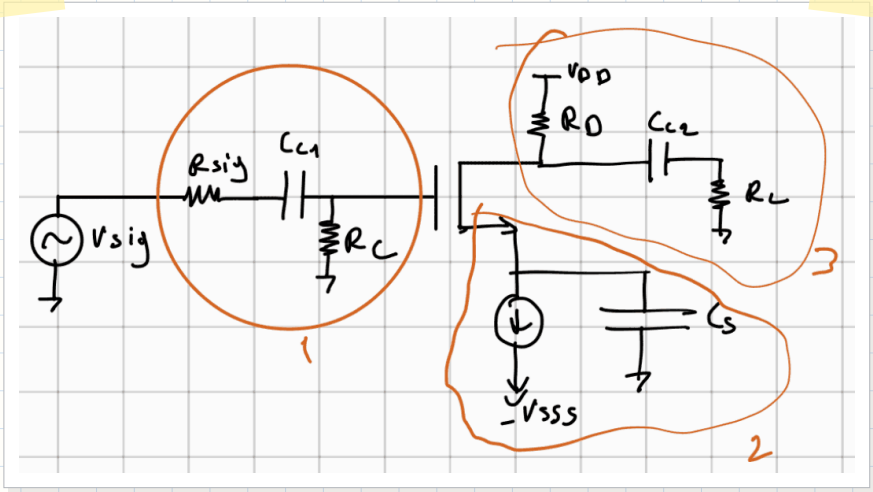
> **Şekil:** Yükselteç frekans cevabı grafiği (basılı): $|V_o/V_{sig}|$ (dB) – f (Hz, log ölçek); alçak frekans bandı, orta bant (tüm kapasiteler ihmal edilebilir; $20 \log |A_M|$ ve 3 dB düşüş) ve yüksek frekans bandı; f_L ve f_H kesim frekansları. *(orijinal notta, s. 11)*

orj. s. 12

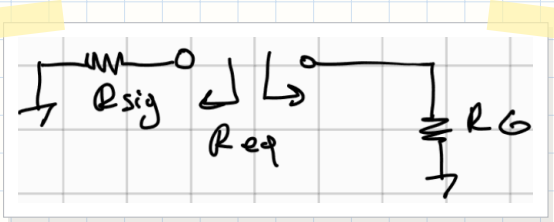


orijinal çizim, s. 12

Low frekansta alt devrelerin analizi yapılırken C'ler short kabul edilir.



orijinal çizim, s. 12

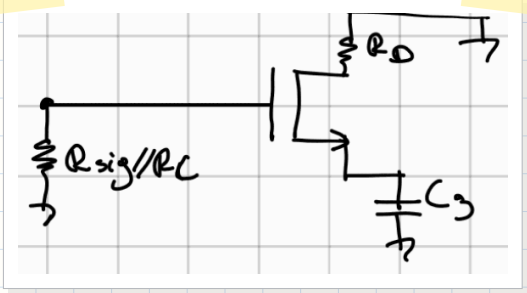


orijinal çizim, s. 12

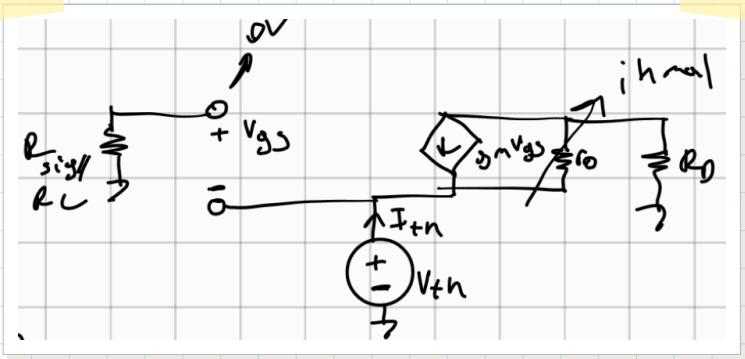
$$\omega_{p1} = \frac{1}{C_{C1}(R_{sig} + R_G)}$$

$$R_{eq} = R_{sig} + R_G$$

2. kapasiteden kaynaklı etkiyi koyalım.



orijinal çizim, s. 12

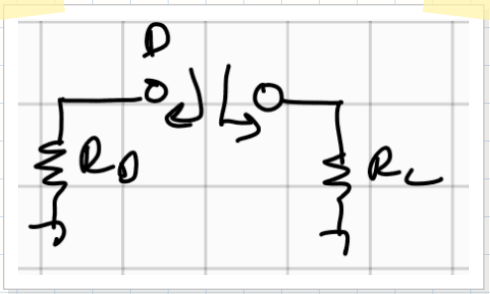


orijinal çizim, s. 12

$$\frac{V_{tn}}{I_{tn}} =? = \frac{-V_{gs}}{-g_m V_{gs}} = \frac{1}{g_m} = R_{P2}$$

$$\omega_{P2} = \frac{1}{C_S (R_{P2})} = \frac{1}{\frac{C_S}{g_m}} = \frac{g_m}{C_S}$$

orj. s. 13



orijinal çizim, s. 13

$$\omega_{P3} = \frac{1}{(R_D + R_L) C_{C2}}$$

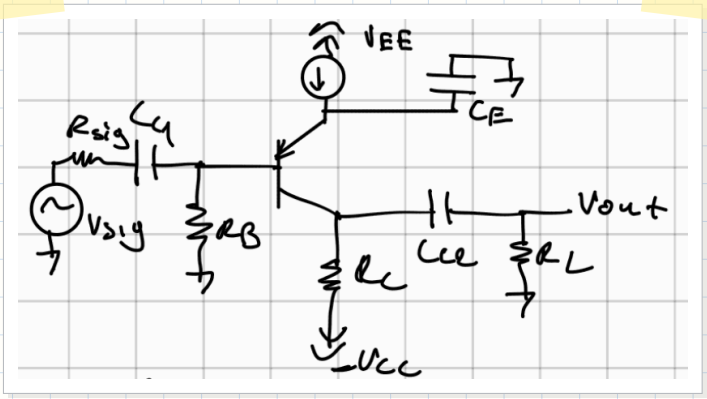
2 pole dominant olur çünkü direnci ?yüksek

$$A_{mid} = -\left[\frac{R_G}{R_{sig} + R_G}\right] g_m (R_D \parallel R_L)$$

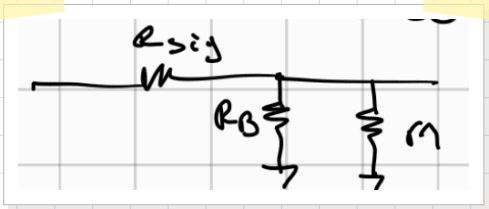
$$A(s) = A_{mid}\left[\frac{s}{s + \omega_{p1}}\right]\left[\frac{s}{s + \omega_{p2}}\right]\left[\frac{s}{s + \omega_{p3}}\right]$$

$$f_c = \frac{1}{2\pi}\left[\frac{1}{R_1 C_1} + \frac{1}{R_2 C_2} + \frac{1}{R_3 C_3}\right]$$

Common emitter amplifier



orijinal çizim, s. 13



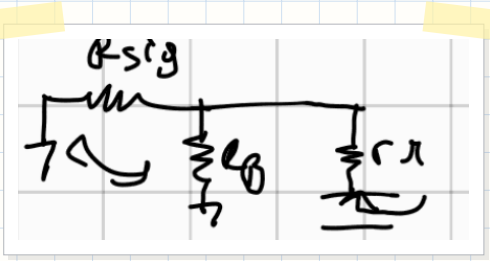
orijinal çizim, s. 13

$$A_m = -g_m (R_C \parallel R_L)\left[\frac{R_B \parallel r_\pi}{R_{sig} + (R_B \parallel r_\pi)}\right]$$

$$R_{p1} = (R_{sig} + R_B \parallel r_\pi)$$

$$\omega_{p1} = \frac{1}{C_{C1}(R_{sig} + R_B \parallel r_\pi)}$$

C_E den bakarken



orijinal çizim, s. 13

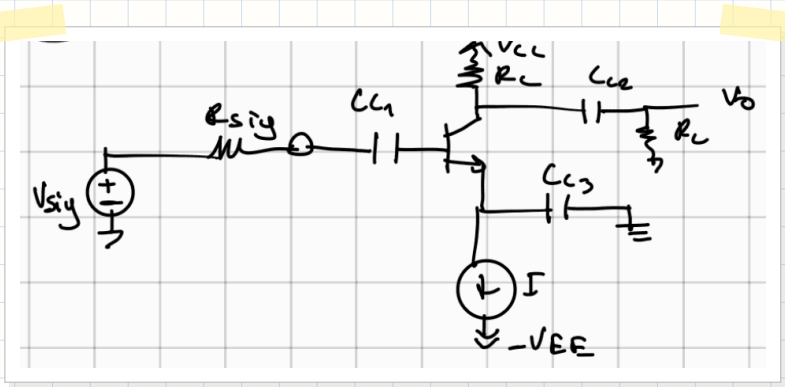
orj. s. 14

$$R_{P2} = R_{CE} = \frac{R_{sig} \parallel R_B + r_\pi}{\beta + 1}$$

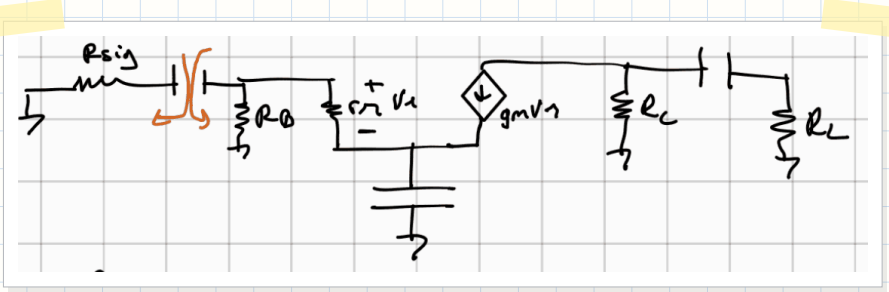
$$\omega_{P2} = \frac{1}{\frac{(R_{sig} \parallel R_B) + r_\pi}{\beta + 1} C_E}$$

$$\omega_{P3} = \frac{1}{C_{C2}(R_C + R_L)}$$

The Common Emitter Amplifier



orijinal çizim, s. 14

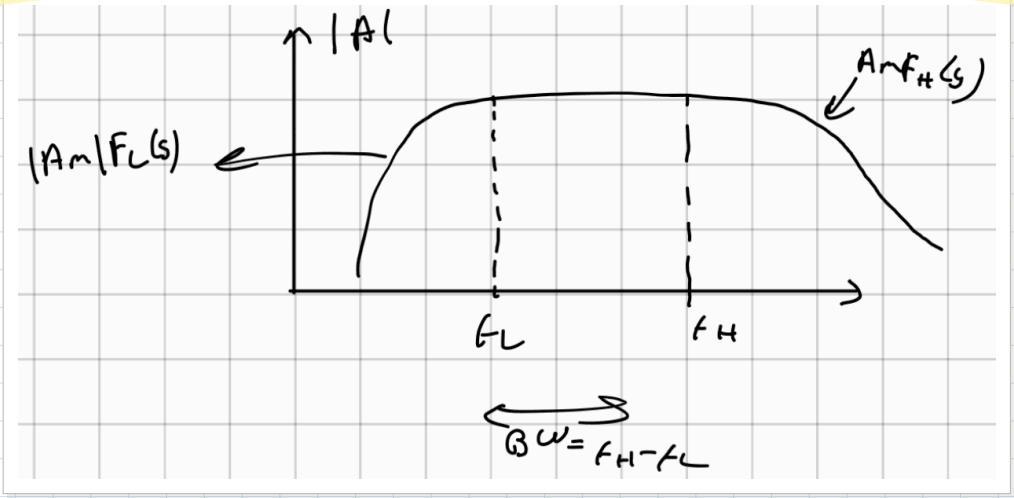


orijinal çizim, s. 14

$$R_{CC1} = R_{sig} + R_B \parallel r_\pi$$

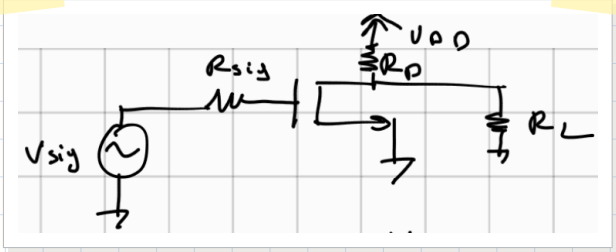
$$R_{CC3} = \frac{R_{sig} \parallel R_B + r_\pi}{\beta + 1} = r_e + \frac{R_{sig} \parallel R_B}{\beta + 1}$$

$$R_{CC2} = R_C + R_L$$

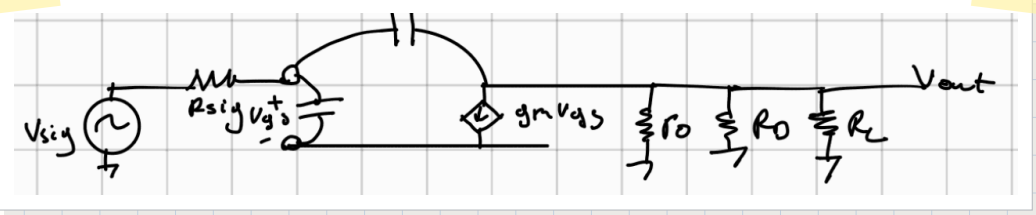


orijinal çizim, s. 14

orj. s. 15

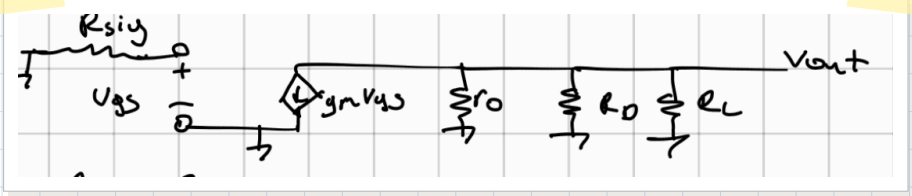


orijinal çizim, s. 15



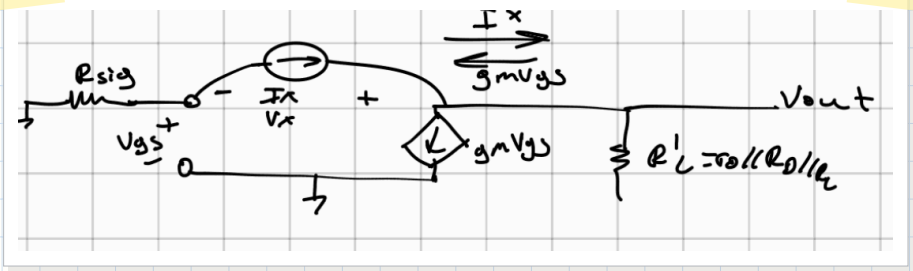
orijinal çizim, s. 15

Analiz yaparken kısa devre yapılırlar



orijinal çizim, s. 15

$$R_{gs} = R_{sig}$$



orijinal çizim, s. 15

$$\frac{V_x}{I_x} = ?$$

$$V_{out} = V_x + V_{gs} = (I_x - g_m V_{gs}) R'_L$$
$$V_{gs} = -R_{sig} I_x$$
$$V_x - R_{sig} I_x = (I_x + g_m R_{sig} I_x) R'_L$$

$$V_x = I_x \left(R_{sig}(1 + g_m R'_L) + R'_L \right)$$

$$\frac{V_x}{I_x} = R_{sig}(1 + g_m R'_L) + R'_L$$

$$R_{gd} = R_{sig}(1 + g_m R'_L) + R'_L$$
$$R_{db} = R'_L$$
$$\tau = RC$$
$$\tau_H = R_{gs} C_{gs} + R_{gd} C_{gd} + R_{db} C_{db}$$

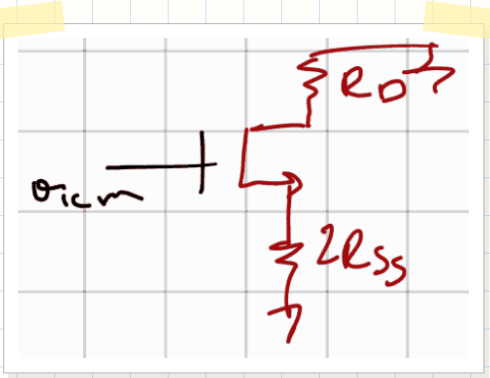
$$f_H = \frac{1}{2\pi \tau_H}$$

orj. s. 16

$$f_T = \frac{g_m}{2\pi (C_{gs} + C_{gd})}$$

Şekil: Miller teoremi şekli (basılı): $V_2 = KV_1$ olan Z empedansı ve eşdeğeri $Z_1 = Z/(1 - K)$, $Z_2 = Z/(1 - \frac{1}{K})$.
(orijinal notta, s. 16)

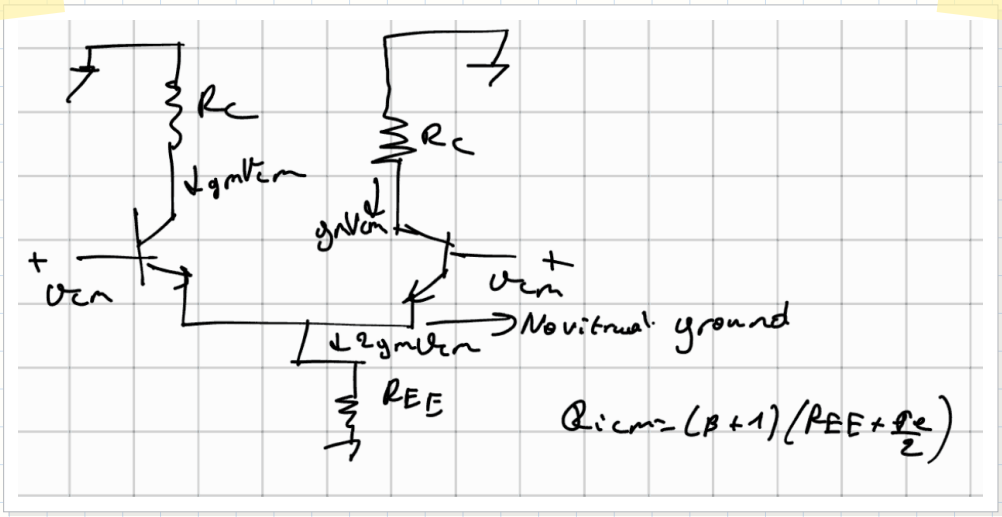
Common mode half circuit



orijinal çizim, s. 16

$$-\frac{R_D}{2R_{SS}}$$

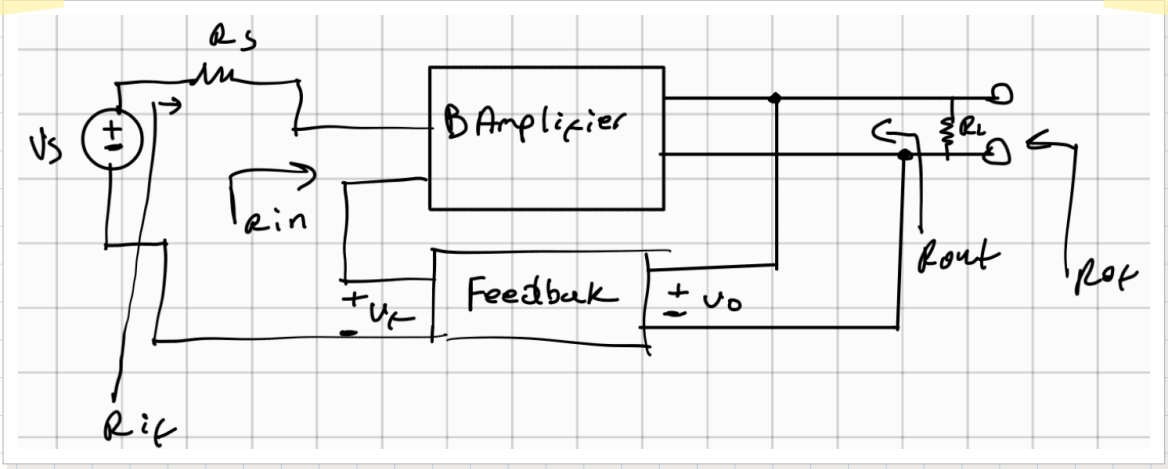
$$CMRR_{single} = \frac{A_{diff\ single}}{A_{cm\ single}}$$



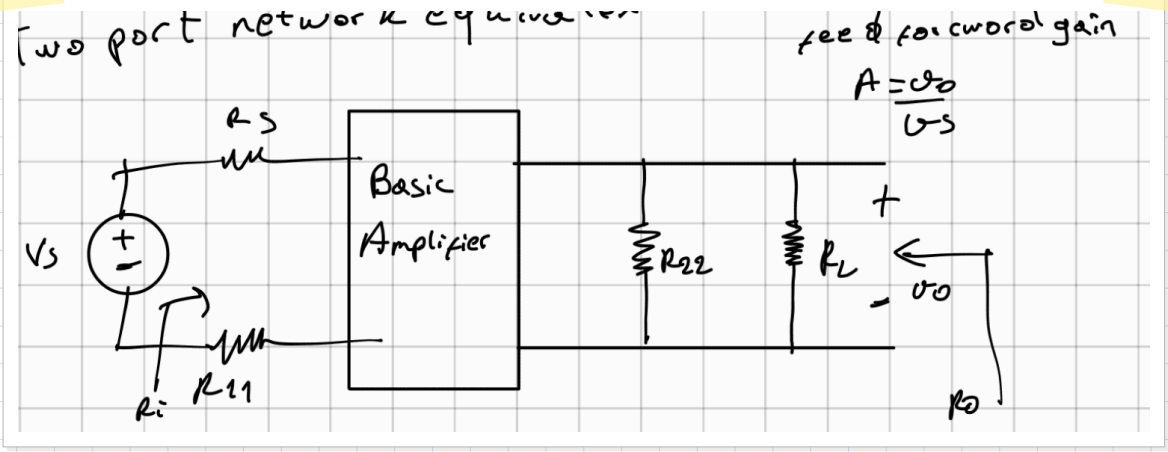
orijinal çizim, s. 16

orj. s. 17

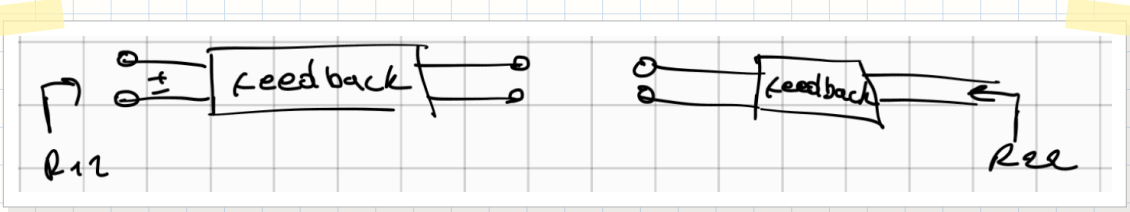
1- Voltage Amplifiers



orijinal çizim, s. 17



orijinal çizim, s. 17



orijinal çizim, s. 17

To find β



orijinal çizim, s. 17

$$\beta = \left.\frac{V_f}{V_o}\right|_{I_1=0}$$

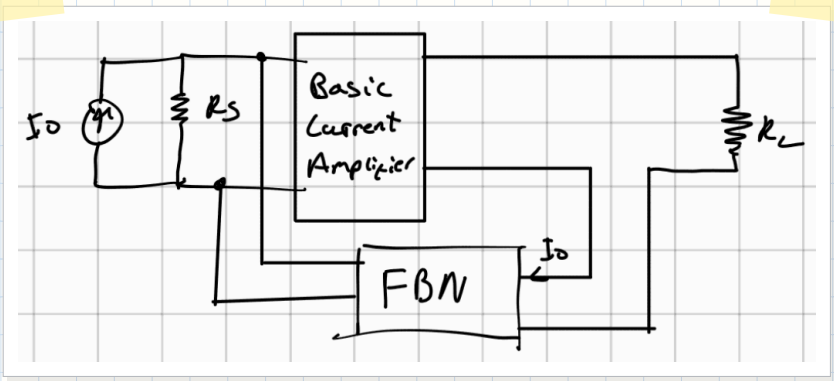


orijinal çizim, s. 17

$$A_f = \frac{A}{1 + A\beta}$$
$$R_{if} = (1 + A\beta) R_i$$
$$R_{of} = \frac{R_o}{1 + A\beta}$$

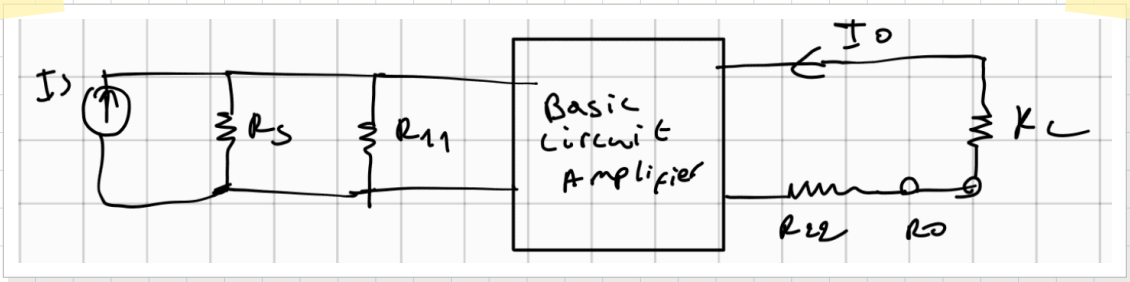
orj. s. 18

2- Current Amplifiers (Series-Shunt)

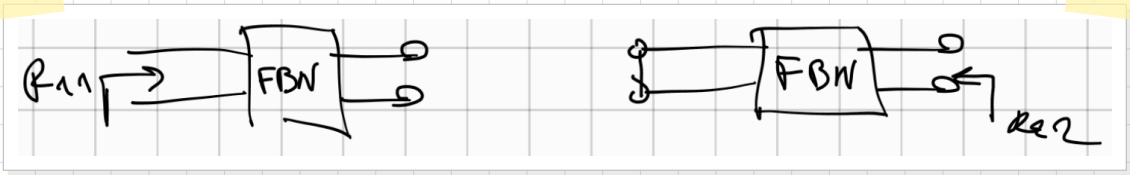


orijinal çizim, s. 18

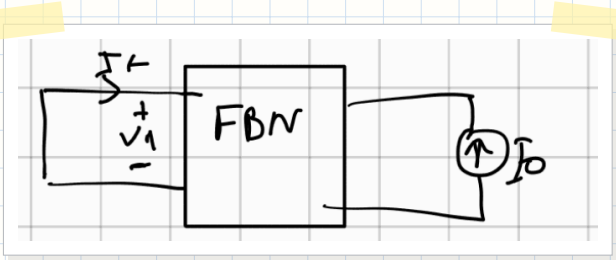
$$A = \frac{I_o}{I_i}$$



orijinal çizim, s. 18



orijinal çizim, s. 18



orijinal çizim, s. 18

$$\beta = \left.\frac{I_f}{I_o}\right|_{V_1=0}$$