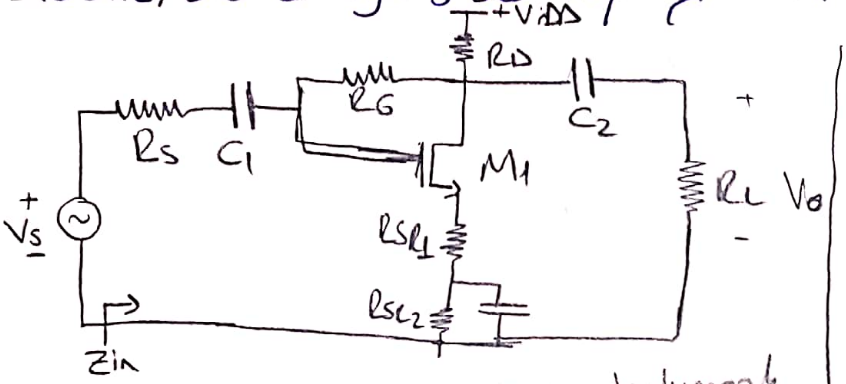
HW # 06

Abdullah MEMİŞOĞLU
171024001

Q1 : Design a common-source NMOS amplifier as shown in fig P7.67 to give a passband gain of ~~20<~~ $20 \leq |A_{PB}| \leq 30$, $Z_{in(mid)} \geq 100k\Omega$, a low 3-dB frequency of $f_L \leq 10kHz$, and a high 3-dB frequency of $f_H = 200kHz$.



$I_{DSS} = 12.5mA$, $I_D = 1mA$

$V_P = -3.5V$

$r_o >> R_D \| R_L$, $R_L >> R_D$

$R_G \to$ very large

$R_D = 10k\Omega$, $g_m = 4.9 \times 10^{-3}$

$R_2 = 500k\Omega$ $R_L = 100k\Omega$ $R_S = 5k\Omega$

$f_L = 9.9kHz$, $f_{C2} = 0.99kHz$

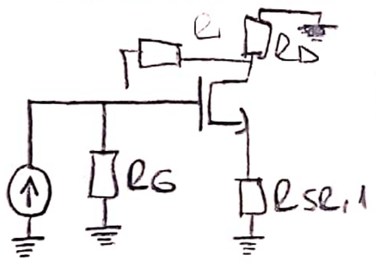
$\downarrow$

$C_1 = 8nF$

$R_{C1} = R_{E1} = 140k\Omega$

Çözüm için W_L, W_H ve gain bulunacak

Analiz sonuçları bilinmesi gereken devre:



Transresister Amplifier feedback Model

$r_{in,TRA,f} = R_G$

$r_{out,TRA,f} = R_G \| R_{out,TRA}$
$= R_G \| R_D \| [r_{o1}(1+g_{m1}R_{SE1})]$

$A_{TRA,f} = \frac{-g_m R_G}{1+g_m R_S} [R_G \| R_D \| [r_{o1}(1+g_{m1}R_{SE1})]]$

$\frac{V_{d1}}{V_{g1}} = \frac{-g_{m1}}{1+g_{m1}R_{SE1}} [R_D \| R_G \| [r_{o1}(1+g_{m1}R_{SE1})]]$

$R_{SE1} >> \frac{1}{g_{m1}}$

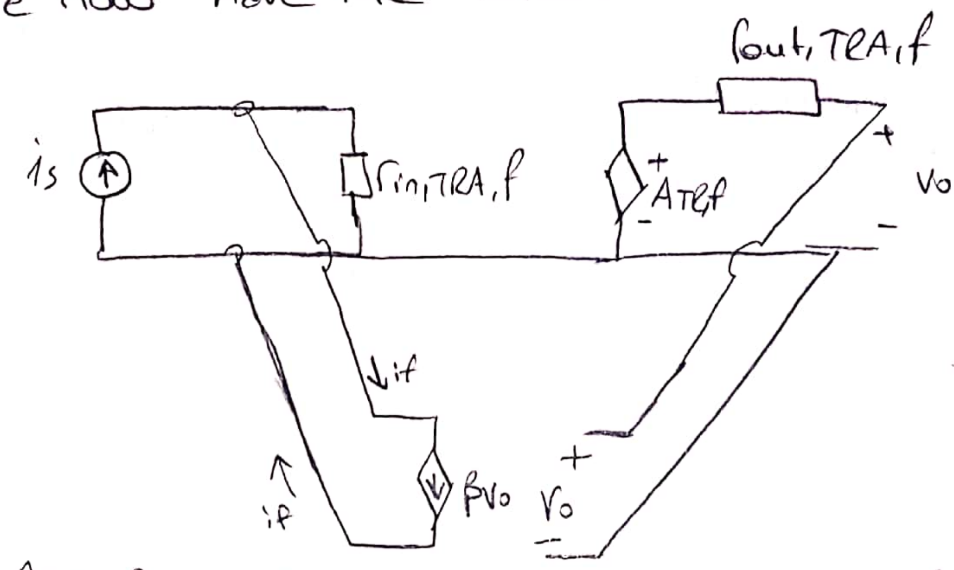
Miller

$C_{gd1,g1} = C_{gd1}\left(1 - \frac{V_{d1}}{V_{g1}}\right)$ $\quad R_{Cgd1,g1} = R_G$, $\tau_{Cgd1,g1} = R_{Cgd1,g1} \cdot C_{gd1,d1}$

$\tau = R_G \cdot C_{gd1} \cdot \left(1 - \frac{V_{d1}}{V_{g1}}\right)$ $\quad W_H = \frac{1}{\tau_{Cgd1,g1}} = \frac{1}{R_G \cdot C_{gd1} \cdot \left(1 - \frac{V_{d1}}{V_{g1}}\right)}$

$\beta = \frac{1}{R_G} \longrightarrow$ for feedback network

We now have the network



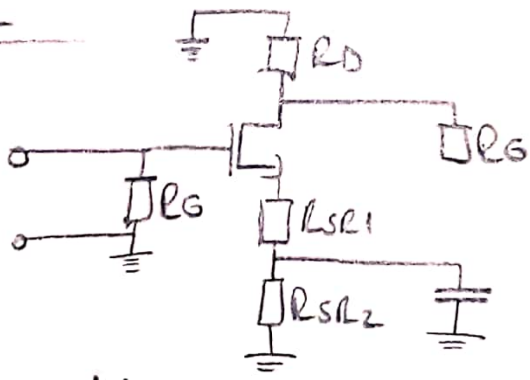
Voltage-Shunt feedback on Trans-Resistance Amplifiers.

$A_{TRA,f} < 0$, $\beta < 0$ $\longrightarrow$ loop gain $\beta . A_{TRA,f} > 0$

$$A_f = \frac{A_{TRA,f}}{1+\beta A_{TRA,f}} \qquad r_{out,f} = \frac{r_{out,TRA,f}}{1+\beta A_{TRA,f}} \qquad W_{H,f} = W_H . (1+\beta . A_{TRA,f})$$

$$r_{in,f} = \frac{r_{in,TRA,f}}{1+\beta A_{TRA,f}}$$

for W_L



$R_{CS} \rightarrow C_S$'in gördüğü direnç.

$\tau_{CS} = R_{CS} . C_{CS}$

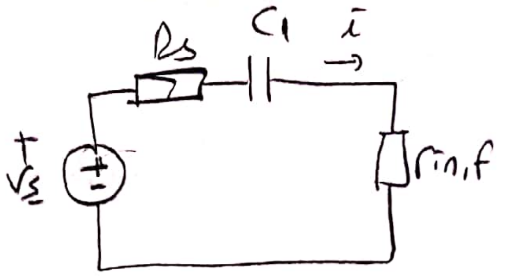
$R_{CS} = R_{SR2} // \left(R_{SR1} + \frac{1}{g_{m1}}\right)$

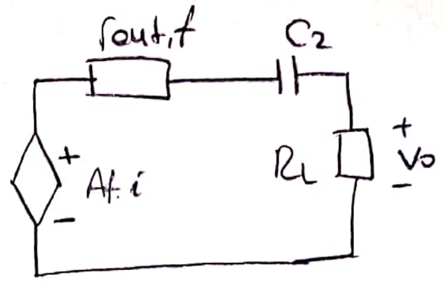
if $r_{o1} >> R_D // R_G$

$$W_L = \frac{1}{\tau_{CS}} = \frac{1}{C_{CS}.\left(R_{SR2} // \left(R_{SR1} + \frac{1}{g_{m1}}\right)\right)}$$

$$W_{L,f} = \frac{W_L}{1+\beta A_{TRA,f}} = \frac{1}{C_{CS}.\left(R_{SR2} // \left(R_{SR1} + \frac{1}{g_{m1}}\right)\right).(1+\beta A_{TRA,f})}$$

Şimdi de tüm devre analiz edilmeli.





$\frac{V_o}{V_s} = ?$ $\qquad i = \frac{V_s}{R_s + r_{in,f}}$ $\qquad V_o = A_f \cdot i \cdot \frac{R_L}{R_L + r_{out,f}}$

$$V_o = A_f \cdot \frac{V_s}{R_s + r_{in,f}} \cdot \frac{R_L}{R_L + r_{out,f}}$$

$$\boxed{\frac{V_o}{V_s} = \frac{A_f}{R_s + r_{in,f}} \cdot \frac{R_L}{R_L + r_{out,f}}}$$

R_{C1}, C_1'in gördüğü direnç. $\tau_{C1} = R_{C1} \cdot C_1$

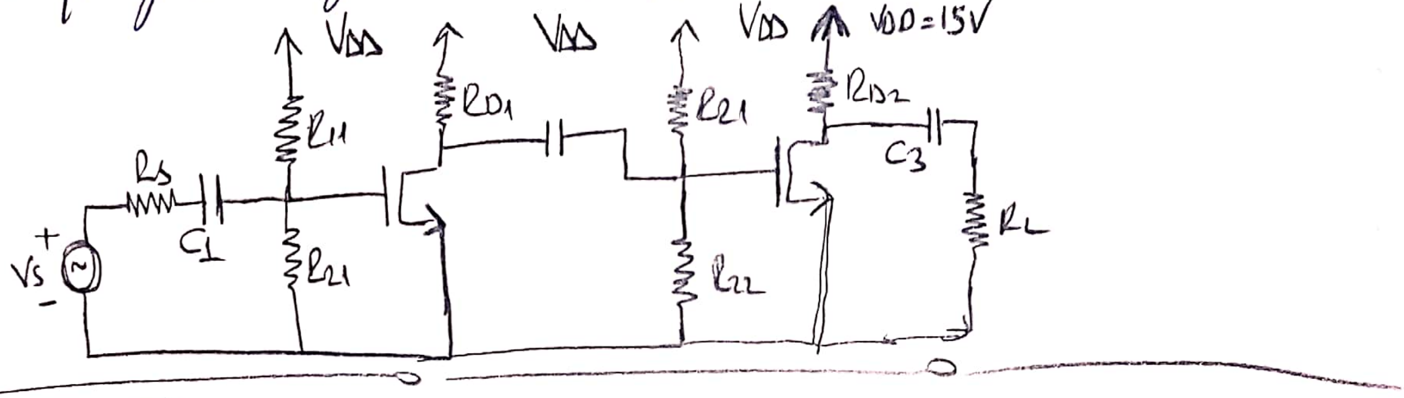
$\boxed{R_{C1} = R_s + r_{in,f}}$

R_{C2} = C_2'nun gördüğü direnç ($\tau_{C2} = R_{C2} \cdot C_2$)

$R_{C2} = r_{out,f} + R_L$

$$W_{L,cir} = \frac{1}{\tau_{CS}(1+\beta A_T R_{A,f})} + \frac{1}{\tau_{C1}} + \frac{1}{\tau_{C2}}$$

Q2. A two stage amplifier is shown in fig. P.7.71. The parameters are $R_S = 1k\Omega$, $R_{11} = 500k\Omega$, $R_{21} = 500k\Omega$, $R_{D1} = 10k\Omega$, $R_{12} = 500k\Omega$, $R_{22} = 500k\Omega$, $R_{D2} = 15k\Omega$, $R_L = 10k\Omega$, $g_{m1} = 20mA/V$, $g_{m2} = 50mA/V$, $C_1 = 1\mu F$, $C_2 = 1\mu F$, $C_3 = 30\mu F$, $C_{gd1} = C_{gd2} = 2pF$, $C_{gs1} = C_{gs2} = 5pF$. Calculate the low 3dB frequency f_L and high cutoff frequency f_H.



SCTC

R_{C1}, C_1'in gördüğü direnç. $(\tau_{C1} = R_{C1} \cdot C_1)$

$R_{C1} = R_S + R_{11} \| R_{21}$, R_{C2}, C_2'nin gördüğü direnç. $(\tau_{C2} = R_{C2} \cdot C_2)$

$R_{C2} = R_{D1} \| r_{o1} + R_{21} \| R_{22}$ R_{C3}, C_3'nin " " $(\tau_{C3} = R_{C3} \cdot C_3)$

$R_{C3} = (R_L + R_D \| r_{o2})$

Midband gain

$$A_m = \frac{V_{g1}}{V_s} \cdot \frac{V_{d1}}{V_{g1}} \cdot \frac{V_{d2}}{V_{g2}} \qquad V_{d1} = V_{g2}$$

$$\left(\frac{R_{11} \| R_{21}}{R_{11} \| R_{21} + R_S}\right) \cdot \left(-g_{m1}(R_{D1} \| R_{21} \| R_{22})\right) \cdot \left(-g_{m2}(R_{DD} \| R_{LL} \| r_{o2})\right)$$

OCTC

$C_{gd1,g1}$ = Miller capacitance at g_1, $C_{gd2,g2} \Rightarrow$ Miller capacitance at g_2

$$C_{gd1,g1} = C_{gd1}\left(1 - \frac{V_{d1}}{V_{g1}}\right) = C_{gd1}\left(1 + g_{m1}(R_D \| R_{21} \| R_{22} \| R_{o1})\right)$$

$$C_{gd2,g2} = C_{gd2}\left(1 - \frac{V_{d2}}{V_{g2}}\right) = C_{gd2}\left(1 + g_{m2}(R_D \| R_L \| r_{o2})\right)$$

$R_{cgd1,g1} = R_S \| R_{11} \| R_{21}$

$R_{cgd2,g2} = R_{21} \| R_{22} \| R_{D1} \| r_{o1}$

$\tau_{cgd1,g1} = R_{cgd1,g1} \cdot C_{gd1,g1}$

$\tau_{cgd1,g1} = (R_S \| R_{11} \| R_{21}) \cdot C_{gd1\,g1}$

$$\tau_{cgd1,g1} = \underbrace{(1k\Omega \| 500k\Omega \| 500k\Omega)}_{\approx 1k\Omega} \cdot 2\times10^{-12} \underbrace{\left(1 - \left(-20mA/V\,\underbrace{(10k\Omega \| 500k\Omega \| 500k\Omega)}_{\approx 10k\Omega}\right)\right)}_{\approx 200}$$

$\tau_{cgd1,g1} = 1000 \cdot 2\times10^{-12} \cdot 200$

$$\boxed{\tau_{cgd1,g1} \approx 2\times10^{-7}}$$

$$C_{gd2,g2} = C_{gd2} \cdot \left(1 - \underbrace{\frac{V_{d2}}{V_{g2}}}_{-g_{m2}(R_{D2} \| R_{L} \| r_{o2})}\right)$$

$\tau_{cgd2,d2} = R_{cgd2,g2} \cdot C_{gd2,g2}$

$\tau_{cgd2,d2} = (R_{21} \| R_{22} \| R_{D1} \| r_{o1}) \cdot C_{gd2} \cdot (1 + g_{m2} \cdot (R_{D2} \| R_L \| r_{o2}))$

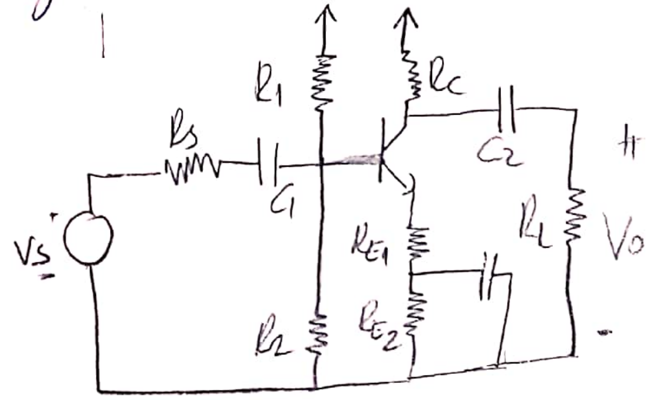
$$\tau_{cgd2,d2} \approx \underbrace{(500k\Omega \| 500k\Omega \| r_{o1})}_{\approx 250k\Omega} \cdot 2\times10^{-12} \left(1 + 50mA/V\,\underbrace{(15k\Omega \| 10k\Omega \| r_{o2})}_{\frac{15 \cdot 10}{25}k\Omega \,=\, 6k\Omega}\right)$$

$\approx 250k\Omega \cdot 2\times10^{-12} \cdot 300$

$$\boxed{\tau_{cgd2,d2} = 150\times10^{-6} = 1.5\times10^{-4}}$$

$$W_H = \frac{1}{\tau_{cgd1,g1} + \tau_{cgd2,d2}} \approx \frac{1}{\tau_{cgd2,d2}} = 6666.66$$

Q3: For Probs 8.54 – 8.59 involving BJT amplifiers, use transistors whose parameters are $\beta_F = 100$, $C_{je} = 8pF$ at $V_{BE} = 0.5V$, $C_\mu = 4pF$ at $V_{CB} = 5V$, $C_{cs} = 6pF$ at $V_{cs} = 8V$, $\beta_f = 100$, $V_{je} = V_{jc} = V_{js} = 0.8V$, and $h_{oe} = 1/r_o = 5\mu ℧$ at $V_{CE} = 10V$. The transition frequency is $f_T = 300MHz$ at $V_{CE} = 20V$, $I_C = 10mA$. The substrate is connected to the ground. Assume $I_C = 5mA$, $V_{CC} = 15V$, $V_{BE} = 0.7V$, $R_S = 1k\Omega$ and $R_L = 10k\Omega$. Use SPICE to check your design by plotting the frequency response and give an approximate cost estimate.



Midband gain

$$A_M = \frac{v_o}{v_s}$$

$$= \frac{R_1 \| R_2 \| R_{in,b1}}{R_1 \| R_2 \| R_{in,b1} + R_S} \left[\frac{-g_{m1}}{1 + g_m R_{E1}}\right] \left[R_C \| R_L \| (r_{o1}(1 + g_{m1} R_{E1}))\right]$$

$$R_{in,b1} \cong r_{\pi 1}[1 + g_{m1} R_{E1}]$$

SCTC $\longrightarrow$ $W_L \cong \frac{1}{\tau_{C1}} + \frac{1}{\tau_{C2}} + \frac{1}{\tau_{CE}}$

$R_{C1} \Rightarrow C_1$'in gördüğü direnç. ($\tau_{C1} = R_{C1} \cdot C_1$)

$$R_{C1} \cong R_S + R_1 \| R_2 \| R_{in,b1} = \boxed{R_S + R_1 \| R_2 \| (r_{\pi 1}[1 + g_{m1} R_{E1}]) = R_{C1}}$$

$$\boxed{R_{CE} = R_{E2} \| \left[R_{E1} + \frac{r_{\pi 1} + R_S \| R_1 \| R_2}{1 + \beta_1}\right]}$$

$$R_{in,C1} = r_{o1}(1 + g_{m1} R_{E1})$$

$R_{C2} \rightarrow C_2$'nun gördüğü direnç. $\boxed{R_{C2} = R_L + R_C \| R_{in,C1}}$

OCTC account for only C_μ (Miller effect for b1)

$$C_{\mu,b1} = C_\mu \left[1 + \frac{g_{m1}}{1 + g_{m1} R_{E1}} (R_C \| R_L \| [r_{o1}(1 + g_{m1} R_{E1})])\right]$$

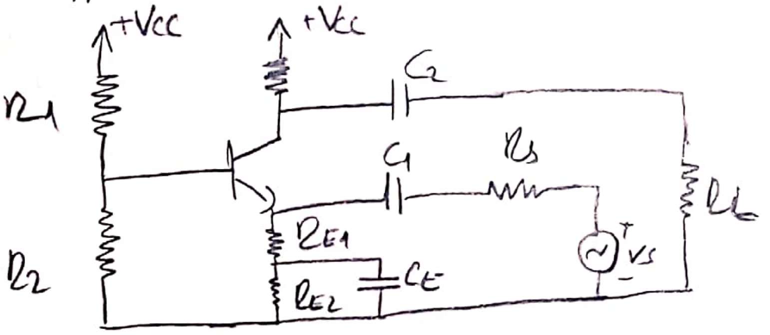
$$R_{C\mu,b1} = R_1 \| R_2 \| R_S \| R_{in,b1} \quad \tau = (R_1 \| R_2 \| R_S \| (r_\pi [1 + g_{m1} R_{E1}])) \cdot C_\mu \left[1 + \frac{g_{m1}}{1 + g_{m1} R_{E1}}\right.$$

$$\left. \cdot (R_C \| R_L \| [r_{o1}(1 + g_m$$

$$\tau = R_1 \| R_2 \| R_s \| (r_\pi [1+g_{m1}R_{E1}]) \cdot C_\mu \left[1+\frac{g_{m1}}{1+g_{m1}R_{E1}}\right] \cdot (R_C \| R_L \| [r_{o1}(1+g_m R_{E1})])$$

$$\cancel{\tau} = \boxed{W_H = \frac{1}{\tau}}$$

Q4 For Probs. 8.54 - 8.59 involving BJT amplifiers, use transistors whose parameters are $\beta_f = 100$, $C_{je} = 8pF$ at $V_{BE} = 0.5V$, $C_\mu = 4pF$ at $V_{CB} = 5V$, $C_s = 4pF$ at $V_{CS} = 8V$, $\beta_f = 100$, $V_{je} = V_{jc} = V_{js} = 0.8V$, and $h_{oe} = 1/r_o = 5\mu\mho$ at $V_{CE} = 10V$. The transition frequency is $f_T = 300MHz$ at $V_{CE} = 20V$, $I_C = 10mA$. The substrate is connected to the ground. Assume $I_C = 5mA$; $V_{CC} = 15V$, $V_{BE} = 0.7V$, $R_s = 1k\Omega$, $R_L = 10k\Omega$. Use SPICE to check your design by plotting the frequency response and give an approximate cost estimate.



SCTC

R_{CE}, C_E'nin gördüğü direnç. $\tau_{CE} = R_{CE} \cdot C_E$

$R_{CE} = R_{E2} \| [R_{E1} + R_s \| \frac{1}{g_{m1}}]$

R_{C1}, C_1'in gördüğü direnç. $\tau_{C1} = R_{C1} \cdot C_1$

$R_{C1} = R_s + R_{E1} \| \frac{1}{g_{m1}}$

R_{C2}, C_2'nin gördüğü direnç.

$R_{C2} = R_L + R_C \| [r_{o1}(1+g_{m1}R_{E1})]$

$$W_L = \frac{1}{\tau_{CE}} + \frac{1}{\tau_{C1}} + \frac{1}{\tau_{C2}} + \frac{1}{\tau_{CB}}$$

R_{CB}, C_B'nin gördüğü direnç.

$R_{CB} = R_1 \| R_2 \| [r_{\pi 1}(1+g_{m1}R_{E1})]$

Midband gain

$$A_M = \frac{V_o}{V_s} = \frac{R_{E1} \| \frac{1}{g_{m1}}}{R_{E1} \| \frac{1}{g_{m1}} + R_s}\, g_{m1}(R_C \| R_L)$$

$\underbrace{C_\pi \text{ ve } C_\mu \text{ yok gnd-edil}}_{\text{SCTC'de}}$

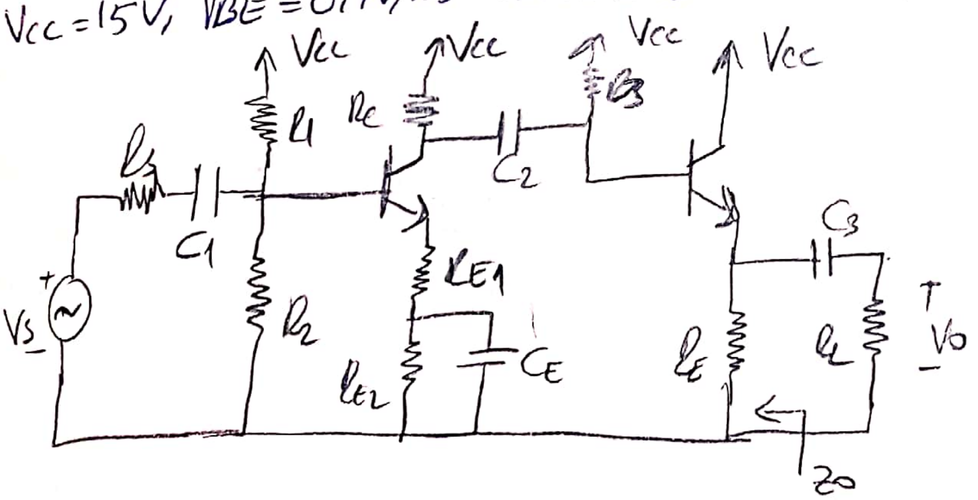
OCTC

$R_{C\mu}$: C_μ'nün gördü. direnci

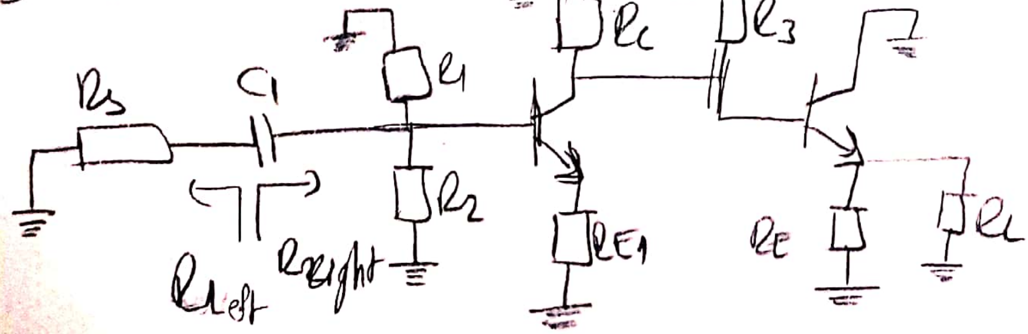
$$R_{C\mu} \cong R_C \| R_L \| [r_{o1}(1+g_{m1}R_{E1})]$$

$$R_{C\pi} \cong R_{E1} \| R_s \| \frac{1}{g_{m1}} \longrightarrow \omega_H = \frac{1}{\tau_{C\mu} + \tau_{C\pi}}$$

For Probs. 8.54–8.59 involving BJT amplifiers, use transistors whose parameters are $\beta_F = 100$, $C_{je} = 8pF$ at $V_{BE} = 0.5V$, $C_\mu = 4pF$ at $V_{CB} = 5V$, $C_{cs} = 4pF$ at $V_{cs} = 5V$, $\beta_F = 100$, $V_{je} = V_{js} = 0.8V$ and $h_{oe} = 1/r_o = 5\mu ℧$ at $V_{CE} = 10V$. The transition frequency is $f_T = 300MHz$ at $V_{CE} = 20V$, $I_C = 10mA$. The substrate is connected to the ground. Assume $I_C = 5mA$, $V_{CC} = 15V$, $V_{BE} = 0.7V$, $R_s = 1k\Omega$, and $R_L = 10k\Omega$. Use SPICE to check your design.

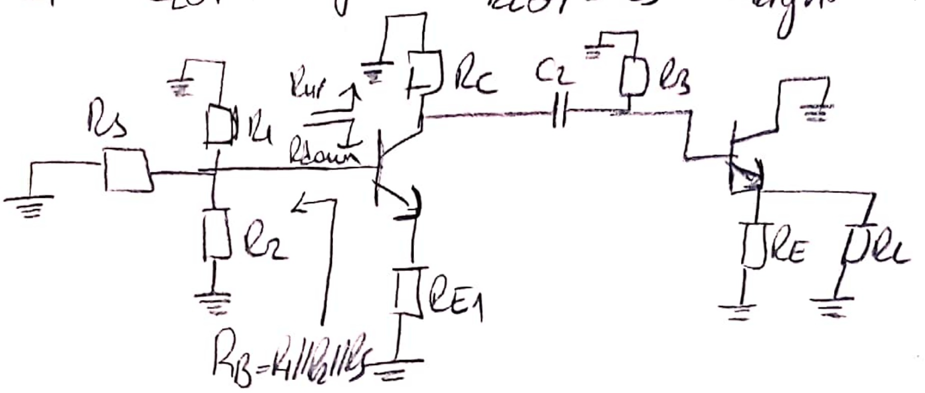


SCTC for ω_L



$R_{C1} = R_{Left} + R_{Right}$ $R_{Left} = R_S$ $R_{Right} = R_1 || R_2 || [(1+g_{m1}R_{E1}) r_{\pi 1}]$

$\tau_{C1} = R_{C1} C_1$



SCTC

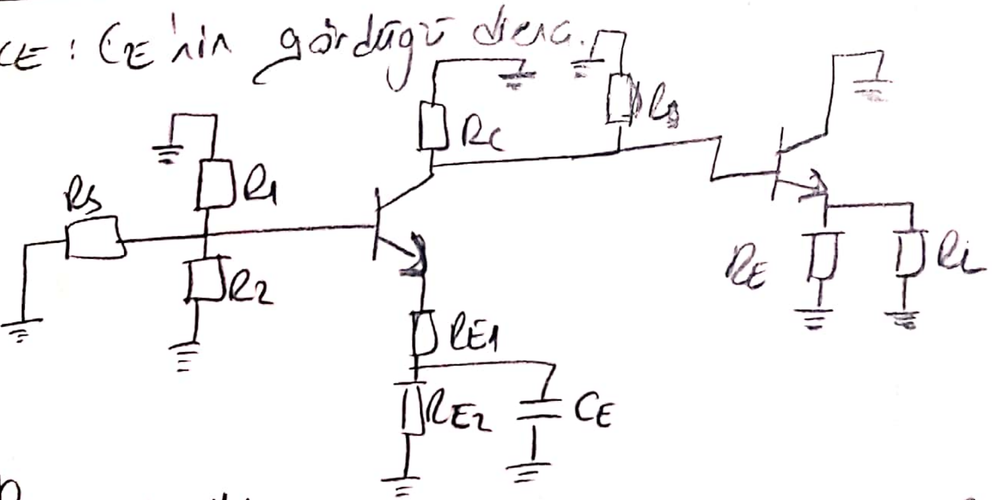
$\rightarrow R_{C2} = R_{left} + R_{right}$

$R_{right} = R_3 || [(1+g_{m2}(R_E || R_L)) r_{\pi 2}]$ $R_{left} = R_{up} || R_{down}$

$R_{up} = R_C$ $R_{down} = r_{o1}\left[1 + \frac{g_{m1} R_{E1} r_{\pi 1}}{R_{E1} + r_{\pi 1} + R_B}\right] + R_{E1} || (r_{\pi 1} + R_B)$

$\tau_{C2} = R_{C2} \cdot C_2$

R_{CE} : C_E'nin gördüğü direnç.

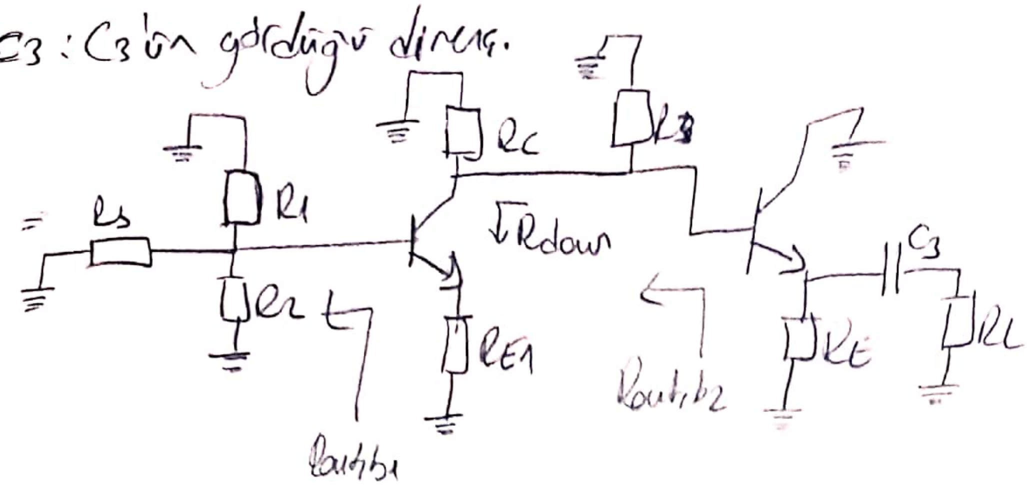


$R_{CE} = R_{up} || R_{down}$

$R_{down} = R_{E2}$

$R_{up} = R_{E1} + \frac{r_{\pi 1} + R_1 || R_2 || R_S}{1 + \beta_1}$ $\tau_{CE} = R_{CE} \cdot C_E$

R_{C3} : C_3'ün gördüğü direnç.



$$R_{C3} = R_L + R_E \parallel \left[\frac{r_{\pi 2} + R_{out,b2}}{1+\beta_2}\right] \qquad R_{out,b2} = R_3 \parallel R_C \parallel R_{down}$$

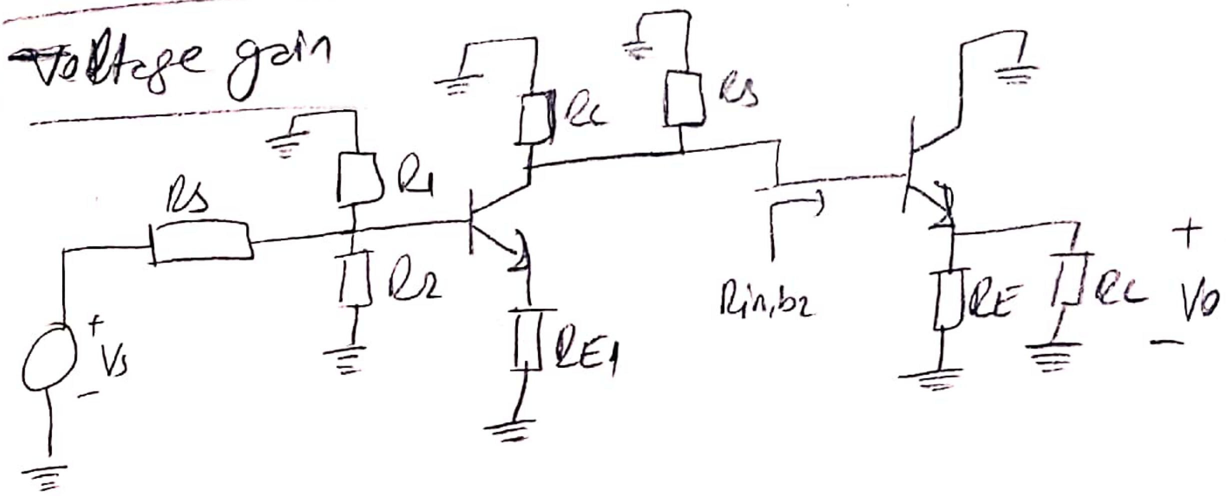
$$R_{down} = r_{o1}\left[1 + \frac{g_{m1} R_{E1} r_{\pi 1}}{R_{E1} + r_{\pi 1} + R_{out,b1}}\right] + R_{E1} \parallel (r_{\pi 1} + R_{out,b1})$$

$$\tau_{C3} = R_{C3} C_3$$

$$w_L = \frac{1}{\tau_{C1}} + \frac{1}{\tau_{C2}} + \frac{1}{\tau_{C3}} + \frac{1}{\tau_{CE}}$$

w_H approximation

~~Voltage~~ gain



$$\frac{V_o}{V_s} = \frac{V_{b1}}{V_s} \cdot \frac{V_{c1}}{V_{b1}} \cdot \frac{V_{e2}}{V_{c1}}$$

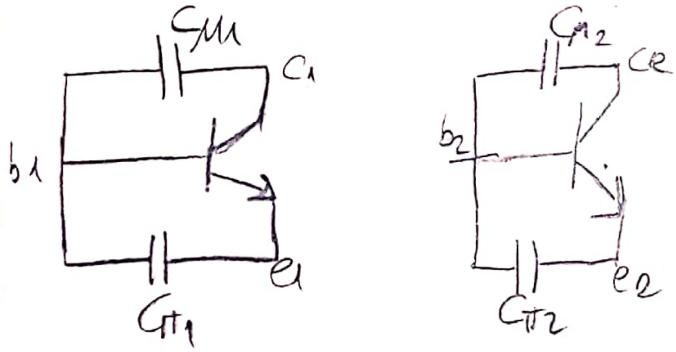
$$\frac{V_{b1}}{V_s} = \frac{R_{in,b1} \| R_1 \| R_2}{R_{in,b1} \| R_1 \| R_2 + R_s} \qquad \frac{V_{c1}}{V_{b1}} \cong \left[\frac{-g_{m1}}{1+g_{m1}R_{E1}}\right]\left[R_C \| R_3 \| R_{in,b2}\right]$$

$$\frac{V_{e2}}{V_{b2}} \cong \frac{R_E \| R_L}{R_E \| R_L + \frac{1}{g_{m2}}}$$

$$R_{in,b1} = r_{\pi 1}(1+g_{m1}R_{E1})$$

$$R_{in,b2} = r_{\pi 2}(1+g_{m2}(R_E \| R_L))$$

Miller Effect



$C_{\mu 1}$: Miller effect

$$C_{\mu 1,b1} = \left(1 - \frac{V_{c1}}{V_{b1}}\right) C_{\mu 1}$$

$$C_{\mu 1,c1} = \left(1 - \frac{V_{b1}}{V_{c1}}\right) C_{\mu 1}$$

$C_{\pi 1}$: $R_{E1} \gg \frac{1}{g_{m1}}$ $\quad \frac{V_{e1}}{V_{b1}} \approx 1$ $\qquad$ $C_{\pi 2}$: $R_E \| R_L \gg \frac{1}{g_{m2}}$ $\quad \frac{V_{e2}}{V_{b2}} \approx 1$

$$C_{\mu 2,b2} = C_{\mu 2}$$

OCTC

$$W_H = \frac{1}{\tau_{C\mu 1,b1}} = \frac{1}{R_{C\mu 1,b1} C_{\mu 1,b1}} \qquad R_{C\mu 1,b1} = R_s \| R_1 \| R_2 \| R_{in,b1}$$

$$R_{in,b1} \cong r_{\pi 1}(1+g_{m1}R_{E1})$$

$$W_H = \frac{1}{(R_s \| R_1 \| R_2 \| (r_{\pi 1}(1+g_{m1}R_{E1})) \cdot \left(1 - \frac{V_{c1}}{V_{b1}}\right) \cdot C_{\mu 1}} \quad //$$