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HW5 In fig P8.19, $\beta = 200$.

a) Find I_B so that the transistor is biased at $I_C = 2.5mA$

b) Find the numerical value of r_π.

c) Write an equation for C so that the low-frequency pole is located at 100 rad/s

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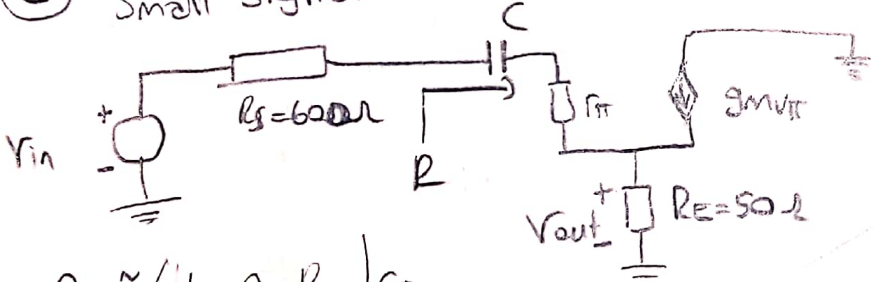
ⓐ $I_C = \beta . I_B \longrightarrow 2.5mA = 200 . I_B \longrightarrow \boxed{I_B = 12.5\mu A}$

ⓑ $g_m r_\pi = \beta \rightarrow r_\pi = \dfrac{\beta}{g_m} = \dfrac{\beta . V_T}{I_C} = \dfrac{200 . 26\times\cancel{10^{-3}}}{2.5\times\cancel{10^{-3}}} = \boxed{2.08k\Omega = r_\pi}$

$g_m = \dfrac{I_C}{V_T}$

ⓒ Small signal Modellerie



$R \cong (1 + g_m R_E) r_\pi$

$$\frac{V_{out}}{V_{in}} = \frac{(1+g_m R_E).r_\pi}{R_s + (1+g_m R_E) r_\pi + \frac{1}{C_s}} . \frac{R_E}{\frac{1}{g_m} + R_E} = \frac{C_s.(1+g_m R_E) r_\pi}{C_s R_s + C_s (1+g_m R_E) r_\pi + 1} . \frac{R_E}{\frac{1}{g_m} + R_E}$$

$$= \frac{C_s.(1+g_m R_E).r_\pi}{1 + \frac{s}{\frac{1}{C.(1+g_m R_E).r_\pi + C.R_s}}} . \frac{R_E}{\frac{1}{g_m} + R_E}$$

Pole $\rightarrow \dfrac{1}{C.(1+g_m R_E) r_\pi + C R_s}$

$g_m = \dfrac{I_C}{V_T} = \dfrac{2.5mA}{26mV} =$

$\boxed{g_m = 96.15mS}$

$$\boxed{Pole = \frac{1}{C.(1+g_m R_E) r_\pi + C R_s}}$$

$$\text{Pole} = \frac{1}{C.\underbrace{(1+g_m R_E) r_\pi}_{11.615k\Omega} + C.R_s} \Rightarrow g_m = 96.15mS, \quad R_E = 50, \quad r_\pi = 2k\Omega$$

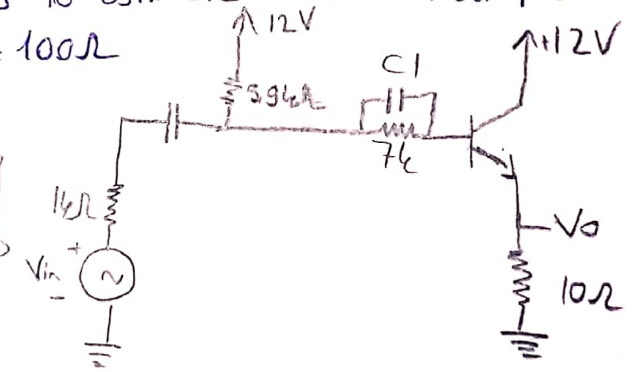
$$\text{Pole} = \frac{1}{C.11.615k\Omega + C.600} \rightarrow \text{Pole} = \frac{1}{C.12.215k\Omega}$$

$w = 100 rad/s$'de pole varsa

$$100 rad/s = \frac{1}{C.12.215k\Omega} \rightarrow C = \frac{1}{12.215\times10^{3}.100} = \frac{10^{-5}}{12.215}$$

$$C = 8.188\times10^{-7} F = \boxed{0.818 \mu F = C}$$

Q2. Use short-circuit time constants to estimate the lower half-power frequency for Fig. P8.20; $\beta = 99$, $r_\pi = 100\Omega$



DC bias

$I_E = (\beta+1) I_B = 100 I_B$

$100 I_B . 10\Omega + 0.7 + (5.9k\Omega + 7k\Omega) I_B = 12V$

$13.9k\Omega . I_B = 11.3V$ $\boxed{I_B = 0.812mA}$ $\boxed{I_E = 100 I_B = 81.29mA}$

SCTC

C_1 short için C_2

$$\tau_2 = C_2[R_s + R_1 \| [(1+g_m R_E) r_\pi]]$$

C_2 short için C_1

$$\tau_1 = C_1[R_2 \| [R_1 \| R_s + (1+g_m R_E) r_\pi]]$$

$$J_1 = C_1\left[R_2 \,//\, \left[R_1 \,//\, R_S + (1+g_m R_E) r_\pi\right]\right]$$

$$J_2 = C_2\left[R_S + R_1 \,//\, \left[(1+g_m R_E) r_\pi\right]\right]$$

$R_1 = 5.9k\Omega$

$R_2 = 7k\Omega$

$R_E = 10\Omega$

$R_S = 1k\Omega$

$$J_1 = C_1 \underbrace{\left[7k \,//\, \left[\underbrace{5.9k \,//\, 1k}_{855} + \underbrace{(1+9.9).100}_{1090}\right]\right]}_{1522.13}$$

$$r_\pi = \frac{\beta . V_T}{I_C} = \frac{V_T}{I_B} = \frac{26mV}{I_B} = 100$$

$I_B = 0.26mA \neq 0.812mA$

$g_m = \frac{\beta}{r_\pi} = 0.99\,\Omega^{-1}$

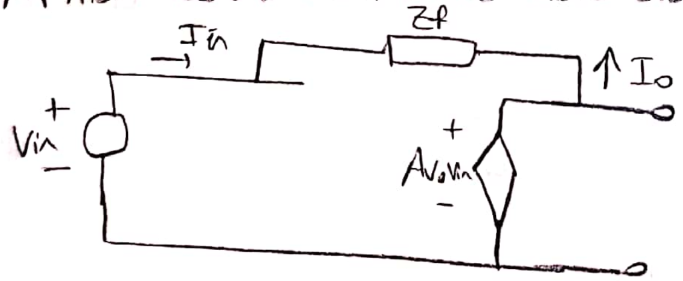
$$\boxed{J_1 = 1522.13\, C_1}$$

$$J_2 = C_2 . \underbrace{\left[1k + \underbrace{5.9k\Omega \,//\, [1090]}_{920.02}\right]}_{1920.02} \rightarrow \boxed{J_2 = C_2 . 1920.02}$$

Q3.

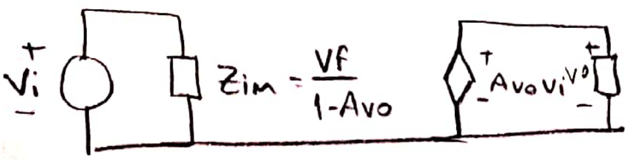
In a particular MOSFET amplifier for which the midband voltage gain between gate and drain is −27 V/V, the NMOS transistor has $C_{gs} = 0.3pF$ and $C_{gd} = 0.1\,pF$. What input capacitance would you expect? For what range of signal-source resistances can you expect the 3dB frequency to exceed 10MHz? Neglect the effect of R_G

Miller Teoremi hatırlatma devre analizi



$$I_{in} = \frac{V_{in} - V_o}{Z_f} = \frac{V_i - A_{vo}V_{in}}{Z_f} = V_i\frac{(1-A_{vo})}{Z_f}$$

$$\frac{V_{in}}{I_{in}} = \frac{Z_f}{1-A_{vo}}, \quad I_o = \frac{V_o - V_{in}}{Z_f} = \frac{V_o - \frac{V_o}{A_{vo}}}{Z_f} \rightarrow \frac{V_o}{I_o} = \frac{Z_f}{1-\frac{1}{A_{vo}}}$$



$$Z_{om} = \frac{Z_f}{1-\frac{1}{A_{vo}}}$$

CamScanner ile tarandı

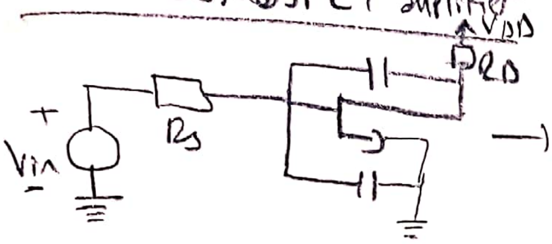
Tipik varsayım $A_{vo} < 0$ ve $|A_{vo}| > 1$

and let $Z_f = \frac{1}{sC_f}$ then $Z_{in} = \frac{1}{sC_f(1-A_{vo})}$ $Z_{om} = \frac{1}{sC_f(1-\frac{1}{A_{vo}})}$

capacitance $\underbrace{\quad}$ $C_f(1-A_{vo})$

capacitance $C_f \cdot (1-\frac{1}{A_{vo}})$ $|A_{vo}| >> 1$ ise $\approx C_f$

Basic CSMOSFET amplifier



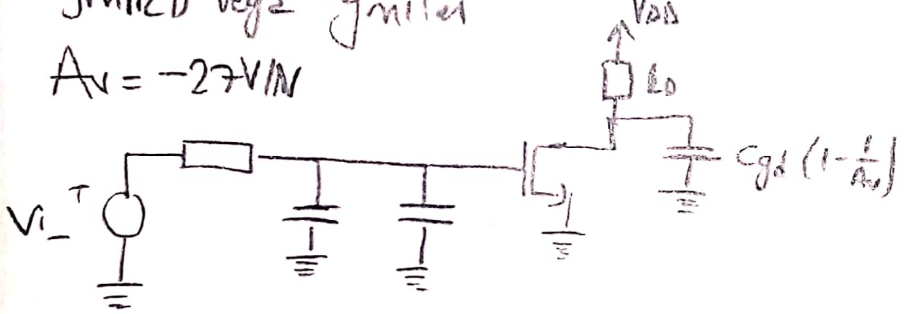
→ midband voltage gain

$-g_{m1}(R_D || r_{o1}) \approx -g_{m1}R_D$

$-g_{m1}R_D$ veya $-g_{m1}r_{o1}$

$A_v = -27 V/V$

R_D akım kaynağı ile değişirse $-g_{m1}r_{o1}$ olur.



OCTC Method ($V_i = 0$ iken)

$C_1 = C_{gs} + C_{gd}(1-A_v)$ $R_1 = R_s$ $C_2 = (1-\frac{1}{A_v})C_{gd}$

$\tau_1 = C_1 . R_1 = [C_{gs} + C_{gd}(1-A_v)] R_s$

$C_2 = C_{gd}(1-\frac{1}{A_v})$ C_2 R_2'yi görüyor $R_2 = R_D || r_{o1}$

$\tau_2 = C_2 R_2 = [C_{gd}(1-\frac{1}{A_v})][R_d || r_{o1}]$

$$W_{3dB} \approx \frac{1}{\tau_1 + \tau_2} = \frac{1}{C_1R_1 + C_2R_2} = \frac{1}{(C_{gs}+C_{gd}(1-A_v))R_s + [C_{gd}(1-\frac{1}{A_v})][R_D || r_{o1}]}$$

$\tau_1 >> \tau_2 \rightarrow W_{3dB} \cong \frac{1}{\tau_1}$

$\checkmark\ W_{3dB} = \underbrace{2\pi f_{3dB}}_{10MHz} = \dfrac{1}{R_s[C_{gs} + C_{gd}(1-A_v)]}$

$C_{gs} = 0.3pF$

$C_{gd} = 0.1pF$

$A_v = -27V/V$

$2\pi \times 10 \times 10^6 = \dfrac{1}{R_s[0.3\times10^{-12} + 0.1\times10^{-12}(28)]}$

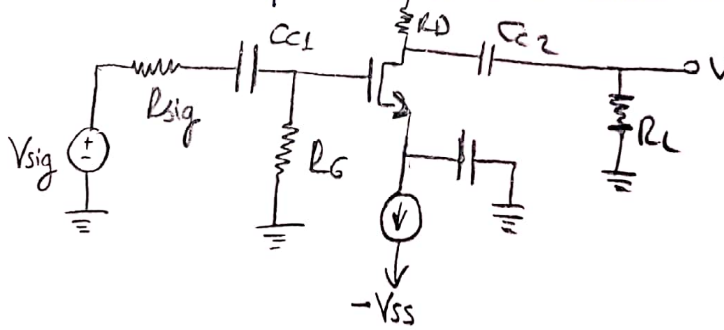
$R_s = \dfrac{1}{2\pi \times 10^7 \cdot 3.1 \cdot 10^{-12}} = \dfrac{10^5}{2\pi \cdot 3.1} = \boxed{5.134 k\Omega = R_s}$

$W_{3dB} > 2\pi \cdot 10MHz$ Olacaksa ise $R_s < 5.134k\Omega$ olmalı

Cc ∞ R a R a

In a fet amplifier, such as that in Fig. 4.49 (a). the resistance of the source $R_{sig} = 100k\Omega$, amplifier input resistance (which is ~~the~~ due to the biasing network) $R_{in} = 100k\Omega$, $C_{gs} = 1pF$, $C_{gd} = 0.2pF$, $g_m = 3mA/V$ $r_o = 50k\Omega$, $R_D = 8k\Omega$ and $R_L = 10k\Omega$. Determine the expected 3-dB cutoff frequency f_H and the midband gain. In evaluating ways to double f_H, a designer considers the alternatives of changing either R_{out} or R_{in}. To raise f_H as described what separate change in each would be required? What midband voltage gain results in each case?

SCTC Method



$V_{sg} = 0$ için

VDD -Vss → gnd

I ise open circuit

$\tau_{e1} = C_{c1} \cdot R_{cc1}$ · R_{cc1} (C_{c1}'in gördüğü direnç ⇒) $R_{sig} + R_G$ → C_{c2} ve C_S kısa devre

$\tau_{e2} = C_{c2}\, R_{cc2}$ → R_{cc2} (C_{c2}'nin " " ⇒) $(R_D // r_o + R_L)$ → C_{c1} ve C_S kısa devre

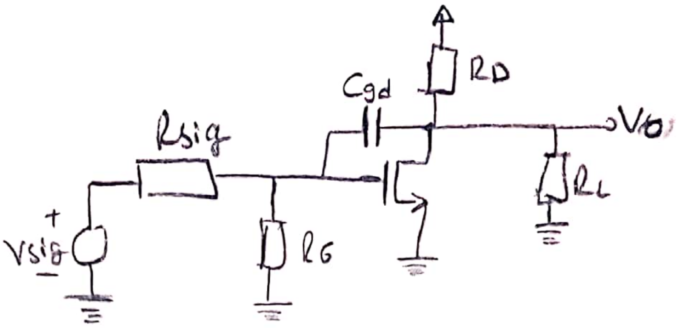
$\tau_{e3} = C_S \cdot R_{cs}$ → R_{cs} (C_S'in " " ⇒) $\dfrac{1}{g_m}$ → C_{c1} ve C_{c2} kısa devre

1

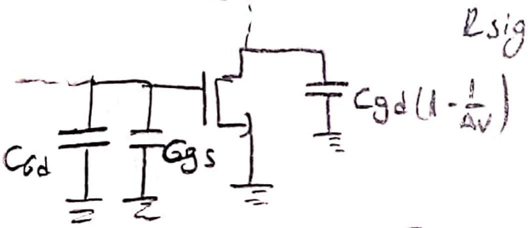
$$W_L = \frac{1}{\tau_{L1}} + \frac{1}{\tau_{L2}} + \frac{1}{\tau_{L3}} = \frac{1}{C_{C1}\cdot(R_{sig}+R_G)} + \frac{1}{C_{C2}\cdot(R_D \parallel r_o + R_L)} + \frac{1}{C_S \cdot \frac{1}{g_m}}$$

High freq. cutoff

C_{C1}, C_{C2} ve C_S



Midband gain = $A_V = \frac{R_G}{R_{sig}+R_g}(-g_m)[R_D \parallel R_L \parallel r_o] < 0$ → ~~Bütü~~ ortak paralel kapasitör çiftinin gördüğü direnç



$$\tau_{H1} = [C_{gs} + C_{gd}(1-A_V)] \cdot [R_{sig} \parallel R_G]$$

$C_{gd}(1-\frac{1}{A_V})$ → open circuit

$$\tau_{H2} = \left[C_{gd}\left(1-\frac{1}{A_V}\right)\right][R_D \parallel R_L \parallel r_o]$$

$$W_H = \frac{1}{\tau_{H1}+\tau_{H2}} \qquad \tau_{H1} \gg \tau_{H2} \text{ ise } \quad W_H \approx \frac{1}{\tau_{H1}}$$

$$\Rightarrow W_H = \frac{1}{[C_{gs}+C_{gd}(1-A_V)]\cdot[R_{sig} \parallel R_G]}$$

$C_{gs} = 1pF$
$C_{gd} = 0.2pF$
A_V bulunacak
$R_{sig} = 100k\Omega$
R_G → bilinmiyor.
$g_m = 3mS$
$R_D = 8k\Omega$
$R_L = 10k\Omega$
$r_o = 50k\Omega$

$$A_V = \frac{R_g}{100k\Omega + R_g}(-3)\cdot[8k\Omega \parallel 10k\Omega \parallel 50k\Omega]$$

$$\frac{80k}{18} \parallel 50k$$

$$\frac{\frac{400}{18}k}{\frac{80}{18}+50} = 408.16$$

$R_g = 100k\Omega$ olsun

$$A_V = \frac{1}{2} \cdot -3 \cdot 408.16$$

$$\boxed{A_V = -612.24}$$

★ Hesaplama $R_G = 100k\Omega$ için yapılmıştır.

$$W_H = \frac{1}{\left[10^{-12} + 0.2\cdot10^{-12}\cdot(1-(-611.24))\right]\cdot\left[\underbrace{100k\Omega \parallel 100k\Omega}_{50k\Omega}\right]}$$

$\boxed{W_H = 161\,749.48}$ $\rightarrow$ $R_G = 100k\Omega$ için

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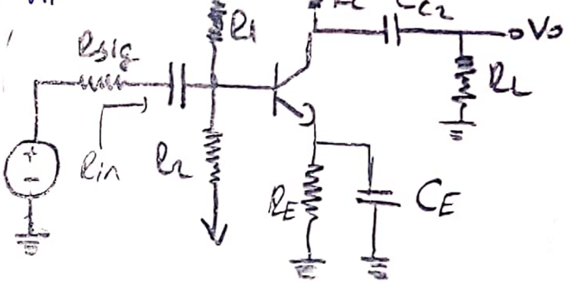
Consider the common-emitter amplifier of Fig. P5.159 under the following conditions: $R_{sig} = 5k\Omega$, $R_1 = 33k\Omega$, $R_2 = 22k\Omega$, $R_E = 3.9k\Omega$, $R_C = 4.7k\Omega$, $R_L = 5.6k\Omega$. $V_{CC} = 5V$. The dc emitter current can be shown to be $I_E \simeq 0.3mA$ at which $\beta_o = 120$, $r_o = 300k\Omega$, and $r_x = 50\Omega$. Find the input resistance R_{in} and the midband gain A_M. If the transistor is specified to have $f_T = 700MHz$ and $C_\mu = 1pF$ find the upper 3-dB frequency f_H



SCTC method for W_L

$\tau_{C1} = C_{C1}\cdot R_{CC1}$

R_{CC1} = C_{C1}'den gördüğü direnç

C_{C1}'in solda gördüğü direnç R_{sig}

" " sağda " " $R_1 \parallel R_2 \parallel r_\pi$

$R_{CC1} = R_{sig} + (R_1 \parallel R_2 \parallel r_\pi)$

$\tau_1 = C_{C1}\cdot(R_{sig} + (R_1 \parallel R_2 \parallel r_\pi)) = C_{C1}\cdot(5k\Omega + (33k\Omega \parallel 22k\Omega \parallel 10.4k))$

$\tau_1 = C_{C1}\cdot(5k\Omega + 5.816k\Omega)$

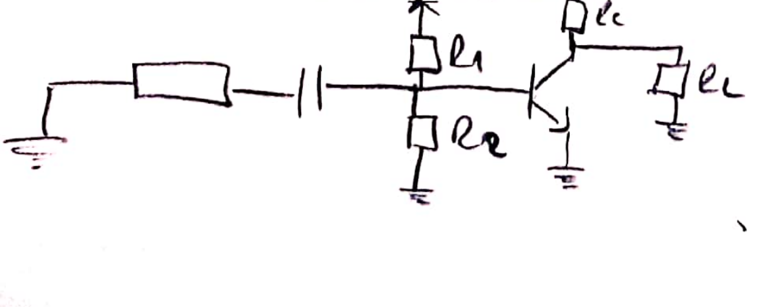
$\boxed{\tau_1 = C_{C1}\cdot 10.816k\Omega}$

$r_\pi = \frac{\beta . V_T}{I_C} = \frac{120\cdot26\times10^{-3}}{0.3\times10^{-3}}$

$I_C \approx I_E$

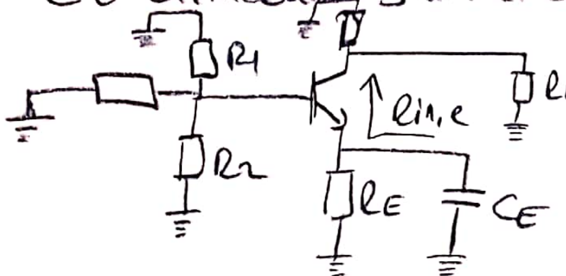
$\boxed{r_\pi = 10.4k\Omega}$

Bu Methodda sadece C_{C1} bırakıldı diğer kapasitörler short circuit



SCTC for CE

CE dışındakiler short circuit $\quad \tau_{CE} = C_E \cdot R_{CE} \quad$ R_{CE}: C_E'nin gördüğü direnç.



$$R_{in,e} \| R_E = R_{CE}$$

$$R_{in,e} = \frac{r_\pi + R_B}{1+\beta}$$

$$\tau_{CE} = C_E \cdot \left(\frac{r_\pi + R_B}{1+\beta} \| R_E \right)$$

$$\tau_{CE} = C_E \cdot \left(\underbrace{\frac{10.4k\Omega + 3.626k\Omega}{121}}_{115.92} \| 39k\Omega \right)$$

$$115.92 \| 39k\Omega \approx 115.92$$

$$\boxed{\tau_{CE} = C_E \cdot 115.92}$$

$\boxed{r_\pi = 10.4k\Omega}$

$R_B = R_{sig} \| R_1 \| R_2$

$R_B = 5k\Omega \| 33k\Omega \| 22k\Omega$

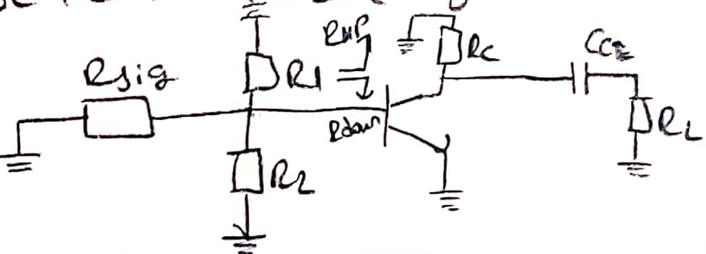
$\boxed{R_B = 3.626k\Omega}$

$R_E = 39k\Omega$

SCTC for C_{C2} (kaynaklar atılır C_{C2} dışındaki kapasitörler kısa devre)

$\tau_{C2} = R_{CC2} \cdot C_{C2}$

R_{CC2}: C_{C2}'nin gördüğü direnç



R_{CC_2}: sağında R_L görür

R_{CC_2}: solunda gördüğüne R_{left} diyelim.

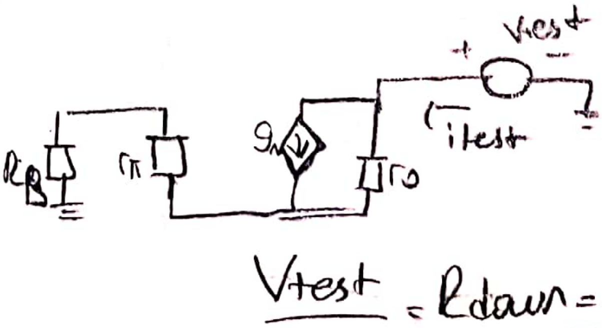
$\boxed{R_{left} = R_{up} \| R_{down}}$

R_{up}, R_{down} belirtilen bölge dirençleri

$\boxed{R_{up} = R_C}$

$R_{left} = R_{up} \| R_{down} = \underline{R_C \| r_o}$

R_{down} için test kaynağı ekleyelim



$$\frac{V_{test}}{i_{test}} = R_{down} = r_o$$

$$\boxed{R_{CC2} = R_L + R_C \| r_o}$$

$$\tau_{CC2} = C_{C2} R_{C2} = C_{C2} \cdot (R_L + R_C \| r_o)$$

$R_L = 5.6k\Omega$

$r_o = 300k\Omega$

$R_C = 4.7k\Omega$

$$\tau_{CC2} = C_{C2} \cdot (5.6k\Omega + \underbrace{4.7k\Omega \| 300k\Omega}_{\approx 4.7k\Omega})$$

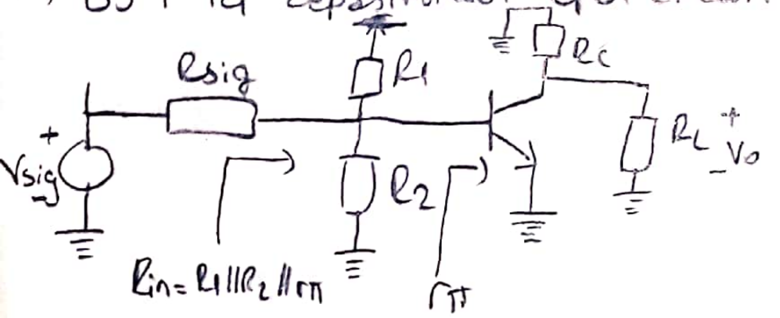
$$\boxed{\tau_{CC2} = C_{C2}(10.3k\Omega)}$$

$$W_L = \frac{1}{\tau_{C1}} + \frac{1}{\tau_{C2}} + \frac{1}{\tau_{C3}} = \boxed{\frac{1}{C_{C1} \cdot 10.816k\Omega} + \frac{1}{C_{C2} \cdot 10.3k\Omega} + \frac{1}{C_E \cdot 115.9}}$$

Midband ile Rin elde etme

Midband'de tüm kapasitörler ~~...~~ short circuit
→ BJT iç kapasitörleri open circuit

} Bu iki değerlendirmeye göre devre aşağıdaki gibi çizilir



$$\frac{V_o}{V_{sig}} = A_m = \underbrace{(-g_m)}_{\frac{i_{out}}{V_{sig}}} \cdot \underbrace{[R_C \| r_o \| R_L]}_{\frac{V_o}{i_{out}}}$$

$$= \underbrace{(-11.53 \times 10^{-3})}_{\frac{i_{out}}{V_{sig}}} \cdot \underbrace{(2.55k\Omega)}_{\frac{V_o}{i_{out}}}$$

$$g_m = \frac{\beta}{r_\pi} = \frac{120}{10.4k\Omega}$$

$$\boxed{g_m = 11.53mS}$$

$R_{in} = R_1 \| R_2 \| r_\pi = 33k \| 22k \| 10.4k = \underline{5.816k\Omega}$

$$= \boxed{A_M = -29.40}$$

$R_C = 4.7k\Omega$

$r_o = 300k\Omega$

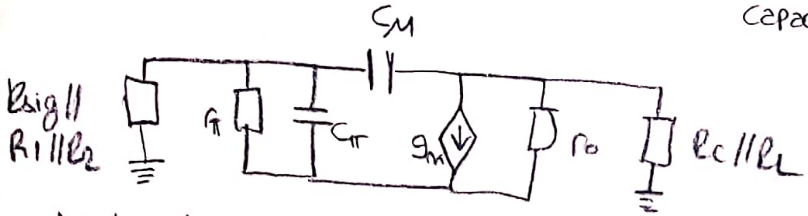
$R_L = 5.6k\Omega$

$R_C << r_o$ $R_L << r_o$

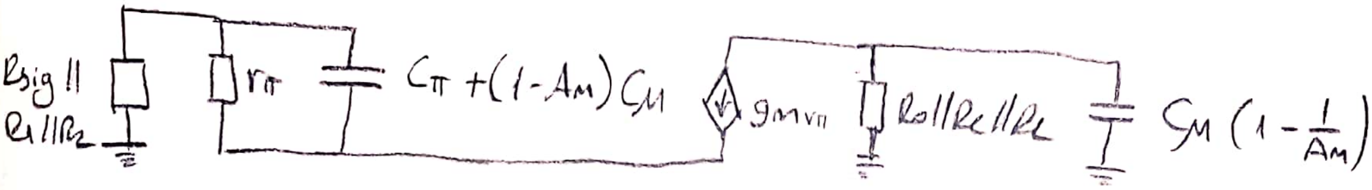
$R_C \| R_L$

$R_{sig} = 5k\Omega$

$W_H \rightarrow$ ÖCTC kullanarak $\rightarrow$ bağımsız kaynakları alır
capacitörler short circuit



Miller teoremi



$1-A_M >> 1$ $\quad 1 < 1-\frac{1}{A_M} < 2$

$A_M < 0$

$C_1 = C_\pi + (1-A_M)C_M$

$C_2 = C_M(1-\frac{1}{A_M})$

= Open circuit C_2, C_1'in gördüğü direnç R_{C1}

$R_{C1} = R_{sig} \| R_1 \| R_2 \| r_\pi$ and $\tau_{C1} = C_1 . R_{C1} = C_1 (R_{sig} \| R_1 \| r_\pi)$

$\tau_{C1} = C_1 . (5k\Omega \| 33k\Omega \| 10.4k\Omega)$

$\boxed{\tau_{C1} = C_1 (3.06k\Omega)}$

open circuit C_1, R_{C2}: C_2'nin gördüğü direnç.

$R_{C2} = r_o \| R_C \| R_L$

$\tau_{C2} = R_{C2} . C_{C2} = C_{C2} . (r_o \| R_C \| R_L)$

$= C_{C2} . (300k\Omega \| 4.7k\Omega \| 5.6k\Omega)$

$\boxed{\tau_{C2} = C_{C2} . 2.55k\Omega}$

$r_\pi = 10.4k\Omega$

$R_{sig} = 5k\Omega$
$R_1 = 33k\Omega$
$R_2 = 22k\Omega$
$R_E = 3.9k\Omega$
$R_C = 4.7k\Omega$
$R_L = 5.6k\Omega$
$V_{CC} = 5V$
$I_C = 0.3mA$
$\beta_0 = 120$
$r_o = 300k\Omega$
$r_x = 50\Omega$
$C_M = 1pF$
$f_T = 700MHz$

$$W_H = \frac{1}{\tau_{C1} + \tau_{C2}} = \frac{1}{C_{C1} \cdot 3.06k\Omega + C_{C2} \cdot 2.55k\Omega}$$

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

$$g_m = \frac{I_C}{V_T} = \frac{\beta}{\beta+1} I_E \cdot \frac{1}{V_T}$$

$\beta = 120$

$$\frac{120}{121} \cdot 0.3 \cdot \frac{1}{25\times10^{-3}} =$$

$$C_\pi + 10^{-12} = \frac{11.90\times10^{-3}}{2\pi \cdot 700 \cdot 10^6}$$

$g_m = 11.90\,mS$

$C_\pi + 10^{-12} = 2.705\times10^{-12}$

$f_T = 700\,MHz$

$C_\mu = 1pF$

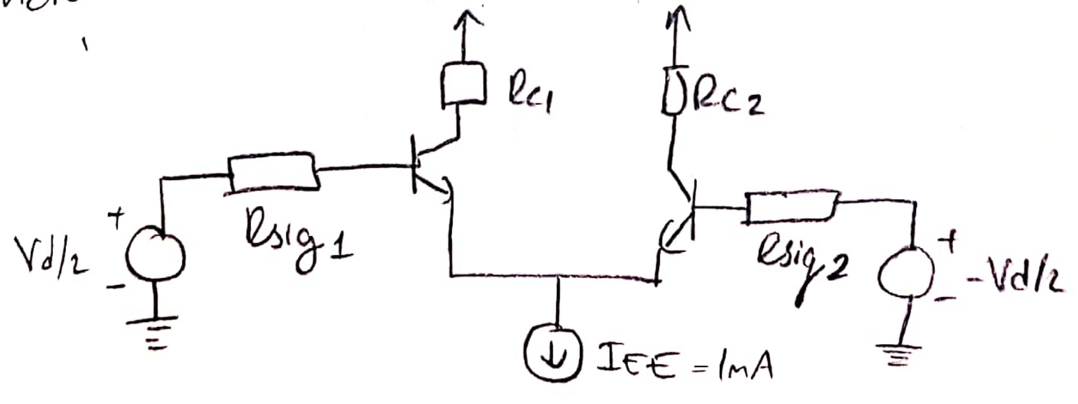
$$\boxed{C_\pi = 1.705\times10^{-12}\,F = 1.705\,pF}$$

Q6. A BJT differential amplifier operating with a 1-mA current source uses transistors for which $\beta = 100$, $f_T = 600MHz$, $C_\mu = 0.5pF$, and $r_x = 100\Omega$. Each of the collector resistances is $10k\Omega$, and r_o is very large. The amplifier is fed in a symmetrical fashion with a source resistance of $10k\Omega$ in series with each of the two input terminals.

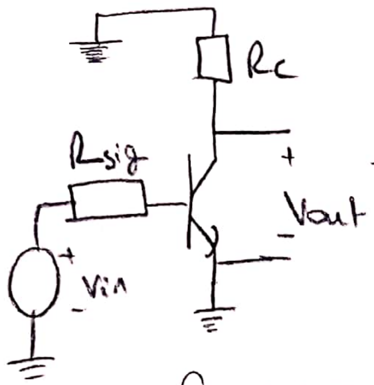
(a) Sketch the differential half-circuit and its high-frequency equivalent circuit

(b) Determine the low-frequency value of the overall differential gain.

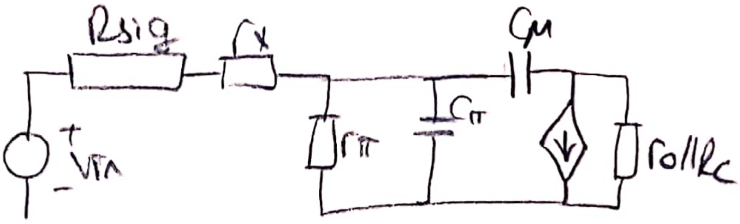
(c) Use Miller's theorem to determine the input capacitance and hence estimate the 3-dB frequency and the gain-bandwidth product



② Half Circuit



high freq. Model



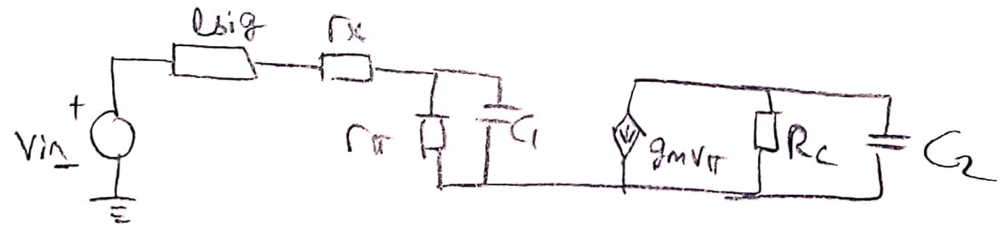
$r_o \to +\infty \quad r_o \| R_C = R_C$

$A = \text{midband gain} = \dfrac{V_c}{V_b} = -g_m R_C$

midband gain $A_M = \underbrace{\dfrac{r_\pi}{r_\pi + R_{sig} + r_x}}_{\frac{V_b}{V_{in}}} \cdot \underbrace{(-g_m R_D)}_{\frac{V_c}{V_b}}$

Miller's theorem – OCTC

$\Rightarrow$ Miller $\to$



$C_1 = C_\pi + C_\mu(1-A) \qquad C_2 = C_\mu\left(1 - \dfrac{1}{A}\right) = C_\mu\left(1 + \dfrac{1}{g_m R_C}\right)$

OCTC C_2 open circuit R_{C1}: C_1'in gördüğü direnç.

$R_{C1} = r_\pi \| (R_{sig} + r_x) \qquad \tau_{C1} = C_1 \cdot R_{C1} = C_1 \cdot (r_\pi \| (R_{sig} + r_x))$

OCTC C_1 open R_{C2}: C_2'nin gördüğü direnç $\qquad r_\pi \gg (R_{sig} + r_x)$

$R_{C2} = R_C$

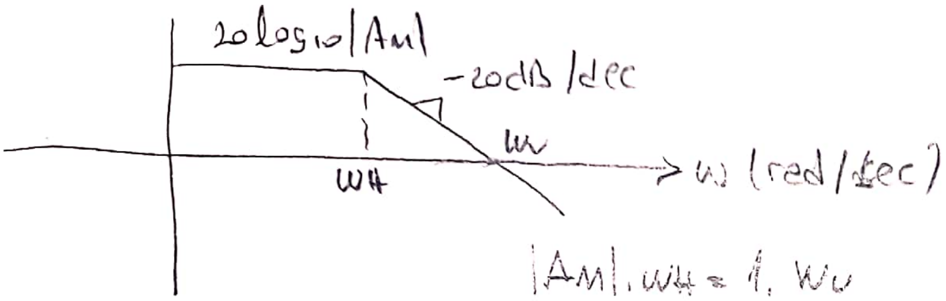
$$W_H = \frac{1}{\tau_{C1} + \tau_{C2}} \cong \frac{1}{\tau_{C1}} = \boxed{\frac{1}{C_1(r_\pi \| (R_{sig} + r_x))}}$$

$\tau_{C1} \gg \tau_{C2}$

(d) Gain-Bandwith product

$$GBW = |A_m| \frac{w_H}{2\pi} = |A_m| \cdot f_H$$

$$= \left| \frac{r_\pi}{r_\pi + r_x + R_{sig}} (-g_m R_C) \right| \cdot \frac{1}{2\pi \tau_{C1}}$$



$$|A_M| \cdot w_H = 1 \cdot w_u$$

$$\frac{GBW}{2\pi} = \frac{w_u}{2\pi} = f_u$$

$$f_T = \frac{g_m}{2\pi (C_\mu + C_\pi)} \longrightarrow \underbrace{C_\mu}_{0.5pF} + C_\pi = \frac{g_m}{2\pi f_T} = \frac{0.02}{2\pi \cdot 600 \times 10^6}$$

$$C_\mu + C_\pi = 5.305 \times 10^{-12}$$

$$C_\pi = 5.305 \times 10^{-12} - 0.5 \times 10^{-12} = 4.805 \times 10^{-12} = \boxed{4.80pF = C_\pi}$$