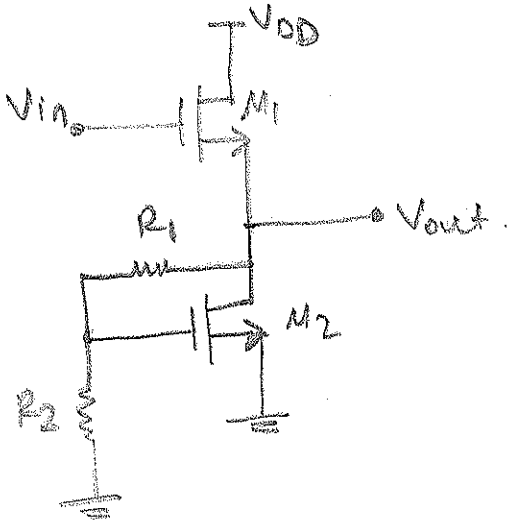
ÖDEV 1 – ÇÖZÜMLER

SORU 1



$V_{out} = V_{DD}/2$

$I_{D1} \simeq I_{D2} = 1mA$ olacak şekilde R_2/R_1 ve giriş gerilimi DC bileşeni nedir?

a) $I_{D1} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_1 (V_{GS}-V_{th})^2$

$V_{GS1} = \sqrt{\frac{2I_{D1}}{\left(\frac{W}{L}\right)_1 \mu_n C_{ox}}} + V_{th} \Rightarrow V_{G1}-V_{S1} = \sqrt{\frac{2I_{D1}}{\left(\frac{W}{L}\right)_1 \mu_n C_{ox}}} + V_{th}$

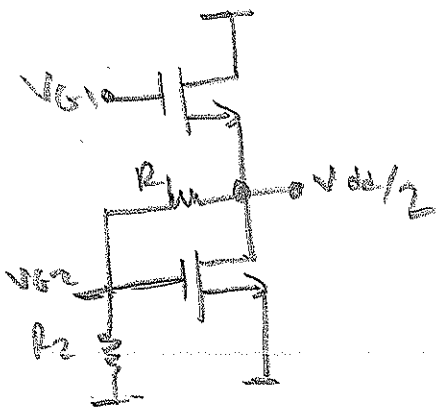
$V_{G1} = \underbrace{V_{S1}}_{V_{out}} + V_{th} + \sqrt{\frac{2I_{D1}}{\left(\frac{W}{L}\right)_1 \mu_n C_{ox}}} = 5 + 0{,}5 + \sqrt{\frac{2 \cdot 1mA}{5 \cdot 100\mu A/V^2}}$

$V_{G1} = 5{,}5 + 2 = 7{,}5V$

$I_{D2} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_2 (V_{GS2}-V_{th})^2$

$V_{GS2} = \sqrt{\frac{2I_{D2}}{\left(\frac{W}{L}\right)_2 \mu_n C_{ox}}} + V_{th} \Rightarrow V_{G2} = \underbrace{V_{S2}}_{0} + V_{th} + \sqrt{\frac{2I_{D2}}{\mu_n C_{ox}\left(\frac{W}{L}\right)_2}}$

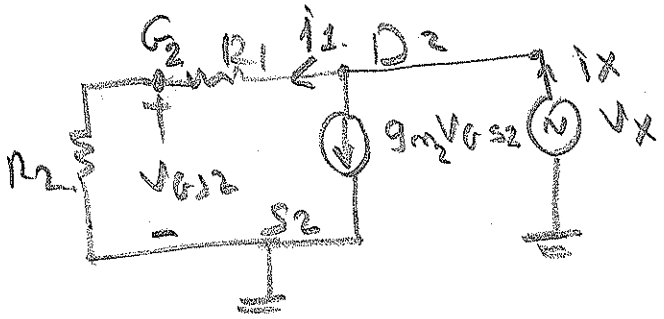
$V_{G2} = 2 + 0{,}5 = 2{,}5V$



$\frac{V_{dd/2}}{V_{G2}} = \frac{R_1+R_2}{R_2} = 1 + \frac{R_1}{R_2} = \frac{5}{2{,}5} = 2$

$\boxed{\frac{R_1}{R_2} = 1}$

b)



$\frac{V_{out}}{V_{in}} = \frac{R_S}{R_S + 1/g_{m1}}$ (Devrenin girişi V_{in}, M_2 transistörünün G ucundan uygulanmıştır).

$i_x = g_{m2} V_{gs2} + i_1$) $V_{gs2} = R_2 \cdot i_1$

$i_1 \cdot (R_1 + R_2) = V_x$

$i_1 = \frac{V_x}{R_1 + R_2}$

$i_x = g_{m2} \cdot i_1 \cdot R_2 + i_1$

$i_x = (g_{m2} R_2 + 1)\, i_1$

$i_x = (g_{m2} R_2 + 1)\, \frac{V_x}{R_1 + R_2}$

$$\frac{V_x}{i_x} = \frac{R_1 + R_2}{1 + g_{m2} R_2}$$

$r_{o1} = r_{o2} = \frac{1}{\lambda I_D} = \frac{1}{0{,}02\,V^{-1} \cdot 1\,mA} = 50k\Omega$.

$$K_v = \frac{V_{out}}{V_{in}} = \frac{\left(\frac{R_1 + R_2}{1 + g_{m2} R_2} \,//\, r_{o2} // r_{o1} \right)}{1/g_{m1} + \left(\frac{R_1 + R_2}{1 + g_{m2} R_2} \,//\, r_{o2} // r_{o1} \right)}$$

$R_1 = 100k\Omega$
$R_2 = 100k\Omega$.

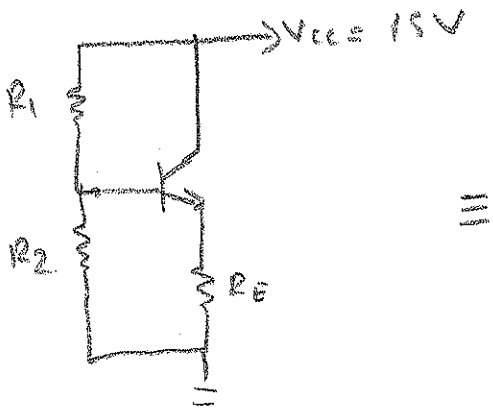
$g_{m1} = 2 \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{th}) = 2 \cdot 10^{-3}$

c) $R_{out} = r_{o2} // r_{o2} // \frac{R_1 + R_2}{1 + g_{m1} R_2} // \frac{1}{g_{m1}} = 50k // 50k // 995 // 500$

$= \underline{328\Omega}$

SORU 2

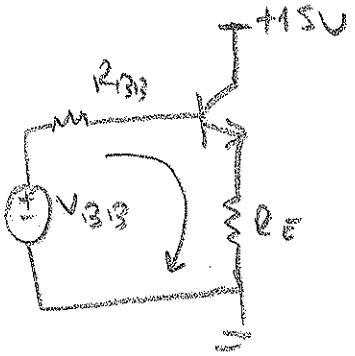
a) DC Analiz için



$\equiv$

Simetrik kurulum için

$V_E = V_{cc}/2 = 7,5V$



$$R_{BB} = \frac{R_1 R_2}{R_1+R_2}, \quad V_{BB} = \frac{V_{cc}}{R_1+R_2} \cdot R_2$$

Gevre denklemnden $V_{BB} = R_{BB} \cdot I_B + V_{BE} + R_E \cdot I_E$

$I_C = 2mA$ ise $I_B = \frac{I_C}{\beta_F} = \frac{2mA}{200} \simeq 7,6\mu A$

$I_E = I_C + I_B \simeq 2,007\,mA$

$V_{BB} = R_{BB} \cdot 7,6\mu A + 0,6V + R_E \cdot 2,007mA$

$\frac{15V}{R_1+R_2} \cdot R_2 = \frac{R_1 R_2}{R_1+R_2} 7,6\mu A + 2mA \cdot R_E + 0,6V$

$\frac{15V \cdot R_2 - R_1 R_2 \cdot 7,6\mu A}{R_1+R_2} = 0,6V + 2mA \cdot \underbrace{R_E}_{3,75k\Omega}$, $V_E = V_{cc}/2 \simeq 7,5V$

$8,1$

$\boxed{R_E = 3,75k\Omega}$

$15V \cdot R_2 - R_1 R_2 7,6\mu A = 8,1 \cdot R_1 + 8,1 \cdot 150k$

$15V \cdot 150k - 8,1 \cdot 150k = \underbrace{7,6mA \cdot 150k \cdot R_1 + 8,1 R_1}_{9,24 R_1}$

$\boxed{R_1 \simeq 112k\Omega}$

b) $\frac{v_o}{v_i} = ?$

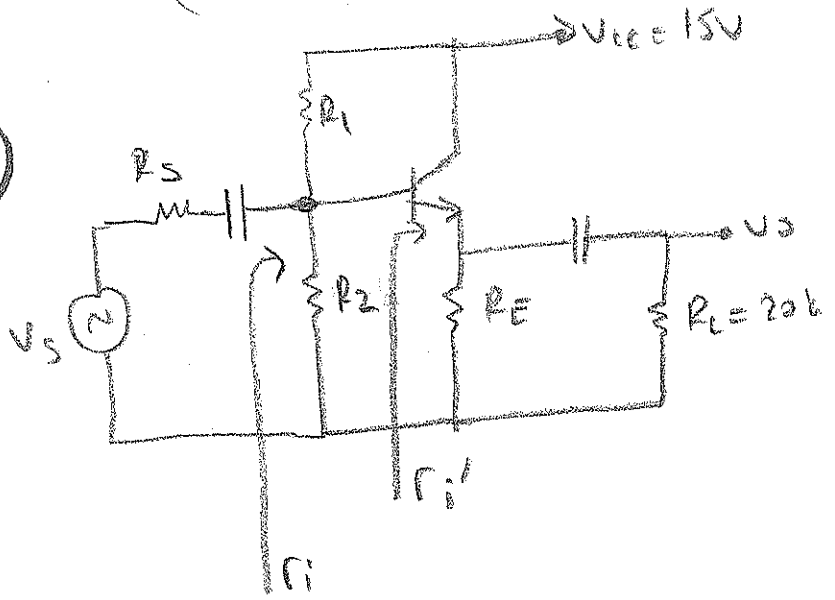
Emetor çıkışlı bir devrenin gerilim kazancı

$$\frac{v_o}{v_i} = \frac{R_e}{R_e + r_e} = \frac{(R_E \parallel R_L)}{(R_E \parallel R_L) + r_e}$$

$$r_e = \frac{V_I}{I_E} = \frac{26mV}{2mA} = 13\Omega$$

$$\frac{v_o}{v_i} = \frac{(3{,}75k \parallel 20k)}{(3{,}75k \parallel 20k) + 13\Omega} = \frac{3{,}15k}{3{,}15k + 13\Omega} \simeq 0{,}99$$

c)



$r_i = r_i' \parallel R_1 \parallel R_2 \Rightarrow r_i' = h_{fe}(R_e + r_e) = 260(3{,}15k + 13\Omega) = 822k\Omega$

$= 822k\Omega \parallel 150k\Omega \parallel 112k\Omega$ (150k ve 112k: 64kΩ)

$\simeq 59{,}3k\Omega$ → giriş direnci

$r_{out} = R_e \parallel \left(\frac{R_g' + r_e}{h_{fe}}\right)$

$R_g' = R_s \parallel R_1 \parallel R_2 \simeq 15k\Omega$ (R_s: 20k, $R_1 \parallel R_2$: 64kΩ)

$= 3{,}75k\Omega \parallel \left(\frac{15k\Omega}{260} + 13\Omega\right)$ (15kΩ/260 = 70Ω)

Tanımlanırken bazen geriye doğru bakınca görülen direnç

$r_{out} \simeq 68\Omega$

Soeu 3

$$I_D = \frac{\beta}{2}(V_{GS} - V_{th})^2$$

$$1mA = \frac{(\mu_p C_{ox} W/L)}{2}(|V_{GS}| - |V_{thn}|)^2$$

$$1mA = \frac{200cm^2/Vs \cdot 10^{-7} F/cm^2 \cdot 100}{2}[|V_{GS}| - (0,7)]^2$$

$$2mA = 2mA/V^2 [|V_{GS}| - 0,7]^2$$

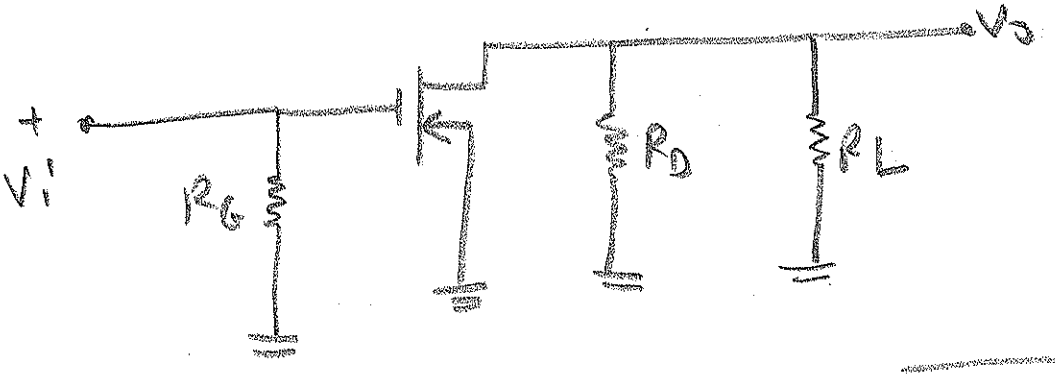
$$[|V_{GS}| - 0,7]^2 = 1V^2$$

$$|V_{GS}| - 0,7 = \pm 1V$$

$|V_{GS}| - 0,7 = 1V \Rightarrow |V_{GS}| = 1,7V \Rightarrow V_{GS} = -1,7V$ almenta

PMOS sign $V_{GS} < 0$ almenta

b)



c) $\frac{V_o}{V_i} = -g_m(R_L \| R_D) \Rightarrow$ $g_m = \sqrt{2\beta I_D} = \sqrt{2 \cdot 2mA/V^2 \cdot 1m}$

$= 2mA/V$

$$\frac{V_o}{V_i} = -2mA/V\ (12k\Omega \| 3k\Omega) = -4,8$$

d)

$|V_{DS}| = |V_{GS}| - |V_t|$ → doğrusal sınır şartı

$|V_{DS}| = 1{,}7 - 0{,}7 \Rightarrow 1 \Rightarrow V_{DS} = -1$

Gerilimlerden $V_{SD} + R_D I_D - 7V = 0 \Rightarrow V_{SD} = -R_D I_D + 7V$

$V_{DS} = R_D I_D - 7V$

$R_D I_D - 7V = -1 \Rightarrow R_D I_D = 6V$

$R_D = 6V / 1mA = \underline{\underline{6k\Omega}}$