VG-01.

1.1. $I_{DA1} = -I_{o2} = -1mA$.

$I_{DA2} = I_{o1} - I_{o2} = 5mA$.

~~Annahme in Aktive~~ Bereich. Abschnitt.

für T_1. P沟道.

~~$U_{GS} < U$~~

$U_{GS} \le U_{GS(th)}$

$U_{GD} > U_{GS(th)}$, $U_{DS} < 0$.

$I_{DA1} = -\frac{\beta}{2}(U_{GS} - U_{th})^2$.

$U_{th} = U_{th,0,p} - \gamma(\sqrt{\phi + U_{BSA1}} - \sqrt{\phi})$

其中 $U_{BSA1} = U_{DD} - U_e + U_{GSA1}$

从中解出 U_{GS}. 查看是否符合假设.

$\Rightarrow -\frac{2I_{DA1}}{\beta} = (U_{GS} - U_{th})^2$.

$U_{GS} - U_{th} = \pm\sqrt{\frac{2I_{DA1}}{\beta}}$ ← 由于 $U_{GS} < U_{th}$, 所以这里为"−"!

$U_{GS} = \pm\sqrt{\frac{2I_{DA1}}{\beta}} + U_{th,0} - \gamma(\sqrt{\phi + U_{BSA1}} - \sqrt{\phi})$

$U_{GSA1} = \pm\sqrt{\frac{2I_{DA1}}{\beta}} + U_{th,0} - \gamma(\sqrt{\phi + U_{DD} - U_e + U_{GSA1}} - \sqrt{\phi})$

$\gamma\sqrt{\phi + U_{DD} - U_e + U_{GSA1}} = -U_{GSA1} \underbrace{- \sqrt{\frac{2I_{DA1}}{\beta}} + U_{th,0} + \gamma\sqrt{\phi}}_{:= U_1}$ ← $[-(U_{GSA1} - U_1)]^2$

$\gamma^2(\phi + U_{DD} - U_e + U_{GSA1}) = U_{GSA1}^2 - 2U_{GSA1} \cdot U_1 + U_1^2$.

$U_{GSA1}^2 - (2U_1 + \gamma^2)U_{GSA1} + (U_1^2 - \gamma^2 U_{DD} + \gamma^2 U_e - \gamma^2\phi) = 0$

$\frac{2U_1 + \gamma^2}{2} \pm \frac{1}{2}\sqrt{(2U_1+\gamma^2)^2 - 4(U_1^2 - \gamma^2 U_{DD} + \gamma^2 U_e - \gamma^2\phi)}$

首先计算 U_1, $U_1 = -\sqrt{\frac{2I_{DA1}}{\beta}} + U_{th,0} + \gamma\sqrt{\phi} \approx -0.66V$.

$-0.535V \pm 0.866V$. 由于 $U_{GSA1} \overset{!}{<} -0.6$. $\Rightarrow U_{GSA1} = -1.401V$

für T_2.

$U_{GSA2} = \sqrt{\frac{2I_{DA2}}{\beta}} + U_{th,n}$. $\Rightarrow U_{GSA2} = 1.6V > 0.6V$. nicht gesperrt

$U_{th} = U_{th,0}$ ~~$+ \gamma$~~ $U_{BS} = 0$.

$U_{DSA1} = U_{DA1} - U_{SA1} = U_{GSA2} - (U_e - U_{GSA1}) = 1.6 - 2 - 1.401 = -1.801V < 0V$.

$U_{DSA2} = U_{SA1} = U_e - U_{GSA1} = 3.401V > 0 V$.

最后检验. 工作状态.

T_1: $U_{GD} > U_{th} \Rightarrow U_{DS} < U_{GS} - U_{th,p}$ ✓ 摆幅上.

T_2: $U_{GD} < U_{th} \Rightarrow U_{DS} > U_{GS} - U_{th,n}$ ✓

$I_{D6} = I_{o2} = I_{D5}$.

$I_{D4} = -I_{o1} = I_{D3}$.

$\rightarrow U_{GS4} + I_{o2} \cdot R_B + U_{GS5} = U_{DD}$.

$U_{GS5} = U_{GS6} = \sqrt{\frac{2I_{D5}}{\beta}} + U_{th,n}$.

$= 1.047V$.

$U_{GS4} = U_{GS3} = -\sqrt{\frac{-2I_{o1}}{\beta}} + U_{th,p}$

$= -1.047V$.

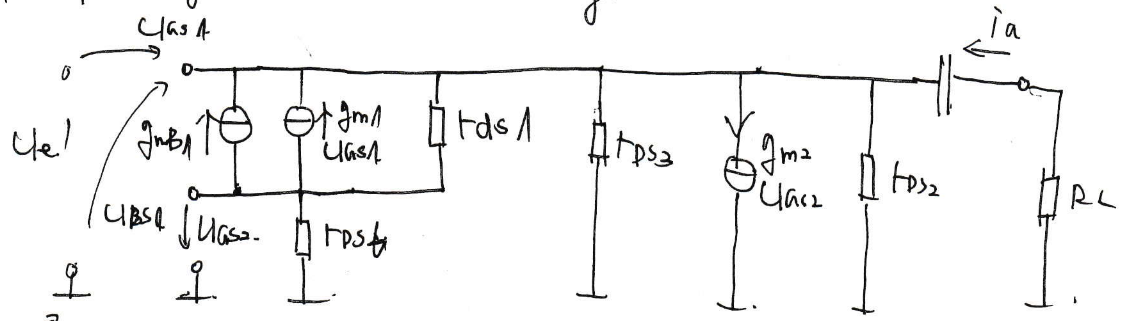
$R_B = \frac{U_{DD} + U_{GS4} - U_{GS5}}{I_{o2}}$

$= \frac{5 - 2.094}{1mA}$

$= 2.906 k\Omega$

$M = \frac{I_{o1}}{I_{o2}} = 6$.

(2) Kleinsignal - Ersatzschaltung.



可以理解为 B.

$$g_{m1} = \sqrt{-2\beta \cdot I_{DA} \cdot (1 - \lambda U_{DSA1})} \approx \sqrt{-2\beta \cdot I_{DA}} = 4.47\,mS$$

$$g_{mB1} = \frac{\gamma \cdot g_m}{2\sqrt{\phi - U_{BSA1}}} = 0.77\,mS$$

$$g_{m2} = \sqrt{2 \cdot \beta \cdot I_{DA2}} = 10\,mS$$

$$r_{DS1} = \frac{\frac{1}{\lambda} - U_{DSA}}{-I_{DA}} \approx -\frac{1}{\lambda I_{DA1}} = 40\,k\Omega$$

$r_{DS6} = r_{DS1} = 40\,k\Omega$ r_{DS3} [illegible]

输出电阻.

$$r_a = \frac{U_a'}{I_a'}\Big|_{U_e'=0}$$

① $$i_a' = \frac{U_a'}{r_{DS2}} + \frac{U_a'}{r_{DS3}} + g_{m2} U_{GS2} + U_{GS2}/r_{ds6}$$

② U_e' 短路, U_e' ⊥, $\rightarrow U_{GS1} = U_{BS1} = -U_a'$

③ $U_a' =$ ~~$g_m\, U_a'(g_{m1} + g_{mB1}) \cdot r_{DS1} + r_{DS6} \cdot U_{GS2}$~~

$$U_{GS2} + \left[(g_{mB1} + g_m)(U_a') + \frac{U_{GS2}}{r_{DS6}}\right] \cdot r_{DS1} \Rightarrow 解出\ g_m U_a'$$

~~$\rightarrow \frac{U_a'}{I_a'}$~~ $U_{GS2} + U_{GS2} \cdot \frac{r_{DS1}}{r_{DS6}} + r_{DS1} \cdot U_a'(g_{mB1} + g_m) = U_a'$

$$U_a' = \frac{U_{GS2} + U_{GS2}\left(\frac{r_{DS1}}{r_{DS6}}\right)}{1 - r_{DS1}(g_{mB1} + g_m)}$$

$I_a' =$

$$g_a = \frac{1}{r} = \frac{I_a}{U_a} = \frac{1}{r_{DS2}} + \frac{1}{r_{DS3}} + \frac{g_m U_{GS2}[1 - r_{DS1}(g_{mB1} + g_m)]}{U_{GS2}\left(1 + \frac{r_{DS1}}{r_{DS6}}\right)} + \frac{[1 + r_{DS1}(g_{mB1} + g_m)]}{r_{ds6}\left[1 + \frac{r_{DS1}}{r_{DS6}}\right]}$$

~~r_{DS2}, r_{DS3}~~

$$r = \frac{1}{\frac{1}{r_{DS2}} + \frac{1}{r_{DS3}} + \frac{g_m}{2}[1 - r_{DS1}(g_{mB1} + g_m)] + \frac{[1 + r_{DS1}(g_{mB1} + g_m)]}{2 r_{ds6}}}$$

$$r_a' = \frac{1}{\frac{1}{r_{DS2}} + \frac{1}{r_{DS3}} + \left(g_{m2} + \frac{1}{r_{DS6}}\right) \cdot \left[\frac{1 + r_{DS1}(g_{m1} + g_m)}{2}\right]}$$

$$\approx \frac{2}{g_{m2}(1 + r_{DS1}(g_{m1} + g_{mB1}))}$$

Also. $r_a' \approx \frac{2}{g_{m2} r_{DS1}(g_{m1} + g_{mB1})} = 0.542 \ [k\Omega] \approx 0.954\ k\Omega$

ms kΩ ms

Verstärkung.

$V' = \frac{U_a'}{U_e'}$

(1) $U_{BS1} = -U_a'$ $U_{GS1} = U_e' - U_a'$

$$\left[\frac{U_a' - U_{GS2}}{r_{DS1}} + g_{mB1} \cdot U_a' - g_{m1}(U_e' - U_a')\right] \cdot r_{DS6} = U_{GS2}$$

$U_a' - U_{GS2} + r_{DS6} \cdot g_{mB1} \cdot U_a' - r_{DS6} \cdot g_{m1} U_e' + g_{m1} r_{DS6} U_a' = U_{GS2}$

$U_a' + r_{DS6}(g_{mB1} + g_{m1}) U_a' - r_{DS6}\, g_{m1} U_e' = 2U_{GS2}$ ①

$\frac{U_{GS2}}{r_{DS6}} + \frac{U_a'}{R_L} + \frac{U_a'}{r_{DS2}} + \frac{U_a'}{r_{DS3}} + g_{m2} U_{GS2} = 0$ ②

$$\Rightarrow U_{GS2} = \frac{-\left[\frac{U_a'}{R_L} + \frac{U_a'}{r_{DS2}} + \frac{U_a}{r_{DS3}}\right]}{\frac{1}{r_{DS6}} + g_{m2}}$$

$$\frac{r_{DS6}\, g_{m1}}{1 + r_{DS6}(g_{mB1} + g_{m1}) + \frac{2\left[\frac{1}{R_L} + \frac{1}{r_{DS2}} + \frac{1}{r_{DS3}}\right]}{\frac{1}{r_{DS6}} + g_{m2}}} = V'$$

↑ 0.84.

减小了负载电阻对电流源影响

VG-02.

Vorlesung 的内容复习:

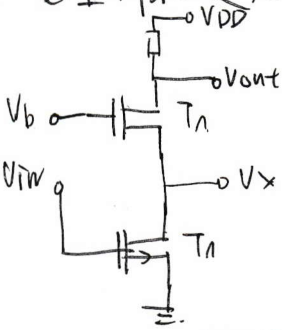
$-U_{DS}+U_{GS}=U_{th} \rightarrow U_{GD}=U_{th}$

$U_a=U_{DS2}+U_{DS4}$; $U_{DS2,sat}=U_{GS}-U_{th}=\sqrt{\frac{2I_a}{\beta}}$

$U_{DS2}=-U_{GS4}+U_{GS3}+U_{GS1}=-U_{GS4}+U_{GS3}+U_{GS2}$.

$U_{GS3}=U_{GS4} \Rightarrow U_{DS2}=U_{GS2}$.

这里联系上了共源一共栅电路



要让两个管子都工作在饱和区.

那么 $V_x \geq V_{in}-V_{th1}$, $V_x=V_b-V_{GS2} \Rightarrow V_b \geq V_{in}-V_{th}+U_{GS2}$.

$V_{out} \geq V_b-V_{th2} \Rightarrow V_{out} \geq V_{in}-V_{th2}+U_{GS2}-V_{th1}$.

在用级联电流源时 $\Delta U_{g2}=\Delta U_{D4}/[r(g_{m3}+g_{mb3})r_{o3}]$

下面我们认为 $U_{DS1}=U_{DS2}$. 对于 Vorlesung $i_{D3}=i_{D4} \Rightarrow U_{GS3}=U_{GS4}$

$U_{DS4min}=U_{DS4,sat}=\sqrt{\frac{2I_a}{\beta}}=0.316$.

$U_{amin}=U_{DS2}+U_{DS4}|_{min}=U_{GS2}+U_{DS4,min}=U_{DS2,sat}+U_{th}+U_{DS4min}$

$=\sqrt{\frac{8I_a}{\beta}}$ ~~1.23~~ V、~~(忽略 U_{th})~~ $+U_{th}=1.23V$.

$U_{DS1} \geq U_{GS1}-U_{th} \rightarrow U_{GS1} \leq U_{DS1}+U_{th} \approx U_{DS1}+U_{DS3}$ ~~$-U_{th}$~~

$\Rightarrow I_{ref}=\frac{I_a}{J} \Rightarrow \beta_J=\frac{\beta}{20}$. 由J和β的关系控制电流.

(1) $U_{amin}=U_{DS2,sat}+U_{DS4,sat}=2\cdot U_{DS,sat}=0.4V$ $U_{DS3} \neq U_{DS4}$

$U_{GSA}-U_{th}=U_{DS,sat} \Rightarrow U_{GSA}=U_{DS,sat}+U_{th}=0.8V$

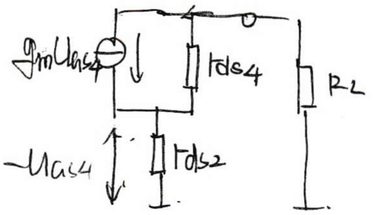
$U_{GA3,4}=U_{GSA}+U_{DS,sat}=0.8+0.2=1V$.

$R_B=\frac{U_{GA3,4}-U_{GSA}}{I_0}=\frac{U_{DS,sat}}{I_0}=\frac{0.2}{1\times10^{-4}}=2\times10^{3}=2k\Omega$. $\beta=J$.

$R_0=$ ~~...~~

$(U_{DD}-U_{GA3,4})/I_0=\frac{2}{1\times10^{-4}}=20k\Omega \Rightarrow R=R_0+R_B=22k\Omega$.

(2) 共源一共栅的输出电阻



$g_m=\frac{2I_D}{}\sqrt{2\beta I_{DA}}=\sqrt{2\cdot J\times0.1}=1mS$

$r_{DS}=\frac{1/\lambda+U_{DSA}}{I_{DA}} \approx \frac{1}{\lambda I_{DA}} \approx 250k\Omega$.

$-\frac{U_{GS4}}{r_{ds2}}=i_a$.

$\left(-\frac{U_{GS4}}{r_{ds2}}-g_mU_{GS4}\right)r_{ds4}-U_{GS4}=U_a$.

$\Rightarrow -(g_mr_{ds4}+2)U_{GS4}=U_a \Rightarrow r_o=r_{ds2}(g_mr_{ds4}+2) \approx 62.5M\Omega$

(3) $U_{GS}(T) = \sqrt{\frac{2I_D}{\beta}} + U_{th}$

$\frac{\partial U_{GS}}{\partial T}\Big|_{T=T_0} =$ ~~$\frac{\partial I_D}{\partial T}\Big|_{T=T_0} + \partial U$~~

$\frac{\partial U_{GS}(T)}{\partial I_D}\Big|_{T=T_0} \cdot \frac{\partial I_D}{\partial T}\Big|_{T=T_0} +$

$\frac{\partial U_{GS}(T)}{\partial \beta}\Big|_{T=T_0} \cdot \frac{\partial \beta}{\partial T}\Big|_{T=T_0} +$

$\frac{\partial U_{GS}(T)}{\partial U_{th}}\Big|_{T=T_0} \cdot \frac{\partial U_{th}}{\partial T}\Big|_{T=T_0}$.

其中. $I_D = I_0$ 为konst.

$\frac{\partial U_{GS}(T)}{\partial \beta} = \frac{-2I_D \cdot \frac{1}{\beta^2}}{2\sqrt{\frac{2I_D}{\beta}}}\Big|_{T=T_0} = -\frac{\sqrt{I_D}\ 1}{\beta^2\sqrt{\frac{2}{\beta I_D}}}$

$\frac{\partial \beta}{\partial T}\Big|_{T=T_0} = \frac{\beta_0}{T_0} \cdot -\frac{3}{2}\left(\frac{T}{T_0}\right)^{-\frac{5}{2}} = -\frac{3}{2}\frac{\beta_0}{T_0}$

$\frac{\partial U_{GS}}{\partial U_{th}}\Big|_{T=T_0} = 1$. $\frac{\partial U_{th}}{\partial T_0}\Big|_{T_0} = -1\,mV/K$.

$\Longrightarrow -\frac{3}{2}\frac{\beta_0}{T_0} \cdot -\frac{\sqrt{2\beta I_D}}{\beta_0^2\ 2} = +\frac{3}{4T_0}\sqrt{\frac{2I_D}{\beta_0}}$

$\frac{\partial U_{GS}}{\partial T}\Big|_{T=T_0} = \frac{3}{4T_0}\sqrt{\frac{2I_D}{\beta_0}} - 1\frac{mV}{K} = -0.5\,mV/K$.