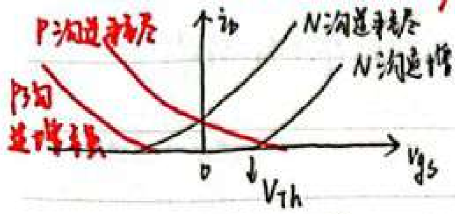
[专题三] 场效应管及放大电路

知识点1: 6种场效应管转移曲线



tips: $v_{GS}=0$时, $i_D>0$ → 耗尽型.

N沟道↗ P沟道↘

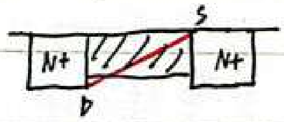
· 耗尽型: 存在导电沟道

· 增强型: 无导电沟道

△ 场效应管又称单极型晶体管, 是因为只有一种载流子参与导电过程.

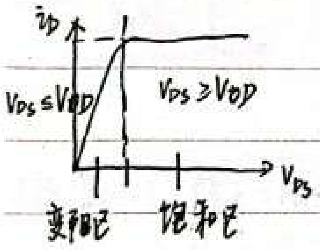
知识点2: 场效应管基本常识及工作原理.

<图解> 以耗尽型-N为例:



由黑→红, 称为预夹断.

栅极长度L, 宽度W



变阻区: $i_D=k_n'\cdot\frac{W}{L}\left[(V_{GS}-V_t)\cdot V_{DS}-\frac{1}{2}V_{DS}^2\right]$

饱和区: → 二次顶点 $\qquad V_{OD}=V_{GS}-V_t$

$$i_D=\frac{1}{2}k_n'\cdot\frac{W}{L}(V_{GS}-V_t)^2$$

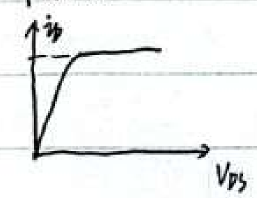
$k_n'=\mu_n\cdot C_{ox}$ (载流子导电能力) → 本质可看作电压控制电流源

△ 在饱和区, 场效应管的漏极电流仅仅取决于 多数 载流子运动产生的.

△ 作为放大管时, 应在饱和区使用

[P2-Ex.1] 解:

钳位态:



变阻区: $i_D=k_n'\cdot\frac{W}{L}\cdot\left[(V_{GS}-V_t)V_{DS}-\frac{1}{2}V_{DS}^2\right]$

饱和区: $i_D=\frac{1}{2}k_n'\cdot\frac{W}{L}\cdot(V_{GS}-V_t)^2 \qquad$ 边界 $V_{GS}-V_t=2V$

① $V_{DS}=1V$. 变阻区 $\quad\therefore i_D=0.05\times10^{-3}\times(2\times1-\frac{1}{2}\times1^2)$

$$=7.5\times10^{-5}A$$

② $V_{DS}=4V$ 饱和区: $i_D=\frac{1}{2}k_n'\cdot\frac{W}{L}\cdot(V_{GS}-V_t)^2=\frac{1}{2}\times0.05\times10^{-3}\times2^2=1\times10^{-4}A$

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知识点3：MOSFET 放大电路

小信号模型：推导见笔记，记一些常用到的：

$$\begin{cases} I_D = \frac{1}{2}k_n' \cdot \frac{W}{L} \cdot (V_{GS}-V_t)^2 \\ i_D = k_n' \cdot \frac{W}{L} \cdot v_{gs} \cdot (V_{GS}-V_t) \end{cases}$$

$g_m = \frac{i_d}{v_{gs}} = k_n' \frac{W}{L} (V_{GS}-V_t)$　代入 $I_D = \frac{1}{2}k_n' \cdot \frac{W}{L} \cdot (V_{GS}-V_t)^2$

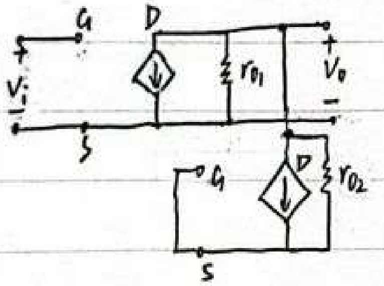
有 $g_m = \frac{I_D}{\frac{1}{2}(V_{GS}-V_t)}$

[P3 - Ex.1] 解：

先算静态：$r_{o1} = r_{o2} = \frac{V_A}{I_D} = \frac{50}{200\times10^{-6}}\ \Omega = 250k\Omega$

$g_{m1} = \frac{I_D}{\frac{1}{2}(V_{GS}-V_t)} = k_n' \cdot \frac{W}{L} \cdot (V_{GS}-V_t) = k_n' \cdot \frac{W}{L} \cdot \sqrt{\frac{2I_D}{k_n' \cdot \frac{W}{L}}} = \sqrt{2I_D \cdot k_n' \cdot \frac{W}{L}} = \sqrt{2\times200\times10^{-6}\times20\times10^{-6}\times1} = 4\sqrt{10}\times10^{-5}$

画小信号：



$R_o = r_{o1} \,//\, r_{o2} = 125k\Omega$

$A_v = \frac{-g_{m1} v_{gs} R_o}{v_{gs}} = -4\sqrt{10}\times10^{-5}\times125\times10^3 = \underline{-15.8}$

[P3 - Ex.2] 解：

静态分析：$I_D = \frac{1}{2}k_n' \cdot \frac{W}{L} \cdot (V_{GS}-V_t)^2$

$v_I = 7V$.　$\underline{v_{GS} = 7 - I_D \cdot R_S}$　∴ $\frac{1}{2} \cdot 0.2\times5\times(6-10I_D)^2 = I_D$

∴ $100i^2 - 120i + 36 = 2i \Rightarrow 50i^2 - 61i + 18 = 0$

$I_{D1} = 0.72mA$　$I_{D2} = 0.5mA$

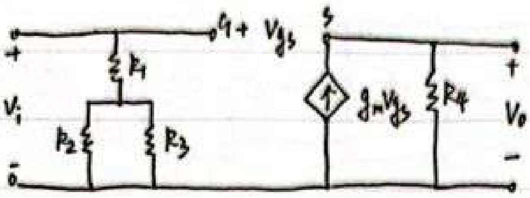
检验饱和区，即 $V_{GS} > V_t$ 且 $V_{DS} > V_{GS} - V_t$

$$\left.\begin{cases} 7 - 10I_D > 1 & \Rightarrow I_D < 0.6mA \\ 15 - 20I_D > 6 - 10I_D & \Rightarrow I_D < 0.9mA \end{cases}\right\} \Rightarrow I_D < 0.6mA$$

故取 $I_D = 0.5mA$

[P3-Ex.3]

画小信号:

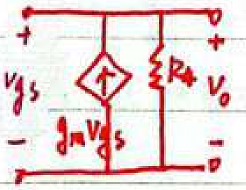


解: $A_u=\dfrac{V_o}{V_i}=\dfrac{g_mV_{gs}R_4}{g_mV_{gs}R_4+V_{gs}1}=\dfrac{0.9\times12}{0.9\times12+1}=0.915$

$R_i=(R_1+R_2/\!/R_3)/\!/\cancel{\left[\dfrac{1}{g_m}+\dfrac{g_mV_{gs}\cdot R_4}{\left(\dfrac{V_{gs}+g_mV_{gs}R_4}{R_1+(R_2/\!/R_3)}\right)}\right]}$ 唉唉.输出回路部分比例别管!

$R_i=R_1+R_2/\!/R_3$

R_o:



$R_o=\dfrac{V_o}{\dfrac{V_o}{R_4}+g_mV_o}=\dfrac{1}{g_m+\dfrac{1}{R_4}}$

[P3-Ex.5] 静态工作点?

$I_D=\frac{1}{2}k_n'\cdot\frac{W}{L}(V_{gs}-V_t)^2$ $V_D=V_{cc}-I_DR$ $\frac{1}{2}k_n'\cdot\frac{W}{L}=\frac{1}{2}\cdot0.4\times10^{-3}\times4=0.8\times10^{-3}$

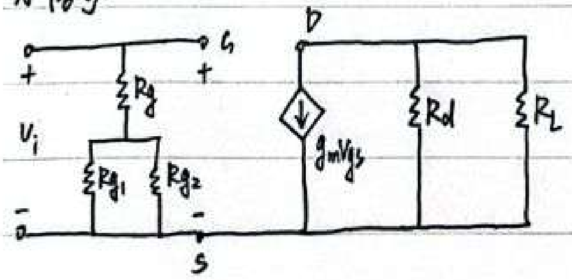
$V_{gs}=V_{DS}=0.7$ $\therefore 1.8-0.8(V_{DS}-0.5)^2R=V_{DS}$

$\Rightarrow 1.8-0.8\times0.2^2\cdot R=0.7$ $R=\dfrac{1.1}{0.8\times0.2^2}=\underline{34.375\,k\Omega}$

[P3-Ex.6]

电路(a):

小信号:



$A_v=\dfrac{-g_mV_{gs}(R_d/\!/R_L)}{V_{gs}}$

$=-g_m(R_d/\!/R_L)=-5.1$

$R_i=R_g+R_{g1}/\!/R_{g2}$

$=5000+47.33=5047\,k\Omega$

$R_o=R_d=5.1\,k\Omega$.

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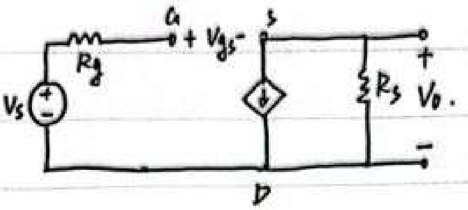
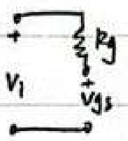
电路(b):

小信号:



$$A_v = \frac{V_o}{V_i} = -\frac{g_m V_{gs} R_s}{V_{gs} + g_m V_{gs} R_s} = -\frac{2\times2}{1+2\times2} = -0.8$$

R_i



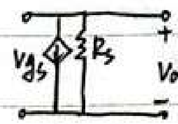
$$R_i = \frac{V_i}{\frac{V_i - V_{gs}}{R_g}} = \frac{V_{gs}' + g_m V_{gs}' R_s}{\frac{g_m V_{gs} R_s}{R_g}} = \frac{1+2\times10^{-3}\times2\times10^{3}}{2\times10^{-3}\times2\times10^{3}} \times 10\times10^{6}\ \Omega$$

$$= 12.\cancel{5\mathrm{M}}\Omega$$

$R_i = \infty$

真TM理解不了,硬记了!

R_o:



$$R_o = \frac{V_o}{\frac{V_o}{R_s} + g_m \cdot V_o} = \frac{1}{\frac{1}{R_s} + g_m} = 400\Omega$$