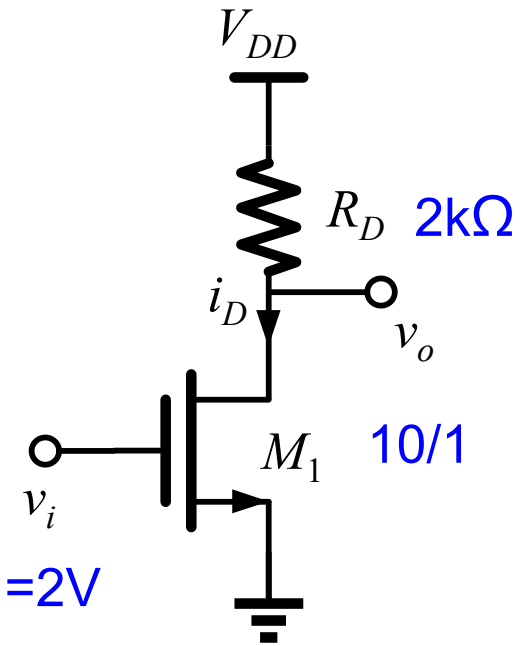
CMOS共源放大电路
手工求解

无源电阻负载
NMOS共源放大电路

OP仿真结果

subckt	
element	0:m1
model	0:n08
region	Saturati
id	1.0701m
ibs	0.
ibd	-28.5986f
vgs	2.0000
vds	2.8599
vbs	0.
vth	700.0000m
vdsat	1.3000
vod	1.3000
beta	1.2664m
gam eff	400.0000m
gm	1.6463m
gds	38.4091u
gmb	393.5324u
cdtot	2.2910f
cgtot	21.1559f
cstot	18.1174f
cbtot	747.3930a
cgs	18.1174f
cgd	2.2910f



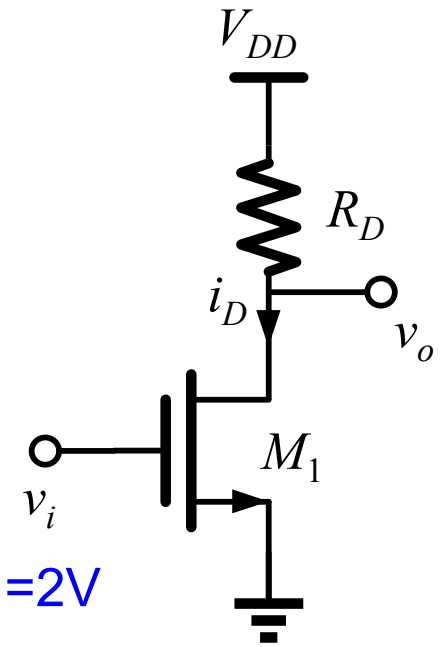
直流工作点计算

- 饱和区电流公式

$$I_D = \frac{\mu_0 C_{ox}}{2}\frac{W}{L}(V_{GS} - V_T)^2$$

$$I_D = \frac{110U}{2}\frac{10U}{1U}(2-0.7)^2 = 929.5U$$

$$v_o = 5 - 929.5U \times 2k = 3.141V$$

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+ PHI = 0.7 MJ = 0.5 MJSW = 0.38 CGBO = 700P CGSO = 220P CGDO = 220P
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.MODEL p08 PMOS VTO = -0.70 KP = 50U GAMMA = 0.57 LAMBDA = 0.05
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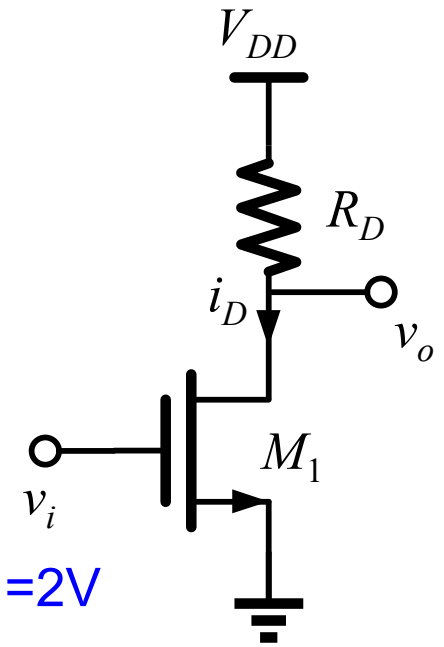
直流工作点计算

- 饱和区电流公式

$$I_D = \frac{\mu_0 C_{ox}}{2}\frac{W}{L}(V_{GS}-V_T)^2(1+\lambda V_{DS})$$

$$\left.\begin{aligned} I_D &= \frac{110U}{2}\frac{10U}{1U}(2-0.7)^2(1+0.04v_o) \\ v_o &= 5 - I_D \times 2k \end{aligned}\right\}$$

$$\Rightarrow v_o = 2.9236V, I_D = 0.001A$$

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二元方程Matlab辅助求解

$$\left.\begin{aligned} I_D &= \frac{110U}{2}\frac{10U}{1U}(2-0.7)^2(1+0.04v_o) \\ v_o &= 5 - I_D \times 2k \end{aligned}\right\}$$

$$\Rightarrow v_o = 2.9236V, I_D = 0.001A$$

```
>> syms Id Vo;
>> [sId sVo]=solve(Id==110e-6/2*10*1.3^2*(1+0.04*Vo), Vo==5-Id*2e3)

sId =

1714624861651303/1651536996919216168


sVo =

603554407661684355/206442124614902021
```

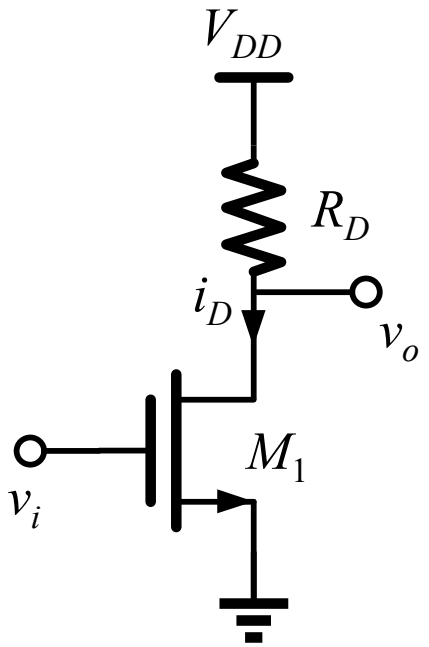
```
>> 1714624861651303/1651536996919216168

ans =

   0.0010

>> 603554407661684355/206442124614902021

ans =

   2.9236
```

小信号等效参数计算

- 跨导公式

$$g_m = \left.\frac{\partial I_D}{\partial V_{GS}}\right|_Q = \mu_0 C_{ox}\frac{W}{L}(V_{GS} - V_T)$$

$$g_m = 110U\frac{10U}{1U}(2 - 0.7) = 1.43m$$

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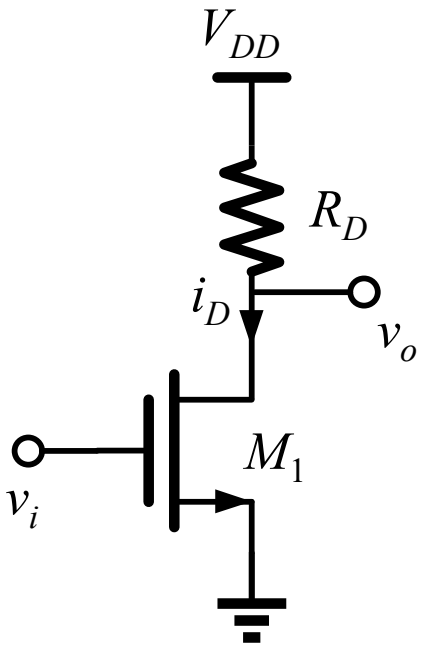
小信号等效参数计算

- 输出电导公式

$$g_{ds} = \left.\frac{\partial I_D}{\partial V_{DS}}\right|_Q$$

$$= \lambda \frac{\mu_0 C_{ox}}{2} \frac{W}{L} (V_{GS} - V_T)^2 \approx \lambda I_{DQ}$$

$$g_{ds} = 0.04 \times \frac{110U}{2} \frac{10U}{1U} (2 - 0.7)^2 = 37.18U$$

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增益计算(略)

- 增益公式

$$A_v = -g_m \left(r_{ds} \parallel R_D \right)$$

直流工作点计算

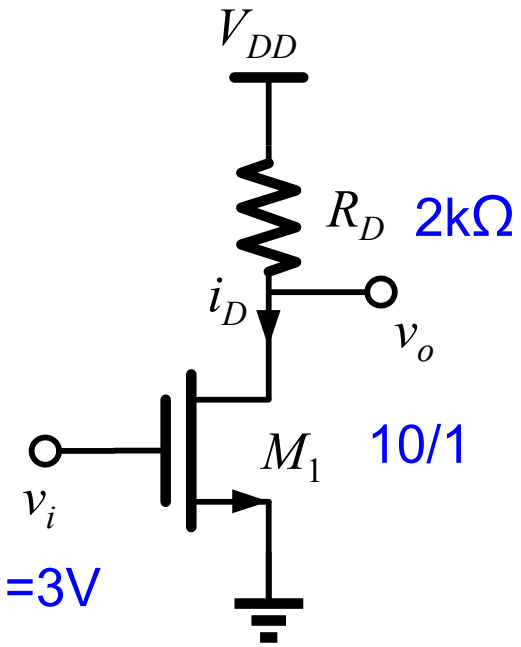
- 饱和区电流公式

$$I_D = \frac{\mu_0 C_{ox}}{2}\frac{W}{L}(V_{GS}-V_T)^2(1+\lambda V_{DS})$$

$$\left.\begin{aligned} I_D &= \frac{110U}{2}\frac{10U}{1U}(3-0.7)^2(1+0.04v_o) \\ v_o &= 5-I_D\times 2k \end{aligned}\right\}$$

$$\Rightarrow v_o = -0.6644$$

与饱和区矛盾

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直流工作点计算

- 改用线性区电流公式

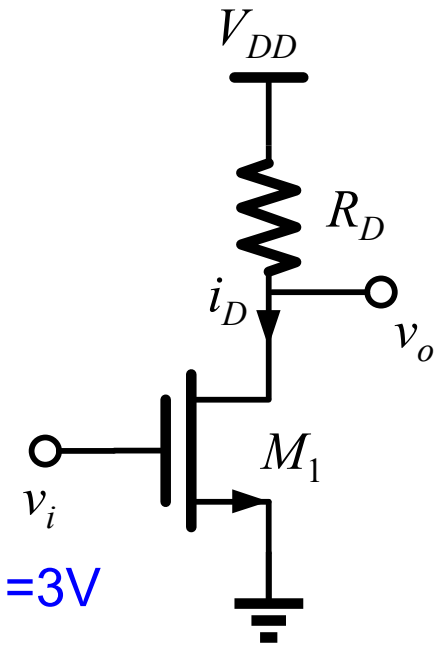
$$I_D = \mu_0 C_{ox} \frac{W}{L}\left[(V_{GS}-V_T)V_{DS} - \frac{V_{DS}^2}{2}\right]$$

$$I_D = 110U \frac{10U}{1U}\left((3-0.7)v_o - \frac{v_o^{\,2}}{2}\right)$$

$$v_o = 5 - I_D \times 2k$$

$$\Rightarrow v_o = 1.0104$$

另1个解舍去

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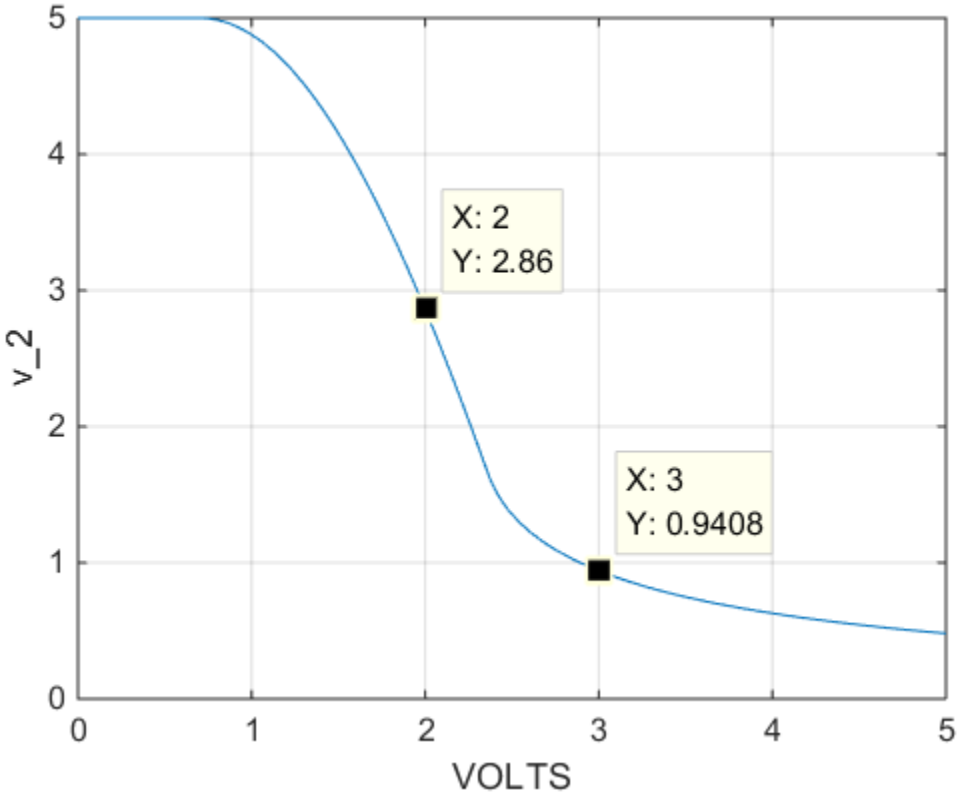
直流转移特性（仿真结果）



有源负载
NMOS共源放大电路

PMOS二极管负载

与仿真结果的比较留作练习

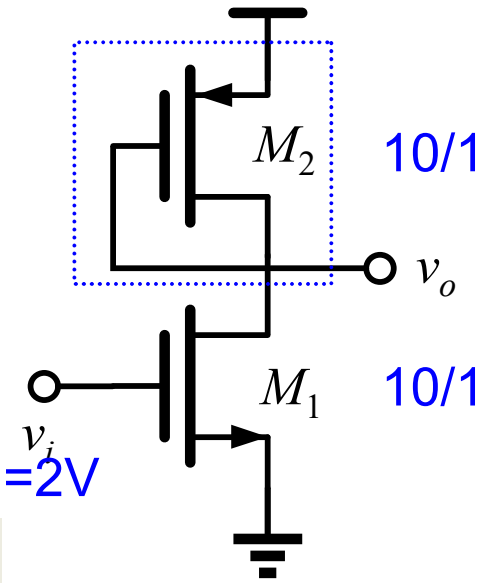
- 直流工作点计算

$$I_D = \frac{\mu_0 C_{ox}}{2}\frac{W}{L}(V_{GS}-V_T)^2\left(1+\lambda V_{DS}\right)$$

$$\left.\begin{aligned} I_D &= \frac{110U}{2}\frac{10U}{1U}(2-0.7)^2(1+0.04v_o) \\ I_D &= \frac{50U}{2}\frac{10U}{1U}(5-v_o-0.7)^2(1+0.05(5-v_o)) \end{aligned}\right\}$$

$$\Rightarrow v_o = 2.4009V, I_D = 0.001A$$

另2个解舍去

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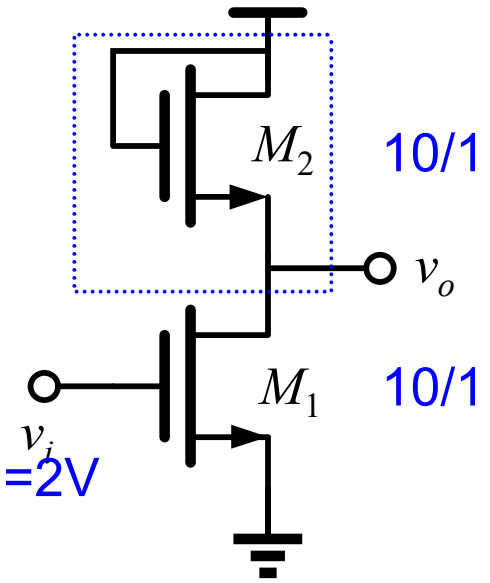
NMOS二极管负载

- 直流工作点计算

$$I_D = \frac{\mu_0 C_{ox}}{2}\frac{W}{L}(V_{GS} - V_T)^2\left(1 + \lambda V_{DS}\right)$$

留作练习

M2存在背栅效应，手工计算时建议忽略

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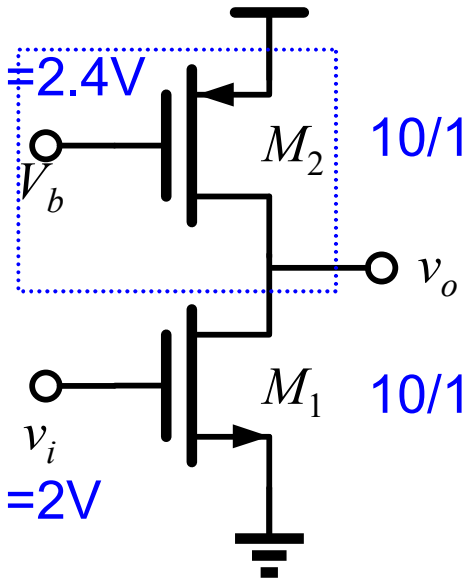
PMOS电流源负载

- 直流工作点计算

$$I_D = \frac{\mu_0 C_{ox}}{2}\frac{W}{L}(V_{GS} - V_T)^2\left(1 + \lambda V_{DS}\right)$$

留作练习

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