学号 PB21511897 姓名 李宵奕 成绩 9'

小测 1

1. 写出以下情况中 NMOS 所在的工作区域及过驱动电压（$\mu_n C_{ox} = 400uA/V^2$，$V_{th} = 0.7V$，忽略体效应影响）：
   a) $V_{GS} = 5V$，$V_{DS} = 5V$
   b) $V_{GS} = 2.5V$，$V_{DS} = 1V$
   c) $V_{GS} = 1.5V$，$V_{DS} = -1.5V$
   d) $V_{GS} = 0.3V$，$V_{SD} = 0.7V$

3'

???

a) 饱和区. $V_{osat} = 5-0.7 = 4.3V$.

b) 三极管 $V_{osat} = 2.5-0.7 = 1.8V$

c) ~~饱和区 $V_{osat} = 1.5-0.7 = 0.8V$~~

1.5V G D=−1.5V S=0V ⇒ S=−1.5V =1.5V D=0V

$V_{GS} = 3V$

$V_{DS} = 1.5V$

$V_{osat} = 3-0.7 = 2.3V$

三极管区

d) 截止区 无过驱动电压

0.3V D −0.7V S 0V ⇒ 1 0 0.7 ⇒ 1 0.7 0 饱 $V_{osat} = V_{GS} - 0.7 = 0.3V$

2. 假设 $V_{th} = 0.7V$，$\mu_n C_{ox}(\frac{W}{L}) = 1mA/V^2$ 的 NMOS 工作在饱和区。如果电流 $I_D = 20uA$，计算需要的V_{GS}的值以及最小需要的V_{DS}。

饱和区有：$\begin{cases} I_D = \frac{1}{2}\beta V_{osat}^2 \\ \beta = \mu_n C_{ox}\frac{W}{L} = 1mA/V^2 \end{cases}$

$\therefore V_{osat} = 0.2V$

$V_{GS} = V_{osat} + V_{TH} = 0.9V$

$V_{DS} \geq V_{osat} = \cancel{0.9V}\ 0.2V$

3'

1. d). $V_S = 0V$ $V_G = 0.3V$ $V_D = -0.7V$

⇒ 0.3V −0.7V 0.3V

⇒ 1V 0V 0.7V

⇒ 1V 0.7V 0V

⇒ $V_{GS} = 1V$

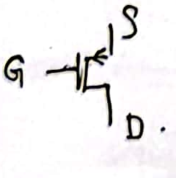
$V_{DS} = 0.7V$

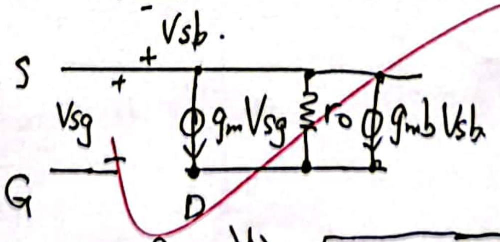
$V_{Dsat} = V_{GS} - V_{TH} = 1-0.7 = 0.3V$

饱和区

3'

3. 画出 PMOS 的小信号模型，$\lambda \neq 0$，$\gamma \neq 0$，不考虑电容





$\begin{cases} g_m = \sqrt{2\mu_p C_{ox}\frac{W}{L} I_D} \\ r_o = \frac{1}{\lambda I_D} \\ g_{mb} = \eta g_m = \frac{\gamma}{2\sqrt{2\Phi_F + V_{SB}}} g_m \end{cases}$

扫描全能王 创建

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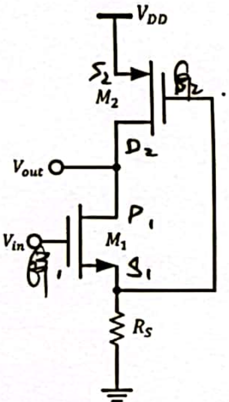
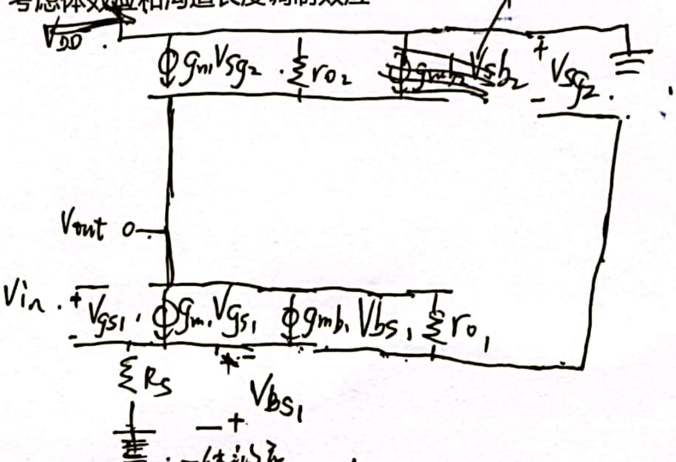
小测二

3'

1、画出下图的小信号模型，考虑体效应和沟道长度调制效应



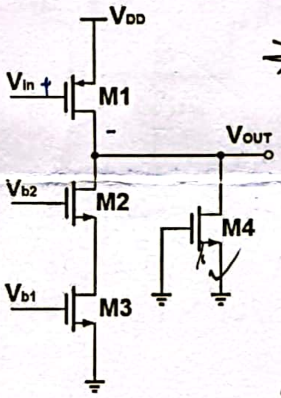


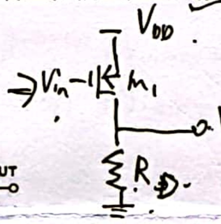
$V_{sb_2}=0$. 无体效应.

1'

2、计算下图电路的电压增益和输出阻抗（$\gamma=0$、$\lambda\neq0$）有 r_o.

无体效应





$R_{out}=R_D // r_{o_1} = r_{o1}//r_{o4}//[r_{o3}(1+g_{m2}r_{o2})+r_{o2}]$

$I = g_{m_1}V_{in}$.

$A_V=\frac{I R_{out}}{V_{in}} = -g_{m_1}(R_D // r_{o_1})$.

$R_D = r_{o4}//[r_{o3}(1+g_{m_2}r_{o2})+r_{o2}]$.

$A_V = -g_{m_1} r_{o1}//r_{o4}//[r_{o3}(1+g_{m2}r_{o2})+r_{o2}]$.

$A_V = -g_{m_1}R_{out}$.

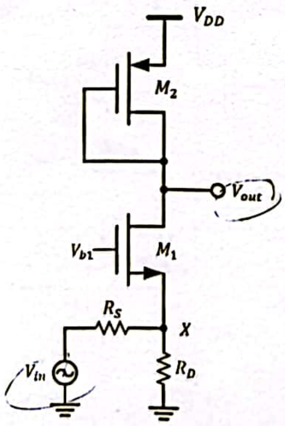
$R_{out} = r_{o1}//[r_{o2}+r_{o3}(1+g_{m_2}r_{o2})]$

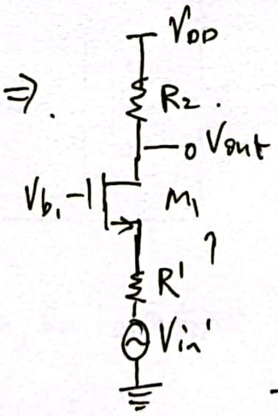
原因: M_4处于截止区关断. 电阻无穷大

4'

3、计算下图电路的等效跨导和输出阻抗（$\gamma=0$、$\lambda\neq0$）

$g=\frac{I}{V}$





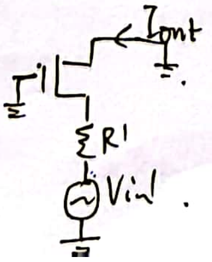
$R_2 = r_{o_2}//\frac{1}{g_{m_2}}$.

$R' = R_S // R_D$.

$V_{in}' = \frac{R_D}{R_D+R_S}V_{in}$.

$R_{out} = R_2 // [R'(1+g_{m_1}r_{o_1})+r_{o_1}]$

$\cancel{\frac{V_{out}}{V_{in}'} = \frac{R_2}{R'+\frac{R_2+r_{o1}}{1+g_{m_1}r_{o_1}}}}$



$G_m = \frac{I_{out}}{V_{in}} = \frac{I_{out}}{V_{in}'}\cdot\frac{V_{in}'}{V_{in}}$

$= \frac{-1}{R'+\frac{r_{o1}}{1+g_{m_1}r_{o_1}}}\cdot\frac{R_D}{R_D+R_S}$.

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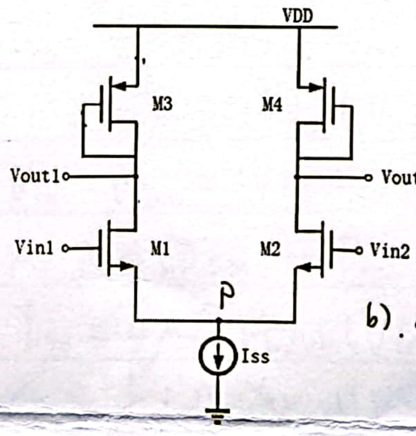
4'

小测三

1、设 $\mu_n C_{ox} = 2\times\frac{10^{-4}F}{V}\cdot S$, $\mu_p C_{ox} = 4\times\frac{10^{-4}F}{V}\cdot S$, $V_{DD} = 3\,V$, $V_{th} = 0.7\,V$, $I_{SS} = 0.5mA$, $(\frac{W}{L})_{1,2} = \frac{2.5}{0.5}$ 。

a）求最大差模输入电压范围。（2 分）

b）求当 V_{th1} 比 V_{th2} 大70 mV时的最大差模输入电压范围。（3 分）



a) Vin max时 一边刚好关断 一边刚好要进入线性区.

$V_{in2} = V_P + V_{TH}$

$V_{in1} - V_{TH} = V_{DD} - |V_{DS3}| = V_{DD} - |V_{GS3}|$

$\cancel{\Delta V_{inmax}}$ $V_P = V_{in1} - V_{GS1}$

$I_{SS} = (V_{GS1} - V_{TH})^2 \frac{1}{2}\mu_n C_{ox}\frac{W}{L} = (|V_{GS3}| - V_{TH})^2 \frac{1}{2}\mu_p C_{ox}\frac{W}{L}$

$\Delta V_{inmax} = V_{in1} - V_{in2} = V_{GS1} - V_{TH} = 1.7 - 0.7 = 1V$

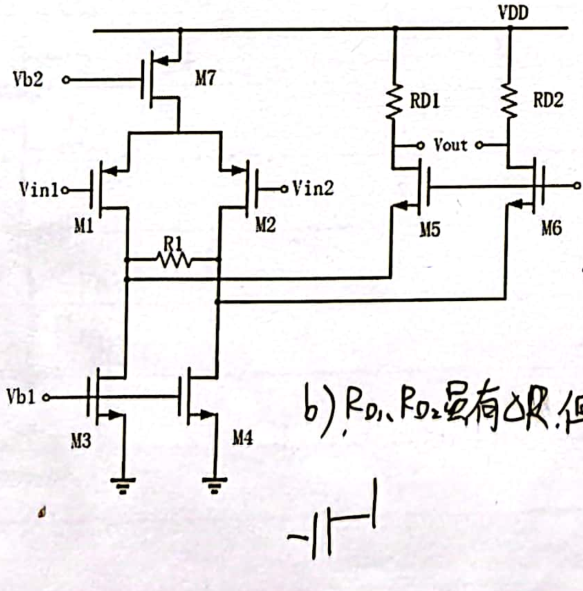
b) $\Delta V_{inmax} = V_{in1} - V_{in2} = V_{in1} - V_{in1} + V_{GS1} - V_{TH2}$

$= 1 + V_{TH1} - V_{TH2} = 1.07V$

2 、下面所示电路，不考虑体效应。$\gamma = 0$

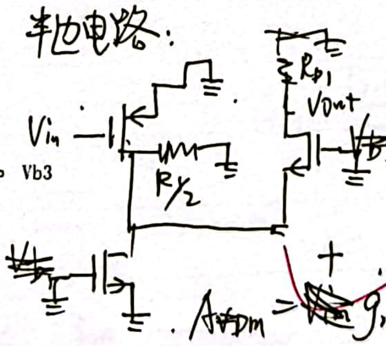
a) $\lambda = 0$, $R_{D1} = R_{D2}$ ，求差动电压增益。（2 分）　$\gamma_0 = \infty$

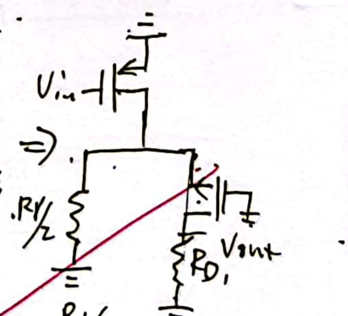
b) 只考虑$M7$沟道长度调制效应，$R_{D1} - R_{D2} = \Delta R$，求$A_{CM-DM}$（3 分）



a) ~~M_7, M_3, M_4为电流源~~.

半边电路:





$A_{DM} = g_{m1} \frac{R_1/2}{R_1/2 + \frac{1}{g_{m5}}} R_{D1}$

b) R_{D1}、R_{D2}虽有ΔR,但电流源不受影响,仍可半边电路.

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小测三 1. a) 由 Razavi P99.

$$\Delta V_{in1} = \sqrt{\frac{2I_{SS}}{\mu_n C_{ox}(\frac{W}{L})_{1,2}}} = 1V.$$

∴差模输入范围 -1V~1V.

b). M_1 占全部 I_{SS}. M_2 截止:

$$I_{SS} = \frac{1}{2}\mu_n C_{ox}(\frac{W}{L})_{1,2}(V_{in1} - V_{TH} - \Delta V_{TH} - V_p)^2$$

$$0 = \frac{1}{2}\mu_n C_{ox}(\frac{W}{L})_{1,2}(V_{in2} - V_{TH} - V_p)^2$$

$$V_{in1} - V_{in2} = 1V + \Delta V_{TH} = 1.07V.$$

M_2 占全部 I_{SS}. M_1 截止.

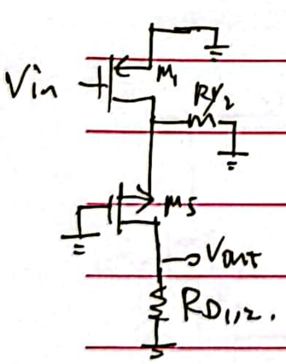
$$I_{SS} = \frac{1}{2}\mu_n C_{ox}(\frac{W}{L})_{1,2}(V_{in2} - V_{TH} - V_p)^2$$

$$0 = \frac{1}{2}\mu_n C_{ox}(\frac{W}{L})_{1,2}(V_{in1} - V_{TH} - \Delta V_{TH} - V_p)^2$$

$$V_{in1} - V_{in2} = 1 - \Delta V_{TH} = -0.93V.$$

∴差模输入范围 -0.93V~1.07V.

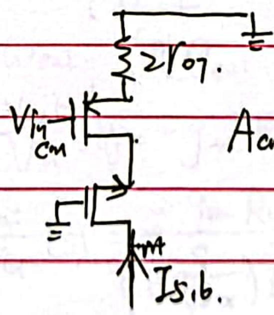
2. a) 半边差模电路.



$$A_v = g_{m1,2} \frac{R/2}{R/2 + \frac{1}{g_{m5,6}}} R_{D1,2}.$$

b). 流过 M_5, M_6 电流相同.

半边共模电路:



$$G_m = \frac{I_{5,6}}{V_{inCM}} = \frac{1}{2r_{o7} + \frac{1}{g_{m1,2}}}$$

$$A_{CM-DM} = \frac{V_{out}}{V_{inCM}} = -G_m \Delta R = -\frac{\Delta R}{2r_{o7} + \frac{1}{g_{m1,2}}}$$

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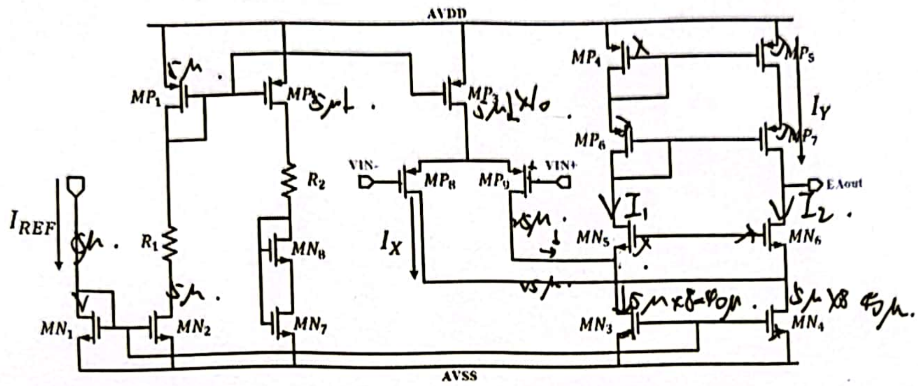
第四次小测

1. 放大器电路图及部分 MOS 管的尺寸比例如图所示，假设I_{REF}为 5uA，计算：
   a) I_X，I_Y电流大小
   b) 仅考虑MP_4~MP_7、MN_3~MN_6的沟道长度效应，写出该放大器的增益

4'



$\frac{W}{L}$ $MN_1{:}MN_2{:}MN_3{:}MN_4 = 1{:}1{:}8{:}8$ $MP_1{:}MP_2{:}MP_3 = 1{:}1{:}10$

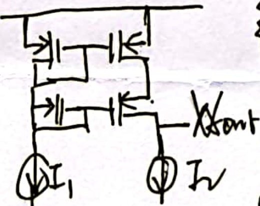
a). $I_X = 5\mu A \times 1 \times 10 \times \frac{1}{2} = \cancel{50}\ 25\mu A$.

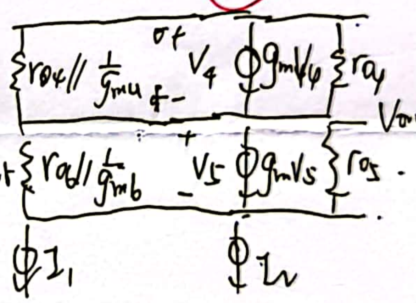
$I_Y = 5\mu \times 8 - I_X = 40\mu - 25\mu = 15\mu A$.

近似解: $A_V = g_{m8,9}(g_{m6,7}r_{o6,7}r_{o4,5} \parallel g_{m5,6}r_{o5,6}r_{o3,4})$.

第一级: b). $\frac{I_1 - I_2}{V_{in}^+ - V_{in-}} = + g_{m8,9}$.
$= g_{m8,9}$

第二级:





2. 假设$\gamma = 0$，$\lambda = 0$，
   a) 列出 X、Y、V_{out} 节点的对地电容。
   b) 列出在该三个节点处的极点表达式。
   c) 列出该电路在密勒近似下的传输函数 $\frac{V_{out}}{V_{in}}(s)$（利用低频增益和极点估算）。

$A_{V stage1} = -\frac{g_{m1}}{g_{m2}}$

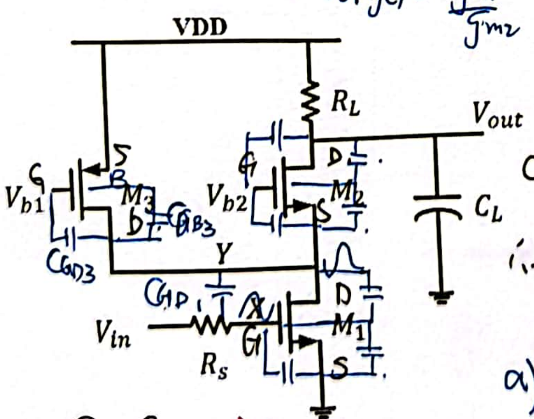
$\omega_Y = \left[\frac{1}{g_{m2}}\left[C_Y + C_{GD}\left(1+\frac{g_{m2}}{g_{m1}}\right)\right]\right]^{-1}$

2'

$\omega_{out} = (R_L C_{out})^{-1}$.

c) $\frac{V_{out}}{V_{in}}(0) = -g_{m1}R_L$.

$\therefore \frac{V_{out}}{V_{in}}(s) = \frac{-g_{m1}R_L}{\left(1+\frac{s}{\omega_X}\right)\left(1+\frac{s}{\omega_Y}\right)\left(1+\frac{s}{\omega_{out}}\right)}$.



a) $C_X = C_{GS1} + \left(1+\frac{g_{m1}}{g_{m2}}\right)C_{GD1}$

$C_Y = C_{GS2} + C_{SB2} + C_{DB1} + C_{GD3} + C_{GB3} + \left(1+\frac{g_{m2}}{g_{m1}}\right)C_{GD1}$

$C_{out} = C_L + C_{GD2} + C_{DB2}$.

b) $\omega_X = [R_S C_X]^{-1}$

$\omega_Y = \left[\frac{C_Y}{g_{m2}}\right]^{-1}$

$\omega_{out} = [R_L C_{out}]^{-1}$.

$\frac{V_{out}}{V_{in}}(s) = \frac{-g_{m1}R_L}{\left(1+\frac{s}{\omega_X}\right)\left(1+\frac{s}{\omega_Y}\right)\left(1+\frac{s}{\omega_{out}}\right)}$

a). $C_X = C_{GS1}$

$C_Y = C_{GS2} + C_{SB2} + C_{DB1} + C_{GD3} + C_{DB3}$.

$C_{out} = C_L + C_{GD2} + C_{DB2}$.

b). $\omega_X = \left\{R_S\left[C_X + C_{GD}\left(1+\frac{g_{m1}}{g_{m2}}\right)\right]\right\}^{-1}$

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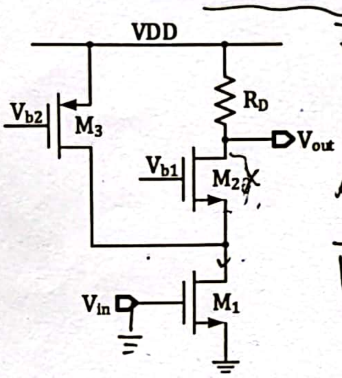
小测五

1. 求下图电路的输入参考热噪声电压，不考虑沟道长度调制效和体效应。（4 分）



$$\overline{V_{nout}^2} = \left(\frac{4kT}{R_D} + 4kT\gamma g_{m1} + 4kT\gamma g_{m3}\right) R_D^2$$

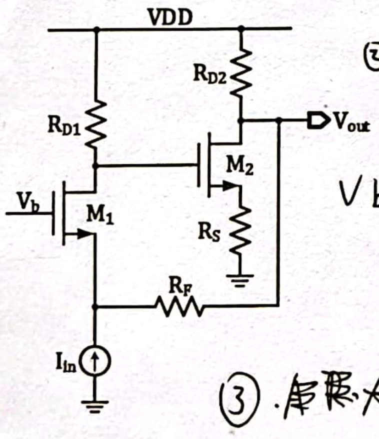
$$= 4kTR_D\left(1 + \gamma(g_{m1}+g_{m3})R_D\right)$$

$$A_v = \frac{V_{out}}{V_{in}} = -g_{m1}R_D$$

$$\overline{V_{nin}^2} = \frac{\overline{V_{nout}^2}}{A_v^2} = \frac{4kT}{g_{m1}^2 R_D}\left[1 + \gamma(g_{m1}+g_{m3})R_D\right]$$

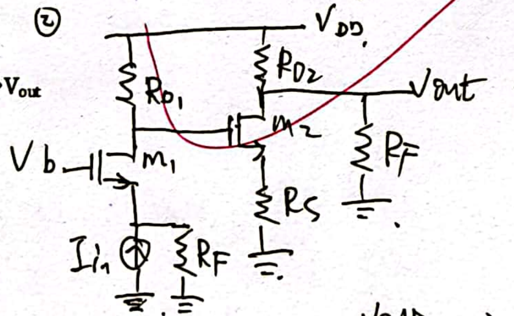
$$= \frac{4kT}{g_{m1}^2 R_D} + \frac{4kT\gamma(g_{m1}+g_{m3})}{g_{m1}^2}$$

2. 不考虑沟道长度调制效和体效应：
① 指出下图电路的反馈类型。（1 分）
② 画出考虑反馈网络的加载效应后的开环电路图。（2 分）
③ 求闭环跨阻。（3 分）



① 电压-电流反馈

②



③ $A_{ropen} = \frac{V_{out}}{I_{in}} = \frac{-R_F}{R_F + \frac{1}{g_{m1}}} R_{D1} \frac{R_{D2}//R_F}{R_S + \frac{1}{g_{m2}}}$

$\beta_g = \frac{-1}{R_F}$

$$A_{rclosed} = \frac{A_{ropen}}{1+\beta_g A_{ropen}} = \frac{-R_F R_{D1}(R_{D2}//R_F)}{(R_F + \frac{1}{g_{m1}})(R_S + \frac{1}{g_{m2}}) + R_{D1}(R_{D2}//R_F)}$$