ECEn 340 Equations, Prof. Chiang

Equations

$I_D = I_s e^{\frac{V_D}{V_T}}$

$I_E = I_B + I_C$

$I_C = \beta I_B$

$I_C = I_s e^{\frac{V_{BE}}{V_T}}$

$I_C = I_s e^{\frac{V_{BE}}{V_T}} \left(1 + \frac{V_{CE}}{V_A}\right)$

$g_m = I_C / V_T$

$r_o = V_A / I_C$

$\beta = g_m r_\pi$

$I_D = \frac{1}{2}\mu C_{ox}\frac{W}{L}\left[2\left(V_{GS} - V_{th}\right)V_{DS} - V_{DS}^2\right]$

$I_D = \frac{1}{2}\mu C_{ox}\frac{W}{L}\left(V_{GS} - V_{th}\right)^2$

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

$g_m = \mu C_{ox}\frac{W}{L}\left(V_{GS} - V_{th}\right)$

$g_m = \sqrt{2\mu C_{ox}\frac{W}{L} I_D}$

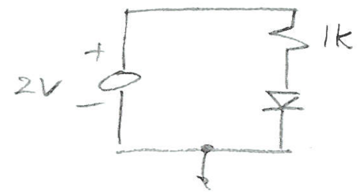
$g_m = 2I_D / \left(V_{GS} - V_{th}\right)$

$r_o = 1 / \left(\lambda I_D\right)$

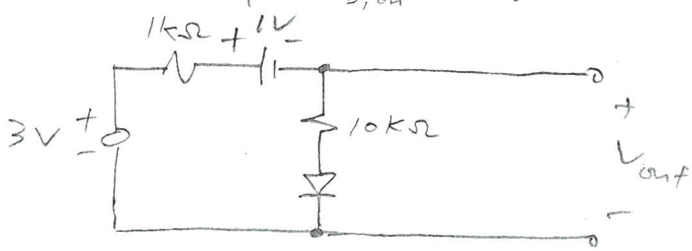
ECEn 340 Practice Midterm 2

Chiang

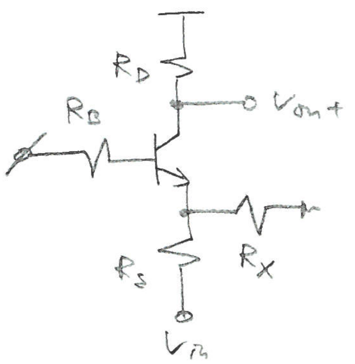
1. Assume the volt. across the diode when it is on is 0.8V. Find I_s



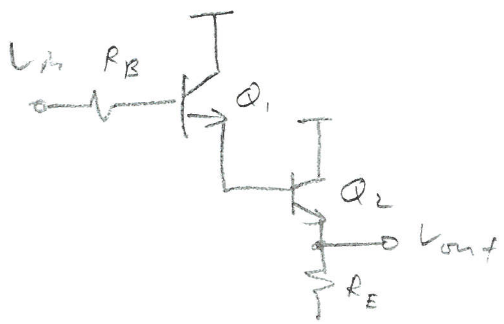
2. Find V_{out}. $V_{D,on} = 0.8V$



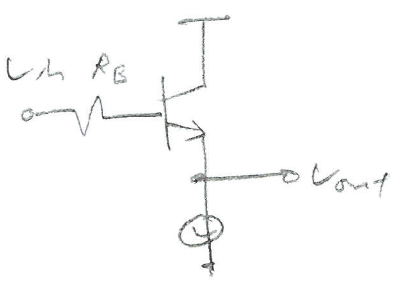
3. Find the gain



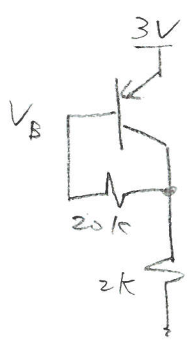
4. Find the gain



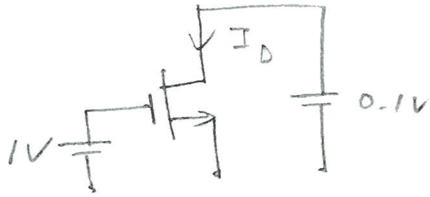
5. Find R_{out}



6. Find V_B. $I_C = 1\,mA$, $\beta = 100$.

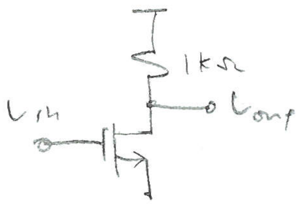


7. Find I_D. $V_{th} = 0.4V$, $\mu C_{ox} = 200\ \mu A/V^2$, $\frac{W}{L} = 10$.

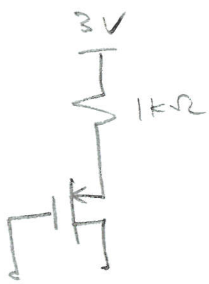


8. A MOSFET has $I_D = 1mA$, $V_{DS} = 0.5V$, $\lambda = 0.1\ V^{-1}$.
Find I_D if $V_{DS} = 1V$.

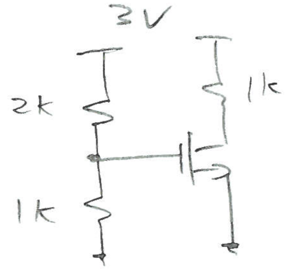
9. Find I_D. $\frac{W}{L} = \frac{20}{0.18}$, $\mu C_{ox} = 200 \times 10^{-6}$, $g_m = 0.02$, $\lambda = 0$.
Assume transistor is in saturation.



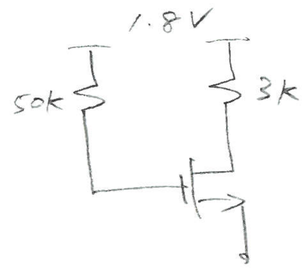
10. Find I_D. $V_{SG} - V_{th} = 0.2V$, $V_{th} = 0.4V$



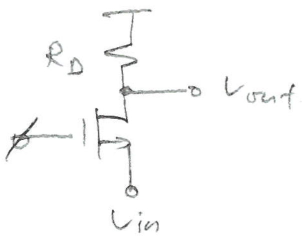
11. Find I_D. $V_{th} = 0.4V$, $\mu C_{ox} = 200\mu A/V^2$, $\frac{W}{L} = 10$, $\lambda = 0$.



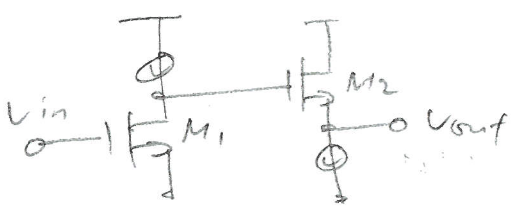
12. Determine max. value of $\frac{W}{L}$ if M_1 is to remain in sat. $V_{th} = 0.4\,V$, $\mu C_{ox} = 200\,\mu A/V^2$, $\lambda = 0$



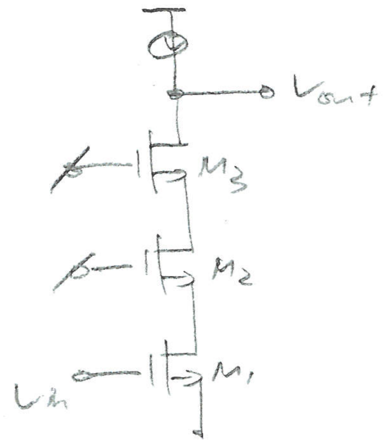
13. Find R_D. Gain = 6, $R_{in} = 150\,\Omega$, $\lambda = 0$



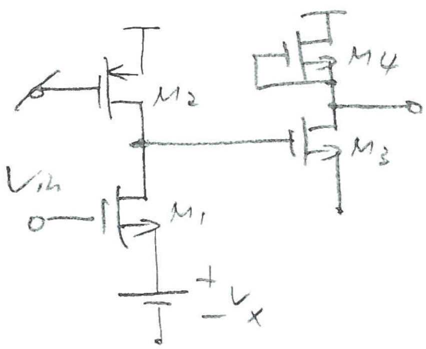
14. Find gain. $\lambda \neq 0$.



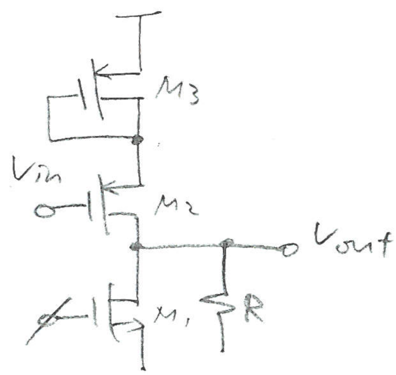
15. Find R_{out}



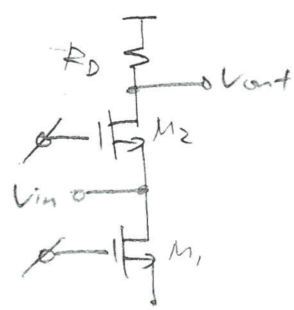
16. Find gain. $\lambda \neq 0$.



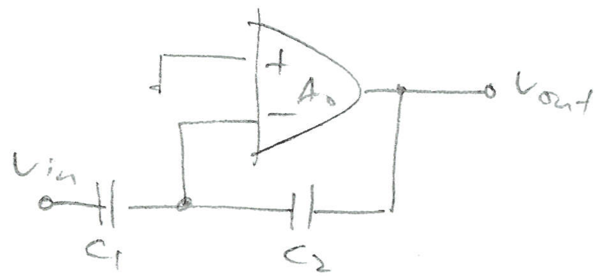
17. Find gain. $\lambda_2 = 0$, $\lambda_{1,3} \neq 0$.



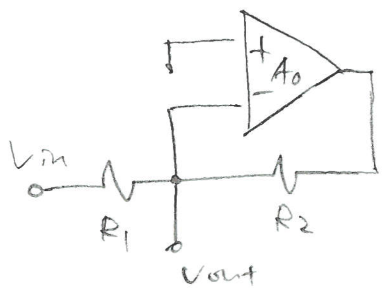
18. Find R_{in}. $\lambda \neq 0$.



19. Find gain. $A_0 = \infty$

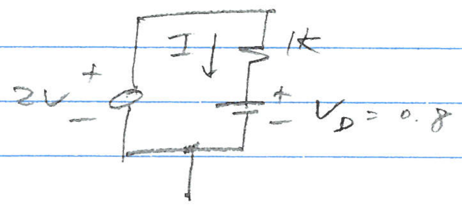


20. Find gain. $A_0 \neq \infty$



ECEn 340 Practice Midterm 2 Solutions

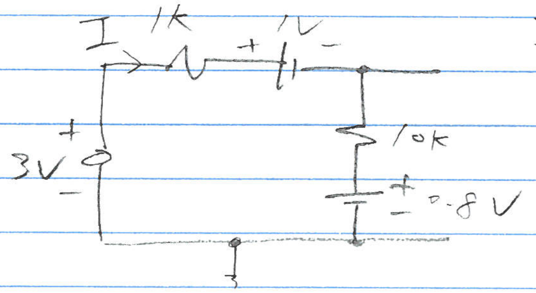
1.



$$I = \frac{2-0.8}{1k} = 1.2\,mA$$

$$I_S = \frac{I_D}{e^{V_D/V_T}} = \frac{1.2m}{e^{0.8/26m}} = 5.2\times10^{-17}$$

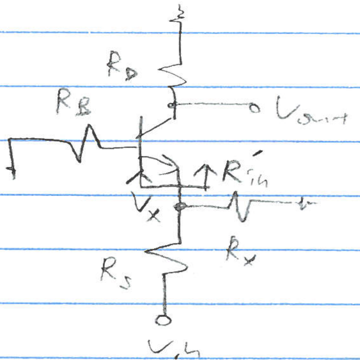
2. Assume diode is on



$$I = \frac{3-1-0.8}{1k+10k} = 0.109\ mA$$

$$V_{out} = 0.8 + I\times10k = 1.89\ V$$

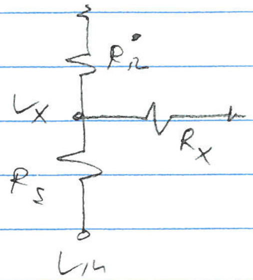
3. s.s.



$$\frac{V_{out}}{V_{in}} = \frac{V_{out}}{V_x}\frac{V_x}{V_{in}}$$

$$\frac{V_{out}}{V_x} = \frac{g_m R_c}{1+\frac{R_B}{r_\pi}}$$

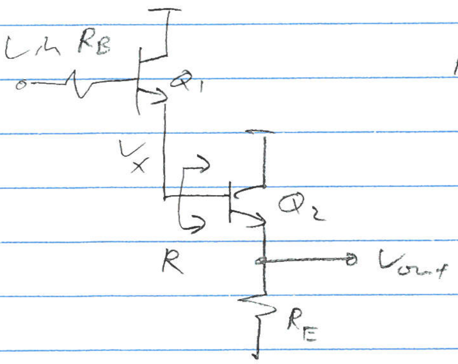
$$R_{in}' = \frac{1}{g_m} + \frac{R_B}{\beta}$$



$$v_x = v_{in} \frac{R_{in} \| R_x}{(R_{in} \| R_x) + R_s}$$

$$\frac{v_{out}}{v_{in}} = \frac{g_m R_C}{1 + \frac{R_B}{r_\pi}} \frac{\left(\frac{1}{g_m} + \frac{R_B}{\beta}\right) \| R_x}{\left[\left(\frac{1}{g_m} + \frac{R_B}{\beta}\right) \| R_x\right] + R_s}$$

4.



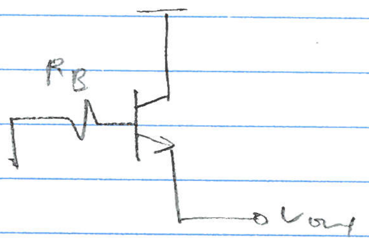
$R = r_{\pi_2} + \beta_2 R_E$

$$\frac{v_x}{v_{in}} = \frac{g_{m_1}(r_{\pi_2} + \beta_2 R_E)}{1 + g_{m_1}(r_{\pi_2} + \beta_2 R_E) + \frac{R_B}{r_{\pi_1}}}$$

$$\frac{v_{out}}{v_x} = \frac{g_{m_2} R_E}{1 + g_{m_2} R_E}$$

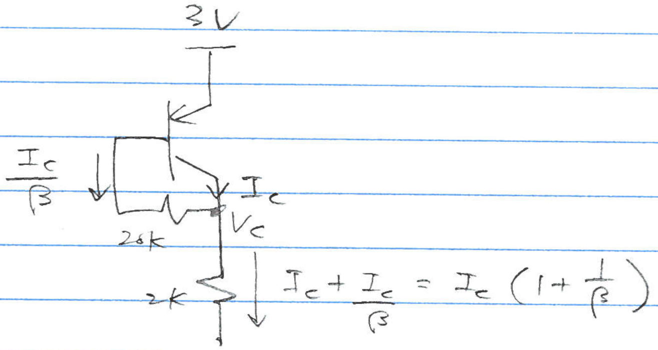
$$\frac{v_{out}}{v_{in}} = \frac{v_{out}}{v_x} \frac{v_x}{v_{in}} = \frac{g_{m_2} R_E}{1 + g_{m_2} R_E} \frac{g_{m_1}(r_{\pi_2} + \beta_2 R_E)}{1 + g_{m_1}(r_{\pi_2} + \beta_2 R_E) + \frac{R_B}{r_{\pi_1}}}$$

5. s.s. , ground V_{in}.



$$R_{out} = \frac{1}{g_m} + \frac{R_B}{\beta}$$

6.



$$V_C = I_c\left(1+\frac{1}{\beta}\right) 2k = 2.02\ V$$

$$V_B = V_C + \frac{I_c}{\beta} 20k = 2.02 + \frac{1m}{100} 20k = 2.22\ V$$

7. $V_{DS} < V_{GS} - V_{th} \rightarrow$ triode

$$I_D = \frac{1}{2}\mu C_{ox}\frac{W}{L}\left[2(V_{GS}-V_{th})V_{DS} - V_{DS}^2\right]$$
$$= 0.11\ mA$$

8. $I_{D_1} = \frac{1}{2}\mu C_{ox}\frac{W}{L}(V_{GS}-V_{th})^2(1+\lambda V_{DS_1})$

$I_{D_2} = \frac{1}{2}\mu C_{ox}\frac{W}{L}(V_{GS}-V_{th})^2(1+\lambda V_{DS_2})$

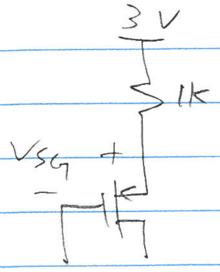
$$I_{D_2} = I_{D_1}\frac{1+\lambda V_{DS_2}}{1+\lambda V_{DS_1}} = 1.048\ mA$$

9.

$$g_m = \sqrt{2\mu C_{ox}\frac{W}{L} I_D}$$

$$I_D = \frac{g_m^2}{2\mu C_{ox}\frac{W}{L}} = 9\ mA$$

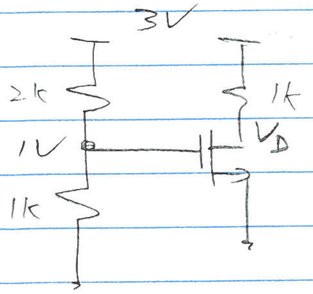
10



$V_{SG} = 0.6\ V$

$$\frac{3-0.6}{1k} = 2.4\ mA$$

11



Assume transistor is in sat.

$$I_D = \frac{1}{2}\mu C_{ox}\frac{W}{L}(V_{GS}-V_{th})^2$$

$$= \frac{1}{2} 200\mu \times 10 (1-0.4)^2$$

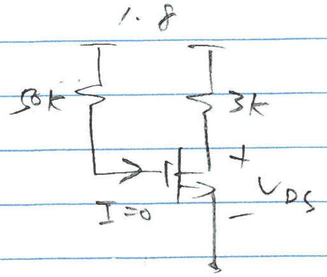
$$= 0.36\ mA$$

check :

$V_D = 3 - I_D \times 1k = 2.64 > V_{GS} - V_{th}$

transistor is in sat.

12



$V_{GS} = 1.8V$

$V_{DS} > V_{GS} - V_{th} = 1.4\ V$ for sat.

Max $\frac{W}{L}$ is when $V_{DS} = V_{GS} - V_{th}$.

$$I_D = \frac{1.8 - V_{DS}}{3k} = \frac{1.8-1.4}{3k} = 0.1333\ mA$$

$$I_D = \frac{1}{2}\mu C_{ox}\frac{W}{L}(V_{GS}-V_{th})^2$$

$$\frac{W}{L} = \frac{I_D}{\frac{1}{2}\mu C_{ox}(V_{GS}-V_{th})^2} = \frac{0.1333\ m}{\frac{1}{2}200\mu \times 1.4^2}$$

$$= 0.68$$

13

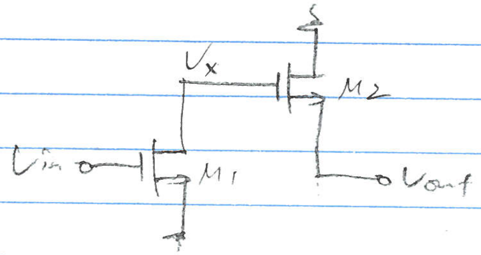
$\text{Gain} = g_m R_D = 6$

$R_{in} = \frac{1}{g_m} = 150$

$g_m = 150^{-1}$

$R_D = \frac{6}{g_m} = 900\ \Omega$

14 S.S.

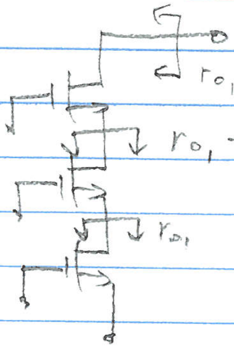


$\frac{V_x}{V_{in}} = -g_{m1} r_{o1}$

$$\frac{V_{out}}{V_x} = \frac{g_{m2} r_{o2} R_S}{r_{o2} + R_S + g_{m2} r_{o2} R_S} \overset{R_S = \infty}{=} \frac{g_{m2} r_{o2}}{1 + g_{m2} r_{o2}}$$

$$\frac{V_{out}}{V_{in}} = \frac{V_{out}}{V_x} \frac{V_x}{V_{in}} = -g_{m1} r_{o1} \frac{g_{m2} r_{o2}}{1 + g_{m2} r_{o2}}$$

15 S.S.

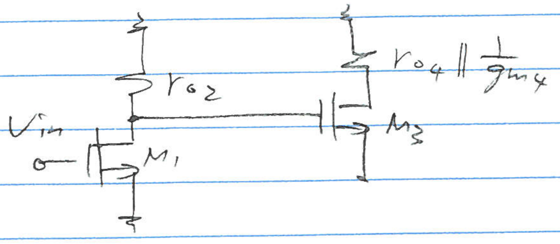


$r_{o1} + r_{o2} + g_{m2} r_{o2} r_{o1} + r_{o3} + g_{m3} r_{o3} (r_{o1} + r_{o2} + g_{m2} r_{o2} r_{o1}) = R_{out}$

$r_{o1} + r_{o2} + g_{m2} r_{o2} r_{o1}$

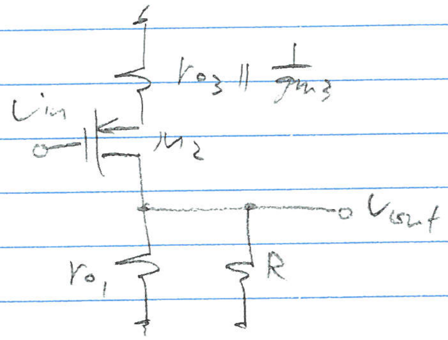
r_{o1}

16. S. S.



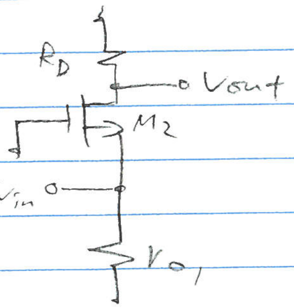
$$\frac{V_{out}}{V_{in}} = g_{m1}(r_{o1} \parallel r_{o2})\, g_{m3}\left(r_{o3} \parallel r_{o4} \parallel \frac{1}{g_{m4}}\right)$$

17. S. S.



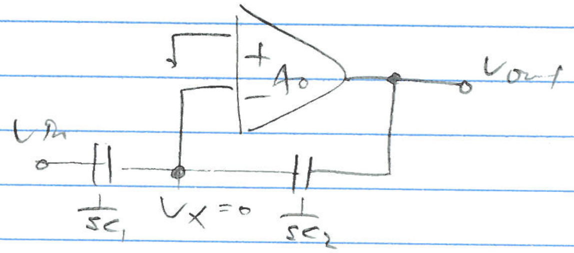
$$\frac{V_{out}}{V_{in}} = \frac{-g_{m2}(r_{o1} \parallel R)}{1 + g_{m2}\left(r_{o3} \parallel \frac{1}{g_{m3}}\right)}$$

18. S. S.



$$R_{in} = r_{o1} \parallel \left(\frac{R_D + r_{o2}}{1 + g_{m2} r_{o2}}\right)$$

19

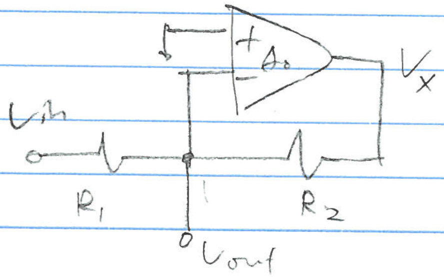


KCL @ amp. negative terminal

$$V_{in} sC_1 + V_{out} sC_2 = 0$$

$$\frac{V_{out}}{V_{in}} = \frac{-sC_1}{sC_2} = \frac{-C_1}{C_2}$$

20



$$V_X = A_0(0 - V_{out})$$

$$V_{out} = V_{in} + (V_X - V_{in})\frac{R_1}{R_1+R_2}$$

$$V_{out} = V_{in} + (-A_0 V_{out} - V_{in})\frac{R_1}{R_1+R_2}$$

$$V_{out}\left(1 + A_0\frac{R_1}{R_1+R_2}\right) = V_{in}\left(1 - \frac{R_1}{R_1+R_2}\right)$$

$$\frac{V_{out}}{V_{in}} = \frac{1 - \frac{R_1}{R_1+R_2}}{1 + A_0\frac{R_1}{R_1+R_2}} = \frac{\frac{R_2}{R_1+R_2}}{1 + A_0\frac{R_1}{R_1+R_2}}$$

$$= \frac{\frac{1}{A_0}\frac{R_2}{R_1}}{\frac{1}{A_0\frac{R_1}{R_1+R_2}} + 1}$$

$$\simeq \frac{1}{A_0}\frac{R_2}{R_1}\left(1 - \frac{1}{A_0\frac{R_1}{R_1+R_2}}\right)$$