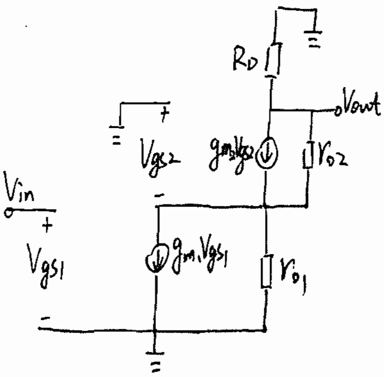
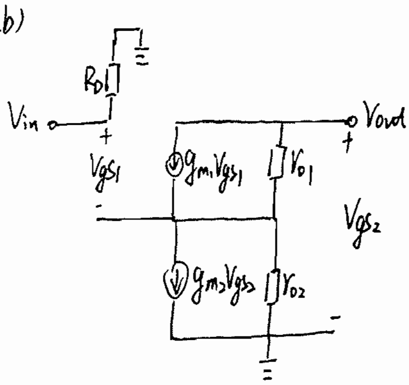
6-38

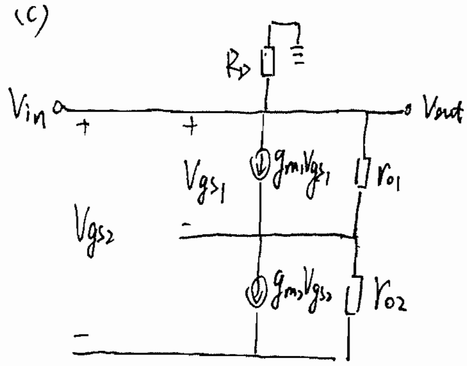
(a)



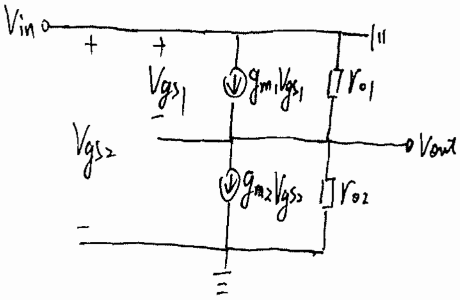
(b)



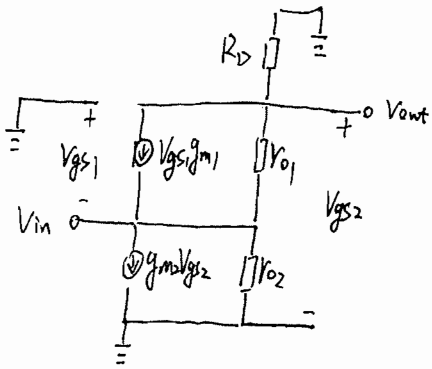
(c)



(d)

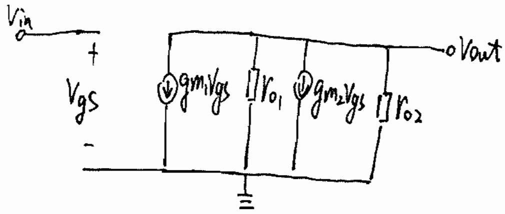


(e)



6-46

(a)



小信号等效电路中，M_1和M_2的源极，漏极和栅极分别相连，所以 M_1和 M_2表现为并联

(b) $V_{out} = -(g_{m1}V_{gs} + g_{m2}V_{gs})(r_{o1} // r_{o2})$

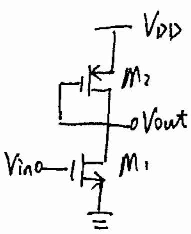
$= -(g_{m1}+g_{m2})(r_{o1}//r_{o2})V_{gs}$

$= -(g_{m1}+g_{m2})(r_{o1}//r_{o2})V_{in}$

$\therefore A_v = \dfrac{V_{out}}{V_{in}} = -(g_{m1}+g_{m2})(r_{o1}//r_{o2})$

7-28

(a)

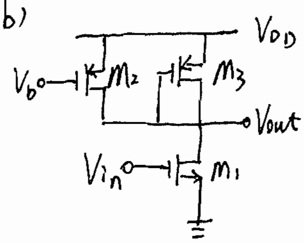


$G_m = -g_{m1}$

$R_L = r_{o1}//r_{o2}//\frac{1}{g_{m2}}$

$\therefore A_v = G_mR_L = -g_{m1}(r_{o1}//r_{o2}//\frac{1}{g_{m2}})$

(b)



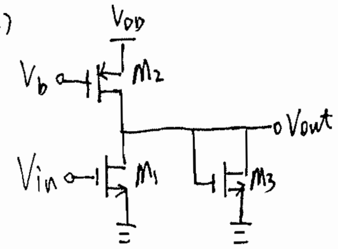
$G_m = -g_{m1}$

$R_L = r_{o1}//r_{o2}//r_{o3}//\frac{1}{g_{m3}}$

$\therefore A_v = G_mR_L = -g_{m1}(r_{o1}//r_{o3}//r_{o2}//\frac{1}{g_{m3}})$

清華大學

(c)

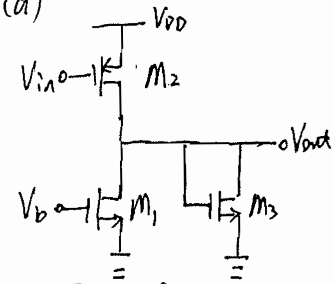


$G_m = -g_{m1}$

$R_L = r_{o1} \| r_{o2} \| r_{o3} \| \frac{1}{g_{m3}}$

$\therefore A_v = G_m R_L = -g_{m1}(r_{o1} \| r_{o2} \| r_{o3} \| \frac{1}{g_{m3}})$

(d)

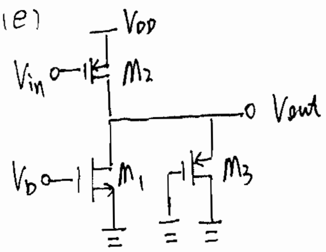


$G_m = -g_{m2}$

$R_L = r_{o1} \| r_{o2} \| r_{o3} \| \frac{1}{g_{m3}}$

$\therefore A_v = G_m R_L = -g_{m2}(r_{o1} \| r_{o2} \| r_{o3} \| \frac{1}{g_{m3}})$

(e)

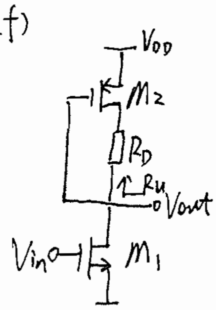


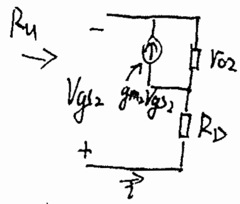
$G_m = -g_{m2}$

$R_L = r_{o1} \| r_{o2} \| r_{o3} \| \frac{1}{g_{m3}}$

$\therefore A_v = -g_{m2}(r_{o1} \| r_{o2} \| r_{o3} \| \frac{1}{g_{m3}})$

(f)





$V_{gs2} = iR_D + (i - g_{m2}V_{gs2})r_{o2}$

$\Rightarrow R_u = \frac{V_{gs2}}{i} = \frac{r_{o2} + R_D}{g_{m2}r_{o2} + 1}$

$G_m = -g_{m1}$

$R_L = r_{o1} \| R_u$

$\therefore A_v = -g_{m1}(r_{o1} \| \frac{r_{o2} + R_D}{g_{m2}r_{o2} + 1})$

(46) $$\frac{v_x}{v_{in}} = -\left(R_{D1} \parallel \frac{1}{g_{m2}}\right) g_{m1}$$

$$\frac{v_{out}}{v_x} = g_{m2} R_{D2}.$$

$$\therefore \frac{v_{out}}{v_{in}} = -g_{m1} g_{m2} R_{D2} \left(R_{D1} \parallel \frac{1}{g_{m2}}\right)$$

Similar to prob. (45), voltage gain approaches that of cascode stage as R_{D1} approaches infinity. The gain is $g_{m1} R_{D2}$.

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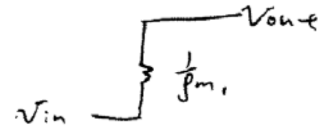
(47) with $\lambda = 0$, M_1 appears as a diode-connected device.

$\therefore$ the circuit becomes :



i.e. $\dfrac{V_{out}}{V_{in}} = 1$ //

This is not a common-gate (CG) amplifier, because the gate is not fixed. (i.e. gate is not at an "a.c. ground")

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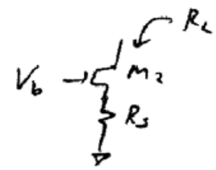
(55) a) $$A_v = \frac{r_{o1} \parallel (R_s + r_{o2})}{\frac{1}{g_{m1}} + r_{o1} \parallel (R_s + r_{o2})}$$

b) $$A_v = \frac{r_{o1} \parallel R_L}{\frac{1}{g_{m1}} + (r_{o1} \parallel R_L)}$$

where R_L is :



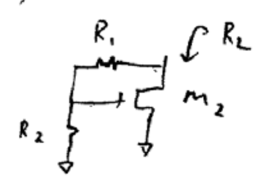
$$R_L = (1 + g_{m2} r_{o2}) R_s + r_{o2}. \quad \text{Eq.}(7.110)$$

$$\therefore A_v = \frac{r_{o1} \parallel [(1 + g_{m2} r_{o2}) R_s + r_{o2}]}{\frac{1}{g_{m1}} + r_{o1} \parallel [(1 + g_{m2} r_{o2}) R_s + r_{o2}]}$$

c). $$A_v = \frac{r_{o1} \parallel \frac{1}{g_{m2}}}{\frac{1}{g_{m1}} + (r_{o1} \parallel \frac{1}{g_{m2}})}$$

d) $$A_v = \frac{r_{o1} \parallel R_L}{\frac{1}{g_{m1}} + (r_{o1} \parallel R_L)}$$

where R_L is :



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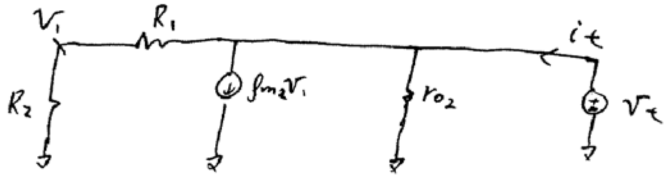
(c) Finding R_L with small-signal model:
(cont'd)



$$R_L = \frac{v_t}{i_t},$$

where
$$i_t = \frac{v_t}{r_{o2}} + g_{m2}v_1 + \frac{v_t}{R_1 + R_2}$$

$$= \frac{v_t}{r_{o2}} + \frac{g_{m2}R_2 v_t}{R_1 + R_2} + \frac{v_t}{R_1 + R_2}$$

$$\therefore R_L = \frac{r_{o2}(R_1 + R_2)}{R_2 + R_1 + r_{o2} + g_{m2} r_{o2} R_2}$$

$$\therefore A_v = \frac{r_{o1} \,//\, \frac{r_{o2}(R_1 + R_2)}{R_2 + R_1 + r_{o2} + g_{m2} r_{o2} R_2}}{\frac{1}{g_{m1}} + r_{o1} \,//\, \frac{r_{o2}(R_2 + R_1)}{R_2 + R_1 + r_{o2} + g_{m2} r_{o2} R_2}}$$

e) $$A_v = \frac{r_{o2} \,//\, (\frac{1}{g_{m1}} \,//\, r_{o3})}{\frac{1}{g_{m2}} + r_{o2} \,||\, (\frac{1}{g_{m1}} \,//\, r_{o3})}$$

f) $$A_v = \frac{r_{o1} \,//\, [(1 + g_{m2} r_{o2}) r_{o3} + r_{o2}]}{\frac{1}{g_{m1}} + \{r_{o1} \,//\, [(1 + g_{m2} r_{o2}) r_{o3} + r_{o2}]\}}$$

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56

$$\frac{v_x}{v_{in}} = \frac{\frac{1}{g_{m2}}}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}}$$

$$\frac{V_{out}}{v_x} = g_{m2} R_D$$

$$\therefore \frac{V_{out}}{V_{in}} = \frac{R_D}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}}$$

b) if $g_{m1} = g_{m2}$,

$$\frac{V_{out}}{V_{in}} = \frac{g_{m1} R_D}{2}$$

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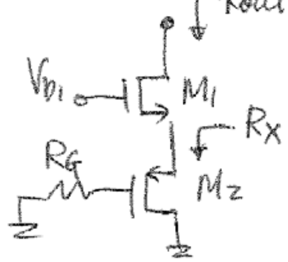
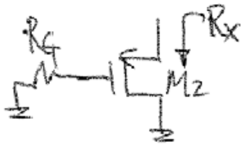
19. (a) R_X is the input impedence of a common-gate configuration:





"Looking into" the source of M_2,

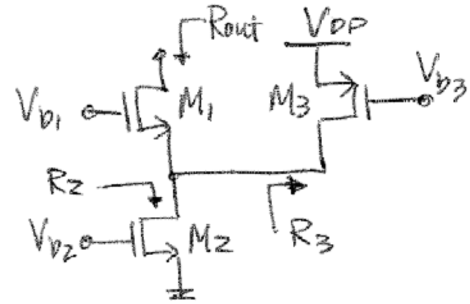
$$R_X = \frac{1}{g_{m2}} \parallel r_{o2}$$

$$\therefore R_{out} = g_{m1} r_{o1} R_X = g_{m1} r_{o1} \left(\frac{1}{g_{m2}} \parallel r_{o2} \right)$$

(b) From observation,

$\rightarrow R_3 = r_{o3}$ ($\because V_{SG} = 0$ in AC)

$\rightarrow R_2 = r_{o2}$ ($\because V_{SG} = 0$ in AC)



$$\therefore R_{out} = g_{m1} r_{o1} (R_2 \parallel R_3) = g_{m1} r_{o1} (r_{o2} \parallel r_{o3})$$

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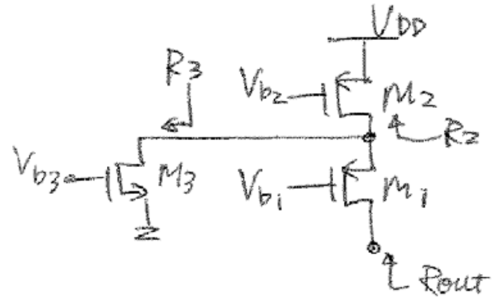
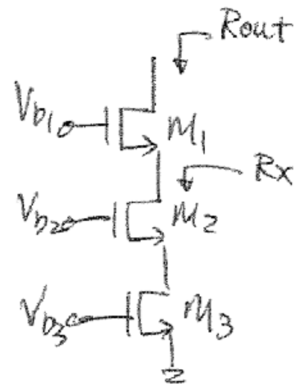
(c) By observation,



$$R_2 = r_{o2} \quad (V_S = V_G = AC\ GND)$$
$$R_3 = r_{o3} \quad (V_S = V_G = AC\ GND)$$

$$\therefore R_{out} = g_{m1} r_{o1} (R_2 // R_3) = g_{m1} r_{o1} (r_{o2} // r_{o3})$$

(d) $R_X = g_{m2} r_{o2} r_{o3}$



$$\Rightarrow R_{out} = g_{m1} r_{o1} R_X$$
$$= g_{m1} g_{m2} r_{o1} r_{o2} r_{o3}$$

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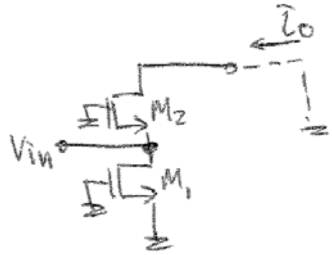
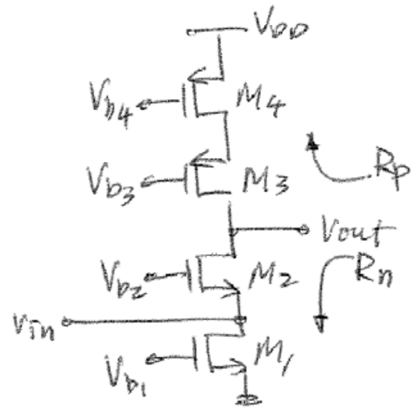
32.





By KCL,

$$\frac{i_o}{V_{in}} = -\left(g_{m2} + \frac{1}{r_{o1} \| r_{o2}}\right) = G_m$$

$$R_n = r_{o2} \qquad R_p \approx g_{m3} r_{o3} r_{o4}$$

$$\therefore A_v = -G_m (R_n \| R_p) = \left(g_m + \frac{1}{r_{o1} \| r_{o2}}\right)(r_{o2} \| g_{m3} r_{o3} r_{o4})$$

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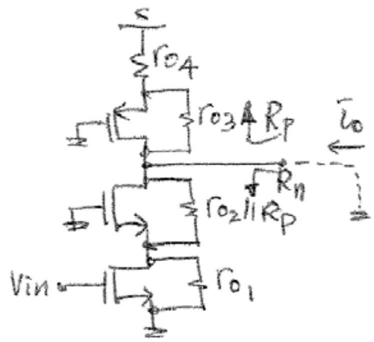
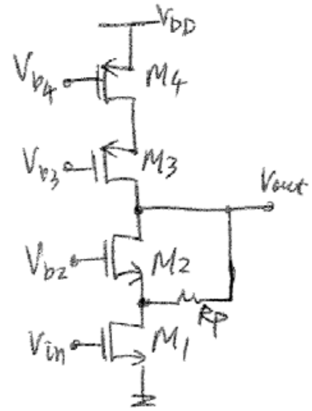
34 (a) Equivalent circuit:



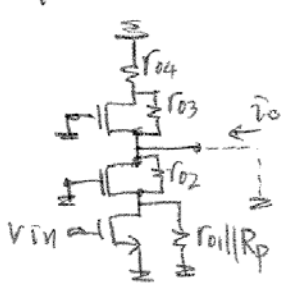


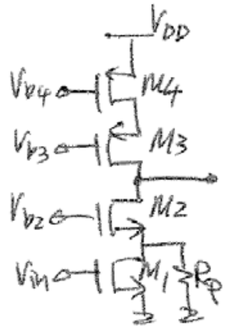
$$G_m = \frac{i_o}{v_{in}} \approx g_{m1} \quad (\because g_m r_o \gg 1)$$

$$R_p = g_{m3} r_{o3} r_{o4} \qquad R_n = g_{m2}(r_{o2} \| R_p) r_{o1}$$

$$\therefore A_v = -G_m R_{out} = -g_{m1}\left[g_{m3} r_{o3} r_{o4} \,\|\, g_{m2}(r_{o2} \| R_p) r_{o1}\right]$$

(b) Equivalent circuit





$$G_m = i_o / v_{in} \approx g_{m1} \quad (\because g_m r_o \gg 1)$$

$$R_p = g_{m3} r_{o3} r_{o4} \qquad R_n = g_{m2}(r_{o1} \| R_p) r_{o2}$$

$$\therefore A_v = -G_m R_{out} = -g_{m1}\left[g_{m3} r_{o3} r_{o4} \,\|\, g_{m2}(r_{o1} \| R_p) r_{o2}\right]$$

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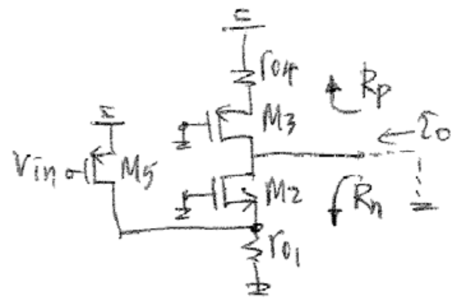
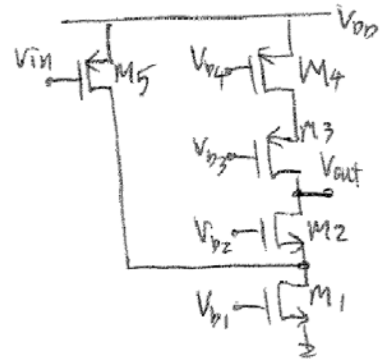
(c) Equivalent circuit:





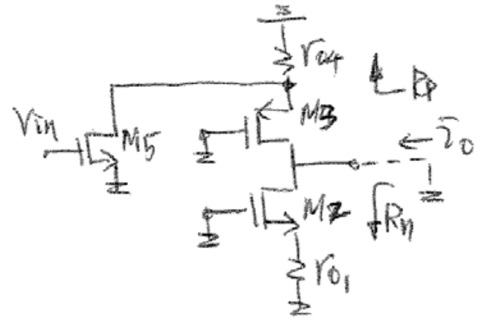
(Realize that r_{o1} & r_{o5} are in parallel.)

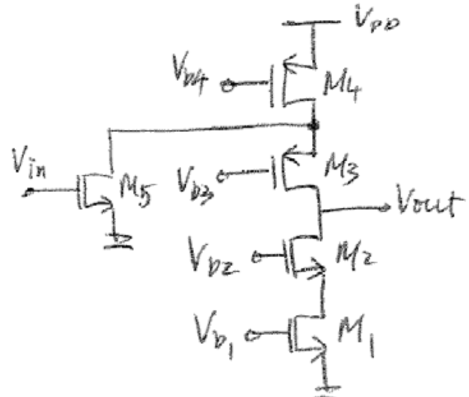
$$G_m = \frac{i_o}{v_{in}} \approx -g_{m5} \qquad (\because g_m r_o \gg 1)$$

$$R_p = g_{m3} r_{o3} r_{o4} \qquad R_n = g_{m2} r_{o2} (r_{o1} \| r_{o5})$$

$$\therefore A_v = -G_m R_{out} = g_{m5} [g_{m3} r_{o3} r_{o4} \| g_{m2} r_{o2} (r_{o1} \| r_{o5})]$$

(d) Equivalent circuit:





$$G_m = \frac{i_o}{v_{in}} \approx g_{m5} \qquad R_p = g_{m3} r_{o3} (r_{o4} \| r_{o5})$$

$$R_n = g_{m2} r_{o2} r_{o1}$$

$$\therefore A_v = -G_m R_{out} = -g_{m5} [g_{m3} r_{o3} (r_{o4} \| r_{o5}) \| g_{m2} r_{o2} r_{o1}]$$

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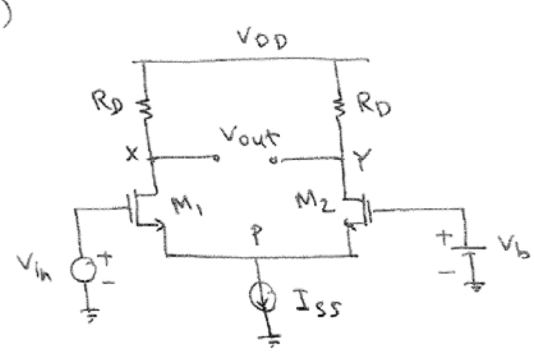
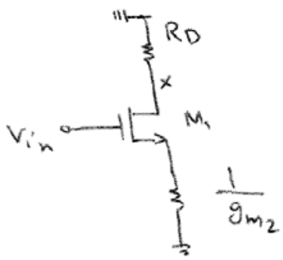
(51)



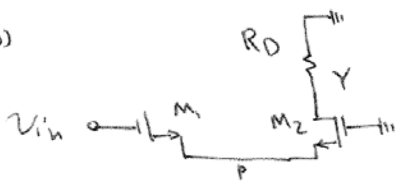
$g_{m1} = g_{m2} = g_m$

(a)



$$v_x = -g_{m1} v_{gs1} R_D = -g_{m1} \frac{\frac{1}{g_{m1}}}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}} v_{in} R_D = -\frac{g_{m1} g_{m2}}{g_{m1} + g_{m2}} R_D v_{in} = -\frac{g_m}{2} R_D v_{in}$$

(b)



$$v_p = \frac{\frac{1}{g_{m2}}}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}} v_{in}$$

$$\Rightarrow v_p = \frac{g_{m1}}{g_{m1} + g_{m2}} v_{in} \Rightarrow$$

$$v_y = -g_{m2} v_{gs2} R_D = g_{m2} v_p R_D = \frac{g_{m1} g_{m2}}{g_{m1} + g_{m2}} R_D v_{in}$$

$$\rightarrow v_y = \frac{g_m}{2} R_D v_{in}$$

(c) $\frac{v_x - v_y}{v_{in}} = -g_m R_D$ This value is equal to the gain of the differential amplifier.

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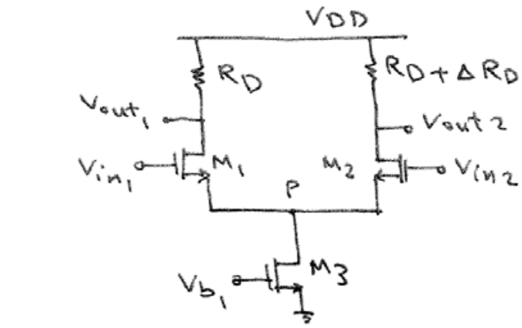
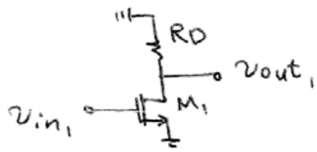
(70)

(a)

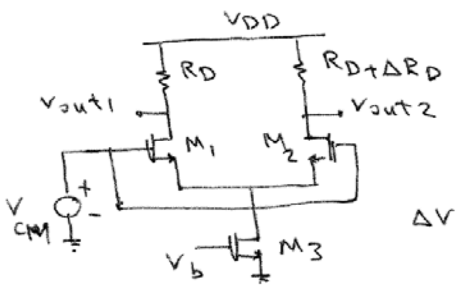


To calculate A_{DM}, using the half circuit:



$$A_{DM} = \frac{v_{out}}{v_{in_1}} = -g_{m_1} R_D$$

To calculate, A_{CM-DM} we have:



$$A_{CM-DM} = \frac{\Delta V_{out}}{\Delta V_{CM}}$$

$$\Delta V_{CM} = \Delta V_{GS} + 2\Delta I_D r_{o3} \Rightarrow$$

$$\Delta V_{CM} = \Delta I_D \left(\frac{1}{g_{m_1}} + 2r_{o3}\right)$$

$$\Delta V_{out} = \Delta V_{out_1} - \Delta V_{out2} = -\Delta R_D \, \Delta I_D \Rightarrow$$

$$A_{CM-DM} = -\frac{\Delta R_D}{\frac{1}{g_{m_1}} + 2r_{o3}} \Rightarrow$$

$$CMMR = \frac{A_{DM}}{A_{CM-DM}} = \frac{g_{m_1} R_D}{\frac{\Delta R_D}{\frac{1}{g_{m_1}} + 2r_{o3}}} = (1 + 2g_{m_1} r_{o3}) \frac{R_D}{\Delta R_D}$$

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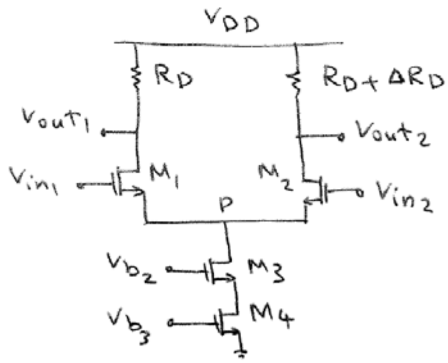
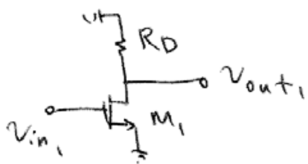
(10) (b)



To calculate A_{DM}, using the half circuit, we have



$$A_{DM} = \frac{v_{out1}}{v_{in1}} = -g_{m1} R_D$$

Similar to part (a) we have:

$$A_{CM-DM} = -\frac{\Delta R_D}{\frac{1}{g_{m1}} + 2\left[g_{m3} r_{o3} r_{o4} + r_{o3} + r_{o4}\right]}$$

$$\Rightarrow CMMR = \frac{A_{DM}}{A_{CM-DM}} = \left(1 + 2 g_{m1}\left[g_{m3} r_{o3} r_{o4} + r_{o3} + r_{o4}\right]\right)\frac{R_D}{\Delta R_D}$$

Notice that CMMR of part (b) is much higher than the one for part (a).

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