

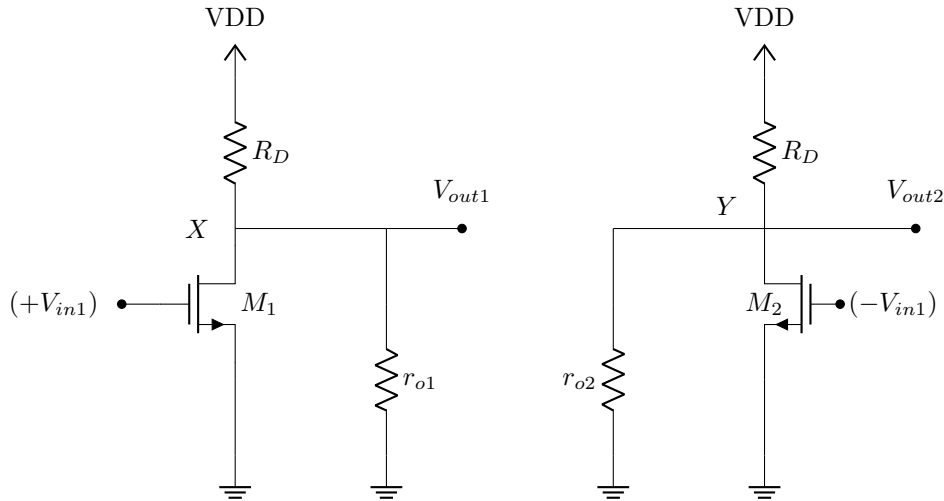
EE-320 – Exercise 8 Solutions - Fall 2024

1

We can apply the half circuit concept $\Rightarrow P = \text{ac ground}$
 (Symmetry) $\checkmark$
 (Differential inputs) $\checkmark$

$$\left\{ \begin{array}{l} \frac{V_X}{(+V_{in1})} = -g_m(R_D || r_{o1}) \\ \frac{V_Y}{(-V_{in1})} = -g_m(R_D || r_{o2}) \\ \text{Symmetry : } r_{o1} = r_{o2} \end{array} \right. \Rightarrow V_X - V_Y = -g_m(R_D || r_o)(2V_{in1}) \quad A_V = \frac{V_X - V_Y}{2V_{in1}} = -g_m(R_D || r_o)$$

(1)



2

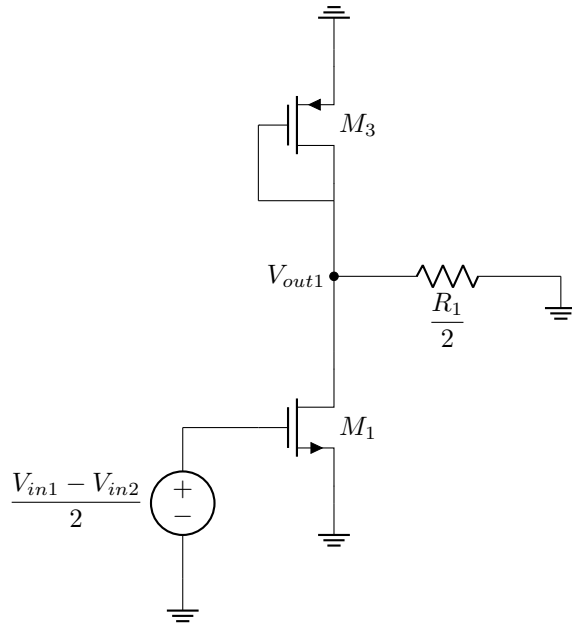
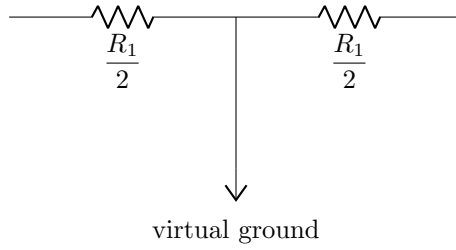
The dc levels of V_{in1} and V_{in2} are equal $\Rightarrow V_{GS1} = V_{GS2}$

$$\begin{aligned} \left(\frac{W}{L}\right)_2 &= 2\left(\frac{W}{L}\right)_1 \Rightarrow I_D = \frac{1}{2}\mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})^2 \\ &\Rightarrow I_{D2} = 2I_{D1} \quad I_{D1} + I_{D2} = I_{SS} \\ &\Rightarrow I_{D2} = \frac{2I_{SS}}{3} \quad I_{D1} = \frac{I_{SS}}{3} \\ g_m &= \frac{2I_D}{V_{GS} - V_{TH}} \Rightarrow g_{m2} = 2g_{m1} \quad g_{m1} = \sqrt{2\mu_n C_{ox} \frac{W}{L} \frac{I_{SS}}{3}} \\ &\Rightarrow \text{Using superposition:} \\ A_V &= \frac{-2R_D}{\frac{1}{g_{m1}} + \frac{1}{g_{m2}}} = \frac{-2R_D}{\frac{1}{g_{m1}} + \frac{1}{2g_{m1}}} = \frac{-4}{3} g_{m1} R_D \end{aligned}$$

3

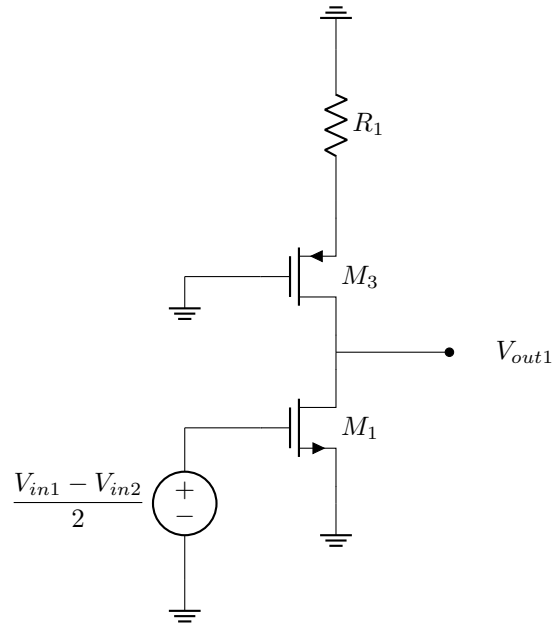
We can use the half-circuit concept:

(a)



$$\begin{aligned}
 A_V &= \frac{V_{out1}}{\frac{V_{in1} - V_{in2}}{2}} = -g_{m1}(r_{o1} || r_{o3} || \frac{1}{g_{m3}} || \frac{R_1}{2}) \\
 &\approx -g_{m1}(\frac{1}{g_{m3}} || \frac{R_1}{2}) \\
 A_{V,diff} &= \frac{V_{out1} - V_{out2}}{V_{in1} - V_{in2}} = -g_{m1}(\frac{1}{g_{m3}} || \frac{R_1}{2}) \\
 &\quad (\text{Since } V_{out2} = -g_{m1}(\frac{1}{g_{m3}} || \frac{R_1}{2})(\frac{V_{in2} - V_{in1}}{2}) \\
 &\quad = -V_{out1})
 \end{aligned}$$

(b)



half-circuit model

$$A_{V,diff} = -g_{m1}(r_{o1} || (g_{m3}r_{o3}R_1 + r_{o3} + R_1))$$

$$\approx -g_{m1}(r_{o1} || g_{m3}r_{o3}R_1)$$