VE311
Electronic Circuits
RC 3

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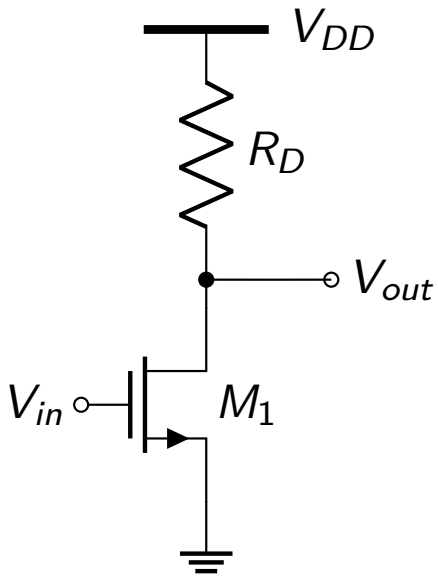
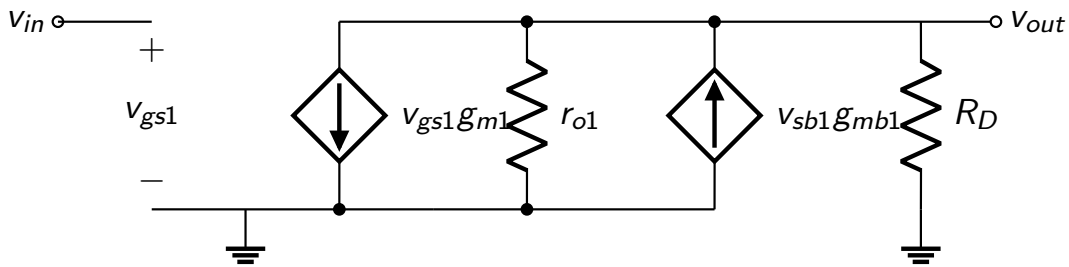
CS with Resistive Load





If no channel-length and body effect:

$$A_v = \frac{v_{out}}{v_{in}} = -g_{m1}R_D \tag{1}$$

No body effect:

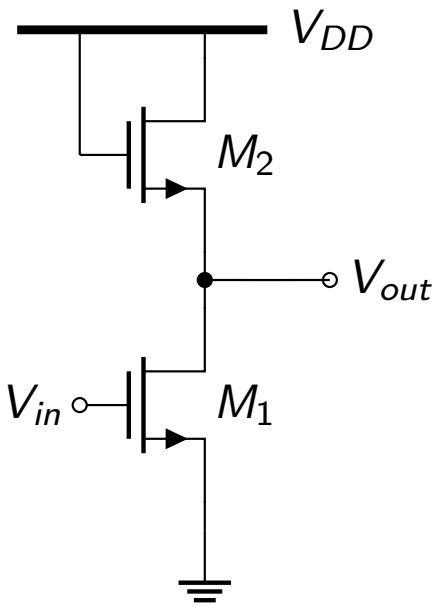
$$A_v = -g_{m1}(R_D \parallel r_{o1}) \tag{2}$$

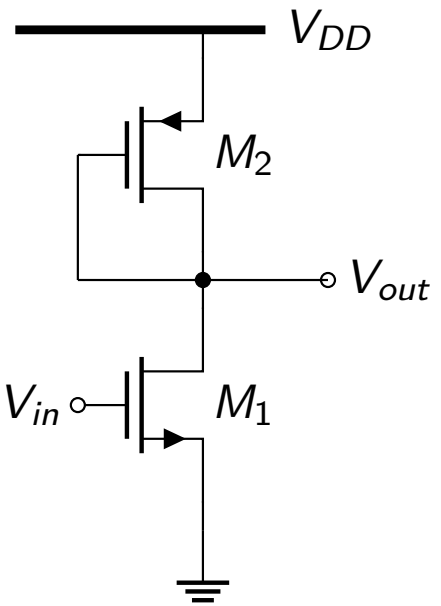
Example 1

In the common source stage amplifier, $V_{DD} = 5V, R_D = 10k\Omega$, change the input voltage and let the current pass through M1 be 0.1mA. What is the gain of the amplifier? (Neglect body effect)
Parameter for NMOS: $V_{THN} = 0.7V$,
$K_n = 110\mu A/V^2, \lambda = 0.04V^{-1}$
Parameter for PMOS: $V_{THP} = -0.7V$,
$K_p = 50\mu A/V^2, \lambda = 0.05V^{-1}$
All the size of transistor is $W = 20\mu m, L = 1\mu m$

Example 1

CS with Diode-connected Load





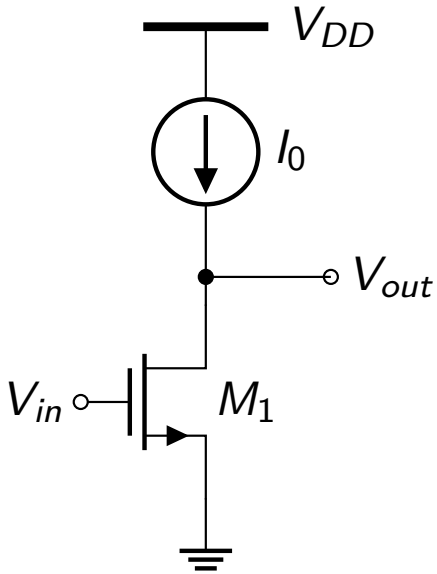
NMOS:

$$A_{\mathrm{v}} = -\sqrt{\frac{(W/L)_1}{(W/L)_2}}\frac{1}{1+\eta} \qquad \eta = g_{\mathrm{mb2}}/g_{\mathrm{m2}} \tag{3}$$

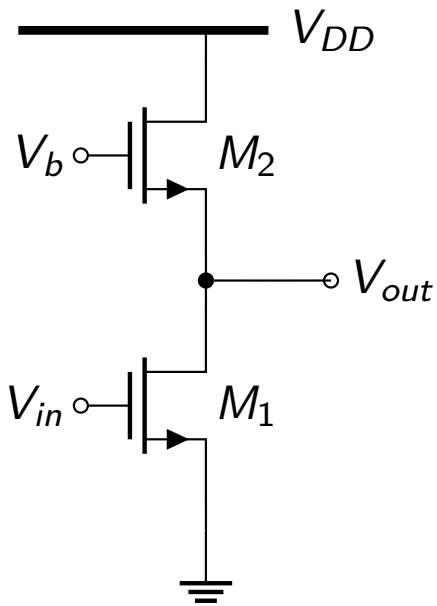
PMOS:

$$A_{\mathrm{v}} = -\sqrt{\frac{\mu_{\mathrm{n}}(W/L)_1}{\mu_{\mathrm{p}}(W/L)_2}} \tag{4}$$

CS with Current Source Load



or



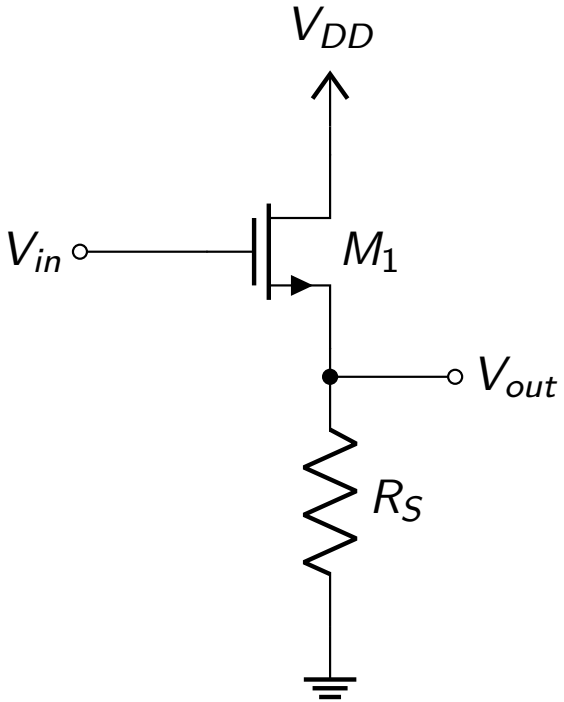
$$A_v = -g_{m1}(r_{o2} \parallel r_{o1}) \tag{5}$$

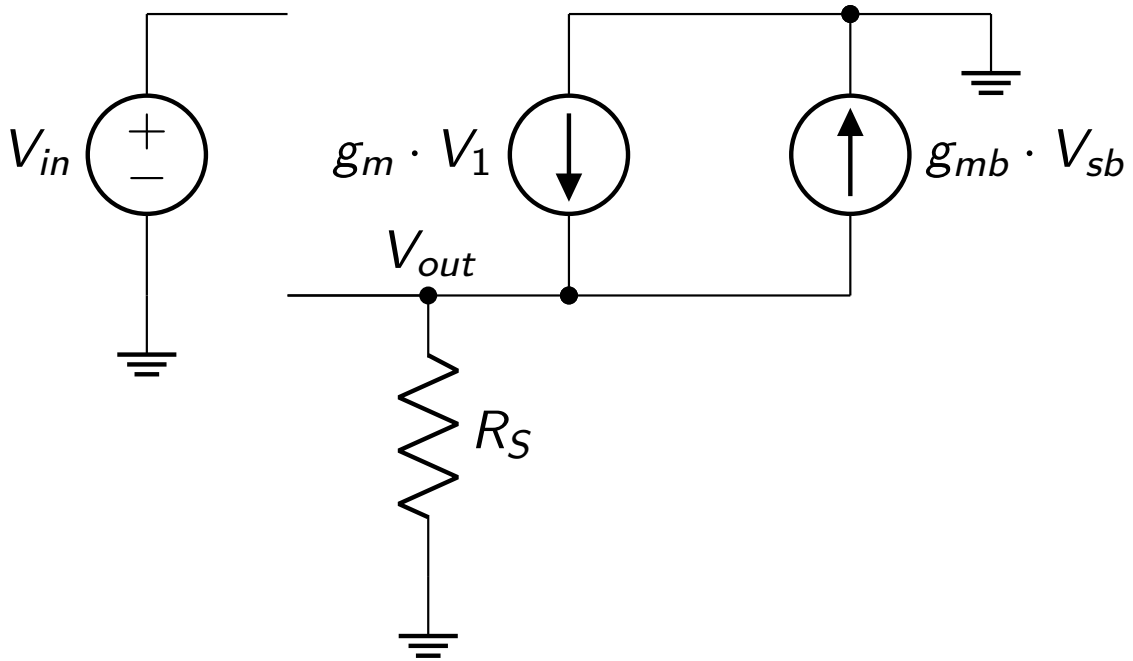
Example 2

In the common source stage amplifier, the current source is ideal. Find the intrinsic gain A_v for the amplifier when $I_0 = 0.01$ and $0.1mA$ respectively. (Neglect body effect)
Parameter for NMOS: $V_{THN} = 0.7V$,
$K_n = 110\mu A/V^2, \lambda = 0.04V^{-1}$
Parameter for PMOS: $V_{THP} = -0.7V$,
$K_p = 50\mu A/V^2, \lambda = 0.05V^{-1}$
All the size of transistor is $W = 20\mu m, L = 1\mu m$

Example 2

Source Follower



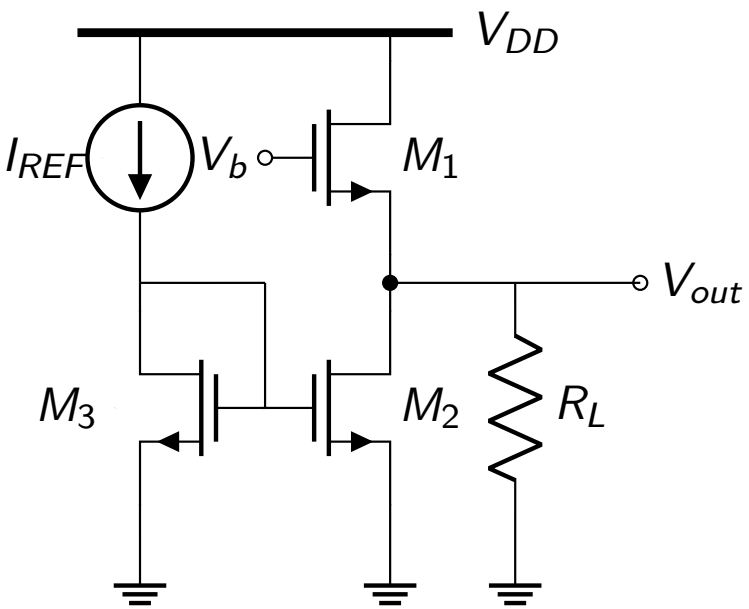


$$A_v = \frac{g_m R_S}{1 + g_m R_S(1+\eta)} = \frac{g_m R_S}{1 + (g_m + g_{mb})R_S} \approx \frac{1}{1+\eta} \qquad (6)$$

Example 3

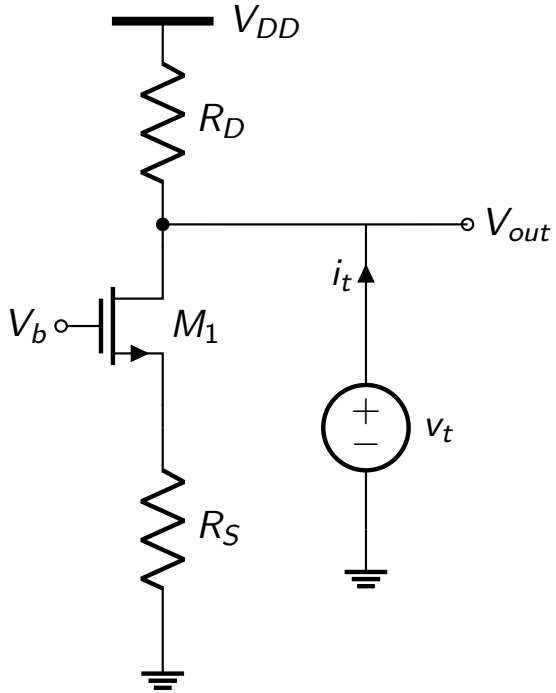
In the source follower with current source load, the current source is ideal. Find the output impedance for the amplifier when $I_0 = 0.01$ and $0.1mA$ respectively. (Neglect body effect)
Parameter for NMOS: $V_{THN} = 0.7V$,
$K_n = 110\mu A/V^2, \lambda = 0.04V^{-1}$
Parameter for PMOS: $V_{THP} = -0.7V$,
$K_p = 50\mu A/V^2, \lambda = 0.05V^{-1}$
All the size of transistor is $W = 20\mu m, L = 1\mu m$

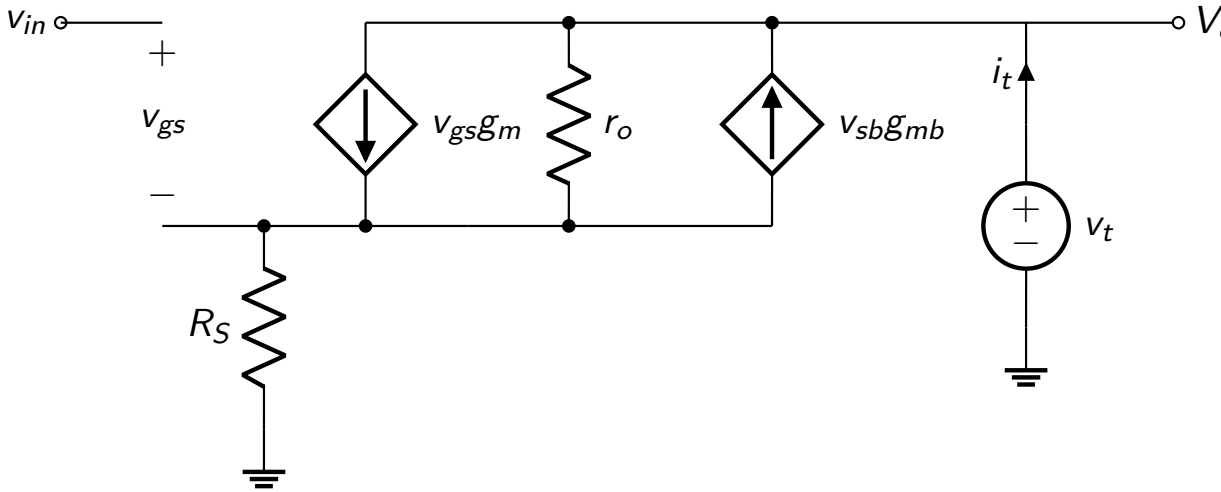
Example 3



Example 3

Common Gate





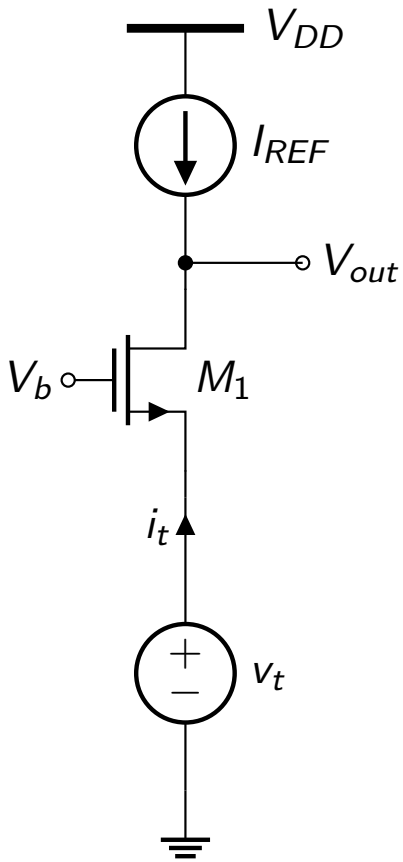
$$R_{in} = \frac{R_D + r_o}{1 + (g_m + g_{mb})r_o} \begin{cases} \text{If } R_D = 0 & R_{in} = r_o \parallel \frac{1}{g_m} \parallel \frac{1}{g_{mb}} \\ \text{If } R_D = \infty & R_{in} = \infty \end{cases} \quad (7)$$

$$R_{out} = [R_S + r_{o1} + (g_{m1} + g_{mb1})r_{o1}R_S] \parallel R_D \quad (8)$$

Example 4

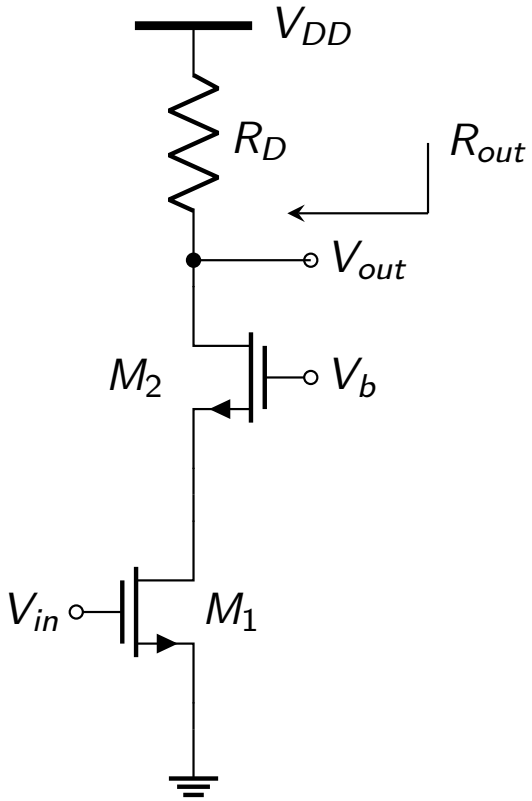
In the common gate stage amplifier , what is the input resistance when $I_{REF} = 0.01mA$ and $0.1mA$ respectively? (Neglect body effect)
Parameter for NMOS: $V_{THN} = 0.7V$,
$K_n = 110\mu A/V^2, \lambda = 0.04V^{-1}$
Parameter for PMOS: $V_{THP} = -0.7V$,
$K_p = 50\mu A/V^2, \lambda = 0.05V^{-1}$
All the size of transistor is $W = 20\mu m, L = 1\mu m$

Example 4



Example 4

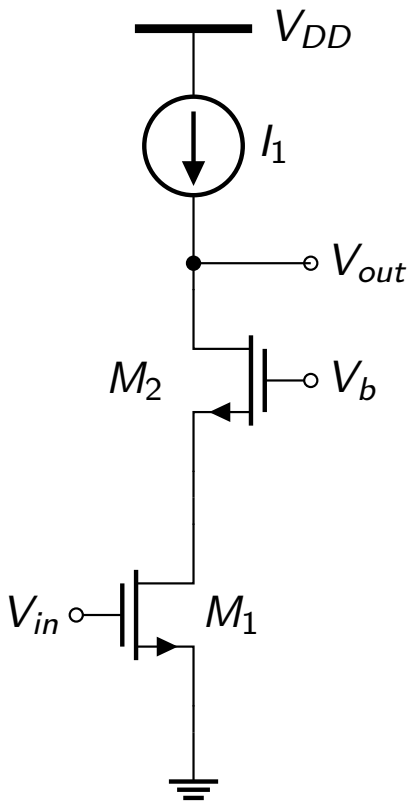
Cascode



$$G_m = -g_{m1} \frac{r_{o1}}{r_{o1} + \left(r_{o2} \parallel \frac{1}{g_{m2}+g_{mb2}} \right)} \quad (9)$$

$$R_{out} = [r_{o1} + r_{o2} + (g_{m2} + g_{mb2}) r_{o2} r_{o1}] \parallel R_D \quad (10)$$

Cascode

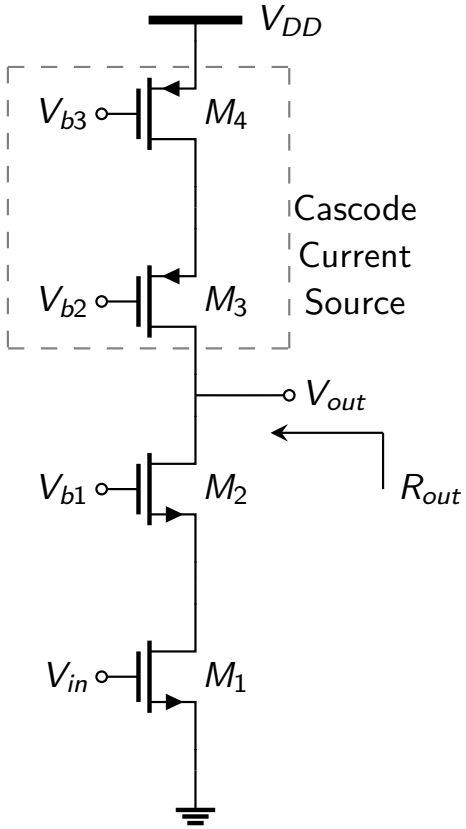


$$G_m = -g_{m1} \frac{r_{o1}}{r_{o1} + \left(r_{o2} \parallel \frac{1}{g_{m2}+g_{mb2}} \right)} \tag{11}$$

$$R_{out} = r_{o1} + r_{o2} + (g_{m2} + g_{mb2}) r_{o2} r_{o1} \tag{12}$$

$$A_v = G_m R_{out} \tag{13}$$

Cascode



$$G_m = -g_{m1}\frac{r_{o1}}{r_{o1} + (r_{o2} \parallel \frac{1}{g_{m2}g_{mb2}})} \quad (14)$$

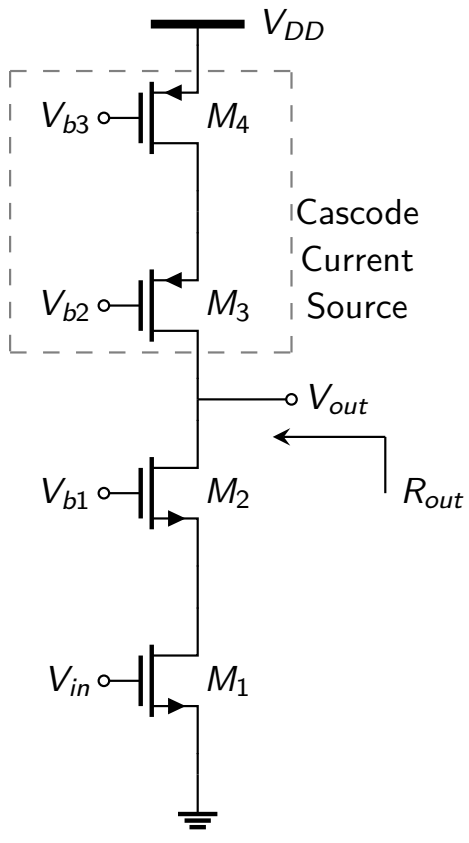
$$R_{out} = [r_{o1} + r_{o2} + (g_{m2} + g_{mb2})r_{o2}r_{o1}] \parallel [r_{o3} + r_{o4} + (g_{m3} + g_{mb3})r_{o3}r_{o4}] \quad (15)$$

$$A_v = G_m R_{out} \quad (16)$$

Example 5

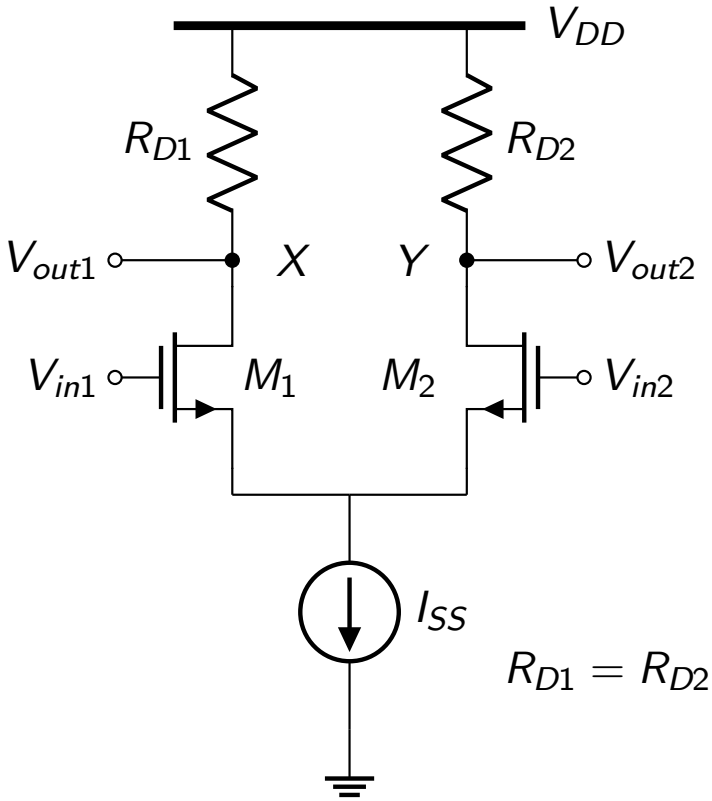
In the cascode amplifier , what is the input resistance when $I_{REF} = 0.01mA$ and $0.1mA$ respectively? (Neglect body effect)
Parameter for NMOS: $V_{THN} = 0.7V$,
$K_n = 110\mu A/V^2, \lambda = 0.04V^{-1}$
Parameter for PMOS: $V_{THP} = -0.7V$,
$K_p = 50\mu A/V^2, \lambda = 0.05V^{-1}$
All the size of transistor is $W = 20\mu m, L = 1\mu m$

Example 5


V_{DD}
V_{b3}
M_4
Cascode
Current
Source
V_{b2}
M_3
V_{out}
R_{out}
V_{b1}
M_2
V_{in}
M_1

Example 5

Differential Pair



$$R_{D1} = R_{D2} = R_D$$

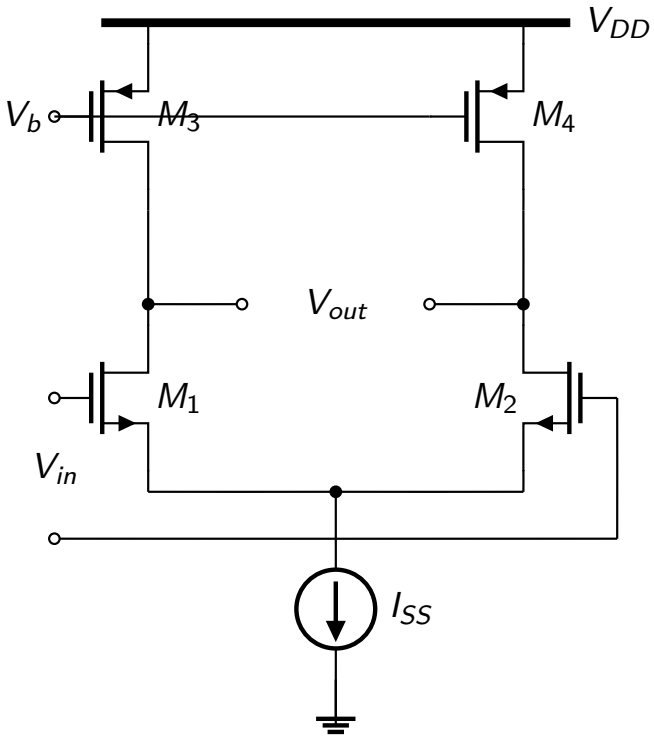
$$A_{DM} = \frac{V_{out1} - V_{out2}}{v_d} = -g_m(R_D \parallel r_o) \quad (17)$$

If the circuit is fully symmetric,

$$A_{CM-DM} = \frac{V_{out1} - V_{out2}}{v_{in,CM}} = 0 \quad (18)$$

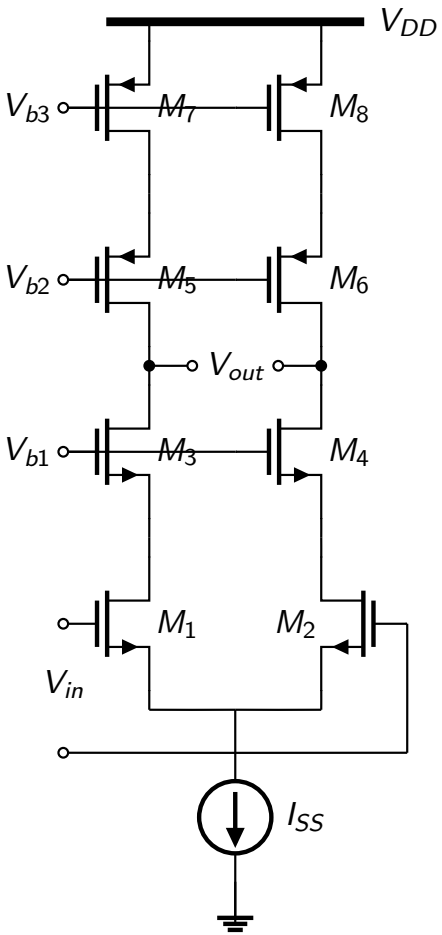
$$CMRR = \left| \frac{A_{DM}}{A_{CM-DM}} \right| = \infty \quad (19)$$

Differential Pair with MOS Loads



$$A_{DM} = -g_{m1,2}(r_{o1,2} \parallel r_{o3,4}) \qquad (20)$$

Differential Pair with Cascode Loads

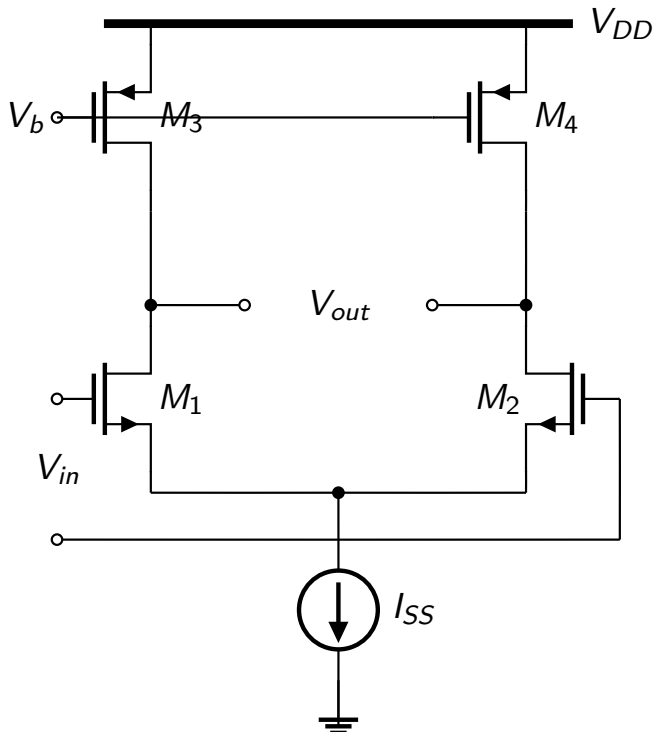


$$A_{DM} \cong -g_{m1,2}[(g_{m3,4} + gmb_{3,4})r_{o3,4}r_{o1,2} \parallel (g_{m5,6} + g_{mb5,6})r_{o5,6}r_{o7,8}] \tag{21}$$

Example 6

In the differential pair , what is the input resistance when $I_{SS} = 0.02mA$ and $0.2mA$ respectively? (Neglect body effect)
Parameter for NMOS: $V_{THN} = 0.7V$,
$K_n = 110\mu A/V^2, \lambda = 0.04V^{-1}$
Parameter for PMOS: $V_{THP} = -0.7V$,
$K_p = 50\mu A/V^2, \lambda = 0.05V^{-1}$
All the size of transistor is $W = 20\mu m, L = 1\mu m$

Example 6



Example 6

END

Thanks