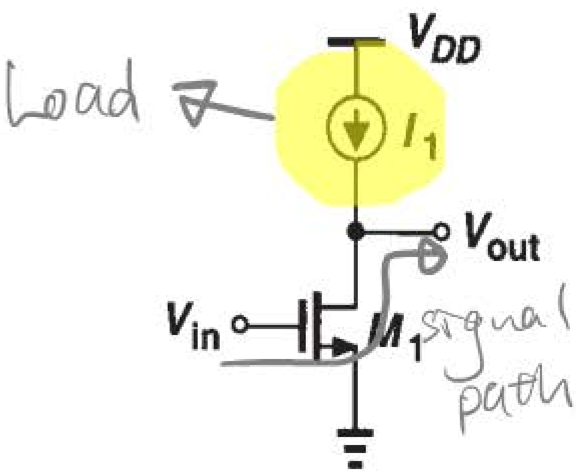
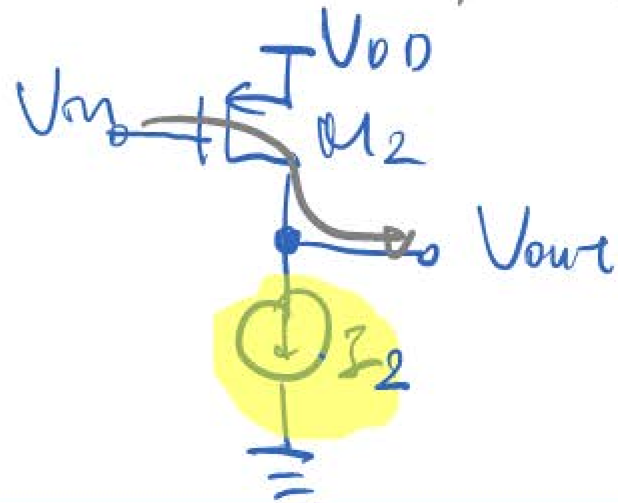
Example

Assuming M_1 in saturation, calculate its small-signal gain. (analytical form)





Solution:

$r \neq 0$

$\lambda \neq 0$

- Small-signal Analysis:

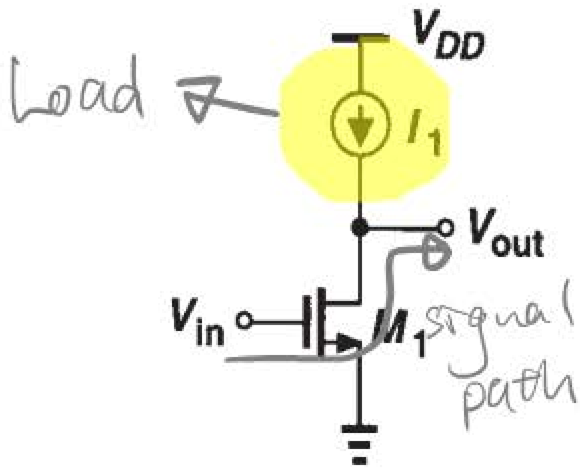
$$A_v = \frac{\upsilon_{out}}{\upsilon_{in}} = -g m_1 r_{o1} \cong \frac{1}{\lambda I_{D1}}$$

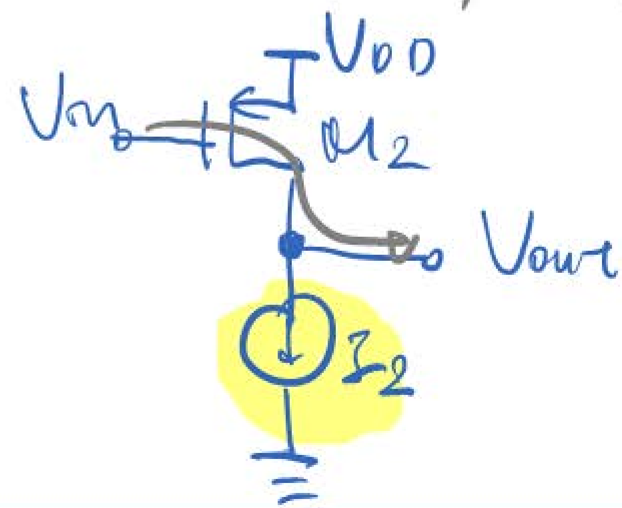
- DC Analysis:

$$I_1 = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{in} - V_{TH})^2(1 + \lambda V_{DS})$$

Example

Assuming M_1 in saturation, calculate its small-signal gain. (analytical form)





Solution:

$\lambda=0$
$r=0$

- Small-signal Analysis:

$$A_v = \frac{\upsilon_{out}}{\upsilon_{in}} = -g_{m1} r_{o1} \rightarrow \infty$$

- DC Analysis:

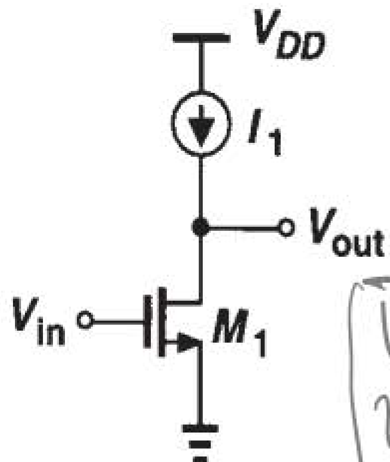
$$I_1 \cancel{=} \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{in} - V_{TH})^2 \rightarrow V_{OUT} \text{ undefined.}$$

(floating)

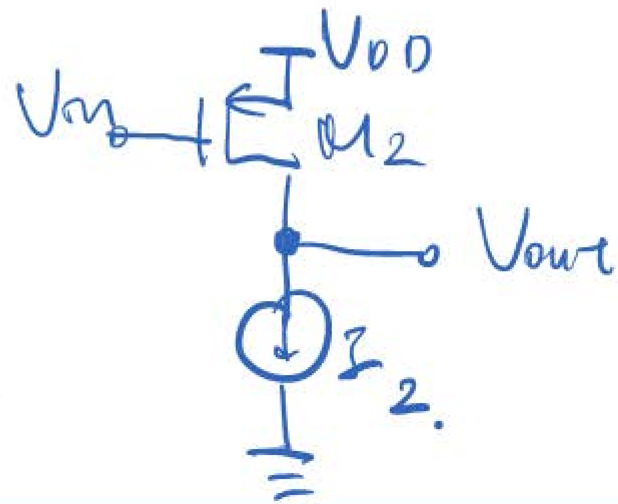
Example

Assuming M_1 in saturation, calculate its small-signal gain.

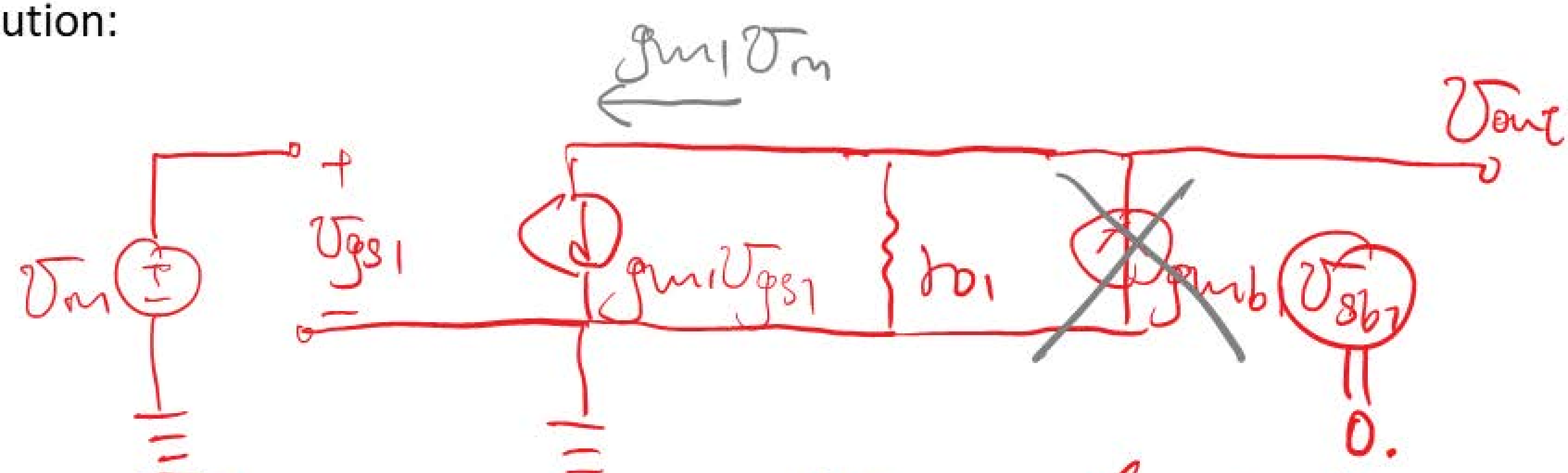
$\lambda \neq 0$
$\gamma \neq 0$



$\boxed{\begin{aligned} V_{SB1} &= 0 \\ v_{sb1} &= 0 \end{aligned}}$



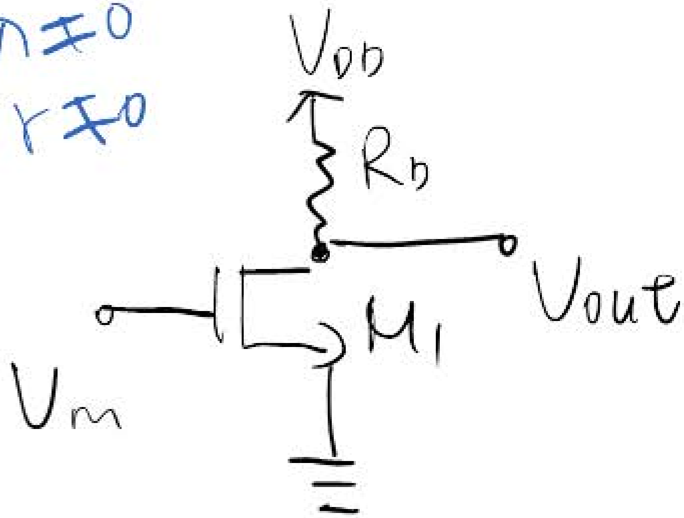
Solution:



$$A_v = \frac{v_{out}}{v_{in}} = -g_{m1} r_{o1}$$

$$v_{out} = -(g_{m1} v_{in}) r_{o1}$$

$\lambda \neq 0$
$r \neq 0$



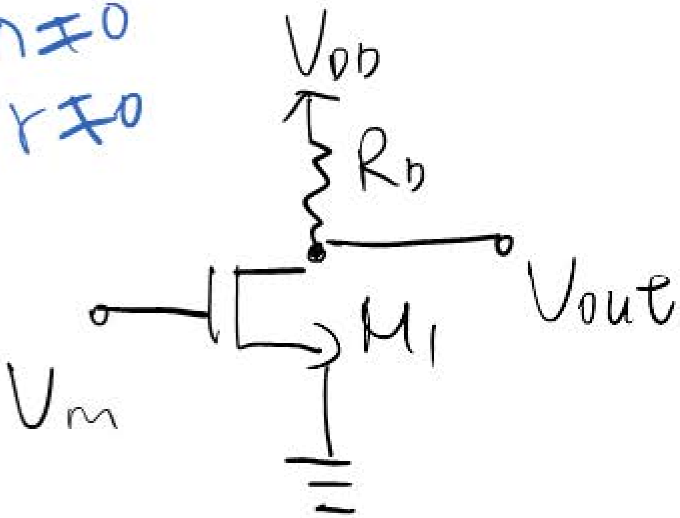
Find out the analytical expressions for A_v, R_{in} and R_{out}?

1° $A_v = -g_{m1}(r_{o1} // R_D)$

2° $R_{out} = ?$

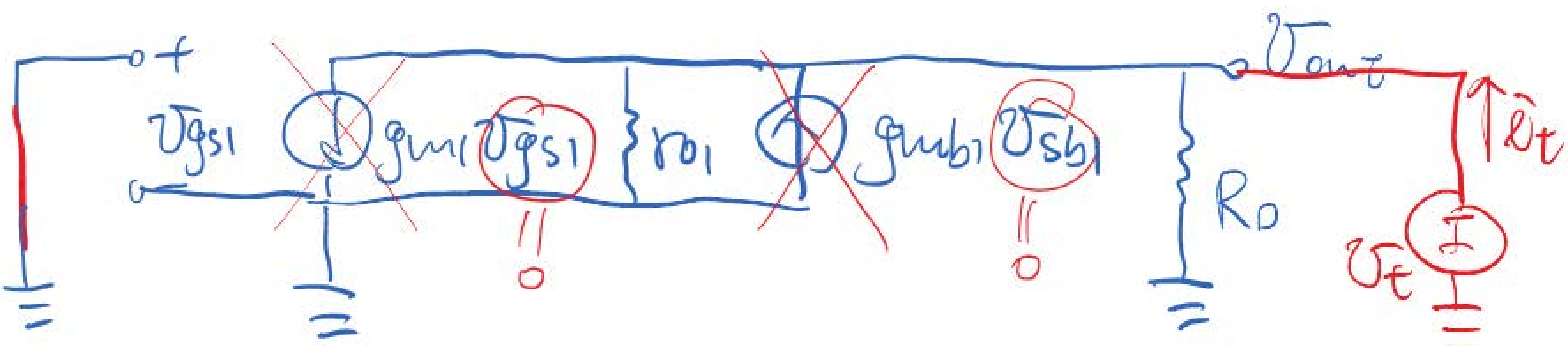
a. In small-signal circuit, turn v_{in} off.
b. Put a test small-signal (v_t) at the output.
c. Calculate small-signal current (i_t) flowing into output.
d. $R_{out} = v_t / i_t$

$\lambda \neq 0$
$\gamma \neq 0$

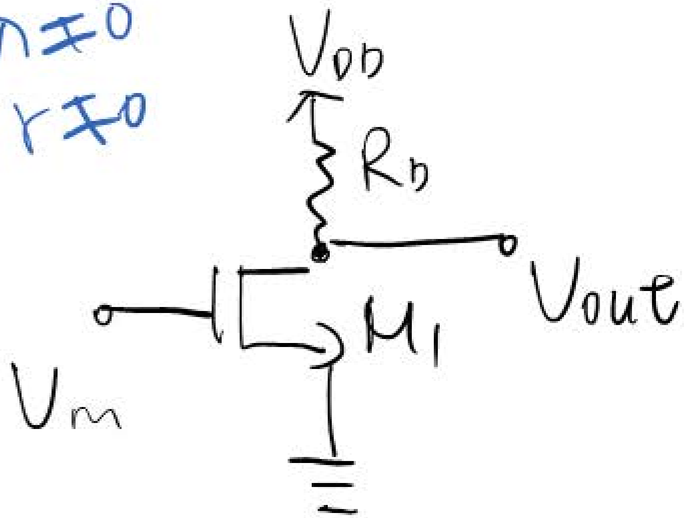


Find out the analytical expressions for A_v, R_{in} and R_{out}?

2° $R_{out} = r_{o1} // R_D$

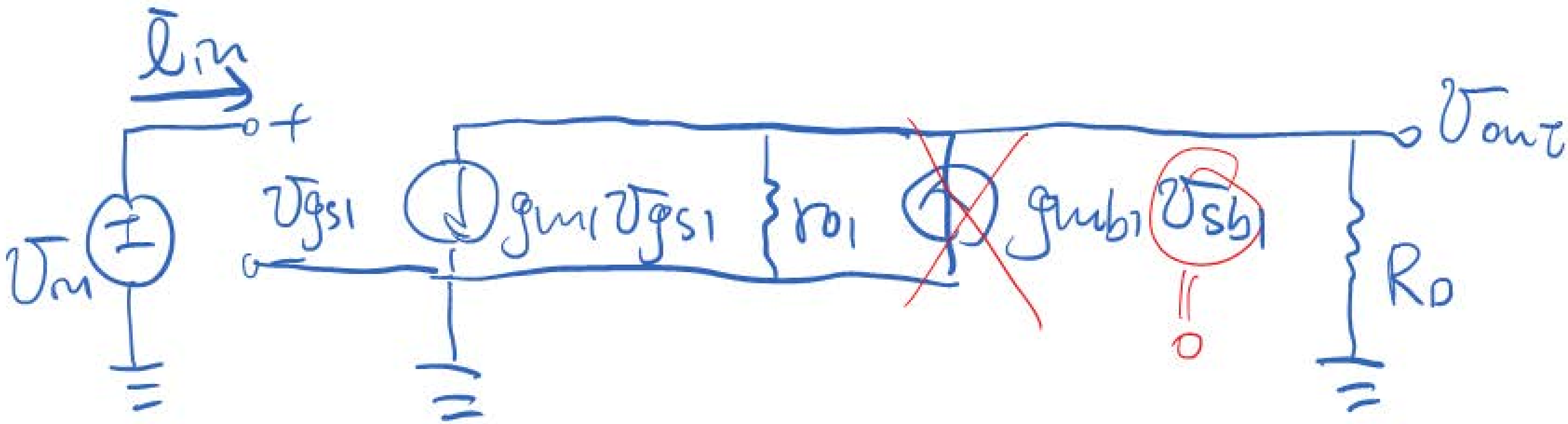


$\lambda \neq 0$
$\gamma \neq 0$

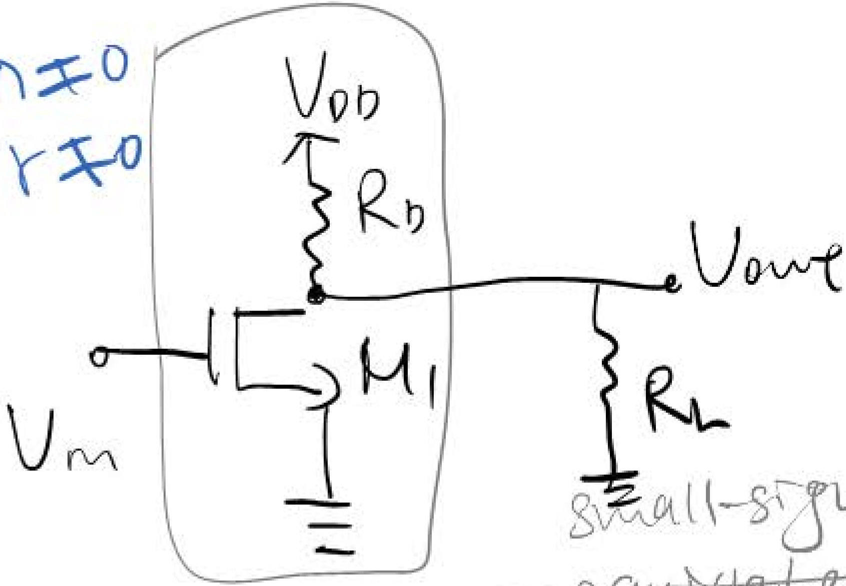


Find out the analytical expressions for A_v, R_{in} and R_{out}?

3° $R_{in} = \dfrac{v_{in}}{i_{in}} = \infty$

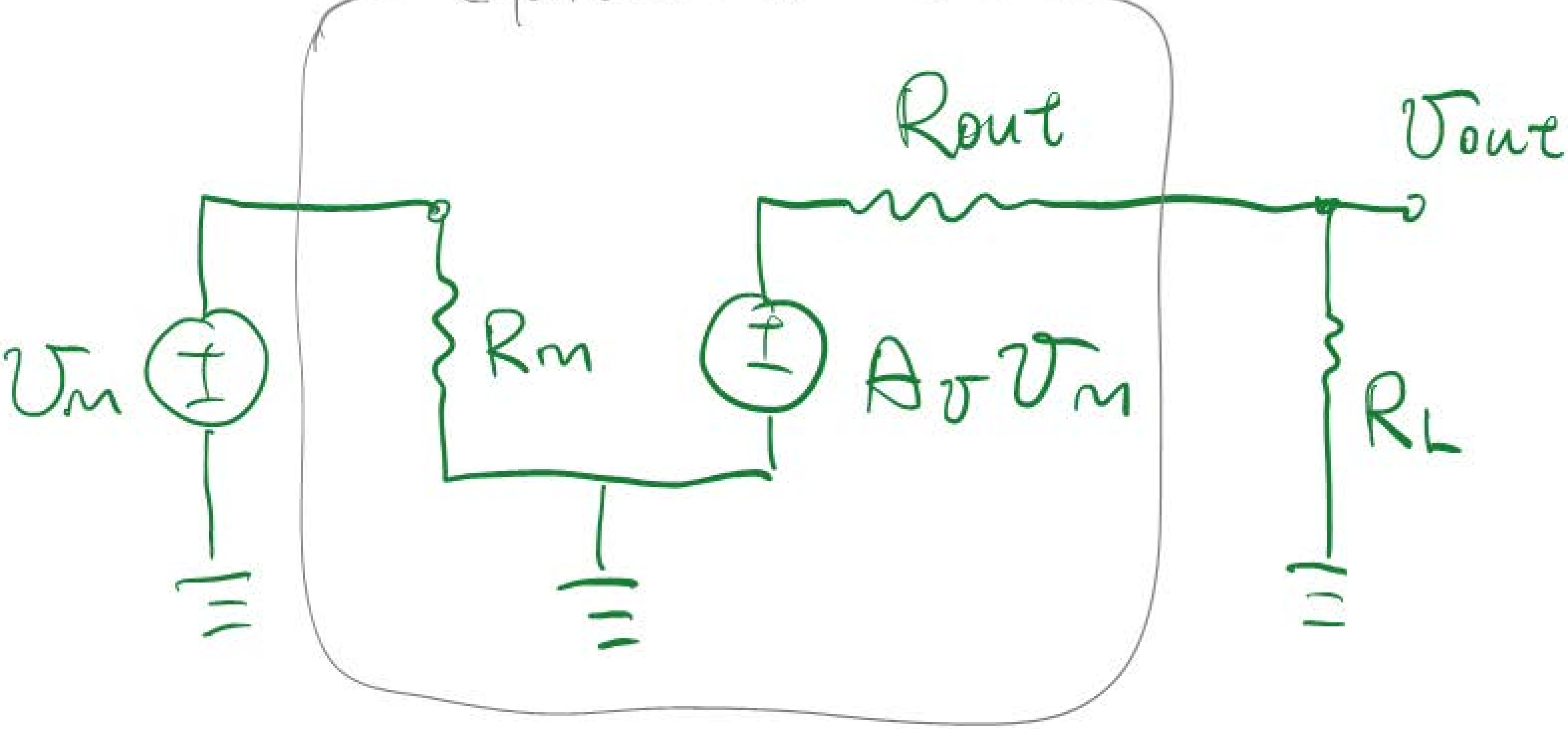


$\lambda \neq 0$
$r \neq 0$

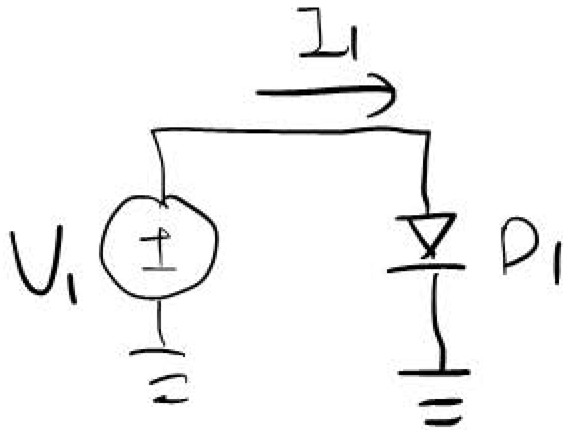


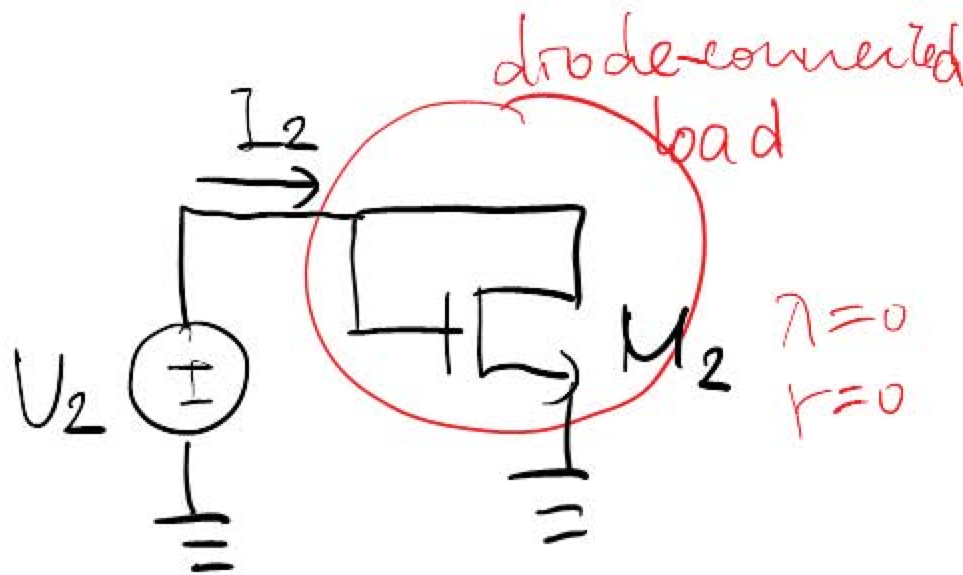
$$v_{out} = v_{in} A_v \frac{R_L}{R_{out} + R_L}$$

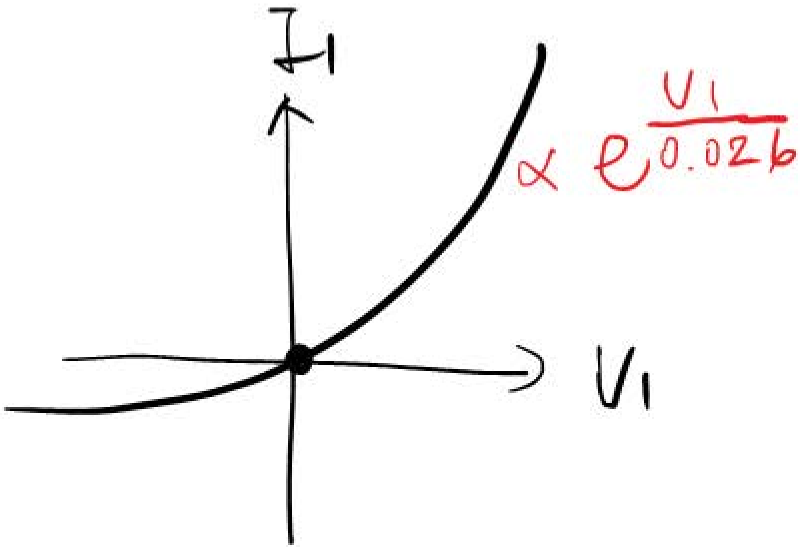
small-signal equivalent circuit.

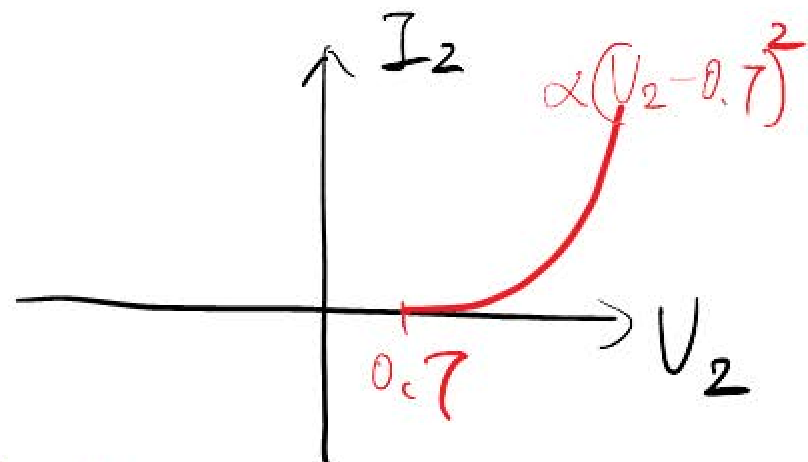


Common-Source with Diode-Connected Load



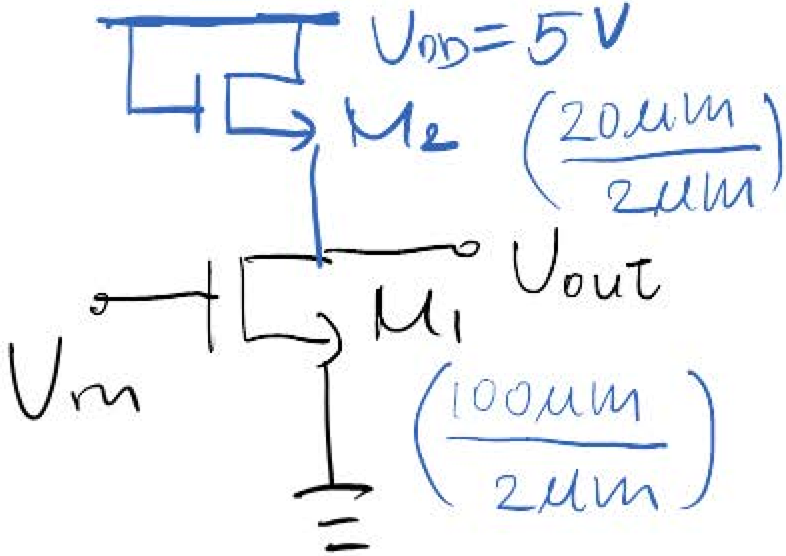






M_2 always in sat.

$$I_2 = \frac{1}{2} \mu_n C_{ox} \frac{W}{L_{eff}} (V_2 - V_{TH})^2$$



$\lambda \neq 0, \gamma \neq 0$

$V_{in} = 0.8 + 0.001 \sin(2\pi 100 t)$

$V_{out} = V_{OUT} + v_{out} = ?$

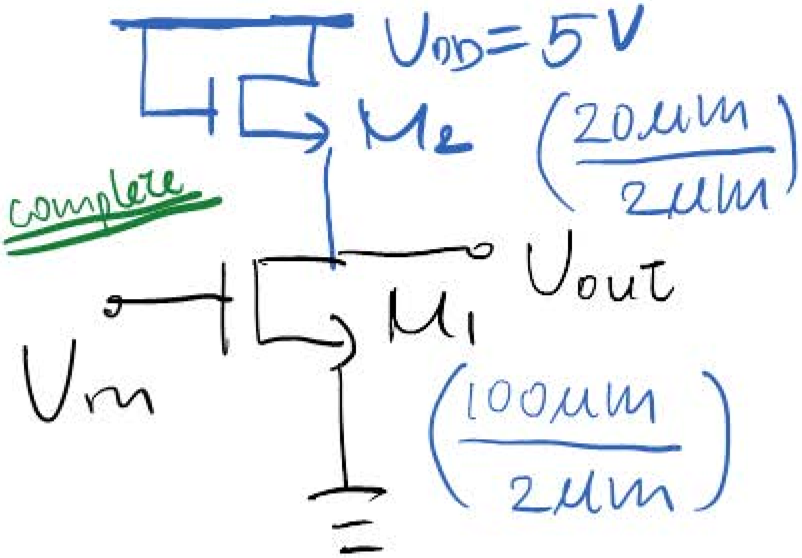
1° Find out $V_{OUT} = ?$

Then we make sure M_1 and M_2 in sat.

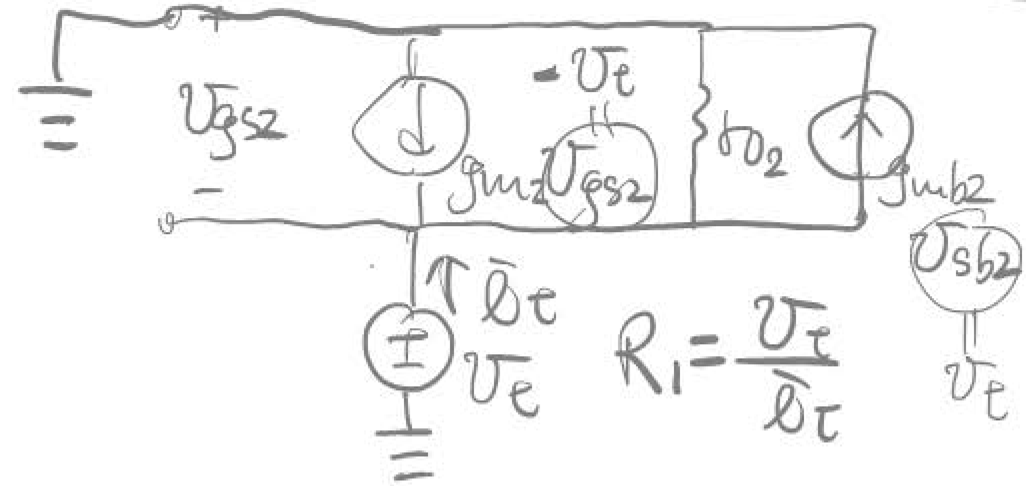
$$\frac{1}{2}\mu_n C_{ox}\left(\frac{100\mu m}{2\mu m - 2L_D}\right)(0.8-0.7)^2 \cdot (1+\lambda V_{OUT})$$

$$= \frac{1}{2}\mu_n C_{ox}\left(\frac{20\mu m}{2\mu m - 2L_D}\right) \cdot (5 - V_{OUT} - V_{TH})^2 \cdot [1+\lambda(5-V_{OUT})]$$

complete



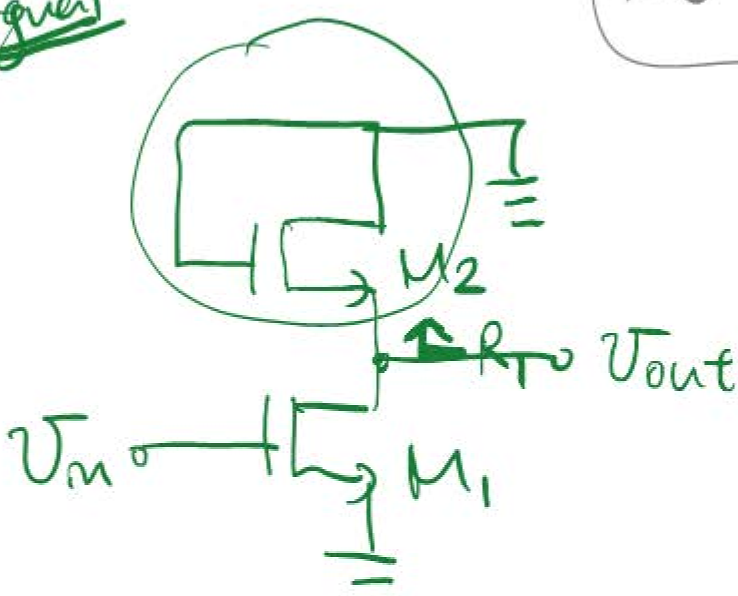
2° Find out $v_{out} = ?$



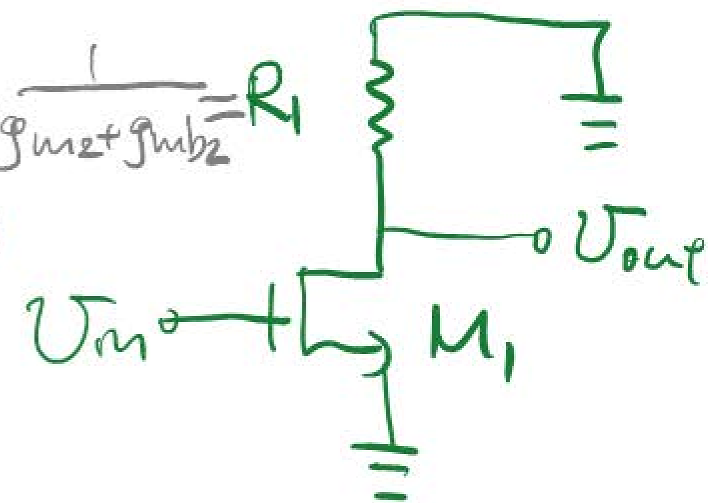
$$R_1 = \frac{v_t}{i_t}$$

$$i_t = g_{m2}v_t + \frac{v_t}{r_{o2}} + g_{mb2}v_t$$

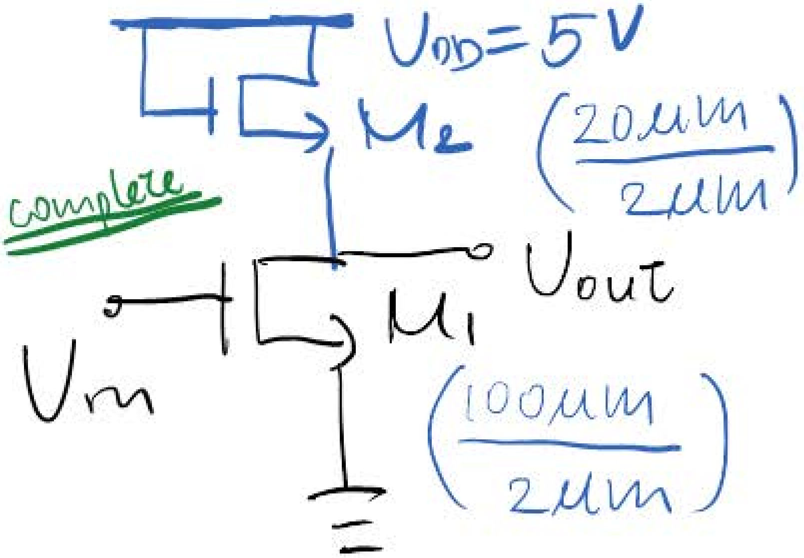
small-signal



$$r_{o2} \parallel \frac{1}{g_{m2}+g_{mb2}} = R_1$$



complete



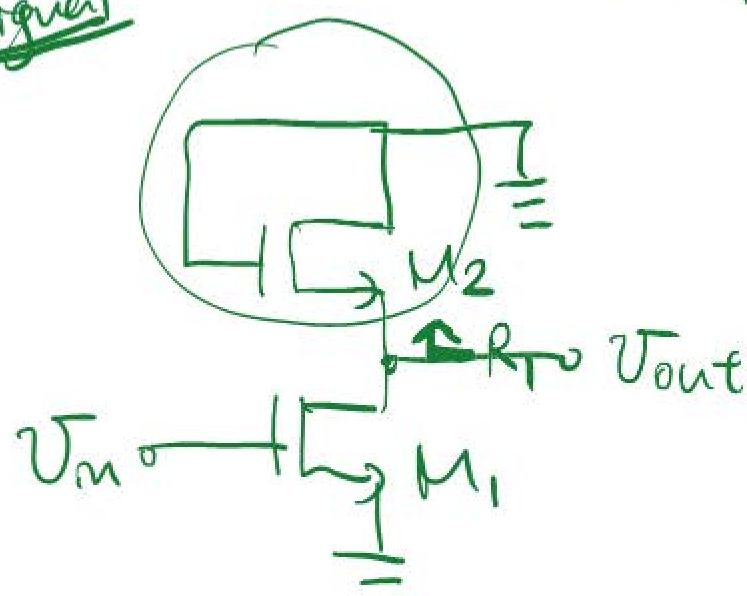
2° Find out $v_{out} = ?$

$$v_{out} = -g_{m1} v_{in} (r_{o1} // R_1)$$

$$= -g_{m1} v_{in} \left(r_{o1} // r_{o2} // \frac{1}{g_{m2}+g_{mb2}}\right)$$

$$\cong -g_{m1} v_{in} \frac{1}{g_{m2}+g_{mb2}} \cong -v_{in} \frac{g_{m1}}{g_{m2}}$$

small-signal



$\Rightarrow$

$$r_{o2} // \frac{1}{g_{m2}+g_{mb2}} = R_1$$