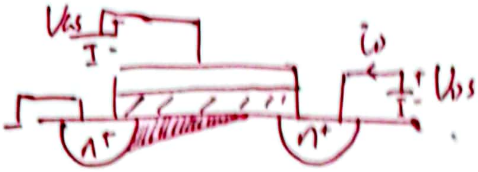
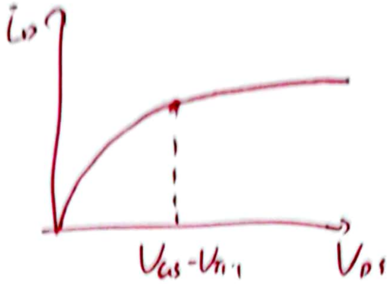
- Channel-Length Modulation





As $V_{DS}\uparrow$, the Channel-Length $\downarrow$

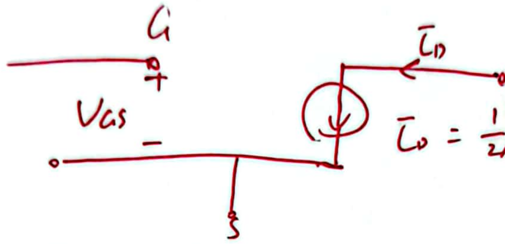
$$\int_0^{L'} I_D\,dx = \int_0^{V_{GS}-V_{TH}} \mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{TH}-V_x)\,dV$$

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

不是直接推的，待会以近似以相乘较.

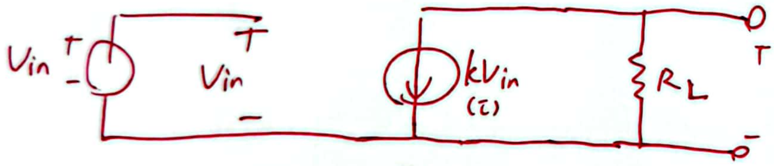
λ: $\frac{1}{V}$ Channel-Length modulation coefficient.

$\Rightarrow$ model 6 current source



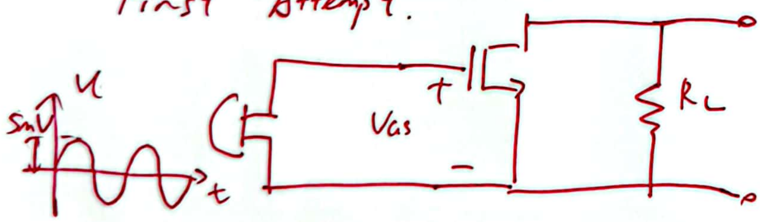
$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{TH})^2(1+\lambda V_{DS})$

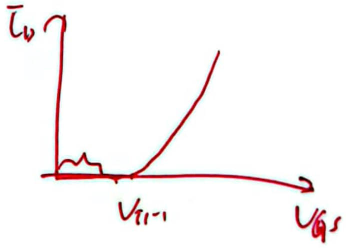
- Let's build an amplifer ($\lambda=0$)



$V_{out} = -kR_L V_{in}$

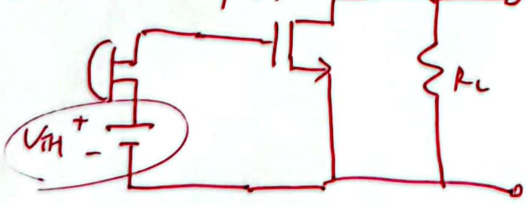
First Attempt.



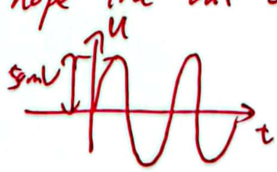


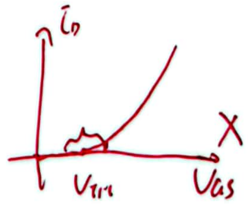
X

Second Attempt.



We hope the out be





assume $\mu_n C_{ox} = 100\,\mu A/V^2$, $\frac{W}{L}=10$, $V_{TH}=0.5V$

$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(\underbrace{V_{GS}-V_{TH}}_{}^{5mV})^2 = 12.5nA \Rightarrow R_L$ should be $\frac{50mV}{12.5nA} = 4M\Omega$

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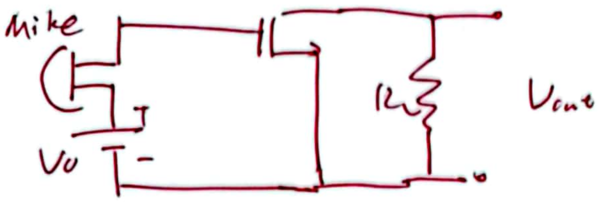
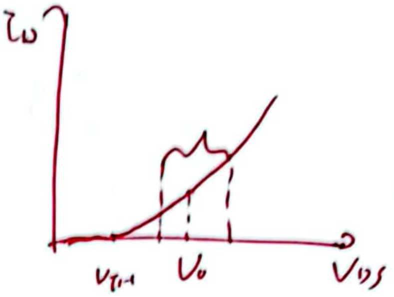
Third Attempt.





$V_0 = 0.9V,\ V_{TH} = 0.5V$

No signal: $I_{D0} = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS} - V_{TH})^2 = 80\mu A$

Max signal: $I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS} \cancel{+V} - V_{TH})^2 = 82\mu A$.

Change in $I_D = 2\mu A \Rightarrow R_L = \frac{50mV}{2\mu A} = 25k\Omega$.

☆ Need to bias the transistor by creating proper current and terminal voltages (in the absence of signals) so that the device can amplify the signal.

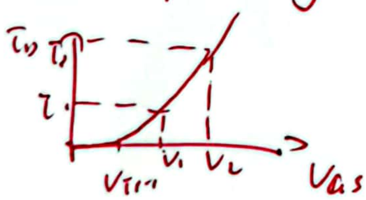
(However, V_{DS} is not taken into consideration, it must make MOS enter sat zone. We'll consider it next day)

Observations:

① A MOS device "converts" a voltage to a current

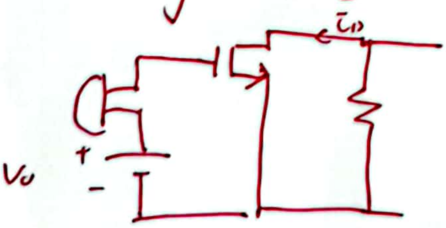
 = V/I converter = Transconductor

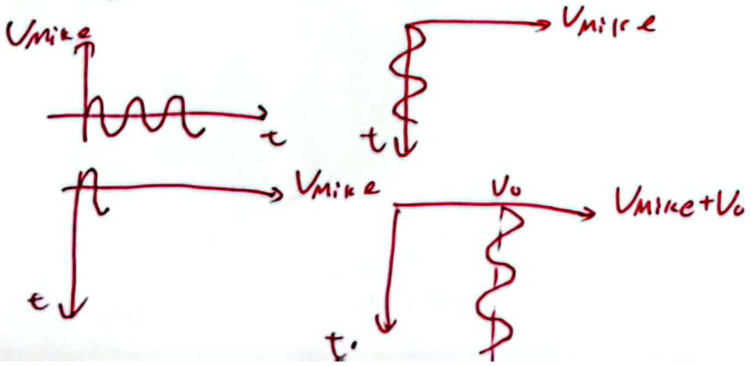
② Which operating point is ~~perfect?~~ prefered?

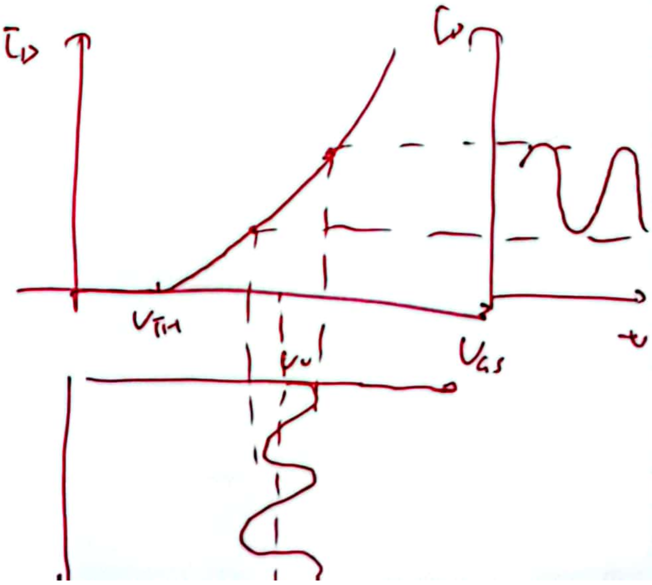


V_2/I_2 is stronger, but need more energy consumption..

Combining Time Response with I/V Characteristics.







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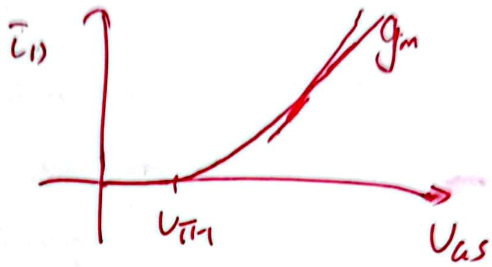
Concept of Transconductance (sat.)

$$g_m = \frac{dI_D}{dV_{GS}}$$

unit: $\frac{1}{\Omega}$. siemens (S)



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

$$g_m = \frac{dI_D}{dV_{GS}} = \mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{TH})$$

☆ $\Rightarrow g_m = \frac{2I_D}{V_{GS}-V_{TH}}$

☆ $\Rightarrow g_m = \sqrt{2I_D\mu_n C_{ox}\frac{W}{L}}$

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