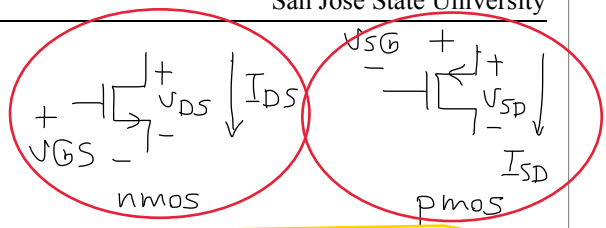
* Mosfet current equations:

$$I_{DS}=\mu_n C_{ox}\frac{W}{L}\left[(V_{GS}-V_{th})V_{DS}-\frac{V_{DS}^2}{2}\right]$$; region II

$$I_{DS}=\frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{th})^2$$; region III

$$I_{DS}=\frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{th})^2\left[1+\lambda(V_{DS}-V_{eff})\right]$$

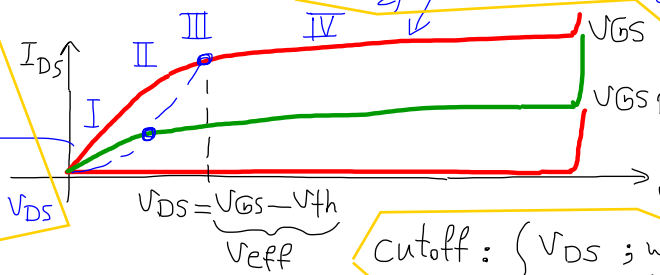


$V_{eff}=V_{ov}$

triode: $V_{DS}<V_{GS}-V_{th}$

$V_{GS}>V_{th}$

$I_{DS}=\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{th})V_{DS}$



saturation: $\begin{cases} V_{DS}\geq V_{eff} \\ V_{GS}\geq V_{th} \end{cases}$

cutoff: $\begin{cases} V_{DS}\ ;\ \text{whatever} \\ V_{GS}<V_{th} \end{cases}$

$I_{DS}=0$

V_{eff} V_{ov}

* effective / overdrive voltage is the minimum voltage applied to drain/source junctions of the transistor to ensure it is operating in the saturation or active operating point

* $V_{eff}\uparrow \Longrightarrow$ transistor becomes more linear, signal swing decreases

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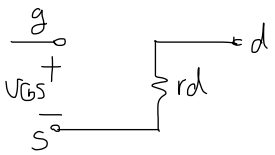
* region I:



$$r_{ds}=\frac{V_{DS}}{I_{DS}}=\frac{1}{\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{th})}$$

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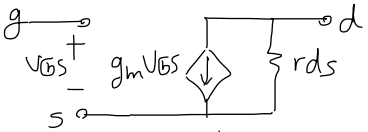
* region IV:

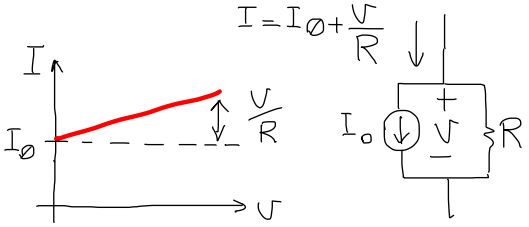


$$r_{ds}=\frac{1}{\frac{\partial I_{DS}}{\partial V_{DS}}}\approx\frac{1}{\lambda I_{DS}}$$; $\lambda\ [V^{-1}]$ Early voltage

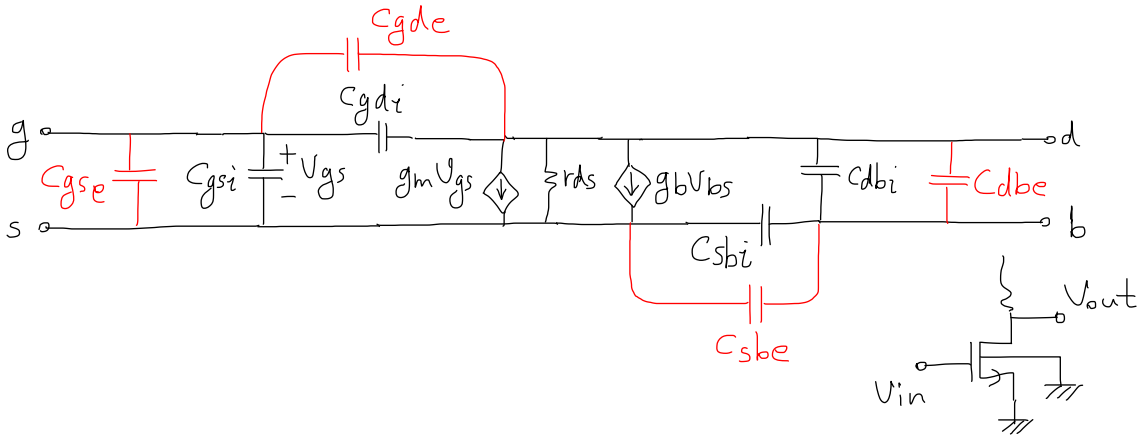
transconductance gain $=\frac{I_{out}}{V_{in}}$, $\lambda\approx 0$

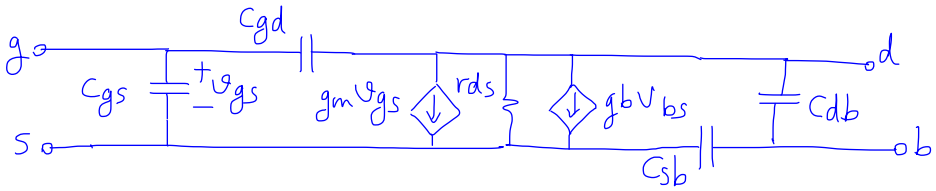
$$g_m=\frac{\partial I_{DS}}{\partial V_{GS}}=\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{th})$$

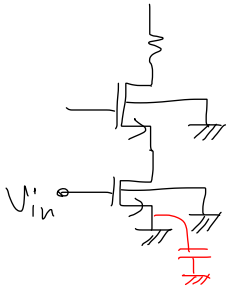
$I=I_0+\frac{V}{R}$

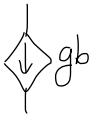


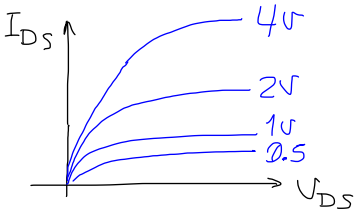
* High Frequency Model of Mosfets in saturation/active :

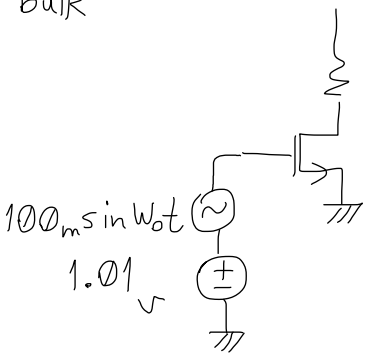




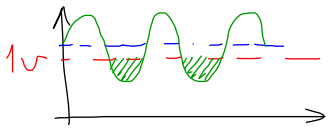


* In triode: remove current sources
* In cutoff: remove current sources and resistor
*  is modeling the body effect of transistor when source has different voltage than bulk





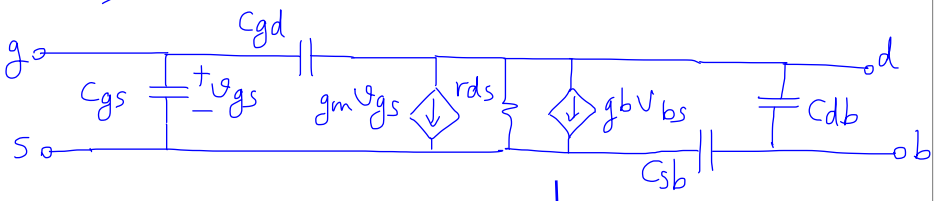
subthreshold → low power → low current

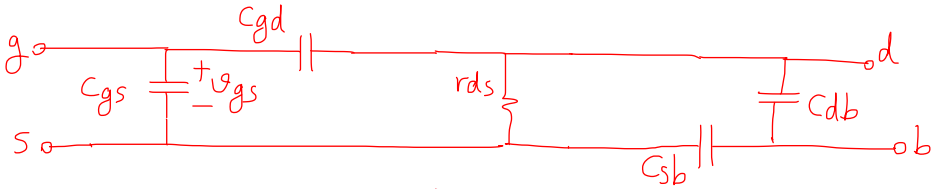


$$I_{DS}=\frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{th})^2\left[1+\lambda\left(V_{DS}-(V_{GS}-V_{th})\right)\right]$$

$$g_m=\frac{\partial I_{DS}}{\partial V_{GS}}\approx \mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{th})$$

$$r_{ds}=\frac{1}{\frac{\partial I_{DS}}{\partial V_{DS}}}\approx\frac{1}{\lambda I_{DS}}$$





$V_{GS}>V_{th}$

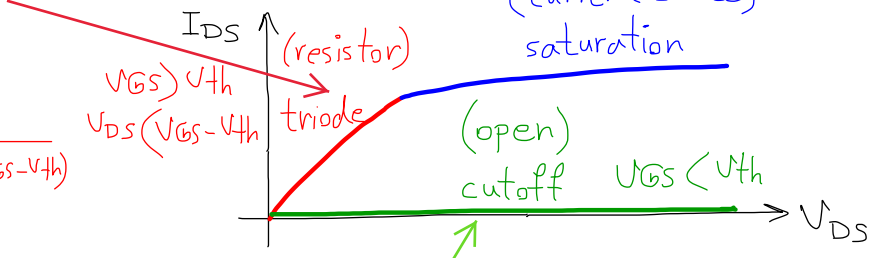
$V_{DS}>V_{GS}-V_{th}$

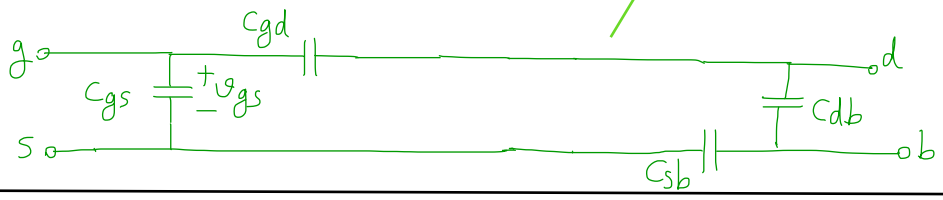
(current source)

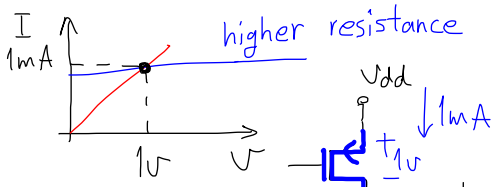
saturation

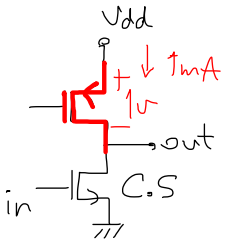
$$I_{DS}=\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{th})V_{DS}$$

$$r_{ds}=\frac{1}{\frac{\partial I_{DS}}{\partial V_{DS}}}=\frac{V_{DS}}{I_{DS}}=\frac{1}{\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{th})}$$









$$A_{v0}=-g_{m1}(r_{ds1}\parallel r_{ds2})$$

↑ triode

$$A_{v0}=-g_{m1}(r_{ds1}\parallel r_{ds2})$$

↑ saturation