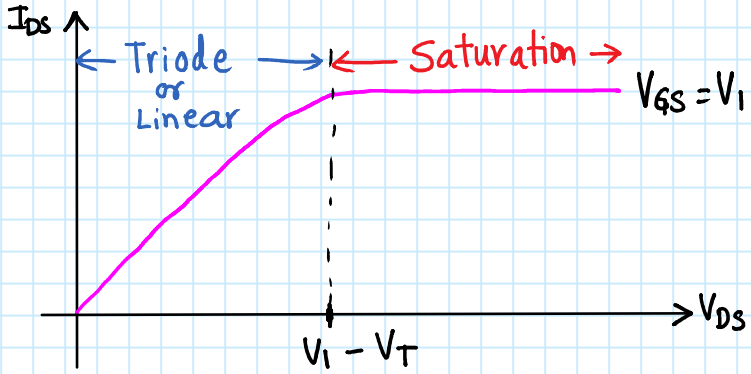
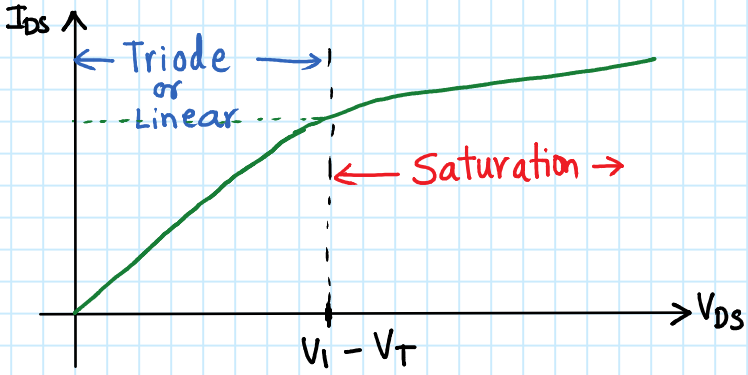
Lecture 14 (MOS Terminal impedances)

"Ideal" MOSFET I_{DS} Vs V_{DS} characteristic:



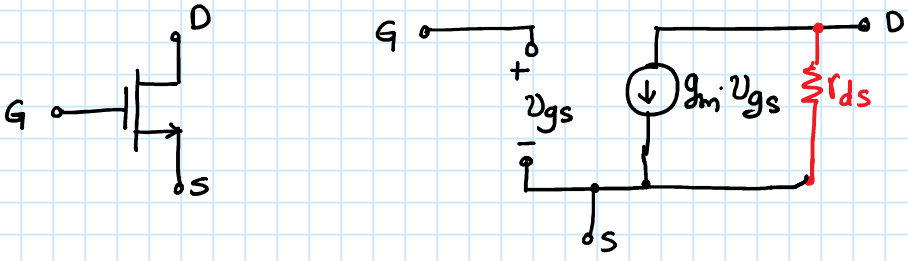
In saturation: $\frac{\partial I_D}{\partial V_{DS}} = 0 \Rightarrow$ resistance between drain & soure $r_{ds} = \infty$

"Practical" MOSFET I_{DS} Vs. V_{DS} characteristic:

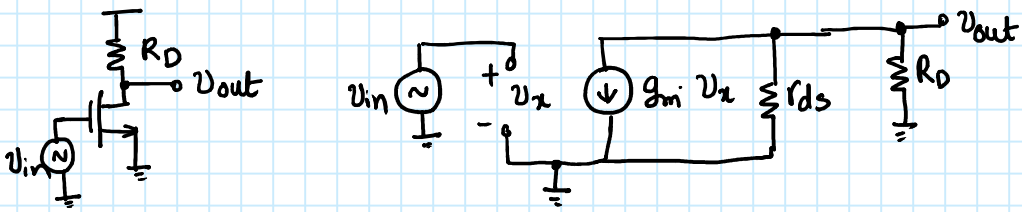


In saturation: $\frac{\partial I_D}{\partial V_{DS}} \neq 0 \Rightarrow r_{ds}$ is finite $\Rightarrow$ "non-ideal" current source

MOSFET incremental model with r_{ds}:

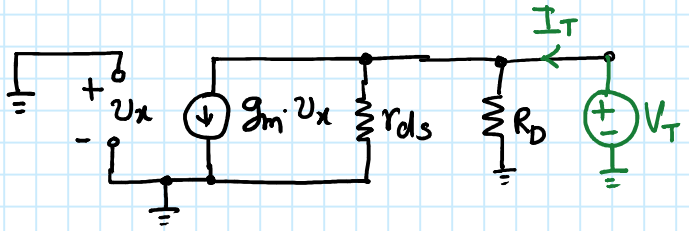


CS amplifier gain calculation with r_{ds}



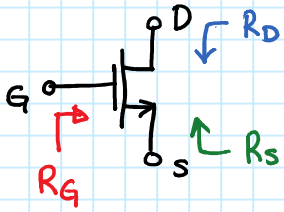
$$A_v = -g_m R_D \| r_{ds}$$

Output impedance of a CS amplifier:



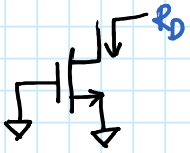
$$R_{OUT} = \frac{V_T}{I_T} = r_{ds} \parallel R_D$$

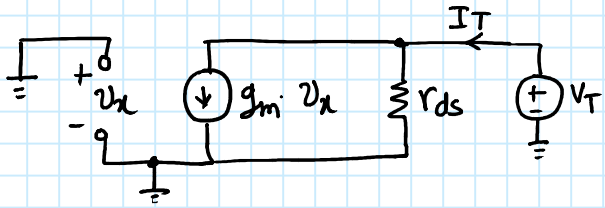
MOSFET terminal impedances:



Impedance looking into gate: $R_G = \infty$

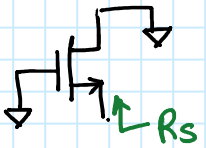
Impedance looking into drain: R_D when gate & drain are at incremental ground

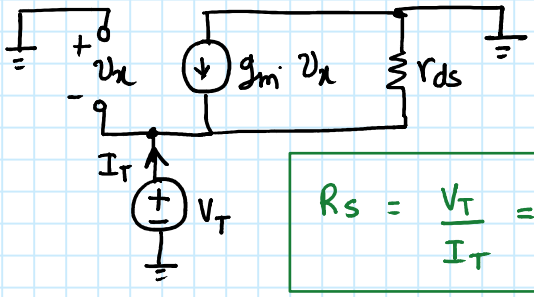




$$R_D = \frac{V_T}{I_T} = r_{ds}$$

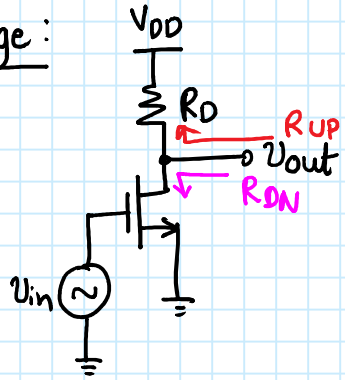
Impedance looking into source: R_S when gate & drain are at incremental ground





$$R_S = \frac{V_T}{I_T} = \frac{1}{g_m} \parallel r_{ds} \approx \frac{1}{g_m} \text{ if } g_m r_{ds} >> 1$$

Revisit CS Stage:

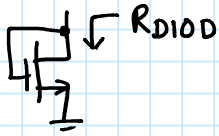


$$R_{OUT} = R_{UP} \parallel R_{DN}$$

$R_{UP} = R_D$ $R_{DN} = r_{ds}$

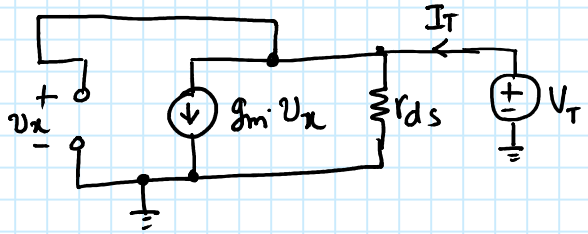
Examples:

(1)



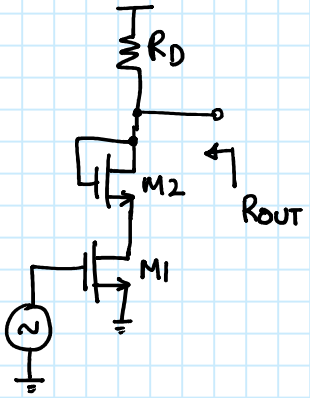
$$R_{DIODE} = \frac{1}{g_m} \parallel r_{ds}$$

Proof:



$$R_{DIODE} = \frac{V_T}{I_T} = \frac{1}{g_m} \parallel r_{ds} \approx \frac{1}{g_m}$$

(2)

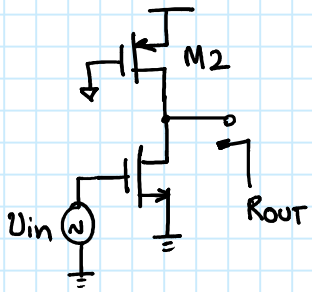


$$R_{OUT} = R_D \parallel \left[\left(\frac{1}{g_{m2}} \parallel r_{ds2} \right) + r_{ds1} \right]$$

$$\approx R_D \parallel \left(\frac{1}{g_{m2}} + r_{ds1} \right)$$

$$\approx R_D \parallel r_{ds1}$$

(3)



$$R_{OUT} = r_{ds1} \parallel r_{ds2}$$