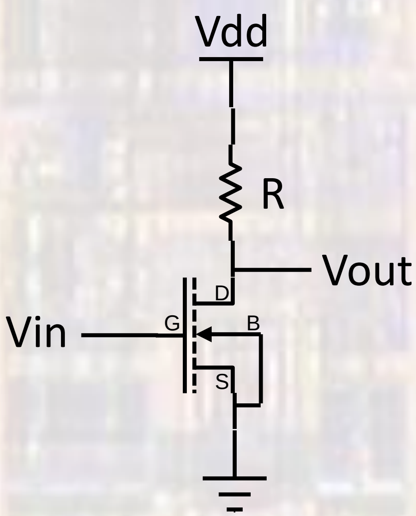
MOS Circuits

Last updated 4/2/22

MOS Circuits

- Simple Inverter - Analysis



Assuming the NMOS device is in saturation

$$I_d = \frac{k'_n}{2}\frac{W}{L}(V_{in} - V_t)^2$$

k' = 5mA/V^2, V_t = 1V, W/L = 10
Vdd = 3V, R = 100Ω

V_{in} = 1.5v

Id = 6.25mA → Vout = 2.375V

Check: Vds > Vgs - Vt

V_{in} = 2.0v

Id = 25mA → Vout = 0.5V

Check: Vds > Vgs - Vt

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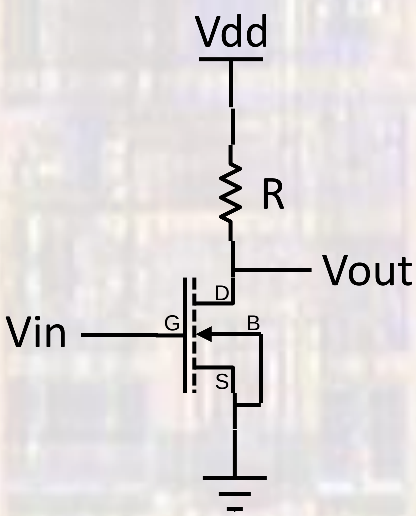


Now know NMOS device is not in saturation

$$I_D = \frac{k'_n}{2}\frac{W}{L}[2(V_{GS} - V_{tn})V_{DS} - V_{DS}^2]$$

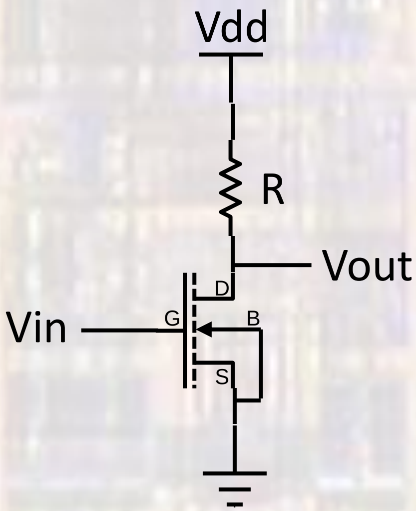
k' = 5mA/V^2, V_t = 1V, W/L = 10
Vdd = 3V, R = 100Ω

V_{in} = 2.0v
Id = 22.9mA → Vout = 0.71V

Check: Vds < Vgs - Vt ☆

MOS Circuits

- Simple Inverter - Design



Assuming Vdd is big enough to keep the NMOS device in saturation at the switching point

$$\frac{V_{dd} - V_{ds}}{R} = \frac{k'_n}{2}\frac{W}{L}(V_{ds} - V_t)^2$$

Desire a switching point mid way

$$V_{out} = V_{in} = {V_{dd}}/{2} = {V_{ds}}/{2}$$

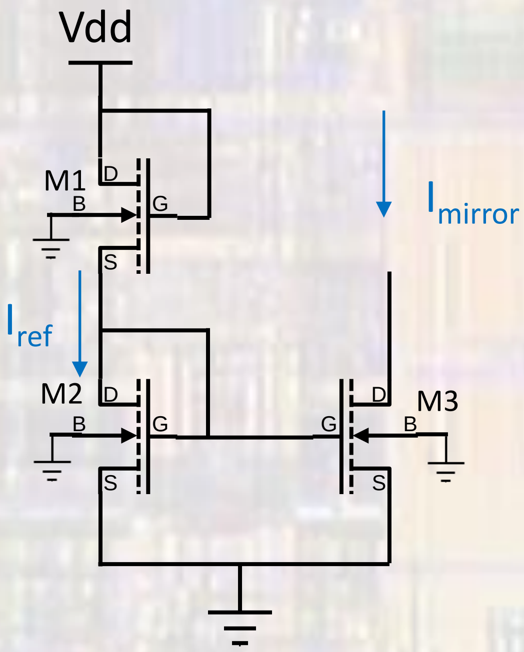
$$\frac{{V_{dd}}/{2}}{R} = \frac{k'_n}{2}\frac{W}{L}\left({V_{dd}}/{2} - V_t\right)^2$$

$$R = \frac{{V_{dd}}/{2}}{\frac{k'_n}{2}\frac{W}{L}\left({V_{dd}}/{2} - V_t\right)^2}$$

$$\frac{W}{L} = \frac{{V_{dd}}/{2}}{R\frac{k'_n}{2}\left({V_{dd}}/{2} - V_t\right)^2}$$

MOS Circuits

- Current Source



Assuming Vdd is big enough to keep the NMOS devices in saturation

$$\frac{k'_{n1}}{2}\frac{W1}{L1}\left(V_{gs1}-V_{t1}\right)^2=\frac{k'_{n2}}{2}\frac{W2}{L2}\left(V_{gs2}-V_{t2}\right)^2$$

Using similar transistors: $V_{t1} = V_{t2} = V_{t3}$, $k'_{n1} = k'_{n2} = k'_{n3}$
and noting: $V_{gs1} + V_{gs2} = V_{dd}$

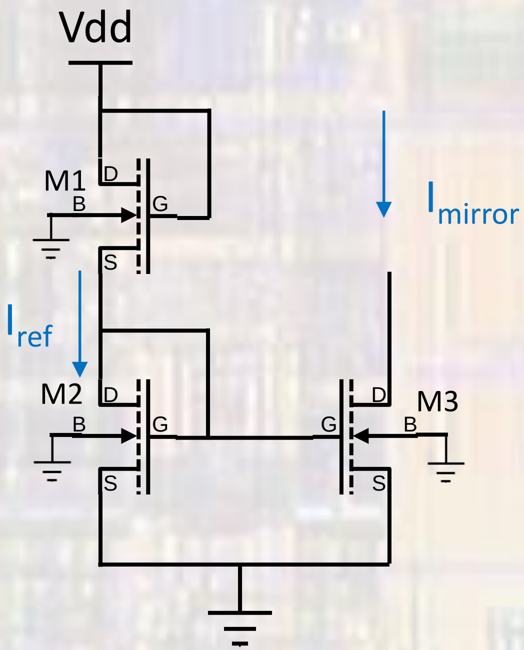
$$V_{gs2}=\frac{\sqrt{\frac{W1}{L1}\frac{L2}{W2}}\left(V_{dd}-V_t\right)+V_t}{1+\sqrt{\frac{W1}{L1}\frac{L2}{W2}}}$$

$$I_{ref}=\frac{k'_n}{2}\frac{W2}{L2}\left[\frac{\sqrt{\frac{W1}{L1}\frac{L2}{W2}}\left(V_{dd}-V_t\right)+V_t}{1+\sqrt{\frac{W1}{L1}\frac{L2}{W2}}}-V_t\right]^2$$

MOS Circuits

- Current Source

$$I_{ref} = \frac{k'_n}{2}\frac{W2}{L2}\left[\frac{\sqrt{\frac{W1}{L1}\frac{L2}{W2}}(V_{dd} - V_t) + V_t}{1 + \sqrt{\frac{W1}{L1}\frac{L2}{W2}}} - V_t\right]^2$$



$$I_{mirror} = \frac{k'_n}{2}\frac{W3}{L3}\left(V_{gs2} - V_t\right)^2$$

$$I_{mirror} = I_{ref}\frac{\frac{k'_n}{2}\frac{W3}{L3}}{\frac{k'_n}{2}\frac{W2}{L2}} = I_{ref}\frac{W3}{L3}\frac{L2}{W2}$$