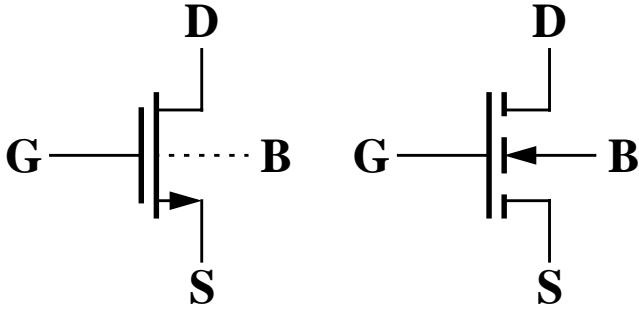


NMOS



Threshold voltage

$$V_T = V_{T0} + \gamma(\sqrt{|\phi_B| + V_{SB}} - \sqrt{|\phi_B|})$$

Saturation region ($V_{DS} > V_{GS} - V_T$)

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

$$g_m = \frac{\partial I_D}{\partial V_{GS}} \approx \mu C_{ox} \frac{W}{L} (V_{GS} - V_T) \approx \frac{2I_D}{V_{GS} - V_T} \approx \sqrt{2\mu C_{ox} \frac{W}{L} I_D}$$

$$g_d = \frac{\partial I_D}{\partial V_{DS}} = \frac{\mu C_{ox} W}{2L} (V_{GS} - V_T)^2 \lambda \approx \lambda I_D = \frac{\lambda'}{L} I_D$$

$$g_{mb} = \frac{\partial I_D}{\partial V_{BS}} = g_m \frac{\gamma}{2\sqrt{|\phi_B| + V_{SB}}}$$

Linear region ($V_{DS} < V_{GS} - V_T$)

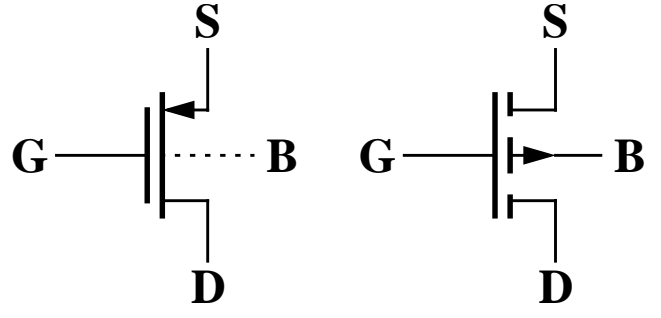
$$I_D = \mu C_{ox} \frac{W}{L} \left((V_{GS} - V_T) V_{DS} - \frac{V_{DS}^2}{2} \right) (1 + \lambda V_{DS})$$

$$g_m = \frac{\partial I_D}{\partial V_{GS}} \approx \mu C_{ox} \frac{W}{L} V_{DS}$$

$$g_d = \frac{\partial I_D}{\partial V_{DS}} \approx \mu C_{ox} \frac{W}{L} (V_{GS} - V_T - V_{DS})$$

$$g_{mb} = \frac{\partial I_D}{\partial V_{BS}} = g_m \frac{\gamma}{2\sqrt{|\phi_B| + V_{SB}}}$$

PMOS



Threshold voltage

$$V_T = V_{T0} - \gamma(\sqrt{|\phi_B| + V_{BS}} - \sqrt{|\phi_B|})$$

Saturation region ($V_{SD} > V_{SG} - |V_T|$)

$$I_D = -\frac{\mu C_{ox} W}{2L} (V_{SG} - |V_T|)^2 (1 + \lambda V_{SD})$$

$$g_m = \frac{\partial I_D}{\partial V_{GS}} \approx \mu C_{ox} \frac{W}{L} (V_{SG} - |V_T|) \approx \frac{2|I_D|}{V_{SG} - |V_T|} \approx \sqrt{2\mu C_{ox} \frac{W}{L} |I_D|}$$

$$g_d = \frac{\partial I_D}{\partial V_{DS}} = \frac{\mu C_{ox} W}{2L} (V_{SG} - |V_T|)^2 \lambda \approx \lambda |I_D| = \frac{\lambda'}{L} |I_D|$$

$$g_{mb} = \frac{\partial I_D}{\partial V_{BS}} = g_m \frac{\gamma}{2\sqrt{|\phi_B| + V_{BS}}}$$

Linear region ($V_{SD} < V_{SG} - |V_T|$)

$$I_D = -\mu C_{ox} \frac{W}{L} \left((V_{SG} - |V_T|) V_{SD} - \frac{V_{SD}^2}{2} \right) (1 + \lambda V_{SD})$$

$$g_m = \frac{\partial I_D}{\partial V_{GS}} \approx \mu C_{ox} \frac{W}{L} V_{SD}$$

$$g_d = \frac{\partial I_D}{\partial V_{DS}} \approx \mu C_{ox} \frac{W}{L} (V_{SG} - |V_T| - V_{SD})$$

$$g_{mb} = \frac{\partial I_D}{\partial V_{BS}} = g_m \frac{\gamma}{2\sqrt{|\phi_B| + V_{BS}}}$$