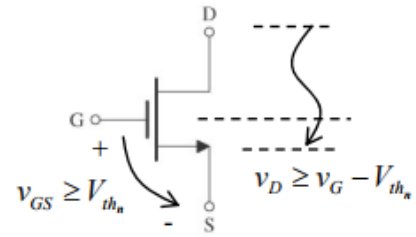


Saturation (also called **active**)

equations:
$$\begin{cases} i_G = 0 \\ i_S = i_D = \frac{k'_n}{2} \cdot \frac{W}{L} \cdot (v_{GS} - V_{th_n})^2 \cdot (1 + \lambda \cdot v_{DS}) \end{cases}$$

check:
$$\begin{cases} v_{GS} \geq V_{th_n} \\ v_{DS} \geq v_{GS} - V_{th_n} \quad \text{or equivalently } v_D \geq v_G - V_{th_n} \end{cases}$$

**Triode** (also called **ohmic**)

equations:
$$\begin{cases} i_G = 0 \\ i_S = i_D = k'_n \cdot \frac{W}{L} \cdot \left[(v_{GS} - V_{th_n}) \cdot v_{DS} - \frac{v_{DS}^2}{2} \right] \end{cases}$$

check:
$$\begin{cases} v_{GS} \geq V_{th_n} \\ v_{DS} < v_{GS} - V_{th_n} \quad \text{or equivalently } v_D < v_G - V_{th_n} \end{cases}$$

Cutoff

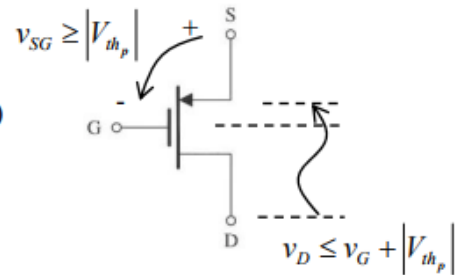
equations:
$$i_G = i_S = i_D = 0$$

check:
$$v_{GS} < V_{th_n}$$

Saturation (also called **active**)

$$\text{equations: } \begin{cases} i_G = 0 \\ i_S = i_D = \frac{k'_p}{2} \cdot \frac{W}{L} \cdot (v_{SG} - |V_{th_p}|)^2 \cdot (1 + \lambda \cdot v_{SD}) \end{cases}$$

$$\text{check: } \begin{cases} v_{SG} \geq -V_{th_p} = |V_{th_p}| \\ v_{SD} \geq v_{SG} - |V_{th_p}| \text{ or equivalently } v_D \leq v_G + |V_{th_p}| \end{cases}$$

**Triode** (also called **ohmic**)

$$\text{equations: } \begin{cases} i_G = 0 \\ i_S = i_D = k'_p \cdot \frac{W}{L} \cdot \left[(v_{SG} - |V_{th_p}|) \cdot v_{SD} - \frac{v_{SD}^2}{2} \right] \end{cases}$$

$$\text{check: } \begin{cases} v_{SG} \geq -V_{th_p} = |V_{th_p}| \\ v_{SD} < v_{SG} - |V_{th_p}| \text{ or equivalently } v_D > v_G + |V_{th_p}| \end{cases}$$

Cutoff

$$\text{equations: } i_G = i_S = i_D = 0$$

$$\text{check: } v_{SG} < -V_{th_p} = |V_{th_p}|$$

7. MOSFETs: NMOS and PMOS regions of operation: For the following transistors, tell me what region of operation they are in. Let's randomly pick a VTN (threshold voltage for the NMOS) of 0.5V, VTP (threshold voltage for the PMOS) of -0.68V, and VDD=3.3V. Make sure to be careful of whether a transistor is a NMOS or a PMOS. The options are active, linear or cutoff.

- PMOS, Vsg = 0, cut-off
- PMOS, Vsg = -1.35V, cut-off
- NMOS, Vgs = 0.55V, linear
- NMOS, Vgs = 3.3V, active
- NMOS, Vgs = 0.02V, cutoff
- NMOS, Vgs = 1V, linear
- NMOS, vg

