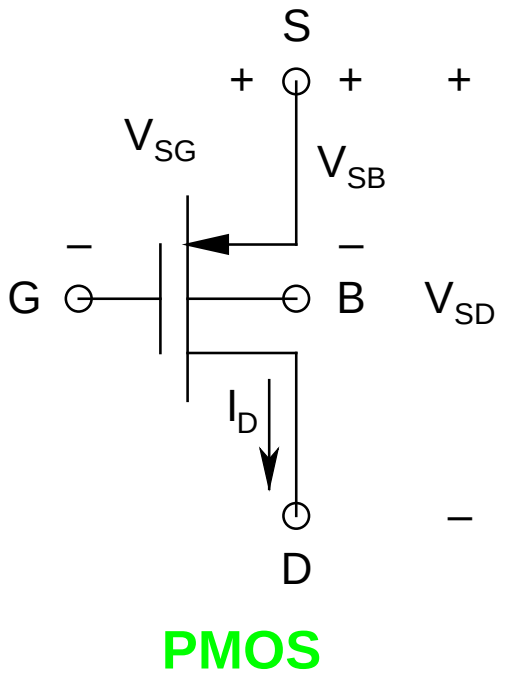
p-channel MOSFET (PMOS)

- Before moving to ***NMOS stages with active load***, it will be prudent to visit some details regarding ***PMOS***
- ***Substrate***: ***n-type*** (N_D)
  - ***Bulk Potential***:

    $\phi_F = V_T \ln(N_D/n_i)$
- ***Source/Drain***: p^+
- ***Channel Carriers***: ***Holes***



- ***Threshold Voltage***:

$$V_{TP} = V_{TP0} - \gamma\left(\sqrt{2\phi_F + V_{BS}} - \sqrt{2\phi_F}\right)$$

V_{TP0}: ***Zero back-bias threshold voltage*** (***negative***)

- ***Body effect coefficient***:

$$\gamma = \frac{\sqrt{2q\varepsilon_s N_D}}{C'_{ox}}$$

  - $V_{BS} \geq 0$ (***to prevent forward biasing of SB junction***)

- ***With back bias***, V_{TP} ***becomes more negative***
- V_{GS} ***has to be less than*** V_{TP} ***to turn device on***

- ***Current-Voltage Relation***:
  - ***Both V_{GS} and V_{DS} negative***
  - ***I_D flows from source to drain*** (the ***same direction of flow as holes***)
  - ***In saturation*** $[|V_{DS}| > (|V_{GS}| - |V_{TP}|)]$:

$$I_D = \frac{k'_P}{2}\frac{W}{L}\left(|V_{GSp}| - |V_{TP}|\right)^2\left(1+\lambda_p|V_{DSp}|\right)$$

  - ***In non-saturation*** $[|V_{DS}| < (|V_{GS}| - |V_{TP}|)]$:

$$I_D = k'_P\frac{W}{L}\left[\left(|V_{GSp}| - |V_{TP}|\right)|V_{DSp}| - |V_{DSp}|^2/2\right]$$

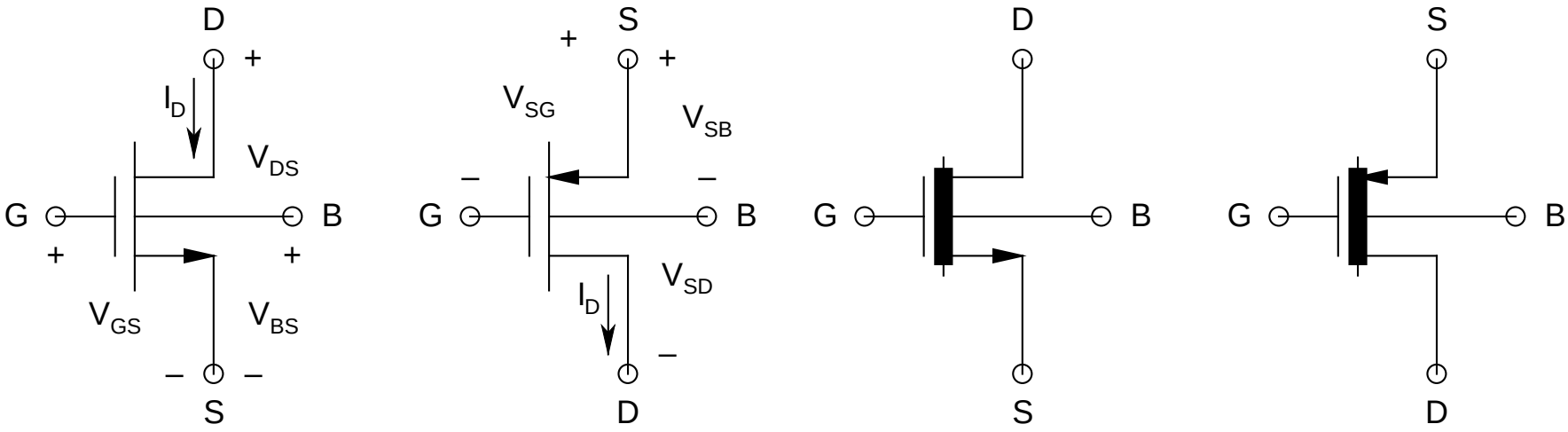
$$k'_P = \mu_p C'_{ox}$$

$=$ ***Process transconductance parameter***

μ_p = ***Channel hole mobility***

- ***Based on the value of V_{TN0} and V_{TP0}***, there are ***two classifications***:
  - ***Enhancement Mode***: ***Normally Off*** (***with $V_{GS} = 0$***)
    - ***V_{TN0} positive*** and ***V_{TP0} negative***
  - ***Depletion Mode***: ***Normally On*** (***with $V_{GS} = 0$***)
    - ***V_{TN0} negative*** and ***V_{TP0} positive***

Symbols



- Note the ***thick band*** in the ***channel region*** for ***depletion mode devices***, which implies that ***channel is present*** even ***with $V_{GS} = 0$***