MOSFET & SPICE Models

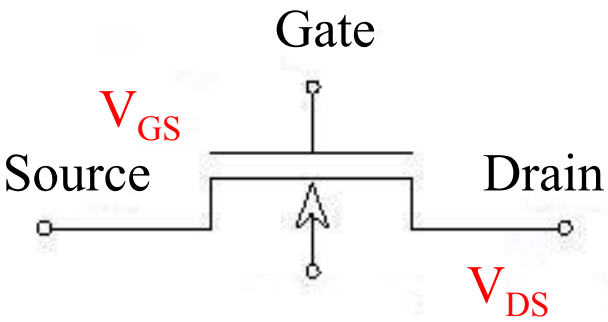
Outline

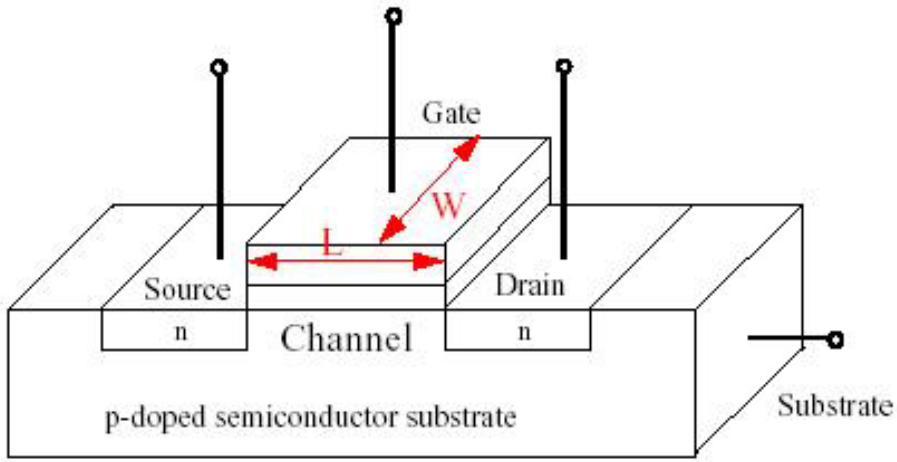
- MOSFET Structure
- MOSFET Operation
- I-V Characteristic
- SPICE Model:
  - Diode
  - MOSFET

This lecture covers Sections 3.2 & 3.3 of your textbook

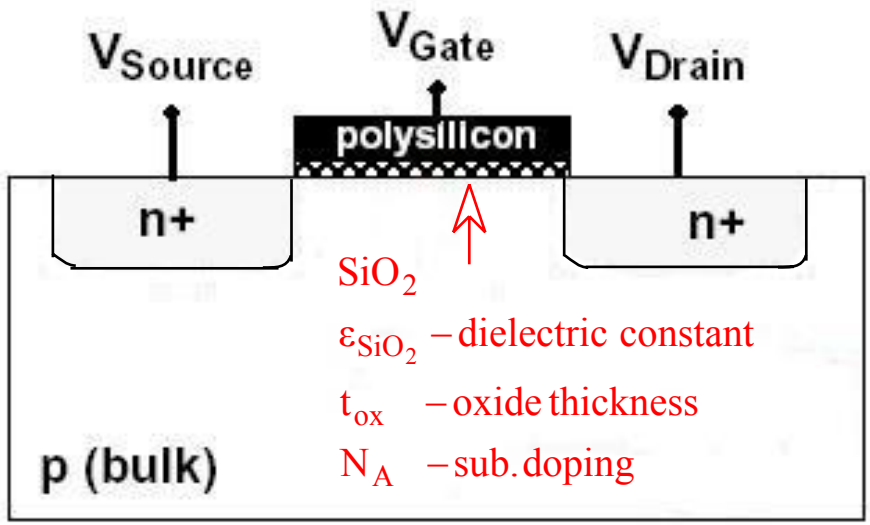
MOSFET STRUCTURE

3D

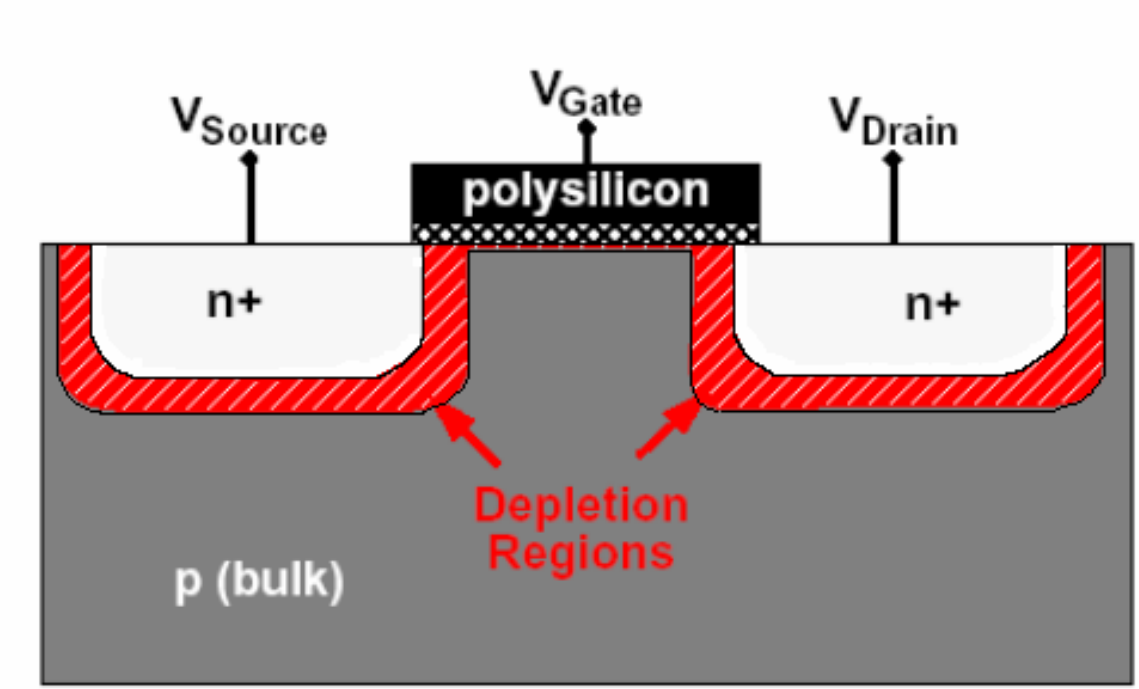


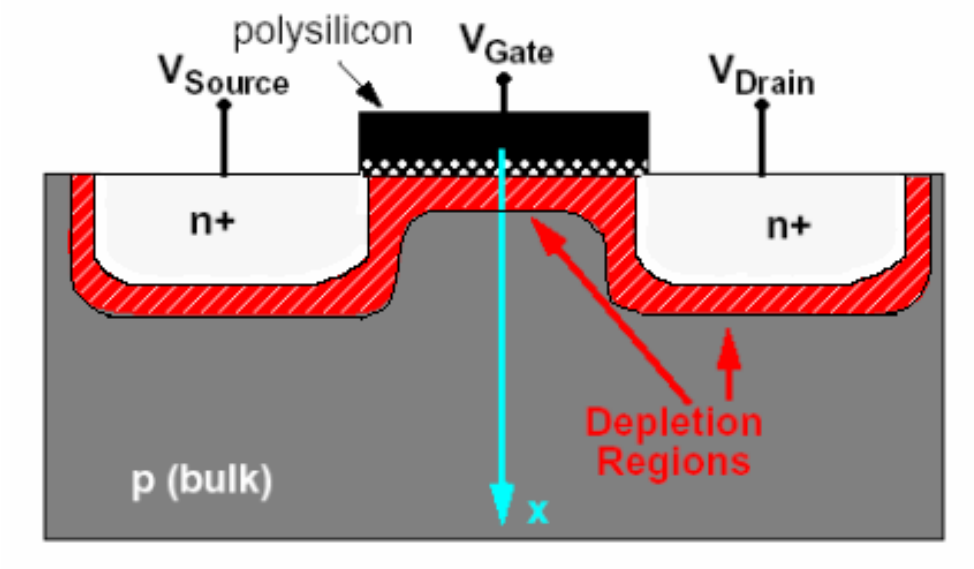


2D

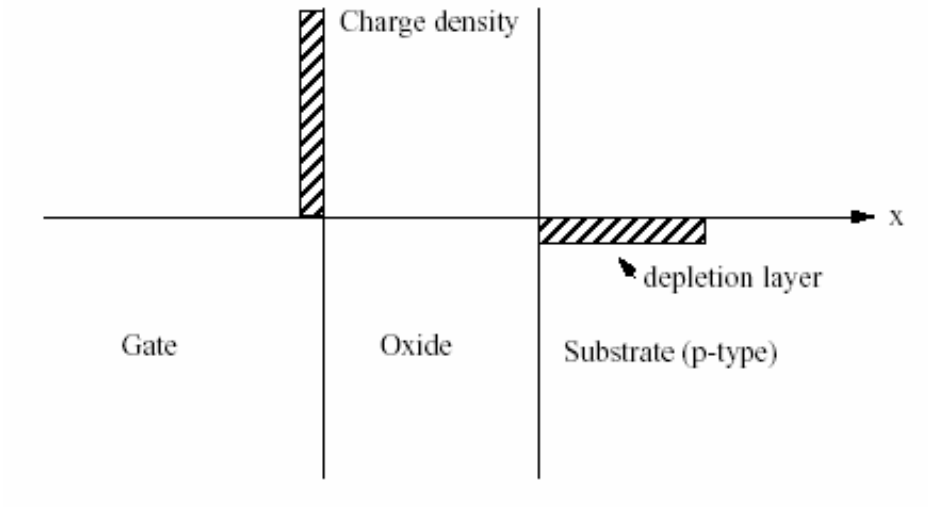


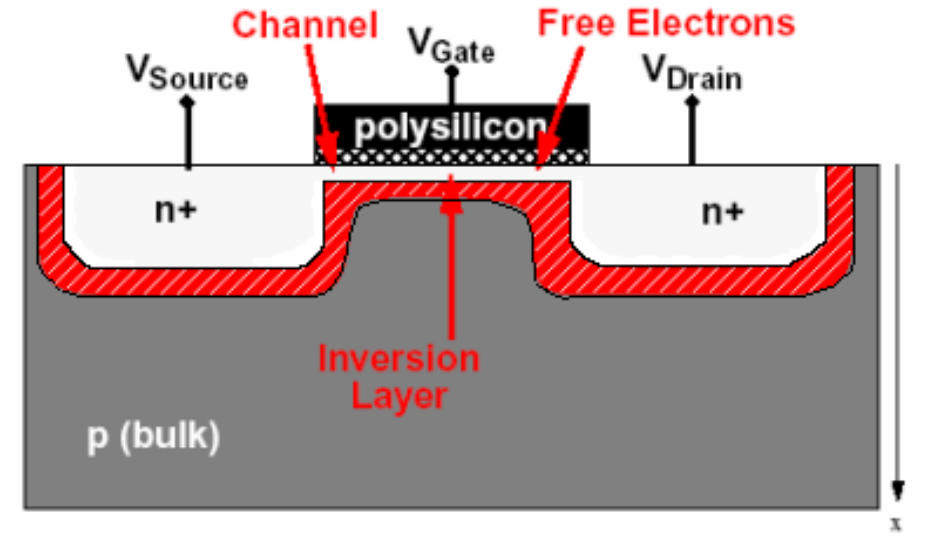
Enhancement NMOS FET





V_S=0V V_G=0.5V V_D=0V

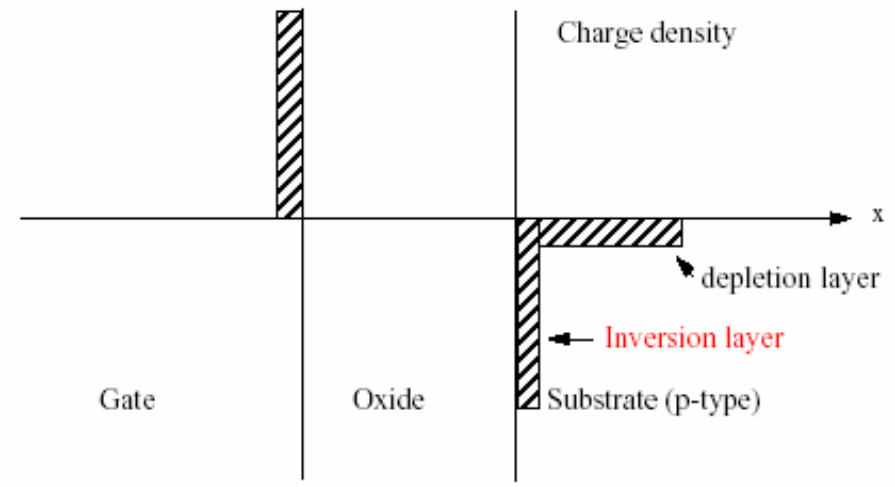




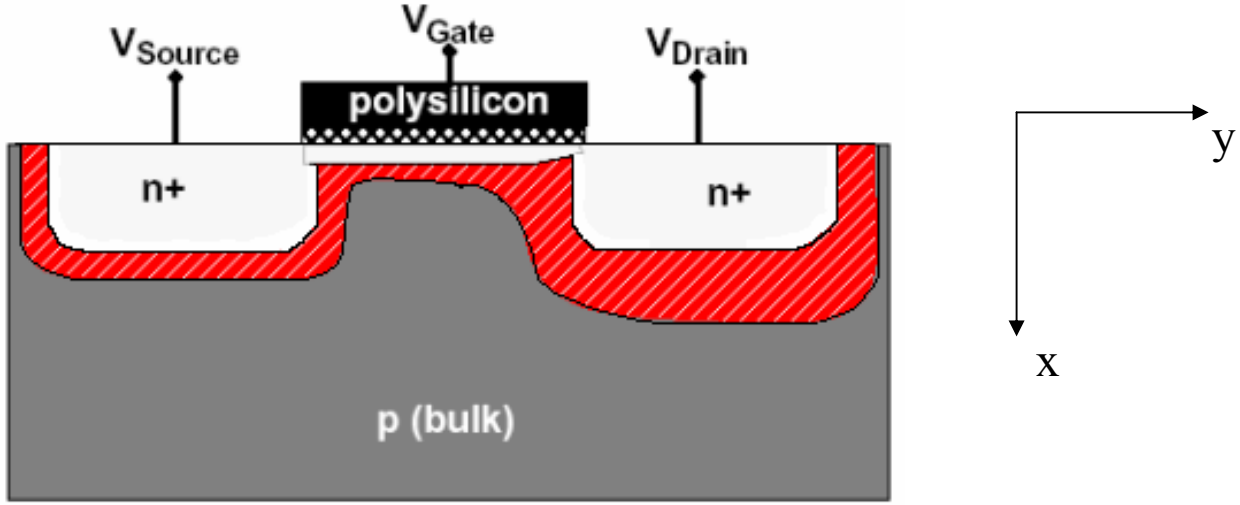
V_S=0V V_G=1V V_D=0V

Assume:
V_T=0.75V

Threshold voltage

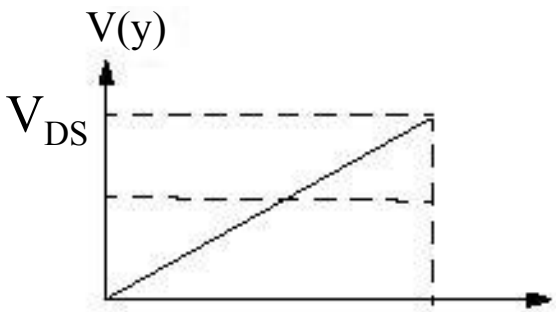


$V_{GS} > V_T$

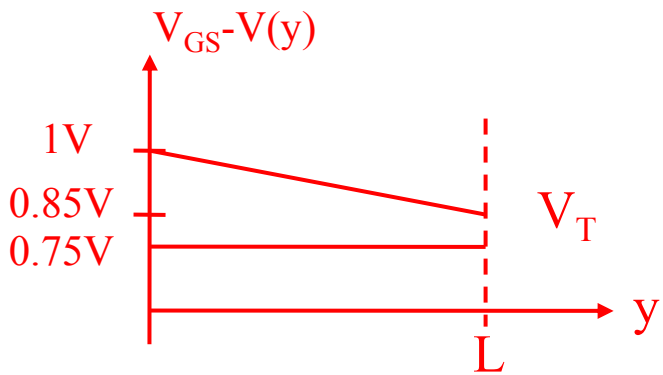


V_S=0V V_G=1V V_D=0.15V

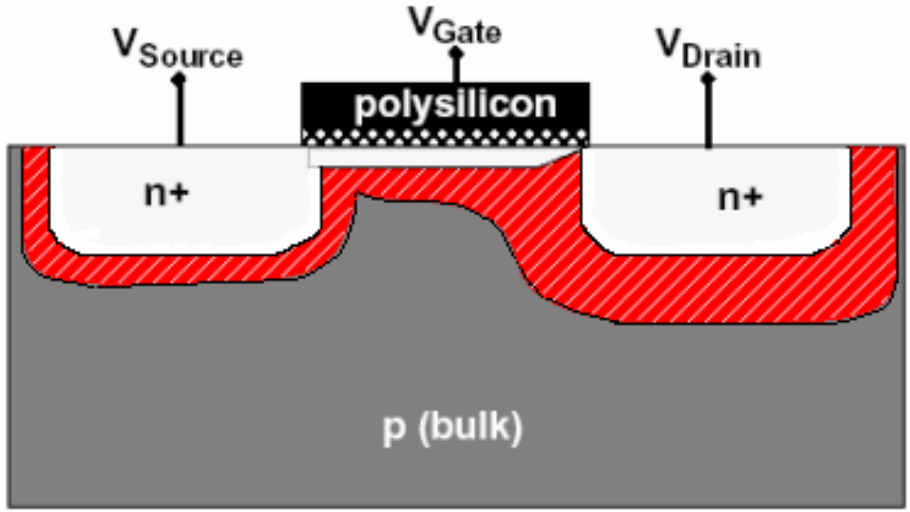
Condition for inversion layer existence: V_{GS}-V(y) > V_T

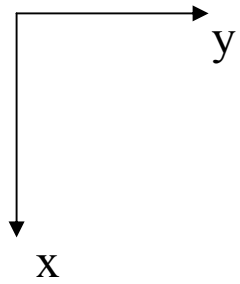


ge value



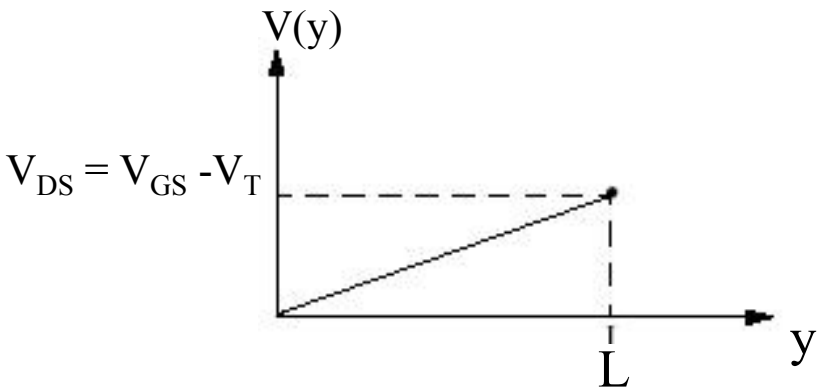
Inversion layer exists in entire channel

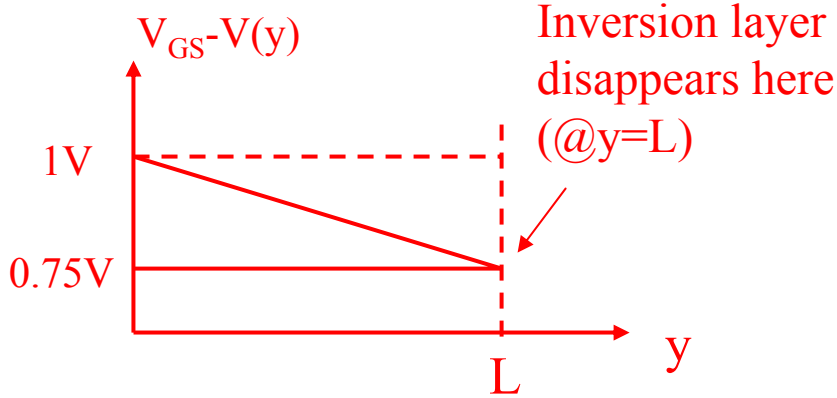




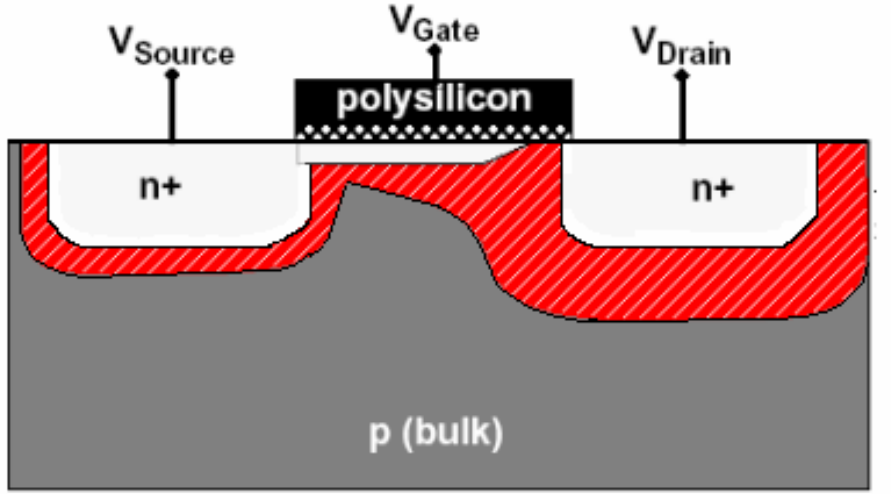
V_S=0V V_G=1V V_D=0.25V

$$V_{DS} = V_{GS} - V_T$$

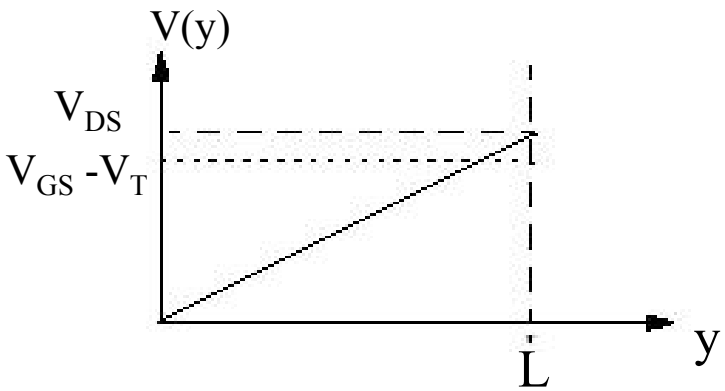


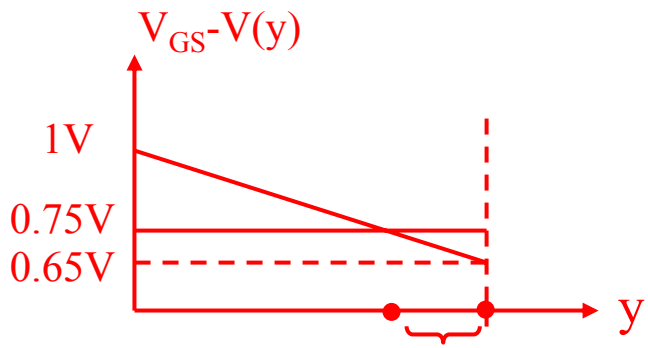


Saturation Condition



V_S=0V V_G=1V V_D=0.35V





No inversion layer here

Channel Length Modulation

Device equations (NMOS)

Non-Saturation: $V_{GS} > V_T \quad \& \quad V_{DS} \le V_{GS} - V_T$

$$I_{DS} = k_n[(V_{GS} - V_T)V_{DS} - \frac{1}{2}V_{DS}^2]$$

Saturation: $V_{GS} > V_T \quad \& \quad V_{DS} \ge V_{GS} - V_T$

$$I_{DS} = \frac{k_n}{2}(V_{GS} - V_T)^2(1 + \lambda V_{DS})$$

Where

λ – channel length modulation

$$k_n = \mu_n \frac{\varepsilon_{ox}}{t_{ox}}\left(\frac{W}{L}\right)_n$$

μ_n – electron mobility (e.g., 500 $\text{cm}^2/\text{volt} \bullet \text{sec}$)

ε_{ox} – dielectric constant of silicon dioxide ($3.9 \times 8.85 \times 10^{-14}$ F/cm)

Threshold Voltage

$$V_T = V_{T0} + \gamma\sqrt{\left|-2\phi_F + V_{SB}\right|} - \sqrt{\left|-2\phi_F\right|}$$

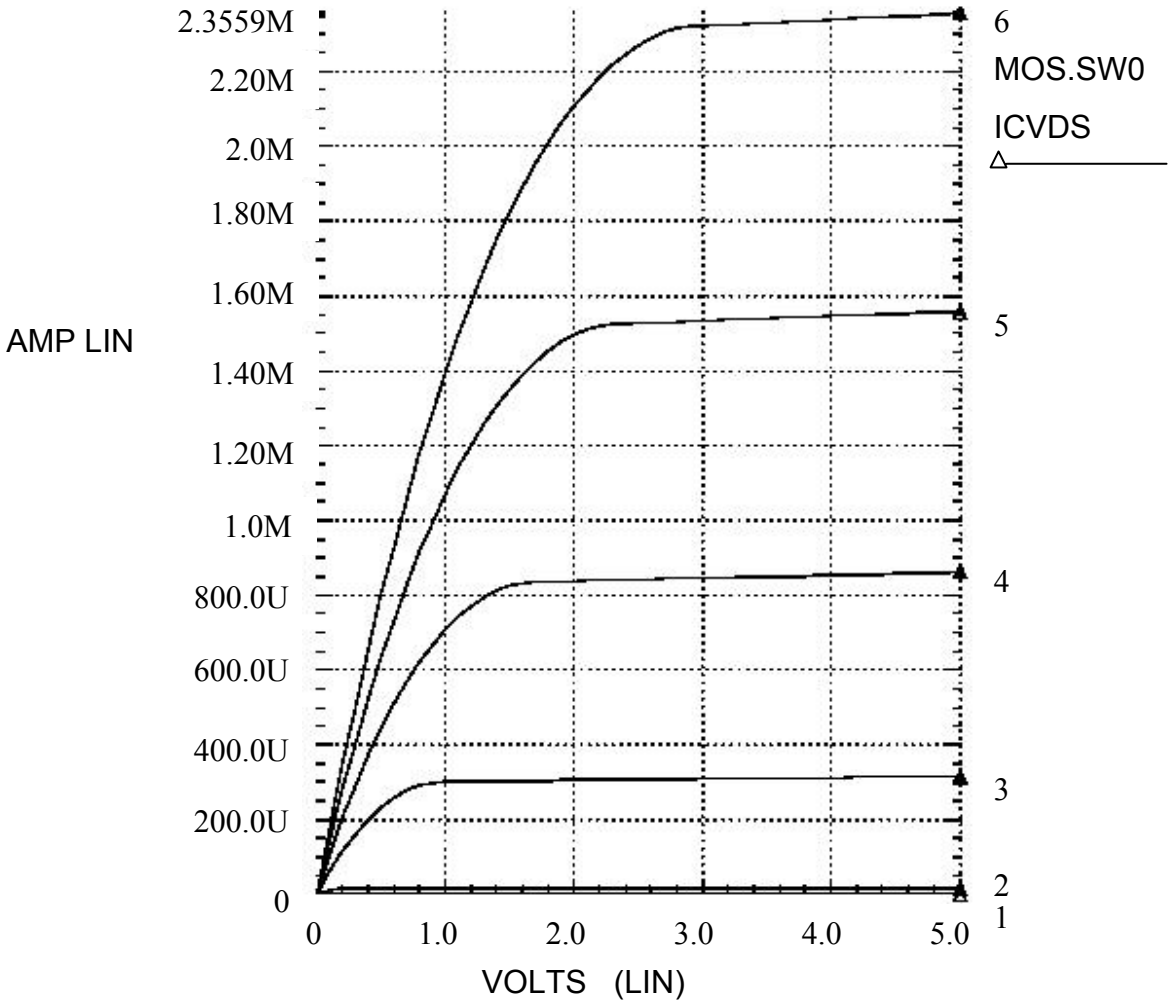
Where:

V_{T0} – Zero bias threshold voltage

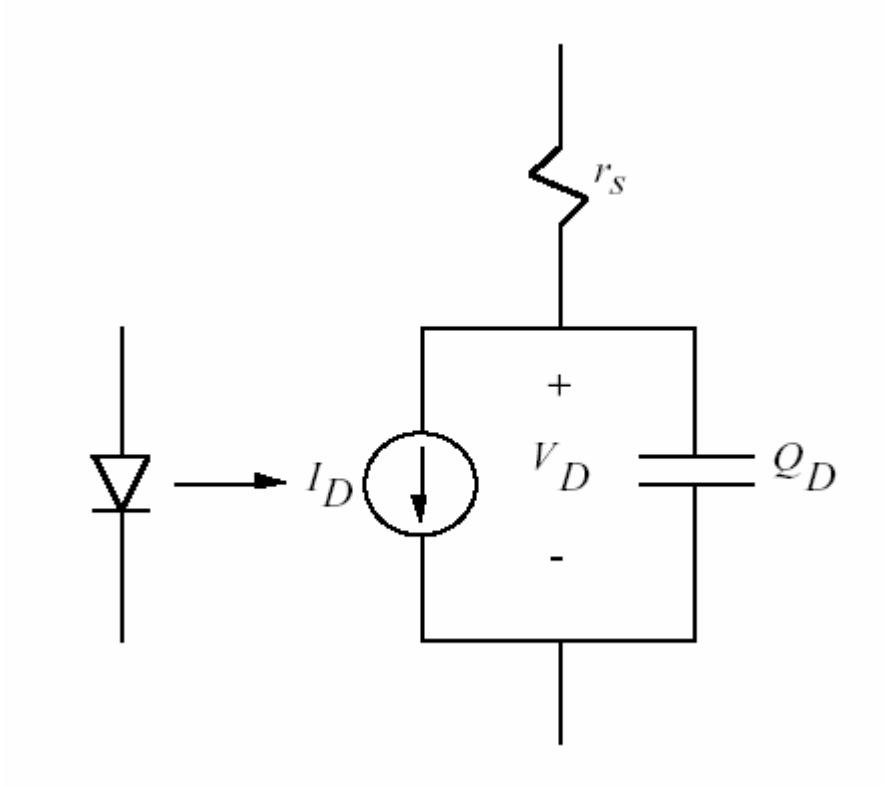
γ – Body-effect coefficient

ϕ_F – Fermi potential

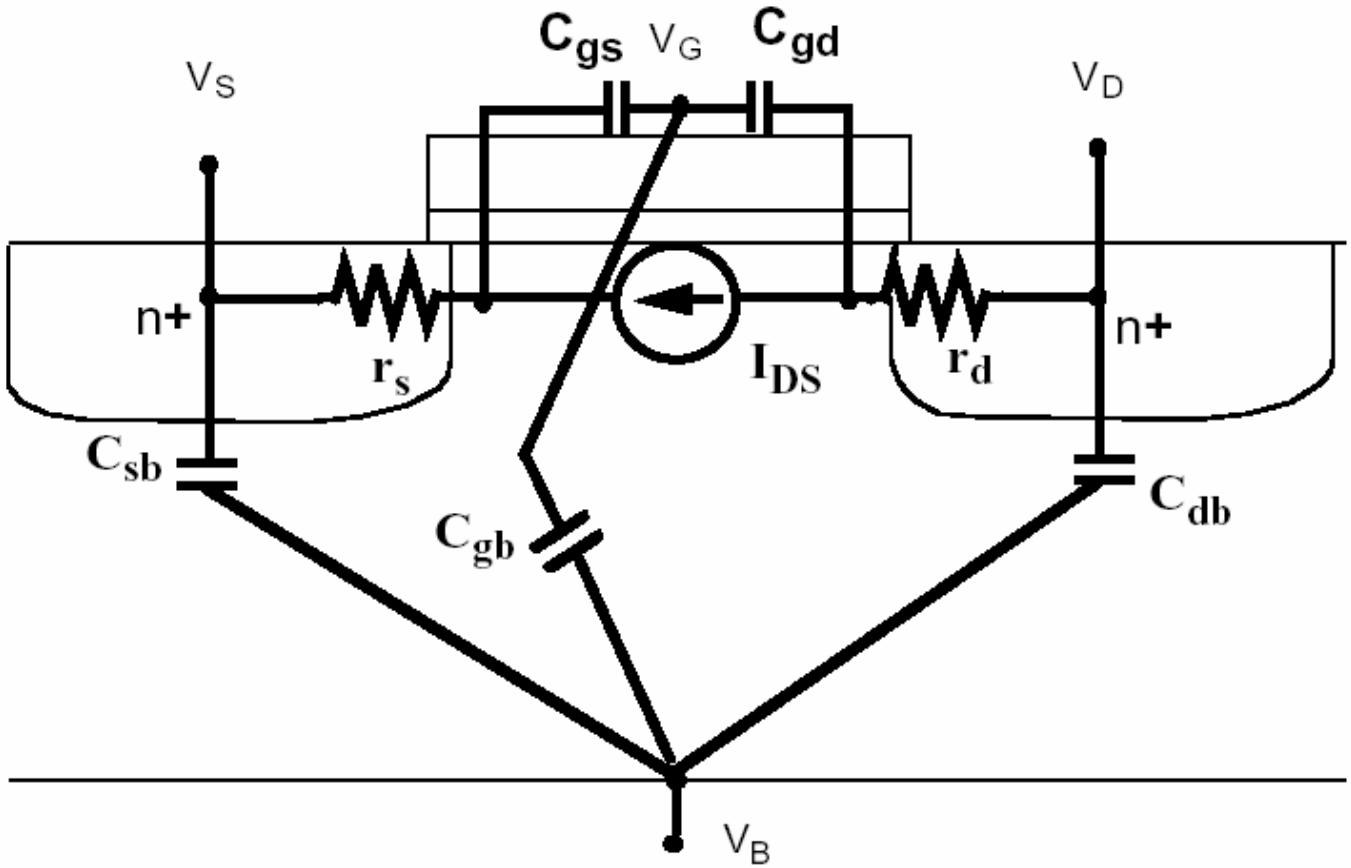
MOSFET IV CHARACTERISTICS



SPICE Model for p-n Diode



SPICE MOSFET Model



NMOS SPICE Model

```
.MODEL nfet NMOS LEVEL=3 PHI=0.600000 TOX=2.1200E-08
+ XJ=0.200000U TPG=1 VTO=0.7860 DELTA=6.9670E-01
+ LD=1.6470E-07 KP=9.6379E-05 UO=591.7 THETA=8.1220E-02
+ RSH=8.5450E+01 GAMMA=0.5863 NSUB=1.6160E+16
+ NFS=5.0000E+12 VMAX=2.0820E+05 ETA=7.0660E-02
+ KAPPA=1.3960E-01 CGDO=4.0241E-10 CGSO=4.0241E-10
+ CGBO=3.6144E-10 CJ=3.8541E-04 MJ=1.1854
+ CJSW=1.3940E-10 MJSW=0.125195 PB=0.800000
```

PMOS SPICE Model

```
.MODEL pfet PMOS LEVEL=3 PHI=0.600000 TOX=2.1200E-08
+ XJ=0.200000U TPG=-1 VTO=-0.9056 DELTA=1.5200E+00
+ LD=2.2000E-08 KP=2.9352E-05 UO=180.2 THETA=1.2480E-01
+ RSH=1.0470E+02 GAMMA=0.4863 NSUB=1.8900E+16
+ NFS=3.46E+12 VMAX=3.7320E+05 ETA=1.6410E-01
+ KAPPA=9.6940E+00 CGDO=5.3752E-11 CGSO=5.3752E-11
+ CGBO=3.3650E-10 CJ=4.8447E-04 MJ=0.5027
+ CJSW=1.6457E-10 MJSW=0.217168 PB=0.850000
```