1 Diodes Characteristics

Forward biased diodes follow exponential rule. i_s is known as the scalar/saturation current. This current can be scaled to match the ratio of cross area section between diodes.

$$i_d = i_s(e^{\frac{v_d}{v_t}} - 1), \simeq i_s(e^{\frac{v_d}{v_t}})$$

V_t = .0862*T mV, (temp in kelvin) at room temperature we know that this is $\simeq$ 25mV
In the constant voltage drop model, a diode's voltage drop is equal to .7v. Any less than .7v and the circuit is open.

1.1 Negative bias region

When voltage across the diode is largely negative, the diode can enter breakdown voltage region, V_z. The slope of the current in breakdown region is $\frac{1}{r_z}$, the diode can be modeled as a battery and resistor.

2 NMOS characteristics

The value of V_{gs} at which a channel is induced is the threshold voltage V_t. For an N-channel MOSFET, V_t is positive. The overdrive voltage V_{ov} is given by:

$$V_{ov} = V_{gs} - V_t$$

The oxide capacitance per unit area C_{ox} is:

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}}$$

where $\varepsilon_{ox} = 3.45 \times 10^{-11}$ F/m is the permittivity of the oxide layer. Typically, the units of the capacitive oxide layer are expressed in femtofarads (10^{-15} F).

The drain current I_{ds} in the saturation region is given by:

$$I_{ds} = G_{ds} \cdot V_{ds}$$

where G_{ds} is:

$$G_{ds} = \mu_n C_{ox} \frac{W}{L} V_{ov}$$

Remember that $r_{ds} = \frac{1}{G_{ds}}$

Here, μ_n is the electron mobility, W is the width of the MOSFET channel, and L is the length of the MOSFET channel. The process transconductance parameter K_n' is defined as:

$$K_n' = \mu_n \cdot C_{ox}$$

Moreover, the MOSFET transconductance parameter, K_n is defined as:

$$K_n = \mu_n \cdot C_{ox} \frac{W}{L}$$

2.1 Small Voltage

When a small voltage is applied to V_{DS}, (and $V_{GS} \geq V_t$), the device acts as a linear resistance whose value is controlled by V_{GS}.
Note that when V_{GS} is smaller than the threshold voltage nothing conducts over the oxide layer, so the VDS resistance is infinite.

2.2 Increased voltage V_{DS}

If V_{DS} is increased and V_{GS} is still greater than V_t the voltage across the channel from source to drain tapers. at the source it is widest and drain it is smallest. The voltage at the source is smallest and at the drain it is widest. The average voltage across the channel is described by. As V_{DS} is increased the resistance increases.

$$AVG_V = \frac{1}{2}V_{DS}$$

For an NMOS transistor, the drain current when V_{GS} is greater than $V_t + V_{OV}$ is equivalent to:

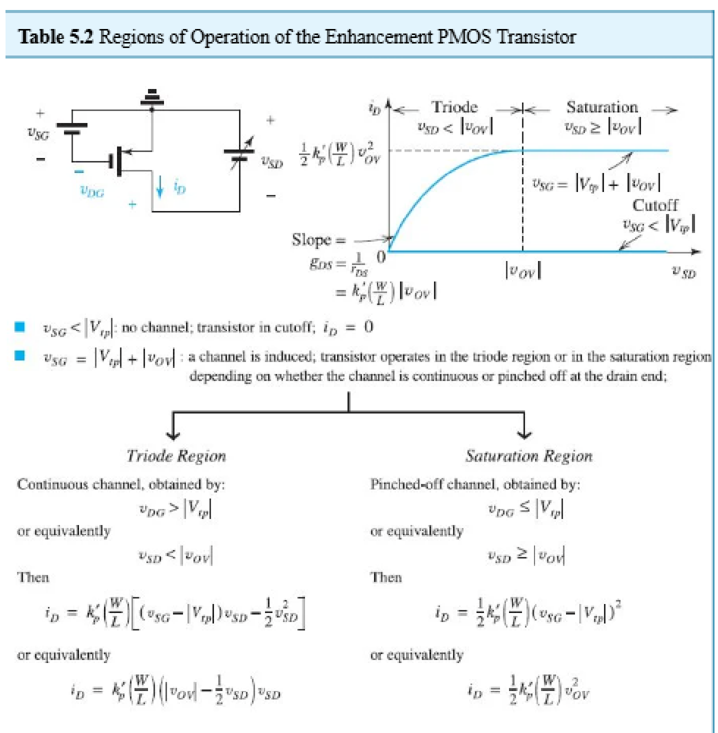
$$i_{Dtriode} = K_n' \frac{W}{L}(V_{OV} - \frac{1}{2}V_{DS})V_{DS}$$

In the parabolic portion of the curve, when $V_{DS} < V_{OV}$ aka $V_{GD} > V_{tn}$

When $V_{DS} \geq V_{OV}$ aka $V_{GD} \leq V_{tn}$, The diode enters saturation region.

$$i_{Dsat} = \frac{1}{2}k_n' \frac{W}{L}V_{OV}^2$$

2.3 PMOS



- $v_{SG} < |V_{tp}|$: no channel; transistor in cutoff; $i_D = 0$
- $v_{SG} = |V_{tp}| + |v_{OV}|$: a channel is induced; transistor operates in the triode region or in the saturation region depending on whether the channel is continuous or pinched off at the drain end;

Triode Region

Continuous channel, obtained by:

$$v_{DG} > |V_{tp}|$$

or equivalently

$$v_{SD} < |v_{OV}|$$

Then

$$i_D = k_p'\left(\frac{W}{L}\right)\left[(v_{SG} - |V_{tp}|)v_{SD} - \frac{1}{2}v_{SD}^2\right]$$

or equivalently

$$i_D = k_p'\left(\frac{W}{L}\right)\left(|v_{OV}| - \frac{1}{2}v_{SD}\right)v_{SD}$$

Saturation Region

Pinched-off channel, obtained by:

$$v_{DG} \leq |V_{tp}|$$

or equivalently

$$v_{SD} \geq |v_{OV}|$$

Then

$$i_D = \frac{1}{2}k_p'\left(\frac{W}{L}\right)(v_{SG} - |V_{tp}|)^2$$

or equivalently

$$i_D = \frac{1}{2}k_p'\left(\frac{W}{L}\right)v_{OV}^2$$

Figure 1: Pmos I and V

Figure 2: SGD P, SGD N