$V_{DS_{SAT}}$: LIMIT TRIODE — ACTIVE REGION

- THERE IS NOT A HARD LIMIT:

$$i_F \gg i_r \longrightarrow \text{ACTIVE, OTHERWISE, TRIODE.}$$

$$q(i_F) - q(i_r) = \frac{V_P - V_S}{V_T} - \frac{V_P - V_D}{V_T} = \frac{V_{DS}}{V_T} \qquad (1)$$

$$\varphi(i_F) - \varphi(i_r) = \sqrt{1+i_F} - 2 + \ln\left(\sqrt{1+i_F} - 1\right) - \sqrt{1+i_r} + 2 - \ln\left(\sqrt{1+i_r} - 1\right) \qquad (2)$$

$$= \left(\sqrt{i_F+1} - 1\right)\left(1 - \frac{\sqrt{1+i_r} - 1}{\sqrt{1+i_F} - 1}\right) + \ln\left(\frac{\sqrt{1+i_F} - 1}{\sqrt{1+i_F} - 1}\right)$$

DENOTE $\left.\right\} = \dfrac{\sqrt{1+i_r} - 1}{\sqrt{1+i_F} - 1}$, COMBINE (1) AND (2)

$$\frac{V_{DS}}{V_T} = \left(\sqrt{1+i_F} - 1\right)\left(1 - \{\right) + \ln\left(\frac{1}{\{}\right)$$

$$\therefore V_{DS} = V_T\left[\ln\left(\frac{1}{\{}\right) + \left(1 - \{\right)\left(\sqrt{1+i_F} - 1\right)\right]$$

$\{$ VERY SMALL $\Rightarrow i_F \gg i_r \Rightarrow$ DEVICE IS ACTIVE

$$\{ = 0.01 \Rightarrow V_{DS_{SAT}} = V_T\left(4.6 + 0.99\left(\sqrt{1+i_F} - 1\right)\right)$$

$$\simeq V_T\left(3.6 + \sqrt{1+i_F}\right)$$

- IN PRACTICE WE WILL USE 3 INSTEAD OF 3.6, THAT IS EQUIVALENT TO $\{ = 0.018$, STILL SMALL.