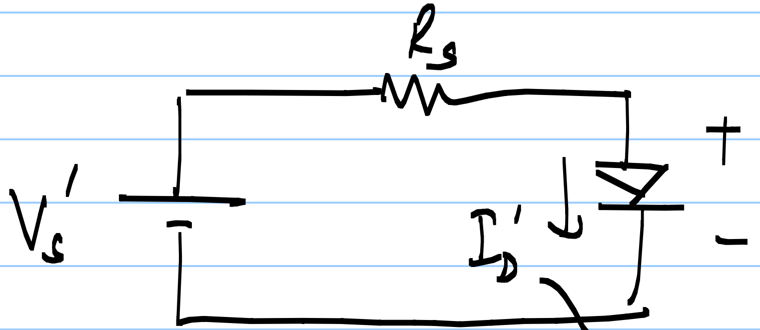
6/8/2020

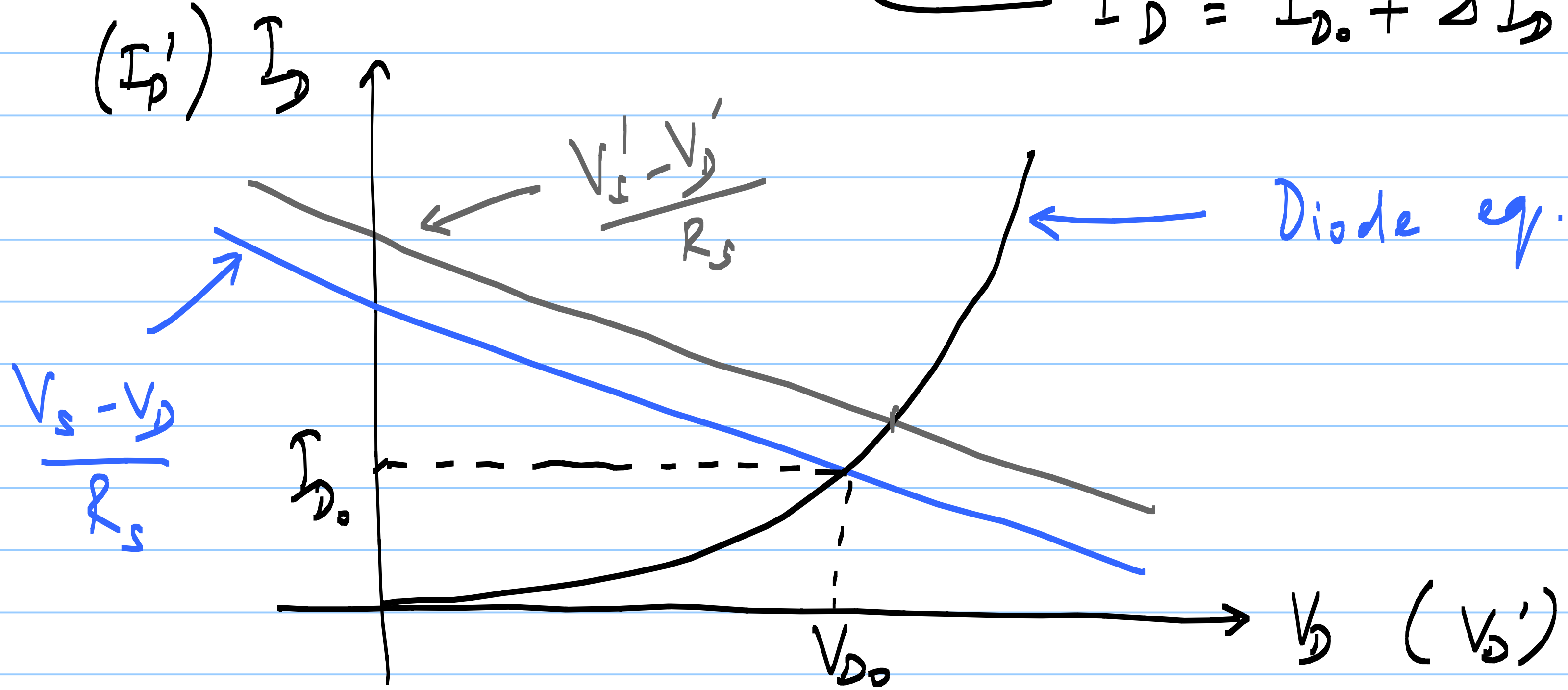
Lecture 3

* If $V_s' = V_s + \Delta V_s$ (increment), what is V_D', I_D'



$V_D' = V_{D_0} + \Delta V_D$

$I_D' = I_{D_0} + \Delta I_D$



Orig.

$$\frac{V_s - V_{D_0}}{R_s} = I_{D_0} = I_s\left[\exp\left(\frac{V_{D_0}}{V_t}\right) - 1\right]$$

New

$$\frac{V_s' - V_D'}{R_s} = I_D' = I_s\left[\exp\left(\frac{V_D'}{V_t}\right) - 1\right]$$

$$\frac{(V_s + \Delta V_s) - (V_{D_0} + \Delta V_D)}{R_s} = I_{D_0} + \Delta I_D$$

$$= I_s\left[\exp\left(\frac{V_{D_0} + \Delta V_D}{V_t}\right) - 1\right]$$

$$\frac{V_S - V_{D0}}{R_S} + \frac{\Delta V_S - \Delta V_D}{R_S} = I_{D0} + \Delta I_D$$

$= \; ?$ — Taylor series expansion around (V_{D0}, I_{D0})

for $Y = f(x)$ around x_0

$$Y = \sum_{n=0}^{\infty} \frac{f^{(n)}(x_0)}{n!} \cdot (x - x_0)^n$$

$$= f(x_0) + f'(x_0) \cdot (x - x_0) + \left(f''(x_0)/2\right) \cdot (x - x_0)^2 + \dots$$

oper. pt.

$$I_s\left[\exp\left(\frac{V_{Do}+\Delta V_D}{V_t}\right)-1\right] = I_s\left[\exp\left(\frac{V_{Do}}{V_t}\right)-1\right]$$

$$+$$

$$\frac{I_s}{V_t}\exp\left(\frac{V_{Do}}{V_t}\right)\cdot(\Delta V_D)$$

$$+ \cdots \longrightarrow \Delta V_D^2, \; \Delta V_D^3 \; \ldots$$

* For small increments (ΔV_D etc.), neglect

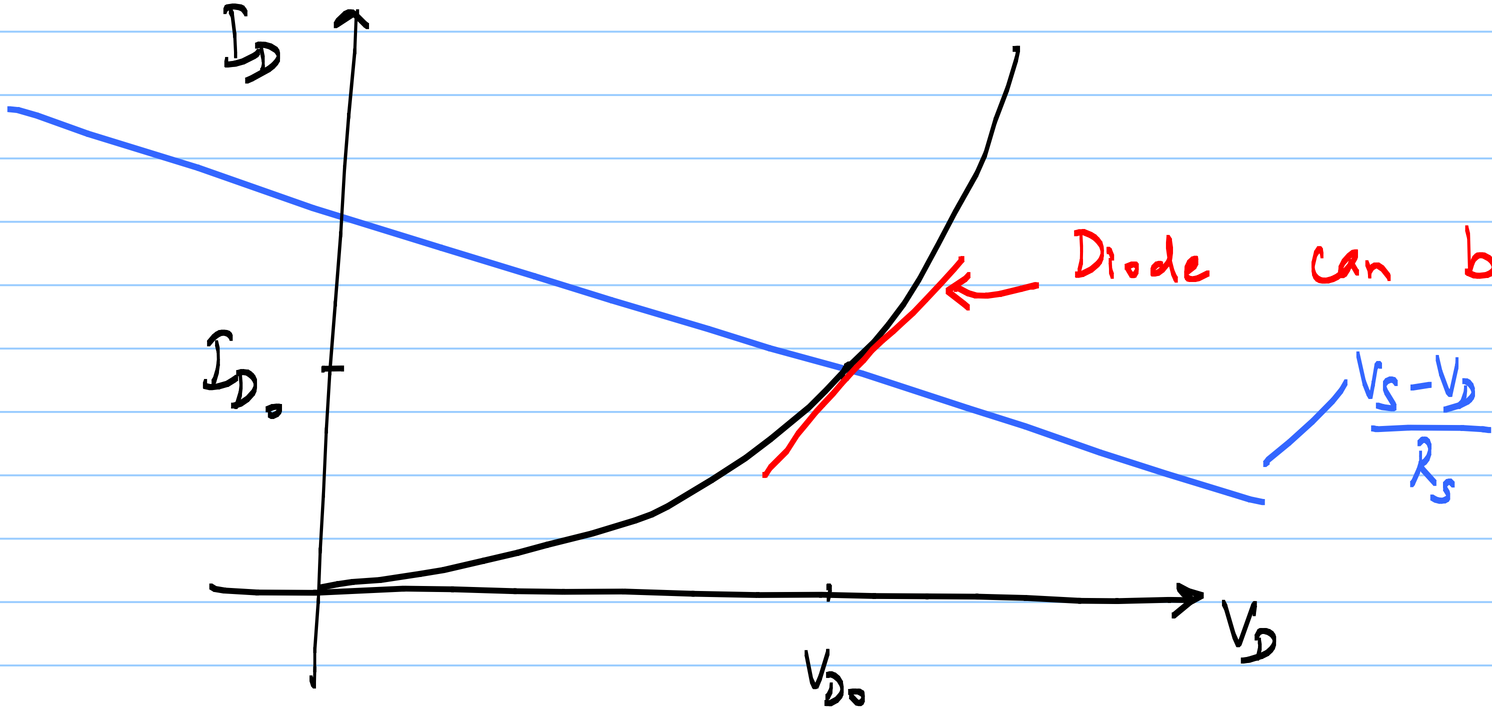
ΔV_D^2, ΔV_D^3 . . .

$$\cancel{\frac{V_s - V_{Do}}{R_s}} + \frac{\Delta V_s - \Delta V_{Do}}{R_s} = \cancel{I_{Do}} + \Delta I_D = \cancel{I_s\left[\exp\left(\frac{V_{Do}}{V_t}\right)-1\right]}$$

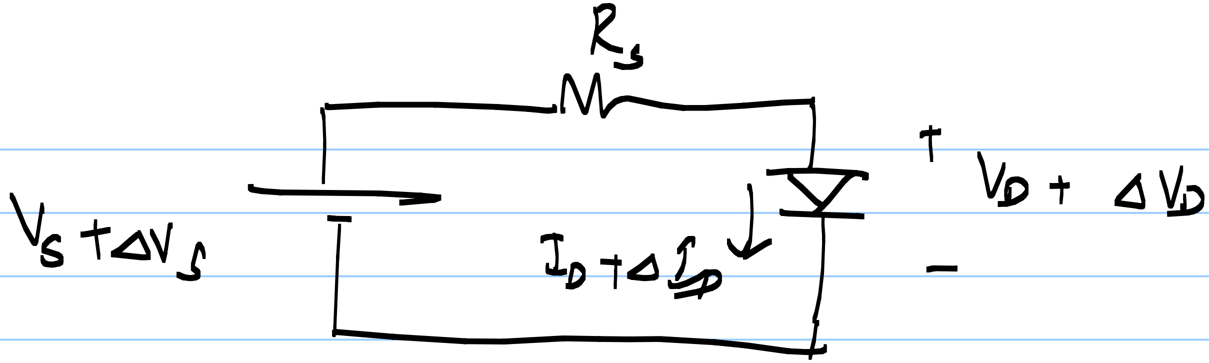
$$+$$

$$\frac{I_s}{V_t}\exp\left(\frac{V_{Do}}{V_t}\right)\cdot\Delta V_D$$

$$\underbrace{\frac{\Delta V_s - \Delta V_D}{R_s} = \Delta I_D = \frac{I_s}{V_t}\exp\left(\frac{V_{D0}}{V_t}\right)\cdot \Delta V_D}_{\text{Linear equations in } \Delta V_s,\ \Delta V_D,\ \Delta I_D}$$



Diode can be replaced by a linearized element for $\Delta V_D, \Delta I_D$



$$\Delta V_s = \Delta I_D \cdot R_s + \Delta V_D$$

$$\Delta I_D = \underbrace{\frac{I_s}{V_t} \exp\left(\frac{V_{D0}}{V_t}\right)}_{\approx I_{D0}} \cdot \Delta V_D \approx \frac{I_{D0}}{V_t} \cdot \Delta V_D$$

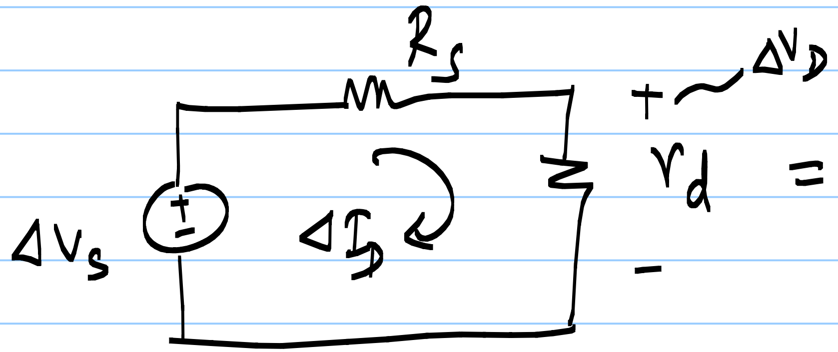
$$\Delta V_D = \underbrace{\frac{V_t}{I_{D0}}}_{\text{"incremental resistance" of diode}} \cdot \Delta I_D$$

$$\Delta V_s = \Delta I_D \cdot R_s + \Delta I_D \cdot \frac{V_t}{I_{D0}}$$

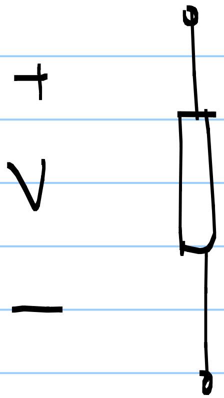
* Any $I = f(V)$ can be linearized around the op. pt.

* Assume $\Delta V_D, \Delta I_D$ etc are "small"

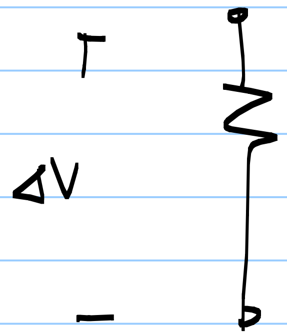
(linear) <u>Incremental eq. circuit</u> for $\Delta I_D = \dfrac{\Delta V_s}{R_s + \frac{V_t}{I_{D0}}}$



$r_d = \dfrac{V_t}{I_{D0}}$ = inc. res. of diode @ I_{D0}



$\downarrow I = f(V) \Rightarrow$



$\downarrow \Delta I = f'(V_0) \cdot \Delta V$

$r = \dfrac{1}{f'(V_0)}$

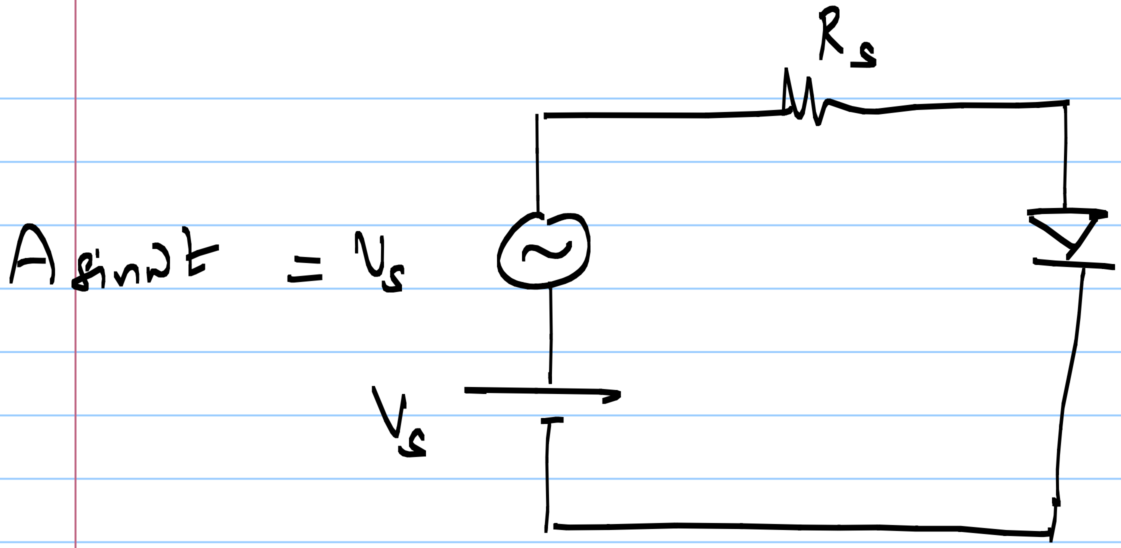
I, V, etc. $\Rightarrow$ DC

I_o, V_o etc $\Rightarrow$ operating point,
bias point
Quiescent point

Δi, Δv $\Rightarrow$ incremental quantities

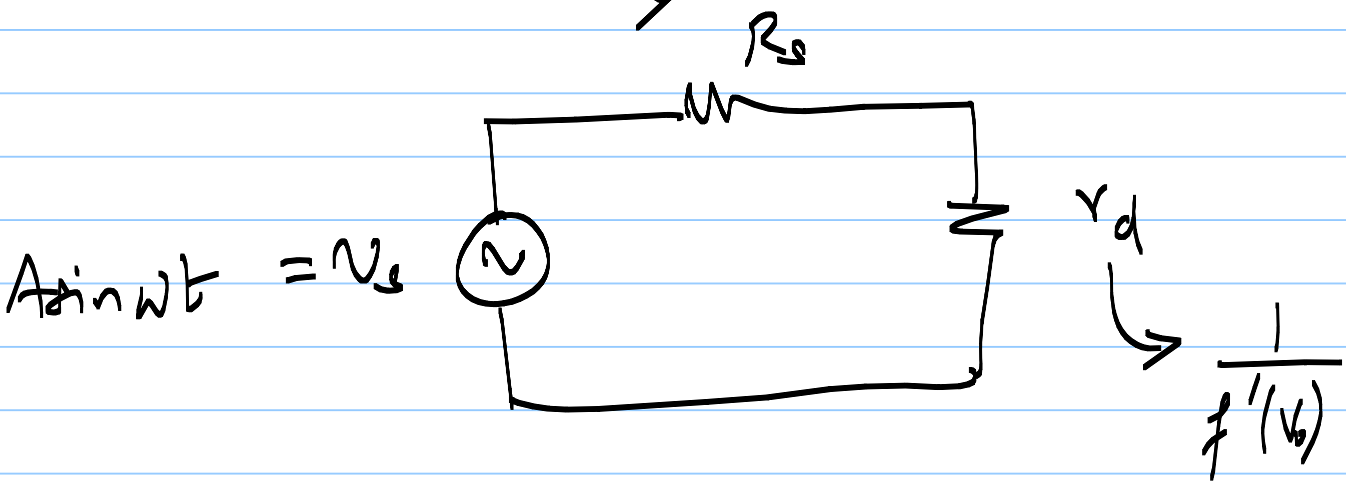
i, v $\Rightarrow$ small-signal quantities

$V_D = V_{Do} + \Delta V_D$ etc. $\Rightarrow$ total quantities



If A is very small:

@ every point of time, instantaneous increments are small enough that linear approx. is valid



small-signal equivalent network

For op. pt. : you have to solve the system of non-linear equations to determine I_{Do}, V_{Do} etc.