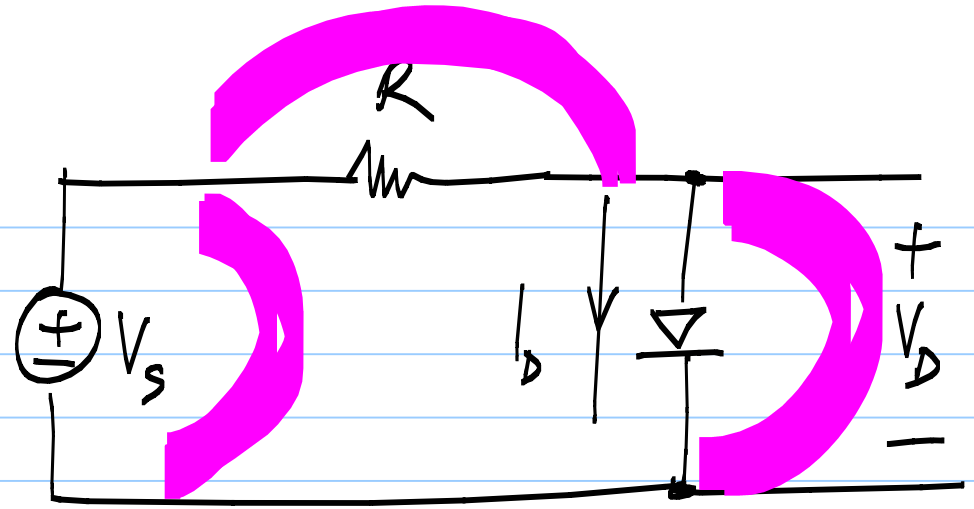
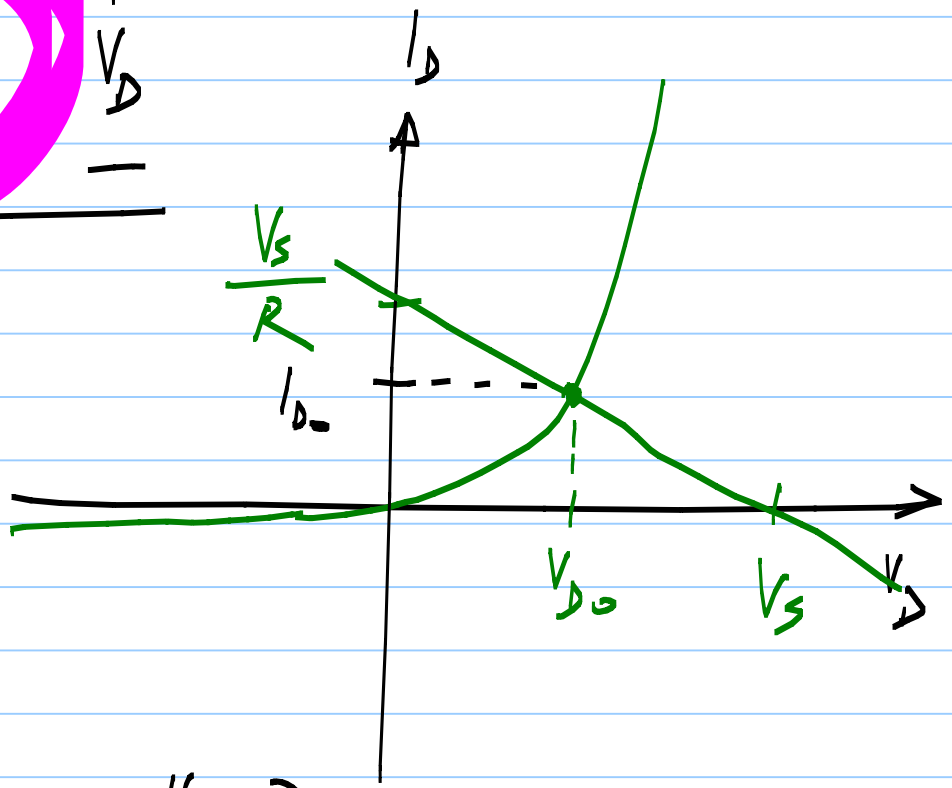


$V_S = 3V$ operating point



$$V_S = V_D + I_D \cdot R$$

$$I_D = I_S \left[\exp\left(\frac{V_D}{V_T}\right) - 1 \right]$$

V_{D_0}, I_{D_0} : operating point of the diode

V_s changes to 3.5 V

$$V_{s_0} = I_{D_0} R + V_{D_0}$$

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

$$V_s = V_{s_0} + \Delta V_s$$

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

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

I_{D_0}: op. point; ΔI_D: increment

$$V_{s_0} + \Delta V_s = (I_{D_0} + \Delta I_D) R + V_{D_0} + \Delta V_D$$

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

higher order term

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

$$V_S = I_D R + V_D \qquad \Delta I_D \cdot R_D$$

(1) $$\Delta V_S = \Delta I_D \cdot R + \Delta V_D$$

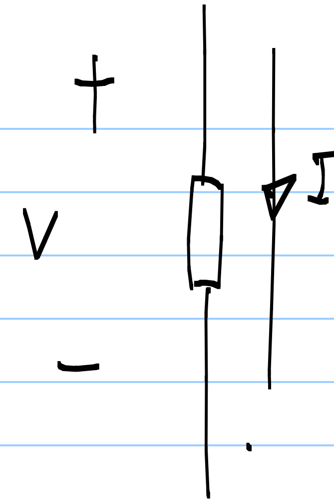
$$\Delta I_D = I_S \left[\frac{1}{V_t} \exp\left(\frac{V_{DO}}{V_t}\right) \cdot \Delta V_D + \text{higher order terms} \right]$$

$\ll$ first order term

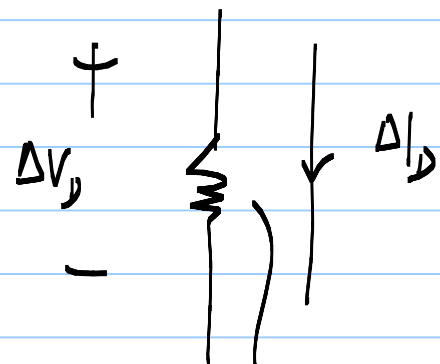
(2) $$\Delta I_D = \left[\frac{I_S}{V_t} \cdot \exp\left(\frac{V_{DO}}{V_t}\right) \right] \cdot \Delta V_D$$

Linear equation in ΔV_D, ΔI_D — easy to solve.

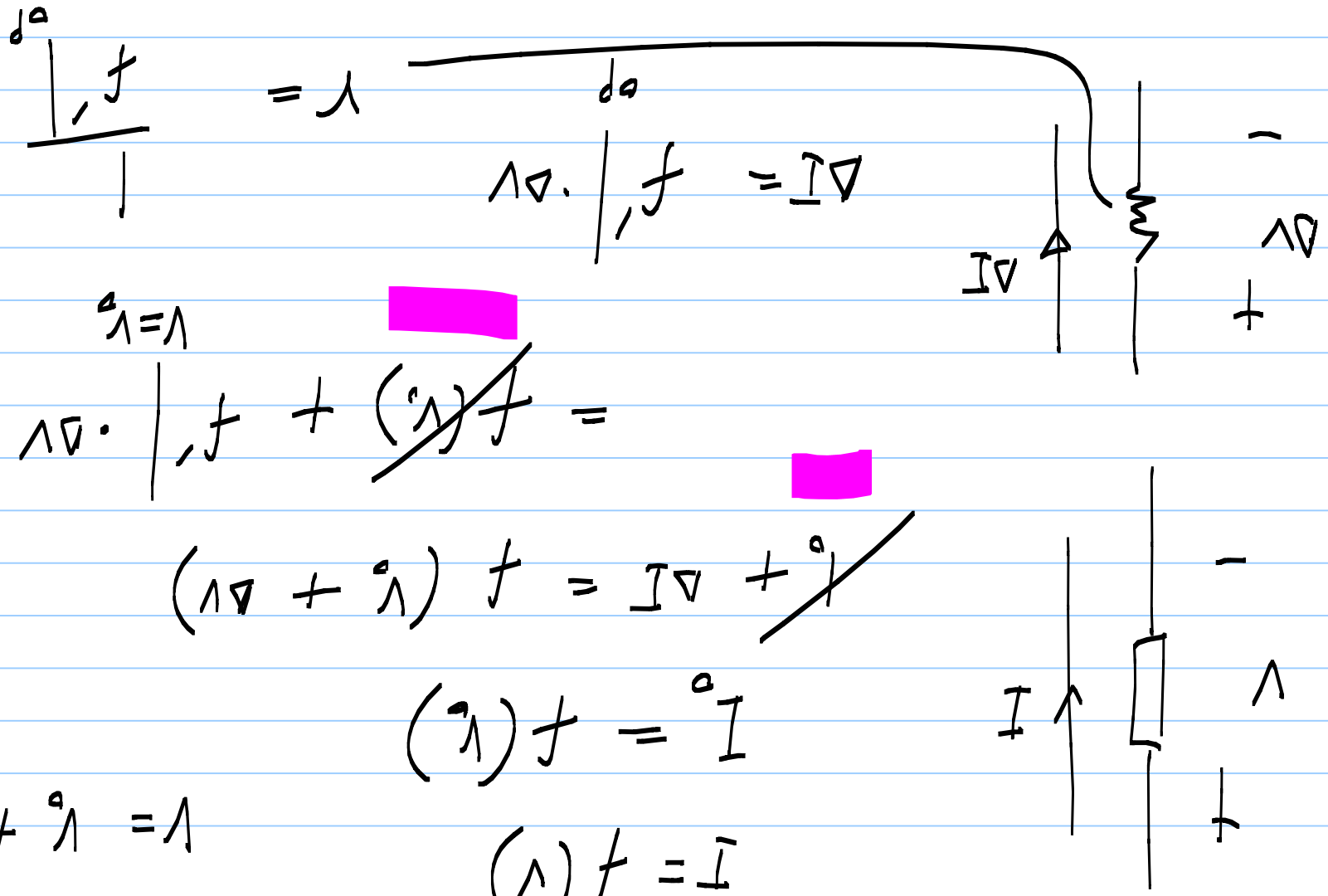
$$\Delta I_D = \left[\frac{I_s}{V_t} \exp\left(\frac{V_{D0}}{V_t}\right) \cdot \right] \Delta V_D$$



$$I = f(V)$$



$$r_D = \frac{V_t}{I_s \exp\left(\frac{V_{D0}}{V_t}\right)}$$



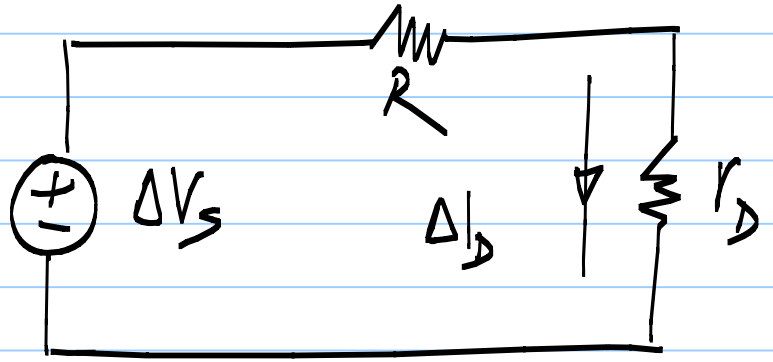
$$V = I R$$

$$V_o = I_o R$$

$$V_o + \Delta V = (I_o + \Delta I) R$$

$$\Delta V = \Delta I \cdot R$$

$$\Delta V_s = \Delta I_D (R + r_d)$$



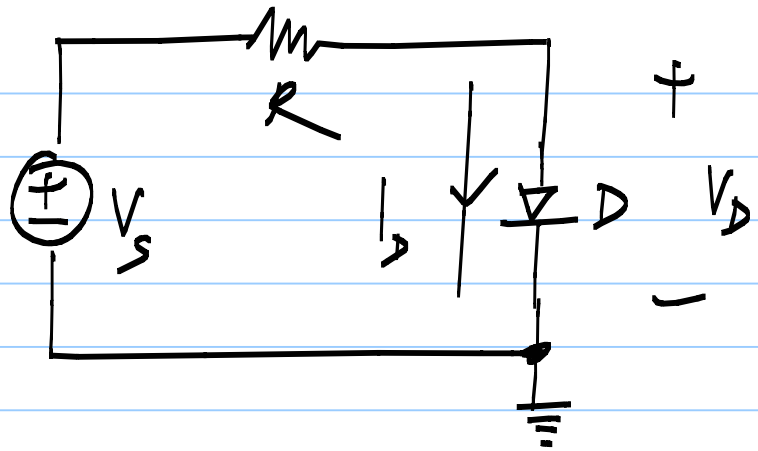
incremental eq.

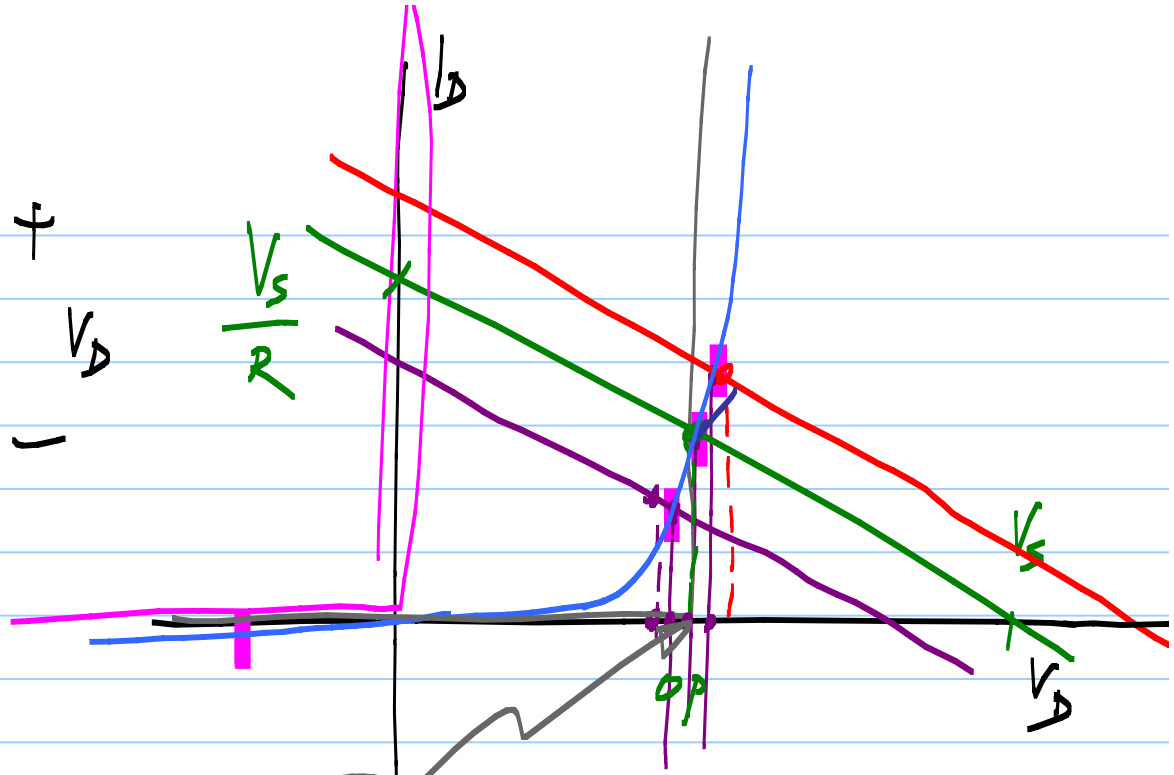
Analysis of nonlinear circuits.

* Evaluate operating pt. — set of nonlinear equations
* obtain the equivalent circuit @ operating point
* Calculate increments from the incremental equivalent ckt.

increments are "small" ⟶ higher order terms

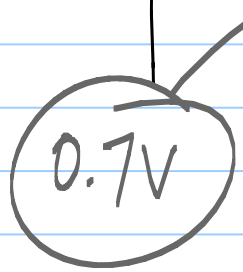
Small signal incremental equivalent negligible.

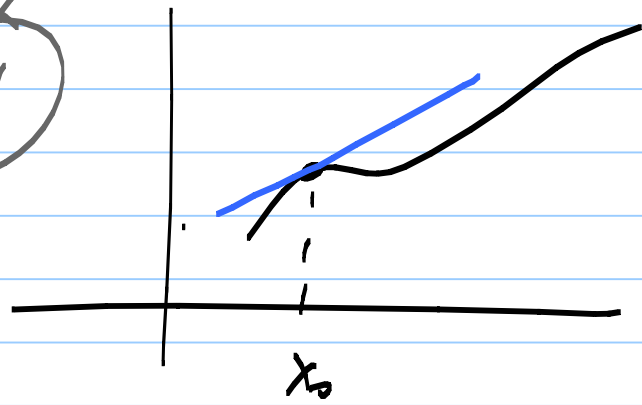


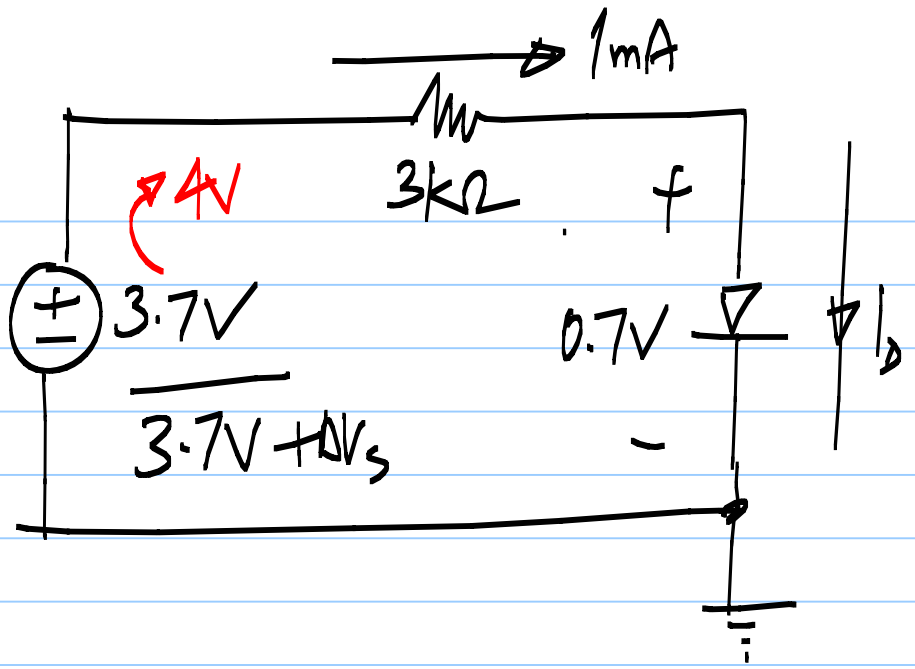


$$f(x_0 + \Delta x)$$

$$= f(x_0) + f'\Big|_{x_0} \cdot \Delta x + f''\Big|_{x_0} \frac{\Delta x^2}{2} + \cdots$$







$$r_D = \frac{V_t}{I_s \exp\left(\frac{V_D}{V_t}\right)} = \frac{V_t}{I_D}$$

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