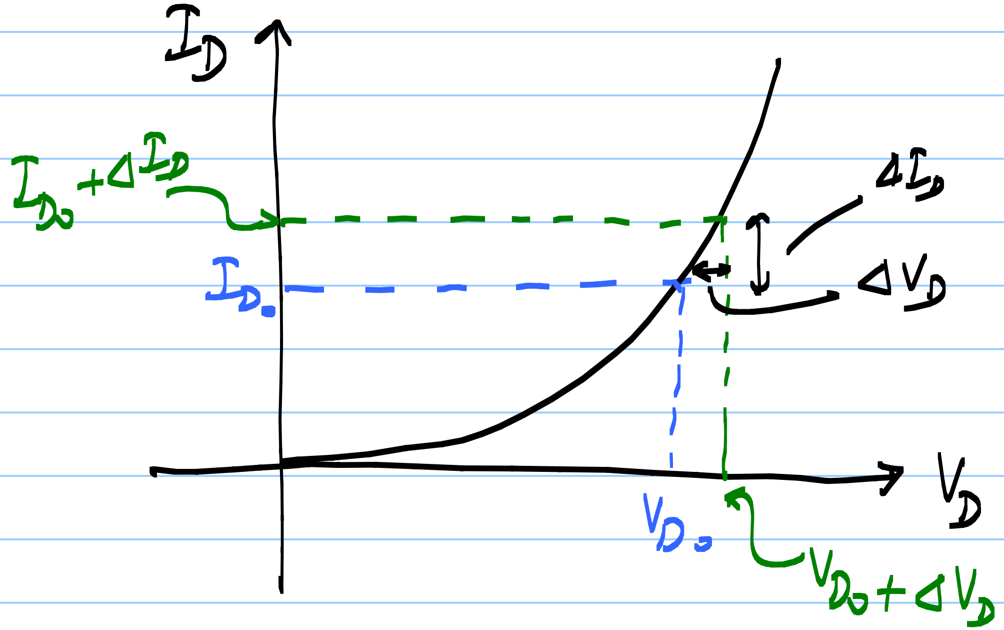
7/8/2020

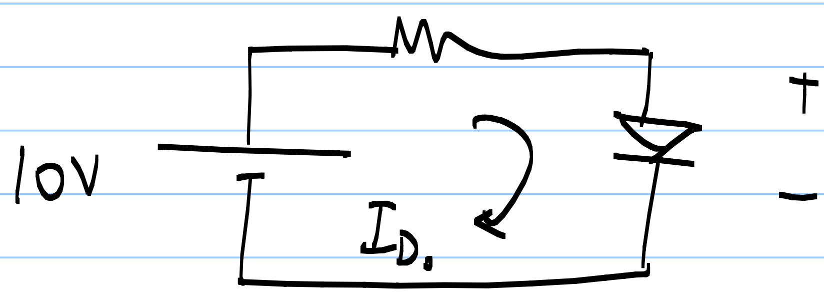
Lecture 4



$$\frac{\Delta I_D}{\Delta V_D} = \left.\frac{dI_D}{dV_D}\right|_{(I_{D_0},\, V_{D_0})}$$

= inc. conductance
(or)
dynamic "
(or)
small-signal "

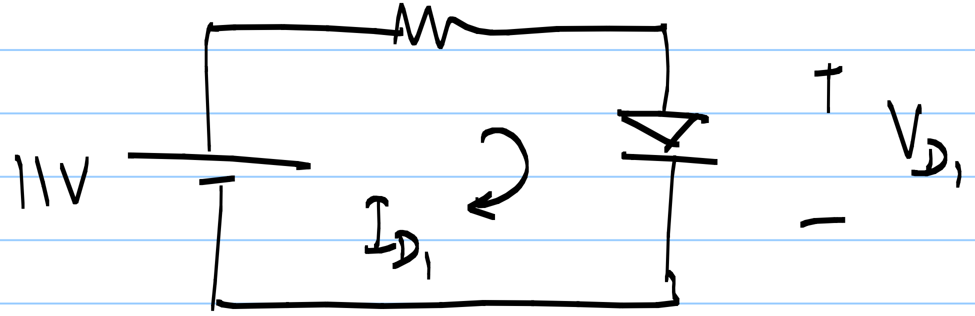
Example



$V_{D_0} \approx 0.65\,V$

$$I_{D_0} = \frac{10 - 0.65}{9.35\,k\Omega} = 1\,mA$$

change 10V ⟶ 11V

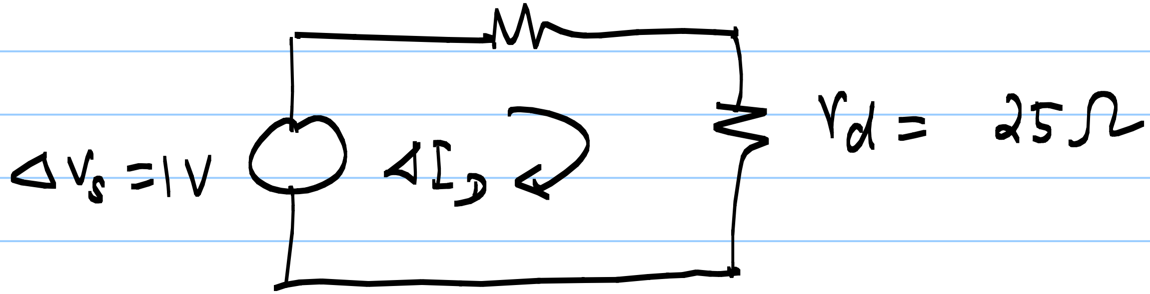


$\Delta V_s = 1V$

$r_d = \frac{V_t}{I_{D_0}} = \frac{25mV}{1mA}$

$= 25\Omega$

Incremental Equivalent Circuit



$$\Delta I_D = \frac{1\,V}{9350 + 25} \approx 106\mu A$$

$$I_{D_1} = I_{D_0} + \Delta I_D = 1.106 mA$$

* If $V_s = 9V$, $I_{D_2} = ?$

$\Delta V_S = -1V \Rightarrow \Delta I_D = -106 \mu A$

$\Rightarrow I_{D_2} = 0.894\ mA$

* If $V_S = 9.5V$, $I_{D_3} = I_{D_0} - \frac{1}{2}(106 \mu A)$

. . .

* If $V_S = 10V + (1V)\sin\omega t$

$I_D = 1mA + (106 \mu A)\sin\omega t$

Next : Is linear approx. valid?

$\Delta V_D = \Delta I_D \cdot r_d = 106 \mu A \times 25 \approx 2.7mV$

$f''(V_{D_0}) = ?$

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

$$f''(V_{D0}) = \frac{I_s}{V_t^2}\exp\left(\frac{V_{D0}}{V_t}\right) \approx \frac{I_{D0}}{V_t^2}$$

Taylor Series 3rd term $= \dfrac{f''(V_{D0})}{2}(\Delta V_D)^2$

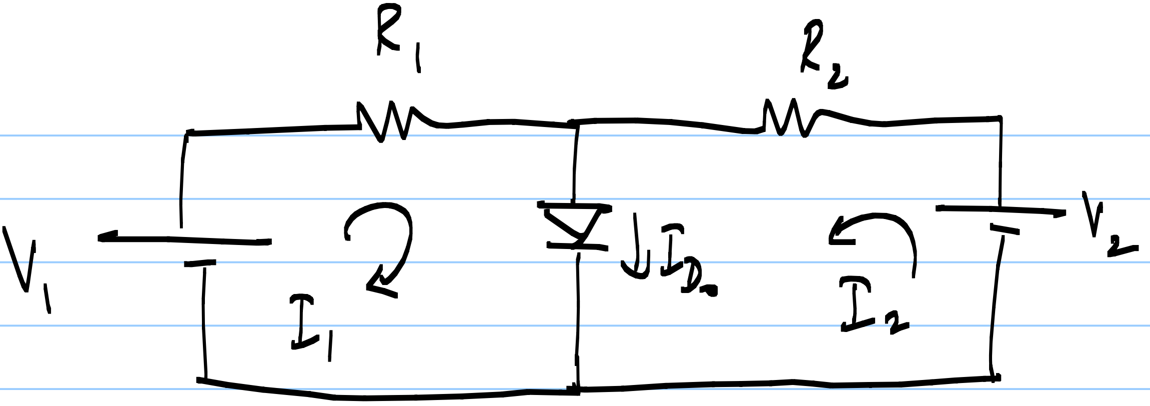
$$= \frac{I_{D0}}{2V_t^2}\cdot(\Delta V_D)^2$$

$$I_D = I_{D0} + \frac{I_{D0}}{V_t}(\Delta V_D) + \frac{I_{D0}}{2V_t^2}(\Delta V_D)^2 + \cdots$$

compare these two

first error term is small if $\Delta V_D << 2V_t$ valid

(ΔV_D ← 2.7mV; $2V_t$ ← 50mV)



Assume $V_D = 0.65$ if fwd. biased

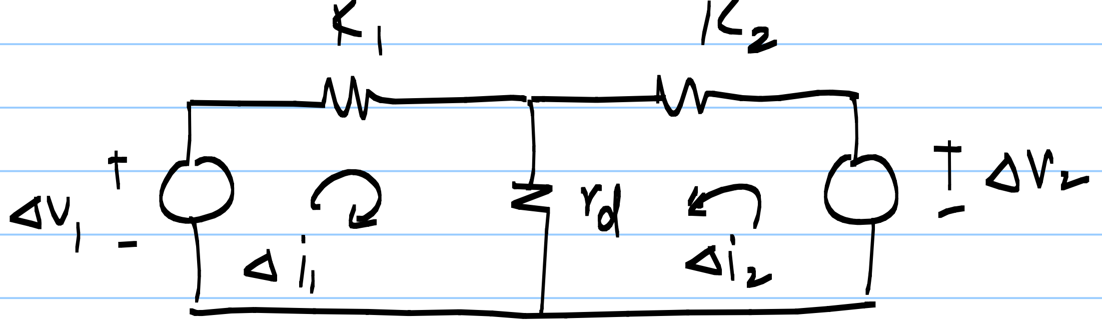
Op. pt. Use NL eqns.

$$I_1 = \frac{V_1 - 0.65}{R_1} \quad \& \quad I_2 = \frac{V_2 - 0.65}{R_2}$$

$$I_{D_0} = I_1 + I_2$$

$$V_1 \rightarrow V_1 + \Delta V_1 \quad \& \quad V_2 \rightarrow V_2 + \Delta V_2$$

Inc. picture:



$$r_d = \frac{V_t}{I_{D_0}}$$

$$\Delta i_d = \Delta i_1 + \Delta i_2$$

Incremental network

* All elements are linear
* No dc sources
* Inc. voltage across NL element

  $\Delta v_d = \Delta i_d \cdot r_d$ $\qquad \left\{ \Delta v_d = \dfrac{r_d}{r_d + 9.35\,k\Omega} \cdot \Delta v_s \right\}$
* Total voltage across diode

  = Quiescent voltage + Incremental voltage

  $\{ 0.65\,V + \Delta v_d \}$
* Can extend to networks with multiple NL elements

  → replace each NL element with its

  inc. resistance $\quad r_i = \dfrac{1}{f_i'(V_{i0})}$