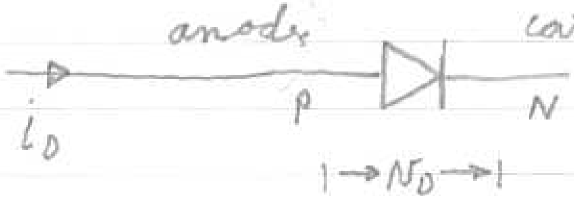
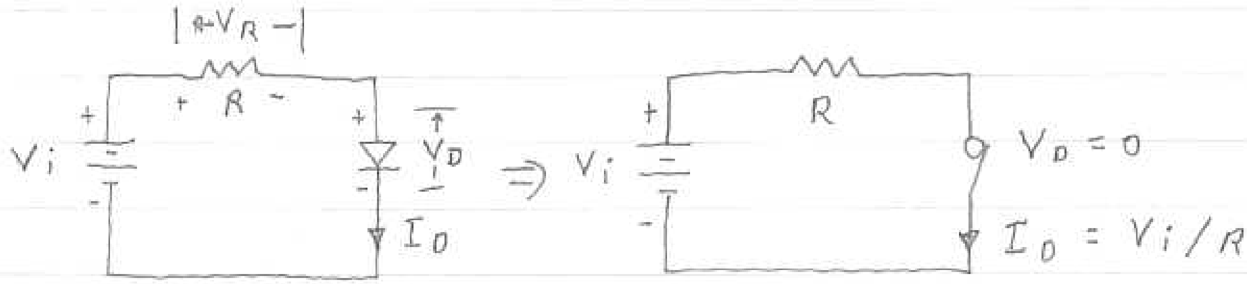
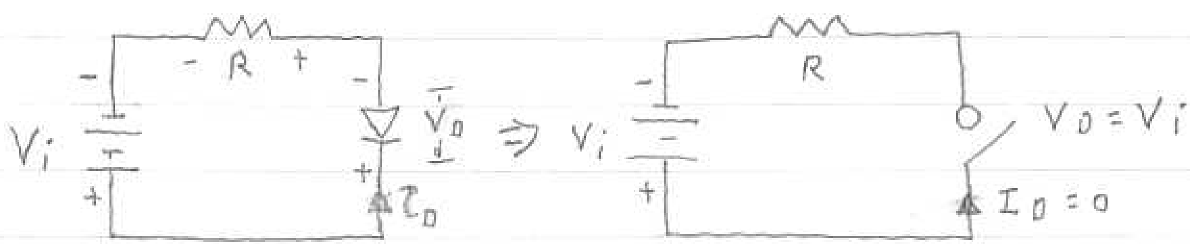
CHAPT 3 Diodes



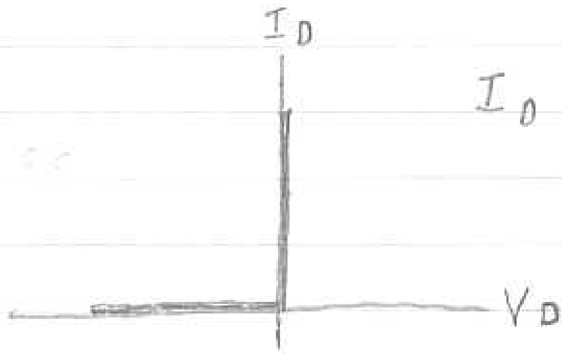
Ideal Diode — Equivalent Circuit





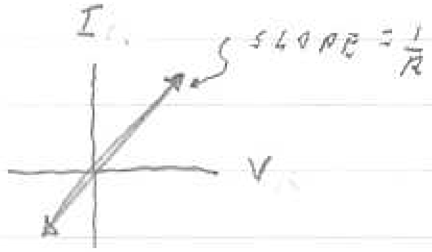
Ideal Diode Characteristics

$I_D = f(V_D)$

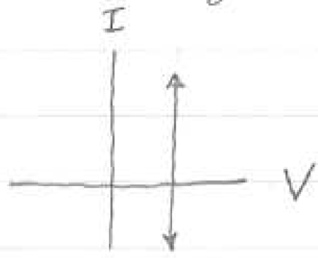


Contrast with:

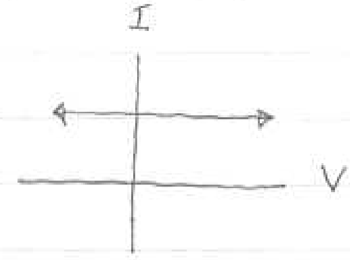
Resistor



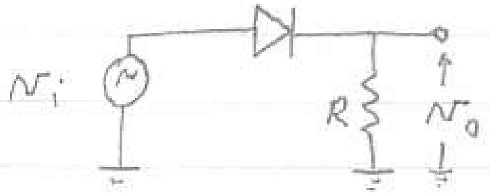
Battery



Current Source

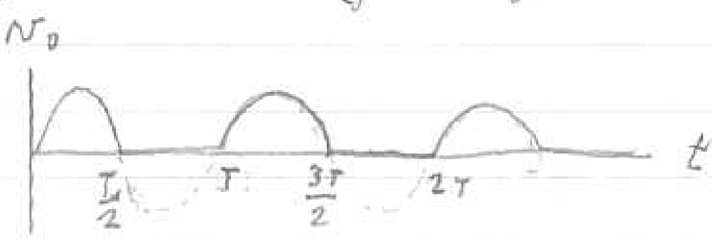


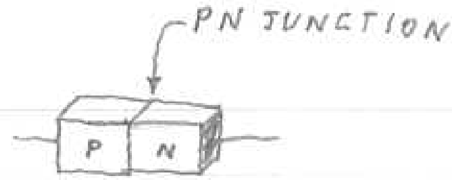
<u>Rectifier</u> (Generates DC from AC)



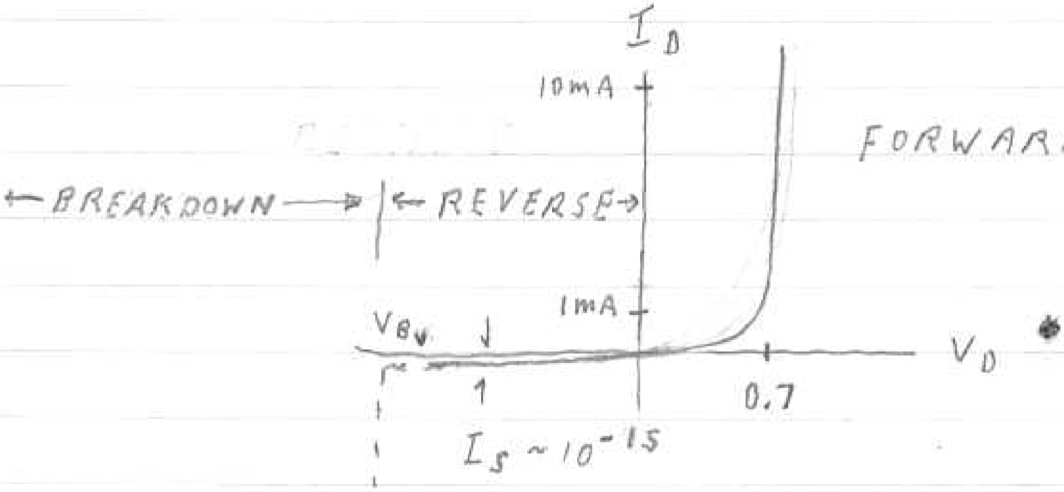
$$v_i = V_p \sin\left(\frac{2\pi}{T} t\right)$$

Eq Circuit (0 to $\frac{T}{2}$) Eq. Circuit ($\frac{T}{2}$ to T)





Real Diode



$$i_D = I_S\left(e^{v_D/V_T n} - 1\right)$$

i_D = diode current
v_D = " voltage
I_S = saturation current ($I_S \propto$ PN JUNCTION AREA)
n = constant between 1 & 2

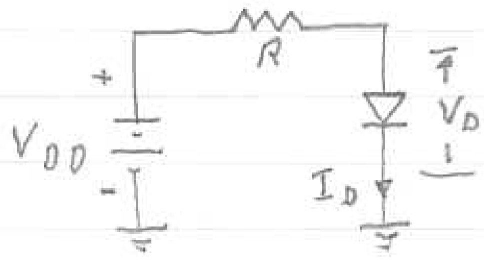
(1) $$V_T = kT/q \approx 2.5\ mV$$

q = Electron charge
k = Boltzman's constant
T = °K

(1a) $i_D \simeq I_S e^{v_D/V_T n}$
(1b) $\therefore\ v_D \simeq n V_T \ln(i_D/I_S)$

$\Bigg\}$ for $v_D > 100\ mV$

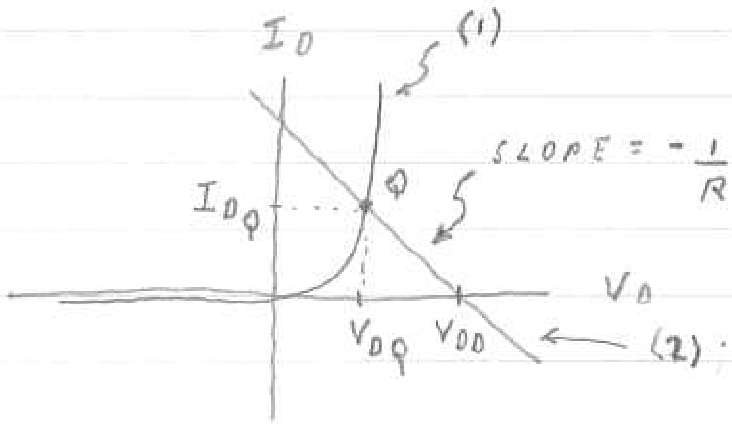
ANALYSIS OF DIODE CIRCUITS



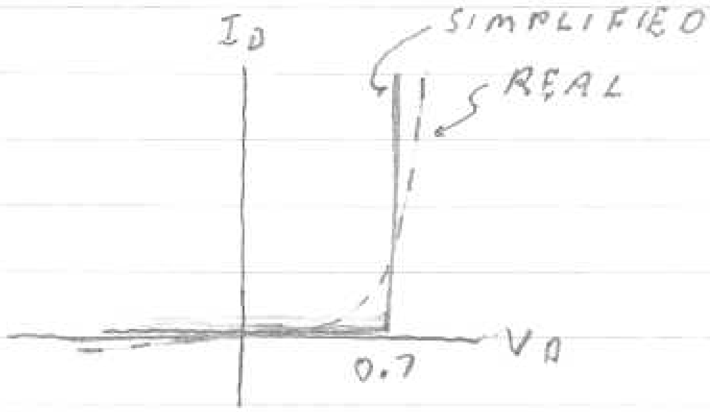
(2) $V_{DD} = V_D + R I_D$ ← load line equation

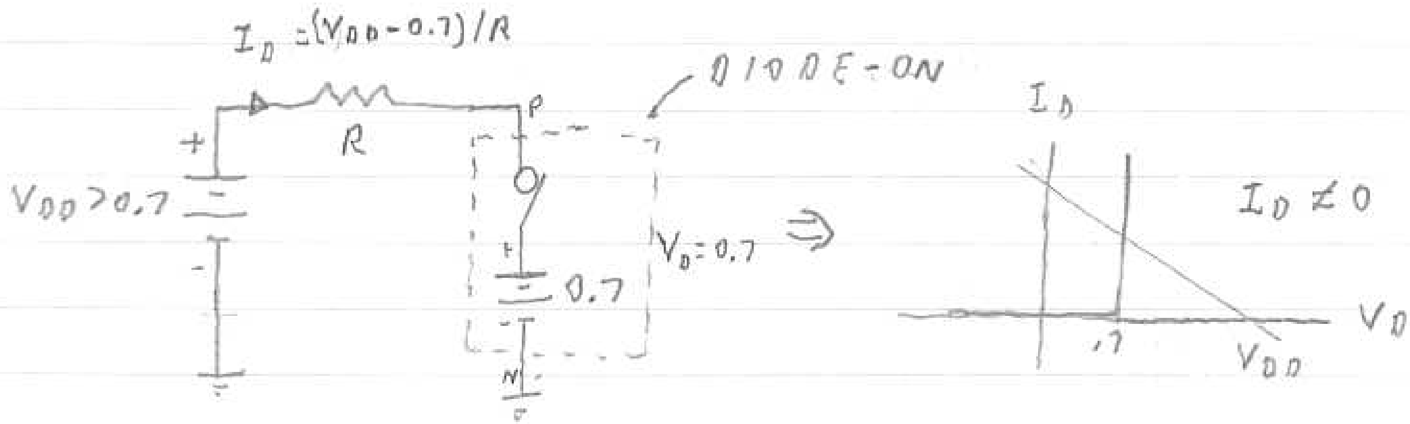
(1) $I_D = I_S(e^{V_D/V_T} - 1)$ ← diode characteristics

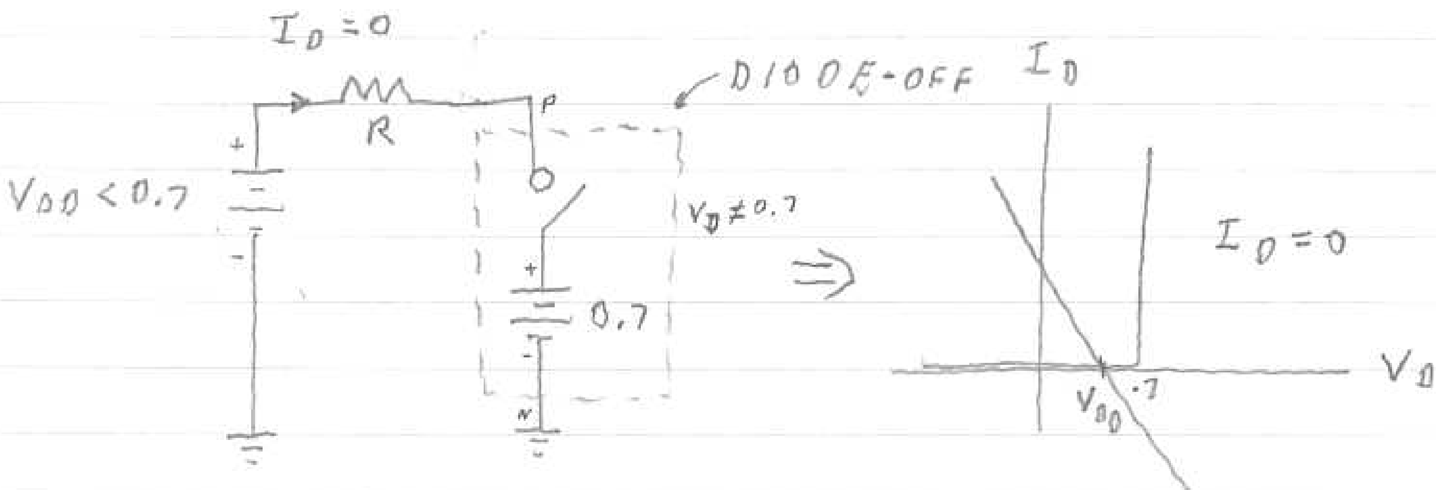
GRAPHICAL ANALYSIS:



SIMPLIFIED DIODE MODEL: USE FOR DC CIRCUIT



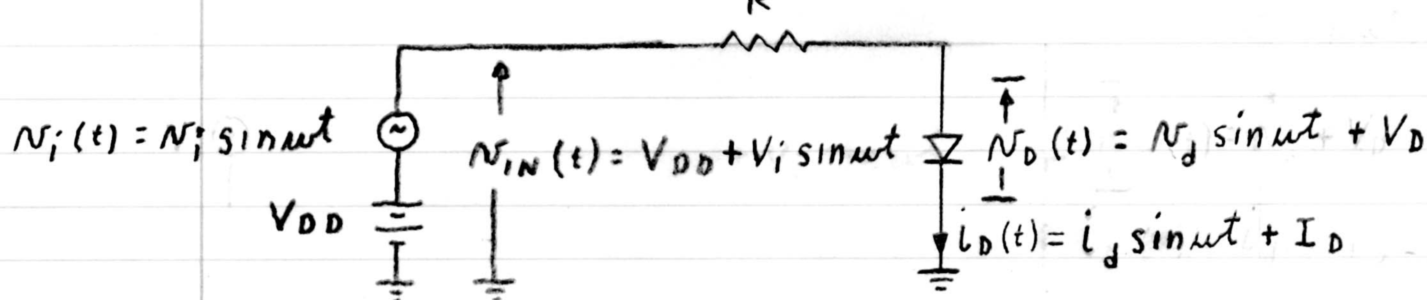




$V > 0.7 \Rightarrow$ DIODE - ON

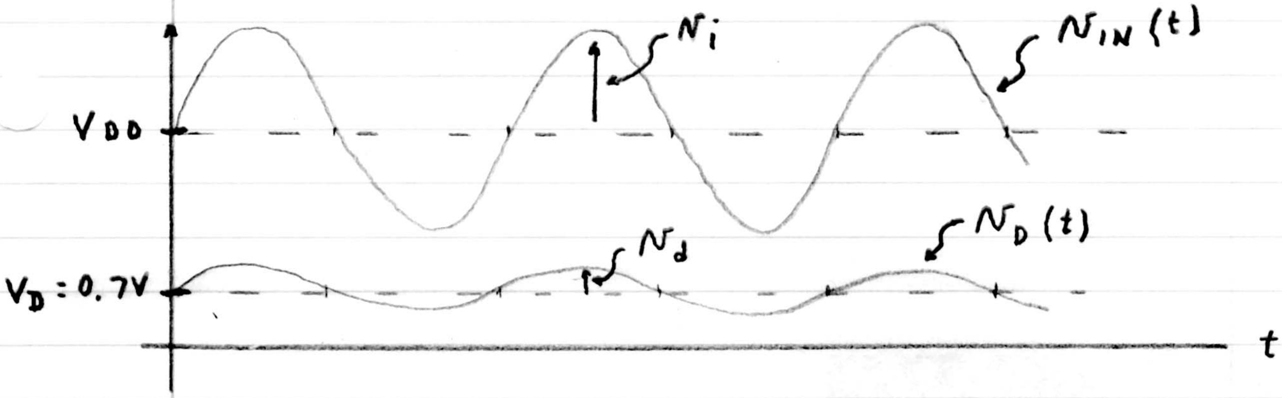
$V < 0.7 \Rightarrow$ DIODE - OFF

ANALYZE A DIODE CIRCUIT WITH AN AC & DC SOURCE

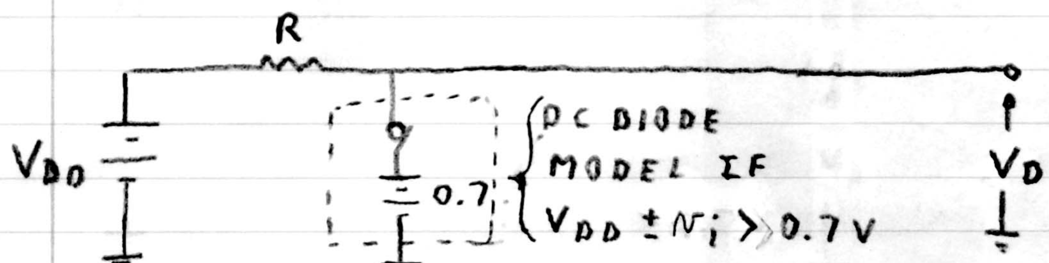


(1) $i_D(t) = I_S\left(e^{v_D(t)/V_T} - 1\right)$

(2) $\underbrace{V_{DD} + v_i \sin \omega t}_{v_{IN}(t)} = v_D(t) + R\, i_D(t)$



I) WE WILL FIND $\underline{V_D}$ AND $\underline{I_D}$ FROM THE $\underline{\text{DC CIRCUIT}}$



V_{DQ}

$$\boxed{\begin{aligned} V_D &= 0.7V \\ I_D &= (V_{DD} - 0.7)/R \end{aligned}}$$

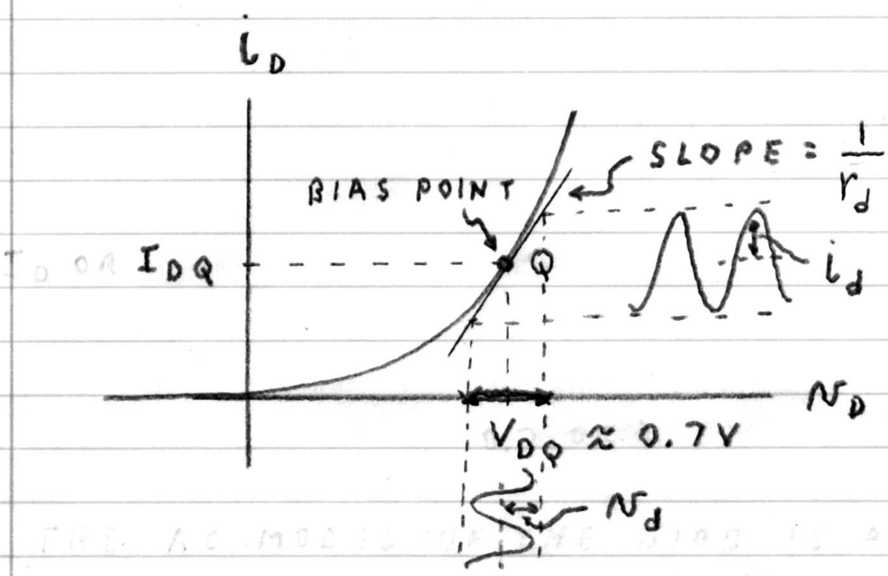
I_{DQ}

THE V_D & I_D THAT RESULTS FROM THE DC SOURCE IS THE BIAS OR 'Q' POINT

II) WE WILL FIND v_d AND i_d FROM THE AC CIRCUIT

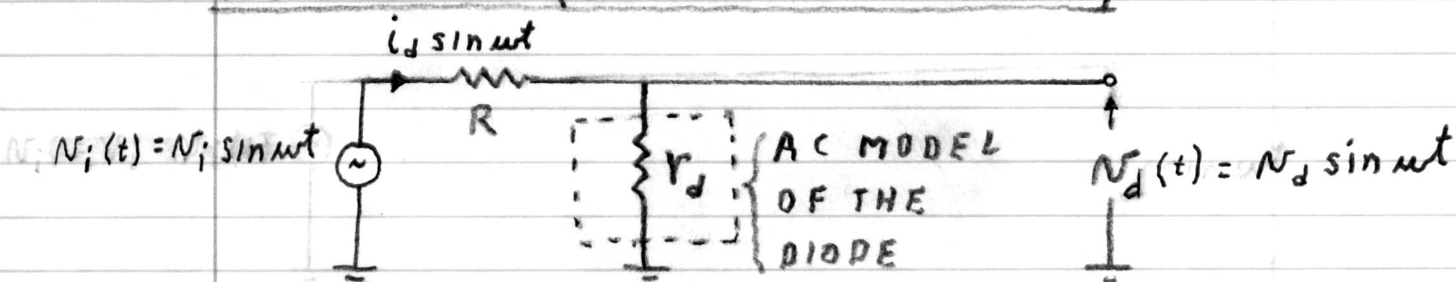
BUT FIRST WE MUST FIND THE "AC" MODEL OF THE DIODE.

SMALL SIGNAL (AC) DIODE MODEL ; USED FOR AC CIRCUIT UNDER SMALL SIGNAL CONDITIONS



THE AC MODEL OF THE DIODE IS A RESISTOR WHOSE VALUE IS EQUAL TO r_d. (r_d IS A DYNAMIC RESISTOR)

AC CIRCUIT (LINEARIZED CIRCUIT)



$$v_d(t) = v_d \sin \omega t = v_i(t)\left[\frac{r_d}{r_d + R}\right] = v_i\left[\frac{r_d}{r_d + R}\right]\sin \omega t$$

$$\boxed{v_d = \frac{v_i\, r_d}{r_d + R}}$$

THUS: $v_D(t) = V_D + v_d \sin \omega t$

$$v_D(t) = \underset{\substack{\uparrow \\ \text{BIAS VOLTAGE}}}{0.7} + \underbrace{v_i \left[\frac{r_d}{r_d + R} \right] \sin \omega t}_{\text{AC SIGNAL}}$$

FIND r_d

$$r_d = \left. \frac{d V_D}{d I_D} \right|_{I_D = I_{DQ}}$$

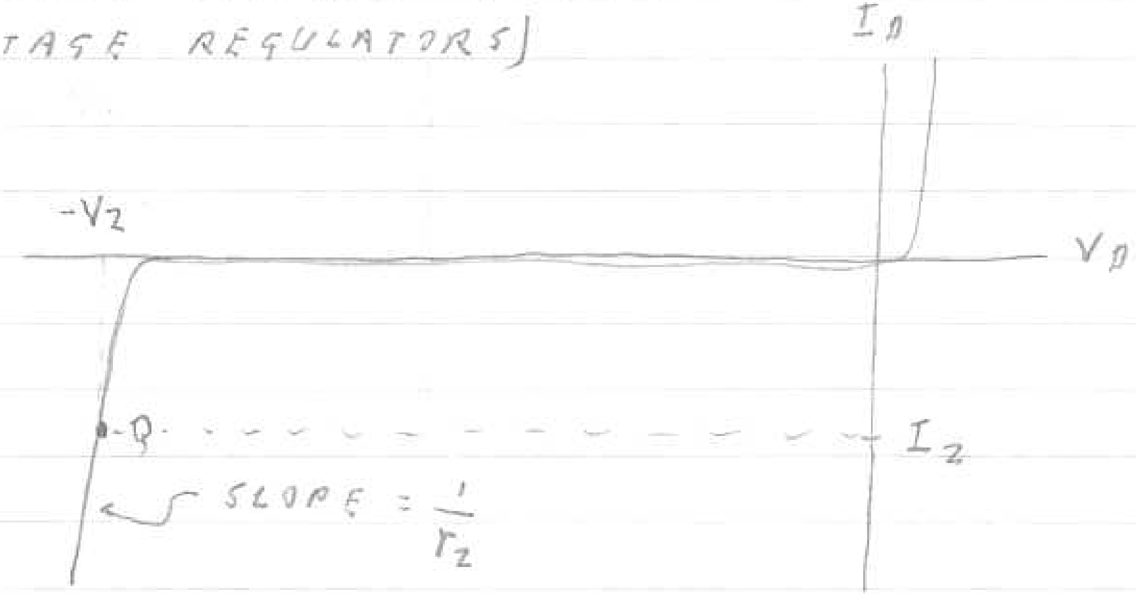
$$I_D = I_S \left(e^{V_D/V_T} - 1 \right) \approx I_S\, e^{V_D/V_T} \quad ; V_D \geq 100\,mV$$

$$1/r_d = \left. \frac{d I_D}{d V_D} \right|_Q = \frac{I_S}{V_T} e^{V_D/V_T} = \left. \frac{I_D}{V_T} \right|_Q = \frac{I_{DQ}}{V_T} \approx \frac{I_{DQ}}{25\,mV}$$

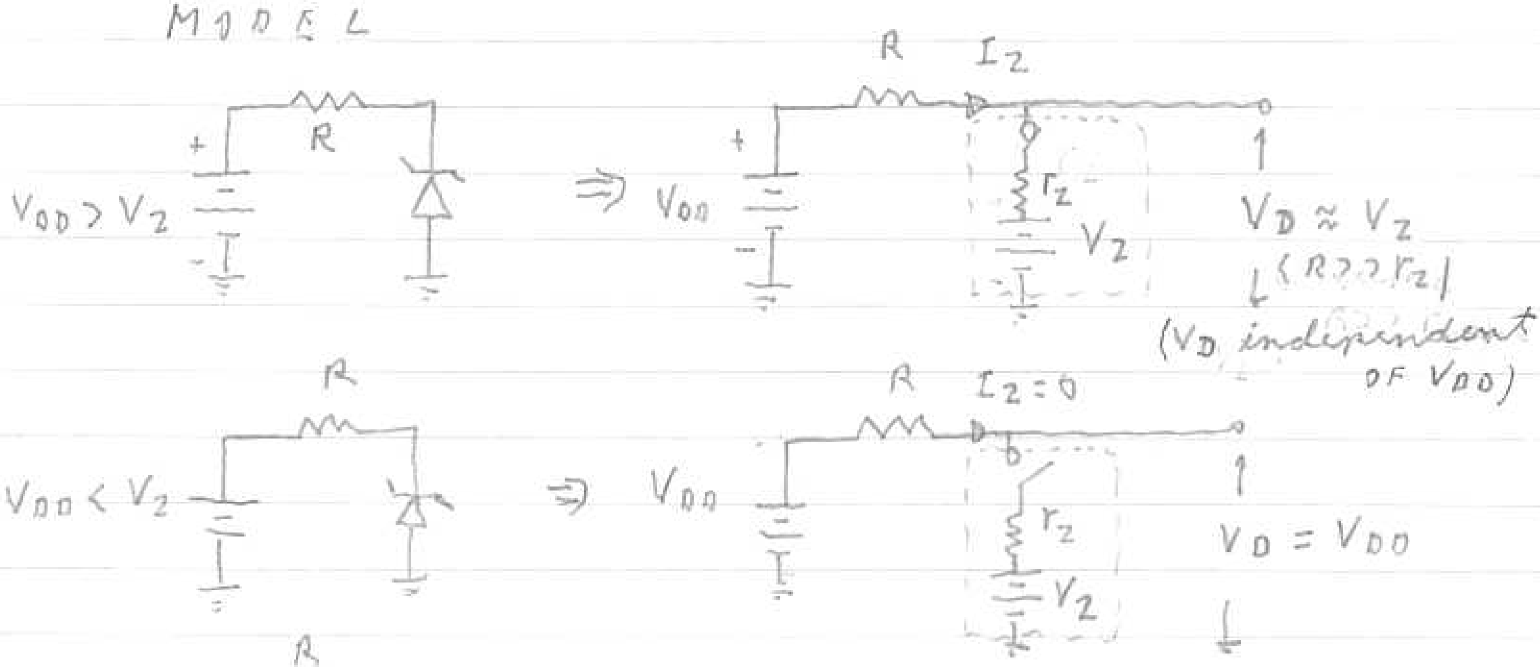
$$\boxed{r_d = V_T / I_{DQ}}$$

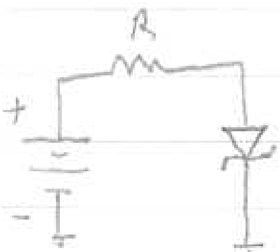
REVERSE BREAKDOWN REGION - ZENER DIODES

(VOLTAGE REFERENCE FOR
VOLTAGE REGULATORS)



MODEL

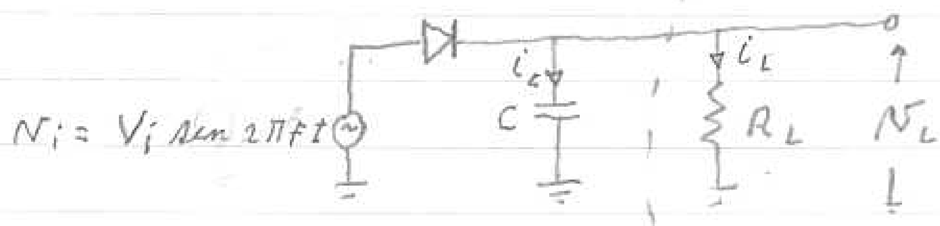




{NORMAL
DIODE IN
FORWARD MODE

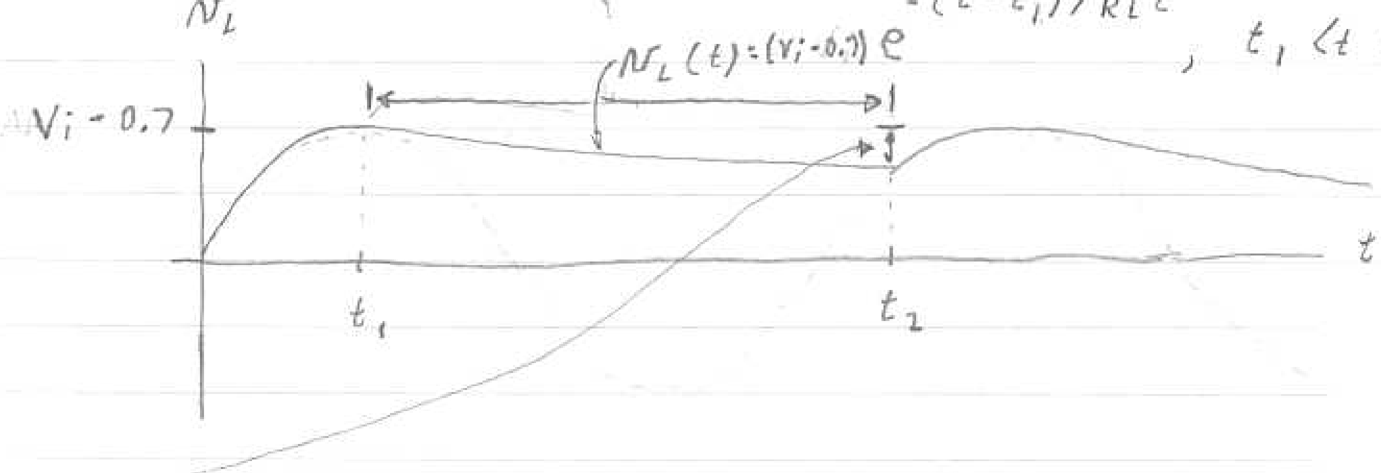
USES OF DIODES

Half Wave Rectifier with filtering Capacitor (Produces DC from AC)



$$V_c = \frac{1}{C}\int_0^t i_c(t)\,dt$$

$$v_L(t) = (V_i - 0.7)\, e^{-(t-t_1)/R_L C}, \quad t_1 < t < t_2$$

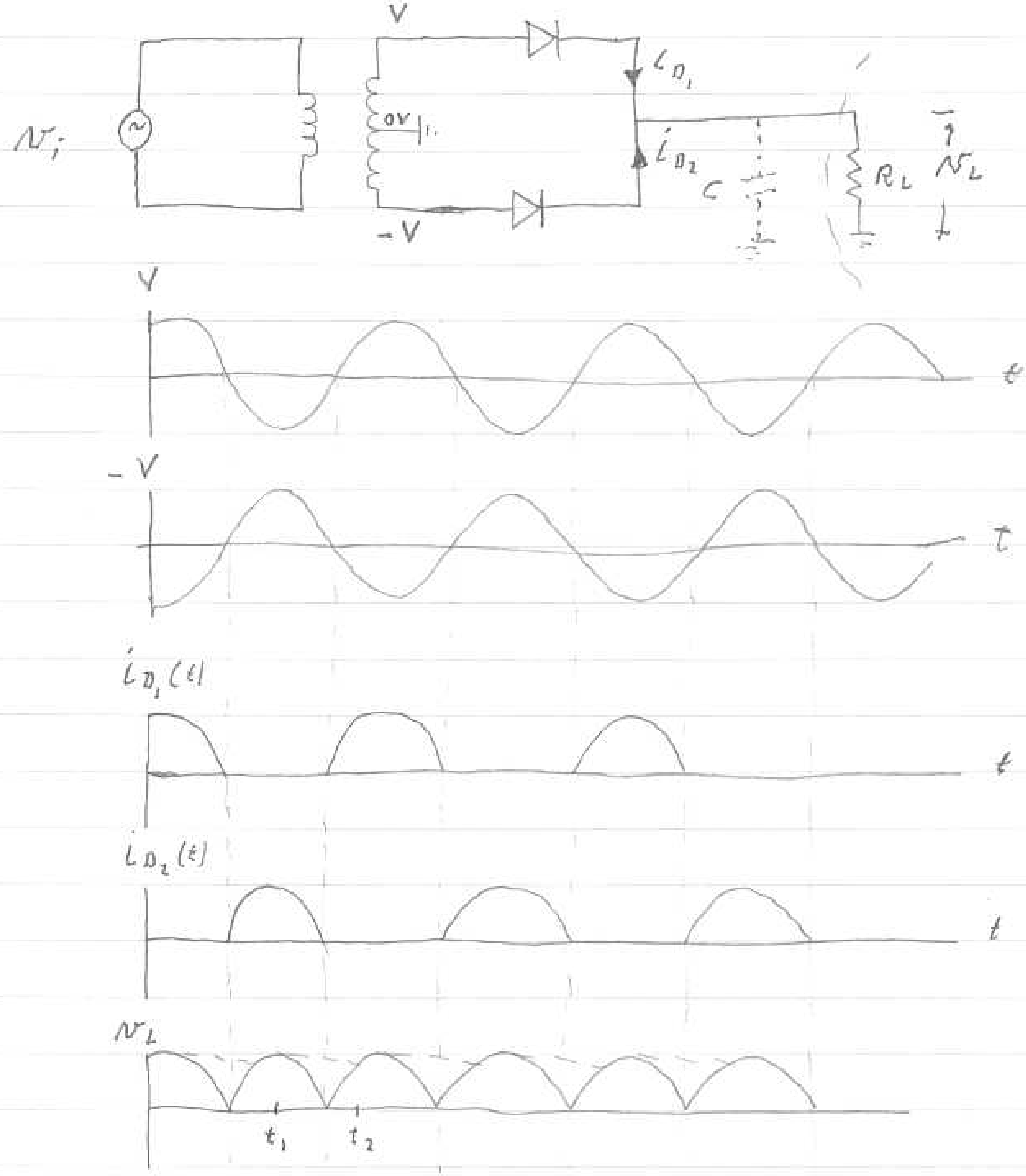


$V_{RIP} \equiv$ Peak to peak ripple

$$V_{RIP} \approx \frac{V_i\,(t_2 - t_1)}{R_L C} \quad \text{for } V_{RIP} \ll V_i$$

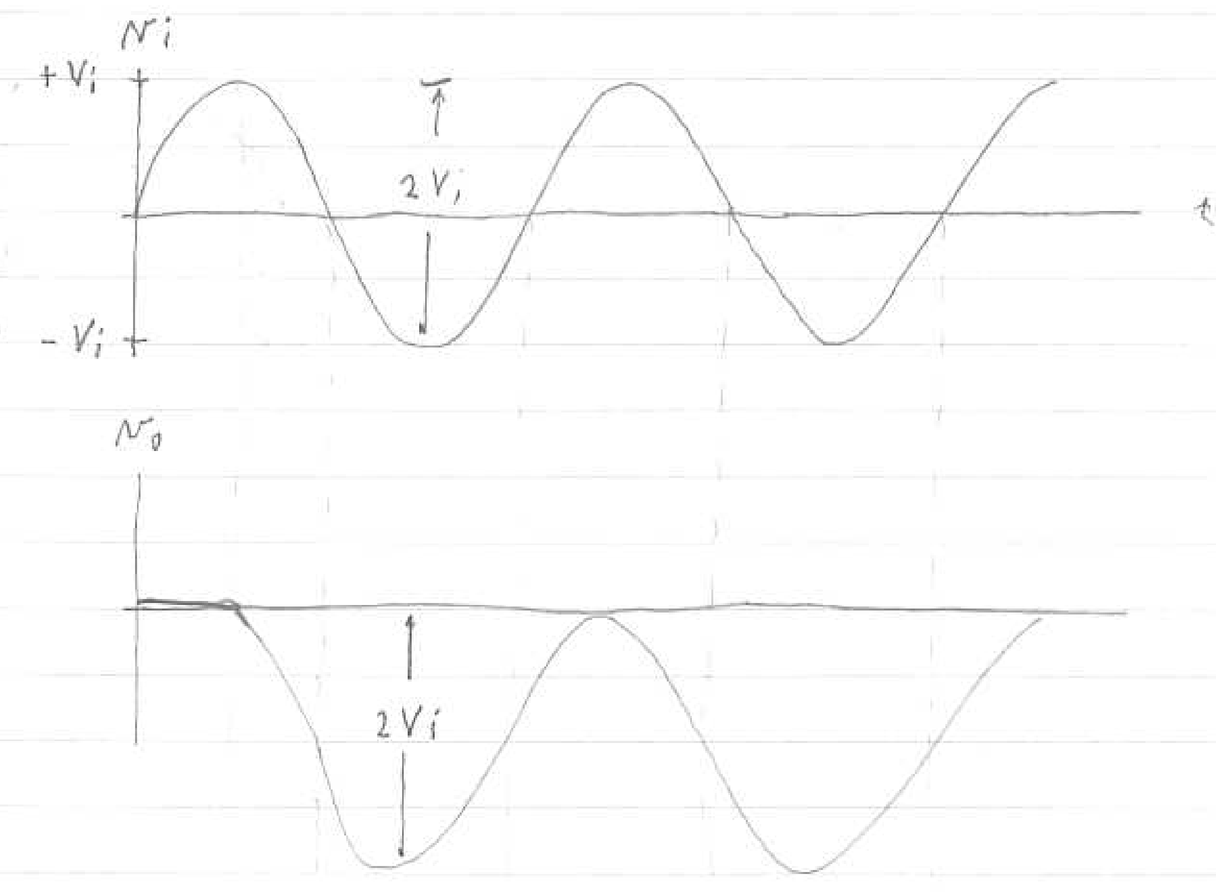
$$\approx \frac{V_i}{RCf}, \qquad t_2 - t_1 \approx \frac{1}{f}$$

Full-wave rectifier



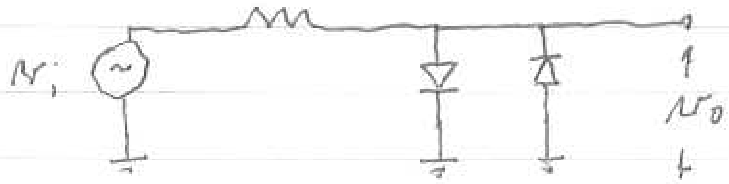
$t_2 - t_1$ is less

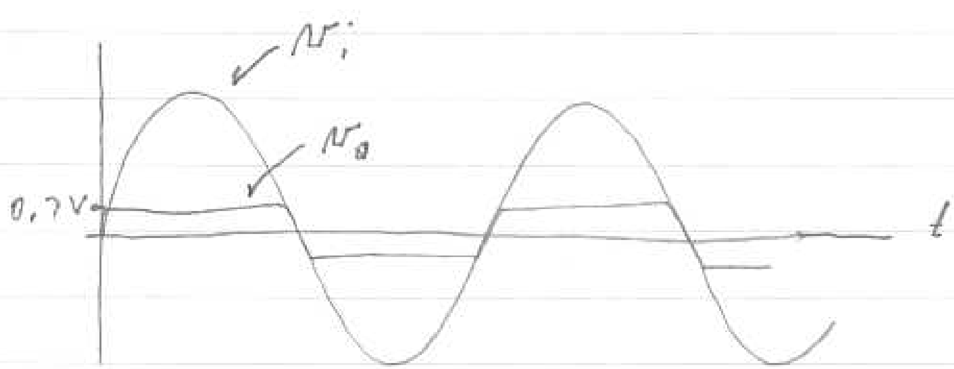
Clamping Circuit



output is shifted down by V_i volts

Limiter





ERROR

Temperature Effects

V_D is a function of temperature mainly because I_S is a function of temperature

$$V_D(T_2) - V_D(T_1) \doteq -k(T_2 - T_1) \quad \text{for } I_D \text{ constant}$$

for silicon diode biased at $V_D \doteq 0.7V$ $k = 2mV/°C$

$$\Delta V_D = -k \, \Delta T$$