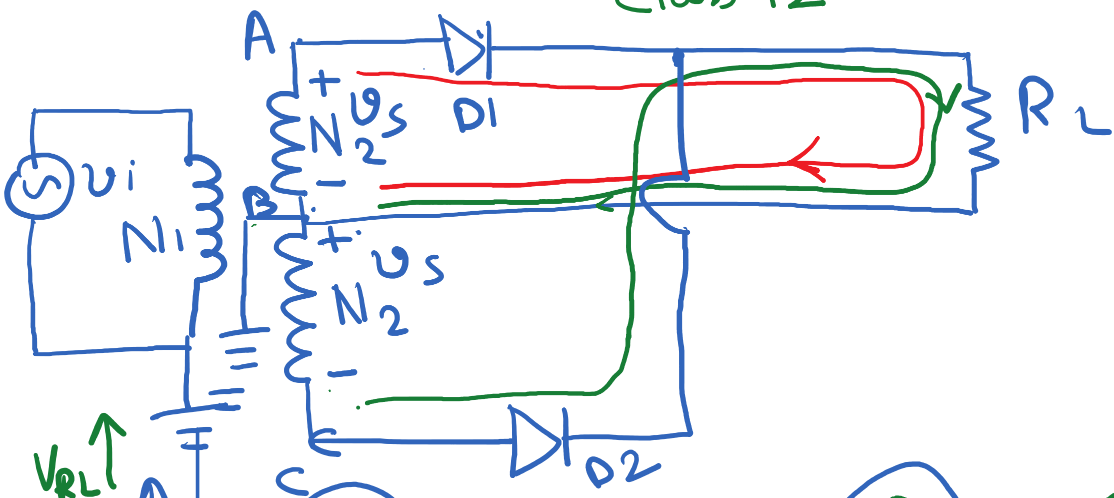
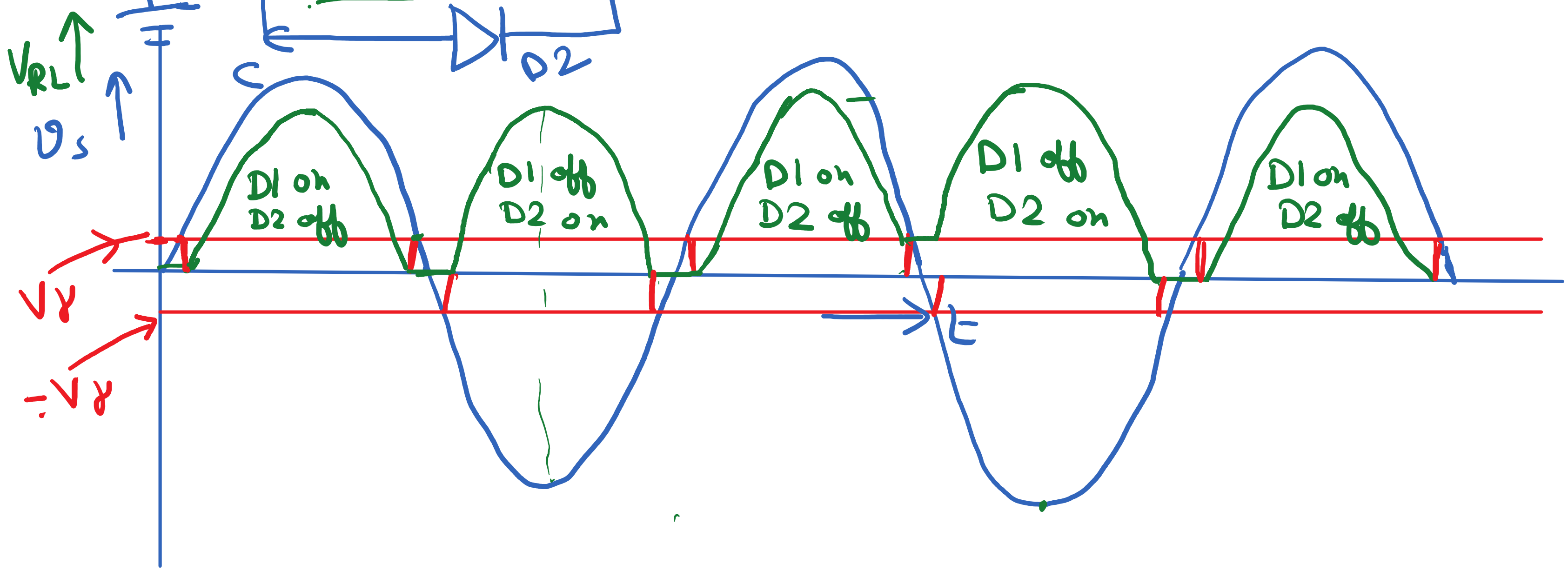
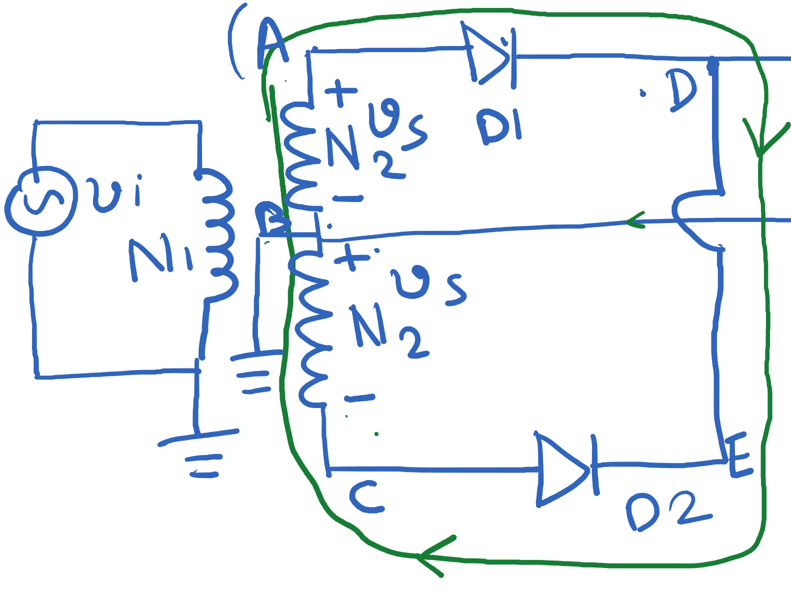
Class-12

Full-wave rectifier with centre tapped transformer







$$\underline{\underline{V_{xy} = V_x - V_y}}$$

KVL:-

$$V_{CA} + V_{AD} + V_{EC} = 0$$

$$\Rightarrow -2v_s + V_\gamma + V_R = 0$$

$$\Rightarrow V_R = 2v_s - V_\gamma.$$

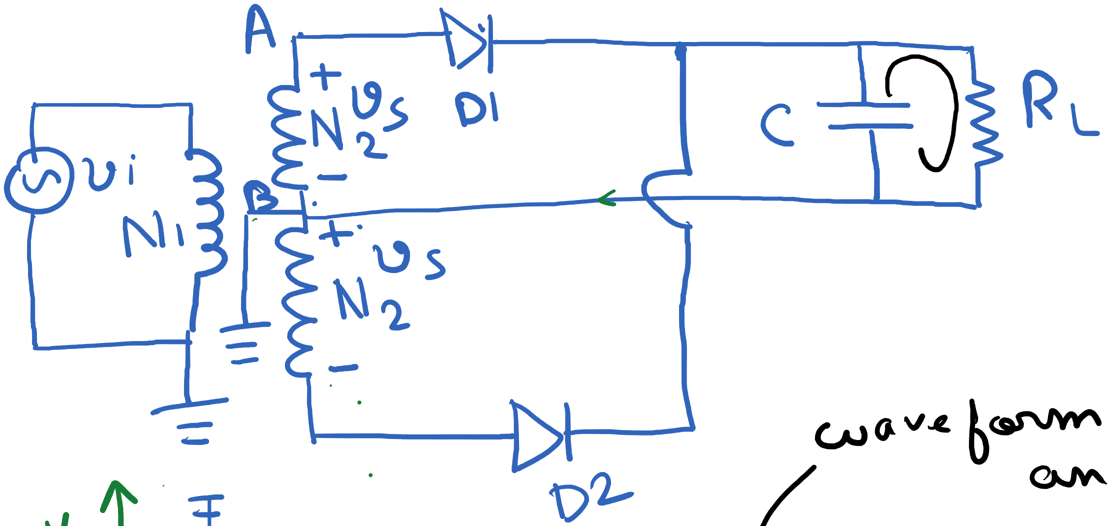
$$\Rightarrow V_R^{max} = 2v_s^{max} - V_\gamma$$

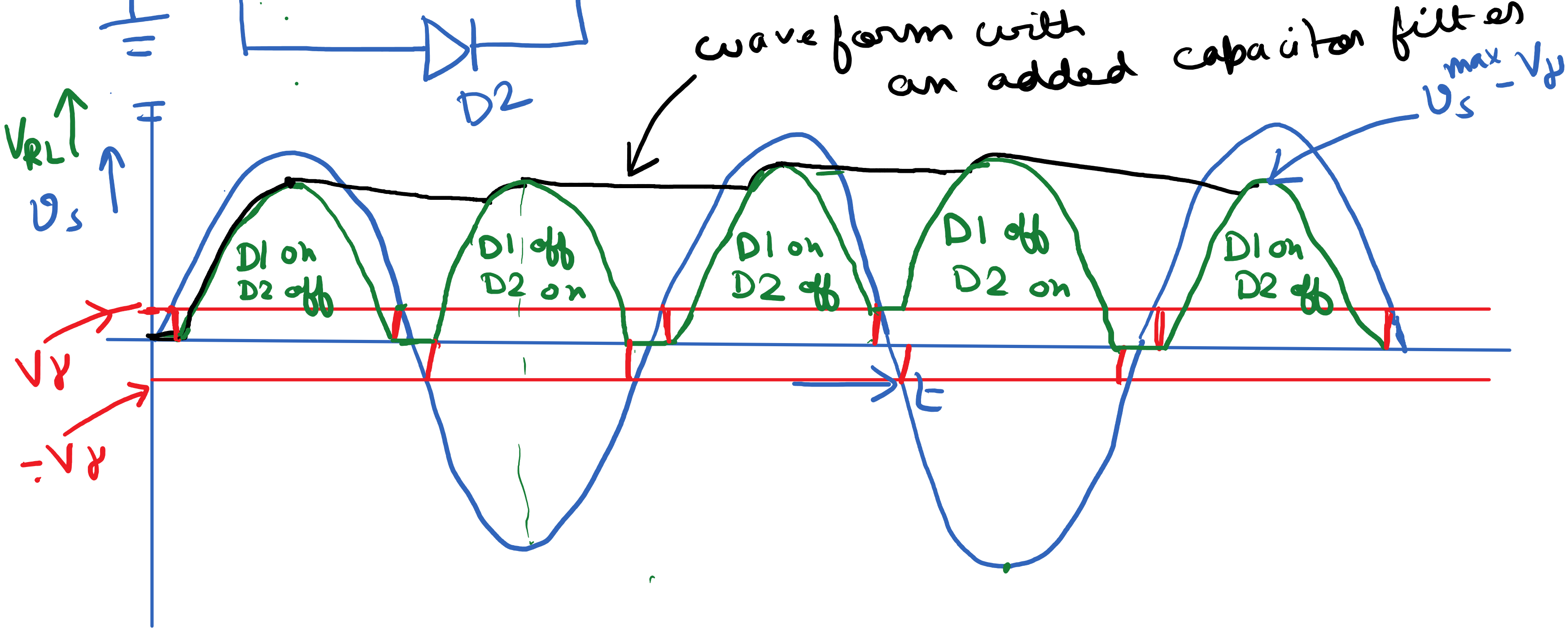
$$PIV = 2v_s^{max} - V_\gamma$$

Disadvantage :- 1) Requires diodes with high PIV rating.

2) Needs twice the number of turns or windings in the secondary coil.

Centre tapped transformer full wave rectifier with capacitor filter





T_p = time period of v_s.

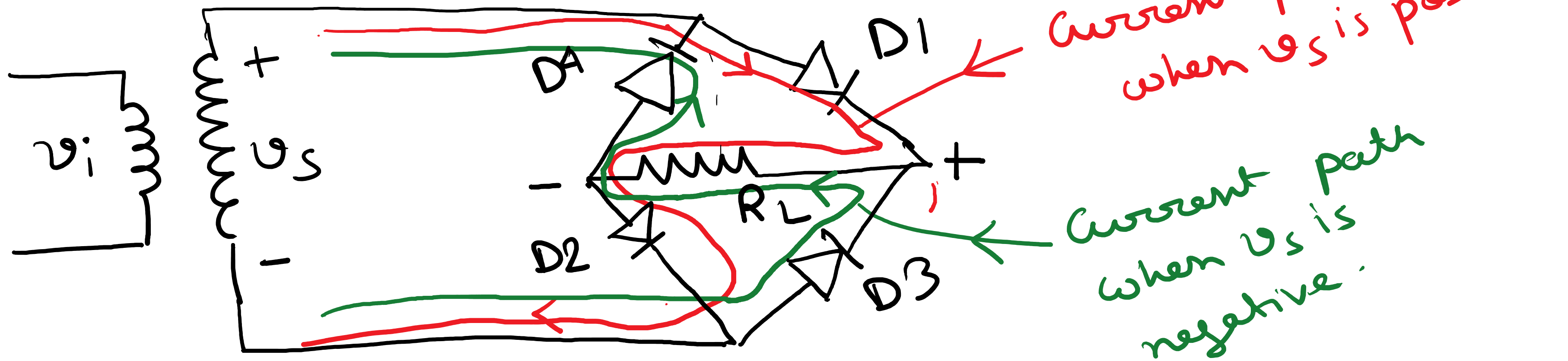
Here the capacitor charges up twice during each time period T_p. So, the time interval between successive charging events is $T_p/2$

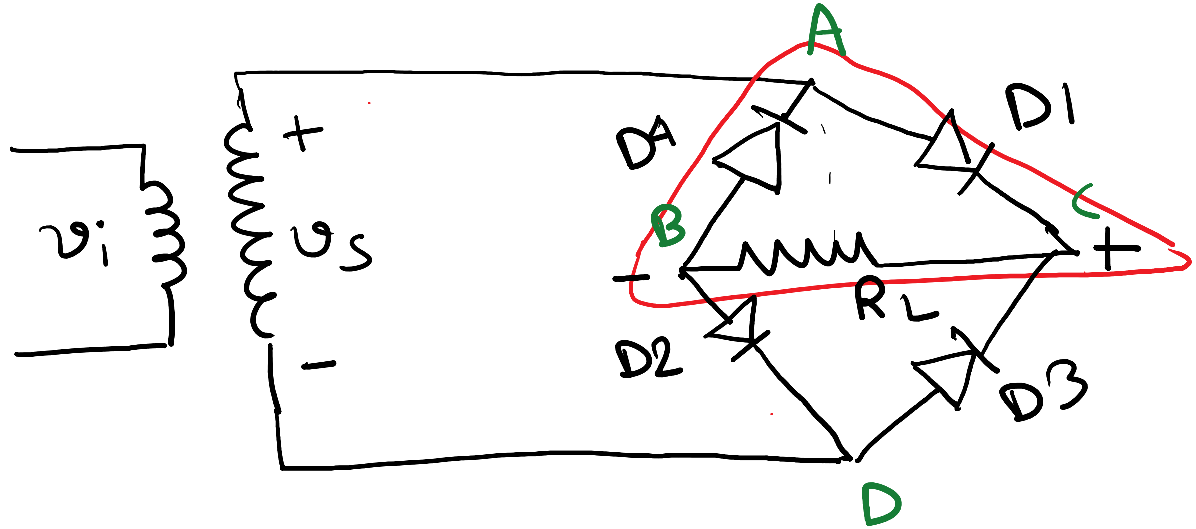
$$V_{Ripple} = V_c^{max} - V_c^{min}$$

$$\simeq \frac{(T_p/2)\, v_c^{max}}{R_L C} = \frac{T_p\, v_c^{max}}{2 R_L C}$$

Ripple voltage of a full wave rectifier with capacitor filter is approximately half of that in a half wave rectifier with a capacitor filter

Full-wave Bridge rectifier :-





$$v_s = v_{D1} + v_{RL} + v_{D2}$$
$$= V_\gamma + v_{RL} + V_\gamma$$
$$\Rightarrow v_{RL} = v_s - 2V_\gamma$$
$$\Rightarrow v_{CB} = v_{RL}$$
$$= v_s - 2V_\gamma$$

KVL: $v_{AC} + v_{CB} + v_{BA} = 0$

$$V_R = v_{AB} = -v_{BA} = (v_{AC} + v_{CB})$$
$$= V_\gamma + (v_s - 2V_\gamma)$$
$$= v_s - V_\gamma$$

$$V_R^{Max} = v_s^{max} - V_\gamma \Rightarrow PIV = v_s^{max} - V_\gamma$$

Adv: 1) Lower PIV rating than that of a centre tapped transformer Full wave rectifier.

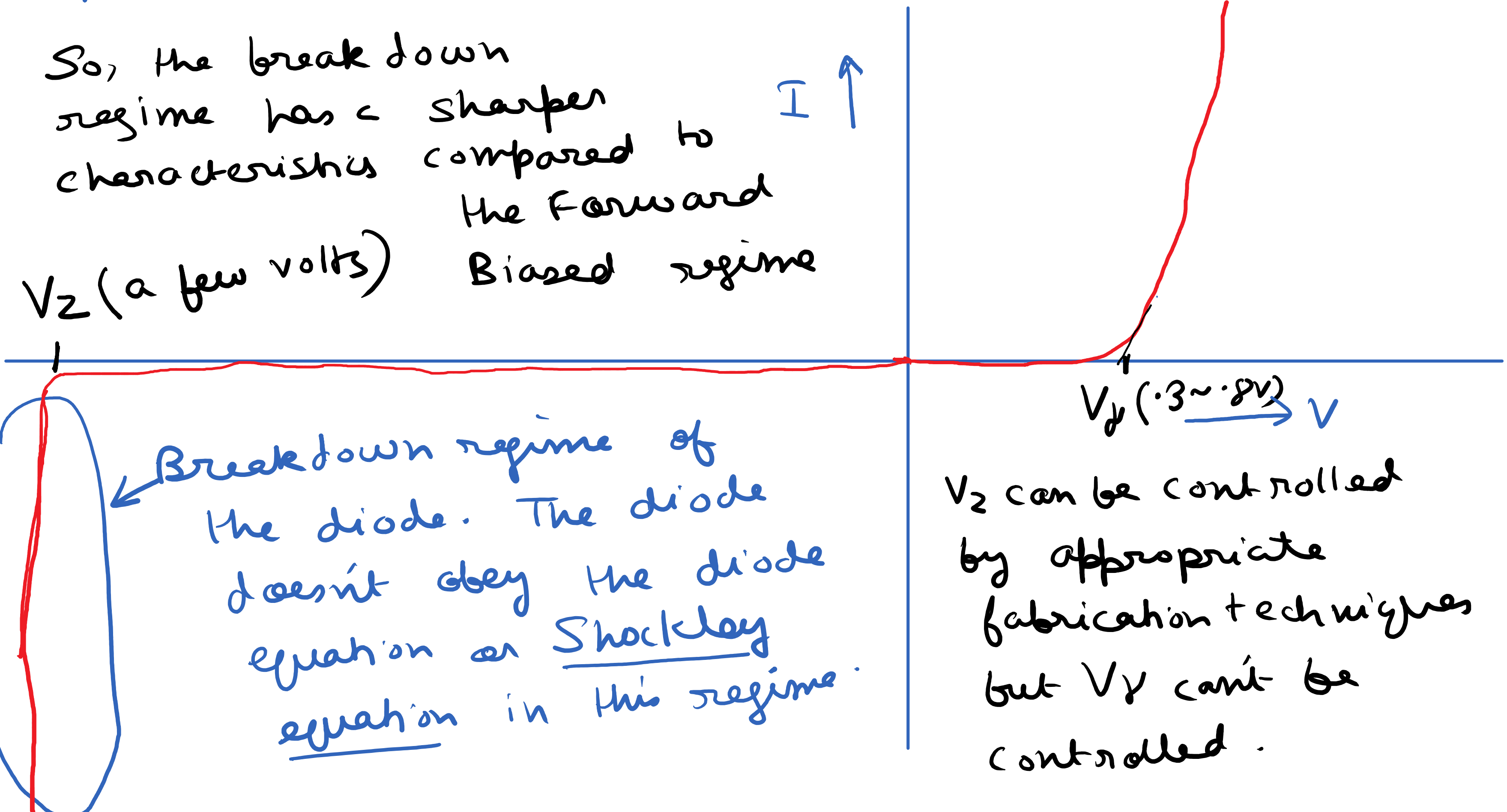
2) Less number of turns in the secondary coil.

Dis:- 1) Need 4 diodes instead of two.

2) The maximum voltage across load resistor is $v_s^{max} - 2V_\gamma$ which lower than that of a centre tapped transformer full wave rectifier.

Application of the Breakdown regime of the Diode :-

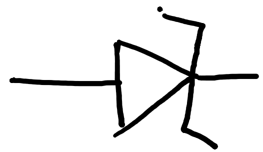
So, the breakdown regime has a sharper characteristics compared to the Forward Biased regime



Breakdown regime of the diode. The diode doesn't obey the diode equation or Shockley equation in this regime.

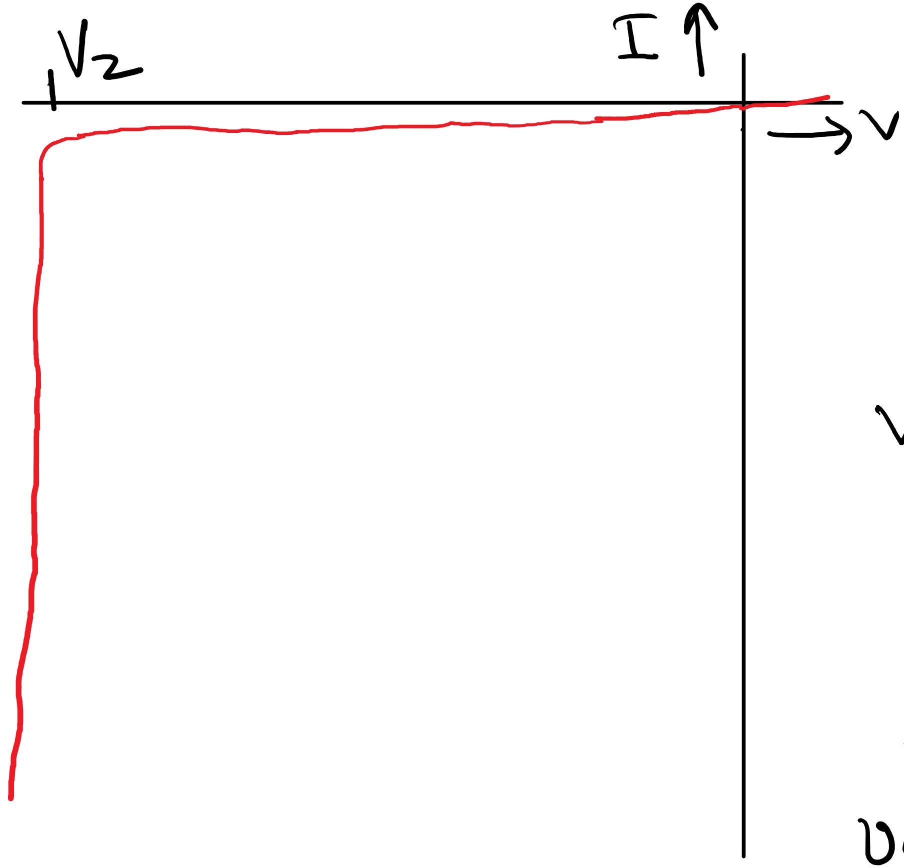
V_Z can be controlled by appropriate fabrication techniques but V_γ can't be controlled.

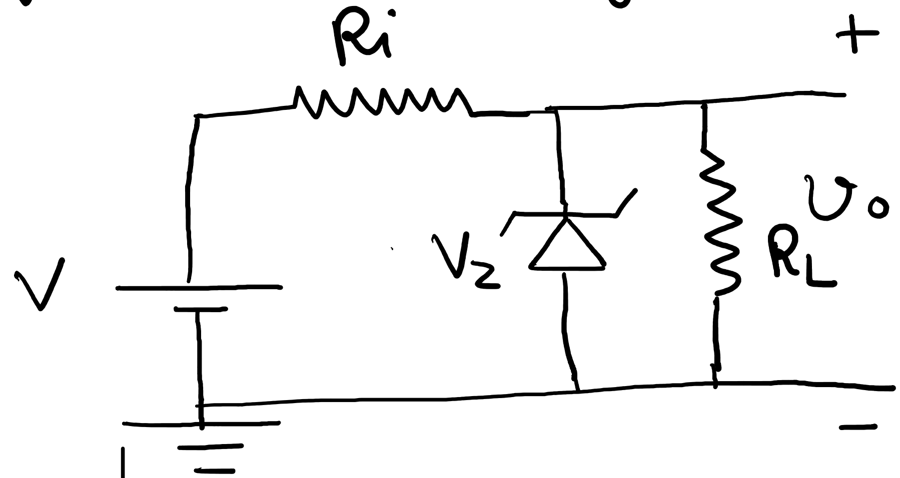
Zener diode :- Highly doped p-n junction where the break down regime depends on quantum tunneling and not on Avalanche mechanism.

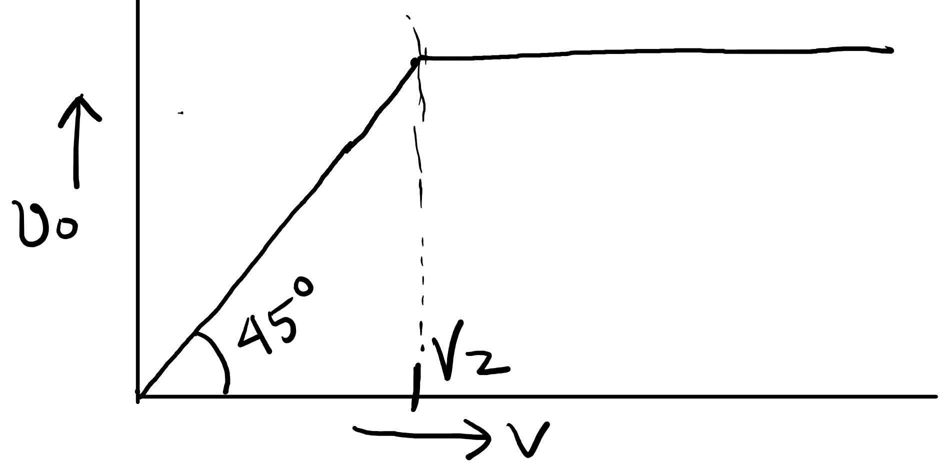


Symbol of a Zener diode.

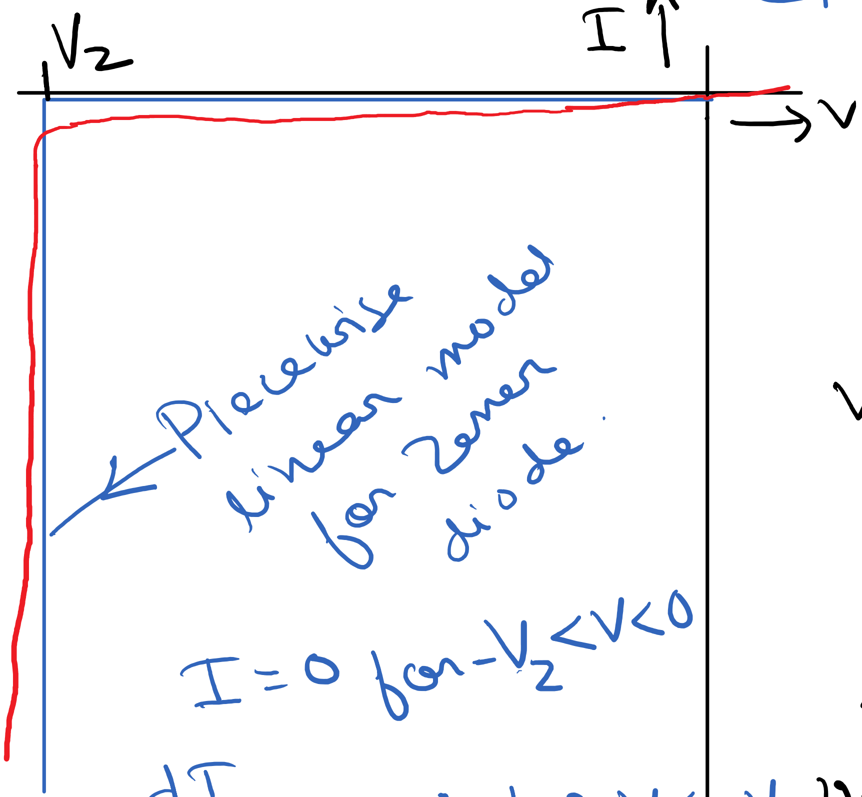
$$V_{R_i} = 0 \text{ for } V < V_z$$
$$= V - V_z \text{ for } V \geq V_z$$







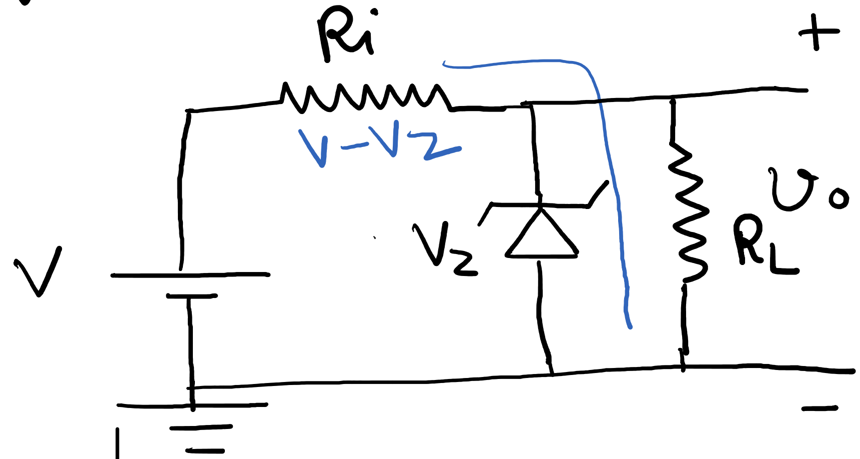
Class-13.

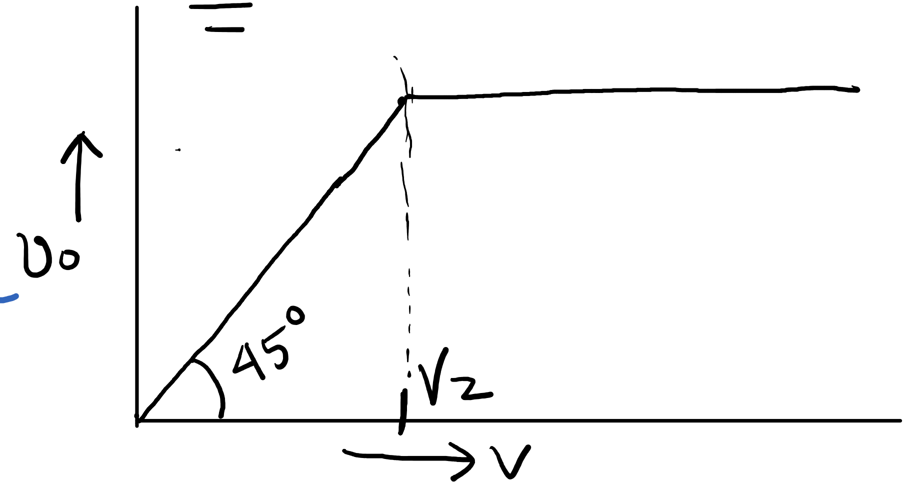


Piecewise linear model for zener diode.

$$I = 0 \text{ for } -V_z < V < 0$$

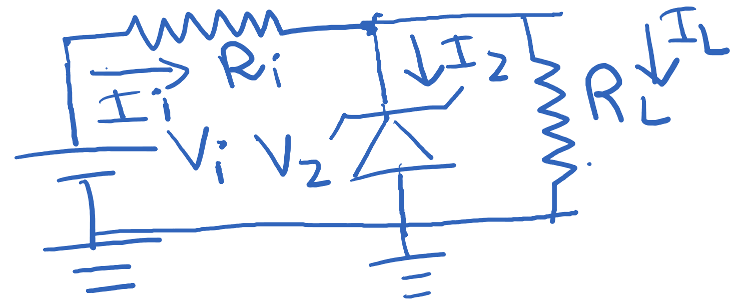
$$\frac{dI}{dV} \to -\infty \text{ for } V < -V_z$$





$V_i = 20V$, $V_Z = 10V$, $R_i = 222\Omega$

$P_Z(max) = 400mW$



(a) $R_L = 380\Omega$, $I_L, I_Z, I_i = ?$

(b) Value of R_L needed to establish $P_Z(max)$

(a) $$I_i = \frac{V_i - V_Z}{R_i} = \frac{20V - 10V}{222\Omega} = 0.045A = 45mA.$$

$$I_L = \frac{V_{R_L}}{R_L} = \frac{V_Z}{R_L} = \frac{10V}{380\Omega} = 0.0263A = 26.3mA$$

$$I_L + I_Z = I_i \Rightarrow I_Z = I_i - I_L = 45mA - 26.3mA$$
$$= 18.7mA$$

(b) $P_Z(max) = I_Z(max) \times V_Z$

$\Rightarrow 400mW = I_Z(max) \times 10V$

$\Rightarrow I_Z(max) = \frac{400}{10} mA = 40mA$

$I_i = 45mA$

$I_L^{min} = I_i - I_Z^{max} = 45mA - 40mA = 5mA$

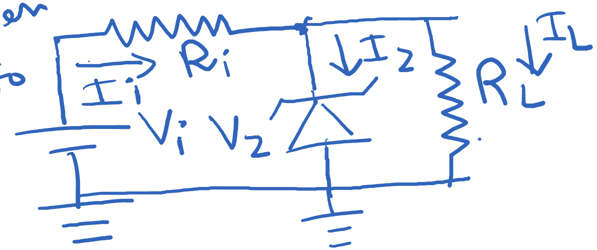
$R_L = \frac{V_{R_L}}{I_L^{min}} = \frac{V_Z}{I_L^{min}} = \frac{10V}{5mA} = 2k\Omega$

Q2 $V_Z = 10V$

$I_Z(\min) = 0.1 I_Z(\max)$

V_i varies between 15V and 20V

given info



Determine the value of R_i such that the Zener diode is in breakdown for I_L between 50mA to 500mA.

$I_Z^{min} \longrightarrow V_i = V_i^{min}$ and $I_L = I_L^{max}$

$I_Z^{max} \longrightarrow \underbrace{V_i = V_i^{max}}$ and $I_L = I_L^{min}$

$I_Z = I_i - I_L \Rightarrow I_Z^{max} = I_i^{max} - I_L^{min}$.

Equation when the current across the Zener diode is at the minimum value.

$$V_i^{min} = R_i(I_L^{max} + I_Z^{min}) + 10V.$$

$$\Rightarrow 15V = R_i(500\,mA + I_Z^{min}) + 10V$$

$$\Rightarrow R_i(500mA + I_Z^{min}) = 5V \quad \text{—} \; (1)$$

Equation when the Zener diode current is at its maximum

$$V_i^{max} = R_i(I_L^{min} + I_Z^{max}) + V_Z$$

$$\Rightarrow 20V = R_i(50mA + I_Z^{max}) + V_Z$$

$$\Rightarrow R_i(50mA + I_Z^{max}) = 10V \quad \text{—} \; (2)$$

$(2) \div (1)$

$$\frac{50mA + I_Z^{max}}{500\,mA + I_Z^{min}} = 2$$

$$\Rightarrow 50\,mA + I_Z^{max}$$

$$= 1000 + 2 I_Z^{min}$$

$$= 1000 + 0.2\, I_Z^{max}$$

$$\Rightarrow 0.8 I_Z^{max} = 950$$

$$\Rightarrow I_Z^{max} = 1187.5\,mA$$

$$= 1.1875\,A$$

$$R_i = \frac{10V}{50mA + 1187.5mA}$$

$$= 0.00808\,k\Omega$$

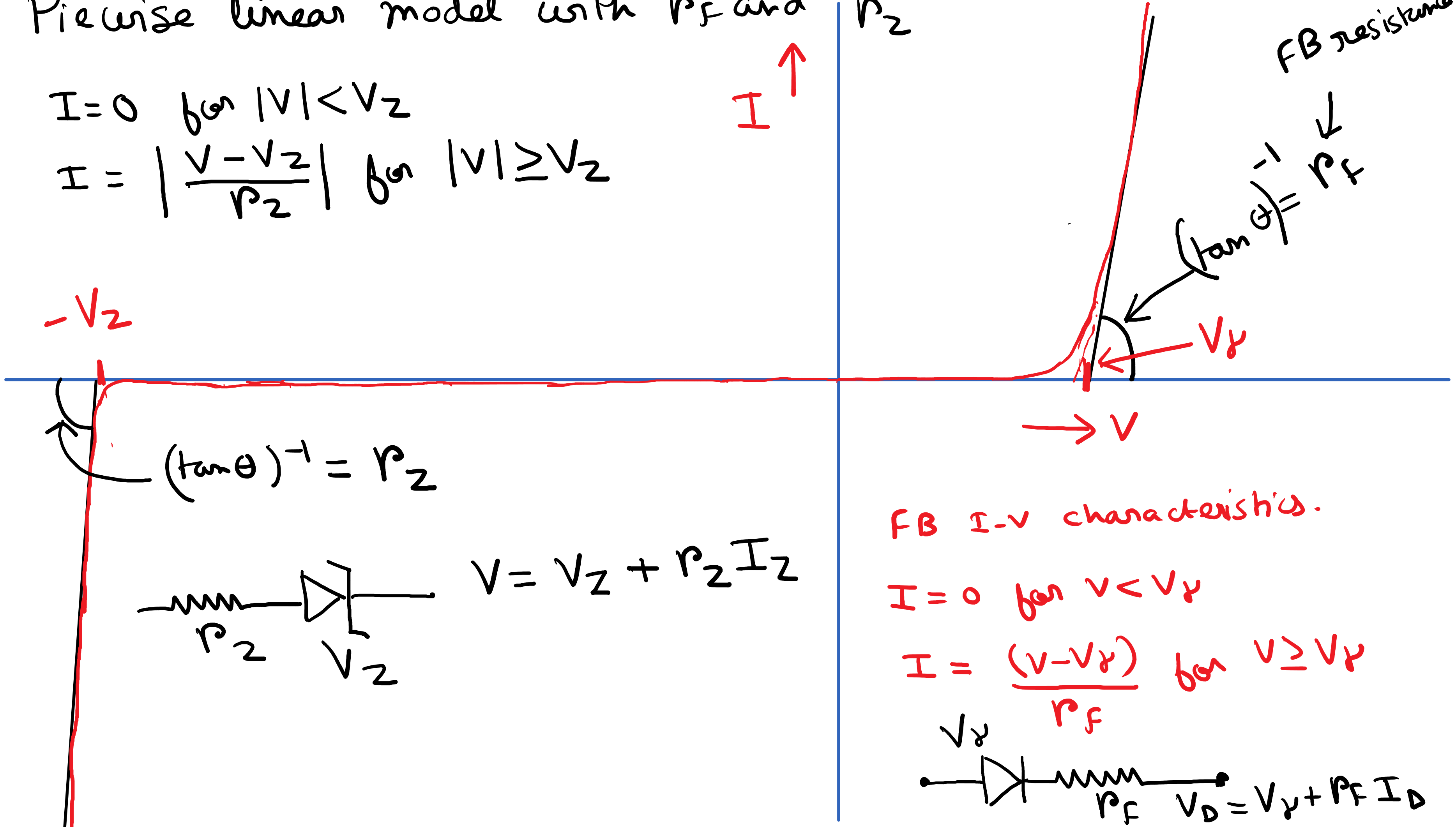
$= 0.00808\ k\Omega$

$= 8.08\ \Omega$

Piecewise linear model with r_F and r_Z

$I = 0$ for $|V| < V_Z$

$I = \left| \frac{V - V_Z}{r_Z} \right|$ for $|V| \geq V_Z$



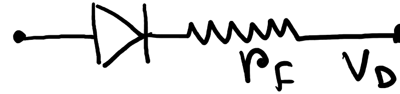
$V = V_Z + r_Z I_Z$

FB I-V characteristics.

$I = 0$ for $V < V_\gamma$

$I = \frac{(V - V_\gamma)}{r_F}$ for $V \geq V_\gamma$

$V_D = V_\gamma + r_F I_D$



$V_D = V_\gamma + r_F I_D$

Q3 $V_i = 20V$ (can vary by $\pm 25\%$)

I_L can vary between 0mA to 20mA

Zener diode is non-ideal with

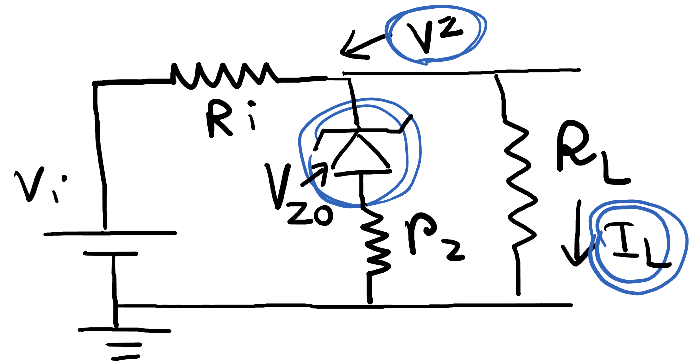
$r_z = 5\Omega$

$I_z(min) = 5mA$.

The voltage across the Zener diode is

10V at $I_z = 25mA$.

What is the value of R_i such that $I_z(min)$ can be maintained under all situations



$$V^z = V_{zo} + I_z r_z$$

$$\Rightarrow 10V = V_{zo} + 25mA \times 0.005k\Omega$$

$$\Rightarrow V_{zo} = 9.875V$$

Zener current is minimum when V_i is minimum and I_L is max

$$V_i^{min} = 20V - \frac{25}{100} \times 20V = 15V$$

$$I_L^{max} = 20mA$$

$$V_i^{min} = R_i \{ I_Z^{min} + I_L^{max} \} + \{ V_{Z0} + r_Z I_Z^{min} \}$$

$$15V = R_i \{ 5mA + 20mA \} + \{ 9.875 + 5\Omega \times 0.005A \}$$

$$\Rightarrow R_i \times 25mA = 15V - 9.875V - 0.025V = 5.1V$$

$$\Rightarrow R_i = \frac{5.1V}{25mA} = 0.204 K\Omega$$

class - 14

Parameters to judge the efficiency of a voltage regulator :-

Source regulation: $\frac{\Delta v_L}{\Delta v_S} \times 100\% \simeq \frac{r_z}{R_i} \times 100\%$

$r_z << R_i, R_L$

Load Regulation $= \frac{v_{L,\,noload} - v_{L,\,full\text{-}load}}{v_{full\text{-}load}} \times 100\%$

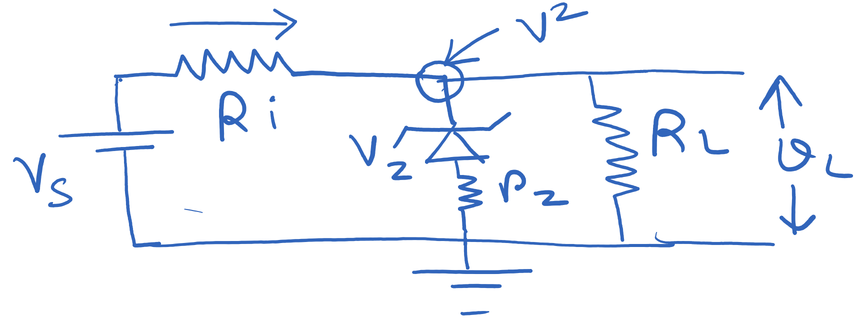
$v_{L,\,no\text{-}load}$ = output voltage when $I_L = 0$

rated ... at maximum ...

$v_{L,\,\text{full-load}}$ = output voltage at [illegible] load current

Assumption :-

$r_z << R_i$ and R_L



Source regulation.

$$\frac{\Delta v_L}{\Delta v_s} \times 100\%$$

$$\Delta I_{R_i} = \frac{\Delta V_s}{R_i} \quad (\because v_L \cong V_z)$$

$$\Delta I_z \cong \Delta I_{R_i} \cong \frac{\Delta V_s}{R_i}$$

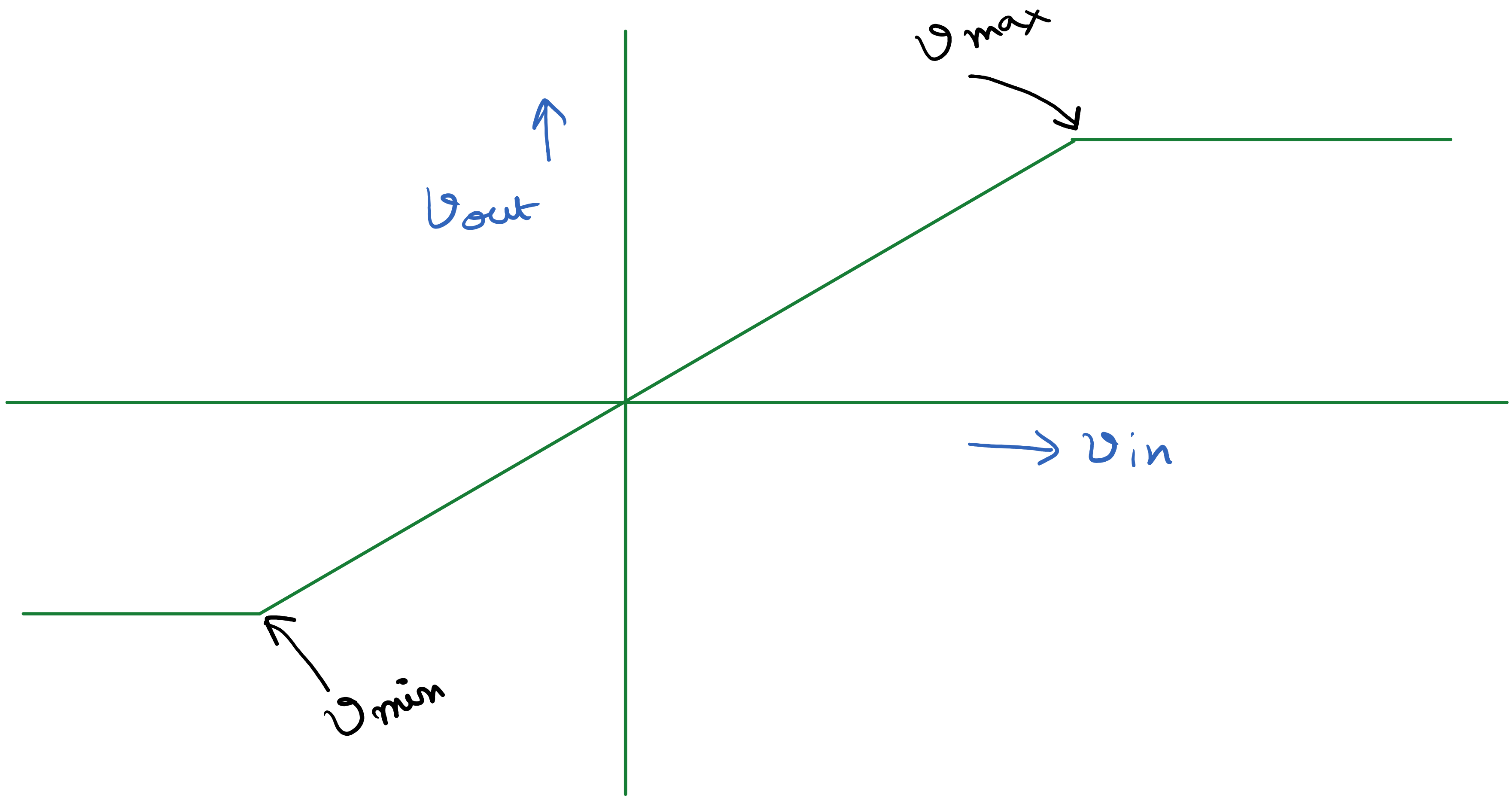
$$\Delta v_L \cong \Delta v^z \cong \Delta I_z \times r_z$$

$$\cong \frac{\Delta v_s}{R_i} \times r_z$$

$$\Rightarrow \Delta v_L / \Delta v_s \cong \frac{r_z}{R_i}$$

Clippers:

Clippers limit the output voltage upto a maximum possible value or a minimum possible value or both. They basically limit the output voltage to a maximum or minimum possible value or both. These are also known as voltage limiters.



v max
v out
v in
v min

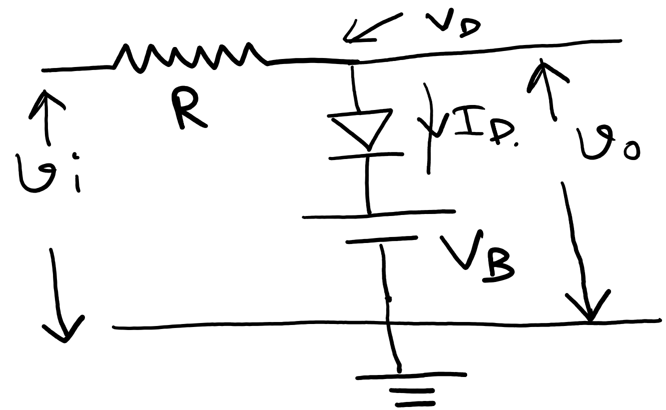
Clippers that limit the maximum positive voltage are called positive clippers.

Clippers that limit the minimum negative voltage are known as negative clippers.

And clippers that limit ~~both~~ the maximum positive voltage and the minimum negative voltage are called Dual clippers

① $V_{in} \geq V_B + V_\gamma \rightarrow$ Diode is conducting.

$V_{in} < V_B + V_\gamma \rightarrow$ Diode is non-conducting



② Diode is conducting $\rightarrow v_o \simeq V_B + V_\gamma$

Diode is not conducting $\rightarrow$ no current flows through the resistor $\rightarrow v_o = v_i$

Assume: Ideal diode

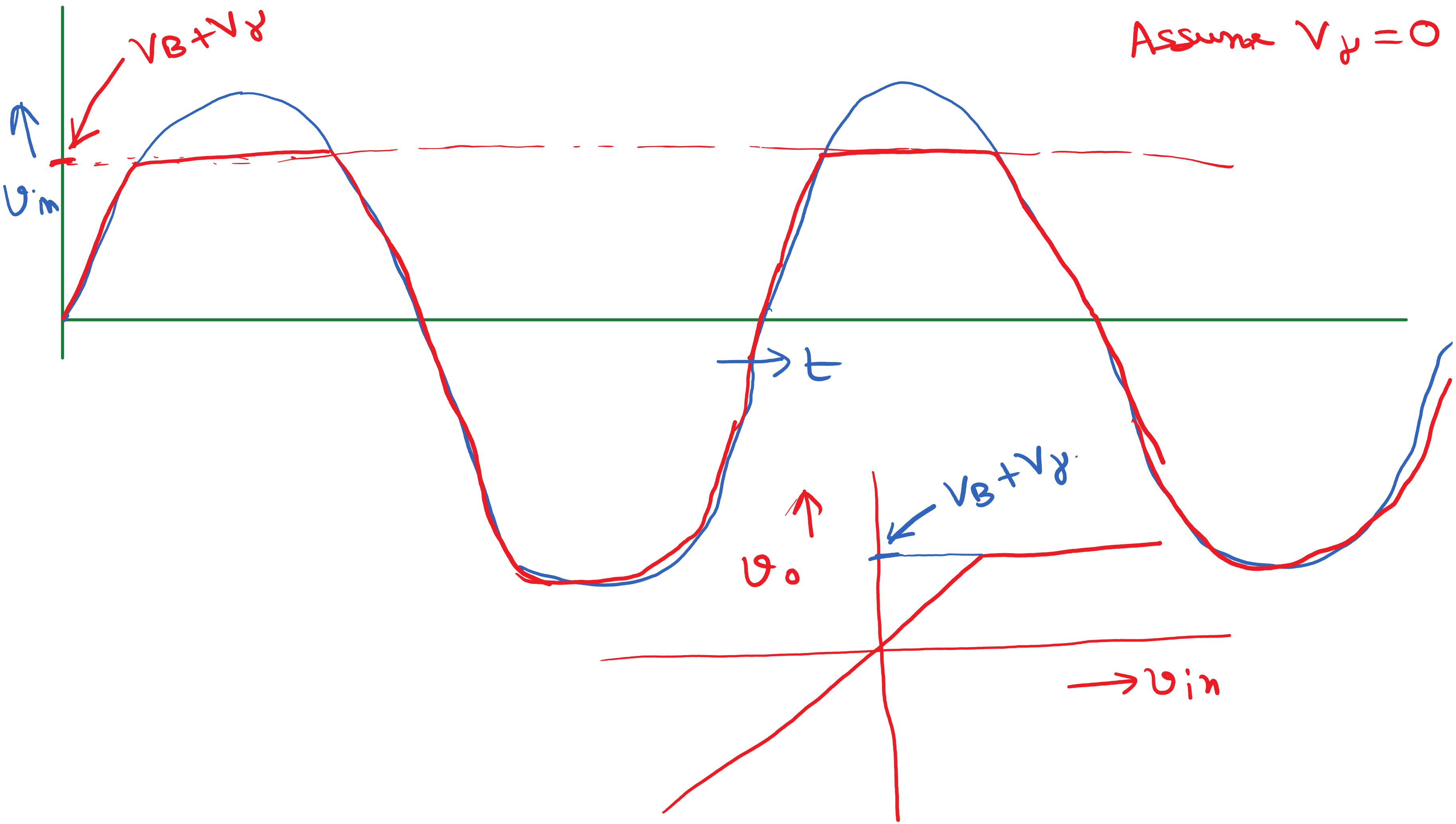
$V_\gamma = 0$

③ $V_{in} \geq V_B + V_\gamma$, $v_o \simeq V_B + V_\gamma$

$V_{in} < V_B + V_\gamma$, $v_o = v_{in}$

Positive clipper

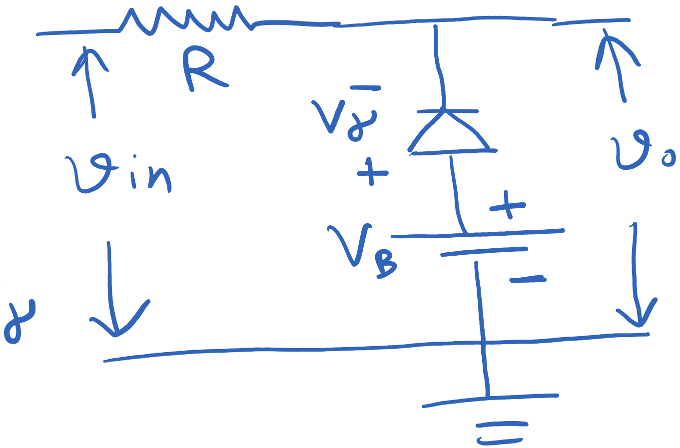
Assume $V_\gamma = 0$



Diode conducting $\rightarrow v_{in} \leq V_B - V_\gamma$

Diode is non-conducting.

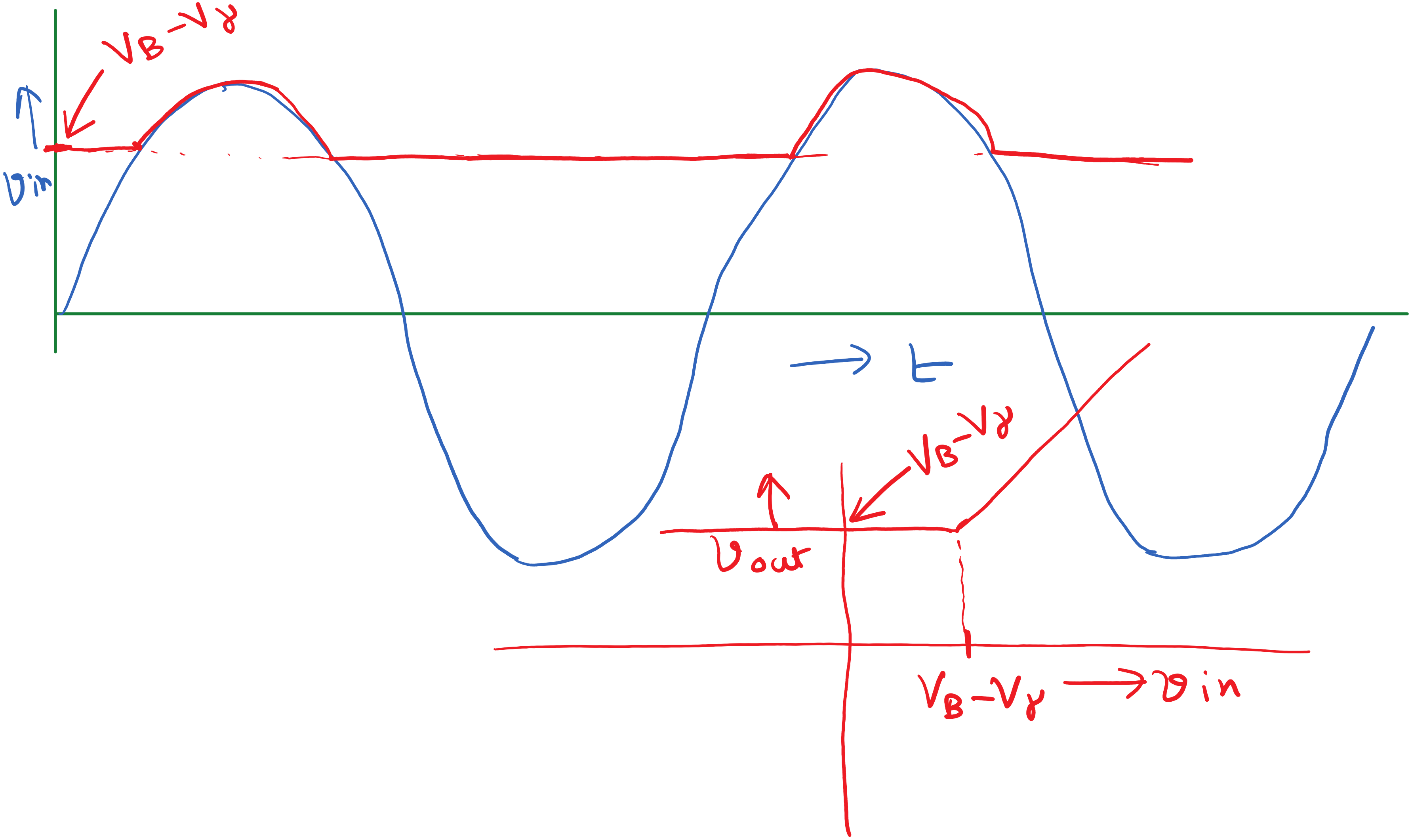
$v_{in} > V_B - V_\gamma$



Diode is conducting $\rightarrow v_o \simeq V_B - V_\gamma$

Diode is non-conducting

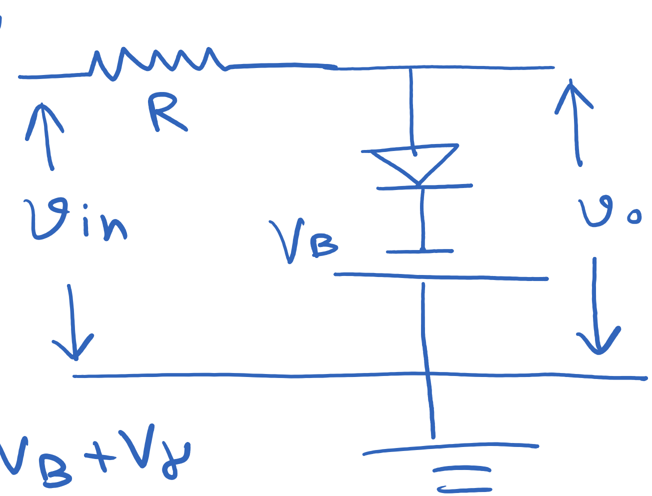
$\rightarrow \quad v_o = v_{in}$


$V_B - V_\gamma$
v_{in}
t
$V_B - V_\gamma$
v_{out}
$V_B - V_\gamma$
v_{in}

Diode is conducting $\rightarrow v_{in} \geq -V_B + V_\gamma$

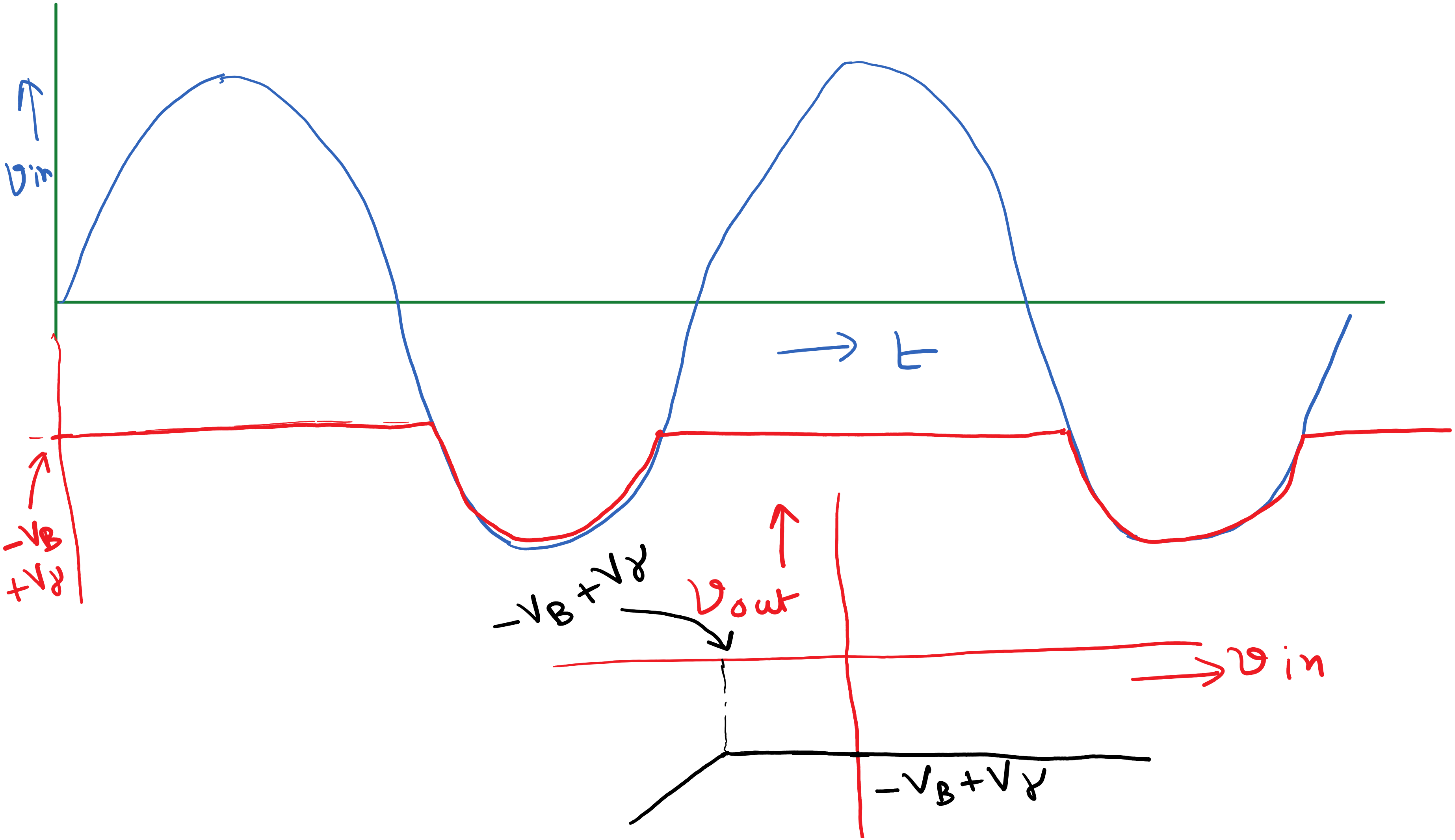
Diode is not conducting $\rightarrow$

$v_{in} < -V_B + V_\gamma$

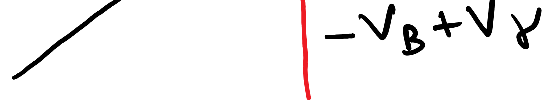


Diode is conducting $\rightarrow v_o \simeq -V_B + V_\gamma$

Diode is not conducting $v_o = v_{in}$



vin
→ t
−VB +Vγ
−VB+Vγ
vout
→ vin
−VB+Vγ

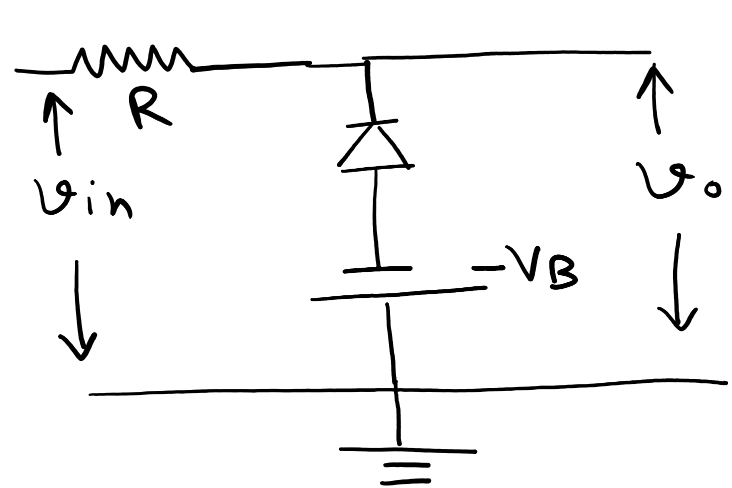

$-V_B+V_\gamma$

Diode is conducting $\rightarrow$

$v_i \leq -V_B - V_\gamma$

Diode is not conducting $\rightarrow$

$v_i > -V_B - V_\gamma$

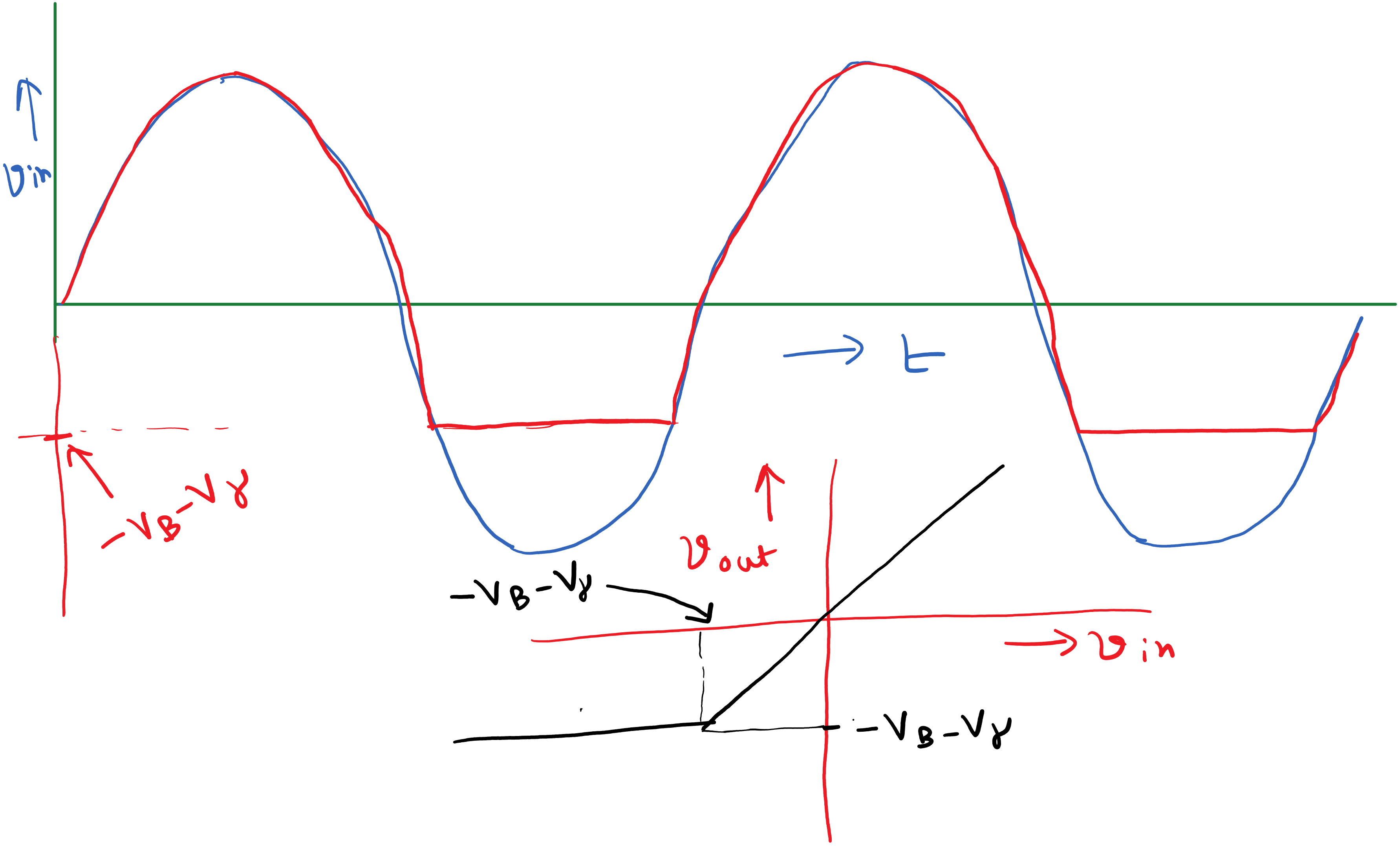


Diode is conducting

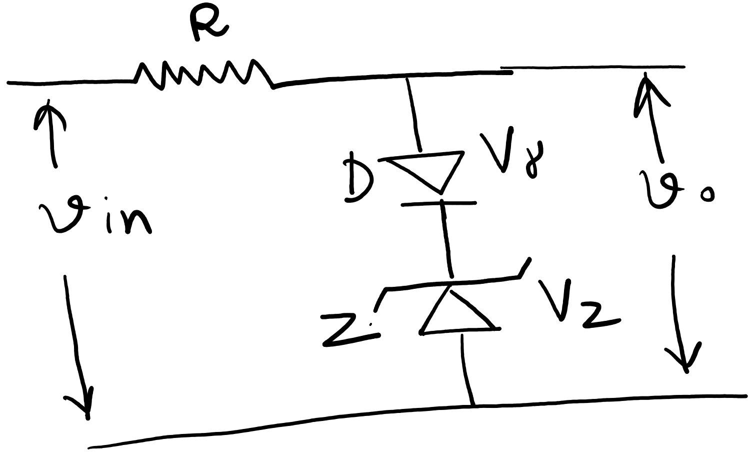
$v_o \simeq -V_B - V_\gamma$

Diode is non-conducting.

$v_o = v_{in}$



v_{in}
$-V_B - V_\gamma$
$\rightarrow t$
v_{out}
$-V_B - V_\gamma$
$\rightarrow v_{in}$
$-V_B - V_\gamma$



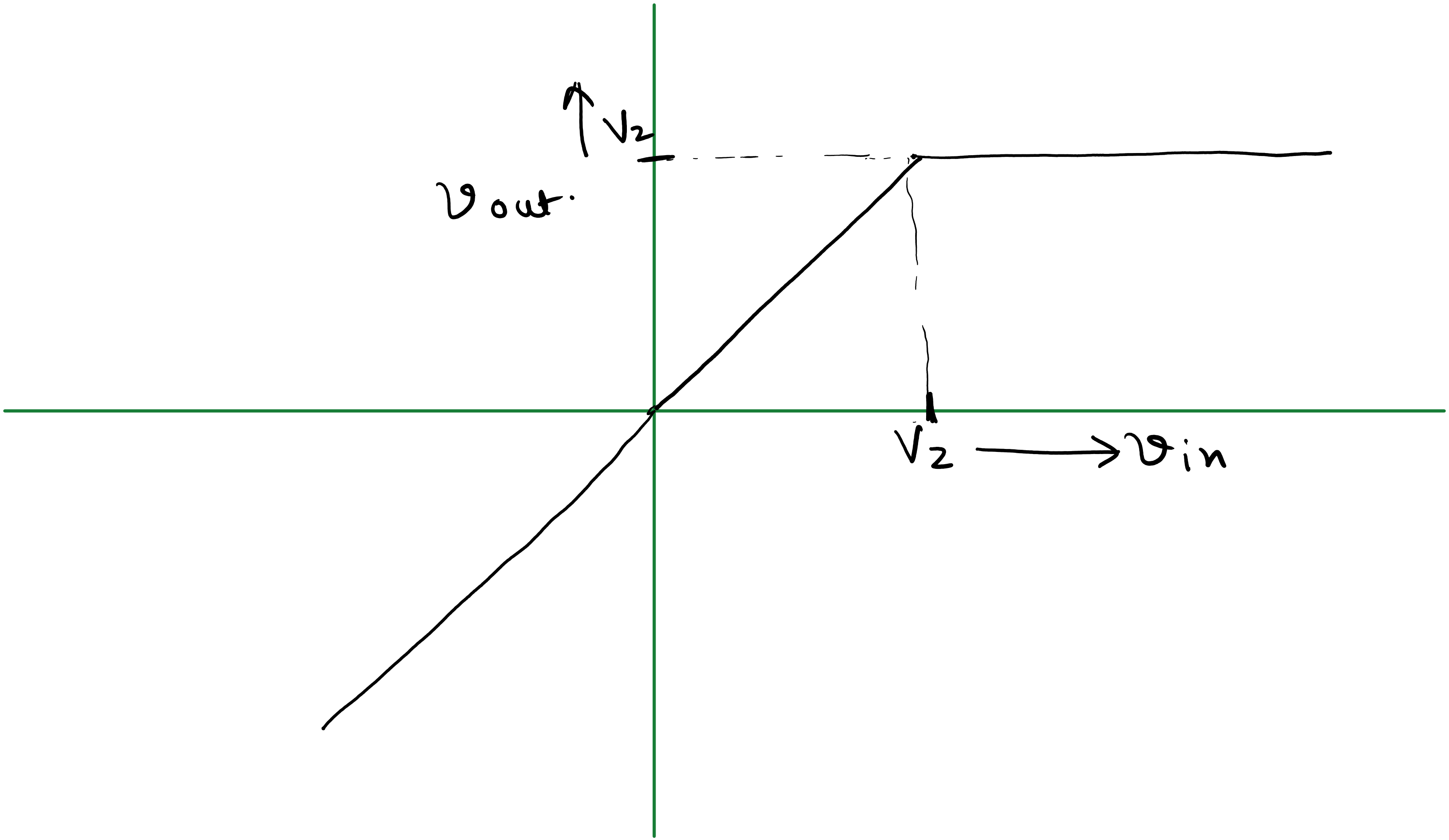
Assume that $V_\gamma = 0$
Assume that D never goes to the breakdown regime for the range of v_i

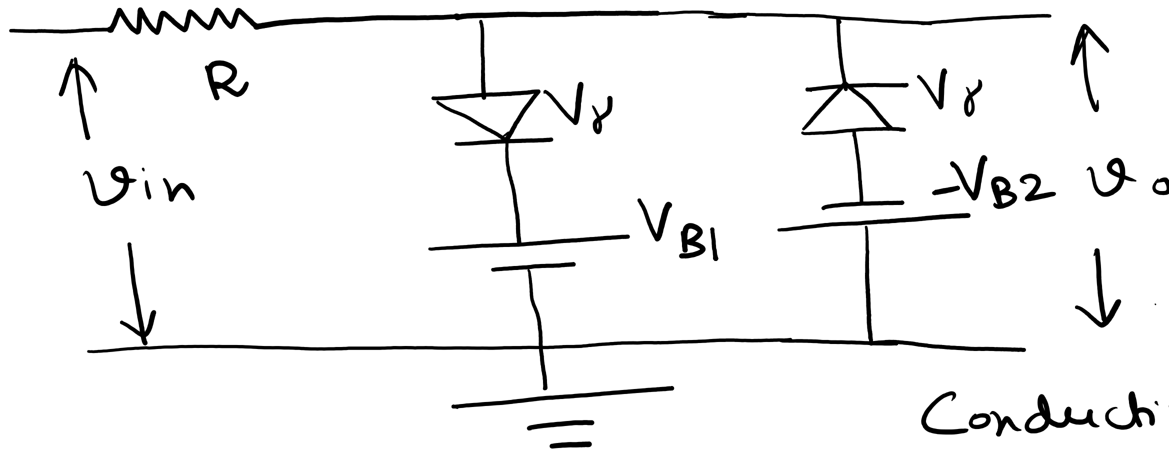
D is conducting when
$v_{in} \geq V_Z + V_\gamma = V_Z \; (\because V_\gamma = 0)$

D is not conducting.
$v_{in} < V_Z + V_\gamma = V_Z \; (\because V_\gamma = 0)$

D conducting
$\Rightarrow v_o \simeq V_Z + V_\gamma$
$= V_Z \; (\because V_\gamma = 0)$

D non-conducting.
$v_o = v_{in}$

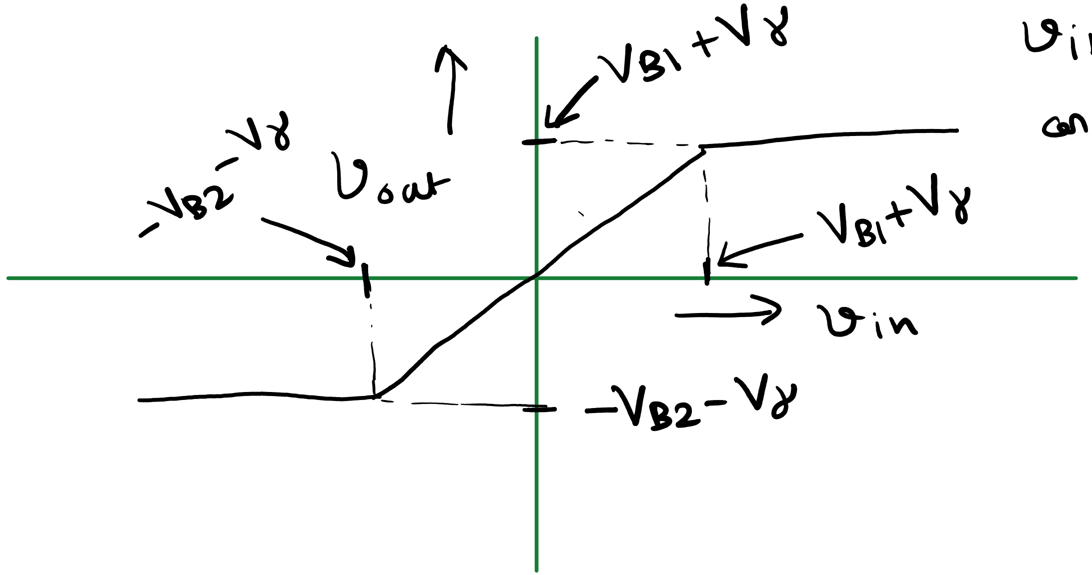

V2
vout.
V2
vin

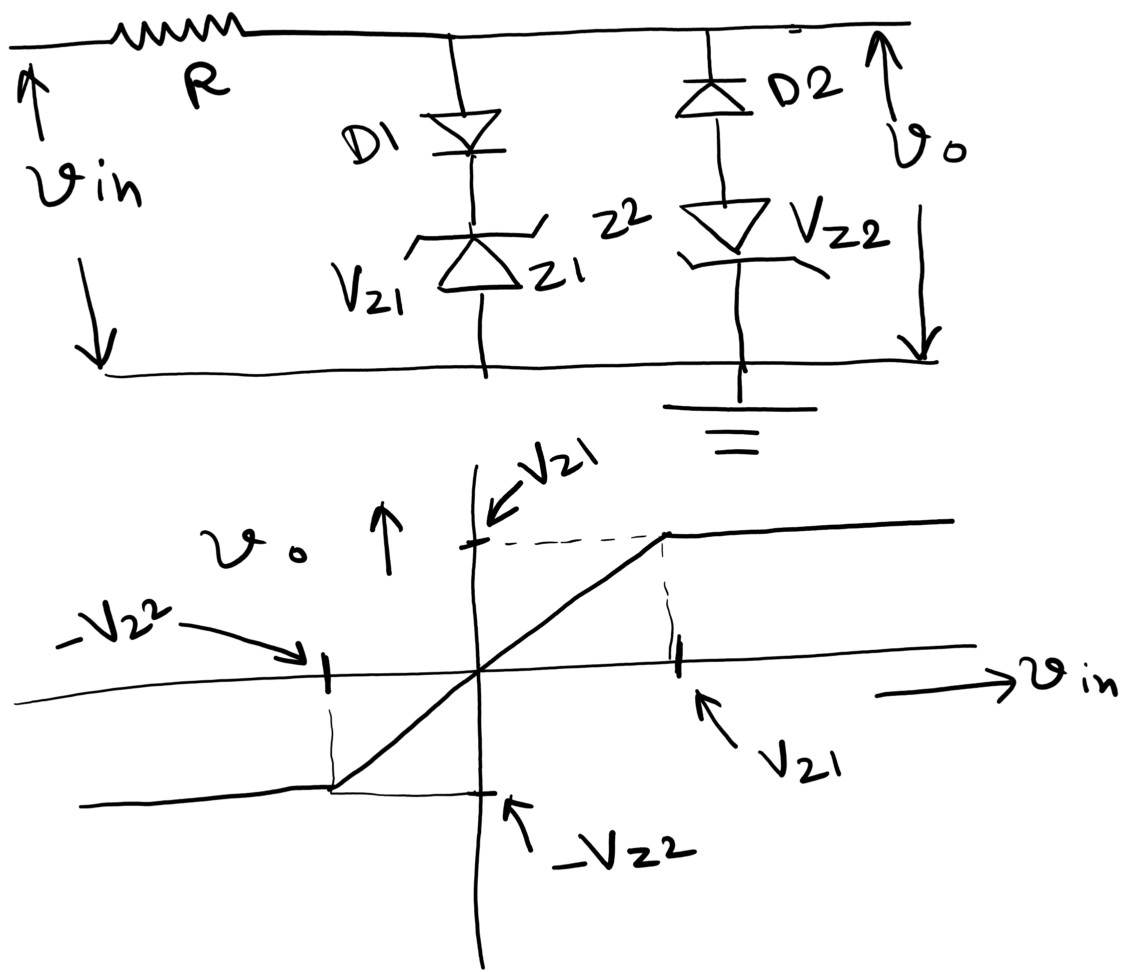


Conducting when

$v_{in} \geq V_{B1} + V_\gamma$

or $v_{in} \leq -V_{B2} - V_\gamma$




R
vin
D1
D2
vo
Z2
Vz2
Vz1
Z1
Vz1
vo
-Vz2
vin
Vz1
-Vz2