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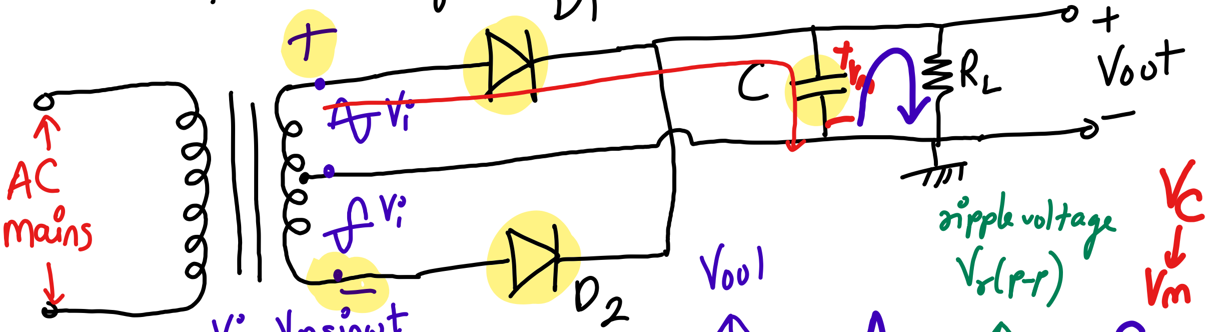
Capacitor filter (C filter):

FWCTR + filter



$V_c(0) = 0$

$V_i = V_m \sin\omega t$

a) +ve h.c → D_1 ON

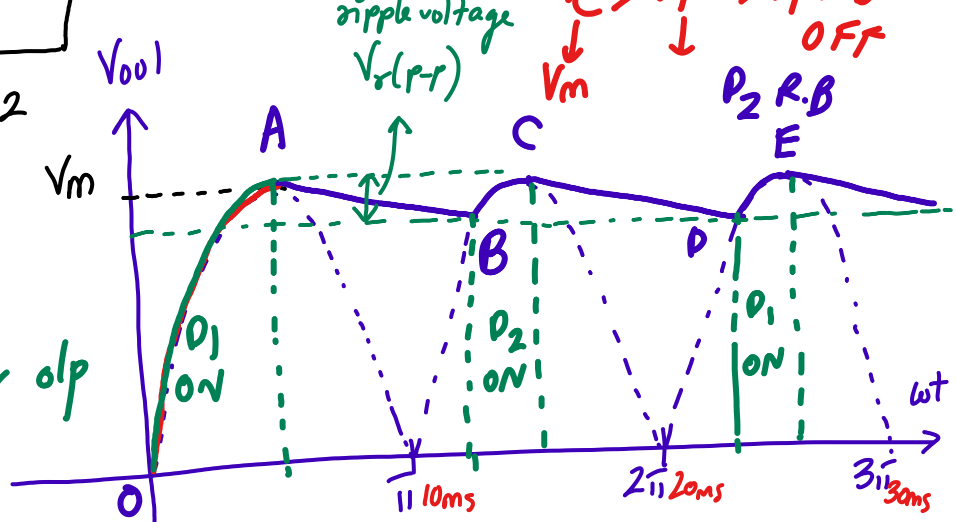
b) −ve h.c → D_2 ON

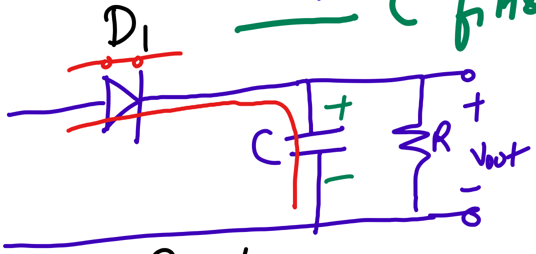
- - - - Rectifier o/p

——— C filter o/p

$V_c > V_i \rightarrow D_1$ RB OFF
↓ V_m ↓ V_i

D_2 R.B



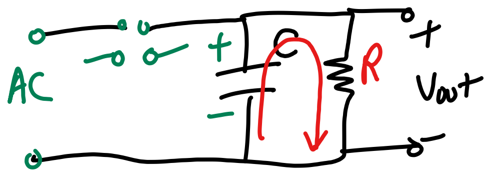


D ON

$C \; \cancel{\mu F}$ 100 $\quad R_{ON} - 1\Omega$ to 3Ω

$\tau_c \quad \tau_d$

$R_{ON}\, C$
↳ 1Ω to 3Ω



$\tau_c \simeq 100\mu \times 1 = 100\mu sec$

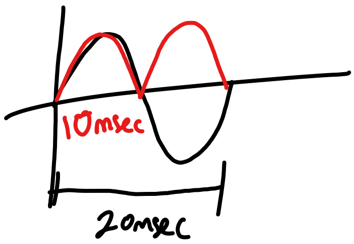
$\tau_c = 0.1\,msec$

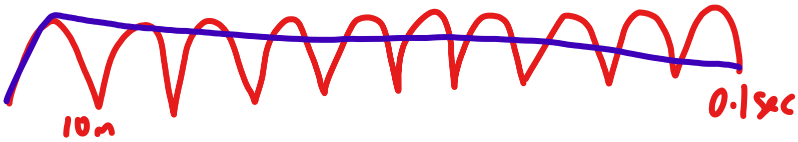
$R = 1K\Omega, \; C = 100\mu F$

$\tau_d = 1K \times 100\mu F = 0.1 sec$

50Hz

T = 20msec





Zener as voltage regulator:-

$V_S\uparrow \rightarrow I_S\uparrow \rightarrow I_Z\uparrow + I_L$

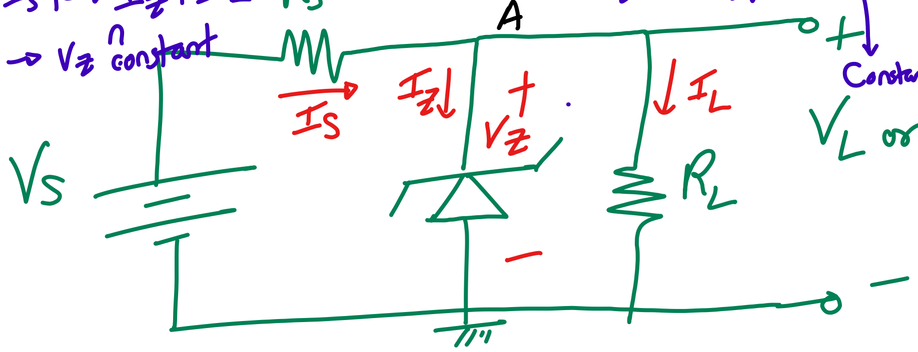
$I_Z\uparrow \rightarrow V_Z$ constant

R_L, V_S constant

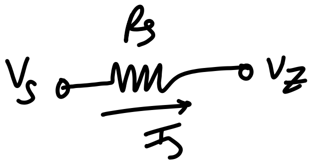
$R_L\uparrow \rightarrow I_L\downarrow \rightarrow I_S = I_Z\uparrow + I_L\downarrow$

I_S → Constant

I_Z → V_Z



Aim:- Keep V_L or V_{out} constant irrespective of line & load variations



① Vs changes

$$I_S = I_Z + I_L$$

② $V_S > V_Z$ → $R_S = \frac{V_S - V_Z}{I_S} = \frac{V_S - V_Z}{I_Z + I_L}$

↓

Z.D

$$I_Z + I_L = \frac{V_S - V_Z}{R_S}$$

$$\boxed{I_Z = \frac{V_S - V_Z}{R_S} - I_L}$$

$$\boxed{I_L = \frac{V_Z \text{ or } V_L}{R_L}}$$

Variables:- I_L, V_S : constant: V_Z, R_S

I_L → R_L → load variations

V_S → Line variations

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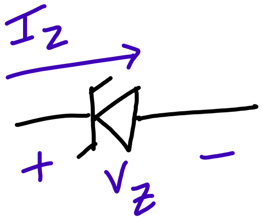
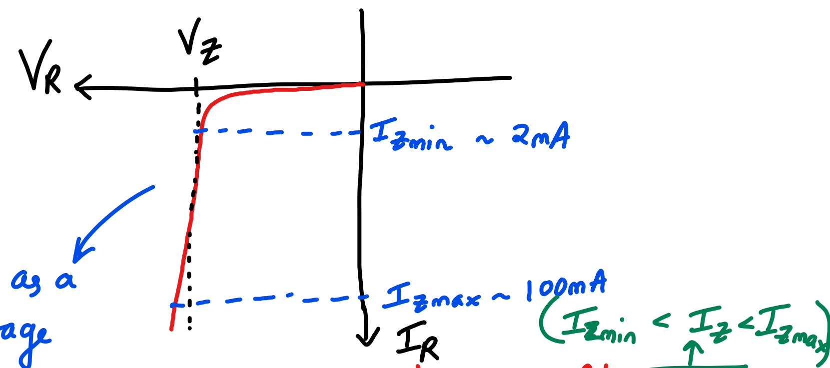
* Zener diode as voltage regulator (Application of zener diode)



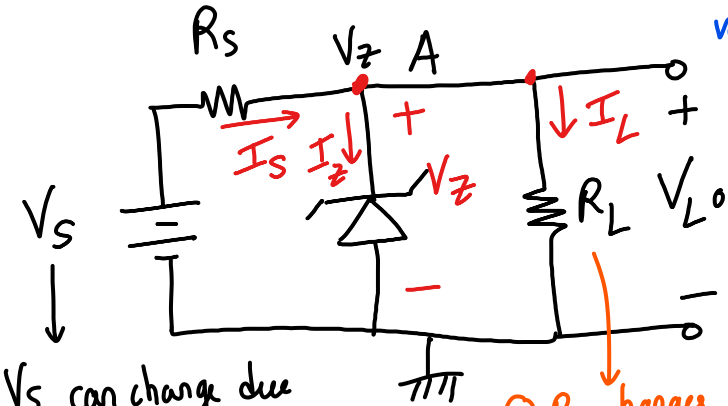
Zener diode symbol



use as a voltage voltage (V_Z is almost constant for a wide range of reverse current)

($I_{Zmin} < I_Z < I_{Zmax}$)

V_Z - breakdown voltage



① V_S can change due to line variations

② R_L changes

I_L - load current
V_L - load voltage
V_Z - Zener voltage
I_Z - Zener current

"Voltage Regulator"

Aim: Keep V_L or V_{out} constant irrespective of Line & load variation

→ $I_S = I_Z + I_L$ — ① (KCL at node A)

→ $R_S = \dfrac{V_S - V_Z}{I_S} = \dfrac{V_S - V_Z}{I_Z + I_L}$ — ②

; $I_Z + I_L = \dfrac{V_S - V_Z}{R_S}$

$$\boxed{I_Z = \frac{V_S - V_Z}{R_S} - I_L} \quad —③$$

$I_L = \dfrac{V_Z \text{ or } V_L}{R_L}$

→ For proper operation,

① Keep $V_S > V_Z$ → Zener operates in breakdown mode

② Keep $I_Z < I_{Zmax}$

variables : I_L, V_S , constant : V_Z, R_S

"R_L" → load variation

V_S → line variation

① Source/Line variation: (If V_S changes, R_L is constant)

a) $V_S\uparrow \rightarrow I_S\uparrow \rightarrow \uparrow I_S = \uparrow I_Z + \underbrace{I_L}_{\text{constant}} \rightarrow I_Z\uparrow \rightarrow V_Z$ remains constant ie V_L constant i.e o/p voltage is regulated

b) $V_S\downarrow \rightarrow I_S\downarrow \rightarrow \downarrow I_S = \downarrow I_Z + \underbrace{I_L}_{\text{constant}} \rightarrow I_Z\downarrow \rightarrow V_Z$ constant → V_L constant ie o/p voltage is regulated

Note: In exam, use full sentences

② **Load variation**: (If R_L changes, V_s constant)

V_s constant → I_s constant

a) If $R_L \uparrow \rightarrow I_L \downarrow \rightarrow I_s = I_z + I_L \downarrow \rightarrow I_z \uparrow \rightarrow V_z$ constant

I_s → constant; I_z → should ↑

ie V_L constant ie o/p is regulated

b) If $R_L \downarrow \rightarrow I_L \uparrow \rightarrow I_s = I_z + I_L \uparrow \rightarrow I_z \downarrow \rightarrow V_z$ constant

I_s → constant; I_z → should ↓

ie V_L constant ie o/p is regulated

③ This is how, zener diode works as a voltage regulator

—×—

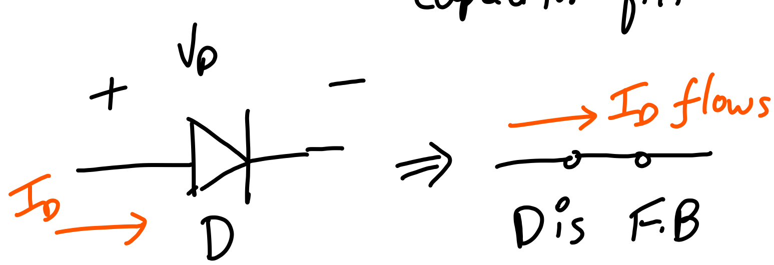
Module 2.1 : Rectifier (Application of diode)

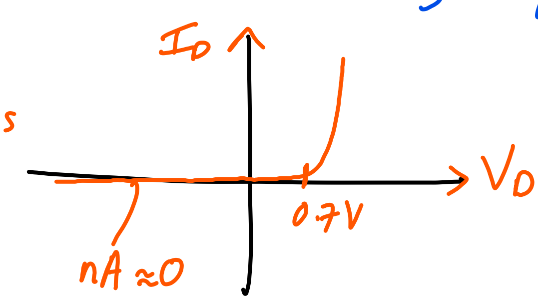
- Half wave rectifier
- Full-wave center tap rectifier
- Full-wave bridge rectifier

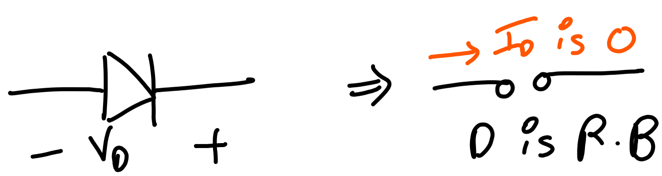
only with 'R' load

Parameters
① Ripple factor
② Rectification efficiency
③ TUF (Transformer utilization factor)

+ Filters (RC filter)
Capacitor filter







D: PN Junction diode

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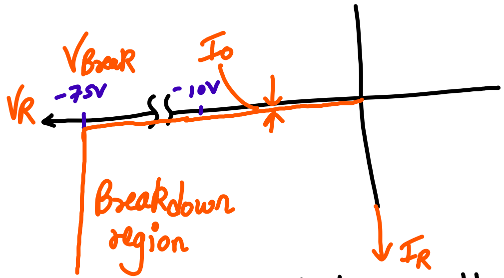
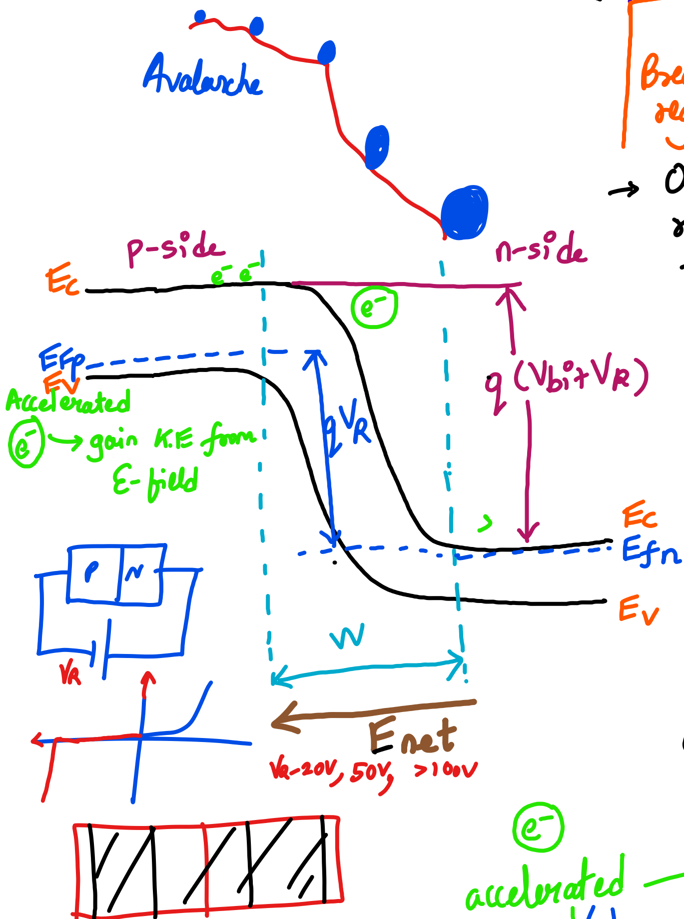
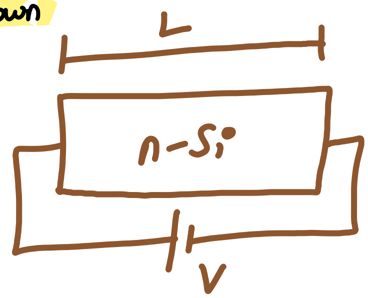
→ Avalanche breakdown:



→ Once breakdown voltage (~75 to 100V) is reached for diode → current flowing through ↑ses sharply due to Avalanche breakdown



V_R↑ W↑



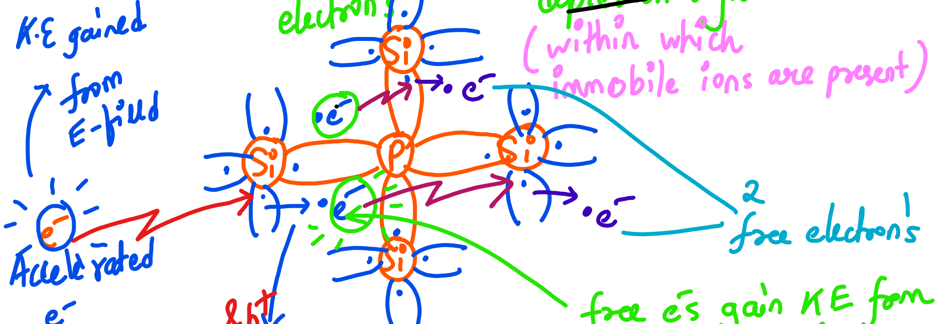
$E = \frac{V}{L}$ V/cm V/m

E↑ → V↑↑ ✓ or L↓↓

{ e^- move more quickly through Depletion region }

e^- accelerated electron's → traverse through depletion region (within which immobile ions are present) → e^- accelerated electrons collides with Si atom

K.E – Kinetic energy



a) accelerated e^- collides with Si atom & knocks off it's bound e's with enough K.E → b) Now, we have 2 free e's, these again K.E from E field & knocks Si atom's which gives rise to more free e's.

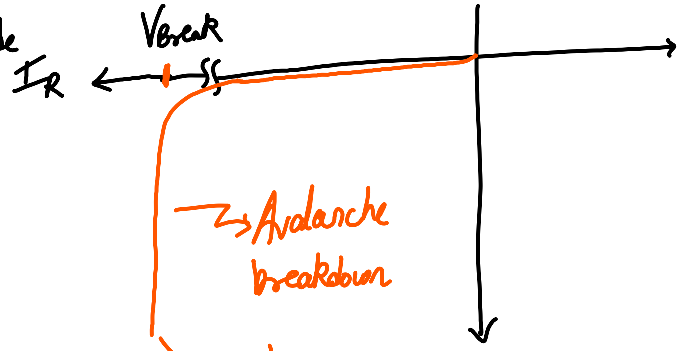
c) Due to these collision's, number of free carrier concentration increases rapidly i.e there is a sudden jump in reverse saturation current

d) This breakdown is caused by impact ionization { high energy charge carriers can knock-out bound e^- from Si atom }

e) This is Avalanche breakdown effect

f) Avalanche breakdown happen at much high breakdown voltage for PN Junction diode

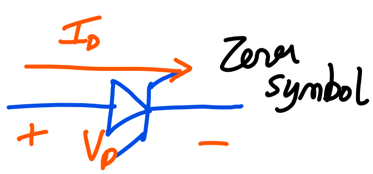
V_{Break} : Breakdown voltage

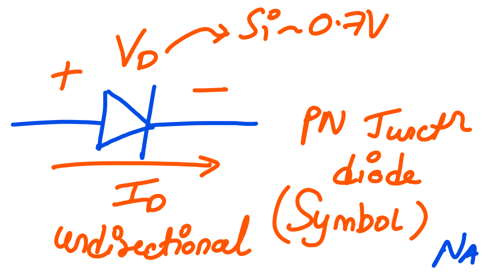


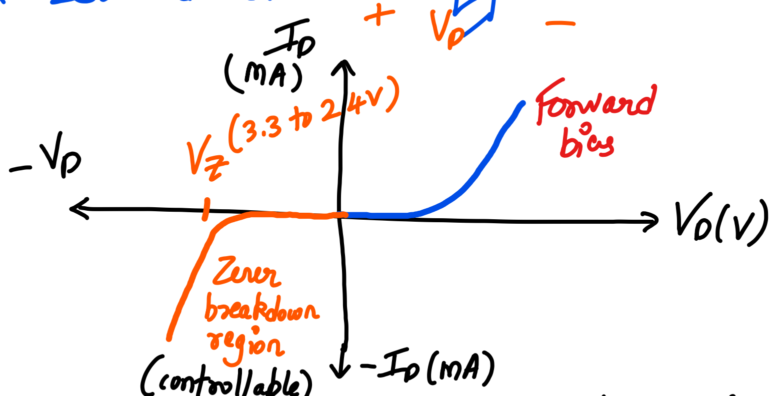
sharp ↑se in reverse current due to impact ionization

Construction of zener diode → ① Zener diode is similar to pn junction diode → except it is very heavily doped i.e N_A & N_D are about $10^{18}/cm^3$

* Zener diode:

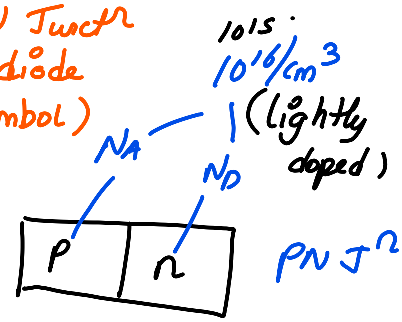


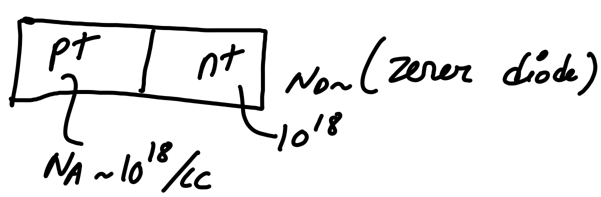




− Zener as a voltage regulator (Application)

Zener:
− heavily doped





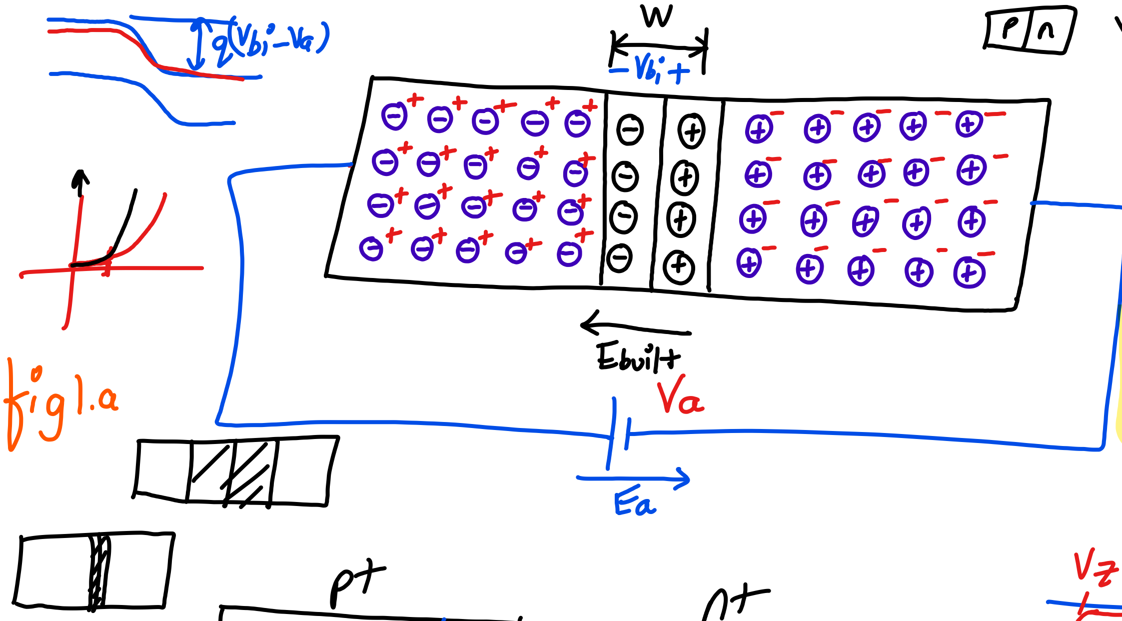


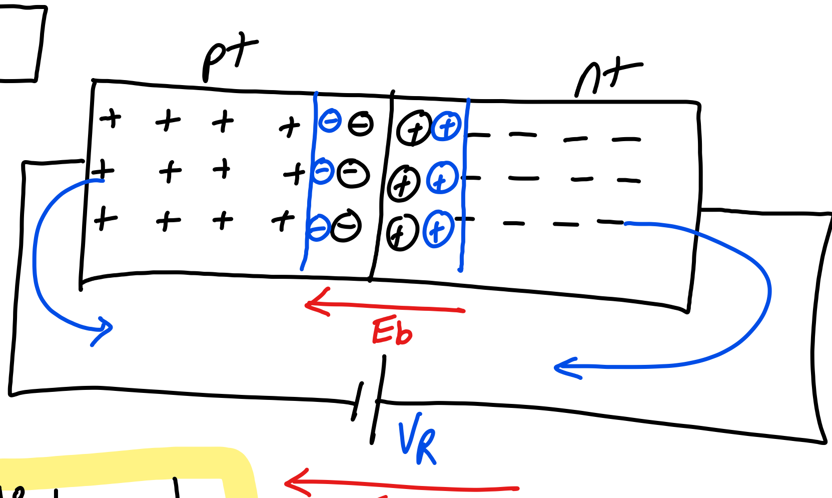
fig 1.a

W reduces as in comparison to pn J n

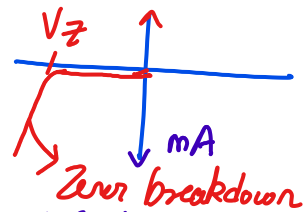
$$E = \frac{V}{W\downarrow}$$

$E\uparrow$

Zener under forward -bias

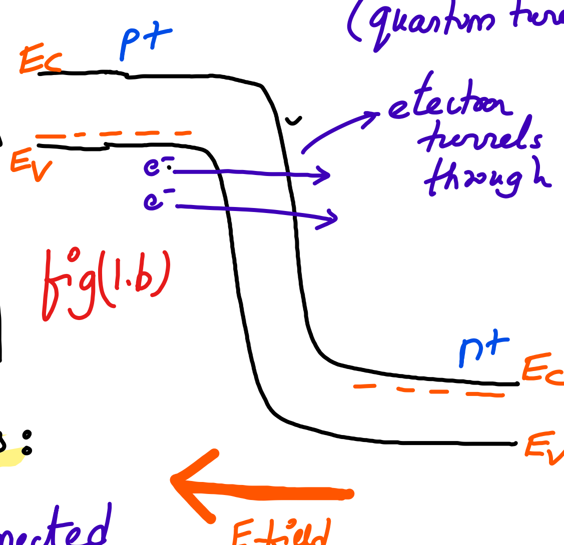


fig(1.c)



Zener breakdown
((ontrolled)

(quantum tunelling)

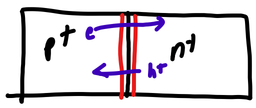


electron tunnels through

Zener diode under reverse bias

Ea → applied electric field

fig(1.b)



Events for zener diode under forward bias:

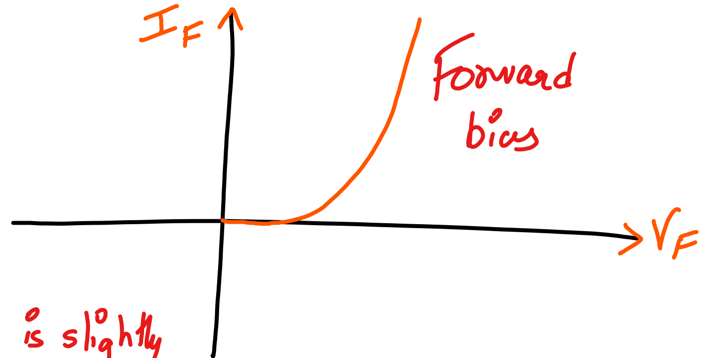
① In forward bias i.e when p^+ side is connected to +ve side of supply Va & n^+ side is connected to -ve side of supply voltage Va, the operation of zener diode is similar to that of pN Junction diode

② Only difference being → depletion region width 'W' is much narrower than p-N Junction diode → due to very heavy doping ie p^+–n^+ junction → Due to this built-in electric field in the depletion region is much stronger too

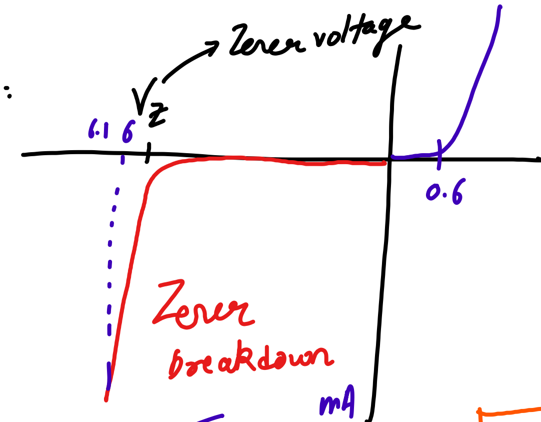
(Refer 1.a)

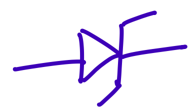
③ So, for zener diode, the forward I-V characteristics are exactly similar to pn Junction diode ie after barrier potential, current I_F ↑ses exponentially with voltage V_F

is slightly less than pN Junction



Event for Zener diode under Reverse-bias:





① In reverse bias, due to applied voltage V_R (refer fig 1.c), E-field is directed as shown in the same direction of built-in electric field

$\longleftarrow E_b$

$\longleftarrow E_a$

$\longleftarrow E_{net}$

$E \propto \frac{V}{L}$

$L \downarrow$

$E \uparrow$

② Thus, the net electric field in reverse bias in zener diode is extremely powerful (due to narrow w)

③ There is absolutely no possibility of electron & hole diffusion since barrier is very high (refer fig 1.d)

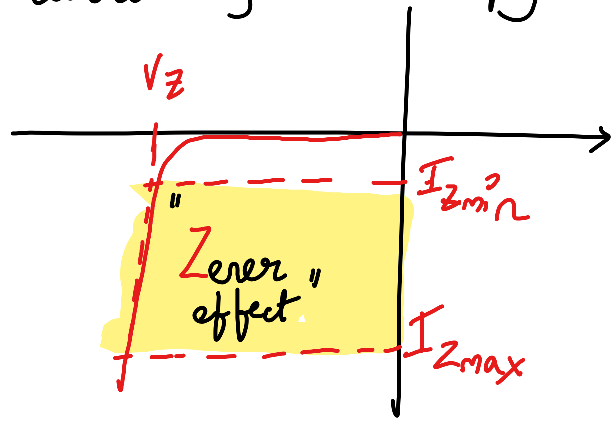
④ So, minority carriers (electron's in p^+ side near the junction & holes in n^+ side near the junction) come under the influence of very powerful E-field → E-field is so powerful that ~~it~~ knocks out bound e^-s of many Si atom at once (since free carrier gain tremendous K.E from electric field & they collide with nearby Si atom in depletion region)

⑤ The result is that e^- funnels through the narrow depletion region & reach other side → This process is called as "Zener breakdown" or "Zener effect" (Quantum tunneling)

⑥ Good news is that at a zener voltage V_Z when zener breakdown takes over → it reversible i.e we can use zener diode as many time we want to

⑦ Wide range of V_Z are available right from 2.2V to 18V commercially

⑧ Due to zener effect, reverse current flows sharply but within safe limits ($I_Z < I_{Zmax}$)



⑨ Since the voltage V_Z is almost constant for wide range of zener current 'I_Z' it main application is "voltage regulation"

* Avalanche breakdown	Zener breakdown
1. It occurs in lightly doped diodes	1. It occurs in heavily doped diodes
2. It occurs due l impact ionization process	2. It occurs due to strong electric field (quantum tunneling)
3. It's effect is s at higher breakdown vol-ages	3. It's effect is seen at low breakdown voltages
4. ith increase in temperature, breakdown voltage ↑ses	4. With increase in temperal, breakdown voltage redu