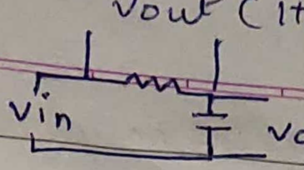
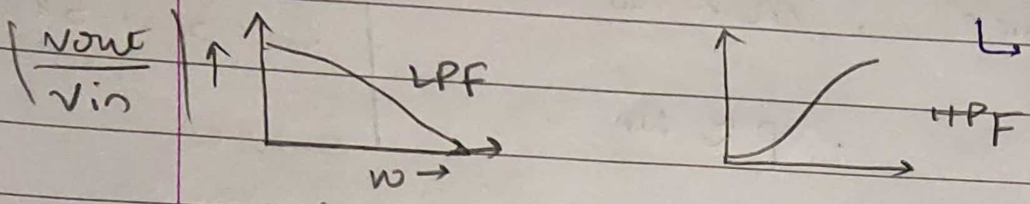
$1.602 \times 10^{-19} = q$

Low pass filter



$$A = \left|\frac{V_{out}}{V_{in}}\right| = \frac{1}{\sqrt{R^2\omega^2C^2+1}}, \quad V_{out}(t) \approx \frac{1}{RC}\int v_{in}(t$$

↳ when $\omega RC >> 1$



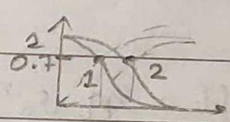
High pass filter

$$A = \left|\frac{V_{out}}{V_{in}}\right| = \frac{R\omega C}{\sqrt{1+R^2\omega^2C^2}}, \quad V_{out}(t) \approx RC\frac{d}{dt}(V_{in}(t)$$

↳ when $\omega RC <<$

~~Citation~~ Cutoff frequency

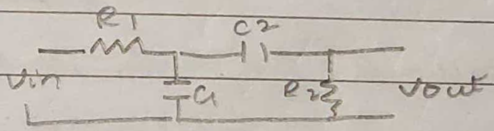
At $\omega = \omega_c$

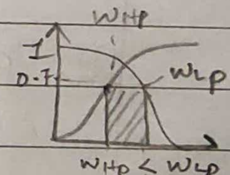


$\omega_{c1} < \omega_{c2}$
$R_1C_1 > R_2C_2$

$A = 1/\sqrt{2} \approx 0.7 \implies \omega_c = 1/RC, \; f_c = \frac{1}{2\pi RC}$

Band Pass Filter

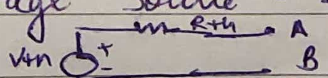




$W_{HP} < W_{LP}$
req band

Thevenin's theorem

- V_{th} = Open circuit voltage about req. pts
- R_{th} = voltage source → short circuit, current → open circuit



Semiconductors
- Valence Band (Full)
- Conduction Band (Empty)

⊢ OK ⊢ Discrete Energy states

VB → shifting bonds (holes) | CB → free bonds (electrons)

1 broken bond = 2 holes

|| Band gap ~1ev at Room temp.

- No of holes in VB = No of e^- in CB

$p_i = n_i$

↳ Dependent on ma...

- Non doped (Intrinsic)
- Doped (Extrinsic)
  - ↳ n-type (Group V) → e^- added
  - ↳ p-type (Group III) → holes added

$N_D >> n_i$ → conc. of intrinsic e^- , $n \approx N_D$ → total e^- conc.

↓ conc. of doped donor

$N_A >> p_i$, $p \approx N_A$

↓ conc. of doped Acceptor

$$\boxed{n \times p = n_i p_i}$$

For Si at 300K

$n_i = p_i = 1.5 \times 10^{10} / cm^3$

Note

If $N_D > N_A$,

$n = N_D - N_A$ → n-type

mixed-type (compensation doping)

Drift current :- (p-n junction)

Mobility of e^-/holes :- $v_d^n = -\mu_n \times E$, $v_d^p = \mu_p \times E$

velocity ↓ opp direction, field

$J_{drift} = n v_d^n (-q) + p v_d^p (+q) = I_{drift} / Area$

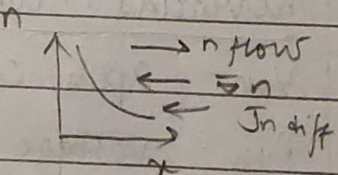
$J_{drift} = (\underbrace{qn\mu_n + pq\mu_p}_{\sigma \text{ (conductivity)}}) E = \sigma E$

Force = QE, $a = QE/m^*$, vel → const, $a \to 0$

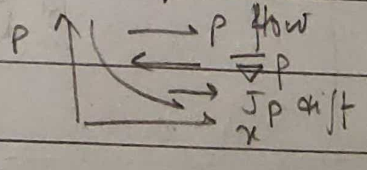
Diffusion current :-

$\overline{J^n}_{diff} = q D_n \overline{\nabla n}$

↓ Diff. coeff of e^- , → spacial gradient



$\overline{J^p}_{diff} = q D_p (-\overline{\nabla p})$



$J_{diff} = J^n_{diff} + J^p_{diff}$

Diff coeff ∝ speed of diff. of e^-/holes respectively

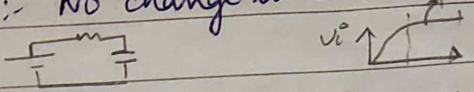
Assume:- $n = Ae^{-\alpha x} \Rightarrow \overline{\nabla} n = \frac{\partial}{\partial x} n\hat{i} + \frac{\partial}{\partial y} n\hat{j} + \frac{\partial}{\partial z} n\hat{k} = -A\alpha e^{-\alpha x} \hat{i}$

$|I_{diff}| = |I_{drift}| \Rightarrow$ total $I = 0$

- Equilibrium :- • No external source of excitation except temp
  • No current/voltage source applied, No flow of I

Law of Mass Action :- Only valid in Equilibrium

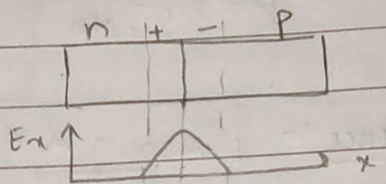
- Steady state :- No change in device measurables with time



P-n junction

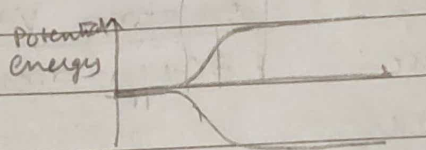
$$\nabla \cdot E = \frac{dE_x}{dx} = \frac{\rho}{\varepsilon}$$

Electricfield; $\rho \rightarrow$ accumulated chargedensity; $\varepsilon \rightarrow$ Permitivity



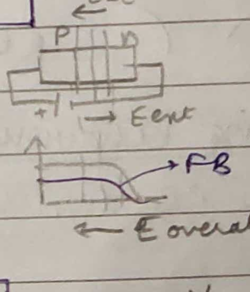
$\rho > 0$, $E_x \uparrow$

$\rho < 0$, $E_x \downarrow$



$$\boxed{V_{bi} = V_{builtin} = \frac{KT}{q} \ln \frac{N_A N_D}{n_i^2}}$$

($\frac{KT}{q} = V_T$)



← diff e^-
← drift holes
→ drift e^-
→ diff holes

Forward Bias

- Idiffusion ↑
- Idrift doesn't change

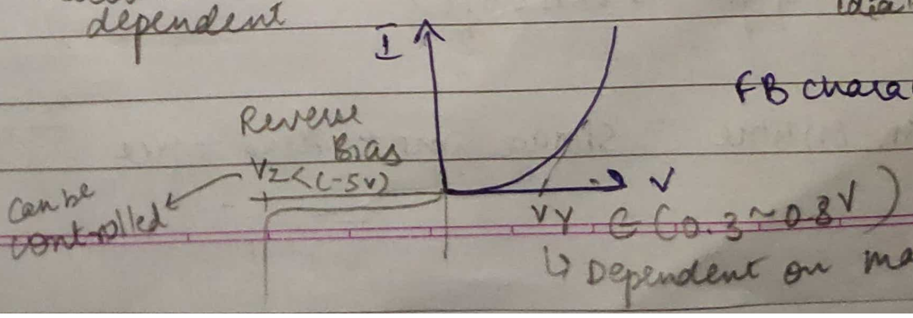
$I =$ ~~dar~~ $I_{drift} + I_{diff}$

$$\boxed{I = I_s \left(e^{\left(\frac{V}{\eta V_T}\right)} - 1 \right)}$$

I_s: material dependent; $e^{(\ldots)}$: diffusion; -1: drift

$V_T = \frac{KT}{q} \cong 25.9$ mev at $T = 300K$

η = identity factor (1 to 2), ideal p-n jn $= 1$

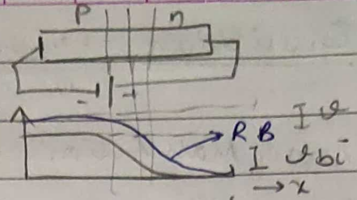


FB characteristics

$V_\gamma \in (0.3 \sim 0.8V)$

↳ Dependent on material

Reverse Bias



$$I = I_s\left(e^{\cancel{V/V_T}} - 1\right) \quad (\to 0)$$

$\cong I_s$ (reverse saturation current)

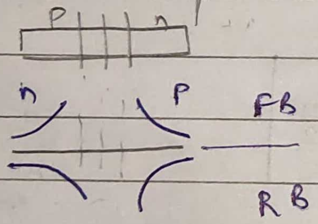
Breakdown :- High E breaks bonds to release e^--hole pair

Minority carriers :-

n-type SC	p-type semi conductor
$p = n_i^2/N_D$	$n = n_i^2/N_A$

Depletion Capacitance :- $\boxed{C_{dep} = dQ_{dep}/dV}$
(in depletion region) on apply V_{AC} || due to oscillation of depletion regⁿ

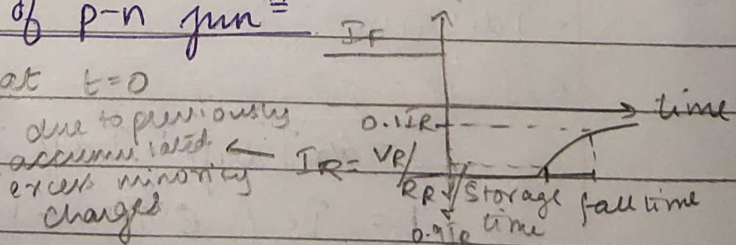
Diffusion Capacitance :- $\boxed{C_{diff} = dQ_{diff}/dV}$
(outside depletion region) due to oscillation of minority charges on application of V_{AC}
(minority charge conc. on either side)



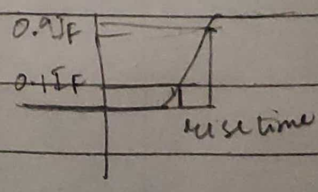
equilibrium

Switching behaviour of p-n junⁿ

FB to RB switch at t=0



Turn-off time = storage time + Fall time
(time req. for FB to RB shift)



Turn-on time = storage time + rise time

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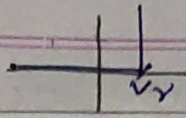
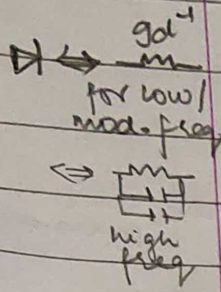
Piecewise linear model



$V < V_\gamma$, $I = 0$
$V \geq V_\gamma$, $dI/dV \to \infty$

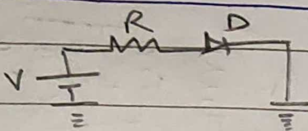
(when current flows through the diode, $V_D = V_\gamma$)

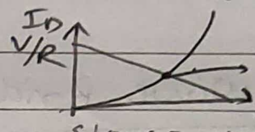


Small signal AC model

$gd = I_{DC}/V_T$ — V_T = 25.9 mV at T = 300K | equivalent resistance $= gd^{-1}$ for AC voltage

Load line Analysis

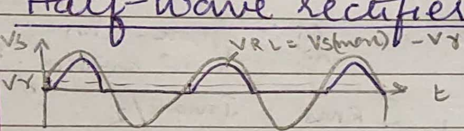


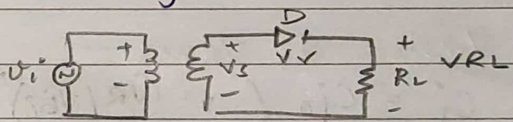


slope $= -1/R$

Transformer : $\dfrac{V_{in}\text{ (primary)}}{V_{out}\text{ (secondary)}} = \dfrac{N_1}{N_2}$ → N_1 primary turns, N_2 → secondary turns

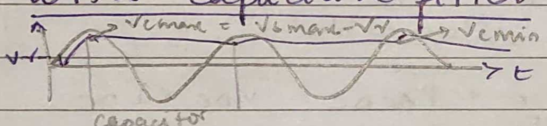
Half-wave rectifier :

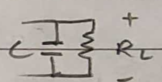




when $V_S > V_\gamma$, $V_{RL} = V_S - V_\gamma$
else $V_{RL} = 0$

With capacitive filter





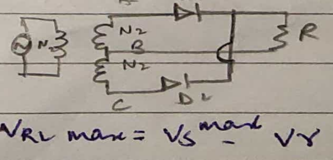
$V_D = V_S - V_C^{max}$
$\leq V_S^{max} - V_C^{max}$
$V_D \leq V_\gamma$ (only when V_S^{max})

$\boxed{PIV} = V_S^{max}$ (without capacitor)
$= |(-2V_S^{max} + V_\gamma)|$ (with capacitor) } always +ve

★ $V_{ripple} = V_{Cmax} - V_{Cmin} = T_P/CR_L$

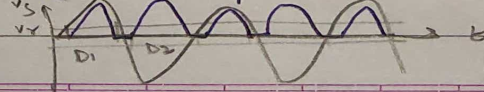
T_P :- Time period of V_S
R_L :- R Load
C :- Capacitance

Full wave rectifier:
(center tapped)



+ve cycle
$V_A > V_B > V_C$
−ve cycle
$V_A < V_B < V_C$

$V_{RL}\ max = V_S^{max} - V_\gamma$



$PIV = |-V_\gamma + 2V_{Smax}|$

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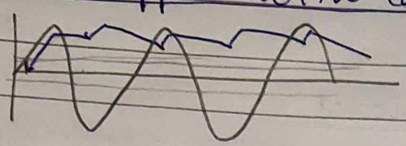
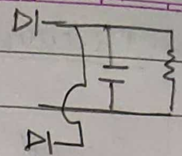
Centre tapped with capacitor

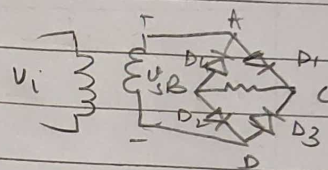




$V_{ripple} = V_c^{max} - V_c^{min} = (T_P/2)\, V_c^{max} / R_L C$

↳ Time period of capacitor $= \frac{1}{2}$ Vs time period

Full Wave Bridge rectifier



$$\boxed{PIV = V_s^{max} - V_\gamma}$$

$R_{L\,max} = V_s^{max} - 2V_\gamma$

- $V_{max} = \sqrt{2}\, V_{RMS}$
- $C_j = C_{jo}\left(1 + (V_R/V_{bi})\right)^{-1/2}$ when RB voltage is applied
  - C_j :- junction capacitance
  - C_{jo} :- zero biased junction cap.
- For HWR, $I_{DC} = I_{max}/\pi$ (Average value), $I_{RMS} = I_{max}/2$

  Output $V_{DC} = I_{DC} \times R_L$
- $v_{ac(rms)}/v_{dc}$ Ripple factor : I_{ac} (output) $/ I_{DC} = \dfrac{\sqrt{I^2_{RMS} - I^2_{dc}}}{I_{dc}}$ → lower ripple factor → good power supply
- Power (ac) = P_{RMS} ; $P_{DC} = V_{DC} \times I_{DC}$
- efficiency $= \eta = \dfrac{P_{dc} \text{ (output)}}{P_{AC} \text{ (Input)}} \times 100 =$
- $n_i = 1.5 \times 10^{10}/cm^3 = B T^{3/2} \left(e^{-\frac{E_g}{2kT}}\right)$ ↳ at $T = 300\,k$
- minority carrier hole conc. $= p_{n_0}\, e^{\left(\frac{V_{applied}}{kV_T}\right)}$ ↳ Equilibrium conc.