EE101: electrical & electronic circuits: week-1:

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*pioneers ✓

maxwell laws:- no decision making. large scale. mechanical. - resistors - capacitors

Small scale. electron flow explanations. - diodes - BJTs. has decision making.

$$\vec{\nabla}\cdot\vec{E} = \frac{\rho_v}{\epsilon_0}$$ } Gauss law for electricity

$$\vec{\nabla}\cdot\vec{B} = 0$$ } Gauss law for magnetism

$$\vec{\nabla}\times\vec{E} = -\frac{\partial \vec{B}}{\partial t}$$ } Lens law | Faradays law.

$$\vec{\nabla}\times\vec{B} = \mu_0\left(\underbrace{I}_{\text{Amperes loop law}}+\epsilon_0\frac{\partial \vec{E}}{\partial t}\right)$$ } maxwell corrected amperes law.

→ linkage b/w two via relay (or) via transistors... most imp discovery in last 100 yrs...

↓ electronic part; controls electrical part.

→ Magnetic properties:-

1) dia:- response opposes the appilied $\vec{B}$.

$\therefore \mu_r < 1$

Eg: Cu; $\mu_r = 0.9999980$

2) para:- response aligns with applied $\vec{B}$

$\therefore \mu_r \geq 1$

Eg: air; $\mu_r = 1.0000004$.

3) ferro: $\mu_r >> 1$. Spontaneous magnetisation persists.

↑↑↑↑↑↑

Iron.

4) Antiferro: net is zero. (due to moment cancellation).

↑↓↑↑↓↓

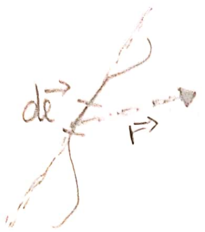
5) Ferri: net is non-zero, but not as strong as Ferro.

↑↓↑↑↑↓

* lorentz force: $\boxed{\vec{F} = q(\vec{E} + \vec{U}\times\vec{B})}$

(same q/m ; can't seperate via mass spectrosocopy)

Biot-savart law:



$$\boxed{\vec{B} = \frac{\mu_0}{4\pi}\, i\, \frac{\vec{dl} \times \vec{r}}{|\vec{r}|^3}}$$ → for a charge q, with velocity V;

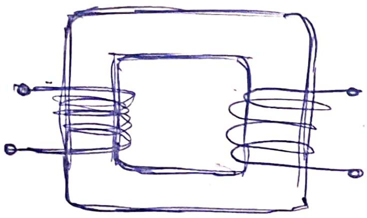
$$\boxed{\vec{B} = \frac{\mu_0}{4\pi} \cdot q \cdot \frac{\vec{V} \times \vec{r}}{|\vec{r}|^3}}$$

transformed designs:

linkage vs leakage.

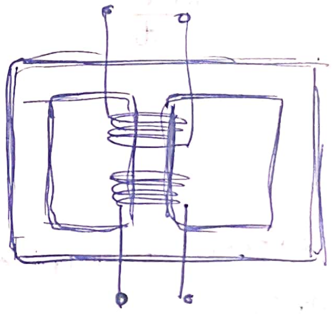
mutual induction

core type:



leakage↓

shell type.



linkage↑

* AC-AC : transformers

AC-DC: rectifiers (via p-n diodes)

-half wafe rectifier

- full wave rectifier.

large DC outputs - commutators.

DC-DC: DC DC converters

both up & down is possible.

DC-AC: inverters

1) motor → current to work.

2) Generator → work to current (AC or DC)

3) inverter → work to current (AC).

↑ current (DC)

- metals: unipolar transport ($\bar{e}$)
- semiconductor: bipolar transport ($\bar{e}$, holes). } band gap theory... is the valid one... — read it.

electronic devices

BJT (bipolar)

MOSFET (unipolar*) → metal oxide semiconductor field effect transistor.

* drift mobility:

* $\boxed{V(n) = -\mu(n) * E}$

mobility $\boxed{cm^2/V\text{-sec.}}$
- dopaine conc. (n or p too!)
- temperature.

$\mu_{\bar{e}}$ (Si, 300K) = 1350 cm^2/Vs
μ_{H^+} (Si 300K) = 450 cm^2/Vs. } In days....

$\boxed{J = \sigma \cdot E}$ → ohms law (macroscopic).

$\boxed{I = \sigma \cdot V}$

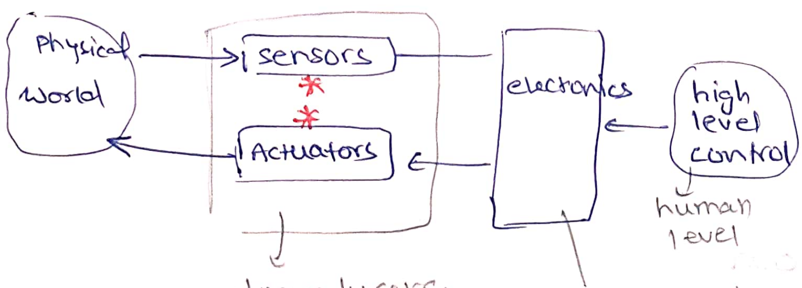
$\boxed{\sigma = q \cdot n \cdot \mu}$

Signal processing: — transduction
Manipulation
Transmission.

- physical world has signals — pressure, — Temp, Light. } Analogue.

*

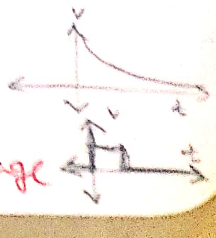
parameters:
Gain
Noise
delay
Bandwidth
power.



transducers. (one energy form to another).

manipulation:
1) Step up voltage
2) Amplify...etc.

* waveforms can be
- time variant
- triansceint or periodic.
sudden burst & falls to zero. Eg: Step voltage



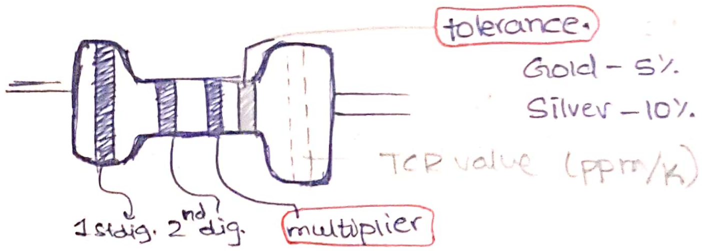
Resistors:-

various types.

* Color coding:- ($\because$ resistors are very small).

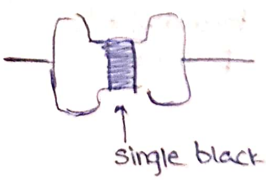
CCR
carbon ... resistors

- powder of graphite & ceramic insulator
- no inductance.



Black	0	$\times 10^0$
Blue	1	$\times 10^1$
Red	2	$\times 10^2$
Orange	3	$\times 10^3$
Yellow	4	$\times 10^4$
Green	5	$\times 10^5$
Blue	6	$\times 10^6$
Violet	7	$\times 10^7$
Gray	8	
White.	9	
* Gold		$\times 10^{-1}$	5% tolerance
* Silver		$\times 10^{-2}$	10% tolerance.

* zero ohm resistor:-



* connects two points on a PCB.

* variable resistors:-] work as sensors.

1) LDR:

light-dependent resistor.

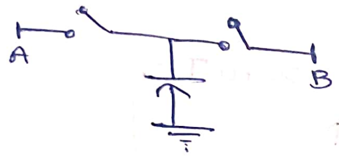
(as light $I\uparrow$, $R\downarrow$)

1) Rheostat. (10)

2) potentiometer.

3) Switched capasitor circuit: (has no resistor; but follows V = IR rule)

• tunable over large range.



but these are not the usual, mechanical switches & capacitors

frequency is KHz

plastic switches break!

• MOSFET capacitor : 1pF – 1nF

• MOSFET Switch : OFF – resistance in GΩ.

transistors

ON – resistance in 0.1KΩ.

switching frequency : 10 Hz (audio) — 10GHz (radio)

$\therefore$ $\boxed{I_{AB} = f \cdot C \cdot \Delta V}$ *

$\therefore$ $\boxed{R = \frac{1}{f \cdot C}}$

f range: 10Hz – 10GHz.

C = 100pF.

$\therefore$ Reff $\rightarrow$ 1kΩ – 1GΩ

→ characteristics:-

1) Power rating:- amount of power, can be dissipated for an indefinite period, without degrading its performance

large size → higher Power rating.

$$I_{max} = \sqrt{\frac{P_{max}}{R}}.$$

2) TCR: temp. coeff...

$R = R_0\,(1 + (T - T_0)\alpha)$

+ve TCR : metals. $\sigma = \mu \cdot nq$ (decreases)

PTC

* Thermistor: Temp. sensing. (so high TC).

negative temperature coefficient:-

(semiconductors)

R decreases as T increases.

$\mu \downarrow$ but $n \uparrow\uparrow$

$\therefore \sigma \uparrow$.

$$\boxed{\sigma = q(n_e \cdot \mu_e + n_p \cdot \mu_p)}$$

* Heavily doped silicon:-

n^{++} – Si
p^{++} – Si
behave like metals.
PTC ✓

* So;
there must be a doping; for zero TC.
i.e. $\mu \downarrow = n \uparrow$

* manganin, constantine. $\simeq$ 0 TCR material.

capacitors:-

$\boxed{\text{Farad}}$.

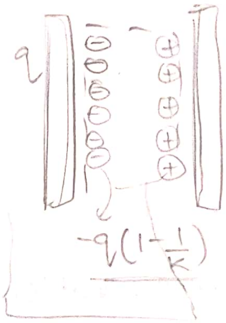
$C = \frac{q}{V}$

$\boxed{\frac{1}{2}CV^2}$ electric, ~~magnetic~~ field

$\boxed{C = \frac{dq}{dV}}$ dynamic capacitance.

Parallel space:-

$$\boxed{C = \frac{\varepsilon_r \cdot \varepsilon_0 A}{d}}$$



net $= \frac{q}{K}$

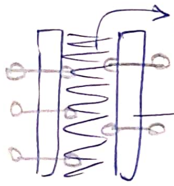
∴ Now, store more charge $(K \cdot q)$ for same voltage.

* capacitors can be used to store information...

DRAM (digital, MOSFET based)

CCD (analoug)
(charge couple device.

* used as Humidity sensor :-



→ some olive oil; absorbs moisture

Porus metal electrodes

$\boxed{\varepsilon_r \text{ charges, when water added}}$

Inductor: 1nH – 1H (Henry).

magnetic field

$\boxed{\frac{1}{2}Li^2}$ $\boxed{Emf = -L \cdot \frac{di}{dt}}$

* To boost inductance, use magnetic core – iron.

* coupled with capacitors, to have RF resonators.
radio frequency.

Wave forms & signal processing:-

SNR: Signal to noise ratio.
goes on getting better.

* circuits involved in manipulating signals:-

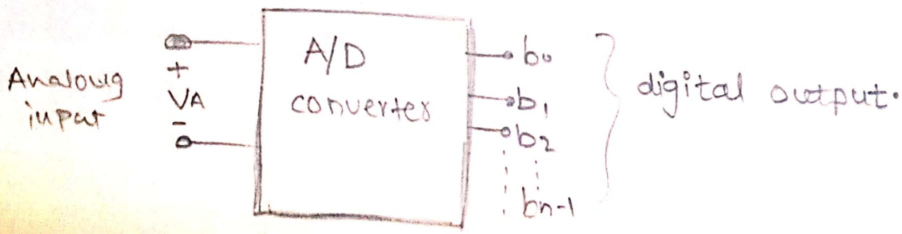
amplifiers
filters
rectifiers
} all will be studied in subsequent section of EE101.

inverter — a logic gate
— a DC to AC.

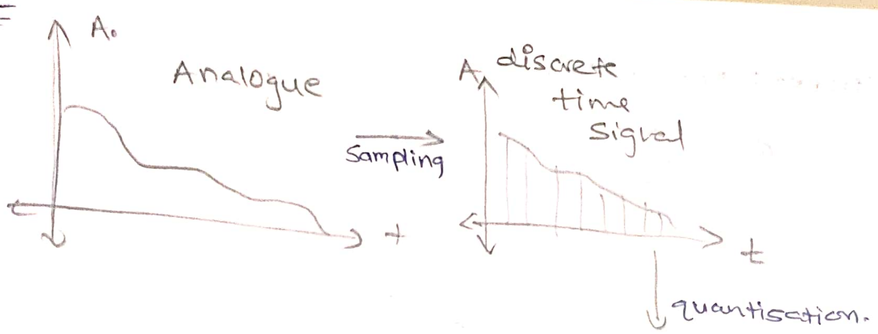
Transducer: convert signal to non EEE & viceversa
actuators — peltier cooler. (gives ΔT wrt ΔV)
sensor — thermocouple. (gives ΔV wrt ΔT)

* **Analogue signal**:- continuous wrt both value in y-axis & time (x-axis)

digital:- quantized (wrt y-values) as well as sampled at discrete points in time.



For eg:-



digital dosen't mean binary.

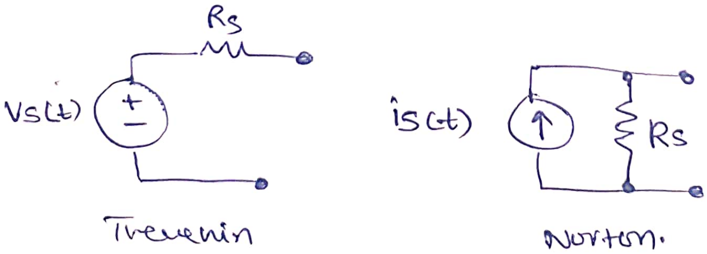
binary is just most famous form for digital signals.

* Representing Source (transducer) in circuits:-

– How are signals represented?

A) Thevenin form:- voltage source (V_s) with series resistance R_s (preferably, when R_s is low; ideally zero).

B) Norton form:- Current Source (I_s) with parallel resistance R_p. (preferably, when R_p is high; ideally ∞).



* Noise sources
- External: cross talks; capacitive coupling, industrial noise; from space.
- Internal: thermal noise (random thermal motion of $\bar{e}, h^+$); Avalanche noise; generation-recombination noise.

flicker noise ($\frac{1}{f}$ noise)

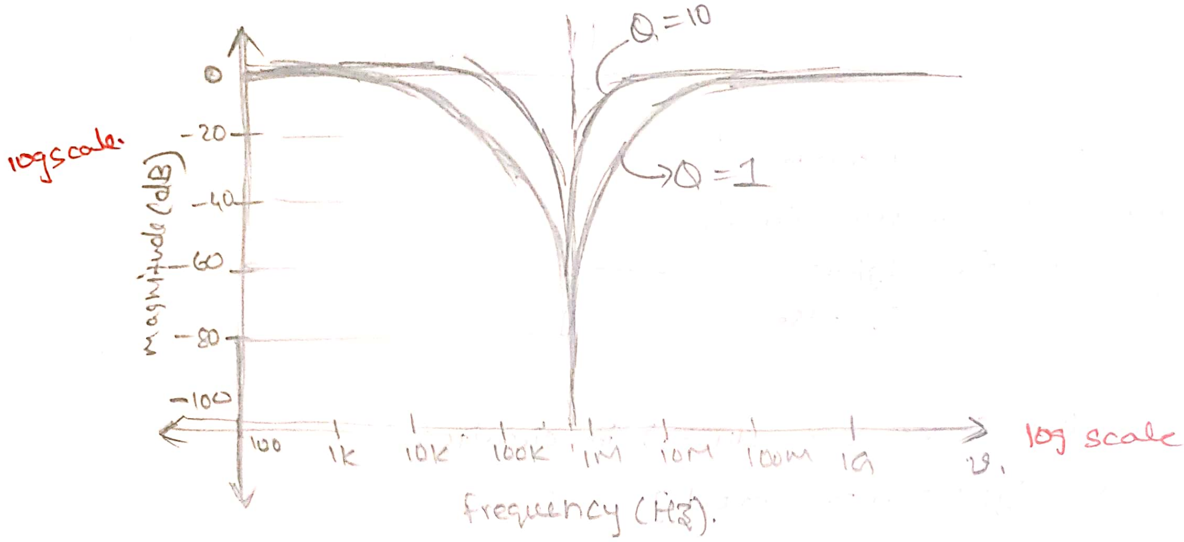
* Noise mitigation techniques:- i) Notch filter @50Hz (analog noise mitigation)

reducing the severity of something.

⋮

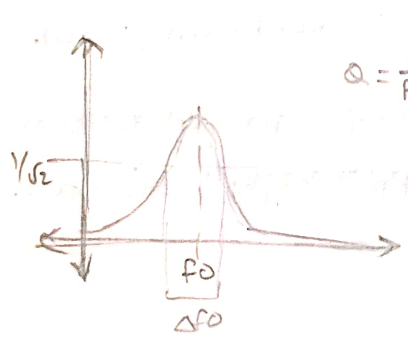
* Frequency response: notch filter.

∴ Quality factor $Q = \frac{f_n}{\Delta f}$



Opposite is RLC resonator:-

$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$.



wave forms:- signals; vary with time.

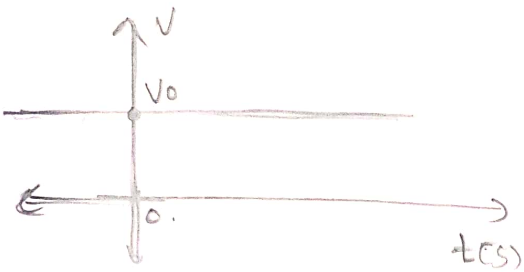
1) periodic or transient:

2) composite waveforms:-

$y = e^{-x} \sin x$

1) DC signal:-

$V(t) = V_0$ for $-\infty < t < \infty$

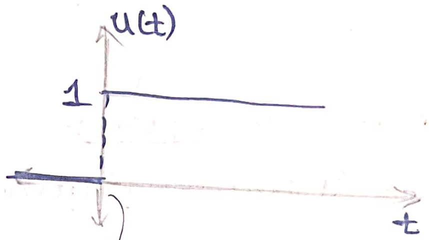


2) step wave form:-

switches turn on & off.

* unit step fu^n; as

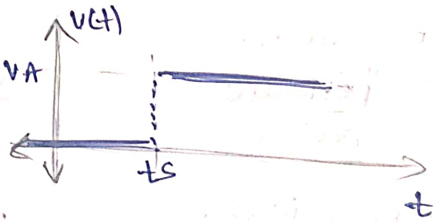
$$u(t) = \begin{cases} 0 & \text{for } t<0 \\ 1 & \text{for } t \geq 0 \end{cases}$$



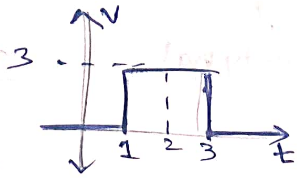
jump discontinuity

* generally;

$$\boxed{V(t) = V_A \cdot u(t - t_s)}$$



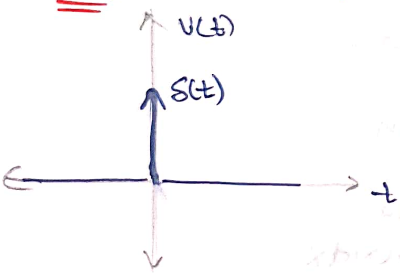
* express in stepfunctions:-



$= 3 \cdot u(t-1)$
$+ -3 \cdot u(t-3)$

3) impulse wave form:-

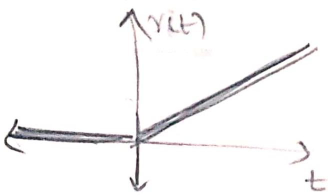
$\delta(t) \rightarrow$ unit waveform-impulse



$$\delta(t) = \frac{du(t)}{dt}$$

4) ramp function:-

$\boxed{r(t)}$ unit rampfunction.



$r(t) = t$ (numerically).

$r(t) = \int u(t) dt$.

unit step
unit impulse
unit ramp
} singularity functions.

5) exp. decay:

$V(t) = V_A \cdot e^{-t/T_c} \cdot u(t)$

$T_c \rightarrow$ time constant.

convention:-
signal goes to '0' after $5T_c$.

6. Sinusoidal waveform:-

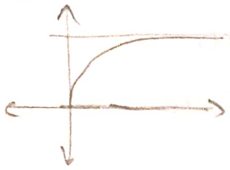
$V(t) = V_A \cdot \sin\left(\frac{2\pi}{T_0} \cdot t\right)$ 2 parameters.... +1, initial phase. (or time shift)

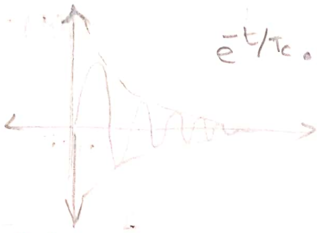
frequency $f_0 = \frac{1}{T_0}$

$\omega_0 = 2\pi f_0$

- Power $\propto V_A^2$ ✓ (do $\int V_A^2 dt$ & chek!)
- Power $\propto \omega_0^2$ ✗.

7) composite waveforms:-





waveform - partial descriptors:-

- characterize important features of a waveform; but not complete waveform.

categories:-

Temporal features:- (time releated.)

- A signal $v(t) = v(t+t_0)$ $\forall t$ & t_0 is smallest. signal is "periodic". t_0 - period

- $v(t)$ is causal if there exists T; s.t. $v(t) = 0$ for $t < T$ → reality na!

Amplitude features:-

- $V_{pp} = V_{max} - V_{min}$.

$V_{avg} = \frac{1}{T} \cdot \int_t^{t+t_0} v(x)\,dx$

$V_{rms} = \sqrt{\frac{1}{T} \cdot \int_t^{t+t_0} (v(x))^2 dx}$

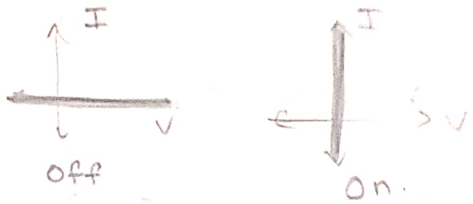
avg. power to resistor $= \frac{V_{rms}^2}{R}$

DC components:- Stuff is defined; based on IV characteristic.

1) Switches:-

MOSFET switch. 10KΩ to 10GΩ.

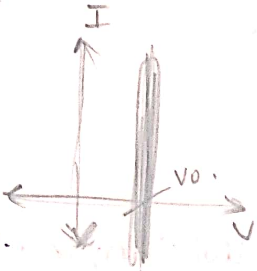
. . . . ✓



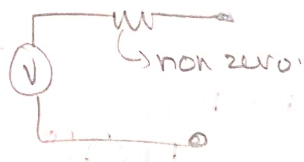
2) Volt source:-

ideal:

also
$R_s = 0$.
(since verticle slope).



Practical:

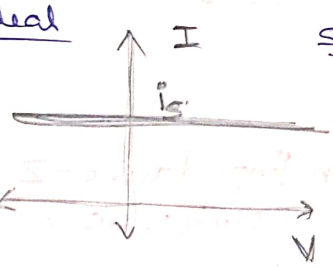


Eg: transducer. (Temp / Pressure } → V_s).] time variant

Battery.] time invariant.

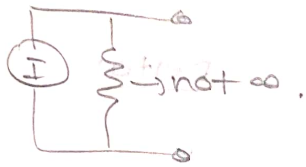
3) Current source:

ideal



Shunt resistance = ∞ Ω.
//el connection.

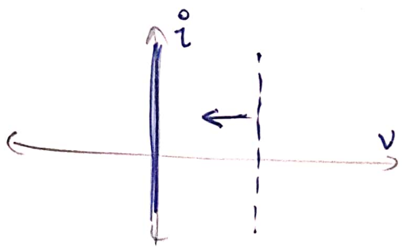
practical:



Eg: Solar cell.

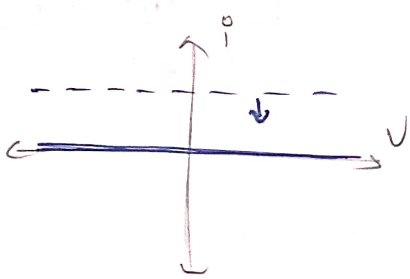
* Switch off action:- → may ask dumb-tricky questions....

1) Voltage source.



∴ replaced by short circuit.

2) Current source:-



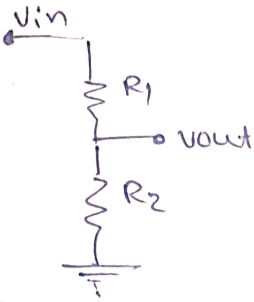
replace by open circuit.

voltage divider:-

- when output voltage is fraction of input voltage.

1) Resistive (R-R)

2) Transformers (L-L)
   (for AC-AC)



$V_{out} = \frac{R_2}{R_1+R_2} \cdot V_{in}$

3) Filters (R-C, R-L, RLC) } offer voltage division; in frequency selective manner.

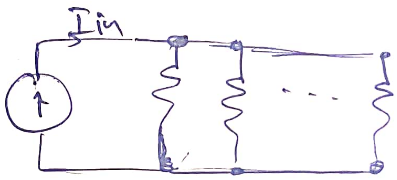
current divider :- current bypass.

1) Shunt resistors

$I_x = \frac{G_x}{\Sigma G_x} \cdot I_{in}$

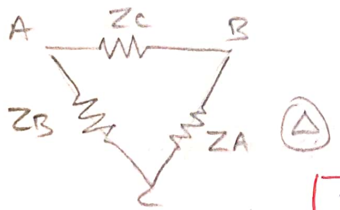
(or)

$I_x = \frac{1/R_x}{\Sigma 1/R_x} \cdot I_n$

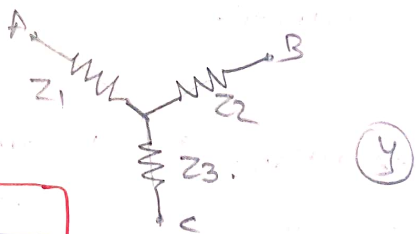


Circuit transformations:- (results are in impedance-Z - similar algebra to R resisters)

Delta:

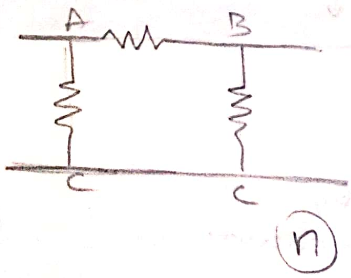


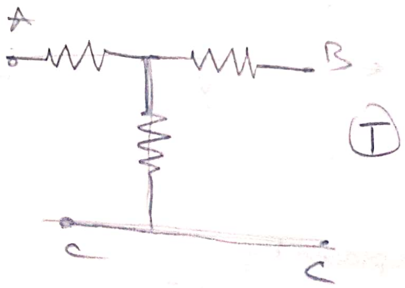
Star:



$\boxed{Z_1 = \frac{Z_B \cdot Z_C}{Z_A+Z_B+Z_C}}$ → proof: compare coefficients, as true ∀ V_A, V_B, V_C.

& cyclic.

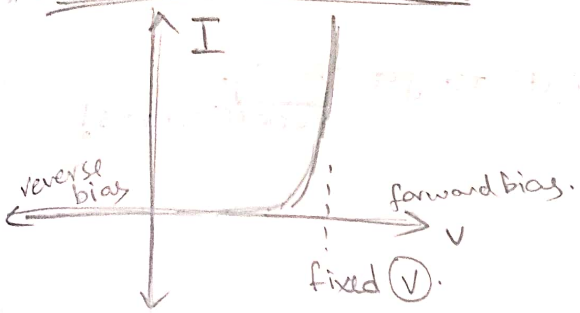




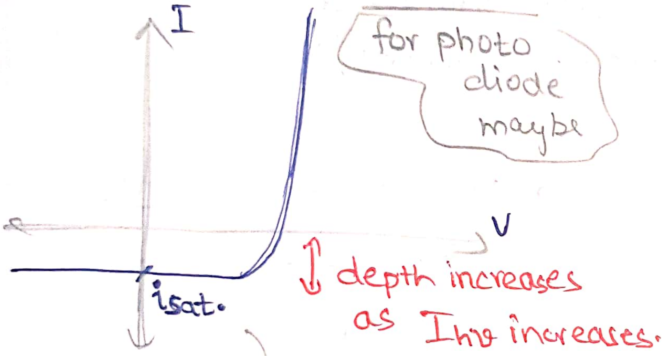
$Z_A = \frac{\Sigma Z_1 Z_2}{Z_1}$

PV cell:-

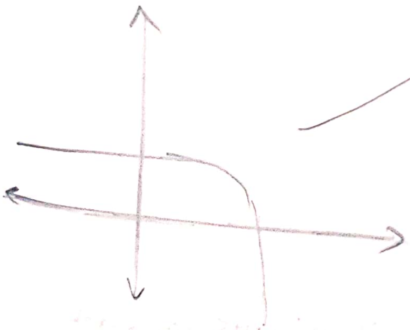
* diode characteristic:-



when light is shine, in PV cell:

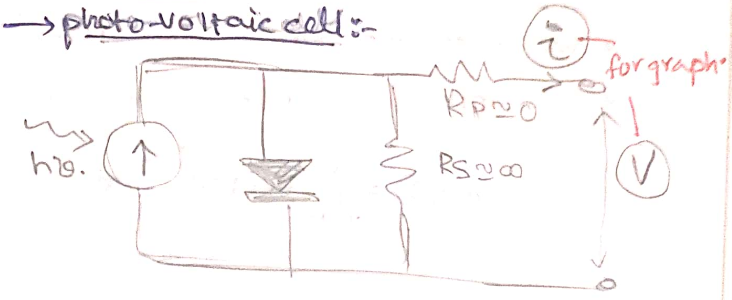


reverse!

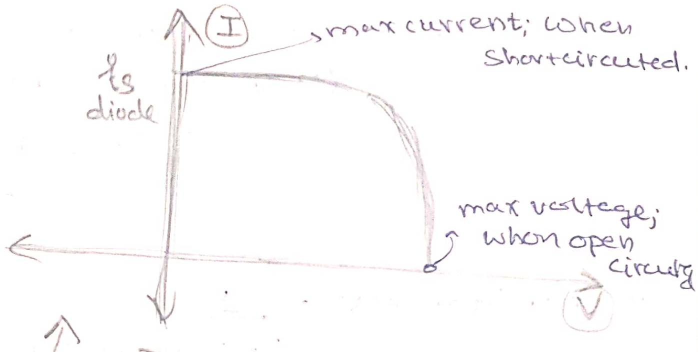


→ Solar cell;

→ photo-voltaic cell:-



iv characteristic is:-



P-V characteristic is:

think once more!

→ S-domain Circuit analysis:- (AC inputs)

- we write impedances for R, L, C.
- We apply fourier transformation on $V_s(t)$ to get $\underbrace{V_s(S)}_{\text{coefficients!}}$.

$$\underbrace{\boxed{V_s(S) = \int_{-\infty}^{\infty} V_s(t).e^{ist}.dt.}}_{\text{complete!}} \quad \text{or} \quad \underbrace{V_s(S) = \int_0^T V_s(t)\cdot \sin(St)\,dt.}_{\text{physical world!....}}$$

& $V_s(t)$ is an odd, periodic... of period T.

- All the laws & equations, applicable to $V_s(t)$ are also true for a $V_s(S)$

($\because$ $V_s(S) = V_s \cdot \sin(St + \phi)$)

& since, $\vec{E}$ is a linear law field, superposition works!)

* Admittance(Y) = $\dfrac{1}{\text{Impedance}(Z)}$

	Z:
Resistance (R) →	R
capacitance (C) →	$\frac{1}{j\omega C}$ or $\frac{1}{SC}$
Reactance (L) (Inductance) →	$L \cdot j\omega$ or SL

Assumption; causal systems:- $V_c(0) = 0$
$q_c(0) = 0$.
$V_s(0) = 0$.
$i_L(0) = 0$.

* Impedance in series.

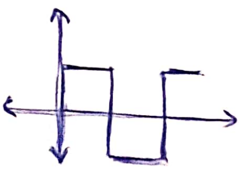
$\Sigma Z_i = Z_{net}$

parallel

$\Sigma \frac{1}{Z_i} = \Sigma \frac{1}{Z_{net}}$

→ wave form transformations:-

Vs	$V_s(t)$	$V_s(S)$ coefficents for each $\sin(St)$
impulse	$\delta(t)$	1
Step	$u(t)$	$\frac{1}{S}$
ramp	$tu(t)$	$\frac{1}{S^2}$



$\frac{4V}{\pi} \cdot \frac{1}{S}$ for S is odd;

$\frac{4V}{\pi} \cdot 0$ for S is even

etc.

• Filters:-

How to examine frequency response?

pass a "sinusoidal" wave of frequency ω.

why?

Because form is conserved.

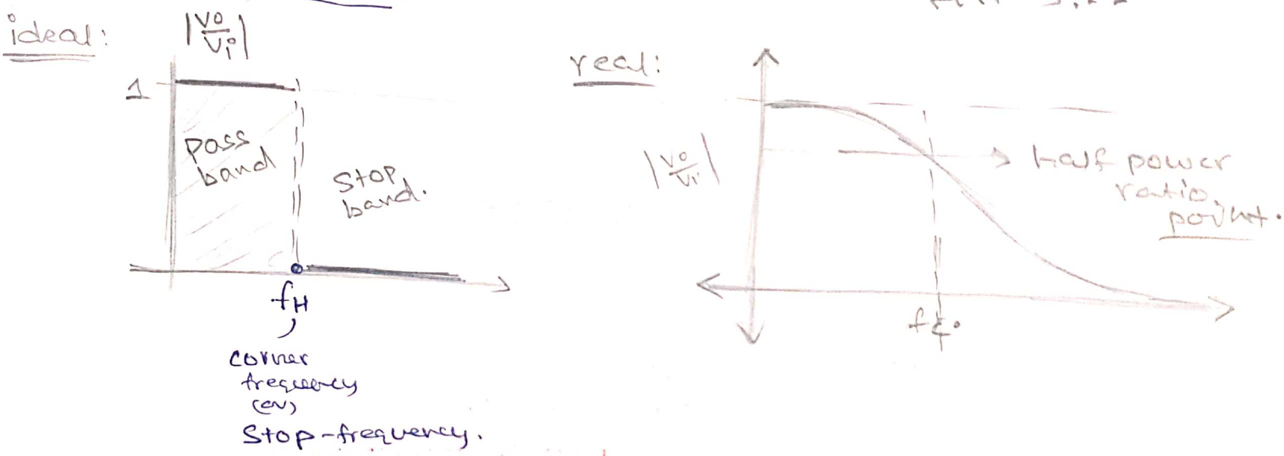
& frequency is conserved.

* two types — passive filters → use of R,L,C. No amplification.! ↳ definitⁿ of passive filters

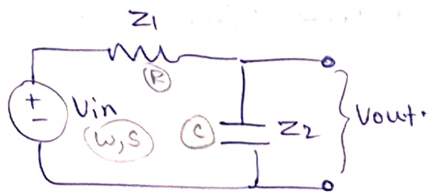
active filters

has semi-condtor devices: amplification takes place (Amplifier.) → defⁿ. of active filters...

Low pass filter, passive:-



first order LPF :- (low pass filter)



$T(S) = \frac{1}{1+\frac{S}{\omega_0}}$

$V_{out} = \frac{Z_2}{Z_1+Z_2} V_{in}$

$T(s) = \frac{\frac{1}{CS}}{\frac{1}{CS}+R}$

$\therefore \boxed{T(S) = \frac{1}{1+(RC)S}}$

for physical frequencies; $S = j\omega$.

$T(j\omega) = \frac{1}{1+j(\omega/\omega_0)}$

$|T(j\omega)| = \frac{1}{\sqrt{1+(\frac{\omega}{\omega_0})^2}}$

$\angle T(j\omega) = -\tan^{-1}(\frac{\omega}{\omega_0})$ Phase difference.

$\omega_0 = \frac{1}{RC}$

so; power $= 1/2 \rightarrow |T(s)| = \frac{1}{\sqrt{2}}$

$\therefore \frac{1}{\sqrt{1+(RC\omega)^2}} = \frac{1}{\sqrt{2}}$

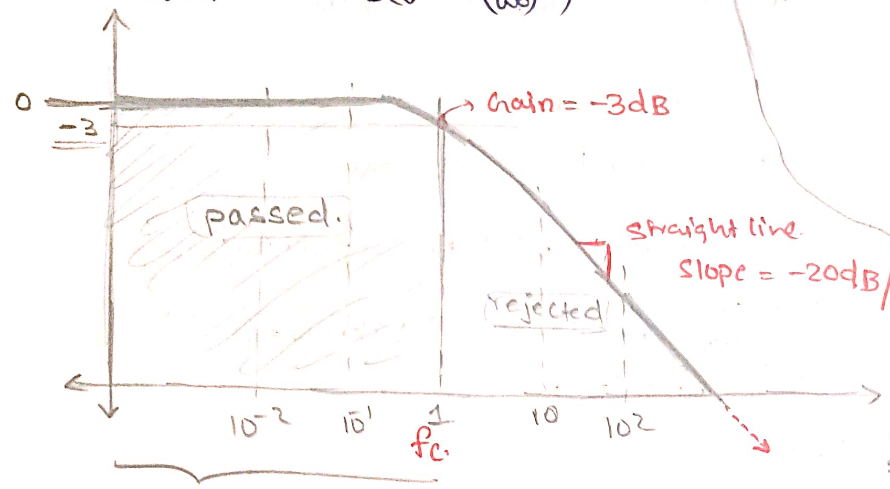
$\boxed{\omega_0 = 1/RC}$: f_{corner}

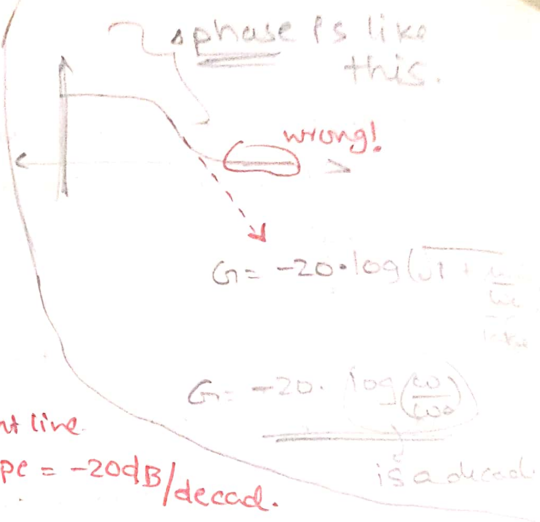
$\Rightarrow |T(\omega)| = \frac{1}{\sqrt{1+(\frac{\omega}{\omega_0})^2}}$

Bode plot:-

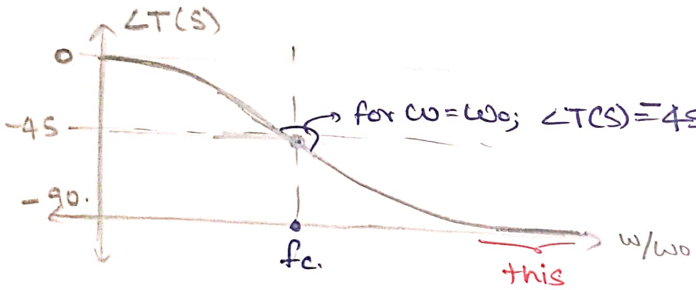
$10\log(\text{Power ratio})$

$$\text{Gain} = -20\cdot\log\left(\sqrt{1+\left(\frac{\omega}{\omega_0}\right)^2}\right)$$





$\Delta\omega$: 0 to ω_0 is Bandwidth.



But NOT in Bodeplots!

Gain → -∞ (log rule!) as ω → higher & higher.

---

for HPF:-

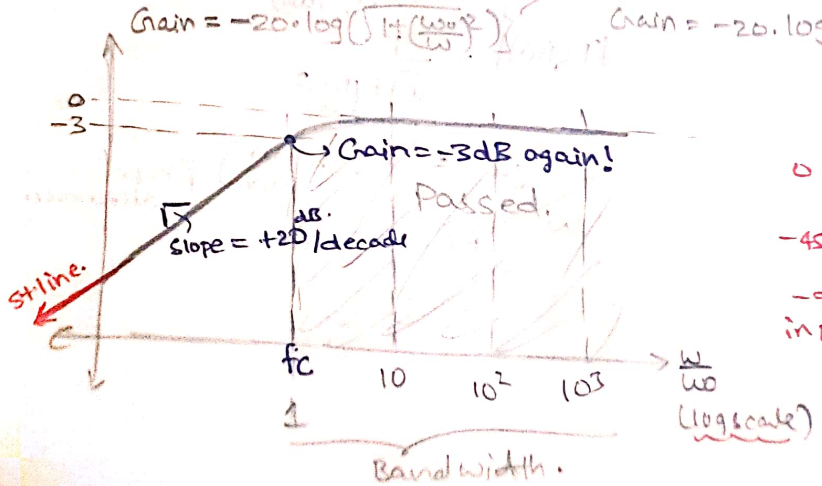
$$|T(j\omega)| = \frac{1}{\sqrt{1+\left(\frac{\omega_0}{\omega}\right)^2}} \qquad \omega_0 = \frac{L}{R} \text{ or } RC.$$

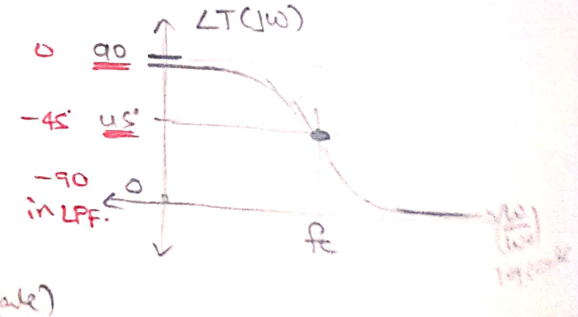
$$\angle T(j\omega) = \tan^{-1}\left(\frac{\omega_0}{\omega}\right).$$

Bodeplots!

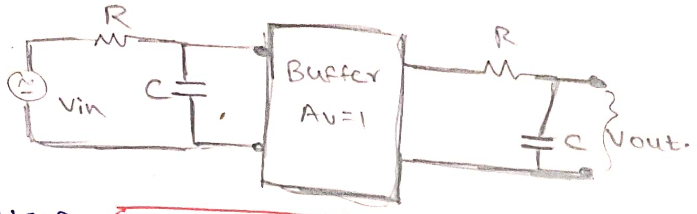
$\text{Gain} = -20\cdot\log\left(\sqrt{1+\left(\frac{\omega_0}{\omega}\right)^2}\right)$; as $\omega \to 0$;

$\text{Gain} = -20\cdot\log\left(\frac{\omega_0}{\omega}\right) = +20\cdot\log\left(\frac{\omega}{\omega_0}\right)$





* cascaded LPF:-



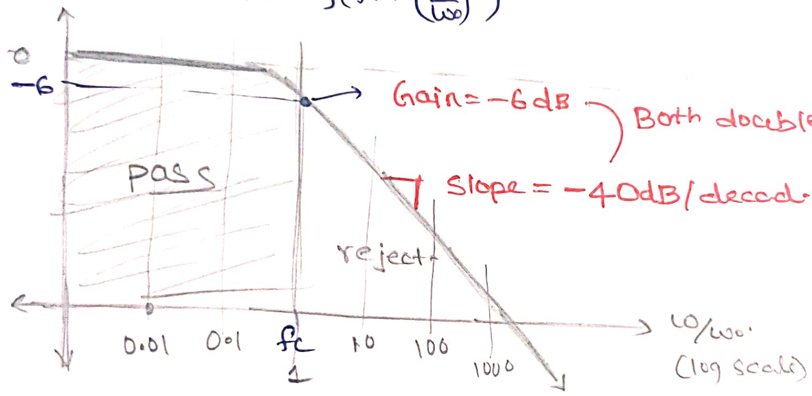
Here; $\boxed{f_{corner} = \frac{1}{2\pi RC}}$ (still !) But not half-power point.

$$|T(j\omega)| = \frac{1}{\sqrt{1+\left(\frac{\omega}{\omega_0}\right)^2}} \times \frac{1}{\sqrt{1+\left(\frac{\omega}{\omega_0}\right)^2}}$$

also; $\angle T(j\omega) = 2 \cdot \tan^{-1}\left(\frac{\omega}{\omega_0}\right)$.

Bode:

$$\text{Gain} = -40 \cdot \log\left(\sqrt{1+\left(\frac{\omega}{\omega_0}\right)^2}\right)$$



Gain = −6dB } Both doubled.

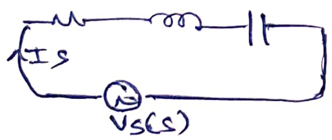
Slope = −40dB/decade

we have same ωcorner.

---

* resonance:- useful as bandpass. | notch filter − stops 50Hz − bandstop filter; R, L, C, source in parallel).

*



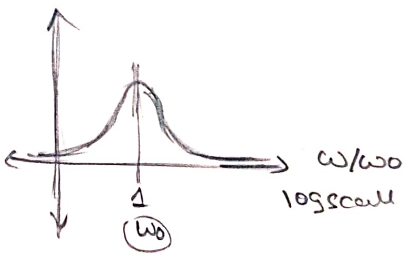
$$|Z(j\omega)| = \sqrt{R^2 + \left(L\omega - \frac{1}{C\omega}\right)^2}$$

$|Z(j\omega)|$ is min for $\boxed{\omega = \omega_0 = \frac{1}{\sqrt{LC}}}$

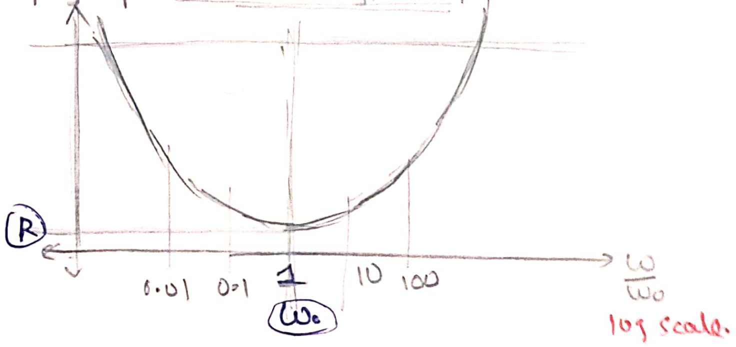
we see $\frac{I_s}{V_s}$ or $\frac{V_s}{I_s}$.

Admittance.

$\therefore$ $$|Z(j\omega)| = \sqrt{R^2 + \frac{L}{C}\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)^2}$$



|Z(jω)| nothing like log|Z(jω)|



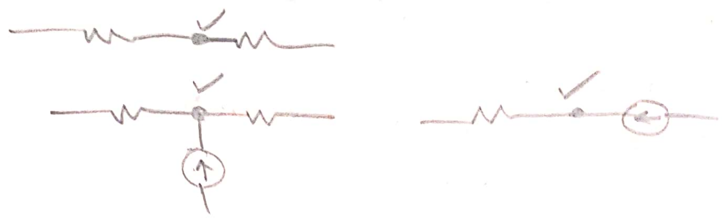
week-2!

IS1 — KCL, KVL
IS2 — Node-voltage law
IS3 — mesh current method
IS4 — Thevenin & norton
superposition.

* In a circuit;

N nodes $\longrightarrow$ (N−1) independent KCL equ^{n}

node means; connection point of 2 or more elements.



'E' two terminal devices $\longrightarrow$ (E−N+1) independent KVL equ^{n}s.

→ Node-voltage analysis:– KCL derived.

1. N-nodes: 1 – reference node (E); Potential = 0.

N−1 : $V_1, V_2, \cdots V_{N-1}$ voltage values.

circuit variables are Node voltage.

2. write KCL at N−1 nodes. (using I-V constraints)

n−1 equations for n−1 variables ($V_1, V_2, \cdots V_{n-1}$)

3. write matrix. (☺!) → marks are given for this.
(comes symmetric)

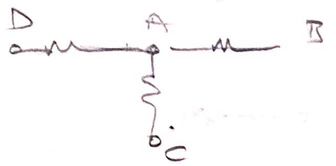
* N-V analysis, preffered when parallel circuit elements.
(n−1) is small na.

current source plural circuits → divided into many.

mesh current preffered when series circuit elem.
(E−N+1) small na.

voltage source plural circuits

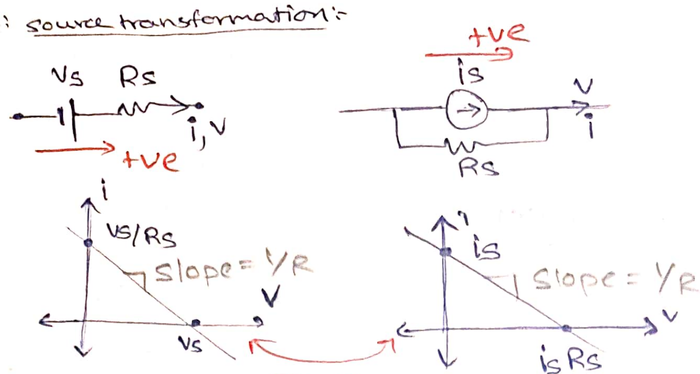
writing $\Sigma V_i\left(\frac{1}{R_i}\right) = 0$ by inspection:-



$V_A \cdot +1\left(\Sigma \frac{1}{R}\right.$ Between A & others)
+
$V_B \cdot -1\left(\Sigma \frac{1}{R}\right.$ between B & A)
+
$V_C \cdot -1\left(\Sigma \frac{1}{R} \cdots\right)$
+
$V_D \cdot -1\left(\Sigma \frac{1}{R} \cdots\right)$

* Voltage-source; is an exception in this approach.
– source transform to current source; or write $V_A - V_B = \Delta V$ as an equ^{n}

Note: source transformation:-



$\boxed{V_s = i_s R_s}$

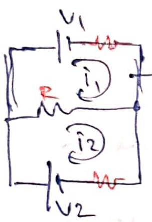
- Resistance, same
- relat^n b/w V_s, i_s is easy.

Same I-V plot;

for elements; no difference "electrically"

so, we exchange.

→ Mesh current analysis:-



→ for this loop;

$V_1 + (i_1 - i_2)R = 0.$

not just i_1....

write absolute current;

following signs as per your alloted direct^n.

1) E−N+1 : mesh current variables

2) write KVL along E−N+1 loops:-

E−N+1 variables, E−N+1 equ^ns.

(use I-V characteristics, if needed).

3) write matrix:

(comes symmetric)

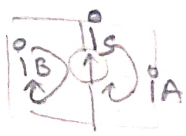
By inspection:-

$\Sigma R_i x_i$ can be written....

* current source is exception in this analysis.

- do source transformat^n, if possible
- or write $i_K = i_{current\ source}$, as one equ^n.
- take equ^n on supermesh & write $i_A - i_B = i_S$,

comb^n of mesh having this as common.



(same; super node analogy in N-V analysis

Supernode.

write $V_A - V_B = V_s$

→ superposition:-

1) mark all current sources; voltage sources.

2) switch on – S_i ; Swith off – remaining all.

if voltage-source; Short circuit!
$V=V_s$ → $V=0$

if i-source; open circuit!
$i=i_s$ → $i=0$

switch off.

3) determine $x/p(S_i)$

4) finally; add all; $x = \sum_i x/p(S_i)$

x can be current; can be voltage difference....
but not Power. → nonlinear.

* superposition; applicable to circuits; comprising of linear circuit elements.
- resistor
- capacitor
- inductor
- i-source
- v-source

& thus source transfrm.

* our switches → active switch
(we control)
- mechanical,
or
voltage operated. } MOSFET switches.

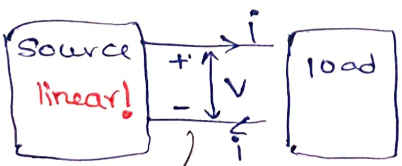
diode → passive switch.
Self deciding.

→ Source circuit, effective representation:-

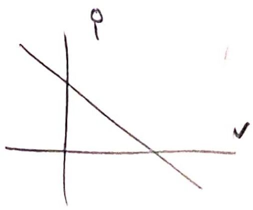
- Thevinin circuit rep.
- Norton circuit rep.

} independent of load – linear or non-linear.

*



i;v graph will be



} should mimic by using

"effective resistor"
&
"effective v-source" | "eff. i-source"
$\boxed{\text{Thevenin}}$ | $\boxed{\text{Norton}}$

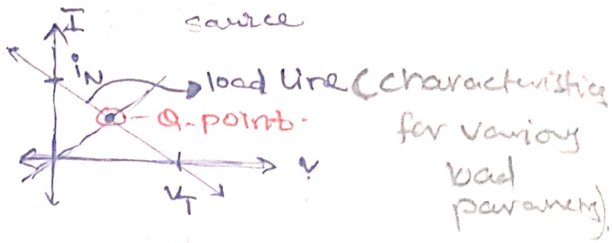
How to proceed:-

1) make load as open.

$V = V_{Thevenin}$; $i = 0$.

2) make load shortcircuit;

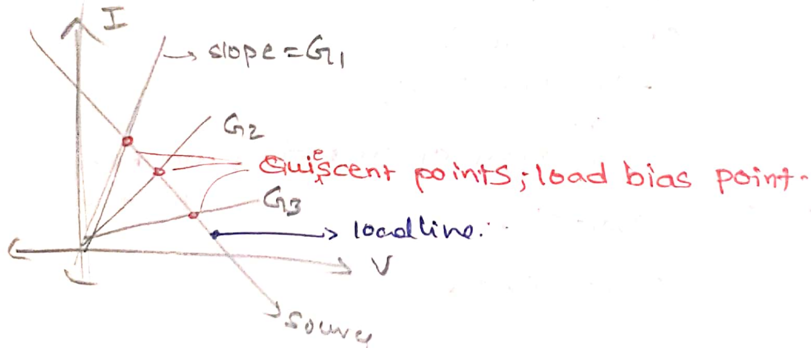
$i = i_{Norton}$; $V = 0$.



3) $R_T = \frac{V_T}{i_N}$

3) also can calculate; R_T by look-back.
(i.e. switch off all V-sources, i-sources)
& calculate Reff.

* Linear Load:-



* maximum power transfer:-

Applications:-

1) communication systems.
2) Speaker.
3) car ignition.

week-3:-

- semiconductor silicon.
- P-N-Diode (biasing, characteristics)
- Rectification (diode applications).
- Regulation. (zener diode).

- semiconductors, means;

σ or ρ values intermediate.

	σ: (SI units)
metal	$>10^2$
semicond.	$10^{-6}-10^{5}$
insulator	$<10^{-10}$

Band-gap model:-

$E_g>6eV$ insulators: forbidden energy gap.

$E_g=0$ metals: overlapping valency & conduct^n band.

Semi conductors:

valence band ~ filled
cond. band ~ empty

$E_g \sim 1eV$

Si Ge GaAs

intrinsic semicond.

→ EEE properties of Silicon:
(electrical & electronic engineering.)

$\mu_{\bar{e}} = 1350\ cm^2/Vs$ $\quad$ $\sigma = 0.3\times10^{-3}\ Sm^{-1}$

$\mu_h = 450\ cm^2/V\text{-}s$

$E_g = 1.1eV$, $K = 11$
dielectric constant.

→ thermal properties:-
→ optical properties:-
→ mechanical properties:-

∘ conduction model)

1) At R.T; some covalent bonds break & generate free electrons.

2) Bandgap:-
for T>0; probability there for excited $\bar{e}$.

* $n_i = n = p$ (pure silicon)
no. of free $\bar{e}$, h^+ in unit volume of intrinsic semicond.

B = some parameter $= 7.3\times10^{15}\ cm^{-3}K^{-3/2}$ for Si

T = temp (K)

E_g = band gap energy = 1.12eV for Si at 300K

$k = 8.62\times 10^{-5}\ eV/K$.

$$\boxed{n_i = B\cdot T^{3/2}\cdot e^{-E_g/2kT}}$$

$p=n=n_i$

* doping: intentional introduction of impurities, to change carrier concentrations.

$N_{impurity} >> n_i$
$10^{12}-10^{20}/cc \qquad 10^{10}/cc$

* $n_{majority} \cong N_{impurity}$.

$$n_{minority} = \frac{n_i^2}{n_{majority}}$$ (∵ thermal equb; between generation of $\bar{e}$, H^+ & recombination of $\bar{e}$, H^+).

* $\overrightarrow{V_{drift}} = \mu \cdot \vec{E}$ for +ve. $\overrightarrow{V_{drift}} = -\mu\vec{E}$ for -ve.

(as $T\uparrow$, $\mu\downarrow$) → vibrating atoms, block paths...

& thus

$J = q \cdot n \cdot \mu \cdot \vec{E}$

$\therefore \underbrace{J_{semiconductors} = (q \cdot n_+ \mu_+ + q \cdot n_- \cdot \mu_-)}_{\sigma_{semiconductors}} \vec{E}$

Diffusion current:-

hole diffusion:-

$J_p = -q\, D_p \cdot \frac{dp(x)}{dx}$

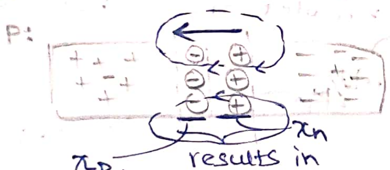
$J_n = +q \cdot D_n \cdot \frac{dp(x)}{dx}$.

$D_p = 12\,cm^2 s^{-1}$ for Si.
$D_n = 35\,cm^2 s^{-1}$ for Si.

Diode:- isolated n or p doped; act as piezo resistors.

* when joined, large density gradient. (10^{16}/cc majority vs 10^{4}/cc minority).
(via doping!)
+
Temp.
will cause n, p to diffuse.

* depletⁿ region formed with no free carriers.



results in pot. V_0 across junction ; $\boxed{\vec{E} = \frac{V_0}{W_{region}}}$ → this field sends ⊕ from N to P
− from P to N.
= i_{drift}, minority current.
→ barrier for majority charge carriers.

& via conc. grad. = i_{diff}.

* depletion width

$W = X_n + X_p$.

(fuⁿ. of doping conc. in N/P blocks)

→ $N \simeq P$; $x_n \sim x_p$

→ $N >> P$, $x_n \sim 0$; $W = x_p$.

→ $N << P$; $x_p \sim 0$; $W = x_n$

universal defⁿ of cathode & anode:
* where i flows into terminal; anode. (in-an)
* where i, flows out from terminal, cathode.

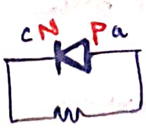
* $V_0 = 0.7\,V$ for Silicon PN.

$V_0 = V_T \cdot \ln\left(\frac{N_A * N_D}{(n_i)^2}\right)$; $V_T = \frac{KT}{q}$ V_T: thermal voltage.

(N_A: acceptor atoms, Holes. N_D: donor atoms, e^-.)

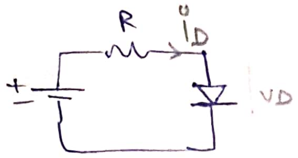
&; total charge on two surroundings of depletion region:

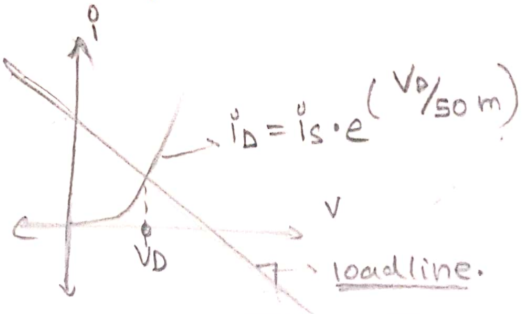
$N_A \cdot x_p = N_D \cdot x_n$

* just 

no current. ; if light incident on diode; EHP generates; & is separated; due to $\vec{E}$ in depletion region; then current ✓.

Forward biasing :- + to P-terminal, − to N-terminal.





$\boxed{\frac{\Delta V_D}{\Delta T} = -2mV/K}$

i_s doubles, every 10 K rise.

V_T = thermal voltage

$V_T = \frac{KT}{q}$, $\simeq 25mV$

* $\boxed{R_{dynamic} = \frac{dv}{di}}$
$= \frac{nV_T}{i_D}$ ....

$\boxed{i_D = i_s \cdot \exp(V_D/nV_T)}$

i_s – scaling current (pA) less.

$V_T = \frac{KT}{q} \simeq 25mV$ at 290K.

$n = 2$.

* diode power handling (mA, mW)

– diode capacitance per area :-

Junct^n cap $= \frac{\varepsilon_0 * \varepsilon_r}{W}$ (per area)

11.7 for Si

– thus; Vext changes W & changes capacitance.

"varactor". (signal modulation)

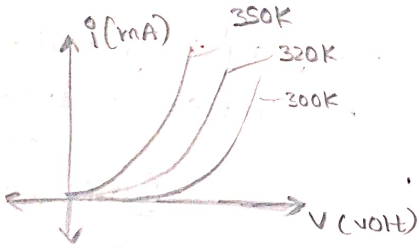
V_0 is less; then; can be used as a one way switch.

Schottky diode.

metal semicond. junction.

* temp effect :-

as T ↑; V_0 decreases.



$\frac{\Delta V}{\Delta T} = -2mV/K$.

i_D is exponential with V_D

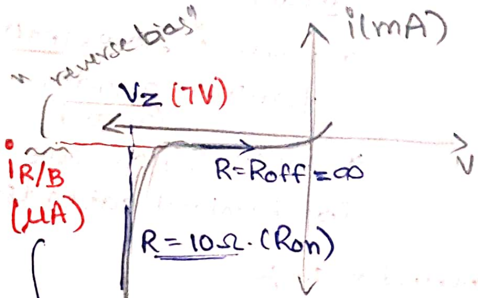
$$i_D = i_s \cdot (\exp(V_D/nV_T) - 1)$$

cascade diodes:

PNPN.

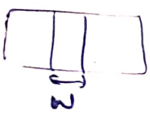
high power apply.

Reverse bias :-



owing to the minority carriers current.

low leakage current.



$\boxed{W = K_i \sqrt{V_R + V_{bi}}}$

as $\vec{E}$ increases:

Breakdown #1 :-

break bonds.

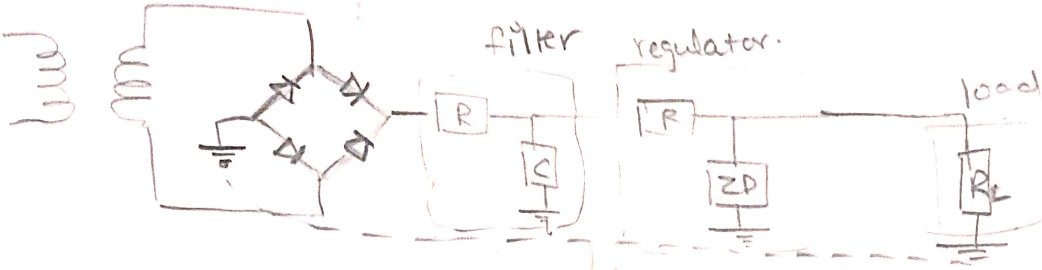
EHP generated (Zener effect) in heavily doped P-N junction as EHP can separate easily High E

Breakdown #2 :-

accelerated 2ndary carrier ↳ (Avalanche effect) in lightly doped P-N junction.

→ Rectifier circuits:- diode - passive switch.

i) diode bridge rectifier. fullwave:-



PIV : peak inverse voltage.
(for breakdown determination).

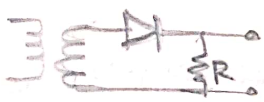
* diode:

V_{bi} = 0.7V (ON) → non-ideal, forward bias.

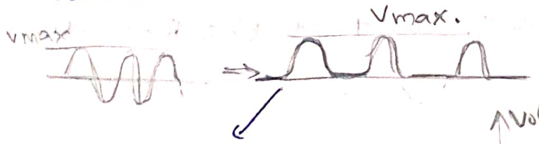
R_{ON} = 0 (10 Ω is practical)

Reverse: $R_{OFF} \to \infty$, $i_{OFF} = 0$.

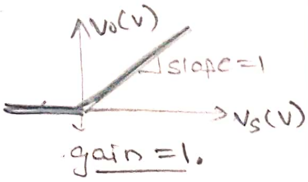
2) half-wave (1-diode):-



> for I-D1:-

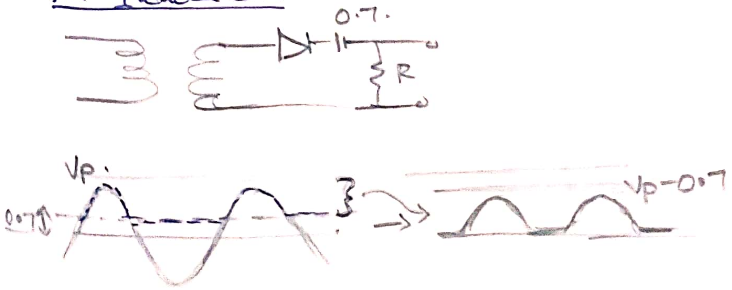


* $V_{avg} = \dfrac{V_{peak}}{\pi}$



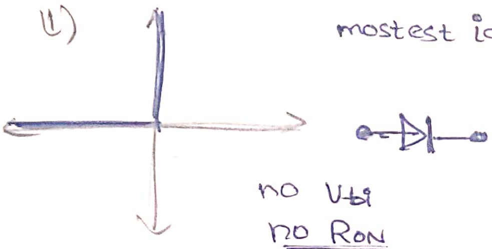
* PIV = − Vmax
peak inverse voltage... when diode, reverse biased.

> for I-diode (2):-



ideal diode models:-

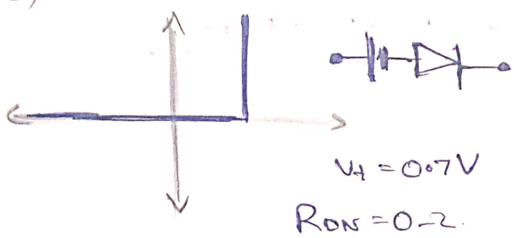
(1)



mostest ideal.

no V_{bi}
no R_{ON}

(2)



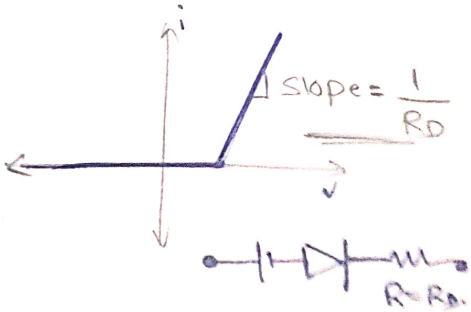
V_d = 0.7V
R_{ON} = 0 Ω.

so rectifier waveform.

V_{out} = V_{source} − 0.7V

* multiple diodes in series; (2D, 1.4V)

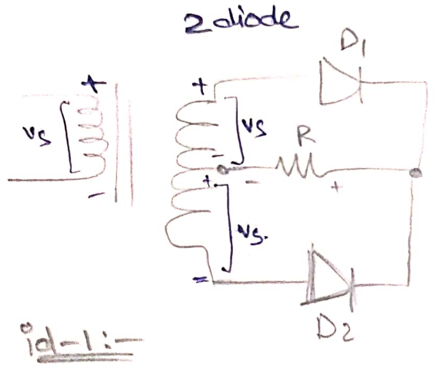
(3)



• $V_{out} = V_s - 0.7 - i_D \cdot R_D$

3) Full wave rectifier:-

2 diode

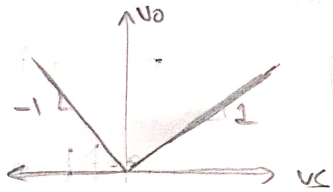


id-1:-

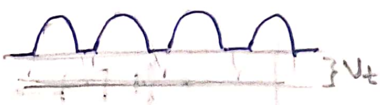
* $V_{avg} = \frac{2 \cdot V_{peak}}{\pi}$

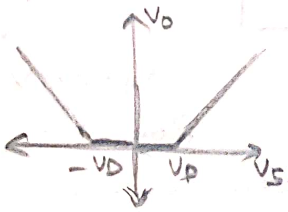
* $\boxed{PIV = 2 \cdot V_s}$ *

since; $V_s + V_s$



ideal diode-2:



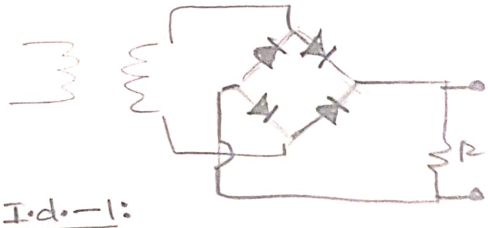


$V_o = V_s - 0.7$

$\boxed{PIV = 2V_s - 0.7}$

not $2V_s$!

4 diodes:



I.d.-1:

$V_{Avg} = \frac{2 \cdot V_{peak}}{\pi}$

$PIV = V_s$ damn!

$V_o = V_s$

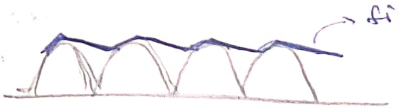
I.D-2:-

$V_o = V_s - 1.4$

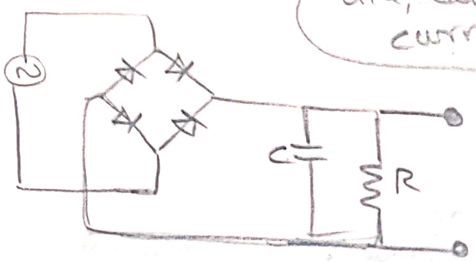
$PIV = V_s - 0.7$

→ Filter capacitor:- /or filter inductor too!

* smoothing of ripple



* time constant; such that; the R-C. discharge slowly.



Like; diodes will cutoff current; when capacitors try to discharge?

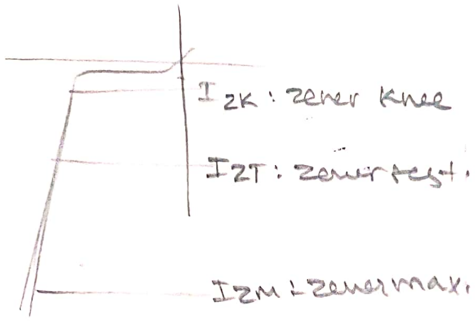
→ Voltage regulation:-

not rectification.

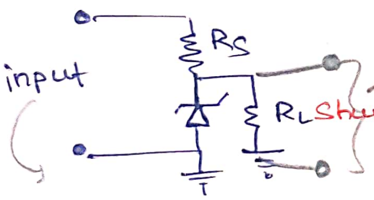
zener diode by:

Aim:
output DC voltage; free from input (source) fluctuations (± 10%)

- reverse breakdown (zener) operation.
- constant voltage; over large current range] Hence regulator.
- switch off for low current.



*



will be $V_{BK} = 4.7$ V

Shunt load.

↳ takes excess current from source.

can vary; like 11–9 V

Week-4:-

• Amplifier.

comprises: dependent sources

* so far we've encountered;

passive circuit elements:- R, L, C, diode.
passive!

• transformers are also passive.

$$V_s I_s + V_p I_p = 0$$ (transformer eqn) (Power is same).

* Active circuits → signal amplication.

(must have external power supply!)

Transistor (triode)

> BJT, MOSFET

Amplifier:
- dependent source.
- active circuit.

takes external power to change signals.

* for AC currents only rq.

Amplifier circuits include transistors, multiple transistors / or Opamps.

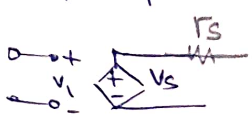
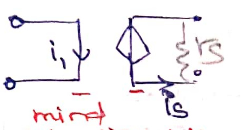
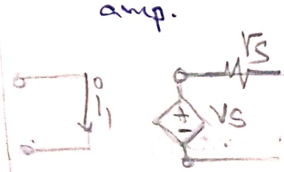
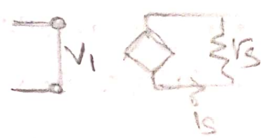
• for cascaded amplifier;

$$G = G(1) \cdot G(2)$$

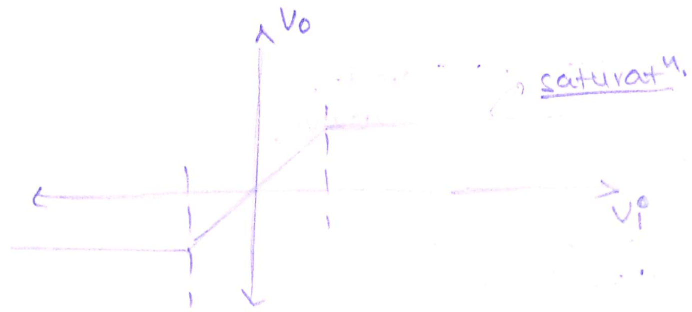
if $G(1) = 20dB$, $G(2) = 10dB$

$G = 30dB$. (∵ dB is log scale).

• 4 kinds:-

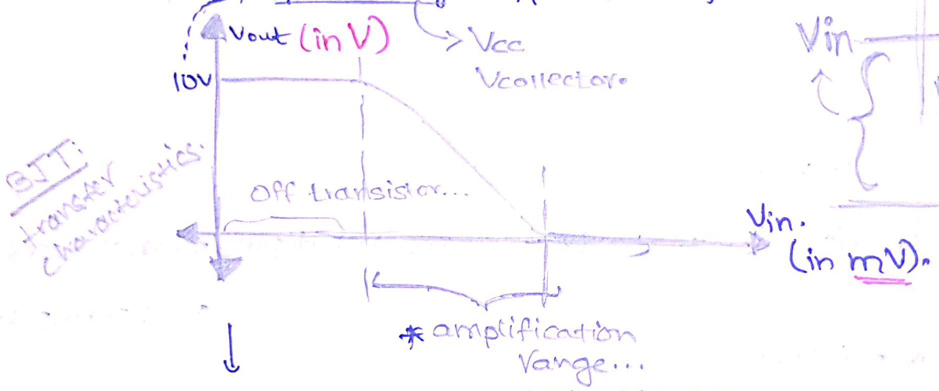
VCVS	CCCS	CCVS	VCCS
voltage amp.	current amp.	trans-resistance amp.	trans-conduct. amp.
			
mind the directn.	mind the directn. (same!) ~~same~~ opp. in cw, acw sense.		
* $\frac{V_s}{V_1} = A_v$ or μ	$\frac{i_s}{i_1} = A_i$ or β	$\frac{V_s}{i_1} = A_R$ or r_m	$\frac{i_s}{V_1} = A_G$ or g_m
units are volt/volt	amp/amp	$\boxed{\text{ohm}}$	$\boxed{\Omega^{-1}}$

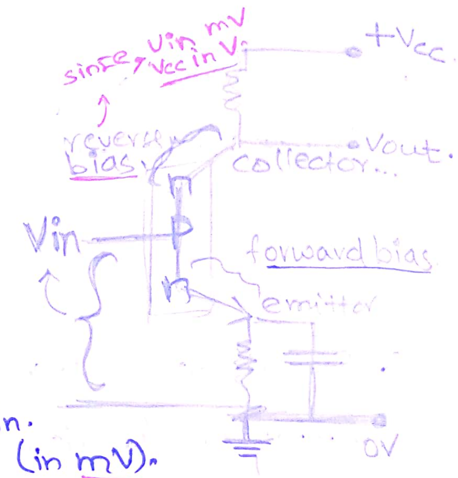
* Amplifier response:-



* transistor ka, Vout vs Vin:-

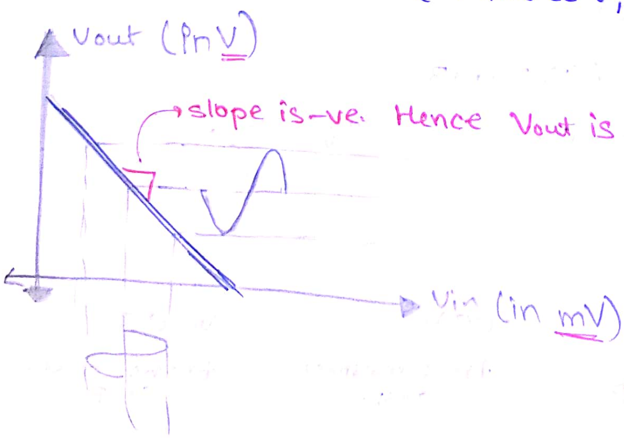
input voltage (supplied) is 10;





(∵ mV to V; but mind you! we have external powersupply)

*



BJT:
Input (B, E)
Output (C, E)

class A amplifiers:-

only 1 transister. (npn)

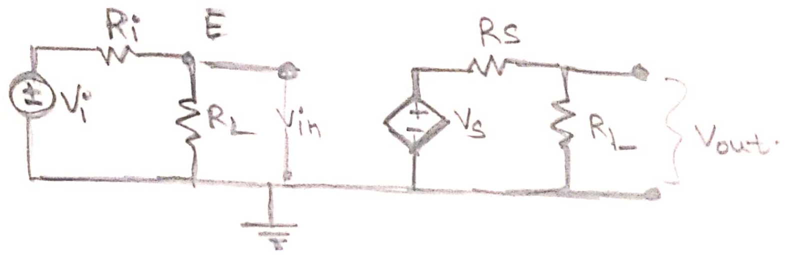
- Linearity is more (so; good match b/w Vin, Vout)
- efficency is less. (since; always on). transistor.

class-B:-

2 transistors (1 npn, 1 pnp)

- less linearity
- more efficiency.

→



Here; Ri, Rs are real life existances!

don't think why we are keeping resistors unnecessarily!

they can't be avoided.

$\boxed{\text{internal resistances}}$

Now; we write $V_s = \beta \cdot V_{in}$

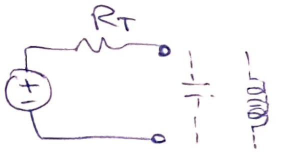
& find $\dfrac{V_{out}}{V_i}$ for 'practical' ~~efficiency~~ (gain) of amplifier.

Week-5:-

+ load as capacitor
+ load as inductor.

1)
* we start by calculating time constant.

- use Thevenin equivalent source.



transient; 5τ

then; capacitor :- $\tau = RC$

inductor :- $\tau = \left(\frac{R}{L}\right)^{-1} = \frac{L}{R}$

2) at $t = 0^-$:

3) at $t = 0^+$: $\qquad X_{general}(t) = X_{t\infty}(1 - e^{-t/\tau}) + X_{t0}(e^{-t/\tau})$

4) at $t = \infty$:

* if $V_{capacitor} = 0$; short circutted.

$V_{inductor} = 0$; whatever.

$I_{inducter} = 0$; open circuit.

Akash! true for any shit!

I think, you wanted to say "at $t = 0^+$"!

& as $t \to \infty$: (universal !)

$i_{capacitor} = 0$

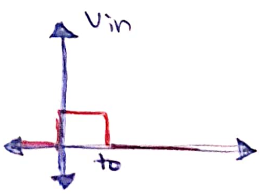
$V_{inductor} = 0$

} for DC. not AC.

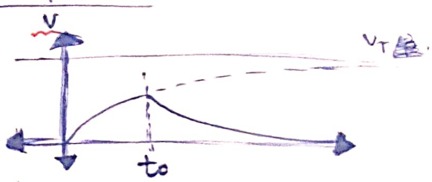
equilibrium state.

inductor dosent allow abrupt change in i_L.
capacitor dosen't allow abrupt change in V_c.
(when series connected to resistance)

* for pulse voltages:-

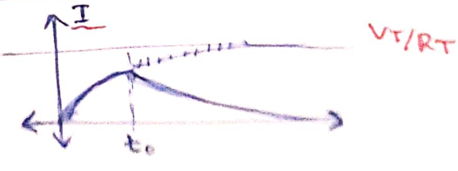


for capacitor:-



But because of opening/closing switch;
V_R, i_R could change abruptly.
(but not i_L, V_c)

for inductor:-

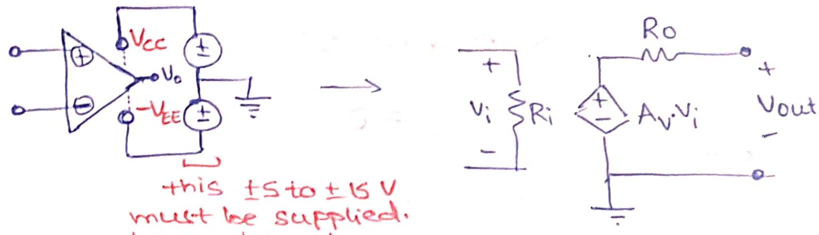


Week-6:

OPAMPS

operational amplifiers.

* equivalent circuit:-



this ±5 to ±15 V must be supplied. (not drawn always).

⊖ —> inverting terminal

⊕ — non-inverting terminal.

Here; cascading transistors.

	Practical
$V_A \rightarrow \infty$	10^5 Holy shit!
$R_i \rightarrow \infty$	$2M\Omega$
$R_o \rightarrow 0$	75Ω

Now!

$(V_+ - V_-)\cdot A_v = V_o$.

& for OP-AMPS; $A_v \rightarrow \infty$. · called as open loop gain. (cascaded transistors).

$\therefore$ $\boxed{V_+ - V_- \cong 0}$ first golden rule.

&;

also $R_i \rightarrow \infty$. (typically larger than other circuit resistors)

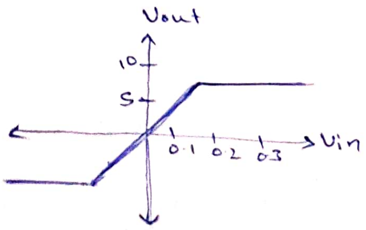
$\therefore$ $\boxed{i_{in} \cong 0}$ second golden rule.

* Note:- • works for AC & DC.

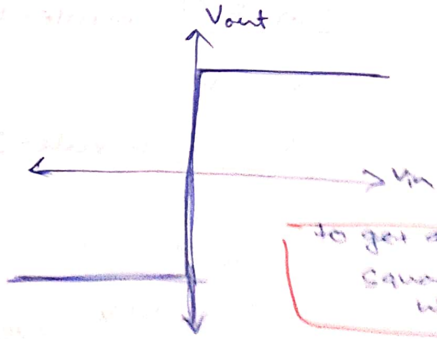
- characteristics of a practical OP-AMP are nearly ideal.
- the DC input power is usually not drawn; But is necessary.

• Broadly; opamps used for two uses.

i) Linear region:

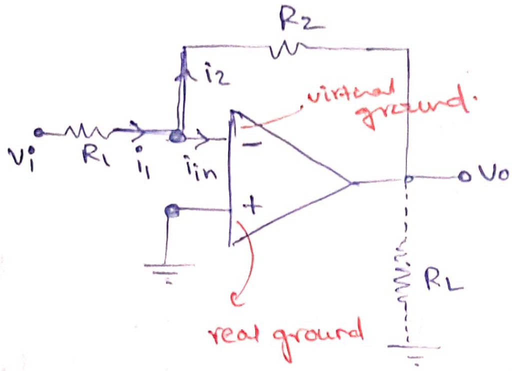


(ii) Saturation region:-



to get a square wave

opamp's amplification action:-



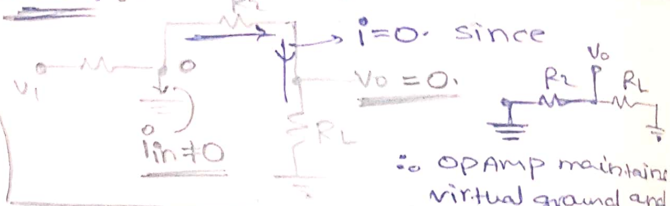
Golden rule -1:-

$i_{in} = 0$

Golden rule -2:-

$V_- = V_+ = 0$ in this case.

what if: (instead of OPAMP)



∴ OpAmp maintains virtual ground and blocks current flow.

$\therefore i_1 = i_2$.

$V_o = -i_2 \cdot R_2$

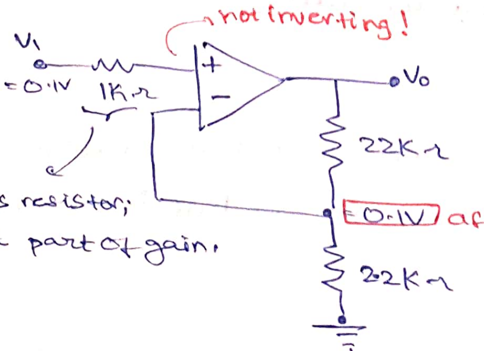
$$\boxed{V_o = -\frac{R_2}{R_1} \cdot V_i}$$

$\left(\frac{-R_2}{R_1}\right)$: closed loop gain

∴ inverting amplifier

- Here, gain changed by changing resistors;
- conventional mei; gain depends on biasing of transistor.

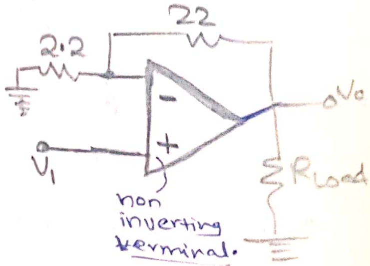
Q)



this resistor; not part of gain.

=0.1V after 2-golden rules.

Same as



non inverting terminal.

Sol)

$i_{in} = 0$ G.rule-1

$\therefore V_+ = V_1$

$\therefore V_- = V_1$ G.rule-2

$\therefore V_o - 0.1 = 10(0.1)$

$V_o = 1.1V$

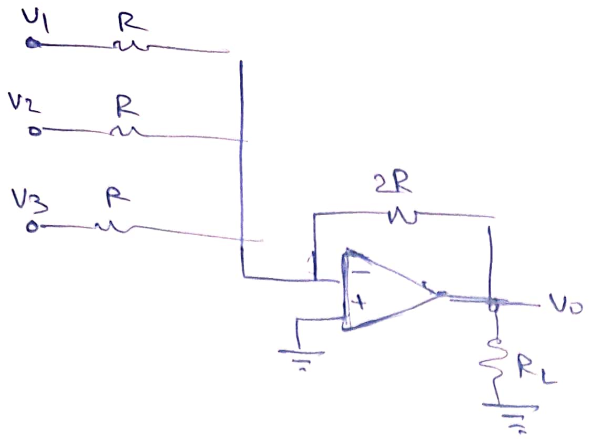
+ve ratio (non-inverting terminal).

Solid justification
Ground Rules:

1) $V_+ - V_- \simeq 0$
since V_o is finite & $A_V \to \infty$

2) $i_{in} = \frac{V_+ - V_-}{R_i} \to 0$.

Summer circuit:-



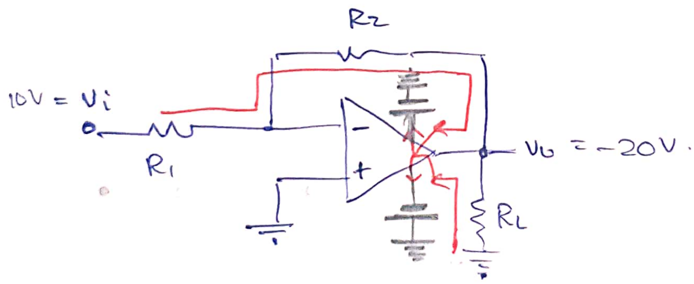
Now; $V_o = -2(V_1 + V_2 + V_3)$

acting as summer.

- works for DC too.

- think of fourier sum; to generate appropiate input voltage to another circuit. (using AC voltages)

where does the current go?-



current in red.

where does the current go?....

the Vcc; & VEE; even though "not drawn all the time"!

all still utterly necessary.

to be present.