POWER ELECTRONICS {ELE 603}

1- Books to be referred :

a) Power Electronics : Converters, applications and design by Mohan, Undeland and Robbins.

b) Daniel Hart

c) M.H. Rashid

d) Issah Batterseh.

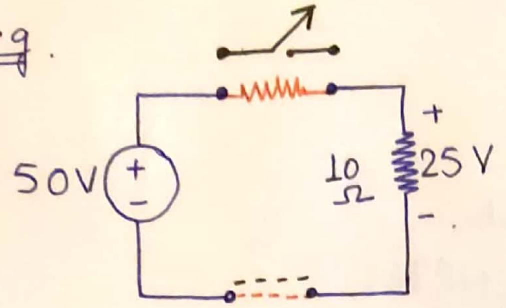
e) Lecture Notes / NPTEL.

LECTURE - I

* What is power electronics?

The control of power through electronics :)

e.g.



25 V is desired.

Soln(1) :→ Using a resistance = 10 Ω to drop 25 V in series.

Problem :→ Efficiency is 50%.

⇒ losses in resistor.

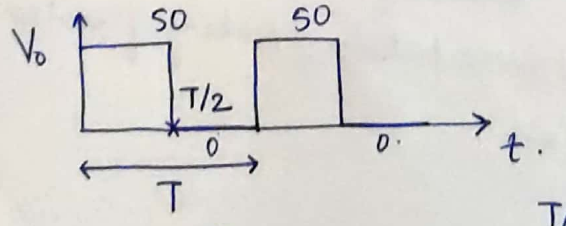
⇒ No control (dynamic) over V_o.

Sol^n (2) :→ Using a switch in series with the load - source arrangement.

Assuming this switch to be ideal :→

when 'S' is ON :→ $V_o = 50V$.

when 'S' is OFF ⇒ $V_o = 0V$.



$$V_{o_{avg}} = \frac{1}{T}\int_0^T v_o(t)\,dt = \frac{1}{T}\int_0^{T/2} 50\,dt = \frac{50}{\cancel{T}}\times\frac{\cancel{T}}{2} = \underline{\underline{25V}}.$$

Advantage: Assuming this switch is ideal.
⇒ efficiency ≈ 100%.

* To Summarize:→.

"The use of electronic switches (devices) to control power is the basis of. power electronics".

Why electronic switch instead of a mechanical switch?.

i). Fast response. (μs versus secs).

ii) Very less losses.

* Now using electronic switches, how can I control power:→.

1). AC-DC {230V, 50Hz, 1-ϕ AC to fixed/variable DC}.

2) DC-DC {fixed DC to variable DC
↳ step-up/step-down.
↳ w/out transformer}.

OR.

{variable DC to fixed DC}.

3). DC-AC {Inverters/UPS}.
fixed DC to AC(V↑, f↑).

4) AC-AC {voltage/frequency control}.

ELECTRONIC SWITCHES / DEVICES.

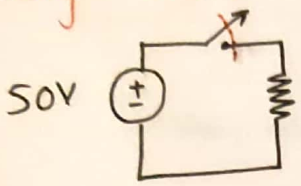
"At power level".

A power electronic device is characterised by 2 features:-

VBC (1) Voltage blocking capability (at 0 current)

CCC (2) Current carrying capability (at 0 voltage drop)

Coming back to the same ckt:-



ON (closed).

→ carrying current (drop is zero) } CCC

} ⇒ OFF (OPEN).

→ current is zero.

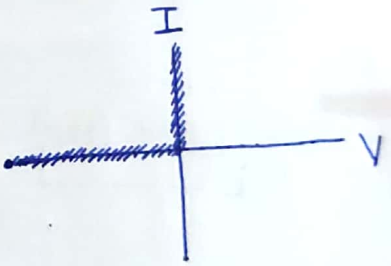
{ 50V across switch } → blocking it VBC

Ratings are decided as per VBC/CCC

DEVICE CHARACTERISTICS.

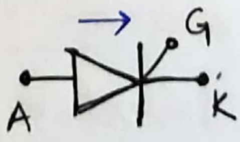
1) Diode (Power) ⇒

⇒

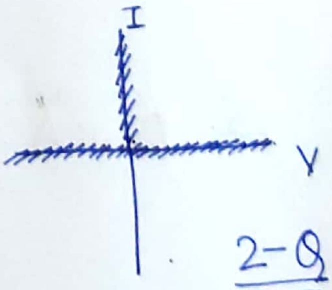


Uncontrolled. 1-Q.

2) Thyristor (SCR) ⇒



⇒



2-Q.

V_{AK} = +ve
→ Forward Bias.
→ does not conduct till gate is high.

Semi-Controlled

Current controlled

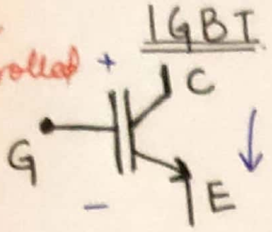
VAK = -ve
→ reverse bias
⇒ OFF
→ irrespective of gate.
⇒ Diode like behaviour.

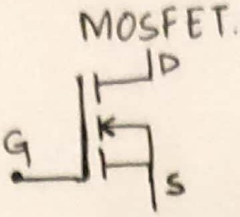
IGBT/MOSFET. similar behaviours
fs↑ ⇒ MOSFET, Ratings ↑ ⇒ IGBT.

3) IGBT (Insulated Gate Bipolar Transistor).

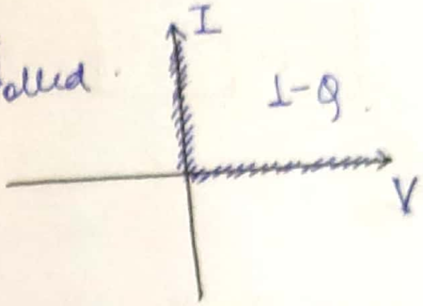
Power MOSFET (Metal-Oxide Field Effect Transistor).

Voltage controlled

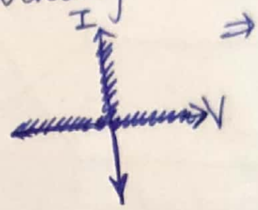




Fully controlled.

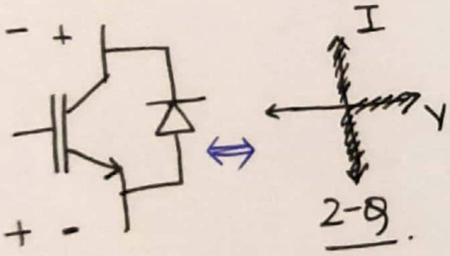


Special type of IGBT called reverse blocking IGBT.

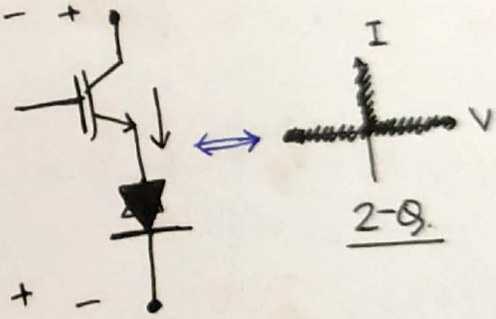


⇒ 2-Q.

Developing a 4-Q switch →

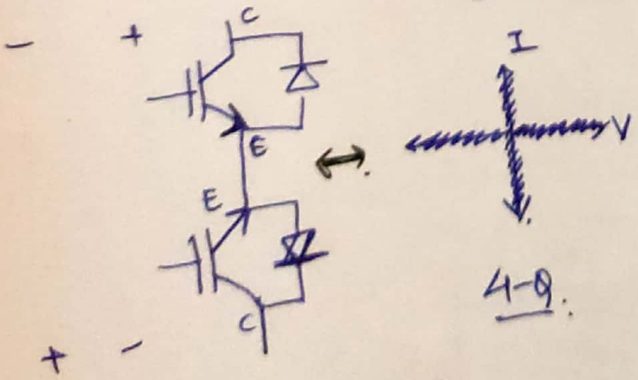


(a).



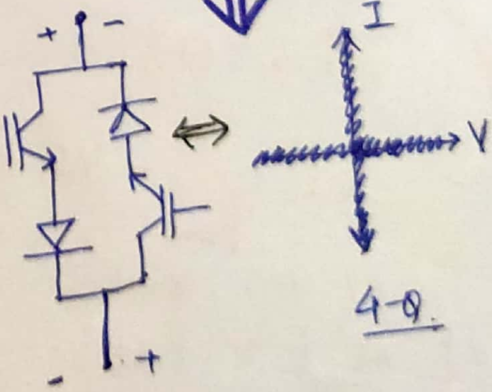
(b).

⇓



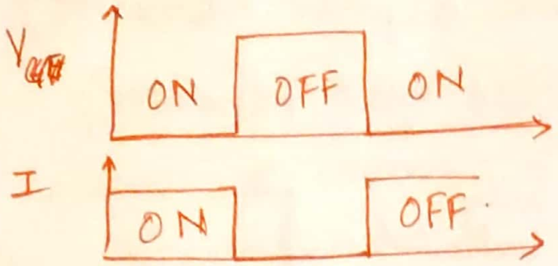
(a)

⇓



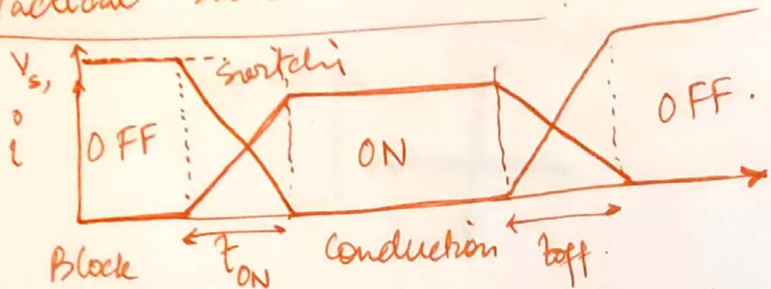
(b).

Ideal Switch Behaviour [LECTURE 2]



$P_{loss} = 0.$

Practical Switch Behaviour.



Loss. ($v \times i$ is finite) during t_{ON} & toff.

$$v(t) = V - \frac{V}{t_{on}} t.$$

$$i(t) = \frac{I}{t_{on}} t.$$

$$P = v(t) \times i(t)$$

$$= VI\, t/t_{on} - VI\, t^2/t_{on}^2.$$

$$P = \frac{dE}{dt} \Rightarrow E = \int_0^{t_{on}} P\,dt = \frac{VI}{t_{on}} \frac{t_{on}^{\cancel{2}}}{2} - \frac{VI}{t_{on}^{\cancel{2}}} \frac{t_{on}^{\cancel{3}}}{3}.$$

Energy loss. $= \frac{VI}{6} \left[t_{on} \right].$

During t_{off} :-

$v(t) = \frac{V}{t_{off}} \times t$, $i(t) = I - \frac{I}{t_{off}} \times t$

$P = v(t) \times i(t) = VI \, t/t_{off} - VI \, t^2/t_{off}^2$.

$E = \int_0^{t_{off}} P \, dt = VI \frac{t_{off}^{\cancel{2}}}{2 \cancel{t_{off}}} - VI \frac{t_{off}^{3}}{3 \cancel{t_{off}^{2}}}$

Energy loss $= \frac{VI}{6} \{t_{off}\}$

Net loss of Energy $= \frac{1}{6} VI \{t_{on} + t_{off}\}$.

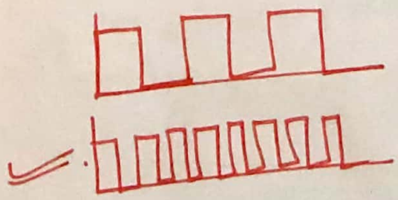
$P = \frac{dE}{dt} = \frac{VI}{6T_s} \{t_{ON} + t_{off}\}$.

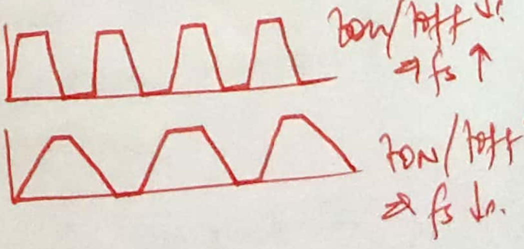
$$\boxed{P = \frac{VI}{6} \times f_s \{t_{ON} + t_{off}\}}$$

$V, I \Rightarrow$ depend on circuit conditions.

$t_{on}/t_{off} \Rightarrow$ device specifics (data-sheet)

$$\boxed{t_{ON}/t_{off} \downarrow \Rightarrow f_s \uparrow}$$





$f_s \uparrow$
* desired

Power MOSFET → t_{ON}/t_{off} ↓ → f_s ↑ → 100-200 kHz.

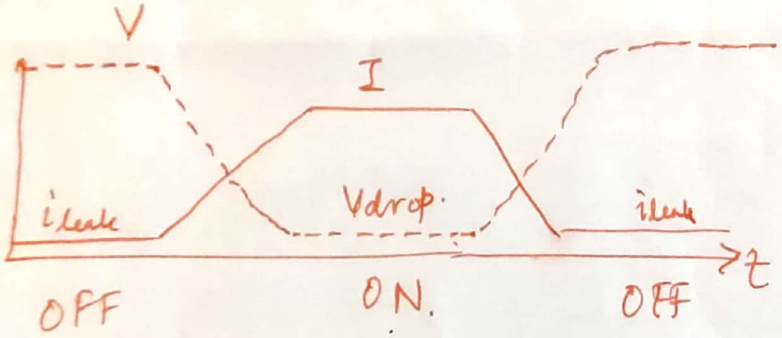
IGBT → t_{ON}/t_{off} ↑ → f_s ↓ → 20kHz.

GTO → lowest f_s ↓ → 200-300 Hz.

Other non-idealities in the switch may also be considered.

i) leakage current when OFF

ii) Voltage drop when ON.



loss = Blocking + Conduction + ON. switching.

$$= (V \times i_{leak}) + (V_{drop} \times I) + (\quad)$$

Switching loss > Conduction loss > Blocking loss.

During t_{on}.

$$\Rightarrow v(t) = V - \frac{(V - V_{drop})}{t_{on}} \times t$$

$$i(t) = i_{leak} + \frac{(I - I_{leak})}{t_{on}} \times t$$

During toff,

$$\Rightarrow v(t) = V_{drop} + \frac{(V - V_{drop})}{t_{off}} \times t.$$

$$i(t) = I - \frac{(I - I_{leak})}{t_{off}} \times t.$$